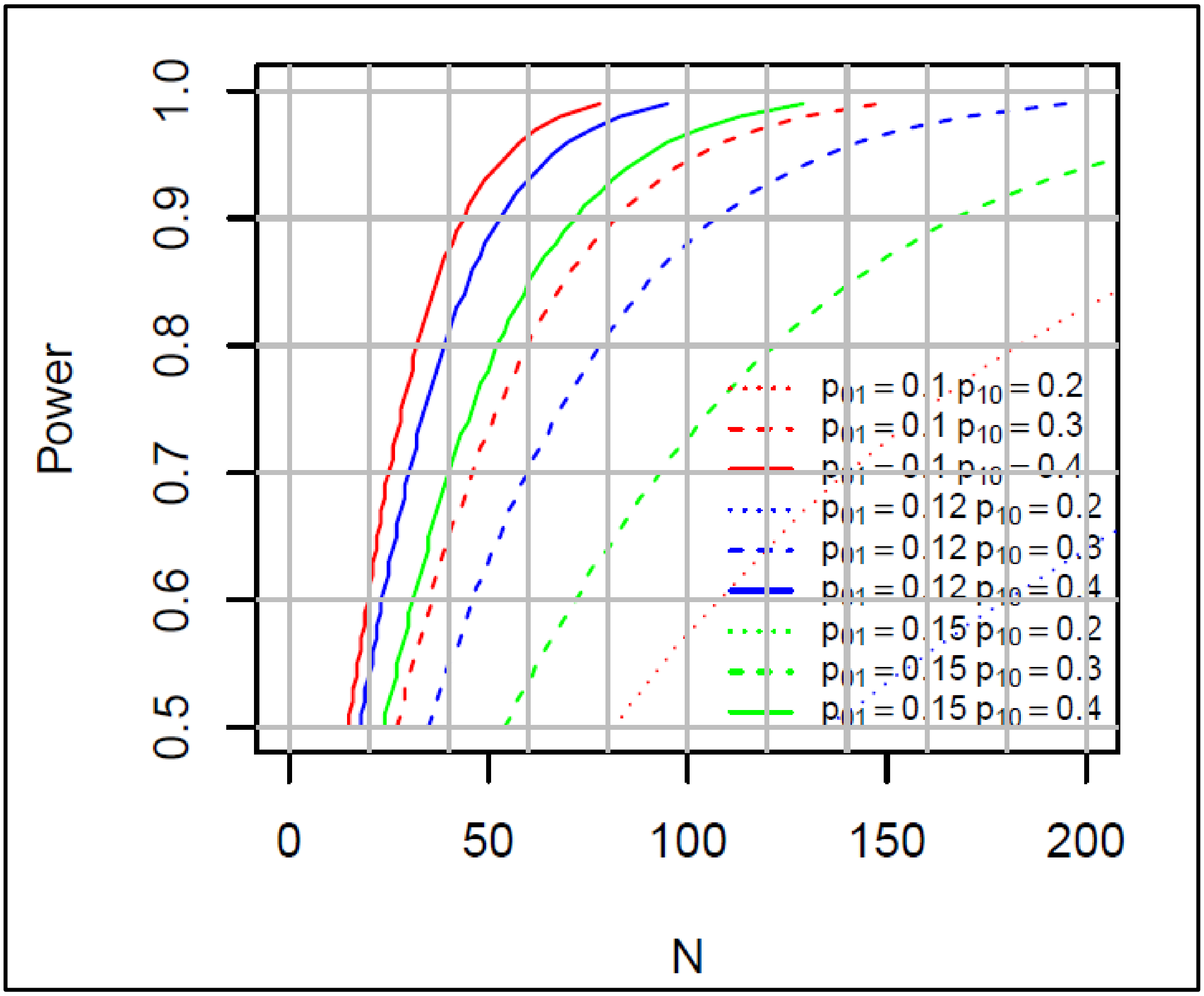

Figure C.45 Arsenic Sample Size Requirements for Equality of Proportions

Cadmium

Baseline concentrations of arsenic are very low site-wide. Between 86% to 100% of cadmium samples at each station in Mary River were below detection limits. Median detected values for cadmium ranged from 0.00001 mg/L to 0.0001 mg/L. The benchmark cadmium equals 0.0001 mg/L. Table C.13 and Table C.14 list the proportions of samples above and below MDL at stations within the Mary River. Based on the McNemar test (using an alpha value of 0.1, for a power equal to 80%), in order to detect a difference in paired proportions with pre-mining data composed of 10% of observations below MDL at impact site and above MDL at control site, requires 50% above MDL at impact and 50% below MDL at control site.

Table C.13 Number of Cadmium Samples Above and Below MDL at Mary River Stations

	E0-10		C0-10		E0-03	
	Control < MDL	**Control > MDL**	**Control < MDL**	**Control > MDL**	**Control < MDL**	**Control > MDL**
Impact < MDL	45	10	47	2	51	2
Impact > MDL	1	1	4	0	6	0

Table C.14 Proportion of Cadmium Samples Above and Below MDL at Mary River Stations

	E0-10		C0-10		E0-03	
	Control < MDL	**Control > MDL**	**Control < MDL**	**Control > MDL**	**Control < MDL**	**Control > MDL**
Impact < MDL	0.94	0.02	0.89	0.04	0.86	0.03
Impact > MDL	0.02	0.02	0.08	0.00	0.10	0.03

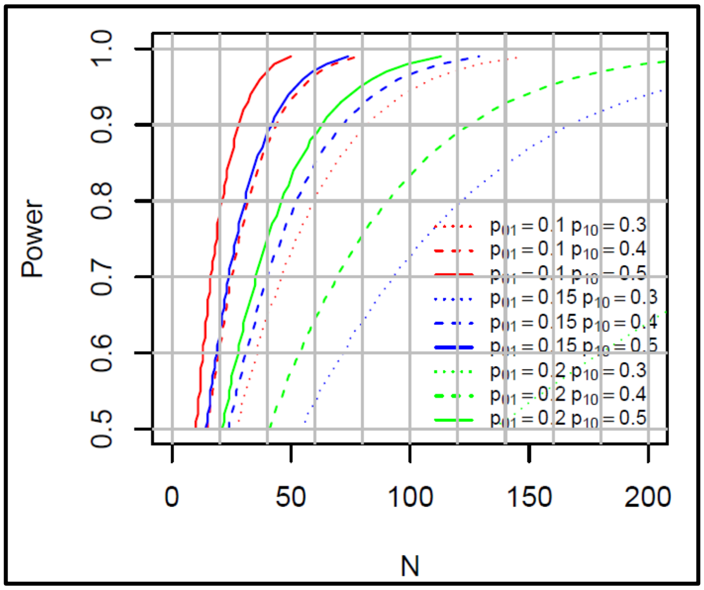

Figure C.46 Cadmium Sample Size Requirements for Equality of Proportions

C.4.3 Recommendations

Power analyses were run on key stations on both the Camp Lake Tributary and the Mary River for key parameters of concern, providing useful information to inform the study design and future power analyses on monitoring data. This analysis identified two major factors that evidently constrain the power analysis for the Camp Lake Tributary samples. First, elevated and variable copper concentrations create difficulties obtaining sufficient power at all stations. Second, the L1-09 and L1-02 station consistently have difficulty obtaining sufficient power with a sample size equal to ten. The Camp Lake Tributary analysis does show that between 5 to 20 samples will be adequate to have good power to detect changes in all parameters at L0-01 (far field EEM station). It is expected that additional sampling during 2014, concurrent to mine construction, but prior to discharge of mine effluents and dispersion of ore dust, will increase the available power.

The power analysis for Mary River identified fewer constraints for Mary River. Power analysis for copper, iron and aluminum concentrations measured during the baseline data collection within Mary River indicate that sufficient sample size can be obtained with between 5 to 10 samples. Parameters with a significant number of concentrations below detection limit might require more samples, although it is expected that additional baseline sampling in 2014 will moderate this requirement.

As a result of these analyses, the following are recommended to augment the study design:

1. Increase the amount of baseline data (this will occur during the one extra season of baseline data collection in 2014, concurrent to mine construction but prior to the discharge of mine effluents and the dispersion of ore dust);
2. Collect additional samples at L1-09 to improve baseline power;
3. Add an additional station in vicinity to L1-09 to provide enough statistical power to detect changes to near-field stations;

4. Recognize that our ability to detect changes to copper and iron are reduced at the Camp Lake Tributary.
5. Add reference station for Camp Lake samples on an adjacent tributary.
6. Four samples (one set of seasonal samples) is likely adequate for most parameters to determine significance. For parameters that require eight to ten post-mining samples, combining the analysis of data from stations with similar effluent additions is recommended.

C.5 REFERENCES

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APPENDIX D

DETAILED REVIEW OF BASELINE SEDIMENT QUALITY

(Pages D-1 to D-37)

ISO 9001 - FS 64925
ISO 14001 - EMS 550121
OHSAS 18001 - OHS 550122

BAFFINLAND IRON MINES CORPORATION
MARY RIVER PROJECT

DETAILED REVIEW OF BASELINE SEDIMENT QUALITY
NB102-181/33-1D

Rev	Description	Date
1	Issued in Final	May 30, 2014

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D – SEDIMENT QUALITY REVIEW

D.1 OVERVIEW

A detailed review of sediment quality within the mine site area was undertaken to facilitate the development of the Core Receiving Environment Monitoring Program (CREMP) for water and sediment quality. As stated in Section 1.2 of the main report, the objectives of the baseline review were as follows:

- Identify data quality issues
- Understand natural enrichment of the mine site area waters and sediment
- Understand the inter-annual variability of sediment quality
- Determine whether or not mineral exploration and bulk sampling activities conducted since 2004 have affected water or sediment quality in the mine site area
- Determine the potential to pool data from multiple sample stations to increase the statistical power of the baseline sediment quality dataset
- Develop a study design for monitoring sediment quality in mine site lakes and streams
- Determine if changes to the existing sediment quality monitoring program are required to meet monitoring objectives

The focus of this review of sediment quality is the mine site area lakes: Camp Lake, Sheardown Lake NW, Sheardown Lake SE and Mary Lake. As discussed in this review, characteristics of streams are such that metals accumulation is variable, and therefore measuring statistically-defensible change in stream sediment is challenging.

The relationship of metals accumulation with total organic carbon (TOC) and fines content in sediment is a focus of this review. Stressors of potential concern (SOPCs) in sediment are the focus of the review. SOPCs include these metals elevated in the iron ore to be produced at site, as well as those metals found to be naturally elevated in the mine site area (see Section 3.4 of the main report).

A review of sediment quality was completed by sediment SOPC, followed by a detailed review by lake and stream. Concentration data measured for the parameters of interest have been log transformed and presented on scatter plots to understand the spatial variability of metals concentrations in sediment. A detailed review of the relationship between metals accumulation and TOC and % sand is completed to identify cut-off values as a means to normalize the influence of each on metals accumulation.

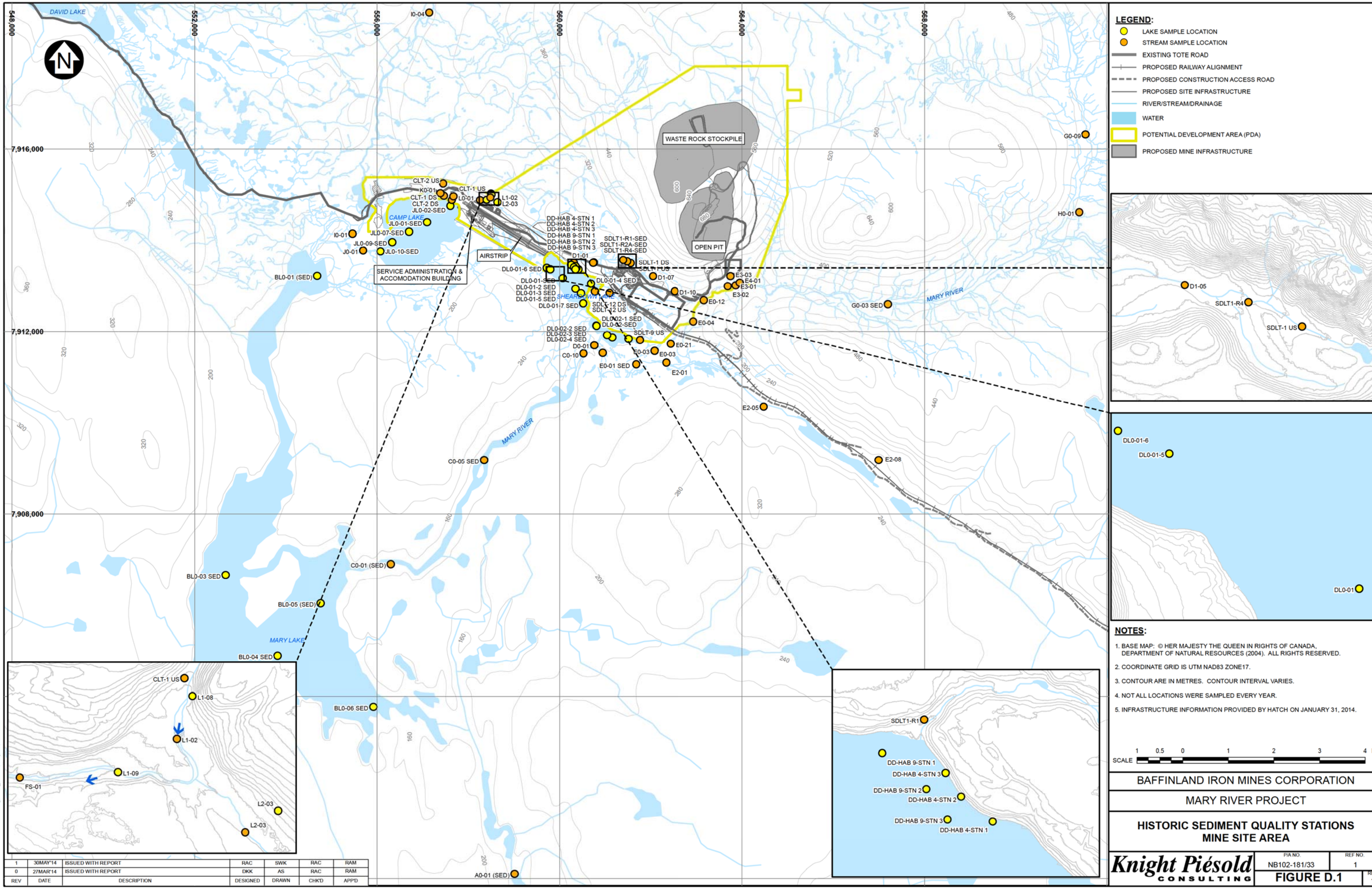
To assist in the development of study designs, parameter and station-specific a priori power analyses were completed in order to determine the power of the proposed sampling program to detect statistical changes. As per the Assessment Approach and Response Framework in the CREMP (see Figure 2.12 in the main report), management action is triggered if the mean concentrations of any parameter at selected stations reach benchmark values. Interim area-wide benchmark values were developed for sediment SOPCs that consider aquatic toxicology, natural enrichment in the Project area, or low concentrations below MDLs (Intrinsik, 2014; see Section 3.6.3 of the main report). Interim area-wide benchmarks were applied in the power analysis of the baseline presented in this detailed review. The resultant study design for the monitoring of Project-related effects to sediment quality is presented in Section 3.6 of the main report.

D.2 REVIEW OF SEDIMENT QUALITY BY PARAMETER

Sediments comprise important habitat within the aquatic ecosystems and may also act as long-term reservoirs for particulate forms of a variety of contaminants. This appendix reviews the metal concentrations recorded within sediment samples taken throughout the Mary River Project's mine site area during baseline conditions. This assessment focuses on the parameters of interest, defined as those with federal sediment quality guidelines (Canadian Environmental Quality Guidelines; CEQG) and/or provincial sediment quality guidelines (Ontario Sediment Quality Guidelines; OSQG) as discussed in Section 3.1 of the report. Sediment quality guidelines provide general scientific reference points for evaluating the potential to observe adverse biological effects in aquatic ecosystems. The parameters of interest identified for the Project include: arsenic, cadmium, chromium, copper, iron, manganese, nickel, lead and zinc.

Metal concentrations currently detected in the lakes and streams are related to the natural enrichment of the area; therefore, an exceedance of the generic sediment quality guidelines is not necessarily indicative of toxicity. There are a variety of physical factors that reduce the bioavailability of metals in the environment (e.g., speciation, availability of dissolved organic carbon, pH, alkalinity, hardness) and a variety of biological processes that modify or reduce toxicity naturally within biota (e.g., acclimation, adaptation). The observations and trends of the baseline data regarding concentrations of specific parameters of concern that have CSQG limits and/or PSQG limits are discussed below.

Historic sediment sampling locations are shown on Figure D.1. Concentrations are also shown graphically in relation to log TOC and percent sand on Figures D.2 through D.10 to understand the relationship between the concentration of a given metal and sediment TOC and fines content. The area of the plotted circle in these plots is proportional to the concentration of the given metal, and the color of the circle is indicative of the lake.


LEGEND:
LAKE SAMPLE LOCATION
STREAM SAMPLE LOCATION
EXISTING TOTE ROAD
PROPOSED RAILWAY ALIGNMENT
PROPOSED CONSTRUCTION ACCESS ROAD
PROPOSED SITE INFRASTRUCTURE
RIVER/STREAM/DRAINAGE
WATER
POTENTIAL DEVELOPMENT AREA (PDA)
PROPOSED MINE INFRASTRUCTURE
NOTES:
1. BASE MAP: © HER MAJESTY THE QUEEN IN RIGHTS OF CANADA, DEPARTMENT OF NATURAL RESOURCES (2004). ALL RIGHTS RESERVED.
2. COORDINATE GRID IS UTM NAD83 ZONE17.
3. CONTOUR ARE IN METRES. CONTOUR INTERVAL VARIES.
4. NOT ALL LOCATIONS WERE SAMPLED EVERY YEAR.
5. INFRASTRUCTURE INFORMATION PROVIDED BY HATCH ON JANUARY 31, 2014.
SCALE 1 0.5 0 1 2 3 4 km
WASTE ROCK STOCKPILE
OPEN PIT
AIRSTRIP
SERVICE ADMINISTRATION & ACCOMODATION BUILDING
DAVID LAKE
CAMP LAKE
SHEARDOWN LAKE
MARY LAKE
MARY RIVER
7,916,000
7,912,000
7,908,000
548,000
552,000
556,000
560,000
564,000
568,000
BAFFINLAND IRON MINES CORPORATION
MARY RIVER PROJECT
HISTORIC SEDIMENT QUALITY STATIONS MINE SITE AREA
Knight Piésold CONSULTING
P/A NO. NB102-181/33
REF NO. 1
FIGURE D.1
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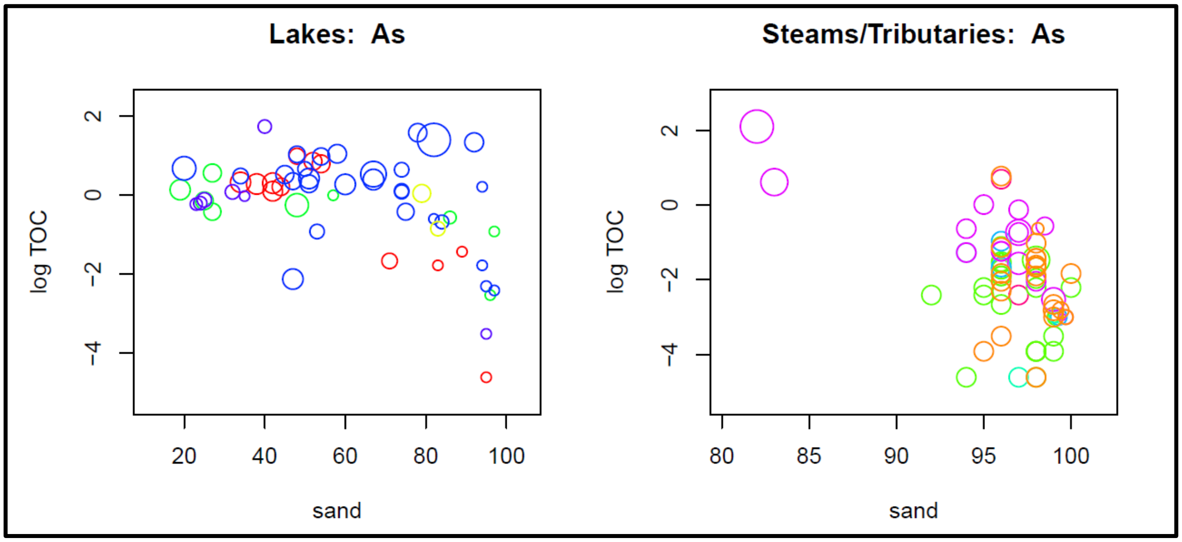
0 27MAR'14 ISSUED WITH REPORT DKK AS RAC RAM
REV DATE DESCRIPTION DESIGNED DRAWN CHK'D APP'D

Arsenic (Figure D.2)

- Lake sediment results show concentrations above the MDL in all areas, with exceedances of guidelines in Sheardown Lake NW. These concentrations exceed the CEQG-TEL guideline and PSQG-LEL guideline but neither exceed the CEQG-PEL or PSQG-SEL guideline.
- Most stream/tributary samples have low arsenic concentrations below MDL and high proportions of sand. Two Sheardown Lake tributary samples report slightly higher arsenic concentrations and a lower proportion of sands.
- No exceedances of sediment quality guidelines were detected in stream sediment samples.



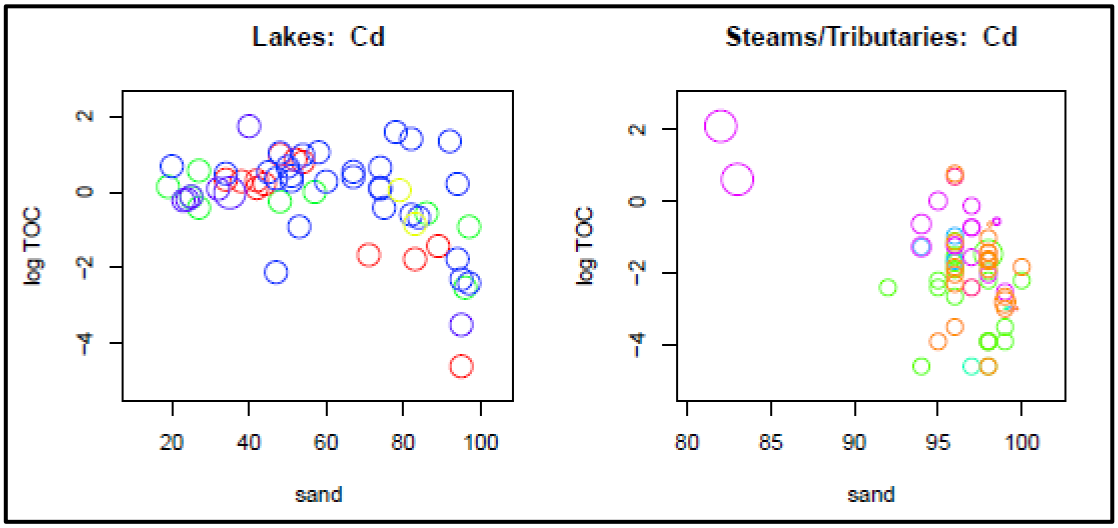
NOTES:

1. RED COLOR REPRESENTS CAMP LAKE; BLUE COLOR INDICATES SHEARDOWN LAKE; GREEN COLOR REPRESENTS MARY LAKE AND YELLOW COLOR REPRESENTS DAVID LAKE.
2. THE X-AXIS REPRESENTS THE % SAND PORTION AND Y-AXIS REPRESENTS THE LOG OF THE TOC (%).
3. THE AREA OF THE DOT REPRESENTS THE CONCENTRATION OF THE METAL.
4. VALUES RECORDED AT OR BELOW DETECTION LIMIT ARE PLOTTED AT THEIR DETECTION LIMIT.

Figure D.2 Arsenic in Sediment as a Function of Log TOC and Percent Sand

Cadmium (Figure D.3)

- All lake concentrations were near to or below the MDL.
- All stream area concentrations were below the MDL with the exception of a Sheardown Lake tributary (the two large circles in the top left) and one instance in a Camp Lake tributary.
- The large proportion of non-detect results for cadmium are evident by the circles being the same diameter for most of the samples (note the scale difference for percent sand between lakes and streams).



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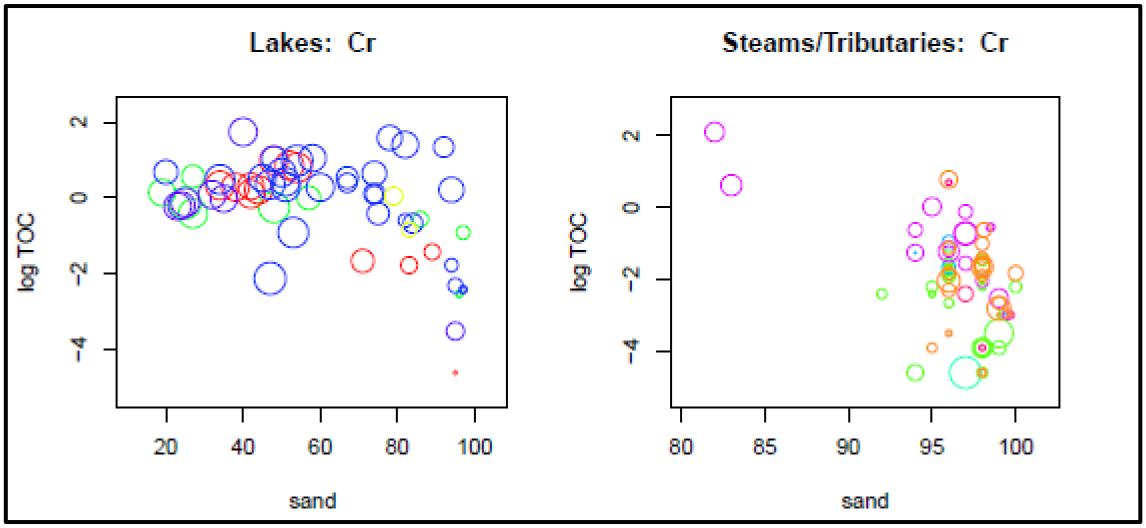
4. VALUES RECORDED AT OR BELOW DETECTION LIMIT ARE PLOTTED AT THEIR DETECTION LIMIT.

Figure D.3 Cadmium in Sediment as a Function of Log TOC and Percent Sand

Chromium (Figure D.4)

- Each of the lake areas reported concentrations above sediment quality guidelines except the near shore dust monitoring stations in Sheardown Lake. The near-shore dust monitoring stations were not in a depositional environment according to low TOC and a low proportion of fines.
- All mine site streams and tributaries show concentrations above sediment quality guidelines except the Tom River and Phillips Creek.



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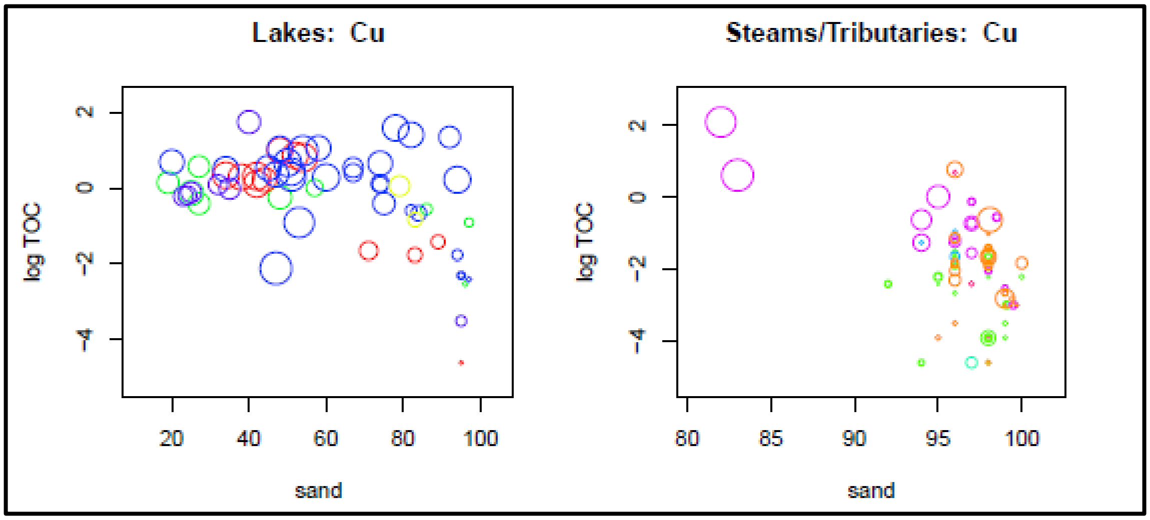
4. VALUES RECORDED AT OR BELOW DETECTION LIMIT ARE PLOTTED AT THEIR DETECTION LIMIT.

Figure D.4 Chromium in Sediment as a Function of Log TOC and Percent Sand

Copper (Figure D.5)

- All lake area results show concentrations above guidelines except the near shore dust monitoring stations in Sheardown Lake (as mentioned above, not located in a depositional environment according to low TOC and a low proportion of fines).
- All stream sample concentrations were below the sediment quality guidelines with the exception of a Sheardown Lake tributary and the Camp Lake tributaries.



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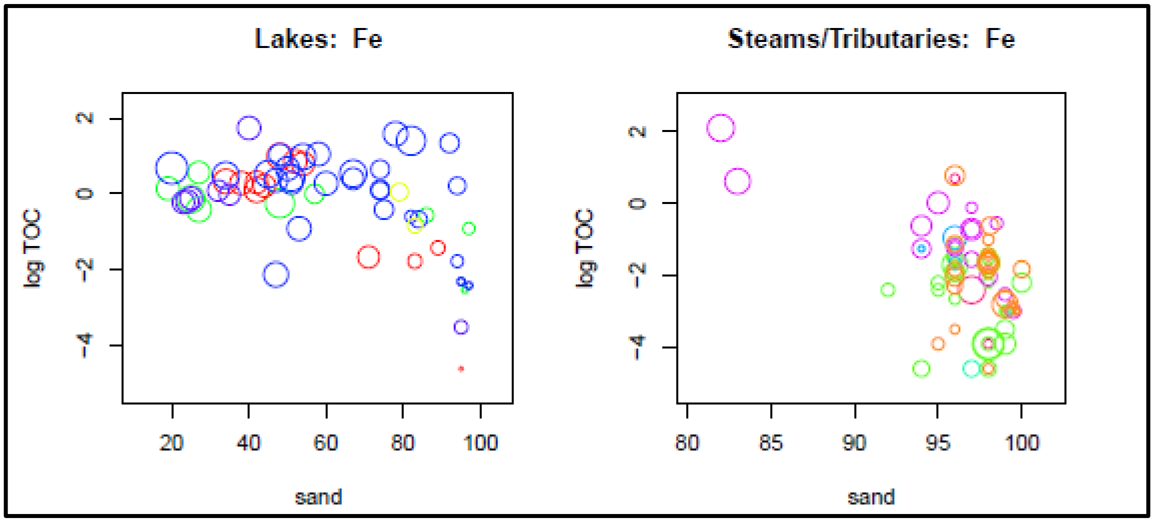
4. VALUES RECORDED AT OR BELOW DETECTION LIMIT ARE PLOTTED AT THEIR DETECTION LIMIT.

Figure D.5 Copper in Sediment as a Function of Log TOC and Percent Sand

Iron (Figure D.6)

- All lake area results show concentrations above guidelines except the near shore dust monitoring stations in Sheardown Lake, and in David Lake located outside of the mine site area.
- Stream sample concentrations exceeded guidelines for at least one sample in most areas.
- Stream samples from the deposit drainage streams, Phillips Creek area and downstream of Mary Lake had concentrations below the guidelines.



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4. VALUES RECORDED AT OR BELOW DETECTION LIMIT ARE PLOTTED AT THEIR DETECTION LIMIT.

Figure D.6 Iron in Sediment as a Function of Log TOC and Percent Sand

Manganese (Figure D.7)

- All lake areas results show concentrations above guidelines for at least one sample, except the near shore dust monitoring stations in Sheardown Lake.
- Stream sample concentrations were below the sediment quality guidelines for all but one sample (Sheardown Lake tributary).

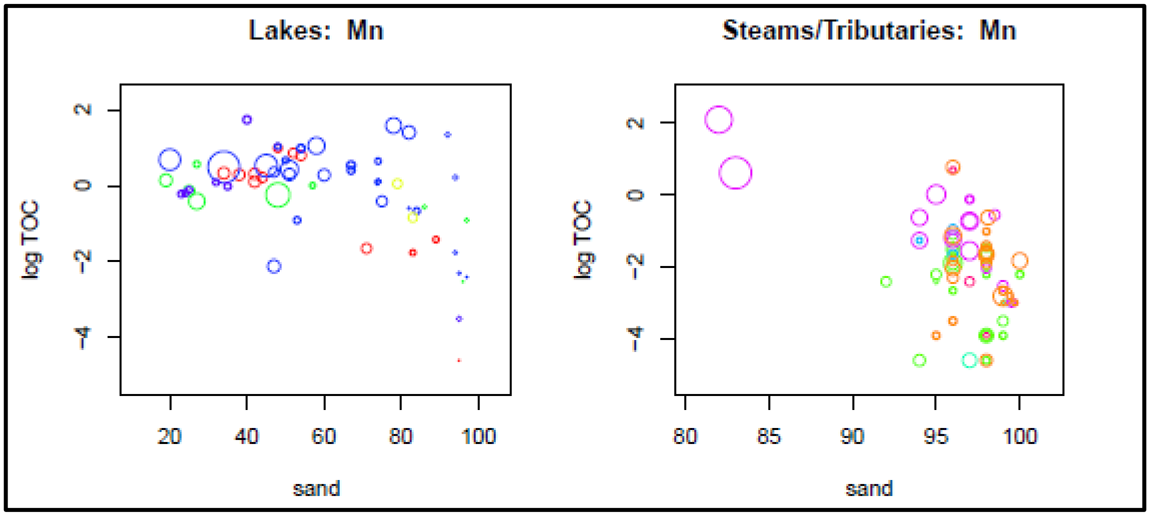

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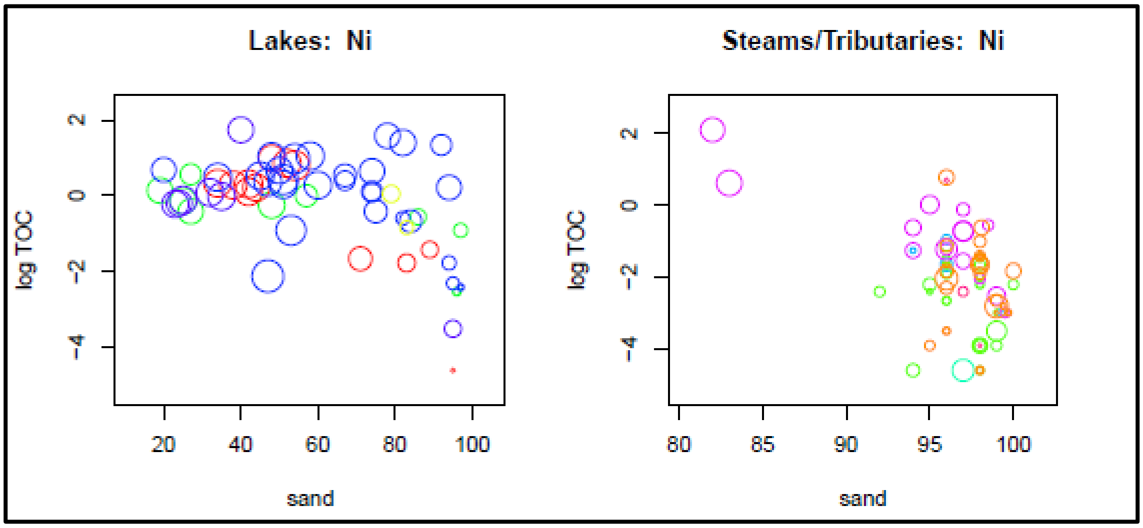
Figure D.7 Manganese in Sediment as a Function of Log TOC and Percent Sand

Mercury (no figure)

- All stream and lake concentrations were below the MDL.

Nickel (Figure D.8)

- Nickel concentrations exceeded the guidelines in each of the mine site lakes.
- Stream sample concentrations exceeded the guidelines for at least one sample in most areas.
- Stream samples from upstream of the deposit, the Tom River area and the Phillips Creek area had concentrations below the guidelines.



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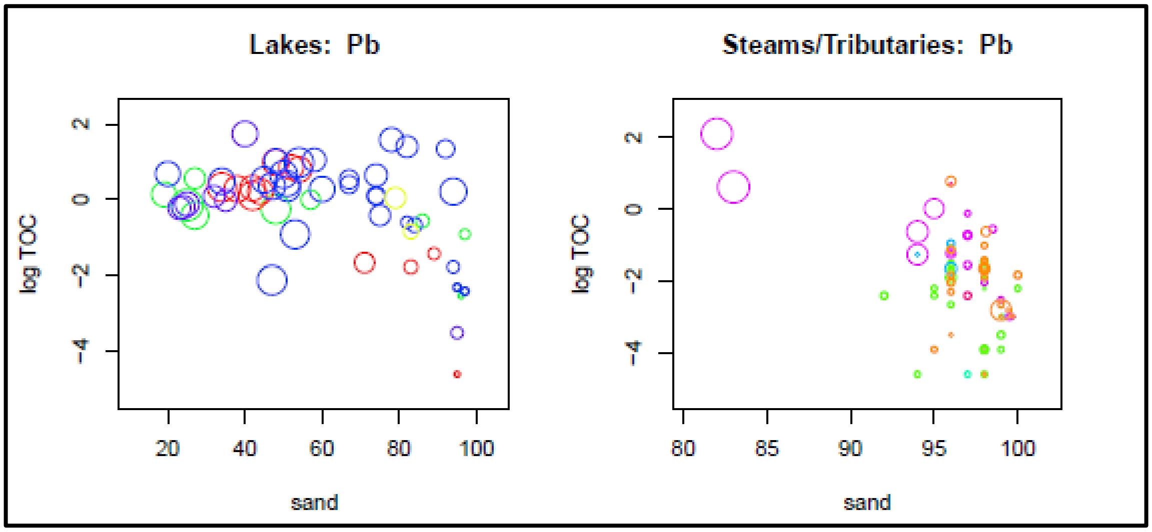
4. VALUES RECORDED AT OR BELOW DETECTION LIMIT ARE PLOTTED AT THEIR DETECTION LIMIT.

Figure D.8 Nickel in Sediment as a Function of Log TOC and Percent Sand

Lead (Figure D.9)

- All lake sample concentrations were below the sediment quality guidelines.
- Most stream areas had low concentrations with only one sediment quality guideline exceeded (Sheardown Lake tributary).



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4. VALUES RECORDED AT OR BELOW DETECTION LIMIT ARE PLOTTED AT THEIR DETECTION LIMIT.

Figure D.9 Lead in Sediment as a Function of Log TOC and Percent Sand

Zinc (Figure D.10)

- All lake samples tested for zinc were below guidelines.
- Stream sample concentrations were below the sediment quality guidelines for all but one sample (Sheardown Lake tributary).

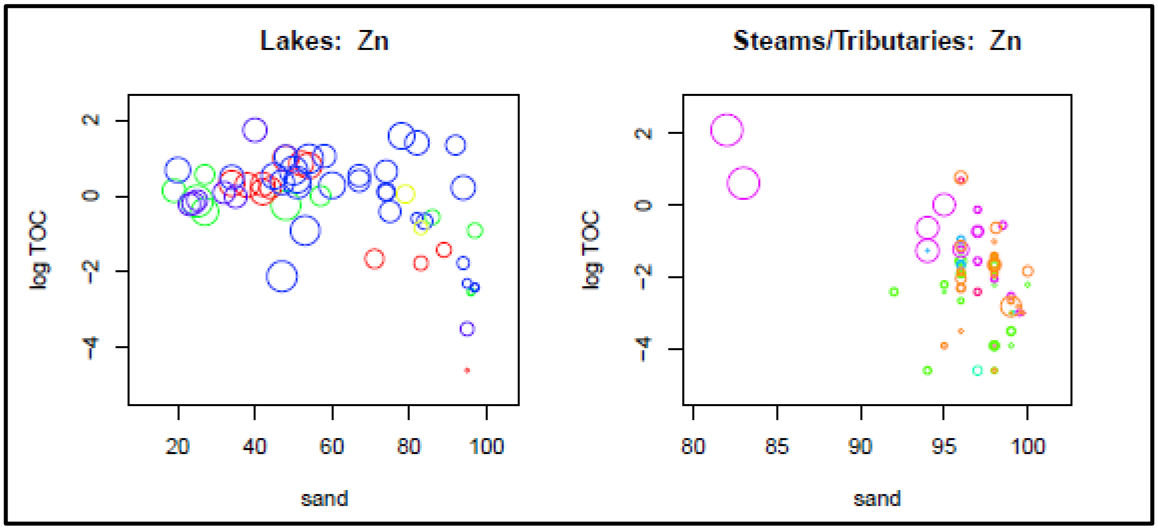

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Figure D.10 Zinc in Sediment as a Function of Log TOC and Percent Sand

Analytical results for the parameters of interest summarized above identify sediment quality guideline concentration exceedances in some areas. These areas have been discussed in the following section and are grouped by stream environments and lake environments.

D.3 SEDIMENT IN STREAM ENVIRONMENTS

Upstream of the Deposits

The three stations positioned upstream of the Project deposits are shown in Figure D.1: G0-09, H0-01 and G0-03. Surface runoff and natural loading contributes to the baseline parameter concentrations in the sediment of Mary River. There were five samples obtained at these stations between 2005 and 2013. Coarse grained sediment (e.g., sand) were the highest proportion of the particle size distribution analysis in this area (≥ 97%).

- **Station G0-09** - The sample results from 2006 show chromium and iron concentrations marginally above the PSQG-LEL criteria. The remaining sample results from this station and surrounding area stations did not show concentrations exceeding sediment quality guidelines.
- **Station H0-01** - One of the two sample results from this station have elevated levels of chromium and iron above their respective PSQG-LEL.
- **Station G0-03** - There is only one result for this station. Sample results from 2007 show elevated chromium and nickel concentrations above their respective CSQG-ISQG and/or PSQG-LEL criteria. These concentrations were the highest detected in this area.

Downstream of the Deposits

These 14 stations are positioned in the Mary River downstream of the waterfall with the exception of Station G0-03 positioned approximately 2.5 km upstream of the waterfall (Figure D.1). The Mary River receives runoff from the deposits that contribute to baseline concentrations found in the stream sediments. There were 25 samples obtained from these stations between 2005 and 2013. Coarse grained sediments (e.g., sand) were the highest proportion of the particle size distribution analysis in this area (≥ 97%). In general, concentrations of chromium, iron and nickel were found in elevated concentrations within this area as discussed below.

- **E-series Stations** - The sample results from the E-series of stations (E0-01, E0-03, E0-04 and E4-01) sampled between 2007 and 2012 show elevated chromium, iron and nickel concentrations. These concentrations were near to or marginally above their respective CSQG-ISQG and/or PSQG-LEL criteria.
- **Station C0-10** - The sample results from 2007 show elevated chromium and iron concentrations above their respective CSQG-ISQG and/or PSQG-LEL criteria. This station is positioned on the Mary River, downstream of the confluence between the Mary River and the Sheardown Lake discharge channel.
- **Station C0-05** - The sample results from 2007 show elevated chromium concentrations close to the PSQG-LEL criteria and below the CSQG-ISQG criteria. This station is positioned on the Mary River, approximately half way between the Sheardown Lake confluence and the outlet to Mary Lake.
- **Station C0-01** - The sample results from 2007 show elevated concentrations of chromium, iron and nickel above their respective CSQG-ISQG and/or PSQG-LEL criteria. This station is positioned less than 2 km from the outlet of the Mary River into Mary Lake. The remaining sample results from this station 2005, 2012 and 2013 did not show concentrations exceeding sediment quality guidelines.

Background Tributary to Mary River

The E2 stream receives surface drainage from the surrounding landscape east of the deposits flows into the Mary River upstream of the confluence with the Sheardown Lake outlet channel (Figure D.1). This area was sampled at three stations to establish baseline sediment conditions outside of the immediate Mary River catchment area. There were four samples obtained between 2005 and 2012, with three of the four samples taken in 2012. Coarse grained sediments (e.g., sand) were the highest proportion of the particle size distribution analysis in this area (≥ 94%). In general, concentrations of iron and nickel were found in elevated concentrations within this area as discussed below.

- **E2-series Stations** - The sample results from station E2-01 (2012) show elevated iron concentrations near to, but above the PSQG-LEL. Similarly, station E2-08 (2012) show elevated nickel concentrations slightly above the PSQG-LEL.

Downstream of Mary Lake

This station is positioned approximately 6 km downstream of the Mary Lake outlet, upstream of Angajurjualuk Lake. This station was sampled twice during the baseline program (2005 and 2007). Coarse grained sediments (e.g., sand) were the highest proportion of the particle size distribution analysis at this station (≥ 97%).

- **Station A0-01** - The sample results from 2007 show elevated chromium and nickel concentrations. Chromium concentrations were above the PSQG-SEL which was the highest reported chromium concentration in the baseline study. Nickel concentrations were above the PSQG-LEL criteria.

Sheardown Lake Tributaries

The Sheardown Lake tributary stations have various labels depending on the field program under which the samples were collected (Figure D.1). Sheardown Lake tributary 1 (SDLT1), historically identified as tributary D1 receives surface water and erosional material from the south slope of the deposit. Streams that receive drainage from the landscape, south of the deposit access road include SDL-Trib 9 and SDL-Trib 12. There were 18 samples obtained from these stations between 2005 and 2013. Coarse grained sediments (e.g., sand) were the highest proportion of the particle size distribution analysis at this station (≥ 82%).

- **Station D1-01** - The sample results from 2012 show elevated chromium and nickel concentrations above the respective CSQG-ISQG and/or PSQG-LEL criteria.
- **Station D1-07** - The sample results from 2011 show elevated cadmium and chromium concentrations above the respective CSQG-ISQG and/or PSQG-LEL criteria. Copper and nickel were measured above their respective PSQG-SEL criteria.
- **Station D1-10** - The sample results from 2011 show elevated total organic carbon (TOC), chromium and copper concentrations above the respective CSQG-ISQG and/or PSQG-LEL criteria. Nickel was above the PSQG-SEL criteria.

- **Station D1-05 (SDLT1-R4 US)** - The sample results show elevated cadmium, chromium, copper, iron, manganese, nickel, lead and zinc concentrations. The 2012 and 2013 sample results had the highest number of sediment quality criteria exceedances, including the only CSQG-ISQG and PSQG-LEL exceedances of lead and zinc of the baseline study. The 2012 sample had the highest TOC concentration of the baseline study, which was above the PSQG-LEL criteria.
- **Station D1-01 (SDLT1-R2A and SDL-Trib 1 DS)** - The sample results show elevated chromium, copper and nickel concentrations. The 2012 chromium results were above the CSQG-ISQG and PSQG-LEL criteria. The 2008 copper results were equal to the PSQG-LEL criteria and below the CSQG-ISQG criteria. The 2008 and 2012 nickel results were above the PSQG-LEL criteria.
- **Station SDLT1-R1** - The sample results from 2008 show elevated chromium and nickel concentrations above the CSQG-ISQG and/or PSQG-LEL criteria.
- **Station SDL-Trib 9 US** - All sample results show elevated chromium and nickel concentrations above the CSQG-ISQG and/or PSQG-LEL criteria.
- **Station SDL-Trib 12 (US and DS)** - The sample results from 2007 show elevated chromium and nickel concentrations above the CSQG-ISQG and PSQG-LEL criteria.

Sample locations D1-10 and D1-05 in the Sheardown Lake tributary 1 are depositional environments that show similar metals accumulation to that of the mine site lakes. These sample locations represent good long-term sampling locations.

Camp Lake Tributaries

The 12 Camp Lake tributary stations have various labels depending on the field program under which the samples were collected (Figure D.1). Camp Lake tributary 1 (CLT-1), historically identified as tributary L1 receives surface water and erosional material from the deposit through the collection of surface water runoff and discharge through the West Pond. The L2 tributary is positioned parallel with the airstrip flowing into the L1 tributary upstream of the tote road. Downstream of the Tote Road, this stream is known as the L0 tributary where station CLT-1 DS is located. Camp Lake tributary 2 or K0 tributary receives runoff from the western portion of the deposit. The J0 station is located in the connecting channel between Camp Lake and the north branch of Mary Lake showing sediment conditions downstream of Camp Lake. A discussion of the sediment quality guideline exceedances has been presented below. There were 22 samples obtained from these stations between 2005 and 2013. Coarse grained sediments (e.g., sand) were the highest proportion of the particle size distribution analysis at this station (≥ 82%).

- **Station CLT-1 US (L1 series)** - The results from 2005, 2007, 2012 and 2013 show elevated concentrations of cadmium, chromium, copper and nickel above the CSQG-ISQG and/or PSQG-LEL criteria. In addition, concentrations of iron were detected above the PSQG-LEL in 2007.
- **Station L2-03** - The results from 2011 to 2013 show all parameter concentrations of interest were below the CSQG-ISQG and/or PSQG-LEL criteria.
- **Station CLT-1 DS (L0 series)** - The results from 2007 show an elevated chromium concentration above the CSQG-ISQG and PSQG-LEL criteria, but below the upstream sample concentration. All other parameter concentrations were below criteria.

- **Station CLT-2 (K0)** - The results from 2013 show an elevated nickel concentration near to, but above the PSQG-LEL. The results from 2005 and 2012 do not show any concentrations above criteria.
- **Station J0-01** - The results from 2012 and 2013 show nickel concentrations near to, but above the PSQG-LEL. The results from 2005 do not show elevated nickel concentrations above criteria.

D.4 SEDIMENT IN LAKE ENVIRONMENTS

Camp Lake

The sample stations are positioned in a northeast to southwest transect across Camp Lake between the CLT-1 inflow stream and the J0-01 outlet stream (Figure D.1). These stations were selected for initial baseline assessments and ongoing monitoring programs. Fine grained sediment (e.g., silt and sand) were the highest percent particle size in the mid lake region, whereas sand was the highest component fraction in most of the other sample areas.

- **Station JL0-01** - This station is located mid-lake and is one of the proposed long-term monitoring stations. Four samples were obtained from this location, two were taken in 2007 and one was taken during the 2012 and 2013 sampling campaigns. The results from all sampling events show elevated TOC, chromium, copper, iron, manganese and Ni concentrations above their respective CSQG-ISQG and/or PSQG-LEL criteria. The samples from this location had the highest manganese concentrations within Camp Lake.
- **Station JL0-02** - This station is positioned offshore from the CLT-1 outlet stream in the northeast corner of Camp Lake. Three samples were obtained from this location, one taken during each of the 2007, 2012 and 2013 sampling campaigns. The results of all samples had elevated TOC, chromium, copper, iron, manganese and nickel concentrations above their respective CSQG-ISQG and/or PSQG-LEL criteria. The 2007 iron concentration was above the PSQG-SEL criteria and was the highest concentration within Camp Lake. This station also had the highest TOC concentrations likely attributable to the contribution of organic inputs from the CLT-1 stream.
- **Station JL0-07** - This station is positioned southwest of station JL0-01 in the main lake basin. One sample was obtained from this location (2007). The results show elevated TOC, chromium, copper, iron, manganese and nickel concentrations above their respective CSQG-ISQG and/or PSQG-LEL criteria.
- **Station JL0-09** - This station is positioned near the outlet channel, upstream of station JL0-10. Three samples were obtained from this location, one taken during each of the 2007, 2012 and 2013 sampling campaigns The results from 2007 show elevated TOC, chromium, copper, iron, manganese and nickel concentrations above the respective CSQG-ISQG and/or PSQG-LEL criteria. The 2012 and 2013 results only show an elevated nickel concentration above the PSQG-LEL criteria. The difference in the number of criteria exceedances between 2007 and the 2012 and 2013 samples may be attributed to the high percent sand content in the recent samples (89% and 83% respectively).
- **Station JL0-10** - This station is located immediately upstream of the outlet channel in the southwest corner of Camp Lake. One sample was obtained from this location (2007). There were no elevated concentrations measured of any of the parameters of concern.

Sheardown Lake (NW Basin)

There were many stations established in the near shore and offshore environment to monitor pre-development sedimentation in these regions of the lake (Figure 3.2). Many stations are included in the ongoing monitoring program. This study will be used for post-Project comparison to baseline condition.

- **Station DL0-01-1** - This is a mid-lake sample station in the deepest area of the lake. Four samples were obtained from this location, one taken during each of the 2007, 2011, 2012 and 2013 sampling campaigns. The sample results from these years show elevated TOC, chromium, copper, iron, manganese and nickel concentrations. The chromium, copper and nickel concentrations were elevated above the respective CSQG-ISQG and/or PSQG-LEL criteria. All iron concentrations were above the PSQG-SEL criteria. The manganese results from 2011, 2012 and 2013 were above the PSQG-SEL, whereas the 2007 results were below this sediment quality guideline criterion. The nickel concentrations were all above the PSQG-LEL with the 2013 concentration also above the PSQG-SEL criteria. The particle size distribution results show a relatively equal proportion of fine grained sediment (e.g., silt and clay) and coarse grained sediment (e.g., sand) at this station.
- **Station DD-Hab 4 series** - There are three stations positioned in the shallow near shore area close to the SDLT-1 inflow stream. One sample was obtained from each station (2008), with one of these results showing elevated nickel concentration equal to the PSQG-LEL criteria. All other concentrations were reported below sediment quality guideline criteria. Particle size distribution data was not available for these samples.
- **Station DD-Hab 9 series** - The three stations in this series are positioned at offshore areas near the SDLT-1 inflow stream. Samples were obtained from each station during the 2008, 2012 and 2013 sampling campaigns. These results show elevated TOC, arsenic, chromium, copper, iron, manganese and nickel concentrations. The TOC concentrations from this series of stations were some of the highest in the lake, likely attributed to the contribution of organic inputs from the SDLT-1 stream. The 2008 arsenic concentration at DD-Hab-9-Stn 3 were reported above the CSQG-ISQG and PSQG-LEL criteria, which was the highest arsenic concentration detected in the lake. The majority of the chromium, copper, iron and nickel concentrations were above the CSQG-ISQG and/or PSQG-LEL criteria. The 2008 manganese concentrations at DD-Hab-9-Stn 2 and DD-Hab-9-Stn 3 were above the PSQG-SEL criteria. The 2008 and 2012 results from DD-Hab-9-Stn 3 reported iron concentrations above the PSQG-SEL. In general, concentrations were higher in this deeper area compared to those reported from the shallow stations (DD-Hab 4 series). Particle size distribution data was not available for these samples.
- **Station DL0-01-5 and -6** - These stations are located in the northwest region of the lake, positioned near the treated sewage effluent outfall from the exploration camp. Four samples were obtained from station DL0-01-5, one taken during each of the 2007, 2008, 2011 and 2013 sampling campaigns, whereas only two samples were obtained from station DL0-01-6 (2007 and 2008). The results show some of the highest chromium, iron, manganese and nickel concentrations within the lake, which were above the CSQG-PEL and/or PSQG-SEL criteria. Copper was generally above the CSQG-ISQG and/or PSQG-LEL criteria. The highest TOC concentrations were measured at station DL0-01-5, which exceeded the PSQG-LEL criteria in 2007, 2008 and 2011. The particle size distribution results for

station DL0-01-5 show a relatively equal proportion of fine grained sediment (e.g., silt and clay) and coarse grained sediment (e.g., sand). The particle size distribution results from station DL0-01-6 show that sand was the dominant fraction in both samples (≥ 75%).

- **Station DL0-01-2 and -3** - These stations are located in the southeast region of this basin, positioned near the largest island in the lake. Three samples were obtained from station DL0-01-2, one taken during each of the 2007, 2008 and 2013 sampling campaigns, whereas only two samples were obtained from station DL0-02-3 (2007 and 2008). The results generally show elevated chromium, copper and nickel concentrations above the CSQG-ISQG and/or PSQG-LEL criteria. The 2008 results from station DL0-01-3 show an elevated arsenic concentration near to, but above the CSQG-ISQG and PSQG-LEL criteria. The manganese concentrations were generally above the PSQG-LEL and/or SEL criteria. All sample results show TOC concentrations above the PSQG-LEL criteria. The particle size distribution results for these stations show a range in the proportion of fine grained sediment (e.g., silt and clay) and coarse grained sediment (e.g., sand) between years. This range is likely due to the variability in substrate types near these stations.
- **Station DL0-01-4** - This station is positioned in a bay at the eastern end of the basin and receives inflow from the SDLT-12 stream. Three samples were obtained from this station one taken during each of the 2007, 2008 and 2013 sampling campaigns. The results show chromium, copper and nickel concentrations above the CSQG-ISQG and PSQG-LEL criteria. The results also show some iron and manganese concentrations above the CSQG-PEL and PSQG-SEL criteria. All sample results show TOC concentrations above the PSQG-LEL criteria and the highest concentration within the lake measured during 2008. The particle size distribution results show that sand was the dominant fraction in these samples (≥ 78%).
- **Station DL0-01-7** - This station is positioned near the outlet channel that connects the Sheardown Lake NW and SE basins. Five samples were obtained from this station, one taken during each of the 2007, 2008, 2011, 2012 and 2013 sampling campaigns. The results show elevated chromium, copper, iron, manganese and nickel concentrations generally above the CSQG-ISQG and PSQG-LEL criteria. The results from 2011 show nickel concentrations were the only parameter above the sediment quality guidelines. The results from 2008 reported the only manganese concentration above the PSQG-LEL criteria. All sample results show TOC concentrations above the PSQG-LEL criteria with the exception of 2011. The particle size distribution results show that sand was the dominant fraction in these samples (≥ 67 %).

Sheardown Lake (SE Basin)

There were four stations established in the near shore and offshore environment to monitor pre-development sedimentation in these regions of the lake (Figure 3.2). One of these stations (DL0-02-3) is included in the ongoing monitoring program. Silt was the highest percent particle size fraction in all but one sample (DL0-02-3 in September 2007). The highest concentrations of the parameters of concern were reported from the stations positioned in the deepest region of the southeast basin.

- **Station DL0-02-1** - This station is located in the northwest corner of this basin and is the first area to receive influent from the NW basin. This area may be subject to increased erosional flows from the NW basin channel during spring freshet that would transport material towards the main lake basin. Two samples have been obtained from this location, both taken during the 2007 sampling campaign. The results show elevated chromium, copper, iron, and nickel concentrations above the CSQG-ISQG and PSQG-LEL criteria.

- **Station DL0-02-2** - This station is located near the deepest area of the SE basin. One sample was obtained from this location (2007). The results show elevated chromium, copper, iron, and nickel concentrations above the CSQG-ISQG and PSQG-LEL criteria.
- **Station DL0-02-3** - This station is located mid-lake, nearest to the outlet channel that connects Sheardown Lake to Mary River. Three samples were obtained from this location, one taken during each of the 2007, 2012 and 2013 sampling campaigns. The 2007 results show elevated chromium and nickel concentrations above the CSQG-ISQG and/or PSQG-LEL criteria. The field sample record from 2007 indicates this material was obtained in a water depth of 1.8 m, which is significantly different than the sample depths in 2012 and 2013 (13 m and 14 m respectively). In addition, it is possible it might not have been obtained in the exact same location. The difference between the TOC results from 2007 (0.03%), 2012 (1.09%) and 2013 (0.98%) suggests the 2007 sample results may not be suitable for comparison to the 2012 and 2013 results. The 2012 and 2013 results show elevated chromium, copper, iron, and nickel concentrations above the CSQG-ISQG and/or PSQG-LEL criteria. In addition, the 2013 results also show an elevated manganese concentration above the PSQG-LEL criteria.
- **Station DL0-02-4** - This station is located in the southeast corner of the basin, in an area that receives influent from the SDLT-9 stream. A single sample was obtained from this location in 2007. The SDLT-9 stream is a source of organic material inputs as shown by the highest TOC concentration within the southeast basin. The results show elevated TOC, chromium, copper, iron, nickel, and manganese concentrations above the CSQG-ISQG and/or PSQG-LEL criteria.

Mary Lake

There are two main basins within Mary Lake (North and South). These basins will eventually receive water and sediment inputs from the mine site and upper reaches of the catchments as previously described. One monitoring station (BL0-01) is located in the north basin, whereas the remaining four stations are located in the south basin (Figure 3.3). The north basin receives influent water from Camp Lake which flows through a network of smaller basins and channels before reporting to the south Mary Lake basin. The majority of the Mary Lake south basin water comes from Mary River. Silt was the highest percent particle size fraction from all stations positioned in the south basin, except station BL0-05. Sand was the highest particle size fraction of the samples obtained from station BL0-01 and station BL0-05. These stations are positioned near the outlet of main streams (Camp Lake outlet and Mary River outlet) and also had the highest concentrations of TOC in Mary Lake.

- **Station BL0-01 (North)** - Two samples were obtained from this location, one taken during each of the 2006 and 2007 sampling campaigns. These results show elevated TOC, chromium, copper, iron and nickel concentrations above the respective CSQG-ISQG and/or PSQG-LEL criteria. The 2007 results also show manganese concentration above the PSQG-SEL criteria.
- **Station BL0-03 (South)** - This station is located in the northwest corner of the Mary Lake south basin, downstream of Station BL0-01. One sample was obtained from this location (2007). These results show elevated chromium, copper, iron, manganese and nickel concentrations.

The copper and nickel concentrations were above the CSQG-ISQG and/or PSQG-LEL criteria. The chromium, iron and manganese concentrations were above their respective CSQG-PEL and PSQG-SEL criteria. Station BL0-03 had the highest iron and manganese concentrations measured in Mary Lake.

- **Station BL0-04 (South)** - This station is located downstream of station BL0-03 and is positioned on the western edge of the deepest lake basin. One sample was obtained from this location (2007). These results show elevated chromium, copper, iron, manganese and nickel concentrations. The copper, iron and nickel concentrations were above the CSQG-ISQG and/or PSQG-LEL criteria. The chromium and manganese concentrations were above their respective CSQG-PEL and/or PSQG-SEL criteria.
- **Station BL0-05 (South)** - This station is positioned at the outlet of Mary River. Two samples were obtained from this location, one taken during each of the 2006 and 2007 sampling campaigns. These results show elevated nickel concentrations above the PSQG-LEL criteria. Results from 2012 show elevated copper, iron and nickel concentrations above the PSQG-LEL criteria, with chromium concentrations above the CSQG-ISQG and PSQG-LEL criteria.
- **Station BL0-06 (South)** - This station is located in the southwestern corner Mary Lake, immediately upstream of the main lake outlet channel. One sample was obtained from this location (2007). These results show elevated chromium, copper, iron, manganese and nickel concentrations. Copper, manganese and nickel concentrations were above the CSQG-ISQG and/or PSQG-LEL criteria. The chromium concentration was above the CSQG-PEL, but below the PSQG-SEL. The iron concentration was above the PSQG-SEL criteria.

David Lake

There were two stations sampled in 2012 to assess baseline sediment quality conditions prior to development. Sand was the highest percent particle size fraction at these locations, followed by silt.

- **Station DL-12-02** - This station is positioned at the western end of the lake in the main basin. The manganese and nickel concentrations were elevated above the PSQG-LEL criteria.
- **Station DL-12-03** - This station is located in the southeastern basin of the lake, near the main inflow stream. The inflow stream is a source of organic material inputs as shown by the high TOC concentration compared to the DL-12-02 station (1.05% and 0.43% respectively). The TOC, chromium, copper, manganese and nickel concentrations were elevated above their respective CSQG-ISQG and/or PSQG-LEL criteria.

D.5 INFLUENCE OF TOC AND FINES ON METALS ACCUMULATION

Metals concentrations in sediment are positively correlated with both finer grained particles as well as higher organic carbon content (Horowitz, 1991; EC, 2012). These relationships are observed within the sediment quality baseline dataset. Metals concentrations are consistently higher in depositional environments that generally have a higher proportion of organic carbon and fines in the substrate. Depositional environments were predominantly found within the mine site lakes, with the exception of select stations within the main tributary of Sheardown Lake (tributary 1). Streams at the mine site most often are high gradient, high energy and are not therefore depositional environments consisting of fine grained sediment or high organic carbon content.

For this reason, metals concentrations in lake sediment were consistently higher than sediment in streams. This is observed when reviewing mean concentrations of key metals as presented in Table D.1 (numbers have been rounded). Stream versus lake sediment sample groupings are shaded different colours.

Additionally, metals concentrations in depositional environments (higher TOC and/or fines) tended to be higher in the same metals. In the three mine site lakes, the mean concentrations of chromium, copper, iron, manganese and nickel exceeded applicable guidelines. Throughout the sediment quality dataset it is observed that depositional environments typically contain exceedances of most of these metals.

Metals concentrations in depositional lake samples are relatively consistent between samples, between sample stations within a given lake, as well as between each of the three mine site lakes (Camp, Mary, Sheardown). Sample location D1-05 within Sheardown Lake tributary 1 also exhibited the same substrate characteristics and elevated metals concentrations.

Conversely, metals concentrations in lake sediment and most stream sediment stations which were low in fines and/or TOC contained comparatively lower concentrations of metals and a high degree of variability in metals concentrations between sampling events between nearby sampling stations.

Table D.1 Mean Concentrations of Key Metals in Sediment at the Mine Site

Sample ID		As µg/g	Cd µg/g	Cr µg/g	Cu µg/g	Fe µg/g	Mn µg/g	Ni µg/g	Pb µg/g	Zn µg/g
CCME	ISQG	5.9	0.6	37.3	35.7				35	123
	PEL	17	3.5	90	197				91.3	315
Ontario Sediment Quality Guidelines	LEL	6	0.6	26	16	20,000	460	16	31	120
	SEL	33	10	110	110	40,000	1,100	75	250	820
	n									
Upstream of Deposits	4	0.9	0.4	12.8	1.9	9,446	41	5	1.6	5.9
Downstream of Deposits	22	<1	<0.5	22.9	4.5	11,795	83	13	2.4	8.5
Drainages Off the Deposits	10	<1	<0.5	28.3	12.8	9,688	135	21	2.9	15.1
Mary River Tributary E2	7	1.0	0.4	18.5	3.8	9,507	64	12	2.5	7.0
Mary River Downstream of Mary Lake	2	0.7	0.3	74.5	7.0	6,050	90	29	1.5	7.8
Sheardown Lake Tributaries	18	1.4	0.65	45.2	27.0	13,524	235	39	12.1	47.6
Camp Lake Tributaries	12	0.9	0.4	27.0	12.3	8,501	95	22	3.7	13.3
Tom River	4	<1	<0.5	14.5	2.3	6,993	48	7	1.5	5.8
Mary Lake	9	2.5	<0.5	54.6	21.7	27,469	1,099	40	13.4	51.6
Camp Lake	12	2.7	<0.5	60.2	33.2	27,748	700	52	14.7	48.8
Sheardown Lake NW	32	3.1	<0.5	59.6	36.8	30,687	1,149	54	14.6	56.6
Sheardown Lake SE	7	1.5	0.6	68.0	23.4	27,462	397	57	13.3	46.3

Therefore, further evaluation of the sediment quality database was undertaken to understand the relationship between TOC, the proportion of fines, and metals concentrations.

Figure D.11 shows clay, sand and silt plotted for the entire sediment quality dataset. Circle size represents the proportion of silt. Figure D.12 shows the same information in another way, plotting the proportion of clay/clay+silt by sand. The figures show the 3-way relationship between sand, silt and clay and the negative association between sand and clay.

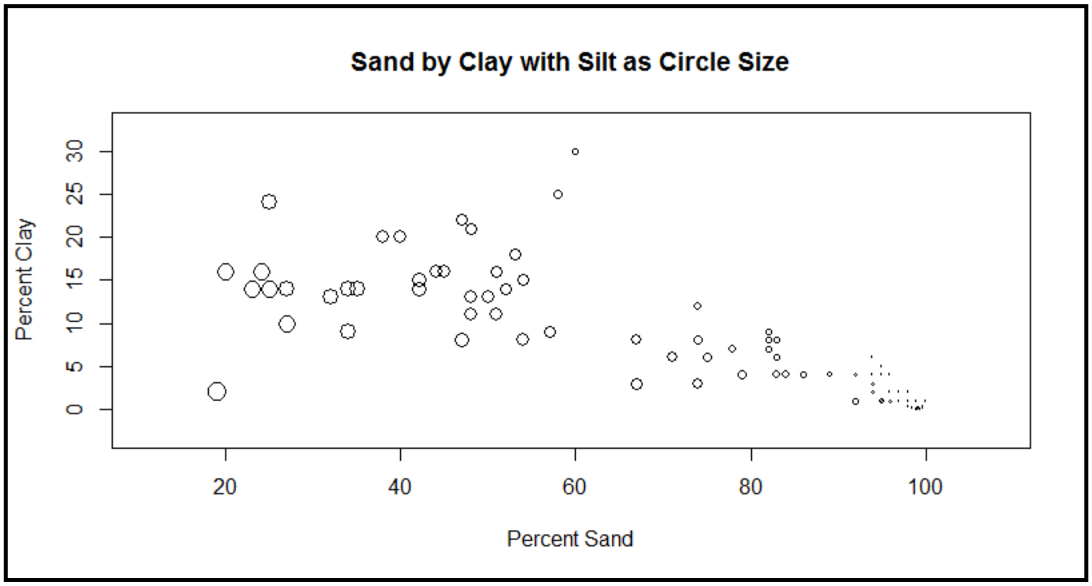

Figure D.11 Clay by Sand with Silt as Circle Size

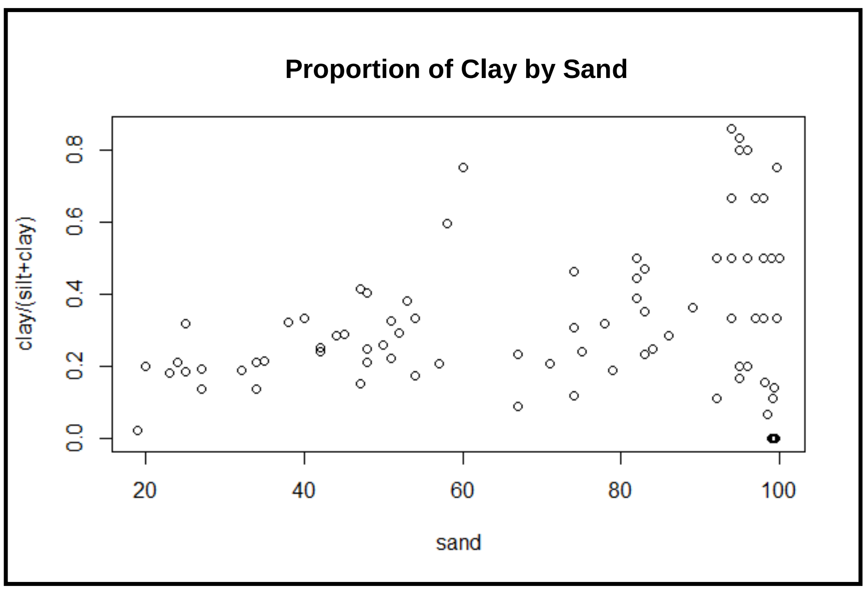

Figure D.12 Dependent Relationship between Sand, Silt and Clay in Sediment

Colored scatter plots (Figure D.13) show the relationship between TOC (or log TOC) and sand for lakes, streams and tributaries. Lakes are plotted using circles, streams and tributaries with triangles.

Colors are used to identify the specific water bodies. Note that the x axis limits for streams and tributaries were adjusted because all the stream data is clumped at high proportions of sand (minimum of 82%). The figure shows that the majority of lake sediment samples contain elevated TOC and higher proportions of fines (a lower proportion of sand), and conversely, the majority of stream samples are low in TOC and low in fines (predominantly sand).

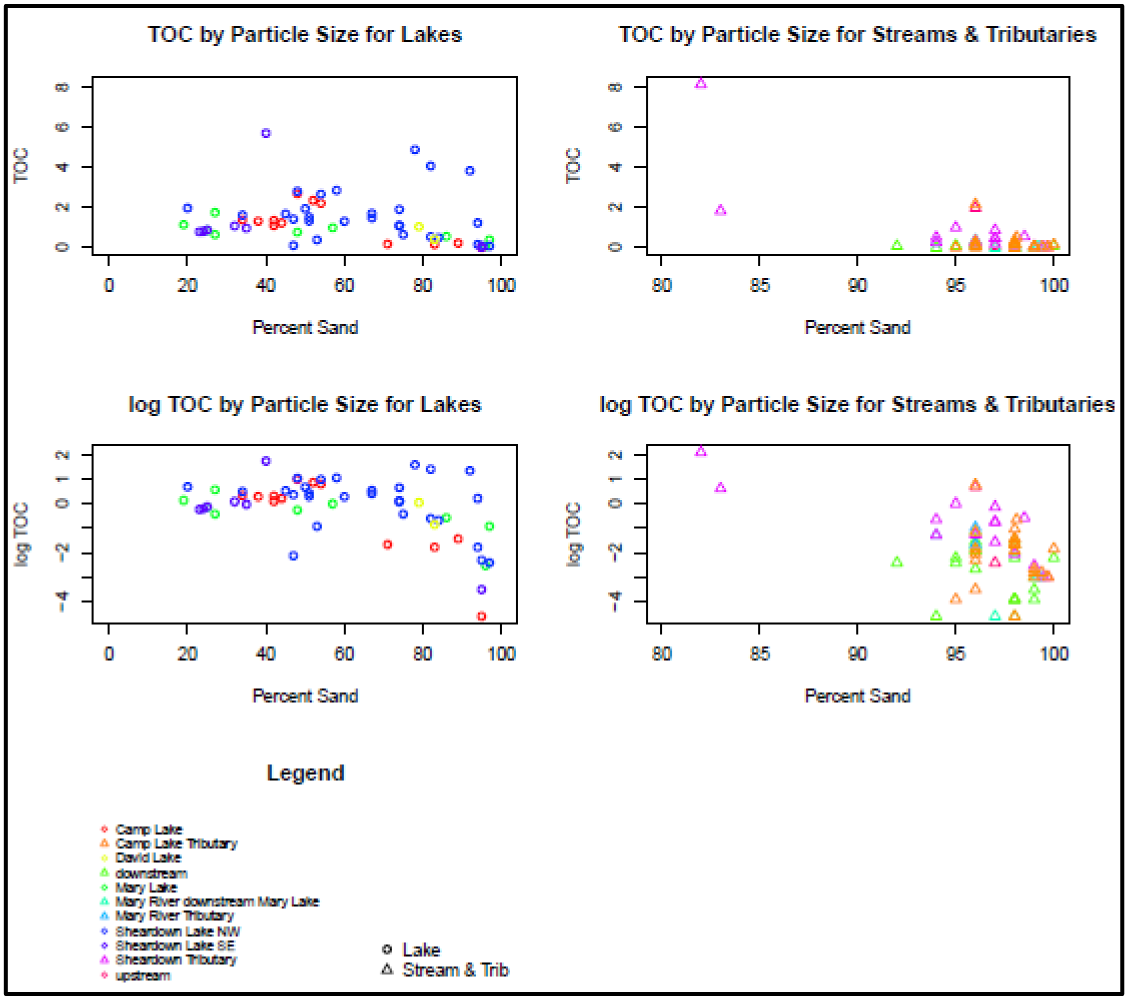

Figure D.13 Sediment TOC versus Particle Size for Lakes and Streams

A further evaluation was undertaken to identify cut offs in TOC and percent sand that could be applied to identify sediment samples in the baseline that can be used for comparison purposes, with the same cut off thresholds for TOC and percent sand applied to sediment samples collected for monitoring. In terms of long-term monitoring, it is recommended that sediment sampling stations in depositional environments be the focus of monitoring and the application of the assessment protocol identified in the AEMP Framework (e.g., detection of a change; establishing if the change is mine related; comparison to AEMP benchmark; undertaking a low or moderate action depending on the result compared to the AEMP benchmark). The high level of variability of metals concentrations within sediment samples characterized by high TOC (low proportion of sand) are likely to mask instead of allow for the detection of Project-related change, as the variability between samples may mask any project-related changes and collection of a sufficient number of samples to obtain statistical power is likely not possible.

D.6 STATISTICAL AND CUT POINT ANALYSIS

Percent sand and TOC are generally related to parameter concentrations. Deposition seems to be limited in sediment samples with high amounts of sand and very little TOC. For the AEMP, the focus of monitoring will be on identified mine-related changes in parameter concentrations. Variability due to TOC and particle size is a nuisance and introduces extraneous noise. In general, it is better to control confounding factors in the study design rather than adjust for them post hoc in the data analysis. Environment Canada (2012) recommends that normalized metal concentrations be used to account for the effects of particle size and organic carbon. This method was considered, but it was found that the best way to minimize the relationship to organic carbon and fines involved creating data cut-offs. Additionally, normalized metals concentrations do not reflect the actual toxicity exposure in the environment.

To identify sensitive depositional environments and minimize variability related to TOC and particle size the data were explored to determine appropriate TOC and particle size cut-offs. Regression analyses were used for 4 key parameters: arsenic, cadmium, iron and nickel.

Several arsenic samples, and many cadmium samples were below MDLs. For this analysis the MDL was used as the estimated concentration for samples below MDLs. Further analysis could be refined by using Tobit regression to account for the left censoring related to MDLs. However, methods to adjust for left censoring may not be appropriate when very large portions of the data are below MDLs as is the case for cadmium.

B-splines were used to obtain flexible, non-linear fits to explore the relationships between percent sand (Figure D.14) and TOC (Figure D.15) and each parameter. The fits using percent sand and TOC are shown in Figure D.16. These plots helped identify cut points in the vicinity of inflection points on the curves. The cut points were used in subsequent linear regression analyses to assess the linear relationship above and below the cut off points (black, green and red lines represent fits using 80%, 85% and 90% cut offs for sand or 0.2%, 0.6% and 1% TOC respectively).

The regression analyses were set up to accommodate separate, but connected, slopes on either side of the cut points. For sand, a cut point of 80% led to relatively gentle regression slopes below 80% and steep negative slopes above 80%. The cut points for TOC were not as clear. However, considering the size of the plotting symbols and the results of bivariate regressions, which include both TOC and percent sand (Figure D.16), defining cut points based on both percent sand and TOC was found to be useful.

A subset of the data was defined which excluded all samples with greater than 90% sand as well as samples with less than 0.6% TOC and greater than 80% sand (indicated in orange in Figure D.17). Alternatively, a cut off could be established such as the sloped black line in Figure D.17. It may be useful to carry out future research with additional data to develop such a rule. Figure D.18 shows the relationships between parameter concentrations and TOC and percent sand were generally negligible for the quantitatively defined subsets. The only exception is cadmium which has a large proportion of data below MDLs.

The selection criterion reduces variability associated with TOC and particle size. For post-mining data, using only samples which meet the criterion is expected to be a conservative approach since samples with more than 80% sand and low TOC tend to have the smallest parameter concentration.

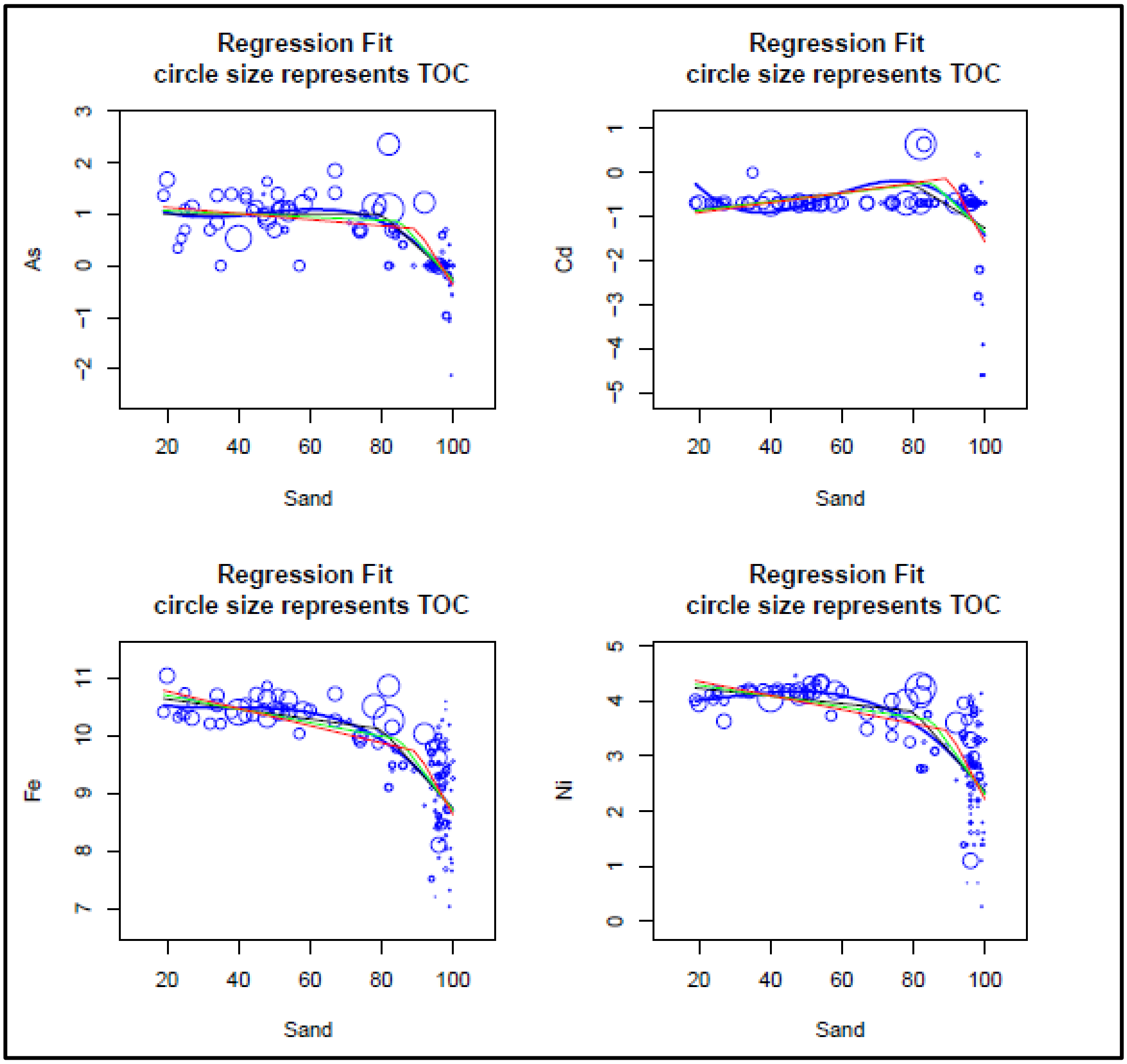

Figure D.14 Concentrations of As, Cd, Fe and Ni in Sediment Based on Percent Sand

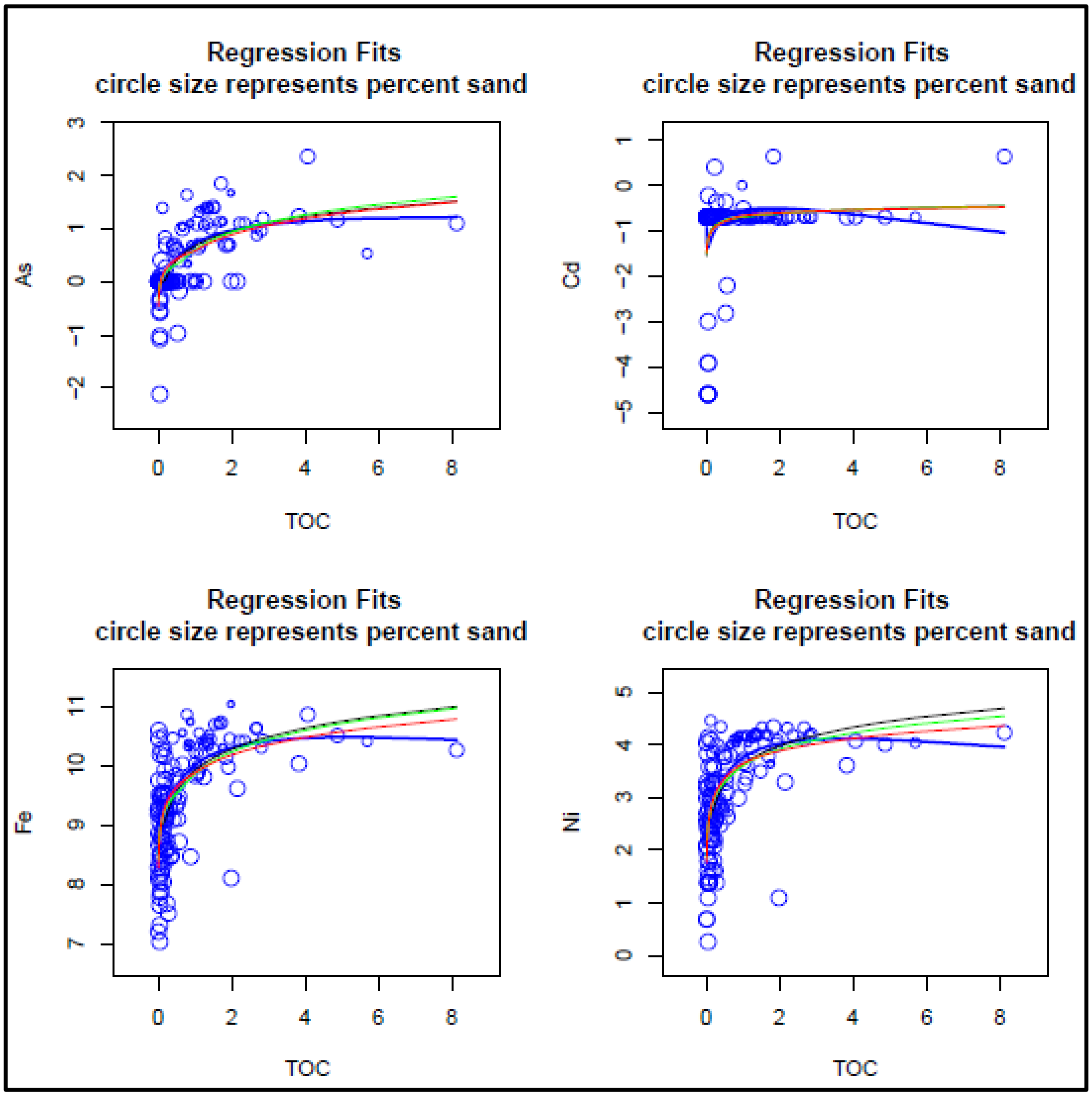

Figure D.15 Concentrations of As, Cd, Fe and Ni in Sediment Based on Percent TOC

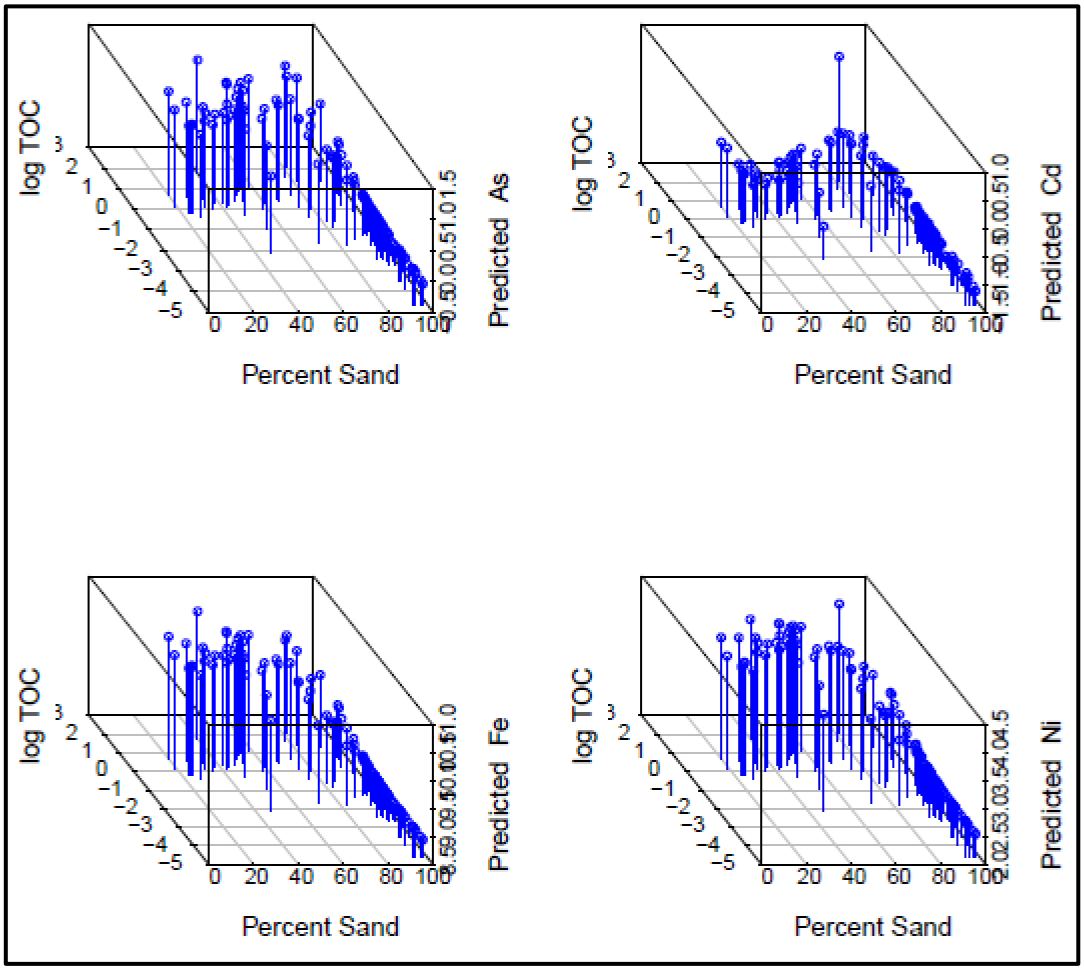

Figure D.16 Concentrations of As, Cd, Fe and Ni in Sediment Based on Log TOC and Percent Sand

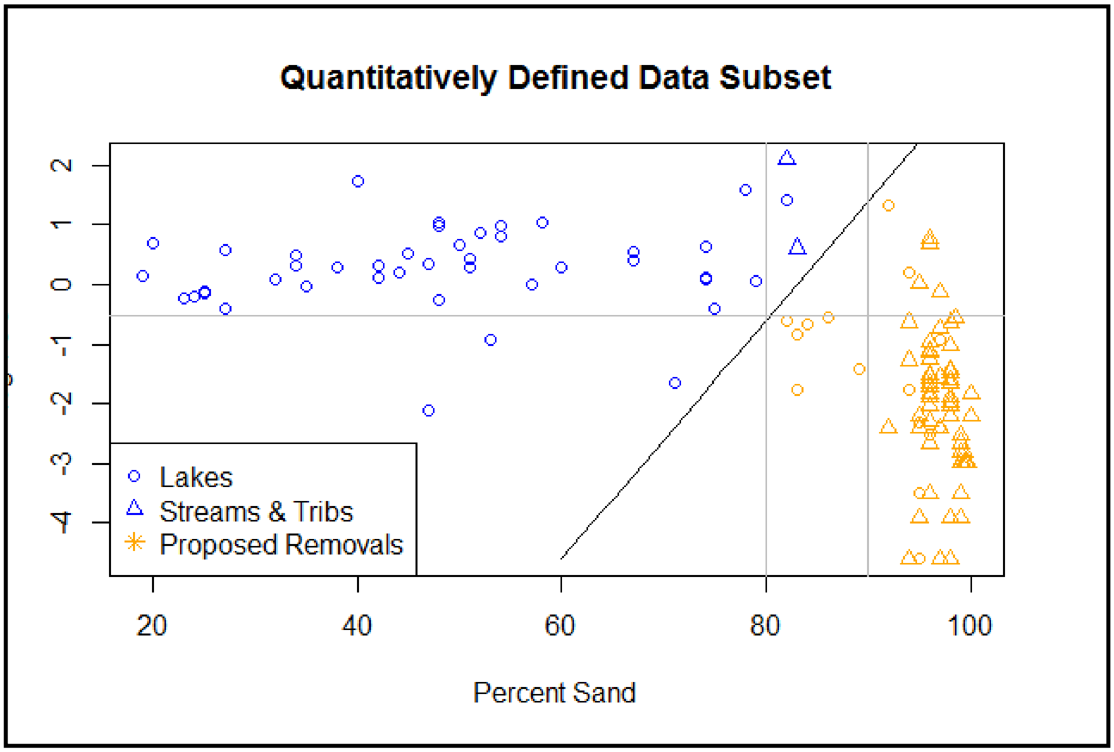

Figure D.17 Results of Cut Point Analysis for Sediment

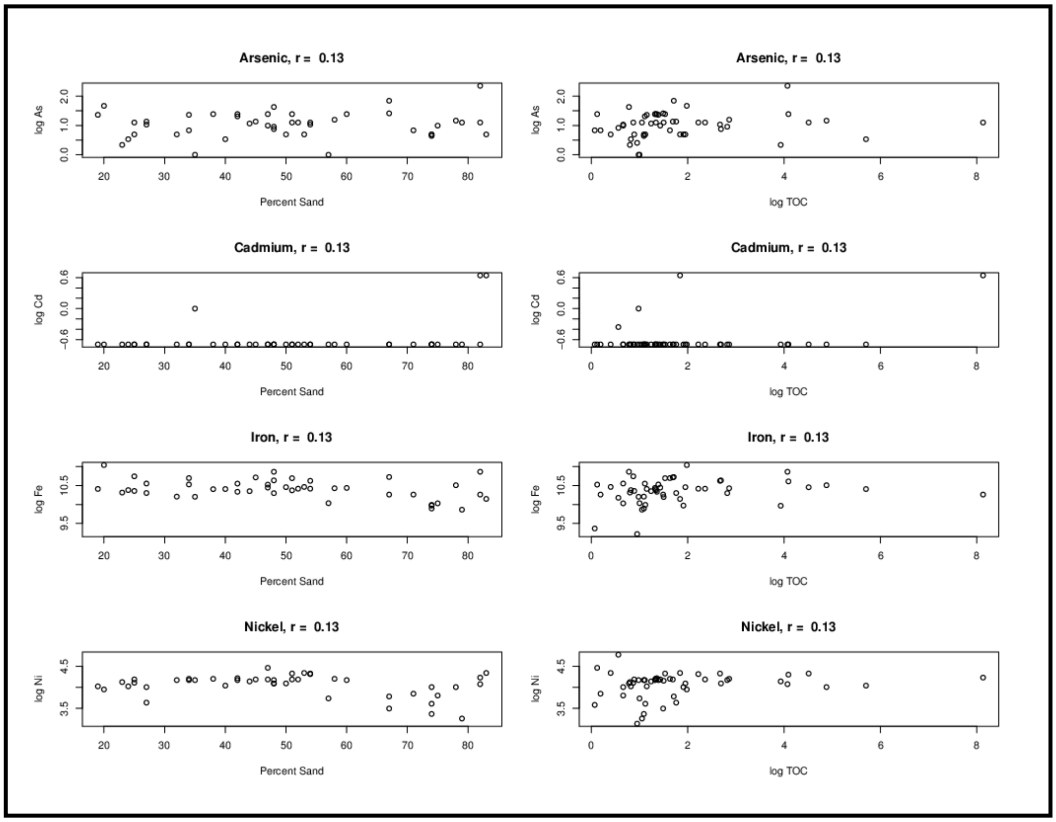

Figure D.18 Correlations between TOC and Percent Sand, and the 4 Key Parameters for the Subset Data, Second Stage Cuts in Blue

D.7 TEMPORAL AND SAMPLING EFFECTS

Sediment sampling from 2005 to 2008 was carried out using of a Petite Ponar dredge sampler to collect a maximum sample collection thickness of 5 cm. This depth is appropriate for monitoring studies where historical contamination is not a priority (Environment Canada, 2012). As a result of a recommendation from Environment Canada that the upper 1 to 2 cm of sediment be collected as part of Project monitoring, collection of a thinner (2 cm) core sediment sample was implemented by Baffinland starting in 2012. A comparison of the lake data from 2006 to 2013 was completed to determine if appreciable differences in sediment concentrations occurred as a result in the change of sampling techniques. Note that 2005 data was not included in the temporal sampling, since lake sampling did not occur in 2005. Review of Figures D.19 and D.20 indicate that significant inter-annual effects do not occur for any of the parameters of interest; however, certain parameters show slightly depressed concentrations in 2006 (chromium, lead, zinc and nickel). Due to the low sample size in 2006, the slightly depressed 2006 concentrations are considered to be influenced by sample size.

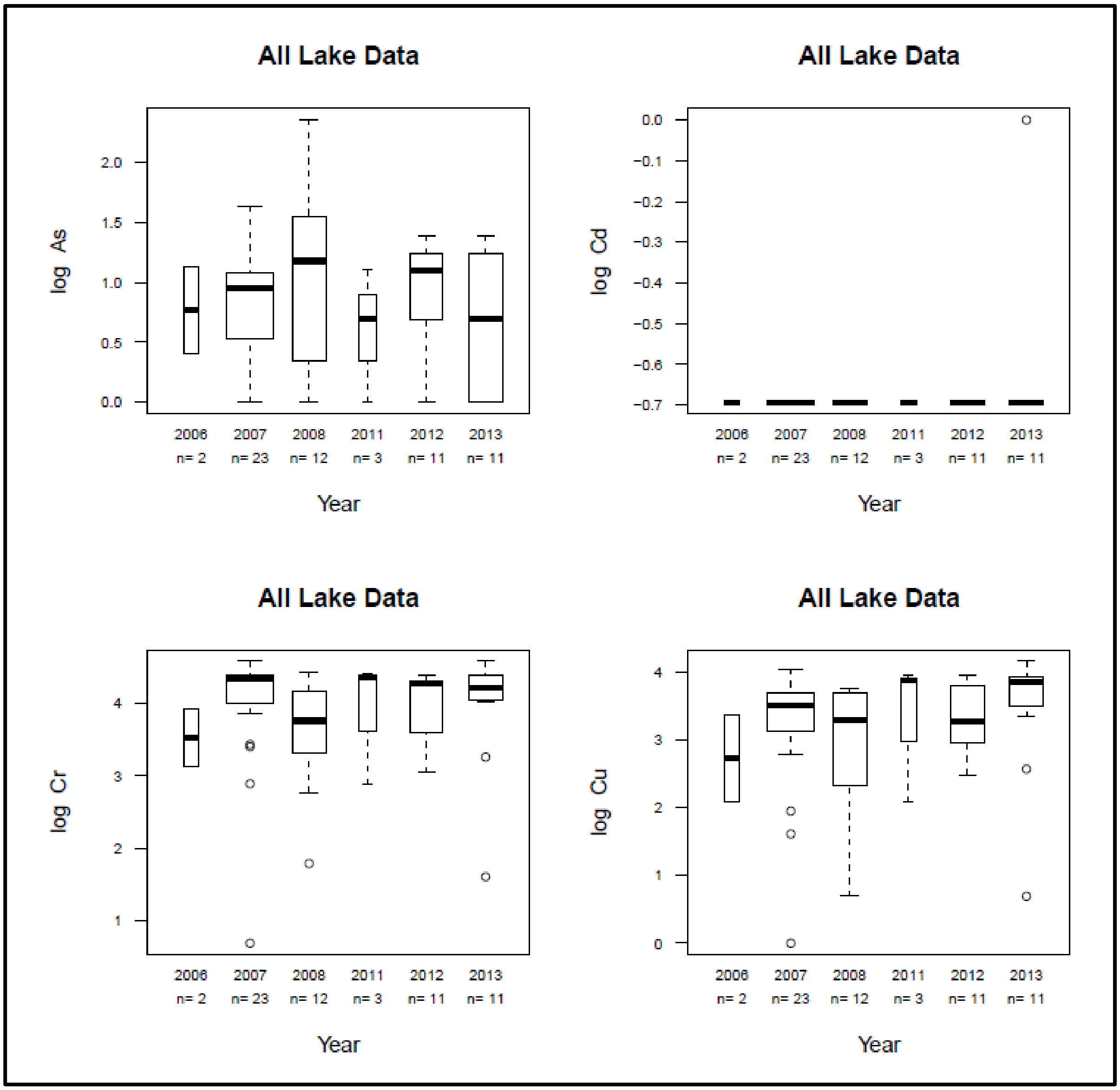

Figure D.19 Inter-Annual Variability for As, Cd, Cr and Cu in Sediment

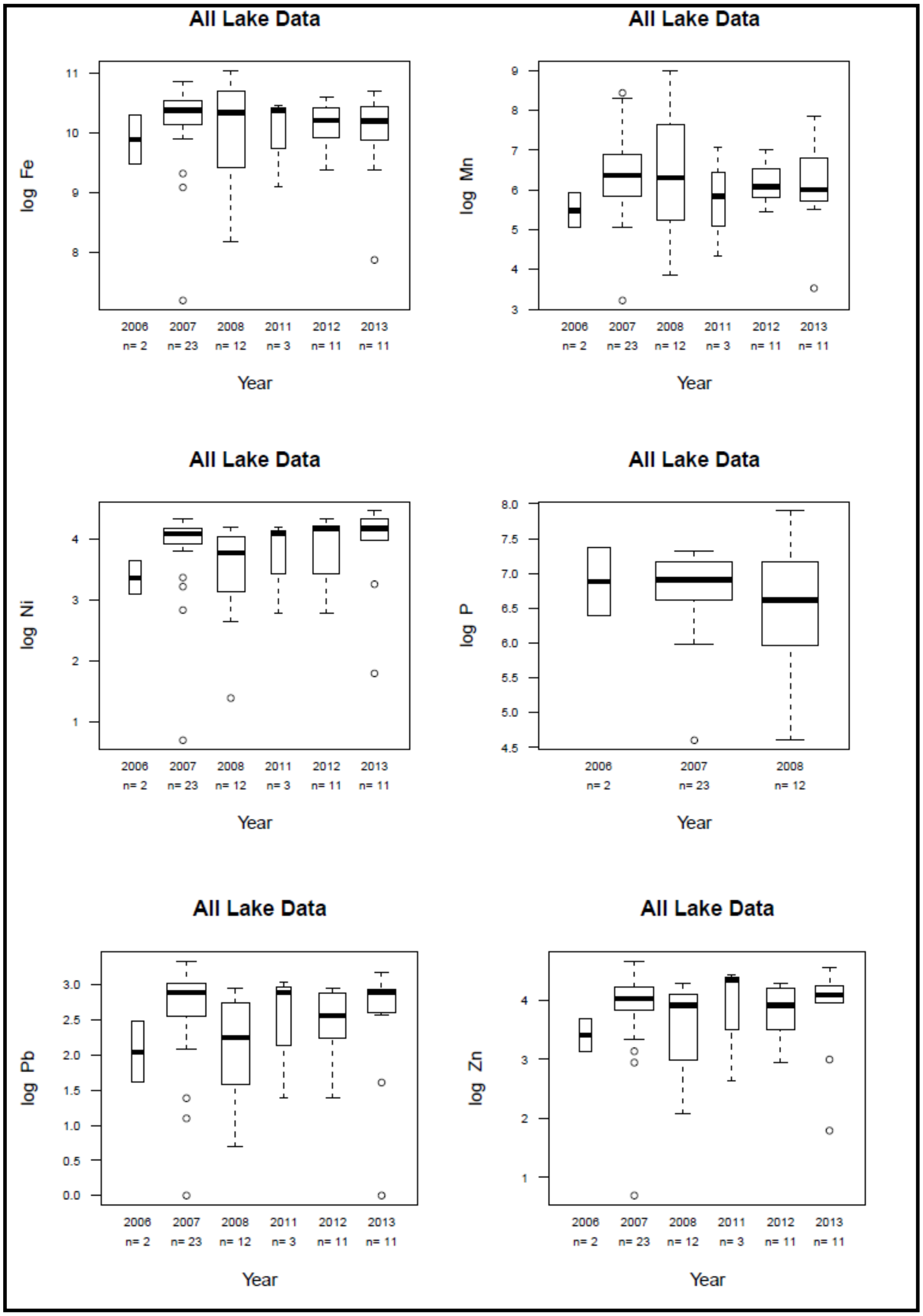

Figure D.20 Inter-Annual Variability for Fe, Mn, Ni, P, Pb and Zn in Sediment

D.8 POWER ANALYSIS

The baseline sediment quality monitoring program results from the stream and lake environments surrounding the Project site show naturally elevated concentrations above the lower sediment quality criteria concentrations for parameters of concern such as chromium, copper, iron, manganese and nickel. The iron and manganese concentrations were also typically above the severe effect levels in the lake environments.

After an initial exploratory analysis of the sediment baseline data, it was decided to retain fifty-two (52) samples that fit the criteria for TOC and percent sand. Sufficient power to detect a change from baseline values was desired for each station. Baseline data was not collected at reference stations and therefore, since baseline reference (control) data was not available, a full BACI design was not used for the power analysis. Instead, a before-after (BA) design was used. The power analysis was carried out using a two sample t-test which assumes independence between the before and after samples.

The sample sizes for each year, at each lake are presented in Table D.2. Further sampling carried out in 2014 will supplement this dataset and provide a better basis for refined power analysis. Here, instead of using highly variable estimates of station means from the limited baseline data, a generic analysis was used. Power to detect a change from a baseline mean to 97.5th percentiles for a normally distributed variable was used to get sample size estimates which apply to all sites and metals. This analysis will be refined for specific stations and metals after 2014 samples are collected and benchmarks have been finalized.

Table D.2 Sediment Sample Sizes for the Mary River Project

Area	**2006**	**2007**	**2008**	**2011**	**2012**	**2013**
Camp Lake	0	5	0	0	2	2
Mary Lake	1	4	0	0	1	0
Sheardown Lake NW	0	7	7	2	4	5
Sheardown Lake SE	0	4	0	0	1	1
David Lake	0	0	0	0	1	0

Site-wide preliminary benchmarks were developed by Intrinsik such that the benchmark was set to either the guideline value or the empirical estimate of the 97.5th percentile of the data, whichever was larger. In all cases, the 97.5th percentile was the lowest value. Therefore, the minimum power to detect a change from baseline mean to the benchmark can be obtained by considering this lower bound of the benchmark (97.5th percentile). For parameters where the benchmark is based on the guideline, the effect size is actually larger than considered here and thus the power will also be larger.

Further analysis was carried out to assess the sample size required to have sufficient power to detect smaller changes which act as early warning flags. The early warning value was set as half way between the baseline mean (or median) and the 97.5th percentile ($z = 1.96/2$; approximately the 84th percentile).

Using this approach, power can be calculated simultaneously for all variables and all sites as follows:

- Assume the data (log transformed) is normally distributed based on other analysis of other larger data sets

- Consider the standardized data; a z-score is obtained by subtracting the mean and dividing by the standard deviation
- For standardized normal data, the mean and median are equal with a z-score of 0; the 97.5th percentile has a z-score of 1.96
- The power to detect a before-after change from the baseline mean 0 (= median) to 1.96 (97.5th percentile) can be calculated using a 2 sample t-test
- Choose a one-tailed type I error of 0.05 or 0.01 since only increases in concentration are of interest

This approach allows a generic assessment of power for all parameters. The power for sample sizes of 5, 10, 15, 20 and 25 are shown for the 97.5th percentile and the mid-point value (z = $z_{97:5}$=2) half way between the median (z_{50} = 0) and 97.5th percentile ($z_{97:5}$ = 1:96). The following tables can be used to assess the sample size requirements for each station provided the 97.5th percentile estimates used for benchmark development is a reasonable estimate for each station. That is, provided the 97.5th percentile of the pooled data (from all stations) is representative of each individual station.

An alpha value of 0.05 was selected to examine the effects of varying the pre-mining and post mining sample size. In order to gain sufficient power, ideally either 15 pre-mining samples are taken and 25 post-mining are taken or 25 pre-mining samples are taken and 15 post-mining samples are taken to have sufficient power to detect early warning flags.

Table D.3 Power Predicted for Various Sample Sizes – Median to 95th Percentile

	N before = 5	N before = 10	N before = 15	N before = 25
N after = 5	0.77	0.89	0.92	0.95
N after = 10	0.97	0.97	0.99	1.00
N after = 15	0.99	0.99	1.00	1.00
N after = 25	1.00	1.00	1.00	1.00

NOTES:
1. ALPHA EQUALS 0.05.
2. THE EFFECT SIZE IS FROM MEDIAN TO THE 95TH PERCENTILE (1.65).

Table D.4 Power Predicted for Various Sample Sizes - Halfway from Median to 95th Percentile

	N before = 5	N before = 10	N before = 15	N before = 25
N after = 5	0.33	0.41	0.46	0.50
N after = 10	0.41	0.55	0.62	0.42
N after = 15	0.46	0.62	0.71	0.80
N after = 25	0.50	0.70	0.80	0.89

NOTES:
1. ALPHA EQUALS 0.05.
2. THE EFFECT SIZE IS HALFWAY FROM MEDIAN TO THE 95TH PERCENTILE (1.65/2).

D.9 RECOMMENDATIONS

The relationship between fine grained sediments and the accumulation of the parameters of concern suggests the sediment monitoring program should focus on the depositional lake environments, since they are the end receiver of stream sediments. Focusing the CREMP to include additional lake sediment monitoring stations and reducing the amount of stream sediment quality monitoring stations would increase the data coverage within the lake basins and strengthen the baseline data set. Stream sediment sampling will be conducted as part of the Environmental Effects Monitoring program required under the MMER in the Mary River and Camp Lake Tributary 1.

In order to achieve the sample sizes required, the following are recommended:

1. An additional year of baseline data collection.
2. Utilization of samples within one lake basin to achieve sufficient pre-mining sample size.
3. Recognition that there will not be sufficient power to complete site-based statistical testing.

D.10 REFERENCES

Environment Canada, 2012. *Metal Mining Technical Guidance for Environmental Effects Monitoring* .National Environmental Effects Monitoring Office.

Horowitz, Arthur J., 1991. *A Primer on Sediment-Trace Element Chemistry, 2nd Edition*. United States Geological Survey, Open File Report 91-76.

Intrinsik Environmental Sciences Inc., 2014. *Development of Water and Sediment Quality Benchmarks for Application in Aquatic Effects Monitoring at the Mary River Project.* Intrinsik Project No. 30-30300.

APPENDIX C

WATER QUALITY DATA

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TABLE C.1

BAFFINLAND IRON MINES CORPORATION
MARY RIVER PROJECT

DRAFT EEM CYCLE ONE STUDY DESIGN
CAMP LAKE TRIBUTARY AREAS: SURFACE WATER QUALITY SUMMARY

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			EEM STATION ID	CLT-NF	CLT-NF	CLT-FF	CLT-FF	CLT-REF2	CLT-REF2	CLT-REF3	CLT-REF3	CLT-REF4	CLT-REF4
			CREMP STATION ID	L1-09	L1-09	L0-01	L0-01						
			SAMPLE DATE	23/07/2013	20/08/2013	23/07/2013	20/08/2013	24/07/2013	24/08/2013	23/07/2013	20/08/2013	23/07/2013	22/08/2013
PARAMETER	**UNIT**	**MRL**	**CWQG**										
In-situ Measurements													
Water Temperature	°C	-	-	13.51	5.88	13.52	6.05	12.50	2.0	12.39	4.70	10.70	1.75
Dissolved Oxygen	mg/L	-	6.5-9.5	10.39	14.3	10.37	13.16	10.45	13.74	10.61	12.52	10.88	13.77
pH	pH units	-	6.5-9.0	7.71	7.40	7.94	7.88	8.12	8.48	7.56	6.63	7.37	8.22
Conductivity	µS/cm	-	-	120	208	130	240	211	286	70	116	54	99
General Parameters													
pH			6.5-9.0	7.59	7.99	7.36	8.08	8.23	8.31	6.88	7.47	7.09	7.16
Alkalinity as CaCO3	mg/L	5	-	58	99	59	103	116	150	18	60	29	52
Conductivity	µS/cm	5	-	119	218	131	227	221	288	54	122	55	105
Dissolved Organic Carbon (DOC)	mg/L	0.5	-	2.6	2.5	2.4	2.4	1.5	1.9	0.9	0.8	1.4	1.3
Total Suspended Solids (TSS)	mg/L	2	-	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Turbidity	NTU	0.1	-	0.4	0.7	0.4	0.4	0.2	0.1	5.2	>100	2.3	1.7
Hardness as CaCO3 (Dissolved)	mg/L	0.5	-	57.6	104	62.3	111	117	158	20.2	55.7	24.4	46.4
Total Dissolved Solids (TDS)	mg/L	1	-	77	142	85	148	144	187	35	79	36	68
Total Organic Carbon (TOC)	mg/L	0.5	-	2.5	2.6	2.5	2.6	1.5	2.2	0.8	1.2	1.4	1.4
Biomass													
Chlorophyll-a	mg/m^3	0.2	-	<0.2	<0.2	<0.2	3.6	1.7	<0.2	<0.2	2.1	<0.2	0.8
Pheophytin-a	mg/m^3	0.2	-	3.4	3.7	1.5	<0.2	<0.2	0.4	8.2	<0.2	11.4	<0.2
Nutrients and Anions													
Bromide	mg/L	0.25	-	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25
Chloride	mg/L	1	120	3	9	3	9	1	2	3	<1	<1	<1
N-NH3 (Ammonia)	mg/L	0.02	Table [7]	<0.02	0.06	<0.02	<0.02	**0.83**	0.04	<0.02	<0.02	<0.02	<0.02
N-NO2 (Nitrite)	mg/L	0.005	0.06	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
N-NO3 (Nitrate)	mg/L	0.1	13	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
NO2 + NO3 as N	mg/L	0.1	-	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Phenols	mg/L	0.001	0.004	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Sulphate	mg/L	3	-	<3	4	6	4	3	5	6	4	<3	4
Total Kjeldahl Nitrogen (TKN)	mg/L	0.1	-	0.1	0.2	0.54	0.14	1.43	0.14	<0.10	0.1	<0.10	<0.10
Total Phosphorus	mg/L	0.003	-	0.005	0.003	0.004	0.013	<0.003	0.003	0.005	0.007	0.004	0.005

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TABLE C.1

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DRAFT EEM CYCLE ONE STUDY DESIGN
CAMP LAKE TRIBUTARY AREAS: SURFACE WATER QUALITY SUMMARY

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			EEM STATION ID	CLT-NF	CLT-NF	CLT-FF	CLT-FF	CLT-REF2	CLT-REF2	CLT-REF3	CLT-REF3	CLT-REF4	CLT-REF4
			CREMP STATION ID	L1-09	L1-09	L0-01	L0-01						
			SAMPLE DATE	23/07/2013	20/08/2013	23/07/2013	20/08/2013	24/07/2013	24/08/2013	23/07/2013	20/08/2013	23/07/2013	22/08/2013
PARAMETER	**UNIT**	**MRL**	**CWQG**										
Total Metals													
Aluminum	ug/L	1	Variable [3]	13.1	9.4	10.7	7.8	<1.0	4.1	**172**	93.4	**105**	77.1
Antimony	ug/L	0.1	-	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Arsenic	ug/L	0.1	5	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Barium	ug/L	0.05	-	6.89	11	7.32	11.3	2.84	3.31	6.08	5.77	3.74	5.7
Beryllium	ug/L	0.02	-	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.10
Bismuth	ug/L	0.5	-	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
Boron	ug/L	10	1,500	<10.0	<10.0	<10.0	<10.0	10	11	<10.0	<10.0	<10.0	<10.0
Cadmium	ug/L	0.01	0.09	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Calcium	mg/L	0.05	-	11.6	22.1	12.6	22.8	32.9	42.6	4.47	12.4	4.92	9.55
Chromium	ug/L	0.02	-	0.12	0.15	0.13	0.15	<0.02	0.12	0.34	0.21	0.2	0.14
Chromium, Trivalent (III)	ug/L	5	8.9	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Chromium Hexavalent (Cr(VI))	ug/L	1	1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Cobalt	ug/L	0.1	-	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Copper	ug/L	0.2	Equation [4]	1.88	1.53	1.47	1.47	<0.20	<0.20	1.07	0.63	0.71	0.66
Iron	ug/L	3	300	43	93	33	66	<3	<3	148	101	47	50
Lead	ug/L	0.05	Equation [6]	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.15	0.07	0.06	0.08
Lithium	ug/L	0.05	-	1.16	2.12	1.32	2.22	1.14	1.47	0.51	<0.05	<0.05	0.9
Magnesium	mg/L	0.1	-	6.84	12.4	7.47	13.1	8.13	11.2	2.26	6.79	2.79	5.42
Manganese	ug/L	0.05	-	2.04	5.44	1.57	2.65	0.056	0.165	1.89	2.55	0.531	0.677
Mercury	ug/L	0.01	0.026	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Molybdenum	ug/L	0.05	73	0.327	0.523	0.319	0.5	<0.050	<0.050	0.256	0.27	0.107	0.221
Nickel	ug/L	0.5	Equation [5]	0.66	0.94	0.73	1.02	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
Potassium	mg/L	0.05	-	1.1	1.45	1.16	1.49	0.306	0.28	0.69	0.614	0.505	0.611
Selenium	ug/L	0.01	1	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.10
Silicon	ug/L	50	-	570	1050	640	1030	580	790	890	860	700	840
Silver	ug/L	0.001	0.1	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.0010
Sodium	mg/L	0.0012	-	0.985	1.89	1.06	2.04	0.539	0.802	1.75	1.54	1.69	3.08
Strontium	ug/L	0.4	-	9.81	32.4	10.9	29.5	23.2	30.1	9.1	9.07	3.83	7.66
Thallium	ug/L	0.001	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.010
Tin	ug/L	0.1	-	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Titanium	ug/L	10	-	<10	<10	<10	<10	<10	<10	10	<10	<10	<10
Uranium	ug/L	0.01	15	0.47	1.67	0.513	1.75	0.231	0.404	0.342	4.43	0.262	1.38
Vanadium	ug/L	1	-	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Zinc	ug/L	3	30	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<0.33

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TABLE C.1

BAFFINLAND IRON MINES CORPORATION
MARY RIVER PROJECT

DRAFT EEM CYCLE ONE STUDY DESIGN
CAMP LAKE TRIBUTARY AREAS: SURFACE WATER QUALITY SUMMARY

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EEM STATION ID				CLT-NF	CLT-NF	CLT-FF	CLT-FF	CLT-REF2	CLT-REF2	CLT-REF3	CLT-REF3	CLT-REF4	CLT-REF4
CREMP STATION ID				L1-09	L1-09	L0-01	L0-01						
SAMPLE DATE				23/07/2013	20/08/2013	23/07/2013	20/08/2013	24/07/2013	24/08/2013	23/07/2013	20/08/2013	23/07/2013	22/08/2013
PARAMETER	**UNIT**	**MRL**	**CWQG**										
Dissovled Metals													
Aluminum	ug/L	1	-	4.7	2.7	3	6	1.2	<1.00	19.8	4.2	17.5	6
Antimony	ug/L	0.1	-	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Arsenic	ug/L	0.1	-	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Barium	ug/L	0.05	-	8.56	11.2	7.19	11.3	2.9	3.35	4.71	5.28	3.31	5.21
Beryllium	ug/L	0.1	-	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Bismuth	ug/L	0.5	-	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
Boron	ug/L	10	-	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0
Cadmium	ug/L	0.01	-	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Calcium	mg/L	0.05	-	11.9	21.6	12.8	23.7	33.5	44.5	4.49	11.6	5.08	9.54
Chromium	ug/L	0.1	-	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Cobalt	ug/L	0.1	-	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Copper	ug/L	0.2	-	1.49	1.23	1.39	1.42	<0.20	0.26	0.65	0.36	0.54	0.56
Iron	ug/L	10	-	20	50	20	40	<10	<10	<10	10	<10	<10
Lead	ug/L	0.05	-	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Lithium	ug/L	0.5	-	0.93	2.19	0.93	2.17	1.19	0.99	<0.50	0.64	<0.50	0.56
Magnesium	mg/L	0.1	-	6.75	12.3	7.36	12.7	8.11	11.5	2.17	6.45	2.84	5.49
Manganese	ug/L	0.05	-	2.74	4.45	0.86	2.2	<0.050	0.051	0.153	1.48	0.086	0.1
Mercury	ug/L	0.01	-	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Molybdenum	ug/L	0.05	-	0.324	0.487	0.299	0.494	<0.050	0.051	0.288	0.267	0.109	0.228
Nickel	ug/L	0.5	-	0.63	0.84	0.72	0.97	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
Potassium	mg/L	0.05	-	1.2	1.5	1.14	1.6	0.315	0.296	0.611	0.569	0.431	0.546
Selenium	ug/L	0.1	-	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Silicon	ug/L	50	-	570	990	630	1030	580	850	610	660	570	680
Silver	ug/L	0.001	-	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Sodium	mg/L	0.0012	-	0.992	1.91	1.01	2.05	0.544	0.822	1.6	1.44	1.45	3.02
Strontium	ug/L	0.4	-	10.4	29.9	10.1	29.8	22.6	29.4	9.34	8.67	3.38	7.78
Thallium	ug/L	0.01	-	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Tin	ug/L	0.1	-	<0.10	<0.10	<0.10	0.29	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Titanium	ug/L	10	-	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Uranium	ug/L	0.01	-	0.469	1.61	0.474	1.57	0.24	0.411	0.263	4.24	0.196	1.33
Vanadium	ug/L	1	-	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Zinc	ug/L	0.33	-	3.5	<0.33	2.2	5.8	1.3	<0.33	1.3	<0.33	<0.33	<0.33

\\NB4\Project$\1\02\00181\34\A\Report\Report 5 Rev B - EEM Study Design\Appendix C - WQ\Individual files\[EEM_Appendix C_WQ_20140313.xlsx]Table C.1

NOTES:
1. SAMPLES ANALYZED BY EXOVA ACCUTEST IN OTTAWA, ON AND ALS LABORATORIES IN VANCOUVER, BC.
2. CANADIAN WATER QUALITY GUIDELINES (CWQG): CANADIAN COUNCIL OF MINISTERS OF THE ENVIRONMENT, CCME.CA; WATER QUALITY GUIDELINES FOR THE PROTECTION OF AQUATIC LIFE, LONG TERM EFFECTS.
3. ALUMINUM CEQG VALUES BASED ON pH: 5µg/L IF pH <6.5, 100 µg/L IF pH ≥6.5.
4. COPPER CEQG VALUES ARE CALCULATED BY SAMPLE USING THE CCME.CA WEBSITE.
5. NICKEL CEQG VALUES ARE CALCULATED BY SAMPLE USING THE CCME.CA WEBSITE.
6. LEAD CEQG VALUES ARE CALCULATED BY SAMPLE USING THE CCME.CA WEBSITE.
7. TOTAL AMMONIA CEQG VALUES ARE BASED ON A TABLE AVAILABLE AT CCME.CA.
8. LABORATORY RESULTS THAT ARE BOLDED AND SHADED ARE EQUAL TO OR ABOVE THE RESPECTIVE CWQG GUIDELINES.

Knight Piésold
CONSULTING

TABLE C.2

BAFFINLAND IRON MINES CORPORATION
MARY RIVER PROJECT

DRAFT EEM CYCLE ONE STUDY DESIGN
MARY RIVER AREAS: SURFACE WATER QUALITY SUMMARY

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			EEM STATION ID	MRY-NF	MRY-NF	MRY-NF	MRY-NF	MRY-FF	MRY-REF1	MRY-REF1	MRY-REF2	MRY-REF2	MRY-REF3	MRY-REF3	MRY-REF4	MRY-REF4
			CREMP STATION ID	E0-20	E0-20	E0-21	E0-21	C0-05							G0-09	G0-09
			SAMPLE DATE	24/07/2013	20/08/2013	24/07/2013	20/08/2013	28/08/2013	24/07/2013	27/08/2013	23/07/2013	25/08/2013	23/07/2013	26/08/2013	25/07/2013	22/08/2013
PARAMETER	**UNIT**	**MRL**	**CWQG**													
In-situ Measurements																
Water Temperature	°C	-	-	13.54	5.54	13.54	5.28	2.18	14.62	2.50	11.69	2.08	9.44	3.16	7.68	6.71
Dissolved Oxygen	mg/L	-	6.5-9.5	9.73	13.40	9.69	13.39	13.73	10.10	13.48	10.97	15.74	11.28	13.37	10.86	13.67
pH	pH units	-	6.5-9.0	7.81	7.67	7.79	7.71	8.25	8.00	8.12	7.45	7.80	7.68	7.72	7.37	8.09
Conductivity	μS/cm	-	-	59	177	57	153	164	122	219	57	92	53	80	60	143
General Parameters																
pH			6.5-9.0	6.95	7.68	7.04	7.65	7.53	7.61	7.83	7.03	7.14	7.22	6.8	6.97	7.39
Alkalinity as CaCO3	mg/L	5	-	34	70	33	67	70	62	89	26	42	37	25	27	61
Conductivity	μS/cm	5	-	70	154	69	149	158	125	195	57	99	70	86	56	148
Dissolved Organic Carbon (DOC)	mg/L	0.5	-	1	0.8	0.9	0.8	1.6	3.4	4.5	1.2	1.9	1.2	1.1	0.6	0.9
Total Suspended Solids (TSS)	mg/L	2	-	<2	2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Turbidity	NTU	0.1	-	4.7	2	5	3.4	1.8	0.8	1.2	2.8	4.3	0.9	6.9	7.7	3.1
Hardness as CaCO3 (Dissolved)	mg/L	0.5	-	31.6	69.8	30.9	66	73.7	61.2	94.4	24.6	44.1	33.9	32.2	24.6	63.5
Total Dissolved Solids (TDS)	mg/L	1	-	46	100	45	97	103	81	127	37	64	46	56	36	96
Total Organic Carbon (TOC)	mg/L	0.5	-	1.2	0.9	0.7	0.8	1.5	3.5	4.4	1.2	1.7	1.3	1.4	0.7	1.1
Biomass																
Chlorophyll-a	mg/m^3	0.2	-	<0.2	0.4	0.3	3.3	0.4	<0.2	0.5	<0.2	<0.2	<0.2	<0.2	<0.2	0.4
Pheophytin-a	mg/m^3	0.2	-	2.8	<0.2	0.9	<0.2	<0.2	1.2	<0.2	8.2	1.2	26.6	1.2	5.1	0.3
Nutrients and Anions																
Bromide	mg/L	0.25	-	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25
Chloride	mg/L	1	120	1	4	1	4	5	2	8	2	4	<1	5	1	7
N-NH3 (Ammonia)	mg/L	0.02	Table [7]	0.14	0.03	0.04	0.04	0.03	0.75	<0.02	<0.02	0.06	<0.02	<0.02	0.06	0.02
N-NO2 (Nitrite)	mg/L	0.005	0.06	<0.005	0.007	<0.005	0.007	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.006	<0.005	0.006
N-NO3 (Nitrate)	mg/L	0.1	13	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
NO2 + NO3 as N	mg/L	0.1	-	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Phenols	mg/L	0.001	0.004	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Sulphate	mg/L	3	-	<3	5	<3	5	5	<3	3	3	5	<3	10	<3	6
Total Kjeldahl Nitrogen (TKN)	mg/L	0.1	-	0.27	0.14	0.14	0.13	0.16	0.83	0.18	0.11	0.11	0.15	<0.10	<0.10	0.1
Total Phosphorus	mg/L	0.003	-	0.006	0.005	0.007	0.011	<0.003	0.003	0.005	0.004	0.007	0.005	0.01	0.014	0.003

Knight Piésold CONSULTING

TABLE C.2

BAFFINLAND IRON MINES CORPORATION
MARY RIVER PROJECT

DRAFT EEM CYCLE ONE STUDY DESIGN
MARY RIVER AREAS: SURFACE WATER QUALITY SUMMARY

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			EEM STATION ID	MRY-NF	MRY-NF	MRY-NF	MRY-NF	MRY-FF	MRY-REF1	MRY-REF1	MRY-REF2	MRY-REF2	MRY-REF3	MRY-REF3	MRY-REF4	MRY-REF4
			CREMP STATION ID	E0-20	E0-20	E0-21	E0-21	C0-05							G0-09	G0-09
			SAMPLE DATE	24/07/2013	20/08/2013	24/07/2013	20/08/2013	28/08/2013	24/07/2013	27/08/2013	23/07/2013	25/08/2013	23/07/2013	26/08/2013	25/07/2013	22/08/2013
PARAMETER	**UNIT**	**MRL**	**CWQG**													
Total Metals																
Aluminum	ug/L	1	Variable [3]	**160**	**153**	**157**	**243**	69.3	18.3	36.7	**110**	**176**	40.3	**503**	**346**	**222**
Antimony	ug/L	0.1	-	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Arsenic	ug/L	0.1	5	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Barium	ug/L	0.05	-	5.48	9.84	5.31	9.9	9.96	3.94	5.82	4.71	7.25	3.69	10.4	6.35	9.85
Beryllium	ug/L	0.02	-	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Bismuth	ug/L	0.5	-	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
Boron	ug/L	10	1,500	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0
Cadmium	ug/L	0.01	0.09	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Calcium	mg/L	0.05	-	6.59	14.9	6.4	14	16	13.8	20	5.19	9.38	7.19	7.29	5.68	13.6
Chromium	ug/L	0.02	-	0.36	0.37	54	0.56	0.23	0.31	0.27	0.21	0.32	0.12	0.97	0.75	0.47
Chromium, Trivalent (III)	ug/L	5	8.9	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Chromium Hexavalent (Cr(VI))	ug/L	1	1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Cobalt	ug/L	0.1	-	<0.10	<0.10	0.12	0.11	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	0.18	0.15	<0.10
Copper	ug/L	0.2	Equation [4]	0.74	0.89	**3.03**	0.92	0.93	0.54	0.55	0.64	0.86	0.53	1.58	1.01	1.12
Iron	ug/L	3	300	125	136	**528**	219	61	85	80	71	132	37	**414**	**325**	176
Lead	ug/L	0.05	Equation [6]	0.12	0.11	0.12	0.18	0.06	<0.05	<0.05	0.07	0.13	<0.05	0.36	0.28	0.14
Lithium	ug/L	0.05	-	0.54	0.74	0.55	0.88	0.9	0.75	1.33	<0.05	0.6	<0.05	0.95	0.92	1.1
Magnesium	mg/L	0.1	-	3.72	8.27	3.54	7.76	9.02	6.8	10.9	2.87	5.05	3.92	3.89	3.23	7.52
Manganese	ug/L	0.05	-	1.63	2.07	6.62	3.2	1.42	1.52	2.89	1.27	1.96	1.13	5.13	3.8	2.15
Mercury	ug/L	0.01	0.026	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Molybdenum	ug/L	0.05	73	0.181	0.415	0.297	0.381	0.467	<0.050	<0.050	0.127	0.212	0.14	0.443	0.132	0.405
Nickel	ug/L	0.5	Equation [5]	<0.50	0.63	1.36	0.63	0.62	<0.50	<0.50	<0.50	<0.50	<0.50	0.61	<0.50	<0.50
Potassium	mg/L	0.05	-	0.643	1.01	0.659	1.02	1.01	0.397	0.587	0.539	0.685	0.474	0.952	0.706	1.18
Selenium	ug/L	0.01	1	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Silicon	ug/L	50	-	770	1050	740	1270	990	490	1210	660	1150	580	2180	1240	1220
Silver	ug/L	0.001	0.1	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Sodium	mg/L	0.0012	-	0.961	2.19	0.988	2.26	2.7	1.04	2.63	1.26	2.03	0.821	2.6	1.05	3.2
Strontium	ug/L	0.4	-	6.03	14	6.07	13.8	14.9	7.43	11.5	5.51	10.8	4.99	16.2	6.49	16.8
Thallium	ug/L	0.001	-	<0.001	0.012	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.011	0.011	<0.001
Tin	ug/L	0.1	-	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Titanium	ug/L	10	-	<10	<10	<10	20	<10	<10	<10	<10	<10	<10	30	20	10
Uranium	ug/L	0.01	15	0.472	2.69	0.497	2.83	2.89	0.221	0.61	0.332	1.05	0.775	0.953	0.606	4.15
Vanadium	ug/L	1	-	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Zinc	ug/L	3	30	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0

Knight Piésold CONSULTING

TABLE C.2

BAFFINLAND IRON MINES CORPORATION
MARY RIVER PROJECT

DRAFT EEM CYCLE ONE STUDY DESIGN
MARY RIVER AREAS: SURFACE WATER QUALITY SUMMARY

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			EEM STATION ID	MRY-NF	MRY-NF	MRY-NF	MRY-NF	MRY-FF	MRY-REF1	MRY-REF1	MRY-REF2	MRY-REF2	MRY-REF3	MRY-REF3	MRY-REF4	MRY-REF4
			CREMP STATION ID	E0-20	E0-20	E0-21	E0-21	C0-05							G0-09	G0-09
			SAMPLE DATE	24/07/2013	20/08/2013	24/07/2013	20/08/2013	28/08/2013	24/07/2013	27/08/2013	23/07/2013	25/08/2013	23/07/2013	26/08/2013	25/07/2013	22/08/2013
PARAMETER	**UNIT**	**MRL**	**CWQG**													
Dissolved Metals																
Aluminum	ug/L	1	-	13.7	5.3	15.8	4.8	4.8	8.9	6	16	7.5	8.6	10.6	14.7	7.8
Antimony	ug/L	0.1	-	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Arsenic	ug/L	0.1	-	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Barium	ug/L	0.05	-	4.37	8.78	4.26	8.64	9.01	3.78	5.58	4.15	6.43	3.57	7.02	3.53	8.24
Beryllium	ug/L	0.1	-	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Bismuth	ug/L	0.5	-	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
Boron	ug/L	10	-	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0
Cadmium	ug/L	0.01	-	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Calcium	mg/L	0.05	-	6.65	14.5	6.57	13.8	15.1	13.5	19.6	5.21	9.31	7.22	7.14	5.19	13.4
Chromium	ug/L	0.1	-	<0.10	<0.10	0.71	<0.10	<0.10	0.1	0.14	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Cobalt	ug/L	0.1	-	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Copper	ug/L	0.2	-	0.56	0.59	0.55	0.57	0.72	0.47	0.45	0.47	0.53	0.43	0.98	0.49	0.73
Iron	ug/L	10	-	<10	<10	20	<10	<10	60	40	10	10	20	20	<10	<10
Lead	ug/L	0.05	-	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Lithium	ug/L	0.5	-	<0.50	0.75	<0.50	0.54	<0.50	0.74	0.79	<0.50	<0.50	<0.50	0.8	0.5	0.93
Magnesium	mg/L	0.1	-	3.64	8.17	3.53	7.65	8.72	6.68	11	2.8	5.07	3.85	3.48	2.81	7.32
Manganese	ug/L	0.05	-	0.257	0.375	0.285	0.263	0.594	1.37	2.37	0.39	0.697	0.713	1.32	0.128	0.124
Mercury	ug/L	0.01	-	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Molybdenum	ug/L	0.05	-	0.192	0.355	0.228	0.344	0.455	<0.050	<0.050	0.126	0.179	0.144	0.408	0.155	0.39
Nickel	ug/L	0.5	-	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
Potassium	mg/L	0.05	-	0.613	0.917	0.604	0.905	0.939	0.388	0.559	0.486	0.616	0.44	0.78	0.549	1.04
Selenium	ug/L	0.1	-	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Silicon	ug/L	50	-	500	680	490	610	810	480	1150	510	740	530	880	440	740
Silver	ug/L	0.001	-	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Sodium	mg/L	0.0012	-	0.978	2.09	0.981	2.23	2.49	1.01	2.38	1.21	2.07	0.823	2.57	0.976	3.14
Strontium	ug/L	0.4	-	5.96	12.9	6.08	12.7	14.3	7.02	11	5.85	10.2	5.19	14.9	5.52	16.3
Thallium	ug/L	0.01	-	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Tin	ug/L	0.1	-	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Titanium	ug/L	10	-	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Uranium	ug/L	0.01	-	0.452	2.59	0.461	2.61	2.9	0.209	0.579	0.317	0.952	0.787	0.712	0.442	3.68
Vanadium	ug/L	1	-	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Zinc	ug/L	0.33	-	<0.33	<0.33	1	<0.33	<0.33	1.6	<0.33	<0.33	<0.33	2.9	1.9	<0.33	<0.33

\\NB4\Project$\1\02\00181\34\A\Report\Report 5 Rev B - EEM Study Design\Appendix C - WQ\Individual files\[EEM_Appendix C_WQ_20140313.xlsx]Table C.2

NOTES:

1. SAMPLES ANALYZED BY EXOVA ACCUTEST IN OTTAWA, ON AND ALS LABORATORIES IN VANCOUVER, BC.
2. CANADIAN WATER QUALITY GUIDELINES (CWQG): CANADIAN COUNCIL OF MINISTERS OF THE ENVIRONMENT, CCME.CA; WATER QUALITY GUIDELINES FOR THE PROTECTION OF AQUATIC LIFE, LONG TERM EFFECTS.
3. ALUMINUM CEQG VALUES BASED ON pH: 5µg/L IF pH <6.5, 100 µg/L IF pH ≥6.5.
4. COPPER CEQG VALUES ARE CALCULATED BY SAMPLE USING THE CCME.CA WEBSITE.
5. NICKEL CEQG VALUES ARE CALCULATED BY SAMPLE USING THE CCME.CA WEBSITE.
6. LEAD CEQG VALUES ARE CALCULATED BY SAMPLE USING THE CCME.CA WEBSITE.
7. TOTAL AMMONIA CEQG VALUES ARE BASED ON A TABLE AVAILABLE AT CCME.CA.
8. LABORATORY RESULTS THAT ARE BOLDED AND SHADED ARE EQUAL TO OR ABOVE THE RESPECTIVE CWQG GUIDELINES.

APPENDIX D

BENTHIC INVERTEBRATE DATA

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1 SAMPLE PROCESSING METHODS AND ENDPOINT SUMMARIES

1.1 SAMPLE PROCESSING

Benthic macroinvertebrate samples for the 2013 characterization program were processed by ZEAS Inc., Nobleton, Ontario. Upon arrival, samples were immediately logged and inspected to ensure adequate preservation to a minimum level of 10% buffered formalin and checked for correct labeling.

Benthic macroinvertebrate samples were sorted at a magnification of between 7 and 10 times with the use of a stereomicroscope. To expedite sorting, prior to processing, all samples were stained with a protein dye that is absorbed by aquatic organisms but not by organic material, such as detritus and algae. The stain has proven to be effective in increasing sorting recovery.

Prior to sorting, samples were washed free of formalin in a 500 µm sieve. In samples containing sand, gravel, or rocks, elutriation techniques were used to separate the lighter benthic macroinvertebrates and associated debris from the heavier sand, gravel and rocks. Elutriation techniques effectively remove almost all organisms except some heavy-bodied organisms such as molluscs and caddisflies with rock cases. As such, the remaining sand and gravel fraction is closely inspected. After elutriation, the remaining debris and benthic macroinvertebrates were washed through a series of two sieves, (i.e., 3.36 mm and 500 µm respectively). The screening of material through a series of sieves is used to facilitate sorting. This procedure separates macroinvertebrates and detritus into a set of size-based fractions that can be sorted under a more constant magnification.

Benthic macroinvertebrates were enumerated and sorted into major taxonomic groups, (i.e., order and family), placed in glass bottles and represerved in 80% ethanol for more detailed taxonomic analysis by senior staff. Each bottle was labeled internally (on 100% cotton paper) with the survey name, date, station and replicate number.

1.1.1 Subsampling

For each sample, material retained on the 3.36 mm sieve, was sorted entirely. Some sample material retained on the 500 µm sieve may have require subsampling due to the large amounts of organic matter or high densities of particular groups.

Subsampling was carried out using the “pie method”. The pie method entails dividing the bottom surface area of the sieve into a desired number of subsamples and then removing one or more of the sub-sample “pie” sections for sorting and detailed identification. Samples are split down to fractions requiring a minimum sorting time of approximately 4 hours.

1.2 DETAILED IDENTIFICATION

All macroinvertebrates were identified to the lowest practical level. Taxonomy was based on the most recent publications. Taxonomic resolution was dependent on available keys, ease of identification, the condition, (i.e., damage), and maturity of the organism, (i.e., only mature larvae can be identified to species). A list of all taxonomic keys is presented below.

1.2.1 Quality Assurance and Quality Control Measures

ZEAS incorporated the following set of QA/QC procedures in all benthic projects undertaken by the company to ensure the generation of high quality and reliable data:

- Samples are logged upon arrival, inspected, and enumerated.
- Samples are checked for proper preservation.
- Samples are stained to facilitate sorting.
- Taxonomic identifications are based on the most updated and widely used keys.
- 10 % of the samples are re-sorted, documenting 90 % recovery.
- Precision and accuracy estimates are calculated (where possible).
- A voucher will be compiled.
- Sorted sediments and debris are represerved in 10 % formalin and are retained for up to three months. For samples subject to subsampling, sorted and unsorted fractions are represerved separately.
- Sorted organisms from each sample are archived at the ZEAS laboratory indefinitely.
- To ensure against data entry errors or incorrect spelling of macroinvertebrate names, the data spreadsheets are inspected by a second person and data are cross-checked with bench sheets.

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1.4 DATA EVALUATION

All data were entered into an electronic database with controlled access. Screening studies were employed to check for transcription errors or suspicious data points. An individual not responsible for entering the data confirmed that the data entered represents the original. Missing data was distinguished from absence of particular taxa by using non-zero value codes, with definitions built into each file.

The benthic communities surveyed in this assessment were characterized using the indices specified in the *Metal Mining Technical Guidance Document For Environmental Effects Monitoring* (EC, 2012) discussed below.

1.4.1 Total Invertebrate Density (TID)

TID was reported as the total number of all individuals of all taxonomic categories expressed per unit area (individuals per m^2). TID were calculated for each station.

1.4.2 Taxonomic Richness

Taxonomic Richness was reported as the total number of families at each station. Taxonomic richness is directly related to diversity and health of the invertebrate community.

1.4.3 Simpson's Diversity Index

Simpson's diversity index (D) takes into account both the abundance patterns and taxonomic richness of the community (EC, 2011). Simpson's Index is heavily weighted towards the most abundant species in the sample, while being less sensitive to species richness. This measure is calculated by determining the proportion of individuals that each taxonomic group at a station contributes to the total number of individuals in the station. Simpson's index (D) represents the probability that two individuals randomly selected from a sample will belong to different families. Simpson's diversity ranges from 0 to 1, with higher values representing greater diversity. Simpson's diversity index was calculated according to Krebs (1985):

$$D = 1 - \sum_{i=1}^{s} (p_i)^2$$

where:	D	=	Simpson's index of diversity
	s	=	the total number of taxa (group) at the station
	p_i	=	the proportion of the i^{th} taxon (group) at the station

1.4.4 Simpson's Evenness Index

Evenness refers to how evenly taxa are distributed within the community. Evenness ranges between 0 and 1; a community with a high number of individuals of one group and few of other groups has low evenness and a low evenness value closer to 0. Evenness (E) was calculated according to Smith and Wilson (1996):

$$E = 1 / \sum_{i=1}^{s} (p_i)^2 / S$$

where:	E	=	Evenness
	p_i	=	the proportion of the i^{th} taxon (group) at the station
	S	=	the total number of taxa (group) at the station

1.4.5 Bray-Curtis Similarity Index

The Bray-Curtis similarity index was used to compare survey results between the exposure areas and candidate reference areas. The Bray-Curtis similarity index was calculated according to Legendre and Legendre (1983):

$$B - C = \frac{\sum_{i=1}^{n} |y_{i1} - y_{i2}|}{\sum_{i=1}^{n} (y_{i1} + y_{i2})}$$

where:	B - C	=	Bray-Curtis distance between sites 1 and 2
	Y_{i1}	=	the count for taxon i at site 1
	Y_{i2}	=	the count for taxon i at site 2
	n	=	the total number of taxa (families) present at the two sites

1.4.5.1 QA/QC

Triplicate field sub-samples from each replicate station were collected for benthic invertebrate analyses, to compensate for the spatial variability encountered with these organisms. Appropriate QA/QC measures related to processing and identification, as outlined in guidance document were followed (EC, 2012). These measures incorporated the proper steps related to re-sorting, sub-sampling and maintenance of a voucher collection, as needed.

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Knight Piésold CONSULTING

TABLE D.1

BAFFINLAND IRON MINES CORPORATION
MARY RIVER PROJECT

DRAFT EEM CYCLE ONE STUDY DESIGN
CAMP LAKE TRIBUTARY STUDY AREAS: BENTHIC INVERTEBRATE TAXONOMIC DATA

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Phyllum	Group (Class/Order)	Family	CLT-NF-1	CLT-NF-2	CLT-NF-3	CLT-NF-4	CLT-NF-5	CLT-FF-1	CLT-FF-2	CLT-FF-3	CLT-FF-4	CLT-FF-5	CLT-REF2-1	CLT-REF2-2	CLT-REF2-3	CLT-REF2-4	CLT-REF2-5	CLT-REF3-1	CLT-REF3-2	CLT-REF3-3	CLT-REF3-4	CLT-REF3-5	CLT-REF4-1	CLT-REF4-2	CLT-REF4-3	CLT-REF4-4	CLT-REF4-5
ROUNDWORMS																											
P. Nemata			23	14	3	7	10	17	38	10	2	4	2	3	1	0	1	16	18	9	13	24	22	7	6	75	4
FLATWORMS																											
P. Platyhelminthes																											
	Cl. Turbellaria		0	0	2	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
ANNELIDS																											
P. Annelida	WORMS																										
	Cl. Oligochaeta	F. Enchytraeidae	7	3	4	2	2	3	78	0	1	3	0	2	3	3	1	2	7	4	1	18	8	1	3	33	2
		F. Lumbriculidae	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0
ARTHROPODS																											
P. Arthropoda	MITES																										
	Cl. Arachnida																										
	Subcl. Acari																										
	O. Trombidiformes																										
		F. Hygrobatidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0
		F. Lebertiidae	0	0	1	0	2	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
		F. Sperchonidae	30	17	57	40	38	42	22	21	19	25	7	12	5	6	10	0	5	9	9	8	25	17	23	17	27
	HARPACTICOIDS																										
	O. Harpacticoida		0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0
	SEED SHRIMPS																										
	Cl. Ostracoda		1	1	3	0	0	1	0	1	0	0	1	0	0	1	1	0	0	0	2	3	6	4	10	3	12
	SPRINGTAILS																										
	Cl. Entognatha																										
	O. Collembola		0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
INSECTS																											
	Cl. Insecta																										
	MAYFLIES																										
	O. Ephemeroptera	F. Baetidae	11	4	2	0	1	3	6	1	4	3	0	0	2	1	3	15	9	4	0	4	21	15	25	26	22
	STONEFLIES																										
	O. Plecoptera	F. Capniidae	0	0	0	0	0	1	2	2	0	0	1	8	2	4	2	0	1	0	0	0	10	4	12	3	11
	CADDISFLIES																										
	O. Trichoptera	F. Limnephilidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	8	0	1	0	0	0
TRUE FLIES																											
	O. Diptera																										
	BITING-MIDGE	F. Ceratopogonidae	0	0	0	0	0	0	2	0	1	0	1	0	4	2	1	0	0	0	0	0	8	75	77	67	31
	MIDGES	F. Chironomidae	304	152	303	220	314	423	500	311	263	239	18	25	21	32	31	343	290	178	87	320	342	248	254	317	185
		F. Empididae	2	0	0	0	4	0	3	3	2	1	13	20	30	24	23	0	1	0	0	1	25	8	30	38	12
		F. Simuliidae	7	4	1	2	0	0	3	0	6	2	0	1	1	0	0	50	2	4	2	28	8	3	6	18	9
		F. Tipulidae	13	23	30	12	25	22	20	29	9	31	24	43	47	89	46	9	16	19	26	30	21	21	26	16	17
TOTAL NUMBER OF ORGANISMS			398	218	406	283	396	513	674	379	307	310	68	114	116	163	119	435	349	228	143	449	496	404	472	614	332

\\NB4\Project$\1\02\00181\34\A\Report\Report 5 Rev B - EEM Study Design\Appendix D - BIC\Individual files\[AppD_Tables_20130304.xlsm]TABLE_D.1

NOTES:

1. BENTHIC INVERTEBRATE SAMPLES SORTED AND IDENTIFIED BY ZEAS INCORPORATED.
2. BENTHIC INVERTEBRATE SAMPLES WERE SORETED TO THEIR ENTIRETY.

Table D.2 Camp Lake Tributary Study Areas: Benthic Invertebrate Taxonomic QA/QC Data

Field Sub-sample	Number of Organisms Recovered in Initial Sort	Number of Organisms Recovered in Re-sort	Percent Recovery
CLT-FF-1C	168	184	91%
CLT-NF-3B	178	190	94%
CLT-REF3-5B	113	116	97%
CLT-REF2-3A	49	50	98%
CLT-REF4-3A	183	189	97%
CLT-REF3-3A	81	81	100%
CLT-NF-5C	134	136	99%
CLT-REF4-5A	149	151	99%
		Average % Recovery	97%

NOTES:

1. BENTHIC INVERTEBRATE SAMPLES SORTED AND IDENTIFIED BY ZEAS INCORPORATED, NOBLETON, ONTARIO.
2. ALL SAMPLES WERE SORTED TO THEIR ENTIRETY.

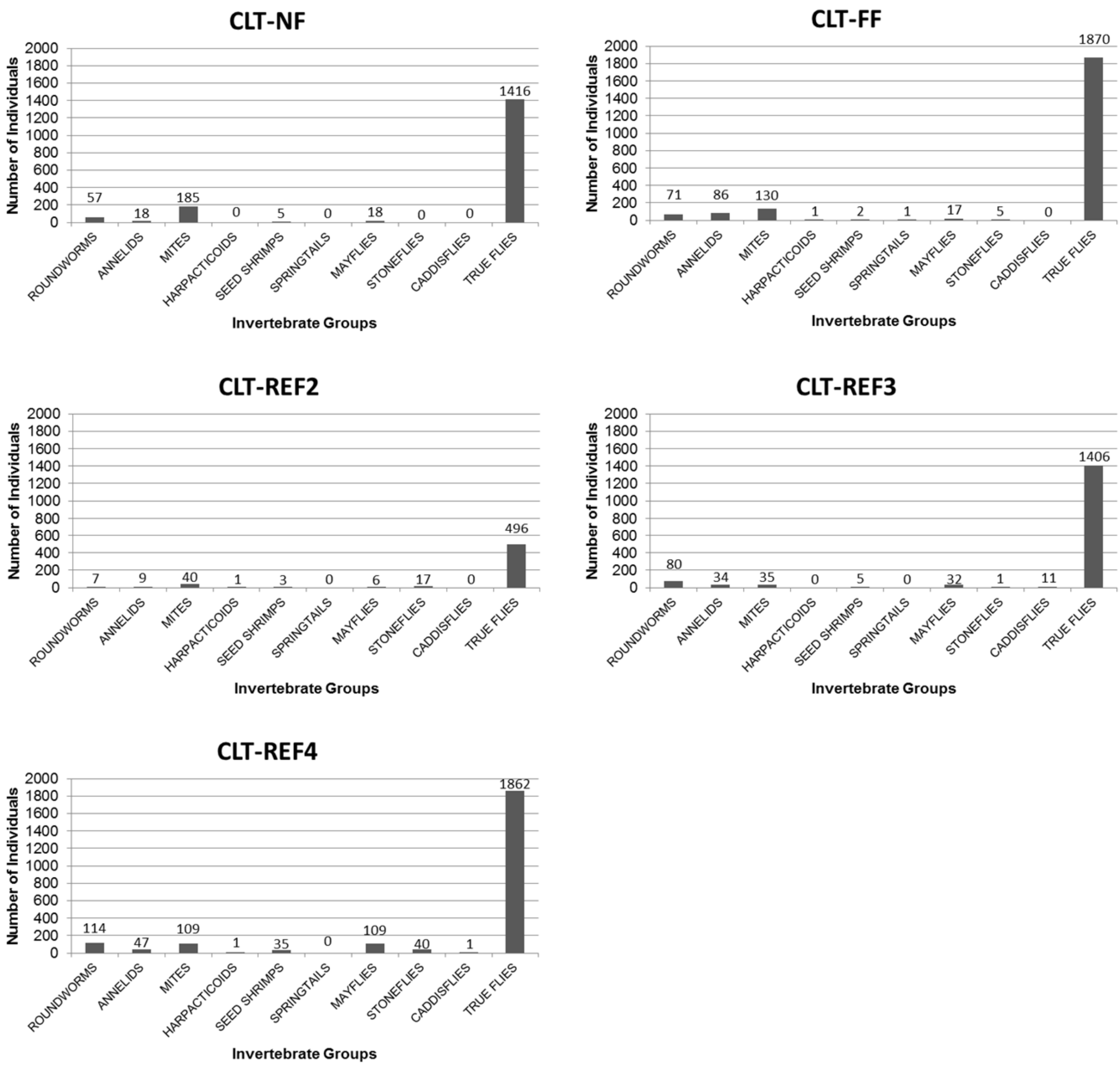

Figure D.1 Camp Lake Tributary Study Areas: Benthic Invertebrate Community Summary

Table D.3 Camp Lake Tributary Study Areas: Benthic Invertebrate Community Summary

Endpoint	Descriptor	CLT-NF	CLT-FF	CLT-REF2	CLT-REF3	CLT-REF4
Total Invertebrate Density(TID)	Data Distributed Normally	Y	Y	Y	Y	Y
	Mean	1269	1634	440	1178	1681
	Standard error (SE)	147	247	60	223	144
	Standard deviation (SD)	328	552	133	498	321
	Median	1450	1426	446	1283	1767
	Minimum	787	1182	248	496	1225
	Maximum	1543	2465	624	1636	2074
	Different from CLT-NF (p<0.10)	**-**	**N[2]**	**Y[2]**	**N[2]**	**N[2]**
Taxa Richness	Data Distributed Normally	N	Y	Y	Y	N
	Mean	6	8	8	8	9
	Standard error (SE)	0	1	1	1	0
	Standard deviation (SD)	1	1	1	2	0
	Median	7	8	8	7	9
	Minimum	5	6	6	5	9
	Maximum	7	9	9	11	10
	Different from CLT -NF (p<0.10)	**-**	**N**	**N**	**N**	**Y**
Simpson's Diversity Index (D)	Data Distributed Normally	Y	Y	N	Y	Y
	Mean	0.36	0.30	0.71	0.36	0.58
	Standard error (SE)	0.02	0.03	0.02	0.04	0.04
	Standard deviation (SD)	0.04	0.06	0.05	0.10	0.08
	Median	0.34	0.28	0.73	0.33	0.62
	Minimum	0.32	0.25	0.63	0.23	0.45
	Maximum	0.42	0.37	0.75	0.49	0.65
	Different from CLT NF (p<0.10)	**-**	**N**	**Y**	**N**	**Y**
Simpson's Evenness Index (E)	Data Distributed Normally	Y	Y	Y	Y	Y
	Mean	0.25	0.19	0.48	0.22	0.27
	Standard error (SE)	0.02	0.01	0.05	0.03	0.02
	Standard deviation (SD)	0.04	0.02	0.11	0.06	0.05
	Median	0.24	0.20	0.46	0.21	0.29
	Minimum	0.21	0.17	0.34	0.15	0.20
	Maximum	0.30	0.22	0.61	0.29	0.31
	Different from CLT -NF (p<0.10)	**-**	**N[2]**	**Y[2]**	**N[2]**	**N[2]**

NOTES:

1. TUKEY TEST RESULTS FOR POST-HOC COMPARISON PRESENTED UNLESS OTHERWISE NOTED.
2. VARIANCE NOT HOMOGENEOUS, GAMES-HOWELL TEST RESULTS PRESENTED.
3. SEE TABLE D.8 FOR CAMP LAKE TRIBUTARY STUDY AREA BRAY-CURTIS POST-HOC COMPARISON.

Table D.4 Camp Lake Tributary Study Areas: Total Invertebrate Density

Test of Normality

Area	Shapiro-Wilk			
	Statistic	df	p-value	Distribution at p>0.05
CLT-NF	0.849	5	0.19	Normal
CLT-FF	0.868	5	0.26	Normal
CLT-REF2	0.919	5	0.52	Normal
CLT-REF3	0.899	5	0.40	Normal
CLT-REF4	0.976	5	0.91	Normal

Test of Homogeneity of Variance

Levene Statistic	df1	df2	p-value	Homogeneity of Variance at p<0.05
3.354	4	20	0.03	Yes – Variance not homogeneous

ANOVA Results

Source of Variation	Sum of Squares	df	Mean Square	F	p-value	Sig. at p<0.05
Between Groups	4968951.4	4	1242237.9	7.94	0.001	Y
Within Groups	3129212.0	20	156460.6			
Total	8098163.4	24				

Multiple Comparison Post-hoc Test

Games-Howell		Mean Difference	Std. Error	p-value	Difference Sig. at p<0.10	95% Confidence Interval	
Exposure Area	Comparison Area	(Exp. – Comp.)				Lower Bound	Upper Bound
CLT-NF	CLT-FF	-364.8	287.46	0.72	N	-1415.4	685.8
	CLT-REF2	829.0	158.48	0.02	Y	206.9	1451.1
	CLT-REF3	91.6	266.87	1.00	N	-866.3	1049.5
	CLT-REF4	-411.4	205.39	0.34	N	-1121.1	298.3

NOTE:
1. SHADED CELLS INDICATE A SIGNIFICANT DIFFERENCE FROM THE EXPOSURE AREA AT P<0.10.

Table D.5 Camp Lake Tributary Study Areas: Taxa Richness

Test of Normality

Area	Shapiro-Wilk			
	Statistic	df	p-value	Distribution at p>0.05
CLT-NF	0.771	5	0.05	Normal
CLT-FF	0.961	5	0.81	Normal
CLT-REF2	0.961	5	0.81	Normal
CLT-REF3	0.932	5	0.61	Normal
CLT-REF4	0.552	5	0.00	Not Normal

Test of Homogeneity of Variance

Levene Statistic	df1	df2	p-value	Homogeneity of Variance at p<0.05
1.669	4	20	0.20	No – Variance homogeneous

ANOVA Results

Source of Variation	Sum of Squares	df	Mean Square	F	p-value	Sig. at p<0.05
Between Groups	19.8	4	5.0	2.95	0.05	N
Within Groups	33.6	20	1.7			
Total	53.4	24				

Multiple Comparison Post-hoc Test

Tukey HSD		Mean Difference	Std. Error	p-value	Difference Sig. at p<0.10	95% Confidence Interval	
Exposure Area	Comparison Area	(Exp. – Comp.)				Lower Bound	Upper Bound
CLT-NF	CLT-FF	-1.2	.82	0.60	N	-3.7	1.3
	CLT-REF2	-1.2	.82	0.60	N	-3.7	1.3
	CLT-REF3	-1.2	.82	0.60	N	-3.7	1.3
	CLT-REF4	-2.8	.82	0.02	Y	-5.3	-0.4

NOTE:

1. SHADED CELLS INDICATE A SIGNIFICANT DIFFERENCE FROM THE EXPOSURE AREA AT P<0.10.

Table D.6 Camp Lake Tributary Study Areas: Simpson's Diversity Index

Test of Normality

Area	Shapiro-Wilk			
	Statistic	df	p-value	Distribution at p>0.05
CLT-NF	0.865	5	0.25	Normal
CLT-FF	0.796	5	0.08	Normal
CLT-REF2	0.715	5	0.01	Not Normal
CLT-REF3	0.978	5	0.92	Normal
CLT-REF4	0.854	5	0.21	Normal

Test of Homogeneity of Variance

Levene Statistic	df1	df2	p-value	Homogeneity of Variance at p<0.05
1.543	4	20	0.23	No – Variance homogeneous

ANOVA Results

Source of Variation	Sum of Squares	df	Mean Square	F	p-value	Sig. at p<0.05
Between Groups	0.6	4	0.154	32.773	0.000	Y
Within Groups	0.1	20	0.005			
Total	0.7	24				

Multiple Comparison Post-hoc Test

Tukey HSD		Mean Difference	Std. Error	p-value	Difference Sig. at p<0.10	95% Confidence Interval	
Exposure Area	Comparison Area	(Exp. – Comp.)				Lower Bound	Upper Bound
CLT-NF	CLT-FF	0.1	0.04	0.67	N	-0.1	0.2
	CLT-REF2	-0.4	0.04	0.000	Y	-0.5	-0.2
	CLT-REF3	0.007	0.04	1.00	N	-0.1	0.1
	CLT-REF4	-0.2	0.04	0.001	Y	-0.4	-0.1

NOTE:

1. SHADED CELLS INDICATE A SIGNIFICANT DIFFERENCE FROM THE EXPOSURE AREA AT P<0..10.

Table D.7 Camp Lake Tributary Study Areas: Simpson's Evenness Index

Test of Normality

Area	Shapiro-Wilk			
	Statistic	df	p-value	Distribution at p>0.05
CLT-NF	0.861	5	0.23	Normal
CLT-FF	0.944	5	0.69	Normal
CLT-REF2	0.953	5	0.76	Normal
CLT-REF3	0.865	5	0.25	Normal
CLT-REF4	0.871	5	0.27	Normal

Test of Homogeneity of Variance

Levene Statistic	df1	df2	p-value	Homogeneity of Variance at p<0.05
4.971	4	20	0.01	Yes – Variance not homogeneous

ANOVA Results

Source of Variation	Sum of Squares	df	Mean Square	F	p-value	Sig. at p<0.05
Between Groups	0.26	4	0.064	14.82	0.000	Y
Within Groups	0.09	20	0.004			
Total	0.34	24				

Multiple Comparison Post-hoc Test

Games-Howell		Mean Difference	Std. Error	p-value	Difference Sig. at p<0.10	95% Confidence Interval	
Exposure Area	Comparison Area	(Exp. – Comp.)				Lower Bound	Upper Bound
CLT-NF	CLT-FF	0.06	0.02	0.17	N	-0.02	0.14
	CLT-REF2	-0.23	0.05	0.04	Y	-0.44	-0.01
	CLT-REF3	0.03	0.03	0.90	N	-0.09	0.15
	CLT-REF4	-0.02	0.03	0.97	N	-0.12	0.08

NOTE:

1. SHADED CELLS INDICATE A SIGNIFICANT DIFFERENCE FROM THE EXPOSURE AREA AT P<0.10.

Table D.8 Camp Lake Tributary Study Areas: Bray-Curtis Similarity Index

Descriptive Statistics

Area	Mean	Standard Error	Standard Deviation	Median	Minimum	Maximum
CLT-REF2	0.73	0.03	0.06	0.74	0.63	0.79
CLT-NF – CLT-REF2	0.14	0.04	0.09	0.09	0.05	0.25
CLT-REF3	0.16	0.04	0.08	0.11	0.08	0.29
CLT-NF – CLT-REF3	0.20	0.08	0.17	0.17	0.03	0.48
CLT-REF4	0.28	0.02	0.05	0.27	0.22	0.37
CLT-NF – CLT-REF4	0.12	0.03	0.06	0.14	0.03	0.17

Test of Normality

Area	Shapiro-Wilk			
	Statistic	df	p-value	Distribution at p>0.05
CLT-NF – CLT-REF2	0.842	5	0.17	Normal
CLT-NF – CLT-REF3	0.867	5	0.25	Normal
CLT-NF – CLT-REF4	0.849	5	0.19	Normal
CLT-REF2	0.871	5	0.27	Normal
CLT-REF3	0.897	5	0.40	Normal
CLT-REF4	0.863	5	0.24	Normal

Test of Homogeneity of Variance

Levene Statistic	df1	df2	p-value	Homogeneity of Variance at p<0.05
1.337	5	24	.283	No – Variance homogeneous

ANOVA Results

Source of Variation	Sum of Squares	df	Mean Square	F	p-value	Sig. at p<0.05
Between Groups	1.4	5	0.272	30.146	0.000	Y
Within Groups	0.2	24	0.009			
Total	1.6	29				

Multiple Comparison Post-hoc Test

Tukey HSD		Mean Difference	Std. Error	p-value	Difference Sig. at p<0.10	95% Confidence Interval	
Exposure Area	Comparison Area	(Exp. – Comp.)				Lower Bound	Upper Bound
CLT-NF – CLT-REF2	CLT-REF2	0.6	0.06	0.000	Y	0.41	0.78
CLT-NF – CLT-REF3	CLT-REF3	-0.1	0.06	0.97	N	-0.23	0.14
CLT-NF – CLT-REF4	CLT-REF4	0.2	0.06	0.11	N	-0.02	0.35

NOTE:

1. SHADED CELLS INDICATE A SIGNIFICANT DIFFERENCE FROM THE EXPOSURE AREA AT P<0.10.

Knight Piésold CONSULTING

TABLE D.9

BAFFINLAND IRON MINES CORPORATION
MARY RIVER PROJECT

DRAFT EEM CYCLE ONE STUDY DESIGN
MARY RIVER STUDY AREAS: BENTHIC INVERTEBRATE TAXONOMIC DATA

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Phyllum	Group (Class/Order)	Family	MRY-NF-1	MRY-NF-2	MRY-NF-3	MRY-NF-4	MRY-NF-5	MRY-FF-1	MRY-FF-2	MRY-FF-3	MRY-FF-4	MRY-FF-5	MRY-REF1-1	MRY-REF1-2	MRY REF1-3	MRY-REF1-4	MRY-REF1-5	MRY-REF2-1	MRY-REF2-2	MRY-REF2-3	MRY-REF2-4	MRY-REF2-5	MRY-REF3-1	MRY-REF3-2	MRY-REF3-3	MRY-REF3-4A	MRY-REF3-5	MRY-REF4-1	MRY-REF4-2	MRY-REF4-3	MRY-REF4-4	MRY-REF4-5
ROUNDWORMS																																
P. Nemata			0	4	3	4	1	3	5	0	4	5	4	9	15	10	17	2	0	1	0	0	1	0	0	3	0	2	0	9	5	2
FLATWORMS																																
P. Platyhelminthes																																
	Cl. Turbellaria		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ANNELIDS																																
P. Annelida	WORMS																															
	Cl. Oligochaeta	F. Enchytraeidae	0	2	13	3	1	3	0	0	2	6	16	7	25	5	0	8	0	1	1	2	0	0	0	0	0	1	0	0	0	0
		F. Lumbriculidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ARTHROPODS																																
P. Arthropoda	MITES																															
	Cl. Arachnida																															
	Subcl. Acari																															
	O. Trombidiformes																															
		F. Hygrobatidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	3	0	0	0	0	0
		F. Lebertiidae	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		F. Sperchonidae	3	2	20	8	2	10	8	3	14	23	10	13	12	2	8	22	24	6	6	2	2	0	0	0	0	14	1	3	4	5
	HARPACTICOIDS																															
	O. Harpacticoida		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	SEED SHRIMPS																															
	Cl. Ostracoda		0	0	0	1	0	0	0	0	0	0	1	0	0	2	0	1	3	1	1	1	0	0	0	0	0	0	0	0	0	0
	SPRINGTAILS																															
	Cl. Entognatha																															
	O. Collembola		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
INSECTS																																
	Cl. Insecta																															
	MAYFLIES																															
	O. Ephemeroptera	F. Baetidae	4	4	0	6	10	7	1	4	11	10	2	0	1	0	0	15	4	4	7	1	0	0	1	0	0	2	0	1	0	0
	STONEFLIES																															
	O. Plecoptera	F. Capniidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	3	1	0	0	1	1	0	2	1	0	1	0	1	0
	CADDISFLIES																															
	O. Trichoptera	F. Limnephilidae	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TRUE FLIES																																
	O. Diptera																															
	BITING-MIDGE	F. Ceratopogonidae	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	1	0	0	0	0	0	0	0	0	0	0
	MIDGES	F. Chironomidae	103	127	691	224	249	188	173	125	270	228	129	359	456	294	537	252	177	172	60	197	36	25	28	59	13	326	244	297	321	231
		F. Empididae	0	2	2	3	2	0	1	0	0	0	0	0	0	1	0	29	14	8	6	7	2	0	0	1	0	0	0	0	0	1
		F. Simuliidae	2	3	1	11	2	11	1	6	10	2	0	0	0	0	0	10	3	20	1	12	1	1	0	2	1	56	29	24	99	11
		F. Tipulidae	0	1	8	6	1	1	0	1	2	1	2	3	3	10	4	4	4	0	5	6	2	0	0	0	0	5	4	6	5	3
TOTAL NUMBER OF ORGANISMS			113	146	738	266	268	223	189	139	313	275	164	391	513	325	567	344	232	219	87	229	45	28	29	67	18	406	279	340	435	253

\\NB4\Project$\1\02\00181\34\A\Report\Report 5 Rev B - EEM Study Design\Appendix D - BIC\Individual files\[AppD_Tables_20130304.xlsm]TABLE_D.9

NOTES:

1. BENTHIC INVERTEBRATE SAMPLES SORTED AND IDENTIFIED BY ZEAS INCORPORATED.
2. BENTHIC INVERTEBRATE SAMPLES WERE SORTED TO THEIR ENTIRETY.

Table D.10 Mary River Study Areas: Benthic Invertebrate Taxonomic QA/QC Data

Field Sub-sample	Number of Organisms Recovered in Initial Sort	Number of Organisms Recovered in Re-sort	Percent Recovery
MRY-NF-5B	57	57	100%
MRY-REF2-5C	27	29	93%
MRY-REF3-5B	4	4	100%
MRY-REF1-2C	236	238	99%
MRY-REF1-3B	231	240	96%
MRY-REF1-4C	95	99	96%
MRY-REF2-3A	108	114	95%
MRY-NF-1B	59	59	100%
MRY-REF1-5C	152	153	99%
		Average % Recovery	98%

NOTES:

1. BENTHIC INVERTEBRATE SAMPLES SORTED AND IDENTIFIED BY ZEAS INCORPORATED, NOBLETON, ONTARIO.
2. ALL SAMPLES WERE SORTED TO THEIR ENTIRETY.

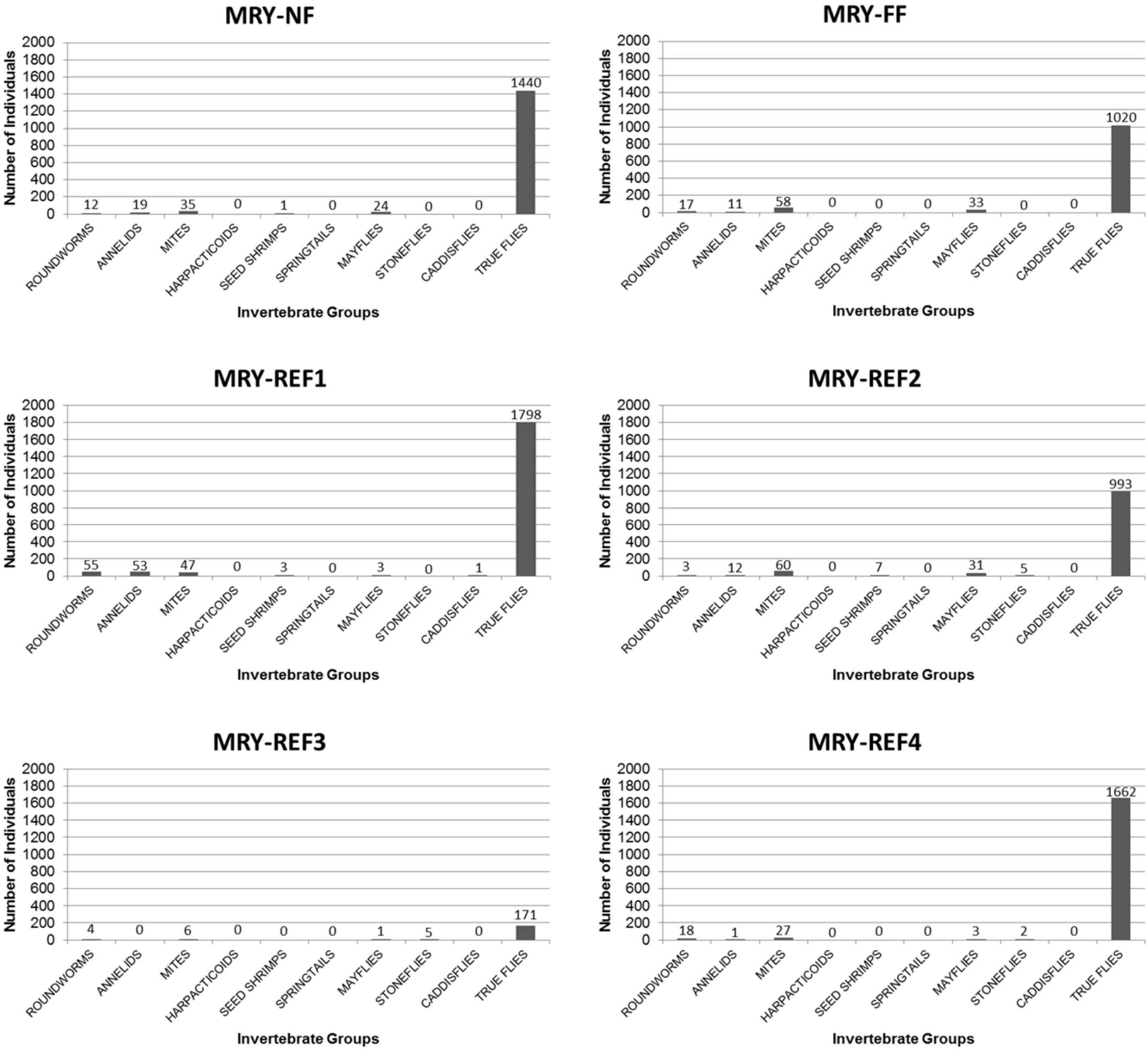

Figure D.2 Mary River Study Areas: Benthic Invertebrate Community Summary

Table D.11 Mary River Study Areas: Benthic Invertebrate Community Summary

ENDPOINT	DESCRIPTOR	MRY-NF	MRY-FF	MRY-REF1	MRY-REF2	MRY-REF3	MRY-REF4
TOTAL INVERTEBRATE DENSITY(TID)	Data Distributed Normally	Y	Y	Y	Y	Y	Y
	Mean	1177	870	1474	853	142	1314
	Standard error (SE)	435	117	269	157	31	134
	Standard deviation (SD)	972	261	601	351	69	300
	Median	1012	853	1481	884	112	1283
	Minimum	438	539	616	333	70	973
	Maximum	2849	1198	2132	1322	248	1667
	Different from MRY-NF (p<0.05)	**-**	**N**	**N**	**N**	**Y**	**N**
TAXA RICHNESS	Data Distributed Normally	Y	N	Y	N	Y	N
	Mean	7	6	5	8	4	5
	Standard error (SE)	1	0	0	0	1	0
	Standard deviation (SD)	1	1	1	1	1	0
	Median	7	6	5	8	4	5
	Minimum	5	5	4	7	2	5
	Maximum	8	6	6	8	6	6
	Different from MRY-NF (p<0.05)	**-**	**N**	**N**	**N**	**N**[2]	**N**
SIMPSON'S DIVERSITY INDEX (D)	Data Distributed Normally	Y	Y	Y	Y	Y	Y
	Mean	0.174	0.215	0.153	0.386	0.236	0.256
	Standard error (SE)	0.026	0.030	0.047	0.041	0.067	0.045
	Standard deviation (SD)	0.058	0.066	0.106	0.092	0.149	0.100
	Median	0.167	0.232	0.116	0.387	0.199	0.224
	Minimum	0.115	0.114	0.046	0.249	0.067	0.151
	Maximum	0.259	0.278	0.327	0.493	0.444	0.389
	Different from MRY-NF (p<0.05)	**-**	**N**	**N**	**Y**	**N**	**N**
SIMPSON'S EVENNESS INDEX (E)	Data Distributed Normally	Y	Y	Y	Y	Y	N
	Mean	0.188	0.229	0.246	0.220	0.367	0.263
	Standard error (SE)	0.015	0.005	0.022	0.019	0.054	0.017
	Standard deviation (SD)	0.033	0.011	0.050	0.043	0.121	0.037
	Median	0.188	0.226	0.262	0.223	0.312	0.248
	Minimum	0.156	0.217	0.189	0.166	0.246	0.235
	Maximum	0.240	0.246	0.297	0.282	0.536	0.328
	Different from MRY-NF (p<0.05)	**-**	**N**	**N**	**N**	**N**[2]	**Y**

NOTES:

1. TUKEY HSD TEST USED FOR COMPARISON BETWEEN MRY-NF AND REF AREAS UNLESS OTHERWISE NOTED.
2. GAMES-HOWELL COMPARISON USED.
3. SEE TABLE D.16 FOR MARY RIVER STUDY AREA BRAY-CURTIS COMPARISON RESULTS.

Table D.12 Mary River Study Areas: Total Invertebrate Density

Test of Normality

AREA	Shapiro-Wilk			
	Statistic	df	p-value	Distribution at p>0.05
MRY-NF	0.782	5	0.06	Normal
MRY-FF	0.984	5	0.95	Normal
MRY-REF1	0.965	5	0.84	Normal
MRY-REF2	0.908	5	0.45	Normal
MRY-REF3	0.923	5	0.55	Normal
MRY-REF4	0.930	5	0.60	Normal

Test of Homogeneity of Variance

Levene Statistic	df1	df2	p-value	Homogeneity of Variance at p<0.05
2.395	5	24	0.07	No – Variance homogeneous

ANOVA Results

Source of Variation	Sum of Squares	df	Mean Square	F	p-value	Sig. at p<0.05
Between Groups	5623175.6	5	1124635.1	4.24	0.01	Y
Within Groups	6372451.2	24	265518.8			
Total	11995626.8	29				

Multiple Comparison Post-hoc Test

Tukey HSD		Mean Difference	Std. Error	p-value	Difference Sig. at p<0.10	95% Confidence Interval	
Exposure Area	Comparison Area	(Exp. – Comp.)				Lower Bound	Upper Bound
MRY-NF	MRY-FF	306.8	325.90	0.93	N	-700.9	1314.5
	MRY-REF1	-297.6	325.90	0.94	N	-1305.3	710.1
	MRY-REF2	323.2	325.90	0.92	N	-684.5	1330.9
	MRY-REF3	1034.8	325.90	0.04	Y	27.2	2042.5
	MRY-REF4	-137.2	325.90	1.00	N	-1144.9	870.5

NOTE:

1. SHADED CELLS INDICATE A SIGNIFICANT DIFFERENCE FROM THE EXPOSURE AREA AT P<0.10.

Table D.13 Mary River Study Areas: Taxa Richness

Test of Normality

AREA	Shapiro-Wilk			
	Statistic	df	p-value	Distribution at p>0.05
MRY-NF	0.961	5	0.81	Normal
MRY-FF	0.684	5	0.01	Not Normal
MRY-REF1	0.821	5	0.12	Normal
MRY-REF2	0.684	5	0.01	Not Normal
MRY-REF3	0.883	5	0.33	Normal
MRY-REF4	0.552	5	0.00	Not Normal

Test of Homogeneity of Variance

Levene Statistic	df1	df2	p-value	Homogeneity of Variance at p<0.05
0.858	5	24	0.52	No – Variance homogeneous

ANOVA Results

Source of Variation	Sum of Squares	df	Mean Square	F	p-value	Sig. at p<0.05
Between Groups	40.3	5	8.1	9.5	0.000	Y
Within Groups	20.4	24	0.9			
Total	60.7	29				

Multiple Comparison Post-hoc Test

Tukey HSD		Mean Difference	Std. Error	p-value	Difference Sig. at p<0.10	95% Confidence Interval	
Exposure Area	Comparison Area	(Exp. – Comp.)				Lower Bound	Upper Bound
MRY-NF	MRY-FF	1.0	0.58	0.54	N	-0.8	2.8
	MRY-REF1	1.6	0.58	0.10	N	-0.2	3.4
	MRY-REF2	-1.0	0.58	0.54	N	-2.8	0.8
	MRY-REF3	2.6	0.58	0.002	Y	0.8	4.4
	MRY-REF4	1.4	0.58	0.20	N	-0.4	3.2

NOTE:
1. SHADED CELLS INDICATE A SIGNIFICANT DIFFERENCE FROM THE EXPOSURE AREA AT P<0.10.

Table D.14 Mary River Study Areas: Simpson's Diversity Index

Test of Normality

AREA	Shapiro-Wilk			
	Statistic	df	p-value	Distribution at p>0.05
MRY-NF	0.945	5	0.70	Normal
MRY-FF	0.922	5	0.54	Normal
MRY-REF1	0.872	5	0.28	Normal
MRY-REF2	0.975	5	0.90	Normal
MRY-REF3	0.969	5	0.87	Normal
MRY-REF4	0.933	5	0.62	Normal

Test of Homogeneity of Variance

Levene Statistic	df1	df2	p-value	Homogeneity of Variance at p<0.05
1.292	5	24	0.30	No – Variance homogeneous

ANOVA Results

Source of Variation	Sum of Squares	df	Mean Square	F	p-value	Sig. at p<0.05
Between Groups	0.2	5	0.03	3.452	0.02	Y
Within Groups	0.2	24	0.01			
Total	0.4	29				

Multiple Comparison Post-hoc Test

Tukey HSD		Mean Difference	Std. Error	p-value	Difference Sig. at p<0.10	95% Confidence Interval	
Exposure Area	Comparison Area	(Exp. – Comp.)				Lower Bound	Upper Bound
MRY-NF	MRY-FF	-0.04	0.06	0.99	N	-0.24	0.15
	MRY-REF1	0.02	0.06	1.00	N	-0.17	0.22
	MRY-REF2	-0.21	0.06	0.03	Y	-0.41	-0.02
	MRY-REF3	-0.06	0.06	0.92	N	-0.26	0.13
	MRY-REF4	-0.08	0.06	0.78	N	-0.28	0.11

NOTE:

1. SHADED CELLS INDICATE A SIGNIFICANT DIFFERENCE FROM THE EXPOSURE AREA AT P<0.10.

Table D.15 Mary River Study Areas: Simpson's Evenness Index

Test of Normality

AREA	Shapiro-Wilk			
	Statistic	df	p-value	Distribution at p>0.05
MRY-NF	0.912	5	0.48	Normal
MRY-FF	0.922	5	0.55	Normal
MRY-REF1	0.871	5	0.27	Normal
MRY-REF2	0.984	5	0.96	Normal
MRY-REF3	0.908	5	0.46	Normal
MRY-REF4	0.754	5	0.03	Not Normal

Test of Homogeneity of Variance

Levene Statistic	df1	df2	p-value	Homogeneity of Variance at p<0.05
7.987	5	24	0.000	Yes – Variance not homogeneous

ANOVA Results

Source of Variation	Sum of Squares	df	Mean Square	F	p-value	Sig. at p<0.05
Between Groups	0.10	5	0.019	5.318	0.002	Y
Within Groups	0.09	24	0.004			
Total	0.18	29				

Multiple Comparison Post-hoc Test

Games-Howell		Mean Difference	Std. Error	p-value	Difference Sig. at p<0.10	95% Confidence Interval	
Exposure Area	Comparison Area	(Exp. – Comp.)				Lower Bound	Upper Bound
MRY-NF	MRY-FF	-0.04	0.02	0.24	N	-0.11	0.03
	MRY-REF1	-0.06	0.03	0.35	N	-0.16	0.04
	MRY-REF2	-0.03	0.02	0.78	N	-0.12	0.06
	MRY-REF3	-0.18	0.06	0.15	N	-0.43	0.07
	MRY-REF4	-0.08	0.02	0.07	Y	-0.16	0.01

NOTE:

1. SHADED CELLS INDICATE A SIGNIFICANT DIFFERENCE FROM THE EXPOSURE AREA AT P<0.10.

Table D.16 Mary River Study Areas: Bray-Curtis Similarity Index (Page 1 of 2)

Descriptive Statistics

Area	Mean	Standard Error	Standard Deviation	Median	Minimum	Maximum
MRY-REF1	0.37	0.07	0.15	0.32	0.22	0.57
MRY-NF - MRY-REF1	0.18	0.07	0.17	0.14	0.00	0.45
MRY-REF2	0.29	0.08	0.18	0.21	0.13	0.60
MRY-NF - MRY-REF2	0.18	0.07	0.17	0.08	0.06	0.45
MRY-REF3	0.76	0.06	0.13	0.80	0.59	0.92
MRY-NF - MRY-REF3	0.21	0.07	0.15	0.19	0.05	0.38
MRY-REF4	0.34	0.07	0.16	0.43	0.16	0.52
MRY-NF - MRY-REF4	0.09	0.02	0.05	0.09	0.01	0.15

Test of Normality

AREA	Shapiro-Wilk			
	Statistic	df	p-value	Distribution at p>0.05
MRY-NF - MRY-REF1	0.908	5	0.45	Normal
MRY-NF - MRY-REF2	0.840	5	0.16	Normal
MRY-NF - MRY-REF3	0.949	5	0.73	Normal
MRY-NF - MRY-REF4	0.842	5	0.17	Normal
MRY-REF1	0.914	5	0.49	Normal
MRY-REF2	0.800	5	0.08	Normal
MRY-REF3	0.863	5	0.24	Normal
MRY-REF4	0.924	5	0.56	Normal

Test of Homogeneity of Variance

Levene Statistic	df1	df2	p-value	Homogeneity of Variance at p<0.05
1.045	7	32	0.42	No – Variance homogeneous

ANOVA Results

Source of Variation	Sum of Squares	df	Mean Square	F	p-value	Sig. at p<0.05
Between Groups	1.5	7	0.21	9.138	0.000	Y
Within Groups	0.7	32	0.02			
Total	2.2	39				

Table D.16 Mary River Study Areas: Bray-Curtis Similarity Index (Page 2 of 2)

Multiple Comparison Post-hoc Test

Tukey HSD		Mean Difference	Std. Error	p-value	Difference Sig. at p<0.10	95% Confidence Interval	
Exposure Area	Comparison Area	(Exp. – Comp.)				Lower Bound	Upper Bound
MRY-NF - MRY-REF1	MRY-REF1	0.2	0.10	0.51	N	-0.1	0.5
MRY-NF - MRY-REF2	MRY-REF2	0.1	0.10	0.94	N	-0.2	0.4
MRY-NF - MRY-REF3	MRY-REF3	0.5	0.10	0.000	Y	0.2	0.9
MRY-NF - MRY-REF4	MRY-REF4	0.3	0.10	0.17	N	-0.1	0.6

NOTE:
1. SHADED CELLS INDICATE A SIGNIFICANT DIFFERENCE FROM THE EXPOSURE AREA AT P<0.10.

APPENDIX E

FISHERIES DATA

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Table E.1 2013 Fall Electrofishing Summary & ARCH Fork Length and Round Weight Descriptive Statistics Summary

STUDY AREA	CLT-NF	CLT-REF2	CLT-REF3	CLT-REF4	MRY-NF	MRY-REF1	MRY-REF2	MRY-REF3
Survey Date(s)	21-Aug-13	22-Aug-13	22-Aug-13	22-Aug-13	25+28-Aug-13	27-Aug-13	25-Aug-13	26-Aug-13
Number of ARCH	120	30	116	117	108	26	22	114
Number of NSSB	0	0	0	1	0	26	0	0
Total Catch	120	30	116	118	108	52	22	114
Realtime Effort	45	60	30	45	120	65	70	120
Electrofishing Effort	14	25	13	22	69	42	31	57
Total CPUE	8.57	1.22	9.11	5.30	1.56	1.22	0.71	2.01
ARCH CPUE	8.57	1.22	9.11	5.25	1.56	0.61	0.71	2.01
Arctic Char Fork Length (mm) Measurement Summary								
Number of samples	100	30	100	100	100	26	22	100
Mean	148	127	90	117	126	121	100	104
Median	142	121	78	107	118	115	100	99
Standard Deviation	28	35	35	37	26	37	21	34
Standard Error	3	6	3	4	3	7	5	3
Minimum	98	49	38	67	76	76	68	46
Maximum	243	210	187	275	204	222	138	204
Arctic Char Weight (g) Measurement Summary								
Number of samples	100	30	100	100	100	26	22	100
Mean	32	23	10	21	23	25	11	15
Median	25	20	5	13	17	17	10	9
Standard Deviation	21	17	12	27	14	28	7	15
Standard Error	2	3	1	3	1	6	1	1
Minimum	7	1	1	3	5	5	3	1
Maximum	151	79	60	191	78	141	27	90
Arctic Char Age (years) Verification Summary								
Number of samples	10	10	10	10	10	10	10	10
Mean	3	4	4	4	4	4	3	3
Median	3	3.5	3.5	4	3.5	3	3	3
Standard Deviation	2	2	2	1	2	1	1	1
Standard Error	1	1	0	0	1	0	0	0
Minimum	1	2	2	3	2	2	2	1
Maximum	7	7	6	7	7	5	3	5
Condition Factor (K)								
Number of samples	100	30	100	100	100	26	22	100
Mean	0.89	0.99	0.95	1.01	1.03	1.07	1.02	0.99
Median	0.88	1.00	0.96	1.01	1.02	1.07	1.02	0.99
Standard Deviation	0.08	0.13	0.11	0.08	0.10	0.08	0.08	0.09
Standard Error	0.01	0.02	0.01	0.01	0.01	0.02	0.02	0.01
Minimum	0.72	0.72	0.63	0.80	0.82	0.86	0.89	0.81
Maximum	1.17	1.18	1.37	1.33	1.43	1.29	1.18	1.23

NOTES:

1. ARCH – ARCTIC CHAR.
2. NSSB – NINESPINE STICKLEBACK.
3. REALTIME – TOTAL NUMBER OF MINUTES ELECTROFISHING.
4. EFFORT – NUMBER OF MINUTES THE ELECTROFISHING UNIT WAS ENGAGED.
5. CPUE – CATCH-PER-UNIT-EFFORT EXPRESSED AS THE NUMBER ON INDIVIDUALS CAUGHT PER MINUTE.

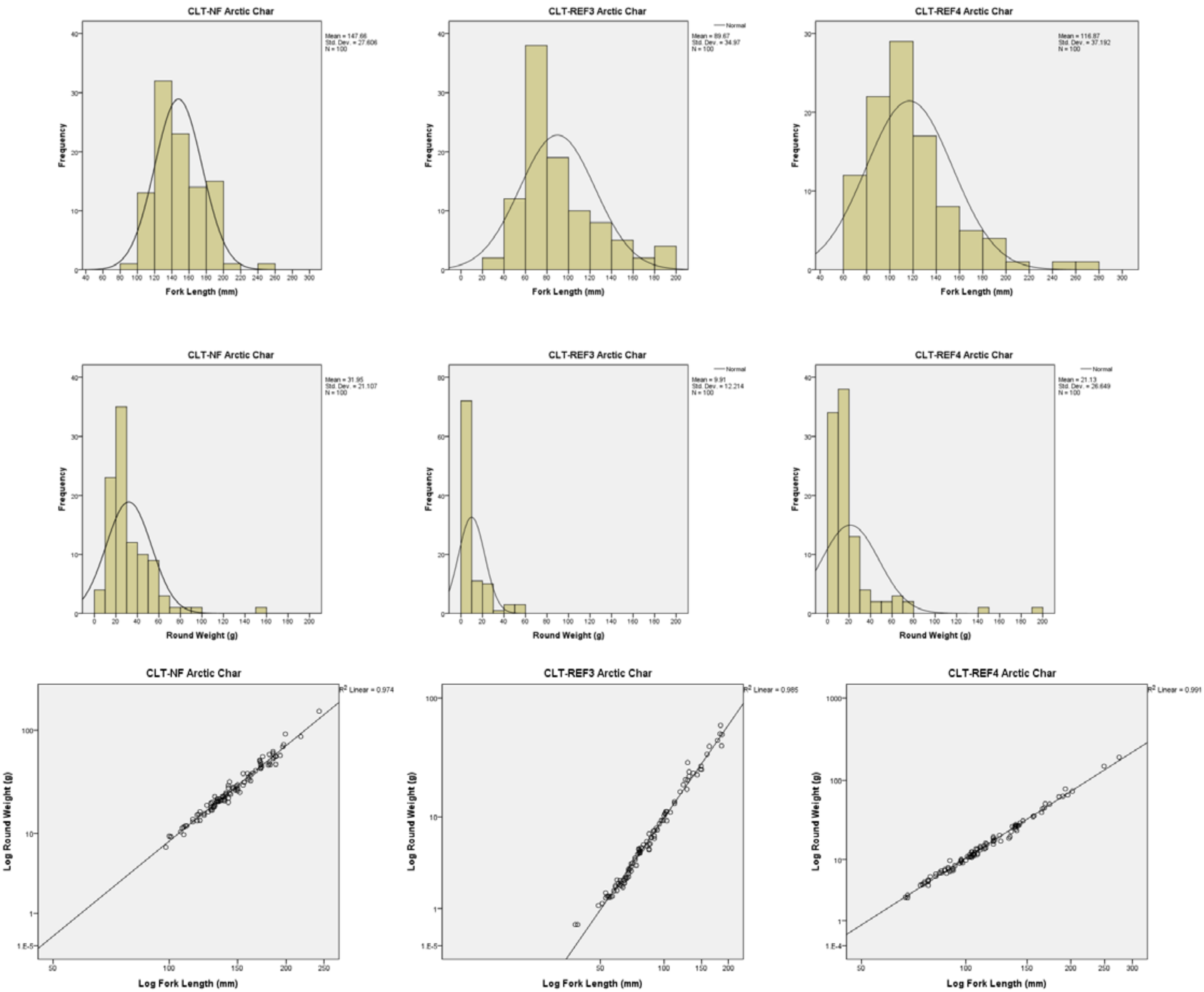

Figure E.1 Camp Lake Tributary Study Areas: Arctic Char Round Weight to Fork Length Data and Comparison

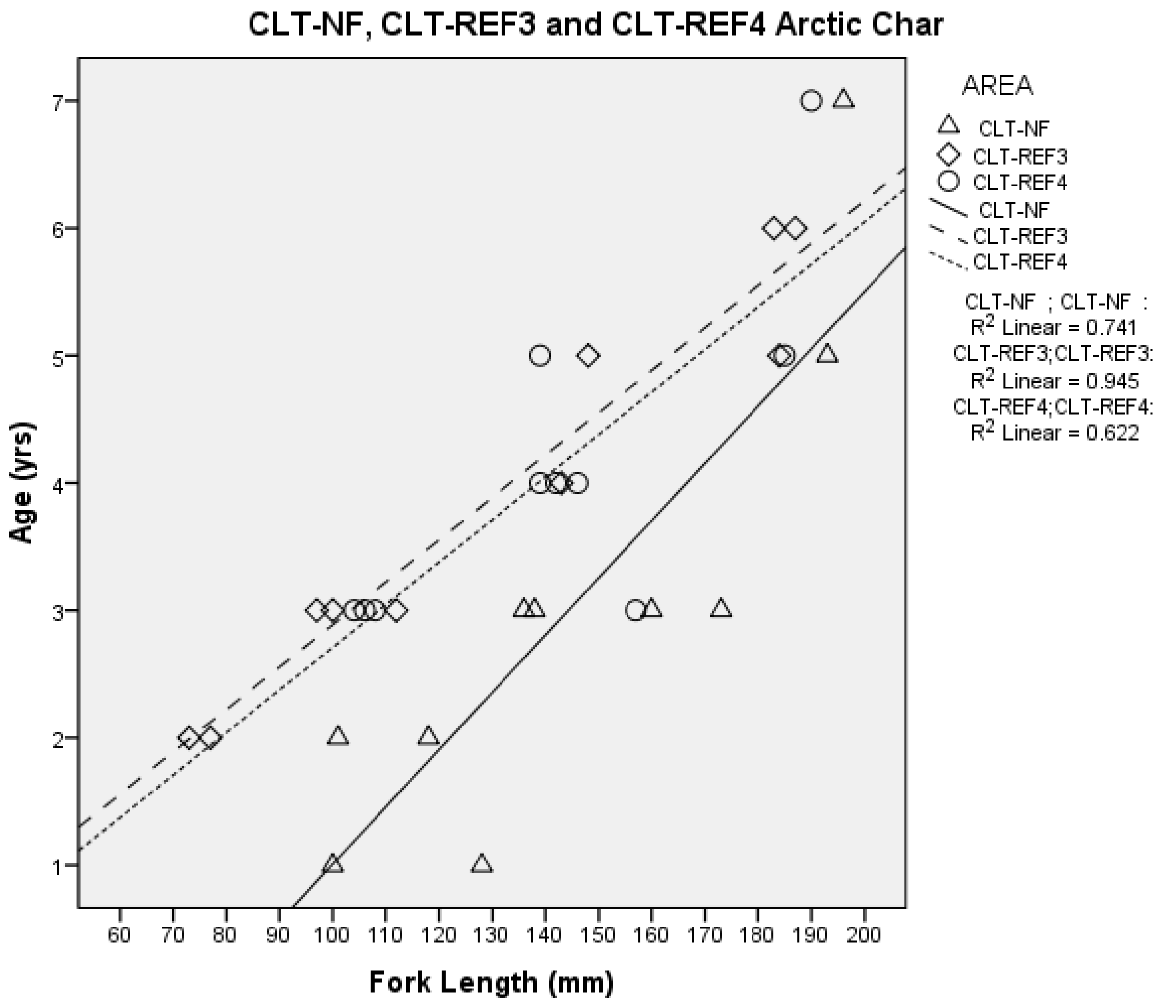

Figure E.2 Camp Lake Tributary NF, REF3 and REF4 Study Areas: Relationship between Arctic Char Age and Fork Length

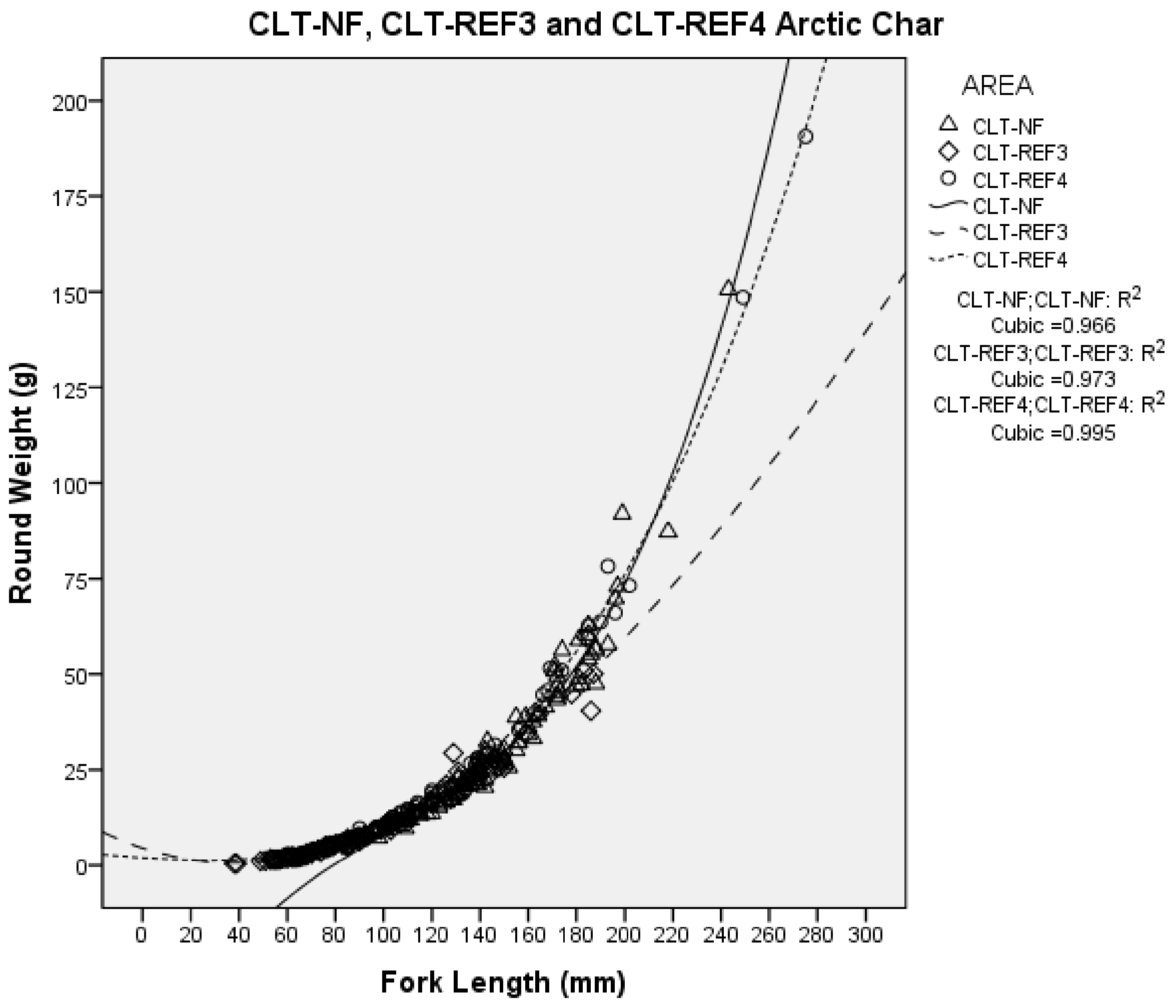

Figure E.3 Camp Lake Tributary NF, REF3 and EF4 Study Areas: Relationship between Arctic Char Round Weight and Fork Length

Table E.2 Camp Lake Tributary Study Areas: ARCH Fork Length and Round Weight Data Comparison Summary (Page 1 of 2)

Test of Normality

Measure	Area	Shapiro-Wilk			
		Statistic	df	p-value	Distribution at p>0.05
Fork Length (mm)	CLT-NF	0.964	100	0.008	Not Normal
	CLT-REF3	0.878	100	0.000	Not Normal
	CLT-REF4	0.874	100	0.000	Not Normal
Round Weight (g)	CLT-NF	0.798	100	0.000	Not Normal
	CLT-REF3	0.699	100	0.000	Not Normal
	CLT-REF4	0.565	100	0.000	Not Normal

Test of Homogeneity of Variance

Measure	Levene Statistic	df1	df2	p-value	Homogeneity of Variance at p<0.10
Fork Length (mm)	1.943	2	297	0.155	No – Variance homogeneous
Round Weight (g)	5.801	2	297	0.003	Yes – Variance not homogeneous

ANOVA Results – Fork Length

Source of Variation	Sum of Squares	df	Mean Square	F	p-value	Sig. at p<0.10
Between Groups	168356.8	2	84178.4	74.98	0.000	Y
Within Groups	333455.9	297	1122.8			
Total	501812.7	299				

ANOVA Results – Round Weight

Source of Variation	Sum of Squares	df	Mean Square	F	p-value	Sig. at p<0.10
Between Groups	24282.8	2	12141.4	27.9	0.000	Y
Within Groups	129179.3	297	435.0			
Total	153462.1	299				

Table E.2 Camp Lake Tributary Study Areas: ARCH Fork Length and Round Weight Data Comparison Summary (Page 2 of 2)

Multiple Comparison Post-hoc Test – Fork Length

Tukey HSD		Mean Difference	Std. Error	p-value	Difference Sig. at p<0.10	95% Confidence Interval	
Exposure Area	Comparison Area	(Exp. – Comp.)				Lower Bound	Upper Bound
CLT-NF	CLT-REF3	58.0	4.74	0.000	Y	46.8	69.2
	CLT-REF4	30.8	4.74	0.000	Y	19.6	42.0

Multiple Comparison Post-hoc Test – Round Weight

Games-Howell		Mean Difference	Std. Error	p-value	Difference Sig. at p<0.10	95% Confidence Interval	
Exposure Area	Comparison Area	(Exp. – Comp.)				Lower Bound	Upper Bound
CLT-NF	CLT-REF3	22.0	2.44	0.000	Y	16.3	27.8
	CLT-REF4	10.8	3.40	0.005	Y	2.8	18.9

NOTE:

1. SHADED CELLS INDICATE A SIGNIFICANT DIFFERENCE FROM THE EXPOSURE AREA AT P<0.10.

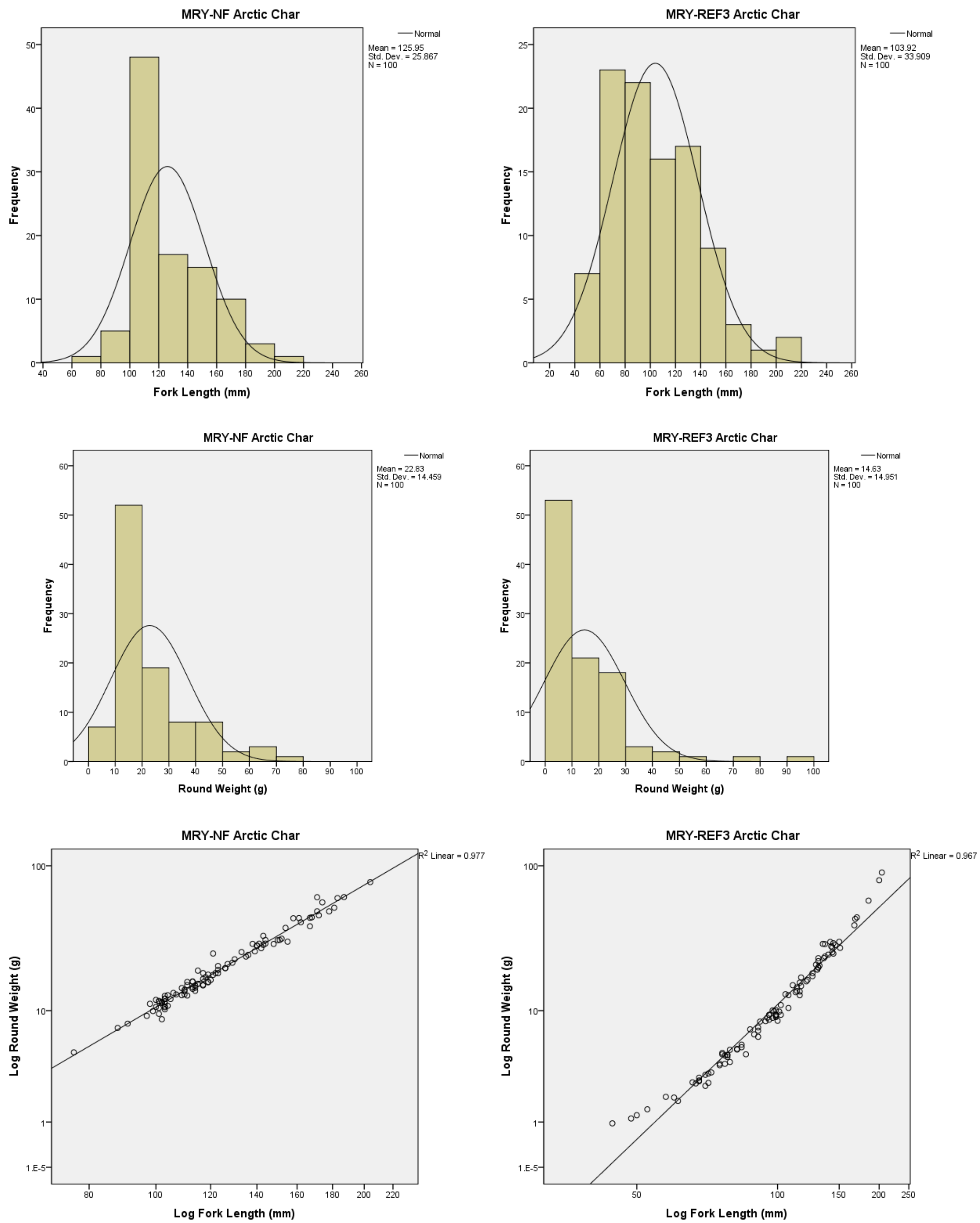

Figure E.4 **Mary River NF and REF3 Study Areas: Arctic Char Round Weight to Fork Length Data and Comparison**

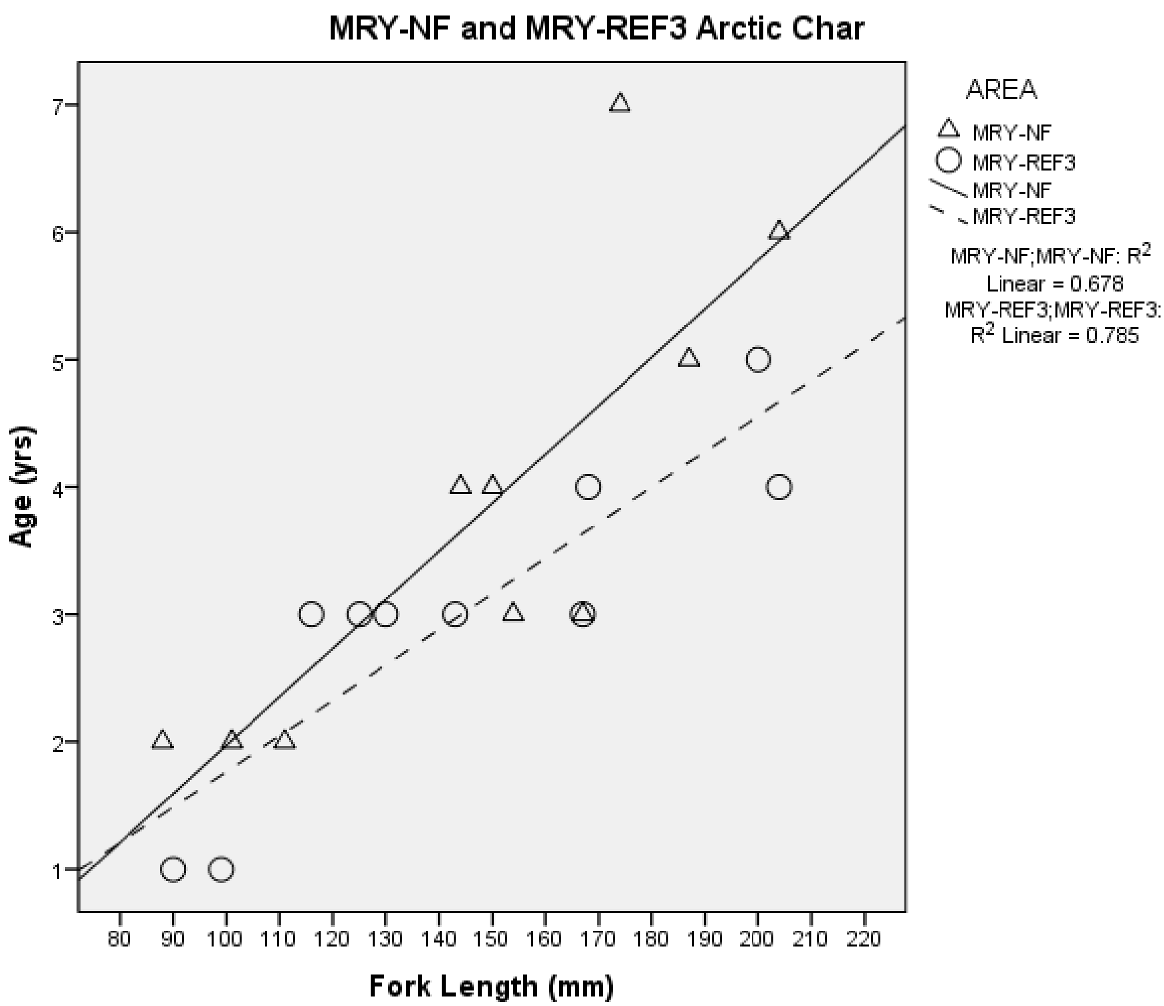

Figure E.5 Mary River NF and REF3 Study Areas: Relationship between Arctic Char Age and Fork Length

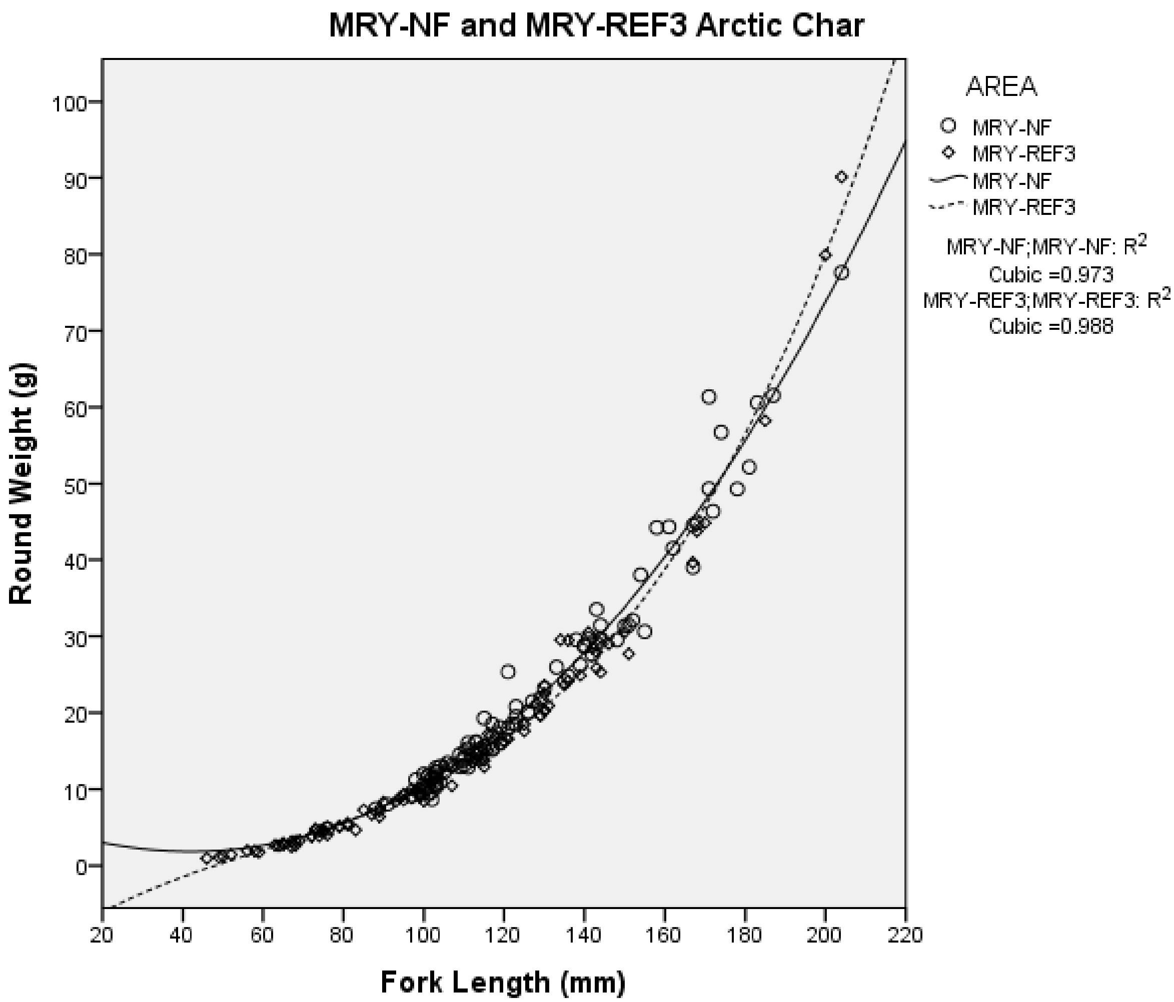

Figure E.6 Mary River NF and REF3 Study Areas: Relationship between Arctic Char Weight and Fork Length

Table E.3 Mary River Study Areas: ARCH Fork Length and Round Weight Data Comparison Summary (Page 1 of 2)

Test of Normality

Measure	Area	Shapiro-Wilk			
		Statistic	df	p-value	Distribution at p>0.05
Fork Length (mm)	MRY-NF	0.922	100	0.000	Not Normal
	MRY-REF3	0.965	100	0.009	Not Normal
Round Weight (g)	MRY-NF	0.834	100	0.000	Not Normal
	MRY-REF3	0.746	100	0.000	Not Normal

Test of Homogeneity of Variance

Measure	Levene Statistic	df1	df2	p-value	Homogeneity of Variance at p<0.10
Fork Length (mm)	6.808	1	198	0.01	Yes – Variance not homogeneous
Round Weight (g)	0.414	1	198	0.52	No – Variance homogeneous

ANOVA Results – Fork Length

Source of Variation	Sum of Squares	df	Mean Square	F	p-value	Sig. at p<0.10
Between Groups	24266.1	1	24266.1	26.682	0.000	Y
Within Groups	180072.1	198	909.5			
Total	204338.2	199				

ANOVA Results – Round Weight

Source of Variation	Sum of Squares	df	Mean Square	F	p-value	Sig. at p<0.10
Between Groups	3359.7	1	3359.7	15.533	0.000	Y
Within Groups	42825.1	198	216.3			
Total	46184.8	199				

Table E.3 Mary River Study Areas: ARCH Fork Length and Round Weight Data Comparison Summary (Page 2 of 2)

Multiple Comparison Post-hoc Test – Fork Length

Tukey HSD		Mean Difference	Std. Error	p-value	Difference Sig. at p<0.10	95% Confidence Interval	
Exposure Area	Comparison Area	(Exp. – Comp.)				Lower Bound	Upper Bound
MRY-NF	MRY-REF3	22.0	4.3	0.000	Y	11.0	33.1
Games-Howell		**Mean Difference**	**Std. Error**	**p-value**	**Difference Sig. at p<0.10**	**95% Confidence Interval**	
Exposure Area	**Comparison Area**	**(Exp. – Comp.)**				**Lower Bound**	**Upper Bound**
MRY-NF	MRY-REF3	22.0	4.3	0.000	Y	11.0	33.1

Multiple Comparison Post-hoc Test – Round Weight

Tukey HSD		Mean Difference	Std. Error	p-value	Difference Sig. at p<0.10	95% Confidence Interval	
Exposure Area	Comparison Area	(Exp. – Comp.)				Lower Bound	Upper Bound
MRY-NF	MRY-REF3	8.2	2.3	0.002	Y	2.3	14.1
Games-Howell		**Mean Difference**	**Std. Error**	**p-value**	**Difference Sig. at p<0.10**	**95% Confidence Interval**	
Exposure Area	**Comparison Area**	**(Exp. – Comp.)**				**Lower Bound**	**Upper Bound**
MRY-NF	MRY-REF3	8.2	2.1	0.001	Y	2.8	13.6

NOTE:

1. SHADED CELLS INDICATE A SIGNIFICANT DIFFERENCE FROM THE EXPOSURE AREA AT P<0.10.

Appendix C

Development of Water and Sediment Quality Benchmarks

SCIENCE INTEGRITY KNOWLEDGE

APPENDIX C

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

June 26, 2014

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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).

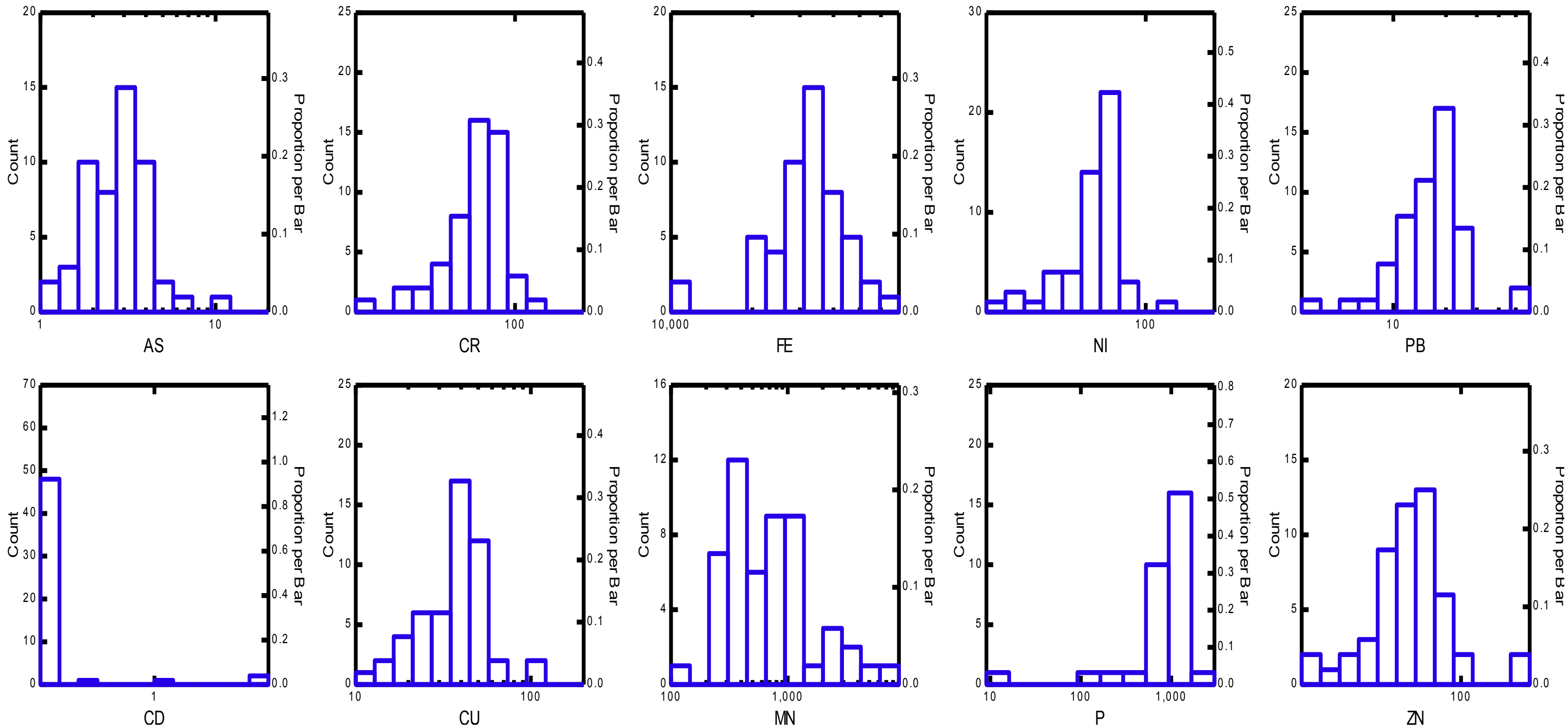

Figure 2-1 Log10 Histograms of Area-Wide Sediment Data (N=52), by Metal of Interest

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

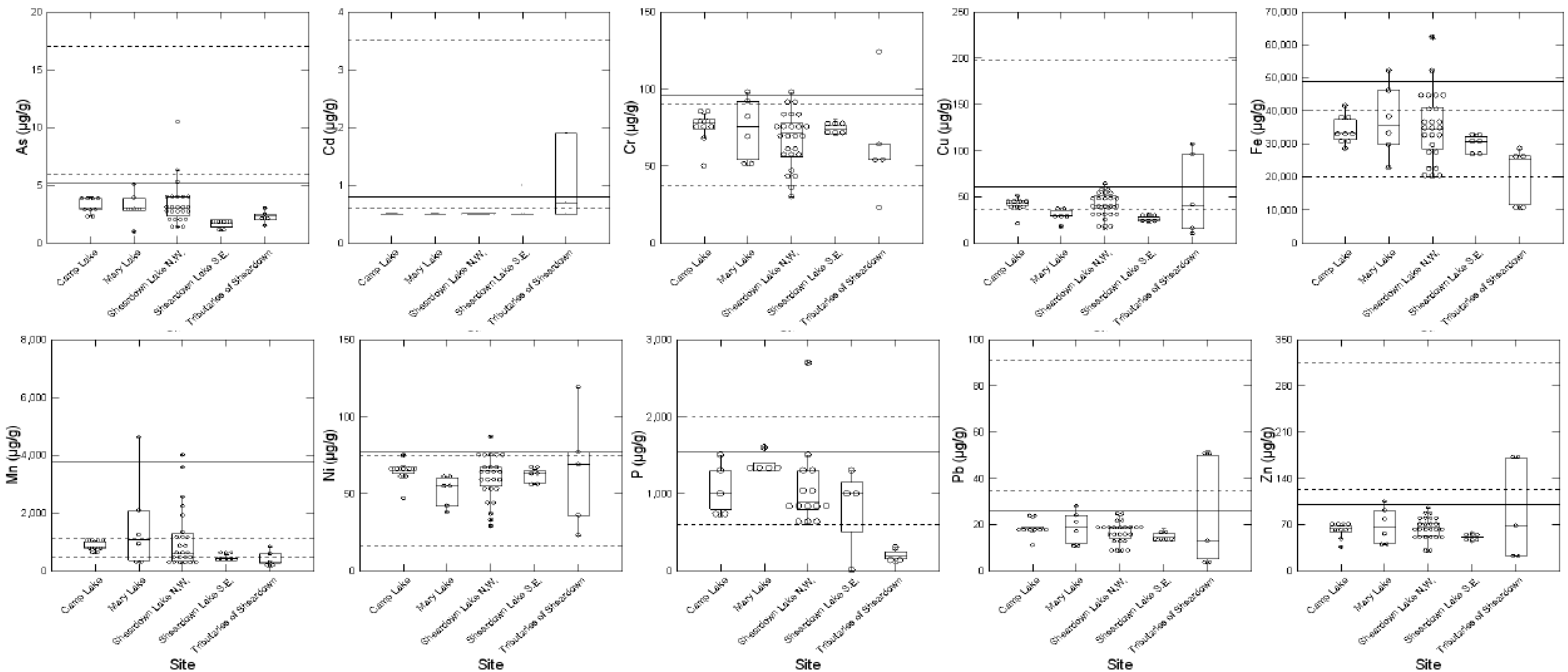

Figure 2-2 Box and Whisker Plots of Metal Concentrations by Area (Solid line represents 95th percentile of area-wide data; dotted lines represent ISQG/LEL and PEL/SEL sediment quality guidelines, respectively)

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.

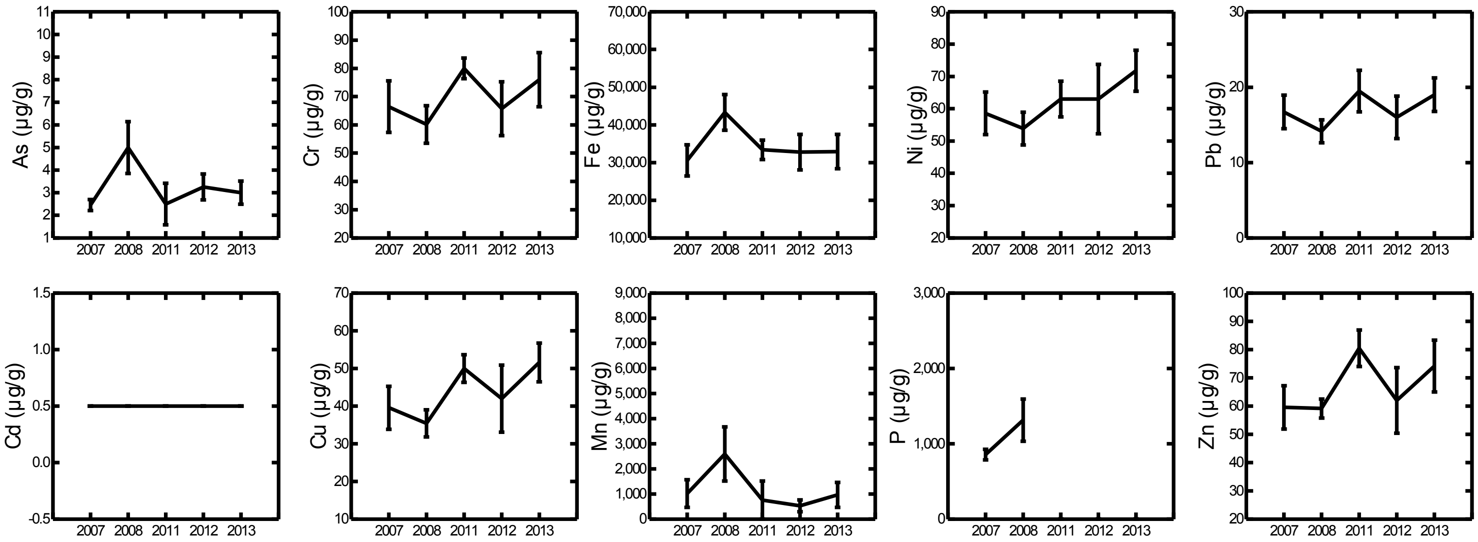

Figure 2-3 Temporal Trend Analysis for Sheardown Lake NW (n = 25) for Various Parameters (mean +/- std error)

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:

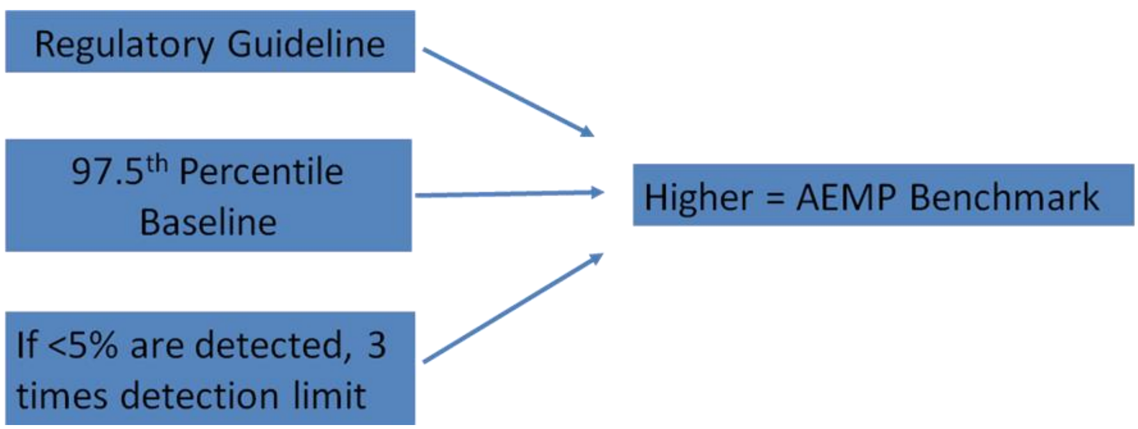

Figure 2-4 Approach for Selecting AEMP Benchmarks

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 97.5thpercentiles) are presented in Table 2-5 without the data from Tributaries of Sheardown Lake.

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

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

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

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

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

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

Notes:

NC = not calculated as all values < MDL

[a =] Tributaries of Sheardown Lake data are not included in interim benchmark development due to elevated results in this area.

A = guideline is based on sediment quality guideline

B = guideline is based on 97.5th%ile of baseline data

C= guideline is based on 3 times MDL, the 97.5th%ile is equal to the MDL

Mercury was not detected in any samples; mercury detection limit is used to represent the 95th and 97.5th percentiles.

C- 3.0 SURFACE WATER EVALUATION AND BENCHMARK DEVELOPMENT

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

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

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

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

Table 3-1 Identification of Metals/Metalloids Naturally Elevated in Area Water, Regulated under MMER and/or Potentially Elevated as a Result of Facility Releases or Having Existing Water Quality Guidelines under CCME

Substance	***Naturally Enriched in Area, Relative to WQG[a]***	***Regulated or Potential to be Regulated Under MMER***	***Potential to be Elevated Due to Mine Site Releases [a]***	***CCME PAL?***
Titanium	No	No	No	No
Uranium[e]	No	No	No	Yes
Vanadium	No	No	Yes [b]	Yes
Zinc	No	Yes	Yes	Yes

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

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

Table 3-2 Selection of General Parameters and Nutrients for Benchmark Development or Exploratory Data Analysis

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

In order to test the effects of pseudoreplication, the possible effects of adding both the deep and shallow data on the calculation of standard deviation and the empirical 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.

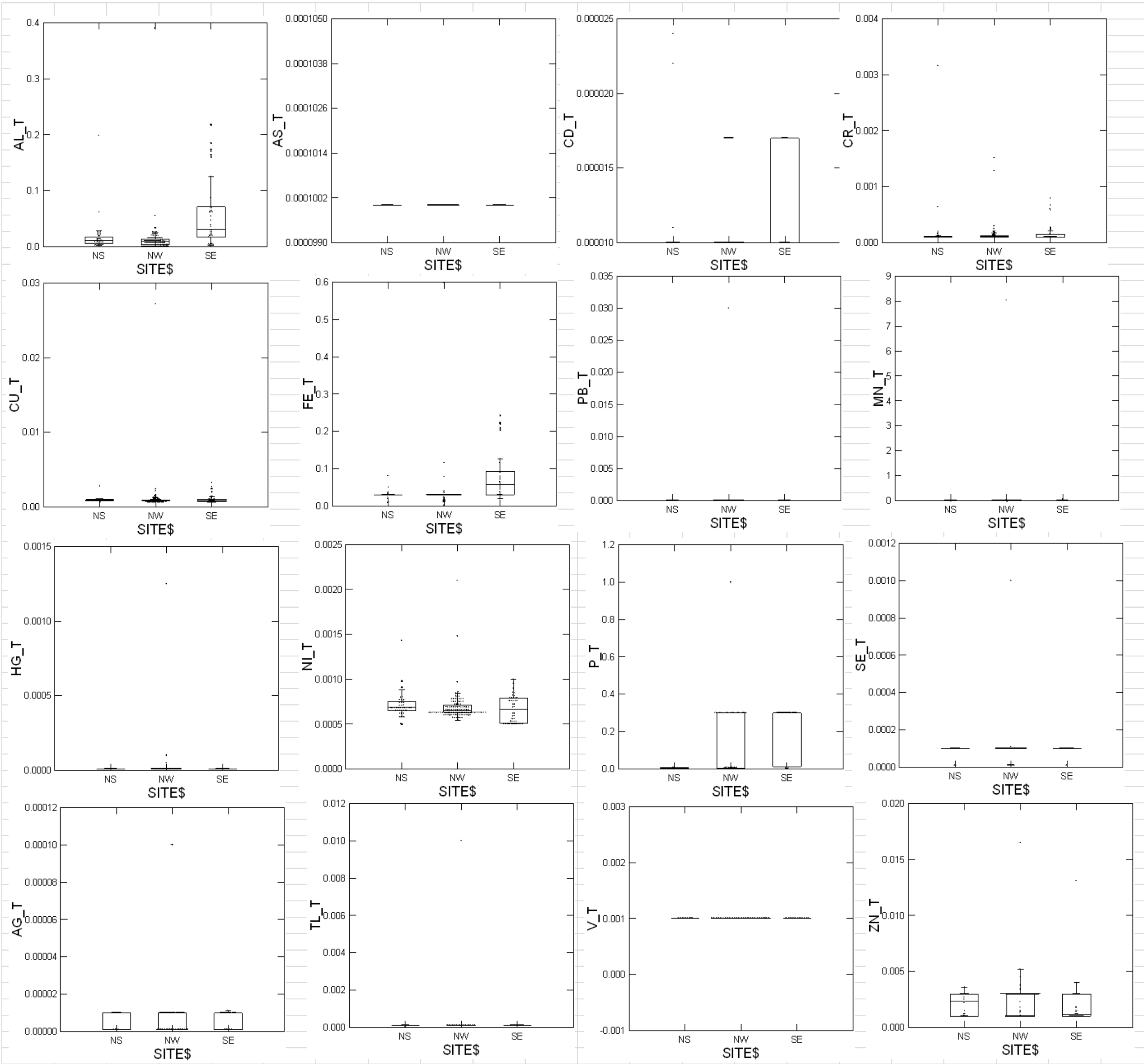

Figure 3-1 Total Metals (mg/L) Compared Between Various Sheardown Lake Sampling Locations (Nearshore (NS), Northwest (NW) and Southeast (SE)); T = total; Non-detectable values replaced with detection limit

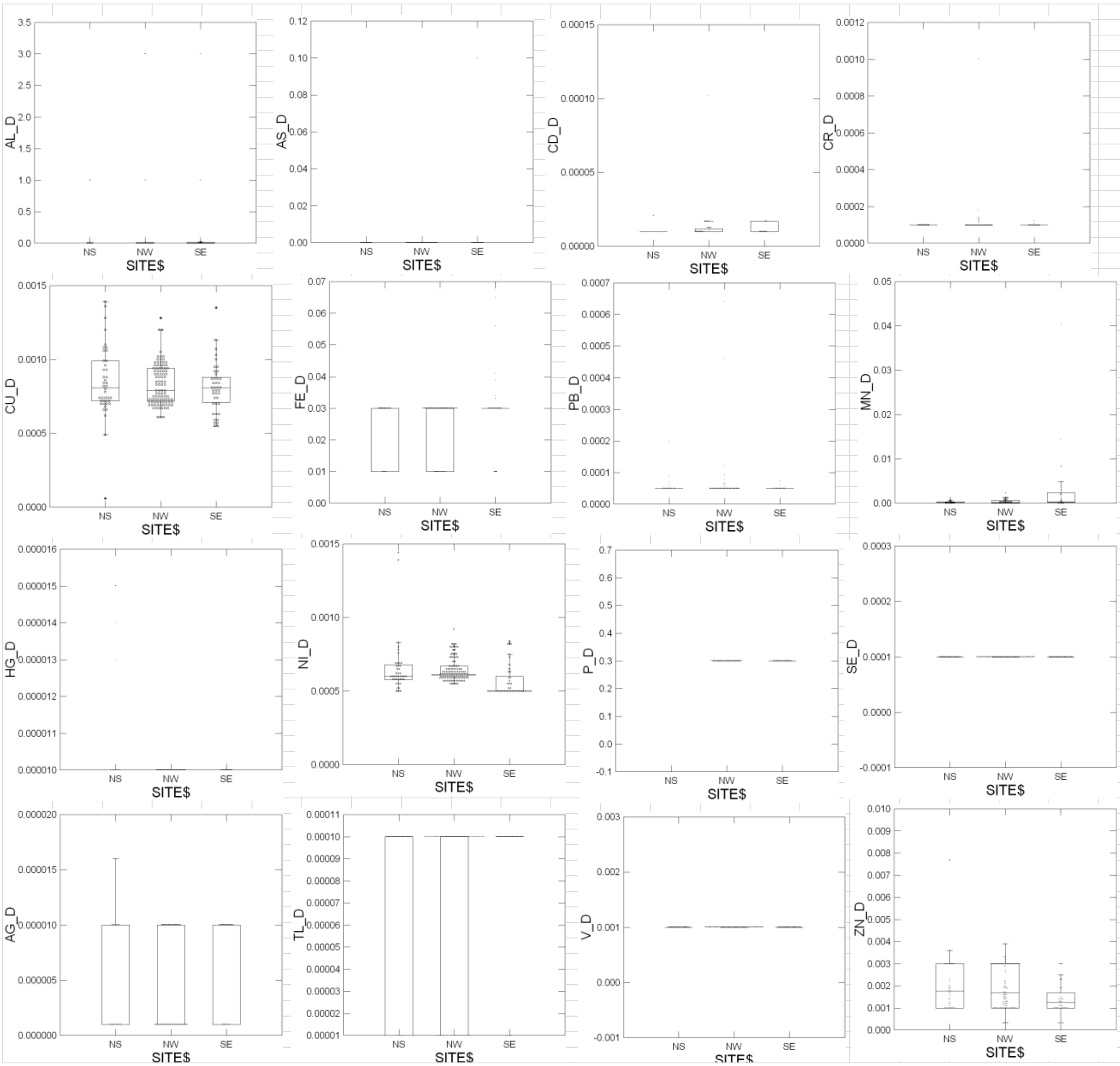

Figure 3-2 Dissolved Metals (mg/L) Compared Between Various Sheardown Lake Sampling Locations (Nearshore (NS), Northwest (NW) and Southeast (SE)); D = Dissolved; Non-detectable values replaced with detection limit

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	°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, 95^{th} percentile, 97^{th} percentile and mean were not calculated
f. mg/L as $CaCO_3$
g. Lowest detected value is less than the lowest non-detected value. Minimum value selected is the lowest detected value.

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

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

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

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

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

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

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

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

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

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

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

Table 3-13 Summary of Camp Lake Tributary Surface Water Analytical Data (Total Metals; 2005 to 2013)									
Parameter	***Units***	***N***	***% Detect***	***Min*** [b]	***Max*** [c]	***Median*** [d]	***95th %ILE*** [d]	***97.5th %ILE*** [d]	***Mean*** [d]
Metals [a]									
Aluminum	mg/L	88	90	<0.004	0.252	0.01	0.106	0.179	0.0247
Arsenic	mg/L	88	6	<0.0001	0.00554	0.0001	0.0001	0.00012	0.00016
Cadmium	mg/L	88	1[e]	<0.00001	0.000096[h]	NC	NC	NC	NC
Chromium	mg/L	88	36	0.000022[g]	0.003	0.0001	0.000699	0.000856	0.00020
Chromium $^{+3}$	mg/L	30	0	<0.005	<0.005	NC	NC	NC	NC
Chromium $^{+6}$	mg/L	30	0	<0.001	<0.001	NC	NC	NC	NC
Cobalt	mg/L	87	2	<0.0001	0.00013[h]	NC	NC	NC	NC
Copper	mg/L	85	95	<0.00001	0.00359	0.0016	0.00204	0.00222	0.00152
Iron	mg/L	88	75	<0.0001	0.44	0.05	0.190	0.326	0.0684
Lead	mg/L	56	20	<0.00005	0.00025[h]	0.00005	0.000268	0.000333	0.000094
Nickel	mg/L	52	75	0.000202[g]	0.00265	0.00077	0.00131	0.00168	0.00085
Silver	mg/L	87	0	<0.000001	<0.00001	NC	NC	NC	NC
Thallium	mg/L	71	14	<0.000001	0.00909	0.0001	0.0002	0.0002	0.00021
Vanadium	mg/L	86	1	<0.0009	0.001[h]	NC	NC	NC	NC
Zinc	mg/L	61	21	<0.00033	0.0104	0.003	0.0032	0.0035	0.00240
Water Quality Parameters									
Chloride (Cl^-)	mg/L	89	100	0.2[g]	121	2	17.8	23	6.06
Ammonia (NH^3+NH^4)	mg N/L	86	52	<0.02	0.8	0.02	0.475	0.60	0.087
Nitrite (NO_2^-)	mg N/L	86	15	0.002[g]	0.014[h]	0.005	0.06	0.095	0.015
Nitrate (NO_3)	mg N/L	89	9	<0.05	0.18	0.1	0.106	0.118	0.0961
Sulphate (SO_4^{2-})	mg/L	88	73	<0.5	8	3	5.7	6	2.8
Major Toxicity Modifying Factors for Guideline Development									
pH	-	84	NA	4.94	8.71	7.88	8.42	8.52	7.80
Hardness	mg/L [f]	87	NA	0.003	317	73.7	133.8	140	76.16
Temperature	^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) =* $[0.2 * e^{\{0.8545[\ln(hardness)]-1.465\}}] / 1000$.
d. Lead guideline based on 25^{th}%ile water hardness and following equation: *CWQG (mg/L)=* $[e^{\{1.273[\ln(hardness)]-4.705\}}] / 1000$
e. 30 day average; approved guideline
f. Nickel guideline based on 25^{th}%ile water hardness and following equation: *CWQG (mg/L) =* $[e^{\{0.76[\ln(hardness)]+1.06\}}] / 1000$.
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

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Appendix D

Development of Final Sediment Quality Benchmarks

SCIENCE INTEGRITY KNOWLEDGE

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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.

[illegible]

[illegible]

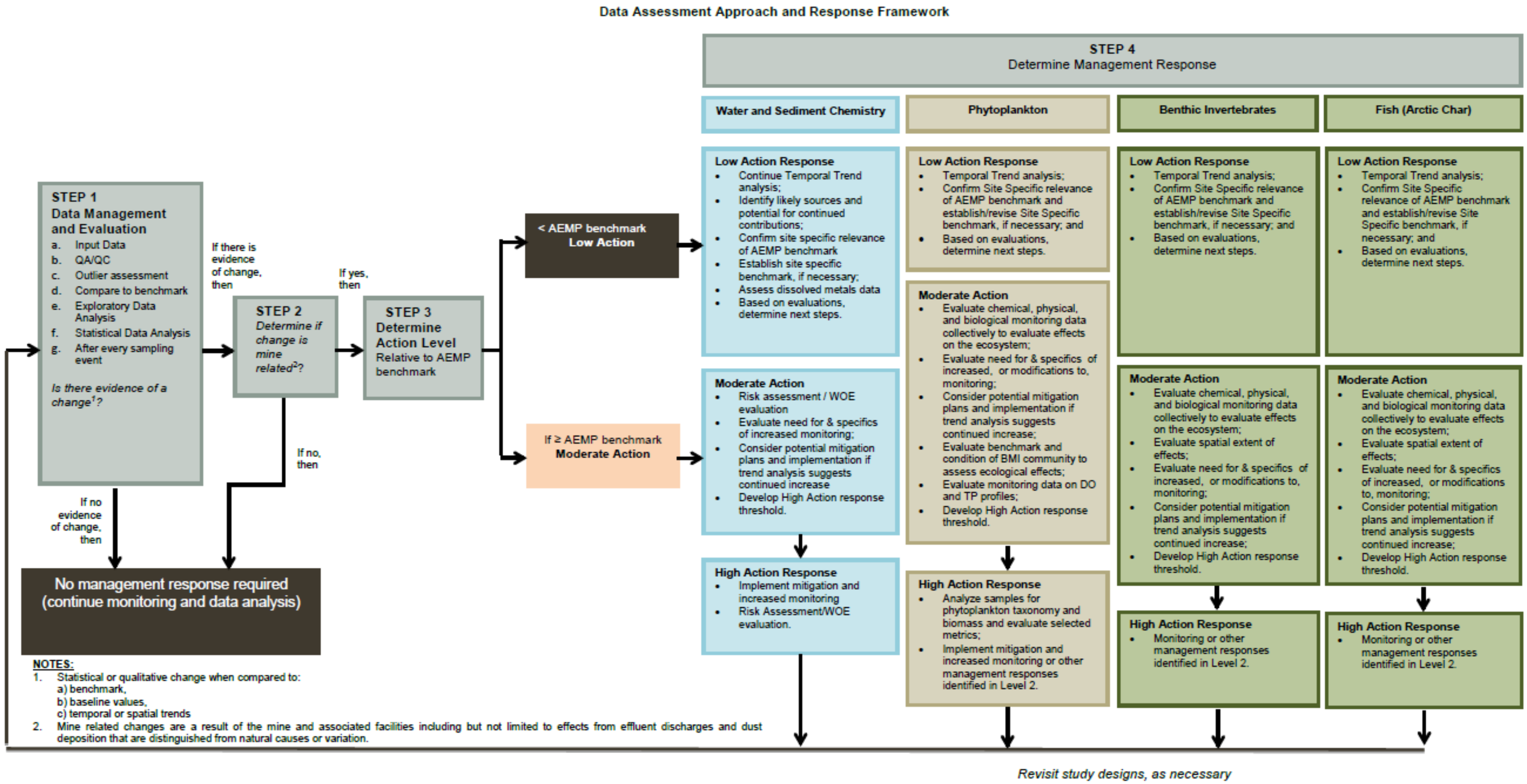
Baffinland Iron Ore Mines Corporation (Baffinland) operates the Mary River Mine in northern Baffin Island. As part of their license to operate, Baffinland is required to have an Aquatic Effects Monitoring Program (AEMP), to monitor the receiving environment for change, related to mining activities. The 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).

[illegible]

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:

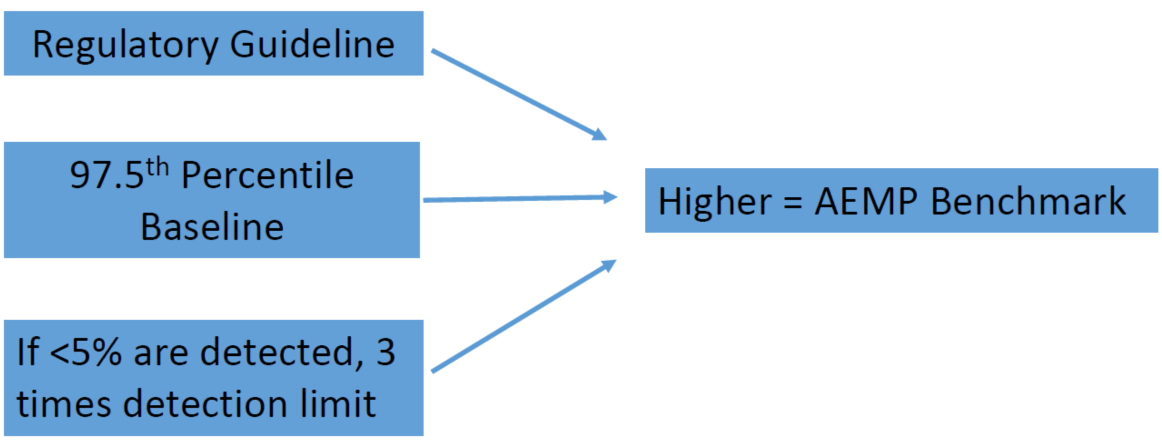
- A sediment and water quality monitoring program in lakes and rivers near to, and distant to the mine;
- A biological monitoring program which includes fish, benthos, and phytoplankton species in the same lakes and rivers as the sediment and water quality program is undertaken.

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.



Data Assessment Approach and Response Framework
STEP 4
Determine Management Response
Water and Sediment Chemistry
Phytoplankton
Benthic Invertebrates
Fish (Arctic Char)
STEP 1
Data Management and Evaluation
a. Input Data
b. QA/QC
c. Outlier assessment
d. Compare to benchmark
e. Exploratory Data Analysis
f. Statistical Data Analysis
g. After every sampling event
Is there evidence of a change1?
If there is evidence of change, then
STEP 2
Determine if change is mine related2?
If yes, then
STEP 3
Determine Action Level
Relative to AEMP benchmark
If no, then
If no evidence of change, then
< AEMP benchmark
Low Action
If ≥ AEMP benchmark
Moderate Action
No management response required
(continue monitoring and data analysis)
Low Action Response
Continue Temporal Trend analysis;
Identify likely sources and potential for continued contributions;
Confirm site specific relevance of AEMP benchmark
Establish site specific benchmark, if necessary;
Assess dissolved metals data
Based on evaluations, determine next steps.
Moderate Action
Risk assessment / WOE evaluation
Evaluate need for & specifics of increased monitoring;
Consider potential mitigation plans and implementation if trend analysis suggests continued increase
Develop High Action response threshold.
High Action Response
Implement mitigation and increased monitoring
Risk Assessment/WOE evaluation.
Low Action Response
Temporal Trend analysis;
Confirm Site Specific relevance of AEMP benchmark and establish/revise Site Specific benchmark, if necessary; and
Based on evaluations, determine next steps.
Moderate Action
Evaluate chemical, physical, and biological monitoring data collectively to evaluate effects on the ecosystem;
Evaluate need for & specifics of increased, or modifications to, monitoring;
Consider potential mitigation plans and implementation if trend analysis suggests continued increase;
Evaluate benchmark and condition of BMI community to assess ecological effects;
Evaluate monitoring data on DO and TP profiles;
Develop High Action response threshold.
High Action Response
Analyze samples for phytoplankton taxonomy and biomass and evaluate selected metrics;
Implement mitigation and increased monitoring or other management responses identified in Level 2.
Low Action Response
Temporal Trend analysis;
Confirm Site Specific relevance of AEMP benchmark and establish/revise Site Specific benchmark, if necessary; and
Based on evaluations, determine next steps.
Moderate Action
Evaluate chemical, physical, and biological monitoring data collectively to evaluate effects on the ecosystem;
Evaluate spatial extent of effects;
Evaluate need for & specifics of increased, or modifications to, monitoring;
Consider potential mitigation plans and implementation if trend analysis suggests continued increase;
Develop High Action response threshold.
High Action Response
Monitoring or other management responses identified in Level 2.
Low Action Response
Temporal Trend analysis;
Confirm Site Specific relevance of AEMP benchmark and establish/revise Site Specific benchmark, if necessary; and
Based on evaluations, determine next steps.
Moderate Action
Evaluate chemical, physical, and biological monitoring data collectively to evaluate effects on the ecosystem;
Evaluate spatial extent of effects;
Evaluate need for & specifics of increased, or modifications to, monitoring;
Consider potential mitigation plans and implementation if trend analysis suggests continued increase;
Develop High Action response threshold.
High Action Response
Monitoring or other management responses identified in Level 2.
NOTES:
1. Statistical or qualitative change when compared to:
a) benchmark,
b) baseline values,
c) temporal or spatial trends
2. Mine related changes are a result of the mine and associated facilities including but not limited to effects from effluent discharges and dust deposition that are distinguished from natural causes or variation.
Revisit study designs, as necessary

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.



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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.

[illegible]

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

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

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

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

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

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

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

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

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	[illegible]	0.486	17	3.5	90	197	NGA	NGA	NGA	NGA	91.3	315
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	[illegible]	2	33	10	110	110	40000	1100	75	2000	250	820
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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
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97.5th %ile: Sheardown Lake SE (2007 – 2014) (N = 11)		<0.1	2	1	79	56	34,400	657	66	1278	18	63
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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
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[illegible]

* = 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.

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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

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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.

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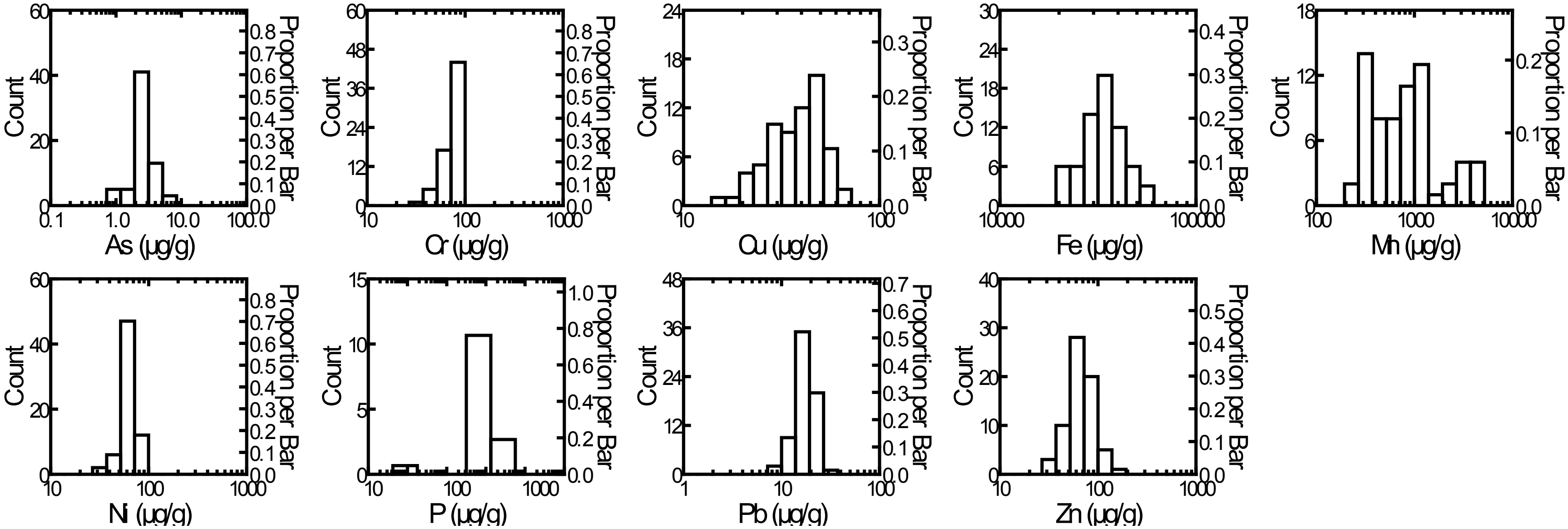
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Cu (µg/g)
Fe (µg/g)
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Ni (µg/g)
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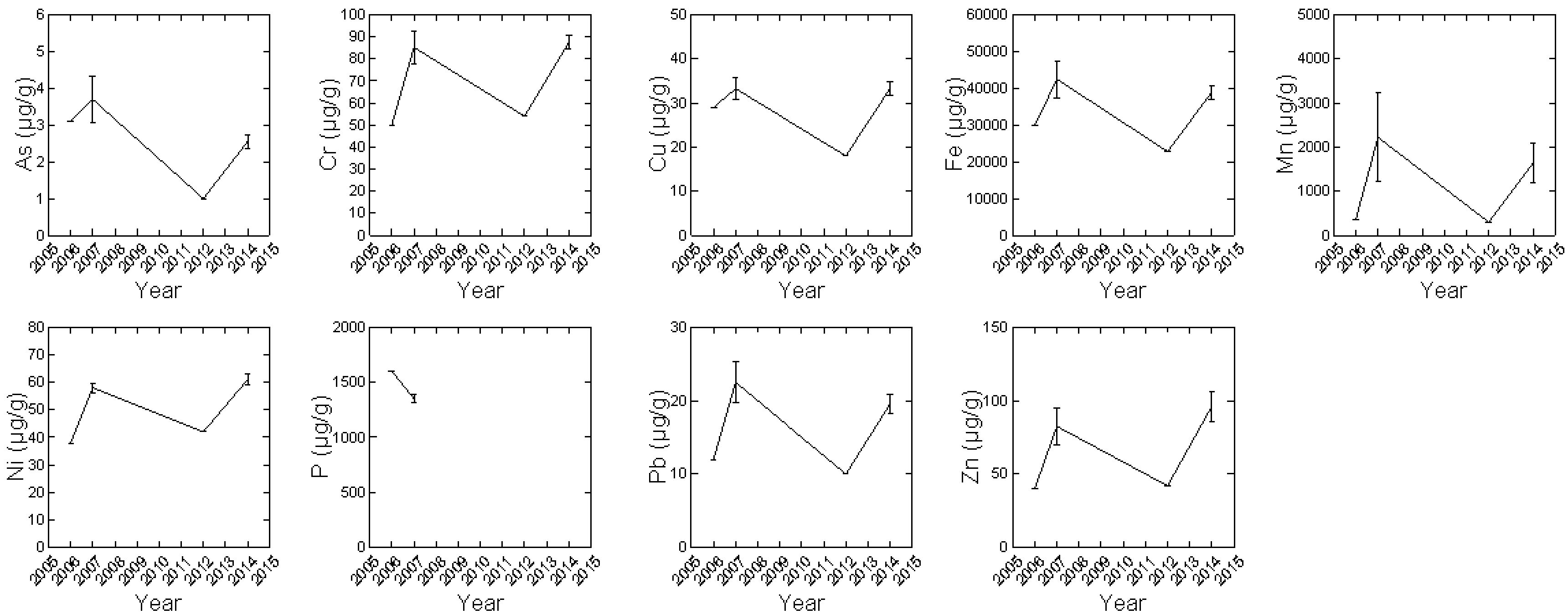
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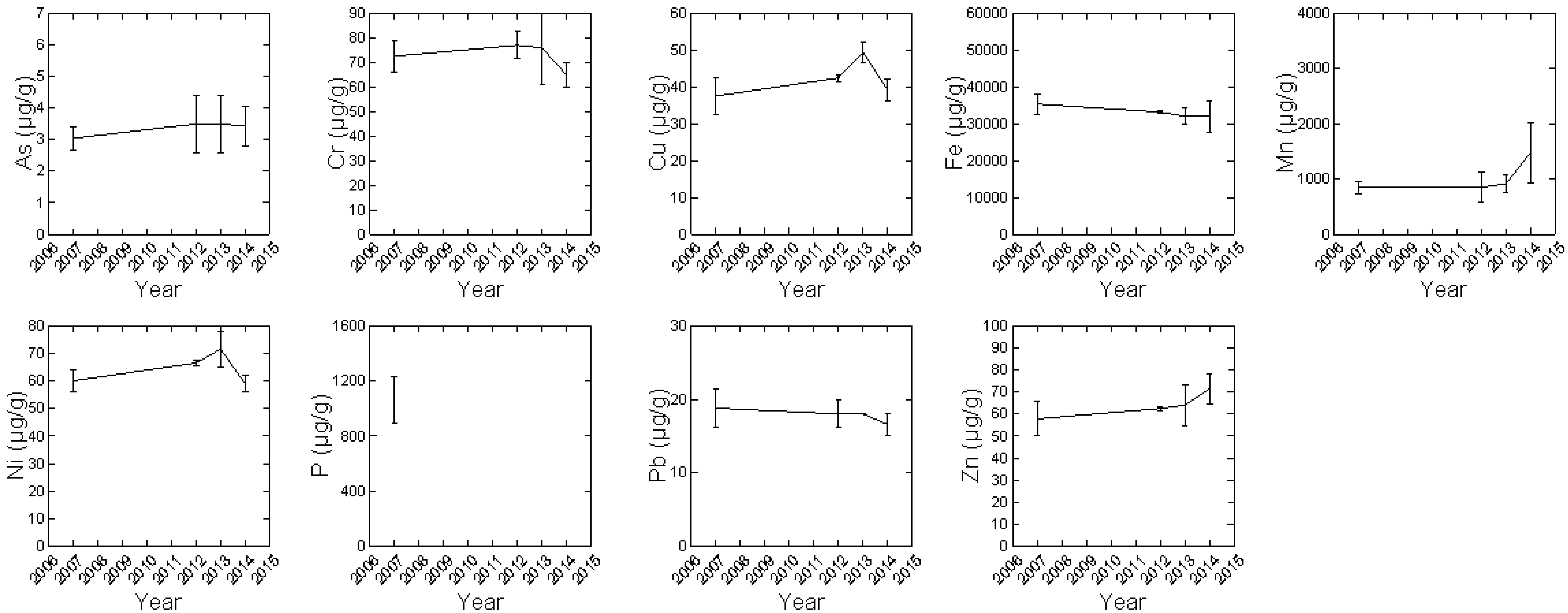
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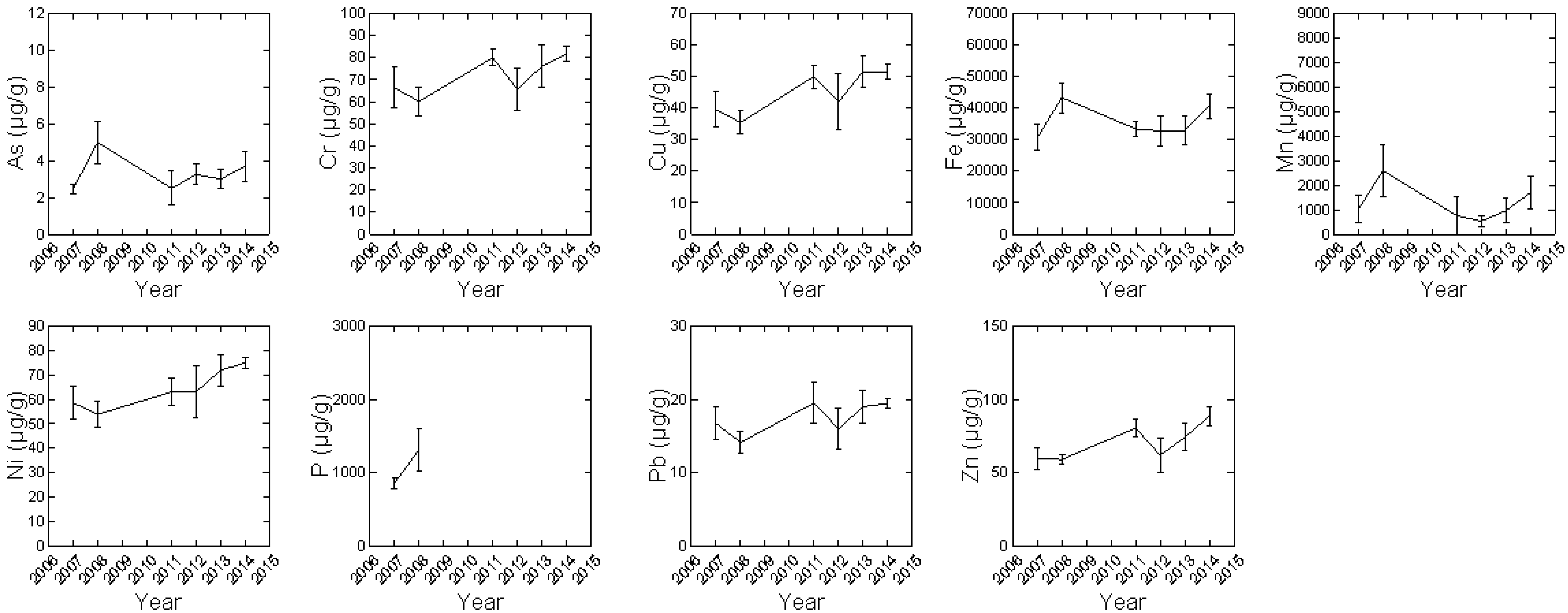
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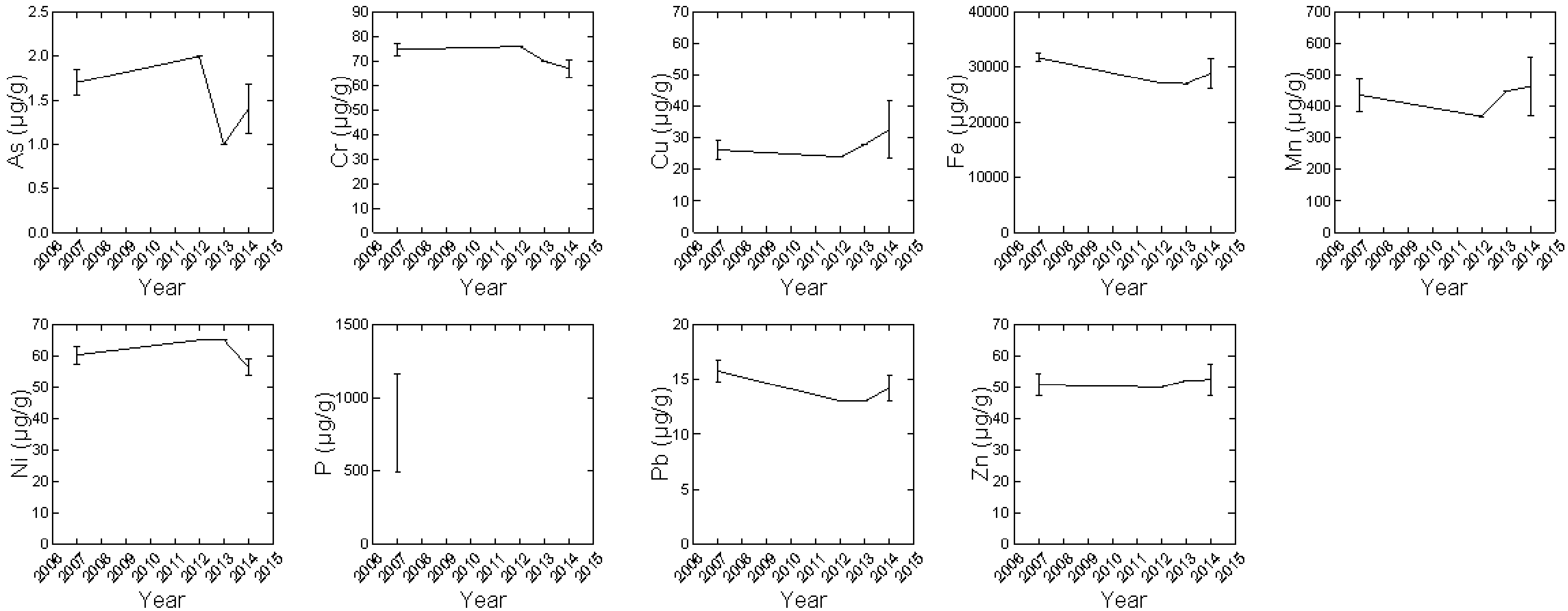
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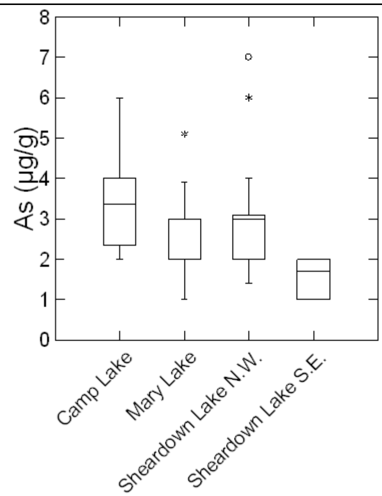
Arsenic		[illegible]	0.468	0.774	[illegible]	0.909	[illegible]	[illegible]

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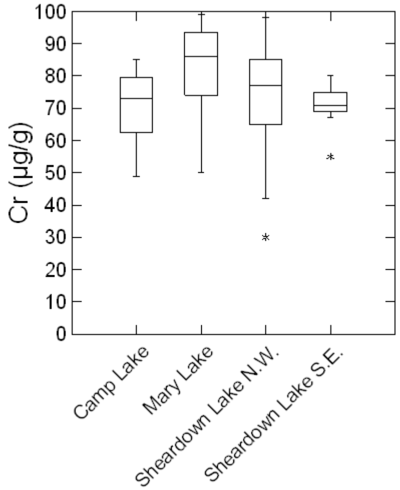
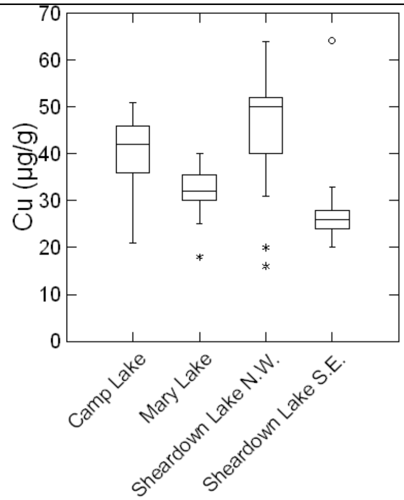
Chromium		0.222	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]
Copper		[illegible]	0.108	0.503	[illegible]	[illegible]	0.627	[illegible]

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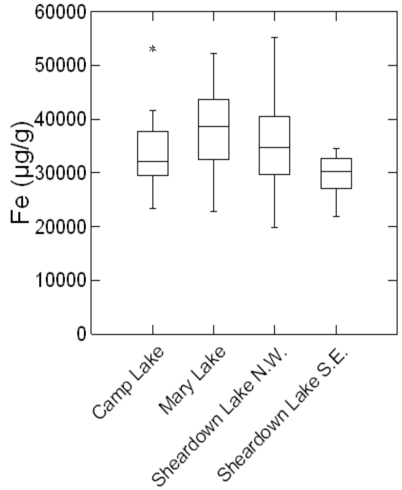
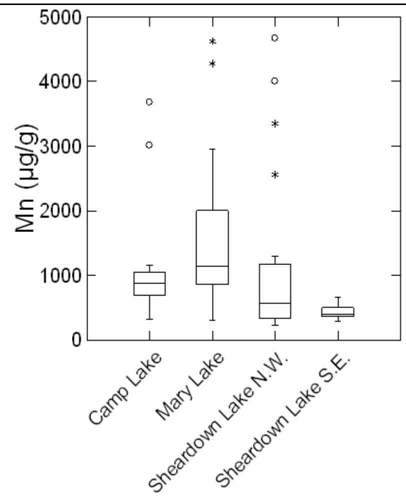
Iron		0.073	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]
Manganese		[illegible]	0.785	0.654	[illegible]	0.143	[illegible]	0.257

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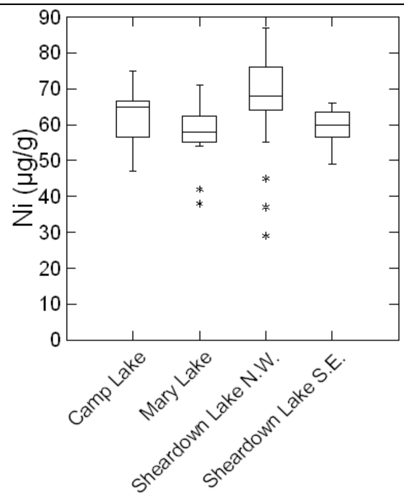
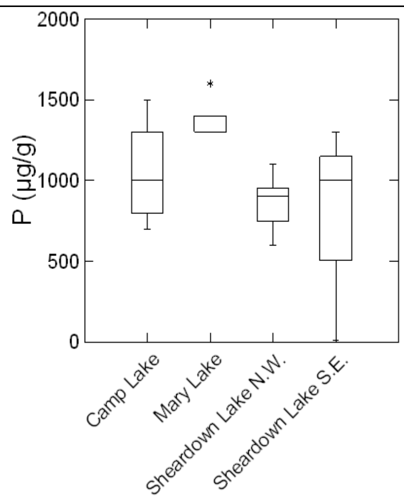
Nickel		0.147	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]
Phosphorus		0.233	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]

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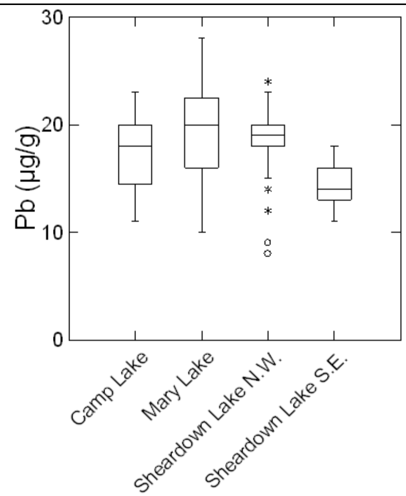
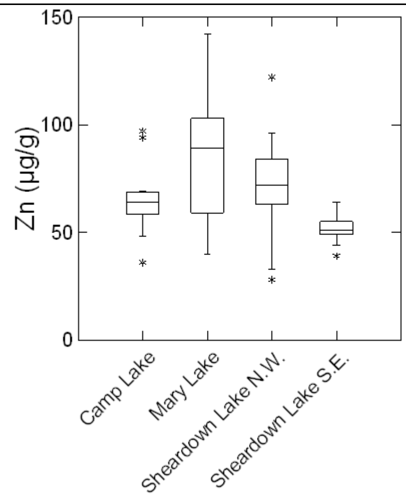
Lead		0.071	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]
Zinc		[illegible]	0.153	0.784	0.244	0.485	[illegible]	[illegible]

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Notes –

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

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

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

Appendix E

Freshwater Biota CREMP Study Design

Baffinland

Mary River Project

April 2016

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

Baffinland

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.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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