
**LEGEND:**

- HISTORIC WATER QUALITY SAMPLE LOCATION
- ACTIVE WATER QUALITY SAMPLE LOCATION
- DIRECTION OF WATER FLOW
- MAJOR CONTOUR
- MINOR CONTOUR
- EXISTING TOTE ROAD
- PROPOSED RAILWAY ALIGNMENT
- PROPOSED CONSTRUCTION ACCESS ROAD
- PROPOSED SITE INFRASTRUCTURE
- RIVER/STREAM/DRAINAGE
- EEM REPLICATE TRANSECT
- WATER
- EEM STUDY DESIGN EXPOSURE AREA

**NOTES:**

1. BASE MAP: © HER MAJESTY THE QUEEN IN RIGHTS OF CANADA, DEPARTMENT OF NATURAL RESOURCES (2009). ALL RIGHTS RESERVED.
2. COORDINATE GRID IS UTM NAD83 ZONE 17.
3. CONTOUR ARE IN METRES. CONTOUR INTERVAL IS 2 m.
4. ORTHO PHOTOS PROVIDED BY EAGLE MAPPING (2006).
5. GOOGLE IMAGERY OBTAINED NOVEMBER 6 2012.

SCALE 200 100 0 200 400 600 800 m

BAFFINLAND IRON MINES CORPORATION

MARY RIVER PROJECT

**MARY RIVER FAR FIELD EEM EXPOSURE AREA**

Knight Piésold CONSULTING

| P/A NO. | REF NO. | |
|---|---|---|
| NB102-181/33 | NB13-00586 | |
| FIGURE 6.5 | | REV 0 |

| REV | DATE | DESCRIPTION | DESIGNED | DRAWN | CHK'D | APP'D |
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| 0 | 15NOV'13 | ISSUED WITH TRANSMITTAL | DKK | AS | RAC | RAC |

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### 6.3.3 Mary River Alternate Far Field Exposure Area

The Mary River Alternate Far Field (MRY-AFF) Exposure Area has been included in this study design in order to provide an option for a far field exposure area should the originally proposed MRY-FF area be deemed unsuitable. The MRY-AFF is located approximately 3km upstream of Mary Lake. Station C0-01 is located at the downstream extend of the MRY-AFF exposure area and has been utilized for baseline environmental monitoring. This study area was not visited during the 2013 site characterization program and will only be considered following receipt and analysis of all characterization data.

Ongoing baseline surface water quality monitoring at station C0-01 has been conducted in 2005, 2006, 2007 and 2012. Sediment quality sampling at station C0-01 was conducted in 2005, 2007 and 2012. A fish community survey has not been conducted at this location. Electrofishing will not be conducted in this area since the MMERs only require collection of fish data in the near field exposure areas and the references areas.

## 6.4 MARY RIVER REFERENCE AREAS

Four candidate reference areas were visited during the 2013 site characterization program. These streams are between 11 km and 27 km away from the MRY-NF exposure area. Three of these candidate areas are in separate drainage basins from MRY-NF. These areas include drainage basins located north of Inuktorfik Lake and two areas near the rail alignment north of Angajurjualuk Lake. The fourth candidate reference area is located on the Mary River, upstream of the Mary River waterfall.

### 6.4.1 Mary River Reference Area 1

Mary River Reference Area 1 (MRY-REF1) flows in a southwest direction, this unnamed stream reports to Inuktorfik Lake east of the Ravn River as shown on Figure 6.2. The land immediately adjacent to the stream is relatively flat. Site characterization in 2013 measured the wetted width at five replicate transects that ranged from 30 m to 44 m. Riparian vegetation includes grasses, mosses, and wildflowers. The dominant substrate is gravel followed by coarse sand (Wentworth, 1922). The substrate of MRY-REF1 has nearly equal ratios of these particle sizes, unlike the higher percentage of gravel at the exposure areas.

Backpack electrofishing captured 26 Arctic char with a low CPUE of 1.2 individuals caught per minute of electrofishing effort. This CPUE indicates this area may not be suitable for an EEM fish population study. The fork lengths measured from these individuals indicate all fish were older than YOY. There was 26 Ninespine stickleback captured from this area in 2013.

Photos 29 to 32 in Schedule 8 show the MRY-REF1 candidate reference area.

### 6.4.2 Mary River Reference Area 2

The Mary River Reference Area 2 (MRY-REF2) is located along the proposed rail alignment. This stream flows in a southern direction reporting to north shore of Angajurjualuk Lake. This area is marginally within the predicted dust plume of the mine as illustrated on Figure 6.2.

The land immediately adjacent to the stream is relatively flat. Site characterization in 2013 measured the wetted width at five replicate transects that ranged from 30 m to 44 m. Riparian vegetation includes grasses, mosses, and wildflowers. The dominant substrate is gravel followed by coarse sand (Wentworth, 1922). The substrate of MRY-REF1 has nearly equal ratios of these particle sizes, unlike the higher percentage of gravel at the exposure areas.

Backpack electrofishing captured 22 Arctic char with a very low CPUE of 0.7 individuals caught per minute of electrofishing effort. The fish sampling activities at this area were only conducted in the downstream reaches and were ended prematurely due to weather conditions. Additional fishing effort may yield higher CPUE in the upstream reaches of this study area. The fork lengths measured from these individuals indicate all fish were older than YOY. There was no Ninespine stickleback captured from this area in 2013.

Photos 33 to 26 in Schedule 8 show the MRY-REF2 candidate reference area.

Baseline data collection programs have been conducted in this area that included station S2-010 and BR-011-1. Baseline surface water quality monitoring at station S2-010 was conducted in 2006 and 2011. Sediment quality sampling has not historically been conducted at this location. An aquatic habitat assessment at station BR-011-1 located upstream of station S2-010 was completed in 2008.

### 6.4.3 Mary River Reference Area 3

Mary River Reference Area 3 (MRY-REF3) is also located along the proposed rail alignment. This stream flows in a south west direction reporting to Angajurjualuk Lake near the outlet of the Ravn River. This area is outside of the predicted dust plum, approximately 27 km south east of the exposure areas.

The land immediately adjacent to the stream is relatively flat. Site characterization in 2013 measured the wetted width at five replicate transects that ranged from 26 m to 46 m. Riparian vegetation includes grasses, mosses, and wildflowers. The dominant substrate is gravel followed by coarse sand (Wentworth, 1922). The substrate of MRY-REF3 was most similar to the substrate found at the near field study area.

Backpack electrofishing captured 114 Arctic char with a moderate CPUE of 2.0 individuals caught per minute of electrofishing effort. This CPUE is higher than the CPUE results from the near field exposure area. The fork lengths measured from the first 100 individuals indicate 93 fish were older than YOY. There was no Ninespine stickleback captured from this area in 2013.

Photos 37 to 40 in Schedule 8 show the MRY-REF3 candidate reference area.

Baseline data collection programs have been conducted in this area that included station S2-020 and BR-025-1. Surface water quality monitoring at station S2-020 was conducted in 2006 and 2011. Sediment quality sampling has historically been conducted at this location. An aquatic habitat assessment was conducted at station BR-025-1 that is located upstream of station S2-020. A fish community survey was also completed at BR-025-1 in 2008.

### 6.4.4 Mary River Reference Area 4

Mary River Reference Area 4 (MRY-REF04) is located upstream of the MR waterfall outside of the predicted dust plume. The land immediately adjacent to the stream has a gentle slope similar to the MRY-FF exposure area. Site characterization in 2013 measured the wetted width at five replicate transects that ranged from 22 m to 30 m. Riparian vegetation includes grasses, mosses, and wildflowers. The dominant substrate is gravel followed by coarse sand (Wentworth, 1922). The substrate of MRY-REF4 was most similar to the substrate found at the far field study area. Since MRY-REF4 is located upstream of the Mary River waterfall, no fishing effort was made.

Photos 41 to 44 in Schedule 8 show the MRY-REF3 candidate reference area.

Baseline data collection programs have been conducted in this area that included surface water quality monitoring at station G0-09 conducted in 2006, 2007, 2012 and 2013. Sediment quality monitoring at station G0-09 was conducted in 2006, 2007, 2009, 2010 and 2012. Similarly, baseline benthic invertebrate and fish community surveys have also taken place at G0-09.

## 6.5 STUDY DESIGN METHODOLOGY

### 6.5.1 Effluent Plume Delineation Study

Site characterization will include an effluent plume delineation study to confirm the estimated effluent concentration and the manner in which mine effluent will mix with the receiving environment. The effluent plume delineation study will follow guidance provided in the *Revised Technical Guidance on How to Conduct Effluent Plume Delineation Studies* document available from Environment Canada (2003) as well as information provided in the technical guidance document for EEM (EC, 2012).

Effluent discharge has been estimated for the MMER final discharge points. The 10-year low flow conditions of the receivers were generated during baseline studies using hydrology data from Project stations (Table 6.2).

The three final discharge points to the Mary River will have a total estimated effluent discharge of 3,340,600 $m^3$/yr. The estimated 10-year low flow conditions of Mary River at the furthest downstream discharge point (E0-21) are 56,793,000 $m^3$/yr. The effluent concentration is estimated to be 6%, with little dilution between E0-21 and the outlet to Mary Lake.

**Table 6.2 Estimated Mine Effluent and Baseline Receiving Water Flows**

| EFFLUENT SOURCE | RECEIVING WATER | STATION ID | BASELINE RECEIVER DISCHARGE AT STN ($m^3$/yr) | ESTIMATED EFFLUENT DISCHARGE ($m^3$/yr) |
|---|---|---|---|---|
| East Pond (MS-09) | Mary River | E0-10 | 53,166,000 | 3,133,000 |
| ROM Pond (MS-07) | Mary River | E0-12 | N/A | 97,600 |
| Ore Stockpile Runoff (MS-06) | Mary River | E0-21 | 56,793,000 | 110,000 |
| | | **TOTAL** | **56,793,000** | **3,340,600** |
| West Pond (MS-08) | Camp Lake Tributary (upstream of L0) | L1-09 | 332,100 | 354,100[1] |
| West Pond (MS-08) | Camp Lake Tributary (upstream of Camp Lake) | L0-01 | 410,100 | 354,100[1] |
| | | **TOTAL** | **410,100** | **354,100** |

**NOTES:**
1. DISCHARGE DATA PROVIDED IN THE FINAL ENVIRONMENTAL IMPACT ASSESSMENT (BAFFINLAND, 2012).

Camp Lake Tributary will receive effluent from the West Pond (MS-08). Effluent concentrations have been estimated at station L1-09, which is located upstream of the L1 and L0 stream confluence (Table 6.2). The estimated 10-year low flow conditions of Camp Lake Tributary, at station L0-01, which is upstream of the outlet to Camp Lake, is 410,110 $m^3$/yr. The estimated effluent concentration in Camp Lake Tributary, before reporting to Camp Lake is 46%.

Based on these calculations, effluent concentrations in the Mary River and Camp Lake Tributary are estimated to be greater than 1% within 250 m of the final discharge points.

### 6.5.2 Water Quality Monitoring

Sampling and analysis of water quality will be undertaken as part of the first cycle EEM study to compare the current water quality of the reference locations to that of the exposure locations. Water quality samples will be taken concurrently with sediment and benthic sampling unless otherwise noted. Samples will be obtained by sub-surface grabs at least 15 cm below the surface (for total water depths of less than 2.0 m) directly into pre-labelled laboratory sample containers. Sampling will proceed from the least "impacted" areas (reference areas) to the most "impacted" station. Field staff will wear nitrile gloves at all times during sampling.

All samples will be preserved according to protocol and stored at 4°C in a chilled cooler until delivered for laboratory analysis. Sample identification, date, time and other pertinent project information will be recorded in a field logbook, on the sample container and on the Chain of Custody (COC) forms.

All water samples will be submitted to the selected analytical laboratory for the following analyses as prescribed by the MMER and the technical guidance document: total metals (Ag, Al, As, Ba, B, Be, Bi, Ca, Cd, Co, Cr, Cu, Fe, Hg, K, Mg, Mn, Mo, Ni, Na, Pb, Sb, Se, Si, Ti, Te, U, V, Zn, Ra 226), CN-, hardness, dissolved anions (Cl-, F-, SO2-4, NO2-, NO3-), total suspended solids, alkalinity, NH3, total P, total organic carbon and pH.

Detection limits for the above parameters will be at or below the site specific receiving water quality criteria based on the CCME guidelines for the protection of freshwater aquatic life. Field measurements of standard water quality parameters; pH, conductivity, dissolved oxygen (DO), temperature and stream discharge will also be recorded at each study area using portable instruments, calibrated daily with standards of known value.

For QA/QC purposes a laboratory prepared trip blank will accompany all water samples during sampling and transport. Field blanks for 10% of the samples will also be performed. In addition, three discrete water quality samples will be collected at each study area as recommended in the technical guidance document (EC, 2012). Laboratory blanks, duplicates, spikes and reference standards will be employed according to standard operating procedures. COC forms will accompany all samples for identification, tracking and transporting purposes. The level of QA/QC employed will provide confidence in the data collected.

### 6.5.3 Sediment Quality Monitoring

Sampling and analysis of sediment quality will be carried out as part of the first cycle EEM program to compare the current sediment quality of the reference locations to that of the exposure locations. Surficial sediment samples (top 2 cm) will be collected from all sampling areas, concurrently with water quality and benthic sampling, using a core-type sampler. Samples will be obtained for chemical, particle size and total organic carbon (TOC) analyses. One discrete sediment sample will be obtained for each replicate benthic sample transect (i.e. five samples from each exposure and reference area) when possible.

Where coarse substrate such as sand, gravel or cobble exists, samples will be obtained for particle size analysis as related to the benthic invertebrate sample stations. The existing baseline data indicates few depositional areas are present in the high energy exposure environments. All samples will be placed in clean, pre-labelled glass jars as per the analytical laboratory requirements. All samples will be kept chilled at 4°C until samples are delivered for laboratory analysis.

All sediment samples submitted to the laboratory will be analyzed for the following chemical parameters; metals (Ag, Al, As, Ba, Be, Bi, Ca, Cd, Co, Cr, Cu, Fe, Hg, K, Mg, Mn, Mo, Ni, Pb, Sb, Se, Ti, Te, U, V, Zn) P, B, S, Si and pH. Particle size distribution and TOC analyses will also be performed on each sample.

For QA/QC purposes, one field duplicate sample will be collected for every ten sediment samples, and will be analyzed separately. COC forms will accompany all samples for identification, tracking and transporting purposes. The level of QA/QC employed will provide confidence in the data collected.

#### 6.5.4 Benthic Invertebrate Survey

A benthic invertebrate community survey will be conducted as part of the first cycle EEM study as required by the MMER. The results of this survey will compare the current benthic invertebrate communities between the exposure and reference areas. It is proposed that the benthic invertebrate survey take place in the late summer or early fall (late July to late August), as previous studies have indicated that this is an appropriate season to ensure the collection of the widest diversity of invertebrates. The collection of benthic invertebrates will take place at the selected sampling areas.

For the benthic survey, the values of $\alpha$ and $\beta$ will both be set at 0.1. This will result in a power of 0.9. To achieve this, the sample size will be set at five. Five replicate stations will be located within each of the exposure and reference sampling areas. Each replicate station will be approximately six times the bankfull width apart.

The spatial extent of each sampling area will be approximately 30 times the bank-full width, or of ample distance to accommodate the required number of replicate samples. Three replicate field sub-samples will be collected at each of the five replicate stations (transects). The replicate field sub-samples will be collected and preserved as discrete samples and analyzed separately. These field sub-samples will be placed randomly within the replicate station so that all members of the benthic community within the area have an equal chance of being collected. Replicates are needed to ensure that a larger surface area at each station is collected, resulting in a larger proportion of the benthic community represented in the results.

Benthic samples will be collected from similar habitats at each of the monitoring areas. At all replicate stations and sampling areas the substrate type, stream width/depth, flow dynamics and vegetation will be evaluated prior to sample collection. The benthic samples will be collected using a Hess sampler at all the stations. The same collection gear will be used at all stations. All samples will be sieved in the field using a 500 micron sieve (tray or bucket).

The surficial area sampled will be recorded for each sample collected. Each replicate will be collected, stored separately and preserved with 10% buffered formalin solution. The habitat at each station will be described in detail while in the field, and the field collection record will be completed for each station. COC forms will accompany all samples for identification, tracking and transporting purposes.

Sample Processing

Benthic samples will be analyzed by a taxonomist. All samples will be sorted with the use of a stereomicroscope (10X). A second independent taxonomist will verify the original analyses.

Samples will be washed through a 500 micron sieve and sorted entirely, except in the following instances: those samples with large amounts of organic matter (i.e., detritus, filamentous algae) and samples with high densities of major taxa. In these cases, samples will be first washed through a large mesh size sieve (3.36 mm), to remove all coarse detritus, leaves, and rocks. Large organisms such as leeches, crayfish, fourth instar dragonflies, stoneflies, and mayflies retained in the sieve will be removed from the associated debris. The remaining sample fraction will be sub-sampled quantitatively, if necessary. Sorted organisms will be re-preserved.

Taxonomy

All invertebrates will be identified to the lowest practical level, usually family level. Additional identification of leeches, oligochaetes, stoneflies, mayflies (*Baetis, Stenomena* and *Hexagenia*), dragonflies, amphipods (*Gammarus*), adult beetles and bugs may be identified to species.

Chironimids and oligochaetes will be mounted on glass slides in a clearing media prior to identification. In samples with large numbers of oligochaetes and chironomids, a random sample of no less than 20% of the selected individuals from each group will be removed from the sample for identification, up to a maximum of 100 individuals.

Following identification and enumeration, a detailed list of individuals collected will be submitted for each replicate field sub-sample. The list will be in a standard spreadsheet format.

Data Evaluation

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

The variation among stations within the study area, among samples within the stations (field sub-samples) and analytical variation (among laboratory replicates) will be calculated as estimates of the components of variation in the data set and compared to the expected values.

The benthic community will be investigated to determine if mine discharge is having an effect on the receiving system, as defined by Environment Canada (2002). An effect will be deemed to have occurred in the benthic community when a significant statistical difference between the exposure and reference areas is found for one or more of the key descriptors. The critical effect size of +/- 2 standard deviations will be used for determining an effect as per the EEM technical guidance document (EC, 2012).

Using the standard community indices within an Analysis of Variance (ANOVA) model for control/impact designs, the benthic community at the exposure areas will be compared to their representative reference area(s) to determine effect and provide supporting data.

**Table 6.3 Benthic Invertebrate Community Survey Effect Indicators and Endpoints**

| EFFECT INDICATOR | EFFECT ENDPOINTS |
|---|---|
| Total benthic invertebrate density (TID) | Number of animals per unit area |
| Evenness index | Simpson's evenness |
| Taxa (family) richness | Number of taxa |
| Similarity index | Bray-Curtis index |

**NOTES:**

1. MODIFIED FROM METAL MINING TECHNICAL GUIDANCE DOCUMENT TABLE 3-1 (EC, 2012).

QA/QC

Triplicate field sub-samples from each replicate station will be 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 the EEM technical guidance document will be followed (EC, 2012). These measures will incorporate the proper steps related to re-sorting, sub-sampling and maintenance of a voucher collection, as needed. The voucher collection will be taxonomically analysed by a second invertebrate taxonomist.

### 6.5.5 Fish Community, Population and Usability Survey

Fish Community

Sufficient historic data have been collected to properly characterize the freshwater fish community in the study areas. Only two fish species are present in the exposure areas; Arctic char and Ninespine stickleback. A fish population survey will be conducted as discussed below; any new fish species collected during this study will be documented in the final interpretive report.

Fish Population

A fish population survey of the exposure and reference areas will be conducted as required under the MMER. This is required as the effluent concentration is estimated to be above 1% at a distance of 250 metres from the final discharge points. This study will attempt to collect sufficient numbers of the two sentinel species, Arctic Char and Ninespine Stickleback, to conduct statistical analyses at the appropriate power. All reasonable efforts will be made to collect sufficient numbers of fish; however, historic collection data indicates anticipated challenges for collection of sufficient numbers of Ninespine Stickleback. EC officials will be notified of insufficient collection numbers and an agreed upon course of action will be followed to complete the study.

Non-destructive capture methods will be employed as the primary methods for all fish population sampling. Non-destructive techniques will include electrofishing, trap-netting and minnow trapping, with electrofishing utilized as the primary means of conducting the survey. As noted in the site characterizations, the study areas provide habitat for immature fish. A non-lethal survey will pose less of an impact on the fish population than a lethal survey.

Sections of aquatic habitat within the vicinity of each sample area will be fished. The operator of the electrofishing unit will start at a downstream location (relative to the area) and fish in an upstream direction towards any natural barriers (e.g., riffle, waterfall or natural dam). In this manner, all fish resident in the section of stream being sampled can be captured for analysis. A summary table of the specific sampling dates, collection method, fish species and corresponding numbers collected as well as a calculated CPUE will be included in the final interpretive report.

The fish community survey will follow the non-lethal fish sampling requirements as outlined in the technical guidance document (EC, 2012). Attempts will be made to capture at least 100 individuals older than young of the year (+YOY) for each of the two sentinel species. Any YOY individuals collected will be measured and the proportion of fish that are YOY will be estimated from the first 100 fish collected.

All fish captured will be released alive except for a sub-sample to be retained for aging purposes. Table 6.4 and Table 6.5 outline the fish survey measurements and effect indicators proposed for this study.

**Table 6.4 Fish Survey Measurements, Expected Precision and Summary Statistics**

| MEASUREMENT REQUIREMENT | EXPECTED PRECISION | REPORTING OF SUMMARY STATISTICS |
|---|---|---|
| Length (fork and total) | +/- 1mm | Mean, median, SD, standard error, minimum and maximum values for sampling areas |
| Total body weight (fresh) | +/- 1.0% | Mean, median, SD, standard error, minimum and maximum values for sampling areas |
| Age | +/- 1year | Mean, median, SD, standard error, minimum and maximum values for sampling areas |
| Abnormalities | N/A | Presence of any lesions, tumours, parasites, or other abnormalities. |
| Sex | N/A | N/A |

**NOTES:**
1. MODIFIED FROM THE TECHNICAL GUIDANCE DOCUMENT TABLE 3-1 (EC, 2012).

**Table 6.5 Fish Population Effect Indicators and Endpoints**

| EFFECT INDICATOR | NON-LETHAL EFFECT AND SUPPORTING ENDPOINTS |
|---|---|
| Survival | Length-frequency distribution<br>Age-frequency distribution (if possible) |
| Growth | Length of YOY (age 0) at end of growth period<br>Weight of YOY (age 0) at end of growth period<br>Size of YOY+ (age 1+)<br>Size at age (if possible) |
| Reproduction | Relative abundance of YOY (% composition of YOY)<br>YOY survival |
| Condition | Body weight at length |

**NOTES:**
1. MODIFIED FROM THE TECHNICAL GUIDANCE DOCUMENT TABLE 3-3 (EC, 2012).

Aging using fin rays will be undertaken. The preservation of additional aging structures (otoliths) will be attempted. Aging structures will be removed from a minimum of 10% of the test populations sampled and from all incidental mortalities. The ratio of male/female specimens retained for age verification will be attempted.

Data will be tested for normality and homogeneity of variance prior to specific hypothesis testing. Transformations of the original data will be performed to normalize or homogenize the variances, where needed. An ANOVA model will be used to test for population differences related to the areas sampled (Reference versus Exposure), for length, weight, and condition factor provided the populations are normally distributed, of equal variance and independent of one another. An ANCOVA model will test for interactions for size-at-age and condition factor (length versus weight by area). These analyses will be robust enough to provide the required information to compare fish populations among areas during this study.

<u>Fish Usability</u>

Effluent quality has been estimated using humidity cell testing results of the ore, local precipitation volumes as well as contact time that precipitation will have with the ore and waste rock stockpiles. The effluent quality is not expected to contain mercury concentrations ≥ 0.01 µg/L, therefore a fish usability study is not proposed in this study design. Should effluent characterization results report concentrations of mercury ≥ 0.01 µg/L a fish usability study will be undertaken as required by the MMER.

## 6.6 SUMMARY AND NEXT STEPS

The 2013 field work confirmed in-situ conditions at the exposure areas and candidate reference areas. This information coupled with the currently outstanding data (e.g., benthic taxonomic identification and fish ageing data) will provide rationale for the selection of suitable reference areas. This section of the AEMP framework document will be updated in the next iteration, following review and analysis of the outstanding data. The anticipated EEM timeline that includes milestones associated with the MMER requirements is subject to change based on regulatory approvals and the start of mining.

| | |
|---|---|
| February 2014 | Benthic invertebrate taxonomic analysis completed for 2013 study |
| April-May 2014 | Mining begins with pre-stripping |
| June 2014 | Mine is subject to MMERs once effluent discharge rate reaches 50 $m^3$/day |
| August 2014 | Submission of Identifying Information & Final Discharge Points (within 60 days after date mine is subject to MMERs) |
| June-August 2014 | Summer field work if required (i.e., further characterization of study areas) |
| September 2014 | Submit Cycle One Study Design (12 months from initial date when Mine was subject to MMERs) |
| August-Sept 2015 | First Cycle Biological Monitoring Study (conducted no sooner than 6 months after Cycle One SD submission date) |
| December 2016 | Submit First Cycle Interpretive Report (within 30 months from initial date when Mine was subject to MMERs) |
| TBD | Subsequent Study Design submitted 6 months prior to subsequent Biological Monitoring Study |
| December 2019 | Subsequent Interpretive Report submitted 36 months following the date on which the previous interpretive report was to be submitted |

# 7 CORE RECEIVING ENVIRONMENT MONITORING PROGRAM

## 7.1 CREMP OVERVIEW

The Core Receiving Environment Monitoring Program (CREMP) is being established to monitor effects of the Project on the downstream aquatic environment. The CREMP focuses on follow-up monitoring to validate predictions to aquatic valued ecosystem components (VECs) and key indicators, as follows:

- Water quantity
- Water and sediment quality
- Freshwater biota (benthic invertebrates indicators, phytoplankton and Arctic Char)

The EEM study design (Section 6) identifies the exposure areas in the freshwater environment that will receive mine effluent discharges. The CREMP encompasses a larger geographic extent than the EEM program and is intended to monitor potential effects to the aquatic environment via other pathways such as dust deposition or changes in water flow due to diversions.

Based on the conclusions in the FEIS, mine site aquatic effects will be primarily confined to the Mary River, Camp Lake, Sheardown Lake and their associated tributaries. Mary Lake is the ultimate receiving water for these drainage areas, but is of sufficient size that detectable effects are not predicted. The CREMP includes monitoring in Mary Lake to confirm this prediction.

The CREMP is intended to monitor effects as follows:

- Camp and Sheardown Lake tributaries - will be affected by dust deposition and water diversions; Camp Lake Tributary 1 will receive waste rock stockpile runoff from the West Pond
- Sheardown Lake - will experience changes in water quality due to airborne dust dispersion and runoff, sewage effluent discharges from the exploration camp during construction, changes in hydrology, and potential changes in productivity to tributaries of Sheardown Lake
- Camp Lake – will receive runoff from tributaries affected by dust deposition and mine effluent (west pond), will be affected by water diversions and withdrawals, as well as changes in water quality due to airborne dust dispersion
- Mary River – will be subject to airborne dust dispersion and will receive three streams of mine effluent as well as treated sewage effluent
- Mary Lake – is the ultimate receiving waters of Camp Lake, Sheardown Lake and the Mary River

Ongoing monitoring of water quantity (hydrology) is discussed in Section 4.2. A description of the baseline integrity review underway for water quality, sediment quality and freshwater biota is provided below.

### 7.1.1 Review of Baseline Data for Water Quality

Baseline water quality information has been collected across the Mine Site area since 2005. The sampling locations provide excellent coverage of the mine site area watersheds, and standard sampling methodologies were consistently applied by the same field staff over nearly the entire sampling record. The baseline data collected from 2005 to 2013 is summarized in a baseline integrity review report (*in-progress*).

The water quality baseline review has included the following steps:

- Identification of the parameters of concern – the FEIS identified the following metals as parameters of potential concern: arsenic, cadmium, chromium, copper and iron
- Identification of trends in the baseline dataset – qualitative identification of locations within the study area that contain naturally elevated concentrations of metals
- A review of method detection limits – higher method detection limits (MDLs) in the historic dataset relative to current water quality objectives (WQOs) presents problems for statistical analysis. A process has been undertaken to remove high MDL results for select parameters from the database, or replace high MDL non-detect results with the lowest MDL values for metals for which a small proportion of the overall database contained detectable concentrations of the metal.
- Aggregation of sample locations – the water quality results for adjacent monitoring stations were reviewed to identify the potential to aggregate the data to increase the statistical power of the dataset
- Review of seasonality of sampling – the baseline dataset has consisted of spring (late June), summer (mid-July) and fall (late August to early September) sampling events
- Statistical analysis – to determine the number of samples required to detect a statistically significant change

The work is nearing completion. Additionally, in 2013, seasonal (spring, summer, fall) water quality sampling was undertaken at the CREMP monitoring locations identified in Figure 7.1.

### 7.1.2 Review of Baseline Data for Sediment Quality

A review of sediment quality data is underway concurrent with the water quality baseline review described above. Preliminary findings indicate that chromium and copper regularly exceed the CCME Interim Sediment Quality Guideline (ISQG) and iron and nickel regularly exceed the Ontario Lower Effect Level (LEL) guideline, and manganese regularly exceed the Ontario Probable Effect Level (PEL) guideline.

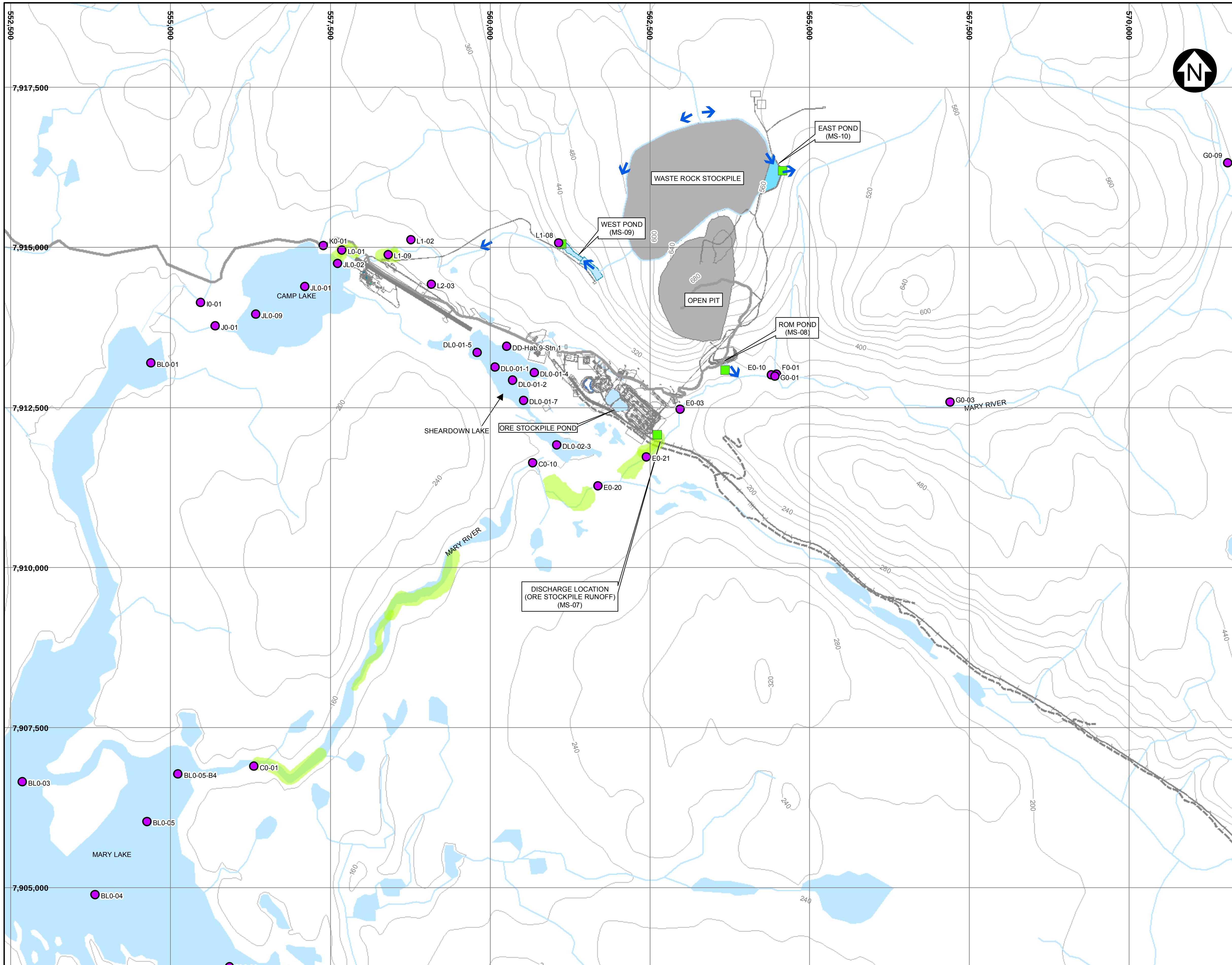
During the FEIS review, Environment Canada requested that Baffinland undertake thin sediment sampling in mine area lakes. This has been completed across the site in 2012 and 2013, and data analysis is underway.

### 7.1.3 Review of Baseline Data for Freshwater Biota

A workshop held on October 29-30, 2012 on aquatic effects monitoring identified several streams and lakes within the Mine Area that are either known to or anticipated to require biological monitoring during construction and/or operation. Specifically, two streams – Camp Lake Tributary 1 and the Mary River - will be the primary receiving environments of mine-related effluents and will be subject to EEM under the MMER (Section 6).

In addition, several other streams, as well as Camp Lake Tributary 1 and the Mary River, may be affected by other pathways of effect, including but not necessarily limited to sewage effluent discharge, dust deposition, changes in flows, and/or non-point sources. Camp, Sheardown, and Mary lakes, which receive drainage from these tributaries / streams may also be affected by these pathways.

A review of baseline data for phytoplankton, benthic invertebrates, and Arctic Char was completed in 2013 (NSC, 2013a). The review informed the design and conduct of additional baseline studies subsequently conducted in 2013. An overview of the freshwater biota and habitat field studies completed in the open-water season of 2013 is provided below.

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**LEGEND:**

- CORE RECEIVING ENVIRONMENTAL MONITORING PROGRAM (CREMP) (WATER, SEDIMENT, BENTHICS AND FISH)
- MINE EFFLUENT DISCHARGE LOCATION
- EXISTING TOTE ROAD
- PROPOSED RAILWAY ALIGNMENT
- PROPOSED CONSTRUCTION ACCESS ROAD
- PROPOSED SITE INFRASTRUCTURE
- RIVER/STREAM/DRAINAGE
- WATER

**CORE RECEIVING ENVIRONMENTAL MONITORING PROGRAM:**

- THIRD LEVEL OF MONITORING FOCUSES ON THE DOWNSTREAM AQUATIC ENVIRONMENT.
- INCLUDES WATER AND SEDIMENT QUALITY, BENTHIC INVERTEBRATES AND FISH.
- RELIES ON ESTABLISHED BASELINE SAMPLING LOCATION FOR WHICH BAFFINLAND HAS SEVERAL YEARS OF DATA.

**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. LAKE SAMPLE LOCATIONS VARY SLIGHTLY DURING WINTER MONTHS DUE TO ICE CONDITIONS.

SCALE 500 250 0 500 1,000 1,500 2,000 2,500 m

BAFFINLAND IRON MINES CORPORATION

MARY RIVER PROJECT

**CREMP WATER AND SEDIMENT MONITORING LOCATIONS**

Knight Piésold CONSULTING

| P/A NO. | REF NO. |
|---|---|
| NB102-181/33 | NB13-00586 |

FIGURE 7.1 REV 0

### 7.1.4 Phytoplankton

Samples for analysis of chlorophyll *a* were collected from Camp, Sheardown Lake NW and SE, and Mary Lake and at selected stream sites in association with the water quality sampling program conducted in 2013 to augment and update the baseline database for this component. Sampling was conducted two times in the open-water season at lake sites though not all sites were sampled during both sampling periods. Sampling in streams occurred between one and three times in the open-water season.

### 7.1.5 Benthic Invertebrates

Sampling of benthic invertebrate communities completed in the Mine Area water bodies through 2011 has been summarized in the baseline integrity review report (NSC, 2013a). Additional sampling was completed in fall 2013 to augment and update the baseline database and focused upon sampling in key (i.e., predominant) habitat types in Camp and Sheardown lakes (Figure 7.2). Five replicate stations were sampled in each of the targeted habitat types. Five sub-samples were collected at each replicate station and preserved separately to facilitate examination of variability between sub-samples (i.e., variability within a replicate station). Due to inclement weather, sampling was not conducted in Mary Lake in 2013. A total of 11 replicate stations (five in each of two habitats, one in the third targeted habitat type) were sampled in Camp Lake, and a total of 10 (five in each of two targeted habitat types) were sampled in each of Sheardown Lake NW and Sheardown Lake SE.

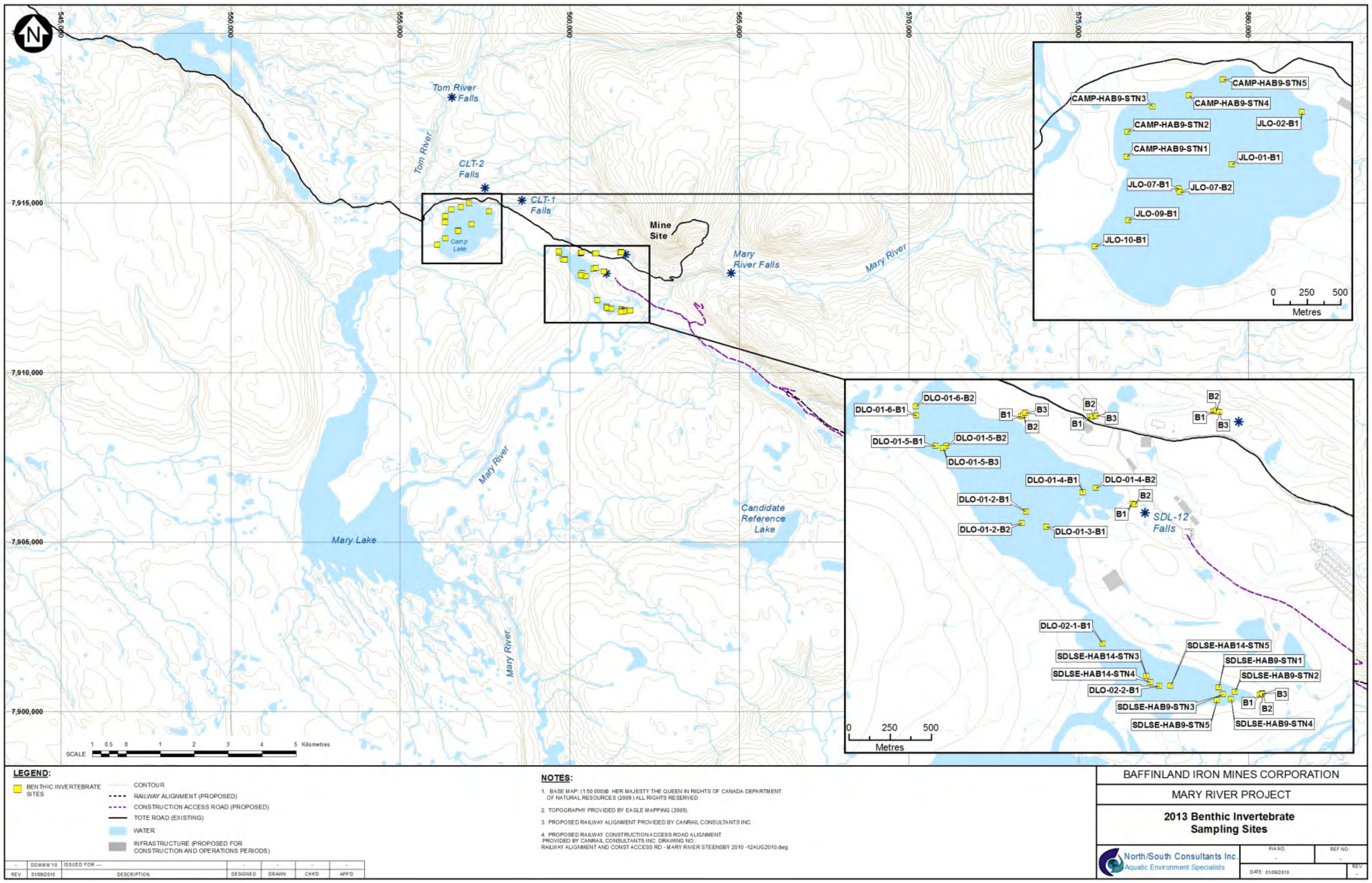
### 7.1.6 Arctic Char

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

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

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

## Figure 7.2 CREMP Benthic Invertebrate Community Sample Locations



A review of baseline data on Arctic Char populations in Mine Area lakes collected through 2012 has been summarized in a baseline integrity review report (NSC, 2013a). This review informed the design of subsequent baseline studies conducted in the open-water season of 2013, which are summarized below.

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

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

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

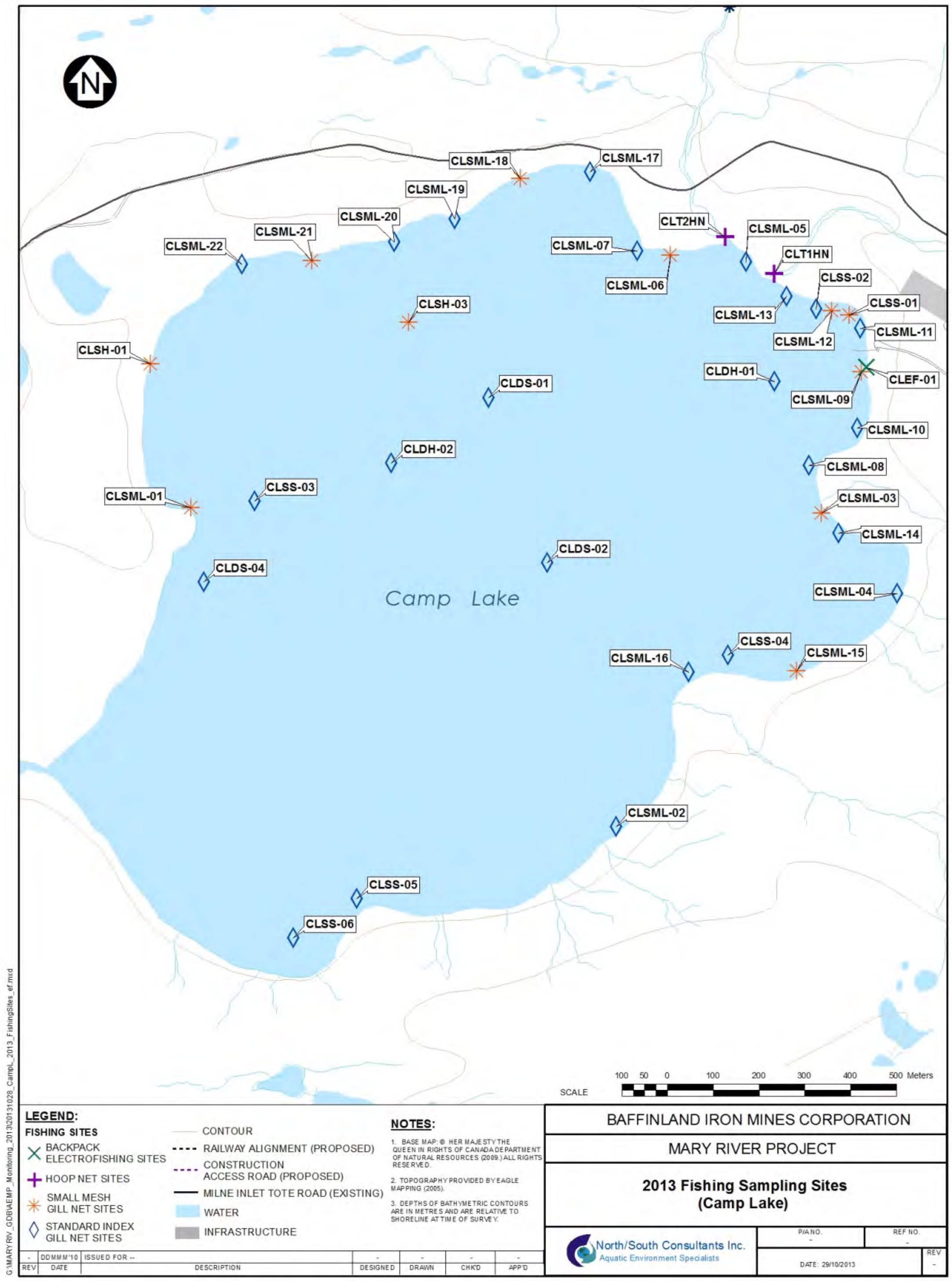
Twenty-four standard index and eleven small mesh gillnet gangs were set in Camp Lake from 27-29 August, 2013 (Figure 7.3). Twelve standard index and 6 small mesh gillnet gangs were set in Sheardown NW Lake on 30 August, 2013 (Figure 7.4). A total of 26 Arctic Char were captured in Camp Lake and 28 were captured Sheardown Lake NW with gill nets.

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

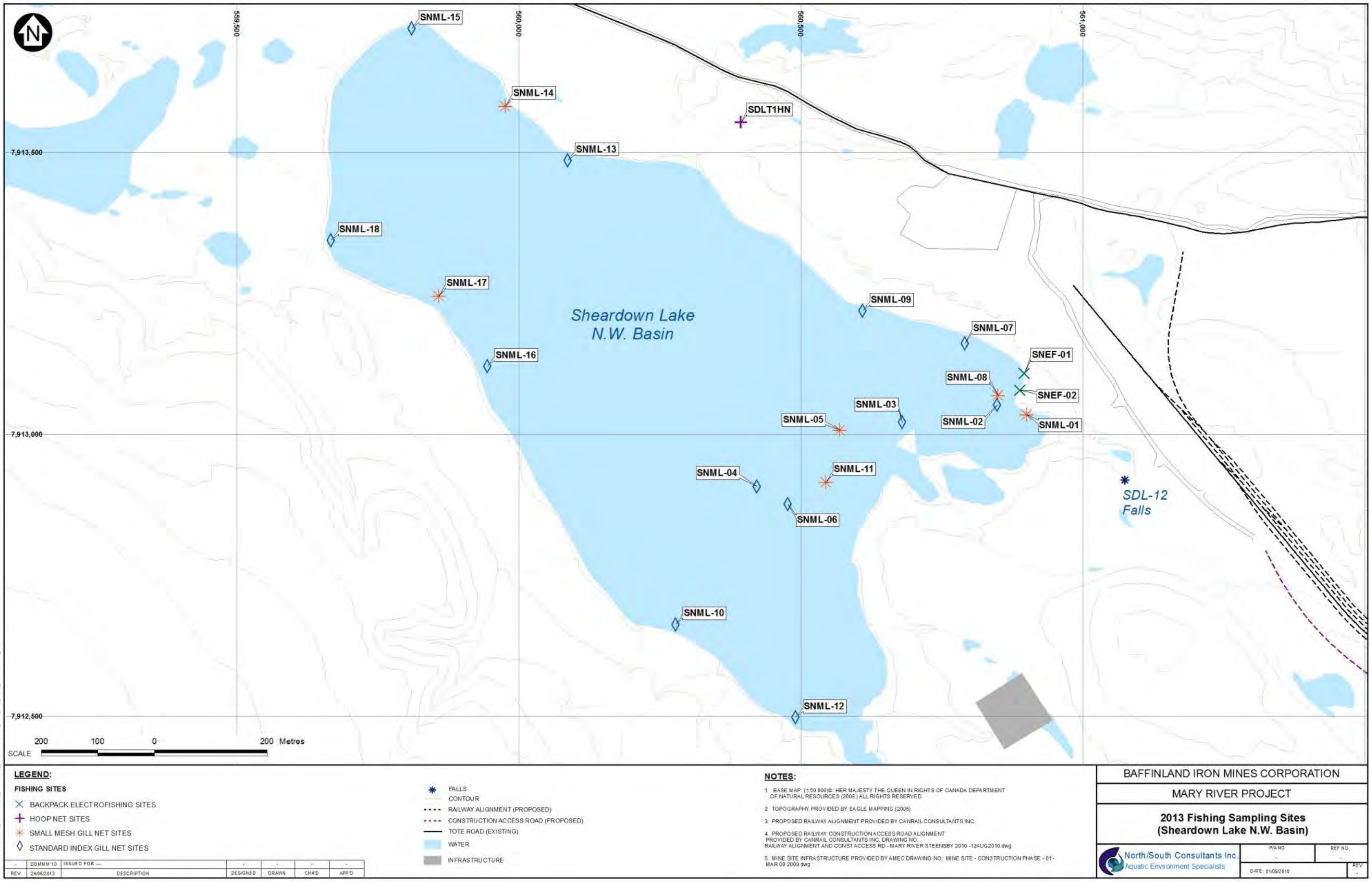
## 7.2 REFERENCE SITES

Desktop and field studies have been conducted to identify suitable reference lakes for Sheardown Lake NW and Camp Lake, located within reasonably close proximity to the lakes. Desktop screening studies were conducted in 2012-2013, building upon an initial screening exercise conducted in 2008, to identify a list of candidate reference lakes to be subject to reconnaissance surveys in the open-water season of 2013 (NSC, 2013b). Several iterations of this screening exercise were completed to capture a sufficient number of candidates for consideration. A brief overview of the screening process and the 2013 reconnaissance surveys completed is provided below.

**Figure 7.3 2013 Camp Lake Fish Sampling Locations**



## Figure 7.4 2013 Sheardown Lake Fish Sampling Locations



### 7.2.1 Desktop Screening Exercise Overview

Lakes within an 80 km radius from Sheardown Lake NW and Camp Lake were evaluated against the following criteria:

- Geology
- Lake surface area
- Lake shape
- Location in drainage basin
- Proximity and practicality
- Elevation
- Drainage basin slope
- Drainage basin: lake area ratio
- Average drainage basin slope
- Existing or potential development

As noted above, several iterations of the screening exercise were completed to generate a sufficient number of candidate lakes. The geological criterion was the most restrictive and screening iterations with and without geology as a criterion were completed. Through these screening exercises, twelve lakes were identified as potential candidates for reconnaissance surveys in 2013.

### 7.2.2 Candidate Reference Lake Reconnaissance Survey Overview

The objective of the reconnaissance surveys was to identify several lakes that could be investigated in detail for consideration as reference lakes in the CREMP. Table 7.1 provides a summary of reconnaissance survey information for all lakes surveyed during the 2013 reconnaissance surveys.

Two surveys of candidate reference lakes were completed in the open-water season of 2013. The first survey was completed in early August shortly following ice-off at the Mine Site, and involved a combination of aerial surveys followed by ground site visits. All twelve of the lakes identified through the desktop screening exercise were initially surveyed by air to identify basic suitability characteristics such as general depth, shoreline substrate and connectivity to other water bodies. Lakes that were identified as unsuitable during the aerial survey were eliminated as potential references. Depth was the primary limiting factor during aerial surveys. Five lakes were eliminated as suitable candidates due to limited depth (estimated as < 3 m); an additional three lakes were eliminated due to the ongoing presence of ice.

Of the remaining four candidate lakes (CR-P3-11, CR-P3-12, CR-P3-09, and CL-P2-13) three were subject to detailed ground surveys; two of the four lakes (CR-P3-11 and CR-P3-12) were immediately adjacent to one another and only one of these (CR-P3-11) was surveyed in detail. Surveys included collection of information on shoreline characteristics (qualitative observations), aquatic habitat (bathymetric and substrate information), fish presence/absence (specifically identification of land-locked resident Arctic Char), and water quality (*in situ* and laboratory measurements) in these three lakes (Figure 7.5) to assist with determining their similarity to Mine Area lakes. Following completion of these surveys, one of the three lakes (CR-P3-09) was subsequently dropped from further consideration due to the suspected presence of a population of dwarf Arctic Char (NSC, 2013b). The remaining two lakes (CR-P3-11 and CR-P3-13) were retained as possible suitable candidates for further consideration. These two lakes were revisited in late August for a second round of water quality sampling and for collection of benthic invertebrate samples.

To provide potential additional options for reference lakes, a second aerial survey was conducted in late August in areas identified as providing potentially suitable lakes for consideration. Eleven alternate lakes to the south of the mine site (ALT-1 to ALT-11) were surveyed aerially for general depth, shoreline substrate and connectivity to other water bodies to expand the list of potential suitable candidates (Figure 7.5). Several lakes appeared potentially suitable as references, but four (ALT-6, ALT-7, ALT-9, and ALT-10) have a combination of abundant, ideal nearshore habitat (cobble), sufficient depths (estimated to be > 10 m), and sufficient size when compared with Camp and/or Sheardown NW lakes.

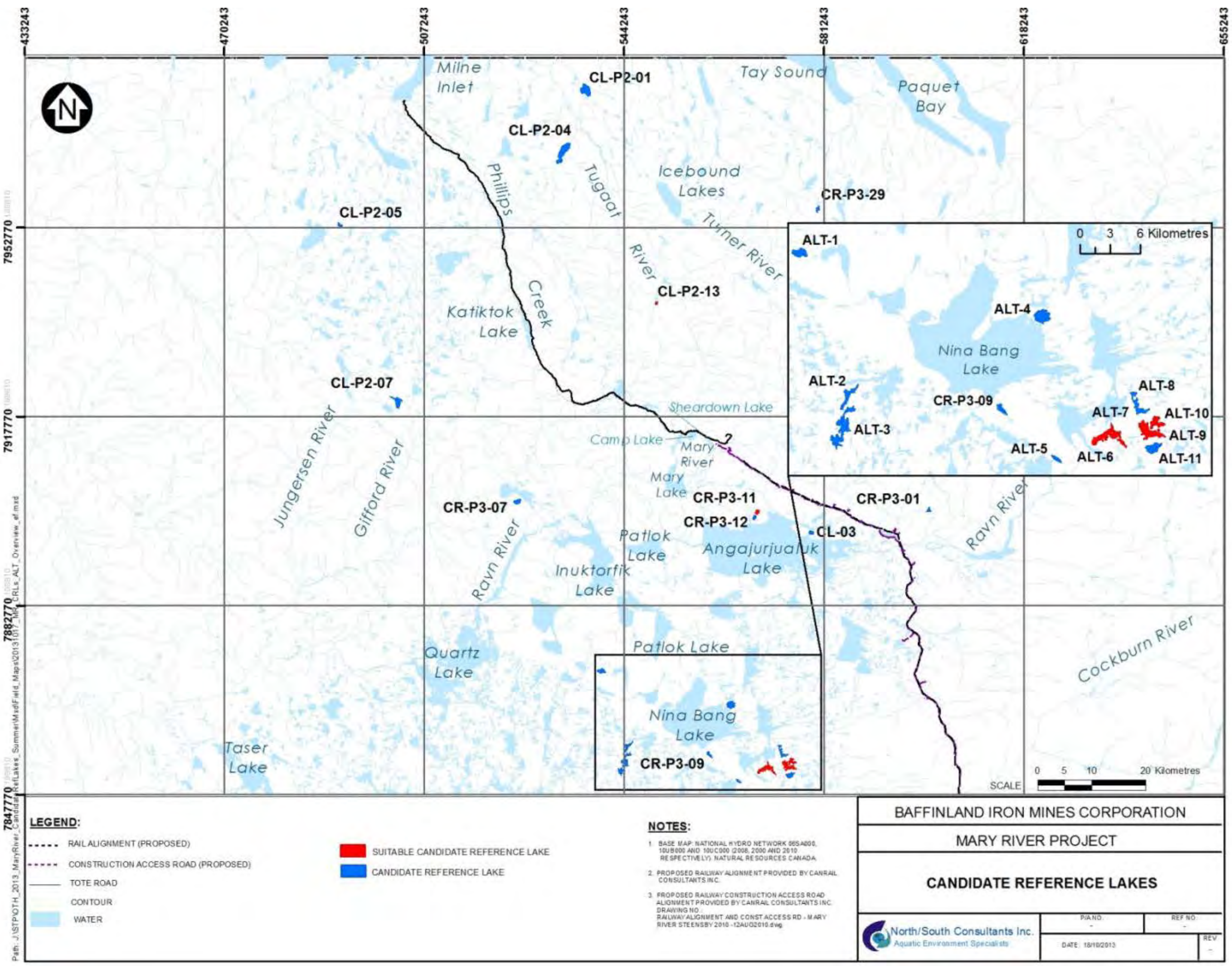
**Table 7.1 Potential Candidate Reference Lakes Surveyed in 2013 for the CREMP**

| LAKE | DATE | SURVEY TYPE | POTENTIAL REFERENCE LAKE STATUS | COMMENTS |
|---|---|---|---|---|
| CR-P3-07 | 03-Aug-13 | Ground | Not Suitable | Too shallow for overwintering or large adult fish use |
| CL-P2-05 | 03-Aug-13 | Aerial | Not Suitable | Too shallow for overwintering or large adult fish use |
| CL-P2-01 | 03-Aug-13 | Aerial | Potentially Suitable | Lake was still ~80% covered in ice and could not be surveyed in detail |
| CR-P3-29 | 03-Aug-13 | Aerial | Potentially Suitable | Lake was still ~90% covered in ice and could not be surveyed in detail |
| CL-P2-04 | 03-Aug-13 | Aerial | Potentially Suitable | Lake was still ~80% covered in ice and could not be surveyed in detail |
| CL-P2-13 | 07-Aug-13 | Ground | Potentially Suitable | Lake is small, but substrate is ideal and there are large, resident Arctic Char |
| CL-P2-07 | 03-Aug-13 | Aerial | Not Suitable | 80-90% of the lake is < 3.0 m deep |
| CR-P3-09 | 05-Aug-13 | Ground | Not Suitable if resident char are stunted | May need more studies to confirm lack of large fish, but seems unlikely as a reference |
| CR-P3-01 | 03-Aug-13 | Aerial | Not Suitable | 50% of the lake is < 3.0 m deep and lake is isolated from other waterbodies |
| CL-03 | 03-Aug-13 | Aerial | Not Suitable | Too shallow for overwintering or large adult fish use |
| CR-P3-11 | 06-Aug-13 | Ground | Potentially Suitable | Substrate not ideal, but resident fish population present |
| CR-P3-12 | 03-Aug-13 | Aerial | Potentially Suitable | Very similar to CR-P3-11, so only one of the two was surveyed in detail |
| ALT-01 | 31-Aug-13 | Aerial | Potentially Suitable | Does not have ideal nearshore habitat (larger cobble), but may qualify for more detailed survey |
| ALT-02 | 31-Aug-13 | Aerial | Potentially Suitable | Nearshore habitat more suitable than ALT-1 |
| ALT-03 | 31-Aug-13 | Aerial | Not Likely Suitable | Substrate decent, but depths a little shallow |
| ALT-04 | 31-Aug-13 | Aerial | Not Suitable | Essentially a bay in Nina Bang Lake |
| ALT-05 | 31-Aug-13 | Aerial | Potentially Suitable | Excellent nearshore habitat and depths, but lake is a little small |
| ALT-06 | 31-Aug-13 | Aerial | Potentially Suitable | Excellent nearshore habitat and depths and lake is larger than other reference sites |
| ALT-07 | 31-Aug-13 | Aerial | Potentially Suitable | Connected to ALT-06, but even better suited as reference |
| ALT-08 | 31-Aug-13 | Aerial | Potentially Suitable | Low shoreline slope and lower quality habitat means this is likely less suitable than others in the area |
| ALT-09 | 31-Aug-13 | Aerial | Potentially Suitable | Among the best nearshore habitat and depth of any ALT lakes |
| ALT-10 | 31-Aug-13 | Aerial | Potentially Suitable | Shallow connection to ALT-09 with similar habitat |
| ALT-11 | 31-Aug-13 | Aerial | Potentially Suitable | Good size and depth, but nearshore habitat not as ideal as ALT-06 or ALT-09/10) |

**NOTES:**

1. LAKES HIGHLIGHTED IN BLUE HAVE BEEN IDENTIFIED AS THE BEST POSSIBLE REFERENCE CANDIDATES.

**Figure 7.5 Candidate Reference Lakes Surveyed in 2013**



# 8 TARGET STUDIES/SPECIFIC EFFECTS STUDIES AND FOLLOW-UP

## 8.1 INTRODUCTION

Specific effects monitoring (or targeted monitoring) is defined as monitoring conducted to address a specific question or potential impact and/or studies that are relatively confined in terms of spatial and/or temporal scope. Targeted environmental studies relate to specific environmental concerns that require further investigation or follow-up but are not anticipated to be components of the core monitoring program. Two targeted studies are described below.

## 8.2 DUST DEPOSITION: SEDIMENTATION IN SURFACE WATERS

In addition to the Core Monitoring Program that will be conducted in the Mine Area, specific effects monitoring will be conducted to monitor effects related to the introduction of dust, and other sources of suspended solids, in surface waters and subsequent deposition in aquatic habitat.

### 8.2.1 Potential Impacts

Dust will be directly deposited on watercourses during the open-water season and on snow and ice during the winter. Dust will be indirectly introduced from runoff within the watersheds; introduction will likely be greatest during the snowmelt/freshet period. Potential effects of dust on aquatic ecosystems includes effects on water quality (i.e., TSS, metals, nutrients, water clarity) when suspended in the water column and effects once deposited on the lake bottom or streambed. Sedimentation of dust in lakes and streams may affect aquatic biota through changes in sediment quality (e.g., metals, nutrients, particle size, organic matter), through changes in habitat quality (i.e., changes in substrate composition), direct effects on benthos (i.e., smothering), and direct effects on fish eggs (i.e., smothering of eggs).

### 8.2.2 Mitigation

Mitigation is described in the Air Quality Management Plan and the Surface Water and Aquatic Ecosystems Management Plan.

### 8.2.3 Monitoring

Potential effects of dust deposition on water and sediment quality are described within the Core Monitoring Program. Monitoring of dust deposition rates within the watersheds is described within the Air Quality Management Plan.

Effects of dust deposition on sedimentation rates in Mine Area lakes will also be monitored through deployment of sediment traps in Sheardown Lake NW. Sheardown Lake NW will receive direct deposition of dust as well as introduction of dust from the drainage basin.

Traps would be located at suspected Arctic Char spawning sites to assess potential effects of sedimentation on Arctic Char eggs, and potentially in other habitat types to assess effects to benthos. Traps would be deployed year-round. Traps would be emptied prior to the spawning period in suspected spawning areas, redeployed at these sites, and again retrieved and emptied following egg hatching to facilitate determination of rates of sedimentation for the egg incubation period.

The proposed benchmark for assessing potential effects on Arctic Char eggs is the benchmark sedimentation rate of 1 mm over the egg incubation period applied in the FEIS.

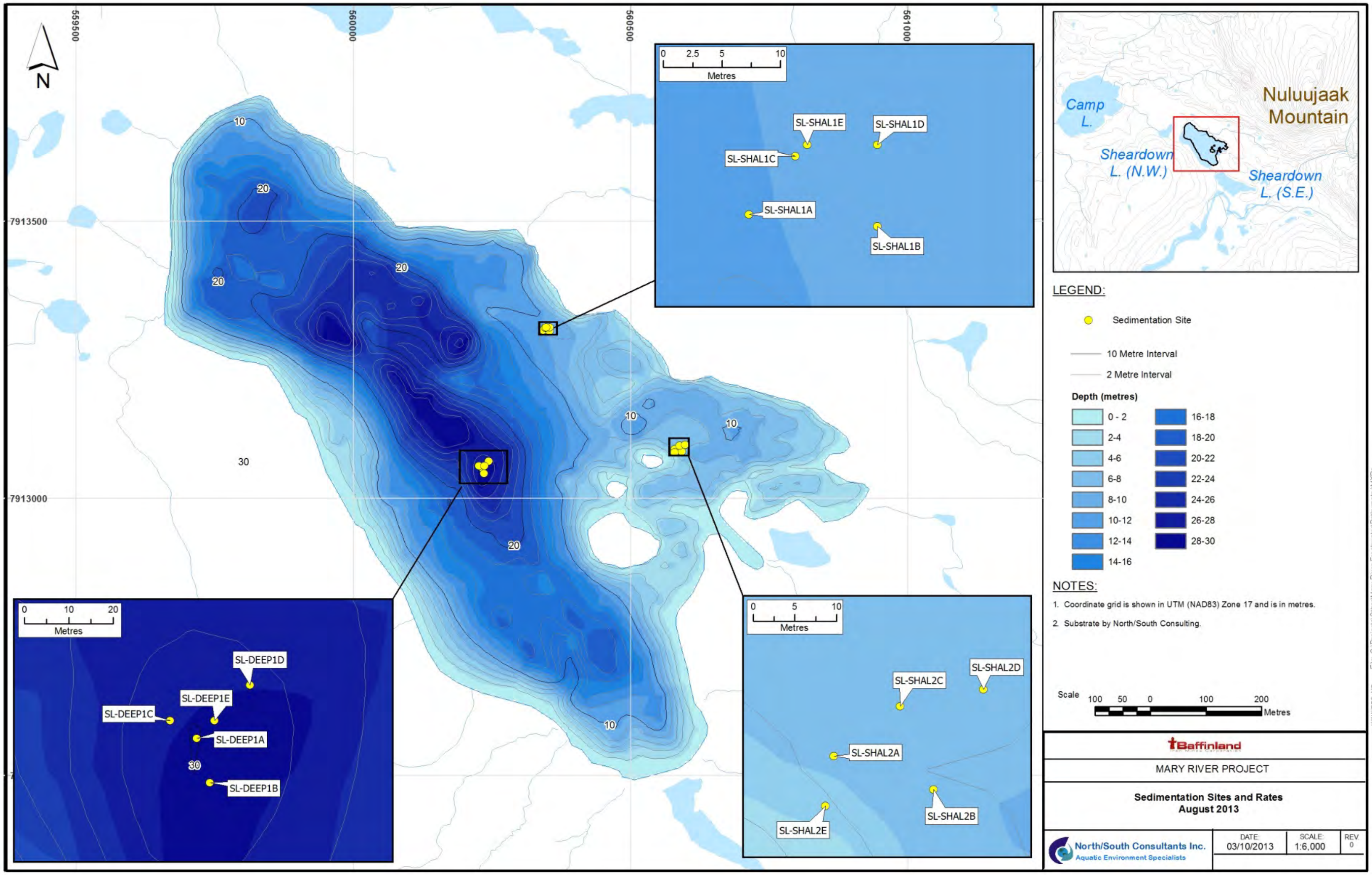
Monitoring for effects of sedimentation in Mine Area water bodies would also include visual assessments of dust deposition in conjunction with Core Monitoring, including sediment quality monitoring (i.e., assuming dust will be readily distinguishable from existing deposited sediments). Sediment cores will be examined for evidence of dust accumulation near the surface of the sediments through visual examination and thickness of the dust deposition layer will be measured if feasible.

#### 8.2.4 Baseline Sedimentation Study

A reconnaissance field sampling program measuring sedimentation in Sheardown Lake NW was undertaken in the open-water season of 2013 to generate baseline information for post-Project comparison. Sediment traps were deployed at three sites in the lake as depicted in Figure 8.1 on August 2, 2013. Five replicates were deployed at each site to ensure adequate sediment was obtained for laboratory analysis and to provide sufficient information to evaluate variability at each site. The sites were selected to generate measurements of sedimentation rates at a deep site, where sedimentation is typically greatest, and at two shallower locations – one of which was located in potential Arctic Char spawning habitat, to generate baseline information on the critical habitat of concern with respect to this effects pathway.

Traps were retrieved near the end of the open-water season (September 6, 2013), emptied, and redeployed. Contents of the traps were submitted to an accredited analytical laboratory (ALS Laboratories, Winnipeg, MB) and analysed for total dry weight. Due to minimal sediment sample size, additional analyses could not be conducted. Traps will be retrieved in 2014 after ice-off to provide measurements of sedimentation rates associated with the spawning and egg incubation periods.

**Figure 8.1 2013 Baseline Sediment Trap Locations**



## 8.3 STREAM DIVERSIONS: EFFECTS ON ARCTIC CHAR MOVEMENTS

In addition to the Core Monitoring Program that will be conducted in the Mine Area, specific effects monitoring will be conducted to monitor effects related to Mine Area stream diversions on Arctic Char movements.

### 8.3.1 Potential Impacts

Stream diversions in the Mine Area have the potential to affect the ability of Arctic Char to access small tributaries in the spring, which are used primarily by juvenile Arctic Char, as well as the ability of Arctic Char to move out of these streams into lakes for overwintering in the fall. Effects on Arctic Char therefore potentially include loss of use of stream habitat if fish passage is impeded in spring and/or mortalities in the event fish became stranded in the streams in fall.

Five tributary streams will be affected by diversions in the Mine Area. These streams are relatively shallow and stranding is presumed to occur occasionally in the current environment. However, there is potential for increased stranding during Project operation, closure, and post-closure.

### 8.3.2 Mitigation

Mitigation would be implemented in the event that monitoring indicated unacceptable effects on Arctic Char and may include:

- Monitoring and salvage fishery(ies) as required
- If required, channel improvement(s) could be considered
- Exclusion of Arctic Char from streams

### 8.3.3 Monitoring

The five affected streams will be monitored in spring and fall during the initial years of operation, targeting low and high flows where possible. Results of this initial monitoring will be reviewed to determine whether mitigation is required and/or if ongoing monitoring would be required.

In spring, all five streams will be visually assessed to monitor for potential barriers and obstructions to upstream fish passage. Baseline studies have been conducted to identify areas of the streams with the greatest potential to create fish barriers and these areas will be targeted during the monitoring program. Mitigation (e.g., channel improvements) may be considered if, based on the results of the initial years of monitoring, upstream movements of Arctic Char appear to have been affected by stream diversions.

To monitor for potential fish stranding in fall, the streams will be visually assessed for fish barriers and presence/stranding of Arctic Char. If stranding is identified, a salvage fishery will be conducted and Arctic Char will be transported and released to the downstream lake(s). Additional mitigation (e.g., channel improvements) may be considered if, based on the results of the initial years of monitoring, downstream movements of Arctic Char appear to have been affected by stream diversions.

# 9 PROPOSED APPROACH FOR ASSESSMENT OF AQUATIC EFFECTS

## 9.1 WATER AND SEDIMENT QUALITY OVERVIEW

As outlined in the Aquatic Effects Monitoring Program (AEMP) Framework, surface water and sediment data will be collected in a number of receiving environment areas associated with the Mary River Project, as well as reference areas throughout the life of mine. The assessment of these data must follow a standardized approach agreed upon by both the regulators, stakeholders and mine operators. This section outlines a proposed approach for sediment and surface water data assessment, including the selection of appropriate benchmarks. The proposed approach ensures a conservative (i.e., protective) evaluation which is in keeping with widely accepted guidance and practices used to evaluate environmental data across Canada (e.g., CCME).

For the sediment and water quality VEC, the list of key indicators that are considered to be most relevant fall into four categories:

- General Parameters (water quality)
- Metals (water and sediment quality)
- Nutrients (water quality)
- Petroleum hydrocarbons (water and sediment quality)

The proposed approach for assessment of sediment data is presented in Section 9.2, with surface water assessment approach being presented in Section 9.3.

## 9.2 PROPOSED APPROACH FOR AEMP SEDIMENT DATA ASSESSMENT

### 9.2.1 Perspective on CCME Sediment Quality Guidelines

The Canadian Council for Ministers of the Environment (CCME) have developed a series of sediment quality guidelines for the protection of aquatic life which are typically used across Canada as assessment benchmarks for monitoring data. These guidelines were developed using a standardized protocol (CCME, 1995) involving the extensive review of field-based (co-located) sediment chemistry and toxicity data. Where data are available, the protocol uses both the National Status and Trends Program approach (NSTP), as well as a spiked sediment toxicity test approach (SSTT), to derive sediment quality guidelines. In the NSTP approach, information relating to sediment concentrations and effects is compiled from numerous geographic locations throughout North America, for many different species and biological end points. Much of the information compiled is field-collected data that considers complex mixtures of chemicals (and thus their interactive effects), various sediment types (i.e., with different particle sizes and concentrations of substances), and varying conditions of bioavailability. These data are entered into a Biological Effects Database for Sediments, or BEDS. Sediment quality guidelines are then statistically derived from the BEDS (CCME, 2002).

Typically, two sediment quality guidelines calculated from this database, as follows:

1) A Threshold Effects Level (TEL), a concentration below which adverse effects are expected to occur rarely.

2) A Probable Effects Level (PEL), a concentration above which adverse effects are expected to occur frequently.

The lower of these values (TEL) can be independently evaluated using the SSTT approach. Data using the SSTT approach are not available for many of the chemicals considered by CCME. Where this is the case, the term Interim Sediment Quality Guideline (ISQG) is used, rather than TEL for the lower of the two guidelines (CCME, 2002).

Both the ISQG and the PEL guidelines are commonly used to assess sediment quality across Canada. These are generic values intended to be conservative, and the CCME recognizes that they do not consider site specific modifying factors that can influence bioavailability of chemicals in sediments, which can alter toxicity. In addition, benthic organisms have the ability to acclimate and adapt to metals in sediments, especially in areas of natural enrichment, which is also not considered in the development of the generic guidelines. In general, CCME (2002) recommends that assessment of potential for adverse effects in biota related to sediment contamination involve the use of not only sediment quality guidelines, but also other assessment tools, such as data on natural background concentrations of substances of interest, biological assessments (such as benthic community analyses), and/or other toxicity data (such as site-specific testing), as needed.

### 9.2.2 Proposed AEMP Sediment Quality Benchmarks

The proposed approach for selecting AEMP sediment benchmarks may include the following:

- Select CCME sediment quality guidelines, where available. The ISQG will be considered as the initial point of comparison, where one exists. The PEL will be also be considered to provide added perspective related to risk potential.
- Where CCME guidelines are not available, a surrogate guideline from another jurisdiction will be selected (e.g., provincial sediment quality guidelines; US EPA, etc.).
- In addition, baseline data will be assessed, and a statistical metric of baseline levels (e.g., $95^{th}$ percentile of baseline data, to be determined) for any naturally occurring substances (metals/metalloids) will be calculated.

The higher of the CCME/surrogate guideline or natural baseline will be selected as the AEMP benchmark.

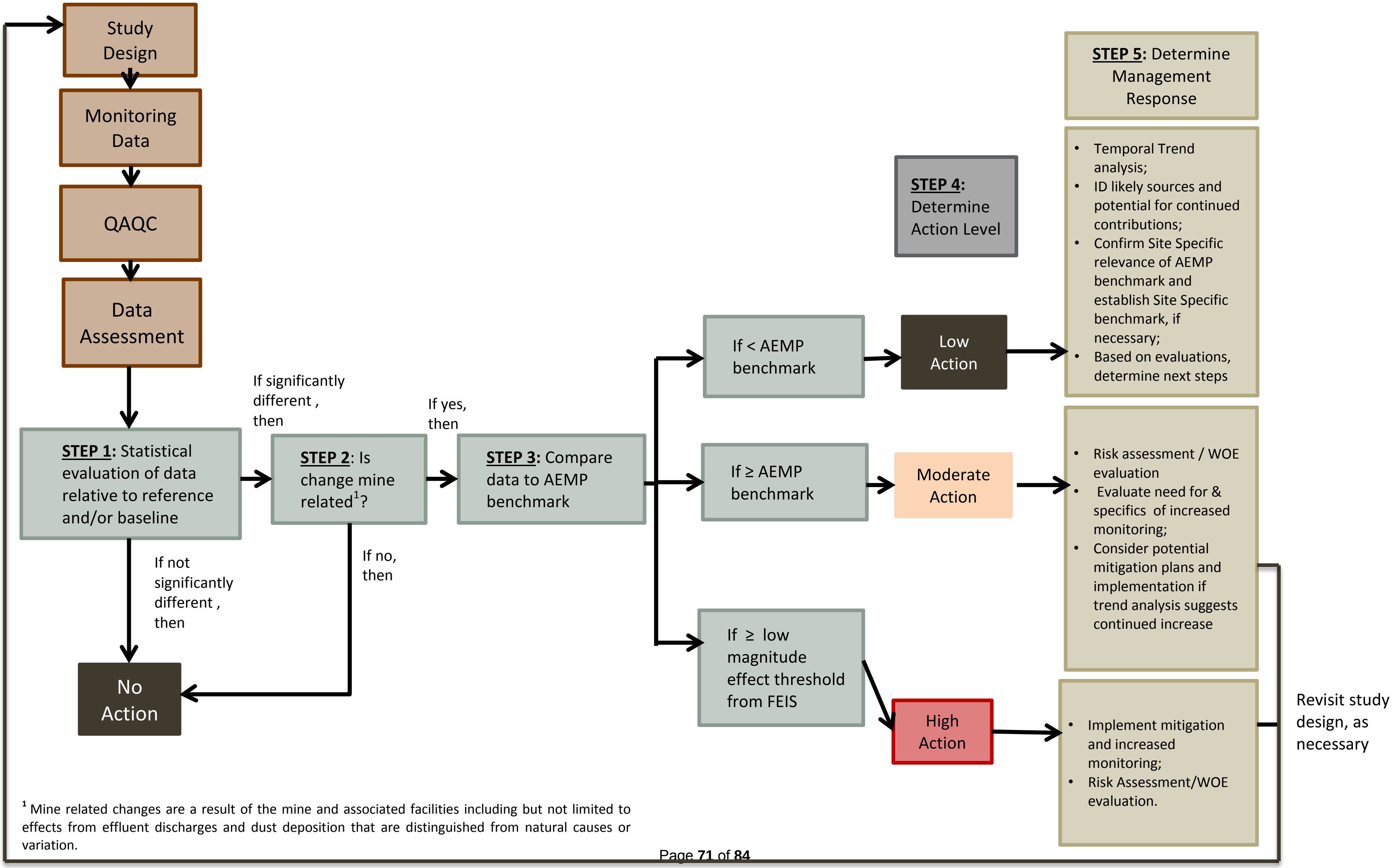
### 9.2.3 Proposed Assessment Approach: AEMP Sediment Data

The proposed approach for assessing sediment data is outlined in Figure 9.1. A 5-step process has been identified which includes the following steps:

- Statistical evaluation of data relative to reference and/or baseline
- Determining if the statistical change is mine-related
- Comparing monitoring data to the AEMP benchmark
- Determining the action level based on the monitoring result relative to the AEMP benchmark
- Implementing one of three courses of action (low, moderate, high)

If the first step does not detect a statistically significant change, then no action is required. If it is determined the effect is likely mine-related, one of three levels of response (low, moderate or high action) will be implemented ranging from increased monitoring and attention (i.e., trend analyses) to the implementation of further mitigation and/or risk assessment.

**Figure 9.1 Proposed Water/Sediment Assessment Approach and Response Framework**




[1] 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.

## 9.3 PROPOSED APPROACH FOR AEMP SURFACE QUALITY ASSESSMENT

The typical starting point for assessment of surface water data collected in any aquatic effects monitoring program are the Canadian Water Quality Guidelines for Protection of Freshwater Aquatic Life (WQGL - PAL) values, established by the Canadian Council of Ministers of the Environment (CCME, various years, with updates up to 2012). These guidelines reflect the most current scientific data at the time they were developed, and are intended to provide protection to all forms of aquatic life and aquatic life cycles, including the most sensitive life stages, at all locations across Canada (CCME, 2007). Since they are generic and do not account for site-specific factors that can alter toxicity, these national guidelines can be modified using widely accepted procedures, to derive site-adapted or site-specific guidelines or objectives for a given project or location (CCME, 2003).

### 9.3.1 Proposed AEMP Surface Water Quality Benchmarks

The proposed approach for selecting AEMP surface water benchmarks will include the following:

- Select CCME WQGIs (PAL – freshwater), where available or a SSWQO, if already derived
- Where CCME guidelines are not available, or are not considered relevant, a surrogate guideline from another jurisdiction will be selected (e.g., provincial water quality guideline; US EPA; relevant guideline from another operator, etc.)
- In addition, baseline data will be assessed, and a statistical metric of baseline levels (e.g., 95$^{th}$ percentile of baseline data, to be determined) for any naturally occurring substances (metals/metalloids) will be calculated
- The higher of the CCME/surrogate guideline or natural baseline will be selected as the AEMP benchmark

### 9.3.2 Proposed Assessment Approach: AEMP Water Quality Data

The same assessment approach used for sediment quality will be applied to water quality (Figure 9.1).

The assessment of surface water and sediment data over the life of the project will be on-going, and the recommended AEMP benchmarks throughout this process may change, as more data becomes available. For example, a SSWQO established early on in the life of the mine may require updating in 10 years, based on new published literature which has become available, or site specific toxicity tests conducted to further understand ETMF or resident species toxicity. The iterative, cyclical nature of data assessment under an AEMP is well established (MacDonald et al, 2009).

## 9.4 CONCEPTUAL APPROACH FOR IDENTIFICATION OF KEY METRICS AND CRITICAL EFFECTS SIZES FOR CREMP BIOTA DATA

An initial review of existing freshwater baseline data were completed in 2013 to assist with:

- Identification of key metrics/indicators for monitoring
- Identification of the robustness of the existing data set for post-Project monitoring
- Identification of issues or potential modifications to sampling methods or designs (e.g., sampling locations)
- Identification of data gaps
- Identification of additional baseline sampling to be conducted in 2013

While not a formal objective of this review, this undertaking also assisted with providing a preliminary measure of the ability of existing data set to be used for monitoring purposes and ultimately the level of change that could be detected by the monitoring program (i.e., the power associated with the existing data to measure change, or to serve as the "before" data set for comparison to "after" in a before/after monitoring program sampling design). As one of the main objectives of this review was to advise on the need to collect additional baseline data to augment the robustness of the dataset for monitoring purposes, this analysis was viewed as a preliminary exercise in the development of potential suitable biological benchmarks or "critical effects sizes (CESs)" for the AEMP. Additional baseline data acquired in 2013, as well as ongoing dialogue with regulatory agencies and refinement of Project description details (e.g., geotechnical studies), will be considered in the development of the final biological CESs that would be applied in the AEMP. Specifically, additional baseline data will further refine estimates of natural variability in biological metrics which will in turn assist with identification of appropriate CESs and sensitive indicators of change for CREMP.

### 9.4.1 Biological Critical Effects Sizes

Unlike water and sediment quality for which there are readily accepted quantitative benchmarks for monitoring (e.g., CCME water and sediment quality guidelines), there are no analogous benchmarks for biological variables. Instead, benchmarks for biological monitoring typically apply CESs, which refer to a specified degree of change or difference for a biological metric in time or space (e.g., comparisons to reference areas). The level of "acceptable change" in a biological community or population must consider site-specific factors and ultimately the level of risk that is deemed acceptable for a given biological attribute. The development of biological CESs involves some degree of best professional judgment and the interpretation of any observed exceedances in identified CESs during a monitoring program should consider the weight-of-evidence (or "multiple lines of evidence"; INAC 2009). Weight-of-evidence assessment provides a systematic and transparent method for integrating the complexity of data generated in environmental assessment and monitoring programs. An exceedance of a biological CES would typically indicate a cause for investigation for the observed change, as statistically significant changes may occur within biological communities due to natural events. Further, it is important to consider results of monitoring activities for a variety of components (e.g., eutrophication indicators, benthic invertebrates) collectively with environmental variables known to affect biological communities (e.g., water quality), including those that may not be affected by the Project (e.g., climate). CESs for biological components are viewed here as monitoring benchmarks that would be used as a mechanism for an action or response within the overall monitoring framework. The actions/responses may include:

- Further analysis of the monitoring data, including consideration of multiple-lines-of-evidence, to assist with interpretation
- Investigation of potential cause(s) of the observed change
- Follow-up monitoring to confirm initial results and/or to assist with interpretation of the results
- Trend analyses or additional statistical analyses (e.g., multivariate statistics)
- Targeted study (e.g., toxicity testing)
- Mitigative measures

Ultimately, the selection of an appropriate biological indicator and an associated CES should consider the limitations of a monitoring program to detect change (e.g., the natural variability of the biological component in question), the level of acceptable risk/uncertainty, species- or community-specific considerations (e.g., resiliency), the sensitivity of the indicator species or metric, ecological relevance of the metric or endpoint, and site-specific considerations (e.g., logistics, safety, and practical limitations on sampling effort).

Although there are no established benchmarks for biological variables (e.g., abundance) 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 in other recent monitoring programs, such as the Meadowbank Gold Mine CREMP (e.g., Azimuth 2012) and the Diavik Diamond Mine (Golder Associates 2011). Other sources of information that would be considered in the final development of biological CESs for the Mary River Project CREMP include INAC (2009), Munkittrick et al. (2009), CCME (1999; updated to 2013), Wek'èezhìi Land and Water Board (2010), and Science Advisory Board for Contaminated Sites in BC (2008).

The review and ongoing development of the AEMP will consider the CESs identified in these initiatives, but will also consider site-specific information and input received from regulatory agencies. As noted above, the initial review of baseline data included consideration of published CESs for application under CREMP and it is anticipated that further refinement and development of biological CESs would occur upon reanalysis of the datasets to incorporate data collected in 2013. Biological CESs may be defined in terms of degree of change from a suitable reference area value or from baseline conditions (i.e., before-after comparisons), or a combination of both (before-after-control-impact). As reference lakes are currently being identified, baseline data collected at the Mine Area lakes were evaluated for variability and power to assist with development of biological CESs.

A discussion pertaining to the development of CESs for the three biological components that may be monitored under CREMP (Arctic Char, benthic invertebrates, and phytoplankton) is provided below.

### 9.4.2 Arctic Char

The CREMP may include monitoring of Arctic Char beyond that conducted as a component of the MMER EEM program to provide monitoring information for areas/water bodies that may be affected by pathways other than MMER effluent discharges (e.g., Sheardown Lake). A preliminary review of existing baseline data for Arctic Char was completed in 2013 to help direct future sampling design and collection of additional baseline data, should monitoring be proposed under CREMP. This exercise included a preliminary review of existing data for selected metrics to be used as a basis for detecting change in potential future monitoring programs. This initial review identified the statistical power of the existing data and indicated that the recommended sample size of 100 fish would be adequate to detect CESs of the magnitude indicated in the EEM guidance document (EC, 2012).

Should monitoring of Arctic Char in Mine Area lakes be adopted under CREMP, it is anticipated that monitoring would include collection of metrics at the individual and population level, such as condition factors and length-frequency-distributions, and that these metrics would serve as the key measurement endpoints for statistical evaluation and thus for which quantitative CESs may be developed. Population level endpoints, such as CPUE, if monitored, would provide additional information to assist with overall interpretation of potential effects on Arctic Char, as informed by individual level metrics as well as supporting information such as changes in habitat and water quality (i.e., weight-of-evidence).

Specific monitoring endpoints and potential CESs will consider the guidance provided by EC for MMER EEM programs (EC 2012), as well as other sources of information as noted above, for the study design that is finalized. The MMER identifies CESs for a fish population as a percentage of change from the "reference mean". The "standard" fish population surveys are based on evaluating fish health on two adult fish species and include indicators of fish growth, reproduction and condition (Table 9.1).

The actual indicators measured depend upon the study design, which is in turn defined on a site-specific basis (e.g., lethal versus non-lethal sampling). As noted by INAC (2009), "these effect sizes do not reflect the method recommended by Environment Canada (2004); namely effect sizes that correspond with unacceptable ecological changes." INAC (2009) also notes that Environment Canada (2008) identified these CES "in the absence of clear scientific understanding of the long-term implications of these effects". However, as further noted by INAC (2009) these CESs "may serve as a starting point for discussions on acceptable effect sizes that occur during AEMP development" and will be considered during development of CESs for the Mary River CREMP.

**Table 9.1 MMER EEM Critical Effects Sizes (CES) for Fish Populations**

| EFFECT INDICATORS | FISH EFFECT ENDPOINT | | CES |
|---|---|---|---|
| | Lethal Adult Survey | Non-Lethal Survey | |
| Growth | Weight-at-age | Length and weight of YOY (age 0) at end of growth period | ± 25% |
| Reproduction | Relative fish gonad size | Relative abundance of YOY (% composition of YOY) | ± 25% |
| Condition | Relative liver size | - | ± 25% |
| | Condition Factor | Condition Factor | ± 10% |
| Survival | Age | Length-frequency-distribution | ± 25% |

**NOTES:**

1. CES WILL BE USED AS GUIDANCE IN THE DEVELOPMENT OF CREMP CESS. ACTUAL CESS DEVELOPED FOR THE MARY RIVER CREMP WILL CONSIDER VARIABILITY IN BASELINE DATA AND SITE-SPECIFIC FACTORS.
2. CES ARE EXPRESSED AS A PERCENTAGE OF THE REFERENCE MEANS.

The conclusion that an "actual effect" has occurred is based on results of two consecutive surveys. This guidance should be considered in the development of actions/responses within the CREMP framework.

### 9.4.3 Benthic Invertebrates

CREMP may include monitoring of benthic invertebrate community composition and richness metrics at selected sampling locations to support the assessment of potential effects on fish habitat beyond that conducted as a component of the MMER EEM program. Benthic invertebrate community descriptors (i.e., metrics) included in statistical analyses as effect endpoints may include total invertebrate density, taxa (i.e., family) richness, evenness index, and similarity index (Environment Canada 2012). Other metrics may be included as supporting metrics (i.e., not statistically analyzed to determine effects), such as diversity index, taxa (i.e., family) density, taxa (i.e., family) proportion, and taxa (i.e., family) presence/absence. Like Arctic Char, the initial review of the existing benthic invertebrate baseline data was completed in 2013 and included an evaluation of these data for the Mine Area. The review assisted with a preliminary assessment of the inherent natural variability in community and richness metrics, which in turn informed the fall 2013 baseline sampling program. This review and the additional baseline data collected in 2013 will ultimately support the development of appropriate CESs for CREMP, if benthic invertebrates are monitored under this program.

The MMER identifies CESs for a benthic invertebrate metric (density, Simpson's evenness, taxa richness, Bray-Curtis index) as multiples of within-reference-area standard deviations (i.e., ±2 standard deviations [SDs]). As for Arctic Char, confirmed effects are based on the results of two consecutive surveys. Again, this guidance should be considered in the development of actions/responses within the CREMP framework.

CESs for the benthic invertebrate community monitoring may consider a spatial aspect as well. For example, CESs may be identified (e.g., 50% change or difference in a benthic invertebrate community metric) in reference to a predefined spatial extent (e.g. the entire area of a small lake, or part of a large lake).

Azimuth (2012) recommended the application of a 20% effect size as a monitoring "trigger" and a 50% effect size as a monitoring "threshold" for benthic invertebrate community metrics (i.e., total abundance and richness), where effect size refers to a change or difference relative to before-after control-impact (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.

The initial review of the benthic invertebrate community data identified the statistical power of the existing data and indicated that the power of the existing data set in Sheardown Lake NW to be able to detect a post-Project change in the mean of ±50% is high for the majority of metrics investigated, with the exception of total macroinvertebrate density. More sensitive metrics to change were identified and these include Chironomidae proportion, Shannon's Equitability, Simpson's Diversity Index, and total taxa richness. Depending on the CES(s) and benthic macroinvertebrate metrics chosen as part of the CREMP, five replicate stations per aquatic habitat type may be adequate; an increase to seven would improve the ability of a few, more sensitive metrics to detect changes in the mean of ±25% and ±20% post-Project.

An assessment of the variability of sub-samples at a replicate station has not been conducted to date, as grabs were composited at each replicate station in previous years prior to identification and enumeration of macroinvertebrates. For 2013, five sub-samples were collected at each replicate station and kept separate to allow further assessment of the number of field sub-samples required to adequately characterize within station variability.

### 9.4.4 Phytoplankton

There is a potential for nutrient enrichment in the Mine Area, notably due to discharge of treated sewage effluent in Sheardown Lake. The CREMP will include monitoring of nutrients in surface waters to provide means for assessing the primary cause of potential eutrophication. However, the CREMP may also include monitoring of eutrophication response variables such as phytoplankton and dissolved oxygen. The latter is considered and described within the CREMP water quality program while monitoring of phytoplankton may be incorporated as a component of the CREMP biological monitoring.

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. Examples of trophic categorization schemes for lakes are provided in Table 2.

Like benthic invertebrate community metrics, 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). 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 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 CESs.

Development of CESs for phytoplankton that are adequately sensitive and ecologically appropriate for Sheardown Lake may consider:

- Natural variability in existing phytoplankton community metrics;
- Limitations associated with the 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
- Information on nutrient-phytoplankton relationships for other comparable northern lakes
- Guidance and frameworks for the development of nutrient criteria (e.g., USEPA 2000)
- Literature in which effects CESs for phytoplankton have been identified or adopted

Additionally, like benthic invertebrates, CESs for phytoplankton may be developed within a spatial context. Specifically, they may consider the spatial extent of effects within or among waterbodies, as it is recognized the spatial extent of effects may occur over a small area (e.g., immediately adjacent to an effluent outfall). This approach has been proposed for the Diavik Diamond Mine for monitoring of potential eutrophication of Lac de Gras (Golder Associates 2011).

It is emphasized that the primary indicator for monitoring for eutrophication in the freshwater environment will be measurements of the nutrients (nitrogen and phosphorus) themselves. Phytoplankton monitoring, if included, would be intended to provide direct measurement of eutrophication response indicators (i.e., primary productivity), as it is the response variables that are of primary concern. Including a response indicator in the monitoring program may be beneficial as the relationships between nutrients and primary productivity may be difficult to predict with existing information, the relationship may be non-linear, and because phytoplankton may be affected by other factors (USEPA, 2000), including water clarity which may also be affected by the Project. Development of CESs for phytoplankton would consider benchmarks developed for nutrients to ensure the monitoring program is appropriate and complementary. Similarly, if phytoplankton were incorporated in CREMP, the results of the phytoplankton monitoring program would not be considered in isolation, but rather would collectively consider nutrient concentrations, water clarity, and other factors that may affect phytoplankton communities in the interpretation of results.

The initial review of existing baseline data (through 2012) was completed in 2013 and indicated relatively low power associated with the two most common metrics employed in phytoplankton monitoring programs (i.e., chlorophyll *a* and total biomass). Low power associated with the baseline chlorophyll *a* data are likely due to the relatively low concentrations that occur in the Study Area lakes and a relatively high frequency of values below analytical detection limits. Phytoplankton biomass is commonly associated with relatively low power due to typically high natural variability. Derived metrics (i.e., diversity, evenness, and richness metrics) were associated with lower variability and greater power. As previously described, additional sampling was conducted in the Mine Area water bodies in the open-water season of 2013 to augment the baseline database. Data will be re-evaluated with the additional information to refine CESs and final design of the CREMP.

**Table 9.2 Summary of Selected Trophic Status Classification Schemes for Lakes**

| Variable | Lake Trophic Status | | | | | | | Reference |
|---|---|---|---|---|---|---|---|---|
| | Ultra-oligotrophic | Oligotrophic | Oligo-mesotrophic | Mesotrophic | Meso-eutrophic | Eutrophic | Hypereutrophic | |
| Total Phosphorus (µg/L) | - | < 10 | - | 10-35 | | 35-100 | > 100 | OECD (1982) |
| | <4 | 4-10 | - | 10-20 | 20-35 | 35-100 | > 100 | CCME (1999; updated to 2012) |
| | - | < 5 | - | 10-30 | - | - | > 100 | Chambers et al. (2001) |
| | < 5 | - | 5-10 | - | 10-30 | 30-100 | > 100 | Wetzel (1983) |
| | - | < 10 | - | 10-30 | - | - | > 100 | Nürnberg (1996) |
| Chlorophyll *a* (µg/L) | - | <2.5 | | 2.5-8 | | 8-25 | > 25 | OECD (1982) |
| | 0.01-0.5 | 0.3-3 | - | 2-15 | - | 10-500 | - | Wetzel (1983) |
| | - | < 3.5 | - | 3.5-9 | - | 9.1-25 | > 25 | Nürnberg (1996) |
| Secchi Disk Depth (m) | - | > 6 | - | 3-6 | - | <1.5 | - | OECD (1982) |
| | - | > 4 | - | 2-4 | - | 1-2.1 | < 1 | Nürnberg (1996) |
| TN (µg/L) | - | < 350 | - | 350-650 | - | 651-1,200 | > 1,200 | Nürnberg (1996) |
| | < 1-250 | - | 250-600 | - | 500-1,100 | - | 500-> 15,000 | Wetzel (1983) |

# 10 QUALITY CONTROL AND QUALITY ASSURANCE (QA/QC)

## 10.1 WATER QUALITY

For QA/QC purposes a laboratory prepared triple blank will accompany all water samples during sampling and transport. Field blanks for 10% of the samples will also be performed. In addition, three discrete water quality samples will be collected at each study area as recommended in the technical guidance document (EC, 2012). Laboratory blanks, duplicates, spikes and reference standards will be employed according to standard operating procedures. Laboratory Chain of Custody (COC) forms will accompany all samples for identification, tracking and transporting purposes.

## 10.2 SEDIMENT QUALITY

For QA/QC purposes, one field duplicate sample will be collected for every ten sediment samples, and will be analyzed separately. COC forms will accompany all samples for identification, tracking and transporting purposes.

## 10.3 BENTHIC INVERTEBRATE SURVEY

Field sub-samples would be collected from each benthic invertebrate monitoring replicate station, to compensate for the spatial variability encountered with these organisms. There were five sub-samples collected at each replicate station during the fall 2013 lake benthic invertebrate field program to facilitate examination of variability between sub-samples. This analysis will inform details of the design in future monitoring programs (i.e., number of sub-samples required, pooling of sub-samples prior to analysis). Appropriate QA/QC measures related to processing and identification, as outlined in the EEM technical guidance document will be followed and are described below (EC, 2012). These measures will incorporate the proper steps related to re-sorting, sub-sampling and maintenance of a voucher collection, as needed. The voucher collection will be taxonomically analysed by a second qualified invertebrate taxonomist.

Benthic samples will be analyzed by a taxonomist. All samples will be sorted with the use of a stereomicroscope (10X). Samples will be washed through a 500 micron sieve and sorted entirely, except in the following instances: those samples with large amounts of organic matter (i.e., detritus, filamentous algae) and samples with high densities of major taxa. In these cases, samples will be first washed through a large mesh size sieve (3.36 mm), to remove all coarse detritus, leaves, and rocks. Large organisms such as leeches, crayfish, late instar dragonflies, stoneflies, and mayflies retained in the sieve will be removed from the associated debris. The remaining sample fraction will be sub-sampled quantitatively, if necessary. For QA/QC evaluation, the sorted sediments and debris will be re-preserved and retained for up to six months following submission of the first cycle interpretive report for the EEM program. For those samples that were sub-sampled, sorted and unsorted fractions will be re-preserved separately. Sorted organisms will be re-preserved.

All invertebrates will be identified to the lowest practical level, usually genus or species level. Chironomids and oligochaetes will be mounted on glass slides in a clearing media prior to identification. In samples with large numbers of oligochaetes and chironomids, a random sample of no less than 20% of the selected individuals from each group will be removed from the sample for identification, up to a maximum of 100 individuals.

Following identification and enumeration, a detailed list of individuals collected will be submitted for each replicate station. The list will be in a standard spreadsheet format.

## 10.4 FISH

QA/QC technical procedures will be utilized for all field sampling, laboratory analysis, data entry and data analysis to produce technically sound and scientifically defensible results. As part of routine QA/QC for field operations, equipment will be regularly inspected, maintained and replaced if necessary. Detailed field notes will be recorded with a daily end of day check to verify completeness and accuracy of the recorded data. All data collection, entry, analysis and QA/QC will be conducted by a trained fish biologist.

The fish ages will be determination by experienced technicians and a minimum of 10% of fish ageing structures that are processed will be independently and blindly aged by a second technician. As a non-lethal survey is proposed, the preferred ageing structure for Arctic Char and that which was collected from mortalities during the baseline studies for ageing purposes (otoliths) will only be collected from incidental mortalities during the monitoring programs. The CREMP and the EEM program are anticipated to employ a non-lethal design and therefore will require use of other ageing structures (i.e., scales or pectoral fin rays) for fish that are live released. Anticipating that scales are the least preferred ageing structure for this species due to their small size, it is assumed that pectoral fin rays will be the primary ageing structure collected during the monitoring program. As part of the QA/QC program, it is recommended to collect both otoliths and pectoral fin rays from incidental mortalities and potentially from a length-stratified sub-sample during the conduct of future studies for the purpose of cross-verification of these two ageing structures. Pectoral fin rays and otoliths were collected from 16 Arctic Char in 2013 to facilitate this comparison.

All data entered electronically will undergo a 100% transcription QA/QC by a second person to identify any transcription errors and/or invalid data.

## 10.5 DATA EVALUATION

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

The variation among stations within the study area, among samples within the stations (field sub-samples) and analytical variation (among laboratory replicates) will be calculated as estimates of the components of variation in the data set and compared to the expected values, where applicable.

# 11 ANNUAL REPORTING

Annual reporting for the AEMP will be completed as specified in the Type A Water Licence, based on the on the Nunavut Watershed Management Areas as follows:

Eclipse Sound Water Management Area No. 48 will provide the results of the monitoring for:

- Milne Port
- The Tote Road
- The Mine Site
- The northern section of the railway

Gifford Water Management Area No 21 will provide results of the monitoring for:

- The southern section of the railway
- Steensby Port

Monitoring and reporting will not be carried out for a water management area if there are no activities carried out within that water management area.

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