5.0 2007 RESULTS FOR INDIVIDUAL WATERSHEDS

This is the main results section of the RAMP 2007 Technical report. Section 5.1 presents 2007 results for the Athabasca River and the Athabasca River Delta; Sections 5.2 to 5.10 present 2007 results for the major tributaries of the Athabasca River in the RAMP Focus Study Area (FSA); Section 5.11 contains the 2007 results for miscellaneous aquatic systems throughout the RAMP FSA that were monitored in 2007.

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

	Athabasca River and Delta	Muskeg	Steepbank	Tar	MacKay	Calumet	Firebag	Ells	Christina-Clearwater	Hangingstone	Miscellaneous Aquatic Systems
Climate and Hydrology	5-4	5-90	5-136	5-158	5-172	5-192	5-206	5-226	5-254	5-296	5-312
Water Quality	5-6	5-91	5-137	5-159	5-173	5-192	5-207	5-227	5-255	5-297	5-314
Benthic Invertebrate Communities	5-8	5-94	5-138	5-160	5-174	5-194	5-208	5-228	5-257	5-298	5-320
Sediment Quality	5-9	5-96	5-139	5-160	5-176	5-194	5-209	5-228	5-258	5-298	5-322
Fish Populations	5-10	5-99	5-140	5-161	5-176	5-194	5-209	5-229	5-258	5-298	5-324

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 AND ATHABASCA RIVER DELTA

Summary of Results

Measurement Endpoint	Summary of 2007 Conditions				
Climate and Hydrology					
	Assessment of Change				
	Negligible	Low	Moderate	High	
Mean open-water season discharge	√				Total flow in the Athabasca River was close to normal in 2007. Based on available hydrologic and focal project information, changes in hydrologic conditions in the Athabasca River basin up to and including 2007 due to focal projects 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 2007[1]		Based on comparisons of water quality between upstream and downstream stations over time, no effects of local human activities were apparent on water quality in the Athabasca River in 2007.
Measurement endpoints with guidelines	2007 Potentially Influenced Stations (n=7)	2007 Reference Stations (n=3)	
Physical variables (max=7 for exp, 3 for ref)	0	0	
Nutrients (max= 14 for exp, 6 for ref)	1	1	
Ions (max=14 for exp, 6 for ref)	0	0	
Selected metals (max= 42 for exp, 18 for ref)	7	3	
Comparison to Regional Baselines	Endpoints in 2007 Compared to Regional Baseline[2]		
Percentile of Regional Baseline Values	2007 Potentially Influenced Stations (n=7 stations X 15 endpoints)[1]	2007 Reference Stations (n=3 stations X 15 endpoints)	
Greater than 95th percentile	0	0	
At or between 5th and 95th percentiles	92	41	
Less than 5th percentile	13	4	

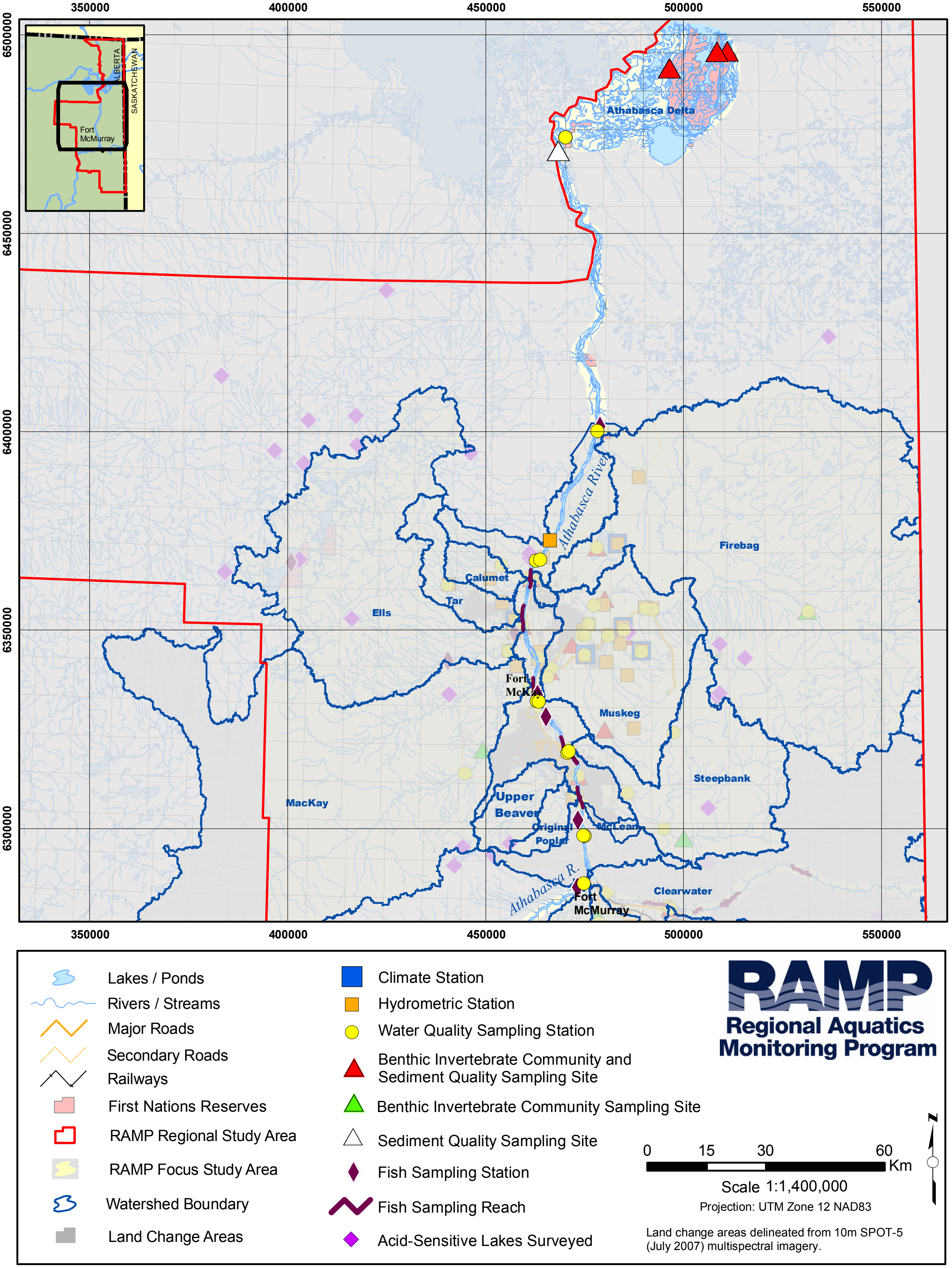
Benthic Invertebrate Communities and Sediment Quality							
Benthic Invertebrate Communities: Comparison to Regional Baselines	Endpoints in 2007 Compared to Regional Baseline						Benthic invertebrate communities in the Athabasca River Delta (ARD) were in generally good condition in 2007 with relatively high diversity for a shifting-sand environment and no evidence of undue deleterious effects on ARD benthic invertebrate communities. Results of fall 2007 and historical sediment surveys in the Athabasca River mainstem and ARD do not suggest changes in sediment quality over time, with the exception of a trend toward finer sediments at Fletcher Channel, which may suggest reducing current velocities in this delta reach over the sampling period.
Values in Relation to Regional Baseline Mean	2007 *Potentially Influenced* Sites (n=3)			2007 *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		3					
Richness		3					
Diversity		3					
Evenness		3					
% EPT		3					
Sediment Quality Guideline Exceedances	Station-Endpoint Combinations Exceeding Guidelines in 2007						
Measurement endpoints with guidelines	2007 Potentially Influenced Sites (n=3)			2007 Reference Sites (n=0)			
Total Hydrocarbons	0						
PAHs	0						

Fish Populations		
Fish Inventory	As of 2007, current and historical fish inventory data from the Athabasca River indicate species-specific variability in relative abundance, length-frequency distribution, and condition factor.	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 focal project development in the Athabasca oil sands region.
Sentinel Studies	Results from the 2007 Athabasca River sentinel species program with trout-perch showed some statistical differences in condition between the reference and potentially influenced sites, but no clear trends in growth, condition and survival between downstream sites and the reference site or between seasons and years.	
Fish Tissue	Level of Risk	
Human Health: Subsistence	Fish tissue studies were not conducted in the Athabasca River in 2007.	
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 and Athabasca River Delta.



K:\Data\Project\RAMP1312\GIS_MXD_TReport\RAMP1312_K01_Mainstem_20080303.mxd

5.1.1 Development Status

For 2007, 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 2007, 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 2007 RAMP stations located on the Athabasca River downstream of the McLean Creek confluence are designated as operational, while all data gathered from 2007 RAMP stations located upstream of the McLean Creek confluence are designated as baseline.

5.1.2 Hydrologic Conditions

5.1.2.1 2007 Hydrologic Conditions for Athabasca River

Total flow in the Athabasca River measured at WSC station 07DA001 (Athabasca River below McMurray) was very close to normal in 2007, with a May 1- October 31 volume of 97% of the long-term average. Relatively high discharges in April and May were balanced by below-normal discharges from mid-June until early November (Figure 5.1-2). The maximum daily discharge of 3,170 m^3/s on May 9 was about 25% higher than the mean annual flood (the mean of the series of annual maximum daily discharges) of 2,500 m^3/s, and almost exactly twice the highest flow of 2006. The minimum open-water season daily discharge of 311 m^3/s was 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 on Athabasca River

Hydrologic effects in 2007 on the Athabasca River were estimated for two cases. The first case considered only 2007 focal projects; that is, those projects owned by 2007 RAMP funders that were under construction or operational in 2007 in the RAMP FSA. The second case considered all 2007 focal projects plus oil sands projects in the RAMP FSA that were under construction or operational in 2007, but were not owned by 2007 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 2007.

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 provided below (details are provided in Table 5.1-1):

- Withdrawals from the Athabasca River by focal projects in 2007 are estimated at 92.4 million m^3;
- Discharges to the Athabasca River by focal projects in 2007 are estimated at 0.261 million m^3;
- A calculated 0.86 million m^3 additional discharge into the Athabasca River in 2007 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]; and

- As of 2007, areas of closed-circuited land change and other land change (not closed-circuited) was 266 km² and 98.2 km², 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 2.4.-1). The effect of these land change areas is estimated to be a loss of 38.7 million m³ of discharge to the Athabasca River in 2007 from areas of closed-circuited land change and a gain of 2.61 million m³ 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 127 million m³ in 2007. Withdrawals from the Athabasca River by focal projects in 2007 are the biggest contributor to the difference between the operational and estimated baseline flows. The estimated cumulative effect in 2007 is that mean open-water season discharge was reduced by 0.45%, mean winter discharge was reduced by 1.23%, annual maximum daily discharge was decreased by 1.3%, and open-water season minimum daily discharge was decreased by 1.2% (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.

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 2007, but were not owned by 2007 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 1.58 million m³ additional discharge into the Athabasca River in 2007 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 0.72 million m³ 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 2007 have been negligible.

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[1] It is assumed that discharges entering the Athabasca River mainstem in 2007 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 2007, water quality samples were collected by RAMP from the following locations in the Athabasca River mainstem:

- Upstream of Donald Creek, east and west banks and cross-channel composite, in fall (ATR-DC-E, ATR-DC-CC, ATR-DC-W) (*reference*, baseline data available most years from 1997 to 2007);
- Upstream of the Steepbank River, east and west banks, the fall (ATR-SR-E and ATR-SR-W, *potentially influenced*, operational data available from 2000 to 2007);
- Upstream of the Muskeg River, east and west banks, in fall (ATR-MR-E and ATR-MR-W, *potentially influenced*, operational data available most years from 1998 to 2007);
- "Downstream of development" (near Susan Lake), east and west banks, in winter, spring, summer and fall (ATR-DD-E and ATR-DD-W, *potentially influenced*, operational data available from 2002 to 2007); and
- Upstream of the Firebag River, cross-channel composite sample, in fall (ATR-FR-CC, *potentially influenced*, operational data available from 2002 to 2007).

Concentrations of water quality measurement endpoints for fall 2007 are presented in Table 5.1-4. Concentrations of selected measurement endpoints (1997 to 2007) 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 2007 at station ATR-DD-W and station ATR-DD-E, the only stations in the Athabasca River that were sampled in all seasons in 2007.

Alberta Environment collects water-quality data monthly from two stations on the Athabasca River, as part of their provincial long-term regional network (LTRN) of water-quality monitoring locations: shortly upstream of Fort McMurray (called ATR-UFM by RAMP, located just upstream the confluence of the Horse River); and at the head of the Athabasca delta at Old Fort (called ATR-OF by RAMP, shortly downstream of the divergence of the Embarrass River). Given the greater intensity of AENV sampling, RAMP also assesses these data annually. Results of this assessment also are included in this section.

Overview of 2007 Results Water quality in the Athabasca River mainstem in fall 2007 was consistent with observations in previous years (Table 5.1-4). Samples from east and west banks at specific stations were generally similar, although major ions (i.e., sodium, calcium, magnesium, chloride, and sulphate) often differed in concentration between east and west banks at station ATR-DC (upstream of Donald Creek). Previous studies have shown that water quality along the east bank of the Athabasca River at this location may be strongly influenced by incompletely mixed water from the Clearwater River (RAMP 2004).

Comparison of Water Quality Measurement Endpoints to Water Quality Guidelines No key water-quality measurement endpoints exceeded relevant guidelines in fall 2007 except total aluminum, which exceeded its CCME/AENV guideline at every RAMP station in the Athabasca River mainstem (*reference* and *potentially influenced*) (Table 5.1-4).

Other Water Quality Guideline Exceedances Water quality guidelines for the following other water quality variables exceeded guidelines in the Athabasca River mainstem (Table 5.1-5):

- *In winter, at ATR-DD(-E,-W):* Total aluminum (-W) ; and total iron (-W,-E);

- *In spring, at ATR-DD(-E,-W)*: Total aluminum (-W,-E); total iron (-W,-E); total lead (-E); total copper (-E); total cadmium (-E,-W); total titanium (-E); total phenolics (-E); total phosphorus (-W,-E); and total nitrogen (-W);
- *In summer, at ATR-DD(-E,-W):* Total aluminum (-W,-E); total iron (-W,-E); total cadmium (-E,-W); and total phosphorus (-W,-E); and
- *In fall, at all RAMP ATR-## stations:* Total iron (all stations); and total phenolics exceeded at ATR-DC (-E,-W, and -CC), ATR-MR-W, and ATR-FR-CC.

Comparison of Water Quality Measurement Endpoints to Natural Variation in Baseline Conditions 133 of a total of 150 observations of water-quality measurement endpoints in the Athabasca River downstream of Fort McMurray in fall 2007 (i.e., 15 endpoints at 10 locations) were within regional reference ranges (i.e., between the 5th and 95th percentile of historical observations at regional reference stations) (Figure 5.1-3 to Figure 5.1-6). Exceptions to this included: total strontium at ATR-DC-W, which has exceeded the 95th percentile of reference concentrations in most years of monitoring (Figure 5.1-3); total chloride at ATR-DC-E, which similarly has consistently exceeded the regional 95th-percentile concentration (Figure 5.1-3); and naphthenic acids and ultra-trace mercury with concentrations that exceeded the regional 95th-percentile concentrations of the Muskeg River (west bank, station ATR-MR-W, Figure 5.1-5).

Ion Balance Ion balance of water from the Athabasca River mainstem has varied within a narrow range between 1997 and 2007 for all stations 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 5.1-7). Multivariate analysis of water quality in 2003 indicated that water quality at station ATR-DC-E was nearly identical to water quality in 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. Differences in ion balance between ATR-DC-E and ATR-DC-W in 2000, 2005, and 2006 also suggest an influence of the Clearwater River on east-bank water quality. In 2007, east-bank results were very similar to those observed in 2004; cross-channel results fell within historical concentrations. West-bank results for 2007 had a greater proportion of sulphate and magnesium ions than in previous years; west-bank results upstream of the Steepbank River (ATR-SR-W) had the highest magnesium and sulphate concentrations of all stations.

Trend Analysis Significant trends in the following water-quality measurement end-points were observed in AENV water-quality data from 1997 to 2007, for stations ATR-UFM (upstream of Fort McMurray) and ATR-OF (Table 5.1-6, Figure 5.1-8):

- Upward trends in pH and total aluminum at both ATR-UFM and ATR-OF, and in total Kjeldahl nitrogen (TKN) at ATR-UFM only; and
- Downward trends in chloride at ATR-UFM and total molybendum at ATR-OF.

Both endpoints that exhibited increasing concentrations in waters of the Athabasca River delta (i.e., pH and total aluminum) also exhibited similar increases in the river upstream of Fort McMurray. Although no significant trends in ultra-trace mercury were noted for either station, concentrations at both stations, particularly ATR-OF, in 2007 were higher than has been observed since monitoring of mercury at ultra-trace levels began in 2003, consistent with RAMP data in 2007 that showed historically high mercury concentrations at some Athabasca River stations.

Summary Based on comparisons of water quality between upstream and downstream stations over time, no effects of local human activities were apparent on water quality in the Athabasca River in 2007.

5.1.4 Benthic Invertebrate Communities and Sediment Quality

5.1.4.1 Benthic Invertebrate Communities in the Athabasca River Delta

Benthic invertebrate community samples were collected in fall 2007 from three depositional channels in the Athabasca River Delta (ARD): Fletcher Channel (station FLC), Goose Island Channel (station GIC) and Big Point Channel (station BPC).

2007 Habitat Conditions The three channels of the ARD selected for analysis of benthic invertebrate communities in fall 2007 were similar in terms of habitat characteristics (Table 5.1-7). All three stations were in depositional habitats with water depths of 2 m and sediments consisting of decreasing amounts of silt, sand and clay (in that order), and low levels of total organic carbon.

Relative Abundance of Benthic Invertebrate Community Taxa in 2007 The benthic invertebrate communities of three channels of the ARD were generally similar (Table 5.1-8), all being dominated numerically by tubificid worms. Chironomids were the second-most dominant group in Fletcher Channel (station FLC) and Goose Island Channel (station GIC), while fingernail clams (Bivalvia) were the second-most dominant group in Big Point Channel (station BPC). A variety of other groups such as nematodes, ostracods, larger insects including Ephemeroptera, Plecoptera and Trichoptera were present, but in lower numbers. The worms were not identified below the Family level, but the high numbers of tubificids is not uncommon because of the characteristic shifting-sand environment of the ARD (Barton and Locke, 1979). As in previous years, the dominant chironomids were *Polypedilum* and *Procladius*. The mayflies *Ametropus neavei* and *Hexagenia* were present in Fletcher Channel (station FLC). Both of these taxa are commonly found in sand environments (Clifford and Barton, 1979; Barton, 1980). Big Point Channel (station BPC) had the highest diversity of larger insects, with mayflies represented by two genera (*Leptophlebia* and *Caenis*), stoneflies represented by three genera (*Isoperla*, *Pteronarcys*, *Taeniopteryx*) and caddisflies represented by three genera (*Brachycentrus*, *Hydropsyche* and *Neureclipsis*). The greater number of larger insect taxa at Big Point Channel (station BPC) suggests that the substrate of the channel was less shifting in fall 2007 than it was in the other two channels (as per Barton, 1980).

Effects of Focal Project Activities and Other Oil Sands Developments The values of benthic invertebrate community measurement endpoints in fall 2007 and in comparison with previous years do not indicate or suggest cumulative effects of focal projects and other oil sands development projects on benthic invertebrate communities in the ARD since sampling started in 2002 (Table 5.1-8; Figure 5.1-9). Overall abundance has fluctuated widely from 5,000 to more than 100,000 individuals/m^2 and richness continues to average about 10 to 11 distinct taxa per sample. Simpson's diversity and evenness continue to range between 0.4 and 0.7 (Figure 5.1-9); these are normal values for these measurement endpoints in shifting-sand environments (Barton, 1980; Barton and Smith, 1984). Similarly, %EPT was generally low in the ARD in fall 2007, but similar to previous years and at a value that is also not atypical for shifting-sand environments (e.g., Barton, 1980; Barton and Smith, 1984). Values of all benthic invertebrate community measurement endpoints in fall 2007 were within the normal range of values for reference depositional reaches in the RAMP FSA (Figure 5.1-9). The ordination of the benthic invertebrate community data (Figure 5.1-10) supports these findings, indicating that benthic invertebrate community conditions in 2007 continued to be well within the normal range measured in depositional reaches designated as *reference* (Figure 5.1-10).

5.1.4.2 Sediment Quality

Sediment quality was sampled in the Athabasca River mainstem and the Athabasca River Delta (ARD) in fall 2007 from: Athabasca River mainstem upstream of Embarras River (station ATR-ER); Goose Island Channel (station GIC -1); Fletcher Channel (station FLC-1); and Big Point Channel (station BPC-1).

2007 Results and Historical Ranges of Concentration Sediment quality at all stations sampled in the Athabasca River mainstem and the ARD in fall 2007 was generally similar to that observed in previous years. Sediments at station ATR-ER, located along the Athabasca River mainstem shortly before it slows and broadens into the ARD, were dominated by sand (Table 5.1-9), while sediments were comprised predominantly of silt at all stations within the ARD proper (i.e., stations GIC-1, Table 5.1-10, FLC-1, Table 5.1-11, BPC-1, Table 5.1-12). Total organic carbon in sediments at all stations was relatively low (i.e., 1.1 to 1.6%, Table 5.1-9 to Table 5.1-12), consistent with historical observations (Figure 5.1-11 to Figure 5.1-14). Silt and organic content of sediments at Fletcher Channel (station FLC-1) have exhibited consistent increases since 2001 (Figure 5.1-13), suggesting an increase in deposition of fine sediments at this station over the sampling period.

Concentrations of hydrocarbons at these four stations in fall 2007 were similar to those sampled in 2005, when the CCME four-fraction hydrocarbon analysis was first applied to ARD sediments (Table 5.1-9 to Table 5.1-12). At all four stations, total hydrocarbons were dominated by Fractions 3 and 4; with low-molecular-weight and more volatile hydrocarbons (i.e., BTEX and F1) being non-detectable at stations ATR-ER (Table 5.1-9), GIC-1 (Table 5.1-10), and BPC-1 (Table 5.1-12).

Total metal concentrations in sediments in fall 2007 were similar to, or lower than, those observed in recent years at all four sampled stations, and were similar among all four stations in fall 2007 (Figure 5.1-11 to Figure 5.1-14). Similarly, concentrations of polycyclic aromatic hydrocarbons (PAHs) at all four stations in fall 2007 were similar to or lower than those observed in recent years, when expressed either as absolute total PAH concentrations, or when carbon-normalized to 1% TOC[2] (Figure 5.1-11 to Figure 5.1-14).

Comparison with Sediment Quality Guidelines There were no measured sediment quality measurement endpoints in fall 2007 with concentrations that exceeded sediment quality guidelines at any of the four sampled stations (Table 5.1-9 to Table 5.1-12).

Regional Context Absolute and carbon-normalized concentrations of total PAHs and total hydrocarbons (i.e., sum of F1-F4), and absolute concentrations of a representative metal, total arsenic, in sediments sampled by RAMP in the Athabasca River mainstem and ARD since 1997 are presented in Figure 5.1-15 to Figure 5.1-19.[3] Historically, the highest concentrations of PAHs and hydrocarbons in sediments sampled from the Athabasca River mainstem and delta have consistently been measured at station ATR-DC, upstream

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[2] As hydrophobic compounds, PAHs may preferentially adsorb to organic particles. Therefore, both absolute and carbon-normalized concentrations of PAHs and other hydrophobic compounds are important to consider in monitoring. Carbon-normalized data may provide a better measure of change over time, as these data exclude the potentially confounding influence of sediment carbon content on PAH concentration.

[3] RAMP sampling of sediments from the Athabasca River between Fort McMurray and the ARD was discontinued in 2004, given the generally non-depositional nature of mainstem sediments, and the confounding effects of variable river wetted widths and eroding bitumen-bearing soils along the river bank at some stations.

of Donald Creek, designated as *reference*, with lower concentrations generally observed at other mainstem stations (although some individual very high measurements have been made at stations ATR-FC and ATR-DD). PAHs and hydrocarbons at all stations in the ARD have been generally stable, and one to several orders of magnitude below those observed at upstream reference station ATR-DC. In contrast, concentrations of total arsenic in sediments of the Athabasca River mainstem and the ARD have generally been similar among all stations and across years, with concentrations at all stations typically exhibiting concentrations near the CCME interim sediment-quality guideline of 5.9 mg/kg (Figure 5.1-19). No longitudinal trends or trends over time are apparent in these data.

5.1.4.3 Summary

Benthic invertebrate communities in the ARD were in generally good condition in 2007 with relatively high diversity for a shifting-sand environment and no evidence of undue deleterious effects on ARD benthic invertebrate communities. In addition, results of fall 2007 and historical sediment surveys in the Athabasca River mainstem and ARD do not suggest changes in sediment quality over time, with the exception of a trend toward finer sediments at Fletcher Channel, which may suggest reducing current velocities in this delta reach over the sampling period.

5.1.5 Fish Populations

Fish population monitoring in 2007 on the Athabasca River included a spring and fall fish inventory, a summer and fall non-lethal sentinel fish species program, and a tag return assessment.

5.1.5.1 Fish Inventory

Species Composition

A total of 2,511 fish were captured within the ten standardized reaches (Figure 3.4-1) during the spring and fall fish inventory on the Athabasca River, of which:

- 1,511 fish comprised of 15 species were captured during the spring sampling (Table 5.1-13); and
- 1,000 fish comprised of 19 species were recorded during the fall sampling (Table 5.1-14).

A total of 19 fish species were captured and observed during the 2007 Athabasca fish inventory (Table 5.1-13 and Table 5.1-14); this is the same number of fish species as was captured in the 2006 Athabasca fish inventory and is near the maximum number of fish species (22) captured during the fish inventory conducted in 1997 (Golder 2003). White sucker followed by walleye were the most abundant large-bodied species captured in spring 2007 (Table 5.1-13), while lake whitefish followed by walleye were the most abundant large-bodied species captured in the fall survey (Table 5.1-14).

Comparisons of spring 2007 species composition to historical spring species composition are summarized as follows (detailed historical information is provided in Figure 5.1-20):

- The percentage of the 2007 spring catch represented by walleye was much lower than almost all historical records and approached the lowest historically-recorded percentage (2001);

- The percentage of the 2007 spring catch represented by goldeye was higher than 2006 and average for the period since 2001 (all of the years since 2001 have been lower than 1997 to 1999);
- The percentage of the 2007 spring catch represented by longnose sucker was similar to recent years, but lower than most years in the data record;
- The percentage of total spring catch in 2007 represented by white sucker was substantially higher than all years in the data record; and
- The percentage of total spring catch in 2007 represented by northern pike was similar to 2005 and 2006 and lower than most years in the data record.

Comparisons of fall 2007 species composition to historical fall species composition are summarized as follows (detailed historical information is provided in Figure 5.1-21):

- The percentage of the 2007 fall catch represented by walleye was the lowest of any year in the data record;
- The percentage of the 2007 fall catch represented by goldeye increase slightly from 2006, but was still the 3rd lowest in the data record;
- The percentage of the 2007 fall catch represented by longnose sucker was lower than 2006, but was still within the mid-range of the data record;
- The percentage of the 2007 fall catch represented by white sucker was greater than 2006, but was still within the mid-range of the data record; and
- The percentage of the 2007 fall catch represented by northern pike was the lowest in the data record.

In 2007, the dominant species captured was white sucker. Northern pike has exhibited the lowest capture percent in all years during spring. In fall, there was large variability in species dominance across years. Generally walleye exhibited consistently high percent capture, but goldeye and longnose sucker exhibited dominance in some years relative to the other species (1998, 1999, 2004 and 2005). Variability in percent capture over time may also be influenced by the timing of sampling effort in each area.

Spatial comparisons of spring 2007 species composition are summarized for Key Indicator Resource (KIR) species as follows (detailed information is provided in Figure 5.1-22):

- White sucker was the dominant species in the Steepbank, Muskeg, Tar-Ells and Fort-Calumet areas of the Athabasca River;
- The percentage of the total catch represented by goldeye and longnose sucker in the Steepbank area was similar to white sucker;
- Walleye was the dominant species in the Poplar area;
- The percentage of the total catch represented by northern pike was low across all areas; and
- There were no clear longitudinal trends in species composition across areas for any large-bodied species.

Spatial comparisons of fall 2007 species composition are summarized for KIR species as follows (detailed information is provided in Figure 5.1-23; lake whitefish, while not classified as a KIR species, was included given that it formed a large proportion of the total catch in fall 2007):

- Lake whitefish was the dominant species in all areas except the Tar-Ells area;
- Walleye was the second-most dominant species in all areas with the exception of the Muskeg area;
- There were no clear longitudinal trends in species composition across areas for any large-bodied species; and
- Percent composition was the greatest in the Steepbank area for lake whitefish, northern pike and walleye and greatest in the Muskeg area for white sucker, goldeye and longnose sucker.

Generally, there was high variability in the proportion of large bodied fish species in each area. In spring, when movement is related to spawning activities in smaller tributaries for most species, the highest proportion of each species were in the upper three areas (i.e., Poplar, Steepbank and Muskeg) with the exception of northern pike (low proportions in all areas), indicating preferential spawning grounds in these tributaries. Interestingly, in fall, when most species are not spawning and the population is made up of resident individuals, the highest proportion of each species were also found in the upper three areas, which potentially indicates low levels of movement between sampling periods.

Fish that were observed during the Athabasca inventory program, but not captured, are summarized in Table 5.1-15.

Catch Per Unit Effort

General The total catch per unit effort (CPUE) for the 2007 spring inventory was the 4th highest in the data record (Figure 5.1-24), while the total CPUE for the 2007 fall inventory was the 2nd highest in the data record, lower than only the 2006 CPUE (Figure 5.1-24).

Spatial Differences and Temporal Trends Spatial differences and temporal trends in CPUE for KIR species are summarized as follows (detailed information is provided in Figure 5.1-25 to Figure 5.1-29:

- Catch per unit effort of walleye was variable with no clear trends in any area over time in both spring and fall; consistently the highest CPUE was in the Poplar area across years with the exception of 2007 in fall when CPUE was highest in the Muskeg area;
- Similarly, catch per unit effort of goldeye was variable with no clear trends in any area over time in both spring and fall; in spring CPUE has been highest in the Poplar area since 2002; in fall, there was no area exhibiting consistently higher CPUE across years;
- Catch per unit effort of longnose sucker also exhibited high variability with no clear trends in any area over time in both spring and fall. In spring, the Poplar area has exhibited the highest CPUE since 2002 with similar CPUE in the Steepbank area in 2007; in fall, CPUE of longnose sucker was consistently low and similar among areas over time, with the exception of higher peaks in 1998 and 2002;

- Catch per unit effort of white sucker was consistent across time in spring with an increase in all areas in 2007 with the exception of the Poplar area; the highest CPUE was in the Poplar for all years except 2007 where CPUE was highest in the Muskeg and Fort-Calumet areas. In fall, there was no area which showed higher CPUE across years; there has been an increase in CPUE in the Muskeg area since 2004 and has the highest CPUE in 2007; and

- Catch per unit effort of northern pike exhibited very little variability over time in both spring and fall with the exception of the Tar-Ells area in spring. There was no area exhibiting consistently higher CPUE across years; the Fort-Calumet area and the Muskeg area had the highest CPUE in 2007 in spring and fall, respectively.

Catch per unit effort of all large bodied species showed high variability with no clear trends moving downstream on the Athabasca River or across years. Generally, the Poplar area exhibited the highest CPUE for most species over time, particularly in spring, suggesting tributary streams in this area or in close proximity to this area may be important for spawning. In fall, spatial CPUE was more variable with no clear dominance in any area over time.

Athabasca River Flows and CPUE Catch per unit effort for each KIR species was compared to monthly mean discharge measurements (m^3/s) in the Athabasca River. Instream Flow Needs (IFN) guidelines for the Athabasca River specify discharge maintenance levels for ecological protection in the system (AENV 2007). In this regard, water withdrawals from oil sands development are regularly monitored to ensure IFN needs are being met. Mean monthly discharges at a Water Survey of Canada hydrology station on the Athabasca River below Fort McMurray (Environment Canada 2007) for May and September (the two Athabasca Inventory sampling months) were compared to relative fish abundance from 1987 to 2007 (Figure 5.1-30 and Figure 5.1-31).

The relationship between discharge and catch per unit effort was highly variable. CPUE of walleye, goldeye and white sucker generally increased with increased discharge rate until a certain threshold (i.e., 1000-1500 m^3/s) at which point CPUE showed high variability, indicating that lower discharge rates influence relative abundance of these species but discharge rates greater than 1500 m^3/s in the Athabasca River have no direct relationship with relative abundance. Catch per unit effort of longnose sucker and northern pike showed a slight decrease with increasing discharge rates, but was generally consistent across the flow range indicating very little direct influence of fluctuations in discharge rate on relative abundance of these two species.

Length-Frequency Analysis

Length-frequency histograms (1997-2007) for the five Key Indicator Resource (KIR) species based on standardized capture data are presented in Figure 5.1-32 to Figure 5.1-36. The Kolmogorov-Smirnoff (K-S) pairwise comparison test (two-sided, $\alpha = 0.05$) was used to compare length-frequency distributions over time for each species. Results showed highly variable significant differences between years for most species with no clear trends over time. Key features of the length-frequency distributions and results from the K-S test for each KIR species are as follows:

- Walleye: the dominant length class of fish captured in 2007 was 401 - 450 mm, similar to 2005, but much higher than the 2006 dominant length class of 101 – 150 mm (RAMP 2007). Although the relative frequency of walleye in the dominant classes was variable over time indicated by the significant difference in the K-S test ($p < 0.05$), the shape of the length frequency distribution has consistently shown two peaks, the first at the 101-150 size class and the second at the 401-450 size class;

- Goldeye: the dominant length class of fish captured in 2007 was 300 - 325 mm, similar to 2006 (RAMP 2007). High catches were recorded in all upper range length classes but there were very few fish captured from the smaller length classes. From 1997 to 2005 there was a significant increase in dominant length class from 251-275 mm to 376-400 mm ($p < 0.05$); in 2006 and 2007, the length-frequency curve showed two peaks within this historical size class range;
- Longnose sucker: the dominant length class of fish captured in 2007 was 400 - 450 mm as compared to 200 - 250 mm in 2006. The dominant length class has significantly varied from year to year with no clear trends in length-frequency distribution over time ($p < 0.05$). Generally the length frequency curve for each year showed a bimodal distribution with one peak in the smaller size classes (101-250 mm) and one peak across the larger size classes (350-501 mm);
- White sucker: the dominant length class of fish captured in 2007 was 400 – 450 mm, which is similar to 2006. The relative frequency in the dominant size class significantly varied over time ($p < 0.05$), but dominance was consistently within the 350 - 400 mm and 400 - 450 mm length classes in all recorded years. A second smaller peak was evident in all years in the 101-150 mm size class; and
- Northern pike: the co-dominant length classes of fish captured in 2007 were 350 - 400, 450 - 500 and 600 - 650 mm. The dominant length class has varied considerably from year to year with several peaks in the length-frequency curve between 300 mm and 600 mm. There were no significant differences between years for northern pike length-frequency distribution which is possibly due to the lack of any clear dominant size class across years but rather consistent smaller peaks over all size classes ($p > 0.05$).

Recruitment to the Sport Fishery

The ratio of undersize (i.e., less than 400 mm) to legal-size (i.e., greater than 400 mm) walleye, an index of the rate of recruitment to the sport fishery, was 1.4 in 2007, a two-fold decrease from 2006 (Figure 5.1-37). However, the 2007 index was within the historical range of 0.7 to 3.3 (Figure 5.1-37) and only slightly lower than the 1997 to 2006 average of 1.7. This suggests that the rate of recruitment to the sport fishery in 2007, as measured using this index, was similar to the long-term average recruitment.

The ratio of under-size to legal-size northern pike was 2.7 in 2007 and is an increase in value from 2006, but still among the lower measured index values in the data record (1.7 - 4.5) (Figure 5.1-38). This ratio has been much higher in previous years, but an increase from 2006 could indicate an improvement in recruitment to the fishery with greater numbers of northern pike reaching the legal size class range.

Condition Factor

Values of mean condition factor from fish captured from 1997 to 2007 in spring and fall are presented in Figure 5.1-39 and Figure 5.1-40, respectively. Generally, there are more instances of significant year-to-year differences in condition factor of fish captured in the spring than in fall. This may be related to varying physiological and behavioural responses to spring spawning. The species-specific results are as follows and displayed in Figure 5.1-39 and Figure 5.1-40 (two p-values are given for each ANCOVA, the first is for the comparison of slopes and the second is for the comparison of intercepts):

- There were significant differences in condition factor among years for walleye in both the spring and fall season (Analysis of covariance, ANCOVA slope: $p > 0.01/p < 0.05$); with mean condition factor ranging from 0.93 (2003) to 1.03 (2005) in spring and 0.99 (1999) to 1.11 (2005) in fall. The direction of change in condition fluctuated over time with no clear temporal trend;

- There were no significant differences in fall condition factor among years for goldeye (ANCOVA $p = 0.09/p > 0.05$). Mean fall condition factor has ranged from 1.07 (2001) to 1.32 (2006). Statistical testing could not be performed on spring goldeye condition because a statistical pre-requisite for performing ANCOVA was not met (i.e., slopes of the weight-length regressions were not equal, $p < 0.01$). Mean spring goldeye condition factor has ranged from 1.07 (2002) to 1.20 (2007);

- There were significant fluctuations in spring condition factor among years for longnose sucker (ANCOVA $p = 0.6/p < 0.05$) with no clear trends but no significant differences in fall condition factor among years (ANCOVA $p = 0.07/p > 0.05$). Mean spring and fall condition factor for longnose sucker has ranged from 1.14 (2005) to 1.38 (2003) and from 1.15 (1998) to 1.38 (2005), respectively;

- There were significant variability in spring condition among years for white sucker (ANCOVA $p = 0.8/p < 0.05$) with no clear trends over time but no significant differences in fall condition among years (ANCOVA $p = 0.9/p > 0.05$). Mean spring and fall condition for white sucker ranged from 1.42 (2002) to 1.75 (2006) and from 1.45 (1998) to 1.67 (2007), respectively; and

- There were no significant differences in the spring condition factor among years for northern pike (ANCOVA $p= 0.5/p > 0.05$); with mean condition factor from 0.65 (2003) to 0.79 (2004). Statistical testing could not be performed on fall northern pike condition factor because the slopes of the weight-length regressions were not equal ($p < 0.01$). Mean fall northern pike condition factor ranged from 0.59 (1999) to 0.81 (2006).

None of the between-year differences described above exceeded the ± 10% difference criterion for condition factor defined by Environment Canada (2005) that would suggest an ecologically relevant level of change in a population. Across all species over time, there was variability in condition factor with no clear increasing or decreasing trends, indicating that changes were most likely due to natural variability in fish populations.

External Health Assessment

External health anomalies observed during the fish inventory were primarily minor skin aberrations or light fin erosion (13% of fish caught). In addition, 1.9% of the fish examined in the Athabasca River fish inventory had evidence of “black spots”, a parasite disease most commonly associated with low water flow levels or eutrophication in the aquatic system. There was no evidence of more serious anomalies such as tumours or neoplasms. The 2007 external pathology index values were within historical ranges for all species, but greater than 2006 for goldeye, northern pike, white sucker and longnose sucker (Table 5.1-16). There has been high variability in the external pathology index over time for all species. Fish examined during the spring inventory had twice as many external anomalies as fish in the fall inventory (i.e., 19% vs. 9%, respectively) perhaps a result of spawning activities taking place in smaller and more confined waterbodies when skin aberrations and fin erosion could occur more frequently.

Summary Assessment for Fish Inventory

As outlined in RAMP (2005b), the Athabasca River fish inventory is generally considered to be a community-driven activity, primarily suited for assessing general trends in abundance and population variables for large-bodied species, rather than detailed fish community structure. As of 2007, current and historical fish inventory data from the Athabasca River indicate species-specific variability in relative abundance, length-frequency distribution, and condition factor. Statistically significant differences were observed between years for condition and length-frequency distributions of the KIR fish species, but there was no clear pattern that would suggest a consistent negative or positive change in the populations (i.e., likely reflects natural variability).

5.1.5.2 Sentinel Species Monitoring

Sentinel species monitoring, using trout-perch, was conducted at five sites on the Athabasca River in summer (August) and fall (October) (Figure 3.4-1). Based on their location with respect to the location of focal project activities in 2007, Sites 1 and 2 are designated as *reference*, while Sites 3, 4, and 5 are designated as *potentially influenced.*

Field Sampling Results

In situ water quality measurements (dissolved oxygen from 8.6 to 11.8 mg/L, conductivity from 196 to 324 μS/cm, and pH from 6.85 to 8.42) indicated suitable conditions at all sites during summer and fall sampling. Mid-afternoon water temperatures ranged from 15.6 to 17.7°C and 5.3 to 7.2°C during summer and fall sampling, respectively. Daily average temperatures between sites over time were generally consistent; water temperatures were slightly lower at site 5 relative to the other sites throughout the sampling period; a drop in water level exposed the data logger at Site 1 between the two sampling periods (Figure 5.1-41).

Sampling was conducted in river sections comprised mainly of slow glides, with wetted widths ranging from 100 to 400 m. Sampling at Site 1 took place in a river reach dominated by large cobble with very little fine substrate; sampling at all other sites took place in reaches with substrate dominated by sand and silt with few cobbles and boulders. These differences in substrate characteristics in Site 1 compared to the other four sites and the relative similarities in substrate characteristics among Sites 2 to 5, resulted in comparisons between *reference* and *potentially influenced* sites being made using Site 2 as the *reference* site.

Given water levels decreased between sampling events, the bank slope changed from steep in summer to gradual in fall. All sites contained woody debris (more at sites 2 and 4 than at sites 1, 3, and 5) and little instream vegetation. Riparian vegetation was mixed at all sites and included shrubs, grasses and deciduous trees.

The average flow velocity across all sites was 0.33 m/s in both summer and fall. Sampling depth across all sites averaged 0.7 m in summer and 1 m in fall. During both seasons, trout-perch were typically found more commonly at depths between 0.5 m and 1.0 m, in slower flows, and in areas close to moderately-sloping banks. Higher numbers of trout-perch were caught in the morning or late afternoon in shady or covered areas.

Target numbers of trout-perch (of 100 fish) were collected at four of five sites in spring and at all sites in fall (Table 5.1-17); most fish were caught using beach seines in summer and all fish in fall were caught by electrofishing.

Survival

Trout-perch length-frequency distributions (2 mm size classes) were significantly different between seasons for each site (Kolmogorov-Smirnov (K-S) pairwise comparison, $p < 0.001$ for all cases); at Site 1 and Site 5, there was a greater proportion of fish caught from larger size classes in summer, whereas at sites 2, 3, and 4 there was a greater proportion of fish caught in the smaller size classes (Figure 5.1-42 to Figure 5.1-46). Length-frequency distributions were also significant between Site 2, *reference*, and all other sites, *potentially influenced*, in both seasons (K-S pairwise comparison, $p < 0.005$ for all cases). Sites 3 and 4 had a higher proportion of fish caught from smaller size classes relative to Site 2 in both spring and fall; Site 5 had a higher proportion of fish caught from larger size classes in summer, but a higher proportion of fish caught from smaller size classes in fall relative to Site 2. Length frequency distributions can be used to evaluate survival in the population. The shape of the curve in the reference area applies to a reference distribution of an undisturbed fish population to which the potentially influenced populations can be compared. Evidence of recruitment to the population is indicative of good survival (i.e., greater proportion of smaller size classes). If the smaller size classes are missing, either reproduction in adults has been disrupted or the survival of young fish is inhibited. Site 2 shows a large proportion of fish from smaller size classes within the YOY cohort (< 57 mm) with a smaller proportion of fish in the larger size classes, indicating good recruitment and survival of young individuals in the population (Figure 5.1-43). Site 3 also shows a large proportion of fish from the YOY cohort with a lower proportion of adult fish, similarly to Site 2 (Figure 5.1-44). Site 4 shows a larger proportion of fish in the YOY cohort relative to fish caught from the adult size class (< 60 mm), consistent with the population at Site 2 (Figure 5.1-45). Site 5 also shows a large proportion of fish from the adult size classes (Figure 5.1-46) relative to the other sites, suggesting greater adult survival/growth or perhaps reduced YOY recruitment (Munkittrick *et al.* 2000).

Growth

Given trout-perch are batch spawners between May and August each year (Magnuson and Smith 1963), there was not one single distinct length-frequency mode across sites within the smaller size ranges (Figure 5.1-42 to Figure 5.1-46). There tended to be several pulses of length-frequency class strength among the smaller size ranges for some sites, while at other sites there was no catch in the small size ranges in summer that corresponded to fall catch results. The most common size range during both summer and fall sampling across all sites was 57-59 mm. The young-of-year (YOY) size cohort was therefore designated as from 12-14 mm (the smallest fish caught) to 57-59 mm (the strongest length-frequency mode, representing the most efficient spawning event). The YOY size class estimate is supported by results from the 2002 Athabasca sentinel species program where aged trout-perch exhibited a YOY size class of 58-60 mm (RAMP 2003), and results from a trout-perch study for Alberta Pacific Forest Industries Inc. Environmental Effects Monitoring Cycle Three Program (Stantec 2004).

YOY growth rate varied from negative growth at Site 5 to 0.36 mm/d at Site 1 (Table 5.1-18). The negative growth at Site 5 could be associated with normal sampling variability (i.e., a higher proportion of fish caught at Site 5 in fall was comprised of YOY fish than in summer) or possibly because growth was limited due to lower water temperatures at this site relative to all other sites (Figure 5.1-41).

The percentage of YOY fish in the captured trout-perch population ranged in summer from 3.8% at Site 1 to 87.2% at Site 3, and in fall from 46% at Site 2 to 97.1% at Site 5 (Table 5.1-19). The percentage of YOY in the captured trout-perch population declined from the summer to the fall season at Site 2 and Site 3, and increased from the summer to the fall season at Sites 1, 4, and 5 (Table 5.1-19).

Condition

Generally, condition factor in fish was higher in the summer at almost all sites (Table 5.1-20, Table 5.1-21, Figure 5.1-47). The significant differences in condition factor among sites and seasons are as follows:

- Condition factor of trout-perch was not statistically different at Site 4 and Site 5 (both *potentially influenced)* relative to fish at Site 2 (*reference*) in both summer and fall (ANCOVA $p > 0.05$);
- Condition factor in fish at Site 3 (*potentially influenced*) was significantly higher than Site 2 (*reference*) in fall (ANCOVA $p < 0.05$), but not significantly different in summer (ANCOVA $p > 0.05$);
- Condition factor was significantly higher at Site 2 relative to Site 1 (ANCOVA $p < 0.05$); and
- Condition factor was significantly higher at Site 4 in summer relative to fall (ANCOVA $p < 0.05$).

Statistical testing could not be performed for all other comparisons because the slopes of the weight-length regressions were significantly different ($p < 0.01$); statistically similar slopes are a pre-requisite for conducting ANCOVA.

Condition factor in fall adult trout-perch in 2007 was compared to 1999 and 2002 (RAMP 2000, RAMP 2003) (Figure 5.1-48)[4]. Adult trout-perch were defined as being greater than 65 mm estimated from lengths of age 1 fish, given that trout-perch spawn as early as 1 year (Nelson and Paetz 1992, Joynt and Sullivan 2003). The results of all the comparisons that were possible (i.e., met the pre-requisite described above for conducting ANCOVA) were:

- Fall condition factor of trout-perch was not significantly different between 2002 and 2007 at Site 1 (ANCOVA $p > 0.05$);
- Fall condition factor was significantly different in 1999 relative to 2002 and 2007 at Site 2 (ANCOVA $p < 0.05$); and
- Fall condition factor was significantly different among all years at Site 3 (ANCOVA $p < 0.05$).

Statistical tests could not be performed for Site 4 and Site 5 given the small sample size of adult fish at these sites in fall 2007.

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[4] The 1999 and 2002 programs were lethal programs and therefore growth was not monitored between seasons. Only sites 2, 3 and 4 were sampled in 1999. In addition, only adult fish condition factor could be statistically compared over time as the 1999 and 2002 programs targeted adult trout-perch.

Discussion

There were numerous differences in measured trout-perch size, growth and condition across all sites and seasons in 2007. Accordingly it was difficult to identify the YOY size class range across sites from the length-frequency distributions, possibly due to varying spawning events between May and August (Nelson and Paetz 1992, Joynt and Sullivan 2003). In an attempt to accurately distinguish the YOY cohort, consideration should be given to sampling before the spawning season to obtain an accurate size range in adult size class before YOY are present in the population.

It was also difficult to determine the most appropriate *reference* site given the influence from the Fort McMurray sewage treatment plant (STP) located between Site 1 and Site 2. In 2002, Site 2 was used as the *reference* site because it provided a more similar chemical environment to the exposure sites (i.e., all four sites were downstream of the STP). However, water quality at two RAMP sites near Donald Creek (ATR-DC-E, ATR-DC-W) located between the STP and Site 2 on the Athabasca River exhibited nutrient concentrations and conductivity similar to water quality sampled upstream of Fort McMurray (ATR-UFM, AENV). Nutrient concentrations were also similar to RAMP water quality sampling sites on the Athabasca near the Muskeg and Firebag rivers. Therefore, water quality data in 2007 indicated that the STP had very little effect on water quality at Site 2, most likely due to dilution (Site 2 is approximately 15 kilometers downstream of the STP). This finding suggests that water quality is not necessarily a suitable criterion to define Site 2 as the more appropriate *reference* site.

More conclusive evidence that Site 2 was a more representative *reference* site was based on physical habitat characteristics. The Athabasca River upstream of Fort McMurray, where Site 1 is located, is comprised predominantly of cobble bars with little fine substrate compared to downstream of Fort McMurray where habitat was predominantly sand and silt with few cobble/boulder areas. Given that differences in habitat could lead to differences in food availability, nutrient enrichment and spawning/rearing habitat, it was more suitable to compare differences in fish survival, growth and condition between Site 2 and sites 3 to 5 instead of Site 1. In order to define the extent of the effects of the STP, consideration should be given to eliminating Site 1 upstream of Fort McMurray and adding a new site between the STP and Site 2 to detect the downstream influence of wastewater form the STP on water quality and resident fish populations like trout-perch.

Impact Analysis

Condition factor can be applied as a measurement endpoint for the sentinel species program. The impact criterion for condition factor defined by Environment Canada (2005) is a ± 10% difference between *potentially influenced* and *reference* sites. A difference greater than 10% indicates a population may be affected by some factor or factors (i.e., ecologically relevant).

Condition factor of YOY trout-perch from the Athabasca River indicated that fish from Site 1 in summer (81%) and Site 3 in fall (28%) were “fatter” than fish at Site 2. Comparatively, condition factor of adult trout-perch from the Athabasca River indicated that fish from Site 5 in summer (12%) were “thinner” than fish at Site 2; mean condition at all sites in fall did not exceed the threshold for adult fish. Given the variability in condition across sites, between seasons and across years (Figure 5.1-47, Figure 5.1-48), it is difficult to assess whether the exceedances in condition factor are due to environmental stressors or natural variability in trout-perch populations.

5.1.5.3 Summary Assessment for the Sentinel Species Program

As outlined in RAMP (2005), the Athabasca River sentinel species program was developed to evaluate both spatial and temporal differences in measurement endpoints between *reference* and *potentially influenced* sites. Results from the 2007 Athabasca River sentinel species program with trout-perch showed some statistical differences in condition between the *reference* and *potentially influenced* sites, but no clear trends in growth, condition and survival between downstream sites and the *reference* site or between seasons and years.

The impact criterion for condition factor defined by Environment Canada (2005) indicated some exceedances of the 10% threshold between Site 2 and the other sites but the direction of change in condition at the *potentially influenced* sites relative to Site 2 is variable with no clear trends (i.e., mean condition is higher at Site 3, similar at Site 4 and lower at Site 5 relative to Site 2).

Based on the results for the Athabasca River sentinel species program, there is little evidence to suggest that characteristics of trout-perch populations between sites (i.e., moving downstream on the Athabasca River), between summer and fall, and between 2007 and historical sampling have changed due to increasing activities from the focal projects and other oil sands developments.

5.1.5.4 Fish Tag Return Assessment

A total of five RAMP Floy tags (indicating capture of five tagged fish) were submitted to Alberta Sustainable Resources Development (ASRD) Fort McMurray office by anglers in 2007. Information provided with each tag return included tag number, species, capture location and date of capture.

Figure 5.1-49 shows the start and finish points, as well as the most direct travel route, for four of the five fish for which tags were returned in 2007 (one record was incomplete). The 2007 tag returns were for walleye (2) and northern pike (3) (Table 5.1-22). A cumulative summary of RAMP tags returned to date is presented in Table 5.1-23 for comparison by species. As in previous years, recaptured walleye in 2007 exhibited the longest overall distance travelled between captures (44 km). In 2007, all recaptured tagged fish were caught in the Clearwater or the Athabasca rivers and were also initially captured in these two rivers. Results to date indicate that, although walleye and northern pike have exhibited an ability to travel long distances (Table 5.1-23), the majority of recaptured individuals have remained and/or return to the area of the Athabasca River downstream of Fort McMurray or to the Clearwater River.

In addition to the angler returns, nine fish (6 walleye, 2 white sucker and 1 northern pike) previously tagged by RAMP were recaptured in the 2007 spring and fall Athabasca River fish inventories.

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 2007 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 2007 than in 2006. It is estimated that focal project activities as of 2007 decreased 2007 mean open-water season discharge by 0.4%, lowered 2007 mean winter discharge by 1.8%, decreased annual maximum daily discharge by 0.18%, and lowered open-water season minimum daily discharge in 2007 by 1.2%. 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.

Based on comparisons of water quality between upstream and downstream stations over time, no effects of local human activities were apparent on water quality in the Athabasca River in 2007.

Benthic invertebrate communities in the ARD were in generally good condition in 2007 with relatively high diversity for a shifting-sand environment and no evidence of undue deleterious effects on ARD benthic invertebrate communities. In addition, results of fall 2007 and historical sediment surveys in the Athabasca River mainstem and ARD do not suggest changes in sediment quality over time, with the exception of a trend toward finer sediments at Fletcher Channel, which may suggest reducing current velocities in this delta reach over the sampling period. In particular, analysis of absolute and carbon-normalized concentrations of total PAHs and total hydrocarbons in sediments indicates that the highest concentrations of PAHs and hydrocarbons in sediments have consistently been measured at the Athabasca river station upstream of Donald Creek, designated as *reference*, with lower concentrations generally observed at other mainstem stations. Concentrations of PAHs and total hydrocarbons in sediments at all locations sampled in the ARD have been generally stable, and one to several orders of magnitude below those observed at the Athabasca river station upstream of Donald Creek. In contrast, concentrations of total arsenic in sediments of the Athabasca River mainstem and the ARD have generally been similar among all stations and across years, with concentrations at all stations typically exhibiting concentrations near the CCME interim sediment-quality guideline (5.9 mg/kg; No longitudinal trends or trends over time are apparent in these data.

As of 2007, current and historical fish inventory data from the Athabasca River indicate species-specific variability in relative abundance, length-frequency distribution, and condition factor. Statistically significant differences were observed between years for condition and length-frequency distributions of the KIR fish species, but there was no clear pattern that would suggest a consistent negative or positive change in the populations (i.e., results likely reflect natural variability).

Results from the 2007 Athabasca River sentinel species program with trout-perch showed some statistical differences in condition between the *reference* and *potentially influenced* sites, but no clear trends in growth, condition and survival between downstream sites and the *reference* site or between seasons and years. Based on the results of this program, there is little evidence to suggest that characteristics of trout-perch populations between sites, between summer and fall, and between 2007 and previous Athabasca River sentinel monitoring programs have changed due to activities from the focal projects and other oil sands developments.

Figure 5.1-2 Athabasca River: 2007 hydrograph and historical context.

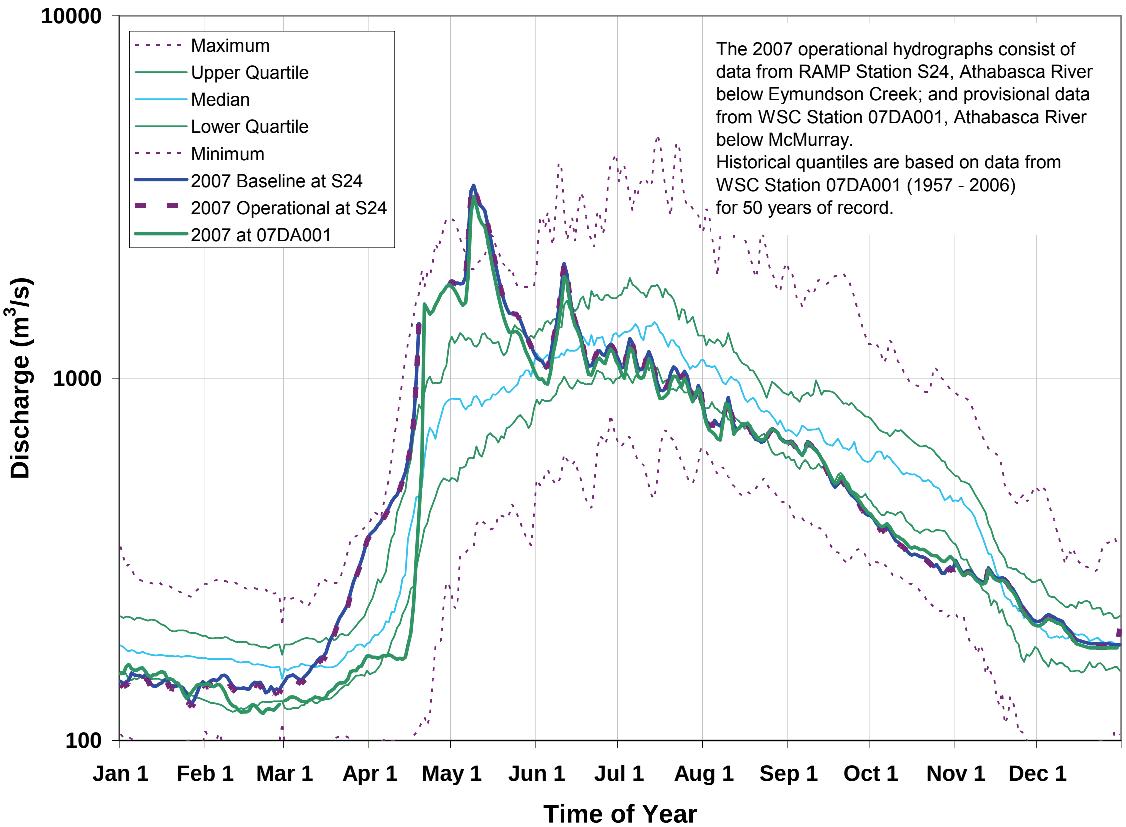


Table 5.1-1 Inputs for calculation of baseline hydrograph at RAMP Station S24, Athabasca River below Eymundson Creek.

Component	Annual Volume (million m^3)		Basis and Data Source
	Focal Projects	Focal Projects Plus All Other Active Oil Sands Projects in RAMP FSA	
Observed hydrograph	19,300	19,300	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 2007	+ 38.7	+ 38.7	266 km^2 within drainages of minor Athabasca River tributaries from Fort McMurray to RAMP station S24 estimated to have been closed-circuited as of 2007 (Table 2.4-1). This includes the McLean Creek and upper Beaver River[1] drainages.
Incremental runoff from areas of land change that are not closed-circuited	- 2.61	- 2.61	98.2 km^2 within drainages of minor Athabasca River tributaries from Fort McMurray to RAMP station S24 estimated to have undergone land change as of 2007, but are not closed-circuited (Table 2.4-1). This includes the McLean Creek and upper Beaver River drainages.
Withdrawals from the Athabasca River by focal project activities	+ 92.4 (total)	+ 92.4 (total)	
	+ 43.6	+ 43.6	Withdrawals by Suncor (annual total[1], Section 2.2)
	+ 36.0	+ 36.0	Withdrawals by Syncrude (monthly values[1], Section 2.2)
	+ 5.71	+ 5.71	Withdrawals by Albian (daily values, Section 2.2)
	+ 7.03	+ 7.03	Withdrawals by CNRL (daily values, Section 2.2)
	+ 0.078	+ 0.078	Withdrawals by Fort Hills (daily values, Section 2.2)
Releases to the Athabasca River by focal project activities	- 0.334	- 0.334	Releases by Syncrude (monthly values[1], Section 2.2)
The difference between operational and baseline hydrographs on tributary streams	- 0.86	- 1.58	Net sum of results of hydrologic analyses from major Athabasca River tributaries (Christina, Ells, Firebag, Fort, Hangingstone, MacKay, Muskeg, Steepbank, and Tar).
Baseline hydrograph (total annual discharge)	19,400	19,400	Estimated baseline flow for 2007.
Incremental flow (change in total annual discharge)	- 127	- 126	Difference in total flow between operational and baseline hydrograph.
Incremental flow (% of observed total annual discharge)	-0.66%	-0.65%	Incremental flow as a percentage of total annual discharge of estimated baseline hydrograph.

[1] Annual or monthly 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	1010	1000	-0.45%
Mean winter discharge	191	187	-1.8%
Annual maximum daily discharge	3410	3400	-0.23%
Open-water season minimum daily discharge	290	286	-1.3%

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	1010	1000	-0.45%
Mean winter discharge	191	187	-1.8%
Annual maximum daily discharge	3410	3400	-0.23%
Open-water season minimum daily discharge	290	286	-1.3%

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 2007.

Measurement Endpoint	Units	Guideline	Upstream of Fort McMurray (ATR-UFM) Fall AENV data, 1976-2006				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	49	7.3	8.1	8.4	8.2	8.3	8.3	8.2	8.3	8.2	8.3	8.3	8.3	8.3
Total suspended solids	mg/L	-	45	1	14.4	344	21	15	10	23	41	28	50	38	28	10
Conductivity	µS/cm	-	46	150	279.5	446	256	282	293	264	300	269	281	267	275	275
Nutrients																
Total dissolved phosphorus	mg/L	0.05[2]	32	0.003	0.00563	0.025	0.016	0.006	0.006	0.01	0.009	0.009	0.009	0.01	0.01	0.007
Total nitrogen*	mg/L	1.0	41	0.133	0.393	**1.903**	0.6	0.6	0.7	0.5	0.5	0.5	0.4	0.5	0.5	0.5
Nitrate+nitrite	mg/L	-	50	<0.001	0.0035	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	12	9	8	9	8	9	9	11	11	9
Ions																
Sodium	mg/L	-	47	4	8.9	20	17	10	9	12	9	11	11	12	13	11
Calcium	mg/L	-	50	19.4	34.9	50.5	22.1	32.5	34.8	30.7	34.8	29.9	33.1	32.1	33.5	31.1
Magnesium	mg/L	-	48	5.4	9.25	14.2	6.8	9.1	9.6	8	11.2	7.6	10.1	9.2	9.7	7.5
Chloride	mg/L	230, 860[3]	50	<1	2.55	7.2	20	5	2	8	3	7	6	7	7	8
Sulphate	mg/L	100[4]	49	13	29	53.1	10.1	25.2	28.6	22.1	39.2	21.7	30.7	24.3	25.6	22.9
Total dissolved solids	mg/L	-	41	109	170	263	156	168	172	164	184	158	155	160	170	174
Total alkalinity	mg/L		50	64.3	118	176	86	112	111	97	104	100	103	102	110	103
Organic compounds																
Naphthenic acids	mg/L	-	-	-	-	-	<1	<1	<1	<1	<1	<1	2	<1	<1	<1
Selected metals																
Total aluminum	mg/L	0.1	10	0.07	**0.34**	**1.29**	**0.791**	**0.553**	**0.566**	**0.836**	**1.01**	**0.988**	**1.57**	**1.58**	**1.02**	**0.482**
Total arsenic	mg/L	0.005	-	-	-	-	0.00082	0.000726	0.00066	0.00079	0.00085	0.00085	0.00105	0.00099	0.00087	0.0007
Dissolved aluminum	mg/L	0.1[2]	7	0.004	0.00976	0.02	0.00868	0.0143	0.0165	0.0112	0.0115	0.0116	0.0147	0.0109	0.0116	0.00949
Total boron	mg/L	1.2[5]	9	0.01	0.0261	0.04	0.0284	0.0193	0.0196	0.0214	0.0267	0.0225	0.0206	0.0227	0.0251	0.0201
Total molybdenum	mg/L	0.073	17	0.00066	0.001	0.018	0.00032	0.00067	0.0007	0.00053	0.00066	0.00055	0.00058	0.00059	0.00071	0.000608
Total mercury (ultra-trace)	ng/L	5, 13[6]	3	0.6	0.6	2.4	<1.2	<1.2	<1.2	<1.2	2.7	<1.2	3.2	<1.2	1.4	2.3
Total strontium	mg/L	-	2	0.22	0.2555	0.291	0.129	0.221	0.233	0.181	0.214	0.192	0.201	0.187	0.194	0.203

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).

Table 5.1-5 List of water quality guideline exceedances in the Athabasca River mainstem, downstream of development (ATR-DD), 2007.

Water Quality Variable	Units	Guideline*	ATR-DD-E	ATR-DD-W
Winter				
Total aluminum	mg/L	0.1	**-**	**0.109**
Total iron	mg/L	0.3	**0.42**	**0.44**
Spring				
Total phenolics	mg/L	0.005	**0.007**	**-**
Phosphorus, Total	mg/L	0.05	**0.402**	**0.315**
Dissolved copper	mg/L	-[3]	**-**	**0.00222**
Total Kjeldahl Nitrogen	mg/L	1.0	**-**	**1.1**
Total nitrogen	mg/L	1.0	**-**	**1.2**
Total aluminum	mg/L	0.1	**9.24**	**7.74**
Total cadmium	mg/L	-[3]	**0.00018**	**0.000123**
Total copper	mg/L	-[3]	**0.00866**	**0.00799**
Total iron	mg/L	0.3	**9.77**	**8.02**
Total lead	mg/L	-[3]	**-**	**0.00511**
Total titanium	mg/L	0.100	**0.111**	**-**
Total mercury (ultra-trace)	ng/L	13	**16**	**19**
Summer				
Total Aluminum	mg/L	0.1	**1.78**	**1.67**
Total iron	mg/L	0.3	**1.64**	**1.45**
Total cadmium	mg/L	-[3]	**0.0000282**	**0.0000247**
Total phosphorus	mg/L	0.05	**0.054**	**0.051**
Fall				
Total Aluminum	mg/L	0.1	**1.58**	**1.02**
Total iron	mg/L	0.3	**1.63**	**1.08**

ns = not sampled

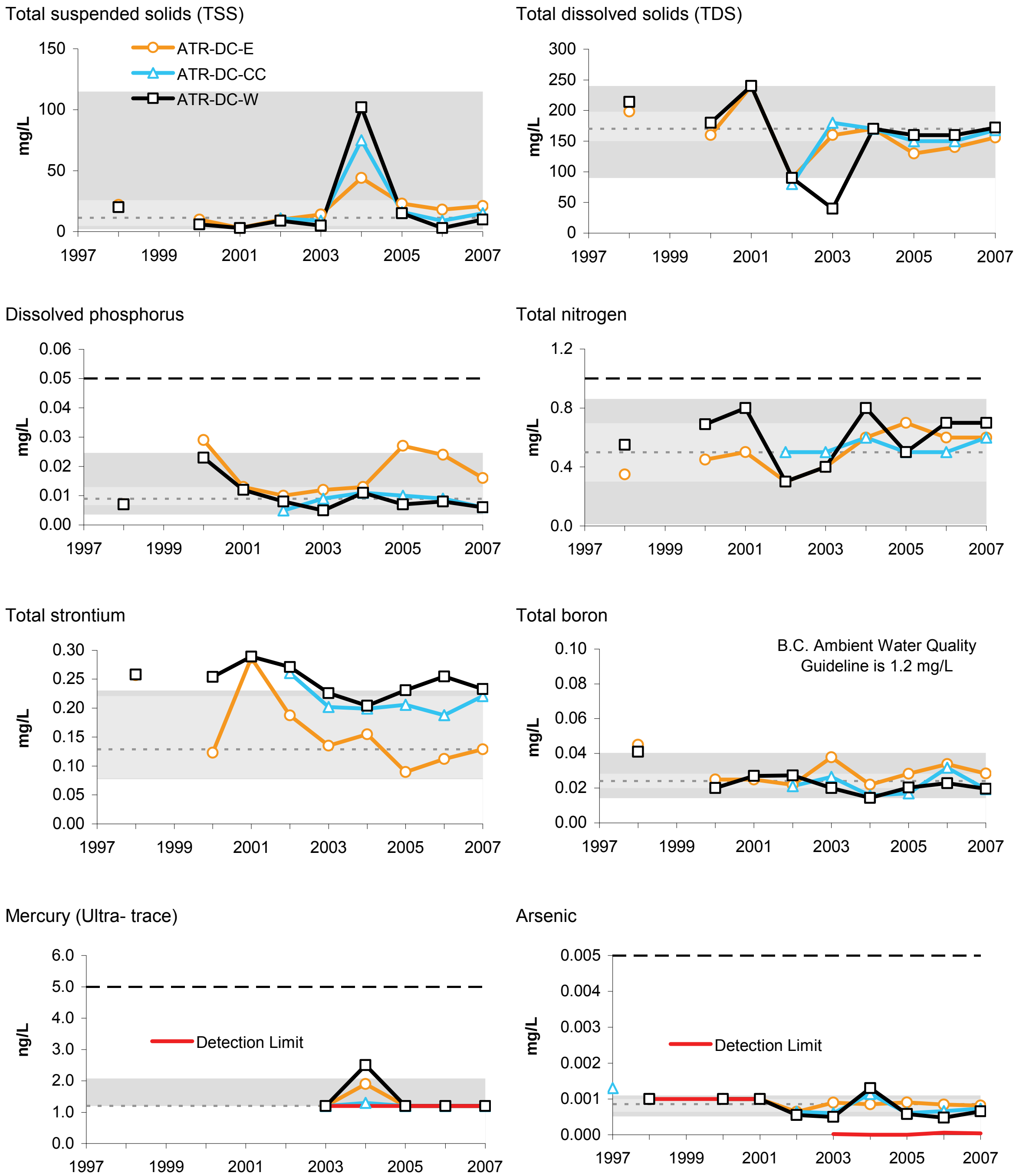
* Guidelines are CCME (2006) or AENV (1999) unless otherwise noted.

[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.

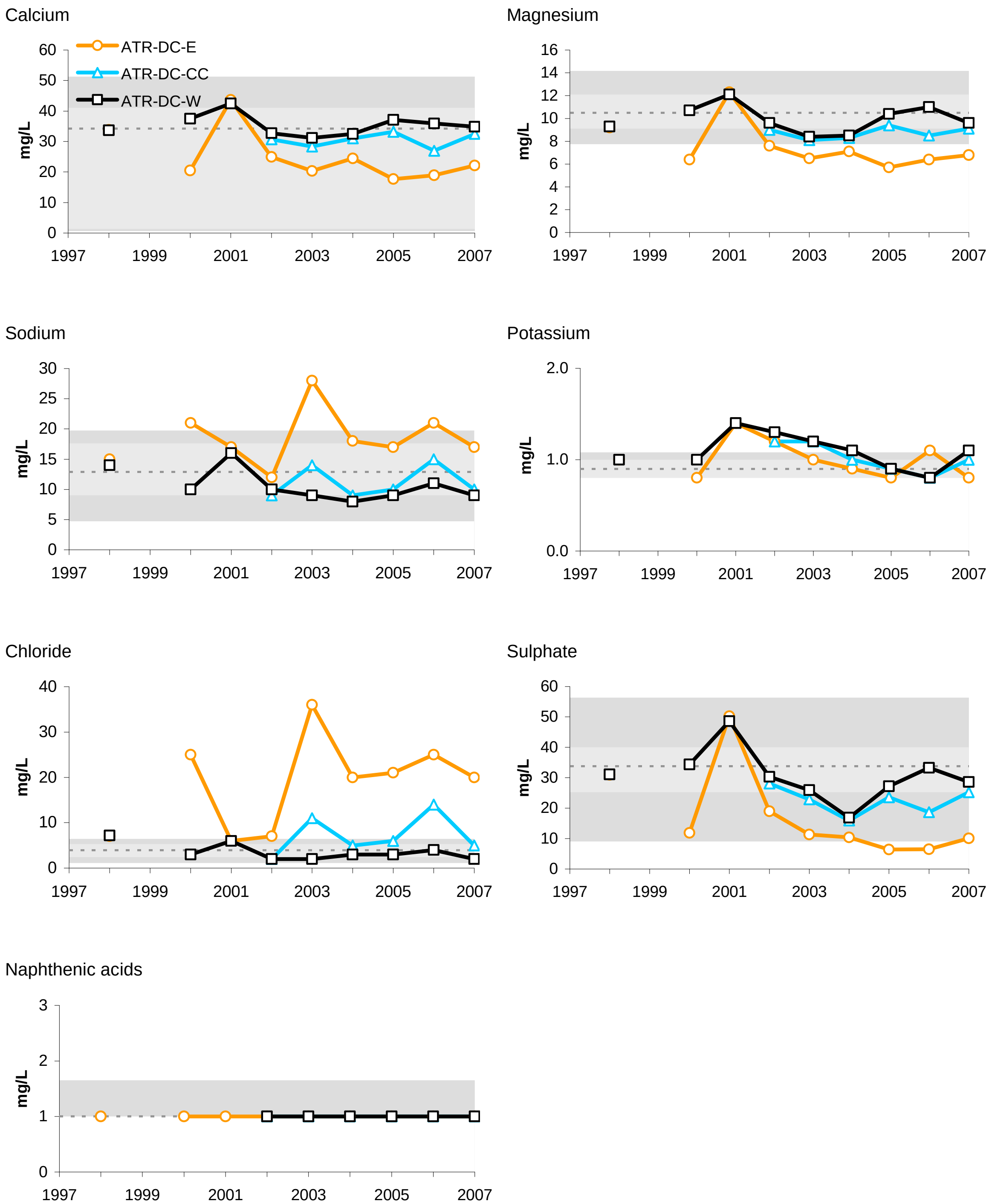
Figure 5.1-3 Concentrations of selected water quality measurement endpoints (fall data) relative to regional baseline fall concentrations, Athabasca River mainstem, upstream of Donald Creek (ATR-DC).



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.

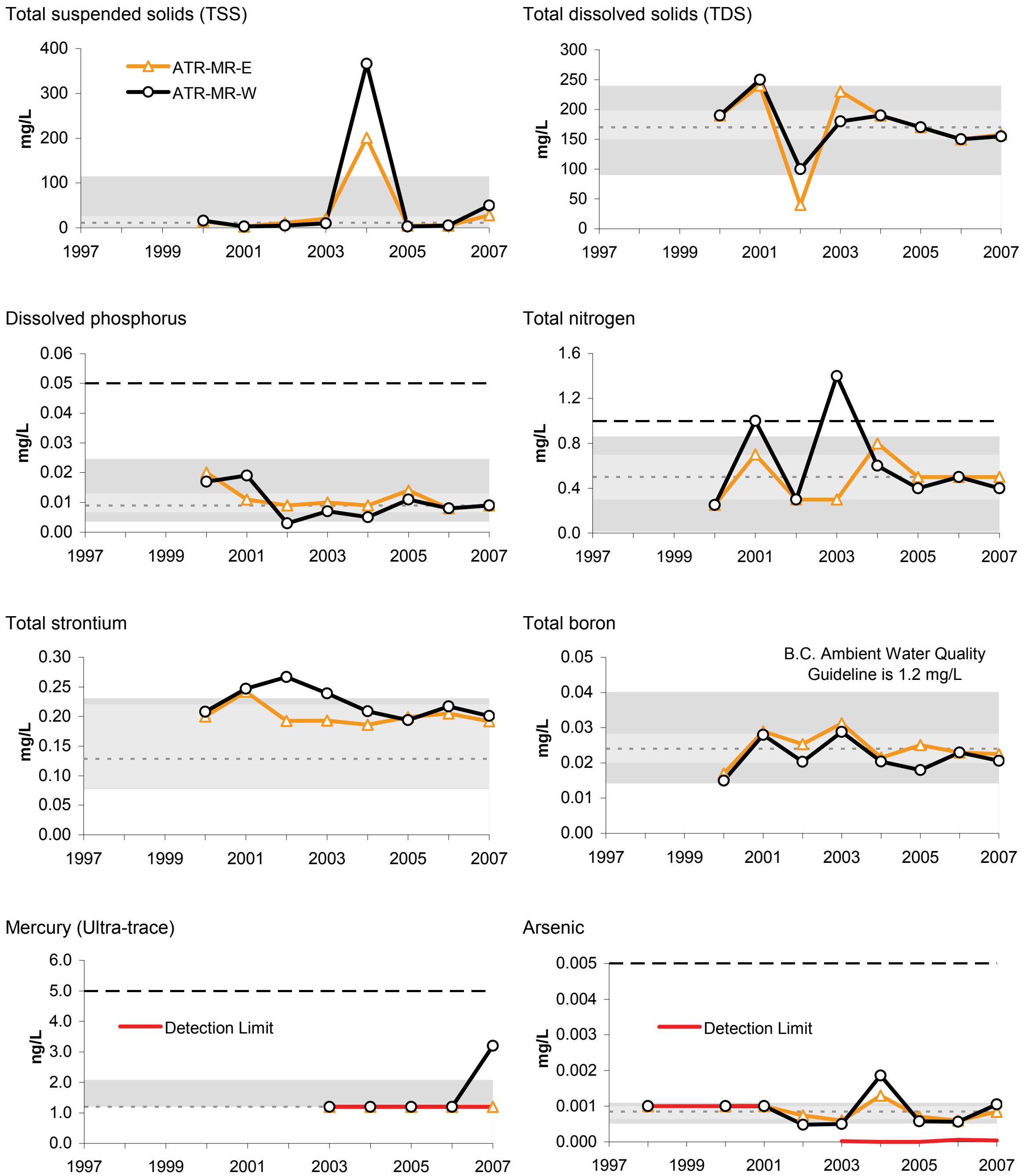
Regional baseline values reflect pooled results for all baseline stations with similar water quality, from all years of RAMP sampling. See Section 3.2.7 for a discussion of this approach, and Appendix D for these regional baseline ranges.

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.

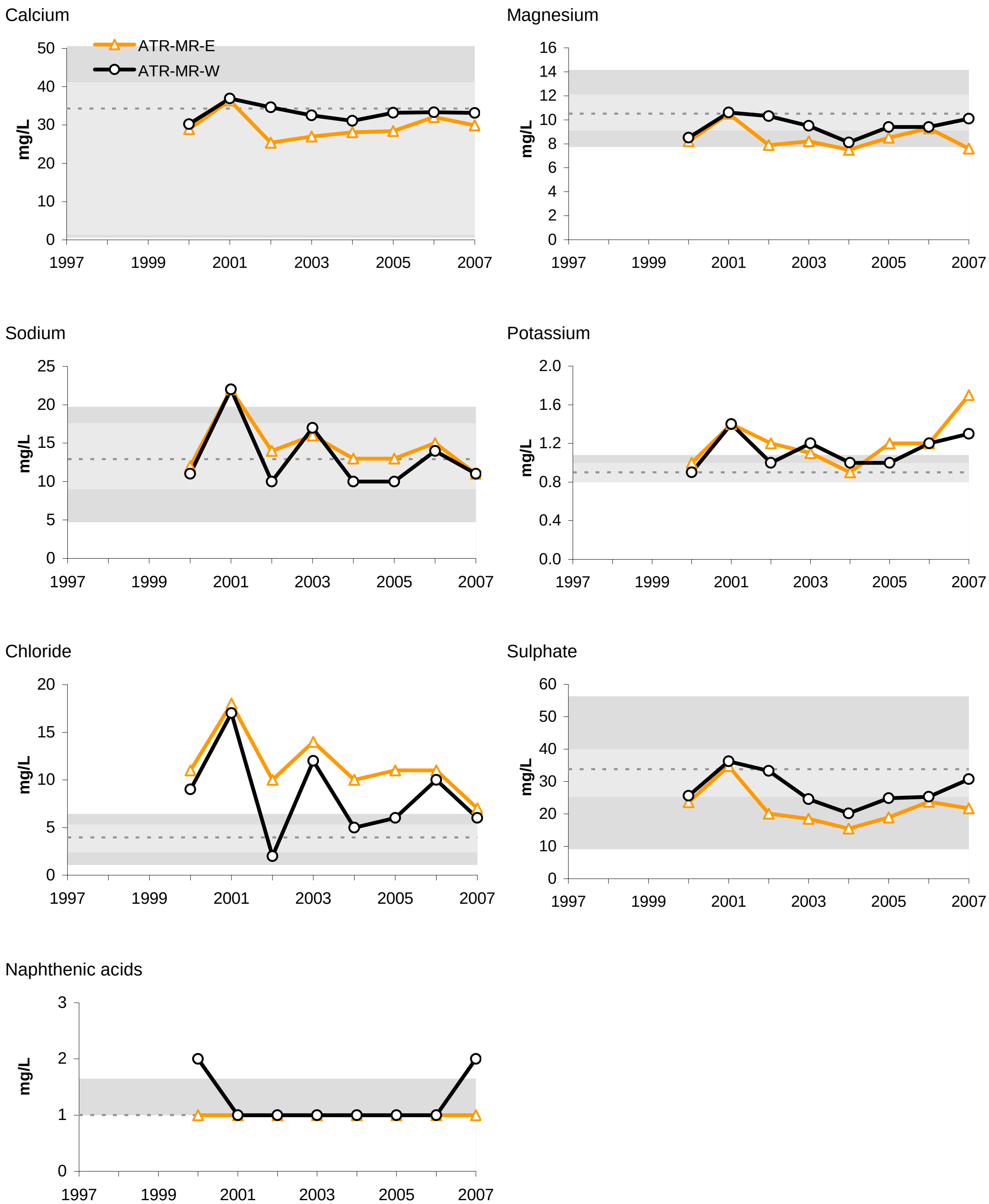
Figure 5.1-5 Concentrations of selected water quality measurement endpoints (fall data) relative to regional baseline fall concentrations, Athabasca River mainstem, upstream of the Muskeg River (ATR-MR).



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.

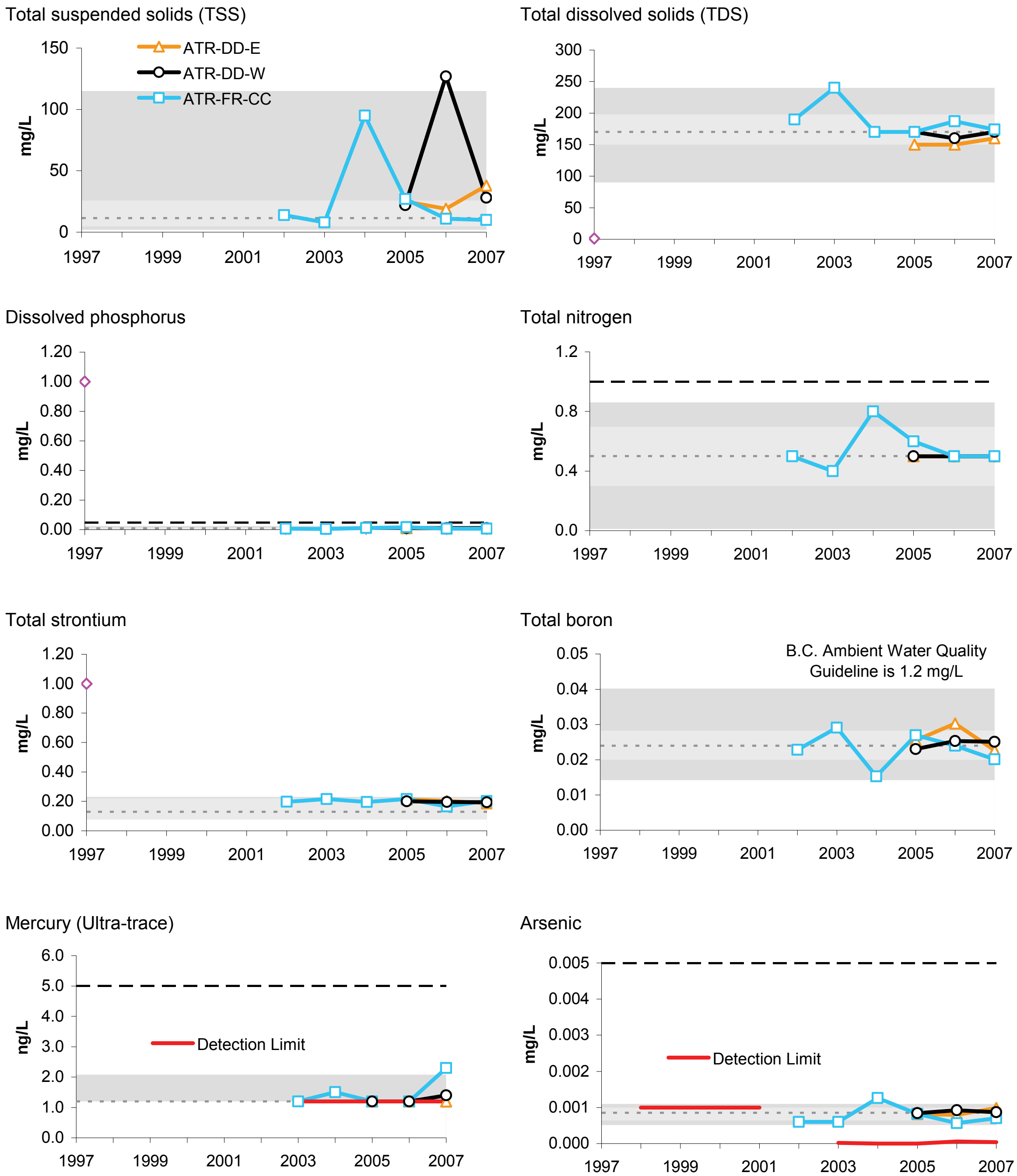
Figure 5.1-5 (Cont'd.)



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.

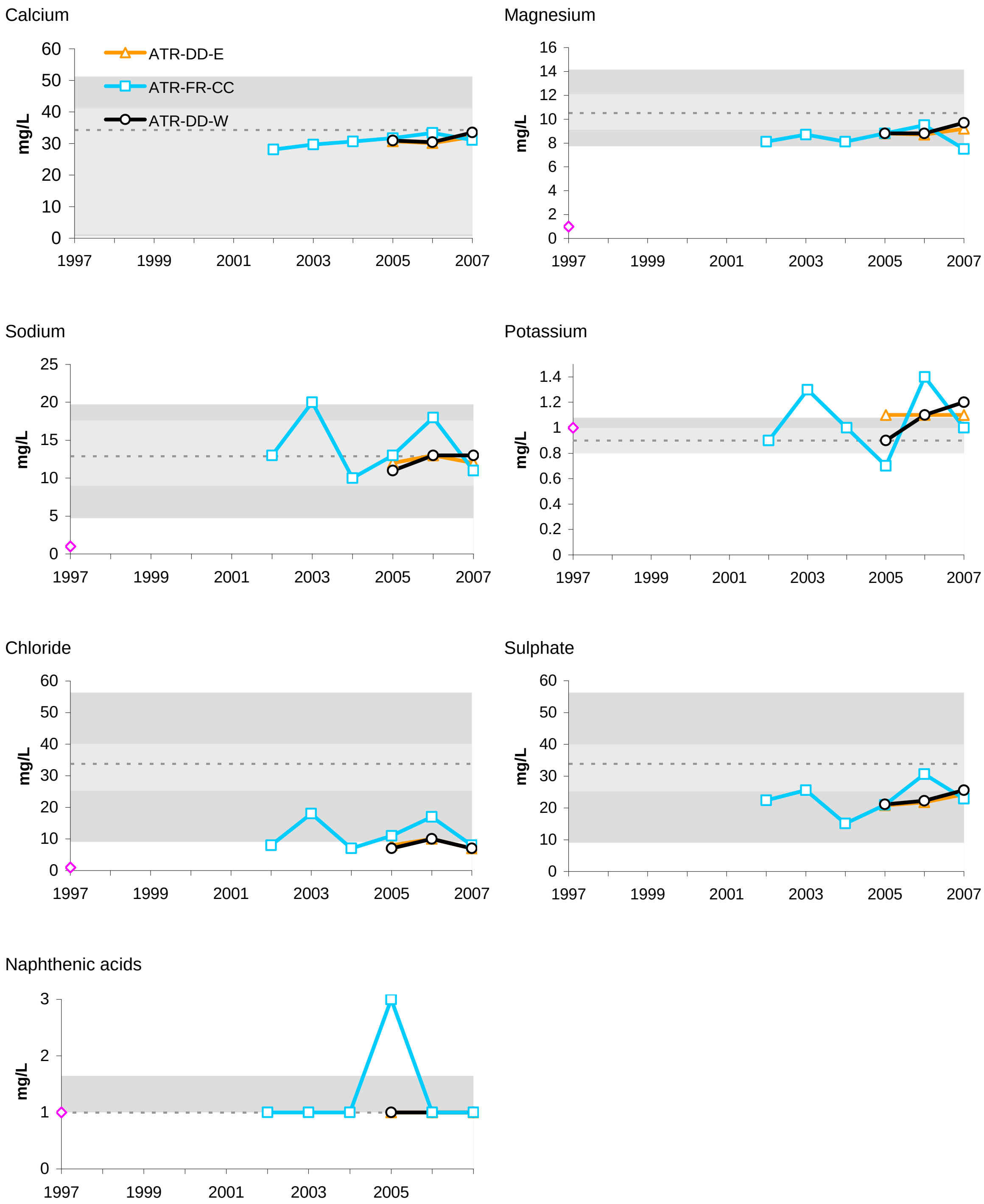
Figure 5.1-6 Concentrations of selected water quality measurement endpoints (fall data) relative to regional baseline fall concentrations, Athabasca River mainstem, downstream of development (ATR-DD) and upstream of the Firebag River (ATR-FR).



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.

Figure 5.1-7 Piper diagram of ion concentrations in Athabasca River mainstem, fall 1997 to 2007.

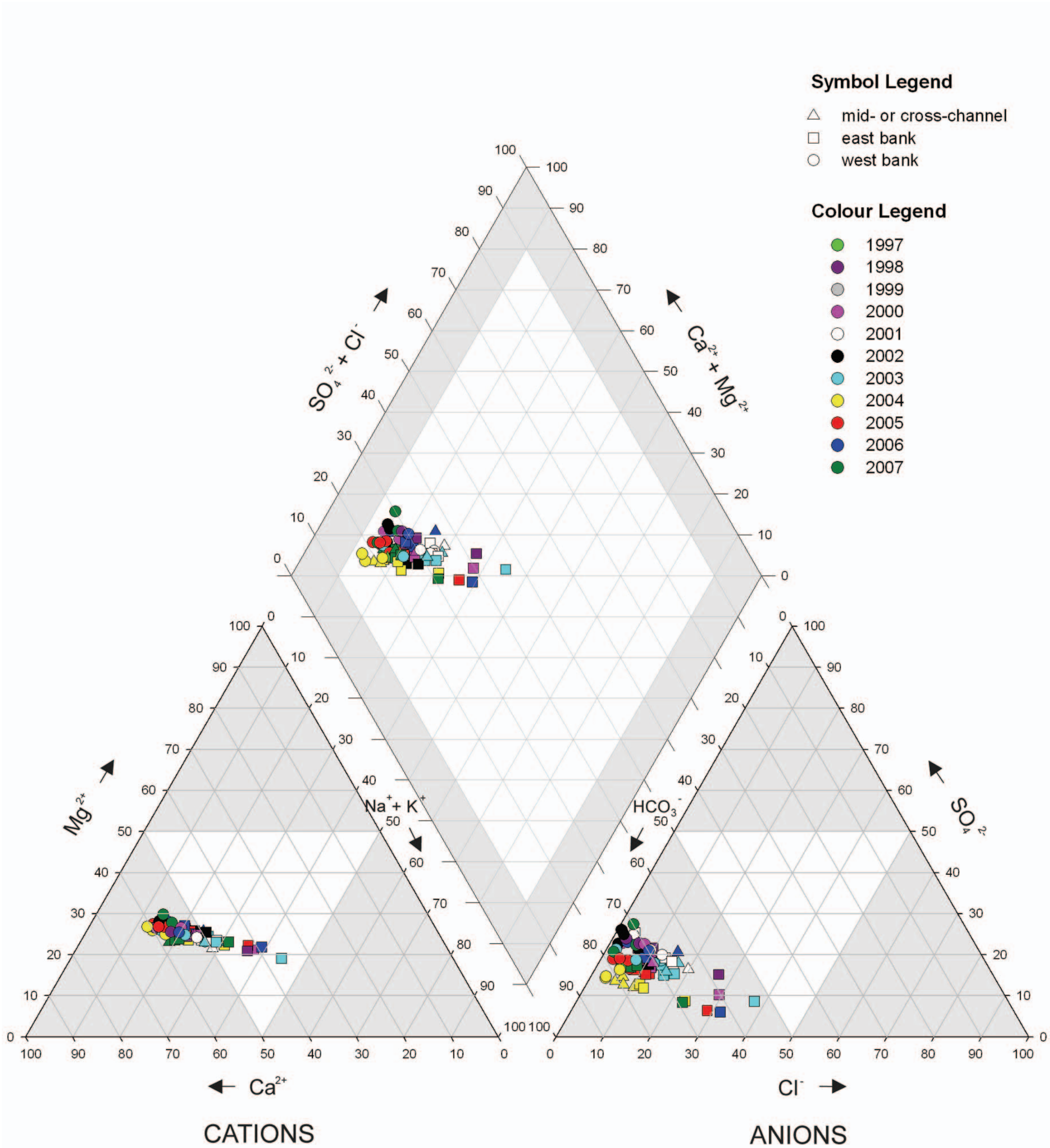


Figure 5.1-8 Water quality measurement endpoints, 1997 to 2007 AENV data for the Athabasca River mainstem.

pH

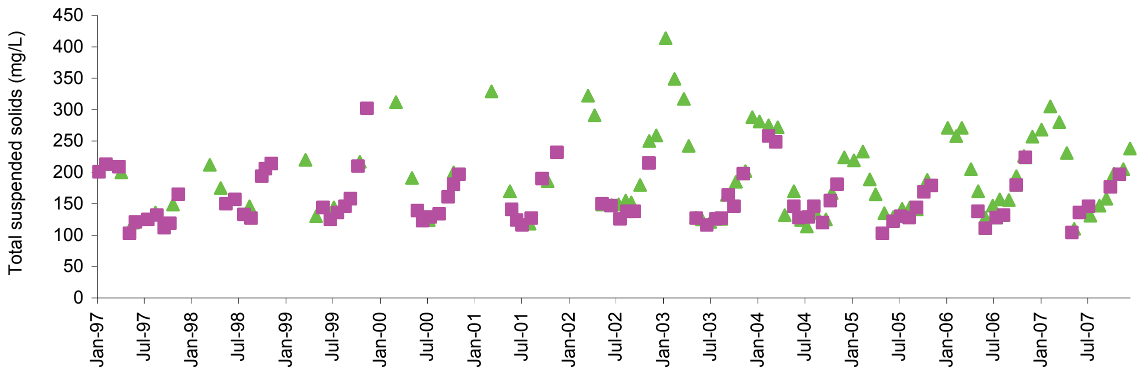
Trend at ATR-UFM: up

Trend at ATR-OF: up

Total dissolved solids

Trend at ATR-UFM: none

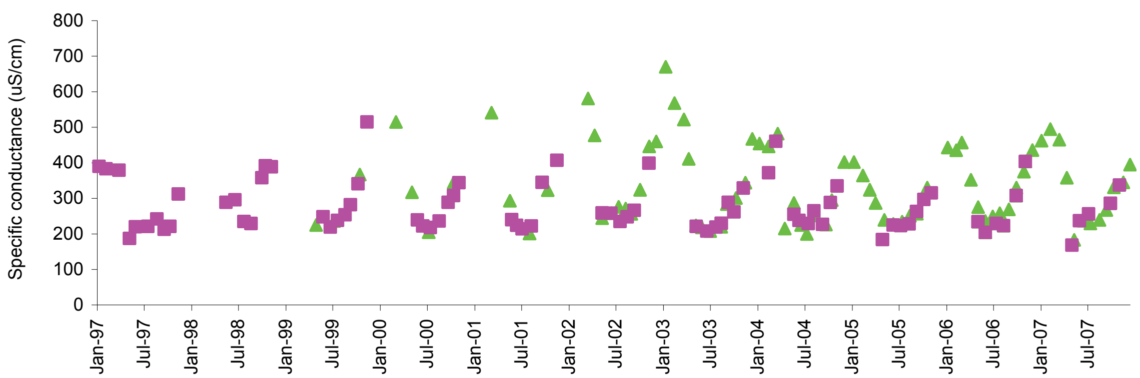
Trend at ATR-OF: none



Specific conductance

Trend at ATR-UFM: none

Trend at ATR-OF: none

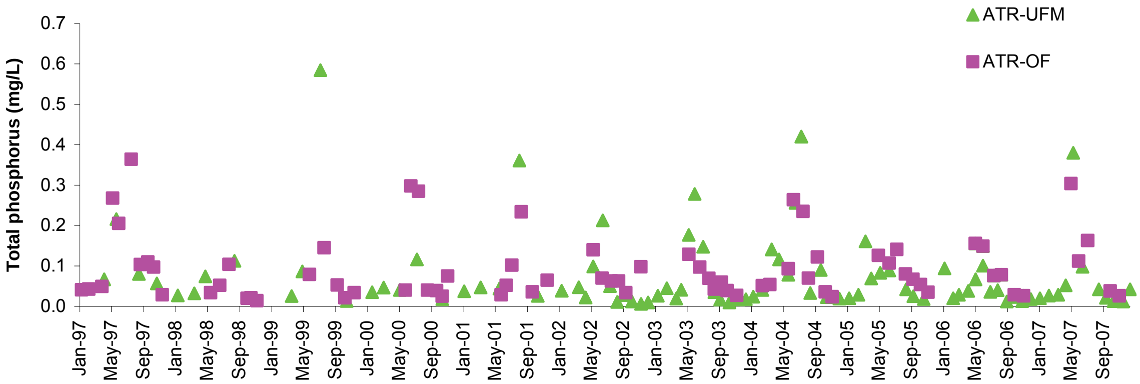


Non-detectable results are shown at the detection limit.

Figure 5.1-8 (Cont'd.)

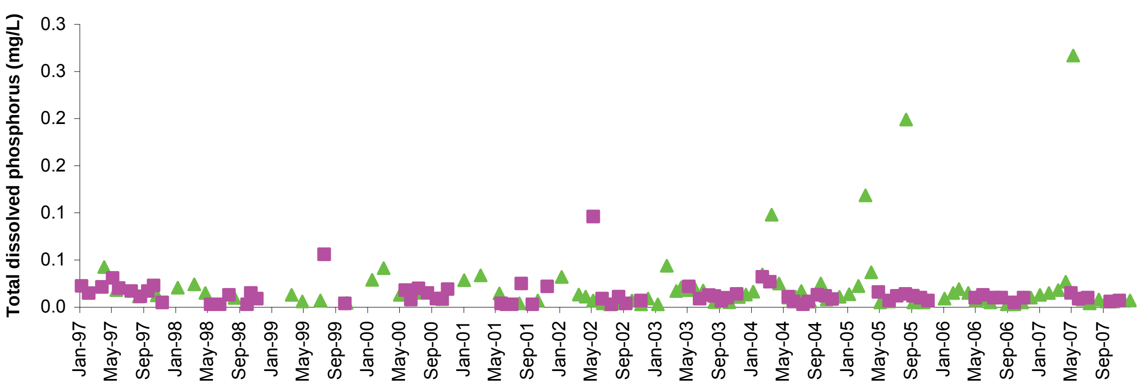
Total phosphorus

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



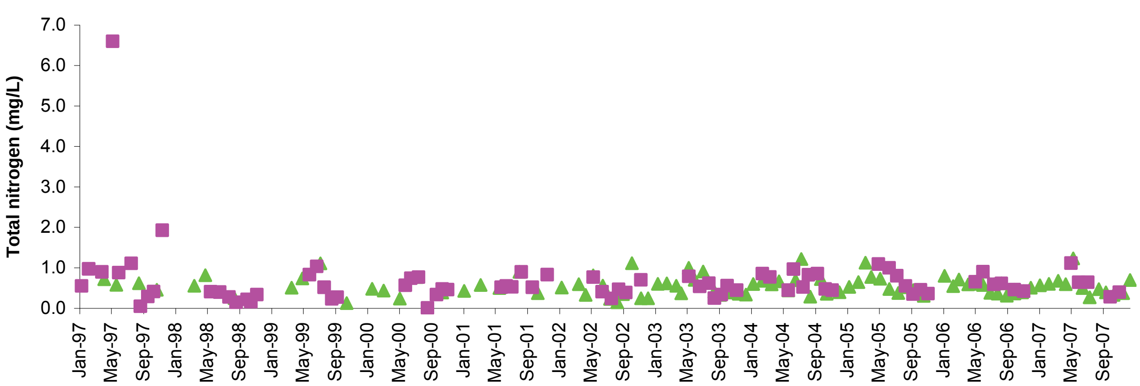
Total dissolved phosphorus

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



Total nitrogen

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

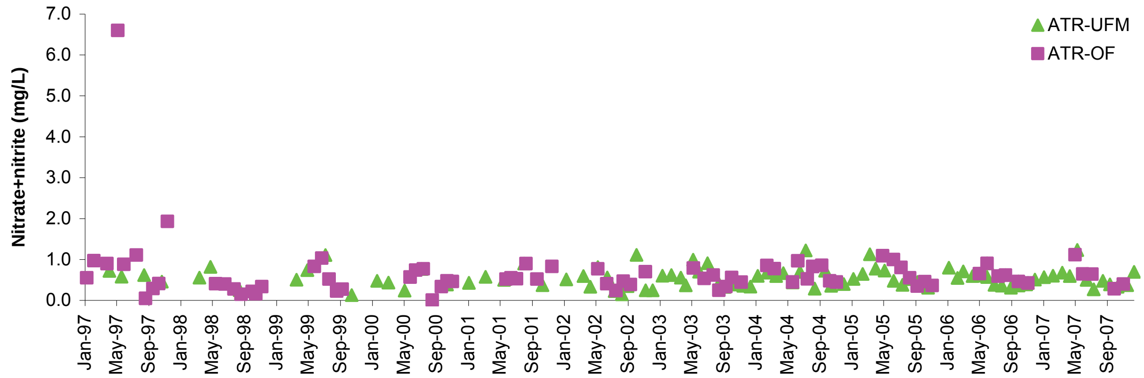


Non-detectable values are shown at the detection limit.

Figure 5.1-8 (Cont'd.)

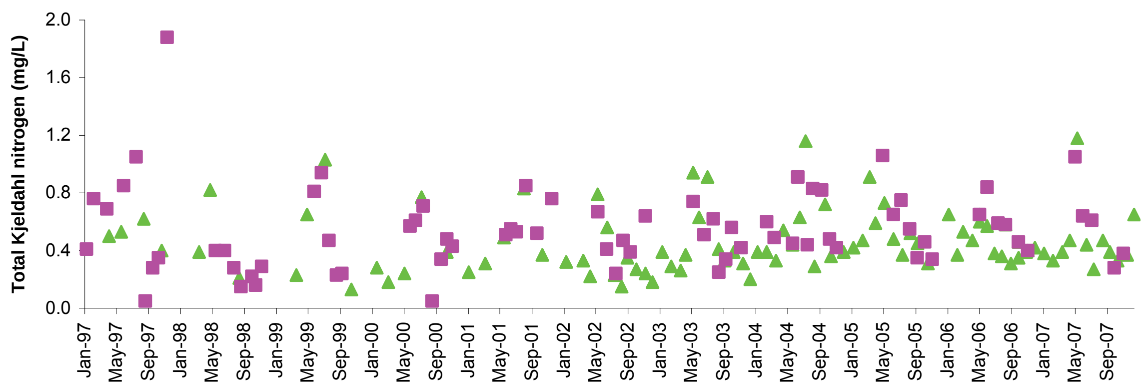
Nitrate + Nitrite

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



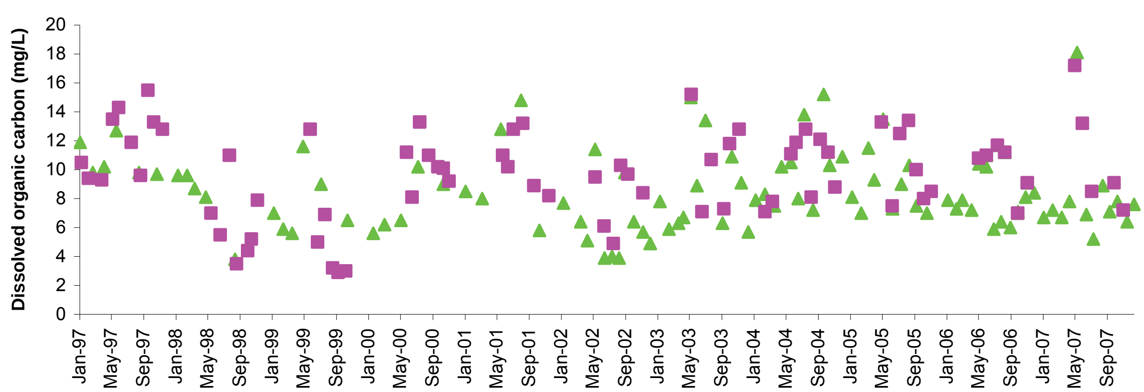
Total Kjeldahl nitrogen

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



Dissolved organic carbon

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

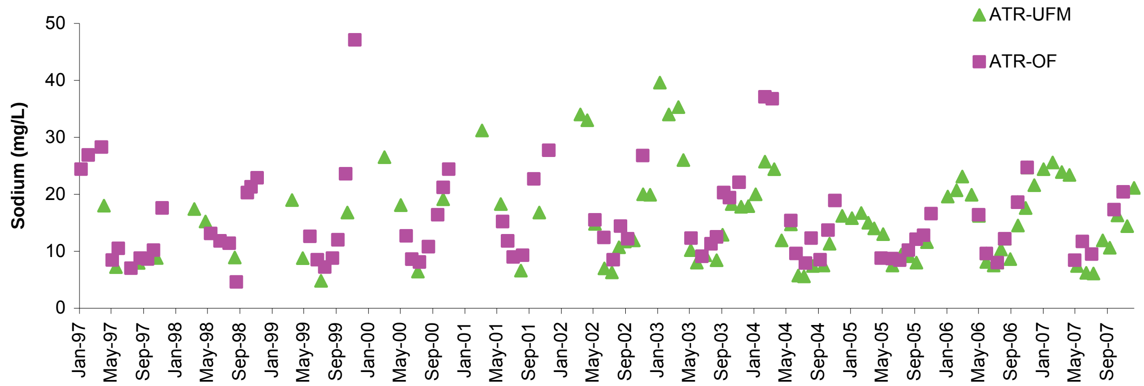


Non-detectable values are shown at the detection limit.

Figure 5.1-8 (Cont'd.)

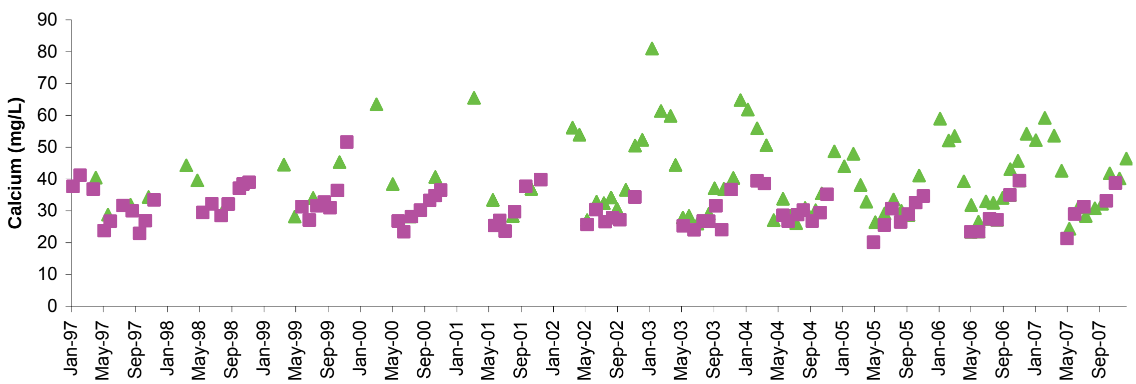
Sodium

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



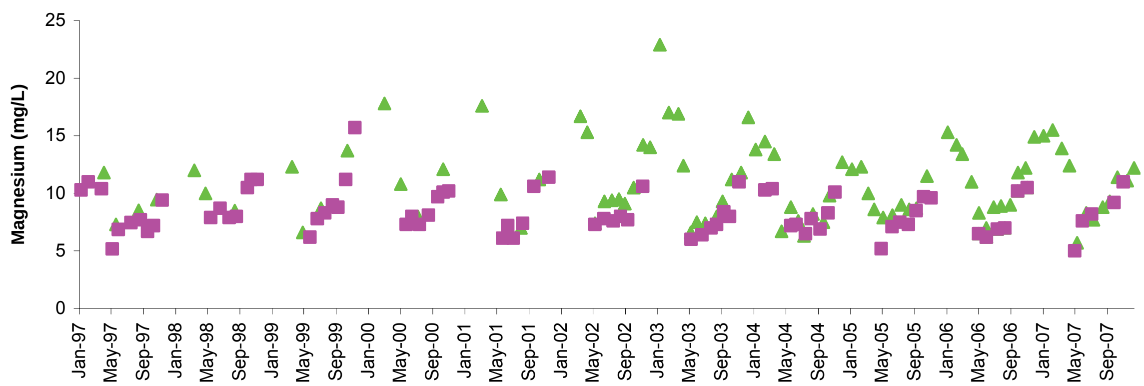
Calcium

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



Magnesium

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



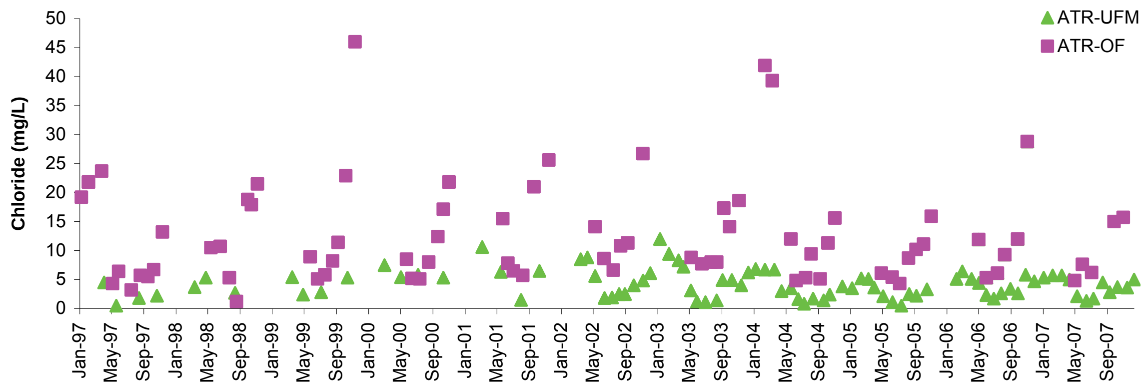
Non-detectable values are shown at the detection limit.

Figure 5.1-8 (Cont'd.)

Chloride

Trend at ATR-UFM: down

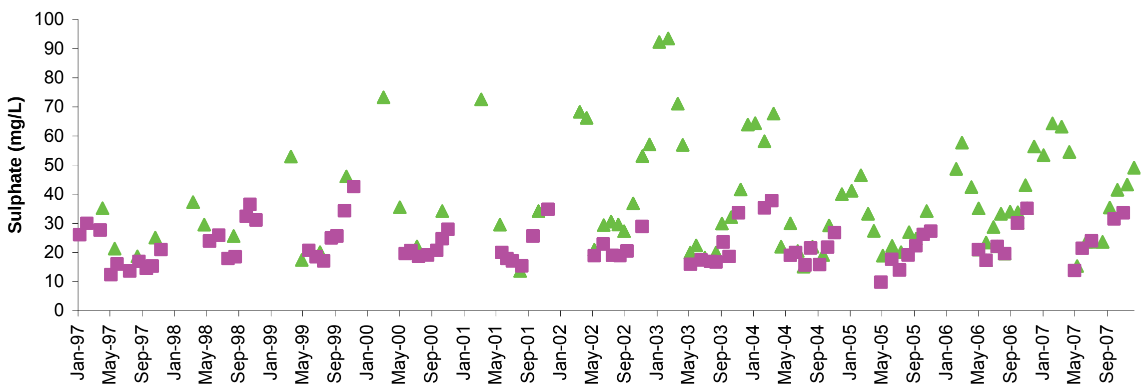
Trend at ATR-OF: none



Sulphate

Trend at ATR-UFM: none

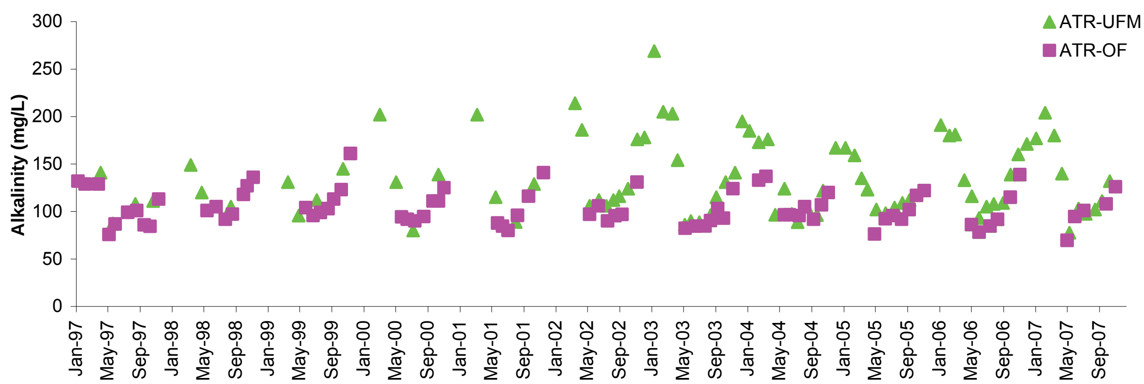
Trend at ATR-OF: none



Alkalinity (as $CaCO_3$)

Trend at ATR-UFM: none

Trend at ATR-OF: none

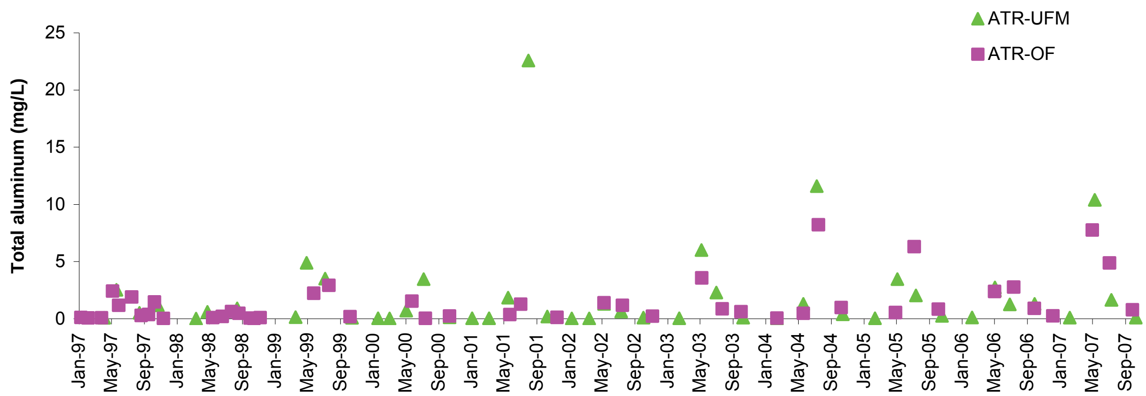


Non-detectable values are shown at the detection limit.

Figure 5.1-8 (Cont'd.)

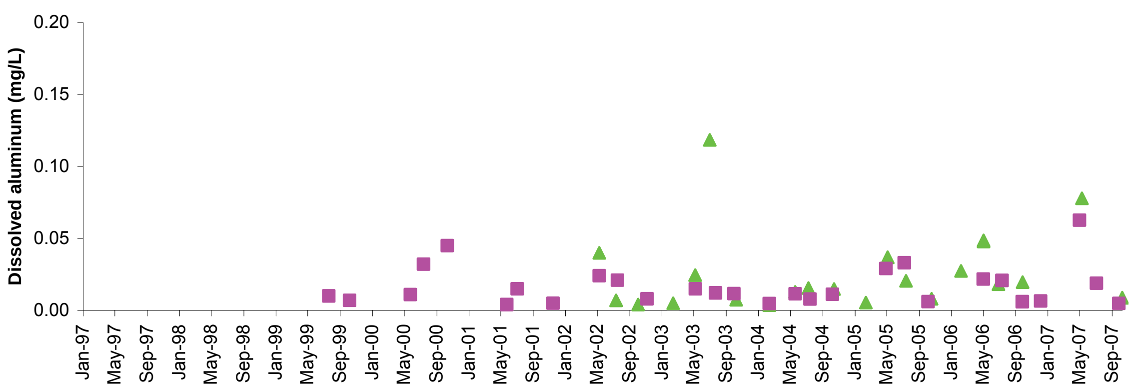
Total aluminum

Trend at ATR-UFM: up   Trend at ATR-OF: up



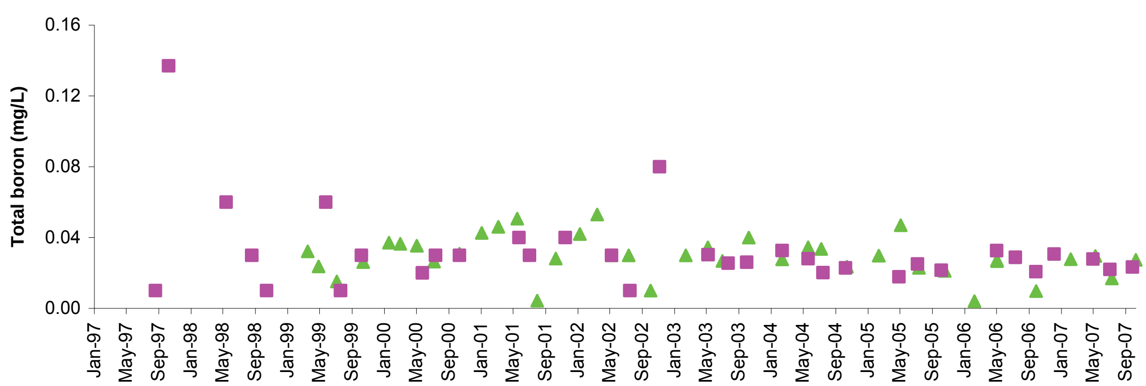
Dissolved aluminum

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



Total boron

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

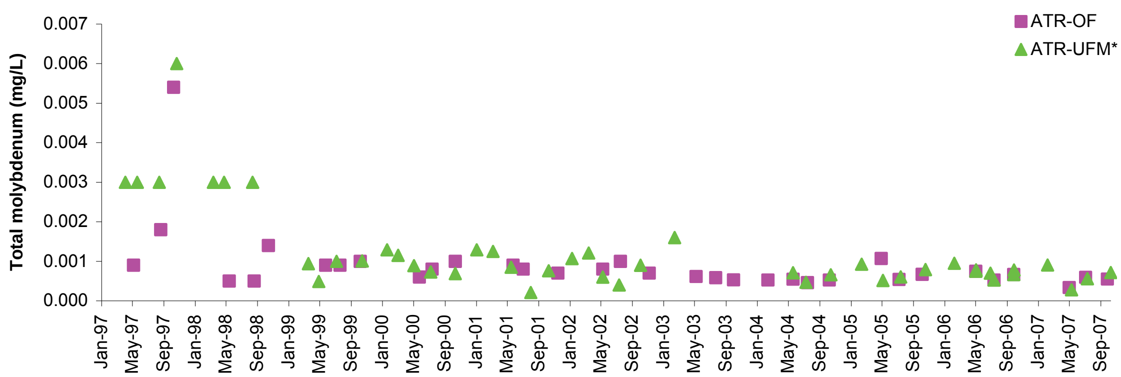


Non-detectable values are shown at the detection limit.

Figure 5.1-8 (Cont'd.)

Total molybdenum

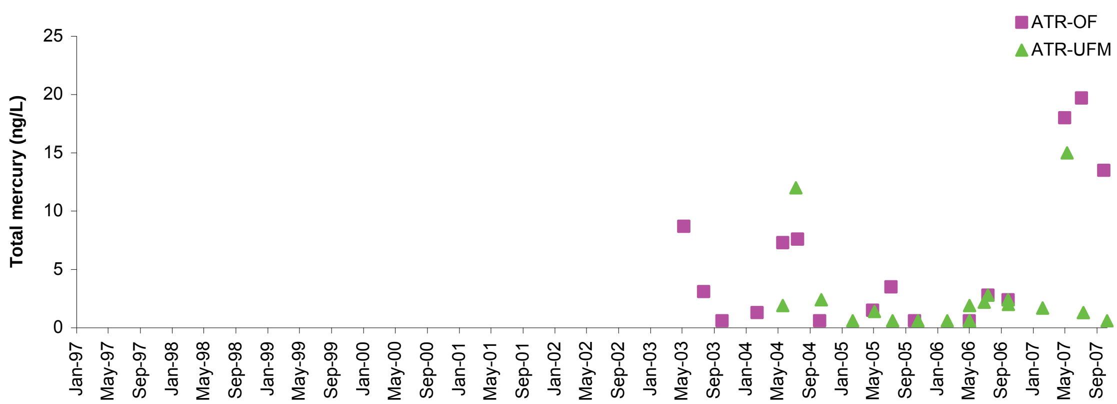
Trend at ATR-UFM: none		Trend at ATR-OF: down



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

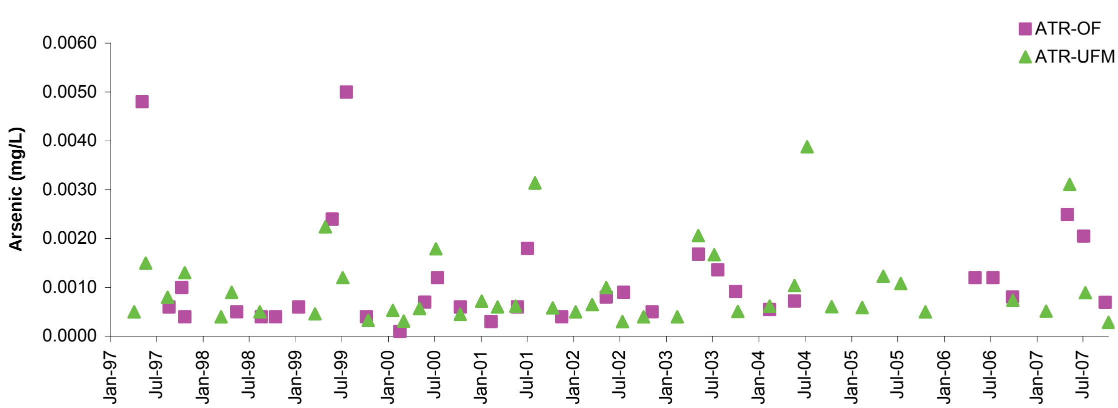
Total mercury (ultra-trace)

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



Total Arsenic

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



Non-detectable values are shown at the detection limit.

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

AENV Analyte	Units	Upstream of Fort McMurray 1997 - 2007 (station ATR-UFM)			At Old Fort 1997 - 2007 (station ATR-OF)		
		n	Trend Direction	Slope Estimate[1] (units per year)	n	Trend Direction	Slope Estimate[1] (units per year)
Physical variables							
pH	pH units	86	up	0.0246	82	up	0.0500
Specific conductance	μS/cm	78	-	-	82	-	-
Nutrients							
Total phosphorus	mg/L	88	-	-	79	-	-
Total dissolved phosphorus	mg/L	89	-	-	76	-	-
Total nitrogen	mg/L	89	-	-	80	-	-
Nitrate+nitrite	mg/L	89	-	-	81	-	-
Total Kjeldahl nitrogen	mg/L	89	up	0.0133	79	-	-
Dissolved organic carbon	mg/L	94	-	-	80	-	-
Ions							
Sodium	mg/L	86	-	-	82	-	-
Calcium	mg/L	86	-	-	82	-	-
Magnesium	mg/L	86	-	-	82	-	-
Chloride	mg/L	85	down	-0.1556	82	-	-
Sulphate	mg/L	85	-	-	82	-	-
Total dissolved solids (calculated)	mg/L	86	-	-	82	-	-
Alkalinity (as $CaCO_3$)	mg/L	86	-	-	82	-	-
Selected metals							
Total aluminum	mg/L	47	up	0.0120	47	up	0.0871
Dissolved aluminum[1]	mg/L	21	-	-	29[2]	-	-
Total boron	mg/L	40	-	-	35[2]	-	-
Total molybdenum	mg/L	35*	-	-	36[2]	down	0.0000
Total mercury (ultra-trace)	mg/L	15[2]	-	-	17[2]	-	-

Critical value at 95% confidence level = 1.960.

* Trend analyzed from 1999 to 2007 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.

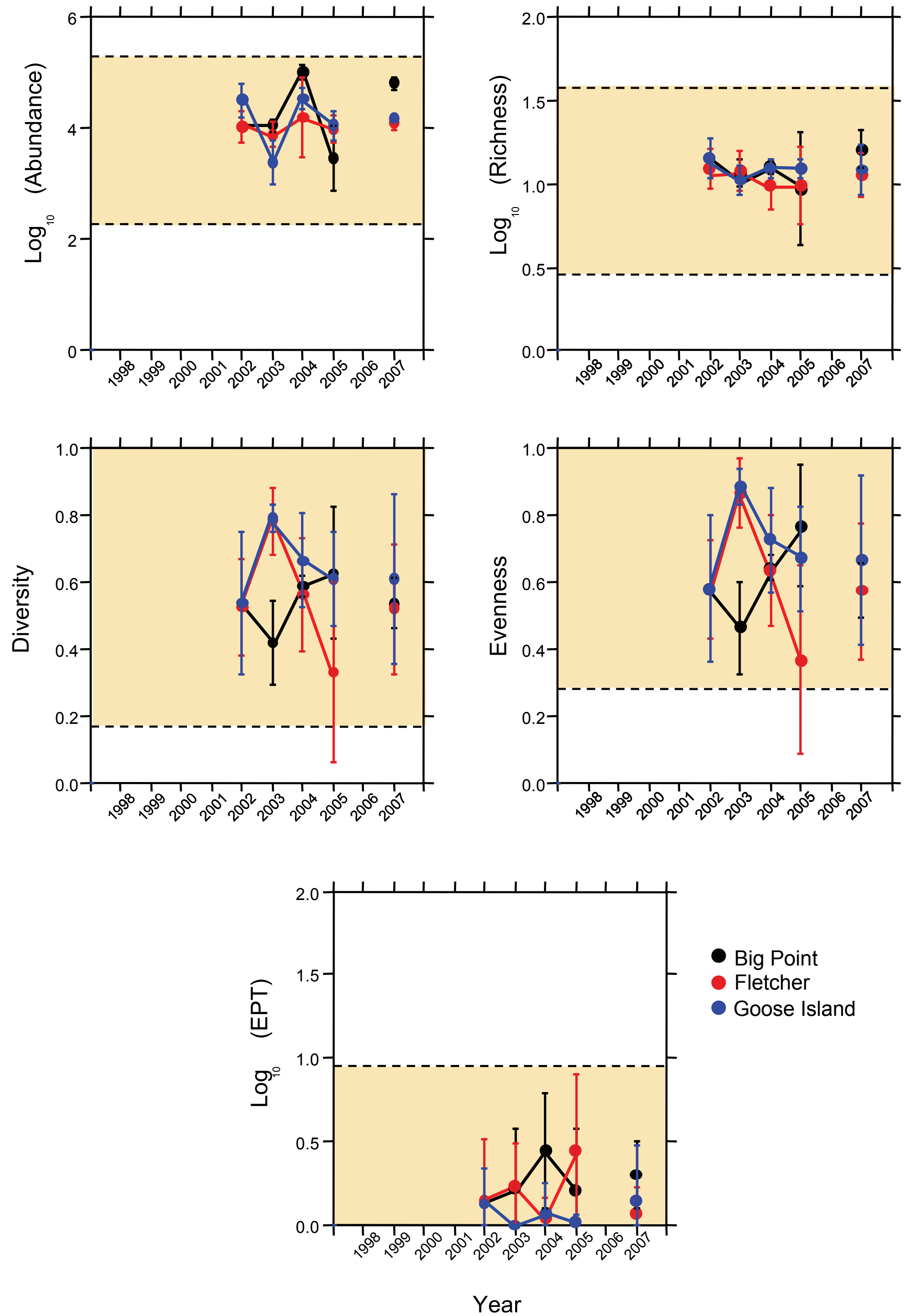
Table 5.1-7 Average habitat characteristics of benthic invertebrate community sampling sites among stations in the Athabasca River Delta.

Variable	Units	Big Point Channel	Fletcher Channel	Goose Island Channel
Sample date	-	Sept. 9, 2007	Sept. 8, 2007	Sept. 9, 2007
Habitat	-	Depositional	Depositional	Depositional
Water depth	m	2	2	2
Current velocity	m/s	n/a	n/a	n/a
Field Water Quality				
Dissolved oxygen	mg/L	n/a	n/a	n/a
Conductivity	µS/cm	290	n/a	n/a
pH	-	8.3	n/a	n/a
Water temperature	°C	14	n/a	n/a
Sediment Composition				
Sand	%	37	38	35
Silt	%	44	48	50
Clay	%	19	14	15
Total Organic Carbon	%	1.4	1.6	1.1

Table 5.1-8 Summary of major taxon abundances and benthic invertebrate community measurement endpoints in reaches of the Athabasca River Delta.

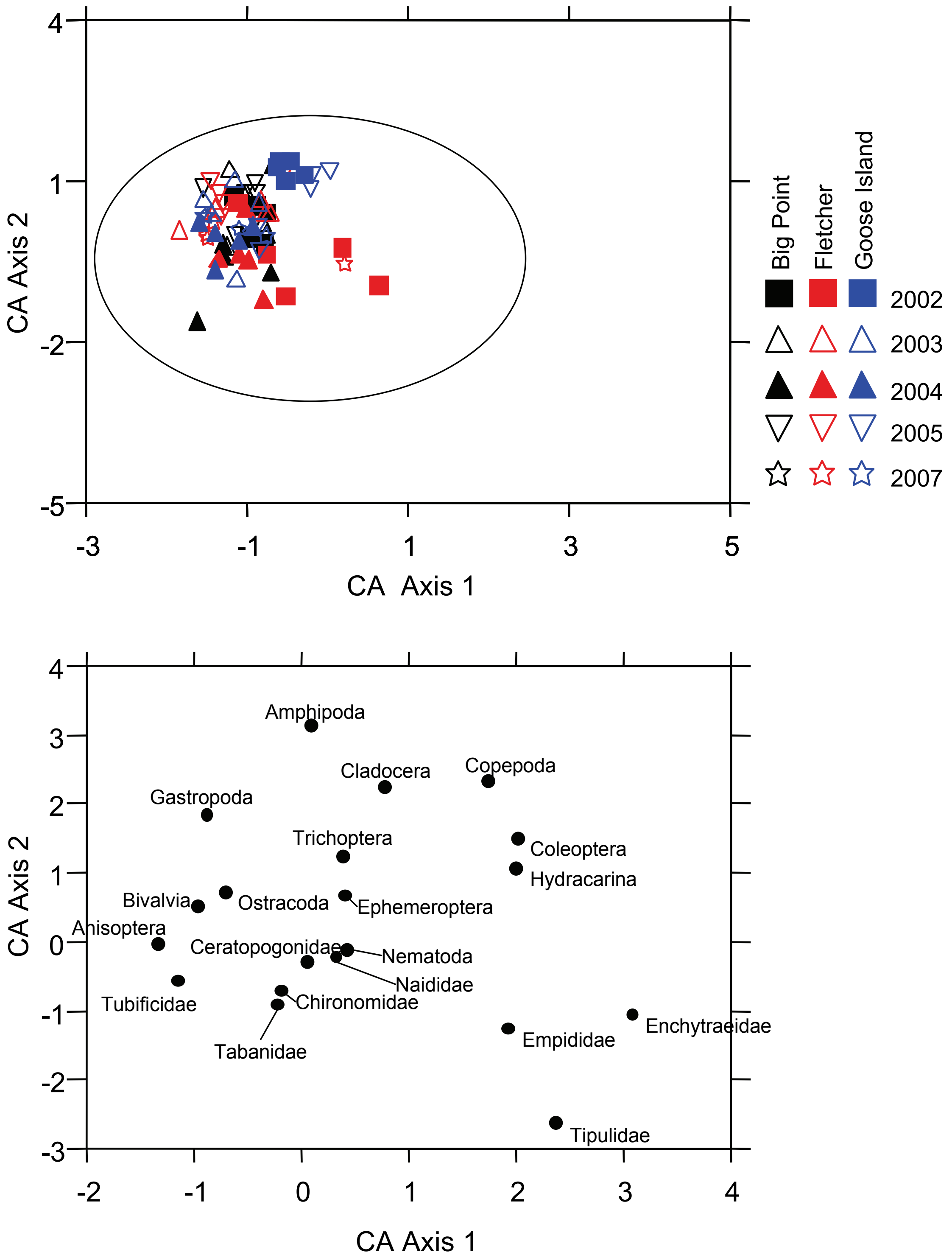
Taxon	Percent Major Taxa Enumerated in Each Year														
	Big Point Channel				**Fletcher Channel**					**Goose Island Channel**				
	2003	**2004**	**2005**	**2007**	**2002**	**2003**	**2004**	**2005**	**2007**	**2002**	**2003**	**2004**	**2005**	**2007**
Amphipoda		<1	2											
Anisoptera	<1	<1	<1	<1		<1	<1	<1	<1	<1	<1	<1		<1
Bivalvia	10	1	8	37	1	13	3	3	2	13	4	2	3	2
Ceratopogonidae	1	<1	7	1	2	10	5	2	8	1	17	3	2	2
Chironomidae	6	40	31	3	86	13	27	4	18	74	28	64	13	24
Copepoda				<1						<1			1	
Empididae					<1									
Ephemeroptera	<1	<1	1	<1	<1	1	<1	<1	<1			<1	<1	
Erpobdellidae		<1												
Gastropoda	4	<1	1	2	1	14	<1	2	1	5	11	<1	<1	1
Heteroptera	<1	<1				<1	<1				<1			
Hydracarina	<1							<1		<1	<1		<1	
Lumbriculidae											<1	<1		
Macrothricidae					<1			<1		<1	2		2	
Megaloptera		<1												
Naididae	1	<1	2	1	<1	15	3		2			<1	7	2
Nematoda	<1	<1	1	1	5	5	<1	<1	1	5		<1	2	2
Ostracoda	<1	2	2	<1	3	2	4	4	1	1	9	3	8	9
Plecoptera				<1				<1						
Tabanidae						<1								
Tipulidae	<1													
Trichoptera	1	2	1	1		<1	<1	2	1	<1				1
Tubificidae	75	52	46	54	2	26	58	81	66	<1	27	27	62	57
Benthic Invertebrate Community Measurement Endpoints														
Total Abundance ($No./m^2$)	11,552	103,983	4,757	63,741	11,897	8,328	27,207	10,843	12,942	36,000	2,914	35,776	12,243	15,216
Richness	11	12	10	15	12	11	9	10	11	14	10	11	11	12
Simpson's Diversity	0.42	0.59	0.63	0.54	0.53	0.78	0.56	0.33	0.52	0.54	0.79	0.66	0.61	0.61
Evenness	0.46	0.64	0.77	0.57	0.58	0.86	0.63	0.37	0.57	0.58	0.89	0.73	0.67	0.67
% EPT	1	2	1	1	1	1	<1	3	<1	<1	0	<1	<1	1

Figure 5.1-9 Variation in benthic invertebrate community measurement endpoints in the Athabasca River Delta between 2002 and 2007.



Note: Lower and upper dotted lines represent ±2 SD of distribution of regional baseline values for depositional sites.

Figure 5.1-10 Ordination (Correspondance Analysis) of depositional benthic invertebrate communities in the Athabasca River Delta.



Notes: Upper Panel is the scatterplot of sample scores while the Lower Panel is the scatterplot of taxa scores. The ellipse in the Upper Panel is for the reference depositional sites.

Table 5.1-9 Concentrations of sediment quality measurement endpoints, Athabasca River mainstem upstream of Embarras River (ATR-ER).

Measurement Endpoint	Units	Guideline	September 2007	1997-2006 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	11	6	10	15	22
Silt	%	-	32	6	29	33	42
Sand	%	-	57	6	36	53	61
Total organic carbon	%	-	1.6	6	0.8	1.05	1.3
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]	24	2	11	19.5	28
Fraction 3 (C16-C34)	mg/kg	400[2]	330	2	220	240	260
Fraction 4 (C34-C50)	mg/kg	2800[2]	240	2	180	185	190
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[3]	0.007	6	0.005	0.009	0.037
Retene	mg/kg	-	0.031	6	0.033	0.046	0.081
Total dibenzothiophenes	mg/kg	-	0.191	6	0.012	0.226	0.329
Total PAHs	mg/kg	-	0.866	6	0.036	0.085	0.135
Total HMW PAHs	mg/kg	-	0.345	6	0.308	0.308	0.308
Total LMW PAHs	mg/kg	-	0.521	6	0.009	0.058	0.107
Predicted PAH toxicity[1]	H.I.	-	0.408	6	0.92	1.16	1.54
Metals that exceed CCME guidelines in 2007							
none	mg/kg	-	-	-	-	-	-
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	ns	3	7	7.4	8
Chironomus growth - 10d	mg/organism	-	ns	3	2.1	2.2	3.5
Hyalella survival - 14d	# surviving	-	ns	1	-	-	10
Hyalella growth - 14d	mg/organism	-	ns	1	-	-	0.09

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).

ns = not sampled

Table 5.1-10 Concentrations of sediment quality measurement endpoints, Goose Island Channel (GIC-1).

Measurement Endpoint	Units	Guideline	September 2007	1997-2006 (fall data only GIC-1)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	14.6	4	20	21	28
Silt	%	-	51.4	4	46	53.5	58
Sand	%	-	34	4	17	25.5	32
Total organic carbon	%	-	1.1	4	1.2	1.75	2.1
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]	17	1	-	-	<5
Fraction 3 (C16-C34)	mg/kg	400[2]	180	1	-	-	360
Fraction 4 (C34-C50)	mg/kg	2800[2]	110	1	-	-	200
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[3]	0.008	4	0.005	0.010	0.015
Retene	mg/kg	-	0.034	4	0.027	0.049	0.078
Total dibenzothiophenes	mg/kg	-	0.202	4	0.214	0.241	0.412
Total PAHs	mg/kg	-	1.016	4	1.236	1.390	2.161
Total HMW PAHs	mg/kg	-	0.309	4	0.528	0.610	0.798
Total LMW PAHs	mg/kg	-	0.707	4	0.593	0.837	1.364
Predicted PAH toxicity[1]	H.I.	-	0.959	4	0.983	1.143	1.182
Metals that exceed CCME guidelines in 2007							
none	mg/kg	-	-	-	-	-	-
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	ns	3	4	7	8
Chironomus growth - 10d	mg/organism	-	ns	3	2.6	2.7	4.2
Hyalella survival - 14d	# surviving	-	ns	1	-	-	9
Hyalella growth - 14d	mg/organism	-	ns	1	-	-	0.11

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).

ns = not sampled

Table 5.1-11 Concentrations of sediment quality measurement endpoints, Fletcher Channel (FLC-1).

Variables	Units	Guideline	September 2007	1997-2006 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	14.8	4	12	15	18
Silt	%	-	52.8	4	18	36.5	49
Sand	%	-	32.4	4	35	47.5	70
Total organic carbon	%	-	1.6	4	0.6	1.15	1.3
Total hydrocarbons							
BTEX	mg/kg	-	30	1	-	-	<5
Fraction 1 (C6-C10)	mg/kg	30[2]	30	1	-	-	<5
Fraction 2 (C10-C16)	mg/kg	150[2]	23	1	-	-	18
Fraction 3 (C16-C34)	mg/kg	400[2]	290	1	-	-	**430**
Fraction 4 (C34-C50)	mg/kg	2800[2]	170	1	-	-	280
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[3]	0.011	4	0.005	0.008	0.011
Retene	mg/kg	-	0.031	4	0.021	0.041	0.048
Total dibenzothiophenes	mg/kg	-	0.259	4	0.147	0.178	0.260
Total PAHs	mg/kg	-	1.357	4	0.837	1.116	1.281
Total HMW PAHs	mg/kg	-	0.404	4	0.334	0.485	0.582
Total LMW PAHs	mg/kg	-	0.953	4	0.437	0.622	0.782
Predicted PAH toxicity[1]	H.I.	-	0.818	4	0.494	0.649	0.910
Metals that exceed CCME guidelines in 2007							
none	mg/kg	-	-	-	-	-	-
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	ns	3	6	6	7
Chironomus growth - 10d	mg/organism	-	ns	3	2.6	2.8	3.6
Hyalella survival - 14d	# surviving	-	ns	1	-	-	9.6
Hyalella growth - 14d	mg/organism	-	ns	1	-	-	0.11

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).

ns = not sampled

Table 5.1-12 Concentrations of sediment quality measurement endpoints, Big Point Channel (BPC-1).

Measurement Endpoint	Units	Guideline	September 2007	1997-2006 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	19.2	6	10	19.5	32
Silt	%	-	43.6	6	26	48	64
Sand	%	-	37.2	6	10	31	64
Total organic carbon	%	-	1.4	6	<0.1	1.15	1.76
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]	23	1	-	-	<5
Fraction 3 (C16-C34)	mg/kg	400[2]	210	1	-	-	190
Fraction 4 (C34-C50)	mg/kg	2800[2]	100	1	-	-	120
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[3]	0.009	6	0.005	0.012	0.024
Retene	mg/kg	-	0.046	5	0.041	0.053	0.096
Total dibenzothiophenes	mg/kg	-	0.275	6	0.150	0.213	0.27
Total PAHs	mg/kg	-	1.358	6	1.045	1.288	1.54
Total HMW PAHs	mg/kg	-	0.403	6	0.252	0.508	0.73
Total LMW PAHs	mg/kg	-	0.954	6	0.502	0.818	1.00
Predicted PAH toxicity[1]	H.I.	-	1.19	6	0.91	1.23	1.46
Metals that exceed CCME guidelines in 2007							
none	mg/kg	-	-	-	-	-	-
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	ns	5	3.2	7	9
Chironomus growth - 10d	mg/organism	-	ns	5	0.89	2	3.6
Hyalella survival - 14d	# surviving	-	ns	1	-	-	9
Hyalella growth - 14d	mg/organism	-	ns	1	-	-	0.12

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

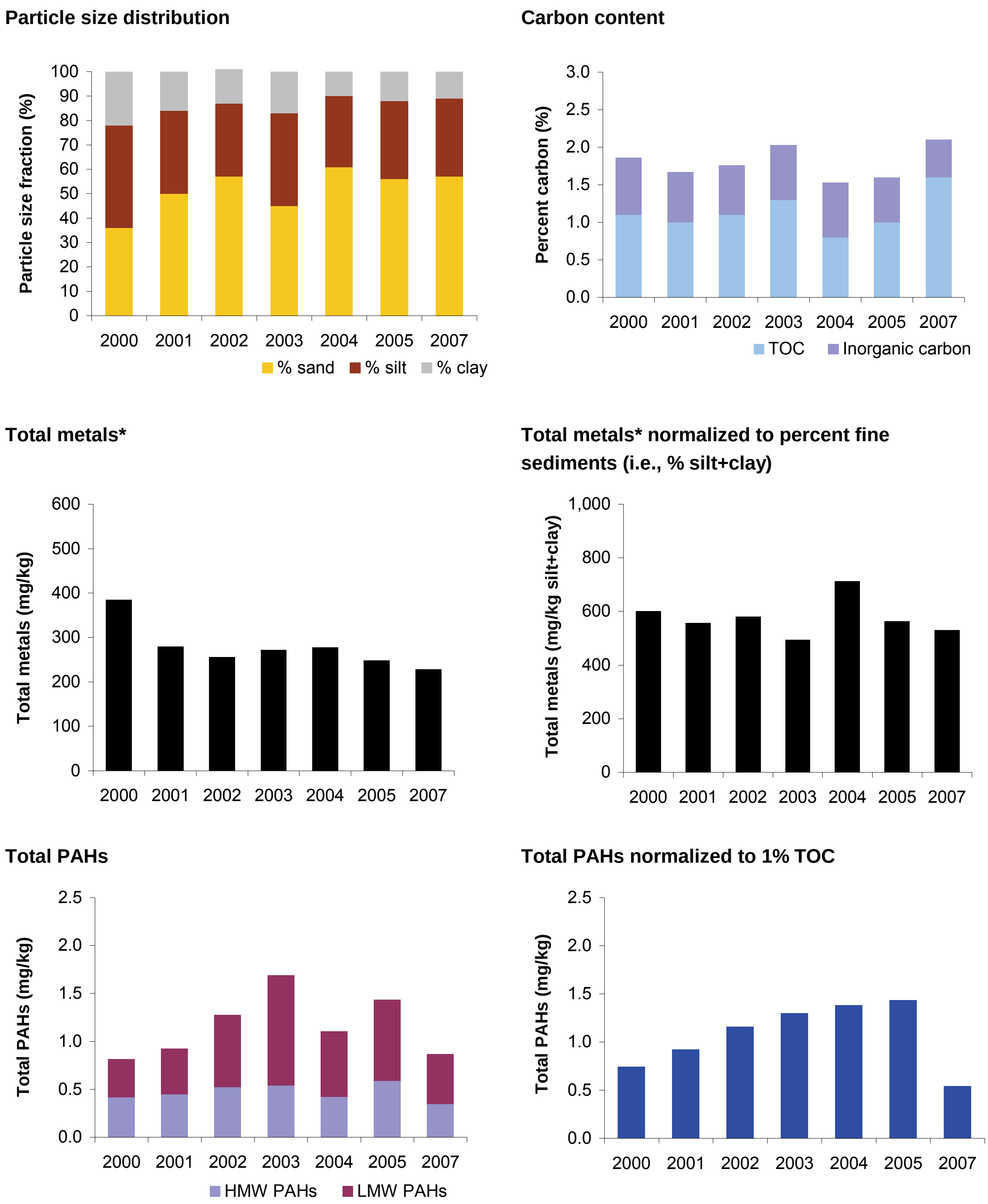
[1] Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species.

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

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

ns = not sampled

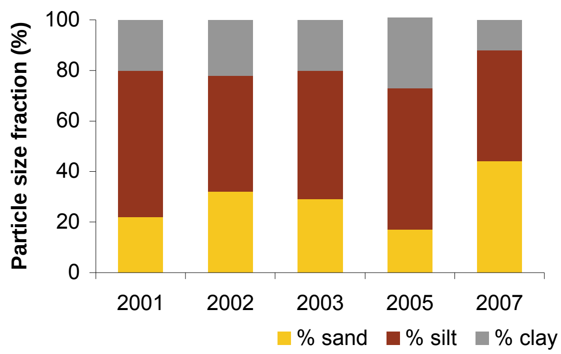
Figure 5.1-11 Characteristics of sediment collected in the Athabasca River upstream of Embarras River, 2000-2007 (fall data only).



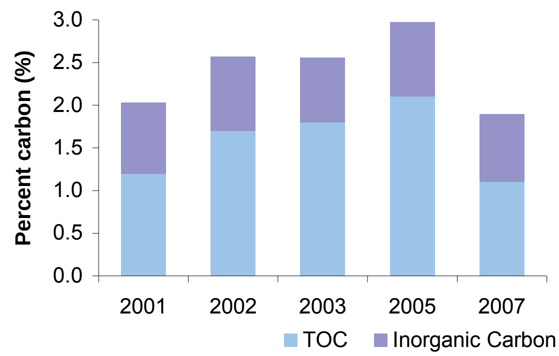
* Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Ag, Sr, Tl, U, V, Zn (measured in all years).

Figure 5.1-12 Characteristics of sediment collected in Goose Island Channel (GIC-1), 2001-2007 (fall data only).

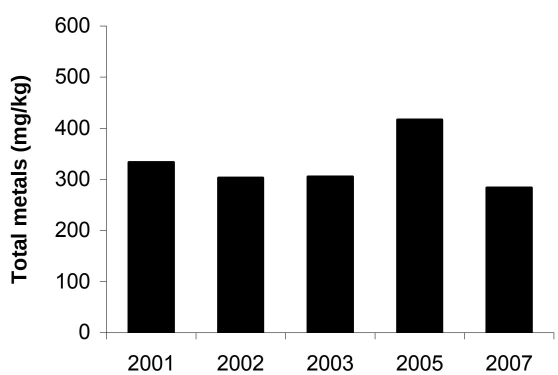
Particle size distribution



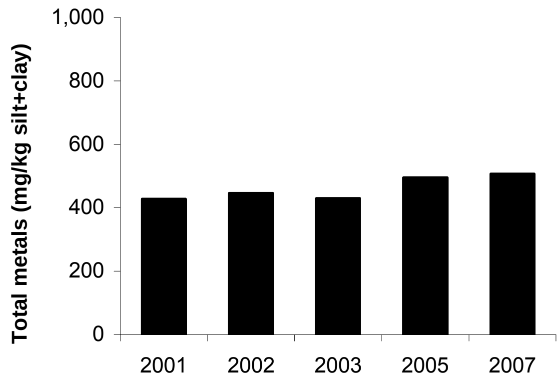
Carbon content



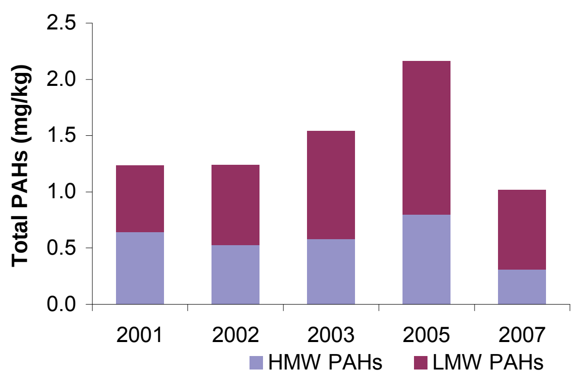
Total metals*



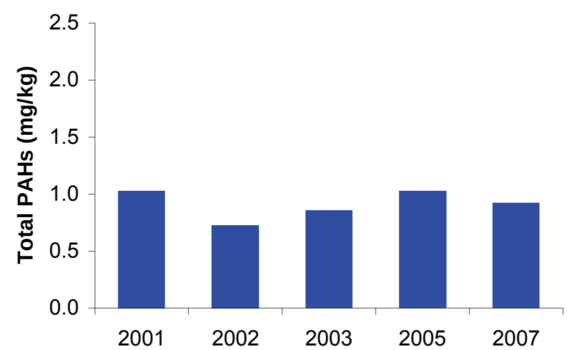
Total metals* normalized to percent fine sediments (i.e., % silt+clay)



Total PAHs



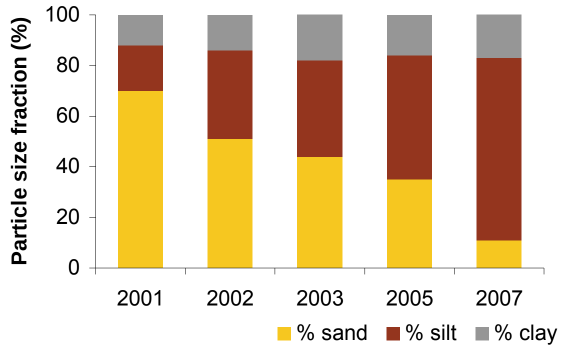
Total PAHs normalized to 1% TOC



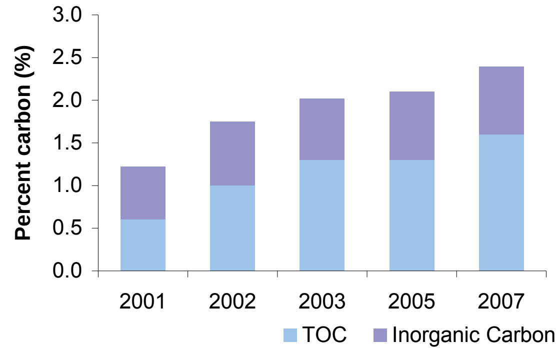
* Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Ag, Sr, Tl, U, V, Zn (measured in all years).

Figure 5.1-13 Characteristics of sediment collected in Fletcher Channel (FLC-1), 2001-2007 (fall data only).

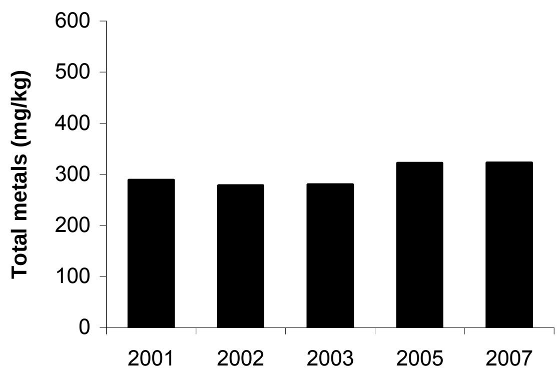
Particle size distribution



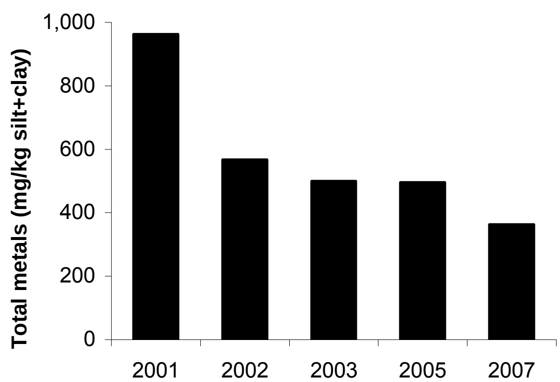
Carbon content



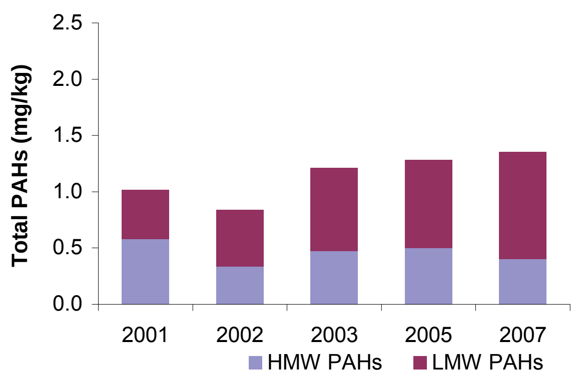
Total metals*



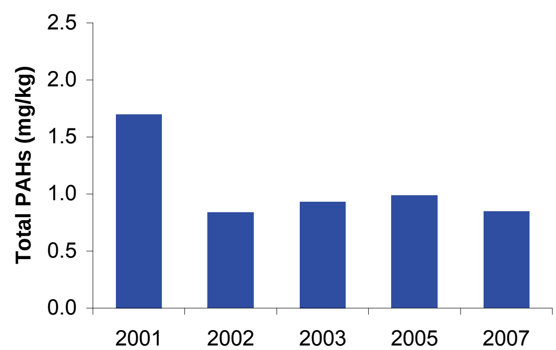
Total metals* normalized to percent fine sediments (i.e., % silt+clay)



Total PAHs



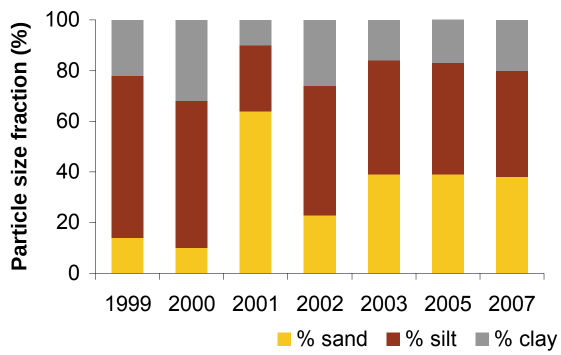
Total PAHs normalized to 1% TOC



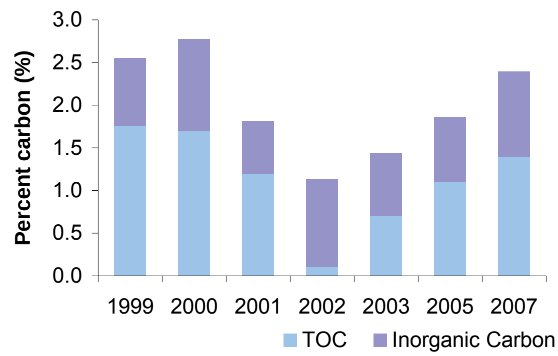
* Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Ag, Sr, Tl, U, V, Zn (measured in all years).
** Non-detectable level of total organic carbon in 2002 (<0.1%).

Figure 5.1-14 Characteristics of sediment collected in Big Point Channel (BPC-1), 1999-2007 (fall data only).

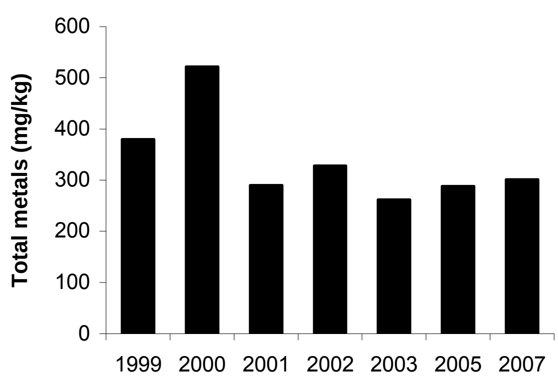
Particle size distribution



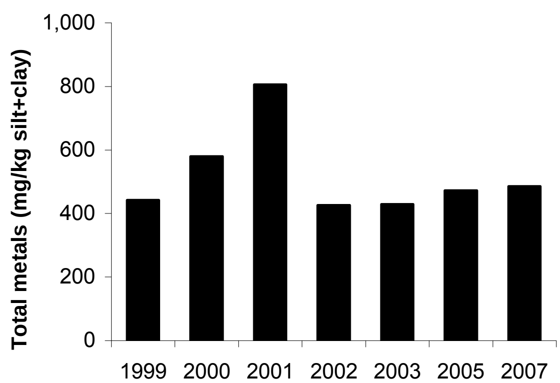
Carbon content



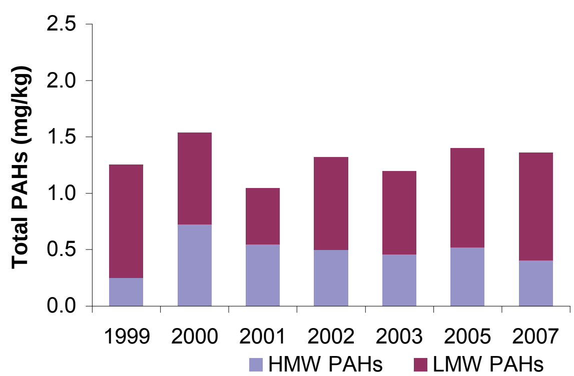
Total metals*



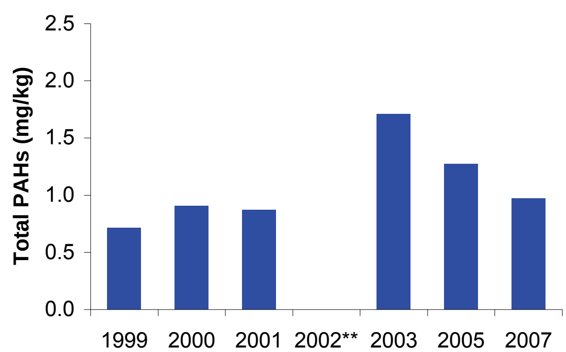
Total metals* normalized to percent fine sediments (i.e., % silt+clay)



Total PAHs



Total PAHs normalized to 1% TOC



* Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Ag, U, V, Zn (measured in all years).
** Non-detectable level of total organic carbon in 2002 (<0.1%).

Figure 5.1-15 Concentrations of total PAHs in sediments sampled by RAMP, Athabasca River mainstem and delta, 1997 to 2007.

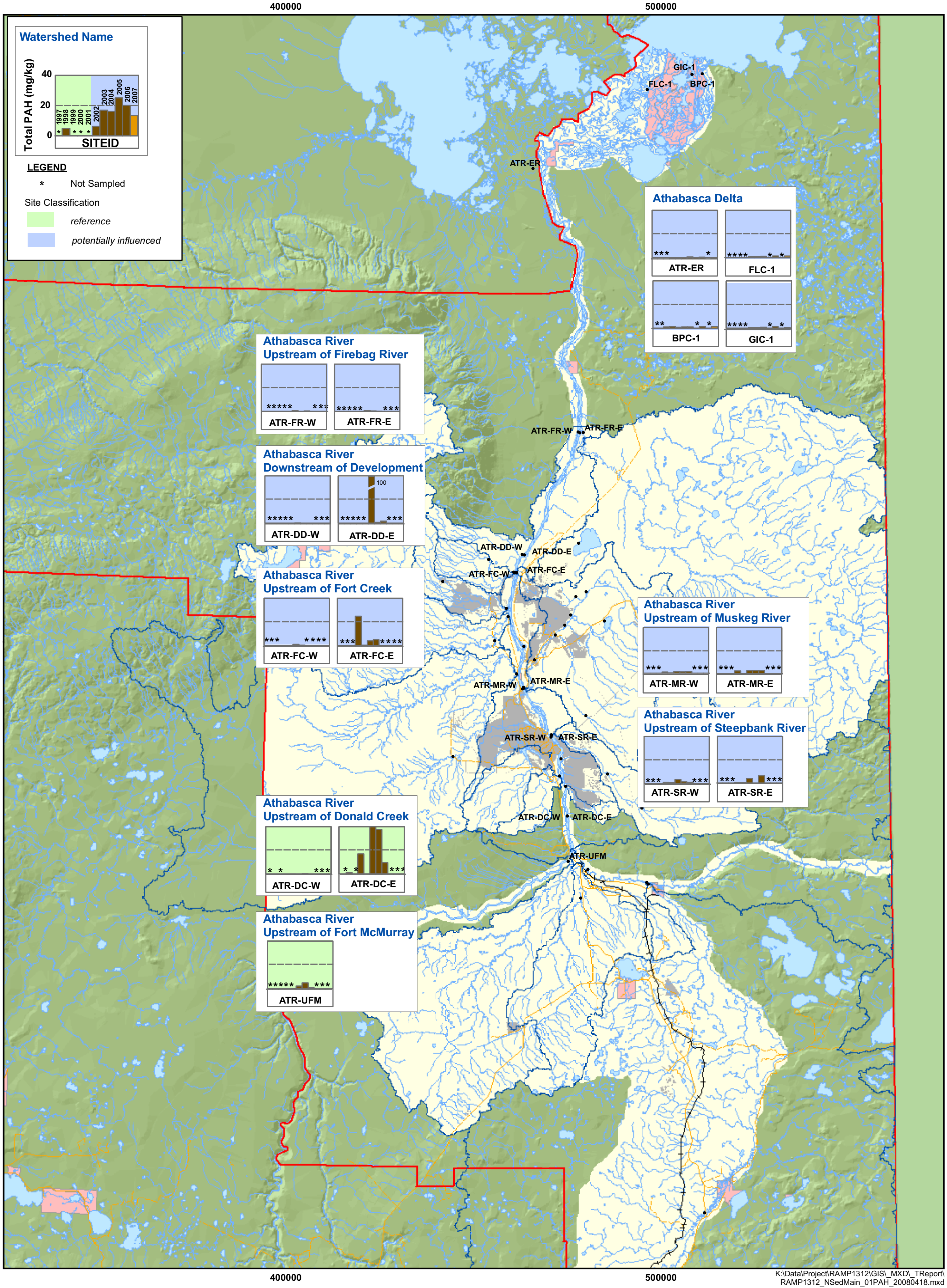


Figure 5.1-16 Carbon-normalized concentrations of total PAHs in sediments sampled by RAMP, Athabasca River mainstem and delta, 1997 to 2007.

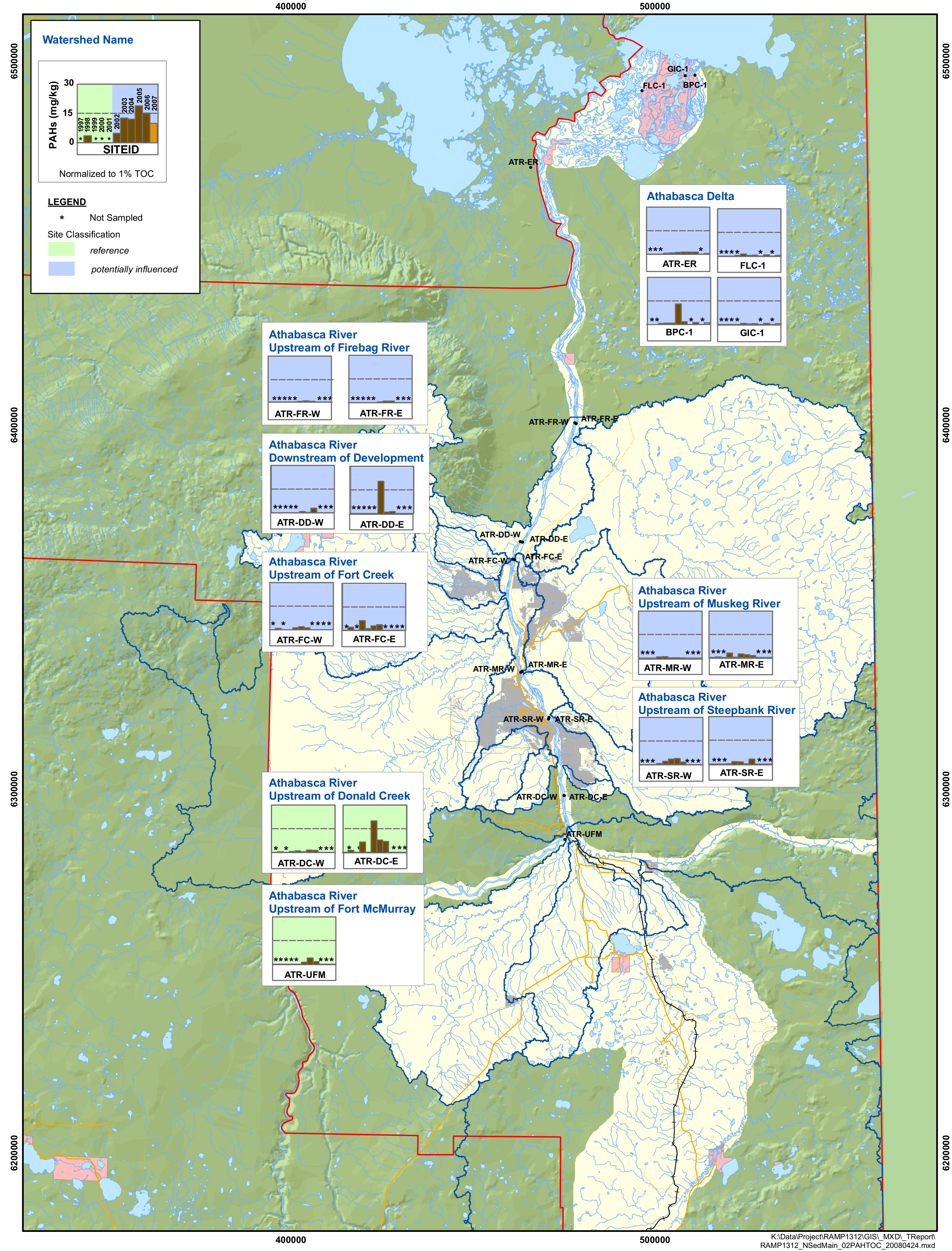


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Figure 5.1-17 Concentrations of total hydrocarbons in sediments sampled by RAMP, Athabasca River mainstem and delta, 1997 to 2007.

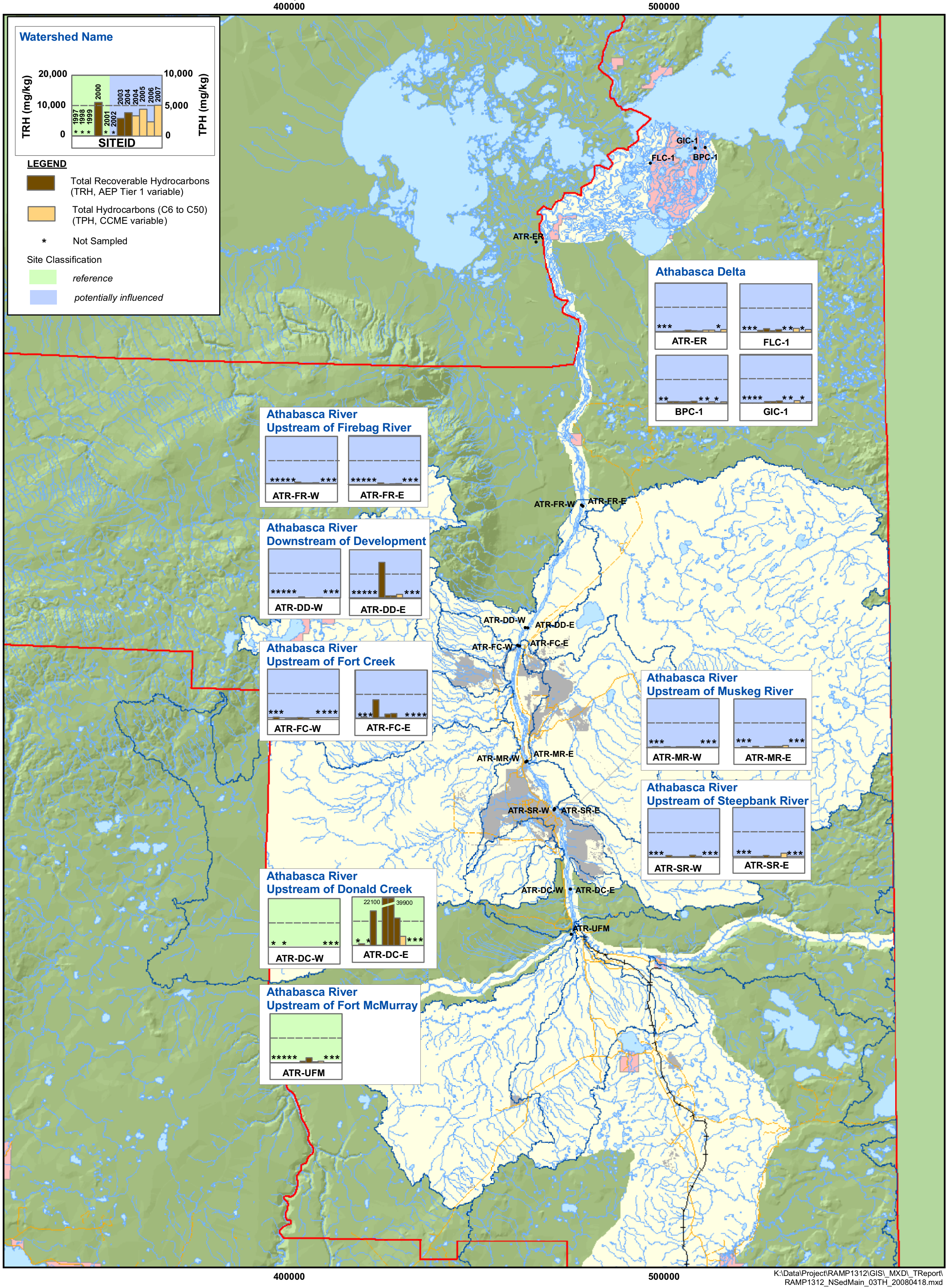


Figure 5.1-18 Carbon-normalized concentrations of total hydrocarbons in sediments sampled by RAMP, Athabasca River mainstem and delta, 1997 to 2007.

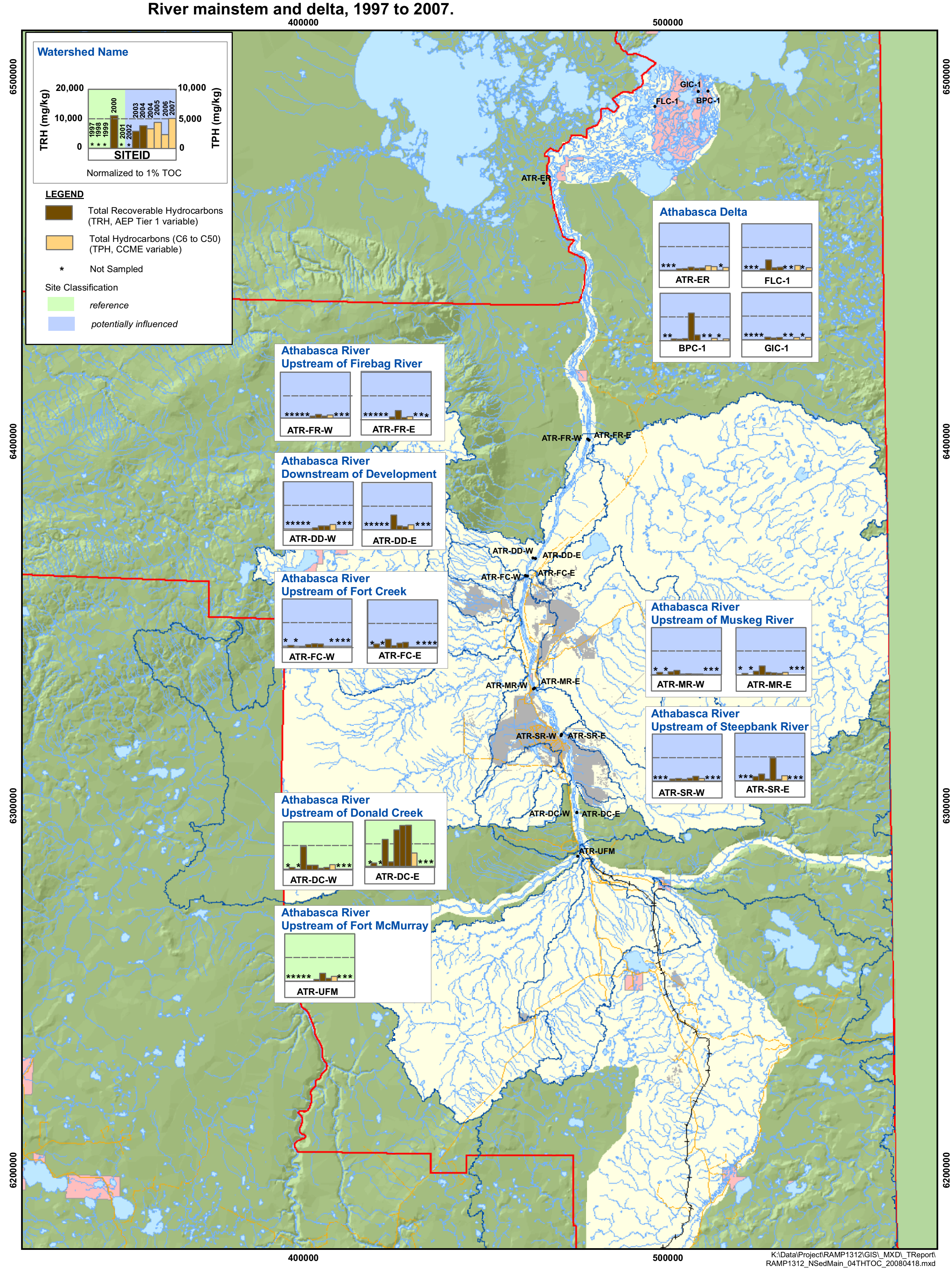


Figure 5.1-19 Concentrations of total arsenic in sediments sampled by RAMP, Athabasca River mainstem and delta, 1997 to 2007.

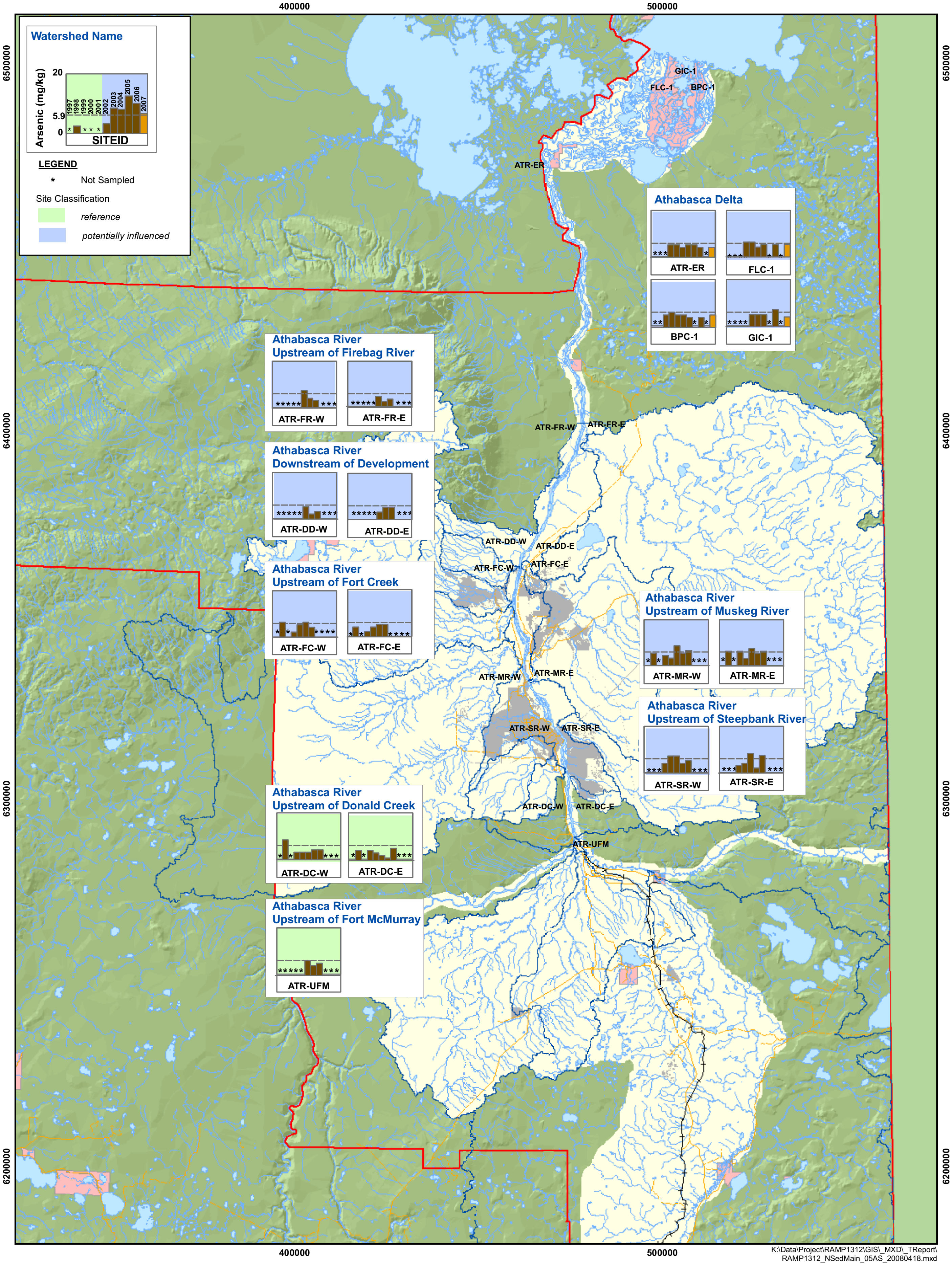


Table 5.1-13 Athabasca River fish inventory results, spring 2007.

Species	No. Captured	% Total Catch
Brook stickleback	1	0.07
Burbot	12	0.79
Emerald shiner	6	0.40
Flathead chub	91	6.02
Goldeye	170	11.25
Lake chub	5	0.33
Lake whitefish	7	0.46
Longnose dace	1	0.07
Longnose sucker	84	5.56
Northern pike	33	2.18
Spoonhead sculpin	2	0.13
Spottail shiner	4	0.26
Trout-perch	385	25.48
Walleye	263	17.41
White sucker	447	29.58
Total	**1511**	**100**

Table 5.1-14 Athabasca River fish inventory results, fall 2007.

Species	No. Captured	% Total Catch
Burbot	2	0.20
Cisco	1	0.10
Emerald shiner	26	2.60
Fathead minnow	4	0.40
Flathead chub	60	6.00
Goldeye	33	3.30
Lake chub	39	3.90
Lake whitefish	286	28.60
Longnose dace	1	0.10
Longnose sucker	42	4.20
Nine spined stickleback	1	0.10
Northern pike	19	1.90
Pearl dace	3	0.30
Slimy sculpin	1	0.10
Spottail shiner	3	0.30
Trout-perch	318	31.80
Walleye	90	9.00
White sucker	54	5.40
Yellow perch	17	1.70
Total	**1000**	**100**

Figure 5.1-20 Percent composition of large-bodied species, Athabasca River spring inventory 1997-2007.

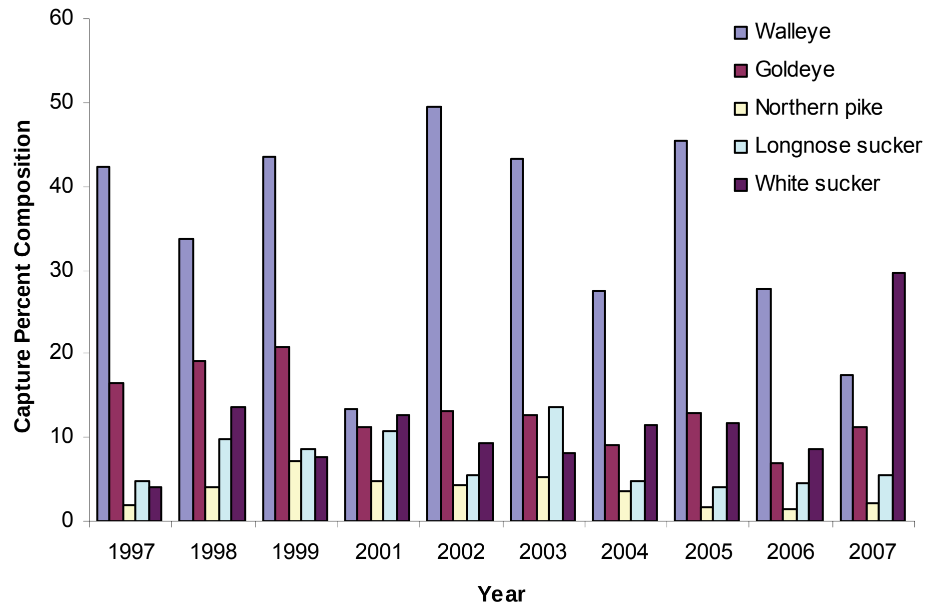


Figure 5.1-21 Percent composition of large-bodied species, Athabasca River, fall inventory, 1997-2007.

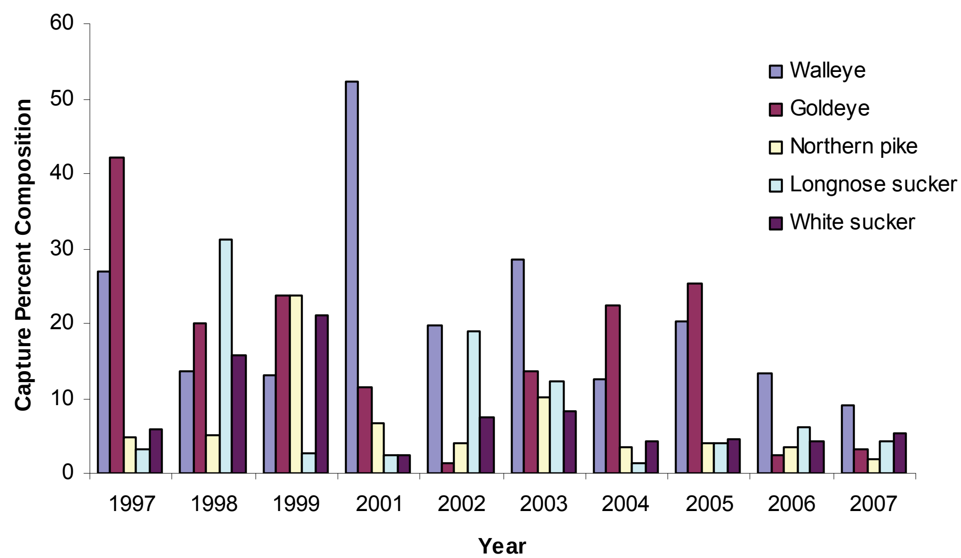


Figure 5.1-22 Percent composition of large-bodied species in each sampled area on the Athabasca River, spring inventory, 2007.

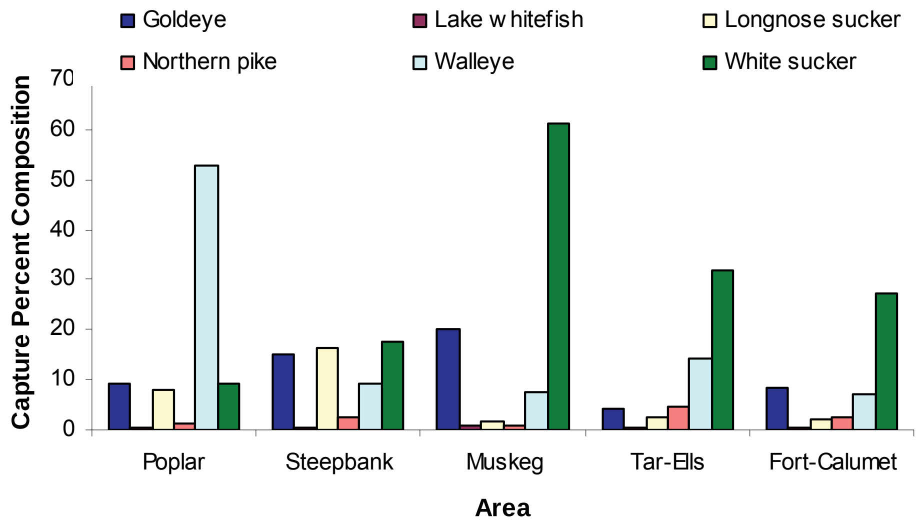


Figure 5.1-23 Percent composition of large-bodied species in each sampled area on the Athabasca River, fall inventory, 2007.

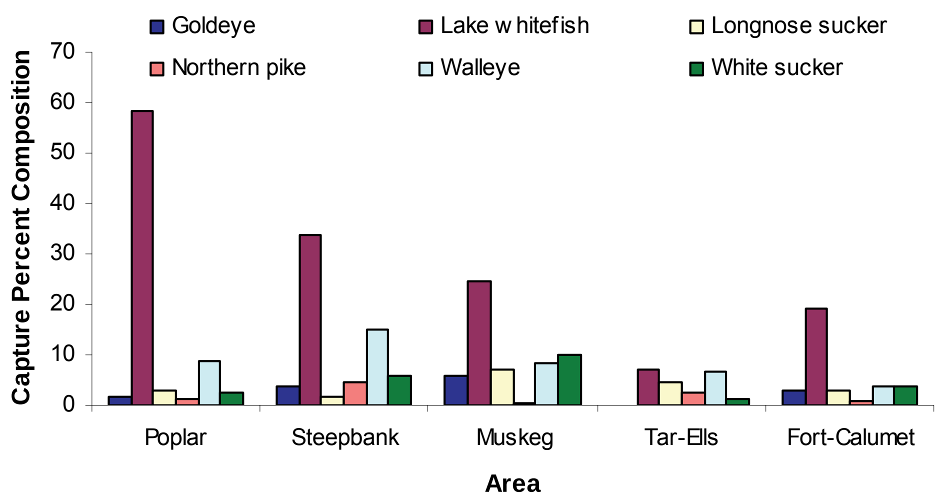


Table 5.1-15 Athabasca River observed but not captured fish inventory results, spring and fall 2007.

Species	Total Observed	
	Spring	Fall
Burbot	9	-
Emerald shiner	9	-
Flathead chub	34	19
Goldeye	89	15
Lake chub	8	5
Longnose sucker	13	429
Northern pike	14	13
Shiner sp.	-	1
Trout-perch	302	177
Walleye	63	20
White sucker	437	27
Yellow perch	-	2
Total	**978**	**708**

Figure 5.1-24 Seasonal CPUE (mean ± SE) for captured fish, all species combined, Athabasca River spring inventory.

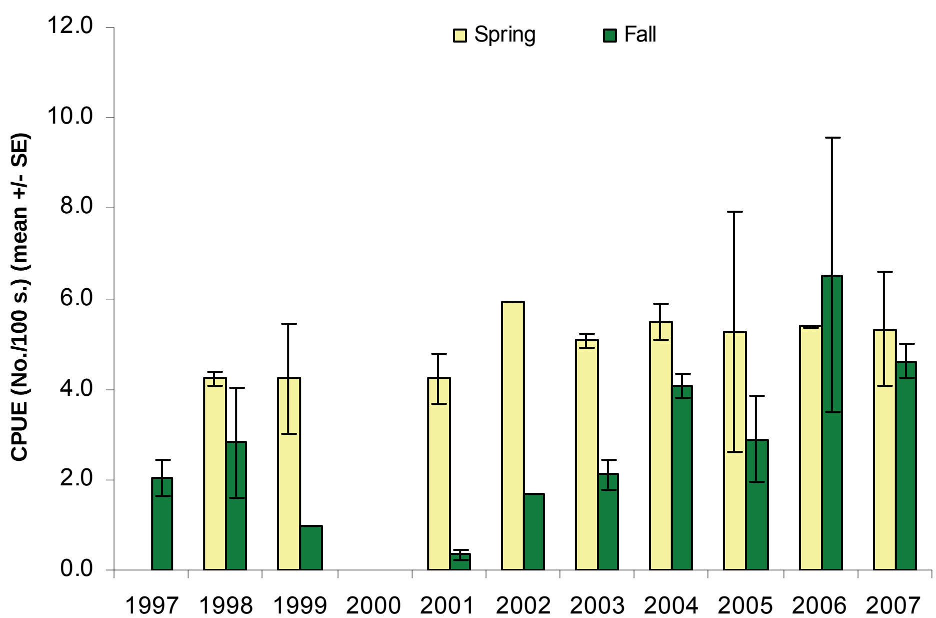
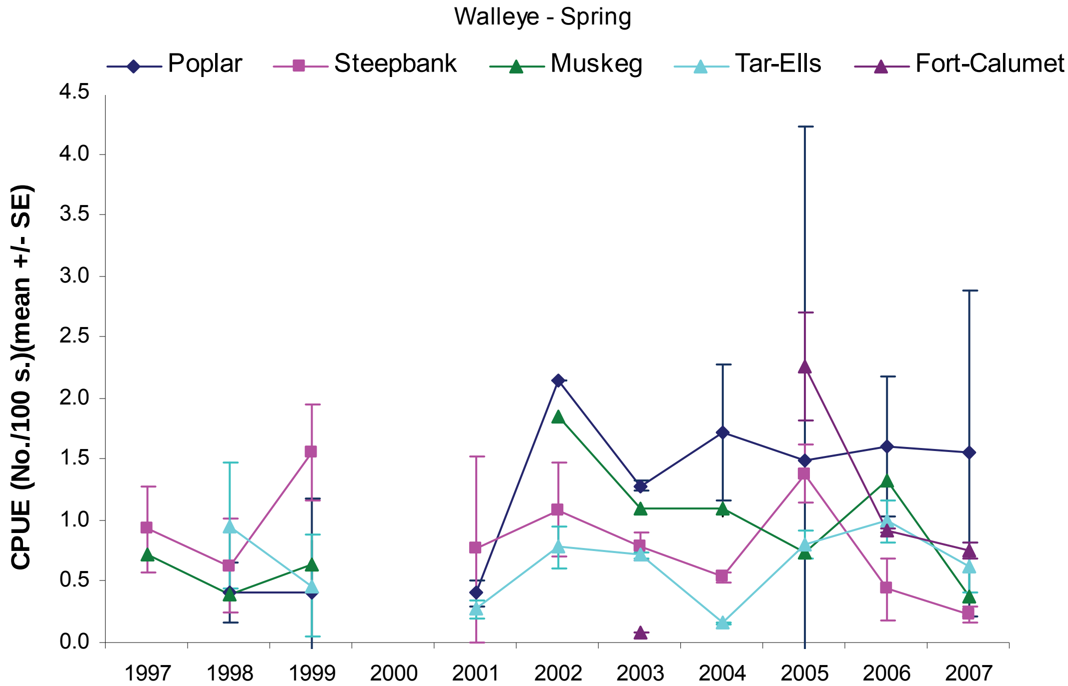


Figure 5.1-25 Seasonal CPUE (mean ± SE) for walleye in each sampled reach on the Athabasca River, spring and fall inventories.



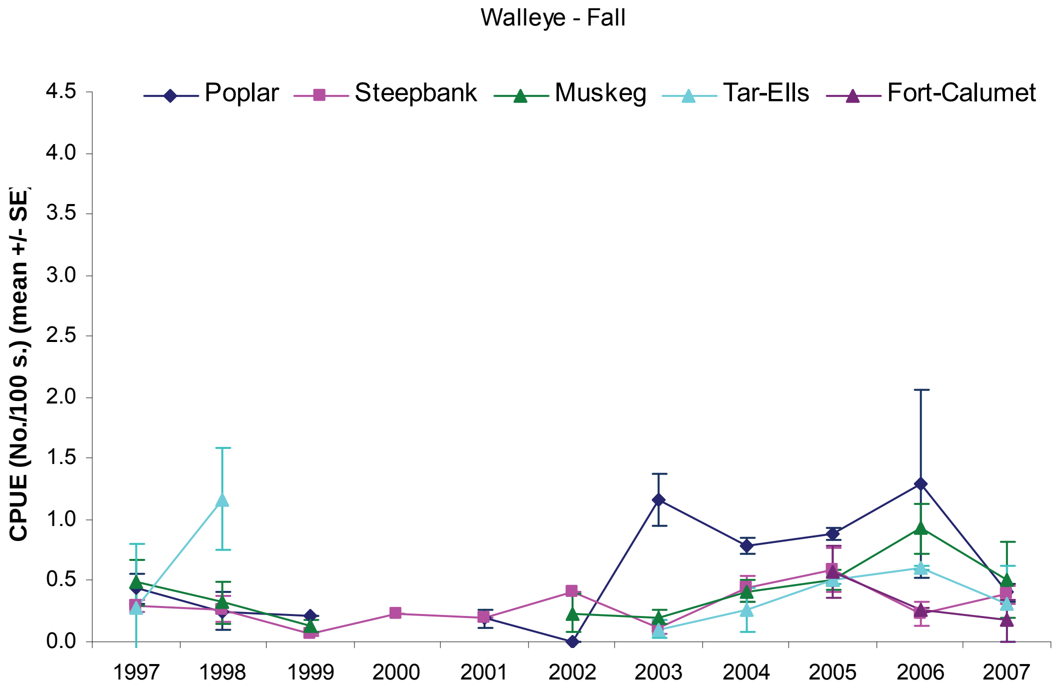
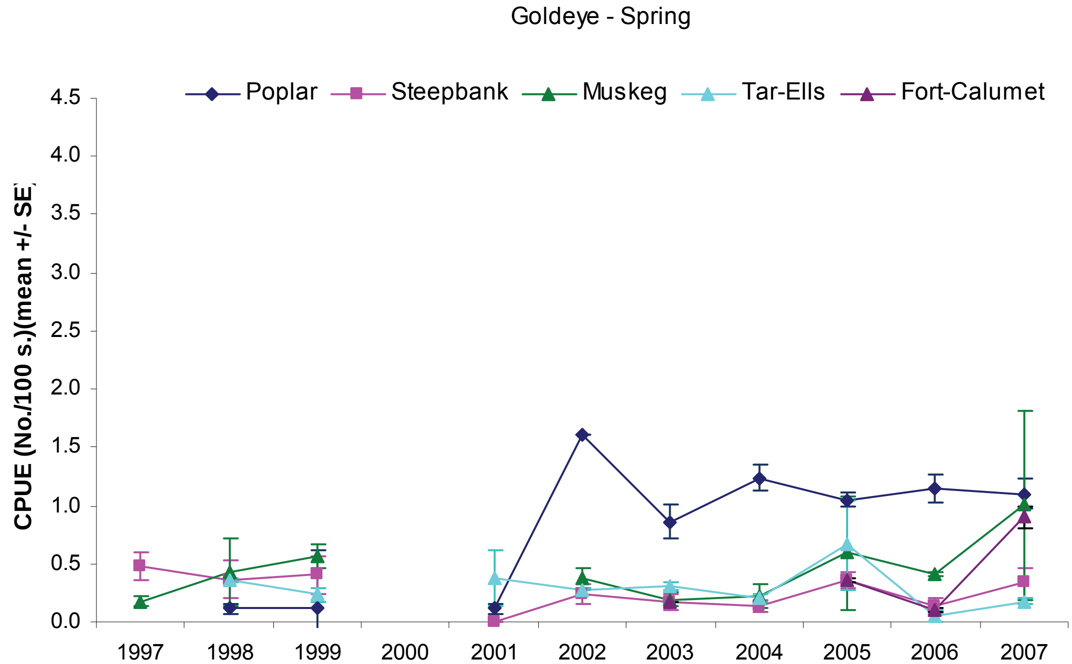


Figure 5.1-26 Seasonal CPUE (mean ± SE) for goldeye in each sampled reach on the Athabasca River, spring and fall inventories.



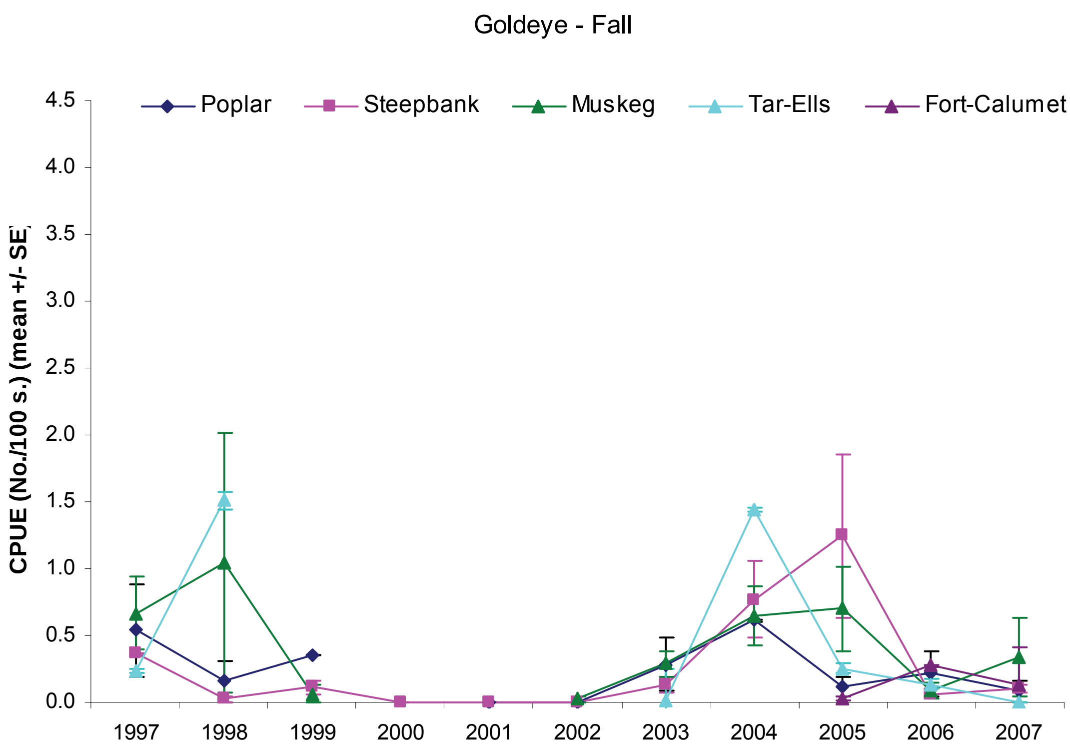
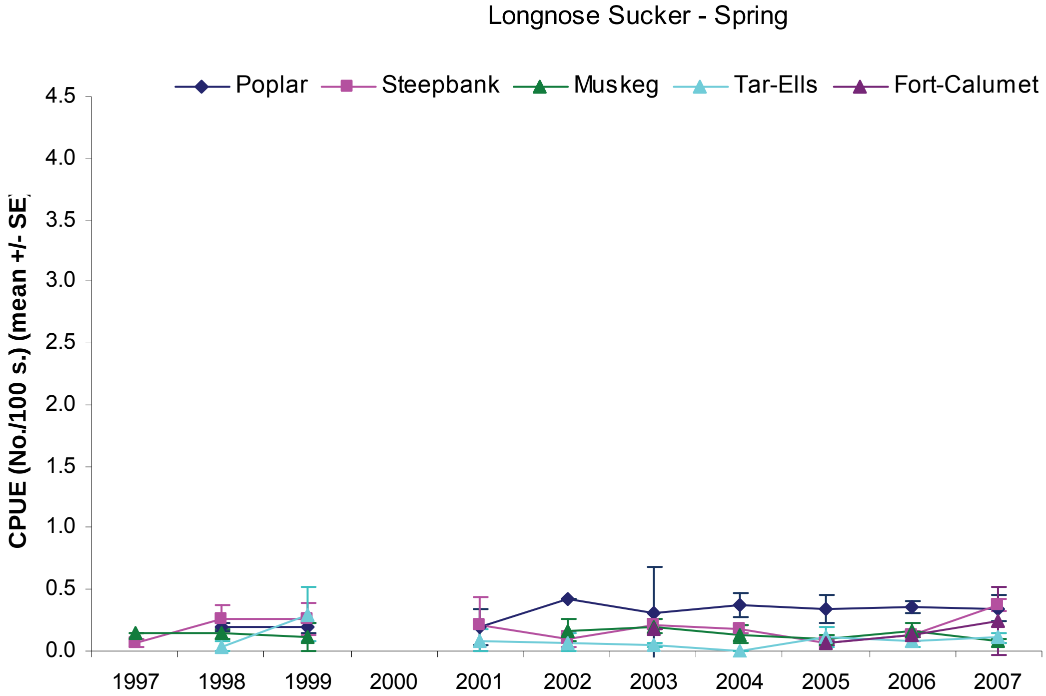


Figure 5.1-27 Seasonal CPUE (mean ± SE) for longnose sucker in each sampled reach on the Athabasca River, spring and fall inventories.



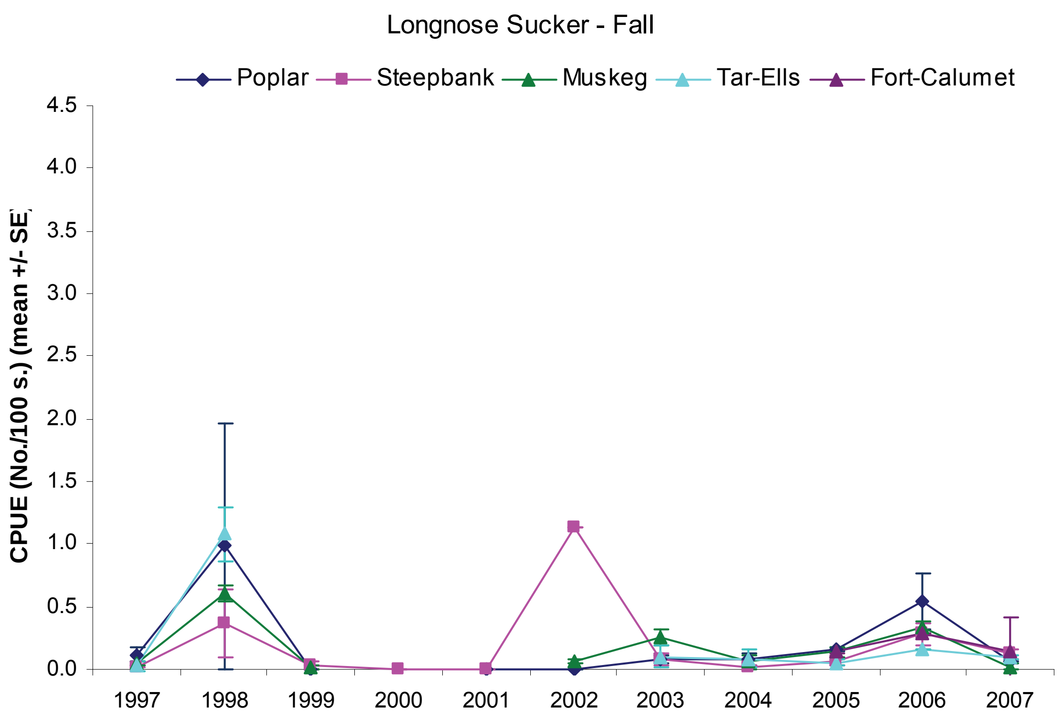


Figure 5.1-28 Seasonal CPUE (mean ± SE) for white sucker in each sampled reach on the Athabasca River, spring and fall inventories.

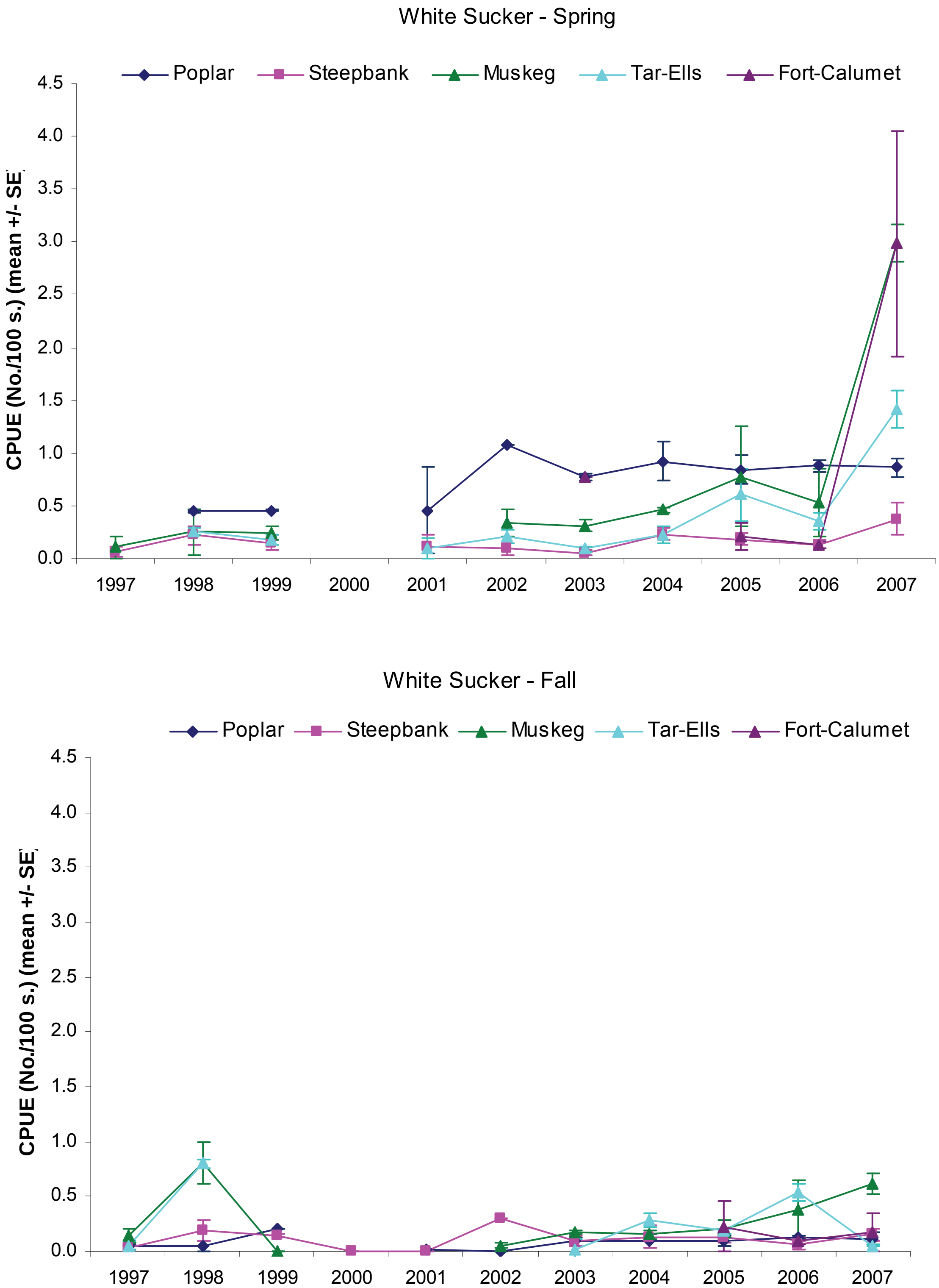
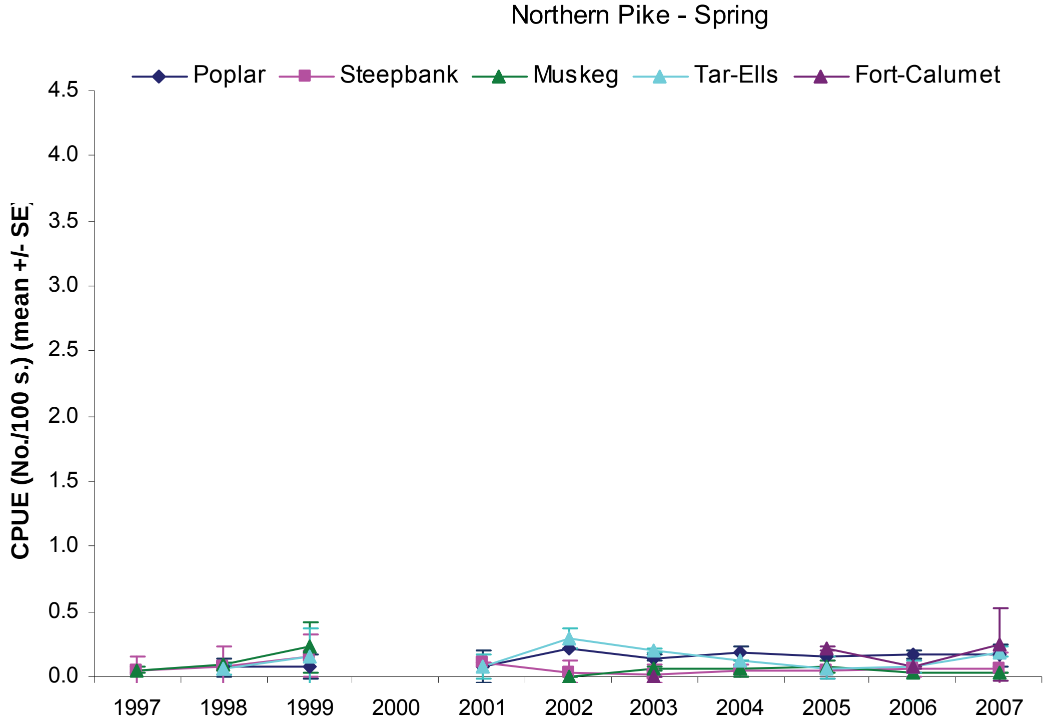


Figure 5.1-29 Seasonal CPUE (mean ± SE) for northern pike in each sampled reach on the Athabasca River, spring and fall inventories.



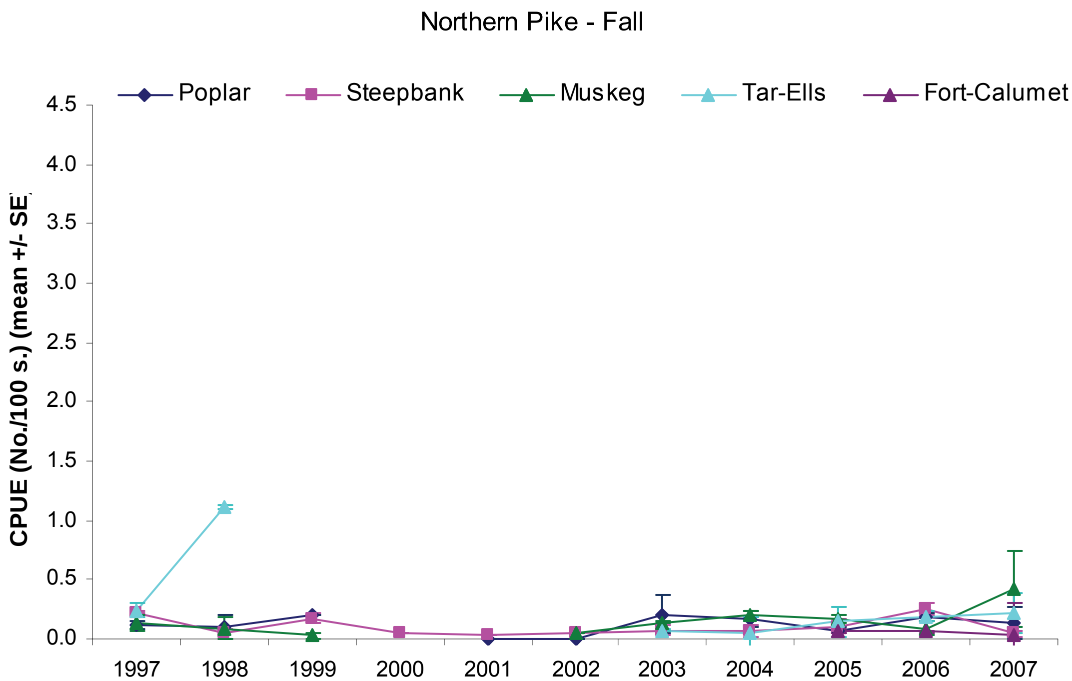


Figure 5.1-30 **Seasonal mean CPUE for all species for all sampled reaches on the Athabasca River relative to mean May discharge rate (m^3/s), spring inventory 1987-2007.**

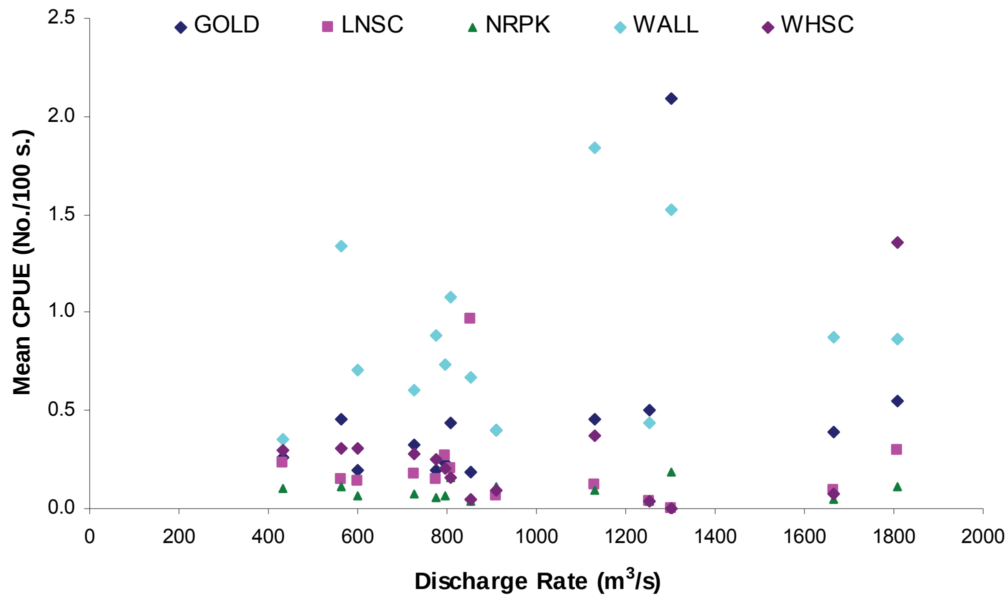


Figure 5.1-31 **Seasonal mean CPUE for all species for all sampled reaches on the Athabasca River relative to mean September discharge rate (m^3/s), fall inventory 1989-2007.**

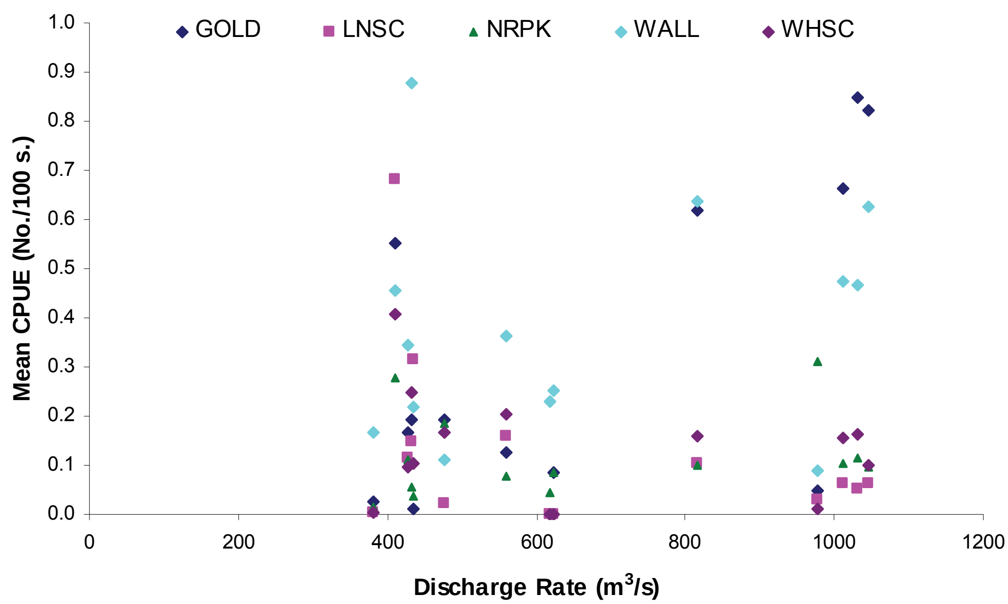
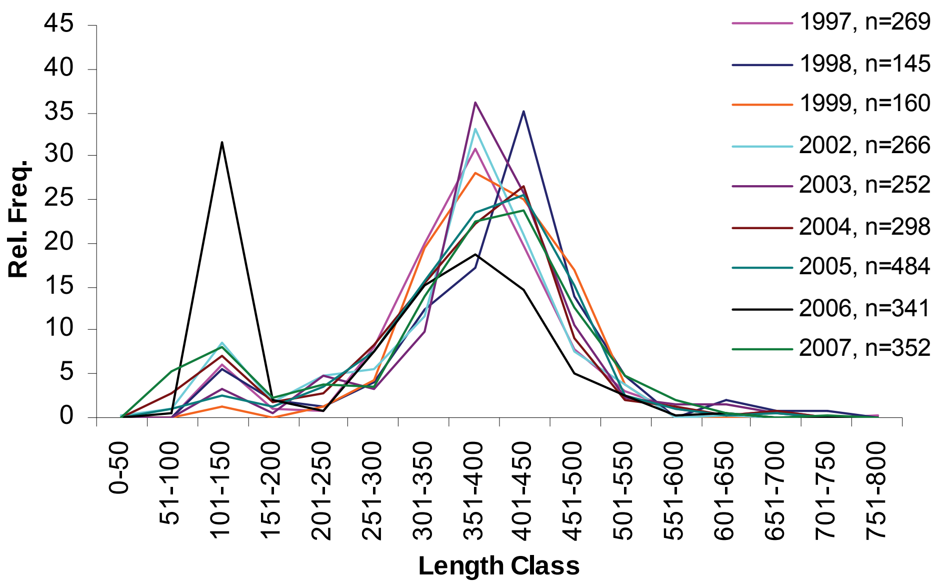


Figure 5.1-32 Relative length-frequency distributions for walleye captured in the Athabasca River, spring and fall, 1997-2007.



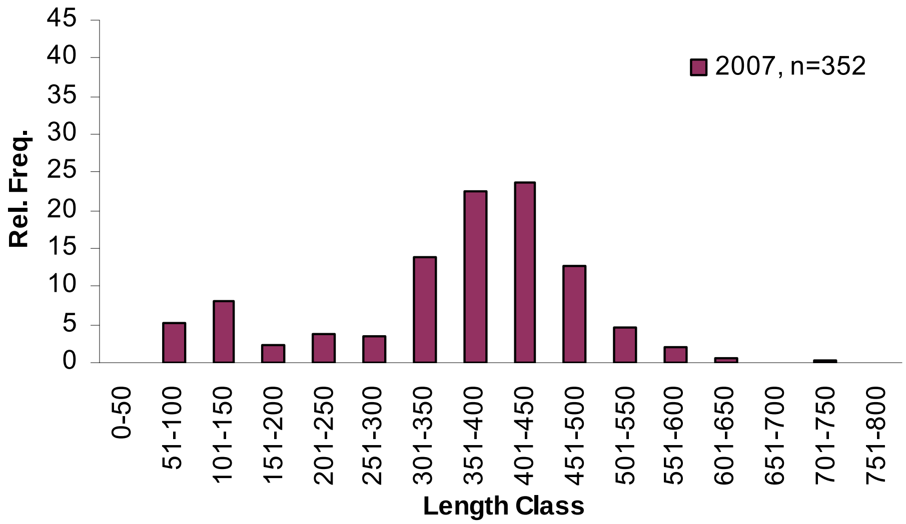
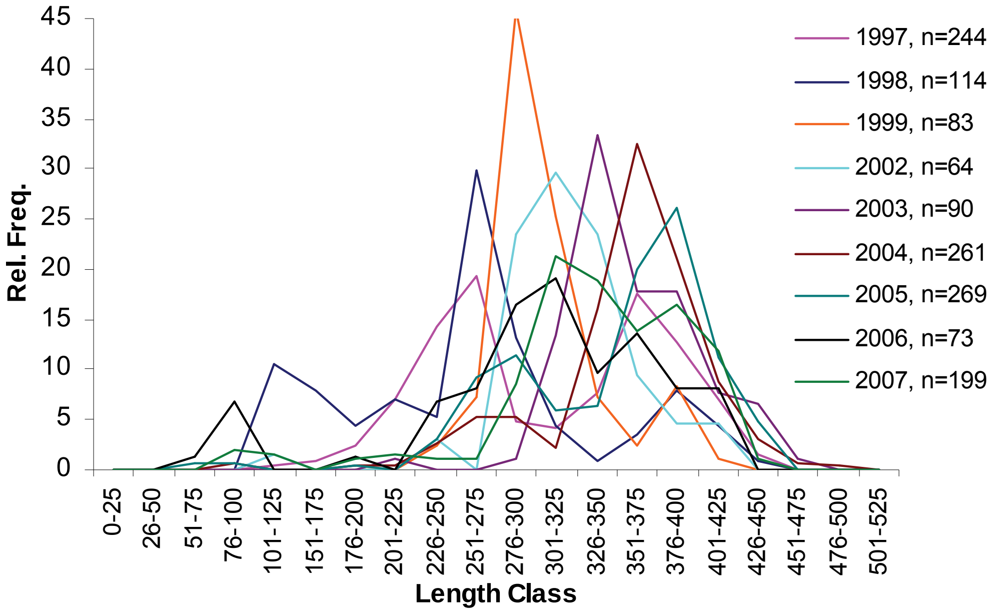


Figure 5.1-33 Relative length-frequency distributions for goldeye captured in the Athabasca River, spring and fall, 1997-2007.



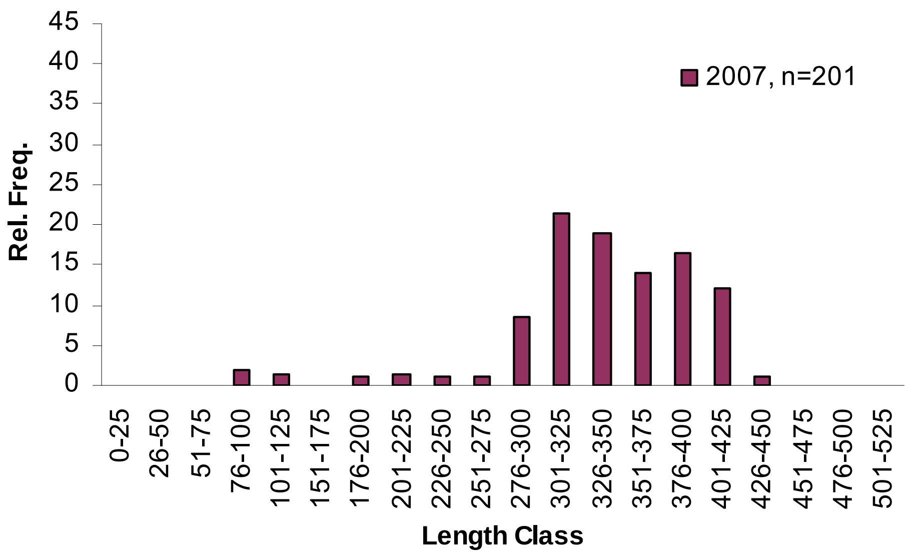
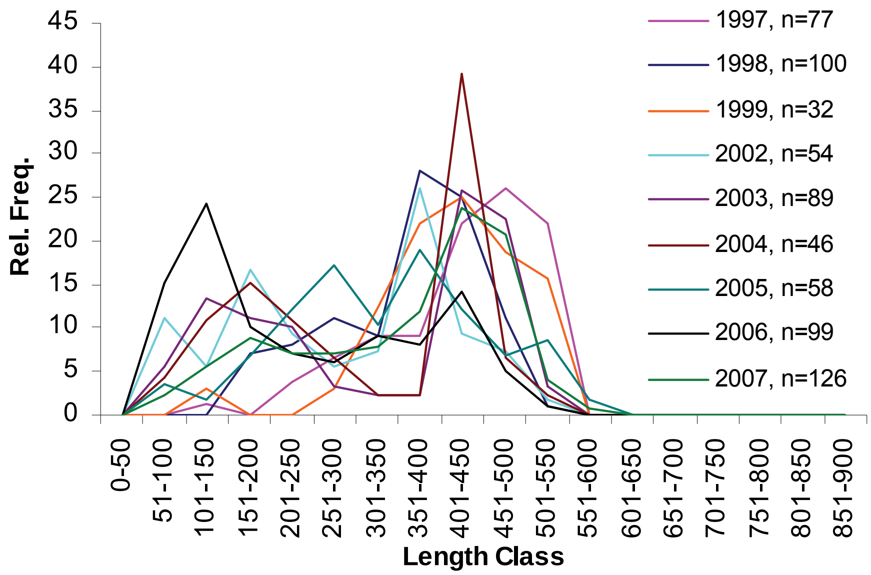


Figure 5.1-34 Relative length-frequency distributions for longnose sucker captured in the Athabasca River, spring and fall 1997-2007.



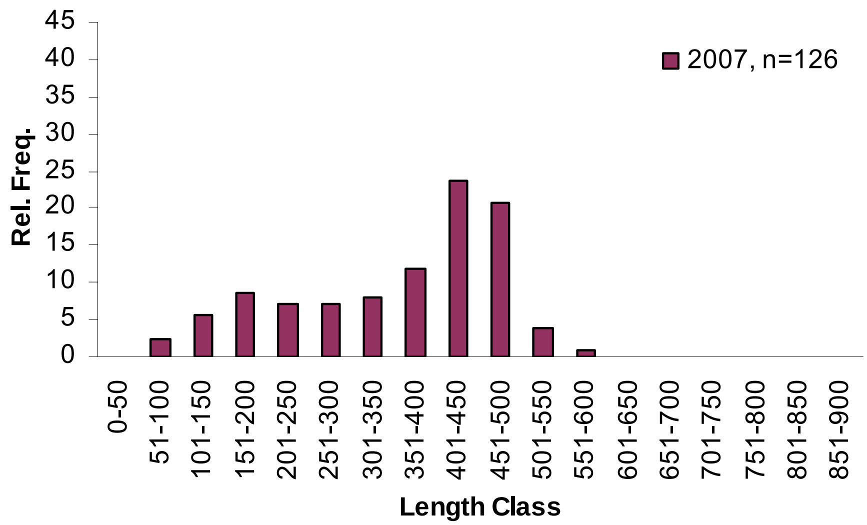
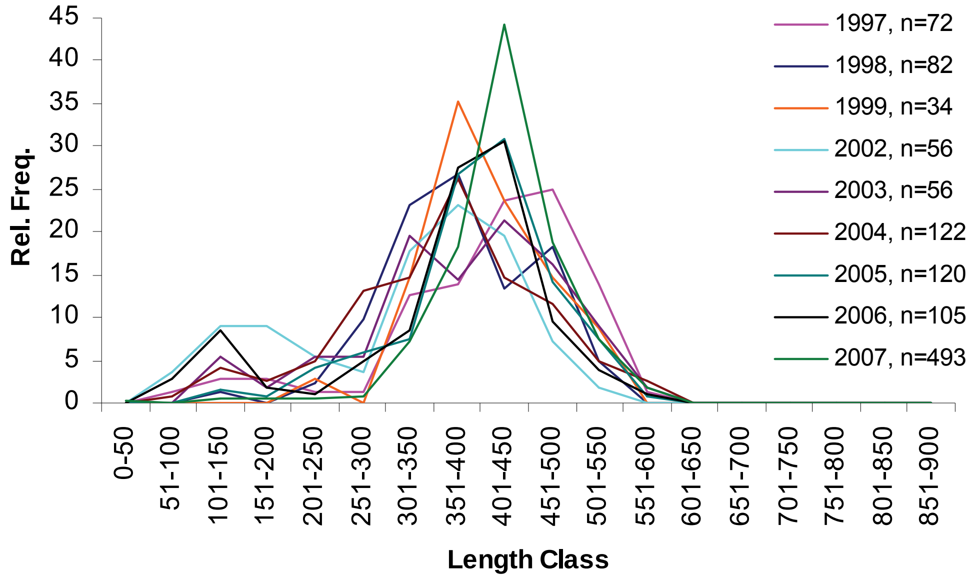


Figure 5.1-35 Relative length-frequency distributions for white sucker captured in the Athabasca River, spring and fall, 1997-2007.



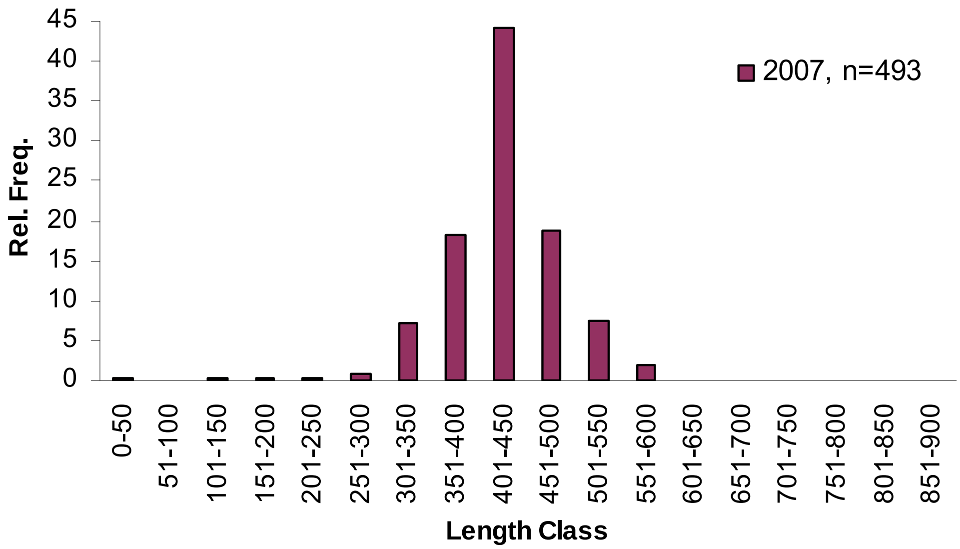
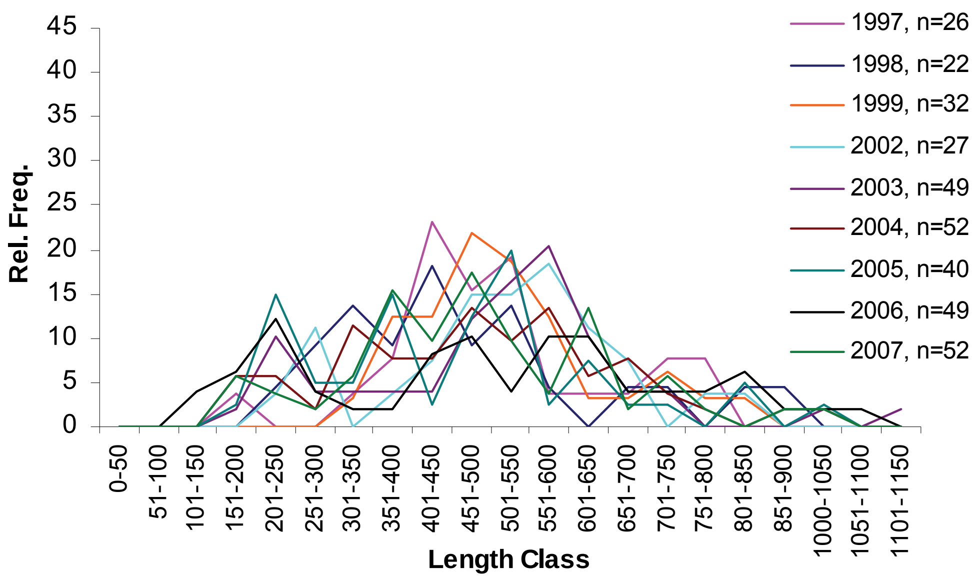


Figure 5.1-36 Relative length-frequency distributions for northern pike captured in the Athabasca River, spring and fall, 1997-2007.



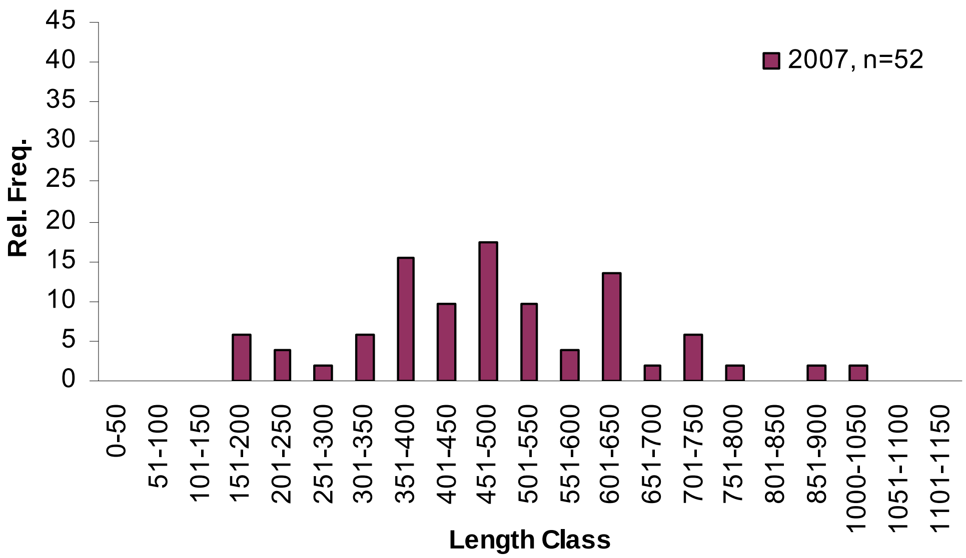


Figure 5.1-37 Ratio of undersize to legal size walleye captured in the Athabasca River, spring and fall 2007.

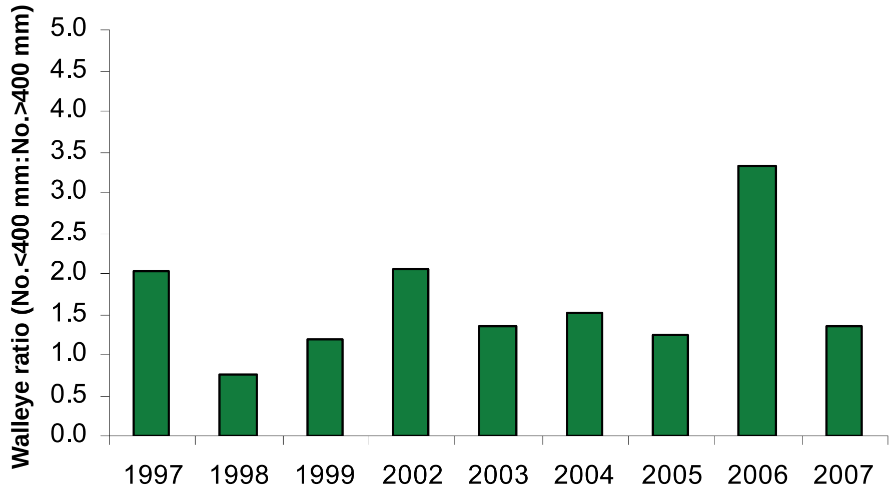


Figure 5.1-38 Ratio of undersize to legal size northern pike captured in the Athabasca River, spring and fall 2007.

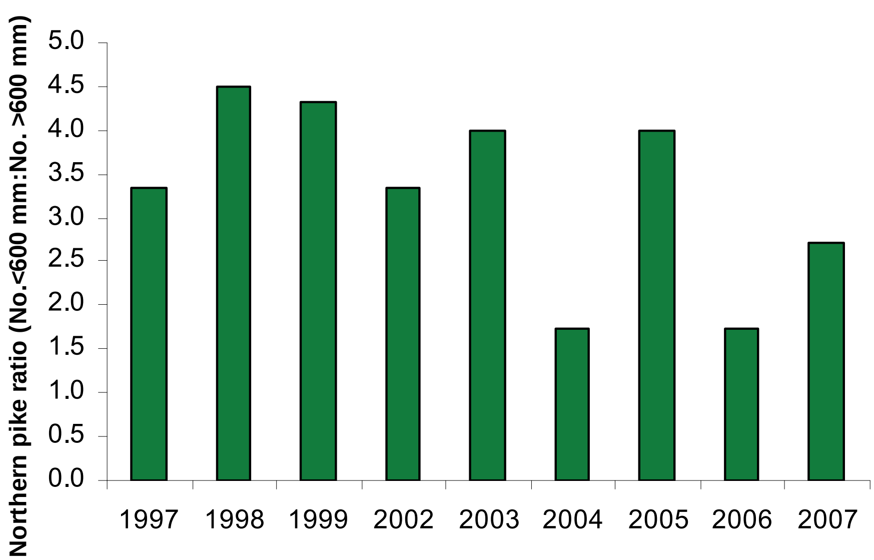


Figure 5.1-39 Mean condition factor for five key indicator fish species, Athabasca River, spring season, 1997-2007.

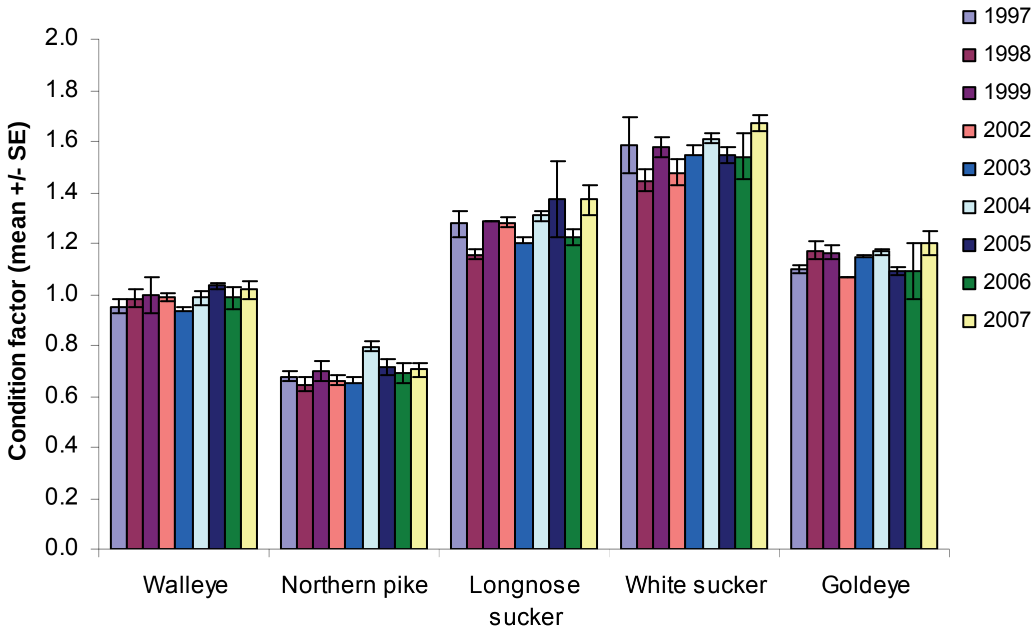


Figure 5.1-40 Mean condition factor for five key indicator fish species, Athabasca River, fall season, 1997-2007.

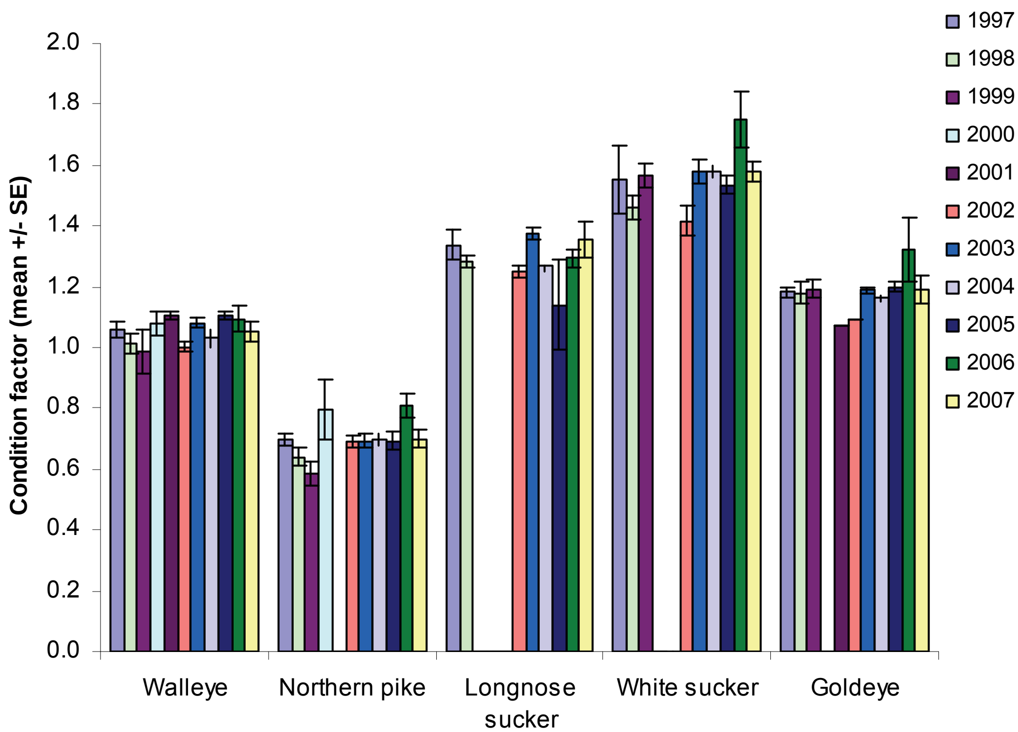


Table 5.1-16 Summary of external pathology indices for five key indicator fish species, Athabasca River, 1997-2007.

Species	Mean Pathology Index										
	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Walleye	1.5	2.1	2.6	0.2	0.8	1.4	1.1	0.3	1.5	1.2	1.2
Goldeye	4.3	0.5	4.3	4.6	0.9	0.4	1.9	0.4	0.7	0.8	1.8
Northern pike	8.3	3	6	3.9	4	1.1	2.8	2.3	2.2	0.8	1.7
Longnose sucker	5.8	3.5	6.3	0	1.2	0.9	0.5	1.4	1.1	0.7	2.2
White sucker	3.2	9.6	2.3	2.1	4	0.6	7.1	0.4	2.5	1.6	4.6

Figure 5.1-41 Daily average water temperatures on the Athabasca River for all sites from summer sampling (August 14, 2007) to fall sampling (October 18, 2007).

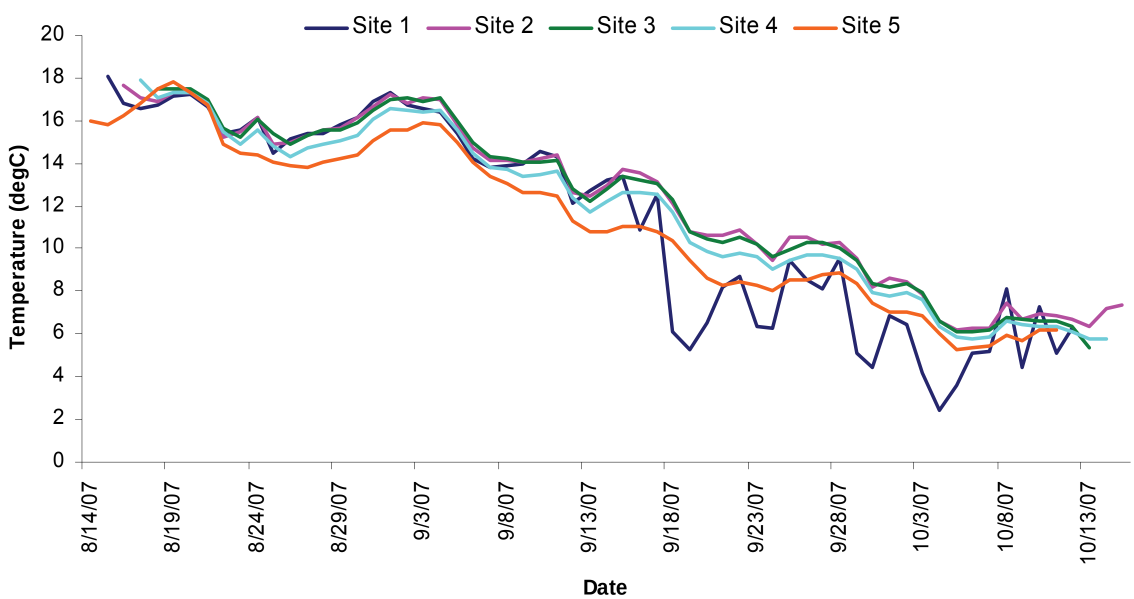


Table 5.1-17 Summary of catch per unit effort and morphometric data (mean 1 ± SE) for trout-perch on the Athabasca River, 2007.

Season/ Site	No. Fish Captured	Effort		CPUE		Morphometric Information (mean ± SE)		
		Electrofishing Effort (s)	No. Seine Pulls	Catch/ 100s	Catch/Seine Pull	Length (mm)	Weight (g)	Condition Factor
Summer								
Site 1	53	2024	5	2.12	1.3	65.81 ± 1.25	3.69 ± 0.14	1.29 ± 0.04
Site 2	101	1323	8	1.59	10.0	51.35 ± 1.55	2.30 ± 0.19	1.41 ± 0.04
Site 3	109	1256	7	1.35	11.5	42.82 ± 1.10	1.28 ± 0.10	1.38 ± 0.03
Site 4	113	1982	1	3.13	51.0	44.60 ± 1.09	1.50 ± 0.10	1.52 ± 0.06
Site 5	99	5515	-	1.80	-	56.46 ± 1.40	2.62 ± 0.16	1.31 ± 0.03
Fall								
Site 1	100	5404	-	1.85	-	53.27 ± 1.10	2.13 ± 0.14	1.25 ± 0.01
Site 2	100	2442	-	4.10	-	59.63 ± 1.11	2.78 ± 0.16	1.18 ± 0.01
Site 3	101	3849	-	2.62	-	50.53 ± 1.24	2.07 ± 0.17	1.43 ± 0.09
Site 4	100	2394	-	4.18	-	47.39 ± 0.69	1.33 ± 0.06	1.19 ± 0.01
Site 5	102	5722	-	1.78	-	41.67 ± 1.02	1.03 ± 0.13	1.18 ± 0.02

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

Figure 5.1-42 Seasonal relative length-frequency distributions of trout-perch from Site 1 on the Athabasca River, 2007.

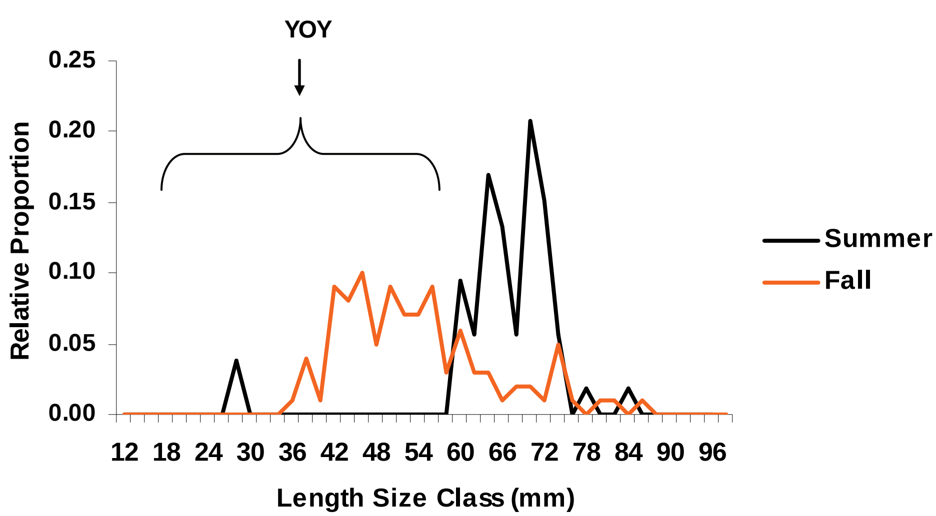


Figure 5.1-43 Seasonal relative length-frequency distributions of trout-perch from Site 2 on the Athabasca River, 2007

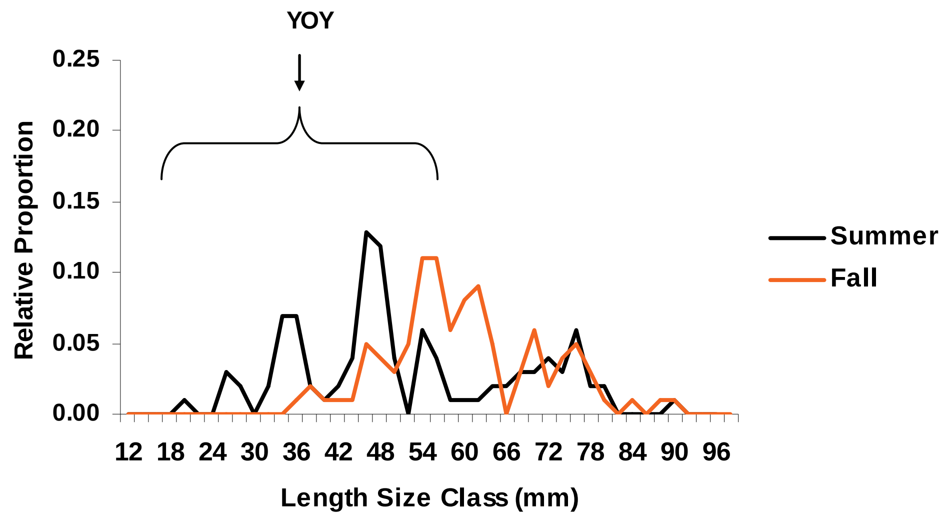


Figure 5.1-44 Seasonal relative length-frequency distributions of trout-perch from Site 3 on the Athabasca River, 2007.

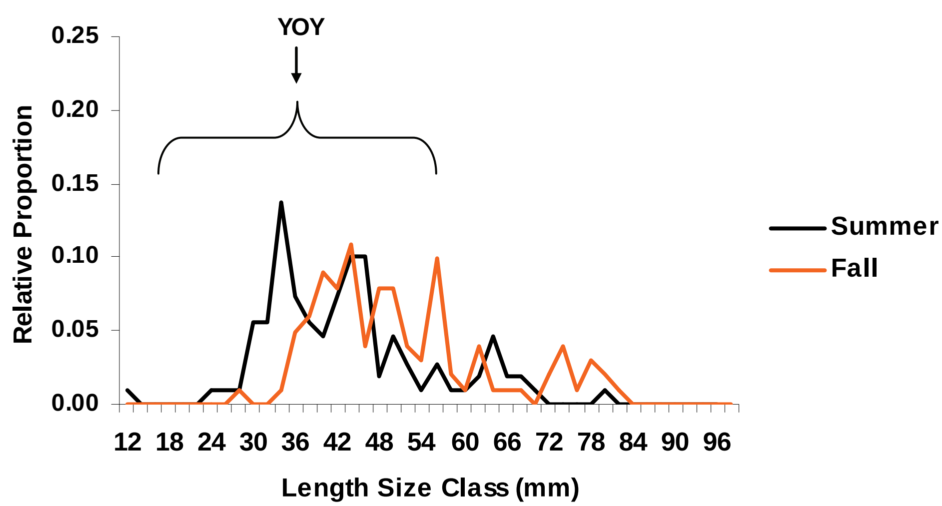


Figure 5.1-45 Seasonal relative length-frequency distributions of trout-perch from Site 4 on the Athabasca River, 2007.

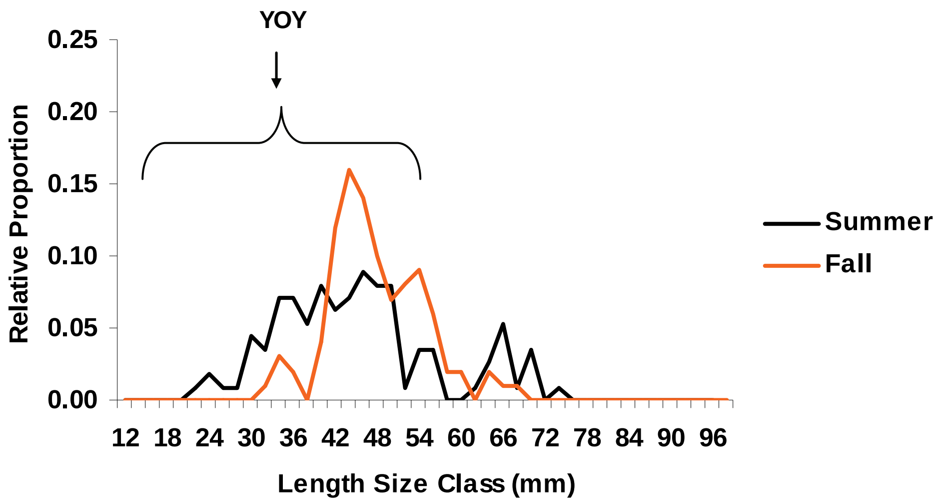


Figure 5.1-46 Seasonal relative length-frequency distributions of trout-perch from Site 5 on the Athabasca River, 2007.

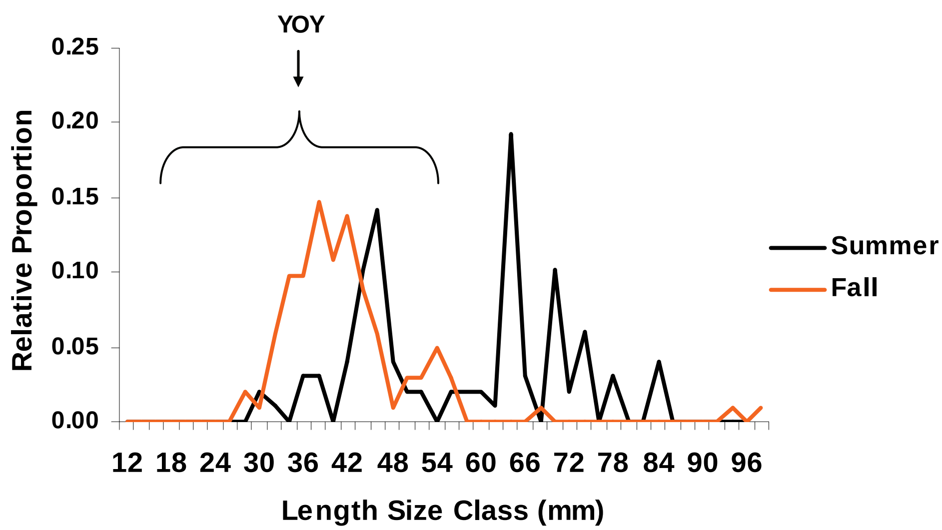


Table 5.1-18 Estimated growth rates of young-of-year trout-perch, 2007.

Site	Summer	Fall	Difference	Estimated Growth (mm/day)
1	27.00	47.55	20.55	0.36
2	42.47	50.35	7.88	0.14
3	39.52	45.20	5.68	0.10
4	41.00	46.38	5.38	0.09
5	43.96	40.32	-3.64	-0.06

Table 5.1-19 Relative proportion of captured trout-perch in young-of-year (YOY) size classes on the Athabasca River, 2007.

Season/Site	Total No. Caught	No. YOY Caught	% YOY
Summer			
Site 1	53	2	3.8
Site 2	101	70	69.3
Site 3	109	95	87.2
Site 4	113	97	85.8
Site 5	99	49	49.5
Fall			
Site 1	100	71	71.0
Site 2	100	46	46.0
Site 3	101	80	79.2
Site 4	100	94	94.0
Site 5	102	99	97.1

YOY defined as being in 58-60 mm size class or smaller.

Figure 5.1-47 Condition factor for trout-perch captured during the sentinel species program on the Athabasca River, summer and fall 2007.

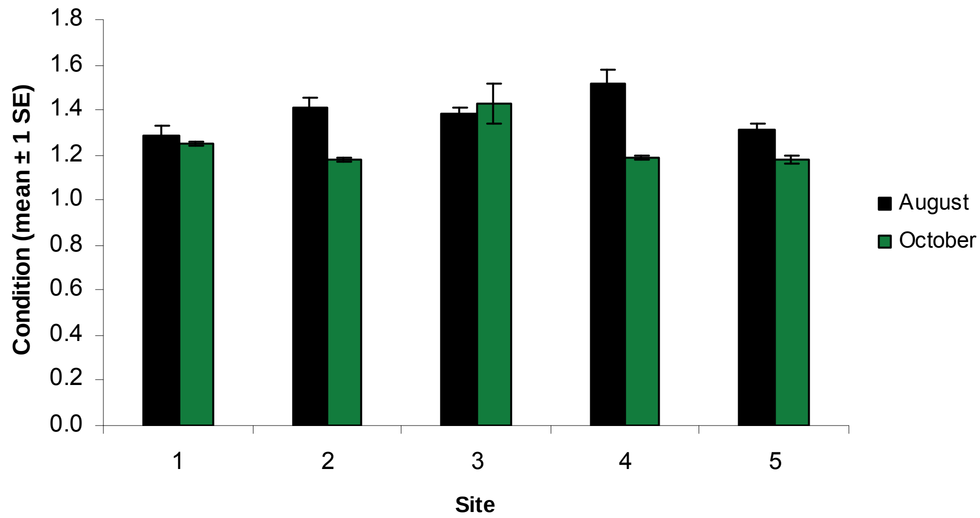


Figure 5.1-48 Condition factor for trout-perch captured during the sentinel species program on the Athabasca River, fall 1999, 2002, and 2007.

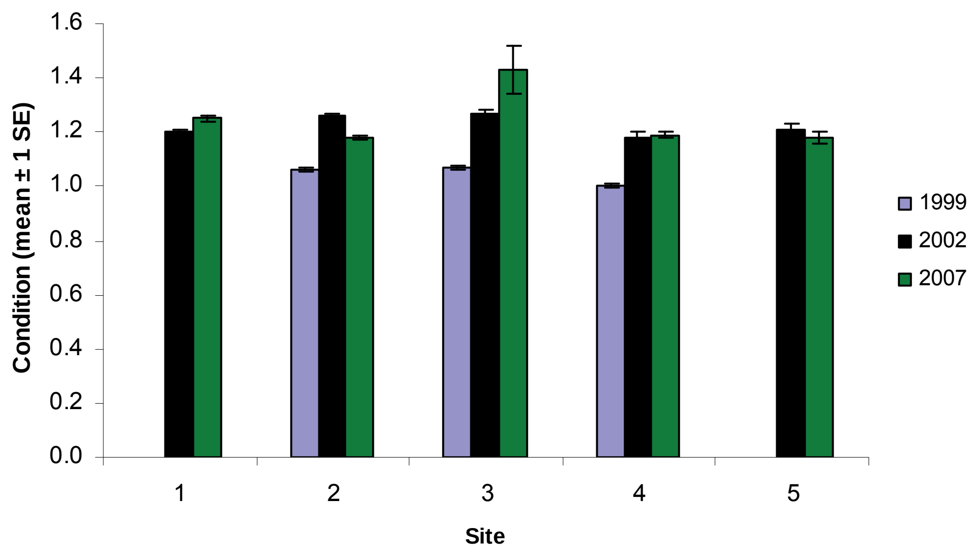


Table 5.1-20 Young-of-year (YOY) morphometrics (mean ± 1 SE) for trout-perch on the Athabasca River, 2007.

Month/Site	# of YOY Captured (n=)	Length (mm)	Weight (g)	Condition
August				
1	2	27 ± 0.00	0.515 ± 0.12	2.62 ± 0.58
2	70	42.47 ± 1.03	1.19 ± 0.07	1.45 ± 0.05
3	95	39.52 ± 0.81	0.92 ± 0.05	1.38 ± 0.03
4	97	41 ± 0.8	1.11 ± 0.06	1.56 ± 0.07
5	49	43.96 ± 1.46	1.23 ± 0.14	1.40 ± 0.08
October				
1	71	47.55 ± 0.67	1.41 ± 0.06	1.26 ± 0.01
2	46	50.35 ± 0.82	1.54 ± 0.07	1.16 ± 0.01
3	80	45.2 ± 0.75	1.41 ± 0.1	1.48 ± 0.12
4	94	46.38 ± 0.59	1.23 ± 0.04	1.18 ± 0.01
5	99	40.32 ± 0.66	0.83 ± 0.04	1.18 ± 0.02

Table 5.1-21 Adult morphometrics (mean ± 1 SE) for trout-perch on the Athabasca River, 2007.

Month/Site	# of Adult Captured (n=)	Length (mm)	Weight (g)	Condition
August				
1	34	69.91 ± 0.64	4.17 ± 0.14	1.21 ± 0.01
2	26	73.35 ± 1.01	5.18 ± 0.18	1.31 ± 0.03
3	6	68.83 ± 2.14	4.26 ± 0.4	1.29 ± 0.04
4	12	67.58 ± 0.89	3.98 ± 0.16	1.29 ± 0.05
5	28	72.86 ± 1.03	4.48 ± 0.19	1.15 ± 0.03
October				
1	15	73.4 ± 1.50	5.01 ± 0.33	1.24 ± 0.02
2	27	74.37 ± 1.09	5.06 ± 0.25	1.21 ± 0.01
3	15	74.67 ± 1.14	5.32 ± 0.29	1.26 ± 0.03
4	2	66 ± 1	3.6 ± 0.32	1.25 ± 0.05
5	3	86 ± 9.07	7.73 ± 1.96	1.16 ± 0.05

Figure 5.1-49 Fish tag recovery locations, 2007.

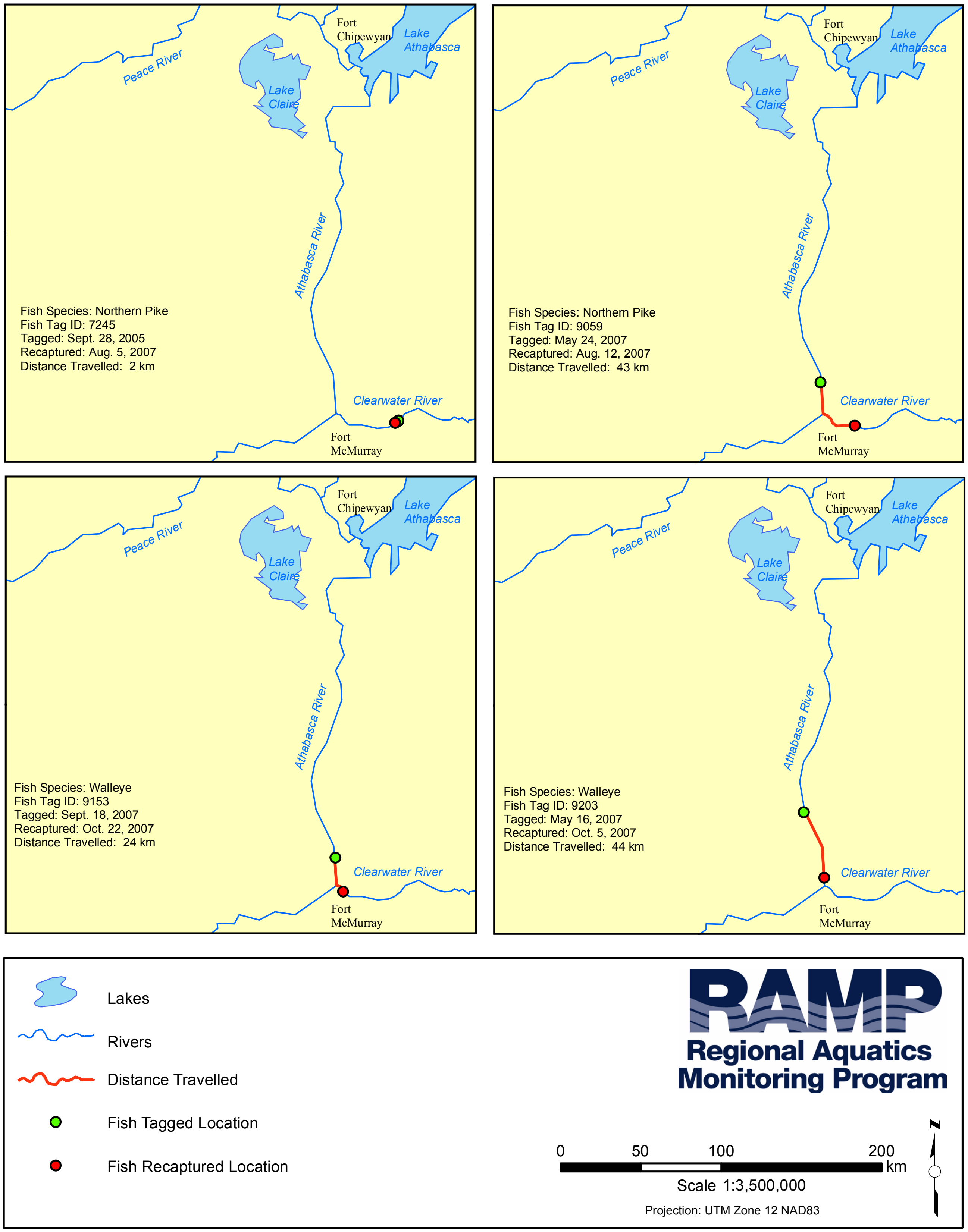


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Table 5.1-22 Results of RAMP fish tag return analysis, 2007.

Parameter	Fish Species	
	Walleye	Northern Pike
No. of Fish Recaptured	2	3
Minimum Distance Traveled (km)	24	2
Maximum Distance Traveled (km)	44	43

Table 5.1-23 Results of RAMP fish tag return analysis, 1999 to 2007.

Parameter	Fish Species				
	Lake Whitefish	Longnose Sucker	Northern Pike	Walleye	White sucker
No. of Fish Recaptured	1	2	14	57	3
Minimum Distance Traveled (km)	271	5.3	0	1	1
Maximum Distance Traveled (km)	271	236	57	715	241

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5.2 MUSKEG RIVER WATERSHED

Summary of Results

Measurement Endpoint	Summary of 2007 Conditions				
Climate and Hydrology					
	Assessment of Change				
	Negligible	**Low**	**Moderate**	**High**	
Mean open-water season discharge		√			Total 2007 runoff was below normal (60% of long-term average). Focal projects are predicted to have increased mean mean winter discharge (6.7%), open-season minimum daily discharge (22%), and decreased annual maximum daily discharge (-4.3%), mean open-water season discharge (-3.1%) for 2007.
Mean winter discharge			√		
Annual maximum daily discharge			√		
Minimum open-water season discharge				√	

Water Quality			
Guideline Exceedances	**Station-Endpoint Combinations Exceeding Guidelines in 2007[1]**		
Measurement endpoints with guidelines	**2007 *Potentially Influenced* Stations (n=5)**	**2007 *Reference Stations* (n=3)**	There were few exceedances of water quality guidelines; concentrations of most water quality measurement endpoints were within historical regional baseline ranges. Elevated levels of dissolved solids and various ions in Stanley Creek were likely due to the operation of the Aurora North Clean Water Discharge. However, with respect to measurement endpoints, water quality in Stanley Creek was similar to other Muskeg River watershed stations. Any changes in water quality in Muskeg River tributaries have not resulted in measurable changes to water quality in lower Muskeg River.
Physical variables (max = 5 for exp, 3 for ref)	0	0	
Nutrients (max = 10 for exp, 6 for ref)	0	0	
Ions (max = 10 for exp, 6 for ref)	0	0	
Selected metals (max=30 for exp, 18 for ref)	0	1	
Comparison to Regional Baselines	**Endpoints in 2007 Compared to Regional Baseline[2]**		
Percentile of Regional Baseline Values	**2007 *Potentially Influenced* Stations (n=5 stations X 15 endpoints)**	**2007 *Reference* Stations (n=3 stations X 15 endpoints)**	
Greater than 95th percentile	5	3	
Between 5th and 95th percentiles	67	42	
Less than 5th percentile	3	0	

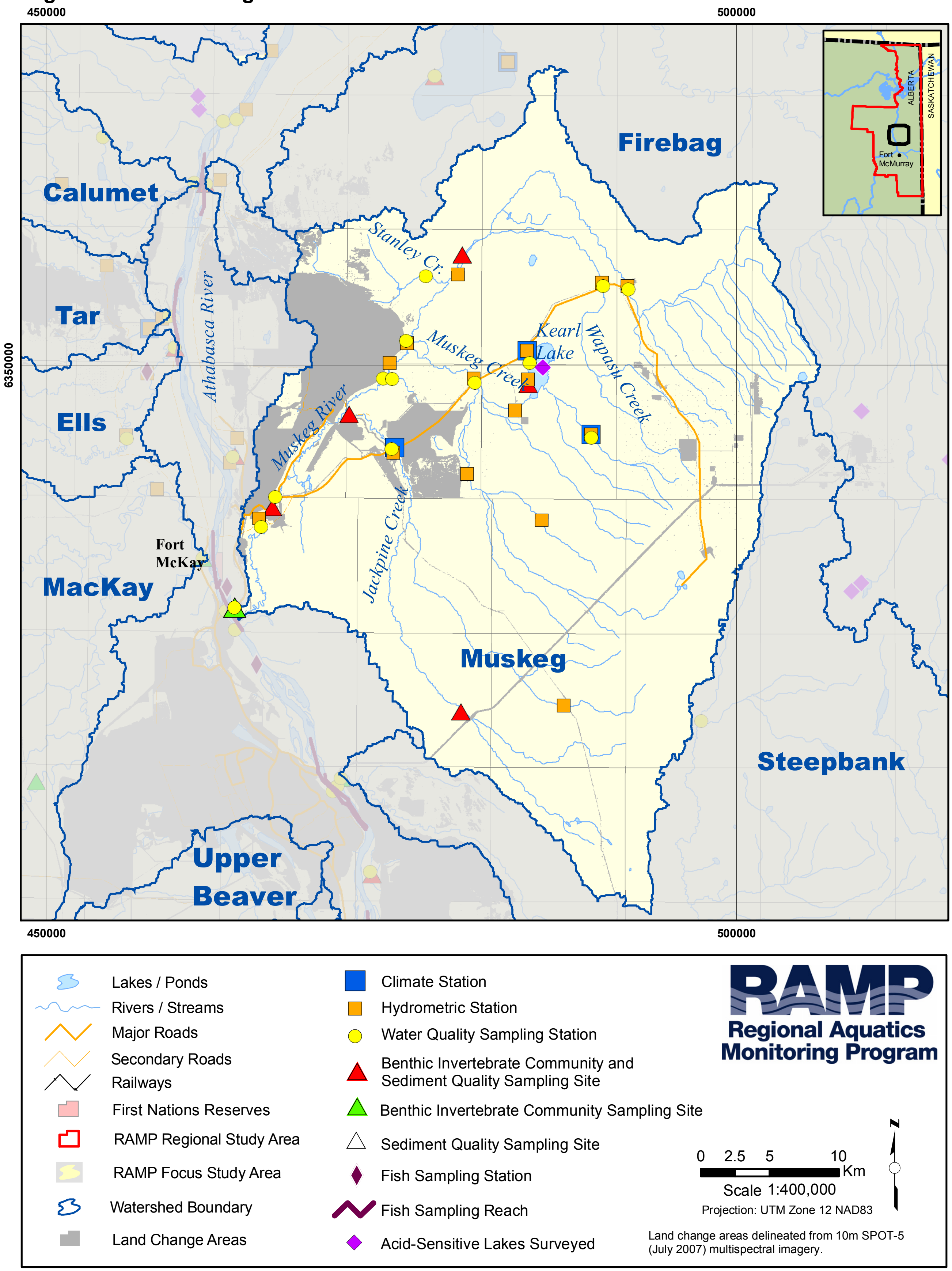
Benthic Invertebrate Communities and Sediment Quality							
Benthic Invertebrate Communities: Comparison to Regional Baselines	**Endpoints in 2007 Compared to Regional Baseline**						While there were some significant differences in benthic invertebrate community measurement endpoints between potentially-influenced and reference reaches, values of all benthic invertebrate community measurement endpoints in 2007 at all reaches 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.
	2007 *Potentially Influenced* Stations (n= 3)			**2007 *Reference* Stations (n= 2)**			
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		3			2		
% EPT		3			2		
Sediment Quality Guideline Exceedances	**Station-Endpoint Combinations Exceeding Guidelines in 2007[1]**						
Measurement endpoints with guidelines	**2007 *Potentially Influenced* Stations (n= 2)**			**2007 *Reference* Stations (n= 2)**			
Total Hydrocarbons(max=8 for exp,8 for ref)	3			1			
PAHs (max=2 for exp, 2 for ref)	0			0			

0	
Fish Inventory	No fish inventory studies conducted in 2007.
Sentinel Studies	No sentinel fish studies conducted in 2007
Fish Tissue	**Level of Risk**
Human Health: Subsistence	No fish tissue program conducted in 2007.
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 5.2-1 Muskeg River watershed.



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5.2.1 Development Status

As of 2007, approximately 9% of the Muskeg River watershed had undergone land change as a result of focal project activities (Table 2.4-2). 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 Aurora North mine, and Jackpine mine leases (Figure 5.2-1) are designated as *potentially influenced*. All data gathered from 2007 RAMP stations located in this area of the watershed are designated as operational data; and

- The remainder of the watershed (Figure 5.2-1) is designated as *reference*, and all data gathered from the 2007 RAMP stations located in these parts of the watershed are designated as baseline data.

5.2.2 Hydrologic Conditions

2007 Hydrologic Conditions Total runoff in the Muskeg River basin in 2007, as measured at RAMP Station S7, Muskeg River near Fort McKay (07DA008), was well below normal at approximately 60% of the long-term average (Figure 5.2-2). Most of the flow occurred in spring. The summer was very dry with flows in the lower quartile, but streamflows rose again in August and September. The annual maximum daily discharge of 18.7 m^3/s was well below the mean annual flood of 24.8 m^3/s, and the minimum open-water season discharge of 0.265 m^3/s was only 25% of 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 5.2-1):

- Discharges to the Muskeg River by focal projects in 2007 are estimated at 1.99 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 2007, areas of closed-circuited land change and other land change (not closed-circuited) was 93.8 km^2 and 36.6 km^2, respectively, in the Muskeg River drainage as a result of cumulative development of focal projects in the watershed (Table 2.4-1), the estimated effects of which were to reduce inflows to the Muskeg River by 4.32 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 2007. These estimated influences are predicted to have decreased mean open-water season discharge by 3.1%, increased mean winter discharge by 6.7%, decreased annual maximum daily discharge by 4.3%, and increased open-season minimum daily discharge by 22% (Table 5.2-2, Figure 5.2-2). These estimated changes in hydrologic measurement endpoints for 2007 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, the effect on mean winter discharge as moderate and the effect on open-season minimum daily discharge 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 2007 (Table 5.2-1). The increased runoff from land change areas that were not closed-circuited was a minor contributor in 2007 to differences between the operational and calculated baseline hydrographs (Figure 5.2-2).

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 2007 have ranged from low to high.

5.2.3 Water Quality

In fall 2007, 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 2007);
- 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 and 2007);
- 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 from 2006 to 2007);
- Muskeg River upstream of Wapasu Creek (station MUR-6, *reference*; baseline data available from 1998 to 2007);
- Muskeg Creek at Canterra Road (station MUC-1, designated as *reference* up to and including 2006, with baseline data available from 1998 to 2006, and designated as *potentially influenced* beginning in 2007);
- Wapasu Creek (station WAC-1, *reference*, baseline data available intermittently from 1998 to 2007); and
- Iynimin Creek (stations IYC-1, *reference*, baseline data available in 2007).

2007 Results and Historical Ranges of Concentration At stations designated as *potentially influenced* in fall 2007, concentrations of 15 (14%) and four (3%) of a possible 110 water quality measurement endpoint-station combinations were below and above, respectively, previously measured minimum and maximum concentrations. These percentages were similar for stations designated as *reference* in fall 2007, where concentrations of six (14%) of a possible 44 water quality measurement endpoint-station combinations were either above or below previously measured minimum and maximum concentrations. Station-specific details are provided below:

- At the mouth of the Muskeg River (station MUR-1), fall 2007 concentrations of all water quality measurement endpoints were within historical ranges (Table 5.2-3);
- At the mouth of Jackpine Creek (station JAC-1), fall 2007 concentrations of all water quality measurement endpoints were within historical ranges (Table 5.2-4);
- Stanley Creek (station STC-1) has received intermittent site-drainage flows from Syncrude's Aurora North development since May 2003, via their Clean Water Discharge. Mean daily flow to Stanley Creek via this discharge in 2007 averaged 5,446 m^3/day (derived from an annual discharge estimate provided to RAMP by Syncrude personnel). Concentrations of water quality measurement endpoints in Stanley Creek at station STC-1 in fall 2007 were within previously-measured minimum and maximum concentrations with the exception of dissolved organic carbon which had a concentration that was higher in fall 2007 than the previously-measured maximum concentration (Table 5.2-5);
- For Shelley Creek (station SHC-1), comparison of 2007 water quality results with historical results is limited due to the lack of data. However, concentrations of a number of major ions and nutrients were lower in 2007 than in 1999 and 2006, and concentrations of total suspended solids and sulphate exceeded previously-measured maximum concentrations at this station (Table 5.2-6);
- In Muskeg Creek (station MUC-1), fall 2007 concentrations of all water quality measurement endpoints were within historical ranges with the exceptions of dissolved organic carbon and total mercury, with fall 2007 concentrations higher than previously-measured maximum fall concentrations, and magnesium, with fall 2007 concentrations lower than previously-measured minimum fall concentrations at this station (Table 5.2-7);
- In the Muskeg River upstream of Wapasu Creek (station MUR-6), fall 2007 concentrations of all water quality measurement endpoints were within historical ranges (Table 5.2-8); and
- At Wapasu Creek (station WAC-1), fall 2007 concentrations of water quality measurement endpoints were within historical ranges with the exceptions of conductivity, total dissolved phosphorus, magnesium, total alkalinity, and total strontium, with fall 2007 concentrations lower than previously-measured minimum fall concentrations, and total mercury, with fall 2007 concentrations higher than previously-measured maximum fall concentrations at this station (Table 5.2-9).

Comparisons with historical results could not be made for Iynimin Creek (IYC-1), given 2007 was the first year this tributary was sampled by RAMP.

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 stations MUR-1, JAC-1, STC-1, MUC-1, SHC-1, WAC-1, or

MUR-6 in fall 2007 (Table 5.2-11). Overall, there was one (1%) of 88[1] possible exceedances in water quality guidelines for the water quality measurement endpoints at all the Muskeg River water quality stations in fall 2007, that being total aluminum in Iynimin Creek (station IYC-1, designated as *reference* in 2007, Table 5.2-11).

Other Water Quality Guideline Exceedances Concentrations of the following other water quality variables exceeded guidelines in the Muskeg River watershed in 2007 (Table 5.2-11):

- Station MUR-1: Sulphide, and total and dissolved iron in fall 2007;
- Station JAC-1: Total iron in fall 2007;
- Station MUC-1: Sulphide and total iron in fall 2007;
- Station WAC-1: Sulphide and total zinc in fall 2007; and
- Station IYC-1: Total phosphorus, total aluminum, dissolved and total iron in summer 2007 and total aluminum and total and dissolved iron in fall 2007.

Comparison of Water Quality Measurement Endpoints to Natural Variation in Baseline Conditions At stations designated as *potentially influenced* in fall 2007, concentrations of 8 (11%) of a possible 75 water quality measurement endpoint-station combinations fell outside the range of regional baseline concentrations (i.e., below the 5th or above the 95th percentile of regional baseline data, Figure 5.2-3, Figure 5.2-4). This was higher than at stations designated as *reference* in fall 2007, where the concentration of three (7%) of a possible 45 water quality measurement endpoint-station combinations were outside the range of regional baseline values (Figure 5.2-3, Figure 5.2-4). The difference in the frequency of guideline exceedance in fall 2007 between *potentially influenced* and *reference* stations was less than differences measured in fall 2006 (15% in stations designated as *potentially influenced* and 1% in stations designated as *reference*, RAMP 2007). Station-specific details are provided below:

- Concentrations of all water quality measurement endpoints were within the range of regional baseline concentrations at both stations on the Muskeg River mainstem, station MUR-1 and station MUR-6 (Figure 5.2-3), in Jackpine Creek, station JAC-1, and Muskeg Creek, station MUC-1 (Figure 5.2-4);
- At Wapasu Creek (station WAC-1), all selected water quality measurement endpoints were within regional baseline ranges except potassium and total mercury, with concentrations that exceeded the 95th percentile of regional baseline concentrations (Figure 5.2-4);
- At Shelley Creek (station SHC-1), all selected water quality measurement endpoints were within regional baseline ranges except dissolved phosphorus, which was below than the 5th percentile of regional baseline concentrations, and potassium, sulphate, and total mercury, which exceeded the 95th percentile of regional baseline concentrations (Figure 5.2-4);
- At Stanley Creek (STC-1), all selected water quality measurement endpoints were within regional baseline ranges except total nitrogen and arsenic, which were below the 5th percentile of regional baseline concentrations, and calcium

[1] Eleven of the selected water quality measurement endpoints have water quality guidelines and water quality was sampled at a total of eight locations in the Muskeg River watershed in fall 2007, making for a total of 88 possible guideline exceedances.

and sulphate, which exceeded the 95th percentile of regional baseline concentrations (Figure 5.2-4); and

- At Iynimin Creek (station IYC-1), all selected water quality measurement endpoints were within regional baseline ranges except total mercury, which exceeded the 95th-percentile regional baseline concentration (Figure 5.2-4).

Ion Balance Ion balance throughout the Muskeg River watershed in fall 2007 was similar to previous years (Figure 5.2-5). Ion balance at Stanley Creek (STC-1) and Shelley Creek (SHC-1) have shown the greatest variability across years of sampling; ion balance in fall 2007 fell within the range of historical observations for these stations.

Trend Analysis As of 2007, sufficient data existed to allow statistical trend analysis of fall water-quality data for Muskeg watershed stations MUR-1 (n=11), MUR-6 (n=10), JAC-1 (n=9), MUC-1 (n=10), and STC-1 (n=7). At these stations, the following statistically significant trends (α=0.05) were observed:

- In the Muskeg River mainstem, downward trends in total arsenic at MUR-1 and MUR-6;
- At Muskeg Creek (MUC-1), downward trends in total arsenic and dissolved calcium;
- In Stanley Creek (STC-1), an upward trend in total strontium;
- In Jackpine Creek (JAC-1), no significant trends were observed.

Summary The influence of the CWD on water quality in Stanley Creek continues to be associated with increased ion concentrations and different ion balance in Stanley Creek (station STC-1) relative to other stations. However, with respect to water quality guideline exceedance and relation to historical ranges of concentration, water quality in Stanley Creek was similar to other stations in the Muskeg River watershed in fall 2007. In addition, any potential changes in water quality in Stanley Creek and in other tributaries of the Muskeg River have not resulted in measurable changes to water quality in the lower Muskeg River mainstem at station MUR-1. There were few exceedances of water quality guidelines throughout the watershed; concentrations of most water quality measurement endpoints throughout the watershed were within historical regional baseline ranges. Total mercury was measurable above the analytical detection limit for the first time in waters from several tributaries, although not in any waterbodies classified as *potentially influenced* except Shelley Creek at station SHC-1. Total mercury was not detectable in the Muskeg River mainstem, in Jackpine Creek, or in Stanley Creek, all of which are designated as *potentially influenced* for 2007. Mercury concentration in Shelley Creek in fall 2007 was below that of Wapasu Creek, station WAC-1, a creek further upstream in the Muskeg River basin and designated as *reference* for 2007.

5.2.4 Benthic Invertebrate Communities and Sediment Quality

5.2.4.1 Benthic Invertebrate Communities

Muskeg River Reaches

In 2007, benthic invertebrate community samples were collected from the following three reaches on the Muskeg River:

- A lower reach near the Muskeg River mouth (reach MUR-E-1, erosional, *potentially influenced*, operational data available from 2000);

- A middle reach near the Canterra Road crossing (reach MUR-D-2, depositional, *potentially influenced*, operational data available from 2000 to 2007); and
- An upper reach located upstream of the Muskeg River and focal project developments (reach MUR-D-3, depositional, *reference*, baseline data available from 2002).

2007 Habitat Conditions The lower reach near the Muskeg River mouth (reach MUR-E-1) was shallow (0.3 m), and had high current velocity (0.7 m/s) and low macrophyte cover (5%) in fall 2007 (Table 5.2-12). Benthic algal biomass (measured as chlorophyll *a*) was similar to previous years and was indicative of oligotrophic conditions (Figure 5.2-6). The substrate at reach MUR-E-1 was comprised of a mixture of coarse materials including boulder, cobble and gravel (Table 5.2-12). By comparison, the middle reach (reach MUR-D-2) and upper reach (reach MUR-D-3) had deeper water with slower current velocities, and with greater macrophyte cover (Table 5.2-12). The substrate at reach MUR-D-2 was dominated by sand, while the substrate at the upper reach (reach MUR-D-3) was more evenly comprised of sand, silt and clay.

Relative Abundance of Benthic Invertebrate Community Taxa in 2007 The benthic invertebrate community of the lower reach near the Muskeg River mouth (reach MUR-E-1) was dominated in fall 2007 by chironomids, mayflies, and mites (Table 5.2-13). Stoneflies and caddisflies were also prevalent, while a number of worms (tubificids, naidids), bivalves (Sphaeriidae fingernail clams), and beetles (Coleoptera) were present in lower abundances. Some of the more sensitive taxa found in the lower reach included the mayfly *Leptophlebia*, and the stoneflies, *Isoperla, Pteronarcys* and *Taeniopteryx*. A single specimen of the stonefly *Claassenia sabulosa* was collected in the 2007 survey. It was much more abundant in this lower reach in 2006. Barton (1980) suggested that this species might be a possible indicator of habitat quality because of its three year life cycle. Other important taxa (numerically) were the mayfly *Baetis*, the caddisflies *Hydropsyche* and *Cheumatopsyche*, the beetle *Optioservus*, and the chironomids *Polypedilum, Stempellina, Stempellinella* and *Lopescladius*. Benthic invertebrates have been sampled regularly in the lower reach since 1998 and community composition (based on measurements endpoints and multivariate descriptors) has consistently reflected the expected community composition based on regional reference ranges for erosional habitats (Figure 5.2-7, Figure 5.2-8). Abundance was approximately 13,000 individuals/m^2 in 2007, and has historically varied between 5,000 and 70,000 individuals/m^2 (Table 5.2-13). The number of taxa (richness) has been close to 30 for the past eight years, while diversity has been very high (>0.8) for the past six years. Percent EPT (25%) was about average in fall 2007 for reach MUR-E-1.

The benthic invertebrate community of the middle reach of the Muskeg River (reach MUR-D-2) was dominated in fall 2007 by midges (chironomids) and biting midges (ceratopogonids) (Table 5.2-13). Sub-dominant taxa included enchytraeid worms, amphipods (*Hyalella azteca*), mayflies (e.g., *Leptophlebia*), gastropods, and mites. Unlike fall 2006, there were no stoneflies, and there were only two specimens of a single caddisfly (*Polycentropus*). Of the chironomids, *Stempellina, Stempellinella* and *Pseudosmittia* were the most common. Total abundance in reach MUR-D-2 was lower in 2007 compared to previous years (Table 5.2-13), but the number of taxa, diversity, and %EPT in fall 2007 were similar to, or higher than the long-term average for this reach and within regional reference ranges for depositional habitats (Figure 5.2-9).

The benthic invertebrate community of the upper reach of the Muskeg River (reach MUR-D-3) was dominated in fall 2007 by chironomids (60%) including some relatively tolerant forms such as *Procladius, Chironomus, Dictrotendipes, Microtendipes*. Sub-dominant groups included Nematoda, worms (Naididae, Tubificidae), and fingernail clams

(Bivalvia). Total abundances in the upper reach were somewhat higher in fall 2007 than in previous years, while the number of taxa (average of 16), diversity (0.82), and %EPT (4%) were all within regional reference ranges for depositional habitats (Table 5.2-13, Figure 5.2-9).

Effects of Focal Project Activities The following linear contrasts were used to test for effects of focal projects for the lower reach (reach MUR-E-1, *potentially influenced*) in comparison with the upper reach (MUR-D-3, *reference*) and the middle reach (reach MUR-D-2, *potentially influenced*) also in comparison with the upper reach (reach MUR-D-3, *reference*):

- A difference between *reference* and *potentially influenced* across all common years;
- A difference in time trends between *reference* and *potentially influenced*; and
- A difference between *reference* and *potentially influenced* in 2007 only.

As in previous years, and as expected, benthic invertebrate community measurement endpoints differed between the lower reach (reach MUR-E-1) and the upper reach (reach MUR-D-3), with reach MUR-E-1 having higher abundance of benthic organisms with greater diversity (richness, Simpson's, evenness) and a higher percentage of EPT taxa (Table 5.2-14). Those differences were expected on the basis that erosional habitats tend to provide a greater diversity of habitat for benthic macroinvertebrates than do depositional habitats, and they tend to support a broader diversity of larval insects including the EPT taxa (Minshall, 1984). Differences between reach MUR-E-1 and reach MUR-D-3 in overall averages and absolute values of benthic invertebrate community measurement endpoints, therefore, cannot be used to indicate a focal project effect for reach MUR-E-1.

There were, however, differences in time trends between the lower reach (reach MUR-E-1) and the upper reach (reach MUR-D-3, Table 5.2-14). Diversity and evenness have been increasing over time in reach MUR-D-3 at a faster rate than has been observed in reach MUR-E-1, to the point that both diversity and evenness were the same in the both reaches in fall 2007 (in previous years, the reach MUR-E-1 had higher diversity and evenness and reach MUR-D-3). However, benthic invertebrate community measurement endpoints in reach MUR-E-1 were well within the normal range of variation for reference erosional reaches (Figure 5.2-8). In addition, the "remainder" (or noise) term associated with this contrast, was larger than any of the effects-based terms (Table 5.2-14), indicating that the random variation was larger than the possible effects related to focal projects.

The benthic invertebrate community of the lower reach (reach MUR-E-1) contained a number of sensitive groups including the mayflies, stoneflies and caddisflies, and had high diversity in fall 2007, all of which indicate a healthy condition (Bode, 1988). The multivariate ordination of the benthic community confirmed that composition of the fauna of the lower reach was well within the normal range of expected conditions relative to reference erosional reaches (Figure 5.2-7). There is therefore little evidence of significant effects of focal projects on the benthic invertebrate community in reach MUR-E-1, and little indication that the benthic invertebrate community of reach MUR-E-1 is shifting towards an unusual condition.

The middle reach (MUR-D-2) had significantly greater abundance, taxa richness, and diversity (Simpson's diversity index and evenness) than the upper reach (reach MUR-D-3, Table 5.2-15). There were significant differences in time trends only for abundance, with the middle reach (reach MUR-D-2) declining slightly over time, and for %EPT, with the %EPT in the upper reach (reach MUR-D-3) increasing over time while being more variable in the middle reach (reach MUR-D-2). All benthic invertebrate community measurement endpoints in both reach MUR-D-2 and MUR-D-3 have remained within the normal range of variability for reference depositional reaches (Figure 5.2-9). The "remainder" (or noise) term for this set of linear contrasts was also larger than any of the effects-based terms. In addition, the ordination of the benthic community from the reach MUR-D-2 indicates that its faunal assemblage has been within the normal range of expected conditions relative to reference depositional reaches (Figure 5.2-10). Similar to the assessment for the lower reach (reach MUR-E-1), there is little evidence of significant effects of focal projects on the benthic invertebrate community in reach MUR-D-2, and little indication that the benthic invertebrate community of reach MUR-D-2 is shifting towards an unusual condition.

Jackpine Creek

Benthic invertebrate community samples were collected from two reaches on Jackpine Creek:

- A depositional lower reach near the mouth of Jackpine Creek (reach JAC-D-1, *potentially-influenced* since 2005, baseline data available from 2002); and
- A depositional upper reach of Jackpine Creek (reach JAC-D-2, *reference*, baseline data available from 2003).

2007 Habitat Conditions Both reaches were shallow (~1 m deep), with no measurable current and minimal macrophyte cover in fall 2007 (Table 5.2-16). Sediments at both reaches were dominated by sand, with low amounts of organic carbon (Table 5.2-16).

Relative Abundance of Benthic Invertebrate Community Taxa in 2007 The benthic invertebrate communities of both reaches were dominated by chironomids (Table 5.2-17). Ephemeroptera (mayflies) were present in both reaches, but in lower numbers in reach JAC-D-1 than in reach JAC-D-2. The mayflies *Caenis* and *Leptophlebia*, dominated the mayfly fauna and were present in both reaches. The upper reach contained the caddisflies *Oxyethira*, and *Lepidostoma*, but in low numbers. The chironomids *Procladius* and *Tanytarsus* were numerically important in both reaches in fall 2007, while *Dictrotendipes*, *Polypedilum* and *Paralauterborniella* were more abundant in reach JAC-D-2 than reach JAC-D-1. Reach JAC-D-2 was more diverse (25 taxa) than the lower reach (JAC-D-1, 16 taxa) and had higher Simpson's diversity and evenness (Table 5.2-17).

Effects of Focal Project Activities Linear contrasts were used to test for the following specific focal project-related effects for the lower reach (reach JAC-D-1, *potentially influenced*) in comparison with the upper reach (reach JAC-D-2, *reference*):

- A difference between *reference* and *potentially influenced* across all common years;
- A difference in time trends between *reference* and *potentially influenced*; and
- A difference between *reference* and *potentially influenced* in 2007 only.

In addition, tests were made for differences in benthic invertebrate community measurement endpoints for reach JAC-D-1 from before to after it was designated as *potentially influenced*.

None of the differences in time trends between *reference* and *potentially influenced* was statistically significant with the exception of %EPT (Table 5.2-18), reflecting the increase in %EPT in reach JAC-D-2, at the same time that %EPT in reach JAC-D-1 has remained more constant (Figure 5.2-11). "Remainder" (noise) variation was larger than variation associated with these contrasts (Table 5.2-18). In all cases, variation in benthic invertebrate community measurement endpoints were within the normal range of variation observed in reference depositional reaches (Figure 5.2-12). Further, the fauna of the lower reach contained representatives of sensitive groups including the mayfly *Leptophlebia*, as well as fingernail clams and gastropods, both of which require relatively stable environments. There is no evidence of significant effects of focal projects on the benthic invertebrate community in reach JAC-D-1.

5.2.4.2 Sediment Quality

Sediment quality was assessed in fall 2007 in depositional reaches of the Muskeg River where benthic invertebrate communities were sampled: reach MUR-D-2 (mid-Muskeg River, *potentially influenced*), reach MUR-D-3 (upper Muskeg River, *reference*), reach JAC-D-1 (lower Jackpine Creek, *potentially influenced*), and reach JAC-D-2 (upper Jackpine Creek, *reference*).

2007 Results and Historical Ranges of Concentration Sediment quality data from all reaches in the Muskeg River sampled in 2007 may be compared directly with data for these reaches sampled in 2006. Prior to integration of the sediment-quality and benthic-invertebrate-community components of RAMP in 2006, current benthic reaches MUR-D-2 and MUR-D-3 correspond with pre-2006 sediment-quality stations MUR-2 and MUR-D2, respectively; current reach JAC-D-1 corresponds with pre-2006 sediment-quality station JAC-1. Current reach JAC-D-2 was established in 2006.

At depositional reaches MUR-D-2 and JAC-D-1, designated as *potentially influenced* in fall 2007, concentrations of 65% and 75% of sediment-quality measurement endpoints, respectively, fell within historical ranges. A similar proportion (i.e., 70%) of endpoints fell within historical ranges at reach MUR-D-3 (*reference*) in fall 2007. All of these comparisons are characterized by small sample sizes (n=2 to 4 years). Concentrations of sediment quality measurement endpoints in fall 2007 that were outside historical ranges 2007 included:

- At reach MUR-D-2: CCME hydrocarbon Fractions 2 and 4, retene, total dibenzothiophenes, total low-molecular-weight (LMW) PAHs, and survival of *Hyalella* (all above historical maxima); and survival of *Chironomus* (below historical minimum) (Table 5.2-19);
- At reach MUR-D-3: Total organic carbon, retene, total PAHs, total LMW PAHs, and *Hyalella* survival (all above historical maxima); and CCME hydrocarbon Fraction 4 (below historical minimum) (Table 5.2-20); and
- At reach JAC-D-1: CCME hydrocarbon Fractions 2, 3 and 4 (above historical maxima); and naphthalene (below historical minimum) (Table 5.2-21).

Only two years of data exist at reach JAC-D2; therefore all 2007 data represent either a historical minimum or maximum. However, most results for 2007 were similar those from 2006, except CCME hydrocarbon fraction 4, which exhibited a concentration twice as high in 2007 as 2006 (Table 5.2-22).

Comparison to Sediment Quality Guidelines Concentrations of CCME Fraction 3 hydrocarbons exceeded the relevant CCME soil-quality guideline at reaches MUR-D-2, MUR-D-3, and JAC-D-1 in fall 2007 (Table 5.2-19 to Table 5.2-21). No other sediment-quality measurement endpoints exceeded relevant guidelines in the Muskeg River in 2007.

Qualitative Among-Reach Comparisons The following comparisons in 2007 concentrations of sediment-quality variables among reaches are noted (Table 5.2-19 to Table 5.2-22):

- Total organic carbon was much higher at upstream reach MUR-D-3 (24.9%) than at mid-river reach MUR-D-2 (3.6%);
- Concentrations of hydrocarbons were highest at mid-river station MUR-D-2, and in most cases higher at Muskeg River stations than those in Jackpine Creek;
- Concentrations of PAHs were much higher at reach MUR-D-2 than other reaches;
- Component PAHs at reaches MUR-D-2 and JAC-D-1 included a greater proportion of bitumen-associated species (e.g., dibenzothiophenes, which comprised approximately 40 to 45% of total PAHs at these reaches) than at reach MUR-D-3, where retene, a diagenic product of organic decomposition, comprising approximately 30% of total PAHs;
- Survival and growth of *Chironomus tentans* were lower at reach MUR-D-2 than at MUR-D3, while results of survival and growth of *Hyalella azteca* were identical in sediments from both reaches; and
- CCME Fraction 1 hydrocarbons (C6-C10) and BTEX (benzene, toluene, ethylene, and xylene) were not detectable in sediments from any reach.

5.2.4.3 Summary

There is little evidence of effects of focal project activities on benthic invertebrate communities in the Muskeg River watershed in 2007. 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 2007 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.

5.2.5 Fish Populations

The Muskeg River fish fence program was planned for spring 2007, but not implemented due to prohibitively high water levels. The RAMP 2007 Fish Population component therefore did not include any activities in the Muskeg River watershed.

5.2.6 Summary of Conditions

The cumulative effects of focal projects at the watershed level for the Muskeg River watershed for 2007 are assessed as follows:

- There appear to be some effects on watershed hydrology, with differences in hydrologic measurement endpoints between observed, *potentially influenced* conditions and estimated *reference* conditions that are assessed as low to high. 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 (i.e., worst case scenario);

- 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 2007 in *potentially influenced* areas of the Muskeg River watershed than in *reference* areas, which is a continuation of conditions measured in 2006; and

- There is little evidence of focal project 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.

Figure 5.2-2 Muskeg River: 2007 hydrograph and historical context.

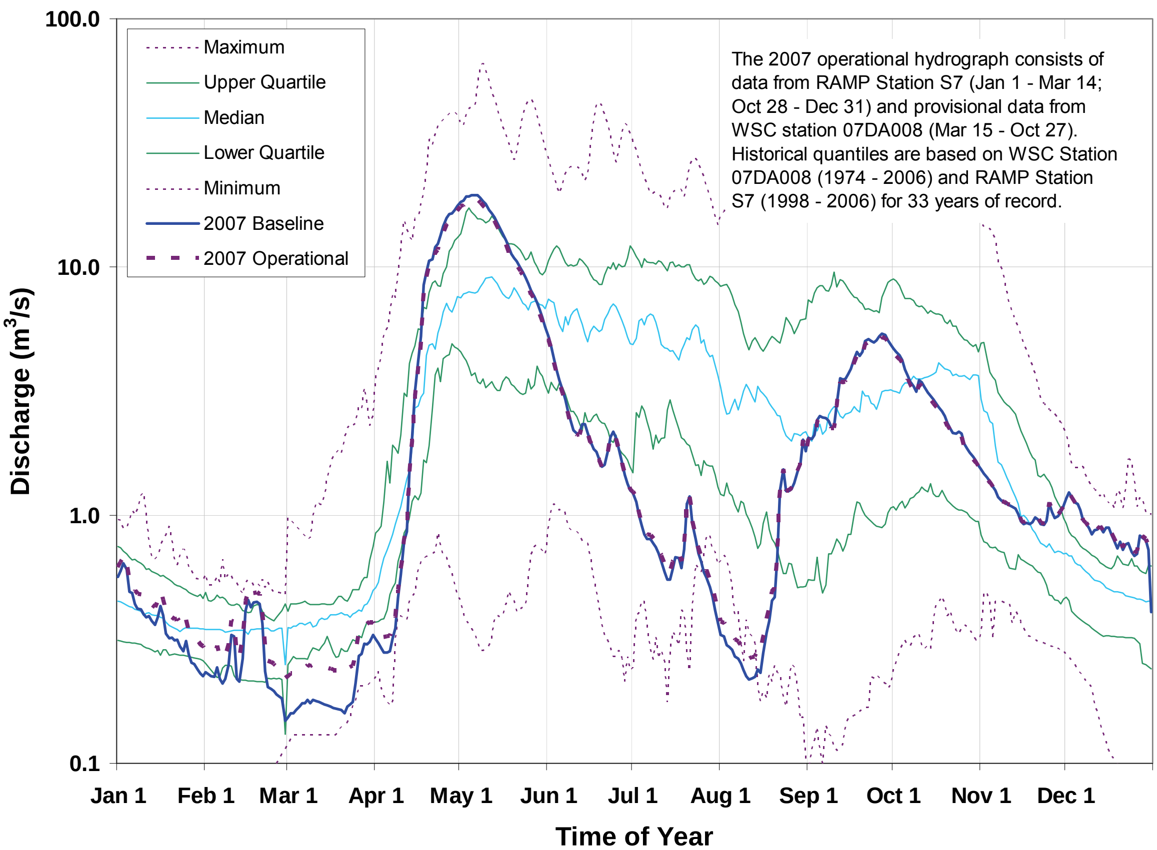


Table 5.2-1 Inputs for calculation of baseline hydrograph at RAMP/WSC Station S7, Muskeg River near Fort McKay (07DA008).

Component	Annual Volume (million m^3)	Basis and Data Source
Observed hydrograph	85.5	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 2007	+ 4.78	93.8 km^2 within Muskeg River drainage estimated to have been closed-circuited by focal projects as of 2007 (Table 2.4-1)
Incremental runoff from areas of land change due to focal project development areas and are not closed-circuited	- 0.458	36.6 km^2 within Muskeg River drainage estimated to have undergone land change by focal projects as of 2007, but are not closed-circuited (Table 2.4-1)
Withdrawals from the Muskeg River by focal project activities	0	Unknown, assumed to be negligible
Releases to the Muskeg River by focal project activities	- 1.99	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	87.8	Estimated baseline ("without focal project") flow for 2007
Incremental flow	-2.33	Difference in total flow between operational and baseline hydrograph
Incremental flow (% of observed total annual discharge)	- 2.7%	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 5.2-2 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	4.09	3.96	-3.1%
Mean winter discharge	0.571	0.609	6.7%
Annual maximum daily discharge	19.5	18.7	-4.3%
Open-water season minimum daily discharge	0.218	0.265	22%

[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 5.2-3 Concentrations of selected water quality measurement endpoints, Muskeg River mouth (station MUR-1), fall 2007.

Measurement Endpoint	Units	Guideline	September 2007	1997-2006 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.4	10	7.4	8.2	8.4
Total suspended solids	mg/L	-[1]	3	10	<3	3	70
Conductivity	µS/cm	-	324	10	220	348.5	671
Nutrients							
Total dissolved phosphorus	mg/L	0.05[2]	0.01	10	0.004	0.014	0.03
Total nitrogen*	mg/L	1.0	0.9	10	0.4	0.8	**1.2**
Nitrate+nitrite	mg/L	-	<0.1	10	<0.05	<0.1	<0.1
Dissolved organic carbon	mg/L	-	24	10	15	21	25
Ions							
Sodium	mg/L	-	13	10	8	12.5	64
Calcium	mg/L	-	43.9	10	28.8	51.3	108
Magnesium	mg/L	-	11.1	10	7.1	12.6	18.9
Chloride	mg/L	230, 860[3]	2	10	1	4	36
Sulphate	mg/L	100[4]	6.4	10	0.6	5.3	91
Total dissolved solids	mg/L	-	229	10	170	280	405
Total alkalinity	mg/L		161	10	105	179	313
Organic compounds							
Naphthenic acids	mg/L	-	<1	10	<1	<1	1
Selected metals							
Total aluminum	mg/L	0.1	0.0999	10	0.027	0.072	**1.2**
Dissolved aluminum	mg/L	0.1[2]	0.00336	10	0.00192	0.006655	0.030
Total arsenic	mg/L	0.005	0.000369	10	0.000251	0.0006535	<0.001
Total boron	mg/L	1.2[5]	0.0479	10	0.032	0.043	0.15
Total molybdenum	mg/L	0.073	0.00007	10	0.00007	0.0001	0.0003
Total mercury (ultra-trace)	ng/L	5, 13[6]	<1.2	4	<1.2	<1.2	<1.2
Total strontium	mg/L	-	0.115	10	0.086	0.129	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).

Table 5.2-4 Concentrations of selected water quality measurement endpoints Jackpine Creek (station JAC-1), fall 2007.

Measurement Endpoint	Units	Guideline	September 2007	1997-2006 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.2	8	7.8	7.96	8.3
Total suspended solids	mg/L	-[1]	<3	8	<3	2.5	8
Conductivity	µS/cm	-	237	8	183	219.5	413
Nutrients							
Total dissolved phosphorus	mg/L	0.05[2]	0.012	8	0.006	0.014	0.026
Total nitrogen*	mg/L	1.0	0.9	8	0.7	0.875	**1.5**
Nitrate+nitrite	mg/L	-	<0.1	8	<0.05	<0.1	<0.1
Dissolved organic carbon	mg/L	-	26	8	18.6	22	28
Ions							
Sodium	mg/L	-	12	8	10	11.5	18
Calcium	mg/L	-	28.9	8	22.2	29.3	56.6
Magnesium	mg/L	-	6.7	8	6.6	8.2	14.2
Chloride	mg/L	230, 860[3]	2	8	1	3	6
Sulphate	mg/L	100[4]	2.7	8	0.5	3.0	4.3
Total dissolved solids	mg/L	-	191	8	110	215	234
Total alkalinity	mg/L		118	8	93	114	227
Organic compounds							
Naphthenic acids	mg/L	-	<1	8	<1	<1	1
Selected metals							
Total aluminum	mg/L	0.1	0.0772	8	0.0179	0.068	0.12
Dissolved aluminum	mg/L	0.1[2]	0.012	8	0.0033	0.0094	0.17
Total arsenic	mg/L	0.005	0.00045	8	0.0003	0.00053	<0.001
Total boron	mg/L	1.2[5]	0.0456	8	0.033	0.0422	0.066
Total molybdenum	mg/L	0.073	0.0000865	8	0.00007	0.0001	0.0002
Total mercury (ultra-trace)	ng/L	5, 13[6]	<1.2	4	<1.2	<1.2	<1.2
Total strontium	mg/L	-	0.102	8	0.085	0.100	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).

Table 5.2-5 Concentrations of selected water quality measurement endpoints, Stanley Creek (station STC-1), fall 2007.

Measurement Endpoint	Units	Guideline	September 2007	1997-2006 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8	6	7.6	8.0	8.2
Total suspended solids	mg/L	-[1]	<3	6	<3	<3	6
Conductivity	µS/cm	-	435	6	271	427.5	760
Nutrients							
Total dissolved phosphorus	mg/L	0.05[2]	0.02	7	0.01	0.01	0.03
Total nitrogen*	mg/L	1.0	0.3	7	0.3	0.4	**2.1**
Nitrate+nitrite	mg/L	-	<0.1	7	<0.1	<0.1	<0.1
Dissolved organic carbon	mg/L	-	10	6	6	7.5	9
Ions							
Sodium	mg/L	-	5	6	2	4.5	26
Calcium	mg/L	-	68.1	6	45.4	69.6	112
Magnesium	mg/L	-	15.2	6	11.1	14.3	20.5
Chloride	mg/L	230, 860[3]	1	6	<1	2	14
Sulphate	mg/L	100[4]	30.9	6	2.4	27.1	**126**
Total dissolved solids	mg/L	-	264	6	200	290	480
Total alkalinity	mg/L		206	6	157	201	260
Organic compounds							
Naphthenic acids	mg/L	-	<1	7	<1	<1	1
Selected metals							
Total aluminum	mg/L	0.1	0.00699	7	0.000994	0.011	0.02
Dissolved aluminum	mg/L	0.1[2]	<0.001	7	0.0003	0.0011	0.02
Total arsenic	mg/L	0.005	0.000103	7	0.0001	0.000172	<0.001
Total boron	mg/L	1.2[5]	0.0197	7	0.018	0.024	0.087
Total molybdenum	mg/L	0.073	0.0000267	7	0.00004	0.0001	0.0002
Total mercury (ultra-trace)	ng/L	5, 13[6]	<1.2	4	<1.2	<1.2	<1.2
Total strontium	mg/L	-	0.157	7	0.075	0.099	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).

Table 5.2-6 Concentrations of selected water quality measurement endpoints, Shelley Creek (station SHC-1), fall 2007.

Measurement Endpoint	Units	Guideline	September 2007	1997-2006 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.1	2	7.16	-	7.9
Total suspended solids	mg/L	-[1]	<3	2	5	-	39
Conductivity	µS/cm	-	419	2	495	-	1172
Nutrients							
Total dissolved phosphorus	mg/L	0.05[2]	0.006	2	0.02	-	0.04
Total nitrogen*	mg/L	1.0	0.8	2	1.2	-	**3.9**
Nitrate+nitrite	mg/L	-	<0.1	2	<0.1	-	<0.1
Dissolved organic carbon	mg/L	-	26	2	25	-	28.6
Ions							
Sodium	mg/L	-	27	2	32	-	96
Calcium	mg/L	-	50.1	2	59.1	-	83.5
Magnesium	mg/L	-	14.3	2	13.8	-	15.8
Chloride	mg/L	230, 860[3]	3	2	15	-	80
Sulphate	mg/L	100[4]	25.7	2	<0.5	-	10
Total dissolved solids	mg/L	-	276	2	340	-	500
Total alkalinity	mg/L		199	2	242	-	354
Organic compounds							
Naphthenic acids	mg/L	-	<1	2	<1	-	1
Selected metals							
Total aluminum	mg/L	0.1	0.00945	2	0.06	-	0.088
Dissolved aluminum	mg/L	0.1[2]	0.00117	2	0.00315	-	<0.01
Total arsenic	mg/L	0.005	0.000391	2	0.00086	-	<0.001
Total boron	mg/L	1.2[5]	0.0776	2	0.0833	-	0.169
Total molybdenum	mg/L	0.073	0.000255	2	0.0001	-	0.000162
Total mercury (ultra-trace)	ng/L	5, 13[6]	2.7	1	-	-	<1.2
Total strontium	mg/L	-	0.154	2	0.207	-	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).

Table 5.2-7 Concentrations of selected water quality measurement endpoints, Muskeg Creek (station MUC-1), fall 2007.

Measurement Endpoint	Units	Guideline	September 2007	1997-2006 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	7.9	9	7.4	7.8	8.2
Total suspended solids	mg/L	-[1]	<3	9	<3	4	9
Conductivity	µS/cm	-	204	9	184	297	671
Nutrients							
Total dissolved phosphorus	mg/L	0.05[2]	0.013	9	0.013	0.018	0.034
Total nitrogen*	mg/L	1.0	1	9	0.4	1.0	**1.15**
Nitrate+nitrite	mg/L	-	<0.1	9	<0.05	<0.1	<0.1
Dissolved organic carbon	mg/L	-	29	9	20	23	28
Ions							
Sodium	mg/L	-	17	9	7	17	64
Calcium	mg/L	-	21.9	9	20.8	34.4	71.1
Magnesium	mg/L	-	6.5	9	7.2	10.4	17.3
Chloride	mg/L	230, 860[3]	2	9	<1	3	36
Sulphate	mg/L	100[4]	4.2	9	2	3.6	8
Total dissolved solids	mg/L	-	166	9	140	230	378
Total alkalinity	mg/L	-	100	9	93	153	313
Organic compounds							
Naphthenic acids	mg/L	-	<1	9	<1	<1	2
Selected metals							
Total aluminum	mg/L	0.1	0.0326	9	0.031	0.050	**0.142**
Dissolved aluminum	mg/L	0.1[2]	0.00647	9	0.0029	0.0100	0.03
Total arsenic	mg/L	0.005	0.000403	9	0.0002	0.000595	<0.001
Total boron	mg/L	1.2[5]	0.0531	9	0.024	0.0570	0.15
Total molybdenum	mg/L	0.073	0.0000546	9	0.00005	0.00010	0.0064
Total mercury (ultra-trace)	ng/L	5, 13[6]	1.8	4	<1.2	<1.2	<1.2
Total strontium	mg/L	-	0.0722	9	0.069	0.111	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);

* 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.

[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 5.2-8 Concentrations of selected water quality measurement endpoints, Muskeg River upstream of Wapasu Creek (station MUR-6), fall 2007.

Measurement Endpoint	Units	Guideline	September 2007	1997-2006 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.1	9	7.2	8.1	8.4
Total suspended solids	mg/L	-[1]	<3	9	<3	3	176
Conductivity	µS/cm	-	288	9	233	331.5	556
Nutrients							
Total dissolved phosphorus	mg/L	0.05[2]	0.013	9	0.011	0.016	0.039
Total nitrogen*	mg/L	1.0	0.7	9	0.3	0.85	**1.65**
Nitrate+nitrite	mg/L	-	<0.1	9	<0.05	<0.1	<0.1
Dissolved organic carbon	mg/L	-	21	9	14	18.5	24
Ions							
Sodium	mg/L	-	3	9	3	4	9
Calcium	mg/L	-	40.5	9	31.3	50.6	85.3
Magnesium	mg/L	-	14.3	9	11.6	16.9	23.4
Chloride	mg/L	230, 860[3]	1	9	<1	1	3
Sulphate	mg/L	100[4]	4.8	9	1.6	4.5	6.6
Total dissolved solids	mg/L	-	204	9	180	260	340
Total alkalinity	mg/L		154	9	120	195	318
Organic compounds							
Naphthenic acids	mg/L	-	<1	9	<1	<1	12
Selected metals							
Total aluminum	mg/L	0.1	0.0203	9	0.0091	0.021	**0.17**
Dissolved aluminum	mg/L	0.1[2]	0.00293	9	0.0017	0.0084	0.08
Total arsenic	mg/L	0.005	0.00031	9	0.0003	0.000699	<0.001
Total boron	mg/L	1.2[5]	0.0112	9	0.006	0.0118	0.081
Total molybdenum	mg/L	0.073	0.000085	9	0.00007	0.0001	0.0003
Total mercury (ultra-trace)	ng/L	5, 13[6]	<1.2	4	<1.2	<1.2	<1.2
Total strontium	mg/L	-	0.0745	9	0.058	0.088	0.327

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 5.2-9 Concentrations of selected water quality measurement endpoints, Wapasu Creek (station WAC-1), fall 2007.

Measurement Endpoint	Units	Guideline	September 2007	1997-2006 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	7.8	4	7.4	7.9	8.2
Total suspended solids	mg/L	-[1]	<3	4	<3	3	23
Conductivity	µS/cm	-	209	4	220	319	524
Nutrients							
Total dissolved phosphorus	mg/L	0.05[2]	0.009	4	0.012	0.014	0.022
Total nitrogen*	mg/L	1.0	0.9	4	0.8	1.0	1.0
Nitrate+nitrite	mg/L	-	<0.1	4	<0.1	<0.1	<0.1
Dissolved organic carbon	mg/L	-	26	4	11	17	26
Ions							
Sodium	mg/L	-	6	4	6	7	9
Calcium	mg/L	-	29.1	4	31.3	44.4	71.7
Magnesium	mg/L	-	8.6	5	9.6	15.4	25.1
Chloride	mg/L	230, 860[3]	2	4	1	2	3
Sulphate	mg/L	100[4]	2.5	4	1.9	3.3	7.6
Total dissolved solids	mg/L	-	166	4	160	240	300
Total alkalinity	mg/L		103	4	114	176	292
Organic compounds							
Naphthenic acids	mg/L	-	<1	4	<1	<1	<1
Selected metals							
Total aluminum	mg/L	0.1	0.0147	4	0.014	0.018	0.05
Dissolved aluminum	mg/L	0.1[2]	0.00414	4	0.0037	0.0064	0.05
Total arsenic	mg/L	0.005	0.000277	4	0.0002	0.000344	<0.001
Total boron	mg/L	1.2[5]	0.021	4	0.014	0.025	0.081
Total molybdenum	mg/L	0.073	0.0000446	4	0.00003	0.00005	0.0004
Total mercury (ultra-trace)	ng/L	5, 13[6]	3.3	3	<1.2	<1.2	<1.2
Total strontium	mg/L	-	0.0669	4	0.071	0.102	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).

Table 5.2-10 Concentrations of selected water quality measurement endpoints, Iyimin Creek (station IYC-1), fall 2007.

Measurement Endpoint	Units	Guideline	September 2007 Value
Physical variables			
pH	pH units	6.5-9.0	8
Total suspended solids	mg/L	-[1]	17
Conductivity	µS/cm	-	143
Nutrients			
Total dissolved phosphorus	mg/L	0.05[2]	0.018
Total nitrogen*	mg/L	1.0	0.9
Nitrate+nitrite	mg/L	-	<0.1
Dissolved organic carbon	mg/L	-	33
Ions			
Sodium	mg/L	-	7
Calcium	mg/L	-	18.8
Magnesium	mg/L	-	6.5
Chloride	mg/L	230, 860[3]	2
Sulphate	mg/L	100[4]	3.9
Total dissolved solids	mg/L	-	134
Total alkalinity	mg/L		72
Organic compounds			
Naphthenic acids	mg/L	-	<1
Selected metals			
Total aluminum	mg/L	0.1	**0.889**
Dissolved aluminum	mg/L	0.1[2]	0.0439
Total arsenic	mg/L	0.005	0.000721
Total boron	mg/L	1.2[5]	0.0254
Total molybdenum	mg/L	0.073	0.000108
Total mercury (ultra-trace)	ng/L	5, 13[6]	2.4
Total strontium	mg/L	-	0.0501

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 5.2-11 List of all 2007 water quality guideline exceedances, Muskeg River.

Water Quality Variable	Units	Guideline*	MUR-1	JAC-1	STC-1	SHC-1	MUR-6	MUC-1	WAC-1	IYC-1
Summer										
Total phosphorus	mg/L	0.05	ns	ns	ns	ns	ns	ns	ns	**0.057**
Total aluminum	mg/L	0.10	ns	ns	ns	ns	ns	ns	ns	**0.294**
Dissolved iron	mg/L	0.3[2]	ns	ns	ns	ns	ns	ns	ns	**0.779**
Total iron	mg/L	0.3	ns	ns	ns	ns	ns	ns	ns	**1.34**
Fall										
Sulphide	mg/L	0.014[1]	**0.015**	-	-	-	-	**0.025**	**0.019**	-
Total aluminum	mg/L	0.10	-	-	-	-	-	-	-	**0.889**
Dissolved iron	mg/L	0.3[2]	**0.351**	-	-	-	-	-	-	**0.301**
Total iron	mg/L	0.3	**0.662**	**0.543**	-	-	-	**0.304**	-	**1.15**
Total zinc	mg/L	0.030	-	-	-	-	-	-	**0.0304**	-

All sites were sampled only in fall 2007 except for IYC-1 which was sampled in summer and fall 2007.

ns = not sampled

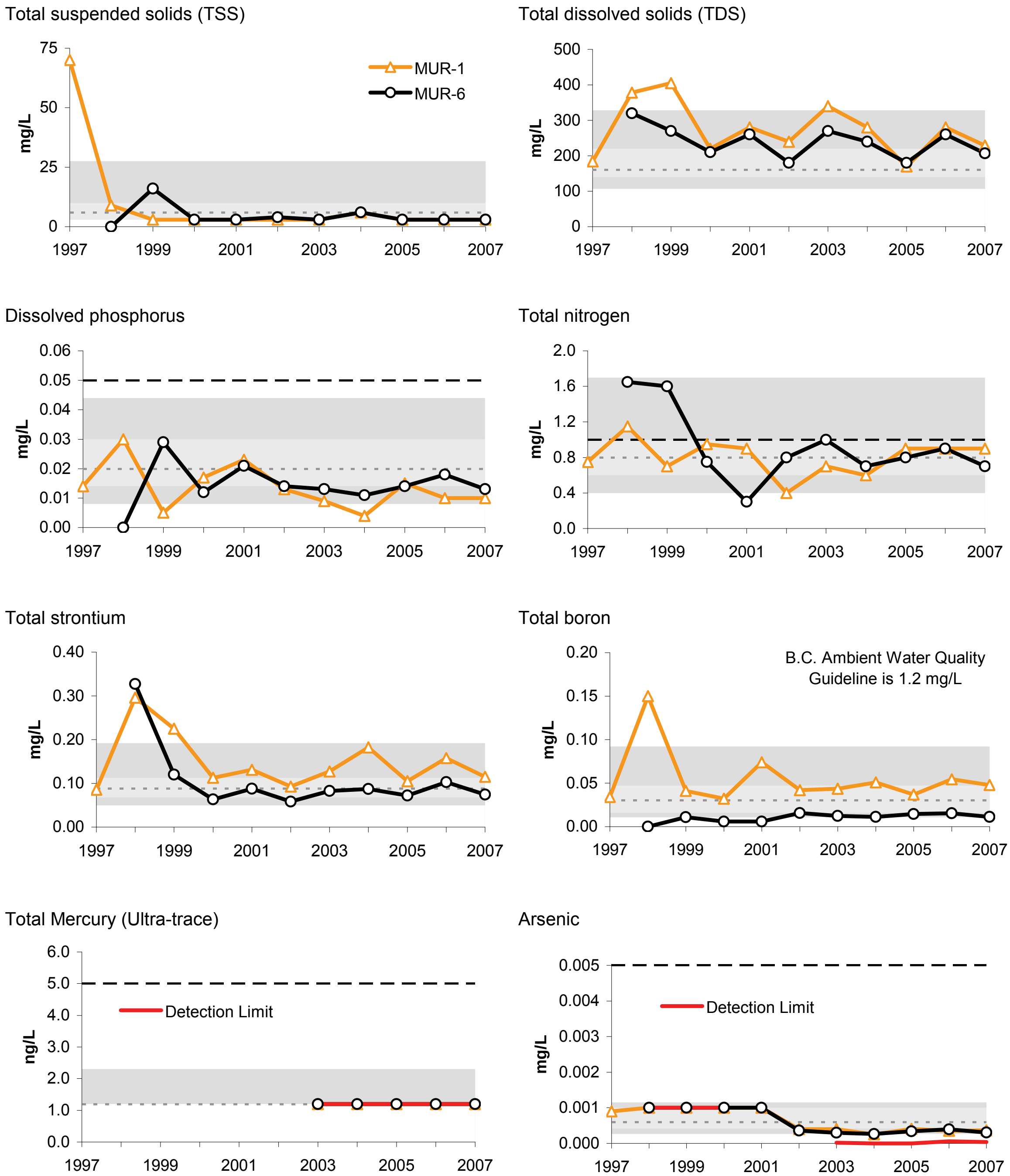
Sampling conducted in fall 2007 only in the Muskeg River watershed.

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

[1] derived from EPA (2002)

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

Figure 5.2-3 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.

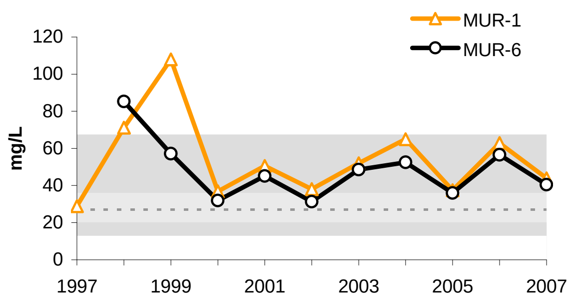


Non-detectable values are shown at the detection limit.

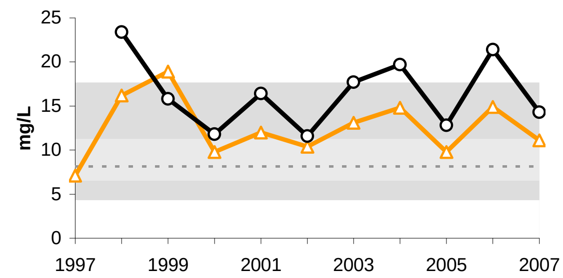
Regional baseline values reflect pooled results for all baseline stations with similar water quality, from all years of RAMP sampling. See Section 3.2.7 for a discussion of this approach, and Appendix D for these regional baseline ranges.

Figure 5.2-3 (Cont'd.)

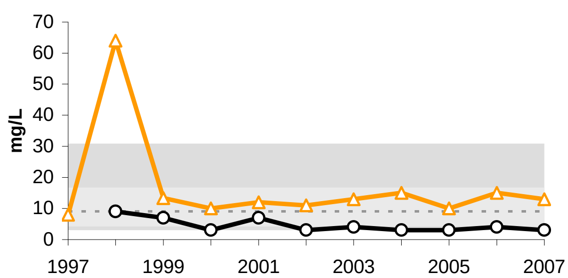
Calcium



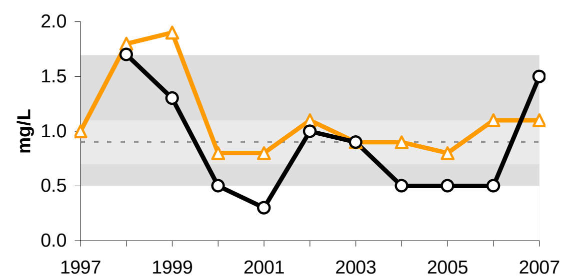
Magnesium



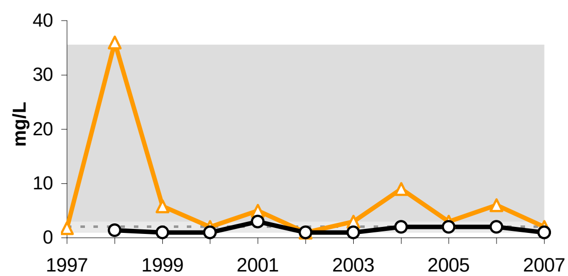
Sodium



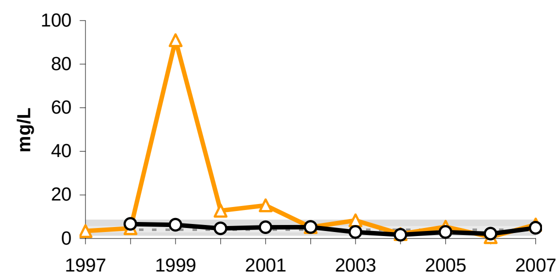
Potassium



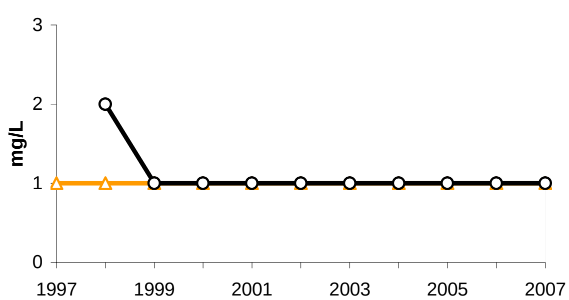
Chloride



Sulphate



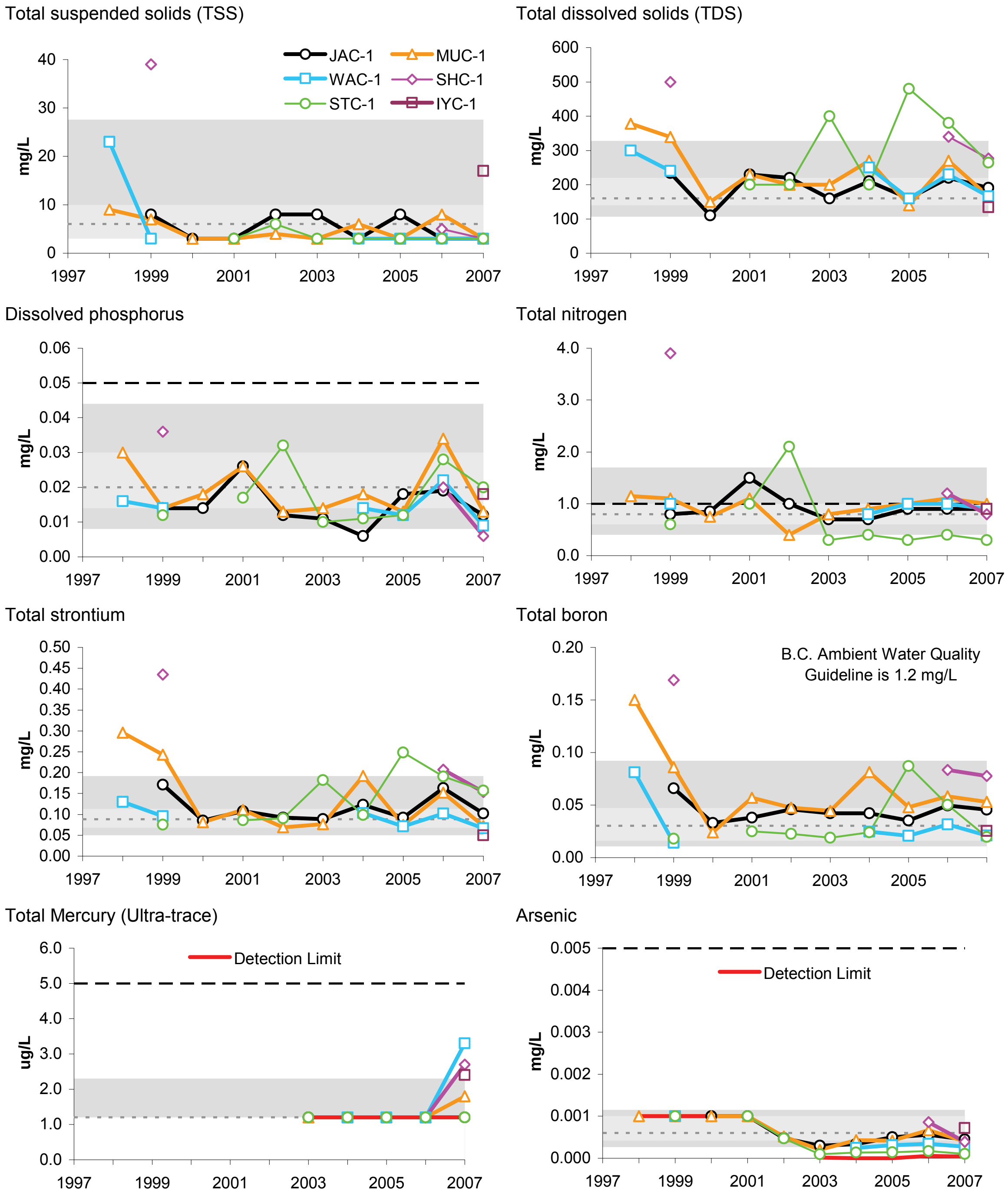
Naphthenic acids



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.

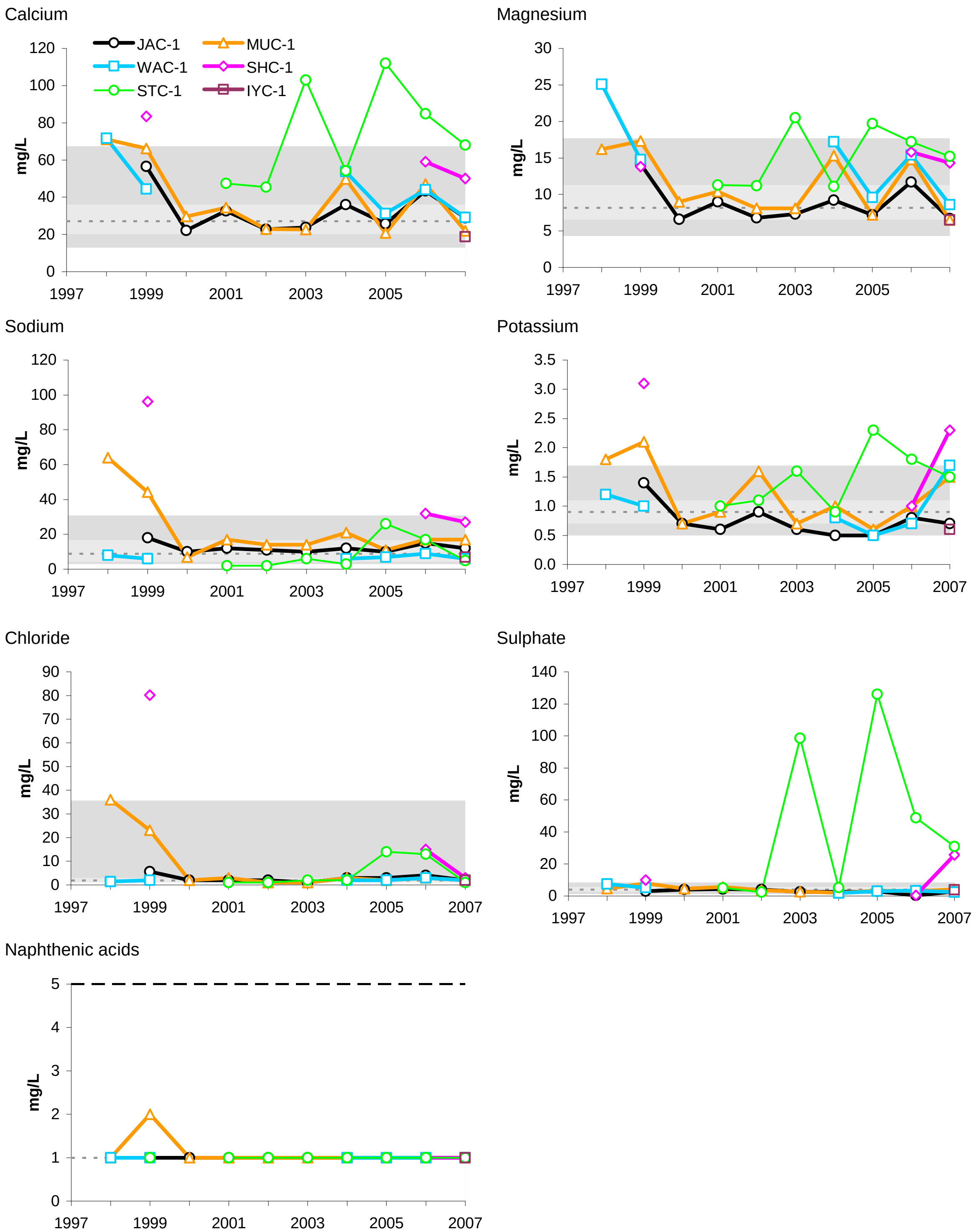
Figure 5.2-4 Selected water quality measurement endpoints in Muskeg River tributaries, fall data, relative to regional baseline fall concentrations.



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 5.2-4 (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 5.2-5 Piper diagram of fall ion concentrations in the Muskeg River and its tributaries, 1997 to 2007.

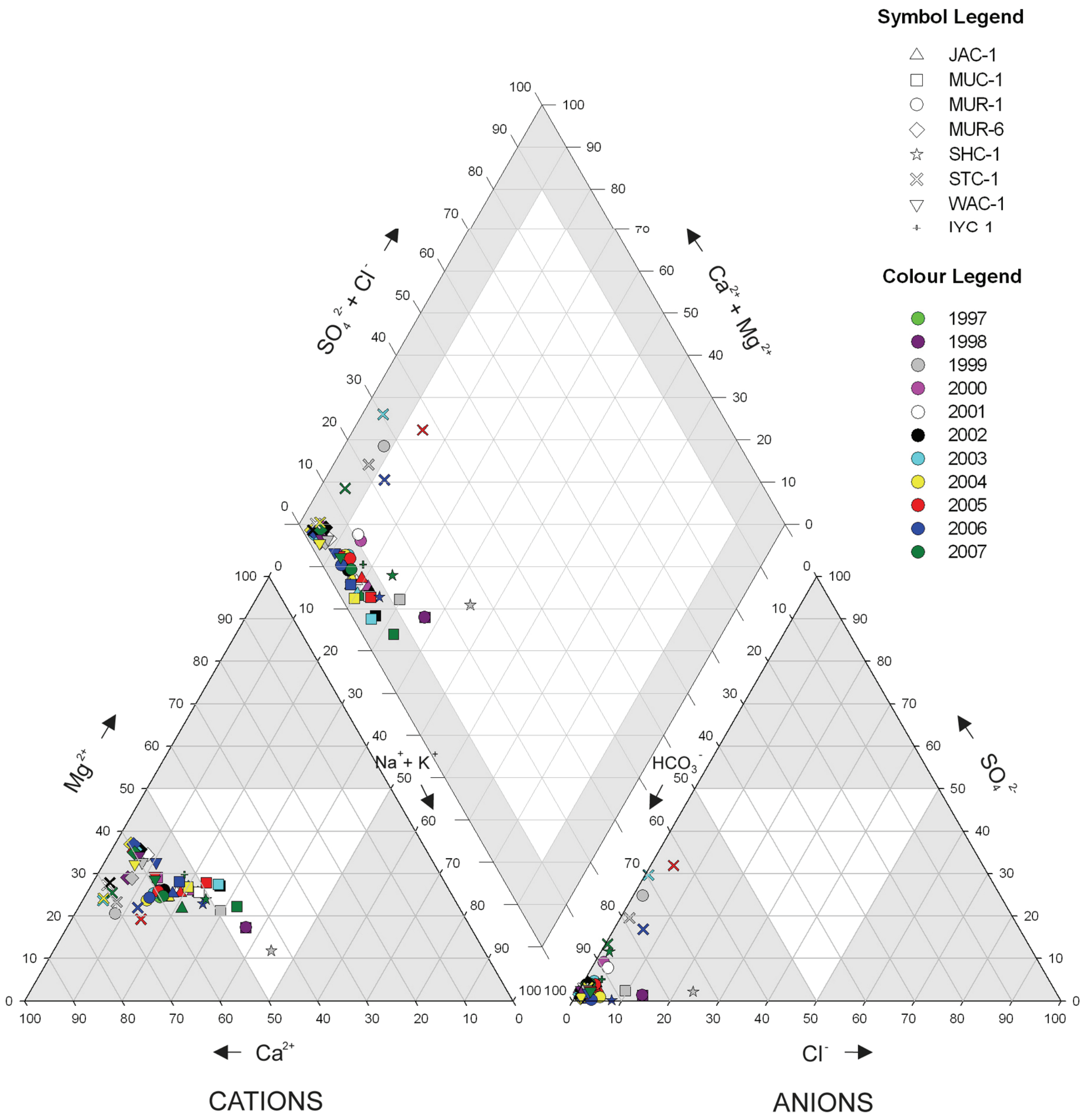


Table 5.2-12 Habitat characteristics of benthic invertebrate community sampling reaches in the Muskeg River, fall 2007.

Variable	Units	MUR-E-1 Lower Reach of the Muskeg River	MUR-D-2 Lower to Mid Reach of the Muskeg River	MUR-D-3 Upper Reach of the Muskeg River
Sample date	-	Sept. 12, 2007	Sept. 13, 2007	Sept. 7, 2007
Habitat	-	Erosional	Depositional	Depositional
Water depth	m	0.3	0.9	2.1
Current velocity	m/s	0.7	n/a	n/a
Macrophyte cover	%	5	81	n/a
Field Water Quality				
Dissolved oxygen	mg/L	12.8	9.6	7.6
Conductivity	µS/cm	351	318	365
pH	-	8.2	8.3	7.7
Water temperature	°C	9.6	9.5	10.9
Sediment Composition				
Sand	%		77	48
Silt			17	21
Clay			6	31
Total Organic Carbon	%		5.2	29.6
Sand/Silt/Clay		0		
Small gravel	%	19		
Large gravel	%	46		
Small cobble	%	30		
Large cobble	%	5		
Boulder	%	0		
Bedrock	%	0		

Figure 5.2-6 Variation in periphyton chlorophyll *a* in the lower Muskeg River (reach MUR-E-1).

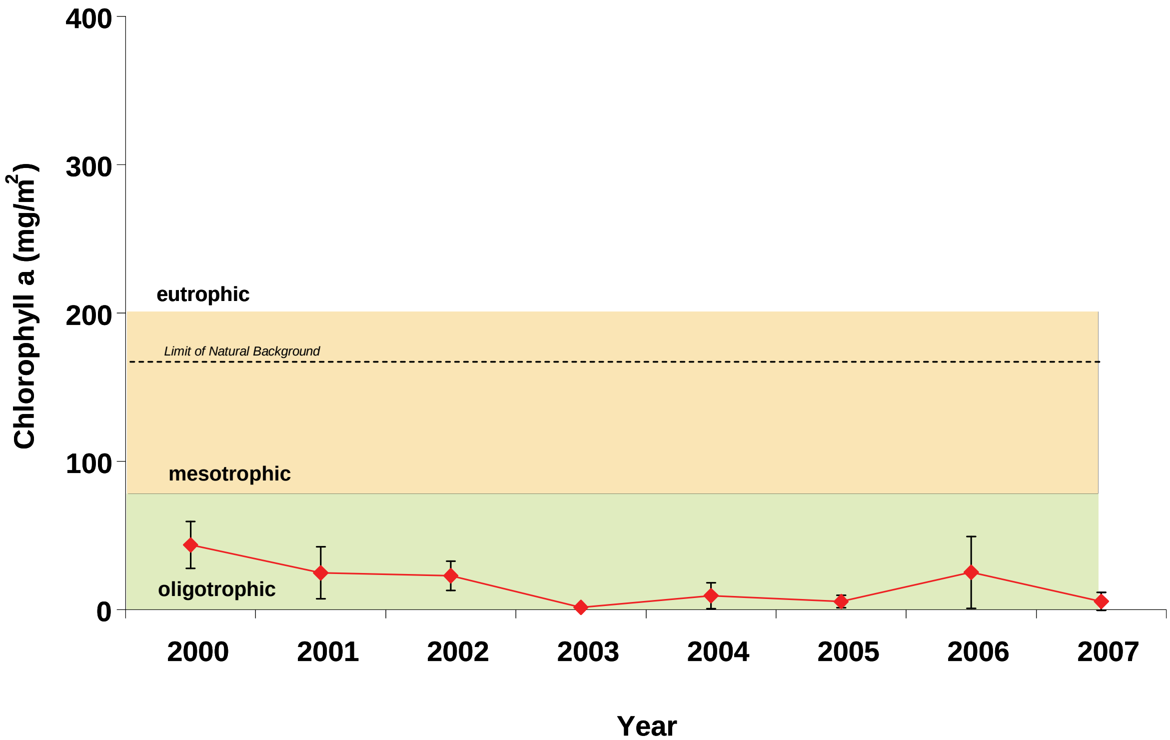
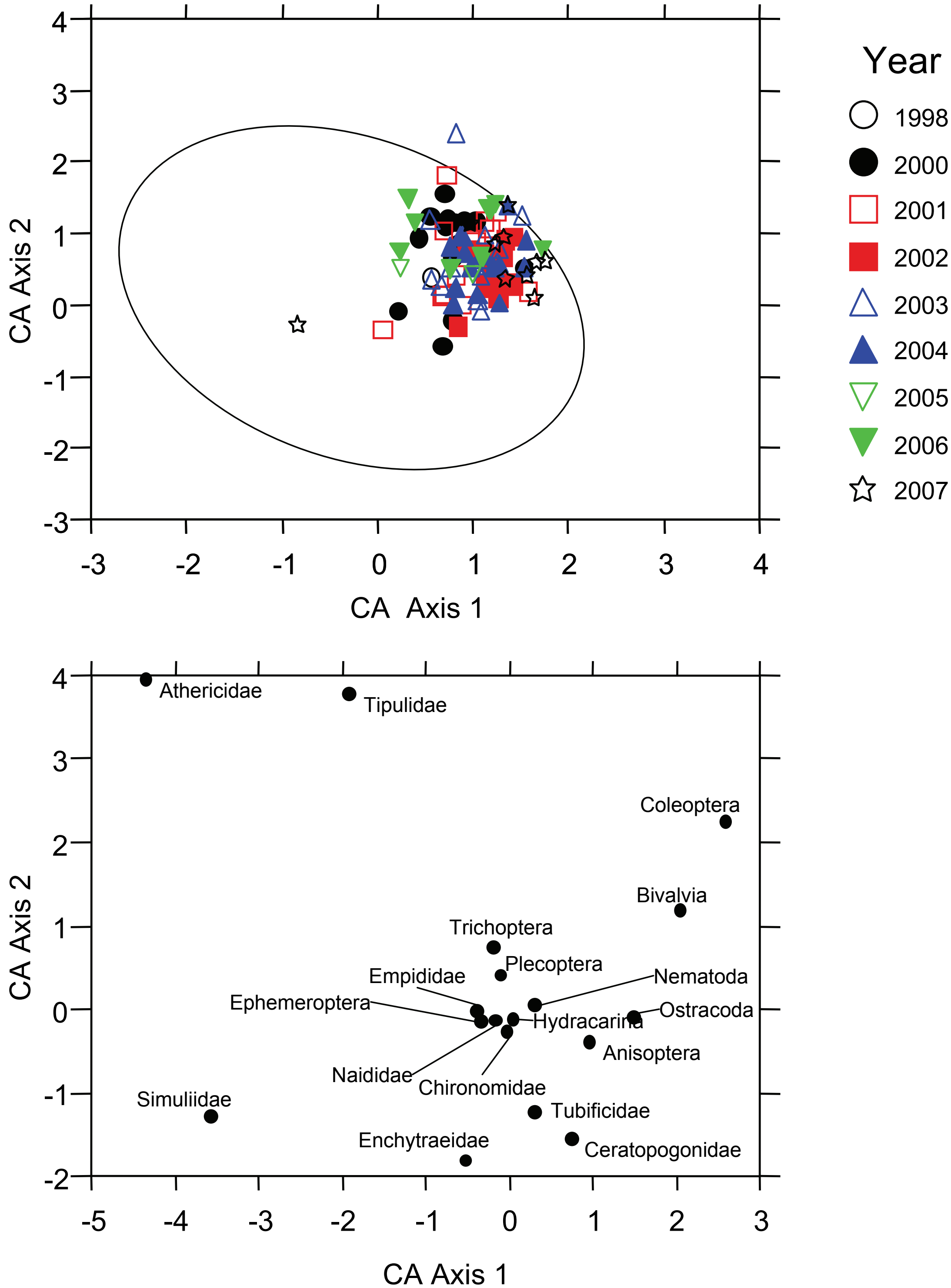


Table 5.2-13 Major taxon percent abundances and benthic invertebrate community measurement endpoints in the Muskeg River.

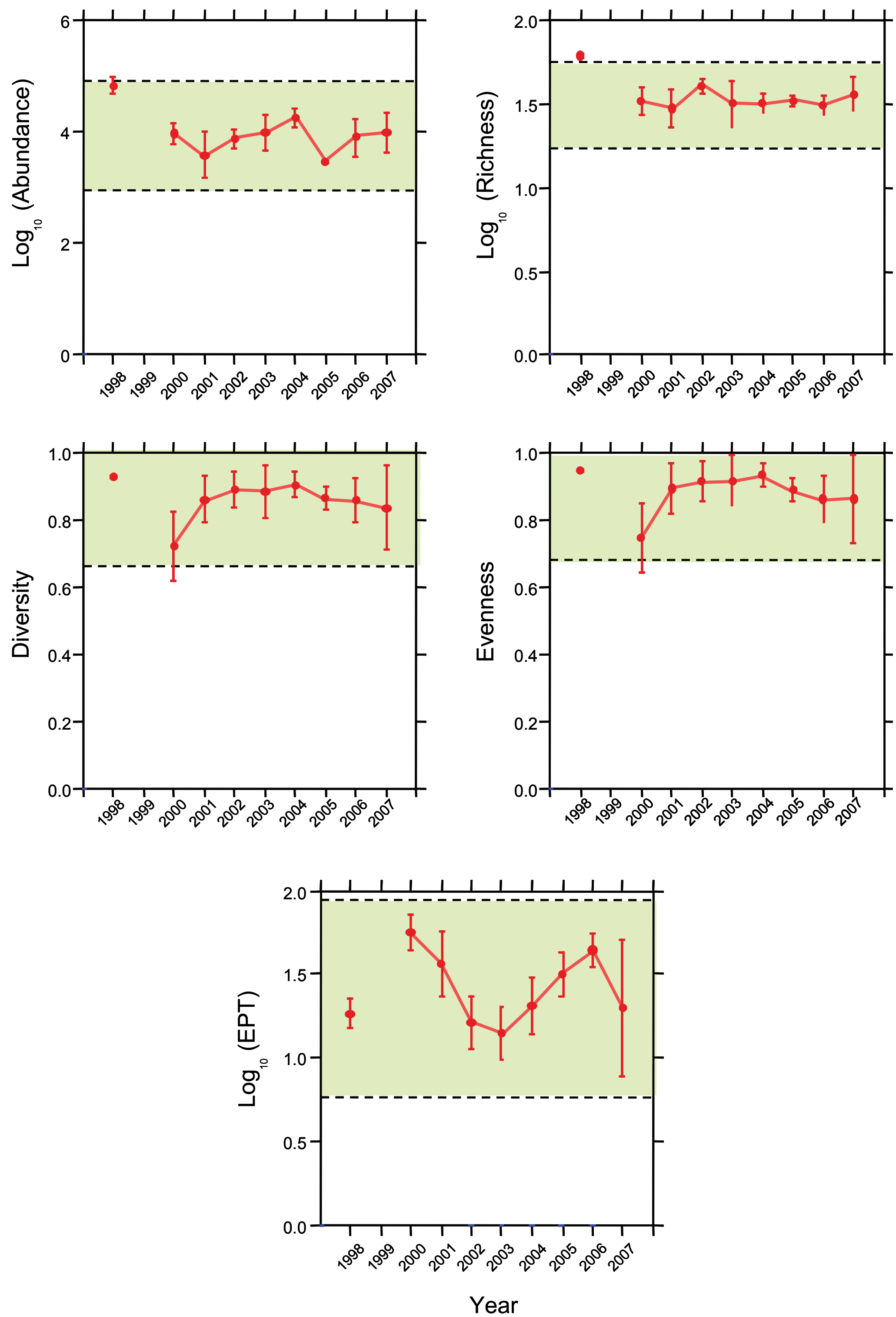
Taxon	Percent Major Taxa Enumerated in Each Year																				
	Reach MUR-E-1									Reach MUR-D-2								Reach MUR-D-3					
	1998	2000	2001	2002	2003	2004	2005	2006	2007	2000	2001	2002	2003	2004	2005	2006	2007	2002	2003	2004	2005	2006	2007
Amphipoda		<1		<1	<1						<1	<1	1	<1	<1	<1	2	<1	1	5	<1	1	<1
Anisoptera	<1	<1	2	1	1	2	<1	<1	1	<1	<1	<1	<1		<1		<1		<1	<1			
Bivalvia	6	1	3	5	1	3	2		5	4	1	3	1	1	<1		2	28	17	18	8		5
Ceratopogonidae	1	<1	<1	1		<1	<1	1	2	1	1	2	3	7	4	2	28	<1	2	2	1	1	1
Chironomidae	32	31	23	37	58	37	20	31	25	75	84	69	81	74	44	55	32	66	65	27	79	54	60
Coleoptera	5	1	2	1	3	10	5	3	2	<1	<1	<1		<1	1	<1	<1		<1	<1			1
Copepoda	<1	<1	<1	2	<1	<1	1		<1	<1	1	<1	<1	1	<1	<1	2		1	3	1		<1
Empididae	4	<1	2	2	3	6	22	1	<1	<1	<1	<1	<1	1	1	1							
Enchytraeidae	<1	<1	1	<1	<1	1	1	<1		<1	1	2	2	3	3	<1	6		<1	1	<1		<1
Ephemeroptera	12	50	28	5	5	9	21	24	20	<1	1	2	1	<1	6	1	2		5	5	2	3	3
Erpobdellidae				<1						<1	<1	<1	<1		<1		<1	<1	<1	<1	<1	<1	<1
Gastropoda	3	<1	<1	<1	<1				7	<1	3	1	<1		<1	1	2	<1	1	2	<1	<1	<1
Glossiphoniidae				<1						<1	<1	<1	<1			<1	<1	<1	1	1	<1	3	<1
Hydra		<1	<1	<1						<1	<1				<1	<1	1				<1	1	<1
Hydracarina	14	6	15	13	13		10	11	17	1	1	2	1	<1	<1	2	<1	<1	1	<1	<1		<1
Lumbriculidae				<1	<1	<1				1	<1	<1	1		<1	<1	<1		<1	1		1	<1
Naididae	5	1	6	14	3	3	1	4	3	2	1	<1	2	1	11	1	4	<1	1	1	2	2	7
Nematoda	2	<1	4	2	3	5	2	1	1	2	1	6	3	3	6	1	6	1	2	6	3	4	5
Ostracoda	3	1	<1	3	<1			<1	2	1	2	5		<1	10	<1	3	4	1	7	1		2
Plecoptera	4	6	5	5	3	8	8	5	3	<1	<1	<1	<1		<1	<1							1
Simuliidae	<1							<1	<1						1						<1		
Tabanidae	0	<1	<1			<1				<1	<1	<1	<1	<1	<1	<1		<1	<1	<1	<1	<1	1
Tipulidae	<1	<1	<1	<1	<1	<1		<1	<1	1	<1			<1		<1	<1						
Trichoptera	2	1	8	5	4	4	2	16	3	<1	<1	<1	<1	<1	1	<1	<1	<1	<1	<1	1		<1
Tubificidae	5	<1	<1	1	1	13	5		7	10	<1	3	2	8	10	31	5	<1	2	15	2	15	16
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	12,296	59,328	64,032	34,672	12,635	10,440	11,948	26,888	14,668	9,905	13,566	7,190	15,887	6,039	14,871
Richness	60	32	29	39	32	31	32	30	36	26	30	21	14	10	17	24	20	12	17	9	11	15	16
Simpson's Diversity	0.93	0.72	0.86	0.89	0.89	0.91	0.87	0.86	0.84	0.75	0.84	0.86	0.7	0.68	0.78	0.69	0.85	0.64	0.78	0.71	0.75	0.84	0.82
Evenness	0.95	0.75	0.89	0.92	0.92	0.94	0.89	0.86	0.86	0.78	0.87	0.91	0.77	0.77	0.83	0.69	0.90	0.71	0.85	0.81	0.83	0.86	0.89
% EPT	18	57	39	16	14	21	31	4	25	<1	1	2	2	<1	5	0	2	<1	6	5	2	<1	4

Figure 5.2-7 Ordination (Correspondence Analysis) of benthic invertebrate communities in the lower reach of the Muskeg River (reach MUR-E-1).



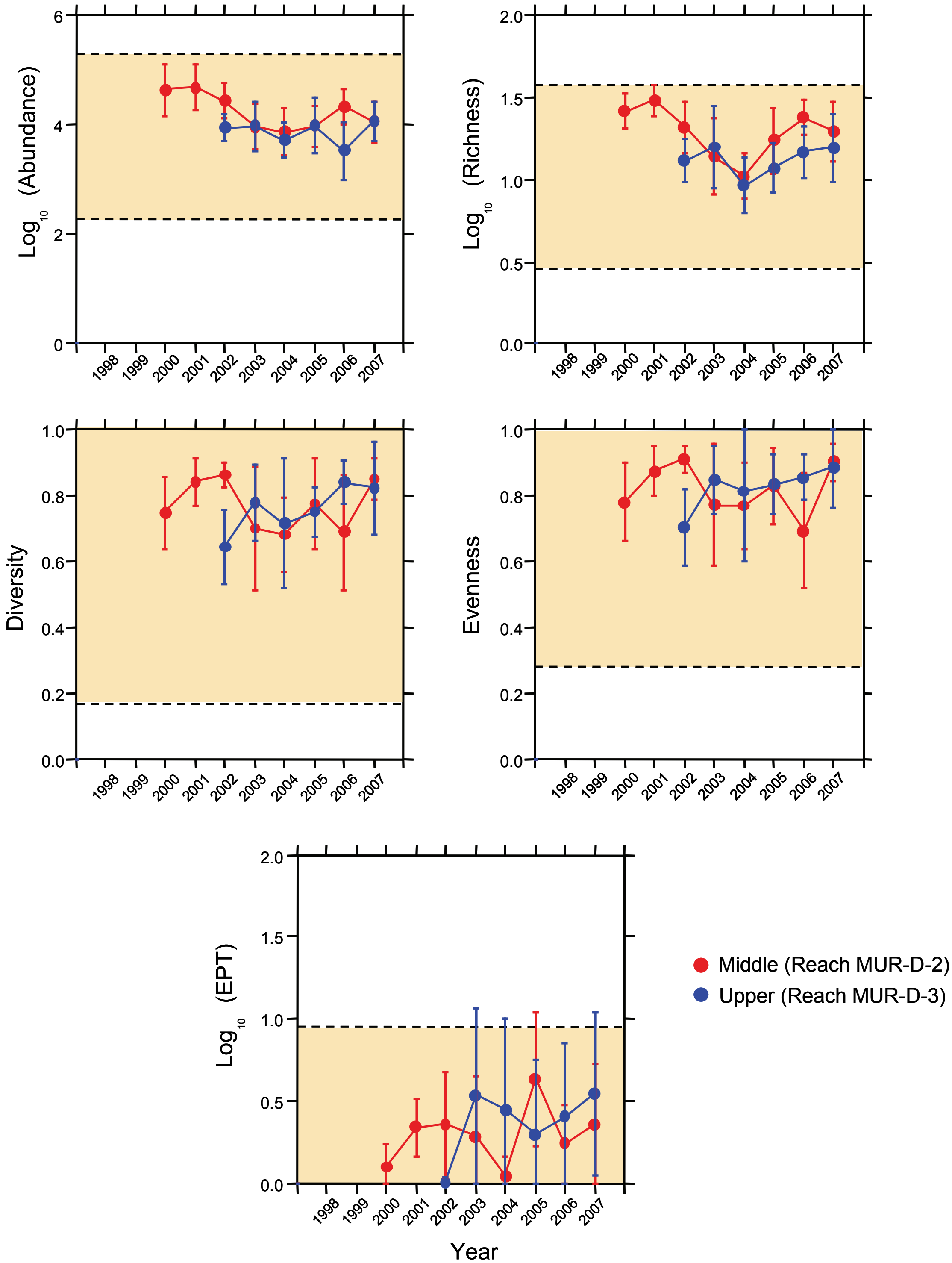
Note: Upper Panel is the scatterplot of sample scores while the Lower Panel is the scatterplot of taxa scores. The ellipse in the Upper Panel is for the reference data for erosional river habitats.

Figure 5.2-8 Variation in benthic invertebrate community measurement endpoints in the lower reach of the Muskeg River (reach MUR-E-1).



Note: Lower and upper dotted lines represent ±2 SD of distribution of regional baseline values for erosional sites.

Figure 5.2-9 Variations 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 habitats.

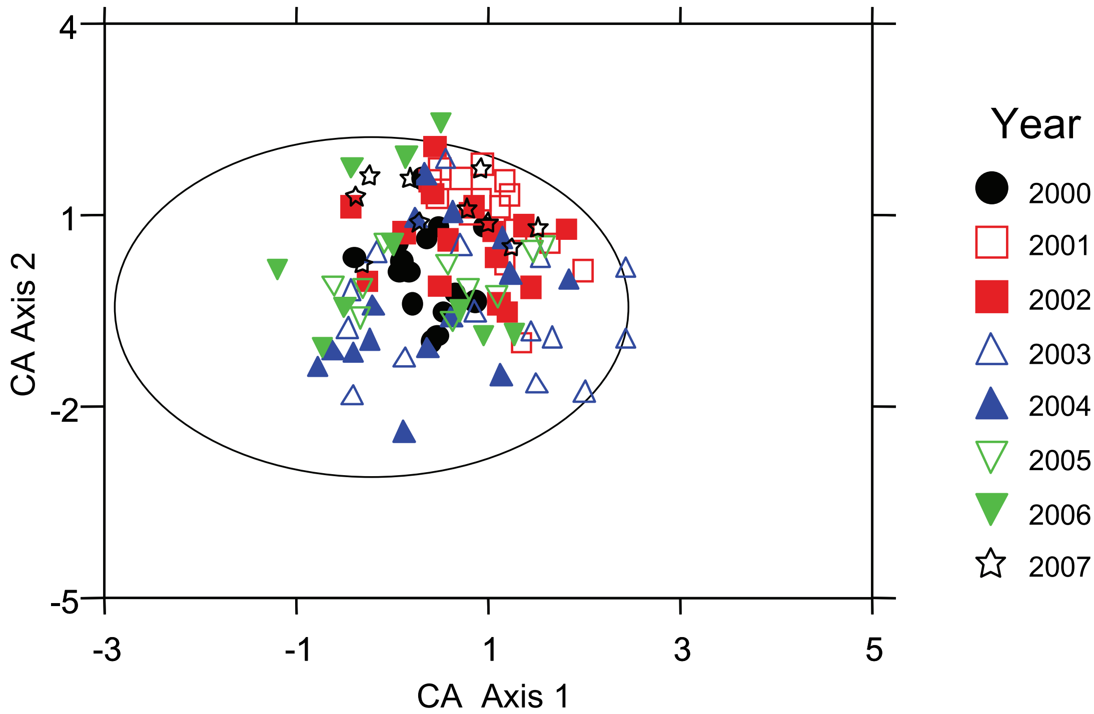
Table 5.2-14 Results of analysis of variance (ANOVA) between the lower (MUR-E-1) and upper (MUR-D-3) reaches of the Muskeg River.

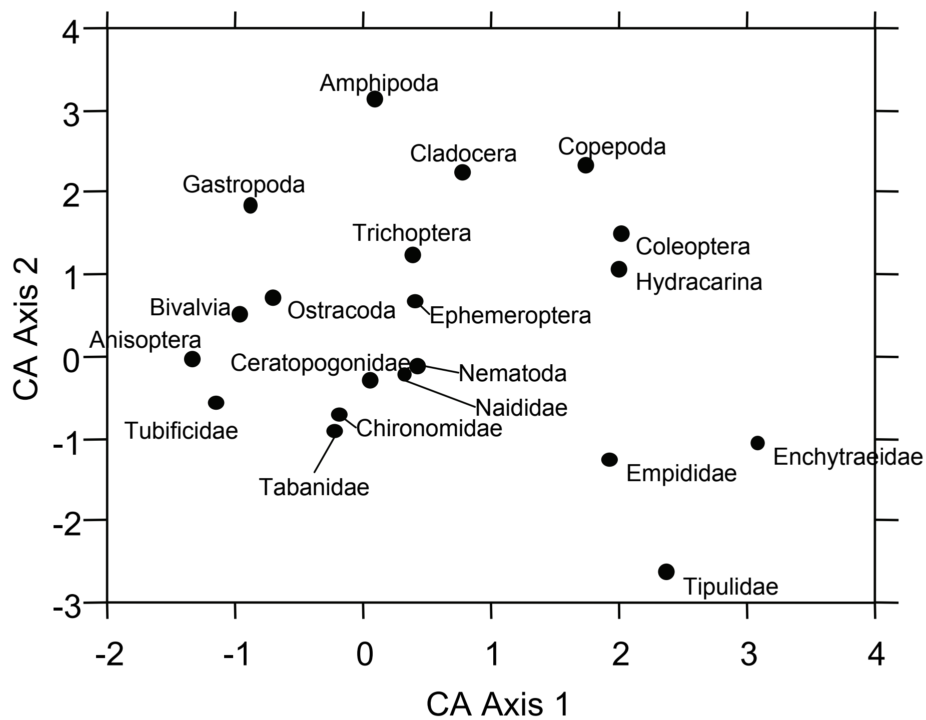
Response Variable	Source	SS	df	F-ratio	p-value
Log Abundance	Treatment (reach-year combinations; 2002 to 2007)	8.86	14	6.06	0.000
	Reference vs Exposure (RE)	0.03	1	0.30	0.585
	Time Trend (T)	0.07	1	0.70	0.405
	RE x T	0.00	1	0.01	0.917
	RE in 2007	0.04	1	0.33	0.566
	Remainder	8.72	1	83.83	0.000
	Error	16.71	160		
Log Richness	Treatment (reach-year combinations; 2002 to 2007)	8.33	14	33.61	0.000
	Reference vs Exposure (RE)	4.35	1	245.7	0.000
	Time Trend (T)	0.00	1	0.22	0.642
	RE x T	0.03	1	1.81	0.180
	RE in 2007	0.67	1	37.83	0.000
	Remainder	3.28	1	182.0	0.000
	Error	2.83	160		
Diversity	Treatment (reach-year combinations; 2002 to 2007)	1.18	14	8.54	0.000
	Reference vs Exposure (RE)	0.35	1	35.43	0.000
	Time Trend (T)	0.04	1	4.38	0.038
	RE x T	0.19	1	19.13	0.000
	RE in 2007	0.00	1	0.11	0.745
	Remainder	0.60	1	60.00	0.000
	Error	1.58	160		
Evenness	Treatment (reach-year combinations; 2002 to 2007)	0.82	14	5.71	0.000
	Reference vs Exposure (RE)	0.14	1	13.68	0.000
	Time Trend (T)	0.02	1	1.83	0.178
	RE x T	0.17	1	16.59	0.000
	RE in 2007	0.00	1	0.31	0.581
	Remainder	0.49	1	48.90	0.000
	Error	1.65	160		
Log of %EPT	Treatment (reach-year combinations; 2002 to 2007)	54.26	14	38.73	0.000
	Reference vs Exposure (RE)	24.60	1	245.9	0.000
	Time Trend (T)	1.53	1	15.26	0.000
	RE x T	0.00	1	0.00	0.977
	RE in 2007	2.83	1	28.28	0.000
	Remainder	25.30	1	253.0	0.000
	Error	16.01	160		

Table 5.2-15 Analysis of variance (ANOVA) between middle (MUR-D-2) and upper (MUR-D-3) reaches of the Muskeg River.

Response Variable	Source	SS	df	F-ratio	p-value
Log Abundance	Treatment (reach-year combinations; 2002 to 2007)	18.80	13	10.06	0.000
	Reference vs Exposure (RE)	1.98	1	13.79	0.000
	Time Trend (T)	0.12	1	0.81	0.369
	RE x T	0.00	1	0.01	0.931
	RE in 2007	0.00	1	0.01	0.931
	Remainder	16.70	1	116.0	0.000
	Error	23.86	166		
Log Richness	Treatment (reach-year combinations; 2002 to 2007)	4.17	13	12.37	0.000
	Reference vs Exposure (RE)	0.46	1	17.86	0.000
	Time Trend (T)	0.13	1	5.15	0.025
	RE x T	0.02	1	0.56	0.455
	RE in 2007	0.05	1	2.01	0.158
	Remainder	3.51	1	135.0	0.000
	Error	4.31	166		
Diversity	Treatment (reach-year combinations; 2002 to 2007)	0.89	13	4.75	0.000
	Reference vs Exposure (RE)	0.00	1	0.01	0.931
	Time Trend (T)	0.11	1	7.50	0.007
	RE x T	0.11	1	7.27	0.008
	RE in 2007	0.00	1	0.28	0.596
	Remainder	0.68	1	48.29	0.000
	Error	2.40	166		
Evenness	Treatment (reach-year combinations; 2002 to 2007)	0.78	13	4.02	0.000
	Reference vs Exposure (RE)	0.01	1	0.33	0.567
	Time Trend (T)	0.05	1	3.13	0.079
	RE x T	0.12	1	7.99	0.005
	RE in 2007	0.00	1	0.08	0.781
	Remainder	0.61	1	40.33	0.000
	Error	2.47	166		
Log of %EPT	Treatment (reach-year combinations; 2002 to 2007)	5.95	13	3.86	0.000
	Reference vs Exposure (RE)	0.10	1	0.83	0.364
	Time Trend (T)	0.59	1	4.93	0.028
	RE x T	0.25	1	2.12	0.148
	RE in 2007	0.18	1	1.48	0.226
	Remainder	4.84	1	40.66	0.000
	Error	19.70	166		

Figure 5.2-10 Ordination (Correspondence Analysis) of depositional reach benthos showing the middle reach (MUR-D-2) of the Muskeg River.





Note: Upper Panel is the scatterplot of sample scores while the Lower Panel is the scatterplot of taxa scores. The ellipse in the Upper Panel is for the reference data.

Table 5.2-16 Habitat characteristics of benthic invertebrate community sampling reaches in Jackpine Creek.

Variable	Units	JAC-D-1 Lower Reach of Jackpine Creek	JAC-D-2 Upper Reach of Jackpine Creek
Sample date	-	Sept 11 2007	Sept 13 2007
Habitat	-	Depositional	Depositional
Water depth	m	0.7	1.2
Current velocity	m/s	n/a	0.1
Macrophyte cover	%	1	14
Field Water Quality			
Dissolved oxygen	mg/L	9.6	9.6
Conductivity	µS/cm	262	280
pH	-	8.3	8.3
Water temperature	°C	10.9	8.5
Sediment Composition			
Sand	%	86	67
Silt	%	10	22
Clay	%	4	11
Total Organic Carbon	%	0.9	1.4

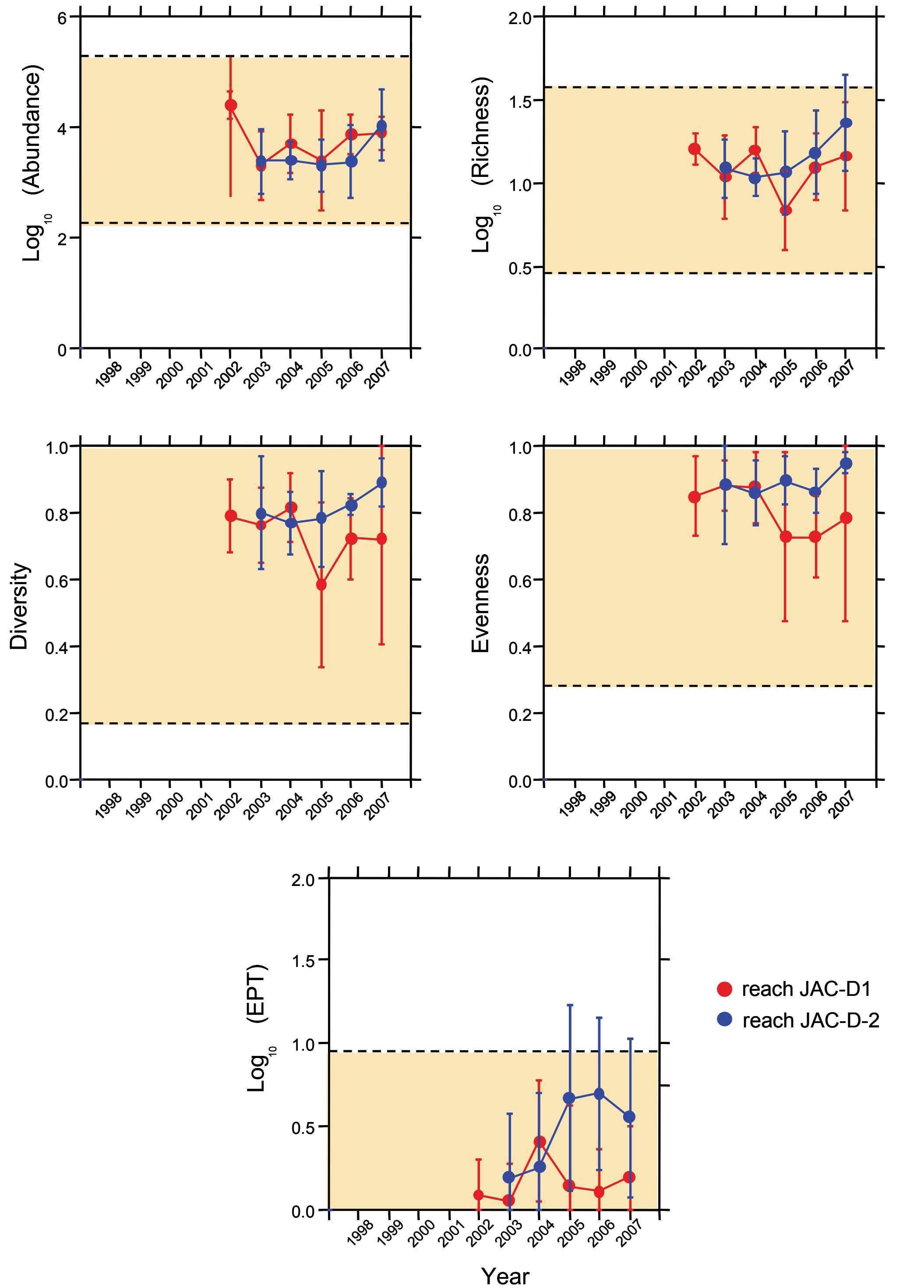
Table 5.2-17 Major taxon percent abundances and indices of benthic invertebrate community composition in Jackpine Creek.

Taxon	Percent Major Taxa Enumerated in Each Year										
	Reach JAC-D-1						Reach JAC-D-2				
	2002	2003	2004	2005	2006	2007	2003	2004	2005	2006	2007
Amphipoda		<1	<1								
Anisoptera	<1	<1	<1		1	<1			<1		
Bivalvia	1	3	<1	<1		<1	<1	<1	<1		<1
Ceratopogonidae	2	2	4		5	2	1	31	4	2	5
Chironomidae	88	66	69	69	86	66	67	3	44	63	66
Cladocera			8		<1	2		<1			<1
Coleoptera		<1	<1				6	3	6	1	2
Copepoda	<1	1	6	1		1		2	3		<1
Empididae	<1	2	2	4	2	1	1	<1	3	3	1
Enchytraeidae	<1	4	<1			<1	1	1	1	2	<1
Ephemeroptera	<1		2	1	1	1	<1	2	1	6	4
Gastropoda	<1		<1			2			<1	<1	<1
Glossiphoniidae		<1									
Hydra			<1								<1
Hydracarina	1	1	1	8	1	5	<1	<1	18	1	2
Naididae	<1	2	2		1	<1	3	1	1	2	8
Nematoda	5	6	1	4	2	2	6	4	2	4	5
Ostracoda	<1		2	4		1	<1	1	3	1	<1
Plecoptera					1		<1				
Tabanidae	<1	<1	<1	<1	<1	<1	1	2	<1	<1	<1
Tipulidae	<1	2	1	1	1	<1	1	13	4	2	<1
Trichoptera	<1	<1	<1	3	<1	<1	<1	1	7	1	2
Tubificidae	<1	<1	1	5	<1	17	2	5	1	2	5
Benthic Invertebrate Community Measurement Endpoints											
Total Abundance (No./m^2)	28,172	4,017	9,230	7,417	9,517	9,560	4,787	3,448	2,957	5,142	16,819
Richness	15	11	15	7	12	16	12	10	12	16	25
Simpson's Diversity	0.79	0.76	0.81	0.58	0.72	0.72	0.8	0.77	0.78	0.82	0.89
Evenness	0.85	0.88	0.88	0.73	0.73	0.78	0.89	0.86	0.9	0.86	0.95
% EPT	<1	<1	2	3	0	1	2	2	7	<1	5

Table 5.2-18 Analysis of variance (ANOVA) between lower (JAC-D-1) and upper (JAC-D-2) reaches of Jackpine Creek.

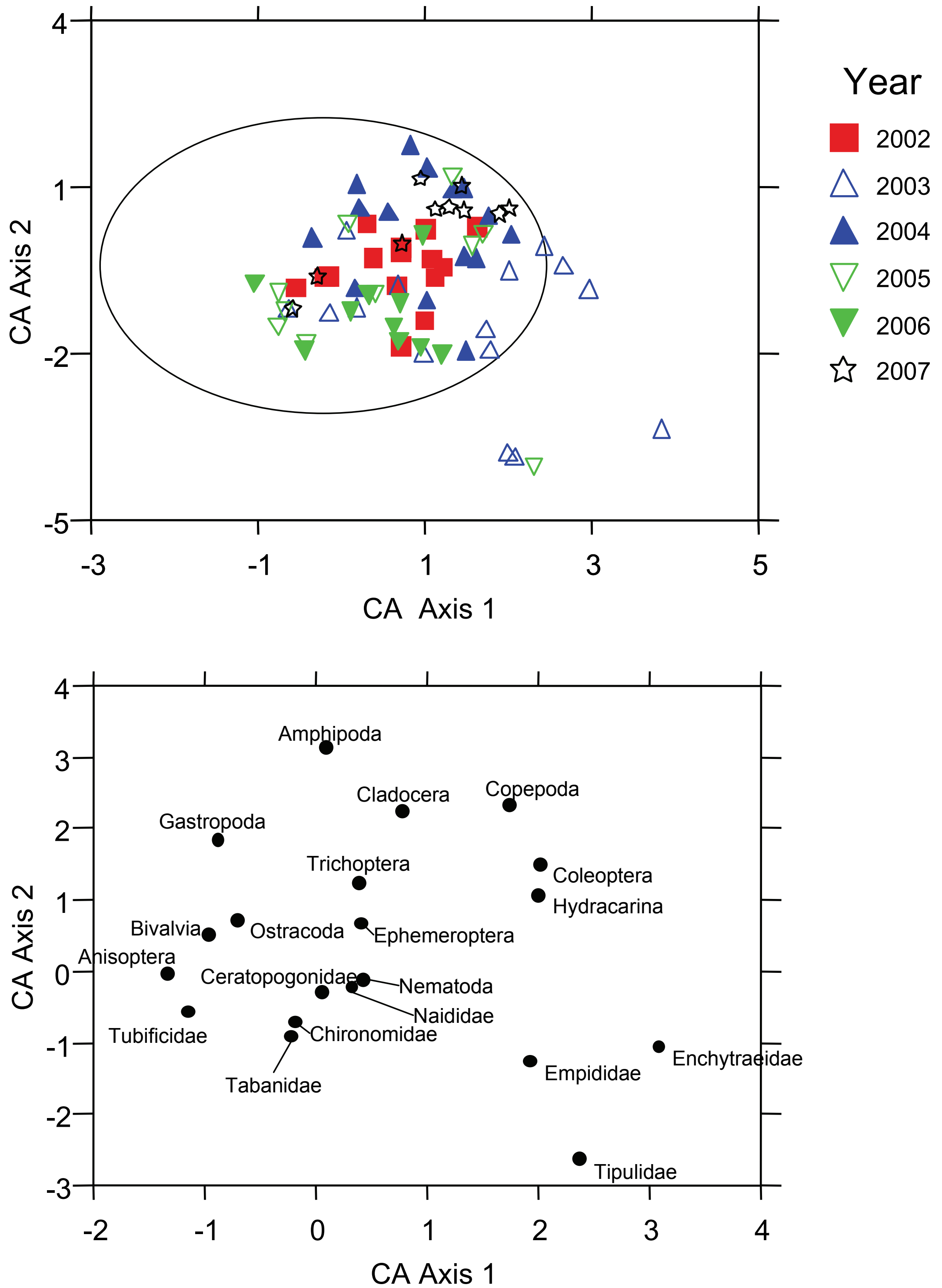
Response Variable	Source	SS	df	F-ratio	p-value
Log Abundance	Treatment (reach-year combinations; 2002 to 2007)	17.07	10	6.51	0.000
	Reference vs Exposure (RE)	0.48	1	1.85	0.177
	Before vs After (BA)	3.75	1	14.30	0.000
	RE x BA	0.04	1	0.16	0.693
	RE in 2007	0.09	1	0.35	0.553
	Remainder	12.71	1	48.50	0.000
	Error	32.50	124		
Log Richness	Treatment (reach-year combinations; 2002 to 2007)	1.91	10	4.65	0.000
	Reference vs Exposure (RE)	0.19	1	4.55	0.035
	Before vs After (BA)	0.65	1	15.83	0.000
	RE x BA	0.07	1	1.78	0.185
	RE in 2007	0.20	1	4.84	0.030
	Remainder	0.80	1	19.54	0.000
	Error	5.10	124		
Diversity	Treatment (reach-year combinations; 2002 to 2007)	0.62	10	2.98	0.002
	Reference vs Exposure (RE)	0.25	1	11.86	0.001
	Before vs After (BA)	0.04	1	1.75	0.189
	RE x BA	0.03	1	1.64	0.203
	RE in 2007	0.15	1	6.93	0.010
	Remainder	0.16	1	7.57	0.007
	Error	2.59	124		
Evenness	Treatment (reach-year combinations; 2002 to 2007)	0.52	10	2.61	0.007
	Reference vs Exposure (RE)	0.25	1	12.40	0.001
	Before vs After (BA)	0.02	1	0.76	0.387
	RE x BA	0.07	1	3.27	0.073
	RE in 2007	0.14	1	7.07	0.009
	Remainder	0.05	1		n/a
	Error	2.46	124		
Log of %EPT	Treatment (reach-year combinations; 2002 to 2007)	6.23	10	4.63	0.000
	Reference vs Exposure (RE)	2.42	1	17.97	0.000
	Before vs After (BA)	0.27	1	2.02	0.158
	RE x BA	0.61	1	4.54	0.035
	RE in 2007	0.64	1	4.75	0.031
	Remainder	2.29	1	17.07	0.000
	Error	16.67	124		

Figure 5.2-11 Variations 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.

Figure 5.2-12 Ordination (Correspondence Analysis) of depositional reach benthos showing the lower reach (JAC-D-1) of Jackpine Creek.



Note: Upper Panel is the scatterplot of sample scores while the Lower Panel is the scatterplot of taxa scores. The ellipse in the Upper Panel is for the reference data.

Table 5.2-19 Concentrations of selected sediment quality measurement endpoints in middle reach of the Muskeg River, near the Canterra Road crossing (reach MUR-D2), fall 2007.

Measurement Endpoint	Units	Guideline	September 2007	1997-2006 (fall data only, reach MUR-D-2, station MUR-2)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	6.1	4	1	6	12
Silt	%	-	17.4	4	13	17.5	22
Sand	%	-	76.5	4	72	76.5	80
Total organic carbon	%	-	5.2	5	2	2.7	29.6
Total hydrocarbons							
BTEX	mg/kg	-	<5	3	<5	<5	<10
Fraction 1 (C6-C10)	mg/kg	30[2]	<5	3	<5	<5	<10
Fraction 2 (C10-C16)	mg/kg	150[2]	**180**	3	<5	110	**160**
Fraction 3 (C16-C34)	mg/kg	400[2]	**2900**	3	**1200**	**1800**	**2900**
Fraction 4 (C34-C50)	mg/kg	2800[2]	2100	3	1100	1400	1600
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[3]	0.0034	5	0.0016	0.0049	0.0200
Retene	mg/kg	-	0.314	5	0.144	0.183	0.285
Total dibenzothiophenes	mg/kg	-	11.04	5	2.81	5.33	10.63
Total PAHs	mg/kg	-	23.94	5	7.84	15.33	30.44
Total HMW PAHs	mg/kg	-	2.11	5	2.11	3.92	9.63
Total LMW PAHs	mg/kg	-	21.82	5	5.73	11.40	20.81
Predicted PAH toxicity[1]	H.I.	-	1.51	5	0.95	1.40	1.75
Metals that exceed CCME guidelines in 2007							
none	mg/kg	-	-	-	-	-	-
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	3	4	6	7	9
Chironomus growth - 10d	mg/organism	-	1.3	4	0.68	2.3	2.5
Hyalella survival - 14d	# surviving	-	9	4	8	8	8
Hyalella growth - 14d	mg/organism	-	0.2	4	0.11	0.19	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 5.2-20 Concentrations of selected sediment quality measurement endpoints in upper reach of the Muskeg River (reach MUR-D3), fall 2007.

Measurement Endpoint	Units	Guideline	September 2007	1997-2006 (fall data only, reach MUR-D-3, station MUR-D2)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	31.2	4	5	6.5	40
Silt	%	-	21.1	4	10	14.5	29
Sand	%	-	47.5	4	31	79.5	85
Total organic carbon	%	-	29.6	4	1.7	15.1	24.9
Total hydrocarbons							
BTEX	mg/kg	-	<5	3	<5	<5	<5
Fraction 1 (C6-C10)	mg/kg	30[2]	<5	3	<5	<5	<5
Fraction 2 (C10-C16)	mg/kg	150[2]	7	3	<5	<5	130
Fraction 3 (C16-C34)	mg/kg	400[2]	**740**	3	52	**540**	**1900**
Fraction 4 (C34-C50)	mg/kg	2800[2]	71	3	210	630	1400
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[3]	0.0145	4	0.0031	0.0052	0.0145
Retene	mg/kg	-	0.522	4	0.156	0.3685	0.498
Total dibenzothiophenes	mg/kg	-	0.15	4	0.10	0.13	0.19
Total PAHs	mg/kg	-	1.39	4	0.67	1.19	1.27
Total HMW PAHs	mg/kg	-	0.28	4	0.20	0.29	0.51
Total LMW PAHs	mg/kg	-	1.11	4	0.47	0.78	0.99
Predicted PAH toxicity[1]	H.I.	-	0.71	4	0.15	0.44	0.72
Metals that exceed CCME guidelines in 2007							
none	mg/kg	-	-	-	-	-	-
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	5	4	3	6.5	8
Chironomus growth - 10d	mg/organism	-	1.4	4	1.43	1.85	2.2
Hyalella survival - 14d	# surviving	-	9	4	7	7.5	8
Hyalella growth - 14d	mg/organism	-	0.2	4	0.11	0.25	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 5.2-21 Concentrations of selected sediment quality measurement endpoints in lower reach of the Jackpine River (reach JAC-D1), fall 2007.

Measurement Endpoint	Units	Guideline	September 2007	1997-2006 (fall data only, reach JAC-D-1, station JAC-1)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	3.4	3	<1	3	18.7
Silt	%	-	10.6	3	0.3	1	11
Sand	%	-	85.9	3	81	87	99
Total organic carbon	%	-	0.9	3	0.2	1.1	2
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]	71	2	13	-	17
Fraction 3 (C16-C34)	mg/kg	400[2]	**510**	2	150	-	**450**
Fraction 4 (C34-C50)	mg/kg	2800[2]	750	2	210	-	530
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[3]	0.0007	3	<0.003	0.0016	<0.0026
Retene	mg/kg	-	0.0422	2	0.0072	-	0.0614
Total dibenzothiophenes	mg/kg	-	0.44	3	0.10	0.72	1.64
Total PAHs	mg/kg	-	1.12	3	0.41	2.13	4.49
Total HMW PAHs	mg/kg	-	0.17	3	0.17	0.49	1.26
Total LMW PAHs	mg/kg	-	0.95	3	0.24	1.65	3.24
Predicted PAH toxicity[1]	H.I.	-	0.30	3	0.21	0.30	1.13
Metals that exceed CCME guidelines in 2007							
none	mg/kg	-	-	-	-	-	-
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	ns	2	7	-	9
Chironomus growth - 10d	mg/organism	-	ns	2	2.4	-	3.2
Hyalella survival - 14d	# surviving	-	ns	2	7	-	9
Hyalella growth - 14d	mg/organism	-	ns	2	0.14	-	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).

ns = not sampled

Table 5.2-22 Concentrations of selected sediment quality measurement endpoints in upper reach of the Jackpine River (reach JAC-D2), fall 2007.

Measurement Endpoint	Units	Guideline	September 2007	1997-2006 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	11.1	1	-	-	13
Silt	%	-	22.8	1	-	-	21
Sand	%	-	66.1	1	-	-	66
Total organic carbon	%	-	1.4	1	-	-	1.9
Total hydrocarbons							
BTEX	mg/kg	-	<5	1	-	-	<10
Fraction 1 (C6-C10)	mg/kg	30[2]	<5	1	-	-	<10
Fraction 2 (C10-C16)	mg/kg	150[2]	8	1	-	-	<5
Fraction 3 (C16-C34)	mg/kg	400[2]	190	1	-	-	160
Fraction 4 (C34-C50)	mg/kg	2800[2]	160	1	-	-	89
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[3]	ns	1	-	-	0.0022
Retene	mg/kg	-	ns	1	-	-	0.0331
Total dibenzothiophenes	mg/kg	-	ns	1	-	-	0.01
Total PAHs	mg/kg	-	ns	1	-	-	0.12
Total HMW PAHs	mg/kg	-	ns	1	-	-	0.04
Total LMW PAHs	mg/kg	-	ns	1	-	-	0.08
Predicted PAH toxicity[1]	H.I.	-	ns	1	-	-	0.18
Metals that exceed CCME guidelines in 2007							
none	mg/kg	-	-	-	-	-	-
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	ns	1	-	-	10
Chironomus growth - 10d	mg/organism	-	ns	1	-	-	2.3
Hyalella survival - 14d	# surviving	-	ns	1	-	-	8
Hyalella growth - 14d	mg/organism	-	ns	1	-	-	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).

ns = not sampled

5.3 STEEPBANK RIVER WATERSHED

Summary of Results

Measurement Endpoint	Summary of 2007 Conditions				
Climate and Hydrology					
	Assessment of Change				
	Negligible	**Low**	**Moderate**	**High**	
Mean open-water season discharge	√				Total 2007 runoff was 25% less than long-term average runoffo. Cumulative, watershed-level changes in hydrologic conditions in the Steepbank River caused by focal project activities in the watershed are assessed as negligible.
Mean winter discharge	not measured				
Annual maximum daily discharge	√				
Minimum open-water season discharge	√				

Water Quality

Guideline Exceedances	**Station-Endpoint Combinations Exceeding Guidelines in 2007[1]**		
Measurement endpoints with guidelines	**2007 Potentially Influenced Stations (n=1)**	**2007 Reference Stations (n=3)**	
Physical variables (max = 1 for exp, 3 for ref)	0	0	As of 2007, focal projects in the Steepbank River watershed have not measurably affected water quality in the lower Steepbank River. Where water quality variables exceeded guidelines in 2007, these exceedences generally occurred at multiple stations throughout the watershed. Concentrations of almost all water quality measurement endpoints in the watershed were within historical regional baseline ranges, and ion balance was consistent throughout the watershed with that measured in previous years.
Nutrients (max = 2 for exp, 6 for ref)	0	0	
Ions (max = 2 for exp, 6 for ref)	0	0	
Selected metals (max=6 for exp, 18 for ref)	1	0	
Comparison to Regional Baselines	**Endpoints in 2007 Compared to Regional Baseline[2]**		
Percentile of Regional Baseline Values	**2007 Potentially Influenced Stations (n=1 station X 15 endpoints)**	**2007 Reference Stations (n=3 stations X 15 endpoints)**	
Greater than 95th percentile	0	0	
Between 5th and 95th percentiles	15	41	
Less than 5th percentile	0	4	

Benthic Invertebrate Communities and Sediment Quality

Benthic Invertebrate Communities: Comparison to Regional Baselines	**Endpoints in 2007 Compared to Regional Baseline**						
	2007 Potentially Influenced Stations (n= 1)			**2007 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		The benthic community of the lower Steepbank River is presently in good condition relative to reference erosinoal reaches, but may be changing over time. Continued monitoring of the lower Steepbank River will determine whether the observed trends are a function of degraded habitat quality or a part of the natural variation.
Richness		1			1		
Diversity		1			1		
Evenness		1			1		
% EPT		1			1		

Sediment Quality Guideline Exceedances	**Station-Endpoint Combinations Exceeding Guidelines in 2007[1]**	
Measurement endpoints with guidelines	**2007 Potentially Influenced Stations (n=0)**	**2007 Reference Stations (n=0)**
Total Hydrocarbons	no sediment quality sampling conducted in Steepbank River watershed in 2007	
PAHs		

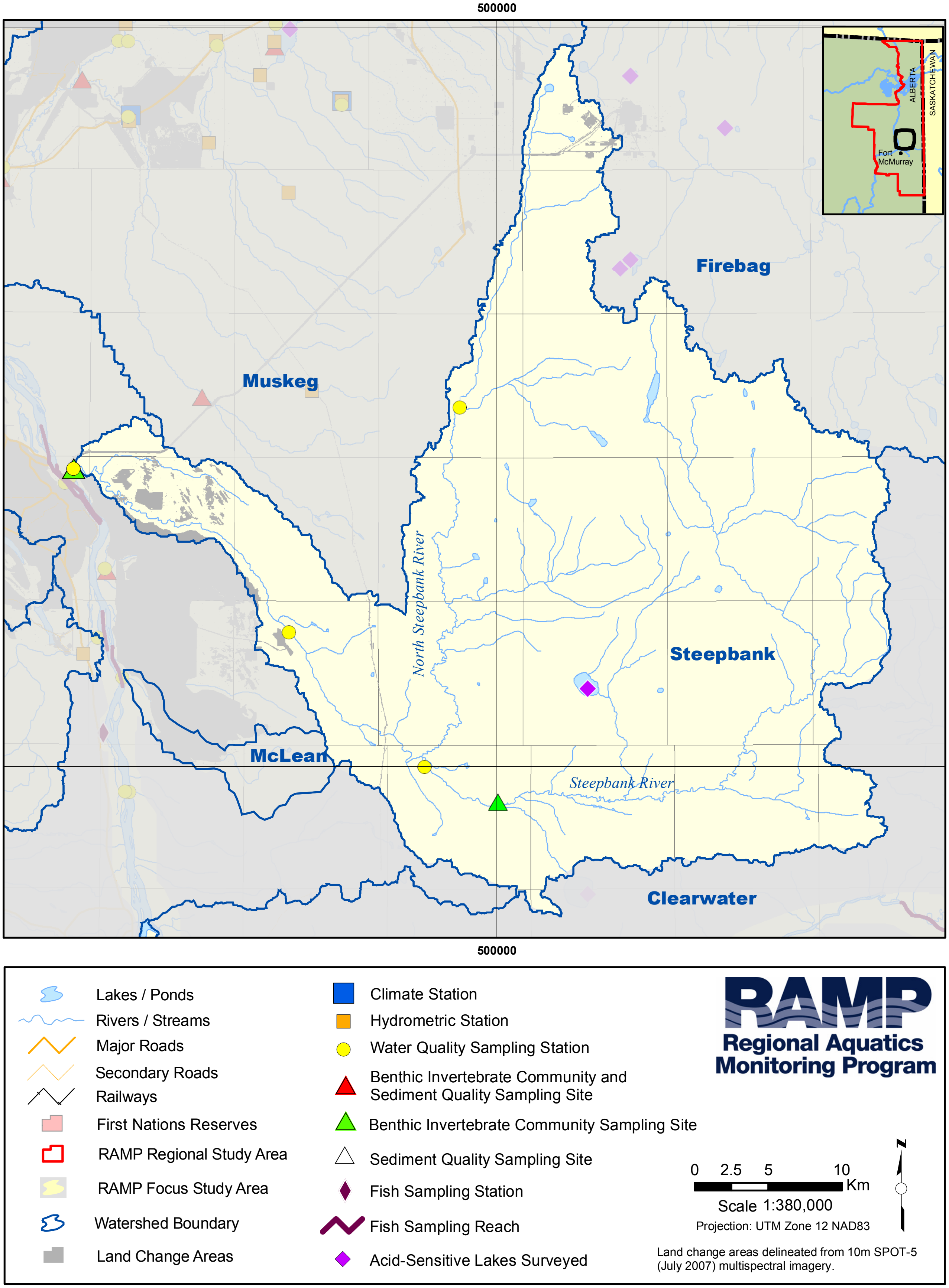
Fish Populations

Fish Inventory	No fish inventory studies conducted in 2007.
Sentinel Studies	No sentinel fish studies conducted in 2007
Fish Tissue	**Level of Risk**
Human Health: Subsistence	No fish tissue program conducted in 2007.
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 Steepbank River watershed.



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5.3.1 Development Status

Approximately 1.3% of the Steepbank River watershed had undergone land change as of 2007 from focal project activities (Table 2.4-2), and much of this land change is concentrated in the lower portion of the watershed. The designations of specific areas of the watershed are as follows:

- The Steepbank River watershed downstream of the Suncor oil sands developments (Figure 5.3-1) is designated as *potentially influenced*. All data gathered from 2007 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 2007 RAMP sampling locations in these parts of the watershed are designated as baseline data.

5.3.2 Hydrologic Conditions

2007 Hydrologic Conditions The Steepbank River basin produced 77 mm of runoff in March to October 2007, about 25% below the historical mean runoff of 103 mm (Figure 5.3-2). The spring runoff was well above normal, peaking in early May, but the summer was relatively dry, with discharges below the historical median flow. Flows recovered to upper quartile values in August following a significant rainfall. The May maximum daily discharge was 25.7 m^3/s, about 75% of the mean annual flood, while the minimum open-water discharge of 0.738 m^3/s was much 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 is provided in Table 5.3-1. As of 2007, the area of closed-circuited and not closed-circuited land change was 1.86 km^2 and 15.4 km^2, respectively, in the Steepbank River watershed as a result of cumulative development of focal projects (Table 2.4-1), the estimated net effects of which were to increase inflows to the Steepbank River by 0.105 million m^3 in 2007.

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 hydrologic influences of the focal projects from the station's operational hydrograph recorded in 2007. These estimated influences are predicted to have increased mean open-water season discharge, annual maximum daily discharge, and open-season minimum daily discharge by 0.1%. 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 5.3-2, Table 5.3-2). 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 2007 have been negligible.

5.3.3 Water Quality

Water quality samples were collected from four stations in the Steepbank River watershed in 2007:

- Station STR-1, near the mouth of the Steepbank River (*potentially influenced*, operational data available from 1997 to 2007);
- Station STR-2, upstream of Suncor's oil sands developments (*reference*, baseline data available from 2002 to 2007);
- Station STR-3, upper Steepbank River, above the confluence with the North Steepbank River (*reference*, baseline data from 2004 to 2007); and
- Station NSR-1, North Steepbank River (*reference*, baseline data from 2002 to 2007).

All stations were sampled in fall 2007, and spring and summer sampling was also conducted at station STR-3 in 2007.

2007 Results and Historical Ranges of Concentration At station STR-1 in fall 2007, sulphate was the only key water quality measurement endpoint that fell outside the range of previous observations (the fall 2007 concentration was lower than previous observations) ***(Table 5.3-3)***.

Concentrations of several water quality measurement endpoints at stations STR-2, STR-3, and NSR-1 fell outside the range of historical observations (Table 5.3-4, Table 5.3-5, Table 5.3-6). At station STR-2, total and dissolved aluminum concentrations in fall 2007 were less than those previously observed. At station STR-3, fall 2007 concentrations of chloride, sulphate and total boron were below the historical range, while conductivity, total aluminum and total arsenic concentrations were above their historical ranges at these stations. At station NSR-1, fall 2007 concentrations of total dissolved solids, total boron and total molybdenum were below historical observations, while dissolved organic carbon was above its historical maximum at this station.

Comparison of Water Quality Measurement Endpoints to Water Quality Guidelines No concentrations of water quality measurement endpoints exceeded relevant water quality guidelines at any of the four stations in the Steepbank River watershed in 2007 with the exception of total aluminum at station STR-1 in fall 2007 (Table 5.3-3 to Table 5.3-6).

Other Water Quality Guideline Exceedances Concentrations of the following other water quality variables exceeded relevant water quality guidelines in 2007 in the Steepbank watershed (Table 5.3-7):

- Total iron and total aluminum at STR-3 (Upper Steepbank River) in spring;
- Total phosphorus, total iron and total phenols at STR-3 in summer;
- Dissolved iron and total iron at all four stations in fall 2007;
- Total phosphorus at station STR-3 in fall 2007;
- Total phenols at stations STR-1, STR-2, and NSR-1 in fall 2007; and
- Total aluminum at station STR-1 in fall 2007.

Comparison of Water Quality Measurement Endpoints to Natural Variation in Baseline Conditions In fall 2007 at station STR-1, the only RAMP station in the Steepbank River watershed designated as *potentially influenced*, concentrations of all water quality measurement endpoints were within the range of regional baseline concentrations (Figure 5.3-3).

Several water quality measurement endpoints that were present mostly or entirely as dissolved species (e.g., total dissolved solids, total boron, total strontium, calcium, magnesium, sodium) were greater at the upper Steepbank River above the confluence of the North Steepbank (station STR-3) than in the North Steepbank River (station NSR-1) (Figure 5.3-3), possibly indicating a greater relative contribution of groundwater to total flow at station STR-3. Concentrations of these water quality variables in the Steepbank River at the stations below the confluence of the North Steepbank (i.e., stations STR-2 and STR-1) were intermediate to the concentrations at stations NSR-1 and STR-3 (Figure 5.3-3).

Ion Balance The ionic composition of water at all stations in the Steepbank River watershed in fall 2007 was dominated by calcium and bicarbonate ions, and the ionic characteristics of water at all stations in the Steepbank River watershed has changed little throughout RAMP (Figure 5.3-4).

Trend Analysis As of 2007, sufficient data existed to allow statistical trend analysis of fall water-quality data for Steepbank River station STR-1 (n=10). The only significant trend observed at this station was a downward trend in sulphate (α=0.05).

Summary As of 2007, focal projects in the Steepbank River watershed have not measurably affected water quality in the lower Steepbank River. Where water quality variables exceeded guidelines in 2007, these exceedences usually occurred at multiple stations throughout the watershed. Concentrations of almost all water quality measurement endpoints in the watershed were within historical regional baseline ranges, and ion balance was consistent throughout the watershed with that measured in previous years.

5.3.4 Benthic Invertebrate Communities and Sediment Quality

5.3.4.1 Benthic Invertebrate Communities

In 2007, benthic invertebrate community samples were collected from:

- A lower operational reach near the mouth of the Steepbank River (reach STR-E-1, erosional, *potentially influenced*, operational data, data available intermittently from 1998 to 2007); and
- From an upper reach upstream of the North Steepbank confluence (reach STR-E-2, erosional, *reference*, baseline data, data available for 2004 to 2007).

2007 Habitat Conditions Both reaches are typical of erosional habitats in the RAMP FSA with relatively high flow velocities (0.6 m/s) and coarse substrate consisting primarily of gravel and cobble (Table 5.3-8). Macrophytes were generally absent in fall 2007, while benthic algal chlorophyll *a* levels were indicative of oligotrophic conditions as in past years (Figure 5.3-5).

Relative Abundance of Benthic Invertebrate Community Taxa in 2007 Chironomids (36%), mites (Acarina, 14%) and tubificid worms (10%) dominated the benthic fauna of reach STR-E-1 (Steepbank River near the mouth), with naidid worms, enchytraeid worms, and snails (Gastropoda) sub-dominant (Table 5.3-9). Abundance in reach STR-E-1 in fall 2007 was about 10,000 individuals/m^2, which is near the long-term average for the reach. The average number of taxa at the sampling locations in reach STR-E-1 was 31, an increase of five taxa from 2006, and just above the long-term average richness for the reach (Figure 5.3-6). Diversity (Simpson's and evenness) was high at reach STR-E-1, while percent EPT was the lowest average recorded (13%) for the reach. All measurement endpoints were within the normal range of variation for *reference* reaches (Figure 5.3-6). A variety of sensitive taxa were present in reach STR-E-1 including the mayflies *Ephemerella* and *Heptagenia*, and the stoneflies *Zapada* and *Taeniopteryx*. The dominant chironomids were *Polypedilum*, *Micropsectra/Tanytarsus* and *Rheotanytarsus*, genera that are not overly sensitive (Bode, 1988).

Chironomids (52%), ostracods (18%) and naidid worms (16%) dominated reach STR-E-2 (upper reach of the Steepbank River) (Table 5.3-9), with caddisflies (6%), mites (8%), mayflies (6%), ceratopogonids (7%) and mayflies (6%) sub-dominant. The number of taxa and other benthic community measurement endpoints for reach STR-E-2 were within expected ranges for *reference* erosional reaches (Figure 5.3-6). Several sensitive taxa were present in the upper reach including the mayflies *Drunella grandis*, the stoneflies *Zapada*, and *Taeniopteryx*, the caddisfly *Brachycentrus* and the caddisfly *Lepidostoma*. The most common mayflies (upper and lower reaches) were *Baetis*, which is a complex genus comprising several species including both tolerant and sensitive forms (Bode, 1988). Chironomids in the upper reach, like the lower reach, were dominated by a variety of groups, but principally *Rheotanytarsus*, and *Micropsectra/Tanytarsus*, as well as the sensitive midge *Potthastia* (*longimana*?).

Effects of Focal Project Activities Linear contrasts were used to test for the following specific focal project-related effects:

- A difference between *reference* and *potentially influenced* across all common years;
- A difference in time trends between *reference* and *potentially influenced*; and
- A difference between *reference* and *potentially influenced* in 2007 only.

The most relevant test of effects of focal projects was for differences in time trends between *reference* and *potentially influenced*. There were significant differences in time trends for richness, diversity (Simpson's and evenness) and for percent EPT taxa between reach STR-E-1, Steepbank River near the mouth, and reach STR-E-2, upper Steepbank River (Table 5.3-10, Figure 5.3-6). Richness and diversity have increased in reach STR-E-1 (lower) over the last four years, and declined in reach STR-E-2 (upper) over the same time period. Percent EPT taxa has declined in reach STR-E-1 from a high of 47% (observed in 1998 and 2001) to a low of 13% in 2007, at the same time that percent EPT has increased in the reach STR-E-2 (upper) from a low of 29% (2004) to a high of 56% in 2007. In addition to the reduction in percent EPT, there was a modest increase in percent tubificid worms (to 10%). "Remainder" variation was not significant for the diversity and percent EPT contrasts, indicating that the differences in time trends should be given some significance. Variations in average measurement endpoint values have been within the normal range of variation for erosional reaches. In addition, the multivariate ordination of erosional reach data (Figure 5.3-7) indicates that the reach STR-E-1 (Steepbank River near the mouth) was within the normal range of expected variability in 2007, despite being outside the normal range of variability in a number of previous years (2002, 2005, 2006).

5.3.4.2 Sediment Quality

As sediment quality in 2007 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 2007.

5.3.4.3 Summary

Benthic invertebrate communities of the lower Steepbank River are presently in good condition relative to reference erosional reaches, but may be changing over time. Continued monitoring of the lower Steepbank River will determine whether the observed trends are a function of changing habitat quality in a part of the river potentially influenced by focal projects or due to natural variability.

5.3.5 Fish Populations

The 2007 RAMP Fish Population component did not include any activities in the Steepbank River watershed.

5.3.6 Summary of Conditions

There is little evidence in 2007 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 2007 have been negligible. In 2007 there were few exceedances of water quality guidelines throughout the watershed, concentrations of all water quality measurement endpoints throughout the watershed were within historical regional baseline ranges, and ion balance in fall 2007 was consistent throughout the watershed with ion balance in previous years. There were some significant differences in time trends for some benthic invertebrate community measurement endpoints between reaches representing areas of the watersheds designated as *potentially-influenced* and areas designated as *reference*, but values of all benthic invertebrate community measurement endpoints in 2007 in the reaches sampled were within the normal range of values observed from regional reference reaches.

Figure 5.3-2 Steepbank River: 2007 hydrograph and historical context.

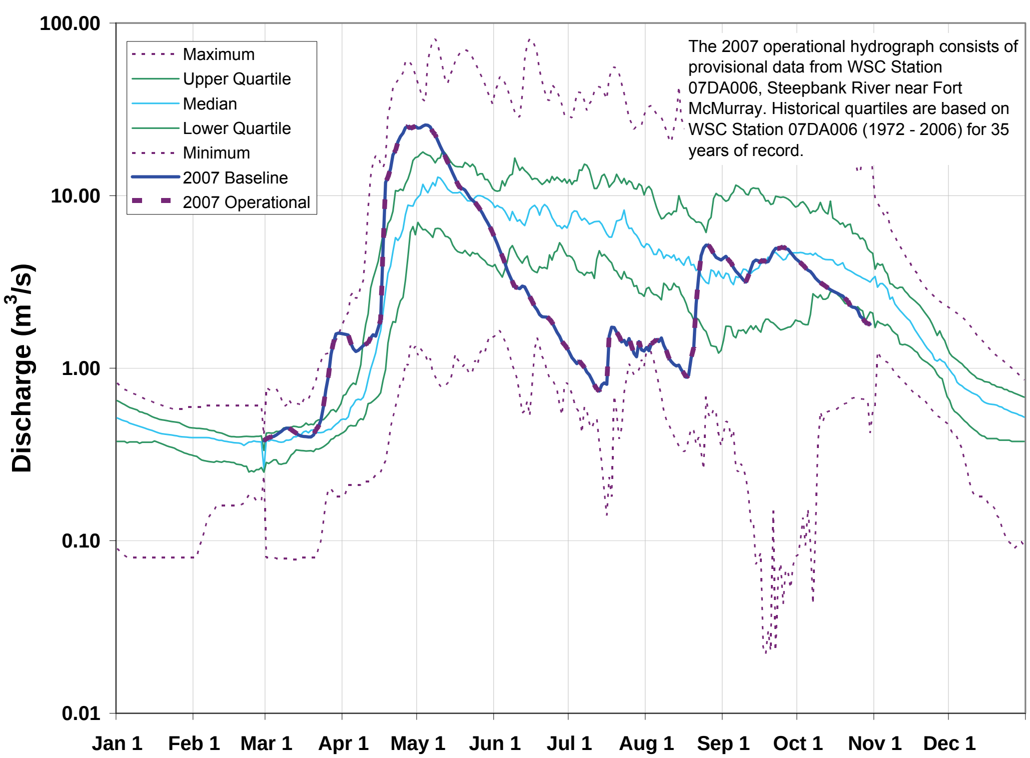


Table 5.3-1 Inputs for calculation of the baseline hydrograph at WSC Station 07DA006, Steepbank River near Fort McMurray.

Component	Seasonal Volume (million m^3)	Basis and Data Source
Observed hydrograph (total discharge during 2007 data record)	102	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 2007	+ 0.133	1.86 km^2 within Steepbank River drainage estimated to have been closed-circuited by focal projects as of 2007 (Table 2.6-1)
Incremental runoff from areas of land change that were not closed-circuited as of 2007	- 0.238	15.4 km^2 within Steepbank River drainage estimated to have undergone land change by focal projects of 2007, 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)	102	Estimated total annual baseline discharge (i.e., without focal projects or other oil sands projects) for 2007
Incremental flow (change in total annual discharge)	+ 0.105	Total annual discharge from operational hydrograph less total annual discharge of estimated 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 change in hydrologic measurement endpoints for the Steepbank River watershed for 2007.

Measurement Endpoint	Baseline Value (m^3/s)	Operational Value (m^3/s)	Percent Change
Mean open-water season discharge	4.84	4.85	+0.1%
Mean winter discharge	not monitored	not monitored	-
Annual maximum daily discharge	25.7	25.7	+0.1%
Open-water season minimum daily discharge	0.737	0.738	+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 5.3-3 Concentrations of water quality measurement endpoints in the Steepbank River (station STR-1), fall 2007.

Measurement Endpoint	Units	Guideline	September 2007	1997-2006 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.2	9	7.7	8.3	8.5
Total Suspended Solids	mg/L	-[1]	5	9	<3	5	60
Conductivity	μS/cm	-	234	9	141	247	516
Nutrients							
Total dissolved phosphorus	mg/L	0.05[2]	0.019	9	0.006	0.021	0.032
Total nitrogen*	mg/L	1.0	0.7	9	0.25	0.7	2.40
Nitrate+Nitrite	mg/L	-	<0.1	9	<0.05	<0.1	<0.1
Dissolved organic carbon	mg/L	-	20	9	10	16	26
Ions							
Sodium	mg/L	-	11	9	6	13	38
Calcium	mg/L	-	30	9	17.2	31.2	50.3
Magnesium	mg/L	-	8.3	9	5.4	9.5	16.2
Chloride	mg/L	230, 860[3]	2	9	1.0	3	8.4
Sulphate	mg/L	100[4]	2.8	9	4.2	4.8	12.3
Total Dissolved Solids	mg/L	-	182	9	120	190	320
Total Alkalinity	mg/L		120	9	63	121	263
Organic compounds							
Naphthenic acids	mg/L	-	<1	9	<1	<1	2
Selected metals							
Total aluminum	mg/L	0.1	**0.108**	9	0.040	**0.120**	**2.73**
Dissolved aluminum	mg/L	0.1[2]	0.00597	9	0.004	0.016	0.099
Total arsenic	mg/L	0.005	0.000631	9	0.0005	0.0008	<0.001
Total boron	mg/L	1.2[5]	0.057	9	0.025	0.076	0.200
Total molybdenum	mg/L	0.073	0.000232	9	0.00015	0.00020	0.00050
Total mercury (ultra-trace)	ng/L	5, 13[6]	<1.2	4	<1.2	<1.2	<1.2
Total strontium	mg/L	-	0.114	9	0.064	0.119	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).

Table 5.3-4 Concentrations of water quality measurement endpoints in the Steepbank River (station STR-2), fall 2007.

Measurement Endpoint	Units	Guideline	September 2007	1997-2006 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.3	5	7.8	8.1	8.3
Total Suspended Solids	mg/L	-[1]	<3	5	<3	8	28
Conductivity	µS/cm	-	219	5	121	178	274
Nutrients							
Total dissolved phosphorus	mg/L	0.05[2]	0.02	5	0.02	**2.51**	**5**
Total nitrogen*	mg/L	1.0	0.7	5	0.6	0.8	**1.5**
Nitrate+Nitrite	mg/L	-	<0.1	5	<0.1	<0.1	0.1
Dissolved organic carbon	mg/L	-	23	5	14	22	29
Ions							
Sodium	mg/L	-	9	5	5	8	16
Calcium	mg/L	-	28.3	5	16.8	23.7	35.9
Magnesium	mg/L	-	8.5	5	5.3	7.0	10.8
Chloride	mg/L	230, 860[3]	1	5	1	2	3
Sulphate	mg/L	100[4]	2.9	5	<0.5	3.5	5.5
Total Dissolved Solids	mg/L	-	160	5	140	160	200
Total Alkalinity	mg/L		114	5	61	91	155
Organic compounds							
Naphthenic acids	mg/L	-	<1	5	<1	<1	1
Selected metals							
Total aluminum	mg/L	0.1	0.0175	5	0.036	**0.243**	**0.536**
Dissolved aluminum	mg/L	0.1[2]	0.00233	5	0.0049	0.0146	0.0294
Total arsenic	mg/L	0.005	0.000533	5	0.0005	0.000663	0.0007
Total boron	mg/L	1.2[5]	0.0926	5	0.0227	0.0456	0.0969
Total molybdenum	mg/L	0.073	0.000261	5	0.00010	0.00016	0.00030
Total mercury (ultra-trace)	ng/L	5, 13[6]	2.3	4	<1.2	<1.2	2.3
Total strontium	mg/L	-	0.16	5	0.053	0.084	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).

Table 5.3-5 Concentrations of water quality measurement endpoints in the Steepbank River (station STR-3), fall 2007.

Measurement Endpoint	Units	Guideline	September 2007	1997-2006 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.3	3	8.0	8.2	8.3
Total Suspended Solids	mg/L	-[1]	3	3	<3	<3	4
Conductivity	µS/cm	-	317	3	196	276	303
Nutrients							
Total dissolved phosphorus	mg/L	0.05[2]	0.03	3	0.027	0.041	0.041
Total nitrogen*	mg/L	1.0	0.6	3	0.6	0.7	0.8
Nitrate+Nitrite	mg/L	-	<0.1	3	<0.1	<0.1	<0.1
Dissolved organic carbon	mg/L	-	17	3	14	20	25
Ions							
Sodium	mg/L	-	15	3	9	15	17
Calcium	mg/L	-	39.3	3	25.5	37.9	40.7
Magnesium	mg/L	-	12	3	7.7	11.1	12.4
Chloride	mg/L	230, 860[3]	1	3	2	2	2
Sulphate	mg/L	100[4]	3	3	3.1	3.2	3.4
Total Dissolved Solids	mg/L	-	199	3	140	210	220
Total Alkalinity	mg/L		170	3	100	165	170
Organic compounds							
Naphthenic acids	mg/L	-	<1	3	<1	<1	1
Selected metals							
Total aluminum	mg/L	0.1	0.089	3	0.021	0.0389	0.041
Dissolved aluminum	mg/L	0.1[2]	0.00615	3	0.0040	0.00523	0.0175
Total arsenic	mg/L	0.005	0.000669	3	0.0005	0.000622	0.000647
Total boron	mg/L	1.2[5]	0.0488	3	0.058	0.0943	0.114
Total molybdenum	mg/L	0.073	0.0002	3	0.00015	0.000241	0.00028
Total mercury (ultra-trace)	ng/L	5, 13[6]	<1.2	3	<1.2	<1.2	1.3
Total strontium	mg/L	-	0.106	3	0.0945	0.149	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).

Table 5.3-6 Concentrations of water quality measurement endpoints in the North Steepbank River (station NSR-1), fall 2007.

Measurement Endpoint	Units	Guideline	September 2007	1997-2006 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8	5	7.5	8	8.1
Total Suspended Solids	mg/L	-[1]	<3	5	<3	4	8
Conductivity	µS/cm	-	138	5	110	143	191
Nutrients							
Total dissolved phosphorus	mg/L	0.05[2]	0.02	5	0.015	0.02	0.042
Total nitrogen*	mg/L	1.0	0.7	5	0.4	0.7	0.8
Nitrate+Nitrite	mg/L	-	<0.1	5	<0.1	<0.1	<0.1
Dissolved organic carbon	mg/L	-	21	5	13	16	20
Ions							
Sodium	mg/L	-	3	5	2	3	4
Calcium	mg/L	-	20.1	5	16.5	23.2	31
Magnesium	mg/L	-	6.1	5	4.9	6.5	8.8
Chloride	mg/L	230, 860[3]	1	5	<1	1	2
Sulphate	mg/L	100[4]	1.8	5	0.5	1.8	5.2
Total Dissolved Solids	mg/L	-	109	5	120	150	160
Total Alkalinity	mg/L		68	5	55	73	106
Organic compounds							
Naphthenic acids	mg/L	-	<1	5	<1	<1	1
Selected metals							
Total aluminum	mg/L	0.1	0.0636	5	0.028	0.050	**0.129**
Dissolved aluminum	mg/L	0.1[2]	0.0111	5	0.0050	0.0117	0.0148
Total arsenic	mg/L	0.005	0.000598	5	0.0005	0.000796	0.00128
Total boron	mg/L	1.2[5]	0.0102	5	0.0109	0.0131	0.0201
Total molybdenum	mg/L	0.073	0.00013	5	0.00015	0.0002	0.000355
Total mercury (ultra-trace)	ng/L	5, 13[6]	<1.2	4	<1.2	<1.2	<1.2
Total strontium	mg/L	-	0.0636	5	0.049	0.071	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).

Table 5.3-7 Water quality guideline exceedances, Steepbank River watershed, 2007.

Water Quality Variable	Units	Guideline*	STR-1	STR-2	STR-3	NSR-1
Spring						
Total iron	mg/L	0.3	ns	ns	**0.764**	ns
Total aluminum	mg/L	0.1	ns	ns	**0.198**	ns
Summer						
Total phosphorus	mg/L	0.05	ns	ns	**0.078**	ns
Total aluminum	mg/L	0.1	ns	ns	**-**	ns
Dissolved iron	mg/L	0.3[1]	ns	ns	**-**	ns
Total iron	mg/L	0.3	ns	ns	**0.76**	ns
Total phenols	mg/L	0.005	ns	ns	**0.007**	ns
Fall						
Total phosphorus	mg/L	0.05	**-**	**-**	**0.051**	**-**
Dissolved iron	mg/L	0.3[1]	**0.372**	**0.459**	**0.405**	**0.343**
Total iron	mg/L	0.3	**0.652**	**0.812**	**0.698**	**0.551**
Total phenols	mg/L	0.005	**0.008**	**0.006**	**-**	**-**
Total aluminum	mg/L	0.1	**0.108**	**-**	**-**	**-**

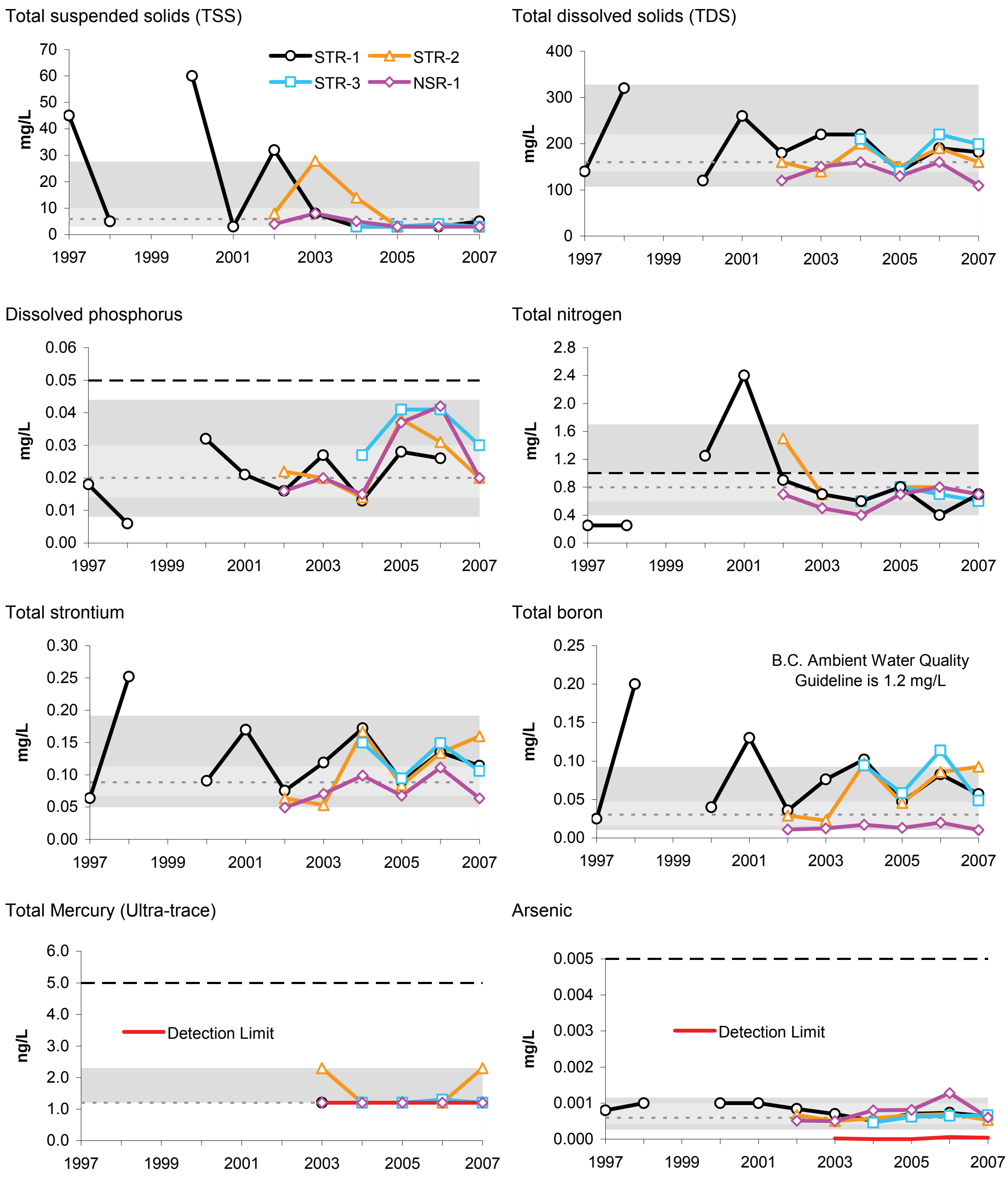
STR-1, STR-2 and NSR-1 were sampled only in fall 2007. STR-3 was sampled in spring, summer and fall 2007.

ns = not sampled

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

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

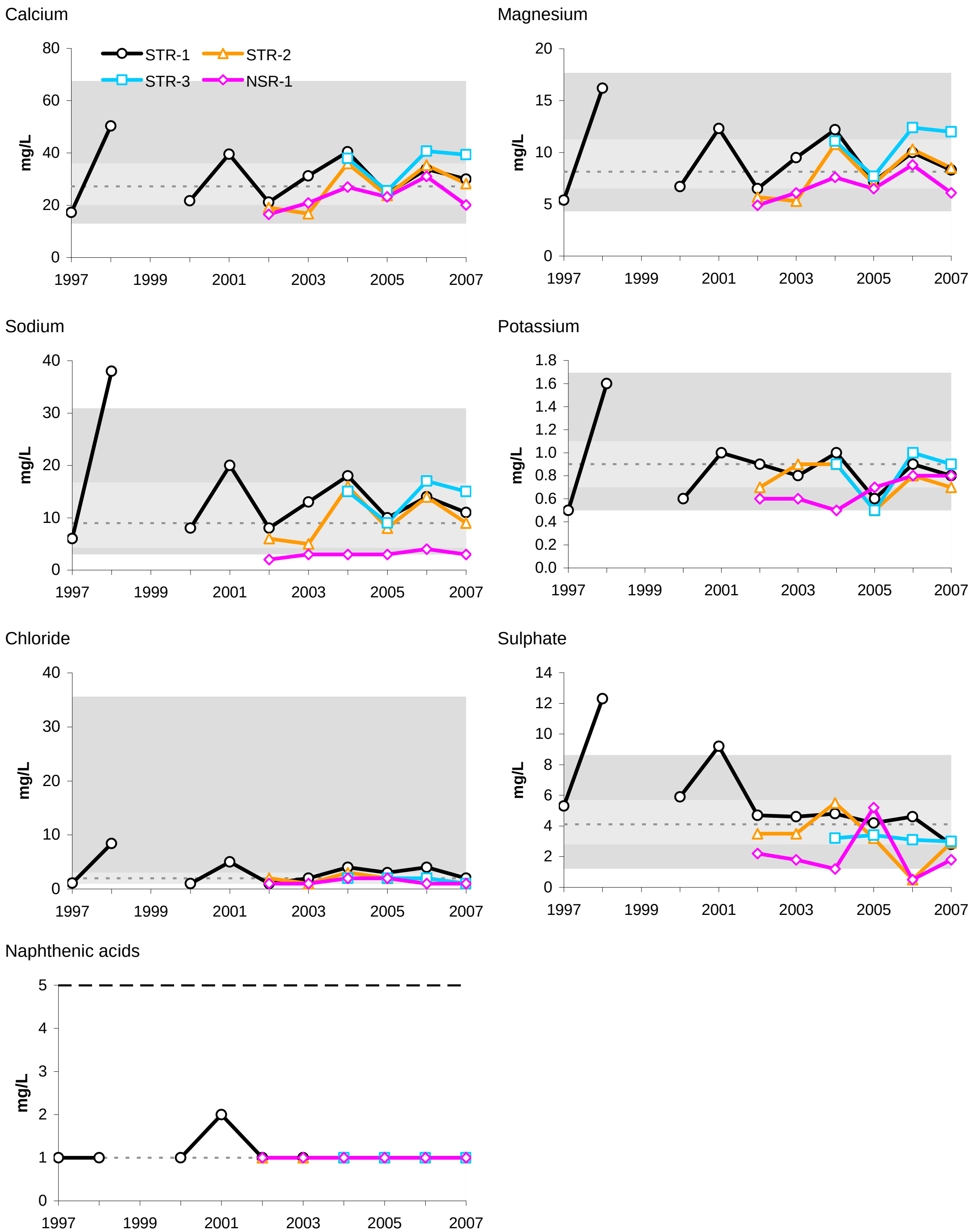
Figure 5.3-3 Concentrations of selected water quality measurement endpoints in the Steepbank River (fall data) relative to regional baseline fall concentrations.



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 5.3-3 (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 Piper diagram of fall ion concentrations in the Steepbank River, fall 2007.

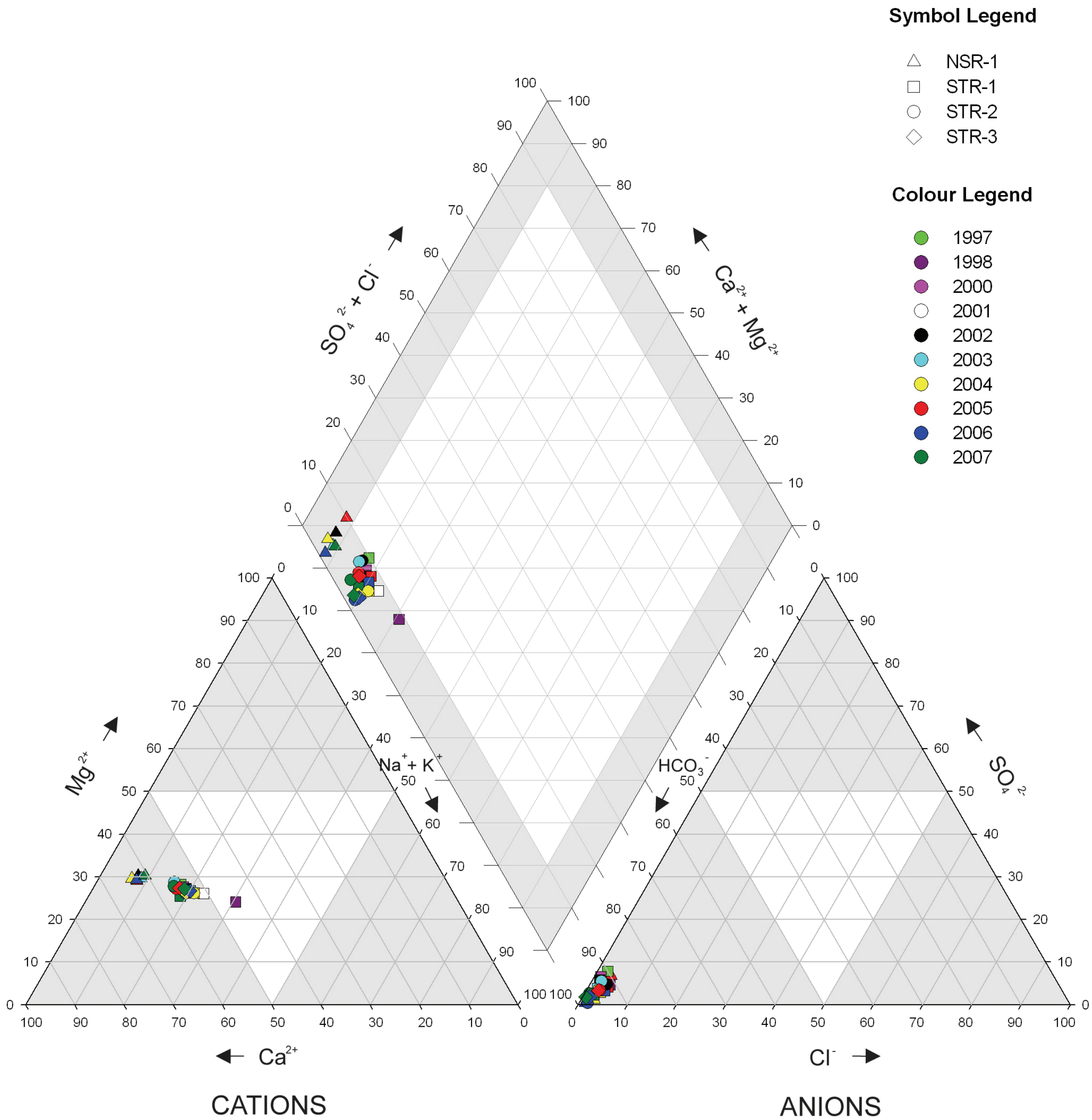


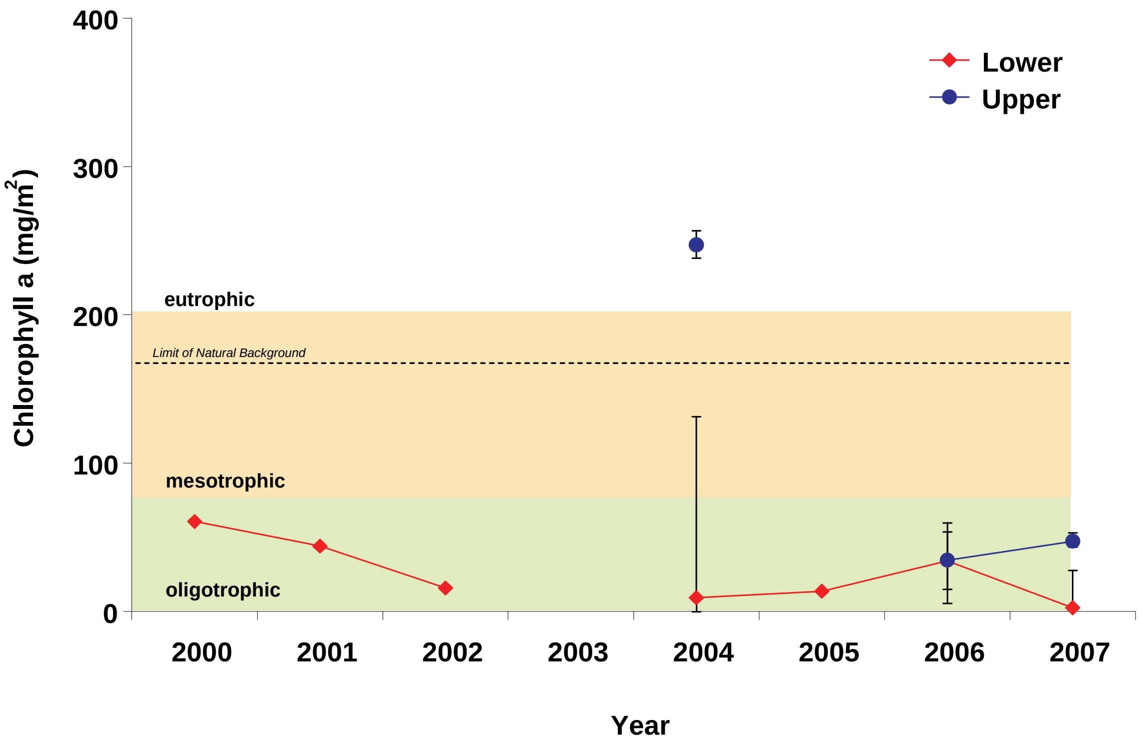
Table 5.3-8 Habitat characteristics of benthic invertebrate community reaches in the Steepbank River.

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 9, 2007	Sept 9, 2007
Habitat	-	Erosional	Erosional
Water depth	m	0.3	0.2
Current velocity	m/s	0.6	0.6
Macrophyte cover	%	2	0
Field Water Quality			
Dissolved oxygen	mg/L	13.0	10.2
Conductivity	µS/cm	241	295
pH		8.1	7.8
Water temperature	°C	10.7	8.2
Sediment Composition			
Sand/Silt/Clay	%	0	4
Small gravel	%	16	0
Large gravel	%	36	8
Small cobble	%	35	51
Large cobble	%	14	25
Boulder	%	0	13
Bedrock	%	0	0

Table 5.3-9 Major taxon percent abundances and indices of benthic invertebrate community composition in the Steepbank River.

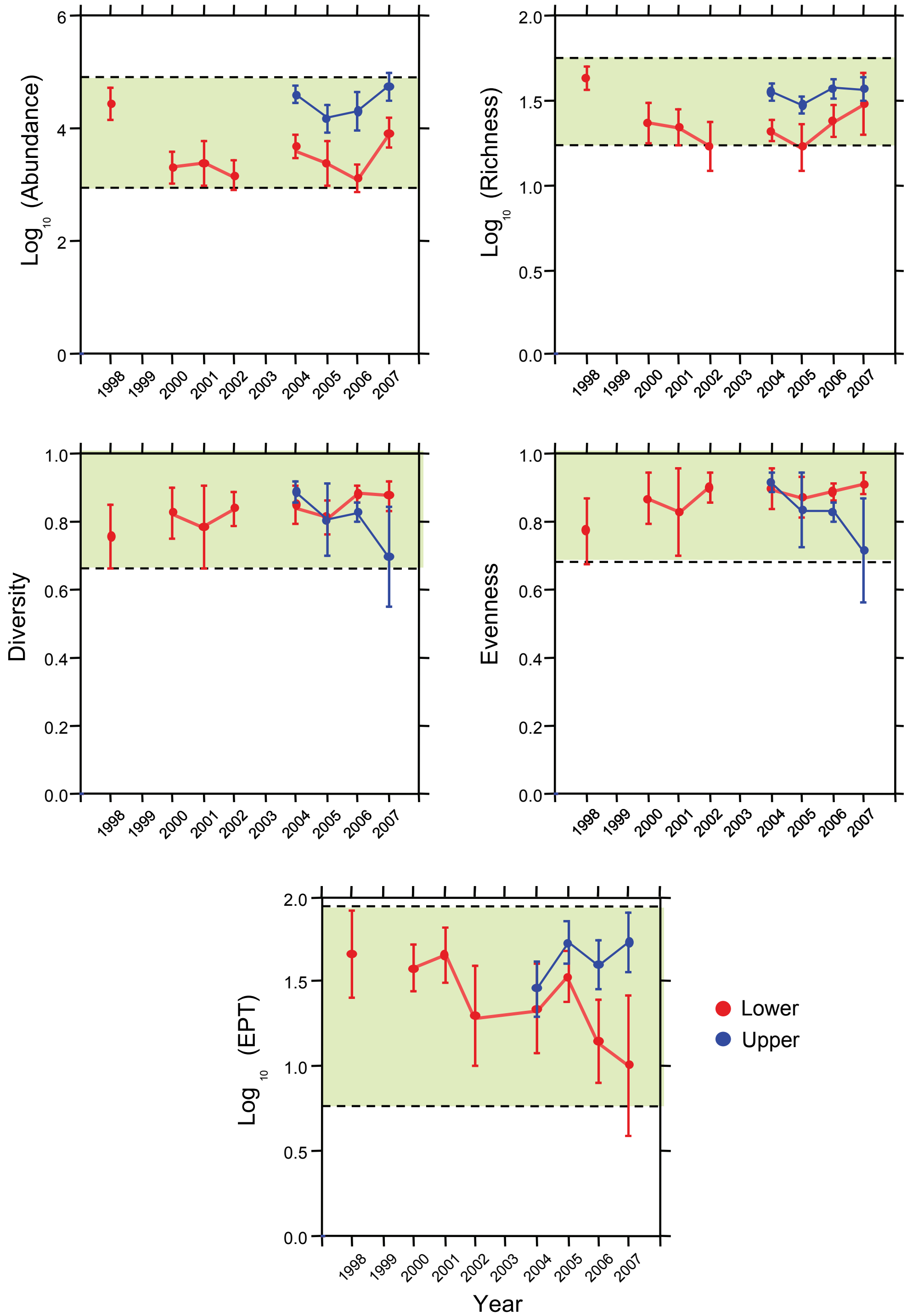
Taxon	Percent Major Taxa Enumerated in Each Year											
	Reach STR-E-1								Reach STR-E-2			
	1998	2000	2001	2002	2004	2005	2006	2007	2004	2005	2006	2007
Anisoptera	<1	<1	<1	1	<1	<1	<1	<1	<1	<1	0.3	<1
Athericidae		<1	<1	<1	<1	<1	<1	1	<1	3	1	1
Bivalvia				<1				<1		<1		1
Ceratopogonidae	<1		<1	<1	<1		<1	3				7
Chironomidae	31	15	25	43	38	25	29	36	46	32	24	52
Cladocera	1	<1							4		<1	1
Collembola	<1	<1						1	<1			
Copepoda	<1	<1	<1	<1		<1		1	4	<1	1	
Empididae	2	1	2	6	4	9	7	<1	2	6	2	<1
Enchytraeidae	1	11	1	9	6	9	15	6	<1	1		
Ephemeroptera	51	42	51	19	23	38	15	1	18	23	17	6
Gastropoda	<1	<1	<1	<1	<1		1	6			<1	<1
Heteroptera		<1	<1	<1								
Hydracarina	6	3	6	4	4	9	15	14	7	3	5	8
Lepidoptera		<1		<1								
Lumbriculidae		<1			<1							
Naididae	2	21	2	2	21	5	13	4	2	2	24	16
Nematoda	1	2	2	2	1	<1	1	1	3	1	1	1
Ostracoda	1	<1	<1	<1			<1	5	1			18
Plecoptera	<1	1	<1	1	1	<1	<1	1	2	4	2	1
Psychodidae		<1										
Simuliidae	3	<1	<1	1	<1	3	1	<1	<1	1	1	<1
Tabanidae	<1	<1			<1			<1	<1	<1	0	<1
Tipulidae	<1	<1						<1	1	1	1	<1
Trichoptera	1	<1	<1	1	1	1	<1	2	9	24	22	6
Tubificidae	2	1	<1	1	<1	1	1	10	<1		1	1
Benthic Invertebrate Community Measurement Endpoints												
Total Abundance (No./m^2)	29,87	2,321	3,156	1,725	5,259	3,105	1,691	9,497	41,844	17,317	26,123	63,294
Richness	41	23	21	17	20	17	23	31	34	29	36	36
Simpson's Diversity	0.76	0.83	0.79	0.84	0.85	0.81	0.88	0.88	0.89	0.81	0.83	0.70
Evenness	0.78	0.87	0.83	0.9	0.9	0.87	0.89	0.91	0.92	0.83	0.83	0.72
% EPT	47	39	47	23	24	34	1	13	29	54	4	56

Figure 5.3-5 Variations in benthic chlorophyll *a* in lower (STR-E-1) and upper (STR-E-2) reaches of the Steepbank River.



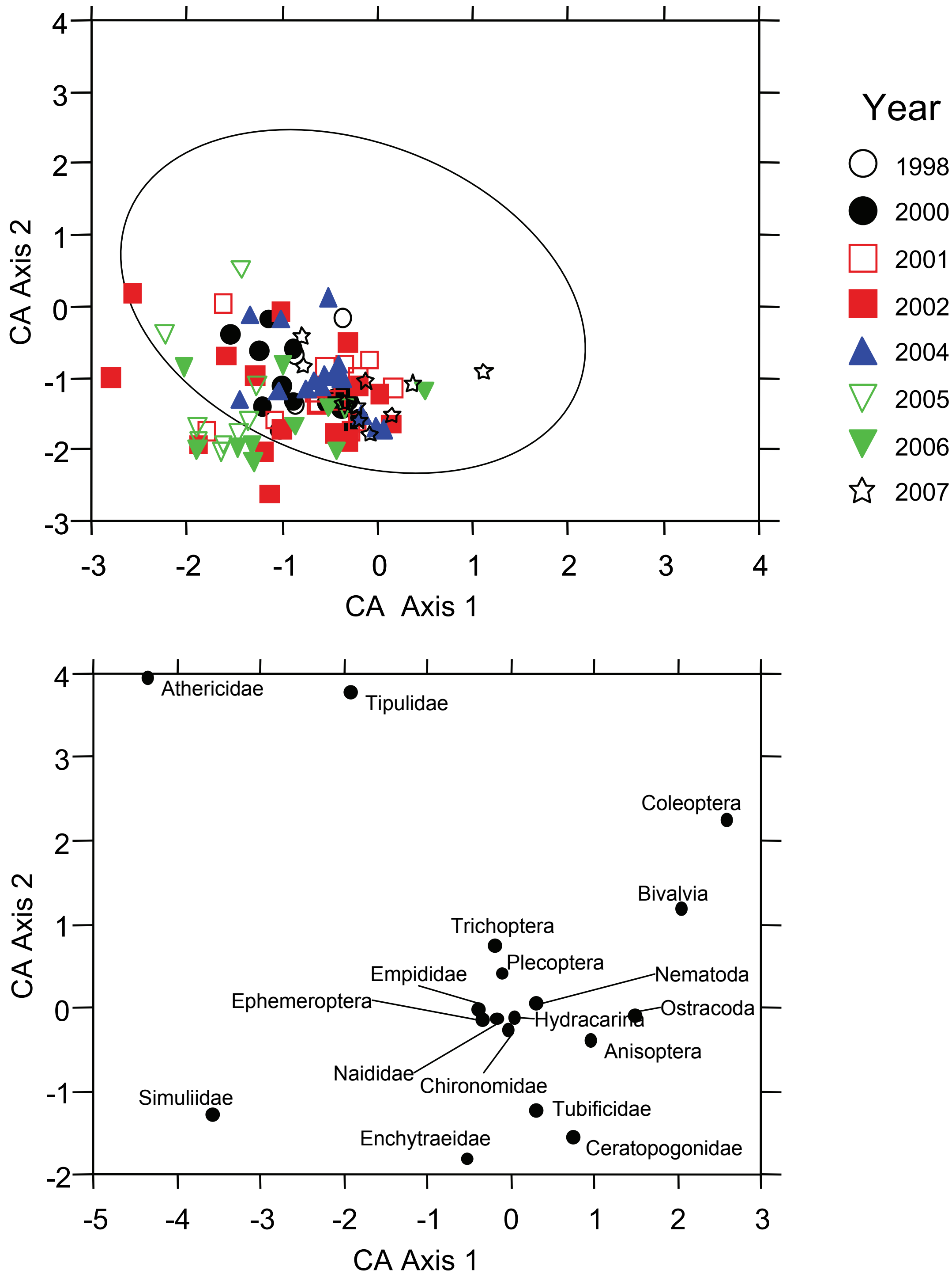
Concentrations defining oligotrophic, mesotrophic and eutrophic conditions are provided in Chapter 3.

Figure 5.3-6 Variations in benthic invertebrate community measurement endpoints in the lower (STR-E-1) and upper (STR-E-2) reaches of the Steepbank River.



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

Figure 5.3-7 Ordination (Correspondence Analysis) of erosional river benthic communities showing the lower reach (STR-E-1) of the Steepbank River.



Note: the upper panel is the scatterplot of sample scores while the lower panel is the scatterplot of taxa scores. The ellipse in the upper panel is for the reference data for erosional reaches.

Table 5.3-10 Results of analysis of variance (ANOVA) between lower (STR-E-1) and upper (STR-E-2) reaches of the Steepbank River.

Response Variable	Source	SS	df	F-ratio	p-value
Log Abundance	Treatment (reach-year combinations; 2002 to 2007)	42.88	11	56.23	0.000
	Reference vs Exposure (RE)	19.09	1	275.4	0.000
	Time Trend (T)	0.28	1	4.06	0.046
	RE x T	0.01	1	0.07	0.799
	RE in 2007	3.43	1	49.48	0.000
	Remainder	20.07	1	290.9	0.000
	Error	8.74	126		
Log Richness	Treatment (reach-year combinations; 2002 to 2007)	2.10	11	18.78	0.000
	Reference vs Exposure (RE)	0.78	1	76.21	0.000
	Time Trend (T)	0.18	1	17.70	0.000
	RE x T	0.07	1	6.97	0.009
	RE in 2007	0.04	1	3.55	0.062
	Remainder	1.04	1	104.1	0.000
	Error	1.28	126		
Diversity	Treatment (reach-year combinations; 2002 to 2007)	0.34	11	5.81	0.000
	Reference vs Exposure (RE)	0.06	1	10.79	0.001
	Time Trend (T)	0.05	1	9.09	0.003
	RE x T	0.15	1	27.41	0.000
	RE in 2007	0.17	1	31.10	0.000
	Remainder	-0.08	1		n/a
	Error	0.68	126		
Evenness	Treatment (reach-year combinations; 2002 to 2007)	0.39	11	6.28	0.000
	Reference vs Exposure (RE)	0.10	1	18.19	0.000
	Time Trend (T)	0.09	1	15.29	0.000
	RE x T	0.13	1	23.39	0.000
	RE in 2007	0.19	1	34.28	0.000
	Remainder	-0.12	1		n/a
	Error	0.71	126		
Log of %EPT	Treatment (reach-year combinations; 2002 to 2007)	6.20	11	12.65	0.000
	Reference vs Exposure (RE)	3.04	1	68.22	0.000
	Time Trend (T)	0.14	1	3.08	0.082
	RE x T	1.26	1	28.17	0.000
	RE in 2007	2.63	1	58.94	0.000
	Remainder	-0.86	1		n/a
	Error	5.62	126		

5.4 TAR RIVER WATERSHED

Summary of Results

Measurement Endpoint	Summary of 2007 Conditions				
Climate and Hydrology					
	Assessment of Change				The May to October 2007 runoff volume was 65% above the historical average. The estimated effects of focal projects were to increase inflows to the Tar River by 1.12 million m^3 in May to October 2007. The effects are assessed as Low to High for the hydrologic measurement endpoints.
	Negligible	**Low**	**Moderate**	**High**	
Mean open-water season discharge			√		
Mean winter discharge	No meaurement of hydrogrology in the Tar River from November to May 2007				
Annual maximum daily discharge		√			
Minimum open-water season discharge				√	

Water Quality			
Guideline Exceedances	**Station-Endpoint Combinations Exceeding Guidelines in 2007[1]**		
Measurement endpoints with guidelines	**2007 *Potentially Influenced* Stations (n=1)**	**2007 *Reference* Stations (n=1)**	
Physical variables (max=1 for exp, 1 for ref)	0	0	
Nutrients (max=2 for exp, 2 for ref)	1	1	
Ions (max=2 for exp, 2 for ref)	1	0	There was evidence of effects of focal project activities on water quality in the lower Tar River in fall 2007, likely related to wastewater treatment plant discharges to the lower Tar River.
Selected metals (max=6 for exp, 6 for ref)	2	1	
Comparison to Regional Baselines	**Endpoints in 2007 Compared to Regional Baseline[2]**		
Percentile of Regional Baseline Values	**2007 *Potentially Influenced* Stations (n=1 station X 15 endpoints)**	**2007 *Reference* Stations (n=1 station X 15 endpoints)**	
Greater than 95th percentile	3	0	
Between 5th and 95th percentiles	12	14	
Less than 5th percentile	0	1	

Benthic Invertebrate Communities and Sediment Quality						
Benthic Invertebrate Communities: Comparison to Regional Baselines	**Endpoints in 2007 Compared to Regional Baseline**					
	2007 *Potentially Influenced* Stations (n=0)			**2007 *Reference* Stations (n=0)**		
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	No sampling of benthic invertebrate communities in the Tar River in 2007					
Richness						
Diversity						
Evenness						
% EPT						

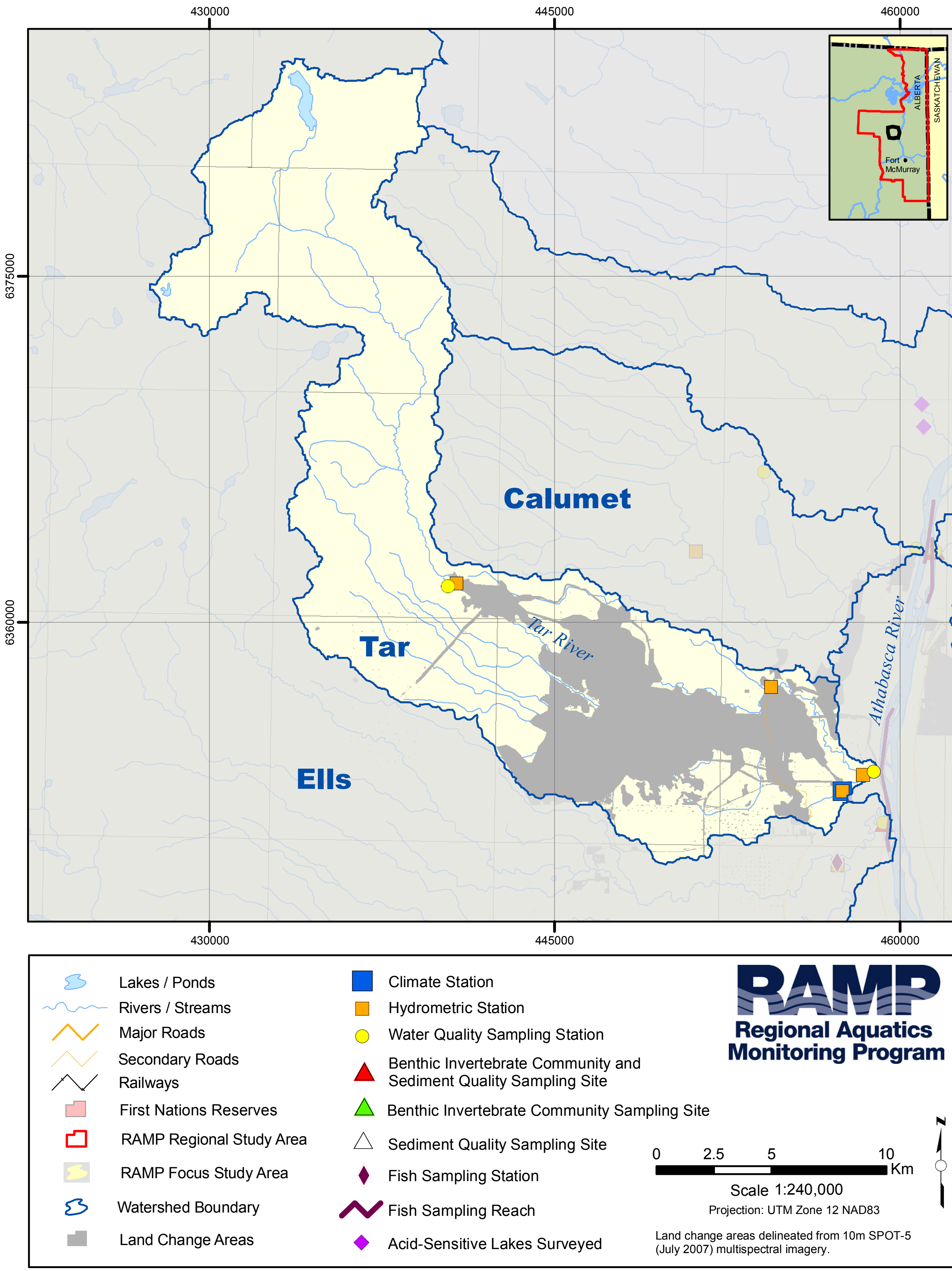
Sediment Quality Guideline Exceedances	**Station-Endpoint Combinations Exceeding Guidelines in 2007[1]**	
Measurement endpoints with guidelines	**2007 *Potentially Influenced Stations* (n=0)**	**2007 *Reference* Stations (n=0)**
Total Hydrocarbons	No sampling of sediment quality in the Tar River in 2007	
PAHs		

Fish Populations	
Fish Inventory	No fish inventory studies conducted in 2007.
Sentinel Studies	No sentinel fish studies conducted in 2007.
Fish Tissue	**Level of Risk**
Human Health: Subsistence	Fish tissue program was not conducted in 2007.
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 Tar River watershed.



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5.4.1 Development Status

As of 2007, slightly more than 21% of the Tar River watershed had undergone land change as a result of focal projects occurring in the watershed (Table 2.4-2). Key activities of the CNRL Horizon project in the Tar River in 2007 included alteration of the main channel drainage pattern in the Tar River in October 2007 as a result of the closure of Dyke No. 10. The designations of specific areas of the watershed are as follows:

- The lower Tar River drainage (Figure 5.4-1) is designated as *potentially influenced*. All data gathered from the 2007 RAMP stations located in this area of the watershed are designated as operational data; and

- All areas of the Tar River drainage upstream of the CNRL Horizon project (Figure 5.4-1) are designated as *reference*. All data gathered from the 2007 RAMP stations located in this area of the watershed are designated as baseline data.

5.4.2 Hydrologic Conditions

2007 Hydrologic Conditions The observed May to October runoff volume in the Tar River watershed, as measured at RAMP station S15A, Tar River near the Mouth, was 65% above normal in 2007 (Figure 5.4-2), primarily because of high flows in spring. Discharges were below median values throughout the summer and fall. The maximum daily discharge of 18.2 m^3/s was more than three times the mean annual flood of 5.0 m^3/s. The minimum open-water discharge was 0.094 m^3/s, which is 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 is as follows (details are provided in Table 5.4-1):

- As of 2007, the area of land change not closed-circuited was 70.4 km^2 in the Tar River drainage as a result of cumulative development of focal projects in the watershed (Table 2.4-1); and

- Discharges to the Tar River by focal projects in 2007 are estimated at 0.221 million m^3 in the May to October 2007 period that RAMP station S15A 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 1.12 million m^3 in the May to October period in 2007. The estimated cumulative effect in 2007 is that mean open-water season discharge was increased by 5.6%, annual maximum daily discharge was increased by 4.6% and open-water season minimum daily discharge was increased by 25% (Figure 5.4-2, Table 5.4-2). The calculated hydrologic effects would have been assessed as Low to High for these hydrologic measurement endpoints in many oil sands EIAs (RAMP 2005b). For the purposes of this assessment, effects on mean open water season discharge are assessed as moderate, effects on annual maximum daily discharge as low, and effects on minimum open-water season discharge as high.

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 2007 have been low to high.

5.4.3 Water Quality

In 2007, 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).

Both stations were sampled in fall 2007, and water quality was also sampled at station TAR-2 in spring and summer 2007.

2007 Results and Historical Ranges of Concentration At station TAR-1, half (11) of the 22 key water quality measurement endpoints in fall 2007 had concentrations that were outside of historical observations at this station (Table 5.4-3). At upstream station TAR-2, seven (32%) of a possible 22 water quality measurement endpoints were outside the historical range of concentrations in fall 2007 (Table 5.4-4). Specifically:

- Concentrations of total nitrogen, sodium, calcium, magnesium, chloride, sulphate, total mercury, total strontium, total dissolved solids, and conductivity all were above previously measured maxima at station TAR-1 (Table 5.4-3);
- The concentration of total dissolved phosphorus was below its previously measured minimum at station TAR-1 (Table 5.4-3);
- Calcium, magnesium, dissolved aluminum, total alkalinity, and conductivity were above previously measured maxima at station TAR-2 (Table 5.4-4); and
- Concentrations of total nitrogen and chloride were below their previously measured minima at station TAR-2 (Table 5.4-4).

Concentrations of many ions in the lower Tar River in fall 2007 were greater than in previous years, and have generally increased since 2005, when development related to CNRL's Horizon project began in this watershed. Similar trends in concentration exist for total dissolved solids, total strontium, total boron, calcium, magnesium, sodium, potassium, and, to a lesser degree, chloride and sulphate (Figure 5.4-3).

The concentration of total mercury in the lower Tar River in September 2007 exceeded historical maxima, the range of regional reference values, and the CCME water-quality guideline of 5 ng/L. Total mercury in the upper Tar River was within historical and regional-reference ranges in September 2007; this suggests a reach-specific effect of elevated mercury in the lower Tar River. It is unknown whether this historically high mercury concentration in the lower Tar River was related to focal project activities.

Concentrations of total nitrogen at station TAR-1 have shown an approximate seven-fold and three-fold increase since 2003 and 2005, respectively (Figure 5.4-3). Historically at both water quality stations on the Tar River, total nitrogen was present mainly as organic nitrogen, as indicated by high values of total Kjeldahl nitrogen relative to total nitrogen, and very low or non-detectable concentrations of ammonia. However, at station TAR-1 in fall 2007, total nitrogen was present mostly as inorganic nitrate/nitrite (1.4 mg/L) and ammonia (1.45 mg/L), while total nitrogen at station TAR-2 in 2007 was still comprised mostly of organic nitrogen. The relative high concentration of ammonia at station TAR-1 suggests that the observed increase in total nitrogen in the lower Tar River since 2005 is related to discharges from the sewage treatment plant at CNRL's Horizon project, which in 2007 discharged an average of 1,059 m^3/day of treated effluent to the lower Tar River just downstream of the Horizon plant site (CNRL, pers. comm. 2007).

Comparison of Water Quality Measurement Endpoints to Water Quality Guidelines Concentrations of four water quality measurement endpoints exceeded water quality guidelines at station TAR-1 in fall 2007: total nitrogen; sulphate; total aluminum; and total mercury (Table 5.4-3). Concentrations of four total dissolved phosphorus and total aluminum exceeded water quality guidelines at station TAR-2 in fall 2007 (Table 5.4-4).

Other Water Quality Guideline Exceedences The following other water quality guideline exceedences were observed in the Tar River in 2007 (Table 5.4-5):

- At station TAR-2 in spring 2007: total aluminum, total cadmium, dissolved phosphorus, total phosphorus, total copper, dissolved iron and total iron;
- At station TAR-2 in summer 2007: total phosphorus, total aluminum, total iron, and total phenols;
- At station TAR-2 in fall 2007: Total phosphorus, total aluminum, total iron, total phenols, dissolved phosphorus and total zinc; and
- At station TAR-1 in fall 2007: Sulphide, total phosphorus, total nitrogen, total aluminum, dissolved iron, total iron, total phenols, total mercury, and sulphate.

Comparison of Water Quality Measurement Endpoints to Natural Variation in Baseline Conditions At station TAR-1 in fall 2007, concentrations of four water quality measurement endpoints were greater than the 95th percentile of regional baseline concentrations: total nitrogen, total mercury, potassium and sulphate (Figure 5.4-3). No water quality measurement endpoints at station TAR-2 were at concentrations that were above the 95th percentile of regional baseline concentrations, but the concentration of total nitrogen was below the 5th percentile at this upstream station (Figure 5.4-3).

Ion Balance Ion balance at station TAR-1 (lower Tar River) has showed steady changes since 2005, toward a greater proportion of sulphate and chloride and a reduced proportion of calcium. In contrast, ion balance at station TAR-2 (upper Tar River) has remained more consistent than that station TAR-1 since monitoring began in the upper Tar River in 2004 (Figure 5.4-4).

Summary There was evidence of effects of focal project activities on water quality in the lower Tar River in fall 2007. The source and cause of high total mercury concentration measured in the lower Tar River in fall 2007 is unknown, and future monitoring data from the lower Tar River in 2008 and onwards will help to clarify if this individual observation was an isolated event or the beginning of a longer-term change in water quality.

5.4.4 Benthic Invertebrate Communities and Sediment Quality

Neither the 2007 RAMP Benthic Invertebrate Community component nor the 2007 Sediment Quality component included any activities in the Tar River watershed.

5.4.5 Fish Populations

The 2007 RAMP Fish Population component did not include any activities in the Tar River watershed, although site-specific fisheries work did occur in the Tar River in 2007 outside RAMP.

5.4.6 Summary of Conditions

Monitoring activities in the Tar River watershed in 2007 consisted of hydrology and water quality. The Tar River watershed in 2007 continued to exhibit changes in aquatic resources measured by RAMP. The effects of focal project activities on hydrologic conditions in 2007 was assessed as low to high 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, and there was evidence of effects on water quality in the lower Tar River as a result of focal project activities.

Figure 5.4-2 Tar River: 2007 hydrograph and historical context.

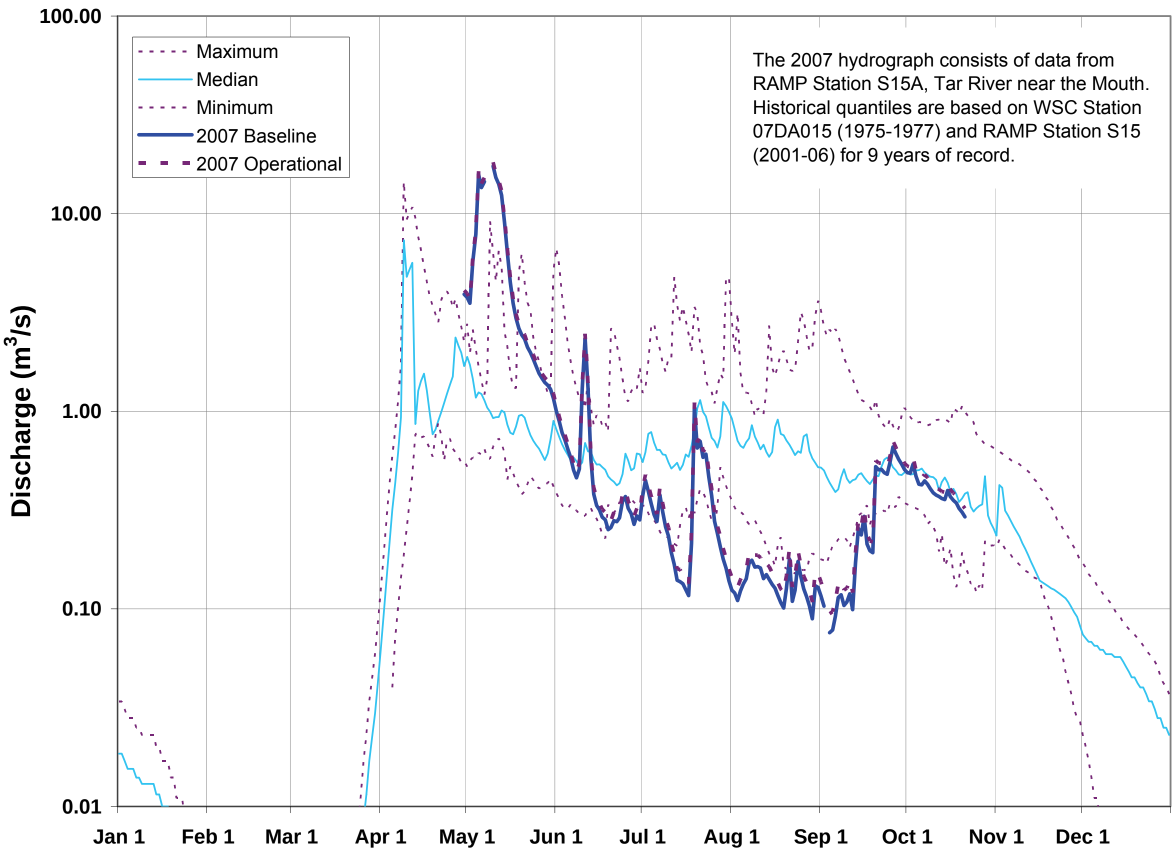


Table 5.4-1 Summary of inputs to the calculation of the Tar River baseline hydrograph at RAMP Station S15A, Tar River near the Mouth.

Component	Seasonal Volume (million m^3)	Basis and Data Source
Observed hydrograph (total discharge during 2007 data record)	20.6	Observed daily discharges obtained from RAMP Station S15A, Tar River near the Mouth
Natural runoff that would have occurred from areas that were closed-circuited as of 2007	0	No land within Tar River watershed closed-circuited by focal projects as of 2007 (Table 2.4-1)
Incremental runoff from areas of land change that were not closed-circuited as of 2007	- 0.894	70.4 km^2 within Tar River watershed estimated to have undergone land change by focal projects of 2007, but are not closed-circuited (Table 2.4-1)
Withdrawals from Tar River for focal project activities	0	Assumed to be negligible
Releases to Tar River from focal project activities	- 0.221	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)	19.5	Estimated total annual baseline discharge (i.e., without focal projects or other oil sands projects) for 2007
Incremental flow (change in total annual discharge)	+ 1.12	Total annual discharge from operational hydrograph less total annual discharge of estimated baseline hydrograph
Incremental flow (% of observed total annual discharge)	+ 5.3%	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 5.4-2 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	1.31	1.38	+5.6%
Mean winter discharge	not measured	not measured	
Annual maximum daily discharge	17.4	18.2	+4.6%
Open-water season minimum daily discharge	0.076	0.094	+25%

Note: As measured at and calculated for RAMP/WSC Station S15A, Tar River near the Mouth

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, lower Tar River (station TAR-1), fall 2007.

Measurement Endpoint	Units	Guideline	September 2007	1997-2006 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.2	6	8.1	8.2	8.5
Total Suspended Solids	mg/L	-[1]	13	6	11	36	214
Conductivity	µS/cm	-	602	6	302	376.5	543
Nutrients							
Total dissolved phosphorus	mg/L	0.05[2]	0.013	6	0.015	0.034	**0.067**
Total nitrogen*	mg/L	1.0	**3.6**	6	0.5	0.825	**2.40**
Nitrate+Nitrite	mg/L	-	1.4	6	<0.05	0.1	1.5
Dissolved organic carbon	mg/L	-	20	6	12	15	21
Ions							
Sodium	mg/L	-	38	6	15	23	36
Calcium	mg/L	-	65.8	6	38	45.45	63.3
Magnesium	mg/L	-	19.8	6	11.3	13.7	19.3
Chloride	mg/L	230, 860[3]	24	6	1.7	4	9
Sulphate	mg/L	100[4]	**95.1**	6	20.4	34.8	**87.9**
Total Dissolved Solids	mg/L	-	393	6	170	290	380
Total Alkalinity	mg/L		185	6	121	166	210
Organic compounds							
Naphthenic acids	mg/L	-	<1	6	<1	<1	1
Selected metals							
Total aluminum	mg/L	0.1	**0.53**	6	**0.36**	**0.72**	**3.95**
Dissolved aluminum	mg/L	0.1[2]	0.00745	6	0.005	0.012	0.026
Total arsenic	mg/L	0.005	0.00126	6	0.0011	0.001735	0.00222
Total boron	mg/L	1.2[4]	0.0986	6	0.054	0.084	0.145
Total molybdenum	mg/L	0.073	0.00108	6	0.000373	0.00120	0.00200
Total mercury (ultra-trace)	ng/L	5, 13[5]	**5.6**	4	<1.2	<1.2	2.8
Total strontium	mg/L	-	0.29	6	0.143	0.179	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] Derived from EPA (2002).

[8] Guideline is for total nitrogen.

Table 5.4-4 Concentrations of water quality measurement endpoints, upper Tar River (station TAR-2), fall 2007.

Measurement Endpoint	Units	Guideline	September 2007	1997-2006 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.3	3	8.0	8.2	8.3
Total Suspended Solids	mg/L	-[1]	5	3	5	6	7
Conductivity	µS/cm	-	383	3	233	297	331
Nutrients							
Total dissolved phosphorus	mg/L	0.05[2]	**0.051**	3	0.024	**0.055**	**0.058**
Total nitrogen*	mg/L	1.0	0.4	3	0.5	0.5	0.60
Nitrate+Nitrite	mg/L	-	<0.1	3	<0.1	<0.1	<0.1
Dissolved organic carbon	mg/L	-	13	3	8	8	14
Ions							
Sodium	mg/L	-	12	3	6	13	16
Calcium	mg/L	-	49	3	31.4	44	45.6
Magnesium	mg/L	-	14.3	3	8.8	13.2	13.7
Chloride	mg/L	230, 860[3]	1	3	2	2	2
Sulphate	mg/L	100[4]	37.6	3	20	29.9	38
Total Dissolved Solids	mg/L	-	234	3	160	210	280
Total Alkalinity	mg/L		162	3	100	131	159
Organic compounds							
Naphthenic acids	mg/L	-	<1	3	<1	<1	1
Selected metals							
Total aluminum	mg/L	0.1	**0.244**	3	0.087	**0.17**	**0.708**
Dissolved aluminum	mg/L	0.1[2]	0.026	3	0.008	0.0161	0.017
Total arsenic	mg/L	0.005	0.00102	3	0.0008	0.00121	0.00123
Total boron	mg/L	1.2[5]	0.0496	3	0.035	0.0556	0.066
Total molybdenum	mg/L	0.073	0.0013	3	0.00083	0.00131	0.00140
Total mercury (ultra-trace)	ng/L	5, 13[6]	1.3	3	<1.2	<1.2	1.4
Total strontium	mg/L	-	0.167	3	0.101	0.118	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).

Table 5.4-5 Water quality guideline exceedances, Tar River, fall 2007.

Water Quality Variable	Units	Guideline*	TAR-1	TAR-2
Spring				
Total aluminum	mg/L	0.1	ns	**3.93**
Total cadmium	mg/L	-[4]	ns	**0.0000973**
Dissolved phosphorus	mg/L	0.05	ns	**0.066**
Total phosphorus	mg/L	0.05	ns	**0.151**
Total copper	mg/L	-[4]	ns	**0.0033**
Dissolved iron	mg/L	0.3[3]	ns	**0.434**
Total iron	mg/L	0.3	ns	**3.53**
Summer				
Total phosphorus	mg/L	0.05	ns	**0.078**
Total aluminum	mg/L	0.1	ns	**0.729**
Total iron	mg/L	0.3	ns	**1.3**
Total phenols	mg/L	0.005	ns	**0.006**
Fall				
Total phosphorus	mg/L	0.05	**0.057**	**0.1**
Total nitrogen	mg/L	1.0	**3.6**	-
Total aluminum	mg/L	0.1	**0.53**	**0.244**
Dissolved iron	mg/L	0.3[3]	**0.335**	**-**
Total iron	mg/L	0.3	**2.22**	**0.856**
Total phenols	mg/L	0.005	**0.006**	**0.014**
Total mercury (ultra-trace)	ng/L	5, 13	**5.6**	-
Total Kjeldahl Nitrogen	mg/L	1.0[5]	**2.2**	-
Sulphate	mg/L	100	**95.1**	-
Dissolved phosphorus	mg/L	0.05[2]	-	**0.051**
Total Zinc	mg/L	0.030	-	**0.0335**

TAR-1 was sampled only in fall 2007. TAR-2 was sampled in spring, summer and fall 2007.

ns = not sampled

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

[1] derived from EPA (2002).

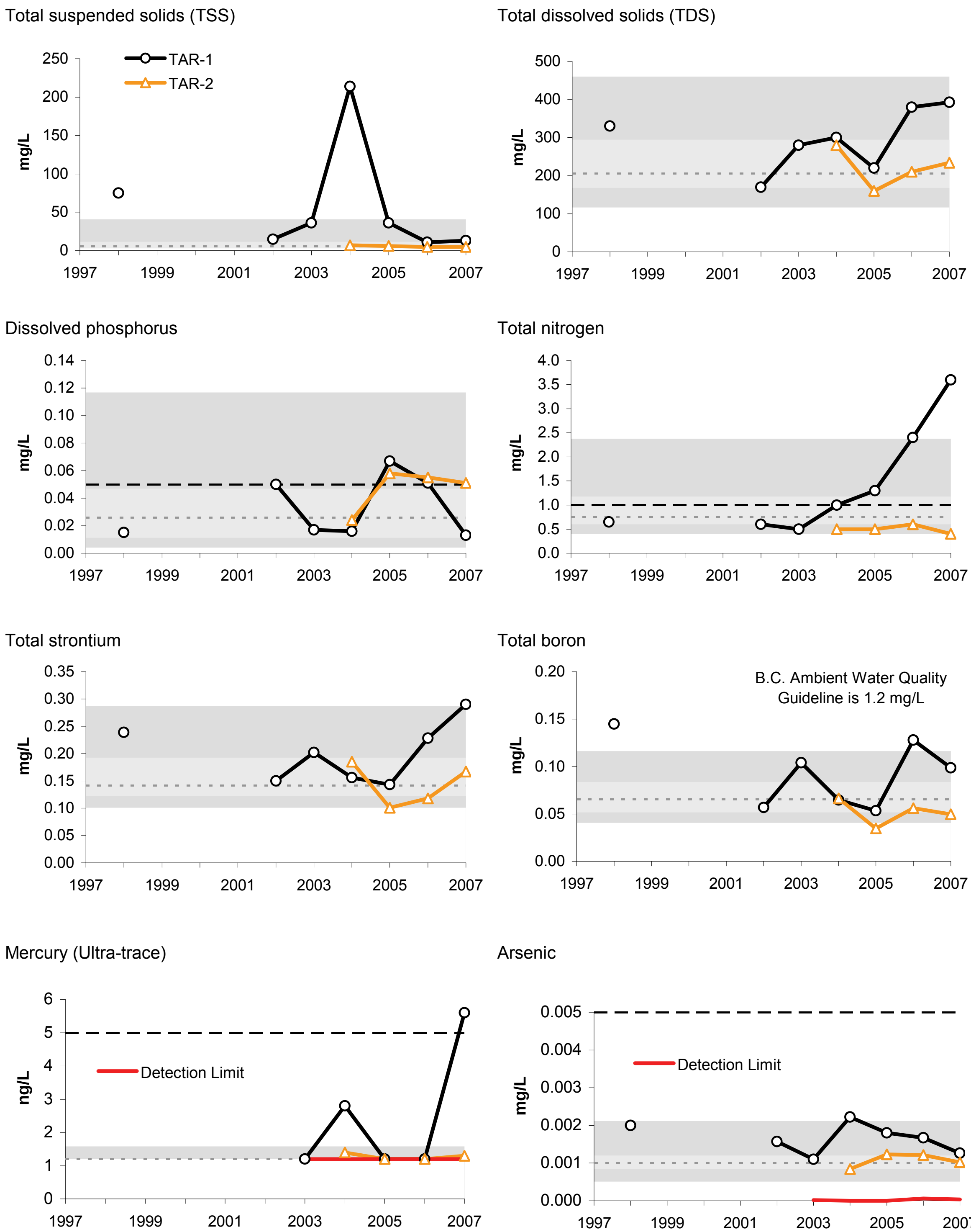
[2] Guideline is for total analyte (no guideline for dissolved species).

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

[4] Guideline is hardness-dependent.

[5] Guideline is for total nitrogen.

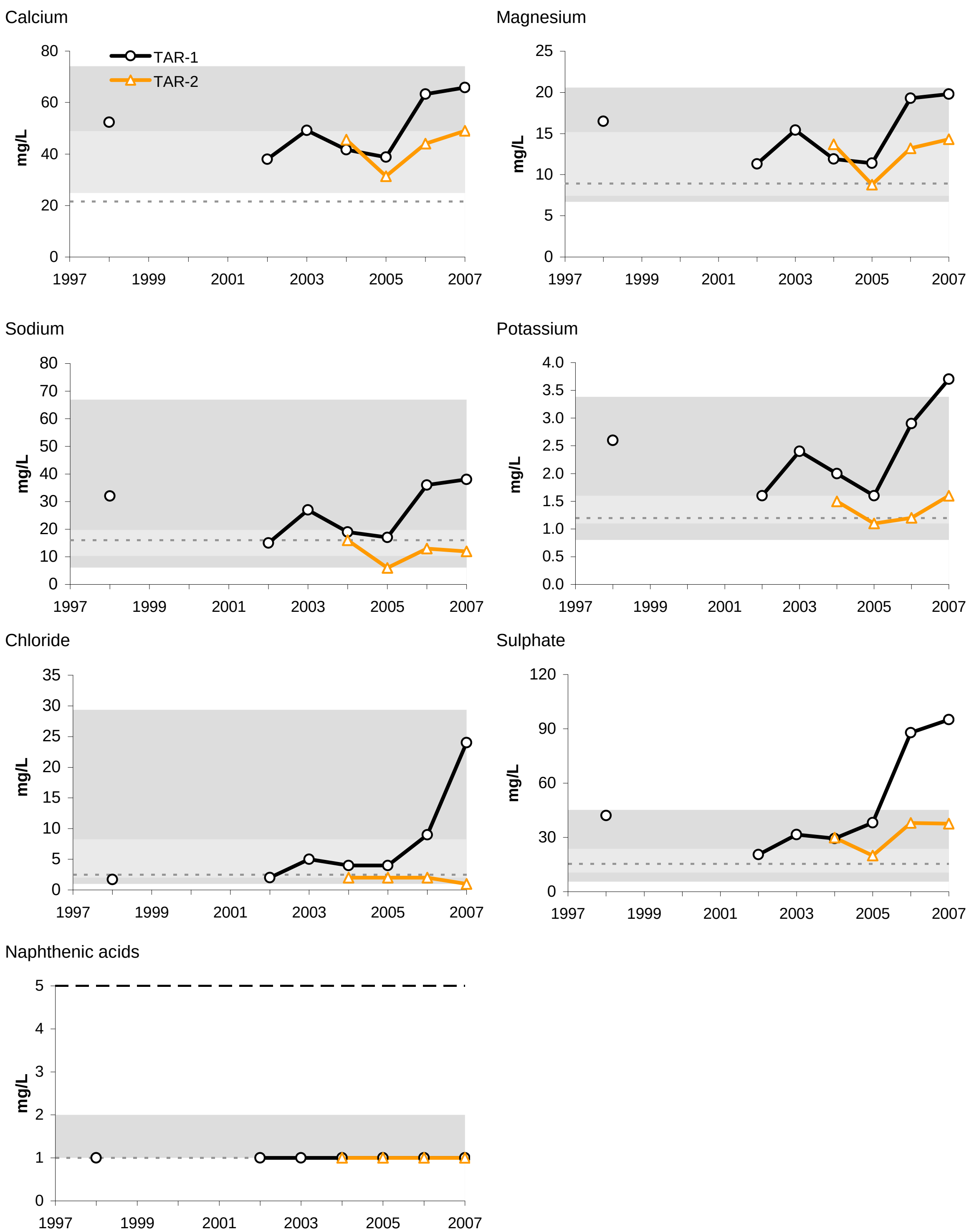
Figure 5.4-3 Concentrations of selected water quality measurement endpoints in the Tar River (fall data) relative to regional baseline fall concentrations.



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.

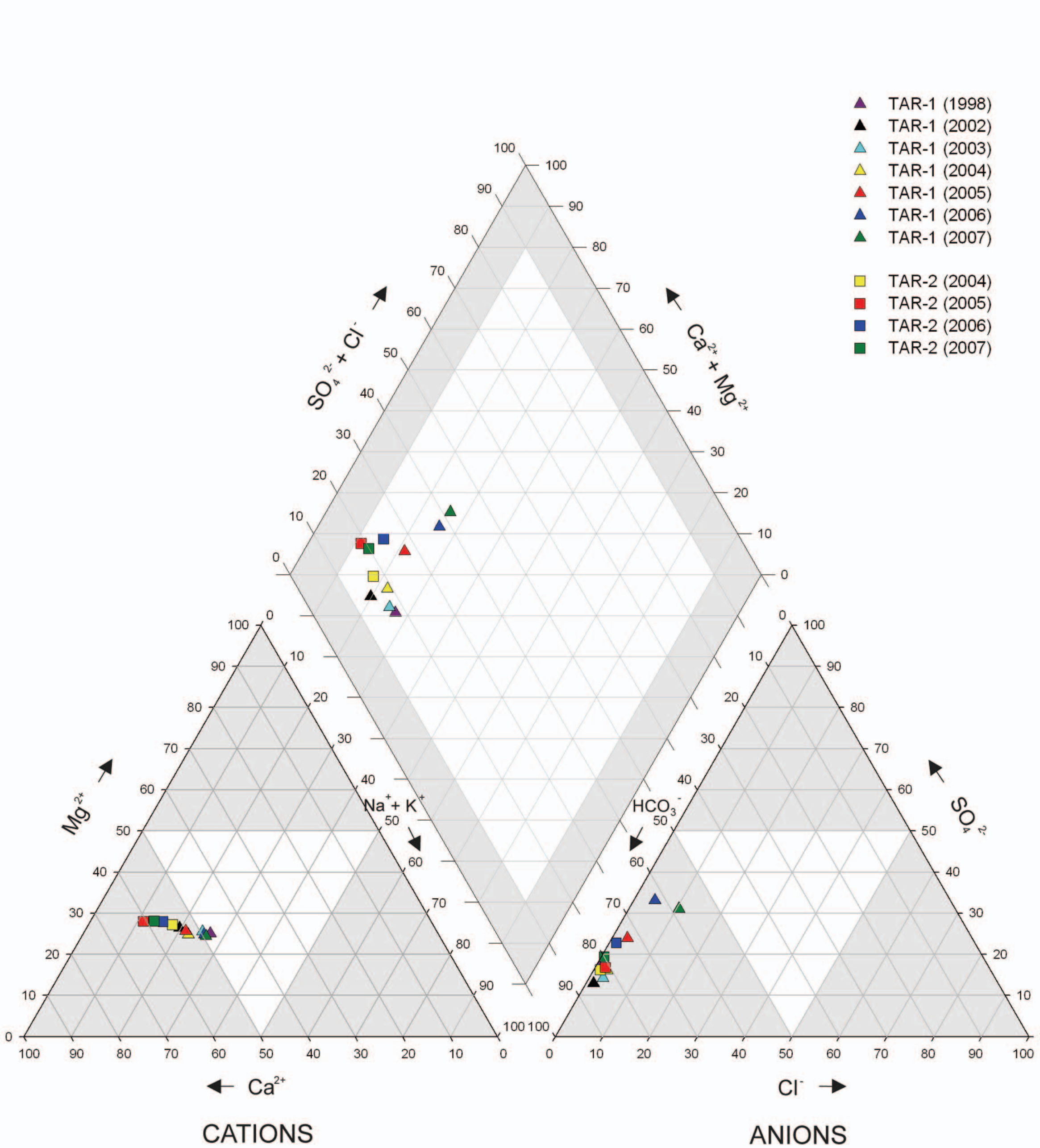
Figure 5.4-3 (Cont'd.)



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 ion concentrations, Tar River.



5.5 MACKAY RIVER WATERSHED

Summary of Results

Measurement Endpoint	Summary of 2007 Conditions				
Climate and Hydrology					
	Assessment of Change				
	Negligible	Low	Moderate	High	
Mean open-water season discharge	√				Total runoff was near the long-term average in 2007. Cumulative, watershed-level changes in hydrologic conditions in the MacKay River caused by focal project activities in the watershed as of 207 have been negligible.
Mean winter discharge	No discharge meaurements in the MacKay River from November to May 2007				
Annual maximum daily discharge	√				
Minimum open-water season discharge	√				

Measurement Endpoint	Summary of 2007 Conditions		
Water Quality			
Guideline Exceedances	Station-Endpoint Combinations Exceeding Guidelines in 2007[1]		
Measurement endpoints with guidelines	2007 Potentially Influenced Stations (n=1)	2007 Reference Stations (n=1)	
Physical variables (max=1 for exp, 1 for ref)	0	0	No measurable effects of focal projects on water quality in the MacKay River to date is indicated by: no instances of guideline exceedences or concentrations outside the 5th and 95th percentile regional baseline concentrations at the mouth of the MacKay River but not at upstream MacKay River in fall 2007; and an absence of any significant temporal trends in the concentration of water quality variables in lower MacKay River.
Nutrients (max=2 for exp, 2 for ref)	1	1	
Ions (max=2 for exp, 2 for ref)	0	0	
Selected metals (max=6 for exp, 6 for ref)	1	1	
Comparison to Regional Baselines	Endpoints in 2007 Compared to Regional Baseline[2]		
Percentile of Regional Baseline Values	2007 Potentially Influenced Stations (n=1 station X 15 endpoints)	2007 Reference Stations (n=1 station X 15 endpoints)	
Greater than 95th percentile	0	1	
Between 5th and 95th percentiles	15	14	
Less than 5th percentile	0	0	

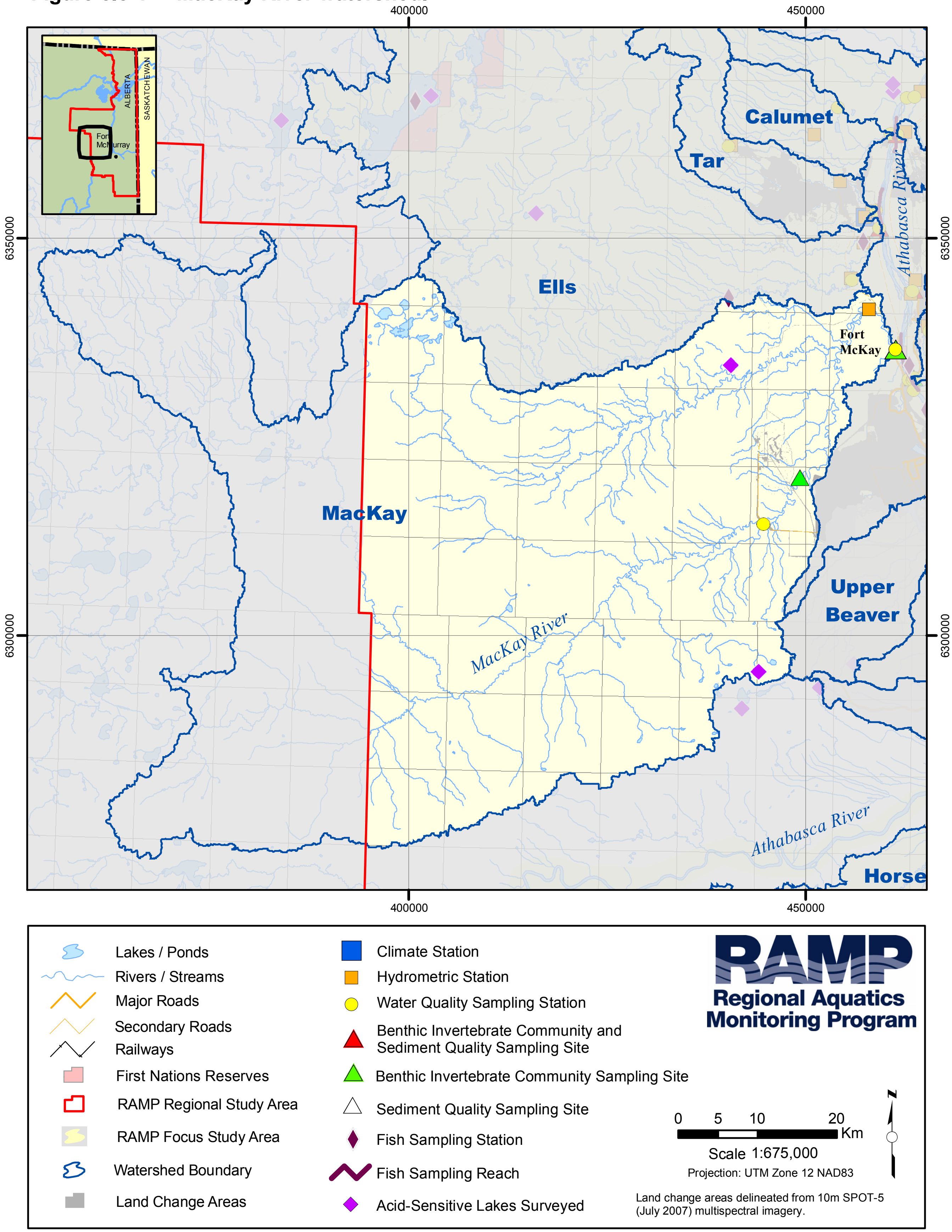
Measurement Endpoint	Summary of 2007 Conditions						
Benthic Invertebrate Communities and Sediment Quality							
Benthic Invertebrate Communities: Comparison to Regional Baselines	Endpoints in 2007 Compared to Regional Baseline						
	2007 Potentially Influenced Stations (n= 1)			2007 Reference Stations (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		As in 2006, there was evidence of subtle watershed-level effects of focal project activities on benthic invertebrate communities in 2007. However, the fact that benthic invertebrate community measurement endpoints in the lower MacKay River continue to be within the normal range of regional baseline conditions for erosional habitats, and the continued presence of a number of sensitive and very sensitive taxa in 2007 in the lower MacKay River reach, suggests factors other than focal project activities may be influencing measured differences in temporal trends between the lower MacKay and upper MacKay River reaches.
Richness		1			1		
Diversity		1			1		
Evenness		1			1		
% EPT		1			1		
Sediment Quality Guideline Exceedances	Sample-Endpoint Combinations Exceeding Guidelines in 2007[1]						
Measurement endpoints with guidelines	2007 Potentially Influenced Stations (n=0)			2007 Reference Stations (n=0)			
Total Hydrocarbons	No sediment quality sampling conducted in MacKay River watershed in 2007.						
PAHs							

Measurement Endpoint	Summary of 2007 Conditions
Fish Populations	
Fish Inventory	No fish inventory studies conducted in 2007.
Sentinel Studies	No sentinel fish studies conducted in 2007.
Fish Tissue	Level of Risk
Human Health: Subsistence	Fish tissue program was not conducted in 2007.
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 5.5-1 MacKay River watershed.



K:\Data\Project\RAMP1312\GIS_MXD_TReport\RAMP1312_K05_MacKay_20080303.mxd

5.5.1 Development Status

As of 2007, less than 1% of the MacKay River watershed had undergone land change as a result of focal developments in the watershed (Table 2.4-2). The designations of specific areas of the watershed are therefore as follows:

- All areas and 2007 RAMP stations located downstream of the Petro-Canada MacKay River *in situ* operations and that part of Syncrude's Mildred Lake operations in the MacKay River watershed (Figure 5.5-1) are designated as *potentially influenced*. All data gathered from the 2007 RAMP stations located in this area of the watershed are designated as operational data; and

- The MacKay River drainage upstream of these oil sands developments and the 2007 RAMP stations located in this part of the watershed (Figure 5.5-1) are designated as *reference*. All data gathered from the 2007 RAMP stations located in this area of the watershed are designated as baseline data.

5.5.2 Hydrologic Conditions

2007 Hydrologic Conditions Streamflow in the MacKay River basin, as measured at RAMP Station S26 and WSC Station 07DB001, was close to normal in 2007 (Figure 5.5-2). The basin produced 77 mm of runoff in 2007. Flows were in the upper quartile from mid-April until late May; after the spring freshet, flows were near normal during the rest of the summer, showing small response to rain events in July and August. The maximum daily discharge of 114 m^3/s that occurred in May was close to the mean annual flood of 123 m^3/s.

Estimation of Hydrologic Effects A summary of the inputs to the water balance model for the MacKay River used to create a baseline hydrograph is provided in Table 5.5-1. As of 2007, areas of closed-circuited land change and other land change (not closed-circuited) was 2.64 km^2 and 8.39 km^2, respectively, in the MacKay River watershed as a result of cumulative development of focal projects in the watershed (Table 2.4-1), the estimated net effects of which were to reduce inflows to the MacKay River by 0.093 million m^3.

The estimated effect of these reduced flows was a reduction of 0.02% in mean open-water season discharge, annual maximum daily discharge, and open-water season minimum daily discharge (Table 5.5-2). Mean winter discharge is estimated to have increased by 0.65%. 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 5.5-2, Table 5.5-2). 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 2007 have been negligible.

5.5.3 Water Quality

In fall 2007, 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 Devon *in situ* developments (station MAR-2, *reference*, first sampled in 2002).

2007 Results and Historical Ranges of Concentration In fall 2007, concentrations of most water quality measurement endpoints were within the historical range of concentrations with the exception of:

- Dissolved organic carbon at the mouth of the MacKay River (station MAR-1), which was above its previously-measured maximum (Table 5.5-3);
- Sulphate and total molybdenum at the mouth of the MacKay River (station MAR-1), which were below their previously-measured minima (Table 5.5-3);
- Nitrate + nitrite, dissolved organic carbon, and dissolved aluminum at the upstream MacKay River station (station MAR-2) which were above previously-measured maxima (Table 5.5-4); and
- Total suspended solids and total molybdenum concentrations at the upstream MacKay River station (station MAR-2) which were below previously observed minima (Table 5.5-4).

Comparison of Water Quality Measurement Endpoints to Water Quality Guidelines The concentration of total aluminum exceeded its water quality guideline at both MAR-1 and MAR-2 in fall 2007 (Table 5.5-3, Table 5.5-4). The guideline exceedance of total aluminum in fall 2007 at both the *reference* and the *potentially-influenced* station makes it unlikely that focal projects are a possible cause of guideline exceedence of total aluminum at station MAR-1 (*potentially influenced*). The high concentrations of total aluminum at station MAR-1 may be due to concentrations of total suspended solids that were twice the historical median value for that station (Table 5.5-3) has been observed previously. The relationship between concentrations of total aluminum and total suspended solids in the MacKay River (Figure 5.6-3 of RAMP 2004 Technical Report, RAMP [2005a]). In addition, the concentration of total nitrogen exceeded its water quality guideline at the upstream MacKay River station (station MAR-2, Table 5.5-4).

Other Water Quality Guideline Exceedences The following other water quality guideline exceedences were observed in fall 2007 at both stations MAR-1 and MAR-2: sulphide, total and dissolved iron, and total phenols (Table 5.5-5). Again, the guideline exceedances of these water quality variables in fall 2007 at both the *reference* and the *potentially-influenced* station makes it unlikely that focal projects are a possible cause for these exceedances.

Comparison of Water Quality Measurement Endpoints to Natural Variation in Baseline Conditions Concentrations of most 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 2007 were at or between the 5^{th} and 95^{th} percentile regional baseline concentrations, with the exception of total mercury at upstream MacKay River (station MAR-2), which had a measured concentration greater than the 95th percentile regional baseline concentration (Figure 5.5-3).

Trend Analysis No significant changes (α=0.05) in concentration for any water quality measurement endpoints at station MAR-1 was observed over the eight consecutive years of water quality data collected at this station.

Ion Balance Ion balance was similar at stations MAR-1 and MAR-2 in fall 2007, and consistent with previous years since 2000 (Figure 5.5-4).

Trend Analysis As of 2007, sufficient data existed to allow statistical trend analysis of fall water-quality data for Mackay River station MAR-1 (n=9). There were no significant trends in water quality endpoints at this station (α=0.05).

Summary There were no instances of either guideline exceedences or concentrations of water quality measurement endpoints outside the 5th and 95th percentile regional baseline concentrations that were measured at the mouth of the MacKay River (station MAR-1, *potentially influenced*) but not at the upstream MacKay River (station MAR-2, *reference*) in fall 2007. These results, plus the absence of any significant temporal trends in the concentration of water quality measurement endpoints at station MAR-1 (*potentially-influenced*), suggest that there have been no measurable effects of focal projects on water quality in the MacKay River to date.

5.5.4 Benthic Invertebrate Communities and Sediment Quality

5.5.4.1 Benthic Invertebrate Communities

In 2007, benthic invertebrate community samples were collected from:

- An erosional reach near in the lower MacKay River (reach MAR-E-1, *potentially influenced* since 2002, sampled first in 1998 and from 2000 onwards); and
- An erosional reach in the upper MacKay River (reach MAR-E-2, *reference*, sampled from 2000 onwards).

2007 Habitat Conditions Both the lower reach and the upper reach are typical erosional habitats, with moderate current velocities (< 1 m/s) and shallow mid-channel water depths (< 0.5 m, Table 5.5-6). Periphyton chlorophyll *a* biomass was low in both reaches, with densities declining from about 40 mg/m^2 in 2006 to about 20 mg/m^2 in 2007 (Figure 5.5-5), indicating oligotrophic conditions at both reaches. Macrophytes covered about 16% of reach MAR-E-1 but were absent at reach MAR-E-2. Substrate was similar in the two reaches, consisting of a broad mixture of sand through boulder. There was more small cobble in lower MacKay River reach (reach MAR-E-1, Table 5.5-6) and somewhat more sand and small gravel in the upper MacKay River reach (reach MAR-E-2).

Relative Abundance of Benthic Invertebrate Community Taxa in 2007 The benthic invertebrate community of the lower MacKay River reach (reach MAR-E-1) was numerically dominated by chironomids (40%), mites (Acarina, 15%) and mayflies (Ephemeroptera, 13%), with naidid worms (9%), nematodes (3%) and stoneflies (Plecoptera (2%) sub-dominant (Table 5.5-7). The numerically-dominant midges included *Polypedilum*, *Micropsectra/Tanytarsus*, *Cryptochironomus*, *Albabesmyia* and *Thienemannimyia*, while the numerically-dominant mayflies included *Acerpenna*, *Acentrella, Ameletus,* and *Leptophlebia*. Other relatively sensitive groups present in relatively high numbers at reach

MAR-E-1 included the caddisflies *Hydroptila*, *Cheumatopsyche* and *Hydropsyche,* the dragonfly *Ophiogomphus*, and the stoneflies *Taeniopteryx*, and *Isoperla*. Mayfly, stonefly and caddisfly taxa accounted for about 15% of total organisms, a value somewhat lower than the long-term average for the reach. Abundance, approximately 7,000 individuals per m^2, was near the historical long-term average and a more than three-fold increase from fall 2006 levels. All measures of diversity were high relative to historical values but % EPT was lower in fall 2007 than in fall 2006 (Figure 5.5-6).

The benthic invertebrate community of the upper MacKay River reach (reach MAR-E-2) was numerically dominated by chironomids (39%), mayflies (16%), and caddisflies (10%), with naidid worms (9%), stoneflies (3%) and tubificid worms (2%) sub-dominant. The numerically-dominant midges included *Thienemannimyia, Demicryptochironomus*, *Microtendipes*, *Polypedilum*, *Cricotopus*/*Orthocladius* and *Lopescladius*, while the dominant mayflies included the sensitive *Leptophlebia* as well as *Ameletus*, *Acerpenna*, *Heptagenia*, and *Rhithrogena*. Common stoneflies included *Acroneuria*, *Claassenia sabulosa* and *Taeniopteryx*. Sensitive and relatively abundant caddisflies included *Brachycentrus*, *Protoptila* and *Psychomyia*. The caddisflies *Cheumatopsyche*, *Hydropsyche* and *Chimarra* and the sensitive dragonfly *Ophiogomphus* were also present in relatively high numbers. Abundance in fall 2007 was slightly more than 12,000 individuals per m^2, was above the historical long-term average abundance for this reach, while all levels of all other benthic invertebrate community measurement endpoints were higher in fall 2007 than in fall 2006 (Figure 5.5-6).

Effects of Focal Project Activities Linear contrasts were used to test for the following specific focal project-related effects:

- A difference between *reference* and *potentially influenced* across all common years;
- A difference in time trends between *reference* and *potentially influenced*; and
- A difference between *reference* and *potentially influenced* in 2007 only.

The most relevant test of effects of focal projects was for differences in time trends between *reference* and *potentially influenced*.

Abundance has decreased over time in reach MAR-E-1 (lower, *potentially influenced*) while remaining more consistent over time in reach MAR-E-2 (upper, *reference*), resulting in a significant difference in time trend between the two reaches (Table 5.5-8). In addition, %EPT has remained relatively consistent in reach MAR-E-1 (lower, *potentially influenced*) while increasing over time in reach MAR-E-2 (upper, *reference*), resulting in a significant difference in time trend between the two reaches (Table 5.5-8) for this measurement endpoint (Table 5.5-8). This suggests a potential effect of focal projects on benthic invertebrate communities in the lower MacKay River. However:

- Values of all benthic invertebrate community measurement endpoints, including total abundance and percent EPT, have generally remained within the normal range of values determined from regional reference erosional reaches, with the exception of diversity and evenness in reach MAR-E-2 (upper, *reference*) in fall 2006 (Figure 5.5-6);
- The “remainder” (noise) term in the ANOVA results described above was very large and significant for both total abundance and percent EPT (Table 5.5-8). This indicates that differences in time trends between *reference* and *potentially*

influenced for these benthic invertebrate community measurement endpoints were at most subtle;

- The multivariate ordination of erosional reach data indicates the overall composition of the benthic community of the lower MacKay River reach (reach MAR-E-1) has remained within the normal range of expected conditions between 1998 and 2007 (Figure 5.5-7); and

- The presence of a number of EPT taxa in the lower MacKay River reach (reach MAR-E-1) including the very sensitive stoneflies *Taeniopteryx* and *Isoperla*, sensitive mayflies *Leptophlebia* and *Ameletus*, and the dragonfly *Ophiogomphus* suggest healthy robust benthic invertebrate community in the lower MacKay River.

5.5.4.2 Sediment Quality

As sediment quality in 2007 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 2007.

5.5.4.3 Summary

There was some evidence of subtle watershed-level effects of focal project activities on benthic invertebrate communities in the MacKay River watershed in 2007; this assessment is similar to that made for the MacKay River as of 2006 (RAMP 2007). There are some statistically significant differences in some benthic invertebrate community measurement endpoints between sampled reaches designated as *potentially-influenced* and *reference* over time. However, the fact that benthic invertebrate community measurement endpoints in the lower MacKay River designated as *potentially-influenced* continue to be within the normal range of regional baseline conditions for erosional habitats, and the continued presence of a number of sensitive and very sensitive taxa in 2007 in the lower MacKay River reach, suggest that factors other than focal project activities may be influencing measured differences in temporal trends between the lower MacKay and upper MacKay River reaches.

5.5.5 Fish Populations

The RAMP 2007 Fish Population component did not include any activities in the MacKay River watershed.

5.5.6 Summary of Conditions

Data collected in the MacKay River in 2007 indicate negligible changes in hydrological conditions as a result of focal project activities, no measurable effects of focal projects on water quality in the MacKay River to date, and, at most, subtle changes in benthic invertebrate communities. These results indicate that focal project activities have had, to 2007, a negligible effect on aquatic resources measured by RAMP at the watershed level in the MacKay River.

Figure 5.5-2 MacKay River: 2007 hydrograph and historical context.

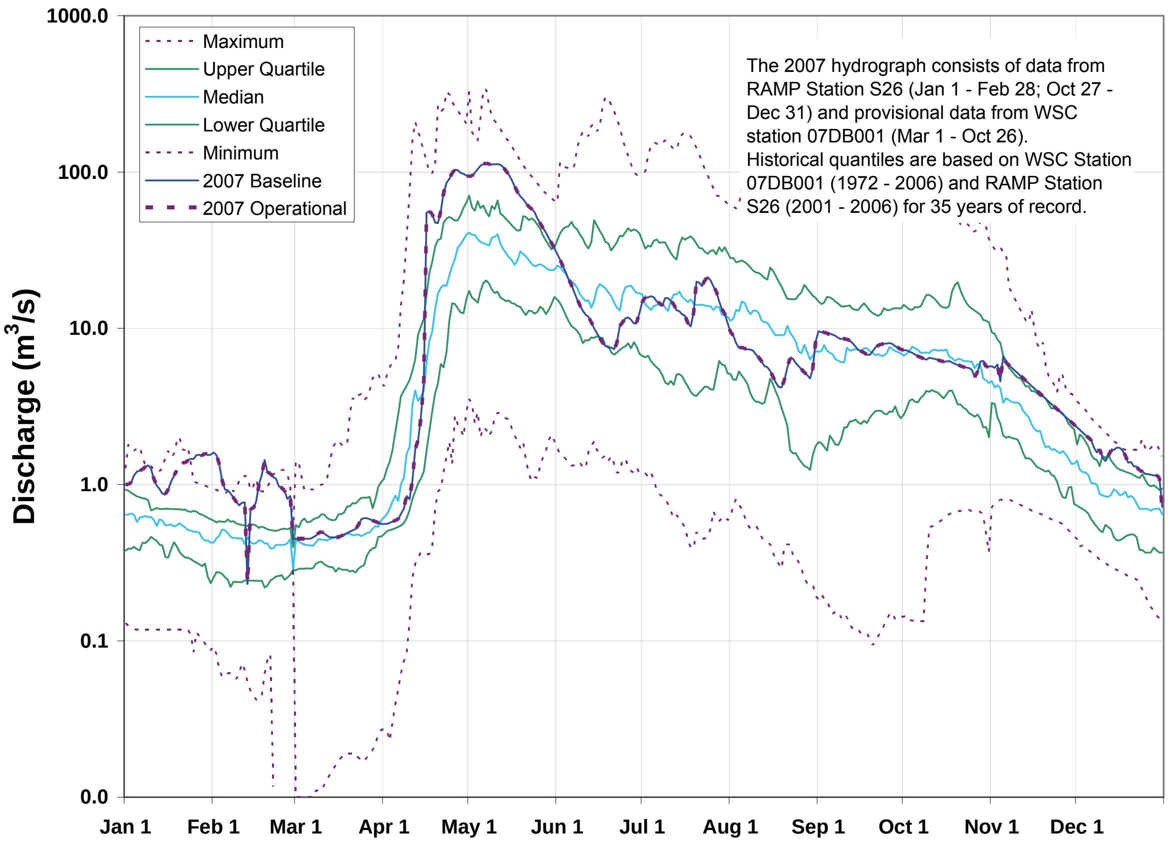


Table 5.5-1 Inputs to calculation of MacKay River baseline hydrograph at RAMP/WSC Station S26, MacKay River near Fort McKay (07DB001).

Component	Annual Volume (million m^3)	Basis and Data Source
Observed hydrograph	470	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 2007	+ 0.235	2.64 km^2 within MacKay River watershed estimated to have been closed-circuited by focal projects as of 2007 (Table 2.6-1)
Incremental runoff from areas of land change due to focal project development areas and are not closed-circuited	- 0.142	8.39 km^2 within MacKay River watershed estimated to have undergone land change by focal projects as of 2007, but area is 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	470	Estimated baseline ("without focal project") flow for 2007
Incremental flow	- 0.093	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 5.5-2 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	22.2	22.2	-0.02%
Mean winter discharge	1.72	1.73	+0.65%
Annual maximum daily discharge	114	114	-0.02%
Open-water season minimum daily discharge	4.19	4.19	-0.02%

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 5.5-3 Concentrations of water quality measurement endpoints, mouth of MacKay River (station MAR-1), fall 2007.

Measurement Endpoint	Units	Guideline	September 2007	1997-2006 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.3	8	7.6	8.15	8.6
Total Suspended Solids	mg/L	-[1]	10	8	<2	5	26
Conductivity	µS/cm	-	268	8	196	265	576
Nutrients							
Total dissolved phosphorus	mg/L	0.05[2]	0.022	8	0.004	0.022	0.047
Total nitrogen*	mg/L	1.0	1	8	0.4	**1.1**	**3.2**
Nitrate+Nitrite	mg/L	-	<0.1	8	<0.05	<0.1	<0.1
Dissolved organic carbon	mg/L	-	34	8	20	24	33
Ions							
Sodium	mg/L	-	22	8	15	20	60
Calcium	mg/L	-	28.5	8	24.7	28.2	44.7
Magnesium	mg/L	-	9.3	8	8.1	9.3	15.9
Chloride	mg/L	230, 860[3]	4	8	3.0	6.5	41.2
Sulphate	mg/L	100[4]	12.1	8	12.7	19.1	35.5
Total Dissolved Solids	mg/L	-	213	8	170	239	342
Total Alkalinity	mg/L		128	8	96	120	202
Organic compounds							
Naphthenic acids	mg/L	-	<1	8	<1	<1	1
Selected metals							
Total aluminum	mg/L	0.1	**0.335**	8	0.050	**0.219**	**0.501**
Dissolved aluminum	mg/L	0.1[2]	0.0271	8	0.010	0.018	0.030
Total arsenic	mg/L	0.005	0.000788	8	0.0007	0.0009495	<0.001
Total boron	mg/L	1.2[5]	0.0736	8	0.063	0.089	0.140
Total molybdenum	mg/L	0.073	0.000189	8	0.000227	0.0004	0.0006
Total mercury (ultra-trace)	ng/L	5, 13[6]	<1.2	4	<1.2	<1.2	<1.2
Total strontium	mg/L	-	0.15	8	0.133	0.163	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).

Table 5.5-4 Concentrations of water quality measurement endpoints, upstream MacKay River (station MAR-2), fall 2007.

Measurement Endpoint	Units	Guideline	September 2007	1997-2006 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.2	5	7.8	8.1	8.3
Total Suspended Solids	mg/L	-[1]	<3	5	3	3	10
Conductivity	μS/cm	-	220	5	182	235	249
Nutrients							
Total dissolved phosphorus	mg/L	0.05[2]	0.031	5	0.008	0.035	0.039
Total nitrogen*	mg/L	1.0	**1.1**	5	0.8	**1.3**	**3.1**
Nitrate+Nitrite	mg/L	-	0.1	5	<0.1	<0.1	<0.1
Dissolved organic carbon	mg/L	-	38	5	22	31	33
Ions							
Sodium	mg/L	-	17	5	11	16	19
Calcium	mg/L	-	23.8	5	21.3	26.6	31.5
Magnesium	mg/L	-	8.4	5	6.9	8.6	10.1
Chloride	mg/L	230, 860[3]	3	5	1	2	3
Sulphate	mg/L	100[4]	8.3	5	8.1	15.4	23.7
Total Dissolved Solids	mg/L	-	201	5	160	190	240
Total Alkalinity	mg/L	-	108	5	81	104	128
Organic compounds							
Naphthenic acids	mg/L	-	<1	5	<1	<1	1
Selected metals							
Total aluminum	mg/L	0.1	**0.174**	5	0.020	**0.159**	**0.468**
Dissolved aluminum	mg/L	0.1[2]	0.0268	5	<0.0002	0.0233	0.0251
Total arsenic	mg/L	0.005	0.000752	5	0.000617	0.000839	0.00101
Total boron	mg/L	1.2[5]	0.0594	5	0.051	0.064	0.105
Total molybdenum	mg/L	0.073	0.000157	5	0.00023	0.00036	0.00054
Total mercury (ultra-trace)	ng/L	5, 13[6]	1.7	4	<1.2	<1.2	1.8
Total strontium	mg/L	-	0.127	5	0.114	0.141	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).

Table 5.5-5 Water quality guideline exceedances, MacKay River watershed, 2007.

Water Quality Variable	Units	Guideline*	MAR-1	MAR-2
Fall				
Sulphide	mg/L	0.014[1]	**0.016**	**0.03**
Total nitrogen	mg/L	1.0	**-**	**1.1**
Total aluminum	mg/L	0.1	**0.335**	**0.174**
Dissolved iron	mg/L	0.3[2]	**0.469**	**0.54**
Total iron	mg/L	0.3	**0.883**	**0.807**
Total phenols	mg/L	0.005	**0.011**	**0.012**

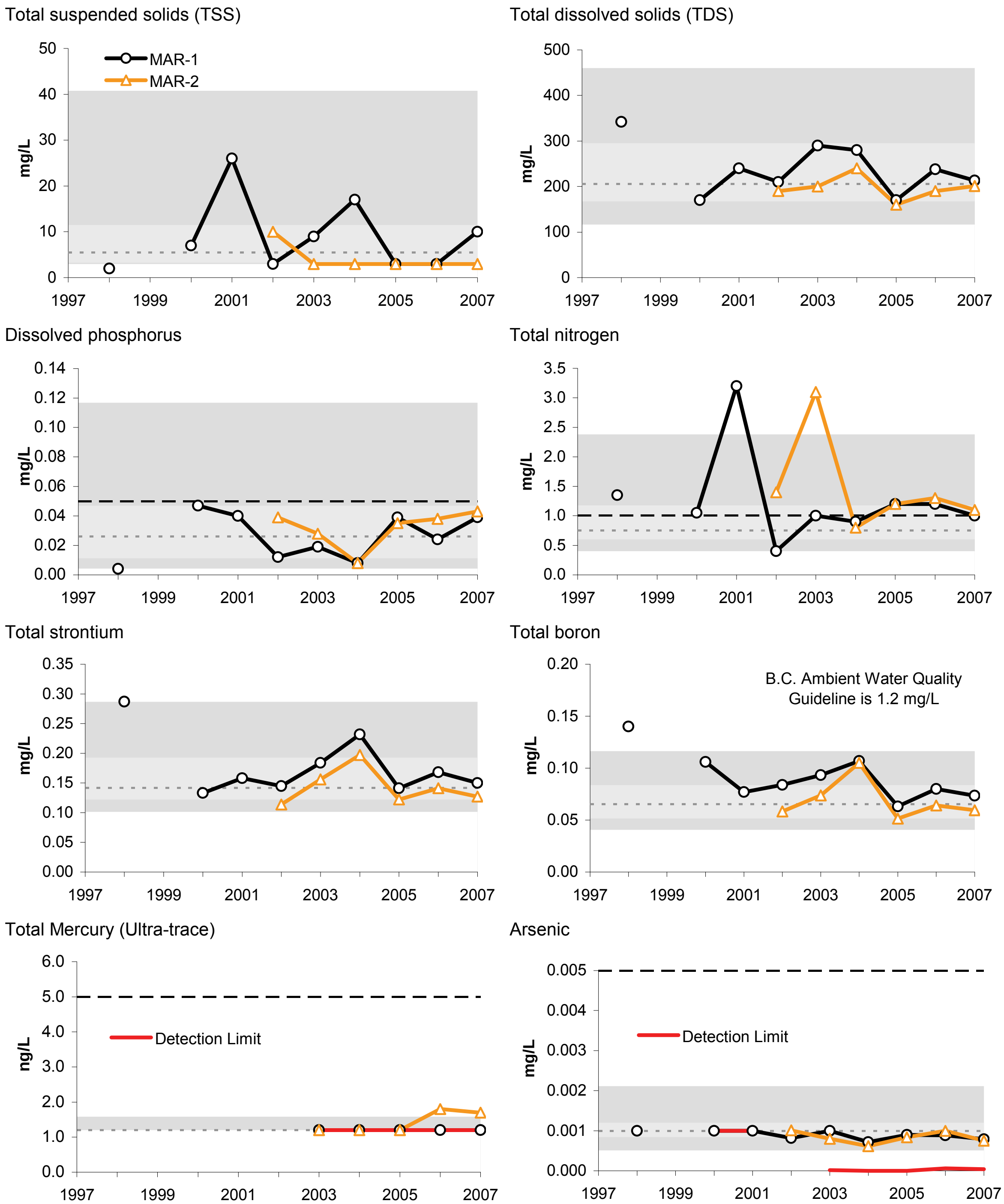
MAR-1 and MAR-2 were sampled only in fall 2007.

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

[1] derived from EPA (2002)

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

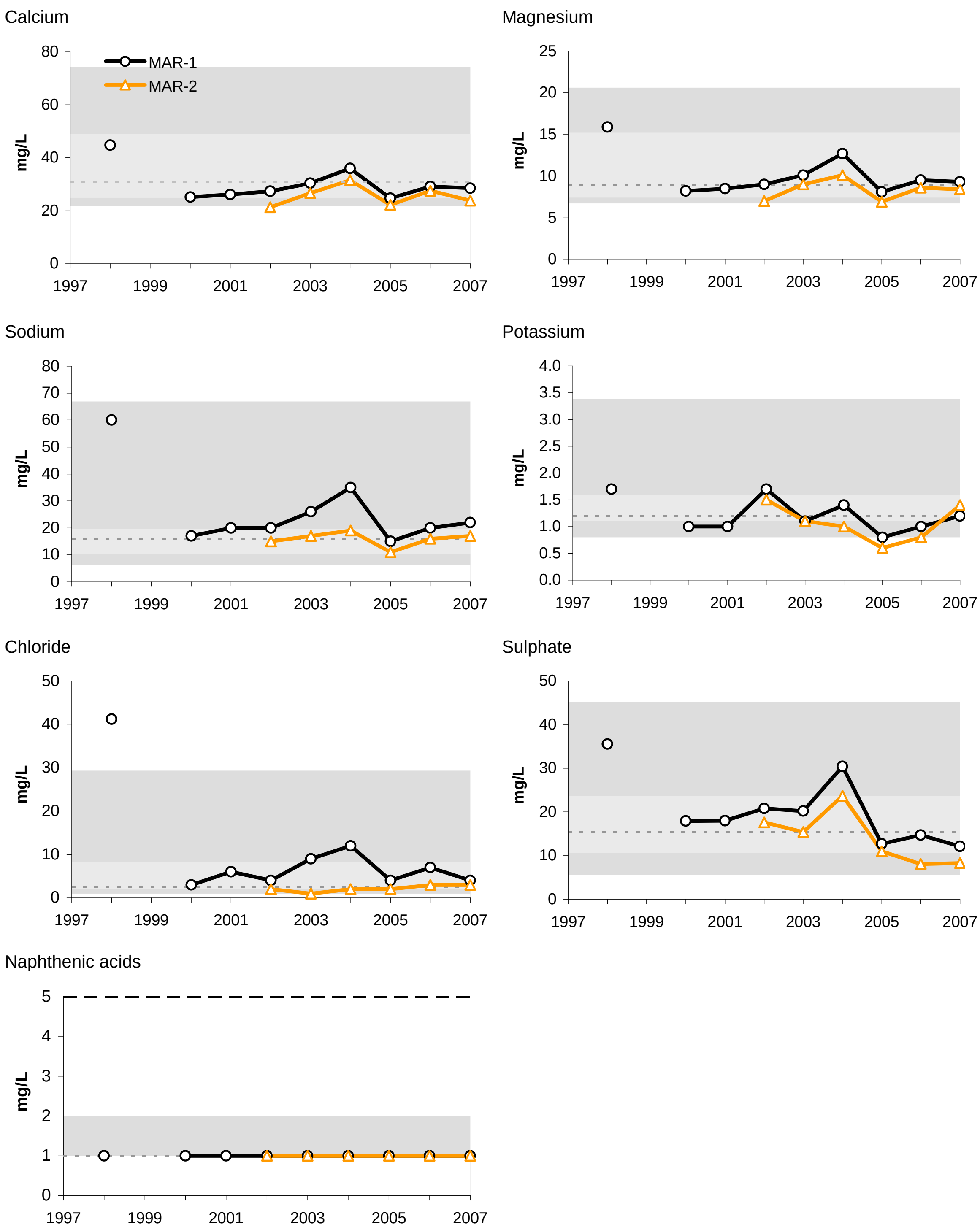
Figure 5.5-3 Concentrations of selected water quality measurement endpoints in the MacKay River (fall data) relative to regional baseline fall concentrations.



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 5.5-3 (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 MacKay River watershed.

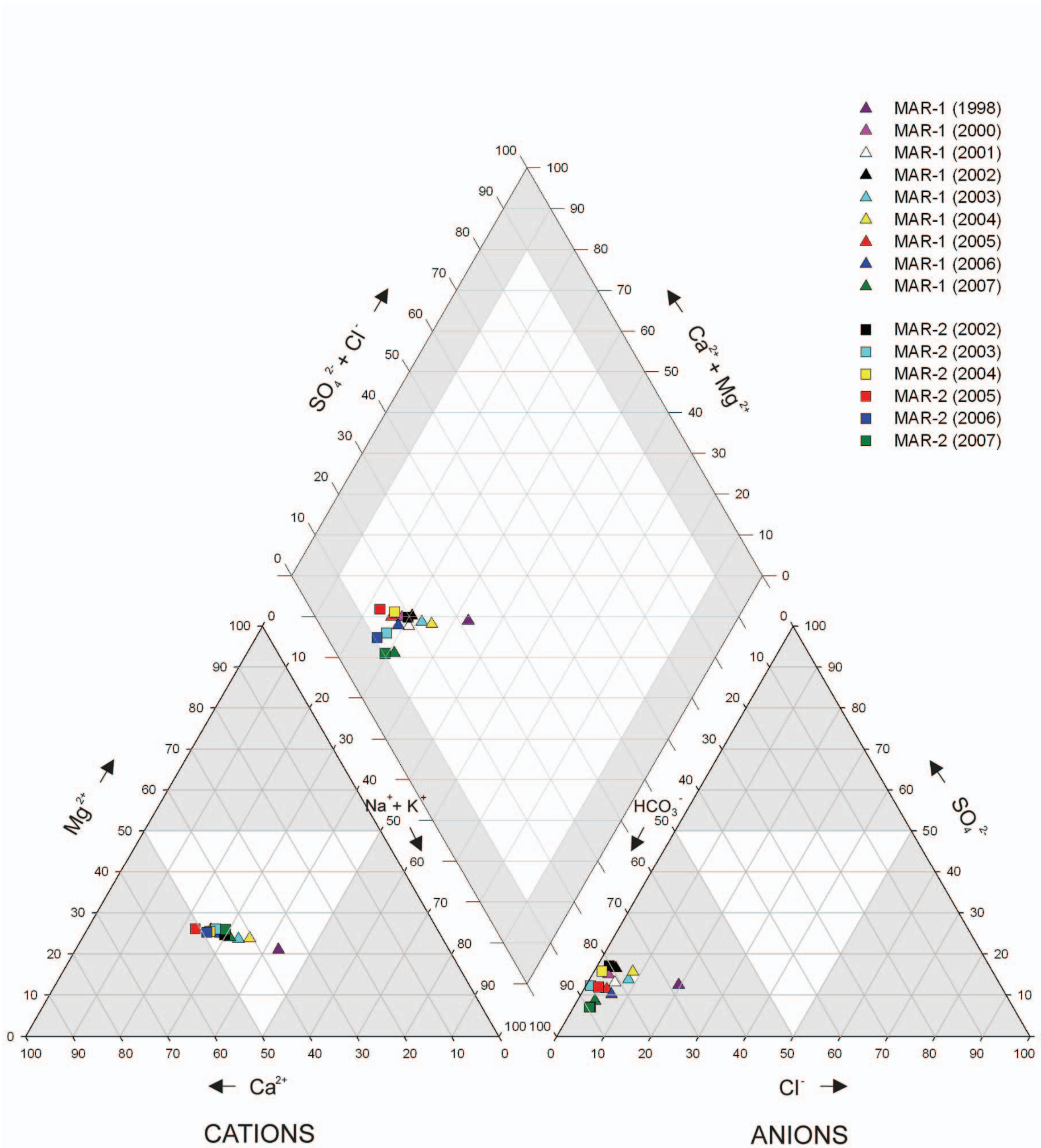


Table 5.5-6 Habitat characteristics of benthic invertebrate community sampling reaches in the MacKay River.

Variable	Units	Reach MAR-E-1 Lower Reach of the MacKay River	Reach MAR-E-2 Upper Reach of the MacKay River
Sample date	-	Sept 14, 2006	Sept 8, 2006
Habitat	-	Erosional	Erosional
Water depth	m	0.3	0.2
Current velocity	m/s	n/a	0.7
Macrophyte cover	%	16	0
Field Water Quality			
Dissolved oxygen	mg/L	n/a	10
Conductivity	µS/cm	n/a	240
pH		n/a	8.1
Water temperature	°C	n/a	16.8
Sediment Composition			
Sand/Silt/Clay	%	31	2
Small gravel	%	29	1
Large gravel	%	11	16
Small cobble	%	12	64
Large cobble	%	6	16
Boulder	%	0	1
Bedrock	%	11	0

Figure 5.5-5 Variation in periphyton chlorophyll a in the lower (MAR-E-1) and upper (MAR-E-2) reaches of the MacKay River.

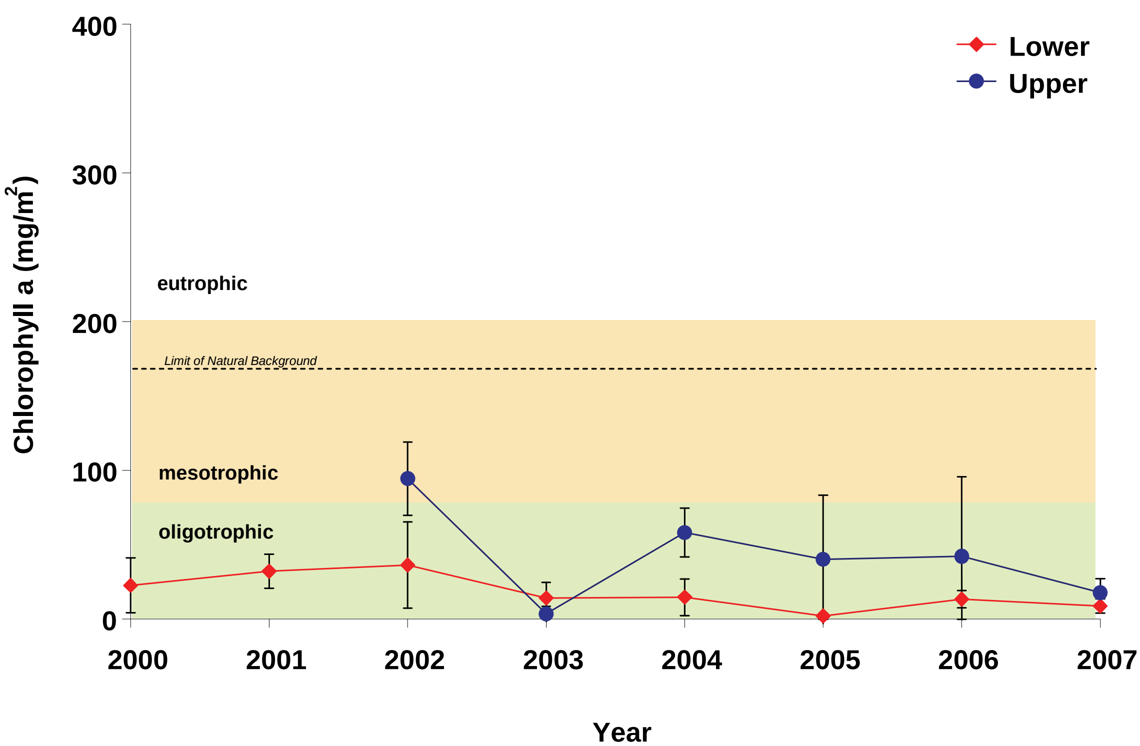
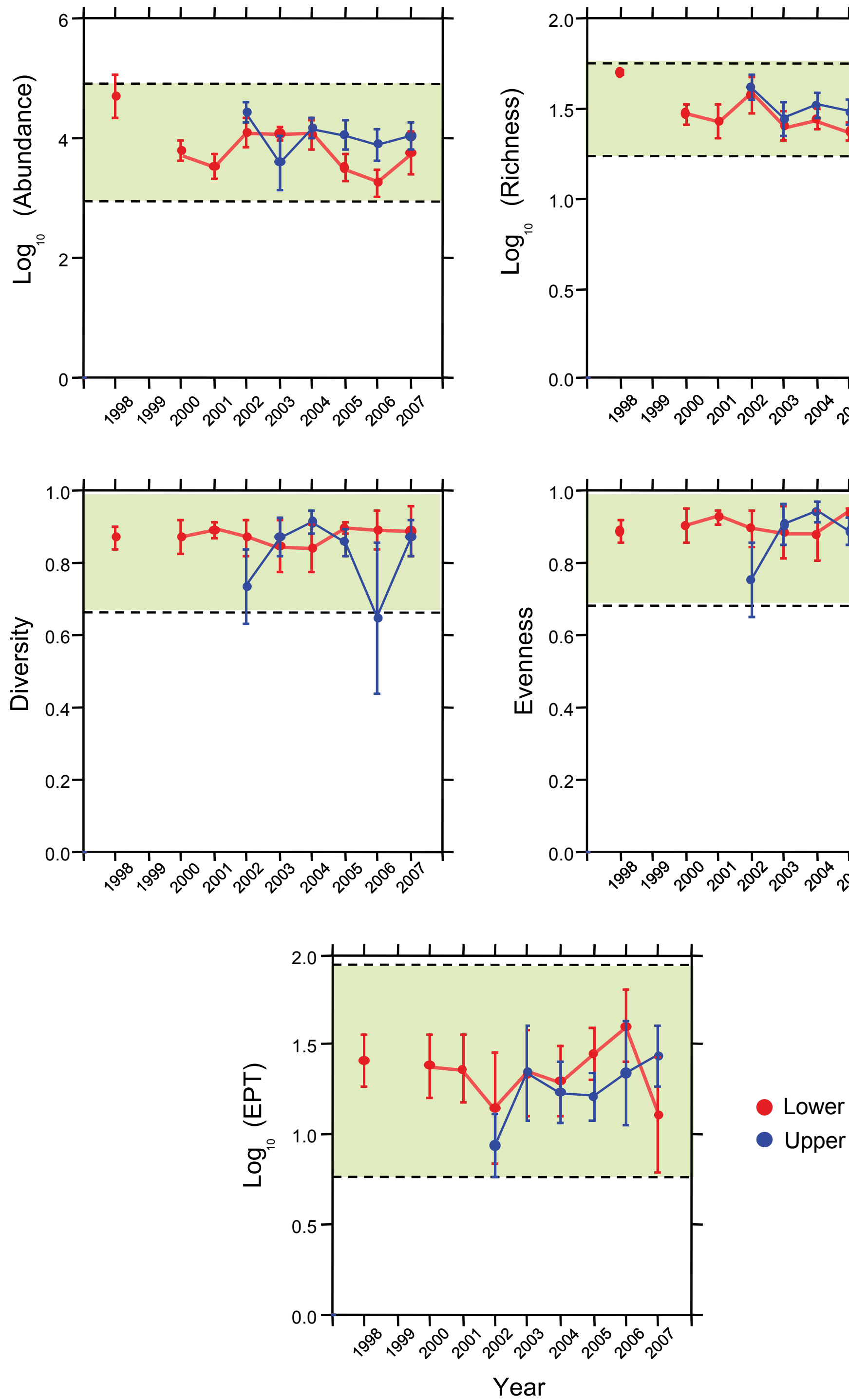


Table 5.5-7 Major taxon percent abundances and indices of benthic invertebrate community composition in reaches of the MacKay River.

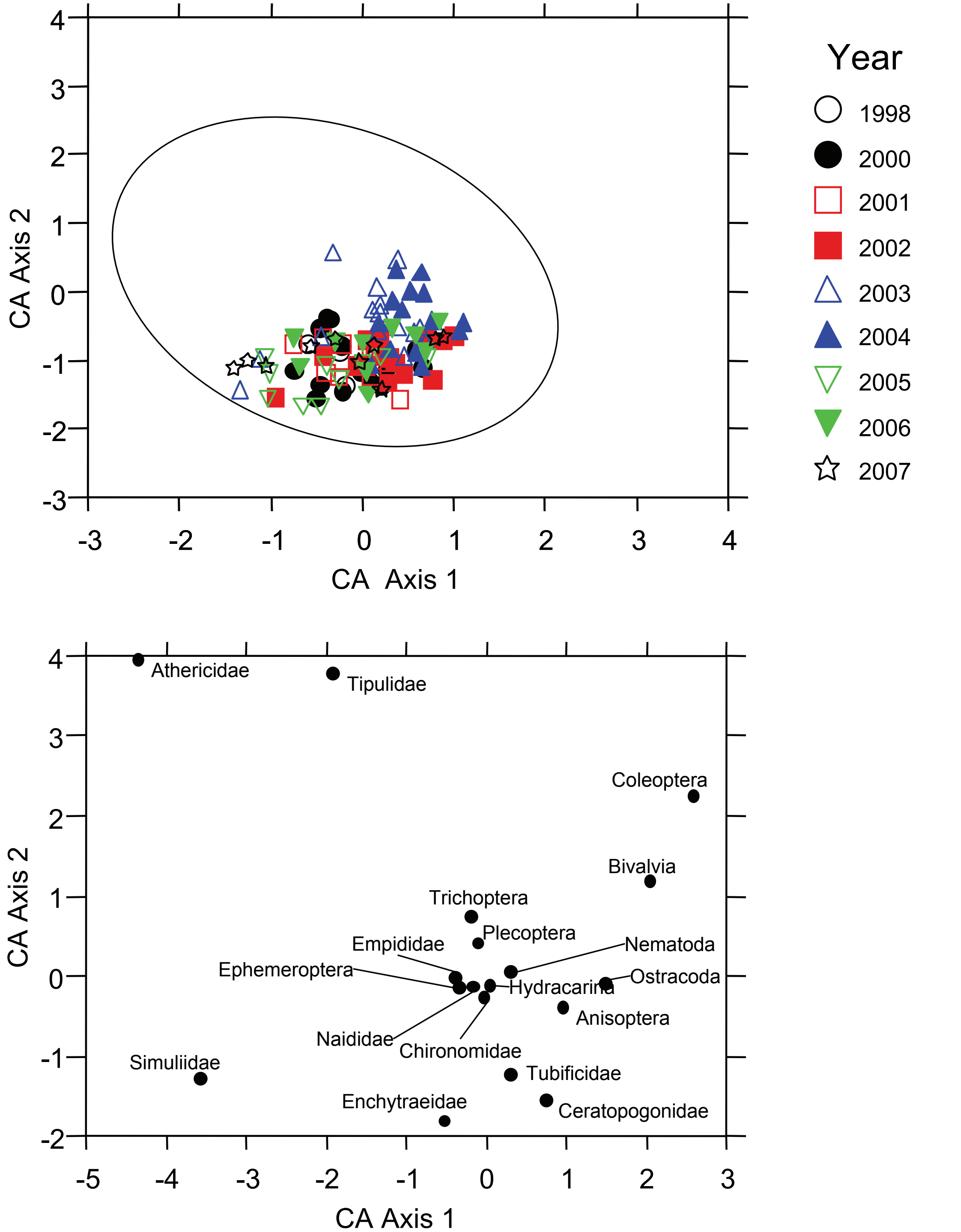
Taxon	Percent Major Taxa Enumerated in Each Year														
	Reach MAR-E-1									Reach MAR-E-2					
	1998	2000	2001	2002	2003	2004	2005	2006	2007	2002	2003	2004	2005	2006	2007
Anisoptera	1	1	2	1	1	3	2	2	1	<1	1	<1	<1	<1	<1
Bivalvia		<1	<1	1	2	2	1		<1	<1	4	1	<1		<1
Ceratopogonidae	1	1	<1	1	<1	1	5	3	1	<1	<1	1	1	1	1
Chironomidae	57	34	4	31	4	57	2	3	40	31	3	59	49	63	39
Coleoptera	<1	<1			<1	<1		<1			<1	<1	<1		<1
Copepoda	<1	<1	<1	<1				0.3	1	<1		<1			
Empididae	1	1	4	3	2	2	12	6	1	1	2	1	5	<1	<1
Enchytraeidae	4	12	1	5	5	1	1	1	1	1	4	3	3	1	1
Ephemeroptera	26	21	18	12	19	13	25	29	13	2	14	11	1	12	16
Erpobdellidae						<1					<1				
Gastropoda	<1	<1	1	2	<1	1		1	1	<1	<1	<1	<1		1
Heteroptera	<1		<1												
Hydra	<1			1	<1					<1					
Hydracarina	1	4	6	3	18	6	1	2	15	7	21	4	9	5	17
Lumbriculidae					<1						<1		<1		1
Macrothricidae		<1		1											
Naididae	2	17	2	24	8	3	11	8	9	48	15	4	15	2	9
Nematoda	2	2	8	6	1	3	1	1	3	3	1	3	1	3	3
Ostracoda	<1	1	1	6		<1		<1	1	<1	<1	<1			1
Plecoptera	2	5	5	<1	1	3	3	8	2	<1	3	3	1	2	3
Simuliidae	1	<1	<1	<1	<1		2	<1	1		<1		<1	0.2	1
Tabanidae					<1		1		1		<1				
Tipulidae	<1	<1			<1				1	<1	<1	<1		0.9	<1
Trichoptera	<1	<1	3	3	2	5	<1	5	1	6	4	3	5	1	10
Tubificidae	2	<1	1	2	<1	1	6	2	1	<1	<1	8	1	1	2
Benthic Invertebrate Community Measurement Endpoints															
Total Abundance (No./m^2)	56,434	6680	3745	14425	12347	13290	3592	2,055	6,916	28,222	5,568	15,733	12,332	9,409	12,130
Richness	49	29	26	37	24	27	23	30	32	40	27	32	30	27	41
Simpson's Diversity	0.87	0.87	0.89	0.87	0.85	0.84	0.9	0.89	0.89	0.74	0.87	0.91	0.86	0.65	0.87
Evenness	0.89	0.91	0.93	0.90	0.89	0.88	0.94	0.89	0.92	0.76	0.91	0.94	0.89	0.65	0.89
% EPT	26	25	24	16	23	20	28	42	15	8	25	17	16	2	28

Figure 5.5-6 Variations in benthic invertebrate community measurement endpoints in the MacKay River, reaches MAR-E-1 and MAR-E-3.



Note: Lower and upper dotted lines represent ±2 SD of distribution of regional baseline values for *reference* and *potentially influenced-other* erosional reaches. Lower reach: reach MAR-E-1; Upper reach: reach MAR-E-3.

Figure 5.5-7 Ordination (Correspondence Analysis) of erosional river benthic communities showing the lower reach (MAR-E-1) of the MacKay River.



Note: Upper Panel is the scatterplot of sample scores while the Lower Panel is the scatterplot of taxa scores. The ellipse in the Upper Panel is for the reference data.

Table 5.5-8 Results of analysis of variance (ANOVA) on MacKay River, reaches MAR-E-1 and MAR-E-3, with planned comparisons.

Response Variable	Source	SS	df	F-ratio	p-value
Log Abundance	Treatment (reach-year combinations; 2002 to 2007)	18.20	14	22.24	0.000
	Reference vs Exposure (RE)	1.96	1	33.55	0.000
	Time Trend (T)	2.92	1	49.97	0.000
	RE x T	1.12	1	19.13	0.000
	RE in 2007	0.43	1	7.36	0.007
	Remainder	11.77	1	202.9	0.000
	Error	9.76	167		
Log Richness	Treatment (reach-year combinations; 2002 to 2007)	1.08	14	14.18	0.000
	Reference vs Exposure (RE)	0.10	1	17.69	0.000
	Time Trend (T)	0.00	1	0.20	0.653
	RE x T	0.00	1	0.01	0.918
	RE in 2007	0.06	1	11.05	0.001
	Remainder	0.92	1	184.6	0.000
	Error	0.91	167		
Diversity	Treatment (reach-year combinations; 2002 to 2007)	0.77	14	11.06	0.000
	Reference vs Exposure (RE)	0.12	1	23.01	0.000
	Time Trend (T)	0.00	1	0.71	0.400
	RE x T	0.01	1	1.75	0.188
	RE in 2007	0.00	1	0.28	0.596
	Remainder	0.64	1	128.6	0.000
	Error	0.83	167		
Evenness	Treatment (reach-year combinations; 2002 to 2007)	0.94	14	13.30	0.000
	Reference vs Exposure (RE)	0.14	1	27.51	0.000
	Time Trend (T)	0.00	1	0.05	0.828
	RE x T	0.01	1	1.94	0.165
	RE in 2007	0.00	1	0.58	0.446
	Remainder	0.79	1	158.2	0.000
	Error	0.85	167		
Log of %EPT	Treatment (reach-year combinations; 2002 to 2007)	4.36	14	7.08	0.000
	Reference vs Exposure (RE)	0.19	1	4.22	0.042
	Time Trend (T)	0.89	1	20.26	0.000
	RE x T	0.25	1	5.76	0.017
	RE in 2007	0.54	1	12.27	0.001
	Remainder	2.49	1	56.57	0.000
	Error	7.34	167		

5.6 CALUMET RIVER WATERSHED

Summary of Results

Measurement Endpoint	Summary of 2007 Conditions			
Climate and Hydrology				
	Assessment of Change			
	Negligible	Low	Moderate	High
Mean open-water season discharge	√			
Mean winter discharge	No information available, as station CR-1 was operational from May to October in 2007			
Annual maximum daily discharge	No information available, as station CR-1 was operational from May to October in 2007			
Minimum open-water season discharge	√			

Cumulative, watershed-level changes in hydrologic conditions in the Calumet River caused by focal project activities in the watershed as of 2007 have been negligible.

Water Quality

Guideline Exceedances	Station-Endpoint Combinations Exceeding Guidelines in 2007[1]	
Measurement endpoints with guidelines	2007 Potentially Influenced Stations (n=1)	2007 Reference Stations (n=1)
Physical variables (max=1 for exp, 1 for ref)	0	0
Nutrients (max=2 for exp, 2 for ref)	1	2
Ions (max=2 for exp, 2 for ref)	0	0
Selected metals (max=6 for exp, 6 for ref)	0	0

Comparison to Regional Baselines	Endpoints in 2007 Compared to Regional Baseline[2]	
Percentile of Regional Baseline Values	2007 Potentially Influenced Stations (n=1 station X 15 endpoints)	2007 Reference Stations (n=1 station X 15 endpoints)
Greater than 95th percentile	2	4
Between 5th and 95th percentiles	13	11
Less than 5th percentile	0	0

Water quality in the lower Calumet River did not appear to be affected by focal project activities in the watershed in 2007. Generally, water quality at CAR-1 in fall 2007 included concentrations of many variables, particularly major ions, at or near previously-measured minimum concentrations. Flow at the upper Calumet River station is becoming increasingly lentic, which may be influencing water quality. Measured differences between the two stations do not suggest any effects of focal projects on water quality.

Benthic Invertebrate Communities and Sediment Quality

Benthic Invertebrate Communities: Comparison to Regional Baselines	Endpoints in 2007 Compared to Regional Baseline					
	2007 Potentially Influenced Stations (n= 0)			2007 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	Benthic invertebrate communities were not sampled in 2007.					
Richness						
Diversity						
Evenness						
% EPT						

Sediment Quality Guideline Exceedances	Station-Endpoint Combinations Exceeding Guidelines in 2007[1]	
Measurement endpoints with guidelines	2007 Potentially Influenced Stations (n=0)	2007 Reference Stations (n=1)
Total Hydrocarbons(max=3)	Sediment quality was not sampled in 2007.	
Metals		
PAHs (max=1)		

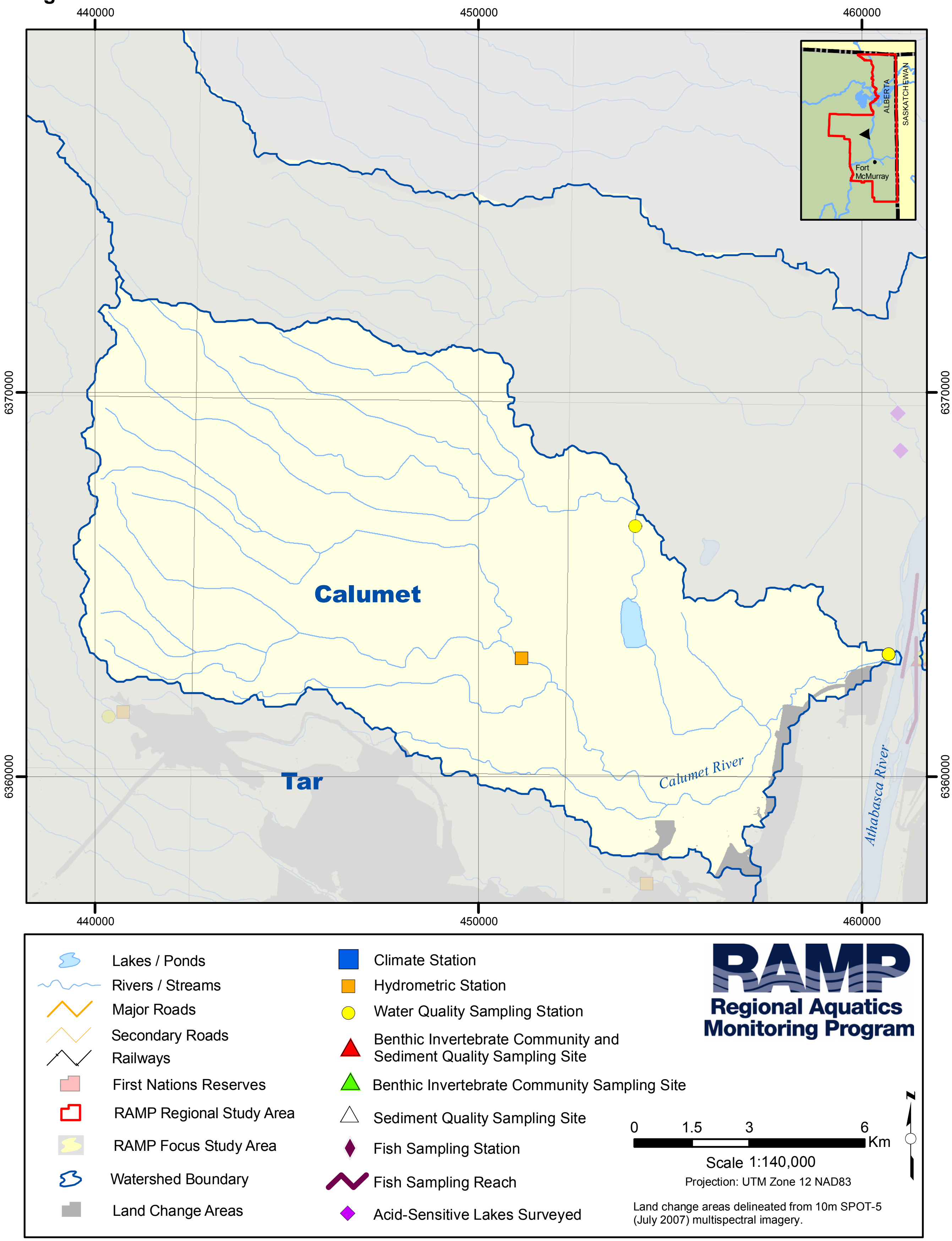
Fish Populations

Fish Inventory	No fish inventory studies conducted in 2007.
Sentinel Studies	No sentinel fish studies conducted in 2007.
Fish Tissue	**Level of Risk**
Human Health: Subsistence	Fish tissue program was not conducted in 2007.
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 5.6-1 Calumet River watershed.



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5.6.1 Development Status

Slightly more than 1% of the Calumet River watershed has undergone land change as a result of focal project activities (Table 2.4-2), and most of this land change has occurred in the lower part of the watershed (Figure 5.6-1). 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 5.6-1) is designated as *potentially influenced* as most of the land changes from focal project activities as of 2007 were in this part of the watershed. All data gathered from RAMP sampling conducted in this part of the watershed in 2007 are designated as operational data; and
- All areas upstream of the last major bend in the Calumet River (Figure 5.6-1) are designated as *reference*; all data gathered from RAMP sampling conducted in this part of the watershed are designated as baseline data.

5.6.2 Hydrologic Conditions

2007 Hydrologic Conditions The 2007 hydrograph for the Calumet River as provided by CNRL for their station CR-1 is presented in Figure 5.6-2. The flow peaked early in May, then dropped below 0.1 m^3/s by early June and remained near or below historical median values for the remainder of the season.

Estimation of Hydrologic Effects A summary of the inputs to the water balance model for the Calumet River for examining possible changes in the hydrologic measurement endpoints is provided in Table 5.6-1. As of 2007, the area of land change not closed-circuited was 2.17 km^2 in the Calumet River drainage as a result of cumulative development of focal projects in the watershed (Table 2.4-1), the estimated net effects of which were to increase flow in the Calumet River by 0.011 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 2007. These estimated influences are predicted to have increased mean open-water season discharge and open-season minimum daily discharge by 0.25%. The cumulative effect is that all hydrologic measurement endpoints for the Calumet 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). 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 2007 have been negligible.

5.6.3 Water Quality

In 2007, water quality samples were collected from:

- The lower Calumet River near its mouth (CAR-1) in fall (established in 2002, designated as *potentially influenced* since 2005); and
- The upper Calumet River (CAR-2) in winter, spring, summer, and fall (station CAR-2, designated as *reference* since establishment in 2005).

2007 Results and Historical Ranges of Concentration In fall 2007, concentrations of several water quality measurement endpoints were outside their historical ranges at both station CAR-1 and station CAR-2 (Table 5.6-3, Table 5.6-4). At station CAR-1, concentrations of sodium, calcium, magnesium, chloride, sulphate, total nitrogen, total dissolved solids, total alkalinity, dissolved aluminum, total molybdenum and conductivity all were below previously-measured minimum concentrations, while the concentration of total boron was above its previously-measured maximum concentration at this station. At station CAR-2, which had been assessed only twice in the fall season prior to 2007, pH conductivity, and concentrations of dissolved organic carbon, sodium, calcium, magnesium, sulphate, total dissolved solids, total alkalinity, total arsenic, total molybdenum, and total strontium were above previously-measured maximum concentrations, while concentrations of total dissolved phosphorus, total nitrogen, dissolved aluminum, and total boron were below previously-measured minimum concentrations at this station.

Comparison of Water Quality Measurement Endpoints to Water Quality Guidelines Concentrations of water quality measurement endpoints exceeded water quality guidelines in three (14%) out of 22[1] possible cases in the Calumet River watershed in fall 2007: concentrations of total aluminum exceeded its water quality guideline at station CAR-1 (Table 5.6-3); and concentrations of total dissolved phosphorus and total nitrogen exceeded water quality guidelines at station CAR-2 (Table 5.6-4).

Other Water Quality Guideline Exceedances Concentrations of a number of other water quality variables exceeded relevant water quality guidelines in the Calumet River watershed in 2007 (Table 5.6-5):

- Station CAR-2 in winter 2007: Sulphide, total dissolved phosphorus, total phosphorus, total nitrogen, total Kjeldahl nitrogen, total and dissolved iron, and total aluminum;
- Station CAR-2 in spring 2007: Sulphide, total dissolved phosphorus, total phosphorus, total nitrogen, total Kjeldahl nitrogen, total and dissolved iron, total aluminum, total cadmium, and total phenols;
- Station CAR-2 in summer 2007: Sulphide, sulphate, total dissolved phosphorus, total phosphorus, total nitrogen, total Kjeldahl nitrogen, total and dissolved iron, total aluminum, total cadmium, and total phenols;
- Station CAR-2 in fall 2007: Sulphide, total dissolved phosphorus, total phosphorus, total nitrogen, total Kjeldahl nitrogen, total and dissolved iron, and total phenols; and
- Station CAR-1 in fall 2007: Total phosphorus, and total and dissolved iron.

Comparison of Water Quality Measurement Endpoints to Natural Variation in Baseline Conditions At station CAR-1 in fall 2007, concentrations of three (20%) of a possible 15[2] water quality measurement endpoints were outside the 5^{th}-to-95^{th} percentile of regional baseline concentrations (Figure 5.6-3): concentrations of sodium and total boron exceeded the 95^{th} percentile; and the concentration of sulphate was below the 5^{th}

[1] There are 22 water quality measurement endpoints, eleven of which have water quality guidelines. Water quality was sampled at two locations in the Calumet River watershed in fall 2007, making for a total of 22 possible guideline exceedances.

[2] Fifteen water quality measurement endpoints were selected for comparison against regional baseline concentrations (Section 3.2.7.4).

percentile. At station CAR-2, concentrations of eight (53%) out of a possible 15 water quality measurement endpoints were above the 95th percentile of regional baseline concentrations in fall 2007 (Figure 5.6-3): total dissolved solids, dissolved phosphorus, total strontium, arsenic, magnesium, sodium, potassium, and sulphate. These relative differences between the stations are similar to fall 2007, but the total number of cases with concentrations outside the 5th to 95th percentile of regional baseline concentrations is lower in fall 2007 than in fall 2006 (concentrations of 15% and 30% of measurement endpoints outside the 5th to 95th percentile regional baseline concentrations for stations CAR-1 and CAR-2, respectively, RAMP [2007]).

Ion Balance The balance of major ions at CAR-2 has been relatively consistent over the period of sampling (Figure 5.6-4). At the mouth of the Calumet River (station CAR-1), ion balance in fall 2007 exhibited a more calcium/bicarbonate-dominated composition than in previous years (Figure 5.6-4). Differences in the ionic character between the two stations appeared to be related primarily to anion concentrations, with the ionic character at station CAR-2 more highly dominated by sulphate and less dominated by bicarbonate than at station CAR-1.

Summary Based on available water quality and information regarding focal projects in the Calumet river watershed, water quality in the lower Calumet River did not appear to be affected by focal project activities in the watershed in 2007. Generally, water quality at CAR-1 in fall 2007 included concentrations of many variables, particularly major ions, at or near previously-measured minimum concentrations. Conversely, water quality at station CAR-2 in fall 2007 included concentrations of many variables, particularly major ions, that exceeded previously-measured maximum concentrations. The upper Calumet River is very slow-flowing; from field observations, flow at this upstream reference site is becoming increasingly lentic over time, which may be influencing water quality. Differences in water quality between the two stations do not suggest any effects of focal projects on water quality at station CAR-1.

5.6.4 Benthic Invertebrate Communities and Sediment Quality

Neither the 2007 RAMP Benthic Invertebrate Community component nor the 2007 Sediment Quality component included any activities in the Calumet River watershed.

5.6.5 Fish Populations

The 2007 RAMP Fish Population component did not include any activities in the Calumet River watershed.

5.6.6 Summary of Conditions

RAMP aquatic resources were measured in the Calumet River watershed in 2007 as being similar to previous years. Values of few measurement endpoints in 2007 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 2007 in the case of hydrologic conditions, and no effects of focal project activities on water quality were detected.

Figure 5.6-2 Calumet River: 2007 hydrograph and historical context.

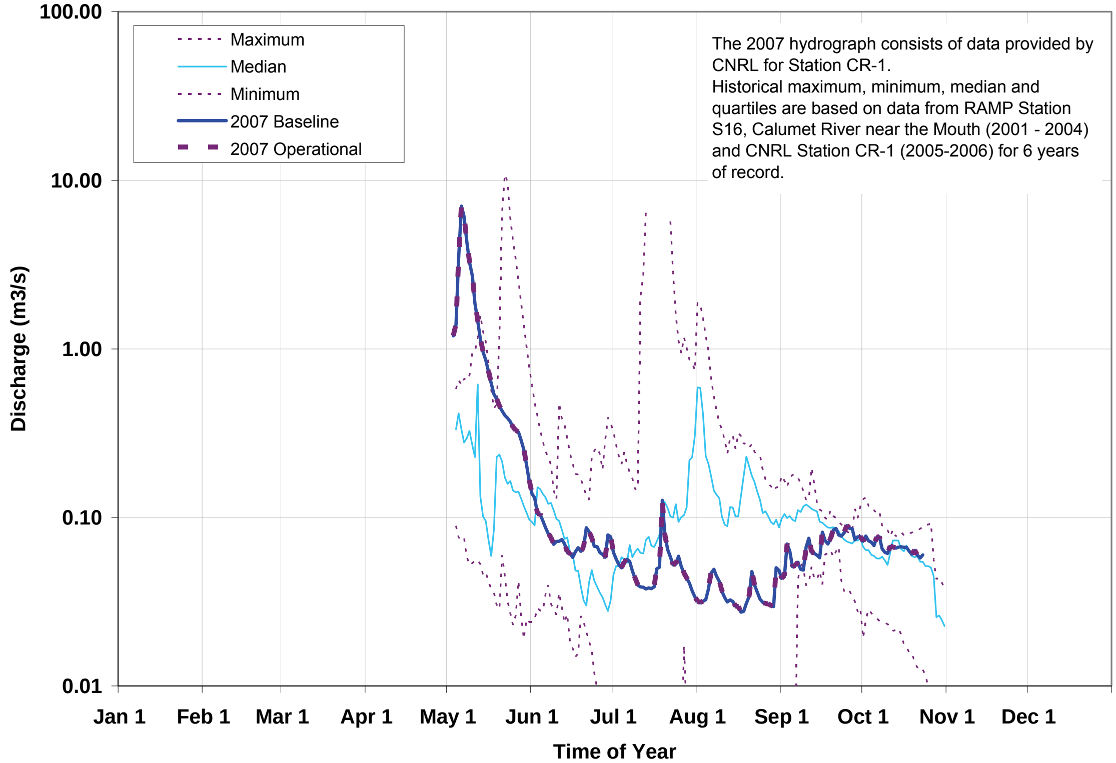


Table 5.6-1 Inputs to calculation of Calumet River baseline hydrograph at CNRL Station CR-1, Calumet River near the Mouth.

Component	Volume During 2007 CR-1 Data Record (million m^3)	Basis and Data Source
Observed hydrograph (total discharge during 2007 CR-1 data record)	4.39	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 2007	0	No land within Calumet River watershed closed-circuited by focal projects as of 2007 (Table 2.4-1)
Incremental runoff from areas of land change that were not closed-circuited as of 2007	-0.011	2.17 km^2 within Calumet River watershed estimated to have undergone land change by focal projects of 2007, but are not closed-circuited (Table 2.4-1)
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 2007 CR-1 data record)	4.38	Estimated total baseline discharge during 2007 CR-1 data record (i.e., without focal projects or other oil sands projects) for 2007
Incremental flow (change in total discharge during 2007 CR-1 data record)	+0.011	Total discharge from operational hydrograph less total discharge of estimated baseline hydrograph for 2007 CR-1 data record
Incremental flow (% of observed total discharge during 2007 CR-1 data record)	+0.25%	Incremental flow as a percentage of total discharge of estimated baseline hydrograph during 2007 CR-1 data record

Note: Definitions and assumptions are discussed in Section 3.1.7.3.

Table 5.6-2 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	0.291	0.292	+0.25%
Mean winter discharge	not measured	not measured	
Annual maximum daily discharge	7.00	7.05	+0.25%
Open-water season minimum daily discharge	0.027	0.027	+0.25%

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 5.6-3 Concentrations of water quality measurement endpoints, mouth of Calumet River (station CAR-1), fall 2007.

Measurement Endpoint	Units	Guideline	September 2007	1997-2006 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.2	5	8.1	8.2	8.4
Total suspended solids	mg/L	-[1]	10	5	<3	11	41
Conductivity	µS/cm	-	188	5	463	631	702
Nutrients							
Total dissolved phosphorus	mg/L	0.05[2]	0.03	5	0.025	0.044	**0.076**
Total nitrogen*	mg/L	1.0	0.8	5	1.0	**1.2**	**1.4**
Nitrate+nitrite	mg/L	-	<0.1	5	<0.1	<0.1	<0.1
Dissolved organic carbon	mg/L	-	30	5	22	30	34
Ions							
Sodium	mg/L	-	7	5	39	65	71
Calcium	mg/L	-	25.3	5	39.4	64.5	67.3
Magnesium	mg/L	-	7.8	5	13.4	20.3	22.5
Chloride	mg/L	230, 860[3]	2	5	12	23	34
Sulphate	mg/L	100[4]	3.6	5	11.2	12.3	14.5
Total dissolved solids	mg/L	-	151	5	300	460	480
Total alkalinity	mg/L		96	5	216	316	337
Organic compounds							
Naphthenic acids	mg/L	-	<1	5	<1	<1	2
Selected metals							
Total aluminum	mg/L	0.1	**0.158**	5	0.040	**0.146**	**0.337**
Dissolved aluminum	mg/L	0.1[2]	0.00134	5	0.0026	0.0043	0.0058
Total arsenic	mg/L	0.005	0.00104	5	0.000877	0.00101	0.0012
Total boron	mg/L	1.2[5]	0.122	5	0.074	0.090	0.117
Total molybdenum	mg/L	0.073	0.000145	5	0.00015	0.00018	0.00030
Total mercury (ultra-trace)	ng/L	5, 13[6]	<1.2	4	<1.2	<1.2	<1.2
Total strontium	mg/L	-	0.275	5	0.195	0.263	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).

Table 5.6-4 Concentrations of water quality measurement endpoints, upper Calumet River (station CAR-2), fall 2007.

Measurement Endpoint	Units	Guideline	September 2007	1997-2006 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.1	2	7.8	-	7.9
Total suspended solids	mg/L	-[1]	3	2	<3	-	5
Conductivity	μS/cm	-	772	2	526	-	577
Nutrients							
Total dissolved phosphorus	mg/L	0.05[2]	**0.12**	2	**0.13**	**-**	**0.31**
Total nitrogen*	mg/L	1.0	**1.8**	2	**2**	**-**	**2.4**
Nitrate+nitrite	mg/L	-	<0.1	2	<0.1	-	<0.1
Dissolved organic carbon	mg/L	-	48	2	40	-	47
Ions							
Sodium	mg/L	-	76	2	53	-	65
Calcium	mg/L	-	68.2	2	44	-	48.5
Magnesium	mg/L	-	26.6	2	18	-	20.6
Chloride	mg/L	230, 860[3]	16	2	14	-	17
Sulphate	mg/L	100[4]	78.4	2	45.3	-	50.6
Total dissolved solids	mg/L	-	538	2	370	-	460
Total alkalinity	mg/L	-	315	2	213	-	234
Organic compounds							
Naphthenic acids	mg/L	-	<1	2	<0.1	-	2
Selected metals							
Total aluminum	mg/L	0.1	0.0495	2	0.0245	-	0.0621
Dissolved aluminum	mg/L	0.1[2]	0.00363	2	0.0132	-	0.0172
Total arsenic	mg/L	0.005	0.00276	2	0.00212	-	0.00245
Total boron	mg/L	1.2[5]	0.0965	2	0.0817	-	0.0876
Total molybdenum	mg/L	0.073	0.000795	2	0.0000892	-	0.00024
Total mercury (ultra-trace)	ng/L	5, 13[6]	<1.2	2	<1.2	-	<1.2
Total strontium	mg/L	-	0.356	2	0.242	-	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).

Table 5.6-5 List of all 2007 water quality guideline exceedances, Calumet River.

Water Quality Variable	Units	Guideline*	CAR-1	CAR-2
Winter				
Sulphide	mg/L	0.014[1]	ns	**1.5**
Total dissolved phosphorus	mg/L	0.05[2]	ns	**1.17**
Total phosphorus	mg/L	0.05	ns	**1.49**
Total nitrogen	mg/L	1.0	ns	**7.6**
Total Kjeldahl nitrogen	mg/L	1.0	ns	**7.5**
Dissolved iron	mg/L	0.3[3]	ns	**3.37**
Total aluminum	mg/L	0.1	ns	**0.381**
Total iron	mg/L	0.3	ns	**4.63**
Spring				
Sulphide	mg/L	0.014[1]	ns	**0.039**
Total phosphorus	mg/L	0.05	ns	**0.292**
Total dissolved phosphorus	mg/L	0.05[2]	ns	**0.253**
Total Kjeldahl nitrogen	mg/L	1.0	ns	**2.3**
Total nitrogen	mg/L	1.0	ns	**2.4**
Dissolved iron	mg/L	0.3[3]	ns	**1.82**
Total aluminum	mg/L	0.1	ns	**0.722**
Total cadmium	mg/L	-[4]	ns	**0.0000368**
Total iron	mg/L	0.3	ns	**3.22**
Total phenols	mg/L	0.005	ns	**0.01**
Summer				
Sulphide	mg/L	0.014[1]	ns	**0.034**
Sulphate	mg/L	100	ns	**126**
Total phosphorus	mg/L	0.05	ns	**0.217**
Total dissolved phosphorus	mg/L	0.05[2]	ns	**0.139**
Total Kjeldahl nitrogen	mg/L	1.0	ns	**1.9**
Total nitrogen	mg/L	1.0	ns	**2**
Dissolved iron	mg/L	0.3[3]	ns	**1.91**
Total cadmium	mg/L	-[4]	ns	**0.000055**
Total iron	mg/L	0.3	ns	**3.68**
Total aluminum	mg/L	0.1	ns	**1.04**
Total phenols	mg/L	0.005	ns	**0.025**
Fall				
Sulphide	mg/L	0.014[1]	**-**	**0.025**
Total phosphorus	mg/L	0.05	**0.066**	**0.311**
Total nitrogen	mg/L	1.0	**-**	**1.8**
Total Kjeldahl nitrogen	mg/L	1.0	**-**	**1.7**
Dissolved iron	mg/L	0.3[3]	**0.456**	**0.404**
Total aluminum	mg/L	0.1	**0.158**	**-**
Total iron	mg/L	0.3	**2.36**	**1.45**
Total phenols	mg/L	0.005	**-**	**0.012**
Total dissolved phosphorus	mg/L	0.05	-	**0.12**

CAR-1 sampled only in fall 2007.

ns = not sampled

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

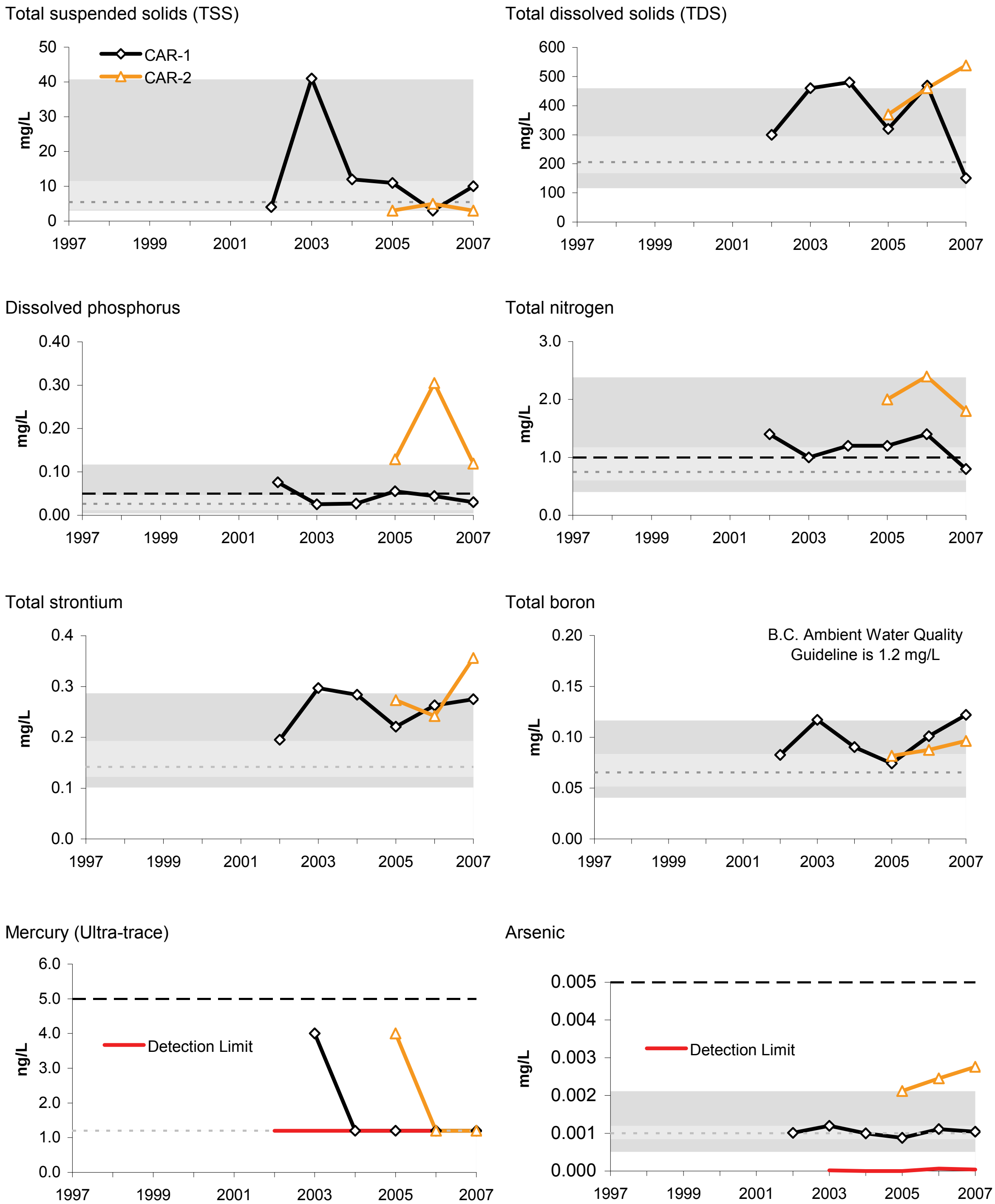
[1] derived from EPA (2002)

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

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

[4] Guidelines are hardness-dependent.

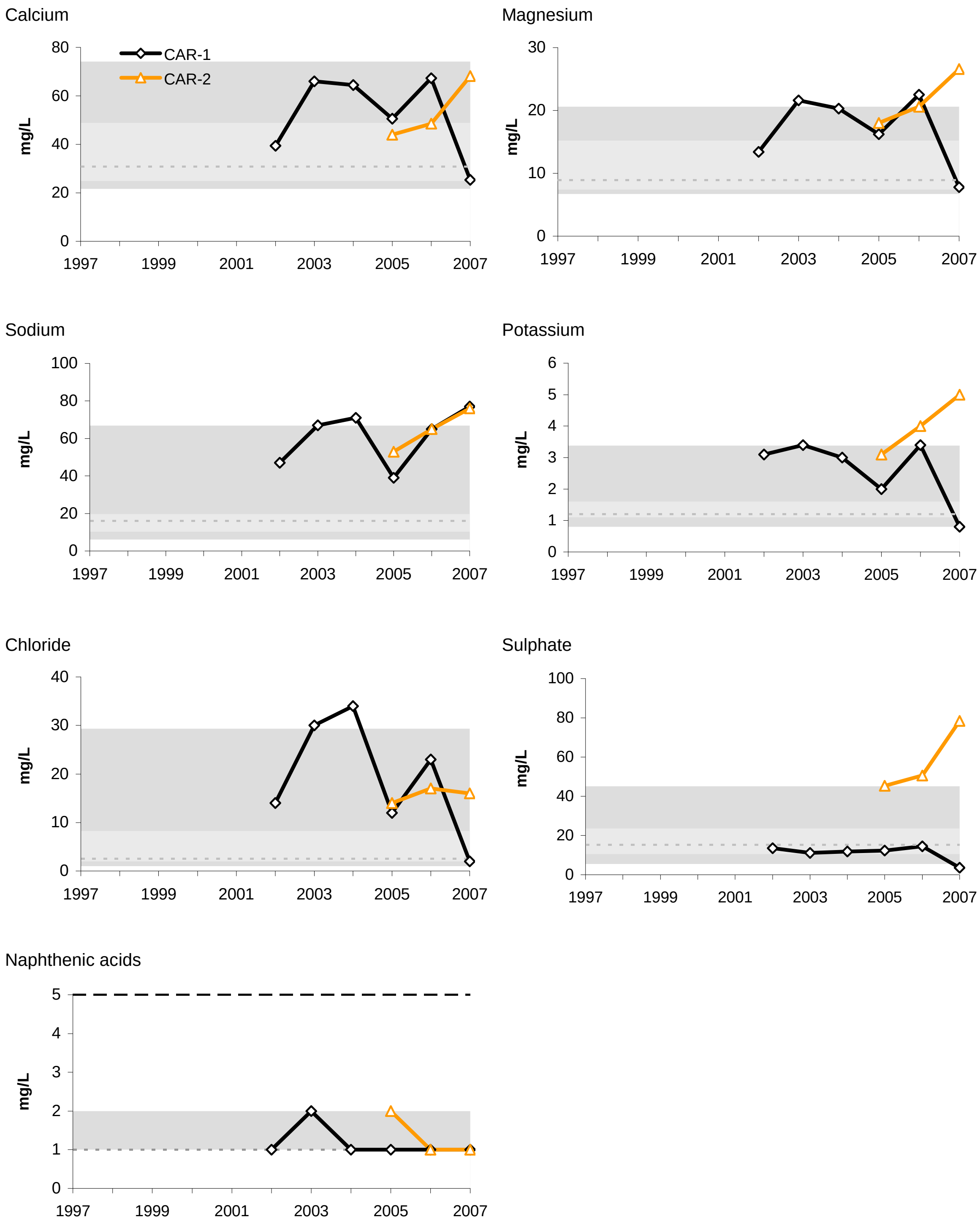
Figure 5.6-3 Concentrations of selected water quality measurement endpoints in the Calumet River (fall data) relative to regional baseline fall concentrations.



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.

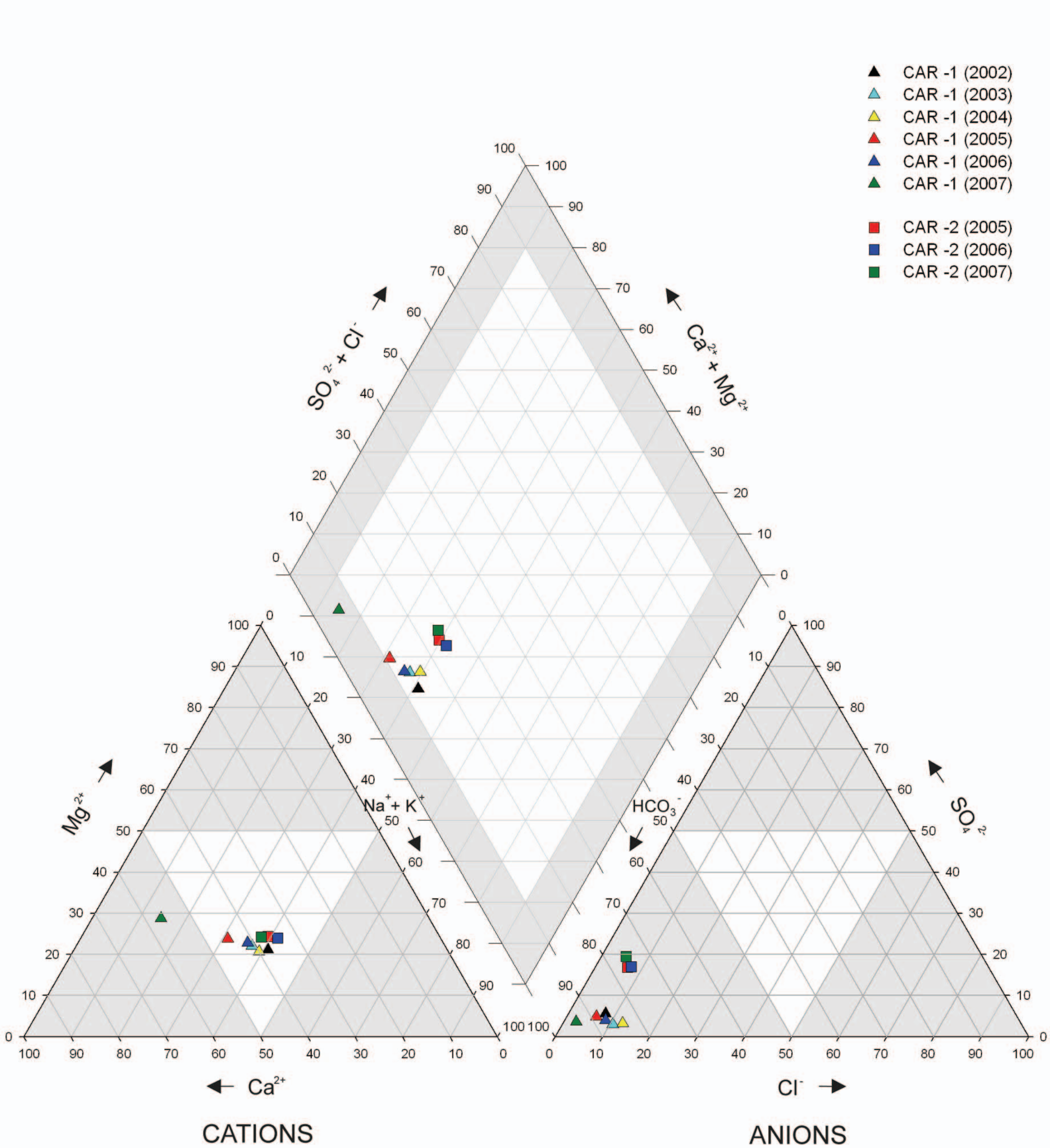
Figure 5.6-3 (Cont'd.)



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 Calumet River watershed.



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5.7 FIREBAG RIVER WATERSHED

Summary of Results

Measurement Endpoint	Summary of 2007 Conditions				
Climate and Hydrology					
	Assessment of Change				
	Negligible	Low	Moderate	High	
Mean open-water season discharge	√				Total runoff in 2007 was above 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 2007 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 2007[1]		
Measurement endpoints with guidelines	2007 Potentially Influenced Stations (n=0)	2007 Reference Stations (n=2)	
Physical variables (max=2)	No water quality sampling stations were designated as potentially influenced in 2007.	0	Water quality in the Firebag River in fall 2007 was generally similar to previous years, with the exception of a number of major ions at the upper Firebag station, concentrations of many of which increased in fall 2007 relative to previous years, in both relative and absolute terms.
Nutrients (max=4)		0	
Ions (max=4)		0	
Selected metals (max=12)		0	
Comparison to Regional Baselines	Endpoints in 2007 Compared to Regional Baseline[2]		
Percentile of Regional Baseline Values	2007 Potentially Influenced Stations (n=0 stations X 15 endpoints)	2007 Reference Stations (n=2 stations X 15 endpoints)	
Greater than 95th percentile	No water quality sampling stations were designated as potentially influenced in 2007.	3	
Between 5th and 95th percentiles		27	
Less than 5th percentile		0	

Benthic Invertebrate Communities and Sediment Quality

Benthic Invertebrate Communities: Comparison to Regional Baselines	Endpoints in 2007 Compared to Regional Baseline						
Values in Relation to Regional Baseline Mean	2007 Potentially Influenced Sites (n=0)			2007 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 2007.				2		Benthic invertebrate community measurement endpoints in fall 2007 in the Firebag River were at levels similar to those previously measured, with generally higher diversity. Many sediment quality measurement endpoints were generally at higher levels and concentrations than previously-recorded.
Richness					2		
Diversity					2		
Evenness					2		
% EPT					2		

Sediment Quality Guideline Exceedances	Station-Endpoint Combinations Exceeding Guidelines in 2007	
Measurement endpoints with guidelines	2007 Potentially Influenced Sites (n=0)	2007 Reference Sites (n=1)
Total Hydrocarbons (max=4)	No sediment quality sampling locations were designated as potentially influenced in 2007.	0
PAHs (max=1)		0

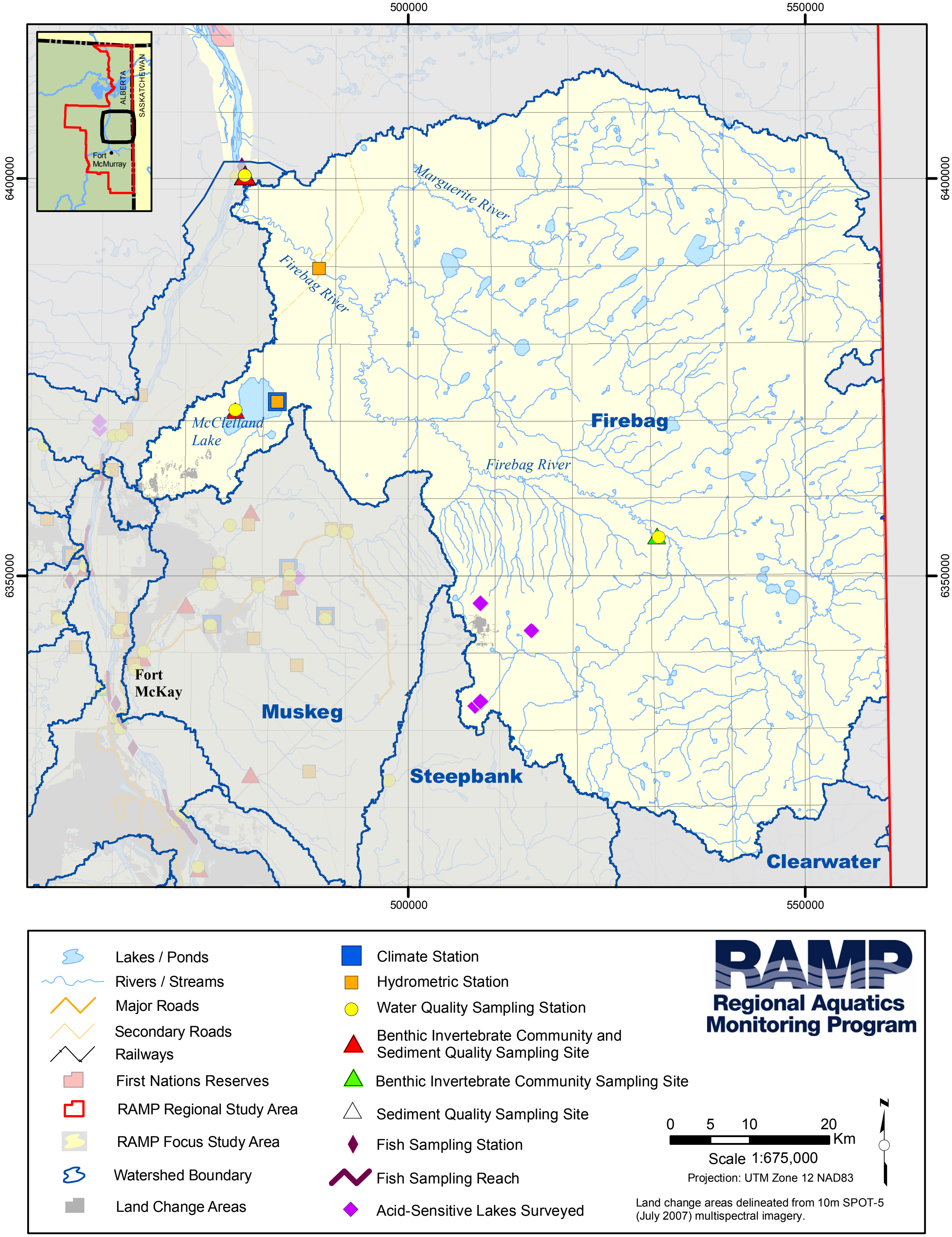
Fish Populations

Fish Inventory	No fish inventory studies conducted in 2007.
Sentinel Studies	No sentinel fish studies conducted in 2007.
Fish Tissue	**Level of Risk**
Human Health: Subsistence	Fish tissue program was not conducted in 2007.
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 Firebag River watershed.



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5.7.1 Development Status

As of 2007, slightly more than 0.2% of the area of the Firebag River watershed had undergone land change from focal project activities (Table 2.4-2). Given this small land change area, all parts of the Firebag River watershed are designated as *reference* for 2007. All RAMP water quality stations, benthic invertebrate community, and sediment quality reaches in the Firebag River watershed in 2007 are designated as *reference* stations reaches, and all data gathered at these locations in 2007 are designated as baseline data. Accordingly, 2007 provides another opportunity to evaluate natural variability in baseline conditions for these RAMP aquatic resources.

5.7.2 Hydrologic Conditions

2007 Hydrologic Conditions Total runoff in the Firebag River watershed in 2007 was above the long-term average, with a May to October runoff depth of 137 mm. The highest flow occurred in spring, with secondary rainfall-driven peaks in August and September (Figure 5.7-2). The maximum daily discharge of 115 m^3/s was slightly higher than the mean annual flood. The minimum open-water discharge was 11.4 m^3/s, below 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 2007. As indicated in Section 3.1.7.2, the hydrologic analysis, unlike most RAMP components, does not require comparison of measurement endpoints between *potentially influenced* and *reference* areas and can be conducted 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 5.7-1. As of 2007, areas of closed-circuited land change and other land change (not closed-circuited) was 2.70 km^2 and 9.82 km^2, respectively, in the Firebag River drainage as a result of cumulative development of focal projects in the watershed (Table 2.4-1), the estimated net effects of which were to reduce inflows to the Firebag River by 0.170 million m^3 in 2007.

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 2007. 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 0.02%. 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 (-0.02%) 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 2007 have been negligible.

5.7.3 Water Quality

In fall 2007, water quality samples were collected from:

- Near the mouth of the Firebag River (station FIR-1, *reference*, first sampled in 2002); and
- On the Firebag River upstream of all focal project developments (station FIR-2, *reference*, first sampled in 2002).

2007 Results and Historical Ranges of Concentration At station FIR-1, concentrations of five (23%) of 22 water quality measurement endpoints in fall 2007 were below previously-measured minimum concentrations at this station, including total suspended solids, sodium, magnesium, sulphate and total boron (Table 5.7-3). Conversely, at station FIR-2, concentrations of 11 (50%) of 22 water quality measurement endpoints in fall 2007 were outside the range of historical values, with 10 exceeding previously-measured maximum concentrations (i.e., conductivity, total nitrogen, sodium, calcium, magnesium, sulphate, total dissolved solids, total alkalinity, total arsenic and total molybdenum), and one (total dissolved phosphorus) below its previously-measured minimum concentration (Table 5.7-4).

Comparison of Water Quality Measurement Endpoints to Water Quality Guidelines No water quality measurement endpoints exceeded water quality guidelines at either station FIR-1 or station FIR-2 in fall 2007 (Table 5.7-3, Table 5.7-4).

Other Water Quality Guideline Exceedences In fall 2007, concentrations of total iron exceeded its water quality guideline at both station FIR-1 and station FIR-2 and concentrations of total phosphorus exceeded its water quality guideline at station FIR-2 (Table 5.7-5).

Comparison of Water Quality Measurement Endpoints to Natural Variation in Baseline Conditions The concentrations of three (10%) of a possible 30 water quality measurement endpoint-station combinations fell outside the range of regional baseline concentrations in fall 2007 (Figure 5.7-3). At station FIR-1, the concentration of sodium was below the 5^{th} percentile of regional baseline concentrations (Figure 5.7-3). At station FIR-2, the concentration of total strontium was less than the 5^{th} percentile of regional baseline concentrations and the concentration of sulphate was greater than the 95^{th} percentile of regional baseline concentrations (Figure 5.7-3). Concentration of sulphate at both stations was greater than the 95^{th} percentile of regional baseline concentrations in fall 2006, but sulphate concentrations at these stations diverged in fall 2007. Sulphate concentration at station FIR-2 in fall 2007 was greater than fall 2006, while sulphate concentration at station FIR-1 decreased from fall 2006 to below the previously-measured minimum concentration.

Ion Balance Relative concentrations of major ions have generally been consistent between stations FIR-1 and FIR-2 and over time since 2002 (Figure 5.7-4). However, in 2007, relative cation and anion concentrations differed at station FIR-2 from previous years, with greater relative sulphate and lower relative bicarbonate concentrations, and greater relative sodium and potassium concentrations and lower relative calcium concentrations relative to previous years. This continues a shift in ion balance at station FIR-2 that was first measured in fall 2006, with shifts in relative concentrations of anions (Figure 5.7-4). Relative ion balance at station FIR-1 was similar to previous years in fall 2007.

Summary Water quality in the Firebag River in fall 2007 was generally similar to previous years, with the exception of a number of major ions at station FIR-2, concentrations of many of which increased in fall 2007 relative to previous years, in both relative and absolute terms.

5.7.4 Benthic Invertebrate Communities and Sediment Quality

5.7.4.1 Benthic Invertebrate Communities

In fall 2007, 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 focal project activities (reach FIR-E-2, *reference*, first sampled in 2003).

2007 Habitat Conditions Reach FIR-D-1 had moderate water depth (0.5 m), slow current velocity (0.3 m/s), and 28% macrophyte cover in fall 2007 (Table 5.7-6). Sand was the dominant material in the substrate at this reach (68%) with lesser amounts of silt (27%) and clay (5%). The total organic carbon content of the sediments of reach FIR-D-1 was 13%, a level that can lead to anoxia in the sediments and have negative effects on benthic invertebrate communities (Persaud *et al*., 1996). Reach FIR-E-2 had shallower water depth (0.3 m) and higher current velocity (0.6 m/s) than the lower reach (reach FIR-D-1), and similar levels of macrophyte cover (31%) in fall 2007 (Table 5.7-6) comprised typically of flat-stemmed pondweed (*Potamogeton zosteriformis*) and tape grass (*Valisneria americana*). Substrate at reach FIR-E-2 was dominated by cobble. Periphyton chlorophyll *a* biomass in fall 2007 was approximately 9 mg/m^2, its lowest measured level at reach FIR-E-2, and indicative of oligotrophic conditions (Figure 5.7-5).

Relative Abundance of Benthic Invertebrate Community Taxa in 2007 Reach FIR-D-1 in fall 2007 was dominated numerically by chironomids (42%), ostracods (18%) and tubificid worms (19%, Table 5.7-7), reflecting the dominance of sand in the substrate. Sub-dominant groups included fingernail clams (Bivalvia, 2%), biting midges (Ceratopogonidae, 2%), and naidid worms (2%). Again, these groups reflect the sand-based texture of the substrate and slower-moving water. The dominant chironomids found in reach FIR-D-1 were all common forms, and included *Procladius*, *Cryptochironomus*, *Polypedilum*, and the pollution-tolerant *Chironomus* (Bode, 1988). The few mayflies found in reach FIR-D-1 included *Baetisca*, *Caenis* and *Leptophlebia*.

Reach FIR-E-2 was numerically dominated in fall 2007 by chironomids (37%), mayflies (13%), and mites (Acarina, 12%), while beetles (Coleoptera, 3%), naidid worms (8%), blackfly larvae (Simuliidae, 3%), caddisflies (2%) and tubificid worms (3%) were sub-dominant (Table 5.7-7). Chironomids included many common forms such as *Thienemanniella*, *Lopescladius*, *Rheotanytarsus*, *Micropsectra*/*Tanytarsus*, *Polypedilum*, *Cryptochironomus* and *Thienemannimyia*. Sensitive organisms included the dragonfly *Ophiogomphus*, the caddisflies *Lepidostoma* and *Brachycentrus*, the stoneflies *Taeniopteryx*, *Pteronarcys* and *Isoperla*, and the mayflies *Leptophlebia* and *Paraleptophlebia*.

Comparison of Benthic Invertebrate Community Measurement Endpoints to Natural Variation in Baseline Conditions Benthic invertebrate community endpoints in fall 2007 for both the reach FIR-D-1 and reach FIR-E-2 were at levels expected for erosional and depositional habitats, respectively (Table 5.7-7, Figure 5.7-6, Figure 5.7-7). At reach FIR-D-1, abundance was about 23,000 individuals per m^2; diversity was higher in 2007 than in previous years with an average of 14 taxa per sample, Simpson's diversity of 0.79, and evenness of 0.86. At reach FIR-E-2, abundance was about 24,500 individuals per m^2, and diversity was very high with an average of 50 taxa per sample, Simpson's diversity of 0.93 and evenness of 0.95.

5.7.4.2 Sediment Quality

Sediment quality was sampled in fall 2007 in reach FIR-D-1, the depositional reach where benthic invertebrate communities were sampled near the mouth of the Firebag River.

2007 Results and Historical Ranges of Concentration Fall 2007 sediment quality data were compared with 2006 data for FIR-D-1, and data from 2003 to 2005 from the previous sediment-quality sampling location FIR-1.

Sediments at the lower Firebag River (reach FIR-D1) in fall 2007 were dominated by sand, with a small proportion of clay and silt; the fraction of silt and clay in sediments sampled in 2007 was greater than in sediments sampled from this site in previous years (Table 5.7-8). Total organic carbon content in these sediments was very high relative to previous years, at 13.2% in 2007 versus 0.1 to 2.2% from 2003 to 2006.

Concentrations of most measurement endpoints in fall 2007 were above previously-measured maximum concentrations (Table 5.7-8). Concentrations of CCME Fraction 2 to 4 hydrocarbons were up to six times higher than previously-measured maximum concentrations (CCME Fraction 1 hydrocarbons and BTEX were not detectable). PAH concentrations were generally higher than previously-measured maximum concentrations, although approximately 62% of the total PAH concentration was comprised of retene, suggesting a predominantly diagenic origin of PAHs in these sediments. However, total dibenzothiphene concentrations were three times higher in fall 2007 than previously-measured maximum concentrations.

Comparison with Sediment Quality Guidelines Only fraction 3 (C16-C34) exceeded sediment quality guidelines at reach FIR-D-1 in fall 2007.

5.7.4.3 Summary

Benthic invertebrate community measurement endpoints in fall 2007 in the Firebag River were at levels similar to those previously measured, with generally higher diversity. Many sediment quality measurement endpoints were generally at higher levels and concentrations than previously-recorded.

5.7.5 Fish Populations

The 2007 RAMP Fish Population component did not include any activities in the Firebag River watershed.

5.7.6 Summary of Conditions

Conditions in the Firebag River in 2007 were generally similar to previous years. Cumulative, watershed-level changes in hydrologic conditions caused by focal project activities in the Firebag River watershed as of 2007 have been negligible. Water quality conditions were similar in 2007 to water quality conditions in previous years, with the exception of a number of major ions at the upper station, concentrations of many of which increased in fall 2007 relative to previous years, in both relative and absolute terms. Benthic invertebrate community measurement endpoints in fall 2007 were at levels similar to those previously measured, with generally higher diversity in fall 2007 than in previous years. Many sediment quality measurement endpoints were generally at higher levels and concentrations than previously-recorded.

Figure 5.7-2 Firebag River: 2007 hydrograph and historical context.

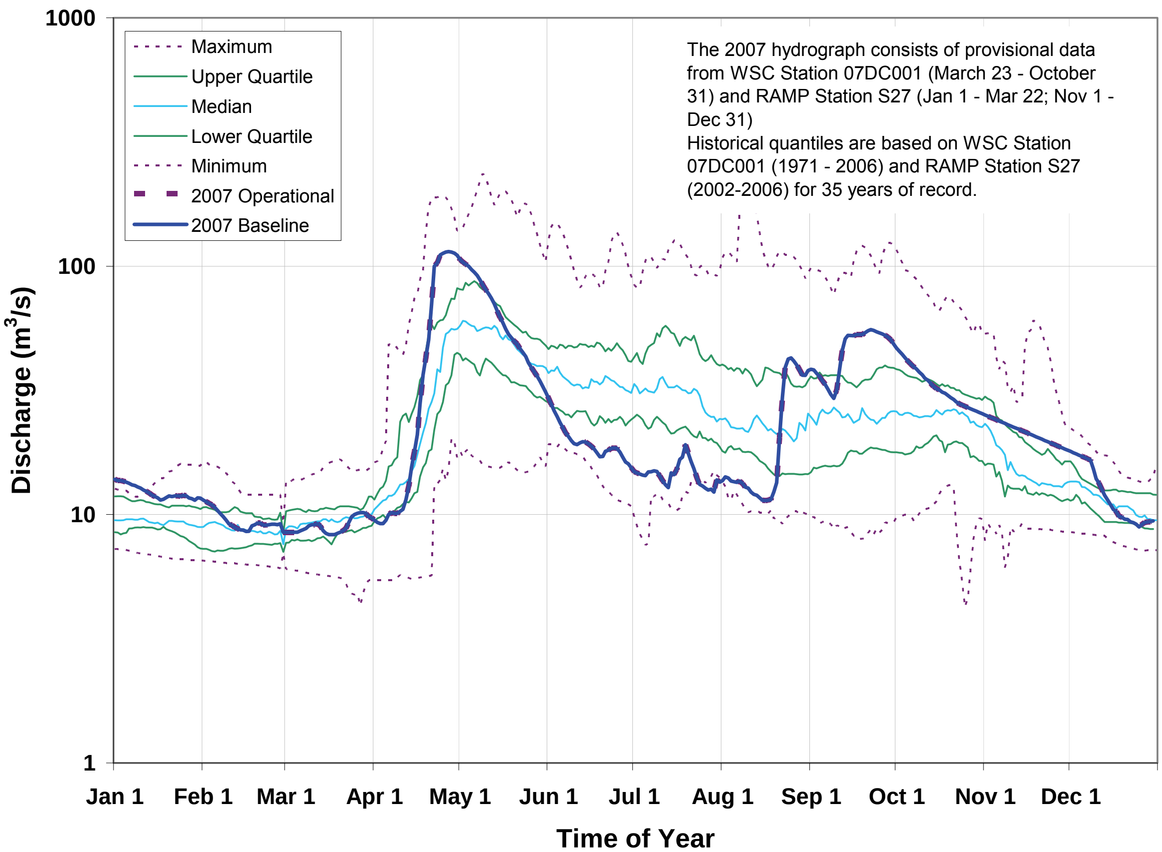


Table 5.7-1 Inputs to calculation of Firebag River baseline hydrograph at RAMP/WSC Station S27, Firebag River near the Mouth (07DC001).

Component	Annual Volume (million m^3)	Basis and Data Source
Observed hydrograph (total discharge during 2007 data record)	819	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 2007	+ 0.438	2.70 km^2 within Firebag River drainage estimated to have been closed-circuited by focal projects as of 2007 (Table 2.6-1)
Incremental runoff from areas of land change that were not closed-circuited as of 2007	- 0.269	9.82 km^2 within Firebag River drainage estimated to have undergone land change by focal projects of 2007, 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)	819	Estimated total annual baseline discharge (i.e., without focal projects or other oil sands projects) for 2007
Incremental flow (change in total annual discharge)	- 0.170	Total annual discharge from operational hydrograph less total annual discharge of estimated 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 5.7-2 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	33.7	33.7	-0.02%
Mean winter discharge	13.0	13.0	-0.02%
Annual maximum daily discharge	115	115	-0.02%
Open-water season minimum daily discharge	11.4	11.4	-0.02%

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 5.7-3 Concentrations of water quality measurement endpoints, mouth of Firebag River (station FIR-1), fall 2007.

Measurement Endpoint	Units	Guideline	September 2007	1997-2006 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.2	5	7.9	8.2	8.2
Total suspended solids	mg/L	-[1]	<3	5	4	7	17
Conductivity	µS/cm	-	199	5	178	196	227
Nutrients							
Total dissolved phosphorus	mg/L	0.05[2]	0.021	5	0.016	0.036	**0.057**
Total nitrogen*	mg/L	1.0	0.6	5	0.4	0.6	**1.7**
Nitrate+nitrite	mg/L	-	<0.1	5	<0.1	<0.1	<0.1
Dissolved organic carbon	mg/L	-	13	5	8	13	16
Ions							
Sodium	mg/L	-	2	5	3	4	4
Calcium	mg/L	-	26.6	5	25.2	30.2	33.2
Magnesium	mg/L	-	6.8	5	8.2	9.4	9.5
Chloride	mg/L	230, 860[3]	2	5	2	3	3
Sulphate	mg/L	100[4]	1.7	5	2.8	3.4	10.3
Total dissolved solids	mg/L	-	137	5	60	140	170
Total alkalinity	mg/L		97	5	87	110	112
Organic compounds							
Naphthenic acids	mg/L	-	<1	4	<1	1	1
Selected metals							
Total aluminum	mg/L	0.1	0.0553	5	0.033	**0.175**	**0.292**
Dissolved aluminum	mg/L	0.1[2]	0.00339	5	0.0028	0.0054	0.0089
Total arsenic	mg/L	0.005	0.000394	5	0.000276	0.00045	0.00055
Total boron	mg/L	1.2[5]	0.0136	5	0.0140	0.0162	0.0190
Total molybdenum	mg/L	0.073	0.000135	4	0.00011	0.00014	0.0002
Total mercury (ultra-trace)	ng/L	5, 13[6]	<1.2	4	<1.2	<1.2	<1.2
Total strontium	mg/L	-	0.0627	4	0.053	0.067	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).

Table 5.7-4 Concentrations of water quality measurement endpoints, Firebag River above the Suncor Firebag project (station FIR-2), fall 2007.

Measurement Endpoint	Units	Guideline	September 2007	1997-2006 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.3	4	7.9	8.1	8.1
Total suspended solids	mg/L	-[1]	<3	4	<3	3	8
Conductivity	µS/cm	-	261	4	160	165.5	174
Nutrients							
Total dissolved phosphorus	mg/L	0.05[2]	0.009	4	0.039	**0.074**	**0.096**
Total nitrogen*	mg/L	1.0	0.8	4	0.5	0.6	0.7
Nitrate+nitrite	mg/L	-	<0.1	4	<0.1	<0.1	<0.1
Dissolved organic carbon	mg/L	-	13	4	8	13	16
Ions							
Sodium	mg/L	-	16	4	3	4	4
Calcium	mg/L	-	28.4	4	22.9	25.35	26.2
Magnesium	mg/L	-	8.7	4	6.4	7.25	7.4
Chloride	mg/L	230, 860[3]	2	4	<1	2	2
Sulphate	mg/L	100[4]	22.6	4	1.9	2.85	8.8
Total dissolved solids	mg/L	-	158	4	110	130	150
Total alkalinity	mg/L		114	4	81	89	93
Organic compounds							
Naphthenic acids	mg/L	-	<1	4	<1	<1	<1
Selected metals							
Total aluminum	mg/L	0.1	0.0364	4	0.0232	0.0324	0.0369
Dissolved aluminum	mg/L	0.1[2]	0.00369	4	0.0031	0.005295	0.0066
Total arsenic	mg/L	0.005	0.000594	4	0.0001	0.000476	0.000582
Total boron	mg/L	1.2[5]	0.013	4	0.0107	0.0128	0.0153
Total molybdenum	mg/L	0.073	0.000213	4	0.00015	0.00017	0.00020
Total mercury (ultra-trace)	ng/L	5, 13[6]	<1.2	4	<1.2	<1.2	<1.2
Total strontium	mg/L	-	0.049	4	0.046	0.049	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).

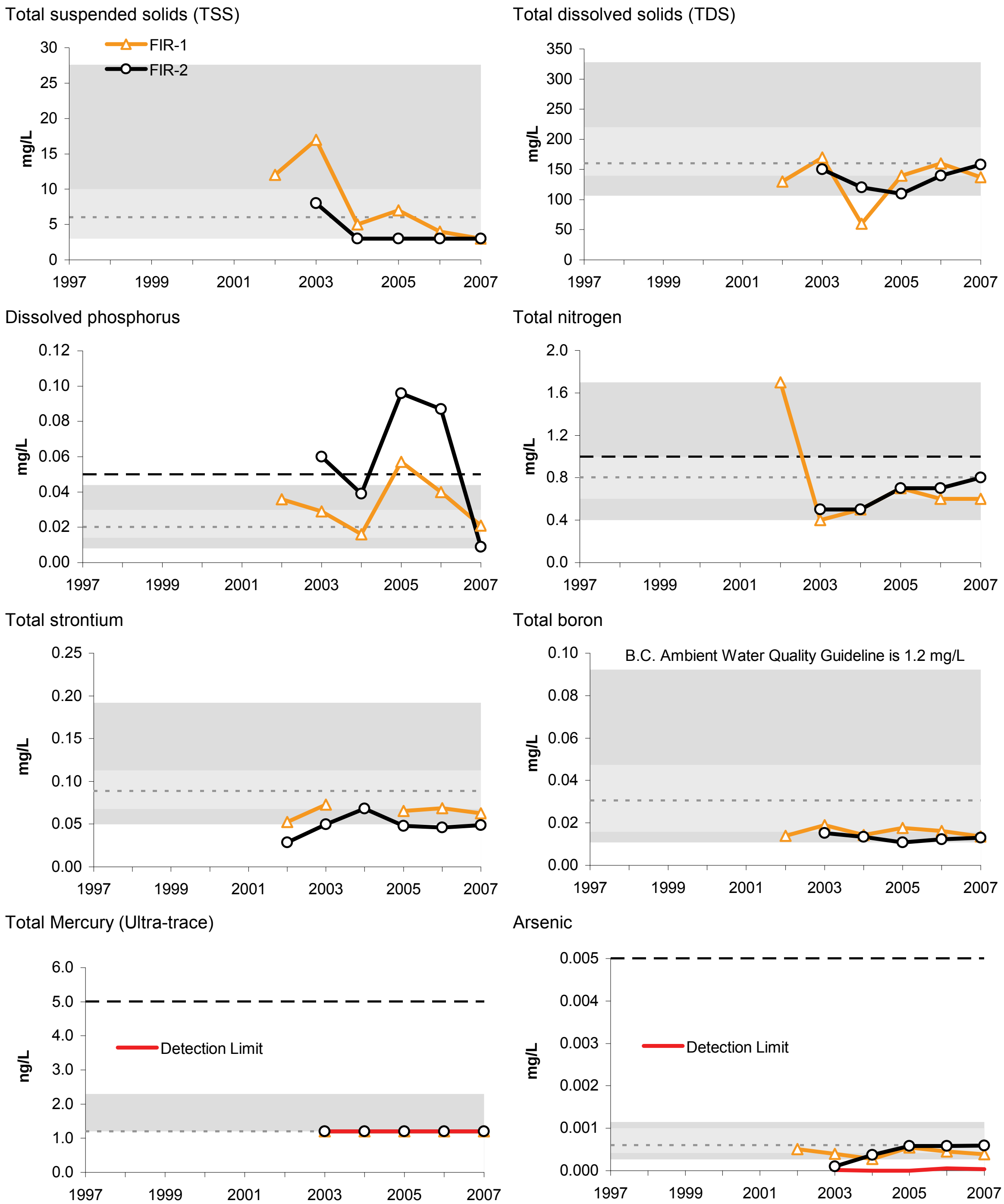
Table 5.7-5 List of all 2007 water quality guideline exceedances, Firebag River, 2007.

Water Quality Variable	Units	Guideline*	FIR-1	FIR-2
Fall				
Total phosphorus	mg/L	0.05	-	**0.129**
Total iron	mg/L	0.3	**0.497**	**0.584**

FIR-1 and FIR-2 sampled only in fall 2007.

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

Figure 5.7-3 Concentrations of selected water quality measurement endpoints in the Firebag River watershed (fall 2007) relative to regional baseline fall concentrations.

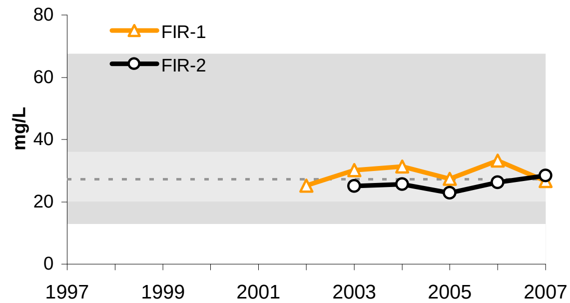


Non-detectable values are shown at the detection limit.

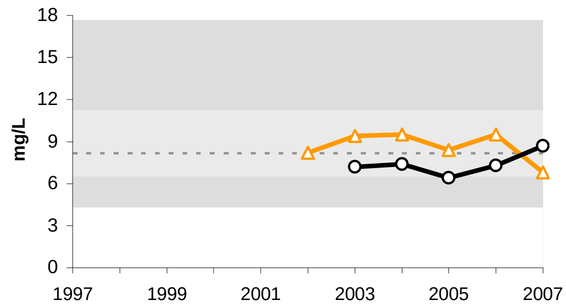
Regional baseline values reflect pooled results for all baseline stations with similar water quality, from all years of RAMP sampling. See Section 3.2.7 for a discussion of this approach, and Appendix D for these regional baseline ranges.

Figure 5.7-3 (Cont'd.)

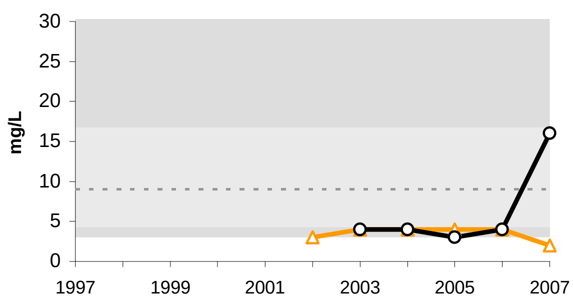
Calcium



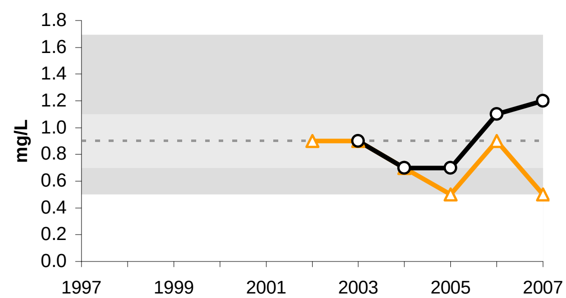
Magnesium



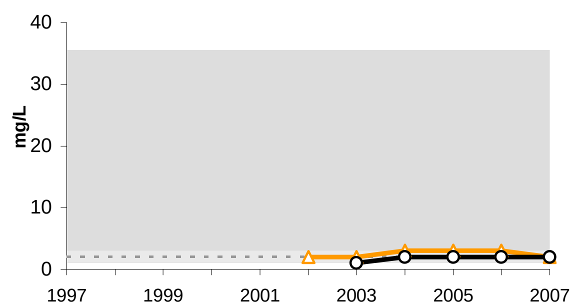
Sodium



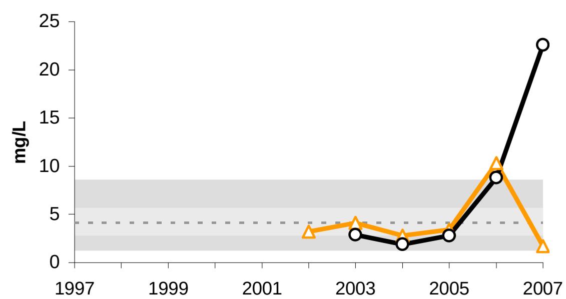
Potassium



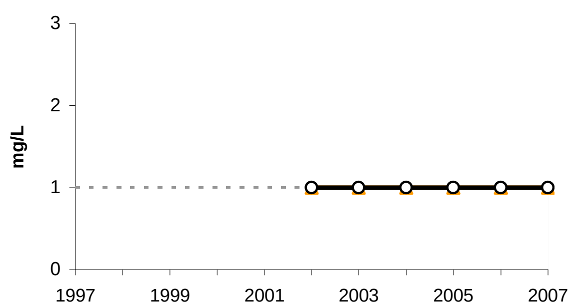
Chloride



Sulphate



Naphthenic acids



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 the Firebag River, fall 2007.

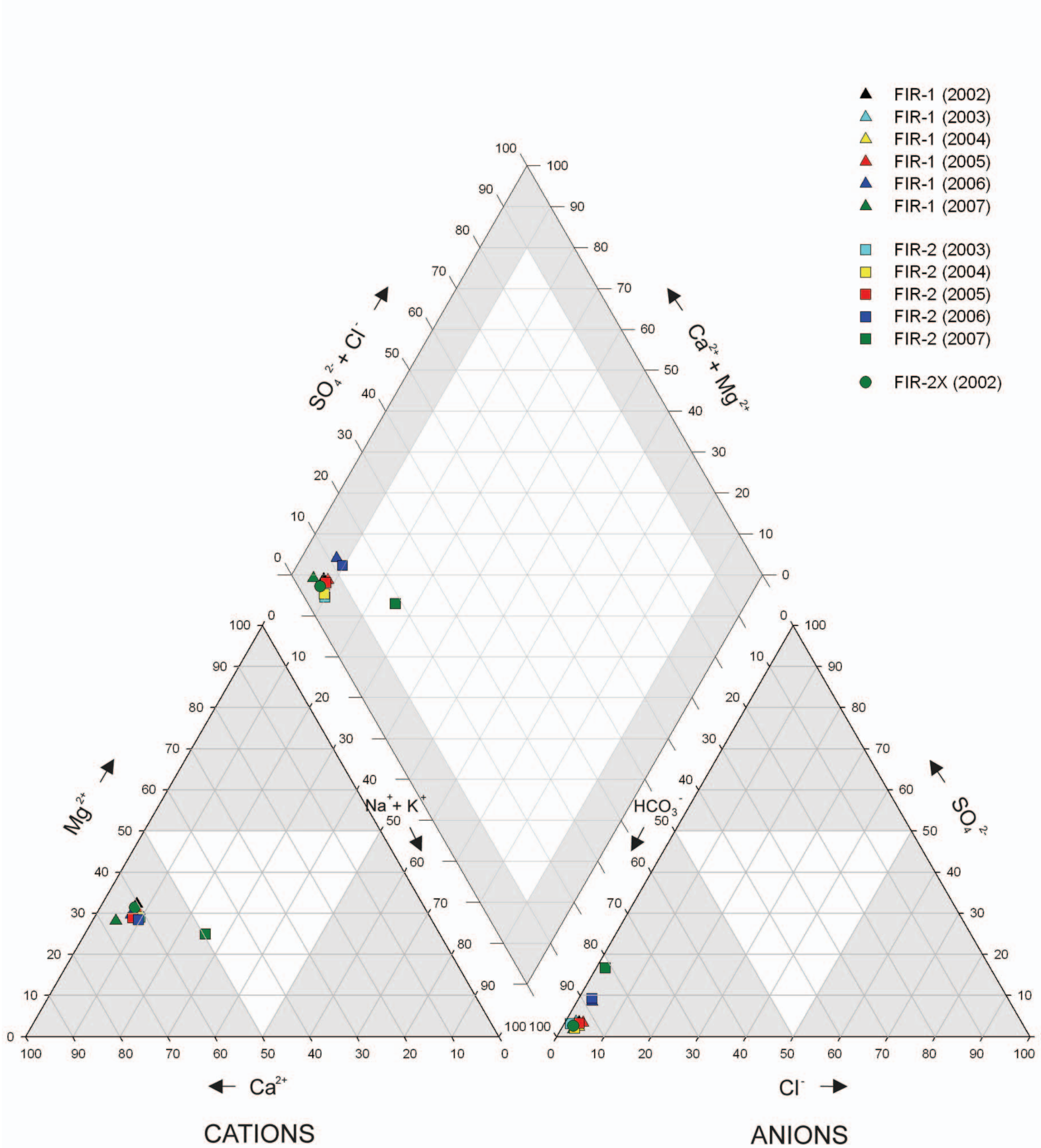


Table 5.7-6 Habitat characteristics of benthic invertebrate community sampling reaches in the Firebag River.

Variable	Units	FIR-D-1 Lower Reach of the Firebag River	FIR-E-2 Upper Reach of the Firebag River
Sample date	-	Sept. 11, 2007	Sept. 7, 2007
Habitat	-	Depositional	Erosional
Water depth	m	0.5	0.3
Current velocity	m/s	0.3	0.6
Macrophyte cover	%	28	31
Field Water Quality			
Dissolved oxygen	mg/L	11.0	n/a
Conductivity	µS/cm	212	n/a
pH	pH units	7.9	n/a
Water temperature	°C	11.5	n/a
Sediment Composition			
Sand	%	68	
Silt	%	27	
Clay	%	5	
Total Organic Carbon		13.2	
Sand/Silt/Clay	%		14
Small gravel	%		1
Large gravel	%		11
Small cobble	%		43
Large cobble	%		30
Boulder	%		0
Bedrock	%		0

Figure 5.7-5 Variation in periphyton chlorophyll *a* in the upper reach of the Firebag River (reach FIR-E-2).

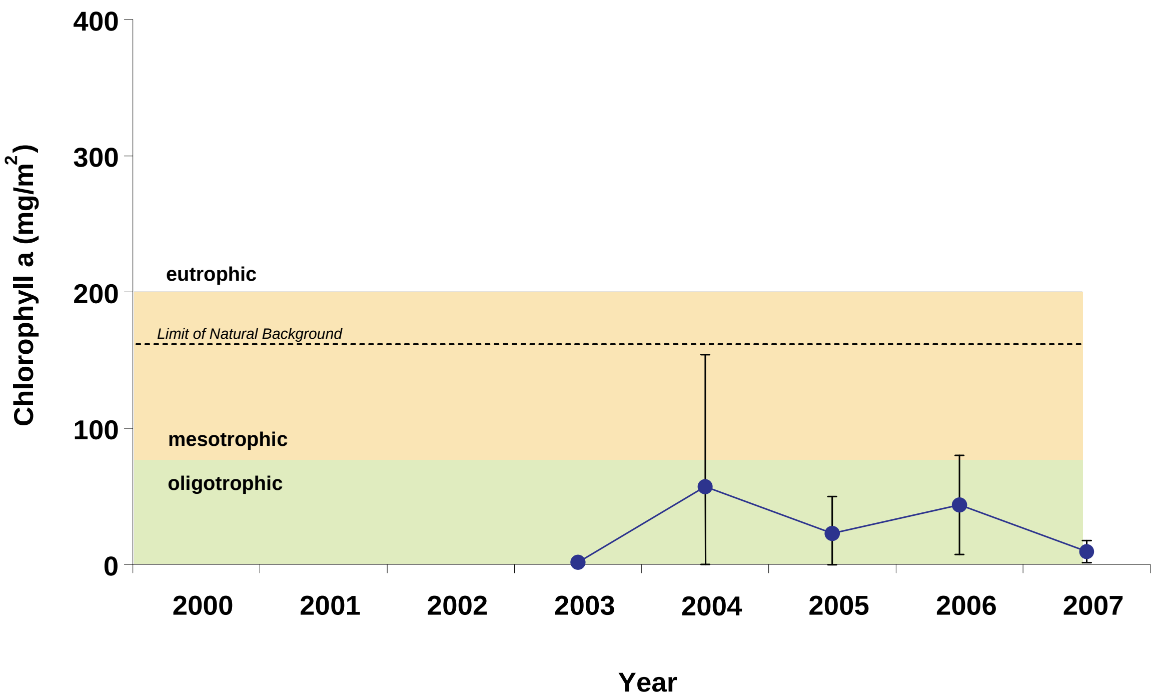


Table 5.7-7 Summary of major taxon abundances and benthic invertebrate community measurement endpoints in reaches in the Firebag River.

Taxon	Percent Major Taxa Enumerated in Each Year									
	Reach FIR-D-1					Reach FIR-E-2				
	2003	2004	2005	2006	2007	2003	2004	2005	2006	2007
Amphipoda						<1	<1			
Anisoptera	<1		<1	1		<1	<1	<1	<1	<1
Bivalvia		4	1		2	3	3	2		4
Ceratopogonidae	<1	2	1	<1	2		<1	<1	1	1
Chironomidae	96	33	36	52	42	63	48	35	7	37
Cladocera					13		<1	<1		<1
Coleoptera						2	4	5	5	3
Copepoda					<1	1	1	<1		<1
Empididae	<1	2			<1				1	<1
Enchytraeidae					1	1	<1	<1	<1	1
Ephemeroptera	<1	3			<1	9	12	15	9	13
Ephydridae		3								
Gastropoda			<1	0.2		1	<1		<1	3
Glossiphoniidae					<1	<1	<1	<1		<1
Heteroptera	1	<1				<1	<1			
Hydra						<1	<1			
Hydracarina		<1				5	1	11	6	12
Lumbriculidae		<1				<1				
Naididae	1	1			2	2	5	4	5	8
Nematoda	<1	4	1	1	1	2	4	3	2	4
Ostracoda		9		<1	18	<1	<1	<1	<1	4
Plecoptera	<1		<1			2	1	1	1	1
Simuliidae					<1	<1	<1	<1	<1	3
Tabanidae	<1			<1	<1	<1	<1	<1	1	1
Tipulidae		9	<1		<1	1	<1	<1	1	<1
Trichoptera			1	<1		5	7	1	7	2
Tubificidae	1	28	6	46	19	1	1	1	<1	3
Benthic Invertebrate Community Measurement Endpoints										
Total Abundance ($No./m^2$)	62,517	1,391	19,722	12,375	22,605	11,930	16,024	12,335	18,871	24,462
Richness	7	7	6	8	14	39	38	38	43	50
Simpson's Diversity	0.4	0.62	0.38	0.46	0.79	0.88	0.92	0.92	0.91	0.93
Evenness	0.47	0.81	0.67	0.47	0.86	0.9	0.95	0.95	0.91	0.95
% EPT	<1	5	1	<1	<1	22	17	25	2	16

Figure 5.7-6 Variation in benthic invertebrate community measurement endpoints in the lower reach (reach FIR-D-1) reach of the Firebag River.

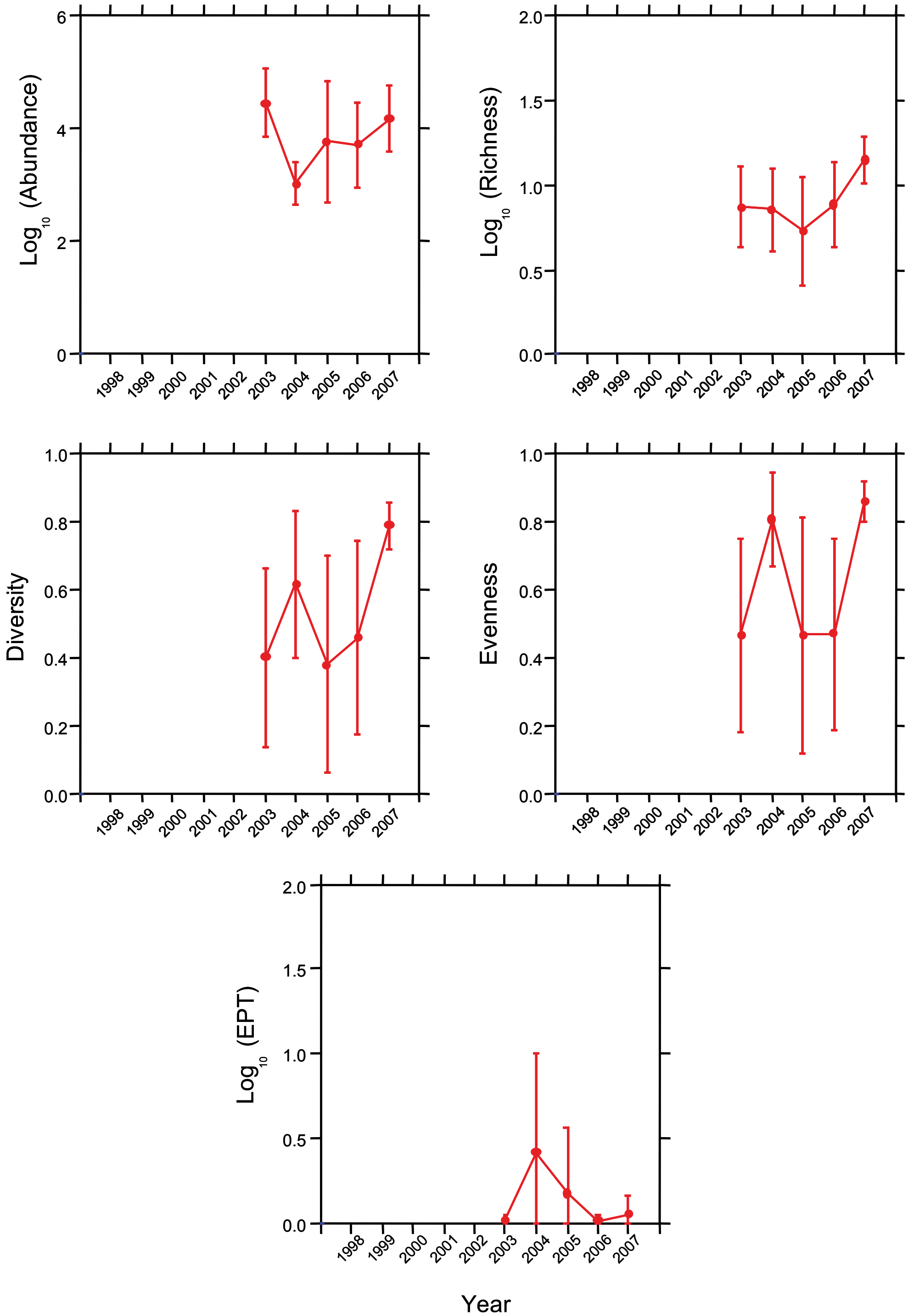


Figure 5.7-7 Variation in indices of benthic invertebrate community composition in the upper reach (reach FIR-E-2) reach of the Firebag River.

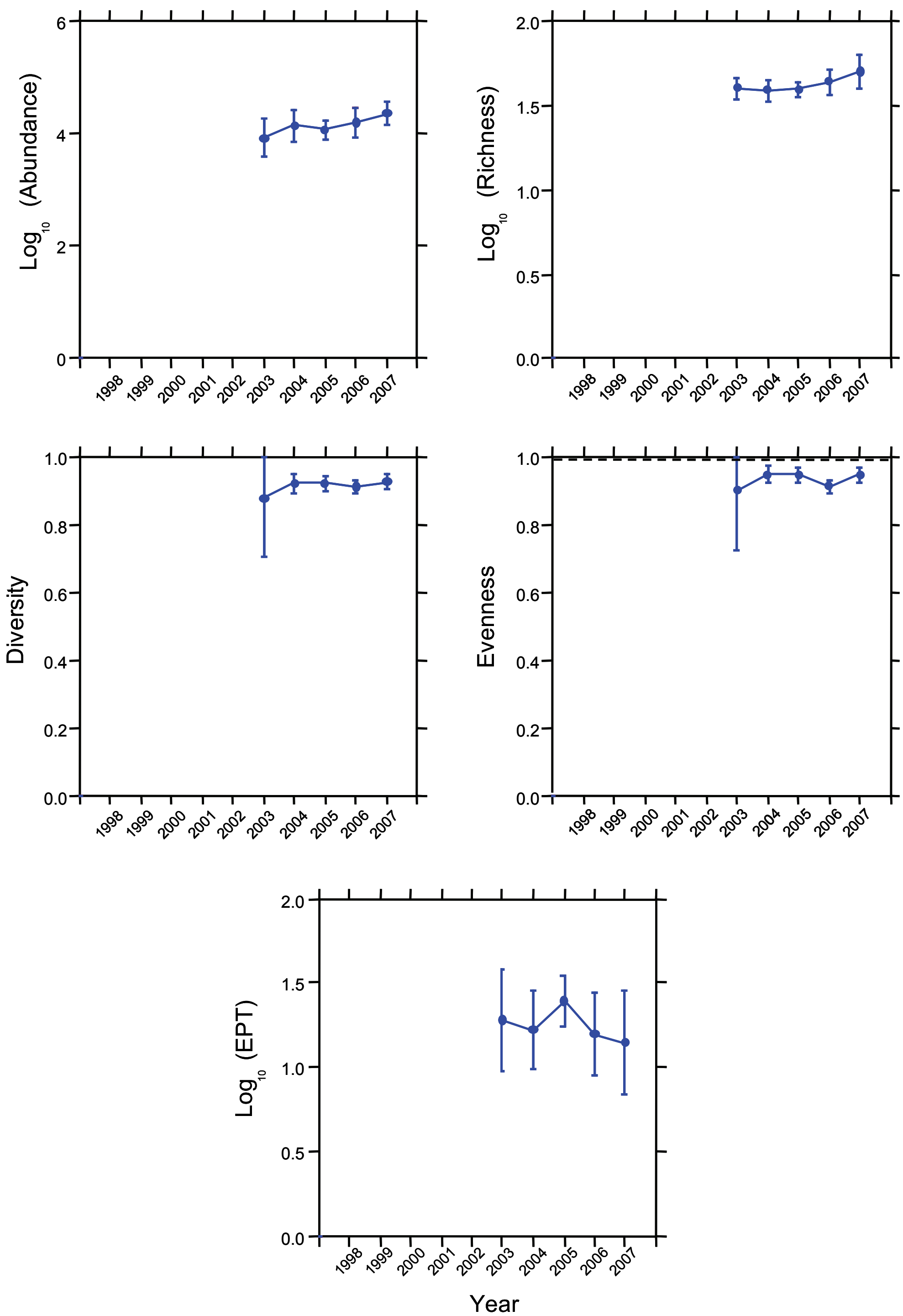


Table 5.7-8 Levels and concentrations of sediment quality measurement endpoints, lower reach near mouth of Firebag River (reach FIR-D-1), fall 2007.

Measurement Endpoints	Units	Guideline	September 2007	1997-2006 (fall data only, station FIR-1, FIR-D-1)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	5.1	4	1	3	6
Silt	%	-	27.4	4	1	5.5	21
Sand	%	-	67.5	4	74	92	100
Total organic carbon	%	-	13.2	4	0.1	0.65	2.2
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]	40	2	14	-	32
Fraction 3 (C16-C34)	mg/kg	400[2]	**1900**	2	140	-	330
Fraction 4 (C34-C50)	mg/kg	2800[2]	1800	2	150	-	280
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[3]	0.0038	4	0.0010	0.0014	0.01
Retene	mg/kg	-	9.06	4	0.0019	0.048	0.125
Total dibenzothiophenes	mg/kg	-	2.12	4	0.02	0.28	0.70
Total PAHs	mg/kg	-	14.57	4	0.17	1.07	3.36
Total HMW PAHs	mg/kg	-	0.28	4	0.10	0.43	1.52
Total LMW PAHs	mg/kg	-	14.29	4	0.07	0.64	1.84
Predicted PAH toxicity[1]	H.I.	-	2.29	4	0.35	0.77	0.92
Metals that exceed CCME guidelines in 2007							
none	mg/kg	-	-	-	-	-	-
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	ns	3	7	8	9
Chironomus growth - 10d	mg/organism	-	ns	3	1.9	1.9	2.6
Hyalella survival - 14d	# surviving	-	ns	2	5	-	9
Hyalella growth - 14d	mg/organism	-	ns	2	0.06	-	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).

ns = not sampled

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5.8 ELLS RIVER WATERSHED

Summary of Results

Measurement Endpoint	Summary of 2007 Conditions				
Climate and Hydrology					
	Assessment of Change				Total 2007 runoff was about 30% greater than normal. All hydrologic measurement endpoints are estimated to be essentially identical to what they would have been in the absence of focal projects. The estimated effect in the measurement endpoints is 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 2007 Conditions		
Water Quality			
Guideline Exceedances	**Station-Endpoint Combinations Exceeding Guidelines in 2007[1]**		Water quality conditions in the Ells River in 2007 were similar to water quality conditions at these stations in previous years.
Measurement endpoints with guidelines	**2007 Potentially Influenced Stations (n=0)**	**2007 Reference Stations (n=2)**	
Physical variables (max=2)	No water quality sampling stations were designated as *potentially influenced* in 2007.	0	
Nutrients (max=4)		1	
Ions (max=4)		0	
Selected metals (max=12)		2	
Comparison to Regional Baselines	**Endpoints in 2007 Compared to Regional Baseline[2]**		
Percentile of Regional Baseline Values	**2007 Potentially Influenced (n=0 stations X 15 endpoints)**	**2007 Reference Stations (n=2 stations X 15 endpoints)**	
Greater than 95th percentile	No water quality sampling stations were designated as *potentially influenced* in 2007.	0	
Between 5th and 95th percentiles		28	
Less than 5th percentile		2	

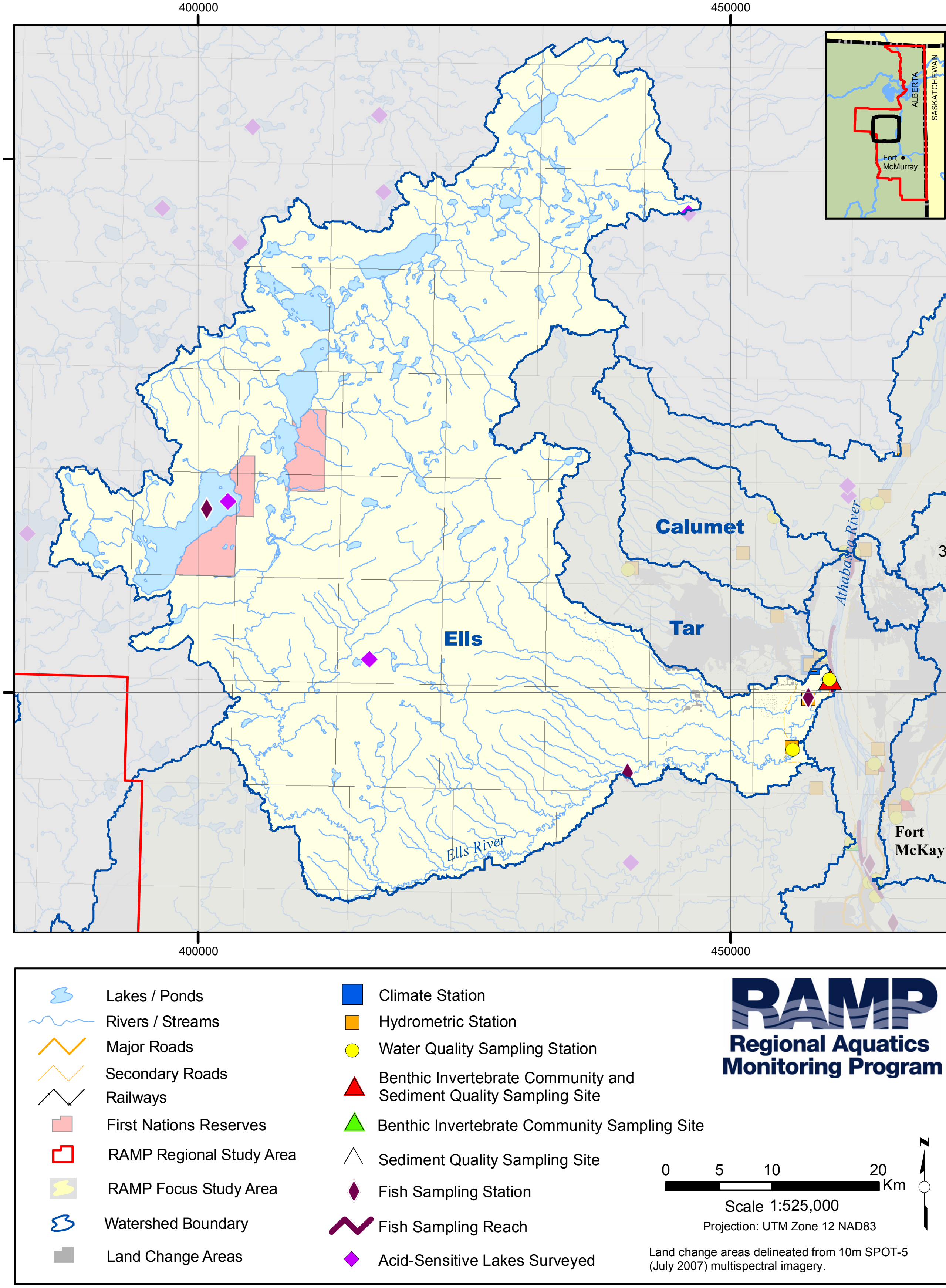
Measurement Endpoint	Summary of 2007 Conditions						
Benthic Invertebrate Communities and Sediment Quality							
Benthic Invertebrate Communities: Comparison to Regional Baselines	**Endpoints in 2007 Compared to Regional Baseline**						Conditions in the two reaches sampled in fall 2007, one depositional 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 2007 to values measured in previous years. Values of most sediment quality measurement endpoints were within the range of previously-measured values for the watershed.
Values in Relation to Regional Baseline Mean	**2007 Potentially Influenced Sites (n=0)**			**2007 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 2007.			No comparisons to regional baselines were made as all RAMP monitoring stations in the Ells River watershed are designated as reference in 2007			
Richness							
Diversity							
Evenness							
% EPT							
Sediment Quality Guideline Exceedances	**Reach-Endpoint Combinations Exceeding Guidelines in 2007**						
Measurement endpoints with guidelines	**2007 *Potentially Influenced* Sites (n=0)**			**2007 *Reference* Sites (n=1)**			
Total Hydrocarbons (max = 4)	No sediment quality sampling locations were designated as potentially influenced in 2007.			1			
PAHs (max = 1)				0			

Measurement Endpoint	Summary of 2007 Conditions	
Fish Populations		
Fish Inventory	No fish inventory studies conducted in Ells River watershed in 2007.	2007 results show no consistent differences in population survival or growth between sites or seasons, and some differences in condition factor that exceeded accepted impact criteria. There are no consistent differences in Ells River longnose dace population survival, growth, or condition factor between years.
Sentinel Studies	Results indicate high variability in longnose dace population survival, growth, and condition between different sites, seasons and years.	
Fish Tissue	**Level of Risk**	
Human Health: Subsistence	Fish tissue program was not conducted in Ells River watershed 2007.	
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; mercury (ultra-trace); arsenic; calcium; magnesium; sodium, potassium, chloride, sulphate; naphthenic acids

Figure 5.8-1 Ells River watershed.



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5.8.1 Development Status

As of 2007, an estimated 0.11% of the area of the Ells River watershed had undergone land change from focal project activities (Table 2.4-2). Given this small cumulative land change area, all parts of the Ells River watershed are designated as *reference* for 2007. All RAMP water quality stations, benthic invertebrate community and sediment quality reaches, and fish population sampling sites in the Ells River watershed in 2007 are designated as *reference* stations reaches, and all data gathered at these locations in 2007 are designated as baseline data. Accordingly, 2007 provides another opportunity to evaluate natural variability in baseline conditions for these RAMP aquatic resources.

5.8.2 Hydrologic Conditions

2007 Hydrologic Conditions Runoff volume in the Ells River basin, as measured at RAMP Station S14A, was above average in 2007 (Figure 5.8-2), with a May to October runoff depth of 79 mm compared to the long-term average of 60 mm. The snowmelt accounted for most of the annual flow, with discharges in the upper quartile for all of May. After that, discharges were well below historical average values throughout the open-water season (Figure 5.8-2). The maximum daily discharge of 52.5 m^3/s was almost double the mean annual flood, and the minimum open-water discharge of 2.27 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 2007. As indicated in Section 3.1.7.2, the hydrologic analysis, unlike most RAMP components, does not require comparison of measurement endpoints between *potentially influenced* and *reference* areas and can be conducted 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 5.8-1. As of 2007, areas of closed-circuited land change and other land change (not closed-circuited) were 0.87 km^2 and 1.46 km^2, respectively. The estimated net effects of cumulative development of focal projects in the Ells River watershed were to reduce inflows to the Ells River by 0.051 million m^3 in 2007 (Table 5.8-1).

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 2007. These estimated influences are predicted to have decreased mean open-water season discharge, annual maximum daily discharge, and open-season minimum daily discharge by approximately 0.03%. These 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 5.8-2, Table 5.8-2), and these estimated incremental changes (-0.03%) would have been assessed as Negligible in all 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 2007 have been negligible.

5.8.3 Water Quality

In 2007, water quality samples were collected 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).

2007 Results and Historical Ranges of Concentration Concentrations of most water quality measurement endpoints in fall 2007 were within the range of previously-measured concentrations at both station ELR-1 and station ELR-2. At station ELR-1 total suspended solids were slightly below the previously observed minimum, while conductivity, total alkalinity, total boron and total strontium were slightly above the previously-measured maximum (Table 5.8-3). At station ELR-2, concentrations of sulphate and sodium were below previously-measured minima, while total suspended solids, total dissolved phosphorus, dissolved aluminum and total strontium were above previously-measured maxima (Table 5.8-4). Water quality has generally been similar between stations in all years, with a notable differences in fall 2007 in dissolved phosphorus (which exhibited historically high concentrations at station ELR-2 but low concentrations at station ELR-1), and several major ions (particularly sulphate, but also all major cations), which exhibited higher concentrations at station ELR-2 than station ELR-1 (Figure 5.8-3).

Comparison of Water Quality Measurement Endpoints to Water Quality Guidelines In fall 2007, the concentration of total aluminum exceeded the CCME guideline at both stations; concentrations of total aluminum in fall 2007 were very near the median of previously-measured concentrations (Table 5.8-3, Table 5.8-4). Total dissolved phosphorus exceeded the guideline concentration at upper station ELR-2 in fall 2007 (Table 5.8-4), but not at lower station ELR-1 (Table 5.8-3).

Other Water Quality Guideline Exceedances Concentrations of the following other water quality variables exceeded guidelines in the Ells River watershed in 2007 (Table 5.8-5):

- ELR-1 in fall: Total iron at both the mouth of the Ells River (station ELR-1) and upstream Ells River (station ELR-2) in fall 2007 and total phenols and total dissolved phosphorus at upstream Ells River station;

- ELR-2 in spring: Total mercury, total phosphorus, total iron, total copper, total phenols, total cadmium, and total lead;

- ELR-2 in summer: Total iron, and total phenols at upstream Ells River (station ELR-2) in summer 2007; and

- ELR-2 in fall: Total iron, total phenols, and total dissolved phosphorus.

Comparison of Water Quality Measurement Endpoints to Natural Variation in Baseline Conditions Concentrations of selected water quality measurement endpoints were generally within the 5^{th}-to-95^{th} percentile range of regional baseline concentrations at both Ells River stations in fall 2007, although ion concentrations were within the lower end of this range at both stations, as has been the case for most ion measurement endpoints since sampling began at these stations (Figure 5.8-3). Concentrations of sodium and sulphate were below the 5th percentile of regional baseline values at upstream station ELR-2.

Ion Balance Ion balance at stations ELR-1 and ELR-2 was generally similar between stations in fall 2007, and similar to previous years, although station ELR-2 had higher relative concentrations of calcium and bicarbonate in 2007 relative to previous years (Figure 5.8-4).

Summary Water quality in the Ells River, as measured at the mouth of the Ells River (station ELR-1) and upstream Ells River (station ELR-2) was similar in 2007 to water quality at these stations in previous years.

5.8.4 Benthic Invertebrate Communities and Sediment Quality

5.8.4.1 Benthic Invertebrate Communities

In fall 2007, 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).

2007 Habitat Conditions Fall 2007 habitat conditions in reach ELR-D-1 near the mouth of the Ells River were typical of depositional habitats in the RAMP FSA, with fine-grained sediments (primarily sand, 77%), shallow water (0.4 m) and high dissolved oxygen concentrations (> 10 mg/L; Table 5.8-6). Total organic carbon content of the sediments 0.4%, which is below concentrations considered detrimental to benthic macroinvertebrates (1%, Persaud et al., 1996).

Relative Abundance of Benthic Invertebrate Community Taxa in 2007 Reach ELR-D-1 near the mouth of the Ells River in fall 2007 was numerically dominated by chironomids (52%), ostracods (18%) and tubificid worms (18%) (Table 5.8-7); this was expected given the dominance of sand in the reach sediments (Table 5.8-6). Sub-dominant taxa included Ceratopogonidae (biting midges, 7%) and naidid worms. The mayfly *Leptophlebia* and the dragonfly *Ophiogomphus* were two of the more sensitive genera present in the reach ELR-D-1 in fall 2007. *Oecetis* was the dominant caddisfly, while *Procladius*, *Paralauterborniella*, *Polypedilum*, *Micropsectra*/*Tanytarsus* and *Stempellinella* were the more common chironomids. At approximately 10,000 individuals per m², the total number of organisms was about equal to the long-term average (Table 5.8-7). Richness (i.e., number of taxa), diversity, and evenness were the highest measured in fall 2007 as compared to previously-measured values (Table 5.8-7).

Comparison of Benthic Invertebrate Community Measurement Endpoints to Natural Variations in Baseline Conditions Benthic invertebrate community abundance, number of taxa and the various measures of diversity have remained relatively consistent since the first benthic invertebrate survey of reach ELR-D-1 in 2003 (Figure 5.8-5).

5.8.4.2 Sediment Quality

Sediment quality was sampled in reach ELR-D-1 in fall 2007, the reach where benthic invertebrate communities were sampled near the mouth of the Ells River.

2007 Results and Historical Ranges of Concentration Fall 2007 data were compared with fall 2006 data from the reach ELR-D-1 and with historical data from the nearest sediment quality sampling location in the Ells River watershed prior to 2006, station ELR-1.

Similar to previous years, sediments in the lower Ells River were dominated by sand, with a relatively small proportion of fines, and low total organic carbon (Table 5.8-8). Concentrations of most sediment quality measurement endpoints in fall 2007 at reach ELR-D-1 were within historical ranges with the exception of total organic carbon, CCME Fraction 2, 3 and 4 hydrocarbons, and naphthalene, all of which were below their historically-measured minima at this station (Table 5.8-8).

All hydrocarbons present were in heavier fractions (i.e., Fractions 2 to 4); no CCME Fraction 1 hydrocarbons or BTEX (benzene, toluene, ethylene, xylene) were detected. Total PAH concentration was within the historical range previously measured in this reach; dibenzothiophenes comprised approximately one-third of all PAHs, suggesting a petrogenic (bitumen) source of these PAHs (Brewer *et al.* 1998).

Comparison to Sediment Quality Guidelines The concentration of CCME Fraction 3 hydrocarbons was above sediment quality guidelines at reach ELR-D-1 in fall 2007. All other sediment-quality variables were within relevant guidelines.

5.8.4.3 Summary

Benthic invertebrate community measurement endpoints in fall 2007 were at similar levels similar to previous years, and sediment quality measurement endpoints were generally within or below historical ranges.

5.8.5 Fish Populations

2007 RAMP Fish Population component activities in the Ells River watershed consisted of longnose dace sentinel species monitoring in summer and fall at two sites (lower and upper) on the river. Longnose dace sentinel species monitoring was last conducted on the Ells River in 2005 (RAMP 2006).

5.8.5.1 Field Sampling Results

In situ water quality measurements including dissolved oxygen (8.5 to 10.4 mg/L), conductivity (228 to 245 μS/cm), and pH (7.5 to 8.4) indicated suitable fish conditions at both reaches during both summer and fall sampling. Mid-afternoon temperatures recorded during summer sampling ranged between 18.7ºC (lower site) and 19.1ºC (upper site), while temperatures in the fall were between 5.2ºC (upper site) and 5.4ºC (lower site).

The lower site was characterized by meandering river sections, mainly riffle habitat (~65%), a gradient of approximately 1%, and a wetted width ranging from 32 to 42 m. The upper site was also characterized by meandering river sections, greater amounts of glide habitat, a similar gradient (1%), and a wetted width ranging from 15 to 25 m. Signs of spring flooding were apparent in both reaches.

Substrate in the lower site was dominated by gravel, with large numbers of boulders, while substrate in the upper site was dominated by a mix of gravel, cobble, and sand; both reaches contained a large number of overlying boulders. Both reaches were characterized by significant amounts instream vegetation (vascular, algae) and trace amounts of woody debris. Some islands were present at the upper site but were absent at the lower site. Riparian vegetation was mixed at both reaches, and included shrubs, sedges, grasses, and deciduous trees.

During both sampling periods, smaller longnose dace were typically found to prefer a depth range of approximately 0.25 to 0.5 m, moderate flows closer to the center of the river, and sand/gravel substrate with some overlying larger substrate (i.e. boulders, some vegetation, or woody debris).

Target numbers of longnose dace (minimum of 100 fish) were collected in each reach during both the summer and fall sampling periods (Table 5.8-9). More electrofishing effort was required in order to achieve the target number of fish during the fall sampling period relative to the summer program. Accordingly, catch-per-unit-effort (CPUE) was much lower during the fall sampling period (1.92 to 2.43 fish/100 s) than the summer sampling period (4.65 to 8.96 fish/100 s) (Table 5.8-9).

5.8.5.2 Population Distribution

Length-frequency distributions for Ells River longnose dace populations were not significantly different between either sites or seasons (

Table 5.8-10, Figure 5.8-6, Figure 5.8-7). This is in contrast to 2005 results in which there were significant differences in longnose dace length-frequency distributions between sites in both seasons as well as between seasons in the lower site (RAMP 2006).

The population distribution at both sites for both seasons in 2007 was characterized by common dominant length classes from 20 mm to 40 mm (Figure 5.8-8, Figure 5.8-9). This is a narrower range of dominant size classes (up to 60 mm) than what was measured in 2005 (RAMP 2006).

5.8.5.3 Growth

Growth is typically evaluated by measuring the magnitude of change in size (i.e., length) of the young-of the-year (YOY) cohort, if present, as it increases in size from one season to the next. However, longnose dace are known to produce multiple clutches between May and early August each year (Nelson and Paetz 1992, Joynt and Sullivan 2003), which makes it challenging to classify YOY size using the typical method of identifying a distinct length-frequency cohort. In 2007, there were several length-frequency cohorts among the smaller size ranges, with the 40 mm size class generally being the largest in both summer and fall (Figure 5.8-8, Figure 5.8-9). Therefore, for both sites and seasons, the YOY size cohort was estimated to range from 16 mm (the estimated length of the smallest catchable fish) to 40 mm.

In 2007, within-site length-frequency distributions were not significantly different between summer and fall (

Table 5.8-10, Figure 5.8-8, Figure 5.8-9) indicating that there was no appreciable growth between sampling events. The amount of time between sampling events (six weeks, August 19 to October 1, 2007) may have been too short to allow for detectable growth. Given the absence of significant shifts in sizes from summer to fall, mean YOY length and weights (Table 5.8-11) were not statistically compared between seasons, and growth rates were not estimated.

There was no observed consistent seasonal trend in proportion of YOY at either site, with the percentage of YOY of the total longnose dace population ranging between 63% and 77% (Table 5.8-12). It is therefore not possible to draw conclusions about reproductive performance and short-term survival of the population over time. The proportion of YOY was less at the lower site (Table 5.8-12); this was also observed in 2005 (RAMP 2006), but the reasons for this are unknown.

5.8.5.4 Condition

Condition factor (length-weight relationship) of longnose dace (all size classes) was significantly different between sites during both seasons, with condition being lower at the lower site compared to the upper site in both summer (p = .001, Figure 5.8-10) and fall (p = .007, Figure 5.8-11)[1]. The condition factor of YOY longnose dace was also significantly different between sites during both seasons, with condition also being lower at the lower site compared to the upper site in both summer (p < .0001, Figure 5.8-12) and fall (p = .003, Figure 5.8-13). This is in contrast to 2005 results when condition was significantly higher at the lower site during both seasons for all longnose dace and for YOY (RAMP 2006).

5.8.5.5 Discussion

2007 was the second year sentinel monitoring was conducted on the Ells River using longnose dace. In 2007, much greater success was achieved in collecting the target sample size of 100 fish per site per season relative to 2005 (RAMP 2006), although catch-per-unit-effort was again substantially lower during the fall in both years. However, in both years difficulties were experienced in identifying a distinct young-of-the-year cohort and hence estimating variables related to recruitment and growth. Evaluating changes in longnose dace populations using size-frequency analysis is challenging because longnose dace are fractional spawners and will typically lay eggs multiple times within the open water season (reference). Accordingly, distinctions among smaller size classes are difficult to identify as new cohorts are recruited into the population. This represents a significant limitation to using longnose dace as a sentinel species for the Ells River; however, no other alternate species was identified during reconnaissance surveys conducted in 2005 (RAMP 2006). It is also possible that discrimination of the YOY cohort was made more difficult given the shortness of the period between the summer and fall sampling events in both years.

If sentinel monitoring on the Ells River using longnose dace is to be continued, other procedures may need to be considered to facilitate the size-frequency analyses including:

- Marking individual fish and/or conducting monitoring prior to the onset of spawning season in May to more accurately isolate and track a single YOY cohort over time;
- Identify and track the 1+ cohort in an effort to distinguish it from the YOY cohort (longnose dace may live 4-5 y [Nelson and Paetz 1992]); and
- Increase the length of time between summer and fall sampling events to increase the spread in size classes due to growth.

5.8.5.6 Impact Analysis

Based on condition factor, YOY longnose dace from the lower site were 23% and 18% “thinner” relative to fish at the upper site in summer and fall, respectively (Table 5.8-11). Both of these differences in mean condition exceed the Environment Canada impact criterion of ± 10% (Environment Canada 2002, 2005). These results are in contrast to the 2005 results in which longnose dace condition was higher at both the lower and upper site for both seasons (RAMP 2006).

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[1] For both the all-size-class and YOY comparisons, the slopes of the length-weight relationships were not significantly different between sites for either season (p > 0.1 in all cases).

Comparatively, condition factor of captured adult longnose dace (length ≥ 55 mm as designated in McPhail [2007]) indicated that fish from the lower site were 20% and 6% "thinner" relative to fish at the upper site in summer and fall, respectively. The difference in mean summer adult condition factor exceeds the Environment Canada impact criterion of (Environment Canada 2002, 2005) (Table 5.8-13). Differences observed in summer may be related spawning, given early August is the end of the longnose dace spawning season.

5.8.5.7 Summary Assessment for Ells River Sentinel Species Monitoring

Results from the 2007 Ells River sentinel species program with longnose dace showed no consistent differences in population survival or growth between sites or seasons. There were differences in condition factor in the lower site as compared to the upper site measured in 2007 that exceeded accepted impact criteria (Environment Canada 2002, 2005); these differences were noted for YOY in both seasons and adults in the summer season. The site differences in adult condition factor were not consistent and did not exceed accepted impact criteria in the fall season. There are no consistent differences in Ells River longnose dace population survival, growth, or condition factor between years (i.e., 2007 vs. 2005). Given the variability observed under reference conditions and challenges experienced in conducting particular analyses, use of longnose dace sentinel monitoring in the Ells River requires further refinement prior to being used when parts of the Ells River watershed become designated as *potentially influenced*.

5.8.6 Summary of 2007 Conditions in the Ells River Watershed

Conditions in the Ells River in 2007 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 2007 have been negligible. Water quality conditions were similar in 2007 to water quality conditions in previous years. Values of benthic invertebrate community measurement endpoints were generally consistent with values measured in previous years at the same locations in the watershed, and values of most sediment quality measurement endpoints were within the range of previously-measured values for the watershed. Results of a second year of Ells River sentinel species monitoring using longnose dace indicate high variability in population survival, growth, and condition between different parts of the Ells River watershed in different seasons and years.

Figure 5.8-2 Ells River: 2007 hydrograph and historical context.

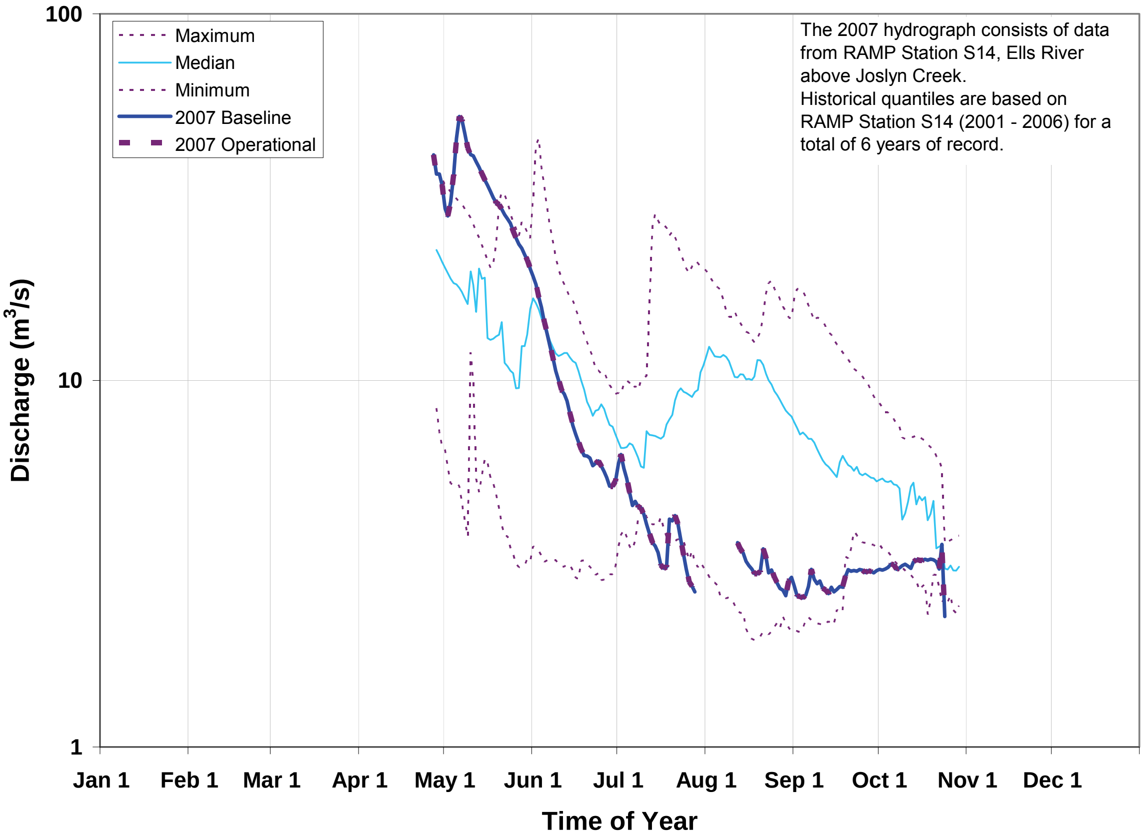


Table 5.8-1 Summary of inputs to the calculation of the Ells River baseline hydrograph at RAMP Station S14, Ells River above Joslyn Creek.

Component	Seasonal Volume (million m^3)	Basis and Data Source
Observed hydrograph (total discharge during 2007 data record)	205	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 2007	+ 0.075	0.87 km^2 within Ells River watershed estimated to have been closed-circuited by focal projects as of 2007 (Table 2.6-1)
Incremental runoff from areas of land change that were not closed-circuited as of 2007	- 0.024	1.46 km^2 within Ells River watershed estimated to have undergone land change by focal projects of 2007, 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)	205	Estimated total annual baseline discharge (i.e., without focal projects or other oil sands projects) for 2007
Incremental flow (change in total annual discharge)	- 0.051	Total annual discharge from operational hydrograph less total annual discharge of estimated baseline hydrograph
Incremental flow (% of observed total annual discharge)	- 0.03%	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.

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

Table 5.8-2 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	9.97	9.96	-0.03%
Mean winter discharge	not measured	not measured	
Annual maximum daily discharge	52.5	52.5	-0.02%
Open-water season minimum daily discharge	2.55	2.55	-0.03%

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 5.8-3 Concentrations of water quality measurement endpoints, mouth of Ells River (station ELR-1), fall 2007.

Measurement Endpoint	Units	Guideline	September 2007	1997-2006 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.2	6	7.8	8.15	8.4
Total suspended solids	mg/L	-[1]	3	6	5	6.5	16
Conductivity	µS/cm	-	272	6	175	211.5	258
Nutrients							
Total dissolved phosphorus	mg/L	0.05[2]	0.008	6	0.003	0.008	0.020
Total nitrogen*	mg/L	1.0	0.6	6	0.3	0.575	0.9
Nitrate+nitrite	mg/L	-	<0.1	6	<0.05	<0.1	<0.1
Dissolved organic carbon	mg/L	-	15	6	11	12	15
Ions							
Sodium	mg/L	-	17	6	8	10	18
Calcium	mg/L	-	29.3	6	21.6	24.55	30.4
Magnesium	mg/L	-	8.9	6	6.5	7.55	9.1
Chloride	mg/L	230, 860[3]	3	6	<0.5	2	4
Sulphate	mg/L	100[4]	23.5	6	10.5	16.55	27.9
Total dissolved solids	mg/L	-	166	6	110	150	220
Total alkalinity	mg/L	-	117	6	76	92	111
Organic compounds							
Naphthenic acids	mg/L	-	<1	6	<1	<1	3
Selected metals							
Total aluminum	mg/L	0.1	**0.264**	6	0.060	**0.2595**	**0.673**
Dissolved aluminum	mg/L	0.1[2]	0.0206	6	0.0077	0.0155	0.078
Total arsenic	mg/L	0.005	0.000743	6	0.0005	0.000928	0.00113
Total boron	mg/L	1.2[5]	0.0834	6	0.0410	0.05605	0.0784
Total molybdenum	mg/L	0.073	0.000722	6	0.00064	0.00074	0.00084
Total mercury (ultra-trace)	ng/L	5, 13[6]	<1.2	4	<1.2	<1.2	<1.2
Total strontium	mg/L	-	0.14	6	0.095	0.1145	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 5.8-4 Concentrations of water quality measurement endpoints, upper Ells River (station ELR-2), fall 2007.

Measurement Endpoint	Units	Guideline	September 2007	1997-2006 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.1	3	7.7	7.8	8.1
Total suspended solids	mg/L	-[1]	6	3	<3.0	4.0	4
Conductivity	µS/cm	-	173	3	164	185	195
Nutrients							
Total dissolved phosphorus	mg/L	0.05[2]	**0.061**	3	0.004	0.009	0.017
Total nitrogen*	mg/L	1.0	0.6	3	0.6	0.7	0.8
Nitrate+nitrite	mg/L	-	<0.1	3	<0.1	<0.1	<0.1
Dissolved organic carbon	mg/L	-	14	3	10	13	16
Ions							
Sodium	mg/L	-	3	3	6	8.0	13
Calcium	mg/L	-	24.5	3	20.5	22.3	24.8
Magnesium	mg/L	-	7	3	6.2	6.9	7.2
Chloride	mg/L	230, 860[3]	2	3	2	2.0	3
Sulphate	mg/L	100[4]	2.2	3	10.8	10.8	18.9
Total dissolved solids	mg/L	-	116	3	110	130	190
Total alkalinity	mg/L	-	91	3	73	84	110
Organic compounds							
Naphthenic acids	mg/L	-	<1	3	<1	<1	1
Selected metals							
Total aluminum	mg/L	0.1	**0.26**	3	0.052	**0.3**	**0.735**
Dissolved aluminum	mg/L	0.1[2]	0.0255	3	<0.0002	0.013	0.0153
Total arsenic	mg/L	0.005	0.000697	3	0.000619	0.0009	0.0011
Total boron	mg/L	1.2[5]	0.0795	3	0.0405	0.046	0.0836
Total molybdenum	mg/L	0.073	0.000686	3	0.00065	0.001	0.00082
Total mercury (ultra-trace)	ng/L	5, 13[6]	<1.2	3	<1.2	<1.2	<1.2
Total strontium	mg/L	-	0.137	3	0.094	0.1	0.11

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 5.8-5 Water quality guideline exceedances, Ells River watershed, 2007.

Water Quality Variable	Units	Guideline*	ELR-1	ELR-2
Spring				
Sulphide	mg/L	0.014[1]	ns	**0.017**
Total phosphorus	mg/L	0.05	ns	**0.293**
Total aluminum	mg/L	0.1	ns	**8.3**
Total iron	mg/L	0.3	ns	**9.68**
Total copper	mg/L	-[2]	ns	**0.00729**
Total phenols	mg/L	0.005	ns	**0.005**
Total cadmium	mg/L	-[2]	ns	**0.0000938**
Total lead	mg/L	-[2]	ns	**0.006**
Summer				
Total aluminum	mg/L	0.1	ns	**0.178**
Total iron	mg/L	0.3	ns	**0.39**
Total phenols	mg/L	0.004	ns	**0.007**
Fall				
Total aluminum	mg/L	0.1	**0.264**	**0.26**
Total iron	mg/L	0.3	**0.49**	**0.396**
Total phenols	mg/L	0.005	-	**0.007**
Total dissolved phosphorus	mg/L	0.05	**-**	**0.061**

ELR-1 sampled only in fall 2007. No winter sampling was conducted in this watershed.

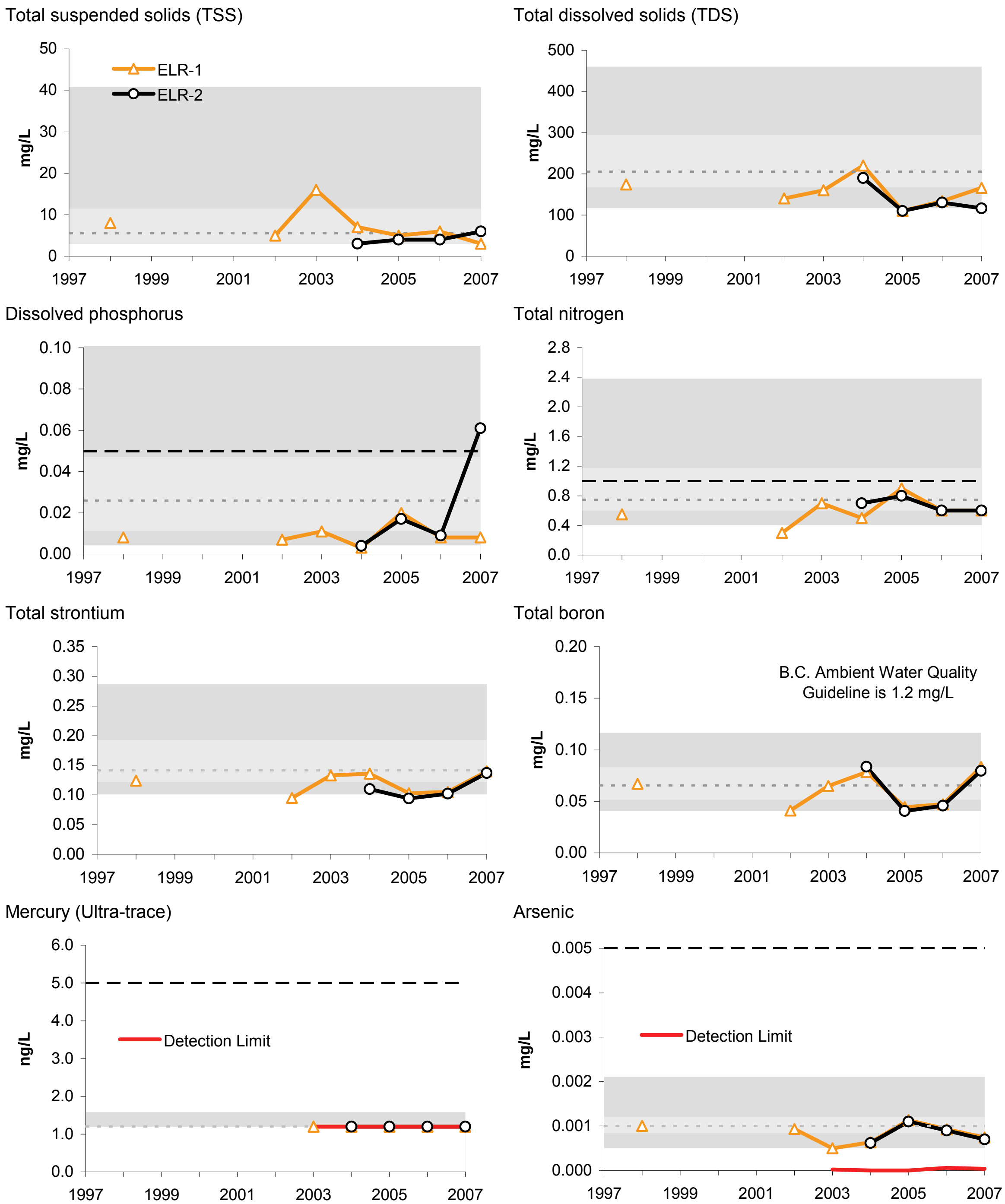
ns = not sampled

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

[1] Derived from EPA (2002).

[2] Guideline is hardness-dependent.

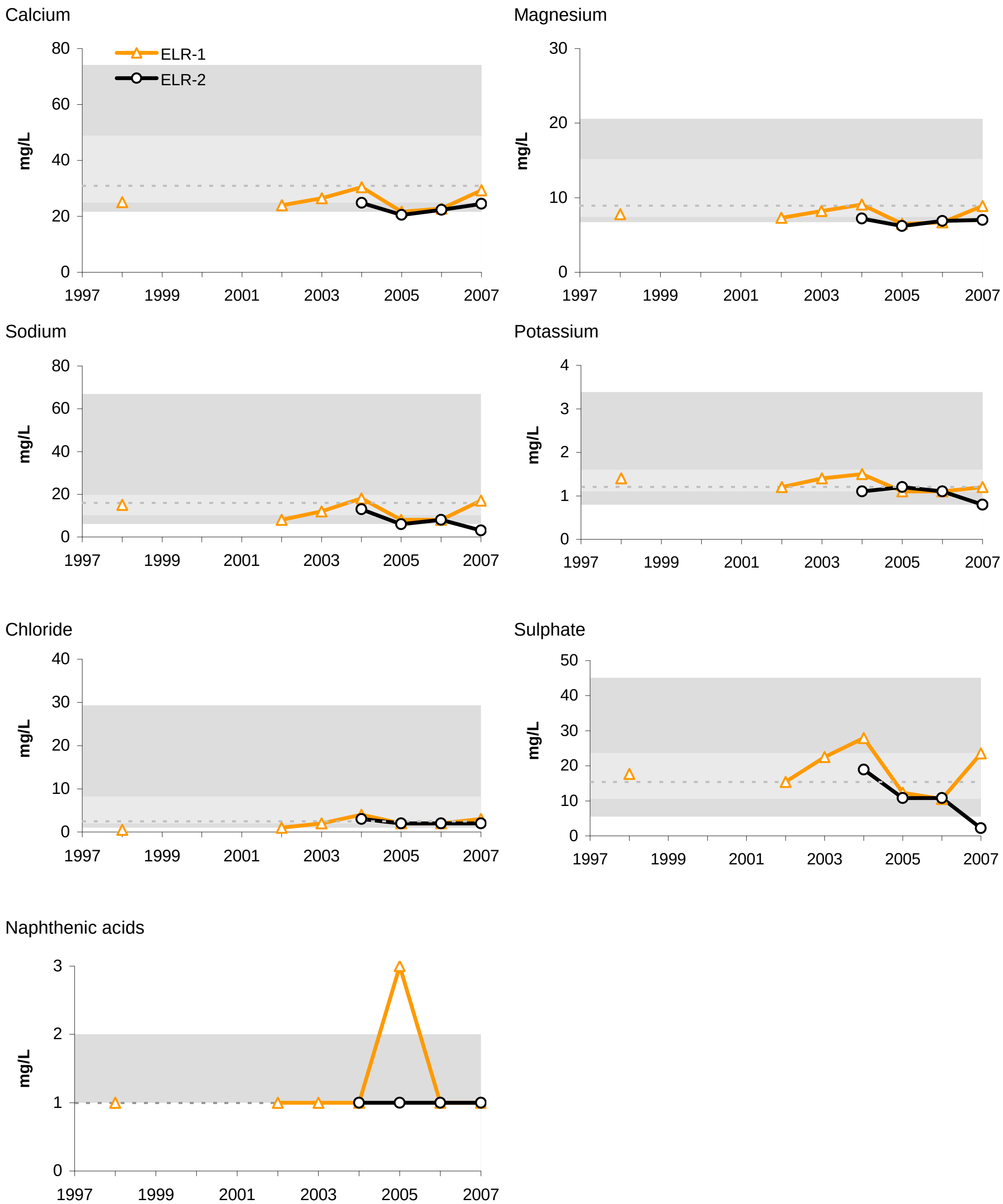
Figure 5.8-3 Selected water quality measurement endpoints in the Ells River (fall data) relative to regional baseline fall concentrations.



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 5.8-3 (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 Ells River watershed.

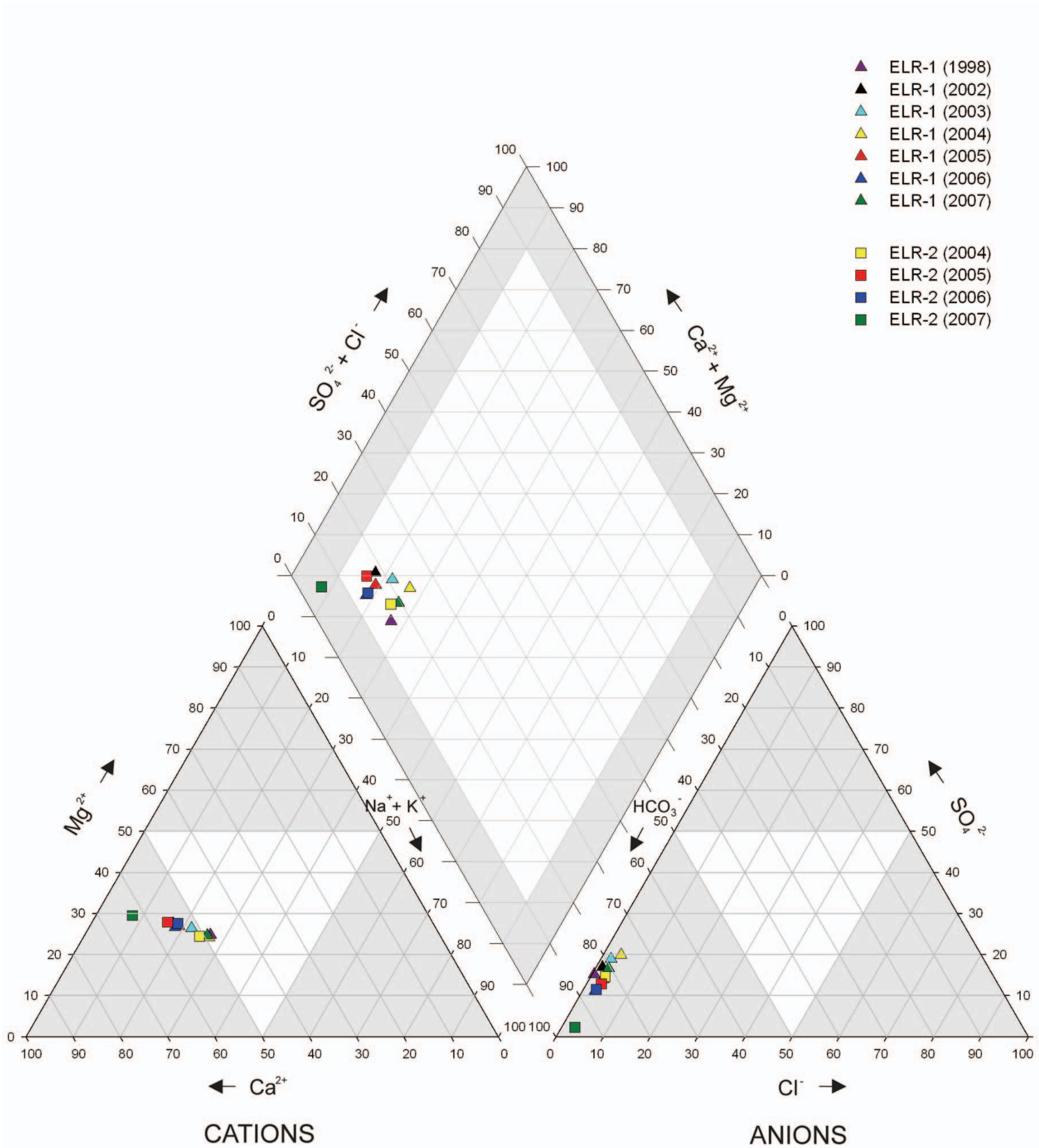


Table 5.8-6 Average habitat characteristics of benthic invertebrate sampling reaches in the Ells River, fall 2007.

Variable	Units	Reach ELR-D-1 Lower Reach of the Ells River
Sample date	-	Sept 7, 2007
Habitat	-	Depositional
Water depth	m	0.4
Current velocity	m/s	0.1
Macrophyte cover	%	36
Field Water Quality		
Dissolved oxygen	mg/L	10.8
Conductivity	µS/cm	246
pH	pH units	9.7
Water temperature	°C	16.6
Sediment Composition		
Sand	%	77
Silt	%	15
Clay	%	8
Total Organic Carbon	%	0.4

Table 5.8-7 Relative abundance of major taxa, and benthic invertebrate community measurement endpoints in the Ells River, fall 2007.

Taxon	Percent Major Taxa Enumerated in Each Year				
	Reach ELR-D-1				
	2003	2004	2005	2006	2007
Anisoptera	<1	<1	<1	<1	<1
Athericidae			<1		
Bivalvia	<1	<1			<1
Ceratopogonidae	3	5	1	5	7
Chironomidae	19	32	17	56	52
Coleoptera		<1			<1
Copepoda	<1				<1
Empididae	<1	<1	<1	2	1
Enchytraeidae		<1			
Ephemeroptera	<1	<1	<1	1	1
Gastropoda	<1	<1			1
Heteroptera	<1				
Hydracarina	<1	<1		1	1
Lepidoptera					
Megaloptera					
Naididae	24	2	17	4	2
Nematoda	<1	2	<1	3	1
Ostracoda		<1	5		18
Plecoptera				<1	
Simuliidae			2		1
Tabanidae	<1	1	<1	<1	
Tipulidae		<1			
Trichoptera	<1	<1			<1
Tubificidae	52	55	57	28	18
Zygoptera		<1			
Benthic Invertebrate Community Measurement Endpoints					
Total Abundance (No./m^2)	30,917	11,129	12,939	8,690	10,315
Richness	12	10	9	10	15
Simpson's Diversity	0.69	0.65	0.47	0.71	0.77
Evenness	0.76	0.73	0.64	0.72	0.85
% EPT	1	1	<1	<1	<1

Figure 5.8-5 Annual variation in benthic invertebrate community measurement endpoints in the lower Ells River (reach ELR-D-1).

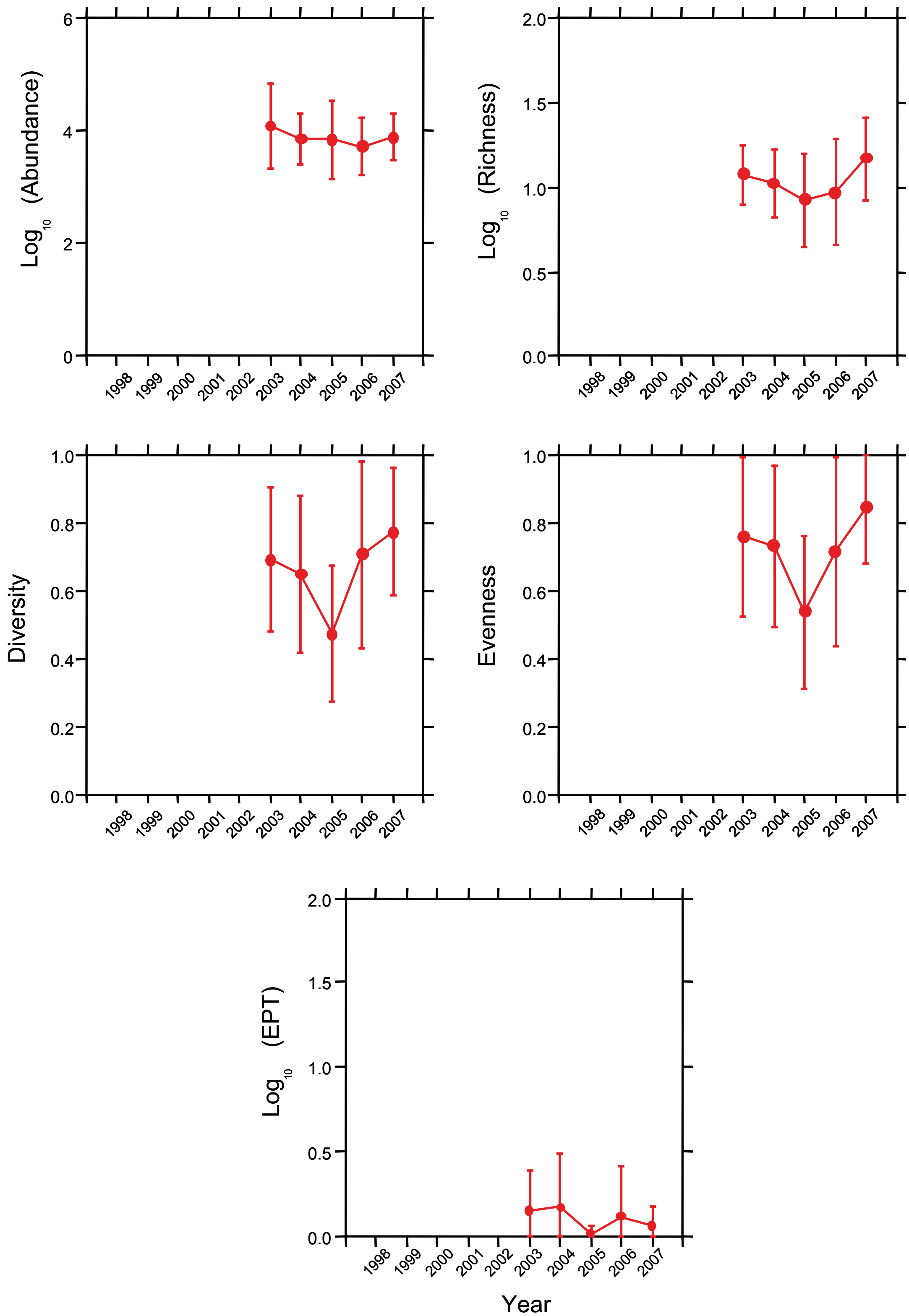


Table 5.8-8 Sediment quality measurement endpoints, lower reach of Ells River near the mouth (reach ELR-D-1), fall 2007.

Measurement Endpoint	Units	Guideline	September 2007	1997-2006 (fall data only, stations ELR-1, ELR-D-1)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	8.2	6	5	7	26
Silt	%	-	14.9	6	8	15.5	51
Sand	%	-	76.9	6	23	78.5	85
Total organic carbon	%	-	0.4	6	0.5	1.325	2.7
Total hydrocarbons							
BTEX	mg/kg	-	<5	3	<5	<5	<5
Fraction 1 (C6-C10)	mg/kg	30[2]	<5	3	<5	<5	<5
Fraction 2 (C10-C16)	mg/kg	150[2]	73	3	150	**310**	**320**
Fraction 3 (C16-C34)	mg/kg	400[2]	**890**	3	**1500**	**2300**	**3000**
Fraction 4 (C34-C50)	mg/kg	2800[2]	510	3	790	1300	1600
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[3]	0.000853	6	0.001	0.004	0.009
Retene	mg/kg	-	0.0956	6	0.067	0.212	0.293
Total dibenzothiophenes	mg/kg	-	4.91	6	1.28	5.64	9.88
Total PAHs	mg/kg	-	13.29	6	4.81	16.51	25.10
Total HMW PAHs	mg/kg	-	4.23	6	0.40	4.24	5.46
Total LMW PAHs	mg/kg	-	9.05	6	4.20	11.88	19.63
Predicted PAH toxicity[1]	H.I.	-	2.25	6	1.18	1.52	2.87
Metals that exceed CCME guidelines in 2007							
none	mg/kg	-		-	-	-	-
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	6	3	5	7	7
Chironomus growth - 10d	mg/organism	-	1	3	0.7	2.1	2.8
Hyalella survival - 14d	# surviving	-	8	3	8	9	10
Hyalella growth - 14d	mg/organism	-	0.1	3	0.1	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 Kow (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 5.8-9 Summary of catch per unit effort and morphometric data (mean ± 1 SE) for longnose dace on the Ells River, 2007.

Sampling Period	No. Fish Captured	Electrofishing Effort (s)	CPUE (No./100 s)	Length (mm)	Weight (g)	Condition Factor
Summer						
Lower Reach	104	1161 s	8.96	40.58 ± 1.46	0.821 ± 0.089	0.929 ± 0.025
Upper Reach	103	2217 s	4.65	37.61 ± 1.04	0.765 ± 0.067	1.232 ± 0.026
Fall						
Lower Reach	123	5065 s	2.43	39.80 ± 1.31	1.073 ± 0.139	1.232 ± 0.033
Upper Reach	115	6005 s	1.92	39.29 ± 1.64	1.299 ± 0.195	1.452 ± 0.062

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

Table 5.8-10 Kolmogorov-Smirnov statistical comparisons of longnose dace length-frequency distributions between sites and seasons, Ells River, 2007.

Comparison	*p*-value of Kolmogorov-Smirnov two-sample test
Between Reaches	
Summer	0.073
Fall	0.381
Between Seasons	
Lower Reach	0.417
Upper Reach	0.151

Figure 5.8-6 Cumulative length-frequency distributions for lower and upper sites, Ells River, summer 2007.

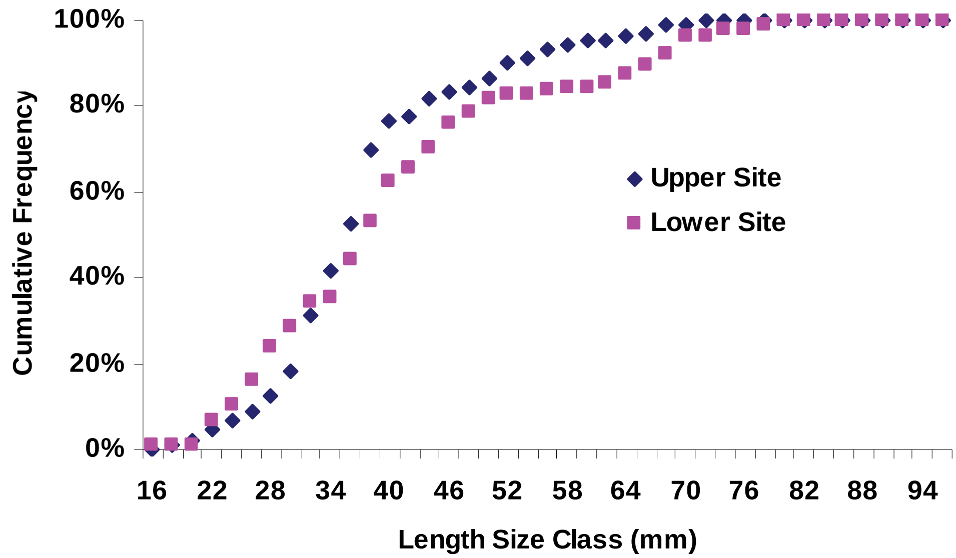


Figure 5.8-7 Cumulative length-frequency distributions for lower and upper sites, Ells River, fall 2007.

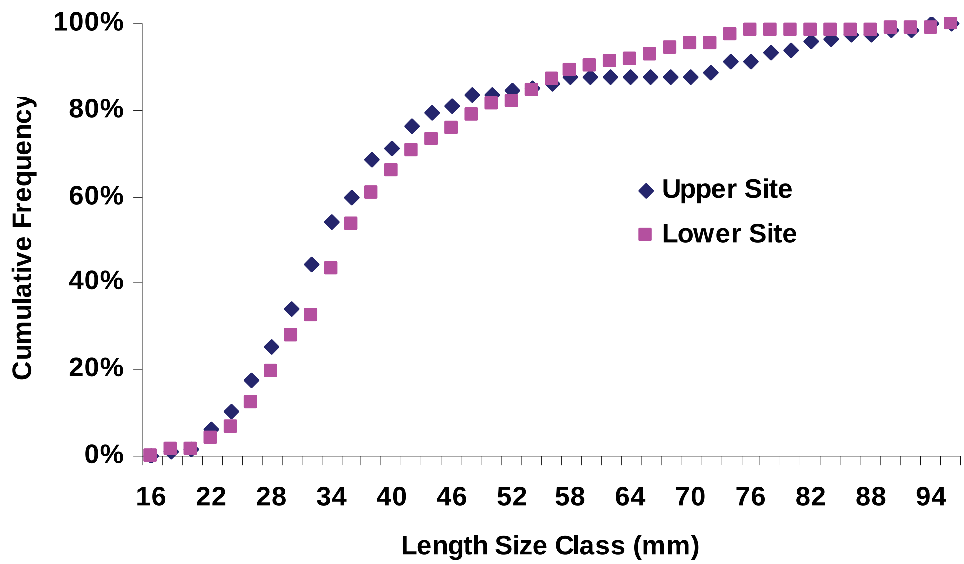


Figure 5.8-8 Relative length-frequency distributions of longnose dace from the upper site on the Ells River, summer and fall 2007.

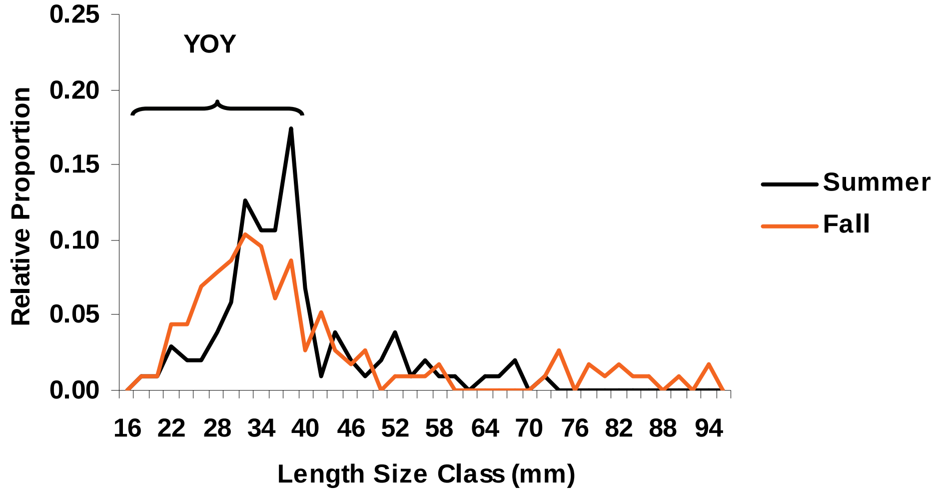


Figure 5.8-9 Relative length-frequency distributions of longnose dace from the lower site on the Ells River, summer and fall 2007.

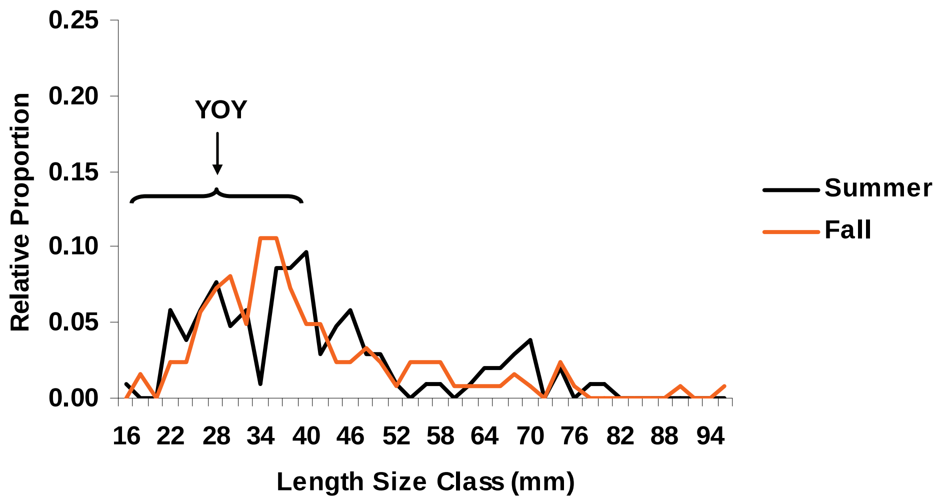


Table 5.8-11 Young-of-year (YOY) morphometrics (mean ± 1 SE) for longnose dace from the Ells River, 2007.

Season/Site	No. YOY Captured	Length (mm)	Weight (g)	Condition Factor
Summer				
Upper	79	32.94 ± 0.579	0.470 ± 0.020	1.273 ± 0.029
Lower	65	31.43 ± 0.779	0.330 ± 0.023	0.982 ± 0.037
Fall				
Upper	82	30.46 ± 0.573	0.447 ± 0.024	1.570 ± 0.083
Lower	81	31.52 ± 0.592	0.415 ± 0.021	1.285 ± 0.047

YOY: 16 mm to 40 mm; Condition Factor = (weight)/length^3) * 10^5

Table 5.8-12 Relative proportion of longnose dace populations represented by young-of-year, Ells River, 2007.

Season/Site	Total Caught	YOY Caught	% YOY
Summer			
Upper	103	79	77%
Lower	104	65	63%
Fall			
Upper	115	82	71%
Lower	123	81	66%

YOY: 16 mm to 40 mm

Figure 5.8-10 Condition factor for all longnose dace captured during sentinel species program on the Ells River, summer (August 19) 2007.

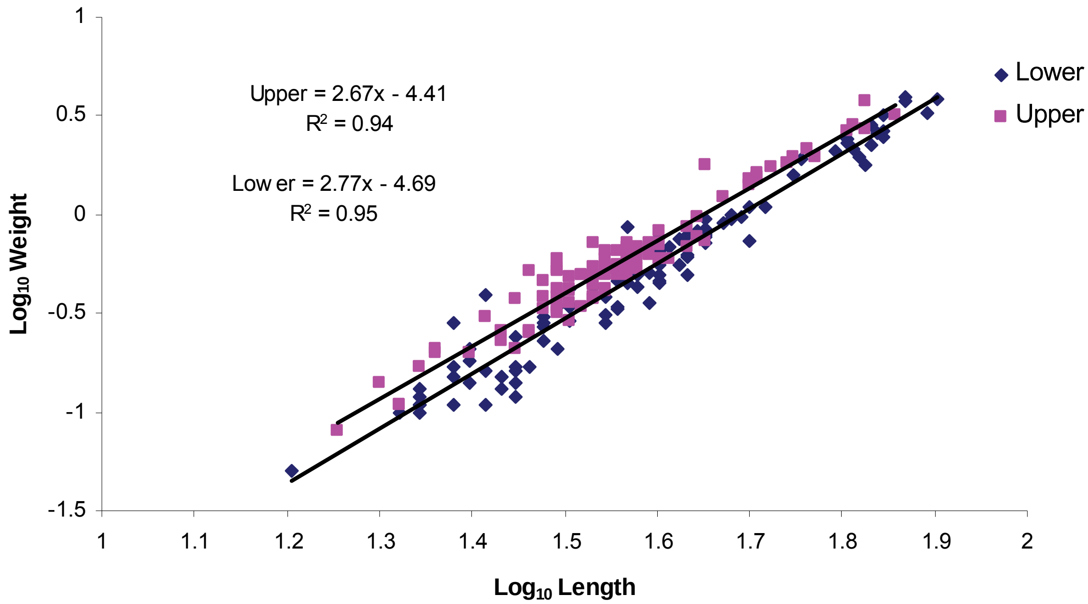


Figure 5.8-11 Condition factor for all longnose dace captured during sentinel species program on the Ells River, fall (October 1) 2007.

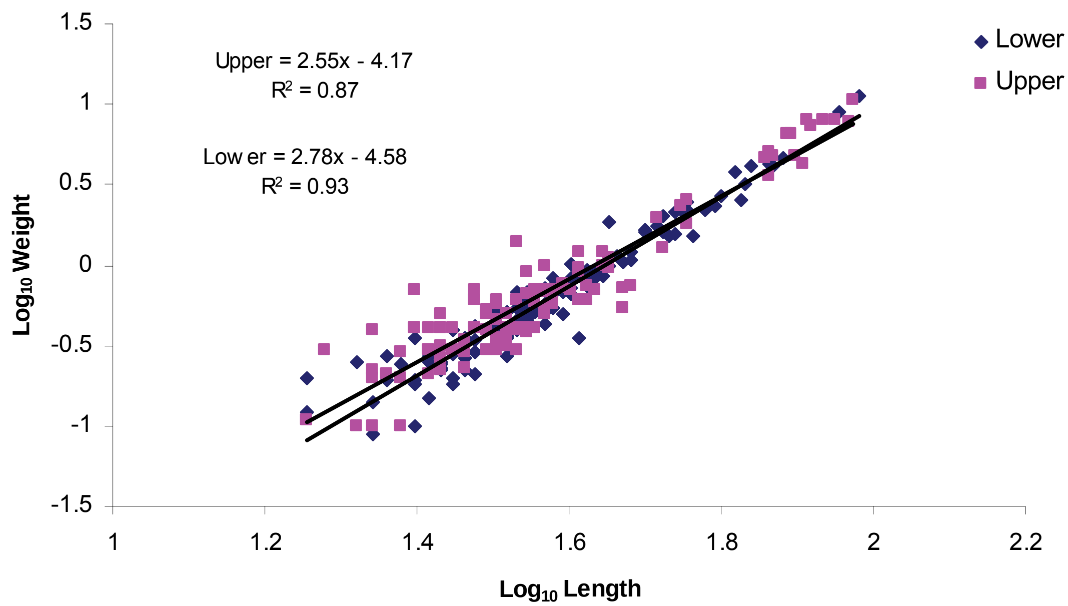


Figure 5.8-12 Condition factor for Ells River young-of-year longnose dace captured during the sentinel species program, August 2007.

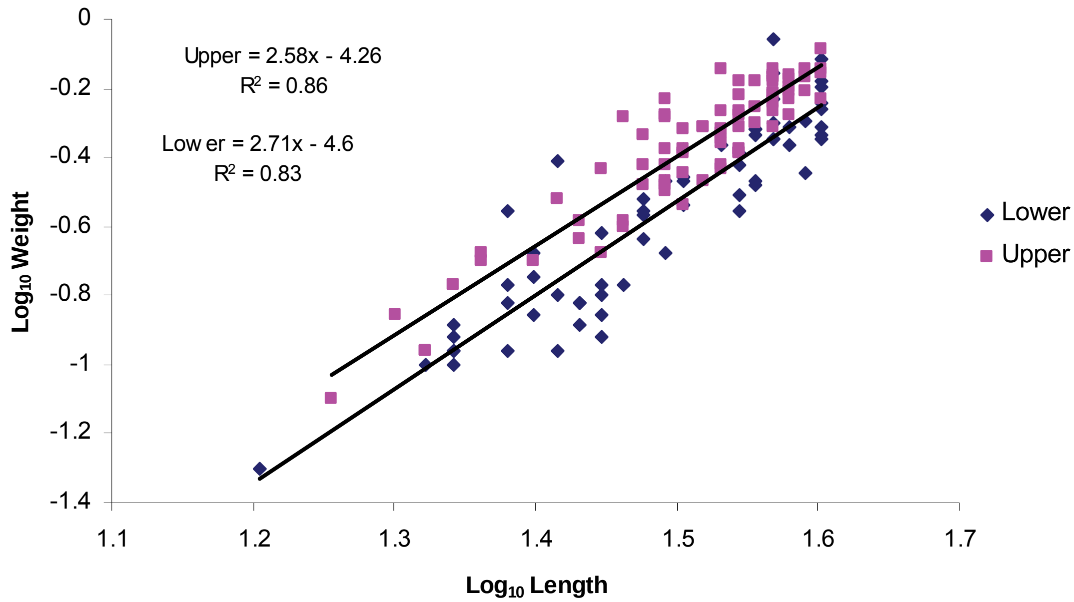


Figure 5.8-13 Condition factor for Ells River young-of-year longnose dace captured during the sentinel species program, October 2007.

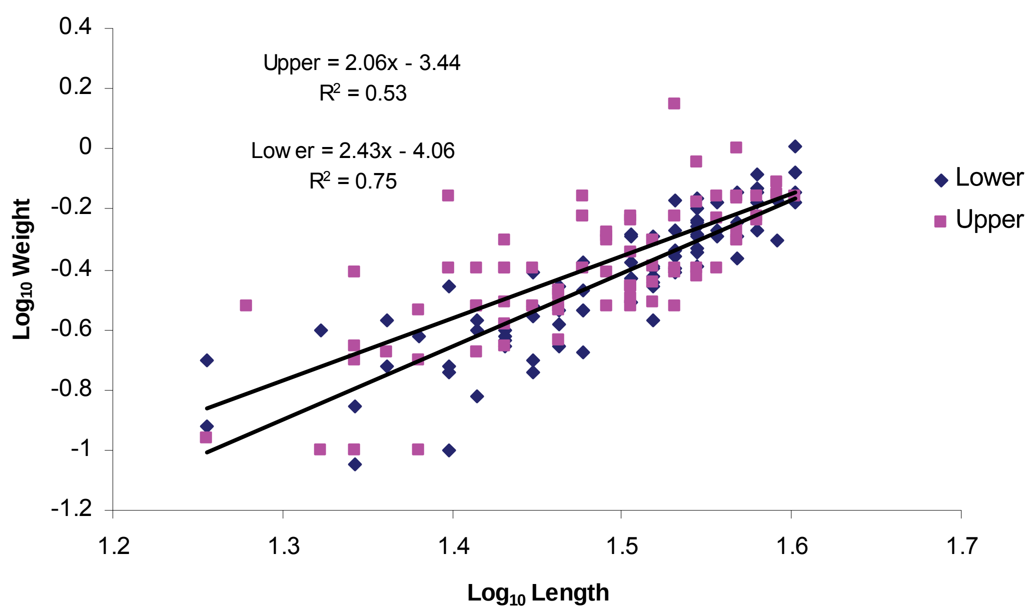


Table 5.8-13 Adult morphometrics (mean ± 1 SE) for longnose dace for the Ells River, summer and fall 2007.

Season/Site	No. Adults	Length (mm)	Weight (g)	Condition Factor
Summer				
Upper	9	62.6 ± 1.94	2.6 ± 0.22	1.037± 0.04
Lower	18	67.9 ± 1.49	2.6 ± 0.17	0.824 ± 0.028
Fall				
Upper	17	76.7 ± 2.82	5.7 ± 0.6	1.19 ± 0.047
Lower	19	67.1 ± 2.63	3.8 ± 0.57	1.12 ± 0.169

Adult: ≥ 55mm (McPhail 2007); Condition Factor = (weight)/length^3) * 10^5

5.9 CLEARWATER-CHRISTINA RIVER SYSTEM

Summary of Results

Measurement Endpoint	Summary of 2007 Conditions				
Climate and Hydrology					
	Assessment of Change				
	Negligible	**Low**	**Moderate**	**High**	Open-water season runoff in 2007 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 2007 Conditions		
Water Quality			
Guideline Exceedances	**Station-Endpoint Combinations Exceeding Guidelines in 2007[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 2007, were similar to water quality conditions in previous years. Station CHR-2A is less similar to the lower Christina River station than the previously sampled CHR-2, and therefore is not a more appropriate reference sampling location than this original upper Christina River station.
Measurement endpoints with guidelines	**2007 Potentially Influenced Stations (n=0)**	**2007 Reference Stations (n=5)**	
Physical variables (max=5)	No water quality sampling stations were designated as potentially influenced in 2007.	0	
Nutrients (max=10)		1	
Ions (max=10)		0	
Selected metals (max=30)		5	
Comparison to Regional Baselines	**Endpoints in 2007 Compared to Regional Baseline[2]**		
Percentile of Regional Baseline Values	**2007 Potentially Influenced Stations (n=0 stations X 15 endpoints)**	**2005 Reference Stations (n=5 stations X 15 endpoints)**	
Greater than 95th percentile	No water quality sampling stations were designated as potentially influenced in 2007.	5	
Between 5th and 95th percentiles		50	
Less than 5th percentile		0	

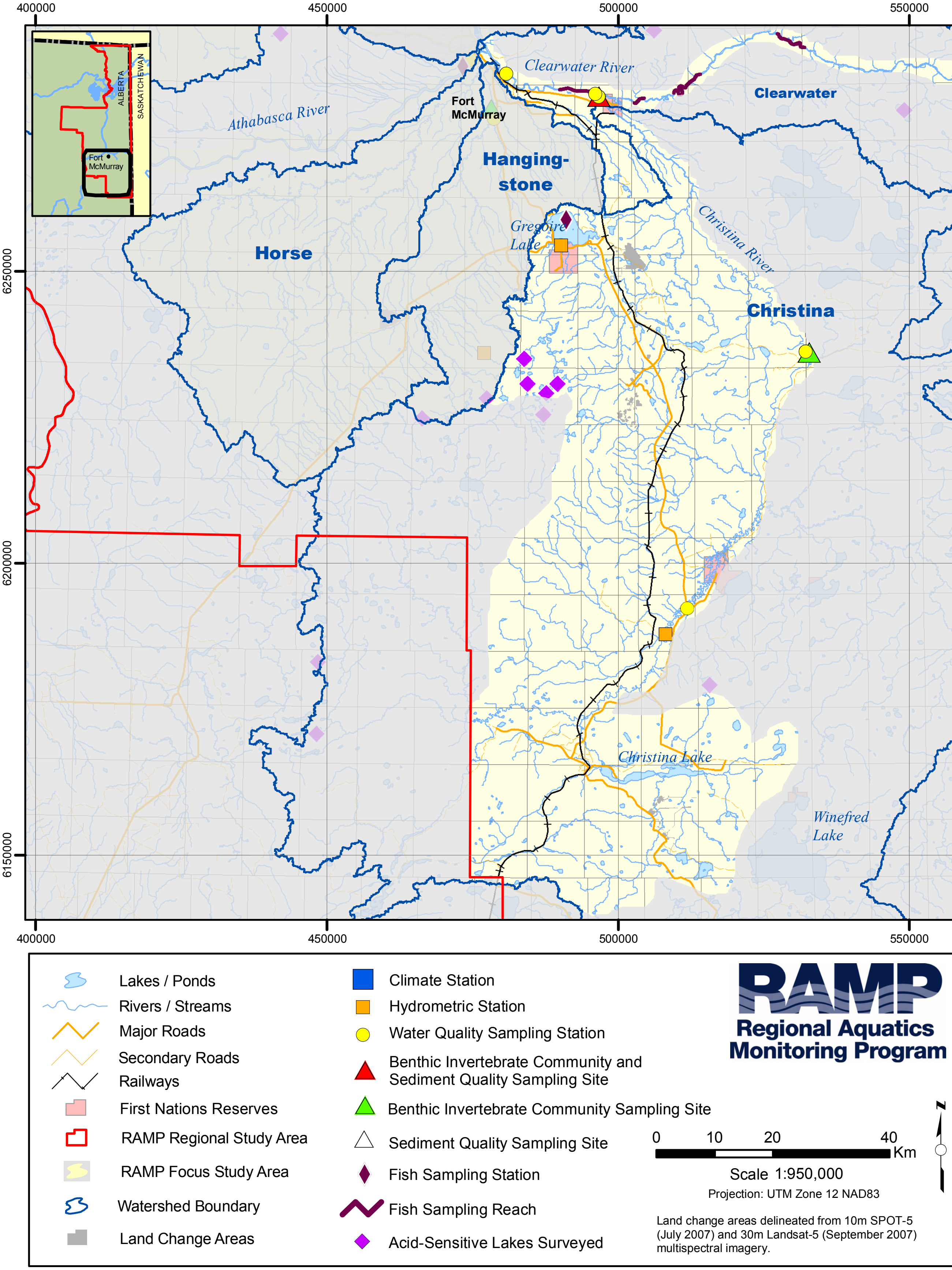
Measurement Endpoint	Summary of 2007 Conditions						
Benthic Invertebrate Communities and Sediment Quality							
Benthic Invertebrate Communities: Comparison to Regional Baselines	**Endpoints in 2007 Compared to Regional Baseline**						Benthic invertebrate community and sediment quality measurement endpoints in the Christina River watershed in fall 2007 continued to be within the normal range of regional baseline conditions for similar habitats in the Christina River watershed.
Values in Relation to Regional Baseline Mean	**2007 Potentially Influenced Sites (n=0)**			**2007 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 2007.				2		
Richness					2		
Diversity					2		
Evenness					2		
% EPT					2		
Sediment Quality Guideline Exceedances	**Station-Endpoint Combinations Exceeding Guidelines in 2007**						
Measurement endpoints with guidelines	**2007 Potentially Influenced Sites (n=0)**			**2007 Reference Sites (n=1)**			
Total Hydrocarbons (max = 4)	No sediment quality sampling locations were designated as potentially influenced in 2007.				1		
PAHs (max = 1)					0		

Measurement Endpoint	Summary of 2007 Conditions	
Fish Populations		
Fish Inventory	2007 results were generally similar to recent results with respect to length-frequency indicators, condition, and external health.	A fifth year of fish inventory work on the Clearwater River was conducted to expand the baseline dataset. Fish community composition, length-frequency relationships external fish health indices, and condition factors were similar to previous years. Mercury tissue concentrations in northern pike measured in 2007 are consistent with the natural range of concentrations observed in this region of northern Alberta.
Sentinel Studies	No sentinel fish studies conducted in 2007.	
Fish Tissue	**Level of Risk**	
Human Health: Subsistence Fishers	Results for northern pike indicate a risk to subsistence fishers characterized by 23% of fish analyzed with mercury concentrations exceeding Health Canada guidelines, and lower risk for recreational fishers and consumers (4% of sampled fish exceeding relevant guidelines). Concentrations of mercury in fish from the Clearwater River were compared to fish mercury concentrations from regional waterbodies; mercury levels in the Clearwater River northern pike were at the lower end of the range of waterbodies sampled. Concentrations of other metals, as well as tainting compounds, were below all relevant criteria, with the exception of arsenic, for which concentrations in all composite samples exceeded at least one USEPA guideline.	
Human Health: Recreational Fishers		
Human Health: Subsistence Consumers		
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 5.9-1 Clearwater-Christina River watershed.



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5.9.1 Development Status

As of 2007, 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 focal projects. Given this small cumulative land change area, all parts of the Christina River watershed are designated as *reference* for 2007. All RAMP water quality stations, benthic invertebrate community and sediment quality reaches, and fish population sampling sites in the Clearwater-Christina system in 2007 are designated as *reference* stations reaches, and sites, and all data gathered at these locations in 2007 are designated as baseline data. Accordingly, 2007 provides another opportunity to evaluate natural variability in baseline conditions for these RAMP aquatic resources in the Clearwater-Christina system.

5.9.2 Hydrologic Conditions

2007 Hydrologic Conditions Open-water season runoff in 2007 was slightly above normal in the Clearwater River basin as a whole at 76 mm, 5% above average. Most of the runoff occurred in spring, with flows in the upper quartile for over a month starting in mid-April (Figure 5.9-2). Following the wet spring, flows were below normal through most of June, all of July and the first half of August. In mid-August, the river rose in response to significant rainfall, and remained near normal for the rest of the year. The April peak of 500 m^3/s was 35% higher than the mean annual flood. The minimum open-water discharge on the Clearwater River was 75.6 m^3/s compared to the mean annual minimum discharge of 46.4 m^3/s.

In the Christina River basin, most of the flow in 2007 also occurred during the spring (Figure 5.9-3). Total runoff for the year was slightly above normal. Snowmelt runoff peaked in April at 104 m^3/s, slightly higher than the mean annual flood. The minimum open-water season discharge was 6.54 m^3/s, slightly above 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 2007. As indicated in Section 3.1.7.2, the hydrologic analysis, unlike most RAMP components, does not require comparison of measurement endpoints between *potentially influenced* and *reference* areas and can be conducted 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 2007 in the Christina River were estimated for two cases. The first case considered only 2007 focal projects; that is, those projects owned by 2007 RAMP funders which were under construction or operational in 2007 in the Christina River watershed. The second case considered all 2007 focal projects plus oil sands projects in the Christina River watershed that were under construction or operation in 2007, but were not owned by 2007 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 2007.

The results of the two cases are presented in Table 5.9-1. In the first case, focal projects only, it is estimated that a baseline hydrograph for 2007 for the Christina River would have 0.077 million m^3 more flow than a 2007 operational hydrograph; this is equivalent to 0.0058 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 2007 for the Christina River would have 0.379 million m^3 less flow than a 2007 operational hydrograph; this is equivalent to a reduction of 0.029 mm of runoff depth for the entire Christina River watershed.

5.9.3 Water Quality

In 2007, water quality was assessed in the Christina and Clearwater rivers at the following stations:

- The Clearwater River upstream of Fort McMurray in spring, summer and fall (station CLR-1, *reference*, baseline data available from 2001);
- The Clearwater River upstream of the Christina River confluence in the spring, summer and fall (station CLR-2, *reference*, baseline data available from 2001);
- The Christina River at the mouth in the winter and fall (station CHR-1, *reference*, baseline data available from 2002);
- The Christina River upstream of Janvier in the winter and fall (station CHR-2, *reference*, baseline data available from 2002); and
- The mid Christina River in the winter and fall (station CHR-2A, *reference*, baseline data available from 2007).

2007 Results and Historical Ranges of Concentration On the Clearwater River, concentrations of water quality measurement endpoints in fall 2007 were generally similar to historically-measured values (Table 5.9-2, Table 5.9-3). At station CLR-1, concentrations of total dissolved phosphorus, dissolved organic carbon, calcium, magnesium, and total alkalinity exceeded previously-measured maximum concentrations, while the concentration of dissolved aluminum was below its previously-measured minimum concentration at this station. At station CLR-2, concentrations of calcium, sulphate, total alkalinity, and total mercury exceeded previously-measured maximum concentrations, while the concentration of arsenic was below its previously-measured minimum concentration.

At the lower Christina River in fall 2007 (station CHR-1), concentrations of all water quality measurement endpoints were within historical ranges, except sodium, with a historically low concentration and total mercury, with a historically high concentration (Table 5.9-4). At the upper Christina River in fall 2007 (station CHR-2) in fall 2007, concentrations of total suspended solids, magnesium, sulphate, total boron, total molybdenum and total strontium were all below their previously-measured minimum concentrations (Table 5.9-5). The mid Christina River station (station CHR-2A) cannot be compared to historical values because 2007 was the first year that this station was sampled (Table 5.9-6).

Station CHR-2A was added in 2007 as a potential replacement for upper Christina station (station CHR-2), because previous water quality measurements indicated the likely influence of a saline seep entering the Christina River between stations CHR-2 and CHR-1 that reduced the suitability of station CHR-2 as a reference station for station CHR-1. However, the results of fall (and winter) 2007 sampling indicate that station

CHR-2A (Table 5.9-6) generally has higher concentrations of selected nutrients and ions than either station CHR-1 (Table 5.9-4) or station CHR-2 (Table 5.9-5).

Comparison of Water Quality Measurement Endpoints to Water Quality Guidelines Concentrations of the following water quality measurement endpoints exceeded water quality guidelines in the Christina or Clearwater River in 2007 (Table 5.9-7):

- Total aluminum at all stations in fall and at station CLR-1 in spring and summer;
- Total dissolved phosphorus at station CLR-1 in spring; and
- Total nitrogen at stations CLR-1, CHR-1, and CHR-2 in winter, and station CHR-2A in winter and fall.

Other Water Quality Guideline Exceedances Concentrations of the following other water quality variables exceeded water quality guidelines in the Christina or Clearwater River in 2007 (Table 5.9-7):

- Station CLR-1: Total phosphorus in spring, summer and fall; dissolved iron in spring and summer, total iron in spring, summer, and fall, total cadmium, total copper and total lead in spring; and total phenols in summer;
- Station CLR-2: Total iron and total phosphorus in fall;
- Station CHR-1: Total phosphorus and total iron in both winter and fall and dissolved iron in fall;
- Station CHR-2: Total iron in both winter and fall, and total phosphorus, dissolved iron and total phenols in fall; and
- Station CHR-2A: total Kjeldahl nitrogen and total iron in both winter and fall, nitrate+nitrite in winter, and sulphide, total phosphorus, dissolved iron and total phenols in fall.

Comparison of Water Quality Measurement Endpoints to Natural Variation in Baseline Conditions Concentrations of all water quality measurement endpoints at stations CLR-1, CLR-2, CHR-1 and CHR-2 fell within regional baseline concentrations (i.e., 5^{th} to 95^{th} percentile of concentrations) in fall 2007, with the exception of total mercury at station CHR-1, whose concentration exceeded the 95^{th} percentile of regional reference values (Figure 5.9-4). At station CHR-2A, total dissolved solids, magnesium, sodium, potassium and sulphate exceeded the 95^{th} percentile of regional reference concentrations. Concentrations of all major ions were higher at CHR-2A than at any other stations sampled in these watersheds in 2007 or previously (Figure 5.9-4).

Ion Balance The ionic composition of water samples collected in fall 2007 was similar to previous years for all stations except station CHR-2 (upper Christina River), where relative ion concentrations from 2004 to 2007 have been lower in chloride and higher in calcium than was measured at this station in 2002 and 2003 (Figure 5.9-5).

Trend Analysis As of 2007, sufficient data existed to allow statistical trend analysis of fall water-quality data for Clearwater River stations CLR-1 (n=7) and CLR-2 (n=7). No significant trends in concentrations of any water quality variables were detected at these stations over the sampling period (α=0.05).

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 207, were similar to those in previous years. Station CHR-2A is less similar to the lower Christina River station than the previously sampled CHR-2, and therefore is not a more appropriate reference sampling location than this original upper Christina River station.

5.9.4 Benthic Invertebrate Communities and Sediment Quality

5.9.4.1 Benthic Invertebrate Communities

In fall 2007, 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
- An erosional middle reach on the Christina River located downstream of Janvier (reach CHR-E-2a, *reference*, baseline data in 2007), located at the water quality station CHR-2a.

2007 Habitat Conditions The lower reach (reach CHR-D-1) had a substrate in which sand was the most common substrate type, followed by silt and clay (Table 5.9-8). Samples were collected from shallow water (0.4 m); macrophytes were present, but covered less than 10% of the river bottom in areas where samples were collected. Water was alkaline with relatively high conductivity (Table 5.9-8).

The middle erosional reach (reach CHR-E-2a) had a substrate dominated by cobble (Table 5.9-8), and was characterized by long flat runs containing cobble and gravel substrate interspersed with riffle areas containing large cobble and boulder substrate. Macrophyte cover was low, current velocities were moderate (0.7 m/s), and water depth at the sampling locations was relatively shallow (0.2 m).

Relative Abundance of Benthic Invertebrate Community Taxa in 2007 The benthic invertebrate community of the lower reach (reach CHR-D-1) was numerically dominated by ostracods (43%), tubificid worms (33%) and chironomids (15%) (Table 5.9-9). Sub-dominant groups included cladocera (3%) and Gastropoda (snails, 2%). The chironomids were represented by several common genera including *Procladius*, *Polypedilum* and *Paralauterborniella*, as well two relatively tolerant genera *Chironomus* and *Cryptochironomus*. Gastropods (snails) were dominated by the limpet *Ferrissia rivularis*, a species more commonly found in riffle habitats, reflecting the presence of large cobble and boulders throughout the reach, despite it being classified as depositional. Some of the more sensitive fauna in the reach included the mayflies *Baetis* and *Hexagenia limbata*, the stoneflies *Taeniopteryx* and *Isoperla*, the caddisflies *Brachycentrus*, *Oecetis* and *Neureclipsis*, and the dragonfly *Ophiogomphus*.

The middle reach (reach CHR-E-2a) was numerically dominated by chironomids (28%), ostracods (28%), and mayflies (17%), with clams (3%), beetles (Coleoptera, 3%), mites (Hydracarina, 2%), naidid worms (9%) and caddisflies (Trichoptera (3%) sub-dominant (Table 5.9-9). Chironomids were dominated by relatively common forms including *Thienemannimiyia*, *Cryptochironomus*, *Polypedilum*, *Cricotopus*/*Orthocladius*, and the more sensitive *Tvetenia*. Other sensitive genera in reach CHR-E-2 included the mayflies *Acentrella*, *Acerpenna*, *Baetis*, *Ephemerella*, *Heptagenia* and *Leptophlebia*, the stoneflies *Isoperla* and *Taeniopteryx* and the caddisfly *Brachycentrus*.

Comparison of Benthic Invertebrate Community Measurement Endpoints to Natural Variation in Baseline Conditions At the lower reach (reach CHR-D-1) total abundance measured in fall 2007 was the highest recorded, averaging just under 80,000 individuals per m^2 (Table 5.9-9, Figure 5.9-6). The average number of taxa per sample in fall 2007 (20) was also the highest recorded for this reach, while measures of diversity were near to long-term average levels (Figure 5.9-6). The middle reach (reach CHR-E-2a) was sampled for the first time in fall 2007; abundance was approximately 7,5000 indiviuals/m^2 comprising 37 different taxa, with diversity and evenness at approximately 0.8, and 23% EPT (Table 5.9-9).

5.9.4.2 Sediment Quality

Sediment quality was sampled in fall 2007 in the lower Christina River (reach CHR-D-1), where benthic invertebrate communities were sampled.

2007 Results and Historical Ranges of Concentration Fall 2007 sediment quality data were compared with 2006 data from CHR-D-1 and with data for 2002 to 2005 from the previous lower Christina River sediment quality station CHR-1.

Sediments at reach CHR-D-1 in fall 2007 were dominated by silt and sand, with a greater proportion of finer particles (i.e., clay and silt) present than in samples from previous years (Table 5.9-10). Total organic carbon was low (1.6%), and CCME hydrocarbons were dominated by Fraction 3 (i.e., C16-C34).

Concentrations of all sediment quality measurement endpoints were within historical ranges at reach CHR-D-1 in fall 2007, with the exceptions of %silt, total organic carbon and CCME hydrocarbon Fractions 1, 2 and 4 which were above previously-measured maximum levels; while %sand was below its previously-measured minimum level (Table 5.9-10).

Comparison to Sediment Quality Guidelines No sediment quality measurement endpoints in fall 2007 exceeded sediment quality guidelines, except CCME Fraction 3 hydrocarbons, which exceeded the guideline of 400 mg/kg (although it fell within the historical ranges of concentrations at this location) (Table 5.9-10).

5.9.4.3 Summary

Benthic invertebrate community and sediment quality measurement endpoints in the Christina River watershed in fall 2007 continued to be within the normal range of regional baseline conditions for similar habitats in the Christina River watershed.

5.9.5 Fish Populations

Fish population monitoring for 2007 in the Clearwater River/Christina River watersheds consisted of a spring and fall fish inventory on the Clearwater River, as well as fish tissue analysis of northern pike captured during the inventory.

5.9.5.1 Fish Inventory

Species Composition

A total of 1,035 fish were captured during the spring and fall fish inventories within the three reaches of the Clearwater River (Figure 3.4-1, only one reach, CR1, was sampled in the fall program due to mechanical malfunctions), of which:

- 769 fish comprised of 18 species were captured in the spring (Table 5.9-11); and
- 266 fish comprised of 14 species were captured in the fall (Table 5.9-12).

A total of 19 species were captured in the 2007 Clearwater River fish inventory. The species richness in 2007 was higher than in recent years (2004-2006) and near the highest-recorded species richness of 21 species in 2003 (Golder 2004).

White sucker was the dominant large-bodied fish species captured in both spring and fall, comprising 44% and 26.3% of the total catch, respectively, followed by northern pike, with 14% and 18.4% of the total catch in spring and fall, respectively. Trout-perch was the dominant small-bodied species captured in the spring (13% of the total catch), and spottail shiner was the dominant small-bodied species captured in the fall (30.1% of the total catch).

The 2007 inventory was the first time lake whitefish had been captured or observed in the Clearwater River in the fall by RAMP. In general, it has been well documented that lake whitefish undertake a fall migration from Lake Athabasca via the Athabasca River to spawning grounds located upstream of Fort McMurray at Cascade and Mountain rapids (Jones *et al*. 1978). To date, there has been no evidence indicating spawning activity in the Clearwater River. Given the very low numbers of whitefish observed in the Clearwater River, it is unlikely these individuals represent any large-scale deviation from the typical spawning pattern in the Athabasca River.

Fish that were observed but not captured are summarized in Table 5.9-13.

Catch per Unit Effort

The total catch per unit effort (CPUE) for spring 2007 was the highest-recorded CPUE in the Clearwater River spring fish inventory, and continues a pattern of continual increases in CPUE in every spring inventory since the beginning of the Clearwater River fish inventory in 2003 (Figure 5.9-7). Similarly, the CPUE for fish captured in reach CR-1 during the 2007 fall inventory program, was also the highest-recorded CPUE for that reach (Figure 5.9-7). A summary of species-specific CPUE results for 2007 and comparisons of 2007 results to previous years are as follows (Figure 5.9-8):

- Spring 2007 walleye CPUE was similar to 2005 and 2006, while fall 2006 walleye CPUE for reach CR-1 was lower than all previous years in which reach CR-1 was sampled;
- Spring 2007 goldeye CPUE was lower than all previous years and was approximately 50% of 2006 spring CPUE. As in all years since 2003, there were no goldeye caught in the fall in reach CR-1;
- Similarly to results from the Athabasca River inventory program, spring 2007 white sucker CPUE was the highest-recorded spring CPUE across years, and approximately twice the 2006 spring CPUE. Fall 2007 white sucker CPUE was also the highest-recorded fall CPUE for the species in reach CR-1;
- Both spring and fall 2007 longnose sucker CPUE were the highest-recorded CPUE for the species for the given seasons; and
- Spring 2007 northern pike CPUE was the highest-recorded spring CPUE for the species, while fall northern pike CPUE for reach CR-1 was lower than in 2006 but higher than all previous years in which reach CR-1 was sampled.

In contrast to the Athabasca River, where CPUE in 2007 was lower than historical years, the Clearwater River relative abundance of each species has increased, particularly for white sucker and northern pike, or remained consistent in both spring and fall. The increase or consistency of CPUE of KIR species in the Clearwater River indicates the use of this river for spawning activities (spring) and as a migration route (fall).

Length-Frequency Analysis

Length-frequency distributions (2003 to 2007) for five key indicator species (KIR) for fall and spring inventories combined are presented in Figure 5.9-9 to Figure 5.9-13 for. Key features of the length-frequency distribution for each species are as follows:

- The two equally-dominant length classes for walleye in 2007 were 351 to 400 mm and 401 to 450 mm (Figure 5.9-9, 56% of all walleye captured in the Clearwater inventory). The 2007 length frequency distribution is similar to historical length-frequency distributions for this species and similar to the 2006 distribution but with a decrease in relative abundance of walleye in the 101 to 150 mm length class. This decrease in walleye abundance in the 101 to 150 mm length class is also evident in the 2007 Athabasca River inventory (Figure 5.1-31). The number of walleye caught in 2007 (57) is low and not necessarily representative of the length-frequency distribution of the whole population;
- The dominant length class for goldeye in 2007 was 401 to 425 mm (Figure 5.9-10), an increase in length from the 2006 dominant length class (375 to 400 mm) and also greater than the dominant goldeye length class in the 2007 Athabasca River fish inventory (Figure 5.1-32, 301 to 225 mm). The goldeye length frequency distribution in the Clearwater River in 2007 was truncated in the smaller length sizes (i.e., less than the 201 to 325 mm class) as compared to 2005 and 2006 The number of goldeye caught in 2007 (12) is very low and not representative of the length-frequency distribution of the whole population;
- The dominant length class for longnose sucker captured in 2007 was 101 to 150 mm (Figure 5.9-11). All captured longnose sucker in 2007 were less than 450 mm. While this is similar to historical results, the dominant length class in 2007 was lower than 2004 to 2006. In contrast, longnose sucker captured in the Athabasca River were larger, with a dominant length class between 401 and 450 mm (Figure 5.1-33). The number of longnose sucker caught in 2007 (58) is low and not necessarily representative of the length-frequency distribution of the whole population;
- The dominant length class for white sucker captured in 2007 was 401 to 450 mm, with a slightly lower relative abundance in the 351 to 400 mm length class (Figure 5.9-12), and similar to historical length-frequency distributions for this species. The white sucker length frequency distribution in the Clearwater River in 2007 was similar to that for white sucker captured in the 2007 Athabasca River inventory (Figure 5.1-34); and
- The co-dominant length classes for northern pike in the 2007 Clearwater inventory were 551-600 mm and 601-650 mm (Figure 5.9-13). The 2007 northern pike length-frequency distribution is truncated both the smaller and larger size classes in comparison to historical distributions for this species in the Clearwater River. The dominant length-class in 2007 is greater than that in 2006 (501 to 550 mm). The northern pike length frequency distribution in the Clearwater River in 2007 was also truncated in the larger size classes in comparison to the length-frequency distribution of northern pike captured in the 2007 Athabasca River inventory (Figure 5.1-34), although the dominant size class of northern pike in the Clearwater River in 2007 is higher than the dominant size class of northern pike in the Athabasca River in 2007 (451 to 500 mm).

Condition Factor

Mean condition factor for KIR fish species captured during the 2007 Clearwater River inventory are presented in Figure 5.9-14 for spring and fall, 2003 to 2007. Separate analysis of covariance (ANCOVA) was performed on spring and fall captured fish. Generally, there are more instances of significant year-to-year differences in condition factor of fish captured in the fall than in the spring. The species-specific results are as follows (two p-values are given for each ANCOVA, the first if for the comparison of slopes and the second is for the comparison of intercepts):

- There were significant differences between years in the condition of fall captured walleye (ANCOVA $p = 0.9/p < 0.05$) but not for spring captured walleye (ANCOVA $p = 0.06/p > 0.05$). Condition in fall walleye was variable among years with no clear trends in one direction;
- There were no significant differences in the condition of spring captured goldeye across years (ANCOVA $p = 0.5/p > 0.05$); there were no goldeye captured during the fall inventory;
- Sample sizes of longnose sucker captured annually in the Clearwater River were too small to detect significant differences in condition factor for both spring and fall;
- There were no significant differences among years in condition of white sucker in spring (ANCOVA $p = 0.9/p > 0.05$); but there were significant differences in condition in fall (ANCOVA $p = 0.4/p < 0.05$). From 2003 to 2005 in fall, condition in white sucker increased and then declined in 2006. The condition of white sucker in 2007 was consistent with 2006 levels; and
- There was significant difference among years in condition of northern pike captured in the spring (ANCOVA $p = 0.1/p < 0.05$) and fall (ANCOVA $p = 0.2/p < 0.05$) captured northern pike. In fall, the condition factor of northern pike was higher in 2004 and 2007 relative to the other three sampling years; in spring, condition decreased in 2007 relative to 2005 and 2006.

External Health Assessment

Observed anomalies were primarily associated with minor skin aberrations or wounds and scars and fin erosion; only three fish showed evidence of parasites in the form of black spots. In 2007, 147 out of 769 fish (19.1%) in the spring and 24 out of 266 fish (8.9%) in the fall were found to have some type of external anomaly. These incidences of external anomalies are more than twice the incidences of external anomalies recorded in 2006 (8% in spring and 3.9% in fall, RAMP [2007]). The 2007 external pathology index scores for KIR fish species collected from the Clearwater River were within historical ranges for longnose sucker and walleye but were higher for goldeye, white sucker and northern pike than previous sampling years (Table 5.9-14).

Summary Assessment for Fish Inventory

The Clearwater fish inventory is 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 assessing detailed fish community structure. Current and historical fish inventory data for the Clearwater show very little changes or trends in condition factor and length frequency distribution but do exhibit increasing trends in spring and fall total CPUE, due largely to a group of species including white sucker, northern pike, spottail shiner and trout-perch, and some level of species-specific variability in relative abundance, length-frequency distribution, and condition factor.

Currently only condition can be applied as a measurement endpoint for the large-bodied species in the Clearwater River fish inventory. The impact criterion for condition factor defined by Environment Canada (2005) is a ± 10% difference between potentially influenced and reference sites. A difference in condition factor that is greater than 10% is considered ecologically relevant. For walleye and northern pike, the two primary sport fishery species, the impact criterion was not exceeded in 2007 when applied to spring and fall condition factor.

5.9.5.2 Fish Tissue Analysis Results

Whole-Organism Metrics

A total of 27 northern pike (4 male, 2 females and 21 unsexed) from the Clearwater River were sampled for fish tissue analysis in conjunction with the 2007 fall inventory. The size of the sampled fish ranged from a 250 mm immature fish to a 948 mm adult fish (unknown sex). The mean length was 526 mm, with males slightly larger than females.

External and internal fish health assessments were conducted on the nine fish that were sacrificed for metal and organics tissue analyses. One male had frayed gills; five males and one female had increased mesenteric fat (< 50%) and one female had greater than 50% mesenteric fat; and three males had fatty livers. No other internal anomalies 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 anomaly was the presence of minor skin aberration consisting of scars (5 out of 25); one of these fish (unknown sex) had minor fin erosion on the upper caudal fin. One male northern pike had a growth (tumour) on the right side of the body.

Mercury

Total mercury concentrations in muscle of non-lethally sampled northern pike collected from the Clearwater River in 2007 are presented in Table 5.9-15. Concentrations ranged from 0.0095 mg/kg in a 366 mm immature fish to 0.624 mg/kg in an 841 mm adult fish.

Overall, mean mercury concentration in northern pike in 2007 was 0.163 mg/kg; which was lower than mean mercury concentrations in 2004 (0.201 mg/kg) and 2006 (0.213 mg/kg) (Figure 5.9-15). The mean concentration of mercury in adult female northern pike (0.206 mg/kg) was slightly higher than for adult males (0.187 mg/kg, Figure 5.9-15); this is similar to 2006 results but opposite from 2004 mean mercury concentrations.

A regression of mercury concentrations in muscle of individual northern pike against fork length was significant ($p < 0.01$; length adjusted $R^2 = 0.33$, Figure 5.9-16). Correlations and regressions of mercury concentration with age or any sex-specific correlations were not conducted due to the small sample size of aged/sacrificed fish.

Other Chemicals

Four composite samples were analyzed for concentrations of other chemicals in tissue samples of northern pike from the Clearwater River: target-sized females (500 to 550 mm); target-sized males (450 to 500 mm); target-sized females and females outside but approaching target size (450-500 mm and 550-600 mm); and target-sized males and males outside but approaching target size (500-600 mm). All analyzed tainting compounds were below analytical detection limits for all composite tissue samples (Table 5.9-16). Concentrations for 13 of 29 metals analyzed were below analytical detection limits. Arsenic concentrations exceeded guidelines for USEPA subsistence fishers in tissue from all males within and approaching the target size (Table 5.9-16); all composite samples exceeded the arsenic USEPA recreational fishers' guideline. No other metals exceeded Health Canada or National USEPA guidelines in northern pike tissue samples.

Screening of Potential Effects on Human Health

Mercury 2007 northern pike tissue mercury concentration data were screened against National USEPA and Health Canada human health criteria for fish consumption (Table 5.9-15). The overall mean mercury concentration (0.163 mg/kg) in northern pike in the Clearwater exceeded the USEPA Region III risk-based criteria (0.14 mg/kg) and the USEPA criteria for subsistence fishers (0.049 mg/kg). Four northern pike of unknown sex exceeded the Health Canada criteria for subsistence fishers (0.2 mg/kg) and one pike of unknown sex exceeded the Health Canada criteria for general consumers (0.5 mg/kg). Northern pike sex-specific mercury concentrations in 2007 were not significantly different from 2004 and 2006 results ($p = 0.2$).

Other Chemicals Arsenic was the only chemical in 2007 that exceeded human health criteria for fish consumption (Table 5.9-16). The arsenic concentrations for the 2007 northern pike composite samples (both male and female) exceeded USEPA screening criteria for subsistence fishers (0.0033 mg/kg) and one composite sample for male northern pike inside and approaching the target size exceeded the USEPA criteria for recreational fishers (0.026 mg/kg).

Screening of Potential Effects on Fish and Fish Health

The following are the results of screening for potential effects of concentrations of chemicals in fish tissue on fish and fish health, comparing the concentrations of chemicals in fish tissue in Table 5.9-16 with the criteria for evaluating potential effects on fish health provided in Table 3.4-9):

- Mercury concentrations did not exceed any of the effects (or no effects) thresholds for fish and fish health; and
- Concentrations of other chemicals did not exceed any of the effects (or no effects) thresholds for fish and fish health with the exceptions of selenium, exceeded the sublethal no-effects threshold, and silver was below the analytical detection limit. Unfortunately the detection limit is higher than the lowest no-effects threshold guideline, and therefore it is not possible to make any definitive conclusions.

Screening of Potential Effects on Palatability of Fish

All tainting compounds in Clearwater River northern pike tissue were present at concentrations well below the 1 mg/kg threshold for effects on palatability as outlined in Jardine and Hrudey (1988).

5.9.5.3 Summary Assessment for Fish Tissue

Measurement endpoints used in the assessment of the results of 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 analysed in the Clearwater River indicate a risk to subsistence fishers characterized by 23% of fish analyzed with mercury concentrations exceeding Health Canada guidelines, and lower risk for recreational fishers and consumers (4% of sampled fish exceeding relevant guidelines). Concentrations of mercury in fish standardized to fish weight from the Clearwater River were compared to fish mercury concentrations from regional waterbodies (Figure 5.11-28); mercury levels in the Clearwater River northern pike were at the lower end of the range of waterbodies sampled. A regional assessment of fish tissue mercury concentrations is further discussed in Section 6.4. Concentrations of other metals, as well as tainting compounds, were below all relevant criteria, with the exception of arsenic, for which concentrations in all composite samples exceeded at least one USEPA guideline. Fish tissue results for 2007 also suggest that there is low potential risk to fish health, with only one metal, selenium, exceeding sublethal no effects threshold. 2007 mercury data from the Clearwater River fish tissue program have been given to Health Canada and Alberta Health and Wellness.

5.9.6 Summary of Conditions

Monitoring activities in the Clearwater River and Christina River watersheds in 2007 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 2007 were to remove 0.0058 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 2007 but which were not owned by 2007 RAMP funders were to remove 0.029 mm of runoff depth from the watershed. Water quality measurement endpoints were generally within historical ranges and within the range for regional reference stations. Benthic invertebrate community and sediment quality measurement endpoints in the Christina River watershed in fall 2007 continued to be within the normal range of regional baseline conditions for similar habitats in the Christina River watershed, and there have been no unusual trends in these measurement endpoints since sampling began in 2002.

A fifth 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 2007 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 relevant screening criteria. No fish tissue effects thresholds for fish and fish health were exceeded with the exception of selenium, 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 5.9-2 Clearwater River: 2007 hydrograph and historical context.

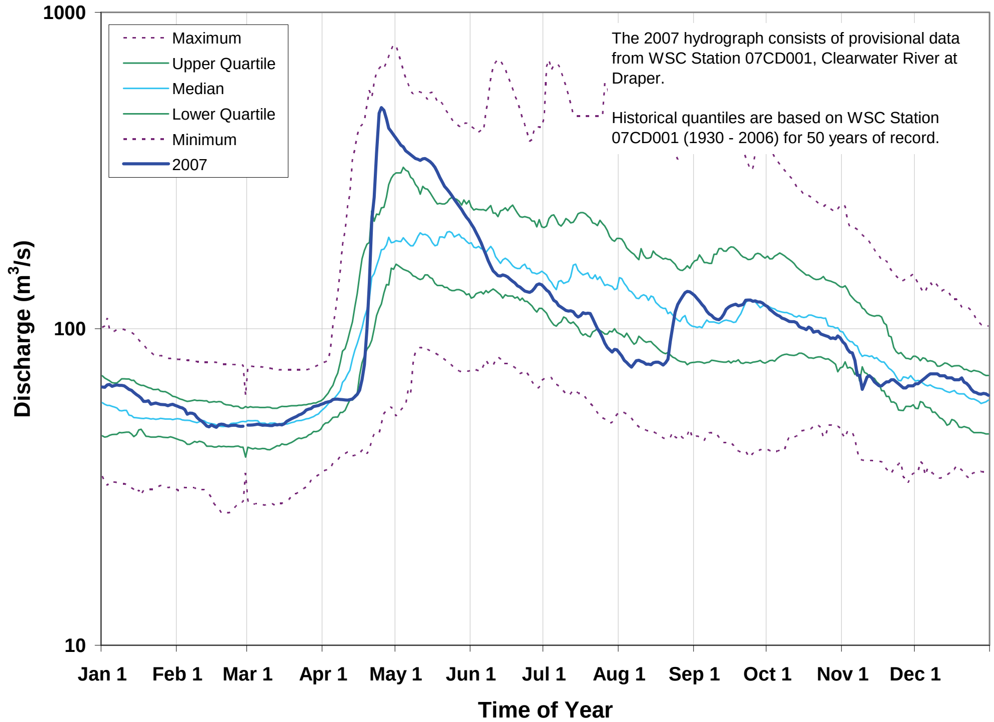


Figure 5.9-3 Christina River: 2007 hydrograph and historical context.

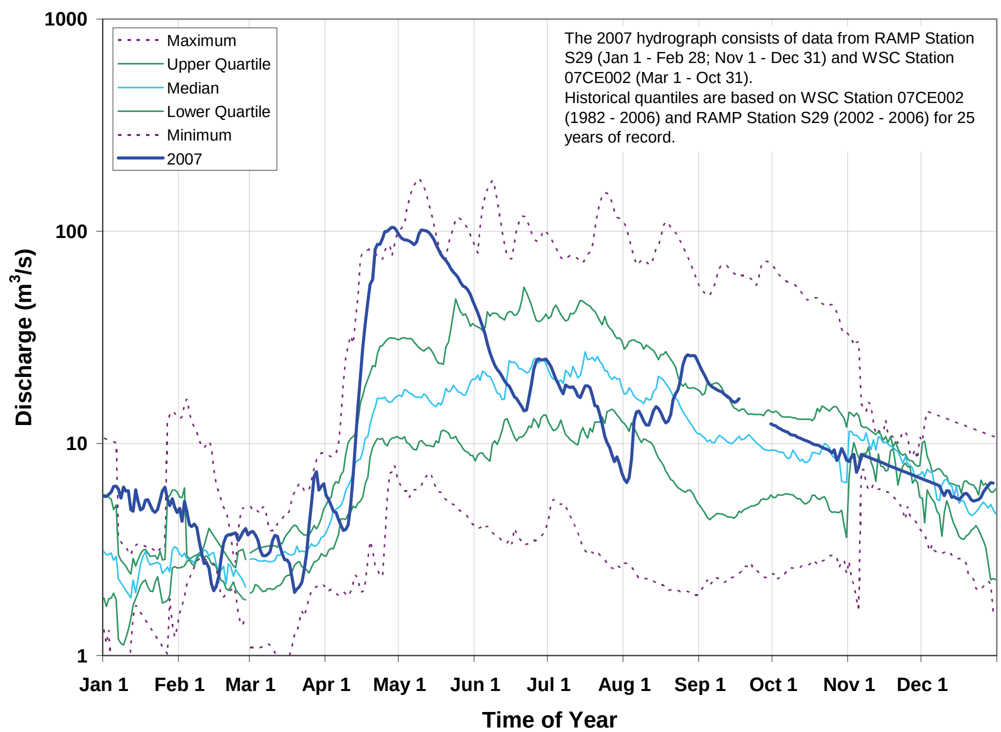


Table 5.9-1 Estimated changes in annual discharge in the Christina River watershed as a result of focal projects and other active oil sands projects in the watershed.

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 2007	+ 0.167	+ 0.825	1.14 km^2 and 5.63 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 2007 (Table 2.4-1).
Incremental runoff from areas of land change that are not closed-circuited	- 0.244	- 0.446	10.0 km^2 and 18.3 km^2 estimated to have undergone land change as of 2007, 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 2007 (Table 2.4-1).
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)	+ 0.077	-0.379	Estimated difference in annual discharge that would have occurred in the baseline case.

Table 5.9-2 Concentrations of water quality measurement endpoints, mouth of Clearwater River (CLR-1), fall 2007.

Measurement Endpoint	Units	Guideline	September 2007	1997-2006 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.1	6	7.5	8	8.2
Total Suspended Solids	mg/L	-[1]	15	6	<3	10	38
Conductivity	µS/cm	-	240	6	177	223.5	291
Nutrients							
Total dissolved phosphorus	mg/L	0.05[2]	0.044	6	0.012	0.0215	0.028
Total nitrogen*	mg/L	1.0	0.6	6	0.3	0.5	0.7
Nitrate+Nitrite	mg/L	-	<0.1	6	<0.1	<0.1	<0.1
Dissolved organic carbon	mg/L	-	16	6	8	10	14
Ions							
Sodium	mg/L	-	22	6	16	23	31
Calcium	mg/L	-	20.1	6	14.7	17.25	18
Magnesium	mg/L	-	6.5	6	5.1	5.6	5.9
Chloride	mg/L	230, 860[3]	25	6	17	29.5	43
Sulphate	mg/L	100[4]	6	6	1.4	6.25	7.7
Total Dissolved Solids	mg/L	-	141	6	60	150	200
Total Alkalinity	mg/L	-	74	6	59	64.5	71
Organic compounds							
Naphthenic acids	mg/L	-	<1	6	<1	<1	2
Selected metals							
Total aluminum	mg/L	0.1	**0.606**	6	**0.14**	**0.56**	**1.46**
Dissolved aluminum	mg/L	0.1[2]	0.00899	6	<0.01	0.0075	0.0148
Total arsenic	mg/L	0.005	0.000831	6	0.0005	0.000798	0.00139
Total boron	mg/L	1.2[5]	0.032	6	0.0275	0.0360	0.0548
Total molybdenum	mg/L	0.073	0.00021	6	0.00016	0.00020	0.00036
Total mercury (ultra-trace)	ng/L	5, 13[6]	<1.2	4	<1.2	<1.2	<1.2
Total strontium	mg/L	-	0.098	6	0.079	0.1035	0.118

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 5.9-3 Concentrations of water quality measurement endpoints, upper Clearwater River (CLR-2), fall 2007.

Measurement Endpoint	Units	Guideline	September 2007	1997-2006 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8	6	7.2	7.75	8.0
Total Suspended Solids	mg/L	-[1]	25	6	7	10.5	36
Conductivity	µS/cm	-	213	6	138	191	249
Nutrients							
Total dissolved phosphorus	mg/L	0.05[2]	0.017	6	0.010	0.021	0.026
Total nitrogen*	mg/L	1.0	0.5	6	0.3	0.45	**1.2**
Nitrate+Nitrite	mg/L	-	<0.1	6	<0.1	<0.1	<0.1
Dissolved organic carbon	mg/L	-	8	6	6	7	9
Ions							
Sodium	mg/L	-	21	6	13	18	29
Calcium	mg/L	-	14.7	6	10.0	11.8	12.8
Magnesium	mg/L	-	4.1	6	3.7	4.2	4.5
Chloride	mg/L	230, 860[3]	30	6	16	26	43
Sulphate	mg/L	100[4]	7.7	6	<0.5	5.7	7.6
Total Dissolved Solids	mg/L	-	106	6	40	122	160
Total Alkalinity	mg/L	-	51	6	39	44	49
Organic compounds							
Naphthenic acids	mg/L	-	<1	6	<1	<1	<1
Selected metals							
Total aluminum	mg/L	0.1	**0.24**	6	**0.13**	**0.27**	**0.70**
Dissolved aluminum	mg/L	0.1[2]	0.00572	6	0.0051	0.0082	0.0400
Total arsenic	mg/L	0.005	0.000468	6	0.000484	0.0005475	<0.001
Total boron	mg/L	1.2[5]	0.0236	6	0.014	0.023	0.030
Total molybdenum	mg/L	0.073	0.000108	6	0.00009	0.0001185	0.00020
Total mercury (ultra-trace)	ng/L	5, 13[6]	1.2	4	<1.2	<1.2	<1.2
Total strontium	mg/L	-	0.0896	6	0.061	0.079	0.094

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, mouth of Christina River (CHR-1), fall 2007.

Measurement Endpoint	Units	Guideline	September 2007	1997-2006 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.3	5	8.1	8.3	8.4
Total Suspended Solids	mg/L	-[1]	15	5	<3	26	38
Conductivity	µS/cm	-	285	5	269	295	375
Nutrients							
Total dissolved phosphorus	mg/L	0.05[2]	0.022	5	0.021	0.025	0.033
Total nitrogen*	mg/L	1.0	0.9	5	0.6	1	**1.6**
Nitrate+Nitrite	mg/L	-	<0.1	5	<0.1	<0.1	<0.1
Dissolved organic carbon	mg/L	-	21	5	14	16	22
Ions							
Sodium	mg/L	-	19	5	20	26	34
Calcium	mg/L	-	26	5	25.9	27.8	29.7
Magnesium	mg/L	-	8	5	7.8	8.5	9.1
Chloride	mg/L	230, 860[3]	22	5	21	28	41
Sulphate	mg/L	100[4]	5.2	5	2.2	6.9	7.9
Total Dissolved Solids	mg/L	-	189	5	140	190	250
Total Alkalinity	mg/L	-	104	5	101	110	118
Organic compounds							
Naphthenic acids	mg/L	-	<1	5	<1	<1	<1
Selected metals							
Total aluminum	mg/L	0.1	**0.62**	5	**0.24**	**0.59**	**0.77**
Dissolved aluminum	mg/L	0.1[2]	0.0115	5	0.0066	0.0092	0.0144
Total arsenic	mg/L	0.005	0.00102	5	0.000702	0.0011	0.00118
Total boron	mg/L	1.2[5]	0.0374	5	0.027	0.054	0.066
Total molybdenum	mg/L	0.073	0.000331	5	0.00016	0.00038	0.00040
Total mercury (ultra-trace)	ng/L	5, 13[6]	2.4	4	<1.2	<1.2	<1.2
Total strontium	mg/L	-	0.111	5	0.078	0.129	0.145

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 5.9-5 Concentrations of water quality measurement endpoints, upper Christina River (CHR-2), fall 2007.

Measurement Endpoint	Units	Guideline	September 2007	1997-2006 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.2	5	8	8.2	8.3
Total Suspended Solids	mg/L	-[1]	<3	5	6	8	13
Conductivity	µS/cm	-	205	5	187	211	266
Nutrients							
Total dissolved phosphorus	mg/L	0.05[2]	0.032	5	0.026	0.038	**0.051**
Total nitrogen*	mg/L	1.0	0.7	5	0.6	0.8	**1.4**
Nitrate+Nitrite	mg/L	-	<0.1	5	<0.1	<0.1	<0.1
Dissolved organic carbon	mg/L	-	18	5	13	15	20
Ions							
Sodium	mg/L	-	6	5	6	7	10
Calcium	mg/L	-	27.4	5	25.5	28.5	35.1
Magnesium	mg/L	-	7.6	5	7.7	8.3	10.6
Chloride	mg/L	230, 860[3]	2	5	<1	2	2
Sulphate	mg/L	100[4]	3.2	5	4.1	5.8	9.6
Total Dissolved Solids	mg/L	-	152	5	130	140	240
Total Alkalinity	mg/L	-	102	5	92	106	138
Organic compounds							
Naphthenic acids	mg/L	-	<1	5	<1	<1	1
Selected metals							
Total aluminum	mg/L	0.1	**0.186**	4	0.049	**0.165**	**0.304**
Dissolved aluminum	mg/L	0.1[2]	0.00747	4	0.0041	0.0096	0.0129
Total arsenic	mg/L	0.005	0.000929	4	0.0007	0.00099	0.00124
Total boron	mg/L	1.2[5]	0.0276	4	0.0309	0.0342	0.0459
Total molybdenum	mg/L	0.073	0.000388	4	0.000419	0.0004	0.0006
Total mercury (ultra-trace)	ng/L	5, 13[6]	<1.2	4	<1.2	<1.2	<1.2
Total strontium	mg/L	-	0.0963	4	0.098	0.108	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).

Table 5.9-6 Concentrations of water quality measurement endpoints, middle Christina River (CHR-2A), fall 2007.

Measurement Endpoint	Units	Guideline	September 2007
			Value
Physical variables			
pH	pH units	6.5-9.0	8.3
Total Suspended Solids	mg/L	-[1]	3
Conductivity	µS/cm	-	703
Nutrients			
Total dissolved phosphorus	mg/L	0.05[2]	0.028
Total nitrogen*	mg/L	1.0	**1.2**
Nitrate+Nitrite	mg/L	-	<0.1
Dissolved organic carbon	mg/L	-	22
Ions			
Sodium	mg/L	-	70
Calcium	mg/L	-	67.5
Magnesium	mg/L	-	22.9
Chloride	mg/L	230, 860[3]	32
Sulphate	mg/L	100[4]	16.7
Total Dissolved Solids	mg/L	-	464
Total Alkalinity	mg/L	-	333
Organic compounds			
Naphthenic acids	mg/L	-	<1
Selected metals			
Total aluminum	mg/L	0.1	**0.346**
Dissolved aluminum	mg/L	0.1[2]	0.00834
Total arsenic	mg/L	0.005	0.000855
Total boron	mg/L	1.2[5]	0.0278
Total molybdenum	mg/L	0.073	0.000289
Total mercury (ultra-trace)	ng/L	5, 13[6]	2.3
Total strontium	mg/L	-	0.0804

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

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 5.9-7 Water quality guideline exceedances, Clearwater-Christina River watersheds, 2007.

Water Quality Variable	Units	Guideline*	CLR-1	CLR-2	CHR-1	CHR-2	CHR-2A
Winter							
Nitrate+Nitrite	mg/L	1.0	ns	ns	-	-	**1.1**
Total phosphorus	mg/L	0.05	ns	ns	**0.051**	-	-
Total Kjeldahl Nitrogen	mg/L	1.0	ns	ns	-	-	**1.4**
Total nitrogen	mg/L	1.0	ns	ns	**1.6**	**1.2**	**2.5**
Total iron	mg/L	0.3	ns	ns	**0.783**	**0.704**	**0.668**
Spring							
Total phosphorus	mg/L	0.05	**0.153**	ns	ns	ns	ns
Total dissolved phosphorus	mg/L	0.05	**0.076**	ns	ns	ns	ns
Total nitrogen	mg/L	1.0	**1.2**	ns	ns	ns	ns
Dissolved iron	mg/L	0.3[1]	**0.34**	ns	ns	ns	ns
Total aluminum	mg/L	0.1	**4.33**	ns	ns	ns	ns
Total cadmium	mg/L	-[3]	**0.0000423**	ns	ns	ns	ns
Total copper	mg/L	-[3]	**0.00337**	ns	ns	ns	ns
Total lead	mg/L	-[3]	**0.00234**	ns	ns	ns	ns
Total iron	mg/L	0.3	**4.77**	ns	ns	ns	ns
Summer							
Total phenols	mg/L	0.005	**0.006**	ns	ns	ns	ns
Total aluminum	mg/L	0.1	**0.666**	ns	ns	ns	ns
Total iron	mg/L	0.3	**0.888**	ns	ns	ns	ns
Total phosphorus	mg/L	0.05	**0.057**	ns	ns	ns	ns
Fall							
Sulphide	mg/L	0.014[2]	-	-	-	-	**0.027**
Total phosphorus	mg/L	0.05	**0.109**	**0.062**	**0.062**	**0.059**	**0.08**
Total aluminum	mg/L	0.1	**0.606**	**0.237**	**0.619**	**0.186**	**0.346**
Dissolved iron	mg/L	0.3[1]	-	-	**0.375**	**0.603**	**0.39**
Total iron	mg/L	0.3	**1.04**	**0.559**	**1.18**	**1.13**	**1.04**
Total Kjeldahl Nitrogen	mg/L	1.0	-	-	-	-	**1.1**
Total nitrogen	mg/L	1.0	-	-	-	-	**1.2**
Total phenols	mg/L	0.005	-	-	-	**0.01**	**0.007**

ns = not sampled

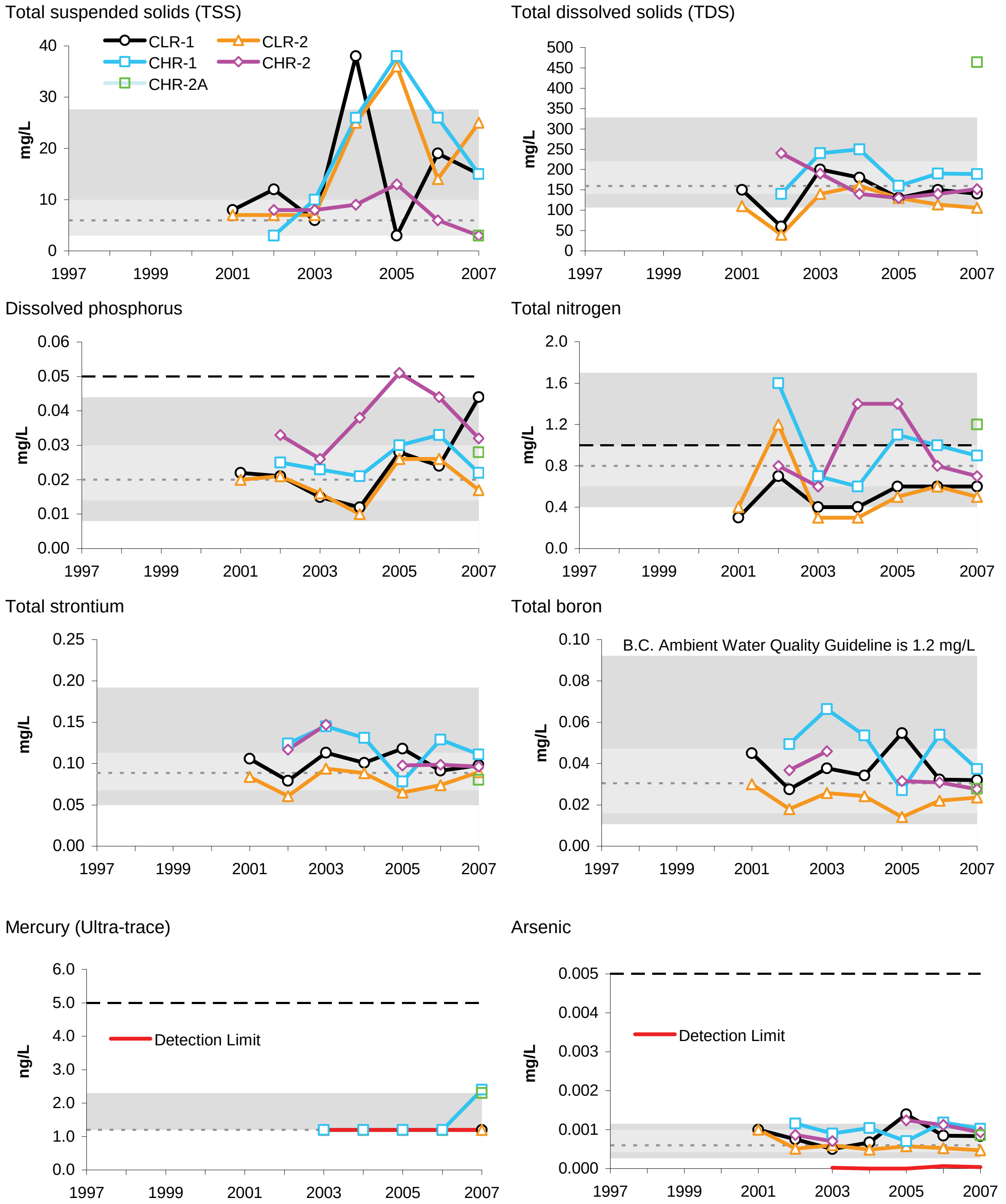
* Guidelines are CCME (2006) or AENV (1999) unless otherwise noted.

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

[2] Derived from EPA (2002).

[3] Guidelines are hardness-dependent.

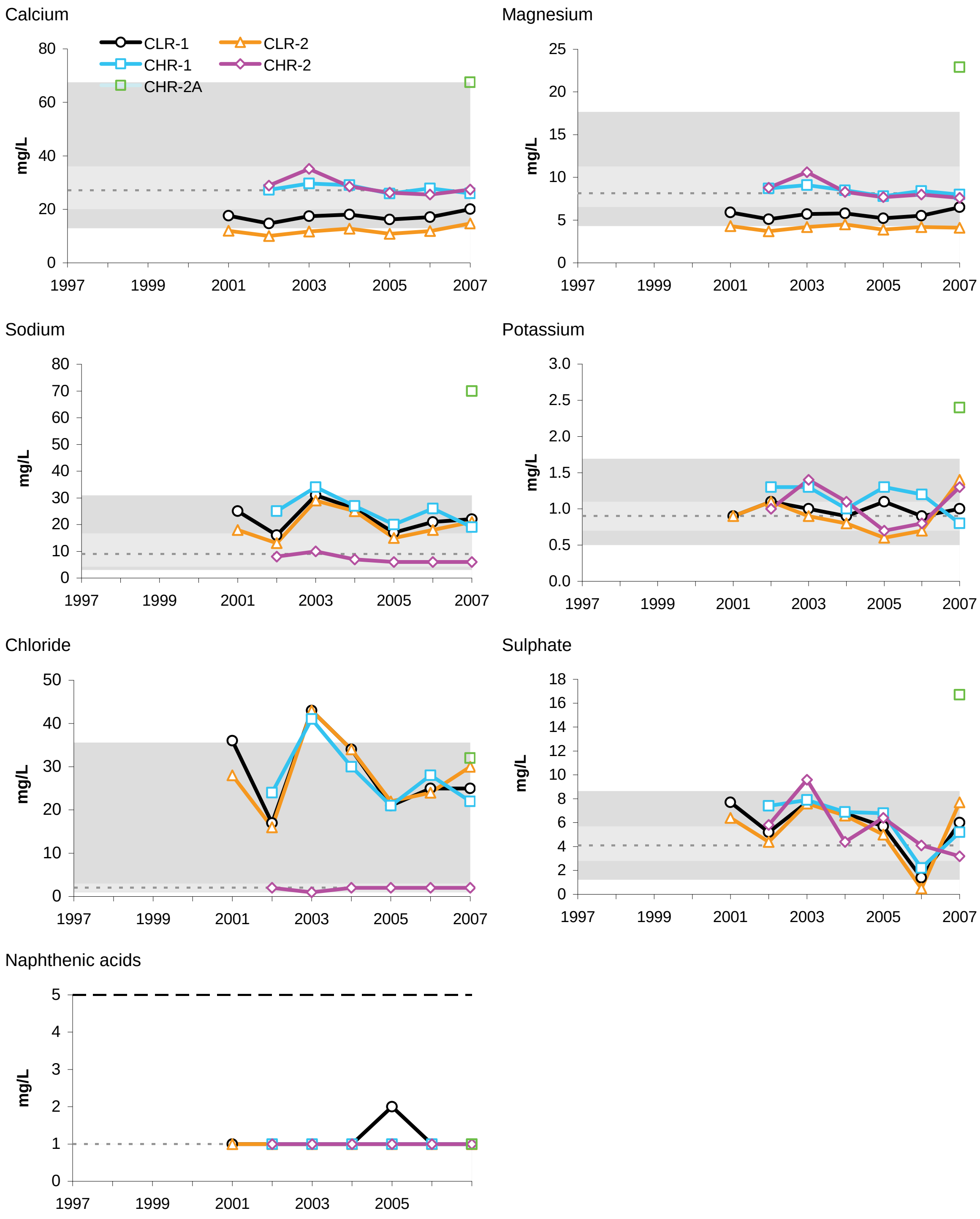
Figure 5.9-4 Concentrations of selected water quality measurement endpoints in the Clearwater and Christina watersheds (fall data) relative to regional baseline fall concentrations.



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 5.9-4 (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 5.9-5 Piper diagram of fall ion concentrations in the Clearwater-Christina River system.

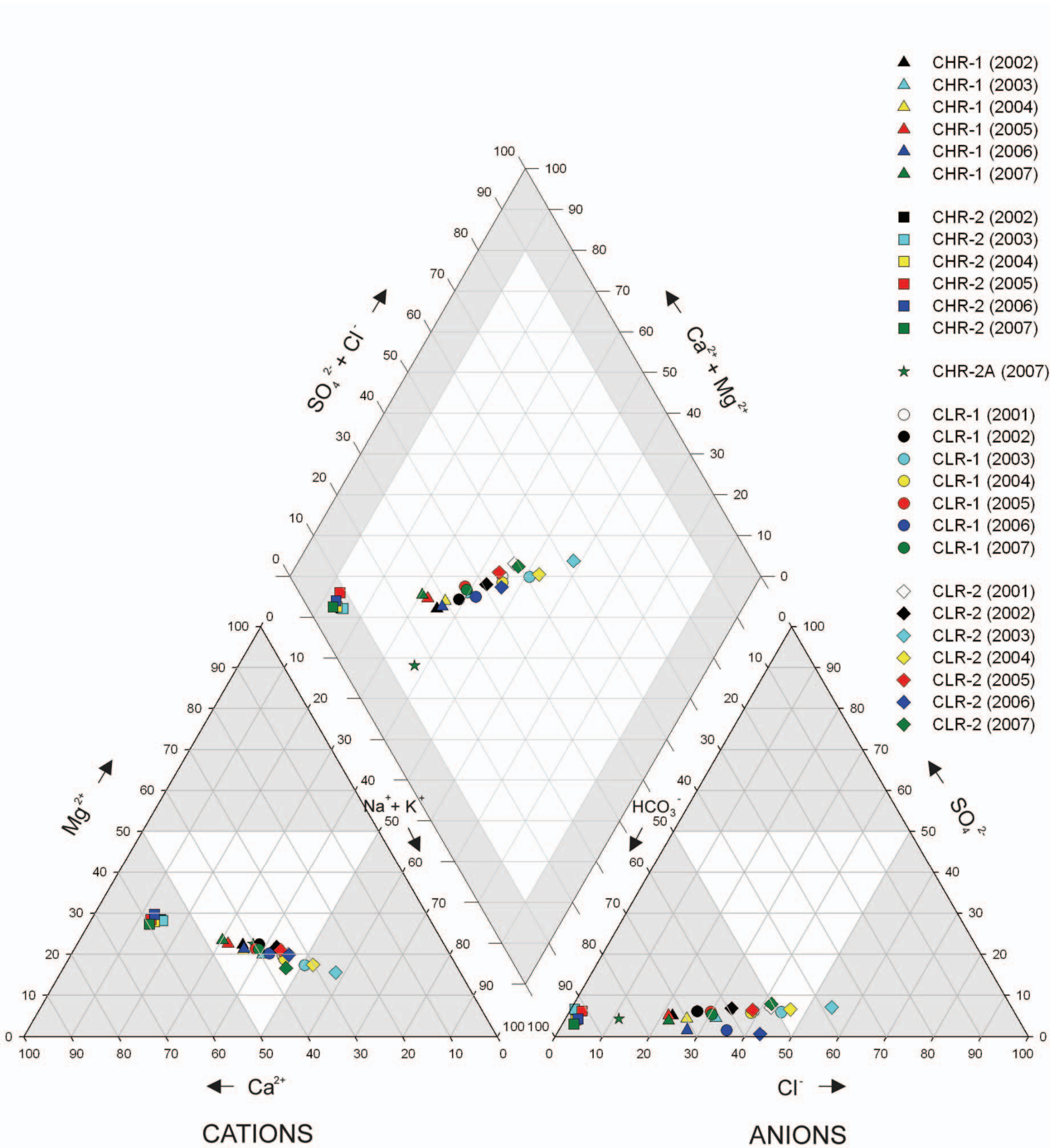


Table 5.9-8 Habitat characteristics of benthic invertebrate community sampling reaches in the Christina River.

Variable	Units	Reach CHR-D-1 Lower Reach of the Christina River	Reach CHR-E2a Middle Reach of the Christina River
Sample date	-	Sept. 10, 2007	Sept. 6, 2007
Habitat	-	Depositional	Erosional
Water depth	m	0.4	0.2
Current velocity	m/s	n/a	0.7
Macrophyte cover	%	8	5
Field Water Quality			
Dissolved oxygen	mg/L	9.8	9.2
Conductivity	µS/cm	286	177
pH	pH units	8.6	7.5
Water temperature	°C	13.0	13.3
Sediment Composition			
Sand	%	53	
Silt	%	31	
Clay	%	15	
Total Organic Carbon	%	1.6	
Sand/Silt/Clay	%		3
Small gravel	%		0
Large gravel	%		14
Small cobble	%		23
Large cobble	%		41
Boulder	%		19
Bedrock	%		0

Table 5.9-9 Major taxon percent abundances and indices of benthic invertebrate community composition in the Christina River.

Taxon	Percent Major Taxa Enumerated in Each Year						
	Reach CHR-D-1						Reach CHR-E-2a
	2002	2003	2004	2005	2006	2007	2007
Anisoptera	<1	<1	<1	<1	<1	1	1
Bivalvia	11	1	1	<1		<1	3
Ceratopogonidae	<1	1	7	3	8	1	<1
Chironomidae	39	23	29	46	70	15	28
Cladocera						3	
Coleoptera						<1	3
Copepoda	<1	<1				<1	<1
Dolichopodidae			<1				1
Empididae		<1	1	1	3		<1
Enchytraeidae				<1			<1
Ephemeroptera		1	1	1	<1	1	17
Ephydridae			<1				
Erpobdellidae		<1	<1				
Gastropoda	2	<1			0.5	2	<1
Glossiphoniidae	<1						
Heteroptera		<1					
Hydracarina						<1	2
Lumbriculidae		<1	<1				
Macrothricidae							
Naididae	<1	5	1	2	<1	1	9
Nematoda	1	1	2	1	1	1	1
Ostracoda	2	<1	9		1	43	28
Plecoptera	<1	<1	<1	<1	<1	<1	3
Tabanidae	<1	<1		<1	0.2	<1	1
Tipulidae			<1			1	<1
Trichoptera	<1	<1		<1	<1	<1	3
Tubificidae	44	66	5	45	16	33	1
Benthic Invertebrate Community Measurement Endpoints							
Total Abundance (No./m^2)	22,928	10,178	6,405	5,052	9,853	77,280	7,601
Richness	11	8	8	7	14	20	37
Simpson's Diversity	0.6	0.51	0.56	0.59	0.77	0.56	0.81
Evenness	0.67	0.62	0.67	0.73	0.79	0.60	0.83
% EPT	<1	2	2	6	<1	<1	23

Figure 5.9-6 Variation in benthic invertebrate community measurement endpoints in the lower reach of the Christina River (reach CHR-D-1).

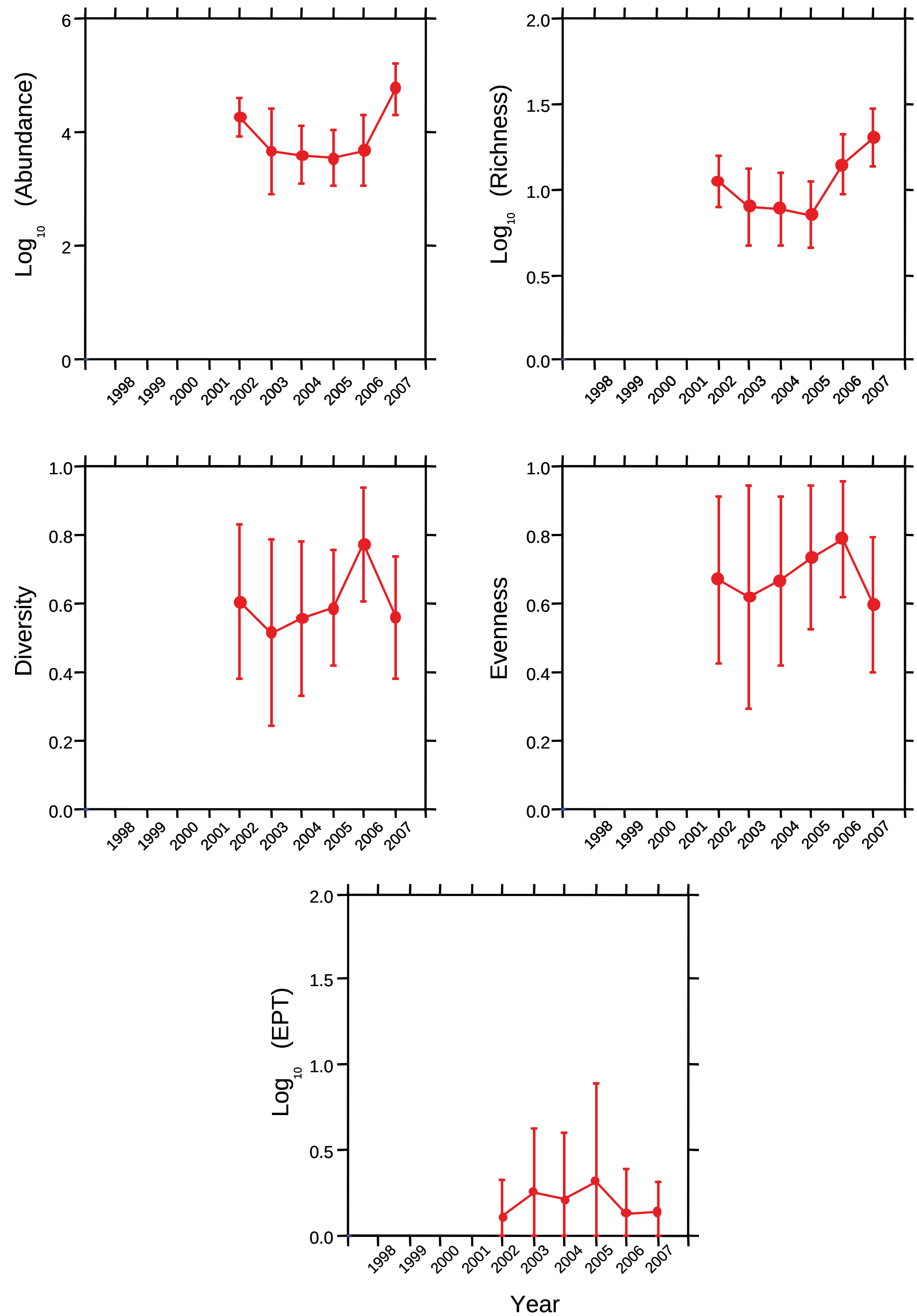


Table 5.9-10 Sediment quality measurement endpoints, lower reach near mouth of Christina River (reach CHR-D-1), fall 2007.

Measurement Endpoint	Units	Guideline	September 2007	1997-2006 (fall data only, station CHR-1, reach CHR-D-1)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	15.3	4	8	11.5	17
Silt	%	-	53.4	4	16	23.5	38
Sand	%	-	31.3	4	54	64	74
Total organic carbon	%	-	1.6	4	0.7	1.3	2
Total hydrocarbons							
BTEX	mg/kg	-	13	2	<5	<5	<5
Fraction 1 (C6-C10)	mg/kg	30[2]	13	2	<5	<5	<5
Fraction 2 (C10-C16)	mg/kg	150[2]	66	2	81	90.5	100
Fraction 3 (C16-C34)	mg/kg	400[2]	**830**	2	200	585	**970**
Fraction 4 (C34-C50)	mg/kg	2800[2]	600	2	130	305	480
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[3]	0.0017	4	0.0012	0.0020	0.0080
Retene	mg/kg	-	0.0422	4	0.0198	0.0622	0.1490
Total dibenzothiophenes	mg/kg	-	1.00	4	0.25	1.15	3.32
Total PAHs	mg/kg	-	2.65	4	1.00	5.33	11.75
Total HMW PAHs	mg/kg	-	0.35	4	0.35	2.04	4.10
Total LMW PAHs	mg/kg	-	2.30	4	0.65	3.30	7.65
Predicted PAH toxicity[1]	H.I.	-	0.65	4	0.70	1.68	2.78
Metals that exceed CCME guidelines in 2007							
none	mg/kg	-	-	-	-	-	-
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	ns	2	9	9	9
Chironomus growth - 10d	mg/organism	-	ns	2	2.1	2.4	2.7
Hyalella survival - 14d	# surviving	-	ns	2	6	7	8
Hyalella growth - 14d	mg/organism	-	ns	2	0.1	0.2	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).

ns = not sampled

Table 5.9-11 Clearwater River fish inventory species composition, spring 2007.

Species	Total Captured	Species Composition
Arctic Grayling	1	0.13
Burbot	6	0.78
Emerald shiner	8	1.04
Flathead chub	3	0.39
Goldeye	12	1.56
Lake chub	11	1.43
Lake whitefish	1	0.13
Longnose dace	2	0.26
Longnose sucker	51	6.63
Mountain Whitefish	13	1.69
Northern pike	108	14.04
Slimy sculpin	4	0.52
Spoonhead sculpin	7	0.91
Spottail shiner	47	6.11
Trout-perch	101	13.13
Walleye	54	7.02
White sucker	338	43.95
Yellow perch	2	0.26
Total	**769**	**100**

Table 5.9-12 Clearwater River fish inventory species composition, fall 2007.

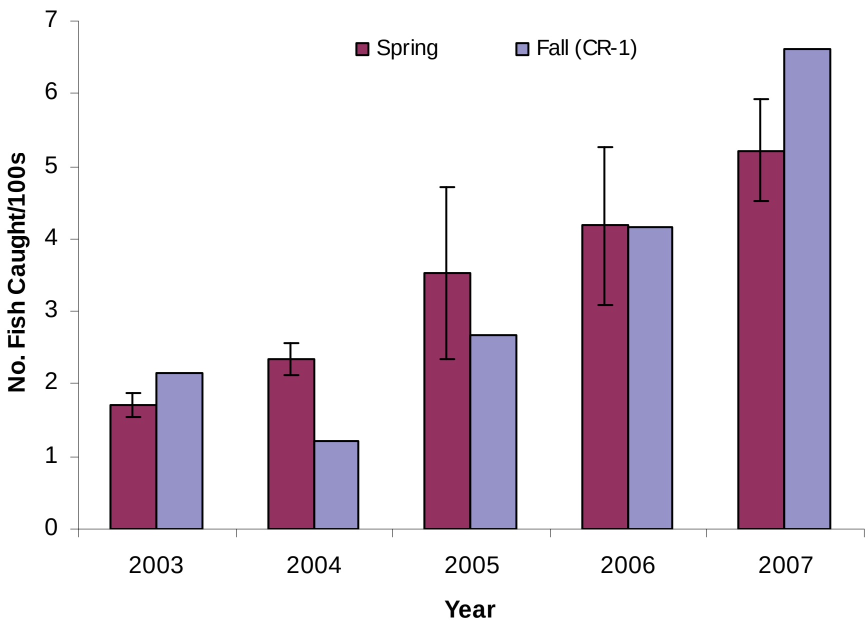
Species	Total Captured	Species Composition
Arctic grayling	12	4.51
Emerald shiner	1	0.38
Fathead minnow	2	0.75
Lake chub	3	1.13
Lake whitefish	4	1.50
Longnose sucker	8	3.01
Mountain whitefish	14	5.26
Northern pike	49	18.42
Spoonhead sculpin	1	0.38
Spottail shiner	80	30.08
Trout-perch	11	4.14
Walleye	3	1.13
White sucker	70	26.32
Yellow perch	8	3.01
Total	**266**	**100**

Note: Only reach CR-1 was surveyed in fall due to mechanical malfunctions of the boat.

Table 5.9-13 Species composition of fish observed but not captured, spring and fall 2007 (counts are approximate).

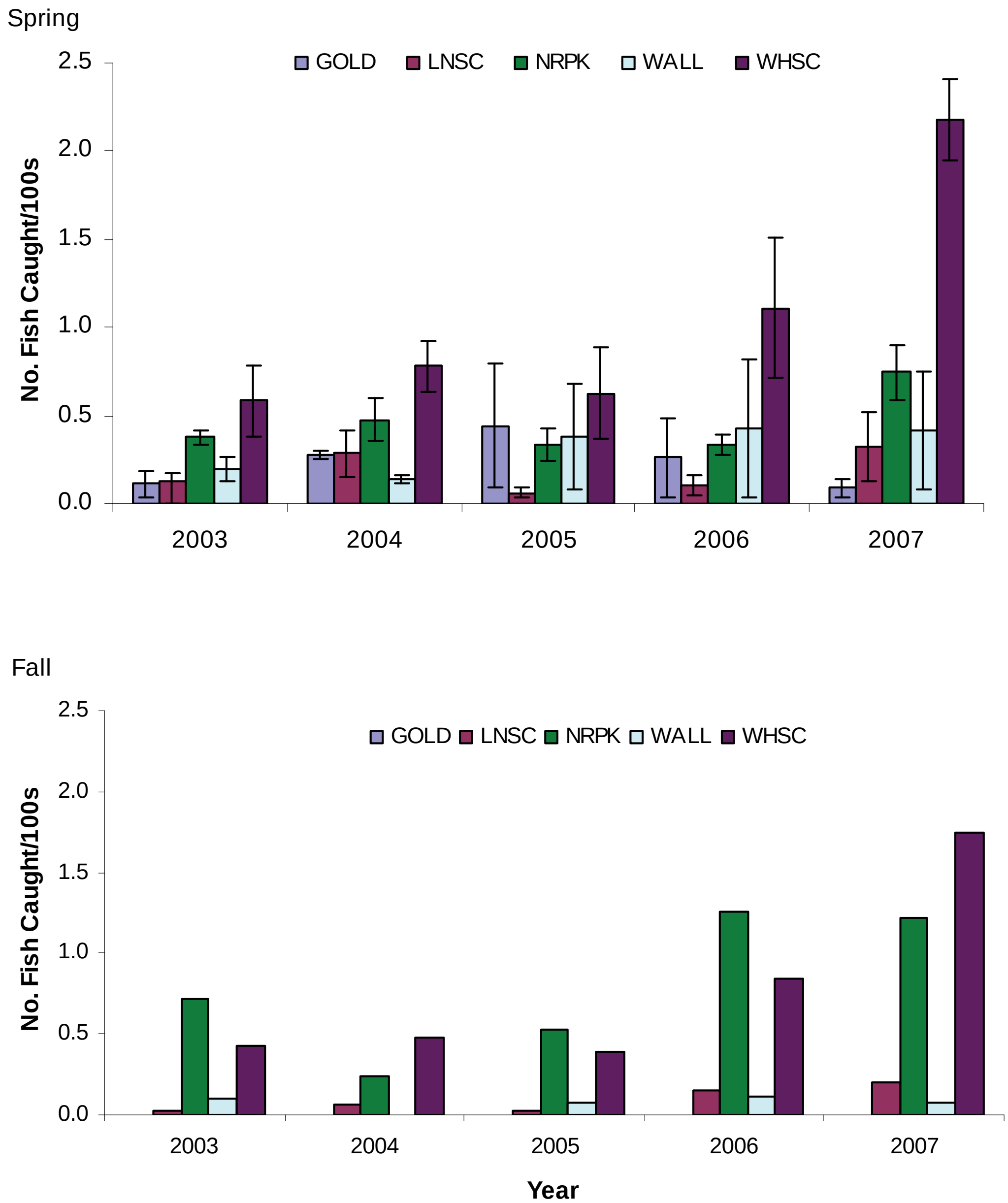
Species	Spring	Fall
Burbot	2	-
Goldeye	11	-
Lake whitefish	2	-
Longnose sucker	1	1
Mountain whitefish	-	1
Northern pike	60	25
Sculpin sp.	15	-
Spoonhead sculpin	1	-
Spottail shiner	241	900
Trout perch	300	210
Walleye	35	-
White sucker	137	12
Yellow perch	-	22
Total	**805**	**1171**

Figure 5.9-7 Seasonal catch per unit effort (mean ± SE) for captured fish of all species combined, Clearwater River. 2003 to 2007.



Note: Only one reach (reach CR-1) was sampled in fall 2007 so 2003-2007 fall figures are for reach CR-1 only.

Figure 5.9-8 Seasonal CPUE (mean ± SE) for five key indicator fish species, spring and fall 2007.



Note: only one reach (reach CR-1) was sampled in fall 2007 so 2003-2007 fall figures are for reach CR-1 only.

Figure 5.9-9 Relative length-frequency distributions for walleye captured in the Clearwater River, spring and fall 2003 to 2007.

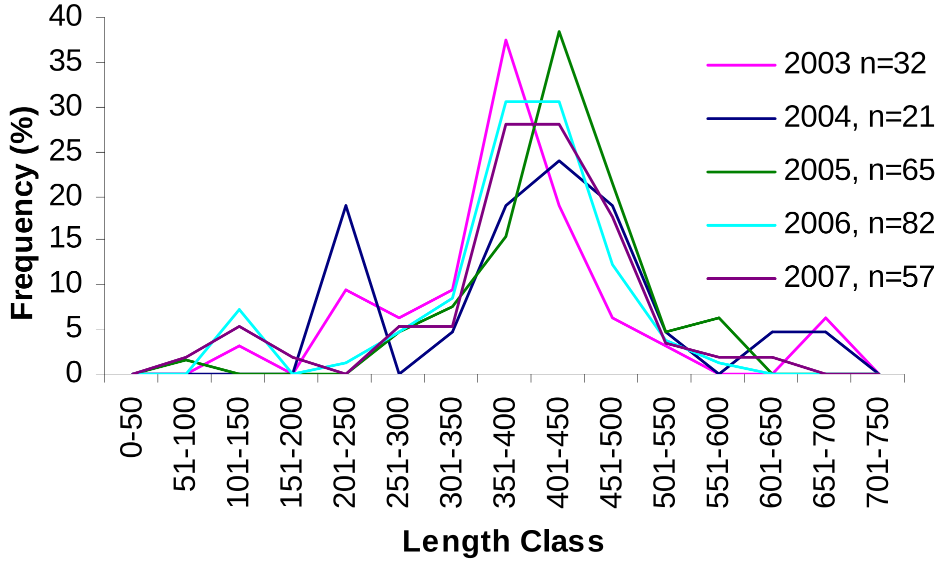


Figure 5.9-10 Relative length-frequency distributions for goldeye captured in the Clearwater River, spring and fall 2003 to 2007.

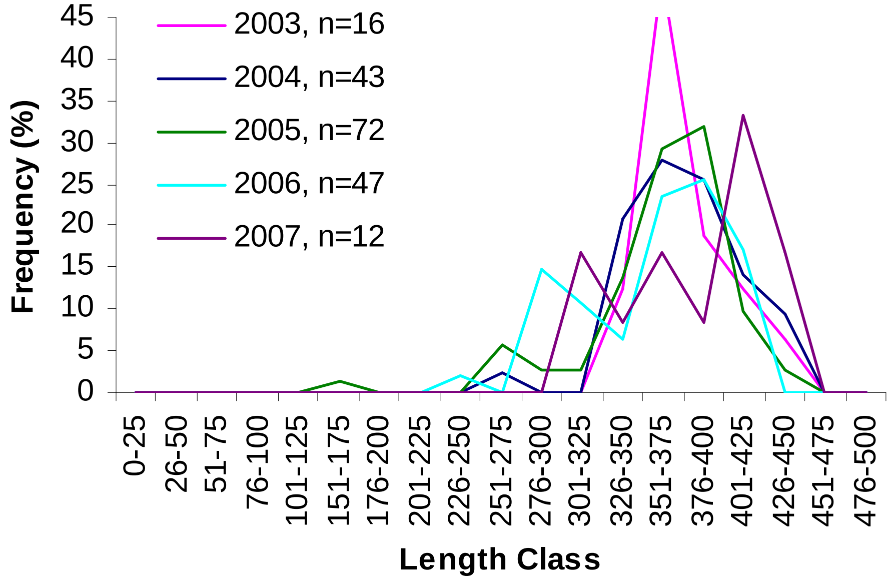
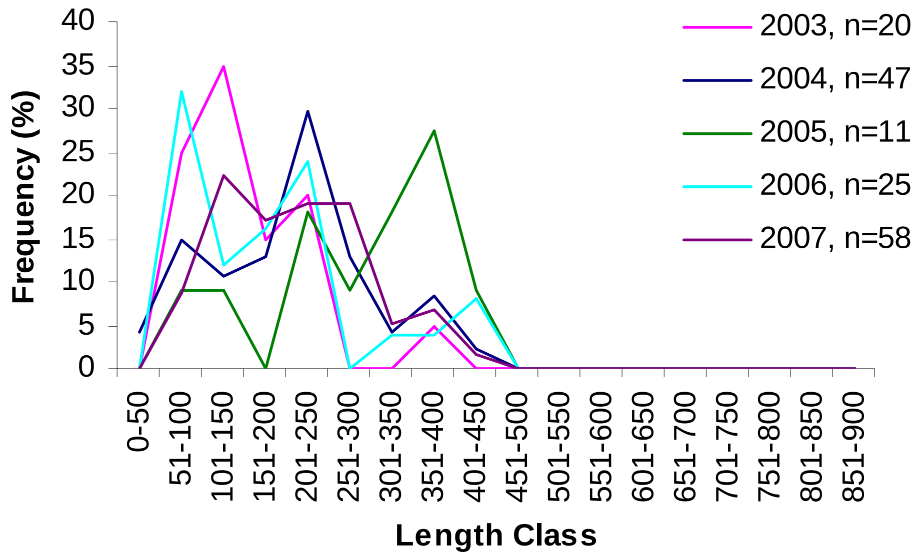


Figure 5.9-11 Relative length-frequency distributions for longnose sucker captured in the Clearwater River, spring and fall 2003 to 2007.



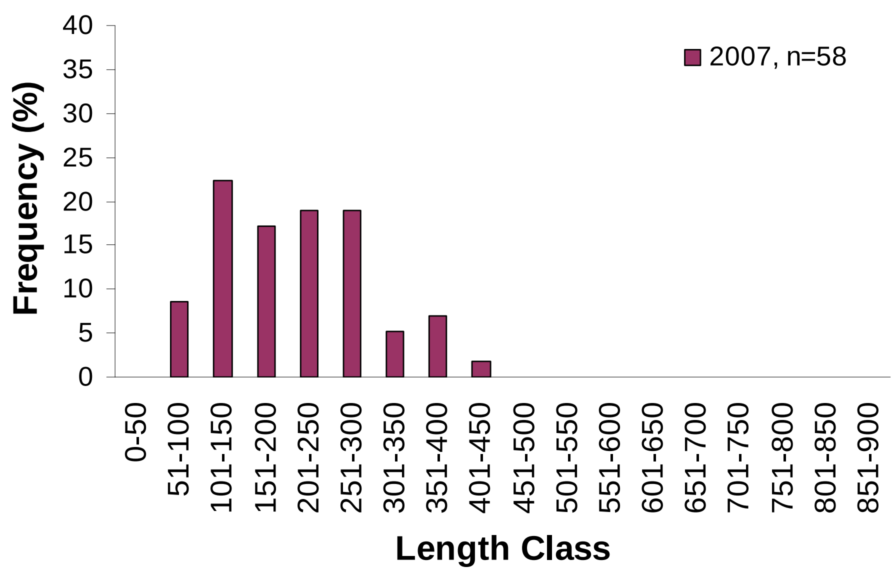
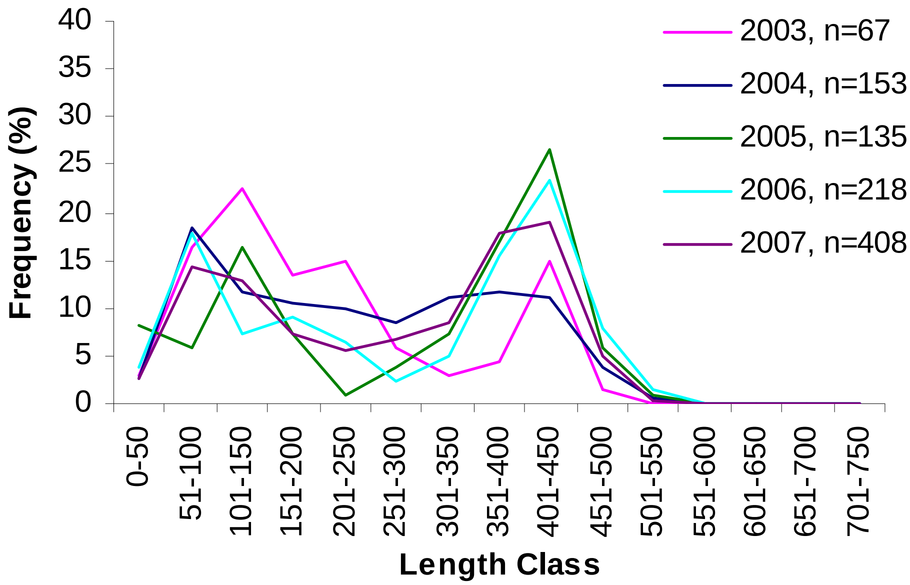


Figure 5.9-12 Relative length-frequency distributions for white sucker captured in the Clearwater River, spring and fall 2003 to 2007.



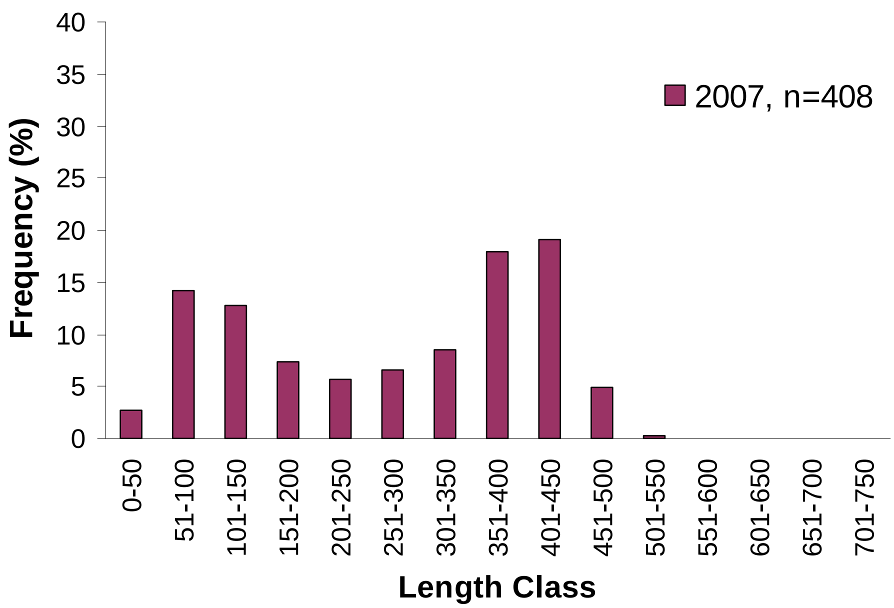
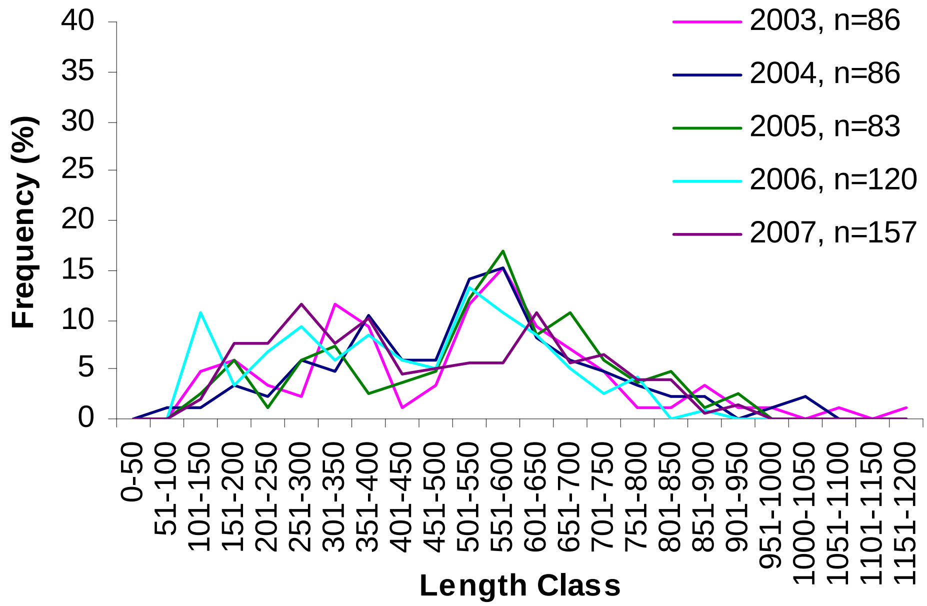


Figure 5.9-13 Relative length-frequency distributions for northern pike captured in the Clearwater River, spring and fall 2003 to 2007.



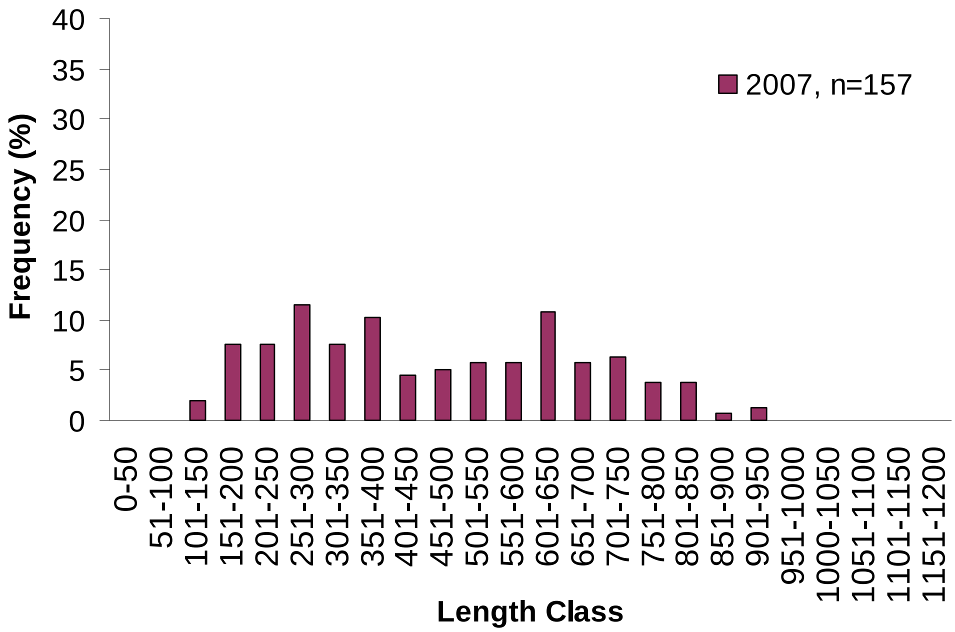
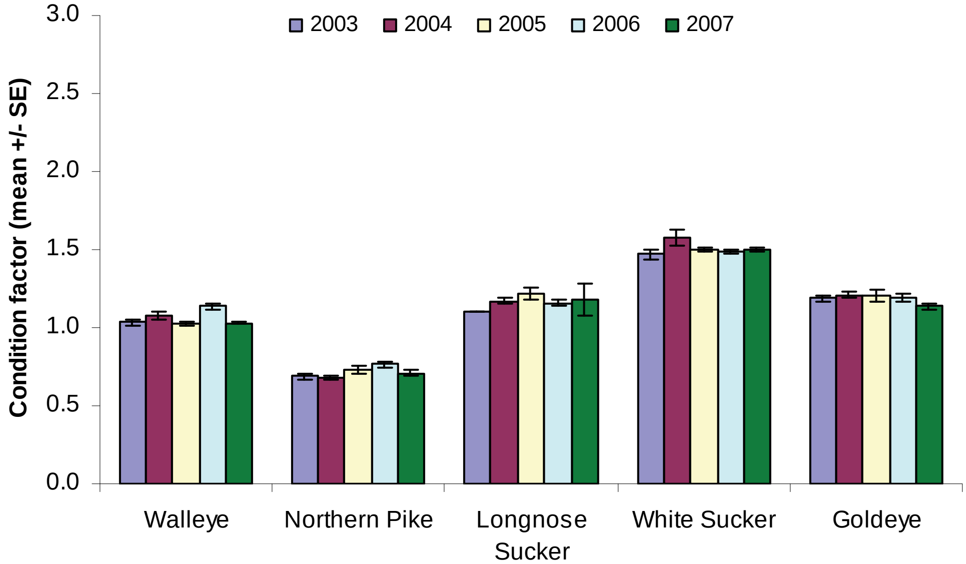
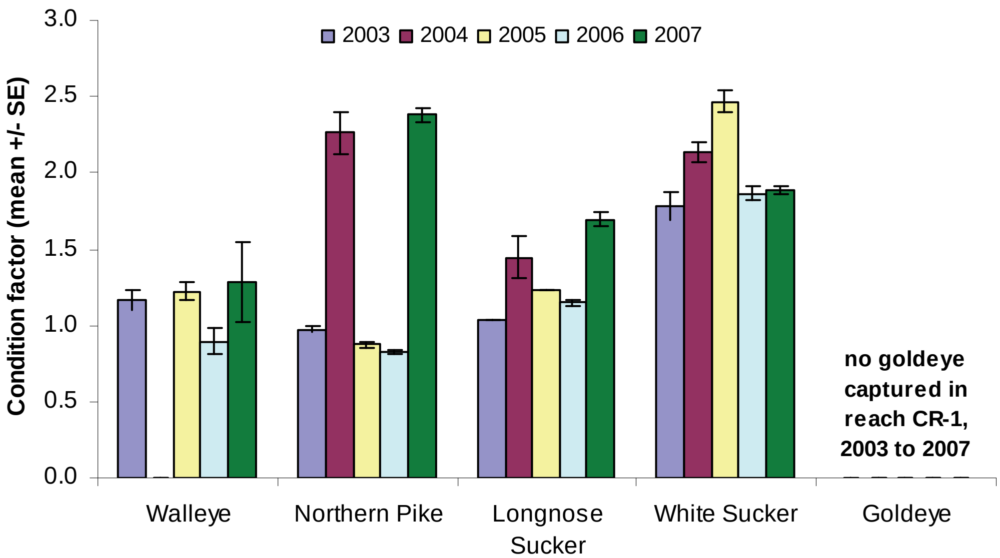


Figure 5.9-14 Condition factor for key indicator fish species, Clearwater River 2003-2007.





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

Table 5.9-14 Summary of external pathology indices for five key indicator fish species, Clearwater River, 2003-2007.

Species	External Pathology Index				
	2003	2004	2005	2006	2007
Walleye	1.0	0.5	0.2	0.7	0.5
Goldeye	1.7	0.2	0.4	1.9	3.3
Northern pike	0.7	2.3	2.5	1.7	3.8
Longnose sucker	0.4	0.3	1.1	1.0	1.0
White sucker	3.0	0.7	0.8	1.4	3.1

Table 5.9-15 Metrics and mercury concentrations in northern pike collected from the Clearwater River, fall 2007, and screening of concentrations against criteria for fish consumption for the protection of human health.

Species	Sex	Fish ID	Stage	Fork Length (mm)	Age	Mercury Concentration (mg/kg)
NRPK	U	CR1A-01	A	948	-	0.0636
NRPK	U	CR1A-02	A	610	-	**0.348**
NRPK	U	CR1A-03	A	708	-	**0.196**
NRPK	U	CR1A-04	A	668	-	**0.344**
NRPK	U	CR1A-05	A	841	-	**0.624**
NRPK	U	CR1A-06	A	647	-	0.0908
NRPK	U	CR1A-07	A	764	-	**0.15**
NRPK	U	CR1A-08	I	384	-	0.112
NRPK	U	CR1A-09	A	407	-	0.077
NRPK	U	CR1A-10	I	305	-	**0.326**
NRPK	U	CR1A-11	I	299	-	0.0867
NRPK	U	CR1A-12	A	826	-	**0.233**
NRPK	U	CR1A-13	A	645	-	0.137
NRPK	U	CR1A-14	A	623	-	**0.217**
NRPK	U	CR1A-15	I	360	-	0.00947
NRPK	U	CR1A-16	I	357	-	0.112
NRPK	M	CR1A-17	A	453	5	0.133
NRPK	M	CR1A-18	A	500	4	**0.145**
NRPK	M	CR1A-19	A	511	-	0.131
NRPK	U	CR1A-20	A	420	-	0.064
NRPK	F	CR1A-21	A	471	4	**0.156**
NRPK	F	CR1A-22	A	509	4	0.113
NRPK	M	CR1A-23	A	520	3	0.127
NRPK	U	CR1B-01	A	591	-	**0.256**
NRPK	U	CR1B-02	I	343	-	0.0521
NRPK	U	CR1B-03	I	254	-	0.0435
NRPK	U	CR1B-04	I	250	-	0.0541
NRPK	U	CR4-01	I	300	-	0.0303
NRPK	U	CR4-02	I	231	-	0.0411
NRPK	U	CR4-03	I	385	-	0.119
NRPK	M	CR4-04	A	595	4	-
NRPK	M	CR4-05	A	515	5	0.0707
NRPK	F	CR4-06	A	582	6	-
NRPK	M	CR4-07	A	530	4	-

F - Female; M - Male; U - Undetermined; A - Adult; I - Immature

exceeds National USEPA Criteria for subsistence fishers (0.049 mg/kg)

exceeds Region III USEPA Risk-Based Criterion

exceeds Health Canada Criterion for subsistence fishers (0.20 mg/kg)

exceeds National USEPA Criteria for recreational fishers (0.40 mg/kg)

exceeds Health Canada Criterion for consumers (0.50 mg/kg)

Figure 5.9-15 Temporal comparison of mercury concentration in northern pike from the Clearwater River, 2004, 2006, 2007.

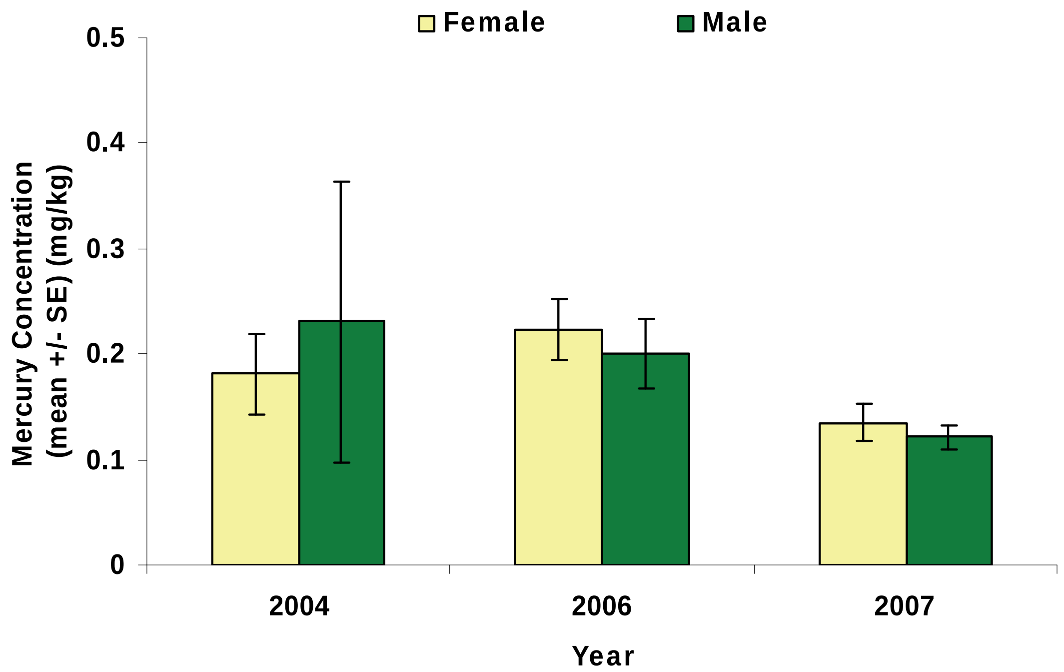


Figure 5.9-16 Regression analysis of mercury concentration in fish muscle versus length and age for northern pike from the Clearwater River, fall 2007.

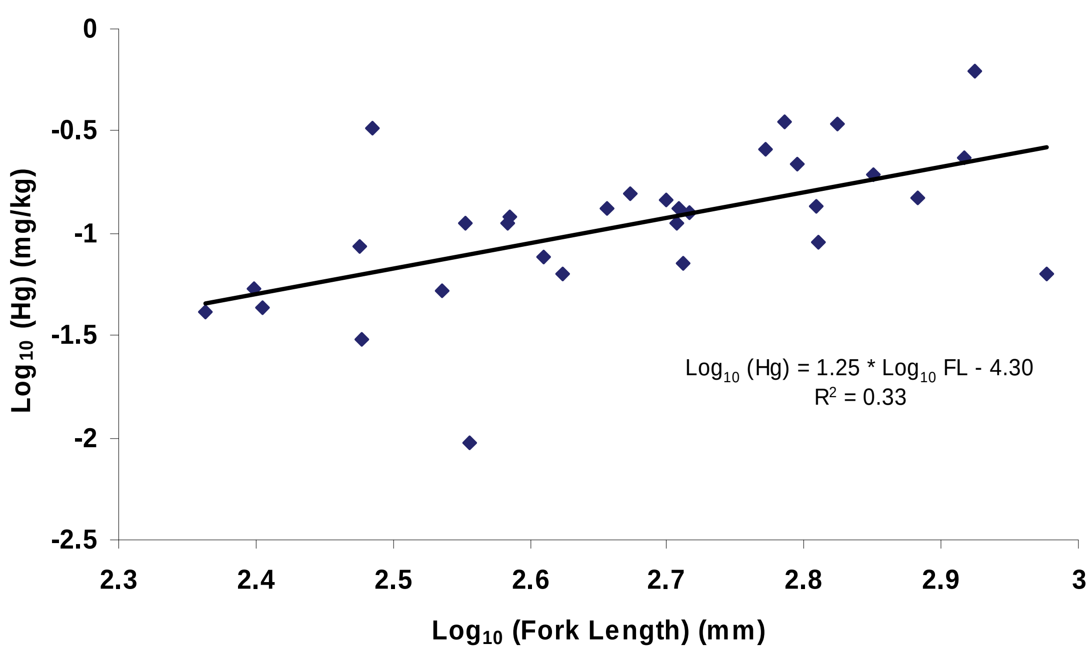


Table 5.9-16 Screening of metals and tainting compounds in northern pike composite samples collected in 2007 from the Clearwater River against criteria fish consumption for the protection of human health.

	Units	DL	Composite[1] NRPK		Composite[2] NRPK		Health Canada Criteria		National USEPA[5]		Region III USEPA[6]
			Female	Male	Female	Male	General[3]	Subsistence[4]	Recreational	Subsistence	Risk-based Criteria
Total Metals											
Aluminum (Al)	mg/kg	2	<2	<2	<2	<2	nc	nc	nc	nc	nc
Antimony (Sb)	mg/kg	0.05	<0.05	<0.05	<0.05	<0.05	nc	nc	nc	nc	0.54
Arsenic (As)	mg/kg	0.002	**<u>0.026</u>**	**<u>0.026</u>**	**<u>0.025</u>**	**<u>0.027</u>** (shaded)	nc	nc	0.026	0.00327	0.0021
Barium (Ba)	mg/kg	0.1	0.2	0.2	0.1	0.1	nc	nc	nc	nc	270
Beryllium (Be)	mg/kg	0.2	<0.2	<0.2	<0.2	<0.2	nc	nc	nc	nc	2.7
Boron (B)	mg/kg	2	<2	<2	<2	<2	nc	nc	nc	nc	120
Cadmium (Cd)	mg/kg	0.01	<0.01	<0.01	<0.01	<0.01	nc	nc	nc	nc	1.4
Calcium (Ca)	mg/kg	20	1170	570	220	310	nc	nc	nc	nc	nc
Chromium (Cr)	mg/kg	0.1	<0.1	<0.1	<0.1	0.1	nc	nc	nc	nc	4.1
Cobalt (Co)	mg/kg	0.1	<0.1	<0.1	<0.1	<0.1	nc	nc	nc	nc	nc
Copper (Cu)	mg/kg	0.05	0.26	0.27	0.26	0.31	nc	nc	nc	nc	54
Iron (Fe)	mg/kg	5	<5	25	<5	<5	nc	nc	nc	nc	410
Lead (Pb)	mg/kg	0.02	<0.02	<0.02	<0.02	<0.02	nc	nc	nc	nc	nc
Lithium (Li)	mg/kg	0.5	<0.5	<0.5	<0.5	<0.5	nc	nc	nc	nc	27
Magnesium (Mg)	mg/kg	5	379	343	345	382	nc	nc	nc	nc	nc
Manganese (Mn)	mg/kg	0.5	1.1	1	<0.5	<0.5	nc	nc	nc	nc	190
Molybdenum (Mo)	mg/kg	0.05	<0.05	<0.05	<0.05	<0.05	nc	nc	nc	nc	6.8
Nickel (Ni)	mg/kg	0.02	0.08	0.05	0.02	0.05	nc	nc	nc	nc	27

<u>value</u> = exceeds USEPA screening value for subsistence fishers; **value** = exceeds region III risk-based criteria

<u>shaded value</u> = exceeds USEPA screening criteria for recreational fishers; nc = no criterion

[1] Composite sample taken from northern pike within the target size class (500 to 550 mm for females, 450 to 500 mm for males).

[2] Composite sample taken from northern pike within and approaching the target size class (450-500 mm and 550-600 mm for females and 500-600 mm for males)

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

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

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

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

[7] Naphthalene was tested for three target analytes: 1-Methylnaphthalene, 2,6-Dimethylnaphthalene, and 2,3,5-Trimethylnaphthalene all with a detection limit of 0.05 mg/kg and have the health criteria guidline.

Table 5.9-16 (Cont'd.)

	Units	DL	Composite[1] NRPK		Composite[2] NRPK		Health Canada Criteria		National USEPA[5]		Region III USEPA[6]
			Female	Male	Female	Male	General[3]	Subsistence[4]	Recreational	Subsistence	Risk-based Criteria
Total Metals (Cont'd.)											
Phosphorus (P)	mg/kg	20	2890	2500	2330	2550	nc	nc	nc	nc	nc
Potassium (K)	mg/kg	20	4430	4380	4230	4640	nc	nc	nc	nc	nc
Selenium (Se)	mg/kg	0.002	0.195	0.175	0.205	0.189	nc	nc	20	2.457	6.8
Silver (Ag)	mg/kg	0.02	<0.02	<0.02	<0.02	<0.02	nc	nc	nc	nc	6.8
Sodium (Na)	mg/kg	20	380	340	350	400	nc	nc	nc	nc	nc
Strontium (Sr)	mg/kg	0.05	1.02	1.01	0.3	0.42	nc	nc	nc	nc	810
Thallium (Tl)	mg/kg	0.05	<0.05	<0.05	<0.05	<0.05	nc	nc	nc	nc	0.095
Tin (Sn)	mg/kg	0.1	<0.1	<0.1	<0.1	<0.1	nc	nc	nc	nc	810
Titanium (Ti)	mg/kg	0.2	0.2	0.7	<0.2	<0.2	nc	nc	nc	nc	nc
Vanadium (V)	mg/kg	0.006	0.015	0.012	0.012	0.012	nc	nc	nc	nc	1.4
Zinc (Zn)	mg/kg	0.5	1.2	0.7	1.1	1.8	nc	nc	nc	nc	410
Tainting Compounds											
Thiophene	mg/kg	0.01	<0.01	<0.01	<0.01	<0.01	nc	nc	nc	nc	nc
Toluene	mg/kg	0.01	<0.01	<0.01	<0.01	<0.01	nc	nc	nc	nc	110
m+p-Xylenes	mg/kg	0.01	<0.01	<0.01	<0.01	<0.01	nc	nc	nc	nc	nc
1,3,5-Trimethylbenzene	mg/kg	0.01	<0.01	<0.01	<0.01	<0.01	nc	nc	nc	nc	nc
Naphthalene[5]	mg/kg	0.05	<0.05	<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

shaded value = exceeds USEPA screening criteria for recreational fishers; nc = no criterion

[1] Composite sample taken from northern pike within the target size class (500 to 550 mm for females, 450 to 500 mm for males).

[2] Composite sample taken from northern pike within and approaching the target size class (450-500 mm and 550-600 mm for females and 500-600 mm for males)

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

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

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

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

[7] Naphthalene was tested for three target analytes: 1-Methylnaphthalene, 2,6-Dimethylnaphthalene, and 2,3,5-Trimethylnaphthalene all with a detection limit of 0.05 mg/kg and have the health criteria guidline.

5.10 HANGINGSTONE RIVER WATERSHED

Summary of Results

Measurement Endpoint	Summary of 2007 Conditions				
Climate and Hydrology					
	Assessment of Change				Total 2007 runoff volume was about 90% of normal. 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.
	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 2007 Conditions		
Water Quality			
Guideline Exceedances	**Station-Endpoint Combinations Exceeding Guidelines in Fall 2007**[1]		Based on available data, water quality in the lower Hangingstone River has remained consistent since monitoring by RAMP began in at this station in 2004.
Measurement endpoints with guidelines	**2007 Potentially Influenced Stations (n=0)**	**2007 Reference Stations (n=1)**	
Physical variables (max=1)	No water quality sampling stations were designated as potentially influenced in 2007.	0	
Nutrients (max=2)		0	
Ions (max=2)		0	
Selected metals (max=6)		1	
Comparison to Regional Baselines	**Endpoints in 2007 Compared to Regional Baseline**[2]		
Percentile of Regional Baseline Values	**2007 Potentially Influenced Stations (n=0 stations X 15 endpoints)**	**2007 Reference Stations (n=1 station X 15 endpoints)**	
Greater than 95th percentile	No water quality sampling stations were designated as potentially influenced in 2007.	0	
Between 5th and 95th percentiles		15	
Less than 5th percentile		0	

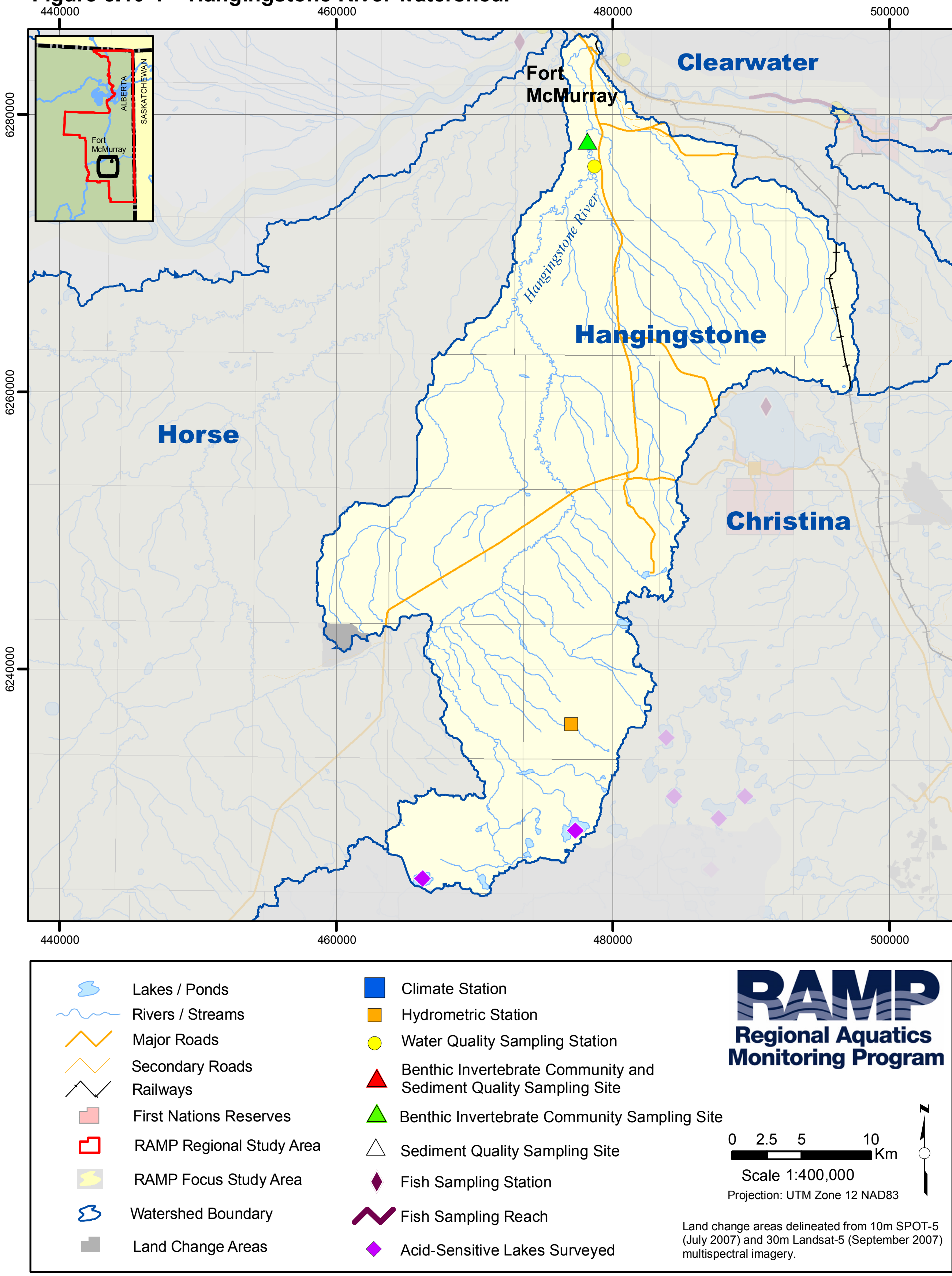
Measurement Endpoint	Summary of 2007 Conditions						
Benthic Invertebrate Communities and Sediment Quality							
Benthic Invertebrate Communities: Comparison to Regional Baselines	**Endpoints in 2007 Compared to Regional Baseline**						Benthic invertebrate community measurement endpoints in fall 2007 in the lower Hangingstone River were at similar levels similar to previous years, with diversity continuing to be high
Values in Relation to Regional Baseline Mean	**2007 Potentially Influenced Sites (n=0)**			**2007 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	No benthic invertebrate community sampling locations were designated as potentially influenced in 2007.			No comparisons to regional baselines were made as all RAMP monitoring stations in the Ells River watershed are designated as reference in 2007			
Richness							
Diversity							
Evenness							
% EPT							
Sediment Quality Guideline Exceedances	**Station-Endpoint Combinations Exceeding Guidelines in 2007**						
Measurement endpoints with guidelines	**2007 Potentially Influenced Sites (n=0)**			**2007 Reference Sites (n=0)**			
Total Hydrocarbons	No sediment quality sampling was conducted in Hangingtsone River watershed in 2007.						
PAHs							

Measurement Endpoint	Summary of 2007 Conditions
Fish Populations	
Fish Inventory	No fish inventory studies conducted in Hangingstone River watershed in 2007.
Sentinel Studies	No sentinel fish studies conducted in Hangingstone River watershed in 2007.
Fish Tissue	**Level of Risk**
Human Health: Subsistence	Fish tissue program was not conducted in 2007.
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; mercury (ultra-trace); arsenic; calcium; magnesium; sodium, potassium, chloride, sulphate; naphthenic acids

Figure 5.10-1 Hangingstone River watershed.



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5.10.1 Development Status

All of the Hangingstone River watershed is designated as *reference* for 2007. As of 2007, none of the 2007 focal projects were located in the watershed and, approximately 0.4% of the watershed area had undergone land change from oil sands development activities from non-RAMP-member companies (Table 2.4-2). All RAMP water quality stations and benthic invertebrate community and sediment quality reaches in the Hangingstone River watershed in 2007 are designated as *reference* stations reaches, and all data gathered at these locations in 2007 are designated as baseline data. Accordingly, 2007 provides another opportunity to evaluate natural variability in baseline conditions for these RAMP aquatic resources.

5.10.2 Hydrologic Conditions

2007 Hydrologic Conditions Total runoff volume in the Hangingstone River watershed, as measured at WSC Station 07CD004, Hangingstone River at Fort McMurray, was below normal in 2007, with a May to October runoff depth of 89 mm compared to the long-term average of 100 mm (Figure 5.10-2). Most of the runoff occurred in April and May. By early June, streamflow subsided to below median levels and remained low for most of the summer. The August rainfall event produced a noticeable runoff response in the Hangingstone River watershed. The highest maximum daily discharge of 31.1 m^3/s, which occurred in late April, was well below the mean annual flood of 40.0 m^3/s. The lowest open-water season discharge was 0.619 m^3/s, while the mean annual minimum open-water discharge was 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 2007. As indicated in Section 3.1.7.2, the hydrologic analysis, unlike most RAMP components, does not require comparison of measurement endpoints between *potentially influenced* and *reference* areas and can be conducted 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 2007. 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 5.10-1. As of 2007, 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 2.4-1), the estimated net effects of which were to reduce inflows to the Hangingstone River by 0.266 million m^3 in 2007. The estimated cumulative effect in 2007 is that mean open-water season discharge was reduced by 0.2%, annual maximum daily discharge was decreased by 0.4% and open-water season minimum daily discharge was reduced by 0.1% (Table 5.10-2). The hydrograph and 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 5.10-2, Table 5.10-2). This calculated incremental change in the hydrologic measurement endpoints would have been assessed as Negligible in oil sands EIAs (RAMP 2005b).

Summary Based on the available hydrologic and oils sands development information:

- As of 2007, 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 2007 have been negligible.

5.10.3 Water Quality

In 2007, water quality sampling was conducted near the mouth of the Hangingstone River (station HAR-1) in spring, summer, and fall. HAR-1 has been designated as a reference station since its establishment in 2004.

2007 Results and Historical Ranges of Concentration In fall 2007, concentrations of several water quality measurement endpoints fell outside the range of previous observations at station HAR-1 (Table 5.10-3). Total and dissolved aluminum, total boron, total mercury and total strontium were equal to or greater than their previously-measured maxima at this station, while concentrations of sulphate and total dissolved solids were below their historical minima.

Comparison of Water Quality Measurement Endpoints to Water Quality Guidelines Total aluminum was the only water quality measurement endpoint that exceeded water quality guidelines at station HAR-1 in 2007 (Table 5.10-4); this guideline was exceeded in 2007 in spring, summer, and fall and, as indicated above, its fall concentration was higher than its previously-measured maximum concentration (Table 5.10-3). The high concentrations of total aluminum at station HAR-1 in fall 2007 may be due to concentrations of total suspended solids that were above historical median value for that station (Table 5.10-3) and the fact the total aluminum and total suspended solids have historically co-varied at station HAR-1 (Figure 5.12-3 of RAMP 2004 Technical Report, RAMP [2005a]).

Other Water Quality Guideline Exceedances The following other water quality variables had concentrations that exceeded relevant guidelines at station HAR-1 in 2007 (Table 5.10-4):

- In spring: total and dissolved iron, total and dissolved phosphorus, total cadmium;
- In summer: total and dissolved iron, total phosphorus, and total phenols; and
- In fall: sulphide, total and dissolved iron, total phosphorus, and total phenols.

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 2007 fell within the 5th-to-95th-percentile of regional baseline concentrations (Figure 5.10-3).

Ion Balance Ion composition in waters in the lower Hangingstone River in 2007 was similar to that observed in previous years, and continues to be dominated by calcium bicarbonate (Figure 5.10-4).

Summary With some exceptions (total aluminum and mercury), water quality in the lower Hangingstone River has remained relatively consistent since monitoring by RAMP began in at this station in 2004.

5.10.4 Benthic Invertebrate Communities and Sediment Quality

5.10.4.1 Benthic Invertebrate Communities

In 2007, benthic invertebrate community samples were collected from a lower erosional reach in the Hangingstone River (reach HAR-E-1, *reference*, first sampled in 2004).

2007 Habitat Conditions The substrate in 2007 at reach HAR-E-1 was dominated by cobble and boulder, with finer particles in the interstices (Table 5.10-5). Current velocities were relatively high (0.5 m/s), while measured periphyton chlorophyll *a* biomass in fall 2007 was similar to previous years and indicating oligotrophic conditions for the lower Hangingstone River (Figure 5.10-5).

Relative Abundance of Benthic Invertebrate Community Taxa in 2007 Similar to previous years, chironomids, mayflies, stoneflies, caddisflies and mites dominated the benthic invertebrate community in reach HAR-E-1 in fall 2007 (Table 5.10-6). Diversity continues to be high, with 40 taxa enumerated in 2007, the highest richness measured at reach HAR-E-1 since sampling commenced in 2004, and Simpson's diversity and evenness near 0.9. A number of sensitive benthic taxa were found in 2007 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* 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 2007 to values measured in previous years (Figure 5.10-6).

5.10.4.2 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 2007.

5.10.4.3 Summary

Benthic invertebrate community measurement endpoints in fall 2007 in the lower Hangingstone River were at levels similar to previous years, with diversity continuing to be high.

5.10.5 Fish Populations

The 2007 RAMP Fish Population component did not include any activities in the Hangingstone River watershed.

5.10.6 Summary of Conditions in 2007 in the Hangingstone River

2007 results confirm that the Hangingstone River is a typical Athabasca River basin watershed, with aquatic resources in 2007 within the range of regional baseline conditions for similar watersheds and habitat types and at levels similar to previous years.

Figure 5.10-2 Hangingstone River: 2007 hydrograph and historical context.

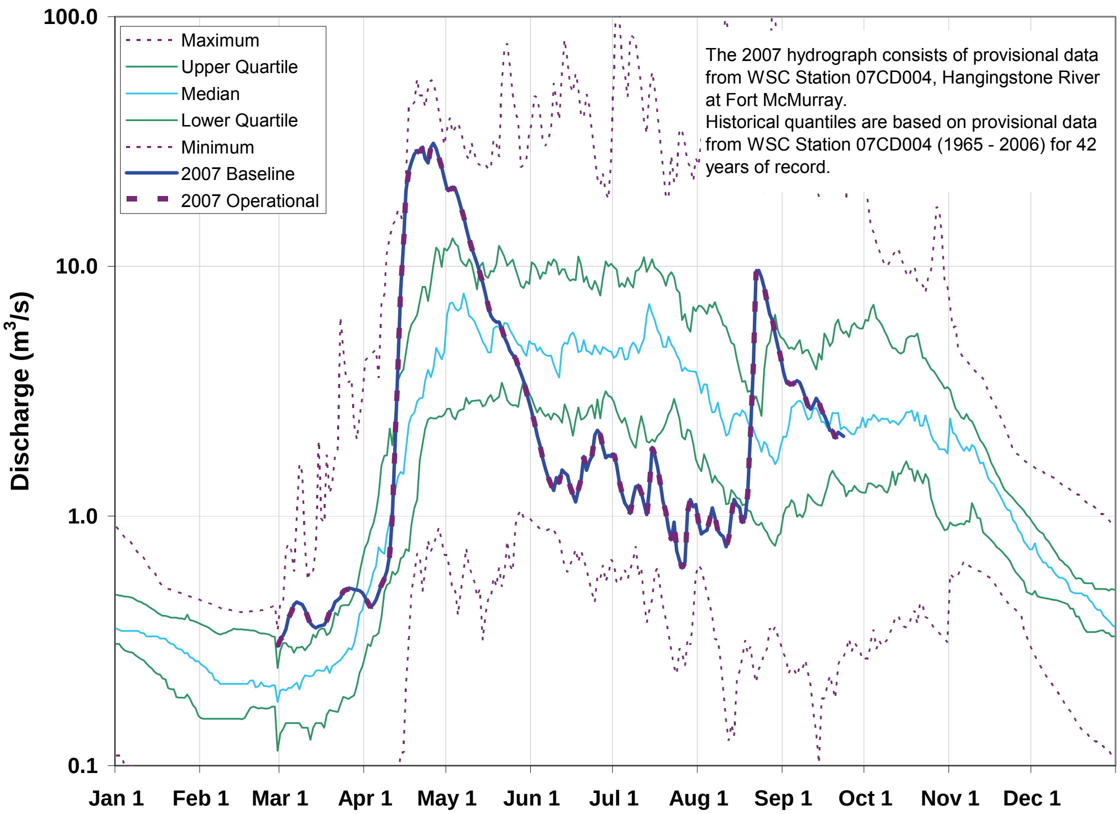


Table 5.10-1 Inputs for calculation of the baseline hydrograph at WSC Station 07CD004, Hangingstone River at Fort McMurray.

Component	Seasonal Volume (million m^3)	Basis and Data Source
Observed hydrograph (total annual discharge)	85.6	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 2007	+ 0.266	3.86 km^2 within Hangingstone River watershed estimated to have been closed-circuited by focal projects and other oil sands projects as of 2007 (Table 2.6-1)
Incremental runoff from areas of land change that were not closed-circuited as of 2007	0	0 km^2 within Hangingstone River watershed estimated to have undergone land change by focal projects and other oil sands projects as of 2007, 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)	85.9	Estimated total annual baseline discharge (i.e., without focal projects or other oil sands projects) for 2007
Incremental flow (change in total annual discharge)	- 0.266	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 5.10-2 Calculated change in hydrologic measurement endpoints for the Hangingstone River watershed for 2007.

Measurement Endpoint	Baseline Value (m^3/s)	Operational Value (m^3/s)	Percent Change
Mean open-water season discharge	3.85	3.84	-0.2%
Mean winter discharge	not monitored	not monitored	-
Annual maximum daily discharge	31.1	31.0	-0.4%
Open-water season minimum daily discharge	0.620	0.619	-0.1%

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 5.10-3 Water quality measurement endpoints, mouth of Hangingstone River (station HAR-1), fall 2007.

Measurement Endpoint	Units	Guideline	September 2007	1997-2006 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.2	3	8.0	8.2	8.3
Total Suspended Solids	mg/L	-[1]	9	3	3	5	12
Conductivity	µS/cm	-	232	3	231	233	278
Nutrients							
Total dissolved phosphorus	mg/L	0.05[2]	0.047	3	0.038	0.046	0.049
Total nitrogen*	mg/L	1.0	1	3	0.7	0.9	0.9
Nitrate+Nitrite	mg/L	-	<0.1	3	<0.1	<0.1	<0.1
Dissolved organic carbon	mg/L	-	29	3	17	21	28
Ions							
Sodium	mg/L	-	18	3	17	17	21
Calcium	mg/L	-	25.8	3	23.2	25.7	31.5
Magnesium	mg/L	-	7.5	3	7.2	7.4	8.3
Chloride	mg/L	230, 860[3]	10	3	9	13	13
Sulphate	mg/L	100[4]	9.6	3	10	10.4	11.8
Total Dissolved Solids	mg/L	-	167	3	170	190	210
Total Alkalinity	mg/L	-	94	3	88	99	119
Organic compounds							
Naphthenic acids	mg/L	-	<1	3	<1	<1	1
Selected metals							
Total aluminum	mg/L	0.1	**1.11**	3	**0.17**	**0.18**	**0.42**
Dissolved aluminum	mg/L	0.1[2]	0.0368	3	0.0113	0.0138	0.0296
Total arsenic	mg/L	0.005	0.0014	3	0.0012	0.00139	0.00174
Total boron	mg/L	1.2[5]	0.0955	3	0.061	0.066	0.0866
Total molybdenum	mg/L	0.073	0.00146	3	0.000746	0.001	0.00156
Total mercury (ultra-trace)	ng/L	5, 13[6]	3.7	3	<1.2	<1.2	1.22
Total strontium	mg/L	-	0.181	3	0.123	0.1280	0.179

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 5.10-4 Water quality guideline exceedances, mouth of Hangingstone River (station HAR-1), fall 2007.

Water Quality Variable	Units	Guideline*	HAR-1
Spring			
Dissolved iron	mg/L	0.3[1]	**0.445**
Dissolved phosphorus	mg/L	0.05	**0.055**
Total phosphorus	mg/L	0.05	**0.057**
Total cadmium	mg/L	-[2]	**0.0000211**
Total aluminum	mg/L	0.1	**1.11**
Total iron	mg/L	0.3	**1.56**
Summer			
Total aluminum	mg/L	0.1	**0.47**
Dissolved iron	mg/L	0.3[1]	**0.355**
Total phosphorus	mg/L	0.05	**0.074**
Total iron	mg/L	0.3	**1.09**
Total phenols	mg/L	0.005	**0.009**
Fall			
Sulphide	mg/L	0.014[3]	**0.018**
Total phosphorus	mg/L	0.05	**0.075**
Total aluminum	mg/L	0.1	**0.499**
Dissolved iron	mg/L	0.3[1]	**0.646**
Total iron	mg/L	0.3	**1.38**
Total phenols	mg/L	0.005	**0.008**

No winter sampling was conducted in this watershed.

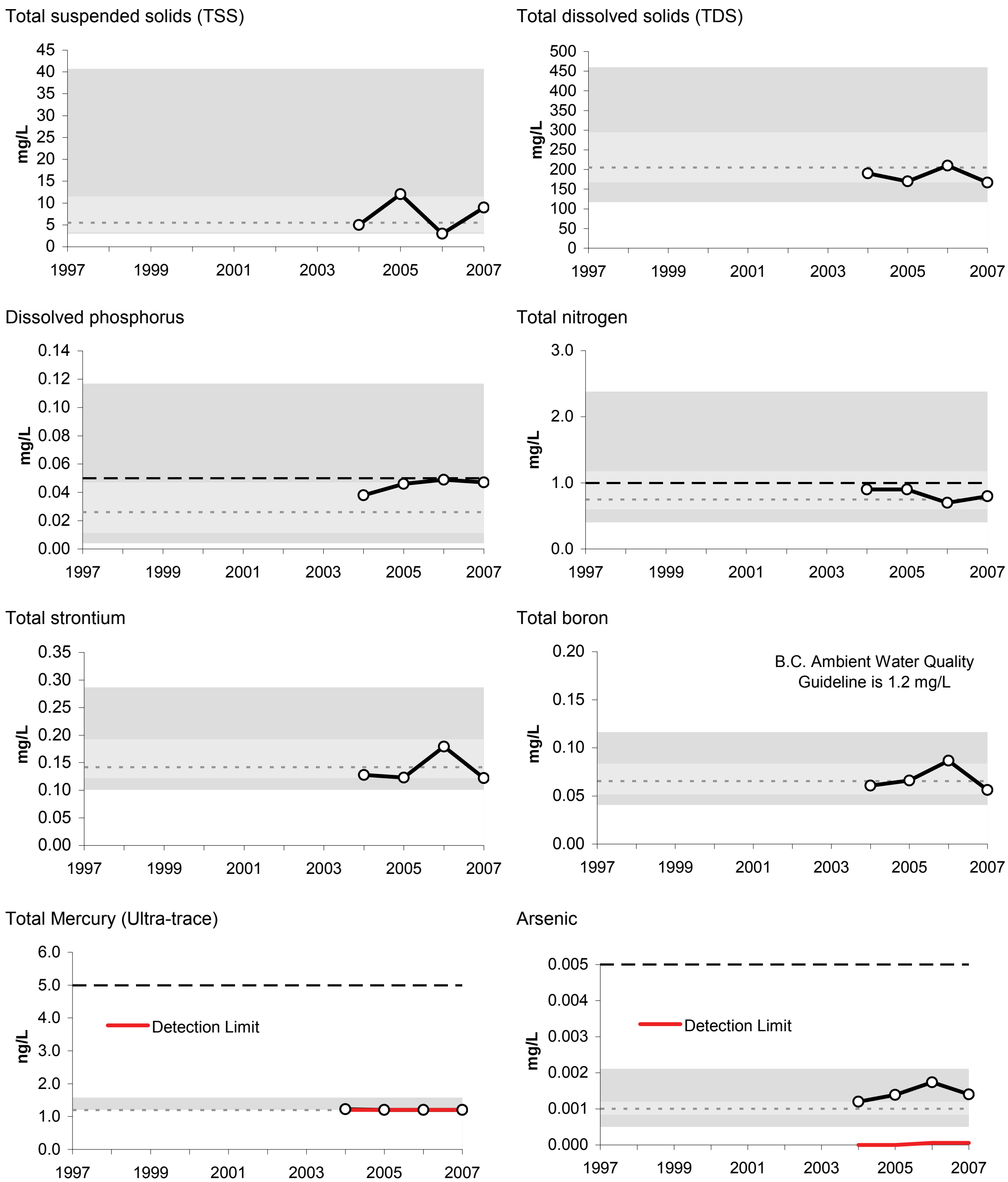
* Guidelines are CCME (2006) or AENV (1999) unless otherwise noted.

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

[2] Guideline is hardness-dependent.

[3] derived from EPA (2002)

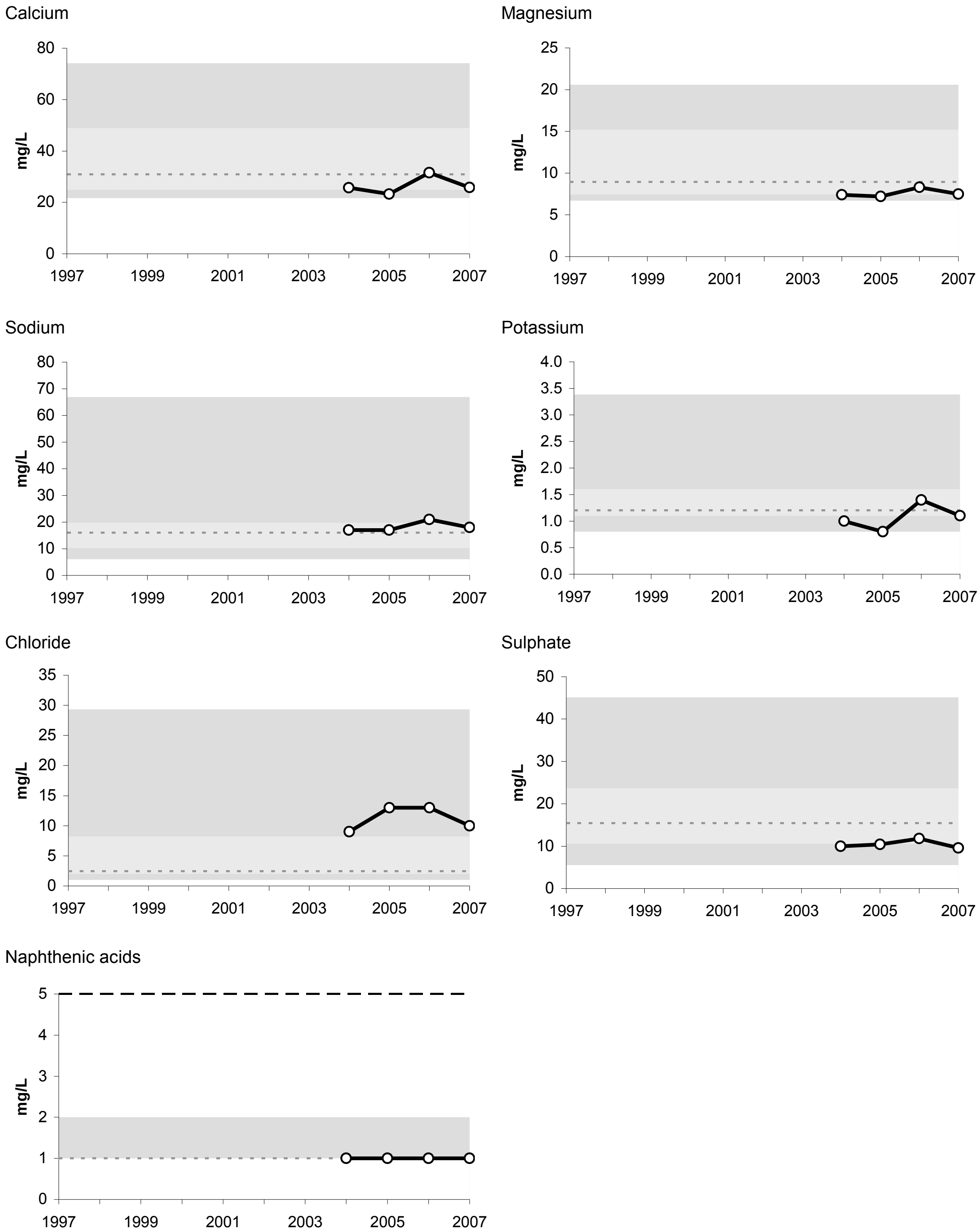
Figure 5.10-3 Concentrations of selected water quality measurement endpoints at the mouth of the Hangingstone River (station HAR-1, fall 2007) relative to regional baseline fall concentrations.



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 5.10-5 (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 5.10-4 Piper diagram of fall ion concentrations, mouth of Hangingstone River (station HAR-1), fall 2007.

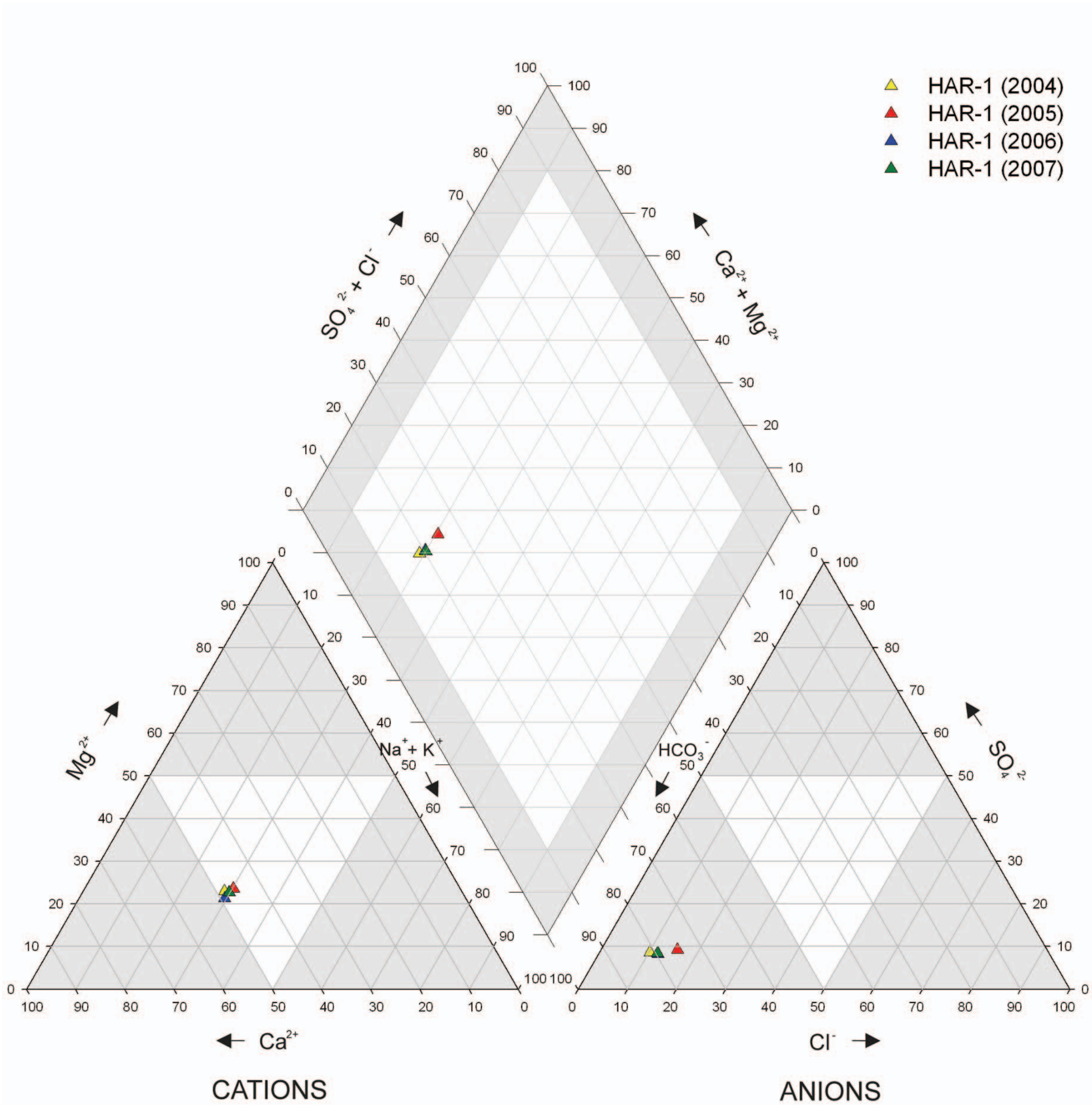


Table 5.10-5 Average habitat characteristics of benthic invertebrate community sampling reaches in the Hangingstone River, fall 2007.

Variable	Units	Lower Reach of Hangingstone River (Reach HAR-E-1)
Sample date	-	Sept 5, 2007
Habitat	-	Erosional
Water depth	m	0.2
Current velocity	m/s	0.6
Macrophyte cover	%	0
Field Water Quality		
Dissolved oxygen	mg/L	9.0
Conductivity	µS/cm	239
pH	pH units	7.5
Water temperature	°C	14.0
Sediment Composition		
Sand/Silt/Clay	%	9
Small gravel	%	1
Large gravel	%	0
Small cobble	%	37
Large cobble	%	37
Boulder	%	15
Bedrock	%	1

Figure 5.10-5 Annual variation in chlorophyll *a* in the lower reach of the Hangingstone River (reach HAR-E-1).

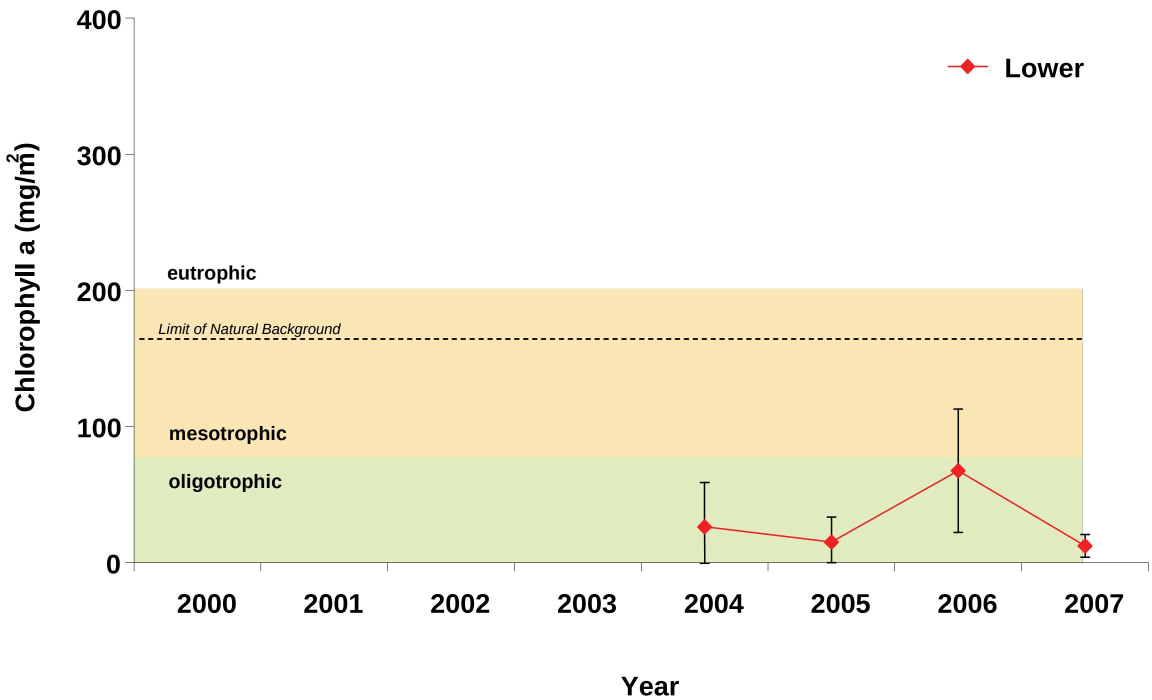
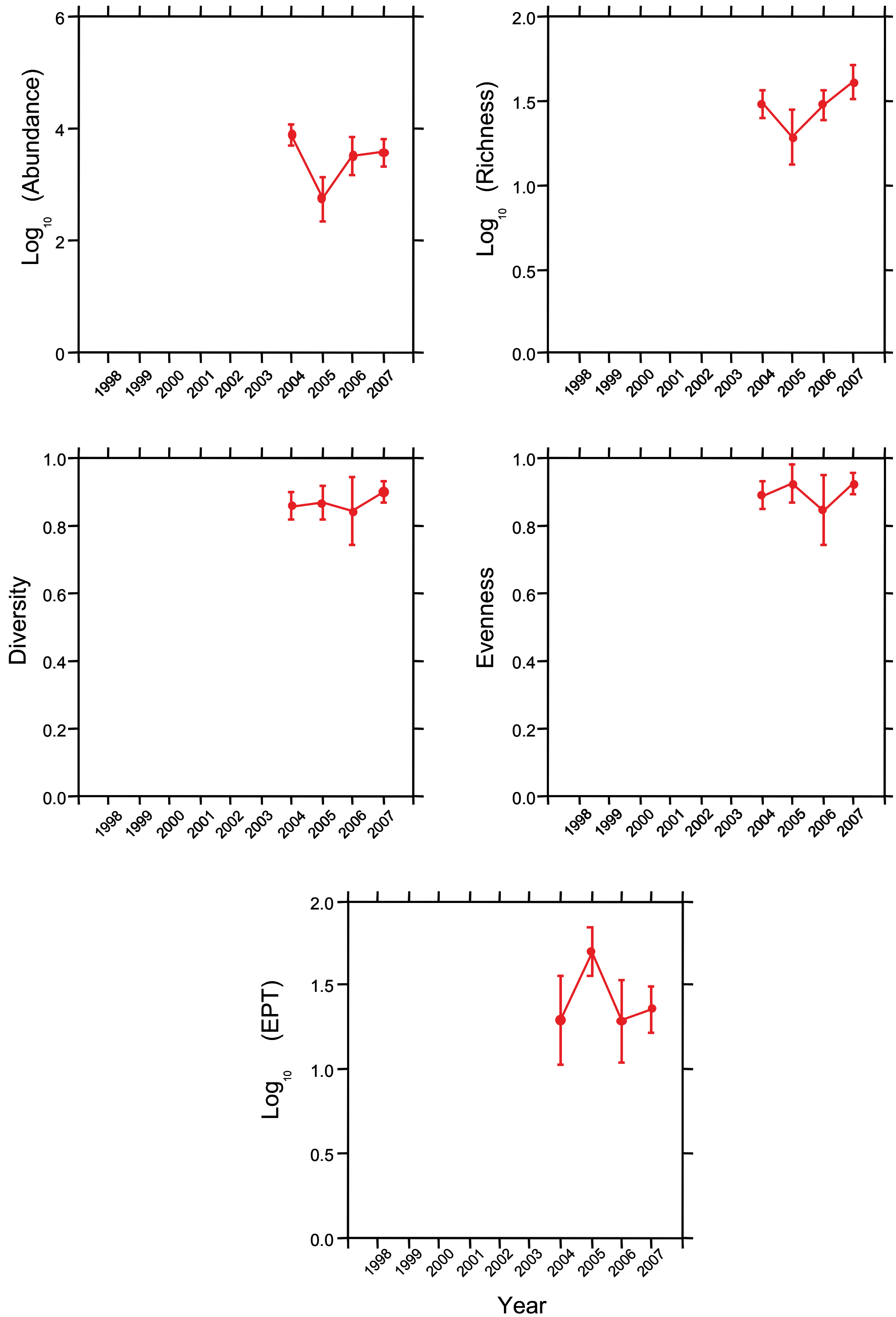


Table 5.10-6 Relative abundance of major taxa, and benthic invertebrate community measurement endpoints in the lower reach of the Hangingstone River (reach HAR-E-1).

Taxon	Percent Major Taxa Enumerated in Each Year			
	Reach HAR-E-1			
	2004	2005	2006	2007
Anisoptera	<1	1	<1	1
Athericidae	<1	3	1	<1
Bivalvia	<1			1
Ceratopogonidae	<1	<1	<1	<1
Chironomidae	33	14	40	30
Coleoptera	<1	<1	<1	<1
Collembola		<1		
Copepoda	<1	<1		1
Dolichopodidae				1
Empididae	2	2	4	1
Enchytraeidae	1	2	1	2
Ephemeroptera	16	34	11	13
Gastropoda	<1			3
Hydra		1		<1
Hydracarina	6	13	5	7
Naididae	24	3	25	13
Nematoda	6	2	2	4
Ostracoda	5		<1	15
Plecoptera	3	10	2	2
Simuliidae		3		
Tabanidae	<1			
Tipulidae		<1		<1
Trichoptera	4	12	8	8
Tubificidae	<1	<1	<1	1
Benthic Invertebrate Community Measurement Endpoints				
Total Abundance (No./m^2)	8,560	773	4,255	4,187
Richness	30	19	29	40
Simpson's Diversity	0.86	0.87	0.84	0.90
Evenness	0.89	0.92	0.85	0.93
% EPT	21	50	2	23

Figure 5.10-6 Annual variation in benthic invertebrate community measurement endpoints in the lower reach of the Hangingstone River (reach HAR-E-1).



5.11 MISCELLANEOUS AQUATIC SYSTEMS

Summary of Results

Measurement Endpoint	Summary of 2007 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 1.13 million m^3 spillway discharge in 2007 represents 40% of total 2007 flow at mouth of 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 2007[1]		
Measurement endpoints with guidelines	2007 Potentially Influenced Stations (n=6)	2007 Reference Stations (n=2)	There was little to distinguish 2007 water quality conditions in the miscellaneous aquatic systems from previous years. There were relatively few exceedances of both water quality guidelines and of regional baseline concentrations in watercourses and waterbodies designated as potentially influenced and in these aquatic systems in comparison to those designated as reference, indicating little effect of focal projects on water quality conditions in these aquatic systems in 2007.
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=36 for exp, 12 for ref)	3	0	
Comparison to Regional Baselines	Endpoints in 2007 Compared to Regional Baseline[2]		
Percentile of Regional Baseline Values	2007 Potentially-Influenced Stations (n=6 stations X 15 endpoints)	2007 Reference Stations (n=2 stations X 15 endpoints)	
Greater than 95th percentile	19	1	
Between 5th and 95th percentiles	70	27	
Less than 5th percentile	1	2	

Benthic Invertebrate Communities and Sediment Quality							
Benthic Invertebrate Communities: Comparison to Regional Baselines	Endpoints in 2007 Compared to Regional Baseline						
	2007 Potentially Influenced Stations (n=3)			2007 Reference Stations (n=2)			
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	Benthic invertebrate communities that were sampled in 2007 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, which showed continued evidence of degraded benthic invertebrate community conditions. There was nothing in the results of sediment quality sampling in the aquatic environments designated as potentially influenced that would suggest effects of focal project activities.
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 2007[1]						
Measurement endpoints with guidelines	2007 Potentially Influenced Stations (n=3)			2007 Reference Stations (n=2)			
Total Hydrocarbons (max=12 for exp,0 for ref)	2			2			
PAHs (max=3 for exp, 0 for ref)	0			0			
Metals	Arsenic: 2 lakes						

Fish Populations		
Fish Inventory	No fish inventory studies conducted in 2007.	Mercury tissue concentrations in walleye, northern pike, and lake whitefish from Gregoire Lake measured in the 2007 Regional Lakes program are consistent with the natural range of concentrations observed in this region of northern Alberta. No fish tissue effects thresholds for mercury and fish and fish health were exceeded in either Gregoire or Namur lakes.
Sentinel Studies	No sentinel fish studies conducted in 2007.	
Fish Tissue	Level of Risk	
Human Health: Subsistence Human Health: Recreational Fishers Human Health: General Consumers Human Health: Tainting	Although mercury concentrations in Gregoire Lake fish exceeded some Health Canada and USEPA guidelines, comparisons with historical regional data indicated they fall within the range of concentrations observed in this region of Alberta. Mercury concentrations in lake trout tissue from Namur Lake were generally higher relative to values reported from RAMP fish tissue studies conducted in other regional lakes on other species. This may be due to their position at the top of the food chain and their relatively large size and age compared to other species.	

[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.

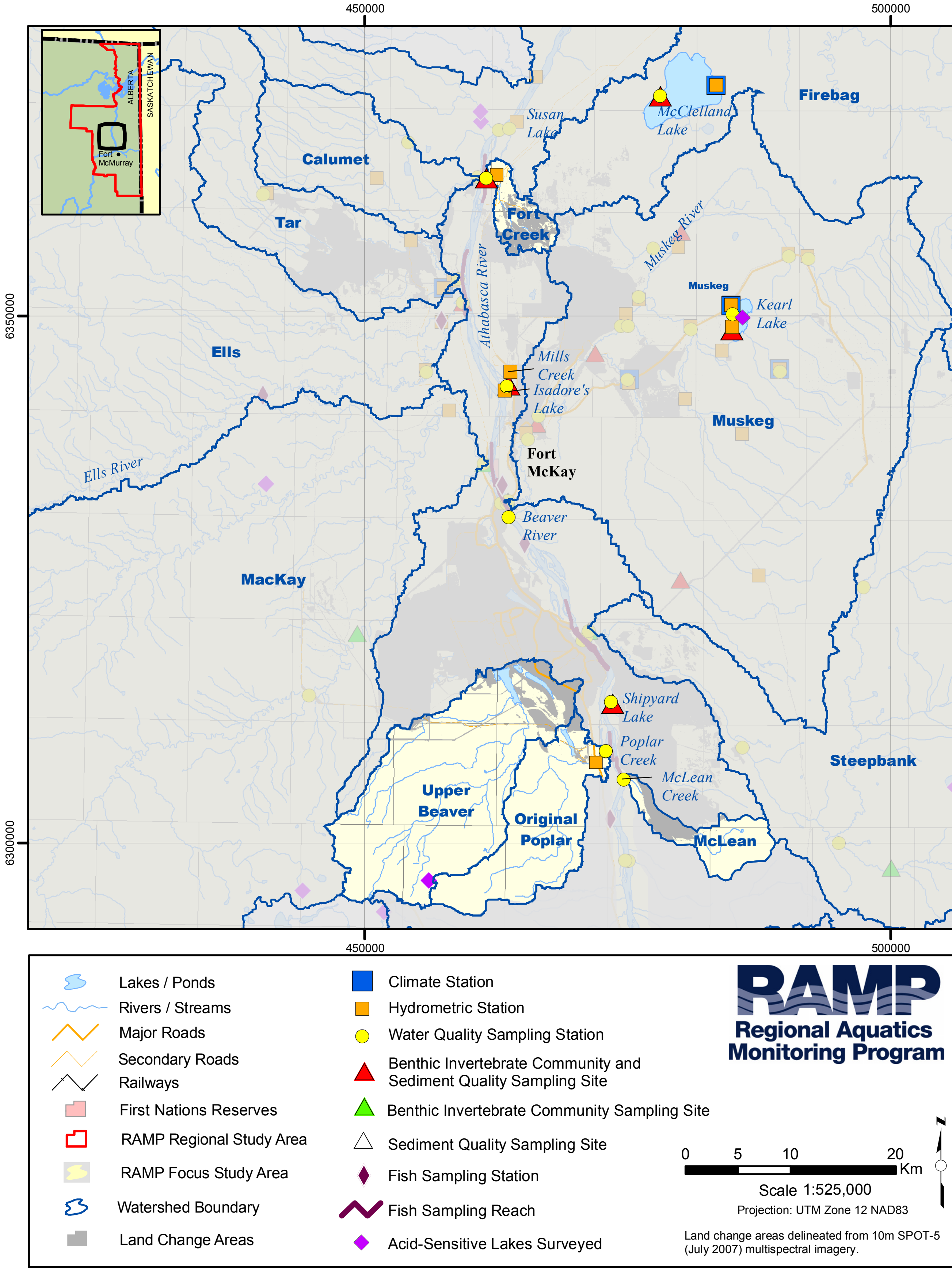
[2] Water quality measurement endpoints: TSS, TDS, dissolved phosphorous, total nitrogen, total strontium, total boron, naphthenic acids, calcium, magnesium, sodium, potassium, chloride, and sulphate.

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 5.11-1 Miscellaneous aquatic systems.



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5.11.1 Development Status

This section includes 2007 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 2007 are designated as operational data. To date, land changes from focal project activities has covered approximately 2.75% of the original Poplar Creek watershed, slightly more than 50% of the Fort Creek watershed, and almost 24% of the McLean Creek watershed (Table 2.4-2); and
- Kearl Lake, McClelland Lake, and the Susan Lake outlet are designated as *reference* for 2007, and all data gathered at these stations in 2007 are designated as baseline data.

5.11.2 Hydrologic Conditions

5.11.2.1 Potentially-Influenced Aquatic Systems

In 2007, hydrologic monitoring was undertaken on the following miscellaneous aquatic systems designated as *potentially-influenced*: Isadore's Lake, Mills Creek, Poplar Creek, and Fort Creek.

2007 Hydrologic Conditions: Isadore's Lake Isadore's Lake water level rose well above its historical median level in April, then fell to close to historical minimum levels in August (Figure 5.11-2). Although the lake level increased in response to August precipitation (Figure 4.1-2, Figure 4.1-3), it remained well below normal for the rest of the year.

2007 Hydrologic Conditions: Mills Creek Flows in Mills Creek were below historical median values and relatively constant throughout the year, with the highest discharge occurring in spring (Figure 5.11-3).

2007 Hydrologic Conditions: Poplar Creek Flow in Poplar Creek, including releases from the Poplar Creek spillway, amounted to a volume of 2.79 million m^3 in the monitored June 12 to October 20 period in 2007. Flows were in the lowest quartile for most of the summer, except for a period in August when releases were made from the Poplar Creek spillway (Figure 5.11-4). A discharge of 8.96 m^3/s was measured in April, slightly more than the mean annual flood of 8.2 m^3/s. The minimum-measured open-water discharge of 0.021 m^3/s was well below the historical average minimum discharge of 0.14 m^3/s.

2007 Hydrologic Conditions: Fort Creek Fort Creek flows were below historical median values throughout the summer and above median values in September and October (Figure 5.11-5). The maximum observed daily discharge was 0.252 m^3/s in mid-April and minimum summer flow was 0.017 m^3/s.

Estimation of Hydrologic Effects: Poplar Creek A summary of the inputs to the water balance model for Poplar Creek for examining possible changes in the hydrologic measurement endpoints is as follows (details are provided in Table 5.11-1):

- As of 2007, areas of closed-circuited land change and other land change (not closed-circuited) were 2.60 km^2 and 1.21 km^2, respectively, in the Poplar Creek drainage as a result of cumulative development of focal projects in the watershed (Table 2.4-1); and

- Discharges to Poplar Creek by focal projects in 2007 during the monitored period alone are estimated at 1.13 million m^3 from the Poplar Creek spillway, primarily in August and October. This is the largest focal project influence on the flows of Poplar Creek and exists as a result of the Beaver River Diversion. Discharge from the Poplar Creek spillway represented 40% of the total flow measured at RAMP Station S11 (Table 5.11-1), 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 estimated cumulative effect in 2007 (considering only the monitored period) is that mean open-water season discharge was increased by 88%, annual maximum daily discharge was increased by 25%, and open-water season minimum daily discharge was created (i.e., the open-water season minimum daily discharge for the estimated baseline hydrograph is 0 m^3/s, Figure 5.11-4, Table 5.11-2). These differences would have been assessed as High in oil sands EIAs (RAMP 2005b).

Estimation of Hydrologic Effects: Fort Creek A summary of the inputs to the water balance model for Fort Creek for examining possible changes in the hydrologic measurement endpoints is provided in Table 5.11-3. As of 2007, areas of closed-circuited land change and other land change (not closed-circuited) was 0.40 km^2 and 16.3 km^2, respectively, in the Fort Creek drainage as a result of cumulative development of focal projects in the watershed (Table 2.4-1). Including releases to Fort Creek from focal project activities, the estimated net effect of focal projects was to increase flows in Fort Creek by 0.109 million m^3 in 2007 as a result of dewatering activities.

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 2007. These estimated influences are predicted to have increased mean open-water season discharge, annual maximum daily discharge, and open-water season minimum daily discharge by 10% (Figure 5.11-5, Table 5.11-4). These calculated incremental changes in the hydrologic measurement endpoints would have been assessed as Moderate to High in most oil sands EIAs (RAMP 2005b).

5.11.2.2 Reference Aquatic Systems

In 2007, hydrologic monitoring was undertaken on the following miscellaneous aquatic systems designated as *reference*: Kearl Lake, McClelland Lake, and the Susan Lake outlet.

2007 Hydrologic Conditions: Kearl Lake Kearl Lake levels were below historical median values for almost the entire year (Figure 5.11-6). In mid-May, the lake reached its highest level for the year but then fell steadily until mid-August. From mid-July until mid-September, lake levels were lower than the previously-recorded minimum levels for that period. The level recovered somewhat following August precipitation events (Figure 4.1-2, Figure 4.1-3), but ended the year approximately 0.1 m below normal. Outflows from the lake were above historical median values in May, but decreased to near zero in August before increasing again with increasing lake levels in fall (Figure 5.11-7).

2007 Hydrologic Conditions: McClelland Lake McClelland Lake water levels in 2007 were close to the 1997 to 2006 median values (Figure 5.11-8). Water levels fluctuated only slightly within the year, with a total range between the highest and lowest observed levels of 0.16 m.

2007 Hydrologic Conditions: Susan Lake Outlet Flow in the Susan Lake Outlet peaked in spring but then was comparatively small for the remainder of the year (Figure 5.11-9). The period of record available for flow in the stream before 2007 consists of only one full season (2006) and one partial year of monitoring in 2002, which is insufficient to provide a useful historical context for the 2007 observations.

5.11.2.3 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 2007:

- Cumulative, watershed-level effects on hydrologic conditions in Poplar Creek caused by focal project activities in the current watershed as of 2007 have been high; and
- Cumulative, watershed-level effects on hydrologic conditions in Fort Creek caused by focal project activities in the watershed as of 2007 have been moderate to high.

5.11.3 Water Quality

5.11.3.1 Potentially-Influenced Aquatic Systems

In 2007, 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 these locations were sampled in fall only, with the exceptions of Isadore's Lake and Shipyard Lake, which were also sampled in summer.

Beaver River

2007 Results and Historical Ranges of Concentration At station BER-1 in fall 2007, concentrations of 19 (86%) of 22[1] measurement endpoints were within the previously-measured range of concentrations at this station; concentrations of total nitrogen, naphthenic acids, and total aluminum were below previously-measured minimum concentrations (Table 5.11-5).

Comparison of Water Quality Measurement Endpoints to Water Quality Guidelines No water quality measurement endpoints measured at station BER-1 in fall 2007 had concentrations that exceeded water quality guidelines (Table 5.11-6).

Other Water Quality Guideline Exceedances Concentrations of sulphate, sulphide, total iron, total phenols, and total selenium exceeded water quality guidelines at station BER-1 in fall 2007 (Table 5.11-6).

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

Comparison of Water Quality Measurement Endpoints to Natural Variation in Baseline Conditions Concentrations of eight (53%) of a possible 15[2] water quality measurement endpoints at station BER-1 in fall 2007 were greater than the 95th percentile of regional baseline concentrations: total dissolved solids, total strontium, total boron, calcium, magnesium, sodium, chloride, and sulphate (Figure 5.11-10). Concentrations of the remaining water quality measurement endpoints were within the 5th and 95th percentile of regional baseline concentrations.

The hydrology of the Beaver River watershed was modified in the early 1970s, during the development of Syncrude's Mildred Lake operations. Many of its lower reaches were impounded within Mildred Lake, its upper reaches were rerouted into Poplar Creek via a series of reservoirs and lakes (i.e., the Beaver River Reservoir, which flows via Ruth Lake, and the Poplar Creek Reservoir), and most of remaining mainstem of Beaver River is comprised of a constructed channel (the West Interception Ditch) that bounds the western edge of the Mildred Lake site (Noton and Chymko 1978). Since water quality monitoring by RAMP began in the Beaver River in 2003, concentrations of a number of dissolved ions and metals at station BER-1 have typically been higher than in other waterbodies (Figure 5.11-10). As reported in previous RAMP technical reports (e.g., RAMP 2004), high concentrations of dissolved constituents of water quality suggest a potential influence of seepage waters from the Mildred Lake site on water quality in lower Beaver River. Ion concentrations have been highly variable across years, with concentrations generally higher in years of low regional water flows, such as 2003, 2006 and 2007. 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.

Ion Balance Ion balance at station BER-1 has remained relatively consistent over the period of sampling (Figure 5.11-11). The anionic composition at BER-1 has historically exhibited a greater proportion of chloride and sulphate relative to lower Poplar Creek, which drains the former upper Beaver River watershed (Figure 5.11-11).

Poplar Creek

2007 Results and Historical Ranges of Concentration At the Poplar Creek station, station POC-1, in fall 2007, concentrations of 17 (77%) of 22 water quality measurement endpoints were within the previously-measured range of concentrations at this station (Table 5.11-7), the same percentage as in fall 2006. Fall 2007 concentrations of total suspended solids, total dissolved phosphorus, and dissolved organic carbon (DOC) were below previously-measured minimum concentrations, while concentrations of total molybdenum and total mercury were greater than their previously-measured maximum concentrations (Table 5.11-7).

Comparison of Water Quality Measurement Endpoints to Water Quality Guidelines Total aluminum was the only water quality measurement endpoint with a concentration that exceeded water quality guidelines at station POC-1 in fall 2007 (Table 5.11-7). The concentration of total aluminum has exceeded its water quality guideline at station POC-1 in every year of sampling under RAMP; its concentration in fall 2007 was less than the median concentration measured at this station under RAMP. In contrast, concentrations of dissolved aluminum have not exceeded the assigned water quality guideline (set as

[2] Fifteen water quality measurement endpoints selected for comparison against regional baseline concentrations (Section 3.2.7.4).

equal to the guideline for total aluminum) at station POC-1 in any fall when water quality has been sampled at this station, including 2007.

Other Water Quality Guideline Exceedences The concentration of total iron and total phenols exceeded water quality guidelines at POC-1 in fall 2007 (Table 5.11-6). Fall concentrations of total iron have exceeded water quality guidelines at station POC-1 in every fall that water quality has been sampled at this station.

Comparison of Key Measurement Endpoints to Natural Variation in Baseline Conditions At station POC-1 in fall 2007, the concentration of chloride exceeded the 95th percentile of regional baseline concentrations (Figure 5.11-10), while the concentration of total boron fell below the 5th percentile of regional baseline concentrations. In fall 2006, concentrations of total boron were above the 95th percentile of regional baseline concentrations; the change in fall 2007 suggests a smaller relative contribution of groundwater flow to lower Poplar Creek than in fall 2006.

Ion Balance Relative to most previous years, ion balance of waters at POC-1 in fall 2007 exhibited a higher proportion of bicarbonate and chloride. In previous years, ion balance at this station has been relatively consistent except in 2001, when higher proportions of sodium, potassium, and chloride were measured (Figure 5.11-11).

Trend Analysis There have been no significant trends in water quality measurement endpoints at station POC-1 over the RAMP sampling period with the exception of a significant decreasing trend in total suspended solids ($\alpha = 0.05$, $n = 8$).

McLean Creek

2007 Results and Historical Ranges of Concentration In fall 2007, concentrations of 20 (91%) of 22 water quality measurement endpoints in lower McLean Creek (station MCC-1) were within historical ranges measured by RAMP since 1999 (n=8 years of observations) (Table 5.11-8); this is a higher percentage than fall 2006 (73%). Concentrations of total arsenic and total molybdenum were lower in fall 2007 than 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 2007 concentration at station MCC-1 that exceeded water quality guidelines (Table 5.11-8). While concentrations of total aluminum have almost always exceeded the 0.1 mg/L guideline at station MCC-1, concentrations of dissolved aluminum at station MCC-1 have always been below this guideline (Table 5.11-8).

Other Water Quality Guideline Exceedences Concentrations of total and dissolved iron, total phosphorus and sulphide also exceeded water quality guidelines at station MCC-1 in fall 2007 (Table 5.11-6).

Comparison of Water Quality Measurement Endpoints to Natural Variation in Baseline Conditions Concentrations of all water quality measurement endpoints were within the 5th to 95th regional baseline concentration at station MCC-1 in fall 2007 except chloride, which exceeded the 95th percentile of regional baseline concentrations (Figure 5.11-10).

Ion Balance Ion balance at station MCC-1 has been highly variable over the period of sampling by RAMP (Figure 5.11-11). In fall 2007, ion balance was generally similar to previous years, although the relative concentration of chloride was somewhat higher than in some previous years.

Trend Analysis There have been no significant trends in water quality measurement endpoints at station MCC-1 over the RAMP sampling period with the exception of a significant decreasing trend in total arsenic (α = 0.05, n = 9).

Isadore's Lake

2007 Results and Historical Ranges of Concentration In fall 2007, concentrations of three (14%) of 22 water quality measurement endpoints were outside historical ranges of concentration measured by RAMP in Isadore's Lake (Table 5.11-9); this percentage is less than in fall 2006 (64%). Concentrations of total aluminum, total arsenic, and total molybdenum were all below their previously-measured minimum concentrations (Table 5.11-9).

Comparison of Measurement Endpoints to Water Quality Guidelines Concentrations of sulphate and total nitrogen exceeded water quality guidelines at station ISL-1 in fall 2007, while concentration of sulphate exceeded water quality guidelines at station ISL-1 in summer 2007 (Table 5.11-6, Table 5.11-9).

Other Water Quality Guideline Exceedances Concentrations of the following water quality variables exceeded water quality guidelines in Isadore's Lake in 2007 (Table 5.11-6): sulphide and total phenols in summer; and sulphide, total phosphorus, and total phenols in fall.

Comparison of Key Measurement Endpoints to Natural Variation in Baseline Conditions Concentrations of magnesium and sulphate in Isadore's Lake in fall 2007 were above the 95th percentile of regional baseline concentrations; concentrations of all other water quality measurement endpoints were within the 5th to 95th percentile of regional baseline concentrations (Figure 5.11-12).

Ion Balance Ion balance in Isadore's Lake has fluctuated between two sets of relative concentrations of bicarbonate and sulphate (Figure 5.11-13). Ionic characteristics of Isadore's Lake in fall 2007 were similar to 2004, 2005, and 2006 conditions (lower bicarbonate-higher sulphate, Figure 5.11-13) than in 2000 and 2001 which were characterized by higher bicarbonate-lower sulphate.

Shipyard Lake

2007 Results and Historical Ranges of Concentration At station SHL-1 fall 2007, concentrations of five (23%) of a possible 22 water quality measurement endpoints were outside the historical range of concentrations previously measured by RAMP (Table 5.11-10); this percentage is lower than in fall 2006 (41%). Concentrations/levels of total boron, pH, and total mercury exceeded previously measured maximum concentrations, while total dissolved phosphorus and total molybdenum were at or below previously measured minimum concentrations.

Comparison of Water Quality Measurement Endpoints to Water Quality Guidelines No water quality measurement endpoints had concentrations that exceeded water quality guidelines in Shipyard Lake in fall 2007 (Table 5.11-10).

Other Water Quality Guideline Exceedances In summer 2007, concentrations of total phenols and total iron exceeded water quality guidelines, while in fall 2007 concentrations total phenols, total iron and total cadmium exceeded water quality guidelines in Shipyard Lake (Table 5.11-6).

Comparison of Water Quality Measurement Endpoints to Natural Variation in Baseline Conditions At station SHL-1 in fall 2007, the concentration of total arsenic was below the 5th percentile of regional baseline concentrations (Figure 5.11-12); concentrations of all other water quality measurement endpoints were within the 5th to 95th percentile of regional baseline concentrations.

Ion Balance Although concentrations of several major ions have increased significantly over the period of sampling (see below), the ionic character of Shipyard Lake water (i.e., relative concentrations of major cations and anions relative to one another) has remained generally consistent over this time (Figure 5.11-13).

Trend Analysis Significant increasing trends in several ions: calcium; magnesium; potassium; and sodium, as well as in total boron have occurred in Shipyard Lake over the RAMP sampling period, as well as a decreasing trend in total arsenic ($\alpha = 0.05$, $n = 9$).

Fort Creek

2007 Results and Historical Ranges of Concentration Three (14%) of a possible 22 water quality measurement endpoints had concentrations that that were outside the historical range of concentrations measured by RAMP in Fort Creek at station FOC-1; this percentage is lower than in fall 2006 (73%). Concentrations of total dissolved phosphorus and dissolved aluminum were below previously-measured minimum concentrations and the concentration of total mercury (1.4 ng/L) exceeded the previously-measured maximum concentration of < 1.2 ng/L (Table 5.11-11).

Comparison of Water Quality Measurement Endpoints to Water Quality Guidelines Total aluminum was the only water quality measurement endpoint with a measured concentration that exceeded water quality guidelines in Fort Creek at station FOC-1 in fall 2007; its fall 2007 concentration was less than half the maximum concentration measured at this station under RAMP (Table 5.11-11).

Other Water Quality Guideline Exceedances The concentration of total iron exceeded its water quality guideline in Fort Creek at station FOC-1 in fall 2007 (Table 5.11-6).

Comparison of Water Quality Measurement Endpoints to Natural Variation in Baseline Conditions At station FOC-1 in fall 2007, concentrations of all water quality measurement endpoints were within the 5th to 95th percentile of regional reference baseline concentrations with the exceptions of total arsenic (less than the 5th percentile of regional baseline concentrations) and calcium (above the 95th percentile of regional baseline concentrations, Figure 5.11-14).

Ion Balance Ionic character of Fort Creek water in fall 2007 was consistent with all previous years of sampling, with anions strongly dominated by bicarbonate (Figure 5.11-15).

5.11.3.2 Reference Aquatic Systems

Water quality monitoring was undertaken in fall 2007 on Kearl Lake and McClelland Lake, both of which were designated as *reference* waterbodies for 2007.

Kearl Lake

2007 Results and Historical Ranges of Concentration Concentrations of three (14%) of 22 water quality measurement endpoints had concentrations that were outside the historical range of concentrations measured by RAMP at Kearl Lake, station KEL-1 (Table 5.11-12); this percentage is similar to fall 2006 (18%). Concentrations of dissolved aluminum and magnesium were below their previously-measured minimum concentrations, while the concentration of chloride exceeded its previously-measured maximum concentration.

Comparison of Water Quality Measurement Endpoints to Water Quality Guidelines Total nitrogen was the only water quality measurement endpoint with a measured concentration in fall 2007 at station KEL-1 that exceeded water quality guidelines (Table 5.11-12).

Other Water Quality Guideline Exceedances Sulphide, total Kjeldahl nitrogen and total phenols were water quality variables not designated as water quality measurement endpoints with concentrations that exceeded water quality guidelines in Kearl Lake in summer and fall of 2007 (Table 5.11-13).

Comparison of Water Quality Measurement Endpoints to Natural Variation in Baseline Conditions In Kearl Lake in fall 2007, concentrations of all water quality measurement endpoints were within the 5^{th} to 95^{th} percentile of regional reference baseline concentrations with the exception of dissolved phosphorus, with a concentration that was below the 5^{th} percentile of regional baseline concentrations (Figure 5.11-16).

Ion Balance The ion balance in Kearl Lake in fall 2007 was consistent with historical observations and was dominated by calcium and bicarbonate (Figure 5.11-17).

Trend Analysis There have been no significant trends in water quality measurement endpoints in Kearl Lake over the RAMP sampling period with the exception of a significant increasing trend in chloride (α = 0.05, n - 9).

McClelland Lake

2007 Results and Historical Ranges of Concentration Concentrations of four (18%) of 22 water quality measurement endpoints had concentrations that were outside the historical range of concentrations measured by RAMP at McClelland Lake, station MCL-1 (Table 5.11-14); this percentage is lower than fall 2006 (50%). Concentrations of sulphate, total aluminum, and total arsenic were below their previously-measured minimum concentrations, while pH exceeded its previously-measured maximum level.

Comparison of Water Quality Measurement Endpoints to Water Quality Guidelines No water quality measurement endpoints had measured concentrations that exceeded water quality guidelines in McClelland Lake in fall 2007 (Table 5.11-14).

Other Water Quality Guideline Exceedances No other water quality variables had measured concentrations that exceeded water quality guidelines in McClelland Lake in fall 2007 (Table 5.11-13).

Comparison of Water Quality Measurement Endpoints to Natural Variation in Baseline Conditions In McClelland Lake in fall 2007, concentrations of all water quality measurement endpoints were within the 5^{th} to 95^{th} percentile of regional reference baseline concentrations with the exception of dissolved phosphorus, arsenic and sulphate with measured concentrations that were below the 5^{th} percentile of regional baseline concentrations and potassium, with a measured concentration that was above the 95^{th} percentile of regional baseline concentrations (Figure 5.11-18).

Ion Balance Ion balance in McClelland Lake in fall 2007 was similar to that of previous years, with relatively high proportions of calcium and magnesium bicarbonate, and relatively low proportions of sodium and potassium chloride (Figure 5.11-17).

5.11.3.3 Summary

There was little to distinguish 2007 water quality conditions in the miscellaneous aquatic systems from previous years. There were relatively few exceedances of water quality guidelines in watercourses and waterbodies designated as *potentially influenced* and in these aquatic systems in comparison to those designated as *reference*. However, concentrations of several ions in Beaver Creek exceeded regional baseline concentrations, consistent with previous years' observations and likely related to modifications to the hydrology of this watershed in the 1970s associated with Syncrude's Mildred Lake development (i.e., rerouting of upper-watershed flows into Poplar Creek). Effects of focal projects on water quality conditions in these aquatic systems (other than Beaver Creek) were not apparent in 2007.

5.11.4 Benthic Invertebrate Communities and Sediment Quality

5.11.4.1 Benthic Invertebrate Communities

In fall 2007, 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 2007);
- 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 2007).

Lakes

2007 Habitat Conditions All four lakes that were sampled in fall 2007 were slightly alkaline and high levels of total organic carbon (with the exception of Isadore's Lake, Table 5.11-15). Substrates were dominated by sand in Kearl and McClelland Lakes, by silt in Isadore's Lake, and by clay in Shipyard Lake. When measured, aquatic macrophyte cover was high with the exception of McClelland Lake. Water depth varied from 1.4 m (Shipyard Lake) to 3.8 m (McLelland Lake, Table 5.11-15).

Relative Abundance of Benthic Invertebrate Community Taxa in 2007 Benthic invertebrate communities in Shipyard Lake were numerically dominated by ostractods (40%), chironomids (27%), and copepods (11%) (Table 5.11-16). Sub-dominant taxa included naidids (6%), Ephemeroptera (3%), gastropods (3%), and Hydracarina (3%). Benthic invertebrate communities in Isadore's Lake were numerically dominated by chironomids (57%) and nematodes (32%). Sub-dominant taxa included Cladocera (4%) and copepods (4%, Table 5.11-16).

Benthic invertebrate communities in Kearl Lake were dominated by copepods (31%), chironomids (24%), amphipods (27%) and clams (7%), with mayflies and caddisflies present, but in low percent abundance (Table 5.11-16). There were also a variety of mites

(Acarina) and worms (Naididae, Tubificidae, Nematoda), but all were generally minor contributors to total numbers. All of the taxa found in Kearl Lake are relatively common forms. The dominant chironomids were *Pagastiella*, *Pseudochironomus, Tanytarsus* and *Procladius*. The genus *Pisidium* represented the clams (bivalves). *Hyalella azteca* and *Gammarus lacustris* represented the amphipods, with *Hyalella* being more abundant. Most of the organisms dominant in 2007 were dominant in previous years.

Benthic invertebrate communities in McClelland Lake were dominated by chironomids (41%), with mayflies and naidid worms being sub-dominant (12%) (Table 5.11-16). Caddisflies (2%), amphipods (4%) and clams (75) were also present. The dominant chironomids included *Dicrotendipes*, *Paratanytarsus*, *Tanytarsus*, *Cricotopus*/*Othrocladius*, and *Procladius,* all of which are very common.

Effects of Focal Project Activities The values of the benthic invertebrate community measurement endpoints of Shipyard Lake in 2007 were within the normal range of conditions based on what has been measured at Kearl and McClelland Lakes (Figure 5.11-19). Total abundance in Shipyard Lake has generally increased from a low of 3,300 individuals per m^2 in 2001 to more than 21,000 individuals per m^2 in 2007, and the lake had an average of 15 taxa per sample in fall 2007, equal to the highest previously-recorded number of taxa (2005).

The values of the benthic invertebrate community measurement endpoints for Isadore's Lake in fall 2007 were also within the normal range of variation for the two reference lakes (Figure 5.11-19). Total abundance was lower in fall 2007, but diversity measures were higher in fall 2007 than in fall 2006 (Table 5.11-16).

Linear contrasts tested for differences in composition between the two lakes designated as *potentially influenced* (Shipyard, Isadore's lakes) and the two lakes designated as *reference* (Kearl and McLelland lakes). The following statistical comparisons were made:

- A difference between *reference* and *potentially influenced* across all common years for both Shipyard and Isadore's lakes;
- A difference in time trends between *reference* and *potentially influenced* for Shipyard Lake; and
- A difference between *reference* and *potentially influenced* in 2007 only for both Shipyard and Isadore's lakes.

Results are provided in Table 5.11-17 for Shipyard Lake and Table 5.11-18 for Isadore's Lake.

Taxa richness was higher in Shipyard Lake than in the two *reference* lakes, while diversity, evenness and percent EPT were not significantly different in Shipyard Lake relative to the two *reference* lakes (Table 5.11-17). With respect to abundance, there is a significant time trend in Shipyard Lake, but not a significant difference in time trends of abundance between Shipyard Lake and the two *reference* lakes. Similarly, there has been a significant positive increase in %EPT, but no difference in time trends of %EPT between between Shipyard Lake and the two *reference* lakes. These results indicate that the benthic invertebrate community measurement endpoints of Shipyard Lake are following trends similar to the trends of these measurement endpoints in McLelland and Kearl lakes. The multivariate ordination (Figure 5.11-20) indicates that fall 2007 benthic invertebrate community conditions in Shipyard Lake were within the normal range of expected variability for *reference* conditions.

With the exception of % EPT, there were no differences in average values of benthic invertebrate community measurement endpoints in Isadore's Lake as compared to average baseline values (Table 5.11-18). The multivariate ordination (Figure 5.11-21) illustrates the uniqueness of the Isadore's Lake benthic community, reflected principally in higher relative abundances of nematodes in both 2006 and 2007. Nematodes are very slender, and most are lost through field-sieving even when fine mesh is used (Barton, 1986). The pollution tolerance of nematodes is poorly described (Bode, 1988), but some consider high relative abundance of nematodes to indicate degraded water and sediment quality (e.g., Burt et al., 1991; Millward and Grant, 2000).

Fort Creek

2007 Habitat Conditions The lower reach of Fort Creek is relatively narrow with a bankfull width of about 5 m. The substrate in fall 2007 was fine-grained and dominated by silt and sand, with some clay (Table 5.11-19). Total organic carbon content was 2%.

Relative Abundance of Benthic Invertebrate Community Taxa in 2007 The benthic community of the lower Fort Creek in fall 2007 was dominated by tubificid worms (66%) and chironomids (18%). Sub-dominant forms included clams (2%), ceratopogonids (biting midges, 8%), and naidid worms. There were only a few genera of chironomids present, including *Cryptochironomus* and *Paratendipes* (the two most common in the reach). Some of the more sensitive genera present include the mayflies *Baetis*, *Ephemerella* and *Leptophlebia*, the stoneflies *Taeniopteryx* and Capniidae family, and the caddisfly *Hydroptila*. Total numbers and richness have increased from lows recorded in 2005. The total number of organisms was approximately 11,000 individuals per m^2 in 2007 compared to less than 1,000 per m^2 measured in 2005. The average number of taxa per sample was 11, compared to a low of 4 recorded in 2005 (Table 5.11-20).

Effects of Focal Project Activities None of the benthic invertebrate community measurement endpoints varied significantly from before to after the initiation of focal projects in the watershed (Table 5.11-21). Measurement endpoints in fall 2007 were within the range of values for *reference* depositional habitats (Figure 5.11-22), and the multivariate ordination of depositional benthic communities indicates that fall 2007 benthic invertebrate community conditions in the lower reach of Fort Creek (reach FOC-D-1) were within the normal range of expected variability for *reference* depositional habitats (Figure 5.11-23).

5.11.4.2 Sediment Quality

Sediment quality in fall 2007 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 2007.

Lakes

2007 Results and Historical Ranges of Concentration As in previous years, sediment composition in Kearl and McClelland lakes (KEL-1, MCL-1) was dominated by sand (Table 5.11-22, Table 5.11-23), while sediment composition in Shipyard Lake and Isadore's Lake (ISL-1, SHL-1) was dominated by silt and clay (Table 5.11-24, Table 5.11-25). Total organic carbon was very high in Kearl and McClelland lakes (>25%), high in Shipyard Lake (18.8%) and lower (3.3%) in Isadore's Lake.

Sediment quality measurements in fall 2007 for Kearl and McClelland lakes exceeded historical maxima of CCME hydrocarbon Fractions 2, 3 and 4 and total PAHs (Table 5.11-22, Table 5.11-23). At Kearl Lake, total dibenzothiophenes, a petrogenic PAH species, exceeded its historical maximum in sediments. At McClelland Lake, retene, a diagenic PAH species, was above its historical maximum. Sediment toxicity was assessed in these lakes for the first time in 2006, precluding comparisons with historical ranges; however, 2007 values were generally very similar to those observed in 2006 (Table 5.11-22, Table 5.11-23).

Concentrations of five out of 19 (26%) sediment quality measurement endpoints exceeded previously recorded maximum concentrations in Shipyard Lake: CCME Fraction 3 hydrocarbons, and various PAHs measures, including total PAHs, total dibenzothiophenes, and predicted PAH toxicity (Table 5.11-24). CCME Fraction 4 hydrocarbons was the only endpoint below its historical minimum in Shipyard Lake. Alkylated species of naphthalene, fluorenes and dibenzothiophenes exhibited highest concentrations of all PAHs observed in Shipyard Lake sediments. Although predicted PAH toxicity was historically high, survival and growth of midges and amphipods exposed to these sediments was similar to, or higher than, historical observations (Table 5.11-24). Relatively high organic content of Shipyard Lake sediments sampled in 2007 (i.e., between historical median and maximum values) may have contributed to the high observed PAH concentrations.

At Isadore's Lake, four sediment quality measurement endpoints exceeded previously observed maxima, namely %-silt, total dibenzothiophenes, total PAHs and total LMW PAHs; predicted PAH toxicity was below its historical minimum for this lake. There was only one year with which to compare total hydrocarbon results; however, the concentration of CCME hydrocarbon Fraction 3 was five times greater in Isadore's Lake in 2007 than was observed in 2006 (Table 5.11-25).

Comparison of Sediment Quality Measurement Endpoints with Sediment Quality Guidelines There were six cases in which concentrations of sediment quality variables exceeded sediment quality guidelines in fall 2007: CCME Fraction 3 hydrocarbons in all four lakes (Table 5.11-22 to Table 5.11-25); and arsenic in Shipyard and Isadore's lakes (Table 5.11-24, Table 5.11-25).

Fort Creek

2007 Results and Historical Ranges of Concentration Fort Creek sediment quality data for FOC-D-1 were compared with 2006 data from this site, and with data collected previous to 2006 at sediment quality station FOC-1; both FOC-1 and FOC-D-1 have been sampled in the same location over the history of RAMP sampling. Sediments at reach FOC-1 were dominated by silt and sand, with a smaller proportion of clay (Table 5.11-26). The lid of a jar loosened in transit to the analytical laboratory on a sediment sample reach FOC-D-1 intended for analysis of total hydrocarbons; this compromised the integrity of the sample and precluded analysis. Concentrations of two out of 14 (14%) sediment quality measurement endpoints were at or below previously-recorded minimum concentrations for this site: total organic carbon, and *Chironomus* growth, while %clay, %silt and retene were above previously recorded maxima (Table 5.11-26).

Comparison of Sediment Quality Measurement Endpoints to Sediment Quality Guidelines No sediment quality endpoints exceeded sediment quality guidelines at reach FOC-D-1 in fall 2007 (Table 5.11-26).

5.11.4.3 Summary

Benthic invertebrate communities that were sampled in 2007 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, which showed continued evidence of degraded benthic invertebrate community conditions. Although PAHs in Shipyard Lake sediments were historically high, benthic invertebrate community data and results of sediment-toxicity testing did not indicate an effect of Shipyard Lake sediments on invertebrates in 2007 relative to previous years. Sediment quality in other aquatic environments designated as *potentially influenced* did not suggest effects of focal project activities.

5.11.5 Fish Populations

The Fish Population component for miscellaneous aquatic systems consisted of tissue analyses on target fish species in the following two regional lakes: Namur Lake (summer sampling) and Gregoire Lake (fall sampling).

5.11.5.1 Gregoire Lake

Whole-Organism Metrics

A total of 21 walleye (11 female, 9 male and 1 unsexed), 26 northern pike (20 female and 6 male), and 13 lake whitefish (4 female and 9 male) from Gregoire Lake were sampled for fish tissue (muscle) analysis. The sizes of fish sampled were:

- Walleye: 214 mm immature male to 606 mm mature female. Females (average fork length: 411 mm) were larger than males (average fork length: 407 mm). The average length of all sampled fish was 402 mm;
- Northern pike: 216 mm immature female to 775 mm mature female. Females (average fork length: 553 mm) were larger than males (average fork length: 497 mm). The average length of all sampled fish was 540 mm; and
- Lake whitefish: 328 mm immature male to 534 mm mature male. Females (average fork length: 469 mm) were larger than males (average fork length: 445 mm). The average length of all sampled fish was 452 mm.

No fish ageing was carried out during the Gregoire Lake tissue program.

Mercury Concentrations

Total mercury concentrations in muscle of individual walleye, northern pike and lake whitefish collected from Gregoire Lake in 2007 are presented in Table 5.11-27. Mercury concentrations in walleye tissue ranged from a low of 0.04 mg/kg in a 235 mm female to a high of 0.43 mg/kg in a 509 mm male. Mercury concentrations in northern pike tissue ranged from 0.02 mg/kg in a 216 mm female to 0.58 mg/kg in a 740 mm female and lake whitefish tissue mercury concentrations ranged from 0.02 mg/kg in a 330 mm male to 0.06 mg/kg in a 502 mm male.

Overall, mean walleye mercury concentration in 2007 was 0.163 mg/kg, which was higher than in 2002 when Gregoire Lake was last sampled for fish tissue (0.130 mg/kg) (Figure 5.11-24). The mean concentration of mercury in adult female walleye (0.127 mg/kg) was lower than for adult males (0.219 mg/kg); this is in contrast to 2002 results in which the mean concentration of mercury in adult male walleye was less than for adult females.

Mean northern pike mercury concentration in 2007 was 0.207 mg/kg, which was higher than 2002 (0.150 mg/kg) (Figure 5.11-24). The mean concentration of mercury in adult female northern pike (0.233 mg/kg) was higher than for adult males (0.120 mg/kg), similar to the 2002 results.

In 2007, mean lake whitefish mercury concentration was 0.038 mg/kg, which was lower than in 2002 (0.140 mg/kg) (Figure 5.11-24). The mean concentration of mercury in adult female lake whitefish (0.044 mg/kg) was higher than for adult males (0.036 mg/kg), also similar to 2002 result.

Mercury concentrations were positively correlated with fork length for all three species (Table 5.11-28). Correlations were stronger for male northern pike and lake whitefish than females of the species, and stronger for female walleye than males. Scatterplots of fork length against mercury concentrations (log_{10}-transformed) in muscle of walleye, northern pike and lake whitefish all indicate a positive relationship between the two variables (Figure 5.11-25). Regressions between mercury concentrations and fork length (log_{10}-transformed) were significant for all three species ($p < 0.01$ for all regressions; fork length adjusted $R^2 = 0.81$ for walleye, 0.87 for northern pike and 0.73 for lake whitefish, Figure 5.11-26).

Results from the 2007 Gregoire Lake fish tissue program were compared to results from regional studies in northern Alberta as reported in Grey *et al*. (1995), RAMP (2004), Golder (2004), and RAMP (2005a); results are provided in Figure 5.11-27 to Figure 5.11-29. Given that the size of fish may be an important determinant of the concentration of mercury in fish (INAC 2003) and may confound comparisons among waterbodies, mercury concentrations were standardized to fish weight. When standardized to fish weight, 2007 mercury concentrations in male and female walleye fell within the mid-range of mercury concentrations in walleye from regional waterbodies but, as indicated above, concentrations in male walleye were higher in 2007 than in 2002 in Gregoire Lake (Figure 5.11-27). Male and female mean mercury concentrations in northern pike from Gregoire Lake in 2007 were within the mid-range of mercury concentrations in northern pike from regional waterbodies including, as indicated above, mercury concentrations in northern pike from Gregoire Lake in 2002 (Figure 5.11-28). Weight standardized mercury concentrations in lake whitefish from Gregoire Lake in 2007 were very low relative to other waterbodies in the region and only slightly greater than mercury concentrations in lake whitefish from Gregoire Lake in 2002 (Figure 5.11-29).

Screening of Potential Effects of Mercury in Fish Tissue on Human Health

2007 walleye, northern pike and lake whitefish muscle mercury concentrations from Gregoire Lake were screened against USEPA and Health Canada human health criteria for fish consumption (Table 5.11-27); a summary of the results is as follows:

- The overall mean mercury concentration (0.163 mg/kg) in walleye exceeded the USEPA Region III risk-based criteria (0.14 mg/kg). Eight of the 21 walleye exceeded the Health Canada guideline for subsistence fishers (0.2 mg/kg) and 2 of the 21 walleye exceeded the USEPA criteria for recreational fishers (0.4 mg/kg);

- The overall mean mercury concentration in 2007 (0.207 mg/kg) in northern pike exceeded the Health Canada criteria for subsistence fishers (0.2 mg/kg), USEPA criteria for subsistence consumers (0.049 mg/kg), and USEPA Region III risk-based criteria (0.14 mg/kg). Twelve of the 26 northern pike captured exceeded the Health Canada guideline for subsistence fishers; 5 of the 26 pike exceeded the USEPA criteria for recreational fishers (0.4 mg/kg); and 1 northern pike exceeded the Health Canada guideline for general consumers (0.5 mg/kg); and

- The mean mercury concentration (0.038 mg/kg) in lake whitefish did not exceed any criteria for fish consumption and no lake whitefish exceeded the Health Canada guideline for general consumers and subsistence fishers or the USEPA criteria for recreational fishers.

Screening of Potential Effects of Mercury in Fish Tissue on Fish and Fish Health

Mercury concentrations in muscle of walleye, northern pike and lake whitefish from Gregoire Lake did not exceed any of the effects (or no effects) thresholds for fish and fish health based on methylmercury concentration ranges described in Table 3.4-9.

Summary Assessment

The measurement endpoint used in the assessment of the results of the Gregoire Lake fish tissue sampling program is mercury concentration in fish tissues, and potential effects on human health were predicted from the fish tissue analyses.

Results for Gregoire Lake walleye indicate a risk to subsistence fishers characterized by 38% of fish analyzed with mercury concentrations exceeding Health Canada guidelines, lower risk for recreational fishers (10% of sampled fish exceeding relevant guidelines), and very little risk for general consumers (0% of sampled fish exceeding relevant guidelines).

Results for Gregoire Lake northern pike indicate a risk to subsistence fishers characterized by 31% of fish analyzed with mercury concentrations exceeding Health Canada guidelines, lower risk for recreational fishers (12% of sampled fish exceeding relevant guidelines), and low risk for general consumers (4% of sampled fish exceeding relevant guidelines).

Results for Gregoire Lake lake whitefish indicate very little risk to subsistence fishers, recreational fishers, or general consumers (0% of sampled fish exceeding any relevant Health Canada guidelines).

Although mercury concentrations in Gregoire Lake walleye, northern pike and lake whitefish exceeded some Health Canada and USEPA guidelines, comparisons with historical regional data indicated that these concentrations fall within the range of mercury concentrations observed in this region of Alberta (Grey *et al*. 1995, RAMP 2004, Golder 2004, RAMP 2005a).

Fish tissue results for Gregoire Lake in 2007 suggest low potential risk to fish health given mercury concentrations did not exceed the effects or no effects thresholds.

5.11.5.2 Namur Lake

Whole-Organism Metrics

A total of 16 lake trout (10 males and 6 females) from Namur Lake were sampled for fish tissue (muscle) analysis. The size of the sampled fish ranged from a 427 mm immature fish to a 741 mm adult female. Mean length for male and female fish combined was 555 mm, with females slightly longer than male lake trout. No fish ageing was carried out during the Namur Lake tissue program.

Mercury Concentrations

Total mercury concentrations in muscle of all 16 lake trout collected from Namur Lake in August 2007 are presented in Table 5.11-29. Concentrations ranged from 0.126 mg/kg in a 427 mm immature fish to 0.772 mg/kg in a 741 mm adult female fish.

Overall, mean mercury concentrations in lake trout from Namur Lake was 0.447 mg/kg. The mean concentration of mercury in adult female lake trout (0.605 mg/kg) was higher than the mean mercury concentration in males (0.443 mg/kg).

Mercury concentrations were positively correlated with fork length for both male and female lake trout and for all fish combined (Table 5.11-30). Mercury concentrations were also strongly positively correlated with fish weight for female lake trout and all fish combined, but were only moderately positively correlated with weight in male lake trout (Table 5.11-30). Scatterplots of fork length versus mercury concentrations (log-transformed) indicated a positive relationship between the two variables (Figure 5.11-30). A regression between fork length and mercury concentration ($\log_{10}$-transformed) was significant ($p < 0.01$; fork length adjusted $R^2 = 0.79$, Figure 5.11-31).

Regional lakes in the northern Athabasca area have usually been sampled for tissue collected from northern pike, walleye and lake whitefish, but generally not from lake trout (Grey *et al*. 1995, RAMP 2004, Golder 2004, RAMP 2005a). In addition, RAMP had not previously completed any studies on mercury concentrations in lake trout. However, to provide some regional context, comparisons were made to tissue mercury concentrations in northern pike given that both species are piscivorous and grow to similar sizes. Mean mercury concentrations in lake trout from Namur Lake were higher than concentrations reported in regional lakes assessments (Grey *et al*. 1995, RAMP 2004, Golder 2004, RAMP 2005a) for northern pike from regional lakes (Figure 5.11-28). Results from Namur Lake in 2000 showed much lower mercury concentrations relative to 2007 (Evans *et al*. 2005, Doetzel 2007, see Section 6.4.1 for more details).

Screening of Potential Effects of Mercury in Fish Tissue on Human Health

2007 lake trout tissue mercury concentrations were screened against USEPA and Health Canada human health criteria for fish consumption (Table 5.11-29). The overall mean mercury concentration (0.447 mg/kg) in lake trout exceeded the Health Canada criteria for subsistence fishers (0.2 mg/kg), USEPA criteria for subsistence consumers (0.049 mg/kg), and USEPA Region III risk-based criteria (0.14 mg/kg). Eleven of the 16 fish exceeded the USEPA criteria for recreational fishers (0.4 mg/kg) and 7 of the 16 fish exceeded the Health Canada guideline for general consumers (0.5 mg/kg).

Screening of Potential Effects of Mercury in Fish Tissue on Fish and Fish Health

Mercury concentrations in lake trout muscle from Namur Lake did not exceed any of the effects (or no effects) thresholds for fish and fish health (Table 5.11-29) as outlined in Table 3.4-9.

Summary Assessment

The endpoint used in the impact assessment for the Namur Lake fish tissue program was mercury concentration in individual fish tissue samples. USEPA and Health Canada criteria were used to assess potential effects on human health from fish consumption.

Results for Namur Lake lake trout indicate a risk to subsistence fishers characterized by 75% of fish analyzed with mercury concentrations exceeding Health Canada guidelines, risk for recreational fishers characterized by 69% of sampled fish exceeding relevant guidelines), and risk for general consumers characterized by 44% of sampled fish exceeding relevant guidelines.

Mercury concentrations in lake trout in Namur Lake were generally high which could be due to their position at the top of the food chain and to the relatively large size and age of lake trout compared to other species (Gunn *et al* 2004). Mercury concentrations in lake trout tissue from Namur Lake were generally higher relative to values reported from other RAMP fish tissue studies conducted in other regional lakes. However, direct comparisons were not possible because similar studies have not been carried out for lake trout in the region. Since lake trout are piscivorous, they are particularly susceptible to mercury bioaccumulation from feeding on prey with elevated tissue mercury concentrations. Gunn *et al* (2004) have reported the bioaccumulation of methyl-mercury in lake trout sampled from several Canadian lakes.

Fish tissue results for Namur Lake in 2007 suggest low potential risk to fish health given mercury did not exceed the effects or no effects thresholds.

5.11.6 Summary of Conditions

Miscellaneous aquatic systems designated as *potentially influenced* in 2007 included Mills Creek, Fort Creek, Poplar Creek, McLean Creek, Isadore's Lake, and Shipyard Lake, while miscellaneous aquatic systems designated as *reference* in 2007 included Kearl Lake and McClelland Lake. 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 2007 water quality conditions in these aquatic systems from previous years, and there was little evidence of effects on focal project activities on water quality conditions in these aquatic systems in 2007. Benthic invertebrate communities in miscellaneous aquatic systems that were sampled in 2007 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 2007 is indicative of a stressed benthic community. There was nothing in the results of sediment quality sampling in the aquatic environments designated as *potentially influenced* that would suggest effects of focal project activities on sediment quality.

Mercury tissue concentrations in walleye, northern pike, and lake whitefish from Gregoire Lake measured in the 2007 Regional Lakes program are consistent with the natural range of concentrations observed in this region of northern Alberta. No fish tissue effects thresholds for mercury and fish and fish health were exceeded in either Gregoire or Namur lakes. 2007 mercury data from Gregoire and Namur lakes have been given to Health Canada and Alberta Health and Wellness.

Figure 5.11-2 Isadore's Lake: 2007 hydrograph and historical context.

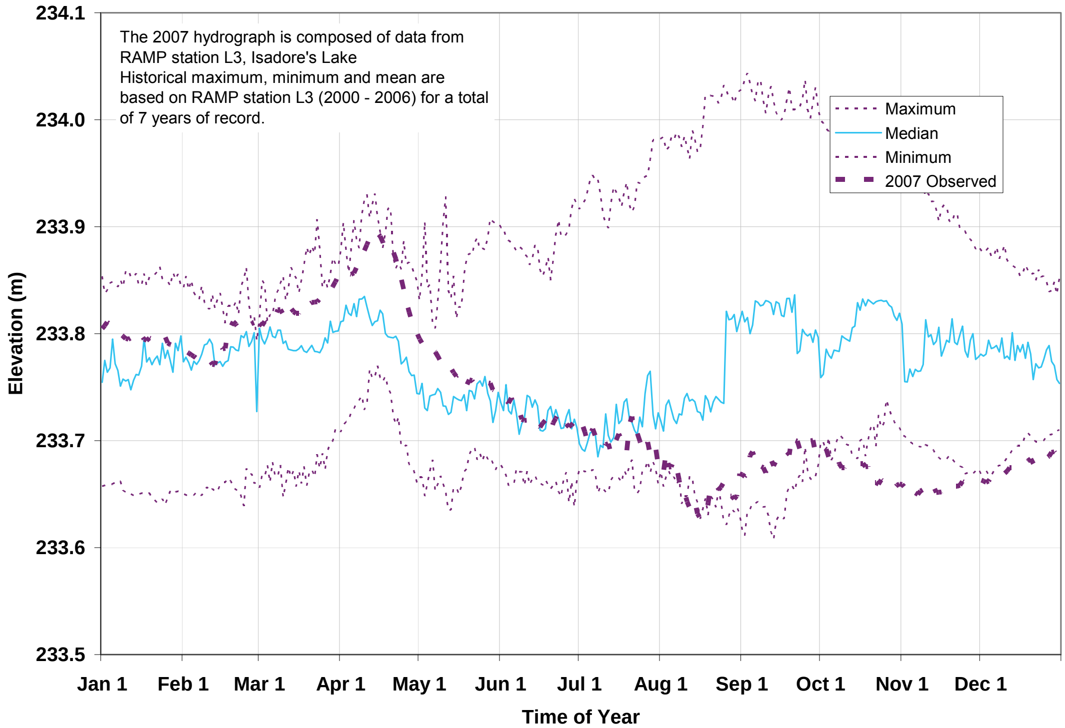


Figure 5.11-3 Mills Creek: 2007 hydrograph and historical context.

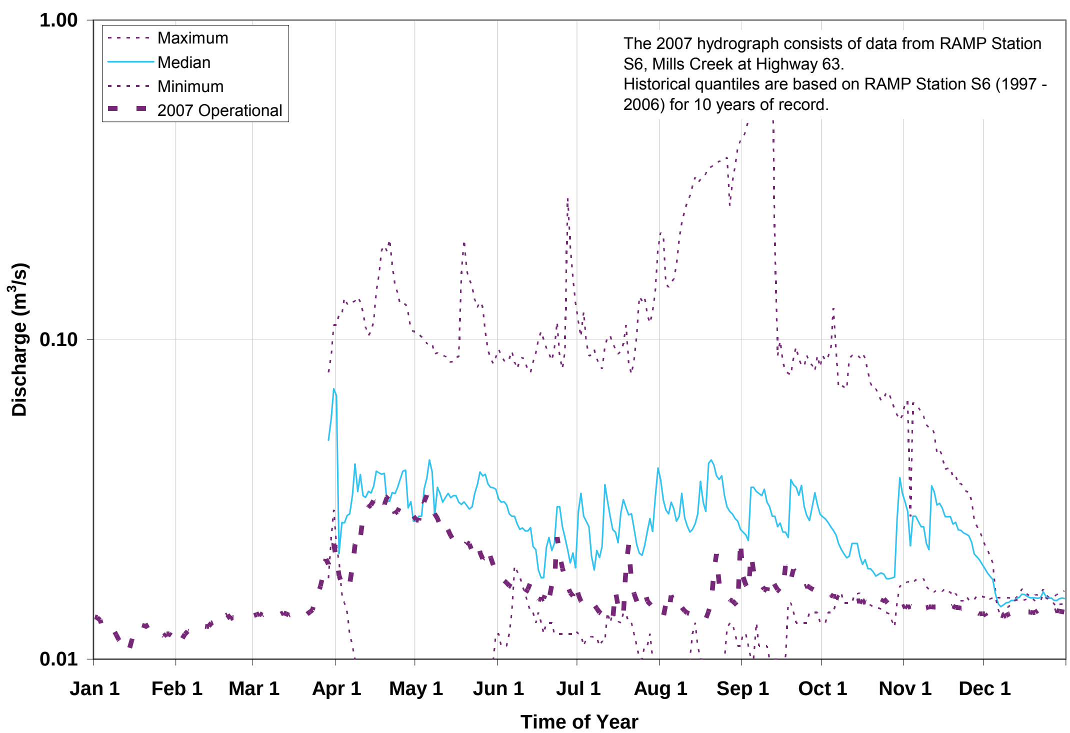


Figure 5.11-4 Poplar Creek: 2007 hydrograph and historical context.

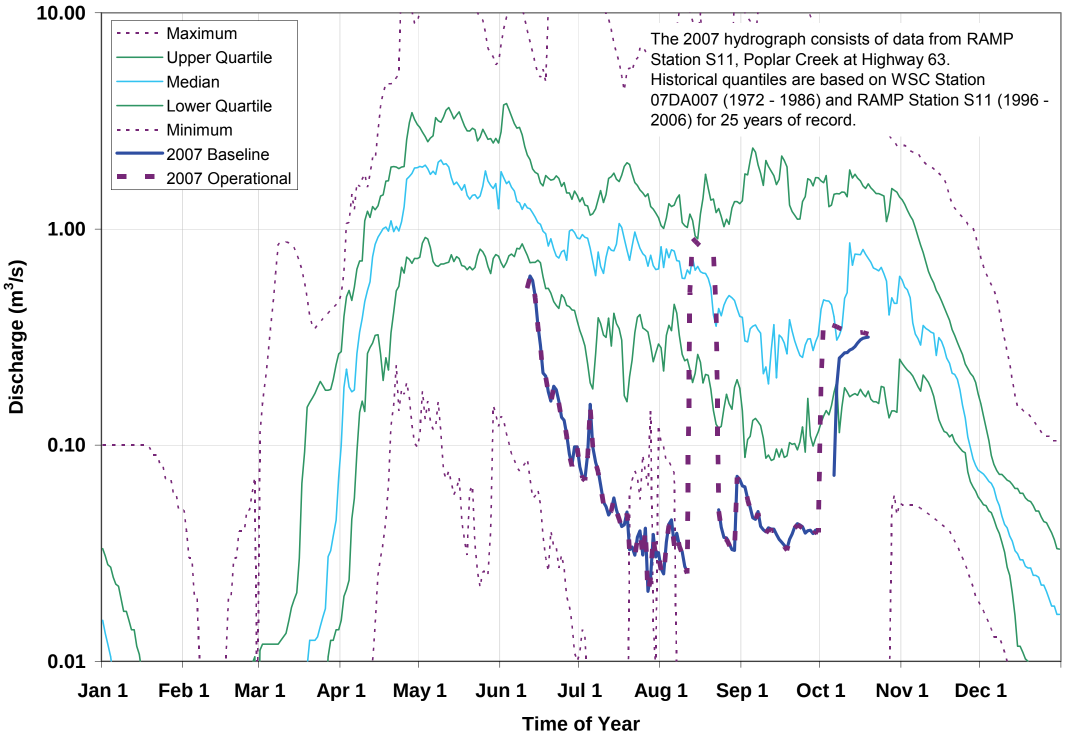


Figure 5.11-5 Fort Creek: 2007 hydrograph and historical context.

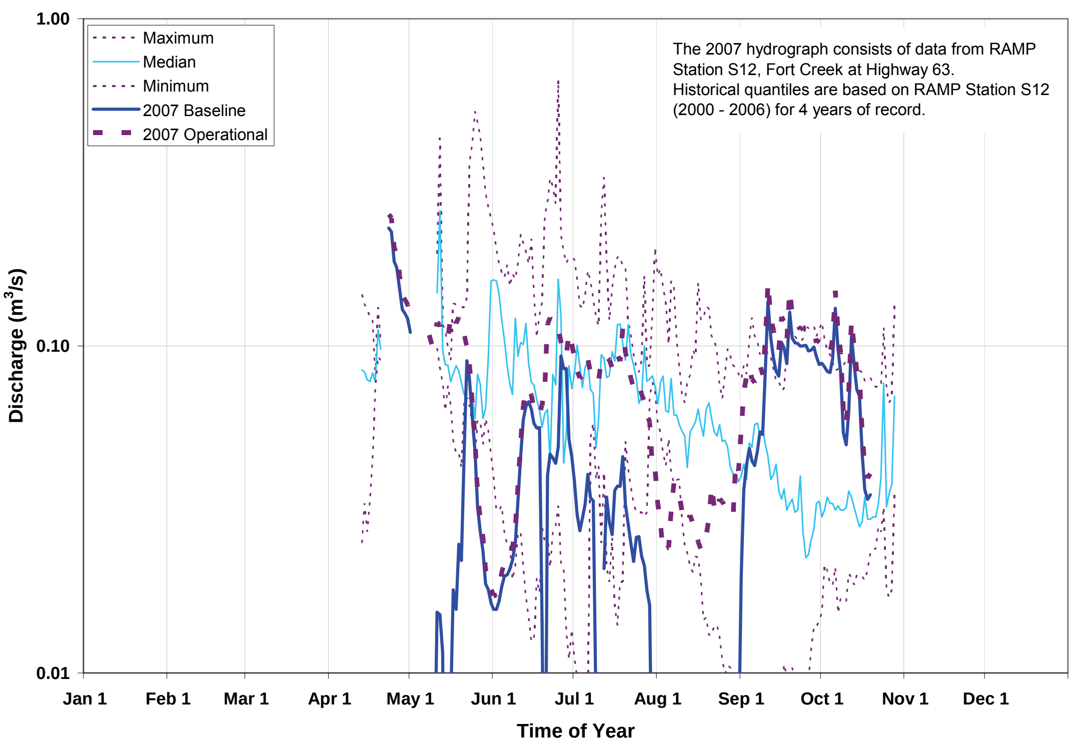


Table 5.11-1 Inputs for calculation of the baseline hydrograph at RAMP Station S11, Poplar Creek at Highway 63 (07DA007).

Component	Annual Volume (million m^3)	Basis and Data Source
Observed hydrograph (total discharge during 2007 data record)	2.79	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 2007	+ 0.048	2.60 km^2 within Poplar Creek watershed estimated to have been closed-circuited by focal projects as of 2007 (Table 2.4-1)
Incremental runoff from areas of land change that were not closed-circuited as of 2007	- 0.005	1.21 km^2 within Poplar Creek watershed estimated to have undergone land change by focal projects of 2007, but are not closed-circuited (Table 2.4-1)
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	- 1.13	Diversion from original upper Beaver River catchment area into Poplar Creek; daily discharges for the Poplar Creek Spillway reported by Syncrude during monitoring period
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)	1.70	Estimated total annual baseline discharge (i.e., without focal projects) for 2007
Incremental flow (change in total annual discharge)	+ 1.09	Total annual discharge from operational hydrograph less total annual discharge of estimated baseline hydrograph
Incremental flow (% of baseline total annual discharge)	+64%	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 Poplar Creek watershed for 2007.

Measurement Endpoint	Baseline Value (m^3/s)	Operational Value (m^3/s)	Percent Change
Mean open-water season discharge	0.094	0.177	88%
Mean winter discharge	not monitored	not monitored	-
Annual maximum daily discharge	7.18	8.96	25%
Open-water season minimum daily discharge	0.000	0.021	-

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 5.11-3 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 2007 data record)	1.19	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 2007	+ 0.014	0.40 km^2 within Fort Creek watershed estimated to have been closed-circuited by focal projects as of 2007 (Table 2.4-1)
Incremental runoff from areas of land change that were not closed-circuited as of 2007	- 0.123	16.3 km^2 within Fort Creek watershed estimated to have undergone land change by focal projects of 2007, but are not closed-circuited (Table 2.4-1)
Withdrawals from Fort Creek for focal project activities	0	None reported, assumed to be negligible
Releases to Fort Creek from focal project activities	0	Releases to Fort Creek reported by Petro-Canada.
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)	1.081	Estimated total annual baseline discharge (i.e., without focal projects) for 2007
Incremental flow (change in total annual discharge)	0.109	Total annual discharge from operational hydrograph less total annual discharge of estimated baseline hydrograph
Incremental flow (% of observed total annual discharge)	+ 9.2%	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 5.11-4 Calculated change in hydrologic measurement endpoints for the Fort Creek watershed for 2007.

Measurement Endpoint	Baseline Value (m^3/s)	Operational Value (m^3/s)	Percent Change
Mean open-water season discharge	0.068	0.075	+10%
Mean winter discharge	not monitored	not monitored	-
Annual maximum daily discharge	0.229	0.252	+10%
Open-water season minimum daily discharge	0.016	0.017	+10%

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 5.11-6 Kearl Lake: 2007 hydrograph and historical context.

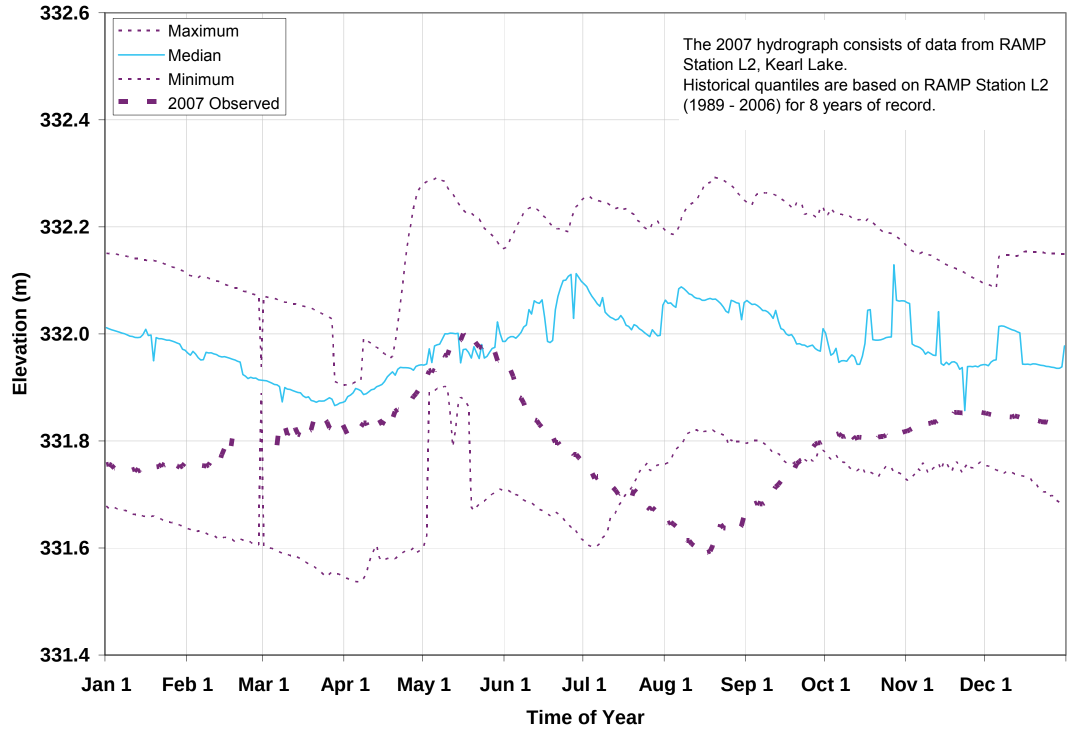


Figure 5.11-7 Kearl Lake outlet: 2007 hydrograph and historical context.

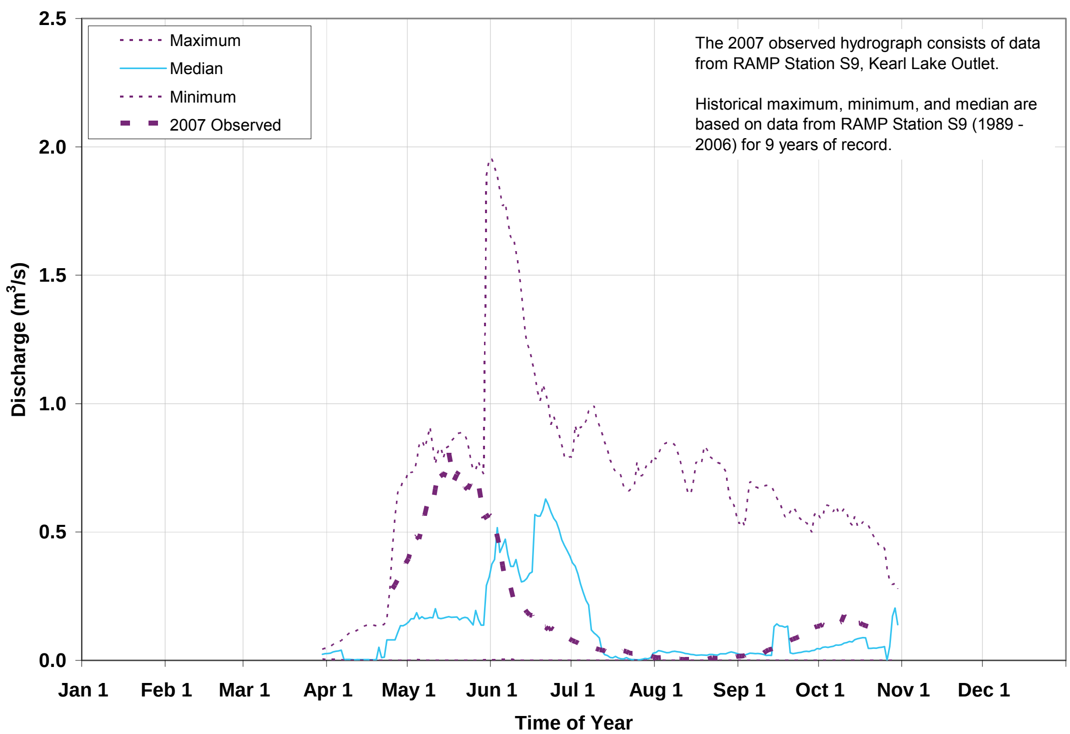


Figure 5.11-8 McClelland Lake: 2007 hydrograph and historical context.

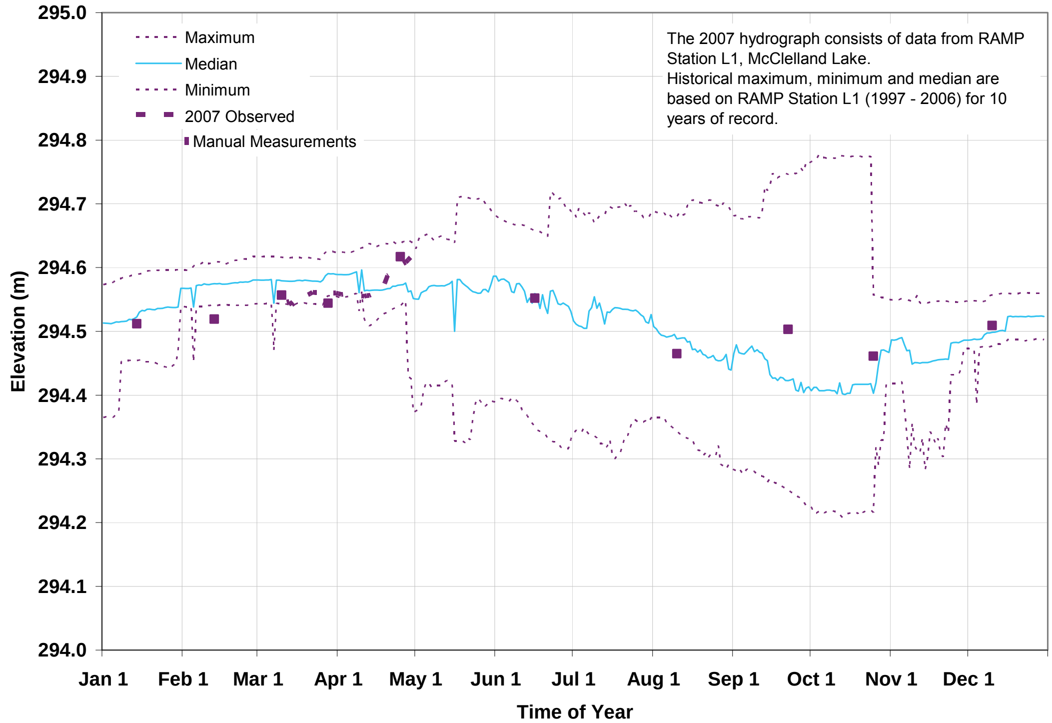


Figure 5.11-9 Susan Lake Outlet: 2007 hydrograph.

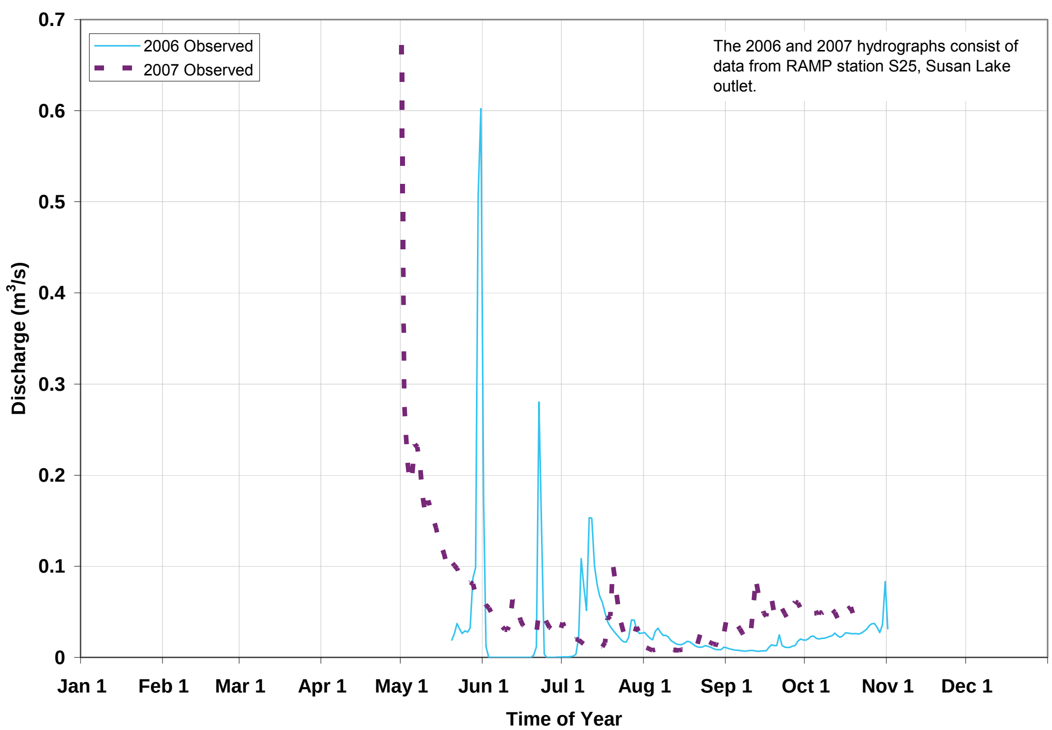


Table 5.11-5 Concentrations of water quality measurement endpoints, lower Beaver River, (BER-1), fall 2007.

Measurement Endpoint	Units	Guideline	September 2007	1997-2006 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.2	4	8.0	8.1	8.2
Total Suspended Solids	mg/L	-[1]	5	4	<3	7	26
Conductivity	µS/cm	-	1070	4	566	862.5	1430
Nutrients							
Total dissolved phosphorus	mg/L	0.05[2]	0.005	4	0.004	0.0065	0.022
Total nitrogen*	mg/L	1.0	0.7	4	0.8	0.9	**1.4**
Nitrate+Nitrite	mg/L	-	<0.1	4	<0.1	<0.1	<0.1
Dissolved organic carbon	mg/L	-	26	4	15	26	52
Ions							
Sodium	mg/L	-	118	4	53	97.5	181
Calcium	mg/L	-	79.7	4	49.1	71	91.4
Magnesium	mg/L	-	24.6	4	15.5	21.15	27.9
Chloride	mg/L	230, 860[3]	105	4	55	101	221
Sulphate	mg/L	100[4]	**105**	4	54	76	**117**
Total Dissolved Solids	mg/L	-	659	4	450	595.5	830
Total Alkalinity	mg/L	-	278	4	158	217.5	294
Organic compounds							
Naphthenic acids	mg/L	-	<1	4	1	1.5	3
Selected metals							
Total aluminum	mg/L	0.1	0.0314	4	0.0983	**0.252**	**0.318**
Dissolved aluminum	mg/L	0.1[2]	0.00179	4	0.0017	0.0086	0.0445
Total arsenic	mg/L	0.005	0.000935	4	0.000729	0.000994	0.0013
Total boron	mg/L	1.2[5]	0.152	4	0.088	0.143	0.169
Total molybdenum	mg/L	0.073	0.000307	4	0.00019	0.000313	0.0004
Total mercury (ultra-trace)	ng/L	5, 13[6]	<1.2	4	<1.2	<1.2	1.3
Total strontium	mg/L	-	0.315	4	0.233	0.2875	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).

Table 5.11-6 Water quality guideline exceedances in the Beaver River (station BER-1), Poplar Creek (station POC-1), McLean Creek (station MCC-1), Isadore's Lake (stations ISL-1), Shipyard Lake (stations SHL-1), and Fort Creek (station FOC-1) 2007.

Water Quality Variable	Units	Guideline*	POC-1	BER-1	MCC-1	ISL-1	SHL-1	FOC-1
Summer								
Sulphate	mg/L	100[1]	ns	ns	ns	**111**	-	ns
Sulphide	mg/L	0.014[2]	ns	ns	ns	**0.021**	-	ns
Total phenols	mg/L	0.005	ns	ns	ns	**0.01**	**0.011**	ns
Total iron	mg/L	0.3	ns	ns	ns	**-**	**0.403**	ns
Fall								
Sulphate	mg/L	100[1]	-	**105**	-	**103**	-	-
Sulphide	mg/L	0.014[2]	**-**	**0.018**	**0.025**	**0.015**	-	**-**
Total phosphorus	mg/L	0.05	**-**	-	**0.011**	**0.052**	**-**	**-**
Total nitrogen	mg/L	1.0	**-**	-	-	**1.1**	-	**-**
Total aluminum	mg/L	0.1	**0.232**	-	**0.102**	-	-	**0.328**
Total cadmium	mg/L	-[3]	**-**	-	-	-	**8.2E-05**	
Total chromium	mg/L	0.0010, 0.0089[5]	**-**	-	-	-	-	**-**
Dissolved iron	mg/L	0.3[4]	**-**	-	**0.449**	-	-	**-**
Total iron	mg/L	0.3	**0.698**	**2.29**	**0.594**	-	**0.402**	**1.12**
Total phenols	mg/L	0.005	**0.019**	**0.006**	-	**0.006**	**-**	**-**
Total selenium	mg/L	0.001	-	**0.00117**	-	-	-	-

BER-1, MCC-1, POC-1, and FOC-1 were sampled only in fall 2007. ISL-1 and SHL-1 were sampled in summer and fall 2007.

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).

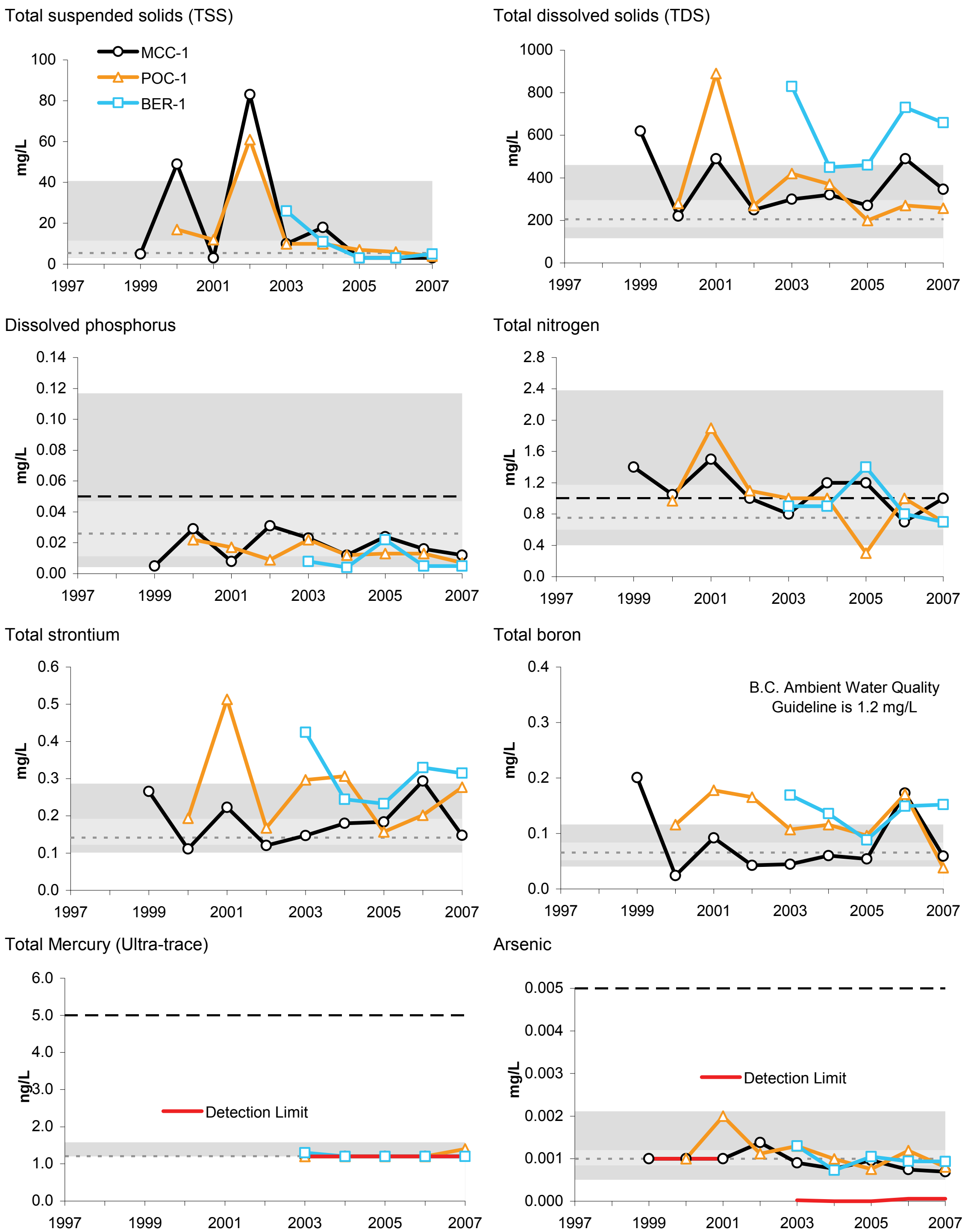
2 Derived from EPA (2002)

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).

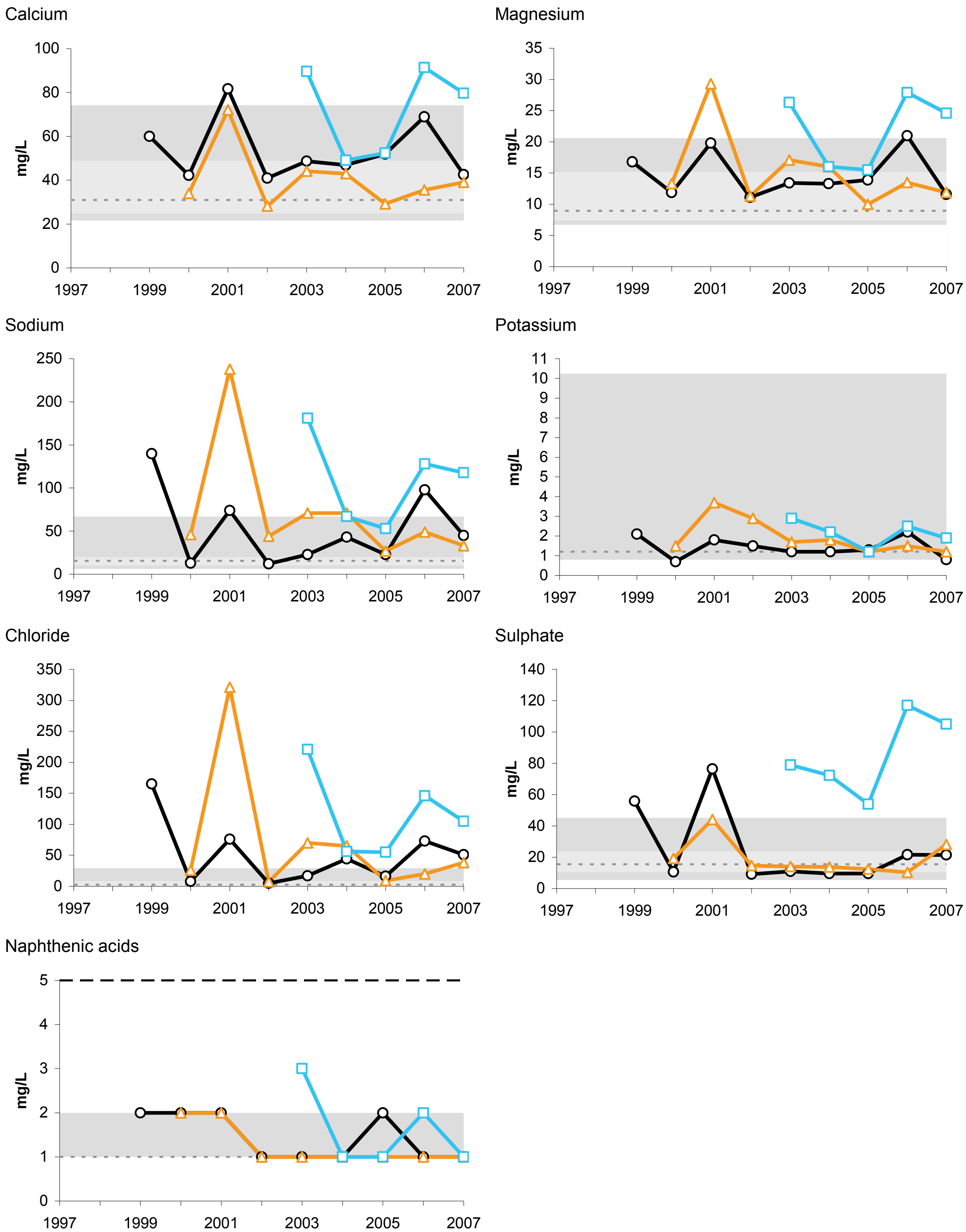
Figure 5.11-10 Concentrations of selected water quality measurement endpoints in the Beaver River (station BER-1), Poplar Creek (station POC-1), and McLean Creek (station MCC-1) (fall 2007) relative to regional baseline fall concentrations.



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 5.11-10 (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 5.11-11 Piper diagram of ion balance in McLean Creek, Beaver River and Poplar Creek, 1999-2007.

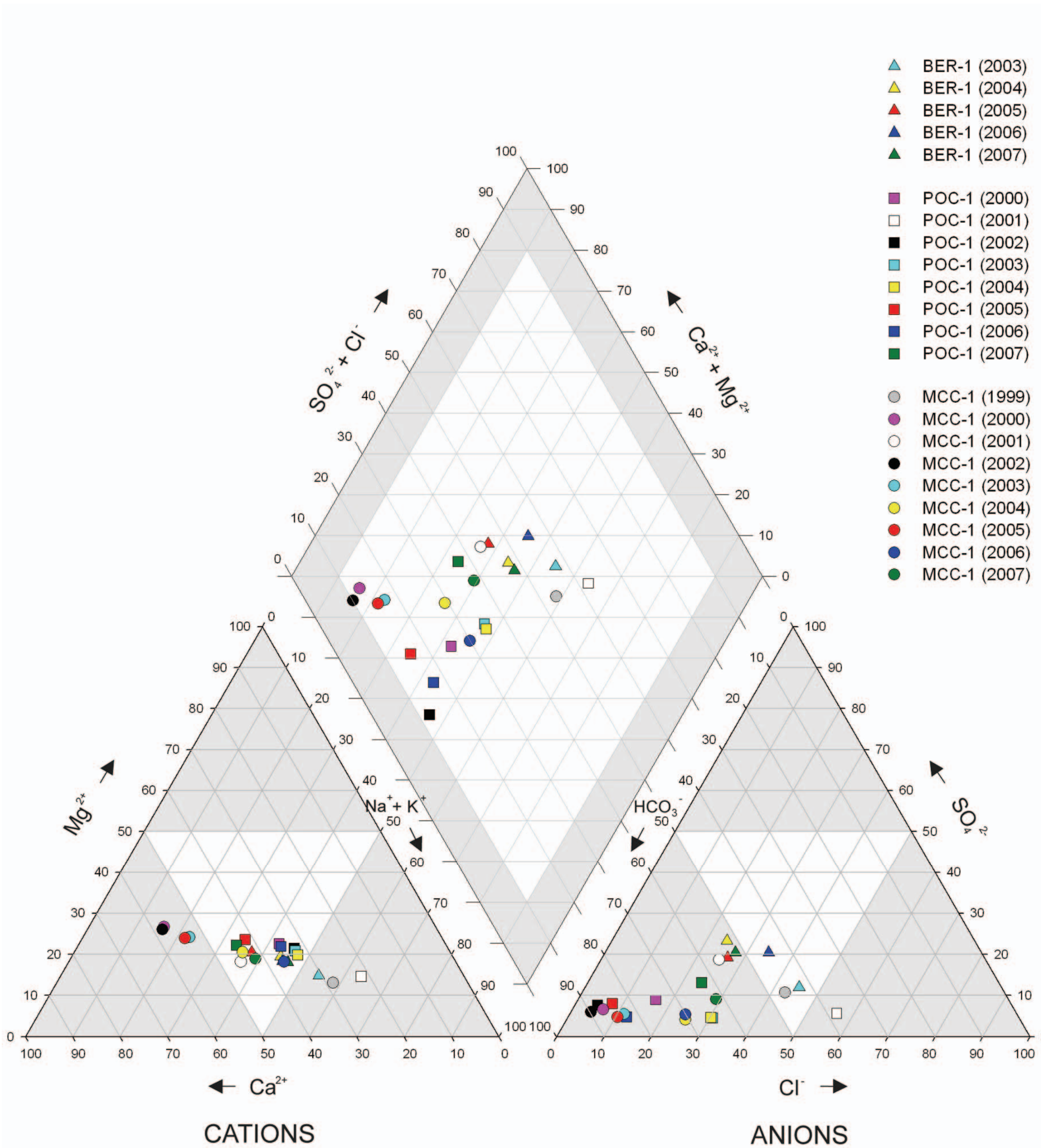


Table 5.11-7 Concentrations of water quality measurement endpoints, Poplar Creek (POC-1), fall 2007.

Measurement Endpoint	Units	Guideline	September 2007	1997-2006 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.3	7	7.9	8.2	8.4
Total Suspended Solids	mg/L	-[1]	4	7	6	10	61
Conductivity	µS/cm	-	459	7	308	442	1590
Nutrients							
Total dissolved phosphorus	mg/L	0.05[2]	0.007	7	0.009	0.013	0.022
Total nitrogen*	mg/L	1.0	0.7	7	0.3	1	**1.9**
Nitrate+Nitrite	mg/L	-	<0.1	7	0.07	<0.1	0.1
Dissolved organic carbon	mg/L	-	10	7	18	24	32
Ions							
Sodium	mg/L	-	33	7	27	49	238
Calcium	mg/L	-	39	7	28.2	35.6	72.1
Magnesium	mg/L	-	11.9	7	10	13.5	29.3
Chloride	mg/L	230, 860[3]	38	7	7	26	**321**
Sulphate	mg/L	100[4]	28.1	7	10.4	14.1	44.2
Total Dissolved Solids	mg/L	-	257	7	200	280	890
Total Alkalinity	mg/L	-	139	7	135	191	304
Organic compounds							
Naphthenic acids	mg/L	-	<1	7	<1	1	2
Selected metals							
Total aluminum	mg/L	0.1	**0.232**	7	**0.207**	**0.320**	**1.44**
Dissolved aluminum	mg/L	0.1[2]	0.00832	7	0.0039	0.0085	0.0121
Total arsenic	mg/L	0.005	0.000803	7	0.000752	0.00112	0.002
Total boron	mg/L	1.2[5]	0.0385	7	0.096	0.116	0.178
Total molybdenum	mg/L	0.073	0.000716	7	0.000198	0.00028	0.0005
Total mercury (ultra-trace)	ng/L	5, 13[6]	1.4	4	<1.2	<1.2	<1.2
Total strontium	mg/L	-	0.277	7	0.157	0.202	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).

Table 5.11-8 Concentrations of water quality measurement endpoints, McLean Creek (MCC-1), fall 2007.

Measurement Endpoint	Units	Guideline	September 2007	1997-2006 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.3	8	8.0	8.35	8.6
Total Suspended Solids	mg/L	-[1]	<3	8	<3	7.5	83
Conductivity	µS/cm	-	507	8	300	404.5	1000
Nutrients							
Total dissolved phosphorus	mg/L	0.05[2]	0.012	8	0.005	0.0195	0.031
Total nitrogen*	mg/L	1.0	1	8	0.7	**1.125**	**1.5**
Nitrate+Nitrite	mg/L	-	<0.1	8	<0.05	<0.1	<1
Dissolved organic carbon	mg/L	-	31	8	14	21.5	34
Ions							
Sodium	mg/L	-	45	8	12	33	140
Calcium	mg/L	-	42.5	8	40.9	50.35	81.7
Magnesium	mg/L	-	11.6	8	11.1	13.65	21
Chloride	mg/L	230, 860[3]	51	8	5	30.5	165
Sulphate	mg/L	100[4]	21.5	8	9.2	10.75	76.4
Total Dissolved Solids	mg/L	-	346	8	220	310	620
Total Alkalinity	mg/L	-	154	8	144	182	319
Organic compounds							
Naphthenic acids	mg/L	-	<1	8	<1	1.5	2
Selected metals							
Total aluminum	mg/L	0.1	**0.102**	8	0.07	**0.34**	**2.58**
Dissolved aluminum	mg/L	0.1[2]	0.00683	8	0.0025	0.0099	0.0157
Total arsenic	mg/L	0.005	0.000693	8	0.000744	0.0009805	0.00138
Total boron	mg/L	1.2[5]	0.0592	8	0.024	0.057	0.201
Total molybdenum	mg/L	0.073	0.000127	8	0.00014	0.0002	0.0005
Total mercury (ultra-trace)	ng/L	5, 13[6]	<1.2	4	<1.2	<1.2	<1.2
Total strontium	mg/L	-	0.148	8	0.111	0.182	0.294

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 5.11-9 Concentrations of water quality measurement endpoints, Isadore's Lake (ISL-1), fall 2007.

Measurement Endpoint	Units	Guideline	September 2007	1997-2006 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.2	5	7.7	8.1	8.3
Total Suspended Solids	mg/L	-[1]	5	5	<3	6	10
Conductivity	µS/cm	-	509	5	353	526	588
Nutrients							
Total dissolved phosphorus	mg/L	0.05[2]	0.009	5	0.004	0.009	**0.067**
Total nitrogen*	mg/L	1.0	**1.1**	5	0.3	0.8	**1.25**
Nitrate+Nitrite	mg/L	-	<0.1	5	<0.05	<0.1	0.3
Dissolved organic carbon	mg/L	-	11	5	8	10	12
Ions							
Sodium	mg/L	-	11	5	6	9	13
Calcium	mg/L	-	49.5	5	37	60.2	72.2
Magnesium	mg/L	-	32.9	5	25.6	28.8	33.2
Chloride	mg/L	230, 860[3]	16	5	4	8	16
Sulphate	mg/L	100[4]	**103**	5	63.9	82.5	**109**
Total Dissolved Solids	mg/L	-	323	5	250	340	380
Total Alkalinity	mg/L	-	147	5	122	170	227
Organic compounds							
Naphthenic acids	mg/L	-	<1	5	<1	<1	1
Selected metals							
Total aluminum	mg/L	0.1	0.0112	5	0.0162	0.040	**0.182**
Dissolved aluminum	mg/L	0.1[2]	<0.001	5	0.000258	0.0020	0.020
Total arsenic	mg/L	0.005	0.000617	5	0.000669	<0.001	0.00116
Total boron	mg/L	1.2[5]	0.0407	5	0.0350	0.0400	0.0491
Total molybdenum	mg/L	0.073	<0.000008	5	0.000018	0.00010	0.000125
Total mercury (ultra-trace)	ng/L	5, 13[6]	<1.2	3	<1.2	<1.2	1.4
Total strontium	mg/L	-	0.178	5	0.162	0.21	0.238

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).

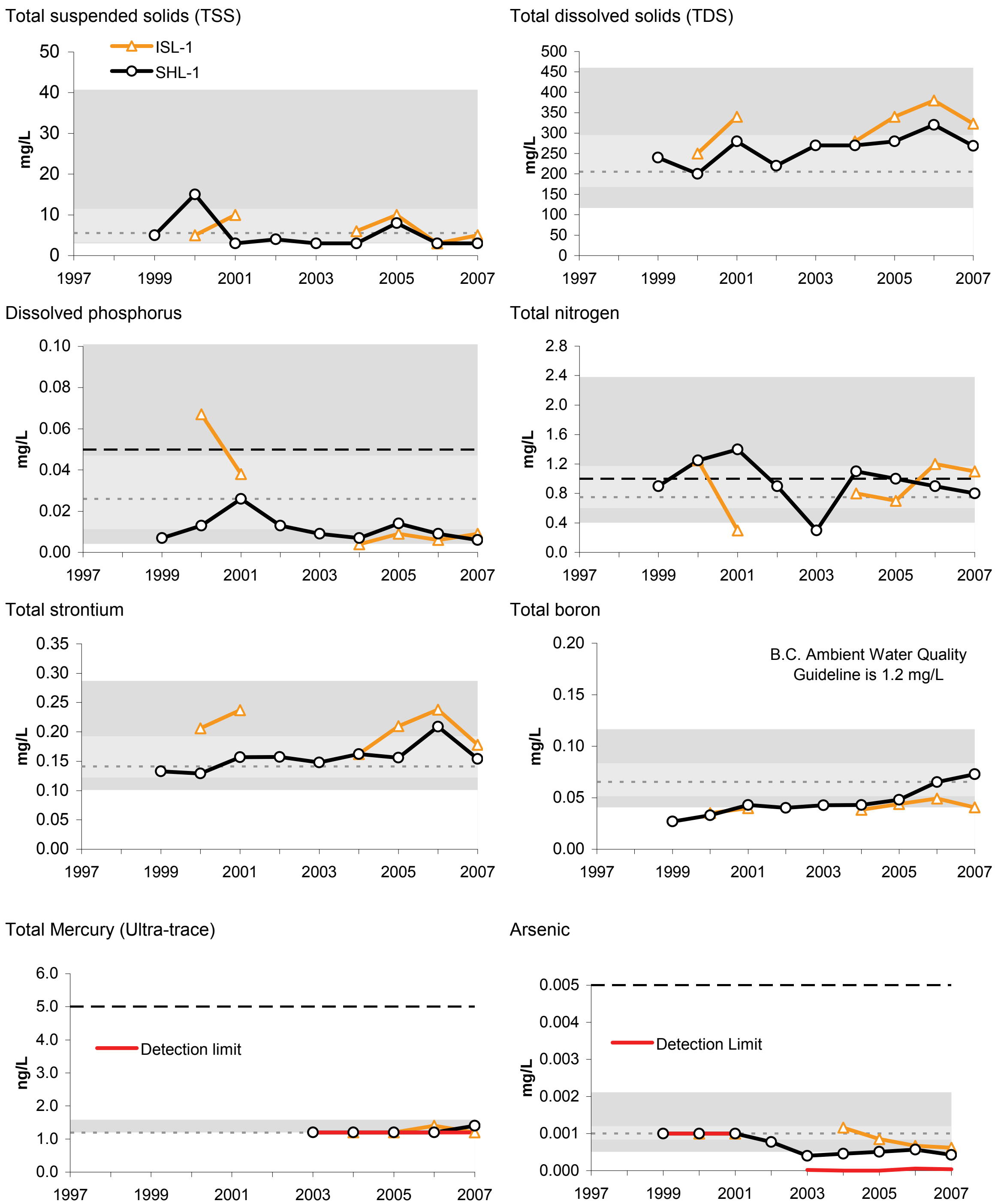
3 U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 1999).

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).

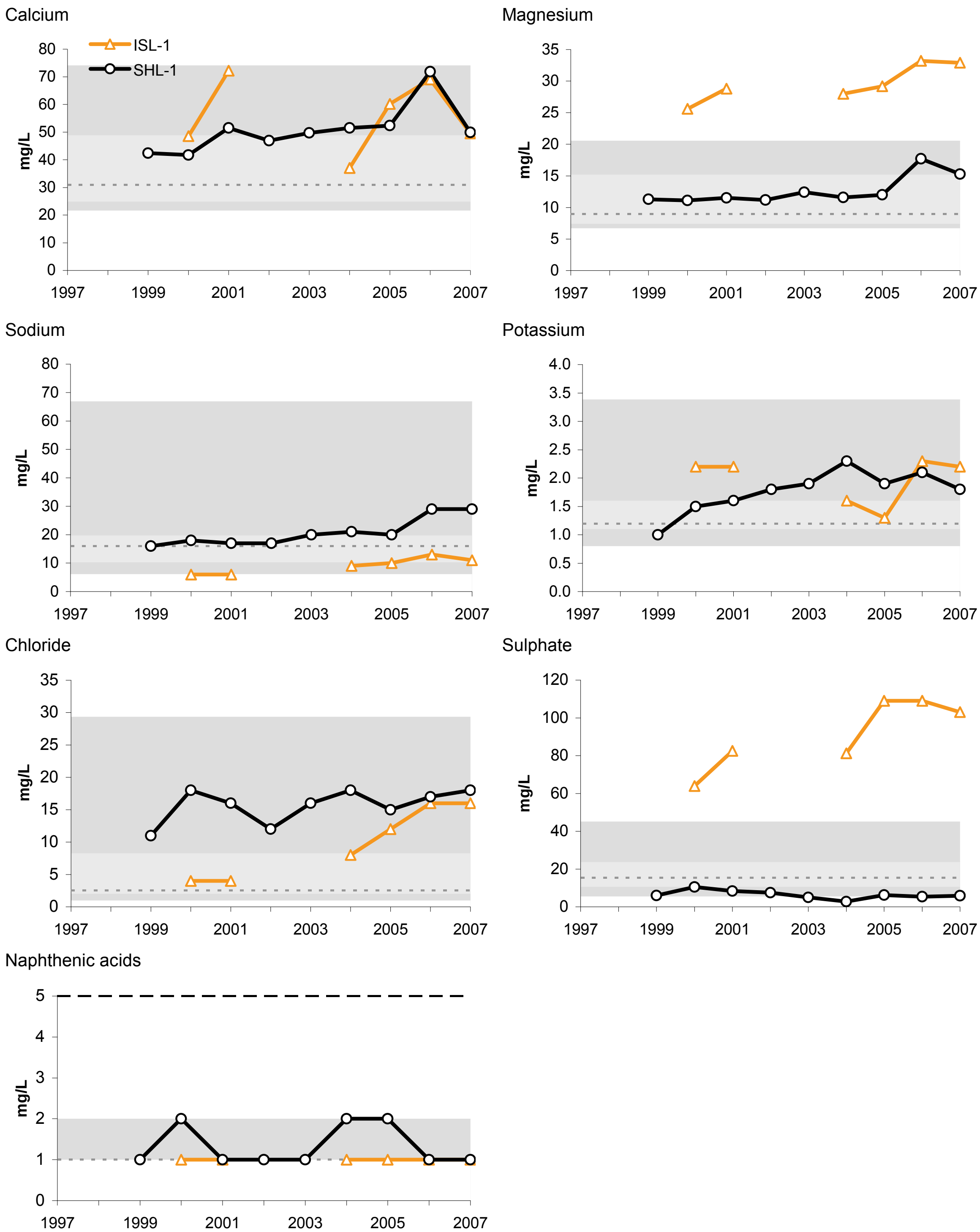
Figure 5.11-12 Concentrations of selected fall water quality measurement endpoints, Shipyard Lake (SHL-1) and Isadore's Lake (ISL-1) (fall 2007), relative to regional fall baseline concentrations.



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 5.11-12 (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 5.11-13 Piper diagram of ion balance in Shipyard Lake and Isadore's Lake, 1999-2007.

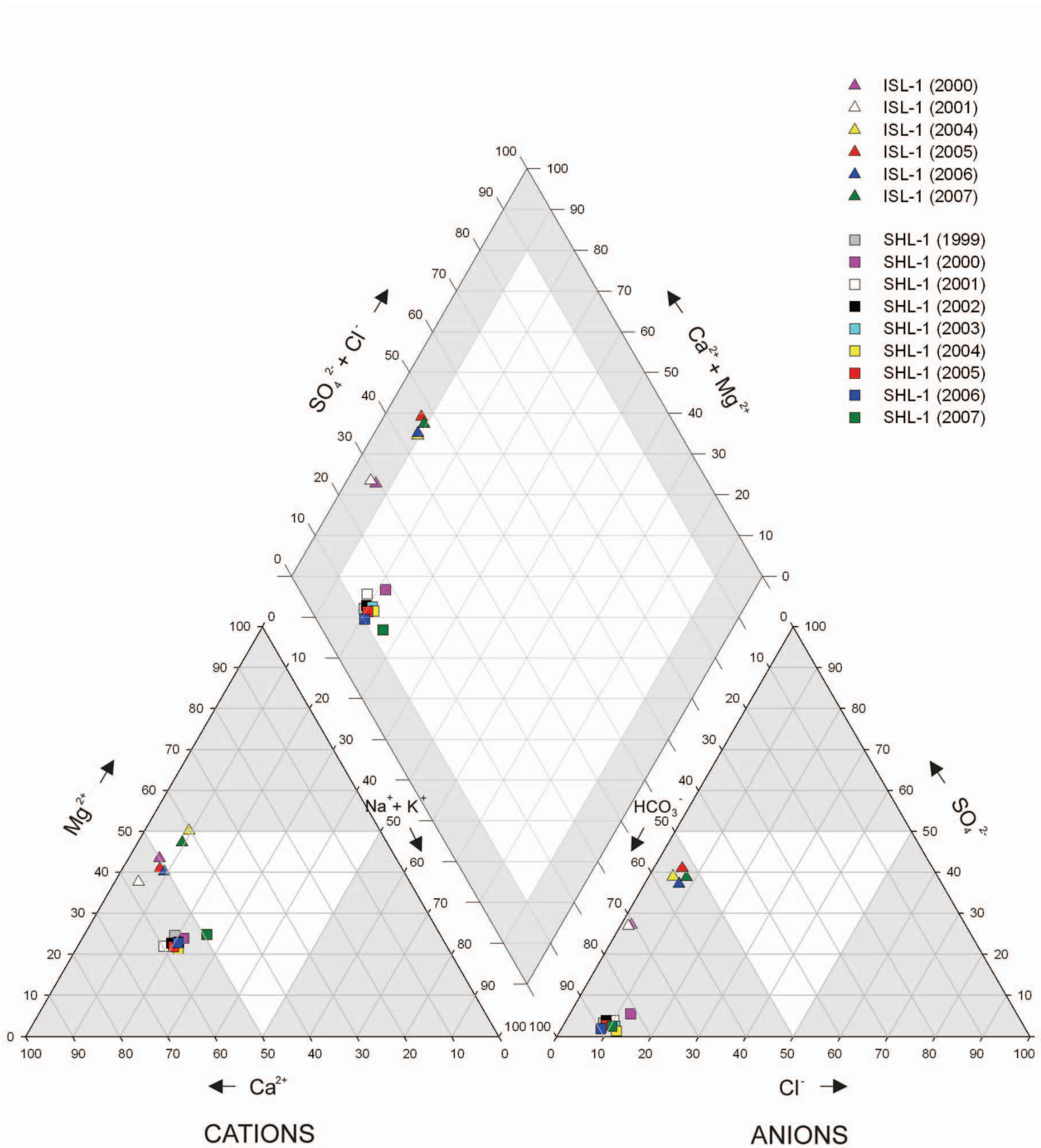


Table 5.11-10 Concentrations of water quality measurement endpoints, Shipyard Lake (SHL-1), fall 2007.

Measurement Endpoint	Units	Guideline	September 2007	1997-2006 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.2	8	7.7	8.1	8.1
Total Suspended Solids	mg/L	-[1]	<3	8	<3	3.5	15
Conductivity	µS/cm	-	434	8	358	384	509
Nutrients							
Total dissolved phosphorus	mg/L	0.05[2]	0.006	8	0.007	0.011	0.026
Total nitrogen*	mg/L	1.0	0.8	8	0.3	1.0	**1.4**
Nitrate+Nitrite	mg/L	-	<0.1	8	<0.05	<0.1	<0.1
Dissolved organic carbon	mg/L	-	21	8	17	19.5	24
Ions							
Sodium	mg/L	-	29	8	16	19	29
Calcium	mg/L	-	49.9	8	41.7	50.6	71.8
Magnesium	mg/L	-	15.3	8	11.1	11.55	17.7
Chloride	mg/L	230, 860[3]	18	8	11	16	18
Sulphate	mg/L	100[4]	5.9	8	2.8	6.1	10.5
Total Dissolved Solids	mg/L	-	269	8	200	270	320
Total Alkalinity	mg/L	-	209	8	159	178.5	251
Organic compounds							
Naphthenic acids	mg/L	-	<1	8	<1	1	2
Selected metals							
Total aluminum	mg/L	0.1	0.00581	8	0.004	0.017	**0.140**
Dissolved aluminum	mg/L	0.1[2]	<0.001	8	0.00049	0.00240	0.01
Total arsenic	mg/L	0.005	0.000425	8	0.0004	0.00067	0.001
Total boron	mg/L	1.2[5]	0.0728	8	0.0270	0.0428	0.0653
Total molybdenum	mg/L	0.073	0.0000294	8	0.000046	0.0000943	0.0002
Total mercury (ultra-trace)	ng/L	5, 13[6]	1.4	4	<1.2	<1.2	<1.2
Total strontium	mg/L	-	0.154	8	0.129	0.1565	0.209

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 5.11-11 Concentrations of water quality measurement endpoints, lower Fort Creek (station FOC-1), fall 2007.

Measurement Endpoint	Units	Guideline	September 2007	1997-2006 (fall data only)			
			Value	n[7]	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.4	6	8.1	8.3	8.4
Total Suspended Solids	mg/L	-[1]	15	6	5	15.5	61
Conductivity	µS/cm	-	503	6	432	501	562
Nutrients							
Total dissolved phosphorus	mg/L	0.05[2]	0.009	6	0.01	0.014	0.02
Total nitrogen*	mg/L	1.0	0.7	6	0.4	0.575	1.0
Nitrate+Nitrite	mg/L	-	<0.1	6	<0.05	<0.1	<0.1
Dissolved organic carbon	mg/L	-	13	6	11	13	14
Ions							
Sodium	mg/L	-	10	6	8	10	18
Calcium	mg/L	-	80.7	6	69.4	76.15	89.6
Magnesium	mg/L	-	17.7	6	14.3	16.7	20.1
Chloride	mg/L	230, 860[3]	2	6	2	2.5	7
Sulphate	mg/L	100[4]	6.7	6	3.7	6.6	11.2
Total Dissolved Solids	mg/L	-	310	6	260	325	360
Total Alkalinity	mg/L	-	275	6	231	271.5	304
Organic compounds							
Naphthenic acids	mg/L	-	<1	6	<1	1	2
Selected metals							
Total aluminum	mg/L	0.1	**0.328**	6	0.04	0.054	**0.85**
Dissolved aluminum	mg/L	0.1[2]	<0.001	6	0.00106	0.003	0.090
Total arsenic	mg/L	0.005	0.000303	6	0.0003	0.0008405	<0.001
Total boron	mg/L	1.2[5]	0.0456	6	0.0260	0.0510	0.0731
Total molybdenum	mg/L	0.073	0.0000451	6	0.00003	0.0001	0.0001
Total mercury (ultra-trace)	ng/L	5, 13[6]	1.4	2	<1.2	<1.2	<1.2
Total strontium	mg/L	-	0.174	6	0.142	0.178	0.224

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).

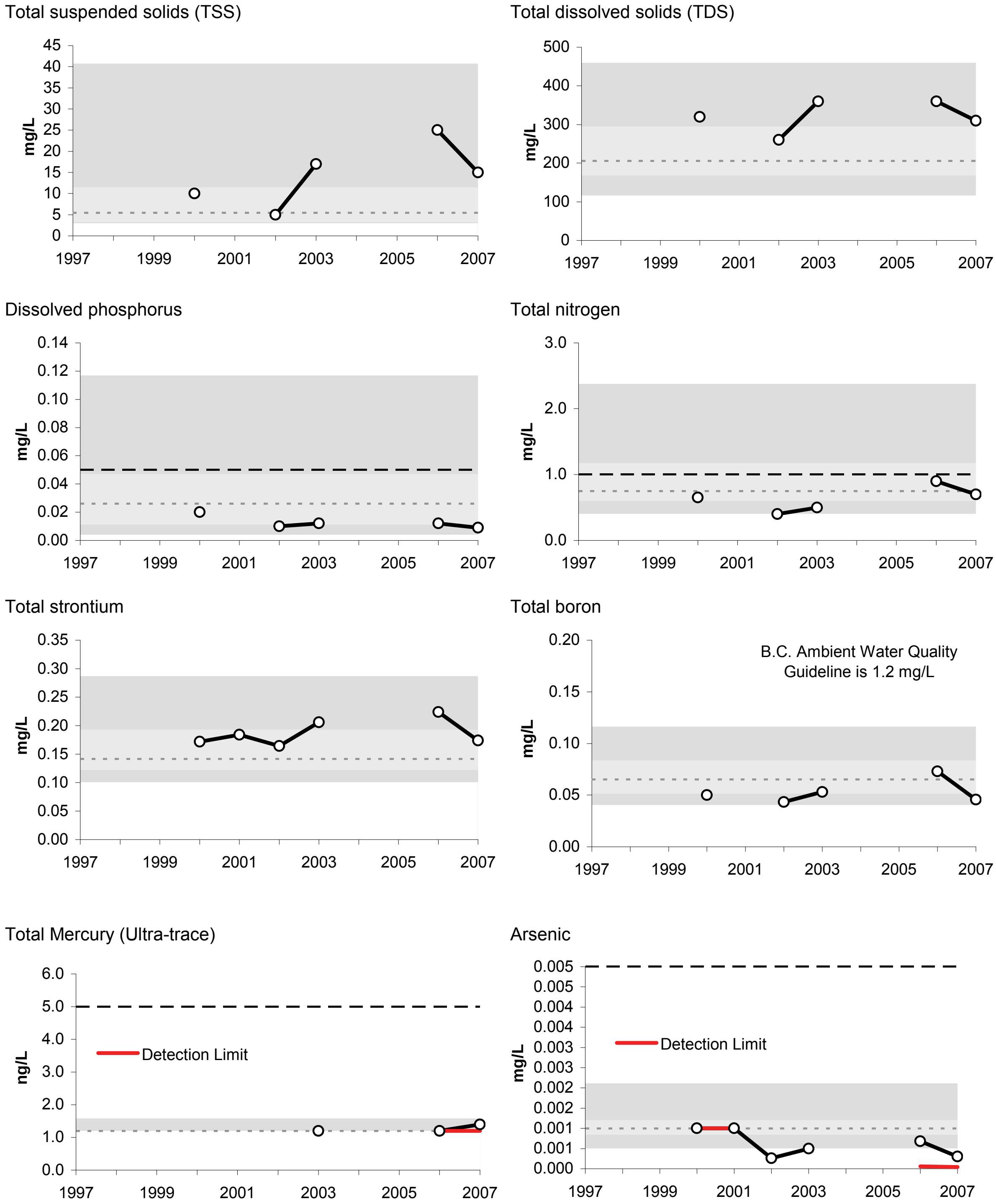
[4] B.C. maximum concentration guideline for sulphate (B.C. Approved Water Quality Guideline, B.C. 2006)

[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] FOC-1 was sampled in both September and October 2000.

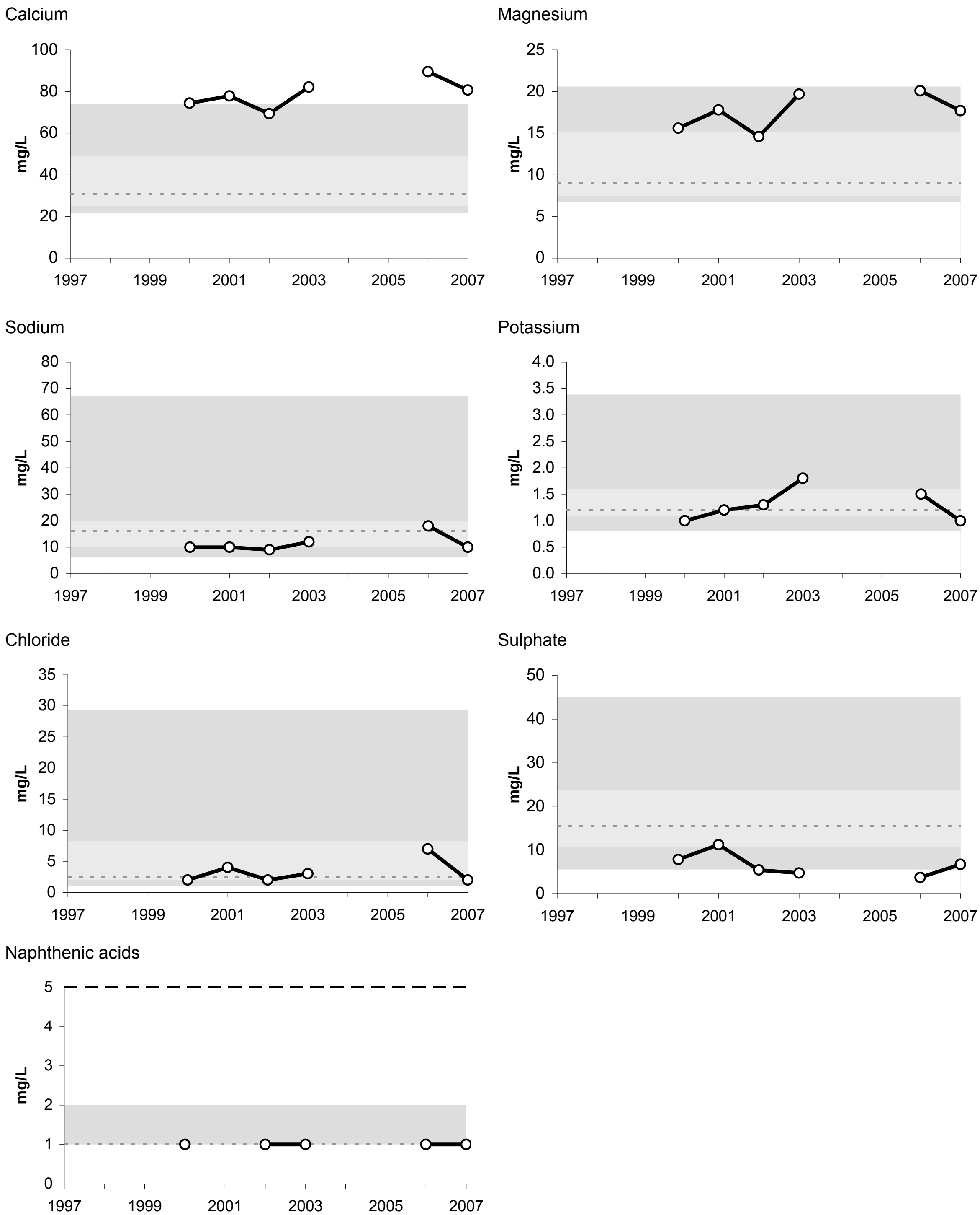
Figure 5.11-14 Concentrations of selected water quality measurement endpoints in Fort Creek (fall 2007) relative to regional baseline fall concentrations.



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 5.11-14 (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 5.11-15 Piper diagram of ion balance in Fort Creek, 2000-2007.

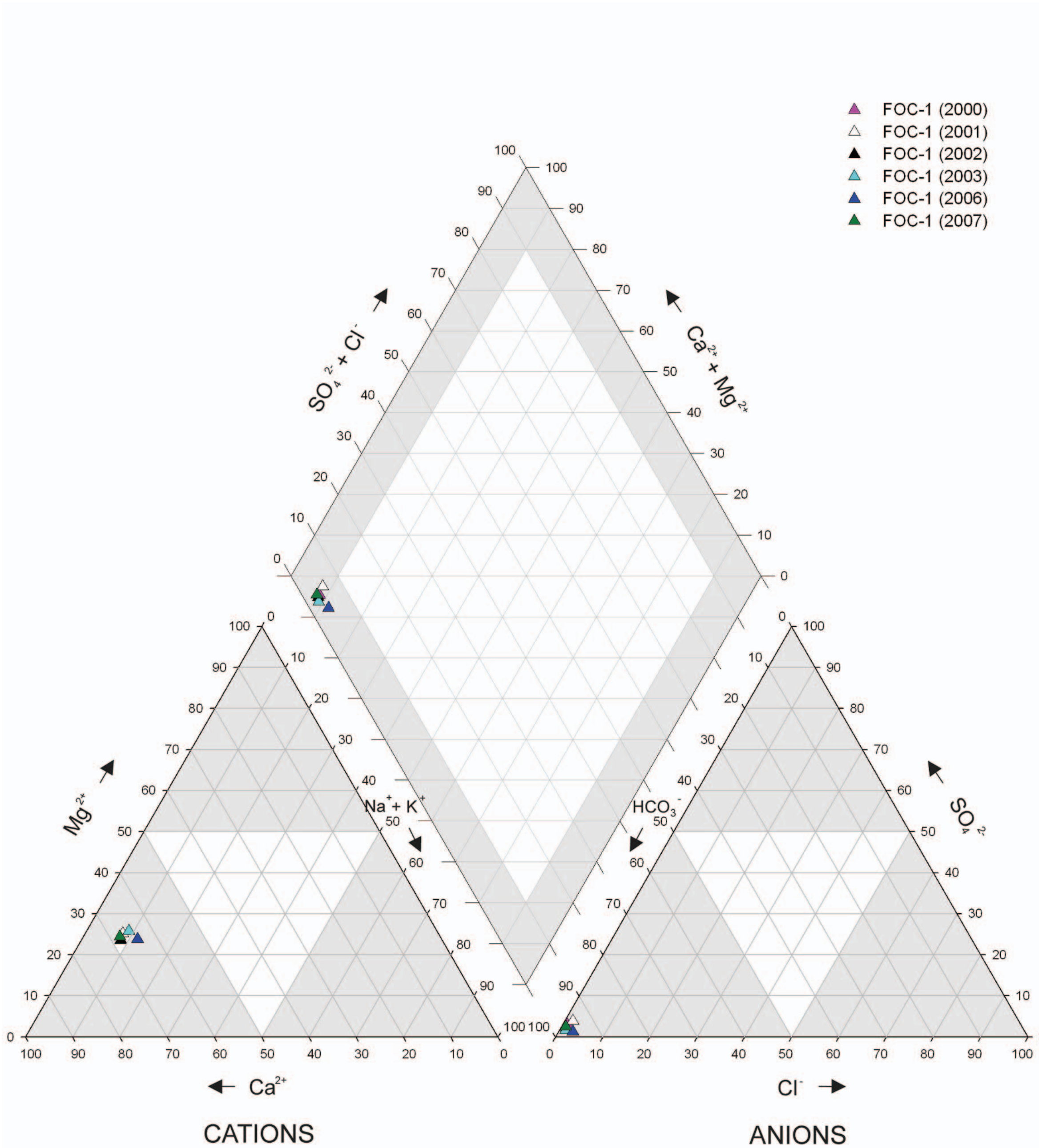


Table 5.11-12 Concentrations of water quality measurement endpoints, Kearl Lake (station KEL-1), fall 2007.

Measurement Endpoint	Units	Guideline	September 2007	1997-2006 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.1	8	7.6	8.0	8.1
Total suspended solids	mg/L	-[1]	13	8	<3	5.5	19
Conductivity	µS/cm	-	174	8	133	174	183
Nutrients							
Total dissolved phosphorus	mg/L	0.05[2]	0.006	8	0.002	0.008	0.013
Total nitrogen*	mg/L	1.0	**1.7**	8	0.45	**1.175**	**1.8**
Nitrate+nitrite	mg/L	-	<0.1	8	<0.05	0.1	0.1
Dissolved organic carbon	mg/L	-	24	8	15	21	24
Ions							
Sodium	mg/L	-	9	8	8	10	11
Calcium	mg/L	-	18.3	8	16.5	19.65	20.6
Magnesium	mg/L	-	5.7	8	6	6.95	7.6
Chloride	mg/L	230, 860[3]	3	8	<0.5	1	2
Sulphate	mg/L	100[4]	3.7	8	2.7	5	5.7
Total dissolved solids	mg/L	-	157	8	94	147	220
Total alkalinity	mg/L		87	8	72	86	93
Organic compounds							
Naphthenic acids	mg/L	-	<1	8	<1	<1	1
Selected metals							
Total aluminum	mg/L	0.1	0.023	8	0.011	0.033	**0.13**
Dissolved aluminum	mg/L	0.1[2]	<0.001	8	0.0014	0.0040	0.030
Total arsenic	mg/L	0.005	0.000369	8	0.0003	0.0004185	<0.001
Total boron	mg/L	1.2[5]	0.0465	8	0.012	0.047	0.0493
Total molybdenum	mg/L	0.073	0.000122	8	0.0001	0.00011	0.0009
Total mercury (ultra-trace)	ng/L	5, 13[6]	<1.2	4	<1.2	<1.2	<1.2
Total strontium	mg/L	-	0.0661	8	0.056	0.0624	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).

Table 5.11-13 Water quality guideline exceedances, Kearl Lake (station KEL-1) and McLelland Lake (station MCL-1), fall 2007.

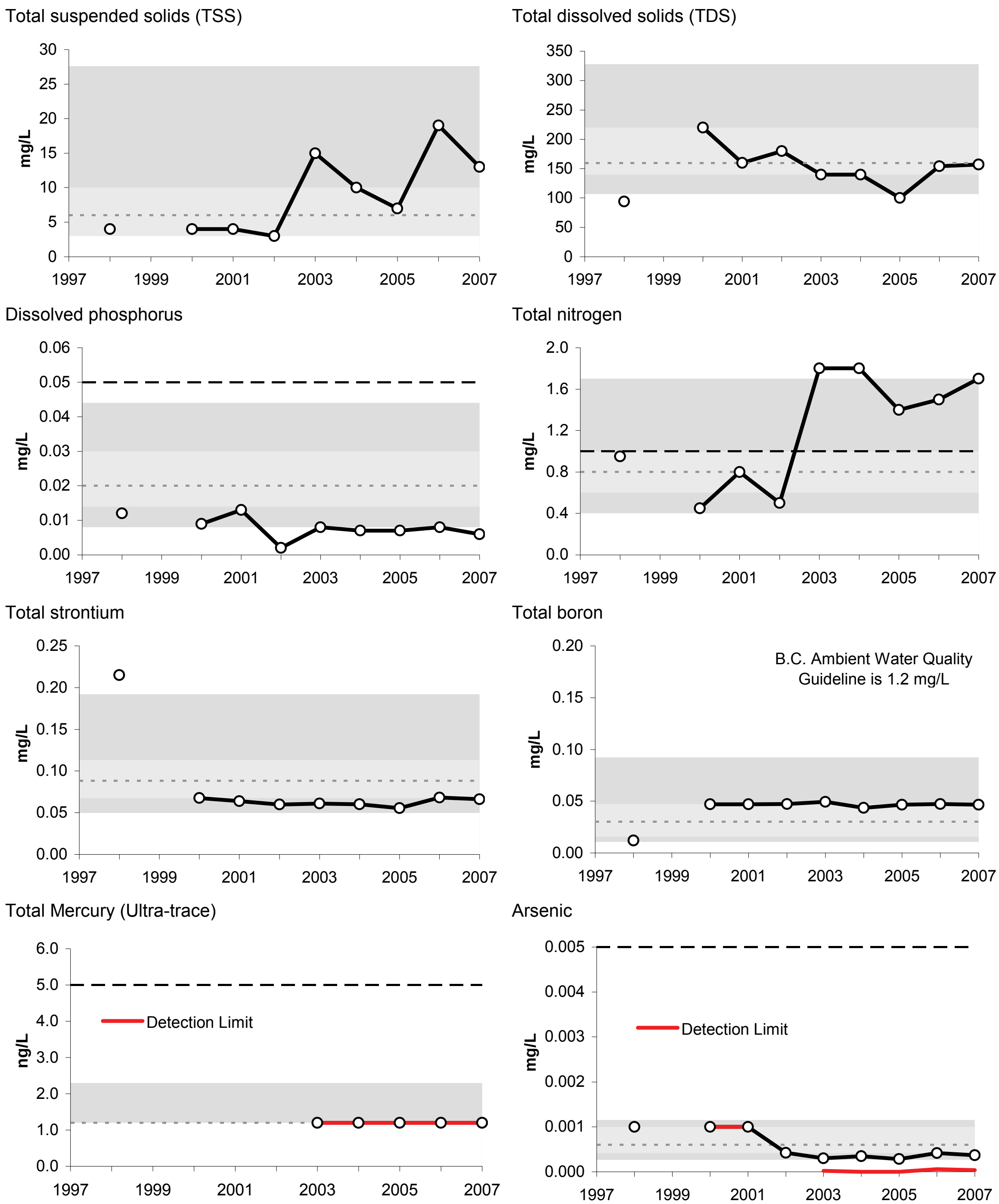
Variable	Units	Guideline	KEL-1	MCL-1
Summer				
Total Kjeldahl nitrogen	mg/L	1.0[1]	**1.2**	ns
Total nitrogen	mg/L	1.0	**1.3**	ns
Total phenols	mg/L	0.004	**0.013**	ns
Fall				
Total phenols	mg/L	0.005	**0.009**	-
Total nitrogen	mg/L	1.0	**1.7**	-
Total Kjeldahl nitrogen	mg/L	1.0[1]	**1.6**	-

KEL-1 sampled only in fall and summer 2007. MCL-1 sampled only in fall 2007.

ns = not sampled

[1] Guideline is for total nitrogen.

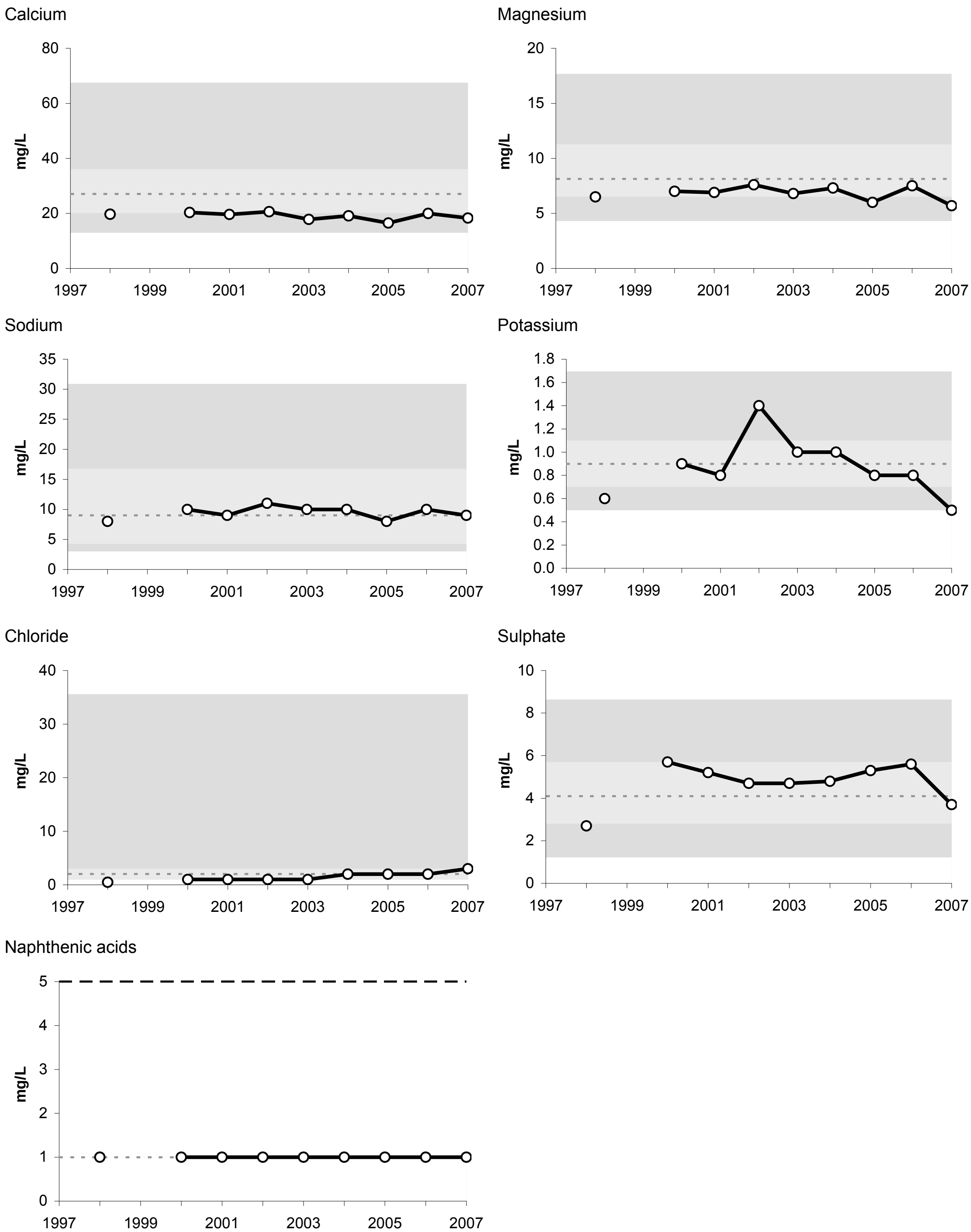
Figure 5.11-16 Concentrations of selected water quality measurement endpoints in Kearl Lake (station KEL-1, fall data) relative to regional baseline fall concentrations.



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 5.11-16 (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 5.11-17 Piper diagram of fall concentrations in Kearl Lake (station KEL-1) and McClelland Lake (station (MCL-1).

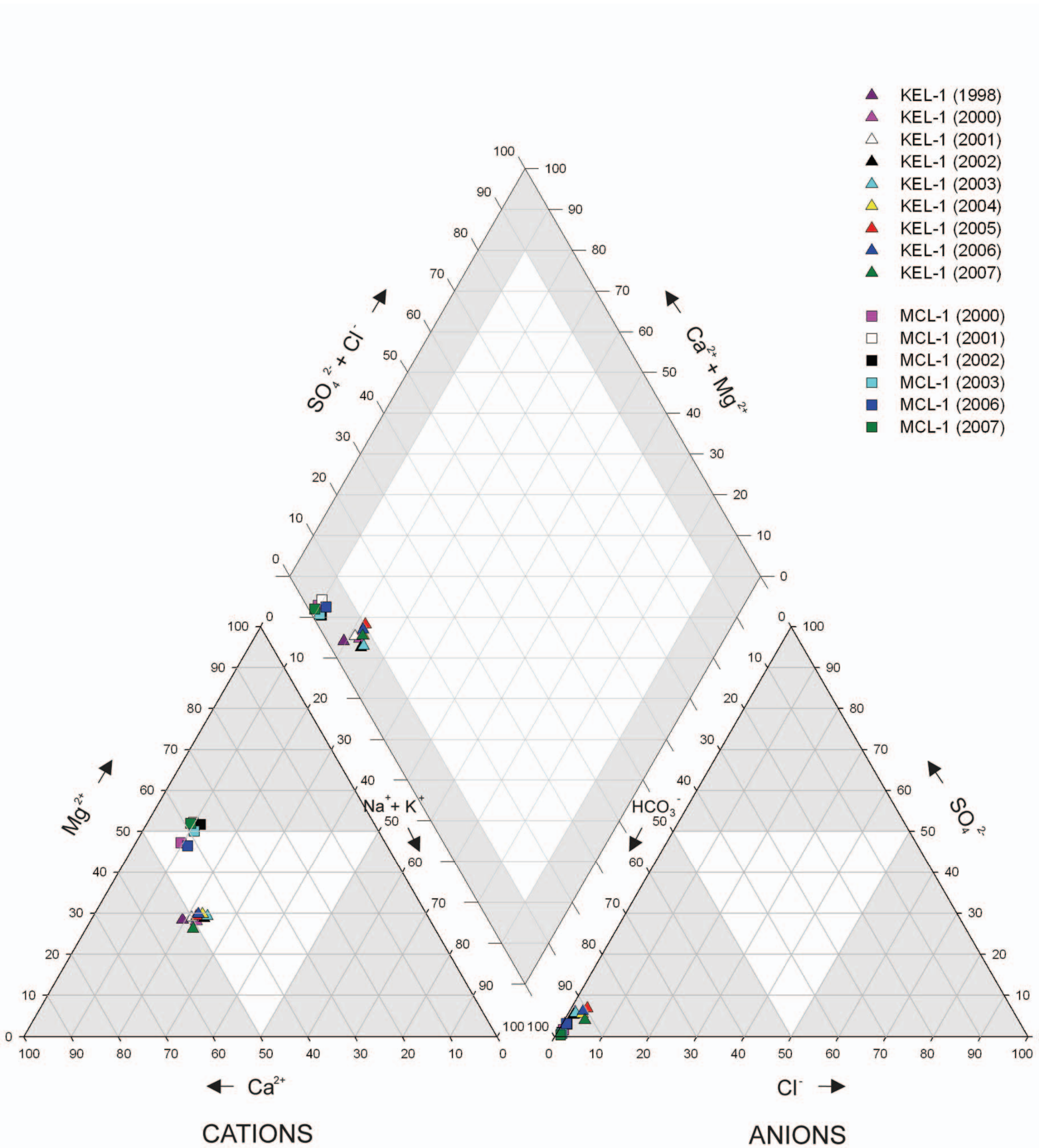


Table 5.11-14 Concentrations of water quality measurement endpoints, McClelland Lake (station MCL-1), fall 2007.

Measurement Endpoint	Units	Guideline	September 2007	1997-2006 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.7	5	8.1	8.3	8.5
Total suspended solids	mg/L	-[1]	<3	5	<3	3	5
Conductivity	µS/cm	-	245	5	224	233	253
Nutrients							
Total dissolved phosphorus	mg/L	0.05[2]	0.003	5	0.002	0.004	0.013
Total nitrogen*	mg/L	1.0	1	5	0.6	1.0	**2.0**
Nitrate+nitrite	mg/L	-	<0.1	5	<0.05	<0.1	<0.1
Dissolved organic carbon	mg/L	-	15	5	11	12	17
Ions							
Sodium	mg/L	-	4	5	4	5	6
Calcium	mg/L	-	20.4	5	19.3	21.3	25.8
Magnesium	mg/L	-	16.6	5	14.6	16.5	17.3
Chloride	mg/L	230, 860[3]	<1	5	<1	<1	1
Sulphate	mg/L	100[4]	<0.5	5	1.0	2.2	4.3
Total dissolved solids	mg/L	-	155	5	80	150	167
Total alkalinity	mg/L		130	5	122	123	135
Organic compounds							
Naphthenic acids	mg/L	-	<1	5	<1	<1	2
Selected metals							
Total aluminum	mg/L	0.1	0.00275	5	0.005	0.020	0.026
Dissolved aluminum	mg/L	0.1[2]	<0.001	5	0.000437	0.0021	0.010
Total arsenic	mg/L	0.005	0.00019	5	0.0002	0.00025	<0.001
Total boron	mg/L	1.2[5]	0.0567	5	0.0513	0.0649	0.0670
Total molybdenum	mg/L	0.073	<0.000008	5	0.0000043	0.00003	<0.0001
Total mercury (ultra-trace)	ng/L	5, 13[6]	<1.2	2	<1.2	<1.2	<1.2
Total strontium	mg/L	-	0.128	5	0.112	0.132	0.145

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).

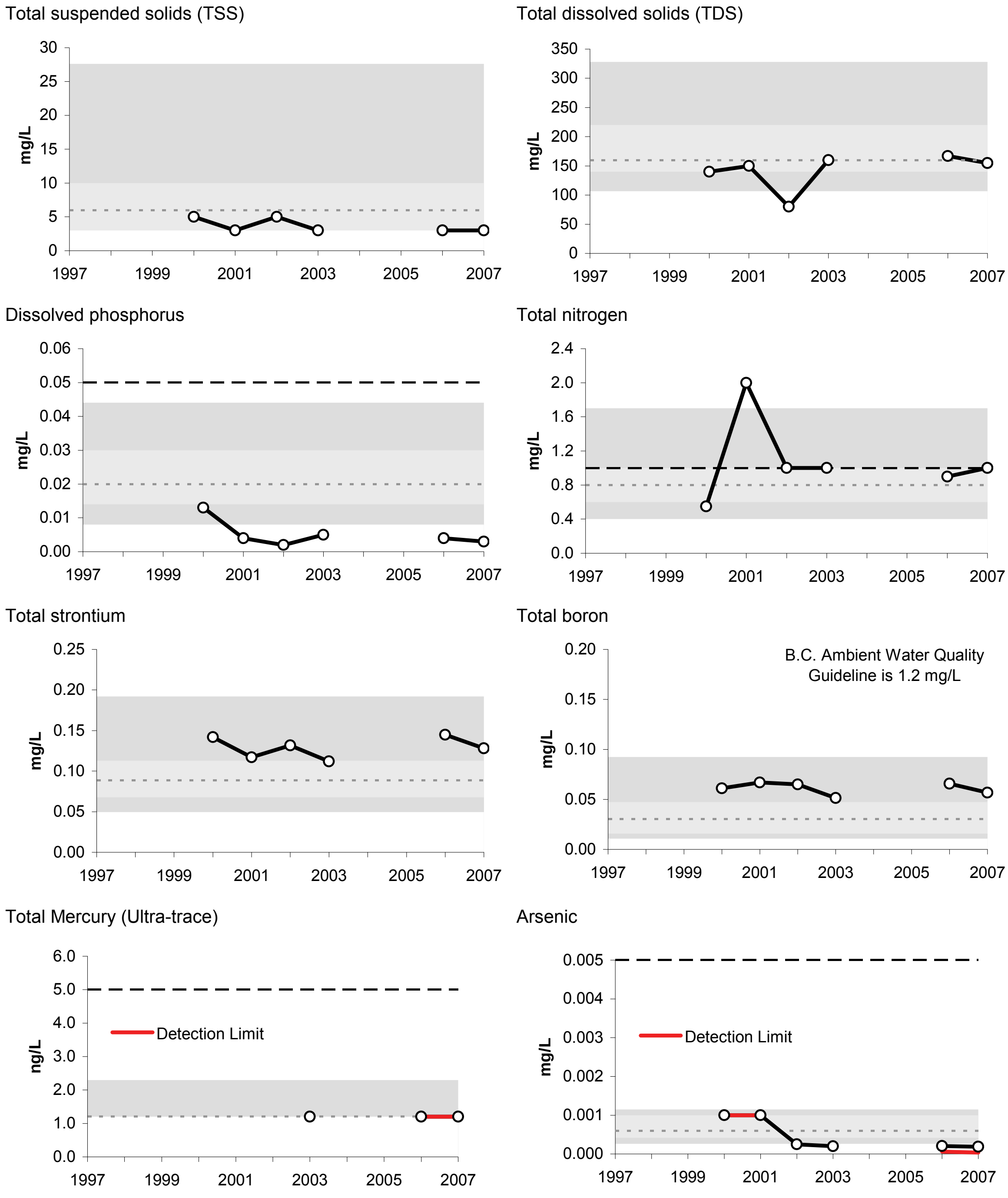
3 U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 1999).

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).

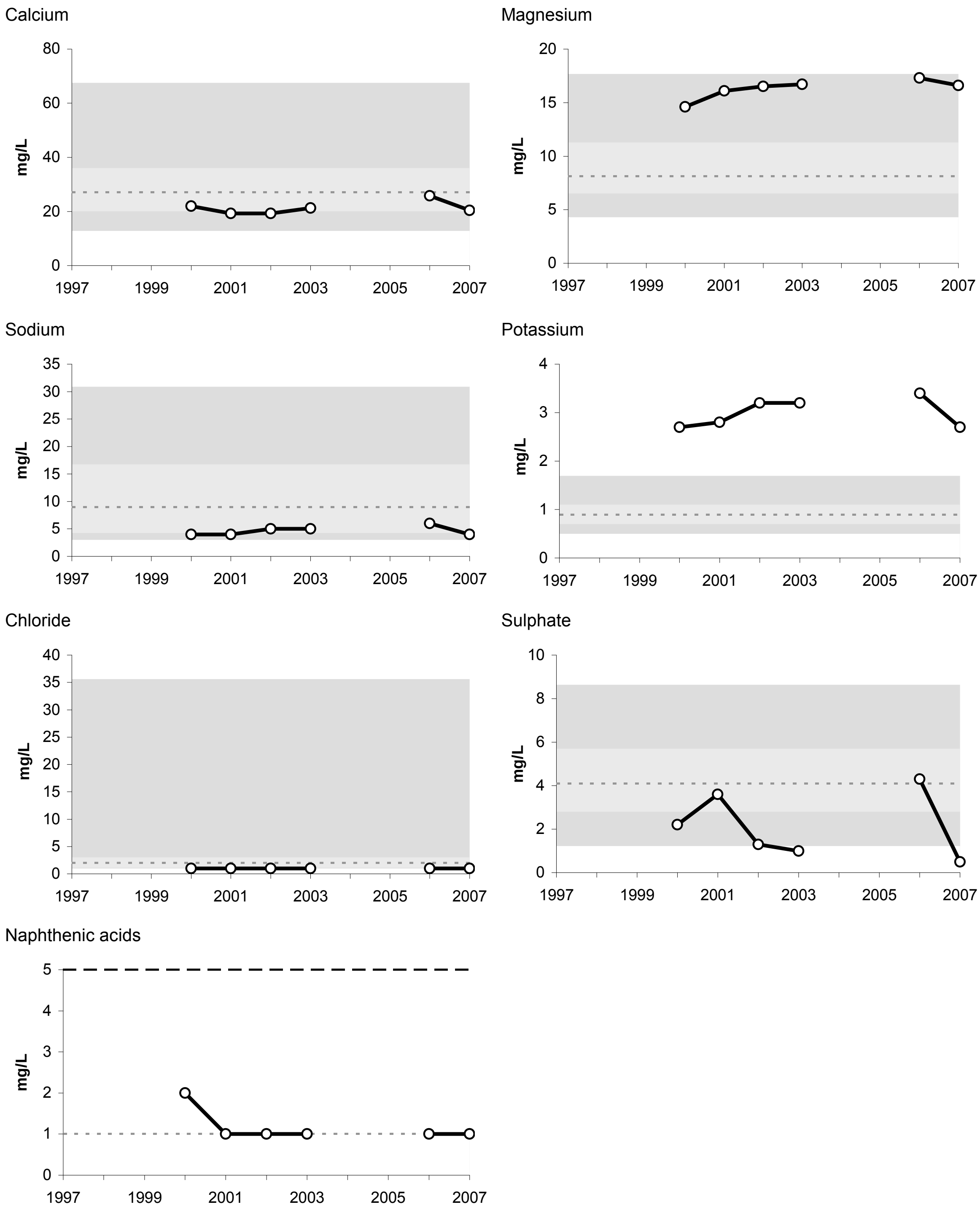
Figure 5.11-18 Concentrations of selected water quality measurement endpoints in McClelland Lake (station MCL-1, fall data) relative to regional baseline fall concentrations.



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 5.11-18 (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 5.11-15 Average habitat characteristics of benthic invertebrate sampling locations in Kearl, McClelland, and Shipyard Lakes.

Variable	Units	Kearl Lake KEL-1	Shipyard Lake SHL-1	McClelland Lake MCC-1	Isadore's Lake ISL-1
Sample date	-	Sept 11, 2007	Sept 6, 2007	Sept 10, 2007	Sept 6, 2007
Habitat	-	Depositional	Depositional	Depositional	Depositional
Water depth	m	2.7	1.4	3.8	2.2
Macrophyte cover	%	n/a	74	11	61
Field Water Quality					
Dissolved oxygen	mg/L	9.0	n/a	9.8	8.6
Conductivity	µS/cm	181	473	247	590
pH	-	7.8	7.1	8.5	7.7
Water temperature	°C	11.7	14.9	12.2	15.9
Sediment Composition					
Sand	%	85	8	68	23
Silt	%	11	37	15	56
Clay	%	4	55	17	21
Total Organic Carbon	%	36.2	18.8	29.2	3.3

Table 5.11-16 Major taxon percent abundances and values of benthic invertebrate community measurement endpoints, Kearl, Shipyard, McClelland, and Isadore's lakes.

	Kearl							McClelland						Shipyard								Isadore's	
Taxon	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2006**	**2007**
Amphipoda	13	46	36	58	25	23	27	11	22	21	7	<1	4	7		2	3		2	2	2	<1	
Anisoptera						<1				<1	1	<1		<1	1	<1			<1				
Bivalvia	4	4	6	9	4	23	7	2	8	6	9	<1	1	7	<1	8	6	1	<1	2	1		
Ceratopogonidae		1	1			<1					1	<1			1	<1	1			6		<1	
Chaoboridae	1						<1							3	53	1	32	1	<1	6		<1	
Chironomidae	6	42	46	20	45	42	24	58	39	24	27	91	41	25	40	48	32	3	30	37	27	2	57
Cladocera	1		<1	1	7	<1		<1		2	2	1	7	3				<1	2		1		4
Copepoda	<1	<1		2	15	<1	31			2	1	1	10	1	<1		9	1	3	1	11	3	4
Ephemeroptera	<1	1				2	1	1	2	8	7	1	12	16	1	2			<1	<1	3		1
Erpobdellidae					<1	<1		1	<1	<1										1			
Gastropoda	1	<1				<1		<1	1		2	<1		18	1	7	5	1	2	<1	3		
Glossiphoniidae	<1	1	1	<1											<1	<1	<1						
Hydracarina	<1		<1				2	1	<1		1				1	<1		<1	1		3		
Lumbriculidae						<1			<1	<1	<1		8						<1				
Naididae		<1	6	5	1	3	2	14	13	7	12	2	12	8	<1	3		4	9	16	6	4	1
Nematoda					1	1	3	1	<1	4	<1	1				3	2	2	1	1	1	72	32
Ostracoda	7	7	4	4	1	<1	1	10	8	15	29	1	3	6	2	25	8	87	5	22	40	1	2
Trichoptera	2	1	1	<1	<1	1	2	1		3	1	<1	2	2	1	<1		<1	1	1	1		
Tubificidae					1	2	1		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	4,217	6,352	4,823	3,504	8,874	40,526	15,591	4,552	3,284	19,780	1,530	30,867	27,930	10,647	21,305	33,987	20,110
Number of Taxa	7	9	8	7	12	17	8	11	11	6	11	23	12	13	6	13	4	9	15	12	15	10	9
Simpsons Diversity	0.73	0.64	0.63	0.6	0.76	0.76	0.71	0.71	0.71	0.66	0.72	0.76	0.72	0.84	0.43	0.77	0.61	0.21	0.63	0.72	0.74	0.41	0.63
Evenness	0.92	0.72	0.79	0.71	0.83	0.76	0.84	0.84	0.81	0.91	0.85	0.76	0.82	0.92	0.55	0.84	0.83	0.24	0.69	0.72	0.81	0.42	0.75
%EPT	3	2	1	<1	<1	2	2	2	2	10	7	2	6	19	1	2	<1	<1	1	<1	2		1

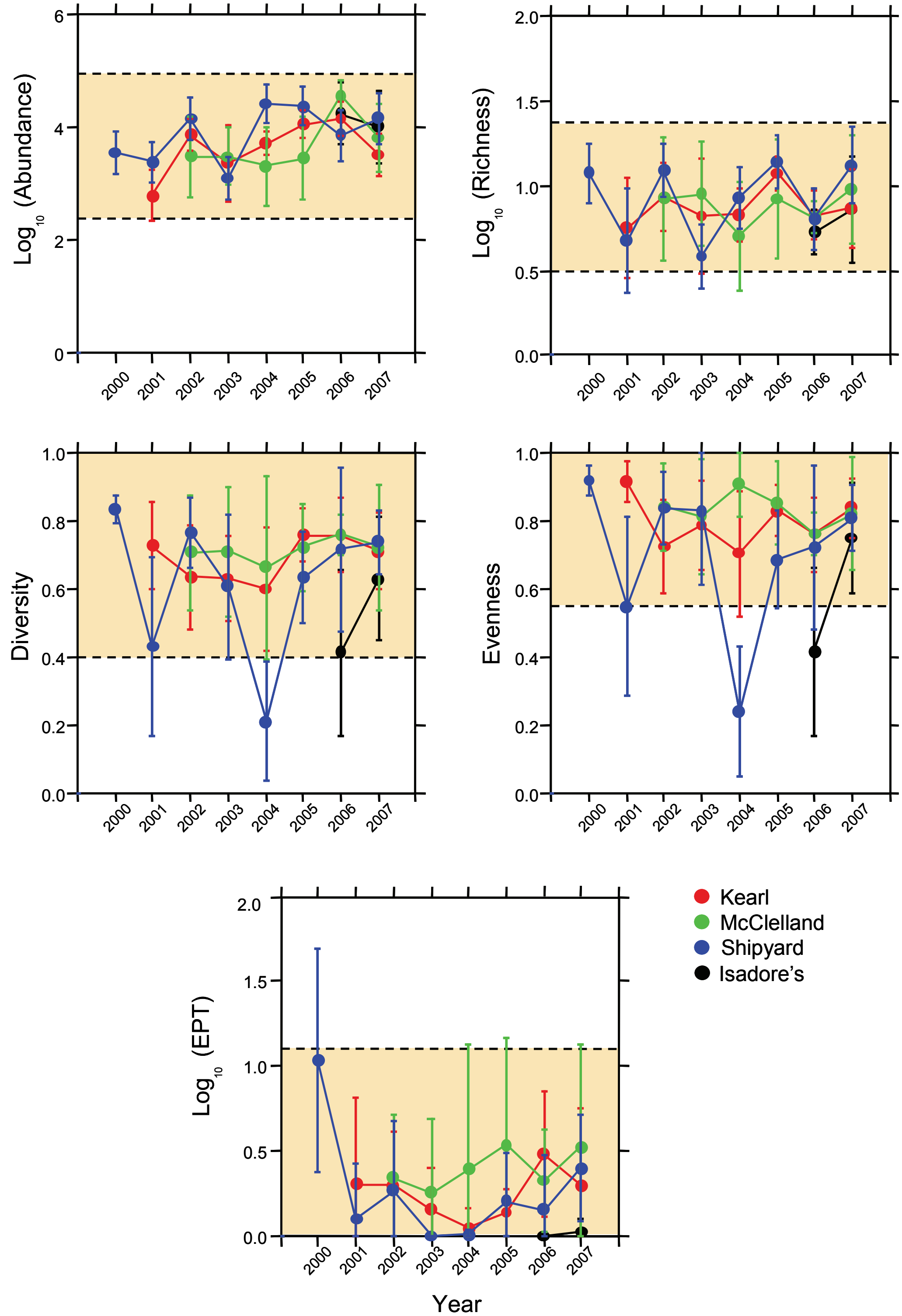
Table 5.11-17 Results of analysis of variance (ANOVA) testing for effects in Shipyard Lake (SHL-1) relative to Kearl and McClelland Lakes.

Response Variable	Source	SS	df	F-ratio	p-value
Log Abundance	Treatment (lake-year combinations; 2002 to 2007)	40.63	20	10.5	0.000
	Reference vs Exposure (RE)	3.00	1	15.5	0.000
	Time Trends (T)	3.23	1	16.7	0.000
	RE x T	0.05	1	0.2	**0.623**
	RE in 2007	1.65	1	8.6	**0.004**
	Remainder	32.71	1	169.5	**0.000**
	Error	35.84	186		
Log Richness	Treatment (lake-year combinations; 2002 to 2007)	4.60	20	4.4	0.000
	Reference vs Exposure (RE)	0.13	1	2.5	0.115
	Time Trends (T)	0.05	1	1.0	0.318
	RE x T	0.10	1	1.9	**0.173**
	RE in 2007	0.25	1	4.8	**0.029**
	Remainder	4.06	1	76.7	**0.000**
	Error	9.79	186		
Diversity	Treatment (lake-year combinations; 2002 to 2007)	3.213	20	6.8	0.000
	Reference vs Exposure (RE)	0.289	1	12.3	0.001
	Time Trends (T)	0.157	1	6.7	0.010
	RE x T	0.000	1	0.0	**0.990**
	RE in 2007	0.003	1	0.1	**0.707**
	Remainder	2.764	1	120.2	**0.000**
	Error	4.368	186		
Evenness	Treatment (lake-year combinations; 2002 to 2007)	3.870	20	10.1	0.000
	Reference vs Exposure (RE)	0.530	1	27.6	0.000
	Time Trends (T)	0.004	1	0.2	0.644
	RE x T	0.003	1	0.2	**0.691**
	RE in 2007	0.003	1	0.2	**0.693**
	Remainder	3.330	1	175.3	**0.000**
	Error	3.568	186		
Log of %EPT	Treatment (lake-year combinations; 2002 to 2007)	10.44	20	3.5	0.000
	Reference vs Exposure (RE)	0.80	1	5.3	0.022
	Time Trends (T)	0.62	1	4.1	0.043
	RE x T	0.00	1	0.0	**0.896**
	RE in 2007	0.00	1	0.0	**0.950**
	Remainder	9.01	1	60.1	**0.000**
	Error	27.99	186		

Table 5.11-18 Results of analysis of variance (ANOVA) testing for effects in Isadore's Lake (SHL-1) relative to Kearl and McClelland Lakes.

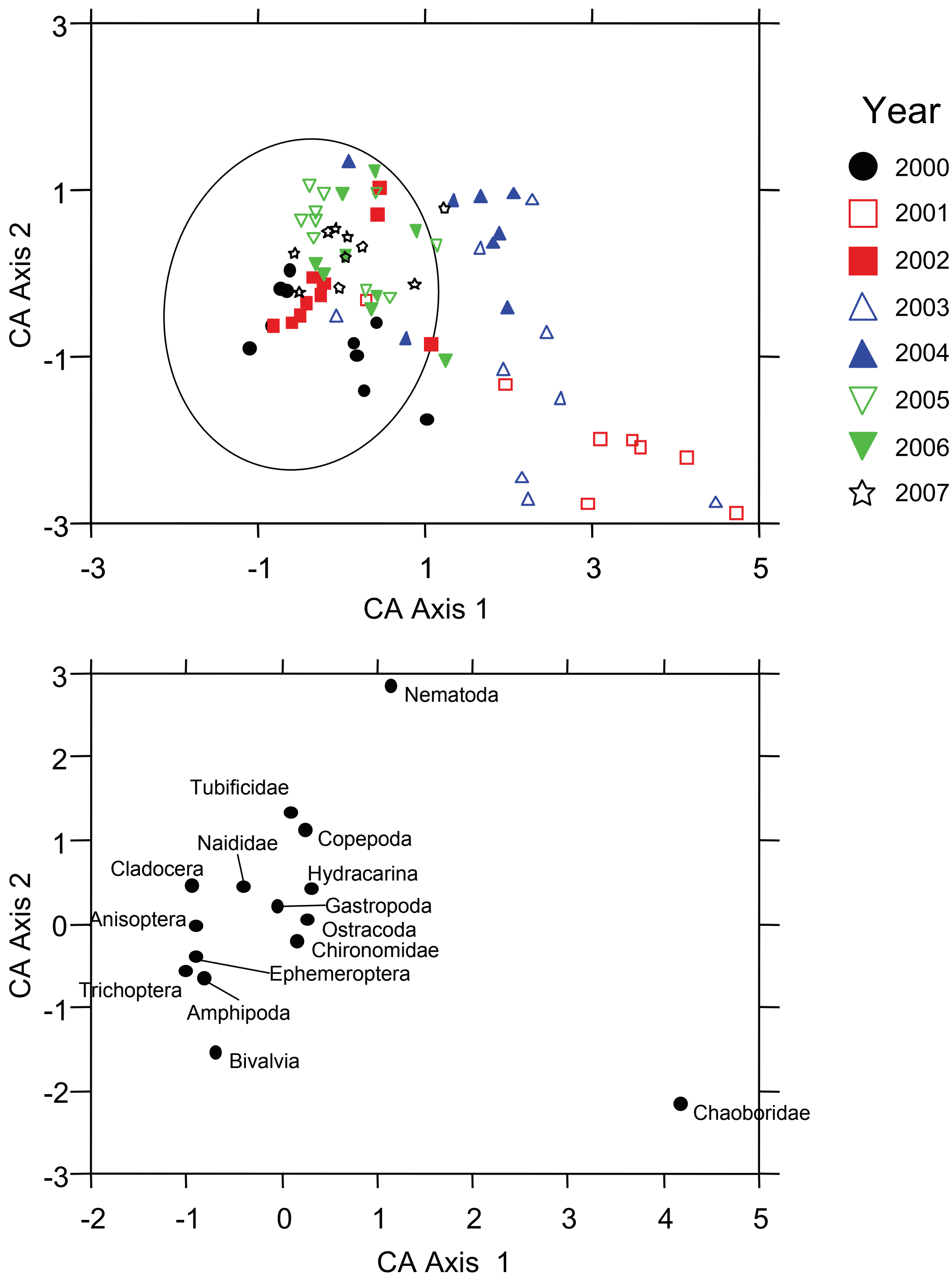
Response Variable	Source	SS	df	F-ratio	p-value
Log Abundance	Treatment (lake-year combinations; 2006 to 2007)	27.00	14	8.07	0.000
	Reference vs Exposure (RE)	0.180	1	0.75	**0.387**
	RE in 2007	0.793	1	3.32	**0.071**
	Remainder	26.03	1	108.89	**0.000**
	Error	32.02	134		
Log Richness	Treatment (lake-year combinations; 2006 to 2007)	1.390	14	1.63	0.078
	Reference vs Exposure (RE)	0.085	1	1.39	**0.240**
	RE in 2007	0.029	1	0.47	**0.493**
	Remainder	1.276	1	20.92	**0.000**
	Error	8.153	134		
Diversity	Treatment (lake-year combinations; 2006 to 2007)	1.117	14	3.32	0.000
	Reference vs Exposure (RE)	0.627	1	26.10	**0.000**
	RE in 2007	0.051	1	2.11	**0.149**
	Remainder	0.439	1	18.29	**0.000**
	Error	3.219	134		
Evenness	Treatment (lake-year combinations; 2006 to 2007)	1.943	14	8.11	0.000
	Reference vs Exposure (RE)	0.610	1	35.63	**0.000**
	RE in 2007	0.044	1	2.55	**0.113**
	Remainder	1.289	1	75.82	0.000
	Error	2.294	134		
Log of %EPT	Treatment (lake-year combinations; 2006 to 2007)	4.192	14	2.00	0.022
	Reference vs Exposure (RE)	2.067	1	13.79	**0.000**
	RE in 2007	0.982	1	6.55	**0.012**
	Remainder	1.143	1	7.62	**0.007**
	Error	20.08	134		

Figure 5.11-19 Values of benthic invertebrate community measurement endpoints in Kearl, McClelland, Shipyard and Isadore's Lakes.



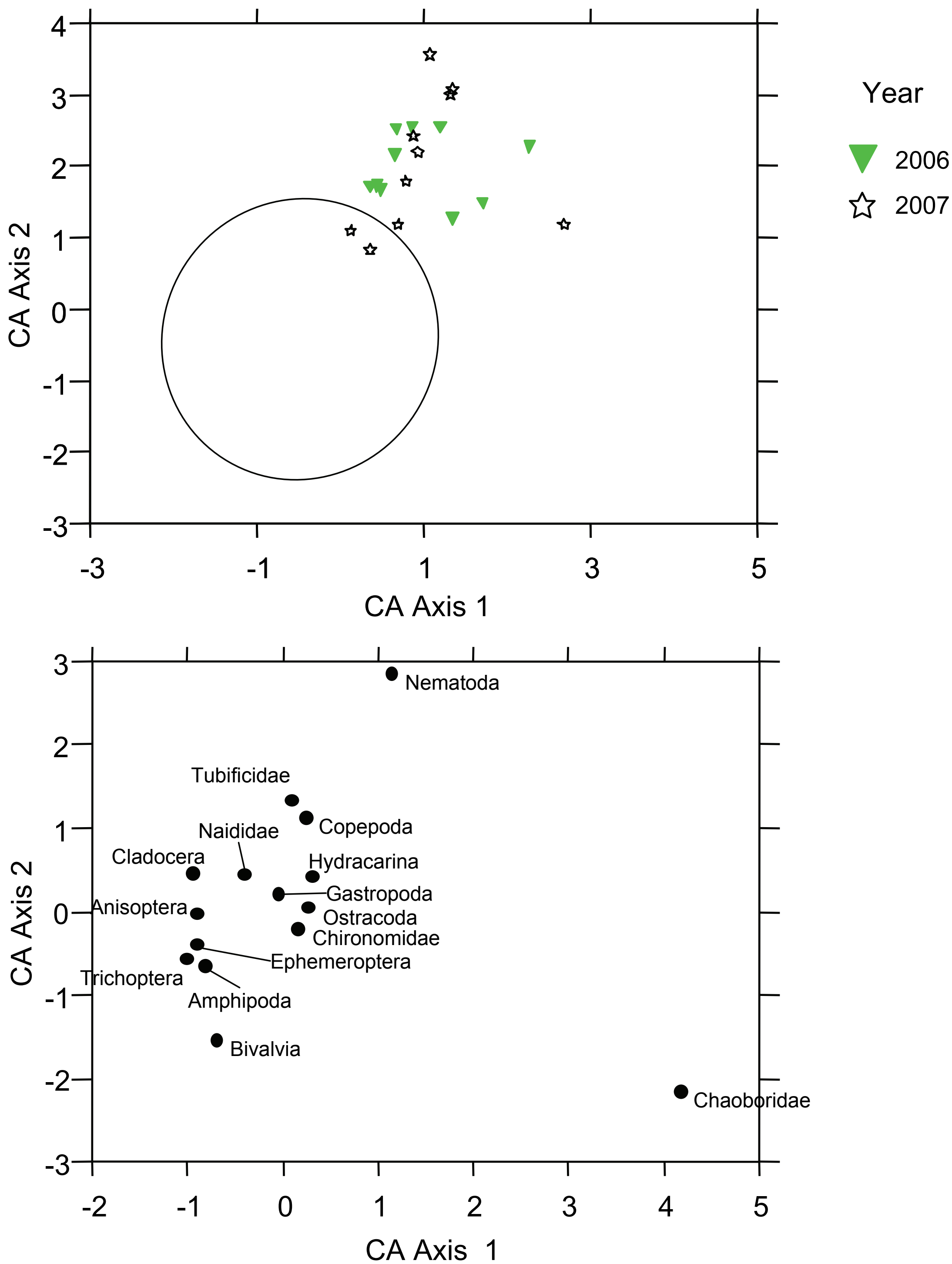
Note: Error bars are ± 2 standard deviations for observations from the Kearl and McClelland lakes, designated as *reference.*

Figure 5.11-20 Ordination (Correspondance Analysis) of lake benthic invertebrate communities showing Shipyard Lake vs reference lakes.



Note: Upper Panel is the scatterplot of sample scores while the Lower Panel is the scatterplot of taxa scores.The ellipse in the Upper Panel is for the *reference* data (i.e., Kearl and McClelland lakes).

Figure 5.11-21 Ordination (Correspondance Analysis) of lake benthic invertebrate communities showing Isadore's Lake vs reference lakes.



Note: Upper Panel is the scatterplot of sample scores while the Lower Panel is the scatterplot of taxa scores.The ellipse in the Upper Panel is for the reference data (Kearl, McClelland).

Table 5.11-19 Average habitat characteristics of reach FOC-D-1, Fort Creek.

Variable	Units	Fort Creek
Sample date	-	Sept 6, 2007
Habitat	-	Depositional
Water depth	m	0.1
Current velocity	m/s	n/a
Macrophyte cover	%	0
Field Water Quality		
Dissolved oxygen	mg/L	n/a
Conductivity	µS/cm	n/a
pH	pH units	n/a
Water temperature	°C	n/a
Sediment Composition		
Sand	%	39
Silt	%	46
Clay	%	15
TOC	%	2.0

Table 5.11-20 Summary of major taxon abundances and benthic invertebrate community measurement endpoints, Fort Creek.

Taxon	Percent Major Taxa Enumerated in Each Year					
	Fort Creek (reach FOC-D-1)					
	2001	2002	2003	2005	2006	2007
Bivalvia	5	1	<1	8		2
Ceratopogonidae	<1	<1	1		2	8
Chironomidae	80	95	95	56	55	18
Copepoda	<1	1	1			
Empididae	1		<1			
Enchytraeidae	1	<1	1		<1	1
Ephemeroptera	<1					<1
Erpobdellidae		<1				
Gastropoda	<1		<1			1
Glossiphoniidae		<1				
Heteroptera			<1			
Hydracarina	<1		<1			
Macrothricidae		<1	<1			
Naididae	1	1	<1		1	2
Nematoda	2	1	1	24	4	1
Ostracoda	1		<1	6	1	1
Simuliidae			<1			
Tabanidae		<1			1	
Tipulidae	8	<1	<1		3	
Trichoptera			<1			1
Tubificidae		1	<1	6	29	66
Benthic Invertebrate Community Measurement Endpoints						
Total Abundance (No./m^2)	4,069	41,905	69,802	913	2,870	11,172
Richness	15	13	13	4	10	11
Simpson's Diversity	0.84	0.69	0.57	0.65	0.76	0.56
Evenness	0.91	0.79	0.68	0.9	0.77	0.62
% EPT	<1	0	2	0	0	5

Table 5.11-21 Results of analysis of variance (ANOVA) for lower Fort Creek (reach FOC-D-1).

Response Variable	Source	SS	df	F-ratio	p-value
Log Abundance	Treatment (reach-year combinations; 2002 to 2007)	4.20	5	1.35	0.282
	Before vs After	0.03	1	0.05	0.832
	Remainder	4.17	1	6.68	0.017
	Error	13.72	22		
Log Richness	Treatment (reach-year combinations; 2002 to 2007)	0.49	5	1.72	0.173
	Before vs After	0.02	1	0.40	0.532
	Remainder	0.47	1	8.19	0.009
	Error	1.26	22		
Diversity	Treatment (reach-year combinations; 2002 to 2007)	0.28	5	2.08	0.106
	Before vs After	0.00	1	0.14	0.708
	Remainder	0.28	1	10.33	0.004
	Error	0.60	22		
Evenness	Treatment (reach-year combinations; 2002 to 2007)	0.29	5	2.18	0.093
	Before vs After	0.09	1	3.43	0.077
	Remainder	0.20	1	7.41	0.012
	Error	0.59	22		
Log of %EPT	Treatment (reach-year combinations; 2002 to 2007)	0.88	5	1.77	0.162
	Before vs After	0.19	1	1.86	0.186
	Remainder	0.69	1	7.00	0.015
	Error	2.19	22		

Figure 5.11-22 Variations in benthic invertebrate community measurement endpoints in Fort Creek, reach FOC-D-1.

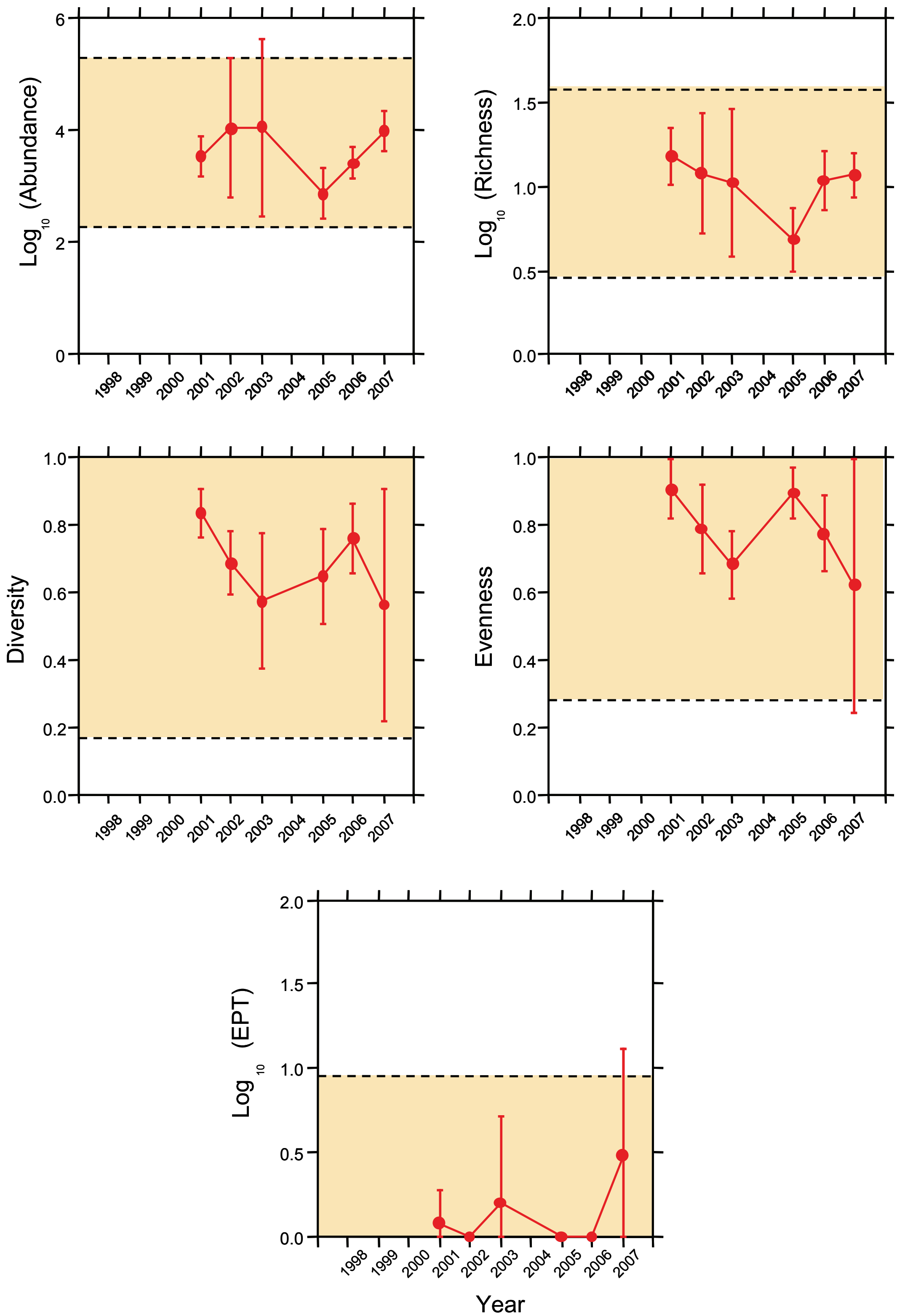
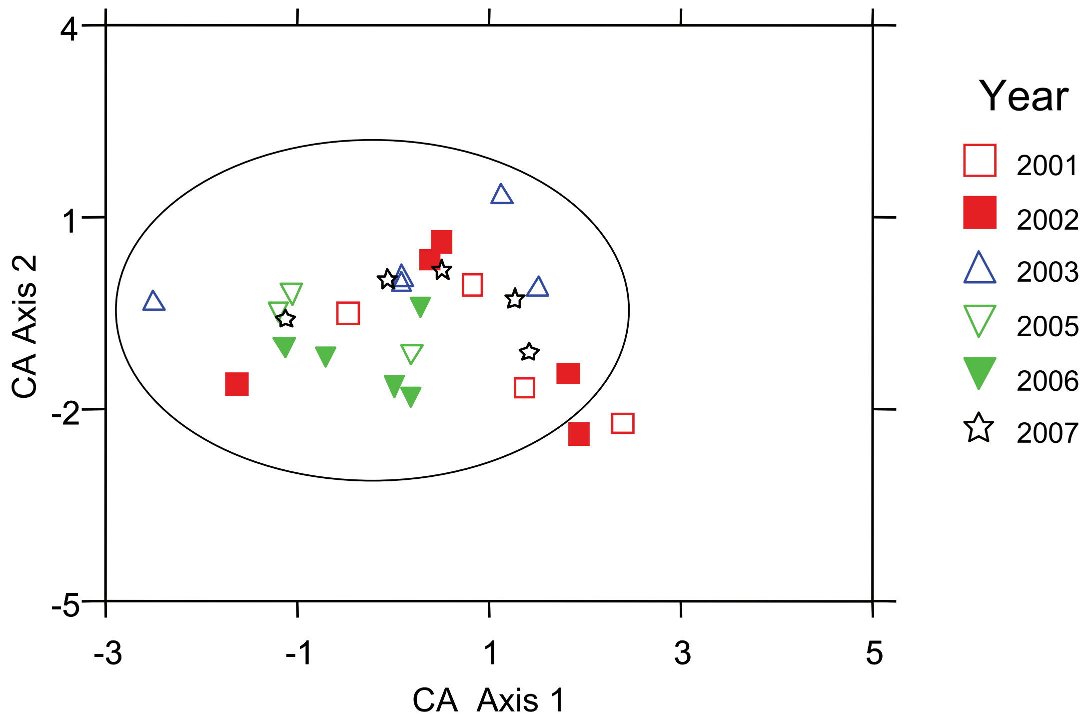
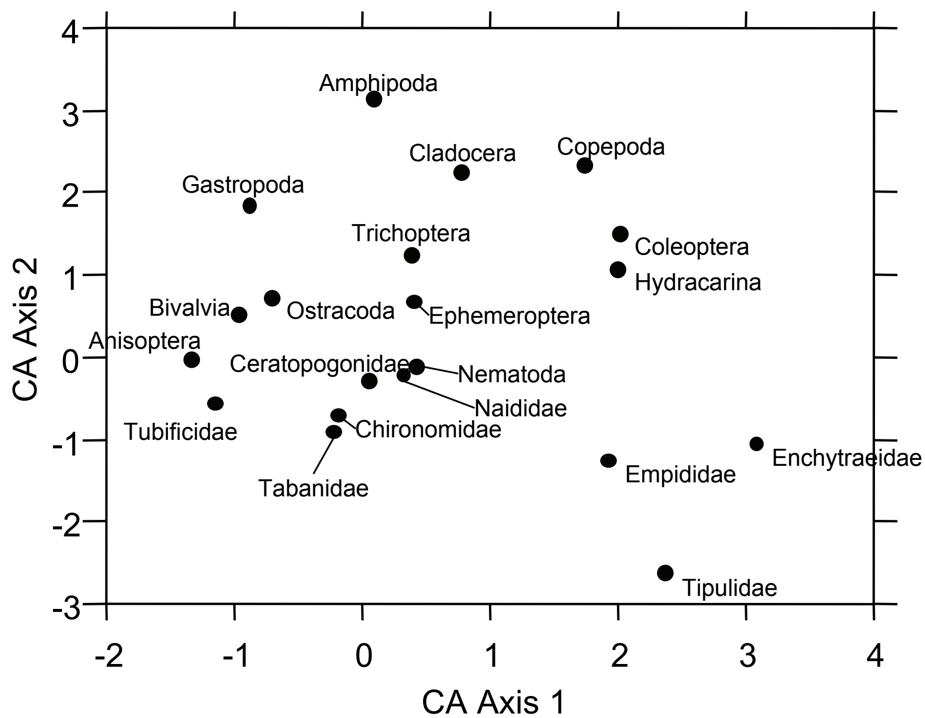


Figure 5.11-23 Ordination (Correspondence Analysis) of depositional reaches, showing lower reach (FOC-D-1) of Fort Creek.





Note: Upper Panel is the scatterplot of sample scores while the Lower Panel is the scatterplot of taxa scores. The ellipse is for *reference* depositional reaches.

Table 5.11-22 Concentrations of sediment quality measurement endpoints, Kearl Lake (KEL-1), fall 2007.

Measurement Endpoint	Units	Guideline	September 2007	1997-2006 (fall data only, station KEL-1)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	3.6	2	<1	-	58
Sand	%	-	85	2	9	-	93
Total organic carbon	%	-	36.2	3	33.5	34.4	38.4
Total hydrocarbons							
BTEX	mg/kg	-	8	2	<5	42.5	<80
Fraction 1 (C6-C10)	mg/kg	30[2]	8	2	<5	42.5	<80
Fraction 2 (C10-C16)	mg/kg	150[2]	13	2	<5	<5	<5
Fraction 3 (C16-C34)	mg/kg	400[2]	**3000**	2	230	275	320
Fraction 4 (C34-C50)	mg/kg	2800[2]	2000	2	81	105.5	130
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[3]	NQ	2	0.012	0.024	**0.0361**
Retene	mg/kg	-	0.0581	3	0.037	0.065	0.113
Total dibenzothiophenes	mg/kg	-	0.08	3	0.03	0.03	0.07
Total PAHs	mg/kg	-	1.43	3	0.86	1.05	1.10
Total HMW PAHs	mg/kg	-	0.11	3	0.11	0.18	0.47
Total LMW PAHs	mg/kg	-	1.32	3	0.58	0.75	0.92
Predicted PAH toxicity[1]	H.I.	-	0.08	3	0.43	0.61	0.97
Metals that exceed CCME guidelines in 2007							
none	mg/kg	-	-	-	-	-	-
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	9	1	-	-	9
Chironomus growth - 10d	mg/organism	-	1.2	1	-	-	1.3
Hyalella survival - 14d	# surviving	-	9	1	-	-	8
Hyalella growth - 14d	mg/organism	-	0.1	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).

NQ = Value could not be quantified, due to insufficient (<5%) recovery of labelled laboratory surrogates in samples.

Table 5.11-23 Concentrations of sediment quality measurement endpoints, McClelland Lake (MCL-1), fall 2007.

Measurement Endpoint	Units	Guideline	September 2007	1997-2006 (fall data only, station MCL-1)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	17.3	3	5	39	49
Silt	%	-	14.7	3	14	34	37
Sand	%	-	68	3	14	27	81
Total organic carbon	%	-	29.2	3	25	27.6	30
Total hydrocarbons							
BTEX	mg/kg	-	<5	1	-	-	<100
Fraction 1 (C6-C10)	mg/kg	30[2]	<5	1	-	-	<100
Fraction 2 (C10-C16)	mg/kg	150[2]	65	1	-	-	<5
Fraction 3 (C16-C34)	mg/kg	400[2]	**2900**	1	-	-	**1200**
Fraction 4 (C34-C50)	mg/kg	2800[2]	2400	1	-	-	580
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[3]	NQ	2	0.011	0.018	0.0241
Retene	mg/kg	-	0.161	3	0.019	0.0861	0.119
Total dibenzothiophenes	mg/kg	-	0.04	3	0.03	0.03	0.08
Total PAHs	mg/kg	-	0.75	3	0.36	0.56	0.73
Total HMW PAHs	mg/kg	-	0.09	3	0.09	0.12	0.14
Total LMW PAHs	mg/kg	-	0.66	3	0.24	0.42	0.64
Predicted PAH toxicity[1]	H.I.	-	0.05	3	0.13	0.19	0.20
Metals that exceed CCME guidelines in 2007							
none	mg/kg	-	-	-	-	-	-
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	8	1	-	-	9
Chironomus growth - 10d	mg/organism	-	1.5	1	-	-	1.4
Hyalella survival - 14d	# surviving	-	8	1	-	-	7
Hyalella growth - 14d	mg/organism	-	0.2	1	-	-	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).

NQ = Value could not be quantified, due to insufficient (<5%) recovery of labelled laboratory surrogates in samples.

Table 5.11-24 Concentrations of sediment quality measurement endpoints, Shipyard Lake (SHL-1), fall 2007.

Measurement Endpoint	Units	Guideline	September 2007	1997-2006 (fall data only, station SHL-1)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	54.8	5	3	53	60
Silt	%	-	37.2	5	36	40	59
Sand	%	-	8.2	5	2	4	39
Total organic carbon	%	-	18.8	5	2	15.0	28.9
Total hydrocarbons							
BTEX	mg/kg	-	<5	2	<5	-	<60
Fraction 1 (C6-C10)	mg/kg	30[2]	<5	2	<5	-	<60
Fraction 2 (C10-C16)	mg/kg	150[2]	<5	2	<5	-	69
Fraction 3 (C16-C34)	mg/kg	400[2]	**780**	2	290	-	**550**
Fraction 4 (C34-C50)	mg/kg	2800[2]	<5	2	130	-	230
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[3]	NQ	4	0.011	0.017	0.041
Retene	mg/kg	-	0.199	5	0.046	0.094	60.1
Total dibenzothiophenes	mg/kg	-	2.62	5	0.26	0.43	0.68
Total PAHs	mg/kg	-	13.87	5	2.28	4.07	8.32
Total HMW PAHs	mg/kg	-	6.05	5	0.96	1.29	6.05
Total LMW PAHs	mg/kg	-	7.81	5	0.98	2.19	3.10
Predicted PAH toxicity[1]	H.I.	-	3.78	5	0.10	0.65	3.61
Metals that exceed CCME guidelines in 2007							
Arsenic	mg/kg	5.9, 17[4]	**6.6**	-	-	-	-
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	8	3	7	8	8
Chironomus growth - 10d	mg/organism	-	1.9	3	1.5	2	2.3
Hyalella survival - 14d	# surviving	-	8	2	6	-	8
Hyalella growth - 14d	mg/organism	-	0.2	2	0.2	-	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.

NQ = Value could not be quantified, due to insufficient (<5%) recovery of labelled laboratory surrogates in samples.

Table 5.11-25 Concentrations of sediment quality measurement endpoints, Isadore's Lake (ISL-1), fall 2007.

Measurement Endpoint	Units	Guideline	September 2007	1997-2006 (fall data only, station ISL-1)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	20.6	2	19	22.5	26
Silt	%	-	56.1	2	46	50	54
Sand	%	-	23.3	2	20	27.5	35
Total organic carbon	%	-	3.3	2	1.3	3.5	5.7
Total hydrocarbons							
BTEX	mg/kg	-	<5	1	-	-	<10
Fraction 1 (C6-C10)	mg/kg	30[2]	<5	1	-	-	<10
Fraction 2 (C10-C16)	mg/kg	150[2]	16	1	-	-	23
Fraction 3 (C16-C34)	mg/kg	400[2]	**790**	1	-	-	150
Fraction 4 (C34-C50)	mg/kg	2800[2]	540	1	-	-	89
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[3]	0.006	2	0.006	0.008	0.009
Retene	mg/kg	-	0.056	2	0.066	0.068	0.071
Total dibenzothiophenes	mg/kg	-	0.24	2	0.14	0.15	0.15
Total PAHs	mg/kg	-	1.52	2	1.28	1.28	1.28
Total HMW PAHs	mg/kg	-	0.52	2	0.52	0.63	0.74
Total LMW PAHs	mg/kg	-	0.99	2	0.54	0.65	0.76
Predicted PAH toxicity[1]	H.I.	-	0.32	2	0.56	0.97	1.38
Metals that exceed CCME guidelines in 2007							
Arsenic	mg/kg	5.9, 17[4]	**6.2**	-	-	-	-
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	7	1	-	-	7
Chironomus growth - 10d	mg/organism	-	2.6	1	-	-	1.9
Hyalella survival - 14d	# surviving	-	10	1	-	-	10
Hyalella growth - 14d	mg/organism	-	0.2	1	-	-	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 5.11-26 Concentrations of sediment quality measurement endpoints, lower Fort Creek (reach FOC-D1), fall 2007.

Measurement Endpoint	Units	Guideline	September 2007	1997-2006 (fall data only, station FOC-1)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	17.8	3	4	15	17
Silt	%	-	52.8	3	12	29	43
Sand	%	-	36.3	3	40	56	84
Total organic carbon	%	-	2	3	3.2	4.7	7.1
Total hydrocarbons							
BTEX	mg/kg	-	ns	1	-	-	<10
Fraction 1 (C6-C10)	mg/kg	30[2]	ns	1	-	-	<10
Fraction 2 (C10-C16)	mg/kg	150[2]	ns	1	-	-	16
Fraction 3 (C16-C34)	mg/kg	400[2]	ns	1	-	-	**440**
Fraction 4 (C34-C50)	mg/kg	2800[2]	ns	1	-	-	450
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[3]	0.008	3	0.008	0.009	0.017
Retene	mg/kg	-	0.629	3	0.033	0.055	<0.38
Total dibenzothiophenes	mg/kg	-	1.39	3	0.16	1.33	3.10
Total PAHs	mg/kg	-	4.99	3	1.85	4.76	14.26
Total HMW PAHs	mg/kg	-	1.11	3	1.11	1.84	8.19
Total LMW PAHs	mg/kg	-	3.89	3	0.75	2.92	6.07
Predicted PAH toxicity[1]	H.I.	-	ns	3	0.43	0.45	1.05
Metals that exceed CCME guidelines in 2007							
none	mg/kg	-	-	-	-	-	-
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	7	2	9	9	9
Chironomus growth - 10d	mg/organism	-	1.2	2	1.5	2.3	3.0
Hyalella survival - 14d	# surviving	-	9	1	-	-	6
Hyalella growth - 14d	mg/organism	-	0.1	1	-	-	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.

ns = not sampled

Table 5.11-27 Metrics and mercury concentrations of walleye, northern pike and lake whitefish from Gregoire Lake, September 2007.

Species	Sex	Fish ID	Stage	Fork Length (mm)	Mercury Concentration (mg/kg)
WALL	F	GL-WALL-01	I	235	0.040
WALL	U	GL-WALL-02	I	252	0.050
WALL	F	GL-WALL-03	M	606	**0.249**
WALL	M	GL-WALL-04	M	479	**0.230**
WALL	F	GL-WALL-05	I	320	0.059
WALL	M	GL-WALL-06	M	444	**0.166**
WALL	M	GL-WALL-07	M	475	**0.291**
WALL	M	GL-WALL-08	I	233	0.059
WALL	F	GL-WALL-09	M	549	**0.198**
WALL	F	GL-WALL-10	I	335	0.055
WALL	F	GL-WALL-11	M	507	**0.192**
WALL	M	GL-WALL-12	I	214	0.044
WALL	M	GL-WALL-13	M	476	**0.263**
WALL	F	GL-WALL-14	I	217	0.040
WALL	F	GL-WALL-15	I	390	0.078
WALL	F	GL-WALL-16	I	317	0.063
WALL	M	GL-WALL-17	M	485	**0.419**
WALL	F	GL-WALL-18	M	520	**0.212**
WALL	M	GL-WALL-19	M	509	**0.432**
WALL	M	GL-WALL-20	M	350	0.068
WALL	F	GL-WALL-21	M	526	**0.208**
NRPK	F	GL-NRPK-01	M	740	**0.584**
NRPK	F	GL-NRPK-02	M	765	**0.409**
NRPK	F	GL-NRPK-03	M	630	**0.380**
NRPK	F	GL-NRPK-04	I	336	0.045
NRPK	F	GL-NRPK-05	I	360	0.045
NRPK	F	GL-NRPK-06	M	665	**0.476**
NRPK	F	GL-NRPK-07	I	358	0.045
NRPK	M	GL-NRPK-08	M	454	0.076
NRPK	F	GL-NRPK-09	M	661	**0.224**
NRPK	M	GL-NRPK-10	M	494	0.116
NRPK	F	GL-NRPK-11	I	378	0.042
NRPK	F	GL-NRPK-12	M	469	0.066
NRPK	M	GL-NRPK-13	M	665	**0.221**
NRPK	M	GL-NRPK-14	M	415	0.060
NRPK	M	GL-NRPK-15	M	492	**0.178**
NRPK	F	GL-NRPK-16	M	702	**0.263**

F - Female; M - Male; U - Undetermined; A - Adult; I - Immature

exceeds National USEPA Criteria for subsistence fishers (0.049 mg/kg)

exceeds Region III USEPA Risk-Based Criterion (0.14 mg/kg)

exceeds Health Canada Criterion for subsistence fishers (0.20 mg/kg)

exceeds National USEPA Criteria for recreational fishers (0.40 mg/kg)

exceeds Health Canada Criterion for consumers (0.50 mg/kg)

Table 5.11-27 (Cont'd.)

Species	Sex	Fish ID	Stage	Fork Length (mm)	Mercury Concentration (mg/kg)
NRPK	F	GL-NRPK-17	M	756	**0.478**
NRPK	F	GL-NRPK-18	I	345	0.044
NRPK	F	GL-NRPK-19	M	568	**0.327**
NRPK	F	GL-NRPK-20	M	775	**0.476**
NRPK	M	GL-NRPK-21	M	462	0.070
NRPK	F	GL-NRPK-22	M	563	**0.186**
NRPK	F	GL-NRPK-23	I	216	0.023
NRPK	F	GL-NRPK-24	M	557	**0.230**
NRPK	F	GL-NRPK-25	M	635	**0.211**
NRPK	F	GL-NRPK-26	M	588	0.098
LKWH	M	GL-LKWH-01	I	330	0.016
LKWH	M	GL-LKWH-02	I	328	0.023
LKWH	M	GL-LKWH-03	M	430	0.032
LKWH	M	GL-LKWH-04	M	391	0.021
LKWH	M	GL-LKWH-05	M	526	0.036
LKWH	M	GL-LKWH-06	M	502	0.064
LKWH	M	GL-LKWH-07	M	438	0.037
LKWH	F	GL-LKWH-08	M	455	0.035
LKWH	F	GL-LKWH-09	M	490	0.056
LKWH	M	GL-LKWH-10	M	534	0.042
LKWH	F	GL-LKWH-11	M	431	0.031
LKWH	F	GL-LKWH-12	M	498	0.057
LKWH	M	GL-LKWH-13	M	524	0.050

F - Female; M - Male; U - Undetermined; A - Adult; I - Immature

exceeds National USEPA Criteria for subsistence fishers (0.049 mg/kg)

exceeds Region III USEPA Risk-Based Criterion (0.14 mg/kg)

exceeds Health Canada Criterion for subsistence fishers (0.20 mg/kg)

exceeds National USEPA Criteria for recreational fishers (0.40 mg/kg)

exceeds Health Canada Criterion for consumers (0.50 mg/kg)

[1] Length standardized mercury = mercury concentration length x 10^4.

Figure 5.11-24 Mean mercury concentration in female and male walleye, northern pike and lake whitefish from Gregoire Lake, 2002 and 2007.

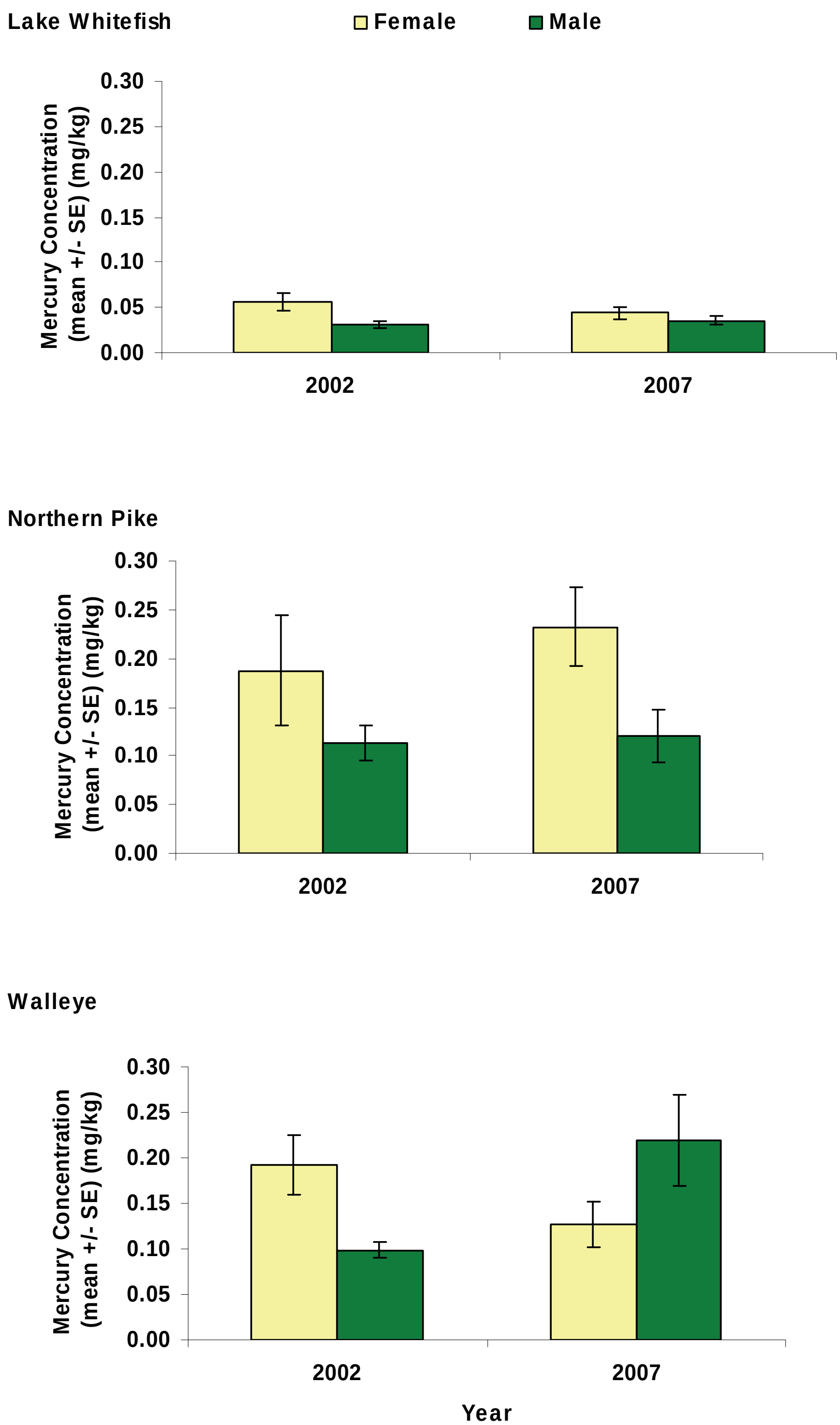


Table 5.11-28 Correlations between mercury concentration and fork length in walleye, northern pike and lake whitefish muscle tissue collected from Gregoire Lake, September 2007.

Species	Correlation with Mercury Concentrations (r_s)		
	Male	Female	Combined
Walleye	0.93 (n=9)	0.92 (n=11)	0.80 (n=20)
Northern pike	0.89 (n=6)	0.90 (n=20)	0.93 (n=26)
Lake whitefish	0.75 (n=9)	1.00 (n=4)	0.78 (n=13)

Figure 5.11-25 Scatterplot of mercury concentration in walleye, northern pike and lake whitefish muscle versus length, Gregoire Lake, 2007.

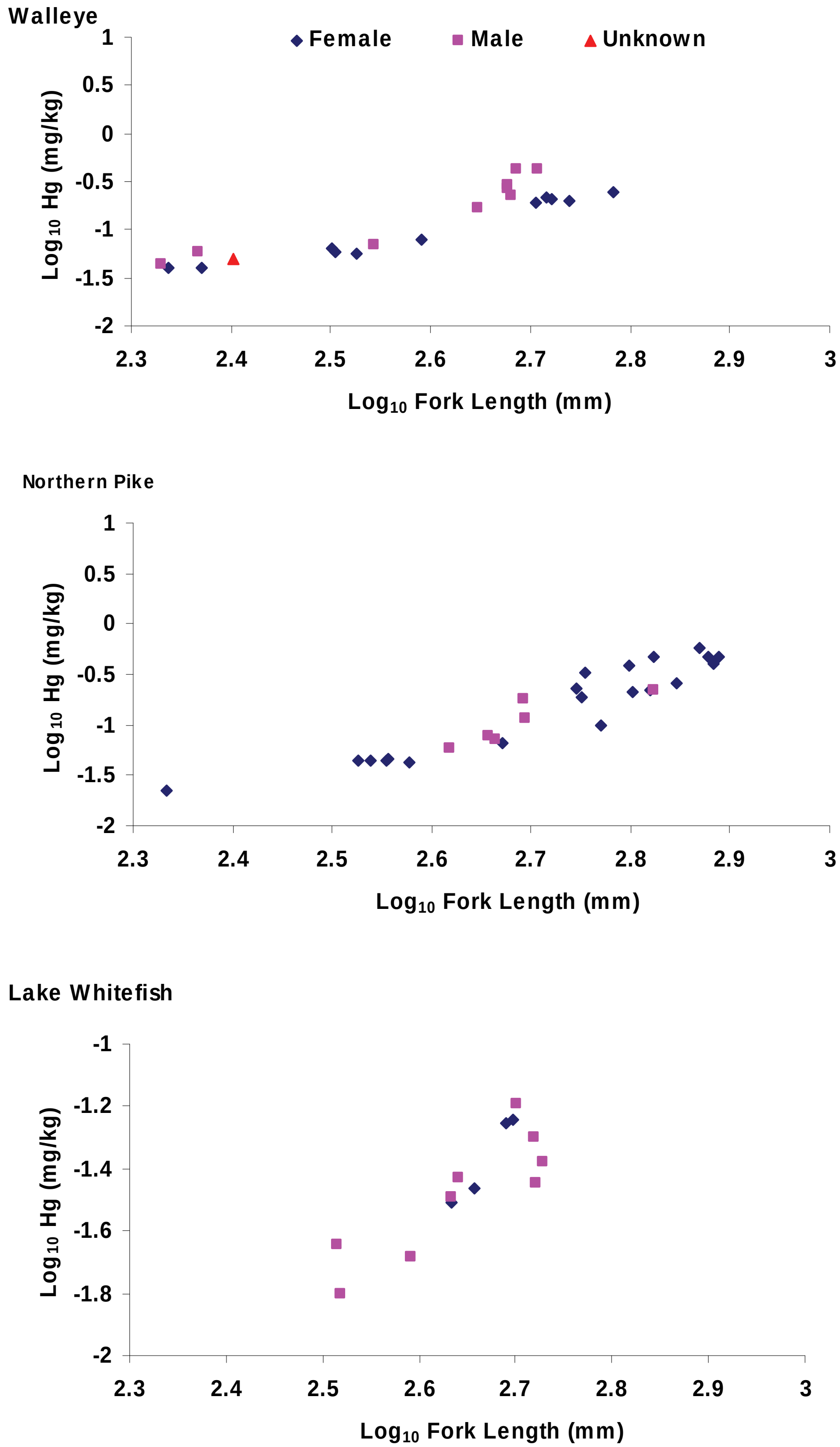
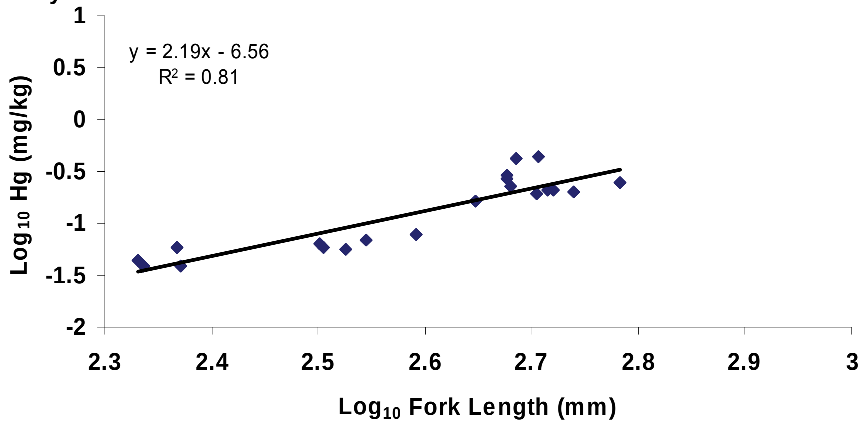
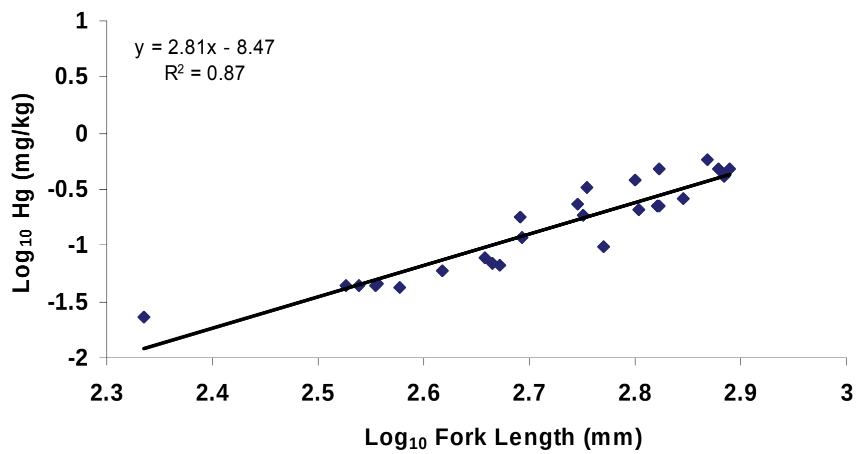


Figure 5.11-26 Regression analysis of mercury concentration in fish muscle versus length for walleye, northern pike and lake whitefish from Gregoire Lake, fall 2007.

Walleye



Northern Pike



Lake Whitefish

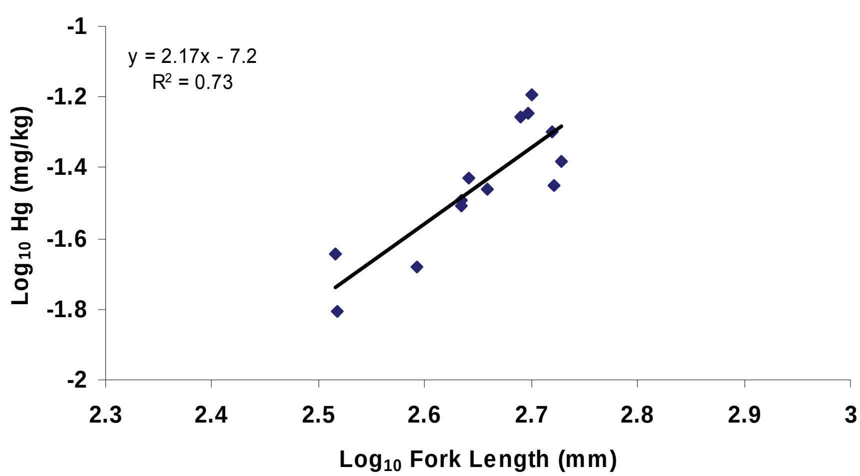
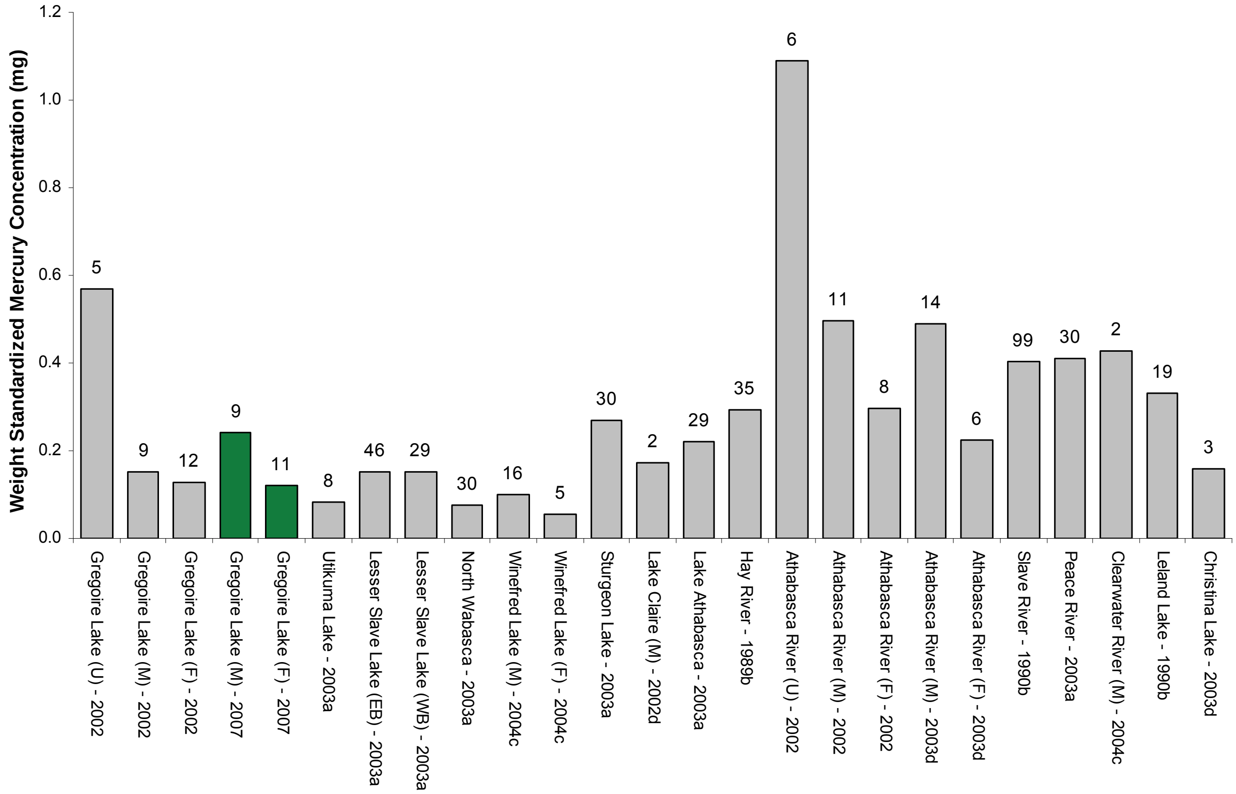
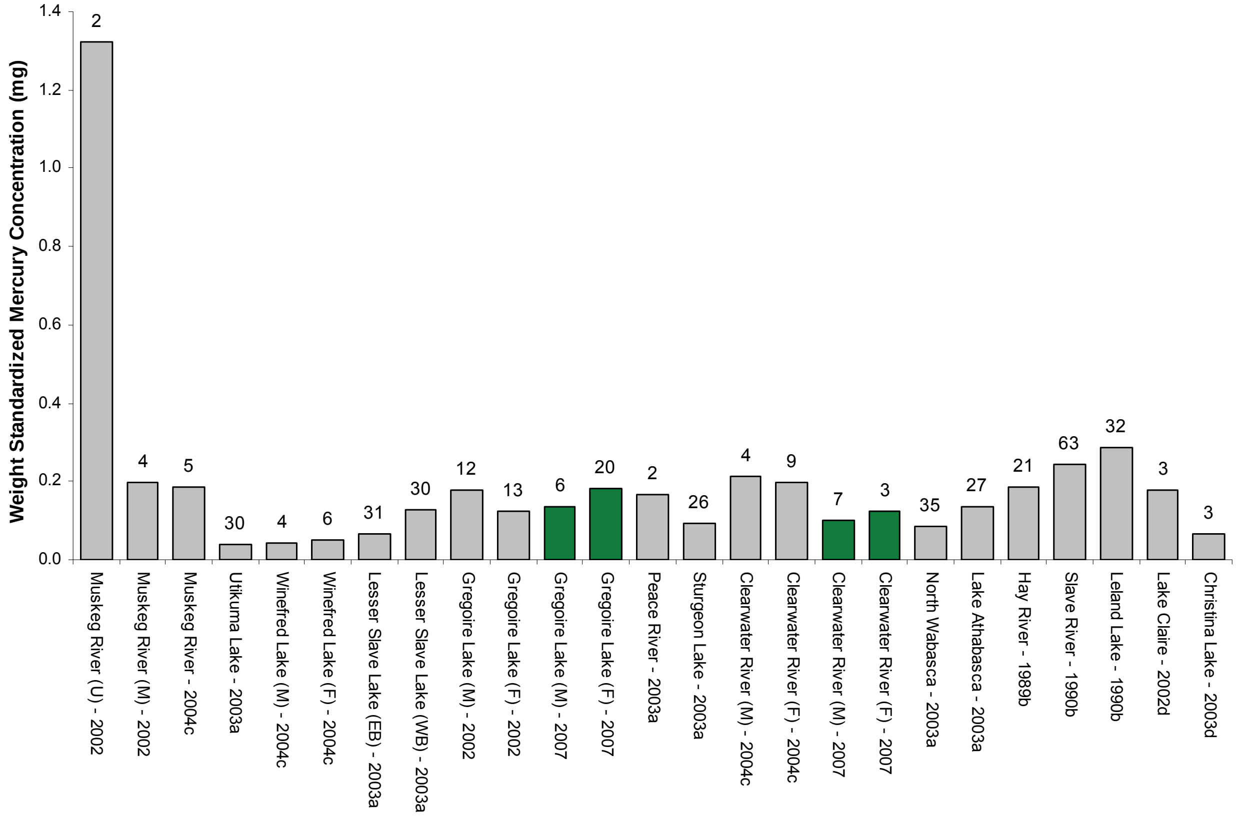


Figure 5.11-27 Mean mercury concentration in walleye muscle tissue, standardized to fish weight, collected from regional waterbodies, 1989-2007.



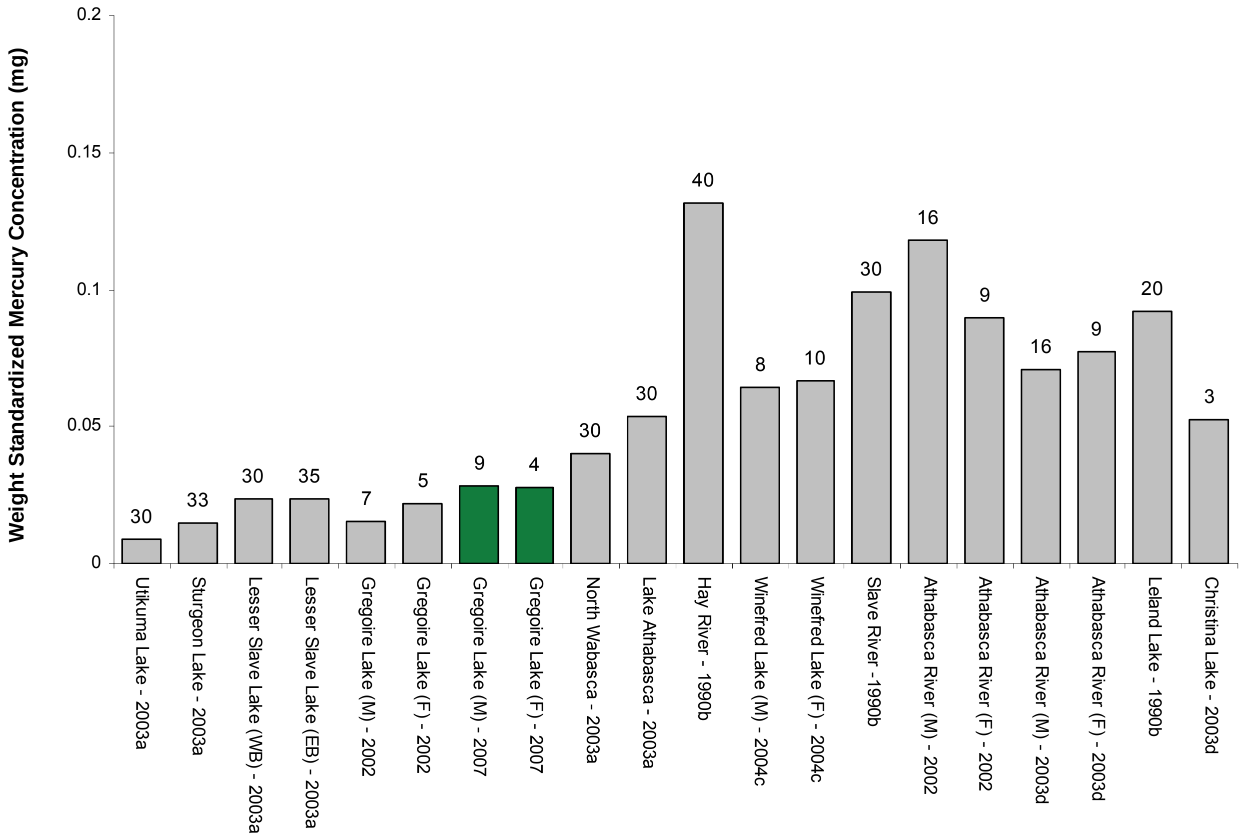
Note: Green bars indicate mercury concentrations from fish collected for the 2007 RAMP Fisheries Program. Years denoted with "a" - data from Golder (2004); Years denoted with "b" – data from Grey *et al*. (1995); Years denoted with "c" – data from RAMP (2004); Years denoted with "d" – data from RAMP (2003)

Figure 5.11-28 Mean mercury concentrations in northern pike muscle tissue, standardized to fish weight, collected from regional waterbodies, 1989-2007.



Note: Green bars indicate mercury concentrations from fish collected for the 2007 RAMP Fisheries Program. Years denoted with "a" - data from Golder (2004); Years denoted with "b" – data from Grey *et al*. (1995); Years denoted with "c" – data from RAMP (2004); Years denoted with "d" – data from RAMP (2003)

Figure 5.11-29 Mean mercury concentration in lake whitefish muscle tissue, standardized to fish weight, collected from regional waterbodies, 1990-2007.



Note: Green bars indicate mercury concentrations from fish collected for the 2007 RAMP Fisheries Program. Years denoted with "a" - data from Golder (2004); Years denoted with "b" – data from Grey *et al*. (1995); Years denoted with "c" – data from RAMP (2004); Years denoted with "d" – data from RAMP (2003)

Table 5.11-29 Metrics and mercury concentrations in lake trout collected from Namur Lake, August 2007.

Species	Sex	FishID	Stage	Fork Length (mm)	Fish Weight (g)	Mercury Concentration (mg/kg)
LKTR	F	NL-14	I	427	730	0.126
LKTR	F	NL-6	I	462	970	0.169
LKTR	F	NL-12	A	608	2120	0.435
LKTR	F	NL-7	A	540	1570	0.510
LKTR	F	NL-1	A	621	2380	0.703
LKTR	F	NL-4	A	741	3660	0.772
LKTR	M	NL-15	A	482	1200	0.193
LKTR	M	NL-11	A	478	1120	0.198
LKTR	M	NL-16	A	485	1160	0.205
LKTR	M	NL-3	A	612	2340	0.404
LKTR	M	NL-10	A	524	1570	0.420
LKTR	M	NL-8	A	580	2180	0.488
LKTR	M	NL-2	A	538	1670	0.545
LKTR	M	NL-9	A	562	1610	0.631
LKTR	M	NL-5	A	612	2240	0.650
LKTR	M	NL-13	A	621	2190	0.698

F - female; M - male; A - adult; I - immature, LKTR - Lake trout

exceeds National USEPA Criteria for subsistence fishers (0.049 mg/kg)

exceeds Region III USEPA Risk-Based Criterion (0.14 mg/kg)

exceeds Health Canada Criterion for subsistence fishers (0.20 mg/kg)

exceeds National USEPA Criteria for recreational fishers (0.40 mg/kg)

exceeds Health Canada Criterion for consumers (0.50 mg/kg)

[1] Length standardized mercury = mercury concentration/fork length x 10^4.

Table 5.11-30 Correlations between mercury concentration in lake trout muscle from Namur Lake versus length and weight, August 2007.

Organism Metric	Correlation with Mercury Concentrations (r_s)		
	Male n=10	Female n=6	Combined n=16
Fork Length (mm)	0.80	0.94	0.88
Weight (g)	0.65	0.94	0.83

Figure 5.11-30 Scatterplot of mercury concentration in lake trout muscle tissue versus length, Namur Lake, 2007.

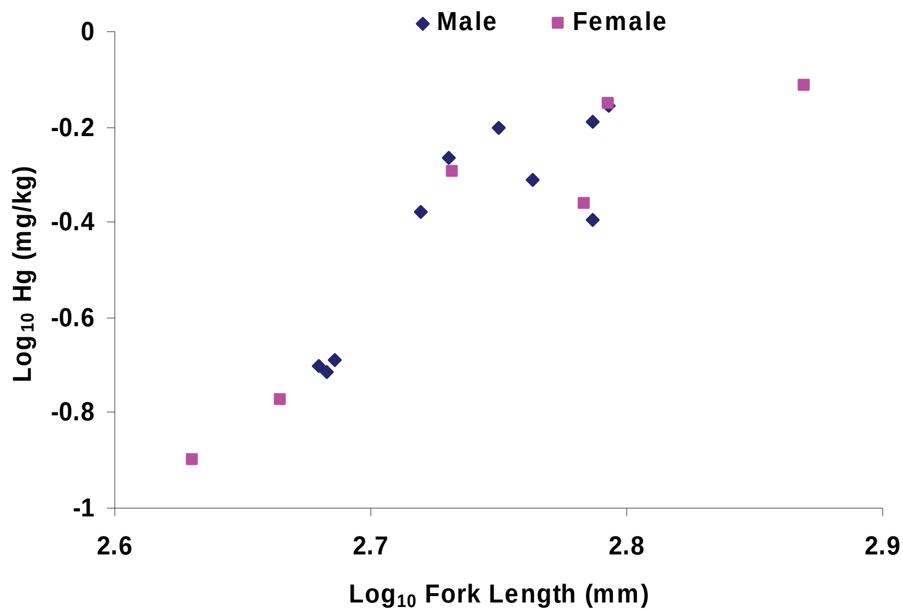


Figure 5.11-31 Regression analysis of mercury concentration in fish muscle versus length for lake trout from Namur Lake, August 2007.