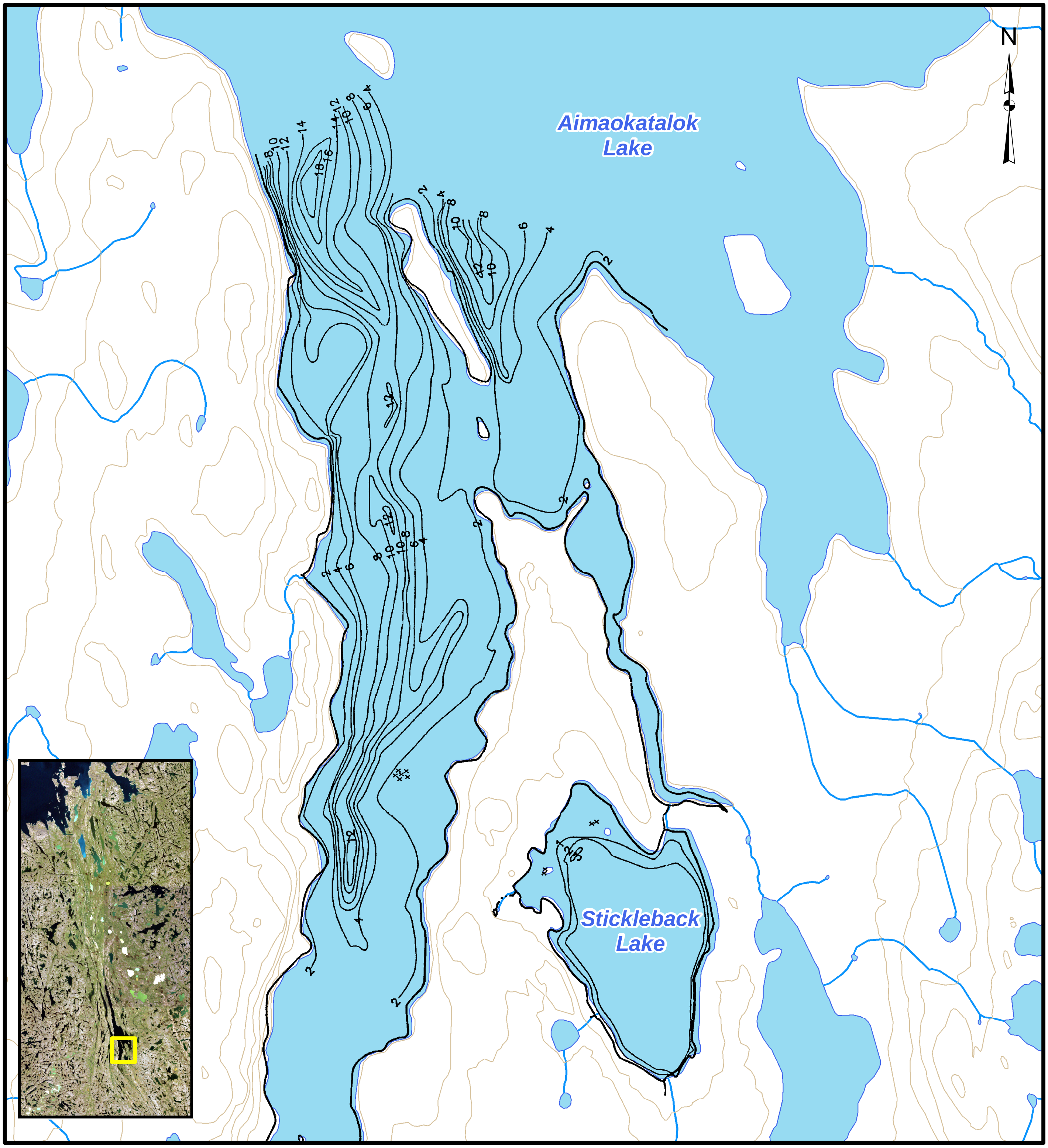


LEGEND

- Bathymetry (from Rescan 1993)
- Contours
- Rivers
- Waterbodies

950 0 950

METRES

MIRAMAR HOPE BAY LTD.

Boston Project
Data Compilation

TITLE

Bathymetry of Stickleback Lake and South Arm of Aimaokatalok Lake, 1993

Golder Associates
Edmonton, Alberta

PROJECT No. 06-1373-028			SCALE AS SHOWN	REV. 0
DESIGN	JP	15 April 2008	FIGURE 2.2	
GIS	RC	17 April 2008		
CHECK	JP	14 May 2008		
REVIEW	GA	10 May 2008		

REFERENCE

Sources: Government of Canada, Natural Resources Canada, Centre for Topographic Information.
Projection: Transverse Mercator Datum: NAD 83 Coordinate System: UTM Zone 13N
This map is for information purposes only. Golder Associates Ltd. does not accept any liability arising from its misuse or misrepresenation.

3 PHYSICAL LIMNOLOGY AND SURFACE WATER QUALITY

This chapter presents information on baseline water quality conditions in the Boston area of the Hope Bay Belt. Water quality data are presented for four lakes and associated streams, Aimaokatalok River, Koignuk River and marine sites in Hope Bay. The data were compiled from seven annual reports (Rescan 1993, 1994, 1995, 1997, 1998, 1999a, 2001).

3.1 METHODS

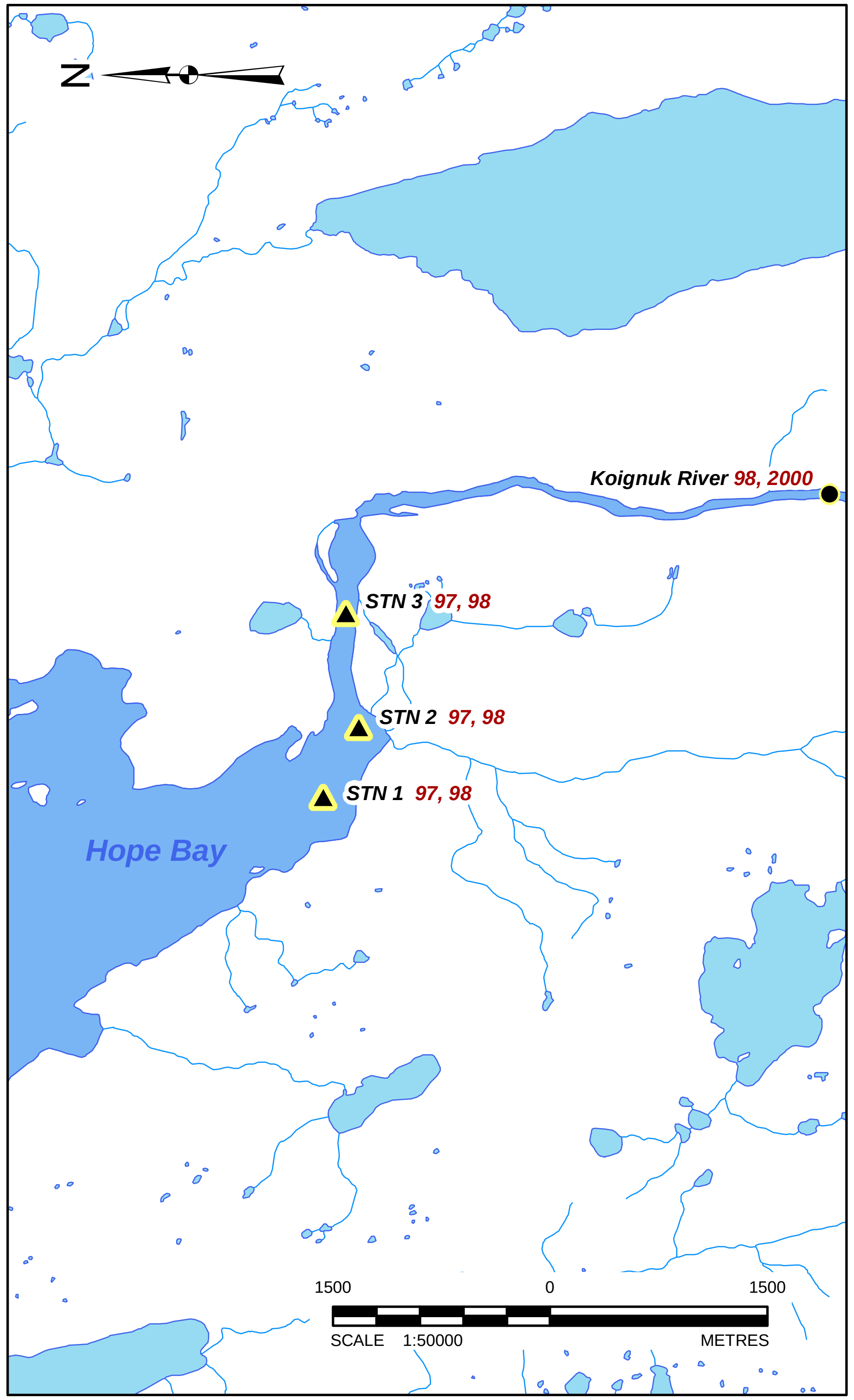
3.1.1 Sampling Locations and Timing

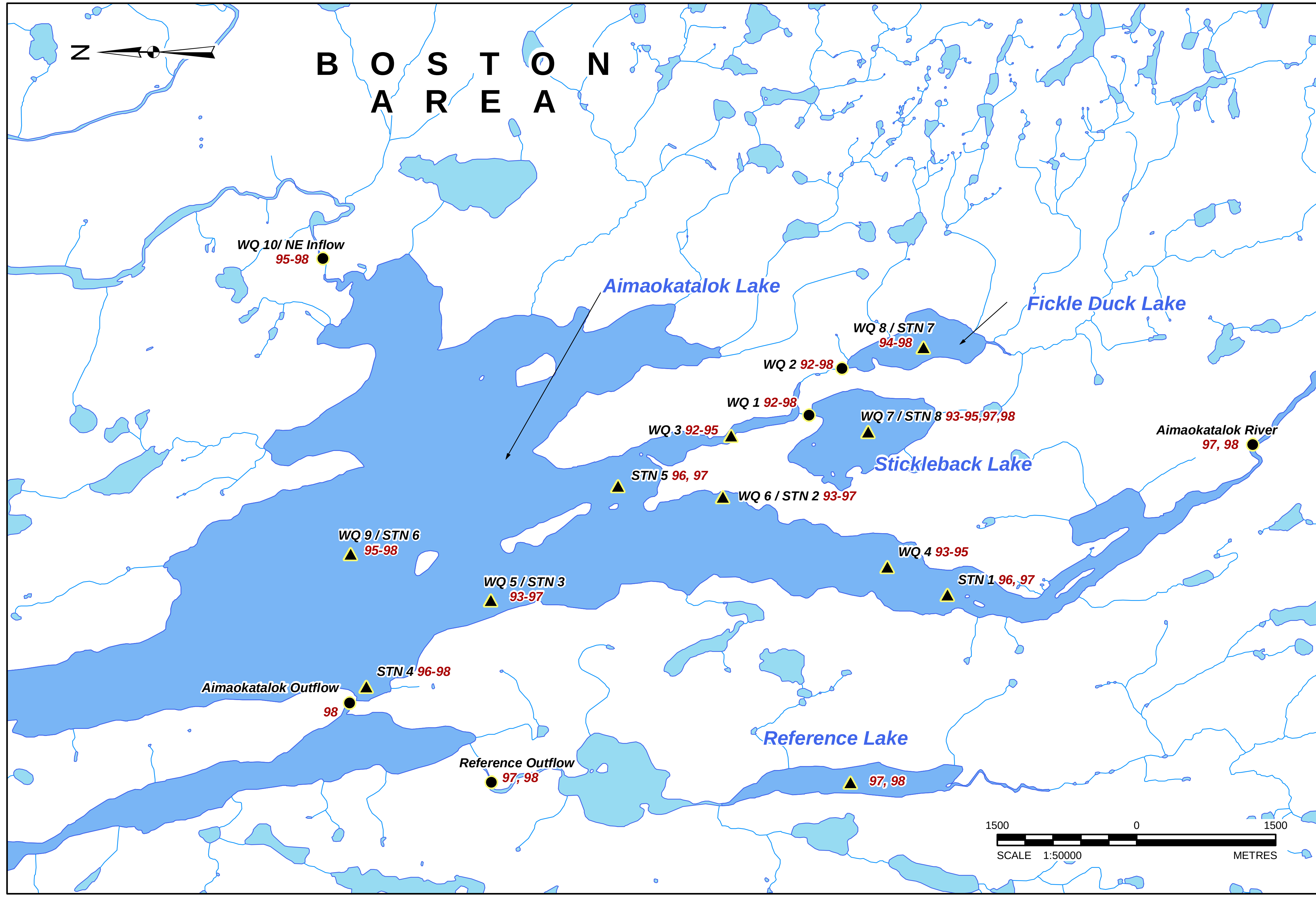
Water quality samples and measurements were collected between 1992 and 2000 from lakes, associated streams and the Koignuk River in the Boston area of the Hope Bay Belt (Figure 3.1, Table 1.1). Detailed sampling methods are presented in Rescan reports (Rescan 1993, 1994, 1995, 1997, 1998, 1999a, 2001); a summary of methods used is also presented in Appendix A1.

The initial sampling effort focused on Aimaokatalok (also known as Spyder and Aimaoktok), Fickle Duck Lake (also known as Trout), and Stickleback lakes and their outflow streams. Sampling sites in Reference Lake, Reference Outflow and Aimaokatalok River were added in 1997. Sampling of Aimaokatalok Outflow and Koignuk River started in 1998. Reference Lake was included as a possible reference site for monitoring potential project influences on the Aimaokatalok outflow watershed.

Except for one spring sample collected in June 1993, lake water quality sampling sessions between 1992 and 1995 were carried out under open-water conditions in July and August (Table 3.1). From 1996 to 1998 both open-water (July-August) and under-ice conditions (April) were sampled. The sampling sites were located in the deepest sections of the lakes: one site in each of Fickle Duck, Stickleback and Reference lakes and several sites in Aimaokatalok Lake (Figure 3.1). At each site, water samples were collected for standard water quality parameters including total and dissolved metals and trace elements. On a few dates, field meters were used to measure vertical profiles for temperature and dissolved oxygen (Table 3.1). In addition, field measurements of pH were obtained between 1993 and 1995; pH was measured only in the laboratory in 1996 and 1998. Secchi depth was measured only in 1997 and 1998.

Project: M:\Projects\2007\1373\0019_Miramar_ EM_ II\MapDocs\Fig3_1_WQSampling_BostonCompilation.mxd - Plot: M:\Projects\2007\1373\0019_Miramar_ EM_ II\PDFs\Fig3_1_WQSampling_BostonCompilation.pdf





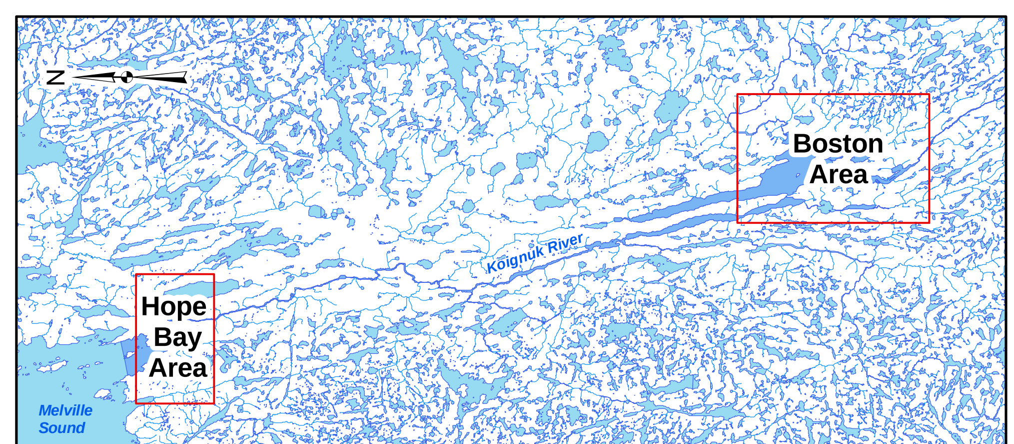
LEGEND

▲	Lake/marine sampling locations	*WQ X / STN X*	Sampling station names from Rescan reports
●	Stream sampling locations	*95-97*	Consecutive years of sampling at station
	Rivers		
	Study area waterbodies		
	Waterbodies		

REFERENCE

Sources: Data Obtained from the Government of Canada, Natural Resources Canada, Centre for Topographic Information
Projection: UTM Zone 13N Datum: NAD 83

This map is for information purposes only. Golder Associates Ltd. does not accept any liability arising from its misuse or misrepresentation.



MIRAMAR HOPE BAY LTD.

Boston Project Data Compilation

TITLE

Water Quality Sampling Locations, 1992 - 2000

Golder Associates
Edmonton, Alberta

PROJECT No.06-1373-028			SCALE AS SHOWN	REV. 1
DESIGN	JP	22 April 2008		
GIS	RC	23 April 2008		
CHECK	JP	14 May 2008		
REVIEW	JP	16 May 2008		

FIGURE 3.1

Table 3.1 Summary of Water Sampling (Number of Sampling Sessions) Conducted in Boston Area Lakes and Streams, 1992 - 2000

Lake	1992	1993		1994	1995	1996		1997		1998	
	Ice Free	Ice Cover	Ice Free	Ice Free	Ice Free	Ice Cover	Ice Free	Ice Cover	Ice Free	Ice Cover	Ice Free
Aimaokatalok	1	1	1p[a]	1	1p[a]	1	2	1p	2p[a]	1p[a]	1p[a]
Stickleback			1	1	1p[a]			1p[a]	2p[a]		1p[a]
Fickle Duck			1	1	1p[a]		2	1p[a]	2p[a]		1p[a]
Reference									2p[a]	1p[a]	1p[a]

Stream	1992		1993		1994		1995	
	Spring	Summer	Spring	Summer	Spring	Summer	Spring	Summer
Aimaokatalok NE Inflow		1	1	1		1		2
Fickle Duck Outflow		1	1	1		1		1
Stickleback Outflow		1	1	1		1		1

Stream	1996		1997		1998		2000	
	Spring	Summer	Spring	Summer	Spring	Summer	Spring	Summer
Aimaokatalok NE Inflow		2	1	2	1			
Aimaokatalok Outflow					2	1		
Aimaokatalok River			1	2	2			
Fickle Duck Outflow	1	2	1	2	1			
Koignuk River					1	1	1	1
Reference Outflow				2	2	1		
Stickleback Outflow	1	3	1	2	1			

[a] "p" indicates vertical profiles of temperature and dissolved oxygen were collected with the sample.

In general, stream sampling was conducted during the spring melt conditions (May/June) and during the summer (July to September) between 1992 and 2000 (Table 3.1). At each site, water samples were collected for standard water quality parameters including total and dissolved metals and trace elements. Field meters were used to measure temperature, pH and dissolved oxygen (DO) between 1993 and 1996. In 1997 and 1998, DO and temperature were not measured in the field, whereas pH was measured in the laboratory only.

Baseline marine water quality sampling was conducted in Hope Bay, which is the final receiving waterbody of the Aimaokatalok Lake drainage via the Koignuk River. Water samples were collected in summer of 1997 and 1998 at three sites within Hope Bay (Figure 3.1). Temperature and DO profiles were also measured at these stations in 1998. In general, methods used for the collection of marine samples were similar to those used for lake sampling (Appendix A1).

3.1.2 Laboratory Analytical Methods and QA/QC Procedures

Water samples were analyzed for standard chemical parameters including nutrients, major ions, total metals and dissolved metals (Appendix A2).

Analytical methods and detection limits for the measured parameters varied from year to year, largely because of different laboratories used, including Analytical Service Laboratories (ASL), Elemental Research Inc. (ERI) and University of British Columbia (UBC).

The details of quality control/quality assurance (QA/QC) procedures varied during the 1992-2000 baseline monitoring program. In general, however, field QA/QC procedures included the use of sample replicates, travel blanks and field blanks, whereas laboratory QA/QC procedures involved the use of sample splits and laboratory method blanks (Appendix A3). The analytical results for QA/QC samples are presented in Appendix A4.

3.1.3 Data Interpretation

Concentrations of the various substances were compared against Canadian Water Quality Guidelines (CCME 2007). In cases where the Canadian Water Quality Guidelines (CWQGs) have not yet been developed, the Northwest Territories and Nunavut jurisdictional guidelines (Statistics Canada 2006) or the British Columbia water quality guidelines (BCMOE 2006) were used.

For quick reference, seasonal summaries of water quality data are presented in text. In the seasonal summaries, data are presented as seasonal medians, minimums and maximums for each water body. Excluding replicates and sample splits, these statistics were derived using all available data, including multiple sampling depths, and all sampling stations on each lake. In order to avoid misrepresentation in the determination of the summary statistics, “no analysis” result is shown for specific parameters on dates when detection limits were substantially greater than the reported maximum values in the Boston lakes. Calculation of medians used the following rules: when the median fell between a detection limit (<value) and an actual concentration, the latter was used for the median value; when the median fell between two detection limits the higher resolution detection limit was cited as the median value. When ranking concentrations compared to detection limits, a concentration of less than half the detection limit was considered lower, while concentrations of half or more of the detection limit were considered higher. For example, values of 0.4 mg/L and less were ranked lower than <1 mg/L detection limit, whereas 0.5 mg/L and greater concentrations were ranked higher than the <1 mg/L detection limit.

Total Suspended Solids and Turbidity

CWQGs for total suspended solids (TSS) and turbidity refer to exceedences above natural levels. The data presented in this report were obtained from baseline studies; therefore, TSS and turbidity values presented in this report can be used in the future as guidelines for determining exceedences when mining begins in the areas.

Aluminum

CWQGs for aluminum depend on the pH of water. The 100 µg/L water quality guideline is used for waters with pH ≥6.5, whereas the 5 µg/L CWQG is used for waters with pH <6.5.

Cadmium

CWQGs for total cadmium vary with water hardness. For water hardness between 30 and 90 mg $CaCO_3$/L the following formula is used to derive the guideline for total cadmium:

$$CWQG=10^{\{0.86[\log(hardness)]-3.2\}}$$

where the water quality guideline (CWQG) is in µg/L and hardness is measured as $CaCO_3$ equivalents in mg/L. When water hardness is ≤30 mg/L, the CWQG for total cadmium is 0.01 µg/L. For water with hardness ≥90 mg $CaCO_3$/L, the CWQG for total cadmium is 0.03 µg/L.

Copper

The CWQGs for total copper are dependent on water hardness ($CaCO_3$ concentrations) as follows:

Water Hardness (mg $CaCO_3$/L)	**CWQG for Total Copper (µg/L)**
<120	2
120–180	3
>180	4

Total Alkalinity

Total alkalinity is a common measure of the acid neutralizing capacity of water. As such, it provides an indication of a waterbody’s sensitivity to acid deposition.

According to Saffran and Trew (1996), acid sensitivity ranges of lakes (study was based on lake data only, no similar studies have been conducted on streams) are based on total $CaCO_3$ alkalinity and are defined as follows:

Total Alkalinity (mg $CaCO_3$/L)	***Acid Sensitivity of Lakes***
• <10	high sensitivity
• 11 to 20	moderate sensitivity
• 21 to 40	low sensitivity
• >40	least sensitive

Total Phosphorus

There are no CWQGs for flowing waters presently available for total phosphorus (TP), whereas for still water, the CWQGs are in the form of a series of trigger ranges (CCME 2007). However, a number of Canadian jurisdictions have developed their own TP guidelines for lentic (still) and lotic (flowing) waters (Statistics Canada 2006). In Northwest Territories and Nunavut, a 0.03 mg/L TP guideline is used for both lentic and lotic waters (Statistics Canada 2006). In this report, the TP concentrations from the Boston area water bodies are compared against the 0.03 mg/L Northwest Territories and Nunavut jurisdictional guideline.

Total vs Dissolved Metal Concentrations

In general, toxicity of the particulate fraction of a metal (included in the total concentration of a metal) is lower than that of the dissolved fraction. Although, the CWQGs pertain to the total metal concentrations, most of these guidelines were based on toxicological studies using dissolved metal concentrations. As such, when a dissolved metal concentration exceeds the CWQGs in a natural setting, it is likely to have more serious effects on the aquatic biota than when only the total concentration of a metal exceeds the guideline. *"Of particular concern is the apparent toxicity of some ionic metals to fish due to adsorption of the metal at the gill surface. Particulate bound forms of the same metal have much reduced toxicity. This is important when comparing the laboratory toxicity results with field situations where more metal binding agents are likely to be present, thereby usually reducing the toxicity of the metal. Conversely, fish tested in the laboratory are usually not fed and do not ingest particulate metals."* (CCME 2007).

3.2 LAKE WATER QUALITY

Analytical results for all available water quality data from Boston area lakes are presented in Appendix A5. Seasonal summaries (under ice cover *vs* summer/fall open water conditions) of standard water quality parameters and total metal concentrations are presented for each lake in the following subsections.

3.2.1 Aimaokatalok Lake

Aimaokatalok Lake is, by far, the largest (approximately 20 km long) of the four lakes sampled in the Boston area (Figure 3.1). It also contains the deepest water quality sampling site (28 m deep), whereas the sampling sites at the remaining three lakes are approximately 3 m deep. Aimaokatalok Lake was sampled on 19 dates between June 1993 and July 1998 (Table 3.1).

Temperature profiles in Aimaokatalok Lake, in both ice covered and ice free conditions, indicate a reasonably well mixed water column (Figure 3.2). A defined thermocline was observed between approximately 2 to 8 m depth in July 1997. The bottom waters were warmest in August, ranging from 8.5°C to 12.5°C; in August the lake was typically isothermic. The warmest temperature recorded in surface waters was 19.5°C, measured at Station 5 in July 1998. The under-ice water temperatures ranged from 0°C just below the ice cover to 2.5°C in near-bottom waters.

Dissolved oxygen (DO) profiles for Aimaokatalok Lake show that on all sampling occasions at least the upper 3 m layer of water column was well oxygenated under both ice cover and ice free conditions. A sharp drop in oxygen concentrations, down to near anoxic levels, was recorded twice — once at Station 4 on 22 April 1998, when DO dropped from 10.69 mg/L at 6 m depth to 3.24 mg/L at 8 m depth; and once at Station 6 on 25 Aug 1997, when DO dropped from 11.5 mg/L at 3 m depth to 2.5 mg/L at 5 m depth, continuing to gradually decline to 1.4 mg/L at 18 m. Notably, when oxygen depletion was observed, it was measured at one site only, while elsewhere in the lake oxygen concentrations were high at similar and much greater depths. Indeed, in July 1998 uniformly high DO concentrations (>10 mg/L) were observed all the way to the bottom at the 28 m deep Station 6 (Figure 3.2). DO values in the deeper layers of the water column fell below the 9.5 mg/L CWQG for early life stages of cold-water biota in 8 of the 21 DO profiles measured. In five of these eight profiles, the DO fell below the 6.5 mg/L CWQG for other life stages of coldwater biota.

Aimaokatalok Lake total suspended solids (TSS) values were typical of clear lakes, with a median TSS of <1 mg/L in spring and 2 mg/L in summer (Table 3.2). The spring and summer maximums for TSS were 22 mg/L and 13 mg/L, respectively. The median turbidity values were similarly low (Table 3.2), with a value of 0.8 NTU in the spring and 1.3 NTU in the summer.

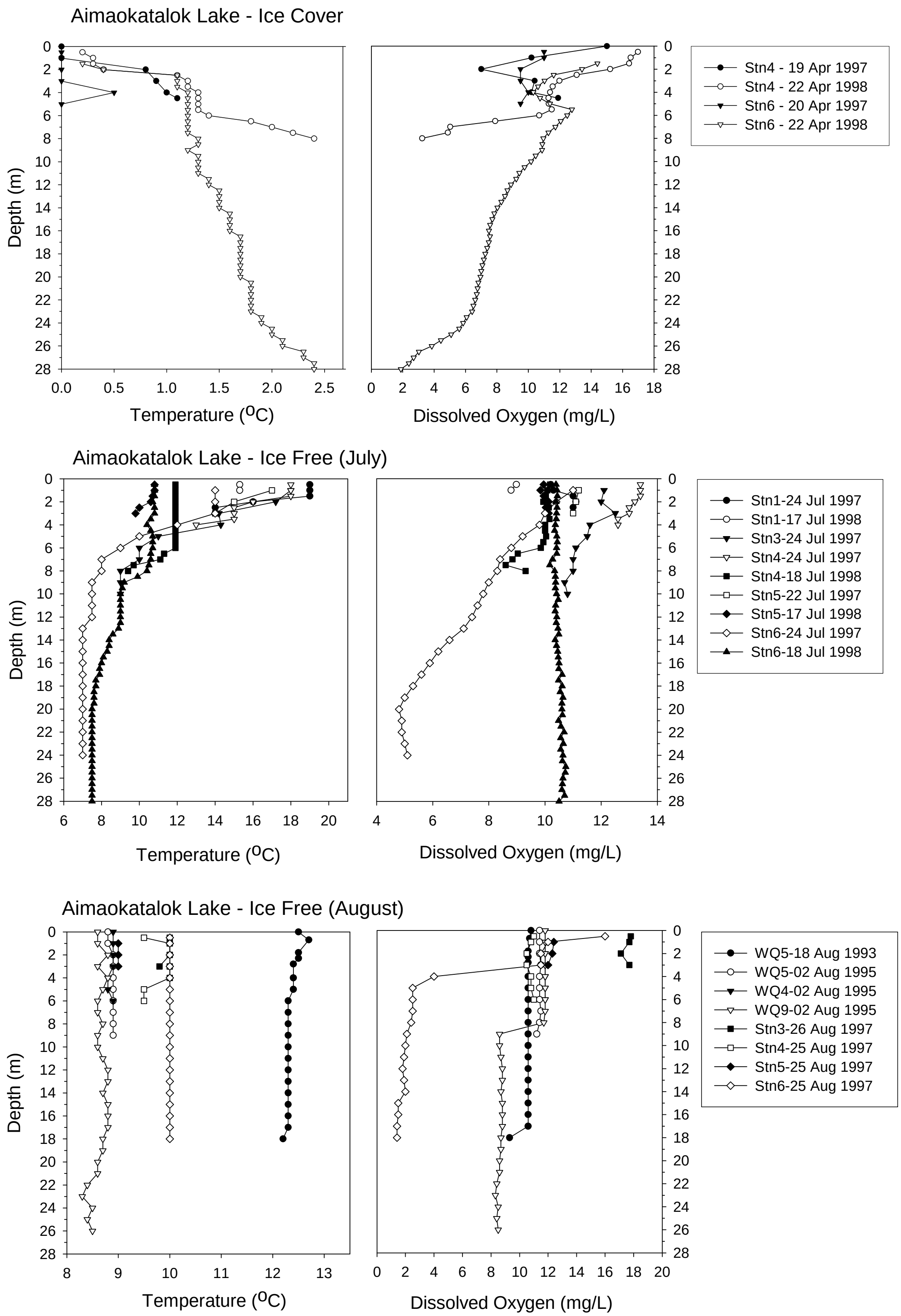


Figure 3.2 Temperature and Dissolved Oxygen Profiles in Aimaokatalok Lake, 1993 to 1998

Table 3.2 Baseline Water Quality in Aimaokatalok Lake, 1993 to 1998

Parameters	Ice Covered (April to June)				Ice free (July and August)				Guidelines for Protection of Aquatic Life
	Median	Min	Max	n	Median	Min	Max	n	
Physical									
Conductivity (µS/cm)	56	37	66	17	40	32	320	70	-
pH (units)	6.7	***6.2***	6.9	17	6.7	***5.7***	8.2	68	6.5 – 9.0
TDS (mg/L)	38	20	46	17	29	13	350	69	-
TSS (mg/L)	<1	<1	22	13	2	<1	13	68	short-term increase <25; long-term increase <5
Turbidity (NTU)	0.8	0.3	18.4	17	1.3	0.3	9.0	70	short-term increase <8; long-term increase <2
Dissolved Anions (mg/L)									
Hardness ($CaCO_3$)	13	8	16	17	9	6	110	70	-
Total Alkalinity	9	5	12	16	7	4	21	70	-
Chloride	10	7	12	12	6	5	98	69	-
Fluoride	0.04	0.03	0.07	12	0.04	<0.05	0.08	69	0.12
Sulphate	2.0	1.0	3.2	16	1.0	<0.5	2.0	70	-
Nutrients (mg/L)									
Dissolved phosphorus	0.004	<0.001	0.013	10	0.003	<0.001	0.029	64	-
Total phosphorus	0.007	<0.001	***0.069***	16	0.008	0.002	0.020	64	0.030 (jurisdictional)
Ammonia nitrogen	0.007	<0.005	0.035	14	0.012	<0.005	0.140	64	1.23[a]
Nitrate - nitrogen	0.035	<0.005	0.120	14	<0.005	<0.001	0.016	64	13
Nitrite - nitrogen	<0.001	<0.001	0.006	14	<0.001	<0.001	0.002	64	0.06
Total Metals (µg/L)									
Aluminium	19	10	***118***	13	38	7	***446***	75	5 or 100[b]
Antimony	<0.1	<0.05	0.30	13	<0.1	<0.05	0.20	75	
Arsenic	0.2	0.1	0.4	13	0.2	<0.1	3.0	76	5.0
Barium	2.4	1.7	4.6	7	1.7	1.1	22.1	48	
Beryllium	<5	<0.5	<5	17	<0.5	<0.5	2.7	76	
Bismuth	<0.5	<0.5	<0.5	6	<0.5	<0.03	0.1	47	
Boron	5	4	7	6	3	1	34	47	
Cadmium	<0.2	<0.05	***0.90***	13	<0.2	<0.05	***0.51***	76	0.017[c]
Calcium	2 820	1 500	3 460	17	1 860	1 340	41 900	76	
Chromium	0.6	0.2	***10.0***	13	0.5	<0.1	***1.7***	59	1.0 or 8.9[d]
Cobalt	<1	<0.1	0.1	13	<1	<0.1	0.3	75	
Copper	***4***	1	***14***	16	0.7	<1	***20***	76	2
Iron	50	<10	***629***	17	100	<10	***440***	76	300
Lead	<1	<0.05	***3***	13	<1	<0.05	***10***	76	1
Lithium	<10	<1	1	16	<10	<1	65	54	
Magnesium	1 560	992	2 000	17	1 105	858	8 090	76	
Manganese	3.0	1.5	49.0	17	4.1	0.3	18.0	76	
Mercury	<0.05	<0.01	<0.05	7	<0.05	<0.01	***0.10***	37	0.026[e]
Molybdenum	<1	<0.05	0.14	13	<1	<0.05	0.30	76	73
Nickel	0.8	<1	12.0	13	0.2	<0.1	2.3	75	25
Potassium	830	660	1 130	13	635	490	2 930	70	

Table 3.2 Baseline Water Quality in Aimaokatalok Lake, 1993 to 1998 (continued)

Parameters	Ice Covered (April to June)				Ice free (July and August)				Guidelines for Protection of Aquatic Life
	Median	Min	Max	n	Median	Min	Max	n	
Selenium	<0.5	<0.5	<0.5	13	<0.5	<0.5	***5***	62	1.0
Silicon	320	160	680	13	240	<50	400	53	
Silver	<0.1	<0.01	<0.1	13	<0.1	<0.01	0.06	75	0.1
Sodium	5 010	2 700	6 150	17	3 370	2 600	11 400	71	
Strontium	13	10	18	17	10	6	362	71	
Thallium	<0.05	<0.05	<0.05	6	<0.05	<0.03	0.05	47	0.8
Tin	<0.1	<0.1	<0.1	6	<0.1	<0.09	0.40	47	
Titanium	<10	<0.01	<10	17	5	<1	19	70	
Tungsten	-	-	-	0	0.1	<0.07	0.2	18	
Uranium	0.02	0.02	0.03	6	0.01	<0.01	0.05	29	
Vanadium	0.3	0.2	1	6	<1	<1	4.0	47	
Zinc	5	<1	16	16	<5	<1	23	76	30
Field WQ									
Temperature (°C)	-	-	-	0	9.5	7.4	14.0	14	-
Dissolved Oxygen (mg/L)	-	-	-	0	12.0	***8.6***	14.2	14	9.5 mg/L early life stages; 6.5 mg/L other life stages
pH (units)	-	-	-	0	7.4	***6.1***	8.2	12	6.5 - 9.0
Secchi (m)	-	-	-	0	-	2.0	3.5	2	-
Chlorophyll *a* (mg/m^3)	-	-	-	0	0.54	0.48	0.72	3	-

Note: italicized, bold values exceed guidelines

TDS = total dissolved solids.

TSS = total suspended solids.

[a] The lowest guideline value determined for the particular temperature and pH ranges (temperature up to 20°C and pH 7.5) when ammonia nitrogen was high in Aimaokatalok Lake (CCME 2007).

[b] 5 µg/L CWQG when pH<6.5; 100 µg/L CWQG when pH≥6.5.

[c] Values compared to guideline corrected for hardness.

[d] 1.0 µg/L CWQG for Cr (VI), 8.9 µg/L interim CWQG for Cr (III).

[e] As CCME (2007) does not provide a guideline for total mercury, this guideline is for inorganic mercury.

The maximum values for spring and summer were 18.4 and 9.0 NTU, respectively.

The laboratory measurements of pH in Aimaokatalok Lake water samples were carried out consistently throughout the 1993 to 1998 studies. The median pH value (pH 6.7), measured in the laboratory, was the same for under ice and ice free conditions. Aimaokatalok Lake water samples ranged from pH 5.7 to 8.2 (Table 3.2). The minimum pH levels measured in the laboratory in both under ice (pH 6.2) and ice free (pH 5.7) water samples were below the minimum CWQG of pH 6.5. The field pH measurements were made only during summer sampling events. The field pH measurements ranged from pH 6.1 to 8.2; the median field pH was 7.4.

Total alkalinity in Aimaokatalok Lake was generally low, ranging from 4 to 21 mg/L (Table 3.2). Based on the Saffran and Trew (1996) classification, Aimaokatalok Lake, most of the time, has moderate to high susceptibility to acidification.

All of the dissolved inorganic forms of nitrogen (ammonia, nitrate and nitrite) were well below the CWQGs. Total phosphorus (TP) in Aimaokatalok Lake was typically below the 0.03 mg/L jurisdictional guideline for Northwest Territories and Nunavut; the median TP values were 0.007 mg/L for under-ice samples and 0.008 mg/L for summer samples. The under ice maximum value for TP (0.069 mg/L) represents the only occasion when the TP concentrations exceeded the 0.03 mg/L jurisdictional guideline. Notably, the concurrent TSS concentration (22 mg/L) was also the maximum value recorded for Aimaokatalok Lake, and therefore, this sample was likely contaminated with sediments (Appendix A5).

Median metal concentrations were below the CWQGs with the exception of the under-ice median for total copper (median of 4 µg/L; maximum of 14 µg/L), which exceeded the 2 µg/L CWQG (Table 3.2). High copper concentrations (dissolved copper was also above the CWQG) occurred in water samples collected under-ice in 1996, 1997 and 1998, with the deepest samples containing the least copper (Appendix A5).

The CWQGs were exceeded by both spring and summer maximum values for the following metals (total): aluminum, cadmium, chromium, copper, iron and lead.

In addition, the summer maxima for mercury (0.10 µg/L) and total selenium (5 µg/L) exceeded the CWQGs (Table 3.2).

The CWQG exceedences for total aluminum occurred whenever turbidity was >5 NTU (and on one occasion when turbidity was lower, at 3 NTU). High turbidity, however, did not seem to co-occur with CWQG exceedences for the remaining above-mentioned metals. Additionally, CWQG exceedences for total aluminum (>5 µg/L) also occurred whenever pH fell below the CWQG (pH <6.5).

The summer spikes in metal concentrations in Aimaokatalok Lake appear to be sporadic and, with the exception of aluminum, iron and turbidity at Station 1 on 23 Aug 1996, there was very little consistency between replicate samples and different depths at the same site when CWQG exceedences occurred. The elevated metal concentrations in these “odd” summer samples were likely due to sample contamination or insufficient precision and accuracy of the laboratory analyses. The latter was definitely an issue with regard to cadmium concentration where the CWQG value was lower than the analytical detection limit.

In contrast, the under-ice exceedences of CWQGs were more consistent between replicate samples and different depths at the same site. It is possible that some CWQG exceedences for metal concentrations, especially in under-ice samples, were due to human activity. Aimaokatalok Lake is likely to receive some discharge from the exploration camp site on its shores, and there is a winter road over the lake. Furthermore, Aimaokatalok Lake and its shores were subjected to intensive exploration drilling during the 1992 to 1998 period. Some of these drilling activities may have contributed to the observed spikes in metal concentrations. In the four years of under-ice sampling (1993, 1996, 1997, 1998), water samples from all locations had at least one metal exceeding the CWQG concentrations; only the occasional, deep-water sample had all metal concentrations below the guidelines (Appendix A5).

Specifically, in June 1993 total iron was above the 300 µg/L CWQG and drilling on the lake, upstream of the water quality sampling locations, was conducted between April and the end of May 1993 (file data, provided by Miramar Hope Bay Ltd. – now Hope Bay Mining Ltd.). In 1998, when the under-ice drilling was conducted closer to the main basin of the lake, there were no elevated iron concentrations but there were substantial exceedences of CWQGs for chromium and copper. In 1996, when there was no drilling on the lake (just on the shore), turbidity, copper and aluminum concentrations were above CWQGs, but not those of chromium or iron. In 1997, when drilling was also confined to the shore, small exceedences of CWQGs occurred in total copper and cadmium concentrations, while total iron concentrations were elevated but not above the CWQG. It should be noted, however, that natural exceedances of many of these parameters occur in waterbodies within the Hope Bay Belt, and so the exceedances in Aimaokatalok Lake may not be related to drilling.

3.2.2 Stickleback Lake

Stickleback Lake was sampled on seven dates between August 1993 and July 1998 (Table 3.1). Temperature profiles in Stickleback Lake, during both ice cover and ice free conditions, were isothermic indicating a well mixed water column (Figure 3.3). Summer temperature ranged from 8 to 19°C, whereas under ice temperatures were slightly above 0°C (Figure 3.3). The dissolved oxygen concentration (DO) in all five DO profiles were above the 9.5 mg/L CWQG for protection of all life-stages of fish.

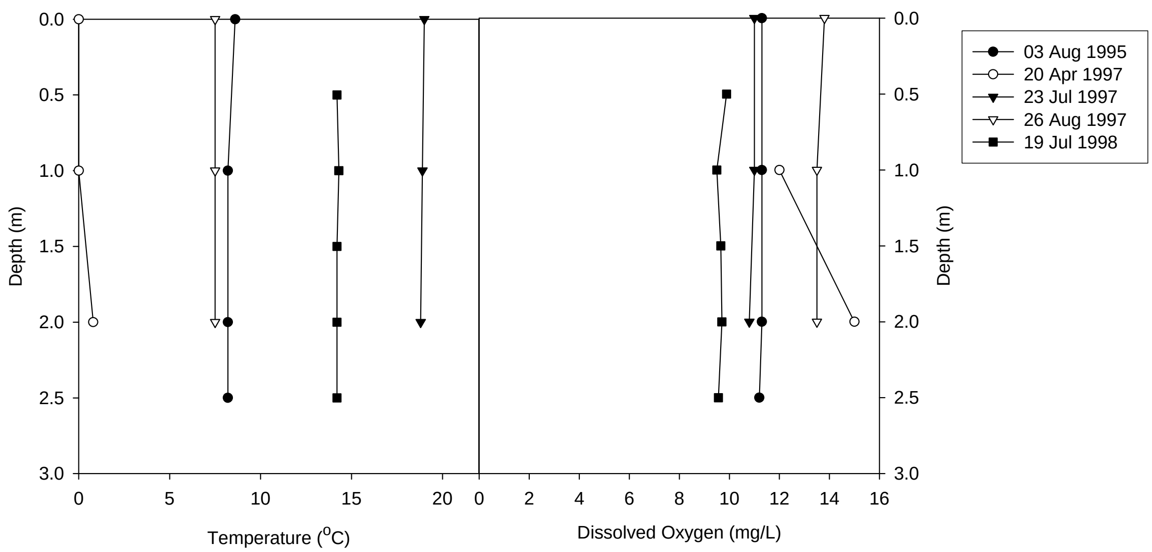


Figure 3.3 Temperature and Dissolved Oxygen Profiles in Stickleback Lake, 1995 to 1998

Stickleback Lake generally had clear water, with median TSS in summer of 3 mg/L and a maximum of 4 mg/L. On the only under-ice sampling occasion, the TSS was 4 mg/L. The turbidity values had a median summer value of 1 NTU and a maximum of 1.4 NTU. The under-ice sample was higher at 7.1 NTU (Table 3.3).

Laboratory readings of pH for Stickleback Lake ranged from pH 6.2 to 8.3. Only the minimum pH (measured in August 1995) was outside the CWQG range of pH 6.5 to 9.0 for the protection of aquatic life. While laboratory readings of pH were available for nine sampling events, the field measurements of pH were taken on three summer sampling occasions. The field pH readings were more alkaline, ranging from pH 7.9 to 8.5 and with a median of pH 8.3 (the laboratory-measured summer median was pH 7.3).

Total alkalinity ranged from 26 to 32 mg/L for the eight summer sampling events. The single under-ice value (20 April 1997 sample) for total hardness was anomalously high (98 mg/L). Using the summer values and based on the Saffran and Trew (1996) classification, Stickleback Lake has low susceptibility to acidification.

Table 3.3 Baseline Water Quality in Stickleback Lake, 1993 to 1998

Parameter	Ice Covered (April)				Ice Free (July and August)				Guidelines for Protection of Aquatic Life
	Median	Min	Max	n	Median	Min	Max	n	
Physical									
Conductivity (µS/cm)	458	-	-	1	160	116	203	7	-
pH (units)	7.1	-	-	1	7.4	***6.2***	8.3	7	6.5 – 9.0
TDS (mg/L)	266	-	-	1	110	79	141	7	-
TSS (mg/L)	4	-	-	1	3	<1	4	7	short-term increase <25; long-term increase <5
Turbidity (NTU)	7.1	-	-	1	1	0.6	1.4	7	short-term increase <8; long-term increase <2
Dissolved Anions (mg/L)									
Hardness ($CaCO_3$)	140	-	-	1	48	35	63	7	-
Total Alkalinity	98			1	31	26	32	7	
Chloride	95	-	-	1	36.5	16.9	42.4	7	-
Fluoride	0.08	-	-	1	0.05	0.03	***0.14***	7	0.12
Sulphate	2	-	-	1	<1	0.3	0.3	7	-
Nutrients (mg/L)									
Dissolved Phosphorus	-	-	-	0	0.004	0.001	0.007	6	
Total Phosphorus	0.013	-	-	1	0.009	0.006	0.020	6	0.030 (jurisdictional)
Ammonia Nitrogen	-	-	-	0	0.017	0.007	0.043	6	1.23[a]
Nitrate - nitrogen	-	-	-	0	<0.005	<0.005	0.003	6	13
Nitrite - nitrogen	-	-	-	0	<0.001	<0.001	0.001	6	0.06
Total Metals (µg/L)									
Aluminum	23	-	-	1	9	<5	11	7	5 or 100[b]
Antimony	0.1			1	<0.1	<0.1	0.10	7	
Arsenic	0.8	-	-	1	0.40	<0.1	2	7	5.0
Barium	20	-	-	1	<10	<10	4	7	
Boron	-	-	-	0	-	<1.2	10	2	
Cadmium	<0.2	-	-	1	<0.2	<0.1	***0.12***	7	0.017[c]
Calcium	34 800	-	-	1	11 700	8 200	15 900	7	
Chromium	<1	-	-	1	<1	<0.3	0.50	7	1.0 or 8.9[d]
Cobalt	<1	-	-	1	<1	<0.6	0.29	7	
Copper	2	-	-	1	<1	<0.5	1.21	7	2
Cyanide	-	-	-	0	-	<5	<5	2	5
Iron	***720***	-	-	1	70	40	90	7	300
Lead	<1	-	-	1	<1	<1	***5***	7	1
Magnesium	13 600	-	-	1	4 570	3 550	5 600	7	
Manganese	343	-	-	1	6.39	<5	10	7	
Mercury	<0.01	-	-	1	<0.05	<0.05	***0.03***	6	0.026[e]
Molybdenum	<1	-	-	1	<1	<1	0.10	7	73
Nickel	<1	-	-	1	<1	<1	0.70	7	25
Potassium	4 600	-	-	1	1 670	1 420	1 800	5	
Selenium	<0.5	-	-	1	<1	<0.5	1	7	1.0

Table 3.3 Baseline Water Quality in Stickleback Lake, 1993 to 1998 (continued)

Parameter	Ice Covered (April)				Ice Free (July and August)				Guidelines for Protection of Aquatic Life
	Median	Min	Max	n	Median	Min	Max	n	
Silicon	1 420	-	-	1	210	190	260	3	
Silver	<0.1	-	-	1	<0.05	<0.01	<0.1	7	0.1
Sodium	29 100	-	-	1	11 200	10 200	12 000	5	
Strontium	170	-	-	1	91	31	110	5	
Thallium	-	-	-	0	-	<0.03	<0.05	2	0.8
Tin	-	-	-	0	-	<0.09	0.2	2	
Titanium	-	-	-	0	-	<0.5	<0.5	2	
Tungsten	-	-	-	0	-	<0.07	<0.1	2	
Vanadium	-	-	-	0	-	<1	<1	2	
Zinc	8	-	-	1	<5	<5	1.23	7	30
Field WQ									
Temperature (°C)	-	-	-	0	12.0	8.6	13.6	3	-
Dissolved Oxygen (mg/L)	-	-	-	0	11.3	10.8	15.7	3	9.5 mg/L early life stages; 6.5 mg/L other life stages
pH (units)	-	-	-	0	8.3	7.9	8.5	3	-
Secchi (m)	-	-	-	0	2.0	-	-	1	-
Chlorophyll *a* (mg/m^3)	-	-	-	0	0.96	-	-	1	-

Note: ***italicized***, ***bold*** values exceed guidelines

TDS = total dissolved solids.

TSS = total suspended solids.

[a] The lowest guideline value determined for the particular temperature and pH ranges (temperature up to 20°C and pH 7.5) when ammonia nitrogen was high in Stickleback Lake (CCME 2007).

[b] 5 µg/L CWQG when pH<6.5; 100 µg/L CWQG when pH≥6.5.

[c] Values compared to guideline corrected for hardness.

[d] 1.0 µg/L CWQG for Cr (VI), 8.9 µg/L interim CWQG for Cr (III).

[e] As CCME (2007) does not provide a guideline for total mercury, this guideline is for inorganic mercury.

All of the dissolved inorganic forms of nitrogen (ammonia, nitrate and nitrite) were below their CWQGs in the 1993 to 1998 samples from Stickleback Lake. TP concentrations were consistently below the 0.03 mg/L jurisdictional guideline and ranged from 0.006 to 0.020 mg/L.

The summer maximum value for fluoride (0.14 mg/L) marginally exceeded the 0.12 mg/L CWQG for protection of aquatic life.

During summer monitoring, the maximum values for total cadmium, lead and mercury exceeded their respective CWQGs. However, it is worth noting that the median values for mercury (<0.05 µg/L) and cadmium (<0.2 µg/L) correspond to method detection limits that are considerably greater than the corresponding CWQGs (0.026 µg/L for mercury; 0.017 µg/L for cadmium).

In the single under-ice sample collected from Stickleback Lake, total metal concentrations were all below the CWQG, with the exception of the total iron concentration, which was 720 µg/L – well above the 300 µg/L CWQG. In the remaining samples (all collected in the summer) iron concentrations ranged from 40 to 110 µg/L.

The under-ice sample may have been contaminated with drainage from waste rock piles or drilling activities as iron compounds (e.g., hematite) are common additives of drilling mud. This water sample also contained at least double the summer maximum concentrations of sodium, chlorine and calcium carbonate (Table 3.3), which are often added to drilling mud (McCosh and Getliff 2003). In addition, in this same under-ice sample, the conductivity, total dissolved solids and the concentrations of total silicon and total magnesium were more than double their summer maximum values. Drilling was carried out on the south-western shores of Stickleback Lake and just north of Stickleback Lake in spring 1997, but it is not known whether drainage from the drilling or rock waste entered the lake.

3.2.3 Fickle Duck Lake

Fickle Duck Lake was sampled on eight dates between August 1994 and July 1998 (Table 3.1). Temperature profiles in Fickle Duck Lake were near isothermic on the four summer sampling dates between 1995 and 1998 (Figure 3.4); the coolest profile (7.5°C) was measured on 26 Aug 1997 and the warmest (20°C) on 23 July 1997. Dissolved oxygen profiles also indicated a well mixed water column. The DO concentrations were above the 9.5 mg/L CWQG for protection of early life stages of fish in 1995 and 1997 and marginally below this guideline during the 1998 survey (Figure 3.4).

Fickle Duck Lake water clarity varied from very clear to turbid. The median ice-free TSS value was 3 mg/L and the maximum was 20 mg/L. TSS was 12 mg/L when the lake was covered with ice. The median turbidity was 3.9 NTU and the maximum was 30 NTU during the ice-free season, whereas turbidity was 19.2 NTU when the lake was covered with ice (Table 3.4). The high TSS and turbidity under ice may have resulted in accidental disturbance of the lake sediment when drilling the hole through the ice in this shallow lake.

Laboratory readings of pH for Fickle Duck Lake ranged from pH 6.1 to 8.4. The minimum pH, measured during summer, was below (outside) the CWQG range of pH 6.5 to 9.0 for protection of aquatic life. The field pH was measured on two dates only, at pH 8.0 and 8.4 (Table 3.4).

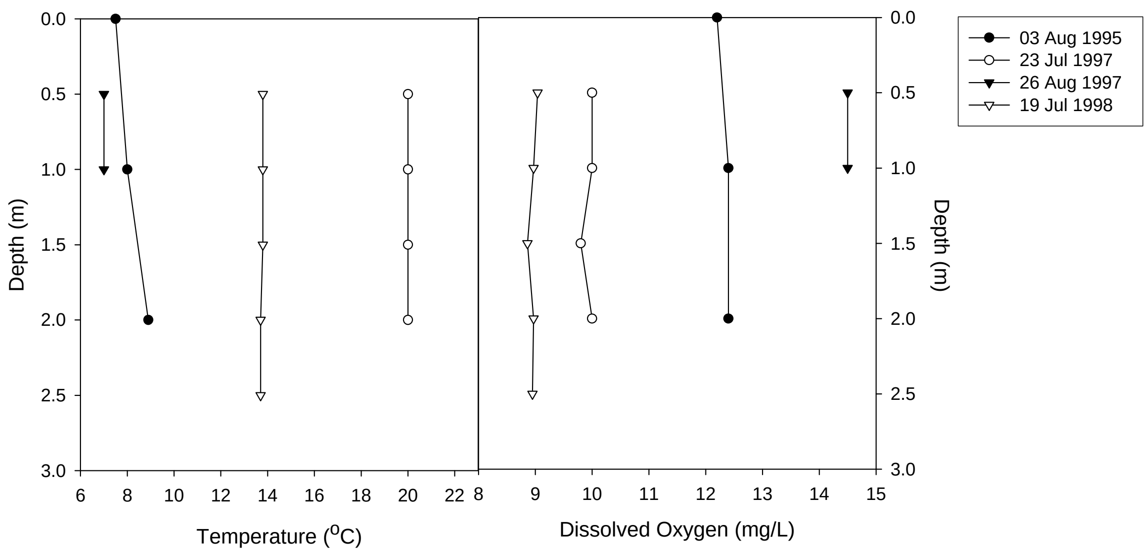


Figure 3.4 Temperature and Dissolved Oxygen Profile in Fickle Duck Lake, 1995 to 1998

Total alkalinity was measured on the eight summer dates and once under-ice. The under-ice value was anomalously high, with 107 mg $CaCO_3$/L, compared to the 18 mg $CaCO_3$/L summer maximum (Table 3.4). Using the summer values, and based on the Saffran and Trew (1996) classification, Fickle Duck Lake has moderate susceptibility to acidification.

All dissolved inorganic forms of nitrogen (ammonia, nitrate and nitrite) were below the CWQGs in Fickle Duck Lake. TP concentrations exceeded the 0.030 mg/L jurisdictional guideline once in August 1996 (0.050 mg/L) and in the single under-ice sample (0.046 mg/L) collected in April 1997.

Summer median concentration of total iron in Fickle Duck Lake was above the CWQG (Table 3.4). This corresponded to total iron exceedences occurring on four of the seven sampling dates. In addition, maximum concentrations of total aluminum, cadmium, chromium, copper, iron and lead in summer exceeded their respective CWQGs. Total lead and aluminum exceedences occurred on three of the seven sampling dates. It is noteworthy that on all summer sampling occasions, the method detection limits for cadmium and mercury were above their respective CWQGs. As such, it is possible that small-scale exceedences of the total cadmium and mercury CWQGs may have occurred undetected.

Table 3.4 Baseline Water Quality in Fickle Duck Lake, 1994 to 1998

Parameter	Ice Covered (April)				Ice Free (July and August)				Guidelines for Protection of Aquatic Life
	Median	Min	Max	n	Median	Min	Max	n	
Physical									
Conductivity (µS/cm)	352	-	-	1	63	54	89	7	-
pH (units)	6.8	-	-	1	7.1	***6.1***	8.4	7	6.5 - 9.0
TDS (mg/)	273	-	-	1	51	44	56	7	-
TSS (mg/L)	12	-	-	1	3	1	20	7	short-term increase: <25; long-term increase <5
Turbidity (NTU)	19.2	-	-	1	3.9	1.2	30	7	short-term increase <8; long-term increase <2
Dissolved Anions (mg/L)									
Hardness (mg$CaCO_3$/L)	128	-	-	1	19	8	24	7	-
Total Alkalinity (mg$CaCO_3$/L)	107	-	-	1	14	10	18	7	-
Chloride	43.9	-	-	1	10.5	7.3	17	7	-
Fluoride	0.08	-	-	1	0.05	0.03	0.08	7	0.12
Sulphate	11	-	-	1	1.1	<0.5	2.1	7	-
Nutrients (mg/L)									
Dissolved Phosphorus	-	-	-	0	0.005	0.003	0.012	6	
Total Phosphorus	***0.046***	-	-	1	0.015	0.012	***0.050***	6	0.030 (jurisdictional)
Ammonia Nitrogen	-	-	-	0	0.018	<0.005	0.020	6	0.14[a]
Nitrate - nitrogen	-	-	-	0	<0.005	<0.001	0.009	6	13
Nitrite - nitrogen	-	-	-	0	0.001	<0.001	0.002	6	0.06
Total Metals (µg/L)									
Aluminum	***260***	-	-	1	92	25	***346***	7	5 or 100[b]
Antimony	0.3	-	-	1	<0.1	<0.05	0.1	7	
Arsenic	0.8	-	-	1	0.3	0.2	1.0	7	5.0
Barium	20	-	-	1	3.6	2.0	7.1	4	
Boron	-	-	-	0	4.0	<1	8.6	4	
Cadmium	***0.6***	-	-	1	<0.2	<0.2	***0.11***	7	0.017[c]
Calcium	36 100	-	-	1	5 130	4 640	6 670	7	
Chromium	***2***	-	-	1	<1	<0.3	0.7	6	1.0 or 8.9[d]
Cobalt	<1	-	-	1	<1	<0.6	0.2	7	
Copper	***8***	-	-	1	1.6	1.0	***2.3***	7	2
Iron	***3 410***	-	-	1	***360***	110	***650***	7	300
Lead	1	-	-	1	0.2	<1	***7.0***	7	1
Lithium	-	-	-	0	1.0	<1	1.0	3	
Magnesium	10 000	-	-	1	1 610	1 460	1 970	7	
Manganese	165	-	-	1	0.4	<5	6.3	7	
Mercury	<0.01	-	-	1	<0.05	<0.05	<0.05	4	0.026[e]
Molybdenum	<1	-	-	1	<1	<0.16	0.10	7	73
Nickel	5	-	-	1	1.1	1.0	1.8	7	25
Potassium	2 770	-	-	1	440	320	650	7	
Selenium	<0.5	-	-	1	<0.5	<0.5	1	6	1.0
Silicon	9 020	-	-	1	600	430	2 310	5	
Silver	<0.1	-	-	1	<0.1	<0.01	0.04	7	0.1

Table 3.4 Baseline Water Quality in Fickle Duck Lake, 1994 to 1998 (continued)

Parameter	Ice Covered (April)				Ice Free (July and August)				Guidelines for Protection of Aquatic Life
	Median	Min	Max	n	Median	Min	Max	n	
Sodium	20 800	-	-	1	5 240	3 380	5 690	7	
Strontium	134	-	-	1	30	16	37	7	
Thallium	-	-	-	0	<0.05	<0.03	0.05	4	0.8
Tin	-	-	-	0	0.2	<0.09	0.3	4	
Titanium	-	-	-	0	0.7	<1	18.0	4	
Tungsten	-	-	-	0		0.07	0.1	2	
Uranium	-	-	-	0		0.04	0.04	2	
Vanadium	-	-	-	0	<1	<1	1	4	
Zinc	22	-	-	1	1	<5	7	7	30
Field WQ									
Temperature (°C)	-	-	-	0	9.3	7.5	11.0	2	-
Dissolved Oxygen (mg/L)	-	-	-	0	12.7	12.2	13.2	2	9.5 mg/L early life stages; 6.5 mg/L other life stages
pH (units)	-	-	-	0	8.0	7.5	8.4	2	6.5-9.0

Note: ***italicized***, **bold** values exceed guidelines

TDS = total dissolved solids.

TSS = total suspended solids.

[a] The lowest guideline value determined for the particular temperature and pH ranges (temperature up to 20°C and pH 8.5) observed in Fickle Duck Lake (CCME 2007).

[b] 5 µg/L CWQG when pH<6.5; 100 µg/L CWQG when pH≥6.5.

[c] Values compared to guideline corrected for hardness.

[d] 1.0 µg/L CWQG for Cr (VI), 8.9 µg/L interim CWQG for Cr (III).

[e] As CCME (2007) does not provide a guideline for total mercury, this guideline is for inorganic mercury.

During the single under-ice sampling event (20 April 1997), six metals exceeded their CWQGs; these were total aluminum, cadmium, chromium, copper and iron. CWQG exceedences for iron were especially high for both the total (3410 µg/L) and dissolved (1660 µg/L) components. The under-ice CWQG exceedences for copper also represented the greatest copper concentrations, both total (8 µg/L) and dissolved (6 µg/L), reported for Fickle Duck Lake (Table 3.4, Appendix A5).

Similar to Stickleback Lake, the Fickle Duck Lake under-ice samples from April 1997 appeared to be contaminated with inputs/drainage from a source high in labile sodium, chlorine, calcium carbonate, potassium, magnesium, silicon and strontium (Table 3.4); however, no drilling activities had been reported in or around Fickle Duck Lake in either 1996 or 1997.

3.2.4 Reference Lake

Reference Lake was sampled on four dates between July 1997 and July 1998 (Table 3.1). Temperature profiles in Reference Lake were near isothermic on the three summer sampling dates during 1997 and 1998; the coolest profile (7.5°C) was measured in August 1997 and the warmest (20°C) on 23 July 1997 (Figure 3.5). Dissolved oxygen profiles also indicated a well mixed water column. Only on 22 July 1998, the dissolved oxygen concentrations at all depths were just below the CWQG of 9.5 mg/L for the protection of early life stages of fish. In July 1997, DO declined with depth, but remained above the 9.5 mg/L CWQG (Figure 3.5).

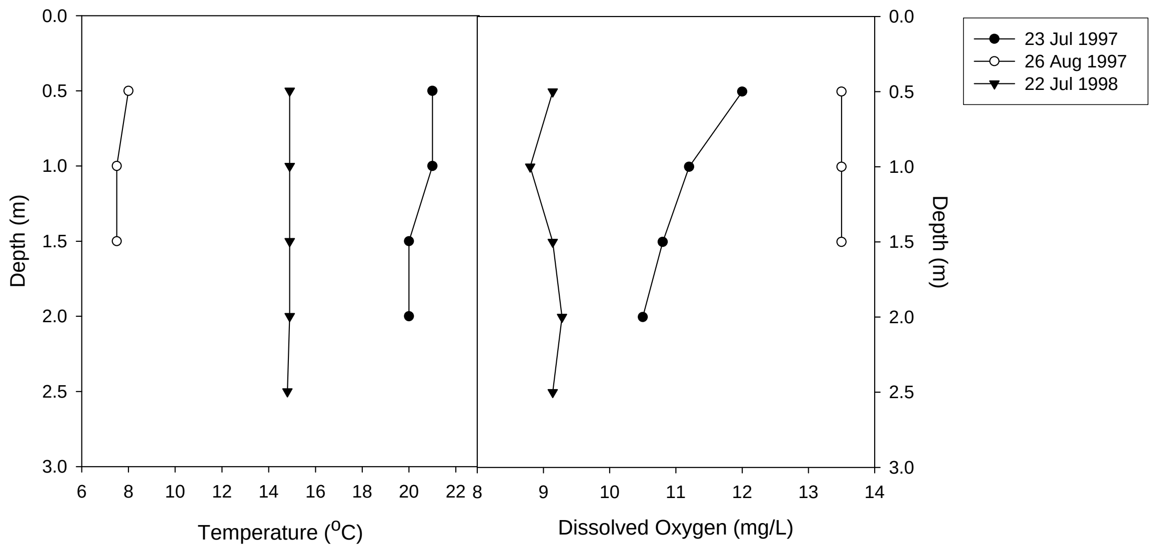


Figure 3.5 Temperature and Dissolved Oxygen Profiles in Reference Lake, 1997 and 1998

The TSS values for Reference Lake were similar in the two years (1997 and 1998) of sampling, with a summer median of 5 mg/L (Table 3.5) and an under-ice value of 4 mg/L (second replicate was contaminated with sediments and resulted in a value of 50 mg/L TSS). Turbidity levels during summer monitoring ranged from 2.0 to 3.9 NTU. Under-ice turbidity was higher, at 7.1 NTU.

Laboratory reading of pH for the single under-ice water sample was pH 7.1. No field measurements of pH were reported for Reference Lake; however, laboratory pH measurements of summer samples ranged from pH 6.6 to pH 6.9 with a median of 6.8 (Table 3.5).

Table 3.5 Baseline Water Quality in Reference Lake, 1997 to 1998

Parameter	Ice Covered (April)				Ice Free (July and August)				Guidelines for Protection of Aquatic Life
	Median	Min	Max	n	Median	Min	Max	n	
Physical									
Conductivity (µS/cm)	228	-	-	1	38	32	52	3	-
pH (units)	7.1	-	-	1	6.8	6.6	6.9	3	6.5 - 9.0
TDS (mg/L)	173	-	-	1	34	20	34	3	-
TSS (mg/L)	4	-	-	1	5	4	6	3	short-term increase:<25; long-term increase <5
Turbidity (NTU)	7.1	-	-	1	3.5	2	3.9	3	short-term increase <8; long-term increase <2
Dissolved Anions (mg/L)									
Hardness ($CaCO_3$)	82	-	-	1	11.8	11.6	14.7	3	-
Total Alkalinity ($CaCO_3$)	66	-	-	1	11	9	12	3	-
Chloride	30	-	-	1	4.5	3.5	4.6	3	-
Fluoride	0.12	-	-	1	0.04	0.03	0.06	3	0.12
Sulphate	8	-	-	1	1	1	1	3	-
Nutrients (mg/L)			-						
Dissolved Phosphorus	0.002	-	-		-	0.0012	0.0012	2	
Total Phosphorus	0.018	-	-	1	-	0.008	0.021	2	0.030 (jurisdictional)
Ammonia nitrogen	0.021	-	-	1	-	0.0017	0.0135	2	1.23[a]
Nitrate - nitrogen	0.226	-	-	1	-	0.0020	0.0027	2	13
Nitrite - nitrogen	<0.001	-	-	1	-	<0.001	<0.001	2	0.06
Total Metals (µg/L)									
Aluminum	37	-	-	1	88	44	***109***	3	5 or 100[b]
Antimony	<0.1	-	-	1	<0.1	<0.1	<0.1	3	
Arsenic	0.8	-	-	1	0.2	0.2	0.3	3	5.0
Barium	20	-	-	1	<10	<10	<10	3	
Cadmium	<0.2	-	-	1	<0.2	<0.2	<0.2	3	0.017[c]
Calcium	21 600	-	-	1	3 170	3 110	3 980	3	
Chromium	***3***	-	-	1	<1	<1	<1	3	1.0 or 8.9[d]
Cobalt	<1	-	-	1	<1	<1	<1	3	
Copper	***30***	-	-	1	2	2	2	3	2
Iron	***1 840***	-	-	1	240	230	240	3	300
Lead	<1	-	-	1	<1	<1	***6***	3	1
Magnesium	6 800	-	-	1	1 000	930	1 270	3	
Manganese	150	-	-	1	6	<5	6	3	
Mercury	<0.05	-	-	1		<0.05	<0.05	3	0.026[e]
Molybdenum	<1	-	-	1	<1	<1	<1	3	73
Nickel	4	-	-	1	<1	<1	<1	3	25
Potassium	2 250	-	-	1	440	360	440	3	
Selenium	0.5	-	-	1	<0.5	<0.5	0.5	3	1.0
Silicon	3 380	-	-	1	240	240	290	3	
Silver	<0.1	-	-	1	<0.1	<0.1	<0.1	3	0.1
Sodium	17 000	-	-	1	2 490	2 130	2 650	3	

Table 3.5 Baseline Water Quality in Reference Lake, 1997 to 1998 (continued)

Parameter	Ice Covered (April)				Ice Free (July and August)				Guidelines for Protection of Aquatic Life
	Median	Min	Max	n	Median	Min	Max	n	
Strontium	59	-	-	1	17	16	19	3	
Zinc	9	-	-	1	<5	<5	<5	3	30

Note: ***italicized***, ***bold*** values exceed guidelines

TDS = total dissolved solids.

TSS = total suspended solids.

[a] The lowest guideline value determined for the particular temperature and pH ranges (temperature up to 20°C and pH 7.5) when ammonia nitrogen was high in Reference Lake (CCME 2007).

[b] 5 µg/L CWQG when pH<6.5; 100 µg/L CWQG when pH≥6.5.

[c] Values compared to guideline corrected for hardness.

[d] 1.0 µg/L CWQG for Cr (VI), 8.9 µg/L interim CWQG for Cr (III).

[e] As CCME (2007) does not provide a guideline for total mercury, this guideline is for inorganic mercury.

Total alkalinity was measured on the three summer sampling occasions and once under-ice. The under-ice value obtained for 22 April 1998 was anomalously high, with 66 mg $CaCO_3$/L, compared to the 12 mg $CaCO_3$/L summer maximum (Table 3.5).

Using the summer values and based on the Saffran and Trew (1996) classification, Reference Lake has moderate to high susceptibility to acidification.

All of the dissolved inorganic forms of nitrogen (ammonia, nitrate and nitrite) were below their respective CWQGs on the four sampling dates (Table 3.5). TP concentrations were consistently below the 0.030 mg/L jurisdictional guideline and ranged from 0.008 to 0.021 mg/L.

Fluoride concentrations in one of the two spring replicate samples reached the 0.12 mg/L guideline concentration, while in the second replicate the fluoride concentration was just below the guideline (Appendix A5).

None of the metals or trace elements in Reference Lake samples had summer median values above their CWQGs for protection of aquatic life (Table 3.5). In terms of the summer monitoring, only the maximum values for total lead and total aluminum exceeded their respective CWQGs. Similar to Fickle Duck and Stickleback Lake sample analyses, the method detection limits for cadmium and mercury were above their respective CWQGs. As such, it is possible that small-scale exceedences of the total cadmium and mercury CWQGs may have occurred undetected during the 1997-1998 monitoring period.

During the single under-ice sampling event (22 April 1998), total chromium concentration (3 µg/L) exceeded the 1 µg/L CWQG. In addition, substantial exceedences in CWQGs were found in the under-ice total copper (30 µg/L) and total iron (1840 µg/L) concentrations (Appendix A5).

Similar to the Stickleback and Fickle Duck lakes in April 1997, the April 1998 Reference Lake's under-ice water appeared to be contaminated with inputs/drainage from a source high in labile sodium, chlorine, calcium carbonate, potassium, magnesium, silicon and strontium and which resulted in a three-fold (total strontium) to 11-fold (total silicon) increase of their maximum concentrations (Appendix A5). Drainage from drilling or leaching from waste rock dumps would be expected to produce similar effects; however, no drilling had been reported in or around Reference Lake during that time.

3.2.5 Summary

Water quality data are presented for Aimaokatalok, Fickle Duck, Reference and Stickleback lakes. Aimaokatalok Lake is considerably larger and deeper than the other three lakes and its monitoring was more intensive, involving multiple sites and five years of open-water and under-ice sampling. In contrast, the other three lakes were sampled at just one site with only a single under-ice sampling event.

In summer, the four Boston area lakes were generally well-mixed; however, a defined thermocline was measured in Aimaokatalok Lake in July 1997. Winter under-ice temperatures were available only for Aimaokatalok Lake (four profiles measured on two dates) and Stickleback Lake (one profile). Similar under-ice trends were measured in both lakes. As expected, water temperature was coolest under-ice in the top 1 m of water column (0 to 0.5°C) and increased with depth to 1.5 - 2.5°C near bottom.

Consistently high and uniform dissolved oxygen concentrations were characteristic of both the under-ice and summer DO profiles for the three smaller lakes (all about 3 m deep). The upper 3 m layer of water in Aimaokatalok Lake was similarly well oxygenated on all sampling occasions. Depressed DO concentrations, falling well below the 6.5 mg/L CWQG, were recorded in bottom waters of Aimaokatalok Lake during 1998 under-ice conditions and at the deepest sampling site in July and August 1997.

Total suspended solids (TSS) typically varied between <1 and 5 mg/L in the four lakes, providing some indication of the natural fluctuation of TSS in these lakes. The closely-related turbidity typically ranged from 1 to 30 NTU.

Laboratory measurements of pH were available for nearly all sampling events at all lakes. In contrast, field measurements were not available for any sampling events at Reference Lake, and only for some of the summer sampling dates at the other three lakes. Reference Lake ranged from pH 6.6 to 7.1, not exceeding the CWQG range of pH 6.5 to 9.0. The other three lakes had more variable pH, specifically the laboratory pH ranged from 5.7 to 8.1 in Aimaokatalok Lake, the pH in Stickleback Lake ranged from 6.2 to 8.3 and the pH in Fickle Duck Lake ranged from 6.1 to 8.4 units. The pH of the three latter lakes was occasionally below the lower limit of the CWQG range.

Aimaokatalok Lake and Reference Lake had moderate to high susceptibility to acidification, as determined from Saffran and Trew (1996) classification using total alkalinity values. Total alkalinity concentrations were similar in summer and winter samples from Aimaokatalok Lake; in contrast, the single winter samples collected from the other three Boston area lakes all had anomalously high total alkalinity concentrations compared with their summer maximum values. Considering only the summer total alkalinity values, Fickle Duck Lake had moderate susceptibility to acidification whereas Stickleback Lake had the greatest total alkalinity concentrations (26 to 32 mg $CaCO_3$/L) and, correspondingly, only a low susceptibility to acidification. The anomalously high winter reading of total alkalinity from the three smaller lakes also co-occurred with some CWQG exceedences (see below for further discussion).

None of the inorganic forms of nitrogen (ammonia, nitrate and nitrite) exceeded their respective CWQGs. Total phosphorus did exceed the 30 µg/L jurisdictional guideline for Northwest Territories and Nunavut in one sample from Aimaokatalok Lake and two samples from Fickle Duck Lake. Notably, all three samples had high total suspended solid concentrations (12 to 22 mg/L), and two of these samples were collected under ice (possibly contaminated with sediments).

Metal concentrations sporadically exceeded CWQGs in all four lakes. Copper concentrations in under-ice water samples from Aimaokatalok Lake were the most common guideline exceedance (median total copper concentration was 4 µg/L compared to CWQG of 2 µg/L). No other median values for either summer or under-ice metal concentrations exceeded their respective guidelines. The maximum copper concentration in Aimaokatalok Lake was 20 µg/L. Total copper concentrations also occasionally exceeded the CWQG in Fickle Duck Lake and Reference Lake. The highest copper concentration (30 µg/L) was measured in under-ice samples from Reference Lake.

Total iron was the only metal to substantially exceed its CWQG (300 µg/L) in all four lakes on at least one occasion. The maximum total iron concentration was measured in Reference Lake, in the same sample that contained the maximum copper concentration for Boston area lakes. Total copper maxima also coincided with total iron maxima in Stickleback Lake and Fickle Duck Lake; however, in Aimaokatalok Lake the trends in total copper concentrations appeared to be unrelated to those in total iron.

Total aluminum exceedences of the 100 µg/L CWQG were most common in Aimaokatalok Lake and Fickle Duck Lake, typically occurring in water samples with higher than normal TSS concentrations. However, with the exception of high total iron concentrations in a summer sample from Aimaokatalok Lake, high turbidity did not seem to co-occur with the CWQG exceedences by the remaining, above-mentioned, metals.

Total chromium occasionally exceeded the 1.0 µg/L (Cr VI) CWQG in Aimaokatalok, Fickle Duck and Stickleback lakes. The 8.9 µg/L (Cr III) CWQG was exceeded on only one occasion (under-ice sample) at two sites in Aimaokatalok Lake. Only total and dissolved chromium analyses have been done on water quality samples, whereas the CWQGs are specifically for Cr (VI) and Cr (III). Cr (III) is the principal species found in surface waters, while Cr (VI) dominates in mildly reducing environments, such as wetlands and sediments. It is likely that Cr (III) and Cr (VI) were below the CWQGs. No other exceedences were measured in these water samples.

Total selenium exceeded the 1.0 µg/L CWQG in two water samples (collected on different dates), both from Aimaokatalok Lake. Notably, the other samples collected from Aimaokatalok Lake, on the same dates but from different sites and from the same site but at different depths, had total selenium concentrations below the CWQG.

Mercury and cadmium method detection limits were greater than their respective CWQGs for the majority of water samples collected between 1993 and 1998. Small exceedences of mercury CWQGs were noted on the odd sampling occasion in Aimaokatalok and Stickleback lakes. When lower detection limits were used, total cadmium exceeded the 0.017 µg/L CWQG on several occasions in Aimaokatalok Lake and twice in each of Fickle Duck Lake and Stickleback Lake. It is possible that small-scale exceedences of the total cadmium and mercury CWQGs may have occurred undetected during the 1993-1998 monitoring period.

The total lead 1 µg/L CWQG was sporadically exceeded in all lakes, with the overall maximum (36 µg/L) being reported for Reference Lake.

It is possible that the exceedences of CWQGs by the metal concentrations, especially of total iron in under-ice samples, were due to human activity. Aimaokatalok Lake was likely to receive some discharge from the camp site on its shores and there was also a winter road over the lake. Furthermore, Aimaokatalok, Fickle Duck, and Stickleback lakes and their shores were subjected to exploration drilling during 1992 to 1998. Some of the drilling activities may have contributed to the observed spikes in metal concentrations. In contrast, no drilling has been reported around Reference Lake, yet the 1998 under-ice sample from this lake appeared to be contaminated with inputs/drainage from a source high in sodium, chloride, calcium carbonate, potassium, magnesium, silicon, and strontium, similar to the under-ice results from Stickleback and Fickle Duck lakes in April 1997 (Appendix A5). It would be prudent (and helpful for planning of future monitoring programs) to investigate the cause of these sporadic increases in iron and associated parameters.

In general, the total number of parameters which exceeded CWQGs was about double in Aimaokatalok and Stickleback lakes compared to Fickle Duck and Reference lakes (Table 3.6).

Table 3.6 Summary of Total Metals and Other Water Quality Parameters That Exceeded CWQGs (✓) at Least Once in the Boston Area Lakes, 1993 to 1998

Lake	pH	Fluoride	TP	Al	Cd	Cr	Cu	Fe	Pb	Hg	Se
Aimaokatalok	✓	-	✓	✓	✓	✓	✓	✓	✓	✓	✓
Stickleback	✓	✓	-	-	✓	-	-	✓	✓	✓	-
Fickle Duck	✓	-	✓	✓	✓	✓	✓	✓	✓	-	-
Reference	-	-	-	✓	-	✓	✓	✓	✓	-	-

3.3 STREAM WATER QUALITY

The following sections present water quality data collected at the various stream sites (lake outflows and inflows) and rivers within the Boston Project area. Analytical results for all water quality samples collected in Aimaokatalok NE Inflow, Aimaokatalok and Koignuk rivers, Aimaokatalok, Stickleback, Fickle Duck, and Reference outflows are presented in Appendix A6. Seasonal summaries of selected water quality data for each stream are presented in individual tables in the following sub-sections. The seasonal summaries were created following the same method as used for the lakes.

3.3.1 Aimaokatalok NE Inflow

Aimaokatalok NE Inflow was sampled on seven dates between August 1995 and June 1998. The field parameters (temperature, dissolved oxygen and field pH) were measured just once in August 1995.

Dissolved oxygen concentration on the one field sampling date was above the 9.5 mg/L CWQG for protection of early life stages of aquatic life.

The TSS summer median was 5 mg/L, with the range being 0 to 15 mg/L. One high TSS value (57 mg/L) collected in spring (15 June 1997) could be a direct result of freshet and the sediment associated with increased surface drainage into the stream. This was also the only occasion when turbidity (26 NTU) was considerably higher than the remaining measurements (0.6 – 6.4 NTU) (Table 3.7; Appendix A6).

All of the dissolved inorganic forms of nitrogen (ammonia, nitrate, and nitrite) were below the CWQGs. Total phosphorus (TP) in Aimaokatalok NE Inflow was typically below the 0.030 mg/L jurisdictional guideline for Northwest Territories and Nunavut; the median summer TP value was 0.008 mg/L. One of the two collected spring samples contained a TP concentration (0.041 mg/L) in excess of the 0.030 mg/L jurisdictional guideline. This maximum value for TP was measured in the same sample that contained the maximum concentration of TSS (22 mg/L), likely originating from sediments brought in by freshet drainage into the stream (Appendix A6).

In spring, both minimum and maximum concentrations for total aluminum and iron exceeded their respective CWQGs (Table 3.7). In summer, the maximum concentrations of total aluminum, cadmium, copper, and iron exceeded their CWQG for the protection of aquatic life. All aluminum and iron exceedences occurred on the same sampling dates, in both spring and summer. The cadmium exceedence occurred on the only date when there were no aluminum or iron exceedences. The only metals for which median concentrations exceeded the CWQG in summer were aluminum and iron. There was no clear association of the metal exceedences of the CWQGs with other measured water quality parameters (Appendix A6).

3.3.2 Aimaokatalok Outflow

Water quality samples were collected from Aimaokatalok Outflow in May, June and August 1998. Field parameters were not measured during sampling.

Table 3.7 Baseline Water Quality in Aimaokatalok NE Inflow, 1992 to 1998

Parameter	Ice Covered (April to June)				Ice free (July and August)				Guidelines for Protection of Aquatic Life
	Median	Min	Max	n	Median	Min	Max	n	
Physical									
Conductivity (µS/cm)	-	44	57	2	78	63	105	5	-
pH (units)	-	***6.3***	6.7	2	6.8	***5.7***	7.0	5	6.5 – 9.0
TDS (mg/L)	-	26	43	2	56	50	75	5	-
TSS (mg/L)	-	2	57	2	6	<1	15	5	short-term increase <25; long-term increase <5
Turbidity (NTU)	-	4.7	26.3	2	6.3	0.6	6.4	5	short-term increase <8; long-term increase <2
Dissolved Anions (mg/L)									
Hardness ($CaCO_3$)	-	11	11	2	16	13	20	5	-
Total Alkalinity ($CaCO_3$)	-	7	9	2	12	6	13	5	-
Chloride	-	8	10	2	14.3	8.7	19	5	-
Fluoride	-	0.03	0.05	2	0.06	0.04	0.1	5	0.12
Sulphate	-	<1	1	2	2	1.2	2	5	-
Nutrients (mg/L)									
Dissolved Phosphorus	0.009	-	-	1	0.006	0.001	0.016	5	-
Total Phosphorus	***0.041***	-	-	1	0.024	0.015	0.026	5	0.030 (jurisdictional)
Ammonia Nitrogen	0.035	-	-	1	0.020	<0.005	0.185	5	1.23[a]
Nitrate - nitrogen	0.006	-	-	1	0.006	<0.005	0.010	5	13
Nitrite - nitrogen	0.005	-	-	1	0.001	<0.001	0.011	5	0.06
Total Metals (µg/L)									
Aluminum	-	***177***	***368***	2	***155***	29	***231***	5	5 or 100[b]
Antimony	-	<0.1	<0.1	2	<0.1	<0.05	0.1	5	
Arsenic	-	0.2	0.3	2	0.6	0.4	2.0	5	5.0
Barium	-	<10	<10	2	<10	2.0	5.9	5	
Beryllium	-	<5	<5	2	0.5	<0.5	0.5	5	
Bismuth	-	-	-	0	<0.5	<0.5	0.07	3	
Boron	-	-	-	0	4	<1	8	3	
Cadmium	-	<0.2	<0.2	2	<0.2	<0.05	***0.14***	5	0.017[c]
Calcium	-	2 140	2 260	2	3 300	2 580	3 840	5	
Chromium	-	<1	1	2	0.5	<1	0.7	4	1.0 or 8.9[d]
Cobalt	-	<1	<1	2	0.1	<0.1	0.1	5	
Copper	-	1	1	2	2	0.5	***2.7***	5	2
Iron	-	***430***	***990***	2	***470***	220	***780***	5	300
Lead	-	<1	<1	2	0.1	0.2	0.2	5	1
Lithium	-	-	-	0	-	<1	1	2	
Magnesium	-	1 500	1 620	2	2 010	1 750	2 750	5	
Manganese	-	10	33	2	13	4	33	5	
Mercury	<0.05	-	-	1	-	<0.05	<0.05	2	0.026[e]
Molybdenum	-	<1	<1	2	0.16	0.10	0.16	5	73
Nickel	-	<1	<1	2	0.7	<1	1.8	5	25
Potassium	-	520	910	2	890	670	920	5	

Table 3.7 Baseline Water Quality in Aimaokatalok NE Inflow, 1992 to 1998 (continued)

Parameter	Ice Covered (April to June)				Ice free (July and August)				Guidelines for Protection of Aquatic Life
	Median	Min	Max	n	Median	Min	Max	n	
Selenium	-	<0.5	<0.5	2	<0.5	<0.5	<0.5	3	1.0
Silicon	-	560	1 010	2	440	380	2 570	4	
Silver	-	<0.1	<0.1	2	<0.1	<0.01	0.06	5	0.1
Sodium	-	4 050	4 530	2	7 500	4 410	9 840	5	
Strontium	-	14	20	2	20	15	29	5	
Thallium	-	-	-	0	<0.05	<0.05	0.05	3	0.8
Tin	-	-	-	0	0.2	<0.1	0.7	3	
Titanium	-	<10	20	2	2.2	1	9	3	
Tungsten	-	-	-	0	0.1	-	-	1	
Uranium	-	-	-	0	0.04	0.03	0.05	2	
Vanadium	-	-	-	0	1	<1	1	3	
Zinc	-	<5	<5	2	6	<5	***31***	5	30
Field WQ									
Temperature (°C)	-	-	-	0	11.9	-	-	1	-
Dissolved Oxygen (mg/L)	-	-	-	0	11.9	-	-	1	9.5 mg/L early life stages; 6.5 mg/L other life stages
pH (units)	-	-	-	0	7.1	-	-	1	6.5 - 9.0

Note: ***italicized***, ***bold*** values exceed guidelines.

TDS = total dissolved solids.

TSS = total suspended solids.

[a] Guideline value determined for the most ammonia – sensitive conditions likely to occur in Aimaokatalok NE Inflow (temperature 15°C and pH 8.5) (CCME 2007).

[b] 5 µg/L CWQG when pH<6.5; 100 µg/L CWQG when pH≥6.5.

[c] Values compared to guideline corrected for hardness.

[d] 1.0 µg/L CWQG for Cr (VI), 8.9 µg/L interim CWQG for Cr (III).Field pH ranged from 5.7 to 7.0 pH units (Table 3.7). Laboratory measurements of pH in the Aimaokatalok NE Inflow water samples were below the pH 6.5 CWQG on two of the seven sampling dates. However, the laboratory pH measurements showed some inconsistencies. For instance, the minimum pH value for Aimaokatalok NE Inflow was measured on 1 August 1995; replicate samples yielded pH 5.7 and 5.9 in the laboratory, whereas the field pH of the same sampling site was pH 7.1. Total alkalinity was typically low, ranging from 5.3 to 20.3 mg/L with the summer median of 12 mg/L and spring median of 8.6 mg/L.

[e] As CCME (2007) does not provide a guideline for total mercury, this guideline is for inorganic mercury.

The TSS concentrations ranged from 1 to 4 mg/L, and the turbidity measurements similarly indicated clear waters, with values ranging from 1.0 to 2.5 NTU. Laboratory pH values ranged from pH 6.7 to 6.9, which is within the CWQG range of pH 6.5 to 9.0. Total alkalinity was low, ranging from 6 to 9 mg/L $CaCO_3$ (Table 3.8).

All of the dissolved inorganic forms of nitrogen (ammonia, nitrate, and nitrite) were below the CWQGs. Total phosphorus in Aimaokatalok Outflow was measured on one occasion (0.001 mg/L) and it was well below the 0.030 mg/L jurisdictional guideline for Northwest Territories and Nunavut (Table 3.8).

Table 3.8 Baseline Water Quality in Aimaokatalok Outflow, May to August 1998

Parameter	Spring (May and June)				Summer (July and August)				Guidelines for Protection of Aquatic Life
	Median	Min	Max	n	Median	Min	Max	n	
Physical									
Conductivity (µS/cm)		36	57	2	36	-	-	1	-
pH (units)		6.7	6.9		6.9	-	-	1	6.5 – 9.0
TDS (mg/L)		19	38	2	35	-	-	1	-
TSS (mg/L)		1	4	2	2	-	-	1	short-term increase <25; long-term increase <5
Turbidity (NTU)		1.0	2.5	2	1.1	-	-	1	short-term increase <8; long-term increase <2
Dissolved Anions (mg/L)									
Hardness ($CaCO_3$)		9.5	13.8	2	10.0	-	-	1	
Total Alkalinity ($CaCO_3$)		6.0	9.0	2	6.0	-	-	1	
Chloride		6.1	8.8	2	5.7	-	-	1	
Fluoride		0.02	0.07	2	0.03	-	-	1	0.12
Sulphate		1	2	2	1	-	-	1	
Nutrients (mg/L)									
Dissolved Phosphorus	0.008			1	-	-	-	-	0.030 (jurisdictional)
Total Phosphorus	0.001			1	-	-	-	-	
Ammonia Nitrogen	0.008			1	-	-	-	-	0.19[a]
Nitrate	0.045			1	-	-	-	-	13
Nitrite	<0.001			1	-	-	-	-	0.06
Total Metals (µg/L)									
Aluminum		12	80	2	26	-	-	1	5 or 100[b]
Antimony		<0.1	<0.1	2	<0.1	-	-	1	
Arsenic		0.1	0.2	2	0.1	-	-	1	5.0
Barium		<10	<10	2	<10	-	-	1	
Cadmium		<0.2	<0.2	2	<0.2	-	-	1	0.017[c]
Calcium		2 180	2 850	2	1 970				
Chromium		<1	<1	2	<1	-	-	1	1.0 or 8.9[d]
Cobalt		<1	<1	2	<1				
Copper		1	***3***	2	<1	-	-	1	2
Iron		30	180	2	70	-	-	1	300
Lead		<1	<1	2	<1	-	-	1	1
Magnesium		1 200	1 700	2	1 200				
Manganese		<5	17	2	7	-	-	1	
Mercury		<0.05	<0.05	2	<0.05	-	-	1	0.026[e]
Molybdenum		<1	<1	2	<1	-	-	1	73
Nickel		<1	<1	2	<1	-	-	1	25
Potassium		630	750	2	590				
Selenium		<0.5	<0.5	2	0.8	-	-	1	1.0
Silicon		300	400	2	210				
Silver		<0.1	<0.1	2	<0.1	-	-	1	0.1
Sodium		3 500	4 430	2	3 120	-	-	1	

Table 3.8 Baseline Water Quality in Aimaokatalok Outflow, May to August 1998 (continued)

Parameter	Spring (May and June)				Summer (July and August)				Guidelines for Protection of Aquatic Life
	Median	Min	Max	n	Median	Min	Max	n	
Strontium		14	19	2	20	-	-	1	
Zinc		<5	<5	2	<5	-	-	1	30

Note: ***italicized***, ***bold*** values exceed guidelines

TDS = total dissolved solids.

TSS = total suspended solids.

[a] Guideline value determined for the most ammonia – sensitive conditions likely to occur in Aimaokatalok Ouflow (temperature 15°C and pH 8.5) (CCME 2007).

[b] 5 µg/L CWQG when pH<6.5; 100 µg/L CWQG when pH≥6.5.

[c] Values compared to guideline corrected for hardness.

[d] 1.0 µg/L CWQG for Cr (VI), 8.9 µg/L interim CWQG for Cr (III).

[e] As CCME (2007) does not provide a guideline for total mercury, this guideline is for inorganic mercury.

Metal concentrations were below the CWQGs for the protection of aquatic life with the exception of total copper, which exceeded the 2 µg/L guideline with a concentration of 3 µg/L in June 1998. The detection limits for mercury and cadmium were above their CWQGs (Table 3.8); therefore, it is possible that small exceedences of the guidelines may have occurred in mercury and total cadmium concentrations without being detected.

3.3.3 Aimaokatalok River

Aimaokatalok River was sampled on five occasions between June 1997 and June 1998. Field parameters were not measured on any of the sampling dates.

The TSS concentrations typically varied between <1 and 4 mg/L, with the exception of one under-ice sample where the TSS was measured at 19 mg/L. This same sample had a turbidity of 4.1 NTU, whereas on remaining dates the turbidity was much lower (ranged from 0.4 to 1.3 NTU). On two sampling dates, the laboratory pH values (pH 6.1 and 6.3) were below (outside) the CWQG range of pH 6.5 to Ph 9.0. In the remaining Aimaokatalok River samples, the pH ranged from 6.5 to 6.9. Total alkalinity was low, with an overall median concentration of 5 mg/L $CaCO_3$ (Table 3.9).

Table 3.9 Baseline Water Quality in Aimaokatalok River, 1997 to 1998

Parameter	Spring (May and June)				Summer (July and August)				Guidelines for Protection of Aquatic Life
	Median	Min	Max	n	Median	Min	Max	n	
Physical									
Conductivity (µS/cm)	34	19	75	3	-	27	37	2	-
pH (units)	6.7	***6.1***	6.9	3	-	***6.3***	6.5	2	6.5 - 9.0
TDS (mg/L)	23	11	52	3	-	18	20	2	-
TSS (mg/L)	4	<1	19	3	-	<1	2	2	short-term increase <25; long-term increase <5
Turbidity (NTU)	1.3	0.4	4.1	3		0.8	1.0	2	short-term increase <8; long-term increase <2
Dissolved Anions (mg/L)									
Hardness ($CaCO_3$)	7.5	5.7	22.0	3	-	6.7	7.8	2	-
Total Alkalinity ($CaCO_3$)	6	4	14	3	-	5	5	2	-
Chloride	4.6	3.2	10.2	3	-	4.3	4.6	2	-
Fluoride	0.03	0.03	0.09	3	-	0.03	0.05	2	0.12
Sulphate	1	<1	3	3	-	1	1	2	-
Nutrients (mg/L)									
Dissolved Phosphorus	-	0.002	0.004	2	-	0.002	0.002	2	-
Total Phosphorus	-	0.012	0.013	2	-	0.004	0.006	2	0.030 (jurisdictional)
Ammonia Nitrogen	-	0.022	0.023	2	-	0.023	0.041	2	0.57[a]
Nitrate - nitrogen	-	0.020	0.077	2	-	0.015	0.017	2	13
Nitrite - nitrogen	-	0.001	0.004	2	-	0.003	0.010	2	0.06
Total Metals (µg/L)									
Aluminum	32	25	***74***	3	-	14	***17***	2	5 or 100[b]
Antimony	<0.1	<0.1	<0.1	3	-	<0.1	<0.1	2	-
Arsenic	0.2	0.1	0.2	3	-	<0.1	0.1	2	5.0
Barium	<10	<10	<10	3	-	<10	<10	2	-
Cadmium	<0.2	<0.2	<0.2	3	-	<0.2	<0.2	2	0.017[c]
Calcium	1 350	1 100	4 990	3	-	1 290	1 480	2	
Chromium	<1	<1	<1	3	-	<1	<1	2	1.0 or 8.9[d]
Cobalt	<1	<1	<1	3	-	<1	<1	2	
Copper	1	<1	2	3	-	<1	1	2	2
Iron	240	120	***550***	3	-	90	170	2	300
Lead	<1	<1	<1	3	-	<1	<1	2	1
Magnesium	1 010	700	2 300	3	-	870	1 040	2	
Manganese	34	<5	57	3	-	<5	<5	2	-
Mercury	-	<0.05	<0.05	2	<0.05			1	0.026[e]
Molybdenum	<1	<1	<1	3	-	<1	<1	2	73
Nickel	<1	<1	1	3	-	<1	<1	2	25
Potassium	640	370	1 970	3	-	430	510	2	
Selenium	<0.5	<0.5	<0.5	3	-	<0.5	<0.5	2	1.0
Silicon	520	150	550	3	-	100	110	2	

Table 3.9 Baseline Water Quality in Aimaokatalok River, 1997 to 1998 (continued)

Parameter	Spring (May and June)				Summer (July and August)				Guidelines for Protection of Aquatic Life
	Median	Min	Max	n	Median	Min	Max	n	
Silver	<0.1	<0.1	<0.1	3	-	<0.1	<0.1	2	0.1
Sodium	2 200	1 520	4 420	3	-	2 260	2 280	2	
Strontium	15	8	17	3	-	13	14	2	
Zinc	<5	<5	<5	3	-	<5	<5	2	30

Note: ***italicized***, ***bold*** values exceed guidelines

TDS = total dissolved solids.

TSS = total suspended solids.

[a] Guideline value determined for the most ammonia – sensitive conditions likely to occur in Aimaokatalok River (temperature 15°C and pH 8.0) (CCME 2007).

[b] 5 µg/L CWQG when pH<6.5; 100 µg/L CWQG when pH≥6.5.

[c] Values compared to guideline corrected for hardness.

[d] 1.0 µg/L CWQG for Cr (VI), 8.9 µg/L interim CWQG for Cr (III).

[e] As CCME (2007) does not provide a guideline for total mercury, this guideline is for inorganic mercury.

All of the dissolved inorganic forms of nitrogen (ammonia, nitrate and nitrite) were below the CWQGs. Similarly, total phosphorus in Aimaokatalok River was below the 0.03 mg/L jurisdictional guideline for Northwest Territories and Nunavut (Table 3.9).

Total metal concentrations were below the CWQGs for the protection of aquatic life, with the exception of aluminum and iron. Total aluminum exceeded the CWQG (5 µg/L when pH<6.5) once in a spring sample (74 µg/L) and once in the summer (17 µg/L) (Table 3.9). Total iron exceeded the 300 µg/L guideline, with a concentration of 550 µg/L in June 1997. The spring samples with total iron and total aluminum concentrations exceeding the CWQGs, also had an unusually high TSS concentration (19 mg/L); therefore, it is possible that the sample was contaminated with sediments.

The detection limits for mercury (0.05 µg/L) and cadmium (0.2 µg/L) were above their respective CWQGs (0.026 µg/L for mercury and 0.017 µg/L for cadmium); therefore, it is possible that small exceedences of the guidelines may have occurred in mercury and cadmium concentrations without being detected.

3.3.4 Stickleback Outflow

Stickleback Outflow was sampled on 12 occasions between August 1992 and June 1998. Field parameters were measured on two sampling dates: 1 August 1994 and 31 July 1995. The outflow's temperatures were measured at 8.0°C in July 1995 and 9.2°C in August 1994. On the July 1995 sampling occasion, dissolved oxygen concentration was 6.3 mg/L, which is just below the 6.5 mg/L CWQG for protection of aquatic life. The stream was well oxygenated (DO was 14.9 mg/L) on the other sampling occasion.

The TSS concentrations ranged from 0 to 6 mg/L, and turbidity was generally low, between 0.6 and 6.3 NTU (Table 3.10).

On two sampling dates, the laboratory measured pH value for Stickleback Outflow was outside the CWQG range of pH 6.5 – 9.0; the measurements were pH 5.8 and 6.4. The laboratory result of pH 5.8 had the corresponding field measurement of pH 6.9 (within the CWQG range). In the remaining Stickleback Outflow samples, the pH ranged from 7.1 to 8.1 (Appendix A6).

All of the dissolved inorganic forms of nitrogen (ammonia, nitrate, and nitrite) were below the CWQGs. Total phosphorus in Stickleback Outflow did not exceed the 0.030 mg/L jurisdictional guideline for Northwest Territories and Nunavut (Table 3.10).

Total aluminum exceeded the 5 µg/L CWQG when pH<6.5 on one sampling date in July 1995. The total concentrations of copper and iron exceeded their respective CWQGs on one summer sampling occasion each (on different dates). The total copper concentration exceedance was 3 µg/L and only slightly above the 2 µg/L CWQGs (Table 3.10). In contrast, the total iron concentration of 1640 µg/L was considerably above the 300 µg/L CWQG. In the same sample, the total calcium and magnesium concentrations were also unusually high (Appendix A6).

The cadmium and mercury detection limits (0.2 µg/L and 0.05 µg/L, respectively) were above their CWQGs (0.017 µg/L for total cadmium and 0.026 µg/L for mercury). Therefore, it is possible that small exceedences of the guidelines may have occurred in mercury and total cadmium concentrations without being detected.

3.3.5 Fickle Duck Outflow

Fickle Duck Outflow was sampled on 12 occasions between August 1992 and June 1998. Field parameters were measured on two sampling dates: 1 August 1994 and 31 July 1995. The outflow’s temperatures were measured at 6.0°C in July 1995 and 8.8°C in August 1994. Dissolved oxygen concentrations did not fall below the 6.5 mg/L CWQG for protection of aquatic life. On one occasion, DO (8.2 mg/L) was measured below the 9.5 mg/L CWQG for protection of early life stages of aquatic life.

Table 3.10 Baseline Water Quality in Stickleback Outflow, 1992 to 1997

Parameter	Spring (June)				Summer (August and September)				Guidelines for Protection of Aquatic Life
	Median	Min	Max	n	Median	Min	Max	n	
Physical									
Conductivity (µS/cm)	126	92	202	4	175	35	284	8	-
pH (units)	7.1	7.0	7.2	4	7.2	***5.8***	8.1	8	6.5 - 9.0
TDS (mg/L)	92	58	119	4	119	28	130	7	-
TSS (mg/L)	2	<1	4	3	2	<1	6	6	short-term increase: <25; long-term increase <5
Turbidity (NTU)	1.0	0.9	1.3	4	1.5	0.6	6.3	8	short-term increase <8; long-term increase <2
Dissolved Anions (mg/L)									
Hardness ($CaCO_3$)	38	23	59	4	49	9	64	8	-
Total Alkalinity ($CaCO_3$)	30	14	41	4	31	6	53	8	-
Chloride	21	15	37	3	36	17	41	7	-
Fluoride	0.04	0.03	0.05	3	0.05	0.03	0.09	7	0.12
Sulphate	<1	<1	2.3	4	0.3	<0.5	2.0	8	-
Nutrients (mg/L)									
Dissolved Phosphorus	-	0.005	0.008	2	0.002	<0.001	0.008	7	-
Total Phosphorus	0.012	0.008	0.020	3	0.008	0.004	0.022	7	0.030 (jurisdictional)
Ammonia Nitrogen	0.150	<0.005	0.020	3	0.027	<0.005	0.390	7	0.572[a]
Nitrate - nitrogen	<0.005	<0.005	0.010	3	0.013	<0.005	0.025	7	13
Nitrite - nitrogen	<0.001	<0.001	0.006	3	<0.001	<0.001	0.001	7	0.06
Total Metals (µg/L)									
Aluminum	13	6	15	3	25	<1	43	6	5 or 100[b]
Antimony	<0.1	<0.05	<0.1	3	<0.2	<0.05	0.1	6	-
Arsenic	0.2	<2	0.3	3	0.4	<1	3.0	7	5.0
Barium	<10	3	<10	4	5.0	4.3	5.2	7	-
Beryllium	<5	<0.5	<5	4	<5	<0.5	1.7	7	
Bismuth	<0.5	-	-	1	<0.5	<0.03	0.06	4	
Boron	6	-	-	1	17	15	32	4	-
Cadmium	<0.2	***0.09***	<10	4	<0.2	<0.05	***0.12***	7	0.017[c]
Calcium	8 960	5 920	14 300	4	13 400	2 080	20 300	7	-
Chromium	<1	<1	0.60	3	0.5	<1	0.9	5	1.0 or 8.9[d]
Cobalt	<1	0.20	<1	3	0.500	<0.1	0.880	6	
Copper	<1	<1	0.5	3	0.7	0.2	***3.0***	7	2
Iron	78	50	170	4	101	30	***1 640***	7	300
Lead	<1	<0.05	<1	3	0.4	0.1	1.0	7	1
Lithium	<10	2	<15	4	<10	2	63	6	
Magnesium	3 700	2 330	5 460	4	5 050	982	10 300	7	
Manganese	71	13	207	4	10	<5	317	7	-
Mercury	<0.05	-	-	1	<0.05	<0.05	<0.05	3	0.026[e]
Molybdenum	<1	<0.05	<1	3	0.1	<0.05	<1	7	73
Nickel	<1	<1	0.5	3	<1	0.1	2.6	6	25
Potassium	950	830	1 530	3	1 490	1 250	2 140	6	
Selenium	<0.5	<0.5	<0.5	3	<0.5	<0.5	1	5	1.0
Silicon	180	150	510	3	250	90	380	5	
Silver	<0.1	<0.01	<0.1	3	0.030	<0.01	<0.1	6	0.1
Sodium	8 740	5 000	13 700	4	11 200	2 400	18 500	7	-
Strontium	43	23	70	4	59	6	93	7	-
Thallium	<0.05	-	-	1	<0.05	<0.03	<0.05	4	
Tin	<0.1	-	-	1	<0.1	<0.1	0.2	4	

Table 3.10 Baseline Water Quality in Stickleback Outflow, 1992 to 1997 (continued)

Parameter	Spring (June)				Summer (August and September)				Guidelines for Protection of Aquatic Life
	Median	Min	Max	n	Median	Min	Max	n	
Titanium	<10	<1	<10	4	<10	<1	6	7	
Tungsten	-	-	-	0	-	0.08	0.10	2	
Uranium	<0.01	-	-	1	-	<0.01	0.05	2	-
Vanadium	<1	-	-	1	<1	<1	1	4	
Zinc	<5	<5	1	4	<5	<1	7	7	30
Field WQ									
Temperature (°C)	-	-	-	-	-	8	9.2	2	-
Dissolved Oxygen (mg/L)	-	-	-	-	-	***6.3***	14.9	2	9.5 mg/L early life stages; 6.5 mg/L other life stages
pH (units)	-	-	-	-	-	6.9	8.1	2	6.5 - 9.0

Note: italicized, bold values exceed guidelines

TDS = total dissolved solids.

TSS = total suspended solids.

[a] Guideline value determined for the most ammonia – sensitive conditions likely to occur in Stickleback Outflow (temperature 15°C and pH 8) (CCME 2007).

[b] 5 µg/L CWQG when pH<6.5; 100 µg/L CWQG when pH≥6.5.

[c] Values compared to guideline corrected for hardness.

[d] 1.0 µg/L CWQG for Cr (VI), 8.9 µg/L interim CWQG for Cr (III).

[e] As CCME (2007) does not provide a guideline for total mercury, this guideline is for inorganic mercury.

The TSS concentrations were variable, ranging from 1 to 74 mg/L. The outflow was more turbid in summer, with both the TSS and turbidity medians being greater than in spring (Table 3.11). The related turbidity measurement ranged from 2 to 40 NTU suggesting that large fluctuations in TSS and turbidity may be common in Fickle Duck Outflow.

On two sampling dates, the laboratory measured pH values for the outflow were pH 5.7 and 6.3 (i.e., outside of the CWQG range of pH 6.5 to 9.0). The laboratory measurement of pH 5.7 corresponded to the field measurement of pH 6.7 (within the CWQG range). In the remaining Fickle Duck Outflow samples, the laboratory measured pH ranged from 6.6 to 7.2.

Table 3.11 Baseline Water Quality in Fickle Duck Outflow, 1992 to 1998

Parameter	Spring (June)				Summer (July and August)				Guidelines for Protection of Aquatic Life
	Median	Min	Max	n	Median	Min	Max	n	
Physical									
Conductivity (µS/cm)	38	34	43	4	68	33	200	8	-
pH (units)	6.9	***6.3***	7.1	4	6.8	***5.7***	7.2	8	6.5 - 9.0
TDS (mg/L)	24	19	32	4	57	27	160	8	-
TSS (mg/L)	1	1	10	3	12	2	74	6	short-term increase: <25; long-term increase <5
Turbidity (NTU)	2.4	2.2	5.9	4	6.5	1.9	40.0	8	short-term increase <8; long-term increase <2
Dissolved Anions (mg/L)									
Hardness ($CaCO_3$)	13	9	14	4	19	9	72	8	-
Total Alkalinity ($CaCO_3$)	10	9	12	4	15	5	79	8	-
Chloride	3	3	4	3	10	8	23	7	-
Fluoride	0.03	0.02	0.04	3	0.05	0.03	0.08	7	0.12
Sulphate	2	<1	3	4	1	1	2	8	-
Nutrients (mg/L)									
Dissolved Phosphorus	-	0.008	0.008	2	0.006	0.001	0.018	7	-
Total Phosphorus	0.016	0.015	0.016	3	0.017	0.010	***0.039***	7	0.030 (jurisdictional)
Ammonia Nitrogen	0.015	0.012	0.030	3	0.100	<0.005	0.397	7	2.6[a]
Nitrate - nitrogen	<0.005	<0.005	0.002	3	<0.005	<0.001	0.006	7	13
Nitrite - nitrogen	<0.001	<0.001	0.007	3	0.002	<0.001	0.010	7	0.06
Total Metals (µg/L)									
Aluminum	72	65	***136***	3	***102***	43	***387***	6	5 or 100[b]
Antimony	<0.1	<0.05	<0.1	3	<0.1	<0.05	0.1	6	-
Arsenic	0.1	<1	0.2	3	0.3	<1	2.0	7	5.0
Barium	<10	<10	2.5	3	4.5	<10	7.7	6	-
Beryllium	<0.5	-	-	1	<0.5	<0.5	0.5	4	-
Bismuth	<0.5	-	-	1	<0.5	<0.03	0.09	4	-
Boron	4	-	-	1	8	<1	11	4	-
Cadmium	<0.2	<0.05	<0.2	3	<0.2	<0.05	***0.140***	7	0.017[c]
Calcium	3 830	2 860	4 020	4	5 540	1 840	28 300	7	-
Chromium	<1	<1	1	3	0.7	<1	1.0	5	1.0 or 8.9[d]
Cobalt	<1	<0.1	<1	3	0.3	<0.1	1.0	6	-
Copper	1	1	1	3	2.0	0.9	***3.5***	7	2
Iron	231	210	***390***	4	***580***	76	***2 320***	7	300
Lead	<1	<1	0.1	3	<1	<0.5	0.3	7	1
Lithium	<10	<1	<10	3	-	<1	1	2	-
Magnesium	974	863	1 000	4	1 830	995	9 560	7	-
Manganese	1	<5	9	4	6	<5	118	7	-
Mercury	<0.05	-	-	1	<0.05	<0.05	<0.05	3	0.026[e]
Molybdenum	<1	<1	0.1	3	<1	<0.16	0.230	7	73
Nickel	<1	<1	0.6	3	1.5	0.8	3.3	6	25
Potassium	290	270	720	3	570	360	3 030	6	-

Table 3.11 Baseline Water Quality in Fickle Duck Outflow, 1992 to 1998 (continued)

Parameter	Spring (June)				Summer (July and August)				Guidelines for Protection of Aquatic Life
	Median	Min	Max	n	Median	Min	Max	n	
Selenium	<0.5	<0.5	<0.6	3	<0.5	<0.5	1.0	5	1.0
Silicon	470	340	830	3	500	277	2 590	5	-
Silver	<0.1	<0.01	<0.1	3	0.01	<0.1	0.06	6	0.1
Sodium	2 160	1 740	2 500	4	4 620	2 400	9 430	7	-
Strontium	12	10	23	4	28	6	67	7	-
Thallium	<0.05	-	-	1	<0.05	<0.03	<0.05	4	0.8
Tin	<0.1	-	-	1	0.10	<0.09	<0.1	4	-
Titanium	1	-	-	1	3	1	21	4	-
Tungsten	-	-	-	0	-	0.07	0.10	2	-
Uranium	<0.01	-	-	1	-	<0.01	0.050	2	-
Vanadium	<1	-	-	1	0.5	<1	1.0	4	-
Zinc	<5	<5	2	4	2	<5	5	7	30
Field WQ									
Temperature (°C)	-	-	-	-	-	6.0	8.8	2	-
Dissolved Oxygen (mg/L)	-	-	-	-	-	***8.2***	12.4	2	9.5 mg/L early life stages; 6.5 mg/L other life stages
pH (units)	-	-	-	-	-	6.7	6.8	2	-

Note: ***italicized***, ***bold*** values exceed guidelines

TDS = total dissolved solids.

TSS = total suspended solids.

[a] Guideline value determined for the most ammonia – sensitive conditions likely to occur in Fickle Duck Outflow (temperature 10°C and pH 7.5) (CCME 2007).

[b] 5 µg/L CWQG when pH<6.5; 100 µg/L CWQG when pH≥6.5.

[c] Values compared to guideline corrected for hardness.

[d] 1.0 µg/L CWQG for Cr (VI), 8.9 µg/L interim CWQG for Cr (III).

[e] As CCME (2007) does not provide a guideline for total mercury, this guideline is for inorganic mercury.

Total alkalinity was generally low, ranging from 5 to 18 mg $CaCO_3$/L, with the exception of one measurement (79 mg $CaCO_3$/L) made in August 1994.

All of the dissolved inorganic forms of nitrogen (ammonia, nitrate, and nitrite) were below the CWQGs. Total phosphorus exceeded the 0.03 mg/L jurisdictional guideline for Northwest Territories and Nunavut on two sampling dates in August 1996. These two exceedences coincided with high turbidity values, which also exceeded the CWQGs. This may have been due to sediment and TP contributions from surface drainage following rainfall events.

The total concentrations of four metals (aluminum, cadmium, copper, and iron) exceeded their respective CWQGs for the protection of aquatic life. The cadmium and copper exceedences occurred on one sampling date each and were only slightly above the CWQGs (Table 3.11). In contrast, the aluminum and iron exceedences, when present, were more substantial and occurred in four of 12 samples for aluminum and in six of 12 samples for iron. The total cadmium exceedance coincided with the greatest TSS and turbidity values, whereas the total copper and the greatest total iron (2320 µg/L) exceedances occurred in the same August 1994 sample with the unusually high total alkalinity (79 mg/L). All samples with a total aluminum exceedence also had total a iron exceedence, but did not appear to be related to TSS.

The mercury analyses were conducted for only four of the samples and with 0.05 µg/L detection limits (higher than the 0.026 µg/L CWQG). The cadmium detection limits for all but two samples were above the CWQG (0.017 µg/L); therefore, it is possible that small exceedences of the guidelines may have occurred in mercury and total cadmium concentrations without being detected. All metal exceedences in Fickle Duck Outflow were also reported for Fickle Duck Lake (there were two more metal exceedences in the lake).

3.3.6 Koignuk River

Koignuk River was sampled on four occasions between June 1998 and September 2000. Field parameters were not measured on any of the sampling dates.

The TSS concentrations ranged from 2 to 12 mg/L in Koignuk River. The related measure of turbidity yielded measurements from 2 to 36.3 NTUs (Table 3.12). Factors such as colour of water were possibly responsible for the greater increases in turbidity, more so than TSS (CCME 2007).

The laboratory measured pH for the river ranged from 6.9 to 7.4 pH units, remaining within the CWQG range of pH 6.5 to 9.0. Total alkalinity was low, ranging from 8 to 15 mg $CaCO_3$/L (Table 3.12).

All of the dissolved inorganic forms of nitrogen (ammonia, nitrate, and nitrite) were below the CWQGs. Total phosphorus in Koignuk River exceeded the 0.030 mg/L jurisdictional guideline for Northwest Territories and Nunavut in one spring sample, with a TP concentration of 0.051 mg/L (Table 3.12).

The total concentrations of four metals (aluminum, chromium, copper, and iron) exceeded their respective CWQGs for the protection of aquatic life. Both the chromium and copper exceedences occurred once, on the same sampling date, and were only slightly above their respective CWQGs (Table 3.12). In contrast, the aluminum and iron exceedences were substantial, and occurred on three of

Table 3.12 Baseline Water Quality in Koignuk River, 1998 to 2000

Parameter	Spring (June)				Summer (August and September)				Guidelines for Protection of Aquatic Life
	Median	Min	Max	n	Median	Min	Max	n	
Physical									
Conductivity (µS/cm)	-	61	90	2	-	65	169	2	-
pH (units)	-	6.9	7.2	2	-	6.8	7.4	2	6.5 - 9.0
TDS (mg/L)	-	47	74	2	-	48	101	2	-
TSS (mg/L)	-	10	12	2	-	2	6	2	short-term increase <25; long-term increase <5
Turbidity (NTU)	-	10.4	36.3	2	-	3.2	8.5	2	short-term increase <8; long-term increase <2
Dissolved Anions (mg/L)									
Hardness (CaCO3)	-	16.2	22.7	2	-	13.7	36.4	2	-
Total Alkalinity	-	9	11	2	-	8	14	2	-
Chloride	-	9.1	14.9	2	-	14.9	35	2	-
Fluoride	-	0.04	0.09	2	-	0.05	0.06	2	0.12
Sulphate	-	2	4	2	-	2	9	2	-
Nutrients (mg/L)									
Dissolved phosphorus	0.007	-	-	1	-	-	-	1	-
Total phosphorus	***0.051***	-	-	1	0.014	-	-	1	0.030 (jurisdictional)
Ammonia nitrogen	-	0.02	0.031	2	0.011	-	-	1	0.19[a]
Nitrate - nitrogen	-	0.009	0.012	2	<0.005	-	-	1	13
Nitrite - nitrogen	-	0.001	0.001	2	<0.001	-	-	1	0.06
Total Organic Carbon	6.5	-	-	1	5.7	-	-	1	
Total Metals (µg/L)									
Aluminum	-	***429***	***1 400***	2	-	100	***282***	2	5 or 100[b]
Antimony	-	<0.05	<0.1	2	-	<0.1	<0.05	2	-
Arsenic	-	0.20	0.4	2	-	0.30	0.30	2	5.0
Barium	-	6.40	20	2	-	<10	6.23	2	-
Beryllium		<0.5	<5	2		<0.5	<5	2	-
Bismuth	<0.5	-	-	1	<0.5	-	-	1	-
Boron	-	<100	5	2	-	<100	8	2	-
Cadmium	-	<0.05	<0.2	2	-	<0.05	<0.2	2	0.017[c]
Calcium	-	3 450	4 070	2	-	2 610	6 630	2	-
Chromium	-	0.9	***3.0***	2	-	<1	0.7	2	1.0 or 8.9[d]
Cobalt	-	<1	0.3	2	-	<1	0.2	2	-
Copper	-	2	***3***	2	-	1	2	2	2
Iron	-	***560***	***1 200***	2	-	140	***360***	2	300
Lead	-	0.24	<1	2	-	<1	0.23	2	1
Lithium	1	-	-	1	2	-	-	1	-
Magnesium	-	1 900	3 100	2	-	1 700	4 800	2	-
Manganese	-	24	41	2	-	9	12	2	-
Mercury	-	<0.05	<0.05	2	-	<0.05	<0.05	2	0.026[e]

Table 3.12 Baseline Water Quality in Koignuk River, 1998 to 2000 (continued)

Parameter	Spring (June)				Summer (August and September)				Guidelines for Protection of Aquatic Life
	Median	Min	Max	n	Median	Min	Max	n	
Molybdenum	-	<1	0.06	2	-	<1	0.09	2	73
Nickel	-	1.1	2	2	-	<1	0.9	2	25
Potassium	-	<2 000	1 940	2	-	650	1 350	2	-
Selenium	-	<1	0.5	2	-	0.6	<1	2	1.0
Silver	-	<0.1	0.02	2	-	<0.01	<0.1	2	0.1
Sodium	-	5 000	9 000	2	-	6 000	14 900	2	-
Strontium	22	-	-	1	24	-	-	1	-
Titanium	70	-	-	1	<10	-	-	1	-
Uranium	0.05	-	-	1	0.05	-	-	1	-
Vanadium	<1	-	-	1	<1	-	-	1	-
Zinc		<5	2	2	-	<5	2	2	30

Note: italicized, bold values exceed guidelines

TDS = total dissolved solids.

TSS = total suspended solids.

[a] Guideline value determined for the most ammonia – sensitive conditions likely to occur in Koignuk River (temperature 15°C and pH 8.5) (CCME 2007).

[b] 5 µg/L CWQG when pH<6.5; 100 µg/L CWQG when pH≥6.5.

[c] Values compared to guideline corrected for hardness.

[d] 1.0 µg/L CWQG for Cr (VI), 8.9 µg/L interim CWQG for Cr (III).

[e] As CCME (2007) does not provide a guideline for total mercury, this guideline is for inorganic mercury.

the four sampling dates. On the one sampling occasion when the four metals were measured at their highest concentrations, turbidity and TSS were both high (Table 3.12). One possibility is that the sample was contaminated with sediments. In addition, the analytical method detection limits for cadmium and mercury were above their respective CWQGs (Table 3.12); therefore, it is possible that small exceedences of the guidelines may have occurred in mercury and total cadmium concentrations in Koignuk River without being detected.

3.3.7 Reference Outflow

Reference Outflow was sampled on five occasions between July 1997 and August 1998. Field parameters were not measured on any of the sampling dates.

The TSS concentrations ranged from <1 to 4 mg/L. The related measure of turbidity was similarly low (Table 3.13). The laboratory measured pH for the outflow ranged from 6.5 to 6.8 pH units, remaining within the CWQG range of pH 6.5 to 9.0. Total alkalinity was low, ranging from 8 to 13 mg $CaCO_3$/L (Table 3.13).

Table 3.13 Baseline Water Quality in Reference Outflow, 1997 to 1998

Parameter	Spring (June)				Summer (July and August)				Guidelines for Protection of Aquatic Life
	Median	Min	Max	n	Median	Min	Max	n	
Physical									
Conductivity (µS/cm)	-	27	37	2	39	38	56	3	-
pH (units)	-	6.6	6.7	2	6.8	6.7	6.8	3	6.5 – 9.0
TDS (mg/L)	-	15	38	2	32	32	34	3	-
TSS (mg/L)	-	<1	4	2	3	3	4	3	short-term increase <25; long-term increase <5
Turbidity (NTU)	-	1.8	3.1	2	2.9	2.4	3.5	3	short-term increase <8; long-term increase <2
Dissolved Anions (mg/L)									
Hardness ($CaCO_3$)	-	10.4	12.0	2	14.8	12.7	17.4	3	-
Total Alkalinity ($CaCO_3$)	-	8.0	10.0	2	12.0	11.0	13.0	3	-
Chloride	-	3.0	3.4	2	4.1	3.0	4.6	3	-
Fluoride	-	0.02	0.03	2	0.06	0.03	0.07	3	0.12
Sulphate	-	<1	1	2	1	1	2	3	-
Nutrients (mg/L)									
Dissolved Phosphorus	0.007	-	-	1	-	<0.001	0.001	2	-
Total Phosphorus	0.026	-	-	1	-	0.008	0.016	2	0.030 (jurisdictional)
Ammonia Nitrogen	<0.005	-	-	1	-	0.132	0.184	2	1.78[a]
Nitrate - nitrogen	<0.005	-	-	1	-	0.003	0.004	2	13
Nitrite - nitrogen	0.002	-	-	1	-	0.001	0.001	2	0.06
Total Metals (µg/L)									
Aluminum	-	38	85	2	47	42	***133***	3	5 or 100[b]
Antimony	-	<0.1	<0.1	2	<0.1	<0.1	<0.1	3	-
Arsenic	-	0.2	0.4	2	0.4	0.4	0.5	3	5.0
Barium	-	<10	<10	2	<10	<10	<10	3	-
Beryllium	-	<5	<5	2	<5	<5	<5	3	-
Cadmium	-	<0.2	<0.2	2	<0.2	<0.2	<0.2	3	0.017[c]
Calcium	-	2 830	3 160	2	4 010	3 570	4 660	3	
Chromium	-	<1	<1	2	<1	<1	<1	3	1.0 or 8.9[d]
Cobalt	-	<1	<1	2	<1	<1	<1	3	
Copper	-	1	2	2	2	2	2	3	2
Iron	-	140	***410***	2	***320***	280	***420***	3	300
Lead	-	<1	<1	2	<1	<1	<1	3	1
Magnesium	-	800	1 000	2	1 200	990	1 410	3	
Manganese	-	<5	158	2	6	6	13	3	-
Mercury	-	<0.05	<0.05	2	-	<0.05	<0.05	2	0.026[e]
Molybdenum	-	<1	<1	2	<1	<1	<1	3	73
Nickel	-	<1	<1	2	<1	<1	<1	3	25
Potassium	-	320	2450	2	370	350	510	3	
Selenium	-	<0.5	<0.5	2	<0.5	<0.5	0.6	3	1.0

Table 3.13 Baseline Water Quality in Reference Outflow, 1997 to 1998 (continued)

Parameter	Spring (June)				Summer (July and August)				Guidelines for Protection of Aquatic Life
	Median	Min	Max	n	Median	Min	Max	n	
Silicon	-	290	330	2	230	200	520		
Silver	-	<0.1	<0.1	2	<0.1	<0.1	<0.1	3	0.1
Sodium	-	1 610	1 680	2	2 370	2 200	2 620	3	-
Strontium	-	6	15	2	19	16	20	3	
Zinc	-	<5	7	2	<5	<5	<5	3	30

Note: italicized, bold values exceed guidelines.

TDS = total dissolved solids.

TSS = total suspended solids.

[a] Guideline value determined for the most ammonia – sensitive conditions likely to occur in Reference Outflow (temperature 15°C and pH 7.5) (CCME 2007).

[b] 5 µg/L CWQG when pH<6.5; 100 µg/L CWQG when pH≥6.5.

[c] Values compared to guideline corrected for hardness.

[d] 1.0 µg/L CWQG for Cr (VI), 8.9 µg/L interim CWQG for Cr (III).

[e] As CCME (2007) does not provide a guideline for total mercury, this guideline is for inorganic mercury.

All of the dissolved inorganic forms of nitrogen (ammonia, nitrate, and nitrite) were below the CWQGs. Total phosphorus in Reference Outflow was measured on three of the sampling dates, and did not exceed the 0.030 mg/L jurisdictional guideline for Northwest Territories and Nunavut (Table 3.13).

The concentrations of total aluminum and iron exceeded their respective CWQGs for the protection of aquatic life. Total aluminum exceeded its 100 µg/L CWQG on one occasion (August 1997) when its concentration reached 133 µg/L. Total iron concentrations were above the 300 µg/L CWQG on three sampling dates (Table 3.13). In addition, the analytical method detection limits for cadmium (<0.2 µg/L) and mercury (<0.05 µg/L) were above their CWQGs, therefore, it is possible that small exceedences of the guidelines may have occurred in mercury and total cadmium concentrations in Reference Outflow without being detected.

3.3.8 Summary

Water quality data are presented for Aimaokatalok NE Inflow, Aimaokatalok Outflow, Aimaokatalok River, Stickleback Outflow, Fickle Duck Outflow, Koignuk River, and Reference Outflow. The largest water quality datasets (n = 12, collected between 1992 and 1998) are available for Fickle Duck and Stickleback outflows.

Field parameters (DO, pH, and temperature) were measured only in Aimaokatalok NE Inflow (on three dates), Fickle Duck Outflow and Stickleback Outflow (on two dates each) during open-water conditions. The stream temperatures ranged from 6 to 11.9°C, and the streams were well oxygenated, with only one DO concentration in Stickleback Lake falling marginally below the 6.5 mg/L CWQG for protection of coldwater aquatic life.

The clarity of the stream and river sites, as represented by TSS and turbidity, was more variable than that of the lake sites. Overall, the TSS ranged from <1 to 74 mg/L, and the turbidity ranged from 0.4 to 40 NTU.

Field measurements of pH were similar (though not the same) to the laboratory measurements of pH (available for nearly all sampling events). On a few occasions, the pH in Aimaokatalok NE Inflow and River, Stickleback Outflow and Fickle Duck Outflow was below (outside) the CWQG range of pH 6.5 to 9.0; however, most of the samples had a pH close to neutral.

Total alkalinity of the flowing waters was similar to the Boston area lakes. Stickleback Outflow typically had the highest mean values (30 and 31 mg $CaCO_3$/L total alkalinity for spring and summer, respectively). Aimaokatalok River had the lowest values (total alkalinity between 4 and 14 mg $CaCO_3$/L). Anomalously high total alkalinity (and other parameters such as conductivity, hardness, and total iron) were measured in August 1994 water quality samples from Stickleback and Fickle Duck outflows (total alkalinity of 53 and 79 mg $CaCO_3$/L, respectively). Such sporadic and major spikes in these parameters were also observed in the lakes, though on different dates.

None of the inorganic forms of nitrogen (ammonia, nitrate, and nitrite) exceeded their respective CWQGs. TP was generally below the 0.030 mg/L jurisdictional guidelines for Northwest Territories and Nunavut except one sample from each of Aimaokatalok NE Inflow (0.041 mg/L) and Koignuk River (0.051 mg/L) and two samples from Fickle Duck Outflow (0.039 mg/L and 0.036 mg/L). Notably, all of these samples also had the highest turbidity values (all exceeding CWQGs) for the particular site.

In all seven flowing waters sampled in the Boston area, exceedences of CWQG occurred for at least one metal (Table 3.14). Overall, total aluminum and total iron comprised the greatest and most frequent exceedences of CWQGs (up to 1400 µg/L of total aluminum in Koignuk River and up to 2320 µg/L of total iron in Fickle Duck Outflow). Only in Aimaokatalok Outflow were both aluminum and iron concentrations below the CWQGs, whereas Aimaokatalok River was the only other flowing site where aluminum (but not iron) was also below the CWQG. Similar to the lake sites, additional exceedences of CWQGs occurred for cadmium, chromium, copper, and lead. Total zinc also exceeded the 30 µg/L CWQG at Aimaokatalok NE Inflow (but not at any of the lake sites). In contrast to the lake samples, no exceedences of CWQGs occurred for mercury or selenium.

Table 3.14 Summary of Total Metals and Other Water Quality Parameters That Exceeded CWQGs (✓) at Least Once in the Boston Area Streams and River Sites, 1992 to 2000

Site	pH	TP	Al	Cd	Cr	Cu	Fe	Zn
Aimaokatalok NE Inflow	✓	✓	✓	✓	✓	✓	✓	✓
Aimaokatalok Outflow	-	-	-	-	-	✓	-	-
Aimaokatalok River	✓	-	✓	-	-	-	✓	-
Stickleback Outflow	✓	-	✓	✓	-	✓	✓	-
Fickle Duck Outflow	✓	✓	✓	✓	-	✓	✓	-
Koignuk River	-	✓	✓	-	✓	✓	✓	-
Reference Outflow	-	-	✓	-	-	-	✓	-

Mercury and cadmium method detection limits were greater than their respective CWQGs for the majority of water samples collected between 1992 and 2000. Therefore, it is possible that small-scale CWQG exceedences of the total cadmium and mercury may have occurred undetected during the 1992 to 2000 monitoring period.

3.4 MARINE WATER QUALITY

3.4.1 Hope Bay

Marine water quality samples were collected from three sites in Hope Bay on 23 August 1997 and 21 July 1998. Analytical results for individual samples are presented in Appendix A7.

Temperature and dissolved oxygen profiles were measured only in July 1998 at the three sampling stations (Figure 3.6). On 21 July 1998, the upper 3 m of water column were warmest, with temperatures ranging from 7.1 to 11.3°C. At the deepest station, the temperature gradually declined to 0.5°C at 7.5 m. The water column was well oxygenated, with DO ranging from 9.5 mg/L near water surface to 11 mg/L at 7.5 m (the cooler temperatures near the bottom increase the capacity of water to carry dissolved oxygen).

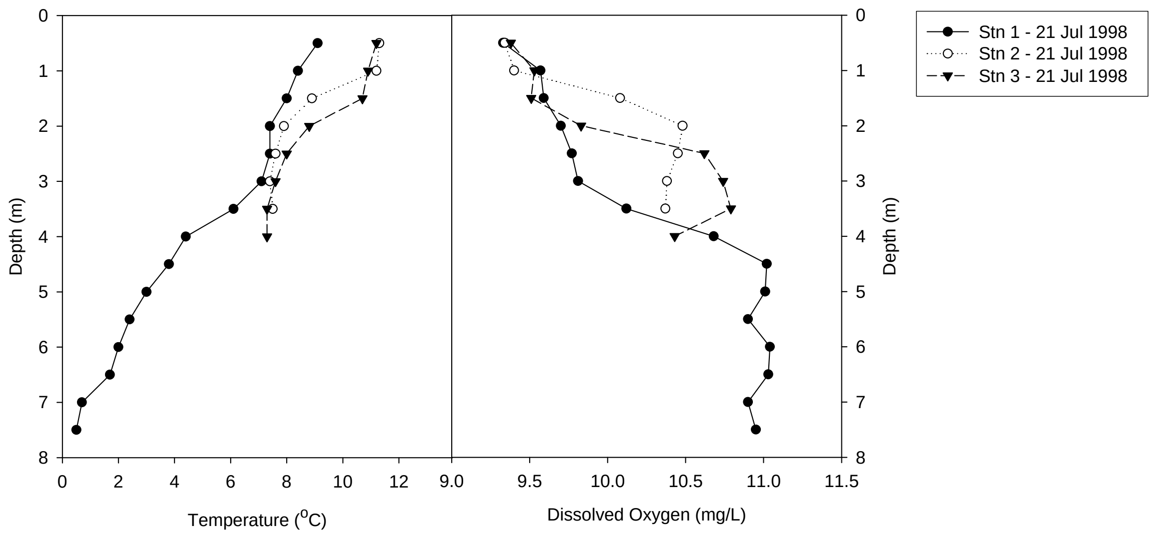


Figure 3.6 Temperature and Dissolved Oxygen Profiles in Hope Bay, 1998

The TSS concentration ranged from 2 to 21 mg/L; the turbidity was less variable, ranging from 0.5 to 2.6 NTU (Table 3.15).

Table 3.15 Baseline Water Quality in Hope Bay, August 1997 and July 1998

Parameter	Ice Free (July and August)				Guidelines for Protection of Marine Aquatic Life[a]
	Median	Min	Max	n	
Physical					
Conductivity (µmhos/cm)	34 100	15 300	48 800	7	-
pH (units)	7.9	7.4	7.9	7	7.0 - 8.7
Total Dissolved Solids (mg/L)	21 700	11 900	25 600	7	-
Total Suspended Solids (mg/L)	10	2	21	7	-
Turbidity (NTU)	1.5	0.5	2.6	7	-
Salinity (‰)	19	10	20	3	
Dissolved Anions (mg/L)					
Hardness ($CaCO_3$)	3 860	2 030	4 430	7	-
Total Alkalinity ($CaCO_3$)	90	60	103	7	-
Chloride	11 600	6 310	14 800	7	-
Fluoride	0.54	0.28	0.70	7	-
Sulphate	1 330	630	1 590	7	-
Nutrients (mg/L)					
Dissolved Phosphorus	0.011	0.005	0.018	4	-
Total Phosphorus	0.021	0.018	0.028	4	-
Ammonia	0.006	0.004	0.010	4	-
Nitrate - nitrogen	0.001	0.001	0.004	4	16[b]

Table 3.15 Baseline Water Quality in Hope Bay, August 1997 and July 1998 (continued)

Parameter	Ice Free (July and August)				Guidelines for Protection of Marine Aquatic Life[a]
	Median	Min	Max	n	
Nitrite - nitrogen	<0.001	<0.001	0.001	4	-
Dissolved Metals (µg/L)					
Antimony	<0.2	<0.1	<0.2	8	-
Arsenic	0.6	0.4	1.0	8	12.5
Cadmium	0.03	0.02	0.04	8	0.12
Calcium	237 000	128 000	287 000	8	
Chromium	<1	<1	<1	8	1.5 or 56[c]
Cobalt	<0.05	<0.05	<0.05	8	
Copper	0.64	0.49	0.81	8	-
Iron	<10	<10	10	8	-
Lead	0.11	<0.05	0.4	8	-
Magnesium	779 000	415 000	903 000	8	
Manganese	1.57	0.95	1.88	8	-
Mercury	0.01	<0.01	***0.02***	8	0.016[d]
Molybdenum	6.5	4.0	9.0	8	-
Nickel	0.57	0.51	0.71	8	-
Selenium	<0.5	<0.5	<0.5	8	2
Silver	<1	<1	<1	8	-
Uranium	1.00	0.59	1.62	8	-
Zinc	0.5	<0.5	2.3	8	-

[a] Marine Guidelines for protection of Aquatic Life (CWQGs) are for total metal concentrations.
[b] Interim guideline for protection from direct toxic effects.
[c] Interim 1.5 µg/L guideline for Cr(VI) and 56 µg/L interim guideline for Cr(III).
[d] Interim guideline may not fully protect high trophic level fish.

Metal analyses in Hope Bay were done only for dissolved metals, for which there are no specific CWQGs; CWQGs exist only for total metal concentrations. Total metal concentrations are either equal to or greater than that of dissolved metals; therefore, if dissolved metal concentrations exceed the CWQGs for total metals, it can be considered an exceedance of the CWQG. Dissolved metal concentrations in Hope Bay were below the CWQG, with the exception of mercury, which was measured at 0.02 µg/L on one occasion. The mercury CWQG for marine waters is 0.016 µg/L. The lower precision of the maximum mercury result for Hope Bay compared to the guideline (two decimal places vs three decimal places) means that it is impossible to determine whether the maximum mercury concentration (0.02 µg/L) was the same as, just above, or just below (e.g., 0.015 µg/L) the CWQG guideline (Table 3.15).

4 SEDIMENT QUALITY

This section presents information on baseline sediment quality conditions for Boston area lakes. The information presented is based on data from annual data reports (Rescan 1994, 1997, and 1998).

Sediment quality data were collected in the summer months of 1993, 1996, and 1997. Due to small sample sizes, summary statistics were not calculated. The results are discussed in the following sections in terms of individual station data.

4.1 METHODS

4.1.1 Sampling Locations and Timing

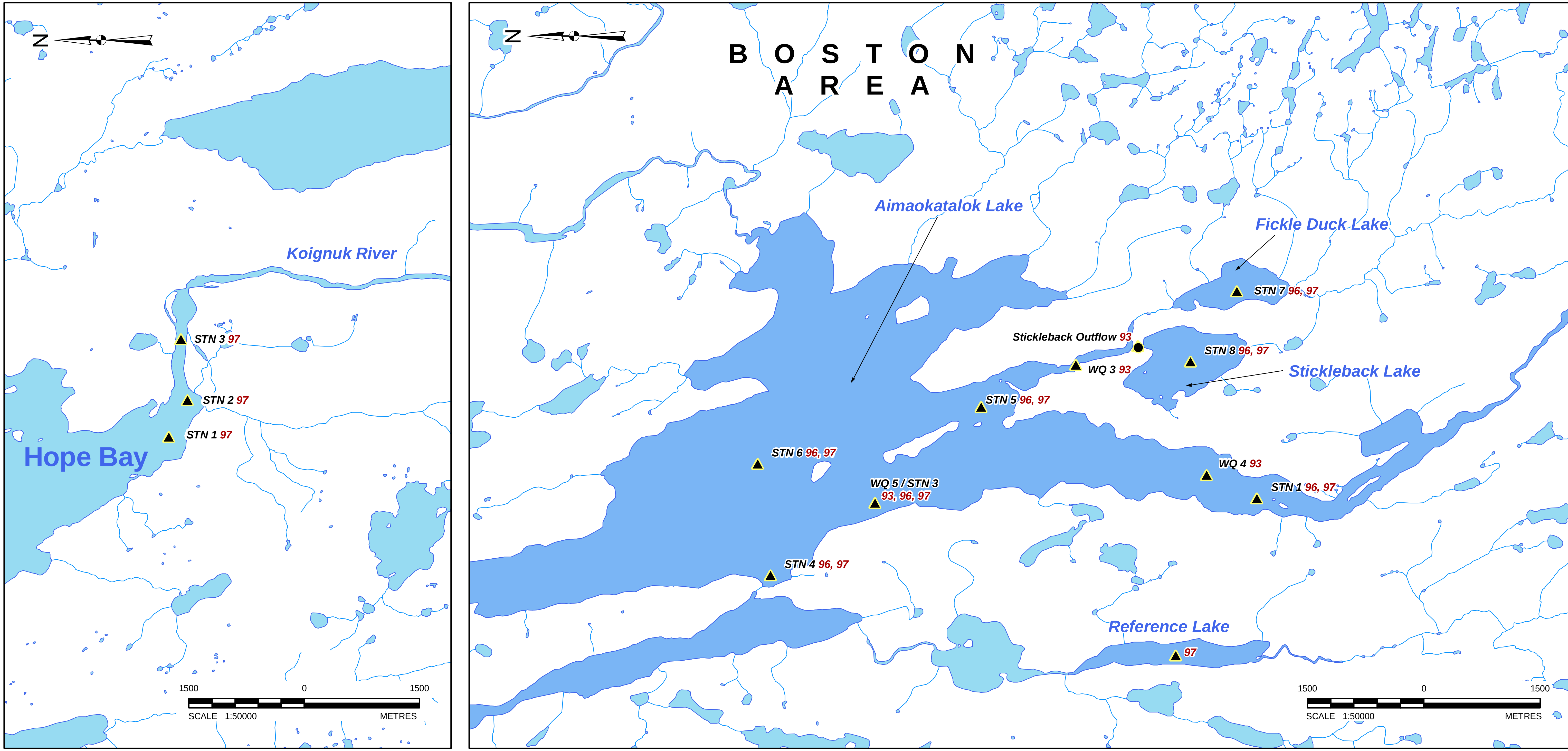
Sediment sampling locations are shown in Figure 4.1 and Table 4.1. Detailed sampling methods are included in the annual reports (Rescan 1994, 1997, and 1998) and summarized in Appendix A1.

Table 4.1 Years of Sediment Sampling in Boston Area Lakes, Outflows, and Hope Bay, 1993 to 1997

Waterbody	Summer 1993	Summer 1996	Summer 1997
Aimaokatalok Lake	√	√	√
Stickleback Lake		√	√
Fickle Duck Lake		√	√
Fickle Duck Outflow	√		
Reference Lake			√
Hope Bay			√

Sediment samples were collected in the lakes during the summer sampling season (i.e., July and August). Bottom sediment samples were collected using an Ekman grab sampler from the deepest parts of the lakes at the same sites used for water quality sampling. Collected sediment grabs were sub-sampled (top 2 to 3 cm) for analysis of various physical and chemical parameters. In addition, sediment grabs were visually examined in the field in 1996 and 1997 for colour, texture, grain size and presence/absence of biota.

Project: N:\GIS\Projects\2006\1373\027\MapDocs\4.1_Boston_Hope_Bay_Areas.mxd Plot: N:\GIS\Projects\2006\1373\027\MapDocs\4.1_Boston_Hope_Bay_Areas.pdf



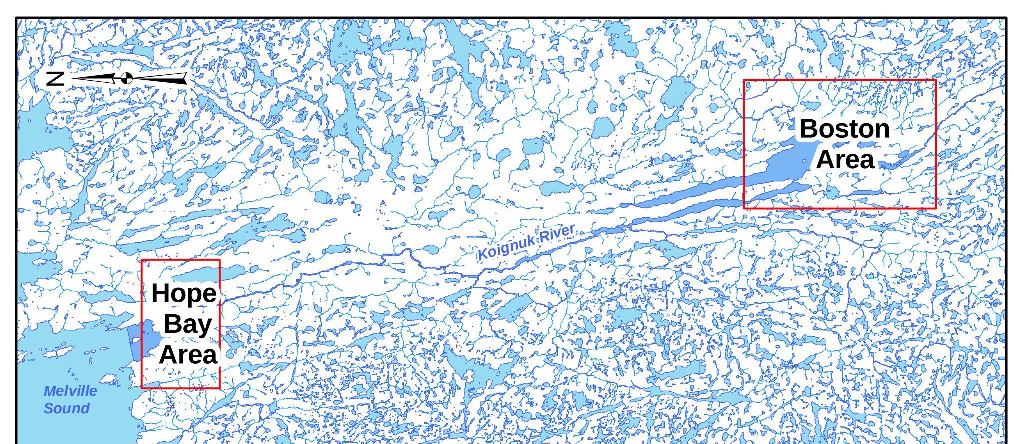
LEGEND

▲ Lake/marine sampling locations	*WQ X / STN X* Sampling station names from Rescan reports
● Stream sampling locations	*95-97* Consecutive years of sampling at station
Rivers	
Study area waterbodies	
Waterbodies	

REFERENCE

Sources: Data Obtained from the Government of Canada, Natural Resources Canada, Centre for Topographic Information
Projection: UTM Zone 13N Datum: NAD 83

This map is for information purposes only. Golder Associates Ltd. does not accept any liability arising from its misuse or misrepresentation.



MIRAMAR HOPE BAY LTD.

Boston Project Data Compilation

TITLE

Sediment Sampling Locations, 1993 - 1997

Golder Associates
Edmonton, Alberta

PROJECT No.06-1373-028			SCALE AS SHOWN	REV. 0
DESIGN	JP	22 April 2008		
GIS	RC	23 April 2008		
CHECK	JP	14 May 2008		
REVIEW	GA	16 May 2008		

FIGURE: 4.1

Baseline marine sediment quality sampling also was conducted in Hope Bay, which is the final receiving waterbody of drainage from the Aimaokatalok Lake watershed. Samples were collected in August 1997 at three marine stations within Hope Bay. In general, methods used for the collection of marine samples were similar to those used for lake sampling (Appendix A1).

4.1.2 Laboratory Analytical Methods

Sediment quality samples were analysed for moisture content, total organic carbon (TOC), and solid phase metals. Analytical detection limits are presented in Table 4.2.

Table 4.2 Detection Limits for Sediment Quality Analysis, 1993 to 1997

Parameter (units)		1993[a]	1996[b]	1997[c]
Physical Parameters	Moisture (%)	n.s.	n.s.	0.1
Organic Parameters	Total Organic Carbon	n.s.	n.s.	0.05
Total Metals	Aluminum (mg/kg)	n.s.	n.a.	50
	Antimony (mg/kg)	0.05	0.05	n.a.
	Arsenic (mg/kg)	n.s.	n.s.	0.05
	Cadmium (mg/kg)	0.1	0.05	0.1
	Colbalt (mg/kg)	n.s.	n.s.	2.0
	Copper (mg/kg)	n.s.	n.s.	1.0
	Chromium (mg/kg)	n.s.	n.s.	2.0
	Iron (mg/kg)	n.s.	n.s.	50
	Lead (mg/kg)	n.s.	n.s.	2.0
	Manganese (mg/kg)	n.s.	n.s.	1.0
	Mercury (mg/kg)	0.005	0.05	0.005
	Nickel (mg/kg)	n.s.	n.s.	2.0
	Selenium (mg/kg)	0.1	0.5	0.1
	Silver (mg/kg)	0.1	n.s.	0.1
	Zinc (mg/kg)	n.s.	n.s	1.0

[a] Detection limits not reported in Rescan (1994).
[b] Detection limits in Rescan (1997).
[c] Detection limits in Rescan (1998).
n.s. = detection limit not specified; n.a. = parameter not analyzed.

It should be noted that analytical methodologies and detection limits used for some parameters varied from year to year, largely because of different laboratories that were involved in the analyses, including Elemental Research Inc. in 1996 and Analytical Service Laboratories in 1997.

4.2 LAKE SEDIMENT QUALITY

Baseline sediment quality information for the various sampled waterbodies including Aimaokatalok, Stickleback, Fickle Duck and Reference lakes, and

Stickleback Outflow are presented in the following sections (Figure 4.1). Sediment samples collected in the various waterbodies are described based on visual characteristics including colour, texture, and grain size. Metal concentrations in sediments are compared with the Canadian Interim Sediment Quality Guidelines for the Protection of Aquatic Life (CISQG) (CCME 2007) to assess whether background sediment metal concentrations are within recommended ranges. The CISQG recommends using two guidelines in assessing sediment quality. The first, referred to as the Threshold Effect Level (TEL), is the concentration below which adverse effects are rare. The second, referred to as the Probable Effect Level (PEL), is the concentration above which adverse effects are likely to occur. This recommended procedure was followed in this report.

4.2.1 Aimaokatalok Lake

Sediments consisted primarily of clay and fine sand particles. The interfacial layer was dark reddish-brown, whereas the underlying upper layer was greenish grey or brownish yellow (Rescan 1998). The TOC concentration was low compared to most of the other study lakes, ranging from 0.3 to 1.9% dry weight (Table 4.3). The concentration of total arsenic (0.8 to 60 mg/kg) was often above the CISQG PEL and occasionally above the CISQG TEL. Similarly, total chromium (21.7 to 98.5 mg/kg) was often above the CISQG PEL and occasionally above the CISQG TEL (Table 4.3). Profile sub-sampling carried out in 1996 and 1997 indicated that total metal concentrations in the interfacial and near-surface layers were essentially indistinguishable (Table 4.3).

4.2.2 Stickleback Lake

The sediments from Stickleback Lake were soft clays or mud. The TOC concentration in the two 1996 samples (0.6 and 0.8% dry weight) were only slightly higher than TOC values in Aimaokatalok Lake. Metal concentrations in these two samples were below CISQG TEL values. A sample collected in 1997 was considerably different than the samples collected in 1996. In 1997, sediments had a TOC concentration of 18.6%. Additionally, total arsenic (5.9 mg/kg) and copper (41 mg/kg) were slightly above CISQC TEL values, but well below CISQC PEL values (Table 4.3).

Table 4.3 Sediment Chemistry in Boston Area Lakes, 1993 to 1997

Parameter	Aimaokatalok Lake							CISCQ	
Date	**1993**	**1993**	**1993**	**23-Aug-96**		**23-Aug-96**		**TEL**	**PEL**
Site	**WQ3**	**WQ4**	**WQ5**	**Stn 1**		**Stn 3**			
Depth of sample	-	-	-	1 m		12 m			
Sediment layer	-	-	-	0 - 1 cm	1 - 3 cm	0 - 1 cm	1 - 3 cm		
Moisture (%)	-	-	-	48.2	30.3	71.6	64.8		
Total Organic Carbon (%)	0.8	0.5	1.3	0.6	0.5	0.8	0.7		
Total Metals (mg/kg)									
Aluminum	63 400	59 600	75 200	-	-	-	-		
Antimony	0.1	<0.05	0.19	<0.05	<0.05	0.29	0.06		
Arsenic	1	1	11	4	1	15	60	6	17
Barium	690	619	794	-	-	-	-		
Cadmium	<0.10	<0.10	<0.10	<0.05	<0.05	0.28	0.16	0.6	3.5
Calcium	18 700	18 900	13 400	-	-	-	-		
Chromium	62.5	21.7	87.0	26.7	21.8	72.3	85.6	37.3	90
Cobalt	10.1	4.3	72.3	6.4	3.2	31.1	19.4		
Copper	19.4	4.3	26.1	8.4	6.8	26.4	27.2	35.7	197
Iron	25 600	15 600	66 400	35 100	13 100	105 000	96 600		
Lead	6.9	2.9	11.5	3.9	3.2	10.0	10.8	35.0	91.3
Magnesium	10 700	5 800	14 900	-	-	-	-		
Manganese	376	333	6 710	522	129	21 800	3 230		
Mercury	<0.005	<0.005	0.023	<0.05	<0.05	<0.05	<0.05	0.17	0.486
Molybdenum	<1.0	<1.0	14	-	-	-	-		
Nickel	19.7	6.1	33.9	10.0	8.4	35.6	30.5		
Selenium	<0.1	<0.1	0.2	<0.5	<0.5	1.0	1.3		
Silver	<0.10	<0.10	<0.10	<0.01	<0.01	<0.01	0.13		
Vanadium	73.9	39.2	118	-	-	-	-		
Zinc	47	25	118	29	25	98	93	123	315

Table 4.3 Sediment Chemistry in Boston Area Lakes, 1993 to 1997 (continued)

Parameter	Aimaokatalok Lake (continued)							CISCQ	
Date	**24-Aug-96**		**24-Aug-96**		**24-Aug-96**		**24-Jul-97**	**TEL**	**PEL**
Site	**Stn 4**		**Stn 5**		**Stn 6**		**Stn1**		
Depth of sample	21 m		4 m		30 m		2.5m		
Selected Sediment	0 - 1 cm	1 - 3 cm	0 - 1 cm	1 - 3 cm	0 - 1 cm	1 - 3 cm	-		
Moisture (%)	75.0	60.1	45.0	42.3	63.3	56.8	27.9		
Total Organic Carbon (%)	0.9	0.8	0.3	0.3	1.2	1.2	1.4		
Total Metals (mg/kg)									
Aluminum	-	-	-	-	-	-	11 000		
Antimony	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	-		
Arsenic	50	20	**6**	**20**	4	4	2	6	17
Barium	-	-	-	-	-	-	-		
Cadmium	0.34	0.20	<0.05	<0.05	0.16	0.10	<0.1	0.6	3.5
Calcium	-	-	-	-	-	-	-		
Chromium	71.6	98.5	**35.1**	**41.6**	**91.1**	**90.6**	27.0	37.3	90.0
Cobalt	33.2	17.9	9.0	7.6	18.2	15.7	5.0		
Copper	28.6	30.4	9.8	10.7	23.8	22.6	10.0	35.7	197
Iron	127 000	75 300	40 400	50 300	53 100	47 700	13 200		
Lead	9.9	12.8	4.1	4.8	10.2	9.4	5.0	35.0	91.3
Magnesium	-	-	-	-	-	-	-		
Manganese	25 400	2 010	1 330	750	762	659	206		
Mercury	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.005	0.17	0.486
Molybdenum	-	-	-	-	-	-	-		
Nickel	41.3	34.4	12.5	14.1	34.1	31.8	11.0		
Selenium	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.1		
Silver	0.22	0.31	0.04	<0.01	0.22	0.15	<0.10		
Vanadium	-	-	-	-	-	-	-		
Zinc	87	116	35	39	103	90	36	123	315

Table 4.3 Sediment Chemistry in Boston Area Lakes, 1993 to 1997 (continued)

Parameter	**Aimaokatalok Lake (continued)**				**Stickleback Lake**			**CISCQ**	
Date	24-Jul-97	24-Jul-97	22-Jul-97	24-Jul-97	25-Aug-96	25-Aug-96	23-Jul-97	TEL	PEL
Site	Stn3	Stn4	Stn5	Stn6	-	-	-		
Depth of sample	11.0m	4.5m	2.5m	24.5m	3 m	3 m	2.5m		
Selected Sediment	-	-	-	-	0 - 1 cm	1 - 2 cm	-		
Moisture (%)	50.4	37.3	34.0	47.7	37.5	29.1	88.6		
Total Organic Carbon (%)	1.9	1.0	0.6	1.5	0.8	0.6	18.6		
Total Metals (mg/kg)									
Aluminum	28 500	19 900	12 000	30 800	-	-	13 700		
Antimony	-	-	-	-	<0.05	<0.05	-		
Arsenic	**26**	**7**	**12**	5.19	2	1	**6**	6	17
Barium	-	-	-	-	-	-	-		
Cadmium	<0.1	<0.1	<0.1	<0.1	0.11	<0.05	0.3	0.6	3.5
Calcium	-	-	-	-	-	-	-		
Chromium	**72.0**	**49.0**	27.0	**83.0**	18.3	14.6	35.0	37.3	90.0
Cobalt	20.0	11.0	5.0	17.0	3.3	3.0	9.0		
Copper	28.0	16.0	8.0	26.0	11.7	7.4	**41.0**	35.7	197.0
Iron	84 700	33 800	30 000	72 000	13 100	12 200	26 200		
Lead	12.0	7.0	5.0	11.0	2.1	1.9	6.0	35.0	91.3
Magnesium	-	-	-	-	-	-	-		
Manganese	4 900	587	360	1 550	105	104	394		
Mercury	0.037	0.012	0.007	0.024	<0.05	<0.05	0.034	0.17	0.486
Molybdenum	-	-	-	-	-	-	-		
Nickel	37.0	22.0	10.0	36.0	7.7	7.5	33.0		
Selenium	0.3	0.2	<0.1	0.2	<0.5	<0.5	0.7		
Silver	<0.1	<0.1	<0.1	0.2	0.3	<0.01	<0.1		
Vanadium	-	-	-	-	-	-	-		
Zinc	108	65	33	109	17	15	54	123	315

Table 4.3 Sediment Chemistry in Boston Area Lakes, 1993 to 1997 (continued)

Parameter	Fickle Duck Lake		Fickle Duck Outflow	Reference Lake	CISCQ	
Date	25-Aug-96	23-Jul-97	1993	23-Jul-97	TEL	PEL
Site	-	-	WQ2	-		
Depth of sample	2 m	2.0m	?	2.5m		
Selected Sediment	surface	-	-	-		
Moisture (%)	68.9	46.2	-	46.0		
Total Organic Carbon (%)	7.1	2.6	5.7	2.13		
Total Metals (mg/kg)						
Aluminum	-	28 600	57 100	23 900		
Antimony	<0.05	-	<0.05	-		
Arsenic	**6**	3	2	6	6	17
Barium	-	-	641	-		
Cadmium	0.41	<0.1	<0.10	<0.1	0.6	3.5
Calcium	-	-	17 600	-		
Chromium	35.7	**72.0**	29.3	**65.0**	37.3	90.0
Cobalt	8.7	11.0	5.2	11.0		
Copper	**96.4**	25.0	10.6	22.0	35.7	197.0
Iron	22 800	34 100	17 300	38 300		
Lead	10.3	9.0	2.8	8.0	35.0	91.3
Magnesium	-	-	5 750	-		
Manganese	146	312	352	351		
Mercury	<0.050	0.014	0.013	0.017	0.17	0.486
Molybdenum	-	-	<1.0	-		
Nickel	42.0	31.0	7.4	28.0		
Selenium	0.5	0.2	<0.1	0.2		
Silver	0.2	<0.1	<0.1	<0.1		
Vanadium	-	-	37	-		
Zinc	93	94	24	87	123	315

Notes: Units are expressed as dry weights. CISQ = Canadian Interim Sediment Quality Guidelines for the Protection of Aquatic Life; TEL= Threshold Effect Level; PEL = Probable Effect Level. Values in bold are equal or greater than the TEL guidelines.

4.2.3 Fickle Duck Lake

The predominantly clay-sized sediment of Fickle Duck Lake was dark grey in colour. The TOC concentrations were high in both 1996 and 1997 (7.1 and 2.6% dry weight, respectively). The concentrations of total arsenic (6 mg/kg) and total copper (96.4 mg/kg) exceeded the CISQG TEL in the 1996 sample. Total chromium (72 mg/kg) exceeded the CISQG TEL in the 1997 sample (Table 4.3).

4.2.4 Fickle Duck Outflow

The sediments of Fickle Duck Outflow were predominantly sand-sized, and colour was not recorded (Rescan 1994). The TOC concentration in 1993 was moderately high (5.7% dry weight), likely due to the aquatic plants and grasses lining this creek area (Rescan 1994). The concentrations of all metals in this sample were below the CISQG TEL values (Table 4.3).

4.2.5 Reference Lake

The sediments of Reference Lake were composed of clay and fine sand-sized material, with the surficial layer being dark grey in colour, whereas the upper layer was yellowish-red (Rescan 1997). The TOC concentration was moderately high (2.1%). The concentration of total chromium (65 mg/kg) exceeded the CISQG TEL (Table 4.3).

4.2.6 Summary

Most lake sediment metal levels fell below the CISQG. The exceptions were total chromium, total arsenic, and total copper. Of these, total chromium values exceeding the guidelines were the most widespread geographically, with concentrations exceeding the CISQG PEL in three of the five waterbodies. Nevertheless, these sediment metal concentrations remained within the range of natural variability for the Slave Structural Province (Puznicki 1996).

Sediment TOC levels varied between lakes. For sediments with relatively elevated TOC (Fickle Duck Lake, Fickle Duck Outflow and Reference Lake), colour and mineralogy indicated that reducing conditions were predominant in the surficial layer as well as the underlying sediments. For lake sediments with relatively low to moderate TOC concentrations, and in which profiling had been carried out (Aimaokatalok Lake), colour and mineralogy indicated a strong redox gradient between an oxic surficial layer and reducing underlying upper layer.

TOC values from Stickleback Lake were low in 1996 but were much higher at the site sampled in 1997.

4.3 MARINE SEDIMENT QUALITY

4.3.1 Hope Bay

Marine sediment samples from Hope Bay were collected during a single sampling event on 23 August 1997 (Figure 4.1). Sediment sampling methods and analysis were similar to those described in Section 4.1. The Hope Bay sediment was primarily clay-sized at the deepest station, and sand-sized at the two shallow stations (Rescan 1998). Concentrations of TOC ranged from 0.08 to 0.77% dry weight, with the deepest station having the highest TOC content (Table 4.4). Moisture content varied between samples, ranging from 17.1% to 29.8%, with the deepest station having the highest moisture content. None of the analyzed metal concentrations exceeded the CISQG TEL guidelines for marine environments.

Table 4.4 Hope Bay Sediment Chemistry, 1997

Parameter[a]	Station 1	Station 2	Station 3	CISQ[b] (Marine)	
Date	23-Aug-97	23-Aug-97	23-Aug-97	TEL	PEL
Depth of Sample	16 m	2 m	4 m		
Selected Sediment Layer	0 – 2 cm	0 – 2 cm	0 – 2 cm		
Moisture (%)	29.8	17.4	17.1		
Total Organic Carbon (%)	0.8	0.1	0.2		
Total Metals (mg/kg)					
Aluminum	15 300	7 870	11 300		
Arsenic	4	2	3	7	42
Cadmium	<0.1	<0.1	<0.1	0.7	4.2
Chromium	40.0	20.0	31.0	52.3	160.0
Cobalt	6.0	5.0	6.0		
Copper	18.0	10.0	15.0	18.7	108
Iron	23 300	12 700	21 300		
Lead	6.0	<2.0	3.0	30.2	112.0
Manganese	224	140	201		
Mercury	0.006	<0.005	<0.005	0.130	0.700
Nickel	17.0	13.0	21.0		
Selenium	0.10	<0.10	<0.10		
Silver	<0.1	<0.1	<0.1		
Zinc	40	21	31	124	271

[a] Total metals are expressed as dry weights.

[b] CISQG = Canadian Interim Sediment Quality Guidelines for the Protection of Aquatic Life; TEL= Threshold Effect Level; PEL = Probable Effect Level.

5 PRIMARY PRODUCERS

5.1 PHYTOPLANKTON IN LAKES

Phytoplankton are tiny, free-floating organisms that use energy from sunlight to convert carbon dioxide and water into organic materials to be used in biological tissues. They live near the water surface where there is sufficient light to support photosynthesis. Phytoplankton form the base of the aquatic food web, providing an essential ecological function for all aquatic life. The data were compiled from six annual reports (Rescan 1993, 1994, 1995, 1997, 1998, and 1999a).

5.1.1 Methods

Phytoplankton samples were collected from four lakes within the Boston area (Figure 5.1). The total number of phytoplankton sampling sessions carried out at each lake between 1993 and 1998 ranged from three in Reference Lake to 17 in Aimaokatalok Lake (Table 5.1).

Table 5.1 Phytoplankton Sampling Dates in Boston Area Lakes, 1993 to 1998

Waterbody	Sampling Station	Date					
		1993	1994	1995	1996	1997	1998
Aimaokatalok Lake	WQ4		Aug				
	WQ5	17 Aug	Aug	Aug			
	Stn 1					24 Jul & 26 Aug	
	Stn 4						18 Jul
	Stn 5				4 & 24 Aug	22 Jul & 26 Aug	
	WQ9 / Stn 6			Aug	4 & 24 Aug	24 Jul & 25 Aug	18 Jul
Stickleback Lake			Aug	Aug	5 & 25 Aug	23 Jul & 26 Aug	19 Jul
Fickle Duck Lake				Aug	5 & 25 Aug	23 Jul & 26 Aug	19 Jul
Reference Lake						23 Jul & 27 Aug	22 Jul

Triplicate phytoplankton samples were collected during each sampling session. Samples were collected from a water depth of either 0.5 or 1 m (depending on the year), transferred into 250-mL bottles and preserved in Lugols's iodine solution. Samples were submitted to Fraser Environmental Services for taxonomic identification and enumeration. Rescan reports identified Cryptophyta and Pyrrophyta as members of the same phylum; however, recent literature (Wehr et al. 2002) makes a distinction between the two taxonomic groups, treating both Cryptophyta and Pyrrophyta as two distinct phyla. For this report, Cryptophyta and Pyrrophyta were analyzed as two separate phyla.

As an indicator of phytoplankton biomass, chlorophyll *a* was measured from single samples collected in 1996 and 1997. Clean 1 L plastic bottles were filled and kept cold and in the dark until returned to camp. Once in camp, samples were gently shaken and filtered through 0.45 µm membrane filters (filter diameter of 47 mm). Filters were carefully folded in half, wrapped in aluminum foil, and frozen until analysis by the fluorometric method described in Parsons et al. (1984).

5.1.2 Aimaokatalok Lake

Seventeen phytoplankton sampling sessions were conducted on Aimaokatalok Lake during the summer: once in 1993, twice in 1994 and 1995, four times in 1996, six times in 1997, and twice in 1998. Mean total algal densities [± 1 standard error (SE)] ranged from 125 ± 17 cells/mL on 24 July 1997 to 3473 ± 1541 cells/mL on 24 July 1996 (Figure 5.2; Appendices B1 and B2).

Phytoplankton communities in Aimaokatalok Lake were typically dominated by Cyanophyta (cyanobacteria or blue-green algae), which contributed between 9.8 and 56.1% towards the mean total number of cells enumerated in each sample. Cyanophyta abundance was unusually low in 1997, but was generally high (>40% of all cells) during other years. The major organisms of this group included *Gomposphaeria* spp., *Lyngbya limnetica*, and *Anacystis* spp. The other major groups in order of abundance were Chlorophyta (generally referred to as green algae; 4.3 to 51.1% of total cell numbers) and Bacillariophyta (diatoms; 2.5 to 37.8% of total cell numbers). The major contributor to Chlorophyta was *Crucigenia* spp. Bacillariophyta was dominated by *Asterionella formosa*, *Cyclotella* spp. and *Fragilaria* spp., Chrysophytes (golden-brown algae) were typically rare in Aimaokatalok Lake; however, they contributed 63.6% of the total number of cells enumerated at Station 5 in July 1997 (Figure 5.2; Appendix B2).

5.1.3 Stickleback Lake

Seven phytoplankton sampling sessions were conducted on Stickleback Lake during the summer: once in 1994, 1995 and 1998, and twice in 1996 and 1997. Mean total algal cell numbers ranged from 527 ± 114 SE cells/mL on 23 July 1997 to 7962 ± 2016 SE cells/mL on 5 August 1996 (Figure 5.3; Appendices B1 and B2).

Phytoplankton communities in Stickleback Lake were typically dominated by Cyanophyta, which contributed between 5.8 and 77.1% towards the mean total number of cells enumerated per sample. The major contributor of this group was *Anacystis* spp. Additionally, large contributions of Bacillariophyta (diatoms), Chlorophyta, Chrysophyta, and Cryptophyta occurred on some sampling dates (Figure 5.3; Appendices B1 and B2). The major contributors to these four groups were *Asterionella formosa*, *Crucigenia* spp., *Dinobryon bavaricum*, and *Chroomonas acuta*, respectively.