Appendix C

Development of Water and Sediment Quality Benchmarks

SCIENCE INTEGRITY KNOWLEDGE

APPENDIX C

DEVELOPMENT OF WATER AND SEDIMENT QUALITY BENCHMARKS FOR APPLICATION IN AQUATIC EFFECTS MONITORING AT THE MARY RIVER PROJECT

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DEVELOPMENT OF WATER AND SEDIMENT QUALITY BENCHMARKS FOR APPLICATION IN AQUATIC EFFECTS MONITORING AT THE MARY RIVER PROJECT

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C- 1.0 INTRODUCTION

As part of the Aquatic Effects Monitoring Program (AEMP) for the Mary River Project in Nunavut, Baffinland Iron Mines Corporation (Baffinland) requires development of benchmarks for comparison of surface water and sediment chemistry data which will be collected under the Core Receiving Environment Monitoring Program (CREMP).

Since the mine site occurs within an area of metals enrichment, generic water quality and sediment quality guidelines established for all areas within Canada may naturally be exceeded near the mine site. Therefore, the selection of appropriate benchmarks must consider established water and sediment quality guidelines, such as those developed by the Canadian Council of Ministers of the Environment (CCME), as well as site-specific natural enrichment, and other factors (such as Exposure Toxicity Modifying Factors (ETMF) including pH, water hardness, dissolved organic carbon, etc.), in the selection or development of final benchmarks for monitoring data comparison (CCME, 2003; 2007).

The assessment of surface water and sediment quality data over the life of the project will be on-going, and the recommended benchmarks of comparison throughout this process may change, as more data become available. For example, a generic water quality guideline established as a benchmark early on in the life of the mine may require updating over time to a Site Specific Water Quality Guideline, based on consideration of published literature and standardized protocols (CCME, 2007), or site specific toxicity tests conducted to further understand ETMF or resident species toxicity. In addition, sediment data will be collected in 2014 prior to mine-related discharge and is expected to be integrated into the baseline data, and will likely result in modifications to the suggested AEMP sediment benchmarks presented herein. The iterative, cyclical nature of modification of benchmarks under an AEMP is well established (MacDonald et al., 2009).

Section 5 of the AEMP outlines the proposed approach for development of the benchmarks. Briefly, the process involves the following steps:

- Determine, using the Final Environmental Impact Statement (FEIS), which substances are present at naturally elevated concentrations, and/or those that could be released at elevated concentrations as a result of mining activities, into the future;
- Evaluate baseline data, and determine a statistical metric of baseline levels which is considered representative of background for any naturally occurring substances (metals/metalloids);
- Evaluate CCME sediment and surface water quality guidelines, where available, or other relevant guidelines from other regulatory jurisdictions (such as Ontario or British Columbia), where appropriate. Appropriate guidelines could include Site-Specific Water

Quality Guidelines (SSWQGl) developed using CCME protocols, and data from the Mary River area, or from other northern Mine sites, where data are appropriate;

- Select the higher of either baseline or regulatory or SSWQGl as the benchmark for adoption in the AEMP.

This appendix outlines the benchmark selection process, and evaluation of data.

C- 2.0 SEDIMENT EVALUATION AND BENCHMARK DEVELOPMENT

C-2.1 Selection of Substances for Benchmark Development

Based on the baseline data collected between 2005 and 2013, and the outcomes of the FEIS, the following substances have the potential to be either naturally elevated in the environment, or elevated as a result of future mine site activities (see Table 2-1).

Table 2-1 Identification of Metals Naturally Elevated in Area, and Potentially Elevated as a Result of Facility Releases

Substance	***Sediment***	
	Naturally Enriched in Area, Relative to Sediment Quality Guidelines[a]	***Potential to be Elevated Due to Mine Site Releases***[b]
Arsenic	No	Yes
Cadmium	Yes	Yes
Chromium	Yes	Negligible
Copper	Yes	Negligible
Iron	Yes	Yes
Lead	No	Negligible
Manganese	Yes	Not determined
Mercury	No	Not determined
Nickel	Yes	Yes
Phosphorus	Yes	Not determined
Selenium	NGA	Not determined
Zinc	No	Negligible

Notes:
NGA = no guideline available
Bolded and shaded chemicals were carried forward for benchmark development based on natural enrichment, relative to guidelines, and consideration of future site contributions.
Bolded substances were carried forward as CCME sediment quality guidelines are available for these parameters.
[a] Determination based on baseline 97.5[th] percentile of all samples, relative to CCME sediment quality guidelines (ISQG) or Ontario sediment quality guidelines (LEL), where available
[b] Final FEIS, Volume 7; SWSQ-17-3; page 170; nickel concentrations were not predicted to exceed the PEL

Based on the information presented in Table 2-1, all bolded substances require benchmark development (*i.e.*, arsenic, cadmium, chromium, copper, iron, manganese, nickel and phosphorus). Three additional substances have CCME sediment quality guidelines, and were also included in the sediment chemistry assessment process (*i.e.,* lead, mercury and zinc).

C-2.2 Baseline Data Evaluation

Baseline sediment data were received from Knight Piésold. Data treatment conducted in the Baseline Integrity Review (Knight Piésold, 2014) involved the following steps:

- Removing all duplicate samples, to avoid "double counting" of data;
- All samples which were non-detect were assumed to equal the detection limit for statistical calculations; and
- Review of sediment quality laboratory detection limits.

The review of detection limits indicated that most were well below the relevant sediment quality guidelines, and that MDLs did not change meaningfully over the sampling years. The MDL reported for mercury is very close to the CSQG/ISQG, and the MDL for cadmium is 0.1 mg/kg less than the CSQG/ISQG. In both cases, increased resolution of detection limits in the future would be helpful in evaluating trends in the data over time, relative to guidelines and baseline.

C-2.2.1 Sediment Data Evaluation for Determining AEMP Benchmarks

Following completion of the data treatment steps present above, a detailed assessment of sediment chemistry was undertaken (Knight Piésold, 2014). Sediment data are available from 2005 through 2013, for various stations. The samples were all analyzed using a similar digest and analytical methodology, and hence are comparable. In addition, while the early sediment samples are all grab samples (ponar), more recent samples from some areas have included core samples (top 2 cm). Assessment of the data from these two approaches was conducted under the Baseline Integrity Review (Knight Piésold, 2014) and concluded the data are comparable, and therefore data from both sampling approaches were included in the data analysis.

A detailed evaluation of sediments was undertaken relative to depositional characteristics of sampling locations, to explore the relationships between depositional characteristics (such as Total Organic Carbon (TOC) (*e.g.,* high TOC represents a higher propensity to accumulate metals) and presence of sand (% sand; *e.g*., high sand content would represent lower potential for accumulation of metals, due to lower binding potential), and metal concentrations. This analysis is presented within the Baseline Integrity Report (Knight Piésold, 2014; Appendix B). It concluded that all sediment sampling locations with TOC concentrations < 60% (0.6) and sand content of > 80% or those stations wherein sand alone was > 90% (irrespective of TOC) do not represent depositional zones, and these stations should no longer be included as potential monitoring stations. As such, these stations should be removed from the baseline chemistry calculations. Removal of these stations is justified since stations exhibiting these characteristics have a low potential to accumulate metals, and hence, will have a low likelihood of exhibiting substantial changes in chemistry in the future. In addition, including the data from these stations in the overall baseline percentile calculations results in considerable variability in the data, which would limit the potential to find statistically significant change over time, relative to future sediment monitoring and the current assessment framework (outlined in AEMP main report Figure 5.1).

The retained depositional stations were examined, and Log10 histograms of the dataset suggest that the data are largely log normally distributed (Figure 2-1), with the exception of cadmium, and mercury (not shown) due to the large number of non-detects, and phosphorus (which has a smaller number of samples, relative to other parameters).

In addition, Table 2-2 provides a summary of the number of sediment samples per year in each lake and depositional tributary area, and total number of samples for the entire area, relative to baseline metric development.

Table 2-2 Number of Sediment Samples Collected in Each Water Body by Year

Year	*Camp Lake*	*Mary Lake*	*Sheardown Lake NW*	*Sheardown Lake SE*	*Tributaries of Sheardown Lake*
2005	0	0	0	0	0
2006	0	1	0	0	0
2007	5	4	7	4	0
2008	0	0	7	0	3
2009	0	0	0	0	0
2010	0	0	0	0	0
2011	0	0	2	0	0
2012	2	1	4	1	1
2013	2	0	5	1	1
Total	9	6	25	6	5

As can be seen in Table 2-2, there are limited samples in some of the area lakes. For the parameters of interest, Table 2-3 presents the total number of samples per lake, and the number of samples greater than the detection limit.

The data were evaluated using two approaches, based on the dataset as a whole (N=52), and also on an area-by-area basis, to determine if area-wide benchmarks could be established, or whether there were differences between lakes which would suggest a need for lake-specific AEMP benchmarks for selected lakes. With respect to possible approaches that can be taken to estimate background, guidance is available for soils and groundwater data from a variety of different regulatory jurisdictions, and is appropriate to apply to sediments. Ontario Ministry of Environment recommends that the 97.5th percent of baseline data be used (OMOE, 2011), whereas BC MOE (2005) suggests using a 95th percentile. US EPA suggests a 95th percentile for non-parametric datasets, or a 95th percentile Upper Prediction Limit (UPL) for datasets that are normally distributed (Singh and Singh, 2010). In several of these cases, consideration of potential outliers is suggested. With respect to other mining projects, the 95th percentile has been used as a baseline metric in the Meadowbank AEMP program (Agnico-Eagle, CREMP Design, 2012), whereas the maximum baseline value (or assessment against the range of baseline data) has been suggested in some other programs (Gahcho Kue Project; Golder, 2012).

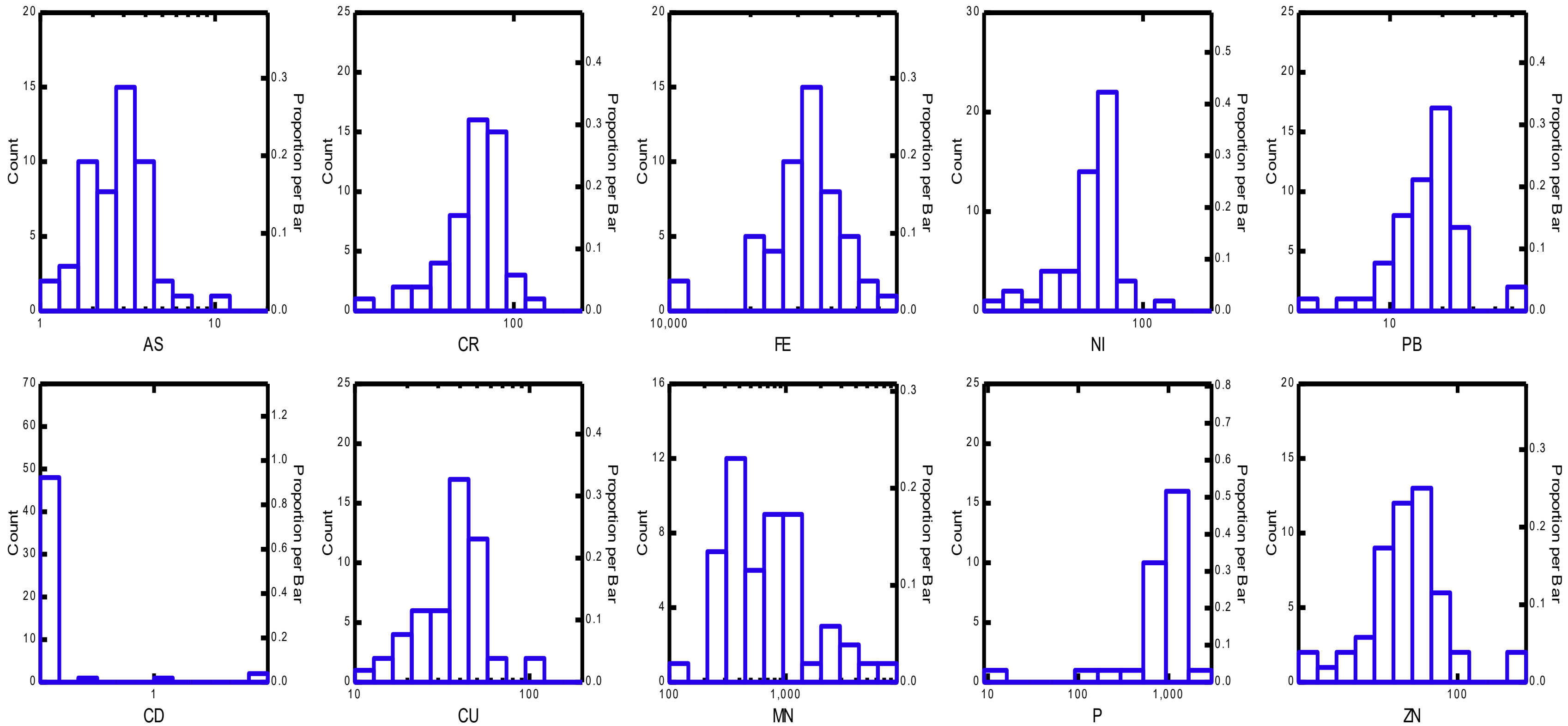

Figure 2-1 Log10 Histograms of Area-Wide Sediment Data (N=52), by Metal of Interest

Table 2-3 Number of Sediment Samples Greater Than Detection Limit by Water Body

Metal	*Camp Lake*		*Mary Lake*		*Sheardown Lake NW*		*Sheardown Lake SE*		*Tributaries of Sheardown Lake*	
	N	*Samples > DL*	*N*	*Samples > DL*	*N*	*Samples > DL*	*N*	*Samples > DL*	*N*	*Samples > DL*
As	9	9	6	6	25	25	6	6	5	5
Cd	9	1	6	0	25	0	6	5	5	3
Cr	9	9	6	6	25	25	6	6	5	5
Co	9	9	6	6	25	25	6	6	5	5
Cu	9	9	6	6	25	25	6	6	5	5
Fe	9	9	6	6	25	25	6	6	5	5
Hg	9	0	6	0	25	0	6	0	5	0
Mn	9	9	6	6	25	25	6	6	5	5
Ni	9	9	6	6	25	22	6	6	5	5
P	5	5	5	5	14	14	4	4	3	3
Pb	9	9	6	6	25	25	6	6	5	5
Zn	9	9	6	6	25	25	6	6	5	5

Notes:
N = number of samples
ND = not detected
> = greater than

Using the entire dataset (N=52) various statistical metrics were calculated to represent possible upper end of normal for the dataset (95^{th} percentile and 97.5^{th} percentile). UPLs were not explored at this time, as additional data collection is being recommended (see below) in light of the small number of samples available for several area lakes.

Sediment quality guidelines were also identified for comparison to baseline metrics. The CCME (2014) have sediment quality guidelines for only a limited number of metals. Where CCME guidelines were lacking, sediment quality guidelines from jurisdictions such as the British Columbia Ministry of Environment (Nagpal et al., 2006) and the Ontario Ministry of the Environment (OMOE, 2008) were reviewed and considered. Many of the British Columbia sediment guidelines are based on CCME values. Guidelines from US EPA (2014) were also reviewed and considered, and several of the guidelines draw on the Ontario guidelines. Where available, both low effect level guidelines [such as ISQGs (Interim Sediment Quality Guidelines) from CCME, and LEL (Lower Effect Level) from Ontario] are presented, as well as effect-level guidelines [such as PELs (Probable Effect Level) from CCME, and SEL (Severe Effect Level)]. It is critical to note the following with respect to the use of these generic benchmarks as comparison points for sediment data:

- Concentrations which are less than the more conservative guidelines (such as the ISQG from the CCME or LEL from Ontario) indicate that toxicity is not expected in the environment;
- Concentrations which are greater than the ISQG or LEL, suggest toxicity is possible;
- Concentrations which are greater than the PEL or SEL, suggest toxicity may be present, but is not certain, due to the number of possible modifying factors affecting toxicity.

Metals are naturally occurring substances, and in the vicinity of mining areas, it is commonplace that some metals may be present in elevated concentrations, relative to these guidelines. There are many site specific factors which play a significant role in modifying toxicity of metals in sediments which are not accounted for in these generic guidelines, most notable, site specific bioavailability of the metal/metalloid. Therefore, conclusions with respect to adverse effects need to be drawn based on site specific considerations and data, as opposed to comparisons to benchmarks alone. In general, CCME (2002) recommends that assessment of potential for adverse effects in biota related to sediment contamination involve the use of sediment quality guidelines, as well as other assessment tools, such as data on natural background concentrations of substances of interest, biological assessments (such as benthic community assessments), and/or other toxicity data (such as site-specific testing), as needed.

Table 2-4 presents the minimum, maximum, median, mean, 95^{th} percentile and the 97.5^{th} percentile for the compiled baseline sediment data for the entire region, relative to available sediment quality guidelines, for the metals/metalloids identified in Table 2-1.

Following this, an area by area assessment of data was conducted, to investigate potential differences between lakes, with respect to metals concentrations, relative to the 95^{th} percentile of the entire dataset. Figure 2-2 illustrates box and whisker plots of the lake data (and tributaries of Sheardown Lake), with number of samples (represented by open circles on the figures).

Table 2-4 Baseline Statistical Calculations for Area-Wide Sediment Data Relative to Available Sediment Quality Guidelines (µg/g)

Jurisdiction and Statistical Metric	*Type of Guideline*	*Hg*	*As*	*Cd*	*Cr*	*Cu*	*Fe*	*Mn*	*Ni*	*P*	*Pb*	*Zn*
CCME	**ISQG**	0.17	5.9	0.6	37.3	35.7	NGA	NGA	NGA	NGA	35	123
	PEL	0.486	17	3.5	90	197	NGA	NGA	NGA	NGA	91.3	315
Ontario Sediment Quality Guidelines	**LEL**	0.2	6	0.6	26	16	20000	460	16	600	31	120
	SEL	2	33	10	110	110	40000	1100	75	2000	250	820
US EPA Sediment Quality Guidelines	**Screening**	0.18	9.8	0.99	43.4	31.6	20000	460	22	NGA	35.8	121
% of Samples Detected		0	100	18	100	100	100	100	100	100	100	100
Minimum		<0.1	1	<0.5	23	10	10,100	128	23	100	3	22
Maximum		<0.1	10.5	1.9	124	107	62,300	8,030	119	2700	52	171
Mean		NC	3.0	0.6	69	40	32,900	1,085	60	1042	18	65
Median		NC	2.3	0.5	72	40	33,100	649	64	1000	18	62
95th Percentile		NC	5.2	0.8	96	61	48,955	3,769	77	1550	26	100
97.5th Percentile		NC	6.0	1.7	98	87	52,200	4,452	84	1875	44	152

Note:
NC = not calculated because <5% of samples were detected; All metals had N= 52, with the exception of P, where N=31

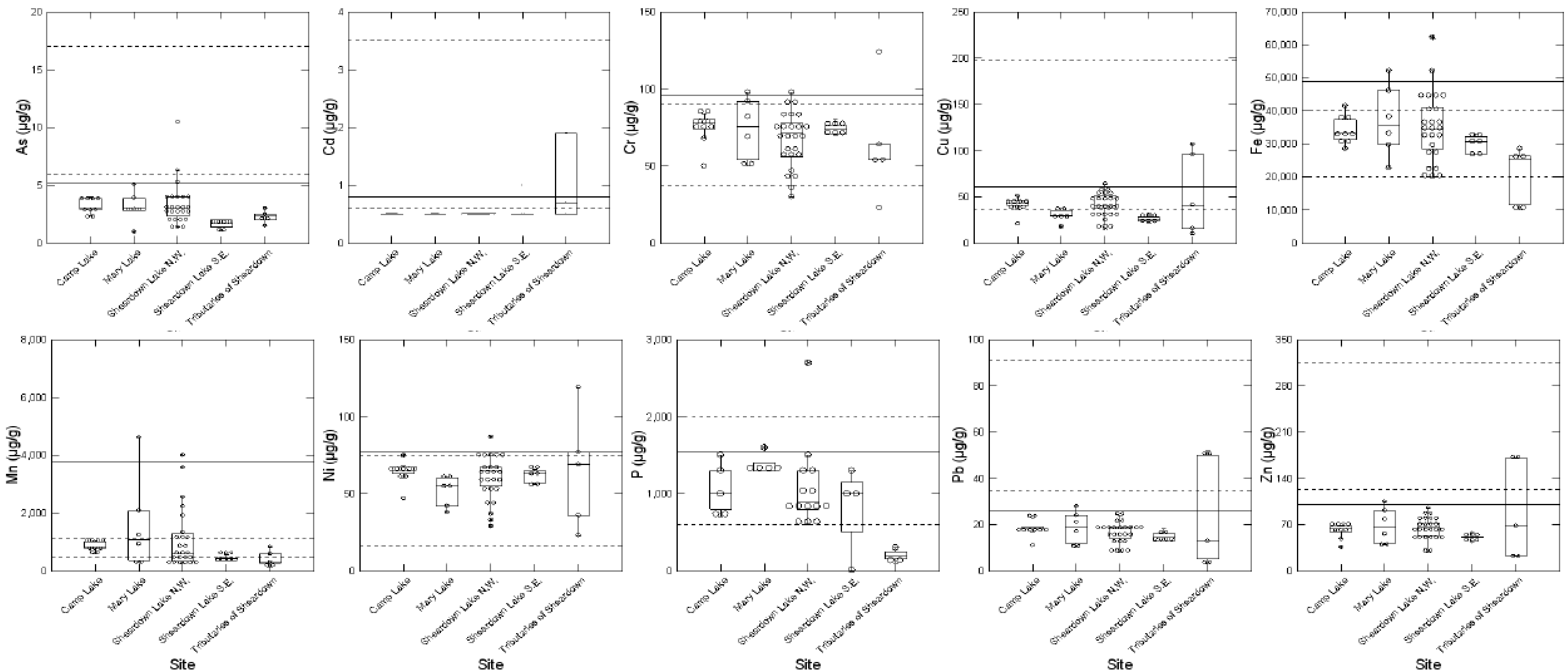

Figure 2-2 Box and Whisker Plots of Metal Concentrations by Area (Solid line represents 95th percentile of area-wide data; dotted lines represent ISQG/LEL and PEL/SEL sediment quality guidelines, respectively)

Median values are represented within each box as the central line, with the 25th and 75th percentiles of the data being represented by the lower and upper parts of the box. Upper and lower "whiskers" extend from the box, and represent the maximum data point within 1.5 interquartile range from the top (or bottom) of the box. Potential outliers are noted as symbols beyond the whiskers. Dotted lines in the figures represent CCME or Ontario ISQG/LEL and PEL/SEL guidelines. The solid line represents the 95th percentile of the area wide sediment data, for each metal.

These box and whisker plots clearly indicate that while there are similarities between some lakes for some metals (e.g., arsenic concentrations in Camp Lake, Mary Lake and, to a lesser extent, the Tributaries of Sheardown Lake), there are also large differences in some cases (e.g., iron and manganese in Sheardown Lake SE and Tributaries of Sheardown are very different from other lakes). Tributaries of Sheardown Lake appear to have some elevated values for cadmium, chromium, copper, lead, nickel, and zinc, relative to other area lakes. While Sheardown Lake NW has adequate sampling to be confident that baseline has been adequately characterized (n = 25), the small number of samples in Camp Lake (n= 9), Mary Lake (n = 6), Sheardown Lake SE (n = 6) and Tributaries of Sheardown Lake (n = 5), limit the understanding of baseline metals levels in these specific lakes.

In order to investigate whether there has been site-related influence over time, a visual temporal trend evaluation was conducted on Sheardown Lake NW, since it had adequate sampling size to conduct this type of analysis. Figure 2-3 illustrates the temporal trends for various metals/metalloids within this basin (mean +/- standard error).

Based on Figure 2-3, there are apparent upward trends in the data related to Cr, Ni and Cu, but less pronounced differences with respect to Pb and Zn, or other parameters. Data are too limited for P to examine trends, and statistical significance tests were not conducted at this time. Further data collection in 2014 will assist in evaluating whether data in this basin are trending upwards, or within natural variability. These trends will be discussed further below, relative to the selection of AEMP benchmarks.

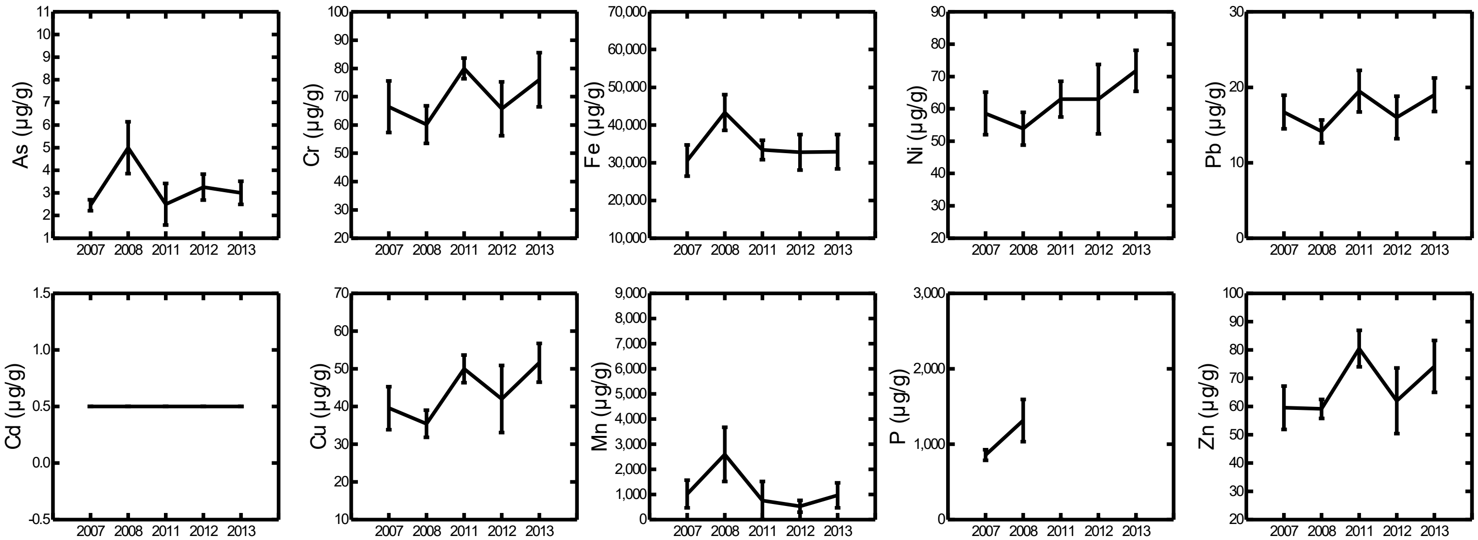

Figure 2-3 Temporal Trend Analysis for Sheardown Lake NW (n = 25) for Various Parameters (mean +/- std error)

C-2.3 AEMP Benchmark Derivation for Sediments

Based on the available data, final AEMP benchmarks were not derived at this time, as several of the lakes would benefit from an increased database to confirm adequate characterization of baseline (Camp Lake, Mary Lake, Tributaries of Sheardown Lake, Sheardown Lake SE). Therefore, the current proposed approach is to select an Interim AEMP sediment benchmark, which will be finalized once more sediment data are collected in the 2014 season.

The approach for selecting sediment AEMP benchmarks is outlined in Figure 2-4:

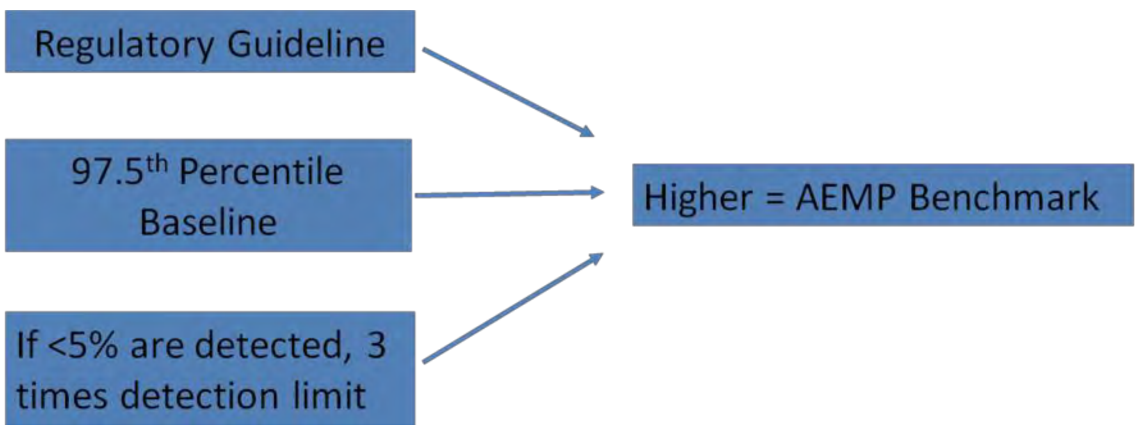

Figure 2-4 Approach for Selecting AEMP Benchmarks

For the AEMP benchmark, the 97.5th percentile was selected to represent the upper estimate "normal" or baseline concentration levels. Comparisons to the baseline range should be made in the overall exploratory data analysis stage (EDA) within Step 1 of the Assessment Approach and Response Framework (Section 5 of the AEMP; Baffinland, 2014), to provide added perspective on monitoring data. Based on the Assessment Approach and Response Framework established for Mary River Project, the 97.5thpercentile is considered to represent a reasonable Interim AEMP benchmark, when coupled with other Exploratory Data Analysis aspects of Step 1 of the framework, and the Low Action management responses, which occur if change is detected in Step 1, and the monitoring data are < AEMP benchmark (see AEMP main report; Figure 5.1).

Table 2-5 presents the 97.5th percentile of each metal/metalloid within each area (lake), compared to the relevant sediment quality guidelines and area-wide 95th and 97.5th percentile calculations. As noted in Table 2-5, the Tributaries of Sheardown Lake appear to have some of the higher 97.5th percentile values, which suggest some potential influence, or natural enrichment in this area. Data are too limited to conduct a temporal analysis of concentrations. In light of the elevations within this lake, area-wide calculations (95th and 97.5thpercentiles) are presented in Table 2-5 without the data from Tributaries of Sheardown Lake.

Proposed area-wide Interim AEMP benchmarks are also presented in Table 2-5, based on the higher of either 97.5th percentile of baseline, or sediment quality guidelines. In the case of Hg, Pb and Zn, the selected benchmark is the sediment quality guideline, as area-wide data were less than or equal to this value. The selection of the guideline at this time for these substances appears reasonable. Further sediment characterization in area lakes in 2014 may result in changes to this decision. In the case of As, Cr, Cu, Fe, Mn, Ni and P, the suggested area-wide Interim AEMP benchmark is the 97.5th percentile of baseline. The use of the area-wide percentiles as an interim benchmark appears reasonable, based on comparisons to both the existing guidelines, and characterization data for the lakes. As discussed earlier, further data collection will assist in better understanding baseline within the lakes, and will assist in final AEMP benchmark development. With respect to the temporal analysis conducted for Sheardown Lake NW, Cr, Cu, and Ni showed some increased trends over time in this basin (see Figure 2-3). Based on the 97.5th percentile calculations presented in Table 2.5 for this basin, these trends are not considered to substantially influence the outcome of the recommended interim AEMP benchmark. This issue will be re-assessed with 2014 data, for final benchmark development. For Cd, the data are largely non-detect, at an MDL of 0.5 mg/kg. The ISQG is 0.6 mg/kg, and due to the close proximity of the MDL to the ISQG, the 3 times MDL approach was applied for AEMP benchmark development.

Based on this analysis of the available data, the following are recommended:

- Additional sediment sampling should be conducted in all lakes (including Sheardown Lake NW), focusing on depositional areas, as per the analysis outlined in the CREMP to gather more data to characterize baseline prior to commencement of mining operations;
- 2014 data will be evaluated for temporal trends, and to determine whether lakes can be aggregated for some or all metals of interest with respect to AEMP benchmark development.

Final AEMP benchmarks will be established following analysis of the 2014 data.

Table 2-5 Comparison of Area-Specific Baseline Calculations to Overall Baseline Calculations, and Relevant Sediment Quality Guidelines (97.5th percentiles, by Area) (mg/kg; dw)

Jurisdiction, Type of Guideline and Statistical Metric		***Hg***	***As***	***Cd***	***Cr***	***Cu***	***Fe***	***Mn***	***Ni***	***P***	***Pb***	***Zn***
CCME (2014)	**ISQG**	0.17	5.9	0.6	37.3	35.7	NGA	NGA	NGA	NGA	35	123
	PEL	0.486	17	3.5	90	197	NGA	NGA	NGA	NGA	91.3	315
Ontario (OMOE, 2008)	**LEL**	0.2	6	0.6	26	16	20000	460	16	600	31	120
	SEL	2	33	10	110	110	40000	1100	75	2000	250	820
US EPA (2014)	**Screening**	0.18	9.8	0.99	43.4	31.6	20000	460	22	NGA	35.8	121
97.5th%iles of Each Lake Area (sample size)												
Tributaries of Sheardown Lake (5)		0.1	2.95	1.9	118	106	28,370	809	115	295	52	171
Mary Lake (6)		0.1	4.95	0.5	97	38	51,463	4,305	61	1580	28	103
Camp Lake (9)		0.1	4	0.5	83	50	40,920	1,057	74	1480	23	69
Sheardown Lake NW (25)		0.1	7.95	0.5	96	60	56,240	5,612	81	2310	24	92
Sheardown Lake SE (6)		0.1	2.0	0.9	80	32	32,988	547	66	1278	18	57
95th%ile of Area-Wide Data (47)[a]		NC	5.2	0.5	93	56	50,430	3,874	76	1565	24	91
97.5th %ile of Area-Wide Data (47)[a]		NC	6.2	0.5	97	58	52,200	4,530	77	1958	24	94
Proposed Interim AEMP Benchmark		**0.17[A]**	**6.2[B]**	**1.5[C]**	**97[B]**	**58[B]**	**52,200[B]**	**4,530[B]**	**77[B]**	**1958[B]**	**35[A]**	**123[A]**

Notes:
NC = not calculated as all values < MDL
a = Tributaries of Sheardown Lake data are not included in interim benchmark development due to elevated results in this area.
A = guideline is based on sediment quality guideline
B = guideline is based on 97.5th%ile of baseline data
C= guideline is based on 3 times MDL, the 97.5th%ile is equal to the MDL
Mercury was not detected in any samples; mercury detection limit is used to represent the 95th and 97.5th percentiles.

C- 3.0 SURFACE WATER EVALUATION AND BENCHMARK DEVELOPMENT

C-3.1 Selection of Substances for Benchmark Development: Lake Water and River/Streams

Based on the baseline data collected between 2005 and 2013, and the outcomes of the FEIS, substances having the potential to be either naturally elevated in the environment, or elevated as a result of future mine site activities in lake water were identified (see Table 3-1). In addition, metals regulated or which may be potentially regulated under MMER for base metal mines (as a result of the current re-evaluation of the MMER regulations) also were identified in Table 3-1. Any metal which was identified as being either naturally enriched, potentially elevated due to mine site released or regulated / potentially regulated under MMER were selected for benchmark development. The metals for which benchmarks will be developed in area surface waters are highlighted in Table 3-1.

In addition to metals, and regulated parameters, other substances, such as nutrients, major ions and conventional parameters are also important to include in benchmark development. Table 3-2 presents some of the nutrients, ions and conventional parameters for which analytical data are available and identifies those carried forward for benchmark development. In some cases, development of benchmarks was not considered necessary, and where appropriate, exploratory data analysis of the parameter is being recommended to assess trends, relative to baseline or reference. If change is noted in these parameters, benchmarks will be developed accordingly. All substances with AEMP benchmarks will also undergo exploratory data analysis (including statistical analysis) as part of the Assessment Approach and Monitoring Framework (AEMP main report Figure 5.1).

Table 3-1	Identification of Metals/Metalloids Naturally Elevated in Area Water, Regulated under MMER and/or Potentially Elevated as a Result of Facility Releases or Having Existing Water Quality Guidelines under CCME			
Substance	***Naturally Enriched in Area, Relative to WQG***[a]	***Regulated or Potential to be Regulated Under MMER***	***Potential to be Elevated Due to Mine Site Releases*** [a]	***CCME PAL?***
Aluminum	Yes	Potential	Yes [b]	Yes
Antimony	No	No	No	No
Arsenic	No	Yes	Yes	Yes
Barium	No	No	No	No
Beryllium	No	No	No	No
Bismuth	No	No	No	No
Boron	No	No	No	Yes
Cadmium	No	No	Yes [b]	Yes
Calcium	No	No	No	No
Chromium	Yes	No	Yes	Yes
Cobalt	No	No	Yes	No
Copper	Yes	Yes	Yes [b]	Yes
Iron	Yes	Potential	Yes	Yes
Lead	No	Yes	Yes [b]	Yes
Lithium	No	No	No	No
Manganese	No	No	No	No
Magnesium	No	No	No	No
Mercury[e]	No	Fish tissue only	No [c]	Yes
Molybdenum	No	No	No	Yes
Nickel	No	Yes	No	Yes
Phosphorus [d]	No	No	Yes	Yes [d]
Potassium	No	No	No	No
Selenium[e]	No	Potential	No [c]	Yes
Silver	No	No	Yes	Yes
Sodium	No	No	No	No
Strontium	No	No	No	No
Thallium	No	No	Yes [b]	Yes
Tin	No	No	No	No

Table 3-1 Identification of Metals/Metalloids Naturally Elevated in Area Water, Regulated under MMER and/or Potentially Elevated as a Result of Facility Releases or Having Existing Water Quality Guidelines under CCME				
Substance	***Naturally Enriched in Area, Relative to WQG***[a]	***Regulated or Potential to be Regulated Under MMER***	***Potential to be Elevated Due to Mine Site Releases*** [a]	***CCME PAL?***
Titanium	No	No	No	No
Uranium[e]	No	No	No	Yes
Vanadium	No	No	Yes [b]	Yes
Zinc	No	Yes	Yes	Yes

Notes:
Bolded cell = indicates chemicals was identified as being either naturally enriched, potentially elevated due to mine site released and / or regulated / potentially regulated under MMER, or there was a CCME freshwater quality guideline available
Shaded cell **=** indicates chemicals was carried forward for benchmark development
WQG = water quality guideline; CCME PAL = Canadian Council of Ministers of the Environment, Canadian Water Quality Guidelines for the Protection of Aquatic Life
a. Determination based on Final FEIS, Volume 7; re-screened such that metals > 0.5 Hazard Quotient are listed above
b. These metals could potentially become elevated in receiving environments if dusting events were significant, as a result of dust runoff into aquatic receiving environments, based on Final FEIS, Volume 7. Therefore, these metals are included as potential Chemicals of Potential Concern (COPCs) requiring benchmark development.
c. The FEIS had identified potentially elevated mercury and selenium in both the baseline water quality and geochemical source terms attributable to laboratory detection limits. Subsequent testing of both metals at lower detection limits has confirmed that these metals are not expected to be elevated in either the baseline or in the mine effluent.
d. Total Phosphorus is inconsistent in area water courses, and hence, an alternative benchmark approach was developed (related to chlorophyll a) to evaluate potential for nutrient enrichment (see CREMP report)
e Mercury, selenium and uranium are not considered to become potentially elevated as a result of mine site releases, and therefore have not been included for AEMP benchmark development. Mercury will be monitored in mine effluent as part of the EEM Program, and a fish tissue study can be triggered under Part 2, Section 9c of the MMER if mercury in the effluent is found to exceed 0.1 µg/L.

Table 3-2 Selection of General Parameters and Nutrients for Benchmark Development or Exploratory Data Analysis				
General Parameters and Nutrients	***CCME PAL?***	***Included for Benchmark Development***	***Included for Exploratory Data Analysis***	***Comments***
pH	Yes	No	Yes	Exposure Toxicity Modifying Factor
Dissolved oxygen	Yes	No	Yes	
Conductivity	No	No	No	
Turbidity	Yes	No	Yes	
Hardness	No	No	Yes	Exposure Toxicity Modifying Factor
Total Dissolved Solids	No	No	Yes	TDS will be evaluated for statistical change
Total Suspended Solids (TSS)	Yes	No	Yes	TSS is considered to be a potential concern if storm water management is not implemented. It is carried forward for exploratory data analysis in light of this concern
Alkalinity	No	No	Yes	Exposure Toxicity Modifying Factor
Bromide (Br-)	No	No	No	
Chloride (Cl-)	Yes	Yes	Yes	Some chloride release has occurred related to exploration drilling activities (near stream environments), therefore it is being included for benchmark development
Sulphate (SO_4^{2-})	No	Yes	Yes	Can be associated with mining activities; recent BC MOE guideline available for sulphate (Meays and Nordin, 2013)
Ammonia (NH_3+NH_4^+)	Yes	Yes	Yes	Can be associated with mining activities; benchmark available
Nitrite (NO_2^-)	Yes	Yes	Yes	Can be associated with mining activities; benchmark available
Nitrate (NO_3^-)	Yes	Yes	Yes	Can be associated with mining activities; benchmark available
Magnesium	No	No	Yes	Associated with hardness and TDS; will be monitored for change
Phosphorus	Yes	No	Yes	Due to variability in natural waters, phosphorus will be included for Exploratory data Analysis; monitoring for eutrophication will be done using Chlorophyll a.
Potassium	No	No	Yes	
Total Organic Carbon (TOC)	No	No	Yes	Exposure Toxicity Modifying Factor
Dissolved Organic Carbon (DOC)	No	No	Yes	Exposure Toxicity Modifying Factor

Table 3-2 Selection of General Parameters and Nutrients for Benchmark Development or Exploratory Data Analysis				
General Parameters and Nutrients	***CCME PAL?***	***Included for Benchmark Development***	***Included for Exploratory Data Analysis***	***Comments***
Total Kjeldahl Nitrogen (TKN)	No	No	No	Assessment of monitoring data for Total ammonia, nitrite, nitrate and Chlorophyll a should provide adequate evaluation tools
Phenols	Yes	No	No	Not anticipated to be associated with facility releases

Notes:
Bolded text = selected for Exploratory Data Analysis only
Shaded text = selected for benchmark development (which will also include Exploratory Data Analysis as part of the Assessment Framework)

Based on the review of the metals, nutrients and general parameters selected for evaluation are provided in Table 3-3.

Table 3-3 List of Metals, Nutrients and Other Parameters Selected for Benchmark Development or Exploratory Data Analysis

Selected For Benchmark Development		*Selected for Exploratory Data Analysis*
Aluminum	Vanadium	pH
Arsenic	Zinc	Hardness
Cadmium		Total Dissolved Solids
Chromium		Total Suspended Solids (TSS)/Turbidity
Copper		Alkalinity
Cobalt	Ammonia (NH_3+NH_4)	Magnesium
Iron	Chloride	Phosphorus
Lead	Nitrite (NO_2^-)	Potassium
Nickel	Nitrate (NO3-)	Total Organic Carbon (TOC)
Silver	Sulphate	Dissolved Organic Carbon (DOC)
Thallium		Dissolved oxygen

Metals/non-metals and other key parameters not selected for benchmark develop will still undergo some degree of trend analysis within Step 1 of the Exploratory Data Analysis. If increasing trends are noticed, benchmark development will be undertaken.

C-3.2 Baseline Surface Water Data Evaluation for Determining AEMP Benchmarks

Baseline water quality data were received from Knight Piésold. Data treatment conducted in the Baseline Integrity Review (Knight Piésold, 2014) involved the following steps:

- Removing all duplicate samples, to avoid "double counting" of data;
- All samples which were non-detect were assumed to equal the detection limit for statistical calculations; and
- Where detection limits were elevated compared to later sampling events, they were substituted with lower detection limits (see Baseline Integrity Report; Knight Piésold, 2014).

Following completion of the data treatment steps present above, a detailed assessment of surface water quality was undertaken (CREMP Main Report and Appendix B; Knight Piésold, 2014). This detailed assessment included Camp Lake, Mary Lake and Sheardown Lake NW in addition to Mary River and Camp Lake Tributary. For Sheardown Lake, Knight Piésold (2014) focused their evaluation on the northwest basin since it is the closest to project activities, its tributary is important to juvenile char and it has been the most studied mainly due to treated sewage effluent discharges. The following sections provide a summary of trends observed in lakes and rivers, respectively in addition to how the data were treated for AMEP benchmark development.

C-3.2.1 Area Lakes (Camp Lake, Mary Lake, Sheardown Lake)

General water quality parameters in Camp Lake, Mary Lake and Sheardown Lake NW and SE were reported to be similar with all lakes being slightly alkaline (median pH values >7.5) and soft, with hardness being mainly carbonate hardness. A summary of the trends observed in Camp Lake, Mary Lake and Sheardown Lake NW and SE by Knight Piésold is provided in Table 3-4. For additional details, please refer to the CREMP Main Report and Appendix B (Knight Piésold, 2014).

Table 3-4 Summary of Trend Analysis of Area Lakes (Knight Piésold, 2014)

Trend	*Lakes*			
	Camp Lake	*Mary Lake*	*Sheardown Lake NW*	*Sheardown Lake SE*
Distinct depth trends	Not observed, suggest lake completely mixed; utilization of both depth and shallow sites to calculate benchmarks deemed appropriate	Not observed, suggest lake completely mixed; utilization of both depth and shallow sites to calculate benchmarks deemed appropriate	Al slightly elevated in deeper samples, suggest lake completely mixed; aggregation of depth and shallow sites appropriate for all parameters except Al	Not observed, suggest lake completely mixed; utilization of both depth and shallow sites to calculate benchmarks deemed appropriate
Geographic trends between discrete sampling sites	Not observed	Slightly elevated concentrations of Al, Cl, Cu, Cr, Fe, hardness and Ni observed at inlet; elevated As concentrations observed at outlet	Little variability	Cu, Fe and Ni (slightly elevated concentrations at DL0-02-4)
Distinct inter annual trends	Chloride and Cr (2011 to 2013 concentrations elevated compared early data)	Fe (2013 data slightly lower concentration than previous years) , Cd (detection limits decreased over course of sampling), Ni (elevated during 2007 winter)	Cd and Fe (decrease in detection limits over years)	Cu and Ni (early data from 2007-2008 elevated compared to more recent data)
Parameters consistently below MDL	As, Cd, nitrate,	As (except for outlet sites), Cd, nitrate,	As, Cd, Cl, nitrate, Fe	As, Cd, nitrate
Elevated parameters	Cu (outliers)	Al, Cu, Cr	Cu	Al, Cu
Parameters do not show seasonal trends	Cl, Cd, As, Fe, nitrate	Cd, Cu, Cr, nitrate	As, Cd, Cl, Cr, Cu, nitrate, Fe	As, Cd, nitrate, Cr and Cu.

Table 3-4 Summary of Trend Analysis of Area Lakes (Knight Piésold, 2014)				
Trend	***Lakes***			
	Camp Lake	***Mary Lake***	***Sheardown Lake NW***	***Sheardown Lake SE***
Parameters with maximum concentrations during summer	Al, nitrate	Al, Fe		Al (and fall), Fe
Parameters with maximum concentrations during fall	Cr	As	Al	
Parameters with maximum concentrations during spring	No sampling	No sampling	No sampling	No sampling
Parameters with maximum concentrations during winter	Cu (and summer), Ni (and summer)	Cl, Ni, Cd	Ni	Cl, Ni

As reported in Table 3-4, with the exception of aluminum in Sheardown Lake NW, distinct depth trends were not observed for Camp Lake, Mary Lake or Sheardown Lake SE and lakes were considered to be completely mixed (Knight Piésold, 2014). This implies that combining the shallow and deep datasets would be appropriate (with the exception of aluminum in Sheardown Lake), except that it constitutes pseudoreplication, since the shallow and deep samples were collected on the same day at the same site. In light of this, Knight Piésold ran a small statistical simulation in order to assess the effects of possible pseudoreplication on the estimation of the standard deviation and 95th percentile.

The statistical model assumes the data is generated in 2 steps:

1) Sample data from a normal distribution with a mean of zero and standard deviation of 1: x
2) Add replication error by adding a random error from a normal distribution with mean 0 and standard deviation of 0.1: y = x + e

In order to consider the data with and without pseudoreplicates, two datasets were created:

1) No pseudo replicates (sample size = n)
2) 3 pseudoreplicates (sample size = 3*n)

In order to test the effects of pseudoreplication, the possible effects of adding both the deep and shallow data on the calculation of standard deviation and the empirical 95^{th} percentile were investigated. The 95^{th} percentile indicates the value below which 95% of the observations in a group occur. Empirical 95^{th} percentiles are indicates the value below which 95% of the observations in a group occur and is calculated using the actual recorded data. Table 1 indicates that the effects of pseudoreplication are small, even at small sample sizes; however, the empirical

95th percentile calculation has some drift with respect to the expected outcome (1.653) at small sample sizes.

Table 3-5 Statistical Model Results indicating effects of Pseudoreplication

Sample Size	*Data*	*Mean*	*Standard Deviation*	*Empirical 95th Percentile*
5	No pseudoreplicates	-0.00715	0.946	1.00
	Pseudoreplicates	-0.00787	0.877	1.2
10	No pseudoreplicates	-0.017	0.98	1.26
	Pseudoreplicates	-0.017	0.94	1.50
25	No pseudoreplicates	0.0067	0.99	1.65
	Pseudoreplicates	0.0056	0.98	1.62
100	No pseudoreplicates	0.0018	1.00	1.60
	Pseudoreplicates	0.0017	1.00	1.63

Note:
1. Based on 1000 simulations.
2. Mean should equal 0 and 95th percentile for normal distribution should equal 1.653

As such, surface and deep water samples for the lakes were combined for determining the AEMP benchmarks, for all lakes and chemicals with the exception of aluminum in Sheardown Lake, which was evaluated separately for surface and deep samples.

The number of water samples collected per year (shallow and deep combined) for each lake is provided in Table 3-6. In addition to Sheardown Lake NW, sample numbers are included for both Sheardown Lake SE and the Sheardown Lake near shore sampling programs, as these samples characterize the SE basin, and nearshore areas of the lakes.

Table 3-6 Number of Water Samples Collected in Area Lakes by Year

Year	*Camp Lake*	*Mary Lake*	*Sheardown Lake NW*	*Sheardown Lake SE*	*Sheardown Lake Near Shore*
2006	3	8	4	4	0
2007	18	24	26	16	0
2008	8	12	22	14	18
2009	0	0	0	0	0
2010	0	0	0	0	0
2011	4	4	20	2	12
2012	6	2	16	4	4
2013	13	21	23	6	8
Total	52	71	111	46	42

Note: not all parameters or chemicals were analyzed for in each sample and as such, total number of samples for a specific parameter or chemical may be less than the values presented here

As can be seen in Tables 3-6, there are a reasonable number of samples obtained from each of the area lakes. As such, Camp Lake, Mary Lake and Sheardown Lake were evaluated separately for the purpose of AEMP development.

To determine if data for Sheardown Lake NW, SE and near shore could be combined, a comparison of select total and dissolved metal concentrations between the various Sheardown Lake sampling locations was conducted. The box and whisker plots in Figures 3-1 and 3-2 respectively show the comparisons of total and dissolved metal concentrations between various Sheardown Lake sampling locations (*i.e*., nearshore, northwest and southeast). In the box and whisker plots, non-detectable values were replaced with detection limits.

Based on the comparisons in Figures 3-1 and 3-2, it was determined that the data for the various areas of Sheardown Lake were similar enough that they could be combined and assessed as a single water body.

Therefore for the purpose of AEMP benchmark development, Camp Lake, Mary Lake and Sheardown Lake (near shore, northwest and southeast data combined) were evaluated separately.

A summary of data for Camp Lake, Mary Lake and Sheardown Lake are provided in Tables 3-7 to 3-9 respectively.

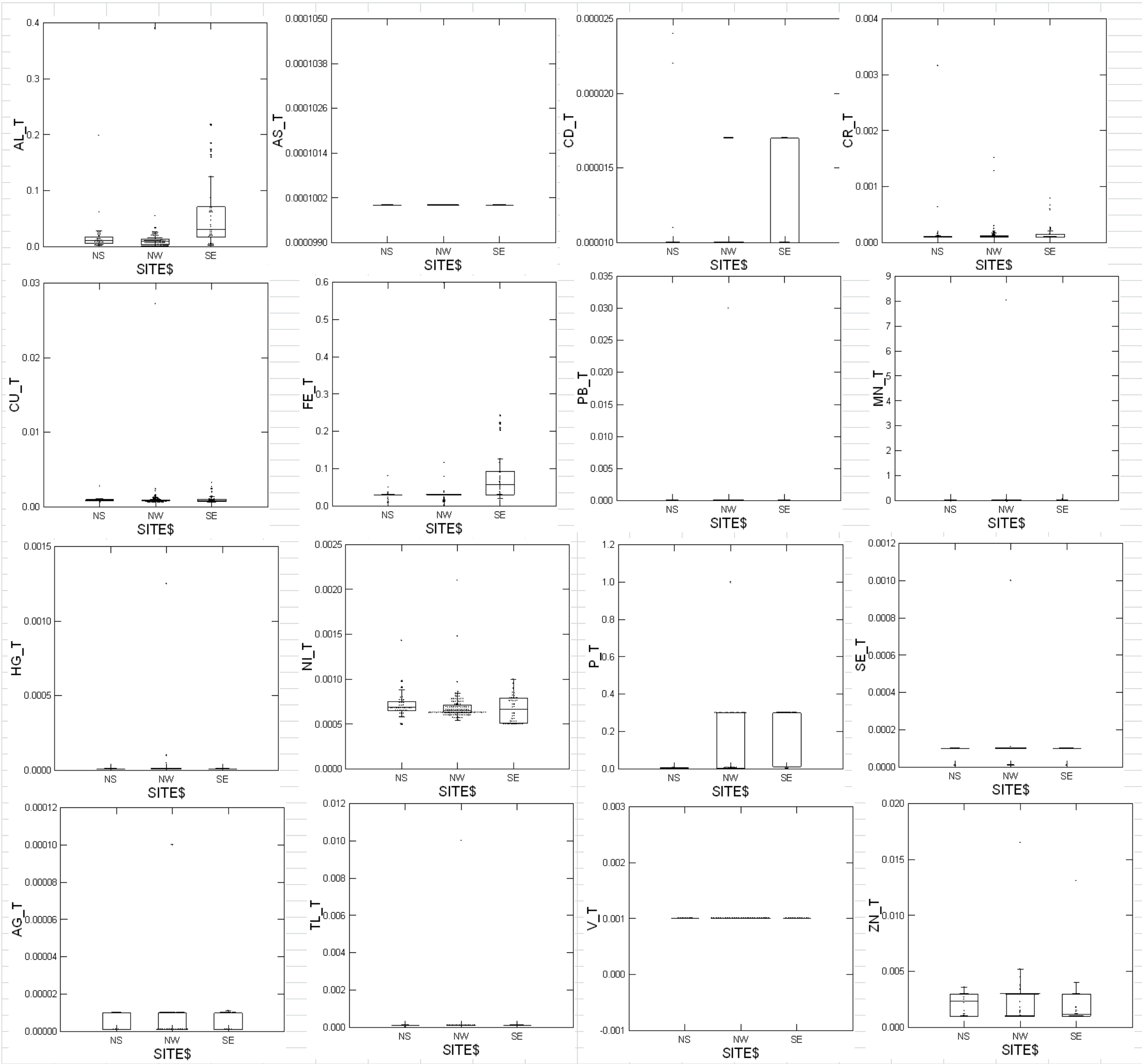

Figure 3-1 Total Metals (mg/L) Compared Between Various Sheardown Lake Sampling Locations (Nearshore (NS), Northwest (NW) and Southeast (SE)); T = total; Non-detectable values replaced with detection limit

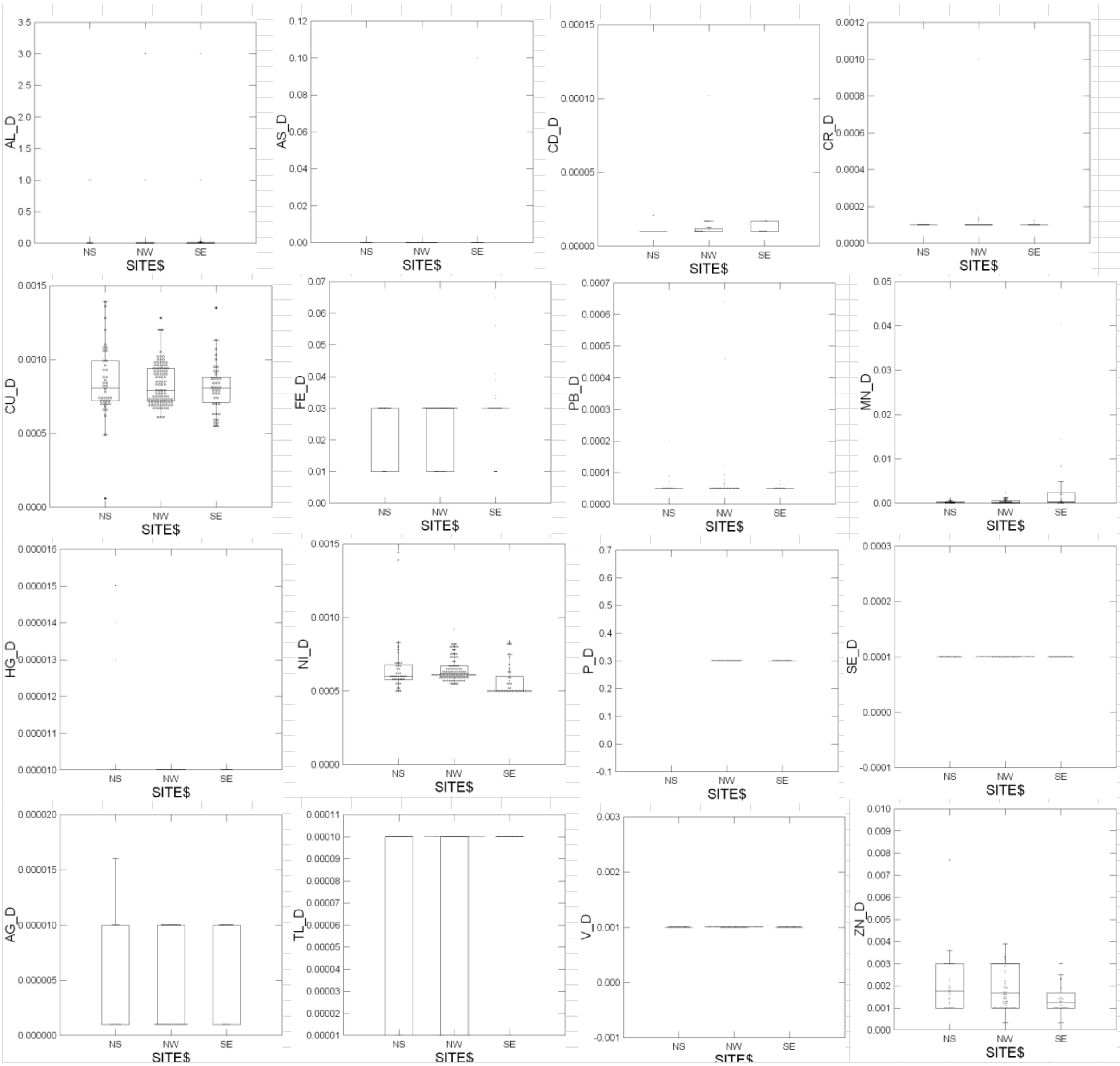

Figure 3-2 Dissolved Metals (mg/L) Compared Between Various Sheardown Lake Sampling Locations (Nearshore (NS), Northwest (NW) and Southeast (SE)); D = Dissolved; Non-detectable values replaced with detection limit

Table 3-7 Summary of Camp Lake Surface Water Analytical Data (Total Metals; 2006 to 2013)

Parameter	*Units*	*N*	*% Detect*	*Min*[b]	*Max*[c]	*Median*[d]	*95th %ILE*[d]	*97.5th %ILE*[d]	*Mean*[d]
Metals[a]									
Aluminium	mg/L	52	92	<0.001	0.0379	0.00615	0.0192	0.0260	0.00801
Arsenic	mg/L	52	0[e]	<0.0001	<0.0001	NC	NC	NC	NC
Cadmium	mg/L	52	4[e]	<0.00001	0.000042	NC	NC	NC	NC
Chromium	mg/L	52	4[e]	<0.0001	0.00014[g]	NC	NC	NC	NC
Chromium $^{+3}$	mg/L	19	0[e]	<0.001	<0.005	NC	NC	NC	NC
Chromium $^{+6}$	mg/L	15	0[e]	<0.001	<0.005	NC	NC	NC	NC
Cobalt	mg/L	52	0[e]	<0.0001	<0.0002	NC	NC	NC	NC
Copper	mg/L	49	100	0.00072	0.019	0.00092	0.00389	0.0113	0.00169
Iron	mg/L	52	23	<0.003	0.057	0.03	0.0343	0.0421	0.0238
Lead	mg/L	49	20	<0.00005	0.000429	0.00005	0.0002	0.000334	0.000074
Nickel	mg/L	49	100	0.00054	0.00114	0.00066	0.00081	0.000914	0.000672
Silver	mg/L	52	0[e]	<0.000001	<0.00001	NC	NC	NC	NC
Thallium	mg/L	49	0[e]	<0.000001	<0.0001	NC	NC	NC	NC
Vanadium	mg/L	52	0[e]	<0.001	<0.001	NC	NC	NC	NC
Zinc	mg/L	49	18	<0.001	0.0049	0.003	0.0032	0.0037	0.0022
Water Quality Parameters									
Chloride (Cl^-)	mg/L	52	27	<1	4	1	4	4	2.02
Ammonia (NH^3+NH^4)	mg N/L	52	92	<0.02	1.41	0.02	0.560	0.84	0.101
Nitrite (NO_2^-)	mg N/L	52	12	<0.002	0.012[e]	0.005	0.1	0.1	0.012
Nitrate (NO_3)	mg N/L	52	0[e]	<0.1	<0.1	NC	NC	NC	NC
Sulphate (SO_4^{2-})	mg/L	52	62	<1	3[e]	2	3	3	2.0
Major Toxicity Modifying Factors for Guideline Development									
pH	-	52	NA	6.8	8.3	7.5	8.3	8.3	7.6
Hardness	mg/L[f]	52	NA	50	77.1	59.7	69.5	73.4	59.4
Temperature	°C	36	NA	0.9	9.0	7.1	8.7	8.9	6.2

Notes:
NC = not calculated; NA = not applicable; %ILE = percentile
a. Total metals unless otherwise noted
b. Minimum values is the lowest of all detected values or the lowest detection limit, whichever is less
c. Maximum values is the maximum detected value or, if no detected values were reported, indicates the maximum detection limit reported
d. For calculation of these summary statistics, non-detect values were replaced with the value of the detection limit
e. Less than 5% of samples were detected, therefore a median, 95th percentile, 97th percentile and mean were not calculated
f. mg/L as $CaCO_3$

Table 3-7 Summary of Camp Lake Surface Water Analytical Data (Total Metals; 2006 to 2013)									
Parameter	*Units*	*N*	*% Detect*	*Min*[b]	*Max*[c]	*Median* [d]	*95th %ILE*[d]	*97.5th %ILE*[d]	*Mean* [d]

g. Maximum detected value is less than highest detection limit. Maximum value selected is the highest detected value.

Table 3-8	Summary of Mary Lake Surface Water Analytical Data (Total Metals; 2006 to 2013)								
Parameter	***Units***	***N***	***% Detect***	***Min***[b]	***Max***[c]	***Median*** [d]	***95th %ILE***[d]	***97.5th %ILE***[d]	***Mean*** [d]
Metals [a]									
Aluminium	mg/L	71	100	0.00284	0.191	0.0387	0.114	0.137	0.0473
Arsenic	mg/L	71	10	0.0001	0.00039	0.0001	0.00015	0.000178	0.000109
Cadmium	mg/L	71	6	<0.00001	0.00024	0.00001	0.000017	0.000023	0.000016
Chromium	mg/L	71	25	0.00012[g]	0.00043[h]	0.0005	0.001	0.001	0.00047
Chromium +3	mg/L	20	10	<0.005	0.005	0.005	0.005	0.005	0.005
Chromium +6	mg/L	21	10	<0.001	0.001	0.001	0.001	0.001	0.001
Cobalt	mg/L	71	3[e]	<0.0001	0.0001[h]	NC	NC	NC	NC
Copper	mg/L	65	100	0.00054	0.00429	0.00079	0.00147	0.00239	0.000949
Iron	mg/L	71	82	<0.01	0.25	0.052	0.135	0.173	0.0619
Lead	mg/L	63	73	<0.00005	0.000149	0.00006	0.00013	0.00013	0.000068
Nickel	mg/L	63	51	<0.0005	0.0009	0.0005	0.00077	0.00080	0.00055
Silver	mg/L	69	3[e]	<0.000001	0.000001[h]	NC	NC	NC	NC
Thallium	mg/L	63	3[e]	<0.000001	0.000001[h]	NC	NC	NC	NC
Vanadium	mg/L	71	11	<0.001	0.0035	0.001	0.001	0.00146	0.00105
Zinc	mg/L	63	14	<0.001	0.003	0.0015	0.003	0.003	0.0020
Water Quality Parameters									
Chloride (Cl^-)	mg/L	71	65	<1	14	2	8	13	3.2
Ammonia (NH_3+NH_4)	mg N/L	71	97	<0.02	0.38	0.05	0.25	0.32	0.087
Nitrite (NO_2^-)	mg N/L	71	27	<0.002	0.1	0.005	0.055	0.1	0.0096
Nitrate (NO_3)	mg N/L	71	6	<0.1	0.14	0.1	0.1	0.11	0.10
Sulphate (SO_4^{2-})	mg/L	64	80	<1	8	3	5	7	2.7
Major Toxicity Modifying Factors for Guideline Development									
pH	-	71	NA	6.7	8.3	7.4	8.2	8.2	7.4
Hardness	mg/L[f]	71	NA	24.9	137	39.5	129	130.5	49.4
Temperature	°C	52	NA	0.6	14.1	7.4	12.9	13.6	6.9

Notes:
NC = not calculated; NA = not applicable; %ILE = percentile
a. Total metals unless otherwise noted
b. Minimum values is the lowest of all detected values or the lowest detection limit, whichever is less
c. Maximum values is the maximum detected value or, if no detected values were reported, indicates the maximum detection limit reported
d. For calculation of these summary statistics, non-detect values were replaced with the value of the detection limit
e. Less than 5% of samples were detected, therefore a median, 95th percentile, 97th percentile and mean were not calculated

Table 3-8	**Summary of Mary Lake Surface Water Analytical Data (Total Metals; 2006 to 2013)**								
Parameter	***Unit s***	***N***	***% Detect***	***Min[b]***	***Max[c]***	***Median [d]***	***95th %ILE[d]***	***97.5th %ILE[d]***	***Mean [d]***

f. mg/L as $CaCO_3$

g. Lowest detected value is less than the lowest non-detected value. Minimum value selected is the lowest detected value.

h. Maximum detected value is less than highest detection limit. Maximum value selected is the highest detected value.

Table 3-9 Summary of Sheardown Lake Surface Water Analytical Data (Total Metals; 2006 to 2013)									
Parameter	***Units***	***N***	***% Detect***	***Min***[b]	***Max***[c]	***Median*** [d]	***95th %ILE***[d]	***97.5th %ILE***[d]	***Mean*** [d]
Metals [a]									
Aluminium (Shallow)	mg/L	91	92	0.0012[g]	0.217	0.0092	0.0102	0.179	0.0223
Aluminum (Deep)	mg/L	90	91	0.001[g]	0.39	0.0134	0.146	0.173	0.030
Arsenic	mg/L	199	10	<0.0001	0.00012	0.0001	0.0001	0.0001	0.0001
Cadmium	mg/L	199	5	<0.00001	0.000024	0.00001	0.00002	0.000017	0.00001
Chromium	mg/L	199	31	<0.0001	0.00316	0.0001	0.0003	0.000641	0.0002
Chromium $^{+3}$	mg/L	47	4[e]	<0.001	0.005	NC	NC	NC	NC
Chromium $^{+6}$	mg/L	47	4[e]	<0.001	0.001	NC	NC	NC	NC
Cobalt	mg/L	199	10	<0.0001	0.00034	0.0001	0.0001	0.0002	0.0001
Copper	mg/L	187	98	0.00046 [g]	0.0272	0.0009	0.0016	0.00243	0.0011
Iron	mg/L	199	46	0.002 [g]	0.598	0.03	0.116	0.211	0.0437
Lead	mg/L	191	33	<0.00005	0.03	0.0001	0.0002	0.00026	0.0002
Nickel	mg/L	191	93	<0.0005	0.0021	0.0007	0.0009	0.000973	0.0007
Silver	mg/L	187	10	<0.000001	0.000011	0.00001	0.00001	0.0000104	0.000008
Thallium	mg/L	179	8	<0.000001	0.0001	0.000100	0.0001	0.0001	0.00012
Vanadium	mg/L	187	8	<0.001	0.001	0.001	0.001	0.001	0.001
Zinc	mg/L	179	26	<0.001	0.0165	0.0022	0.00322	0.00391	0.00220
Water Quality Parameters									
Chloride (Cl^-)	mg/L	202	98	<1	7	3	4	5	2.8
Ammonia (NH_3+NH_4)	mg N/L	201	45	<0.02	0.99	0.02	0.26	0.44	0.060
Nitrite (NO_2^-)	mg N/L	189	7	<0.002	0.009	0.005	0.1	0.1	0.014
Nitrate (NO_3)	mg N/L	201	1[e]	<0.1	0.18	NC	NC	NC	NC
Sulphate (SO_4^{2-})	mg/L	202	85	<1	5	3	4	5	2.7

Table 3-9 Summary of Sheardown Lake Surface Water Analytical Data (Total Metals; 2006 to 2013)									
Parameter	***Units***	***N***	***% Detect***	***Min[b]***	***Max[c]***	***Median [d]***	***95th %ILE[d]***	***97.5th %ILE[d]***	***Mean [d]***
Major Toxicity Modifying Factors for Guideline Development									
pH	-		NA	6.7	8.4	7.6	8.2	8.3	7.6
Hardness	mg/L [f]		NA	0.5	82.2	60.5	76.7	77.9	58.5
Temperature	°C	142	NA	1.1	14.4	8.0	10.8	11.9	7.3

Notes:
NC = not calculated; NA = not applicable; %ILE = percentile
a. Total metals unless otherwise noted
b. Minimum values is the lowest of all detected values or the lowest detection limit, whichever is less
c. Maximum values is the maximum detected value or, if no detected values were reported, indicates the maximum detection limit reported
d. For calculation of these summary statistics, non-detect values were replaced with the value of the detection limit
e. Less than 5% of samples were detected, therefore a median, 95th percentile, 97th percentile and mean were not calculated
f. mg/L as $CaCO_3$
g. Lowest detected value is less than the lowest non-detected value. Minimum value selected is the lowest detected value.

C-3.2.2 Area Rivers (Mary River, Camp Lake Tributary)

Similar to the lakes, Mary River and the Camp Lake Tributary are slightly alkaline and are considered soft to moderately soft, with hardness being mainly carbonate hardness (Knight Piésold, 2014). The intense spring run-off acts to dilute seasonal input with lower metal concentration in spring and higher concentrations in summer. Nitrate, As and Cd concentrations are generally below the MDLs while chloride and Ni are generally above MDL but lower than guidelines. Mary River and the Camp Lake Tributary have slightly different trends for Al and Fe (Knight Piésold, 2014).

A summary of the trends observed in Mary River and the Camp Lake Tributary by Knight Piésold is provided in Table 3-10. For additional details, please refer to the CREMP Main Report and Appendix C (Knight Piésold, 2014). The number of water samples collected per year for Mary River and Camp Lake Tributary is provided in Table 3-11.

Table 3-10 Summary of Analysis of Area Rivers (Knight Piésold, 2014)

Trend	***Streams***	
	Mary River	***Camp Lake Tributary***
Distinct depth trends	NA	NA
Geographic trends between discrete sampling sites	Cl (slightly lower upstream concentrations);	Fe, Cl, Ni (slightly elevated concentrations at L2-03 compared to other sites); Cu (lower concentrations at L2-03).
Distinct inter annual trends	Nitrate (changes in MDL over time); Ni (early data elevated compared to more recent data)	Al (2012 and 2013 data slightly elevated compared to other years); Cr (2012 and 2013 data elevated compared to other years)
Parameters consistently below MDL	As, Cd, nitrate	As, Cd, nitrate
Elevated parameters	Al, Cu, Cr, Fe	Al (spring and summer outliers), Cu, Fe, Cr
Parameters do not show seasonal trends	As, Cd, nitrate (MDL interference, but outliers occur in the fall), Ni, Cr	Fe, Ni, Cr
Parameters with maximum concentrations during summer	Al, Cu (and fall), Fe	Cu (muted trend)
Parameters with maximum concentrations during fall	Cl	Cl
Parameters with maximum concentrations during spring		Al
Parameters with maximum concentrations during winter	No sampling	No sampling

Table 3-11 Number of Water Samples Collected in Area Rivers by Year

Year	***Mary River***	***Camp Lake Tributary***
2005	15	11
2006	71	12
2007	80	14
2008	103	16
2009	35	0
2010	8	0
2011	16	6
2012	25	15
2013	26	15
Total	379	89

Note: not all parameters or chemicals were analyzed for in each sample and as such, total number of samples for a specific parameter or chemical may be less than the values presented

The samples numbers for Mary River and Camp Lake Tributary are sufficiently large such that these rivers were evaluated separately for the purpose of AEMP development. A summary of data for Mary River and Camp Lake Tributary are provided in Tables 3-12 to 3-13 respectively.

Table 3-12 Summary of Mary River Surface Water Analytical Data (Total Metals; 2005 to 2013)									
Parameter	*Units*	*N*	*% Detect*	*Min*[b]	*Max*[c]	*Median* [d]	*95th %ILE*[d]	*97.5th %ILE*[d,i]	*Mean* [d]
Metals [a]									
Aluminium	mg/L	381	100	0.0019	2.97	0.148	0.725	0.97	0.225
Arsenic	mg/L	381	7	<0.0001	0.00095	0.0001	0.00011	0.00013	0.0001
Cadmium	mg/L	381	8	<0.00001	0.00015	0.00001	0.000017	0.00002	0.00001
Chromium	mg/L	380	38	<0.0001	0.054	0.0001	0.002	0.0023	0.0007
Chromium $^{+3}$	mg/L	63	6	<0.001	0.003[h]	0.005	0.005	0.005	0.0041
Chromium $^{+6}$	mg/L	51	2	<0.0001	0.0015[h]	NC[e]	NC	NC	NC
Cobalt	mg/L	376	24	<0.0001	0.0006	0.0002	0.00031	0.0004	0.00018
Copper	mg/L	270	97	0.00023[g]	0.0044	0.0010	0.0022	0.0024	0.0012
Iron	mg/L	381	90	<0.01	2.2	0.14	0.64	0.874	0.213
Lead	mg/L	223	78	<0.00005	0.0013	0.00016	0.00056	0.00076	0.0002
Nickel	mg/L	211	69	<0.0005	0.0026	0.00063	0.0015	0.0018	0.00078
Silver	mg/L	376	6	<0.000001	0.0004	0.00001	0.0001	0.0001	0.000044
Thallium	mg/L	279	6	<0.000001	0.0002	0.0001	0.0002	0.0002	0.00009
Vanadium	mg/L	376	14	<0.0009	0.0035	0.001	0.0016	0.002	0.0011
Zinc	mg/L	236	44	<0.00033	0.0167	0.0028	0.01	0.01	0.003
Water Quality Parameters									
Chloride (Cl^-)	mg/L	350	74	0.3[g]	73	4	18	21.55	6.14
Ammonia (NH^3+NH^4)	mg N/L	330	44	<0.02	1.03	0.02	0.40	0.60	0.07
Nitrite (NO_2^-)	mg N/L	330	31	<0.002	0.05[h]	0.005	0.06	0.06	0.01
Nitrate (NO_3)	mg N/L	387	7	<0.05	0.36	0.1	0.11	0.14	0.102
Sulphate (SO_4^{2-})	mg/L	336	65	<0.05	9	3	6.2	8	3.1
Major Toxicity Modifying Factors for Guideline Development									
pH	-	339	NA	6.26	8.57	7.86	8.25	8.35	7.77
Hardness	mg/L [f]	374	NA	4.4	891	52.2	108.7	121.4	57.41
Temperature	°C	338	NA	-0.1	17.07	6.05	13.36	14.12	5.91

Notes:
NC = not calculated; NA = not applicable; %ILE = percentile
a. Total metals unless otherwise noted
b. Minimum values is the lowest of all detected values or the lowest detection limit, whichever is less
c. Maximum values is the maximum detected value or, if no detected values were reported, indicates the maximum detection limit reported
d. For calculation of these summary statistics, non-detect values were replaced with the value of the detection limit
e. Less than 5% of samples were detected, therefore a median, 95th percentile, 97th percentile and mean were not calculated
f. mg/L as $CaCO_3$
g. Lowest detected value is less than the lowest non-detected value. Minimum value selected is the lowest detected value.
h. Maximum detected value is less than highest detection limit. Maximum value selected is the highest detected value.
i. One sample (outlier) containing chemical concentrations orders of magnitude above other values was not included in the calculations for Mary River.

Table 3-13 Summary of Camp Lake Tributary Surface Water Analytical Data (Total Metals; 2005 to 2013)

Parameter	*Units*	*N*	*% Detect*	*Min*[b]	*Max*[c]	*Median*[d]	*95th %ILE*[d]	*97.5th %ILE*[d]	*Mean*[d]
Metals[a]									
Aluminum	mg/L	88	90	<0.004	0.252	0.01	0.106	0.179	0.0247
Arsenic	mg/L	88	6	<0.0001	0.00554	0.0001	0.0001	0.00012	0.00016
Cadmium	mg/L	88	1[e]	<0.00001	0.000096[h]	NC	NC	NC	NC
Chromium	mg/L	88	36	0.000022[g]	0.003	0.0001	0.000699	0.000856	0.00020
Chromium +3	mg/L	30	0	<0.005	<0.005	NC	NC	NC	NC
Chromium +6	mg/L	30	0	<0.001	<0.001	NC	NC	NC	NC
Cobalt	mg/L	87	2	<0.0001	0.00013[h]	NC	NC	NC	NC
Copper	mg/L	85	95	<0.00001	0.00359	0.0016	0.00204	0.00222	0.00152
Iron	mg/L	88	75	<0.0001	0.44	0.05	0.190	0.326	0.0684
Lead	mg/L	56	20	<0.00005	0.00025[h]	0.00005	0.000268	0.000333	0.000094
Nickel	mg/L	52	75	0.000202[g]	0.00265	0.00077	0.00131	0.00168	0.00085
Silver	mg/L	87	0	<0.000001	<0.00001	NC	NC	NC	NC
Thallium	mg/L	71	14	<0.000001	0.00909	0.0001	0.0002	0.0002	0.00021
Vanadium	mg/L	86	1	<0.0009	0.001[h]	NC	NC	NC	NC
Zinc	mg/L	61	21	<0.00033	0.0104	0.003	0.0032	0.0035	0.00240
Water Quality Parameters									
Chloride (Cl^-)	mg/L	89	100	0.2[g]	121	2	17.8	23	6.06
Ammonia (NH^3+NH^4)	mg N/L	86	52	<0.02	0.8	0.02	0.475	0.60	0.087
Nitrite (NO_2^-)	mg N/L	86	15	0.002[g]	0.014[h]	0.005	0.06	0.095	0.015
Nitrate (NO_3)	mg N/L	89	9	<0.05	0.18	0.1	0.106	0.118	0.0961
Sulphate (SO_4^{2-})	mg/L	88	73	<0.5	8	3	5.7	6	2.8
Major Toxicity Modifying Factors for Guideline Development									
pH	-	84	NA	4.94	8.71	7.88	8.42	8.52	7.80
Hardness	mg/L[f]	87	NA	0.003	317	73.7	133.8	140	76.16
Temperature	°C	85	NA	-0.17	17.81	6.05	14.15	17.33	6.52

Notes:
NC = not calculated; NA = not applicable; %ILE = percentile
a. Total metals unless otherwise noted
b. Minimum values is the lowest of all detected values or the lowest detection limit, whichever is less
c. Maximum values is the maximum detected value or, if no detected values were reported, indicates the maximum detection limit reported
d. For calculation of these summary statistics, non-detect values were replaced with the value of the detection limit
e. Less than 5% of samples were detected, therefore a median, 95th percentile, 97th percentile and mean were not calculated
f. mg/L as $CaCO_3$
g. Lowest detected value is less than the lowest non-detected value. Minimum value selected is the lowest detected value.
h. Maximum detected value is less than highest detection limit. Maximum value selected is the highest detected value.

C-3.3 AMEP Benchmark Derivation for Surface Waters

The focus of AEMP benchmark development was on Total Metals, since available Canadian water quality guidelines focus on Total Metals benchmarks, as opposed to dissolved metals data. Dissolved data will be assessed under the Assessment Approach and Response Framework in the Exploratory Data Analysis (Step 1 of Figure 5.1) to examine trends, and where deemed appropriate, based on assessment of both dissolved and total analyses, benchmarks will be considered for development if data are suggesting mine-related increases are occurring. Dissolved water quality guidelines are available for some parameters from the US EPA (http://water.epa.gov/scitech/swguidance/standards/criteria/current/index.cfm#altable), as well as British Columbia Ministry of Environment, and these guidelines would be considered as a first point of comparison, in conjunction with baseline levels, as well as SSWQG, where appropriate.

For the total metals, and other selected parameters, the process used to select the AEMP benchmark was similar to that presented for sediments, in Figure 2-4. Briefly, the higher of either the 97.5th percentile, the CCME PAL, or 3 times the method detection limit were chosen to represent the AEMP benchmark.

To develop AEMP benchmarks for water quality parameters, appropriate guidelines were identified from the CCME freshwater aquatic life guidelines (CCME, 2014). Modifications were required based on site specific parameters, such as hardness or pH, the 25%ile hardness and 25%ile pH values for the water body in question was used in order to calculate a protective guideline. For ammonia, the 75th percentile temperature and pH were used to calculate the guideline. Where parameters are trending up towards these AEMP benchmarks, site-specific values should be substituted for comparison purposes (in Low Action).

Where no CCME guideline was available for a substance of interest, a BC MOE (Ministry of the Environment) Approved or Working guideline for the water column were used, where available (Nagpal et al, 2006). The guidelines selected for use in developing the AEMP benchmarks are provided in Table 3-14.

Table 3-14 Water Quality Guidelines Selected for Chemicals Carried Forward for Benchmark Development

Chemical	***Freshwater Aquatic Life Guideline (mg/L)***	***Reference***
Aluminum (Al)	0.1[a]	CCME, 1987
Arsenic (As)	0.005	CCME, 1997
Cadmium (Cd)	Camp Lake = 0.0001[b] Mary Lake / Mary River = 0.00006 Sheardown Lake = 0.00009 Camp Lake Tributary = 0.00008	CCME, 2014
Chromium III (Cr)	0.0089	CCME, 1997
Chromium VI (Cr)	0.001	CCME, 1997
Cobalt (Co)	0.004 [e]	BC MOE (Nagpal, 2004)
Copper (Cu)	0.002 [c]	CCME, 1987
Iron (Fe)	0.3	CCME, 1987
Lead (Pb)	0.001 [d]	CCME, 1987
Nickel (Ni)	0.025 [f]	CCME, 1987
Silver (Ag)	0.0001	CCME, 1987
Thallium (Tl)	0.0008	CCME, 1999
Vanadium (V)	0.006 [g]	BCMOE (Nagpal et al., 2006)
Zinc (Zn)	0.030	CCME, 1987
Ammonia	Based on pH and temperature (look up table provided in CCME, on-line) [h]	CCME, 2011
Chloride	120	CCME, 2012
Nitrogen – Nitrite	0.060 NO_2 – N (equivalent to 0.197 mg nitrite / L)	CCME, 2001
Nitrogen – Nitrate	13	CCME, 1987
Sulphate	218[i]	BC MOE, (Meays and Nordin, 2013)

Notes:

25th percentile pH: Camp Lake 7.3; Mary Lake 6.9; Sheardown Lake 7.3; Camp Lake Tributary 7.7; Mary River 7.6

25th percentile hardness (as $CaCO_3$): Camp Lake 55.3; Mary Lake 33.2; Sheardown Lake 53.5; Camp Lake Tributary 41.0; Mary River 28.0

a. pH Guideline of 0.1 mg/L selected since 25th%ile pH in all lakes and rivers was ≥ 6.5

b. Cadmium guideline based on 25%ile water hardness and following equation: $CWQG\ (mg/L) = [10^{\{0.83(\log[hardness]) - 2.46\}}] / 1000$.

c. Copper guideline based on 25th%ile water hardness and following equation: $CWQG\ (mg/L) = [0.2 * e^{\{0.8545[\ln(\underline{hardness})]-1.465\}}] / 1000$.

d. Lead guideline based on 25th%ile water hardness and following equation: $CWQG\ (mg/L) = [e^{\{1.273[\ln(\underline{hardness})]-4.705\}}] / 1000$

e. 30 day average; approved guideline

f. Nickel guideline based on 25th%ile water hardness and following equation: $CWQG\ (mg/L) = [e^{\{0.76[\ln(\underline{hardness})]+1.06\}}] / 1000$.

g. Working guideline; reported as Ontario's water quality objective

h. Based on pH and temperature (look up table provided in CCME, on-line); calculated based on 75%ile temperature data, to be conservative, and 75%ile pH of 7.5. These values equate to a pH of 8 and a temperature of 10 degrees C, in the summary table, which yields a guideline of 0.855 mg/L total ammonia-N.

i. 30-day average (minimum of 5 evenly-spaced samples collected in 30 days); Approved guideline

The selected water quality guidelines were then compared to baseline data to determine an AEMP benchmark for each of the selected chemicals. As per the sediment benchmark evaluation approach, a statistical representation of baseline concentrations was calculated to determine an upper estimate of natural concentrations. As per sediment AEMP benchmarks, the 97.5^{th} percentile concentration was used as the statistical metric. A comparison of the selected water quality guidelines to the 97.5^{th} percentile concentrations in each water body are provided in Tables 3-15 and 3-16 for area lakes and rivers, respectively, with the recommended parameter-specific AEMP benchmark. The basis of the recommended AEMP benchmark is identified in Tables 3-15 and 2-16 as follows:

- Method A: Water Quality Guideline was higher than 97.5%ile, and therefore was selected
- Method B: 97.5%ile was higher than the Water Quality Guideline, and therefore was selected; or
- Method C: Parameter has < 5% detected values, and either the Water Quality Guideline was selected (if available), or 3 * MDL was used to derive benchmark

If Method B was selected, additional assessment of the data was conducted to ensure the percentile calculations were not being driven by elevated detection limits, or other factors.

In most cases, the recommended AEMP benchmarks are consistent between lakes and rivers, with the vast majority of selected benchmarks being regulatory water quality guidelines. A summary table is presented (Table 3-17). Where natural concentrations varied, and exceeded available water quality guidelines, or < 5% of values were detected, recommended AEMP benchmarks varied (see Tables 3-15 and 3-16 and 3-17).

As discussed in the CREMP, some parameters have been shown to exhibit some changes in concentrations with season. For those parameters, Step 1 of the assessment framework should include an evaluation of seasonality trends relative to the AEMP benchmark and baseline. AEMP benchmarks may need to be re-visited for these compounds, and SSWQG can be considered.

Several water quality guidelines established by the CCME are currently under revision (i.e., lead and iron) or have been released in draft form for comments (silver). Once finalized, these revised benchmarks should be evaluated, using the benchmark selection process outlined, and AEMP benchmarks updated accordingly.

Table 3-15 Comparison of 97.5th Percentile Concentrations in Area Lakes to Water Quality Guidelines and Selection of AEMP Benchmarks							
Parameter	***Units***	***Water Quality Guideline***	***Camp Lake***	***Mary Lake***	***Sheardown Lake***	***Selected AEMP Benchmark***	***Benchmark Method***
Metals [a]							
Aluminium	mg/L	0.1	0.026	0.137	0.179 (Shallow) 0.173 (Deep)	CL = 0.1 ML = 0.13; SDL shallow/deep = 0.179/0.173	A (CL), B (ML/SDL)
Arsenic	mg/L	0.005	NC	0.00018	0.0001	0.005	A
Cadmium	mg/L	0.0001 (CL) 0.00006 (ML) 0.00009 (SDL)	NC	0.000023	0.000017	0.0001 (CL) 0.00006 (ML) 0.00009 (SDL)	A
Chromium	mg/L	NGA	NC	0.001	0.000641	0.0003 (CL) (ML) = 0.0005[f] (SDL) = 0.000642[g]	B (ML/SDL), C (CL)
Chromium +3	mg/L	0.0089	NC	0.005	NC	0.0089	A
Chromium +6	mg/L	0.001	NC	0.001	NC	0.003 – 0.015 (CL)[c] 0.003 (ML/SDL)[c]	C
Cobalt	mg/L	0.004	NC	NC	0.0002	0.004	A
Copper	mg/L	0.002	0.0113	0.00239	0.00243	(CL) = 0.004[e] (ML) = 0.0024 (SDL) = 0.0024	B
Iron	mg/L	0.3	0.0421	0.173	0.211	0.3	A
Lead	mg/L	0.001	0.000334	0.00013	0.00026	0.001	A
Nickel	mg/L	0.025	0.000941	0.00080	0.000973	0.025	A
Silver	mg/L	0.0001	NC	NC	0.0000104	0.0001	A
Thallium	mg/L	0.0008	NC	NC	0.0001	0.0008	A
Vanadium	mg/L	0.006	NC	0.00146	0.001	0.006	A
Zinc	mg/L	0.030	0.0037	0.003	0.00391	0.030	A
Water Quality Parameters							
Chloride (Cl^-)	mg/L	120	4	13	5	120	A
Ammonia (NH_3+NH_4)	mg total ammonia-N/L	0.855[b]	0.84	0.32	0.44	0.855	A
Nitrite (NO_2^-)	mg N/L	0.060	0.1[d]	0.1[d]	0.1[d]	0.060	A

Table 3-15 Comparison of 97.5th Percentile Concentrations in Area Lakes to Water Quality Guidelines and Selection of AEMP Benchmarks

Parameter	*Units*	*Water Quality Guideline*	*Camp Lake*	*Mary Lake*	*Sheardown Lake*	*Selected AEMP Benchmark*	*Benchmark Method*
Nitrate (NO_3)	mg N/L	13	NC	0.11	NC	13	A
Sulphate	mg/L	218	3	7	5	218	A

Notes:
NGA = no guideline available; NC = Not Calculated; TBD = To Be Determined; Guideline still under development; CL = Camp Lake; ML = Mary Lake; SDL = Sheardown Lake
Method A = Water Quality Guideline from CCME/B.C. MOE; Method B = 97.5%ile of baseline; Method C = 3* MDL
a. Total metals unless otherwise noted
b. Assumes temperature at 10 degrees C, and pH of 8
c. The 2013 detection limit for Cr^{6+} increased in 2013 from 0.001 to 0.005, hence this affects the 3* MDL calculation for the benchmark in Camp Lake. Efforts will be made to reduce this MDL in 2014, and comparisons to the lower of the 2 benchmarks would then be applied in Camp Lake. If detection limits improve, Method A (selection of the guideline) may be implemented.
d. These values are elevated detection limits, and hence, the guideline has been selected as the AEMP benchmark
e. The maximum value of 0.0113 mg/L copper was removed to calculate the 97.5th percentile, as this value appears to be an outlier.
f. An elevated detection limit of 0.001 mg/L was removed from the dataset and calculations, and the AEMP selected was the 97.5th percentile, which is 0.0005 mg/L.
g. Several detected values ranging from 0.00079 – 0.00316 mg/L Cr have been reported in the dataset for SDL, and hence, these values were considered to represent baseline, and were included in the 97.5th percentile calculation.

Table 3-16 Comparison of 97.5th Percentile Concentrations in Area Rivers to Water Quality Guidelines and Selection of AEMP Benchmarks

Parameter	*Units*	*Water Quality Guideline*	*Camp Lake Tributary*	*Mary River*[a]	*Selected AEMP Benchmark*	*Benchmark Method*
Metals [b]						
Aluminum	mg/L	0.1	0.179	0.97	CLT = 0.179 MR = 0.966	B
Arsenic	mg/L	0.005	0.00012	0.00013	0.005	A
Cadmium	mg/L	0.00008 (CLT) 0.00006 (MR)	NC	0.00002	CLT = 0.00008 MR = 0.00006	A
Chromium	mg/L	NGA	0.000856	0.0023	CLT = 0.000856 MR = 0.0023	B
Chromium $^{+3}$	mg/L	0.0089	NC	0.005	0.0089	A
Chromium $^{+6}$	mg/L	0.001	NC	NC	0.003[c]	C
Cobalt	mg/L	0.004	NC	0.0004	0.004	A
Copper	mg/L	0.002	0.00222	0.0024	CLT = 0.0022 MR = 0.0024	B
Iron	mg/L	0.3	0.326	0.874	CLT = 0.326 MR = 0.874	B
Lead	mg/L	0.001	0.000333	0.00076	0.001	A
Nickel	mg/L	0.025	0.00168	0.0018	0.025	A
Silver	mg/L	0.0001	NC	0.0001	0.0001	A
Thallium	mg/L	0.0008	0.0002	0.0002	0.0008	A
Vanadium	mg/L	0.006	NC	0.002	0.006	A
Zinc	mg/L	0.030	0.0035	0.01	0.030	A
Water Quality Parameters						
Chloride (Cl^-)	mg/L	120	23	21.55	120	A
Ammonia (NH_3+NH_4)	mg total ammonia-N/L	0.855[d]	0.60	0.60	0.855	A
Nitrite (NO_2^-)	mg N/L	0.060	0.095[e]	0.06	0.060	A
Nitrate (NO_3)	mg N/L	13	0.118	0.14	13	A
Sulphate	mg/L	218	6	8	218	A

Notes:
NGA = no guideline available; NC = Not Calculated; TBD = To Be Determined; Guideline still under development; MR = Mary River; CLT = Camp Lake Tributary
Method A = Water Quality Guideline from CCME/B.C. MOE; Method B = 97.5%ile of baseline; Method C = 3* MDL
a. One sample (outlier) containing chemical concentrations orders of magnitude above other values was not included in the calculations for Mary River.
b. Total metals unless otherwise noted
c. Efforts will be made to reduce this MDL in 2014, and comparisons to the higher of the Method A or C would then be applied as the AEMP benchmark
d. Assumes temperature at 10 degrees C, and pH of 8.0
e. 97.5th percentile is being driven by elevated detection limit, therefore, the guideline was selected

C- 4.0 REFERENCES

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Appendix D

Development of Final Sediment Quality Benchmarks

SCIENCE INTEGRITY KNOWLEDGE

ESTABLISHMENT OF FINAL SEDIMENT QUALITY AQUATIC EFFECTS MONITORING PROGRAM BENCHMARKS

FINAL REPORT

Date March 23, 2015

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ESTABLISHMENT OF FINAL SEDIMENT QUALITY AQUATIC EFFECTS MONITORING PROGRAM BENCHMARKS

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EXECUTIVE SUMMARY

This report provides an evaluation of sediment benchmarks which can be used to assess sediment chemistry data collected under the Aquatic Effects Monitoring Program (AEMP) for the Mary River Mine, in Baffin Island. The development of these benchmarks involved an evaluation of baseline sediment chemistry data, collected prior to commencement of mining, and various effect-based sediment quality guidelines. The selection of the final sediment quality benchmarks for selected metals of interest was based on the higher of either the 97.5th percentile of baseline, or the sediment quality benchmark from reputed regulatory agencies, or 3 times the method detection limit, in instances were all data were non-detect.

ESTABLISHMENT OF FINAL SEDIMENT QUALITY AQUATIC EFFECTS MONITORING PROGRAM BENCHMARKS

1.0 INTRODUCTION

Baffinland Iron Ore Mines Corporation (Baffinland) operates the Mary River Mine in northern Baffin Island. As part of their license to operate, Baffinland is required to have an Aquatic Effects Monitoring Program (AEMP), to monitor the receiving environment for change, related to mining activities. The AEMP is multifaceted, and provides an over-arching umbrella for a number of sub-monitoring programs or studies, including the Core Receiving Environment Monitoring Program (CREMP), the Environmental Effects Monitoring (EEM) program, under the Federal Metal Mining Effluent Regulations (MMER), a Lake Sedimentation Monitoring Program, a Dustfall Monitoring Program, and a Stream Diversion Barrier Study. These programs are described in detail in the AEMP (Baffinland, 2014).

1.1 Background on the CREMP

The CREMP is designed to assess the potential for both long and short term changes in the environment, and will be used to evaluate the accuracy of predictions made in the Final Environmental Impact Statement (FEIS). It can also be used to assess the effectiveness of mitigations which are implemented to reduce change. Within the CREMP, there are two main aspects, as follows:

- A sediment and water quality monitoring program in lakes and rivers near to, and distant to the mine;
- A biological monitoring program which includes fish, benthos, and phytoplankton species in the same lakes and rivers as the sediment and water quality program is undertaken.

As part of the AEMP (Baffinland, 2014), an Assessment Approach and Response Framework was developed to explain the data evaluation process, to outline various management response actions as a result of mine-related change being detected in the environment. This assessment framework is presented in Figure 1-1. This approach clearly identifies that once mine-related change is identified for a given parameter, comparisons to an AEMP benchmark will take place, and actions resulting from that comparison will occur.

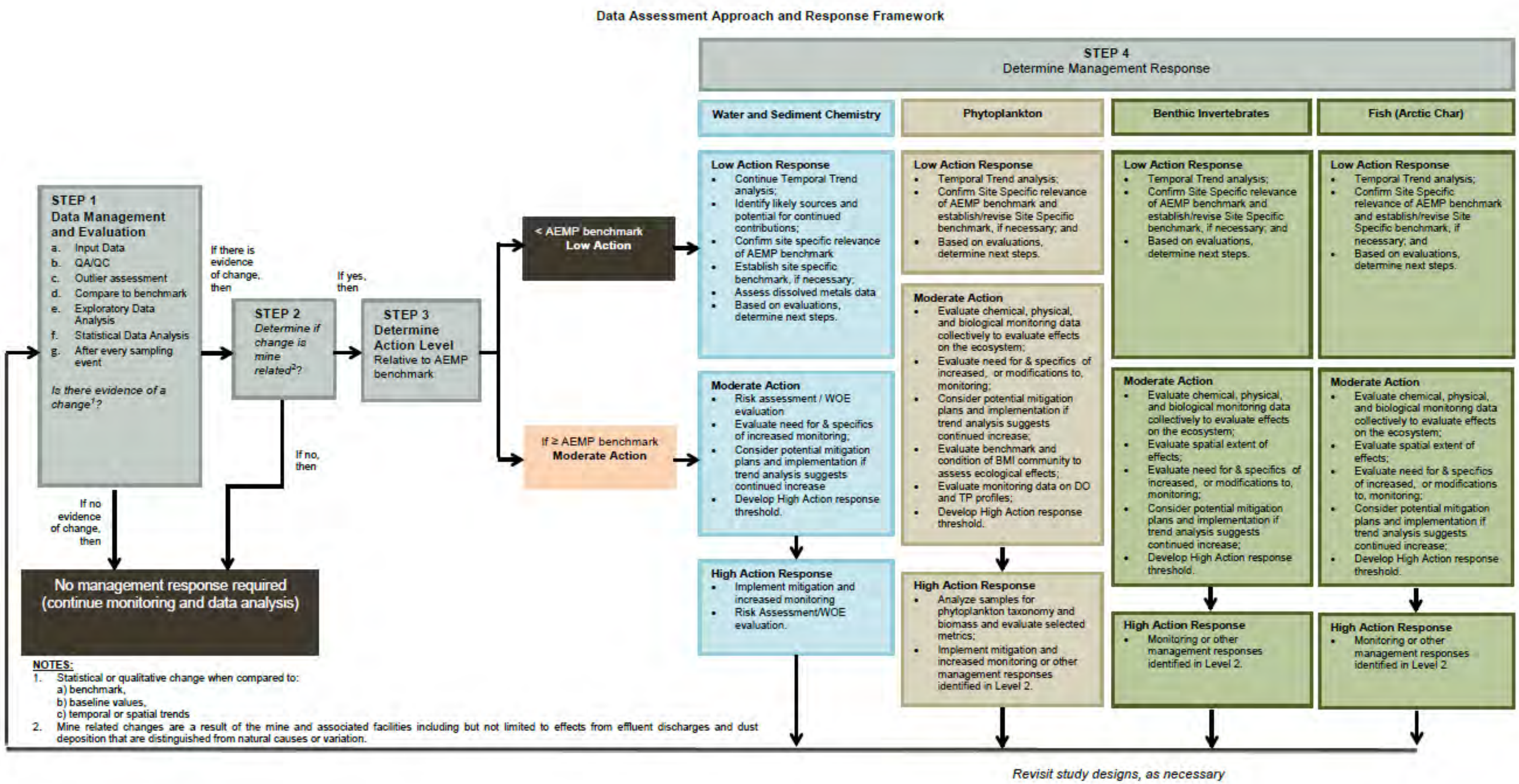


Figure 1-1 Data Assessment Approach and Response Framework

As part of this process, AEMP benchmarks were established for surface water quality (Baffinland, 2014). The process used to develop these benchmarks involved the assessment of baseline water chemistry for various metals, nutrients, and other water quality parameters, as well as the identification of water quality guidelines from regulatory agencies, such as the Canadian Council for Ministers of the Environment (CCME), and the British Columbia Ministry of Environment (BC MOE). Where an upper percentile of baseline (the 97.5th%ile) was greater than a regulatory guideline, this metric of baseline was chosen to represent the AEMP benchmark. Where the regulatory guideline was greater than baseline, it was selected. If data were largely non-detect, a multiplier of the reported detection limit was selected as the benchmark. Further details, and surface water benchmarks, are presented in Baffinland (2014). In addition to surface water benchmark, sediment benchmarks were also developed. The benchmarks established for sediments in Baffinland (2014) were considered “interim” as several of the lakes had limited baseline data Camp Lake, N = 9; Mary Lake, N = 6; Sheardown Lake South East, N = 6, and Sheardown Lake North west, N = 25). The small number of baseline samples limited the ability to statistically evaluate whether any of the water bodies of interest should have separate benchmarks, or whether the lakes were similar enough to have identical benchmarks. The interim sediment benchmarks were established based on all lakes combined, using the approach outlined in Figure 1-2.

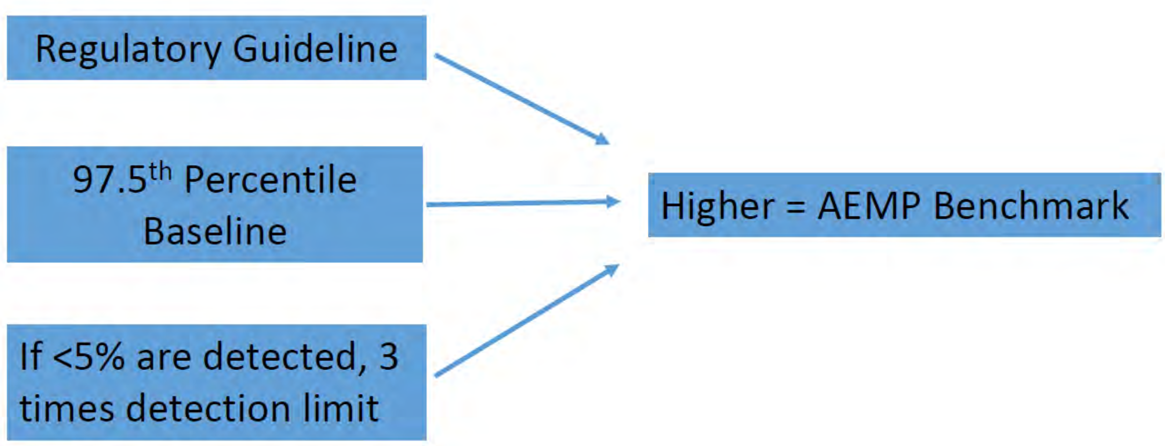


Figure 1-2 Process Used to Derive AEMP Sediment Benchmarks

Objective of Current Report

One of the goals of the 2014 sampling program was to increase the understanding of baseline sediment concentrations within each of the lakes of interest, by increasing the number of samples taken. Sediment (and water quality) monitoring in 2014 was undertaken during the late winter, spring, summer and fall, with the latter concluding prior to the start of mining. Therefore, all 2014 water and sediment quality sampling was conducted concurrent with construction activities at the mine site, but without the potential influence of mining activities (which was initiated in mid-September, 2014).

In this report, the 2014 sediment quality data are evaluated to determine whether they can be considered "baseline" or whether the activities at the site in 2013 and 2014 may have influenced some of the metals concentrations.

2.0 ASSESSMENT OF 2014 SEDIMENT DATA AND ESTABLISHMENT OF SEDIMENT BENCHMARKS

As established in the AEMP (Baffinland, 2014), sediment data collected in the 2014 field season were initially evaluated based on Total Organic Carbon (TOC) content, as per the screening process developed in 2014. Samples with less than 0.6% TOC and > 80% sand, or where sand was > 90% were excluded from development of baseline AEMP benchmarks, as they were not considered to have characteristics wherein metals would tend to accumulate (ie. Depositional stations), and hence, were not considered further.

The retained depositional stations for Mary Lake, Camp Lake, Sheardown Lake NW, tributaries of Sheardown Lake and Sheardown Lake SE were examined, and Log10 histograms of the dataset (2007 – 2014) suggest that the data are largely log normally distributed (Figure A-1), with the exception of cadmium, and mercury, which were excluded from further analysis due to the large proportion of non-detects (2 detected out of 74 samples for cadmium, with a method detection limit of 0.05 mg/kg; and none detected for mercury, with a detection limit of 0.1 mg/kg). The raw data from 2014, relative to baseline data, are presented and discussed in detail in the Core Receiving Environment Monitoring Program report (CREMP; Knight Piésold, 2015).

The stability of sediment metal concentrations in each lake over time was investigated by plotting the reported concentrations for each metal of interest against the year of sampling for the period between 2007 and 2014 (Figure A-2). Note, following the TOC and sand content screening described above, there were only seven sediment samples remaining from the Tributaries of Sheardown Lake for this time period. Due to this limited data, it was not possible to evaluate trends over time in the Tributaries of Sheardown Lake and data from this area were excluded from further baseline statistical evaluations. For Camp Lake, Mary Lake and Sheardown Lake SE, a visual evaluation of the graphs suggested that metals within these lakes did not increase over time (see Figure A-2). Therefore, all years of data for these lakes were considered representative of baseline conditions and were retained for further consideration in the sediment benchmark development process. With respect to Sheardown Lake NW, the available data for some metals of interest (e.g., chromium, copper, nickel and zinc) indicated possible increases in sediment concentrations over time, whereas the trend figures for other key metals of interest (e.g., arsenic, iron, and manganese), indicate a peak in 2008, followed by lower levels between 2011 and 2014 (Figure A-2). In light of these results, a review of historic activities near Sheardown Lake NW was conducted and events were identified that may have impacted Sheardown Lake NW sediment metal concentrations (i.e., historical crushing of a bulk sample of ore in 2008 and associated dusting events). Additionally, the sediment sampling approach was changed in 2012 from a 5 cm depth ponar grab sample to a 2 cm depth core sample, which limits the comparability between pre-2012 sediments to post 2012 sediments. In addition, some historical stations were not included in the 2014 sampling program, in an effort to align with other monitoring programs, which limits temporal trend analysis within the lake at these stations. With this in mind, the 2008 data for Sheardown Lake NW were eliminated from consideration in the development of baseline for this lake, but at this stage, other Sheardown Lake NW data were retained for further statistical analyses.

In order to determine whether each lake required separate sediment metal concentration benchmarks, separate analyses of variance (ANOVAs) of the log-transformed sediment metal concentrations were performed to investigate differences between lakes for each of the following metals (arsenic, chromium, copper, iron, manganese, nickel, phosphorus, lead and zinc). For the reasons described above, this analysis included data for all years (2007 – 2014) for Sheardown Lake SE, Mary Lake, and Camp Lake and excluded 2008 data for Sheardown Lake NW. Mercury and cadmium were non-detect, and therefore were not analyzed using this approach. Statistical outcomes are presented in Table A-1. Significant ANOVA test results ($p<0.05$) were followed by Tukey multiple comparison tests to determine which sites differed from each other. No significant differences ($p>0.05$) between lakes were noted for chromium, iron, nickel, phosphorus, and lead. However, for arsenic, copper, manganese and zinc, the Tukey multiple comparison tests revealed that Sheardown Lake SE had significantly lower ($p<0.05$) sediment metal concentrations than at least one other lake (lower than all other lakes for arsenic and copper, less than Camp and Mary Lake for manganese, and less than Mary and Sheardown Lake NW for zinc). Therefore no significant differences ($p>0.05$) between any of the other lakes for these metals.

Consideration of all of this information, led to the following decisions:

- Sheardown Lake SE would have lake-specific benchmarks, based on the dataset of 2007 – 2014;
- Mary Lake and Camp Lake would have combined, lake-specific benchmarks, based on the dataset of 2007 – 2014:
- Due to complicating factors related to the Sheardown Lake data set, it is difficult to determine, based on the available dataset, whether recent construction-related activities have influenced sediment chemistry in this lake. The main factors include the change in sediment sampling protocol (ponar grab of top 5 cm in early years, versus a 0 – 2 cm coring approach since 2012), the lack of monitoring of several long standing stations in 2014, which limits temporal comparisons at specific locations. As a result, further study is recommended in 2015 for Sheardown Lake NW, and the interim benchmarks are suggested for comparison purposes for the 2014 dataset.

Based on this approach, a 97.5^{th}%ile of the combined datasets for each of these lake scenarios are presented in Table 1, in conjunction with sediment quality guidelines. The higher of either the 97.5^{th}%ile of baseline, the CCME or Ontario Ministry of the Environment sediment quality guidelines, or 3 times the detection limit was selected as the lake-specific benchmarks, as per the Figure 1-2.

Table 1 provides appropriate regulatory sediment quality guidelines, the 97.5^{th} percentiles of sediment data for area lakes and the proposed AEMP benchmark for Mary Lake, Camp Lake and Sheardown Lake NW, as well as Sheardown Lake SE.

Table 2-1 Development of Area-Specific Aquatic Effects Sediment Benchmarks, based on Area-Specific Baseline Calculations and Relevant Sediment Quality Guidelines (mg/kg; dw)

Jurisdiction, Type of Guideline and Statistical Metric		**Hg**	**As**	**Cd**	**Cr**	**Cu**	**Fe**	**Mn**	**Ni**	**P***	**Pb**	**Zn**
CCME (2014)	**ISQG**	0.17	5.9	0.6	37.3	35.7	NGA	NGA	NGA	NGA	35	123
	PEL	0.486	17	3.5	90	197	NGA	NGA	NGA	NGA	91.3	315
Ontario (OMOE, 2008)	**LEL**	0.2	6	0.6	26	16	20000	460	16	600	31	120
	SEL	2	33	10	110	110	40000	1100	75	2000	250	820
97.5th%iles of Lake Areas and Lake-Specific Benchmarks by Area												
97.5th%ile: Mary Lake (2007 – 2014) and Camp Lake (2007 – 2014) (N = 31)		<0.1	5.3	<0.5	98	50	52,400	4,370	72	1580	25	135
Proposed AEMP Benchmark – Mary Lake and Camp Lake		**0.17**[A]	**5.9**[A]	**1.5**[C]	**98**[B]	**50**[B]	**52,400**[B]	**4,370**[B]	**72**[B]	**1580**[B]	**35**[A]	**135**[B]
97.5th %ile: Sheardown Lake SE (2007 – 2014) (N = 11)		<0.1	2	1	79	56	34,400	657	66	1278	18	63
Proposed AEMP Benchmark –Sheardown Lake SE		**0.17**[A]	**5.9**[A]	**1.5**[C]	**79**[B]	**56**[B]	**34,400**[B]	**657**[B]	**66**[B]	1278[B]	**35**[A]	**123**[A]
97.5th%ile of Sheardown Lake NW (2007 – 2014, excluding 2008) (N = 25)		<0.1	6.4	<0.5	96	62	53,000	4,300	84	1100	24	107
Interim AEMP Benchmark –Sheardown Lake NW (from Baffinland, 2014; Appendix C)		**0.17**[A]	**6.2**[B]	**1.5**[C]	**97**[B]	**58**[B]	**52,200**[B]	**4,530**[B]	**77**[B]	**1958**[B]	**35**[A]	**123**[A]

Notes:
* = N for phosphorus is lower than other elements.
A = guideline is based on sediment quality guideline; B = guideline is based on 97.5th%ile of baseline data; C= guideline is based on 3 times MDL
Where mercury and cadmium were not detected in any samples in a given area; the detection limit is used to represent the 97.5th percentiles.

3.0 REFERENCES

Baffinland, 2014. Baffinland Iron Mines Corporation. Aquatic Effects Monitorinjg Program. BAF-Ph1-830-P16-0039. Rev 0. Prepared By: Jim Millard, Baffinland Iron Mines. Part 1, Item 2 of Type A Water Licence No. 2AM-MRY1325

CCME, 2014. Canadian Council of Ministers of the Environment. Sediment Quality Guidelines Summary Table: http://st-ts.ccme.ca/en/index.html

Knight Piésold, 2015. Core Receiving Environment Monitoring Program Report. 2014 Water and Sediment CREMP Monitoring Report. NB102-181/34-6. March, 2015.

OMOE, 2008. Guidelines for Identifying, Assessing and Managing Contaminated Sediments in Ontario: An Integrated Approach. May, 2008. R. Fletcher, P. Welsh, and T. Fletcher.Standards Development Branch. PIBS 6658e.

ATTACHMENT A

SUPPORTING FIGURES AND STATISTICAL ANALYSIS OUTCOMES

Figure A-1: Log 10 Histograms of All Sediment Data (2007 – 2014) for Camp Lake, Mary Lake, Sheardown Lake SE, Sheardown Lake NW

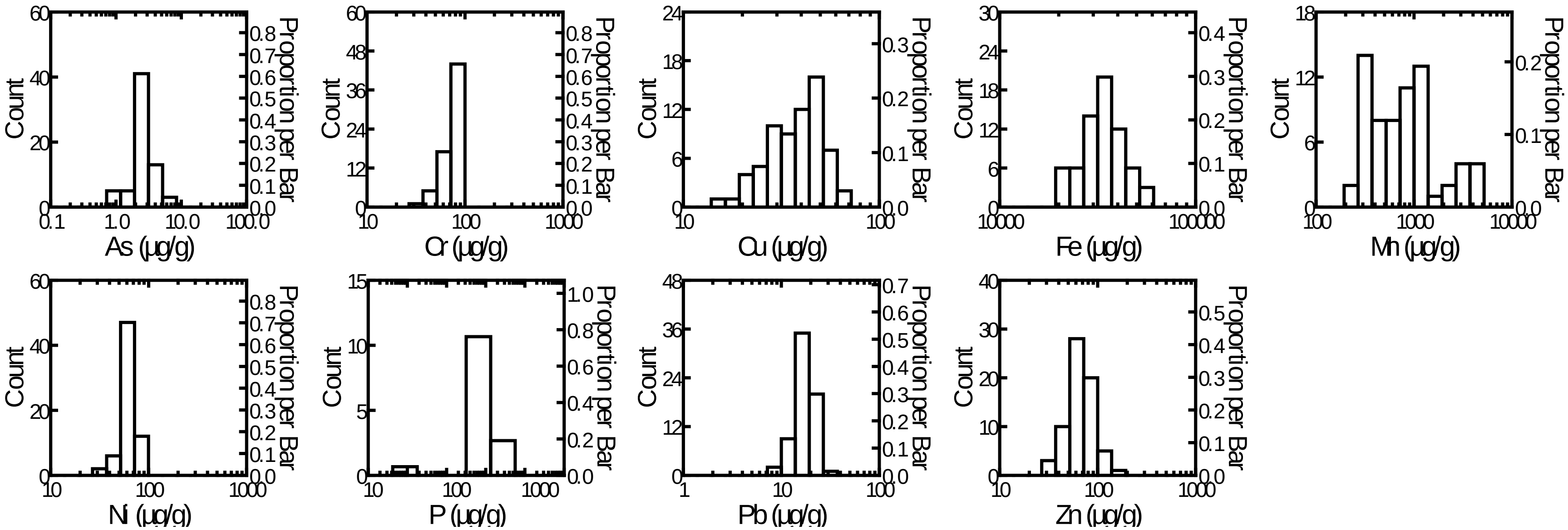


Figure A-2: Trend Analysis of All Lakes (2007 – 2014). Plotted data indicate mean ± standard error for each sampled year.

Figure A-2.1 Mary Lake (2007 – 2014)

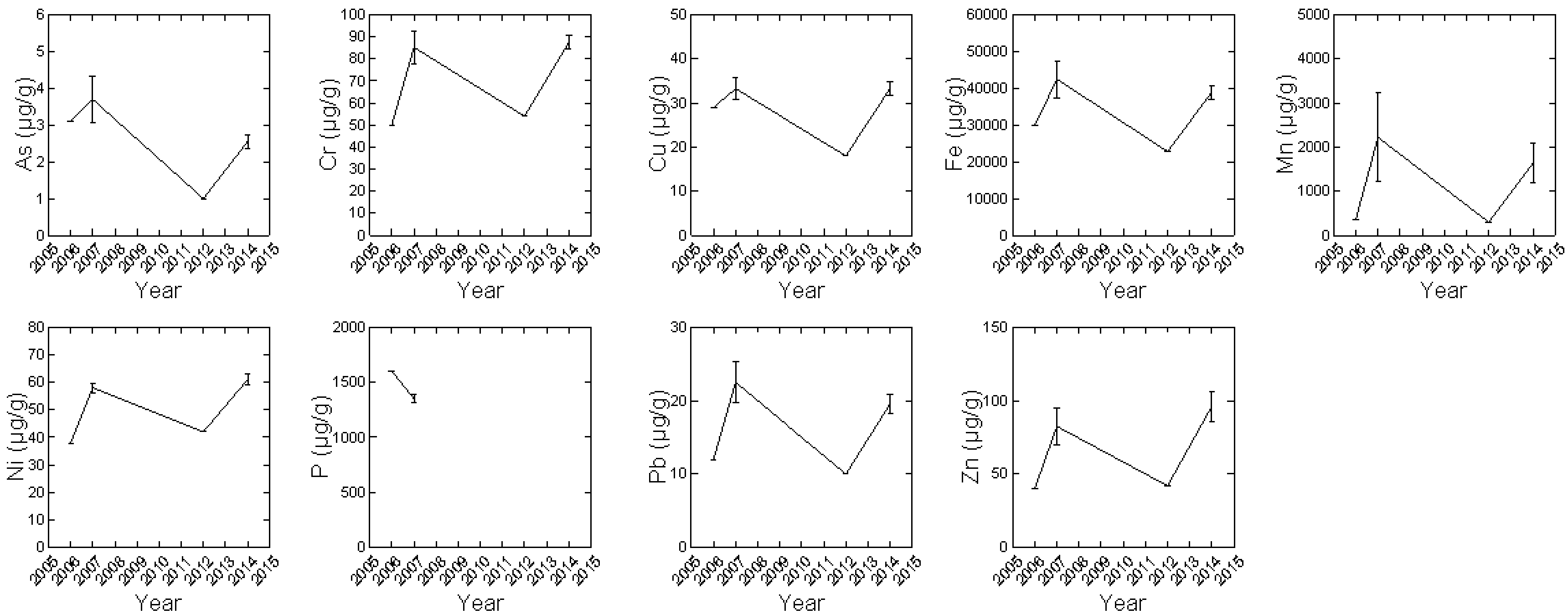


Figure A-2.2 Camp Lake (2007 – 2014)

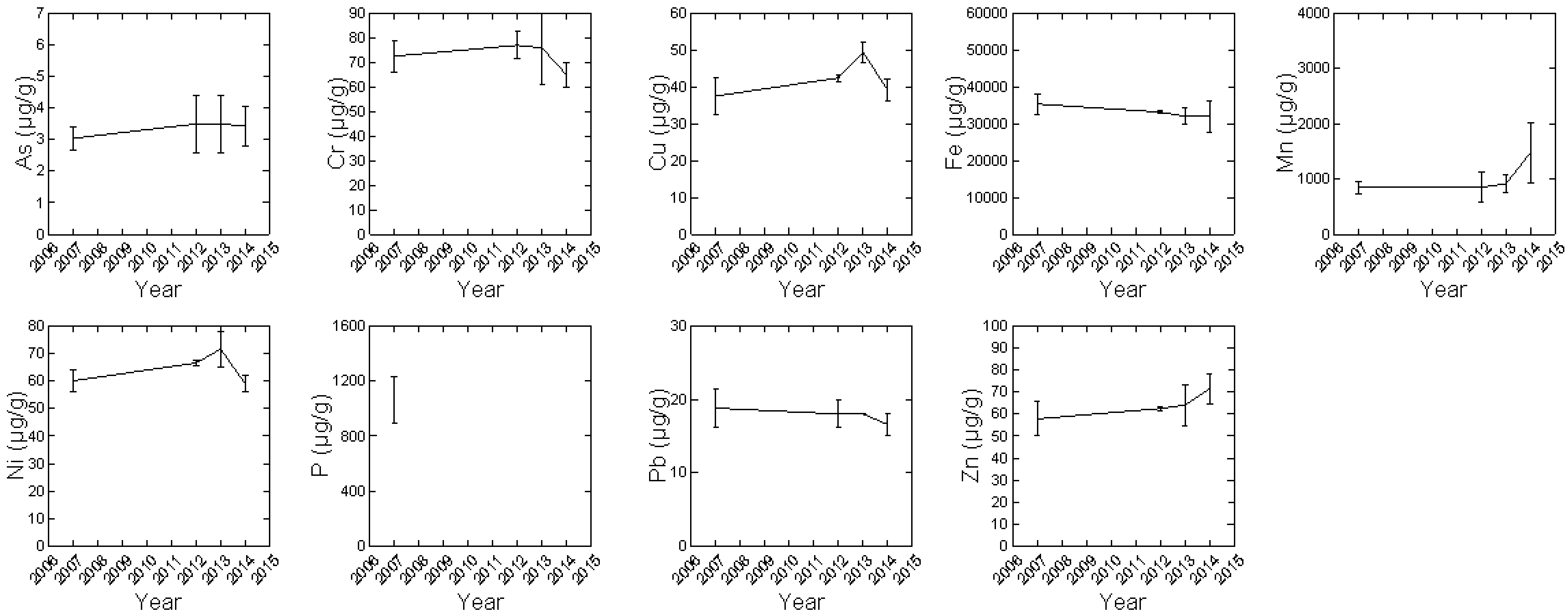


Figure A-2.3 Sheardown Lake NW (2007 – 2014)

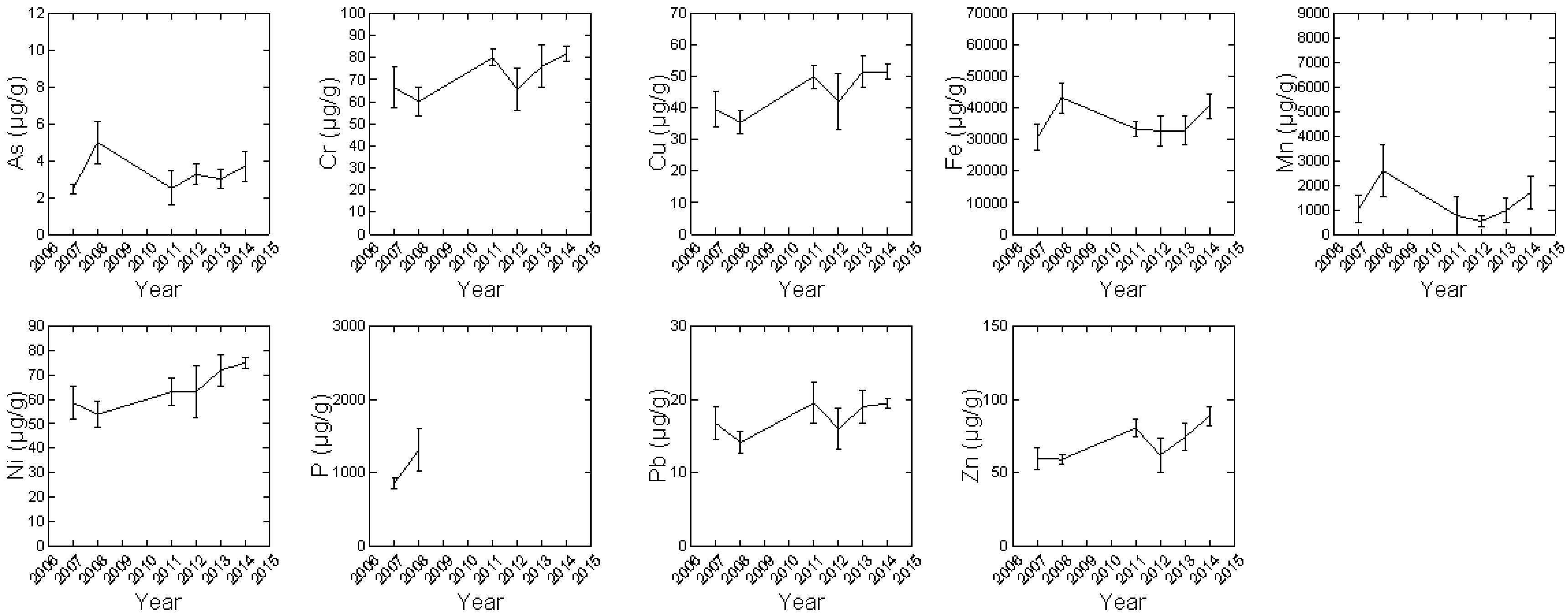


Figure A-2.4 Sheardown Lake SE (2007 – 2014)

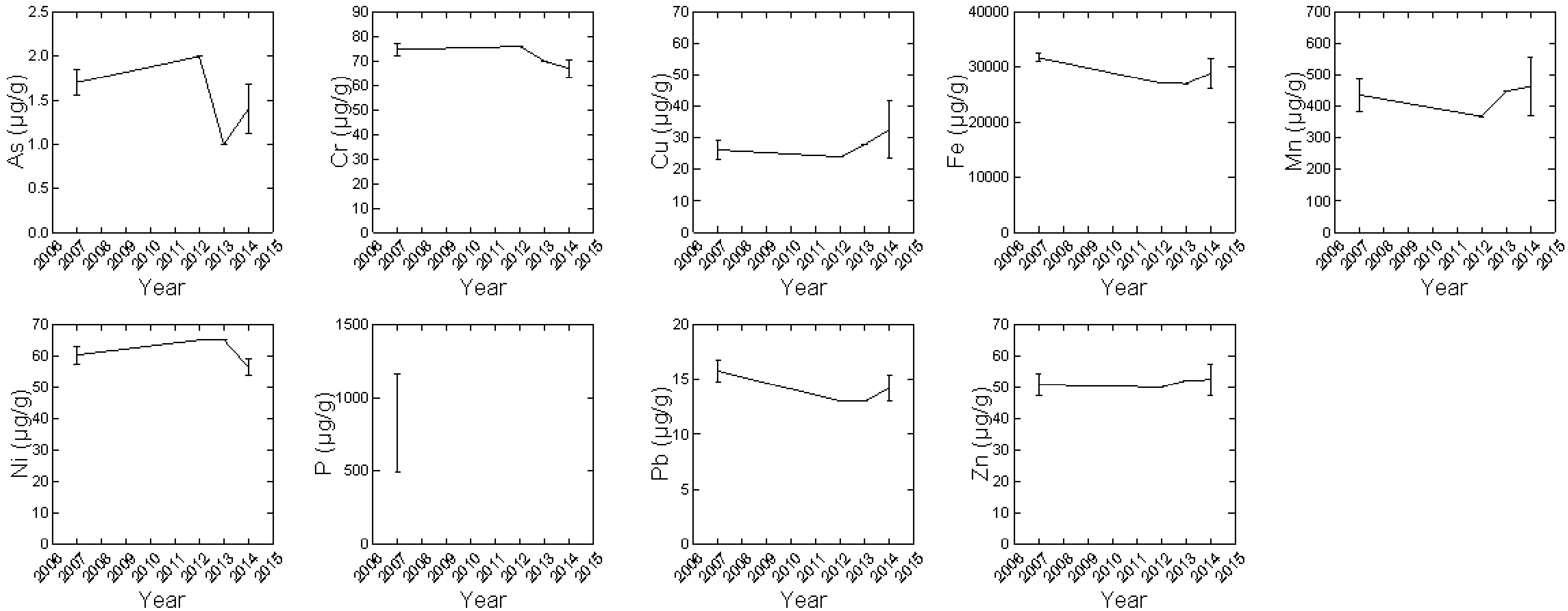
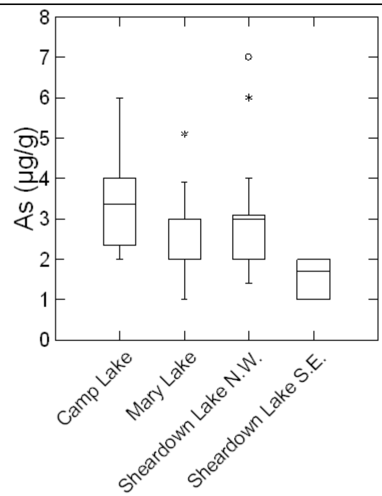
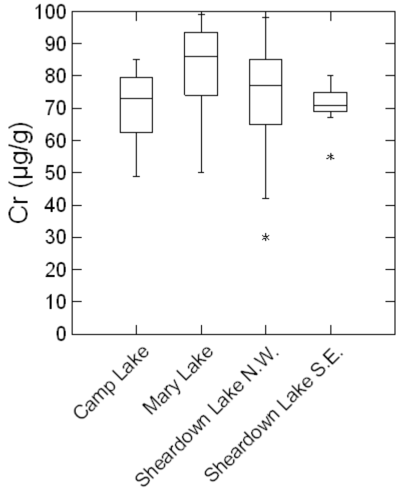
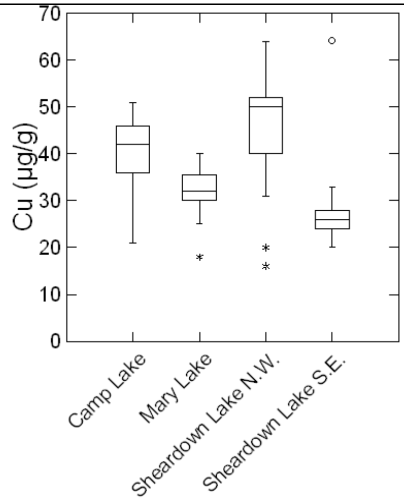
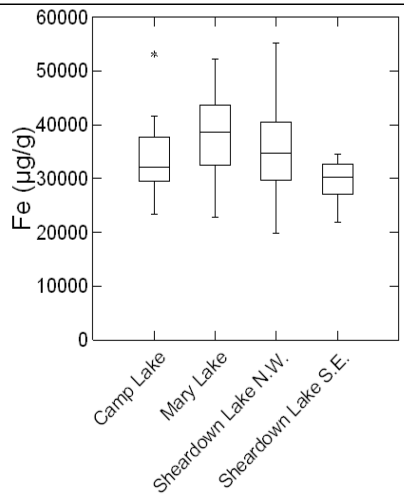
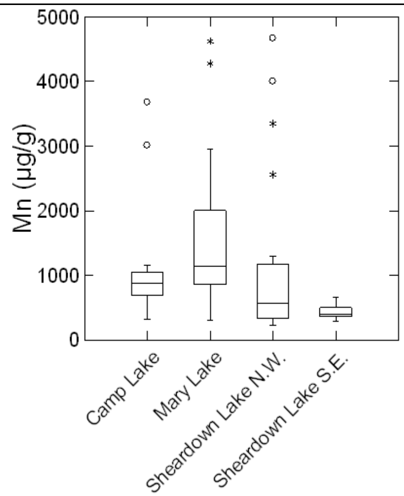
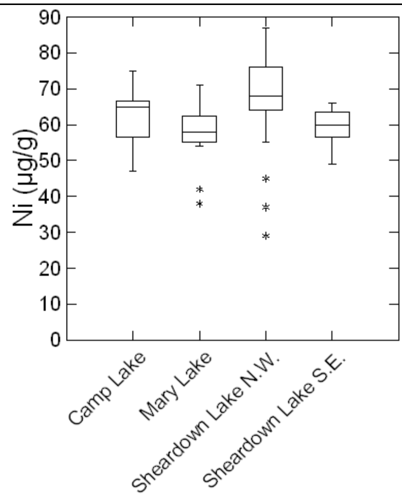
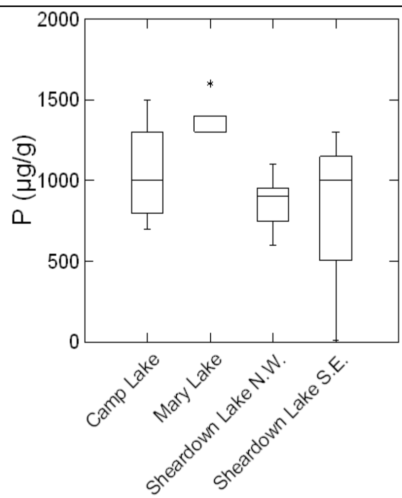


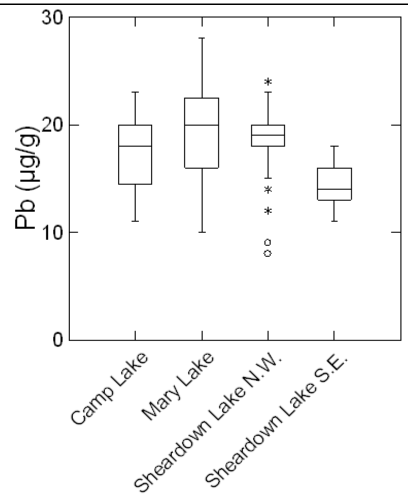
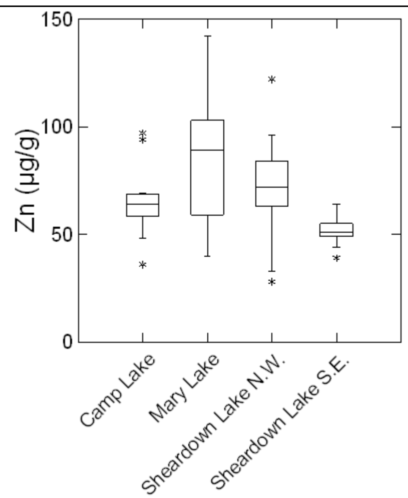
Table A-1: Boxplots and Statistical Comparisons By Site using Data for Camp Lake (2007 – 2014), Mary Lake (2007 – 2014), Sheardown Lake SE (2007 – 2014) and Sheardown Lake NW (2007 – 2014, excluding 2008)

Analyte	Boxplot[b]	ANOVA[b] Results (p-value)	Tukey Test Results (p-values)					
			Camp Lake vs. Mary Lake	Camp Lake vs. Sheardown Lake N.W.	Camp Lake vs. Sheardown Lake S.E.	Mary Lake vs. Sheardown Lake N.W.	Mary Lake vs. Sheardown Lake S.E.	Sheardown Lake N.W. vs. Sheardown Lake S.E.
Arsenic		**<0.001**	0.468	0.774	**<0.001**	0.909	**<0.001**	**<0.001**

Analyte	Boxplot[b]	ANOVA[b] Results (p-value)	Tukey Test Results (p-values)					
			Camp Lake vs. Mary Lake	Camp Lake vs. Sheardown Lake N.W.	Camp Lake vs. Sheardown Lake S.E.	Mary Lake vs. Sheardown Lake N.W.	Mary Lake vs. Sheardown Lake S.E.	Sheardown Lake N.W. vs. Sheardown Lake S.E.
Chromium		0.222	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]
Copper		**<0.001**	0.108	0.503	**0.008**	**0.001**	0.627	**<0.001**

Analyte	Boxplot[b]	ANOVA[b] Results (p-value)	Tukey Test Results (p-values)					
			Camp Lake vs. Mary Lake	Camp Lake vs. Sheardown Lake N.W.	Camp Lake vs. Sheardown Lake S.E.	Mary Lake vs. Sheardown Lake N.W.	Mary Lake vs. Sheardown Lake S.E.	Sheardown Lake N.W. vs. Sheardown Lake S.E.
Iron		0.073	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]
Manganese		**0.006**	0.785	0.654	**0.047**	0.143	**0.005**	0.257

Analyte	Boxplot[b]	ANOVA[b] Results (p-value)	Tukey Test Results (p-values)					
			Camp Lake vs. Mary Lake	Camp Lake vs. Sheardown Lake N.W.	Camp Lake vs. Sheardown Lake S.E.	Mary Lake vs. Sheardown Lake N.W.	Mary Lake vs. Sheardown Lake S.E.	Sheardown Lake N.W. vs. Sheardown Lake S.E.
Nickel		0.147	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]
Phosphorus		0.233	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]

Analyte	Boxplot[b]	ANOVA[b] Results (p-value)	Tukey Test Results (p-values)					
			Camp Lake vs. Mary Lake	Camp Lake vs. Sheardown Lake N.W.	Camp Lake vs. Sheardown Lake S.E.	Mary Lake vs. Sheardown Lake N.W.	Mary Lake vs. Sheardown Lake S.E.	Sheardown Lake N.W. vs. Sheardown Lake S.E.
Lead		0.071	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]
Zinc		**0.003**	0.153	0.784	0.244	0.485	**0.002**	**0.028**

Analyte	Boxplot[b]	ANOVA[b] Results (p-value)	Tukey Test Results (p-values)					
			Camp Lake vs. Mary Lake	Camp Lake vs. Sheardown Lake N.W.	Camp Lake vs. Sheardown Lake S.E.	Mary Lake vs. Sheardown Lake N.W.	Mary Lake vs. Sheardown Lake S.E.	Sheardown Lake N.W. vs. Sheardown Lake S.E.

Notes –

[a] The top and bottom of each box indicate the 75th and 25th percentiles of the data, respectively. The middle line in each box indicates the median (50th percentile). The whiskers indicate the lowest datum that is within 1.5 times the interquartile range (IQR, which equals the 75th percentile minus the 25th percentile) from the bottom of the box and the highest datum that is within 1.5 IQR from the top of the box. Values that are greater than 1.5 IQR but less than or equal to 3 IQR from the box are indicated with asterisks. Values that are more than 3 IQR from the box are indicated by empty circles.

[b] Data were log-transformed prior to analysis to improve data normality

[c] NA = not applicable. Tukey test comparison not performed since ANOVA was not significant.

Appendix E

Freshwater Biota CREMP Study Design

Baffinland

Mary River Project

April 2016

Core Receiving Environment Monitoring Program (CREMP): Freshwater Biota Design

Core Receiving Environment Monitoring Program (CREMP) Study Design: Freshwater Biota

Rev 1

April 2016

Prepared By: Andrew Vermeer
Department: Environment
Title: Environmental Coordinator
Date: April 8, 2016

Approved By: Jim Millard
Department: Environment
Title: Environmental Manager
Date: April 8, 2016

DOCUMENT REVISION RECORD

Issue Date MM/DD/YY	Revision	Prepared By	Approved By	Issue Purpose
June 1, 2014	0	North South Consultants Inc.	North South Consultants Inc.	AEMP Design
March 31, 2016	1	AV	JM	Modify CREMP Biota Design to reflect recommendations proposed by Minnow in 2016

Index of Major Changes/Modifications in Revision 1

Item No.	Description of Change	Relevant Section
1	Discussed Minnow's recommendations for future CREMP freshwater biota monitoring.	1.0
2	Updated water quality/phytoplankton monitoring locations to reflect Minnow's recommendations.	2.3
3	Clarified sampling frequency and schedule for chlorophyll a and phytoplankton sampling.	2.4
4	Updated chlorophyll a sampling protocol to reflect Minnow's recommendation to change water quality/chlorophyll a sampling to mid-depth at lake monitoring sites.	2.5
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PREFACE

This document was originally written by North/South Consultants in June 2014 for Baffinland Iron Mines Corporation (Baffinland). This document has been revised by Baffinland to reflect the recommendations proposed by Minnow Environmental Inc. in 2016 regarding modifications to the CREMP Study Design.

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LIST OF ABBREVIATIONS

AEMP	Aquatic Effects Monitoring Program
ANOVA	Analysis of variance
ANCOVA	Analysis of covariance
ANFO	Ammonium nitrate fuel oils
BMI	Benthic macroinvertebrate(s)
CALA	Canadian Association for Laboratory Accreditation Inc.
CES	Critical effect size
CPUE	Catch-per-unit-effort
CREMP	Core Receiving Environment Monitoring Program
DELTs	Deformities, erosion, lesions, and tumours
DO	Dissolved oxygen
EC	Environment Canada
EEM	Environmental Effects Monitoring
ERP	Early Revenue Phase
FEIS	Final Environmental Impact Statements
INAC	Indian and Northern Affairs Canada
MMER	Metal Mining Effluent Regulations
NSC	North/South Consultants Inc.
OECD	Organization for Economic Cooperation and Development
QA/QC	Quality assurance/quality control
SD	Standard deviation
SE	Standard error of the mean
TP	Total phosphorus
TN	Total nitrogen
TSS	Total suspended solids
USEPA	United States Environmental Protection Agency
UTM	Universal Transverse Mercator
YOY	Young-of-the-year

1.0 INTRODUCTION

The following describes the general background, approach, and methods for biological monitoring under the Core Receiving Environment Monitoring Program (CREMP) for the Baffinland Iron Mines Corporation Mary River Iron Ore Mine Project. Monitoring components include phytoplankton, benthic macroinvertebrates (BMI), and Arctic Char (*Salvelinus alpinus*).

This document was prepared, and the CREMP was designed, with baseline information available at the time of preparation of this report. As not all results of baseline sampling conducted in 2013 were available at the time of preparation of this report, recommendations for modification to the CREMP may be made upon receipt and analysis of these additional data.

A desktop technical review of freshwater biota baseline data was conducted in 2013 to provide a preliminary review of the adequacy of existing baseline data for the CREMP component of the overall Aquatic Effects Monitoring Program (AEMP) for the Mary River Project Mine site (North/South Consultants Inc. [NSC] 2013). This initial report was based on available baseline data for the period of 2006 through 2012 and identified data gaps and recommendations for additional baseline sampling for the 2013 field season.

The initial technical review document was subsequently updated in 2014 to incorporate additional information acquired in 2013 and to reflect further development of the CREMP (e.g., selection of benchmarks). The revised document is provided as Appendix 1 of this document. These baseline review reports were used as the foundation for the development of the biological programs for the CREMP. Several of the key conclusions and findings of this review have been considered and integrated into the current CREMP document.

In 2015, Minnow Environmental Inc. (Minnow) was contracted to assist Baffinland in completing the fieldwork and reporting requirements of several of the AEMP component studies, including the CREMP. After completing the CREMP in 2015, Minnow proposed several modifications to the CREMP to provide greater efficiencies to the program and improve the program's ability to achieve its objectives (i.e. to evaluate short and long term effects of the Project on aquatic ecosystems). This document has been revised by Baffinland to reflect all of the recommendations proposed by Minnow in 2016 regarding CREMP biota monitoring.

2.0 PHYTOPLANKTON

The following section provides a description of monitoring of phytoplankton under the CREMP. The program includes the monitoring of lakes and streams in the Mine Area, where potential for eutrophication is greatest, as well as respective reference areas used for the evaluation of mine influences.

2.1 PATHWAYS OF EFFECT AND KEY QUESTIONS

Key questions were developed for the CREMP to guide the review of baseline data adequacy and, ultimately, design of the monitoring program. These questions and metrics focus upon key potential effects identified in the Final Environmental Impact Statement (FEIS) and the Addendum to the FEIS for the Early Revenue Phase (ERP), as well as metrics commonly applied for characterizing phytoplankton communities.

The key pathways of potential effects of the Project on phytoplankton communities include:

- Water quality changes related to discharge of ore or stockpile runoff to freshwater systems (immediate receiving environments: Mary River and Camp Lake Tributary 1);
- Water quality changes (primarily nutrients and total suspended solids [TSS]) related to discharge of treated sewage effluent (immediate receiving environments: Mary River and Sheardown Lake NW);
- Water quality changes due to deposition of dust in lakes and streams (Mine Area in zone of dust deposition); and
- Water quality changes due to non-point sources, such as site runoff and use of Ammonium nitrate fuel oil (ANFO) explosives (Mine Area).

The key question related to the pathways of effect is:

- What are the combined effects of point and non-point sources on phytoplankton abundance in Mine Area lakes?

2.2 PARAMETERS AND METRICS

The key metric for phytoplankton monitoring will be chlorophyll *a*. Chlorophyll *a* is the most widely used indicator of phytoplankton abundance and is relatively easy to sample. It is also associated with lower analytical variability and is more cost effective than biomass and community composition metrics. Further, biological benchmarks for phytoplankton community metrics have not been developed to the same extent as for chlorophyll *a* and phytoplankton indices are not as strongly linked to primary drivers of eutrophication (i.e., nutrients). While this parameter is associated with relatively high variability in the lakes currently, the variability is largely a function of low concentrations and in particular, a relatively high frequency of censured values (i.e., below detection; Appendix 1).

Although chlorophyll *a* will be the key metric for this component, samples will also be collected and archived for potential analysis of phytoplankton biomass and taxonomy during the CREMP. These samples will provide the ability to conduct additional analyses should monitoring of water quality, chlorophyll *a*, and/or other biological components indicate that effects to primary productivity may be of concern and would benefit from these additional data.

Phytoplankton monitoring is intended to address the potential for eutrophication effects in Mine Area lakes, and therefore analysis of monitoring data will also consider related/supporting variables including nutrients (phosphorus and nitrogen), measures of water clarity (i.e., TSS, turbidity, Secchi disk depth), and temperature in the data analysis and reporting phase.

2.3 BENCHMARKS

As noted in Section 2.1, phytoplankton abundance either may be increased by the Project through nutrient enrichment or may be decreased by the Project through changes in other factors such as water clarity. Therefore, the phytoplankton monitoring component is intended to monitor for either increases or decreases in algal abundance. However, owing to the particular concern related to nutrient enrichment and potential for eutrophication in Mine Area lakes related to phosphorus additions, the benchmark for the CREMP was developed to address potential increases in chlorophyll *a*. In addition, decreases in chlorophyll *a* relative to current (baseline) conditions would be difficult to measure owing to the low concentrations and high frequency of censured values.

Other recent/ongoing monitoring programs in northern Canada have identified effects sizes and/or benchmarks for phytoplankton using different approaches. Azimuth (2012) recommended the application of a 20% effect size as a monitoring "trigger" and a 50% effect size as a monitoring "threshold" for phytoplankton community metrics (i.e., total biomass and number of species), where effect size refers to a change or difference relative to before-after-control-impact (BACI). Under this program, the mean of three months of monitoring is compared to the trigger and threshold. The authors note that the terms "threshold" and "trigger" are intended to be applied less strictly for biological variables, relative to chemical variables such as water or sediment quality, due to the inherent high natural variability in biological parameters and the need to consider the cause of any observed statistical "changes" in the biological communities. The rationale provided for the identification of the 20% and 50% criteria is "to maintain a transparent (fixed) effect size that is more likely to be ecologically relevant." Inherent to this discussion, is the importance of considering the variability in existing data in identifying appropriate critical effects sizes (CESs).

A revised AEMP was recently issued for the Diavik Diamond Mines Inc. (DDMI) operation at Lac de Gras, NT, which includes a specific monitoring component related to eutrophication in Lac de Gras (Golder Associates 2014). The key metric identified was chlorophyll *a*, which is sampled once in the open-water season. The assessment approach includes a number of action levels defined based on magnitude of changes in chlorophyll *a* concentrations and in consideration of the spatial extent of the effects. The lowest action level is considered to be exceeded where the 95^{th} percentile of chlorophyll *a* concentrations (defined based on pooled data for the open-water season sampling period) is higher than the "normal range". The normal range is defined as the mean ± 2 x standard deviation (SD) of reference area values (open-water season). Additional action levels compare monitoring results to a benchmark value. The benchmark value was based on maintaining an oligotrophic status in the lake, using trophic boundaries defined in the scientific literature. Specifically, the benchmark (4.5 µg/L) was defined as the average concentration of the upper limit of the oligotrophic boundary and the lower limit of the mesotrophic boundary from the literature. A higher action level (termed an "effects threshold") is identified in concept but has not been defined quantitatively; this step would be undertaken in the future if lower action levels were exceeded.

With respect to the Mary River Project, development of benchmarks or CESs for phytoplankton that are adequately sensitive and ecologically appropriate for Mine Area lakes considered:

- Natural variability in existing phytoplankton community metrics;
- Limitations associated with the existing data set - specifically issues associated with chlorophyll *a* concentrations being below the analytical detection limits;
- Relationships between nutrients (notably phosphorus) and phytoplankton metrics for Mine Area lakes;
- Lake trophic categorization schemes and trophic status of the Mine Area lakes; and

- Literature in which CESs for phytoplankton have been identified or adopted, such as AEMPs for the Diavik Diamond Mine and the Meadowbank projects.

While there are no established benchmarks for phytoplankton metrics for application in monitoring programs, there is an extensive literature base regarding the issue of eutrophication of freshwater ecosystems as well as numerous trophic categorization schemes for lakes and several for freshwater streams. Mine Area lakes are currently oligotrophic based on several different lake trophic categorization schemes using chlorophyll *a* (Table 2-1). While a significant relationship was found between total phosphorus (TP) and chlorophyll *a* in Mine Area lakes (Appendix 1), the relationship is weak and cannot be used to construct a predictive model linking nutrient concentrations to phytoplankton. Therefore, a benchmark for chlorophyll *a* was derived based on existing baseline data and in consideration of approaches applied in other recent/ongoing arctic AEMPs and trophic categories/status.

The benchmark for chlorophyll *a* for the Mary River Project (3.7 µg/L) is based on maintaining the trophic status (i.e., oligotrophic) of Mine Area lakes. The benchmark was derived using a similar approach and rationale as was recently applied for the DDMI Project. Specifically, the benchmark represents the average of the upper and lower ranges of trophic boundaries for lakes based on chlorophyll *a*, as designated and/or adopted in the scientific literature (Table 2-2). This value is lower than the benchmark adopted by DDMI due to some differences in the literature incorporated in this calculation. Two of the literature sources utilized for the DDMI benchmark derivation (United States Environmental Protection Agency [USEPA] 1974 and 1988) were omitted due to the age of the documents and because the USEPA has applied a different trophic status categorization scheme in a more recent report (USEPA 2009). The values applied in USEPA (2009) were included in the calculation instead. In addition, the values presented in CCME (2004) were omitted since these values are reproductions of the Organization for Economic Cooperation and Development (OECD 1982) values, which are already included in the data set. Similarly, Alberta Environment (2013) also applies the same boundaries as the OECD (1982) but this was not included as a separate entry in the calculations for the same reason. Lastly, the trophic categorization scheme applied by the Swedish EPA (2000) was also included in the calculation.

As previously noted, the benchmark (3.7 µg/L) for Mary River lakes is lower than the recently developed benchmark for Lac de Gras in relation to the Diavik Diamond Mines Project. Lac de Gras has a similar background concentration of chlorophyll *a* than Sheardown Lake NW but a lower concentration than other Mine Area lakes (Table 2-3);

the "normal range" of chlorophyll *a* in Lac de Gras (mean±2 x SD) was identified as 0.89 µg/L and the mean was 0.52 µg/L for the open-water season (Golder Associates 2014).

2.4 MONITORING AREA AND SAMPLING SITES

The monitoring area for phytoplankton includes Mine Area lakes, specifically Camp and Mary lakes, and Sheardown Lake NW and SE, and selected streams (Figure 2-1 and Figure 3-2). In addition, monitoring will be conducted at Reference Lake 3.

Three sites will be monitored for chlorophyll *a* in Camp Lake, Reference Lake 3 Sheardown Lake NW and SE during each sampling period; four sites will be monitored in Mary Lake. Samples will also be collected at these same locations for phytoplankton biomass and taxonomy but will be archived following collection. Sites are located at the same locations as water quality monitoring sites in order to provide supporting information for interpretation and analysis of results (e.g., nutrient concentrations and water clarity).

Chlorophyll *a* will also be monitored at stream locations in conjunction with water quality monitoring (see Figure 2-1 for locations). Monitoring will include several sites on the Mary River, including sites upstream and downstream of effluent discharges, and small tributaries to Sheardown Lake NW and SE and Camp Lake.

In assessing the water quality baseline data and the most recent data from the 2015 CREMP, no consistent spatial differences in water chemistry is evident in any of the mine exposed lakes or Reference Lake 3. In addition, *in-situ* water quality profile data collected during 2015 and baseline studies indicates that all of the study lakes are generally well mixed both laterally and vertically, and as a result, water chemistry is likely to be relatively uniform throughout these lakes during most sampling conditions. Because of this, the sampling of several water quality/phytoplankton monitoring stations within these lakes is redundant. Figure 2-1 shows the phytoplankton (water quality) stations that will be monitored in future CREMP studies and reflects the modifications proposed by Minnow in 2016.

2.5 SAMPLING FREQUENCY AND SCHEDULE

Sampling will be conducted three times per annum during the initial years of operation but sampling frequency should be regularly evaluated (i.e., each year) to determine if modifications are warranted. Sampling of chlorophyll a in lakes will consist of two open-water periods (summer and late summer/fall) and once in late winter. Streams will also be sampled three times in the open-water season for chlorophyll a. Sampling of phytoplankton biomass and taxonomy will occur twice a year (summer and late summer/fall). These sampling frequencies are consistent with baseline sampling programs conducted in the Mine Area to date.

Sampling will be conducted in conjunction with the water quality sampling program to provide data for supporting indicators, including TP, total nitrogen (TN), and water clarity. Dissolved oxygen (DO) profiles will also be collected at each lake and stream to evaluate potential for DO depletion (i.e., a eutrophication response variable).

2.6 FIELD AND LABORATORY METHODS

Chlorophyll *a* samples will be collected with a sampling device (i.e., Kemmerer) at the same depths as corresponding water quality samples (refer to Appendix B of the AEMP), transferred to sample bottles provided by the analytical laboratory, kept cool and in the dark and submitted to a laboratory accredited under the Canadian Association for Laboratory Accreditation (CALA) Inc. Additional information will be recorded at the time of sampling including:

- Field crew;
- Site coordinates (universal transmercator units [UTMs]);
- Date and time of sampling;
- Sampling depth/methods and any deviations from the sampling protocol;
- Total water depth (and ice thickness in winter); and
- Site conditions/observations.

As chlorophyll *a* will be sampled at the same sites and times and using the same collection methods as other water quality parameters, additional water quality data, including nutrients, will be collected concurrently to assist with data analysis. *In situ* profiles of DO, temperature, pH, and conductivity and Secchi disk depths (average of two measurements) will also be measured at select deep profundal stations at each lake. For information on water quality sampling, see Appendix B of the AEMP.

Samples for phytoplankton taxonomy and biomass will be collected as depth-integrated samples using a tube-sampler. The sampling depth will be calculated as 3 x the average Secchi disk depth (i.e., an estimate of the euphotic zone depth), to a maximum of 10 m. Due to the high water clarity of Mine Area lakes, euphotic zone depths may exceed 10 m in some sampling periods at some sites. Where this occurs, a second sample should be collected from the 10 m depth to the estimated depth of the euphotic zone. Samples will be transferred to sample bottles and preserved with Lugol's solution. Following collection, samples will be archived for potential future analysis.

2.7 QUALITY ASSURANCE/QUALITY CONTROL (QA/QC)

The QA/QC program will include the following components:

- Development and use of sampling protocols;
- Incorporation of field QA/QC samples; and
- Review of data for transcription errors, omissions, and outliers.

The field QA/QC program will include:

- Collection of replicate samples for chlorophyll *a* and phytoplankton biomass and taxonomy; and
- Analysis of field, equipment and trip blanks for chlorophyll *a*.

2.8 STUDY DESIGN AND DATA ANALYSIS

As existing baseline data for Reference Lake 3 is minimal, the monitoring program will focus upon before-after comparisons of the key metric (i.e., chlorophyll *a*) within the Mine Area waterbodies, with an emphasis on Mine Area lakes. Trends will also be examined over time to determine if phytoplankton abundance indicates increasing or decreasing concentrations over a number of years. Lastly, frequency of detection of chlorophyll *a* will also be calculated and compared to baseline data as a further means of assessing change.

Chlorophyll *a* data collected in Reference Lake 3 and reference streams will also be considered within the interpretation of the monitoring data at the Mine Site. Specifically these data will assist with determining if observed changes in Mine Area lakes and streams are Project-related or a function of regional natural variability. Once sufficient data are acquired for the reference waterbodies, statistical comparisons to Mine Area waterbodies may be undertaken under the CREMP.

Results reported below the analytical detection limit will be assigned a value equal to the detection limit for subsequent data analyses. Statistical comparisons (spatial and/or temporal) will be conducted by an analysis of variance (ANOVA) where data meet the assumptions of equal variance and normality or by non-parametric methods (i.e., Kruskal-Wallis test followed by the Dunn's multiple pairwise comparisons procedure or the Mann-Whitney test) where the assumptions are not met. Transformations of data (e.g., log transformations) will be explored where applicable to attempt to meet the assumptions of ANOVA. Where the qualitative review of the monitoring results indicates a potential increase in chlorophyll *a*, one-tailed statistical analyses will be conducted. Statistical comparisons (before –after) will be done on a lake-wide basis for each sampling season. All tests will be assessed with a significance level of 0.05.

Additional analyses may be conducted including correlation analyses and/or regression analyses examining relationships between the key metric (chlorophyll *a*) and other related variables such as nutrients. These regressions, where significant, may be used as a tool for projecting long-term trends in chlorophyll *a* and/or to assist with delineating cause(s) of observed changes in chlorophyll *a*.

2.9 ASSESSMENT FRAMEWORK

Monitoring data will be assessed during each year of monitoring and would follow the assessment framework as outlined in Figure 2-2 and described below.

2.9.1 Step 1: Initial Data Analysis

Step 1 of the assessment will include initial review, screening, QA/QC, and exploratory analyses of the data set and determination if the data indicate potential increases or decreases in chlorophyll *a* concentrations relative to baseline conditions. Data will be summarized graphically and/or in tabular format and will include generation of summary statistics and graphing of data for evaluating temporal trends. Data will also be compared to the benchmark to identify if conditions indicate further analysis of the data is warranted.

Section 2.4 provides a description and rationale for the identification of a benchmark for chlorophyll *a* (3.7 µg/L). The mean chlorophyll *a* concentration measured during each sampling period in each lake will be compared to this benchmark. If Step 1 indicates exceedance of a benchmark, statistically significant differences relative to baseline conditions, and/or qualitative review of the data suggest that the Project could potentially have resulted in a change in the indicator, the analysis would proceed to Step 2. If it is concluded that there is no evidence of change, no management response would be required.

2.9.2 Step 2: Determine if Change is Mine Related

Step 2 involves determining if the changes in chlorophyll *a* are due to the Project or due to natural variability or other causes. This question will be addressed through several possible approaches:

- Evaluating spatial patterns in chlorophyll *a* results for the Mine Area as a whole, including Mine Area lakes and streams, to evaluate if changes are widespread or specific to certain waterbodies, and to identify the spatial extent and pattern of observed changes. This exercise would assist with identifying potential stressors/pathways of effects;

- Comparing data from Mine Area lakes to Reference Lake 3 and potentially data from Mine Area streams to reference streams. This would further assist with determining whether the observed changes were due to natural variability or the Project;

- Evaluating monitoring results for nutrients, notably phosphorus, in Mine Area waterbodies (lakes and streams) to assess whether nutrients have similarly changed and in the same spatial pattern/magnitude as observed for chlorophyll *a*;

- Evaluating other factors that affect phytoplankton abundance such as water clarity and temperature; and

- Evaluating Project activities with the potential to alter nutrients and/or conditions that may affect phytoplankton. This may include evaluating effluent quality, discharge regime/rates, and loading, notably in relation to sewage effluent, dust deposition, and other point/non-point sources as required.

If the Step 2 analysis concludes that the changes in chlorophyll *a* are, or are likely, due to the Project, the assessment would proceed to Step 3. If it is concluded the observed differences relative to baseline conditions are not due to the Project, no management response would be required.

2.9.3 Step 3: Determine Action Level

Step 3 involves determination of the action level associated with the observed monitoring results through comparisons to the benchmark. If the benchmark is not exceeded, a low action response would be undertaken and may include:

- Evaluate temporal trends: this will be a qualitative exercise and consist of graphical presentation of data over time to evaluate increasing or decreasing trends. It is important to note that several years of data will be required to begin to assess temporal trends;

- Investigate and summarize potential causes and pathways of effect of the observed changes;

- Review and summarize monitoring results for other metrics of relevance to phytoplankton (i.e., drivers) and eutrophication including nutrients, water clarity, and DO. Trend analysis results for these metrics, notably phosphorus, will also be considered in the interpretation of phytoplankton monitoring results;

- Review/assess the benchmark with acquisition of data (note: this will be undertaken over the course of monitoring). This may include updating the regression analysis relating chlorophyll *a* to TP concentrations with additional data to generate a site-specific model; and

- Based on the above evaluations, determine next steps.

If the benchmark is exceeded and it is concluded to be due to, or likely due to, the Project, a moderate action level response would be undertaken and may include the following:

- Evaluate indicators of nutrient enrichment (i.e., nitrogen and phosphorus) and other eutrophication response indicators (i.e., dissolved oxygen, Secchi disk depth) to assess overall trophic status and relationships between nutrients and chlorophyll *a*;

- Evaluate chemical, biological, and physical monitoring results collectively with chlorophyll *a* monitoring results to evaluate effects on the ecosystem. Key metrics would be evaluated to determine if increases in chlorophyll *a* are adversely affecting other biota, specifically BMI and Arctic Char. It is anticipated that BMI metrics would be the most sensitive for evaluating these linkages;

- Evaluate the need for additional monitoring (e.g., confirmation monitoring) and/or modifications to the CREMP;

- Consider results of the trend analysis (i.e., trend analysis indicates an upward trend) and evaluation of potential pathways of effect (i.e., causes of observed changes) to determine if management/mitigation is required; and

- Identify next steps based on the above analyses. Next steps may include those identified for the high action level response.

A quantitative trigger for the high action level response has not been identified as the need for additional study and/or mitigation will depend on the ultimate effects of the observed increases in chlorophyll *a* on the lakes as a whole and because the benchmark may need to be revised in consideration of ongoing monitoring results. Increases in nutrients and primary productivity may lead to increased productivity in other trophic levels, such as fish, which is an effect that can be perceived as positive. The precise relationships between nutrients, phytoplankton, and higher trophic levels is difficult to predict and it is therefore suggested that actions undertaken under the moderate action level response will attempt to explore these relationships to advise on overall effects to the ecosystem. Additional actions that may be implemented in a subsequent phase (i.e., high action level response) include:

- Analysis of phytoplankton samples collected from Mine Area lakes for biomass and taxonomy (i.e., samples previously collected and archived under the CREMP). This information would provide additional data regarding phytoplankton abundance (i.e., biomass) as well as information to characterize the community composition. Derived metrics such as diversity, richness, and evenness could be examined to evaluate shifts in the phytoplankton communities that may trigger cascading effects across trophic levels. This information may be useful in exploring causes or pathways of effects across higher trophic levels if they are observed (e.g., changes in BMI communities);

- Implementation of increased monitoring to confirm effects and/or define magnitude and spatial extent of effects if warranted; and

- Implementation of mitigation measures or other management actions that may be identified under the moderate action level response.

3.0 BENTHIC MACROINVERTEBRATES

The following section provides a description of monitoring of BMI under the CREMP, with an emphasis upon monitoring of lakes in the Mine Area, where potential for sedimentation and eutrophication is greatest and where Arctic Char overwinter.

3.1 PATHWAYS OF EFFECT AND KEY QUESTIONS

Key questions were developed for the CREMP to guide the review of baseline data adequacy (see Appendix 1 for details) and, ultimately, design of the monitoring program. These questions and metrics focus upon key potential effects identified in the FEIS, as well as metrics commonly applied for characterizing the BMI community.

The key pathways of potential effects of the Project on the BMI community include:

- Water quality changes related to discharge of ore or stockpile runoff to freshwater systems (immediate receiving environments: Mary River and Camp Lake Tributary 1);
- Water quality changes (primarily nutrients and TSS) related to discharge of treated sewage effluent (immediate receiving environments: Mary River and Sheardown Lake NW);
- Water quality changes due to deposition of dust in lakes and streams (Mine Area in zone of dust deposition);
- Water quality changes due to non-point sources, such as site runoff and use of ANFO explosives (Mine Area);
- Changes in water levels and/or flows due to water withdrawals, diversions, and effluent discharges (i.e., alteration or loss of aquatic habitat);
- Changes in sediment quality due to effluent discharge and/or dust deposition;
- Dust deposition in aquatic habitat (i.e., sedimentation); and
- Effects of the Project on primary producers.

The key question related to the pathways of effect is:

- What are the combined effects of point and non-point sources, aquatic habitat loss or alteration, sedimentation, and changes in primary producers on BMI abundance and community composition in Mine Area lakes?

3.2 COMMUNITY METRICS

The review of existing baseline data (through 2011; see Appendix 1) evaluated a number of BMI metrics for inclusion in the CREMP, including: abundance (total macroinvertebrate density [individuals/m^2±SE])); composition (Chironomidae proportion [% of total density], Shannon's Equitability [evenness], and the Simpson's Diversity Index); and richness metrics (total taxa and Hill's Effective richness, both at the genus level); Magurran 1988, 2004). The variability of the BMI metrics measured during the baseline studies program were evaluated and described to assist with identifying the most robust metrics for further statistical exploration and consideration under the CREMP. The least variable metrics identified for both Mine Area lakes and streams through this process were:

- Chironomidae proportion;
- Shannon's Equitability;
- Simpson's Diversity Index; and
- Total Taxa Richness.

Total macroinvertebrate density was associated with a relatively high variability in all lake habitat types and stream reaches. However, this metric was retained as it is one of the most commonly used indicators of the status of benthic macroinvertebrate communities in waterbodies.

In June 2014, Environment Canada reviewed the final draft of the AEMP and requested that the Bray-Curtis Index of Dissimilarity (Bray-Curtis Index) be added to the list of BMI metrics used to assess CREMP benthic macroinvertebrate data. In order to comply with the request, Baffinland has added the Bray-Curtis Index to the list of metrics above.

3.3 BENCHMARKS

Unlike water or sediment, where protection of aquatic life guidelines may be used to develop triggers or thresholds for effects assessment, there are no universal benchmarks for biological variables such as abundance or diversity. Rather, the magnitude of change or difference relative to expected conditions is typically used to establish CESs for biological variables.

Environment Canada (EC 2012) identifies CESs for a BMI metric as multiples of within-reference-area standard deviations (i.e., ±2 SD]). As for fish, confirmed effects are based on the results of two consecutive surveys.

Recent and ongoing monitoring programs in northern Canada have identified effects sizes and/or benchmarks for BMI using different approaches. For the Diavik Diamond Mine, a significant adverse effect as it relates to aquatic biota was defined in the Environmental Assessment as a change in fish population(s) that is greater than 20% (Government of Canada 1999). This effect must have a high probability of being permanent or long-term in nature and must occur throughout the receiving environment (Lac de Gras). The "Significance Thresholds" for this AEMP, therefore, are related to impacts that could result in a change in fish population(s) that is greater than 20% (Golder 2014).

Azimuth (2012) recommended the application of a 20% effect size as a monitoring "trigger" and a 50% effect size as a monitoring "threshold" for BMI metrics for the Meadowbank Mine Project (i.e., total abundance and richness), where effect size refers to a change or difference relative to BACI. They further note that the terms "threshold" and "trigger" are intended to be applied less strictly for biological variables, relative to chemical variables such as water or sediment quality, due to the inherent natural variability in biological parameters and the need to consider the cause of any observed statistical "changes" in the biological communities. The rationale provided for the identification of the 20% and 50% criteria is "to maintain a transparent (fixed) effect size that is more likely to be ecologically relevant." Where natural variability is high, use of two standard deviations for benthic invertebrate metrics could potentially mean that large and ecologically-relevant effects could occur to some endpoints without being higher than the CES. On the other hand, the limitation of using percentage change to define the CES for a metric when variability is high is reduced statistical power to detect change. Integral to this discussion is the importance of considering the variability in existing data in identifying appropriate CESs.

With respect to the Mary River Project, development of a benchmark(s) or CES(s) for the BMI that is adequately sensitive and ecologically appropriate considered:

- Natural variability in existing BMI metrics;
- the available baseline data set (i.e., baseline BMI community sampling has only been conducted once or twice at the majority of Mine Area lakes/streams and/or aquatic habitat types); and
- Literature in which benchmarks or CESs for BMI metrics have been adopted or identified, such as AEMPs for the Diavik Diamond Mine and Meadowbank projects.

The benchmark for the BMI program that will be conducted under the CREMP is a change of ± 50% in the mean of key metrics. A preliminary assessment of the statistical power of baseline data collected up to and including the 2013 CREMP field program (see Appendix 1) indicated that the power of the data sets for a representative lake (Sheardown Lake NW) and stream (Sheardown Lake Tributary 1, Reach 4) to be able to detect a post-Project change in the mean of ± 50% was, with the exception of total macroinvertebrate density, high for the majority of metrics investigated (Tables 3-1 and 3-2). More sensitive metrics to change were identified and these include Chironomidae proportion, Shannon's Equitability, Simpson's Diversity Index, and total taxa richness. In before-after comparisons of metrics, the power to detect differences is greater when there are more monitoring events in the before and after periods included in the analysis. Overall, it is expected that the CREMP will be capable of detecting larger impacts in a short time period, but will require longer time periods to detect more subtle effects (i.e., as more data are acquired).

3.4 MONITORING AREA AND SAMPLING SITES

The monitoring area for BMI includes Mine Area lakes, specifically Camp, Sheardown NW and SE, and Mary lakes, and Sheardown Lake tributaries 1, 9, and 12, several sites on the Mary River located upstream and downstream of effluent discharges, and Camp Lake tributaries 1 and 2 (Figure 3-1). Although monitoring will be conducted in areas of the Mary River and Camp Lake Tributary 1 under the Metal Mining Effluent Regulations (MMER) Environmental Effects Monitoring (EEM) program (Appendix A of the AEMP), additional monitoring in these waterbodies is proposed under the CREMP to augment the EEM monitoring program. In addition, monitoring will be conducted at Reference Lake 3 along with one reference stream (to be determined during the 2016 field program; e.g., CLT-REF4) as presented in Figure 2-1 and Figure 3-2.

3.4.1 Lakes

Benthic macroinvertebrate composition, distribution and relative abundance of dominant groups, including metal-sensitive taxa, naturally differ significantly between littoral (shallow) and profundal (deep) habitats of areas lakes. The sampling of benthic invertebrates at profundal, depths can confound the evaluation of mine related effects on biota due to the fact that at deeper depths/habitats natural factors, such as low oxygen and food resources, become more important drivers in shaping BMI community structure than mine-related contaminants. Because of this, Minnow has recommended that benthic invertebrate community sampling stations be established solely in littoral habitats. Five (5) replicate stations will be sampled in each lake with each replicate station consisting of five benthic macroinvertebrate field sub-samples/grabs. BMI stations will coincide with each study lake's five (5) littoral sediment quality stations (Figure 3.1 and Figure 3.2). Utilizing the same littoral stations for both sediment quality and benthic macroinvertebrate community sampling will provide supporting information for interpretation and analysis of BMI results (e.g., metals concentrations) and allow the CREMP to establish potential linkages between sediment metal concentrations and their potential effects on benthic macroinvertebrates.

Field crews will verify the aquatic habitat attributes of replicate stations (i.e., appropriate water depth, substrate type, and presence/absence of aquatic macrophytes) prior to sample collection.

3.4.2 Streams

Five replicate stations separated by approximately three wetted stream widths will be sampled in each stream reach (Figure 3-1). Each replicate station will consist of three benthic macroinvertebrate field sub-samples. Sub-samples will be collected moving in an upstream direction and, whenever possible, they will be collected from representative microhabitats across the stream. Figure 3-1 has been updated to reflect Minnow's recommendations of: (1) discontinuing BMI monitoring on the two upper reaches of Sheardown Lake Tributary 1; (2) adding a BMI monitoring station near L2-03 to monitor the effect of mine-influenced water quality changes on BMI communities and (3) establishing a stream reference BMI community station at one of the reference streams currently used for water quality monitoring (e.g., CLT-REF4; to be determined during the 2016 field study, based on similarity in habitat features with the mine-exposed streams).

3.5 SAMPLING FREQUENCY AND SCHEDULE

Sampling will be conducted in the first three years of operation during the ERP of the Project; subsequent sampling and sampling frequency will be evaluated following completion of the first 3 years of monitoring and in consideration of the current plans for mining activities at that time (e.g., will mine production be increased or remain at a similar level). Sampling frequency will be evaluated (i.e., each year of monitoring) to determine if modifications are warranted.

Timing of sampling will be concentrated within a single sampling season (i.e., late summer/fall). Benthic invertebrate sampling has been consistently conducted in the Mine

Area in late summer/fall, which is an ecologically relevant time for sampling and is most appropriate considering the effluent discharge regime (i.e., discharge during the open-water season only), hydrology (i.e., streams/rivers freeze solid), and dust deposition (i.e., introduction during the open-water season).

3.6 FIELD AND LABORATORY METHODS

Sampling methods for BMI and supporting variables are indicated below. BMI samples will be submitted to an analytical laboratory for processing and taxonomic identification. Laboratory methods for BMI samples will be in accordance with guidance provided in EC (2012). Samples for analysis of supporting sediment variables (i.e., particle size, TOC) will be submitted to an analytical laboratory accredited under CALA.

3.6.1 Lakes

By EEM definition, a replicate station is a specific, fixed sampling location within an area/polygon that can be recognized, re-sampled and defined quantitatively (e.g., UTM position and a written description). The geographic extent of each replicate station will be minimally 10 m x 10 m and separated from other replicate stations by at least 20 m. Within each habitat type(s), a replicate station will consist of five randomly collected benthic invertebrate sub-samples. Field sub-samples will be collected using a random number table and from designated sampling locations around an anchored boat within the 10 m x 10 m replicate station area.

For each field sub-sample/grab:

1. The petite Ponar (area of opening 0.23 m^2) will be slowly lowered until it rests on the bottom to prevent shock waves that could physically move or disturb organisms and sediment from beneath the sampler.
2. The petite Ponar will be closed using a messenger.
3. The petite Ponar will be slowly raised, to minimize turbulence, and the sample will be immediately placed into a pail.
4. An acceptable sample requires that the jaws be completely closed upon retrieval.
5. If the jaws are not completely closed the sample will be discarded into a bucket (and disposed of once sampling is completed) and the procedure will be repeated.

6. The depth of penetration of each successful sample will be recorded; grab sample penetration of approximately 6-8 cm substrate-depth will be considered an acceptable sample.

All sampling equipment will be rinsed before sampling at the next replicate station.

Benthic invertebrate samples will be carefully sieved through a 500 µm mesh rinsing bucket or bag. All materials, including invertebrates, retained by the screen will be transferred to labelled plastic jars and fixed with 10% buffered formalin. Fixed and labelled samples will be shipped to the analytical laboratory for processing and archiving.

3.6.2 Streams

Five replicate stations separated by approximately three wetted stream widths will be sampled in each stream reach. Each replicate station will consist of three benthic macroinvertebrate field sub-samples. Sub-samples will be collected moving in an upstream direction and, whenever possible, they will be collected from representative microhabitats across the stream.

Each sub-sample will be collected by placing a Surber sampler (the sampling equipment used during the baseline field programs) on a flat area of the streambed, facing upstream. The surface area sampled by the Surber sampler is equivalent to 0.097 m^2. Macroinvertebrates will be collected over a two minute time period by rubbing the rocks and disturbing the sediment in the substrate area framed by the Surber net. All sub-samples will be rinsed from the netting into a 500 µm sieve. Forceps will be used to collect any macroinvertebrates remaining on the netting after rinsing. The sample will then be washed, transferred into a sample jar, and fixed as soon as possible in 10% buffered formalin. Fixed and labelled samples will be shipped to the analytical laboratory for processing and archiving.

3.6.3 Supporting Environmental Variables

Supporting environmental variables will be measured in order to link aquatic habitat attributes with benthic invertebrate community metrics. Supporting environmental variables measured at each replicate station will include:

- Sample date and start/end sample time;
- UTM position (using a hand-held GPS receiver);
- Water transparency (using a Secchi disk; lakes only); and

- Water temperature (using a hand-held thermometer for water surface measurement).

Supporting environmental variables measured/recorded at each sub-sample/grab site will include:

- Water depth (using a hand-held depth sounder or metered petit Ponar rope);
- Presence/absence of aquatic macrophytes in sub-sample;
- Substrate composition (visual description e.g., % cobble, gravel, silt, etc.) and compaction (soft, medium) of sub-sample. A visual description of benthic grab samples should be recorded to describe sediment colour, odour, texture (e.g., % sand, silt, clay, etc.) and debris content (e.g., woody debris, aquatic macrophyte, etc.); and
- Depth of penetration (cm) of each successful sub-sample/grab.

One grab sample will be collected for sediment from each replicate station for a total of five sediment samples per lake). Each sediment grab will be sub-sampled with a 5 cm diameter core tube (0.002 m^2 surface area) to provide a sample of approximately 100 mL of sediment for the analysis of supporting variables (i.e., total organic carbon and particle size). Additionally, DO, pH, conductivity, temperature, and turbidity will be measured *in situ* near the sediment-water interface at each replicate lake and stream station.

3.7 QUALITY ASSURANCE/QUALITY CONTROL

QA/QC procedures for benthic macroinvertebrate field operations, laboratory operations (sorting efficiency, sub-sampling), and data handling will conform to current EEM recommendations provided in EC (2012).

3.8 STUDY DESIGN AND DATA ANALYSIS

As existing baseline data for Reference Lake 3 and reference streams are minimal, the monitoring program will focus upon before-after comparisons of key metrics within the Mine Area waterbodies. The Overall objective of this program is the evaluation of mine related influences to benthic invertebrates in the Mine Area lakes and streams.

For Sheardown Lake NW and SE, Camp Lake, Mary Lake, and Reference Lake 3, only littoral habitats (5 replicate stations per lake) will be sampled. For Sheardown Lake tributaries 1, 9, and 12, Camp Lake tributaries 1 and 2, and the Mary River, representative stream reaches (5 replicate stations per reach) will also be sampled.

To prepare the data for analysis, the abundance of macroinvertebrates in each replicate will be converted to density (number of invertebrates per square meter [individuals/m^2]) by dividing the total number of invertebrates per sample by the bottom area of the sampling device (0.023 m^2 for petit Ponar dredge; 0.97 m^2 for Surber sampler). Benthic invertebrate metrics will be calculated for each replicate and included in statistical analyses to describe the community. Metrics will be plotted as box plots to visually assess the occurrence of extreme outliers and to provide a preliminary visual assessment of potential spatial and/or yearly differences. Summary statistics (n, mean, median, SD, standard error [SE], minimum, maximum, and 95th percentile) for each metric will be derived for each lake by aquatic habitat type and by year, and for each stream by reach and by year to examine spatial and inter-annual differences. Efforts will be made to include as many taxa as possible in the analysis; however, Diptera, Chironomidae and Empididae pupae will be excluded from metric calculations where genus level identifications are used (e.g., evenness, Simpson's Diversity Index). Taxonomic richness (i.e., the number of taxa) is determined at the genus level. If a group is identified to a higher level (e.g., class or order), then it will be assumed that only one genus is represented and this may result in a conservative estimate of the number of taxa; pupae will not be included in the determination of richness.

Additionally, the number of field sub-samples (i.e., grabs) per replicate station that would provide an estimate with 20% precision (i.e., an acceptable level of variance) for each metric will be determined for each lake for each year. The number of field sub-samples will be calculated as follows:

$n = s^2 / D^2 * X^2$

where:

X = the sample mean

n = the number of field sub-samples

s = the sample variance

D = the index of precision (i.e., 0.20)

Inter-annual differences in macroinvertebrate metrics will be assessed statistically for each lake and for each stream by reach (where multiple years of data are available). All data will be tested for normality prior to statistical analysis and data that are normally distributed will be assessed using parametric statistics while non-normally distributed data will be analysed using non-parametric tests. Differences between years (and before-after comparisons) will be assessed using the t-test (parametric) or Mann-Whitney U-test (non-parametric) when two years of data are available; ANOVA with Bonferroni pairwise comparison (parametric) or Kruskal-Wallis test followed by multiple pairwise comparison (Dunn's procedure) (non-parametric) will be used when three years of data are available. All tests will be assessed with a significance level of 0.1 as per Environment Canada (2012) guidance.

3.9 ASSESSMENT FRAMEWORK

BMI data will be assessed during each year of monitoring and would follow the assessment framework as outlined in Figure 2-2 and described below.

3.9.1 Step 1: Initial Data Analysis

Section 3.3 provides a description and rationale for the development of a benchmark for BMI metrics (change in the mean of ± 50%). As existing baseline data for Reference Lake 3 and reference streams are minimal, the monitoring program will focus upon before-after comparisons of key metrics within the Mine Area waterbodies, with an emphasis on Mine Area lakes. As additional data are acquired from reference waterbodies, comparisons to these datasets may also be undertaken in the future.

Step 1 will involve preparing the BMI data for analysis (i.e., convert number of macroinvertebrates to density), calculating metrics for each replicate station, preliminary review of data through graphical presentations (e.g., box plots) to visually assess the occurrence of extreme outliers and potential spatial and/or yearly differences, calculation of summary statistics, and statistical comparisons between baseline data and monitoring data for each lake and each stream by reach (and by year when data are available). Summary statistics for each metric will be derived for each lake and each stream by reach.

Statistical comparisons will be done by metric based on data collected in each Mine Area lake/reach pre- and post-Project. Data would then be compared to the benchmark (change in the mean of ± 50% as described in Section 3.3). If there is no evidence of change for any metric, no management response would be required; however, spatial and temporal analyses would be continued. In this instance, more robust metrics would be plotted graphically or in table format to facilitate visual analysis of changes over time and assessment of whether there is an upward or downward change that may suggest mounting effects. If there is evidence of a change for any metric, the assessment would proceed to Step 2 to determine if the change is Mine-related.

3.9.2 Step 2: Determine if Change is Mine-Related

Step 2 involves determining whether the evidence of change in a BMI metric(s) is related to the Project, other causes, or natural variability. This question will be addressed through several possible approaches:

- Evaluating spatial patterns for metric results for the Mine Area as a whole, including Mine Area lakes and streams (CREMP and EEM results), to evaluate if changes are widespread or specific to certain waterbodies (i.e., identify the spatial extent and pattern of observed changes). This exercise would assist with identifying potential stressors/pathways of effects;

- Comparing data from Mine Area lakes to Reference Lake 3 and potentially data from Mine Area streams to reference streams. This would further assist with determining whether the observed changes were related to natural variability or the Project;

- Evaluating other factors that may affect the BMI community such as water quality, sediment quality, and physical habitat attributes; and

- Evaluating Project activities with the potential to alter water quality and/or other conditions that could ultimately affect the benthic macroinvertebrate community. This may include evaluating effluent quality, discharge regime/rates, and loading, notably in relation to sewage effluent, dust deposition, and other point/non-point sources as required.

If the Step 2 analysis concludes that the changes in one or more BMI metrics are, or are likely, related to the Project, the assessment would proceed to Step 3. If it is concluded that it is unlikely that the changes are related to the Project, no management response would be required; spatial and temporal analyses would be continued as in Step 1.

3.9.3 Step 3: Determine Action Level

Step 3 involves determination of the action level associated with the observed monitoring results through comparisons to the benchmark (change in the mean of ± 50% as described in Section 3.3). If the benchmark is not exceeded the assessment would proceed to a low action level response; if it is equalled or exceeded, the assessment would proceed to a moderate action level response.

If the benchmark is not exceeded, a low action level response would be undertaken and may include:

- Conduct a spatial and temporal analysis – this will be a qualitative exercise and consist of graphical presentation of data for each lake and over time within a lake to evaluate differences among lakes and changes within a lake over time. It is important to note that several years of data will be required to begin to assess temporal trends;

- Investigate and summarize potential relationships to the Project and pathways of effect for the observed changes;

- Review and summarize monitoring results for other metrics of relevance to the BMI community, including nutrients, water clarity, DO, and sediment quality (including sedimentation). Spatial and temporal analysis results for these metrics, notably eutrophication and sedimentation, will also be considered in the interpretation of BMI monitoring results;

- Review/assess benchmark with acquisition of data (note: this will be undertaken over the course of monitoring). This may include performing a power analysis to assess the power of the current data set for detecting post-Project change (i.e., Before-After comparisons) and explore samples sizes (i.e., number of replicate stations within an aquatic habitat type) required for detecting pre-defined levels of change; and

- Based on the above evaluations, determine next steps.

If the benchmark is met or exceeded, a moderate action level response would be undertaken and may include the following:

- Evaluate chemical, biological, and physical monitoring results collectively with BMI monitoring results to evaluate effects on the ecosystem. For example, key metrics would be evaluated to determine if any observed increases in chlorophyll *a* are adversely affecting other biota, specifically BMI and Arctic Char;

- Evaluate the need for additional monitoring (e.g., targeted studies to confirm monitoring results) and/or modifications to the CREMP;

- Consider results of the temporal analysis (i.e., analysis indicates a substantive change) to determine if management/mitigation is required;

- Evaluate the benchmark to determine if it should be modified, as described above; and

- Identify next steps based on the above analyses. Next steps may include those identified for a high action level response.

A quantitative trigger (i.e., threshold) for a high action level response has not been identified as the need for additional study and/or mitigation will depend on the ultimate effects of the observed changes in BMI metrics on the lakes and streams as a whole and because the benchmark may need to be revised in consideration of ongoing monitoring results. For example, increases in nutrients and primary productivity (i.e., eutrophication) may lead to increased productivity in other trophic levels, such as BMI and fish, which may be perceived as a positive effect. The precise relationships between nutrients, phytoplankton, and higher trophic levels is difficult to predict and it is therefore suggested that actions undertaken under a moderate action level response attempt to explore these relationships to advise on overall effects to the ecosystem. Additional actions that may be implemented in a subsequent phase (i.e., high action level response) include:

- Implement increased monitoring to confirm effects and/or define magnitude and spatial extent of effects if warranted; and
- Implement mitigation measures or other management actions that may be identified in a moderate action level response.

4.0 ARCTIC CHAR

The following section provides a description of monitoring of Arctic Char under the CREMP.

4.1 PATHWAYS OF EFFECT AND KEY QUESTIONS

Key questions were developed for the CREMP to guide the review of baseline data adequacy and, ultimately, design of the fish monitoring program. These questions and metrics focus upon key potential effects identified in the FEIS, as well as metrics commonly applied for characterizing fish populations (growth, reproduction, condition and survival) and recommended by EC (2012).

The key pathways of potential residual effects of the Project on Arctic Char include:

- Water quality changes related to discharge of ore or stockpile runoff to freshwater systems (immediate receiving environments: Mary River and Camp Lake Tributary 1);
- Water quality changes related to discharge of treated sewage effluent (immediate receiving environments: Mary River and Sheardown Lake NW);
- Water quality changes due to deposition of dust in lakes and streams (Mine Area in zone of dust deposition);
- Water quality changes due to non-point sources, such as site runoff and use of ANFO explosives (Mine Area);
- Changes in water levels and/or flows due to water withdrawals, diversions, and effluent discharges (i.e., alteration or loss of aquatic habitat);
- Dust deposition (i.e., sedimentation) in Arctic Char spawning areas (habitat) and on Arctic Char eggs; and
- Effects of the Project on primary and secondary producers.

The key question related to the pathways of effect is:

- What are the combined effects of point and non-point sources, sedimentation, habitat loss or alteration, and changes in primary or secondary producers on Arctic Char in Mine Area lakes (Sheardown Lake NW and SE, Camp Lake, and Mary Lake)?

Arctic Char will be monitored downstream of discharges of ore and waste rock stockpile runoff (i.e., Camp Lake Tributary 1 and the Mary River) under the MMER EEM program. A description of the MMER EEM program is provided in Appendix A of the AEMP and is not considered here. The CREMP provides a description of Arctic Char monitoring that will be conducted in addition to the MMER EEM program. The objective of the CREMP fish program is to augment monitoring in time and/or space beyond that captured by the EEM program to address all key effects pathways. For example, EEM monitoring will occur exclusively in streams, but Mine Area lakes, which provide overwintering and spawning habitat and support a broader range of age classes than streams, may be affected by the Project differently than streams.

4.2 PARAMETERS AND METRICS

The Mine Area streams and lakes support only two fish species: land-locked Arctic Char; and, Ninespine Stickleback (*Pungitius pungitius*). Of these, abundance and distribution of Ninespine Stickleback are relatively limited and highly localized while Arctic Char are overwhelmingly the most abundant and widely distributed fish species in the area. As Mine Area streams freeze solid during winter, overwintering habitat is provided exclusively by lakes.

EC (2012) recommends monitoring of sexually mature individuals of a minimum of two fish species for EEM programs and use of invasive sampling (i.e., lethal) if acceptable. Alternative study designs include non-lethal sampling methods for fish populations/communities, as well as studies of juvenile fish if appropriate and/or required.

Given that there are only two fish species present in the area, fish monitoring in the Mine Area would be limited to successful capture of sufficient numbers of both of these fish species in the exposure areas. In most lakes and streams in the exposure area, Arctic Char are sufficiently abundant that successful capture of enough fish for monitoring purposes is possible. In contrast, Ninespine Stickleback are absent or uncommon in a number of waterbodies. It is unlikely, even with extensive effort, that sufficient numbers of Ninespine Stickleback could be captured for monitoring purposes from either the receiving environments or from prospective reference areas. For these reasons only a single species, Arctic Char, will be targeted under the CREMP program.

Non-lethal sampling methods will be used to the extent possible to minimize impacts of monitoring on the Arctic Char populations. As a result, metrics that can be reliably obtained from live fish will be included in CREMP. Metrics will include indicators of fish growth, condition, and reproduction.

EC (2012) recommends that non-lethal sampling should include fork length for fish with a forked caudal fin (± 1 mm), total body weight (± 1.0%), assessment of external condition (i.e., deformities, erosion, lesions, and tumours [DELTs]), external sex determination (if possible), and age (where possible; ± 1 year). Metrics based on these measurements that will be examined under the CREMP are indicated in Table 4-1. In addition, catch-per-unit-effort (CPUE) will be calculated and examined in the analysis and reporting as a general indicator of abundance.

4.3 BENCHMARKS

Although there are no established benchmarks for biological variables (e.g., abundance), including fish, that can be readily adopted or considered for monitoring effects on freshwater biota, CESs for selected biological metrics are prescribed in the MMER EEM Guidance Document (EC 2012) and have been proposed and applied in other recent monitoring programs that fall outside of MMER EEM requirements, such as the DDMI project (Golder Associates 2014).

A revised AEMP was recently issued for the DDMI Project at Lac de Gras, NT, which includes lethal monitoring of the fish community (Golder Associates 2014). Effects and subsequent action levels associated with the fish community monitoring represent a range, as follows (note action level 4 is not defined):

- statistical differences relative to reference areas (action levels 1 and 2) where effects indicate a toxicological response;
- metrics beyond the normal range (action level 3); and
- benchmark of "indications of severely impaired reproduction or unhealthy fish likely to cause a > 20% change in fish population(s)" (action level 5).

The MMER identifies CESs for a fish population as a percentage of change from the "reference mean" (Table 4-2). As noted by Indian and Northern Affairs Canada (INAC 2009), "these effect sizes do not reflect the method recommended by Environment Canada (2004); namely effect sizes that correspond with unacceptable ecological changes." However, the CESs will be utilised by Baffinland in analyses for the program provided a good reference area is selected

As it is not possible to identify a level of change in Arctic Char population metrics that would be indicative of long-term effects or "unacceptable ecological changes" for the Mine Area fish populations, the CREMP will initially apply the recommended benchmarks developed for MMER EEM (Table 4-2). However, it is recommended that the applicability/appropriateness of these benchmarks be reviewed on a regular basis and, if appropriate, modified as the CREMP progresses. The management response framework should also be regularly reviewed and adjusted over time to ensure the program is effective, sensitive, and ecologically meaningful.

4.4 MONITORING AREA AND SAMPLING SITES

The monitoring area for Arctic Char includes Mine Area lakes, specifically Camp Lake Mary Lake, and Sheardown Lake NW and SE. Monitoring of lakes is a key component of the CREMP because the Mine Area lakes provide overwintering and spawning habitat, support the full range of age classes, and because they may be affected differently than streams. In addition, monitoring will be conducted at Reference Lake 3.

4.5 SAMPLING FREQUENCY AND SCHEDULE

Sampling will be conducted in the first three years of operation during the ERP of the Project; subsequent sampling and sampling frequency will be evaluated following completion of the first 3 years of monitoring and in consideration of the current plans for mining activities at that time (e.g., will mine production be increased or remain at a similar level). Sampling frequency should be regularly evaluated (i.e., each year of monitoring) to determine if modifications are warranted. Monitoring will be conducted in late summer/fall near the end of the growing season.

4.6 FIELD METHODS

4.6.1 Lakes

The lake-based Arctic Char sampling program is designed to be non-lethal and is based upon Environment Canada's EEM survey design (EC 2012). As such, the lake-based sampling program is focused upon obtaining measures of metrics for Age 1+ and young of the year (YOY) fish using standardized sampling methods (i.e., standard gang index gillnetting and shoreline backpack electrofishing). The program will include sampling in major habitat types in each of the lakes defined in terms of water depth and substrate as follows:

- Deep (> 12 m)/hard;
- Deep/soft;
- Shallow (2-12 m)/hard; and

- Shallow/soft.

Following Minnow's 2016 recommendations, capture of juvenile (age 0+ and 4+) will be conducted through targeted sampling in nearshore habitats, and adults (age 8+ and over) will be conducted at littoral/profundal areas of each lake. Gear will include standard gang index gill nets (38 – 64 mm) and nearshore backpack electrofishing to obtain the required minimum target sample size (and range of fish ages/sizes. The juvenile survey should target a sample size of a 100 fish using a backpack electrofisher while the adult survey should target a sample size of 50 fish using gill nets. Only standard gang index gill nets with mesh sizes ranging from 38 – 64 mm will be used in the adult survey since field programs conducted to date have shown this mesh size to be the most effective. In doing so, it is anticipated that fewer incidental mortalities will be encountered (e.g. reduced handling time) and additional sampling efficiencies will be gained.

Fish will be identified to species, enumerated by location, and measured for fork length (±1 mm), round weight (±1%), examined for (DELTs, and where possible, sex and maturity. Metadata that will be recorded will include site UTMs, date and time of net deployment and retrieval (or start and end time of electrofishing), and water temperature. Mortalities will be retained and examined internally to determine sex and state of sexual maturity (i.e., had never spawned, preparing to spawn in the current year, had just completed spawning in the current year, or had spawned in a previous year but would not be spawning in the current year), where possible.

The preferred structure for ageing Arctic Char is the otolith (Baker and Timmons 1991). However, where non-lethal sampling methods are employed, fish are typically aged with pectoral fin rays. The results of a study comparing pectoral fin rays and otoliths for ageing Arctic Char in the mine area indicates that the former method underestimates fish ages (NSC 2014). Based on this study, pectoral fin rays will be collected from live fish but a sub-sample of Arctic Char will be sacrificed for collection of otoliths for age validation. Additional comparison of these two ageing structures may be undertaken to determine if a conversion factor can be developed for application in future monitoring.

4.7 QUALITY ASSURANCE/QUALITY CONTROL (QA/QC)

The QA/QC program will include the following components:

- Application of established sampling protocols;
- Review of data for transcription errors, omissions, and outliers; and

- QA/QC of fish ageing data.

A minimum of 10% of fish ageing structures will be aged by a second technician.

4.8 STUDY DESIGN, DATA ANALYSIS, AND SAMPLE SIZE

The study design is a non-lethal fish survey, which would consist of a lake-based program in late summer/fall using a combination of gear types.

Review of baseline data for Arctic Char was conducted in 2013 to advise on a study design for the CREMP (NSC 2013). This review indicated that the recommended sample size of 100 fish in the EEM Guidance Document (EC 2012) would be more than adequate to detect low levels of change in Arctic Char length, weight, and condition factor.

However, in assessing the data acquired during the 2015 CREMP, power analysis indicated that the total sample size could be reduce from 100 to 50 fish while still maintaining the ability to detect changes between lakes and/or between study periods with sufficient power. Therefore, only a sample size of 50 adult Arctic Char per lake should be targeted in future CREMP studies.

Arctic Char metrics will be statistically assessed against baseline data in the initial years of operation. Once sufficient data are acquired for the reference waterbody, statistical comparisons to Mine Area waterbodies may be undertaken under the CREMP. Trends will also be examined over time to determine if fish metrics are increasing or decreasing.

Data analysis methods will follow guidance provided by EC (2012) and will include preliminary review of data for identification of outliers, calculation of summary statistics, and conduct of statistical comparisons to baseline data. Statistical analyses will vary depending on the metric but will include ANOVA, analysis of covariance (ANCOVA), and the Kolmorgorov-Smirnov test. If required, data transformations and/or non-parametric methods will be employed. All tests will be assessed with a significance level of 0.05.

4.9 ASSESSMENT FRAMEWORK

Monitoring data will be assessed during each year of monitoring and would follow the assessment framework as outlined in Figure 2-2 and described below.

4.9.1 Step 1: Initial Data Analysis

Step 1 would involve collation and QA/QC review of data, preliminary review of data through graphical presentations to assist with identification of outliers, calculation of summary statistics, statistical comparisons to baseline and/or reference area data, and comparison to the benchmarks. Statistical comparisons between pre- and post-Project data (i.e., before-after comparisons) will be undertaken initially. However, as data is acquired at Reference Lake 3, comparisons may also be made in the future to reference areas. If this analysis indicates a statistically significant or qualitative difference between pre- and post-Project data, the assessment would proceed to Step 2. If there is no indication of change, no management response would be required.

4.9.2 Step 2: Determine if Change is Mine Related

Step 2 involves determining if the observed change in a fish metric is due to the Project or due to natural variability or other causes. This question will be addressed through several possible approaches:

- Evaluating observed changes in all of the fish metrics collectively to assist with interpretation of the results;
- Evaluating spatial patterns in results for the Mine Area as a whole to evaluate if changes are widespread or specific to certain waterbodies, and to identify the spatial extent and pattern of observed changes. This exercise would assist with identifying potential stressors/pathways of effects;
- Comparing data from Mine Area lakes to a reference lake(s). This would further assist with determining whether the observed changes were due to natural variability or the Project;
- Evaluating monitoring results from other components monitored under the CREMP including water quality, sediment quality, benthic macroinvertebrates, phytoplankton, water levels/flows, and dust deposition/sedimentation; and
- Considering supporting information such as climatological factors (e.g., length of growing season) and water temperature.

If the observed differences are not attributable to the Project, no management response would be required. If the results of this analysis indicate the changes are due or likely due to the Project, the assessment would proceed to Step 3.

4.9.3 Step 3: Determine Action Level

Step 3 involves determination of the action level associated with the observed monitoring results through comparisons to the benchmark. If the benchmark is not exceeded, a low action level response would be undertaken and may include:

- Conduct a temporal trend analysis: this will be a qualitative exercise and consist of graphical presentation of data over time to evaluate increasing or decreasing trends. It is important to note that several years of data will be required to begin to assess temporal trends;
- Investigate and summarize potential causes and pathways of effect of the observed changes;
- Review and summarize monitoring results for other metrics of relevance to Arctic Char (i.e., drivers) such as water levels and flows, water temperature, and/or chemical and other biological metrics;
- Review/assess benchmarks with acquisition of data (note: this will be undertaken over the course of monitoring); and
- Based on the above evaluations, determine next steps.

If a benchmark is exceeded, a moderate action level response would be undertaken and may include the following:

- Evaluate the need for additional monitoring (e.g., confirmation monitoring) and/or modifications to the CREMP;
- Consider results of the trend analysis (i.e., trend analysis indicates an upward or downward trend) to determine if management/mitigation is required;
- Consider if effects are indicative of nutrient enrichment (i.e., increased growth or productivity) or due to either a toxicological response or a physical effect such as changes in habitat; and
- Identify next steps based on the above analyses. Next steps may include those identified for the high action level response.

Actions should consider whether the statistical differences and benchmark exceedances are observed in two consecutive monitoring periods to confirm the effects.

A quantitative trigger for the high action level response has not been identified as the need for additional study and/or mitigation will depend on the ultimate effects of the observed changes and because the benchmarks may need to be revised in consideration of ongoing monitoring results and the ecological significance of the results. For example, increases in nutrients and primary productivity may lead to increased productivity in other trophic levels, such as fish, which is an effect that can be perceived as positive. Additional actions that may be implemented in a subsequent phase (i.e., high action level response) include:

- Implement increased monitoring to confirm effects and/or define magnitude and spatial extent of effects if warranted; and
- Implement mitigation measures or other management actions that may be identified under the moderate action level response.

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Table 2-1. Lake trophic classification schemes based on chlorophyll *a* and mean concentrations in Mine Area lakes.

Lake Trophic Status: Chlorophyll *a* (µg/L)						Comments	Reference
Ultra-oligotrophic	**Oligotrophic**	**Mesotrophic**	**Meso-eutrophic**	**Eutrophic**	**Hypereutrophic**		
<1	<2.5	2.5-8		8-25	> 25	International; Alberta	OECD (1982) and AENV (2014)
	Mean: <1.7 Range: 0.3-4.5	Mean: 4.7 Range: 3-11		Mean: 14.3 Range: 3-78	Range: 100-150	International Lakes and Reservoirs (modified from Vollenweider 1979)	Wetzel (2001)
-	< 3.5	3.5-9	-	9.1-25	> 25		Nürnberg (1996)
	<2.6	2.6-6.4	6.4-20	>20			Carlson (1977)
≤2	2-5	5-12		12-25	>25	Sweden	Swedish EPA (2000)
	<2	2-7		7-30	>30	US	USEPA (2009)
	<3	3-7		7-40	>40	Florida	University of Florida (2002)
	1-3	3-8		8-25		Quebec	Galvez-Cloutier R. and M. Sanchez. 2007
Mean: <1 Max: 2.5	Mean: <2.5 Max: 8	Mean: 2.5-8 Max: 8-25		Mean: 8-25 Max: 25-75	Mean: >25 Max: >75	International	Ryding and Rast (1989)
Sheardown Lake NW Mean: 0.35							
Sheardown Lake SE Mean: 0.78							
Camp Lake Mean: 0.57							
Mary Lake Mean: 1.18							
All Lakes Mean: 0.67							

Table 2-2. Derivation of the benchmark for chlorophyll *a*.

Reference	Chlorophyll *a* (µg/L)	
	Maximum Oligotrophic	**Minimum Mesotrophic**
OECD (1982) and AENV (2014)	2.5	2.5
Wetzel (2001)	4.5	3
Nürnberg (1996)	3.5	3.5
Carlson (1977)	2.6	2.6
Swedish EPA (2000)	5	5
USEPA (2009)	2	2
University of Florida (2002)	3	3
Galvez-Cloutier R. and M. Sanchez. (2007)	3	3
Ryding and Rast (1989)	8	8
Mean	**3.79**	**3.62**

Table 2-3. Summary of baseline chlorophyll *a* concentrations in Mine Area lakes.[1]

	Sheardown Lake NW			Sheardown Lake SE			Camp Lake			Mary Lake			All Lakes
	All Data (2007, 2008, 2013)	Summer	Late Summer/Fall	All Data (2007, 2008, 2013)	Summer	Late Summer/Fall	All Data (2007, 2008, 2013)	Summer	Late Summer/Fall	All Data (2007, 2008, 2013)	Summer	Late Summer/Fall	2007, 2008, and 2013
Mean	0.35	0.42	0.29	0.57	0.60	0.54	0.57	0.60	0.52	1.18	1.06	1.39	0.68
Median	0.20	0.30	0.20	0.20	0.20	0.30	0.25	0.20	0.30	1.05	1.20	0.90	0.20
Minimum	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Maximum	0.90	0.90	0.90	2.10	2.10	1.70	2.10	2.10	1.70	3.50	2.10	3.50	3.50
SD	0.24	0.28	0.19	0.60	0.67	0.54	0.59	0.67	0.51	1.00	0.80	1.33	0.73
SE	0.04	0.07	0.05	0.14	0.20	0.19	0.13	0.20	0.17	0.22	0.22	0.50	0.08
N	30	15	15	19	11	8	20	11	9	20	13	7	86
95th Percentile	0.90	0.90	0.62	1.74	1.80	1.46	1.72	1.80	1.42	1.80	2.04	3.35	2.10
97.5th Percentile	0.90	0.90	0.76	1.92	1.95	1.58	1.91	1.95	1.56	3.26	2.07	3.43	2.28
% Detections	50	67	33	53	45	63	55	45	67	70	69	71	53
COV (%)	69	66	67	105	111	100	104	111	97	85	76	96	108
Mean + 2 x SD	0.84	0.97	0.67	1.78	1.93	1.62	1.74	1.93	1.54	3.17	2.67	4.05	2.14
2 x Mean	0.71	0.84	0.57	1.15	1.20	1.08	1.13	1.20	1.04	2.35	2.12	2.77	1.35
Mean + 50%	0.53	0.63	0.43	0.86	0.90	0.81	0.85	0.90	0.78	1.76	1.59	2.08	1.02

[1] Data used included chlorophyll a data collected up to and including the 2013 CREMP field program.

Table 3-1. Power of existing BMI data in Sheardown Lake NW to detect pre-defined levels of change.[2]

Metric	Habitat Type 4 (2008; n = 8)		
	Mean +/-50%	Mean +/-25%	Mean +/-20%
Total macroinvertebrate density	0.247	0.148	0.123
Chironomidae proportion	0.957	0.536	0.402
Shannon's Equitability	1.000	0.935	0.813
Simpson's Diversity Index	1.000	0.982	0.938
Total taxa richness	1.000	1.000	1.000
Metric	**Habitat 9 (2007 and 2008; n = 22)**		
	Mean +/-50%	**Mean +/-25%**	**Mean +/-20%**
Total macroinvertebrate density	0.807	0.387	0.282
Chironomidae proportion	1.000	1.000	1.000
Shannon's Equitability	1.000	1.000	0.999
Simpson's Diversity Index	1.000	1.000	1.000
Total taxa richness	1.000	0.992	0.943
Metric	**Habitat Type 14 (2007, 2008, 2011; n = 12)**		
	Mean +/-50%	**Mean +/-25%**	**Mean +/-20%**
Total macroinvertebrate density	0.441	0.170	0.154
Chironomidae proportion	1.000	1.000	1.000
Shannon's Equitability	0.990	0.681	0.495
Simpson's Diversity Index	0.892	0.446	0.317
Total taxa richness	1.000	0.866	0.712

[2] Data used included BMI data collected up to and including the 2011 CREMP field program.

Table 3-2. Power of BMI data in Sheardown Lake Tributary 1, Reach 4 to detect pre-defined levels of change.[3]

Metric	2007, 2008, 2011; n = 9		
	Mean +/-50%	Mean +/-25%	Mean +/-20%
Total macroinvertebrate density	0.564 [1]	0.248 [2]	0.209 [3]
Chironomidae proportion	1.000	1.000	1.000
Shannon's Equitability	1.000	0.791	0.602
Simpson's Diversity Index	1.000	0.750	0.578
Total taxa richness	1.000	0.844	0.651

[1] metric not normally distributed: -50%, 0.785

[2] metric not normally distributed: -25%, 0.276

[3] metric not normally distributes: -20%, 0.109

[3] Data used included BMI data collected up to and including the 2011 CREMP field program.

Table 4-1. Summary of fish metrics and statistical analysis methods recommended under EEM (EC 2012). Metrics indicated with an asterisk are endpoints used for determining effects under EEM, as designated by statistically significant differences between exposure and reference areas. Other endpoints may be used to support analyses.

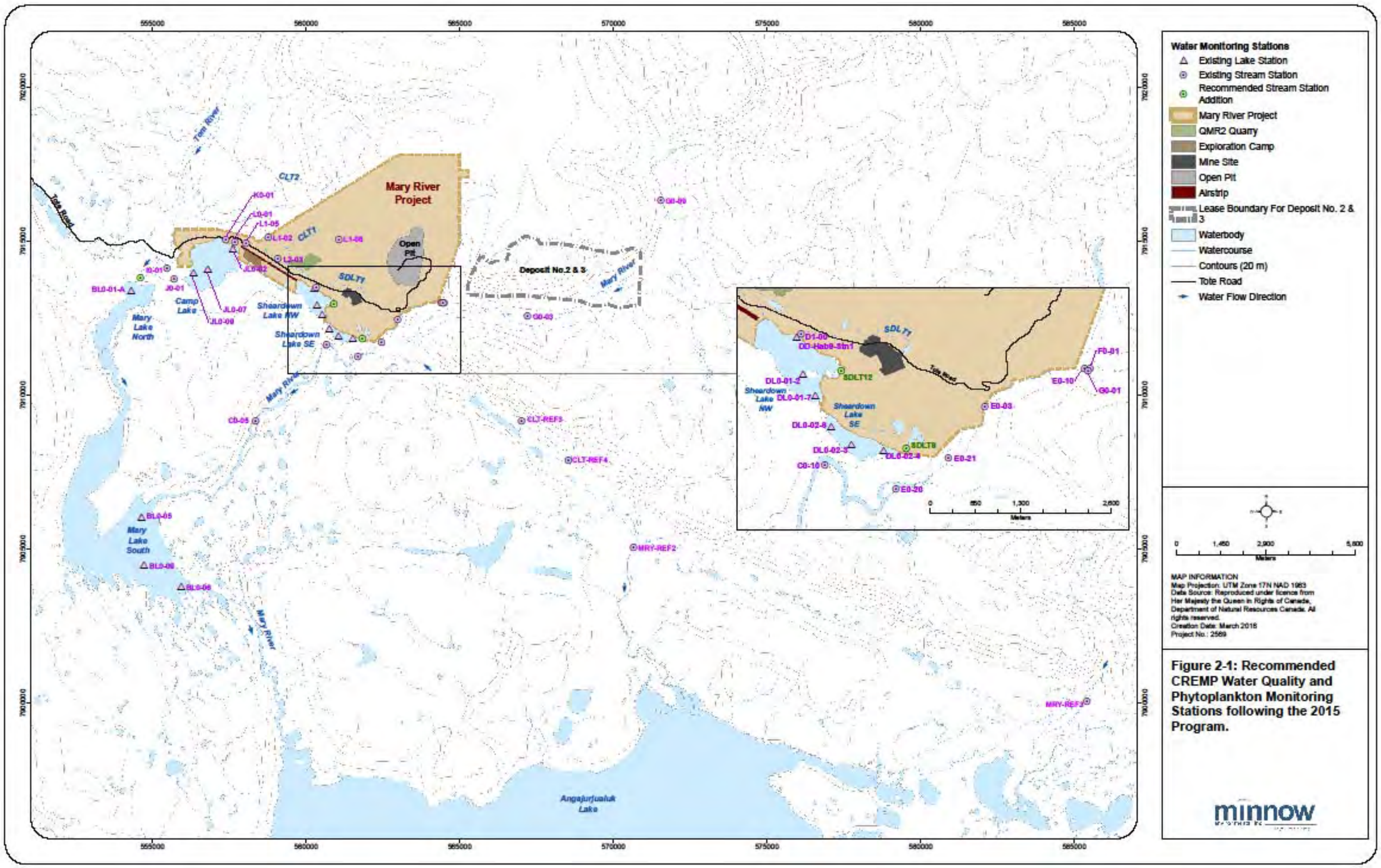
Effect Indicators	Fish Effect Endpoint	
	Non-Lethal Survey	Statistical Test
Growth	*Length of YOY (age 0) at end of growth period	ANOVA
	*Weight of YOY (age 0) at end of growth period	ANOVA
	*Size of 1+ fish	ANOVA
	*Size-at-age (body weight at age)	ANCOVA
	Length-at-age	ANCOVA
	Body Weight	ANOVA
	Length	ANOVA
Reproduction	*Relative abundance of YOY (% composition of YOY)	Kolmorgorov-Smirnov test performed on length-frequency distributions with and without YOY included; OR proportions of YOY can be tested using a Chi-squared test.
	OR relative age-class strength	
Condition	*Condition Factor	ANCOVA
Survival	*Length-frequency distribution	2-sample Kolmorgorov-Smirnov test
	*Age-frequency distribution (if possible)	2-sample Kolmorgorov-Smirnov test
	YOY Survival	

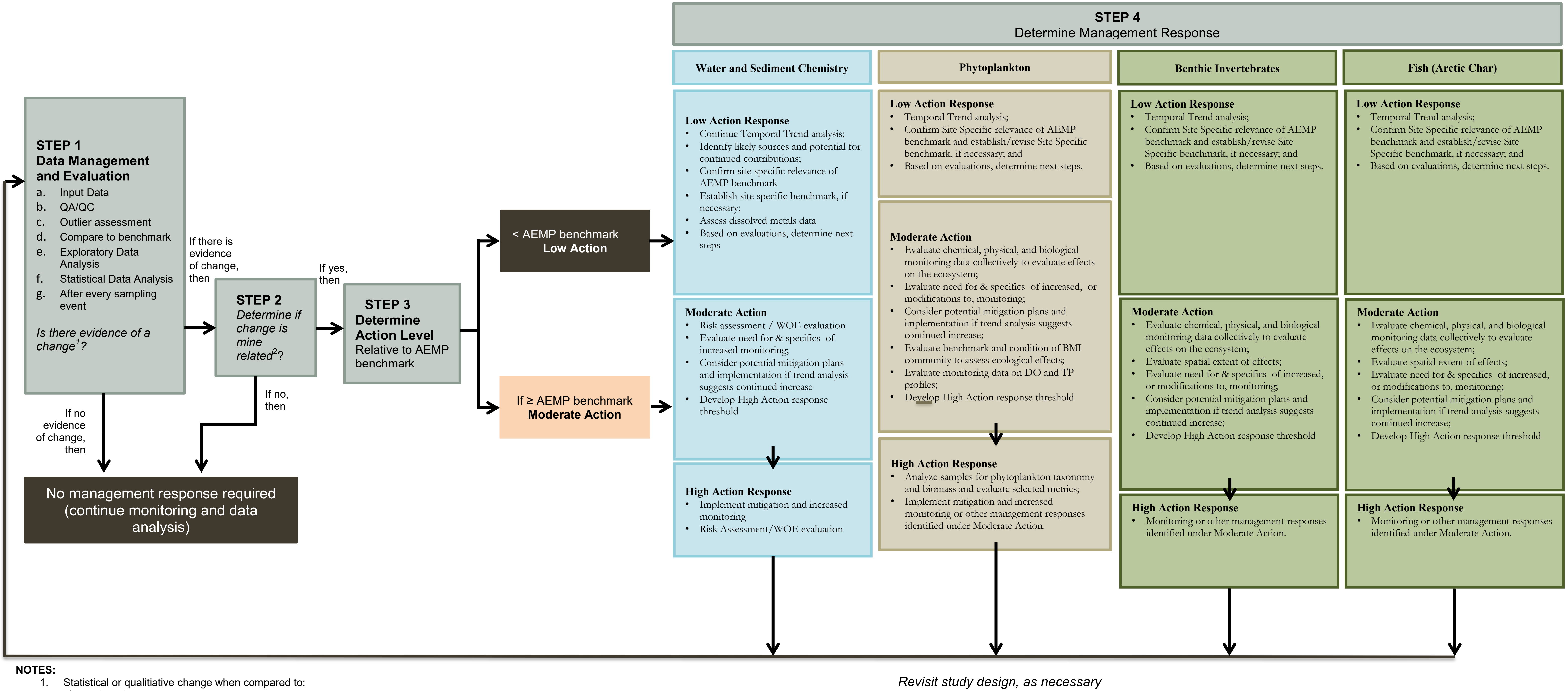
Table 4-2 MMER EEM Critical Effects Sizes (CES) for Fish Populations Using Non-Lethal Sampling.

Effect Indicators	Fish Effect Endpoint	CES[1]
Growth	Length and weight of YOY (age 0) and age 1+ at end of growth period	± 25%
Reproduction	Relative abundance of YOY (% composition of YOY) OR relative age-class strength	± 25%
Condition	Condition Factor	± 10%
Survival	Length or age frequency distribution	± 25%

[1] CESs are expressed as a percentage of the reference means.

Figure 2-1 Recommended CREMP Water Quality and Phytoplankton Monitoring Stations following the 2015 Program





NOTES:

1. Statistical or qualitative change when compared to:
   a) benchmark,
   b) baseline values,
   c) temporal or spatial trends

2. Mine related changes are a result of the mine and associated facilities including but not limited to effects from effluent discharges and dust deposition that are distinguished from natural causes or variation

Figure 2-2. Assessment approach and response framework.

Figure 3-1 Recommended CREMP Sediment and BMI Monitoring Stations following the 2015 Program

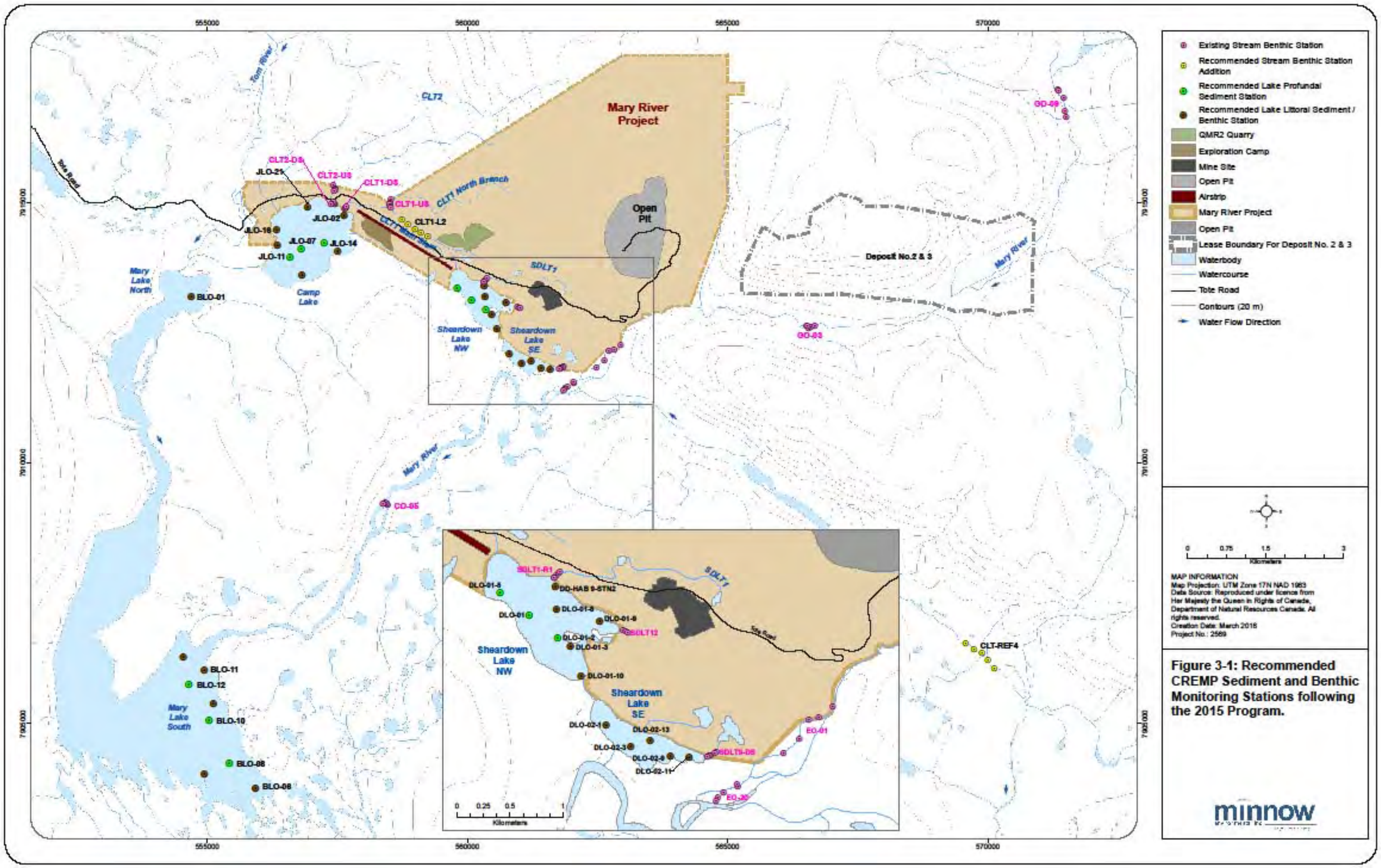
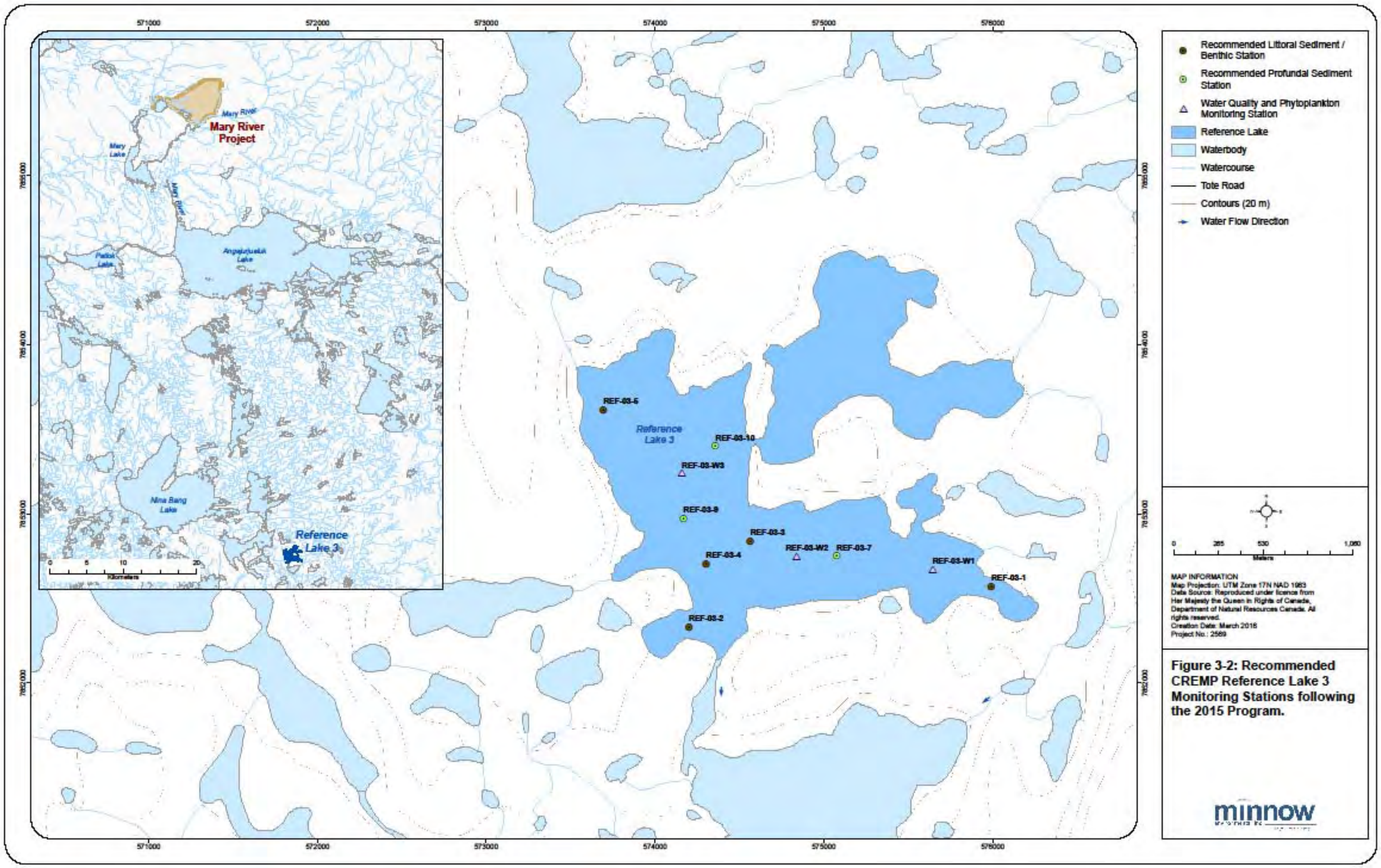


Figure 3-2 Recommended CREMP Reference Lake 3 Monitoring Stations following the 2015 Program



APPENDIX 1. REVIEW OF BASELINE DATA FOR FRESHWATER BIOTA: MARY RIVER MINE SITE.

Mary River Project

June 2014

Review of Baseline Data for Freshwater Biota:

Mary River Mine Site

North/South Consultants Inc.
Aquatic Environment Specialists

Review of Baseline Data for Freshwater Biota: Mary River Mine Site

June, 2014

Prepared by

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For

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LIST OF ABBREVIATIONS

AEMP	Aquatic Effects Monitoring Program
ANOVA	Analysis of variance
ANCOVA	Analysis of covariance
ANFO	Ammonium nitrate fuel oils
BIM	Baffinland Iron Mines Corporation
BMI	Benthic macroinvertebrate(s)
CES	Critical effect size
COV	Coefficient of variation
CPUE	Catch-per-unit-effort
CREMP	Core Receiving Environment Monitoring Program
DELTs	Deformities, erosion, lesions, and tumours
EC	Environment Canada
EEM	Environmental Effects Monitoring
EF	Electrofishing
ERP	Early Revenue Phase
FEIS	Final Environmental Impact Statements
GPS	Global positioning system
INAC	Indian and Northern Affairs Canada
MMER	Metal Mining Effluent Regulations
NSC	North/South Consultants Inc.
OECD	Organization for Economic Cooperation and Development
QA/QC	Quality assurance/quality control
SD	Standard deviation
SE	Standard error of the mean
TP	Total phosphorus
TN	Total nitrogen
TSS	Total suspended solids
UTM	Universal Transverse Mercator

YOY	Young-of-the-year
ZEAS	Zaranko Environmental Assessment Services

1.0 INTRODUCTION

A desktop technical review of freshwater biota baseline data was conducted in 2013 to provide a preliminary review of the adequacy of existing baseline data for the Core Receiving Environment Monitoring Program (CREMP) component of the overall Aquatic Effects Monitoring Program (AEMP) for the Mary River Project at the mine site (North/South Consultants Inc. [NSC] 2013). This initial report was based on available baseline data for the period of 2006 through 2012 and identified data gaps and recommendations for additional baseline sampling for the 2013 field season.

This report represents an updated version of the initial baseline data review and includes results of additional data analyses undertaken during the development of the CREMP. Overviews of the field programs completed in 2013 are also provided to document additional data collected since the initial baseline review.

Biotic components reviewed included phytoplankton, benthic macroinvertebrates (BMI), and fish. The main tasks completed included:

- An inventory of sampling methods and baseline data;
- A summary of key pathways of potential effects (i.e., linkages) and development of key questions to advise on study design for the CREMP;
- A review existing baseline data, including variability of the datasets and sampling design (i.e., sampling sites, frequency, and methods):
- Identification of key metrics for consideration under the CREMP and for exploratory statistical analysis;
- Exploratory power analyses of baseline data for key areas and key metrics to assist with:
    - Evaluation of the power of the existing data for post-Project comparisons;
    - Identification of sample sizes for the CREMP;
    - Identification of the most sensitive metrics for the CREMP; and
    - Development and evaluation of critical effects sizes (CESs) or “benchmarks” for the CREMP.

- Identification of issues that could affect use of data for post-Project monitoring; and
- A review of sampling design and methods.

Sampling methods and baseline data inventories were prepared for Mine Area lakes and streams based on all sampling completed through 2013. However, the detailed review of baseline data (i.e., statistical analyses) focused primarily upon the period of 2007-2012; most results of sampling conducted in 2013 were not available for analysis at the time of preparation of this report. Data collected in 2013 included in this review are restricted to results for chlorophyll *a* sampling conducted in Mine Area lakes and streams.

2.0 PHYTOPLANKTON

The following sections provide an inventory of available baseline phytoplankton data, a description of key pathways of effect and key questions respecting the Project, a detailed examination of baseline phytoplankton data, a review of sampling sites, methods, and frequency, and a summary of sampling completed in 2013.

2.1 INVENTORY OF FRESHWATER BASELINE DATA

The following sections provide an inventory of existing baseline data for phytoplankton in the Mine Area to assist with evaluating the existing dataset and advising on future sampling and monitoring. Specifically, the following provides:

- an overview of the sampling methods employed for collection and analysis of phytoplankton in the Mine Area waterbodies; and
- an inventory of existing baseline phytoplankton data for Mine Area waterbodies.

2.1.1 Sampling Methods

Chlorophyll *a* samples were collected using the same methods as applied for water quality sampling. Specifically, in lakes, chlorophyll *a* samples were collected approximately 1 m below the water surface ("near-surface samples") and from approximately 1 m above the sediments ("bottom samples") using a Kemmerer water sampler. Sample bottles provided by the analytical laboratory were then filled and the samples were submitted to EXOVA Laboratories for analysis. Replicate samples and field blanks were incorporated into the sampling program in 2007, 2008, and 2013 as a component of the Quality Assurance/Quality Control (QA/QC) program.

Samples for taxonomic identification and enumeration were collected in the 2007, 2008, and 2013 open-water seasons as depth-integrated samples of surface water collected across the euphotic zone (estimated as three times the Secchi Disk depth measured at the time of sampling, Cole 1983). A depth-integrated sample of water was collected from across the euphotic zone using a 10-m long tube sampler (up to a maximum depth of 10 m). Where the euphotic zone was calculated to exceed depth at a site, samples were collected by lowering the tube sampler to a depth 1 m from the bottom of the lake (to a maximum of 10 m).

Sample bottles provided by the analytical laboratory were then filled and a sufficient quantity of Lugol's solution was added to render the sample "tea coloured". The sample was then mixed and additional Lugol's was added on site or at the end of the day as required. Samples were submitted to ALS Laboratories, Winnipeg, MB for taxonomic identification and enumeration. Only samples collected in 2007 and 2008 have been analysed; 2013 samples have been archived.

2.1.2 Baseline Data Inventory

Baseline field studies included collection and analysis of surface water samples for characterization of phytoplankton in Mine Area lakes and streams. Specifically, chlorophyll *a* (sestonic) was measured at selected sites in lakes and streams and phytoplankton biomass and community composition was measured in Mine Area lakes. The following provides an inventory of baseline phytoplankton data for lakes and streams separately.

2.1.2.1 Lakes

Samples were collected for analysis of phytoplankton community composition and biomass and chlorophyll *a* from Mine Area lakes in the open-water seasons of 2007, 2008, and 2013. The sampling program was conducted in conjunction with and, therefore, at the same locations and times, as the water quality sampling program (Figure 2-1). These locations included:

- Mary Lake;
- Sheardown Lake Northwest;
- Sheardown Lake Southeast; and
- Camp Lake.

Sampling for phytoplankton was conducted twice each year (2007, 2008, and 2013), though not all sites were sampled in fall 2008 or 2013, as follows:

- August 7-14, 2007, July 29-August 6, 2008, and July 25-28, 2013 (summer sampling); and
- September 13-20, 2007, September 2, 2008 (fall sampling – Sheardown Lake only), and August 24-29, 2013.

Nearshore sampling for analysis of chlorophyll *a* was also conducted at six sites in Sheardown Lake NW in 2008 in spring (June 25, 2008), summer (July 31 and August 7, 2008), and fall (September 14, 2008). In addition, chlorophyll *a* was measured at four sites in Sheardown Lake NW and one site in Sheardown Lake SE following discharge of treated sewage effluent in August 2009.

Water sampling locations where chlorophyll *a* and phytoplankton samples were collected and periods sampled for the Mine Area are presented in Tables 2-1 and 2-2, respectively. As described in Section 2.1.1, during most sampling events, chlorophyll *a* was measured in near surface (1 m below water surface) and bottom (1 m above the sediments) samples. Table 2-1 presents the total number of near-surface samples collected from lakes.

2.1.2.2 Streams

A number of streams, including the Mary and Tom rivers and tributaries to Sheardown Lake, Camp Lake and Mary Lake, were sampled for analysis of chlorophyll *a* during the conduct of the water quality sampling program in 2007, 2008, and 2013 (Table 2-3, Figure 2-1). A total of 138 samples were collected over this period, with approximately half of them collected from the Mary River.

2.2 PATHWAYS OF EFFECT AND KEY QUESTIONS

Key questions were developed to guide the review of baseline data adequacy and, ultimately, design of the monitoring program. The adequacy of baseline data to address these key questions is addressed in Section 2.3. These questions focus upon key potential residual effects identified in the Final Environmental Impact Statement (FEIS; Baffinland Iron Mines Corporation [BIM] 2012) and the Addendum to the FEIS for the Early Revenue Phase (ERP; BIM 2013).

The key pathways of potential residual effects of the Project on phytoplankton communities include:

- Water quality changes related to discharge of ore or stockpile runoff to freshwater systems (immediate receiving environments: Mary River and Camp Lake Tributary 1);
- Water quality changes (primarily nutrients and total suspended solids [TSS]) related to discharge of treated sewage effluent (immediate receiving environments: Mary River and Sheardown Lake NW);
- Water quality changes due to deposition of dust in lakes and streams (Mine Area in zone of dust deposition); and
- Water quality changes due to non-point sources, such as site runoff and use of Ammonium nitrate fuel oil (ANFO) explosives (Mine Area).

The key question related to the pathways of effect is:

- What are the combined effects of point and non-point sources on phytoplankton abundance in Mine Area lakes?

The primary issue of concern with respect to the phytoplankton community is related to nutrient enrichment and eutrophication, though effects on water clarity (e.g., changes in TSS) could also affect primary productivity. As such, the CREMP and the baseline data review focused upon waterbodies most at risk to eutrophication; in general, lakes (rather than streams) are most vulnerable to eutrophication in the Mine Area. Sheardown Lake NW has received treated sewage effluent discharge during the construction phase and may also be affected by dust deposition, stream diversions, and non-point sources during the operation period. Although treated sewage effluent will be discharged to the Mary River during the operation phase, Mary Lake is the ultimate receiving environment for all point sources in the Mine Area, including discharge of treated sewage effluent, and is more vulnerable to effects of nutrient enrichment due to its lacustrine nature.

2.3 EVALUATION OF DATA FOR POST-PROJECT MONITORING

2.3.1 Description of Existing Data

2.3.1.1 Data Analysis

To explore the robustness of various potential metrics for phytoplankton for the CREMP, several metrics were derived as indicated in Table 2-4. A number of community metrics were calculated to describe the richness and diversity of the communities sampled. Calculations followed those in Hill (1973), Magurran (1988), and Begon et al. (1996), and included:

- Species richness (S);
- Simpson's diversity index (D = 1-G);
- Simpson's evenness (E_D = 1/G x 1/S);
- Shannon's heterogeneity (H = -$\sum P_i$ x [$\ln P_i$]);
- Shannon's evenness (E_H = H/ln[S]);
- Hill's effective richness (e^H); and
- Hill's evenness (e^H/S).

Where G is Simpson's diversity for sampling with no replacement ($[\sum n_i(n_i-1)]/[N(N-1)]$), P_i is the proportional contribution of species i to the total biomass, n_i is the number of individuals of the i^{th} species, and N is the total number of individuals. Diversity and evenness metrics range for 0 to 1, with values close to 0 having low diversity/evenness and values close to 1 having high diversity/evenness.

Metrics were plotted as box plots to visually assess the occurrence of extreme outliers and to provide a preliminary visual assessment of potential spatial and/or seasonal differences. However, owing to the inherently high variability of the phytoplankton dataset, no data points were removed from the analysis as outlier identification is complicated by the high natural variability.

Summary statistics (mean, median, standard error [SE], standard deviation [SD], minimum, maximum, n, coefficient of variation [COV], and 95th percentile) were derived for each lake using data from all sites sampled in that waterbody (i.e. sites pooled). Summary statistics were also derived for Sheardown Lake NW by sampling period and by year to examine seasonal and interannual differences. Chlorophyll *a* values reported as below the measurement detection limit (0.2 µg/L; i.e., 'censured values') were assigned a value equal to the detection limit. Duplicate samples were averaged and the mean was used for all data analyses.

COV was calculated as SD/mean x 100; COV facilitated comparisons of the variability of various datasets to assist with identifying the most robust metrics as well as to assist with advising on sampling design. The variability of the metrics examined was then described to facilitate identification of those metrics with the lowest natural variation for further consideration and statistical analysis.

Correlation analyses were conducted for phytoplankton metrics, including chlorophyll *a*, biomass, and evenness and richness indices to assist with identifying the most suitable metrics for monitoring. Spearman rank correlations ($\alpha = 0.05$) were conducted for all phytoplankton data collected in all Mine Area lakes in summer and late/summer fall for the years 2007, 2008, and 2013 collectively. The broader dataset was used for this analysis to augment the number of data points. Note that the only additional data available from 2013 for this analysis were chlorophyll *a*, total nitrogen (TN), and total phosphorus (TP).

Statistical comparisons between lakes and between seasons and years for Sheardown Lake NW were undertaken to advise on spatial and temporal variability in the environment. For parameters exhibiting a normal distribution, analyses were conducted using an analysis of variance (ANOVA) and a Tukey's test ($\alpha = 0.05$). For parameters not meeting the assumptions of a normal distribution (normality was tested on raw, untransformed data and log-transformed data), analyses were performed using the non-parametric Kruskal-Wallis test followed by the Dunn's multiple pairwise comparisons procedure (two-tailed; $\alpha = 0.05$).

In addition, although this report focused upon review of biological metrics, correlation and linear regression analyses were also conducted between phytoplankton metrics and TP as the primary pathway of potential effects relates to nutrient enrichment, and nutrient ratios indicate that phosphorus is the limiting nutrient.

2.3.1.2 Results

Chlorophyll a

Chlorophyll *a* concentrations are relatively low in Mine Area lakes (Mean of 0.66 µg/L and range of <0.2 – 3.5 µg/L) and a relatively high proportion of measurements were below the analytical detection limit of 0.2 µg/L in 2007, 2008, and 2013 (Table 2-5). As a result, the data exhibited high variability and were not normally distributed. Based on a commonly applied trophic categorization scheme for lakes (Organization for Economic Cooperation and Development [OECD] 1982), chlorophyll *a* concentrations indicate oligotrophic conditions (i.e., chlorophyll *a* < 2.5 µg/L) based on mean or maximum chlorophyll *a* concentrations measured across the lakes.

Data collected from Sheardown Lake NW were examined in greater detail as a representative waterbody for the Mine Area. Considering only offshore sites, there was no seasonal (i.e., comparisons to summer and late/summer fall periods) or interannual patterns observed for this lake (Figure 2-2; Table 2-6). The COVs were similarly high when derived by sampling season or for the whole year combined, though the lowest variability was observed for the 2013 dataset.

Concentrations of chlorophyll *a* measured in nearshore areas in 2008 (water depths of 1.2 m) were generally higher than offshore sites and inclusion of these data increased the overall means and maximums for the lake as a whole (Figure 2-3). In particular, higher concentrations of chlorophyll *a* were measured in nearshore areas in late summer/fall of 2008. Sampling in nearshore areas was undertaken as a component of a study examining potential effects of localized dust deposition and may not be representative of the lake as a whole. Therefore, data collected from the nearshore areas were excluded from power analyses described in Section 2.3.2.

Considering all Mine Area lakes collectively, there did not appear to be a consistent seasonal or annual pattern in chlorophyll *a* concentrations across all of the lakes (Figure 2-4). Conversely, chlorophyll *a* was statistically lower in Sheardown Lake NW than Mary Lake over the baseline sampling period (Figure 2-5). Due to this observed difference, exploratory power analyses for chlorophyll *a* were conducted for both Sheardown Lake NW and Mary Lake (see Section 2.3.2).

Phytoplankton Biomass

Phytoplankton biomass varied across sampling periods and years in Mine Area lakes and was highest in fall 2008 in lakes where sampling occurred (Figure 2-6). Open-water season means for the 2007-2008 period were highest in Sheardown Lake NW, however, Camp and Mary lakes were not sampled in fall 2008, when the biomass was highest in Sheardown Lake NW (Table 2-7, Figure 2-6). COVs for total biomass, which ranged from 60 to 89% across the Mine Area lakes, were lower than COVs observed for chlorophyll *a* (Table 2-7). This likely reflects the relatively high frequency of measurements of chlorophyll *a* below the analytical detection limit.

Within Sheardown Lake NW, biomass was significantly higher in 2008 than 2007 but no significant differences were observed between the summer and late summer/fall sampling periods (Table 2-8). COVs were greater between sampling periods than between years (Table 2-8).

Phytoplankton Taxonomic Metrics

Metrics of phytoplankton diversity and evenness were relatively similar between Camp Lake, Sheardown Lake NW, and Sheardown Lake SE (Table 2-9). These metrics were lower in Mary Lake. Species richness, Simpson's diversity indices, and Shannon's evenness indices yielded the lowest COVs for Sheardown Lake NW and for all lakes combined, all of which were less than 40%. Seasonal and interannual differences were evident for some lakes and periods (Figures 2-7 to 2-12).

Within Sheardown Lake NW, all taxonomic metrics yielded a COV of less than 40% when both years of baseline data were considered collectively (Table 2-10). The least variable metrics were species richness, Simpson's diversity index, and Shannon's evenness. All phytoplankton taxonomic metrics had lower variability (expressed as COVs) than either chlorophyll *a* or phytoplankton biomass.

All taxonomic metrics were significantly higher in 2007 than 2008 in Sheardown Lake NW. Conversely, of the phytoplankton taxonomic metrics examined, only Simpson's Evenness was significantly higher in summer relative to the fall period (Table 2-10).

Correlations and Regressions

Correlations between phytoplankton metrics were explored to assist with identifying metrics most suitable for monitoring effects of nutrient enrichment. Additionally, as noted in Section 2.3.1.1, relationships between phytoplankton metrics and TP were also explored to assist with identification of the most suitable metrics for monitoring effects of nutrient enrichment (i.e., phosphorus enrichment).

Spearman rank correlations indicated significant correlations between total biomass and a number of taxonomic parameters (Table 2-11); biomass of diatoms (r = 0.96), green algae (r = 0.46), chrysophytes (r = 0.53), cryptophytes (r = 0.32), and dinoflagellates (r = 0.30) were positively correlated to total biomass while several metrics of evenness and diversity were negatively correlated to total biomass including Simpson's diversity index (r = -0.60), Simpson's evenness (r = -0.71), Shannon's evenness (r = -0.65), Hill's effective richness (r = -0.55), and Hill's evenness (r = -0.71). Biomass was not significantly correlated to either species richness or chlorophyll *a*.

The conventional paradigm for lakes is a positive relationship between TP and chlorophyll *a* – though the relationship is not necessarily linear – and typically, phosphorus is the limiting nutrient in freshwater ecosystems. TN:TP molar ratios for Mine Area lakes indicate strong phosphorus limitation.

As introduction of phosphorus from discharge of treated sewage effluent and subsequent eutrophication is a potential concern in the Mine Area, regression analyses were conducted between chlorophyll *a* and TP measured in Mine Area lakes. Spearman correlations indicated no significant relationship between TP and total biomass but did indicate a weak but significant relationship with chlorophyll *a* (r = 0.29).

Due to the relatively low frequency of detection, chlorophyll *a* was only weakly significantly correlated with TP for all lakes combined or within Sheardown Lake NW only (Figure 2-13). However, regressions were stronger when only chlorophyll *a* measurements that exceeded the analytical detection limit in Sheardown Lake NW were included in the analysis (Figure 2-13).

2.3.1.3 Chlorophyll a in Streams

Though this review and the phytoplankton component of the CREMP focuses on Mine Area lakes, some exploratory analyses of baseline chlorophyll *a* data for streams was undertaken to inform selection of stream monitoring sites and sampling periods for the CREMP. Specifically, data collected from the Mary River were examined visually with boxplots for spatial and seasonal differences. Available data suggest chlorophyll *a* is somewhat higher at downstream sites relative to the headwaters of the Mary River (Figure 2-14). There is also some indication of seasonal differences, though the differences do not appear to be consistent between all sites (Figure 2-15).

2.3.2 Power Analysis

2.3.2.1 Methods

Power analysis was conducted following general guidance provided in the Environment Canada (EC) Metal Mining Environmental Effects Monitoring (EEM) Guidance Document (EC 2012), though it is noted that the EEM program does not discuss monitoring of phytoplankton. Specifically, values for α (Type I error) and β (Type II error) were set at 0.1 as advised in EC (2012). Datasets were tested for normality for all phytoplankton metrics prior to the conduct of the power analyses. All metrics were normally distributed excepting chlorophyll *a*.

Power analysis by simulation was implemented using PopTools (Hood 2010).Two types of power analyses were used one based on a t-test (parametric) and one based on the Mann-Whitney (nonparametric) U-test.

The power of existing baseline data to be used for demonstrating changes in the various metrics was explored for a range of effects sizes. Using the dNormalDev(mean, SD) function, random data were generated for the observed baseline and hypothetical monitoring scenarios. The Excel formula for a t-test was used keeping the first row fixed. This process was iterated 1000 times by Monte Carlo simulation to determine the frequency of a realised t-probability greater than α (Type I error). This provided an estimate of β (Type II error) with the power of the test being 1-β. Both α and β were set at 0.10 for a power of 90% following the EEM Guidelines (EC 2012).

For nonparametric tests, the same process was used, but baseline data were first fit to a distribution and then, using the appropriate functions (e.g., dLogNormalDev(Mean, SD)), random deviates were generated. The test was iterated 1000 times to estimate β Type II error. As in the parametric tests, the theoretical shifts were assessed as percent changes from baseline.

Phytoplankton Taxonomy and Biomass

The most robust taxonomic/biomass metrics identified through review of the baseline data for further statistical exploration and consideration under the CREMP were subject to a power analysis to:

- Provide a preliminary analysis of the power of the existing dataset to be used as the foundation for detecting post-Project change (i.e., Before-After comparisons);
- Explore samples sizes (i.e., number of sites within a waterbody or area of a waterbody) required for detecting pre-defined levels of change;
- Advise on key metrics for consideration under the CREMP; and
- Advise on the need for collection of additional baseline data and/or modifications to future sampling programs (i.e., number of sites for the CREMP).

Evaluation of power of the existing baseline data was conducted using data collected from Sheardown Lake NW as a representative data set.

The variability of numerous phytoplankton metrics measured during the baseline studies program was evaluated and described in Section 2.3.1 to assist with identifying the most robust metrics for further statistical exploration and consideration under the CREMP. Metrics that were subject to a power analysis included:

- Total biomass;
- Species Richness;
- Simpson’s diversity index; and
- Shannon’s evenness.

COVs for the taxonomic metrics were less than 20% for the whole baseline dataset (2007 and 2008 combined) in Sheardown Lake NW and were therefore identified for further analysis. COVs for total biomass were high but this metric was retained as it is one of two metrics used to describe phytoplankton abundance.

CESs utilized for power analysis were selected based on the Metal Mining EEM Guidance document (EC 2012), scientific literature, and other recent/current AEMPs and/or guidance documents (Azimuth 2012, Indian and Northern Affairs Canada [INAC] 2009, Munkittrick et al. 2009). Where initial power analyses indicated low power associated with the CESs identified *a priori*, larger CESs were explored.

Power analyses were conducted using all data collected in the open-water seasons of 2007 and 2008 (i.e., summer and late summer/fall sampling) in Sheardown Lake NW, as well as for the fall datasets alone. The latter was conducted to explore the additional power achieved with two sampling periods as opposed to sampling only in the fall.

Chlorophyll a

Power analyses for the key metric for phytoplankton (i.e., chlorophyll *a*) were conducted to determine if the power of the baseline data is sufficient to detect a change relative to the benchmark identified for the CREMP and to advise on sample sizes for the CREMP (see Section 2.3 of the main body of the CREMP for details). Power analyses for this parameter were conducted for both Sheardown Lake NW and Mary Lake since, as noted in Section 2.3.1, chlorophyll *a* was statistically significantly different between these lakes.

Power analyses were conducted using all data collected in the open-water seasons of 2007, 2008, and 2013 (i.e., summer and late summer/fall sampling) in Sheardown Lake NW and Mary Lake. Power analyses were based on one-tailed Mann-Whitney U-test conducted for each season and lake using the benchmark (3.7 µg/L) and a lower CES equal to two times the mean. For datasets with a high frequency of values below the analytical detection limit (i.e., censured values), data were assumed to follow a true distribution below detection limit. There were two assumptions associated with this method for censured values: (1) the data between zero and the analytical detection limit were part of a 'real' distribution; and (2) that the effect sizes tested were shifting from the fitted baseline to one more representative of what would be expected with a 'real' trophic shift.

2.3.2.2 Results

Phytoplankton Taxonomy and Biomass

Minimum sample sizes identified through the exploratory power analyses are presented in Table 2-12. As expected, power is greatest for the phytoplankton community metrics, owing to the relatively low COVs for these parameters. Power analysis indicated that a reasonably small sample size (i.e., n = 3) would be required to detect changes in phytoplankton community metrics on the order of 20-50% relative to baseline conditions, if sampling consisted of two sampling periods. A similar level of effort (i.e., n = 3-4) would be required for detecting these levels of change with sampling the fall period only.

The power associated with the total biomass dataset is lower than for the community metrics (Table 2-12). The existing baseline dataset would be sufficient to detect change on the order of 100% with a relatively small number of samples (8 samples for the entire dataset and 6 samples for the fall dataset). Smaller levels of change would require a prohibitively high number of samples to be detected. Because the fall dataset is slightly less variable than the entire dataset, there is greater power associated with the former and a slightly smaller number of samples would be required to demonstrate changes from baseline conditions.

Chlorophyll a

Power analyses indicate relatively high power to detect a change of the magnitude of the benchmark for each sampling season in each lake (Figure 2-16). Power is greater for Sheardown Lake NW owing to the lower baseline concentrations of chlorophyll *a* than Mary Lake. A sample size of five for Sheardown Lake NW and a sample size of six for Mary Lake are associated with high power in relation to the benchmark. Power was also evaluated for an effects size of 2 x the mean; relatively high power (0.7 for Mary Lake and 0.8 for Sheardown Lake NW) is also associated with this level of change.

2.3.3 Sampling Sites and Areas

The Project will result in introduction of nutrients to Mine Area waterbodies which may stimulate primary productivity, but may also adversely affect primary productivity through changes in water clarity and water chemistry. A sample size of 5 for Sheardown Lake NW and SE and Camp Lake and a sample size of 6 for Mary Lake has been identified for the CREMP.

2.3.4 Sampling Methods

Chlorophyll *a* samples have been collected from Mine Area lakes using the same methods as the water quality sampling program (i.e., samples collected with a water sampler at 1 m below the water surface and 1 m above the sediments). While this methodology ensures consistency with supporting water quality variables, notably nutrients such as TP, it may under or over represent phytoplankton density across the water column. Chlorophyll *a* should continue to be analysed in grab samples (near surface samples) in the future to maintain continuity with the methods used for the existing datasets.

Conversely, samples for measurement of phytoplankton taxonomy and biomass have been collected from across the euphotic zone of lakes which generally provides a more accurate representation of phytoplankton in lacustrine environments. The depth of lake euphotic zones was estimated as 3 x the average Secchi disk depth, to a maximum of 10 m. Due to the high water clarity of Mine Area lakes, euphotic zone depths were calculated to exceed 10 m (the length of the sampling tube) in some sampling periods at some sites.

2.3.5 Sampling Frequency

The results of the power analyses on Sheardown Lake NW phytoplankton data indicate similar levels of power for detecting changes associated with sampling during two periods as sampling only in the fall period. This suggests that one sampling period may be adequate for monitoring purposes. However, it is recommended to retain two rounds of sampling in Mine Area lakes for the initial years of monitoring. The results of the CREMP should be reviewed regularly to determine the need for two sampling periods.

2.4 OVERVIEW OF 2013 SAMPLING

Sampling for analysis of chlorophyll *a* and phytoplankton taxonomy and biomass was undertaken in Mine Area lakes in the open-water season of 2013. In addition, chlorophyll *a* was measured at selected stream sampling sites. Sampling sites are presented in Figure 2-17 and summaries of sampling completed in lakes and streams in 2013 is provided in Tables 2-13 and 2-14, respectively. Due to inclement weather, not all sites were resampled during each sampling period. As previously noted, samples were analysed for chlorophyll *a* and the results were incorporated into this review. Samples for phytoplankton taxonomy and biomass have been archived.

3.0 BENTHIC MACROINVERTEBRATES

The following sections provide an inventory of available baseline benthic macroinvertebrate data, a description of key pathways of effect and key questions respecting the Project, a detailed examination of baseline BMI data, a review of sample size, sampling sites, methods, and timing, and taxonomic analyses, and an overview of sampling completed in 2013.

As the results from the 2013 sampling were not available at the time of completion of this review, the review of baseline benthic macroinvertebrate data provided in Section 3.3 is restricted to data collected over the period of 2006 through 2011. Section 3.1 (inventory of freshwater baseline data) refers to all sampling completed through 2013.

3.1 INVENTORY OF FRESHWATER BASELINE DATA

The following sections provide an inventory of existing baseline data (through 2013) for BMI in the Mine Area to assist with evaluating the existing dataset and advising on future sampling and monitoring. Specifically, the following provides:

- An overview of the sampling methods employed for collection and analysis of benthic macroinvertebrates (i.e., benthos) in the Mine Area waterbodies; and
- An inventory of existing baseline BMI sampling completed for Mine Area lakes and streams.

3.1.1 Sampling Methods

3.1.1.1 Lakes

Lake BMI samples were collected using either an Ekman dredge (2006) or a petit Ponar dredge (2007, 2008, 2011, 2013) sampling device (each with a sampling area of 0.023 m^2; Table 3-1). Sample characteristics, which included substratum composition, colour, odour, sample depth, and Universal Transverse Mercator (UTM) coordinates for each replicate site, were documented.

In 2006, 2007, and 2011, three replicate samples were collected at each sampling site while in 2008 three to seven replicate stations were sampled for each habitat type investigated in Sheardown Lake NW. In 2013, five replicate stations were sampled in each of two habitat types in the Mine Area lakes; an additional replicate station was collected in a third habitat type in Camp Lake.

At most sites and times, each replicate sample was a composite of five grabs (i.e., five sub-samples were combined per replicate site); sub-samples were preserved separately in 2013. However, each replicate sample was composed of only a single grab due to equipment malfunction in Mary Lake in 2007 and at Sheardown Lake in 2011 the three replicates were composed of one, three, and one grabs, respectively, due to poor weather conditions and time restrictions during the field program.

At each sampling location, the dredge was slowly lowered until it rested on the bottom to prevent shock waves that could physically move or disturb organisms and sediment from beneath the sampler. Following completion of a grab, the dredge was slowly raised, to minimize turbulence, and the sample was immediately placed into a pail. An acceptable sample required that the jaws be completely closed upon retrieval. If the jaws were not completely closed the sample was discarded into a bucket (and disposed of once sampling was completed) and the procedure was repeated.

For each replicate collected in 2006 and 2007, five sub-samples approximately 1 m apart were collected from the same side of the boat. The three replicate samples were separated by approximately 10 m. For each habitat type sampled in 2008, 2011, and 2013 three to seven replicate stations were sampled, each resulting in a single composite sample consisting of one to five benthic macroinvertebrate field sub-samples/grabs; sub-samples were preserved separately in 2013. The geographic extent of each replicate station was at least 10m x 10m and replicate stations were separated by at least 20 m.

Samples were taken to shore and sieved through a 500 µm sieve bucket. A weed sprayer was sometimes used on a gentle setting to help break down clay. Samples were then rinsed into labelled sampling jars and fixed in 10% formalin. Sodium bicarbonate (’baking soda’) was used to buffer samples where molluscs/shells were present. Sampling equipment was rinsed on shore before the next site was sampled.

Benthic macroinvertebrate samples were submitted to Zaranko Environmental Assessment Services (ZEAS) Inc. (Nobleton, ON) for processing and identification; laboratory methods were consistent over the study period.

3.1.1.2 Streams

As benthic samples were collected at or near habitat assessment sites in the Mine Area streams, site characteristics were noted extensively. Three replicate samples separated by approximately three wetted stream widths were collected at each sampling site in 2006 through 2008, and 2011; only one replicate sample was collected at each sampling site in

2005 (Table 3-2). In 2013, two to three replicate stations were collected at each sampling site (Table 3-2). Within each replicate site, five sub-samples were combined into one large sample in all years excepting 2013. In 2013, two to five sub-samples were collected and preserved separately, with the exception of Sheardown Lake, Tributary 1 Replicate Stations B1, B2, and B3 where sub-samples were composited. Sub-samples were collected moving in an upstream direction and, whenever possible, they were collected from representative microhabitats across the stream.

Each sub-sample was collected by placing a Surber sampler on a flat area of the streambed, facing upstream. The surface area sampled by the Surber sampler was equivalent to 0.097 m^2. Macroinvertebrates were collected over a two minute time period by rubbing the rocks and disturbing the sediment in the substrate area framed by the Surber net. With the exception of 2005 when a 250 µm mesh size was used, all sub-samples were rinsed from the netting into a 500 µm sieve. Forceps were used to collect any macroinvertebrates remaining on the netting after rinsing. The sample was washed, transferred into a sample jar, and fixed as soon as possible in 10% formalin.

Benthic macroinvertebrate samples were submitted to ZEAS Inc. for processing and identification; laboratory methods were consistent over the four years of investigation.

3.1.2 Baseline Data Inventory

Benthic macroinvertebrate community sampling was initiated in 2005 in the Mine Area, and initially included sampling of streams only. The program was expanded in 2006 to include lakes and additional stream sampling sites. The following sub-sections provide an inventory of baseline BMI samples collected from lakes and streams.

3.1.2.1 Lakes

Benthic macroinvertebrate sampling in lakes was conducted in fall (August 31 and September 5, 2006; August 31 to September 20, 2007; September 8-12, 2008; September 3, 2011; September 5-8, 2013) from Camp (2007, 2013), Sheardown NW (2007, 2008, 2011, and 2013), Sheardown SE (2007, 2013), and Mary (2006, 2007) lakes (Table 3-3). Inclement weather reduced the length of the fall sampling season in 2008, which prevented the completion of the full planned program for Sheardown Lake NW. Inclement weather also prevented sampling of Mary Lake in 2013. Sampling of BMIs in Sheardown NW in September, 2011 was limited to a single site. Locations of BMI sampling sites and sampling dates are presented in Table 3-4 and Figure 3-1.

3.1.2.2 Streams

BMI sampling in streams was conducted in summer 2005 (August 6-17, 2005) and fall 2006-2008, 2011, and 2013 (August 23 to September 1, 2006; August 31 to September 5, 2007; September 10-11, 2008; August 28 to September 4, 2011; August 29-31, 2013) from the Mary (2005, 2006, 2007, 2011) and Tom (2006, 2007) rivers, and Camp Lake (2005, 2007, 2011) and Sheardown Lake (2005, 2007, 2008, 2011, 2013) tributaries (Table 3-3). Locations of benthic macroinvertebrate sampling sites and sampling dates are presented in Table 3-5 and Figure 3-2.

3.2 PATHWAYS OF EFFECT AND KEY QUESTIONS

Key questions were developed to guide the review of baseline data adequacy and, ultimately, design of the monitoring program. The adequacy of baseline data to address these key questions is addressed in the Section 3.3. These questions and metrics focus upon key potential residual effects identified in the FEIS (BIM 2012) and the Addendum to the FEIS for the ERP (BIM 2013), as well as metrics commonly applied for characterizing the BMI community.

The key pathways of potential effects of the Project on BMIs include:

- Water quality changes related to discharge of ore or stockpile runoff to freshwater systems (immediate receiving environments: Mary River and Camp Lake Tributary 1);
- Water quality changes (primarily nutrients and TSS) related to discharge of treated sewage effluent (immediate receiving environments: Mary River and Sheardown Lake NW);
- Water quality changes due to deposition of dust in lakes and streams (Mine Area in zone of dust deposition);
- Water quality changes due to non-point sources, such as site runoff and use of ANFO explosives (Mine Area);
- Changes in water levels and/or flows due to water withdrawals, diversions, and effluent discharges (i.e., alteration or loss of aquatic habitat);
- Dust deposition in aquatic habitat (i.e., sedimentation); and
- Effects of the Project on primary producers.

The key question related to the pathways of effect is:

- What are the combined effects of point and non-point sources, aquatic habitat loss or alteration, sedimentation, and changes in primary producers on BMI abundance and community composition in Mine Area lakes and streams?

Overall, effects on lower trophic level biota are primarily related to the introduction of dust to surface waters, discharge of treated sewage effluent to Sheardown Lake NW and the Mary River, release of wasterock and ore stockpile runoff to surface waters (Camp Lake Tributary 1, Mary River), general non-point sources in the Mine Area, and release of pit water during the post-closure phase. The baseline data review focused upon waterbodies most at risk to sedimentation and eutrophication and that are not captured under the Metal Mining Effluent Regulation (MMER) EEM program as follows: Camp Lake; Sheardown Lake NW; Mary Lake; and tributaries to Sheardown Lake (specifically, Tributary 1). Dust is predicted to be deposited directly on surface waters in the Mine Area, including Sheardown and Camp lakes, portions of the Mary River, and numerous small tributaries to these waterbodies. Sheardown Lake NW has received treated sewage effluent discharge during the construction phase and may also be affected by dust deposition, stream diversions, and non-point sources during Project operation. Although treated sewage effluent will be discharged to the Mary River during the operation phase, Mary Lake is the ultimate receiving environment for all point sources in the Mine Area, including discharge of treated sewage effluent and is considered more vulnerable to effects of nutrient enrichment due to its lacustrine nature.

3.3 EVALUATION OF DATA FOR POST-PROJECT MONITORING

The following provides a description and critical review of baseline data for the period of 2005 through 2011.

3.3.1 Description of Existing Data

3.3.1.1 Data Analysis

To explore the ability of various BMI community metrics to detect change as part of the CREMP, several were derived as outlined in Table 3-6. Methods for the derivation of these calculated metrics are described below.

Locations in Mine Area lakes sampled for BMIs were classified according to aquatic habitat types based on water depth and light availability, substrata type, and the presence or absence of rooted aquatic vegetation (Table 3-7).

To prepare the data for analysis, the abundance of BMIs in each replicate was converted to density (number of macroinvertebrates per square meter [individuals/m^2]) by dividing the total number of macroinvertebrates per sample by the bottom area of the sampling device (0.023 m^2 for the Ekman and petit Ponar dredges; 0.97 m^2 for the Surber sampler). Benthic macroinvertebrate metrics were calculated for each replicate and included in statistical analyses to describe the community. Metrics included: abundance (total macroinvertebrate density [individuals/m^2±SE])); composition (Chironomidae proportion [% of total density], Shannon's Equitability [evenness], and the Simpson's Diversity Index); and richness metrics (total taxa and Hill's Effective richness, both at the genus level; Magurran 1988, 2004).

Evenness measures the similarity of population sizes of different species, with values closer to 1 indicating that macroinvertebrates of different species are more similar in abundance and values of 0 indicating that only one species is present. A diversity index provides an estimate of the probability that two individuals in a sample belong to the same species. The higher the index (0 to 1), the less likely it is that two individuals belong to the same species (i.e., likely the higher the diversity; Magurran 1988, 2004). However, it is important to consider that this index is not itself a true estimate of diversity and it is highly nonlinear. Diversity indices attempt to summarize the relative abundance of various taxa. An index may provide more succinct information about benthic macroinvertebrate communities than abundance or richness alone. Simpson's Diversity index de-emphasizes rare taxa, while highlighting common taxa and evenness among taxa (i.e., similarity of population sizes of different species; Mandaville 2002). Hill's Effective Richness provides an indication of the number of genera that contribute to the majority of the community represented in the sample collected. For example, if total richness = 28 and effective richness = 11, then of the 28 genera identified in the sample, 11 taxa are considered dominant.

Metrics were plotted as box plots to visually assess the occurrence of extreme outliers and to provide a preliminary visual assessment of potential spatial and/or yearly differences (for lakes only). However, owing to the inherently high variability of the benthic macroinvertebrate dataset, no data were removed from the analysis as outlier identification is complicated by the high natural variability of biotic data.

Metrics were calculated for each replicate sample and summary statistics (n, mean, median, SD, SE, minimum, maximum, COV, and 95th percentile) were derived for each lake by aquatic habitat type and each stream reach to examine spatial differences. Summary statistics were also derived for Sheardown Lake NW by aquatic habitat type and by year and Sheardown Lake NW Tributary 1 by reach and by year to examine inter-annual differences. Efforts were made to include as many taxa as possible in the analysis; however, Diptera, Chironomidae and Empididae pupae were excluded from metric calculations where genus level identification was used (e.g., evenness, Simpson's Diversity Index). Taxonomic richness (i.e., the number of taxa) was determined at the genus level. If a group was identified to a higher level (e.g., class or order), then it was assumed that only one genus was represented and this likely resulted in a conservative estimate of the number of taxa; pupae were not included in the determination of richness.

Additionally, the number of field sub-samples (i.e., grabs) per replicate station that would provide an estimate with 20% precision (i.e., an acceptable level of variance) for each metric was determined for Sheardown Lake NW by aquatic habitat type and year and Sheardown Lake NW Tributary 1 by reach and by year; these results are discussed in Section 3.3.4. The number of field sub-samples was calculated as follows:

$n = s^2 / D^2 * X^2$

where:

X = the sample mean

n = the number of field sub-samples

s = the sample variance

D = the index of precision (i.e., 0.20)

COV was calculated as SD/mean x 100; COV facilitated comparisons of the variability of various datasets to assist with identifying the most robust metrics as well as to assist with advising on sampling design. The variability of the metrics examined was then described to facilitate identification of those metrics with the lowest natural variation for further consideration and statistical analysis.

Detailed statistical analyses were conducted on the Sheardown Lake NW dataset as a representative lake dataset for the Mine Area. The baseline dataset is largest for this waterbody and would conceptually therefore provide the most robust pre-Project database for use in post-Project monitoring. Inter-annual differences in macroinvertebrate metrics were assessed statistically for each habitat type in Sheardown Lake NW (where multiple years of data were available). Similarly, Sheardown Lake NW Tributary 1 was explored in detail as the representative data set for Mine Area streams, as the baseline dataset is largest for this stream, particularly Reach 4.

All data were tested for normality prior to statistical analysis and data that were normally distributed were assessed using parametric statistics while non-normally distributed data were analysed using non-parametric tests. Differences between years were assessed using the t-test (parametric) or Mann-Whitney U-test (non-parametric) when two years of data were available; ANOVA with Bonferroni pairwise comparison (parametric) or Kruskal-Wallis test followed by multiple pairwise comparison (Dunn's procedure) (non-parametric) was used when three years of data are available. All tests were assessed with significance level of 0.05; analyses were performed using XLStat Version 2007.4.

3.3.1.2 Lake Results

Abundance

Total macroinvertebrate density was variable among Mine Area lakes and among habitat types sampled within waterbodies, ranging from a mean of 14 individuals/m^2 (Camp Lake, Habitat Type 4) to 18,562 individuals/m^2 (Sheardown Lake SE, Habitat Type 10; Table 3-8). The data exhibited relatively high variability (COVs up to 173%), but were normally distributed with the exception of Sheardown Lake NW, Habitat Type 9. COVs of samples collected were somewhat lower from deeper water depths (Profundal Zone, Habitat Type 14) in comparison to shallower water depths (particularly the Shoreline Zone, Habitat Type 4). This may reflect the more variable nature of the shallower areas of the lakes (i.e., strongly affected by water level fluctuations and wave energy, increased substrate heterogeneity, and potentially affected by anthropogenic factors).

For the representative waterbody (i.e., Sheardown Lake NW), there were notable differences in total density among habitat types and between years within the same habitat type, with no clear pattern among habitat types (Figure 3-3).The COVs were somewhat higher at shallower water depths in comparison to deeper water habitat, with the lowest variability being observed in Habitat 14 in 2007 (Table 3-9). Within Habitat Type 9, total density was significantly lower in 2008 in comparison to 2007, and within Habitat Type 14, each year was significantly different from the other with total density being the lowest in 2008 and highest in 2011.

Composition

The proportion of Chironomidae contributing to the total macroinvertebrate density was relatively similar among Mine Area lakes within the same habitat type (Table 3-10). The exception to this was Camp Lake, Habitat Type 4, where Chironomidae only made up 7% of the total in comparison to 66% in Sheardown Lake NW and 55% in Sheardown Lake SE. Differences among habitat types within a lake were evident, with the proportion of Chironomidae observed in samples increasing with water depth (Figure 3-4). The data exhibited less variability (lower COVs) in comparison to total BMI density, and were normally distributed, with the exception of Mary Lake habitat types 9 and 14. As the proportion of Chironomidae increased with water depth, the corresponding COV declined. Within Sheardown Lake NW, COVs were less than 15% when each habitat type was considered annually, with the exception of Habitat Type 4 (28%; 2008 only), and declined with increasing water depth (Table 3-11). No significant differences were observed between years within habitat types 9 and 14.

Within a habitat type, evenness and diversity indices tended to be somewhat similar among Mine Area lakes, more so than among habitat types within a lake (Tables 3-12 and 3-13). As with the proportion of Chironomidae, differences among habitat types within a lake were evident for these two indices. Both indices decreased with increasing water depth, particularly for the Profundal Zone (Habitat Type 14; Figure 3-5 and 3-6). An exception to this was the diversity index for Camp Lake; however, the sample size for determining this metric in Habitat Type 4 was reduced to 1 due to the lack of macroinvertebrates in two of the three replicates. Data for these two indices were normally distributed, with the exception of diversity in Sheardown Lake NW, Habitat Type 9, and Mary Lake, Habitat Type 14. COVs for these two metrics were less than or equal to 40%, with the exception of diversity in Mary Lake, Habitat Type 14 (46%). Within a lake, COVs for both indices tended to increase with increasing water depth, particularly for the Profundal Zone; an exception to this was evenness in Sheardown Lake SE.

Within Sheardown Lake NW, COVs ranged between 20 and 33% for evenness and 10 and 41% for diversity when each habitat type was considered annually and both were notably higher in the Profundal Zone (Tables 3-14 and 3-15). No significant differences were observed between years within habitat types 9 and 14 for either evenness or diversity indices.

Richness

COVs for total and effective metrics were less than 40%, with the exception of total richness in Camp Lake Habitat Type 4 (173%) and Mary Lake Habitat Type 14 (64%), and effective richness in Sheardown Lake SE Habitat Type 4 (46%).

Within a lake, COV for total richness increased with increasing water depth (Table 3-16); an exception to this was Camp Lake. The pattern of COV for effective richness within a lake was inconsistent (Table 3-17). Data from Sheardown Lake NW demonstrated that there were differences in both richness metrics among habitat types and inter-annually within the same habitat type; however, both tended to decrease with increasing water depth (Figures 3-7 and 3-8). COVs ranged between 7 and 28% for total richness and 19 and 28% for effective richness when each habitat type was considered annually (Tables 3-18 and 3-19). COVs tended to be somewhat higher for effective richness in comparison to total richness in an aquatic habitat for any given year. Within Habitat Type 9, total richness was significantly higher in 2008 in comparison to 2007. No other significant differences were observed.

3.3.1.3 Stream Results

Abundance

Total macroinvertebrate density was higher in the furthest upstream reach and declined in downstream reaches, ranging from a mean of 3,332 individuals/m^2 in Reach 4 (furthest upstream) to 299 individuals/m^2 in Reach 1 (furthest downstream; Table 3-20). The data exhibited relatively high variability (COVs ranged from 25% to 97%), with the exception of Reach 1 (COV 18%). COVs of samples collected were somewhat higher in the furthest upstream reach in comparison to those collected from the middle and, particularly, the downstream reach; this may reflect increased heterogeneity of aquatic habitat in further upstream stream reaches. There were no statistically significant inter-annual differences in reaches 2 (2007, 2008) and 4 (2007, 2008, 2011).

Composition

Similar to total BMI density, the proportion of Chironomidae contributing to the macroinvertebrate community was higher in the furthest upstream reach and declined in downstream reaches, ranging from a mean of 91% in Reach 4 (furthest upstream) to 69% in Reach 1 (furthest downstream; Table 3-21). The data exhibited less variability (lower COVs) in comparison to total macroinvertebrate density, with the exception of Reach 2 in 2007 (COV of 36% for 2007 samples). There were no statistically significant inter-annual differences in reaches 2 and 4 (Table 3-21).

Evenness and diversity indices were both somewhat lower in the furthest upstream reach in comparison to more downstream reaches (Tables 3-22 and 3-23). Data for these two indices were normally distributed and COVs were well below 20%, with the exception of samples collected from Reach 4 in 2007 (COV 29% and 31% for evenness and diversity, respectively). No significant differences were observed between years with stream reaches 2 and 4 for either evenness or diversity indices.

Richness

Total taxa richness was slightly higher in the furthest upstream reach in comparison to more downstream reaches; however, effective richness was similar among the three reaches (Tables 3-24 and 3-25). Data for these two metrics were normally distributed and COVs were below 20%, with the exception of total taxa richness in Reach 4 in 2007 (COV 29%) and effective richness in Reach 4 in 2007, 2008, and 2011 (COV 51%, 34%, and 32%, respectively). No significant inter-annual differences were noted for either reach 2 or 4 for either richness metric.

3.3.2 Power Analysis

3.3.2.1 Data Analysis Methods

The most robust metrics identified through review of the baseline data for further statistical exploration and consideration under the CREMP were subject to a power analysis to:

- Provide a preliminary analysis of the power of the existing dataset to be used as the foundation for detecting post-Project change (i.e., Before-After comparisons);
- Explore samples sizes (i.e., number of replicate stations within a waterbody or area of a waterbody) required for detecting pre-defined levels of change; and
- Advise on the need for collection of additional baseline data and/or modifications to future sampling programs (i.e., number of replicate stations).

Power analysis was conducted following general guidance provided in the EC Metal Mining EEM Guidance Document (EC 2012). Specifically, values for α (Type I error) and β (Type II error) were set at 0.1 as advised in EC (2012); resulting power is 0.900. Evaluation of power of the existing baseline data for BMI community metrics was conducted using data collected from Sheardown Lake NW (evaluated by habitat type for pooled years of data) and Sheardown Lake Tributary 1, Reach 4 (also for pooled years of data). As noted previously, Sheardown Lake NW and its tributaries could be affected by a number of pathways of effects including effects on water clarity (dust, sewage discharge, and runoff), effects on other water quality parameters, and/or effects on hydrology. Additionally, Tributary 1 provides important juvenile Arctic Char rearing habitat.

Metrics that were subject to a power analysis included:

- Total macroinvertebrate density;
- Chironomidae proportion;
- Shannon's Equitability;
- Simpson's Diversity Index; and
- Total Taxa Richness.

COVs for the composition and richness metrics were typically less than 20% for each habitat type in Sheardown Lake NW and Tributary 1, Reach 4 and were therefore identified for further analysis; exceptions included Chironomidae proportion (Habitat 4), and Shannon's Equitability, Simpson's Diversity Index, and total taxa richness for Habitat 14 in Sheardown Lake NW (Tables 3-11, 3-14, 3-15, and 3-18). COVs for total macroinvertebrate density were high in all lake habitat types and Reach 4, but this metric was retained as it is one of the most commonly used indicators of the status of the BMI community in waterbodies.

CESs utilized for power analysis of Sheardown Lake NW and Tributary 1, Reach 4 are summarized in Tables 3-26 and 3-27, respectively. The CESs were selected based on the Metal Mining EEM Guidance document, scientific literature, and other recent/current AEMPs (see Section 3.3 of the main body of the CREMP for details). For metrics with a non-normal distribution (total taxa richness, Habitat Type 4; total macroinvertebrate density and Simpson's Diversity Index, Habitat Type 9; total macroinvertebrate density, Reach 4), all distributions were fitted to a log-normal prior to analyses; for Simpson's Diversity Index, it was truncated at 1. Analyses were run using PopTools version 3.2 (build 5) add-in for Microsoft Excel 2010. See Section 2.3.2 for additional details regarding power analysis methods.

3.3.2.2 Lake Results

Total Macroinvertebrate Density

The power of the existing total BMI density dataset from Sheardown Lake NW for detecting a pre-defined level of change (i.e., mean ± 50%, mean ± 25%, mean ± 20%) tends to be low for all scenarios explored and varies depending on the aquatic habitat type (Table 3-28). The aquatic habitat type with the highest power for detecting change post-Project is Habitat Type 9, with a power of 0.807 for detecting a change in the mean of ±50%.

Sample sizes (i.e., the number of replicate stations within an aquatic habitat type) required for detecting pre-defined levels of change in the density metric were high for all aquatic habitat types, likely related to the high variability in the existing dataset (COVs up to 94%; Table 3-29). A total of 31, 43, and 64 replicate stations would be required in habitat types 9, 14, and 4, respectively, to detect a change in the mean of ±50% (power of 0.900).

Chironomidae Proportion

The power of the existing dataset for the Chironomidae proportion metric to be able to detect a pre-defined level of change is high for all change scenarios explored in habitat types 9 and 14 (power of 1.000), but somewhat lower for Habitat Type 4 (Table 3-28). The power in Habitat Type 4 ranges from a high of 0.957 (mean ± 50%) to a low of 0.402 (mean ± 20%).

Sample sizes required for detecting pre-defined levels of change in the Chironomidae proportion metric were notably lower than those determined for the total macroinvertebrate density metric and varied by habitat type (Table 3-29). A total of 6, 22, and 37 replicate stations would be required in Habitat Type 4 to detect a change in the mean of 50%, ±25%, and ±20%, respectively (power of 0.900). Corresponding sample sizes in Habitat Type 9 were calculated to be 2, 4, and 6. Due to the low variability of this metric in Habitat 14, a sample of size of 1 would be sufficient to detect a change in the mean of ±20%.

Shannon's Equitability

The power of the existing dataset for the evenness metric (Shannon`s equitability) to be able to detect change post-Project is high for Habitat Type 9 for all scenarios examined (power of 1.000; Table 3-28). The power is high in habitat types 4 and 14 to be able to detect a change in the mean of ±50% (power of 1.000 and 0.990, respectively), but declines for changes in the mean of ±25% and ±20%.

With respect to required sample sizes, Habitat Type 9 is estimated to require 2, 4, and 6 replicate stations to be able to detect changes in the mean of ±50%, ±25%, and ±20%, respectively (Table 3-29). The number of replicate stations required in habitat types 4 and 14 for corresponding changes in the mean are higher, ranging between 3 and 10, and 7 and 37, respectively.

Simpson's Diversity Index

The power of the diversity index metric dataset to be able to detect change is high for habitat types 4 and 9 for all scenarios examined (Table 3-28). The power is also high in Habitat Type 14 to be able to detect a change in the mean of ±50% (power of 0.892), but declines for changes in the mean of ±25% and ±20%.

To detect a ±50% change in the mean, habitat types 4, 9, and 14 are estimated to require 3, <5, and 12 replicate stations, respectively (Table 3-29). The number of replicate stations required in Habitat Type 14 to be able to detect smaller changes in the mean increases notably in comparison to the other two habitat types.

Total Taxa Richness

The power of the existing total taxa richness dataset from Sheardown Lake NW for detecting a pre-defined level of change is high for all change scenarios and habitat types explored (Table 3-28). However, power is somewhat lower in Habitat Type 14 in comparison to the other habitat types to be able to detect a change in the mean of ±25% and ±20% (power of 0.866 and 0.712, respectively).

To detect a ±50% change in the mean, habitat types 4, 9, and 14 require <<3, 4, and 4 replicate stations, respectively (Table 3-29). The number of replicate stations required in habitat types 9 and 14 to be able to detect smaller changes in the mean increases similarly for both in comparison to Habitat Type 4.

3.3.2.3 Streams Results

Total Macroinvertebrate Density

The power of the existing total BMI dataset from Sheardown Lake Tributary 1, Reach 1 for detecting a pre-defined level of change (i.e., mean ± 50%, mean ± 25%, mean ± 20%) is low for all change scenarios explored (Table 3-30). The highest power of 0.785 is for a change in the mean of -50% (0.564: +50%) and the lowest is 0.109 for -20% (0.209: +20%).

Sample sizes (i.e., the number of replicate stations within a stream reach) required for detecting pre-defined levels of change in the density metric were high for all scenarios, which is likely related to the high variability in the existing dataset (COVs up to 97%; Table 3-31). A total of 13 (-50%) and 22 (+50%) replicate stations would be required to detect a change in the mean of ±50% (power of 0.900).

Chironomidae Proportion

The power of the existing dataset for this metric to be able to detect a pre-defined level of change is very high (power of 1.000) for all scenarios (Table 3-30). Due to the low variability of this metric (COVs of only 2-4%), a sample size of 2 would be sufficient to detect a change in the mean of ±50%; sample size only increases to 3 to be able to detect a change of ±20% (Table 3-31).

Shannon's Equitability

The power of the existing dataset for the evenness metric is high to be able to detect a change in the mean of ±50% (power of 1.000), but declines for changes in the mean of ±25% (0.791) and ±20% (0.602) (Table 3-30). With respect to required sample sizes, Reach 4 requires 4, 12, and 18 replicate stations to be able to detect a change in the mean of ±50%, ±25%, and ±20%, respectively (Table 3-31).

Simpson's Diversity Index

The power of the existing dataset for the diversity index is high to be able to detect a change in the mean of ±50% (power of 1.000), but declines for changes in the mean of ±25% (0.750) and ±20% (0.578) (Table 3-30). Similar to the evenness metric, Reach 4 requires 5, 13, and 19 replicate stations to be able to detect a change in the mean of ±50%, ±25%, and ±20%, respectively (Table 3-31).

Total Taxa Richness

The power of the existing dataset for total taxa richness is high to be able to detect a change in the mean of ±50% (power of 1.000), but declines for changes in the mean of ±25% (0.844) and ±20% (0.651) (Table 3-30). Reach 4 requires 4, 10, and 16 replicate stations to be able to detect a change in the mean of ±50%, ±25%, and ±20%, respectively (power of 0.900; Table 3-31).

3.3.3 Sampling Sites and Areas

3.3.3.1 Lakes

In lakes, EC (2012) recommends the spatial extent of each of the exposure and reference areas should be at least 100 m x 100 m and large enough to accommodate the required number of replicate stations, with sufficient separation. Replicate stations should encompass a minimum of a 10 m x 10 m area and be separated by at least 20 m.

Baseline sampling in the Mine Area lakes has included between three and seven replicate stations per habitat type (Table 3-1). Replicate stations were separated by approximately 10 m in 2006 and 2007, and by at least 20 m in 2008 and 2011.

3.3.3.2 Streams

In rivers and streams, EC (2012) recommends the spatial extent of each of the exposure and reference areas should be at least 100 m x 100 m and large enough to accommodate the required number of replicate stations, with sufficient separation. Replicate stations should encompass a longitudinal stretch of the river that includes one pool/riffle sequence; a river distance of six times the bankfull width should be adequate. Replicate stations should be separated by a minimum of three times the bankfull width between stations of similar habitat.

Baseline sampling in rivers/streams in the Mine Area included a minimum separation of three wetted stream widths between each replicate station (where more than one replicate station was sampled; Table 3-2).

3.3.4 Sample Size

EC (2012) recommends BMI sampling should include at a minimum, five replicate stations, each consisting of a minimum of three sub-samples, for both the exposure and reference areas. Replicate stations should be located within the dominant habitat class to reduce variability (where possible). Actual number of samples may vary on a site-specific basis and existing data should be analysed to identify adequate sample size.

Baseline sampling has included between three and seven replicate stations within streams and lakes in the Mine Area, depending on the year and area sampled; the exception was in 2005 when only one replicate station was sampled (Table 3-2). In general, five sub-samples were collected for each replicate station (the exception was for Mary Lake in 2007 where only one sub-sample was collected for logistical reasons and at Sheardown Lake in 2011 where the three replicates were composed of one, three, and one grabs, respectively).

3.3.4.1 Lakes

The power of the existing dataset in Sheardown Lake NW to be able to detect a post-Project change in the mean of ±50% is high for the majority of metrics investigated, with the exception of total macroinvertebrate density (Table 3-28). Habitat Type 9 has a power of 0.807 for detecting a ±50% change in the mean of total macroinvertebrate density;

whereas habitat types 4 and 14 have power of 0.247 and 0.441, respectively. Depending on the aquatic habitat type, the power of numerous metrics remains high to be able to detect a change in the mean of ±25% and 20%, particularly in habitat types 4 and 9; existing power in Habitat Type 14 is notably lower in comparison for all metrics except Chironomidae proportion.

Sample sizes (i.e., the number of replicate stations within an aquatic habitat type) required for detecting pre-defined levels of change (i.e., mean ± 50%, mean ± 25%, mean ± 20%; power of 0.900) in total macroinvertebrate density in Sheardown Lake NW are high for all aquatic habitat types (minimum of 31 required to detect change in mean of ± 50%; Table 3-29). Minimum sample sizes for other metrics required to detect a change in the mean of ± 50% ranged from 1 (Chironomidae proportion, Habitat Type 14) to 12 (Simpson's Diversity Index, Habitat Type 14), with the majority being 7 or less. Depending on the aquatic habitat type, the sample size required for several metrics is 7 or less to be able to detect a change in the mean of ±25% and 20%. More sensitive metrics to change include:

- Shannon's Equitability, Simpson's Diversity Index, and total taxa richness in Habitat Type 4;
- Chironomidae proportion, Shannon's Equitability, and Simpson's Diversity Index in Habitat Type 9; and
- Chironomidae proportion in Habitat Type 14.

The number of field sub-samples (i.e., grabs) per replicate station was determined for Sheardown Lake NW by aquatic habitat type and year that would provide an estimate with 20% precision (i.e., an acceptable level of variance) for each metric (Tables 3-9, 3-11, 3-14, 3-15, 3-18, and 3-19). For total macroinvertebrate density, this number ranged between 1 and 22 sub-samples, depending on the habitat type and year; whereas for all other metrics the number of sub-samples ranged from 1 to 5. EC has recommended that sub-samples collected at replicate stations in the future be assessed separately, rather than composited as in previous years, to evaluate variability. Five sub-samples were collected at each replicate station and preserved separately in 2013 to allow for an assessment of the number of field sub-samples required.

3.3.4.2 Streams

The power of the existing dataset in Sheardown Lake Tributary 1, Reach 4 to be able to detect a post-Project change in the mean of ±50% is very high for the majority of metrics investigated, with the exception of total macroinvertebrate density (power of 0.564; Table 3-30). The power of numerous metrics remains high to be able to detect a change in the mean of ±25% and 20%, particularly the Chironomidae proportion metric.

Sample size (i.e., the number of replicate stations within an aquatic habitat type) required for detecting pre-defined levels of change (i.e., mean ± 50%, mean ± 25%, mean ± 20%; power of 0.900) in total macroinvertebrate density in Reach 4 is comparatively high for all change scenarios (minimum sample size of 22; Table 3-31). Minimum sample sizes for other metrics required to detect a change in the mean of ± 50% ranged from 2 (Chironomidae proportion) to 5 (Simpson's Diversity Index). The sample size required for the Chironomidae proportion metric is 3 to be able to detect a change in the mean of ±25% and 20%. More sensitive metrics to change include Chironomidae proportion, followed by total taxa richness, Shannon's Equitability, and Simpson's Diversity Index.

The number of field sub-samples (i.e., grabs) per replicate station was determined for Reach 4 by year that would provide an estimate with 20% precision (i.e., an acceptable level of variance) for each metric (Tables 3-20 to 3-25). For total macroinvertebrate density, this number ranged between 1 and 23 sub-samples, depending on year; whereas for all other metrics the number of sub-samples ranged from 1 to 6. An assessment of the variability of sub-samples at a replicate station has not been conducted to date, as grabs were composited at each replicate station in previous years prior to identification and enumeration of macroinvertebrates. As described for lakes, EC has recommended that sub-samples collected at replicate stations in the future be assessed separately. Sub-samples were collected at each replicate station and preserved separately in 2013 to allow for an assessment of the number of field sub-samples required.

3.3.5 Sampling Methods

EC (2012) recommends the use of quantitative sampling equipment and specifically, grab samplers such as a petit Ponar or Ekman dredge for depositional habitats and stream-net samplers for erosional habitats in freshwater systems. All baseline data collected in lakes used either an Ekman or a petit Ponar dredge which is consistent with EC (2012) recommendations. Although stream sampling has been conducted with a Surber sampler rather than the recommended Neill-Hess type sampler, a Surber sampler is similar to a Neill-Hess cylinder-type sampler. BMIs in streams should continue to be sampled using a Surber sampler in the future to maintain continuity with the methods used for the existing datasets to facilitate before-after comparisons. The importance of maintaining continuity in sampling methods is fundamental for monitoring programs and is acknowledged by EC (2012).

EC (2012) recommends the use of a 500 µm mesh size for the freshwater environment and preservation of samples in 10% buffered formalin. All sampling for the Mine Area lakes and streams, with the exception of samples collected in 2005 when a mesh size of 250 µm was used, used a 500 µm mesh size and 10% buffered formalin for sample preservation.

3.3.6 Timing of Sampling

Timing of sampling should be concentrated within a single sampling season and should consider timing of previous sampling and the most ecologically relevant season. EC (2012) indicates that timing should also occur during effluent discharge but after the receiving environment has been exposed to the effluent for sufficient period during which effects would reasonably be expected to occur (i.e., generally within 3-6 months) in relation to Metal Mining EEM. Similarly, timing of sampling should consider the temporal aspects of other impact pathways being addressed through monitoring (e.g., changes in hydrology, dust deposition).

BMI sampling has been consistently conducted in the Mine Area in late summer/fall. This is an ecologically relevant time for sampling and would be most appropriate considering the effluent discharge regime (i.e., discharge during the open-water season only), hydrology (i.e., streams/rivers freeze solid), and dust deposition (i.e., introduction during the open-water season).

3.3.7 Taxonomy

EC (2012) recommends taxonomic identification to the family level for first and subsequent monitoring of freshwater systems under the MMER EEM, but that finer taxonomic resolution may be required to detect more subtle effects.

All BMI sorting and taxonomic identifications were conducted by the same laboratory (ZEAS Inc., Nobleton, ON), using the same laboratory methods among study years. Macroinvertebrates were identified to the lowest practical level using the most recent publications. Most taxa were identified to the level of Genus or Species, with the exception of flatworms, mites, and harpacticoid crustaceans, which were identified to Order.

3.3.8 Summary

Existing BMI community data are appropriate to use for post-Project monitoring; the robustness of these data was assessed through conduct of a power analysis (Section 3.3.2) to determine appropriate sample sizes for the 2013 freshwater field program and subsequent development of the CREMP. See Section 3.4 for an overview of the 2013 sampling program.

3.4 OVERVIEW OF 2013 SAMPLING

As BMI community sampling had only been conducted once at the majority of waterbodies and/or aquatic habitat types, sampling in the fall of 2013 was conducted to augment the baseline database and improve its utility for post-Project comparisons. Results of this program were not yet available at the time of this review; a summary of sampling that was completed is provided below.

3.4.1 Lakes

The Mine Area lakes program focused upon sampling in key (i.e., predominant habitat utilized by Arctic Char) habitat types in Camp and Sheardown lakes (Figure 3-9). Five replicate stations were sampled in each of the targeted habitat types. Five sub-samples were collected at each replicate station and preserved separately to facilitate examination of variability between sub-samples (i.e., variability within a replicate station). Due to inclement weather, sampling was not conducted in Mary Lake in 2013. A total of 11 replicate stations (five in each of two habitats, one in the third targeted habitat type) were sampled in Camp Lake, and a total of 10 (five in each of two targeted habitat types) were sampled in each of Sheardown Lake NW and Sheardown Lake SE.

3.4.2 Streams

The Mine Area tributaries program focused upon tributaries to Sheardown Lake based on the following rationale:

- Three stream reaches in Tributary 1 (Sheardown Lake NW): Arctic char bearing and primary open-water rearing habitat for juveniles. Tributary 1 may be affected by stream diversion and dust deposition;
- One stream reach in Tributary 9 (Sheardown Lake SE): Arctic char bearing. Tributary 9 may be affected by stream diversion and dust deposition;
- Two stream reaches in Tributary 12 (Sheardown Lake NW): Arctic char bearing. Tributary 9 may be affected by stream diversion and dust deposition (Figure 3-9).

Within a stream reach, 2-3 replicate stations, each consisting of 2-5 randomly collected benthic invertebrate sub-samples, were collected. The sub-samples were kept separate to provide an estimate of variability in the benthic community at each station (with the exception of Tributary 1, Replicate Stations B1, B2, and B3 where sub-samples were composited).

4.0 ARCTIC CHAR

The following sections provide an inventory of available baseline Arctic Char (*Salvelinus alpinus*) data, a description of key pathways of effect and key questions respecting the Project, a preliminary examination of baseline Arctic Char data, a review of sample size, sampling sites, methods, and timing, and an overview of sampling completed in 2013.

Sampling of the fish community was initiated in 2005 in the Mine Area; Year 1 of the baseline studies was primarily a reconnaissance exercise aimed at identifying fish species present in the area and general distribution. Subsequent studies examined:

- Fish distribution across the Mine Area streams and identification of fish barriers;
- Fish movements (Arctic Char) between waterbodies;
- Fish population characteristics and condition (catch-per-unit-effort [CPUE], age structure, length/size at age, sex and sexual maturity, condition factors, deformities, erosion, lesions, and tumours [DELTs], and internal and external parasites);
- Seasonal movement of Arctic Char from lakes into and out of streams/rivers;
- Anadromy;
- Seasonal use of various habitat types by different life history stages;
- Metals in liver and muscle; and
- Spawning areas/timing.

This review focused upon metrics that were identified for the CREMP (i.e., individual and population level metrics of growth, survival, condition and reproduction) and did not therefore discuss data regarding fish movements/anadromy or metals in fish. Information on fish movements and habitat use were considered as supporting information for the review of baseline data and in the design of the CREMP.

While this review focused upon consideration of baseline data in Mine Area lakes, for the purposes of providing a general overview of available baseline data for Arctic Char in the Mine area, and because data collected in streams could be used to augment or support lake monitoring programs, Section 4.1 provides a brief description of baseline studies programs conducted in lakes and streams.

The detailed review of baseline data was completed in 2013 prior to the open-water season (NSC 2013) in part to provide recommendations for additional baseline data collection for the 2013 field season. A field program was subsequently completed in 2013, as summarized in Section 3.4. The detailed review of baseline data provided in Section 4.3 is based on data collected from 2005 through 2012 in the Mine Area.

4.1 INVENTORY OF FRESHWATER BASELINE DATA

The following sections provide an inventory of baseline studies for Arctic Char in the Mine Area. Specifically, the following provides:

- An overview of the sampling methods employed for collection and analysis of Arctic Char in the Mine Area waterbodies; and
- An inventory of existing baseline Arctic Char data for Mine Area waterbodies.

4.1.1 Sampling Methods

4.1.1.1 Lakes

A Smith-Root Model 11A or LR-24 backpack electrofisher was used during 2007, 2008 and 2013 to assess the use of wadeable nearshore lake habitat by small fish. During summer 2007, approximately 50-100 m long sections of shoreline with a variety of substrates (e.g., sand, cobble/boulder, gravel/cobble) were electrofished to assess habitat use by small fish in most Mine Area lakes. During spring 2008, electrofishing effort was focused on substrate types (cobble/boulder) thought to be preferred Arctic Char rearing habitat. The presence of recently hatched young-of-the-year (YOY) Arctic Char in nearshore habitat during early spring would provide some evidence of nearby fall spawning. Captured fish were sampled and released. During fall 2013, rocky habitats were fished in an attempt to collect sufficient numbers of juvenile Arctic Char for AEMP analyses.

During the open-water seasons of 2006-2008 and 2013, standard gang index gill nets were used to sample fish at sites in Camp, Sheardown, and Mary lakes. Small mesh gill nets were also used in 2013. During 2006, gillnet sites were selected opportunistically. In 2007, sites were selected to achieve good spatial coverage of Camp, Sheardown, and Mary lakes. In 2008, the focus of the gillnetting program was on the identification of Arctic Char spawning habitat. In 2013, the focus of the gillnetting was to capture a sufficient number of fish (n = 100) across all size ranges of Arctic Char as part of a baseline study to support the CREMP. Standard index gillnet gangs consisted of six 22.9

m long by 1.8 m deep twisted nylon or monofilament panels of 1.5, 2.0, 3.0, 3.75, 4.25, and 5.0 inch (38, 51, 76, 95, 108, and 127 mm, respectively) stretched mesh. Small mesh gangs consisted of three 10 m long by 1.8 m deep panels of 16, 20 and 25 mm stretched mesh. Nets were set on the bottom and left in place for short periods of time (typically less than 4 hours) to minimize fish mortality. Winter gillnetting conducted in May 2007 used different gang arrangements and different methods and are not comparable with open-water gillnetting. Therefore, winter gillnetting data were excluded from the analyses presented in this report. Locations (i.e., UTMs) of all captured fish were recorded using a hand-held global positioning system (GPS) unit.

Biological data were collected for most fish captured in both gear types; however, the amount of data collected varied by year, gear type, and size and condition (i.e., live or mortalities) of fish. In all surveys, fish were identified to species, enumerated by location, and measured for fork length (± 1 mm). For fish less than 250 mm in length, round weight was measured to an accuracy of ± 1 g in 2006-2008 and 0.01 g in 2013, while larger fish were consistently weighed to an accuracy of ± 25 g. When possible (i.e., during fall), live fish were examined for sex and maturity by gently massaging the abdomen and identifying any extruded gametes. Mortalities and fish in poor condition from all years were retained and examined internally to determine sex and state of sexual maturity (i.e., had never spawned, preparing to spawn in the current year, had just completed spawning in the current year, or had spawned in a previous year but would not be spawning in the current year), where possible. Ageing structures (otoliths) were collected from a length-stratified sub-sample of gillnet-caught fish from all Mine Area lakes and from a length-stratified sub-sample of electrofishing-caught fish from Mary River from 2006-2008. In 2013, pectoral fin rays were collected from live released fish and both otoliths and fin rays were collected from incidental mortalities.

4.1.1.2 Streams

Backpack electrofishing was conducted from 2006-2008 using a Smith-Root Model 11A or LR-24 backpack electrofisher to assess the use of streams and rivers within the Mine Area by fish. Electrofishing surveys were primarily confined to reaches of streams and rivers where the results of aquatic habitat surveys suggested some potential to support fish. Stream reaches that either were ephemeral, or were cut off from lakes by impassable barriers typically were not fished. Streams and rivers electrofished in 2006 were confined to summer surveys, whereas most streams and rivers electrofished in 2007 were surveyed during spring, summer, and fall to document seasonal use of the tributaries. During 2008, several tributaries that had not been electrofished previously (particularly tributaries to Mary Lake) were fished during spring and summer.

Streams were subdivided into reaches based primarily on changes in dominant habitat types. Sections of each reach (50 m long) were isolated with barrier nets, where possible, and electrofished to estimate total fish use and compare between habitat types. Three passes were made in a downstream direction along each reach and the number of fish captured during each pass was recorded. All captured fish were released back into the reach from which they were captured at the completion of sampling.

Additional information on the fish use of selected tributaries was collected using hoop nets. Hoop nets oriented to capture fish moving downstream were installed in Camp Lake Tributary 2 (CLT2) and Sheardown Lake Tributary 1 (SDLT1) during fall 2007 to assess downstream movements of fish out of these tributaries. During 2008, hoop nets were installed during spring and fall to identify timing and magnitude of movements of fish into and out of these two streams after spring melt and prior to freeze-up. Upstream and downstream movements were monitored in CLT2 during spring and fall and in SDLT1 during spring, 2008. Low water levels during fall 2008 prevented monitoring of upstream movements in SDLT1. During fall 2013, downstream facing hoop nets were installed in Camp Lake Tributaries 1 and 2 and Sheardown Lake NW Tributary 1.

Hoop nets were constructed of fine-mesh beach seine material, were 0.6 m in diameter, and had 5 m long wings. Each hoop net was positioned as close to the confluences as possible at sufficient depths to remain submerged. Each wing and the cod end of the net were anchored so that it remained taut and spanned the width of the stream. Wings were lengthened with rock barriers, where necessary, to achieve 100% blockage of the channel in either upstream or downstream configurations. All captured fish were released into the stream on the opposite side of the hoop net in which they were caught at the completion of sampling.

Biological data were collected for most fish captured in all gear types; however, the amount of data collected varied by gear type and size of fish. Fish were identified to species, enumerated by location, and measured for fork length (± 1 mm). For hoopnet-caught fish, only the first 50 fish captured each day were measured for fork length. For fish less than 250 mm in length, round weight was measured to an accuracy of ± 1 g, while larger fish were weighed to an accuracy of ± 25 g. Fish longer than 250 mm, and in good condition, were marked with individually numbered Floy® FD-94 tags inserted at the base of the dorsal fin. During 2013, pectoral fin rays were also collected from a subsample of fish and otoliths were collected from incidental mortalities.

4.1.2 Baseline Data Inventory

4.1.2.1 Lakes

Fish were sampled in lakes in the Mine Area using angling, minnow traps, backpack electrofishing, and standard gang and small mesh index gill nets during the open-water periods of 2005 to 2008, 2010 and 2013 and using gill nets deployed under the ice in May 2007 (Figure 4-1, Table 4-1). Sampled lakes included Camp, Sheardown (northwest and southeast basins), and Mary (north and south basins) lakes.

4.1.2.2 Streams

Fish were sampled in streams within the Mine Area using angling, minnow traps, backpack electrofishing, and hoop nets during the open-water periods of 2005 to 2008 and 2013 (Figure 4-2, Table 4-1). Sampled streams and rivers included inflows to Camp Lake, Sheardown Lake (northwest and southeast basins), and Mary Lake (north and south basins), as well as the Mary and Tom rivers. The largest data sets were obtained from the hoopnetting programs conducted at the confluences of tributary streams with Camp and Sheardown lakes. These data improve robustness of the baseline database respecting YOY and age 1+ juvenile datasets for lakes.

4.2 PATHWAYS OF EFFECT AND KEY QUESTIONS

Key questions were developed to guide the review of baseline data adequacy and, ultimately, design of the monitoring program. The adequacy of baseline data to address these key questions is addressed in Section 4.3. These questions and metrics focus upon key potential residual effects identified in the FEIS (BIM 2012) and the Addendum to the FEIS for the ERP (BIM 2013), as well as metrics commonly applied for characterizing fish populations (growth, reproduction, condition and survival) and recommended by EC (2012).

The key pathways of potential residual effects of the Project on Arctic Char include:

- Water quality changes related to discharge of ore or stockpile runoff to freshwater systems (immediate receiving environments: Mary River and Camp Lake Tributary 1);

- Water quality changes related to discharge of treated sewage effluent (immediate receiving environments: Mary River and Sheardown Lake NW);
- Water quality changes due to deposition of dust in lakes and streams (Mine Area in zone of dust deposition);
- Water quality changes due to non-point sources, such as site runoff and use of ANFO explosives (Mine Area);
- Changes in water levels and/or flows due to water withdrawals, diversions, and effluent discharges (i.e., alteration or loss of aquatic habitat);
- Dust deposition (i.e., sedimentation) in Arctic Char spawning areas (habitat) and on Arctic Char eggs; and
- Effects of the Project on primary and secondary producers.

The key question related to the pathways of effect is:

- What are the combined effects of point and non-point sources, sedimentation, habitat loss or alteration, and changes in primary or secondary producers on Arctic Char in Mine Area lakes (Sheardown Lake NW and SE, Camp Lake, and Mary Lake)?

Arctic Char will be monitored downstream of discharges of ore and waste rock stockpile runoff (i.e., Camp Lake Tributary 1 and the Mary River) under the MMER EEM program. Of the remaining waterbodies, potential effects of the Project on Arctic Char populations are predicted to be greatest in the Camp Lake and Sheardown Lake drainages.

4.3 EVALUATION OF DATA FOR POST-PROJECT MONITORING

The Mine Area streams and lakes support only two fish species: land-locked Arctic Char; and, Ninespine Stickleback (*Pungitius pungitius*). Of these, abundance of Ninespine Stickleback is relatively limited and highly localized while Arctic Char are overwhelmingly the most abundant fish species in the area. As Mine Area streams freeze solid during winter, overwintering habitat is provided exclusively by lakes.

EC (2012) recommends monitoring of sexually mature individuals of a minimum of two fish species for EEM programs and use of invasive sampling (i.e., lethal) if acceptable. Alternative study designs include non-lethal sampling methods for fish populations/communities, as well as studies of juvenile fish if appropriate and/or required.

Given that there are only two fish species present in the area, fish monitoring in the Mine Area would be limited to successful capture of sufficient numbers of both of these fish species in the exposure areas. In most lakes and streams in the exposure area, Arctic Char are sufficiently abundant that successful capture of enough fish for monitoring purposes is possible. In contrast, Ninespine Stickleback are absent or uncommon in a number of waterbodies. Similar results have been observed in most waterbodies surveyed for all components of the Mary River Project. It is unlikely, even with extensive effort, that sufficient numbers of Ninespine Stickleback could be captured for monitoring purposes from either the receiving environments or from prospective reference areas. For this reason, only a single species, Arctic Char, will be monitored used for the CREMP program.

4.3.1 Description of Existing Data

The following provides a description of existing data for Arctic Char based on backpack electrofishing and open-water gillnetting data collected in Mine Area lakes in 2006-2008 and hoopnetting data collected in streams in 2006-2008.

4.3.1.1 Data Analysis

To explore the robustness of various potential metrics for Arctic Char for the CREMP, several metrics were derived as indicated in Table 4-2, using the datasets indicated in Table 4-3. The CREMP and MMER EEM programs will employ non-lethal sampling methods to minimize impacts of monitoring on the Arctic Char populations. Therefore the metrics identified and assessed for the CREMP are those that can be measured using non-lethal sampling methods. Metric data for Arctic Char were analysed where sample sizes were ≥ 10, by waterbody, year, gear type (gill net and electrofishing only), and sex. When sex could not be determined for sufficient numbers of fish (e.g., electrofishing catches), data were pooled. Age data collected from a subsample of gillnetted fish in each lake were pooled to provide a sufficient sample size. Annual gillnetting data collected from 2006-2008 and shoreline electrofishing data (Sheardown Lake NW only) collected in 2007 and 2008 were analysed. Methods for the calculation of derived metrics are described below.

All fish catch and life history data were tabulated and reviewed for transcription errors as part of routine QA/QC measures and, if warranted, outliers were eliminated from datasets. Fish catches were examined by lake, species, gear type, and year.

For Arctic Char, mean length, weight, and condition factor were calculated by lake, year, gear type, and, where possible, sex. CPUE was calculated for fish captured by electrofishing (#fish/minute of electrofishing) and in gill nets (#fish/100 m of net/24 hrs). Summary statistics (mean, median, SE, SD, minimum, maximum, n, COV, and 95th percentile) for each of these metrics were derived for each year, waterbody, gear type and, where possible, sex using data from all sites sampled concurrently in that waterbody.

COV was calculated as SD/mean x 100; COV facilitated comparisons of the variability of various datasets to assist with identifying the most robust metrics as well as to assist with advising on sampling design. The variability of the metrics examined was then described to facilitate identification of those metrics with the lowest natural variation for further consideration and statistical analysis.

Additional summary statistics were conducted on YOY and fish aged 1+, including length-frequency analyses, length-at-age and weight-at-age to provide estimates of growth and survival of these early life stages.

Some hoop net data from streams (i.e., lengths and weights for YOY and 1+ fish) were pooled with shoreline electrofishing data in Sheardown Lake NW to improve robustness of the lake dataset for analysis.

4.3.1.2 Results

Fork Length (mm)

Mean lengths of Arctic Char show variation between lake, year, and sex (Tables 4-4 to 4-6). However, there were no significant differences observed between males and females sampled within the same year in any lakes and with one exception, there were no significant differences observed between years for this metric (Table 4-7). The sole exception occurred for females captured in Camp Lake where lengths were significantly different between years.

Comparing datasets between lakes revealed that Camp Lake had the smallest mean length and highest COV while the catches from the Mary Lake basins had the highest mean length and lowest variability (Tables 4-4 and 4-6). There were no significant differences for any between-lake comparisons of datasets (Table 4-8).

Weight (g)

Mean weights of Arctic Char show even greater variation between lake, year, and sex (Tables 4-9 to 4-11) than mean fork lengths. No significant differences between sexes or years were observed for Sheardown Lake NW or Mary Lake South. Weights of females were significantly lower than males captured in 2006, 2008, and with all years combined (2006-2008) and weights of both males and females were significantly different between years in Camp Lake (Table 4-12).

Comparing datasets between lakes revealed that north basin of Mary Lake had the smallest mean weight and COV while the south basin had the highest mean weight and Camp Lake had the highest variability (Tables 4-9 to 4-11). There were no significant differences for any between-lake comparisons of datasets (Table 4-13).

Condition Factor (K)

In contrast to length and weight metrics, mean condition factor of Arctic Char showed little variation between datasets and lower COVs than fork lengths (Tables 4-14 to 4-16). Mean condition factor was similar between males and females and between years in Camp Lake with consistently low COVs (Table 4-14). Mean condition factor of Arctic Char captured in Sheardown Lake was slightly lower than for Camp Lake, but also showed consistency between sexes and across years with low COVs for the gillnetting catch (Table 4-15). Condition factors of fish captured by electrofishing in Sheardown Lake NW was greater than for fish captured with gill nets, however the electrofishing dataset also exhibited higher COVs. In the south basin of Mary Lake, mean condition factor was higher in 2006 than in 2007, but relatively consistent between sexes and variability was low (Table 4-16).

Non-parametric analysis revealed significant interannual differences for males captured in Sheardown Lake NW and between males and females from Sheardown Lake NW in 2006 (Table 4-17). There were no significant differences for any between-lake comparisons of condition factor datasets (Table 4-18).

Catch-Per-Unit-Effort

As is commonly observed, CPUE for Arctic Char showed consistently high variation among datasets (Table 4-19). The highest COV was observed in the Sheardown Lake datasets. Data for males and females were not analysed separately because sex could not be identified for all captured fish, particularly during summer sampling.

Significant interannual differences (P value < 0.05) were observed for gillnetting datasets for Camp Lake and Mary Lake south and for the electrofishing dataset from Sheardown Lake NW (Table 4-20). In addition, there were significant differences for all between-lake comparisons (Table 4-21).

Age

Summary statistics for age data from Arctic Char are presented in Table 4-22. Fish sampled from Sheardown and Mary lakes had the highest average age while those sampled from Mary River had the lowest. Variation is relatively low between individual lakes and high between lakes and rivers. Length and weight-at-age statistics show a general increase in size with increasing age (Table 4-23). Growth rates appear to be higher between the ages of 2 and 10 than in older fish. Analysis of covariance (ANCOVA) tests show a significant effect of age on both length and weight (Table 4-24).

4.3.2 Power Analysis

4.3.2.1 Methods

Selected Arctic Char metrics (Table 4-25) were subject to a power analysis to:

- Provide a preliminary analysis of the power of the existing dataset to be used as the foundation for detecting post-Project change (i.e., Before-After comparisons);
- Explore samples sizes required for detecting pre-defined levels of change; and
- Advise on the need for collection of additional baseline data and/or modifications to future sampling programs (i.e., number of sites).

The variability of selected Arctic Char metrics measured during the baseline studies program was evaluated and described in Section 4.3.1 to assist with identifying the most robust metrics for further statistical exploration and consideration under the CREMP. Metrics that were subject to a power analysis included:

- Age 0+ and 1+ Length (mm);
- Age 1+ Weight (g); and
- Age 1+ Condition Factor.

Condition factor and weight of Age 0+ (i.e., YOY) fish could not be subject to a power analysis due to the precision of the weight measurements for the existing baseline datasets.

Power analysis was conducted following general guidance provided in the EC Metal Mining EEM Guidance Document (2012). Specifically, values for α (Type I error) and β (Type II error) were set at 0.1 as advised in EC (2012). Data were evaluated for assumptions of normality and equal variance and transformed where required. Baseline data on Arctic Char populations collected in Sheardown Lake NW and Camp Lake from 2006-2010 were evaluated statistically for consideration of monitoring under the CREMP.

For non-lethal sampling, EC (2012) recommends sampling of a minimum of 100 fish older than YOY for each study site but also recommends retaining and measuring all YOY collected during the sampling for older fish. Where possible, fish older than YOY should represent the whole range of fish sizes and be representative of the population (mature and immature).

A Priori Power Analyses

Power analysis by simulation was implemented using PopTools (Hood 2010).Two types of power analyses were used; one based on a *t*-test (parametric) and one based on the Mann-Whitney (nonparametric) *U*-test.

The power of existing baseline data to be used for demonstrating changes in the various metrics was explored for a range of effects sizes (i.e., ±10%, ±20%, and ±25%). Using the dNormalDev(mean, SD) function, random data were generated for the observed baseline and hypothetical monitoring scenarios. The Excel formula for a t-test was used keeping the first row fixed. This process was iterated 1000 times by Monte Carlo simulation to determine the frequency of a realised t-probability greater than α (Type I error). This provided an estimate of β (Type II error) with the power of the test being 1-β. Both α and β were set at 0.10 for a power of 90% following the EEM Guidelines (EC 2012).

4.3.2.2 Results

The power analyses indicated that a sample size of 100 fish is sufficient to detect changes in length of 10%, in weight of 20%, and in condition factor of 10% (Table 4-25). Weights were the most variable of these three metrics and the power associated with this metric is the lowest. The power analyses indicate that relatively small samples sizes are required to detect 10% changes in length (n = 25 YOY and n = 11 for Age 1+) and condition factor (n = 9 for Age 1+).

4.3.3 Study Design

Monitoring of Arctic Char in the Mine Area under the CREMP would utilize a non-lethal sampling design. The objective of the lake monitoring programs is to examine cumulative effects of the Project on Arctic Char populations. Lakes provide critical habitat for Arctic Char, as streams freeze solid in winter and spawning and overwintering habitat is restricted to lakes. The CREMP would examine the collective Project effects through monitoring Arctic Char in Mine Area lakes as a whole.

The lake-based CREMP sampling program is focused upon obtaining measures of metrics for Age 1+ fish using standardized sampling methods (i.e., standard gang index gillnetting). The monitoring program will consist of direct before-after comparisons within a lake and, depending on the suitability of the final reference lakes incorporated into the CREMP, may also include control-impact comparisons (or, ideally, before-after-control-impact comparisons).

Gear would be primarily standard gang index gill nets, supplemented with smaller mesh nets (i.e., Swedish nets) and/or electrofishing as required to obtain the required minimum target sample size and range of fish ages/sizes.

4.3.4 Timing of Sampling

EC (2012) indicates that timing of sampling should consider the time of year, hydrology/habitat variability, stage of reproductive development, and effluent discharge regime. Fish biology also affects timing of sampling (e.g., seasonal use of exposure areas) and reference and exposure areas should be sampled as close in time as feasible and should consider water temperature explicitly.

For Arctic Char, the recommended sampling period is 4-6 weeks prior to first spawn (EC 2012). For non-lethal surveys that include collection of YOY, EC (2012) recommends that sampling be conducted when YOY are a catchable size in the gear being used. They further recommend sampling YOY in late fall where appropriate, though timing should consider variability in YOY size distributions of the population being monitored, or ideally, at the beginning and end of the growing period.

From 2006-2008, baseline sampling programs conducted in Camp, Sheardown and Mary Lakes with standard gang index gill nets typically occurred during summer (late July/early August) and covered all habitat types throughout the lake. These data were supplemented with limited fall sampling intended to identify spawning locations. Fall gillnetting was primarily restricted to areas where preferred spawning substrates were located. Sampling in streams was conducted during spring, summer and fall in all available habitat types to document seasonal use of stream habitat by both species of fish.

In 2013, the Arctic Char sampling program was conducted in late summer/fall in Mine Area lakes to target the end of the growing season prior to spawning. During Project operation, this timing would allow for sampling of Arctic Char following a prolonged period of exposure to effluent (which will be discharged in the open-water season) and other non-point sources such as dust.

4.3.5 Sampling Areas

EC (2012) provides detailed direction on identifying exposure areas for the fish monitoring component under MMER EEM. As the objective of the MMER EEM programs is to monitor for effects of metal mining effluent on fish populations, these exposure areas are intentionally selected in areas affected by effluent discharges. Reference areas are then identified with, ideally, identical features and characteristics (e.g., habitat), for comparison.

Baseline sampling of Mine Area lakes with standard gang index gill nets was designed to provide quantitative estimates of Arctic Char populations for each lake and to identify spawning areas, while backpack electrofishing in all available nearshore habitat types of the lakes was conducted to identify habitat preferences of juveniles and assist with identification of spawning areas. During 2006, gillnet sites were selected opportunistically. In 2007, sites were selected to achieve good spatial and habitat coverage of Camp, Sheardown, and Mary lakes. In 2008, the focus of the gillnetting program was on the identification of Arctic Char spawning habitat.

In 2013, the program was designed to collect 100 fish from all size classes in each lake to provide baseline information for the CREMP. The CREMP is intended to monitor the cumulative effects of the Project on Arctic Char populations in Mine Area lakes and is not intended to focus upon mining effluent or any one particular effects pathway. As such the CREMP adopts a broader spatial scope and is intended to provide information on a lake-wide basis, rather than on a focused area of each lake.

4.3.6 Sample Size

For non-lethal sampling, EC (2012) recommends sampling of a minimum of 100 fish older than YOY for each study area but also recommends retaining and measuring all YOY collected during the sampling for older fish. Where possible, fish older than YOY should represent the whole range of fish sizes and be representative of the population (mature and immature).Where abundance of YOY is “extremely high” (i.e., >80-90% of the first 100 fish captured during the program), sampling should continue until 100 non-YOY fish are captured.

Results of the power analyses conducted on the Sheardown Lake NW datasets indicates that this recommended sample size will be adequate to detect CESs between 10 and 25% on selected metrics. However, the power analyses were based on baseline data collected from a representative lake (Sheardown Lake NW) using a different study design than recommended for the CREMP. Therefore the CREMP will target a minimum of 100 individuals per lake, as recommended by EC (2012).

4.3.7 Metrics

EC (2012) recommends that non-lethal sampling should include fork length for fish with a forked caudal fin (± 1 mm), total body weight (± 1.0%), assessment of external condition (i.e., DELTs), external sex determination (if possible), and age (where possible; ± 1 year). They further recommend the use of a 3-decimal scale for measuring weights of small-sized fish.

Baseline studies included measurement of all of these metrics but some metrics were not measured to the recommended precision for all fish sampled. Future programs will employ the level of precision identified by EC (2012) for all fish captured.

Arctic Char were aged using otoliths - the preferred ageing structure for this species – during most of the baseline studies. The CREMP will employ a non-lethal design and therefore will require use of another ageing structure (i.e., pectoral fin rays) for fish that are live released. Based on the results of a comparative analysis of pectoral fin rays and otoliths for ageing Arctic Char in the Mine Area (NSC 2014), it will be necessary to sacrifice fish from a length-stratified sub-sample during the conduct of future studies. Ageing measurements will also be independently confirmed on a minimum of 10% of samples, as recommended by EC (2012).

4.3.8 Sampling Equipment

EC (2012) indicates the same gear type should be used for sampling reference and exposure areas and ideally only one gear type is used for the fish study. In nearshore areas of lakes, backpack electrofishing has been the primary method of sampling and will be used for sampling these areas during the CREMP program as needed. Standard gang index gillnetting has been used for baseline lake surveys and will continue to be used during the CREMP program as the primary sampling method. Small mesh nets may also be used to capture sufficient numbers of fish, in particular smaller size ranges. However, small mesh nets have proven relatively ineffective for capture of fish smaller than 250 mm in length and it is anticipated that backpack electrofishing will be required in future programs to obtain Arctic Char in this length range.

4.4 OVERVIEW OF 2013 SAMPLING

The Arctic Char sampling program conducted in Mine Area lakes in 2013 was designed to be non-lethal and was based upon EC's EEM survey design (EC 2012). As such, the lake-based sampling program was focused upon obtaining measures of metrics for Age 1+ fish using standardized sampling methods (i.e., standard gang index gillnetting). The program was habitat-based, with sampling effort weighted in accordance with the proportions of major habitat types in each of the lakes. Major habitat types were defined in terms of water depth and substrate as follows:

- Deep (> 12 m)/hard;
- Deep/soft;
- Shallow (2-12 m)/hard; and
- Shallow/soft.

Sites were randomly selected within these habitats in each lake. Catch rates were lower than anticipated based on gillnetting surveys conducted from 2006-2008 and sampling was enhanced by addition of sites most likely to optimize catches (e.g., probable spawning areas). Gear included standard gang index gill nets, supplemented with smaller mesh nets (i.e., Swedish nets) and nearshore backpack electrofishing to obtain the required minimum target sample size (100 fish) and range of fish ages/sizes.

Twenty-four standard index and eleven small mesh gillnet gangs were set in Camp Lake from 27-29 August, 2013 (Figure 4-3). Twelve standard index and 6 small mesh gillnet gangs were set in Sheardown NW Lake on 30 August, 2013 (Figure 4-4). A total of 26 Arctic Char were captured in Camp Lake and 28 were captured Sheardown Lake NW with gill nets.

To supplement the small gillnetting catches, backpack electrofishing was conducted at one site in Camp Lake and two sites in Sheardown Lake NW. Fifty-seven juvenile Arctic Char were captured in Camp Lake and 183 Arctic Char and one Ninespine Stickleback were captured in Sheardown Lake NW during electrofishing surveys.

As noted in Section 4.3.7, pectoral fin rays and otoliths were collected from incidental mortalities of Arctic Char during the 2013 field program to facilitate comparison of the two ageing structures. The results of this comparison are provided in NSC (2014).

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TABLES AND FIGURES

Table 2-1. Summary of number of sites sampled for analysis of chlorophyll *a* in Mine Area lakes (near surface sampling).

Sampling Period	Sheardown Lake NW	Sheardown Lake SE	Camp Lake	Mary Lake
May 2007	3	2	3	4
August 2007	5	3	3	4
September 2007	5	3	3	4
June 2008	6	0	0	0
July/August 2008	22	6	3	3
September 2008	11	3	0	0
August/September 2009	4	1	0	0
July 2013	6	1	5	6
August 2013	6	1	5	3
Total	68	20	22	24
Total: Open-water Period	65	18	19	20

Table 2-2. Summary of number of sites sampled for analysis of phytoplankton taxonomy and biomass in Mine Area lakes.

Sampling Period	Sheardown Lake NW	Sheardown Lake SE	Camp Lake	Mary Lake
August 2007	5	3	3	5
September 2007	5	3	3	5
July/August 2008	5	3	3	4
September 2008	5	3	0	0
July 2013	11	8	10	10
August 2013	6	1	10	0
Total	37	21	29	24

Table 2-3. Summary of number of sites sampled for analysis of chlorophyll *a* in Mine Area streams.

Sampling Period	Mary River	Tom River	Sheardown Lake Tributaries						Camp Lake Tributaries		Tributary to CL Trib 1	Outlet of Camp Lake	Camp Lake Reference stream s		N. Trib of Mary River	Tributaries to Mary Lake	Mary River Reference Streams		Tributary to Katiktok Lake
			SDL NW Trib 1	SDL SE Trib 9	SDL NW Trib 12	SDL NW Trib 13	Unnamed Trib A SDL NW	Unnamed Trib B SDL NW	CL Trib 1	CL Trib 2			No. 3	No. 4		Mary Lake Trib 2	No. 2	No. 3	
Jun-07	7	2	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Jul-07	8	2	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sep-07	7	2	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jun-08	3	2	3	1	1	1	1	0	0	0	0	0	0	0	0	1	0	0	0
Jul-08	8	0	3	1	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Sep-08	2	1	2	1	1	0	1	1	0	0	0	0	0	0	0	1	0	0	0
Jun-13	9	1	0	0	0	0	0	0	4	1	1	1	0	0	1	0	0	0	1
Jul-13	10	1	2	0	0	0	0	0	4	1	1	1	1	1	1	0	1	1	0
Aug-13	9	1	2	0	0	0	0	0	4	1	1	1	1	0	1	0	0	0	0
Total	**63**	**12**	**15**	**4**	**6**	**2**	**2**	**1**	**12**	**3**	**3**	**3**	**2**	**1**	**3**	**3**	**1**	**1**	**1**

Table 2-4. Phytoplankton metrics considered for CREMP.

Effect Indicator	Metric	Unit
Algal Abundance/Density	Chlorophyll *a*	(µg/L)
	Total Biomass	(mg/m^3)
	Biomass of Major Groups	(mg/m^3)
	Biomass of Major Groups	(% of total biomass)
Evenness	Simpson's evenness	-
	Shannon's evenness	-
	Hill's evenness	-
Taxa Richness	Total number of species	-
	Hill's effective richness	-
	Simpson's diversity index	-

Table 2-5. Summary statistics for chlorophyll *a* (µg/L) measured in Mine Area lakes in summer and late summer/fall: 2007, 2008, and 2013. Analytical detection limit = 0.2 µg/L. Nearshore sampling sites excluded.

	Sheardown Lake NW	Sheardown Lake SE	Camp Lake	Mary Lake	All Lakes: 2007, 2008, and 2013
Mean	0.35	0.78	0.57	1.18	0.66
Median	0.20	0.20	0.20	1.05	0.20
Minimum	<0.20	<0.20	<0.20	<0.20	<0.20
Maximum	1.50	2.30	2.10	3.50	3.50
SD	0.29	0.78	0.60	1.00	0.72
SE	0.05	0.19	0.14	0.22	0.08
n	35	17	19	20	91
95th Percentile	0.90	2.14	1.74	1.80	2.10
% Detections	43	41	53	70	51
COV (%)	83	101	105	85	110
Mean + 2 x SD	0.92	2.34	1.78	3.17	2.10
2 x Mean	0.69	1.55	1.15	2.35	1.31
Mean + 50%	0.52	1.16	0.86	1.76	0.99
Mean + 25%	0.43	0.97	0.72	1.47	0.82
Mean + 20%	0.41	0.93	0.69	1.41	0.79

Table 2-6. Summary statistics and results of Kruskal-Wallis tests for chlorophyll *a* (µg/L) measured in Sheardown Lake NW in summer and late summer/fall: 2007, 2008, and 2013. Analytical detection limit = 0.2 µg/L. Nearshore sampling sites excluded. The mean of samples collected in July and August 2008 were averaged to represent the summer sampling period.

	Summer	Late Summer/Fall	2007	2008	2013	All Data (2007, 2008, and 2013)
Mean	0.42	0.29	0.38	0.28	0.40	0.35
Median	0.30	0.20	0.20	0.20	0.35	0.20
Minimum	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Maximum	0.90	0.90	0.90	0.90	0.80	0.90
SD	0.28	0.19	0.29	0.22	0.22	0.24
SE	0.07	0.05	0.09	0.07	0.07	0.04
n	15	15	10	10	10	30
95th Percentile	0.90	0.62	0.90	0.63	0.76	0.90
% Detections	67	33	60	20	70	50
COV (%)	66	67	76	79	55	69
Mean + 2 x SD	0.97	0.67	0.96	0.72	0.84	0.84
2 x Mean	0.84	0.57	0.76	0.56	0.80	0.71
Mean + 50%	0.63	0.43	0.57	0.42	0.60	0.53
Mean + 25%	0.53	0.36	0.48	0.35	0.50	0.44
Mean + 20%	0.50	0.34	0.46	0.34	0.48	0.42
P value[1]	0.134		0.235			-

[1]Differences between two groups tested with a Kruskal-Wallis test at alpha = 0.05.

Table 2-7. Summary statistics for total phytoplankton biomass (mg/m^3) measured in Mine Area lakes in summer and late summer/fall: 2007 and 2008.

	Phytoplankton biomass (mg/m^3)			
	Sheardown Lake NW	**Sheardown Lake SE**	**Camp Lake**	**Mary Lake**
Mean	204	125	122	149
Median	160	62	109	173
Minimum	42	43	43	28
Maximum	456	336	250	415
SD	134	111	73	106
SE	30	32	24	28
n	20	12	9	14
95th Percentile	430	312	243	298
COV	66	89	60	71
Mean + 2 x SD	471	347	268	360
2 x Mean	408	250	243	298
Mean + 50%	306	188	183	223
Mean + 25%	255	157	152	186
Mean + 20%	245	150	146	179

Table 2-8. Summary statistics and results of Kruskal-Wallis tests for total phytoplankton biomass (mg/m^3) measured in Sheardown Lake NW in summer and late summer/fall: 2007 and 2008.

	Phytoplankton biomass (mg/m^3)				
	Summer	Late Summer/Fall	2007	2008	All Data (2007 and 2008)
Mean	182	226	87	321	204
Median	145	208	92	302	160
Minimum	42	88	42	183	42
Maximum	429	456	137	456	456
SD	137	134	30	79	134
SE	43	42	10	25	30
n	10	10	10	10	20
95th Percentile	378	410	129	444	430
COV	75	59	35	25	66
Mean + 2 x SD	456	493	148	479	471
2 x Mean	364	451	173	642	408
Mean + 50%	273	338	130	481	306
Mean + 25%	228	282	108	401	255
Mean + 20%	218	271	104	385	245
P value[1]	0.315		<0.0001		-

[1]Differences between two groups tested with a Kruskal-Wallis test at alpha = 0.05.

Table 2-9. Mean, SD, COV, and 95th percentiles for phytoplankton species diversity, evenness, and richness metrics measured in Mine Area lakes in summer and late summer/fall: 2007 and 2008.

	MEANS					
	Simpson's Diversity Index	Simpson's Evenness	Species Richness	Shannon's Evenness	Hill's Effective Richness	Hill's Evenness
Sheardown Lake NW	0.71	0.22	18	0.61	6.19	0.34
Sheardown Lake SE	0.71	0.29	16	0.61	6.10	0.37
Camp Lake	0.72	0.22	17	0.60	5.55	0.33
Mary Lake	0.52	0.20	15	0.47	3.84	0.28
All lakes combined	0.66	0.23	17	0.58	5.47	0.33
	SD					
	Simpson's Diversity Index	Simpson's Evenness	Species Richness	Shannon's Evenness	Hill's Effective Richness	Hill's Evenness
Sheardown Lake NW	0.12	0.08	3	0.10	1.94	0.08
Sheardown Lake SE	0.88	0.43	20	0.77	9.31	0.54
Camp Lake	0.07	0.05	3	0.04	1.18	0.04
Mary Lake	0.19	0.15	4	0.17	2.00	0.15
All lakes combined	0.17	0.11	3	0.14	2.18	0.11
	COV					
	Simpson's Diversity Index	Simpson's Evenness	Species Richness	Shannon's Evenness	Hill's Effective Richness	Hill's Evenness
Sheardown Lake NW	17	34	16	16	31	25
Sheardown Lake SE	27	42	18	26	41	34
Camp Lake	9	25	20	7	21	13
Mary Lake	36	75	28	36	52	55
All lakes combined	26	47	21	24	40	34
	95TH PERCENTILE					
	Simpson's Diversity Index	Simpson's Evenness	Species Richness	Shannon's Evenness	Hill's Effective Richness	Hill's Evenness
Sheardown Lake NW	0.84	0.34	22	0.74	8.9	0.46
Sheardown Lake SE	0.87	0.42	19	0.76	9.2	0.51
Camp Lake	0.81	0.28	23	0.66	7.5	0.37
Mary Lake	0.84	0.52	21	0.78	7.5	0.56
All lakes combined	0.87	0.42	22	0.77	9.1	0.53

Table 2-10. Summary statistics and results of Kruskal-Wallis tests for phytoplankton taxonomy metrics measured in Sheardown Lake NW in summer and late summer/fall: 2007 and 2008.

	Simpson's Diversity Index				
	Summer	Late Summer/Fall	2007	2008	All Data (2007 and 2008)
Mean	0.76	0.66	0.80	0.62	0.71
Median	0.79	0.70	0.81	0.62	0.76
Minimum	0.59	0.41	0.71	0.41	0.41
Maximum	0.87	0.81	0.87	0.78	0.87
SD	0.10	0.13	0.05	0.11	0.12
SE	0.03	0.04	0.01	0.04	0.03
n	10	10	10	10	20
95th Percentile	0.86	0.80	0.86	0.77	0.84
COV	13	20	6	18	17
Mean + 2 x SD	0.95	0.93	0.89	0.85	0.96
2 x Mean	1.52	1.32	1.60	1.24	1.42
Mean + 50%	1.14	0.99	1.20	0.93	1.07
Mean + 25%	0.95	0.83	1.00	0.78	0.89
Mean + 20%	0.91	0.79	0.96	0.75	0.85
P value[1]	0.075		<0.0005		-

	Simpson's Evenness				
	Summer	Late Summer/Fall	2007	2008	All Data (2007 and 2008)
Mean	0.27	0.18	0.27	0.18	0.22
Median	0.27	0.17	0.26	0.17	0.20
Minimum	0.15	0.13	0.17	0.13	0.13
Maximum	0.40	0.26	0.40	0.32	0.40
SD	0.08	0.05	0.07	0.06	0.08
SE	0.02	0.01	0.02	0.02	0.02
n	10	10	10	10	20
95th Percentile	0.37	0.25	0.37	0.28	0.34
COV	29	25	27	32	34
Mean + 2 x SD	0.42	0.27	0.41	0.30	0.38
2 x Mean	0.53	0.36	0.53	0.36	0.45
Mean + 50%	0.40	0.27	0.40	0.27	0.34
Mean + 25%	0.33	0.23	0.33	0.23	0.28
Mean + 20%	0.32	0.22	0.32	0.22	0.27
P value[1]	0.007		0.009		-

Table 2-10. - continued -

	Species Richness				
	Summer	Late Summer/Fall	2007	2008	All Data (2007 and 2008)
Mean	18	18	19.9	16.0	18.0
Median	17	20	20.0	15.5	18.5
Minimum	13	13	16.0	13.0	13.0
Maximum	22	22	22.0	20.0	22.0
SD	3	3	1.9	2.4	2.9
SE	1	1	0.6	0.8	0.7
n	10	10	10	10	20
95th Percentile	21	22	22.0	20.0	22.0
COV	16	17	9	15	16
Mean + 2 x SD	23	24	23.6	20.9	23.8
2 x Mean	35	37	40	32	36
Mean + 50%	26	27	30	24	27
Mean + 25%	22	23	25	20	22
Mean + 20%	21	22	24	19	22
P value[1]	0.614		0.002		-

	Shannon's Evenness				
	Summer	Late Summer/Fall	2007	2008	All Data (2007 and 2008)
Mean	0.66	0.57	0.68	0.54	0.61
Median	0.69	0.59	0.69	0.56	0.62
Minimum	0.54	0.39	0.59	0.39	0.39
Maximum	0.77	0.72	0.77	0.69	0.77
SD	0.08	0.10	0.05	0.09	0.10
SE	0.03	0.03	0.02	0.03	0.02
n	10	10	10	10	20
95th Percentile	0.75	0.69	0.75	0.65	0.74
COV	12	18	8	16	16
Mean + 2 x SD	0.82	0.78	0.79	0.72	0.81
2 x Mean	1.31	1.14	1.37	1.09	1.23
Mean + 50%	0.98	0.86	1.02	0.81	0.92
Mean + 25%	0.82	0.71	0.85	0.68	0.77
Mean + 20%	0.79	0.68	0.82	0.65	0.74
P value[1]	0.105		0.001		-

Table 2-10. - continued -

	Hill's Effective Richness				
	Summer	**Late Summer/Fall**	**2007**	**2008**	**All Data (2007 and 2008)**
Mean	6.8	5.6	7.7	4.6	6.2
Median	6.8	5.9	7.6	4.5	6.1
Minimum	4.4	2.8	5.9	2.8	2.8
Maximum	9.7	8.9	9.7	6.2	9.7
SD	1.8	2.0	1.1	1.2	1.9
SE	0.6	0.6	0.4	0.4	0.4
n	10	10	10	10	20
95th Percentile	9.2	8.2	9.3	6.1	8.9
COV	27	35	15	25	31
Mean + 2 x SD	10.5	9.5	10.0	6.9	10.1
2 x Mean	13.5	11.2	15.5	9.3	12.4
Mean + 50%	10.1	8.4	11.6	6.9	9.3
Mean + 25%	8.5	7.0	9.7	5.8	7.7
Mean + 20%	8.1	6.7	9.3	5.6	7.4
P value[1]	0.280		<0.0001		-

	Hill's Evenness				
	Summer	**Late Summer/Fall**	**2007**	**2008**	**All Data (2007 and 2008)**
Mean	0.38	0.30	0.39	0.29	0.34
Median	0.40	0.30	0.40	0.30	0.32
Minimum	0.28	0.21	0.30	0.21	0.21
Maximum	0.52	0.42	0.52	0.45	0.52
SD	0.08	0.07	0.07	0.07	0.08
SE	0.03	0.02	0.02	0.02	0.02
n	10	10	10	10	20
95th Percentile	0.49	0.39	0.49	0.39	0.46
COV	21	22	17	24	25
Mean + 2 x SD	0.55	0.43	0.53	0.43	0.51
2 x Mean	0.77	0.60	0.78	0.58	0.68
Mean + 50%	0.58	0.45	0.59	0.44	0.51
Mean + 25%	0.48	0.37	0.49	0.36	0.43
Mean + 20%	0.46	0.36	0.47	0.35	0.41
P value[1]	0.052		0.004		-

[1]Differences between two groups tested with a Kruskal-Wallis test at alpha = 0.05.

Table 2-11. Spearman rank correlation coefficients for phytoplankton metrics and total phosphorus (TP). Values in bold indicate significant correlations at α = 0.05. Correlation analysis includes data collected from all Mine Area lakes in 2007, 2008, and 2013. RA = relative abundance; > DL = detections only.

Variables	TN	TP	TN:TP	Chlorophyll *a* (>DL)	Chlorophyll *a*	Total Biomass	Diatom Biomass	Green-Algae Biomass	Chrysophyte Biomass	Cryptophyte Biomass	Blue-Green Algae Biomass	Euglenoid Biomass	Dinoflagellate Biomass	Diatom RA	Green-Algae RA	Green-Algae RA	Green-Algae RA	Green-Algae RA	Green-Algae RA	Green-Algae RA	Maximum Species Biomass	Simpson's Diversity Index	Simpson's Evenness	Species Richness	Shannon's Evenness	Hill's Effective Richness
TP	-0.099	**1**																								
TN:TP Molar Ratios	**0.679**	**-0.763**	**1**																							
Chlorophyll *a* (>DL)	0.242	**0.519**	-0.271	**1**																						
Chlorophyll *a*	0.049	**0.286**	-0.197	**1.000**	**1**																					
Total Biomass	-0.044	0.119	-0.018	0.272	-0.068	**1**																				
Diatom Biomass	0.009	0.046	0.060	0.148	-0.038	**0.957**	**1**																			
Green-Algae Biomass	0.066	-0.058	0.132	0.156	-0.224	**0.462**	**0.377**	**1**																		
Chrysophyte Biomass	-0.148	0.230	-0.186	0.130	-0.018	**0.533**	**0.457**	**0.323**	**1**																	
Cryptophyte Biomass	-0.146	0.129	-0.171	0.252	0.121	**0.318**	**0.288**	0.107	0.236	**1**																
Blue-Green Algae Biomass	-0.095	0.113	-0.102	0.204	0.007	0.224	0.091	0.045	0.159	0.059	**1**															
Euglenoid Biomass	-0.046	-0.164	0.106	-0.231	0.123	-0.244	-0.188	-0.253	**-0.310**	0.036	-0.061	**1**														
Dinoflagellate Biomass	0.063	-0.055	0.179	0.007	-0.070	**0.303**	0.223	0.218	0.120	0.157	0.195	0.017	**1**													
Diatom RA	0.070	-0.103	0.088	-0.194	0.165	0.035	**0.267**	**-0.431**	-0.085	-0.102	**-0.426**	0.079	**-0.398**	**1**												
Green-Algae RA	0.061	-0.226	0.192	-0.191	-0.256	-0.095	-0.167	**0.803**	-0.018	-0.036	-0.030	-0.074	0.053	**-0.528**	**1**											
Chrysophyte RA	-0.153	0.152	-0.192	0.022	0.032	0.001	-0.051	-0.003	**0.805**	0.032	0.075	-0.197	-0.098	-0.059	-0.067	**1**										
Cryptophyte RA	-0.145	0.134	-0.196	0.233	0.164	-0.067	-0.083	-0.110	0.009	**0.885**	-0.024	0.176	0.018	-0.131	-0.043	0.004	**1**									
Blue-Green Algae RA	-0.115	0.111	-0.125	0.183	0.028	0.140	0.000	0.028	0.096	0.032	**0.988**	-0.060	0.145	**-0.447**	0.008	0.048	-0.021	**1**								
Euglenoid RA	-0.024	-0.183	0.125	-0.258	0.112	**-0.289**	-0.237	-0.250	**-0.319**	-0.002	-0.051	**0.992**	0.026	0.048	-0.047	-0.184	0.156	-0.047	**1**							
Dinoflagellate RA	0.109	-0.093	0.230	0.003	-0.091	0.168	0.088	0.147	0.035	0.126	0.167	0.061	**0.970**	**-0.429**	0.078	-0.122	0.041	0.126	0.079	**1**						
Maximum Species Biomass	-0.012	0.142	-0.015	0.193	0.012	**0.951**	**0.957**	**0.360**	**0.513**	**0.284**	0.136	-0.227	0.181	0.184	-0.189	0.018	-0.083	0.047	**-0.274**	0.047	**1**					
Simpson's Diversity Index	-0.003	-0.244	0.126	-0.098	-0.183	**-0.595**	**-0.651**	-0.055	**-0.353**	-0.122	0.127	0.217	0.154	**-0.421**	**0.337**	-0.069	0.126	0.185	0.258	0.246	**-0.786**	**1**				
Simpson's Evenness	0.045	-0.084	0.015	0.073	-0.144	**-0.706**	**-0.781**	-0.094	**-0.282**	-0.156	0.010	0.062	-0.023	**-0.394**	**0.317**	0.077	0.115	0.083	0.109	0.089	**-0.858**	**0.901**	**1**			
Species Richness	-0.107	**-0.434**	0.269	**-0.582**	-0.170	0.008	0.061	0.023	-0.260	-0.006	0.190	**0.429**	**0.370**	-0.058	0.111	**-0.282**	-0.003	0.176	**0.417**	**0.353**	-0.108	**0.446**	0.052	**1**		
Shannon's Evenness	0.045	-0.164	0.091	-0.008	-0.099	**-0.645**	**-0.701**	-0.049	**-0.299**	-0.105	0.079	0.198	0.101	**-0.416**	**0.348**	0.019	0.156	0.137	0.241	0.192	**-0.811**	**0.969**	**0.936**	**0.307**	**1**	
Hill's Effective Richness	0.004	**-0.282**	0.169	-0.185	-0.159	**-0.551**	**-0.588**	-0.029	**-0.314**	-0.110	0.146	**0.289**	0.214	**-0.395**	**0.346**	-0.051	0.113	0.194	**0.326**	**0.294**	**-0.733**	**0.974**	**0.826**	**0.566**	**0.946**	**1**
Hill's Evenness	0.070	-0.084	0.035	0.062	-0.087	**-0.711**	**-0.770**	-0.089	**-0.276**	-0.137	0.021	0.123	0.017	**-0.386**	**0.318**	0.092	0.127	0.085	0.168	0.122	**-0.850**	**0.905**	**0.979**	0.103	**0.965**	**0.862**

Table 2-12. Summary of power analysis results for selected phytoplankton community metrics. Values represent the minimum number of samples required for achieving 90% power.

Metric	Minimum Sample Size					
	All data 2007-2008			Fall data 2007-2008		
	CES			CES		
	50%	25%	20%	50%	25%	20%
Simpson's Diversity Index	3	8	12	4	11	16
Species Richness	3	7	11	3	8	12
Shannon's Evenness	3	8	11	3	9	13
Total Biomass	8	27	99	6	22	86

Table 2-13. Overview of phytoplankton sampling conducted in Mine Area lakes: 2013.

Site ID	Sample Date	Season	Chlorophyll *a*		Biomass and Taxonomy
			No. of Replicates		No. of Replicates
			Surface	Bottom	
Camp Lake					
JL0-01	27-Jul-13	Summer	2	-	1
	26-Aug-13	Fall	2	-	1
JL0-02	27-Jul-13	Summer	1	1	3
	24-Aug-13	Fall	1	1	3
JL0-09	27-Jul-13	Summer	1	1	1
	26-Aug-13	Fall	1	1	1
JL0-10	27-Jul-13	Summer	1	-	1
	25-Aug-13	Fall	1	-	1
JL0-11	27-Jul-13	Summer	1	-	1
	26-Aug-13	Fall	1	-	1
JL0-PHYTO1	27-Jul-13	Summer	-	-	1
	25-Aug-13	Fall	-	-	1
JL0-PHYTO2	27-Jul-13	Summer	-	-	1
	25-Aug-13	Fall	-	-	1
JL0-PHYTO3	27-Jul-13	Summer	-	-	1
	26-Aug-13	Fall	-	-	1
JL0-PHYTO4	27-Jul-13	Summer	-	-	1
	26-Aug-13	Fall	-	-	1
JL0-PHYTO5	27-Jul-13	Summer	-	-	1
	27-Aug-13	Fall	-	-	1
Sheardown Lake NW					
DD-HAB9-STN1	25-Jul-13	Summer	1	1	1
DD-HAB9-STN1	28-Aug-13	Fall	1	1	1
DL0-01-1	26-Jul-13	Summer	1	1	1
	28-Aug-13	Fall	1	1	1
DL0-01-2	26-Jul-13	Summer	1	1	1
	28-Aug-13	Fall	1	1	3
DL0-01-4	26-Jul-13	Summer	1	1	1
	28-Aug-13	Fall	2	2	1
DL0-01-5	26-Jul-13	Summer	2	1	1
	27-Aug-13	Fall	1	1	1
DL0-01-7	26-Jul-13	Summer	1	1	1
	28-Aug-13	Fall	1	1	1
DL0-01-PHYTO 1	26-Jul-13	Summer	-	-	1
		Fall	-	-	NS
DL0-01-PHYTO 2	26-Jul-13	Summer	-	-	1
		Fall	-	-	NS
DL0-01-PHYTO 3	26-Jul-13	Summer	-	-	1
		Fall	-	-	NS
DL0-01-PHYTO 4	26-Jul-13	Summer	-	-	1
		Fall	-	-	NS
DL0-01-PHYTO 5	26-Jul-13	Summer	-	-	1
		Fall	-	-	NS

Table 2-13. - continued –

Site ID	Sample Date	Season	Chlorophyll *a*		Biomass and Taxonomy
			No. of Replicates		No. of Replicates
			Surface	Bottom	
Sheardown Lake SE					
DL0-02-1	26-Jul-13	Summer	NS	NS	1
		Fall	NS	NS	NS
DL0-02-3	26-Jul-13	Summer	1	1	1
	29-Aug-13	Fall	1	1	1
DL0-02-4	26-Jul-13	Summer	NS	NS	3
		Fall	NS	NS	NS
DL0-02-6	26-Jul-13	Summer	-	-	1
		Fall	-	-	NS
DL0-02-7	26-Jul-13	Summer	NS	NS	1
		Fall	NS	NS	NS
DL0-02-8	26-Jul-13	Summer	NS	NS	1
		Fall	NS	NS	NS
DL0-02-PHYTO 1		Summer	-	-	NS
		Fall	-	-	NS
DL0-02-PHYTO 2		Summer	-	-	NS
		Fall	-	-	NS
DL0-02-PHYTO 3	26-Jul-13	Summer	-	-	1
		Fall	-	-	-
DL0-02-PHYTO 4	26-Jul-13	Summer	-	-	1
		Fall	-	-	-
Mary Lake South					
BL0-03	28-Jul-13	Summer	1	1	1
		Fall	NS	1	NS
BL0-04	28-Jul-13	Summer	1	1	1
		Fall	1	1	NS
BL0-05	28-Jul-13	Summer	1	1	1
		Fall	1	1	NS
BL0-06	28-Jul-13	Summer	1	1	3
		Fall	1	1	NS
BL0-07	28-Jul-13	Summer	1	-	3
		Fall	NS	-	NS
BL0-PHYTO1	28-Jul-13	Summer	-	-	1
		Fall	-	-	NS
BL0-PHYTO2	28-Jul-13	Summer	-	-	3
		Fall	-	-	NS
BL0-PHYTO3	28-Jul-13	Summer	-	-	1
		Fall	-	-	NS
BL0-PHYTO4	28-Jul-13	Summer	-	-	1
		Fall	-	-	NS
BL0-PHYTO5		Summer	-	-	NS
		Fall	-	-	NS
Mary Lake North					
BL0-01	27-Jul-13	Summer	1	1	3
		Fall	NS	NS	NS

NS = not sampled

Table 2-14. Number of samples collected for chlorophyll *a* in Mine Area streams: 2013.

Stream	June	July	August
Mary River	9	10	9
N. Tributary of Mary River, D/S of Falls	1	1	1
Sheardown Lake Tributary 1	0	2	2
Tom River	1	1	1
Camp Lake Tributary 1	4	4	4
Stream north of airstrip - confluence with Camp Lake Tributary 1	1	1	1
Camp Lake Tributary 2	1	1	1
Outlet channel of Camp Lake	0	1	1
Proposed CLT Reference stream No. 3	0	1	0
Proposed CLT Reference stream No. 4	0	1	0
Proposed Mary River Reference stream No. 2	0	1	0
Proposed Mary River Reference stream No. 3	0	1	0

Table 3-1. Summary of benthic macroinvertebrate sampling methods for Mine Area lakes (2006-2013).

Year	Equipment	Mesh Size (µm)	Replicate Stations per Site or Habitat Type	Sub-samples per Replicate Station	Taxonomy	Description/Comments
2006	Ekman Dredge (sampling area of 0.023 m^2)	500	3	5	Genus level by qualified taxonomist (ZEAS Inc.)	Sub-samples approx. 1 m apart; replicates approx. 10 m apart
2007	Petit Ponar Dredge (sampling area of 0.023 m^2)	500	3	5 [1]	Genus level by qualified taxonomist (ZEAS Inc.)	Sub-samples approx. 1 m apart; replicates approx. 10 m apart
2008	Petit Ponar Dredge (sampling area of 0.023 m^2)	500	3-7	5	Genus level by qualified taxonomist (ZEAS Inc.)	Sub-samples approx. 1 m apart; replicates min. of 20 m apart
2009	-	-	-	-	-	-
2010	-	-	-	-	-	-
2011	Petit Ponar Dredge (sampling area of 0.023 m^2)	500	3	1, 3, 1 [2]	Genus level by qualified taxonomist (ZEAS Inc.)	Sub-samples approx. 1 m apart; replicates min. of 20 m apart
2013	Petit Ponar Dredge (sampling area of 0.023 m^2)	500	5	5	-	Sub-samples approx. 1 m apart; replicates min. of 20 m apart

[1] excepting Mary Lake where only 1 sub-sample/replicate was collected

[2] sampling occurred at one site in Sheardown Lake NW only

Table 3-2. Summary of benthic macroinvertebrate sampling methods for Mine Area streams (2005-2013).

Year	Equipment	Mesh Size (µm)	Replicate Stations per Site or Habitat Type	Sub-samples per Replicate Station	Taxonomy	Description/Comments
2005	Surber sampler (sampling area of 0.097 m^2)	250	1	5	Genus level by qualified taxonomist (ZEAS Inc.)	-
2006	Surber sampler (sampling area of 0.097 m^2)	500	3	5	Genus level by qualified taxonomist (ZEAS Inc.)	replicates separated by 3 wetted stream widths
2007	Surber sampler (sampling area of 0.097 m^2)	500	3	5	Genus level by qualified taxonomist (ZEAS Inc.)	replicates separated by 3 wetted stream widths
2008	Surber sampler (sampling area of 0.097 m^2)	500	3	5	Genus level by qualified taxonomist (ZEAS Inc.)	replicates separated by 3 wetted stream widths
2009	-	-	-	-	-	-
2010	-	-	-	-	-	-
2011	Surber sampler (sampling area of 0.097 m^2)	500	3	5	Genus level by qualified taxonomist (ZEAS Inc.)	replicates separated by 3 wetted stream widths
2013	Surber sampler (sampling area of 0.097 m^2)	500	2-3 [1]	2-5 [2]	-	replicates separated by 3 wetted stream widths

[1] KP field personnel were unable to find 3 suitable replicate stations in Sheardown Lake Tributary 12, downstream reach

[2] KP field personnel were unable to find 5 suitable locations in Sheardown Lake Tributary 1, Reach 4, and Sheardown Lake Tributary 12, downstream reach for required number of sub-samples

Table 3-3. Summary of benthic macroinvertebrate sampling periods in Mine Area lakes and streams (2005-2013).

Waterbody	Sampling Period							
	2005	2006	2007	2008	2009	2010	2011	2013
Lakes								
Mary Lake	-	Aug. 31-Sept.5	Aug. 31-Sept. 20	-	-	-	-	-
Camp Lake	-	-	Aug. 31-Sept. 20	-	-	-	-	Sept. 5-8
Sheardown Lake NW	-	-	Aug. 31-Sept. 20	Sept. 8-12	-	-	Sept. 3	Sept. 5-8
Sheardown Lake SE	-	-	Aug. 31-Sept. 20	-	-	-	-	Sept. 5-8
Streams								
Mary River	Aug. 6-17	Aug. 23-Sept. 1	Aug. 31-Sept. 5	-	-	-	Aug. 28-29	-
Tom River	-	Aug. 23-Sept. 1	Aug. 31-Sept. 5	-	-	-	-	-
Camp Lake Tributaries	Aug. 6-17	-	Aug. 31-Sept. 5	-	-	-	-	-
Sheardown Lake Tributaries	Aug. 6-17	-	Aug. 31-Sept. 5	Sept. 10-11	-	-	Sept. 4	Aug. 29-31

Table 3-4. Locations of benthic macroinvertebrate lake sampling sites in the Mine Area (2006-2013).

Waterbody	Site ID	Habitat Type	UTM			Sample Date
			Zone	Easting	Northing	
Camp Lake	JLO-10-B1	4	17W	556085	7913755	2-Sep-07
	JLO-10-B2			556085	7913753	2-Sep-07
	JLO-10-B3			556087	7913757	2-Sep-07
	JLO-10-B1			556085	7913755	7-Sep-13
	Stn 1	9	17W	556320	7914417	7-Sep-13
	Stn 2			556325	7914603	7-Sep-13
	Stn 3			556510	7914791	7-Sep-13
	Stn 4			556781	7914872	6-Sep-13
	Stn 5			557031	7914989	6-Sep-13
	JLO-01-B1	14	17W	557099	7914360	1-Sep-07
	JLO-01-B2			557105	7914375	1-Sep-07
	JLO-01-B3			557104	7914374	1-Sep-07
	JLO-01-B1			557099	7914360	7-Sep-13
	JLO-02-B1	14	17W	557617	7914749	31-Aug-07
	JLO-02-B2			557621	7914750	31-Aug-07
	JLO-02-B3			557624	7914747	31-Aug-07
	JLO-02-B1			557617	7914749	7-Sep-13
	JLO-07-B1	14	17W	556705	7914182	2-Sep-07
	JLO-07-B2			556715	7914157	2-Sep-07
	JLO-07-B3			556719	7914170	2-Sep-07
	JLO-07-B1			556705	7914182	7-Sep-13
	JLO-07-B2			556715	7914157	7-Sep-13
	JLO-09-B1	14	17W	556332	7913948	2-Sep-07
	JLO-09-B2			556342	7913946	2-Sep-07
	JLO-09-B3			556324	7913946	2-Sep-07
	JLO-09-B1			556332	7913948	7-Sep-13
Sheardown Lake NW	SDL-Hab4-Stn1	4	17W	560401	7912573	8-Sep-08
	SDL-Hab4-Stn2			560503	7912526	8-Sep-08
	SDL-Hab4-Stn3			560605	7912654	8-Sep-08
	SDL-Hab4-Stn4			560582	7912730	8-Sep-08
	SDL-Hab4-Stn5			560561	7912801	8-Sep-08
	DD-Hab4-Stn-1	4	17W	560420	7913355	12-Sep-08
	DD-Hab4-Stn-2			560374	7913391	12-Sep-08
	DD-Hab4-Stn-3			560351	7913426	12-Sep-08

Table 3-4. - continued -

Waterbody	Site ID	Habitat Type	UTM			Sample Date
			Zone	Easting	Northing	
Sheardown Lake NW continued	DD-Hab9-Stn-1	9	17W	560259	7913455	12-Sep-08
	DD-Hab9-Stn-2			560323	7913402	12-Sep-08
	DD-Hab9-Stn-3			560354	7913358	12-Sep-08
	DLO-01-3-B1	9	17W	560466	7912837	15-Sep-07
	DLO-01-3-B2			560485	7912833	15-Sep-07
	DLO-01-3-B3			560496	7912815	15-Sep-07
	DLO-01-3-B1			560474	7912833	12-Sep-08
	DLO-01-3-B1			560474	7912833	5-Sep-13
	DLO-01-4-B1	9	17W	560690	7913045	7-Sep-07
	DLO-01-4-B2			560678	7913055	7-Sep-07
	DLO-01-4-B3			560683	7913060	7-Sep-07
	DLO-01-4-B1			560695	7913043	9-Sep-08
	DLO-01-4-B2			560775	7913069	9-Sep-08
	DLO-01-4-B1			560695	7913043	6-Sep-13
	DLO-01-4-B2			560775	7913069	6-Sep-13
	DLO-01-6-B1	9	17W	559705	7913525	14-Sep-07
	DLO-01-6-B2			559721	7913526	14-Sep-07
	DLO-01-6-B3			559705	7913506	14-Sep-07
	DLO-01-6-B1			559685	7913509	11-Sep-08
	DLO-01-6-B2			559680	7913564	11-Sep-08
	DLO-01-6-B1			559685	7913509	5-Sep-13
	DLO-01-6-B2			559680	7913564	5-Sep-13
	DLO-01-7-B1	9	17W	560520	7912616	7-Sep-07
	DLO-01-7-B2			560509	7912603	7-Sep-07
	DLO-01-7-B3			560481	7912619	7-Sep-07
	DLO-01-7-B1			560525	7912609	9-Sep-08
	DLO-01-7-B2			560572	7912619	9-Sep-08
	DLO-01-2-B1	14	17W	560337	7912913	15-Sep-07
	DLO-01-2-B2			560342	7912915	15-Sep-07
	DLO-01-2-B3			560357	7912917	15-Sep-07
	DLO-01-2-B1			560353	7912924	12-Sep-08
	DLO-01-2-B2			560326	7912854	12-Sep-08
	DLO-01-2-B1			560353	7912924	5-Sep-13
	DLO-01-2-B2			560326	7912854	5-Sep-13
	DLO-01-5-B1	14	17W	559775	7913350	15-Sep-07
	DLO-01-5-B2			559788	7913335	15-Sep-07
	DLO-01-5-B3			559800	7913340	15-Sep-07
	DLO-01-5-B1			559798	7913356	9-Sep-08
	DLO-01-5-B1			559800	7913325	3-Sep-11
	DLO-01-5-B2			559867	7913325	3-Sep-11
	DLO-01-5-B3			559847	7913310	3-Sep-11
	DLO-01-5-B1			559800	7913325	5-Sep-13
	DLO-01-5-B2			559867	7913325	5-Sep-13
	DLO-01-5-B3			559847	7913310	5-Sep-13

Table 3-4. - continued -

Waterbody	Site ID	Habitat Type	UTM			Sample Date
			Zone	Easting	Northing	
Sheardown Lake SE	DLO-02-3-B1	4	17W	560950	7911919	4-Sep-07
	DLO-02-3-B2			560947	7911926	4-Sep-07
	DLO-02-3-B3			560958	7911925	4-Sep-07
	Stn 1	9	17W	561520	7911857	8-Sep-13
	Stn 2			561620	7911832	8-Sep-13
	Stn 3			561546	7911816	8-Sep-13
	Stn 4			561546	7911816	8-Sep-13
	Stn 5			561510	7911779	8-Sep-13
	DLO-02-4-B1	10	17W	561127	7911708	4-Sep-07
	DLO-02-4-B2			561133	7911717	4-Sep-07
	DLO-02-4-B3			561145	7911699	4-Sep-07
	DLO-02-1-B1	14	17W	560816	7912124	6-Sep-07
	DLO-02-1-B2			560824	7912125	6-Sep-07
	DLO-02-1-B3			560818	7912111	6-Sep-07
	DLO-02-1-B1			560816	7912124	8-Sep-13
	DLO-02-2-B1	14	17W	561161	7911866	6-Sep-07
	DLO-02-2-B2			561170	7911872	6-Sep-07
	DLO-02-2-B3			561164	7911864	6-Sep-07
	DLO-02-2-B1			561161	7911866	8-Sep-13
	Stn 3	14	17W	561082	7911929	8-Sep-13
	Stn 4			561107	7911890	8-Sep-13
	Stn 5			561229	7911868	8-Sep-13
Mary Lake	BLO-01 -B1	9	17W	554695	7913212	19-Sep-07
	BLO-01 -B2			554695	7913212	19-Sep-07
	BLO-01 -B3			554695	7913212	19-Sep-07
	BLO-05-B1	9	17W	554780	7906047	20-Sep-07
	BLO-05-B2			554769	7906066	20-Sep-07
	BLO-05-B3			554785	7906078	20-Sep-07
	BLO-06-B1	9	17W	555912	7903757	20-Sep-07
	BLO-06-B2			555913	7903734	20-Sep-07
	BLO-06-B3			555890	7903721	20-Sep-07
	BLO-01 -B1	14	17W	554695	7913212	31-Aug-06
	BLO-01-B2			554695	7913212	31-Aug-06
	BLO-01- B3			554695	7913212	31-Aug-06
	BLO-05-B1	14	17W	554771	7906033	31-Aug-06
	BLO-05-B2			554771	7906033	31-Aug-06
	BLO-05-B3			554771	7906033	31-Aug-06
	BLO-03-B1	14	17W	552387	7906645	20-Sep-07
	BLO-03-B2			552360	7906630	20-Sep-07
	BLO-03-B3			552356	7906635	20-Sep-07
	BLO-04-B1	14	17W	553799	7904897	20-Sep-07
	BLO-04-B3			553824	7904871	20-Sep-07

Table 3-5. Locations of benthic macroinvertebrate stream sampling sites in the Mine Area (2005-2013).

Waterbody	Site ID	UTM			Sample Date
		Zone	Easting	Northing	
Mary River	AO-01	17W	559019	7900094	1-Aug-05
	CO-01	17W	556305	7906894	1-Aug-05
	DO-01	17W	560765	7911692	1-Aug-05
	DO-01	17W	560765	7911692	28-Aug-11
	EO-01a (E2-01)	17W	562348	7911310	1-Aug-05
	EO-01a (E0-03)	17W	562974	7912472	1-Aug-05
	HO-01	17W	571409	7917611	1-Aug-05
	AO-01 B1	17W	559034	7900064	5-Sep-07
	AO-01 B2	17W	558997	7900112	5-Sep-07
	AO-01 B3	17W	558994	7900151	5-Sep-07
	CO-01 B1	17W	556291	7906919	3-Sep-07
	CO-01 B2	17W	-	-	3-Sep-07
	CO-01 B3	17W	556323	7906925	3-Sep-07
	CO-05 B1	17W	558364	7909231	3-Sep-07
	CO-05 B2	17W	558389	7909248	3-Sep-07
	CO-05 B3	17W	558411	7909298	3-Sep-07
	CO-05 B1	17W	-	-	28-Aug-11
	CO-05 B2	17W	558352	7909170	28-Aug-11
	CO-05 B3	17W	-	-	28-Aug-11
	CO-10 B1	17W	560490	7911370	30-Aug-06
	CO-10 B2	17W	560490	7911370	30-Aug-06
	CO-10 B3	17W	560490	7911370	30-Aug-06
	CO-10 B1	17W	560616	7911666	4-Sep-07
	CO-10 B2	17W	560661	7911687	4-Sep-07
	CO-10 B3	17W	560708	7911701	4-Sep-07
	EO-20 B1	17W	561688	7911724	29-Aug-11
	EO-20 B2	17W	561680	7911258	29-Aug-11
	EO-20 B3	17W	561649	7911241	29-Aug-11
	EO-01 B1	17W	560926	7911488	4-Sep-07
	EO-01 B2	17W	560940	7911429	4-Sep-07

Table 3-5. - continued -

Waterbody	Site ID	UTM			Sample Date
		Zone	Easting	Northing	
Mary River continued	EO-01 B3	17W	560906	7911533	4-Sep-07
	GO-03 B1	17W	567194	7912596	5-Sep-07
	GO-03 B2	17W	567220	7912598	5-Sep-07
	GO-03 B3	17W	567247	7912602	5-Sep-07
	GO-09 B1	17W	571665	7916111	1-Sep-06
	GO-09 B2	17W	571665	7916111	1-Sep-06
	GO-09 B3	17W	571665	7916111	1-Sep-06
	GO-09 B1	17W	571572	7916367	5-Sep-07
	GO-09 B2	17W	571577	7916330	5-Sep-07
	GO-09 B3	17W	571566	7916302	5-Sep-07
Tom River	IO-01 B1	17W	555441	7914175	25-Aug-06
	IO-01 B2	17W	555441	7914175	25-Aug-06
	IO-01 B3	17W	555441	7914175	25-Aug-06
	IO-01 B1	17W	555407	7914291	5-Sep-07
	IO-01 B2	17W	555449	7914160	5-Sep-07
	IO-01 B3	17W	555496	7914154	5-Sep-07
	IO-04 B1	17W	557136	7918889	23-Aug-06
	IO-04 B2	17W	557136	7918889	23-Aug-06
	IO-04 B3	17W	557136	7918889	23-Aug-06
	IO-04 B1	17W	557132	7918928	5-Sep-07
	IO-04 B2	17W	557153	7918972	5-Sep-07
	IO-04 B3	17W	557155	7918994	5-Sep-07
Camp Lake Tributaries	FS-01 (Trib.1, Reach 1)	17W	558264	7914877	Aug-05
	KO-01 (Trib.2, Reach 2)	17W	557390	7915030	Aug-05
	JO-01 (lake outlet stream)	17W	555701	7913773	Aug-05
	CLT-1 DS B1	17W	557641	7914880	2-Sep-07
	CLT-1 DS B2	17W	557648	7914888	2-Sep-07
	CLT-1 DS B3	17W	557653	7914898	2-Sep-07
	CLT-1 US B1	17W	558515	7915032	4-Sep-07
	CLT-1 US B2	17W	558509	7915020	4-Sep-07
	CLT-1 US B3	17W	558497	7914999	4-Sep-07
	L1-09	17W	558407	7914890	1-Sep-11
	L1-09	17W	558393	7914889	1-Sep-11
	L1-09	17W	558407	7914882	1-Sep-11

Table 3-5. - continued -

Waterbody	Site ID	UTM			Sample Date
		Zone	Easting	Northing	
Camp Lake Tributaries continued	L1-08	17W	558513	7914893	1-Sep-11
	L1-08	17W	558507	7914907	1-Sep-11
	L1-08	17W	558494	7914919	1-Sep-11
	L2-03	17W	558593	7914797	1-Sep-11
	L2-03	17W	558605	7914784	1-Sep-11
	L2-03	17W	554641	7914753	1-Sep-11
	CLT-2 DS B1	17W	557466	7914969	2-Sep-07
	CLT-2 DS B2	17W	557465	7914977	2-Sep-07
	CLT-2 DS B3	17W	557449	7914956	2-Sep-07
	CLT-2 US B1	17W	557448	7915324	2-Sep-07
	CLT-2 US B2	17W	557450	7915287	2-Sep-07
	CLT-2 US B3	17W	557464	7915251	2-Sep-07
Sheardown Lake Tributaries	SDLT-1 Reach 1 B1	17W	560320	7913504	10-Sep-08
	SDLT-1 Reach 1 B2	17W	560337	7913512	10-Sep-08
	SDLT-1 Reach 1 B3	17W	560346	7913525	10-Sep-08
	SDLT-1 Reach 1 B1	17W	560320	7913504	29-Aug-13
	SDLT-1 Reach 1 B2	17W	560337	7913512	29-Aug-13
	SDLT-1 Reach 1 B3	17W	560346	7913525	30-Aug-13
	SDLT-1 Reach 2a	17W	560753	7913507	Aug-05
	SDLT-1 DS Reach 2 B1	17W	560710	7913504	31-Aug-07
	SDLT-1 DS Reach 2 B2	17W	560716	7913506	31-Aug-07
	SDLT-1 DS Reach 2 B3	17W	560722	7913504	31-Aug-07
	SDLT-1 Reach 2 B1	17W	560739	7913502	10-Sep-08
	SDLT-1 Reach 2 B2	17W	560756	7913502	10-Sep-08
	SDLT-1 Reach 2 B3	17W	560774	7913598	10-Sep-08
	SDLT-1 Reach 2 B1	17W	560739	7913502	30-Aug-13
	SDLT-1 Reach 2 B2	17W	560756	7913502	30-Aug-13
	SDLT-1 Reach 2 B3	17W	560774	7913508	30-Aug-13
	SDLT-1 US Reach 4 B1	17W	561503	7913541	31-Aug-07
	SDLT-1 US Reach 4 B2	17W	-	-	31-Aug-07
	SDLT-1 US Reach 4 B3	17W	561521	7913524	31-Aug-07
	SDLT-1 Reach 4 B1	17W	561490	7913533	11-Sep-08
	SDLT-1 Reach 4 B2	17W	561506	7913538	11-Sep-08
	SDLT-1 Reach 4 B3	17W	561511	7913536	11-Sep-08
	SDLT-1 Reach 4 B1	17W	561476	7913550	4-Sep-11

Table 3-5. - continued -

Waterbody	Site ID	UTM			Sample Date
		Zone	Easting	Northing	
Sheardown Lake Tributaries continued	SDLT-1 Reach 4 B2	17W	561483	7913546	4-Sep-11
	SDLT-1 Reach 4 B3	17W	561490	7913533	4-Sep-11
	SDLT-1 Reach 4 B1	17W	561490	7913533	30-Aug-13
	SDLT-1 Reach 4 B2	17W	561506	7913538	30-Aug-13
	SDLT-1 Reach 4 B3	17W	561526	7913531	31-Aug-13
	SDLT-9 US B1	17W	561771	7911813	1-Sep-07
	SDLT-9 US B2	17W	561774	7911814	1-Sep-07
	SDLT-9 US B3	17W	561784	7911819	1-Sep-07
	SDLT-9 US B1	17W	561771	7911813	31-Aug-13
	SDLT-9 US B2	17W	561774	7911820	31-Aug-13
	SDLT-9 US B3	17W	561784	7911819	31-Aug-13
	SDLT-12 DS B1	17W	561000	7942973	1-Sep-07
	SDLT-12 DS B2	17W	561011	7912970	1-Sep-07
	SDLT-12 DS B3	17W	561027	7912966	1-Sep-07
	SDLT-12 DS B1	17W	561000	7942973	31-Aug-13
	SDLT-12 DS B2	17W	561011	7912970	31-Aug-13
	SDLT-12 US B1	17W	561091	7912833	1-Sep-07
	SDLT-12 US B2	17W	561092	7912848	1-Sep-07
	SDLT-12 US B3	17W	561097	7912837	1-Sep-07

Table 3-6. Benthic macroinvertebrate metrics considered for the CREMP.

Effect Indicator	Metric	Unit
Abundance/Density	Total Macroinvertebrate Density	(individuals/m^2)
Composition	Chironomidae Proportion	(% of total density)
	Shannon's Equitability (evenness)	-
	Simpson's Diversity Index	-
Richness	Total Taxa Richness	genus-level
	Hill's Effective Richness	genus-level

Table 3-7. Classification of lacustrine habitats in the Mine Area.

<table>
<tr><th>Zone</th><th colspan="2">Substrata Type/ Aquatic Macrophytes</th><th>Habitat Type</th></tr>
<tr><td rowspan="5">Shoreline Zone
(≤ 2 m water depth)</td><td colspan="2">Cobble/Boulder</td><td>1</td></tr>
<tr><td colspan="2">Gravel/Pebble</td><td>2</td></tr>
<tr><td colspan="2">Sand</td><td>3</td></tr>
<tr><td rowspan="2">Fine Sand, Silt/Clay</td><td>Macrophytes Absent</td><td>4</td></tr>
<tr><td>Macrophytes Present</td><td>5</td></tr>
<tr><td rowspan="5">Littoral/Euphotic Zone
(> 2-12 m water depth)</td><td colspan="2">Cobble/Boulder</td><td>6</td></tr>
<tr><td colspan="2">Gravel/Pebble</td><td>7</td></tr>
<tr><td colspan="2">Sand</td><td>8</td></tr>
<tr><td rowspan="2">Fine Sand, Silt/Clay</td><td>Macrophytes Absent</td><td>9</td></tr>
<tr><td>Macrophytes Present</td><td>10</td></tr>
<tr><td rowspan="4">Profundal Zone
(> 12 m water depth)</td><td colspan="2">Cobble/Boulder</td><td>11</td></tr>
<tr><td colspan="2">Gravel/Pebble</td><td>12</td></tr>
<tr><td colspan="2">Sand</td><td>13</td></tr>
<tr><td>Fine Sand, Silt/Clay</td><td>Macrophytes Absent</td><td>14</td></tr>
</table>

Table 3-8. Summary statistics for total macroinvertebrate density: all Mine Area lakes by aquatic habitat type.

Metric	Total Macroinvertebrate Density (individuals/m^2)									
Habitat Type	**4**			**9**		**10**	**14**			
Lake	**Camp**	**SDL NW**	**SDL SE**	**Mary**	**SDL NW**	**SDL SE**	**Camp**	**Mary**	**SDL NW**	**SDL SE**
Year	2007	2008	2007	2007	2007, 2008	2007	2007	2006, 2007	2007, 2008, 2011	2007
n (rep. stn.)	3	8	3	9	22	3	12	11	12	6
Mean	14	829	4270	4005	3658	18562	2649	2668	1588	5042
Median	0	507	1026	3957	2165	15235	1978	2670	1665	4674
SD	25.10	782.76	6137.08	2879.22	3428.83	11312.34	1496.51	2057.11	1233.42	1350.49
SE	14.49	276.75	3543.24	959.74	731.03	6531.18	432.01	620.24	356.06	551.34
Min	0	162	435	783	250	9287	730	609	102	3548
Max	43	2129	11348	8870	10470	31165	6226	7017	4652	6730
Sub-samples (20% precision)	75	22	52	13	22	9	8	15	15	2
95th Percentile	39.1	2022.8	10315.7	8243.5	10027.8	29572.2	5250.4	5917.0	3384.8	6700.0
COV (%)	173	94	144	72	94	61	57	77	78	27
Mean + 2 x SD	64.70	2394.87	16543.73	9763.27	10515.84	41187.00	5641.58	6782.20	4054.50	7743.01
2 x Mean	28.99	1658.70	8539.14	8009.66	7316.36	37124.64	5297.10	5335.96	3175.32	10084.06
Mean +50%	21.74	1244.03	6404.36	6007.25	5487.27	27843.48	3972.83	4001.97	2381.49	7563.05
Mean -50%	7.25	414.68	2134.79	2002.42	1829.09	9281.16	1324.28	1333.99	793.83	2521.02
Mean +25%	18.12	1036.69	5336.96	5006.04	4572.73	23202.90	3310.69	3334.98	1984.58	6302.54
Mean -25%	10.87	622.01	3202.18	3003.62	2743.64	13921.74	1986.41	2000.99	1190.75	3781.52
Mean +20%	17.39	995.22	5123.48	4805.80	4389.82	22274.78	3178.26	3201.58	1905.19	6050.44
Mean -20%	11.59	663.48	3415.66	3203.86	2926.54	14849.86	2118.84	2134.38	1270.13	4033.62
Data Normally Distributed	- [1]	Yes	- [1]	Yes	No	- [1]	Yes	Yes	Yes	Yes

[1] insufficient data points to determine

Table 3-9. Summary statistics for total macroinvertebrate density: Sheardown Lake NW by aquatic habitat type and year.

Metric	Total Macroinvertebrate Density (individuals/m^2)					
Habitat Type	4	9		14		
Year	2008	2007	2008	2007	2008	2011
n (rep. stn.)	8	12	10	6	3	3
Mean	829	6026	817	1577	149	3048
Median	507	5887	798	1665	158	2348
SD	782.76	2970.50	448.25	218.79	42.98	1392.69
SE	276.75	857.51	141.75	89.32	24.81	804.07
Min	162	2026	250	1226	102	2145
Max	2129	10470	1677	1783	186	4652
Sub-samples (20% precision)	22	6	8	0.5	2	5
95th Percentile	2022.8	10259.1	1516.9	1769.6	183.3	4421.7
COV (%)	94	49	55	14	29	46
Mean + 2 x SD	2394.87	11967.09	1713.20	2014.39	234.66	5833.68
2 x Mean	1658.70	12052.18	1633.40	3153.62	297.40	6096.62
Mean +50%	1244.03	9039.14	1225.05	2365.22	223.05	4572.46
Mean -50%	414.68	3013.05	408.35	788.41	74.35	1524.15
Mean +25%	1036.69	7532.61	1020.88	1971.01	185.88	3810.39
Mean -25%	622.01	4519.57	612.53	1182.61	111.53	2286.23
Mean +20%	995.22	7231.31	980.04	1892.17	178.44	3657.97
Mean -20%	663.48	4820.87	653.36	1261.45	118.96	2438.65
Data Normally Distributed	Yes	No		Yes		
Significant Inter-annual Difference	-	Yes [1]		Yes - all years [2]		

[1] p-value <0.0001 (Mann-Whitney U-test)

[2] p-value 2007 vs 2008 0.015; 2007 vs 2011 0.013; 2008 vs 2011 0.001 (ANOVA with Bonferroni pairwise comparison)

Table 3-10. Summary statistics for Chironomidae proportion: all Mine Area lakes by aquatic habitat type.

Metric	Chironomidae Proportion (% of total density)									
Habitat Type	4			9		10	14			
Lake	Camp	SDL NW	SDL SE	Mary	SDL NW	SDL SE	Camp	Mary	SDL NW	SDL SE
Year	2007	2008	2007	2007	2007, 2008	2007	2007	2006, 2007	2007, 2008, 2011	2007
n (rep. stn.)	3	8	3	9	22	3	12	11	12	6
Mean	7	66	55	90	83	73	95	96	94	97
Median	0	64	56	96	86	68	96	99	95	98
SD	11.55	18.28	41.93	10.47	9.05	13.05	4.32	4.54	2.55	2.85
SE	6.67	6.46	24.21	3.49	1.93	7.54	1.25	1.37	0.74	1.16
Min	0	40	13	70	67	62	88	89	88	92
Max	20	88	97	99	98	87	100	100	97	100
Sub-samples (20% precision)	75	2	14	0.3	0.3	1	0.1	0.1	0.02	0.02
95th Percentile	18.0	87.7	92.5	98.8	95.3	85.3	100.0	100.0	96.6	99.7
COV (%)	173	28	76	12	11	18	5	5	3	3
Mean + 2 x SD	29.76	102.33	138.95	111.05	101.48	98.66	103.57	105.52	99.28	102.71
2 x Mean	13.33	131.54	110.18	180.22	166.76	145.12	189.87	192.88	188.36	194.02
Mean +50%	10.00	98.66	82.64	135.17	125.07	108.84	142.40	144.66	141.27	145.52
Mean -50%	3.33	32.89	27.55	45.06	41.69	36.28	47.47	48.22	47.09	48.51
Mean +25%	8.33	82.21	68.86	112.64	104.23	90.70	118.67	120.55	117.73	121.26
Mean -25%	5.00	49.33	41.32	67.58	62.54	54.42	71.20	72.33	70.64	72.76
Mean +20%	8.00	78.92	66.11	108.13	100.06	87.07	113.92	115.73	113.02	116.41
Mean -20%	5.33	52.62	44.07	72.09	66.70	58.05	75.95	77.15	75.34	77.61
Data Normally Distributed	-[1]	Yes	-[1]	No	Yes	-[1]	Yes	No	Yes	Yes

[1] insufficient data points to determine

Table 3-11. Summary statistics for Chironomidae proportion: Sheardown Lake NW by aquatic habitat type and year.

Metric	Chironomidae Proportion (% of total density)					
Habitat Type	4	9		14		
Year	2008	2007	2008	2007	2008	2011
n (rep. stn.)	8	12	10	6	3	3
Mean	66	83	84	95	93	93
Median	64	87	85	96	95	93
SD	18.28	10.67	7.17	1.58	4.08	1.91
SE	6.46	3.08	2.27	0.64	2.36	1.10
Min	40	67	75	92	88	91
Max	88	98	95	97	96	94
Sub-samples (20% precision)	2	0.4	0.2	0.01	0.05	0.01
95th Percentile	87.7	96.5	94.4	96.7	95.7	94.3
COV (%)	28	13	9	2	4	2
Mean + 2 x SD	102.33	104.34	98.19	98.58	101.33	96.55
2 x Mean	131.54	166.00	167.70	190.84	186.34	185.46
Mean +50%	98.66	124.50	125.78	143.13	139.76	139.10
Mean -50%	32.89	41.50	41.93	47.71	46.59	46.37
Mean +25%	82.21	103.75	104.81	119.28	116.46	115.91
Mean -25%	49.33	62.25	62.89	71.57	69.88	69.55
Mean +20%	78.92	99.60	100.62	114.50	111.80	111.28
Mean -20%	52.62	66.40	67.08	76.34	74.54	74.18
Data Normally Distributed	Yes	Yes		Yes		
Significant Inter-annual Difference	-	No [1]		No - all years [2]		

[1] p-value 0.833 (t-test)

[2] p-value 2007 vs 2008 0.224; 2007 vs 2011 0.152; 2008 vs 2011 0.828 (ANOVA with Bonferroni pairwise comparison)

Table 3-12. Summary statistics for Shannon's Equitability: all Mine Area lakes by aquatic habitat type.

Metric	**Shannon's Equitability (evenness)**									
Habitat Type	**4**			**9**		**10**	**14**			
Lake	**Camp**	**SDL NW**	**SDL SE**	**Mary**	**SDL NW**	**SDL SE**	**Camp**	**Mary**	**SDL NW**	**SDL SE**
Year	2007	2008	2007	2007	2007, 2008	2007	2007	2006, 2007	2007, 2008, 2011	2007
n (rep. stn.)	1	8	3	9	22	3	12	11	12	6
Mean	0.72	0.65	0.67	0.70	0.72	0.65	0.56	0.52	0.40	0.59
Median	-	0.64	0.61	0.76	0.74	0.69	0.57	0.56	0.41	0.59
SD	-	0.10	0.16	0.16	0.08	0.09	0.13	0.21	0.11	0.09
SE	-	0.03	0.09	0.05	0.02	0.05	0.04	0.06	0.03	0.04
Min	-	0.49	0.56	0.37	0.56	0.54	0.33	0.00	0.23	0.46
Max	-	0.79	0.86	0.86	0.84	0.71	0.82	0.81	0.57	0.68
Sub-samples (20% precision)	-	1	1	1	0.3	0	1	4	2	1
95th Percentile	0.72	0.77	0.83	0.84	0.83	0.71	0.75	0.73	0.56	0.68
COV (%)	0	15	24	22	11	14	24	40	28	15
Mean + 2 x SD	0.72	0.84	1.00	1.01	0.87	0.82	0.83	0.94	0.63	0.76
2 x Mean	1.44	1.29	1.35	1.39	1.43	1.29	1.12	1.04	0.81	1.17
Mean +50%	1.08	0.97	1.01	1.04	1.07	0.97	0.84	0.78	0.61	0.88
Mean -50%	0.36	0.32	0.34	0.35	0.36	0.32	0.28	0.26	0.20	0.29
Mean +25%	0.90	0.81	0.84	0.87	0.89	0.81	0.70	0.65	0.50	0.73
Mean -25%	0.54	0.48	0.51	0.52	0.54	0.48	0.42	0.39	0.30	0.44
Mean +20%	0.86	0.77	0.81	0.84	0.86	0.78	0.67	0.62	0.48	0.70
Mean -20%	0.58	0.52	0.54	0.56	0.57	0.52	0.45	0.42	0.32	0.47
Data Normally Distributed	- [1]	Yes	- [1]	Yes	Yes	- [1]	Yes	Yes	Yes	Yes

[1] insufficient data points to determine

Table 3-13. Summary statistics for Simpson's Diversity Index: all Mine Area lakes by aquatic habitat type.

Metric	**Simpson's Diversity Index**									
Habitat Type	**4**			**9**		**10**	**14**			
Lake	**Camp**	**SDL NW**	**SDL SE**	**Mary**	**SDL NW**	**SDL SE**	**Camp**	**Mary**	**SDL NW**	**SDL SE**
Year	2007	2008	2007	2007	2007, 2008	2007	2007	2006, 2007	2007, 2008, 2011	2007
n (rep. stn.)	1	8	3	9	22	3	12	11	12	6
Mean	0.33	0.73	0.73	0.67	0.76	0.71	0.60	0.50	0.37	0.61
Median	-	0.72	0.67	0.73	0.79	0.77	0.61	0.58	0.37	0.65
SD	-	0.09	0.12	0.12	0.08	0.12	0.12	0.23	0.14	0.15
SE	-	0.03	0.07	0.04	0.02	0.07	0.03	0.07	0.04	0.06
Min	-	0.57	0.66	0.43	0.56	0.57	0.39	0.00	0.15	0.35
Max	-	0.83	0.87	0.77	0.86	0.78	0.76	0.69	0.58	0.75
Sub-samples (20% precision)	-	0.4	1	1	0.3	1	1	5	4	1
95th Percentile	0.33	0.83	0.85	0.77	0.86	0.78	0.76	0.68	0.56	0.74
COV (%)	0	13	16	17	10	17	19	46	39	24
Mean + 2 x SD	0.33	0.91	0.97	0.90	0.92	0.95	0.83	0.96	0.65	0.90
2 x Mean	0.66	1.46	1.47	1.34	1.53	1.42	1.20	1.00	0.73	1.22
Mean +50%	0.50	1.09	1.10	1.01	1.15	1.06	0.90	0.75	0.55	0.91
Mean -50%	0.17	0.36	0.37	0.34	0.38	0.35	0.30	0.25	0.18	0.30
Mean +25%	0.41	0.91	0.92	0.84	0.96	0.89	0.75	0.63	0.46	0.76
Mean -25%	0.25	0.55	0.55	0.50	0.57	0.53	0.45	0.38	0.27	0.46
Mean +20%	0.40	0.88	0.88	0.80	0.92	0.85	0.72	0.60	0.44	0.73
Mean -20%	0.26	0.58	0.59	0.54	0.61	0.57	0.48	0.40	0.29	0.49
Data Normally Distributed	- [1]	Yes	- [1]	Yes	No	- [1]	Yes	No	Yes	Yes

[1] insufficient data points to determine

Table 3-14. Summary statistics for Shannon's Equitability: Sheardown Lake NW by aquatic habitat type and year.

Metric	Shannon's Equitability (evenness)					
Habitat Type	4	9		14		
Year	2008	2007	2008	2007	2008	2011
n (rep. stn.)	8	12	10	6	3	3
Mean	0.65	0.73	0.70	0.36	0.52	0.39
Median	0.64	0.75	0.72	0.39	0.56	0.33
SD	0.10	0.08	0.08	0.10	0.08	0.13
SE	0.03	0.02	0.03	0.04	0.05	0.07
Min	0.49	0.57	0.56	0.23	0.42	0.30
Max	0.79	0.84	0.83	0.45	0.57	0.54
Sub-samples (20% precision)	1	0.3	0.3	2	1	3
95th Percentile	0.77	0.81	0.81	0.45	0.57	0.51
COV (%)	15	10	12	27	16	33
Mean + 2 x SD	0.84	0.88	0.86	0.55	0.68	0.64
2 x Mean	1.29	1.46	1.40	0.71	1.03	0.78
Mean +50%	0.97	1.09	1.05	0.53	0.77	0.58
Mean -50%	0.32	0.36	0.35	0.18	0.26	0.19
Mean +25%	0.81	0.91	0.88	0.44	0.65	0.49
Mean -25%	0.48	0.55	0.53	0.27	0.39	0.29
Mean +20%	0.77	0.87	0.84	0.43	0.62	0.47
Mean -20%	0.52	0.58	0.56	0.28	0.41	0.31
Data Normally Distributed	Yes	Yes		Yes		
Significant Inter-annual Difference	-	No [1]		No - all years [2]		

[1] p-value 0.416 (t-test)

[2] p-value 2007 vs 2008 0.051; 2007 vs 2011 0.659; 2008 vs 2011 0.155 (ANOVA with Bonferroni pairwise comparison)

Table 3-15. Summary statistics for Simpson's Diversity Index: Sheardown Lake NW by aquatic habitat type and year.

Metric	Simpson's Diversity Index					
Habitat Type	**4**	**9**		**14**		
Year	**2008**	**2007**	**2008**	**2007**	**2008**	**2011**
n (rep. stn.)	8	12	10	6	3	3
Mean	0.73	0.77	0.76	0.32	0.49	0.32
Median	0.72	0.79	0.78	0.35	0.55	0.24
SD	0.09	0.07	0.09	0.13	0.12	0.15
SE	0.03	0.02	0.03	0.05	0.07	0.09
Min	0.57	0.59	0.56	0.15	0.36	0.22
Max	0.83	0.86	0.86	0.47	0.58	0.49
Sub-samples (20% precision)	0.4	0.2	0.3	4	1	5
95th Percentile	0.83	0.85	0.85	0.46	0.57	0.47
COV (%)	13	10	12	41	24	47
Mean + 2 x SD	0.91	0.92	0.94	0.59	0.73	0.62
2 x Mean	1.46	1.54	1.52	0.65	0.99	0.64
Mean +50%	1.09	1.15	1.14	0.49	0.74	0.48
Mean -50%	0.36	0.38	0.38	0.16	0.25	0.16
Mean +25%	0.91	0.96	0.95	0.40	0.62	0.40
Mean -25%	0.55	0.58	0.57	0.24	0.37	0.24
Mean +20%	0.88	0.92	0.91	0.39	0.59	0.38
Mean -20%	0.58	0.61	0.61	0.26	0.40	0.25
Data Normally Distributed	Yes	No		Yes		
Significant Inter-annual Difference	-	No [1]		No - all years [2]		

[1] p-value 0.974 (Mann-Whitney U-test)

[2] p-value 2007 vs 2008 0.103; 2007 vs 2011 0.961; 2008 vs 2011 0.140 (ANOVA with Bonferroni pairwise comparison)

Table 3-16. Summary statistics for total taxa richness: all Mine Area lakes by aquatic habitat type.

Metric	Total Taxa Richness (genus-level)									
Habitat Type	4			9		10	14			
Lake	Camp	SDL NW	SDL SE	Mary	SDL NW	SDL SE	Camp	Mary	SDL NW	SDL SE
Year	2007	2008	2007	2007	2007, 2008	2007	2007	2006, 2007	2007, 2008, 2011	2007
n (rep. stn.)	3	8	3	9	22	3	12	11	12	6
Mean	1	15	15	8	13	13	9	9	7	9
Median	0	16	15	8	14	13	9	8	8	10
SD	1.15	1.04	1.53	1.42	2.72	1.53	2.76	5.66	1.62	2.83
SE	0.67	0.37	0.88	0.47	0.58	0.88	0.80	1.71	0.47	1.15
Min	0	13	14	5	8	12	6	1	4	4
Max	2	16	17	10	20	15	14	18	9	12
Sub-samples (20% precision)	75	0.1	0.2	1	1	0.3	2	10	1	2
95th Percentile	1.8	16.0	16.8	9.2	16.0	14.8	13.5	16.5	9.0	11.8
COV (%)	173	7	10	19	20	11	31	64	22	31
Mean + 2 x SD	2.98	17.32	18.39	10.40	18.85	16.39	14.53	20.24	10.66	14.66
2 x Mean	1.33	30.50	30.67	15.11	26.82	26.67	18.00	17.82	14.83	18.00
Mean +50%	1.00	22.88	23.00	28.50	20.11	20.00	13.50	13.36	11.13	13.50
Mean -50%	0.33	7.63	7.67	9.50	6.70	6.67	4.50	4.45	3.71	4.50
Mean +25%	0.83	19.06	19.17	23.75	16.76	16.67	11.25	11.14	9.27	11.25
Mean -25%	0.50	11.44	11.50	14.25	10.06	10.00	6.75	6.68	5.56	6.75
Mean +20%	0.80	18.30	18.40	22.80	16.09	16.00	10.80	10.69	8.90	10.80
Mean -20%	0.53	12.20	12.27	15.20	10.73	10.67	7.20	7.13	5.93	7.20
Data Normally Distributed	- [1]	No	- [1]	Yes	Yes	- [1]	Yes	Yes	Yes	Yes

[1] insufficient data points to determine

Table 3-17. Summary statistics for Hill's effective richness: all Mine Area lakes by aquatic habitat type.

Metric	Hill's Effective Richness (genus-level)									
Habitat Type	4			9		10	14			
Lake	Camp	SDL NW	SDL SE	Mary	SDL NW	SDL SE	Camp	Mary	SDL NW	SDL SE
Year	2007	2008	2007	2007	2007, 2008	2007	2007	2006, 2007	2007, 2008, 2011	2007
n (rep. stn.)	1	8	3	9	22	3	12	11	12	6
Mean	2	6	7	4	6	5	4	3	2	4
Median	-	6	5	5	6	6	3	4	2	4
SD	-	1.63	3.06	1.05	1.47	1.23	1.24	1.31	0.66	1.15
SE	-	0.58	1.77	0.35	0.31	0.71	0.36	0.40	0.19	0.47
Min	-	4	5	2	4	4	2	1	1	2
Max	-	8	10	5	9	6	6	5	3	5
Sub-samples (20% precision)	-	2	5	2	1	1	3	4	2	2
95th Percentile	1.6	8.1	9.7	5.3	8.7	6.4	5.5	4.9	3.3	5.0
COV (%)	0	27	46	26	23	23	35	39	28	31
Mean + 2 x SD	1.65	9.25	12.78	6.21	9.40	7.89	6.03	5.96	3.65	6.01
2 x Mean	3.30	11.98	13.33	8.22	12.94	10.85	7.11	6.68	4.68	7.43
Mean +50%	2.47	8.98	10.00	6.17	9.70	8.14	5.33	5.01	3.51	5.57
Mean -50%	0.82	2.99	3.33	2.06	3.23	2.71	1.78	1.67	1.17	1.86
Mean +25%	2.06	7.49	8.33	5.14	8.09	6.78	4.44	4.18	2.92	4.65
Mean -25%	1.24	4.49	5.00	3.08	4.85	4.07	2.67	2.51	1.75	2.79
Mean +20%	1.98	7.19	8.00	4.93	7.76	6.51	4.27	4.01	2.81	4.46
Mean -20%	1.32	4.79	5.33	3.29	5.18	4.34	2.84	2.67	1.87	2.97
Data Normally Distributed	- [1]	Yes	- [1]	Yes	Yes	- [1]	Yes	Yes	Yes	Yes

[1] insufficient data points to determine

Table 3-18. Summary statistics for total taxa richness: Sheardown Lake NW by aquatic habitat type and year.

Metric	Total Taxa Richness (genus-level)					
Habitat Type	4	9		14		
Year	2008	2007	2008	2007	2008	2011
n (rep. stn.)	8	12	10	6	3	3
Mean	15	12	15	8	8	7
Median	16	13	15	9	8	6
SD	1.04	2.35	2.67	2.07	0.58	1.73
SE	0.37	0.68	0.84	0.85	0.33	1.00
Min	13	8	11	4	7	6
Max	16	15	20	9	8	9
Sub-samples (20% precision)	0.1	1	1	2	0.1	2
95th Percentile	16.0	15.0	18.2	9.0	8.0	8.7
COV (%)	7	19	18	28	8	25
Mean + 2 x SD	17.32	17.03	20.04	11.65	8.82	10.46
2 x Mean	30.50	24.67	29.40	15.00	15.33	14.00
Mean +50%	22.88	18.50	22.05	11.25	11.50	10.50
Mean -50%	7.63	6.17	7.35	3.75	3.83	3.50
Mean +25%	19.06	15.42	18.38	9.38	9.58	8.75
Mean -25%	11.44	9.25	11.03	5.63	5.75	5.25
Mean +20%	18.30	14.80	17.64	9.00	9.20	8.40
Mean -20%	12.20	9.87	11.76	6.00	6.13	5.60
Data Normally Distributed	No	Yes		Yes		
Significant Inter-annual Difference	-	Yes [1]		No - all years [2]		

[1] p-value 0.039 (t-test)

[2] p-value 2007 vs 2008 0.897; 2007 vs 2011 0.699; 2008 vs 2011 0.655 (ANOVA with Bonferroni pairwise comparison)

Table 3-19. Summary statistics for Hill's effective richness: Sheardown Lake NW by aquatic habitat type and year.

Metric	Hill's Effective Richness (genus-level)					
Habitat Type	4	9		14		
Year	2008	2007	2008	2007	2008	2011
n (rep. stn.)	8	12	10	6	3	3
Mean	6	6	7	2	3	2
Median	6	6	7	2	3	2
SD	1.63	1.38	1.60	0.51	0.56	0.86
SE	0.58	0.40	0.51	0.21	0.32	0.49
Min	4	4	4	1	2	2
Max	8	9	9	3	3	3
Sub-samples (20% precision)	2	1	1	1	1	4
95th Percentile	8.1	8.5	9.1	2.6	3.3	3.1
COV (%)	27	22	24	24	19	38
Mean + 2 x SD	9.25	9.05	9.90	3.11	4.03	3.97
2 x Mean	11.98	12.56	13.39	4.19	5.82	4.50
Mean +50%	8.98	9.42	10.04	3.15	4.37	3.38
Mean -50%	2.99	3.14	3.35	1.05	1.46	1.13
Mean +25%	7.49	7.85	8.37	2.62	3.64	2.81
Mean -25%	4.49	4.71	5.02	1.57	2.18	1.69
Mean +20%	7.19	7.54	8.04	2.52	3.49	2.70
Mean -20%	4.79	5.02	5.36	1.68	2.33	1.80
Data Normally Distributed	No	Yes		Yes		
Significant Inter-annual Difference	-	No [1]		No - all years [2]		

[1] p-value 0.520 (t-test)

[2] p-value 2007 vs 2008 0.094; 2007 vs 2011 0.729; 2008 vs 2011 0.222 (ANOVA with Bonferroni pairwise comparison)

Table 3-20. Summary statistics for total macroinvertebrate density: Sheardown Lake Tributary 1 by reach and year.

Metric	Total Macroinvertebrate Density (individuals/m^2)							
Stream Reach	**1**	**2**			**4**			
Year	**2008**	**2007**	**2008**	**All**	**2007**	**2008**	**2011**	**All**
n (rep. stn.)	3	3	3	6	3	3	3	9
Mean	299	441	647	544	4520	3042	2432	3332
Median	315	421	429	425	2043	3225	1454	2266
SD	53.49	110.73	465.01	322.72	4372.64	702.61	1711.24	2549.53
SE	30.88	63.93	268.47	131.75	2524.55	405.65	987.99	849.84
Min	239	342	332	332	1948	2266	1435	1435
Max	342	561	1181	1181	9569	3635	4408	9569
Sub-samples (20% precision)	1	2	13	9	23	1	12	15
95th Percentile	339.6	546.8	1106.2	1026.3	8816.5	3594.0	4112.8	7504.7
COV (%)	18	25	72	59	97	23	70	77
Mean + 2 x SD	405.95	662.69	1577.44	1189.78	13265.56	4447.14	5854.79	8430.56
2 x Mean	597.94	882.47	1294.85	1088.66	9040.55	6083.85	4864.60	6663.00
Mean +50%	448.45	661.86	971.13	816.49	6780.41	4562.89	3648.45	4997.25
Mean -50%	149.48	220.62	323.71	272.16	2260.14	1520.96	1216.15	1665.75
Mean +25%	373.71	551.55	809.28	680.41	5650.34	3802.41	3040.38	4164.38
Mean -25%	224.23	330.93	485.57	408.25	3390.21	2281.44	1824.23	2498.63
Mean +20%	358.76	529.48	776.91	653.20	5424.33	3650.31	2918.76	3997.80
Mean -20%	239.18	352.99	517.94	435.46	3616.22	2433.54	1945.84	2665.20
Data Normally Distributed	- [1]	No			No			
Significant Inter-annual Difference	-	No [2]			No [3]			

[1] insufficient data points to determine

[2] p-value 1.000 (Mann-Whitney U-test)

[3] p-value 0.561

Table 3-21. Summary statistics for Chironomidae proportion: Sheardown Lake Tributary 1 by reach and year.

Metric	**Chironomidae Proportion (% of total density)**							
Stream Reach	**1**	**2**			**4**			
Year	**2008**	**2007**	**2008**	**All**	**2007**	**2008**	**2011**	**All**
n (rep. stn.)	3	3	3	6	3	3	3	9
Mean	69	64	78	71	92	94	87	91
Median	70	74	76	75	93	93	86	92
SD	1.97	22.96	4.20	16.56	3.84	2.19	2.68	4.06
SE	1.13	13.26	2.42	6.76	2.21	1.27	1.55	1.35
Min	67	38	75	38	88	92	85	85
Max	71	81	83	83	95	96	90	96
Sub-samples (20% precision)	0.02	3	0.1	1	0.04	0.01	0.02	0.05
95th Percentile	70.5	80.1	81.9	82.1	95.3	95.7	89.4	95.7
COV (%)	3	36	5	23	4	2	3	4
Mean + 2 x SD	73.03	110.04	86.22	104.09	99.87	97.97	92.12	98.96
2 x Mean	138.19	128.24	155.64	141.94	184.41	187.16	173.50	181.69
Mean +50%	103.64	96.18	116.73	106.46	138.31	140.37	130.12	136.27
Mean -50%	34.55	32.06	38.91	35.49	46.10	46.79	43.37	45.42
Mean +25%	86.37	80.15	97.28	88.71	115.25	116.98	108.44	113.56
Mean -25%	51.82	48.09	58.37	53.23	69.15	70.19	65.06	68.13
Mean +20%	82.91	76.95	93.39	85.17	110.64	112.30	104.10	109.01
Mean -20%	55.28	51.30	62.26	56.78	73.76	74.86	69.40	72.68
Data Normally Distributed	- [1]	No			Yes			
Significant Inter-annual Difference	-	No [2]			No [3]			

[1] insufficient data points to determine

[2] p-value 0.400 (Mann-Whitney U-test)

[3] p-value 2007 vs 2008 0.592; 2007 vs 2011 0.067; 2008 vs 2011 0.031

Table 3-22. Summary statistics for Shannon's Equitability: Sheardown Lake Tributary 1 by reach and year.

Metric	Shannon's Equitability (evenness)							
Stream Reach	1	2			4			
Year	2008	2007	2008	All	2007	2008	2011	All
n (rep. stn.)	3	3	3	6	3	3	3	9
Mean	0.77	0.70	0.71	0.71	0.62	0.66	0.62	0.63
Median	0.77	0.70	0.72	0.71	0.67	0.68	0.65	0.67
SD	0.06	0.03	0.03	0.03	0.18	0.08	0.11	0.11
SE	0.03	0.02	0.01	0.01	0.10	0.05	0.06	0.04
Min	0.72	0.67	0.69	0.67	0.42	0.57	0.50	0.42
Max	0.83	0.73	0.74	0.74	0.76	0.72	0.71	0.76
Sub-samples (20% precision)	0.1	0.1	0.03	0.04	2	0.4	1	1
95th Percentile	0.82	0.73	0.73	0.74	0.75	0.72	0.70	0.75
COV (%)	7	5	4	4	29	12	17	18
Mean + 2 x SD	0.89	0.77	0.76	0.76	0.97	0.82	0.83	0.86
2 x Mean	1.55	1.40	1.43	1.41	1.23	1.31	1.24	1.26
Mean +50%	1.16	1.05	1.07	1.06	0.93	0.98	0.93	0.95
Mean -50%	0.39	0.35	0.36	0.35	0.31	0.33	0.31	0.32
Mean +25%	0.97	0.87	0.89	0.88	0.77	0.82	0.77	0.79
Mean -25%	0.58	0.52	0.53	0.53	0.46	0.49	0.46	0.47
Mean +20%	0.93	0.84	0.86	0.85	0.74	0.79	0.74	0.76
Mean -20%	0.62	0.56	0.57	0.56	0.49	0.52	0.50	0.50
Data Normally Distributed	- [1]	Yes			Yes			
Significant Inter-annual Difference	-	No [2]			No [3]			

[1] insufficient data points to determine

[2] p-value 0.595 (t-test)

[3] p-value 2007 vs 2008 0.732; 2007 vs 2011 0.983; 2008 vs 2011 0.747

Table 3-23. Summary statistics for Simpson's Diversity Index: Sheardown Lake Tributary 1 by reach and year.

Metric	Simpson's Diversity Index							
Stream Reach	**1**	**2**			**4**			
Year	**2008**	**2007**	**2008**	**All**	**2007**	**2008**	**2011**	**All**
n (rep. stn.)	3	3	3	6	3	3	3	9
Mean	0.82	0.77	0.76	0.76	0.69	0.74	0.73	0.72
Median	0.83	0.76	0.75	0.76	0.77	0.81	0.76	0.77
SD	0.04	0.03	0.03	0.03	0.21	0.12	0.11	0.14
SE	0.02	0.02	0.02	0.01	0.12	0.07	0.06	0.05
Min	0.78	0.73	0.73	0.73	0.45	0.61	0.62	0.45
Max	0.85	0.80	0.80	0.80	0.85	0.81	0.82	0.85
Sub-samples (20% precision)	0.05	0.04	0.1	0.04	2	1	1	1
95th Percentile	0.85	0.80	0.79	0.80	0.84	0.81	0.82	0.84
COV (%)	4	4	5	4	31	16	15	19
Mean + 2 x SD	0.90	0.83	0.83	0.82	1.12	0.98	0.95	0.99
2 x Mean	1.65	1.53	1.52	1.53	1.38	1.48	1.47	1.44
Mean +50%	1.23	1.15	1.14	1.14	1.03	1.11	1.10	1.08
Mean -50%	0.41	0.38	0.38	0.38	0.34	0.37	0.37	0.36
Mean +25%	1.03	0.96	0.95	0.95	0.86	0.93	0.92	0.90
Mean -25%	0.62	0.57	0.57	0.57	0.52	0.56	0.55	0.54
Mean +20%	0.99	0.92	0.91	0.92	0.83	0.89	0.88	0.87
Mean -20%	0.66	0.61	0.61	0.61	0.55	0.59	0.59	0.58
Data Normally Distributed	- [1]	Yes			Yes			
Significant Inter-annual Difference	-	No [2]			No [3]			

[1] insufficient data points to determine

[2] p-value 0.856 (t-test)

[3] p-value 2007 vs 2008 0.684; 2007 vs 2011 0.726; 2008 vs 2011 0.954

Table 3-24. Summary statistics for total taxa richness: Sheardown Lake Tributary 1 by reach and year.

Metric	Total Taxa Richness (genus-level)							
Stream Reach	1	2			4			
Year	2008	2007	2008	All	2007	2008	2011	All
n (rep. stn.)	3	3	3	6	3	3	3	9
Mean	12	15	13	14	16	16	17	16
Median	12	15	13	14	16	17	17	17
SD	1.00	1.00	1.00	1.41	2.52	4.58	1.53	2.74
SE	0.58	0.58	0.58	0.58	1.45	2.65	0.88	0.91
Min	11	14	12	12	14	11	15	11
Max	13	16	14	16	19	20	18	20
Sub-samples (20% precision)	0.2	0.1	0.1	0.3	1	2	0.2	1
95th Percentile	12.9	15.9	13.9	15.8	18.7	19.7	17.9	19.6
COV (%)	8	7	8	10	15	29	9	17
Mean + 2 x SD	14.00	17.00	15.00	16.83	21.37	25.17	19.72	21.81
2 x Mean	24.00	30.00	26.00	28.00	32.67	32.00	33.33	32.67
Mean +50%	18.00	22.50	19.50	21.00	24.50	24.00	25.00	24.50
Mean -50%	6.00	7.50	6.50	7.00	8.17	8.00	8.33	8.17
Mean +25%	15.00	18.75	16.25	17.50	20.42	20.00	20.83	20.42
Mean -25%	9.00	11.25	9.75	10.50	12.25	12.00	12.50	12.25
Mean +20%	14.40	18.00	15.60	16.80	19.60	19.20	20.00	19.60
Mean -20%	9.60	12.00	10.40	11.20	13.07	12.80	13.33	13.07
Data Normally Distributed	- [1]	Yes			Yes			
Significant Inter-annual Difference	-	No [2]			No [3]			

[1] insufficient data points to determine

[2] p-value 0.070 (t-test)

[3] p-value 2007 vs 2008 0.901; 2007 vs 2011 0.901; 2008 vs 2011 0.804

Table 3-25. Summary statistics for Hill's effective richness: Sheardown Lake Tributary 1 by reach and year.

Metric	Hill's Effective Richness (genus-level)							
Stream Reach	1	2			4			
Year	2008	2007	2008	All	2007	2008	2011	All
n (rep. stn.)	3	3	3	6	3	3	3	9
Mean	7	7	6	6	6	6	6	6
Median	7	7	6	6	6	8	6	6
SD	1.17	0.48	0.43	0.47	3.20	2.20	1.94	2.18
SE	0.68	0.28	0.25	0.19	1.85	1.27	1.12	0.73
Min	6	6	6	6	3	4	4	3
Max	8	7	7	7	9	8	8	9
Sub-samples (20% precision)	1	0.1	0.1	0.1	6	3	3	3
95th Percentile	7.8	6.9	6.6	6.9	9.1	7.8	7.6	8.8
COV (%)	17	7	7	7	51	34	32	35
Mean + 2 x SD	9.24	7.60	7.09	7.37	12.70	10.82	9.86	10.59
2 x Mean	13.80	13.28	12.45	12.87	12.59	12.83	11.95	12.46
Mean +50%	10.35	9.96	9.34	9.65	9.44	9.62	8.96	9.34
Mean -50%	3.45	3.32	3.11	3.22	3.15	3.21	2.99	3.11
Mean +25%	8.62	8.30	7.78	8.04	7.87	8.02	7.47	7.79
Mean -25%	5.17	4.98	4.67	4.82	4.72	4.81	4.48	4.67
Mean +20%	8.28	7.97	7.47	7.72	7.55	7.70	7.17	7.48
Mean -20%	5.52	5.31	4.98	5.15	5.04	5.13	4.78	4.98
Data Normally Distributed	- [1]	Yes			Yes			
Significant Inter-annual Difference	-	No [2]			No [3]			

[1] insufficient data points to determine

[2] p-value 0.331 (t-test)

[3] p-value 2007 vs 2008 0.955; 2007 vs 2011 0.881; 2008 vs 2011 0.837

Table 3-26. Critical effects sizes for select benthic macroinvertebrate community metrics from Sheardown Lake NW.

Metric	Habitat Type 4 (2008; n = 8)					
	Mean +50%	Mean -50%	Mean +25%	Mean -25%	Mean +20%	Mean -20%
Total macroinvertebrate density	1244.03	414.68	1036.69	622.01	995.22	663.48
Chironomidae proportion	98.66	32.89	82.21	49.33	78.92	52.62
Shannon’s Equitability	0.97	0.32	0.81	0.48	0.77	0.52
Simpson’s Diversity Index	1.09	0.36	0.91	0.55	0.88	0.58
Total taxa richness	22.88	7.63	19.06	11.44	18.30	12.20

Metric	Habitat 9 (2007 and 2008; n = 22)					
	Mean +50%	Mean -50%	Mean +25%	Mean -25%	Mean +20%	Mean -20%
Total macroinvertebrate density	5487.27	1829.09	4572.73	2743.64	4389.82	2926.54
Chironomidae proportion	125.07	41.69	104.23	62.54	100.06	66.70
Shannon’s Equitability	1.07	0.36	0.89	0.54	0.86	0.57
Simpson’s Diversity Index	1.15	0.38	0.96	0.57	0.92	0.61
Total taxa richness	20.11	6.70	16.76	10.06	16.09	10.73

Metric	Habitat Type 14 (2007, 2008, 2011; n = 12)					
	Mean +50%	Mean -50%	Mean +25%	Mean -25%	Mean +20%	Mean -20%
Total macroinvertebrate density	2381.49	793.83	1984.58	1190.75	1905.19	1270.13
Chironomidae proportion	141.27	47.09	117.73	70.64	113.02	75.34
Shannon’s Equitability	0.61	0.20	0.50	0.30	0.48	0.32
Simpson’s Diversity Index	0.55	0.18	0.46	0.27	0.44	0.29
Total taxa richness	11.13	3.71	9.27	5.56	8.90	5.93

Table 3-27. Critical effects sizes for select benthic macroinvertebrate community metrics from Sheardown Lake Tributary 1, Reach 4.

Metric	2007, 2008, 2011; n = 9					
	Mean +50%	Mean - 50%	Mean +25%	Mean - 25%	Mean +20%	Mean - 20%
Total macroinvertebrate density	4997.25	1665.75	4164.38	2498.63	3997.80	2665.20
Chironomidae proportion	136.27	45.42	113.56	68.13	109.01	72.68
Shannon’s Equitability	0.95	0.32	0.79	0.47	0.76	0.50
Simpson’s Diversity Index	1.08	0.36	0.90	0.54	0.87	0.58
Total taxa richness	24.50	8.17	20.42	12.25	19.60	13.07

Table 3-28. Power of existing benthic macroinvertebrate data to detect pre-defined levels of change in Sheardown Lake NW.

Metric	Habitat Type 4 (2008; n = 8)		
	Mean +/-50%	Mean +/-25%	Mean +/-20%
Total macroinvertebrate density	0.247	0.148	0.123
Chironomidae proportion	0.957	0.536	0.402
Shannon's Equitability	1.000	0.935	0.813
Simpson's Diversity Index	1.000	0.982	0.938
Total taxa richness	1.000	1.000	1.000

Metric	Habitat 9 (2007 and 2008; n = 22)		
	Mean +/-50%	Mean +/-25%	Mean +/-20%
Total macroinvertebrate density	0.807	0.387	0.282
Chironomidae proportion	1.000	1.000	1.000
Shannon's Equitability	1.000	1.000	0.999
Simpson's Diversity Index	1.000	1.000	1.000
Total taxa richness	1.000	0.992	0.943

Metric	Habitat Type 14 (2007, 2008, 2011; n = 12)		
	Mean +/-50%	Mean +/-25%	Mean +/-20%
Total macroinvertebrate density	0.441	0.170	0.154
Chironomidae proportion	1.000	1.000	1.000
Shannon's Equitability	0.990	0.681	0.495
Simpson's Diversity Index	0.892	0.446	0.317
Total taxa richness	1.000	0.866	0.712

Table 3-29. Sample sizes (i.e., number of replicate stations) required for detecting pre-defined levels of change in Sheardown Lake NW.

Metric	Habitat Type 4		
	Mean +/-50%	Mean +/-25%	Mean +/-20%
Total macroinvertebrate density	64	>180	>>180
Chironomidae proportion	6	22	37
Shannon's Equitability	3	7	10
Simpson's Diversity Index	3	5	7
Total taxa richness	<<3	<3	3

Metric	Habitat 9		
	Mean +/-50%	Mean +/-25%	Mean +/-20%
Total macroinvertebrate density	31	>60	>>60
Chironomidae proportion	2	4	6
Shannon's Equitability	2	4	6
Simpson's Diversity Index	<5	5	6
Total taxa richness	4	12	18

Metric	Habitat Type 14		
	Mean +/-50%	Mean +/-25%	Mean +/-20%
Total macroinvertebrate density	43	167	>180
Chironomidae proportion	1	1	1
Shannon's Equitability	7	22	37
Simpson's Diversity Index	12	45	70
Total taxa richness	4	13	21

Table 3-30. Power of existing benthic macroinvertebrate data to detect pre-defined levels of change in Sheardown Lake Tributary 1, Reach 4.

Metric	2007, 2008, 2011; n = 9		
	Mean +/- 50%	**Mean +/- 25%**	**Mean +/- 20%**
Total macroinvertebrate density	0.564 [1]	0.248 [2]	0.209 [3]
Chironomidae proportion	1.000	1.000	1.000
Shannon's Equitability	1.000	0.791	0.602
Simpson's Diversity Index	1.000	0.750	0.578
Total taxa richness	1.000	0.844	0.651

[1] metric not normally distributed: -50%, 0.785

[2] metric not normally distributed: -25%, 0.276

[3] metric not normally distributes: -20%, 0.109

Table 3-31. Sample sizes (i.e., number of replicate stations) required for detecting pre-defined levels of change in Sheardown Lake Tributary 1, Reach 4.

Metric	2007, 2008, 2011; n = 9		
	Mean +/- 50%	**Mean +/- 25%**	**Mean +/- 20%**
Total macroinvertebrate density	22 [1]	>61 [2]	>>61 [3]
Chironomidae proportion	2	3	3
Shannon's Equitability	4	12	18
Simpson's Diversity Index	5	13	19
Total taxa richness	4	10	16

[1] metric not normally distributed: -50%, 13

[2] metric not normally distributed: -25%, 59

[3] metric not normally distributed: -20%, 60

Table 4-1. Summary of baseline electrofishing and gillnetting Arctic Char data collections in selected Mine Area waterbodies, 2006-2008 and 2013.

Waterbody	Year	Season	Gear Type[1]	Sampling Effort[2]	Catch
Camp Lake	2006	Summer	Gill Net	2	21
	2007	Winter	Gill Net	2	3
		Summer	Gill Net	20	94
			Electrofishing	1	8
	2008	Fall	Gill Net	14	22
	2013	Fall	Gill Net	35	26
			Electrofishing	1	57
Camp Lake Tributary 1	2006	Summer	Electrofishing	3	8
	2007	Summer	Electrofishing	3	196
		Fall	Electrofishing	3	211
Sheardown Lake NW	2006	Summer	Gill Net	1	17
	2007	Winter	Gill Net	2	5
		Summer	Gill Net	12	92
			Electrofishing	5	220
	2008	Spring	Electrofishing	10	36
		Fall	Gill Net	4	5
	2013	Fall	Gill Net	18	28
			Electrofishing	2	184
Sheardown Lake SE	2007	Winter	Gill Net	2	7
		Summer	Gill Net	2	30
			Electrofishing	2	32
	2008	Spring	Electrofishing	4	4
		Fall	Gill Net	4	63

Table 4-1. - continued -

Waterbody	Year	Season	Gear Type[1]	Sampling Effort[2]	Catch
Sheardown Lake Tributary 1	2006	Summer	Electrofishing	1	5
	2007	Spring	Electrofishing	4	4
		Summer	Electrofishing	4	145
		Fall	Electrofishing	4	52
			Hoop Net	23	1240
	2008	Spring	Electrofishing	2	33
			Hoop Net[3]	18	849
		Summer	Electrofishing	2	55
		Fall	Electrofishing	2	13
			Hoop Net	17	469
Mary Lake – South	2006	Summer	Gill Net	2	62
			Electrofishing	1	
	2007	Summer	Gill Net	24	168
	2008	Spring	Electrofishing	7	2
Mary Lake – North	2007	Summer	Gill Net	8	98
	2008	Spring	Electrofishing	3	4

1 Does not include minnow trap or angling data.

2 Effort for gill nets described as the number of standard index gillnet gangs set in each lake; electrofishing effort is the number of 50-100 m sections of shoreline or stream sampled, and hoopnetting effort is the number of days traps were installed.

3 Data include two hoop nets (one facing upstream and one downstream) that each fished for 18 days.

Table 4-2. Summary of fish metrics and statistical analysis methods recommended under EEM (EC 2012). Metrics indicated with an asterisk are endpoints used for determining effects under EEM, as designated by statistically significant differences between exposure and reference areas. Other endpoints may be used to support analyses.

Effect Indicators	Fish Effect Endpoint			
	Non-Lethal Survey	**Statistical Test**	**Lethal Adult Survey**	**Statistical Test**
Growth	*Length of YOY (age 0) at end of growth period	ANOVA	-	
	*Weight of YOY (age 0) at end of growth period	ANOVA	-	
	*Size of 1+ fish if possible	ANOVA		
	*Size-at-age (body weight at age) - if possible	ANCOVA	*Size-at-age (body weight at age)	ANCOVA
	Length-at-age	ANCOVA	Length-at-age	ANCOVA
	Body Weight	ANOVA		
	Length	ANOVA		
Reproduction	*Relative abundance of YOY (% composition of YOY)	Kolmorgorov-Smirnov test performed on length-frequency distributions with and without YOY included; OR proportions of YOY can be tested using a Chi-squared test.	-	
	OR relative age-class strength		*Gonad weight at body weight	ANCOVA
	-		Gonad weight at length	
	-		Fecundity	
Condition	*Condition Factor	ANCOVA	*Condition Factor	ANCOVA
	-		*Liver size at body weight	ANCOVA
	-		Liver weight at length	
	-		Egg weight at body weight and/or age (mature females only)	
Survival	*Length-frequency-distribution	2-sample Kolmorgorov-Smirnov test[1]	Length-frequency-distribution	2-sample Kolmorgorov-Smirnov test
	*Age-frequency distribution (if possible)	2-sample Kolmorgorov-Smirnov test	*Age-frequency distribution (if possible)	2-sample Kolmorgorov-Smirnov test
	YOY Survival		*Age	ANOVA

[1] Examine YOY alone and for both sizes combined

Table 4-3. Datasets analysed for Arctic Char metrics.

Waterbody	Year	Gear Type	Sex
Camp Lake	2006	Gill Net	M, F, Total
	2007	Gill Net	M, F, Total
	2008	Gill Net	M, F, Total
	All Years	Gill Net	M, F, Total
Sheardown Lake	2006	Gill Net	M, F, Total
	2007	Electrofishing	Total
		Gill Net	M, F, Total
	2008	Electrofishing	Total
		Gill Net	M, F, Total
	All Years	Electrofishing	Total
		Gill Net	M, F, Total
Mary Lake – South	2006	Gill Net	M, F, Total
	2007	Gill Net	M, F, Total
	All Years	Gill Net	M, F, Total
Mary Lake – North	2007	Gill Net	Total

Table 4-4. Summary statistics for fork lengths (mm) of Arctic Char captured during backpack electrofishing (EF) and gillnetting surveys in Camp Lake, 2006-2008.

Statistic	2006			2007			2008			All Years		
	Males	Females	All	Males	Females	All	Males	Females	All	Males	Females	All
n	11	10	21	3	3	99	9	2	22	23	15	134
Mean	335	224	282	291	329	305	465	394	401	380	267	332
Median	265	221	230	312	338	321	430	394	368	350	236	323
SD	195	39	151	38	45	117	137	100	117	171	80	114
SE	59	12	33	22	26	12	46	71	25	36	21	10
Minimum	170	175	170	247	280	40	342	323	236	170	175	170
Maximum	751	311	751	315	368	682	745	464	745	751	464	751
95^{th} Percentile	699	286	647	315	365	542	680	457	582	735	397	578
COV (%)	58	18	54	13	14	38	29	25	29	45	30	34

Table 4-5. Summary statistics for fork lengths (mm) of Arctic Char captured during backpack electrofishing (EF) and index gillnetting surveys in Sheardown Lake, 2006-2008.

Statistic	2006			2007				2008				All Years			
	Gillnetting			EF	Gillnetting			EF	Gillnetting			EF	Gillnetting		
	Males	Females	All		Males	Females	All		Males	Females	All		Males	Females	All
n	6	2	14	252	12	15	116	39	27	8	68	291	45	25	198
Mean	313	385	346	76	367	353	372	83	402	383	387	77	381	365	375
Median	281	385	293	65	371	335	369	87	403	380	385	66	388	364	377
SD	142	142	137	29	59	69	82	28	37	18	38	29	70	63	76
SE	58	101	37	2	17	18	8	4	7	6	5	2	10	13	5
Minimum	180	284	180	33	278	240	178	26	360	364	276	26	180	240	178
Maximum	572	485	599	180	507	508	587	140	552	420	552	180	572	508	599
95^{th} Percentile	519	475	581	139	449	497	541	127	441	410	431	138	495	491	531
COV (%)	45	37	39	38	16	20	22	34	9	5	10	37	18	17	20

Table 4-6. Summary statistics for fork lengths (mm) of Arctic Char captured in standard index gill nets deployed in the north and south basins of Mary Lake, 2006-2007.

Statistic	South Basin									North Basin
	2006			2007			All Years			2007
	Males	Females	All	Males	Females	All	Males	Females	All	
n	26	33	62	14	12	161	40	45	223	98
Mean	386	370	384	383	375	383	385	372	384	379
Median	390	370	384	394	373	392	395	372	391	389
SD	132	116	133	74	43	71	114	102	92	41
SE	26	20	17	20	13	6	18	15	6	4
Minimum	165	181	165	266	266	197	165	181	165	198
Maximum	685	658	705	548	432	671	685	658	705	458
95th Percentile	594	586	648	485	424	457	573	552	559	432
COV (%)	34	31	35	19	12	18	30	27	24	11

Table 4-7. Comparison of Arctic Char length between sexes and years. Data represent fish captured during backpack electrofishing (EF) and index gillnetting (GN) surveys in study area lakes, 2006-2008. Values in red indicate significant difference at $p < 0.05$.

Lake	Comparison			P value[1]
	Dataset 1	Dataset 2	Dataset 3	
Camp Lake	2006 GN Males	2006 GN Females	-	0.58
	2007 GN Males	2007 GN Females	-	0.38
	2008 GN Males	2008 GN Females	-	0.37
	All Years Males	All Years Females	-	0.17
	2006 GN Males	2007 GN Males	2008 GN Males	0.11
	2006 GN Females	2007 GN Females	2008 GN Females	0.04
	2006 GN All Fish	2007 GN All Fish	2008 GN All Fish	0.70
Sheardown Lake	2006 GN Males	2006 GN Females	-	0.11
	2007 GN Males	2007 GN Females	-	0.98
	2008 GN Males	2008 GN Females	-	0.47
	All Years GN Males	All Years GN Females	-	0.66
	2006 GN Males	2007 GN Males	2008 GN Males	0.91
	2006 GN Females	2007 GN Females	2008 GN Females	0.77
	2006 GN All Fish	2007 GN All Fish	2008 GN All Fish	0.98
	2007 EF All Fish	2008 EF All Fish	-	0.76
Mary Lake - S	2006 GN Males	2006 GN Females	-	0.79
	2007 GN Males	2007 GN Females	-	0.43
	All Years Males	All Years Females	-	0.72
	2006 GN Males	2007 GN Males	-	0.55
	2006 GN Females	2007 GN Females	-	0.60
	2006 GN All Fish	2007 GN All Fish	-	0.72

[1]Differences between two groups tested with a Kruskal-Wallis test at alpha = 0.05.

Table 4-8. Inter-lake comparisons of fork lengths (mm) of Arctic Char captured during index gillnetting surveys, 2006-2008.

Comparison				P value[1]
Dataset 1	Dataset 2	Dataset 3	Dataset 4	
Camp L. 2006 GN	Sheardown L. 2006 GN	Mary L – S 2006 GN	-	0.74
Camp L. 2007 GN	Sheardown L. 2007 GN	Mary L – S 2007 GN	Mary L – N 2007 GN	0.94
Camp L. 2008 GN	Sheardown L. 2008 GN	-	-	0.52
Camp L. All GN	Sheardown L. All GN	Mary L – S All GN	Mary L – N All GN	0.94

[1]Differences between two groups tested with a Kruskal-Wallis test at alpha = 0.05.

Table 4-9. Summary statistics for weights (g) of Arctic Char captured in Camp Lake, 2006-2008.

Statistic	2006			2007			2008			All Years		
	Males	Females	All	Males	Females	All	Males	Females	All	Males	Females	All
n	11	9	20	3	3	91	9	2	22	23	14	133
Mean	823	139	515	275	342	435	1450	625	876	997	252	520
Median	200	150	150	325	400	350	750	625	463	375	150	350
SD	1512	69	1152	109	146	509	1705	460	1181	1506	234	785
SE	456	23	258	63	85	53	568	325	252	314	62	68
Minimum	50	75	50	150	175	25	375	300	200	50	75	25
Maximum	4900	300	4900	350	450	3050	5600	950	5600	5600	950	5600
95^{th} Percentile	3650	240	2525	348	445	1475	4320	918	2368	4650	625	1965
COV (%)	184	49	224	40	43	117	118	74	135	151	93	151

Table 4-10. Summary statistics for weights (g) of Arctic Char captured during backpack electrofishing (EF) and gillnetting surveys in Sheardown Lake, 2006-2008.

Statistic	2006			2007				2008				All Years			
	Gillnetting			EF	Gillnetting			EF	Gillnetting			EF	Gillnetting		
	Males	Females	All		Males	Females	All		Males	Females	All		Males	Females	All
n	6	2	8	230	12	15	116	36	27	8	68	266	45	25	192
Mean	479	600	509	7	435	396	494	9	698	591	604	7	599	475	533
Median	200	600	225	4	400	350	425	8	675	575	538	4	525	425	500
SD	711	566	640	9	218	209	317	6	249	101	209	8	348	227	306
SE	290	400	226	1	63	54	29	1	48	36	25	1	52	45	22
Minimum	50	200	50	1	150	125	50	1	475	450	250	1	50	125	50
Maximum	1900	1000	1900	59	1000	950	1800	28	1750	725	1750	59	1900	1000	1900
95^{th} Percentile	1538	1900	1585	27	780	828	1119	20	948	716	850	26	998	915	1086
COV (%)	148	94	126	123	50	53	64	70	36	17	35	115	58	48	57

Table 4-11. Summary statistics for weights (g) of Arctic Char captured in standard index gill nets set in the north and south basins of Mary Lake, 2006-2007.

Statistic	South Basin									North Basin
	2006			2007			All Years			2007
	Males	Females	All	Males	Females	All	Males	Females	All	
n	26	33	62	14	12	161	40	45	223	98
Mean	736	639	743	534	467	548	665	593	602	493
Median	600	525	600	513	475	525	575	450	525	500
SD	596	600	709	329	132	344	523	522	481	125
SE	117	104	90	88	38	27	83	78	32	13
Minimum	25	75	25	125	175	75	25	75	25	75
Maximum	2350	2450	3300	1425	700	3050	2350	2450	3300	850
95th Percentile	1825	2060	2348	1019	645	825	1630	1780	1590	679
COV (%)	81	94	95	62	28	63	79	88	80	25

Table 4-12. Comparison of Arctic Char weights between sexes and years. Data represent fish captured during backpack electrofishing (EF) and index gillnetting (GN) surveys in study area lakes, 2006-2008. Values in red indicate significant difference at p < 0.05.

Lake	Comparison			P value[1]
	Dataset 1	Dataset 2	Dataset 3	
Camp Lake	2006 GN Males	2006 GN Females	-	**< 0.01**
	2007 GN Males	2007 GN Females	-	0.32
	2008 GN Males	2008 GN Females	-	**0.02**
	All Years Males	All Years Females	-	**0.01**
	2006 GN Males	2007 GN Males	2008 GN Males	**< 0.01**
	2006 GN Females	2007 GN Females	2008 GN Females	**< 0.01**
	2006 GN All Fish	2007 GN All Fish	2008 GN All Fish	0.34
Sheardown Lake	2006 GN Males	2006 GN Females	-	0.55
	2007 GN Males	2007 GN Females	-	0.76
	2008 GN Males	2008 GN Females	-	0.29
	All Years GN Males	All Years GN Females	-	0.40
	2006 GN Males	2007 GN Males	2008 GN Males	0.42
	2006 GN Females	2007 GN Females	2008 GN Females	0.28
	2006 GN All Fish	2007 GN All Fish	2008 GN All Fish	0.92
	2007 EF All Fish	2008 EF All Fish	-	0.77
Mary Lake - S	2006 GN Males	2006 GN Females	-	0.95
	2007 GN Males	2007 GN Females	-	0.42
	All Years Males	All Years Females	-	0.85
	2006 GN Males	2007 GN Males	-	0.33
	2006 GN Females	2007 GN Females	-	0.12
	2006 GN All Fish	2007 GN All Fish	-	0.31

[1]Differences between two groups tested with a Kruskal-Wallis test at alpha = 0.05.

Table 4-13. Inter-lake comparisons of weights (g) of Arctic Char captured during index gillnetting surveys, 2006-2008.

Comparison				P value[1]
Dataset 1	Dataset 2	Dataset 3	Dataset 4	
Camp L. 2006 GN	Sheardown L. 2006 GN	Mary L – S 2006 GN	-	0.71
Camp L. 2007 GN	Sheardown L. 2007 GN	Mary L – S 2007 GN	Mary L – N 2007 GN	0.91
Camp L. 2008 GN	Sheardown L. 2008 GN	-	-	0.14
Camp L. All GN	Sheardown L. All GN	Mary L – S All GN	Mary L – N All GN	0.67

[1]Differences between two groups tested with a Kruskal-Wallis test at alpha = 0.05.

Table 4-14. Summary statistics for condition factors of Arctic Char captured in standard index gill nets set in Camp Lake, 2006-2008.

Statistic	2006			2007			2008			All Years		
	Males	Females	All	Males	Females	All	Males	Females	All	Males	Females	All
n	11	9	20	3	3	91	9	2	22	23	14	133
Mean	1.00	1.10	1.04	1.06	0.91	0.96	1.03	0.92	1.02	1.02	1.03	0.99
Median	1.01	1.06	1.02	1.04	0.90	0.98	1.01	0.92	0.95	1.01	1.01	0.99
SD	0.13	0.15	0.14	0.08	0.12	0.19	0.16	0.04	0.23	0.14	0.16	0.19
SE	0.04	0.05	0.03	0.05	0.07	0.02	0.05	0.03	0.05	0.03	0.04	0.02
Minimum	0.84	0.89	0.84	1.00	0.80	0.47	0.86	0.89	0.82	0.84	0.80	0.47
Maximum	1.23	1.35	1.35	1.15	1.04	1.43	1.35	0.95	1.67	1.35	1.35	1.67
95^{th} Percentile	1.19	1.32	1.27	1.14	1.02	1.23	1.30	0.95	1.51	1.23	1.29	1.28
COV (%)	12.77	13.39	13.69	7.62	13.11	19.45	15.93	4.66	22.03	13.28	15.00	19.25

Table 4-15. Summary statistics for condition factors of Arctic Char captured during backpack electrofishing (EF) and gillnetting surveys in Sheardown Lake, 2006-2008.

Statistic	2006			2007				2008				All Years			
	Gillnetting			EF	Gillnetting			EF	Gillnetting			EF	Gillnetting		
	Males	Females	All		Males	Females	All		Males	Females	All		Males	Females	All
n	6	2	8	230	12	15	116	36	27	8	68	266	45	25	192
Mean	0.91	0.87	0.90	0.98	0.82	0.86	0.85	1.21	1.04	1.05	1.02	1.01	0.97	0.92	0.91
Median	0.89	0.87	0.87	1.02	0.80	0.90	0.87	1.13	1.03	1.02	1.01	1.02	0.98	0.93	0.93
SD	0.08	0.00	0.07	0.24	0.07	0.11	0.13	0.29	0.09	0.11	0.13	0.26	0.13	0.13	0.15
SE	0.03	0.00	0.02	0.02	0.02	0.03	0.01	0.05	0.02	0.04	0.02	0.02	0.02	0.03	0.01
Minimum	0.83	0.87	0.83	0.44	0.70	0.59	0.54	0.72	0.86	0.93	0.49	0.44	0.70	0.59	0.49
Maximum	1.02	0.88	1.02	2.04	0.93	0.98	1.16	2.02	1.24	1.22	1.51	2.04	1.24	1.22	1.51
95th Percentile	1.01	0.88	1.00	1.36	0.93	0.96	1.05	1.80	1.19	1.21	1.21	1.40	1.17	1.16	1.16
COV (%)	8.37	0.28	7.37	24.04	8.65	12.62	15.06	23.98	8.75	10.35	12.86	25.30	13.37	14.69	16.29

Table 4-16. Summary statistics for condition factors of Arctic Char captured in standard index gill nets set in the north and south basins of Mary Lake, 2006-2007.

Statistic	South Basin									North Basin
	2006			2007			All Years			2007
	Males	Females	All	Males	Females	All	Males	Females	All	
n	26	33	62	14	12	161	40	45	223	98
Mean	1.03	1.00	1.01	0.85	0.86	0.88	0.96	0.96	0.92	0.90
Median	1.02	0.99	0.99	0.86	0.87	0.88	0.88	0.96	0.90	0.91
SD	0.27	0.16	0.21	0.08	0.08	0.11	0.24	0.16	0.16	0.13
SE	0.05	0.03	0.03	0.02	0.02	0.01	0.04	0.02	0.01	0.01
Minimum	0.56	0.77	0.56	0.66	0.71	0.60	0.56	0.71	0.56	0.60
Maximum	1.93	1.64	1.93	1.01	0.98	1.41	1.93	1.64	1.93	1.20
95^{th} Percentile	1.46	1.23	1.39	0.97	0.97	1.04	1.41	1.21	1.15	1.11
COV (%)	26.24	16.42	20.97	9.87	9.08	12.37	24.64	16.45	16.96	14.94

Table 4-17. Comparison of Arctic Char condition factors between sexes and years. Data represent fish captured during backpack electrofishing (EF) and index gillnetting (GN) surveys in study area lakes, 2006-2008. Values in red indicate significant difference at $p < 0.05$.

Lake	Comparison			P value[1]
	Dataset 1	Dataset 2	Dataset 3	
Camp Lake	2006 GN Males	2006 GN Females	-	0.44
	2007 GN Males	2007 GN Females	-	0.38
	2008 GN Males	2008 GN Females	-	0.29
	All Years Males	All Years Females	-	0.79
	2006 GN Males	2007 GN Males	2008 GN Males	0.86
	2006 GN Females	2007 GN Females	2008 GN Females	0.42
	2006 GN All Fish	2007 GN All Fish	2008 GN All Fish	0.85
Sheardown Lake	2006 GN Males	2006 GN Females	-	**< 0.01**
	2007 GN Males	2007 GN Females	-	0.60
	2008 GN Males	2008 GN Females	-	0.85
	All Years GN Males	All Years GN Females	-	0.69
	2006 GN Males	2007 GN Males	2008 GN Males	**< 0.01**
	2006 GN Females	2007 GN Females	2008 GN Females	0.19
	2006 GN All Fish	2007 GN All Fish	2008 GN All Fish	0.67
	2007 EF All Fish	2008 EF All Fish	-	0.49
Mary Lake - S	2006 GN Males	2006 GN Females	-	0.95
	2007 GN Males	2007 GN Females	-	0.42
	All Years Males	All Years Females	-	0.85
	2006 GN Males	2007 GN Males	-	0.33
	2006 GN Females	2007 GN Females	-	0.12
	2006 GN All Fish	2007 GN All Fish	-	0.31

[1]Differences between two groups tested with a Kruskal-Wallis test at alpha = 0.05.

Table 4-18. Inter-lake comparisons of condition factors of Arctic Char captured during index gillnetting surveys, 2006-2008.

Comparison				P value[1]
Dataset 1	Dataset 2	Dataset 3	Dataset 4	
Camp L. 2006 GN	Sheardown L. 2006 GN	Mary L – S 2006 GN	-	0.51
Camp L. 2007 GN	Sheardown L. 2007 GN	Mary L – S 2007 GN	Mary L – N 2007 GN	0.84
Camp L. 2008 GN	Sheardown L. 2008 GN	-	-	0.63
Camp L. All GN	Sheardown L. All GN	Mary L – S All GN	Mary L – N All GN	0.85

[1]Differences between two groups tested with a Kruskal-Wallis test at alpha = 0.05.

Table 4-19. Summary statistics for catch-per-unit-effort (#fish/24 hours/100 m net) of Arctic Char captured in standard index gill nets deployed in Mine Area lakes, 2006-2008.

Statistic	Camp Lake				Sheardown Lake				Mary Lake – South Basin			Mary Lake – North Basin
	2006	2007	2008	All	2006	2007	2008	All	2006	2007	All	Males
n	2	21	14	36	1	14	8	23	2	24	26	8
Mean	13.4	41.8	10.1	29.0	13.8	92.8	57.8	77.2	27.1	73.4	69.9	175.2
Median	13.4	34.9	10.0	18.0	-	55.6	41.8	53.9	27.1	66.2	64.4	169.1
SD	5.0	37.5	8.4	32.6	-	86.3	64.0	78.6	12.4	55.5	54.7	59.8
SE	3.5	8.2	2.2	5.4	-	23.1	22.6	16.4	8.7	11.3	10.7	21.1
Minimum	9.9	0.0	0.0	0.0	13.8	0.0	0.0	0.0	18.4	0.0	0.0	78.8
Maximum	16.9	157.2	22.9	157.2	13.8	314.4	189.9	314.4	35.9	216.7	216.7	286.3
95^{th} Percentile	16.5	99.8	21.4	86.1	-	219.0	158.3	187.6	35.0	159.9	159.2	259.7
COV (%)	37.1	89.7	83.2	112.4	-	93.0	110.8	101.9	45.6	75.6	78.3	34.1

Table 4-20. Comparison of catch-per-unit-effort (#fish/24 hours/100 m net) of Arctic Char between years. Data represent fish captured during backpack electrofishing (EF) and index gillnetting (GN) surveys in study area lakes, 2006-2008. Values in red indicate significant difference at $p < 0.05$.

Lake	Comparison			P value[1]
	Dataset 1	Dataset 2	Dataset 3	
Camp Lake	2006 GN All Fish	2007 GN All Fish	2008 GN All Fish	**< 0.01**
Sheardown Lake	2007 GN All Fish	2008 GN All Fish	-	0.23
	2007 EF All Fish	2008 EF All Fish	-	**< 0.01**
Mary Lake - S	2006 GN All Fish	2007 GN All Fish	-	**< 0.01**

[1]Differences between two groups tested with a Kruskal-Wallis test at alpha = 0.05.

Table 4-21. Inter-lake comparisons of catch-per-unit-effort (#fish/24 hours/100 m net) of Arctic Char captured during index gillnetting surveys, 2006-2008. Values in red indicate significant difference at $p < 0.05$.

Comparison				P value[1]
Dataset 1	Dataset 2	Dataset 3	Dataset 4	
Camp L. 2006 GN	Mary L – S 2006 GN	-	-	**< 0.01**
Camp L. 2007 GN	Sheardown L. 2007 GN	Mary L – S 2007 GN	Mary L – N 2007 GN	**0.02**
Camp L. 2008 GN	Sheardown L. 2008 GN	-	-	**< 0.01**
Camp L. All GN	Sheardown L. All GN	Mary L – S All GN	Mary L – N All GN	**0.01**

[1]Differences between two groups tested with a Kruskal-Wallis test at alpha = 0.05.

Table 4-22. Summary statistics for age of Arctic Char captured during standard index gillnetting and backpack electrofishing surveys in selected mine area lakes and in the Mary River, 2006-2008.

Statistic	Camp Lake	Sheardown Lake	Mary Lake	Mary River	All Waterbodies
n	28	35	97	29	189
Mean	9.5	13.3	13.2	2.6	11.1
Median	9	13	13	2	11
SD	3.7	4.5	3.6	0.9	5.2
SE	0.7	0.8	0.4	0.2	0.4
Minimum	4	5	7	2	2
Maximum	19	22	24	5	24
95th Percentile	16.7	21	19.4	4.6	19
COV (%)	39.2	33.8	27.5	33.5	47.3

Table 4-23. Length and weight-at-age for Arctic Char pooled from all Study Area waterbodies, 2006-2008.

Age	Fork Length (mm)				Weight (g)			
	n	Mean	SD	Range	n	Mean	SD	Range
2	17	88	12	63 - 108	17	10	4	4 - 18
3	9	106	13	86 - 128	9	17	7	7 - 28
4	2	179	69	130 - 228	2	92	82	33 - 150
5	5	189	44	149 - 240	4	92	53	44 - 150
6	4	186	13	170 - 197	4	69	24	50 - 100
7	7	228	46	171 - 301	7	125	76	50 - 275
8	9	246	59	172 - 331	9	178	90	75 - 300
9	15	273	48	192 - 351	15	210	111	75 - 450
10	14	294	78	167 - 496	14	300	306	50 - 1300
11	19	337	63	181 - 465	19	400	230	75 - 1100
12	12	364	39	312 - 451	12	473	154	275 - 800
13	13	398	107	241 - 658	13	685	625	100 - 2450
14	12	404	81	315 - 615	12	756	573	325 - 2300
15	11	390	17	370 - 418	11	525	51	450 - 600
16	16	404	43	357 - 490	16	608	232	350 - 1200
17	7	488	98	354 - 647	7	1114	691	350 - 2400
18	4	385	8	373 - 391	4	494	94	375 - 600
19	5	541	143	384 - 751	5	1985	1753	525 - 4900
20	0	-	-	-	-	-	-	-
21	3	440	62	387 - 508	3	608	163	450 - 775
22	1	507	-	-	1	1000	-	-
23	3	529	93	424 - 602	3	1408	610	725 - 1900
24	1	685	-	-	1	2350	-	-
Total	189	316	136	63 - 751	188	462	570	4 - 4900

Table 4-24. Results of Analysis of Covariance (ANCOVA) tests of length and weight-at-age for Arctic Char captured in Study Area waterbodies.

Statistic	Degrees of Freedom	R^2	Sum of Squares	Mean Squares	Pr > F[1]
Length	157	0.581	1544.568	772.284	< 0.0001
Weight	156	0.351	913.208	456.604	< 0.0001

[1] Fisher's F-test significance

Table 4-25. Results of power analyses for selected Arctic Char metrics for Sheardown Lake.

Effect Indicator	Metric	Effect Size	Sample Size @ $\beta = 0.1$
Growth	Age 0+ Length	10%	25
		20%	8
		25%	6
	Age 1+ Length	10%	11
		20%	4
		25%	3
	Age 1+ Weight	10%	250
		20%	62
		25%	42
Condition	Age 1+ Condition	10%	9
		20%	3
		25%	3

.

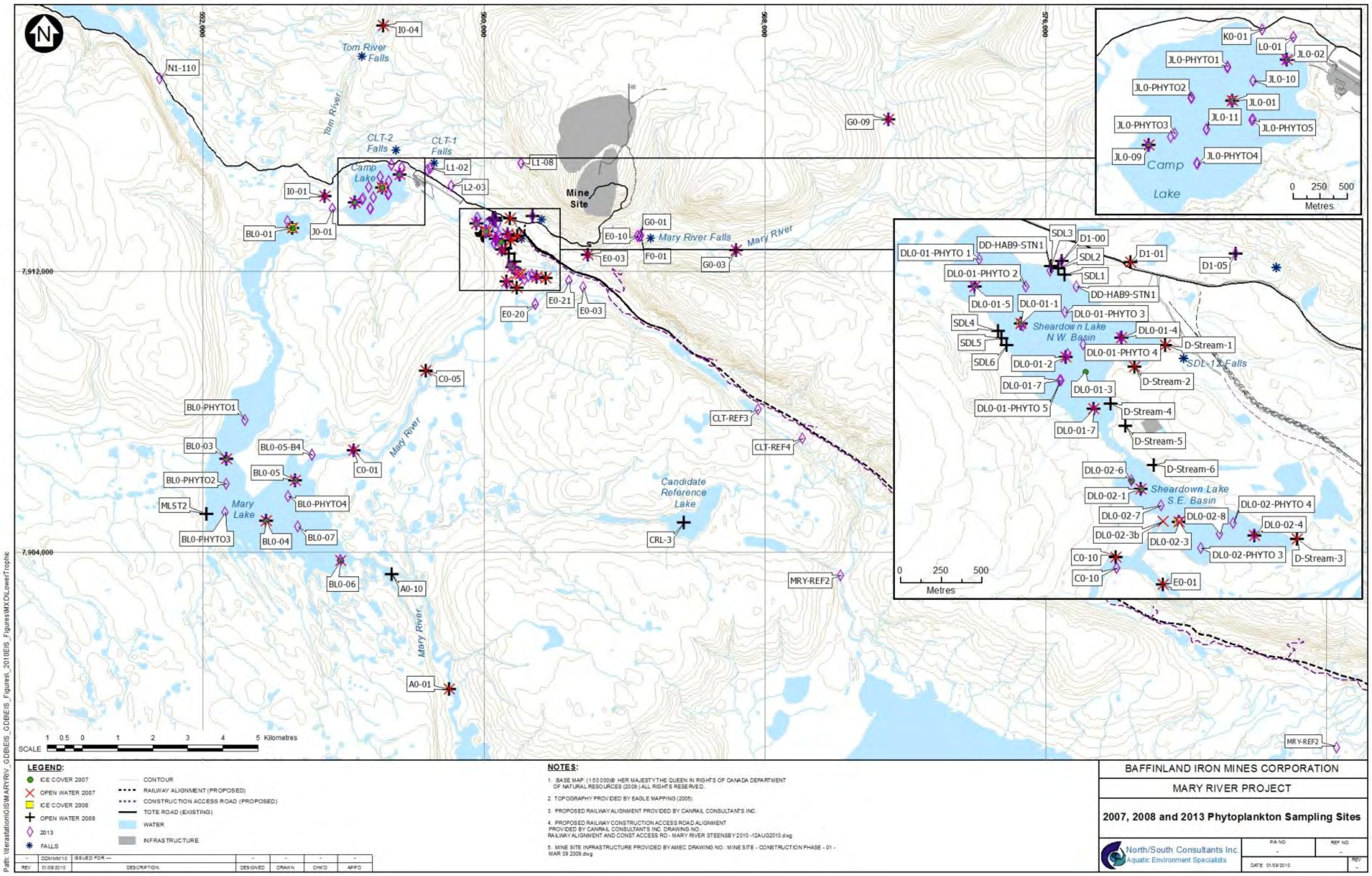


Figure 2-1. Locations of sites where phytoplankton taxonomy and biomass and/or chlorophyll *a* were measured in Mine Area lakes and streams: 2007-2013.

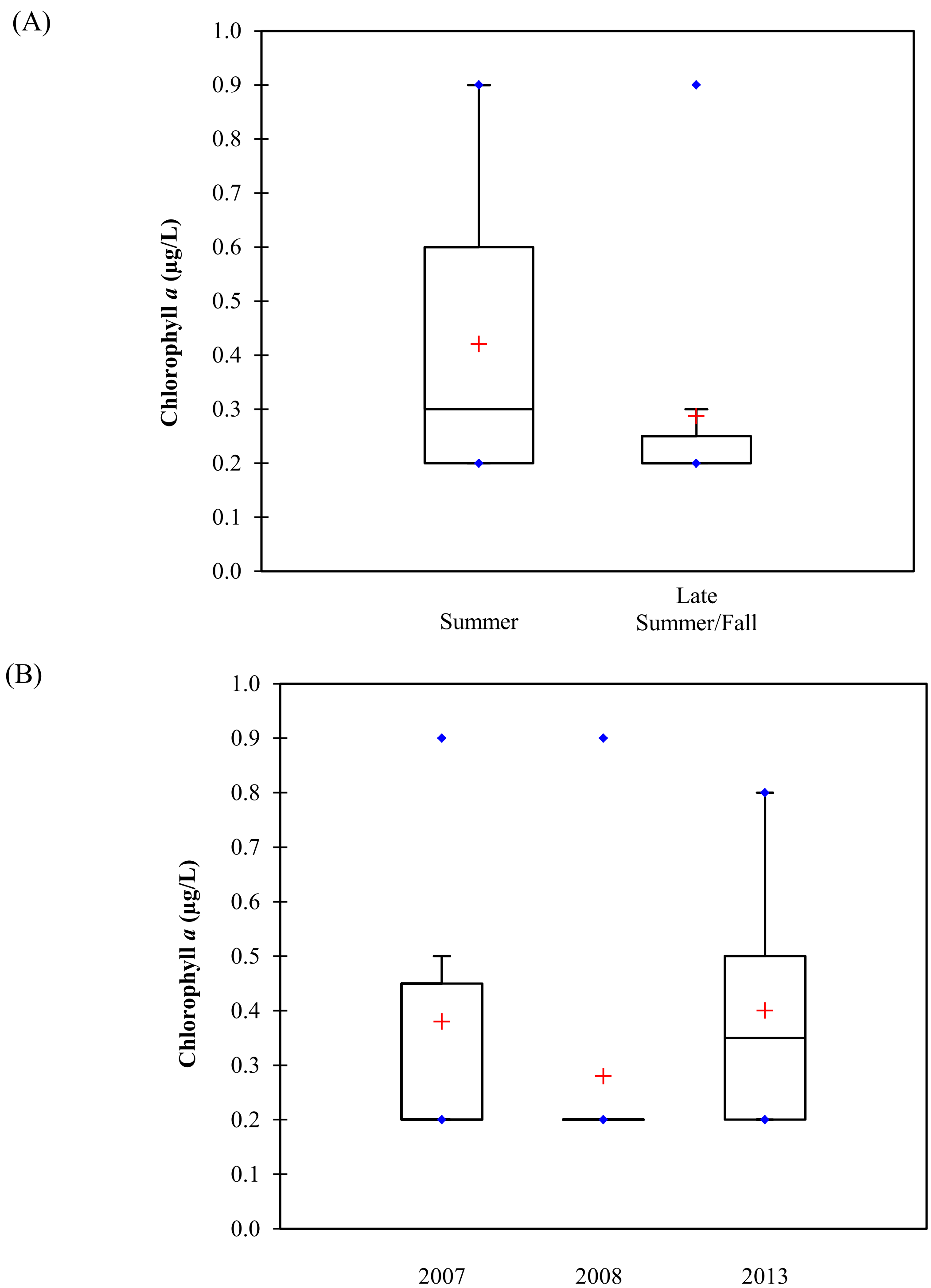


Figure 2-2. Box plots of chlorophyll *a* measured in Sheardown Lake NW by (A) sampling period and (B) sampling year. Data include offshore sampling measurements collected in summer and late summer/fall in 2007, 2008, and 2013.

(A)

(B)

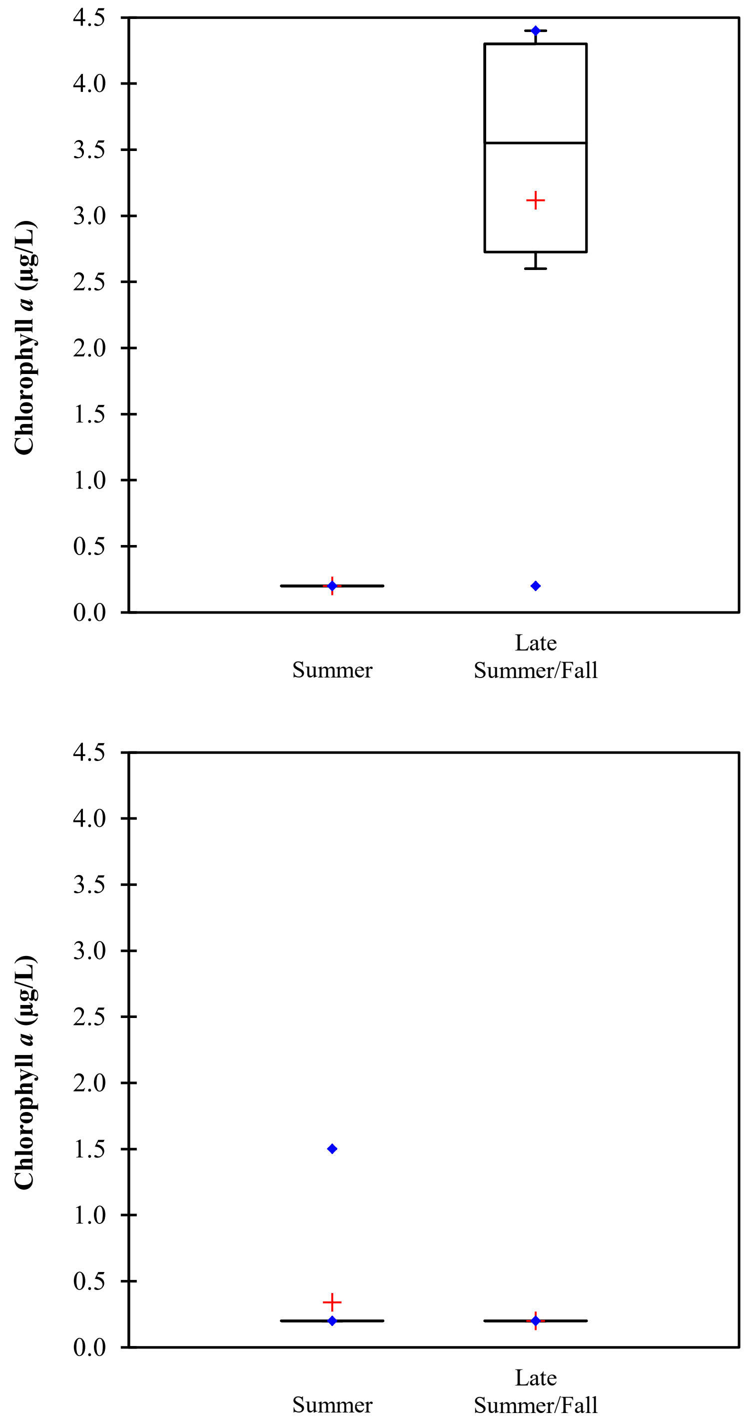


Figure 2-3. Comparisons of chlorophyll *a* measured in Sheardown Lake (A) nearshore sites and (B) offshore sites. Data include measurements collected in summer and late summer/fall in 2008.

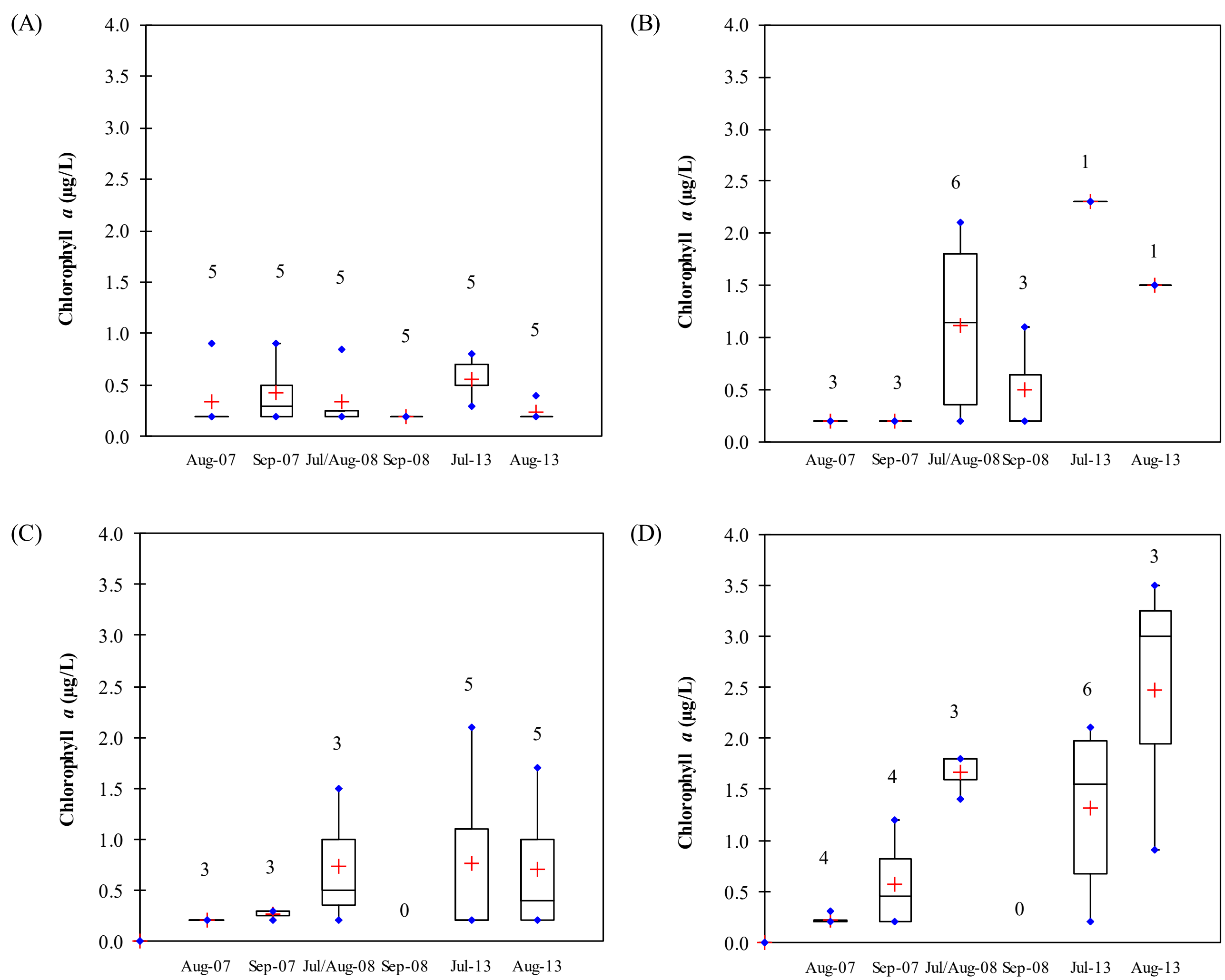


Figure 2-4. Comparisons of chlorophyll *a* measured in the open-water season of 2007, 2008, and 2013: (A) Sheardown Lake NW; (B) Sheardown Lake SE; (C) Camp Lake; and (D) Mary Lake. Where two samples were collected in summer 2008 (Sheardown Lake NW and SE), the data points were averaged to normalize sample sizes. Sample sizes are indicated above each box.

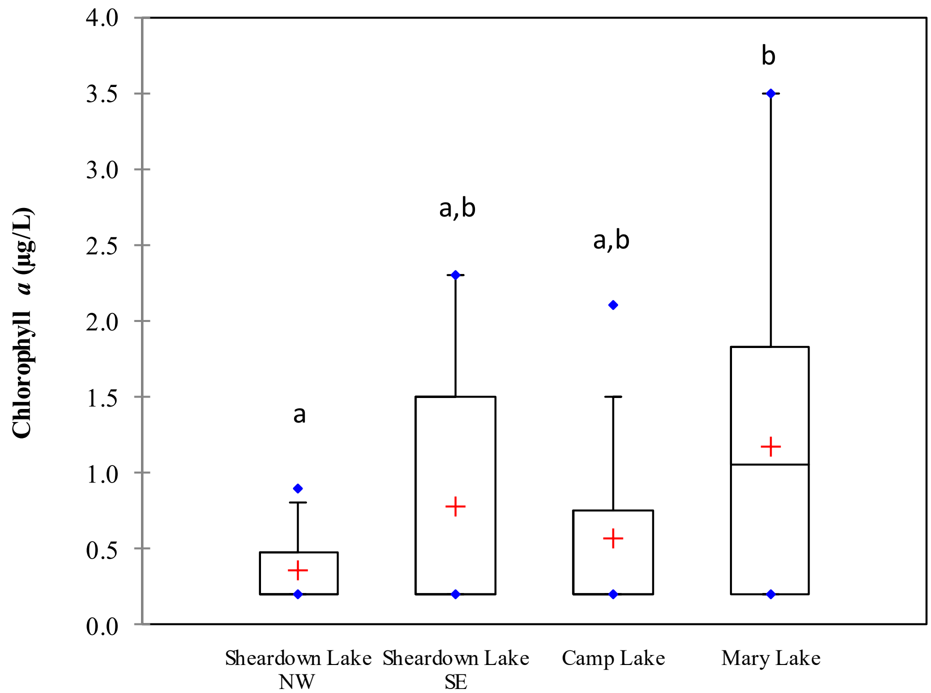


Figure 2-5. Chlorophyll *a* measured in Mine Area lakes: 2007-2013. Statistically significant spatial differences are denoted with different superscripts ($p < 0.05$).

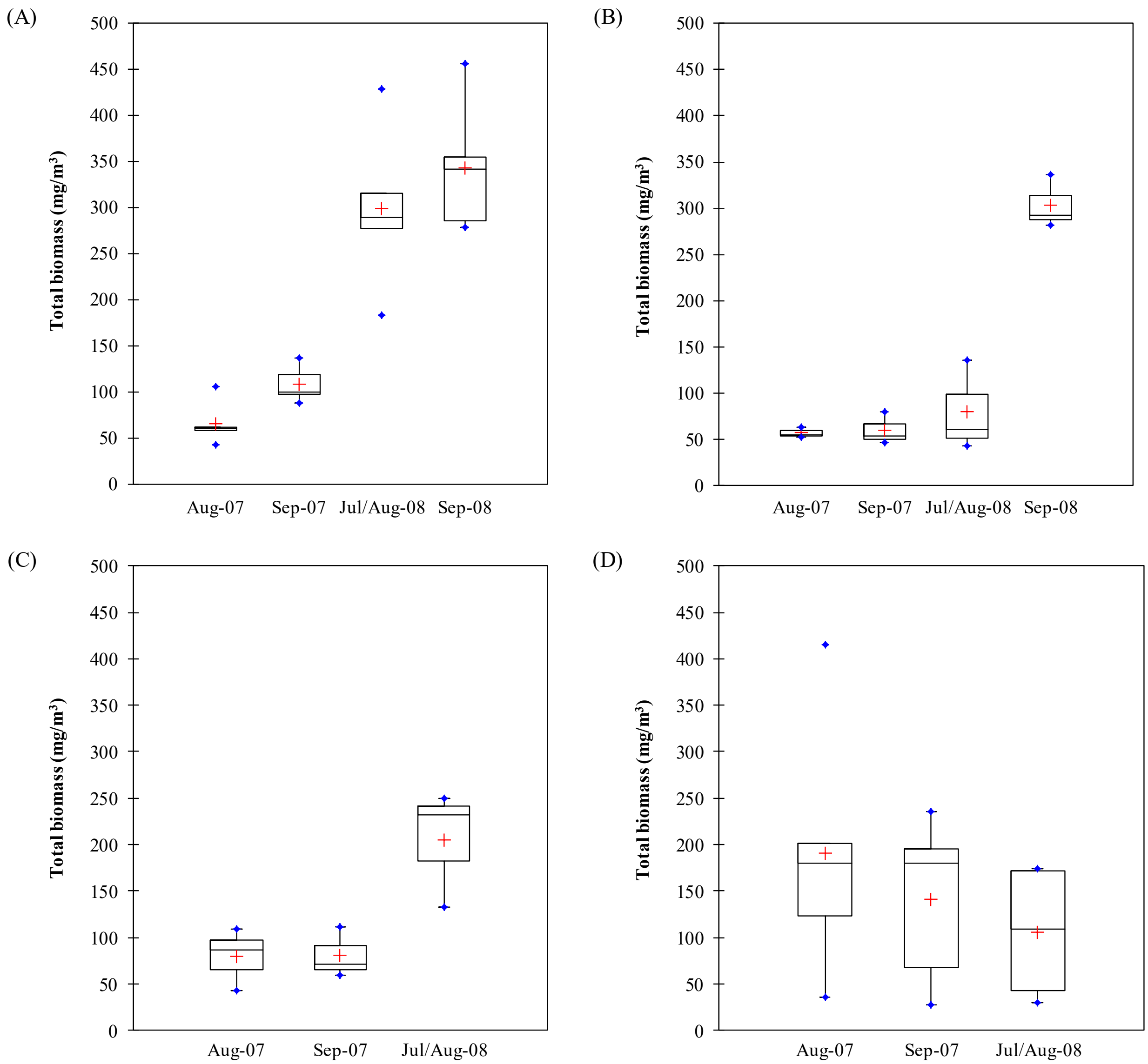


Figure 2-6. Total biomass of phytoplankton measured by sampling period in Mine Area lakes, 2007-2008: (A) Sheardown Lake NW; (B) Sheardown Lake SE; (C) Camp Lake; and (D) Mary Lake.

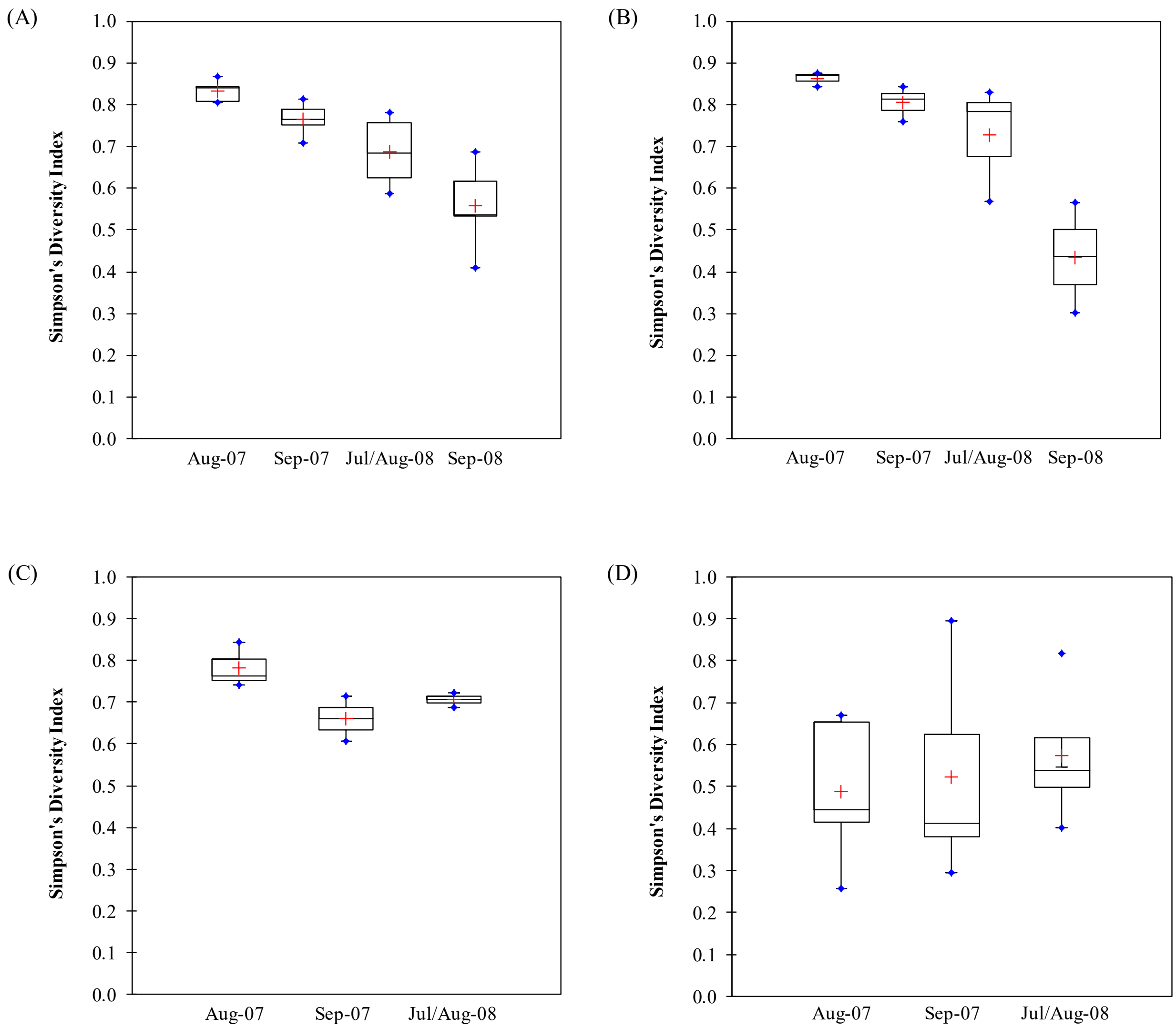


Figure 2-7. Phytoplankton Simpson's Diversity Index by sampling period in Mine Area lakes, 2007-2008: (A) Sheardown Lake NW; (B) Sheardown Lake SE; (C) Camp Lake; and (D) Mary Lake.

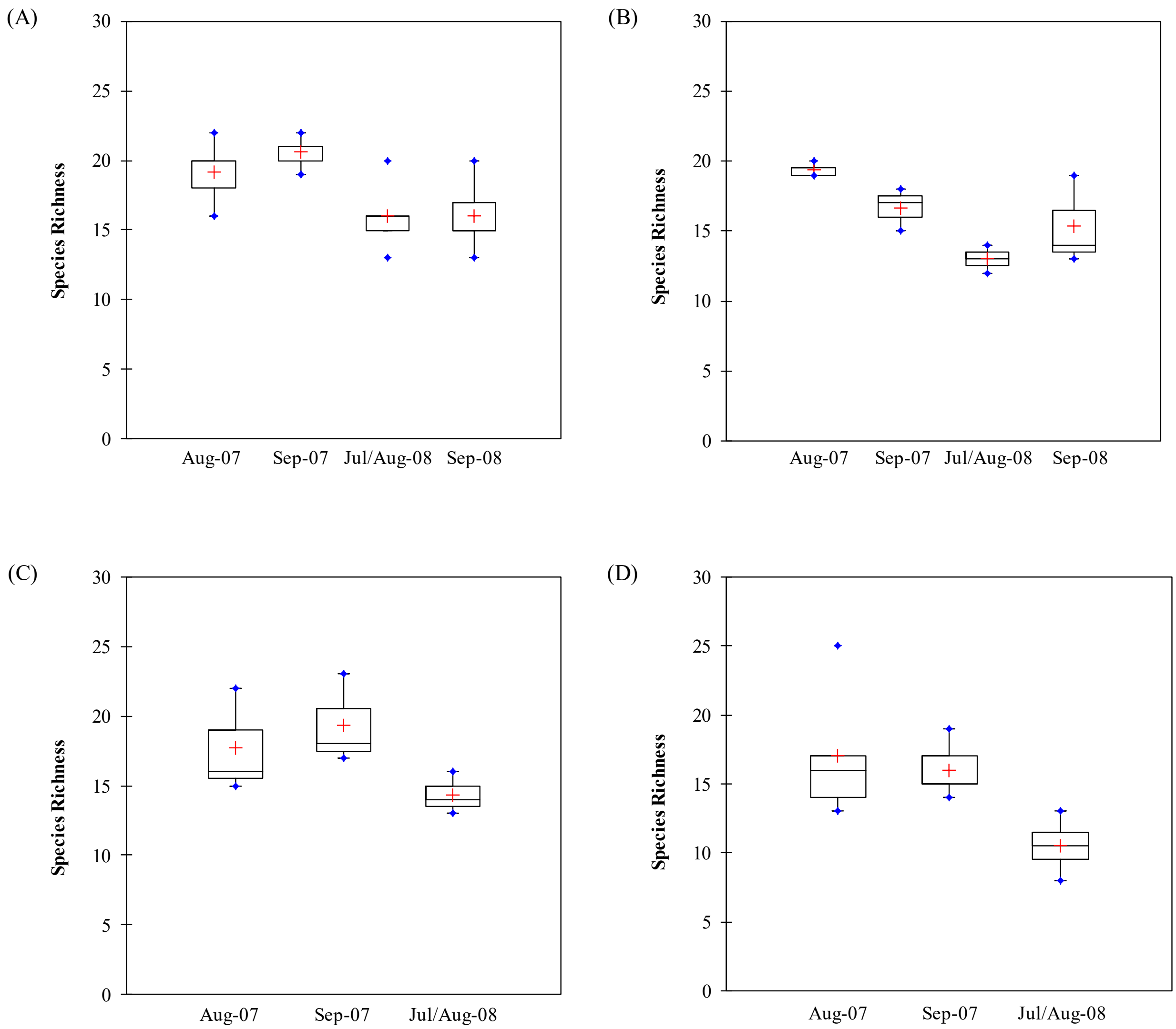


Figure 2-8. Phytoplankton species richness by sampling period in Mine Area lakes, 2007-2008: (A) Sheardown Lake NW; (B) Sheardown Lake SE; (C) Camp Lake; and (D) Mary Lake.

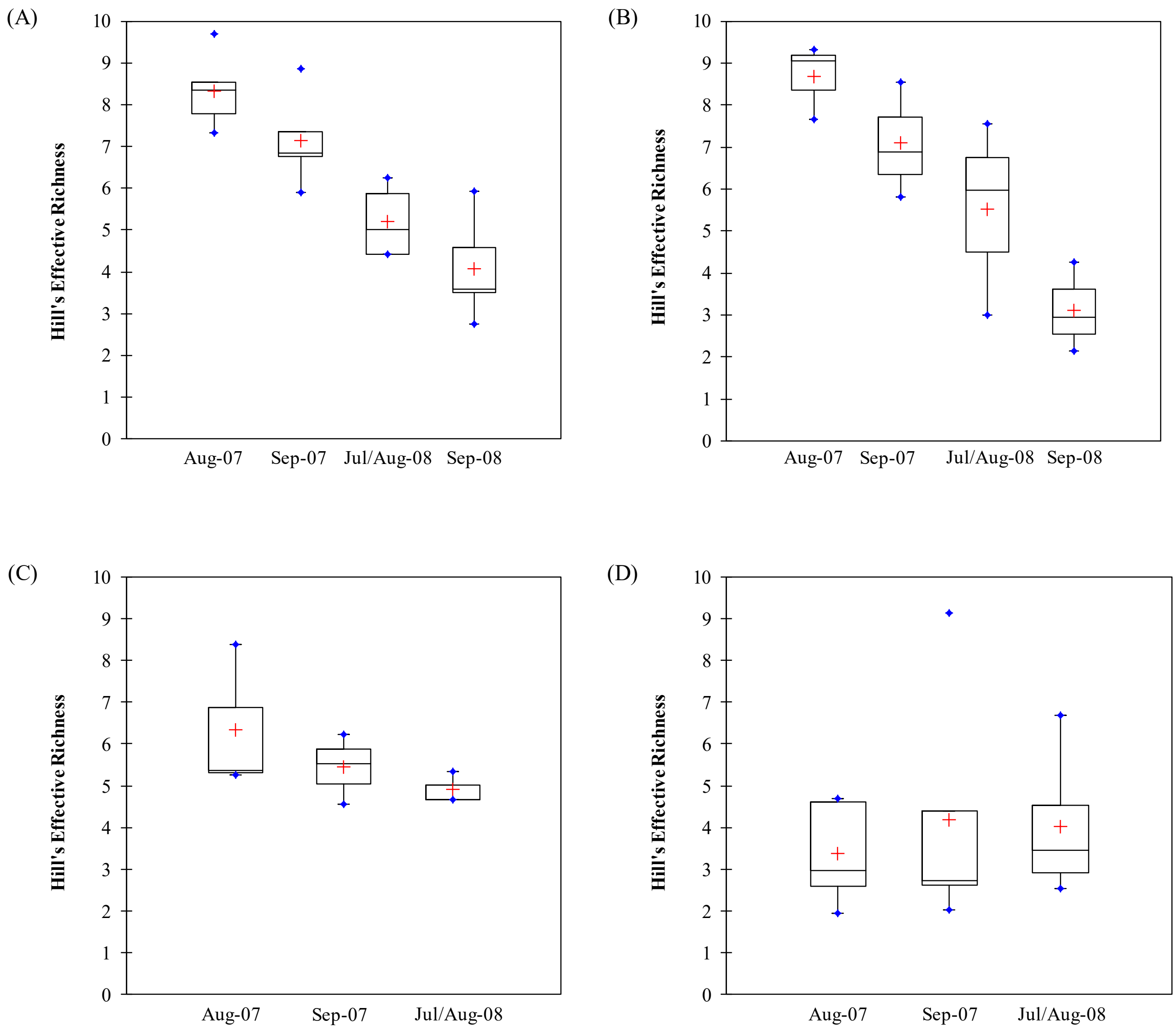


Figure 2-9. Phytoplankton Hill's effective richness by sampling period in Mine Area lakes, 2007-2008: (A) Sheardown Lake NW; (B) Sheardown Lake SE; (C) Camp Lake; and (D) Mary Lake.

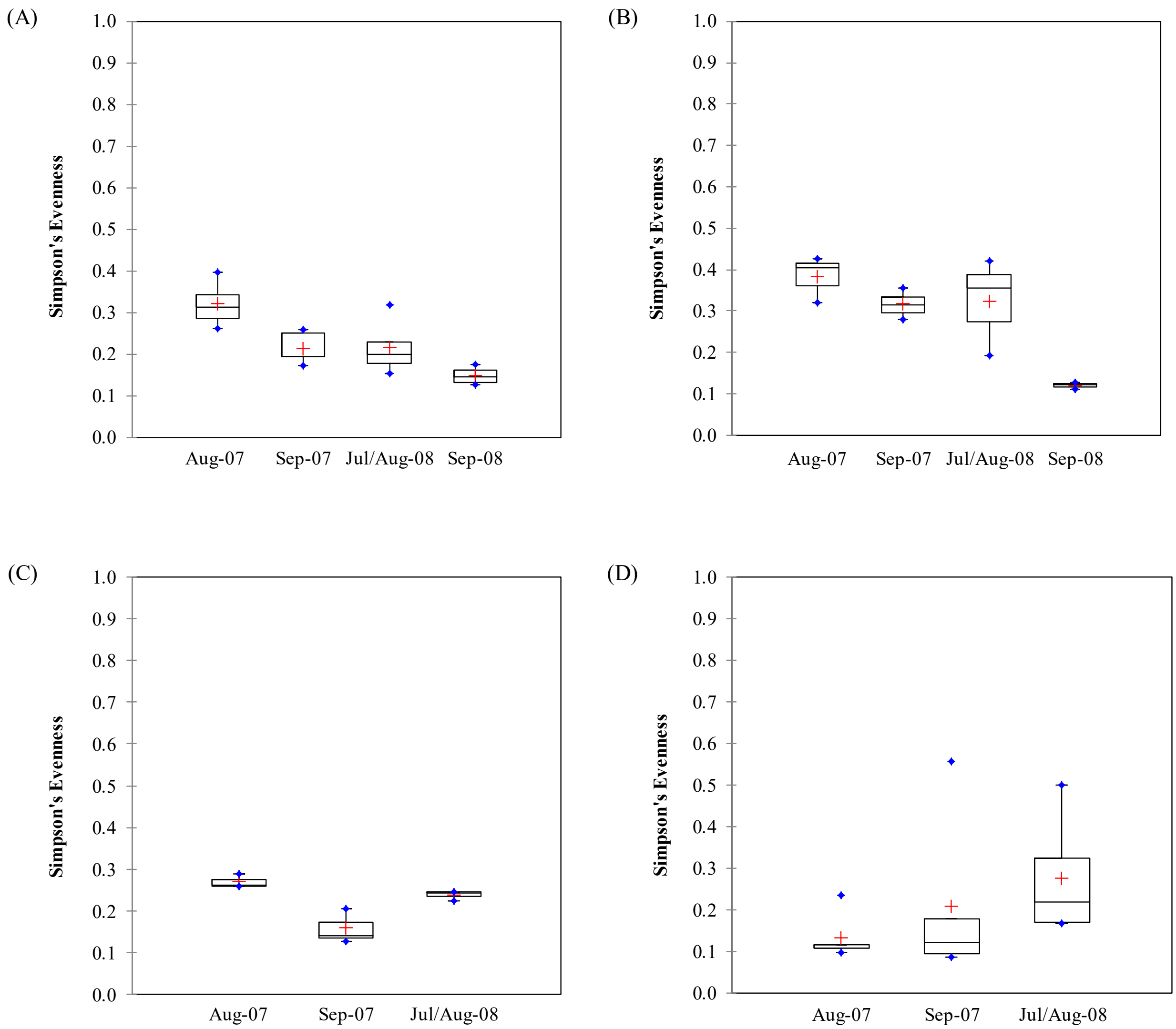


Figure 2-10. Phytoplankton Simpson’s evenness by sampling period in Mine Area lakes, 2007-2008: (A) Sheardown Lake NW; (B) Sheardown Lake SE; (C) Camp Lake; and (D) Mary Lake.

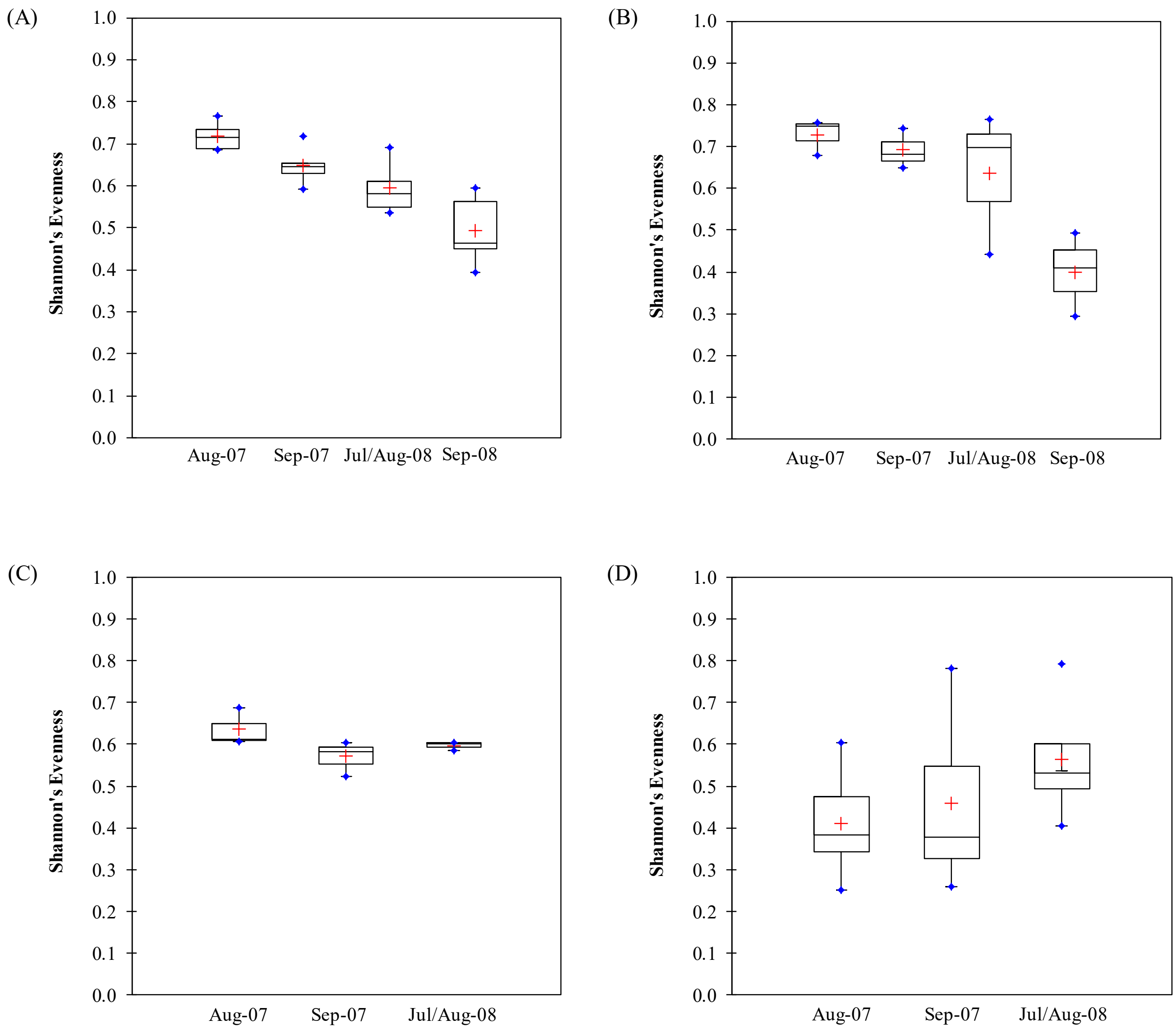


Figure 2-11. Shannon's evenness by sampling period in Mine Area lakes, 2007-2008: (A) Sheardown Lake NW; (B) Sheardown Lake SE; (C) Camp Lake; and (D) Mary Lake.

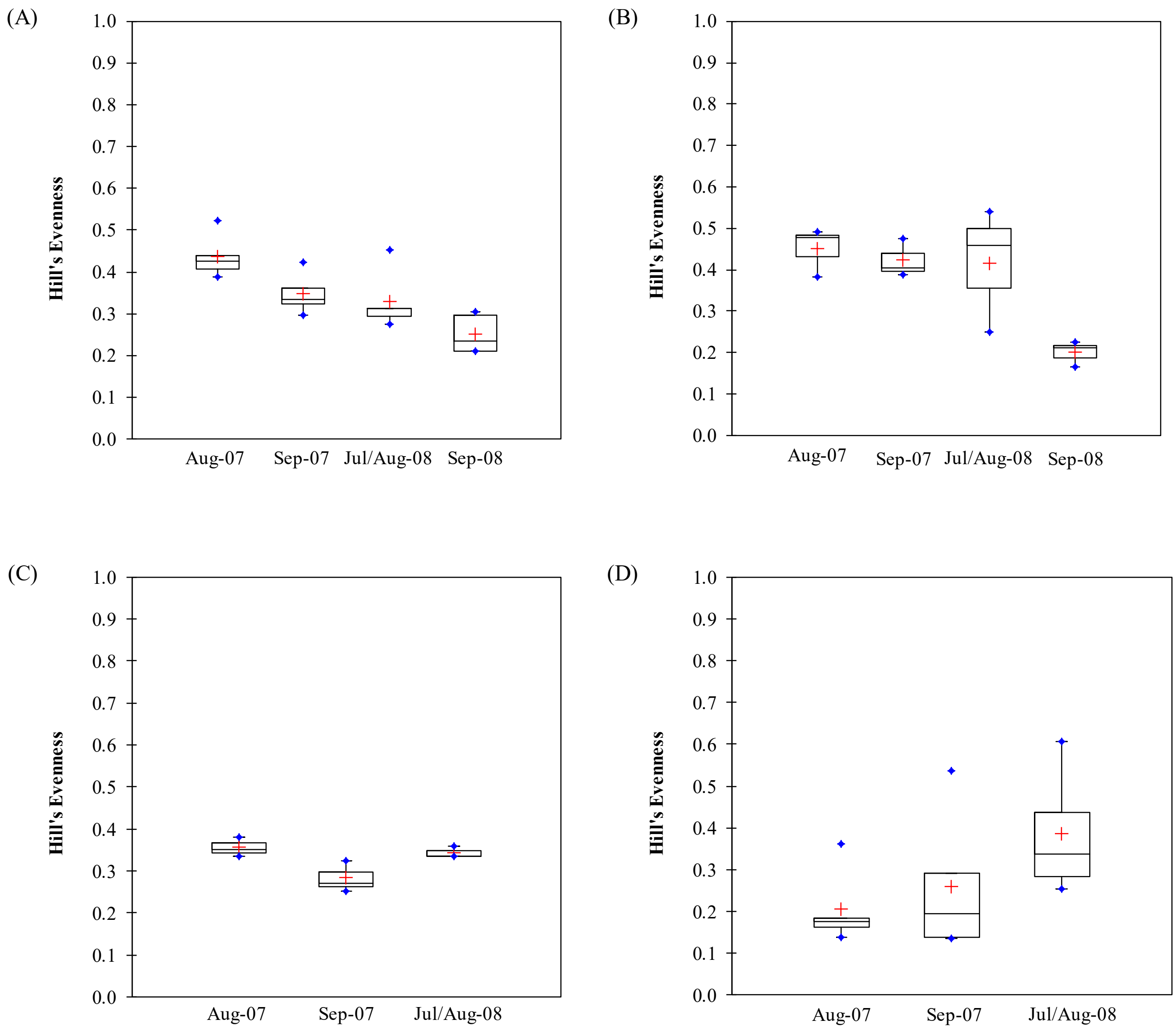


Figure 2-12. Phytoplankton Hill's evenness by sampling period in Mine Area lakes 2007-2008: (A) Sheardown Lake NW; (B) Sheardown Lake SE; (C) Camp Lake; and (D) Mary Lake.

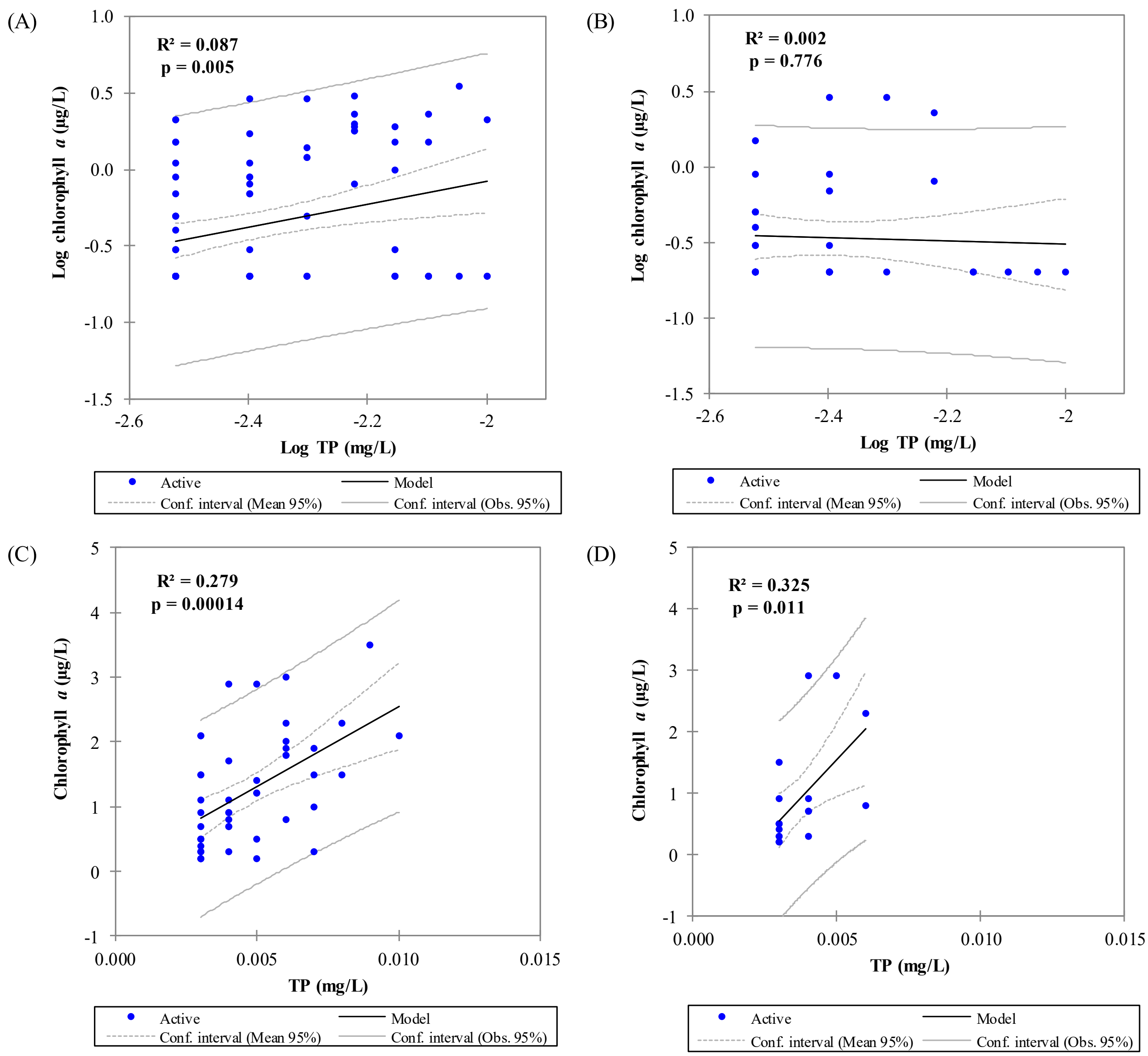


Figure 2-13. Linear regressions between total phosphorus (TP) and chlorophyll *a* (nearshore samples excluded) in Mine Area lakes. (A) and (B) present regressions for all lakes and Sheardown Lake NW, respectively, using all data points. (C) and (D) present regressions for all lakes and Sheardown Lake NW, respectively, using only chlorophyll *a* measurements that exceeded the analytical detection limits.

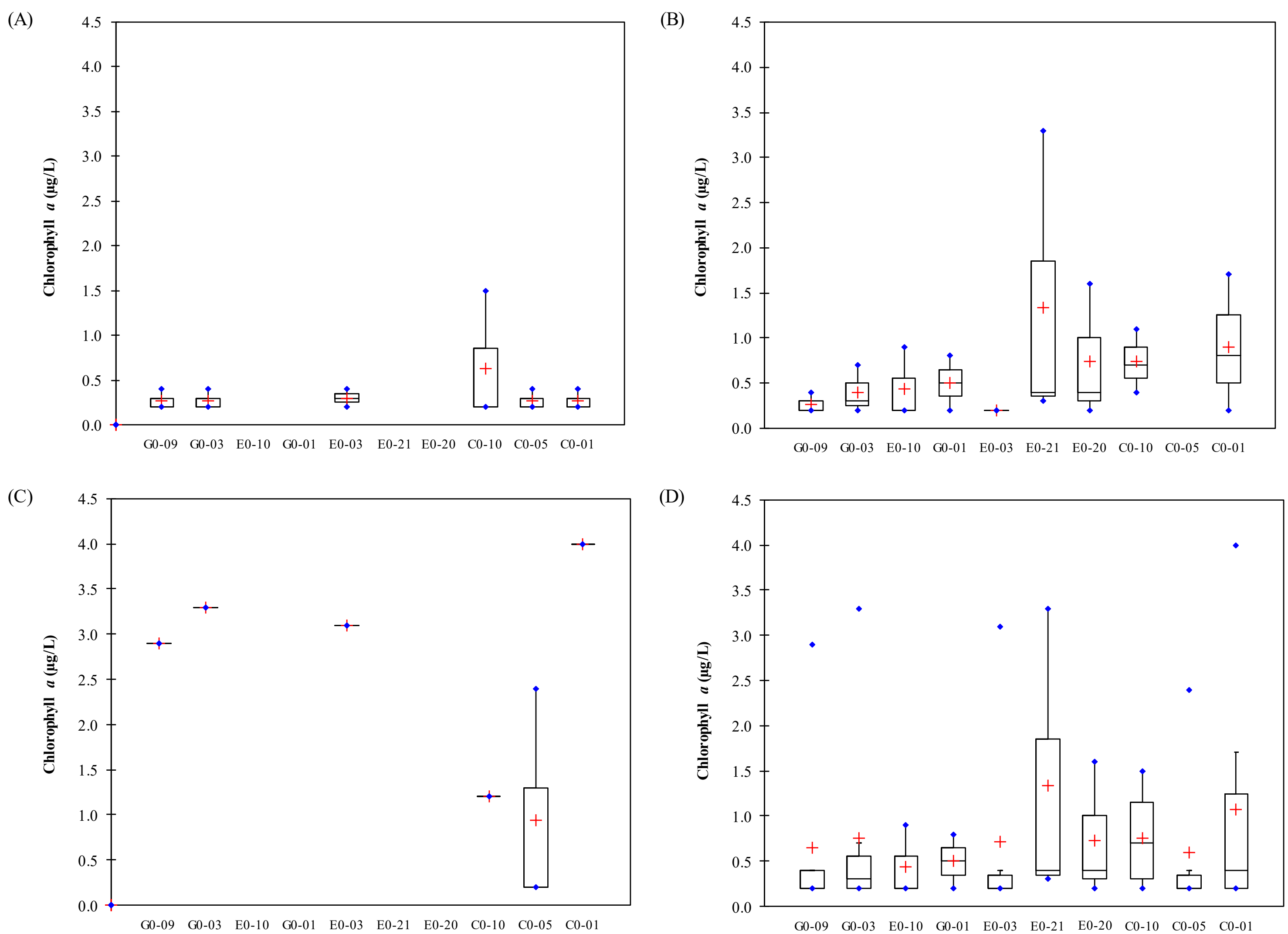


Figure 2-14. Chlorophyll *a* measured in the Mary River, 2007-2013: (A) 2007; (B) 2008; (C) 2013; and (D) all years combined.

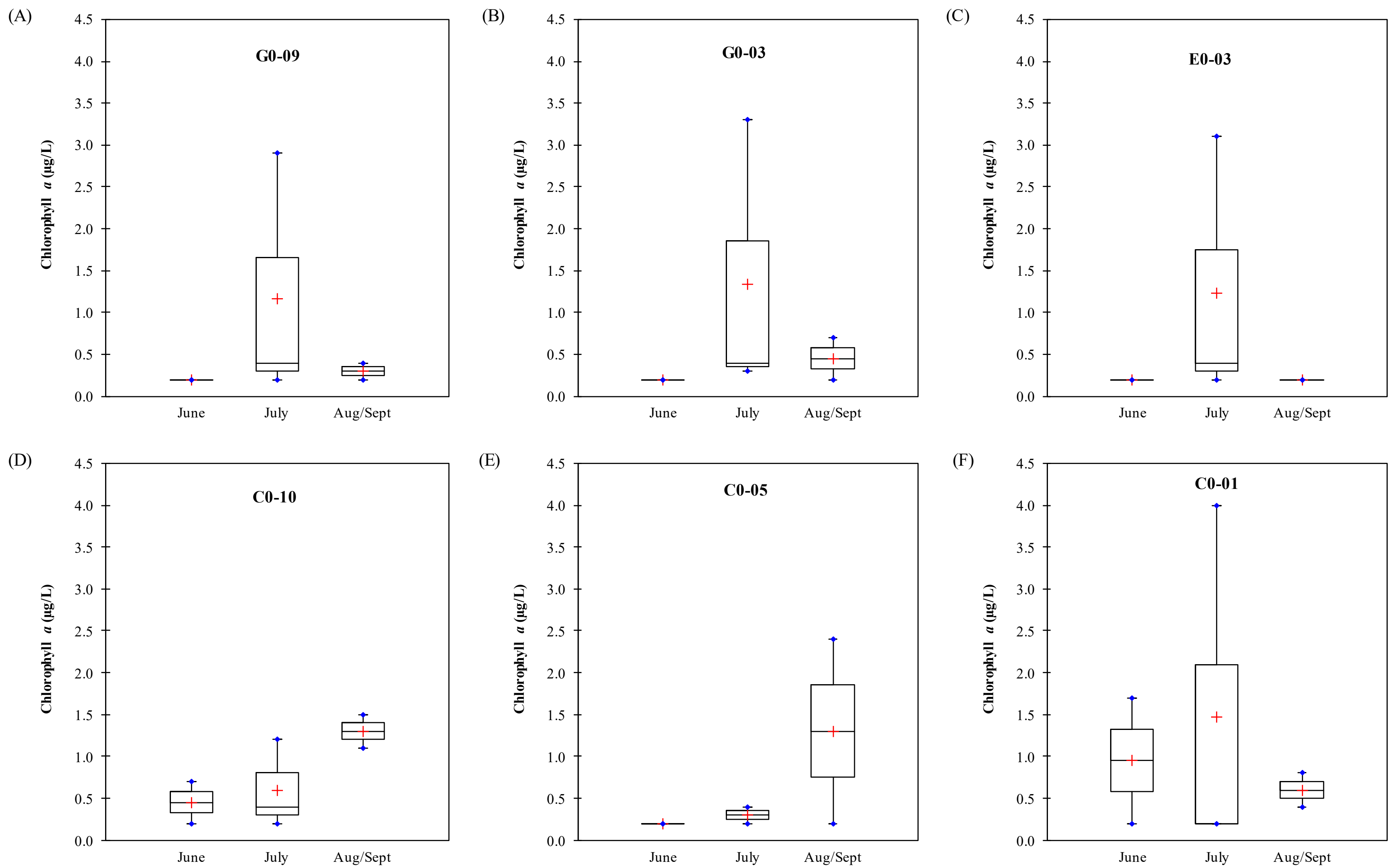
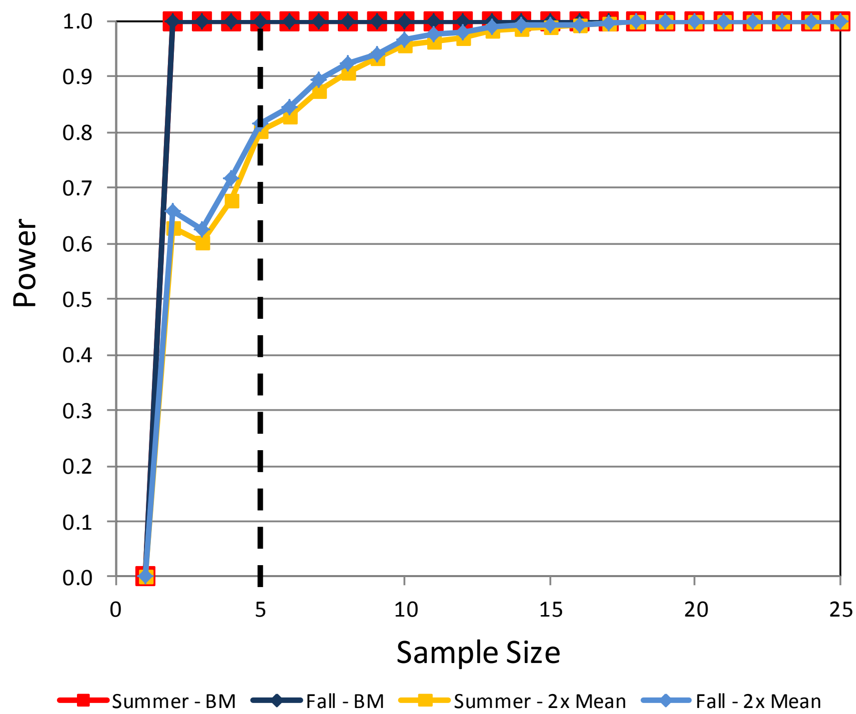


Figure 2-15. Seasonal boxplots of chlorophyll *a* measured at sites along the Mary River, 2007-2013: (A) G0-09; (B) G0-03; (C) E0-03; (D) C0-10; (E) C0-05; and (F) C0-01.

(A)



(B)

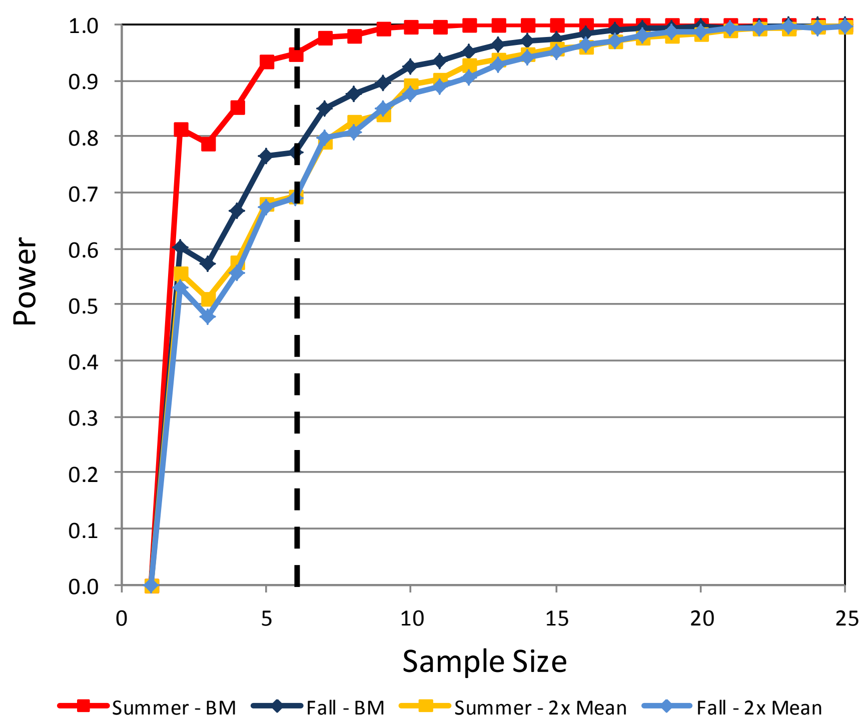


Figure 2-16. Results of *an priori* power analysis for chlorophyll *a* in (A) Sheardown Lake NW and (B) Mary Lake. BM = benchmark.

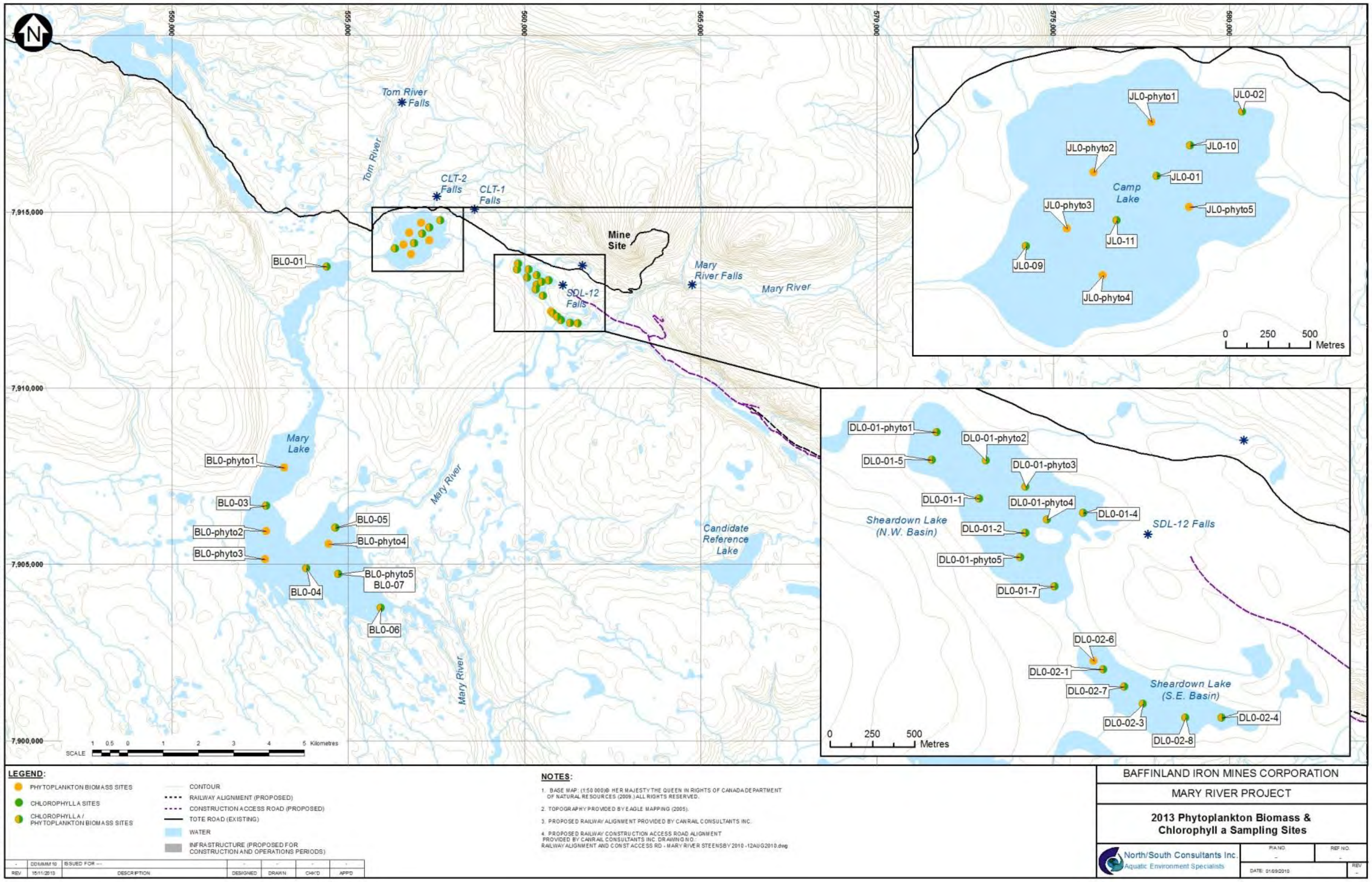


Figure 2-17. Locations of sites where phytoplankton taxonomy and biomass and/or chlorophyll *a* were measured in Mine Area lakes: 2013.

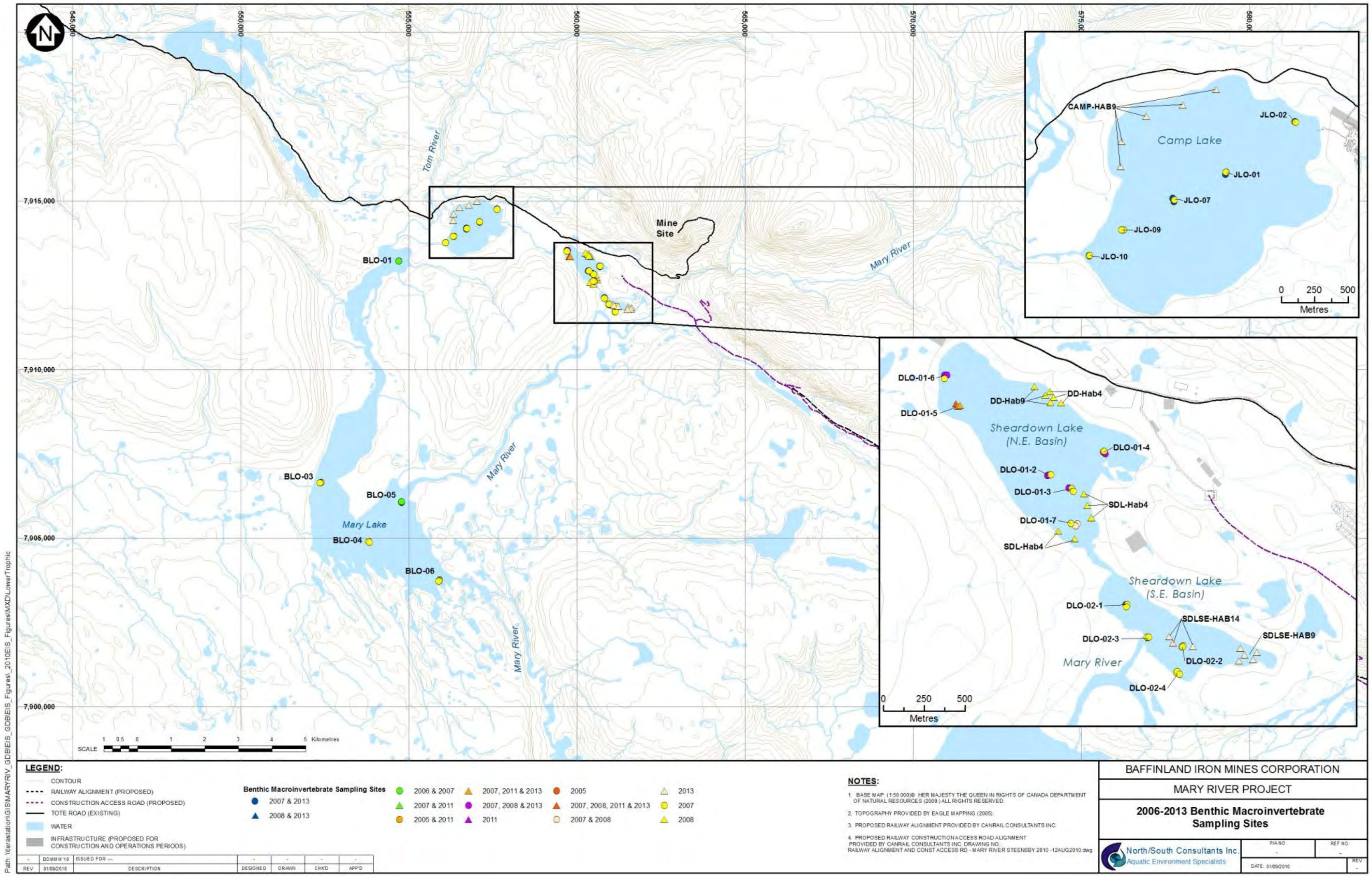


Figure 3-1. Benthic invertebrate sampling sites in Mine Area lakes.

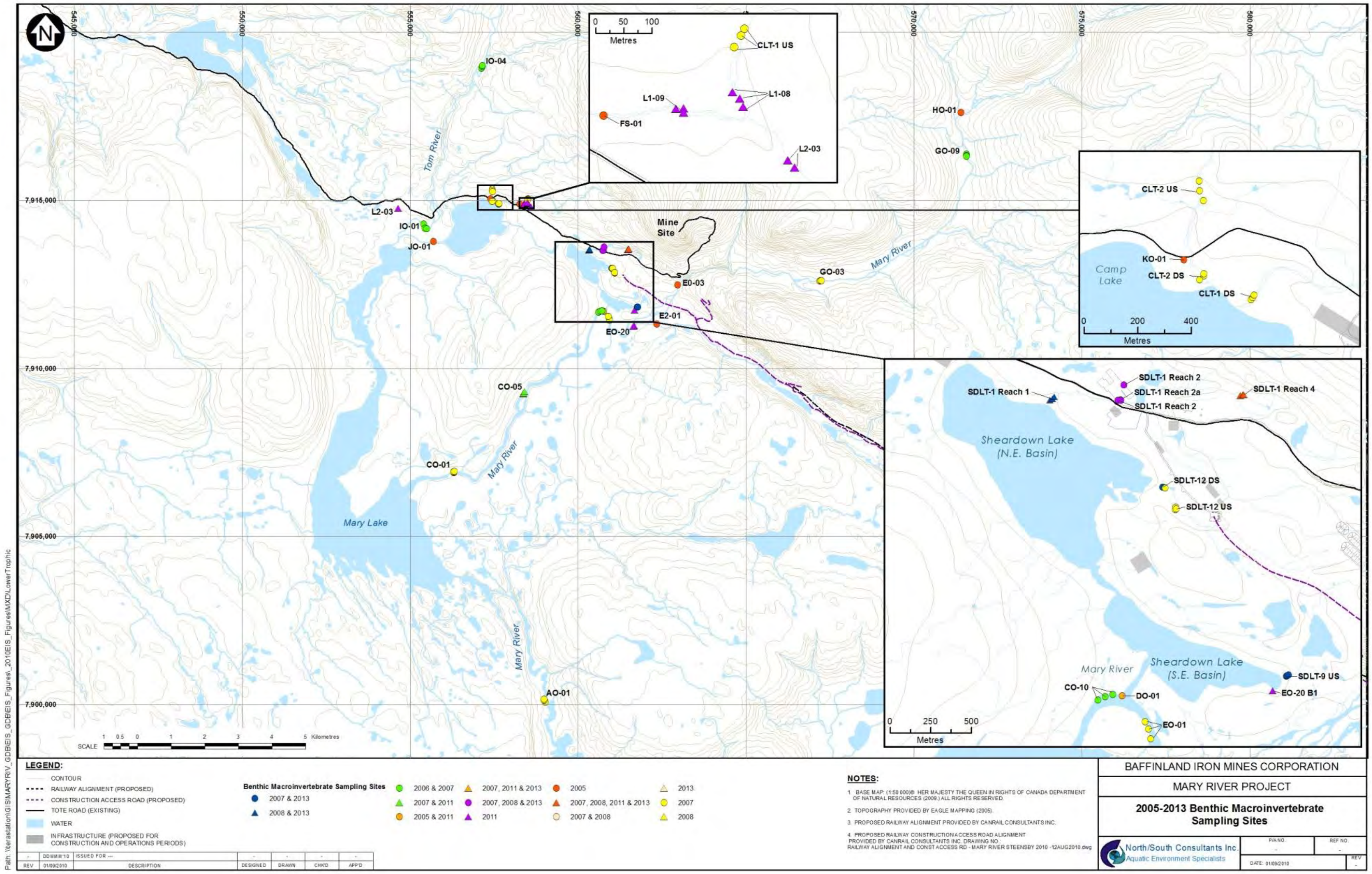


Figure 3-2. Benthic invertebrate sampling sites in Mine Area streams.

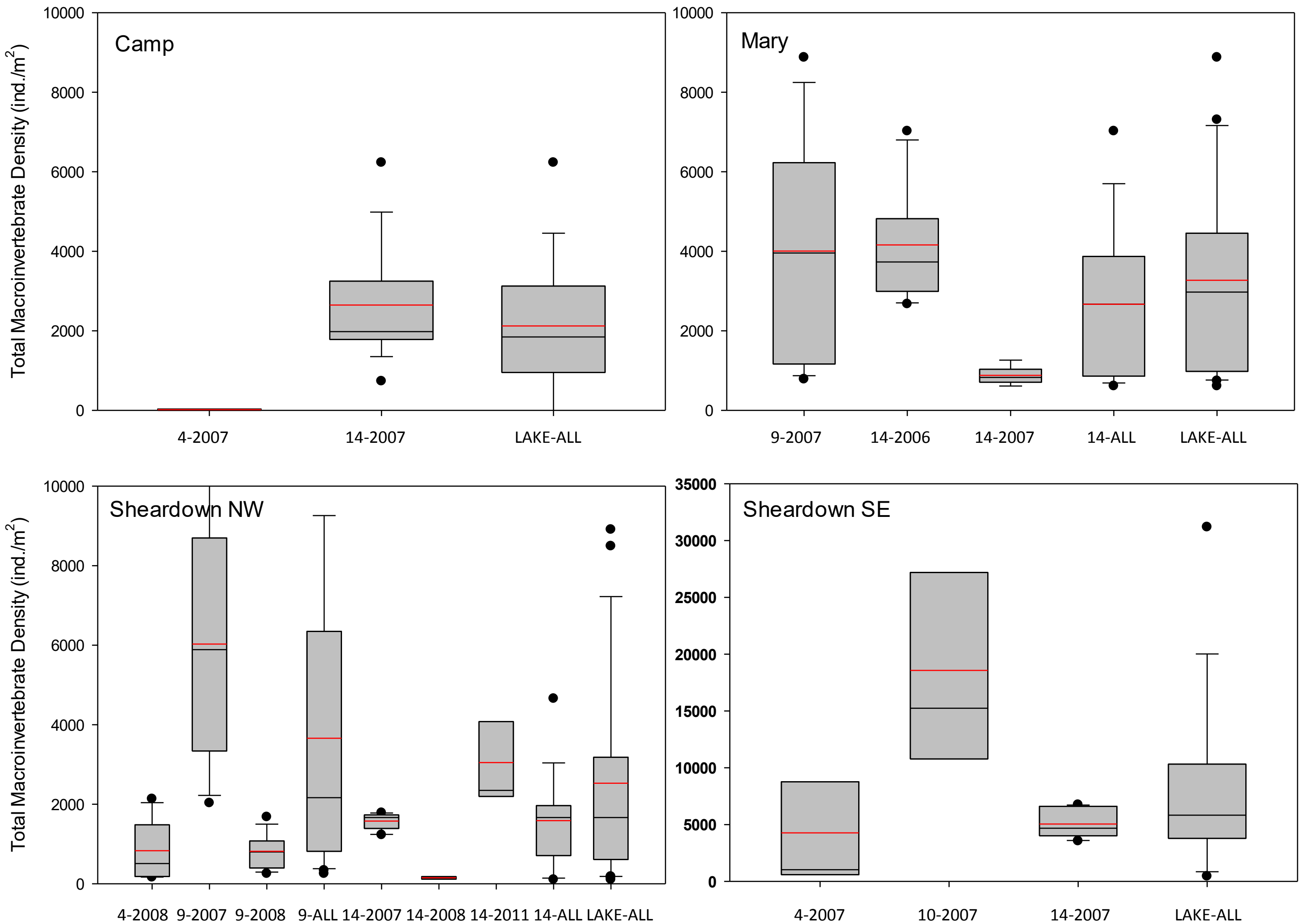


Figure 3-3. Boxplot of total macroinvertebrate density (ind./m^2) for all Mine Area lakes, by aquatic habitat type and year. Mean is represented by red line. Note different vertical scale for Sheardown SE.

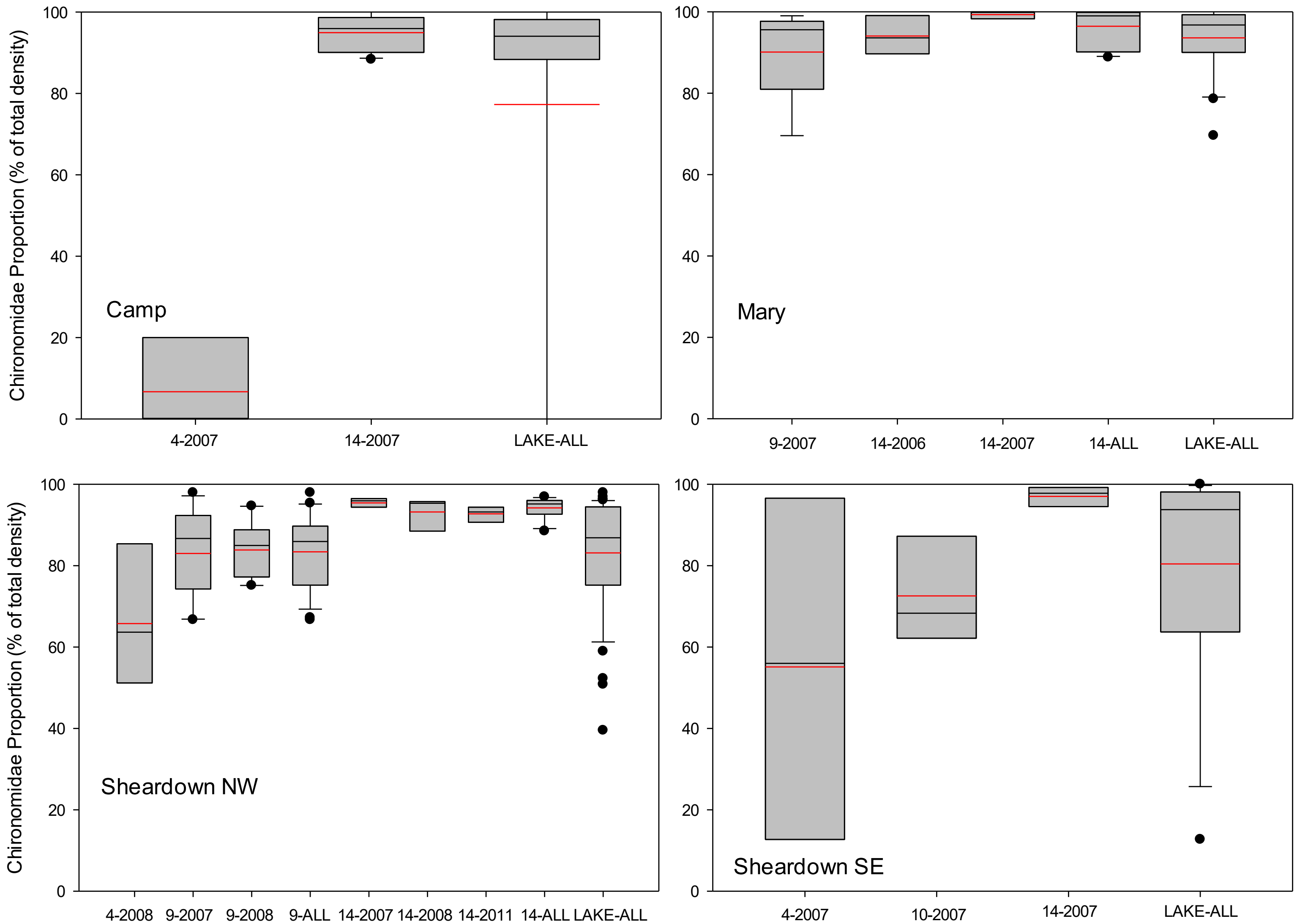


Figure 3-4. Boxplot of Chironomidae proportion (% of total density) for all Mine Area lakes, by aquatic habitat type and year.

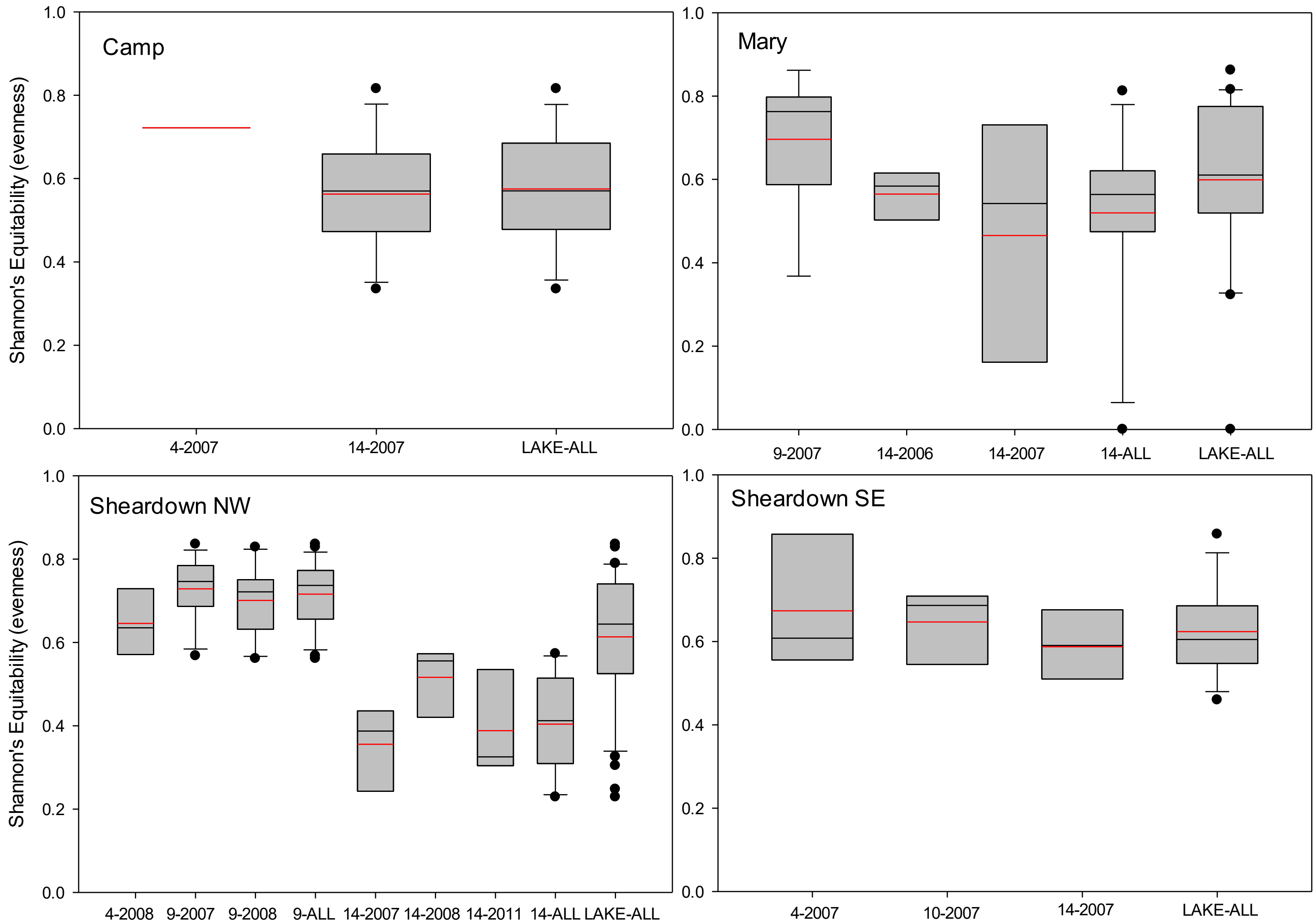


Figure 3-5. Boxplot of Shannon's Equitability (evenness) for all Mine Area lakes, by aquatic habitat type and year.

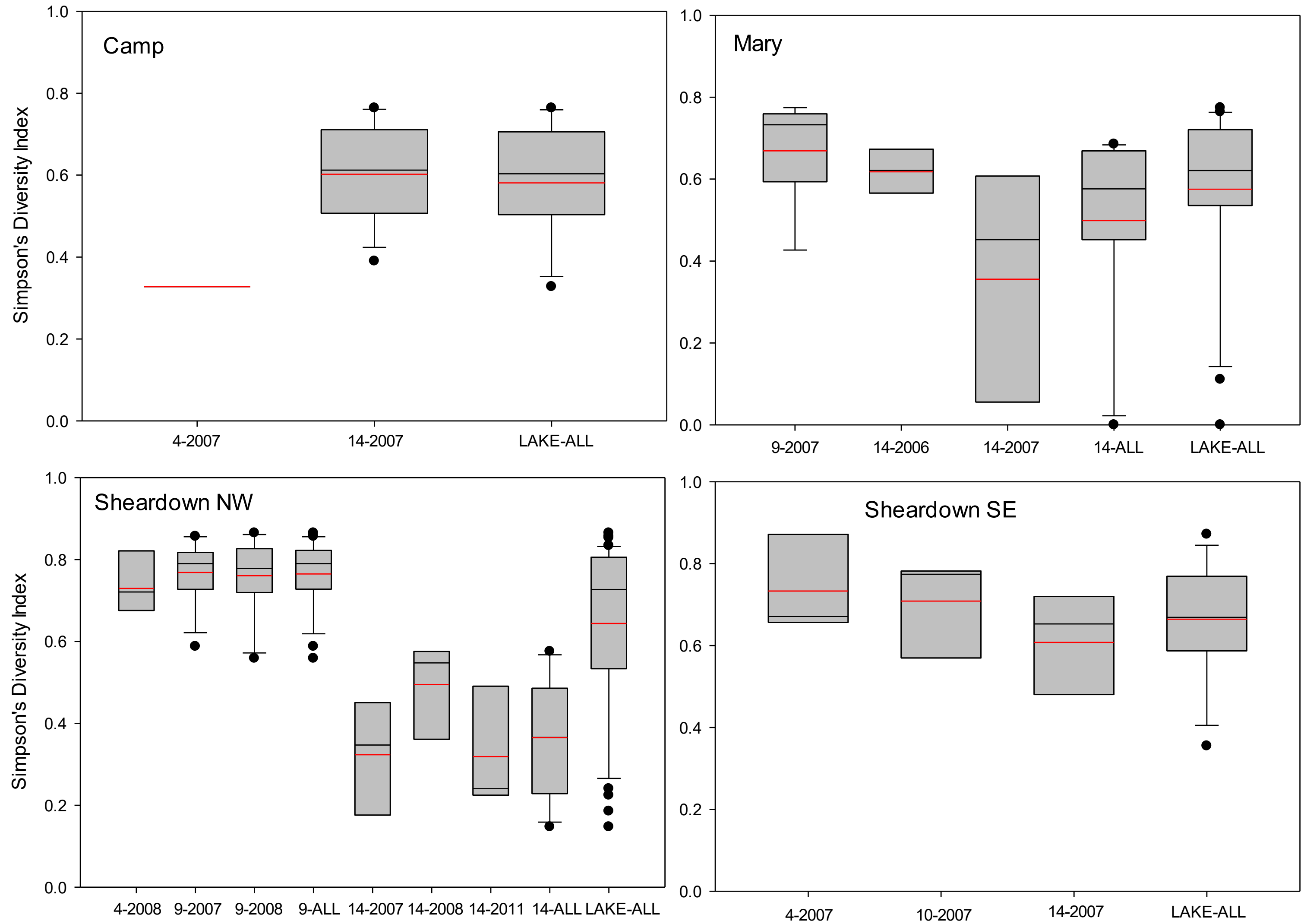


Figure 3-6. Boxplot of Simpson's Diversity Index for all Mine Area lakes, by aquatic habitat type and year.

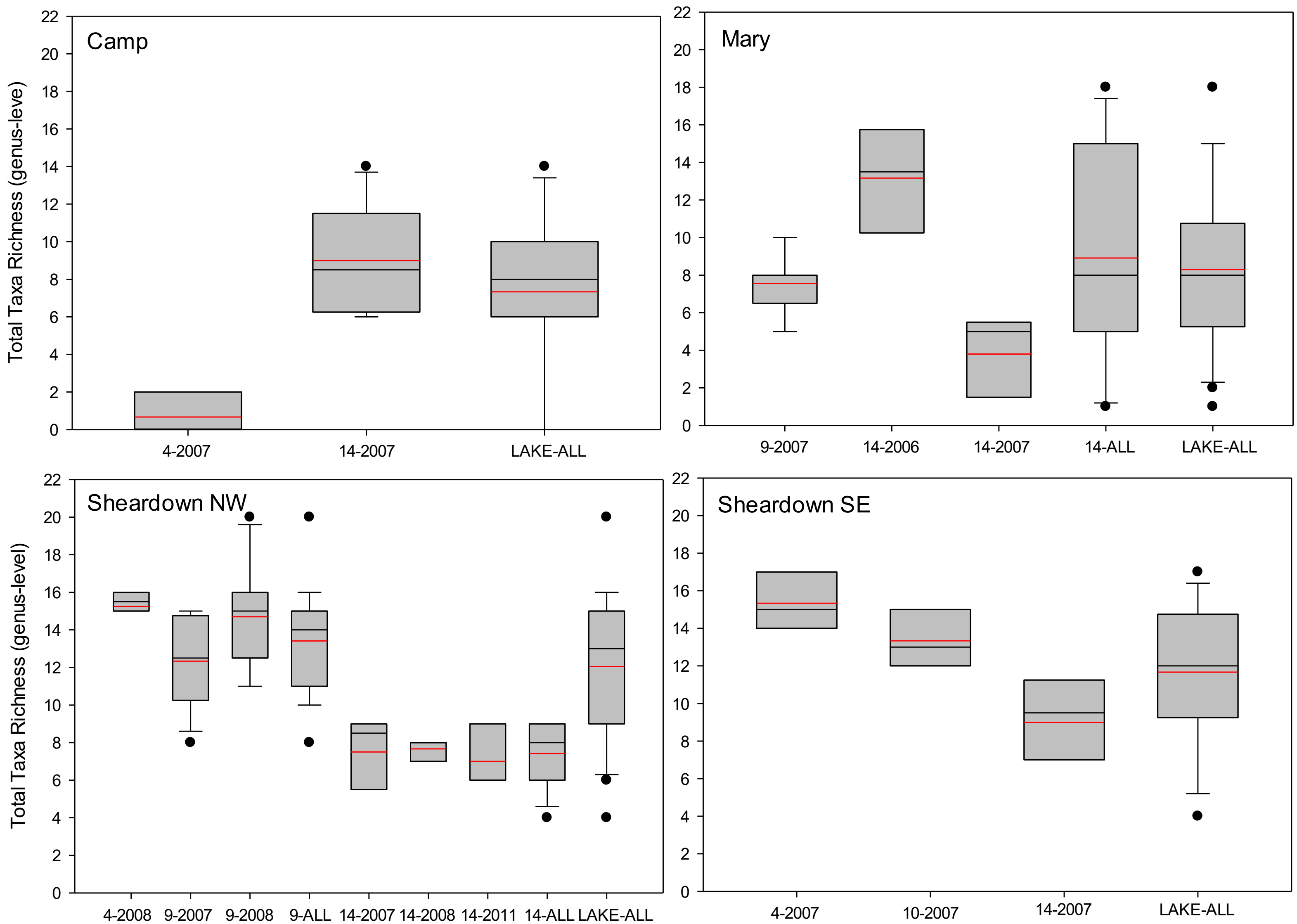


Figure 3-7. Boxplot of total taxa richness (genus-level) for all Mine Area lakes, by aquatic habitat type and year.

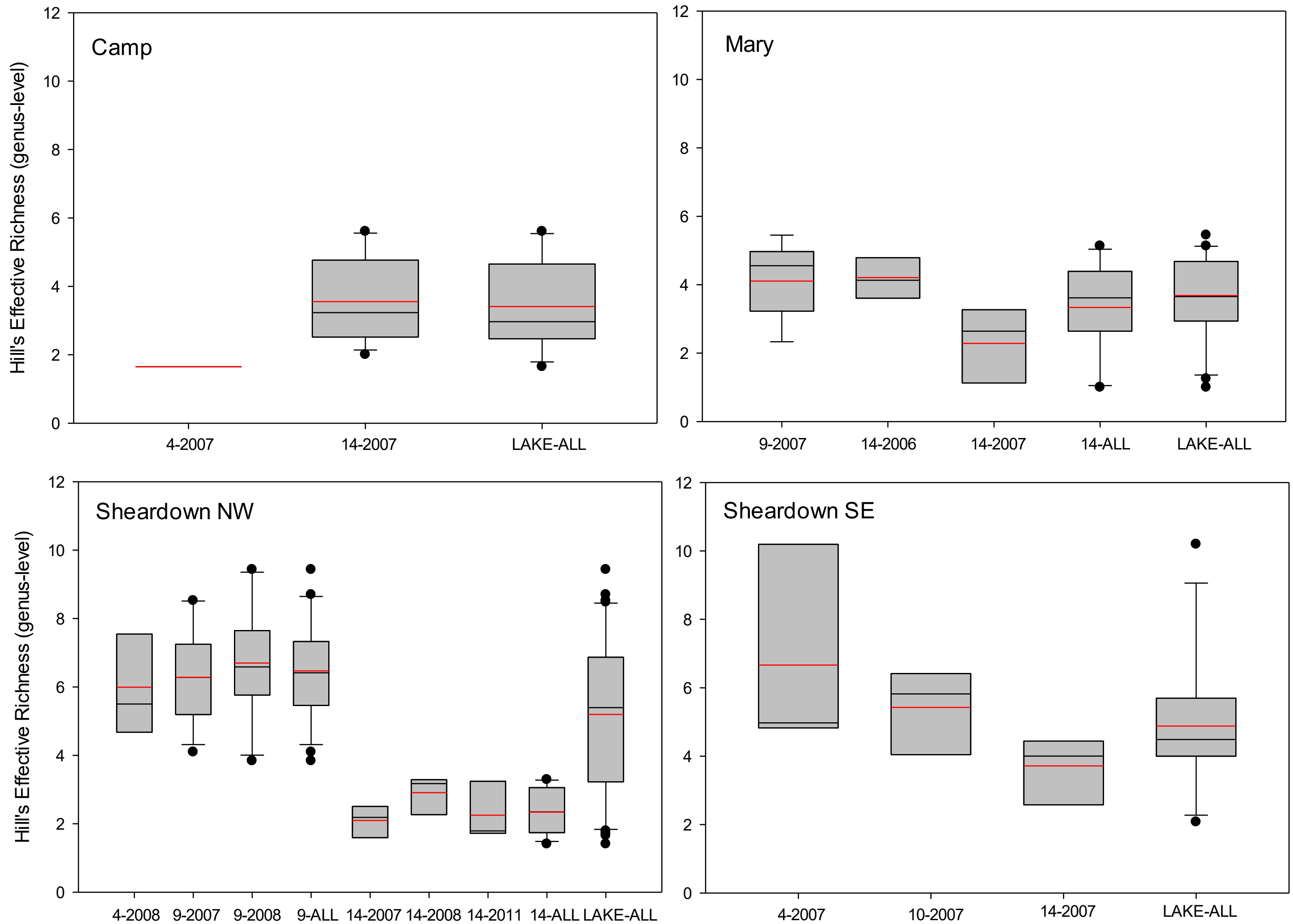


Figure 3-8. Boxplot of Hill's effective richness (genus-level) for all Mine Area lakes, by aquatic habitat type and year.

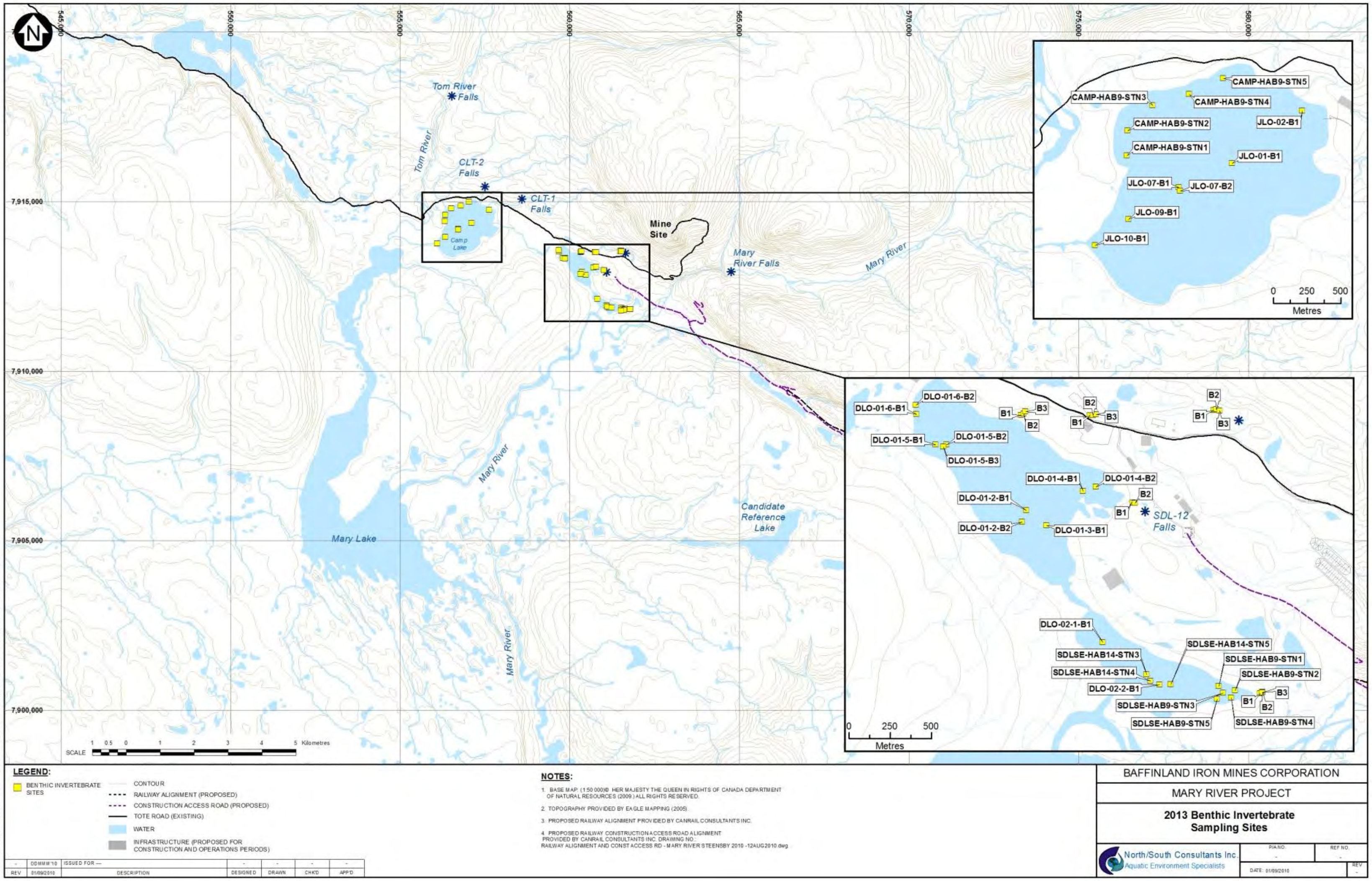


Figure 3-9. Benthic invertebrate sampling sites: 2013.

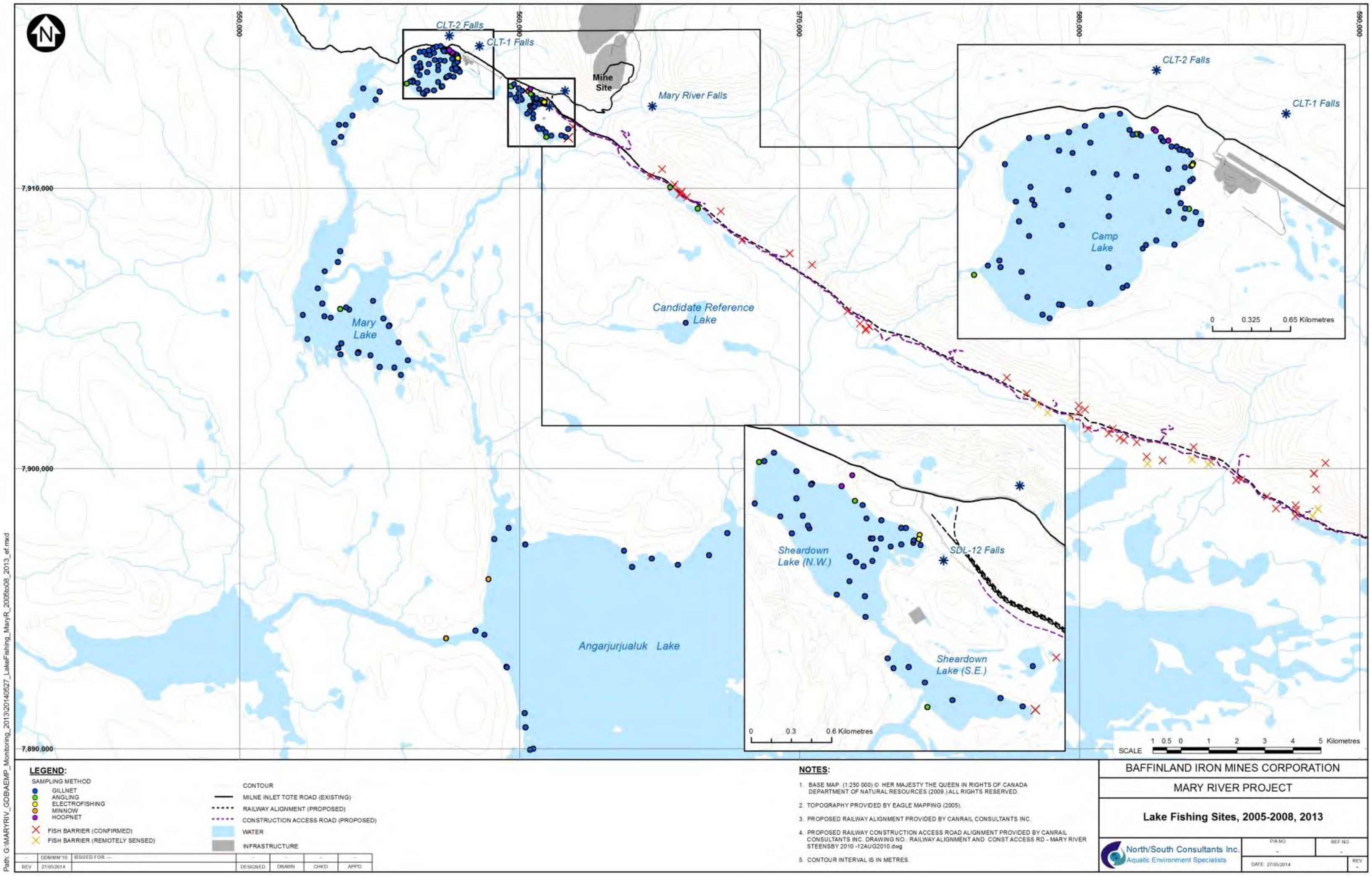


Figure 4-1. Fish sampling sites in Mine Area lakes.

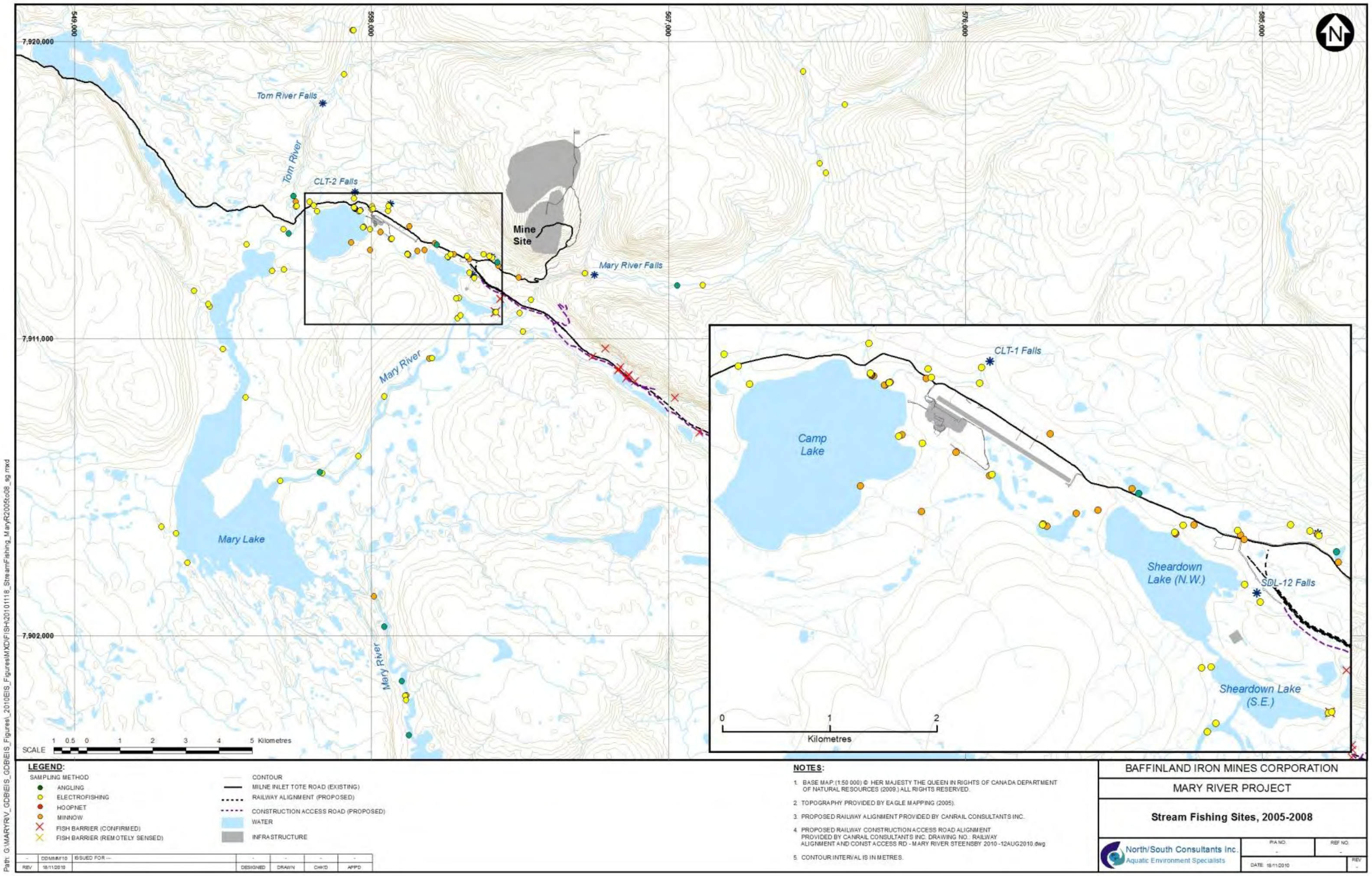


Figure 4-2. Fish sampling sites in Mine Area streams.

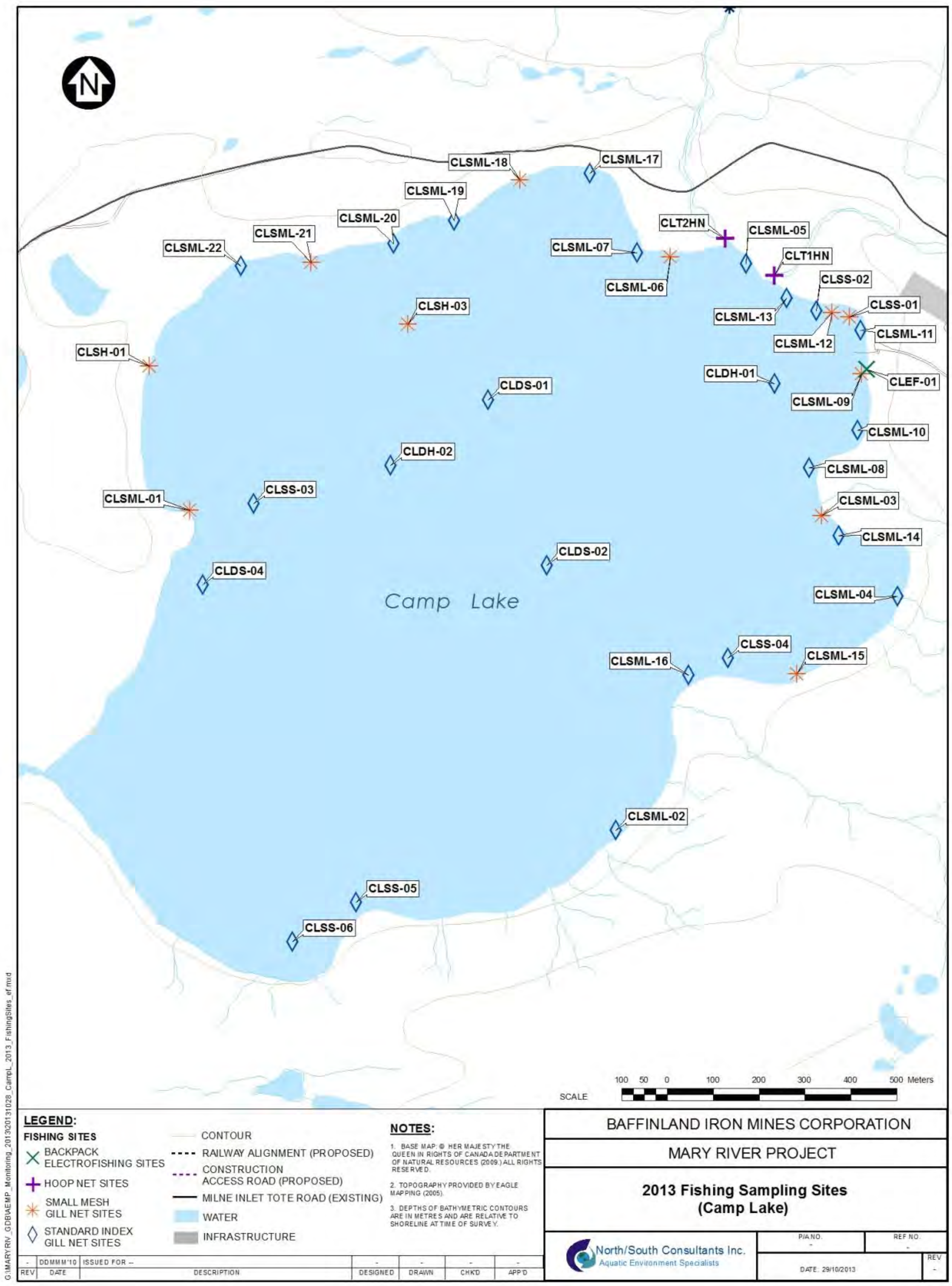


Figure 4-3. Fish sampling locations in Camp Lake: 2013.

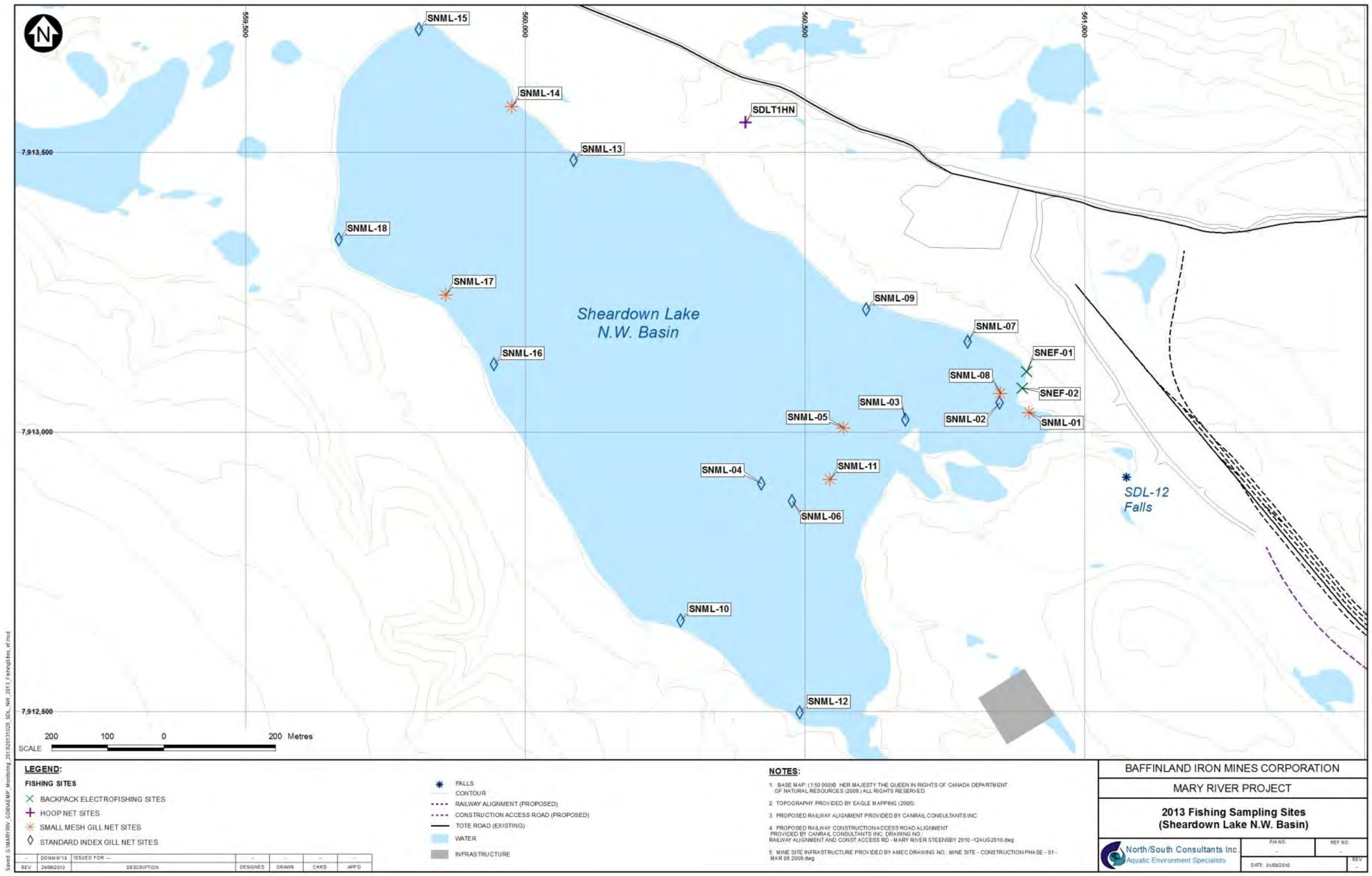


Figure 4-4. Fish sampling locations in Sheardown Lake: 2013.

Appendix F

2014 Reference Lakes Evaluation

Mary River Project

March 2015

Candidate Reference Lakes: Results of the 2014 Field Program

North/South Consultants Inc.
Aquatic Environment Specialists

Candidate Reference Lakes: Results of the 2014 Field Program

March 2015

Prepared by

North/South Consultants Inc.

For

Baffinland Iron Mines Corporation

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1.0 INTRODUCTION AND OVERVIEW

The Aquatic Effects Monitoring Plan (AEMP) for the Mary River Project includes monitoring of lakes and streams in the vicinity of the mine site, as well as reference lakes (Baffinland Iron Mines Corporation [BIM] 2014). Preliminary identification of candidate reference lakes comparable to Camp Lake and Sheardown Lake NW in the mine area was accomplished through a series of desktop screening exercises completed in 2013. These screening exercises, described in North/South Consultants Inc. (NSC) and Knight Piésold (2013), identified 12 potential reference lakes for Camp and/or Sheardown lakes within an 80 km radius of the Mary River mine site.

Reconnaissance surveys of these 12 candidate reference lakes were conducted during the open-water season of 2013, with the objective of collecting information on the biota, physical habitat, and chemical conditions (i.e., water quality) at the three most suitable lakes as identified through this initial survey. The field surveys included the determination of the presence/absence of land-locked resident Arctic Char (*Salvelinus alpinus*), completion of coarse aquatic habitat surveys, and collection of water quality, phytoplankton, zooplankton, and benthic macroinvertebrate (BMI) samples (all from a single site) in the open-water season of 2013 in each of three lakes to assist with selection of the final reference lake(s).

The first reconnaissance survey conducted in August 2013 identified two potentially suitable reference lakes (Reference Lake 1 – formerly called Lake CL-P2-13 - and Reference Lake 2 – formerly called Lake CR-P3-11), which were surveyed as indicated above. As the overall objective was to identify three candidate reference lakes, an aerial reconnaissance survey was completed in fall 2013 to identify additional lakes for consideration during 2014 surveys. Results of the 2013 surveys are presented in NSC (2014).

Detailed field sampling of candidate Reference lakes 1 and 2 was undertaken in 2014, to provide water quality, sediment quality, lower trophic level, and Arctic Char data. In addition, a reconnaissance level survey was completed in one of the lakes (Reference Lake 3 – formerly identified as ALT-09) identified during the fall 2013 aerial surveys as being a potentially suitable reference lake. The following provides a description of the methods and results (where available) of the reference lake surveys completed for the three candidate reference lakes in the open-water season of 2014. This report also provides an overall comparison between reference and mine area lakes.

2.0 METHODS

2.1 SUMMER SURVEY

The objective of the 2014 reference lake program was to conduct both summer and fall sampling in each of the three lakes for comparison with data collected from mine area lakes. However, persistent ice cover (into early August) on all three reference lakes prevented the conduct of the summer sampling.

2.2 FALL SURVEY

Fall surveys of the lakes were conducted in late August and included detailed sampling of Reference lakes 1 and 2, as well as a preliminary ground survey of Reference Lake 3 (Figure 1). Physical habitat information for Reference lakes 1 and 2 was collected, and the presence of Arctic Char established, during 2013 surveys. The 2014 surveys primarily included the collection of additional water quality (*in situ* and laboratory measurements), sediment quality, lower trophic level, and juvenile and adult fish population data (Table 1).

Reference Lake 3 was only surveyed aerially in 2013. Reconnaissance level ground surveys were conducted in 2014 and included an aquatic habitat survey, assessment of the presence/absence of Arctic Char, and collection of water quality, sediment quality, phytoplankton, zooplankton, and BMIs from a single site (Table 1).

2.3 FIELD SAMPLING METHODS

As monitoring of reference lakes is a component of the AEMP, specifically a component of the Core Receiving Environment Monitoring Program (CREMP), the sampling programs and methods employed for the reference lake program were consistent with those identified in the AEMP (BIM 2014). Sampling methods for water quality, sediment quality, phytoplankton, BMIs, and fish employed for the reference lake program in 2014 were therefore consistent with those described in detail in the AEMP (BIM 2014). Brief descriptions of these methods are provided below. Detailed descriptions of sampling methods for components that are not described in the AEMP (i.e., aquatic habitat and zooplankton) are also provided below.

2.3.1 AQUATIC HABITAT

Aquatic habitat surveying (i.e., bathymetry and substrate) is not a component of the AEMP. The following therefore provides a detailed description of field methods employed for the aquatic habitat survey completed in candidate Reference Lake 3 in August, 2014.

Boat-Based Hydroacoustic Depth and Bottom-Type Surveys

Hydroacoustic technologies, utilizing Sound Navigation and Ranging (SoNAR) principles, are commonly employed to collect data pertaining to physical aquatic habitat variables (depth, bottom type, and cover). On August 30, 2014 a bathymetric and bottom-typing sonar survey was conducted from a 4 m Zodiac on Reference Lake 3, which had an approximate lake level of 99.1 m above sea level (ASL). Surveys were conducted with a BioSonics Habitat MX 200 kHz single-beam scientific-grade echosounder. Visual Acquisition software was used to log the returned acoustic waveform data measuring depth and bottom characteristics (hardness, roughness), in addition to the differentially corrected positions from an internal global positioning system (GPS) receiver. Surveys were conducted at boat speeds of approximately 5-10 km/hr. The transducer mount was affixed to the gunwale at mid-point side of the vessel. The transducer depth below the water surface was 0.40 m.

Surveys consisted of tracking and recording acoustic data and positions at 1 second intervals along transects spaced 50-500 m apart, depending on the complexity of the area being surveyed. A single long transect or E-Line transect was surveyed across the maximum width of the lake. The survey conformed to the British Columbia Ministry of the Environment's (BCMOE) bathymetric standards for lake inventories (BCMOE 2009). The bathymetric mapping in this study did not follow a specific hydrographic standard and therefore it is advised that the map products should not be relied upon for navigation.

Bottom Type Validation

Substrate validation to support sonar bottom-typing was conducted visually (i.e., where the lake bottom could be visually assessed) or with sediment grabs. Water clarity allowed visual confirmation of substrate composition to depths of at least 5 m throughout the lake. In deeper water, substrate samples were periodically collected using a petite Ponar dredge. At each sample site, depth of penetration of the petite Ponar and relative proportion (%) of each substrate type within the sample was visually estimated and recorded. Substrate size classification was based on Wentworth (1922), and included the following:

- Boulder: > 256 mm
- Cobble: 64-256 mm
- Gravel (aggregate): 2-64 mm
- Sand (aggregate): 62.5 µm – 2 mm
- Silt: 3.9-62.5 µm
- Clay: < 3.9 µm

2.3.2 WATER QUALITY

Water quality sampling was conducted at five sites in Reference lakes 1 and 2 and at a single site in Reference Lake 3 in fall 2014. Sampling included *in situ* measurements of total water depth, Secchi disk depth, and depth profiles (at 1 m intervals) for dissolved oxygen (DO), turbidity, temperature, pH, and specific conductance using a hand-held YSI EXO-2 water quality multimetre. Samples for laboratory analysis were collected at 1 m below the water surface and 1 m above the sediment-water interface with a Kemmerer water sampler. Universal Transverse Mercator units (UTMs) were recorded for each site using a hand-held GPS unit. Samples were transferred to sample bottles provided by the analytical laboratory and preserved where applicable, kept cool (4°C) and in the dark, and submitted to the analytical laboratory (Exova Environmental, Ottawa, ON), which is accredited under the Canadian Association for Laboratory Accreditation (CALA). See BIM (2014) for additional details.

2.3.3 SEDIMENT QUALITY

Sediment quality was sampled at five sites in Lakes 1 and 2 and at a single site in Lake 3 in fall 2014. UTMs were recorded for each site using a hand-held GPS unit. Surficial sediment samples were collected with a petite Ponar dredge (area of opening 0.23 m^2); sediment cores could not be collected due to malfunction of the sediment core sampling device. Due to analytical volume requirements, five grab samples were collected at each site and the samples were homogenized. Depth of penetration of the petite Ponar dredge and relative proportion (%) of each substrate type within the sample was visually estimated and recorded. Substrate size classification was based on Wentworth (1922).

The upper 2 cm of sediment was removed from the dredge sample with a corer, placed in a pre-cleaned stainless steel bowl, and the sample was homogenized. Sediment was then transferred to sample bottles provided by the analytical laboratory, samples were kept cool and in the dark, and shipped to Exova Environmental (Ottawa, ON) for analysis.

2.3.4 LOWER TROPHIC LEVEL BIOTA

Phytoplankton

Phytoplankton samples were collected at each of the water quality sampling sites. Secchi disk depth (average of two measurements) was measured and used to calculate the euphotic zone depth for each site (estimated as Secchi disk depth x 3). Depth-integrated samples of water were collected using a tube sampler from across the euphotic zone (as estimated above) or across the majority of the water column (i.e., to within approximately 1 m of the bottom) where euphotic zone depth exceeded the total water depth. The sample was transferred to a sample bottle provided by the analytical laboratory, and samples were preserved by adding a sufficient quantity of Lugol's solution to render the sample "tea coloured". See BIM (2014) for additional details.

Zooplankton

Zooplankton samples were collected at each of the water quality sampling sites. Samples were collected in vertical, bottom-to-surface tows using a 63 μm conical net 1.0 m in length with a 0.23 m long codend. The net, complete with a weighted PVC codend attached to a single 0.25 m diameter steel hoop frame, was lowered to the bottom, codend first, and then slowly retrieved by hand. The number of tows and water depth were recorded for each site. The number of tows, tow depth, and diameter of the net opening were used to calculate the volume of water filtered.

Zooplankton captured in the net were rinsed into the codend collecting cup, washed into a labeled jar (250 or 500 mL), and fixed in 10% formalin. A sufficient number of tows were collected at each site until at least 100 individuals are visible in the sample jar; in all instances only one tow was required to meet this target.

Benthic Macroinvertebrates

The BMI lake monitoring program described in the AEMP is a habitat-based program, which focuses upon predominant habitats in mine area lakes. Specifically, monitoring is to be conducted at five replicate stations in two habitat types: Habitat Type 9 (depth of 2-12 meters, fine sand, silt/clay substrate, aquatic macrophytes absent); and Habitat Type 14 (depth > 12 m, fine sand, silt/clay substrate). To provide comparable data, BMI sampling in reference lakes focussed on sampling these same habitat types.

Sampling was completed with a petite Ponar dredge (sampling area of 0.023 m^2) and five sub-samples (i.e., five grabs) were collected and pooled at each of the five stations. Samples were sieved through a 500 μm mesh and fixed in buffered formalin. For sampling sites where sediment quality was not measured, sediment samples for the analysis of supporting variables (sediment total organic content [TOC] and particle size analysis [PSA]) were collected at each replicate station using a petite Ponar dredge, placed in large Zip-loc freezer bags and frozen for long-term storage for potential future analysis. Water depth, site UTMs, sediment description, and the presence/absence of macrophytes were recorded at each site. See BIM (2014) for additional details.

Fish

Fish capture methods differed slightly between reference lakes. There was no pre-existing fish population information for Reference Lake 3, and the objective of the reconnaissance survey was to determine presence/absence of Arctic Char. Two standard gang index gill nets were set at random locations in Reference Lake 3 for approximately 7.5 hours to meet this objective.

With basic fish population status established during 2013 surveys in Reference lakes 1 and 2, the objective for the 2014 sampling was to collect detailed biological data from approximately 100 fish per lake, sampling multiple size classes, but with an emphasis on smaller juveniles. Standard gang index gill nets and a backpack electrofisher were used to sample the fish population in both lakes. Given the relative lack of detailed fish population information from these lakes, gillnetting sites were selected to provide broad coverage across a range of habitat types. To maximize catches of small juveniles, electrofishing sites focussed on nearshore areas with abundant cobble/boulder habitat.

All captured fish were enumerated, identified to species, and measured for fork length (± 1 mm). Fish captured during the gillnetting program were weighed to an accuracy of ± 25 g (i.e., 1% of total body weight for a fish weighing 2,500 g). Fish captured and released during electrofishing were not weighed in the field. Large, live fish were examined for sex and maturity by gently massaging the abdomen and identifying any extruded gametes. Ageing structures (pectoral fin rays) were collected from all live gillnet-caught fish and from a length-stratified sub-sample of electrofished individuals. All live fish were released following collection of biological data.

All incidental mortalities and a length-stratified subsample of small juvenile fish from electrofishing surveys were retained and frozen for detailed laboratory examination. Fish were shipped to the laboratory at NSC (Winnipeg, MB) for detailed necropsies and removal of otoliths for ageing.

2.4 LABORATORY METHODS

2.4.1 LOWER TROPHIC LEVEL BIOTA

Zooplankton and BMI samples were transported to the laboratory at NSC (Winnipeg, MB), catalogued, and transferred to 70% ethanol with a few drops of glycerin for long-term storage. Phytoplankton samples were checked for adequate preservation (i.e., as indicated by colouration of the samples), catalogued, and archived at NSC.

2.4.2 FISH NECROPSIES

Detailed laboratory necropsies were conducted on all frozen fish. Biological data collected included: fork length (± 1 mm); weight (± 1 g for fish larger than 150 mm, ± 0.1 g for smaller fish); sex and maturity; diet; and general parasite load. Diet items were enumerated (estimated if quantities were large) and identified to the Family level or higher. Parasites were enumerated and identified to the lowest taxonomic level possible. Otoliths, the only (and preferred) ageing structure collected in past mine area lake surveys, were also collected from necropsied fish and submitted for ageing.

2.4.3 FISH AGEING

Arctic Char were aged using otoliths processed by thin sectioning. Otoliths were placed in Cold Cure™ epoxy and left to set (harden) for 48 hours. The nucleus was marked with a fine tipped marker and two points were marked on either side of the nucleus using a micrometer on the microscope. Using a Struers Minitom™ (low speed sectioning saw) the otolith was sectioned on either side of the line (connecting the two outside dots) leaving the nucleus in the section. The section of otolith was then permanently mounted on a microscope slide with Cytosel-60™. The mounted sections were viewed under a microscope with transmitted light and the numbers of annuli were counted. All fin rays collected from live fish and mortalities were archived for future analysis.

2.5 DATA ANALYSIS METHODS

2.5.1 AQUATIC HABITAT

Depth Data Processing

Biosonics Habitat MX sounding data were processed with Biosonics Visual Habitat software. Bottom depth is detected in the field based on a signal threshold decibel (dB) level. Data were reanalyzed in Visual Habitat MX software and depths were manually edited by interpreting the bottom from the echogram where automated signal threshold detection did not capture the true lake bottom. During the manual editing process the acoustic data were checked for signal error, invalid depths, and acoustic waveform anomalies. Erroneous data were filtered out. The data were exported to a .csv text format and imported into Microsoft® Excel. In Excel, these data were then merged with the Biosonics data and subsequently corrected for transducer to water surface offsets.

Bathymetric Surface Modelling and Mapping

Spatial autocorrelation software was used to interpolate a continuous surface of depths or bed elevations given a set of known measurements. Golden Software's Surfer® 11 was used to develop a linear Kriging spatial interpolation depth model for Reference Lake 3. Kriging is an exact interpolator, in that it honors the input depth data points, but provides a realistic representation of the data-poor areas within an irregularly spaced data set based on trends within the measured input data points.

The corrected depth data points were imported into Surfer 11 from an ESRI shapefile .dbf format. A CanVec 1:50000 scale vector shoreline was selected as the representative shoreline for mapping. Depth points with values of zero were extracted at a 5 m interval along the vector shoreline and used as an additional data input for the depth model. A 10 m grid resolution depth model was produced using the Kriging interpolation technique.

The resulting depth grid was converted to a tiff format and imported into ArcGIS 10.2 software for mapping and calculation of statistics. The depth model was used to produce 2 m interval vector contours. The depth grid was classed into 2 m intervals and symbolized using a light blue (shallow) to dark blue (deep) colour gradient. Depth data were summarized in ArcGIS by running a zonal statistics procedure, which was used to output mean and maximum depth statistics and volume. The depth statistics were then tabulated in Excel.

Bottom-Type Classification and Mapping

BioSonics' Visual Habitat MX software uses multivariate principal component analysis and an unsupervised clustering technique to classify the acoustic data collected in the field into a specified number of bottom type classes. The user-supplied number of clusters informs the algorithm how many bottom types to sort the data into. The initial number of clusters was based on a review and spatial analysis of the validation data collected in the field and was adjusted and re-analyzed based on those results.

The bottom type maps, which depict substrate and cover, were interpreted and digitized in ArcGIS 10.2 using the classified Biosonics acoustic track data. After the substrate class polygons were created, the areas were attributed according to their corresponding bottom type class. All classes were then symbolized and mapped for report presentation. Substrate areas were calculated in ArcGIS and the summary data was tabulated in Excel.

2.5.2 WATER QUALITY

Water quality data were compared to Canadian Council of Ministers of the Environment (CCME 1999; updated to 2015) water quality guidelines for the protection of aquatic life (PAL). Trophic status of reference lakes was assessed through application of trophic classification schemes for total phosphorus (TP), total nitrogen (TN), and chlorophyll *a*, as follows:

- TP: the trophic state categorization scheme based on TP presented in the CCME Canadian phosphorus guidance framework for the management of freshwater systems (CCME 1999; updated to 2015);
- TN: the categorization scheme for TN presented by Nürnberg (1996); and

- Chlorophyll *a*: the benchmark (3.7 µg/L) developed for the AEMP that defines the boundary between oligotrophic and mesotrophic conditions (BIM 2014; Table 2).

Measurements reported as less than the analytical detection limit were set equal to the detection limit for derivation of summary statistics, statistical comparisons, and presentation in figures. Duplicate sample results that exceeded five times the analytical detection limit were evaluated by calculating relative percent mean difference (RPMD) and comparing to the criterion of 25%, in accordance with British Columbia Ministry of Environment, Lands, and Parks (BCMELP 1998) guidance. RPMD was calculated as:

RPMD = (Value 1 – Value 2)/((Value 1 + Value 2)/2) x 100

Water quality results from the reference lakes were compared to water quality data collected from mine area lakes to evaluate their suitability. Analyses were performed using the non-parametric Kruskal-Wallis test followed by the Dunn's multiple pairwise comparisons procedure (two-tailed; $\alpha = 0.05$). Comparisons of reference lake water quality to mine area lakes were based on the period of record (i.e., 2006-2014 for mine area lakes and 2013-2014 for reference lakes), data collected in the open-water season, and near surface measurements. For Sheardown Lake NW, nearshore data collected in 2008 were omitted from the analysis. Some data were removed from the datasets for mine area lakes for statistical analysis purposes. Specifically, measurements made with high analytical detection limits (i.e., primarily associated with the 2006 data sets) and values that qualitatively appeared to be transcription errors and/or outliers were removed from the analysis.

2.5.3 SEDIMENT QUALITY

Sediment quality was compared to CCME interim sediment quality guidelines (ISQGs) and probable effect levels (PELs; CCME 1999; updated to 2015) where available, and to the province of Ontario lowest effect level (LEL) and a severe effect level (SEL) for sediments (Persaud et al. 1993) for parameters not currently included in the CCME (1999; updated to 2015) guidelines.

Measurements reported as less than the analytical detection limit were set equal to the detection limit for derivation of summary statistics, statistical comparisons, and presentation in figures. Duplicate sample results that exceeded five times the analytical detection limit were evaluated by calculating the RPMD and comparing to the criterion of 25%, in accordance with BCMELP (1998) guidance. RPMD was calculated as indicated in Section 2.5.2.

Sediment quality results from the candidate reference lakes were compared to sediment quality data collected from mine area lakes to evaluate their suitability. Analyses were performed using the non-parametric Kruskal-Wallis test followed by the Dunn's multiple pairwise comparisons procedure (two-tailed; $\alpha = 0.05$). Data employed for comparisons included sediment quality data collected from 2006-2014 for Camp and Mary lakes and Sheardown Lake SE, and data collected in 2007 only from Sheardown Lake NW (Knight Piésold Ltd. 2015).

2.5.4 FISH

The gillnetting and electrofishing catches were tabulated by lake and site. Gillnetting catch-per-unit-effort (CPUE) was calculated as the number of fish caught per 100 m gillnet gang per 24 hours. Electrofishing CPUE was expressed as the number of fish captured per 60 seconds of electrofishing.

Mean fork length (mm), weight (g), age and condition factor (K) were calculated for each species. Condition factor was calculated for fish where fork length and round weight were measured, using the following formula (after Fulton 1911, in Ricker 1975):

$K = \text{round weight (g)} \times 10^5/(\text{fork length})^3$

Fish population results from the reference lakes were qualitatively compared to similar data collected from mine area lakes, to evaluate their suitability.

3.0 RESULTS

The following sections provide a brief summary of the results of the 2014 surveys, based on information currently available.

3.1 REFERENCE LAKE 1

3.1.1 WATER QUALITY

Laboratory and *in situ* water quality data collected in fall 2014 at Reference Lake 1 (formerly called CL-P2-13), and results of duplicate samples analysed in 2014, are provided in Appendix 1. A statistical summary of water quality parameters measured in 2013 and 2014 from this lake is provided in Tables 3 and 4. Sampling sites are indicated in Figure 2.

Reference Lake 1 has high water clarity, is highly oxygenated, and is very soft on the basis of the Canadian Council of Resource and Environment Ministers (CCREM 1987) hardness scale. The dominant cation is calcium, followed by magnesium. Considering all data collected in 2013 and 2014, on the basis of TP, the lake is ultra-oligotrophic, whereas on the basis of TN and chlorophyll *a*, the lake is mesotrophic and oligotrophic, respectively (Figure 3). Quality assurance/quality control (QA/QC) results for total Kjeldahl nitrogen (TKN) in 2013, notably those associated with the summer sampling period, indicate potential issues with precision and accuracy of the data. Considering only the 2014 dataset, TN concentrations indicate oligotrophic conditions. Nutrient ratios indicate strong phosphorus limitation.

A number of metals were not detected in Reference Lake 1 in 2014 including antimony, arsenic, beryllium, bismuth, boron, cadmium, chromium, cobalt, lithium, mercury, molybdenum, nickel, selenium, silver, tin, titanium, thallium, vanadium, and zinc (Appendix 1). All metals, DO, pH, ammonia, nitrate, nitrite, and chloride were within the CCME PAL guidelines (CCME 1999; updated to 2015).

3.1.2 SEDIMENT QUALITY

Sediment quality data collected in fall 2014 at Reference Lake 1 are provided in Appendix 2 and the sampling sites are indicated in Figure 2. A statistical summary of sediment quality conditions measured in Reference Lake 1 is provided in Table 5.

Arsenic, cadmium, mercury, and zinc were below the CCME ISGQs in all samples collected from Reference Lake 1. Copper exceeded the ISQGs in all samples and the majority of samples exceeded the PEL for chromium. The mean concentration of iron and manganese exceeded the Ontario SEL.

3.1.3 LOWER TROPHIC LEVEL BIOTA

Samples of phytoplankton, zooplankton, and BMIs collected from Reference Lake 1 in fall 2014 were preserved and archived at NSC (Winnipeg, MB) for potential future analysis. Metadata associated with this sampling are presented in Appendix 3 and sampling sites are presented in Figures 2 and 4.

Chlorophyll *a* concentrations measured in Reference Lake 1 in 2013 and 2014 indicate oligotrophic conditions (Table 3, Figure 3).

3.1.4 FISH

Preliminary gillnetting surveys conducted in Reference Lake 1 in 2013 captured two Arctic Char with fork lengths of 395 and 558 mm. In addition, the main tributary stream, though providing a connection to other lakes, appeared to be of insufficient depth to allow for passage of fish larger than about 200 mm. These preliminary data suggested that large char were permanent residents of the lake. Five gill nets were set for 4.3-5.0 hours in 2014 (Figure 5); however, no fish were captured (Table 6). If Reference Lake 1 supports a resident population of Arctic Char, available information suggests the population may be relatively small.

Ninety-five juvenile Arctic Char were captured in two electrofishing runs of rocky nearshore habitat in Reference Lake 1 during fall 2014 (Table 7; Figure 6). Mean length of the electrofishing catch was 83 mm (Table 8). Otoliths and left pectoral fin rays were collected from ten mortalities and an additional 20 fin rays were collected from live-released fish (Table 8). Fin rays were not aged and have been archived. Age information obtained from eight otoliths (the preferred ageing structure) indicated a mean of 3.4 years (range of 1-6 years) for fish within a size range of 50-136 mm. Although precise numbers cannot be determined, based on these age and size data, small numbers of YOY (n = 5 or fewer) were captured. The majority of the captured fish were 1 or 2 years old.

Stomach contents were observed in seven of the ten mortalities (i.e., stomachs of three fish were empty). Four stomachs contained invertebrate remains, two contained larval or pupal Chironomidae, and one contained Trichoptera. One individual had small numbers of larval cestode cysts along the gut.

3.2 REFERENCE LAKE 2

3.2.1 WATER QUALITY

Laboratory and *in situ* water quality data collected in fall 2014 at Reference Lake 2 are provided in Appendix 1. A statistical summary of water quality parameters measured in 2013 and 2014 is provided in Tables 3 and 4. Sampling sites are indicated in Figure 7.

Like Reference Lake 1, Reference Lake 2 has high water clarity, is highly oxygenated, and is very soft on the basis of the CCREM (1987) hardness scale. Also like Reference Lake 1, the dominant cation is calcium, followed by magnesium. Considering data collected in 2013 and 2014, Reference Lake 2 is oligotrophic on the basis of TP and chlorophyll *a*, and lies on the oligotrophic-mesotrophic boundary on the basis of TN (Figure 3). As noted in Section 3.1.1, TKN data from 2013 are considered to be suspect. Considering only 2014 results, when the TN concentration was lower, the lake would be classified as oligotrophic. Nutrient ratios indicate strong phosphorus limitation.

A number of metals were not detected in Reference Lake 2 in 2014 including antimony, arsenic, beryllium, bismuth, boron, cadmium, chromium, cobalt, iron, lead, lithium, mercury, nickel, selenium, silver, tin, titanium, thallium, vanadium, and zinc (Appendix 1). All metals, DO, pH, ammonia, nitrate, nitrite, and chloride were within the CCME PAL guidelines (CCME 1999; updated to 2015).

3.2.2 SEDIMENT QUALITY

Arsenic, cadmium, copper, lead, mercury and zinc were below the CCME ISQGs in all samples, whereas chromium exceeded the ISQG in four of the five samples (Appendix 2). On average, manganese, nickel, and TKN exceeded the Ontario LEL and iron exceeded the SEL (Table 5).

3.2.3 LOWER TROPHIC LEVEL BIOTA

Samples of phytoplankton, zooplankton, and BMIs collected during fall from Reference Lake 2 were preserved and archived at the laboratory at NSC (Winnipeg, MB) for potential future analyses. Metadata associated with this sampling are presented in Appendix 3 and sampling sites are presented in Figures 7 and 8.

Chlorophyll *a* concentrations measured in Reference Lake 2 in 2013 and 2014 indicate oligotrophic conditions (Table 3, Figure 3).

3.2.4 FISH

Reference Lake 2 has tributaries suitable for use by juvenile Arctic Char, but of insufficient depth for adult use. Any fish in the lake are, therefore, likely resident and non-migratory. Eight Arctic Char were captured in three standard gang index gill nets set for short duration in the lake (Figure 9), with CPUE ranging from 0.0-17.4 fish/100 m/24 hours (Table 6). The captured fish ranged in size from 211-463 mm (Table 9). Three females and one male, all preparing to spawn, were identified from the catch, indicating that spawning likely occurs within the lake. A single gillnet mortality was frozen and returned to the laboratory at NSC (Winnipeg, MB) for detailed examination of sex, maturity, diet, parasite load, and age. This fish was a 14-year-old pre-spawn female with an empty stomach and 25-100 cestode cysts (likely *Diphyllobothrium* sp.) present along the exterior surface of the digestive tract.

Shallow (< 1.5 m), nearshore areas in Reference Lake 2 are almost 100% sand/silt, which is unsuitable habitat for juvenile Arctic Char rearing. Backpack electrofishing efforts were, therefore, concentrated near the confluence of a small inlet stream (Figure 10). A total of 128 fish (99 Arctic Char and 29 Ninespine Stickleback, *Pungitius pungitius*) were captured during a single electrofishing pass (Table 7). The Arctic Char catch ranged in size from 23-178 mm with a mean of 107 mm (Table 8).

Otoliths and pectoral fin rays were extracted from 19 mortalities while fin rays were collected from an additional 16 fish. Fin rays have not been aged and have been archived. Otoliths from 16 Arctic Char were aged (Table 8) with a mean of 1.6 years (range of 0-4 years) for fish spanning a size range of 44-126 mm. Stomach contents were observed in 13 of 20 total mortalities (i.e., stomachs of seven fish were empty). Chironomidae (62% of stomachs with contents), invertebrate remains (38%), and juvenile Ninespine Stickleback (31%) were the most common diet items. Larval Tipulidae and Collembola were also found.

3.3 REFERENCE LAKE 3

3.3.1 WATER QUALITY

Laboratory and *in situ* water quality data collected in fall 2014 at Reference Lake 3 are provided in Appendix 1 and Tables 3 and 4. Sampling completed at this lake in 2014 represented a single site (Figure 11) and sampling event; as previously noted this lake was not sampled in 2013.

Like Reference lakes 1 and 2, Reference Lake 3 has high water clarity and is highly oxygenated. Also like Reference lakes 1 and 2, the dominant cation is calcium, followed by magnesium. While hardness is still relatively low, Reference Lake 3 is “soft” on the CCREM (1987) hardness scale. Based on a single sample collected in fall 2014, Reference Lake 3 is mesotrophic based on

TN and oligotrophic based on TP and chlorophyll *a* (Figure 3). Like the other reference lakes, the nutrient ratio indicates strong phosphorus limitation.

A number of metals were not detected in Reference Lake 3 in 2014 including antimony, arsenic, beryllium, bismuth, boron, cadmium, chromium, cobalt, iron, lithium, mercury, nickel, selenium, silver, tin, titanium, thallium, vanadium, and zinc (Appendix 1). All metals, DO, pH, ammonia, nitrate, nitrite, and chloride were within the CCME PAL guidelines (CCME 1999; updated to 2015).

3.3.2 SEDIMENT QUALITY

Arsenic, cadmium, chromium, copper, lead, mercury and zinc were below the CCME ISQGs in the single sample collected from Reference Lake 3 in 2014. Iron, manganese, nickel, and TKN exceeded the Ontario LEL in this lake (Appendix 2; Table 5).

3.3.3 LOWER TROPHIC LEVEL BIOTA

Samples of phytoplankton, zooplankton, and BMIs collected during fall 2014 from Reference Lake 3 were preserved and archived at the laboratory at NSC (Winnipeg, MB) for potential future analysis. Metadata associated with this sampling are presented in Appendix 3 and sampling sites are presented in Figures 11 and 12.

Chlorophyll *a* measured in Reference Lake 3 in 2014 indicates oligotrophic conditions (Table 3, Figure 3).

3.3.4 FISH AND FISH HABITAT

Reference Lake 3 has the largest surface area of the three reference lakes under consideration (Figure 11). There are small tributaries suitable for use by juvenile Arctic Char and a major connection to another large lake that would allow for passage of adult fish, similar to the connections between Sheardown Lake NW and Sheardown Lake SE, and Camp and Mary lakes. The shoreline of Reference Lake 3 is predominantly rocky with a frequently steep gradient (Photo 1). Nearshore substrate (to at least 5 m depth) is dominated by cobble/boulder throughout the lake (Photo 2, Figure 13; Table 10), including in the shallow bays (< 1 m depth) that could not be navigated by boat. Sandy loam and silt/clay (often very loosely compacted) were dominant at depths greater than 5 m. The lake is characterized by broad, shallow areas to the north, south and east and two deep (> 30 m) basins separated by a relatively shallow, flat plain (Figure 11). Maximum recorded depth in this lake was 38.3 m with a mean of 11.8 m.

Although backpack electrofishing was not conducted in 2014, juvenile Arctic Char (30-100 mm fork length) were observed in rocky nearshore areas, confirming the presence of smaller size classes. A single Arctic Char (620 mm fork length) was captured during a preliminary gillnetting survey of the lake (Figure 14; Tables 6 and 9). Sex and maturity could not be confirmed in the field, but the bright orange colouration suggested this fish was a current year spawner. Given this observation and the abundance of preferred spawning habitat (rocky substrate 2-10 m deep) in the lake, the lake is expected to support a resident, spawning char population. Though preliminary, the 2014 survey of habitat and fish populations indicates that this lake is a suitable reference.

4.0 SUMMARY AND COMPARISON TO MINE AREA LAKES

The following provides a discussion of the suitability of the three lakes as reference areas for the CREMP. This discussion is based upon data collected in 2013 and 2014 from the reference lakes and baseline data collected from mine area lakes.

4.1 WATER QUALITY

As discussed in NSC (2014), water quality of Reference lakes 1 and 2 is similar to mine area lakes for some parameters and different for others (Tables 11 and 12). Statistical comparisons of water quality between these lakes using all available data (open-water season only) indicated a number of parameters, including DO, pH (*in situ* and laboratory), Secchi disk depth, ammonia, TKN, TN, TP, chlorophyll *a*, and several metals (iron, lead, sodium, and zinc) were not significantly different between Reference lakes 1 and 2 and Camp Lake or Sheardown Lake NW. Statistical comparisons could not be undertaken for a number of parameters that did not exceed the analytical detection limit in any samples collected from the reference lakes including nitrite, nitrate, nitrate/nitrite, total suspended solids (TSS), bromide, sulphate (Reference Lake 2), phenols, antimony, arsenic, beryllium, bismuth, boron, cadmium, cobalt, lithium, mercury, selenium, silver, thallium, tin, titanium, and vanadium.

Differences between one or both of the reference lakes and one or both of Camp Lake and Sheardown Lake NW were noted for several routine parameters. Alkalinity (Figure 15), total dissolved solids (TDS; Figure 16), conductivity (Figure 17), and hardness (Figure 18) were significantly lower in both reference lakes in comparison to the mine area lakes. In addition, dissolved organic carbon (DOC; Figure 19), TOC (Figure 20), and chloride (Figure 21) were lower than either mine area lake, and turbidity was higher in Reference Lake 1 in comparison to Camp Lake (Figure 22).

In addition, a number of total metals were significantly lower in one or both of the reference lakes in comparison to one or both mine area lakes, including barium (Figure 23), calcium (Figure 24), copper (Figure 25), magnesium (Figure 26), molybdenum (Figure 27), nickel (Figure 28), potassium (Figure 29), silicon (Figure 30), strontium (Figure 31), and uranium (Figure 32). One metal (chromium; Figure 33) was higher in both reference lakes than mine area lakes, aluminum (Figure 34) was higher in Reference Lake 1 than Sheardown Lake NW, and manganese was higher in Reference Lake 2 than Sheardown Lake NW (Figure 35).

Results of statistical analyses for TP (Reference Lake 1), chromium, copper (Reference Lake 2), iron, lead, nickel (Reference Lake 1), and zinc, and possibly other metals, may be artefacts of a high frequency of censured data points and/or varying analytical detection limits.

Overall, available information indicates that Reference lakes 1 and 2 have similar levels of key nutrients (i.e., TN and TP) and chlorophyll *a*, water clarity, pH, DO, and a number of metals to Camp Lake and/or Sheardown Lake NW. The key differences between the reference and mine area lakes relate to the former being more dilute, softer, and containing lower concentrations of some major cations and metals. Reference Lake 1 also contains more organic carbon.

The results of the reconnaissance survey conducted in Reference Lake 3 in 2014 are limited to a single sampling site and sampling event and therefore were not amenable to statistical comparisons. However, qualitative comparison of water quality from Reference Lake 3 to mine area lakes indicates that overall, water quality conditions may be more similar to mine area lakes than Reference lakes 1 and 2. Specifically, water quality parameters that are similar between mine area lakes and Reference lakes 1 and 2, are also similar for Reference Lake 3. However, several water quality parameters that are significantly lower in Reference lakes 1 and/or 2 than mine area lakes, such as major cations (calcium, magnesium, and potassium), alkalinity, TDS, conductivity, and hardness, are more similar to mine area lakes for Reference Lake 3.

4.2 SEDIMENT QUALITY

Sediment quality measured in the three reference lakes in 2014 was compared to sediment quality of mine area lakes collected over the period of 2006-2014 to evaluate similarities among lakes. This analysis was done by comparing exceedances of CCME and Ontario sediment quality guidelines (SQGs), based on mean concentrations, and through statistical comparisons.

Exceedances of either CCME or Ontario SQGs were generally similar between reference and mine area lakes. Specifically, where one or more of the reference lakes exceeded an SQG, this was also observed in one or more mine area lakes (Table 5). This indicates general similarities in sediment quality among the waterbodies.

Regarding statistical comparisons, a number of parameters were either not significantly different between Reference lakes 1 and 2 and mine area lakes, or statistical comparisons could not be made due to a high frequency of censured data points. These parameters include: antimony; arsenic; barium; beryllium; boron; cadmium; cobalt; iron; manganese; mercury; molybdenum; nickel; selenium; silver; sodium; thallium; nitrite; nitrate; and nitrate/nitrite. Four parameters were significantly higher in Reference Lake 1 than Camp Lake: aluminum (Figure 36); chromium (Figure 37); strontium (Figure 38); and, percent clay (Figure 39). No parameters were significantly different between Reference Lake 2 and either Camp Lake or Sheardown Lake NW.

While few statistically significant differences were noted between Reference lakes 1 and 2 and Camp Lake or Sheardown Lake NW, these results may reflect limitations associated with sample sizes. Qualitative comparisons of data suggest several parameters may differ between Reference

Lake 2 and mine area lakes including magnesium (Figure 40), nickel (Figure 41), potassium (Figure 42), TKN (Figure 43), TOC (Figure 44), and percent silt (Figure 45).

Statistical comparisons between Reference Lake 3 and mine area lakes could not be undertaken as the 2014 survey of Reference Lake 3 was a reconnaissance level program and only one sample was collected. However, sediment quality parameters measured in the single sample from Reference Lake 3, fell within the ranges measured in mine area lakes.

Overall, available sediment quality data indicate that conditions are generally similar between the three reference lakes sampled in 2014 and Camp Lake and Sheardown Lake NW in the mine area.

4.3 LOWER TROPHIC LEVEL BIOTA

With the exception of chlorophyll *a*, lower trophic level samples, including phytoplankton (taxonomy and biomass), zooplankton, and BMIs, collected in 2014 from the three reference lakes were archived. Therefore, the following presents a summary of conclusions presented in NSC (2014), supplemented with consideration of chlorophyll *a* data collected in 2014.

4.3.1 PHYTOPLANKTON

As discussed in Section 4.1, chlorophyll *a* concentrations were not significantly different between Reference lakes 1 and 2 and Camp Lake or Sheardown Lake NW. The single sample collected from Reference Lake 3 was also similar to mine area lakes (i.e., within the range of concentrations observed in mine area lakes). Available information therefore indicates similar levels of primary productivity among the lakes.

Based on phytoplankton samples collected in 2013, there is some indication of differences in community composition between the Reference lakes 1 and 2 and mine area lakes (NSC 2014). The former were dominated by dinoflagellates (Dinophyceae) whereas the latter were typically dominated by diatoms.

While the differences in community composition are not ideal, the community composition of all the lakes (candidate reference lakes and mine area lakes) is consistent with nutrient-poor Arctic lakes. Other studies have reported high abundance of dinoflagellates, and specifically the Genus *Gymnodinium*, in other Arctic lakes (e.g., Snap Lake and a reference lake; De Beers 2002; Golder Associates 2012).

4.3.2 ZOOPLANKTON

Densities and composition of the zooplankton communities were similar between mine area lakes (as measured in 2007 and 2008) and Reference lakes 1 and 2 (as measured in 2013; NSC 2014).

4.3.3 BENTHIC MACROINVERTEBRATES

Benthic macroinvertebrate abundance and composition metrics were similar between mine area lakes (as measured in 2006, 2007, 2008, 2011, and 2013) and Reference lakes 1 and 2 (as measured in 2013; NSC 2014).

4.4 FISH AND FISH HABITAT

In terms of lake morphometry, Reference Lake 3 is most similar to mine area lakes, particularly Camp Lake, due its relatively larger volume and surface area, and greater depth (Table 13). Maximum observed depth in Reference Lake 3 was 38.3 m with a mean of 11.8 m, which is similar to Camp Lake. The drainage basin area: lake surface area ratio of Reference Lake 3 is also the most similar to mine area lakes, most notably Camp Lake. Reference Lake 3 also has a higher proportion of sand substrate than Reference lakes 1 and 2, which is more similar to mine area lakes.

Available information regarding Arctic Char populations and aquatic habitat in the three candidate reference lakes indicate all three lakes support what are likely land-locked resident populations and at least two (Reference lakes 1 and 2) are supplied by tributary streams that appear to provide juvenile rearing habitat (similar to mine area lakes). Reference lakes 1 and 3 also provide abundant juvenile rearing habitat in rocky nearshore areas. All three potential reference lakes also appear to provide suitable overwintering and spawning habitat. However, spawning has only been indirectly confirmed (based on extrusion of mature gametes from fall 2014 catches) in Reference Lake 2. Spawning adults have not yet been identified from Reference lakes 1 or 3, though suitable spawning habitat is abundant in both.

Based on available information, the fish population in Reference Lake 1 may be the least suitable of the three for comparison with mine area lakes. Low catch rates suggest the population of large Arctic Char in Reference Lake 1 may be small. Although there are large numbers of small Arctic Char using rocky nearshore habitat in the lake, it is not known if these fish are produced by spawning in the lake or simply move into the lake via a connecting stream. In addition, preliminary age data suggest that growth rates may be lower in Reference Lake 1 relative to mine area lakes. For example, mean otolith age for 25 Arctic Char sampled from the Mary River in

2008 was 2.6 years at a size range of 63-150 mm compared with a mean of 3.4 years for eight fish 50-136 mm in length from Reference Lake 1.

Reference Lake 2, with its lack of rocky habitat, may be the least similar to mine area lakes in terms of habitat, but fish population data (CPUE, size, and age) suggest a good match with either Camp Lake or Sheardown Lake NW. For example, the maximum CPUE for Reference Lake 2 in fall 2014 (17.37 fish/100 m/24 hours) was similar to that observed for gill nets set in Camp Lake (21.8 fish/100 m/24 hours). Captured Reference Lake 2 fish also ranged in size from 211-463 mm, similar to the 318-464 mm observed for Camp Lake fish. A summary of fish population and habitat suitability for all three lakes is provided in Table 14.

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TABLES, FIGURES, AND PHOTOGRAPHS

Table 1. Sampling programs completed in candidate reference lakes, fall 2014.

Lake	Bathymetry & Substrate	Water Quality			Phytoplankton	Zooplankton	Benthic Macroinvertebrates	Fish	
		In situ	Surface Sample	Bottom Sample				Shoreline Electrofishing	Gillnetting
Reference Lake 1		+	+	+	+	+	+	+	+
Reference Lake 2		+	+	+	+	+	+	+	+
Reference Lake 3	+	+	+	+	+	+	+		+

Table 2. Trophic classification schemes for lakes.

Parameter		Trophic categories						Reference
		Ultra-oligotrophic	**Oligotrophic**	**Mesotrophic**	**Meso-eutrophic**	**Eutrophic**	**Hypereutrophic**	
TP	(mg/L)	<0.004	0.004-0.010	0.010-0.020	0.020-0.035	0.035-0.100	> 0.100	CCME (1999; updated to 2015)
Chlorophyll *a*	(µg/L)	-	<3.7	>3.7	-			Mary River Benchmark (BIM 2014)
TN	(mg/L)	-	<0.350	0.350-0.650	-	0.651-1200	>1200	Nurnberg (1996)

Table 3. Routine water quality measured in candidate Reference lakes 1, 2, and 3 (RL1, RL2, and RL3) and mine area lakes in the open-water seasons of 2013 and 2014. Values represent means, minimums, maximums, and samples size (N) of surface water samples. CL = Camp Lake, SDL NW = Sheardown Lake northwest, SDL SE = Sheardown Lake southeast , and ML = Mary Lake.

Parameter	Unit	RL1				RL2				RL3		CL				SDL NW				SDL SE				ML			
		2013-2014				2013-2014				2014		2006-2014				2006-2014				2006-2014				2006-2014			
		Mean	Min	Max	N	Mean	Min	Max	N	Replicate 1	N	Mean	Min	Max	N	Mean	Min	Max	N	Mean	Min	Max	N	Mean	Min	Max	N
***In Situ* Parameters**																											
DO	(mg/L)	12.0	11.5	12.3	7	11.86	11.33	12.05	7	12.09	1	11.78	10.14	14.30	21	14.28	11.70	9.15	39	12.0	9.4	14.5	26	11.3	9.8	12.8	39
pH		7.79	7.42	8.23	7	7.62	7.44	8.10	7	7.82	1	7.86	6.93	8.23	19	7.87	7.90	6.76	50	7.75	6.76	8.32	24	7.73	6.78	8.55	35
Secchi Disk Depth	(m)	4.6	4.3	5.0	7	5.7	5.3	6.5	7	5.8	1	6.0	3.5	10.8	20	5.7	5.5	3.7	39	2.4	1.0	4.4	26	2.7	0.6	4.8	30
Laboratory Parameters																											
pH		7.36	6.69	7.67	7	7.32	6.64	7.62	7	7.73	1	7.67	6.84	8.30	29	7.60	6.85	8.32	66	7.75	7.01	8.20	29	7.56	6.71	8.29	47
Alkalinity as $CaCO_3$	(mg/L)	23	21	31	7	15	14	17	7	31	1	58	50	73	29	57	49	65	66	48	38	61	29	39	24	90	47
Total Dissolved Solids	(mg/L)	28	27	29	7	25	25	27	7	49	1	78	61	99	29	77	61	84	66	67	53	81	29	54	34	123	47
Conductivity	µS/cm	43	41	45	7	39	39	41	7	76	1	118	93	129	28	118	94	130	66	103	82	124	29	83	52	190	47
Ammonia	mg N/L	0.21	<0..02	1.01	7	0.09	0.03	0.17	7	0.18	1	0.09	<0.02	1.41	28	0.05	<0.02	0.18	66	0.05	<0.02	0.20	29	0.09	<0.02	0.38	46
Nitrite	mg N/L	<0.005	<0.005	<0.005	7	<0.005	<0.005	<0.005	-	<0.005	1	<0.1	<0.002	<0.1	29	<0.1	<0.002	<0.1	66	<0.1	<0.002	<0.1	29	<0.1	<0.002	0.1	47
Nitrate	mg N/L	<0.1	<0.1	<0.1	7	<0.1	<0.1	<0.1	-	<0.1	1	<0.1	<0.1	<0.1	29	<0.1	<0.1	0.18	66	<0.1	<0.1	<0.1	29	<0.1	<0.1	0.1	47
Nitrate/nitrite	mg N/L	<0.1	<0.1	<0.1	7	<0.1	<0.1	<0.1	-	<0.1	1	<0.1	<0.005	<0.1	29	<0.1	<0.005	0.18	66	<0.1	<0.005	<0.1	29	<0.1	<0.005	0.1	47
Total Kjeldahl Nitrogen	(mg/L)	0.37	0.10	1.42	7	0.23	<0.10	0.68	7	0.34	1	0.26	<0.1	1.57	27	0.15	<0.10	0.41	64	0.19	<0.10	0.46	27	0.16	<0.10	0.35	42
Total Nitrogen [1]	(mg/L)	0.42	0.15	1.47	7	0.30	<0.20	0.73	7	0.44	1	0.33	<0.11	1.67	27	0.24	<0.11	0.51	64	0.25	<0.11	0.56	27	0.21	<0.105	0.45	42
Total Phosphorus	(mg/L)	0.003	<0.003	0.004	7	0.005	<0.003	0.014	7	0.004	1	0.004	<0.003	0.015	27	0.004	<0.003	0.020	65	0.004	<0.003	0.009	27	0.005	<0.003	0.020	44
TN:TP [1, 2]		567	221	2167	7	189	36	413	7	216	1	215	29	1231	27	143	57	332	64	150	49	391	27	121	31	249	43
Dissolved Organic Carbon	(mg/L)	1.0	0.8	1.3	7	1.9	1.7	2.2	7	3.0	1	1.74	1.00	2.10	27	1.66	1.20	2.10	64	1.39	0.50	1.80	27	1.30	0.80	1.90	43
Total Organic Carbon	(mg/L)	1.2	1.0	1.4	7	2.1	1.7	2.4	7	3.1	1	1.83	1.30	2.20	27	1.79	1.40	2.40	64	1.58	1.20	1.90	26	1.54	1.10	2.80	39
Total Suspended Solids	(mg/L)	<2	<2	<2	7	<2	<2	<2	7	<2	1	<2	<2	2.0	27	3.0	<2.0	42.0	64	2.2	<2.0	5.0	27	2.5	<2	20.0	43
Turbidity	(NTU)	0.8	0.8	0.9	7	0.6	0.3	0.8	7	0.3	1	0.5	0.2	2.6	28	0.5	0.2	1.8	66	1.7	0.4	3.9	29	1.7	0.5	6.3	46
Chlorophyll *a*	(µg/L)	1.3	<0.2	3.4	7	0.4	<0.2	0.7	7	2.3	1	1.1	<0.2	3.6	22	0.6	<0.2	2.9	42	0.8	<0.2	6.5	25	1.1	<0.2	3.5	39
Pheophytin *a*	(µg/L)	1.0	<0.2	2.8	7	<0.2	<0.2	0.2	7	<0.2	1	0.5	<0.2	2.7	22	1.4	<0.2	14.3	42	1.8	<0.2	13.1	25	0.8	<0.2	3.0	39
Phenols	(mg/L)	<0.001	<0.001	<0.001	7	<0.001	<0.001	<0.001	7	<0.001	1	<0.001	<0.001	<0.001	29	<0.001	<0.001	<0.001	66	<0.001	<0.001	0.001	29	<0.001	<0.001	0.001	-
Bromide	(mg/L)	<0.25	<0.25	<0.25	7	<0.25	<0.25	<0.25	7	<0.25	1	<0.25	<0.05	<0.25	29	<0.25	<0.05	<0.25	66	<0.25	<0.05	<0.25	29	<0.25	<0.05	<0.25	47
Chloride	(mg/L)	1	<1	1	7	2	2	2	7	2	1	2	<1	4	29	3	1	4	66	2	2	5	29	2	<1	6	47
Sulphate	(mg/L)	<3	<1	<3	7	<3	1	<3	7	4	1	2	<1	4	24	3	1	4	66	2	<1	4	29	2	<1	5	43
Hardness as $CaCO_3$ (Total)	(mg/L)	20.3	18.2	21.0	7	17.6	16.2	18.0	7	38	1	59.2	50.0	76.5	29	59.2	43.0	65.2	62	49.6	22.0	63.1	26	40.4	24.0	96.1	47
Hardness as $CaCO_3$ (Dissolved)	(mg/L)	20.3	18.5	21.0	7	17.4	15.8	18.0	7	38	1	67.3	62.0	78.1	7	59.3	57.0	62.0	12	48.7	41.0	54.0	10	39.2	26.0	67.0	20

[1] Calculated
[2] Molar ratio

Table 4. Total metals measured in candidate Reference lakes 1, 2, and 3 (RL1, RL2, and RL3) and mine area lakes in the open-water seasons of 2013 and 2014. Values represent means, minimums, maximums, and samples size (N) of surface water samples. CL = Camp Lake, SDL NW = Sheardown Lake northwest, SDL SE = Sheardown Lake southeast , and ML = Mary Lake.

Parameter	Unit	RL1				RL2				RL3		CL				SDL NW				SDL SE				ML			
		2013-2014				2013-2014				2014		2006-2014				2006-2014				2006-2014				2006-2014			
		Mean	Min	Max	N	Mean	Min	Max	N	Replicate 1	N	Mean	Min	Max	N	Mean	Min	Max	N	Mean	Min	Max	N	Mean	Min	Max	N
Aluminum	(mg/L)	0.0312	0.0250	0.0410	7	0.0142	0.0050	0.0218	7	0.004	1	0.0076	0.0010	0.0280	29	0.0143	0.0029	0.1990	66	0.0710	0.0050	0.2170	28	0.0555	0.0030	0.1450	47
Antimony	(mg/L)	<0.0001	<0.0001	<0.0001	7	<0.0001	<0.0001	<0.0001	7	<0.0001	1	<0.0001	<0.0001	0.0002	27	<0.0001	<0.0001	0.0001	64	<0.0001	<0.0001	<0.0001	26	<0.0001	<0.0001	0.0002	43
Arsenic	(mg/L)	0.0001	<0.0001	0.0001	7	<0.0001	<0.0001	<0.0001	7	<0.0001	1	<0.0001	<0.0001	<0.0001	29	<0.0001	<0.0001	0.0001	66	<0.0001	<0.0001	<0.0001	28	<0.0001	<0.0001	0.0004	47
Barium	(mg/L)	0.00222	0.00208	0.00248	7	0.00262	0.00250	0.00284	7	0.00619	1	0.00527	0.00443	0.00666	27	0.00488	0.00423	0.00543	64	0.00490	0.00391	0.00662	26	0.00450	0.00258	0.01000	45
Beryllium	(mg/L)	<0.0005	<0.00002	<0.0005	7	<0.0005	<0.00002	<0.0005	7	<0.0005	1	<0.0005	<0.00002	<0.0005	27	<0.0005	<0.00002	0.0005	64	<0.0001	<0.00002	<0.0001	26	<0.0005	<0.00002	<0.0005	43
Bismuth	(mg/L)	<0.0005	<0.0005	<0.0005	7	<0.0005	<0.0005	<0.0005	7	<0.0005	1	<0.0005	<0.0005	<0.0005	27	<0.0005	<0.0005	0.0005	64	<0.0005	<0.0005	<0.0005	26	<0.0005	<0.0005	0.0005	43
Boron	(mg/L)	<0.01	<0.01	<0.01	7	<0.01	<0.01	<0.01	7	<0.01	1	<0.01	<0.01	<0.01	29	<0.01	<0.01	0.011	66	<0.01	<0.01	0.01	28	<0.01	<0.01	0.01	47
Cadmium	(mg/L)	<0.00001	<0.00001	<0.00001	7	<0.00001	<0.00001	<0.00001	7	<0.00001	1	<0.000017	<0.00001	<0.000017	29	<0.000017	<0.00001	<0.000017	66	<0.000017	<0.00001	<0.000017	28	<0.000017	<0.00001	<0.000017	47
Calcium	(mg/L)	4.09	3.68	4.27	7	3.74	3.47	3.84	7	7.56	1	12.16	10.00	15.50	29	11.87	10.00	13.10	66	10.38	8.21	12.90	28	8.40	5.17	19.70	47
Chromium	(mg/L)	0.0008	<0.0005	0.0028	7	<0.0005	<0.0005	<0.0005	7	<0.0005	1	<0.0005	<0.0001	<0.0005	29	<0.0005	<0.0001	0.0032	66	<0.00067	<0.0001	<0.00067	28	<0.0005	0.0001	<0.0005	43
Cobalt	(mg/L)	<0.0001	<0.0001	<0.0001	7	<0.0001	<0.0001	<0.0001	7	<0.0001	1	<0.0001	<0.0001	<0.0002	29	<0.0002	<0.0001	<0.0002	66	<0.0002	<0.0001	<0.0002	28	<0.0002	<0.0001	<0.0002	47
Copper	(mg/L)	0.00089	0.00050	0.00292	7	<0.0005	<0.0002	0.00050	7	0.0009	1	0.00101	0.00072	0.00324	27	0.00134	0.00073	0.02720	64	0.00092	0.00063	0.00246	26	0.00085	0.00050	0.00429	43
Iron	(mg/L)	0.044	<0.03	0.111	7	<0.03	<0.03	<0.03	7	<0.03	1	<0.03	<0.003	0.044	29	<0.03	0.011	0.037	66	0.082	<0.03	0.221	28	0.064	<0.03	0.180	47
Lead	(mg/L)	0.00007	<0.00005	0.00013	7	<0.00005	<0.00005	<0.00005	7	<0.00005	1	<0.00005	<0.00005	0.00008	27	0.00006	<0.00005	0.00095	64	0.00010	<0.00005	0.00029	26	0.00008	<0.00005	0.00017	43
Lithium	(mg/L)	<0.001	<0.00005	<0.001	7	<0.001	<0.00005	<0.001	7	<0.001	1	<0.005	<0.00056	<0.005	27	<0.005	<0.00005	<0.005	64	<0.005	0.00005	<0.005	26	<0.005	<0.00005	<0.005	43
Magnesium	(mg/L)	2.44	2.19	2.53	7	1.98	1.83	2.04	7	4.56	1	7.13	6.00	9.18	29	7.20	6.00	8.02	66	5.96	4.92	7.27	28	4.77	3.00	11.20	47
Manganese	(mg/L)	0.00207	0.00187	0.00256	7	0.00266	0.00038	0.00534	7	0.00078	1	0.00160	0.00014	0.00288	27	0.00158	0.00082	0.00259	64	0.00334	0.00033	0.00553	26	0.00225	0.00088	0.02000	44
Mercury	(mg/L)	<0.00001	<0.00001	<0.00001	7	<0.00001	<0.00001	<0.00001	7	<0.00001	1	<0.00001	<0.00001	<0.00001	29	<0.00001	<0.00001	0.00017	66	<0.00001	<0.00001	<0.00001	28	<0.00001	<0.00001	0.00001	47
Molybdenum	(mg/L)	0.00016	<0.00005	0.00076	7	<0.00005	<0.00005	0.00006	7	0.00018	1	0.00021	<0.00005	0.00052	27	0.00064	0.00026	0.00093	64	0.00037	0.00010	0.00076	26	0.00010	<0.00005	0.00027	43
Nickel	(mg/L)	0.00062	<0.0005	0.00134	7	<0.0005	<0.0005	<0.0005	7	<0.0005	1	0.00064	0.00050	0.00073	27	0.00066	0.00054	0.00097	64	0.00062	0.00050	0.00085	26	0.00051	<0.00050	0.00068	43
Potassium	(mg/L)	0.30	0.29	0.32	7	0.32	0.20	0.40	7	0.8	1	0.82	0.59	1.07	23	0.83	0.67	0.91	50	0.69	0.50	0.87	22	0.52	0.30	0.81	39
Selenium	(mg/L)	<0.001	<0.00001	<0.001	7	<0.001	<0.00001	<0.001	7	<0.001	1	<0.001	<0.00001	<0.001	29	<0.001	<0.00001	0.001	60	<0.001	<0.00001	<0.001	28	<0.001	<0.00001	<0.001	47
Silicon	(mg/L)	0.39	0.35	0.40	7	0.28	0.20	0.30	7	0.5	1	0.43	0.36	0.57	27	0.63	0.57	0.70	58	0.71	0.49	1.16	26	0.55	0.40	0.90	43
Silver	(mg/L)	<0.00001	<0.000001	0.000016	7	<0.00001	<0.000001	<0.00001	7	<0.00001	1	<0.00001	<0.000001	<0.00001	29	<0.0001	<0.000001	0.00010	60	<0.00001	<0.000001	<0.00001	28	<0.00001	<0.000001	<0.00001	47
Sodium	(mg/L)	0.71	0.65	0.80	7	1.02	0.99	1.09	7	0.73	1	0.91	0.47	1.28	23	0.91	0.48	1.16	49	0.78	0.48	1.30	22	0.87	0.41	1.48	39
Strontium	(mg/L)	0.0036	0.0034	0.0038	7	0.0049	0.0048	0.0050	7	0.0086	1	0.0078	0.0052	0.0111	29	0.0075	0.0064	0.0084	60	0.0080	0.0049	0.0128	28	0.0066	0.0036	0.0144	47
Thallium	(mg/L)	<0.0001	<0.000001	<0.0001	7	<0.0001	<0.000001	<0.0001	7	<0.0001	1	<0.0001	<0.000001	<0.0001	27	<0.0001	<0.000001	0.0001	57	<0.0001	<0.000001	<0.0001	26	<0.0001	<0.000001	<0.0001	43
Tin	(mg/L)	0.00021	<0.0001	0.00077	7	<0.0001	<0.0001	0.00030	7	<0.0001	1	<0.0001	<0.0001	0.0002	27	<0.0001	<0.0001	0.00016	58	0.00012	<0.0001	0.00038	26	<0.0001	<0.0001	0.0006	43
Titanium	(mg/L)	<0.01	<0.01	<0.01	7	<0.01	<0.01	<0.01	7	<0.01	1	<0.01	<0.01	<0.01	27	<0.01	<0.01	0.01	58	<0.01	<0.01	0.02	26	<0.01	<0.01	<0.01	43
Uranium	(mg/L)	0.00014	0.00013	0.00014	7	0.00006	0.00006	0.00008	7	0.00027	1	0.00051	0.00034	0.00071	27	0.00079	0.00036	0.00096	58	0.00063	0.00036	0.00097	26	0.00063	0.00027	0.00235	43
Vanadium	(mg/L)	<0.001	<0.001	<0.001	7	<0.001	<0.001	<0.001	7	<0.001	1	<0.001	<0.001	<0.001	29	<0.001	<0.001	0.001	60	<0.001	<0.001	<0.001	28	<0.001	<0.001	0.004	47
Zinc	(mg/L)	<0.003	<0.003	0.004	7	0.005	<0.003	0.019	7	<0.003	1	<0.003	<0.001	0.004	27	<0.003	<0.001	0.017	58	<0.003	<0.001	0.003	26	<0.003	<0.001	0.005	43

Table 5. Sediment quality measured in candidate Reference lakes 1, 2, and 3 and mine area lakes. Values represent means for Reference lakes 1 and 2 and mine area lakes and results of the single sample collected in Reference Lake 3. Values in blue and red indicate exceedances of CCME (non-italicized) or Ontario SQGs (italicized). CL = Camp Lake; SDL NW = Sheardown Lake northwest; SDL SE = Sheardown Lake southeast; and ML = Mary Lake.

Parameter	Unit	Reference Lakes			Mine Area Lakes				SQGs			
		RL1	RL2	RL3	CL	SDL NW	SDL SE	ML	CCME		Ontario	
		2014	2014	2014	2007-2014	2007	2007-2014	2006-2014	ISQG	PEL	LEL	SEL
Aluminum	(µg/g)	24140	11200	8450	11200	8450	13020	14443				
Antimony	(µg/g)	<1	<1	<1	<1	<1	<1	<1				
Arsenic	(µg/g)	3	2	<1	2	<1	3	3	5.9	17		
Barium	(µg/g)	103	71	49	71	49	68	76				
Beryllium	(µg/g)	2	<1	<1	<1	<1	1	1				
Boron	(µg/g)	0.7	1.0	<0.5	1.0	<0.5	1.0	3.7				
Cadmium	(µg/g)	<0.5	<0.5	<0.5	<0.5	<0.5	0.5	<0.5	0.6	3.5		
Calcium	(µg/g)	3120	2260	3200	2260	3200	2950	3061				
Chromium	(µg/g)	98	42	31	42	31	62	66	37.3	90		
Cobalt	(µg/g)	18	11	7	11	7	15	12				
Copper	(µg/g)	45	25	35	25	35	35	40	35.7	197		
Iron	(µg/g)	*48920*	*61020*	*20400*	*61020*	*20400*	*29304*	*30571*			*20000*	*40000*
Lead	(µg/g)	22.4	11	7	11	7	15	17	35	91.3		
Magnesium	(µg/g)	13080	4080	5200	4080	5200	10037	8934				
Manganese	(µg/g)	*1328*	*625*	*483*	*625*	*483*	*987*	*1019*			*460*	*1100*
Mercury	(µg/g)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.170	0.486		
Molybdenum	(µg/g)	<1	2	1	2	1	1	3				
Nickel	(µg/g)	*63*	*24*	*22*	*24*	*22*	*55*	*59*			*16*	*75*
Potassium	(µg/g)	4740	1900	2100	1900	2100	3169	3583				

Table 5. - continued -

Parameter	Unit	Reference Lakes			Mine Area Lakes				SQGs			
		RL1	RL2	RL3	CL	SDL NW	SDL SE	ML	CCME		Ontario	
		2014	2014	2014	2007-2014	2007	2007-2014	2006-2014	ISQG	PEL	LEL	SEL
Selenium	(µg/g)	<1	<1	<1	<1	<1	1	<1				
Silver	(µg/g)	<0.2	<0.2	<0.2	<0.42	<0.42	<0.42	<0.42				
Sodium	(µg/g)	260	180	200	238	357	321	367				
Strontium	(µg/g)	20	16	7	10	11	11	12				
Thallium	(µg/g)	<1	<1	<1	<1	<1	<1	<1				
Vanadium	(µg/g)	71	33	30	49	48	44	52				
Zinc	(µg/g)	84	53	43	57	60	49	74	123	315		
Nitrite	(µg N/g)	<1	<1	<1	<1	<1	<1	<1				
Nitrate	(µg N/g)	<1	<1	<1	1	1	4	2				
Nitrate/nitrite	(µg N/g)	<1	<1	<1	2	2	5	3				
Total Kjeldahl Nitrogen	(µg/g)	*2700*	*4220*	*1500*	*1458*	*2000*	*1142*	*813*			*550*	*4800*
Total Organic Carbon	(%)	*3.34*	*5.00*	*1.91*	*1.35*	*2.04*	*1.23*	*0.95*			*1*	*10*
Sand (>0.050mm)	(%)	38	61	76	57	57	33	40				
Silt (>0.002-0.050mm)	(%)	30	7	18	32	32	51	44				
Clay (<=0.002mm)	(%)	32	33	6	11	10	16	17				
Moisture	(%)	77	81	68	53	-	43	49				

Table 6. Catch totals for Arctic Char and catch-per-unit-effort (CPUE) for gillnetting surveys in potential reference lakes, fall 2014.

Waterbody	Site ID	Set Duration (dec.hrs)	Catch Total (ARCH)	CPUE[1]
Reference Lake 1	RL1-14-01	4.9	0	0.00
	RL1-14-02	5.0	0	0.00
	RL1-14-03	5.0	0	0.00
	RL1-14-04	4.3	0	0.00
	RL1-14-05	4.3	0	0.00
	Total		*0*	*0.00*
Reference Lake 2	RL2-14-01	6.0	6	17.37
	RL2-14-02	6.2	2	5.59
	RL2-14-03	6.3	0	0.00
	Total		*8*	*7.65*
Reference Lake 3	RL3-14-01	7.5	1	2.32
	RL3-14-02	7.6	0	0.00
	Total		*1*	*1.16*

[1] CPUE calculated as #fish/100 m net/24 hours

Table 7. Catch totals and catch-per-unit-effort (CPUE) for backpack electrofishing surveys in potential reference lakes, fall 2014.

Waterbody	Site ID	Duration (s)	Catch Total [1]	CPUE [2]
Reference Lake 1	RL1-14-01	255	36	8.5
	RL1-14-02	308	59	11.5
Reference Lake 2	RL2-14-01	289	128	26.6

[1] RL2-14-01 catch included 29 Ninespine Stickleback
[2] CPUE calculated as #fish/min of electrofishing

Table 8. Summary of size and age data for Arctic Char captured during electrofishing surveys of potential reference lakes, fall 2014.

Waterbody	Fork Length (mm)				Weight (g)				Condition Factor			
	n [1]	Mean	SD [2]	Range	n	Mean	SD	Range	n	Mean	SD	Range
Reference Lake 1	85	83	21	30 - 136	10	8.4	6.4	0.6 - 17.0	10	0.90	0.13	0.68 - 1.16
Reference Lake 2	59	107	33	23 - 178	20	11.7	14.4	0.1 - 60.0	20	0.94	0.16	0.70 - 1.27

Waterbody	Otolith Age			
	n	Mean	SD	Range
Reference Lake 1	8	3.4	2.0	1 - 6
Reference Lake 2	16	1.6	1.0	0 - 4

[1] n = number of fish measured; may not equal total number captured
[2] SD = standard deviation

Table 9. Summary of length, weight and condition factor of Arctic Char captured in gillnetting surveys of potential reference lakes, fall 2014.

Waterbody	Fork Length (mm)				Weight (g)				Condition Factor			
	n [1]	Mean	SD [2]	Range	n	Mean	SD	Range	n	Mean	SD	Range
Reference Lake 2	8	346	88	211 - 463	8	475	345	50 - 1000	8	0.91	0.20	0.53 - 1.14
Reference Lake 3	1	620	-	-	1	1900	-	-	1	0.80	-	-

[1] n = number of fish measured; may not equal total number captured
[2] SD = standard deviation

Table 10. Substrate types in Reference Lake 3.

Substrate Type	Shoreline Zone (0-2 m)		Euphotic Zone (2-12 m)		Profundal Zone (>12 m)		Total	
	(m^2)	%	(m^2)	%	(m^2)	%	(m^2)	%
Boulder/Cobble	239,701	66.0	240,443	27.5	35,803	4.4	515,947	25.1
Sandy Loam	1,614	0.4	517,124	59.2	575,459	70.0	1,094,197	53.1
Silt/Clay	179	0.0	111,016	12.7	206,607	25.1	317,802	15.4
Unclassified	121,787	33.5	5,305	0.6	3,888	0.5	130,980	6.4
Grand Total	363,280	100.0	873,888	100.0	821,757	100.0	2,058,925	100.0

Table 11. Summary of non-parametric statistical comparisons between reference lake routine water quality and Camp Lake and Sheardown Lake NW routine water quality. NS = no significant difference. Dashes indicate where data were not amenable to statistical analysis due to a high frequency of censured data.

Parameter	**RL1**	**RL2**
***In Situ* Parameters**		
DO	NS	NS
pH	NS	NS
Secchi Disk Depth	NS	NS
Laboratory Parameters		
pH	NS	NS
Alkalinity as $CaCO_3$	Lower than CL and SDL NW	Lower than CL and SDL NW
Total Dissolved Solids	Lower than CL and SDL NW	Lower than CL and SDL NW
Conductivity	Lower than CL and SDL NW	Lower than CL and SDL NW
Ammonia	NS	NS
Nitrite	-	-
Nitrate	-	-
Nitrate/nitrite	-	-
Total Kjeldahl Nitrogen	NS	NS
Total Nitrogen	NS	NS
Total Phosphorus	NS [1]	NS
Dissolved Organic Carbon	Lower than CL and SDL NW	NS
Total Organic Carbon	Lower than CL and SDL NW	NS
Total Suspended Solids	-	-
Turbidity	Higher than CL	NS
Chlorophyll *a*	NS	NS
Pheophytin *a*	NS	NS
Phenols	-	-
Bromide	-	-
Chloride	Lower than CL and SDL NW	NS
Sulphate	-	NS
Hardness as $CaCO_3$ (Total)	Lower than CL and SDL NW	Lower than CL and SDL NW

[1] Data sets include a high frequency of censured values.

Table 12. Summary of non-parametric statistical comparisons between reference lake total metals and Camp Lake and Sheardown Lake NW total metals in surface water. NS = no significant difference. Dashes indicate where data were not amenable to statistical analysis due to a high frequency of censured data.

Parameter	**RL1**	**RL2**
Aluminum	Higher than CL	NS
Antimony	-	-
Arsenic	-	-
Barium	Lower than CL and SDL NW	Lower than CL and SDL NW
Beryllium	-	-
Bismuth	-	-
Boron	-	-
Cadmium	-	-
Calcium	Lower than CL and SDL NW	Lower than CL and SDL NW
Chromium	Higher than CL and SDL NW [1]	Higher than SDL NW [1]
Cobalt	-	-
Copper	Lower than CL and SDL NW	Lower than CL and SDL NW [1]
Iron	NS [1]	NS [1]
Lead	NS [1]	NS [1]
Lithium	-	-
Magnesium	Lower than CL and SDL NW	Lower than CL and SDL NW
Manganese	NS	Higher than SDL NW
Mercury	-	-
Molybdenum	Lower than SDL NW	Lower than SDL NW
Nickel	Lower than CL and SDL NW [1]	-
Potassium	Lower than CL and SDL NW	Lower than CL and SDL NW
Selenium	-	-
Silicon	Lower than SDL NW	Lower than SDL NW
Silver	-	-
Sodium	NS	NS
Strontium	Lower than CL and SDL NW	Lower than CL and SDL NW
Thallium	-	-
Tin	-	-
Titanium	-	-
Uranium	Lower than SDL NW	Lower than SDL NW
Vanadium	-	-
Zinc	NS [1]	NS [1]

[1] Data sets include a high frequency of censured values.

Table 13. Comparison of aquatic habitat and lake characteristics for reference lakes and mine area lakes.

Lake	Drainage Basin Area (km^2)	Lake Area (km^2)	Drainage Basin: Lake Area Ratio	Mean Depth (m)	Maximum Depth (m)	Volume (1,000,000 m^3)	Substrate			
							Cobble/ Boulder (%)	Gravel/ Pebble (%)	Sand (%)	Fine Sand and Silt/Clay (%)
Camp Lake	26.5	2.21	11.98	13.0	35.1	27.5	5.1	28.2	61.1	5.6
Sheardown Lake NW	6.55	0.678	9.66	12.1	30.1	8.18	10.1	41.8	46	2.0
Reference Lake 1	3.39	0.228	14.9	9.4	15.3	2.27	18.1	12.6	8.4	60.9
Reference Lake 2	2.35	0.484	4.86	6.1	11.7	3.01	8.8	1.6	35.8	53.8
Reference Lake 3 [1]	23.2	2.05	11.32	11.8 [2]	38.3	22.6 [2]	25.1	-	53.1	15.4

[1] 6.4% of substrate was unclassified.

[2] Metrics based on area of Reference Lake 3 surveyed in 2014. Actual numbers may differ.

Table 14. Summary of information collected during surveys of three potential reference lakes in 2013 and 2014 and suitability of reference lakes in relation to fish and fish habitat.

Lake	UTM Coordinates		Maximum Depth (m)	Dominant Substrate (0-5 m depth)	Dominant Substrate (> 5 m depth)	Arctic Char				Fish and Fish Habitat Suitability [1]	
	Easting	Northing				Juvenile Rearing	Adult Feeding	Adult Spawning	Overwintering	Similarities	Differences
Reference Lake 1	550244	7938780	15.3	Sand/Cobble/Boulder	Sand/Silt/Clay	Y	Y	Unknown	Probable	Ideal substrate composition; juvenile use of nearshore habitat	Lake is small; only two adult ARCH captured in five gill nets set; spawning not confirmed; growth rates may be lower
Reference Lake 2	568893	7900087	11.7	Sand	Sand/silt	Y	Y	Y	Probable	Resident fish populations of ARCH and NNST present; juvenile use of nearshore areas and tributary streams; spawning likely based on presence of adult in spawning condition	Lake is shallow and large differences in substrate composition and distribution
Reference Lake 3	574427	7852874	38.3	Mainly Cobble	NA	Y	Y	Y	Probable	Presence of adult and juvenile ARCH; ideal, abundant habitat; sufficient depths	Nearshore areas rockier than Camp Lake

[1] ARCH = Arctic Char; NNST = Ninespine Stickleback

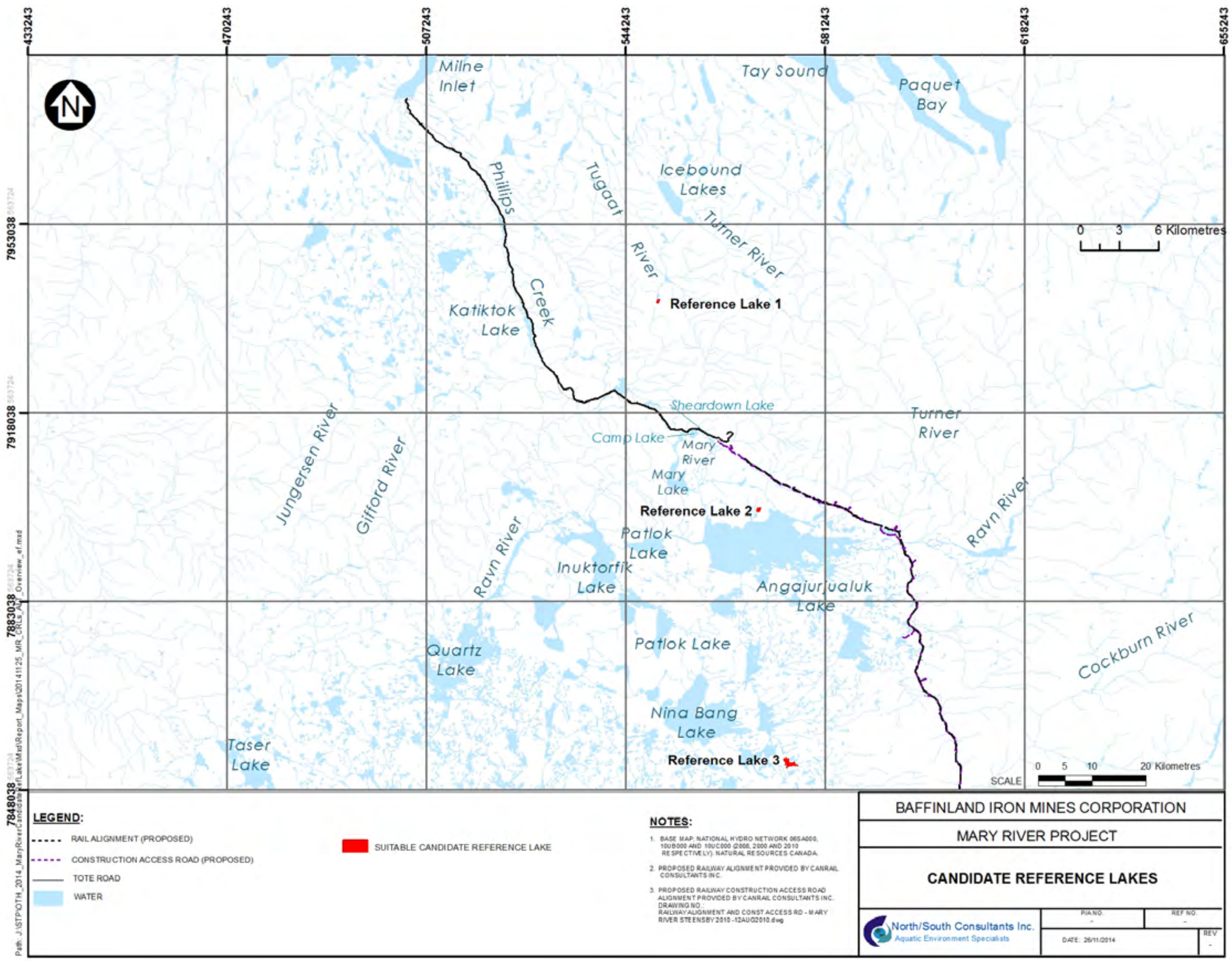

Figure 1. Reference lakes surveyed during fall 2014.

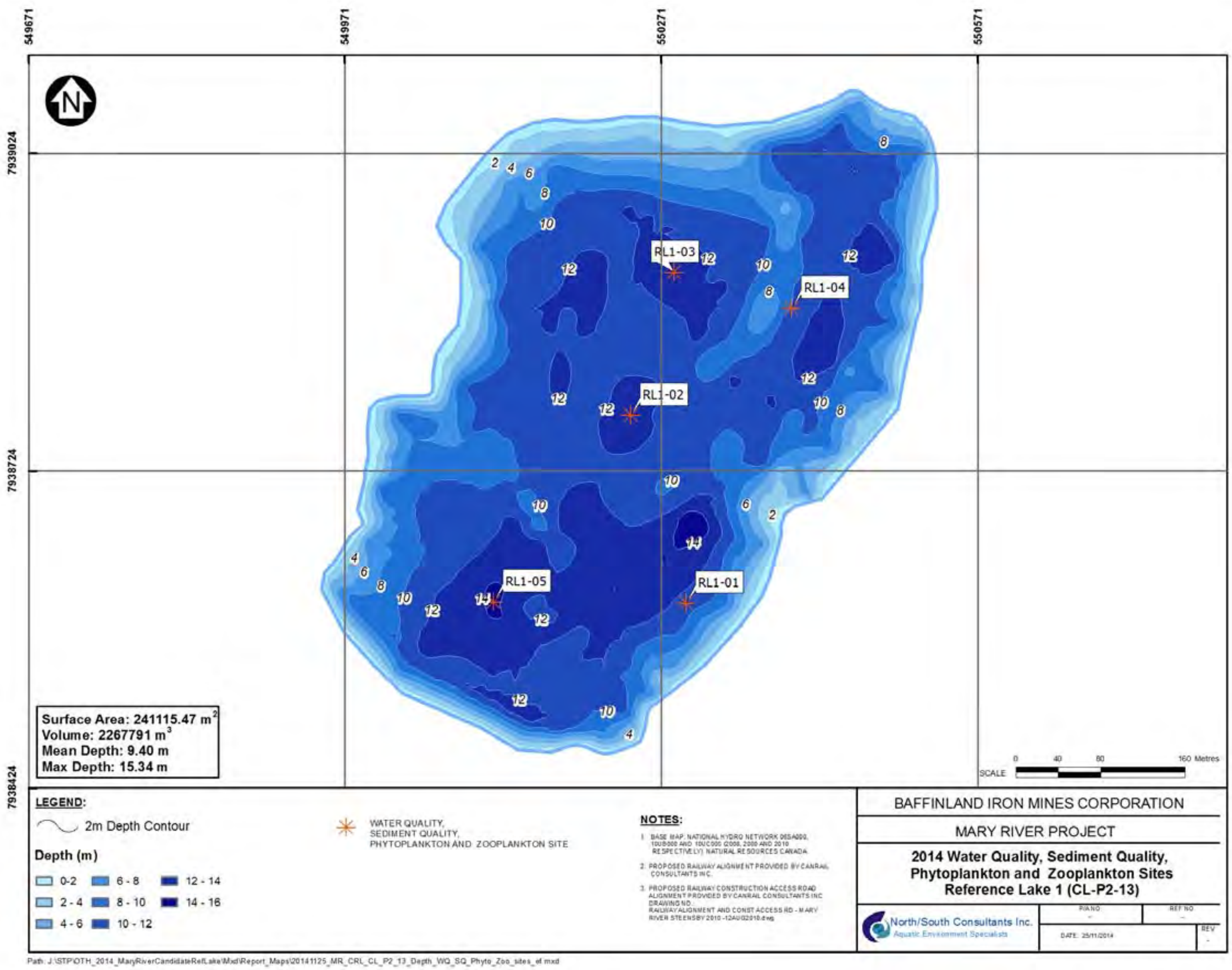

Figure 2. Locations of water quality, sediment quality, phytoplankton, and zooplankton sampling sites in Reference Lake 1, fall 2014.

(A)

(B)

(C)

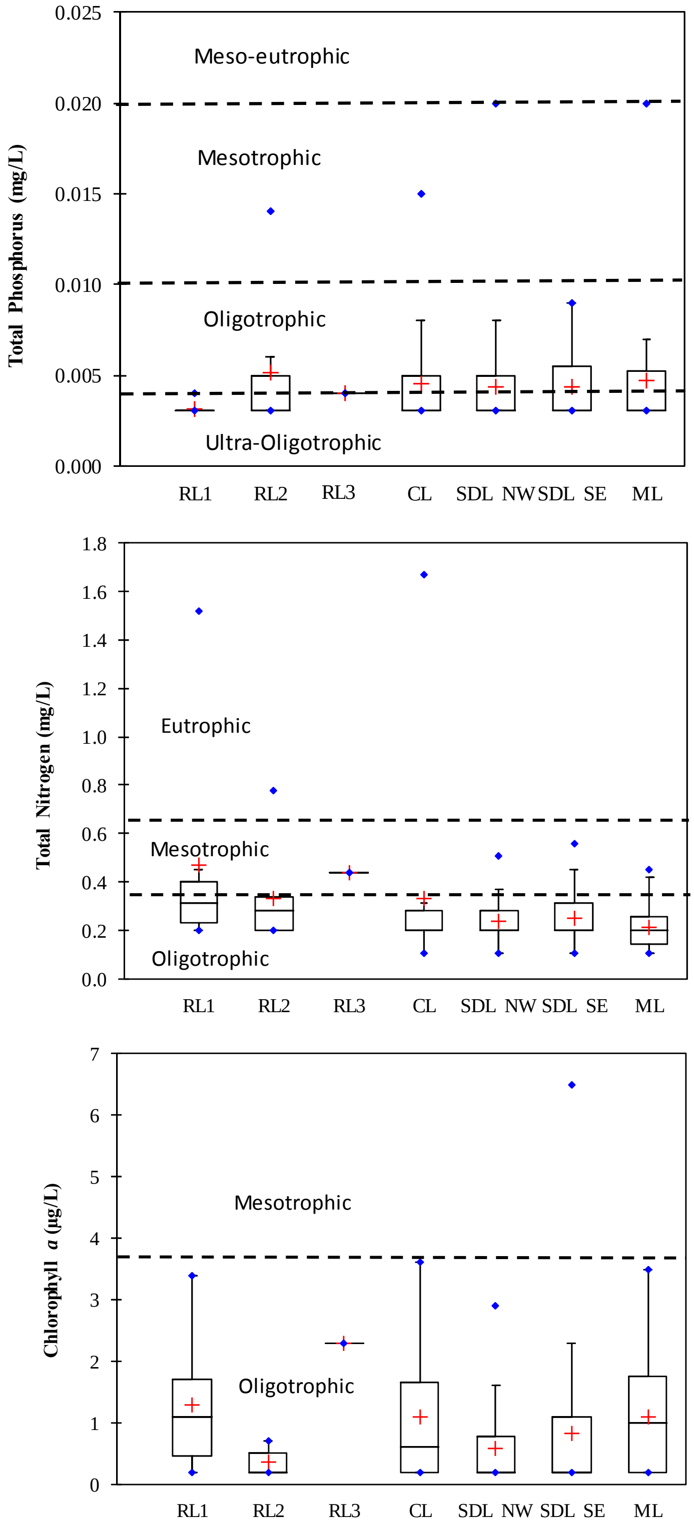

Figure 3. Boxplots of total phosphorus, total nitrogen, and chlorophyll *a* and comparison to trophic classification schemes in reference lakes and mine area lakes. Data represent 2013-2014 data for reference lakes and 2006-2014 for mine area lakes.

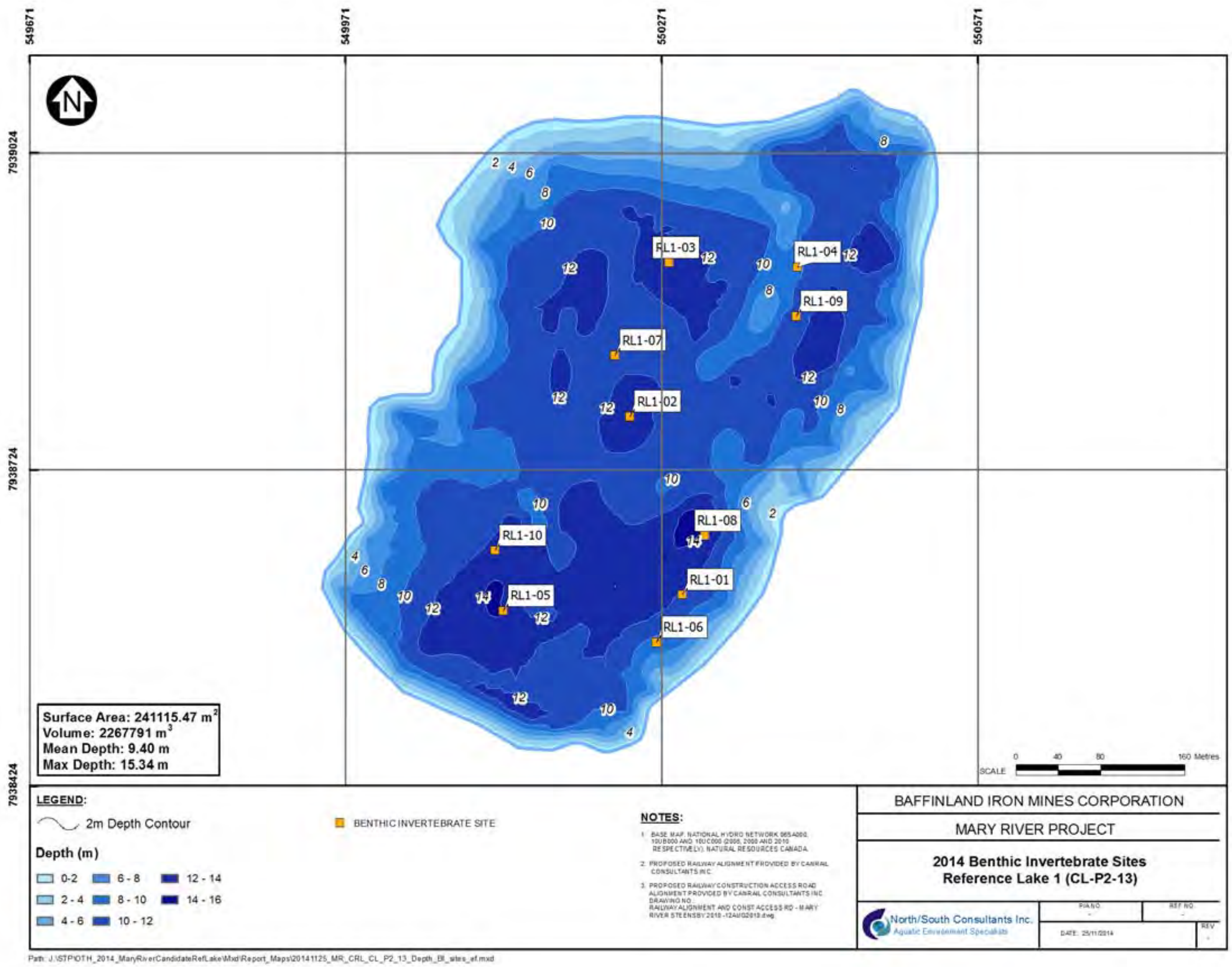

Figure 4. Locations of benthic macroinvertebrate sampling sites in Reference Lake 1, fall 2014.

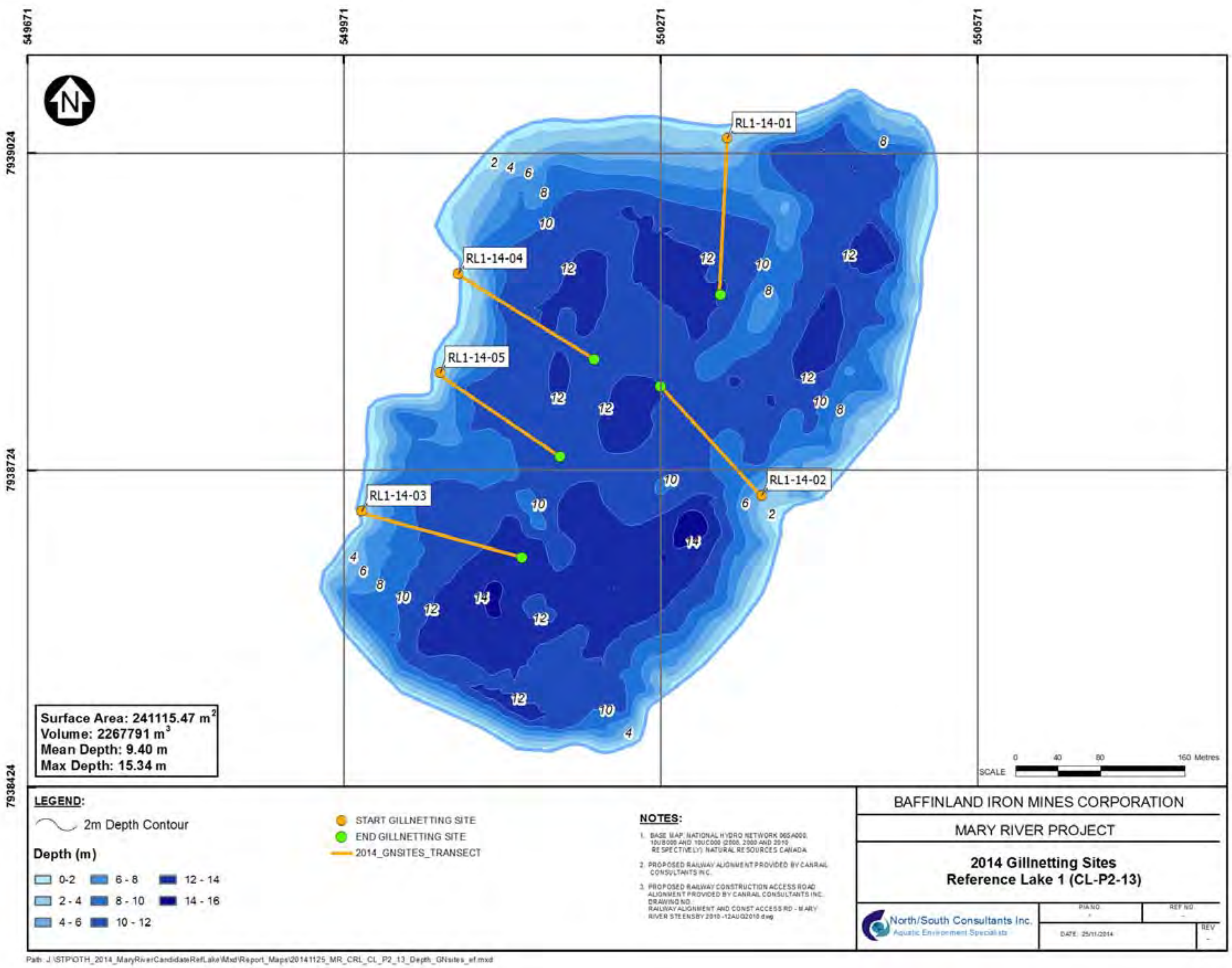

Figure 5. Locations of gillnet sampling sites in Reference Lake 1, fall 2014.

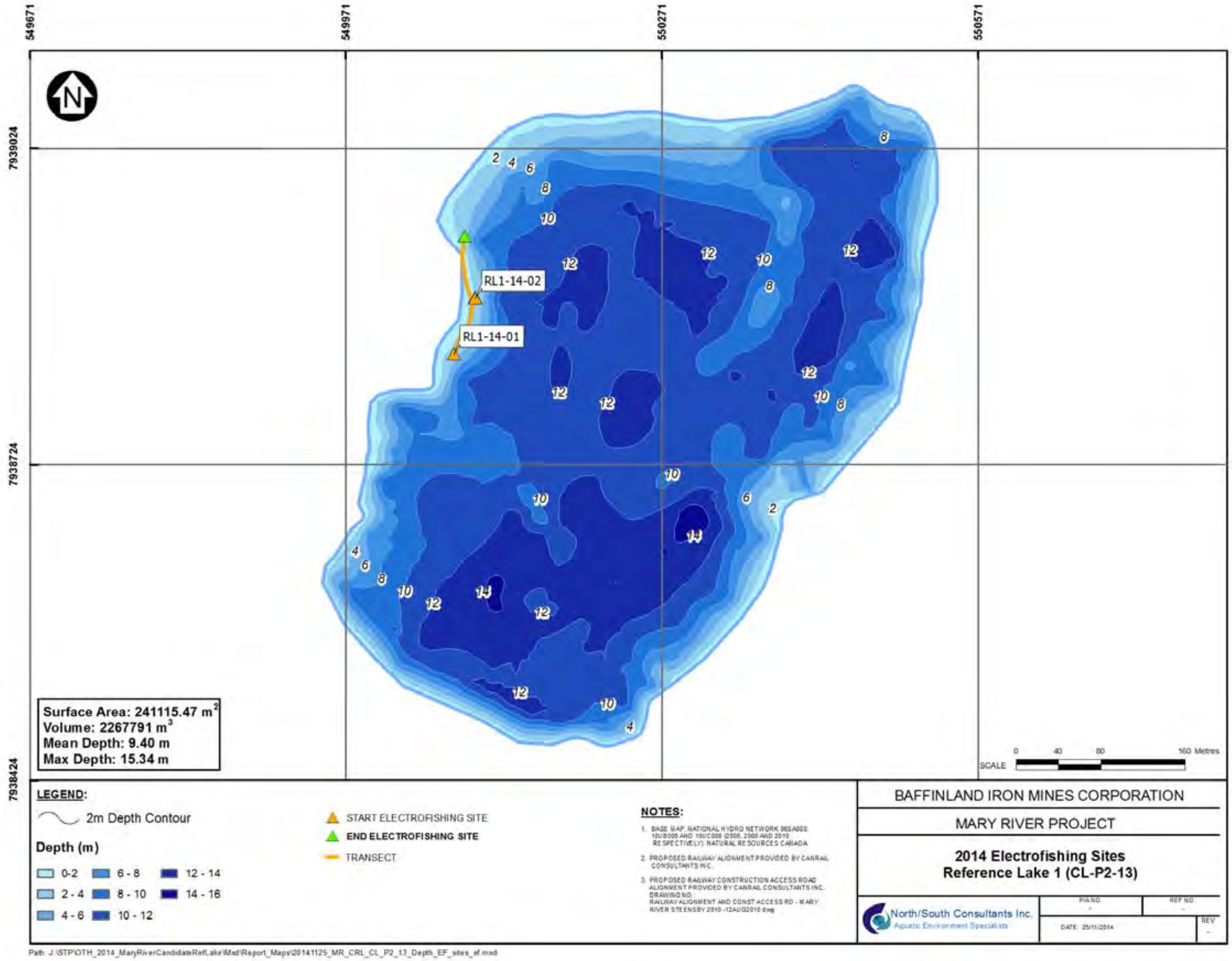

Figure 6. Locations of backpack electrofishing sampling sites in Reference Lake 1, fall 2014.

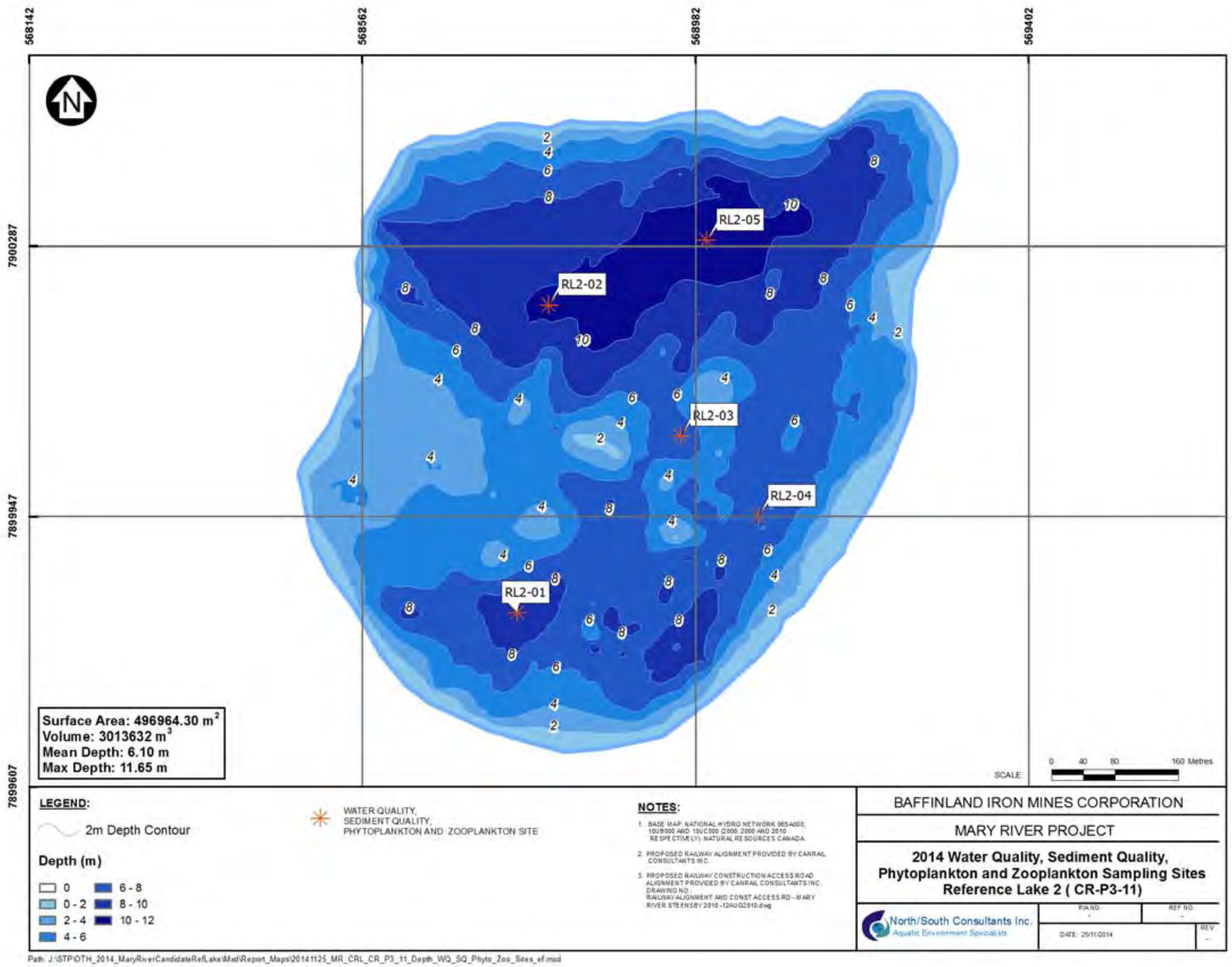

Figure 7. Locations of water quality, sediment quality, phytoplankton, and zooplankton sampling sites in Reference Lake 2, fall 2014.

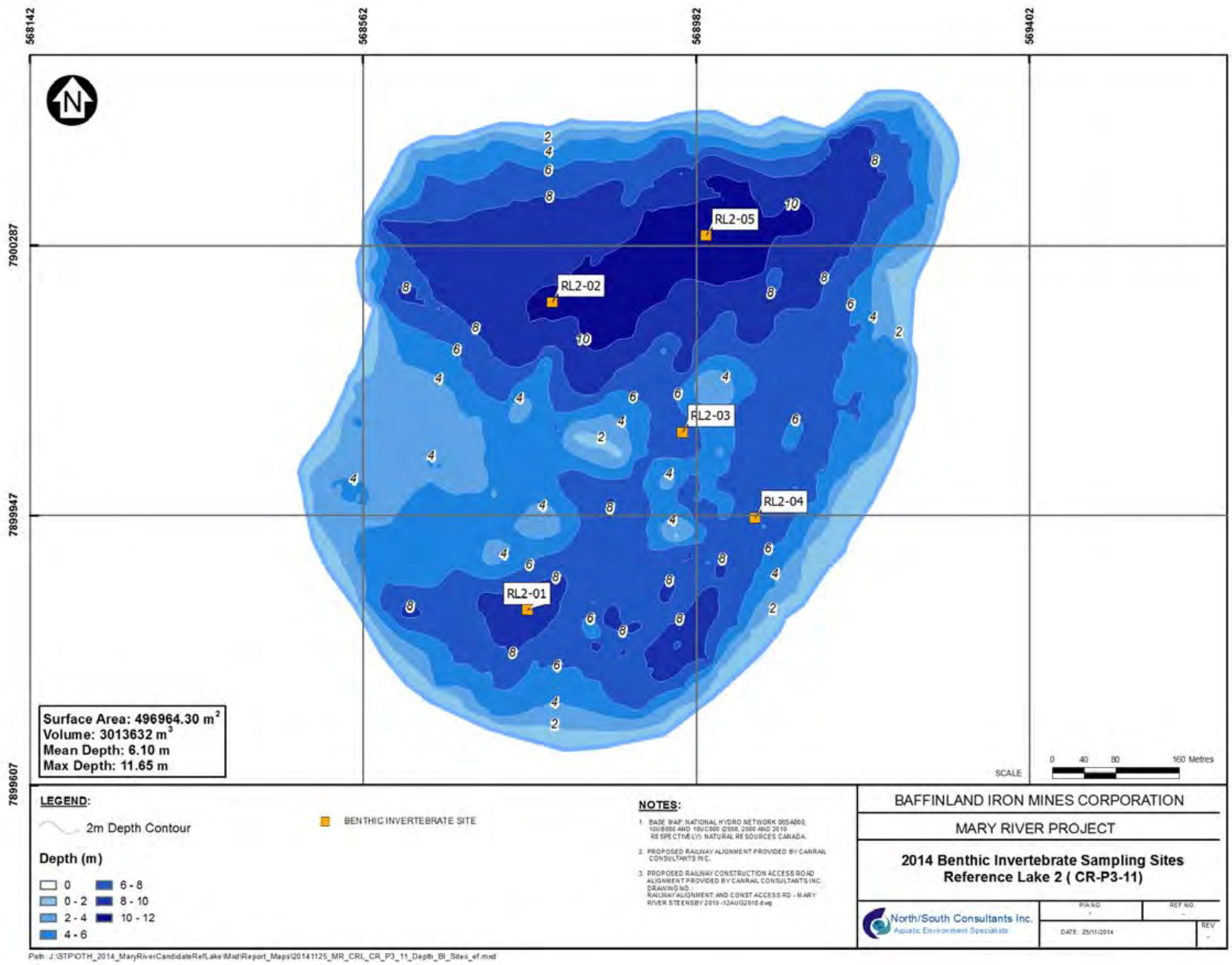

Figure 8. Locations of benthic macroinvertebrate sampling sites in Reference Lake 2, fall 2014.

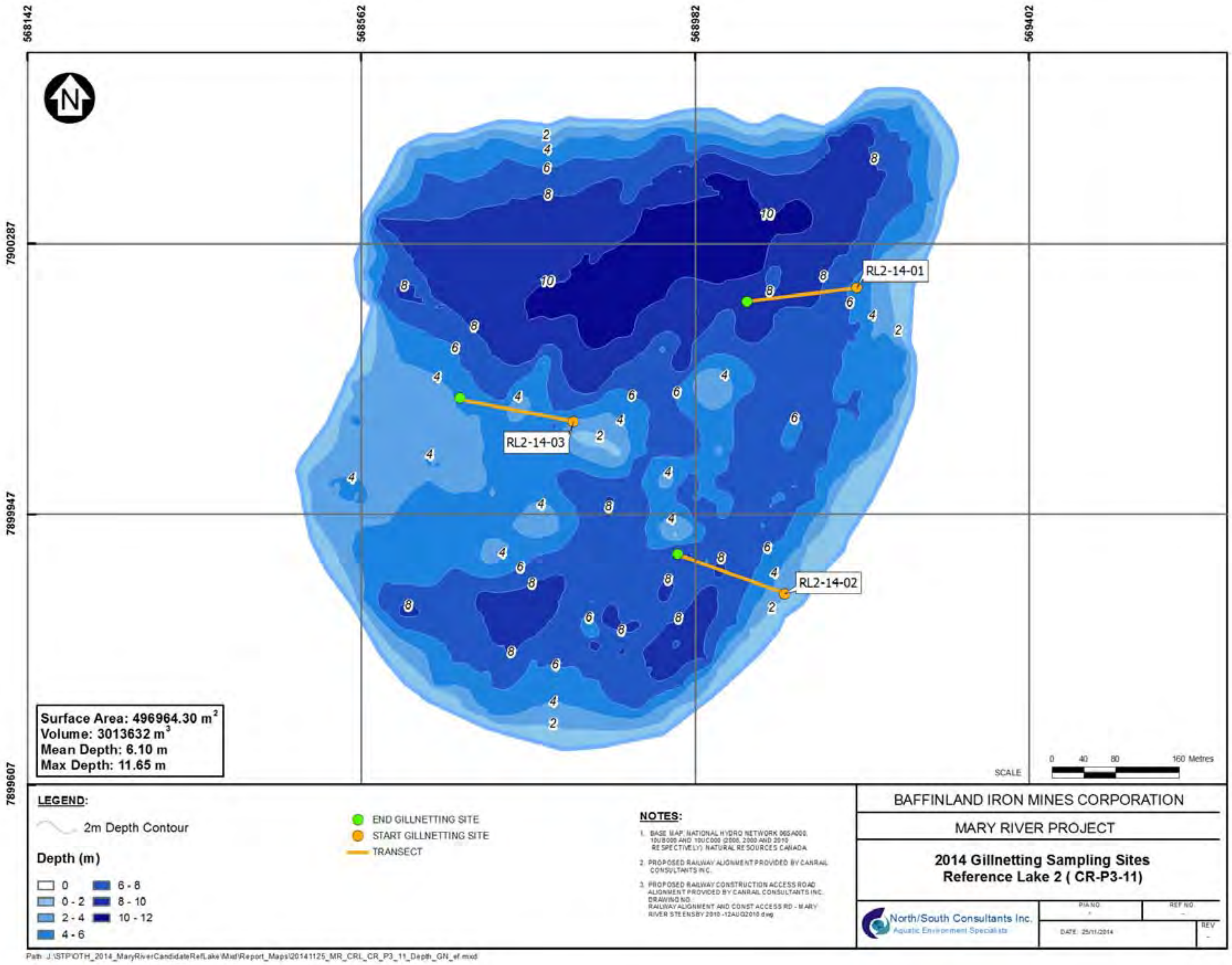

Figure 9. Locations of gillnet sampling sites in Reference Lake 2, fall 2014.

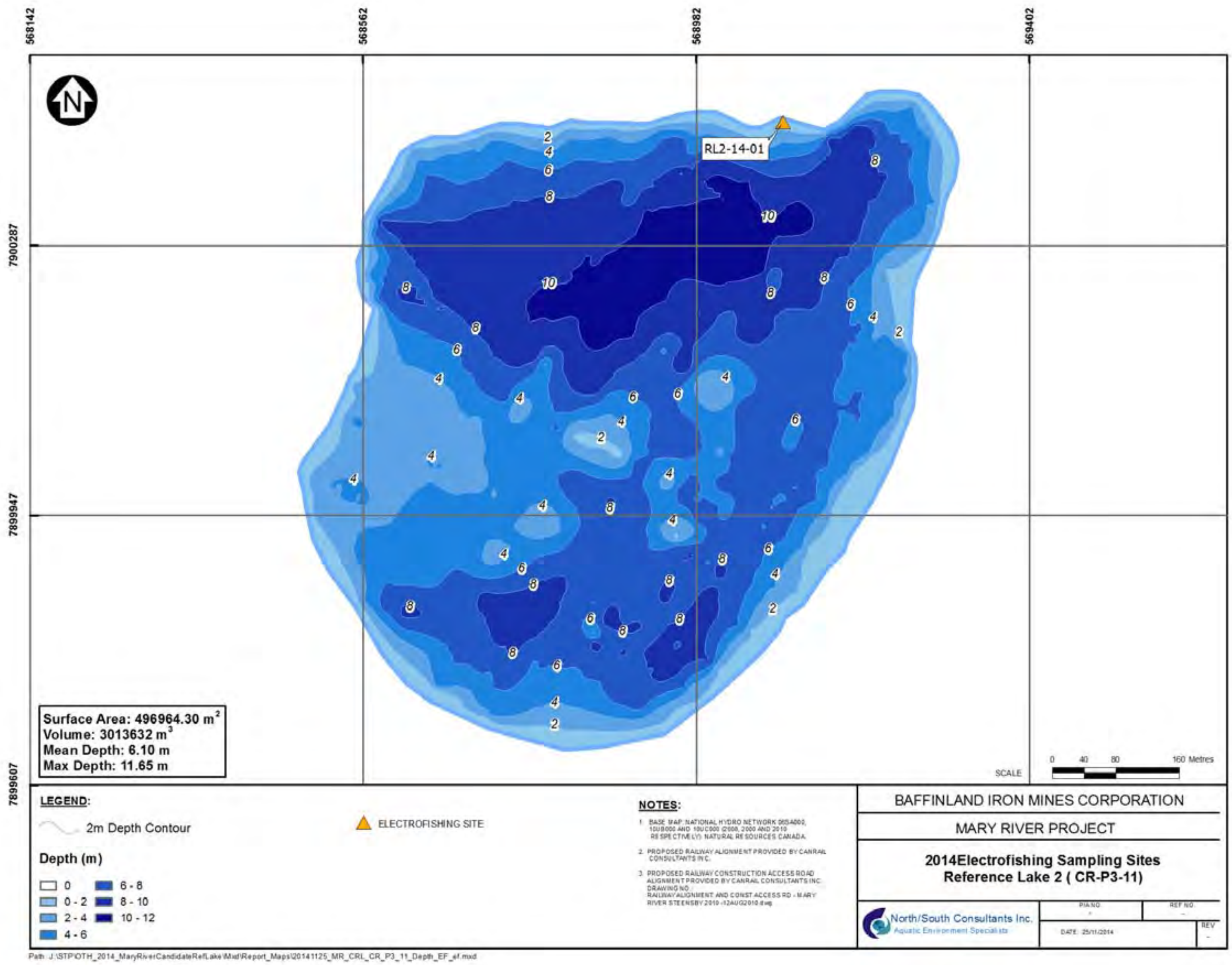

Figure 10. Location of a backpack electrofishing site in Reference Lake 2, fall 2014.

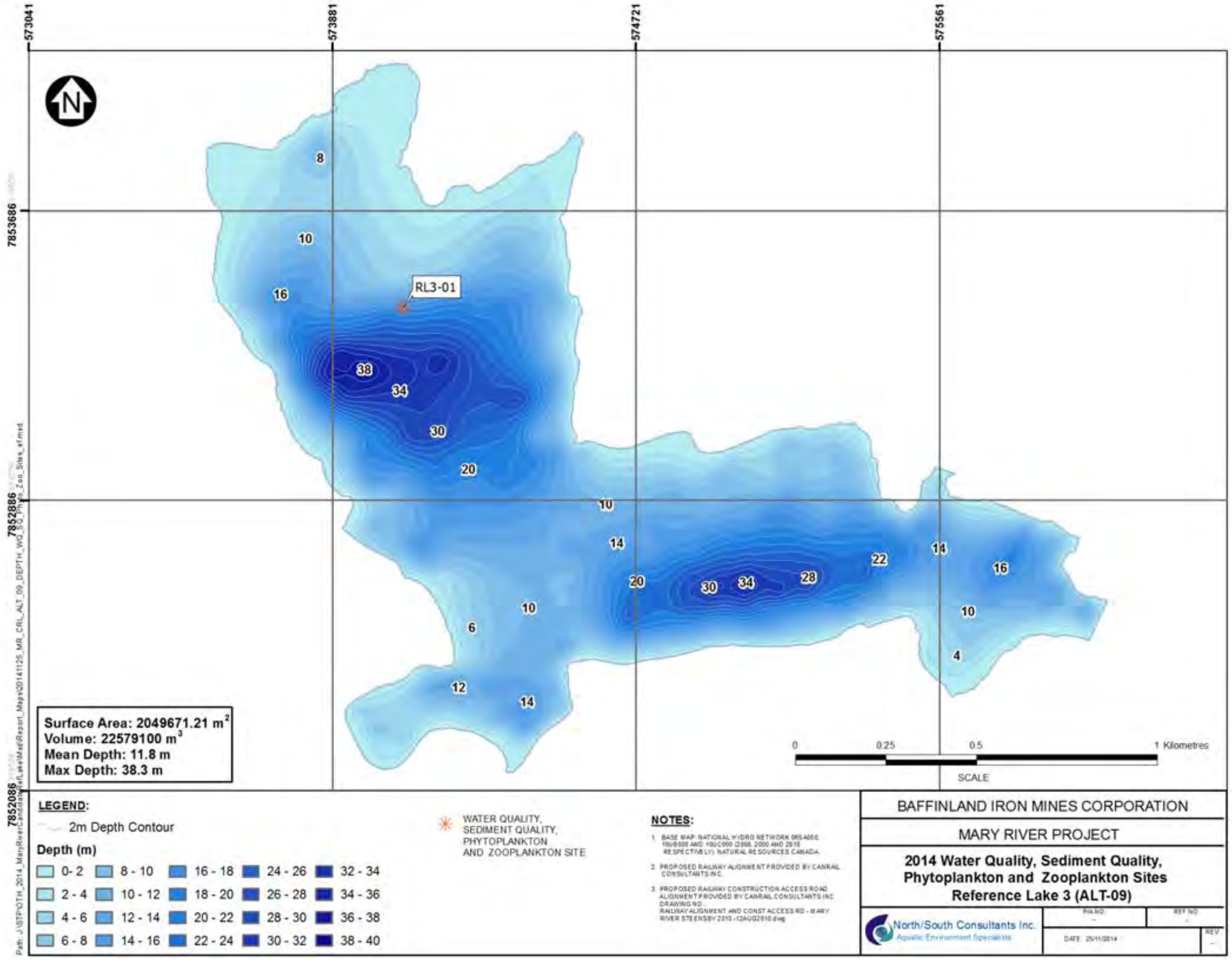

Figure 11. Bathymetry and location of the water quality, sediment quality, phytoplankton, and zooplankton sampling site in Reference Lake 3, fall 2014.

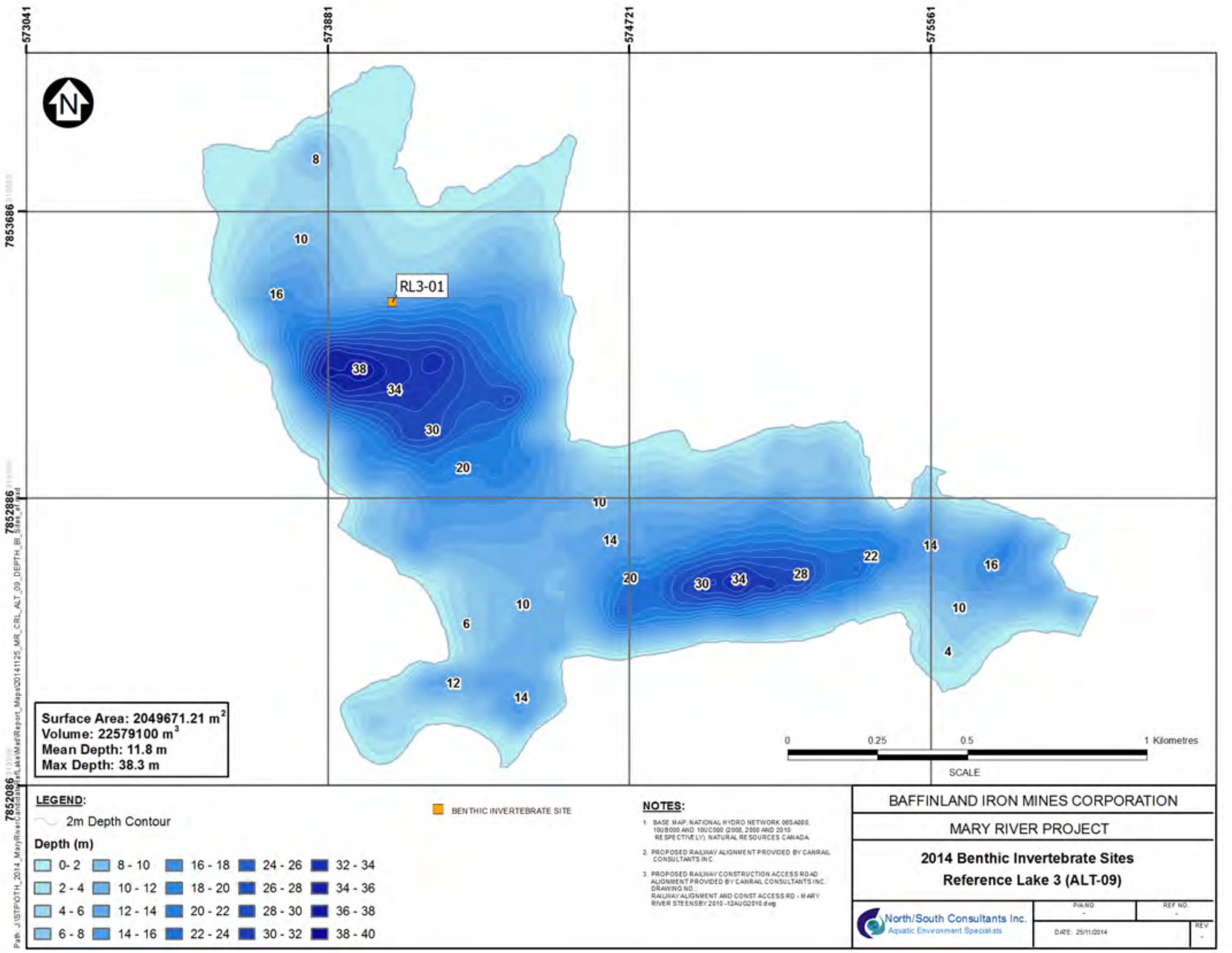

Figure 12. Location of benthic macroinvertebrate sampling site in Reference Lake 3, fall 2014.

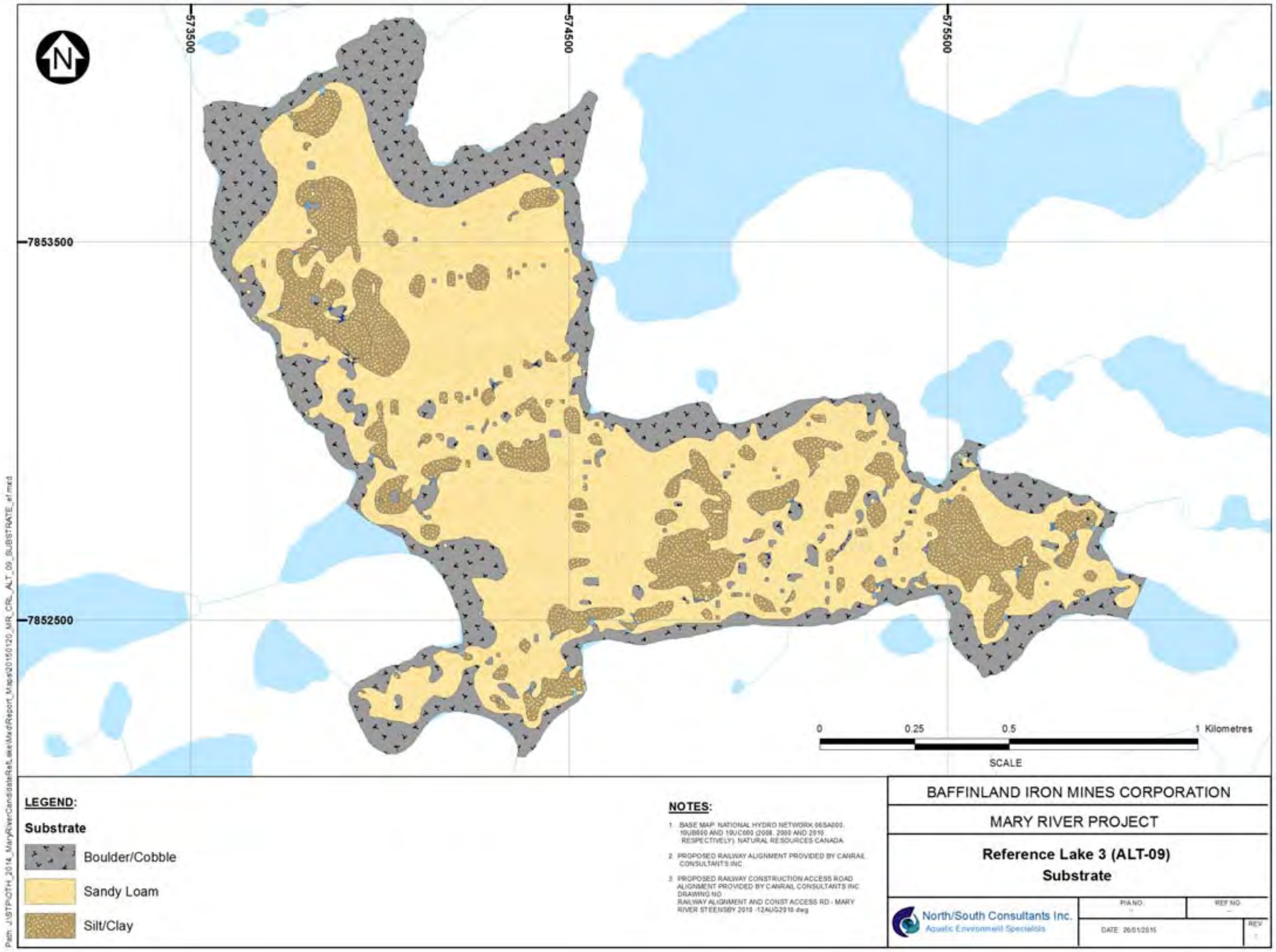

Figure 13. Substrate composition of Reference Lake 3, fall 2014.

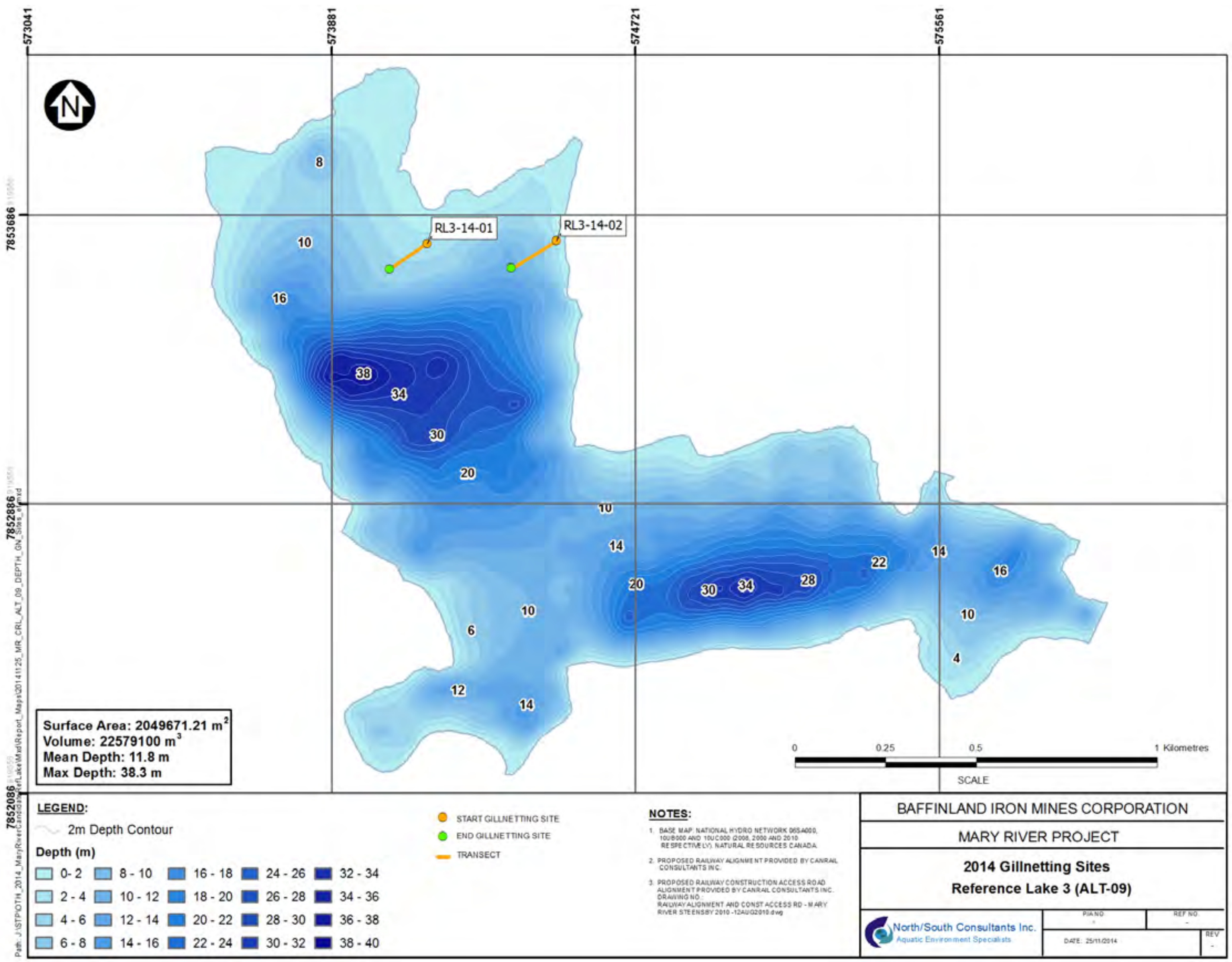

Figure 14. Location of gillnet sampling site in Reference Lake 3, fall 2014.

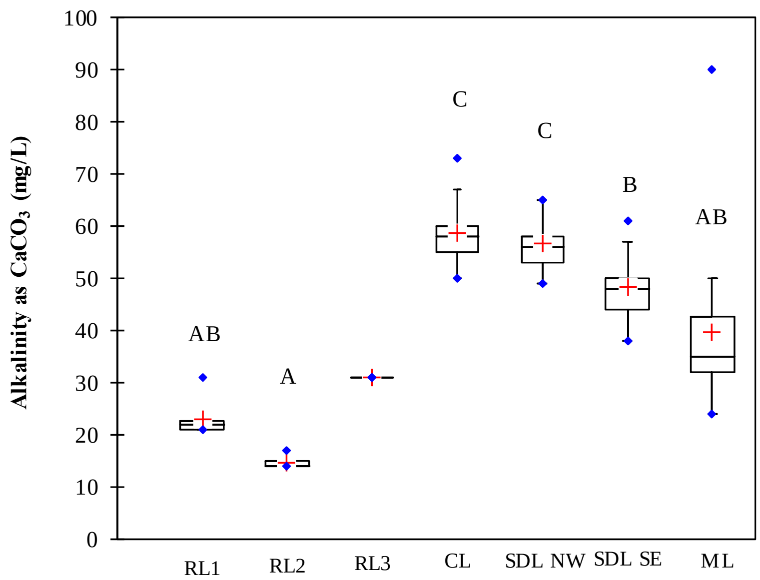

Figure 15. Alkalinity measured in surface water samples from reference and mine area lakes. Data represent 2013-2014 data for reference lakes and 2006-2014 for mine area lakes. Statistically significant differences are denoted with different superscripts.

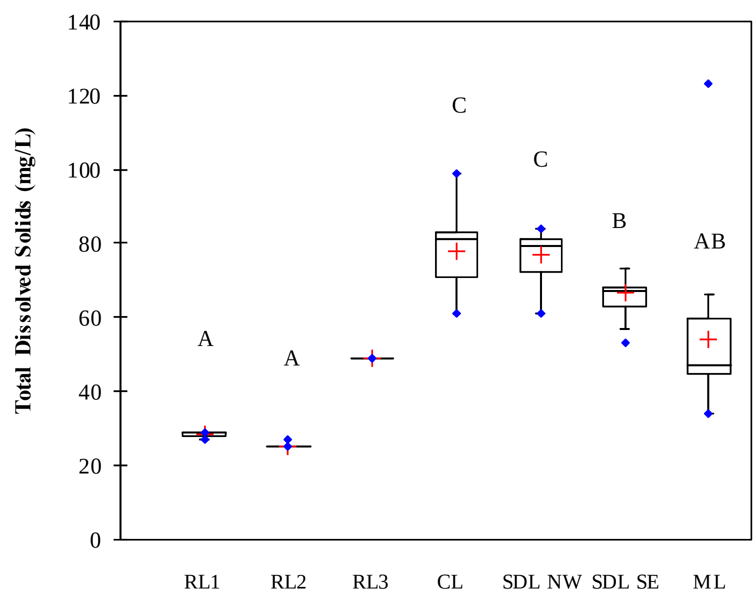

Figure 16. Total dissolved solids measured in surface water samples from reference and mine area lakes. Data represent 2013-2014 data for reference lakes and 2006-2014 for mine area lakes. Statistically significant differences are denoted with different superscripts.

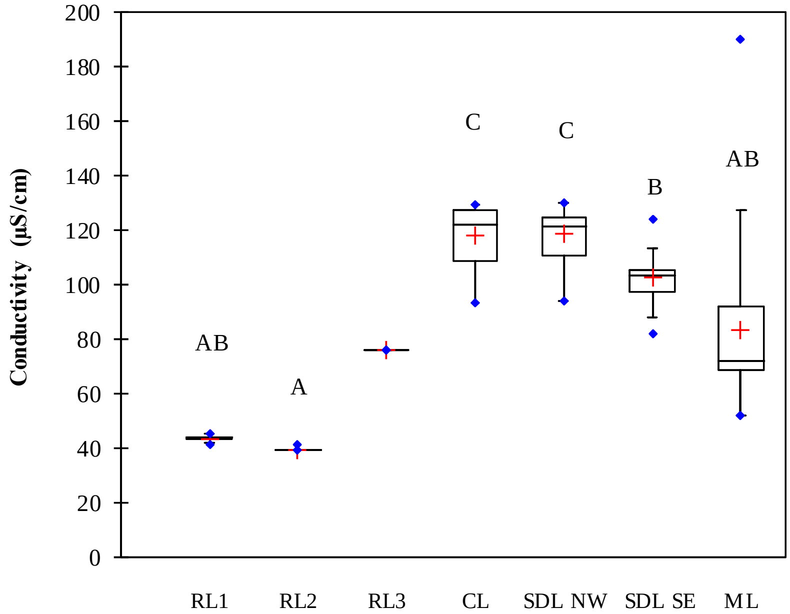

Figure 17. Laboratory conductivity measured in surface water samples from reference and mine area lakes. Data represent 2013-2014 data for reference lakes and 2006-2014 for mine area lakes. Statistically significant differences are denoted with different superscripts.

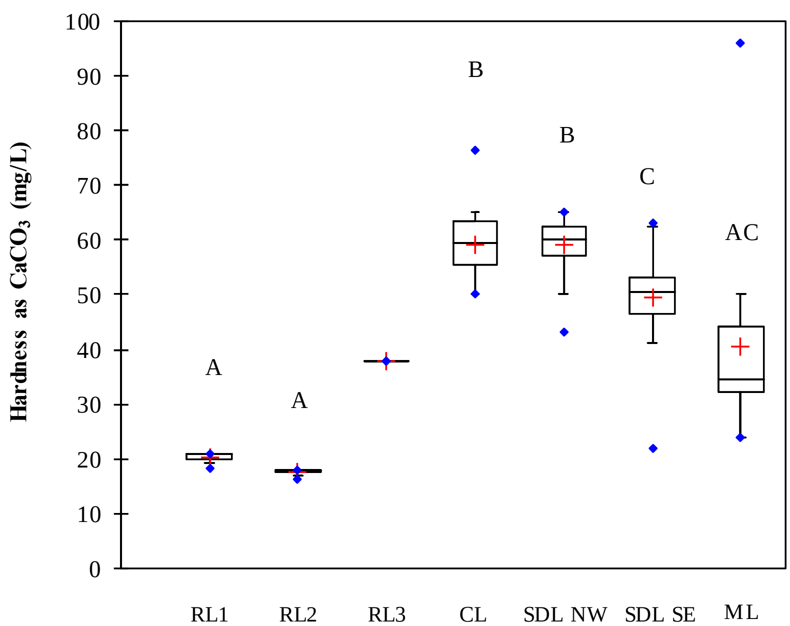

Figure 18. Hardness measured in surface water samples from reference and mine area lakes. Data represent 2013-2014 data for reference lakes and 2006-2014 for mine area lakes. Statistically significant differences are denoted with different superscripts.

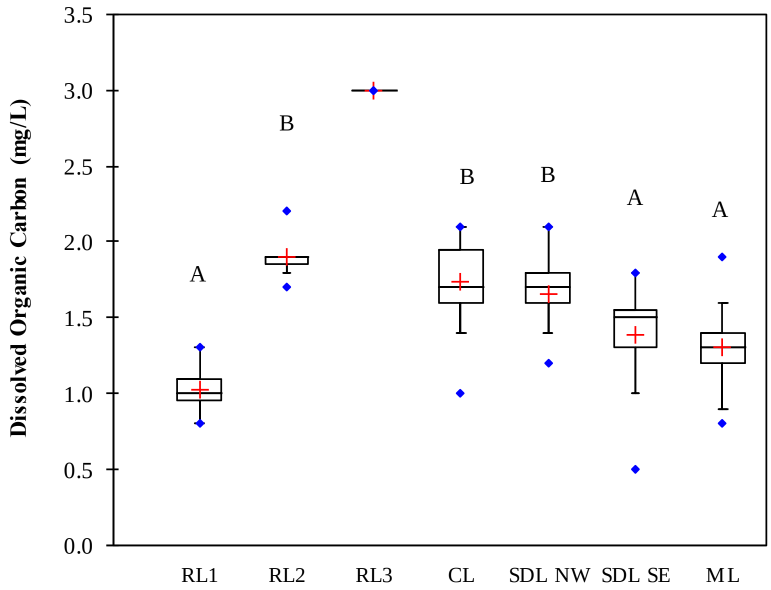

Figure 19. Dissolved organic carbon measured in surface water samples from reference and mine area lakes. Data represent 2013-2014 data for reference lakes and 2006-2014 for mine area lakes. Statistically significant differences are denoted with different superscripts.

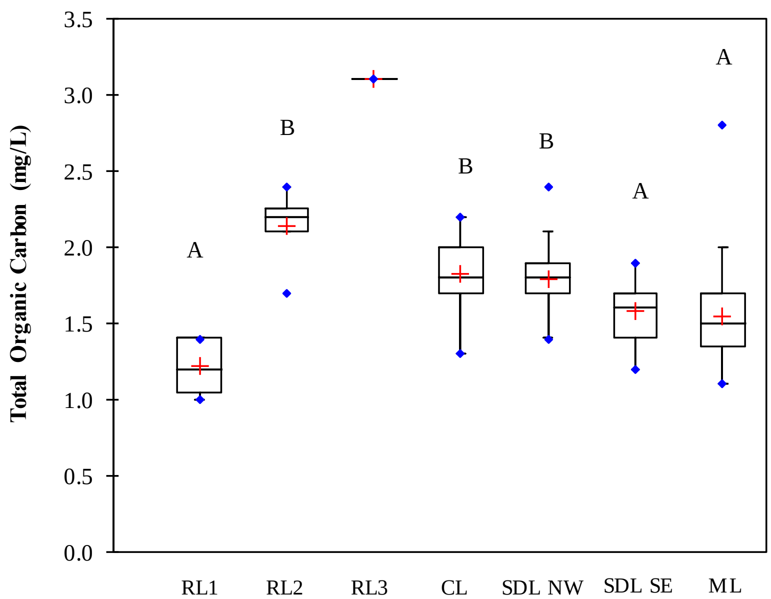

Figure 20. Total organic carbon measured in surface water samples from reference and mine area lakes. Data represent 2013-2014 data for reference lakes and 2006-2014 for mine area lakes. Statistically significant differences are denoted with different superscripts.

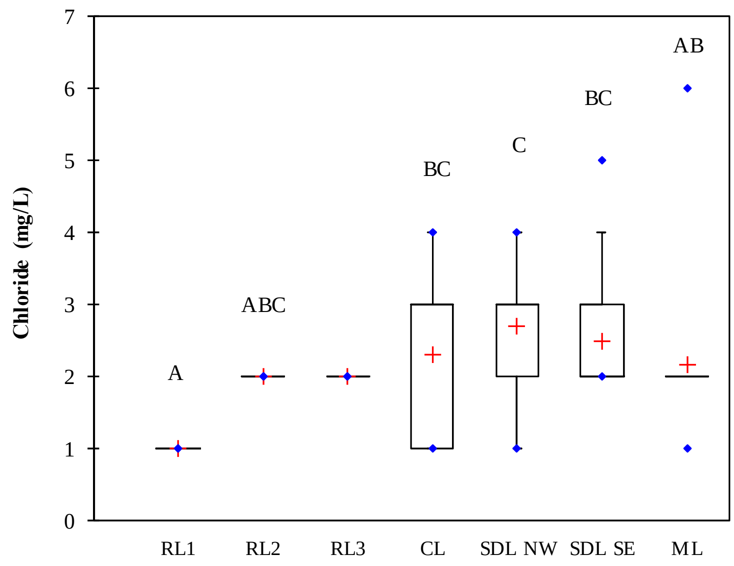

Figure 21. Chloride measured in surface water samples from reference and mine area lakes. Data represent 2013-2014 data for reference lakes and 2006-2014 for mine area lakes. Statistically significant differences are denoted with different superscripts.

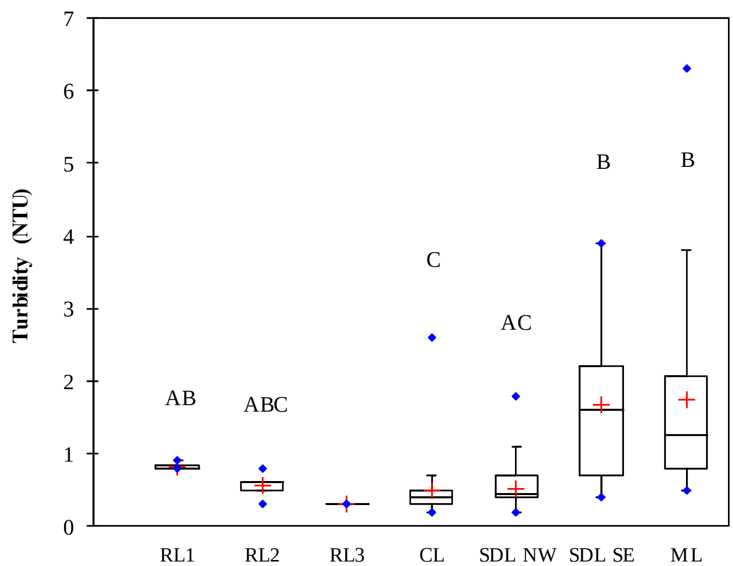

Figure 22. Laboratory turbidity measured in surface water samples from reference and mine area lakes. Data represent 2013-2014 data for reference lakes and 2006-2014 for mine area lakes. Statistically significant differences are denoted with different superscripts.

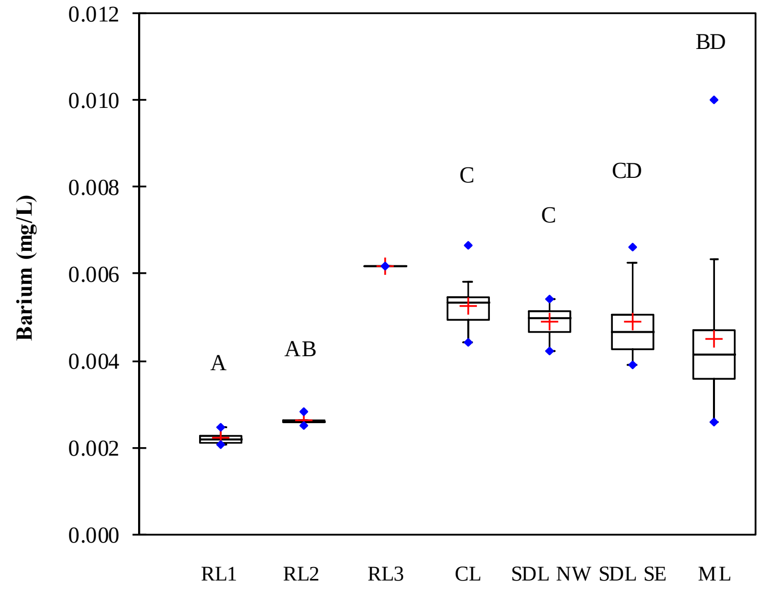

Figure 23. Total barium measured in surface water samples from reference and mine area lakes. Data represent 2013-2014 data for reference lakes and 2006-2014 for mine area lakes. Statistically significant differences are denoted with different superscripts.

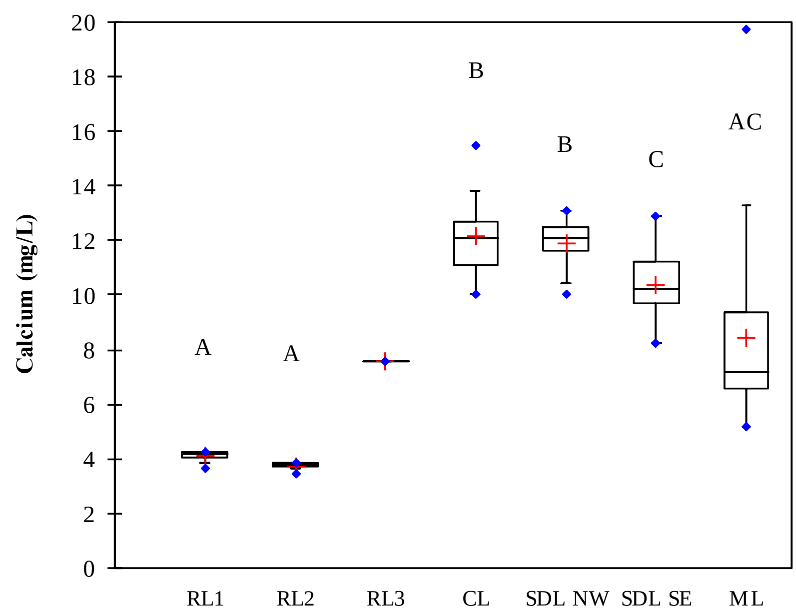

Figure 24. Total calcium measured in surface water samples from reference and mine area lakes. Data represent 2013-2014 data for reference lakes and 2006-2014 for mine area lakes. Statistically significant differences are denoted with different superscripts.

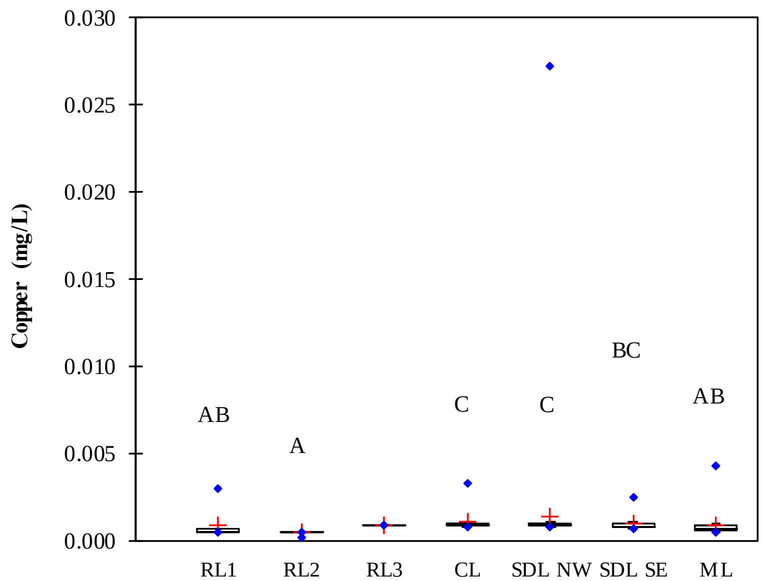

Figure 25. Total copper measured in surface water samples from reference and mine area lakes. Data represent 2013-2014 data for reference lakes and 2006-2014 for mine area lakes. Statistically significant differences are denoted with different superscripts.

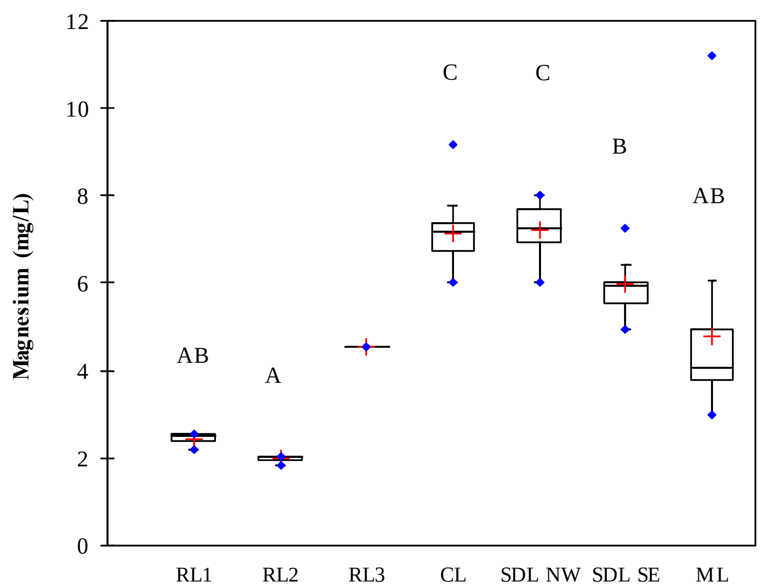

Figure 26. Total magnesium measured in surface water samples from reference and mine area lakes. Data represent 2013-2014 data for reference lakes and 2006-2014 for mine area lakes. Statistically significant differences are denoted with different superscripts.

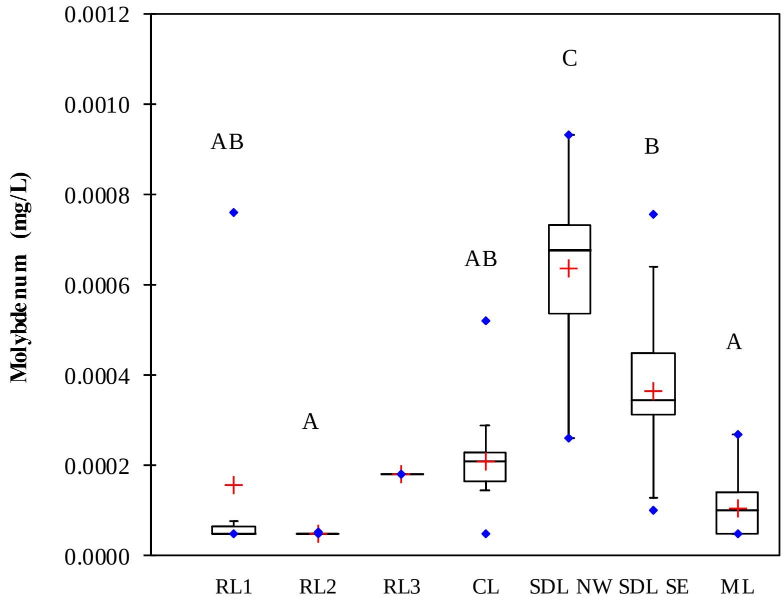

Figure 27. Total molybdenum measured in surface water samples from reference and mine area lakes. Data represent 2013-2014 data for reference lakes and 2006-2014 for mine area lakes. Statistically significant differences are denoted with different superscripts.

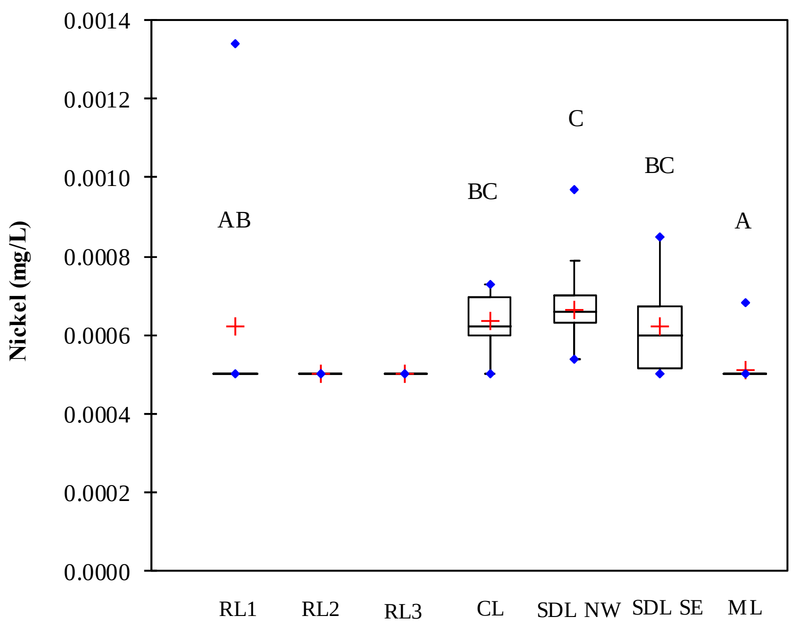

Figure 28. Total nickel measured in surface water samples from reference and mine area lakes. Data represent 2013-2014 data for reference lakes and 2006-2014 for mine area lakes. Statistically significant differences are denoted with different superscripts.

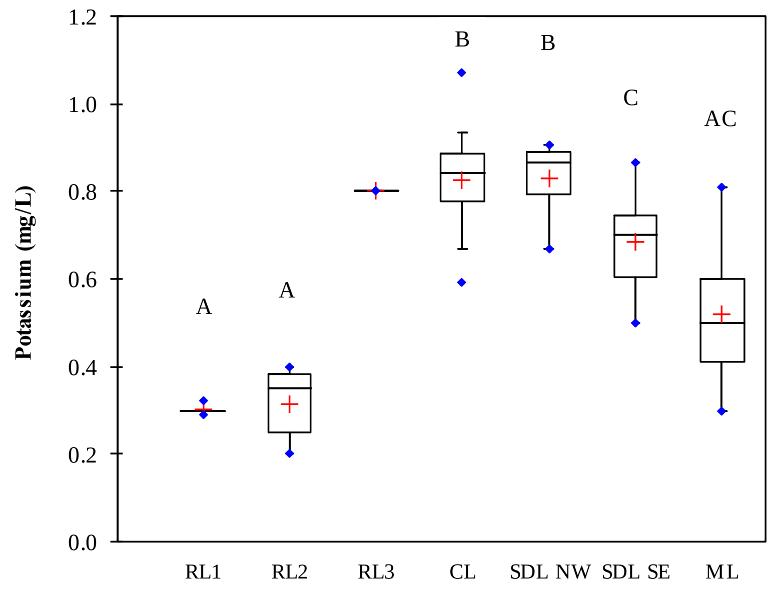

Figure 29. Total potassium measured in surface water samples from reference and mine area lakes. Data represent 2013-2014 data for reference lakes and 2006-2014 for mine area lakes. Statistically significant differences are denoted with different superscripts.

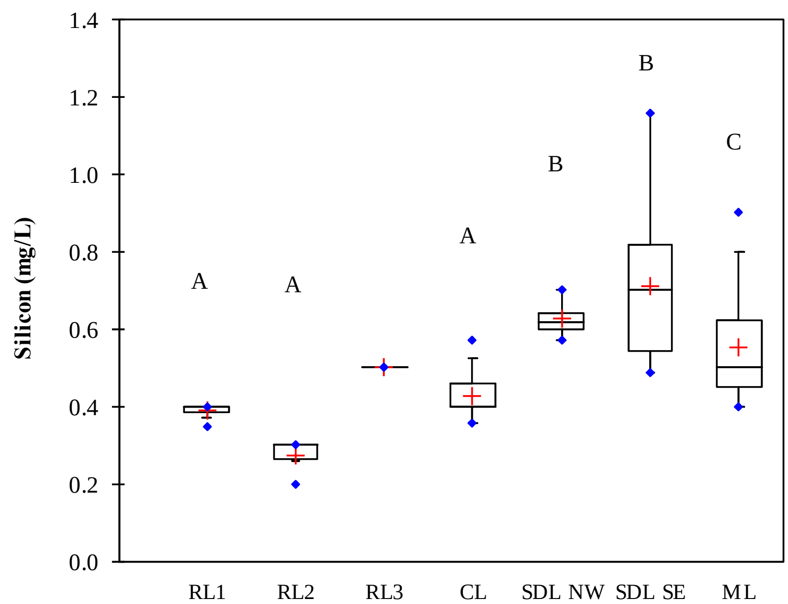

Figure 30. Total silicon measured in surface water samples from reference and mine area lakes. Data represent 2013-2014 data for reference lakes and 2006-2014 for mine area lakes. Statistically significant differences are denoted with different superscripts.

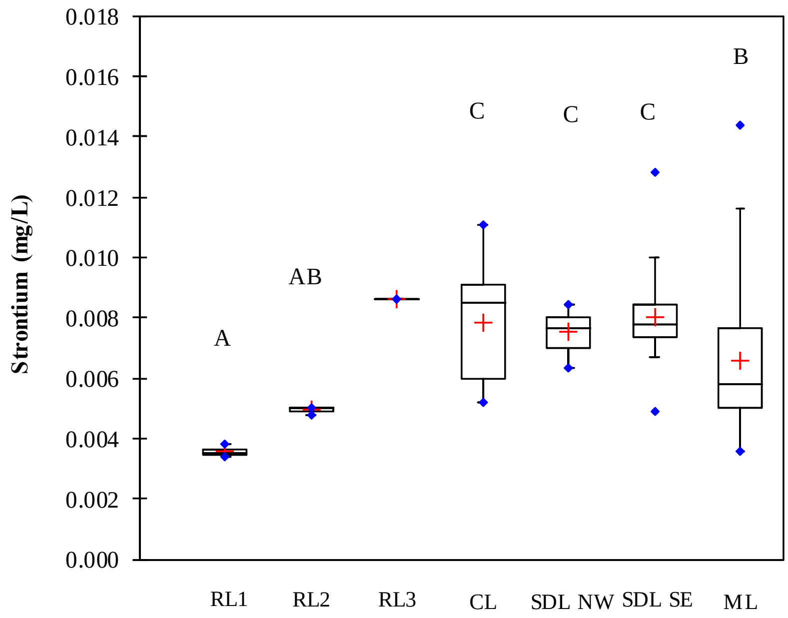

Figure 31. Total strontium measured in surface water samples from reference and mine area lakes. Data represent 2013-2014 data for reference lakes and 2006-2014 for mine area lakes. Statistically significant differences are denoted with different superscripts.

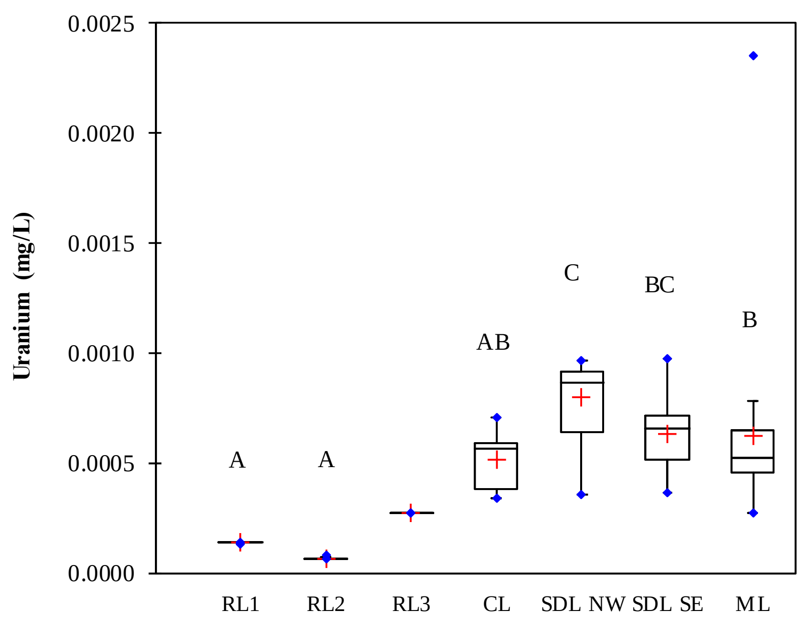

Figure 32. Total uranium measured in surface water samples from reference and mine area lakes. Data represent 2013-2014 data for reference lakes and 2006-2014 for mine area lakes. Statistically significant differences are denoted with different superscripts.

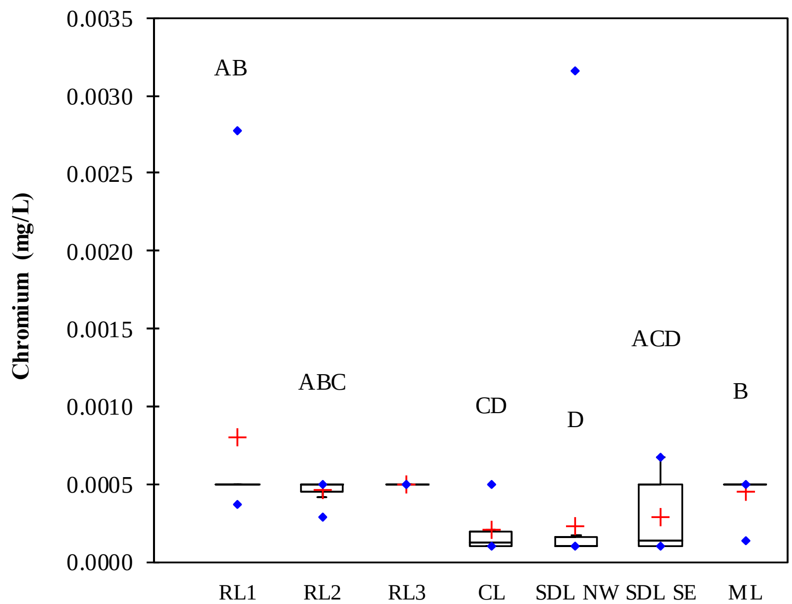

Figure 33. Total chromium measured in surface water samples from reference and mine area lakes. Data represent 2013-2014 data for reference lakes and 2006-2014 for mine area lakes. Statistically significant differences are denoted with different superscripts.

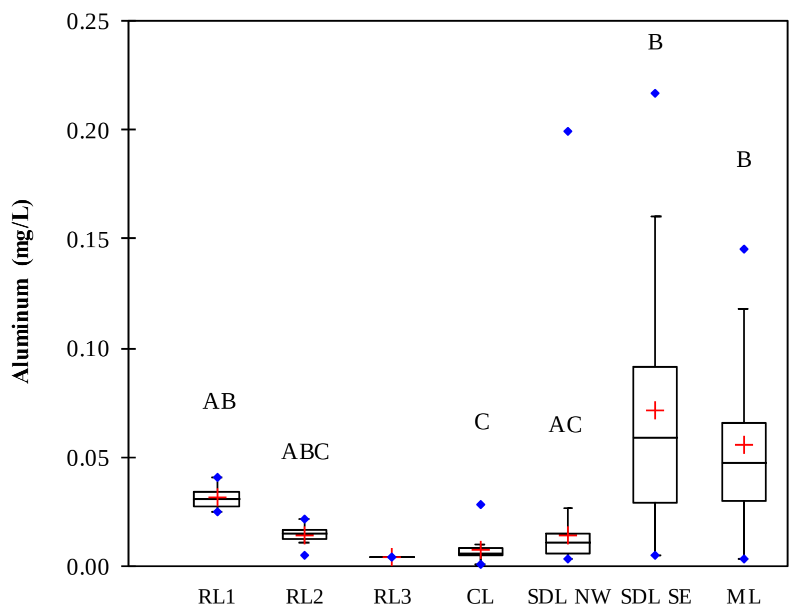

Figure 34. Total aluminum measured in surface water samples from reference and mine area lakes. Data represent 2013-2014 data for reference lakes and 2006-2014 for mine area lakes. Statistically significant differences are denoted with different superscripts.

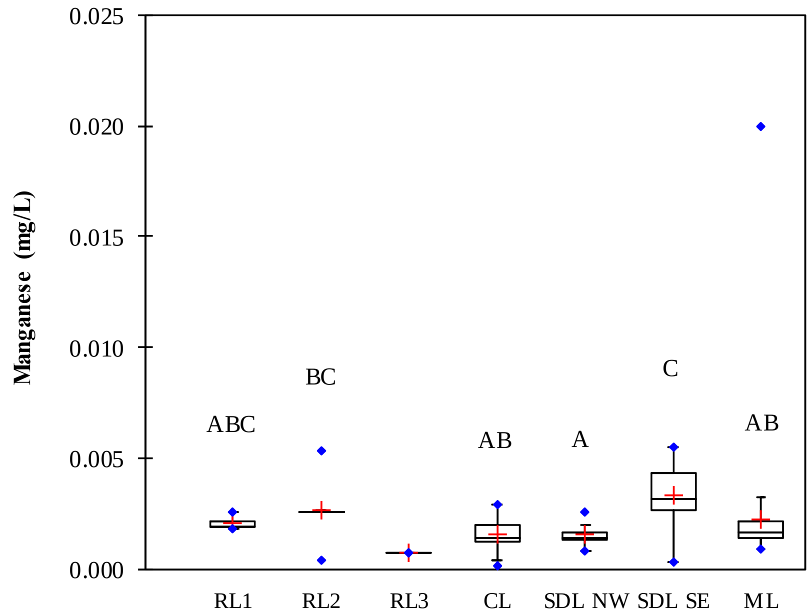

Figure 35. Total manganese measured in surface water samples from reference and mine area lakes. Data represent 2013-2014 data for reference lakes and 2006-2014 for mine area lakes. Statistically significant differences are denoted with different superscripts.

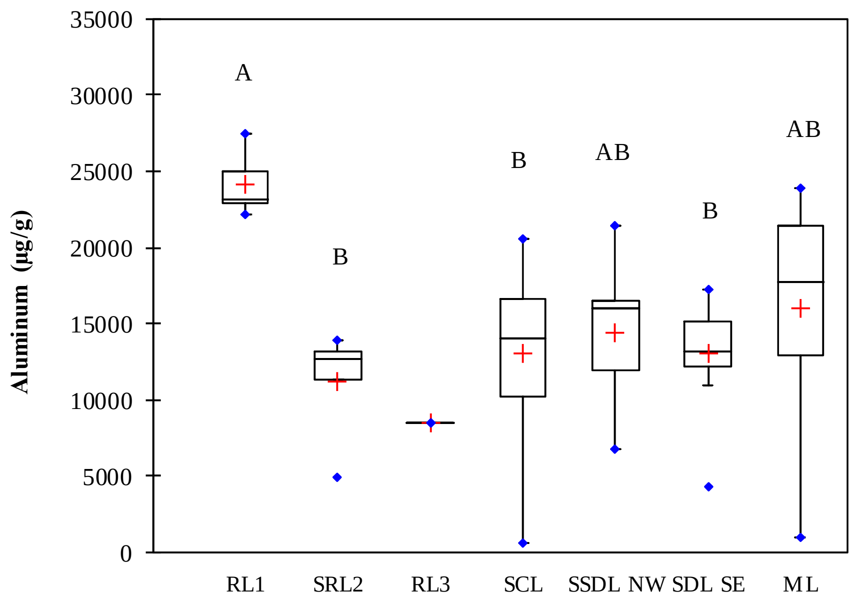

Figure 36. Aluminum measured in reference and mine area lake sediments. Statistically significant differences are denoted with different superscripts.

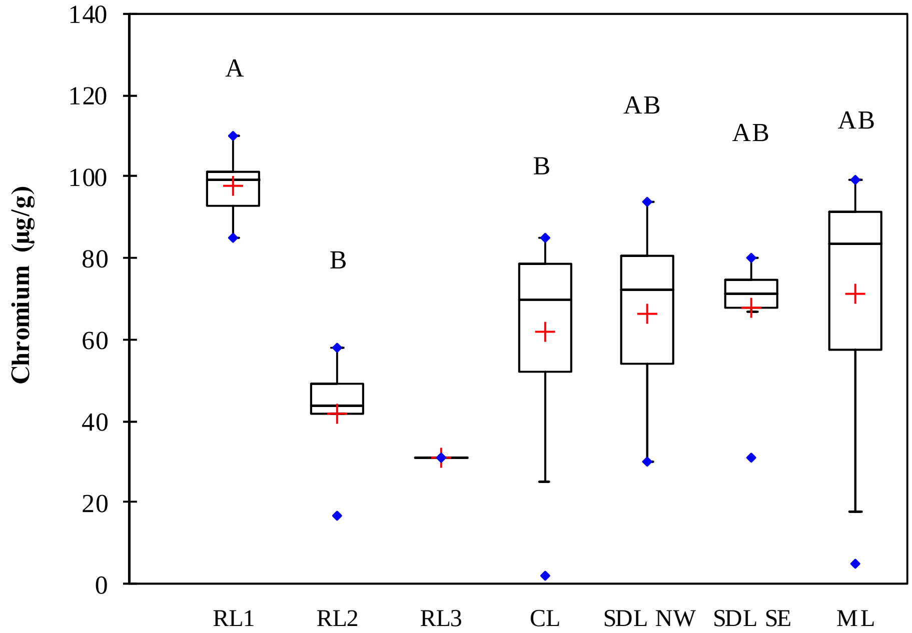

Figure 37. Chromium measured in reference and mine area lake sediments. Statistically significant differences are denoted with different superscripts.

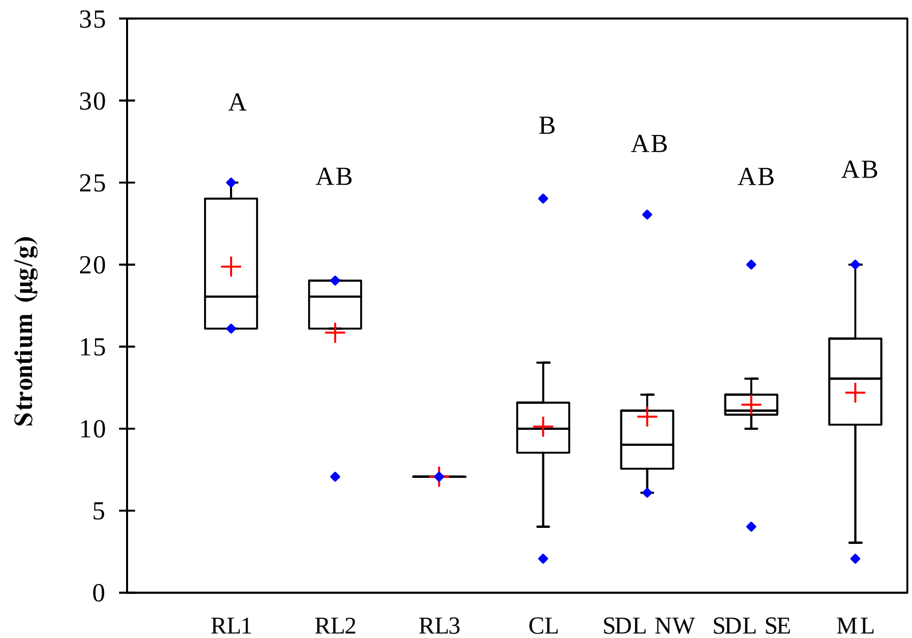

Figure 38. Strontium measured in reference and mine area lake sediments. Statistically significant differences are denoted with different superscripts.

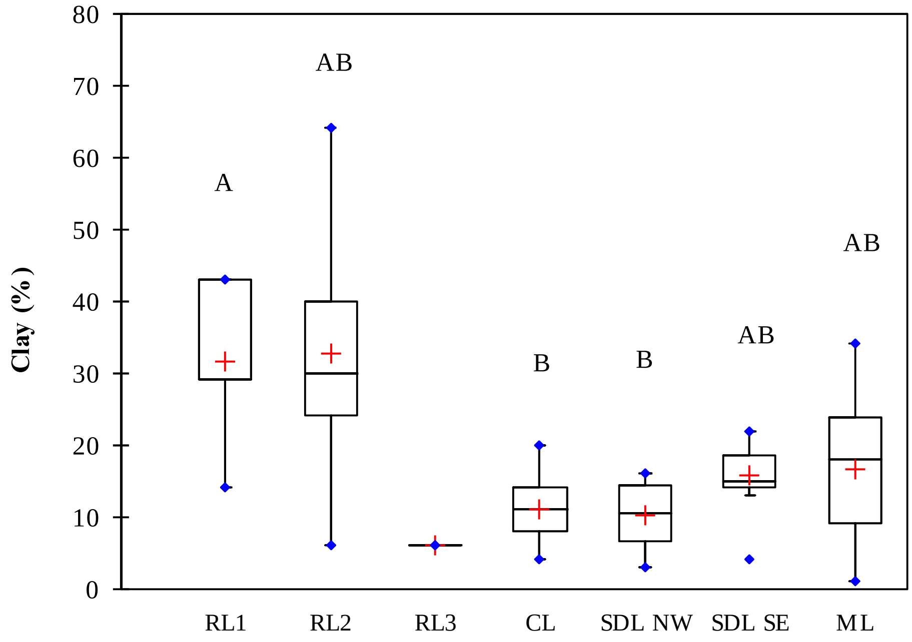

Figure 39. Clay content measured in reference and mine area lake sediments. Statistically significant differences are denoted with different superscripts.

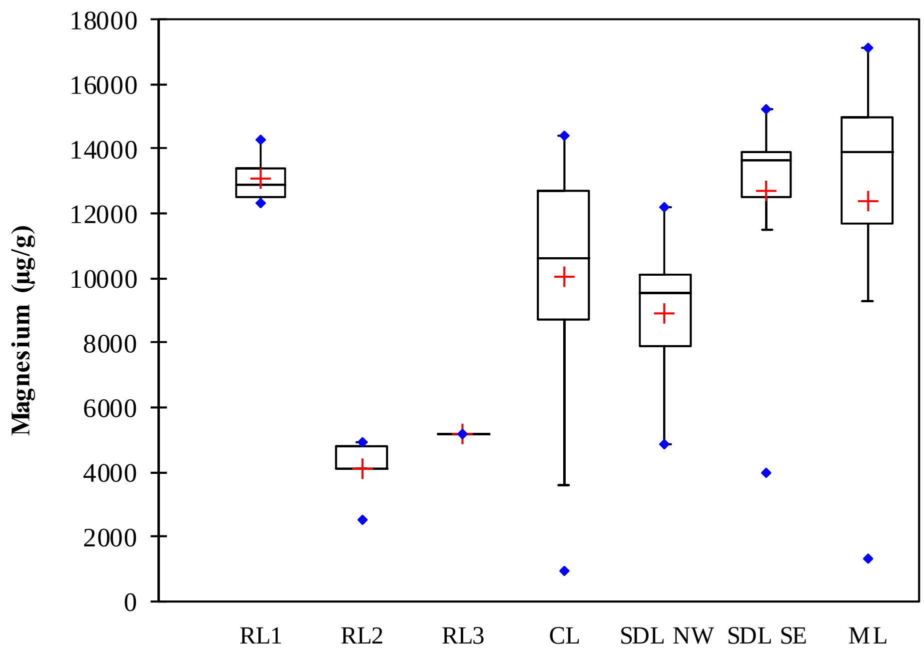

Figure 40. Magnesium measured in reference and mine area lake sediments. No statistically significant differences were noted.

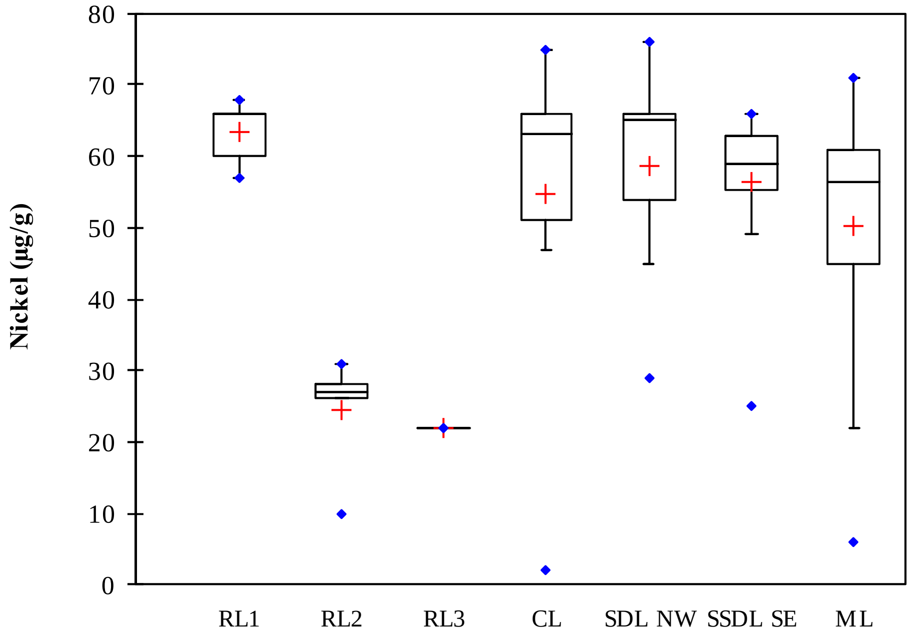

Figure 41. Nickel measured in reference and mine area lake sediments. No statistically significant differences were noted.

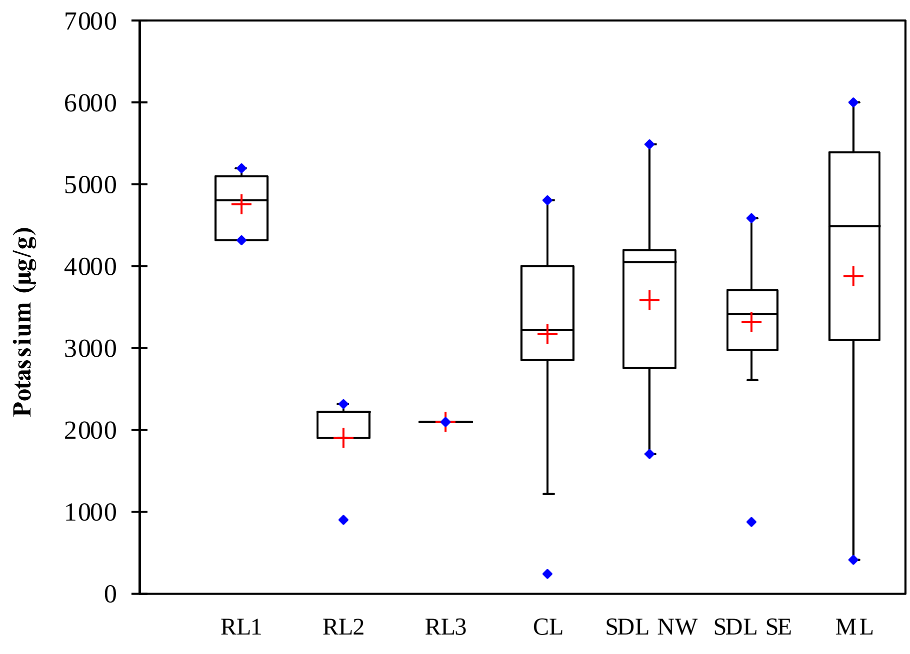

Figure 42. Potassium measured in reference and mine area lake sediments. No statistically significant differences were noted.

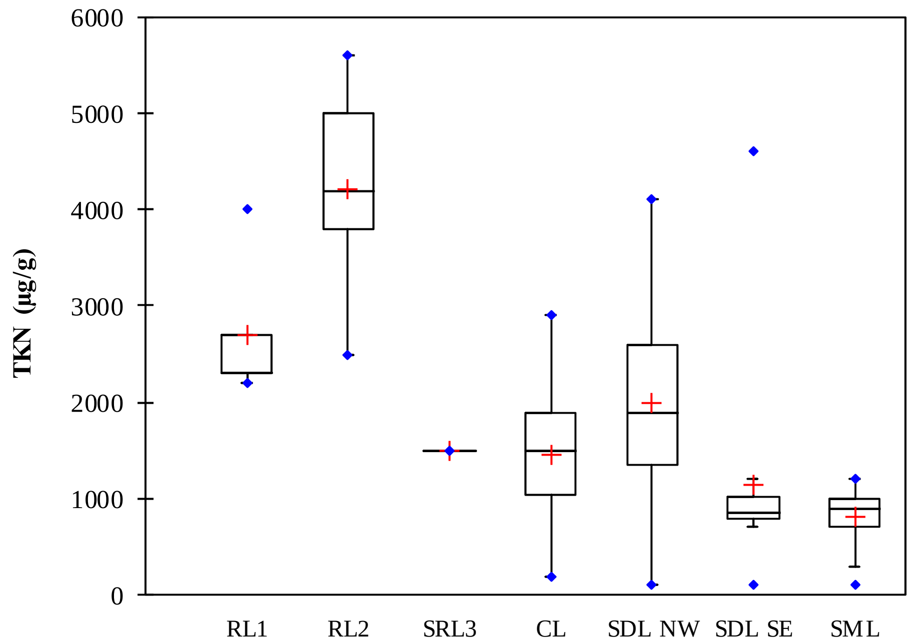

Figure 43. Total Kjeldahl nitrogen (TKN) measured in reference and mine area lake sediments. No statistically significant differences were noted.

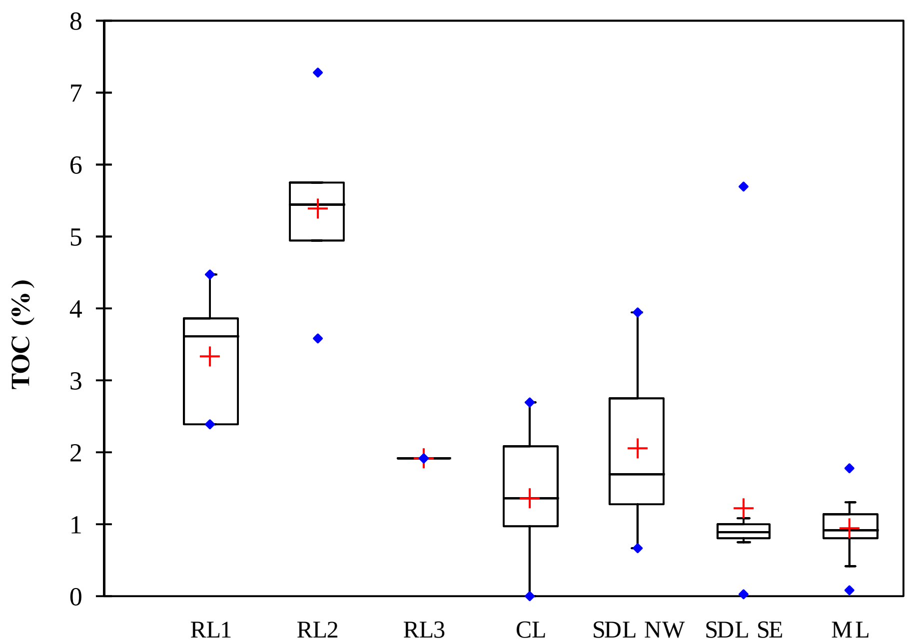

Figure 44. Total organic carbon (TOC) measured in reference and mine area lake sediments. No statistically significant differences were noted.

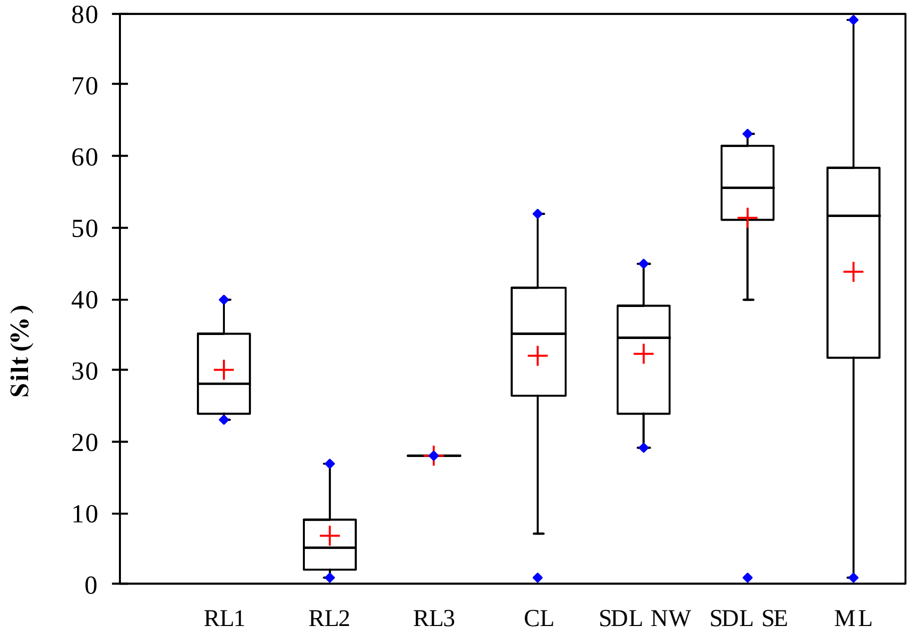

Figure 45. Silt content measured in reference and mine area lake sediments. No statistically significant differences were noted.

Photograp 1. Typical shoreline of Reference Lake 3.

Photograph 2. Typical nearshore substrate in Reference Lake 3.

APPENDIX 1. CANDIDATE REFERENCE LAKE WATER QUALITY DATA, 2014

Table A1-1. Summary of water quality sampling site information in candidate reference lakes, 2014.

Waterbody	Sample ID	Previous Site ID	Site UTM (17W)		Sample Date	Sample Time	Site Depth (m)	Secchi Depth (m)	*In Situ* Sample	Surface Sample	Bottom Sample
			Easting	Northing							
Reference Lake 1	RL1-01	CL-P2-13-1	550295	7938599	27-Aug-14	9:58	10.6	4.5	Y	Y	Y
	RL1-02	CL-P2-13-2	550241	7938777	27-Aug-14	10:30	12.1	4.7	Y	Y	Y
	RL1-03	CL-P2-13-3	550283	7938912	27-Aug-14	11:12	11.7	5.0	Y	Y	Y
	RL1-04	CL-P2-13-4	550395	7938912	27-Aug-14	11:45	6.3	4.9	Y	Y	Y
	RL1-05	CL-P2-13-5	550112	7938600	27-Aug-14	12:22	14.0	4.5	Y	Y	Y
Reference Lake 2	RL2-01	CR-P3-11-1	568757	7899826	29-Aug-14	10:00	8.6	5.7	Y	Y	Y
	RL2-02	CR-P3-11-2	568797	7900214	29-Aug-14	10:55	10.2	5.4	Y	Y	Y
	RL2-03	CR-P3-11-3	568963	7900049	29-Aug-14	11:00	6.6	5.3	Y	Y	Y
	RL2-04	CR-P3-11-4	569061	7899948	29-Aug-14	12:05	5.6	5.4	Y	Y	Y
	RL2-05	CR-P3-11-5	568997	7900295	29-Aug-14	12:40	10.1	5.8	Y	Y	Y
Reference Lake 3	RL3-01	ALT-09-01	574077	7853419	30-Aug-14	16:02	14.6	5.8	Y	Y	Y

Table A1-2. Laboratory water quality results for candidate reference lakes, 2014.

Waterbody	Site ID [1]	Previous Site ID	Sampling Date	pH	Alkalinity as $CaCO_3$	Total Dissolved Solids	Conductivity	Ammonia	Nitrite	Nitrate	Nitrate/ Nitrite	Total Kjeldahl Nitrogen
					(mg/L)	(mg/L)	(µS/cm)	mg N/L	mg/L	mg/L	mg/L	mg/L
Analytical Detection Limit					5	1	5	0.02	0.005	0.1	0.1	0.10
Reference Lake 1	RL1-01-S	CL-P2-13-1S	2014-08-27	7.54	22	29	44	0.10	<0.005	<0.10	<0.10	0.25
	RL1-01-B	CL-P2-13-1B	2014-08-27	7.62	21	29	44	0.05	<0.005	<0.10	<0.10	0.20
	RL1-02-S	CL-P2-13-2S	2014-08-27	7.63	21	29	44	0.09	<0.005	<0.10	<0.10	0.21
	RL1-02-B	CL-P2-13-2B	2014-08-27	7.60	22	29	44	0.07	<0.005	<0.10	<0.10	0.22
	RL1-03-S	CL-P2-13-3S	2014-08-27	7.67	31	29	45	0.10	<0.005	<0.10	<0.10	0.14
	RL1-03-B	CL-P2-13-3B	2014-08-27	7.61	20	29	44	0.07	<0.005	<0.10	<0.10	<0.10
	RL1-04-S	CL-P2-13-4S	2014-08-27	7.60	21	29	44	0.09	<0.005	<0.10	<0.10	0.10
	RL1-04-B	CL-P2-13-4B	2014-08-27	7.62	21	29	44	0.09	<0.005	<0.10	<0.10	0.13
	RL1-05-S	CL-P2-13-5S	2014-08-27	7.62	21	29	44	0.07	<0.005	<0.10	<0.10	0.12
	RL1-05-B	CL-P2-13-5B	2014-08-27	7.65	22	29	45	0.06	<0.005	<0.10	<0.10	<0.10
Reference Lake 2	RL2-01-S	CR-P3-11-1S [3]	2014-08-29	7.53	14	25	39	0.08	<0.005	<0.10	<0.10	<0.10
	RL2-01-B	CR-P3-11-1B [3]	2014-08-29	7.55	14	25	39	0.10	<0.005	<0.10	<0.10	<0.10
	RL2-02-S	CR-P3-11-2S	2014-08-29	7.54	14	25	39	0.11	<0.005	<0.10	<0.10	0.18
	RL2-02-B	CR-P3-11-2B	2014-08-29	7.54	14	25	39	0.11	<0.005	<0.10	<0.10	0.17
	RL2-03-S	CR-P3-11-3S	2014-08-29	7.57	14	25	39	0.17	<0.005	<0.10	<0.10	0.23
	RL2-03-B	CR-P3-11-3B	2014-08-29	7.58	14	25	39	0.06	<0.005	<0.10	<0.10	0.13
	RL2-04-S	CR-P3-11-4S	2014-08-29	7.62	14	25	39	0.14	<0.005	<0.10	<0.10	0.24
	RL2-04-B	CR-P3-11-4B	2014-08-29	7.60	14	25	39	0.06	<0.005	<0.10	<0.10	<0.10
	RL2-05-S	CR-P3-11-5S	2014-08-29	7.60	14	25	39	0.04	<0.005	<0.10	<0.10	<0.10
	RL2-05-B	CR-P3-11-5B	2014-08-29	7.58	14	25	39	0.11	<0.005	<0.10	<0.10	<0.10
Reference Lake 3	RL3-01-S	ALT-09-01S	2014-08-30	7.73	31	49	76	0.18	<0.005	<0.10	<0.10	0.34
	RL3-01-S Dup [4]	ALT-09-01S Dup	2014-08-30	7.81	31	49	76	0.13	<0.005	<0.10	<0.10	0.13
	RL3-01-B	ALT-09-01B	2014-08-30	7.81	31	49	76	0.17	<0.005	<0.10	<0.10	0.12

[1] S = surface; B = bottom
[2] Calculated
[3] Sample bottle labels were reversed on laboratory Chain of custody.
[4] Duplicate sample

Table A1-2. - continued -

Waterbody	Site ID [1]	Previous Site ID	Sampling Date	Total Nitrogen [2]	Total Phosphorus	TN:TP [2]	Dissolved Organic Carbon	Total Organic Carbon	Total Suspended Solids	Turbidity	Chlorophyll *a*	Pheophytin *a*
				(mg/L)	(mg/L)		(mg/L)	(mg/L)	(mg/L)	(NTU)	(µg/L)	(µg/L)
Analytical Detection Limit				-	0.003	-	0.5	0.5	2	0.1	0.2	0.2
Reference Lake 1	RL1-01-S	CL-P2-13-1S	2014-08-27	0.35	<0.003	258	1.3	1.2	<2	0.8	<0.2	2.8
	RL1-01-B	CL-P2-13-1B	2014-08-27	0.30	<0.003	221	1.0	1.0	<2	0.8	2.4	<0.2
	RL1-02-S	CL-P2-13-2S	2014-08-27	0.31	<0.003	229	1.0	1.4	<2	0.9	1.9	<0.2
	RL1-02-B	CL-P2-13-2B	2014-08-27	0.32	<0.003	236	1.0	1.4	<2	0.8	1.9	<0.2
	RL1-03-S	CL-P2-13-3S	2014-08-27	0.24	<0.003	177	1.0	1.4	<2	0.8	1.1	1.6
	RL1-03-B	CL-P2-13-3B	2014-08-27	<0.10	<0.003	74	1.0	1.0	<2	0.8	0.7	1.1
	RL1-04-S	CL-P2-13-4S	2014-08-27	0.20	<0.003	147	0.9	1.0	<2	0.8	3.4	<0.2
	RL1-04-B	CL-P2-13-4B	2014-08-27	0.23	<0.003	170	1.0	1.0	<2	0.9	<0.2	1.5
	RL1-05-S	CL-P2-13-5S	2014-08-27	0.22	<0.003	162	1.0	1.0	<2	0.8	0.7	0.3
	RL1-05-B	CL-P2-13-5B	2014-08-27	<0.10	<0.003	74	0.9	1.0	<2	0.8	<0.2	2.2
Reference Lake 2	RL2-01-S	CR-P3-11-1S [3]	2014-08-29	0.10	<0.003	147	1.8	2.4	<2	0.6	<0.2	<0.2
	RL2-01-B	CR-P3-11-1B [3]	2014-08-29	0.10	0.006	37	2.0	2.3	<2	0.9	0.3	<0.2
	RL2-02-S	CR-P3-11-2S	2014-08-29	0.23	0.014	36	1.9	2.3	<2	0.5	<0.2	<0.2
	RL2-02-B	CR-P3-11-2B	2014-08-29	0.22	0.006	81	1.9	2.4	<2	0.3	0.4	0.4
	RL2-03-S	CR-P3-11-3S	2014-08-29	0.28	<0.003	413	1.9	2.1	<2	0.6	0.7	<0.2
	RL2-03-B	CR-P3-11-3B	2014-08-29	0.23	0.006	85	2.0	2.4	<2	0.7	<0.2	1.1
	RL2-04-S	CR-P3-11-4S	2014-08-29	0.34	0.003	251	1.9	2.2	<2	0.6	<0.2	<0.2
	RL2-04-B	CR-P3-11-4B	2014-08-29	<0.10	<0.003	74	1.9	2	<2	1.1	0.7	<0.2
	RL2-05-S	CR-P3-11-5S	2014-08-29	<0.10	0.003	74	1.9	2.1	<2	0.5	0.3	<0.2
	RL2-05-B	CR-P3-11-5B	2014-08-29	<0.10	0.003	74	2.0	2	<2	0.6	<0.2	0.3
Reference Lake 3	RL3-01-S	ALT-09-01S	2014-08-30	0.44	0.004	243	3.0	3.1	<2	0.3	2.3	<0.2
	RL3-01-S Dup [4]	ALT-09-01S Dup	2014-08-30	0.23	<0.003	170	3.0	3	<2	0.4	0.3	<0.2
	RL3-01-B	ALT-09-01B	2014-08-30	0.22	0.003	162	3.0	3	<2	0.3	<0.2	<0.2

Table A1-2. - continued –

Waterbody	Site ID [1]	Previous Site ID	Sampling Date	Phenols	Bromide	Chloride	Sulphate	Hardness as $CaCO_3$ (Total)	Hardness as $CaCO_3$ (Dissolved)	Total Aluminum	Total Antimony	Total Arsenic
				(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
Analytical Detection Limit				0.001	0.25	1	1	1	1	0.003	0.0001	0.0001
Reference Lake 1	RL1-01-S	CL-P2-13-1S	2014-08-27	<0.001	<0.25	1	<1	21	21	0.035	<0.0001	<0.0001
	RL1-01-B	CL-P2-13-1B	2014-08-27	<0.001	<0.25	1	<1	21	22	0.030	<0.0001	<0.0001
	RL1-02-S	CL-P2-13-2S	2014-08-27	<0.001	<0.25	1	<1	21	21	0.041	<0.0001	<0.0001
	RL1-02-B	CL-P2-13-2B	2014-08-27	<0.001	<0.25	1	<1	21	21	0.025	<0.0001	<0.0001
	RL1-03-S	CL-P2-13-3S	2014-08-27	<0.001	<0.25	1	<1	21	21	0.027	<0.0001	<0.0001
	RL1-03-B	CL-P2-13-3B	2014-08-27	<0.001	<0.25	1	<1	21	21	0.032	<0.0001	<0.0001
	RL1-04-S	CL-P2-13-4S	2014-08-27	<0.001	<0.25	1	<1	21	21	0.031	<0.0001	<0.0001
	RL1-04-B	CL-P2-13-4B	2014-08-27	<0.001	<0.25	1	<1	21	21	0.034	<0.0001	<0.0001
	RL1-05-S	CL-P2-13-5S	2014-08-27	<0.001	<0.25	1	<1	21	21	0.025	<0.0001	<0.0001
	RL1-05-B	CL-P2-13-5B	2014-08-27	<0.001	<0.25	1	<1	22	22	0.025	<0.0001	<0.0001
Reference Lake 2	RL2-01-S	CR-P3-11-1S [3]	2014-08-29	<0.001	<0.25	2	1	18	18	0.005	<0.0001	<0.0001
	RL2-01-B	CR-P3-11-1B [3]	2014-08-29	<0.001	<0.25	2	1	18	18	0.014	<0.0001	<0.0001
	RL2-02-S	CR-P3-11-2S	2014-08-29	<0.001	<0.25	2	1	18	18	0.015	<0.0001	<0.0001
	RL2-02-B	CR-P3-11-2B	2014-08-29	<0.001	<0.25	2	1	18	18	0.017	<0.0001	<0.0001
	RL2-03-S	CR-P3-11-3S	2014-08-29	<0.001	<0.25	2	1	18	18	0.017	<0.0001	<0.0001
	RL2-03-B	CR-P3-11-3B	2014-08-29	<0.001	<0.25	2	1	18	18	0.015	<0.0001	<0.0001
	RL2-04-S	CR-P3-11-4S	2014-08-29	<0.001	<0.25	2	1	18	18	0.014	<0.0001	<0.0001
	RL2-04-B	CR-P3-11-4B	2014-08-29	<0.001	<0.25	2	1	18	18	0.014	<0.0001	<0.0001
	RL2-05-S	CR-P3-11-5S	2014-08-29	<0.001	<0.25	2	1	18	18	0.016	<0.0001	<0.0001
	RL2-05-B	CR-P3-11-5B	2014-08-29	<0.001	<0.25	2	1	17	18	0.017	<0.0001	<0.0001
Reference Lake 3	RL3-01-S	ALT-09-01S	2014-08-30	<0.001	<0.25	2	4	38	38	0.004	<0.0001	<0.0001
	RL3-01-S Dup [4]	ALT-09-01S Dup	2014-08-30	<0.001	<0.25	2	4	38	38	0.005	<0.0001	<0.0001
	RL3-01-B	ALT-09-01B	2014-08-30	<0.001	<0.25	2	4	38	38	0.003	<0.0001	<0.0001

Table A1-2. - continued –

Waterbody	Site ID [1]	Previous Site ID	Sampling Date	Total								
				Barium	Beryllium	Bismuth	Boron	Cadmium	Calcium	Chromium	Cobalt	Copper
				(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
Analytical Detection Limit				0.00005	0.0005	0.0005	0.010	0.00001	0.05	0.0005	0.0001	0.0005
Reference Lake 1	RL1-01-S	CL-P2-13-1S	2014-08-27	0.00218	<0.0005	<0.0005	<0.010	<0.00001	4.18	<0.0005	<0.0001	0.0005
	RL1-01-B	CL-P2-13-1B	2014-08-27	0.00216	<0.0005	<0.0005	<0.010	<0.00001	4.20	<0.0005	<0.0001	0.0005
	RL1-02-S	CL-P2-13-2S	2014-08-27	0.00224	<0.0005	<0.0005	<0.010	<0.00001	4.27	<0.0005	<0.0001	0.0007
	RL1-02-B	CL-P2-13-2B	2014-08-27	0.00205	<0.0005	<0.0005	<0.010	<0.00001	4.21	<0.0005	<0.0001	0.0005
	RL1-03-S	CL-P2-13-3S	2014-08-27	0.0021	<0.0005	<0.0005	<0.010	<0.00001	4.2	<0.0005	<0.0001	0.0005
	RL1-03-B	CL-P2-13-3B	2014-08-27	0.00215	<0.0005	<0.0005	<0.010	<0.00001	4.21	<0.0005	<0.0001	0.0006
	RL1-04-S	CL-P2-13-4S	2014-08-27	0.00213	<0.0005	<0.0005	<0.010	<0.00001	4.22	<0.0005	<0.0001	0.0005
	RL1-04-B	CL-P2-13-4B	2014-08-27	0.00208	<0.0005	<0.0005	<0.010	<0.00001	4.22	<0.0005	<0.0001	0.0005
	RL1-05-S	CL-P2-13-5S	2014-08-27	0.00208	<0.0005	<0.0005	<0.010	<0.00001	4.22	<0.0005	<0.0001	0.0005
	RL1-05-B	CL-P2-13-5B	2014-08-27	0.00218	<0.0005	<0.0005	<0.010	<0.00001	4.34	<0.0005	<0.0001	0.0005
Reference Lake 2	RL2-01-S	CR-P3-11-1S [3]	2014-08-29	0.0025	<0.0005	<0.0005	<0.010	<0.00001	3.78	<0.0005	<0.0001	<0.0005
	RL2-01-B	CR-P3-11-1B [3]	2014-08-29	0.00253	<0.0005	<0.0005	<0.010	<0.00001	3.76	<0.0005	<0.0001	<0.0005
	RL2-02-S	CR-P3-11-2S	2014-08-29	0.0026	<0.0005	<0.0005	<0.010	<0.00001	3.8	<0.0005	<0.0001	<0.0005
	RL2-02-B	CR-P3-11-2B	2014-08-29	0.00256	<0.0005	<0.0005	<0.010	<0.00001	3.8	<0.0005	<0.0001	0.0006
	RL2-03-S	CR-P3-11-3S	2014-08-29	0.0026	<0.0005	<0.0005	<0.010	<0.00001	3.84	<0.0005	<0.0001	<0.0005
	RL2-03-B	CR-P3-11-3B	2014-08-29	0.0026	<0.0005	<0.0005	<0.010	<0.00001	3.75	<0.0005	<0.0001	<0.0005
	RL2-04-S	CR-P3-11-4S	2014-08-29	0.00261	<0.0005	<0.0005	<0.010	<0.00001	3.84	<0.0005	<0.0001	<0.0005
	RL2-04-B	CR-P3-11-4B	2014-08-29	0.00258	<0.0005	<0.0005	<0.010	<0.00001	3.77	<0.0005	<0.0001	<0.0005
	RL2-05-S	CR-P3-11-5S	2014-08-29	0.00262	<0.0005	<0.0005	<0.010	<0.00001	3.82	<0.0005	<0.0001	<0.0005
	RL2-05-B	CR-P3-11-5B	2014-08-29	0.00255	<0.0005	<0.0005	<0.010	<0.00001	3.74	<0.0005	<0.0001	<0.0005
Reference Lake 3	RL3-01-S	ALT-09-01S	2014-08-30	0.00619	<0.0005	<0.0005	<0.010	<0.00001	7.56	<0.0005	<0.0001	0.0009
	RL3-01-S Dup [4]	ALT-09-01S Dup	2014-08-30	0.00637	<0.0005	<0.0005	<0.010	<0.00001	7.66	<0.0005	<0.0001	0.0008
	RL3-01-B	ALT-09-01B	2014-08-30	0.00625	<0.0005	<0.0005	<0.010	<0.00001	7.58	<0.0005	<0.0001	0.0008

Table A1-2. - continued –

Waterbody	Site ID [1]	Previous Site ID	Sampling Date	Total Iron (mg/L)	Total Lead (mg/L)	Total Lithium (mg/L)	Total Magnesium (mg/L)	Total Manganese (mg/L)	Total Mercury (mg/L)	Total Molybdenum (mg/L)	Total Nickel (mg/L)
Analytical Detection Limit				0.03	0.00005	0.001	0.05	0.00005	0.00001	0.00005	0.0005
Reference Lake 1	RL1-01-S	CL-P2-13-1S	2014-08-27	<0.030	<0.00005	<0.001	2.49	0.00195	<0.00001	<0.00005	<0.0005
	RL1-01-B	CL-P2-13-1B	2014-08-27	<0.030	<0.00005	<0.001	2.50	0.00194	<0.00001	<0.00005	<0.0005
	RL1-02-S	CL-P2-13-2S	2014-08-27	0.040	0.00009	<0.001	2.52	0.00243	<0.00001	<0.00005	<0.0005
	RL1-02-B	CL-P2-13-2B	2014-08-27	<0.030	<0.00005	<0.001	2.51	0.00192	<0.00001	<0.00005	<0.0005
	RL1-03-S	CL-P2-13-3S	2014-08-27	<0.030	<0.00005	<0.001	2.53	0.00189	<0.00001	<0.00005	<0.0005
	RL1-03-B	CL-P2-13-3B	2014-08-27	<0.030	<0.00005	<0.001	2.49	0.00199	<0.00001	<0.00005	<0.0005
	RL1-04-S	CL-P2-13-4S	2014-08-27	0.030	<0.00005	<0.001	2.53	0.00190	<0.00001	<0.00005	<0.0005
	RL1-04-B	CL-P2-13-4B	2014-08-27	0.030	<0.00005	<0.001	2.52	0.00192	<0.00001	<0.00005	<0.0005
	RL1-05-S	CL-P2-13-5S	2014-08-27	<0.030	<0.00005	<0.001	2.53	0.00190	<0.00001	<0.00005	<0.0005
	RL1-05-B	CL-P2-13-5B	2014-08-27	<0.030	<0.00005	<0.001	2.58	0.00191	<0.00001	<0.00005	<0.0005
Reference Lake 2	RL2-01-S	CR-P3-11-1S [3]	2014-08-29	<0.030	<0.00005	<0.001	1.99	0.00038	<0.00001	<0.00005	<0.0005
	RL2-01-B	CR-P3-11-1B [3]	2014-08-29	<0.030	<0.00005	<0.001	1.98	0.00254	<0.00001	0.00005	<0.0005
	RL2-02-S	CR-P3-11-2S	2014-08-29	<0.030	<0.00005	<0.001	2.04	0.00257	<0.00001	<0.00005	<0.0005
	RL2-02-B	CR-P3-11-2B	2014-08-29	<0.030	<0.00005	<0.001	2.00	0.00260	<0.00001	<0.00005	<0.0005
	RL2-03-S	CR-P3-11-3S	2014-08-29	<0.030	<0.00005	<0.001	2.04	0.00255	<0.00001	<0.00005	<0.0005
	RL2-03-B	CR-P3-11-3B	2014-08-29	<0.030	<0.00005	<0.001	1.97	0.00257	<0.00001	<0.00005	<0.0005
	RL2-04-S	CR-P3-11-4S	2014-08-29	<0.030	<0.00005	<0.001	2.03	0.00261	<0.00001	<0.00005	<0.0005
	RL2-04-B	CR-P3-11-4B	2014-08-29	<0.030	<0.00005	<0.001	1.98	0.00253	<0.00001	<0.00005	<0.0005
	RL2-05-S	CR-P3-11-5S	2014-08-29	<0.030	<0.00005	<0.001	2.03	0.00255	<0.00001	<0.00005	<0.0005
	RL2-05-B	CR-P3-11-5B	2014-08-29	<0.030	<0.00005	<0.001	1.95	0.00258	<0.00001	<0.00005	<0.0005
Reference Lake 3	RL3-01-S	ALT-09-01S	2014-08-30	<0.030	<0.00005	<0.001	4.56	0.00078	<0.00001	0.00018	<0.0005
	RL3-01-S Dup [4]	ALT-09-01S Dup	2014-08-30	<0.030	<0.00005	<0.001	4.62	0.00060	<0.00001	0.00016	<0.0005
	RL3-01-B	ALT-09-01B	2014-08-30	<0.030	0.00045	<0.001	4.61	0.00061	<0.00001	0.00015	<0.0005

Table A1-2. - continued –

Waterbody	Site ID [1]	Previous Site ID	Sampling Date	Total Potassium (mg/L)	Total Selenium (mg/L)	Total Silicon (mg/L)	Total Silver (mg/L)	Total Sodium (mg/L)	Total Tin (mg/L)	Total Strontium (mg/L)	Total Titanium (mg/L)
Analytical Detection Limit				0.2	0.001	0.1	0.00001	0.05	0.0001	0.0001	0.010
Reference Lake 1	RL1-01-S	CL-P2-13-1S	2014-08-27	0.3	<0.001	0.4	<0.00001	0.68	<0.0001	0.0036	<0.010
	RL1-01-B	CL-P2-13-1B	2014-08-27	0.3	<0.001	0.4	<0.00001	0.71	<0.0001	0.0036	<0.010
	RL1-02-S	CL-P2-13-2S	2014-08-27	0.3	<0.001	0.4	<0.00001	0.80	<0.0001	0.0037	<0.010
	RL1-02-B	CL-P2-13-2B	2014-08-27	0.3	<0.001	0.4	<0.00001	0.70	<0.0001	0.0035	<0.010
	RL1-03-S	CL-P2-13-3S	2014-08-27	0.3	<0.001	0.4	<0.00001	0.69	<0.0001	0.0034	<0.010
	RL1-03-B	CL-P2-13-3B	2014-08-27	0.3	<0.001	0.4	<0.00001	0.71	<0.0001	0.0035	<0.010
	RL1-04-S	CL-P2-13-4S	2014-08-27	0.3	<0.001	0.4	<0.00001	0.70	<0.0001	0.0035	<0.010
	RL1-04-B	CL-P2-13-4B	2014-08-27	0.3	<0.001	0.4	<0.00001	0.70	<0.0001	0.0034	<0.010
	RL1-05-S	CL-P2-13-5S	2014-08-27	0.3	<0.001	0.4	<0.00001	0.71	<0.0001	0.0034	<0.010
	RL1-05-B	CL-P2-13-5B	2014-08-27	0.3	<0.001	0.4	<0.00001	0.70	<0.0001	0.0034	<0.010
Reference Lake 2	RL2-01-S	CR-P3-11-1S [3]	2014-08-29	0.2	<0.001	0.2	<0.00001	1.01	<0.0001	0.0048	<0.010
	RL2-01-B	CR-P3-11-1B [3]	2014-08-29	0.3	<0.001	0.2	<0.00001	0.97	<0.0001	0.0049	<0.010
	RL2-02-S	CR-P3-11-2S	2014-08-29	0.4	<0.001	0.3	<0.00001	0.99	<0.0001	0.0050	<0.010
	RL2-02-B	CR-P3-11-2B	2014-08-29	0.3	<0.001	0.3	<0.00001	0.98	<0.0001	0.0050	<0.010
	RL2-03-S	CR-P3-11-3S	2014-08-29	0.3	<0.001	0.3	<0.00001	0.99	<0.0001	0.0050	<0.010
	RL2-03-B	CR-P3-11-3B	2014-08-29	0.4	<0.001	0.3	<0.00001	0.98	<0.0001	0.0050	<0.010
	RL2-04-S	CR-P3-11-4S	2014-08-29	0.4	<0.001	0.3	<0.00001	1.00	<0.0001	0.0050	<0.010
	RL2-04-B	CR-P3-11-4B	2014-08-29	0.3	<0.001	0.3	<0.00001	0.97	<0.0001	0.0050	<0.010
	RL2-05-S	CR-P3-11-5S	2014-08-29	0.2	<0.001	0.3	<0.00001	1.00	<0.0001	0.0050	<0.010
	RL2-05-B	CR-P3-11-5B	2014-08-29	0.3	<0.001	0.3	<0.00001	0.99	<0.0001	0.0049	<0.010
Reference Lake 3	RL3-01-S	ALT-09-01S	2014-08-30	0.8	<0.001	0.5	<0.00001	0.73	<0.0001	0.0086	<0.010
	RL3-01-S Dup [4]	ALT-09-01S Dup	2014-08-30	0.7	<0.001	0.5	<0.00001	0.72	<0.0001	0.0083	<0.010
	RL3-01-B	ALT-09-01B	2014-08-30	0.8	<0.001	0.5	<0.00001	0.74	<0.0001	0.0087	<0.010

Table A1-2. - continued –

Waterbody	Site ID [1]	Previous Site ID	Sampling Date	Total				Dissolved			
				Thallium	Uranium	Vanadium	Zinc	Aluminum	Antimony	Arsenic	Barium
				(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
Analytical Detection Limit				0.0001	0.00001	0.001	0.003	0.003	0.0001	0.0001	0.00005
Reference Lake 1	RL1-01-S	CL-P2-13-1S	2014-08-27	<0.0001	0.00014	<0.001	<0.003	0.004	<0.0001	<0.0001	0.00201
	RL1-01-B	CL-P2-13-1B	2014-08-27	<0.0001	0.00014	<0.001	<0.003	0.005	<0.0001	<0.0001	0.00203
	RL1-02-S	CL-P2-13-2S	2014-08-27	<0.0001	0.00014	<0.001	<0.003	0.004	<0.0001	<0.0001	0.00227
	RL1-02-B	CL-P2-13-2B	2014-08-27	<0.0001	0.00014	<0.001	<0.003	0.004	<0.0001	<0.0001	0.00204
	RL1-03-S	CL-P2-13-3S	2014-08-27	<0.0001	0.00014	<0.001	<0.003	0.004	<0.0001	<0.0001	0.00207
	RL1-03-B	CL-P2-13-3B	2014-08-27	<0.0001	0.00014	<0.001	<0.003	0.004	<0.0001	<0.0001	0.00210
	RL1-04-S	CL-P2-13-4S	2014-08-27	<0.0001	0.00014	<0.001	<0.003	0.005	0.0002	<0.0001	0.00204
	RL1-04-B	CL-P2-13-4B	2014-08-27	<0.0001	0.00014	<0.001	<0.003	0.007	0.0001	<0.0001	0.00206
	RL1-05-S	CL-P2-13-5S	2014-08-27	<0.0001	0.00014	<0.001	<0.003	0.003	<0.0001	<0.0001	0.00207
	RL1-05-B	CL-P2-13-5B	2014-08-27	<0.0001	0.00015	<0.001	<0.003	0.004	<0.0001	<0.0001	0.00207
Reference Lake 2	RL2-01-S	CR-P3-11-1S [3]	2014-08-29	<0.0001	0.00006	<0.001	<0.003	0.013	0.0001	<0.0001	0.00253
	RL2-01-B	CR-P3-11-1B [3]	2014-08-29	<0.0001	0.00006	<0.001	<0.003	0.006	0.0003	<0.0001	0.00263
	RL2-02-S	CR-P3-11-2S	2014-08-29	<0.0001	0.00006	<0.001	<0.003	0.004	<0.0001	<0.0001	0.00232
	RL2-02-B	CR-P3-11-2B	2014-08-29	<0.0001	0.00006	<0.001	<0.003	0.005	<0.0001	<0.0001	0.00236
	RL2-03-S	CR-P3-11-3S	2014-08-29	<0.0001	0.00006	<0.001	<0.003	0.007	<0.0001	<0.0001	0.00239
	RL2-03-B	CR-P3-11-3B	2014-08-29	<0.0001	0.00006	<0.001	<0.003	0.005	<0.0001	<0.0001	0.00235
	RL2-04-S	CR-P3-11-4S	2014-08-29	<0.0001	0.00006	<0.001	<0.003	0.006	<0.0001	<0.0001	0.00244
	RL2-04-B	CR-P3-11-4B	2014-08-29	<0.0001	0.00006	<0.001	<0.003	0.004	<0.0001	<0.0001	0.00242
	RL2-05-S	CR-P3-11-5S	2014-08-29	<0.0001	0.00006	<0.001	<0.003	0.004	<0.0001	<0.0001	0.00242
	RL2-05-B	CR-P3-11-5B	2014-08-29	<0.0001	0.00006	<0.001	<0.003	0.005	<0.0001	<0.0001	0.00243
Reference Lake 3	RL3-01-S	ALT-09-01S	2014-08-30	<0.0001	0.00027	<0.001	<0.003	0.004	<0.0001	<0.0001	0.00626
	RL3-01-S Dup [4]	ALT-09-01S Dup	2014-08-30	<0.0001	0.00027	<0.001	<0.003	<0.003	<0.0001	<0.0001	0.00628
	RL3-01-B	ALT-09-01B	2014-08-30	<0.0001	0.00027	<0.001	<0.003	<0.003	<0.0001	<0.0001	0.00629

Table A1-2. - continued –

Waterbody	Site ID [1]	Previous Site ID	Sampling Date	Dissolved							
				Beryllium	Bismuth	Boron	Cadmium	Calcium	Chromium	Cobalt	Copper
				(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
Analytical Detection Limit				0.0005	0.0005	0.010	0.00001	0.05	0.0005	0.0001	0.0005
Reference Lake 1	RL1-01-S	CL-P2-13-1S	2014-08-27	<0.0005	<0.0005	<0.010	<0.00001	4.28	<0.0005	<0.0001	<0.0005
	RL1-01-B	CL-P2-13-1B	2014-08-27	<0.0005	<0.0005	<0.010	<0.00001	4.32	<0.0005	<0.0001	<0.0005
	RL1-02-S	CL-P2-13-2S	2014-08-27	<0.0005	<0.0005	<0.010	<0.00001	4.30	<0.0005	<0.0001	<0.0005
	RL1-02-B	CL-P2-13-2B	2014-08-27	<0.0005	<0.0005	<0.010	<0.00001	4.31	<0.0005	<0.0001	<0.0005
	RL1-03-S	CL-P2-13-3S	2014-08-27	<0.0005	<0.0005	<0.010	<0.00001	4.33	<0.0005	<0.0001	<0.0005
	RL1-03-B	CL-P2-13-3B	2014-08-27	<0.0005	<0.0005	<0.010	<0.00001	4.30	<0.0005	<0.0001	<0.0005
	RL1-04-S	CL-P2-13-4S	2014-08-27	<0.0005	<0.0005	<0.010	<0.00001	4.30	<0.0005	<0.0001	<0.0005
	RL1-04-B	CL-P2-13-4B	2014-08-27	<0.0005	<0.0005	<0.010	<0.00001	4.30	<0.0005	<0.0001	<0.0005
	RL1-05-S	CL-P2-13-5S	2014-08-27	<0.0005	<0.0005	<0.010	<0.00001	4.30	<0.0005	<0.0001	<0.0005
	RL1-05-B	CL-P2-13-5B	2014-08-27	<0.0005	<0.0005	<0.010	<0.00001	4.46	<0.0005	<0.0001	<0.0005
Reference Lake 2	RL2-01-S	CR-P3-11-1S [3]	2014-08-29	<0.0005	<0.0005	<0.010	<0.00001	3.84	<0.0005	<0.0001	<0.0005
	RL2-01-B	CR-P3-11-1B [3]	2014-08-29	<0.0005	<0.0005	<0.010	<0.00001	3.80	<0.0005	<0.0001	<0.0005
	RL2-02-S	CR-P3-11-2S	2014-08-29	<0.0005	<0.0005	<0.010	<0.00001	3.82	<0.0005	<0.0001	<0.0005
	RL2-02-B	CR-P3-11-2B	2014-08-29	<0.0005	<0.0005	<0.010	<0.00001	3.88	<0.0005	<0.0001	<0.0005
	RL2-03-S	CR-P3-11-3S	2014-08-29	<0.0005	<0.0005	<0.010	<0.00001	3.82	<0.0005	<0.0001	<0.0005
	RL2-03-B	CR-P3-11-3B	2014-08-29	<0.0005	<0.0005	<0.010	<0.00001	3.82	<0.0005	<0.0001	<0.0005
	RL2-04-S	CR-P3-11-4S	2014-08-29	<0.0005	<0.0005	<0.010	<0.00001	3.83	<0.0005	<0.0001	<0.0005
	RL2-04-B	CR-P3-11-4B	2014-08-29	<0.0005	<0.0005	<0.010	<0.00001	3.88	<0.0005	<0.0001	<0.0005
	RL2-05-S	CR-P3-11-5S	2014-08-29	<0.0005	<0.0005	<0.010	<0.00001	3.86	<0.0005	<0.0001	<0.0005
	RL2-05-B	CR-P3-11-5B	2014-08-29	<0.0005	<0.0005	<0.010	<0.00001	3.84	<0.0005	<0.0001	<0.0005
Reference Lake 3	RL3-01-S	ALT-09-01S	2014-08-30	<0.0005	<0.0005	<0.010	<0.00001	7.62	<0.0005	<0.0001	0.0009
	RL3-01-S Dup [4]	ALT-09-01S Dup	2014-08-30	<0.0005	<0.0005	<0.010	<0.00001	7.66	<0.0005	<0.0001	0.0008
	RL3-01-B	ALT-09-01B	2014-08-30	<0.0005	<0.0005	<0.010	<0.00001	7.69	<0.0005	<0.0001	0.0008

Table A1-2. - continued –

Waterbody	Site ID [1]	Previous Site ID	Sampling Date	Dissolved Iron (mg/L)	Dissolved Lithium (mg/L)	Dissolved Magnesium (mg/L)	Dissolved Manganese (mg/L)	Dissolved Mercury (mg/L)	Dissolved Molybdenum (mg/L)	Dissolved Nickel (mg/L)	Dissolved Lead (mg/L)
Analytical Detection Limit				0.030	0.001	0.05	0.00005	0.00001	0.00005	0.0005	0.00005
Reference Lake 1	RL1-01-S	CL-P2-13-1S	2014-08-27	<0.030	<0.001	2.55	0.00020	<0.00001	<0.00005	<0.0005	<0.00005
	RL1-01-B	CL-P2-13-1B	2014-08-27	<0.030	<0.001	2.60	0.00040	<0.00001	<0.00005	<0.0005	<0.00005
	RL1-02-S	CL-P2-13-2S	2014-08-27	<0.030	<0.001	2.57	0.00022	<0.00001	<0.00005	<0.0005	<0.00005
	RL1-02-B	CL-P2-13-2B	2014-08-27	<0.030	<0.001	2.58	0.00019	<0.00001	<0.00005	<0.0005	<0.00005
	RL1-03-S	CL-P2-13-3S	2014-08-27	<0.030	<0.001	2.56	0.00018	<0.00001	<0.00005	<0.0005	<0.00005
	RL1-03-B	CL-P2-13-3B	2014-08-27	<0.030	<0.001	2.55	0.00019	<0.00001	<0.00005	<0.0005	<0.00005
	RL1-04-S	CL-P2-13-4S	2014-08-27	<0.030	<0.001	2.57	0.00031	<0.00001	<0.00005	<0.0005	<0.00005
	RL1-04-B	CL-P2-13-4B	2014-08-27	<0.030	<0.001	2.57	0.00024	<0.00001	<0.00005	<0.0005	<0.00005
	RL1-05-S	CL-P2-13-5S	2014-08-27	<0.030	<0.001	2.56	0.00023	<0.00001	<0.00005	<0.0005	0.00007
	RL1-05-B	CL-P2-13-5B	2014-08-27	<0.030	<0.001	2.67	0.00023	<0.00001	<0.00005	<0.0005	<0.00005
Reference Lake 2	RL2-01-S	CR-P3-11-1S [3]	2014-08-29	<0.030	<0.001	2.03	0.00261	<0.00001	0.00005	<0.0005	<0.00005
	RL2-01-B	CR-P3-11-1B [3]	2014-08-29	<0.030	<0.001	1.98	0.00050	<0.00001	0.00008	0.0011	0.00007
	RL2-02-S	CR-P3-11-2S	2014-08-29	<0.030	<0.001	1.99	0.00034	<0.00001	0.00006	<0.0005	<0.00005
	RL2-02-B	CR-P3-11-2B	2014-08-29	<0.030	<0.001	2.06	0.00033	<0.00001	0.00006	<0.0005	<0.00005
	RL2-03-S	CR-P3-11-3S	2014-08-29	<0.030	<0.001	2.01	0.00045	<0.00001	0.00005	0.0015	<0.00005
	RL2-03-B	CR-P3-11-3B	2014-08-29	<0.030	<0.001	2.04	0.00036	<0.00001	<0.00005	<0.0005	<0.00005
	RL2-04-S	CR-P3-11-4S	2014-08-29	<0.030	<0.001	2.00	0.00053	<0.00001	<0.00005	<0.0005	<0.00005
	RL2-04-B	CR-P3-11-4B	2014-08-29	<0.030	<0.001	2.09	0.00033	<0.00001	<0.00005	<0.0005	<0.00005
	RL2-05-S	CR-P3-11-5S	2014-08-29	<0.030	<0.001	2.02	0.00038	<0.00001	<0.00005	<0.0005	<0.00005
	RL2-05-B	CR-P3-11-5B	2014-08-29	<0.030	<0.001	2.03	0.00036	<0.00001	<0.00005	<0.0005	<0.00005
Reference Lake 3	RL3-01-S	ALT-09-01S	2014-08-30	<0.030	<0.001	4.60	0.00022	<0.00001	0.00034	<0.0005	<0.00005
	RL3-01-S Dup [4]	ALT-09-01S Dup	2014-08-30	<0.030	<0.001	4.60	0.00019	<0.00001	0.00025	<0.0005	0.00009
	RL3-01-B	ALT-09-01B	2014-08-30	<0.030	<0.001	4.64	0.00014	<0.00001	0.00018	<0.0005	0.00006

Table A1-2. - continued –

Waterbody	Site ID [1]	Previous Site ID	Sampling Date	Dissolved Potassium (mg/L)	Dissolved Selenium (mg/L)	Dissolved Silicon (mg/L)	Dissolved Silver (mg/L)	Dissolved Sodium (mg/L)	Dissolved Tin (mg/L)	Dissolved Strontium (mg/L)	Dissolved Titanium (mg/L)
Analytical Detection Limit				0.2	0.001	0.1	0.00001	0.05	0.0001	0.0001	0.010
Reference Lake 1	RL1-01-S	CL-P2-13-1S	2014-08-27	0.3	<0.001	0.4	<0.00001	0.73	<0.0001	0.0036	<0.010
	RL1-01-B	CL-P2-13-1B	2014-08-27	0.3	<0.001	0.4	<0.00001	0.71	<0.0001	0.0035	<0.010
	RL1-02-S	CL-P2-13-2S	2014-08-27	0.3	<0.001	0.4	<0.00001	0.72	<0.0001	0.0036	<0.010
	RL1-02-B	CL-P2-13-2B	2014-08-27	0.3	<0.001	0.4	<0.00001	0.72	<0.0001	0.0036	<0.010
	RL1-03-S	CL-P2-13-3S	2014-08-27	0.2	<0.001	0.4	<0.00001	0.71	<0.0001	0.0035	<0.010
	RL1-03-B	CL-P2-13-3B	2014-08-27	0.3	<0.001	0.4	<0.00001	0.72	<0.0001	0.0037	<0.010
	RL1-04-S	CL-P2-13-4S	2014-08-27	0.2	<0.001	0.4	<0.00001	0.74	<0.0001	0.0037	<0.010
	RL1-04-B	CL-P2-13-4B	2014-08-27	0.3	<0.001	0.4	<0.00001	0.73	<0.0001	0.0036	<0.010
	RL1-05-S	CL-P2-13-5S	2014-08-27	0.3	<0.001	0.4	<0.00001	0.71	<0.0001	0.0035	<0.010
	RL1-05-B	CL-P2-13-5B	2014-08-27	0.3	<0.001	0.4	<0.00001	0.72	<0.0001	0.0036	<0.010
Reference Lake 2	RL2-01-S	CR-P3-11-1S [3]	2014-08-29	0.4	<0.001	0.2	<0.00001	1.01	<0.0001	0.0048	<0.010
	RL2-01-B	CR-P3-11-1B [3]	2014-08-29	0.4	<0.001	0.3	0.00001	0.98	<0.0001	0.0049	<0.010
	RL2-02-S	CR-P3-11-2S	2014-08-29	0.2	<0.001	0.2	<0.00001	0.99	<0.0001	0.0046	<0.010
	RL2-02-B	CR-P3-11-2B	2014-08-29	0.3	<0.001	0.2	<0.00001	1.02	<0.0001	0.0045	<0.010
	RL2-03-S	CR-P3-11-3S	2014-08-29	0.3	<0.001	0.2	<0.00001	1.00	<0.0001	0.0045	<0.010
	RL2-03-B	CR-P3-11-3B	2014-08-29	0.4	<0.001	0.2	<0.00001	1.00	<0.0001	0.0046	<0.010
	RL2-04-S	CR-P3-11-4S	2014-08-29	0.2	<0.001	0.2	<0.00001	0.99	<0.0001	0.0046	<0.010
	RL2-04-B	CR-P3-11-4B	2014-08-29	0.2	<0.001	0.2	<0.00001	1.00	<0.0001	0.0046	<0.010
	RL2-05-S	CR-P3-11-5S	2014-08-29	0.4	<0.001	0.2	<0.00001	1.01	<0.0001	0.0046	<0.010
	RL2-05-B	CR-P3-11-5B	2014-08-29	0.4	<0.001	0.2	<0.00001	0.99	<0.0001	0.0048	<0.010
Reference Lake 3	RL3-01-S	ALT-09-01S	2014-08-30	0.9	<0.001	0.5	<0.00001	0.74	<0.0001	0.0085	<0.010
	RL3-01-S Dup [4]	ALT-09-01S Dup	2014-08-30	0.8	<0.001	0.5	<0.00001	0.73	<0.0001	0.0086	<0.010
	RL3-01-B	ALT-09-01B	2014-08-30	0.7	<0.001	0.5	<0.00001	0.75	<0.0001	0.0086	<0.010

Table A1-2. - continued –

Waterbody	Site ID [1]	Previous Site ID	Sampling Date	Dissolved		
				Uranium	Vanadium	Zinc
				(mg/L)	(mg/L)	(mg/L)
Analytical Detection Limit				0.00001	0.001	0.003
Reference Lake 1	RL1-01-S	CL-P2-13-1S	2014-08-27	0.00013	<0.001	<0.003
	RL1-01-B	CL-P2-13-1B	2014-08-27	0.00013	<0.001	<0.003
	RL1-02-S	CL-P2-13-2S	2014-08-27	0.00013	<0.001	<0.003
	RL1-02-B	CL-P2-13-2B	2014-08-27	0.00012	<0.001	<0.003
	RL1-03-S	CL-P2-13-3S	2014-08-27	0.00012	<0.001	<0.003
	RL1-03-B	CL-P2-13-3B	2014-08-27	0.00012	<0.001	<0.003
	RL1-04-S	CL-P2-13-4S	2014-08-27	0.00014	<0.001	<0.003
	RL1-04-B	CL-P2-13-4B	2014-08-27	0.00013	<0.001	<0.003
	RL1-05-S	CL-P2-13-5S	2014-08-27	0.00013	<0.001	<0.003
	RL1-05-B	CL-P2-13-5B	2014-08-27	0.00014	<0.001	<0.003
Reference Lake 2	RL2-01-S	CR-P3-11-1S [3]	2014-08-29	0.00007	<0.001	<0.003
	RL2-01-B	CR-P3-11-1B [3]	2014-08-29	0.00007	<0.001	0.004
	RL2-02-S	CR-P3-11-2S	2014-08-29	0.00006	<0.001	<0.003
	RL2-02-B	CR-P3-11-2B	2014-08-29	0.00006	<0.001	<0.003
	RL2-03-S	CR-P3-11-3S	2014-08-29	0.00006	<0.001	0.005
	RL2-03-B	CR-P3-11-3B	2014-08-29	0.00006	<0.001	<0.003
	RL2-04-S	CR-P3-11-4S	2014-08-29	0.00006	<0.001	<0.003
	RL2-04-B	CR-P3-11-4B	2014-08-29	0.00006	<0.001	<0.003
	RL2-05-S	CR-P3-11-5S	2014-08-29	0.00006	<0.001	<0.003
	RL2-05-B	CR-P3-11-5B	2014-08-29	0.00006	<0.001	<0.003
Reference Lake 3	RL3-01-S	ALT-09-01S	2014-08-30	0.00027	<0.001	<0.003
	RL3-01-S Dup [4]	ALT-09-01S Dup	2014-08-30	0.00027	<0.001	<0.003
	RL3-01-B	ALT-09-01B	2014-08-30	0.00026	<0.001	<0.003

Table A1-3. *In situ* water quality parameters measured in candidate Reference Lake 1, August 27, 2014.

Site	Total Depth (m)	Depth (m)	Temperature (°C)	Specific Conductance (µS/cm)	DO (%)	DO (mg/L)	pH	Turbidity (FNU)	Secchi Disk Depth (m)
RL1-01	10.6	1	4.2	60.0	93.0	12.12	7.81	0.53	4.5
		2	4.2	58.8	93.5	12.18	7.81	0.56	
		3	4.2	58.0	93.7	12.21	7.80	0.53	
		4	4.2	57.8	93.9	12.23	7.80	0.55	
		5	4.2	57.8	93.8	12.23	7.80	0.50	
		6	4.2	57.7	93.8	12.23	7.80	0.53	
		7	4.2	57.8	93.8	12.23	7.79	0.55	
		8	4.2	57.7	93.8	12.23	7.79	0.53	
		9	4.2	57.9	93.7	12.23	7.79	0.52	
		10	4.2	57.8	93.7	12.22	7.79	0.60	
RL1-02	12.1	1	4.3	55.4	94.5	12.27	7.80	0.50	4.7
		2	4.3	55.6	94.5	12.29	7.80	0.48	
		3	4.3	55.5	94.4	12.29	7.80	0.51	
		4	4.2	55.5	94.3	12.28	7.80	0.51	
		5	4.2	55.6	94.6	12.28	7.80	0.52	
		6	4.2	55.5	94.1	12.28	7.80	0.51	
		7	4.2	55.7	94.0	12.27	7.80	0.51	
		8	4.2	55.7	94.0	12.27	7.80	0.53	
		9	4.2	55.7	93.9	12.26	7.80	0.52	
		10	4.1	55.5	93.8	12.25	7.80	0.51	
		11	4.1	55.7	93.8	12.25	7.80	0.51	
RL1-03	11.7	1	4.3	55.3	94.5	12.30	7.76	0.50	5.0
		2	4.3	55.1	94.4	12.30	7.76	0.53	
		3	4.2	54.9	94.4	12.30	7.76	0.51	
		4	4.2	55.2	94.3	12.30	7.76	0.56	
		5	4.2	55.3	94.3	12.30	7.76	0.50	
		6	4.2	55.3	94.2	12.30	7.77	0.51	
		7	4.2	55.3	94.2	12.29	7.77	0.51	
		8	4.2	55.3	94.1	12.29	7.77	0.54	
		9	4.1	55.3	94.0	12.28	7.77	0.47	
		10	4.1	55.5	94.0	12.27	7.77	0.48	
		11	4.1	55.5	93.3	12.27	7.77	0.50	
RL1-04	6.3	1	4.3	54.7	94.4	12.28	7.80	0.47	4.9
		2	4.3	54.8	94.5	12.30	7.80	0.50	
		3	4.3	54.8	94.5	12.30	7.80	0.47	
		4	4.3	55.0	94.4	12.30	7.80	0.51	
		5	4.2	54.8	94.4	12.30	7.80	0.50	
		6	4.2	54.7	94.3	12.29	7.80	0.51	
RL1-05	14	1	4.3	55.1	94.8	12.33	7.68	0.54	4.5
		2	4.2	55.2	94.7	12.34	7.68	0.52	
		3	4.2	55.2	94.6	12.34	7.68	0.52	
		4	4.1	55.0	94.3	12.33	7.68	0.47	
		5	4.1	55.1	94.3	12.32	7.68	0.51	
		6	4.1	55.1	94.2	12.32	7.68	0.50	
		7	4.1	55.1	94.1	12.31	7.68	0.51	
		8	4.1	55.2	94.1	12.30	7.68	0.50	
		9	4.1	55.1	94.0	12.29	7.68	0.51	
		10	4.1	55.3	93.9	12.29	7.68	0.51	
		11	4.0	55.7	93.7	12.27	7.68	0.51	
		12	4.0	56.2	93.5	12.26	7.68	0.51	
		13	4.0	56.5	93.4	12.25	7.68	0.48	

Table A1-4. Relative percent mean difference for the duplicate surface water quality samples for parameters that exceeded five times the analytical detection limit. Values in red exceed 25%.

Waterbody	Site ID [1]	Previous Site ID	Sampling Date	pH	Alkalinity as $CaCO_3$	Total Dissolved Solids	Conductivity	Ammonia	Dissolved Organic Carbon	Total Organic Carbon	Hardness as $CaCO_3$ (Total)	Hardness as $CaCO_3$ (Dissolved)
					(mg/L)	(mg/L)	(µS/cm)	mg N/L	(mg/L)	(mg/L)	(mg/L)	(mg/L)
Analytical Detection Limit					5	1	5	0.02	0.5	0.5	1	1
Reference Lake 3	RL3-01-S	ALT-09-01S	2014-08-30	7.73	31	49	76	0.18	3.0	3.1	38	38
	RL3-01-S Dup [3]	ALT-09-01S Dup	2014-08-30	7.81	31	49	76	0.13	3.0	3.0	38	38
Mean				7.77	31	49	76	0.16	3.0	3.1	38	38
RPMD				1	0	0	0	**32**	0	3	0	0

Waterbody	Site ID [1]	Previous Site ID	Sampling Date	Total							
				Barium	Calcium	Magnesium	Manganese	Silicon	Sodium	Strontium	Uranium
				(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
Analytical Detection Limit				0.00005	0.05	0.05	0.00005	0.1	0.05	0.0001	0.00001
Reference Lake 3	RL3-01-S	ALT-09-01S	2014-08-30	0.00619	7.56	4.56	0.00078	0.5	0.73	0.0086	0.00027
	RL3-01-S Dup [3]	ALT-09-01S Dup	2014-08-30	0.00637	7.66	4.62	0.00060	0.5	0.72	0.0083	0.00027
Mean				0.00628	7.61	4.59	0.00069	0.5	0.73	0.0085	0.00027
RPMD				3	1	1	**26**	0	1	4	0

Waterbody	Site ID [1]	Previous Site ID	Sampling Date	Dissolved							
				Barium	Calcium	Magnesium	Molybdenum	Silicon	Sodium	Strontium	Uranium
				(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
Analytical Detection Limit				0.00005	0.05	0.05	0.00005	0.1	0.05	0.0001	0.00001
Reference Lake 3	RL3-01-S	ALT-09-01S	2014-08-30	0.00626	7.62	4.60	0.00034	0.5	0.74	0.0085	0.00027
	RL3-01-S Dup [3]	ALT-09-01S Dup	2014-08-30	0.00628	7.66	4.60	0.00025	0.5	0.73	0.0086	0.00027
Mean				0.00627	7.64	4.60	0.00030	0.5	0.735	0.00855	0.00027
RPMD				0	1	0	**31**	0	1	1	0

Table A1-5. *In situ* water quality parameters measured in candidate Reference Lake 2, August 29, 2014.

Site	Total Depth (m)	Depth (m)	Temperature (°C)	Specific Conductance (µS/cm)	DO (%)	DO (mg/L)	pH	Turbidity (FNU)	Secchi Disk Depth (m)
RL2-01	8.6	1	6.4	49.5	96.0	11.84	7.47	0	5.7
		2	6.4	49.0	97.9	12.06	7.47	0	
		3	6.4	49.4	98.0	12.07	7.47	0	
		4	6.4	49.1	98.0	12.07	7.47	0	
		5	6.4	49.2	98.1	12.09	7.48	0	
		6	6.4	49.2	98.1	12.08	7.48	0	
		7	6.4	49.3	98.0	12.07	7.49	0	
RL2-02	10.2	1	6.4	49.3	97.8	12.05	7.44	0	5.4
		2	6.4	49.7	97.8	12.05	7.44	0	
		3	6.4	49.5	97.8	12.05	7.44	0	
		4	6.4	49.6	97.8	12.05	7.44	0	
		5	6.5	49.4	97.8	12.05	7.45	0	
		6	6.4	49.6	97.7	12.04	7.45	0	
		7	6.4	49.5	97.7	12.04	7.45	0	
		8	6.4	49.5	97.6	12.04	7.45	0	
		9	6.4	49.5	97.6	12.04	7.45	0	
RL2-03	6.6	1	6.5	48.9	97.9	12.02	7.46	0	5.3
		2	6.5	48.8	97.9	12.03	7.46	0	
		3	6.5	48.7	97.9	12.03	7.46	0	
		4	6.5	48.9	97.9	12.03	7.46	0	
		5	6.5	49.0	97.8	12.03	7.46	0	
		6	6.5	48.9	97.8	12.03	7.46	0	
RL2-04	5.6	1	6.5	48.4	98.0	12.02	7.48	0	5.4
		2	6.5	48.4	98.0	12.03	7.48	0	
		3	6.5	48.7	98.0	12.04	7.48	0	
		4	6.5	48.6	98.0	12.04	7.48	0	
		5	6.5	48.8	98.0	12.04	7.48	0	
RL2-05	10.1	1	6.5	48.3	97.9	12.01	7.48	0	5.8
		2	6.5	48.6	97.8	12.01	7.49	0	
		3	6.5	48.4	97.9	12.02	7.49	0	
		4	6.5	48.5	97.8	12.01	7.49	0	
		5	6.5	48.7	97.8	12.01	7.49	0	
		6	6.5	48.3	97.7	12.01	7.49	0	
		7	6.5	48.6	97.7	12.00	7.49	0	
		8	6.5	48.5	97.6	12.00	7.49	0	
		9	6.5	48.9	97.6	11.99	7.49	0	

Table A1-6. *In situ* water quality parameters measured in candidate Reference Lake 3, August 30, 2014.

Site	Total Depth (m)	Depth (m)	Temperature (°C)	Specific Conductance (µS/cm)	DO (%)	DO (mg/L)	pH	Turbidity (FNU)	Secchi Disk Depth (m)
RL3-01	14.6	1	6.1	80.1	97.3	12.09	7.82	0	5.8
		2	6.1	80.1	97.5	12.11	7.82	0	
		3	6.0	80.0	97.5	12.12	7.82	0	
		4	6.0	80.4	97.5	12.12	7.82	0	
		5	6.0	80.3	97.5	12.13	7.82	0	
		6	6.0	80.6	97.5	12.13	7.82	0	
		7	6.0	80.5	97.4	12.13	7.82	0	
		8	6.0	80.5	97.4	12.12	7.82	0	
		9	6.0	80.6	97.3	12.12	7.82	0	
		10	6.0	80.7	97.3	12.12	7.82	0	
		11	6.0	80.6	97.2	12.11	7.82	0	
		12	6.0	80.8	97.2	12.11	7.82	0	
		13	5.9	80.8	97.1	12.10	7.82	0	

APPENDIX 2. CANDIDATE REFERENCE LAKE SEDIMENT QUALITY DATA, 2014

Table A2-1. Summary of sediment quality sampling site information for candidate reference lakes, 2014.

Lake	Site ID	Previous Site ID	Date Sampled	Year	UTM			Water depth	Depth of Sediment Collected	Sediment Appearance	# Subsamples
					Zone	Easting	Northing	(m)	(cm)		
Reference Lake 1	RL1-01	CL-P2-13-1 [1]	28-Aug-14	2014	17W	550291	7938605	11.0	2	Brown, soft, silt/clay, no vegetation	5
	RL1-01	CL-P2-13-1B [1]	28-Aug-14	2014					2	Brown, soft, silt/clay, no vegetation	5
	RL1-02	CL-P2-13-2	28-Aug-14	2014	17W	550241	7938774	12.2	2	Brown, soft, silt/clay, no vegetation	5
	RL1-03	CL-P2-13-3	28-Aug-14	2014	17W	550278	7938920	11.8	2	Brown, soft, silt/clay with gelatinous consistency after sieving	5
	RL1-04	CL-P2-13-4	28-Aug-14	2014	17W	550400	7938916	7.8	2	Brown, soft, silt/clay, no vegetation	5
	RL1-05	CL-P2-13-5	28-Aug-14	2014	17W	550121	7938590	13.9	2	Brown, firm clay/silt	5
Reference Lake 2	RL2-01	CR-P3-11-1	29-Aug-14	2014	17W	568770	7899828	9.2	2	Brownish grey at surface, black beneath, firm clay/silt	5
	RL2-02	CR-P3-11-2	29-Aug-14	2014	17W	568801	7900216	10.2	2	Greyish brown, soft, silt/sand/clay	5
	RL2-03	CR-P3-11-3	29-Aug-14	2014	17W	568965	7900052	6.7	2	Brown, soft, silt/sand/clay	5
	RL2-04	CR-P3-11-4	29-Aug-14	2014	17W	569057	7899944	6.2	2	Black, soft, clay/silt, occasional macrophytes	5
	RL2-05	CR-P3-11-5	29-Aug-14	2014	17W	568995	7900300	10.0	2	Brown firm clay	5
Reference Lake 3	RL3-01	ALT-09-01	31-Aug-14	2014	17W	574061	7853433	14.6	2	Greyish brown, soft, silt/sand/clay	5

[1] Duplicate samples.

Table A2-2. Sediment quality results for candidate reference lakes, 2014, and comparison to CCME and Ontario sediment quality guidelines.

Lake	Site ID	Previous Site ID	Date	Aluminum (µg/g)	Antimony (µg/g)	Arsenic (µg/g)	Barium (µg/g)	Beryllium (µg/g)	Boron (µg/g)	Cadmium (µg/g)	Calcium (µg/g)	Chromium (µg/g)	Cobalt (µg/g)	Copper (µg/g)
Analytical Detection Limit				5	1	1	1	1	0.5	0.5	100	1	1	1
Reference Lake 1	RL1-01	CL-P2-13-1	28-Aug-14	22900	<1	3	116	2	IS [2]	<0.5	5100	93	21	42
	RL1-01B	CL-P2-13-1B [1]	28-Aug-14	23600	<1	4	112	1	0.7	<0.5	2400	90	20	39
	RL1-02	CL-P2-13-2	28-Aug-14	27400	<1	5	99	2	0.8	<0.5	3100	99	16	46
	RL1-03	CL-P2-13-3	28-Aug-14	23200	<1	2	117	2	0.8	<0.5	2700	110	17	51
	RL1-04	CL-P2-13-4	28-Aug-14	25000	<1	2	90	2	<0.5	<0.5	2400	101	21	44
	RL1-05	CL-P2-13-5	28-Aug-14	22200	<1	5	93	1	0.6	<0.5	2300	85	17	43
Reference Lake 2	RL2-01	CR-P3-11-1	29-Aug-14	4900	<1	<1	25	<1	<0.5	<0.5	1900	17	7	11
	RL2-02	CR-P3-11-2	29-Aug-14	12700	<1	<1	68	<1	1.3	<0.5	2800	44	8	24
	RL2-03	CR-P3-11-3	29-Aug-14	13900	<1	3	97	<1	0.8	<0.5	2000	49	15	29
	RL2-04	CR-P3-11-4	29-Aug-14	11300	<1	3	90	<1	IS [2]	<0.5	2300	42	14	34
	RL2-05	CR-P3-11-5	29-Aug-14	13200	<1	2	75	<1	0.7	<0.5	2300	58	10	27
Reference Lake 3	RL3-01	ALT-09-01	31-Aug-14	8450	<1	<1	49	<1	<0.5	<0.5	3200	31	7	35
CCME [3]	ISQG					5.9				0.6		37.3		35.7
	PEL					17				3.5		90		197
OMOE [4]	*LEL*													
	SEL													

[1] Duplicate sample
[2] IS = Insufficient Sample
[3] CCME Interim Sediment Quality Guidelines (ISQGs) and Probable Effect Levels - CCME (1999 updated to 2015)
[4] OMOE Lowest Effect Level (LEL) and Severe Effect Level (SEL) - Persaud et al. (1993)

Table A2-2. - continued -

Lake	Site ID	Previous Site ID	Date	Iron	Lead	Magnesium	Manganese	Mercury	Molybdenum	Nickel	Potassium	Selenium	Silver
				(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)
Analytical Detection Limit					5	1	100	1	0.1	1	1	100	1
Reference Lake 1	RL1-01	CL-P2-13-1	28-Aug-14	*47600*	22	12300	*3690*	<0.1	1	*66*	4300	<1	<0.2
	RL1-01B	CR-P2-13-1B [1]	28-Aug-14	*45500*	20	12300	*3400*	<0.1	1	*60*	4600	<1	<0.2
	RL1-02	CL-P2-13-2	28-Aug-14	*41300*	22	13400	436	<0.1	<1	*60*	5200	<1	<0.2
	RL1-03	CL-P2-13-3	28-Aug-14	*35500*	26	14300	416	<0.1	<1	*68*	5100	<1	0.2
	RL1-04	CL-P2-13-4	28-Aug-14	*52500*	22	12500	*1550*	<0.1	<1	*66*	4300	<1	<0.2
	RL1-05	CL-P2-13-5	28-Aug-14	*67700*	20	12900	*546*	<0.1	<1	*57*	4800	<1	<0.2
Reference Lake 2	RL2-01	CR-P3-11-1	29-Aug-14	*38100*	6	2500	210	<0.1	<1	10	900	<1	<0.2
	RL2-02	CR-P3-11-2	29-Aug-14	*22200*	12	4900	334	<0.1	1	*26*	2300	<1	<0.2
	RL2-03	CR-P3-11-3	29-Aug-14	*109000*	13	4800	*1130*	<0.1	3	*31*	2200	<1	<0.2
	RL2-04	CR-P3-11-4	29-Aug-14	*91900*	12	4100	*836*	<0.1	3	*28*	1900	<1	<0.2
	RL2-05	CR-P3-11-5	29-Aug-14	*43900*	13	4100	*614*	<0.1	2	*27*	2200	<1	<0.2
Reference Lake 3	RL3-01	ALT-09-01	31-Aug-14	*20400*	7	5200	*483*	<0.1	1	*22*	2100	<1	<0.2
CCME [3]	ISQG				35			0.170					
	PEL				91.3			0.486					
OMOE [4]	*LEL*			*20000*			*460*			*16*			
	SEL			*40000*			*1100*			*75*			

Table A2-2. - continued -

Lake	Site ID	Previous Site ID	Date	Sodium (µg/g)	Strontium (µg/g)	Thallium (µg/g)	Vanadium (µg/g)	Zinc (µg/g)	Nitrite (µg/g)	Nitrate (µg/g)	Nitrate/nitrite (µg/g)
Analytical Detection Limit				100	1	1	2	2	1	1	1
Reference Lake 1	RL1-01	CL-P2-13-1	28-Aug-14	200	25	<1	69	86	<1	<1	<1
	RL1-01B	CL-P2-13-1B [1]	28-Aug-14	200	17	<1	64	73	<1	2	2
	RL1-02	CL-P2-13-2	28-Aug-14	300	18	<1	69	84	<1	<1	<1
	RL1-03	CL-P2-13-3	28-Aug-14	300	24	<1	82	91	<1	<1	<1
	RL1-04	CL-P2-13-4	28-Aug-14	200	16	<1	71	82	<1	<1	<1
	RL1-05	CL-P2-13-5	28-Aug-14	300	16	<1	63	75	<1	<1	<1
Reference Lake 2	RL2-01	CR-P3-11-1	29-Aug-14	<100	7	<1	19	26	<1	<1	<1
	RL2-02	CR-P3-11-2	29-Aug-14	200	18	<1	32	52	<1	<1	<1
	RL2-03	CR-P3-11-3	29-Aug-14	200	19	<1	37	63	<1	<1	<1
	RL2-04	CR-P3-11-4	29-Aug-14	200	16	<1	36	66	<1	<1	<1
	RL2-05	CR-P3-11-5	29-Aug-14	200	19	<1	40	57	<1	<1	<1
Reference Lake 3	RL3-01	ALT-09-01	31-Aug-14	200	7	<1	30	43	<1	<1	<1
CCME [3]	ISQG							123			
	PEL							315			
OMOE [4]	*LEL*										
	SEL										

Table A2-2. - continued -

Lake	Site ID	Previous Site ID	Date	Total Organic Carbon (%)	Sand (>0.050mm) (%)	Silt (>0.002-0.050mm) (%)	Clay (<=0.002mm) (%)	Moisture (%)
Analytical Detection Limit				0.01	1	1	1	0.1
Reference Lake 1	RL1-01	CL-P2-13-1	28-Aug-14	*2.38*	46	40	14	75.2
	RL1-01B	CL-P2-13-1B [1]	28-Aug-14	*2.30*	37	35	28	75.2
	RL1-02	CL-P2-13-2	28-Aug-14	*4.47*	36	35	29	74.8
	RL1-03	CL-P2-13-3	28-Aug-14	*3.85*	34	23	43	81.1
	RL1-04	CL-P2-13-4	28-Aug-14	*2.38*	29	28	43	77.3
	RL1-05	CL-P2-13-5	28-Aug-14	*3.62*	47	24	29	75.2
Reference Lake 2	RL2-01	CR-P3-11-1	29-Aug-14	*3.57*	89	5	6	68.6
	RL2-02	CR-P3-11-2	29-Aug-14	*5.74*	34	2	64	84.0
	RL2-03	CR-P3-11-3	29-Aug-14	*4.93*	67	9	24	84.6
	RL2-04	CR-P3-11-4	29-Aug-14	*7.28*	60	<1	40	83.4
	RL2-05	CR-P3-11-5	29-Aug-14	*5.44*	53	17	30	83.3
Reference Lake 3	RL3-01	ALT-09-01	31-Aug-14	*1.91*	76	18	6	68.0
CCME [3]	ISQG							
	PEL							
OMOE [4]	*LEL*			*1*				
	SEL			*10*				

Table A2-3. Relative percent mean difference (RPMD) for the duplicate sediment quality samples. Values in red exceed 25%.

Lake	Site ID	Previous Site ID	Date	Aluminum	Antimony	Arsenic	Barium	Beryllium	Boron	Cadmium	Calcium	Chromium	Cobalt
				(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)
Analytical Detection Limit				5	1	1	1	1	0.5	0.5	100		1
Reference Lake 1	RL1-01	CL-P2-13-1 [1]	28-Aug-14	22900	<1	3	116	2	IS [2]	<0.5	5100	93	21
	RL1-01B	CR-P2-13-1B [1]	28-Aug-14	23600	<1	4	112	1	0.7	<0.5	2400	90	20
Mean				23250	<1	4	114	2	0.7	<0.5	3750	92	21
RPMD				3	-	-	4	-	-	-	72	3	5

Lake	Site ID	Previous Site ID	Date	Copper	Iron	Lead	Magnesium	Manganese	Mercury	Molybdenum	Nickel	Potassium	Selenium
				(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)
Analytical Detection Limit				1	5	1	100	1	0.1	1	1	100	1
Reference Lake 1	RL1-01	CL-P2-13-1 [1]	28-Aug-14	42	47600	22	12300	3690	<0.1	1	66	4300	<1
	RL1-01B	CR-P2-13-1B [1]	28-Aug-14	39	45500	20	12300	3400	<0.1	1	60	4600	<1
Mean				41	46550	21	12300	3545	<0.1	1	63	4450	<1
RPMD				7	5	10	0	8	-	-	10	7	-

Lake	Site ID	Previous Site ID	Date	Silver	Sodium	Strontium	Thallium	Vanadium	Zinc	Nitrite	Nitrate	Nitrate/ nitrite	Total Kjeldahl Nitrogen
				(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)
Analytical Detection Limit				0.2	100	1	1	2	2	1	1	1	100
Reference Lake 1	RL1-01	CL-P2-13-1 [1]	28-Aug-14	<0.2	200	25	<1	69	86	<1	<1	<1	2200
	RL1-01B	CR-P2-13-1B [1]	28-Aug-14	<0.2	200	17	<1	64	73	<1	2	2	2800
Mean				<0.2	200	21	<1	67	80	<1	2	2	2500
RPMD				-	-	38	-	8	16	-	-	-	24

Table A2-3 - continued –

Lake	Site ID	Previous Site ID	Date	Total Organic Carbon	Sand (>0.050mm)	Silt (>0.002-0.050mm)	Clay (<=0.002mm)	Moisture
				(%)	(%)	(%)	(%)	(%)
Analytical Detection Limit				0.01	1	1	1	0.1
Reference Lake 1	RL1-01	CL-P2-13-1 [1]	28-Aug-14	2.38	46	40	14	75.2
	RL1-01B	CR-P2-13-1B [1]	28-Aug-14	2.30	37	35	28	75.2
Mean				2.34	42	38	21	75.2
RPMD				3	22	13	**67**	0

[1] Duplicate sample

[2] IS = Insufficient Sample

APPENDIX 3. SUMMARY OF LOWER TROPHIC LEVEL SAMPLING CONDUCTED IN CANDIDATE REFERENCE LAKES, 2014

Table A3-1. Summary of phytoplankton sampling completed in candidate reference lakes, 2014.

Waterbody	Sample ID	Site UTM (17W)		Sample Date	Sample Time	Site Depth (m)	Secchi Depth (m)	Euphotic Zone Depth (m)	Sampled Depth Range (m)
		Easting	Northing						
Reference Lake 1	RL1-01	550295	7938599	27-Aug-14	10:17	10.6	4.5	13.50	0-10
	RL1-02	550241	7938777	27-Aug-14	11:03	12.1	4.7	14.10	0-11
	RL1-03	550283	7938912	27-Aug-14	11:12	11.7	5.0	14.85	0-11
	RL1-04	550395	7938912	27-Aug-14	12:14	6.3	4.9	14.55	0-6
	RL1-05	550112	7938600	27-Aug-14	12:50	14.0	4.5	13.50	0-13
Reference Lake 2	RL2-01	568757	7899826	29-Aug-14	10:15	8.6	5.7	17.03	0-7
	RL2-02	568797	7900214	29-Aug-14	10:10	10.2	5.4	16.20	0-9
	RL2-03	568963	7900049	29-Aug-14	11:15	6.6	5.3	15.98	0-6
	RL2-04	569061	7899948	29-Aug-14	12:20	5.6	5.4	16.20	0-5
	RL2-05	568997	7900295	29-Aug-14	13:00	10.1	5.8	17.25	0-9
Reference Lake 3	RL3-01	574077	7853419	30-Aug-14	16:35	14.6	5.8	17.48	0-13

Table A3-2. Summary of zooplankton sampling completed in candidate reference lakes, 2014.

Waterbody	Sample ID	Site UTM (17W)		Sample Date	Sample Time	Replicate	Site Depth (m)	Secchi Disk Depth (m)	Sampled Depth Range (m)	No. of Tows	Codend Length (m)	Mesh Size (µm)	Mouth Diameter (m)
		Easting	Northing										
Reference Lake 1	RL1-01	550295	7938599	27-Aug-14	10:22	REP 1	10.6	4.5	0-10	1	0.23	63	0.25
						REP 2							
						REP 3							
	RL1-02	550241	7938777	27-Aug-14	11:07	REP 1	12.1	4.7	0-11	1	0.23	63	0.25
	RL1-03	550283	7938912	27-Aug-14	11:45	REP 1	11.7	5.0	0-11	1	0.23	63	0.25
	RL1-04	550395	7938912	27-Aug-14	12:18	REP 1	6.3	4.9	0-6	1	0.23	63	0.25
	RL1-05	550112	7938600	27-Aug-14	12:53	REP 1	14.0	4.5	0-13	1	0.23	63	0.25
Reference Lake 2	RL2-01	568757	7899826	29-Aug-14	10:15	REP 1	8.6	5.7	0-7	1	0.23	63	0.25
	RL2-02	568797	7900214	29-Aug-14	10:10	REP 1	10.2	5.4	0-9	1	0.23	63	0.25
	RL2-03	568963	7900049	29-Aug-14	11:15	REP 1	6.6	5.3	0-6	1	0.23	63	0.25
	RL2-04	569061	7899948	29-Aug-14	12:20	REP 1	5.6	5.4	0-5	1	0.23	63	0.25
	RL2-05	568997	7900295	29-Aug-14	13:00	REP 1	10.1	5.8	0-9	1	0.23	63	0.25
Reference Lake 3	RL3-01	574077	7853419	30-Aug-14	16:35	REP 1	14.6	5.8	0-13	1	0.23	63	0.25

Table A3-3. Summary of benthic macroinvertebrate sampling completed in candidate reference lakes, 2014.

Waterbody	Sample ID	Site UTM (17W)		Sample Date	Sample Time	Site Depth (m)	Number of Subsamples	Depth Range of Grabs (m)	Macrophyte Abundance	Dominant Substrate(s)
		Easting	Northing							
Reference Lake 1	RL1-01	550291	7938605	26-Aug-14	11:55	10.9	5	10.6 - 10.9	Absent	Silt/Clay
	RL1-02	550241	7938774	26-Aug-14	12:50	12.6	5	12.3 - 12.6	Absent	Silt/Clay
	RL1-03	550278	7938920	26-Aug-14	13:45	12.3	5	12.1 - 12.3	Absent	Silt/Clay
	RL1-04	550400	7938916	26-Aug-14	14:45	8.7	5	7.8 - 8.7	Absent	Silt/Clay
	RL1-05	550121	7938590	26-Aug-14	16:40	14.0	5	12.5 - 13.1	Absent	Silt/Clay
	RL1-06	550266	7938560	26-Aug-14	12:20	9.9	5	9.4 - 9.9	Absent	Silt/Clay
	RL1-07	550227	7938832	26-Aug-14	13:21	11.7	5	11.5 - 11.7	Absent	Silt/Clay
	RL1-08	550312	7938661	26-Aug-14	14:15	13.1	5	12.9 - 13.1	Absent	Silt/Clay
	RL1-09	550399	7938869	26-Aug-14	15:22	10.5	5	10.4 - 10.5	Absent	Silt/Clay
	RL1-10	550113	7938647	26-Aug-14	17:00	13.0	5	12.6 - 13.0	Absent	Silt/Clay
Reference Lake 2	RL2-01	568770	7899828	28-Aug-14	15:55	9.4	5	9.0 - 9.4	Absent	Clay/Silt
	RL2-02	568801	7900216	28-Aug-14	16:19	10.3	5	10.2 - 10.3	Absent	Clay/Silt
	RL2-03	568965	7900052	28-Aug-14	16:43	6.8	5	6.7 - 6.8	Absent	Clay/Silt
	RL2-04	569057	7899944	28-Aug-14	17:04	6.3	5	6.0 - 6.3	Present	Clay/Silt
	RL2-05	568995	7900300	28-Aug-14	17:26	10.1	5	10.0 - 10.1	Absent	Clay
Reference Lake 3	RL3-01	574061	7853433	31-Aug-14	8:15	14.8	5	12.0 - 14.8	Absent	Silt/Clay

Appendix G

Lake Sedimentation Monitoring Program

Mary River Project

June 2014

Aquatic Effects Monitoring Program:

Lake Sedimentation Monitoring Program

North/South Consultants Inc.
Aquatic Environment Specialists

Mary River Project

Aquatic Effects Monitoring Program: Lake Sedimentation Monitoring Program

June, 2014

Prepared by

North/South Consultants Inc.

For

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LIST OF ABBREVIATIONS

AEMP	Aquatic Effects Monitoring Program
BIM	Baffinland Iron Mines Corporation
BMI	Benthic macroinvertebrate(s)
DFO	Department of Fisheries and Oceans
ERP	Early Revenue Phase
FEIS	Final Environmental Impact Statements
NSC	North/South Consultants Inc.
QA/QC	Quality assurance/quality control
TSS	Total suspended solids
UTM	Universal Transverse Mercator

1.0 INTRODUCTION AND BACKGROUND

The Mary River Project is expected to result in increased sediment deposition in Mine Area waterbodies, including lakes, due to dust deposition and potentially due to introduction of suspended solids from various activities (e.g., wastewater discharges). Dust will be directly deposited on watercourses during the open-water season and on snow and ice during the winter. Dust will be indirectly introduced from runoff within the watersheds which will likely be greatest during the snowmelt/freshet period.

Potential effects of dust on aquatic ecosystems include effects on water quality (i.e., total suspended solids [TSS], metals, nutrients, water clarity) when suspended in the water column and effects once deposited on the lake bottom or streambed. Sedimentation of dust in lakes and streams may affect aquatic biota through changes in sediment quality (e., metals, nutrients, particle size, organic matter), through changes in habitat quality (i.e., changes in substrate composition), direct effects on benthic macroinvertebrates (BMI; i.e., smothering), and direct effects on fish eggs (i.e., smothering of eggs).

Baffinland Iron Mines Corporation (BIM) proposed a targeted study, which was subsequently recommended by the Department of Fisheries and Oceans (DFO), to measure rates of sediment deposition in Mine Area lakes. The following describes the general background, approach, and methods for this targeted study to monitor sediment deposition in Mine Area lakes during Project operation as part of the Aquatic Effects Monitoring Program (AEMP).

2.0 PATHWAYS OF EFFECT AND KEY QUESTIONS

The Project may affect sediment deposition in Mine Area lakes through airborne dust deposition and through introduction of suspended materials (i.e., TSS) to lakes via tributary streams and/or aqueous point or non-point sources. Potential pathways of effect on freshwater biota in lakes include:

- Increased sediment deposition in lakes may adversely affect BMI communities which may in turn affect Arctic Char populations;
- Increased sediment deposition in lakes may alter Arctic Char (*Salvelinus alpinus*) habitat, notably Arctic Char spawning habitat, through changes in substrate composition; and
- Increased sediment deposition in lakes during the Arctic Char egg incubation period (i.e., over winter) may adversely affect egg survival and hatching success.

The key question related to the pathways of effect is:

- What are the combined effects of point and non-point sources of suspended materials on sedimentation rates in Mine Area lakes?

The primary issue of concern in relation to Mine Area lakes is the potential effect of the Project on sediment deposition on Arctic Char eggs.

3.0 PARAMETERS

The key parameter that will be monitored under this special study is total sediment deposition, measured as total dry weight of sediment deposited in a known area over a known duration (i.e., $mg/cm^2/day$). Measurements will also allow for determination of the total mass of sediment deposited over the sampling period. Results of a baseline sampling program conducted over the open-water season of 2013 in Sheardown Lake NW indicate that sufficient volumes of sediment for laboratory analysis of total dry weight of sediment can be obtained during this period (North/South Consultants Inc. [NSC] 2014). Sediment deposition monitoring over the ice-cover season is ongoing and it is unknown whether sufficient volumes of sediments can be obtained from the lake over this period for reliable laboratory analysis. Results of the winter sedimentation program will be reviewed when available and details of this study may be modified in accordance.

If sufficient sample was collected in future lake sedimentation monitoring, bulk density would also be measured to facilitate estimates of total depth of sediment deposition in lakes (i.e., mm of sediment). However required volumes for these measurements were not realized in the open-water season of 2013 due to low rates of sedimentation (even with deployment of multiple traps and sample compositing) in the Mine Area. Therefore, it is anticipated that due to logistical restrictions, samples will only be analysed for total dry weight of sediment in the lake sedimentation monitoring program.

4.0 MONITORING AREA AND SAMPLING SITES

In the Mine Area, Arctic Char spawning habitat is restricted to lakes, as rivers and streams freeze solid in winter, and lakes provide the sole overwintering habitat for Arctic Char. The results of air quality modeling presented in the Final Environmental Impact Statement (FEIS) and the Addendum to the FEIS for the Early Revenue Phase (ERP), indicate that Sheardown Lake will experience the largest increases in sediment deposition of the Mine Area lakes. The lake sediment deposition special study is therefore focused on monitoring in Sheardown Lake NW. However, monitoring at additional Mine Area lakes may be undertaken in the future upon review of initial monitoring results collected during the ERP and/or during full production if increased effects (e.g., greater rates of dust deposition) are measured.

Increases in sedimentation rates may affect BMIs (through smothering and changes in substrate characteristics), Arctic Char habitat (notably spawning areas which are typically hard substrates), and/or Arctic Char eggs (through deposition on incubating eggs). Therefore the sampling sites will include a suspected Arctic Char spawning area, a shallow, soft substrate area, and a deep-water location. Collectively this information will provide information on sedimentation rates in different habitat types in the lake. Sites sampled during baseline studies will be retained for operation monitoring. A brief description of these sites is provided below.

Specific spawning sites have not been identified within Sheardown Lake NW and the FEIS conservatively assumed that areas of hard substrate at water depths ranging from 2-12 m in the lakes could potentially provide spawning habitat. One area in Sheardown Lake NW best matched these criteria and was selected for sediment trap deployment in 2013 to represent potential Arctic Char spawning habitat (Figure 1). A second sampling site was selected at a similar depth range (2-12 m), but with a soft substrate for comparison. A third sampling site was selected near the deepest point in the lake as these areas are typically the ultimate depositional areas in lakes and because sampling the profundal zone (i.e., depth > 12 m) would provide a measure of a dominant aquatic habitat type.

5.0 SAMPLING FREQUENCY AND SCHEDULE

Sediment traps will be deployed year-round in Sheardown Lake NW but will be retrieved and emptied in late summer/fall prior to freeze up and again in spring following ice breakup on the lake. This will provide a means for quantifying annual deposition rates in the lake as well as rates associated with the open-water and ice-cover seasons.

Baseline studies are on-going and will continue into fall 2014. Monitoring during Project operation will commence this fall and will continue for three years, following which a review of the program and results will be undertaken to advise on monitoring during full production.

6.0 FIELD AND LABORATORY METHODS

Sedimentation rates will be measured through deployment of sediment traps with an aspect ratio of > 5:1 as recommended for cylindrical sediment traps (Mudroch and MacKnight 1994). Traps will be anchored such that the trap is suspended off the bottom and secured with a buoy.

Five replicate traps (i.e., subsamples) will be deployed within close proximity at each of the three sites. The number of replicates may be modified pending the results of the ongoing baseline studies and initial results of monitoring during operation. Total water depth, substrate, date, time, and universal transverse mercator units (UTMs) will be recorded at each site.

Traps will be retrieved and emptied in late summer/fall and in spring following breakup. Trap contents will be transferred to sample bottles, kept cool and in the dark and transported to an analytical laboratory for analysis.

Samples will be analysed by filtering samples, which includes sediments and water, through a pre-weighed 0.70 µm glass fibre filter, rinsing the filter apparatus and container three times, and drying the filter at 105 ^{o}C for two hours. Samples are then allowed to cool for one hour and weighed.

7.0 QUALITY ASSURANCE/QUALITY CONTROL

Quality assurance/quality control (QA/QC) measures will include verifications that sediments are not disturbed (i.e., resupended) during sediment deployment and retrieval and inclusion of sample replicates to measure variability.

8.0 STUDY DESIGN AND DATA ANALYSIS

As the objective of this study is to monitor rates of sediment deposition in Mine Area lakes as it may affect BMIs, habitat, and Arctic Char eggs, the study is designed to provide measures of sediment deposition on a seasonal (i.e., open-water vs. ice-cover season) basis. Rates will be measured through deployment of sediment traps in Sheardown Lake NW year-round, but with retrieval of samples at the end of the open-water and ice-cover seasons to provide measures for both periods. This will facilitate examination of sedimentation rates during the Arctic Char incubation period as well as during the growing season in Sheardown Lake NW.

Measured sedimentation rates will be compared to effects predictions presented in the FEIS and the Addendum to the FEIS for the ERP, as well as to the effects threshold applied in the impact assessment (i.e., 1 mm of deposition on fish eggs). Sedimentation rates exceeding 1 mm during the egg incubation period have been identified as exerting adverse effects on fish eggs (e.g., Fudge and Bodaly 1984). The FEIS and Addendum to the FEIS indicated that sedimentation is not expected to exceed this threshold in Mine Area lakes.

The study is designed to compare results directly to the threshold rather than to demonstrate statistically significant differences. Therefore, true replicates for each habitat type are not included in the design of the monitoring program. Rather, replicates will be included to provide a measure of variability at each site (i.e., subsamples) and to provide additional contingency in the event that traps cannot be located and/or quantities of sediments collected in the traps are so low that sample compositing is required. As previously indicated, results of open-water season sampling completed in 2013 indicate that sufficient sediment volumes will likely be obtainable in the open-water season, however, it is unknown whether this can be attained for winter.

Results of the targeted study may also be compared to baseline data collected in 2013 and 2014 from Sheardown Lake NW to provide a means of identifying Project-related effects on this parameter.

This document was prepared, and the special study was designed, with baseline information available at the time of preparation of this report. It is noted that not all results of additional baseline sampling initiated in 2013 were available at the time of preparation of this report; upon receipt and analysis of these additional data, recommendations for modification to the special study may be made. Results of the baseline program completed in the open-water season of 2013 are presented in NSC (2014).

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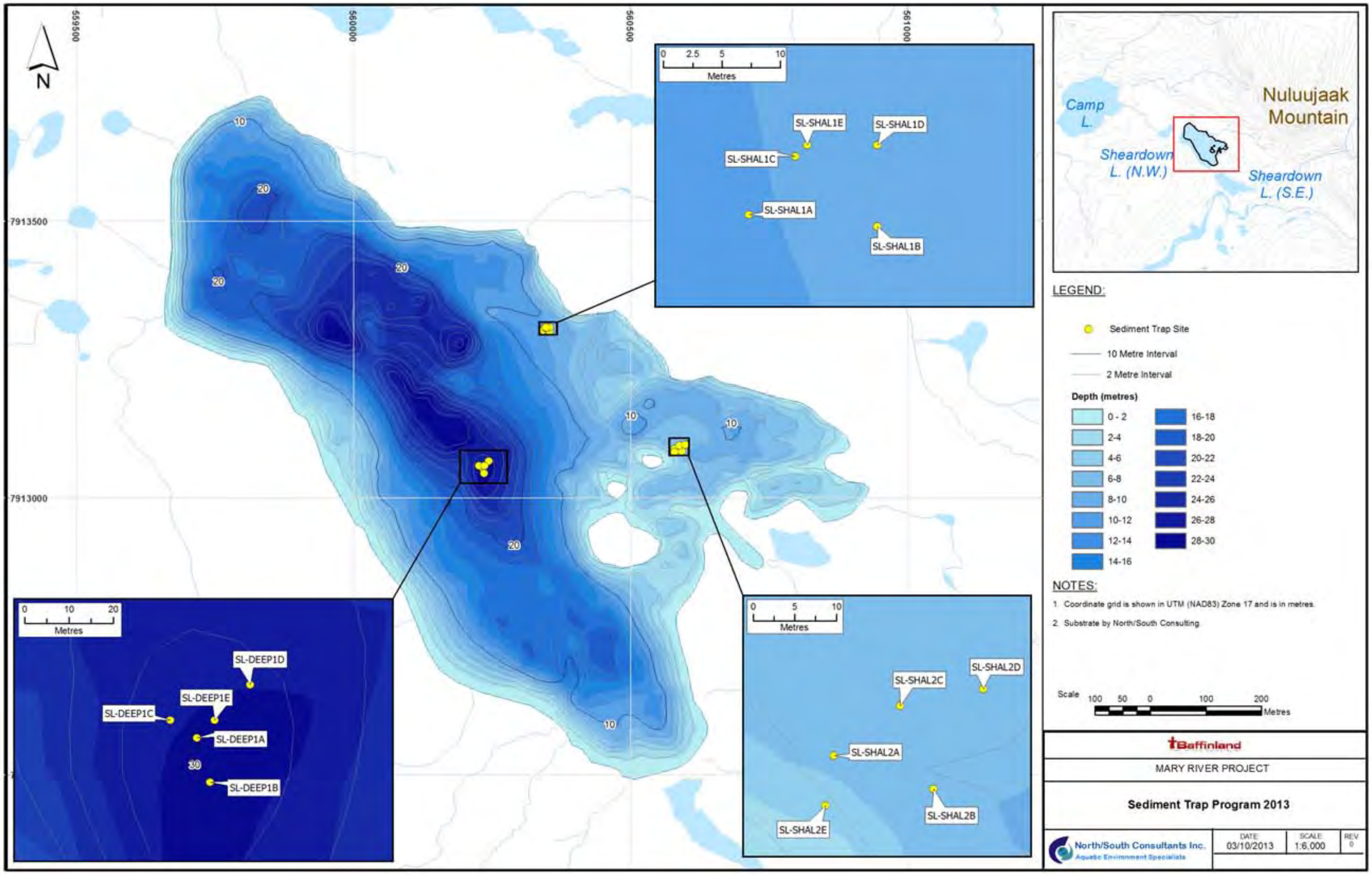

Figure 1. Sediment trap sampling sites in Sheardown Lake NW, 2013.

Appendix H

Dustfall Monitoring Program

VEGETATION MONITORING: DUST FALL

The potential impacts of dust deposition on soil and vegetation are an issue of concern for the Project. In particular, other studies have shown dust deposition to have a detrimental effect on vegetation health, and dust deposition on caribou forage (i.e., lichen) has been suggested as a potential mechanism causing caribou to avoid habitat at a distance of up to 14 km (Boulager et al. 2012). The main sources of dust emissions are fugitive sources, specifically bulk handling operations, crushing, blasting, storage, and dust emissions from vehicle and equipment traffic, although natural sources of dust fall also exist (e.g. wind erosion). The largest amount of dust fall generated by the Project is expected to be associated with use of the existing Tote road linking the Mine site with the port at Milne Inlet; however, there will also be dust fall generation from the railway and from point source locations at both the Mine site and ports.

The Mary River dust fall monitoring program was initiated in the summer of 2013 with sampling stations set up at the Mine site, Milne Port, along the Tote road, and at reference sites within the RSA. At this time, the railway and Steensby Port are not included in the dust fall monitoring program, due to access issues. Future construction of the railway linking Steensby Port with the Mine site will initiate dust fall monitoring for the southern section of the RSA. In addition to dust fall, this program component includes tracking and enumeration of traffic on the Tote Road, recorded as 'vehicle passes'. General traffic data are tracked via Baffinland security in a specially designed MS Excel form, and ore haul vehicle passes are tracked by Baffinland Mine Operations. All traffic data are compiled and reviewed as part of the dust fall monitoring program annual reports. The dust fall monitoring program was developed using knowledge gathered from other similar monitoring programs (Ekati Mine, High Lake Project, Rescan 2006), as well as applicable caribou research. Dust fall sampling is carried out in accordance with the American Society for Testing and Materials (ASTM) ASTM D1739-98 sampling method (ASTM 2004).

Objectives

The objectives of the dust fall monitoring program are to:

1. Quantify the extent and magnitude of dust fall generated by Project activities;
2. Determine seasonal variations in dust fall at all sampling locations; and
3. Determine if annual changes in dust fall at sampling locations exceed identified thresholds associated with isopleth dispersion models.

Thresholds

There are no known dust deposition thresholds specific to effects on vegetation. Health Canada/Environment Canada's national ambient air quality objectives for particulate matter

(CEPA/FPAC Working Group 1998) state that for the lack of quantitative dose-effect information, it is not possible to define a reference level for vegetation and dust deposition. In the absence of published thresholds for dust effects on vegetation, the High Lake Project (Wolfden Resources Inc. 2006), a proposed base metal mine in western Nunavut, developed thresholds in consideration of effects to vegetation health ranging from 4.6 g/m²/year for a low magnitude effect to ≥50 g/m²/year for a high magnitude effect. These values were based on a combination of the Alberta (AB) and Ontario (ON) ambient air quality criteria for human health purposes, and values reported by Spatt and Miller (1981) specific to effects of road dust on vegetation.

In addition to the consideration of thresholds developed by the High Lake Project, isopleth dispersion models (CALPUFF dispersion models) were used to predict deposition patterns from all sources during the operations phase of the Project. The CALPUFF dispersion model was recommended by a number of regulatory agencies and has been the *de facto* standard for environmental assessments in Canada's North. To refer to activities that are included in the assessment of the operations phase refer to the ERP Addendum to FEIS Volume 5.

To align with results of the isopleth dispersion models and the thresholds described above, the following annual TSP depositions thresholds will be used for the Mary River Project (summarized in Table 1):

Low: 1–4.6 g/m²/year;

Moderate: 4.6–50 g/m²/year; and

High: ≥ 50 g/m²/year.

Table 1. Dust (TSP) Deposition Rates and Criteria for Potential Effects on Vegetation Health.

Source of Information	Dust (TSP) deposition rate	Equivalent annual dust deposition rate (g/m²/year)	Comments
High Lake Impact Assessment (Wolfden 2006)	1.0–4.6 g/m²/year	1.0–4.6	Predicted low magnitude effect on vegetation health
	4.6–50 g/m²/year	4.6–50	Predicted moderate magnitude effect on vegetation health
	50–200 g/m²/year	50–200	Predicted high magnitude effect on vegetation health
Spatt and Miller (1981)	0.07 g/ m²/ d	26	Some effects to Sphagnum species
	1.0-2.5 g/ m²/ d	365-913	Decline in Sphagnum species abundance

Table 1. Dust (TSP) Deposition Rates and Criteria for Potential Effects on Vegetation Health.

Source of Information	Dust (TSP) deposition rate	Equivalent annual dust deposition rate ($g/m^2/year$)	Comments
Alberta	5.3 $g/m^2/30$ d	64	Alberta Guidelines for Residential and Recreational Areas (human health)
Ontario	4.6 $g/m^2/year$	4.6	Ontario Ambient Air Quality Criteria (human health)

Methods

The dust fall monitoring program began in July 2013 with 26 dust fall monitoring sites across the RSA. An additional eight sites were added in August 2014. Dust fall sampling locations were chosen to represent areas of various expected dust fall concentrations based on isopleth dispersion models and considering the direction of prevailing winds within the RSA, excluding areas of future infrastructure development. The 26 dust fall sample sites for the 2013/14 season included:

- Five dust fall samplers located at the Mine Site (three within the Mine Site and two references sites; one to the northeast, and one to the south);
- Three dust fall samplers located at Milne Port (two within the port itself, and one northeast and upwind of the port);
- 16 dust fall samplers divided between two sites along the Tote Road. These two sites are organized into transects, each composed of eight dust fall samplers distributed both north and south of the Tote Road centerline at 30 m, 100 m, 1 km, and 5 km. The prevalent wind direction is roughly parallel to the roadway as opposed to perpendicular, therefore no 'upwind' and 'downwind' directions from the road are identified; and

Two reference dust fall samplers located 14 km southwest of the Tote Road.

Additional sites were added in August 2014 to increase sampling coverage of dust fall in the areas around Milne Port and the Mine Site:

- Four additional dust fall samplers at Milne Port (resulting in a total of seven dust fall samplers in that area); and
- Four additional dust fall samplers located at the Mine Site (resulting in a total of eight dust fall samplers in that area).

Each site is comprised of one sampling apparatus, which is made up of a hollow post (~ 2m long) and terminal bowl shaped holder for the dust collection vessel (Photo 1). The terminal bowl is topped with bird spikes to prevent contamination by bird fecal matter. The sampling apparatus was installed by pounding 5-foot rebar into the ground, placing the post over the rebar, and then stabilizing with guy wires. Dust collection vessels are placed in the holder, pre-charged with 250 mL of algaecide in summer and 250 mL of alcohol in winter. Collection vessels are changed out every month (28–31 days) and shipped to an accredited laboratory for analysis of total, fixed and volatile insoluble particulate matter.

Caribou present are present in the area of the Baffinland Mine Site year-round; therefore, sampling of the dust fall monitoring stations occurs on a year-round basis; however, during the winter, the sampling program is limited to a subset of the monitoring sites. Winter monitoring activities are restricted by safety consideration associated with accessing the more remote reference sites.

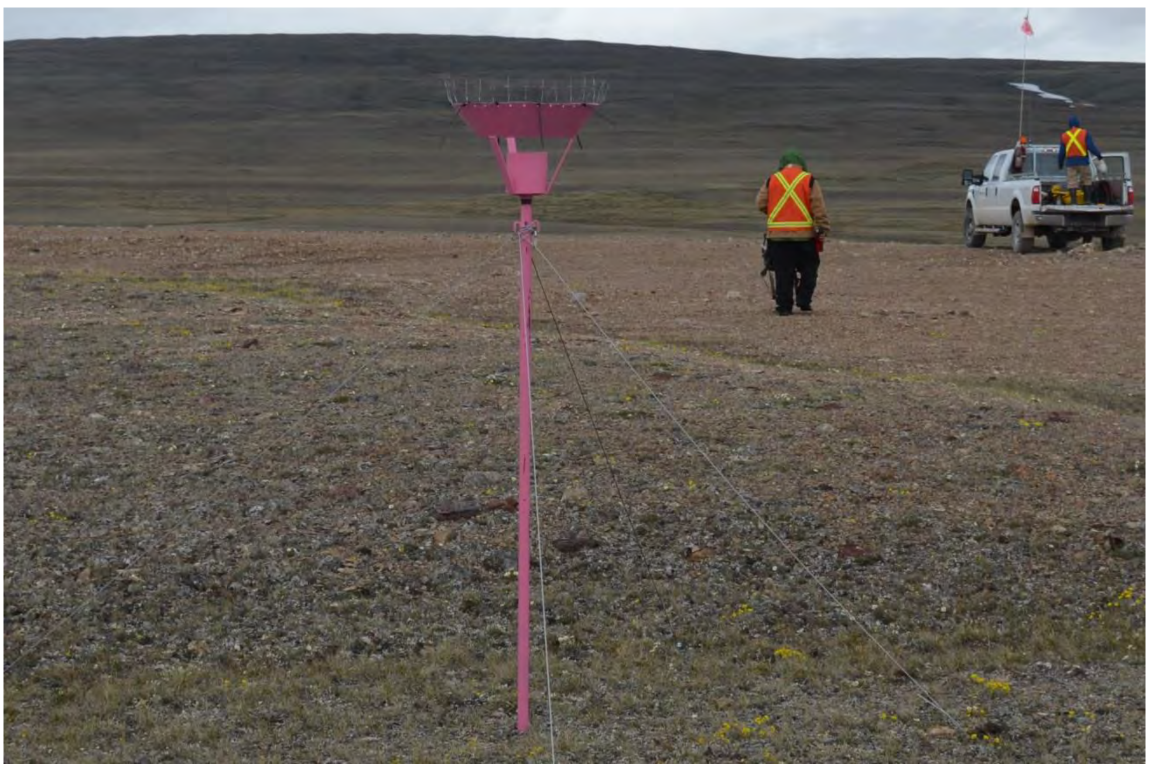

Photo 1. Dust fall collector sampling apparatus, July 10, 2013.

Annual dust fall results are analyzed against the predicted dust deposition thresholds for the Project to determine if dust fall exceeds the applicable indicator threshold. Results are also reviewed to investigate dust fall on a temporal and spatial scale relative to background with focus on seasonal differences in dust fall data.

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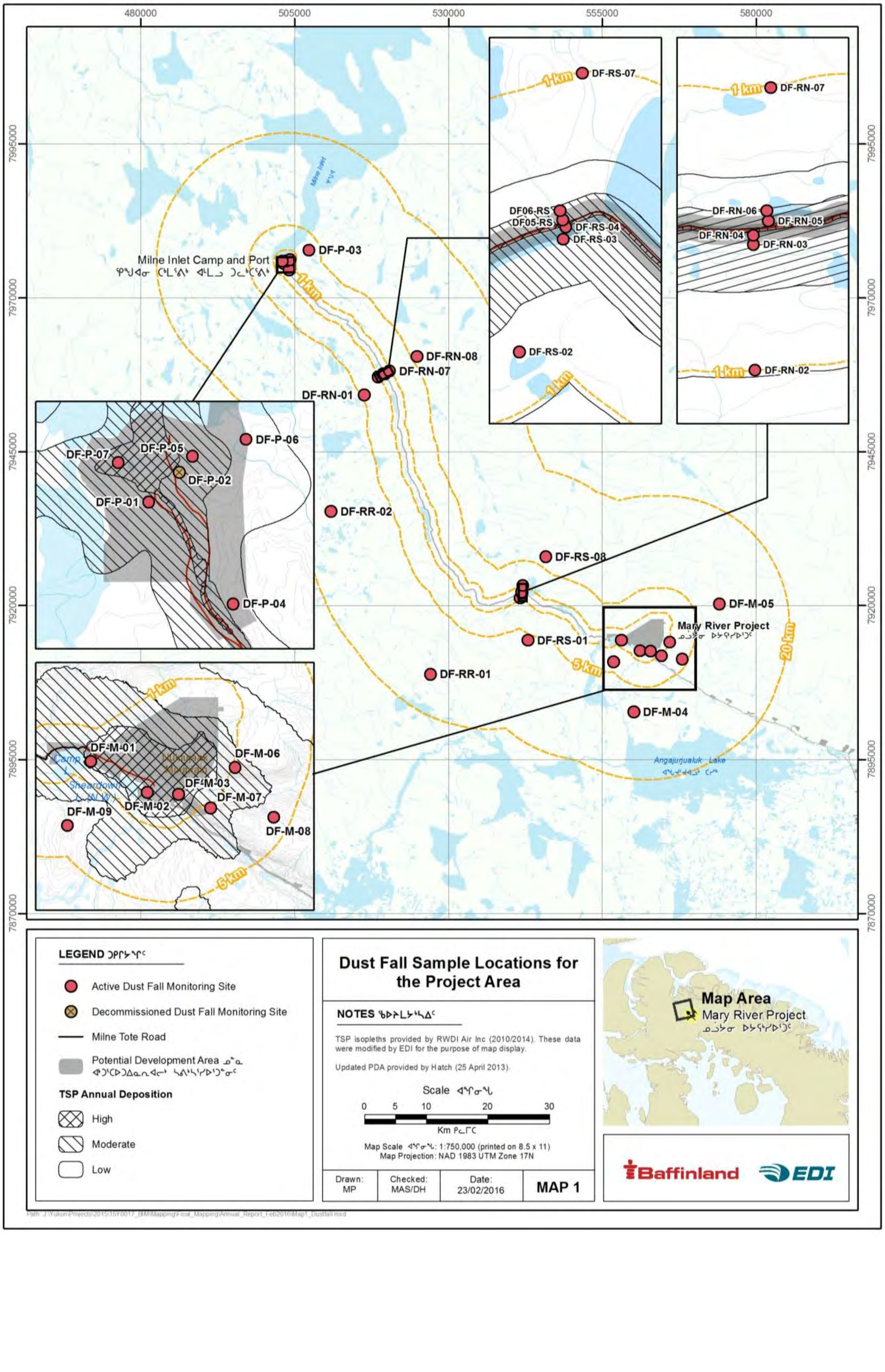
Table 2. Dust fall sample sites within the Project RSA.

Site ID	Location	Sample period	Distance to PDA (m)	Dust isopleth zone	Latitude	Longitude
DF-M-01	Mine Site	year round	Within PDA	High	71.3243	-79.3747
DF-M-02	Mine Site	year round	Within PDA	High	71.3085	-79.2906
DF-M-03	Mine Site	year round	Within PDA	High	71.3072	-79.2433
DF-M-04	Mine Site	summer only	9,000	Nil	71.2197	-79.3277
DF-M-05	Mine Site	summer only	9,000	Nil	71.3731	-78.9230
DF-M-06	Mine Site	year round	1,000	Moderate	71.3196	-79.1560
DF-M-07	Mine Site	year round	1,000	Moderate	71.3000	-79.1953
DF-M-08	Mine Site	year round	4,000	Moderate	71.2945	-79.1002
DF-M-09	Mine Site	year round	2,500	Low	71.2936	-79.4127
DF-RS-01	Tote Road - south	summer only	5,000	Nil	71.3275	-79.8001
DF-RS-02	Tote Road - south	summer only	1,000	Low	71.3893	-79.8324
DF-RS-03	Tote Road - south	year round	100	Moderate	71.3967	-79.8228
DF-RS-04	Tote Road - south	year round	30	Moderate	71.3975	-79.8222
DF-RS-05	Tote Road - south	year round	30	Moderate	71.3980	-79.8228
DF-RS-06	Tote Road - south	year round	100	Moderate	71.3986	-79.8234
DF-RS-07	Tote Road - south	summer only	1,000	Nil	71.4077	-79.8182
DF-RS-08	Tote Road - south	summer only	5,000	Nil	71.4489	-79.7106
DF-RN-01	Tote Road - north	summer only	5,000	Nil	71.6883	-80.5363
DF-RN-02	Tote Road - north	summer only	1,000	Low	71.7145	-80.4704
DF-RN-03	Tote Road - north	year round	100	Moderate	71.7186	-80.4473
DF-RN-04	Tote Road - north	year round	30	Moderate	71.7189	-80.4456
DF-RN-05	Tote Road - north	year round	30	Moderate	71.7185	-80.4414
DF-RN-06	Tote Road - north	year round	100	Moderate	71.7189	-80.4397
DF-RN-07	Tote Road - north	summer only	1,000	Nil	71.7226	-80.4165
DF-RN-08	Tote Road - north	summer only	5,000	Nil	71.7435	-80.2898
DF-P-01	Milne Port	year round	Within PDA	Moderate	71.8802	-80.9072
DF-P-02	Milne Port	decommissioned	Within PDA	Moderate	71.8850	-80.8912
DF-P-03	Milne Port	year round	3,000	Nil	71.8996	-80.7884
DF-P-04	Milne Port	year round	Within PDA	Low	71.8710	-80.8828
DF-P-05	Milne Port	year round	Within PDA	Moderate	71.8843	-80.8945
DF-P-06	Milne Port	year round	Within PDA	Low	71.8858	-80.8790
DF-P-07	Milne Port	year round	Within PDA	High	71.8838	-80.9160
DF-RR-01	Reference – Road	summer only	14,000	Nil	71.2805	-80.2450
DF-RR-02	Reference – Road	summer only	14,000	Nil	71.5189	-80.6923



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Milne Inlet Camp and Port
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DF-RN-08
DF-RN-07
DF-RN-01
DF-RR-02
DF-RS-08
DF-RS-01
DF-RR-01
DF-M-05
DF-M-04
Mary River Project
Angajurjualuk Lake
1 km
5 km
20 km
DF-RS-07
DF06-RS
DF05-RS
DF-RS-04
DF-RS-03
DF-RS-02
DF-RN-06
DF-RN-05
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DF-P-04
DF-M-01
DF-M-06
DF-M-03
DF-M-02
DF-M-07
DF-M-09
DF-M-08
LEGEND
Active Dust Fall Monitoring Site
Decommissioned Dust Fall Monitoring Site
Milne Tote Road
Potential Development Area
TSP Annual Deposition
High
Moderate
Low
Dust Fall Sample Locations for the Project Area
NOTES
TSP isopleths provided by RWDI Air Inc (2010/2014). These data were modified by EDI for the purpose of map display.
Updated PDA provided by Hatch (25 April 2013).
Scale
0 5 10 20 30
Km
Map Scale: 1:750,000 (printed on 8.5 x 11)
Map Projection: NAD 1983 UTM Zone 17N
Drawn: MP
Checked: MAS/DH
Date: 23/02/2016
MAP 1
Map Area
Mary River Project
Baffinland
EDI

Appendix I

Initial Stream Diversion Barrier Study

Knight Piésold
CONSULTING

www.knightpiesold.com

MEMORANDUM

To:	Mr. Oliver Curran	Date:	June 25, 2014
Copy To:		File No.:	NB102-181/34-A.01
From:	Dale Klodnicki	Cont. No.:	NB14-00160
Re:	Initial Stream Diversion Barrier Study - Rev. 0 Mary River Project - Aquatic Effects Monitoring Program		

1 – INTRODUCTION

A stream diversion barrier study was identified as a follow-up program in the Final Environmental Impact Statement (FEIS) for the Mary River Project (Baffinland, 2012). The primary objectives of the study are to monitor the effects of both increases and reductions in streamflow at several mine site streams and to further understand how Project-related reductions in streamflow may result in the creation of fish barriers that have the potential to occur at low flows. The monitoring program may identify the need for mitigation measures to address Project-related fish stranding.

The stream diversion barrier study is a “targeted study”, which forms part of Baffinland’s Aquatic Effects Monitoring Program (AEMP). This memorandum describes the initial study that was focussed on obtaining a better understanding for existing flow conditions and, in particular, the frequency and duration of the occurrence of fish barriers and fish stranding that was identified in five (5) mine site streams (North/South Consultants Inc. - NSC, 2008; Knight Piésold Ltd. - KP, 2012).

Since the stream diversion barrier study was identified in the FEIS, Baffinland has developed plans that are now in the final stages of approval to initiate an Early Revenue Phase (ERP) of the Project (Baffinland, 2013). The ERP will involve mining 3.5 million tonnes per annum (Mt/a) of iron ore. The iron ore will be transported year-round by truck to Milne Port and then to market by ship during the open water season. Baffinland has contemplated a 5-year operating plan for the ERP, after which time the full-scale railway project would also be brought on-line. This development schedule is subject to a commercial decision by Baffinland to proceed and will be influenced by both market conditions and available financing.

The reduced production rate associated with the ERP will result in a considerably smaller mining footprint (open pit and waste rock stockpile) than was originally envisioned. As such, Project-related stream diversions will be negligible. The absence of diversions provides Baffinland with an opportunity to better understand existing flow conditions as it relates to fish passage. This initial study is exploratory in nature with the following objectives (which contribute to the primary objectives stated above):

- Develop an understanding of low-flow conditions that may result in barriers to fish passage within two tributaries of Camp Lake and three tributaries of Sheardown Lake (Figure 1).
- Document fish presence throughout the stream length under various flow conditions. It is important to document upstream access during spring freshet, since high water velocities in the spring can prevent fish passage. It is also important to document the downstream passage of fish in the fall, when they are returning to overwintering habitat in the lakes.

Stream gauging stations are seasonally operated on three of the five targeted streams (Figure 1). The conditions observed throughout each season and between years can be related to the calculated flows in the streams. An understanding of the relationship between flow conditions and the presence of fish barriers and fish presence, understanding that streams are dynamic systems that change over time.

2 – PROJECT EFFECTS AND PROPOSED MONITORING

2.1 GENERAL

The Project footprint (including water management features) will reduce flows in five mine site streams. The resulting flow reduction will result in a loss of fish habitat that was assessed to be minor (low magnitude) in the FEIS. The flow reductions also have the potential to affect the ability of Arctic Char (primarily juveniles) to access small tributaries in the mine site area, particularly in the spring as fish move into the streams and in fall when fish return to the lakes to overwinter. The creation of barriers (or increased frequency or changed timing of existing barriers) due to reduced flows could impede fish passage upstream or downstream in the tributaries. Although considered unlikely, mortalities are possible in the event fish became stranded in the streams in fall.

The development of the open pit, a waste rock stockpile, and associated water management facilities (ditches, berms and settling ponds) will divert and redirect runoff away from certain watercourses during the operational phase of the Mary River Project (Baffinland, 2012). Five tributary streams are anticipated to be affected by diversions in the Mine Area (Figure 1).

2.2 CAMP LAKE TRIBUTARY 1 (CLT-1)

CLT-1 provides approximately 5.7 km of probable or confirmed fish-bearing habitat within the main channel and its smaller tributaries. This habitat is generally shallow (typically < 0.5 m deep), with predominantly cobble substrates (NSC, 2012; see Figure 2). Habitat in the upper reaches of the tributaries typically consists of a shallow series of cascades and riffles, with intermittent flow that provides only small amounts of habitat for aquatic life. The L1 branch of CLT-1 extends from the north-eastern shore of Camp Lake for approximately 1,400 m before reaching an impassable barrier (waterfall). It consists predominantly of riffle/pool habitat with cobble substrata. Undercut banks, deep pools and boulders provide ample cover in this stream. The utilization of the L1 branch of CLT-1 by Arctic Char is high. During surveys by Knight Piésold and NSC, one area on the L1 branch of CLT-1 between the lake and the falls was identified as a potential fish barrier under low flow conditions (Figures 1 and 2). Baffinland has continued to operate a seasonal stream gauge on the L1 branch of CLT-1 since 2006 (Figure 1).

A secondary channel (L2, referred to in NSC (2012) as Tributary 1b), continues an additional 1.25 km from downstream of the impassable falls into a series of broad and shallow ponds. This channel runs parallel to the airstrip along the base of the mountain. This channel is a low gradient area where several large, shallow (0.5 m) pools with cobble bottoms where limited in-stream cover is present. Limited sampling in the L2 stream suggests a much lower level of fish utilization compared with the L1 branch.

The west pond will collect runoff from the west half of the waste rock stockpile area and discharge it to the L1 stream of the Camp Lake Tributary 1 (CLT-1). This will result in an overall increase in flows in the L1 stream of CLT-1 that will be not be typical of the natural hydrograph. The L2 branch (CLT-1 L2 stream) will not receive flows from the west pond and will experience a flow reduction.

Flow regimes in CLT-1 for the FEIS predicted (Page 225 in Volume 7; Baffinland, 2012):

- An 8% reduction in flows during July
- A 25 to 39% increase in flows during June, August and September during operation and closure
- A 7 to 22% increase in flows throughout the open water period during post-closure

These predictions considered the total flow of CLT-1, including the L1 and L2 streams. A section of CLT-1 L1 was identified as a potential barrier under low flow conditions. Increased flow in CLT-1 L1 has the potential to create a barrier to upstream movement during the spring.

A detailed survey of L2 stream was not conducted. Anticipated effects from flow diversion are different between these streams. The L2 stream of CLT-1 flows parallel to the airstrip, and experiences a net reduction in flow as a result of west pond discharges being directed solely into the L1 stream. The L2 stream is identified as Arctic Char habitat, though it is lower quality habitat compared with the main channel of CLT-1 (L1 stream).

Monitoring within CLT-1 will initially include the potential barrier location on the L1 branch under low flow conditions and support a better understanding of the flow conditions and fish utilization of the L2 branch under different flow conditions (i.e., in spring and fall).

2.3 CAMP LAKE TRIBUTARY 2 (CLT-2)

CLT-2 is characterized by moderate to steep gradient, coarse bed material and a channel that tends to be braided (multiple channels, split by unvegetated islands and bars). Falls are located approximately 600 m from the mouth of the tributary (Figures 1 and 2). This tributary is heavily utilized by Arctic Char. During surveys by Knight Piésold and NSC, one area between the mouth and the falls on CLT-2 was identified as a potential fish barrier under low flow conditions (KP, 2011 and 2012; NSC, 2012).

Diversion of runoff from the west waste rock stockpile area and open pit will also alter discharge to CLT-2. The reduction in mean monthly flows is predicted to be 15 to 32% throughout the open-water period during operation, closure and post-closure (Page 225 in Volume 7; Baffinland, 2012). This reduction is predicted for the fish barrier location. Due to the apparent absence of any substantial inflows between the fish barrier and Camp Lake, the 15 to 32% reduction in flows is expected to be a fairly accurate estimate at its confluence with Camp Lake. No significant depth reduction was predicted within the fish-bearing section between Camp Lake and the upstream barrier that would impede fish access to habitat in CLT-2.

Since no barriers are expected under baseline flow conditions, limited “baseline” monitoring of CLT-2 will be undertaken during this initial study to validate predictions made in the FEIS. The stream will be visited opportunistically in the spring and fall during low flow years. More detailed monitoring of the fish-bearing section of CLT-2 will be undertaken once the Project has advanced to full-scale mining and the potential flow reductions identified in the FEIS have been realized.

2.4 SHEARDOWN LAKE TRIBUTARY 1 (SLDT-1)

Only four tributaries of Sheardown Lake support fish, and, of these, only one is of substantial size (SLDT-1). Three of the four fish-bearing tributaries (SDLT 1, SLDT 9, and SLDT 12) will be affected by a combination of open pit mining, ore stockpile placement and the associated water management practices during the Project’s operations and closure phases (Page 226 in Volume 7; Baffinland, 2012).

SDLT-1 (Tributary 1) and its main branch (Tributary 1b) flow into the northwest basin of Sheardown Lake and provide approximately 3 km of fish-bearing stream channel before reaching parts of the tributary that would not be passable to fish (Figure 3). Much of the stream is riffle or riffle/pool habitat over a predominantly cobble substrate and it is shallow (<0.1 m deep). The stream depth increases in the mid-section (up to 0.5 m) and both riffles and pools are present. Further upstream, the tributary forms a series of broad shallow pools. Stream habitat upstream of these pools is limited, consisting of a shallow (<0.1 m) stream with a cobble/boulder substrate and little cover. Cover in Tributary 1 varies with position, but is provided by boulders, undercut banks, and deep pools. SDLT-1 is the largest tributary of Sheardown Lake, providing important open water habitat for juvenile Arctic Char. Two potential barriers were identified within SDLT-1 (Figure 3).

The SDLT-1 stream contains stream gauge station H11 (established in 2011). Discharge hydrographs and rating curves have been developed for this stream.

During the operating and closure phases of the Project, SDLT-1 will experience flow reductions in the range of 21 to 35%. Post-closure, SDLT-1 will continue to experience a reduction in flows of 6 to 20% throughout the open-water period due to diversion of water around the open pit.

Monitoring within SDLT-1 will include the identified potential barrier locations within the lower reach near the outlet to the northwest lake basin and the other reach near the mine access road upstream. The proposed monitoring program will improve the mine’s understanding of the flow and fish utilization conditions under different flow regimes (i.e., in the spring and fall).

2.5 SHEARDOWN LAKE TRIBUTARY 9 (SDLT-9)

SDLT-9 is characterized by cascade/pool habitat over cobble with varying amounts of boulder, gravel and/or sand (NSC, 2012). SDLT-9 drains a small fish-bearing lake with sufficient depth for overwintering, but an impassable barrier prevents upstream access from Sheardown Lake. Use of Tributary 9 habitat downstream of the barrier can also be limited due to lack of connectivity to Sheardown Lake under low flow conditions.

During operation of the railway project, SDLT-9 will experience an estimated 29% reduction in open-water season flows during operation and closure. Ore stockpiles will be removed at closure, so SDLT-9 flows will only be impacted during operations and closure. No Project-related reduction in flows is anticipated in SDLT-9 during the ERP, since there are no ERP facilities within this catchment.

SDLT-9 will be monitored during this initial program to understand the frequency and duration of fish barriers between Sheardown Lake and the small lake during low flow conditions (Figure 3). The presence and/or absence of fish will also be noted during low flow conditions.

2.6 SHEARDOWN LAKE TRIBUTARY 12 (SDLT-12)

SDLT-12 is similar to SDLT-9 and characterized by cascade/pool habitat over cobble with varying amounts of boulder, gravel and/or sand. Fish use of SDLT-12 is limited by an impassable waterfall and low flows during much of the open-water season.

SDLT-12 will experience an estimated 15% reduction in open-water season flows during operation and closure. Ore stockpiles will be removed at closure, so SDLT-12 flows will only be impacted during operations and closure. No Project-related reduction in flows is anticipated in SDLT-12 during the ERP, since there are no ERP facilities within this catchment.

SDLT-12 will be monitored during this initial program to understand the frequency and duration of fish barriers between Sheardown Lake and the permanent fish barrier (waterfall) during low flow conditions. The presence and/or absence of fish will also be noted during low flow conditions.

3 – MONITORING PROGRAM METHODOLOGY

The five streams of interest will be monitored in spring and fall during the initial years of operation. Low and high flow periods will be targeted where possible. Results of this initial monitoring will be reviewed to determine whether mitigation and/or ongoing monitoring is required. In spring, all five streams will be visually assessed to monitor for potential barriers and obstructions to upstream fish passage.

Surveys will document conditions within the monitoring streams between the upstream fish barriers and their outlets into Camp Lake and Sheardown Lake. The survey will utilize a field sheet (Appendix A) to document in situ conditions, including:

- A visual inspection along the targeted stream reaches
- Measurements of total water depth and point velocities at locations that may pose barriers to fish passage
- Instantaneous flow measurements within the SDLT-9 and SDLT-12 tributaries (not currently gauged)
- Photographing the potential natural barriers (facing upstream, downstream and the left and right banks). A minimum of 4 photos will be taken at each location.
- Documenting the presence and location of fish during the stream inspections

A target of two (2) spring surveys and three (3) fall surveys has been set. The number of surveys completed will be subject to on-site resource availability.

Other monitoring programs will contribute data relevant to this study. For example, Baffinland`s hydrology monitoring program includes stream gauges on three streams monitored under this program, and the freshwater biota monitoring will be undertaken as part of the Core Receiving Environment Monitoring Program (CREMP). Monitoring data from both these programs will be used in the analysis of data from this initial stream diversion monitoring study.

4 – ANALYSIS OF MONITORING RESULTS

The proposed Initial Stream Diversion Study will be completed annually over the next three years (2014, 2015 and 2016) followed by a review at the end of 2016. At the end of the three-year initial program, a report will be produced that summarizes the monitoring data and presents an analysis of results, including:

- Hydrographs from the existing stream gauging stations - The hydrograph results for the three years will be compared to historical hydrology records to better understand how flows varied throughout the year and how the flow rates compared to historical norms.
- The flow and water depths will also be compared to the values presented in support of the FEIS (KP, 2011 and 2012).
- Presentation of fish barrier identification information - This information will be summarized in tabular format and will most likely be organized by fish barrier or transect location. Comments will be provided on how the presence of specific fish barriers relate to flow conditions. This may help identify when specific sections of the streams become barriers to fish passage.
- Fish stranding information - A discussion on the frequency, timing and duration of current fish stranding. Comments will be provided on whether these events are likely to result in fish mortalities.

The 3-year initial stream diversion study monitoring report will be presented with the AEMP Annual Monitoring Report in the first half of 2017. The report will also include recommendations on potential mitigation measures and future monitoring.

Continuation of the monitoring program will depend upon the schedule and size of the Project. The Approved Project (18 Mt/a) will result in meaningful reductions in streamflow and monitoring will be required to identify Project-related fish barriers and fish stranding. If the ERP were to continue beyond 2017 and the 3-year study has met the stated objectives, then this targeted study may be discontinued until such time as the Approved Project proceeds. If possible, monitoring for the Approved Project will start one year prior to the start of larger scale mining.

5 – POTENTIAL MITIGATION MEASURES

A number of mitigation measures have been identified in the FEIS (Baffinland, 2012) and the Updated AEMP Framework (Baffinland, 2013), including:

- Monitoring and salvage fisheries
- Channel improvements
- Exclusion of Arctic Char from streams

Since the ERP will result in minimal to no changes in flows, implementation of mitigation measures will not be required within the initial three year study period. These mitigation options will be carried forward for consideration when the Project has reached full scale and the Project-related changes in flow can be expected to occur.

6 – REFERENCES

Baffinland Iron Mines Corporation, 2012. *Mary River Project Final Environmental Impact Statement*. February 2012.

Baffinland Iron Mines Corporation, 2013. *Mary River Project - Addendum to the Final Environmental Impact Statement*. June 2013.

Knight Piésold Ltd., 2011. Memorandum to: Richard Remnant, North/South Consultants Inc. Re: *Mary River Project - Revised Habitat Assessment Support*. December 16. Ref. No. VA11-01684.

Knight Piésold Ltd., 2012. Memorandum to: Richard Remnant, North/South Consultants Inc. Re: *Mary River Project - Fish Passage Barrier Assessment Support*. January 9. Ref. No. VA12-00095.

North/South Consultants Inc., 2008. *Freshwater Aquatic Environment Baseline Report: Fish and Fish Habitat 2007 DRAFT*. April 2008.

North/South Consultants Inc., 2012. *Freshwater Aquatic Biota and Habitat Baseline Synthesis Report 2005-2011*. January 2012.

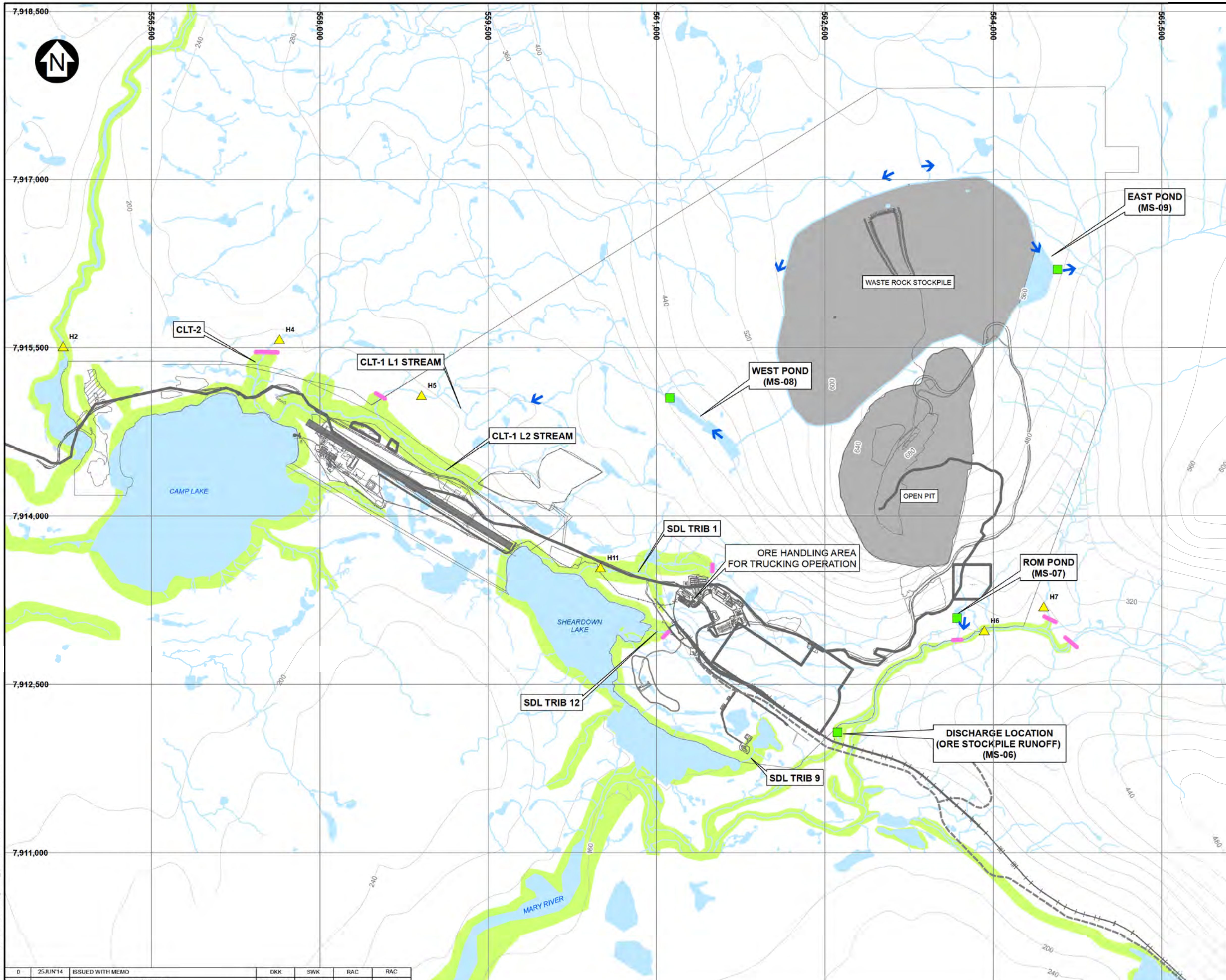
Signed: for Dale Klodnicki, C.E.T. - Environmental Technologist

Reviewed and Approved: Richard Cook, B.Sc. - Senior Scientist

Attachments:

Figure 1 Rev 0	Diversion Study Area Streams
Figure 2 Rev 0	Camp Lake Tributaries Subject to Monitoring
Figure 3 Rev 0	Sheardown Lake Tributaries Subject to Monitoring
Appendix A	Stream Diversion Field Data Sheet

/dkk



LEGEND:

- FINAL DISCHARGE POINT
- STREAM FLOW GAUGING STATION
- FISH BARRIER
- EXISTING TOTE ROAD
- PROPOSED RAILWAY ALIGNMENT
- PROPOSED CONSTRUCTION ACCESS ROAD
- PROPOSED SITE INFRASTRUCTURE
- RIVER/STREAM/DRAINAGE
- WATER
- CONFIRMED ARCTIC CHAR HABITAT

NOTES:

1. BASE MAP: © HER MAJESTY THE QUEEN IN RIGHTS OF CANADA, DEPARTMENT OF NATURAL RESOURCES (2004). ALL RIGHTS RESERVED.
2. COORDINATE GRID IS UTM NAD83 ZONE17.
3. CONTOURS ARE IN METRES. CONTOUR INTERVAL VARIES.
4. INFRASTRUCTURE INFORMATION PROVIDED BY HATCH ON JANUARY 31, 2014.
5. ARCTIC CHAR HABITAT (PRESENCE) FROM NSC, 2012 MARY RIVER PROJECT FRESHWATER AQUATIC BASELINE SYNTHESIS. REPORT: 2005-2011.

SCALE 250 125 0 250 500 750 1,000 1,250 1,500 m

BAFFINLAND IRON MINES CORPORATION

MARY RIVER PROJECT

DIVERSION STUDY AREA STREAMS

Knight Piésold CONSULTING

P/A NO	REF NO
NB102-181/34	NB14-00160

FIGURE 1 REV 0

REV	DATE	DESCRIPTION	DESIGNED	DRAWN	CHK'D	APP'D
0	25JUN'14	ISSUED WITH MEMO	DKK	SWK	RAC	RAC

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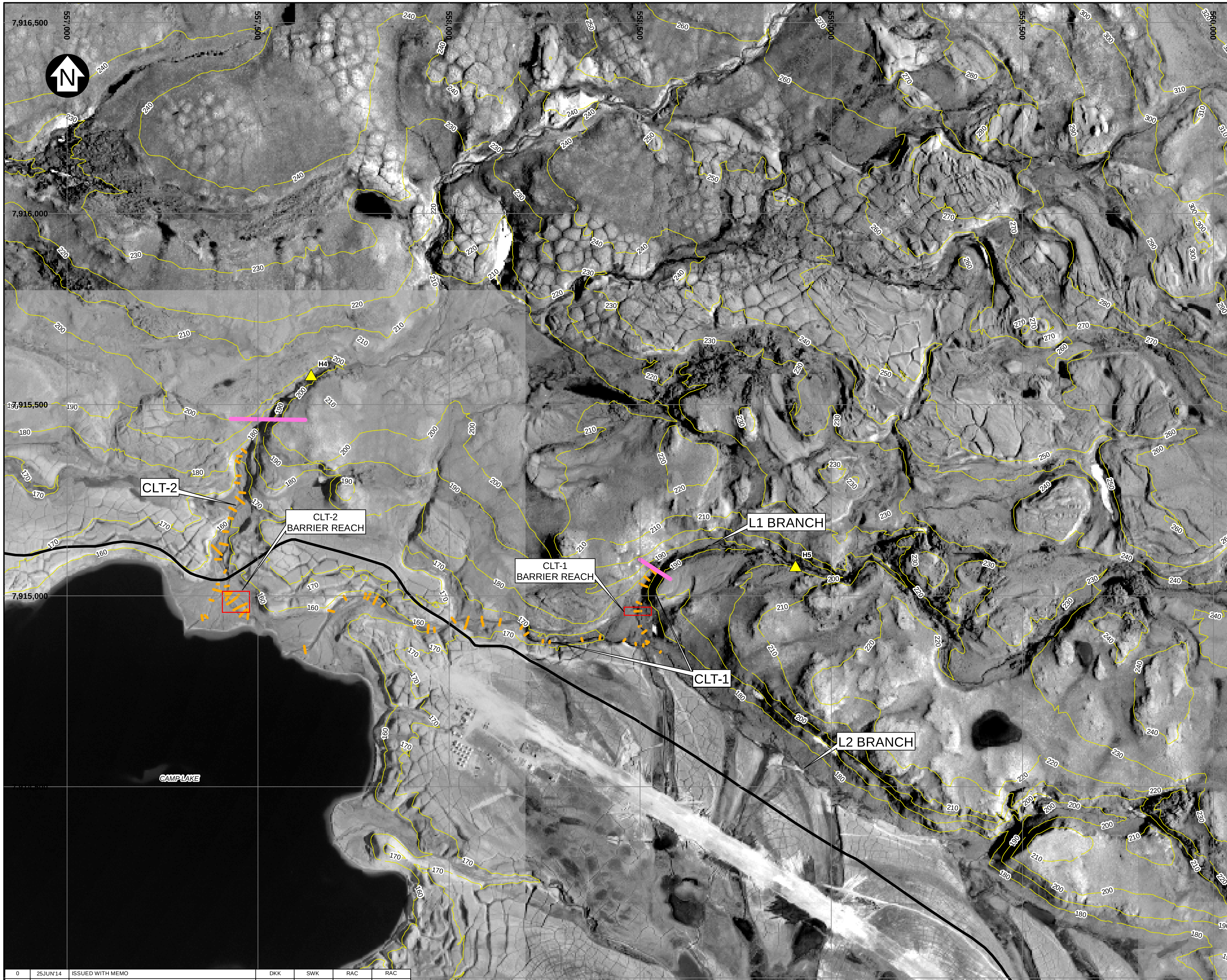

LEGEND:

- STREAM FLOW GAUGING STATION
- FISH BARRIER
- PREVIOUS TRANSECT LINE (KNIGHT PIESOLD, 2011)
- MILNE INLET TOTE ROAD
- CONTOUR

NOTES:

1. TOPOGRAPHY AND ORTHOPHOTOS PROVIDED BY EAGLE MAPPING (2005).
2. COORDINATE GRID IS IN METRES. COORDINATE SYSTEM: NAD 1983 UTM ZONE 17N.
3. CONTOUR INTERVAL IS 10 METRES.

SCALE 100 50 0 100 200 300 400 500 m

BAFFINLAND IRON MINES CORPORATION

MARY RIVER PROJECT

CAMP LAKE TRIBUTARIES SUBJECT TO MONITORING

Knight Piésold CONSULTING

P/A NO.	REF NO.
NB102-181/34	NB14-00160

FIGURE 2 REV 0

0	25JUN'14	ISSUED WITH MEMO	DKK	SWK	RAC	RAC
REV	DATE	DESCRIPTION	DESIGNED	DRAWN	CHK'D	APP'D

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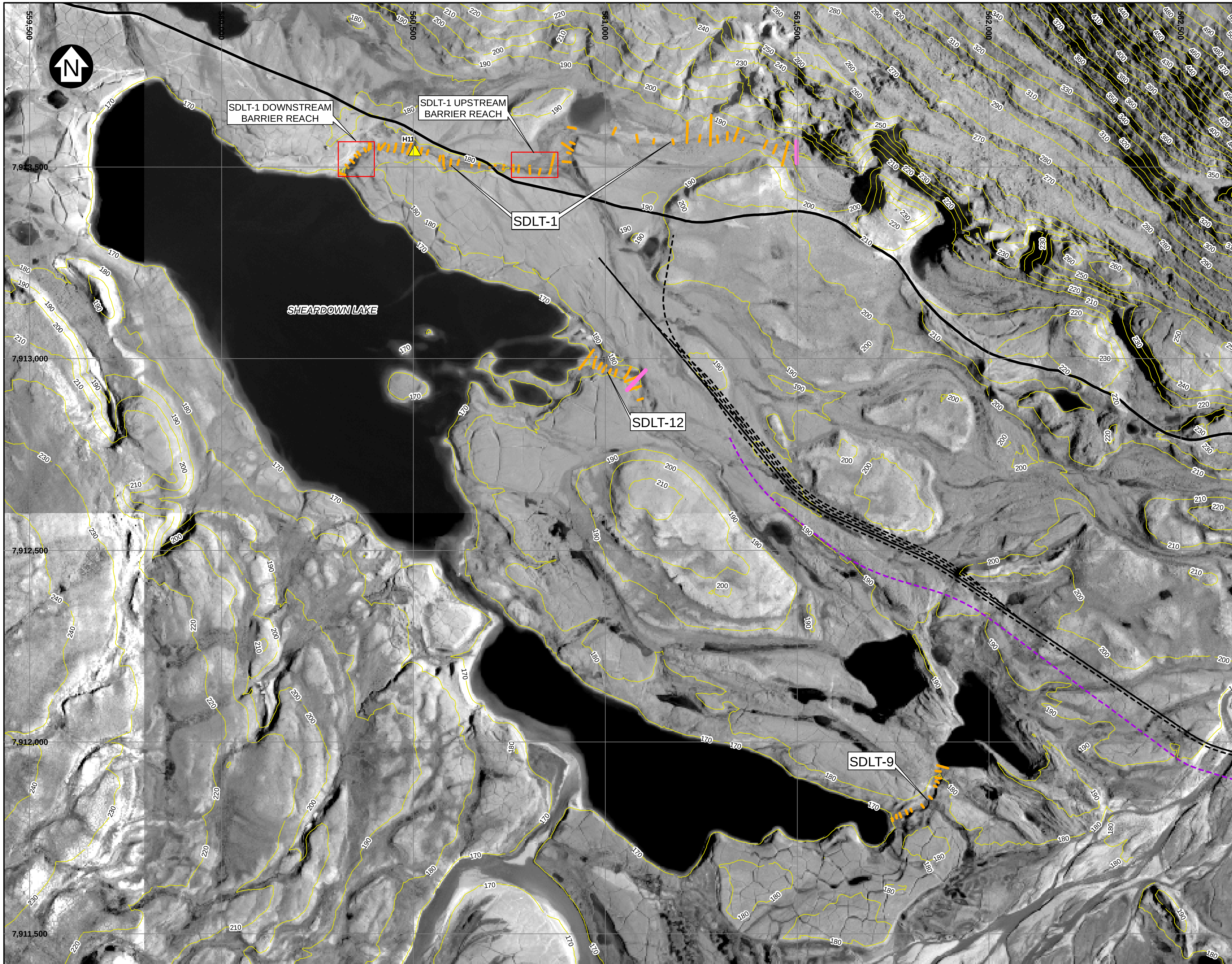

LEGEND:

- STREAM FLOW GAUGING STATION
- FISH BARRIER
- PREVIOUS TRANSECT LINE (KNIGHT PIESOLD, 2011)
- MILNE INLET TOTE ROAD
- PROPOSED RAILWAY ALIGNMENT
- PROPOSED CONSTRUCTION ACCESS ROAD
- CONTOUR

NOTES:

1. TOPOGRAPHY AND ORTHOPHOTOS PROVIDED BY EAGLE MAPPING (2005).
2. COORDINATE GRID IS IN METRES. COORDINATE SYSTEM: NAD 1983 UTM ZONE 17N.
3. CONTOUR INTERVAL IS 10 METRES.
4. RAILWAY ALIGNMENT PROVIDED BY CANARAIL CONSULTANTS INC. (AUGUST, 2010).

SCALE 100 50 0 100 200 300 400 500 m

BAFFINLAND IRON MINES CORPORATION

MARY RIVER PROJECT

SHEARDOWN LAKE TRIBUTARIES SUBJECT TO MONITORING

Knight Piésold CONSULTING

P/A NO.	REF NO.
NB102-181/34	NB14-00160

FIGURE 3 REV 0

REV	DATE	DESCRIPTION	DESIGNED	DRAWN	CHK'D	APP'D
0	25JUN'14	ISSUED WITH MEMO	DKK	SWK	RAC	RAC

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Knight Piésold
CONSULTING

APPENDIX A

STREAM DIVERSION FIELD DATA SHEET

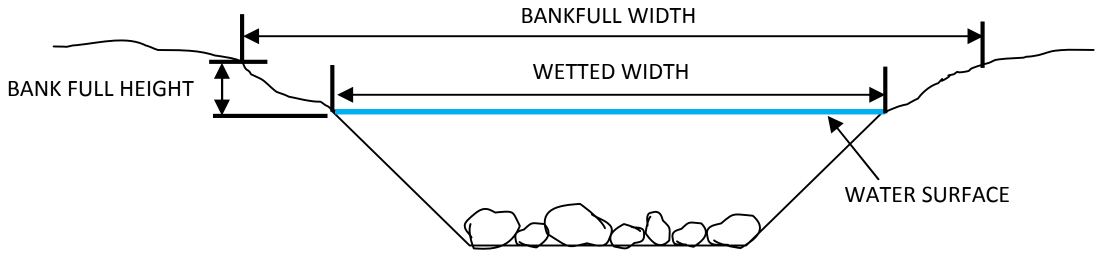
(Page A-1)

Knight Piésold CONSULTING

STREAM DIVERSION FIELD DATA SHEET

PROJECT NO: NB102-181/34	**WATER BODY:**	**DATE(ddmmmyyyy):**
FIELD CREW:	**START TIME:**	**END TIME:**
WEATHER:		

CHANNEL CHARACTERISTICS



Station ID:	**UTM Easting (m):**	**UTM Northing (m):**
Wetted Width (m):	**Bank Full Width (m):**	**Bank Full Height (m):**

Photos (check): ☐ Upstream ☐ Right Bank ☐ Downstream ☐ Left Bank

Depth/Point Velocity measurements across the stream

Total Depth (m):	m	m	m	m	m	m
Velocity (m/s):	m/s	m/s	m/s	m/s	m/s	m/s
Total Depth (m)	m	m	m	m	m	m
Velocity (m/s):	m/s	m/s	m/s	m/s	m/s	m/s

Fish Presence (circle US/DS) : US / DS >10 individuals US / DS <10 individuals US / DS No Fish Observed

Comments:

Station ID:	**UTM Easting (m):**	**UTM Northing (m):**
Wetted Width (m):	**Bank Full Width (m):**	**Bank Full Height (m):**

Photos (check): ☐ Upstream ☐ Right Bank ☐ Downstream ☐ Left Bank

Depth/Point Velocity measurements across the stream

Total Depth (m):	m	m	m	m	m	m
Velocity (m/s):	m/s	m/s	m/s	m/s	m/s	m/s
Total Depth (m)	m	m	m	m	m	m
Velocity (m/s):	m/s	m/s	m/s	m/s	m/s	m/s

Fish Presence (circle US/DS) : US / DS >10 individuals US / DS <10 individuals US / DS No Fish Observed

Comments:

Incidental Fish Observations

UTM Easting (m)	**UTM Northing (m)**	**Fish:**	☐ >10 individuals	☐ <10 individuals
UTM Easting (m)	**UTM Northing (m)**	**Fish:**	☐ >10 individuals	☐ <10 individuals
UTM Easting (m)	**UTM Northing (m)**	**Fish:**	☐ >10 individuals	☐ <10 individuals
UTM Easting (m)	**UTM Northing (m)**	**Fish:**	☐ >10 individuals	☐ <10 individuals
UTM Easting (m)	**UTM Northing (m)**	**Fish:**	☐ >10 individuals	☐ <10 individuals
UTM Easting (m)	**UTM Northing (m)**	**Fish:**	☐ >10 individuals	☐ <10 individuals
UTM Easting (m)	**UTM Northing (m)**	**Fish:**	☐ >10 individuals	☐ <10 individuals