Appendix B

Development of CREMP Water and Sediment Quality Benchmarks

SCIENCE INTEGRITY KNOWLEDGE

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

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 97.5th 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).

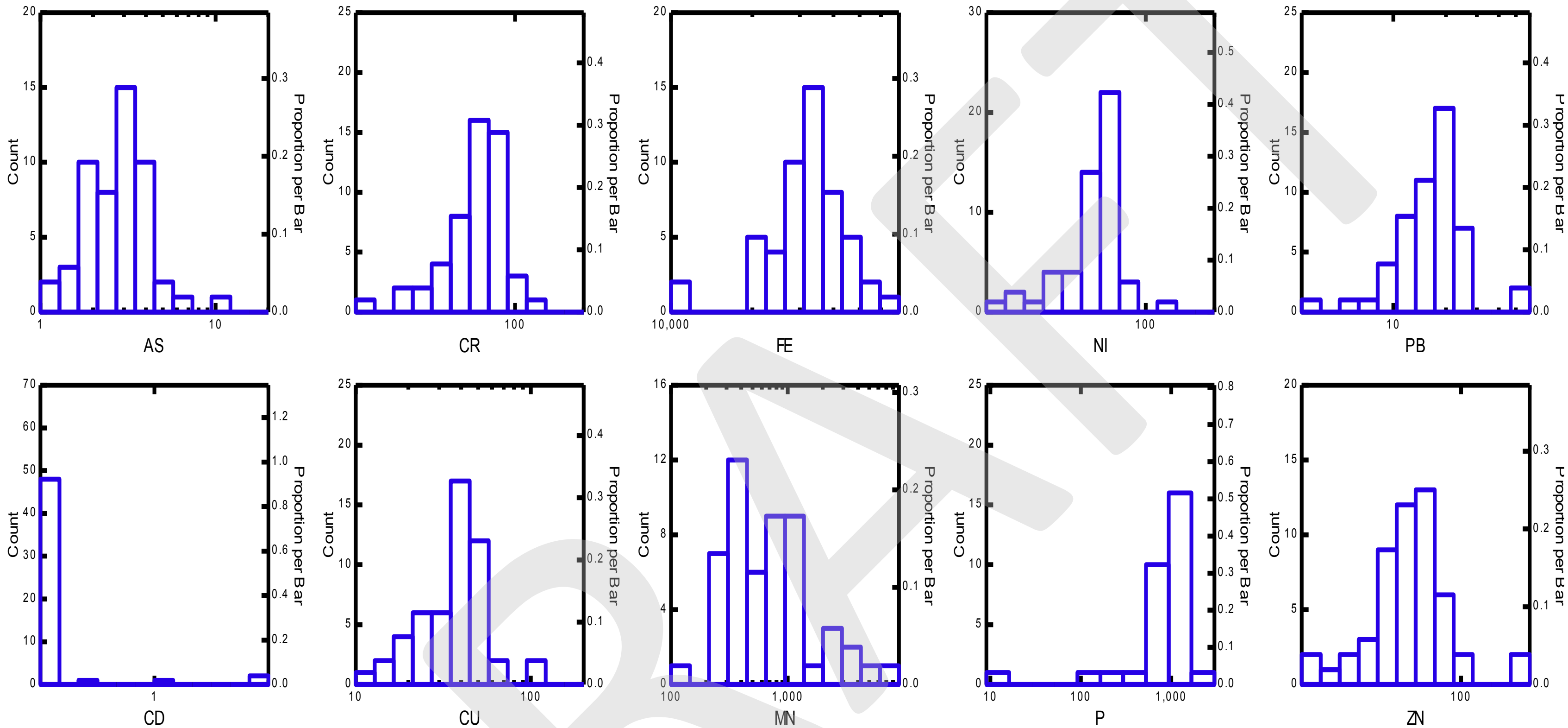

Figure 2-1 Log10 Histograms of Area-Wide Sediment Data (N=52), by Metal of Interest

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 (95th percentile and 97.5th 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, 95th percentile and the 97.5th 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 95th 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

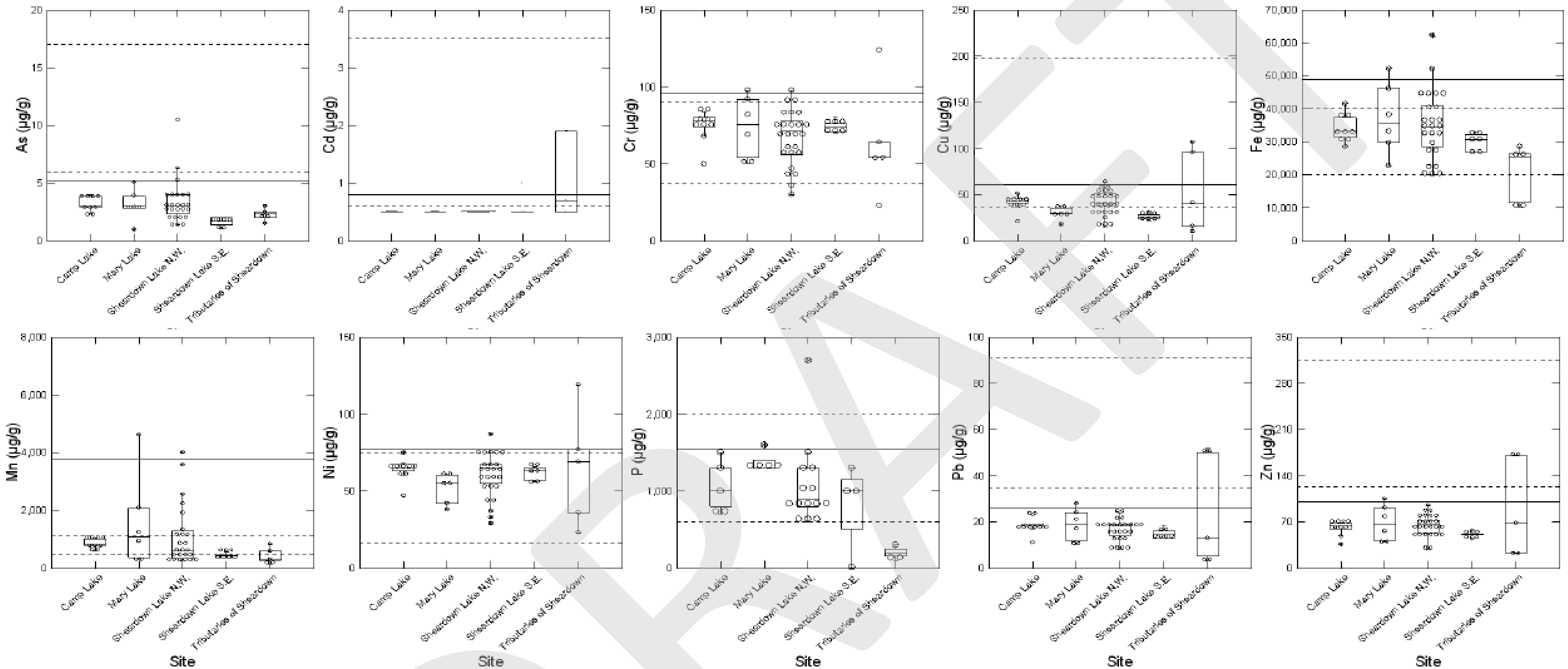

Figure 2-2 Box and Whisker Plots of Metal Concentrations by Area (Solid line represents 95th percentile of area-wide data; dotted lines represent ISQG/LEL and PEL/SEL sediment quality guidelines, respectively)

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.

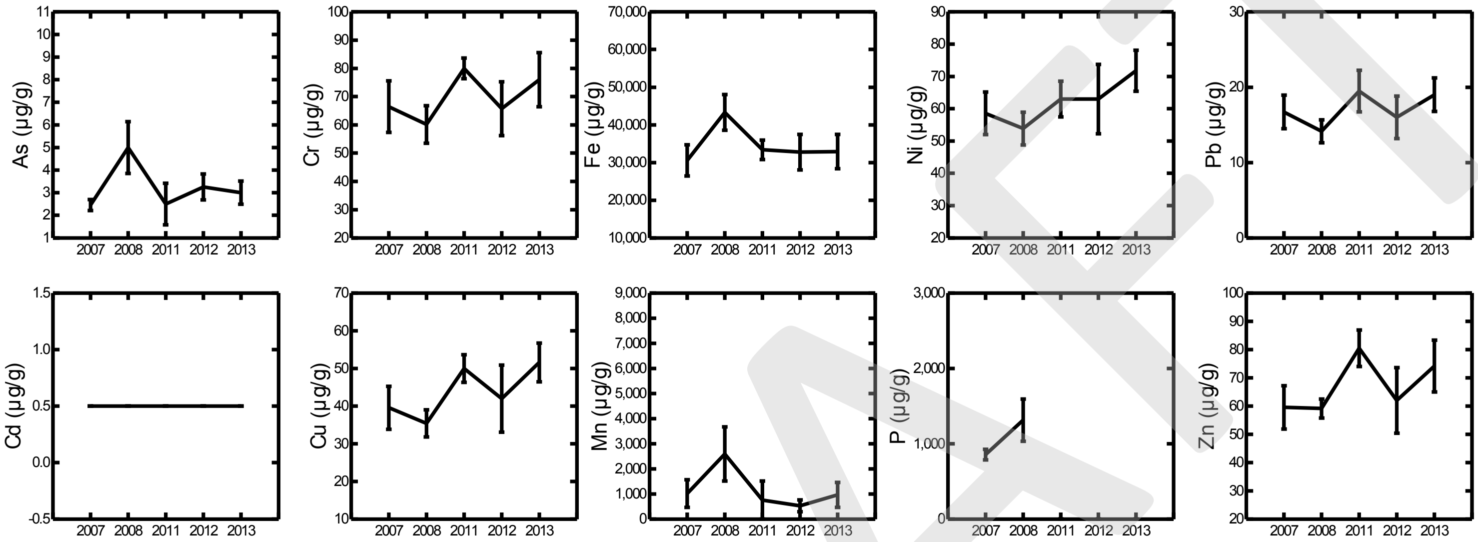

Figure 2-3 Temporal Trend Analysis for Sheardown Lake NW (n = 25) for Various Parameters (mean +/- std error)

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:

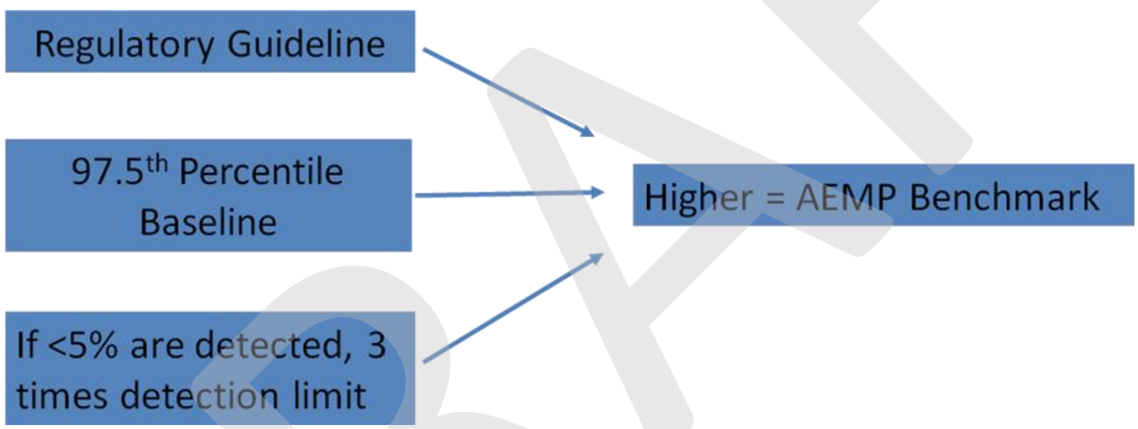

Figure 2-4 Approach for Selecting AEMP Benchmarks

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 97.5th percentiles) 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 95th percentile were investigated. The 95th percentile indicates the value below which 95% of the observations in a group occur. Empirical 95th 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.

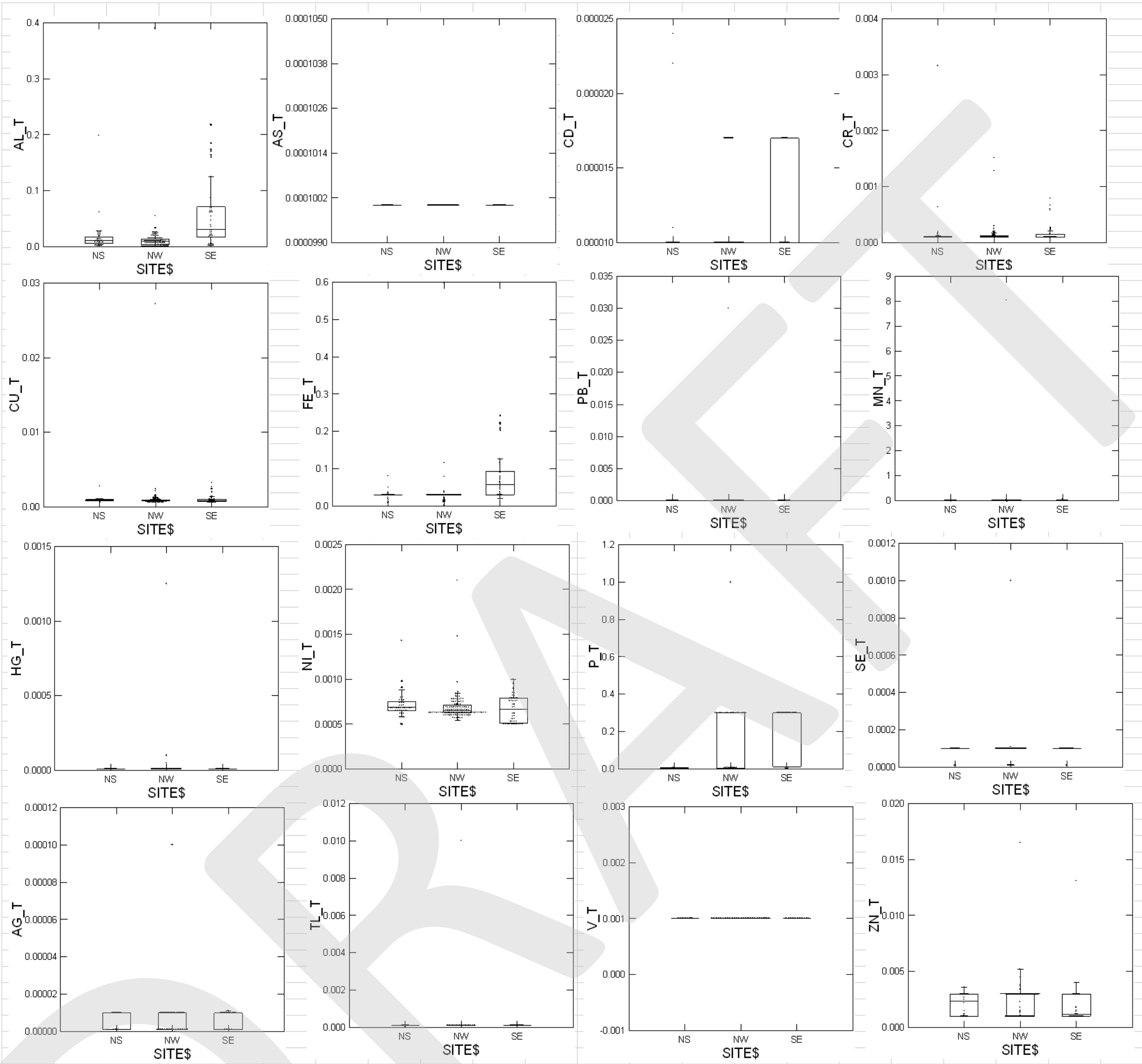

Figure 3-1 Total Metals (mg/L) Compared Between Various Sheardown Lake Sampling Locations (Nearshore (NS), Northwest (NW) and Southeast (SE)); T = total; Non-detectable values replaced with detection limit

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	^{o}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	^{o}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	***Units***	***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	^{o}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	^oC	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	^oC	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:
25^{th} percentile pH: Camp Lake 7.3; Mary Lake 6.9; Sheardown Lake 7.3; Camp Lake Tributary 7.7; Mary River 7.6
25^{th} 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 25^{th}%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 25^{th}%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 25^{th}%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 97.5th percentile concentration was used as the statistical metric. A comparison of the selected water quality guidelines to the 97.5th 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

Agnico-Eagle, 2012. Core Receiving Environment Monitoring Program (CREMP): Design Document 2012 Meadowbank Mine. Prepared for Agnico-Eagle Mines Limited. Baker Lake, Nunavut. Prepared by: Azimuth Consulting Group Inc., Vancouver, B.C.

CCME (Canadian Council of Ministers of the Environment), 2002. Canadian sediment quality guidelines for the protection of aquatic life: Introduction.

CCME (Canadian Council of Ministers of the Environment). 2003. Canadian water quality guidelines for the protection of aquatic life: Guidance on the site-specific application of water quality guidelines in Canada: Procedures for deriving numerical water quality objectives. In: Canadian environmental quality guidelines, 1999. Winnipeg, MB.

CCME (Canadian Council of Ministers of the Environment). 2007. Canadian water quality guidelines for the protection of aquatic life: Summary table. Updated December 2007. In: Canadian environmental quality guidelines, 1999. Winnipeg, MB.

CCME (Canadian Council of Ministers of the Environment). 2014. Canadian Water Quality Guidelines for the Protection of Aquatic Life: Summary Table. http://ceqg-rcqe.ccme.ca/

CCME, 1987. Water Quality for the Protection of Aquatic Life. Guidelines for Aluminium, Copper, Iron, Lead, Nickel, Silver, Zinc, and Nitrogen-Nitrate. Summary Table http://ceqg-rcqe.ccme.ca/

CCME, 1997a. Sediment Quality for the Protection of Aquatic Life. Guidelines for Cadmium and Mercury. Summary Table http://ceqg-rcqe.ccme.ca/

CCME, 1997b. Water Quality for the Protection of Aquatic Life. Guidelines for Arsenic, Chromium III, and Chromium VI. Summary Table http://ceqg-rcqe.ccme.ca/

CCME, 1998. Sediment Quality for the Protection of Aquatic Life. Guidelines for Arsenic, Chromium, Copper, Lead and Zinc. Summary Table http://ceqg-rcqe.ccme.ca/

CCME, 1999. Water Quality for the Protection of Aquatic Life. Guidelines for Thallium. Summary Table http://ceqg-rcqe.ccme.ca/

CCME, 2001. Water Quality for the Protection of Aquatic Life. Guidelines for Nitrogen-Nitrite.Summary Table http://ceqg-rcqe.ccme.ca/

CCME, 2011. Water Quality for the Protection of Aquatic Life. Guidelines for Ammonia. Summary Table http://ceqg-rcqe.ccme.ca/

CCME, 2012. Water Quality for the Protection of Aquatic Life. Guidelines for Chloride. Summary Table http://ceqg-rcqe.ccme.ca/

CCME, 2014. Water Quality for the Protection of Aquatic Life. Guidelines for Cadmium. Summary Table http://ceqg-rcqe.ccme.ca/

Golder, 2012. Water Quality Objectives (WQO) and Sediment Quality Objectives (SQO) for the Proposed Gahcho Kue Project – Recommendations. Technical Memorandum. September 14, 2012. To: Veronica Chisholm, De Beers Canada, Inc. From: Peter M. Chapman.

Knight Piésold, 2014. Appendix B, AEMP. Water and Sediment Quality Review and CREMP Study Design. Knight Piésold Ltd. 1650 Main Street, North Bay, Ontario.,

MacDonald. D.D., B. Zajdlik, and INAC Water Resources. 2009. Guidelines for Designing and Implementing Aquatic Effects Monitoring Programs for Development Projects in the Northwest Territories. Overview Report. Version 1, June 2009.

Meays, C., and R. Nordin, 2013. Ambient Water Quality Guidelines for Sulphate. Technical Appendix Update. 2013. Ministry of Environment, Province of British Columbia. Water Protection & Sustainability Branch. http://www2.gov.bc.ca/assets/gov/topic/C61AC40F96CC4628C24A5C95F5E09E1F/sulphate_final_guideline_april_2013.pdf

Nagpal, N.K. 2004.Technical Report – Water Quality Guidelines for Cobalt. Water Protection Section. Water, Air and Climate Change Branch. Ministry of Water, Land and Air Protection, British Columbia. (http://www.env.gov.bc.ca/wat/wq/BCguidelines/cobalt/cobalt_tech.pdf)

Nagpal, N.K., L. W. Pommen, L. G. Swain. 2006. A Compendium of Working Water Quality Guidelines for British Columbia (http://www.env.gov.bc.ca/wat/wq/BCguidelines/working.html#table1)

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.

OMOE (Ontario Ministry of Environment). 2011. Rationale for the development of soil and ground water standards for use at contaminated sites in Ontario. PIBS 7386e01. http://www.ene.gov.on.ca/stdprodconsume/groups/lr/@ene/@resources/documents/resource/stdprod_086518.pdf. Accessed January 28th, 2013.

Singh and Singh 2010. ProUCL Version 4.1.00 Technical Guide (Draft), EPA/600/R-07/041

US EPA, 2014. Freshwater Sediment Screening Benchmarks. Accessed in February, 2014. http://www.epa.gov/reg3hscd/risk/eco/btag/sbv/fwsed/screenbench.htm

Appendix C

Development of Final Sediment Quality Benchmarks

SCIENCE INTEGRITY KNOWLEDGE

intrinsik

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.

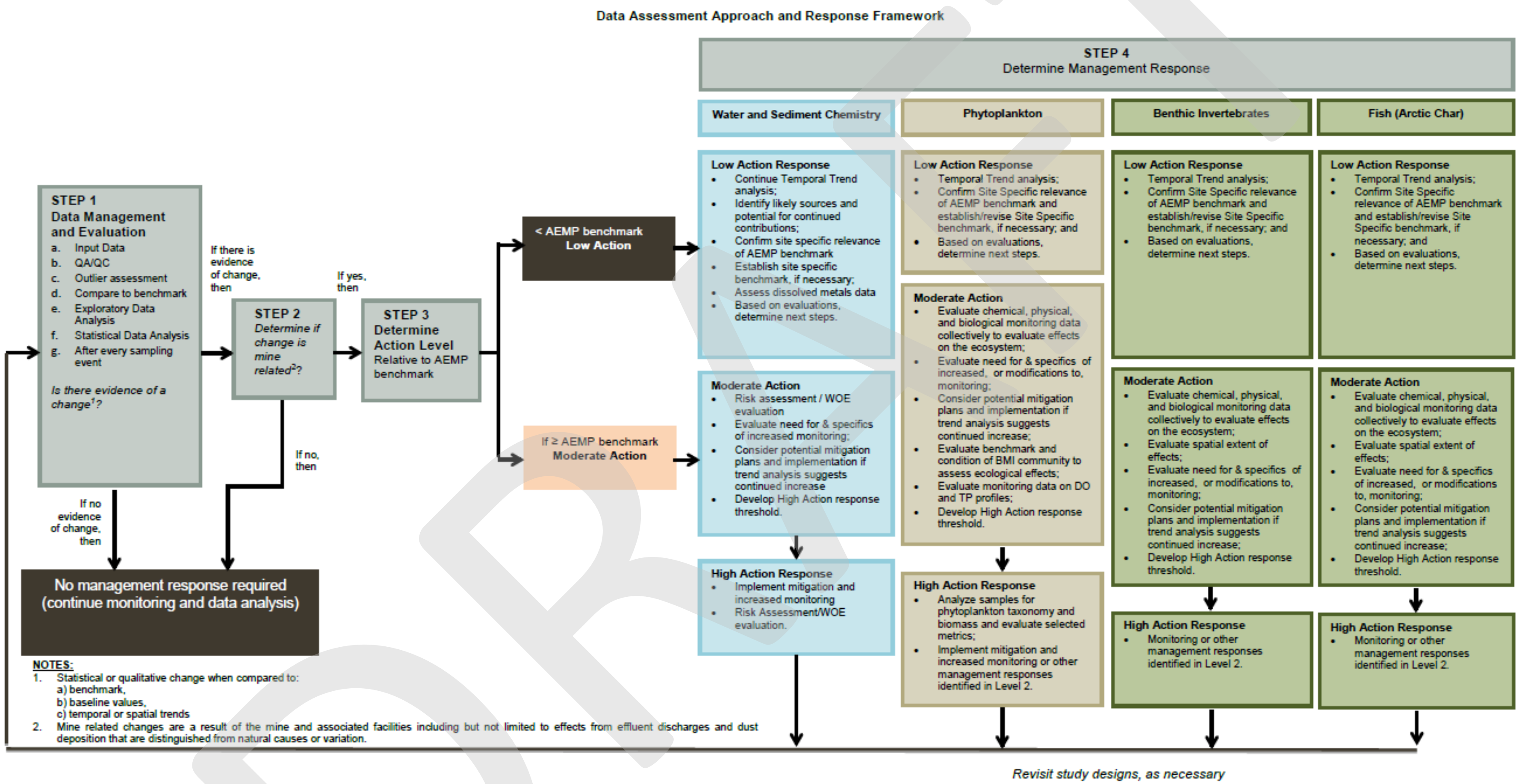


Figure 1-1 Data Assessment Approach and Response Framework

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 97.5^{th}%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.

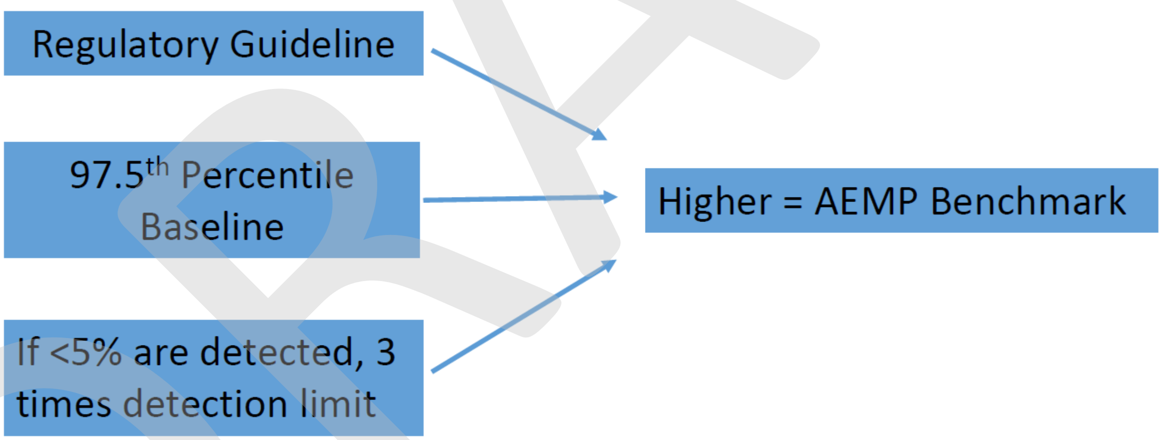


Figure 1-2 Process Used to Derive AEMP Sediment Benchmarks

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 97.5th%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 97.5th%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 97.5th 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

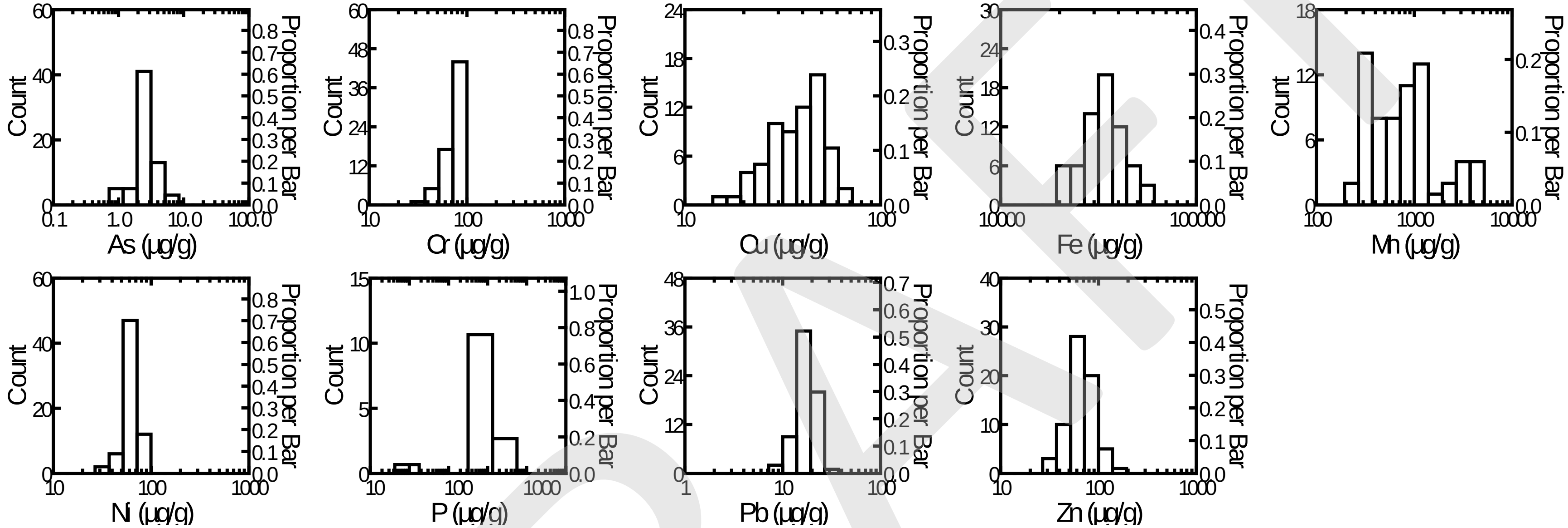


Figure A-2: Trend Analysis of All Lakes (2007 – 2014). Plotted data indicate mean ± standard error for each sampled year.

Figure A-2.1 Mary Lake (2007 – 2014)

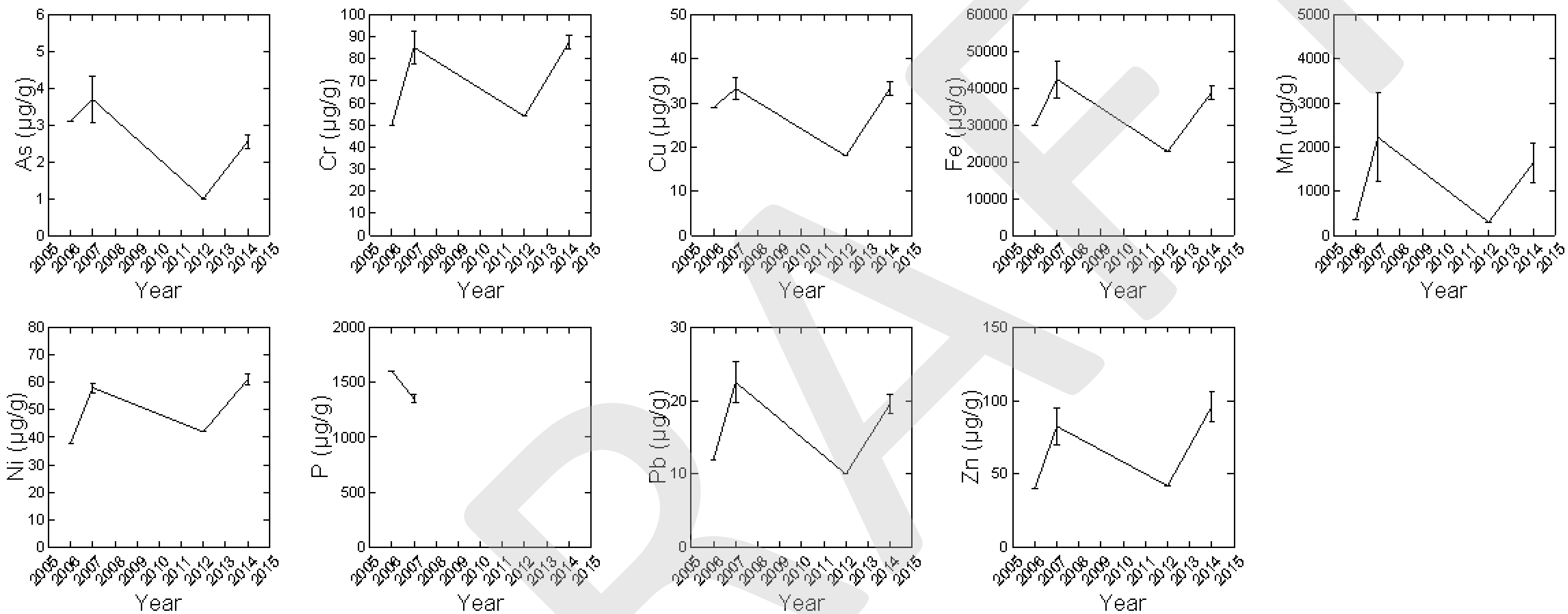


Figure A-2.2 Camp Lake (2007 – 2014)

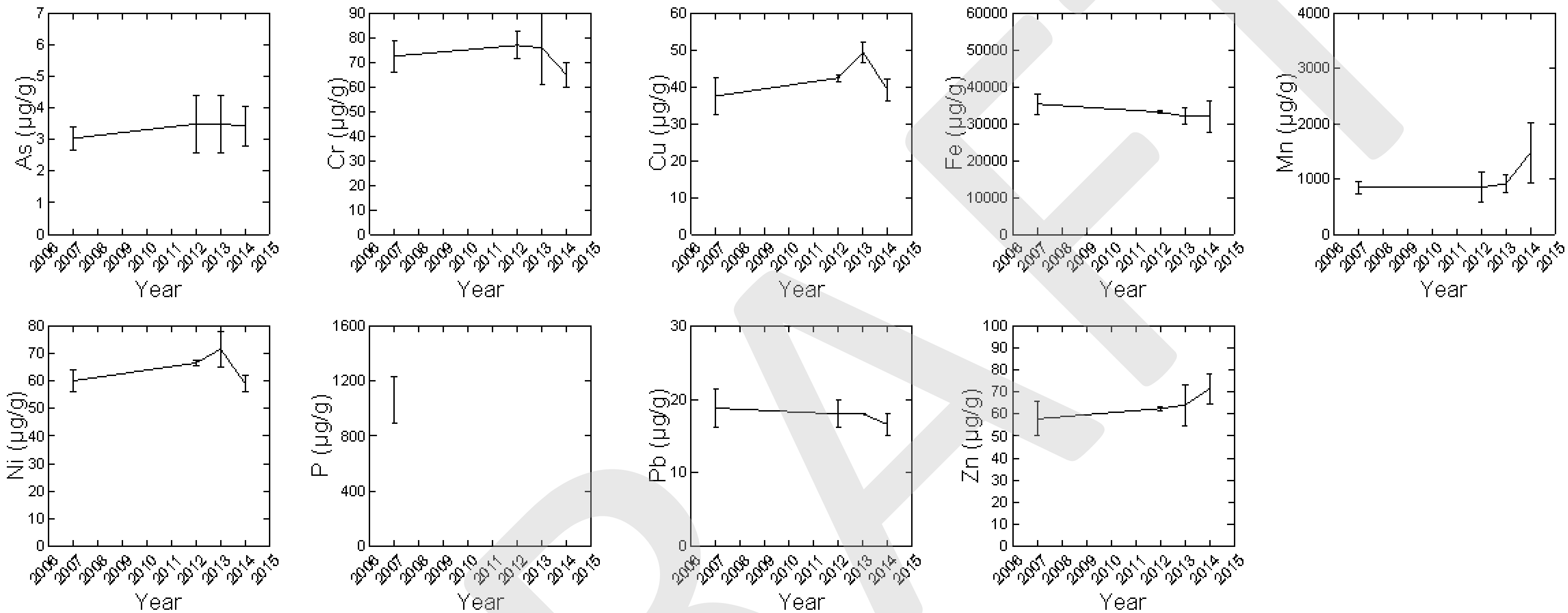


Figure A-2.3 Sheardown Lake NW (2007 – 2014)

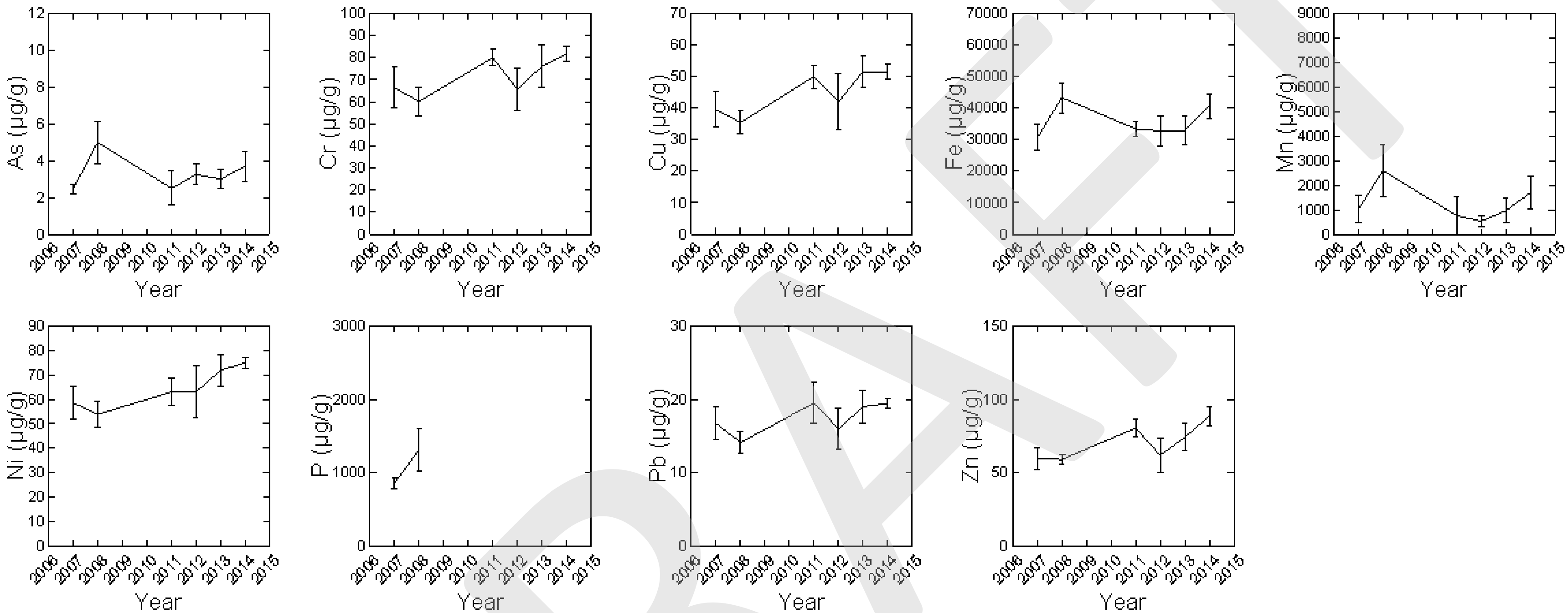


Figure A-2.4 Sheardown Lake SE (2007 – 2014)

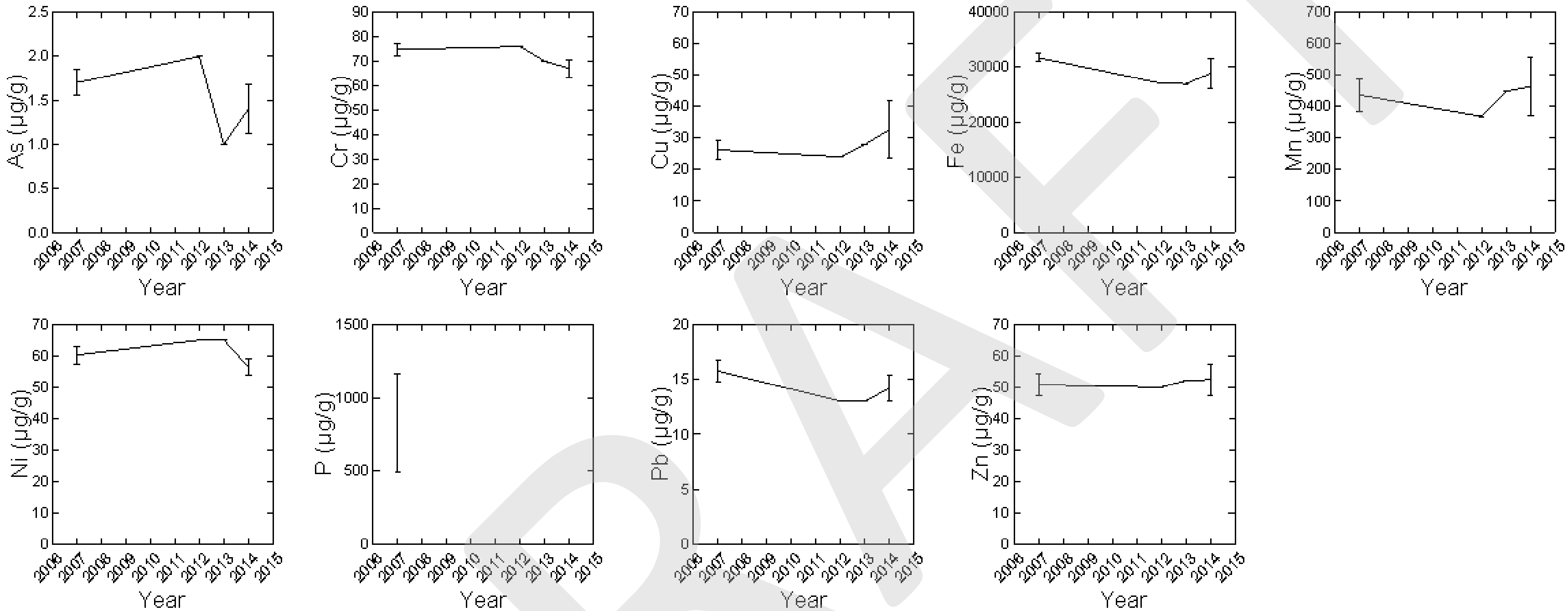
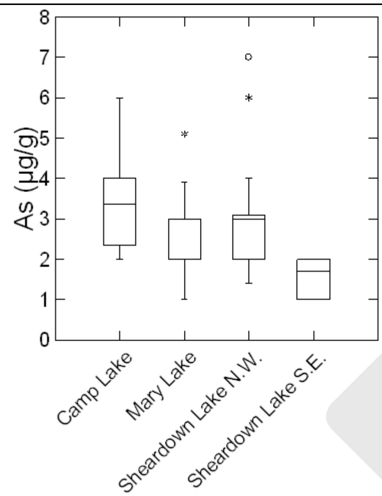
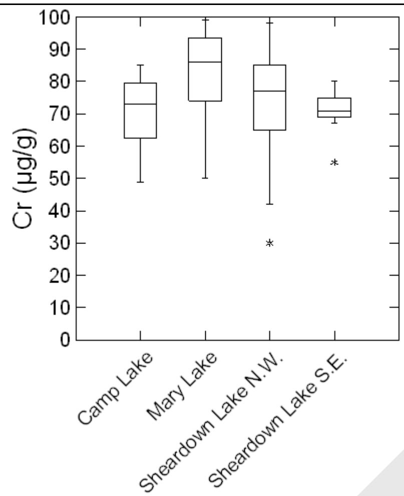
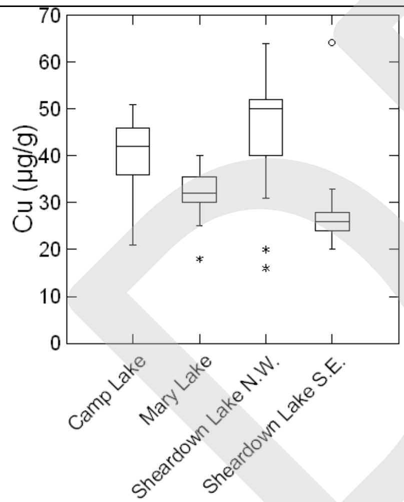
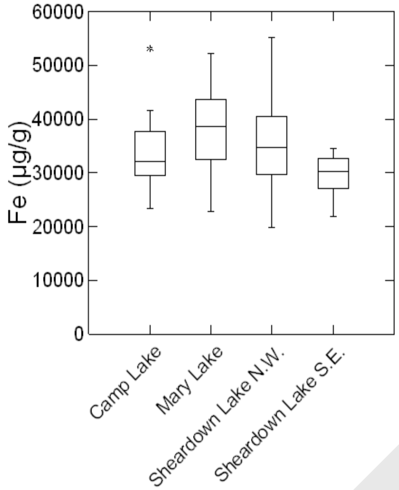
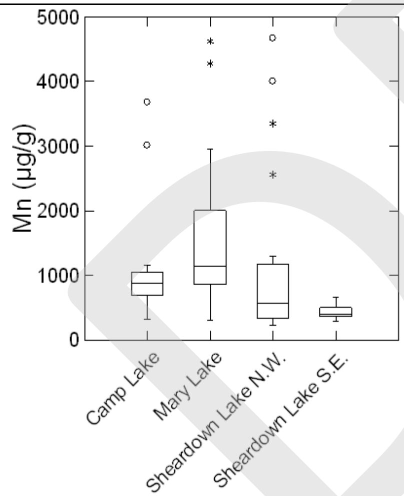
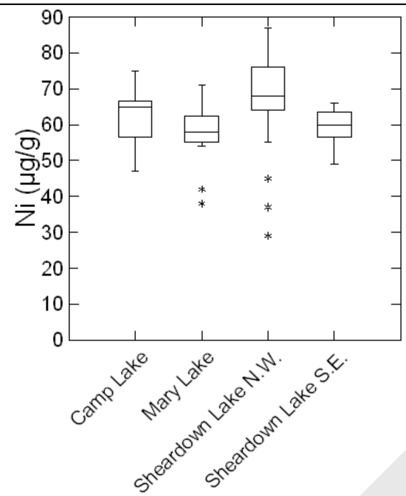
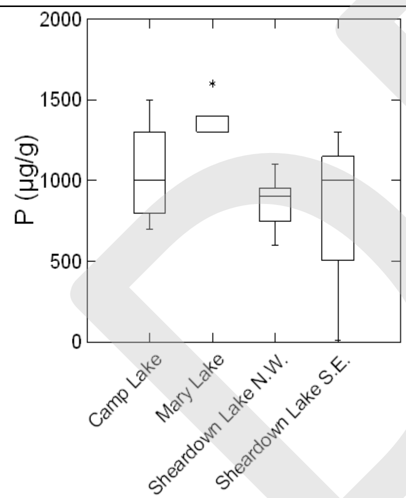


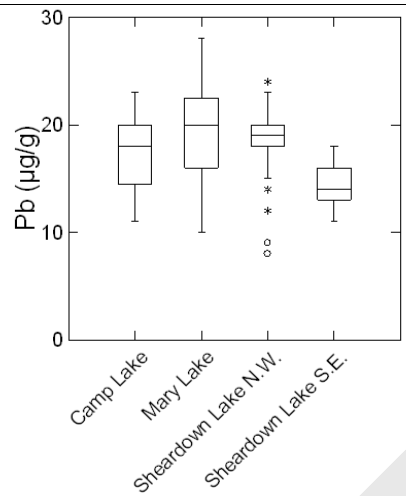
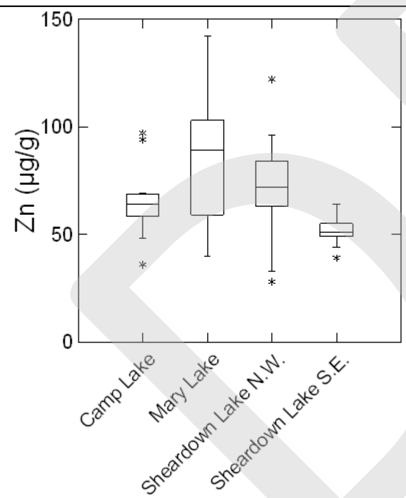
Table A-1: Boxplots and Statistical Comparisons By Site using Data for Camp Lake (2007 – 2014), Mary Lake (2007 – 2014), Sheardown Lake SE (2007 – 2014) and Sheardown Lake NW (2007 – 2014, excluding 2008)

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.

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
5	Added the Bray Curtis Index of Dissimilarity to the list of BMI metrics used to assess BMI data in future CREMP studies. (This was one of Environment Canada's requests/comments after reviewing final draft of AEMP in June 2014)	3.2
6	Updated BMI monitoring locations to reflect Minnow's proposed recommendations.	3.4.1
7	Changed BMI study design to focus on littoral habitats in lakes in order to reflect Minnow's proposed recommendations.	3.8
8	Updated adult fish survey protocol to reflect Minnow's recommendation of using gills nets with a standardized mesh size to reduce incidental mortalities and increase sampling efficiencies.	4.6
9	Reduced size of adult fish survey in lakes to 50 fish from 100 fish to reflect Minnow's recommendation.	4.8

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 95th 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.

5.0 LITERATURE CITED

Alberta Environment. (updated 2013). Lake water trophic status. http://environment.alberta.ca/01715.html. Accessed February 22, 2014.

Baker, T.T., and L.S. Timmons. 1991. Precision of ages estimated from five bony structures of Arctic char (*Salvelinus alpinus*) from the Wood River System, Alaska. Can. J. Fish. Aquat. Sci. 48: 1007-1014.

Carlson R.E. 1977. A trophic state index for lakes. Limnol. Oceanogr. 22: 361-369.

Environment Canada (EC). 2012. Metal mining technical guidance for Environmental Effects Monitoring. ISBN 978-1-100-20496-3.

EC. 2004. Canadian guidance framework for the management of phosphorus in freshwater systems. Ecosystem Health: Science-based Solutions Report No. 1-8. National Guidelines and Standards Office, Water Policy and Coordination Directorate, Environment Canada. 114 p.

Galvez-Cloutier R. and M. Sanchez. 2007. Trophic status evaluation for 154 lakes in Quebec, Canada: monitoring and recommendations. Wat. Qual. Res. J. Can. 42: 252-268.

Golder Associates. 2014. Diavik Diamond Mines aquatic effects monitoring program study design Version 3.4. Prepared for Diavik Diamond Mines Inc. by Golder Associates Ltd., Calgary, AB, January 2014. 318 p.

Government of Canada. 1999. The Canadian Environmental Assessment Act Comprehensive Study Report. Diavik Diamonds Project. June 1999.

Indian and Northern Affairs Canada (INAC). 2009. Guidelines for designing and implementing aquatic effects monitoring programs for development projects in the Northwest Territories. Yellowknife. June 2009. Volumes 1-6.

Magurran, A. E. 2004. Measuring biological diversity. Blackwell. Malden Massachusetts.

Magurran, A.E.1988. Ecological diversity and its measurement. Princeton University Press. New Jersey.

North/South Consultants Inc. (NSC). 2014. Arctic Char ageing structure comparison. Technical Memorandum prepared for Baffinland Iron Mines Inc., May 24, 2014.

NSC. 2013. Preliminary review of baseline data for freshwater biota: Mary River Mine Site. November 2013.

Nürnberg G.K. 1996. Trophic state in clear and colored, soft and hardwater lakes with special consideration of nutrients, anoxia, phytoplankton and fish. Lake Reserv. Manage. 12: 432-447.

Organization for Economic Cooperation and Development (OECD). 1982. Eutrophication of waters. Monitoring, assessment and control. Final report, OECD cooperative programme on monitoring of inland waters (eutrophication control), Environment Directorate. OECD, Paris. 154 p.

Ryding., S.-O. and W. Rast. 1989. *The Control of Eutrophication of Lakes and Reservoirs.* Vol. 1. UNESCO, Paris and the Parthenon Publishing, United Kingdom. 314 p.

Swedish Environmental Protection Agency (EPA). 2000. Environmental quality criteria. Lakes and watercourses. Swedish EPA Report 5050. 102 p.

University of Florida, Florida Lakewatch. 2002. Trophic state: a waterbody’s ability to support plants, fish and wildlife. Gainesville, FL, USA.

United States Environmental Protection Agency (USEPA). 2009. National lake assessment: A collaborative survey of the nation’s lakes. EPA 841-R-09-001. USEPA, Office of Water and Office of Research and Development, Washington, D.C.104 p.

USEPA. 1988. The lake and reservoir restoration guidance manual. 1st Ed. Prepared by the North American Lake Management Society under EPA cooperative agreement No. CR813531-0, Corvallis, OR, USA.

USEPA. 1974. National Eutrophication Survey Methods for Lakes Sampled in 1972. National Eutrophication Survey Working Paper No. 1. U.S. Environmental Protection Agency, National Eutrophication Research Program, Corvallis, OR, USA.

Wetzel, R.G. 2001. Limnology. Lake and river ecosystems. Third Edition, Elsevier Academic Press, San Diego, CA.1006 p.

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

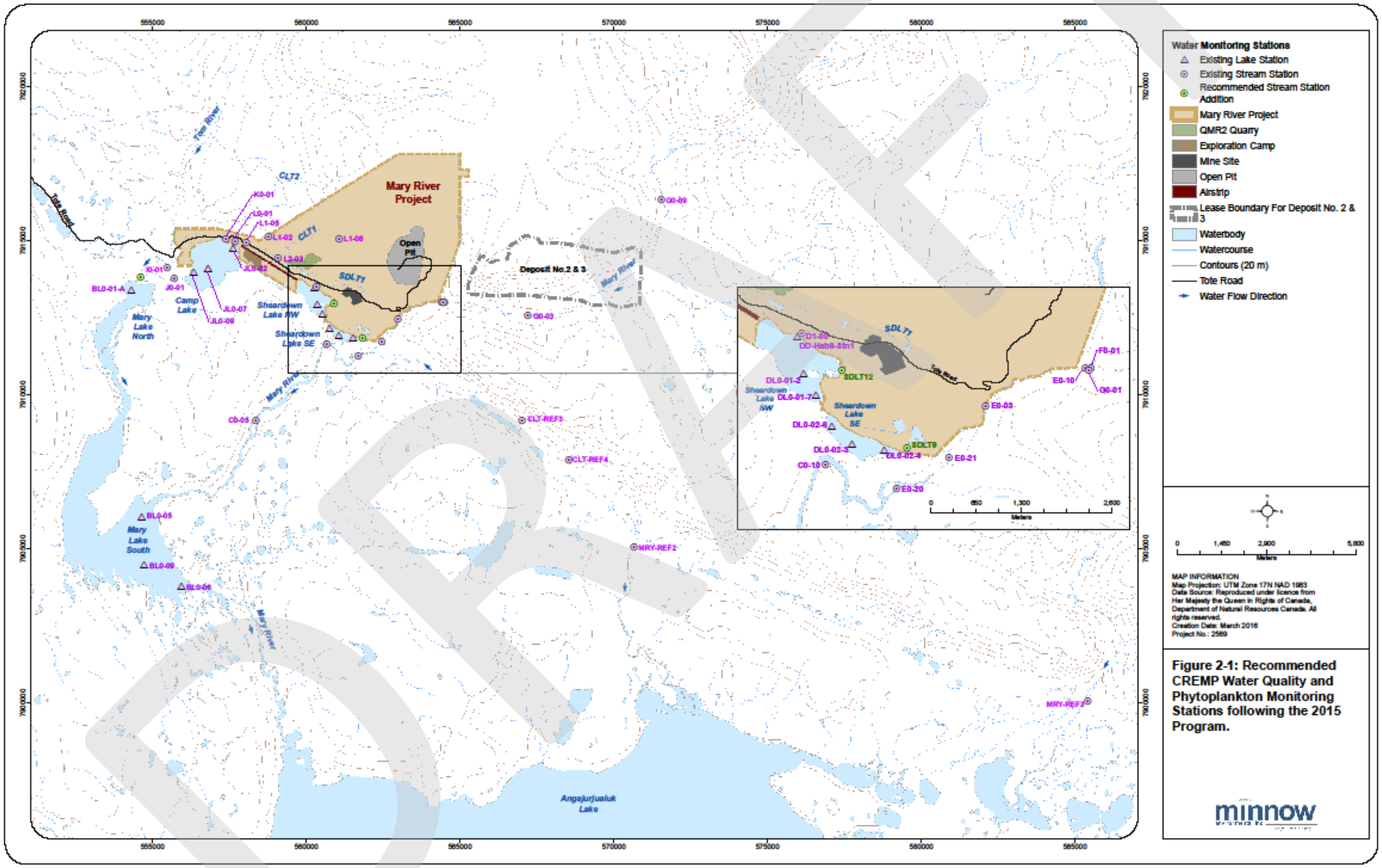


Figure 2-1: Recommended CREMP Water Quality and Phytoplankton Monitoring Stations following the 2015 Program.

Figure 2-2 Assessment approach and response framework

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

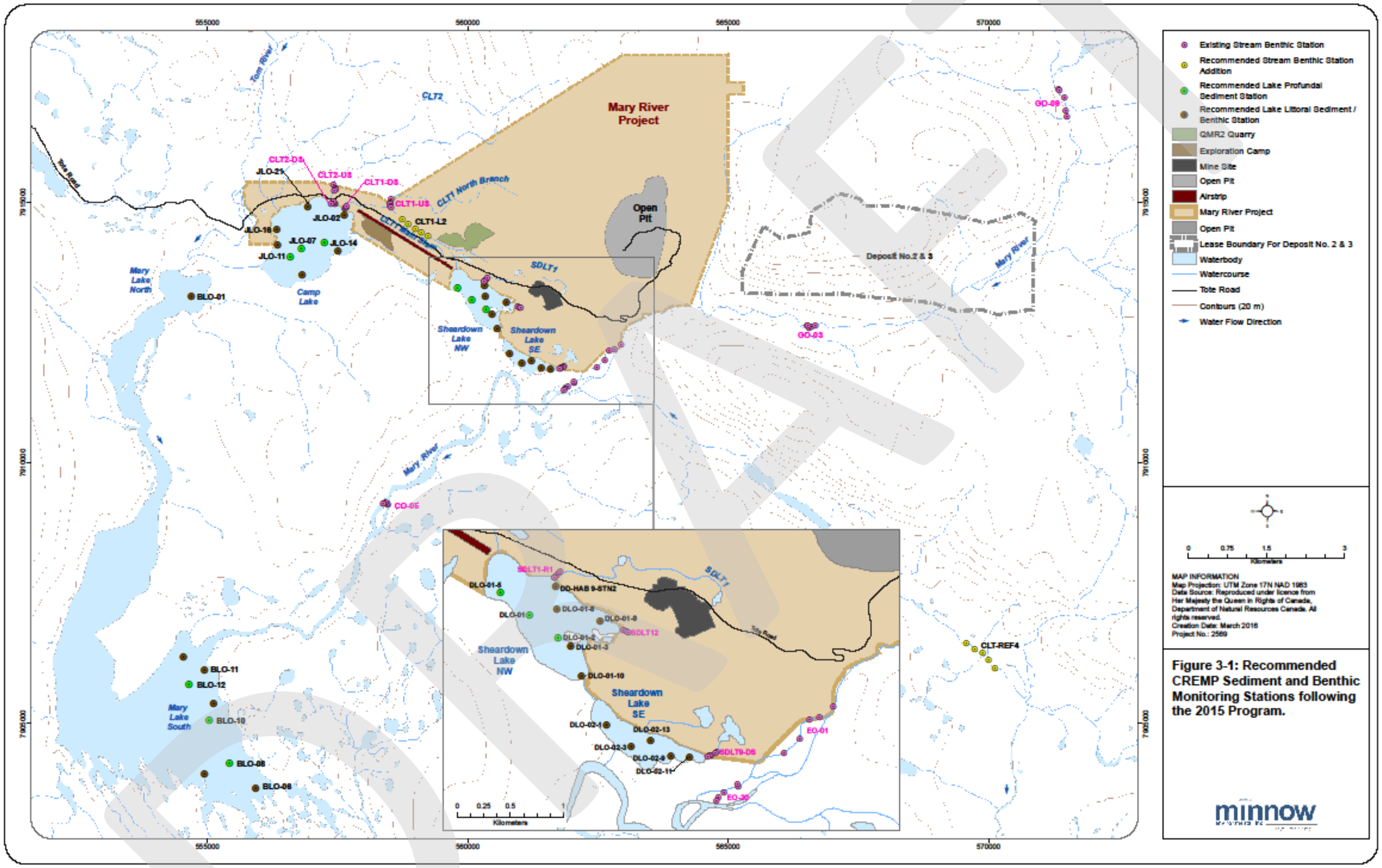
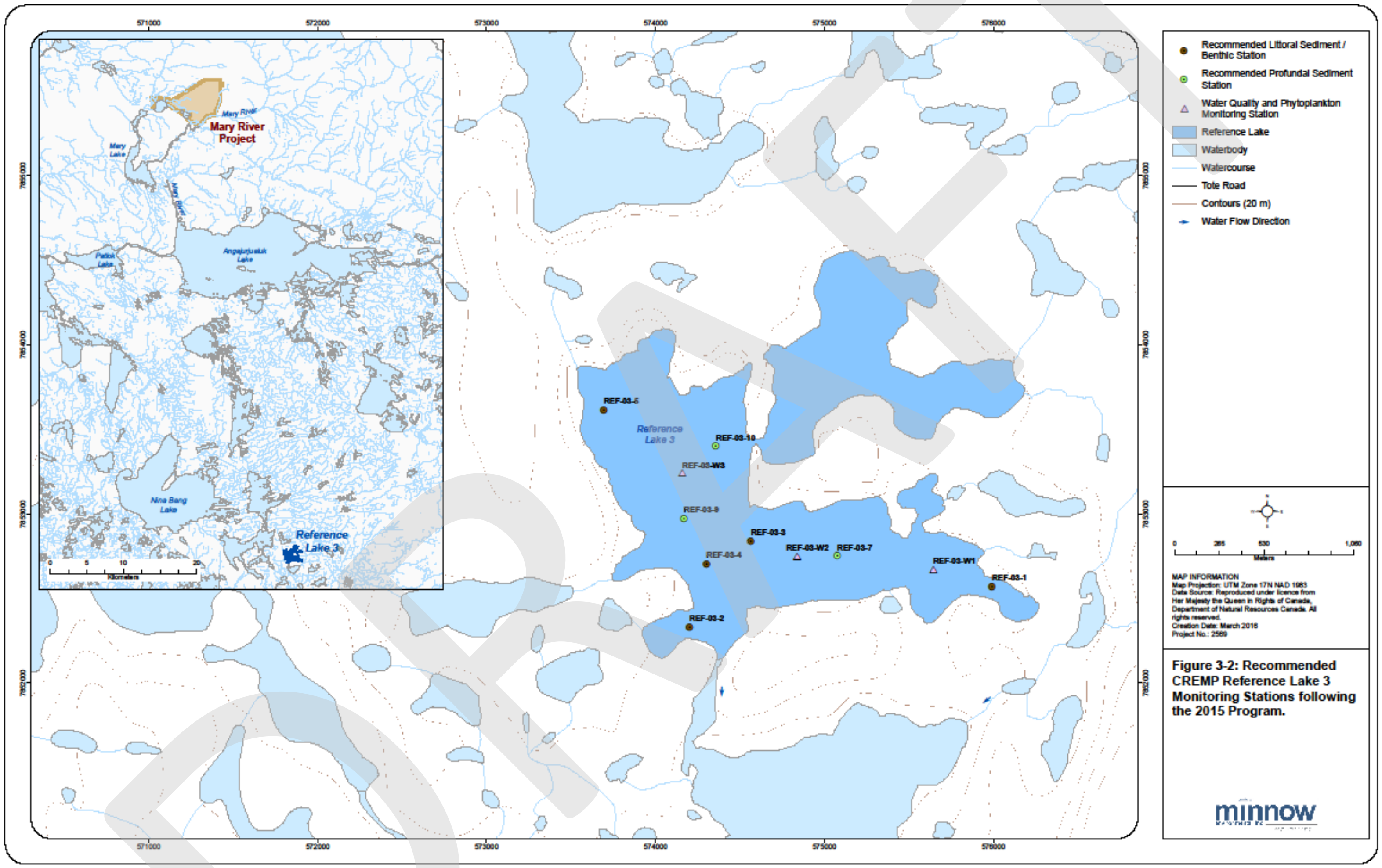


Figure 3-1: Recommended CREMP Sediment and Benthic Monitoring Stations following the 2015 Program.

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



Appendix E

2014 Reference Lake Evaluation

Mary River Project

June 2014

Candidate Reference Lakes:

Preliminary Survey 2013

North/South Consultants Inc.
Aquatic Environment Specialists

Candidate Reference Lakes: Preliminary Survey 2013

June, 2014

Prepared by

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For

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AEMP	Aquatic Effects Monitoring Program
BMI	Benthic macroinvertebrate(s)
CCME	Council of Ministers of the Environment
CCREM	Canadian Council of Resource and Environment Ministers
COV	Coefficient of variation
CREMP	Core Receiving Environment Monitoring Program
DO	Dissolved oxygen
NSC	North/South Consultants Inc.
PAL	Protection of aquatic life
PRSD	Percent relative standard deviation
PSA	Particle size analysis
RPMD	Relative percent mean difference
SD	Standard deviation
SE	Standard error of the mean
TDS	Total dissolved solids
TN	Total nitrogen
TP	Total phosphorus
TOC	Total organic carbon

1.0 INTRODUCTION AND OVERVIEW

The Core Receiving Environment Monitoring Program (CREMP) of the aquatic effects monitoring program (AEMP) for the Mary River Project incorporates monitoring in reference waterbodies. The AEMP identifies that a minimum of one reference lake would be monitored for chemical and biological parameters in parallel with the CREMP which will be conducted in the Mine Area.

Preliminary identification of candidate reference lakes for the CREMP and AEMP was completed through a series of desktop screening exercises completed in 2013. This exercise, which is 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 (Figure 1).

This interim report provides a description of reconnaissance surveys conducted in the open-water season of 2013 to identify reference lakes for Camp and Sheardown lakes at the mine site. Reconnaissance surveys were planned for 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 an initial survey. Ultimately, the objective was to determine presence/absence of land-locked resident Arctic Char (*Salvelinus alpinus*), conduct a coarse aquatic habitat survey, and collect water quality, phytoplankton, zooplankton, and benthic macroinvertebrate (BMI) samples (all from a single site) in each of three lakes to assist with selecting the final reference lake(s).

The first reconnaissance survey conducted in summer (i.e., early August 2013) identified two potentially suitable reference lakes and these lakes were surveyed as indicated above. As the overall objective was to identify three candidate lakes, a second reconnaissance survey was completed in fall 2013 with the intent to identify additional lakes for consideration.

The following provides a description of the aerial and ground reconnaissance surveys completed for candidate reference lakes in the open-water season of 2013, a description of results of the field programs, and qualitative comparisons to Mine Area lakes.

2.0 SUMMER RECONNAISSANCE SURVEY

The first reconnaissance survey was undertaken in early August and included an initial aerial survey to identify the most suitable lakes of the 12 candidates identified through the desktop screening exercise, followed by ground surveys of the these lakes.

2.1 AERIAL SURVEYS

Twelve potential reference lakes for Camp and/or Sheardown lakes were initially identified within an 80 km radius of the Mary River Mine Site through the desktop screening exercise (Figure 1, NSC and Knight Piésold 2013). On August 3, 2013, these 12 lakes were surveyed by helicopter to identify basic suitability characteristics such as general depth, shoreline substrate and connectivity to other waterbodies. Lakes that were identified as unsuitable during the aerial survey were eliminated as potential references. Depth was the primary limiting factor identified during aerial surveys. Based on several ground-truthed surveys of other lakes in the study area, depths < 3.0 m, which are insufficient for overwintering, can be identified reliably from aerial surveys.

Table 1 provides a summary of reconnaissance survey information for the 12 candidate reference lakes surveyed in early August. Five of the lakes were eliminated as potential references due to shallow depths observed during aerial surveys. An additional three lakes remained largely frozen in early August . These three lakes are located in a mountain range to the north of the Mine Area at significantly higher altitudes than Camp and Sheardown lakes and may remain at least partially ice-covered during most summers. For this reason, these lakes were disregarded from further consideration. Aerial surveys indicated four of the 12 lakes may be suitable candidates as reference lakes.

2.2 DETAILED GROUND SURVEYS

Of the four lakes identified as potentially suitable candidates through the aerial reconnaissance survey, detailed ground surveys were conducted at lakes CR-P3-11, CR-P3-09, and CL-P2-13. Lake CR-P3-12 appeared to have nearly identical physical characteristics to the adjacent Lake CR-P3-11, including a largely sandy shoreline, and only one (Lake CR-P3-11) of these two lakes was chosen for a detailed ground survey.

Ground surveys included collection of information on shoreline characteristics (qualitative observations), an aquatic habitat reconnaissance survey (collection of bathymetric and substrate information), determination of fish presence/absence (specifically identification of land-locked resident Arctic Char), collection of water quality information (*in situ* and laboratory measurements) and collection of phytoplankton and zooplankton samples (Table 2).

3.0 FALL RECONNAISSANCE SURVEY

The second round of the reconnaissance surveys was conducted in late August and included revisiting and sampling two of the candidate lakes visited in early August (CR-P3-11 and CL-P2-13), as well as conduct of a second aerial reconnaissance survey to identify additional potential candidate lakes for consideration. The third lake (Lake CR-P3-09) that was surveyed in early August was subsequently dropped from further consideration and was not sampled in late August due to the suspected presence of a population of dwarf Arctic Char (see Section 4.1.3 for a detailed description of results).

3.1 AERIAL SURVEY

Results from aerial and ground surveys conducted on potential reference lakes in early August confirmed only two lakes as likely suitable candidates. Both lakes are smaller than Sheardown and Camp lakes and one has primarily sandy substrate (less preferred by Arctic Char for spawning and rearing). As a result, 11 alternate lakes to the south of the mine site (ALT-1 to ALT-11) were surveyed aerially in late August for general depth, shoreline substrate and connectivity to other waterbodies to expand the list of potential suitable candidates (Figure 1).

Table 1 provides a summary of reconnaissance survey information for these 11 lakes. Several lakes appeared potentially suitable as references, but four have a combination of abundant, ideal nearshore habitat (cobble), sufficient depths (estimated to be > 10 m), and sufficient size when compared with Camp and/or Sheardown NW lakes.

3.2 DETAILED GROUND SURVEYS

Detailed sampling was completed in fall at lakes CR-P3-11 and CL-P2-13 and included collection of information on water quality, phytoplankton, zooplankton and BMIs (Table 2). Detailed ground surveys of the four alternate lakes identified during the aerial reconnaissance in late August could not be completed due to inclement weather conditions and time constraints.

4.0 SUMMARY OF RESULTS

The following sections provide a brief summary of the results of the ground reconnaissance surveys completed in 2013 and qualitative comparisons to Mine Area lakes to provide an initial screening of the suitability of the lakes as reference waterbodies.

4.1 LAKE CR-P3-09

4.1.1 WATER QUALITY

In situ water quality measurements are presented in Appendix 1 and the sampling site is indicated in Figure 2. As this lake was subsequently eliminated as a candidate reference lake, detailed review of water quality for this lake was not undertaken.

4.1.2 LOWER TROPHIC LEVEL BIOTA

Samples for taxonomic analysis of phytoplankton and zooplankton were collected from Lake CR-P3-09 in summer and have been archived at the laboratory at NSC in Winnipeg, MB. BMIs were not sampled in Lake CR-P3-09 as the lake was eliminated as a candidate following the summer sampling period. Metadata associated with the summer sampling period are presented in Appendix 2 and sampling sites are presented in Figure 2.

4.1.3 FISH AND FISH HABITAT

Lake CR-P3-09 is isolated from all nearby waterbodies. Both the inflow and outflow provide insufficient depth or flows for adult or juvenile Arctic Char use. Any fish in the lake are, therefore, resident and non-migratory. The shoreline of this lake is typically cobble/boulder with a relatively steep gradient (Photo 1). Nearshore substrate (to about 5-6 m depth) is a continuation of the cobble/boulder shoreline (Photo 2). As depth increases, cobble is replaced with increasing amounts of sand and silt (Figure 3). Silt is the dominant substrate at depths greater than 10 m. Maximum observed depth in this lake was 29.81 m with a mean of 11.92 m (Figure 2).

Juvenile Arctic Char (30-70 mm fork length) were observed in nearshore rocky habitat. Five Arctic Char were captured in two standard gang index gill nets set for short duration in the lake. The captured fish ranged in size from 191-332 mm. One fish (193 mm) died in the net and was frozen and transported to the laboratory at NSC in Winnipeg for further examination of sex, maturity, diet, parasite load and age. Laboratory examination indicated this fish was a sexually mature male aged 11 years with a diet of chironomids and a parasite infracommunity that included cestode cysts (probably *Diphyllobothrium* sp.) along the exterior surface of the digestive tract. The presence of a sexually mature 11-year-old male at that size, and the lack of

Photo 1. Typical shoreline of reference lake CR-P3-09.

Photo 2. Typical nearshore substrate in reference lake CR-P3-09.

any fish larger than about 330 mm in the gill nets, suggest that this lake likely contains a stunted population of Arctic Char. On this basis Lake CR-P3-09 is likely not a suitable reference for Camp or Sheardown lakes. As previously noted, this lake was subsequently dropped from further consideration as a candidate reference lake based on this observation. Therefore, fall sampling was not undertaken in this lake.

4.2 LAKE CR-P3-11

4.2.1 WATER QUALITY

Laboratory and *in situ* water quality results collected in summer and fall at Lake CR-P3-11 are provided in Appendix 1 and the sampling site is indicated in Figure 4. Qualitative comparison of water quality conditions in Lake CR-P3-11 to Mine Area lakes (2013 data) indicates similarities for some parameters but differences for others (Table 3 and Figures 5-9).

Like Mine Area lakes, Lake CR-P3-11 was well-oxygenated and had a relatively high clarity. Nutrient concentrations were also relatively similar between this candidate reference lake and the Mine Area lakes (Figure 5) and the lake ranked as oligotrophic on the basis of total phosphorus (TP). Total nitrogen (TN) to TP ratios indicate this lake is strongly phosphorus limited, like Mine Area lakes (Table 3). Concentrations of many metals were also similar to Mine Area lakes, with a number of metals below detection (on average) in all of the lakes including antimony, beryllium, bismuth, boron, cadmium, cobalt, mercury, selenium, thallium, tin, titanium, and vanadium. Aluminum, iron, and copper were also similar to Mine Area lakes (Figure 6).

The primary difference between Lake CR-P3-11 and the Mine Area lakes relates to total dissolved solids (TDS)/conductivity, major cations, alkalinity, and hardness, all of which were lower in Lake CR-P3-11 (Table 3, Figure 7). Conductivity was less than half the levels measured in Sheardown Lake NW and SE and Camp Lake, but more similar to the more dilute Mary Lake (Figure 7). Lake CR-P3-11 ranked as very soft, whereas Mine Area lakes ranked as soft to moderately soft based on the Canadian Council of Resource and Environment Ministers (CCREM 1987) water hardness categories. These differences likely reflect differences in local geology.

Lake CR-P3-11 contains lower concentrations of calcium, magnesium, and potassium, but similar concentrations of sodium, than Mine Area lakes (Figure 8). Although concentrations of a number of metals were lower in Lake CR-P3-11, chromium, nickel, zinc (Figure 9) and manganese (Figure 6) were higher. Lake CR-P3-11 was not thermally stratified during the two sampling periods in 2013, whereas Mine Area lakes stratify during some sampling periods.

All water quality parameters measured in Lake CR-P3-11 in 2013 were within the Canadian Council of Ministers of the Environment (CCME) guidelines for the protection of aquatic life (PAL; CCME 1999; updated to 2014).

4.2.1 LOWER TROPHIC LEVEL BIOTA

Samples of phytoplankton, zooplankton, and BMIs were collected during summer and/or fall from Lake CR-P3-11. Metadata associated with this sampling are presented in Appendix 2 and sampling sites are presented in Figure 4.

Phytoplankton

Chlorophyll *a* concentrations measured in Lake CR-P3-11 were similar to those measured in Mine Area lakes in the open-water season of 2013 (Table 3, Figure 10), indicating similar levels of primary productivity.

Detailed phytoplankton results for samples collected in summer and fall at Lake CR-P3-11 are provided in Appendix 3. Qualitative comparisons of the phytoplankton community in Lake CR-P3-11 measured in the open-water season of 2013 to data collected in the open-water seasons of 2007 and 2008 from Mine Area lakes indicated that the community composition differs (Table 4; Figure 11). Unlike Mine Area lakes where diatoms dominated the phytoplankton community, dinoflagellates dominated the phytoplankton community and diatoms formed a small portion of the phytoplankton biomass in Lake CR-P3-11 (Figure 11). However, the dominant taxa (*Gymnodinium* and *Peridinium* sp.) were also present in Mine Area lakes in 2007 and 2008. Species diversity and richness were also higher in Lake CR-P3-11 in 2013 than in the Mine Area lakes in 2007 and 2008 (Table 4). Three phytoplankton not identified in the Mine Area lakes were observed in CR-P3-11, including: *Rhoicosphenia* sp. (Diatom), *Staurodesmus* sp. (Charophyta), and *Bitrichia* sp. (Charophyta).

During the summer, three phytoplankton replicates were collected and two of these were analysed for phytoplankton composition and biomass to assess variability (Appendix 3). The relative percent mean difference (RPMD) for biomass was high (63%) indicating that there is a high degree in variation in the phytoplankton. Variability of replicates of this order of magnitude is not uncommon for environmental monitoring programs (e.g., Coordinated Aquatic Monitoring Program 2014).

Zooplankton

Detailed zooplankton results for samples collected in summer and fall at Lake CR-P3-11 are provided in Appendix 4. Qualitative comparisons of the zooplankton community in CR-P3-11 to

Mine Area lakes (2007 and 2008 data) indicated that the communities were generally comparable (Table 5, Figure 12). A total of five crustacean zooplankton taxa were identified from vertical tows in Lake CR-P3-11, within the range of the number of taxa observed in the Mine Area lakes. As observed in Mine Area lakes, copepods, particularly cyclopoids, dominated the community and consisted of two species, *Cyclops scutifer* and *Diaptomus minutus*. The cladoceran community was primarily composed of two small-bodied taxa, *Bosmina longirostris* and *Daphnia longiremis*. The other cladoceran observed, *Holopedium gibberum*, was rare in comparison. As is typical, cladoceran density increased through the growing season and these organisms contributed to a greater proportion of the community sampled in the fall in comparison to the summer. Cyclopoid copepods and smaller-bodied cladocerans are more likely to be present in lakes with fish predators (i.e., Arctic char).

During the summer sampling period, three replicate samples of zooplankton were collected in Lake CR-P3-11 (Appendix 4). Percent relative standard deviation (PRSD) of zooplankton density for the three replicates was low (9%). Higher levels of variability were observed for individual taxa.

Benthic Macroinvertebrates

The objective of the BMI program was to sample aquatic habitat type 14 for comparison to Mine Area lakes. Habitat type 14 is characterized by water depths greater than 12 m, fine sand, silt, clay substrate, and an absence of macrophytes. While mean water depth in CR-P3-11 was only 8.8 m, it was decided that the samples represented the offshore profundal habitat based on its maximum depth of 11.65 m. Supporting variables for the BMI program (i.e., sediment total organic carbon [TOC] and particle size analysis [PSA]) were measured at each replicate station.

Detailed taxonomic results for BMI samples collected in the fall at Lake CR-P3-11 are provided in Appendix 5. Qualitative comparisons of BMI metrics in CR-P3-11 (2013; n=1) were made to the same habitat type within the Mine Area lakes using available data as follows: Sheardown Lake NW (2007, 2008, 2011, 2013; n=17); Sheardown Lake SE (2007; n=6); Camp Lake (2007; n=12); and Mary Lake (2006, 2007; n=11). Statistics for six community metrics: total density, proportion of Chironomidae, Shannon's evenness index, Simpson's diversity index, taxa richness (total number of genera), and Hill's effective richness, were graphically compared using summary statistics. Reference lake values were visually comparable to the mine site lake values for most of the metrics (Figures 13 and 14).

A total of 3,861 individuals/m^2 were collected in Lake CR-P3-11 which was in the range of BMI densities measured in all Mine Area lakes (Table 6). Chironomidae comprised 98% of the total abundance, and was compositionally similar to the Mine Area lakes. Evenness and diversity indices were also similar amongst all lake sites. Mean taxa richness and Hill's effective richness values for Lake CR-P3-11 were both within the ranges for all Mine Area lakes.

Supporting sediment analysis results for Lake CR-P3-11 (n=1) are provided in Figure 15. The benthic sediment was predominantly silt (47.8%), loam in texture; and TOC was 3.17%.

4.2.1 FISH AND FISH HABITAT

The shoreline of Lake CR-P3-11 is predominantly sandy with occasional small patches of rocks and a gradient ranging from low to high (Photos 3 and 4). Nearshore substrate (to about 5-6 m depth) is largely sand with occasional gravel or cobble (Figure 16). Silt and sand are dominant at depths greater than 5 m with occasional patches of coarser material. The most predominant substrate type in this lake is fines (i.e., fine sand, silt, and clay) but hard substrates are present at depths greater than 2 m, indicating the lake provides suitable spawning habitat for Arctic Char (Table 8). Maximum observed depth in this lake was 11.65 m with a mean of 6.10 m (Figure 4). The greatest depths were located in the northern third of the lake. There are several shallow shoals in the southern two thirds of the lake.

Lake CR-P3-11 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. Juvenile Arctic Char (30-70 mm fork length) were observed in tributary streams and in pools along the lake margin that had become isolated as water levels decreased. Fifteen Arctic Char were captured in two standard gang index gill nets set for short duration in the lake. The captured fish ranged in size from 313-431 mm. There were five mortalities, which were frozen and returned to the laboratory at NSC in Winnipeg for further examination of sex, maturity, diet, parasite load and age. Of the five mortalities, four were immature males (FL = 318-334 mm) and one was a resting female (FL = 355 mm). These fish were aged 10-13 years. Stomachs from all five mortalities contained chironomids and cestode cysts (probably *Diphyllobothrium* sp.) were present along the exterior surface of the digestive tracts. One fish was also infected with adult nematodes (likely *Cystidicola* sp.) in the body cavity, which may have been in the swim bladder before it was punctured during the necropsy.

Although the largely sandy nearshore substrate differs from the nearshore substrate of Camp or Sheardown lakes, which contain greater amounts of coarser substrate, and the lake is smaller and shallower than Camp or Sheardown lakes (Table 8), preliminary analysis of the fish population shows that basic meristics, growth rates, diet and parasite load are similar to populations in the Mine Area lakes. As previously noted, the lake also contains habitat that could support Arctic Char spawning.

Photo 3. Low-relief shoreline in reference lake CR-P3-11.

Photo 4. High-relief shoreline in reference lake CR-P3-11.

4.3 LAKE CL-P2-13

4.3.1 WATER QUALITY

Laboratory and *in situ* water quality results collected in summer and fall at Lake CL-P2-13 are provided in Appendix 1 and the sampling site is indicated in Figure 17. Qualitative comparison of water quality conditions in Lake CL-P2-13 to Mine Area lakes (2013 data) indicates some similarities but also a number of differences (Table 3 and Figures 5-9).

Like Mine Area lakes, Lake CL-P2-13 was well-oxygenated and had a relatively high clarity. Secchi disk depth was within the range measured at the Mine Area lakes, though was most similar to the less clear Mary Lake (Table 3). TP concentrations were also relatively similar between this candidate reference lake and the Mine Area lakes (Figure 5) and the lake ranked as oligotrophic on the basis of TP. TN to TP ratios indicate this lake is strongly phosphorus limited, like Mine Area lakes (Table 3). Concentrations of many metals were similar to Mine Area lakes, with a number of metals below detection (on average) in all of the lakes including antimony, beryllium, bismuth, boron, cadmium, cobalt, mercury, selenium, thallium, tin, titanium, and vanadium. Aluminum, iron, and copper were similar to Mine Area lakes, though the mean iron concentration was slightly higher than Mine Area lakes or Lake CR-P3-11 (Figure 6).

Like Lake CR-P3-11, the primary difference between Lake CL-P2-13 and the Mine Area lakes relates to TDS/conductivity, major cations, alkalinity, and hardness, all of which are lower in Lake CL-P2-13 (Table 3). Conductivity was less than half the levels measured in Sheardown Lake NW and SE and Camp Lake, but more similar to the more dilute Mary Lake (Figure 7). Lake CL-P2-13 ranked as very soft, whereas Mine Area lakes ranked as soft to moderately soft based on the CCREM (1987) water hardness categories. These differences likely reflect differences in local geology. Lake CL-P2-13 contains lower concentrations of calcium, magnesium, potassium, and sodium than Mine Area lakes (Figure 8). Although concentrations of a number of metals were lower in Lake CL-P2-13 than Mine Area lakes, like Lake CR-P3-11, chromium and nickel were higher (Figure 9). Lake CL-P2-13 was not thermally stratified during the two sampling periods in 2013, whereas Mine Area lakes stratify during some sampling periods.

All water quality parameters measured in Lake CL-P2-13 in 2013 were within the CCME PAL guidelines (CCME 1999; updated to 2014).

4.3.2 LOWER TROPHIC LEVEL BIOTA

Samples of phytoplankton, zooplankton, and BMIs were collected during summer and/or fall from Lake CL-P2-13. Metadata associated with this sampling are presented in Appendix 2 and sampling sites are presented in Figure 17.

Phytoplankton

Chlorophyll *a* concentrations measured in Lake CL-P2-13 were similar to those measured in Mine Area lakes and Lake CR-P3-11 in the open-water season of 2013 (Table 3, Figure 10), indicating similar levels of primary productivity.

Detailed results of phytoplankton biomass and community composition analyses of samples collected in summer and fall at Lake CR-P3-13 are provided in Appendix 3. Qualitative comparisons of the phytoplankton community in Lake CR-P3-13 to Mine Area lakes (2007 and 2008 data) indicates that the communities are different, but compared to Lake CR-P3-11, the phytoplankton community of Lake CR-P3-13 is more similar to the Mine Area lakes (Table 4; Figure 11). Unlike Mine Area lakes where diatoms dominated, dinoflagellates dominated the phytoplankton community in Lake CR-P3-13 (Figure 11).

In general, species diversity was similar to Mine Area lakes, but a greater number of species (i.e., richness) was observed in Lake CR-P3-13 in 2013 than in the Mine Area lakes in 2007 and 2008 (Table 4). The phytoplankton *Bitrichia* sp. (Charophyta) was observed in CR-P3-13, but was not identified in the Mine Area lakes.

During the fall, three phytoplankton replicates were collected and two of these were analysed for phytoplankton composition and biomass to evaluate variability (Appendix 3). The RPMD for biomass was low (8%) indicating good precision in the estimate of phytoplankton biomass.

Zooplankton

Detailed zooplankton results for samples collected in summer and fall at Lake CL-P2-13 are provided in Appendix 3. Qualitative comparisons of the zooplankton community in CL-P2-13 to Mine Area lakes (2007 and 2008 data) indicate that the communities are generally comparable (Table 5, Figure 12). Total zooplankton density in CL-P2-13 was somewhat lower than in Mine Area lakes and Lake CR-P3-11, but within the range of densities observed in the Mine Area lakes throughout the open-water season. The distribution of zooplankton is inherently patchy (i.e., these organisms are often highly aggregated). Spatial (e.g., within a lake or among lakes in the same area) and temporal (e.g., seasonal) variation in lake zooplankton density is typical and may be related to a variety of factors such as water depth, prevailing wind direction, water temperature regimes, and fish predation pressure.

A total of five crustacean zooplankton taxa were identified from vertical tows in Lake CL-P2-13, which is within the range of the number of taxa observed in the Mine Area lakes. As observed in Mine Area lakes and Lake CR-P3-11, copepods, particularly cyclopoids, dominated the community and consisted of two species, *Cyclops scutifer* and *Diaptomus minutus*. The cladoceran community was primarily composed of two small-bodied taxa, *Bosmina longirostris* and *Daphnia longiremis*. The other cladoceran observed, *Holopedium gibberum*, was rare in comparison.

During the summer, three zooplankton replicate samples were collected in CL-P2-13 (Appendix 4). PRSD for total zooplankton density was relatively low (26%) but higher variability was observed among the replicates for the various taxa.

Benthic Macroinvertebrates

BMIs were sampled in the profundal zone of Lake CL-P2-13 (i.e., aquatic habitat type 14) in the fall of 2013. Detailed taxonomic results for BMI samples are provided in Appendix 5. Qualitative comparisons of BMI metrics measured in Lake CL-P2-13 (2013; n=1) were made to the data collected from the same habitat type within the Mine Area lakes as follows: Sheardown Lake NW (2007, 2008, 2011, 2013; n=17); Sheardown Lake SE (2007; n=6); Camp Lake (2007; n=12); and Mary Lake (2006, 2007; n=11). Statistics for six community metrics: total density, proportion of Chironomidae, Shannon's evenness index, Simpson's diversity index, taxa richness (total number of genera), and Hill's effective richness, were graphically compared using summary statistics. Reference lake values were visually comparable to the mine site lake values for most of the metrics (Figures 13 and 14).

A total of 1,593 individuals/m^2 were collected in CL-P2-13 which was in the range of BMI densities for Mine Area lakes, except for Sheardown Lake SE (Table 6). Chironomidae comprised 100% of the total abundance, and was compositionally similar to the Mine Area lakes, except for Sheardown Lake NW. Evenness and diversity indices were also similar amongst all lake sites. Mean taxa richness and Hill's effective richness values for Lake CL-P2-13 were both within the ranges for all Mine Area lake sites.

Supporting sediment analysis results for Lake CL-P2-13 (n=1) are provided in Figure 15. The sediment was predominantly silt (73.0%), silt loam in texture; and TOC was 2.02%.

4.3.3 FISH AND FISH HABITAT

Lake CL-P2-13 has the smallest surface area of the three lakes that were surveyed in detail in 2013 (Figure 17). There are 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. The shoreline of this lake is predominantly rocky with a gradient ranging from low to high (Photo 5). Nearshore substrate (to about 5-6 m depth) ranged from almost 100% sand in some areas to almost 100% cobble/boulder in others (Photo 6, Figure 18). Silt and sand were dominant at depths greater than 5 m, however, the northwest section of the lake consisted of large amounts of cobble to at least 12 m depth. The predominant substrate type in this lake is fines (i.e., fine sand, silt, and clay) but hard substrates are present at depths greater than 2 m, indicating the lake provides suitable spawning habitat for Arctic Char (Table 9).The lake is characterized by steep shorelines typically reaching depths of 8-10 m within 50 m of shore tapering to a broad basin ranging from 10-15 m deep (Figure 17). Maximum observed depth in this lake was 15.34 m with a mean of 9.40 m.

Juvenile Arctic Char (30-70 mm fork length) were observed in tributary streams and in rocky nearshore areas. Two Arctic Char were captured in two standard gang index gill nets set for short duration in the lake. The captured fish ranged in size from 395-558 mm. One mortality (FL = 395 mm) was frozen and returned to the NSC laboratory in Winnipeg for further examination of sex, maturity, diet, parasite load and age. The fish was an immature male aged 17 years with chironomids in the stomach and larval cestode (likely *Diphyllobothrium* sp.) cysts along the gut and adult cestodes (possibly *Proteocephalus* sp.) in the stomach. Although this fish is older than most similarly-sized fish from Mine Area lakes, it is immature and may not necessarily be indicative of an overall slower growth rate for fish in this lake. Additional data are required to more thoroughly assess the fish population compatibility with Mine Area lakes.

Despite a smaller surface area, a higher proportion of fines, and a shallower basin than the Mine Area lakes (Table 8), preliminary surveys indicate Lake CL-P2-13 may be suitable as a reference lake.

Photo 5. Typical shoreline of reference lake CL-P2-13.

Photo 6. Typical nearshore substrate in reference lake CL-P2-13.

5.0 SUMMARY AND RECOMMENDATIONS

5.1 WATER QUALITY

Some water quality variables, notably water clarity, dissolved oxygen (DO), nutrients, and numerous metals, were similar between candidate reference lakes and Mine Area lakes. The primary differences observed relate to hardness, TDS/conductivity, and major cations – all of which were lower in candidate reference lakes than Mine Area lakes, notably Camp Lake and Sheardown Lake NW. These parameters were more similar to Mary Lake, which is softer and more dilute than other Mine Area lakes.

5.2 LOWER TROPHIC LEVEL BIOTA

5.2.1 PHYTOPLANKTON

The key findings of the phytoplankton analyses are:

- Primary productivity was similar between the candidate reference lakes and Mine Area lakes based on chlorophyll *a* concentrations; and
- Phytoplankton community composition varied between the candidate reference lakes and Mine Area lakes. 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).

5.2.2 ZOOPLANKTON

Densities and composition of the zooplankton communities were similar between Mine Area lakes (as measured in 2007 and 2008) and the candidate reference lakes CR-P3-11 and CL-P2-13 (as measured in 2013).

5.2.3 BENTHIC MACROINVERTEBRATES

Benthic macroinvertebrate abundance and composition metrics were similar between Mine Area lakes (as measured in 2006, 2007, 2008, 2011, and 2013) and the candidate reference lakes CR-P3-11 and CL-P2-13 (as measured in 2013).

5.3 FISH AND FISH HABITAT

Available information regarding Arctic Char populations and aquatic habitat in the two candidate reference lakes indicate both lakes support what are likely land-locked resident populations and both are supplied by tributary streams that appear to provide juvenile rearing habitat (similar to Mine Area lakes). Also like Mine Area lakes, Lakes CR-P3-11 and CL-P21-13 likely provide overwintering and spawning habitat. Of the two lakes, growth rates of Arctic Char in Lake CL-P2-13 may be slower than Mine Area lakes. However, due to limited sample size this suggestion requires further investigation.

5.4 RECOMMENDATIONS

Although some differences in aquatic habitat, water quality, and lower trophic level biota were noted between the candidate reference lakes and Mine Area lakes based on the results of the 2013 survey and comparison to existing data for Mine Area lakes, it is recommended to retain one or both of these lakes for further consideration as reference lakes. However, additional sampling is required to confirm the suitability of these lakes as reference systems, in particular in relation to the Arctic Char populations.

Should additional reference lakes be desired, lakes ALT-06, ALT-07, ALT-09 and ALT-10 (Figure 1) were deemed to be the most likely suitable candidates based on aerial surveys conducted in fall 2013. These lakes have suspected depths, nearshore substrates and, in particular, surface areas that appear to suitably match Camp and Sheardown NW lakes. Surface areas of these lakes area greater than lakes CR-P3-11 and CL-P2-13 and more comparable to the surface areas of Camp and Sheardown NW lakes. If additional reference lakes are to be identified, these lakes could be subject to a ground level screening comparable to that conducted in lakes CR-P3-11 and CL-P2-13 in 2013 to evaluate physical, chemical, and biological conditions.

6.0 LITERATURE CITED

Canadian Council of Ministers of the Environment (CCME). 1999. Canadian environmental quality guidelines. Canadian Council of Ministers of the Environment, Winnipeg, MB. Updated to 2014.

Canadian Council of Resource and Environment Ministers (CCREM). 1987. Canadian water quality guidelines. Canadian Council of Resource and Environment Ministers, Winnipeg, MB.

Coordinated Aquatic Monitoring Program (CAMP). 2014. Three year summary report (2008-2010). Report prepared for the Manitoba/Manitoba Hydro MOU Working Group by North/South Consultants Inc.,Winnipeg, MB.

De Beers Canada Mining Inc. 2002. Snap Lake Diamond Project Environmental Impact Assessment. Chapter 9.

Golder Associates. 2012. Snap Lake aquatic effects re-evaluation report. Submitted to De Beers Canada Inc.

North/South Consultants (NSC) and Knight Piésold Ltd. 2013. Desktop screening for candidate reference lakes: Mary River Mine Site. Report prepared for Baffinland Iron Mines Corporation, July 2013.

TABLES AND FIGURES

Table 1. Summary of information collected during preliminary surveys of potential reference lakes, August 2013. Lakes highlighted in bold, blue lettering have been identified as the best possible candidates.

Lake	Date	Survey Type	Maximum Depth (m)	Dominant Substrate (0-5 m depth)	Dominant Substrate (> 5 m depth)	Fish Community	Potential Reference Lake Status	Comments
CR-P3-07	03-Aug-13	Ground	3.0	Cobble	NA	Small juveniles observed along shore	Not Suitable	Too shallow for overwintering or large adult fish use
CL-P2-05	03-Aug-13	Aerial	< 3.0	NA	NA	Unknown	Not Suitable	Too shallow for overwintering or large adult fish use
CL-P2-01	03-Aug-13	Aerial	> 5.0	Appears to be cobble	NA	Unknown	Potentially Suitable	Lake was still ~80% covered in ice and could not be surveyed in detail
CR-P3-29	03-Aug-13	Aerial	> 5.0	Appears to be cobble	NA	Unknown	Potentially Suitable	Lake was still ~90% covered in ice and could not be surveyed in detail
CL-P2-04	03-Aug-13	Aerial	> 5.0	Appears to be cobble	NA	Unknown	Potentially Suitable	Lake was still ~80% covered in ice and could not be surveyed in detail
CL-P2-13	**07-Aug-13**	**Ground**	**13.0-15.0**	**Cobble/boulder**	**Sand/silt with rocky patches**	**Small juveniles along shore and in tributary streams; large adults captured in lake**	**Potentially Suitable**	**Lake is small, but substrate is ideal and there are large, resident Arctic Char**
CL-P2-07	03-Aug-13	Aerial	~ 5.0	Appears to be cobble	NA	Unknown	Not Suitable	80-90% of the lake is < 3.0 m deep

Table 1. - continued -

Lake	Date	Survey Type	Maximum Depth (m)	Dominant Substrate (0-5 m depth)	Dominant Substrate (> 5 m depth)	Fish Community	Potential Reference Lake Status	Comments
CR-P3-09	05-Aug-13	Ground	28.0-30.0	Cobble/ boulder	Sand/silt with rocky patches	Probable isolated stunted Arctic Char population	Not Suitable if resident char are stunted	May need more studies to confirm lack of large fish, but seems unlikely as a reference
CR-P3-01	03-Aug-13	Aerial	~ 5.0-10.0	Appeared to be cobble	NA	Unknown	Not Suitable	50% of the lake is < 3.0 m deep and lake is isolated from other waterbodies
CL-03	03-Aug-13	Aerial	< 2.0	NA	NA	Unknown	Not Suitable	Too shallow for overwintering or large adult fish use
CR-P3-11	**06-Aug-13**	**Ground**	**10.0-12.0**	**Sand**	**Sand/silt**	**Small juveniles along shore and in tributary streams; large adults captured in lake**	**Potentially Suitable**	**Substrate not ideal, but resident fish population present**
CR-P3-12	03-Aug-13	Aerial	~10.0-15.0	Sand	Sand/silt	Probable juvenile and adult use	Potentially Suitable	Very similar to CR-P3-11, so only one of the two was surveyed in detail
ALT-01	31-Aug-13	Aerial	> 10	Sand	NA	Probable juvenile and adult use	Potentially Suitable	Does not have ideal nearshore habitat (larger cobble), but may qualify for more detailed survey
ALT-02	31-Aug-13	Aerial	> 10	Cobble/sand	NA	Probable juvenile and adult use	Potentially Suitable	Nearshore habitat more suitable than ALT-1

Table 1. - continued -

Lake	Date	Survey Type	Maximum Depth (m)	Dominant Substrate (0-5 m depth)	Dominant Substrate (> 5 m depth)	Fish Community	Potential Reference Lake Status	Comments
ALT-03	31-Aug-13	Aerial	~ 5.0-10.0	Cobble/sand	NA	Unknown	Not Likely Suitable	Substrate decent, but depths a little shallow
ALT-04	31-Aug-13	Aerial	> 10	Cobble/sand	NA	Probable juvenile and adult use	Not Suitable	Essentially a bay in Nina Bang Lake
ALT-05	31-Aug-13	Aerial	> 10	Mainly Cobble	NA	Probable juvenile and adult use	Potentially Suitable	Excellent nearshore habitat and depths, but lake is a little small
ALT-06	**31-Aug-13**	**Aerial**	**> 10**	**Mainly Cobble**	**NA**	**Probable juvenile and adult use**	**Potentially Suitable**	**Excellent nearshore habitat and depths and lake is larger than other reference sites**
ALT-07	**31-Aug-13**	**Aerial**	**> 10**	**Mainly Cobble**	**NA**	**Probable juvenile and adult use**	**Potentially Suitable**	**Connected to ALT-06, but even better suited as reference**
ALT-08	31-Aug-13	Aerial	> 10	Sand/Cobble	NA	Unknown	Potentially Suitable	Low shoreline slope and lower quality habitat means this is likely less suitable than others in the area
ALT-09	**31-Aug-13**	**Aerial**	**> 10**	**Mainly Cobble**	**NA**	**Probable juvenile and adult use**	**Potentially Suitable**	**Among the best nearshore habitat and depth of any ALT lakes**
ALT-10	**31-Aug-13**	**Aerial**	**> 10**	**Mainly Cobble**	**NA**	**Probable juvenile and adult use**	**Potentially Suitable**	**Shallow connection to ALT-09 with similar habitat**
ALT-11	31-Aug-13	Aerial	> 10	Sand/Cobble	NA	Probable juvenile and adult use	Potentially Suitable	Good size and depth, but nearshore habitat not as ideal as ALT-06 or ALT-09/10)

Table 2. Sampling programs completed in candidate reference lakes, summer and fall 2013.

Lake	Season	Bathymetry & Substrate	Water Quality			Phytoplankton	Zooplankton	Benthic Macroinvertebrates	Fish
			in situ	Surface Sample	Bottom Sample				
CR-P3-09	Summer	+	+	+[1]		+	+		+
	Fall								
CR-P3-11	Summer	+	+	+	+	+	+		+
	Fall		+	+	+	+	+	+	
CL-P2-13	Summer	+	+	+	+	+	+		+
	Fall		+	+	+	+	+	+	

[1] Sample was collected by not analysed.

Table 3. Water quality measured in candidate reference lakes CR-P3-11 and CL-P2-13 and Mine Area lakes in the open-water season of 2013. Values represent means of surface samples. SDL NW = Sheardown Lake northwest and SDL SE = Sheardown Lake southeast.

Parameter	Unit	Reference Lakes		Mine Area Lakes			
		CR-P3-11	CR-P2-13	SDL NW	SDL SE	Camp L.	Mary L.
In situ							
Temperature	°C	Summer: 9.6 Fall: 4.4	Summer: 6.9 Fall: 3.8	Summer: 8.6 Fall: 6.9	Summer: 10.0 Fall: 6.3	Summer: 4.6 Fall: 6.9	Summer: 6.2 Fall: 5.9
Dissolved oxygen	mg/L	11.54	11.55	12.20	12.09	12.20	12.37
pH	pH units	8.01	7.83	7.87	7.62	7.54	7.53
Specific conductance	µS/cm	40.1	42.0	120	100	122	64.3
Secchi Disk Depth	m	6.13	4.30	7.48	4.17	7.15	4.56
Laboratory Routine							
Lab pH	pH units	6.70	6.73	7.44	7.35	7.42	7.02
Lab Conductivity	µS/cm	41	42	121	106	124	67
Lab Turbidity	NTU	0.60	0.90	0.43	0.65	0.27	1.30
Total Alkalinity (as $CaCO_3$)	mg/L	17	22	57	50	59	33
Bromide	mg/L	<0.25	<0.25	<0.25	<0.25	0.25	<0.25
Chloride	mg/L	2.0	<1	3.0	2.5	3.2	2.0
Dissolved Hardness	mg/L	16.0	18.8	58.7	48.7	59.1	31.0
Total Hardness	mg/L	16.7	18.7	61.1	51.2	61.2	31.7
Ammonia	mg N/L	0.03	0.52	0.08	<0.02	0.28	0.14
Nitrite	mg N/L	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Nitrite/nitrate	mg N/L	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Nitrate	mg N/L	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Sulphate	mg/L	3	<3	4	4	<3	<3
Total Dissolved Solids	mg/L	26.7	27.5	79	68.5	80.7	43.6
Total Suspended Solids	mg/L	<2	<2	<2	<2	<2	<2
Total Phosphorus	mg/L	0.005	0.005	0.005	0.006	0.004	0.005
Total Kjeldahl Nitrogen	mg/L	0.75	0.80	0.20	<0.10	0.60	0.22
Total Nitrogen	mg/L	0.85	0.90	0.30	<0.2	0.70	0.32
TN:TP Molar Ratios	-	533	556	163	101	493	144
Phenols	mg/L	<0.001	0.009	<0.001	<0.001	<0.001	<0.001
Total Organic Carbon	mg/L	2.0	1.2	1.8	1.6	1.9	1.4
Dissolved Organic Carbon	mg/L	1.9	1.1	1.7	1.4	1.8	1.3
Chlorophyll *a*	µg/L	0.45	0.90	0.59	1.90	0.73	1.70
Pheophytin *a*	µg/L	0.72	0.80	0.75	0.20	2.22	0.42

Table 3. - continued -

Parameter	Unit	Reference Lakes		Mine Area Lakes			
		CR-P3-11	CR-P2-13	SDL NW	SDL SE	Camp L.	Mary L.
Total Metals							
Al	mg/L	0.0164	0.0346	0.0090	0.0356	0.0060	0.0425
Sb	mg/L	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
As	mg/L	<0.00010	0.00012	<0.00010	<0.00010	<0.00010	<0.00010
Ba	mg/L	0.00276	0.00243	0.00502	0.00462	0.00548	0.00372
Be	mg/L	<0.00002	<0.00002	<0.00002	<0.00002	<0.00002	<0.00002
Bi	mg/L	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
B	mg/L	<0.0100	<0.0100	<0.0100	<0.0100	<0.0100	<0.0100
Cd	mg/L	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010
Ca	mg/L	3.6	3.8	12.2	10.4	12.3	6.5
Cr	mg/L	0.00077	0.00175	0.00038	0.00019	0.00014	0.00023
Cu	mg/L	0.00046	0.00179	0.00312	0.00076	0.00087	0.00066
Co	mg/L	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Fe	mg/L	0.03	0.08	0.02	0.04	0.01	0.05
Pb	mg/L	0.00007	0.00009	<0.00005	<0.00005	<0.00005	0.00007
Li	mg/L	<0.00005	<0.00005	0.00034	<0.00005	0.00082	<0.00005
Mg	mg/L	1.89	2.24	7.42	6.15	7.39	3.77
Mn	mg/L	0.00402	0.00232	0.00203	0.00276	0.00230	0.00168
Hg	mg/L	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010
Mo	mg/L	0.00006	0.00042	0.00077	0.00047	0.00022	0.00011
Ni	mg/L	0.0008	0.0010	0.0007	0.0006	0.0006	<0.00050
K	mg/L	0.355	0.310	0.873	0.706	0.881	0.471
Se	mg/L	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
Si	mg/L	0.27	0.37	0.61	0.57	0.40	0.47
Ag	mg/L	<0.000001	0.0000085	<0.000001	<0.000001	<0.000001	<0.000001
Na	mg/L	1.09	0.70	1.06	1.06	1.04	0.94
Sr	mg/L	0.00492	0.00368	0.00795	0.00706	0.00919	0.00513
Tl	mg/L	<0.000001	<0.000001	<0.000001	<0.000001	<0.000001	<0.000001
Sn	mg/L	<0.00010	0.00050	<0.00010	<0.00010	<0.00010	<0.00010
Ti	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
U	mg/L	0.000074	0.000136	0.000931	0.000695	0.000584	0.000498
V	mg/L	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Zn	mg/L	0.013	0.004	<0.0030	<0.0030	<0.0030	<0.0030

Table 3. - continued -

Paramaeter	Unit	Reference Lakes		Mine Area Lakes			
		CR-P3-11	CR-P2-13	SDL NW	SDL SE	Camp L.	Mary L.
Dissolved Metals							
Al	mg/L	0.0043	0.0039	<0.00100	0.0022	<0.00100	0.0073
Sb	mg/L	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
As	mg/L	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Ba	mg/L	0.00274	0.00220	0.00494	0.00439	0.00546	0.00349
Be	mg/L	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Bi	mg/L	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
B	mg/L	<0.0100	<0.0100	<0.0100	<0.0100	<0.0100	<0.0100
Cd	mg/L	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010
Ca	mg/L	3.44	3.83	11.73	9.81	11.97	6.38
Cr	mg/L	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Cr(VI)	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cr(III)	mg/L	-	-	<0.005	<0.005	<0.005	<0.005
Co	mg/L	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Cu	mg/L	0.00036	0.00041	0.00074	0.00059	0.00279	0.00049
Fe	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Pb	mg/L	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005
Li	mg/L	<0.00005	<0.00005	0.00090	0.00095	0.00113	0.00117
Mg	mg/L	1.81	2.24	7.16	5.85	7.08	3.66
Mn	mg/L	0.00116	0.00084	0.00041	0.00032	0.00063	0.00072
Hg	mg/L	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010
Mo	mg/L	<0.00005	0.00012	0.00072	0.00045	0.00021	0.00015
Ni	mg/L	0.00050	0.00109	0.00060	<0.00050	0.00054	<0.00050
K	mg/L	0.349	0.288	0.852	0.694	0.876	0.458
Se	mg/L	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Si	mg/L	0.23	0.32	0.59	0.49	0.36	0.36
Ag	mg/L	<0.0000010	<0.0000010	<0.0000010	<0.0000010	<0.0000010	<0.0000010
Na	mg/L	1.11	0.670	1.05	0.92	1.05	0.959
Sr	mg/L	0.00475	0.00352	0.00756	0.00667	0.00857	0.00480
Tl	mg/L	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010
Sn	mg/L	<0.00010	0.00082	<0.00010	<0.00010	<0.00010	<0.00010
Ti	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.02
U	mg/L	0.000063	0.000118	0.000897	0.000666	0.000552	0.000455
V	mg/L	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Zn	mg/L	0.00139	0.00255	0.00133	0.00092	0.00217	0.00199

Table 4. Mean, standard deviation (SD), coefficient of variation (COV), and 95th percentiles for phytoplankton species diversity, evenness, and richness metrics measured in reference lakes (summer and fall 2013) and Mine Area lakes (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**
CR-P3-11	0.82	0.24	24	0.70	9.20	0.39
CL-P2-13	0.69	0.18	22	0.59	6.41	0.30
Camp Lake	0.72	0.22	17	0.60	5.55	0.33
Sheardown Lake NW	0.71	0.22	18	0.61	6.19	0.34
Sheardown Lake SE	0.71	0.29	16	0.61	6.1	0.37
Mary Lake	0.52	0.2	15	0.47	3.84	0.28
	SD					
	Simpson's Diversity Index	**Simpson's Evenness**	**Species Richness**	**Shannon's Evenness**	**Hill's Effective Richness**	**Hill's Evenness**
CR-P3-11	0.00	0.00	1	0.02	0.44	0.03
CL-P2-13	0.17	0.09	1	0.14	2.81	0.12
Camp Lake	0.07	0.05	3	0.04	1.18	0.04
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
Mary Lake	0.19	0.15	4	0.17	2.00	0.15
	COV					
	Simpson's Diversity Index	**Simpson's Evenness**	**Species Richness**	**Shannon's Evenness**	**Hill's Effective Richness**	**Hill's Evenness**
CR-P3-11	1	1	3	3	5	8
CL-P2-13	25	53	3	24	44	41
Camp Lake	9	25	20	7	21	13
Sheardown Lake NW	17	34	16	16	31	25
Sheardown Lake SE	27	42	18	26	41	34
Mary Lake	36	75	28	36	52	55
	95TH PERCENTILE					
	Simpson's Diversity Index	**Simpson's Evenness**	**Species Richness**	**Shannon's Evenness**	**Hill's Effective Richness**	**Hill's Evenness**
CR-P3-11	0.83	0.24	24	0.72	9.5	0.41
CL-P2-13	0.80	0.24	22	0.68	8.2	0.37
Camp Lake	0.81	0.28	23	0.66	7.5	0.37
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
Mary Lake	0.84	0.52	21	0.78	7.5	0.56

Table 5. Summary statistics for total crustacean zooplankton density (individuals/m^3) by waterbody (seasonally) for the candidate reference (2013) and Mine Area (2007 and 2008) lakes.

Waterbody	Season	n [1]	Mean	SD	Min	Max	Taxonomic Richness [2]
Lake CR-P3-11							
	Summer	3	7,942	741	7,153	8,623	5
	Fall	1	7,920	-	-	-	4
Lake CL-P2-13							
	Summer	1	1,163	-	-	-	5
	Fall	3	1,619	414	1,354	2,096	5
Camp Lake							
	Summer	6	11,772	8,442	3,244	22,619	4
	Fall	3	9,829	6,269	5,561	17,027	5
Sheardown Lake NW							
	Summer	10	11,878	8,335	2,637	26,211	7
	Fall	10	19,966	17,352	3,753	53,307	6
Sheardown Lake SE							
	Summer	6	13,127	10,132	3,303	31,074	6
	Fall	6	10,578	5,707	4,776	16,854	6
Mary Lake							
	Summer	9	2,713	2,246	750	7,811	9
	Fall	5	6,147	5,159	1,528	13,832	5

[1] number of samples collected

[2] total number of taxa observed to species-level, not the average number of taxa

Table 6. Mean, median, standard deviation (SD), standard error (SE), minimum (Min), maximum (Max), precision (20%), 95th percentile, and coefficient of variation (%COV) for BMI composition and richness metrics measured from the offshore profundal habitat of candidate reference lakes and Mine Area lakes.

Metric	**Total Macroinvertebrate Density (individuals/m^2)**					
Habitat Type	**Offshore Profundal (14)**					
Lake	**CL-P2-13**	**CR-P3-11**	**SDL NW**	**SDL SE**	**Camp**	**Mary**
Sample Year(s)	2013	2013	2007, 2008, 2011, 2013	2007	2007	2006, 2007
n (rep. stn.)	1	1	17	6	12	11
Mean	1593	3861	1871	5042	2649	2668
Median	--	--	1783	4674	1978	2670
SD	--	--	1143.36	1350.49	1496.51	2057.11
SE	--	--	277.31	551.34	432.01	620.24
Min	--	--	102	3548	730	609
Max	--	--	4652	6730	6226	7017
Sub-samples (20% precision)	--	--	9.33	1.79	7.98	14.86
95th Percentile	--	--	3603.56	6700.00	5250.43	5917.00
COV (%)	--	--	61.10	26.78	56.50	77.10

Metric	**Chironomidae Proportion (% of total density)**					
Habitat Type	**Offshore Profundal (14)**					
Lake	**CL-P2-13**	**CR-P3-11**	**SDL NW**	**SDL SE**	**Camp**	**Mary**
Sample Year(s)	2013	2013	2007, 2008, 2011, 2013	2007	2007	2006, 2007
n (rep. stn.)	1	1	17	6	12	11
Mean	100	98	91	97	95	96
Median	--	--	94	98	96	99
SD	--	--	7.68	2.85	4.32	4.54
SE	--	--	1.86	1.16	1.25	1.37
Min	--	--	70	92	88	89
Max	--	--	98	100	100	100
Sub-samples (20% precision)	--	--	0.18	0.02	0.05	0.06
95th Percentile	--	--	97.08	99.74	100.00	100.00
COV (%)	--	--	8.46	2.94	4.55	4.71

Metric	**Shannon's Evenness Index**					
Habitat Type	**Offshore Profundal (14)**					
Lake	**CL-P2-13**	**CR-P3-11**	**SDL NW**	**SDL SE**	**Camp**	**Mary**
Sample Year(s)	2013	2013	2007, 2008, 2011, 2013	2007	2007	2006, 2007
n (rep. stn.)	1	1	17	6	12	11
Mean	0.63	0.67	0.45	0.59	0.56	0.52
Median	--	--	0.43	0.59	0.57	0.56
SD	--	--	0.14	0.09	0.13	0.21
SE	--	--	0.03	0.04	0.04	0.06
Min	--	--	0.23	0.46	0.33	0.00
Max	--	--	0.68	0.68	0.82	0.81
Sub-samples (20% precision)	--	--	2.53	0.54	1.41	4.09
95th Percentile	--	--	0.66	0.68	0.75	0.73
COV (%)	--	--	31.80	14.65	23.75	40.42

Table 6. - continued -

Metric	Simpson's Diversity Index					
Habitat Type	Offshore Profundal (14)					
Lake	CL-P2-13	CR-P3-11	SDL NW	SDL SE	Camp	Mary
Sample Year(s)	2013	2013	2007, 2008, 2011, 2013	2007	2007	2006, 2007
n (rep. stn.)	1	1	17	6	12	11
Mean	0.51	0.67	0.41	0.61	0.60	0.50
Median	--	--	0.44	0.65	0.61	0.58
SD	--	--	0.16	0.15	0.12	0.23
SE	--	--	0.04	0.06	0.03	0.07
Min	--	--	0.15	0.35	0.39	0.00
Max	--	--	0.63	0.75	0.76	0.69
Sub-samples (20% precision)	--	--	4.06	1.46	0.94	5.38
95th Percentile	--	--	0.61	0.74	0.76	0.68
COV (%)	--	--	40.30	24.13	19.41	46.38

Metric	Total Taxa Richness (genus-level)					
Habitat Type	Offshore Profundal (14)					
Lake	CL-P2-13	CR-P3-11	SDL NW	SDL SE	Camp	Mary
Sample Year(s)	2013	2013	2007, 2008, 2011, 2013	2007	2007	2006, 2007
n (rep. stn.)	1	1	17	6	12	11
Mean	9 [1]	17 [1]	9	9	9	9
Median	--	--	9	10	9	8
SD	--	--	2.27	2.83	2.76	5.66
SE	--	--	0.55	1.15	0.80	1.71
Min	--	--	4	4	6	1
Max	--	--	12	12	14	18
Sub-samples (20% precision)	--	--	1.77	2.47	2.36	10.11
95th Percentile	--	--	12.00	11.75	13.45	16.50
COV (%)	--	--	26.58	31.43	30.70	63.59

[1] Total number of taxa observed to genus-level, not the average number of taxa

Metric	Hill's Effective Richness					
Habitat Type	Offshore Profundal (14)					
Lake	CL-P2-13	CR-P3-11	SDL NW	SDL SE	Camp	Mary
Sample Year(s)	2013	2013	2007, 2008, 2011, 2013	2007	2007	2006, 2007
n (rep. stn.)	1	1	17	6	12	11
Mean	3	5	3	4	4	3
Median	--	--	2	4	3	4
SD	--	--	0.88	1.15	1.24	1.31
SE	--	--	0.21	0.47	0.36	0.40
Min	--	--	1	2	2	1
Max	--	--	4	5	6	5
Sub-samples (20% precision)	--	--	2.82	2.39	3.04	3.85
95th Percentile	--	--	3.94	5.03	5.52	4.90
COV (%)	--	--	33.60	30.89	34.85	39.27

Table 7. Substrate types in Lake CR-P3-11.

Substrate Type	Shoreline Zone (0-2 m)		Euphotic Zone (2-12 m)		Total	
	(m^2)	%	(m^2)	%	(m^2)	%
Boulder / Cobble	6,687	17	36,976	8	43,663	9
Gravel/Pebble	5,843	15	2,241	0.5	8,084	2
Sand	9,623	25	167,909	37	177,532	36
Fine Sand, Silt/Clay	16,504	43	250,251	55	266,754	54
Grand Total	38,657	100	457,376	100	496,033	100

Table 8. Comparison of aquatic habitat and lake characteristics.

Lake	Drainage Basin Area (km^2)	Lake 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	26.47	2.21	2.21	11.98	13.03	35.08	27.5	5.1	28.2	61.1	5.6
Sheardown Lake NW	6.55	0.678	0.678	9.66	12.11	30.1	8.18	10.1	41.8	46.0	2.0
CR-P3-11	2.35	0.496	0.484	4.86	6.1	11.65	3.01	8.8	1.6	35.8	53.8
CL-P2-13	3.39	0.241	0.228	14.9	9.4	15.34	2.27	18.1	12.6	8.4	60.9

Table 9. Substrate types in Lake CL-P2-13.

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	3,128	30.4	35,752	19.5	4,547	9.8	43,427	18.1
Gravel/Pebble	1,031	10.0	23,035	12.6	6,102	13.2	30,169	12.6
Sand	5,164	50.1	14,918	8.1	157	0.3	20,238	8.4
Fine Sand, Silt/Clay	982	9.5	109,761	59.8	35,443	76.6	146,186	60.9
Grand Total	10,305	100.0	183,466	100.0	46,250	100.0	240,021	100.0

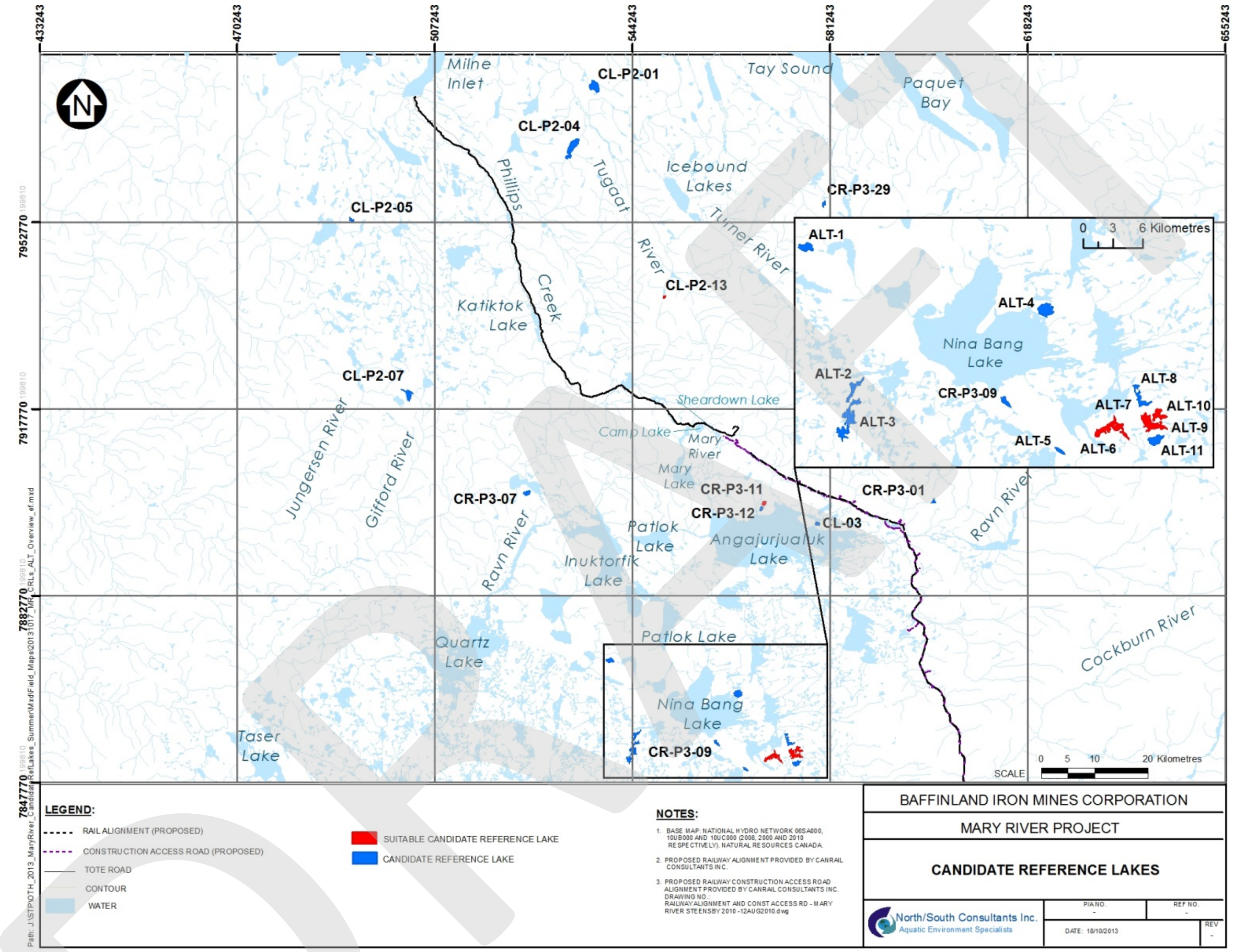


Figure 1. **Proposed candidate reference lakes surveyed during summer and fall 2013. Lakes highlighted in red were identified as those most likely to be suitable as references for Camp and/or Sheardown NW lakes.**

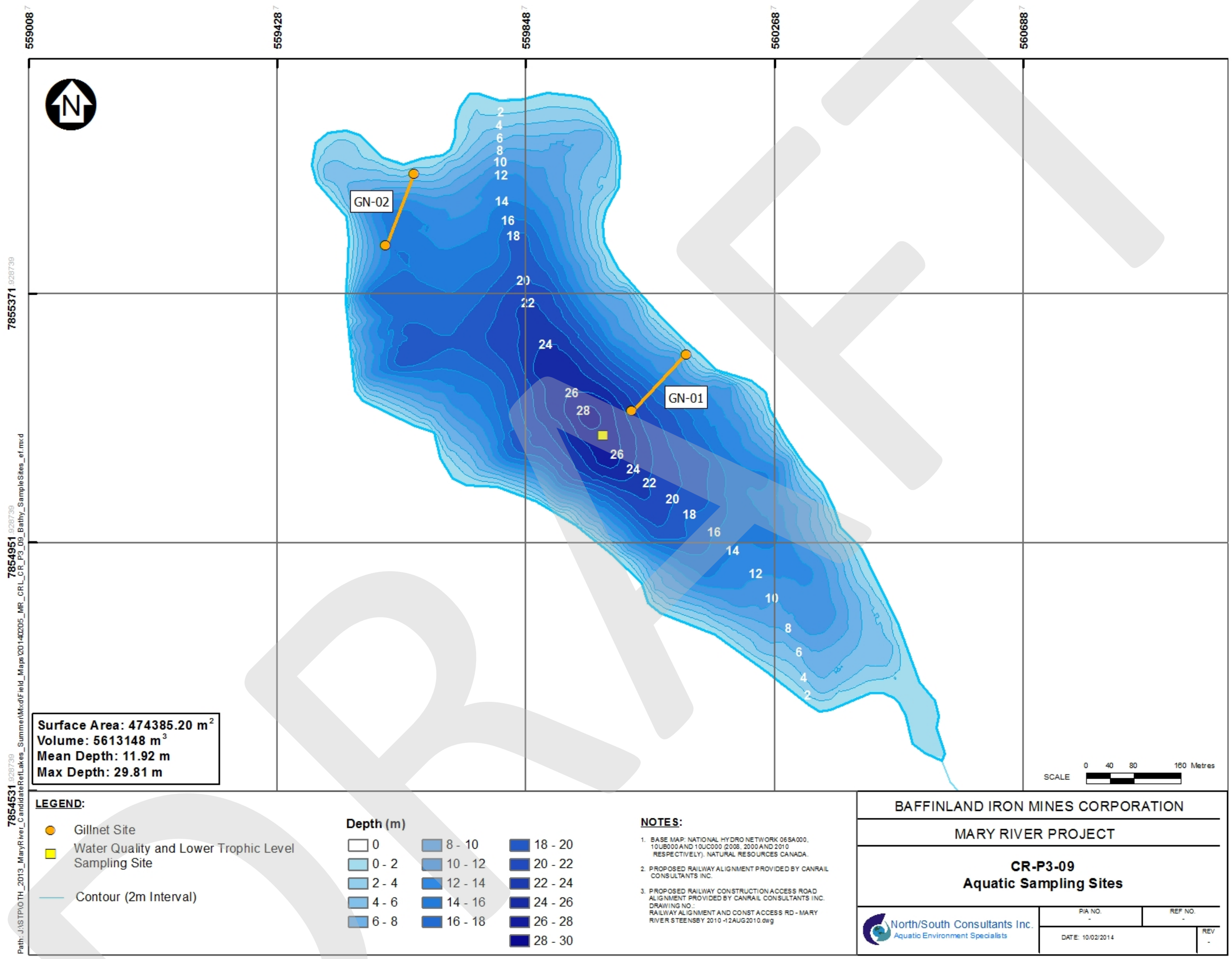


Figure 2. **Bathymetry and locations of water quality, lower trophic level (phytoplankton & zooplankton), and fish sampling sites in Lake CR-P3-09.**

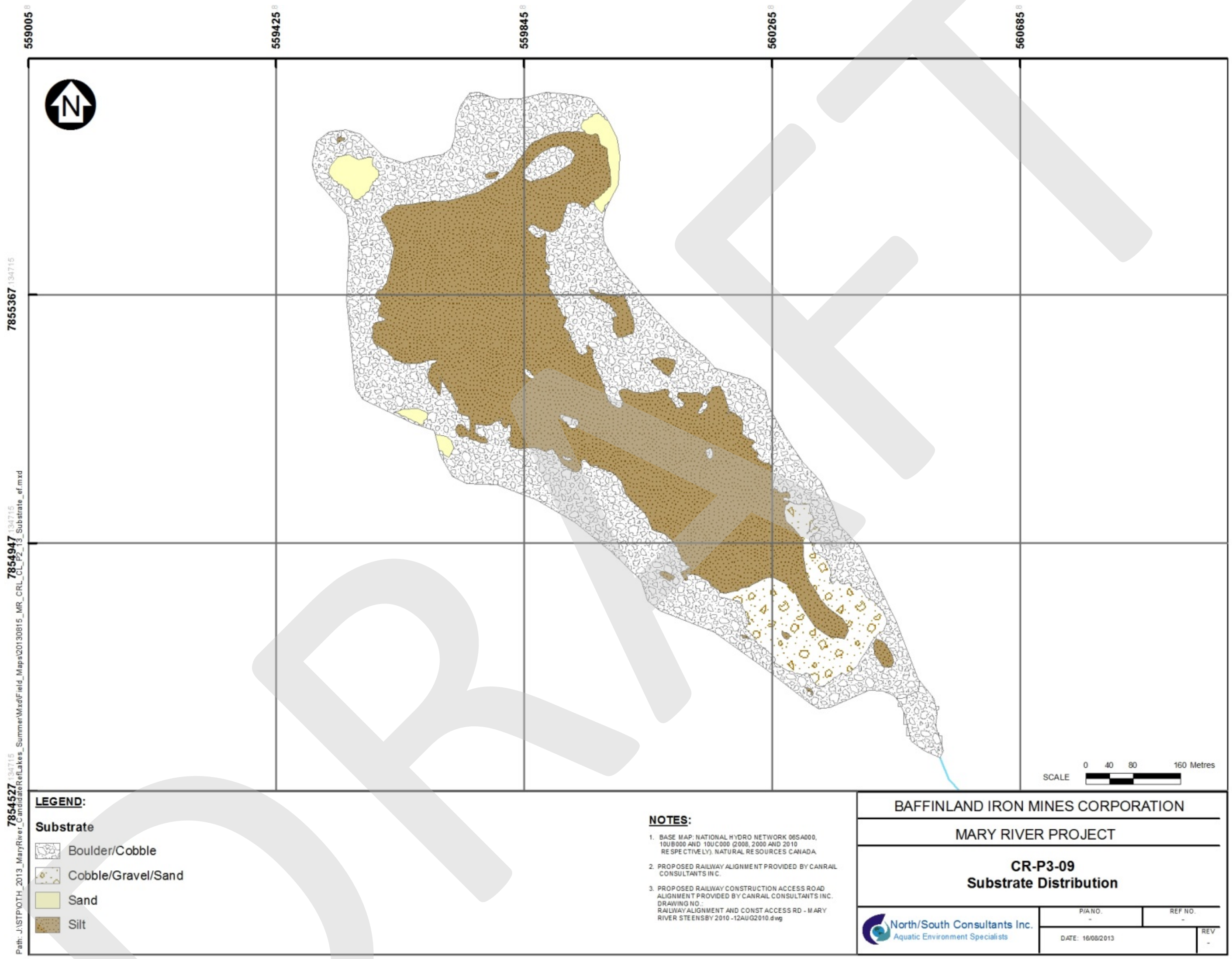


Figure 3. Substrate distribution map for Lake CR-P3-09, summer 2013.

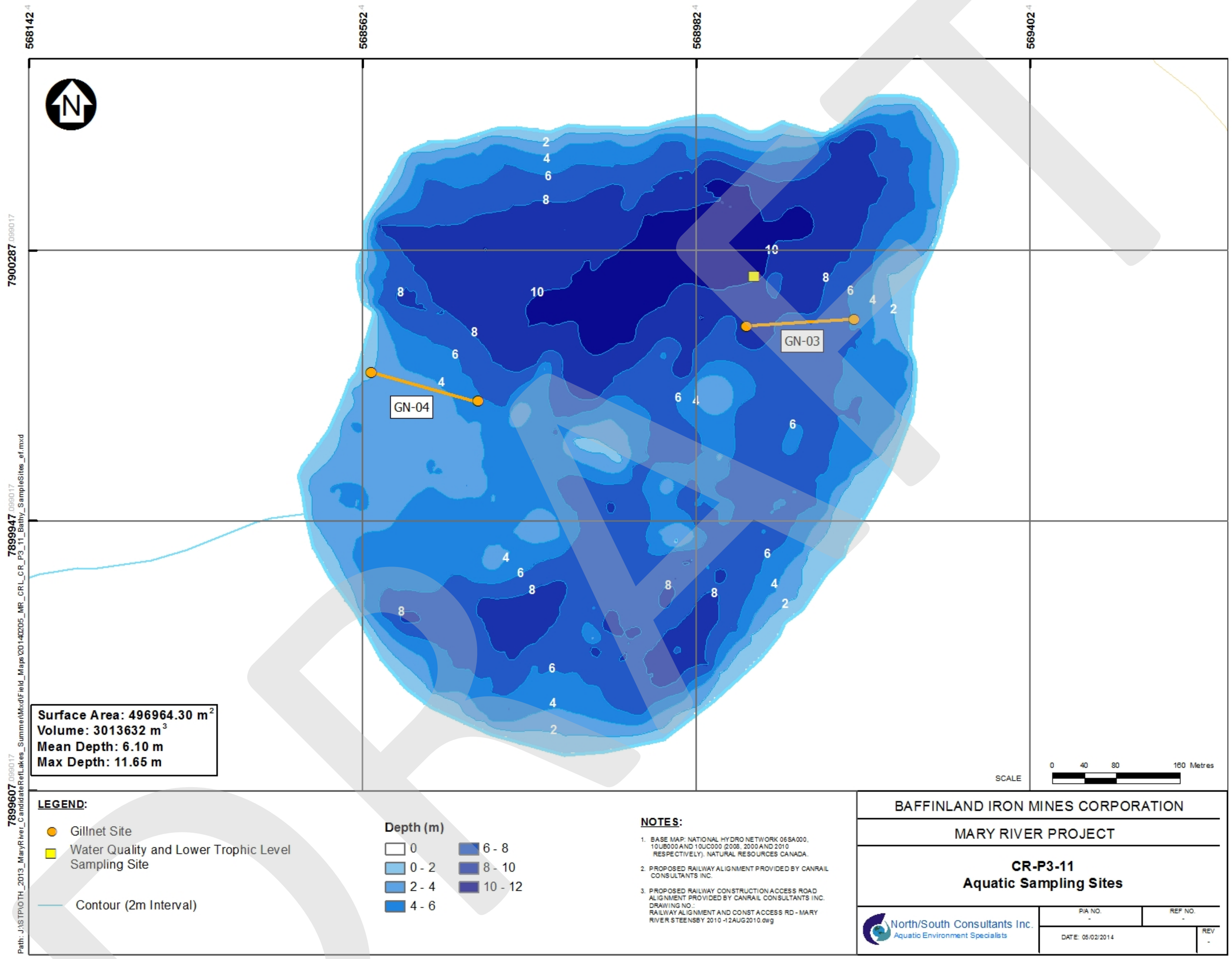
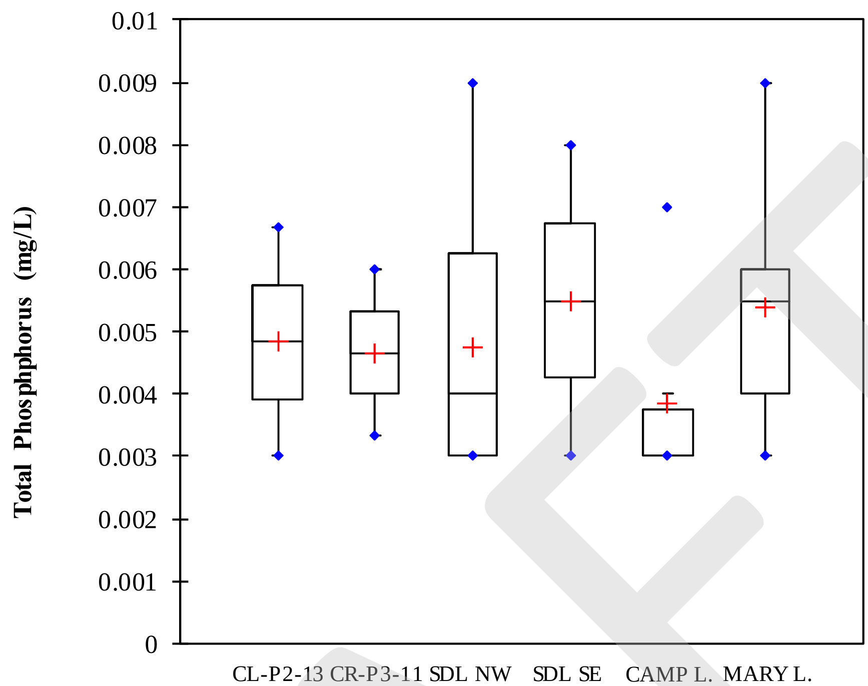


Figure 4. **Bathymetry and locations of water quality, lower trophic level (phytoplankton, zooplankton & BMI), and fish sampling sites in Lake CR-P3-11.**

(A)



(B)

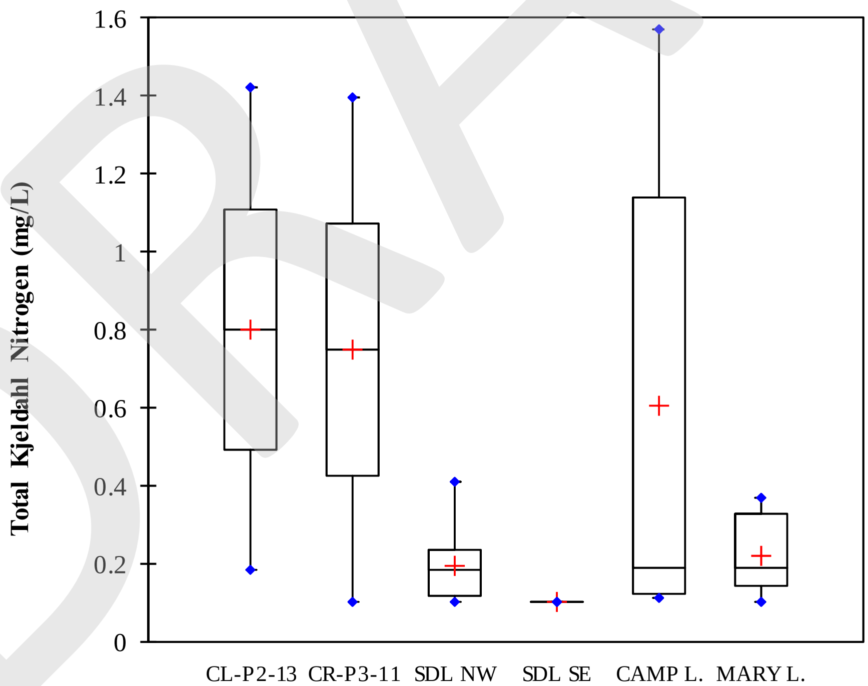


Figure 5. Total phosphorus (A) and total Kjeldahl nitrogen (B) measured in candidate reference lakes and Mine Area lakes in the open-water season, 2013.

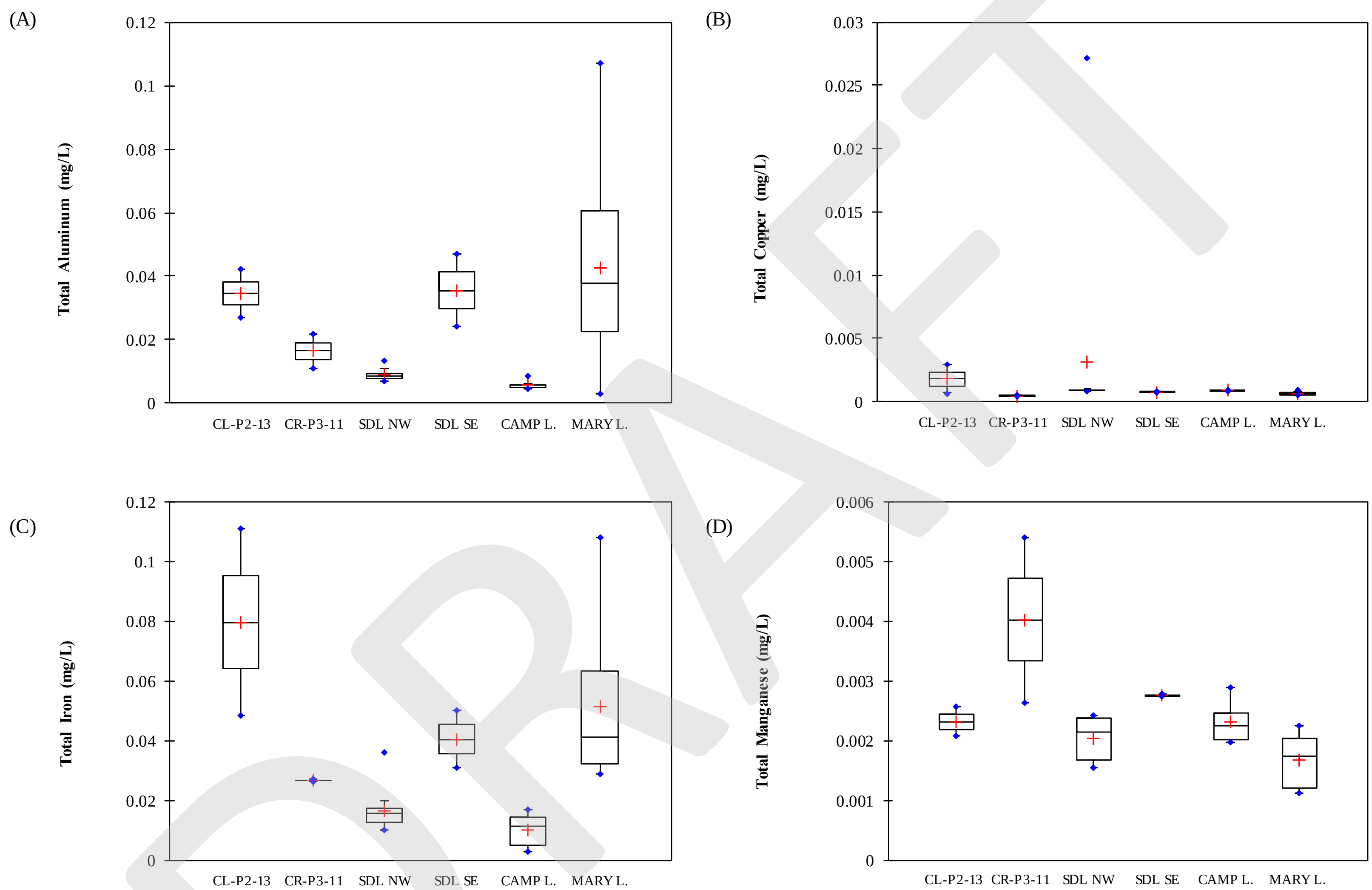


Figure 6. Total aluminum (A), total copper (B), total iron (C), and total manganese (D) measured in candidate reference lakes and Mine Area lakes in the open-water season, 2013.

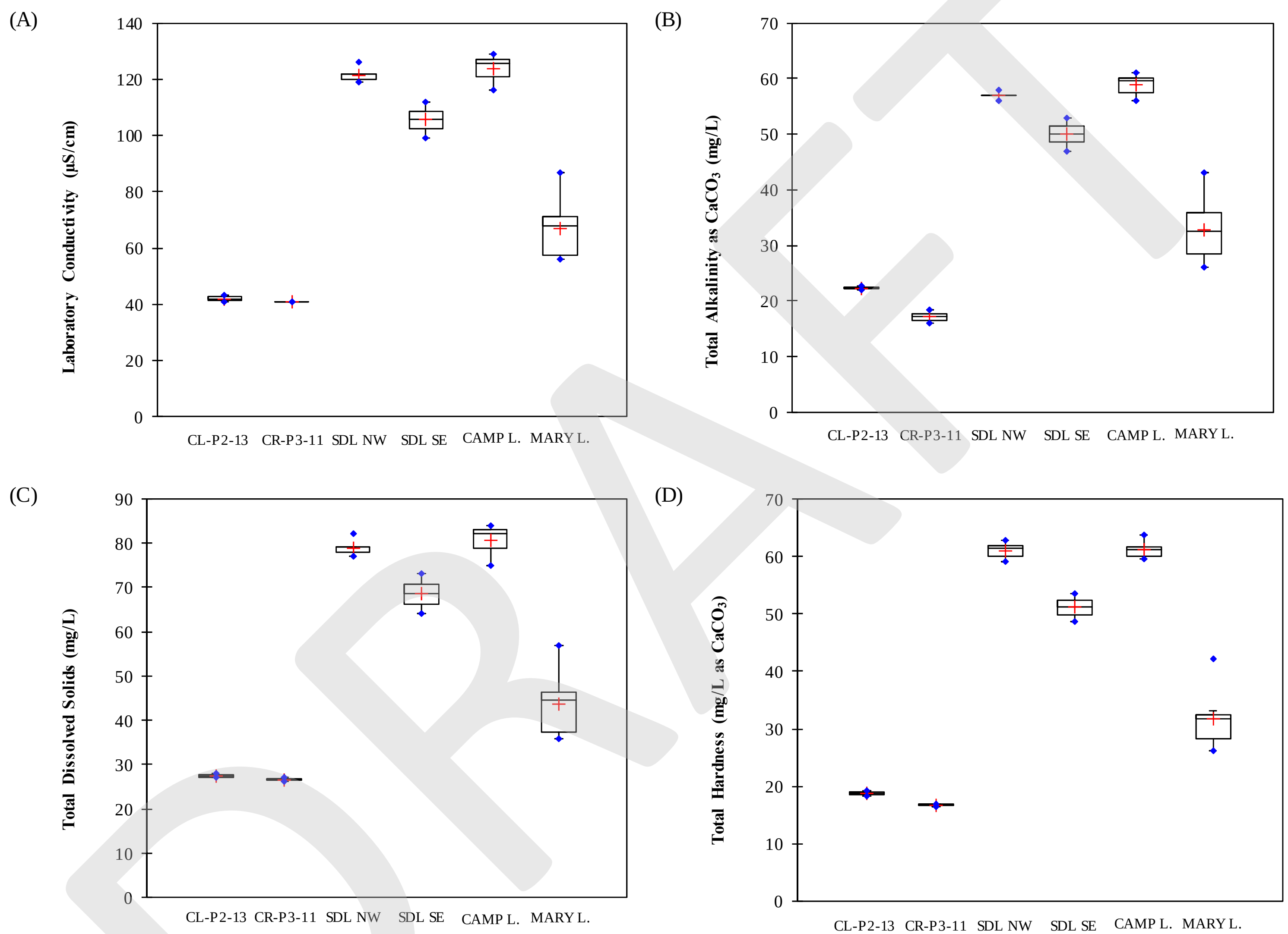


Figure 7. **Laboratory conductivity (A), total alkalinity (B), total dissolved solids (C), and hardness (D) measured in candidate reference lakes and Mine Area lakes in the open-water season, 2013.**

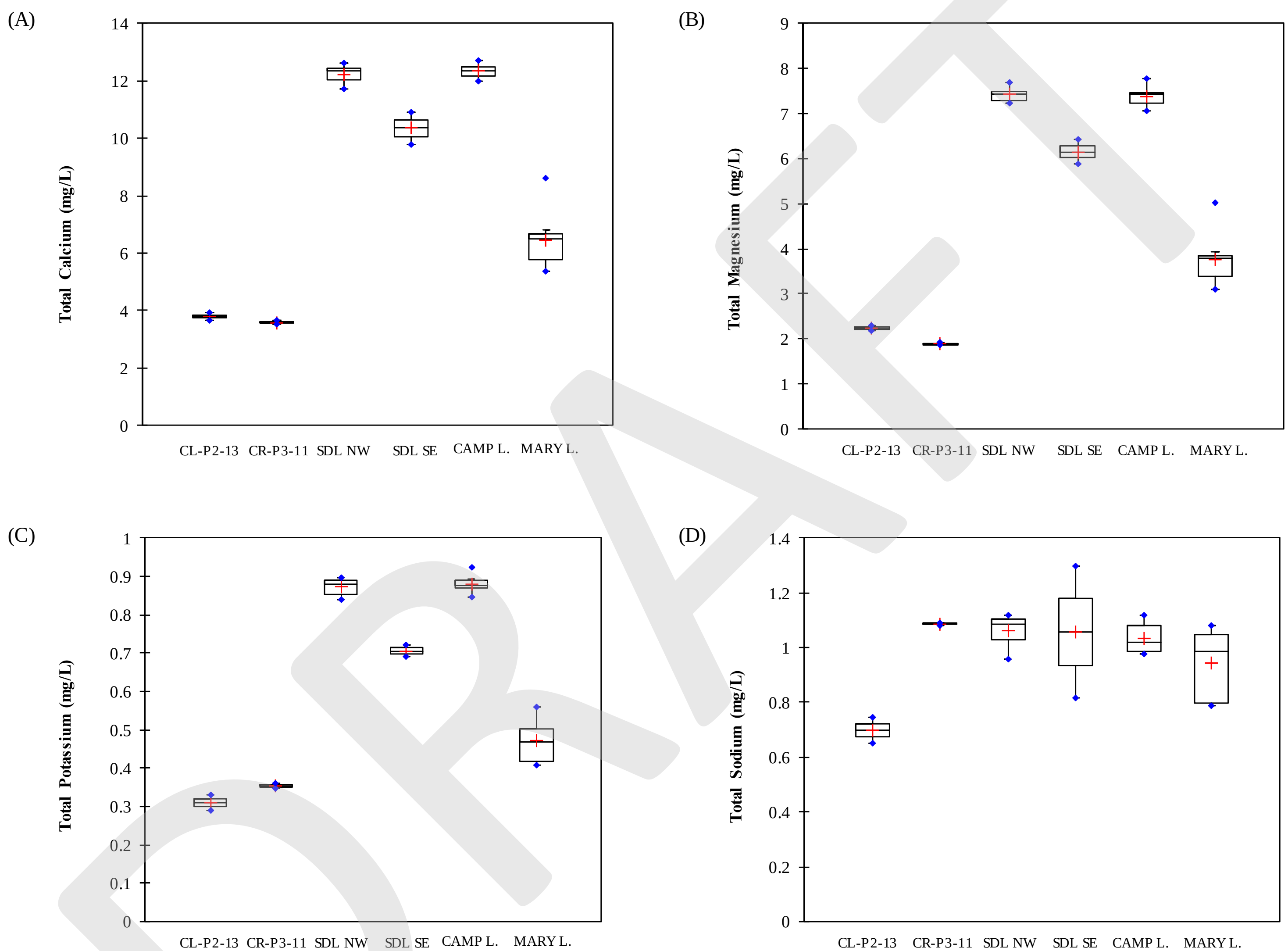


Figure 8. Total calcium (A), total magnesium (B), total potassium (C), and total sodium (D) measured in candidate reference lakes and Mine Area lakes in the open-water season, 2013.

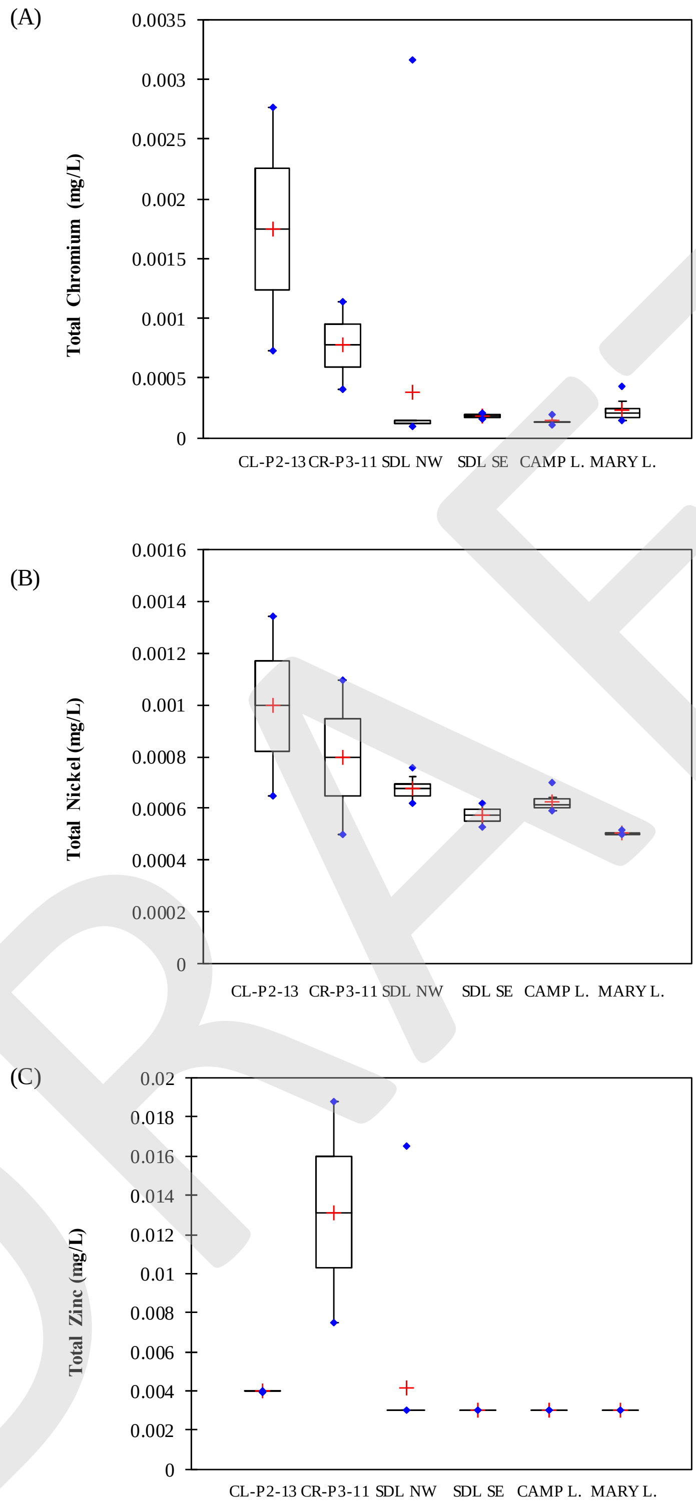


Figure 9. Total chromium (A), total nickel (B), and total zinc (C) measured in candidate reference lakes and Mine Area lakes in the open-water season, 2013.

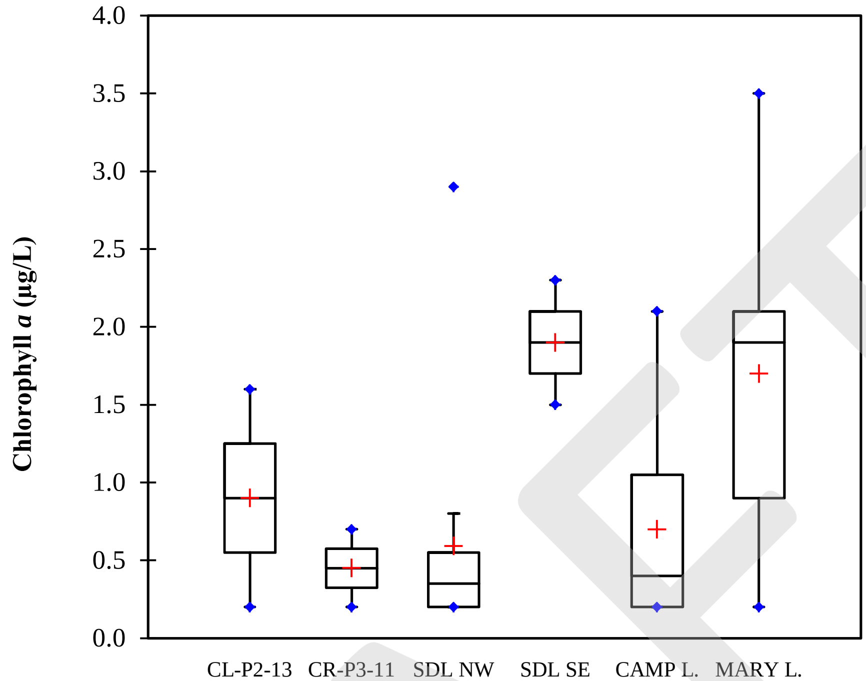


Figure 10. Chlorophyll *a* measured in candidate reference lakes and Mine Area lakes in the open-water season, 2013.

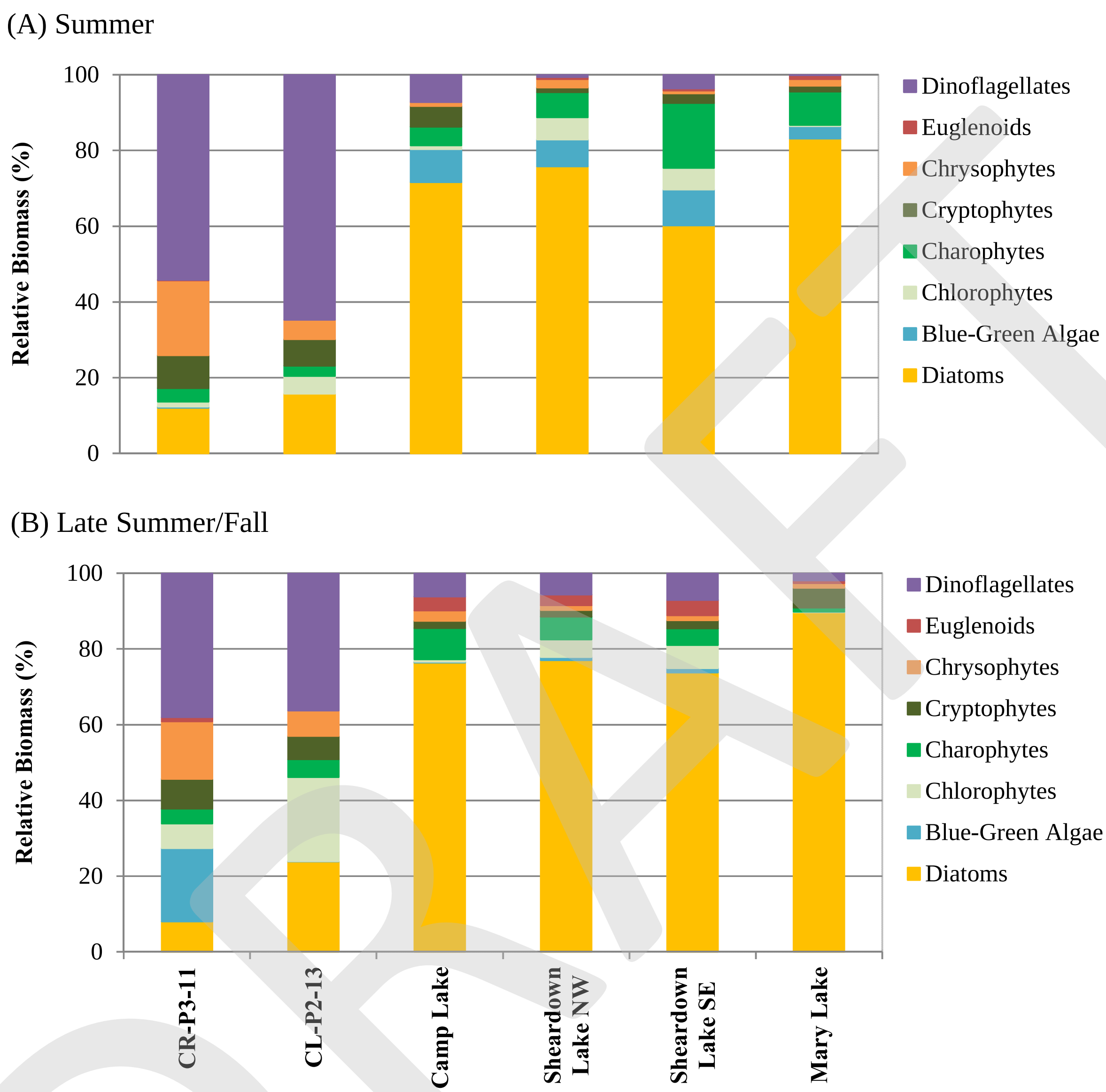


Figure 11. Percent relative biomass of major groups of phytoplankton measured in reference lakes (summer and fall 2013) and Mine Area lakes (summer and late summer/fall, 2007 and 2008).

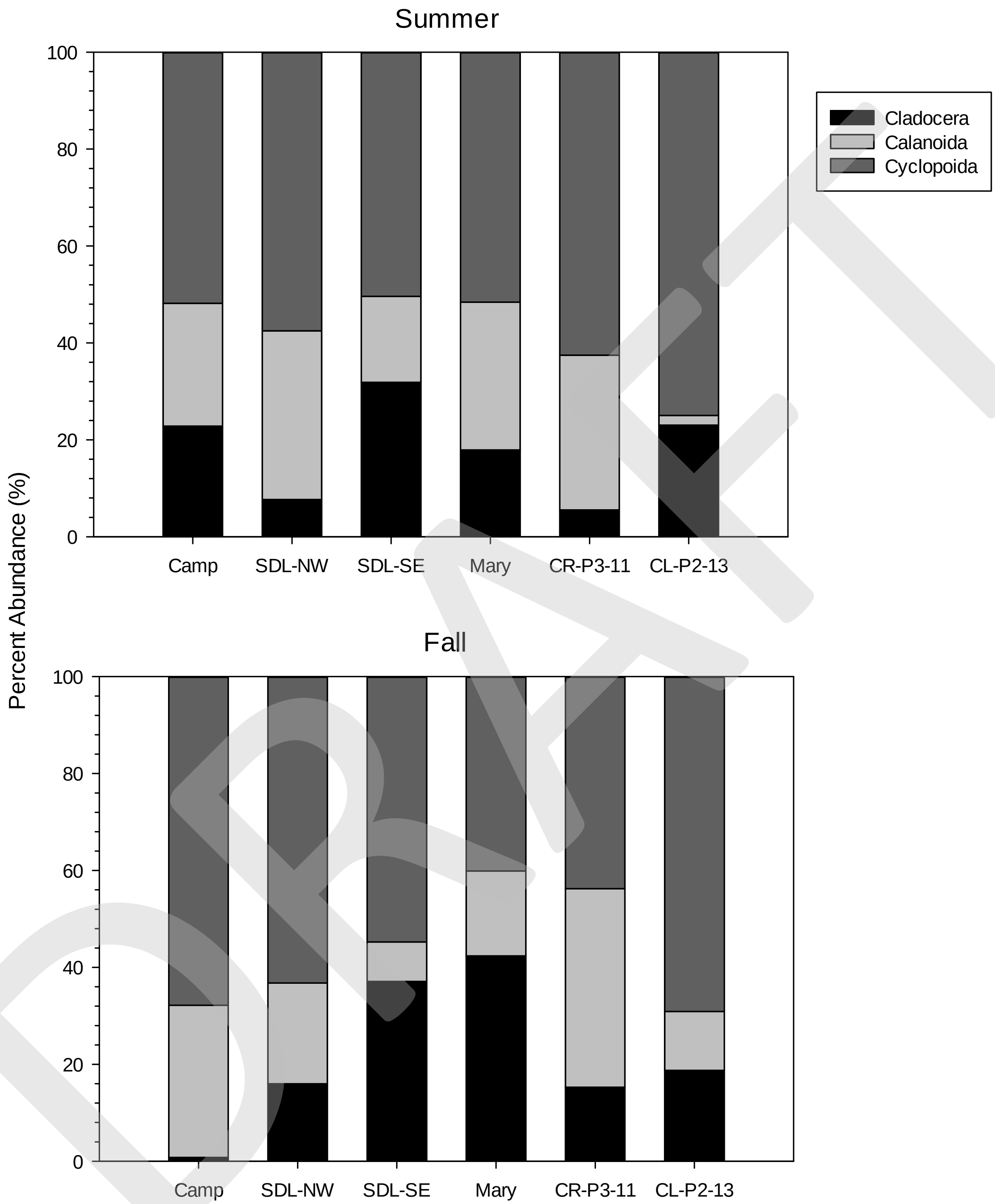


Figure 12. Seasonal relative abundance of crustacean zooplankton in Mine Area (2007 and 2008) and candidate reference (2013) lakes.

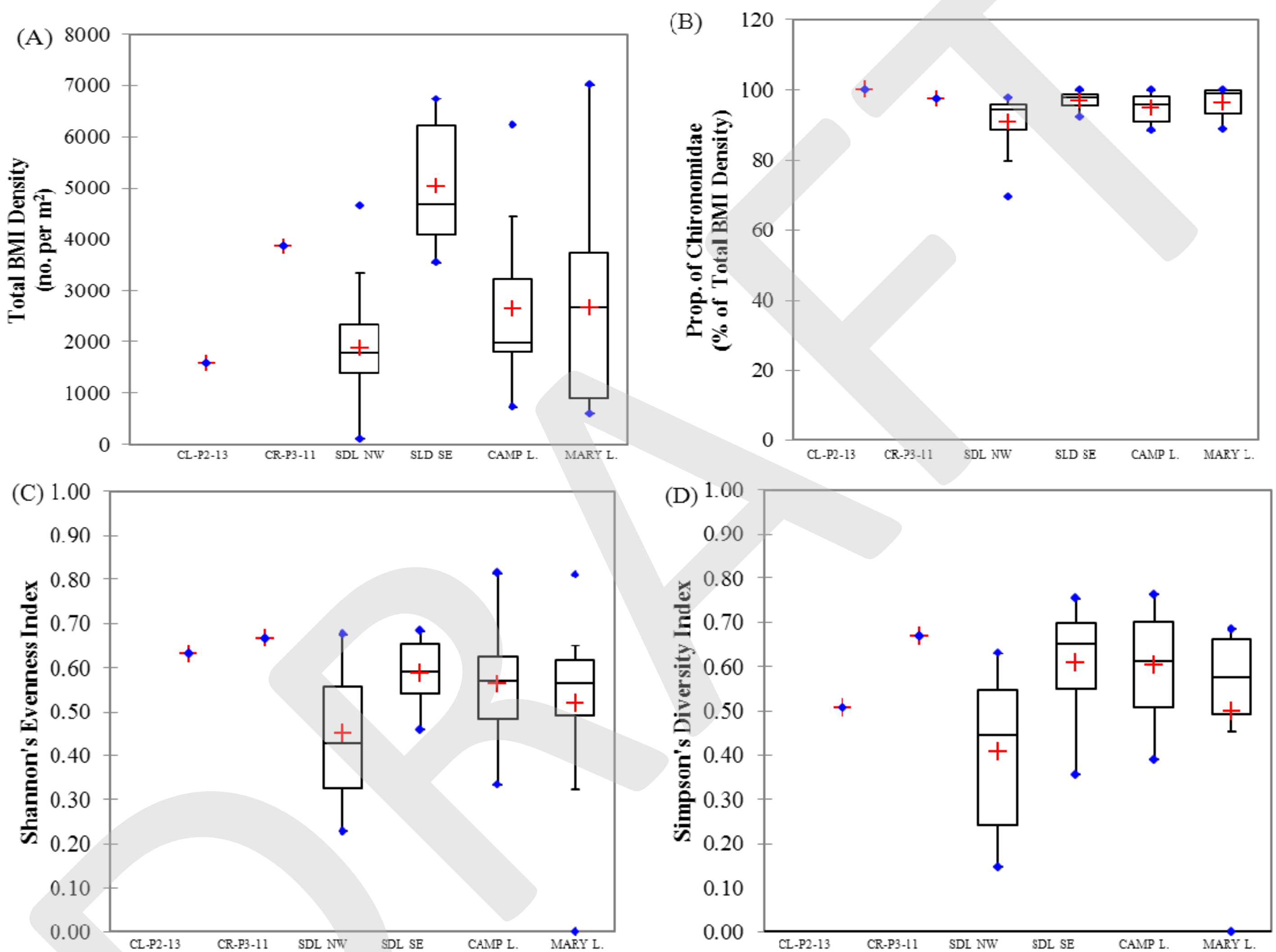


Figure 13. Total benthic macroinvertebrate (BMI) density (A), proportion of Chironomidae (B), Shannon's evenness index (C), and Simpson's diversity index (D) measures calculated from samples collected in the offshore profundal zone of candidate reference lakes (2013) and Mine Area lakes (2006, 2007, 2008, 2011, 2013).

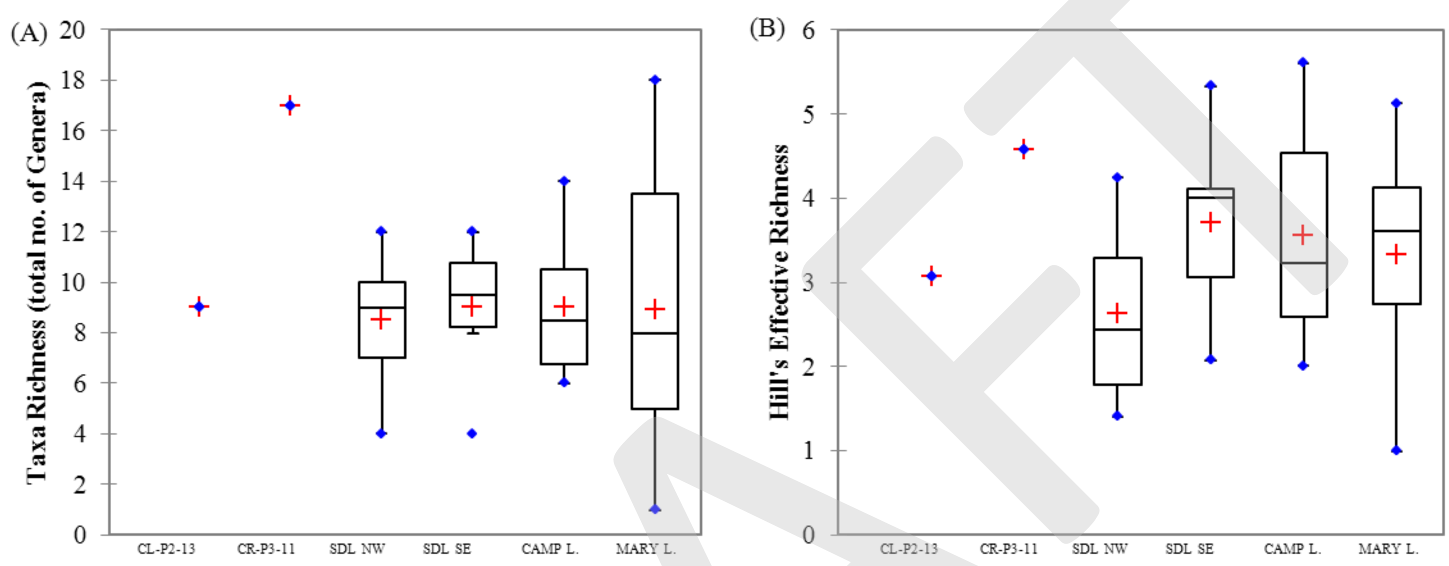


Figure 14. Total number of benthic macroinvertebrate taxa (genus-level) (A), and Hill's effective richness (B) measures calculated from samples collected in the offshore profundal zone of candidate reference lakes (CL-P2-13 and CR-P3-11; 2013) and Mine Area lakes (2006, 2007, 2008, 2011, 2013). Note: taxa richness for candidate reference lakes is the total number of taxa observed, not the average number of taxa.

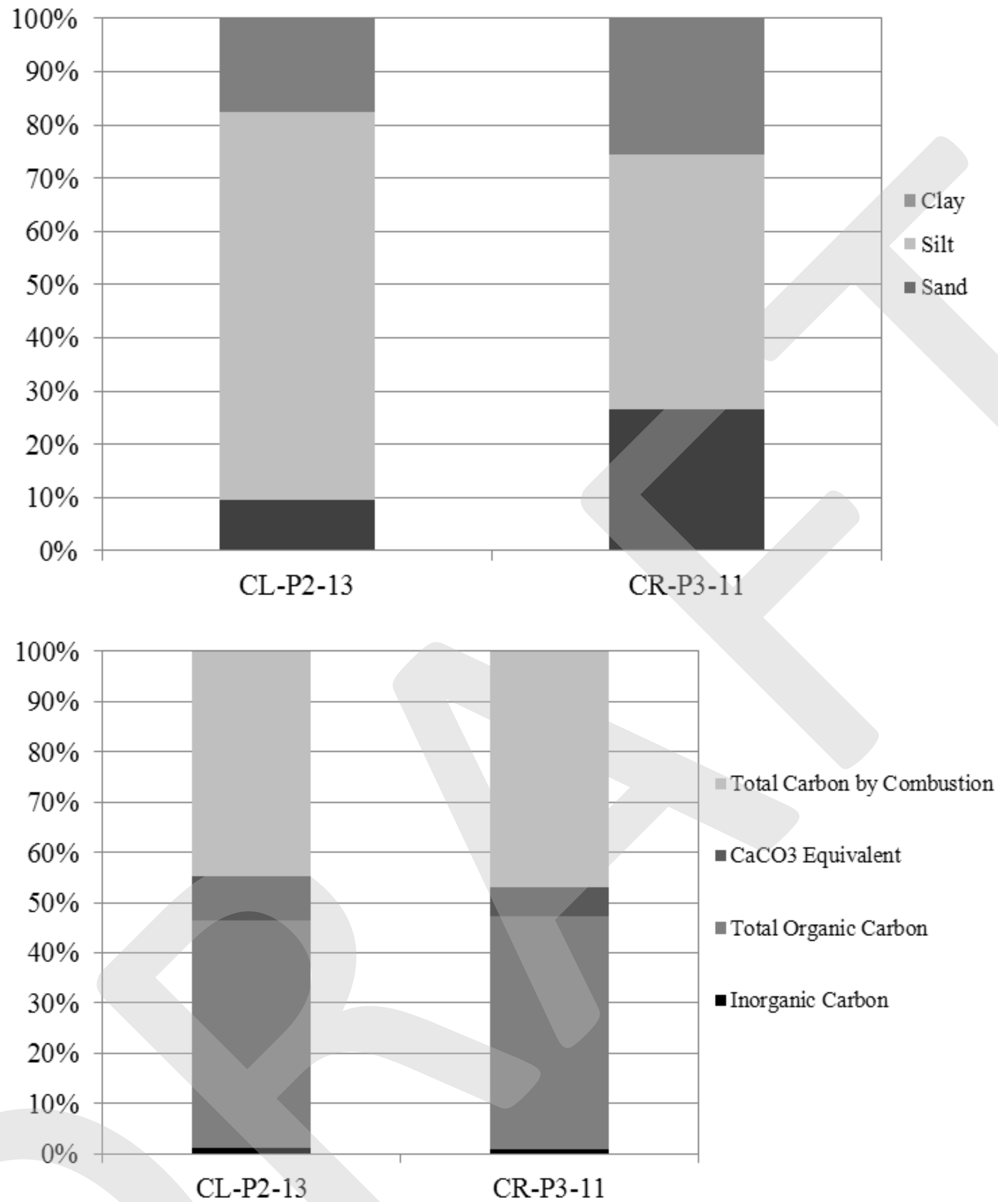


Figure 15. Particle size (% sand, % silt, % clay) (A) and organic carbon analyses (%) (B) from benthic sediment samples collected in the offshore profundal zone of candidate reference lakes (CL-P2-13 and CR-P3-11; 2013).

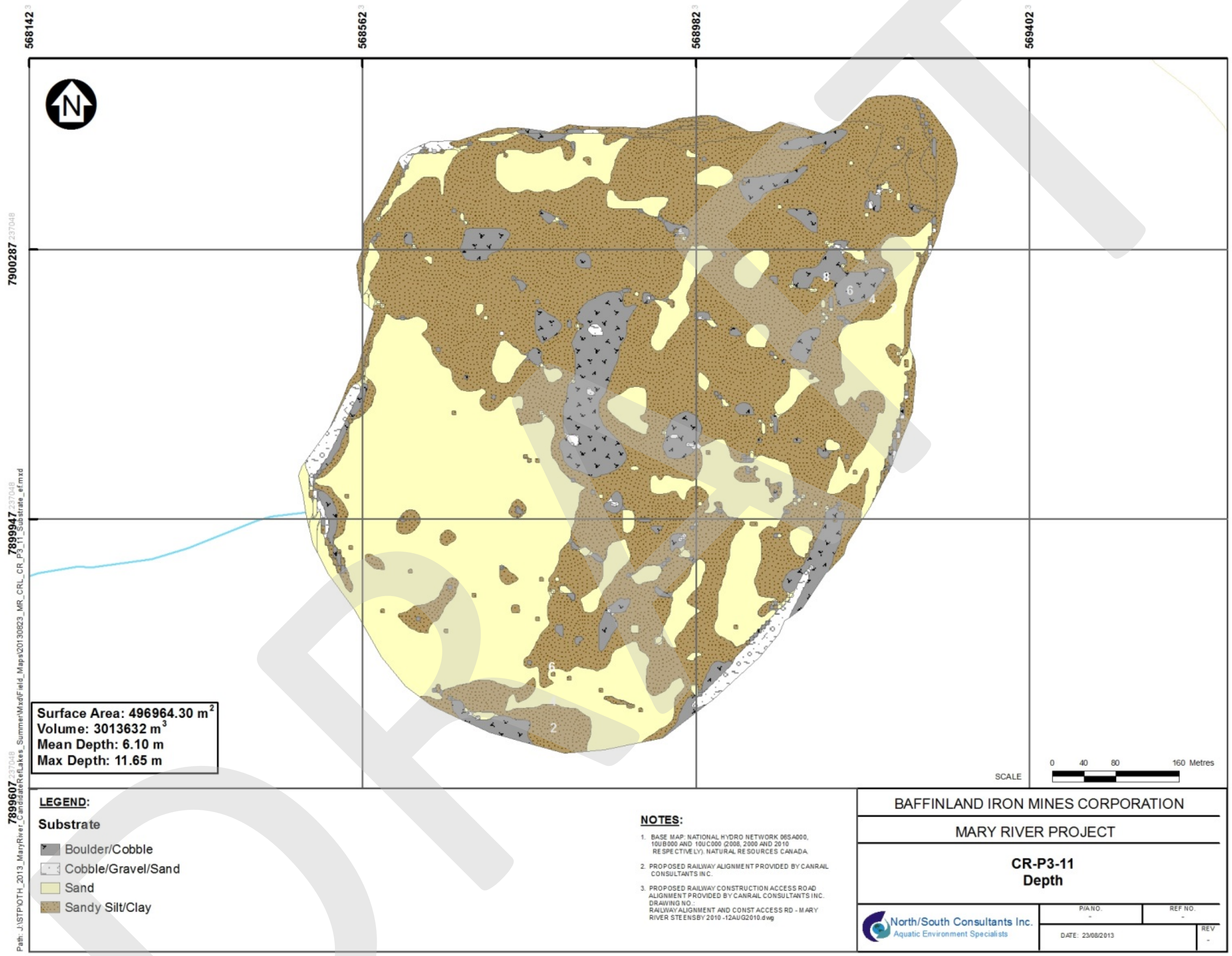


Figure 16. Substrate distribution map for Lake CR-P3-11, summer 2013.

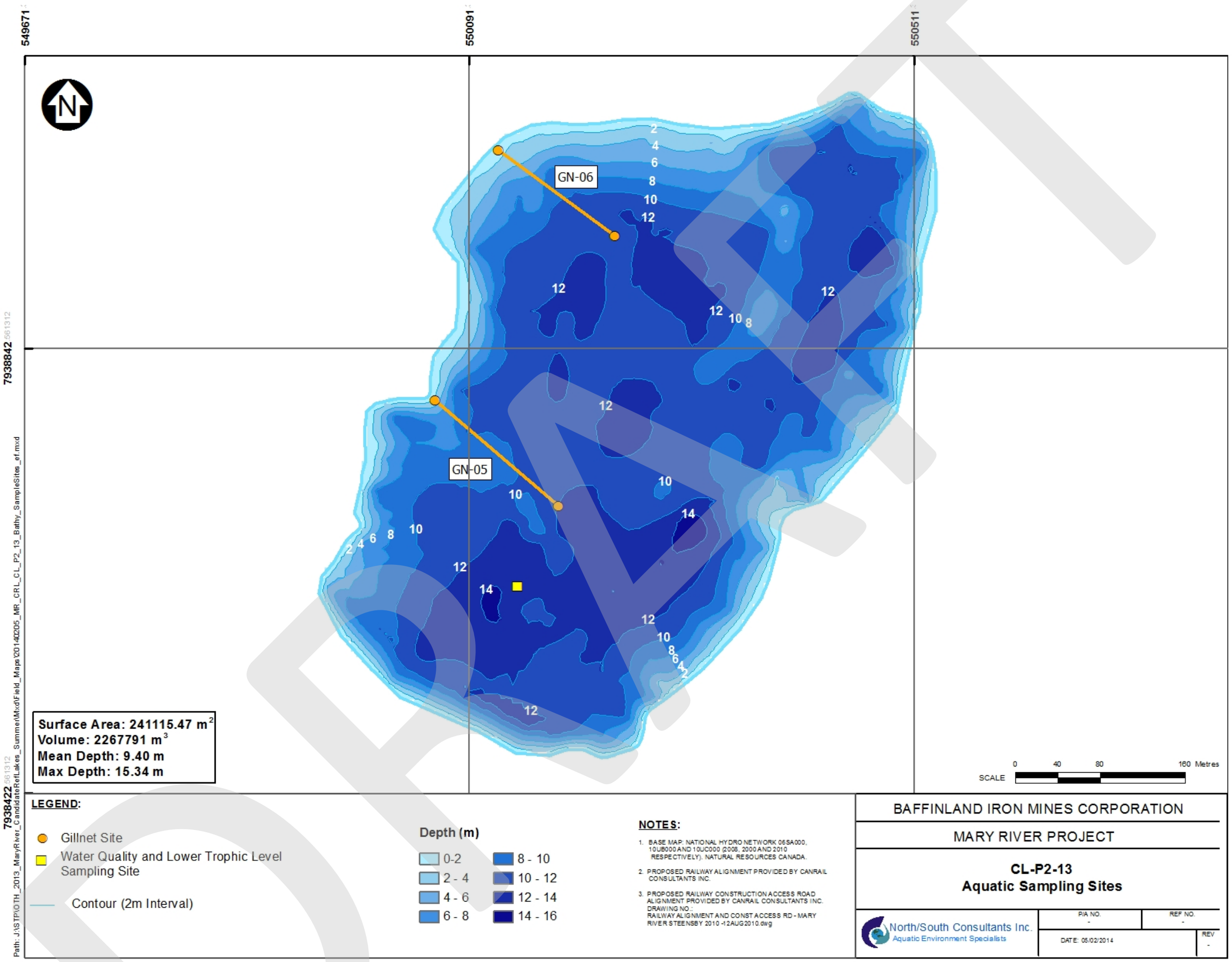


Figure 17. Bathymetry and locations of water quality, lower trophic level (phytoplankton, zooplankton & BMI), and fish sampling sites in Lake CL-P2-13.

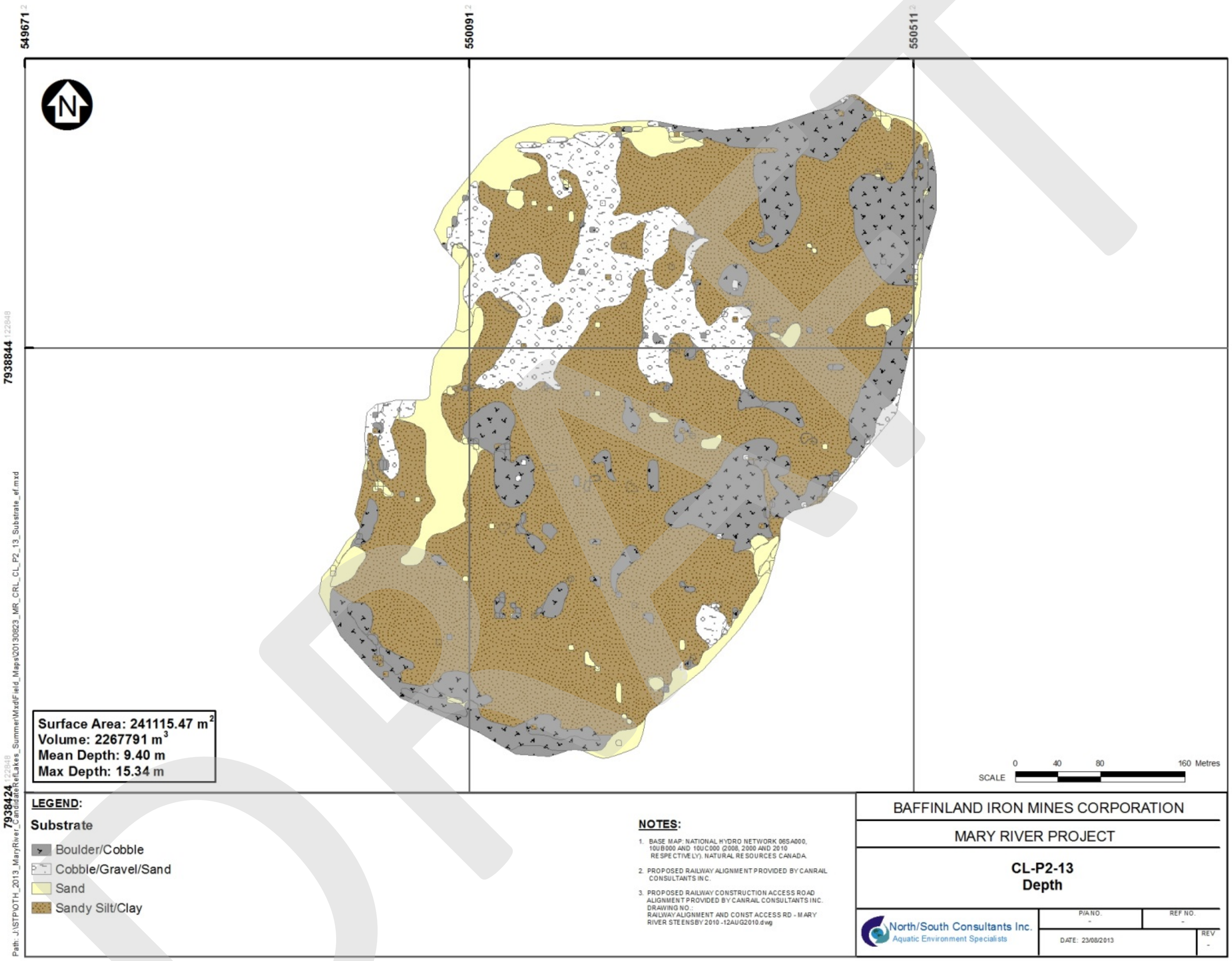


Figure 18. Substrate distribution map for Lake CL-P2-13, summer 2013.

APPENDIX 1. CANDIDATE REFERENCE LAKE WATER QUALITY DATA, 2013

Table A1-1. Summary of water quality sampling conducted in candidate reference lakes, 2013.

Waterbody	Sample ID	Site UTM (17W)		Sample Date	Sample Time	Site Depth (m)	Secchi Depth (m)	*in situ* Sample	Surface Sample	Bottom Sample
		Easting	Northing							
CR-P3-09	WQ-01	559980	7855131	05-Aug-13	15:10	28.4	9.25	Y	Y	N
CR-P3-11	WQ-02	569055	7900254	06-Aug-13	17:00	10.5	6.50	Y	Y	Y
CL-P2-13	WQ-03	550137	7938617	07-Aug-13	14:00	12.9	4.35	Y	Y	Y

Table A1-2. *In situ* water quality parameters measured in Lake CR-P3-09, summer 2013.

Depth (m)	Temperature (°C)	Specific Conductance (µS/cm)	DO (% saturation)	DO (mg/L)	pH	Turbidity (FNU)	Secchi Disk Depth (m)
1	8.5	44.9	95.8	11.30	8.11	0.04	9.25
2	8.2	44.9	96.6	11.43	8.03	0.08	
3	7.6	45.2	96.4	11.53	7.94	0.04	
4	7.6	45.2	96.8	11.58	7.88	0.05	
5	7.4	45.3	96.2	11.58	7.85	0.04	
6	7.3	45.5	96.5	11.63	7.71	0.06	
7	7.2	45.5	96.4	11.63	7.69	0.03	
8	7.2	45.5	96.2	11.64	7.68	0.05	
9	7.1	45.5	96.1	11.65	7.68	0.05	
10	7.0	45.6	96.1	11.66	7.67	0.06	
11	7.0	45.5	96.0	11.67	7.65	0.06	
12	6.9	45.6	95.9	11.67	7.66	0.04	
13	6.8	45.6	95.7	11.69	7.65	0.04	
14	6.7	45.6	95.5	11.71	7.64	0.05	
15	6.6	45.6	95.5	11.72	7.64	0.05	
16	6.5	45.6	95.3	11.73	7.63	0.05	
17	6.2	45.6	94.9	11.77	7.62	0.05	
18	6.1	45.6	95.0	11.79	7.61	0.04	
19	6.1	45.6	95.0	11.79	7.60	0.04	
20	6.0	45.6	94.8	11.80	7.59	0.05	
21	6.0	45.6	94.7	11.80	7.58	0.03	
22	5.8	45.6	94.6	11.81	7.58	0.06	
23	5.9	45.6	94.6	11.80	7.58	0.04	
24	5.9	45.6	94.6	11.81	7.57	0.05	
25	5.8	45.6	94.5	11.81	7.57	0.04	

Table A1-3. *In situ* water quality parameters measured in potential reference Lake CR-P3-11, summer and fall 2013.

Depth (m)	Temperature (°C)	Specific Conductance (µS/cm)	DO (%)	DO (mg/L)	pH	Turbidity (FNU)	Secchi Disk Depth (m)
August 6, 2013							
1	9.6	38.7	99.4	11.33	7.91	0.06	6.5
2	9.6	38.7	99.8	11.37	7.83	0.06	
3	9.6	38.7	99.9	11.39	7.77	0.06	
4	9.4	38.7	99.8	11.42	7.73	0.07	
5	9.4	38.7	99.8	11.43	7.67	0.08	
6	9.3	38.7	99.8	11.46	7.64	0.07	
7	9.3	38.7	99.7	11.45	7.61	0.08	
8	9.0	38.7	99.4	11.50	7.60	0.08	
9	8.2	38.6	98.3	11.60	7.57	0.05	
September 4, 2013							
1	4.4	41.5	90.6	11.75	8.10	0.32	5.75
2	4.4	44.1	91.8	11.90	7.82	0.29	
3	4.4	44.1	91.2	11.82	7.74	0.33	
4	4.4	44.0	91.5	11.87	7.63	0.32	
5	4.4	44.0	91.4	11.85	7.59	0.32	
6	4.4	44.0	91.2	11.84	7.52	0.30	
7	4.4	44.0	91.2	11.83	7.50	0.29	
8	4.4	43.9	90.4	11.73	7.56	0.37	
9	4.4	43.8	90.5	11.74	7.55	0.32	

Table A1-4. *In situ* water quality parameters measured in potential reference Lake CL-P2-13, summer and fall 2013.

Depth (m)	Temperature (°C)	Specific Conductance (µS/cm)	DO (%)	DO (mg/L)	pH	Turbidity (FNU)	Secchi Disk Depth (m)
August 7, 2013							
1	6.9	40.8	93.7	11..46	8.23	0.58	4.35
2	6.8	40.7	96.3	11.75	8.02	0.60	
3	6.8	40.7	97.3	11.88	7.96	0.58	
4	6.8	40.7	97.7	11.92	7.82	0.63	
5	6.7	40.7	97.6	11.93	7.73	0.57	
6	6.6	40.7	97.4	11.96	7.59	0.61	
7	6.4	40.7	97.6	12.01	7.42	0.59	
8	6.4	40.8	97.5	12.01	7.37	0.62	
9	5.8	40.6	96.8	12.08	7.29	0.59	
10	5.6	40.7	96.7	12.14	7.23	0.58	
11	5.4	40.6	96.4	12.18	7.20	0.61	
September 4, 2013							
1	3.8	43.2	87.8	11.55	7.42	0.73	4.25
2	3.8	43.2	87.5	11.52	7.66	0.74	
3	3.8	43.3	87.2	11.49	7.58	0.71	
4	3.8	43.3	87.1	11.47	7.66	0.67	
5	3.8	43.2	87.0	11.46	7.61	0.66	
6	3.8	43.3	86.9	11.45	7.48	0.70	
7	3.8	43.2	86.8	11.43	7.43	0.64	
8	3.8	43.2	86.7	11.43	7.62	0.70	
9	3.8	43.3	86.7	11.42	7.60	0.66	
10	3.8	43.2	86.6	11.41	7.51	0.70	
11	3.8	43.2	86.5	11.40	7.46	0.70	
12	3.8	43.3	86.5	11.39	7.38	0.67	

Table A1-5. Laboratory water quality results for lakes CR-P3-11 and CL-P2-13, 2013.

Waterbody	Site ID	Sampling Date	Surface/ Bottom	Notes	Chlorophyll *a*	Pheophytin *a*	pH	Conductivity	Turbidity	Alkalinity as $CaCO_3$	Bromide	Chloride	Hardness as $CaCO_3$ (Dissolved)	Hardness as $CaCO_3$ (Total)	Ammonia	Nitrite	Nitrate/nitrite	Nitrate	Sulphate	Total Dissolved Solids	Total Suspended Solids
					µg/L	µg/L		µS/cm	NTU	mg/L	mg/L	mg/L	mg/L	mg/L	mg N/L	mg N/L	mg N/L	mg N/L	mg/L	mg/L	mg/L
CP-P3-11	CP-P3-11SA	2013-08-06	Surface	Replicate 1	<0.2	0.2	6.72	39	0.3	17	<0.25	2	15.8	16.2	0.03	<0.005	<0.10	<0.10	<3	25	<2
CP-P3-11	CP-P3-11SB	2013-08-06	Surface	Replicate 2	<0.2	2.8	6.71	39	0.4	17	<0.25	2	15.9	16.5	0.04	<0.005	<0.10	<0.10	<3	25	<2
CP-P3-11	CP-P3-11SC	2013-08-06	Surface	Replicate 3	<0.2	0.7	6.86	45	0.5	21	<0.25	2	15.9	16.7	0.03	<0.005	<0.10	<0.10	<3	29	<2
CP-P3-11	CP-P3-11Bot	2013-08-06	Bottom		1.1	<0.2	6.71	39	0.5	16	<0.25	2	15.8	16.2	0.04	<0.005	<0.10	<0.10	<3	25	<2
CP-P3-11	CR-P3-11S	2013-09-04	Surface		0.7	<0.2	6.64	41	0.8	16	<0.25	2	16.2	17.0	0.03	<0.005	<0.10	<0.10	<3	27	<2
CP-P3-11	CR-P3-11Bot	2013-09-04	Bottom		1.8	<0.2	6.63	41	0.7	17	<0.25	2	16.0	16.8	0.05	<0.005	<0.10	<0.10	<3	27	<2
CL-P2-13	CL-P2-13S	2013-08-07	Surface		<0.2	1.4	6.77	41	0.8	22	<0.25	<1	18.5	18.2	1.01	<0.005	<0.10	<0.10	<3	27	<2
CL-P2-13	CL-P2-13BOT	2013-08-07	Bottom		<0.2	2.7	6.76	41	0.9	22	<0.25	<1	18.8	18.0	0.04	<0.005	<0.10	<0.10	<3	27	<2
CL-P2-13	CL-P2-13S	2013-09-04	Surface	Replicate 1	1.5	<0.2	6.69	42	0.9	23	<0.25	<1	18.7	19.1	<0.02	<0.005	<0.10	<0.10	<3	27	<2
CL-P2-13	CL-P2-13SA	2013-09-04	Surface	Replicate 2	2.3	<0.2	6.68	43	1.1	22	<0.25	<1	19.1	19.3	<0.02	<0.005	<0.10	<0.10	<3	28	<2
CL-P2-13	CL-P2-13SB	2013-09-04	Surface	Replicate 3	1.0	<0.2	6.71	44	1.0	23	<0.25	<1	19.2	19.2	<0.02	<0.005	<0.10	<0.10	<3	29	<2
CL-P2-13	CL-P2-13Bot	2013-09-04	Bottom		3.8	<0.2	6.69	43	0.8	23	<0.25	<1	18.9	19.1	0.93	<0.005	<0.10	<0.10	<3	28	<2
	CL-P2-13F	2013-08-07		Field Blank	<0.2	<0.2	5.75	<5	0.1	<5	<0.25	<1	<0.5	<0.5	0.17	<0.005	<0.10	<0.10	<3	<1	<2
	Trip Blank	2013-09-04		Trip Blank	1.5	<0.2	6.19	<5	<0.1	<5	<0.25	<1	<0.5	<0.5	<0.02	<0.005	<0.10	<0.10	<3	<1	<2
	Field Blank	2013-09-04		Field Blank	2.0	<0.2	5.72	<5	<0.1	<5	<0.25	<1	<0.5	<0.5	<0.02	<0.005	<0.10	<0.10	<3	<1	<2

Table A1-5. - continued -

Waterbody	Site ID	Sampling Date	Surface/ Bottom	Notes	Total Phosphorus	Total Kjeldahl Nitrogen	Phenols	Total Organic Carbon	Dissolved Organic Carbon	Aluminum (Dissolved)	Aluminum (Total)	Antimony (Dissolved)	Antimony (Total)	Arsenic (Dissolved)	Arsenic (Total)	Barium (Dissolved)	Barium (Total)	Beryllium (Dissolved)	Beryllium (Total)	Bismuth (Dissolved)	Bismuth (Total)
					mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
CP-P3-11	CP-P3-11SA	2013-08-06	Surface	Replicate 1	0.004	0.68	<0.001	1.7	1.7	0.0042	0.0106	<0.00010	<0.00010	<0.00010	<0.00010	0.0026	0.00260	<0.00010	<0.00002	<0.00050	<0.00050
CP-P3-11	CP-P3-11SB	2013-08-06	Surface	Replicate 2	0.003	0.14	<0.001	1.8	1.6	0.0039	0.0114	<0.00010	<0.00010	<0.00010	<0.00010	0.00261	0.00269	<0.00010	<0.00002	<0.00050	<0.00050
CP-P3-11	CP-P3-11SC	2013-08-06	Surface	Replicate 3	0.003	3.37	<0.001	2	1.7	0.0039	0.0112	<0.00010	<0.00010	<0.00010	<0.00010	0.00259	0.00274	<0.00010	<0.00002	<0.00050	<0.00050
CP-P3-11	CP-P3-11Bot	2013-08-06	Bottom		0.003	0.11	<0.001	1.8	1.7	0.0047	0.0136	<0.00010	<0.00010	<0.00010	<0.00010	0.00268	0.00263	<0.00010	<0.00002	<0.00050	<0.00050
CP-P3-11	CR-P3-11S	2013-09-04	Surface		0.006	<0.10	<0.001	2.2	2.2	0.0046	0.0218	<0.00010	<0.00010	<0.00010	<0.00010	0.00287	0.00284	<0.00010	<0.00002	<0.00050	<0.00050
CP-P3-11	CR-P3-11Bot	2013-09-04	Bottom		0.005	0.11	<0.001	2	2	0.0044	0.0237	<0.00010	<0.00010	<0.00010	<0.00010	0.00287	0.00287	<0.00010	<0.00002	<0.00050	<0.00050
CL-P2-13	CL-P2-13S	2013-08-07	Surface		<0.003	1.42	<0.001	1.1	0.8	0.0040	0.0271	<0.00010	<0.00010	<0.00010	<0.00010	0.00215	0.00233	<0.00010	<0.00002	<0.00050	<0.00050
CL-P2-13	CL-P2-13BOT	2013-08-07	Bottom		0.003	1.33	<0.001	0.9	0.8	0.0046	0.0287	<0.00010	<0.00010	<0.00010	<0.00010	0.00211	0.00218	<0.00010	<0.00002	<0.00050	<0.00050
CL-P2-13	CL-P2-13S	2013-09-04	Surface	Replicate 1	0.004	0.35	<0.001	1.4	1.2	0.0033	0.0323	<0.00010	<0.00010	<0.00010	0.00013	0.00231	0.00248	<0.00010	<0.00002	<0.00050	<0.00050
CL-P2-13	CL-P2-13SA	2013-09-04	Surface	Replicate 2	0.009	<0.10	0.021	1.1	1.3	0.0037	0.0504	<0.00010	<0.00010	<0.00010	0.00014	0.00223	0.00248	<0.00010	<0.00002	<0.00050	<0.00050
CL-P2-13	CL-P2-13SB	2013-09-04	Surface	Replicate 3	0.007	<0.10	0.029	1.2	1.4	0.0044	0.0434	<0.00010	<0.00010	<0.00010	0.00015	0.00222	0.00263	<0.00010	<0.00002	<0.00050	<0.00050
CL-P2-13	CL-P2-13Bot	2013-09-04	Bottom		0.06	1.12	<0.001	1.1	1.2	0.0042	0.3870	<0.00010	<0.00010	<0.00010	<0.00010	0.00226	0.00381	<0.00010	<0.00002	<0.00050	<0.00050
	CL-P2-13F	2013-08-07		Field Blank	<0.003	0.37	<0.001	<0.5	<0.5	<0.001	<0.001	<0.00010	<0.00010	<0.00010	<0.00010	0.000788	0.000596	<0.00010	<0.00002	<0.00050	<0.00050
	Trip Blank	2013-09-04		Trip Blank	<0.003	<0.10	<0.001	<0.5	<0.5	<0.001	<0.001	<0.00010	<0.00010	<0.00010	<0.00010	<0.000050	<0.000050	<0.00010	<0.00002	<0.00050	<0.00050
	Field Blank	2013-09-04		Field Blank	<0.003	<0.10	<0.001	<0.5	<0.5	<0.001	<0.001	<0.00010	<0.00010	<0.00010	<0.00010	<0.000050	<0.000050	<0.00010	<0.00002	<0.00050	<0.00050

Table A1-5. - continued -

Waterbody	Site ID	Sampling Date	Surface/ Bottom	Notes	Boron (Dissolved)	Boron (Total)	Cadmium (Dissolved)	Cadmium (Total)	Calcium (Dissolved)	Calcium (Total)	Chromium (Dissolved)	Chromium (Total)	Hexavalent Chromium (dissolved(	Cobalt (Dissolved)	Cobalt (Total)	Copper (Dissolved)	Copper (Total)	Iron (Dissolved)	Iron (Total)
					mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
CP-P3-11	CP-P3-11SA	2013-08-06	Surface	Replicate 1	<0.01	<0.01	<0.000010	<0.000010	3.37	3.47	<0.00010	0.00029	<0.001	<0.00010	<0.00010	0.0003	<0.00020	<0.01	0.02
CP-P3-11	CP-P3-11SB	2013-08-06	Surface	Replicate 2	<0.01	<0.01	<0.000010	<0.000010	3.4	3.53	<0.00010	0.0022	<0.001	<0.00010	<0.00010	0.00031	0.0005	<0.01	0.032
CP-P3-11	CP-P3-11SC	2013-08-06	Surface	Replicate 3	<0.01	<0.01	<0.000010	<0.000010	3.38	3.57	<0.00010	0.00092	<0.001	<0.00010	<0.00010	0.00034	0.00054	<0.01	0.027
CP-P3-11	CP-P3-11Bot	2013-08-06	Bottom		<0.01	<0.01	<0.000010	<0.000010	3.37	3.45	<0.00010	0.00951	<0.001	<0.00010	<0.00010	0.00039	0.00052	<0.01	0.059
CP-P3-11	CR-P3-11S	2013-09-04	Surface		<0.01	<0.01	<0.000010	<0.000010	3.5	3.65	<0.00010	0.00041	<0.001	<0.00010	<0.00010	0.0004	0.0005	<0.01	0.027
CP-P3-11	CR-P3-11Bot	2013-09-04	Bottom		<0.01	<0.01	<0.000010	0.000021	3.43	3.58	0.00015	0.00037	<0.001	<0.00010	<0.00010	0.00037	<0.00020	<0.01	0.03
CL-P2-13	CL-P2-13S	2013-08-07	Surface		<0.01	<0.01	<0.000010	<0.000010	3.73	3.68	<0.00010	0.00277	<0.001	<0.00010	<0.00010	0.00045	0.00292	<0.01	0.111
CL-P2-13	CL-P2-13BOT	2013-08-07	Bottom		<0.01	<0.01	<0.000010	<0.000010	3.79	3.65	<0.00010	0.00019	<0.001	<0.00010	<0.00010	0.00053	0.00053	<0.01	0.028
CL-P2-13	CL-P2-13S	2013-09-04	Surface	Replicate 1	<0.01	<0.01	<0.000010	<0.000010	3.81	3.88	0.0001	0.00037	<0.001	<0.00010	<0.00010	0.00054	0.00063	<0.01	0.038
CL-P2-13	CL-P2-13SA	2013-09-04	Surface	Replicate 2	<0.01	<0.01	<0.000010	<0.000010	3.96	3.94	<0.00010	0.0009	<0.001	<0.00010	<0.00010	0.00026	0.00071	<0.01	0.055
CL-P2-13	CL-P2-13SB	2013-09-04	Surface	Replicate 3	<0.01	<0.01	<0.000010	<0.000010	3.99	3.95	<0.00010	0.00093	<0.001	<0.00010	<0.00010	0.00031	0.00066	<0.01	0.052
CL-P2-13	CL-P2-13Bot	2013-09-04	Bottom		<0.01	<0.01	<0.000010	<0.000010	3.87	3.77	<0.00010	0.00137	<0.001	<0.00010	0.00021	0.00046	0.00133	<0.01	0.522
	CL-P2-13F	2013-08-07		Field Blank	<0.01	<0.01	<0.000010	<0.000010	0.115	0.126	<0.00010	<0.00002	<0.001	<0.00010	<0.00010	<0.00020	<0.00020	<0.01	<0.003
	Trip Blank	2013-09-04		Trip Blank	<0.01	<0.01	<0.000010	<0.000010	<0.050	<0.050	<0.00010	<0.00002	<0.001	<0.00010	<0.00010	<0.00020	<0.00020	<0.01	<0.003
	Field Blank	2013-09-04		Field Blank	<0.01	<0.01	<0.000010	<0.000010	<0.050	<0.050	<0.00010	<0.00002	<0.001	<0.00010	<0.00010	<0.00020	<0.00020	<0.01	<0.003

Table A1-5. - continued -

Waterbody	Site ID	Sampling Date	Surface/ Bottom	Notes	Lead (Dissolved)	Lead (Total)	Lithium (Dissolved)	Lithium (Total)	Magnesium (Dissolved)	Magnesium (Total)	Manganese (Dissolved)	Manganese (Total)	Mercury (Dissolved)	Mercury (Total)	Molybdenum (Dissolved)	Molybdenum (Total)	Nickel (Dissolved)	Nickel (Total)	Potassium (Dissolved)	Potassium (Total)
					mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
CP-P3-11	CP-P3-11SA	2013-08-06	Surface	Replicate 1	<0.00005	<0.00005	<0.00005	<0.00005	1.80	1.83	0.00168	0.00534	<0.000010	<0.000010	<0.000050	<0.000050	<0.00050	<0.00050	0.342	0.351
CP-P3-11	CP-P3-11SB	2013-08-06	Surface	Replicate 2	<0.00005	<0.00005	<0.00005	<0.00005	1.80	1.86	0.00154	0.00556	<0.000010	<0.000010	<0.000050	0.000072	<0.00050	0.00173	0.341	0.348
CP-P3-11	CP-P3-11SC	2013-08-06	Surface	Replicate 3	<0.00005	0.00019	<0.00005	<0.00005	1.81	1.90	0.00171	0.00532	<0.000010	<0.000010	<0.000050	0.000063	<0.00050	0.00106	0.341	0.342
CP-P3-11	CP-P3-11Bot	2013-08-06	Bottom		<0.00005	0.00006	<0.00005	<0.00005	1.80	1.83	0.00170	0.00647	<0.000010	<0.000010	0.000075	0.000216	0.00167	0.00524	0.347	0.336
CP-P3-11	CR-P3-11S	2013-09-04	Surface		<0.00005	<0.00005	<0.00005	<0.00005	1.82	1.91	0.000671	0.00263	<0.000010	<0.000010	<0.000050	0.000056	<0.00050	<0.00050	0.357	0.362
CP-P3-11	CR-P3-11Bot	2013-09-04	Bottom		<0.00005	<0.00005	<0.00005	<0.00005	1.80	1.90	0.00144	0.00257	<0.000010	<0.000010	0.052	<0.000050	<0.00050	<0.00050	0.346	0.357
CL-P2-13	CL-P2-13S	2013-08-07	Surface		<0.00005	0.00013	<0.00005	<0.00005	2.24	2.19	0.00121	0.00256	<0.000010	<0.000010	0.000181	0.00076	0.00166	0.00134	0.286	0.290
CL-P2-13	CL-P2-13BOT	2013-08-07	Bottom		<0.00005	<0.00005	<0.00005	<0.00005	2.26	2.17	0.000627	0.00192	<0.000010	<0.000010	0.000087	0.000052	0.00061	<0.00050	0.286	0.285
CL-P2-13	CL-P2-13S	2013-09-04	Surface	Replicate 1	<0.00005	0.00005	<0.00005	<0.00005	2.24	2.28	0.000505	0.00187	<0.000010	<0.000010	0.000075	0.000077	0.00051	<0.00050	0.289	0.322
CL-P2-13	CL-P2-13SA	2013-09-04	Surface	Replicate 2	<0.00005	0.00006	<0.00005	<0.00005	2.23	2.29	0.000447	0.00217	<0.000010	<0.000010	<0.000050	0.000073	<0.00050	0.00078	0.287	0.334
CL-P2-13	CL-P2-13SB	2013-09-04	Surface	Replicate 3	<0.00005	0.00006	<0.00005	<0.00005	2.24	2.28	0.000439	0.00217	<0.000010	<0.000010	<0.000050	0.000064	0.00053	0.00067	0.296	0.333
CL-P2-13	CL-P2-13Bot	2013-09-04	Bottom		<0.00005	0.00033	<0.00005	0.00061	2.25	2.35	0.000444	0.0109	<0.000010	<0.000010	0.000053	0.000056	<0.00050	0.00105	0.299	0.449
	CL-P2-13F	2013-08-07		Field Blank	<0.00005	<0.00005	<0.00005	<0.00005	<0.10	<0.10	<0.000050	0.000092	<0.000010	<0.000010	<0.000050	<0.000050	<0.00050	<0.00050	<0.050	<0.050
	Trip Blank	2013-09-04		Trip Blank	<0.00005	<0.00005	<0.00005	<0.00005	<0.10	<0.10	<0.000050	<0.000050	<0.000010	<0.000010	<0.000050	<0.000050	<0.00050	<0.00050	<0.050	<0.050
	Field Blank	2013-09-04		Field Blank	<0.00005	<0.00005	<0.00005	<0.00005	<0.10	<0.10	<0.000050	<0.000050	<0.000010	<0.000010	<0.000050	<0.000050	<0.00050	<0.00050	<0.050	<0.050

Table A1-5. - continued -

Waterbody	Site ID	Sampling Date	Surface/ Bottom	Notes	Selenium (Dissolved)	Selenium (Total)	Silicon (Dissolved)	Silicon (Total)	Silver (Dissolved)	Silver (Total)	Sodium (Dissolved)	Sodium (Total)	Strontium (Dissolved)	Strontium (Total)	Thallium (Dissolved)	Thallium (Total)	Tin (Dissolved)	Tin (Total)	Titanium (Dissolved)	Titanium (Total)
					mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
CP-P3-11	CP-P3-11SA	2013-08-06	Surface	Replicate 1	<0.0001	<0.00001	0.25	0.26	<0.0000010	<0.0000010	1.06	1.08	0.00462	0.00481	<0.000010	<0.000001	0.00031	0.00019	<0.01	<0.01
CP-P3-11	CP-P3-11SB	2013-08-06	Surface	Replicate 2	<0.0001	<0.00001	0.25	0.26	<0.0000010	<0.0000010	1.07	1.1	0.0046	0.00479	<0.000010	<0.000001	0.00023	0.00018	<0.01	<0.01
CP-P3-11	CP-P3-11SC	2013-08-06	Surface	Replicate 3	<0.0001	<0.00001	0.25	0.26	<0.0000010	<0.0000010	1.07	1.07	0.00461	0.00483	<0.000010	<0.000001	0.00039	0.0004	<0.01	<0.01
CP-P3-11	CP-P3-11Bot	2013-08-06	Bottom		<0.0001	<0.00001	0.26	0.26	<0.0000010	<0.0000010	1.12	1.12	0.00467	0.00479	<0.000010	<0.000001	0.00098	0.00098	<0.01	<0.01
CP-P3-11	CR-P3-11S	2013-09-04	Surface		<0.0001	<0.00001	0.21	0.27	<0.0000010	<0.0000010	1.15	1.09	0.00489	0.00502	<0.000010	<0.000001	0.00047	0.0003	<0.01	<0.01
CP-P3-11	CR-P3-11Bot	2013-09-04	Bottom		<0.0001	<0.00001	0.19	0.27	<0.0000010	<0.0000010	1.09	1.12	0.00475	0.00498	<0.000010	<0.000001	0.00038	0.0002	<0.01	<0.01
CL-P2-13	CL-P2-13S	2013-08-07	Surface		<0.0001	<0.00001	0.32	0.35	<0.0000010	0.000016	0.667	0.652	0.00353	0.00352	<0.000010	<0.000001	0.0014	0.00077	<0.01	<0.01
CL-P2-13	CL-P2-13BOT	2013-08-07	Bottom		<0.0001	<0.00001	0.32	0.35	<0.0000010	<0.0000010	0.656	0.636	0.00344	0.0035	<0.000010	<0.000001	0.00036	0.00021	<0.01	<0.01
CL-P2-13	CL-P2-13S	2013-09-04	Surface	Replicate 1	<0.0001	<0.00001	0.33	0.37	<0.0000010	<0.0000010	0.67	0.709	0.00357	0.00379	<0.000010	<0.000001	0.0005	0.00021	<0.01	<0.01
CL-P2-13	CL-P2-13SA	2013-09-04	Surface	Replicate 2	<0.0001	<0.00001	0.32	0.42	<0.0000010	<0.0000010	0.668	0.732	0.00351	0.00382	<0.000010	<0.000001	<0.00010	0.00019	<0.01	<0.01
CL-P2-13	CL-P2-13SB	2013-09-04	Surface	Replicate 3	<0.0001	<0.00001	0.32	0.37	<0.0000010	<0.0000010	0.679	0.791	0.00345	0.00391	<0.000010	<0.000001	<0.00010	0.00027	<0.01	<0.01
CL-P2-13	CL-P2-13Bot	2013-09-04	Bottom		<0.0001	<0.00001	0.34	1.02	<0.0000010	0.000019	0.728	0.68	0.00358	0.00381	<0.000010	<0.000001	0.00034	0.00015	<0.01	0.02
	CL-P2-13F	2013-08-07		Field Blank	<0.0001	<0.00001	<0.050	<0.050	<0.0000010	<0.0000010	<0.0012	<0.0012	<0.00040	<0.00040	<0.000010	<0.000001	<0.00010	<0.00010	<0.01	<0.01
	Trip Blank	2013-09-04		Trip Blank	<0.0001	<0.00001	<0.050	<0.050	<0.0000010	<0.0000010	<0.0012	<0.0012	<0.00040	<0.00040	<0.000010	<0.000001	<0.00010	<0.00010	<0.01	<0.01
	Field Blank	2013-09-04		Field Blank	<0.0001	<0.00001	<0.050	<0.050	<0.0000010	<0.0000010	<0.0012	<0.0012	<0.00040	<0.00040	<0.000010	<0.000001	<0.00010	<0.00010	<0.01	<0.01

Table A1-5. - continued -

Waterbody	Site ID	Sampling Date	Surface/ Bottom	Notes	Uranium (Dissolved)	Uranium (Total)	Vanadium (Dissolved)	Vanadium (Total)	Zinc (Dissolved)	Zinc (Total)
					mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
CP-P3-11	CP-P3-11SA	2013-08-06	Surface	Replicate 1	0.00006	0.00007	<0.001	<0.001	<0.00033	<0.003
CP-P3-11	CP-P3-11SB	2013-08-06	Surface	Replicate 2	0.000063	0.00007	<0.001	<0.001	<0.00033	<0.003
CP-P3-11	CP-P3-11SC	2013-08-06	Surface	Replicate 3	0.000062	0.00007	<0.001	<0.001	0.0014	0.0164
CP-P3-11	CP-P3-11Bot	2013-08-06	Bottom		0.000061	0.000071	<0.001	<0.001	0.0016	<0.003
CP-P3-11	CR-P3-11S	2013-09-04	Surface		0.000065	0.000077	<0.001	<0.001	0.0021	0.0188
CP-P3-11	CR-P3-11Bot	2013-09-04	Bottom		0.000066	0.000078	<0.001	<0.001	0.0013	<0.003
CL-P2-13	CL-P2-13S	2013-08-07	Surface		0.000113	0.000127	<0.001	<0.001	0.0018	0.004
CL-P2-13	CL-P2-13BOT	2013-08-07	Bottom		0.000121	0.000136	<0.001	<0.001	0.0014	<0.003
CL-P2-13	CL-P2-13S	2013-09-04	Surface	Replicate 1	0.000126	0.000141	<0.001	<0.001	0.0011	<0.003
CL-P2-13	CL-P2-13SA	2013-09-04	Surface	Replicate 2	0.000121	0.000142	<0.001	<0.001	0.0051	0.004
CL-P2-13	CL-P2-13SB	2013-09-04	Surface	Replicate 3	0.000124	0.000149	<0.001	<0.001	0.0037	0.0049
CL-P2-13	CL-P2-13Bot	2013-09-04	Bottom		0.000133	0.000242	<0.001	<0.001	<0.00033	<0.003
	CL-P2-13F	2013-08-07		Field Blank	<0.000010	<0.000010	<0.001	<0.001	0.0012	<0.003
	Trip Blank	2013-09-04		Trip Blank	<0.000010	<0.000010	<0.001	<0.001	<0.00033	<0.003
	Field Blank	2013-09-04		Field Blank	<0.000010	<0.000010	<0.001	<0.001	<0.00033	<0.003

APPENDIX 2. SUMMARY OF LOWER TROPHIC LEVEL SAMPLING CONDUCTED IN CANDIDATE REFERENCE LAKES, 2013

Table A2-1. Summary of phytoplankton sampling completed in candidate reference lakes, 2013.

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						
CR-P3-09	PHYTO-01U	559980	7855131	05-Aug-13	15:10	28.4	9.25	27.75	0-10
CR-P3-09	PHYTO-01L	559980	7855131	05-Aug-13	15:10	28.4	9.25	27.75	10-27
CR-P3-11	PHYTO-02	569055	7900254	06-Aug-13	17:00	10.5	6.50	19.50	0-9
CL-P2-13	PHYTO-03	550137	7938617	07-Aug-13	14:00	12.9	4.35	13.05	0-11

Table A2-2. Summary of zooplankton sampling completed in candidate reference lakes, 2013.

Waterbody	Sample ID	Site UTM (17W)		Sample Date	Sample Time	Site Depth (m)	Secchi Depth (m)	Sampled Depth Range (m)	No. of Tows
		Easting	Northing						
CR-P3-09	ZOO-01	559980	7855131	05-Aug-13	15:10	28.4	9.25	0-27	1
CR-P3-11	ZOO-02	569055	7900254	06-Aug-13	17:00	10.5	6.50	0-9	1
CL-P2-13	ZOO-03	550137	7938617	07-Aug-13	14:00	12.9	4.35	0-11	1
CR-P3-11	ZOO-02	569055	7900254	04-Sep-13	12:05	10.6	5.75	0-9	1
CL-P2-13	ZOO-03	550137	7938617	04-Sep-13	15:40	12.5	4.25	0-11	1

Table A2-3. Summary of benthic macroinvertebrate sampling completed in candidate reference lakes, 2013.

Waterbody	Sample ID	Site UTM (17W)		Sample Date	Sample Time	Secchi Depth (m)	No. of Replicate Grabs	Depth Range of Grabs (m)	Macrophyte Abundance	Dominant Substrate(s)
		Easting	Northing							
CR-P3-11	BMI-01	569055	7900254	04-Sep-13	12:57	18:00	5	8.2 - 9.7	Absent	Sand/Silt
CL-P2-13	BMI-02	550137	7938617	04-Sep-13	18:10	6:00	5	12.1 - 13.8	Absent	Silt/Sand

APPENDIX 3. PHYTOPLANKTON COMMUNITY COMPOSITION IN CANDIDATE REFERENCE LAKES, 2013.

Table A3-1. Phytoplankton biomass and composition measured in reference lakes in 2013. Means and relative percent mean difference (RPMD) have been calculated for duplicate samples.

Waterbody	Sample ID	Sample Date	Sample Type	Major Group	Diatoms						
				Class	Bacillariophyceae					Coscinodiscophyceae	
				Genus	*Eunotia*	*Navicula*	*Nitzschia*	*Rhoicosphenia*	*Surirella*	*Cyclotella*	*Rhizosolenia*
				Species	*sp.*	*sp.*	*sp.*	*sp.*	*sp.*	*sp.*	*sp.*
CR-P3-11	CR-P3-11 A	6-Aug-13	Duplicate		1.35	10.00	0.77	-	-	4.50	-
	CR-P3-11 B	6-Aug-13	Duplicate		13.50	4.80	0.77	-	-	6.66	-
	CR-P3-11	6-Aug-13	Mean		7.43	7.40	0.77	-	-	5.58	-
			RPMD		164	70	0	-	-	39	-
	CR-P3-11	4-Sep-13	Normal		-	-	7.17	0.45	-	4.50	-
CL-P2-13	CL-P2-13	7-Aug-13	Normal		3.60	-	1.60	-	-	49.60	1.55
	CL-P2-13 REP 1	4-Sep-13	Duplicate		-	-	0.77	-	6.40	54.40	0.71
	CL-P2-13 REP 2	4-Sep-13	Duplicate		5.00	4.80	0.77	-	-	24.80	1.67
	CL-P2-13	4-Sep-13	Mean		2.50	2.40	0.77	-	3.20	39.60	1.19
			RPMD		200	200	0	-	200	75	81

Table A3-1. - continued -

Waterbody	Sample ID	Sample Date	Sample Type	Diatoms				Chlorophyta			
				Fragilariophyceae				Chlorophyceae			
				Asterionella	*Diatoma*	*Synedra*	*Tabellaria*	*Botryococcus*	*Dictyosphaerium*	*Elakatothrix*	*Tetraedron*
				formosa	*sp.*	*sp.*	*sp.*	*sp.*	*sp.*	*sp.*	*minimum*
CR-P3-11	CR-P3-11 A	6-Aug-13	Duplicate	4.70	0.96	15.07	8.80	-	-	6.25	0.20
	CR-P3-11 B	6-Aug-13	Duplicate	3.46	2.00	17.09	-	-	-	3.35	0.20
	CR-P3-11	6-Aug-13	Mean	4.08	1.48	16.08	4.40	-	-	4.80	0.20
			RPMD	30	70	13	200	-	-	60	0
	CR-P3-11	4-Sep-13	Normal	2.70	2.00	3.00	0.80	-	-	11.61	-
CL-P2-13	CL-P2-13	7-Aug-13	Normal	22.79	0.96	26.08	-	10.80	-	6.70	1.71
	CL-P2-13 REP 1	4-Sep-13	Duplicate	18.74	0.96	30.13	-	-	135.94	8.71	3.01
	CL-P2-13 REP 2	4-Sep-13	Duplicate	14.74	-	11.99	-	-	-	3.13	2.26
	CL-P2-13	4-Sep-13	Mean	16.74	0.48	21.06	-	-	67.97	5.92	2.64
			RPMD	24	200	86	-	-	200	94	29

Table A3-1. - continued -

Waterbody	Sample ID	Sample Date	Sample Type	Chlorophyta			Charophyta			Chrysophytes		
				Trebouxiophyceae			Conjugophyceae			Chrysophyceae		
				Lagerheimia *sp.*	*Monoraphidium* *sp.*	*Oocystis* *sp.*	*Cosmarium* *sp.*	*Staurastrum* *sp.*	*Staurodesmus* *sp.*	*Bitrichia* *sp.*	*Dinobryon* *bavaricum*	*Dinobryon* *sp.*
CR-P3-11	CR-P3-11 A	6-Aug-13	Duplicate	-	-	-	-	1.35	10.00	0.15	9.40	26.78
	CR-P3-11 B	6-Aug-13	Duplicate	-	-	-	14.40	-	2.40	0.47	20.09	22.79
	CR-P3-11	6-Aug-13	Mean	-	-	-	7.20	0.68	6.20	0.31	14.74	24.79
			RPMD	-	-	-	200	200	123	102	73	16
	CR-P3-11	4-Sep-13	Normal	-	-	5.00	-	-	10.00	0.15	4.00	12.74
CL-P2-13	CL-P2-13	7-Aug-13	Normal	0.32	9.53	2.40	18.00	-	-	0.32	0.65	16.74
	CL-P2-13 REP 1	4-Sep-13	Duplicate	0.64	1.63	-	26.65	-	-	0.15	-	1.35
	CL-P2-13 REP 2	4-Sep-13	Duplicate	0.15	8.18	-	8.05	-	-	0.15	-	14.74
	CL-P2-13	4-Sep-13	Mean	0.40	4.91	-	17.35	-	-	0.15	-	8.05
			RPMD	123	133	-	107	-	-	0	-	166

Table A3-1. - continued -

Waterbody	Sample ID	Sample Date	Sample Type	Chrysophytes	Cryptophytes		Blue-Green Algae				
				Chrysophyceae	Cryptophyceae		Cyanophyceae				
				small chrysophytes	*Cryptomonas sp.*	*Unidentified*	*Anabaena sp.*	*Aphanocapsa sp.*	*Aphanothece sp.*	*Oscillatoria sp.*	*Planktolyngbya sp.*
CR-P3-11	CR-P3-11 A	6-Aug-13	Duplicate	32.22	44.40	5.68	-	-	-	-	1.20
	CR-P3-11 B	6-Aug-13	Duplicate	42.85	14.40	3.84	-	-	-	-	1.20
	CR-P3-11	6-Aug-13	Mean	37.54	29.40	4.76	-	-	-	-	1.20
			RPMD	28	102	39	-	-	-	-	0
	CR-P3-11	4-Sep-13	Normal	21.90	14.40	5.68	0.86	18.23	29.60	0.58	0.19
CL-P2-13	CL-P2-13	7-Aug-13	Normal	16.83	44.40	2.84	-	-	-	-	-
	CL-P2-13 REP 1	4-Sep-13	Duplicate	16.03	7.20	7.60	-	-	-	-	-
	CL-P2-13 REP 2	4-Sep-13	Duplicate	17.22	14.40	16.20	-	-	-	-	0.58
	CL-P2-13	4-Sep-13	Mean	16.63	10.80	11.90	-	-	-	-	0.29
			RPMD	7	67	72	-	-	-	-	200

Table A3-1. - continued -

Waterbody	Sample ID	Sample Date	Sample Type	Blue-Green Algae	Euglenoids	Dinoflagellates		Total Biomass
				Cyanophyceae	Euglenophyceae	Dinophyceae		
				Pseudanabaena sp.	*Euglena sp.*	*Gymnodinium sp.*	*Peridinium sp.*	(mg/m^3)
CR-P3-11	CR-P3-11 A	6-Aug-13	Duplicate	0.10	1.20	72.90	-	258.0
	CR-P3-11 B	6-Aug-13	Duplicate	-	-	178.20	172.80	525.3
	CR-P3-11	6-Aug-13	Mean	0.05	0.60	125.55	86.40	391.6
			RPMD	200	200	84	200	68
	CR-P3-11	4-Sep-13	Normal	-	2.70	97.20	-	255.5
CL-P2-13	CL-P2-13	7-Aug-13	Normal	-	-	434.70	-	672.1
	CL-P2-13 REP 1	4-Sep-13	Duplicate	-	-	32.40	-	353.4
	CL-P2-13 REP 2	4-Sep-13	Duplicate	-	-	234.90	-	383.7
	CL-P2-13	4-Sep-13	Mean	-	-	133.65	-	365.4
			RPMD	-	-	152	-	8

APPENDIX 4. ZOOPLANKTON ABUNDANCE AND COMMUNITY COMPOSITION IN CANDIDATE REFERENCE LAKES, 2013.

Table A4-1. Crustacean zooplankton (individuals/m^3) collected in vertical net tows from reference lakes during 2013. Individual abundances may not add up to totals due to rounding.

Waterbody	Lake CR-P3-11										
Site ID	**Stn CR P3-11**										
Sampling Date	**6-Aug-13**							**4-Sep-13**		**Overall**	
Replicate	**A**	**B**	**C**	**Mean**	**SD [1]**	**% [2]**	**PRSD [3]**		**%**	**Mean**	**%**
water volume filtered (m^3)	0.09	0.09	0.09	-	-	-	-	0.09	-		
Cladocera (water fleas)											
Alona guttata	0	0	0	0	0	0	-	0	0	0	0
Bosmina longirostris	197	219	219	212	13	3	6	395	5	258	3
Chydorus sphaericus	0	0	0	0	0	0	-	0	0	0	0
Daphnia longiremis	132	307	176	205	91	3	45	812	10	357	4
Holopedium gibberum	44	22	0	22	22	0	*100*	0	0	16	0
Total Cladocera	**373**	**549**	**395**	**439**	**96**	**6**	**22**	**1207**	**15**	**631**	**8**
Copepoda (copepods)											
Calanoida											
Diaptomus minutus	1404	1163	1646	1404	241	18	17	2743	35	1739	22
Limnocalanus macrurus	0	0	0	0	0	0	-	0	0	0	0
Calanoida copepodite	658	1426	1316	1134	415	14	37	505	6	976	12
Total Calanoida	**2062**	**2589**	**2962**	**2538**	**452**	**32**	**18**	**3247**	**41**	**2715**	**34**
Cyclopoida											
Cyclops scutifer	2567	2194	2084	2282	253	29	11	1997	25	2210	28
Cyclopoida nauplii	2150	2721	3181	2684	517	34	19	1470	19	2381	30
Total Cyclopoida	**4717**	**4915**	**5266**	**4966**	**278**	**63**	**6**	**3467**	**44**	**4591**	**58**
Harpacticoida	0	0	0	0	0	0	-	0	0	0	0
Total Copepoda	**6780**	**7504**	**8228**	**7504**	**724**	**94**	**10**	**6714**	**85**	**7306**	**92**
OVERALL TOTAL	**7153**	**8052**	**8623**	**7942**	**741**	**100**	**9**	**7920**	**100**	**7937**	**100**
Taxonomic Richness [4]	**5**	**5**	**4**	**5**	**-**	**-**	**-**	**4**	**-**	**5**	**-**

Table A4-1. - continued -

Waterbody	Lake CL-P2-13										
Site ID	**Stn CL P2-13**										
Sampling Date	**7-Aug-13**		**4-Sep-13**							**Overall**	
Replicate		**%**	**A**	**B**	**C**	**Mean**	**SD**	**%**	**PRSD**	**Mean**	**%**
water volume filtered (m³)	0.13		0.13	0.13	0.13	-	-		-		
Cladocera (water fleas)											
Alona guttata	0	0	0	0	0	0	0	0	-	0	0
Bosmina longirostris	214	18	260	130	84	158	91	10	*58*	172	11
Chydorus sphaericus	0	0	0	0	0	0	0	0	-	0	0
Daphnia longiremis	46	4	199	76	138	138	61	9	44	115	8
Holopedium gibberum	8	1	0	0	23	8	13	0	*173*	8	1
Total Cladocera	**268**	**23**	**459**	**207**	**245**	**303**	**136**	**19**	**45**	**294**	**20**
Copepoda (copepods)											
Calanoida											
Diaptomus minutus	23	2	444	38	8	163	243	10	*149*	128	9
Limnocalanus macrurus	0	0	0	0	0	0	0	0	-	0	0
Calanoida copepodite	0	0	31	54	15	33	19	2	*58*	25	2
Total Calanoida	**23**	**2**	**474**	**92**	**23**	**196**	**243**	**12**	***124***	**153**	**10**
Cyclopoida											
Cyclops scutifer	849	73	765	765	773	767	4	47	1	788	52
Cyclopoida nauplii	23	2	398	344	314	352	43	22	12	270	18
Total Cyclopoida	**872**	**75**	**1163**	**1109**	**1086**	**1119**	**39**	**69**	**4**	**1057**	**70**
Harpacticoida	0	0	0	0	0	0	0	0	-	0	0
Total Copepoda	**895**	**77**	**1637**	**1201**	**1109**	**1316**	**282**	**81**	**21**	**1210**	**80**
OVERALL TOTAL	**1163**	**100**	**2096**	**1407**	**1354**	**1619**	**414**	**100**	**26**	**1505**	**100**
Taxonomic Richness [4]	**5**	-	**4**	**4**	**5**	**5**	-	-	-	**5**	-

[1] Standard deviation
[2] Percent abundance of the overall total
[3] Percent relative standard deviation; evaluation of precision for triplicate samples
[4] Total number of taxa observed to species-level, not the average number of taxa

APPENDIX 5. BENTHIC MACROINVERTEBRATE ABUNDANCE AND COMMUNITY COMPOSITION IN CANDIDATE REFERENCE LAKES, 2013.

Table A5-1. Benthic macroinvertebrates (no. of individuals/m^2) collected in petite Ponar grab (area 0.023 m^2) samples from reference lake candidate CR-P3-11 during 2013. Individual abundances may not add up to totals due to rounding.

Waterbody				**CR-P3-11**				
Habitat Type				**Offshore Profundal (14)**				
Subsample no.				**1**	**2**	**3**	**4**	**5**
Sample ID				**CR-P3-11-1**	**CR-P3-11-2**	**CR-P3-11-3**	**CR-P3-11-4**	**CR-P3-11-5**
Number of invertebrates per m^2								
ROUNDWORMS				0	0	0	0	0
P. Nemata				0	0	0	0	43
ANNELIDS				0	0	0	0	0
P. Annelida				0	0	0	0	0
	WORMS			0	0	0	0	0
	Cl. Oligochaeta			0	0	0	0	0
		F. Naididae		0	0	0	0	0
	S.F. Tubificinae			0	0	0	0	0
			Aulodrilus limnobius	0	0	0	0	0
		F. Lumbriculidae		0	0	0	0	0
			Lumbriculus	0	0	0	0	0
ARTHROPODS				0	0	0	0	0
P. Arthropoda				0	0	0	0	0
	MITES			0	0	0	0	0
	Cl. Arachnida			0	0	0	0	0
	Subcl. Acari			43	87	43	87	43
	HARPACTICOIDS			0	0	0	0	0
	O. Harpacticoida			0	0	0	0	0
	SEED SHRIMPS			0	0	0	0	0
	Cl. Ostracoda			0	43	0	43	0
INSECTS				0	0	0	0	0
	Cl. Insecta			0	0	0	0	0
	CADDISFLIES			0	0	0	0	0
	O. Trichoptera			0	0	0	0	0
		F. Apataniidae		0	0	0	0	0
			Apatania	0	0	0	0	0
TRUE FLIES				0	0	0	0	0
	O. Diptera			0	0	0	0	0
	MIDGES			0	0	0	0	0
		F. Chironomidae		0	0	0	0	0
			chironomid pupae	0	0	0	0	0
	S.F. Chironominae			0	0	0	0	0
			Chironomus	0	0	2640	1169	1169
			Corynocera	0	0	173	0	0
			Micropsectra	87	303	0	0	0
			Paratanytarsus	0	0	0	0	0
			Sergentia	0	0	0	0	0
			Stictochironomus	173	649	0	43	0
			Tanytarsus	390	519	1342	3246	2554
	S.F. Diamesinae			0	0	0	0	0
			Protanypus	0	0	43	0	0
			Pseudodiamesa	0	0	0	0	0

Table A5-1. - continued -

Waterbody				CR-P3-11				
Habitat Type				Offshore Profundal (14)				
Subsample no.				1	2	3	4	5
Sample ID				CR-P3-11-1	CR-P3-11-2	CR-P3-11-3	CR-P3-11-4	CR-P3-11-5
Number of invertebrates per m^2								
	S.F. Orthocladiinae			0	0	0	0	0
			Abiskomyia	87	87	346	260	216
			Corynoneura	0	0	0	0	0
			Cricotopus/Orthocladius	0	0	0	0	0
			Genus "Greenland"	0	0	0	0	0
			Heterotrissocladius	693	173	173	216	260
			Mesocricotopus	0	0	0	0	0
			Paracladius	0	0	0	0	43
			Parakiefferiella	43	43	0	0	0
			Psectrocladius	87	260	0	0	0
			Pseudosmittia	0	0	43	0	0
			Zalutschia	0	43	43	43	0
			indeterminate	0	0	0	0	0
	S.F. Tanypodinae			0	0	0	0	0
			Procladius	390	822	0	0	0
			Thienemannimyia complex	0	0	0	0	0
Total Density (no. per m^2)				1991	3030	4848	5107	4328
Proportion of Chironomidae (% of total density)				98	96	99	97	98
Shannon's Evenness Index				0.82	0.82	0.58	0.53	0.58
Simpson's Diversity Index				0.79	0.83	0.62	0.54	0.57
Taxonomic Richness (genus-level) [1]				9	11	9	8	7
Hill's Effective Richness				6.01	7.21	3.60	3.01	3.07

[1] Total number of taxa observed to genus-level

Table A5-2. Benthic macroinvertebrates (no. of individuals/m^2) collected in petite Ponar grab (area 0.023 m^2) samples from reference lake candidate CL-P2-13 during 2013. Individual abundances may not add up to totals due to rounding.

Waterbody				**CL-P2-13**				
Habitat Type				**Offshore Profundal (14)**				
Subsample no.				**1**	**2**	**3**	**4**	**5**
Sample ID				**CL-P2-13-1**	**CL-P2-13-2**	**CL-P2-13-3**	**CL-P2-13-4**	**CL-P2-13-5**
Number of invertebrates per m^2								
ROUNDWORMS				0	0	0	0	0
P. Nemata				0	0	0	0	0
ANNELIDS				0	0	0	0	0
P. Annelida				0	0	0	0	0
	WORMS			0	0	0	0	0
	Cl. Oligochaeta			0	0	0	0	0
		F. Naididae		0	0	0	0	0
	S.F. Tubificinae			0	0	0	0	0
			Aulodrilus limnobius	0	0	0	0	0
		F. Lumbriculidae		0	0	0	0	0
			Lumbriculus	0	0	0	0	0
ARTHROPODS				0	0	0	0	0
P. Arthropoda				0	0	0	0	0
	MITES			0	0	0	0	0
	Cl. Arachnida			0	0	0	0	0
	Subcl. Acari			0	0	0	0	0
	HARPACTICOIDS			0	0	0	0	0
	O. Harpacticoida			0	0	0	0	0
	SEED SHRIMPS			0	0	0	0	0
	Cl. Ostracoda			0	0	0	0	0
INSECTS				0	0	0	0	0
	Cl. Insecta			0	0	0	0	0
	CADDISFLIES			0	0	0	0	0
	O. Trichoptera			0	0	0	0	0
		F. Apataniidae		0	0	0	0	0
			Apatania	0	0	0	0	0
TRUE FLIES				0	0	0	0	0
	O. Diptera			0	0	0	0	0
	MIDGES			0	0	0	0	0
		F. Chironomidae		0	0	0	0	0
			chironomid pupae	0	0	0	0	0
	S.F. Chironominae			0	0	0	0	0
			Chironomus	43	43	3333	1212	0
			Corynocera	0	0	0	0	0
			Micropsectra	0	43	43	0	0
			Paratanytarsus	0	0	0	0	0
			Sergentia	0	0	0	0	0
			Stictochironomus	0	43	0	87	0
			Tanytarsus	0	0	0	0	0
	S.F. Diamesinae			0	0	0	0	0
			Protanypus	216	0	43	43	87
			Pseudodiamesa	0	0	0	0	0

Table A5-2. - continued -

Waterbody	CL-P2-13				
Habitat Type	Offshore Profundal (14)				
Subsample no.	1	2	3	4	5
Sample ID	CL-P2-13-1	CL-P2-13-2	CL-P2-13-3	CL-P2-13-4	CL-P2-13-5
Number of invertebrates per m²					
S.F. Orthocladiinae	0	0	0	0	0
Abiskomyia	87	130	0	130	0
Corynoneura	0	0	0	0	0
Cricotopus/Orthocladius	0	0	0	0	0
Genus "Greenland"	0	0	0	0	0
Heterotrissocladius	87	0	0	43	519
Mesocricotopus	0	0	0	0	0
Paracladius	476	260	0	87	606
Parakiefferiella	0	43	0	216	0
Psectrocladius	0	0	0	0	0
Pseudosmittia	0	0	0	0	0
Zalutschia	43	0	0	0	0
indeterminate	0	0	0	0	0
S.F. Tanypodinae	0	0	0	0	0
Procladius	0	0	0	0	0
Thienemannimyia complex	0	0	0	0	0
Total Density (no. per m²)	952	563	3419	1818	1212
Proportion of Chironomidae (% of total density)	100	100	100	100	100
Shannon's Evenness Index	0.78	0.83	0.12	0.61	0.82
Simpson's Diversity Index	0.68	0.71	0.05	0.53	0.56
Taxonomic Richness (genus-level) [1]	6	6	3	7	3
Hill's Effective Richness	4.06	4.41	1.15	3.25	2.46

[1] Total number of taxa observed to genus-level