Baffinland Iron Mines Corporation

AQUATIC EFFECTS MONITORING PLAN

BAF-PH1-830-P16-0039

Rev 1

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DOCUMENT REVISION RECORD

Issue Date MM/DD/YY	Revision	Prepared By	Approved By	Issue Purpose
06/27/14	0	Jim Millard	Oliver Curran	Part I, Item 2 of Type A Water Licence No. 2AM-MRY1325
10/30/15	1	William Bowden		Part I, Item 2 of Type A Water Licence N0. 2AM-MRY1325 Amendment No.1

Index of Major Changes/Modifications in Revision 1

Item No.	Description of Change	Relevant Section
1	Updated: Issued date and scope of Type A Water Licence 2AM-MRY1325 – Amendment No.1 pertaining to the AEMP	Section 1.1
2	Updated: Reference to monitoring MS-08 and Mine pit discharge	Section 2.1.1
3	Updated: Water consumption restrictions under the Amended Type A Water Licence	Section 2.2
4	Updated: Additional Water licence sites established for hydrological monitoring	Section 3.3
5	Updated: Hydrometric stations operated in consideration of the Water Survey of Canada's national standards	Section 3.3
6	Updated: Additional new monitoring stations and status; Table 3.2 Established SNP Monitoring Stations Associated with ERP	Section 3.5
7	Updated: Additional SNP monitoring stations; Figure 3.2 Mine Site Surveillance Network Program (SNP)	Section 3.5
8	Updated: Additional SNP monitoring stations; Figure 3.3 Milne Port Surveillance Network Program (SNP)	Section 3.5
9	Updated: Status of Table 3.3 Future SNP stations Associated with ERP	Section 3.5
10	Updated: Tote Road Monitoring details prescribed under the Amended Type A Water Licence	Section 3.6.1
11	Updated: Lake Sedimentation Monitoring Program methodology justification	Section 4.3.1
12	Updated: Stream Diversion Barrier Study methodology justification	Section 4.3.3
13	Updated: Preferred and alternative statistical methodology	Section 5.2

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ABBREVIATIONS

*** Project	the project
AANDC	Aboriginal Affairs and Northern Development Canada
AEMP	the Aquatic Effects Monitoring Plan
ANFO	Ammonium Nitrate Fuel Oil
BC MOE	Ministry of the Environment
CanNor	Canadian Northern Economic Development Agency
CCME	Canadian Council of Ministers of the Environment
CES	Critical Effect Size
CREMP	Core Receiving Environmental Monitoring Program
CWQG-PAL	Canadian Water Quality Guidelines for Protection of Freshwater Aquatic Life
DFO	Department of Fisheries and Oceans
EC	Environment Canada
EDA	Exploratory Data Analysis
EEM	Environmental Effects Monitoring Program
ERP	Early Revenue Phase
ETMF	Exposure Toxicity Modifying Factors
FEIS	Final Environmental Impact Statement
HADD	Harmful Alternation, Disruption or Destruction of Fish Habitat
INAC	Indian and Northern Affairs Canada
MHTO	Mittimatalik Hunters and Trappers Organization
MMER	Metal Mining Effluent Regulations
NLCA	Nunavut Land Claims Agreement
NSC	North/South Consultants Inc.
NWB	Nunavut Water Board
QIA	Qikiqtani Inuit Association
ROM	Run-of-Mine
SDA	Statistical Data Analysis
SNP	Surveillance Network Program
SSWQO	Site-specific Water Quality Objective
TAP	Technical Advisory Panel
TEMMP	Terrestrial Environment Management and Monitoring Plan
TEWG	Terrestrial Environment Working Group
TOC	Total Organic Carbon
TSP	Total Suspended Particulate
TSS	Total Suspended Solids
VECs	Valued Ecosystem Components
WWTF	Wastewater Treatment Facility

1 INTRODUCTION

This Aquatic Effects Monitoring Plan (AEMP) describes how monitoring of the aquatic environment will be undertaken at the Mary River Project. The AEMP was identified as a follow-up monitoring program in Baffinland`s Final Environmental Impact Statement (FEIS; Baffinland, 2012) and is prescribed by Baffinland`s Type A Water Licence No. 2AM-MRY1325 Amendment No. 1. The AEMP is a monitoring program designed to:

- Detect short-term and long-term effects of the Project's activities on the aquatic environment resulting from the Project;
- Evaluate the accuracy of impact predictions;
- Assess the effectiveness of planned mitigation measures; and
- Identify additional mitigation measures to avert or reduce unforeseen environmental effects.

The AEMP focuses on the key potential impacts to freshwater environment valued ecosystems components (VECs), as identified in the FEIS and the Addendum to the FEIS (FEIS Addendum; Baffinland, 2013a) for the Early Revenue Phase (ERP). The freshwater VECs are:

- Water quantity;
- Water and sediment quality; and
- Freshwater biota and fish habitat.

The AEMP has been structured to serve as an overarching 'umbrella' that conceptually provides an opportunity to integrate results of individual but related aquatic monitoring programs. Table 1.1 describes the organization of the AEMP document.

Table 1.1 AEMP Document Organization

Section	Heading	Description
1	Introduction	The scope of the AEMP, the applicable regulatory requirements for an AEMP, and consultation undertaken during its development.
2	Problem Formulation	An overview of key issues and pathways in which the Project may affect freshwater aquatic valued ecosystem components (VECs). Potential issues and concerns are also presented by project component and water management area.
3	AEMP-Related Programs	A brief description of ongoing monitoring programs that are peripheral to but may inform monitoring as part of the AEMP.
4	AEMP Component Studies	A summary of the various long-term and targeted component studies included under the AEMP umbrella, for which detailed study designs are presented in appendices.
5	Assessment Approach and Management Response	A description of the process used to develop benchmarks for comparison for the various AEMP components (i.e., water, sediment, nutrients, and biota) and the common approach to reviewing and assessing monitoring data and implementing action if necessary.
6	Quality Assurance and Quality Control	An overview of the QA/QC measures to be implemented in the collection of samples and the handling of data, for the various aquatic components.
7	Annual Reporting	A description of the content and frequency of reporting under the AEMP
8	List of Contributors	Key Baffinland staff and consultants involved in the development of the AEMP

Section	Heading	Description
9	References	Documents referenced in the report

The AEMP targets flows, water and sediment quality, primary productivity (phytoplankton), benthic community structure and fish (specifically Arctic Char) within the streams and lakes potentially affected by project activities. Development of individual monitoring programs/studies under the umbrella AEMP has allowed for the application of a common platform in terms of study design and sampling protocols.

The following are the component studies that comprise the AEMP:

- **Environmental Effects Monitoring (EEM) Program**, as required under the Metal Mining Effluent Regulations (MMER);
- **Core Receiving Environment Monitoring Program (CREMP)**, which includes monitoring of the core mine site area (water, sediment, benthic invertebrates and fish);
- **Lake Sedimentation Monitoring Program**, evaluating baseline and project-influenced lake sedimentation rates;
- **Dustfall Monitoring Program**, evaluating dustfall rates in proximity to the road, port and mine; and
- **Stream Diversion Barrier Study**, an initial study evaluating potential for fish barriers under natural conditions and due to Project-related stream diversions.

The EEM Program is a legal requirement of metal mines such as the Mary River mine. The Draft EEM Cycle One Study Design has been included under the umbrella of the AEMP and follows a separate but related regulatory function. Baffinland proposes to meet the requirements of the MMER on its own, but report the outcome of EEM monitoring as part of the AEMP.

The CREMP forms the backbone of the AEMP. The CREMP is a detailed aquatics monitoring program intended to complement and expand the scope of an EEM Program required under the MMER. The CREMP is intended to monitor the effects of multiple stressors on the aquatic environment, including the discharge of mine effluents and treated sewage effluent as well as ore dust deposition. The CREMP will include the monitoring of water, sediment, phytoplankton, benthic invertebrates and fish in the mine site area streams and lakes.

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. The Lake Sedimentation Study, Dustfall Monitoring Program, and the Stream Diversion Monitoring Study are such studies.

Stand-alone study designs have been prepared. These are briefly described in Section 4 and are included in the appendices of this report. Table 1.2 lists and provides a description of the stand-alone study designs and related technical support documents.

Monitoring prescribed under the related and water licence prescribed Surveillance Network Program (SNP) focuses on detecting short-term project-related effects. The AEMP is designed to detect project-related impacts at greater temporal and spatial scales that are ecologically relevant (i.e., on a basin spatial scale).

The AEMP is a living document that is expected to be updated periodically throughout the life of the mine to account for the close-out of shorter-term monitoring programs, changes in study designs that are driven by the findings of monitoring or changes to the Project, and new information in the field of aquatic effects monitoring including updated toxicological data.

The AEMP components and the relationship of the AEMP to the Water Licence and other aquatic monitoring activities are shown on Figure 1.1.

Table 1.2 AEMP Component Studies and Technical Support Documents

Appendix	Document Title	Description
Appendix A	Draft EEM Cycle One Study Design	A draft of the initial (cycle one) study design report, which will be formally submitted to Environment Canada 12 months from initial date when Mine was subject to the Metal Mining Effluent Regulations (MMER)
Appendix B	Water and Sediment Quality Review and CREMP Study Design	Presents the water and sediment quality CREMP including a review of the water and sediment quality baseline
Appendix C	Development of Water and Sediment Quality Benchmarks for Application in Aquatic Effects Monitoring at the Mary River Project	A technical document describing the process and outcome for development of benchmarks for application in the water and sediment quality CREMP
Appendix D	Core Receiving Environment Monitoring Program: Freshwater Biota	Presents the freshwater biota CREMP including a review of the freshwater biota baseline
Appendix E	Candidate Reference Lakes: Preliminary Survey 2013	Presents work completed to date on candidate reference lakes, supporting the CREMP.
Appendix F	Lake Sedimentation Monitoring Program	A targeted study on baseline and project-influences lake sedimentation rates
Appendix G	Dustfall Monitoring Program	The dustfall monitoring program contained in the Terrestrial Environment Management and Monitoring Plan (TEMMP; Baffinland, 2014)
Appendix H	Initial Stream Diversion Barrier Study	A targeted study on monitoring the effects of Project-related Stream Diversion

1.1 WATER LICENCE REQUIREMENTS

The Nunavut Water Board (NWB) issued Type A Water Licence No: 2AM-MRY1325 to Baffinland on June 10, 2013. The licence is valid for 12 years, expiring on June 10, 2025.

Part I of the licence outlines conditions related to general and aquatic effects monitoring. Part I (1) approved with the issuance of the water licence for the construction phase of the Project an AEMP Framework prepared in February 2013 (Baffinland, 2013b). Part I (1) also required Baffinland, upon further consultation, submit a revised AEMP Framework that considered recommendations received during the final technical review and public hearing during the water licensing process. An Updated AEMP Framework was submitted to the Nunavut Water Board on November 29, 2013 (Baffinland, 2013c).

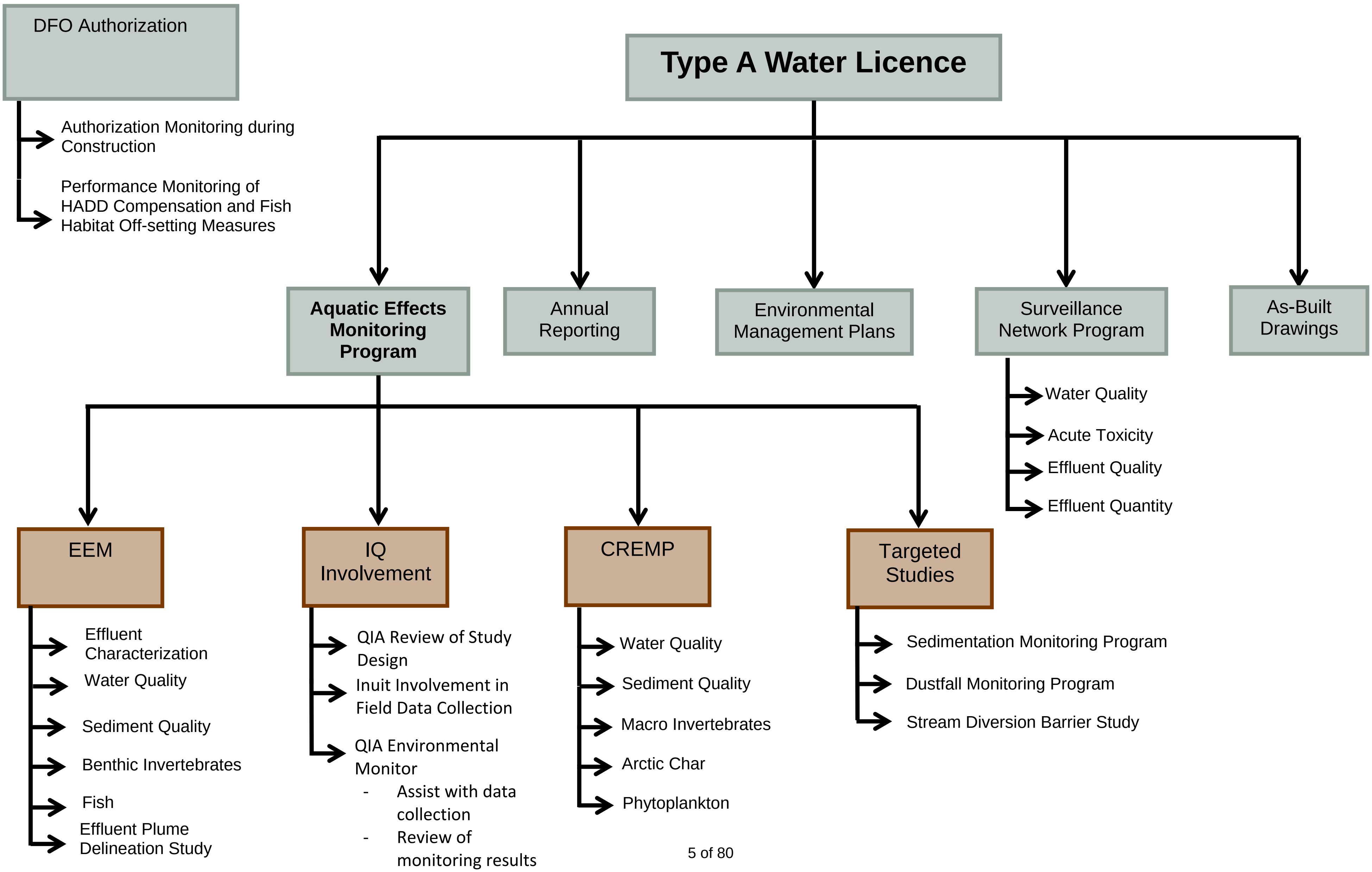
Part I (2) of the licence requires Baffinland to submit to the board for approval in writing an Aquatic Effects Management Plan (AEMP) at least 60 days prior to commencing the operating phase of the project. This document will be submitted to the NWB in fulfillment of this requirement.

On September 2, 2015 The Nunavut Water Board (NWB) issued the Type A Water Licence No: 2AM-MRY1325 Amendment No.1 to Baffinland. The Amended Licence incorporates the entire scope of the

Type “B” Water Licences Nos. 8BC-MRY1314 and 8BC-MRY1416, issued to the Mary River Project for construction and site preparation work; specific elements on the scope of Type “B” Licence No 2BE-MRY1421, issued to the project for Exploration and Bulk Sample Programs; most of the scope of the Amendment No.1 Application, which includes the Early Revenue Phase (ERP) activities and facilities.

Part I, Item 2 requires Baffinland to submit to the board for approval in writing a revised version of the AEMP 60 days following the issuance of the Amended Type A Water Licence. The submission of this document satisfies this condition once approved

Figure 1.1 AEMP Components and Relationship to Other Monitoring Programs



1.2 RELEVANT PROJECT CERTIFICATE CONDITIONS

NIRB issued Project Certificate No. 005 to Baffinland on December 28, 2012. Through 2013 and the first half of 2014, Baffinland sought an amendment to its Project Certificate (PC) to allow for an Early Revenue Phase (ERP) of the Project. At the time of writing, the NIRB Board and the federal Minister of Aboriginal Affairs and Northern Development Canada (AANDC) have approved the Project in writing and NIRB hosted a project certificate workshop. NIRB has issued a final hearing report for the ERP identifying proposed amendments and additions to the terms and conditions in PC No. 005 (NIRB, 2014). Baffinland anticipates that an amended PC will be received in the near future.

A number of Project Certificate terms and conditions (PC Conditions) relate to the protection of the aquatic environment, namely #16 through 19 (hydrology and hydrogeology); #20 through 24 (ground and surface waters); and #41 through 48 (freshwater aquatic environment including biota and habitat). PC Conditions not captured directly by permits, licences, authorizations and approvals (including the Type A Water Licence Amendment No. 1) have been incorporated into the various management plans required by the Type A Water Licence Amendment No. 1 and/or the PC No.005.

PC Condition #21 relates specifically to the AEMP, and states the following (from NIRB, 2014):

The Proponent shall ensure that the scope of the Aquatic Effects Monitoring Plan (AEMP) includes, at a minimum:

a. monitoring of non-point sources of discharge, selection of appropriate reference sites, measures to ensure the collection of adequate baseline data and the mechanisms proposed to monitor and treat runoff, and sample sediments; and

b. measures for dustfall monitoring designed as follows:

i. To establish a pre-trucking baseline and collect data during Project operation for comparison;

ii. To facilitate comparison with existing guidelines and potentially with thresholds to be established using studies of Arctic char egg survival and/or other studies recommended by the Terrestrial Environment Working Group (TEWG); and,

iii. To assess the seasonal deposition (rates, quantities) and chemical composition of dust entering aquatic systems along representative distance transects at right angles to the Tote Road and radiating outward from Milne Port and the Mine Site.

The AEMP addresses Part (a) of PC Condition #21. Part (b) overlaps with the current dustfall monitoring program described in the TEMMP (Baffinland, 2014). The existing dustfall monitoring program from the TEMMP is included in Appendix G. Interpretation of the dustfall monitoring data in relation to the aquatic environment forms part of the lake sedimentation targeted study described in Section 4.3.1 and Appendix F.

1.3 CONSULTATION DURING DEVELOPMENT OF THE AEMP

Baffinland would like to acknowledge the participation and contributions of a number of stakeholder agencies in the development of this AEMP:

- Aboriginal Affairs and Northern Development Canada (AANDC);
- Canadian Northern Economic Development Agency (CanNor);
- Department of Fisheries and Oceans Canada (DFO);

- Environment Canada (EC);
- Nunavut Water Board (NWB); and
- Qikiqtani Inuit Association (QIA).

The above organizations were invited and participated in workshops and on-line presentations, and reviewed various iterations of an AEMP Framework document that was circulated. Key consultation activities in the development of this AEMP are listed in Table 1.3.

Table 1.3 Consultation during AEMP Development

Date	Activity
July 6, 2012	Initial AEMP Consultation Meeting by WebEx
November 13, 2012	Conceptual Framework Development Workshop, 1-day workshop held in-person and by WebEx at Hatch Associated Ltd. Offices in Mississauga
December 12, 2012	Draft AEMP Framework filed with NWB and circulated to interested parties
January 14-18, 2013	Technical Meetings on the Type A Water Licence Application, held in Pond Inlet
February 12, 2013	Second AEMP Framework Development Workshop, 1-day workshop held in-person and by WebEx at Hatch Associated Ltd. Offices in Mississauga
February 26, 2013	AEMP Framework filed with NWB and circulated to interested parties
April 23-25, 2013	Final Hearings for the Type A Water Licence Application, held in Pond Inlet
November 15, 2013	Draft Updated AEMP Framework circulated to interested parties
November 21, 2013	WebEx Presentation on Draft Updated AEMP Framework with interested parties
November 29, 2013	Updated AEMP Framework filed with NWB and circulated to interested parties in accordance with Part I, Section 1 of the Type A Water Licence
April 3, 2014	WebEx meeting presenting refined AEMP component study plans to appear in this AEMP document

As mentioned above, Baffinland is grateful for the participation and contributions of the interested parties listed above.

2 PROBLEM FORMULATION

2.1 PROJECT DESCRIPTION

The Project is an iron ore mine with a production rate of 21.5 Mt/a, consisting of the following major components:

- Milne Port;
- Mine Site;
- Railway; and
- Steensby Port.

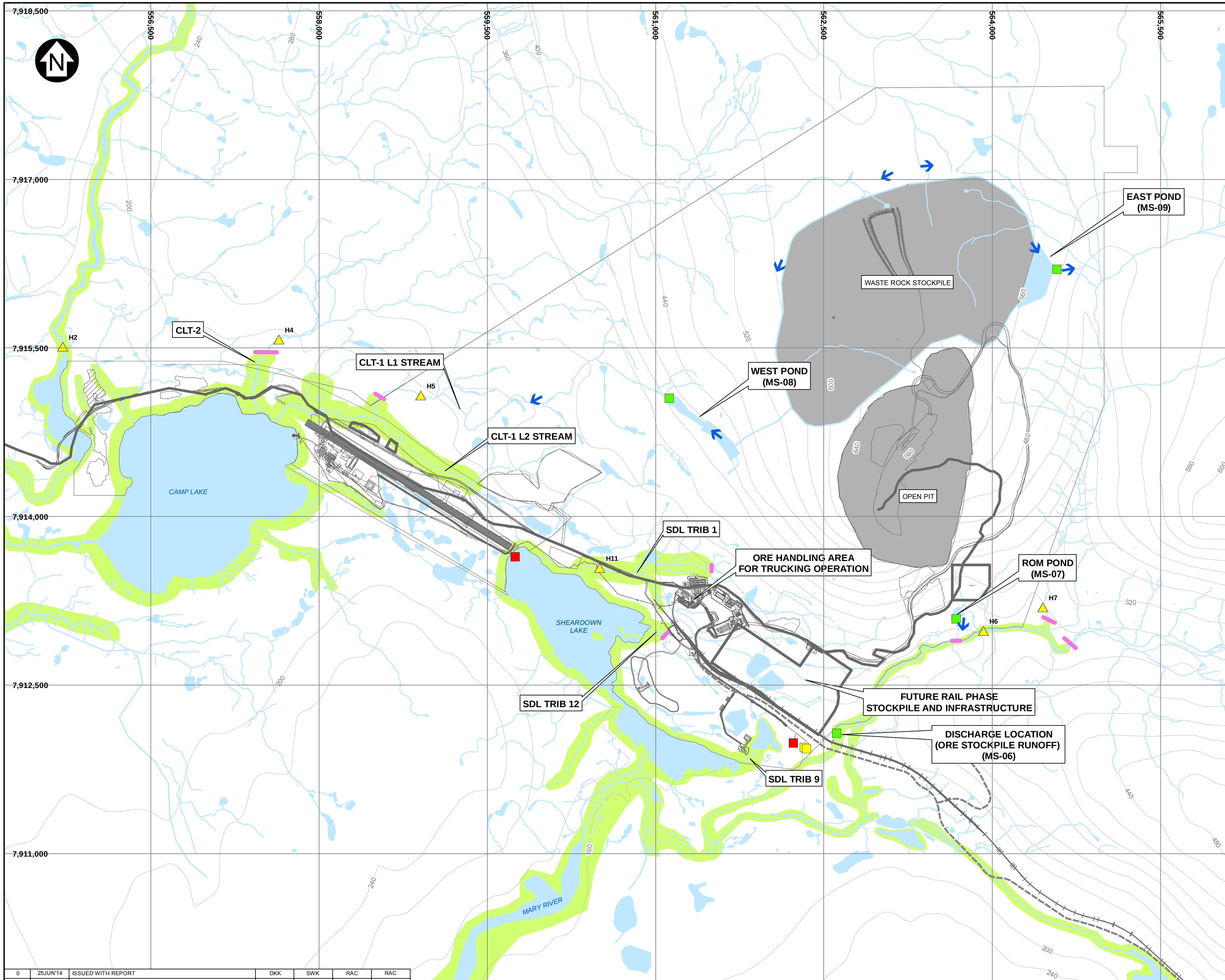
Each development site (excluding the railway) will have all the facilities it needs to operate effectively including maintenance and administrative buildings, warehouses and laydown areas, ore stockpiles and associated runoff management facilities, camps, water supply, wastewater treatment plants, waste management facilities including landfills, power generation, fuel depots, telecommunication facilities, and airstrips.

Baffinland is approved to mine Deposit No. 1 at the mine site by open pit mining methods. Since the Mary River iron ore is of a very high-grade, there is no need to have a process plant (or mill) on site, resulting in no tailings being generated. As such, no tailings pond will be required. This is accomplished by crushing and screening of the ore to produce two iron ore products:

- Lump ore – sized between 6.3 mm and 31.5 mm (about golf ball size); and
- Fine ore - sized less than 6.3 mm (about pea size).

Ore will be stockpiled at the mine site and transported either by truck to Milne Port or by railway to Steensby Port. Ore handling facilities at the mine site will consist of the open pit, separate ore stockpiles for the trucking and railway operations, and water management facilities to collect runoff from ore stockpiles. Waste rock will be stockpiled in a single stockpile next to the open pit, and up to two ponds will collect runoff from the stockpile. The trucking and railway operations will have separate ore stockpiles and runoff collection ponds but will otherwise share common water management facilities and final discharge points (Figure 2.1).

Mining began September 2014 with a low-capital trucking operation involving the mining of 3.5 million tonnes per annum (Mt/a) of iron ore being transported year-round by truck to Milne Port, with marine shipping to market during the open water season. Ore handling facilities at Milne Port consist of truck unloading facilities, ore stockpiles and ship-loading facilities at an ore dock. Runoff from the stockpile area at Milne Port will be collected inponds that will discharge to the marine waters of Milne Inlet. Environment Canada has advised Baffinland that the mine effluent discharge to Milne Inlet will not be subject to the MMER, though the *Fisheries Act* still apply, including Section 36(3) regarding the prohibition of discharges of a deleterious substance in waters frequented by fish (Anne Wilson, pers.comm.) Monitoring of effects to the marine environment is beyond the scope of this AEMP.



LEGEND:

- MINE EFFLUENT FINAL DISCHARGE POINT
- SUMMER DISCHARGE LOCATION OF TREATED SEWAGE EFFLUENT
- WINTER LAND DISCHARGE LOCATION OF TREATED SEWAGE EFFLUENT TO MARY RIVER
- STREAM FLOW GAUGING STATION
- FISH BARRIER
- EXISTING TOTE ROAD
- PROPOSED RAILWAY ALIGNMENT
- PROPOSED CONSTRUCTION ACCESS ROAD
- PROPOSED SITE INFRASTRUCTURE
- RIVER/STREAM/DRAINAGE
- WATER
- CONFIRMED ARCTIC CHAR HABITAT

NOTES:

1. BASE MAP: © HER MAJESTY THE QUEEN IN RIGHTS OF CANADA, DEPARTMENT OF NATURAL RESOURCES (2004). ALL RIGHTS RESERVED.
2. COORDINATE GRID IS UTM NAD83 ZONE17.
3. CONTOUR ARE IN METRES. CONTOUR INTERVAL VARIES.
4. INFRASTRUCTURE INFORMATION PROVIDED BY HATCH ON JANUARY 31, 2014.
5. ARCTIC CHAR HABITAT (PRESENCE) FROM NSC, 2012 MARY RIVER PROJECT FRESHWATER AQUATIC BASELINE SYNTHESIS. REPORT: 2005-2011.

SCALE 250 125 0 250 500 750 1,000 1,250 1,500 m

BAFFINLAND IRON MINES CORPORATION

MARY RIVER PROJECT

MINE SITE LAYOUT

Knight Piésold CONSULTING

P/A NO.	REF NO.
NB102-181/34	1

FIGURE 2.1	REV 0

REV	DATE	DESCRIPTION	DESIGNED	DRAWN	CHK'D	APP'D
0	25JUN'14	ISSUED WITH REPORT	DKK	SWK	RAC	RAC

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At some point in the future when the iron ore market and economic conditions for financing capital-intensive projects improves, an 18 Mt/a railway operation will be constructed. This will involve the construction and operation of a 149-km railway to Steensby Port. Steensby Port, once constructed, will be equipped with a railway car dumper and associated conveying equipment, an ore stockpile, and ship-loading facilities to load ore onto ice-breaking ore carriers.

Shipping of ore from Steensby Port will take place year-round. Runoff from the ore stockpile at Steensby Port will be collected and discharged to the marine waters in Steensby Inlet. Environment Canada similarly advised that the mine effluent discharge to marine waters from the ore stockpile at Steensby Port would not be subject to the MMER but would otherwise be subject to the *Fisheries Act*.

A number of proven mitigation measures have been included in the Project to reduce potential effects on water quality, freshwater fish, fish habitat, and other aquatic organisms. At each of the ore handling locations, crushers and screens will be installed inside buildings, and conveyors will be covered and equipped with wind ventilation hoods to reduce wind exposure and the potential for dust generation. All ventilation ducts will be routed to dust collectors which will limit dust emissions. Specific management plans detail the many ways that water will be protected (Baffinland, 2012).

The operational life of the Project, based on current ore reserves and a production rate of 21.5 Mt/a, is 21 years. The Closure of the facilities is expected to be carried out over a three to five year period and post-closure monitoring will follow for an additional five years. If closure objectives are not met, post closure would extend beyond five years.

2.1.1 Water Management Facilities and Final Discharge Points

A total of four ponds will collect runoff from stockpiles and the open pit at the mine site:

- West Pond – will collect runoff from the west side of the waste rock stockpile;
- East Pond – will collect runoff from the east side of the waste rock stockpile;
- ROM Pond – will collect runoff from the ROM stockpile; and
- Ore Stockpile Pond – will collect runoff from the ore stockpiles. Initially this will be one smaller pond for the ERP, and eventually a second pond will be constructed to support the rail phase.

Monitoring of the Waste Rock Pile (MS-08) in a settling pond commenced during the summer of 2015 which coincided with the early development of the waste rock pile. Currently, the pit has not developed sufficiently to the point that there is a sump with active discharge. A suitable monitoring location and analytical schedule will be established once this has occurred.

Mine effluent will be discharged to two watercourses (Figure 2.1):

- Mary River; and
- Camp Lake Tributary 1.

There will be three final discharge points that will discharge mine effluent to the Mary River as follows:

- East Pond discharge collecting stormwater from the east side of the waste rock stockpile;
- Run-of-mine (ROM) stockpile discharge; and
- Ore stockpile discharges (trucking and rail phases) at the rail load-out area

There will be one final discharge point to Camp Lake Tributary 1, from the West Pond collecting stormwater from the west side of the waste rock stockpile.

2.1.2 Stream Diversions

The development of the open pit, a waste rock stockpile, and associated water management facilities (ditches, berms and settling ponds) will divert and redirect runoff away from certain watercourses during the operational phase of the Mary River Project (Baffinland, 2012). Five tributary streams are anticipated to be affected by diversions in the Mine Area (Figure 2.1).

The reduced production rate associated with the ERP will result in a considerably smaller mining footprint (open pit and waste rock stockpile) than associated with the future rail phase. As such, Project-related stream diversions will be negligible during the ERP.

A discussion of the Project's effects on the freshwater VECs follows.

2.2 WATER QUANTITY

Article 20 Inuit Water Rights of the Nunavut Land Claims Agreement (NLCA) formally recognizes the importance of water quantity and flow to the Inuit. Under the NLCA, Inuit require compensation if a project or activity will substantially affect the quantity of water flowing through Inuit-Owned Lands. Therefore, water quantity has been identified as a VEC. The water quantity VEC can be defined as the spatial and temporal variability of the volume of water within the RSA that may be subject to alteration by Project activities.

Conditions applying to water use and management have been outlined in Part E of the Water Licence (NWB, 2013). These conditions will be adhered to throughout applicable timeframe of this licence. The current limits on water use in the Type A Water Licence Amendment No.1 are 1,888 m^3/day and 689,000 m^3/year total water use from all sources during the construction phase, and 967 m^3/day or 353,000 m^3/year during the operation phase, for total domestic camp and industrial water use from all sources.

Key Issues and Pathways for Water Quantities

Key issues identified for freshwater quantity are listed below:

- Water Withdrawal;
- Water Diversion (stream diversion or changes to flow patterns in a specific watershed); and
- Runoff or effluent discharge.

Key Indicators and Benchmarks

The key indicators for water quantity are listed below:

- Water withdrawn for consumption (measured in cubic metres – m^3); and
- Streamflow increase or decrease (measured as a percent change of mean).

The benchmarks are the water quantities authorized under the Type A Water Licence Amendment No.1.

Diversions, Drainage Flows (Runoff) and Effluent Discharges

Diversions, drainage flows and effluent discharges are mainly impacted at the Mine Site and have potential effects on fish habitat due to reduction or increase in flows that result from the site development. This is discussed in Section 4.3.3.

2.3 WATER AND SEDIMENT QUALITY VEC

Key Issues and Pathways

Key issues considered for the surface water and sediment quality VEC are summarized in Table 2.1.

Table 2.1 Key Issues for Water and Sediment Quality at the Mine Site

PATHWAY	KEY ISSUES	LOCATION	PROJECT PHASES
Surface runoff	Uncontrolled runoff at construction site Erosion and sediment entrainment Site drainage control Spills and contamination Drainage from quarry sites	All	Construction Operation Closure
Discharges from secondary containment	Fuel depots/storage - contact water may be contaminated with hydrocarbon/petroleum products	Milne Port, Mine Site, Railway construction, Steensby Port, Quarry sites	Construction Operation Closure
Discharge of brine used for drilling in permafrost	Salinity of the discharge	Railway tunnels	Construction
Pooling water in landfarm	Pooling water maybe contaminated with hydrocarbon/petroleum product and may require treatment prior to discharge	Milne Port Mine Site Steensby Port	Construction Operation Closure
Pooling water in landfill	Pooling water maybe contaminated with metals, hydrocarbon/petroleum product and may require treatment prior to discharge	Mine Site Steensby Port	Construction Operation Closure
Treated sewage effluent discharges	Effectiveness of treatment - pH, flows, Biological oxygen demand (BOD), Faecal Coliform (FC), TSS, nutrient, metals, oil and grease	Sheardown Lake Mary River outfall	Construction Operation Closure
Treated oily water treatment plant discharge	Effectiveness of treatment - pH, flows, TSS, metals, oil and grease	Mary River outfall	Construction Operation Closure
Dustfall	TSS in runoff, sediment deposition on stream and lake bottoms	Mine Site	Construction Operation Closure
Run of mine ore stockpile contact water	Metals, TSS	Mary River	Operation
Ore stockpile contact water	Metals, TSS	Mary River	Operation
Mine pit dewatering	Metals, TSS, blasting residue (ammonia)	Camp Lake Tributary	Operation
Waste rock stockpile runoff – west pond	ARD, metals, TSS, blasting residue (ammonia)	Camp Lake Tributary	Operation Closure Post-closure
Waste rock stockpile runoff – east pond	ARD, metals, TSS, blasting residue (ammonia)	Mary River	Operation Closure Post-closure

PATHWAY	KEY ISSUES	LOCATION	PROJECT PHASES
Surface runoff	Uncontrolled runoff at construction site Erosion and sediment entrainment Site drainage control Spills and contamination Drainage from quarry sites	All	Construction Operation Closure
Discharges from secondary containment	Fuel depots/storage - contact water may be contaminated with hydrocarbon/petroleum products	Milne Port, Mine Site, Railway construction, Steensby Port, Quarry sites	Construction Operation Closure
Discharge of brine used for drilling in permafrost	Salinity of the discharge	Railway tunnels	Construction
Pooling water in landfarm	Pooling water maybe contaminated with hydrocarbon/petroleum product and may require treatment prior to discharge	Milne Port Mine Site Steensby Port	Construction Operation Closure
Pooling water in landfill	Pooling water maybe contaminated with metals, hydrocarbon/petroleum product and may require treatment prior to discharge	Mine Site Steensby Port	Construction Operation Closure
Treated sewage effluent discharges	Effectiveness of treatment - pH, flows, Biological oxygen demand (BOD), Faecal Coliform (FC), TSS, nutrient, metals, oil and grease	Sheardown Lake Mary River outfall	Construction Operation Closure
Treated oily water treatment plant discharge	Effectiveness of treatment - pH, flows, TSS, metals, oil and grease	Mary River outfall	Construction Operation Closure
Dustfall	TSS in runoff, sediment deposition on stream and lake bottoms	Mine Site	Construction Operation Closure
Run of mine ore stockpile contact water	Metals, TSS	Mary River	Operation
Ore stockpile contact water	Metals, TSS	Mary River	Operation
Mine pit water	ARD, metals	Open pit	Post-closure

2.4 FRESHWATER AQUATIC BIOTA AND HABITAT

Key Issues and Pathways

Arctic Char (*Salvelinus alpinus*) are the primary freshwater biota of interest regarding potential effects of the Project on the aquatic environment. Potential linkages between the Project components/activities and Arctic Char are presented on Figure 2.2. These linkage pathways can be categorised into three key issues as follows:

- Key Issue #1: Potential effects on the health and condition of Arctic Char;
- Key Issue #2: Potential effects on Arctic Char habitat; and
- Key Issue #3: Potential effects on direct mortality of Arctic Char.

2.4.1 Potential Effects on the Health and Condition of Arctic Char

Project-related changes in water and/or sediment quality have the potential to affect the health and condition of Arctic Char. The major pathways of effects are based on the residual effects identified in the water and sediment quality assessment. Linkages considered for potential effects include three general categories:

- Point source discharges (treated sewage effluent, waste rock stockpile runoff, ore stockpile runoff, mine pit water, run of mine stockpile runoff, and exploration drilling runoff);
- Aqueous non-point sources (NPS; including effects related to sediment and erosion, release of blasting residues, general site runoff, development of quarries and borrow pits); and
- Dust emissions and introduction to surface waters.

Effects considered under this key issue relate to sub-lethal effects of Project-related changes in water and/or sediment quality on fish health and condition.

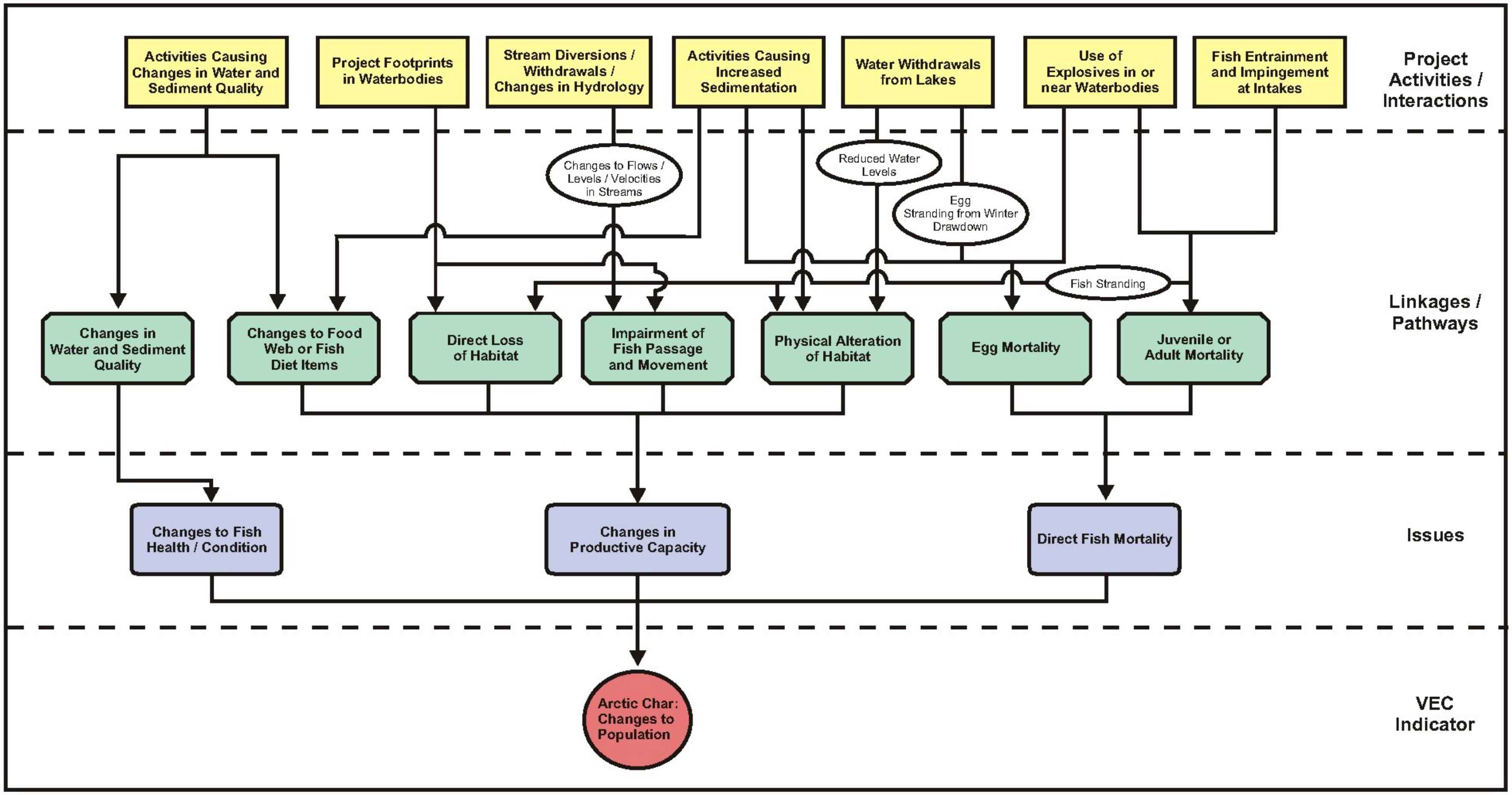
2.4.2 Potential Effects on Fish Habitat

Project activities with the potential to affect Arctic Char habitat include the following:

- Placement of Project infrastructure in water bodies (e.g., water intakes, sewage outfalls, stream crossings, lake encroachments, laydown areas);
- Various Project-related effects pathways that may alter other aquatic biota that are food sources for Arctic Char or form a component of the food web and thus may affect the productive capacity of their habitat (i.e., lower trophic level biota);
- Project-related effects on sedimentation rates that may result in alteration of habitat quality (e.g., due to dust deposition);
- Project-related changes to hydrology and subsequent effects on aquatic habitat (e.g., water withdrawal, stream diversion);
- Project-related effects on fish passage, with subsequent effects on the availability of habitat, including:
    - Stream crossing construction and operation; and
    - Changes in hydrology that may alter hydraulic conditions necessary for fish passage (e.g., stream velocities, water depth).

Most of these key issues relate to construction activities in or near water bodies.

Figure 2.2 Project Activities/Pathways of Potential Effects to Arctic Char



The following changes are associated with mine site development and also have the potential to affect fish and fish habitat:

- Water withdrawn from Camp Lake for domestic and industrial consumption will be discharged (after treatment) to the Mary River;
- Water withdrawal from Camp Lake will affect lake water levels and outflow discharge;
- Drainage patterns where the Mine site infrastructures/facilities are located will be altered. Most site runoff will be redirected to Mary River. As a result, less runoff will discharge to Sheardown Lake and Camp Lake. Tributaries of Sheardown Lake will be impacted. Lower flows may create barriers to fish passage; and
- Mine pit dewatering will be directed to the waste rock sedimentation pond which discharges into a Camp Lake tributary, thus diverting flows from the Mary River.

2.4.3 Potential Effects on Direct Fish Mortality

Project-related activities with the potential to cause direct mortality of Arctic char that are considered include the following:

- Effects of sedimentation on mortality of eggs;
- Potential egg stranding related to winter drawdown at water source lakes;
- Blasting in or near Arctic Char habitat;
- Placement of Project infrastructure in Arctic Char habitat (i.e., potential spawning areas);
- Potential for entrainment and/or impingement of Arctic Char eggs and juveniles at water intakes; and
- Potential fish stranding related to water diversions and/or alterations in discharge or water levels.

Potential effects of sedimentation on survival (hatching success) of Arctic Char eggs will be addressed through monitoring sediment deposition rates in Sheardown Lake as a target study (see Section 8). Potential for winter drawdown to cause egg stranding will be addressed through monitoring of water levels as the primary indicator, supported by information on Arctic char population monitoring (e.g., year class strengths, recruitment). Potential effects of blasting in or near Arctic Char habitat is addressed through the blasting management and monitoring program (see Section 4.11). The potential for placement of Project infrastructure to cause direct mortality of Arctic Char (i.e., placement of infrastructure on fish eggs) is addressed through mitigation and management, specifically through avoidance of potential spawning areas and/or by adherence to timing windows to avoid the egg incubation period. Potential for entrainment and impingement of fish at water intakes will be mitigated through adherence to DFO`s Freshwater intake end-of-pipe fish screen guideline (DFO, 1995). The last potential pathway of effect will be addressed through a follow-up target study to confirm fish passage at Mine area streams affected by water diversions (see Section 8.1.2).

2.4.4 Potential Effects of Blasting on Fish

Blasting will be conducted to support the construction and operation phases of the Project. The concern for potential effects on fish due to blasting overpressure mainly arises for the railway construction along Cockburn Lake where significant blasting is required for the following project components:

- The railway embankment on the east flank of Cockburn Lake; and
- The tunnel construction.

Effects of blasting on free-swimming Arctic Char and their eggs will be mitigated through the implementation of a detailed blasting management plan developed in accordance with DFO's blasting guidelines (Wright and Hopky, 1998).

2.4.5 Stream and River Crossing Construction and Lake Encroachments

Construction activities at watercourse crossings along the railway, railway access road, and Milne Inlet Tote Road have the potential to cause the following effects:

- Stranding of Arctic Char due to the need for isolation of the watercourses. This effect will be mitigated through the use of appropriate timing windows for construction when possible and through fish salvage operations when required.
- Potential impediments to fish passage at stream crossings due to changes in water levels, flows and/or velocities. This potential pathway of effect would be addressed through follow-up monitoring at selected stream crossings (i.e., a subset) to evaluate fish passage. This monitoring is described in detail in Appendix H.

2.5 POTENTIAL ISSUES AND CONCERNS BY PROJECT COMPONENT

Potential effects on aquatic ecosystems are presented below for each of the Project components within the two geographical areas for the construction and operation phases of the Project. Since abandonment and reclamation activities are similar in nature to construction activities, the concerns identified for the construction phase are also relevant for the closure phase.

2.5.1 Mine Site (Water Management Area 48)

The Mine Site includes the infrastructure required to support mining activities (camp, maintenance shops, fuel depots, wastewater treatment facility (WWTF), laydown areas, waste handling and storage facilities, landfill site and landfarm, explosives storage, manufacture and use). The freshwater supply for the Mine Site will be drawn from Camp Lake. Two quarries will be developed within the Mine Site area to provide aggregate material for the site development.

Potential aquatic effects at the Mine Site are listed in Table 2.2. The locations of all controlled discharges from the mine site are presented in Section 3.4.

2.5.2 Milne Port (Water Management Area 48)

The construction period at Milne Port began in the summer of 2013 following issuance of the Type A Water Licence (NWB, 2013). Milne Port will serve as the main staging areas for material and equipment required for the construction activities at the Mine Site and the northern section of the railway. The site includes the airstrip, fuel depots, camp and WWTF, laydown areas, maintenance facilities, and, temporary waste transit areas. Two sites have been identified for the fresh water supply for this facility (Phillip's Creek in summer; Km32 Lake in winter). Two quarries will be developed to provide aggregate for the site development.

Table 2.2 Potential Residual Effects to the Mine Site Aquatic Environment

VEC	CONCERN	PATHWAY	INDICATOR
Water Quantity	Withdrawal of water from Camp Lake		Volume withdrawn
	Flow diversion from Sheardown Lake		Visual – water level
Water and Sediment Quality	Earthworks	Surface runoff discharging to Camp Lake, Sheardown Lake, lake tributaries and Mary River	TSS, dust, spills
	Construction activities		TSS, dust, spills
	Site drainage		TSS, dust, spills
	Quarry site drainage		TSS, dust, spills, residual ammonia
	Fuel tank farms	Discharges from secondary containment areas to receiving environment – surface drainage	Hydrocarbons
	Waste storage area		Metals
	Bermed storage area		Metals, hydrocarbon
	Landfarm		Metals, hydrocarbon
	Landfill		Metals, hydrocarbon
	Treated Sewage Effluent (exploration camp)	Outfall to Sheardown Lake	BOD, TSS, nutrient
	Treated Sewage Effluent (main camp)	Outfall to Mary River	BOD, TSS, nutrient
	Treated Effluent from Oily Water Treatment Plant	Outfall to Mary River	TSS, hydrocarbon
	Waste rock stockpile drainage	Discharge to Camp Lake tributary	TSS, metals, nutrients
	Waste rock stockpile drainage	Discharge to Mary River	TSS, metals, nutrients
	ROM stockpile drainage	Discharge to Mary River	TSS, metals, nutrients
	Ore stockpile drainage	Discharge to Mary River	TSS, metals, nutrients
	Mine pit dewatering	Discharge to Camp Lake tributary	TSS, metals, nutrients/blasting residues
	Mine pit water post closure	End of life mine life pit water quality	Metals
	Dust	TSS in runoff	TSS
Freshwater Biota and Fish Habitat	Footprint of facilities in water bodies – water crossings	Loss of habitat – crossing of Mary River , Camp Lake tributaries	Habitat compensation
	Integrity of water crossing	Alteration of habitat	Erosion, blockage
	Fish passage	Alteration of habitat	Blockage, barrier
	Water diversions – changes in streams	Alteration or loss of habitat	Low flow and barrier to fish passage
	Changes in water and sediment quality (point and non-point sources)	Effects on Arctic Char health and condition; effects on lower trophic level biota (Arctic Char habitat)	Arctic char health and condition; population metrics; benthic invertebrate community metrics
	Dust Deposition	Alteration of habitat	Increased sediment deposition in streams and lakes Benthic invertebrate community metrics
		Deposition on Arctic Char eggs – reduced egg survival	Sedimentation rates in Arctic Char spawning habitat
Groundwater quality	Landfill	seepage in groundwater	Metals

At Milne Port, all site drainage is channeled to a central ditch that discharges into Milne Inlet (Figure 3.3). Treated sewage effluent as well as treated oily water effluent also discharge to this ditch at a distance of approximately 200 m from the Milne Inlet shoreline. As a result, site drainage and effluent discharge have no effects on the freshwater receiving environment. The original location of this ditch will be relocated to the east as a result of the final development plan for Milne Port.

The concerns for potential freshwater aquatic effects during the construction, operation and closure of the Milne Port site are listed below:

<u>Water Quantity</u>

- Withdrawal of water from Philips Creek (summer) and KM 32 Lake (winter)

<u>Water and Sediment Quality</u>

- Quarry management (runoff quality, ARD potential, residual ammonia from blasting activities)
- Construction of water intakes - TSS/turbidity
- Spills caused by accidents and malfunctions

<u>Freshwater Biota and Fish Habitat</u>

- Low magnitude effects to fish and fish habitat related to water quality changes

The discharge criteria for the effluent and runoff water quality are presented in the Type A Water Licence Amendment No.1 . The locations of all controlled discharges from the Milne Port site are presented in Section 3.4.

2.5.3 Tote Road (Water Management Area 48)

The Milne Inlet Tote Road connects Milne Port to the Mine Site. All material received at Milne Port will be transported by truck on the Tote Road. Realignment and re-grading of some road sections will be required. Select water crossings may be rebuilt as part of the ongoing maintenance of the road. A number of borrow pits have been identified along the Tote Road that will provide the necessary aggregate and material for ongoing road maintenance and road improvement.

The concerns for potential aquatic effects during construction, operation and closure of the Tote road are related to:

<u>Water and Sediment Quality</u>

- Dustfall from road traffic and related effects on water quality
- Drainage management from borrow pits

<u>Freshwater Biota and Fish Habitat</u>

- Construction and ongoing maintenance of stream crossing
- Changes in water quality that may affect biota
- Bank erosion, stability, blockage, integrity of the water crossings, fish passage

2.5.4 Railway (Water Management Areas 48 and 21)

Ore will be transported from the Mine Site to the Steensby Port by railway. The concerns for potential aquatic effects occur mainly during the construction period of the railway embankment. Four construction camps (with sewage treatment plant and waste incinerators) will be established at the onset of the construction period. Sewage effluent from these camps will be transported by truck to either the Mine Site or the Steensby Port sewage treatment facilities for treatment. There will be no local discharges of treated effluent (trucked to Steensby or Mine site sewage treatment plant). Domestic water supply and water required for construction activities will be drawn from a number of local lakes. A number of quarries will be developed along the railway alignment in order to provide the necessary rock and aggregate required for the rail embankment, stream crossing and bridge construction.

The concerns for potential aquatic effects during construction, operation and closure of the railway are related to the loss or alteration of fish habitat:

Water Quantity (Potable Water and Construction Activities)

- Water withdrawals affecting downstream flows

Water and Sediment Quality

- Surface runoff water quality (TSS, spills, dust from traffic)
- Quarry management (runoff water quality, TSS, ARD, blasting and ammonia)

Freshwater biota and fish habitat

- Stream/river crossings - flow velocity, TSS, erosion, fish stranding, fish passage and integrity of the water crossing
- Lake and river encroachment - loss of habitat, TSS (construction)
- Changes in water quality (e.g., dust, sewage effluent) - effects on Arctic Char health and condition/habitat
- Blasting near water (blasting overpressure) along Cockburn Lake

2.5.5 Steensby Port (Management Area 21)

The iron ore will be sized and stockpiled at Steensby Port prior to being loaded into the ore carriers for shipment. Steensby Port will contain large infrastructure required for ongoing support of the Port, the railway operation as well as the mine. The infrastructure at Steensby will include an airstrip, maintenance facilities (vehicles and railway), fuel depots, camps, a WWTF, warehouses, laydown areas, waste handling and storage facilities, landfill site, landfarm, explosives storage facilities, a freight dock, an ore stockpile and the ore loading dock. The freshwater supply for the Steensby Port will be drawn from two local lakes. Two quarries will be developed to provide aggregate for the development of the site.

At the Steensby site, surface drainage will be directed toward Steensby Inlet. Treated sewage effluent and treated oily water will discharge to Steensby Inlet via an outfall at a 35 m depth. As a result, site drainage and effluent discharge have minimal effects on the freshwater receiving environment.

The concerns for potential freshwater aquatic effects during the construction, operation and closure of the Steensby port are related to:

Water Quantity

- Withdrawal of water from 3 KM Lake (dust suppression and other minor uses) and ST347 Lake (permanent camp)

Water and Sediment Quality

- Quarry management (runoff quality, ARD potential, residual ammonia from blasting activities)
- Construction of water intakes - TSS/turbidity
- Spills caused by accidents and malfunctions

Freshwater Biota and Fish Habitat

- Stream/river crossings - flow velocity, TSS, erosion, fish stranding, fish passage and integrity of the water crossing
- Lake and river encroachment - loss of habitat, TSS (construction)
- Construction of water intakes - avoidance of spawning areas

The discharge criteria for the effluent and runoff water quality are presented in the Type A Water Licence Amendment No.1.

3 AEMP RELATED MONITORING PROGRAMS

A number of environmental monitoring programs relate to and support the AEMP.

3.1 INUIT QAUJIMAJATUQANGIT

The INAC (2009) AEMP Guidelines provide a basis for incorporating traditional knowledge (in the case of Nunavut this is termed Inuit Qaujimajatuqangit or IQ) into AEMP programs in an efficient and effective manner. The guidelines recognize a need for a flexible process for developing and implementing AEMPs that provide opportunities for input by interested parties including local communities and organizations. This is to ensure that Inuit interests and needs are understood and respected, especially in regard to potential effects of land or water use in potentially affected watersheds. The INAC (2009) AEMP Guidelines identify three key sources of IQ that contribute to an understanding of the environment.

1. Shared information within the community, and an oral history spanning multiple generations including specific observations, patterns of biophysical, social, and cultural phenomena, inferences relative to cause and effect, and predictions of the impacts of human activities. This information is obtained by means of direct observation and experience of the Inuit peoples.
2. Essential information on the use and management of the environment which can enhance understanding of cultural practices and social activities, land use patterns, archeological sites, harvesting practices, and harvesting levels, both now and in the past.
3. Information on the values that people place on the environment.

During the development of the AEMP, the Qikiqtani Inuit Association (QIA) participated in the consultation activities listed in Section 1.3, so that IQ may be incorporated into AEMP development and the implementation process. During these meetings, several of the participants had extensive experience with past projects where attempts were made to incorporate IQ and western science based programs as part of the AEMP. These participants openly shared their experiences with meeting attendees especially in regard to the difficulties involved in successfully incorporating IQ into AEMPs which by their very nature are highly scientific and statistical. However, success was made, and based on suggestions and discussions between Baffinland and QIA, and the application of the INAC Guidelines (2009), the following initiatives are proposed for consideration.

- As has been the practice over the last two years, Baffinland will continue to recruit and train local skilled Inuit environmental technologists to assist with future AEMP field sampling and monitoring programs. In this way, Baffinland Project staff can continue to mentor local Inuit in regards to the scientific and technical aspects of the AEMP and the Inuit can share their practical, historical, and traditional knowledge with Baffinland personnel.
- The QIA will have an Environmental Monitor on-site. The Environmental Monitor will be involved in field data collection and will have an opportunity to review and comment on monitoring results.
- The QIA is expected to continue to utilize suitably qualified technical staff and consultants to review the AEMP and future revisions as well as monitoring data.

In the first half of 2014, Baffinland consulted with the Mittimatalik Hunters and Trappers Organization (MHTO) regarding plans for fish habitat compensation off-sets in the marine environment, related to construction of the ore dock at Milne Port. This type of opportunistic discussion and consultation on aquatic related programs and monitoring will be undertaken from time to time.

3.2 METEOROLOGICAL STATIONS

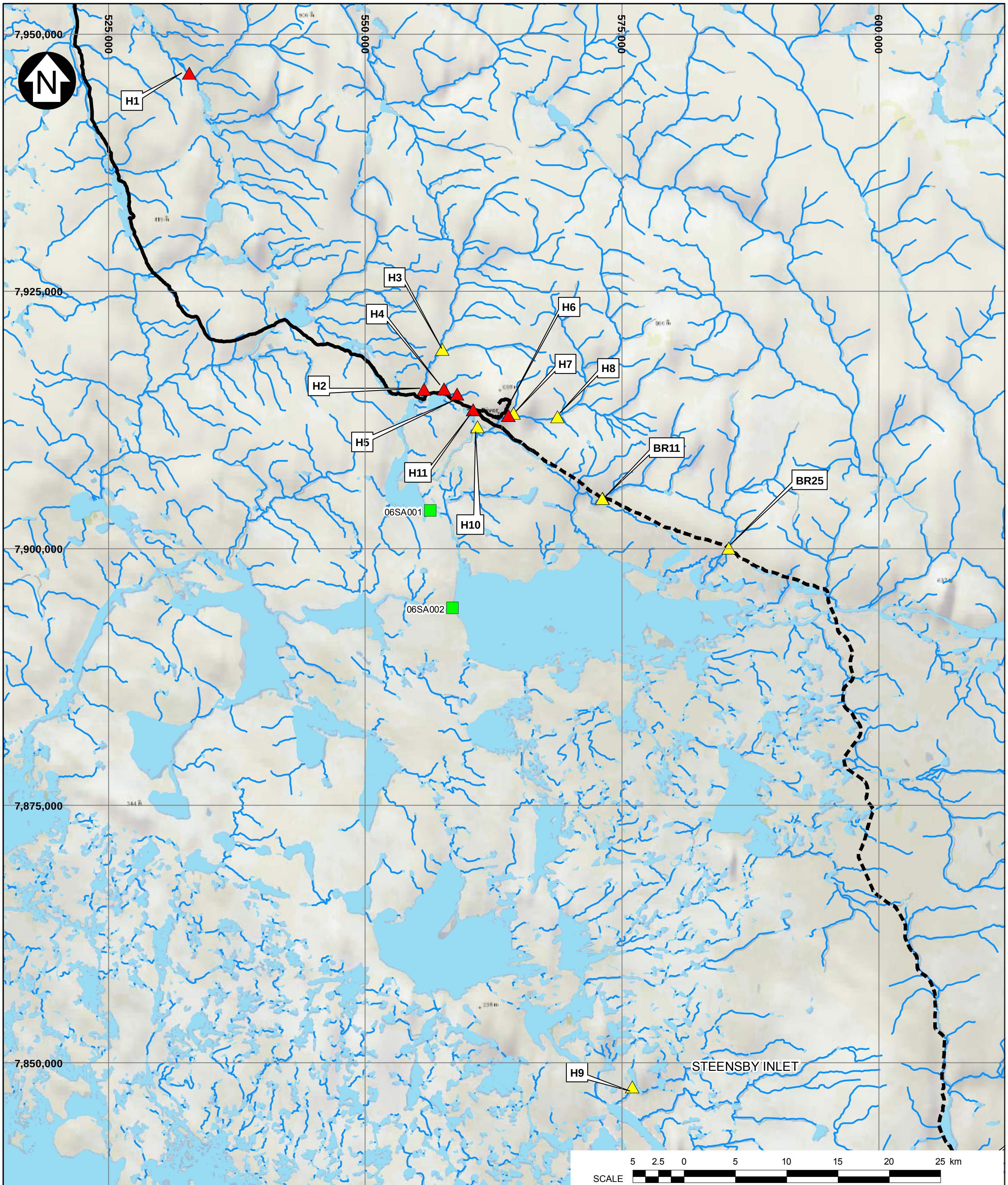
Three meteorological stations have been established, one each at the mine site, Steensby Port, and Milne Port locations. The stations record air temperature, relative humidity, precipitation, wind direction, and wind speed.

3.3 STREAMFLOW MONITORING

A long-term hydrological record does not exist for the North Baffin Region. Stream flow has been monitored at the Mary River Project since 2006, with up to 16 seasonal stream gauges on smaller river/creek systems and four year-round hydrometric stations operated by the Water Survey of Canada operated at various times. Table 3.1 summarizes the stream flow record. Six of the stations will continue to be operated in 2015 and onward (bolded in Table 3.1; shown on Figure 3.1). In addition to these six stations, nine Surveillance Network Monitoring (SNP) stations have hydrometric stations installed, six at the mine site and three at Milne Port (indicated in Table 3.2; depicted in Figure 3.2, 3.3). The 9 hydrometric monitoring stations were installed to measure surface water discharge at or near each of the SNP stations.

Table 3.1 Project Stream Gauging Record

STATION ID	STATION TYPE	PERIOD OF RECORD	DRAINAGE AREA (km^2)	COORDINATES (UTM)		
				Zone	Easting	Northing
H01	Stream flow	2006-2008, 2011-2013	250	17W	532831	7946247
H02	Stream flow	2006-2008, 2010, 2012, 2013	210	17W	555712	7915514
H03	Stream flow	2006-2008, 2010	30.5	17W	557485	7919401
H04 (CLT-2)	Stream flow	2006-2008, 2010, 2012, 2013	8.3	17W	557639	7915579
H05 (CLT-1 L1)	Stream flow	2006-2008, 2010-2013	5.3	17W	558906	7915079
H06 (Mary River)	Stream flow	2006-2008, 2010-2013	240	17W	563922	7912984
H07	Stream flow	2006-2008, 2011, 2013	14.7	17W	564451	7913194
H08	Stream flow	2006-2008	208	17W	568732	7912881
H09	Stream flow	2006-2008	158	17W	576011	7847687
H10	Water Level	2008	8.2	17W	560905	7911838
H11 (SDLT-1)	Stream flow	2011-2013	3.6	17W	560503	7913545
H12	Water Level	2011, 2012	-	17W	597867	7800065
BR11	Stream flow	2008, 2012	53	17W	573122	7904914
BR25	Stream flow	2008, 2012	113	17W	585420	7900082
BR96-2	Stream flow	2008, 2012	31	17W	609300	7839474
BR137	Stream flow	2008,2010-2012	314	17W	598663	7807981
Isortoq River	Stream flow	2006-2012	7170	18W	432810	7780920
Mary River	Stream flow	2006-2012	690	17W	556360	7903750
Raven River	Stream flow	2006-2012	8220	17W	558020	7894160
Rowley River	Stream flow	2006-2012	3500	18W	411230	7818830



LEGEND:

- ACTIVE STREAM FLOW GAUGING STATION
- INACTIVE STREAM FLOW GAUGING STATION
- WATER SURVEY OF CANADA HYDROMETRIC STATION (2006-2012)
- MILNE INLET TOTE ROAD
- PROPOSED RAIL ALIGNMENT
- RIVER/STREAM/DRAINAGE
- WATER

NOTES:

1. BASE MAP: © HER MAJESTY THE QUEEN IN RIGHTS OF CANADA, DEPARTMENT OF NATURAL RESOURCES (2004). ALL RIGHTS RESERVED.
2. COORDINATE GRID IS SHOWN IN UTM NAD83 ZONE 17 AND IS IN METRES.
3. PROPOSED RAIL ALIGNMENT PROVIDED BY CANARAIL CONSULTANTS INC. IN OCTOBER 2010.

BAFFINLAND IRON MINES CORPORATION

MARY RIVER PROJECT

MINE SITE HYDROLOGY MONITORING STATION LOCATIONS

Knight Piésold CONSULTING

P/A NO.	REF NO.
NB102-181/34	1

FIGURE 3.1 REV 0

REV	DATE	DESCRIPTION	DESIGNED	DRAWN	CHK'D	APP'D
0	25JUN'14	ISSUED WITH REPORT	DKK	SWK	RAC	RAM

SAVED: I:\102\00181\34\A\GIS\Figs\A14_r0.mxd; Jun 26, 2014 04:12 PM;

The following stream gauges are directly relevant to the stream diversion study (Section 4.3.3 and Appendix H):

- Station H05 – located on Camp Lake Tributary 1 (CLT-1), which will receive mine effluent from the west pond (Station H05);
- Station H04 – located on Camp Lake Tributary 2 (CLT-2), which will experience reductions in streamflow during the full-scale Project; and
- Station H11 – located on Sheardown Lake Tributary 1 (SDLT-1), which will experience decreased flows due to diversions associated with the west pond and open pit.

In addition, Station H06 is located on the Mary River, which will receive mine effluent from the east pond, ROM pond and ore stockpiles along with treated sewage effluent from the camp.

The data quality to date has been good though the record is relatively short. The AEMP and Water Licence stations have been installed and are operated in consideration of the national standards set out by the Water Survey of Canada (WSC). Baffinland is committed to maintaining and operating all the hydrometric stations to the WSC standards whenever possible.

3.4 SURVEILLANCE NETWORK PROGRAM

3.4.1 Surveillance Network Program Overview

The Surveillance Network Program (SNP) is a compliance-based monitoring program defined in the Type A Water Licence Amendment No.1. The SNP is the “General Monitoring Program” outlined in Schedule I of the Type A Water Licence Amendment No.1, Conditions Applying to General and Aquatic Effects Monitoring. Data generated by the SNP will help inform effects evaluations conducted as part of the AEMP by providing the loading information on controlled and authorized discharges (flow and quality).

A number of discharges are authorized and regulated by the Type A Water Licence Amendment No.1, including:

- Mine effluent (pit water and runoff from ore and waste rock stockpiles);
- Treated sewage effluent;
- Sewage sludge;
- Oily water;
- Solid waste landfilled on-site;
- Hazardous and non-hazardous wastes taken off-site for disposal;
- Landfill seepage/effluent;
- Water from bulk fuel storage containment facilities;
- Hydrocarbon impacted soil treated in landfarms; and
- Waste rock disposal.

The coordinates for each discharge location and SNP monitoring stations are listed in Table 3.2 and are shown on the following figures:

- Mine Site Surveillance Network Program (Figure 3.2);
- Milne Port Surveillance Network Program (Figure 3.3); and
- Steensby Port Surveillance Network Program (Figure 3.4).

SNP stations that include hydrological monitoring are denoted in Table 3.2 and distinguished in Figure 3.2 and Figure 3.3.

In addition, the SNP stations listed in Table 3.3 are those associated with future ERP infrastructure that has not yet been built. SNP stations associated with the rail project that are identified in the Type A Water Licence Amendment No.1 will be listed in a future revision to the AEMP, once that project phase is pursued by Baffinland.

Schedule I, Table 12 of the Type A Water Licence Amendment No.1 presents the monitoring group parameters. Tables 13, 14 and 15 of Schedule I present the SNP stations at the Milne Port, the Mine Site and Steensby Port, respectively.

Some SNP stations will be utilized for monitoring of contact mine water under the EEM Program (Section 4.1). The SNP results are integrated into interpretation and recommendations of the annual AEMP program.

3.4.2 Effluent Quantity and Quality

The Water Licence requires the reporting of monthly and annual volumes of effluents and wastes discharged by the Project, as well as discharge quality criteria applicable to the various effluents generated by the Project. Effluent quantity and quality together provide loadings data for downstream receiving environments.

3.4.3 Acute Toxicity

Periodic acute toxicity testing for end of pipe sewage effluent discharge locations provides data on possible acute impacts to effluent exposure areas. Testing of treated sewage effluent is required by the licence to confirm that the effluent is not acutely toxic.

3.5 AIR QUALITY MONITORING

The Air and Noise Abatement Management Plan provides guidance on the abatement and management of air emissions and noise from construction and operation activities. The plan also describes the air quality monitoring that will be carried out for the Project.

Passive and active air quality monitoring will be conducted at Milne Port, the Mine Site and Steensby Port. Active monitoring will involve measuring total suspended particulate (TSP) in areas of activity at the mine site and Steensby Port. Passive sampling will include collecting sulphur dioxide (SO_2), nitrogen dioxides (NO_2), ozone (O_3), and dustfall samples simultaneously.

During both construction and operation, the monitoring program will focus on TSP and dust deposition. Air quality data will be collected via active (TSP) and passive sampling methods (SO_2, NO_2, O_3, and dustfall, including metal deposition). Emission testing is being conducted on Project incinerators. Snow-core sampling may be used to determine dust fall at specified locations. Dustfall monitoring is being conducted at transects along the Milne Inlet Tote Road, at Milne Port and the Mine Site as part of the TEMMP (Appendix G).

The approach, indicators, thresholds and proposed response actions are described in the Air and Noise Abatement Management Plan.

Air quality monitoring program is a supporting monitoring program to the AEMP as dustfall monitoring is required by PC Condition #21. Dustfall monitoring may be able inform the findings of monitoring of the aquatic environment under the AEMP, as well as measure changes in dustfall due to changes in the Project or in the application of mitigation measures (Section 4.3.2; Appendix G).

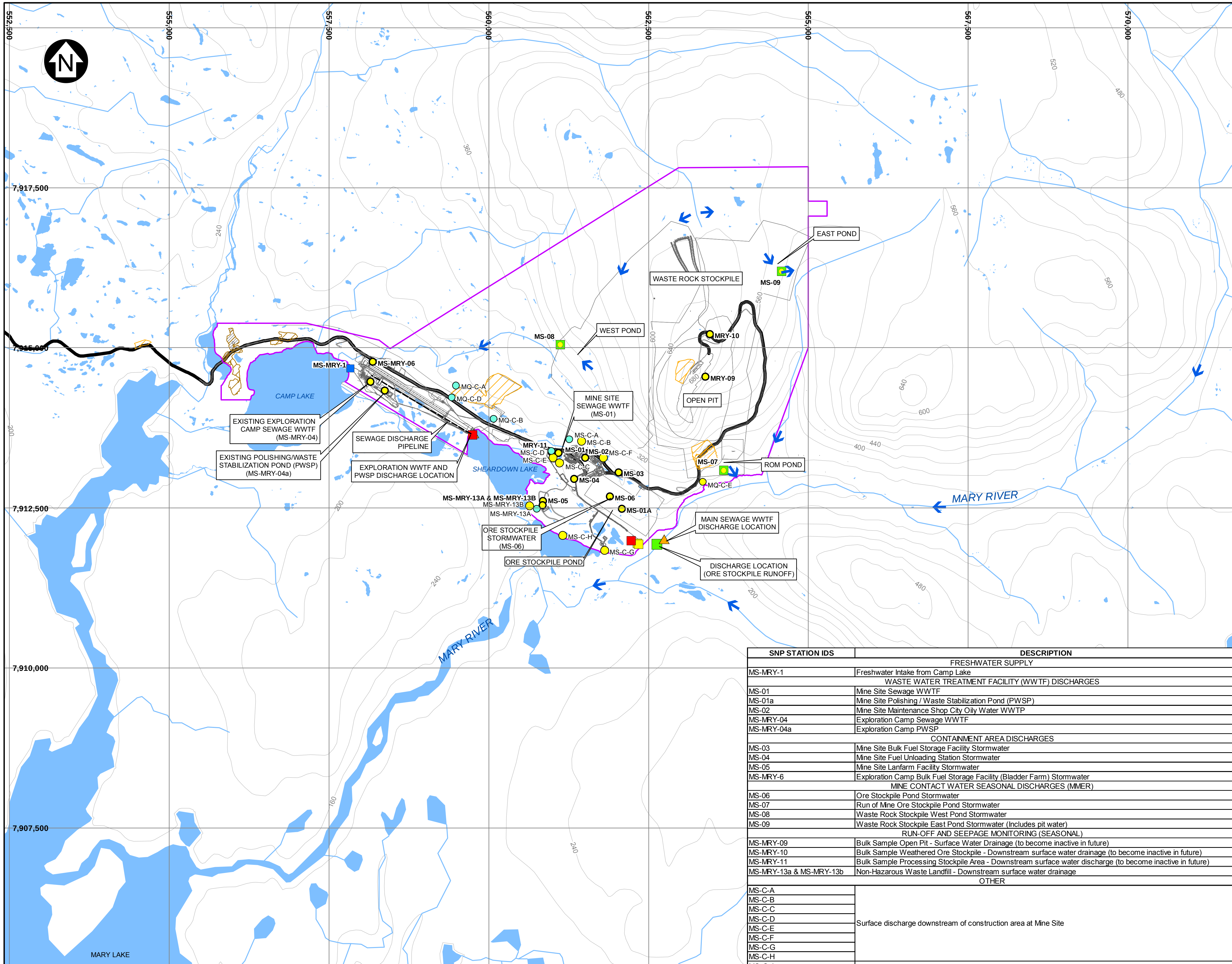
Table 3.2 Established SNP Monitoring Stations Associated with ERP

Monitoring Station	Description	UTM Coordinates (NAD83, Zone 17) Easting (m)	Northing (m)	Status
Milne Port Site				
MP-MRY-2	Fresh Water Intake at Philips Creek (Summer)	514,503	7,964,579	Future
MP-MRY-3	Fresh Water Intake from Km 32 Lake (Winter)	521,547	7,953,735	Active
MP-01	Milne Port Sewage Treatment Facilities (discharge into ditch prior to ocean)	503,209	7,976,485	Active
MP-01a	Milne Port Waste Stabilisation Pond	503,625	7,976,015	Active
MP-02	Milne Port Maintenance Shop Oily water	503,319	7,975,805	Future
MP-05	Milne Port Ore Stockpile Settling Pond (East)	503,069	7,976,338	Future
MP-06	Milne Port Ore Stockpile Settling Pond (West)	503,459	7,976,366	Future
MP-MRY-04[1]	Milne Exploration Phase Sewage Treatment Facilities	503,462	7,975,764	Inactive
MP-MRY-04a[1]	Milne Exploration Phase Sewage PWSP	503,344	7,976,118	Inactive
MP-MRY-7[1]	Milne Exploration Phase Bladder Farm Fuel Storage Facility Storm water	503,309	7,976,097	Inactive
MP-MRY-12	Bulk Sample Stockpile Area Seepage	503,357	7,976,453	Inactive
MP-C-A	Surface discharge downstream of construction area at Milne Port	503,214	7,976,483	Inactive
MP-C-B		503,191	7,975,396	Active / Hydrology
MP-C-C		503,436	7,975,427	Inactive
MP-C-D		503,651	7,976,363	Inactive
MP-C-E		503,736	7,976,346	Inactive
MP-C-F		503,922	7,976,304	Inactive
MP-C-G		503,006	7,976,484	Inactive
MP-C-H		504,113	7,976,509	Active
MP-Q1-01	Surface Runoff and or Discharge Quarries	503,828	7,975,062	Active / Hydrology
MP-Q1-02		503,811	7,975,272	Active / Hydrology
Mine Site				
MS-MRY-1	Fresh Water Intake from Camp Lake	557,793	7,914,684	Active
MS-01	Mine Site Sewage Treatment Facilities	561,322	7,913,257	Active
MS-09	Waste Rock Stockpile Pond	562,984	7,916,316	Active
MS-MRY-4	Exploration Camp Sewage Treatment Facility	558,141	7,914,427	Inactive
MS-MRY-4a	Exploration Camp Polishing Waste Stabilization Ponds	558,470	7,914,237	Active
MS-MRY-6	Exploration Camp Bulk Fuel Storage Facility (Bladder Farm) Stormwater	558,186	7,914,780	Active
MS-MRY-9[1]	Bulk Sample Open Pit - Surface water drainage	563,246	7,914,632	Active
MS-MRY-10[1]	Bulk Sample Weathered Ore Stockpile - Downstream surface water drainage	563,488	7,915,197	Active
MRY-11[1]	Bulk Sample Processing - Downstream surface water discharge	560,690	7,913,350	Active
MS-MRY-13a & MS-MRY-13b	Non-Hazardous Waste Landfill - Downstream surface water drainage	13a: 560,754 13b: 560,642	13a: 7,912,484 13b: 7,912,527	Active / Hydrology
MS-C-A	Surface discharge downstream of construction area at Mine Site	561,263	7,913,571	Active / Hydrology
MS-C-B		561,454	7,913,537	Active
MS-C-C		561,110	7,913,199	Active

Monitoring Station	Description	UTM Coordinates (NAD83, Zone 17)		Status
		Easting (m)	Northing (m)	
MS-C-D	Surface discharge downstream of construction area at Mine Site	561,008	7,913,280	Active
MS-C-E		560,980	7,913,388	Active / Hydrology
MS-C-F		561,797	7,913,278	Active
MS-C-G		561,813	7,911,830	Active
MS-C-H		561,162	7,912,067	Active
MQ-C-A	Surface Runoff and or Discharge Quarries	559,489	7,914,408	Active / Hydrology
MQ-C-B		560,083	7,913,905	Active / Hydrology
MQ-C-D		559,447	7,914,258	Active / Hydrology

NOTE:

1. SNP STATION WILL BECOME INACTIVE IN THE FUTURE.



LEGEND:

- SURVEILLANCE NETWORK PROGRAM (SNP) STATION
- SURVEILLANCE NETWORK PROGRAM (SNP) STATION INCLUDING HYDROLOGY MONITORING
- MINE EFFLUENT FINAL DISCHARGE POINT
- SUMMER DISCHARGE LOCATION OF TREATED SEWAGE EFFLUENT
- WINTER DISCHARGE LOCATION OF TREATED SEWAGE EFFLUENT TO MARY RIVER
- TREATED SEWAGE DISCHARGE LOCATION
- FRESHWATER INTAKE LOCATION
- EXISTING TOTE ROAD
- PROPOSED RAILWAY ALIGNMENT
- PROPOSED CONSTRUCTION ACCESS ROAD
- PROPOSED SITE INFRASTRUCTURE
- RIVER/STREAM/DRAINAGE
- WATER

SURVEILLANCE NETWORK PROGRAM (SNP):

- FIRST LEVEL OF MONITORING FOCUSES ON DISCHARGE QUALITY.
- THERE IS OFTEN AN OVERLAP WITH SNP STATIONS AND EEM STATIONS REQUIRED UNDER THE METAL MINING EFFLUENT REGULATION (MMER).

SNP STATION IDS	DESCRIPTION
	FRESHWATER SUPPLY
MS-MRY-1	Freshwater Intake from Camp Lake
	WASTE WATER TREATMENT FACILITY (WWTF) DISCHARGES
MS-01	Mine Site Sewage WWTF
MS-01a	Mine Site Polishing / Waste Stabilization Pond (PWSP)
MS-02	Mine Site Maintenance Shop City Oily Water WWTP
MS-MRY-04	Exploration Camp Sewage WWTF
MS-MRY-04a	Exploration Camp PWSP
	CONTAINMENT AREA DISCHARGES
MS-03	Mine Site Bulk Fuel Storage Facility Stormwater
MS-04	Mine Site Fuel Unloading Station Stormwater
MS-05	Mine Site Lanfarm Facility Stormwater
MS-MRY-6	Exploration Camp Bulk Fuel Storage Facility (Bladder Farm) Stormwater
	MINE CONTACT WATER SEASONAL DISCHARGES (MMER)
MS-06	Ore Stockpile Pond Stormwater
MS-07	Run of Mine Ore Stockpile Pond Stormwater
MS-08	Waste Rock Stockpile West Pond Stormwater
MS-09	Waste Rock Stockpile East Pond Stormwater (Includes pit water)
	RUN-OFF AND SEEPAGE MONITORING (SEASONAL)
MS-MRY-09	Bulk Sample Open Pit - Surface Water Drainage (to become inactive in future)
MS-MRY-10	Bulk Sample Weathered Ore Stockpile - Downstream surface water drainage (to become inactive in future)
MS-MRY-11	Bulk Sample Processing Stockpile Area - Downstream surface water discharge (to become inactive in future)
MS-MRY-13a & MS-MRY-13b	Non-Hazarous Waste Landfill - Downstream surface water drainage
	OTHER
MS-C-A	Surface discharge downstream of construction area at Mine Site
MS-C-B	
MS-C-C	
MS-C-D	
MS-C-E	
MS-C-F	
MS-C-G	
MS-C-H	
MQ-C-A	Surface Runoff and or Discharge Quarries
MQ-C-B	
MQ-C-D	

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 ZONE 17.
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

MINE SITE SURVEILLANCE NETWORK PROGRAM (SNP)

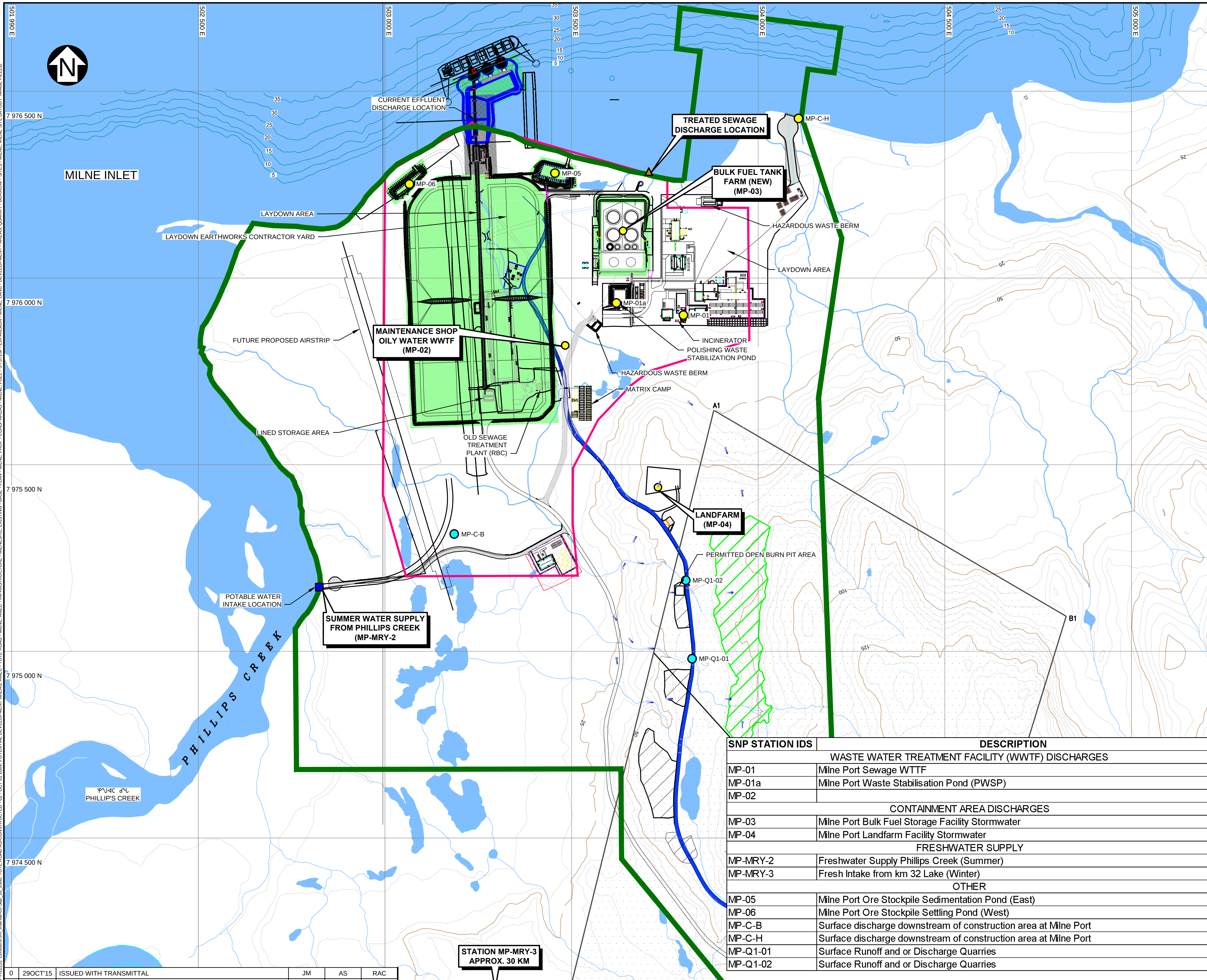
Knight Piésold CONSULTING

P/A NO.	REF NO.
NB102-181/36	NB15-00491

FIGURE 3.2 REV 0

REV	DATE	DESCRIPTION	DESIGNED	DRAWN	REVIEWED
0	29OCT'15	ISSUED WITH TRANSMITTAL	JM	AS	RAC

SAVED: I:\102\00181\36\A\GIS\Figs\B34_r0.mxd; Oct 29, 2015 10:32 AM; asimpson



SNP STATION IDS	DESCRIPTION
	WASTE WATER TREATMENT FACILITY (WWTF) DISCHARGES
MP-01	Milne Port Sewage WTTF
MP-01a	Milne Port Waste Stabilisation Pond (PWSP)
MP-02	
	CONTAINMENT AREA DISCHARGES
MP-03	Milne Port Bulk Fuel Storage Facility Stormwater
MP-04	Milne Port Landfarm Facility Stormwater
	FRESHWATER SUPPLY
MP-MRY-2	Freshwater Supply Phillips Creek (Summer)
MP-MRY-3	Fresh Intake from km 32 Lake (Winter)
	OTHER
MP-05	Milne Port Ore Stockpile Sedimentation Pond (East)
MP-06	Milne Port Ore Stockpile Settling Pond (West)
MP-C-B	Surface discharge downstream of construction area at Milne Port
MP-C-H	Surface discharge downstream of construction area at Milne Port
MP-Q1-01	Surface Runoff and or Discharge Quarries
MP-Q1-02	Surface Runoff and or Discharge Quarries

LEGEND:

- WATER
- LAYDOWN AREA
- RIVER/STREAM/DRAINAGE
- MILNE INLET TOTE ROAD
- POTENTIAL DEVELOPMENT AREA
- FLOW DIRECTION
- MONITORING LOCATION
- SURVEILLANCE NETWORK PROGRAM (SNP) STATION INCLUDING HYDROLOGY MONITORING
- FRESHWATER INTAKE LOCATION
- TREATED SEWAGE DISCHARGE LOCATION

NOTES:

1. TOPOGRAPHY PROVIDED BY EAGLE MAPPING (2005).
2. COORDINATE GRID IS SHOWN IN UTM (NAD83) ZONE 17 AND IS IN METRES.
3. CONTOURS ARE IN METRES. CONTOUR INTERVAL IS 5 METRES.
4. SITE INFRASTRUCTURE PROVIDED BY SIKUMIUT (NOVEMBER, 2012).
5. CONTOURED BATHYMETRY PROVIDED BY ENTERPRISES NORMAND JUNEAU INC., DATED SEPTEMBER 9, 2010 (CONTOUR INTERVAL 1m).

SCALE A 100 50 0 100 200 300 400 500 m

BAFFINLAND IRON MINES CORPORATION

MARY RIVER PROJECT

MILNE PORT SURVEILLANCE NETWORK PROGRAM (SNP)

Knight Piésold CONSULTING

P/A NO.	REF NO.
NB102-181/36	NB15-00491

FIGURE 3.3 REV 0

REV	DATE	DESCRIPTION	DESIGNED	DRAWN	REVIEWED
0	29OCT'15	ISSUED WITH TRANSMITTAL	JM	AS	RAC

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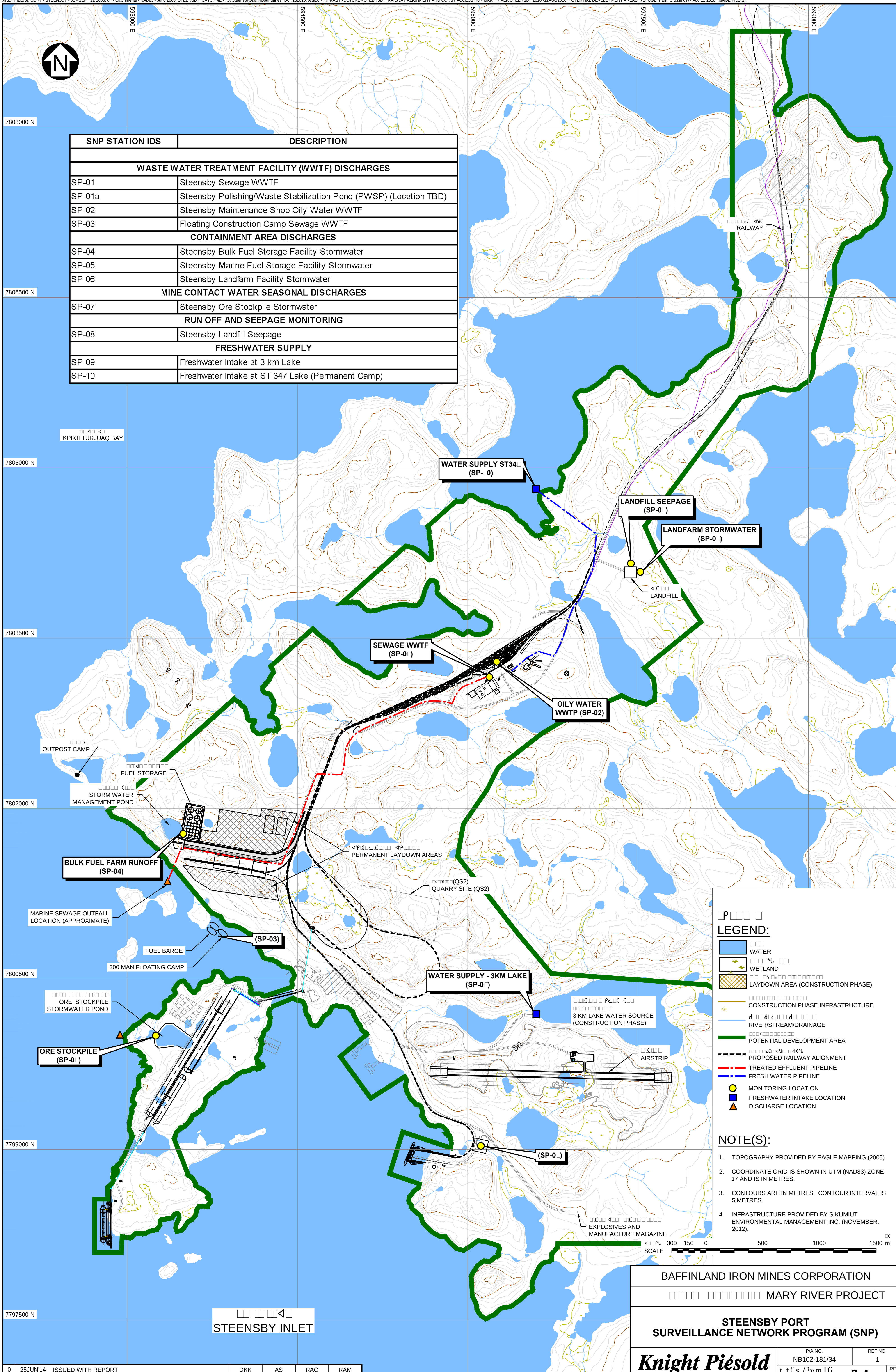
SAVED: I:\1\02\00181\34\A\Acad\FIGS\B13_r0 , 6/27/2014 10:01:09 AM , ASIMPSON PRINTED: 6/27/2014 10:03:28 AM , PORTRAIT , ASIMPSON
XREF FILE(S): CONT - STEENSBY - 01 - SEPT 22 2008; 04 - Catchments - NAD83 - Jul 8 2008; STEENSBY_CATCHMENTS; SteensbyQuarryBoundaries_OCT182010; AMEC - INFRASTRUCTURE - STEENSBY; RAILWAY ALIGNMENT AND CONST ACCESS RD - MARY RIVER STEENSBY 2010 -12AUG2010; POTENTIAL DEVELOPMENT AREAS; REFUGE (Farm Crossings) - Aug 12 2010 IMAGE FILE(S):



SNP STATION IDS	DESCRIPTION
WASTE WATER TREATMENT FACILITY (WWTF) DISCHARGES	
SP-01	Steensby Sewage WWTF
SP-01a	Steensby Polishing/Waste Stabilization Pond (PWSP) (Location TBD)
SP-02	Steensby Maintenance Shop Oily Water WWTF
SP-03	Floating Construction Camp Sewage WWTF
CONTAINMENT AREA DISCHARGES	
SP-04	Steensby Bulk Fuel Storage Facility Stormwater
SP-05	Steensby Marine Fuel Storage Facility Stormwater
SP-06	Steensby Landfarm Facility Stormwater
MINE CONTACT WATER SEASONAL DISCHARGES	
SP-07	Steensby Ore Stockpile Stormwater
RUN-OFF AND SEEPAGE MONITORING	
SP-08	Steensby Landfill Seepage
FRESHWATER SUPPLY	
SP-09	Freshwater Intake at 3 km Lake
SP-10	Freshwater Intake at ST 347 Lake (Permanent Camp)

NOTE(S):

1. TOPOGRAPHY PROVIDED BY EAGLE MAPPING (2005).
2. COORDINATE GRID IS SHOWN IN UTM (NAD83) ZONE 17 AND IS IN METRES.
3. CONTOURS ARE IN METRES. CONTOUR INTERVAL IS 5 METRES.
4. INFRASTRUCTURE PROVIDED BY SIKUMIUT ENVIRONMENTAL MANAGEMENT INC. (NOVEMBER, 2012).

BAFFINLAND IRON MINES CORPORATION

MARY RIVER PROJECT

STEENSBY PORT
SURVEILLANCE NETWORK PROGRAM (SNP)

Knight Piésold CONSULTING

P/A NO.	REF NO.
NB102-181/34	1

FIGURE		REV
FIGURE	3.4	0

REV	DATE	DESCRIPTION	DESIGNED	DRAWN	CHK'D	APP'D
0	25JUN'14	ISSUED WITH REPORT	DKK	AS	RAC	RAM

Table 3.3 Future SNP Stations Associated with ERP

Monitoring Station	Description	Status
MP-03	Milne Port Bulk Fuel Storage Facility Stormwater	Active
MP-04	Milne Port Landfarm Facility Storm water	Active
MS-01a	Mine Site Polishing/Waste Stabilization Pond (PWSP)	Active
MS-02	Mine Site Maintenance Shop Oily Water WWTF	Future
MS-03	Mine Site Bulk Fuel Storage Facility Stormwater	Active
MS-04	Mine Site Fuel Unloading Station Stormwater	Future
MS-05	Mine Site Landfarm Facility Stormwater	Future
MS-06+	Ore Stockpile Pond Stormwater	Future
MS-07	Run of Mine Ore Stockpile Pond Stormwater	Future
MS-08	Waste Rock Stockpile West pond	Active
MS-09	Waste Rock Stockpile East pond	Future

3.6 HABITAT COMPENSATION

Baffinland must obtain appropriate authorizations or letters of advice from the DFO for in-water construction activities such as at water crossings. Section 35 of the *Fisheries Act* prohibits the serious harm to fish that are part of, or that support, a commercial, recreational or Aboriginal fishery, and provides the Minister with the power to authorize terms and conditions which would allow projects to proceed in compliance with the *Act*. Serious harm occurs when the physical, chemical, or biological features of a water body are sufficiently altered, such that habitat becomes less suitable for one or more life history processes of fish. Habitat offsetting is an option for mitigating residual impacts of projects on habitat productive capacity that are deemed harmful after other less invasive options have been implemented. Habitat offsetting involves replacing the loss of fish habitat with newly created habitat or improving the productive capacity of some other natural habitat. Depending on the nature and scope of the compensatory works proposed, habitat offsetting may require multiple seasons of post-construction monitoring. A Fish Habitat Offsetting Plan is a requirement of a *Fisheries Act* authorization.

Mitigation measures are likely to be implemented during the project's planning, design, construction and/or operation phases in order to protect fish and fish habitat. The mitigation plans are prepared and implemented by the Company with advice typically provided by DFO staff.

Commonly used mitigation measures can include:

- Working within fisheries timing windows to minimize interference with fish migration and spawning
- Selecting the least harmful equipment/materials/construction methods
- Ensuring fish passage around obstructions during and after construction
- Implementing measures to control siltation at construction sites

Upgrades to some of the existing Tote Road crossings will be required to support the construction phase of the project and the installation of new crossings and encroachments within lakes will be required as part of the railway construction and operation.

Permanent or temporary water crossings are also authorized under the Type A Water Licence Amendment No.1, provided the DFO has granted authorizations for undertaking the proposed work.

3.6.1 Tote Road Upgrade (Water Management Area 48)

The Bulk Sampling Program completed in 2007-2008 involved upgrading the Milne Inlet Tote Road to all-season capability. The upgrades completed included adjustments to the road alignment to facilitate haul road travel, road bed improvements, road widening and installation of drainage crossings along the route. The Tote Road upgrades were designed to enhance the flow conditions of the waterways, reduce potential erosion-related effects, and improve the opportunity for fish to access upstream habitat.

The DFO issued a HADD authorization (Harmful Alteration, Disruption or Destruction of Fish Habitat authorization; now a Serious Harm authorization) for approximately 8,500 m^2 of fish habitat that was to be disturbed for the Tote Road upgrade. Based on subsequent monitoring, this estimate was revised to 7,850 m^2 of disturbance with habitat compensation (now habitat offsetting) measures to be implemented that would restore and enhance approximately 15,000 m^2 of habitat. The original *Fisheries Act* Authorization and Fish Habitat No Net Loss and Monitoring Plan to support the construction of 25 crossings identified as HADD (and 14 crossings identified as Habitat Compensation) were issued and approved in 2007 (Knight Piésold, 2007). The Plan outlined the measures necessary to mitigate and compensate, to the greatest possible extent practicable, the impacts to fish habitat at the Tote Road watercourse crossings. The plan also described a monitoring plan to be implemented during and after construction. A fisheries biologist conducts a survey of the performance of the stream crossings on an annual basis and the results of this survey are provided in an annual report provided to the DFO and other regulators/agencies including the QIA. Monitoring downstream of quarries and borrow source operations is currently a requirement of the Water Licence as well as quarry and borrow source management plans that are submitted under the Water Licence. The Water Licence provides water quality criteria for areas downstream of construction and quarries/borrow sources. This plan has been implemented during the period of construction (2007-2009) and post-construction from 2009 to the present. Baffinland has submitted annual reports for the above to DFO each year since 2007.

In addition, Letters of Advice were issued by the DFO to for construction of smaller watercourses along the road.

Road upgrades associated with the mine development project include the replacement of box culvert (sea can) crossings with bridge structures. DFO has/is issuing Letters of Advice for this work and has indicated that an authorization under the *Fisheries Act* will not be required. Nevertheless, monitoring of the tote road crossings continues as per the original authorization and Fish Habitat No Net Loss and Monitoring Plan (Knight Piésold, 2007).

3.6.2 Milne Port Ore Dock (Water Management Area 48)

In accordance with the revised *Fisheries Act*, the footprint of the Milne Ore Dock was determined by DFO to constitute a Serious Harm to fish habitat. In its decision, DFO has indicated that the required Habitat Offset can be addressed through designed-in mitigation in the form of placement of coarse habitat features along the perimeter of the structure. DFO is currently reviewing an Application for *Fisheries Act* Authorization that reflects this approach to meeting *Fisheries Act* requirements.

3.6.3 Rail Phase Infrastructure (Water Management Areas 21 and 48)

The northern portion of the railway is located in Water Management Area 48. The southern portion of the railway and Steensby Port are located in Water Management Area 21.

Once Baffinland decides to pursue the rail phase of the Project, the company will seek an authorization under the revised *Fisheries Act* for components of the Project that DFO constitutes a Serious Harm to fish habitat. This may include the following infrastructure:

- Select crossings and lake encroachments along the railway
- Steensby ore and freight docks

It is expected that habitat offsets will be required under a future *Fisheries Act* authorization. The authorization will require the implementation of various mitigation measures, and will specify monitoring required during and following construction.

3.7 OTHER ENVIRONMENTAL MANAGEMENT AND MONITORING PLANS

A number of management and monitoring plans (EMMPs) were developed as part of the FEIS and/or the Amended Type A Water Licence. These plans include:

- Environmental Protection Plan
- Surface Water and Aquatic Ecosystems Management Plan
- Quarry and Borrow Pit Management Plan
- Waste Water Management Plan
- Waste Management Plan
- Hazardous Materials and Hazardous Waste Management Plan
- Explosives Management Plan
- Blasting Management Plan
- Waste Rock Management Plan
- Emergency Response and Spill Contingency Plan
- Abandonment and Reclamation Plan

The above management plans all have linkages to water, and the issues and concerns identified in Section 2 involve mitigation measures identified in the above plans. Like the AEMP, these plans are living documents which will be updated periodically throughout the Project life to account for changes in the Project, the success of mitigation measures and the results of monitoring.

4 AEMP COMPONENT STUDIES

As described in Section 1, the following are component studies that comprise the AEMP:

- **EEM Program**, as required under the MMER;
- **CREMP**, which includes monitoring of the core mine site area (water, sediment, benthic invertebrates and fish);
- **Lake Sedimentation Monitoring Program**, evaluating baseline and project-influenced lake sedimentation rates;
- **Dustfall Monitoring Program**, evaluating dustfall rates in proximity to the road, port and mine; and
- **Stream Diversion Barrier Study**, an initial study evaluating potential for fish barriers under natural conditions and due to Project-related stream diversions.

The EEM Program is a legal requirement of metal mines such as the Mary River mine. The Draft EEM Cycle One Study Design has been included under the umbrella of the AEMP and follows a separate but related regulatory function.

The CREMP forms the backbone of the AEMP. The CREMP is a detailed aquatics monitoring program intended to complement and expand the scope of an EEM Program required under the MMER. The CREMP is intended to monitor the effects of multiple stressors on the aquatic environment, including the discharge of mine effluents and treated sewage effluent as well as ore dust deposition. The CREMP will include the monitoring of water, sediment, phytoplankton, benthic invertebrates and fish in the Project's mine site streams and lakes.

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. The Lake Sedimentation Targeted Study, Dustfall Monitoring Program, and the Stream Diversion Monitoring Targeted Study are such studies.

Stand-alone study designs have been prepared. These are briefly summarized below and are included in the appendices of this report.

4.1 EEM CYCLE ONE STUDY DESIGN

4.1.1 Overview

As a metal mine, the discharge of mine effluents from this metal mine is regulated by the MMER. These regulations, administered under the federal *Fisheries Act*, apply to mining and milling operations that discharge effluent(s) at a rate greater than 50 m^3/day. Mining began September 2014, at which time temperatures are below zero, precipitation falls as snow, and runoff has ceased in local rivers and streams. Therefore, the 50 m^3/day mine effluent discharge rate was achieved during freshet in on July 10, 2015.

The MMER outline requirements for routine effluent monitoring, acute lethality testing, and EEM. The objective of EEM is to determine whether mining activity is causing an effect on fish, benthic invertebrate communities and/or the use of fisheries resources (based on mercury accumulation in fish tissues).

This Cycle One EEM study design in Appendix A has been prepared in accordance with the MMER as prescribed by the Environment Canada (2012) EEM technical guidance document. The study design describes in detail how the Cycle One EEM biological monitoring study will be undertaken. It outlines the proposed activities involved in the investigation of water quality, sediment quality, and freshwater biota community to meet the objectives of the EEM program in accordance with the MMER. In accordance with the technical guidance document (Environment Canada, 2012), this study will take into account all relevant site characterization information, previous biological monitoring data, and comments and/or recommendations stemming from previous efforts in the area.

Any comments on this draft study design will be incorporated into a final study design that will be formally submitted for review and approval by the Environment Canada Technical Advisory Panel (TAP) prior to initiation of the Cycle One EEM biological monitoring study field work.

4.1.2 Final Discharge Points

Mine effluent will be discharged to two watercourses (Figure 4.1):

- Mary River; and
- Camp Lake Tributary 1.

There will be three final discharge points will discharge mine effluent to the Mary River as follows:

- East Pond discharge (MS-08) collecting stormwater from the east side of the waste rock stockpile;
- Run-of-mine (ROM) stockpile discharge; and
- The main ore stockpile at the rail load-out area.

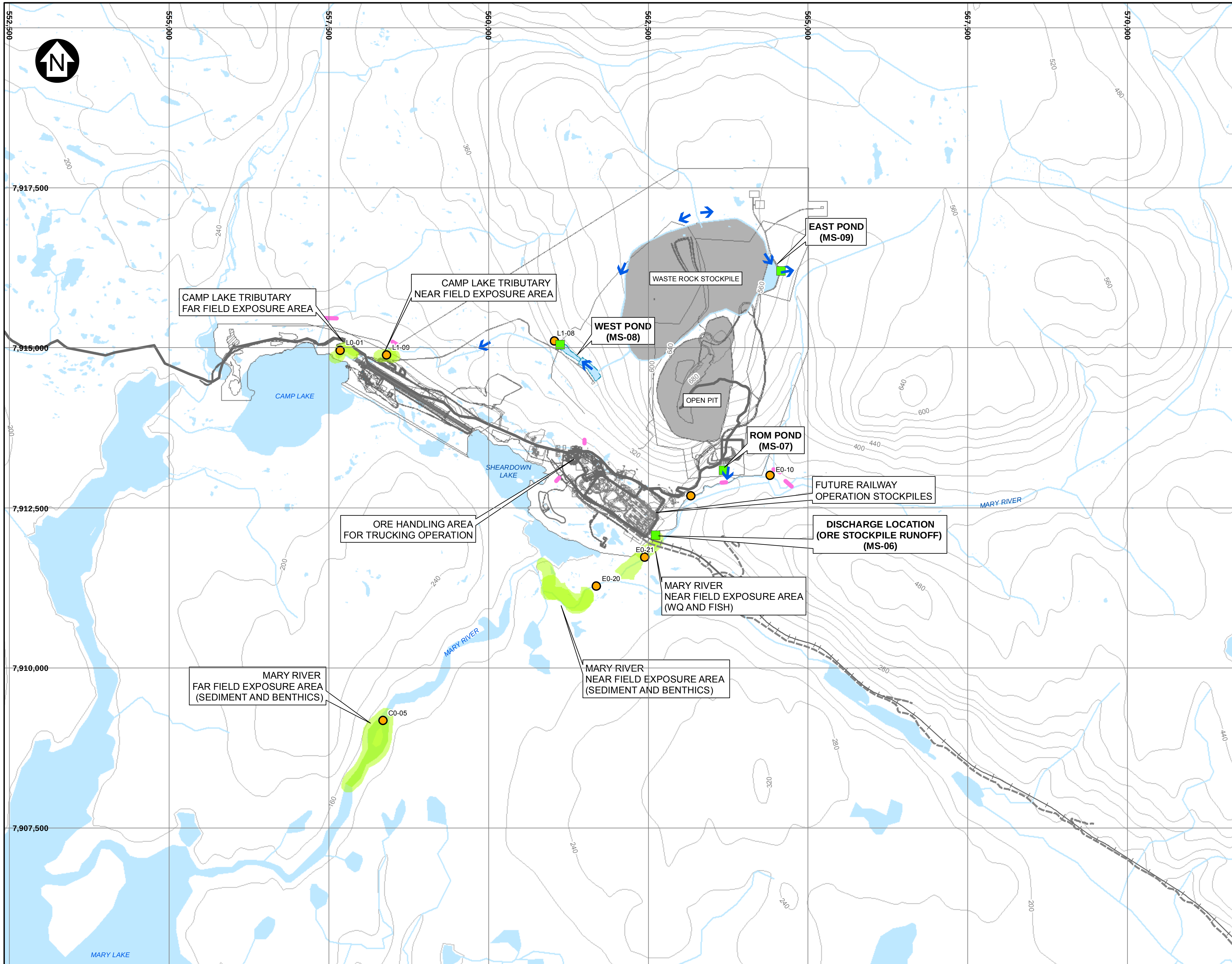
There will be one final discharge point to Camp Lake Tributary 1, from the West Pond collecting stormwater from the west side of the waste rock stockpile.

4.1.3 Site Characterization

Baseline environmental data has been collected at the exposure and reference areas by North/South Consultants Inc. (NSC) and Knight Piésold Ltd. (KP) on behalf of Baffinland. The exposure and candidate reference areas are listed in Table 4.1. The study area site characterization program involved:

- Identifying the in-situ habitat conditions;
- In-situ and laboratory water quality sampling;
- Sediment quality sampling;
- Benthic invertebrate community sampling; and
- Fish community and population sampling.

The exposure area habitat information was used to evaluate suitability of the candidate reference study areas, and to position the proposed field replicate stations. Candidate reference areas are shown on Figure 4.2. Characterizing more than one reference site for each exposure area increases the ability to evaluate natural variability, ecological relevance and confounding factors, and improves the ability to evaluate the adequacy of the chosen reference site(s) (Environment Canada, 2012).



LEGEND:

- MINE EFFLUENT FINAL DISCHARGE POINT
- ENVIRONMENTAL EFFECTS MONITORING STATION (EEM) (WATER, SEDIMENT, BENTHICS AND FISH)
- EEM STUDY DESIGN EXPOSURE AREA
- FISH BARRIER
- EXISTING TOTE ROAD
- PROPOSED RAILWAY ALIGNMENT
- PROPOSED CONSTRUCTION ACCESS ROAD
- PROPOSED SITE INFRASTRUCTURE
- RIVER/STREAM/DRAINAGE
- WATER

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.
5. INFRASTRUCTURE INFORMATION PROVIDED BY HATCH ON JANUARY 31, 2014.

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

BAFFINLAND IRON MINES CORPORATION

MARY RIVER PROJECT

EEM PROGRAM EXPOSURE AREAS

Knight Piésold CONSULTING

P/A NO. NB102-181/34 | REF NO. 1

FIGURE 4.1 REV 0

REV	DATE	DESCRIPTION	DESIGNED	DRAWN	CHK'D	APP'D
0	25JUN'14	ISSUED WITH REPORT	DKK	SWK	RAC	RAM

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Table 4.1 Freshwater EEM Study Design Exposure and Candidate Reference Areas

Study Area ID	Latitude (Deg. Min. Sec.)	Longitude (Deg. Min. Sec.)
Camp Lake Tributary Near Field Exposure Area	71° 19' 46" N	79° 21' 46" W
Camp Lake Tributary Far Field Exposure Area	71° 19' 46" N	79° 22' 46" W
Camp Lake Tributary Reference Area 2	71° 31' 51" N	80° 15' 42" W
Camp Lake Tributary Reference Area 3	71° 15' 56" N	79° 06' 27" W
Camp Lake Tributary Reference Area 4	71° 15' 28" N	79° 04' 23" W
Mary River Near Field Exposure Area (Surface water & Fish at outfall)	71 17' 50" N	79° 15' 57" W
Mary River Near Field Exposure Area (Sediment & Benthos)	71° 17' 42" N	79° 16' 47" W
Mary River Far Field Exposure Area	71° 16' 42" N	79° 22' 11" W
Mary River Reference Area 1	71° 12' 47" N	79° 56' 17" W
Mary River Reference Area 2	71° 13' 21" N	79° 02' 46" W
Mary River Reference Area 3	71° 10' 26" N	78° 39' 31" W
Mary River Reference Area 4	71° 20' 43" N	79° 00' 04" W

NOTE:

1. AREA COORDINATES REPRESENT THE UPSTREAM EXTENT OF EACH STUDY AREA.

4.1.4 Study Design Methodology

4.1.4.1 Effluent Plume Delineation Study

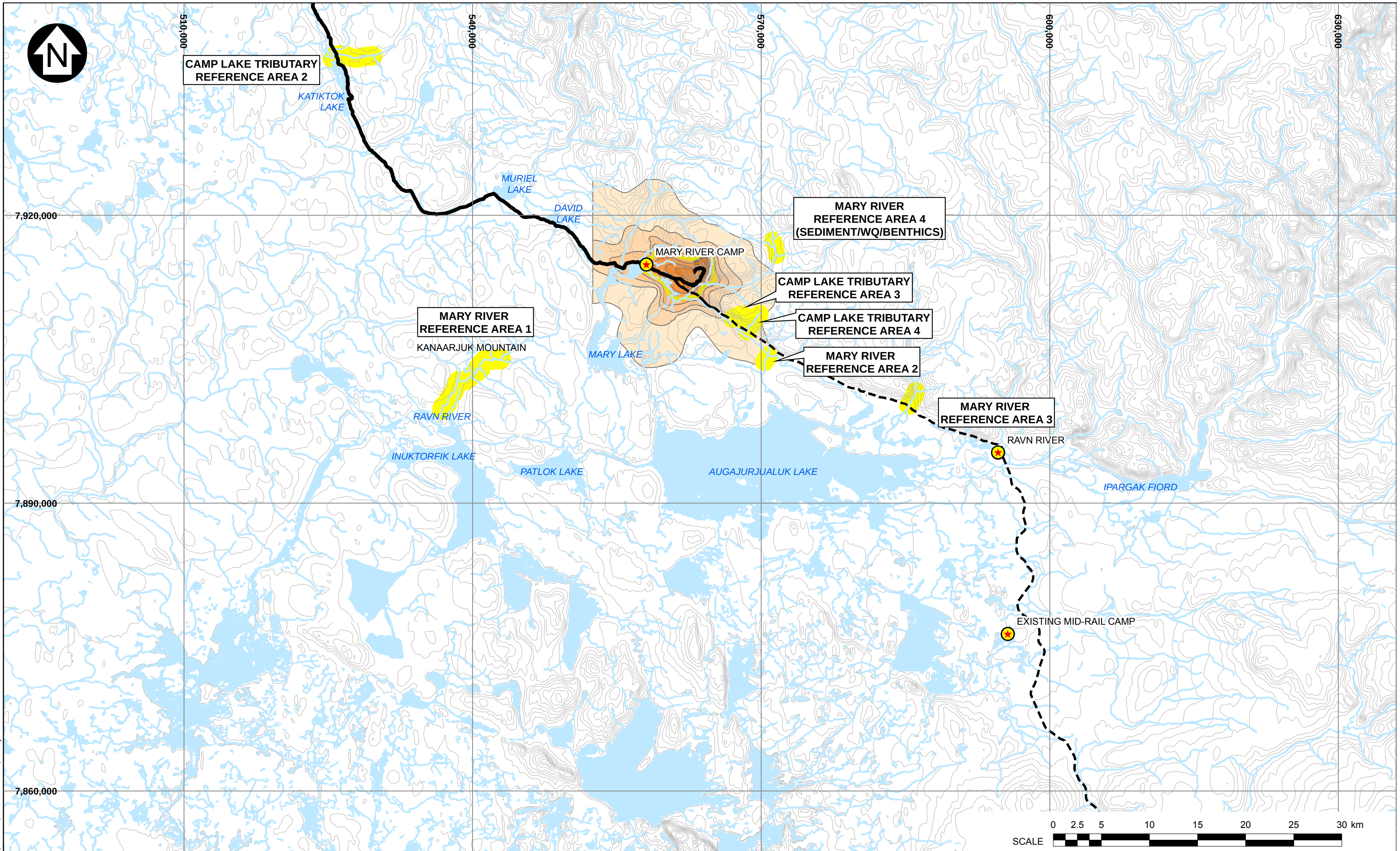
Based on estimated effluent discharge volumes compared with the estimated 10-year low flow conditions of the receivers, effluent concentrations in the Mary River and Camp Lake Tributary are estimated to be greater than 1% within 250 m of the final discharge points. Therefore, an effluent plume delineation study will be carried out 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 by Environment Canada (2003 and 2012).

4.1.4.2 Water Quality Monitoring

Sampling and analysis of water quality will be undertaken as part of the cycle one EEM biological monitoring 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.

4.1.4.3 Supporting Benthic Invertebrate Community Measures

Supporting measures for the benthic invertebrate community survey will be recorded to support the appropriateness of the selected reference areas. These measures include hydrology, stream morphology and substrate characterization.



LEGEND:

- EXISTING TOTE ROAD
- PROPOSED RAILWAY ALIGNMENT
- PROPOSED CONSTRUCTION ACCESS ROAD
- PROPOSED SITE INFRASTRUCTURE
- RIVER/STREAM/DRAINAGE
- PHOTO/VIDEO RECORD (2012-2013)
- WATER

Annual TSP Dep. ($g/m^2/yr$)

- 2 - 7.5
- 7.5 - 15
- 15 - 30
- 30 - 55
- 55 - 120
- 120 - 240
- 240 - 480
- > 480

NOTES:

1. BASE MAP: © HER MAJESTY THE QUEEN IN RIGHTS OF CANADA DEPARTMENT OF NATURAL RESOURCES (2009). ALL RIGHTS RESERVED.
2. COORDINATE GRID IS IN METRES. COORDINATE SYSTEM: NAD 1983 UTM ZONE 17N.
3. CONTOUR INTERVAL IS 20 METRES.
4. TOTAL SUSPENDED PARTICULATE CONTOURS PROVIDED BY RWDI AIR INC. (2011). PRESENTED IN THE FINAL ENVIRONMENT IMPACT ASSESSMENT.

BAFFINLAND IRON MINES CORPORATION

MARY RIVER PROJECT

CANDIDATE REFERENCE AREAS FOR EEM PROGRAM

Knight Piésold CONSULTING

P/A NO.	REF NO.
NB102-181/34	1

FIGURE 4.2 REV 0

REV	DATE	DESCRIPTION	DESIGNED	DRAWN	CHK'D	APP'D
0	25JUN'14	ISSUED WITH REPORT	DKK	SWK	RAC	RAM

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4.1.4.4 Benthic Invertebrate Community Survey

A benthic invertebrate community survey will be conducted as part of the cycle one EEM biological study as required by the MMER. The results of this survey will compare the 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.

Benthic samples will be analyzed by a taxonomist. Following identification and enumeration, a list of individuals collected for each sample will be included in the final interpretive report.

The benthic community will be investigated to determine if mine discharge is having an effect on the receiving system, as defined by Environment Canada (2012).

4.1.4.5 Fish Community, Population and Usability Survey

Sufficient historical 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 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 (n=100) of the proposed sentinel species (Arctic char). The absence of ninespine stickleback in suitable numbers in the exposure and proposed reference areas precludes their use as a second sentinel species. Environment Canada officials will be notified of insufficient collection numbers during the study, and an agreed upon course of action will be followed to complete the study.

Non-destructive capture methods will be employed for all fish population sampling. Backpack electrofishing will be utilized as the primary means of sampling. A non-lethal survey will pose less of an impact on the fish population than a lethal survey.

Aging using otoliths as the primary structure for 10% (min. n=10) of the individuals collected will be undertaken. Pectoral fin rays will also be sampled from the retained individuals to evaluate accuracy of ages between ageing structures. This will evaluate the need for 10% intentional mortality future studies versus a completely non-lethal survey utilizing fin rays as the primary ageing structure.

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.

4.1.5 Summary and Schedule

The 2013 site characterization program confirmed in-situ conditions at the exposure areas and candidate reference areas. The most suitable reference areas to evaluate the benthic invertebrate community effect endpoints are as follows:

- Camp Lake Tributary Near Field (CLT-NF):
  - Camp Lake Tributary Reference Area 3 (CLT-REF3)
  - Camp Lake Tributary Reference Area 4 (CLT-REF4)
- Mary River Near Field (MRY-NF):
  - Mary River Reference Area 2 (MRY-REF2)
  - Mary River Reference Area 4 (MRY-REF4)

The statistical comparisons of the fish population data between the exposure and reference areas for both receivers show significant difference within and between all groups. As such, additional data analysis may be performed following discussions with Environment Canada to determine an acceptable reference area for the fish component of the EEM cycle one biological monitoring study.

The current and anticipated timeline that includes milestones associated with the MMER requirements is provided below, and is subject to change based on regulatory approvals and the start of mining.

July 10 2015	Mine is subject to MMERs once effluent discharge rate reaches 50 m^3/day
September 2015	Submission of Identifying Information & Final Discharge Points (within 60 days after date mine is subject to MMERs)
December 2015	Submission Cycle One Study Design (12 months from initial date when Mine was subject to MMERs)
	Environment Canada review of Cycle One Study Design (6 months)
August-Sept 2016	Conduct Cycle One Biological Monitoring Study (conducted no sooner than 6 months after Cycle One SD submission date)
November 2017	Submission of Cycle One Interpretive Report (within 30 months from initial date when Mine was subject to MMERs)

Based on comments on the draft study design presented in Appendix A and summarized above, the Cycle One Study Design report will be formally submitted to Environment Canada in accordance with the schedule outlined above.

4.2 CREMP STUDY DESIGN

4.2.1 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; and
- Freshwater biota (benthic invertebrate indicators, phytoplankton and Arctic Char).

The EEM study design (Section 4.1) 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 (Figure 2.1). 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; and
- Mary Lake – is the ultimate receiving waters of Camp Lake, Sheardown Lake and the Mary River.

A brief description of the CREMP by component is provided below. The water and sediment quality CREMP is presented in more detail in Appendix B (Knight Piésold, 2014a), and the freshwater biota CREMP (inclusive of phytoplankton, benthic invertebrates and fish) is presented in Appendix D (NSC, 2014a).

4.2.2 Water Quality

The key pathways of potential effects of the Project on water quality include:

- Water quality changes related to discharge of ore or stockpile runoff to freshwater systems (immediate receiving environments: Mary River and CLT-1);
- Water quality changes (primarily nutrients and total suspended solids [TSS]) related to discharge of treated sewage effluent (immediate receiving environments: Mary River and Sheardown Lake NW);
- Water quality changes due to deposition of dust in lakes and streams (Mine Area in zone of dust deposition); and

- Water quality changes due to non-point sources, such as site runoff and use of Ammonium nitrate fuel oil (ANFO) explosives (Mine Area).

The key question related to the pathways of effect is:

- What is the estimated mine-related change in contaminant concentrations in the exposed area?

The primary issue of concern with respect to water quality is related to the combined effects on metal and TSS concentration from mine effluent discharges and ore dust deposition on water quality in adjacent lakes and streams. As such, the CREMP and the baseline data review focused on waterbodies that will receive mine effluent discharges and are closest to the sources of ore dust. Camp Lake and CLT-1, as well as the Mary River and Mary Lake, will receive mine effluent discharges. These waterbodies, along with Sheardown Lake, may also be affected by ore dust deposition and non-point sources of fugitive dust (i.e., road dust).

The discharge of treated sewage effluent also has the potential to cause eutrophication, with phosphorus being the limiting nutrient. TP concentrations are highly variable, however, making it a poor indicator. While TP will continue to be monitored as part of the CREMP, Chlorophyll a will be monitored as a more reliable indicator of potential eutrophication, as part of the freshwater biota CREMP (Section 4.2.4 and Appendix D).

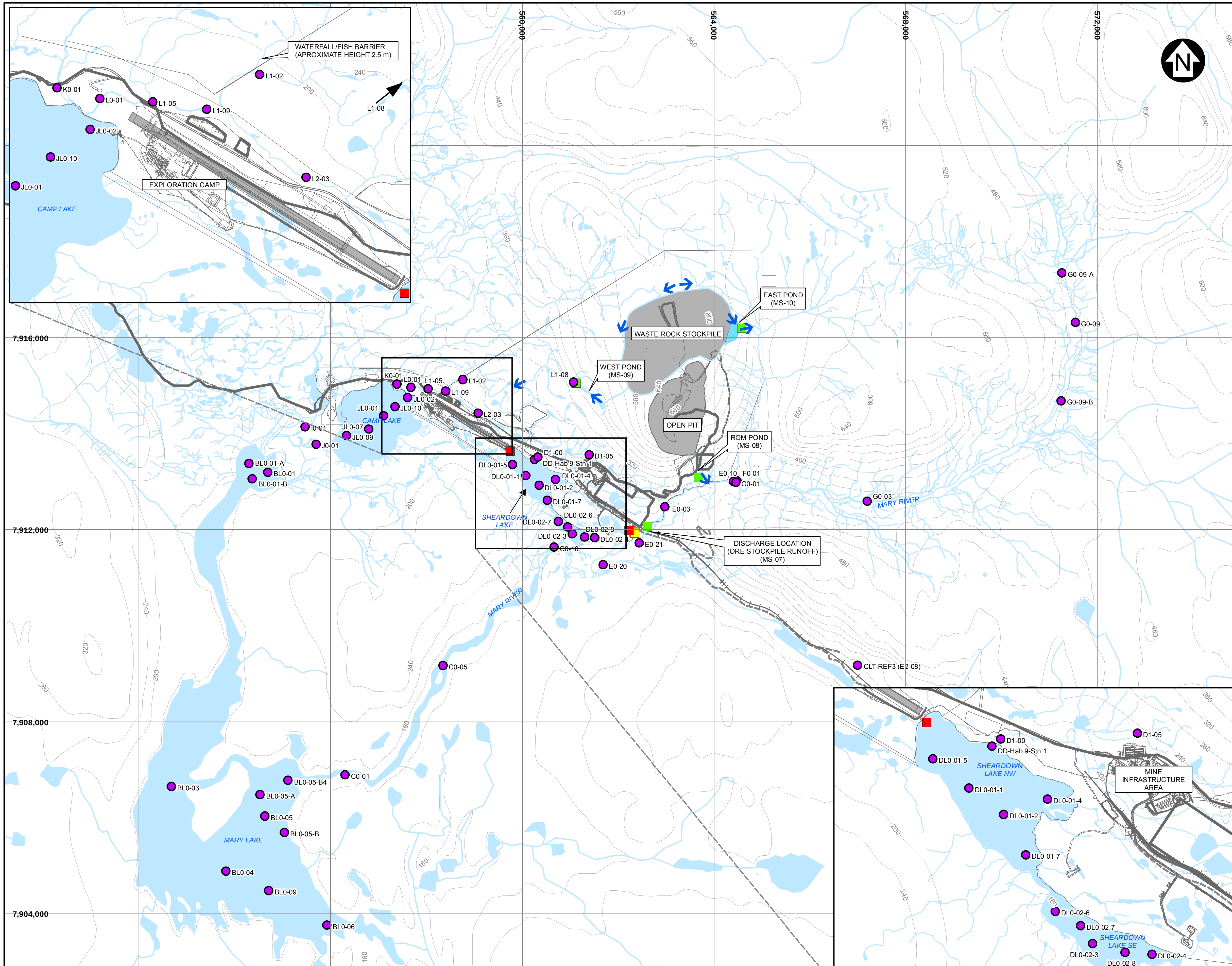
The proposed water quality CREMP stations are shown on Figure 4.3. An *a priori* power analysis supported a monitoring program that uses the existing baseline stations, and recommended the addition of the following stations:

- Two stations within the basin at the north arm of Mary Lake, near BL0-01 (stations BL0-01-A and BL0-01-B);
- Two additional stations within the main basin of Mary Lake, near the Mary River inlet near BL0-05 (BL0-05-A and BL0-05-B);
- Sampling of an additional station within Sheardown Lake SE (existing station DL0-02-6);
- Addition of a station in vicinity of L1-09, location to be determined (L1-05);
- Addition of one or two reference stations upstream on Mary River (G0-09-A, G0-09-B); and
- Sampling of identified reference lakes, consistent with EEM program and as identified in Appendix E.

The following sampling frequencies are recommended for each of the different programs:

- Lakes - three sampling events in each available season (winter, summer and fall) during the first three years of mine operation are expected to have adequate power to detect early warning flag concentrations for lake data; and
- Streams - four samples (one set of seasonal samples) per year is likely adequate for most parameters to determine significance.

Sampling will be conducted annually during the initial years of operation but sampling frequency will be evaluated regularly (i.e., each year) to determine if modifications are warranted. The sampling frequency and schedule will be evaluated after three years of monitoring.



LEGEND:

- WATER QUALITY CREMP STATION
- SUMMER DISCHARGE LOCATION OF TREATED SEWAGE EFFLUENT
- WINTER LAND DISCHARGE LOCATION OF TREATED SEWAGE EFFLUENT TO MARY RIVER
- MINE EFFLUENT FINAL DISCHARGE POINT
- EXISTING TOTE ROAD
- PROPOSED RAILWAY ALIGNMENT
- PROPOSED CONSTRUCTION ACCESS ROAD
- PROPOSED SITE INFRASTRUCTURE
- RIVER/STREAM/DRAINAGE
- PROPOSED SITE INFRASTRUCTURE
- WATER

NOTES:

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2. COORDINATE GRID IS UTM (WGS84/NAD83) ZONE17.
3. CONTOUR ARE IN METRES. CONTOUR INTERVAL VARIES.
4. LAKE SAMPLE LOCATIONS VARY SLIGHTLY DURING WINTER MONTHS DUE TO ICE CONDITIONS.
5. INFRASTRUCTURE INFORMATION PROVIDED BY HATCH ON JANUARY 31, 2014.

SCALE 1 0.5 0 1 2 3 4 km

BAFFINLAND IRON MINES CORPORATION

MARY RIVER PROJECT

CREMP WATER QUALITY STATIONS

Knight Piésold CONSULTING

P/A NO.	REF NO.
NB102-181/34	1

FIGURE 4.3 — REV 0

REV	DATE	DESCRIPTION	DESIGNED	DRAWN	CHK'D	APP'D
0	25JUN'14	ISSUED WITH REPORT	RAC	SWK	RAC	RAM

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4.2.3 Sediment Quality Study Design

The key pathways of potential effects of the Project on sediment quality include:

- Sediment quality changes related to discharge of ore or stockpile runoff to freshwater systems (immediate receiving environments: Mary River and Camp Lake Tributary 1);
- Sediment quality changes (primarily nutrients and TSS) related to discharge of treated sewage effluent (immediate receiving environments: Mary River and Sheardown Lake NW);
- Sediment quality changes due to direct deposition of dust in lakes and streams (Mine Area in zone of dust deposition); and
- Sediment quality changes due to dust deposition on land and subsequent runoff into lakes and streams (Mine Area in zone of dust deposition).

The key question related to the pathways of effect is:

- What is the estimated mine-related change in contaminant concentrations in the exposed area?

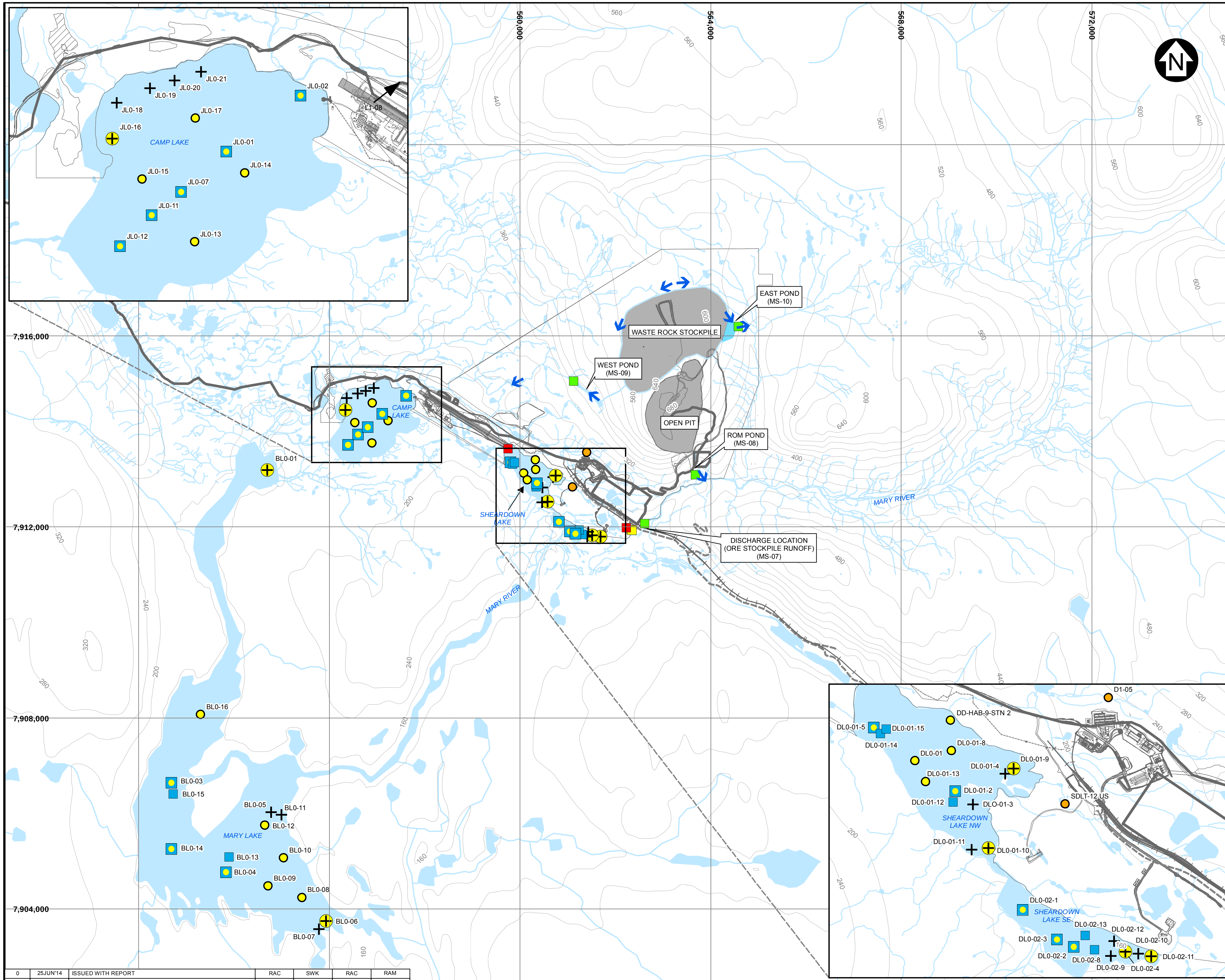
The primary issue of concern with respect to sediment quality is the effect of ore dust containing elevated metals being deposited on, or running off into, lakes and streams. As such, the CREMP will focus upon waterbodies that are closest to the sources of ore dust, with an emphasis on lakes compared with streams. The review of baseline sediment quality noted that the high-energy streams in the mine site area do not readily accumulate metals, and metals concentrations tend to be highly variable, in comparison to depositional lake sediment stations typically characterized by high organic carbon content and a higher proportion of fines (Knight Piésold, 2014a).

Preliminary sediment sampling locations are shown on Figure 4.4 and are listed in Table 3.7. The review of sediment quality baseline identified the need for additional sediment quality stations in the mine site lakes. The lake sediment stations make use of existing and new (proposed) stations as follows:

- Camp Lake – 14 stations including three historic stations and 11 new stations;
- Sheardown Lake NW - 14 stations including six historic stations and eight new stations;
- Sheardown Lake SE – 10 stations including four historic stations and six new stations; and
- Mary Lake – 15 stations including five historic stations and 10 new stations.

Lake sediment samples will be collected along transects positioned along the anticipated path of effluent (i.e., direction of inflow stream). A portion of the additional lake sediment stations correspond to proposed benthic invertebrate monitoring stations to be monitored under the freshwater biota CREMP (Section 4.2.5; Appendix D). At each station, field technicians will establish final locations for the sediment stations that are within depositional areas of the lake. This field fit of the sampling stations will likely result in some modifications to the gradient study design.

Additional pre-mining sediment sampling will be carried out in 2014 to increase the number of baseline sediment samples for comparison in future monitoring. It will be necessary to identify additional stations in depositional areas characterized by high TOC and fines content (or lower sand content), as the depositional areas are more sensitive to change.



REV	DATE	DESCRIPTION	DESIGNED	DRAWN	CHK'D	APP'D
0	25JUN'14	ISSUED WITH REPORT	RAC	SWK	RAC	RAM

LEGEND:

- LAKE SEDIMENT SAMPLE LOCATION
- STREAM SEDIMENT SAMPLE LOCATION
- BIC HAB 14 LAKE SAMPLE LOCATION
- BIC HAB 9 LAKE SAMPLE LOCATION
- SEDIMENT AND BIC HAB 14 SAMPLE LOCATION
- SEDIMENT AND BIC HAB 9 SAMPLE LOCATION
- MINE EFFLUENT FINAL DISCHARGE POINT
- SUMMER DISCHARGE LOCATION OF TREATED SEWAGE EFFLUENT
- WINTER LAND DISCHARGE LOCATION OF TREATED SEWAGE EFFLUENT TO MARY RIVER
- EXISTING TOTE ROAD
- PROPOSED RAILWAY ALIGNMENT
- PROPOSED CONSTRUCTION ACCESS ROAD
- PROPOSED SITE INFRASTRUCTURE
- RIVER/STREAM/DRAINAGE
- PROPOSED SITE INFRASTRUCTURE
- WATER

NOTES:

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3. CONTOUR ARE IN METRES. CONTOUR INTERVAL VARIES.
4. LAKE SAMPLE LOCATIONS VARY SLIGHTLY DURING WINTER MONTHS DUE TO ICE CONDITIONS.
5. INFRASTRUCTURE INFORMATION PROVIDED BY HATCH ON JANUARY 31, 2014.

SCALE 1 0.5 0 1 2 3 4 km

BAFFINLAND IRON MINES CORPORATION

MARY RIVER PROJECT

SEDIMENT QUALITY CREMP STATIONS

Knight Piésold CONSULTING

P/A NO. NB102-181/34 | REF NO. 1

FIGURE 4.4 | REV 0

In the long-term, sediment sampling under the CREMP will be conducted every three years, coinciding with biological monitoring studies. However, Baffinland will conduct sediment sampling in 2014 to collect additional pre-mining baseline data, and then annually for the first three years of mining. After monitoring three operating (mining) years, the sediment sampling program will be conducted on a three year cycle. The increased number of sediment samples proposed for 2014 may be reduced over time, depending on the outcome of initial monitoring.

4.2.4 Phytoplankton

The following section provides a description of monitoring of phytoplankton under the CREMP, with an emphasis on monitoring of lakes in the Mine Area, where potential for eutrophication is greatest.

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

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

The key question related to the pathways of effect is:

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

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

The selected indicator will be chlorophyll *a* and the benchmark will be 3.7 µg/L. Further description on the selection of a suitable indicator and derivation of the benchmark is provided in Section 5.3.4.

The monitoring area for phytoplankton includes mine area lakes, specifically Camp and Mary lakes, and Sheardown Lake NW and SE, and selected streams. In addition, monitoring will be conducted at a minimum of one reference lake (NSC, 2014b; Appendix E).

An *a priori* power analysis was conducted using existing baseline data for chlorophyll *a* for Sheardown Lake NW and Mary Lake to advise on the power of the existing dataset and to identify sample sizes for the CREMP; these two lakes represent the range of baseline conditions for the Mine Area lakes as a whole. Power analyses indicate relatively high power to detect a change of the magnitude of the benchmark for each sampling season in each lake. Power is greater for Sheardown Lake NW owing to the lower baseline concentrations of chlorophyll *a* than Mary Lake.

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

Phytoplankton data will be assessed during each year of monitoring and would follow the assessment framework presented in Section 5.2. The phytoplankton CREMP study design and review of baseline data is described in detail in Appendix D.

4.2.5 Benthic Invertebrates

Key questions were developed to guide the design of the monitoring program. These questions and metrics focus upon key potential effects identified in the FEIS, as well as metrics commonly applied for characterizing the BMI community.

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

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

The key question related to the pathways of effect is:

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

A description of the selection of BMI indicators and derivation of benchmarks is provided in Section 5.3.5.

The overall objective of this program is to collect habitat-based abundance, composition, and distribution information for the BMI community across a range of habitat types in the Mine Area lakes and streams.

The monitoring area for BMI includes Mine Area lakes, specifically Camp, Sheardown NW and SE, and Mary lakes, and Sheardown Lake tributaries 1, 9, and 12, several sites on the Mary River located upstream and downstream of effluent discharges, and Camp Lake tributaries 1 and 2. In addition, monitoring will be conducted at a minimum of one reference lake and one reference stream.

Two lake habitat types will be targeted: habitat types 9 (nearshore) and 14 (offshore). Replicate stations will overlap sediment quality sampling locations where feasible, to provide supporting information for interpretation and analysis of results (e.g., metals concentrations). Five replicate stations will be sampled in each lake habitat type and each stream reach.

Timing of sampling will be concentrated within a single sampling season; benthic invertebrate sampling has been consistently conducted in the mine area in late summer/fall. This is an ecologically relevant time for sampling and is most appropriate considering the effluent discharge regime (i.e., discharge during the open-water season only), hydrology (i.e., streams/rivers freeze solid), and dust deposition (i.e., introduction during the open-water season).

As existing baseline data for potential reference lakes and streams are minimal the monitoring program will focus upon before-after comparisons of key metrics within the mine area waterbodies, with an emphasis on mine area lakes.

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

BMI data will be assessed during each year of monitoring and would follow the assessment framework presented in Section 5.2. The BMI CREMP study design and baseline data review is described in detail in Appendix D.

4.2.6 Fish (Arctic Char)

Key questions were developed to guide the design of the fish monitoring program. The key pathways of potential residual effects of the Project on Arctic Char include:

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

The key question related to the pathways of effect is:

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

Given that there are only two fish species present in the area, fish monitoring in the mine area would be limited to successful capture of sufficient numbers of both of these fish species in the exposure areas. In most lakes and streams in the exposure area, Arctic Char are sufficiently abundant that successful capture of enough fish for monitoring purposes is possible. In contrast, Ninespine Stickleback are absent or uncommon in a number of waterbodies. For these reasons only a single species, Arctic Char, will be targeted under the CREMP.

Non-lethal sampling methods will be used to the extent possible to minimize impacts of monitoring on the Arctic Char populations. As a result, metrics that can be reliably obtained from live fish will be included in CREMP. Metrics will include indicators of fish growth, condition, and reproduction. The evaluation and selection of indicators and benchmarks for Arctic Char are presented in Section 5.3.6.

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

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

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

Fish data will be assessed during each year of monitoring and would follow the assessment framework presented in Section 5.2. The fish CREMP study design and baseline data review is described in detail in Appendix D.

4.3 TARGETED STUDIES

As described in Section 1, specific effects monitoring (or targeted monitoring) programs/studies have been identified to address specific questions or potential impacts. These are programs 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. The Lake Sedimentation Study, Dustfall Monitoring Program, and the Stream Diversion Barrier Study are the targeted studies identified in this AEMP.

4.3.1 Lake Sedimentation Monitoring Program

A specific effects monitoring study 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 (NSC, 2014c; Appendix F).

Sedimentation rates will be monitored in Sheardown Lake NW through deployment of sediment traps, as described in detail in Appendix F. In brief, the program will involve year-round deployment of sediment traps in different lake habitat types for the analysis of total dry weight of sediment. Traps will be emptied and redeployed after ice-off and in fall to provide measures of seasonal (i.e., open-water and ice-cover season) deposition rates. A sampling program was initiated in 2013 and is on-going. Through comparisons of the measured sedimentation at Sheardown Lake NW to sedimentation amounts known to adversely affect salmonid egg survival that are available from published literature, the current lake sedimentation monitoring program will provide a strong scientific basis for the determination of any sediment deposition effects on Arctic charr egg survival at Sheardown Lake NW.

4.3.2 Dustfall Monitoring Program

The amended NIRB Project Certificate No. 005 included requirements for dustfall monitoring. In 2013, Baffinland implemented a dustfall monitoring program as part of the TEMMP that meets the requirements (Baffinland, 2014). A description of this program is included in Appendix G. The dustfall monitoring program consists of operating dustfall buckets positioned along transects radially out from the main development areas: Milne Port, the tote road and the mine site, along with reference dustfall monitoring stations. Dustfall measurements (the amount of dustfall per unit time) will be completed seasonally (summer and winter) and the dustfall will be analyzed to determine the metals composition of the dust.

The dustfall monitoring results will be reviewed to estimate the seasonal deposition (rates, quantities) and chemical composition of dust entering aquatic systems along representative distance transects at right angles to the Tote Road and radiating outward from Milne Port and the Mine Site, as per PC Condition #21.

4.3.3 Initial Stream Diversion Barrier Study

A streamflow reduction barrier study was identified as a follow-up program in the FEIS (Baffinland, 2012). The Initial Stream Diversion Barrier Study is presented in Appendix H (Knight Piésold, 2014c).

The primary objectives of the study are to monitor the effects of both increases and reductions in streamflow at several mine site streams and to further understand how Project-related reductions in streamflow may result in the creation of fish barriers that have the potential to occur at low flows. The monitoring program may identify the need for mitigation measures to address Project-related fish stranding.

An initial study is proposed that will focus on obtaining a better understanding for existing flow conditions and, in particular, the frequency and duration of the occurrence of fish barriers and fish stranding that was identified in five (5) mine site streams (see Figure 1.1):

- CLT-1;
- CLT-2;
- SDLT-1;
- SDLT-9;

- AndSDLT-12.

Since the stream diversion barrier study was identified in the FEIS, Baffinland has developed plans to initiate an Early Revenue Phase (ERP) of the Project (Baffinland, 2013). The ERP will involve mining 3.5 million tonnes per annum (Mt/a) of iron ore. The iron ore will be transported year-round by truck to Milne Port and then to market by ship during the open water season. Baffinland has contemplated a 5-year operating plan for the ERP, after which time the full-scale railway project would also be brought on-line. This development schedule is subject to a commercial decision by Baffinland to proceed and will be influenced by both market conditions and available financing.

The reduced production rate associated with the ERP will result in a considerably smaller mining footprint (open pit and waste rock stockpile) than was originally envisioned. As such, Project-related stream diversions will be negligible. The absence of diversions provides Baffinland with an opportunity to better understand existing flow conditions as it relates to fish passage. This initial study is exploratory in nature with the following objectives (which contribute to the primary objectives stated above):

- Develop an understanding of low-flow conditions that may result in barriers to fish passage within two tributaries of Camp Lake and three tributaries of Sheardown Lake; and
- Document fish presence throughout the stream length under various flow conditions. It is important to document upstream access during spring freshet, since high water velocities in the spring can prevent fish passage. It is also important to document the downstream passage of fish in the fall, when they are returning to overwintering habitat in the lakes.

The five streams of interest will be monitored in spring and fall during the initial years of operation. Low and high flow periods will be targeted where possible. Results of this initial monitoring will be reviewed to determine whether mitigation and/or ongoing monitoring are required. In spring, all five streams will be visually assessed to monitor for potential barriers and obstructions to upstream fish passage. Surveys will document conditions within the monitoring streams between the upstream fish barriers and their outlets into Camp Lake and Sheardown Lake. Implementation of these visual assessments by an experienced biologist will allow effective determination of whether perceived barriers result in the prevention of fish migration within each tributary, and thus electro fishing surveys are not deemed necessary for the assessment. During report preparation, the combination of visual observations of barriers, fish presence and associated flows at the time of the survey can be used to determine the conditions in which fish migration will be limited within each tributary under various flow conditions

Other monitoring programs will contribute data relevant to this study. For example, Baffinland`s hydrology monitoring program includes stream gauges on three streams monitored under this program, and the freshwater biota monitoring will be undertaken as part of the CREMP. Monitoring data from both these programs will be used in the analysis of data from this initial stream diversion monitoring study.

The 3-year initial stream diversion study monitoring report will be presented with the AEMP Annual Monitoring Report in the first half of 2017. The report will also include recommendations on potential mitigation measures and future monitoring.

Continuation of the monitoring program will depend upon the schedule and size of the Project. The Approved Project (18 Mt/a) will result in meaningful reductions in streamflow and monitoring will be required to identify Project-related fish barriers and fish stranding. If the ERP were to continue beyond 2017 and the 3-year study has met the stated objectives, then this targeted study may be discontinued until such time as the Approved Project proceeds. If possible, monitoring for the Approved Project will start one year prior to the start of larger scale mining.

5 ASSESSMENT APPROACH AND MANAGEMENT RESPONSE

5.1 OBJECTIVES

As stated in Section 1, the AEMP is a monitoring program designed to:

- Detect short-term and long-term effects of the Project's activities on the aquatic environment resulting from the Project;
- Evaluate the accuracy of impact predictions;
- Assess the effectiveness of planned mitigation measures; and
- Identify additional mitigation measures to avert or reduce unforeseen environmental effects.

Monitoring data will be collected from the various programs. A common approach for the assessment of data and the implementation of a management response will be applied to all AEMP monitoring programs.

5.2 ASSESSMENT APPROACH AND RESPONSE FRAMEWORK

Monitoring data collected through the AEMP requires a systematic data evaluation process, as well as management responses that would be taken, in response to certain data evaluation outcomes. A common assessment (data evaluation) and management response framework will be implemented, as outlined on Figure 5.1.

This multi-step process includes the following:

Step 1 - Data Management and Evaluation

This step includes the QA/QC; comparisons to the AEMP benchmark and to reference and/or baseline; and review of the data using various tools such as Exploratory Data Analysis (EDA) and Statistical Data Analysis (SDA), to determine if change is occurring. A change may be detected statistically or qualitatively, relative to benchmarks, baseline values and/or spatial or temporal trends. A change may be statistically significant, but professional judgement will also be applied using the various evaluation tools to detect a change qualitatively.

If Step 1 does not detect change, then no action is required. If a change is observed, then further evaluation of the data for that/those indicator(s) will be carried out under Step 2.

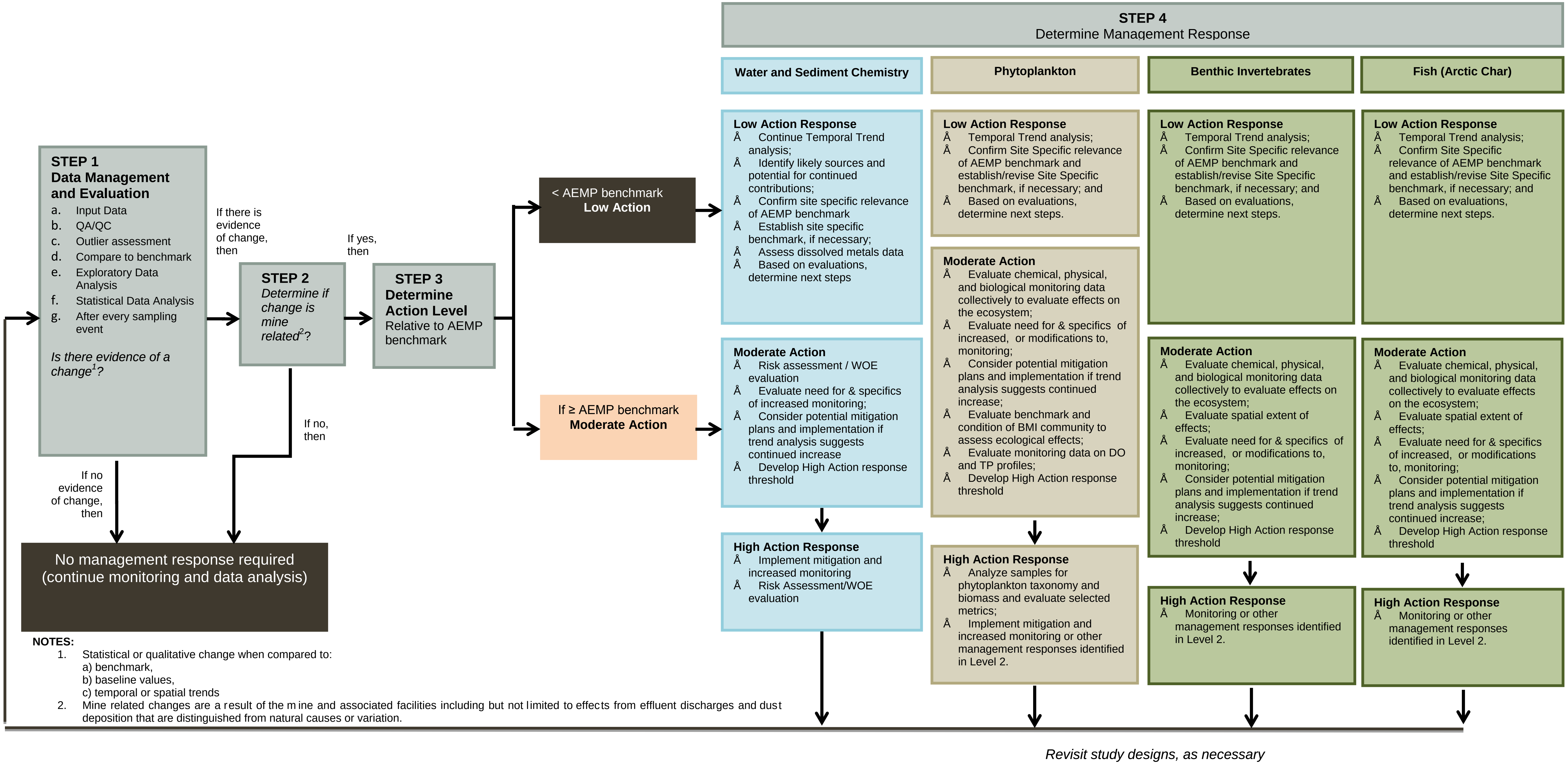
Step 2 – Determining Whether the Observed Change is Mine-Related

Step 2 involves determining if the changes in the indicator(s) of concern are due to the Project or due to natural variability or other causes.

Project activities with the potential to induce the observed change will be reviewed to identify potential Project-related causes or sources. This could include evaluating effluent quality, discharge regime/rates, and loading, dust deposition, and other point/non-point sources as required. Also, any evidence of potential natural causes (i.e., a major erosional event such as a slumping riverbank) will be investigated. Sampling data sheets and site personnel will be a source of this information.

This question will be addressed using EDA and subsequently using SDA. EDA will be completed to visualize overall data trends, and could include evaluating spatial patterns, to examine the spatial extent and pattern of observed changes.

Figure 5.1 Data Assessment Approach and Response Framework



NOTES:
1. Statistical or qualitative change when compared to:
   a) benchmark,
   b) baseline values,
   c) temporal or spatial trends
2. Mine related changes are a result of the mine and associated facilities including but not limited to effects from effluent discharges and dust deposition that are distinguished from natural causes or variation.

The exploratory data analyses could include comparisons of data from Mine Area streams to data from reference streams and comparisons of Mine Area Lakes to reference lake(s). This can further assist with determining whether the observed changes were due to natural variability or the Project. Graphical analyses may be used to confirm assumptions required for statistical testing (normality, sample size, independence). Differences in fish and other biotic endpoints between mine-exposed and reference areas will be preferentially tested using pair-wise, single factor ANOVA. Prior to ANOVA, all data will be evaluated for normality and homogeneity of variance to ensure that applicable statistical test assumptions will be met. In instances in which normality cannot be achieved through data transformation, non-parametric Mann-Whitney U-test statistics will be used to confirm the statistical results from the ANOVA using transformed data. Similarly, in instances in which variances of normal data could not be homogenized by transformation, pair-wise comparisons will be conducted using Student's t-tests assuming unequal variance to confirm the statistical findings of the ANOVA tests. SDA will be used as outlined in the individual assessment frameworks and can be applied to the parameters of interest to test the primary hypothesis for the effects of mine-related change.

If the Step 2 analysis concludes that the changes in water quality parameters of concern are, or are likely, due to the Project, the assessment will proceed to Step 3. If it is concluded the observed differences relative to baseline conditions are not due to the Project, no management response will be required.

Step 3 - Determine Action Level

If the evaluation conducted in Step 2 has indicated with some certainly that the measured change is project-related, Step 3 involves determination of the action level associated with the observed monitoring results through comparisons to the benchmark. Three levels of action have been identified: low, moderate, and high; and the response actions range from increased monitoring and data analysis (e.g., trend analysis); identification of possible sources; to risk assessment and/or mitigation. The specifics for each aquatic component (water and sediment quality, phytoplankton, benthic invertebrates and arctic char) are summarized in Figure 5.1 and are described further in each of the component study designs. Below is a generic description of each of the levels of response.

If the benchmark is not exceeded, a **low action response** would be undertaken and could include any number of potential responses, including the following:

- Evaluate temporal trends
- Identify likely source(s) and potential for continued contributions
- Confirm the site-specific relevance of benchmark and establish a site-specific benchmark, if necessary
- Further evaluation of data (for example, for water quality, review dissolved metals data or supporting variables).
- Based on evaluations, determine next steps

If the benchmark is exceeded and it is concluded to be Project-related, a **moderate action level response** would be undertaken and could include, in addition to analyses identified for a low action response, the following:

- Consider a weight-of-evidence (WOE) evaluation and/or risk assessment, considering other monitoring results collectively with the indicator that has changed, to evaluate effects on the ecosystem
- Evaluate the need for and specifics of increased monitoring

- Evaluate the need for additional monitoring (e.g., confirmation monitoring) and/or modifications to the CREMP
- Consider results of the trend analysis (i.e., trend analysis indicates an upward trend) and evaluation of potential pathways of effect (i.e., causes of observed changes) to determine if management/mitigation is required
- Identify next steps based on the above analyses. Next steps may include those identified for the high action level response.

A quantitative trigger for the **high action level response** has not been identified as the need for additional study and/or mitigation will depend on the ultimate effects of the observed increases in the indicator parameter(s) of concern on the lakes as a whole. Also, the benchmark may need to be revised in consideration of ongoing monitoring results. The precise relationships between water quality, sediment quality and lower trophic level changes and the collective effects on fish is difficult to predict and therefore actions undertaken under Level 2 will attempt to explore these relationships to advise on overall effects to the ecosystem. Results would be discussed with regulatory agencies and the next steps would be identified. Additional actions that may be implemented in a subsequent phase (i.e., high action level response) could include:

- Implementation of increased monitoring to further assess the potential for effects and/or define magnitude and spatial extent if warranted
- Implementation of mitigation measures or other management actions that may be identified under the moderate action level response

The specifics of how the framework is implemented are described in the individual study designs in the appendices.

5.3 INDICATORS AND BENCHMARKS

Indicators are measurable parameters that can be used to detect change in the environment. Benchmarks are established for various indicators to establish the point at which actions will be triggered before unacceptable adverse effects occur (INAC, 2009). Benchmarks have been identified for each of the aquatic components to be monitored at the mine.

5.3.1 Process for Developing Water and Sediment Quality Benchmarks

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

The assessment of surface water and sediment quality data over the life of the project will be on-going, and the identified benchmarks may change throughout this process, as more data become available. For example, an AEMP benchmark established early on in the life of the mine may require updating in 10 years to a site-specific water quality objective (SSWQO), based on new published literature which has become available, or site specific toxicity tests conducted to further understand ETMF or resident species toxicity. In addition, sediment data will be collected in 2014 prior to mine-related discharge to augment the baseline database and is expected to be integrated into the baseline data, and will likely result in modifications to the suggested AEMP sediment benchmarks presented herein. The iterative, cyclical nature of modification of benchmarks under an AEMP is well established (MacDonald et al., 2009).

The approach for benchmark development involved the following steps:

- Determine, using the FEIS, which substances are present at naturally elevated concentrations, and/or those that could be released at elevated concentrations as a result of mining activities, into the future, as well as substances regulated or potentially regulated under the MMER;
- Evaluate baseline data, and determine a statistical metric of baseline levels which is considered representative of background for any naturally occurring substances (metals/metalloids);
- Evaluate national (CWQG-PAL or CSQG-PAL) or other relevant guidelines from other regulatory jurisdictions, where appropriate. Appropriate guidelines could include Site-Specific Water Quality Objectives (SSWQOs) developed using data from the Mary River area, or from other northern Mine sites, where data are appropriate; and
- Select the higher of either baseline or regulatory or SSWQO as the benchmark for the AEMP.

The specifics of the benchmark selection process for both sediment and surface water are outlined in Appendix C, with a summary provided herein.

5.3.2 Water Quality Benchmarks

Selection of Substances for Benchmark Development

Based on the baseline data collected between 2005 and 2013, and the outcomes of the FEIS, substances having the potential to be either naturally elevated in the environment, or elevated as a result of future mine site activities in lake water were identified as requiring AEMP benchmarks. In addition, metals regulated or which may be potentially regulated under MMER for base metal mines (as a result of the current re-evaluation of the MMER regulations) were similarly considered for benchmark development. The substances of interest shortlisted for benchmark development in surface waters were as follows:

- Metals/Metalloids: Al, As, Cd, Cr, Co, Cu, Fe, Pb, Ni, Ag, Tl, V, Zn; and
- General Parameters and Nutrients: Chloride, Sulphate, Ammonia, Nitrite, Nitrate.

In addition, numerous parameters will be evaluated in the Exploratory Data Analysis (Step 1 of Assessment Framework), including pH, DO, hardness, TSS, Alkalinity, Mg, P, K, Total Organic Carbon and Dissolved Organic Carbon, to monitor potential change. If changes in these substances are noted, benchmarks can be developed at a later stage.

Baseline Data Evaluation

Data treatment conducted in the water and sediment quality baseline review (Knight Piésold, 2014a; Appendix B) involved the following steps:

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

A detailed assessment of lake and river/stream data is presented in the Water and Sediment Quality CREMP Study Design and the baseline review in the appendices (Appendix B). A summary of trends observed in lakes and rivers, respectively, in addition to how the data were treated for benchmark development is as follows (details are provided in Intrinsik, 2014; Appendix C):

- Geographic trends between discrete sampling sites within lakes were not observed in Camp Lake or Sheardown Lake NW, although some substances were elevated within Mary Lake at the inlet. No geographic trends were observed within Mary River, but within Camp Lake Tributary, Station L0-01 had higher concentrations of several substances;
- Within lakes, distinct depth trends were not observed for Camp Lake, Mary Lake or Sheardown Lake NW and lakes were considered to be completely mixed (Knight Piésold, 2014; Appendix B), with the exception of aluminum in Sheardown Lake NW. This suggests that combining the shallow and deep datasets would be appropriate (with the exception of aluminum), since the shallow and deep samples were collected on the same day at the same site. The possible effects of pseudoreplication (since both shallow and deep samples were taken on the same day) were explored, and deemed to be not significant, and hence, these samples were combined.
- An evaluation of the water quality samples from Sheardown Lake NW, Sheardown Lake SE and Sheardown Lake near shore was also undertaken, to determine if these datasets could be combined to calculate a lake-specific AEMP benchmark, and it was concluded that this was a reasonable approach.
- Seasonality was observed for several substances in lakes (e.g., Aluminium had higher concentrations in summer in all lakes; whereas copper, nickel and/or arsenic tended to have higher concentrations in winter).

For the purposes of water quality benchmark development, each water body was assessed separately. Statistical summaries are provided in Appendix C of all lakes and rivers, with respect to minimum, maximum, % detects, mean, median, 95^{th} percentile, and 97.5^{th} percentile for each substance of interest (Intrinsik, 2014).

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 (CWQG-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).

The focus of AEMP benchmark development was on total metals, since available CWQG-PAL focus on total metals benchmarks, as opposed to dissolved metals data. Dissolved data will be assessed under the Assessment Approach and Response Framework in the Low Action Response (Step 3 of Figure 5.1) to examine trends, and where deemed appropriate, based on assessment of both dissolved and total analyses, dissolved benchmarks will be considered for development if data are suggesting mine-related increases are occurring. Dissolved water quality guidelines are available for some parameters from the US EPA (2014), as well as British Columbia Ministry of Environment, and these guidelines would be considered as a first point of comparison, in conjunction with baseline levels, as well as SSWQO, where appropriate.

The approach for selecting water quality benchmarks was the following:

- Select CWQG-PAL guideline, where available or a SSWQO, if already derived;
- Where CWQG-PAL are not available, or are not considered relevant, a surrogate guideline from another jurisdiction was selected (e.g., provincial water quality guideline; US EPA; relevant guideline from another operator, etc.);
- In addition, baseline data was assessed, and a statistical metric of baseline levels (e.g., 97.5th percentile of baseline data) for any naturally occurring substances (metals/metalloids) was calculated;
- The higher of the CWQG-PAL/surrogate guideline or natural baseline was selected as the benchmark;
- Where no water quality guidelines are available, the 97.5th percentile was selected to represent the benchmark;
- Where data had <5% detected values, the higher of the water quality guideline (where available), or 3 times the method detection limit (MDL) was selected;
- Where modifications were required based on site-specific parameters, such as hardness or pH, the 25% percentile hardness and 25% percentile pH values for the water body in question was used in order to calculate a protective guideline. For ammonia, the 75th percentile temperature and pH were used to calculate the guideline. Where parameters are trending up towards these benchmarks, site-specific values should be substituted for comparison purposes (in Low Action).
- Where no CWQG-PAL guideline was available for a substance of interest, a BC MOE (Ministry of the Environment) Approved or Working guideline for the water column were used, where available (BC MOE, undated website). In addition, several water quality guidelines established by the CCME are currently under revision (i.e., lead and iron) or have been released in draft form for comments (silver). Once finalized, these revised benchmarks should be evaluated, using the benchmark selection process outlined, and benchmarks updated accordingly. Details on the specific guidelines selected are presented in Appendix C (Intrinsik, 2014).

Based on the approach used, proposed water quality benchmarks for area lakes and rivers are presented in Tables 5.1 and 5.2, respectively. In most cases, the recommended AEMP benchmarks are consistent between lakes and rivers, with the vast majority of selected benchmarks being regulatory water quality guidelines.

Table 5.1 Selected Water Quality Benchmark Approach and Values for Mine Site Lakes

Parameter	Units	Water Quality Guideline	Camp Lake	Mary Lake	Sheardown Lake	Selected Benchmark	Benchmark Method
Metals [3]							
Aluminium	mg/L	0.1	0.026	0.137	0.179 (Shallow) 0.173 (Deep)	CL = 0.1 ML = 0.13; SDL shall/deep = 0.179/0.173	A (CL), B (ML/SDL)
Arsenic	mg/L	0.005	NC	0.00018	0.0001	0.005	A
Cadmium	mg/L	0.0001 (CL) 0.00006 (ML) 0.00009 (SDL)	NC	0.000023	0.000017	0.0001 (CL) 0.00006 (ML) 0.00009 (SDL)	A
Chromium	mg/L	NGA	NC	0.001	0.000641	0.0003 (CL) (ML) = 0.0005[8] (SDL) = 0.000642[9]	B (ML/SDL), C (CL)
Chromium $^{+3}$	mg/L	0.0089	NC	0.005	NC	0.0089	A

Parameter	Units	Water Quality Guideline	Camp Lake	Mary Lake	Sheardown Lake	Selected Benchmark	Benchmark Method
Chromium +6	mg/L	0.001	NC	0.001	NC	0.003 – 0.015 (CL)[5] 0.003 (ML/SDL)[5]	C
Cobalt	mg/L	0.004	NC	NC	0.0002	0.004	A
Copper	mg/L	0.002	0.0113	0.00239	0.00243	(CL) = 0.004[7] (ML) = 0.0024 (SDL) = 0.0024	B
Iron	mg/L	0.3	0.0421	0.173	0.211	0.3	A
Lead	mg/L	0.001	0.000334	0.00013	0.00026	0.001	A
Nickel	mg/L	0.025	0.000941	0.00080	0.000973	0.025	A
Silver	mg/L	0.0001	NC	NC	0.0000104	0.0001	A
Thallium	mg/L	0.0008	NC	NC	0.0001	0.0008	A
Vanadium	mg/L	0.006	NC	0.00146	0.001	0.006	A
Zinc	mg/L	0.030	0.0037	0.003	0.00391	0.030	A
Water Quality Parameters							
Chloride (Cl^-)	mg/L	120	4	13	5	120	A
Ammonia (NH_3+NH_4)	mg N/L	0.855[4]	0.84	0.32	0.44	0.855	A
Nitrite (NO_2^-)	mg N/L	0.060	0.1[6]	0.1[6]	0.1[6]	0.060	A
Nitrate (NO_3)	mg N/L	13	NC	0.11	NC	13	A
Sulphate	mg/L	218	3	7	5	218	A

NOTES:

1. NGA = NO GUIDELINE AVAILABLE; NC = NOT CALCULATED; TBD = TO BE DETERMINED; GUIDELINE STILL UNDER DEVELOPMENT; CL = CAMP LAKE; ML = MARY LAKE; SDL = SHEARDOWN LAKE.
2. METHOD A = WATER QUALITY GUIDELINE FROM CCME/B.C. MOE; METHOD B = 97.5%ILE OF BASELINE; METHOD C = 3* MDL.
3. TOTAL METALS UNLESS OTHERWISE NOTED.
4. ASSUMES TEMPERATURE AT 10 DEGREES C, AND pH OF 8.
5. THE 2013 DETECTION LIMIT FOR Cr^{6+} INCREASED IN 2013 FROM 0.001 to 0.005, HENCE THIS AFFECTS THE 3* MDL CALCULATION FOR THE BENCHMARK IN CAMP LAKE. EFFORTS WILL BE MADE TO REDUCE THIS MDL IN 2014, AND COMPARISONS TO THE LOWER OF THE 2 BENCHMARKS WOULD THEN BE APPLIED IN CAMP LAKE. IF DETECTION LIMITS IMPROVE, METHOD A (SELECTION OF THE GUIDELINE) MAY BE IMPLEMENTED.
6. THESE VALUES ARE ELEVATED DETECTION LIMITS, AND HENCE, THE GUIDELINE HAS BEEN SELECTED AS THE AEMP BENCHMARK.
7. THE MAXIMUM VALUE OF 0.0113 MG/L COPPER WAS REMOVED TO CALCULATE THE 97.5TH PERCENTILE, AS THIS VALUE APPEARS TO BE AN OUTLIER.
8. AN ELEVATED DETECTION LIMIT OF 0.001 MG/L WAS REMOVED FROM THE DATASET AND CALCULATIONS, AND THE AEMP SELECTED WAS THE 97.5th PERCENTILE, WHICH IS 0.0005 mg/L.
9. SEVERAL DETECTED VALUES RANGING FROM 0.00079 - 0.00316 mg/L Cr HAVE BEEN REPORTED IN THE DATASET FOR SDL, AND HENCE, THESE VALUES WERE CONSIDERED TO REPRESENT BASELINE, AND WERE INCLUDED IN THE 97.5th PERCENTILE CALCULATION.

Table 5.2 Selected Water Quality Benchmark Approach and Values for Mine Site Streams

Parameter	Units	Water Quality Guideline	Camp Lake Tributary	Mary River[3]	Selected Benchmark	Benchmark Method
Metals[4]						

Parameter	Units	Water Quality Guideline	Camp Lake Tributary	Mary River[3]	Selected Benchmark	Benchmark Method
Aluminum	mg/L	0.1	0.179	0.97	CLT = 0.179 MR = 0.966	B
Arsenic	mg/L	0.005	0.00012	0.00013	0.005	A
Cadmium	mg/L	0.00008 (CLT) 0.00006 (MR)	NC	0.00002	CLT = 0.00008 MR = 0.00006	A
Chromium	mg/L	NGA	0.000856	0.0023	CLT = 0.000856 MR = 0.0023	B
Chromium $^{+3}$	mg/L	0.0089	NC	0.005	0.0089	A
Chromium $^{+6}$	mg/L	0.001	NC	NC	0.003[5]	C
Cobalt	mg/L	0.004	NC	0.0004	0.004	A
Copper	mg/L	0.002	0.00222	0.0024	CLT = 0.0022 MR = 0.0024	B
Iron	mg/L	0.3	0.326	0.874	CLT = 0.326 MR = 0.874	B
Lead	mg/L	0.001	0.000333	0.00076	0.001	A
Nickel	mg/L	0.025	0.00168	0.0018	0.025	A
Silver	mg/L	0.0001	NC	0.0001	0.0001	A
Thallium	mg/L	0.0008	0.0002	0.0002	0.0008	A
Vanadium	mg/L	0.006	NC	0.002	0.006	A
Zinc	mg/L	0.030	0.0035	0.01	0.030	A
Water Quality Parameters						
Chloride (Cl^-)	mg/L	120	23	21.55	120	A
Ammonia (NH_3+NH_4)	mg N/L	0.855[6]	0.60	0.60	0.855	A
Nitrite (NO_2^-)	mg N/L	0.060	0.095[7]	0.06	0.060	A
Nitrate (NO_3)	mg N/L	13	0.118	0.14	13	A
Sulphate	mg/L	218	6	8	218	A

NOTES:

1. NGA = NO GUIDELINE AVAILABLE; NC = NOT CALCULATED; TBD = TO BE DETERMINED; GUIDELINE STILL UNDER DEVELOPMENT; MR = MARY RIVER; CLT = CAMP LAKE TRIBUTARY.
2. METHOD A = WATER QUALITY GUIDELINE FROM CCME/B.C. MOE; METHOD B = 97.5%ILE OF BASELINE; METHOD C = 3* MDL.
3. ONE SAMPLE (OUTLIER) CONTAINING CHEMICAL CONCENTRATIONS ORDERS OF MAGNITUDE ABOVE OTHER VALUES WAS NOT INCLUDED IN THE CALCULATIONS FOR MARY RIVER.
4. TOTAL METALS UNLESS OTHERWISE NOTED.
5. EFFORTS WILL BE MADE TO REDUCE THIS MDL IN 2014, AND COMPARISONS TO THE HIGHER OF THE METHOD A OR C WOULD THEN BE APPLIED AS THE AEMP BENCHMARK.
6. ASSUMES TEMPERATURE AT 10 DEGREES C, AND pH of 8.0.
7. 97.5th PERCENTILE IS BEING DRIVEN BY ELEVATED DETECTION LIMIT, THEREFORE, THE GUIDELINE WAS SELECTED.

In most cases, the benchmarks are consistent between lakes and streams, with the vast majority of selected benchmarks being generic WQOs (i.e., CWQG-PAL or surrogate). Where natural concentrations varied, and exceeded available WQOs, or < 5% of values was detected, recommended benchmarks varied.

5.3.3 Sediment Quality Benchmarks

Selection of Substances for Benchmark Development

Based on the baseline data collected between 2005 and 2013, and the outcomes of the FEIS, the following substances have the potential to be either naturally elevated in the environment, or elevated as a result of future mine site activities. Therefore, these substances merited benchmark development:

- Arsenic;
- Cadmium;
- Chromium;
- Copper;
- Iron;
- Manganese;
- Nickel; and
- Phosphorus.

In addition, lead, mercury and zinc were also included for benchmark development, as CCME sediment quality guidelines exist for these substances. Further details are presented in Appendix C (Intrinsik, 2014).

Baseline Data Evaluation

Data treatment conducted in the Water and Sediment Quality Baseline Review (Knight Piésold, 2014; Appendix B) involved the following steps:

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

Additional assessment of baseline data was conducted to examine metals concentrations relative to depositional characteristics of sampling locations, in order to explore the relationships between depositional characteristics (such as Total Organic Carbon (TOC) (e.g., high TOC represents a higher propensity to accumulate metals) and presence of sand (% sand; e.g., high sand content would represent lower potential for accumulation of metals, due to lower binding potential), and metal concentrations (Appendix B). This assessment concluded that all sediment sampling locations with TOC concentrations < 60% (0.6) and sand content of > 80% or those stations wherein sand alone was > 90% (irrespective of TOC) do not represent depositional zones, and these stations should no longer be included as potential monitoring stations. As such, these stations were removed from the baseline chemistry calculations. Removal of these stations is justified since stations exhibiting these characteristics have a low potential to accumulate metals, and hence, will have a low likelihood of exhibiting substantial changes in chemistry in the future.

The remaining data were evaluated using two approaches, based on the dataset as a whole (N=52), and also on an area-by-area basis, to attempt to evaluate similarities and differences between the lakes, and to determine if there were differences between lakes which would suggest a need for differing AEMP benchmarks for different lakes. With respect to possible approaches that can be taken to estimate background, upper percentile values are frequently used (either 95th percentile or 97.5th percentile) as reasonable metrics for characterizing upper estimate of baseline. While both statistical metrics are presented, the final metric used to represent baseline was the 97.5th percentile, based on approaches established by Ontario Ministry of Environment (OMOE, 2011). Details of the assessment of the entire area-wide dataset, as well as lake by lake comparisons, are presented in Appendix C (Intrinsik, 2014). The outcomes of the assessment can be summarized as follows:

- Sample sizes within a number of area lakes were limited (e.g., Camp Lake, n=9; Sheardown Lake SE, n=6; Mary Lake, n=6, Tributaries of Sheardown Lake, n=5), compared with Sheardown Lake NW (n=25). In light of this, more sediment data will be collected in 2014 prior to commencement of mining, to further characterize baseline sediment concentrations in these lakes and confirm whether enrichment for metals/metalloids may require lake-specific sediment quality benchmarks. As a result of the need for more sediment data to more fully characterize baseline, only interim sediment quality benchmarks are presented at this time;
- An assessment of temporal changes within Sheardown Lake NW was conducted, to examine whether concentrations in that basin have increased over time. The data suggest that Cr, Cu and Ni appear to be trending upwards, although this has not been confirmed statistically. Phosphorus data are too limited to interpret. Collection of additional data in 2014 will assist in interpretation of trends, and influenced data would be removed from final AEMP benchmark calculations. All Sheardown Lake NW has been retained for the interim benchmark calculations.
- Interim benchmarks are based on the area-wide data from all depositional watercourses, with the exception of the Tributaries of Sheardown Lake (n=5). It was determined that some metal concentrations within the Tributaries of Sheardown Lake were increasing the 95th and 97.5th percentile calculations for the area-wide data set, and hence these data were removed for the purposes of interim benchmark calculations. This area will be sampled in 2014, and further assessment of the data will occur at that time, relative to other areas, and earlier sediment data.

The proposed approach for selecting AEMP sediment benchmarks included 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 is also being 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., 97.5th percentile of baseline data) for any naturally occurring substances (metals/metalloids) will be calculated.

The higher of the CCME/surrogate guideline or natural baseline was selected as the Interim AEMP benchmark. The outcome of this evaluation process is presented in Table 5.1.

As mentioned above, additional sediment sampling will be conducted in all mine site lakes, focusing on depositional areas, as per the analysis outlined in the CREMP to gather more data to characterize baseline prior to commencement of mining operations. 2014 data will be evaluated for temporal trends, and to determine whether lakes can be aggregated for some or all metals of interest with respect to AEMP benchmark development. Final AEMP benchmarks will be established following analysis of the 2014 data, and interim sediment quality benchmarks can be used for assessment purposes until that time.

5.3.4 Nutrient/Eutrophication Indicators and Benchmarks

During the NIRB review of the FEIS as well as the water licensing technical review and final hearings, Environment Canada expressed concern regarding the potential for discharges of treated sewage effluent to result in eutrophication of the receiving waters (Sheardown Lake NW and Mary River).

Although phosphorus is typically the limiting nutrient in freshwater ecosystems, eutrophication response variables (e.g., abundance of phytoplankton, dissolved oxygen depletion) are typically what are of concern in freshwater environments.

Therefore, while nutrients (i.e., TP and TN) will continue to be monitored under the water quality component of the CREMP, effects of nutrient enrichment on Mine Area waterbodies will be monitored through measurement of primary productivity (i.e., phytoplankton).

The indicator for phytoplankton abundance will be chlorophyll *a* (NSC, 2014a; Appendix D). Chlorophyll *a* is the most widely used indicator of phytoplankton abundance and is relatively easy to sample. It is also associated with lower analytical variability and is more cost-effective than biomass and community composition metrics. Further, biological benchmarks for phytoplankton community metrics have not been developed to the same extent as for chlorophyll *a* and phytoplankton indices are not as strongly linked to primary drivers of eutrophication (i.e., nutrients). While this parameter is associated with relatively high variability in the lakes currently, the variability is largely a function of low concentrations and in particular, a relatively high frequency of censured values (i.e., below detection; Appendix D).

The phytoplankton monitoring program will also consider related/supporting variables including nutrients (phosphorus and nitrogen), measures of water clarity (i.e., TSS, turbidity, Secchi disk depth), and temperature in the data analysis and reporting phase.

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

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

Table 5.3 Selected Approach and Interim Area-Wide Sediment Quality Benchmarks

Jurisdiction, Type of Guideline and Statistical Metric		Hg	As	Cd	Cr	Cu	Fe	Mn	Ni	P	Pb	Zn
CCME	**ISQG**	0.17	5.9	0.6	37.3	35.7	NGA	NGA	NGA	NGA	35	123
	PEL	0.486	17	3.5	90	197	NGA	NGA	NGA	NGA	91.3	315
Ontario Sediment Quality Guideline	**LEL**	0.2	6	0.6	26	16	20,000	460	16	600	31	120
	SEL	2	33	10	110	110	40,000	1100	75	2,000	250	820
US EPA Sediment Quality Guidelines	**Screening**	0.18	9.8	0.99	43.4	31.6	20,000	460	22	NGA	35.8	121
97.5^{th} Percentiles of Each Lake Area (sample size)												
Tributaries of Sheardown Lake (5)		0.1	2.95	1.9	118	106	28,370	809	115	295	52	171
Mary Lake (6)		0.1	4.95	0.5	97	38	51,463	4,305	61	1,580	28	103
Camp Lake (9)		0.1	4	0.5	83	50	40,920	1,057	74	1,480	23	69
Sheardown Lake NW (25)		0.1	7.95	0.5	96	60	56,240	5,612	81	2,310	24	92
Sheardown Lake SE (6)		0.1	2.0	0.9	80	32	32,988	547	66	1,278	18	57
95^{th} Percentile of Area-Wide Data (47)[2]		NC	5.2	0.5	93	56	50,430	3,874	76	1,565	24	91
97.5^{th} Percentile of Area-Wide Data (47)[2]		NC	6.2	0.5	97	58	52,200	4,530	77	1,958	24	94
Proposed Interim AEMP Benchmark		**0.17**	**6.2**	**1.5**	**97**	**58**	**52,200**	**4,530**	**77**	**1,958**	**35**	**123**
Benchmark Method		A	B	C	B	B	B	B	B	B	A	A

NOTES:

1. NC = NOT CALCULATED AS ALL VALUES < MDL.
2. TRIBUTARIES OF SHEARDOWN LAKE DATA ARE NOT INCLUDED DUE TO ELEVATED RESULTS IN THIS AREA.
3. GUIDELINE IS BASED ON SEDIMENT QUALITY GUIDELINE.
4. GUIDELINE IS BASED ON 97.5^{TH}%ILE OF BASELINE DATA.
5. GUIDELINE IS BASED ON 3 TIMES MDL, THE 97.5^{TH}%ILE IS EQUAL TO THE MDL.
6. MERCURY WAS NOT DETECTED IN ANY SAMPLES; MERCURY DETECTION LIMIT IS USED TO REPRESENT THE 95^{TH} AND 97.5^{TH} PERCENTILES.

The benchmark for chlorophyll *a* for the Mary River Project (3.7 µg/L) is based on maintaining the trophic status (i.e., oligotrophic) of Mine Area lakes. Specifically, the benchmark represents the average of the upper and lower ranges of trophic boundaries for lakes based on chlorophyll *a*, as designated and/or adopted in the scientific literature (Table 5.4).

This benchmark is lower than the recently developed benchmark for Lac de Gras in relation to the Diavik Diamond Mines Project. Lac de Gras has a similar background concentration of chlorophyll *a*; the "normal range" of chlorophyll *a* in Lac de Gras (mean±2 x SD) was identified as 0.89 µg/L and the mean was 0.52 µg/L for the open-water season (Golder Associates Ltd., 2014). This value is similar to the same statistic for Sheardown Lake NW but much lower than statistics for the other mine area lakes.

Table 5.4 Derivation of the Benchmark for Chlorophyll a

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

5.3.5 Benthic Macroinvertebrate Indicators and Benchmarks

A number of BMI metrics were reviewed for inclusion in the CREMP, including:

- abundance - total macroinvertebrate density (individuals/m^2±SE);
- composition - Chironomidae proportion (% of total density);
- Shannon's Equitability (evenness);
- Simpson's Diversity Index; and
- Richness metrics (total taxa and Hill's Effective richness, both at the genus level).

The variability of the BMI metrics measured during the baseline studies program were evaluated and described to assist with identifying the most robust metrics for further statistical exploration and consideration under the CREMP. The least variable metrics identified for both mine area lakes and streams through this process were:

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

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

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

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

The benchmark for the BMI program that will be conducted under the CREMP is a change of ± 50% in the mean of key metrics. A preliminary assessment of the statistical power of baseline data indicated that the power of the data set for Sheardown Lake NW and Tributary 1, Reach 4 to be able to detect a post-Project change in the mean of ± 50% was 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. In before-after comparisons of metrics, the power to detect differences is greater when there are more monitoring events in the before and after periods included in the analysis. Overall, it is expected that the CREMP will be capable of detecting larger impacts in a short time period, but will require longer time periods to detect more subtle effects (i.e., as more data are acquired).

5.3.6 Arctic Char Indicators and Benchmarks

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

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

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

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

Environment Canada (2012) recommends that non-lethal sampling should include fork length for fish with a forked caudal fin (±1 mm), total body weight (±1.0%), assessment of external condition (i.e., deformities, erosion, lesions, and tumours [DELTs]), external sex determination (if possible), and age (where possible; ±1 year). Metrics based on these measurements that will be examined under the CREMP are indicated in Table 5.4. In addition, catch-per-unit-effort (CPUE) will be calculated and examined in the analysis and reporting as a general indicator of abundance.

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

The MMER identifies CESs for a fish population as a percentage of change from the “reference mean” (Table 5.5). As noted by Indian and Northern Affairs Canada (INAC 2009), “these effect sizes do not reflect the method recommended by Environment Canada (2004); namely effect sizes that correspond with unacceptable ecological changes.” INAC (2009) also notes that Environment Canada (2008) identified these CESs “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”.

As it is not possible to identify a level of change in Arctic Char population metrics that would be indicative of long-term effects or “unacceptable ecological changes” for the mine area fish populations, the CREMP will initially apply the recommended EEM benchmarks (Table 5.6). However, it is recommended that the applicability/appropriateness of these benchmarks be reviewed on a regular basis and, if appropriate, modified as the CREMP progresses. The management response framework should also be regularly reviewed and adjusted over time to ensure the program is effective, sensitive, and ecologically meaningful.

5.4 EFFECTS EVALUATION FRAMEWORK

A risk-based approach to integrating the results of the component monitoring programs will be undertaken, drawing from the approach applied at the Meadowbank Mine (Azimuth, 2010). Monitoring results will be evaluated using the following risk-oriented criteria:

- Magnitude – the degree to which an indicator approaches or exceeds the established benchmark (or other guideline, if different than the benchmark)
- Extent – the scale at which the change or exceedance occurs
- Causation – the strength of evidence for a mine-related cause
- Reversibility – the likelihood that the effect may be reversed over time
- Uncertainty – the confidence or lack thereof in the findings regarding the above criteria

Table 5.5 Fish Metrics and Statistical Analysis Methods Recommended Under EEM

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

NOTE:
1. METRICS INDICATED WITH AN ASTERISK ARE ENDPOINTS USED FOR DETERMINING EFFECTS UNDER EEM, AS DESIGNATED BY STATISTICALLY SIGNIFICANT DIFFERENCES BETWEEN EXPOSURE AND REFERENCE AREAS. OTHER ENDPOINTS MAY BE USED TO SUPPORT ANALYSES.

Table 5.6 MMER EEM Critical Effects Sizes for Fish Populations Using Non-Lethal Sampling

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

NOTE:
1. CES'S ARE EXPRESSED AS A PERCENTAGE OF THE REFERENCE MEANS.

The above criteria will be applied to each monitoring indicator for each aquatic component, with results summarized using the rating system presented in Table 5.7.

5.5 INTEGRATED DATA EVALUATION

Once data are summarized for each component program, key findings from each program will be evaluated together in the AEMP so that issues can be identified and response actions developed. The data evaluation will be based on the Data Assessment Approach and Response Framework presented as Figure 5.1, applied at the AEMP level.

5.6 MANAGEMENT ACTIONS

Management actions will be implemented as identified in the low and moderate action responses for each aquatic component, based on assessment of whether the change is considered to be mine-related, and the action level determined relative to the benchmark(s) (Figure 5.1). In the instance of detecting change among multiple stressors, action will be implemented according to a weight of evidence evaluation.

Table 5.7 Aquatic Effects Evaluation Rating Criteria

Criteria	Classification	
Magnitude The degree of change; specific to the Indicator/VEC and the impact	Level I	Change to the Indicator is not distinguishable from natural variation and is well below benchmark
	Level II	Change to the Indicator is clearly distinguishable and approaching benchmark
	Level III	Change to the Indicator is clearly distinguishable and exceeds to the benchmark
Extent The physical extent of the effect, relative to study area boundaries	Level I	Isolated occurrence or very small area
	Level II	Moderately sized area affected, such as a portion of a basin
	Level III	An entire lake basin or lake is likely to be affected
Causation The strength of evidence that the effect is mine-related	Level I	No evidence that effect is mine-related
	Level II	Some likelihood that the effect is mine-related
	Level III	Very likely to be mine-related
Reversibility The likelihood of the Indicator/VEC to recover from the effect	Level I	Fully reversible in less than 10 years
	Level II	Reversible over a long period of time (i.e., decades)
	Level III	Largely irreversible for at least several decades
Certainty Degree of certainty or uncertainty in the findings of the monitoring data	High	Limited or conflicting monitoring data, resulting in a low certainty
	Medium	Moderate certainty in findings based on monitoring data
	Low	High certainty in findings based on monitoring data

Mitigation measures will be evaluated, as outlined in Figure 5.1, and implemented on a case-by-case basis, based on an issue-specific assessment of the situation, and action level. Exceedance of a benchmark triggers a moderate action response. Moderate Action Responses may include mitigation measures that are easily implemented at low-cost and in a short time-frame. Such mitigation measures may already be identified as contingency or adaptive management measures within various management plans for the Project.

One of the moderate action responses is to develop a High Action Responses, which will be implemented if the trend over time is a continued change relative to the benchmark (increase in the magnitude of the effect). High Action Responses will be reviewed by key regulatory agencies prior to implementation.

6 QUALITY ASSURANCE AND QUALITY CONTROL

Each of the monitoring programs comprising the AEMP will implement standard QA/QC measures as follows:

- Staffing the project with experienced and properly trained individuals
- Ensuring that representative, meaningful data are collected through planning and efficient research
- Using standard protocols for sample collection, preservation, and documentation
- Calibrating and maintaining all field equipment

Various additional QA/QC measures will be implemented for each of the components studies, as described below.

6.1 WATER AND SEDIMENT QUALITY

A strict QA/QC program is in place to ensure that high quality and representative data are obtained in a manner that is scientifically defensible, repeatable and well documented. This program aims to ensure that the highest level of QA/QC standard methods and protocols are used for the collection of all environmental media samples. Quality assurance is obtained at the project management level through organization and planning, and the enforcement of both external and internal quality control measures. In addition to those standard QA/QC measures listed in Section 6 above, the following QA/QC procedures and practices will be implemented in water and sediment quality programs:

- Internal Quality Control:
  - Collecting duplicate, blank, filter and travel blank samples for submission for analysis (approximately 10% of overall samples)
- External Quality Control:
  - Employing fully accredited analytical laboratories for the analysis of all samples
  - Determining analytical precision and accuracy through the interpretation of the analysis reports for the blind duplicate, blank, filter and travel blank samples

The field sampling protocols being applied to the water and sediment quality program is presented as an appendix of the water and sediment quality CREMP in Appendix B (Knight Piésold, 2014b).

The quality of the data obtained for a project is assessed via their adherence to the pre-set data quality objectives (DQOs). DQOs provide a means of assessing whether the data in question are precise, accurate, representative, and complete. The results from QA/QC samples are reviewed to determine if sample contamination occurred. These data are further used to determine if the contamination occurred during collection, handling, storage, or shipping. Upon receipt from the laboratory, the data are uploaded into a database along with copies of field notes, photos, Sample Receipt Confirmations, Microsoft Excel data, and Certificates of Analysis.

6.2 BENTHIC INVERTEBRATE SURVEY

Field sub-samples will be collected from each BMI replicate station, to compensate for the spatial variability encountered with these organisms. Sub-samples collected from Sheardown Lake NW in 2013 were analysed separately to evaluate precision and to advise on study design. The results of this analysis indicated a high level of precision associated with five sub-samples and the CREMP will therefore continue to collect five sub-samples but will pool the sub-samples in the field.

Appropriate QA/QC measures related to processing and identification of BMI samples, as outlined in the EEM technical guidance document will be followed and are described below (Environment Canada, 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.

BMI samples will be sorted with the use of a stereomicroscope. 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.

6.3 FISH

QA/QC technical procedures will be utilized for all field sampling, laboratory analysis, data entry and data analysis.

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.

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

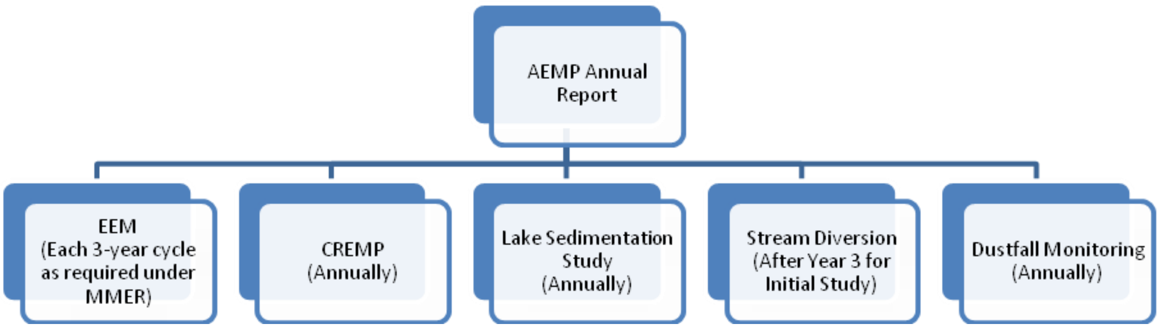
6.4 DATA EVALUATION

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.

7 ANNUAL REPORTING

AEMP monitoring results will be presented an a AEMP Annual Report that will accompany the Type A Water Licence Amendment No.1 Annual Report, as required by Schedule B, Section e, Item (i) of the Water Licence. The AEMP Annual Report will consist of a high level summary of monitoring activities and outcomes and any management responses. Monitoring results will be presented in technical reports for each component study, as appendices to the AEMP Annual Report. The AEMP Annual Report structure and frequency of reporting of component studies is shown on Figure 7.1.

Figure 7.1 AEMP Annual Report Structure



The AEMP Annual Report will provide a compilation, assessment and interpretation of findings across monitoring programs, and present an evaluation of effects. Revisions to study designs or management response actions will be summarized and discussed for each key issue.

The AEMP will be updated periodically, as required. Updates to the AEMP will be filed with the Water Licence Annual Report in accordance with Schedule B, Section g, Item (ii) of the Water Licence. Updates to the AEMP may consist of modifications to study designs, or termination of shorter-term targeted studies accompanied by adequate rationale.

8 LIST OF CONTRIBUTORS

This document has been prepared by Baffinland and a consultant team as follows:

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- Erik Madsen – Overall corporate responsibility
- Oliver Curran – Primary client contact and reviewer
- Jim Millard – technical review
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- Richard Cook – Consultant Team Project Manager; contributions to the water and sediment quality CREMP; management response framework; senior review
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- Pierre Stecko (Minnow Environmental) – senior technical review of EEM Study Design
- Laurie Ainsworth – Graphical analysis and statistical design of water and sediment quality baseline and CREMP
- Elizabeth Ashby – water and sediment quality baseline review and CREMP study design

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- Leanne Zrum – benthic macroinvertebrate baseline review and CREMP study design

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- Christine Moore – development of management response framework and benchmarks for water and sediment quality; senior review

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APPENDICES

Appendix A

Draft EEM Cycle One Study Design

APPENDIX A

STUDY AREA CHARACTERIZATION DATA

(Pages A-1 to A-14)

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TABLE A.1

BAFFINLAND IRON MINES CORPORATION
MARY RIVER PROJECT

DRAFT EEM CYCLE ONE STUDY DESIGN
2013 STUDY AREAS: REPLICATE STATION LOCATION SUMMARY

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Study Area ID	Replicate Station ID	UTM Easting	UTM Northing	Latitude	Longitude	Latitude-Degrees	Latitude-Minutes	Latitude-Seconds	Longitude-Degrees	Longitude-Minutes	Longitude-Seconds
CLT-NF	CLT-NF-1	558493	7914937	71.32949	-79.3627138	71	19	46.14645	-79	21	45.76973
	CLT-NF-2	558516	7914899	71.32914	-79.3620992	71	19	44.9003	-79	21	43.55694
	CLT-NF-3	558511	7914871	71.32889	-79.3622603	71	19	44.00128	-79	21	44.13689
	CLT-NF-4	558479	7914872	71.32891	-79.3631547	71	19	44.06153	-79	21	47.35698
	CLT-NF-5	558422	7914879	71.32898	-79.3647441	71	19	44.33718	-79	21	53.07857
CLT-FF	CLT-FF-1	557896	7914927	71.32954	-79.3794235	71	19	46.34319	-79	22	45.9247
	CLT-FF-2	557863	7914945	71.32971	-79.3803333	71	19	46.95251	-79	22	49.19981
	CLT-FF-3	557831	7914975	71.32999	-79.3812061	71	19	47.94811	-79	22	52.34189
	CLT-FF-4	557776	7915001	71.33023	-79.3827254	71	19	48.83451	-79	22	57.81143
	CLT-FF-5	557705	7914980	71.33006	-79.3847275	71	19	48.21825	-79	23	5.019129
CLT-REF2	CLT-REF2-1	526096	7936773	71.53094	-80.261927	71	31	51.36724	-80	15	42.93705
	CLT-REF2-2	526051	7936769	71.5309	-80.2632009	71	31	51.25588	-80	15	47.52339
	CLT-REF2-3	526009	7936767	71.53089	-80.2643894	71	31	51.20786	-80	15	51.8018
	CLT-REF2-4	525970	7936787	71.53107	-80.2654854	71	31	51.86865	-80	15	55.74755
	CLT-REF2-5	525917	7936785	71.53106	-80.266985	71	31	51.82489	-80	16	1.145894
CLT-REF3	CLT-REF3-1	567828	7908060	71.26541	-79.107605	71	15	55.48167	-79	6	27.37784
	CLT-REF3-2	567792	7908083	71.26563	-79.1085886	71	15	56.26002	-79	6	30.91898
	CLT-REF3-3	567784	7908119	71.26595	-79.1087803	71	15	57.42946	-79	6	31.60896
	CLT-REF3-4	567754	7908137	71.26612	-79.109601	71	15	58.04043	-79	6	34.56369
	CLT-REF3-5	567732	7908119	71.26597	-79.1102301	71	15	57.48195	-79	6	36.82838
CLT-REF4	CLT-REF4-1	569095	7907235	71.25766	-79.0730137	71	15	27.57547	-79	4	22.84922
	CLT-REF4-2	569090	7907203	71.25737	-79.0731814	71	15	26.54832	-79	4	23.45315
	CLT-REF4-3	569066	7907186	71.25723	-79.0738654	71	15	26.02461	-79	4	25.91531
	CLT-REF4-4	569055	7907155	71.25695	-79.0741994	71	15	25.03588	-79	4	27.11793
	CLT-REF4-5	569034	7907136	71.25679	-79.0748015	71	15	24.44455	-79	4	29.28542
MRY-NF	MRY-NF-1	561572	7911165	71.29491	-79.2795794	71	17	41.68817	-79	16	46.48597
	MRY-NF-2	561498	7911053	71.29393	-79.2817348	71	17	38.14268	-79	16	54.24531
	MRY-NF-3	561346	7910945	71.293	-79.2860648	71	17	34.79759	-79	17	9.833226
	MRY-NF-4	561012	7911183	71.29522	-79.2952038	71	17	42.78106	-79	17	42.73356
	MRY-NF-5	560944	7911420	71.29736	-79.2969164	71	17	50.48928	-79	17	48.8989
MR-FF	MRY-FF-1	558400	7909217	71.27824	-79.3696302	71	16	41.67648	-79	22	10.66857
	MRY-FF-2	558253	7908669	71.27337	-79.374143	71	16	24.12339	-79	22	26.91465
	MRY-FF-3	558082	7908529	71.27215	-79.3790179	71	16	19.75458	-79	22	44.46431
	MRY-FF-4	558031	7908390	71.27092	-79.3805443	71	16	15.31393	-79	22	49.95946
	MRY-FF-5	557921	7908227	71.26949	-79.383734	71	16	10.14982	-79	23	1.442342
MRY-REF1	MRY-REF1-1	538165	7901502	71.21313	-79.9381601	71	12	47.25956	-79	56	17.37647
	MRY-REF1-2	538066	7901337	71.21166	-79.9409943	71	12	41.99067	-79	56	27.57936
	MRY-REF1-3	537916	7901249	71.2109	-79.9452091	71	12	39.2353	-79	56	42.75266
	MRY-REF1-4	537754	7901067	71.20929	-79.9498027	71	12	33.45272	-79	56	59.2896
	MRY-REF1-5	537598	7900717	71.20618	-79.9543094	71	12	22.24464	-79	57	15.51376
MRY-REF2	MRY-REF2-1	570185	7903339	71.22243	-79.0461442	71	13	20.76502	-79	2	46.11894
	MRY-REF2-2	570159	7903134	71.22061	-79.0470515	71	13	14.17908	-79	2	49.3855
	MRY-REF2-3	570198	7902946	71.21891	-79.0461356	71	13	8.07375	-79	2	46.08823
	MRY-REF2-4	570199	7902749	71.21714	-79.0462848	71	13	1.71772	-79	2	46.62513
	MRY-REF2-5	570288	7902506	71.21494	-79.0440281	71	12	53.78594	-79	2	38.50122
MRY-REF3	MRY-REF3-1	584306	7898429	71.17394	-78.6587003	71	10	26.19909	-78	39	31.32108
	MRY-REF3-2	584254	7898260	71.17245	-78.6603242	71	10	20.8137	-78	39	37.16713
	MRY-REF3-3	584189	7898080	71.17086	-78.6623202	71	10	15.08973	-78	39	44.35286
	MRY-REF3-4	584018	7897936	71.16963	-78.6672174	71	10	10.65884	-78	40	1.982762
	MRY-REF3-5	583948	7897837	71.16876	-78.6692648	71	10	7.553149	-78	40	9.353098
MRY-REF4	MRY-REF4-1	571350	7917079	71.34521	-79.0011024	71	20	42.76226	-79	0	3.968775
	MRY-REF4-2	571393	7917037	71.34482	-78.9999376	71	20	41.3615	-78	59	59.77538
	MRY-REF4-3	571452	7916972	71.34422	-78.9983463	71	20	39.20169	-78	59	54.04653
	MRY-REF4-4	571482	7916886	71.34344	-78.9975862	71	20	36.39546	-78	59	51.31044
	MRY-REF4-5	571491	7916771	71.34241	-78.997441	71	20	32.67622	-78	59	50.78743

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NOTES:

1. UTM COORDINATES WERE COLLECTED USING A HANDHELD GPS ONSITE IN ZONE 17 W, NAD83 DATUM.

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TABLE A.2

BAFFINLAND IRON MINES CORPORATION
MARY RIVER PROJECT

DRAFT EEM CYCLE ONE STUDY DESIGN
MARY RIVER STUDY AREAS: STREAM MEASUREMENTS

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STUDY AREA		CLT-NF-1	CLT-NF-2	CLT-NF-3	CLT-NF-4	CLT-NF-5	CLT-FF-1	CLT-FF-2	CLT-FF-3	CLT-FF-4	CLT-FF-5	CLT-REF2-1	CLT-REF2-2	CLT-REF2-3	CLT-REF2-4	CLT-REF2-5	CLT-REF3-1	CLT-REF3-2	CLT-REF3-3	CLT-REF3-4	CLT-REF3-5	CLT-REF4-1	CLT-REF4-2	CLT-REF4-3	CLT-REF4-4	CLT-REF4-5
CHARACTERIZATION DATE		20-Aug-13					29-Aug-13					24-Aug-13					22-Aug-13					22-Aug-13				
MEASUREMENT	UNIT																									
Distance to U/S Replicate Station	m	-	48	28	32	58	-	40	45	62	75	-	47	48	43	56	-	46	38	38	30	-	33	40	40	29
TOTAL DISTANCE	m	166					222					194					152					142				
Wetted Width	m	5.5	6.3	4.7	5.85	6.5	5.15	3.38	4.9	5.95	5.1	22.6	17.4	10.8	13.45	12.95	4.3	3.3	5.65	5.7	4.15	2.25	3.6	2.2	2.7	2
MEAN WETTED WIDTH	m	5.8					4.9					15.4					4.6					2.6				
TD1	m	0.10	0.10	0.14	0.15	0.12	0.12	0.12	0.12	0.13	0.06	0.22	0.26	0.13	0.3	0.26	0.07	0.24	0.16	0.23	0.17	0.18	0.16	0.06	0.16	0.16
VEL1	m/sec	0.48	0.08	0.19	0.06	0.10	0.31	0.47	0.19	0.27	0.25	0.38	0.28	0.8	0.59	0.85	0.47	0.16	0.25	0.2	0.05	0.3	0.16	0.13	0.44	0.38
TD2	m	0.08	0.08	0.20	0.26	0.15	0.16	0.07	0.11	0.14	0.06	0.31	0.3	0.15	0.22	0.29	0.09	0.2	0.15	0.17	0.22	0.13	0.2	0.08	0.18	0.14
VEL2	m/sec	0.22	0.21	0.46	0.14	0.10	0.51	0.61	0.46	0.4	0.07	0.49	0.69	0.65	0.59	0.2	0.11	0.23	0.08	0.16	0.03	0.14	0.48	0.39	0.52	0.5
TD3	m	0.10	0.06	0.20	0.26	0.20	0.18	0.08	0.18	0.18	0.1	0.27	0.2	0.2	0.24	0.24	0.18	0.13	0.17	0.18	0.22	0.17	0.17	0.08	0.24	0.18
VEL3	m/sec	0.12	0.06	0.20	0.38	0.40	0.28	0.39	0.21	0.17	0.34	0.45	0.54	0.28	0.55	0.84	0.08	0.12	0.09	0.14	0.03	0.2	0.35	0.52	0.44	0.48
TD4	m	0.16	0.10	0.18	0.30	0.26	0.14	0.13	0.21	0.22	0.11	0.34	0.24	0.22	0.2	0.16	0.1	0.15	0.12	0.18	0.25	0.11	0.17	0.1	0.2	0.15
VEL4	m/sec	0.26	0.20	0.41	0.40	0.30	0.74	0.32	0.5	0.48	0.34	0.77	0.64	0.59	0.61	0.72	0.19	0.42	0.12	0.24	0.04	0.05	0.31	0.25	0.17	0.26
TD5	m	0.11	0.09	0.20	0.18	0.28	0.22	0.18	0.18	0.18	0.1	0.07	0.16	0.2	0.12	0.1	0.08	0.24	0.05	0.18	0.24	0.17	0.18	0.14	0.12	0.08
VEL5	m/sec	0.35	0.29	0.11	0.25	0.29	0.5	0.53	0.45	0.54	0.41	0.11	0.66	0.58	0.4	0.38	0.41	0.23	0.03	0.07	0.08	0.5	0.4	0.56	0.3	0.42
TD6	m	0.10	0.06	0.22	0.09	0.16	0.14	0.1	0.22	0.13	0.08	0.1	0.13	0.16	0.18	0.14	0.06	0.12	0.13	0.21	0.24	0.18	0.13	0.14	0.14	0.07
VEL6	m/sec	0.56	0.21	0.22	0.46	0.45	0.46	0.59	0.33	0.31	0.43	0.41	0.24	0.47	0.53	0.34	0.28	0.43	0.16	0.27	0.16	0.41	0.25	0.5	0.31	0.22
TD7	m	0.11	0.18	0.18	0.16	0.17	0.17	0.18	0.15	0.1	0.13	0.16	0.08	0.21	0.16	0.12	0.08	0.2	0.2	0.18	0.17	0.08	0.07	0.14	0.08	0.08
VEL7	m/sec	0.05	0.12	0.30	0.45	0.85	0.68	0.54	0.3	0.13	0.5	0.55	0.17	0.47	0.51	0.32	0.36	0.47	0.23	0.11	0.18	0.02	0.2	0.54	0.37	0.52
TD8	m	0.10	0.15	0.06	0.30	0.14	0.14	0.14	0.24	0.08	0.13	0.12	0.14	0.2	0.14	0.2	0.1	0.2	0.24	0.14	0.19	0.12	0.06	0.06	0.13	0.14
VEL8	m/sec	0.23	-0.02	0.16	0.36	0.34	0.21	0.62	0.32	0.18	0.49	0.56	0.32	0.78	0.66	0.41	0.48	0.34	0.16	0.13	0.2	0.35	0.42	0.57	0.49	0.56
TD9	m	0.14	0.20	0.14	0.20	0.12	0.13	0.18	0.13	0.06	0.14	0.1	0.36	0.24	0.11	0.16	0.12	0.17	0.2	0.18	0.16	0.09	0.16	0.17	0.16	0.15
VEL9	m/sec	0.60	0.17	0.41	0.16	0.34	0.61	0.43	0.39	0.15	0.15	0.57	0.46	0.77	0.22	0.55	0.12	0.12	0.02	0.14	0.06	0.2	0.68	0.33	0.49	0.6
TD10	m	0.12	0.10	0.26	0.14	0.19	0.1	0.16	0.12	0.08	0.19	0.3	0.44	0.28	0.14	0.25	0.22	0.13	0.12	0.21	0.2	0.1	0.12	0.1	0.19	0.12
VEL10	m/sec	0.41	0.18	0.28	0.35	0.05	0.39	0.47	0.07	0.13	0.35	0.31	0.53	1	0.39	0.42	0.36	0.54	0.06	0.31	0.12	0.3	0.58	0.17	0.4	0.44
MEAN TOTAL DEPTH	m	**0.11**	**0.11**	**0.18**	**0.20**	**0.18**	**0.15**	**0.13**	**0.17**	**0.13**	**0.11**	**0.20**	**0.23**	**0.20**	**0.18**	**0.19**	**0.11**	**0.18**	**0.15**	**0.19**	**0.21**	**0.13**	**0.14**	**0.11**	**0.16**	**0.13**
MEAN VELOCITY	m/sec	**0.33**	**0.15**	**0.27**	**0.30**	**0.32**	**0.47**	**0.50**	**0.32**	**0.28**	**0.33**	**0.46**	**0.45**	**0.64**	**0.51**	**0.50**	**0.29**	**0.31**	**0.12**	**0.18**	**0.10**	**0.25**	**0.38**	**0.40**	**0.39**	**0.44**
MINIMUM DEPTH	m	**0.06**					**0.06**					**0.07**					**0.05**					**0.06**				
MAXIMUM DEPTH	m	**0.30**					**0.24**					**0.44**					**0.25**					**0.24**				
MEAN TOTAL DEPTH	m	**0.16**					**0.14**					**0.20**					**0.17**					**0.13**				
MINIMUM VELOCITY	m/sec	**-0.02**					**0.07**					**0.11**					**0.02**					**0.02**				
MAXIMUM VELOCITY	m/sec	**0.85**					**0.74**					**1.00**					**0.54**					**0.68**				
MEAN VELOCITY	m/sec	**0.28**					**0.38**					**0.51**					**0.20**					**0.37**				

\\NB4\Project$\1\02\00181\34\A\Report\Report 5 Rev B - EEM Study Design\Appendix A - Site Char\Individual Files\[EEM_Appendix A_Table A1 to A3.xlsx]TABLE_A.2

NOTES:

1. TOTAL DEPTH AND VELOCITY MEASUREMENTS TAKEN USING A MRCH MCBIRNEY FLO-MATE WITH TOP-SETTING WADING ROD.
2. MEASUREMENTS TAKEN AT BENTHIC INVERTEBRATE REPLICATE STATIONS, NEAR THE FIELD SUB-SAMPLE LOCATIONS.

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TABLE A.3

BAFFINLAND IRON MINES CORPORATION
MARY RIVER PROJECT

DRAFT EEM CYCLE ONE STUDY DESIGN
MARY RIVER STUDY AREA STREAM MEASUREMENTS

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STUDY AREA		MRY-NF-1	MRY-NF-2	MRY-NF-3	MRY-NF-4	MRY-NF-5	MRY-FF-1	MRY-FF-2	MRY-FF-3	MRY-FF-4	MRY-FF-5
CHARACTERIZATION DATE		23-Aug-13	23-Aug-13	23-Aug-13	23-Aug-13	23-Aug-13	28-Aug-13	28-Aug-13	28-Aug-13	28-Aug-13	28-Aug-13
MEASUREMENT	**UNIT**										
Distance to U/S Replicate Station	m	-	170	195	440	275	-	564	215	145	196
TOTAL DISTANCE	m			**1080**					**1120**		
Wetted Width	m	33	32	46	38	30	98	47	52	37	46
AVERAGE WIDTH	m			**36**					**56**		
TD1	m	0.32	0.22	0.20	0.20	0.27	0.19	0.32	0.26	0.28	0.33
VEL1	m/sec	0.66	0.22	0.18	0.39	0.55	0.23	0.26	0.25	0.50	0.36
TD2	m	0.25	0.28	0.32	0.26	0.35	0.26	0.24	0.46	0.26	0.29
VEL2	m/sec	0.55	0.36	0.39	0.38	0.50	0.22	0.25	0.38	0.40	0.50
TD3	m	0.16	0.36	0.32	0.30	0.33	0.18	0.28	0.39	0.19	0.16
VEL3	m/sec	0.14	0.29	0.32	0.39	0.56	0.34	0.23	0.58	0.36	0.36
TD4	m	0.16	0.37	0.43	0.29	0.31	0.20	0.40	0.34	0.18	0.16
VEL4	m/sec	0.08	0.38	0.50	0.45	0.46	0.22	0.29	0.50	0.43	0.29
TD5	m	0.22	0.30	0.29	0.30	0.36	0.27	0.40	0.29	0.20	0.19
VEL5	m/sec	0.18	0.36	0.48	0.42	0.50	0.40	0.36	0.40	0.25	0.28
TD6	m	0.28	0.36	0.26	0.39	0.29	0.32	0.36	0.30	0.26	0.14
VEL6	m/sec	0.23	0.50	0.38	0.56	0.58	0.34	0.32	0.37	0.26	0.26
TD7	m	0.37	0.49	0.22	0.41	0.27	0.34	0.31	0.28	0.22	0.24
VEL7	m/sec	0.40	0.51	0.23	0.36	0.51	0.22	0.39	0.38	0.15	0.28
TD8	m	0.42	0.47	0.25	0.36	0.27	0.30	0.10	0.26	0.10	0.22
VEL8	m/sec	0.49	0.46	0.35	0.52	0.65	0.03	0.17	0.42	0.19	0.34
TD9	m	0.36	0.26	0.19	0.36	0.30	0.14	0.22	0.24	0.14	0.28
VEL9	m/sec	0.23	0.18	0.29	0.45	0.58	0.14	0.34	0.31	0.08	0.08
TD10	m	0.26	0.17	0.33	0.32	0.31	0.19	0.16	0.20	0.17	0.22
TD10	m/sec	0.23	0.29	0.38	0.34	0.47	0.19	0.24	0.26	0.20	0.53
MEAN TOTAL DEPTH	m	**0.28**	**0.33**	**0.28**	**0.32**	**0.31**	**0.24**	**0.28**	**0.30**	**0.20**	**0.22**
MEAN VELOCITY	m/sec	**0.32**	**0.36**	**0.35**	**0.43**	**0.54**	**0.23**	**0.29**	**0.39**	**0.28**	**0.33**
MINIMUM DEPTH	m			**0.16**					**0.10**		
MAXIMUM DEPTH	m			**0.49**					**0.46**		
MEAN TOTAL DEPTH	m			**0.30**					**0.25**		
MINIMUM VELOCITY	m/sec			**0.08**					**0.03**		
MAXIMUM VELOCITY	m/sec			**0.65**					**0.58**		
MEAN VELOCITY	m/sec			**0.40**					**0.30**		

STUDY AREA		MRY-REF1-1	MRY-REF1-2	MRY-REF1-3	MRY-REF1-4	MRY-REF1-5	MRY-REF2-1	MRY-REF2-2	MRY-REF2-3	MRY-REF2-4	MRY-REF2-5
CHARACTERIZATION DATE		27-Aug-13	27-Aug-13	27-Aug-13	27-Aug-13	27-Aug-13	25-Aug-13	25-Aug-13	25-Aug-13	25-Aug-13	25-Aug-13
MEASUREMENT	**UNIT**										
Distance to U/S Replicate Station	m	-	210	167	262	410	-	220	224	226	258
TOTAL DISTANCE	m			**1049**					**928**		
Wetted Width	m	44	38	30	35	37	31	35	52	43	50
AVERAGE WIDTH	m			**37**					**42**		
TD1	m	0.20	0.48	0.46	0.40	0.50	0.36	0.16	0.19	0.16	0.10
VEL1	m/sec	0.29	0.07	0.26	0.21	0.47	0.49	0.31	0.60	0.45	0.36
TD2	m	0.22	0.31	0.54	0.46	0.54	0.24	0.14	0.22	0.22	0.10
VEL2	m/sec	0.40	0.02	0.18	0.18	0.57	0.35	0.40	0.90	0.37	0.25
TD3	m	0.26	0.32	0.44	0.49	0.56	0.30	0.13	0.22	0.24	0.16
VEL3	m/sec	0.33	0.33	0.38	0.39	0.42	0.65	0.18	0.95	0.64	0.18
TD4	m	0.30	0.30	0.32	0.40	0.44	0.24	0.13	0.24	0.26	0.18
VEL4	m/sec	0.37	0.29	0.10	0.36	0.21	0.40	0.22	0.64	0.61	0.45
TD5	m	0.24	0.28	0.25	0.46	0.42	0.32	0.21	0.28	0.30	0.20
VEL5	m/sec	0.49	0.30	0.36	0.39	0.20	0.32	0.23	0.78	0.70	0.56
TD6	m	0.25	0.20	0.29	0.57	0.50	0.24	0.22	0.14	0.27	0.22
VEL6	m/sec	0.59	0.42	0.18	0.25	0.26	0.21	0.51	0.57	0.61	0.51
TD7	m	0.34	0.26	0.32	0.48	0.36	0.14	0.22	0.18	0.14	0.16
VEL7	m/sec	0.33	0.31	0.39	0.30	0.27	0.15	0.42	0.55	0.32	0.39
TD8	m	0.16	0.30	0.28	0.46	0.36	0.20	0.18	0.14	0.24	0.13
VEL8	m/sec	0.48	0.32	0.30	0.40	0.26	0.43	0.32	0.32	0.49	0.53
TD9	m	0.20	0.22	0.34	0.36	0.28	0.14	0.18	0.12	0.22	0.14
VEL9	m/sec	0.27	0.09	0.31	0.26	0.24	0.50	0.34	0.24	0.70	0.45
TD10	m	0.28	0.28	0.42	0.34	0.29	0.12	0.26	0.14	0.27	0.23
TD10	m/sec	0.30	0.38	0.32	0.29	0.17	0.65	0.41	0.36	0.61	0.66
MEAN TOTAL DEPTH	m	**0.25**	**0.30**	**0.37**	**0.44**	**0.43**	**0.23**	**0.18**	**0.19**	**0.23**	**0.16**
MEAN VELOCITY	m/sec	**0.39**	**0.25**	**0.28**	**0.30**	**0.31**	**0.42**	**0.33**	**0.59**	**0.55**	**0.43**
MINIMUM DEPTH	m			**0.16**					**0.10**		
MAXIMUM DEPTH	m			**0.57**					**0.36**		
MEAN TOTAL DEPTH	m			**0.35**					**0.20**		
MINIMUM VELOCITY	m/sec			**0.02**					**0.15**		
MAXIMUM VELOCITY	m/sec			**0.59**					**0.95**		
MEAN VELOCITY	m/sec			**0.31**					**0.46**		

STUDY AREA		MRY-REF3-1	MRY-REF3-2	MRY-REF3-3	MRY-REF3-4	MRY-REF3-5	MRY-REF4-1	MRY-REF4-2	MRY-REF4-3	MRY-REF4-4	MRY-REF4-5
CHARACTERIZATION DATE		26-Aug-13	26-Aug-13	26-Aug-13	26-Aug-13	26-Aug-13	30-Aug-13	30-Aug-13	30-Aug-13	30-Aug-13	30-Aug-13
MEASUREMENT	**UNIT**										
Distance to U/S Replicate Station	m	-	188	200	220	125	-	60	88	93	115
TOTAL DISTANCE	m			**733**					**356**		
Wetted Width	m	46	34	45	26	40	22	25	27	30	24
AVERAGE WIDTH	m			**38**					**26**		
TD1	m	0.31	0.26	0.21	0.25	0.19	0.44	0.32	0.18	0.28	0.22
VEL1	m/sec	0.18	0.25	0.40	0.76	0.33	0.15	0.23	0.15	0.54	0.09
TD2	m	0.34	0.18	0.10	0.25	0.14	0.36	0.30	0.10	0.24	0.29
VEL2	m/sec	0.30	0.77	0.13	0.70	0.16	0.20	0.24	0.21	0.06	0.10
TD3	m	0.32	0.34	0.16	0.28	0.21	0.38	0.42	0.24	0.19	0.20
VEL3	m/sec	0.37	1.06	0.67	0.51	0.34	0.20	0.23	0.30	0.24	0.20
TD4	m	0.36	0.30	0.14	0.21	0.20	0.36	0.30	0.11	0.18	0.24
VEL4	m/sec	0.12	0.46	0.38	0.58	0.08	0.36	0.09	0.15	0.45	0.13
TD5	m	0.33	0.32	0.15	0.20	0.22	0.40	0.28	0.18	0.14	0.24
VEL5	m/sec	0.40	0.50	0.33	0.70	0.30	0.49	0.10	0.36	0.33	0.26
TD6	m	0.24	0.23	0.12	0.20	0.26	0.33	0.25	0.14	0.14	0.24
VEL6	m/sec	0.34	0.20	0.13	0.66	0.44	0.22	0.11	0.22	0.21	0.10
TD7	m	0.32	0.20	0.19	0.22	0.35	0.28	0.28	0.11	0.22	0.24
VEL7	m/sec	0.45	0.24	0.26	0.30	0.52	0.22	0.20	0.16	0.17	0.20
TD8	m	0.20	0.16	0.25	0.16	0.34	0.22	0.34	0.08	0.12	0.22
VEL8	m/sec	0.53	0.44	0.40	0.45	0.36	0.14	0.21	0.10	0.31	0.07
TD9	m	0.20	0.14	0.28	0.26	0.13	0.11	0.36	0.20	0.23	0.33
VEL9	m/sec	0.26	0.32	0.47	0.26	0.17	0.06	0.24	0.33	0.45	0.21
TD10	m	0.16	0.15	0.24	0.26	0.30	0.16	0.36	0.30	0.17	0.29
TD10	m/sec	0.40	0.27	0.24	0.32	0.10	0.20	0.12	0.38	0.21	0.16
MEAN TOTAL DEPTH	m	**0.28**	**0.23**	**0.18**	**0.23**	**0.23**	**0.30**	**0.32**	**0.16**	**0.19**	**0.25**
MEAN VELOCITY	m/sec	**0.34**	**0.45**	**0.34**	**0.52**	**0.28**	**0.22**	**0.18**	**0.24**	**0.30**	**0.15**
MINIMUM DEPTH	m			**0.10**					**0.08**		
MAXIMUM DEPTH	m			**0.36**					**0.44**		
MEAN TOTAL DEPTH	m			**0.23**					**0.25**		
MINIMUM VELOCITY	m/sec			**0.08**					**0.06**		
MAXIMUM VELOCITY	m/sec			**1.06**					**0.49**		
MEAN VELOCITY	m/sec			**0.39**					**0.22**		

\\NB4\Project$\1\02\00181\34\A\Report\Report 5 Rev B - EEM Study Design\Appendix A - Site Char\Individual Files\[EEM_Appendix A_Table A1 to A3.xlsx]TABLE_A.3

NOTES:

1. TOTAL DEPTH AND VELOCITY MEASUREMENTS TAKEN USING A MRCH MCBIRNEY FLO-MATE WITH TOP-SETTING WADING ROD.
2. MEASUREMENTS TAKEN AT BENTHIC INVERTEBRATE REPLICATE STATIONS, NEAR THE FIELD SUB-SAMPLE LOCATIONS.

PHOTO 1 – CLT-NF-1 facing upstream towards waterfall barrier.

PHOTO 2 – CLT-NF-3 facing downstream.

PHOTO 3 – CLT-NF-4 and CLT-NF-5 facing upstream.

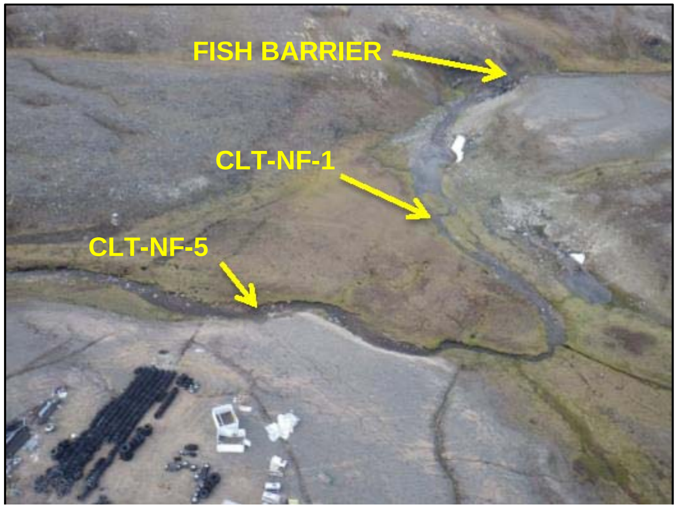

PHOTO 4 – CLT-NF aerial view including fish barrier upstream.

PHOTO 5 – CLT-FF-1 facing upstream to Tote Road culverts.

PHOTO 6 – CLT-FF-1 facing downstream.

PHOTO 7 – CLT-FF-4 facing downstream.

PHOTO 8 – CLT-FF-5 facing downstream towards Camp Lake.

PHOTO 9 – CLT-REF2-1 facing downstream.

PHOTO 10 – CLT-REF2-1 facing upstream.

PHOTO 11 – CLT-REF2-3 facing downstream.

PHOTO 12 – CLT-REF2-5 facing downstream towards Tote Road.

PHOTO 13 – CLT-REF3-1 facing downstream.

PHOTO 14 – CLT-REF3-2 facing downstream.

PHOTO 15 – CLT-REF3-4 facing downstream.

PHOTO 16 – CLT-REF3 aerial view of study area.

PHOTO 17 – CLT-REF4-1 facing upstream.

PHOTO 18 – CLT-REF4-3 facing downstream.

PHOTO 19 – CLT-REF4-5 facing upstream.

PHOTO 20 – CLT-REF4 aerial view of study area.

PHOTO 21 – MRY-NF-1 facing upstream, Deposit No.1 on horizon.

PHOTO 22 – MRY-NF-4 facing upstream.

PHOTO 23 – MRY-NF sediment characterization and BIC study area.

PHOTO 24 – MRY-NF fish community and water quality study area.

PHOTO 25 – MRY-FF-2 facing upstream.

PHOTO 26 – MRY-FF-4 facing upstream.

PHOTO 27 – MRY-FF-5 facing upstream from right bank.

PHOTO 28 – MRY-FF aerial view of study area facing upstream.

PHOTO 29 – MRY-REF1-1 facing upstream.

PHOTO 30 – MRY-REF1-3 facing downstream.

PHOTO 31 – MRY-REF1-5 facing upstream.

PHOTO 32 – MRY-REF1 aerial view facing upstream.

PHOTO 33 – MRY-REF2-1 facing downstream.

PHOTO 34 – MRY-REF2-2 facing upstream.

PHOTO 35 – MRY-REF2-5 facing downstream.

PHOTO 36 – MRY-REF2-1 to REF2-4 aerial view of study area.

PHOTO 37 – MRY-REF3-1 facing downstream.

PHOTO 38 – MRY-REF3-2 facing upstream.

PHOTO 39 – MRY-REF3-5 facing downstream.

PHOTO 40 – MRY-REF3 aerial view of study area facing upstream.

PHOTO 41 – MRY-REF4-1 facing upstream.

PHOTO 42 – MRY-REF4-2 facing left bank.

PHOTO 43 – MRY-REF4-3 facing downstream.

PHOTO 44 – MRY-REF4-5 facing downstream.

APPENDIX B

SEDIMENT QUALITY DATA

(Pages B-1 to B-3)

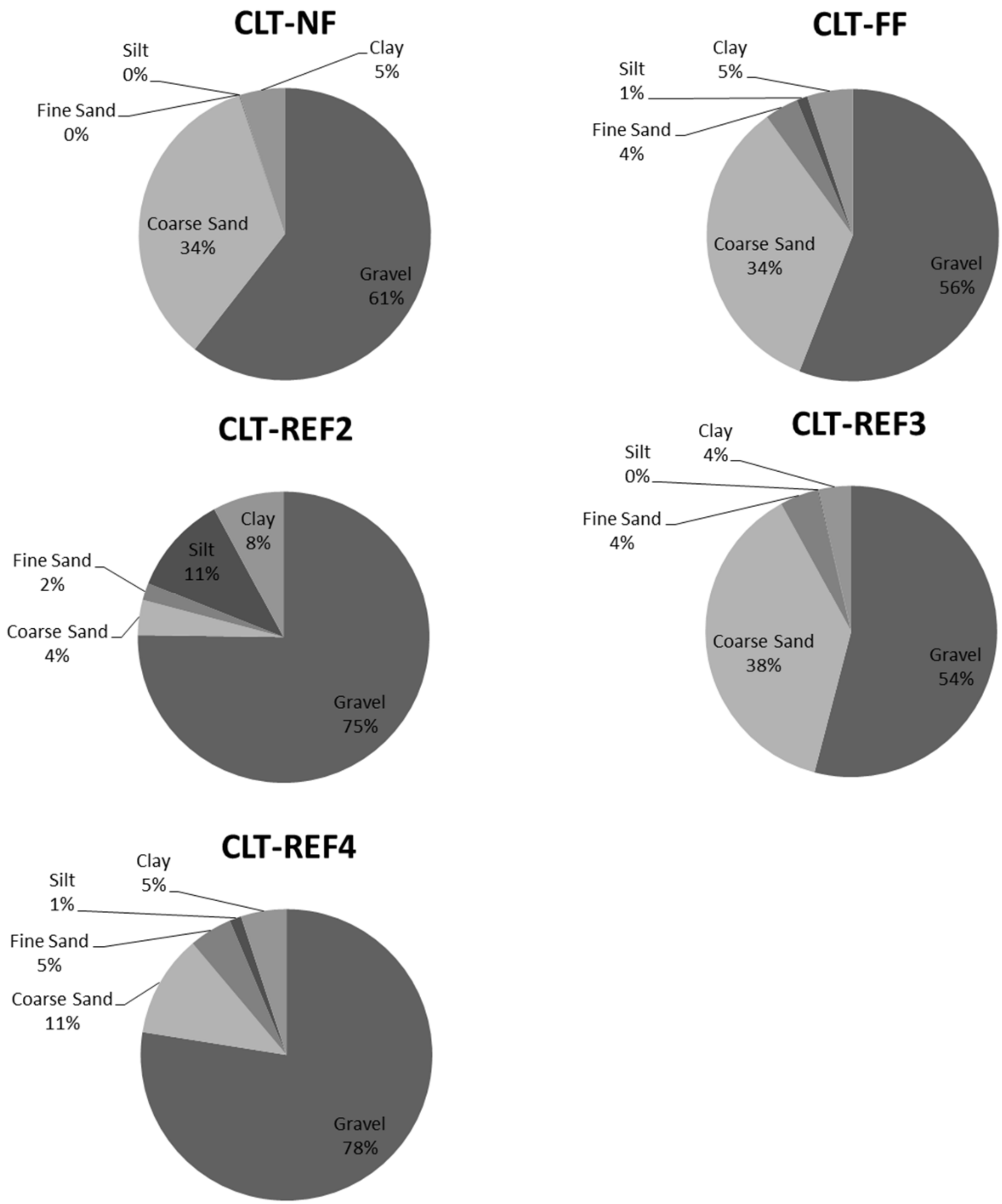

Figure B.1 Camp Lake Tributary Study Areas: Particle Size Distribution and TOC Summary

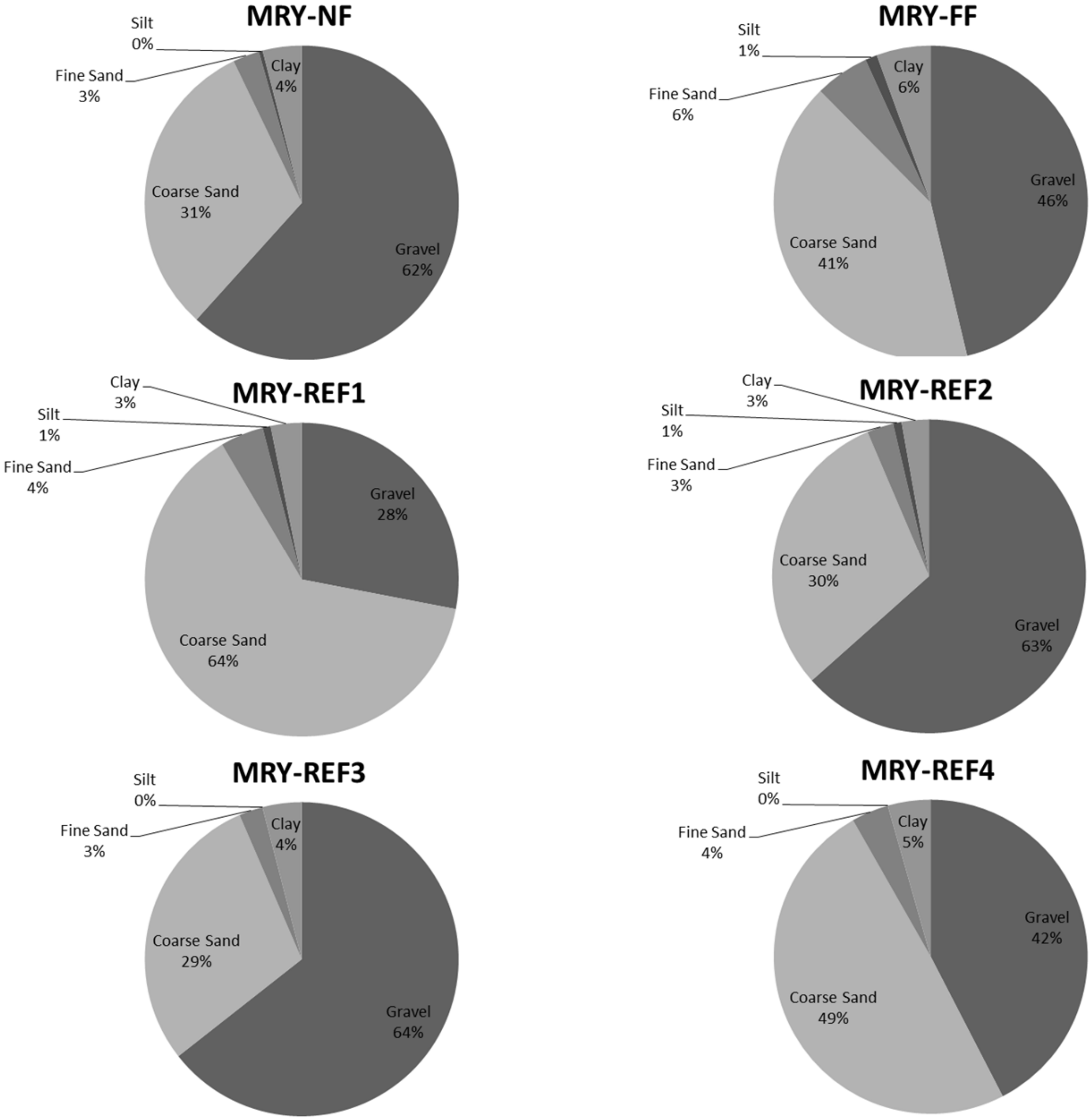

Figure B.2 Mary River Study Areas: Particle Size Distribution and TOC Summary

APPENDIX C

WATER QUALITY DATA

(Pages C-1 to C-6)

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TABLE C.1

BAFFINLAND IRON MINES CORPORATION
MARY RIVER PROJECT

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

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

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TABLE C.1

BAFFINLAND IRON MINES CORPORATION
MARY RIVER PROJECT

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

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

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TABLE C.1

BAFFINLAND IRON MINES CORPORATION
MARY RIVER PROJECT

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

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

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

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

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TABLE C.2

BAFFINLAND IRON MINES CORPORATION
MARY RIVER PROJECT

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

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

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TABLE C.2

BAFFINLAND IRON MINES CORPORATION
MARY RIVER PROJECT

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

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

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TABLE C.2

BAFFINLAND IRON MINES CORPORATION
MARY RIVER PROJECT

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

Print Jun/26/14 11:49:00

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

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

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

APPENDIX D

BENTHIC INVERTEBRATE DATA

(Pages D-1 to D-26)

1 SAMPLE PROCESSING METHODS AND ENDPOINT SUMMARIES

1.1 SAMPLE PROCESSING

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

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

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

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

1.1.1 Subsampling

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

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

1.2 DETAILED IDENTIFICATION

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

1.2.1 Quality Assurance and Quality Control Measures

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

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

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1.4 DATA EVALUATION

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

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

1.4.1 Total Invertebrate Density (TID)

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

1.4.2 Taxonomic Richness

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

1.4.3 Simpson's Diversity Index

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

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

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

1.4.4 Simpson's Evenness Index

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

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

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

1.4.5 Bray-Curtis Similarity Index

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

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

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

1.4.5.1 QA/QC

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

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TABLE D.1

BAFFINLAND IRON MINES CORPORATION
MARY RIVER PROJECT

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

Print Jun/26/14 12:09:21

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

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

NOTES:

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

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

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

NOTES:

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

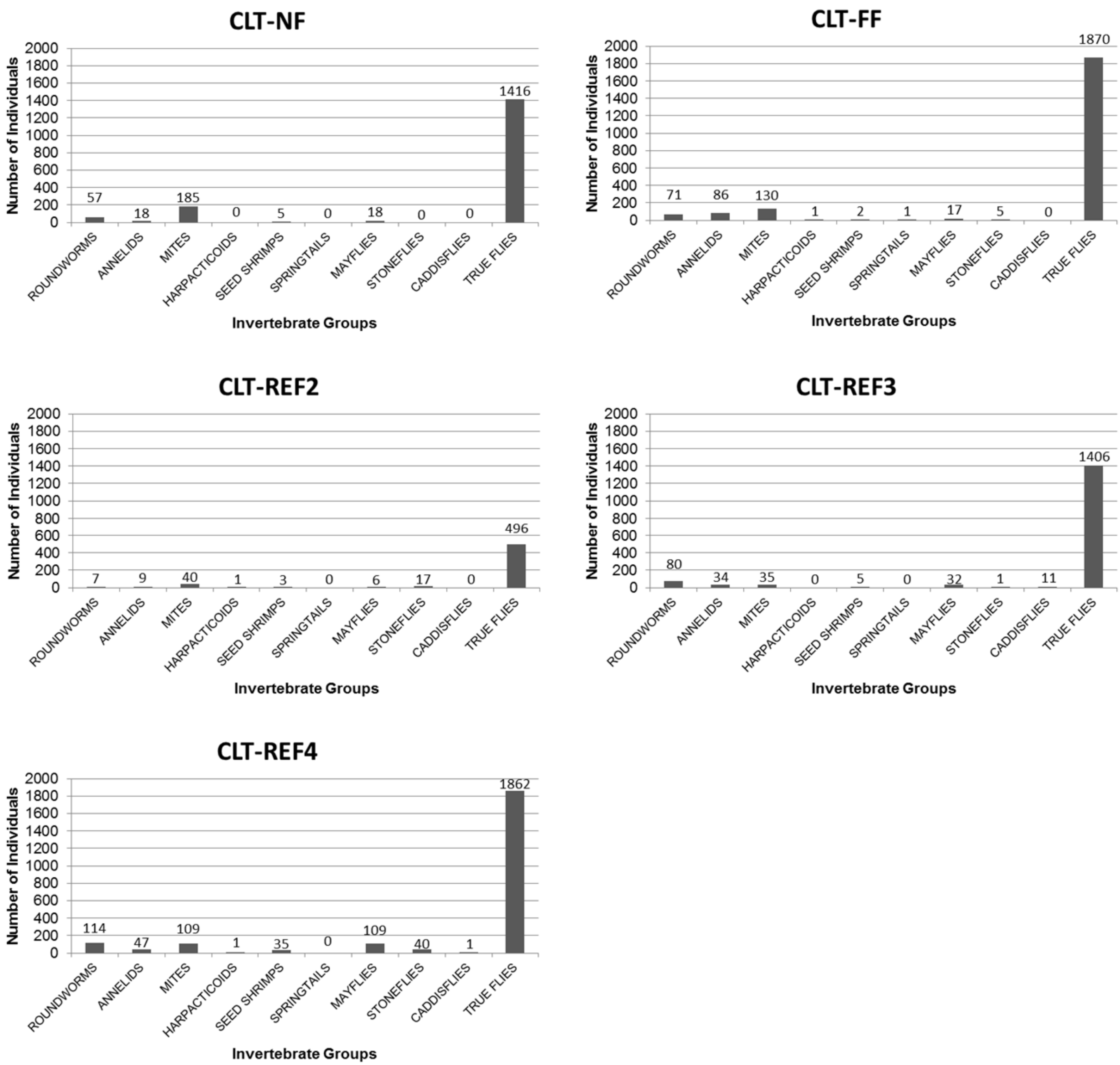

Figure D.1 Camp Lake Tributary Study Areas: Benthic Invertebrate Community Summary

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

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

NOTES:

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

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

Test of Normality

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

Test of Homogeneity of Variance

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

ANOVA Results

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

Multiple Comparison Post-hoc Test

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

NOTE:

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

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

Test of Normality

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

Test of Homogeneity of Variance

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

ANOVA Results

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

Multiple Comparison Post-hoc Test

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

NOTE:

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

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

Test of Normality

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

Test of Homogeneity of Variance

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

ANOVA Results

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

Multiple Comparison Post-hoc Test

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

NOTE:

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

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

Test of Normality

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

Test of Homogeneity of Variance

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

ANOVA Results

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

Multiple Comparison Post-hoc Test

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

NOTE:

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

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

Descriptive Statistics

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

Test of Normality

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

Test of Homogeneity of Variance

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

ANOVA Results

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

Multiple Comparison Post-hoc Test

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

NOTE:

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

Knight Piésold
CONSULTING

TABLE D.9

BAFFINLAND IRON MINES CORPORATION
MARY RIVER PROJECT

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

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

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

NOTES:

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

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

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

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

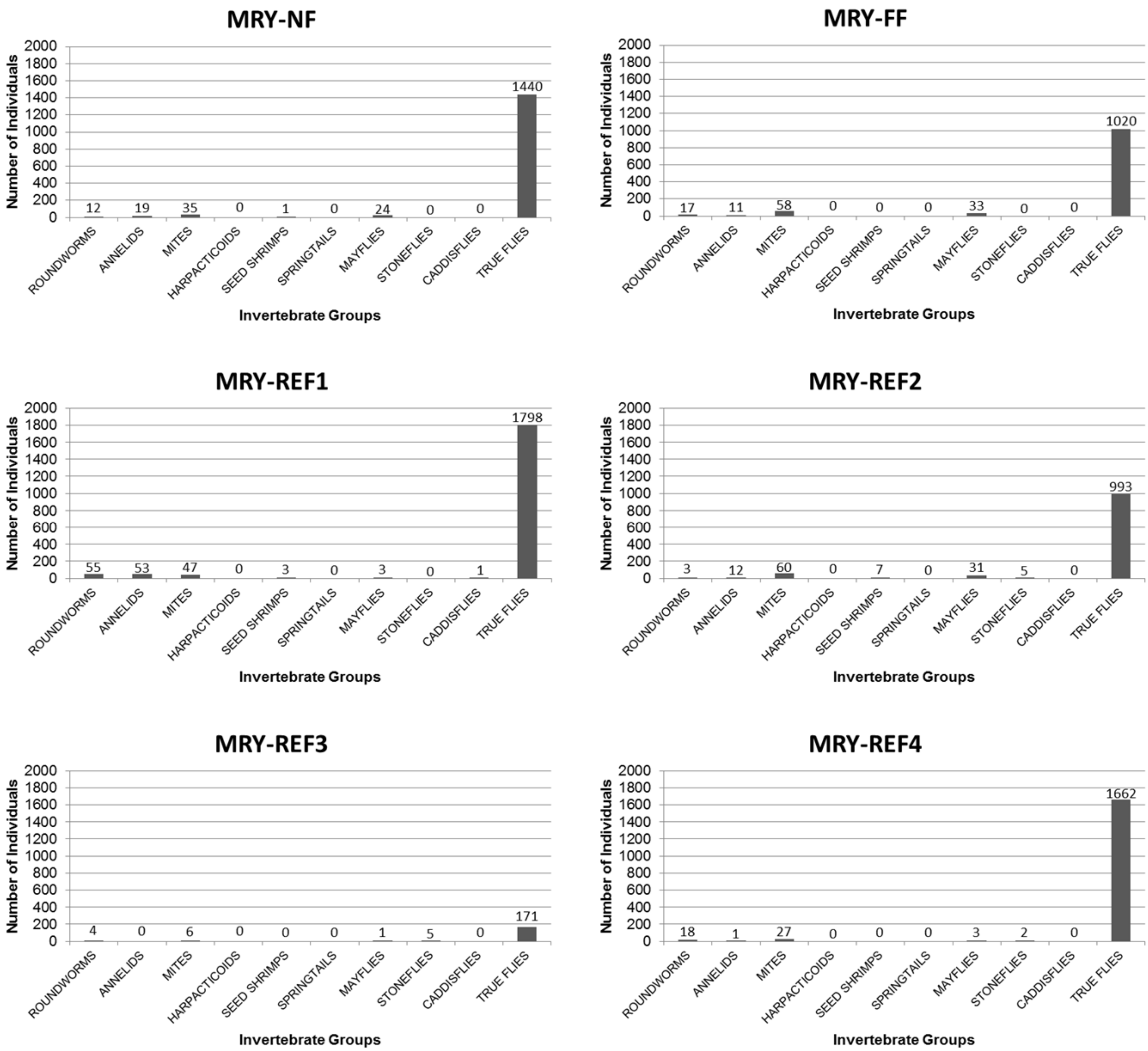

Figure D.2 Mary River Study Areas: Benthic Invertebrate Community Summary

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

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

NOTES:

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

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

Test of Normality

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

Test of Homogeneity of Variance

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

ANOVA Results

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

Multiple Comparison Post-hoc Test

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

NOTE:

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

Table D.13 Mary River Study Areas: Taxa Richness

Test of Normality

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

Test of Homogeneity of Variance

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

ANOVA Results

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

Multiple Comparison Post-hoc Test

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

NOTE:

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

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

Test of Normality

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

Test of Homogeneity of Variance

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

ANOVA Results

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

Multiple Comparison Post-hoc Test

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

NOTE:

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

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

Test of Normality

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

Test of Homogeneity of Variance

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

ANOVA Results

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

Multiple Comparison Post-hoc Test

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

NOTE:

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

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

Descriptive Statistics

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

Test of Normality

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

Test of Homogeneity of Variance

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

ANOVA Results

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

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

Multiple Comparison Post-hoc Test

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

NOTE:

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

APPENDIX E

FISHERIES DATA

(Pages E-1 to E-11)

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

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

NOTES:

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

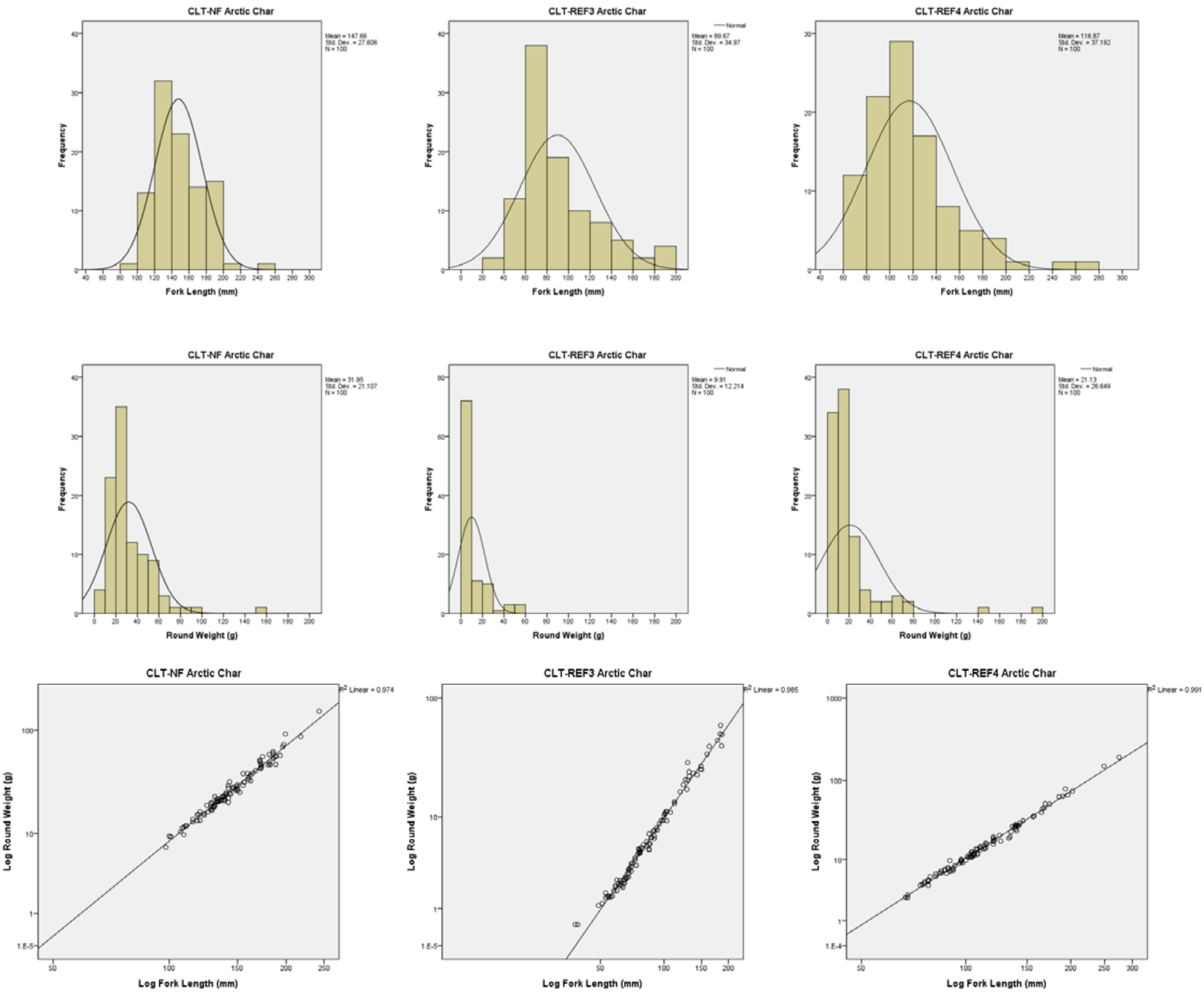

Figure E.1 Camp Lake Tributary Study Areas: Arctic Char Round Weight to Fork Length Data and Comparison

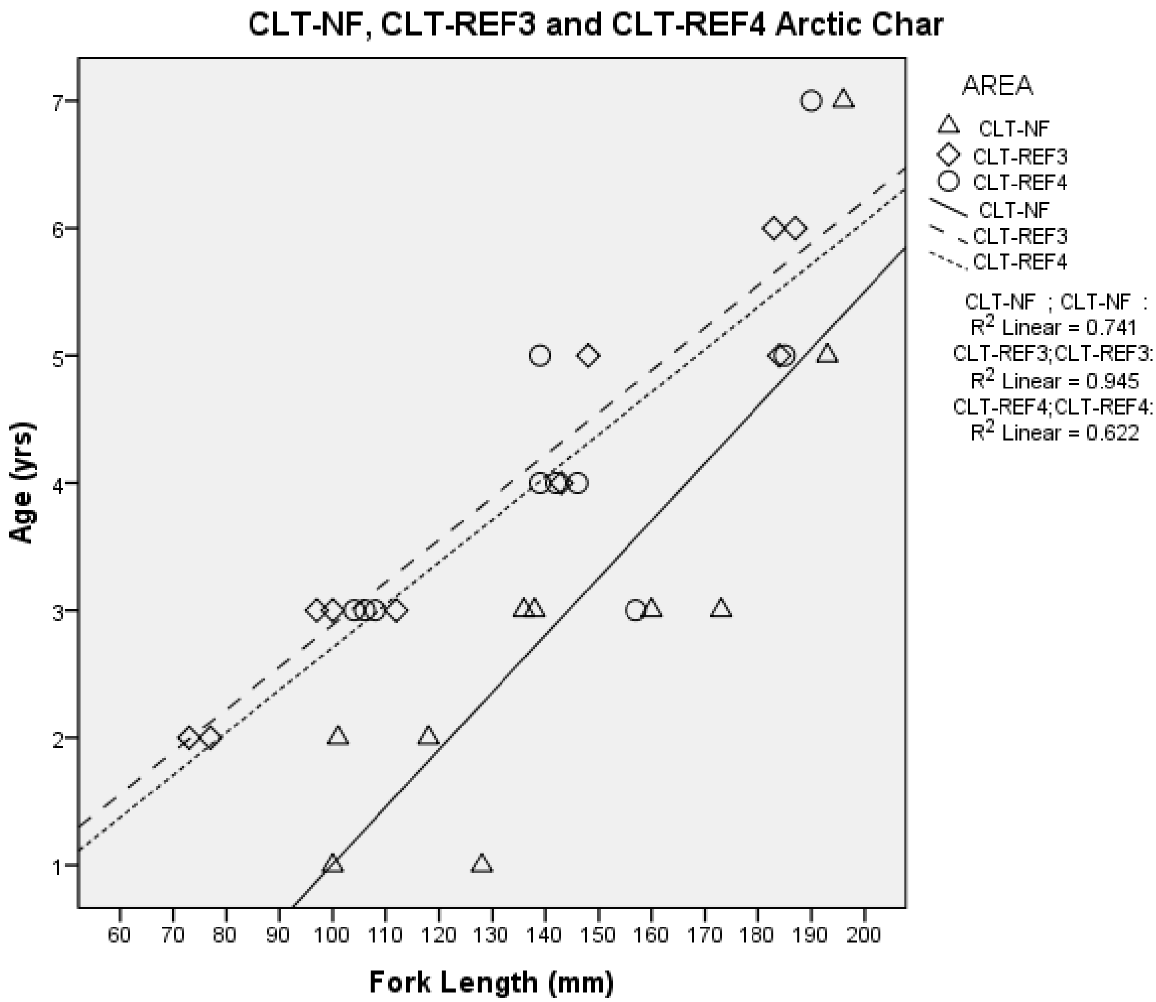

Figure E.2 Camp Lake Tributary NF, REF3 and REF4 Study Areas: Relationship between Arctic Char Age and Fork Length

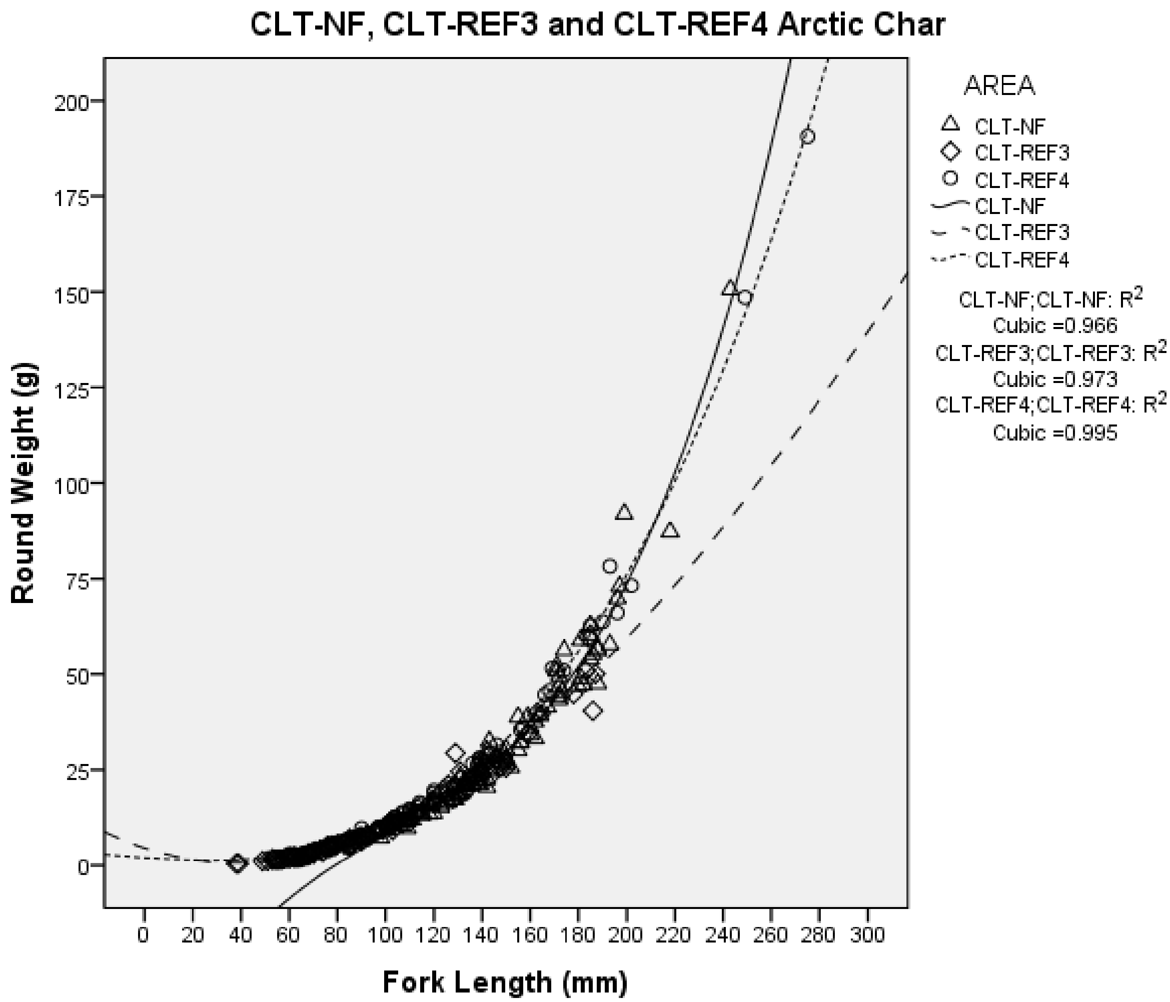

Figure E.3 Camp Lake Tributary NF, REF3 and EF4 Study Areas: Relationship between Arctic Char Round Weight and Fork Length

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

Test of Normality

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

Test of Homogeneity of Variance

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

ANOVA Results – Fork Length

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

ANOVA Results – Round Weight

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

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

Multiple Comparison Post-hoc Test – Fork Length

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

Multiple Comparison Post-hoc Test – Round Weight

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

NOTE:

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

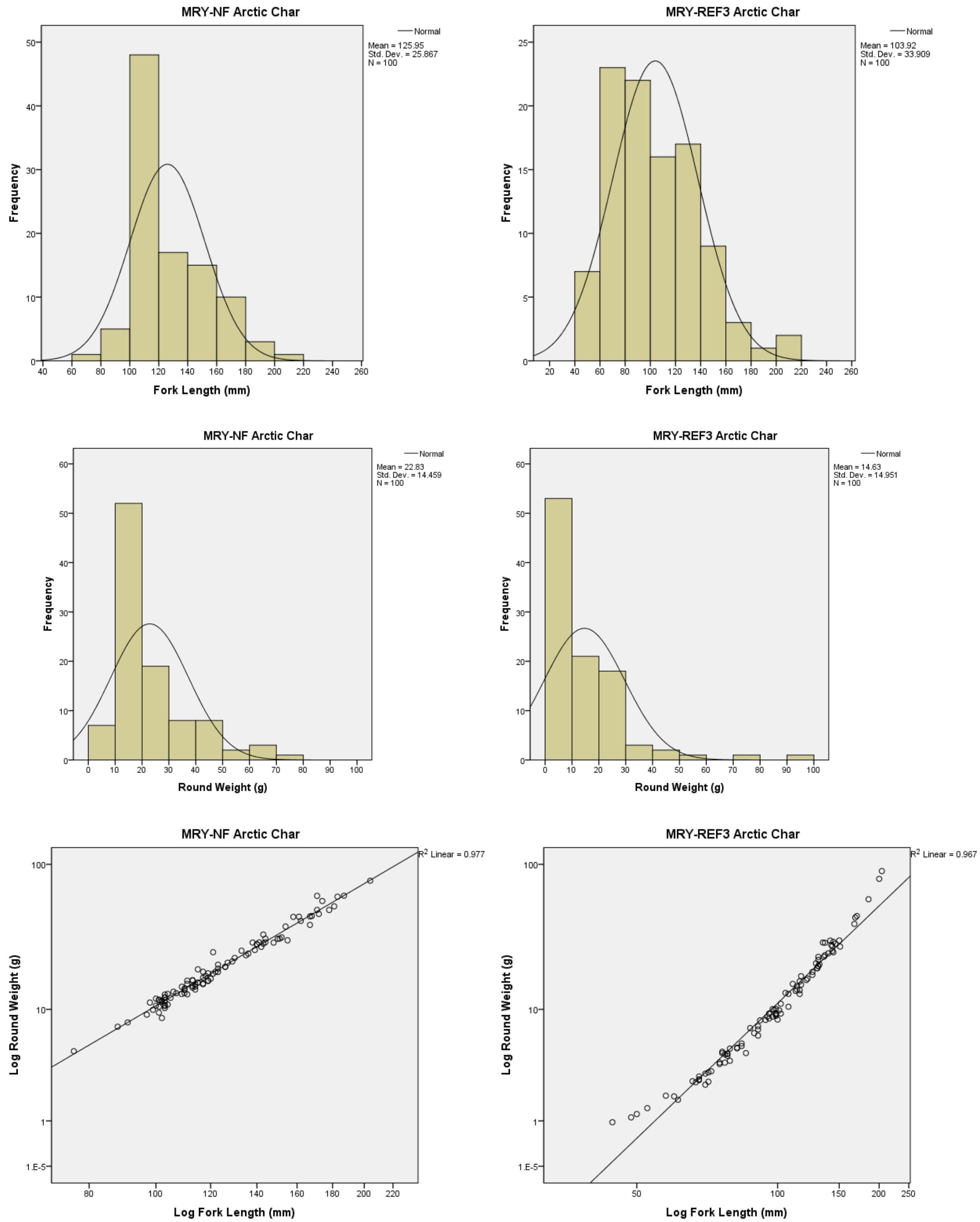

Figure E.4 Mary River NF and REF3 Study Areas: Arctic Char Round Weight to Fork Length Data and Comparison

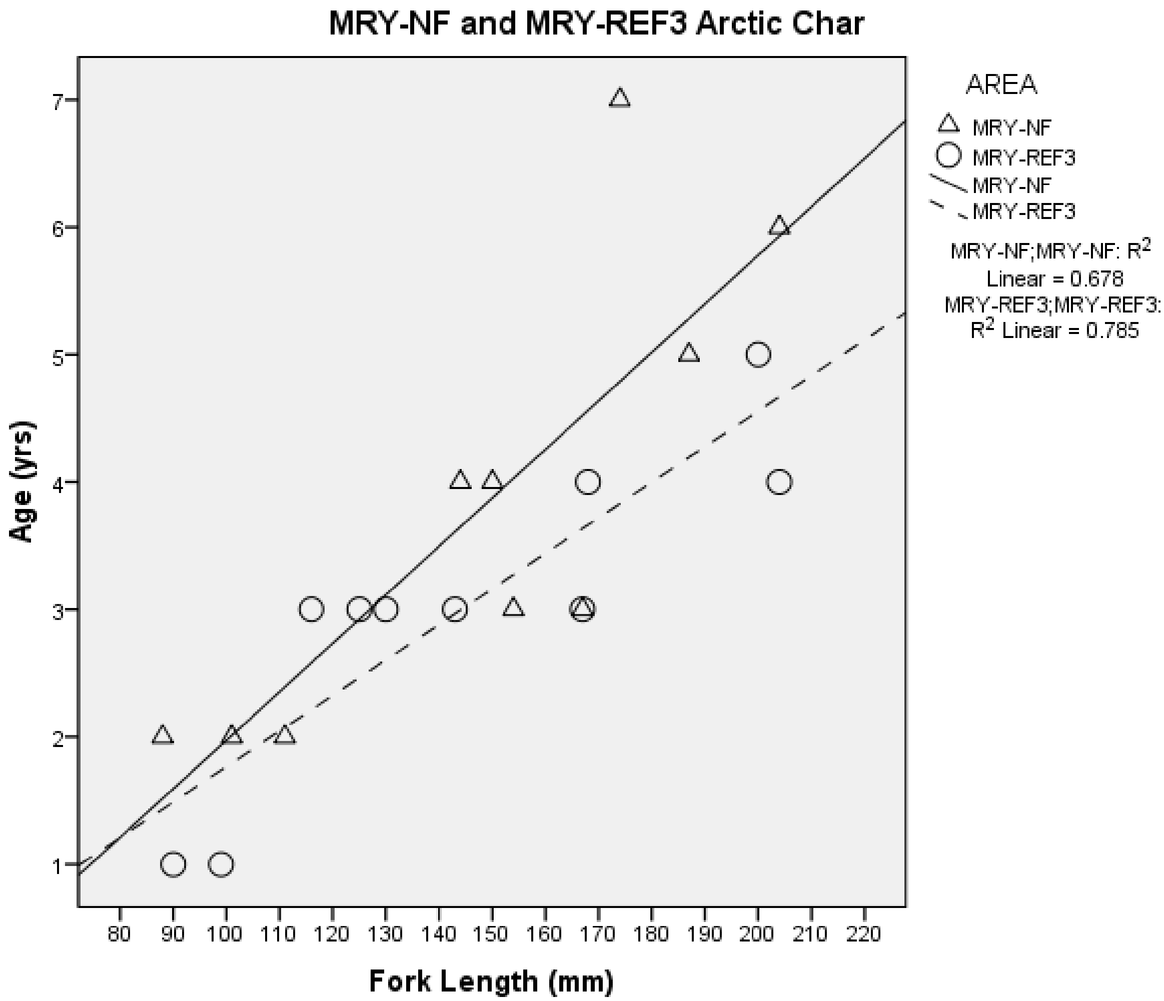

Figure E.5 Mary River NF and REF3 Study Areas: Relationship between Arctic Char Age and Fork Length

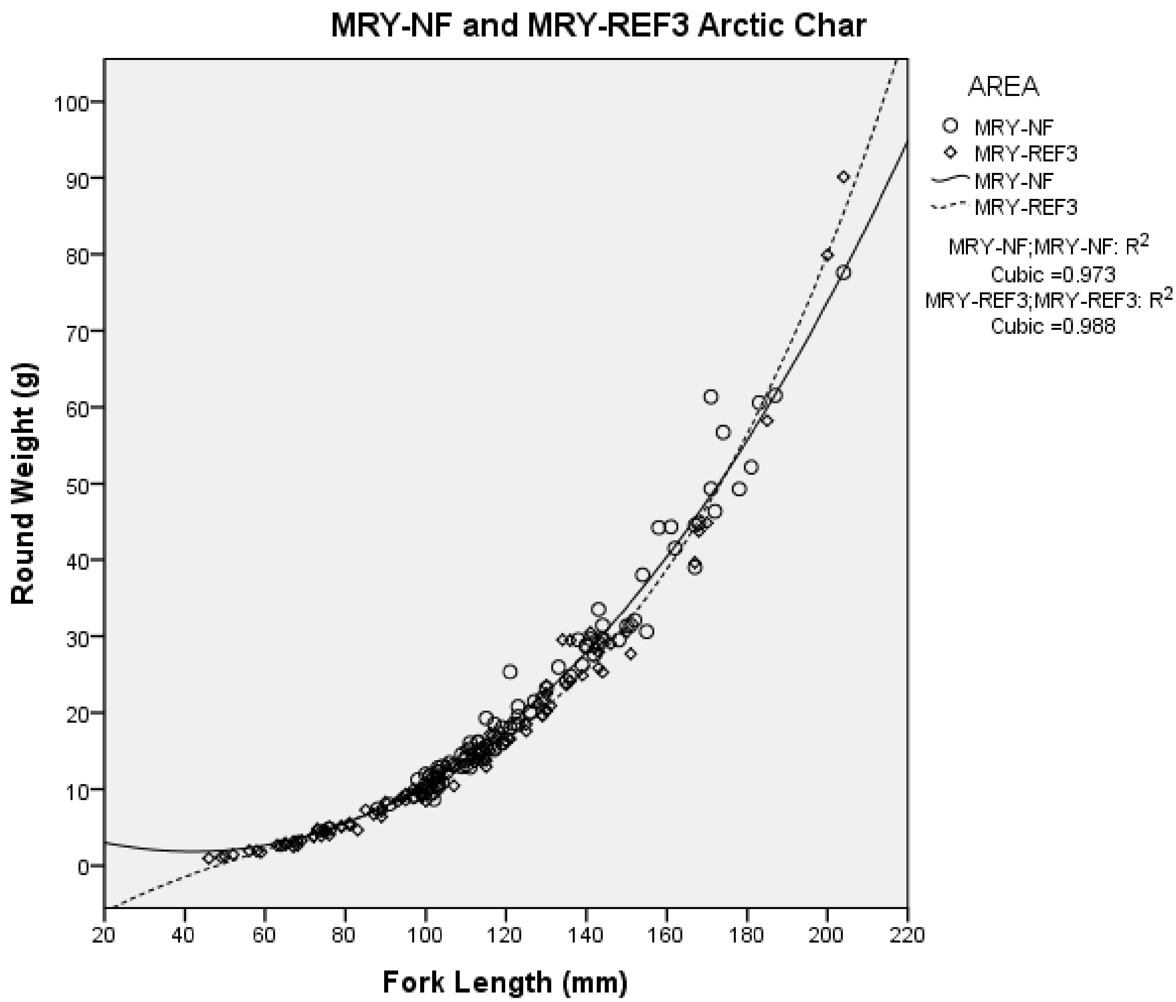

Figure E.6 Mary River NF and REF3 Study Areas: Relationship between Arctic Char Weight and Fork Length

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

Test of Normality

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

Test of Homogeneity of Variance

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

ANOVA Results – Fork Length

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

ANOVA Results – Round Weight

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

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

Multiple Comparison Post-hoc Test – Fork Length

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

Multiple Comparison Post-hoc Test – Round Weight

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

NOTE:

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

Appendix A

Draft EEM Cycle One Study Design

Baffinland

MARY RIVER PROJECT

DRAFT – REV B
EEM CYCLE ONE STUDY DESIGN

JUNE 2014

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TABLES

FIGURES

APPENDICES

1 INTRODUCTION

1.1 OVERVIEW

The Mary River Project is an iron ore mine located on northern Baffin Island in the Qikiqtani Region of Nunavut. The Project is owned by Baffinland Iron Mines Corporation (Baffinland).

As a metal mine, the discharge of mine effluents from this metal mine is regulated by the Metal Mining Effluent Regulations (MMER) (MOJ, 2012). These regulations, administered under the federal *Fisheries Act* (1985), apply to mining and milling operations that discharge effluent(s) at a rate greater than 50 m^3/day. Mining is expected to begin as early as the second half of September 2014 at which time temperatures are below zero, precipitation falls as snow, and runoff has ceased in local rivers and streams. Therefore, the 50 m^3/day mine effluent discharge rate will be achieved during freshet in June 2015.

The MMER outline requirements for routine effluent monitoring, acute lethality testing, and Environmental Effects Monitoring (EEM). The objective of EEM is to determine whether mining activity is causing an effect on fish, benthic invertebrate communities and/or the use of fisheries resources (based on mercury accumulation in fish tissues).

This Draft EEM Cycle One Study Design has been prepared in accordance with the MMER as prescribed by the EEM technical guidance document (EC, 2012), for inclusion as a component study to Baffinland's Aquatic Effects Monitoring Plan (AEMP). The study design describes in detail how the Cycle One EEM biological monitoring study will be undertaken. It outlines the proposed activities involved in the investigation of water quality, sediment quality, and freshwater biota community to meet the objectives of the EEM program in accordance with the MMER. In accordance with the technical guidance document (EC, 2012), this study will take into account all relevant site characterization information, previous biological monitoring data, and comments and/or recommendations stemming from previous efforts in the area.

Any comments on this draft study design will be incorporated into a final study design that will be formally submitted for review and approval by the Environment Canada Technical Advisory Panel (TAP) prior to initiation of the Cycle One EEM biological monitoring study field work.

1.2 OTHER MONITORING PROGRAMS

With respect to regulations that apply to the discharge of contact water and surface runoff from the Mary River Mine, and in addition to the MMER, the Nunavut Water Board (NWB) issued a Type A Water Licence (2AM-MRY1325) that came into effect on June 10, 2013 and is due to expire on June 10, 2025 (NWB, 2013). This Type A Water Licence is a requirement under the Nunavut Waters and Nunavut Surface Rights Tribunal Act and the Agreement between the Inuit of the Nunavut Settlement Area and Her Majesty the Queen in Right of Canada (referred to as the Nunavut Land Claims Agreement; NLCA).

The Type A Water Licence effluent quality limits for the open pit, stockpile and sedimentation ponds are generally more restrictive than those in the MMER (Table 1.1). The points of compliance at the mine for the effluent quality standards included in this Licence are the final points of control at stations MS-06, MS-07, MS-08, and MS-09 as shown on Figure 1.1. All test results for the effluent water quality parameters listed in this Licence shall be provided by a laboratory accredited by the Canadian Association for

Laboratory Accreditation (CALA). Effluent characterization and water quality monitoring conducted under the Type A Water Licence is consistent with MMER protocols.

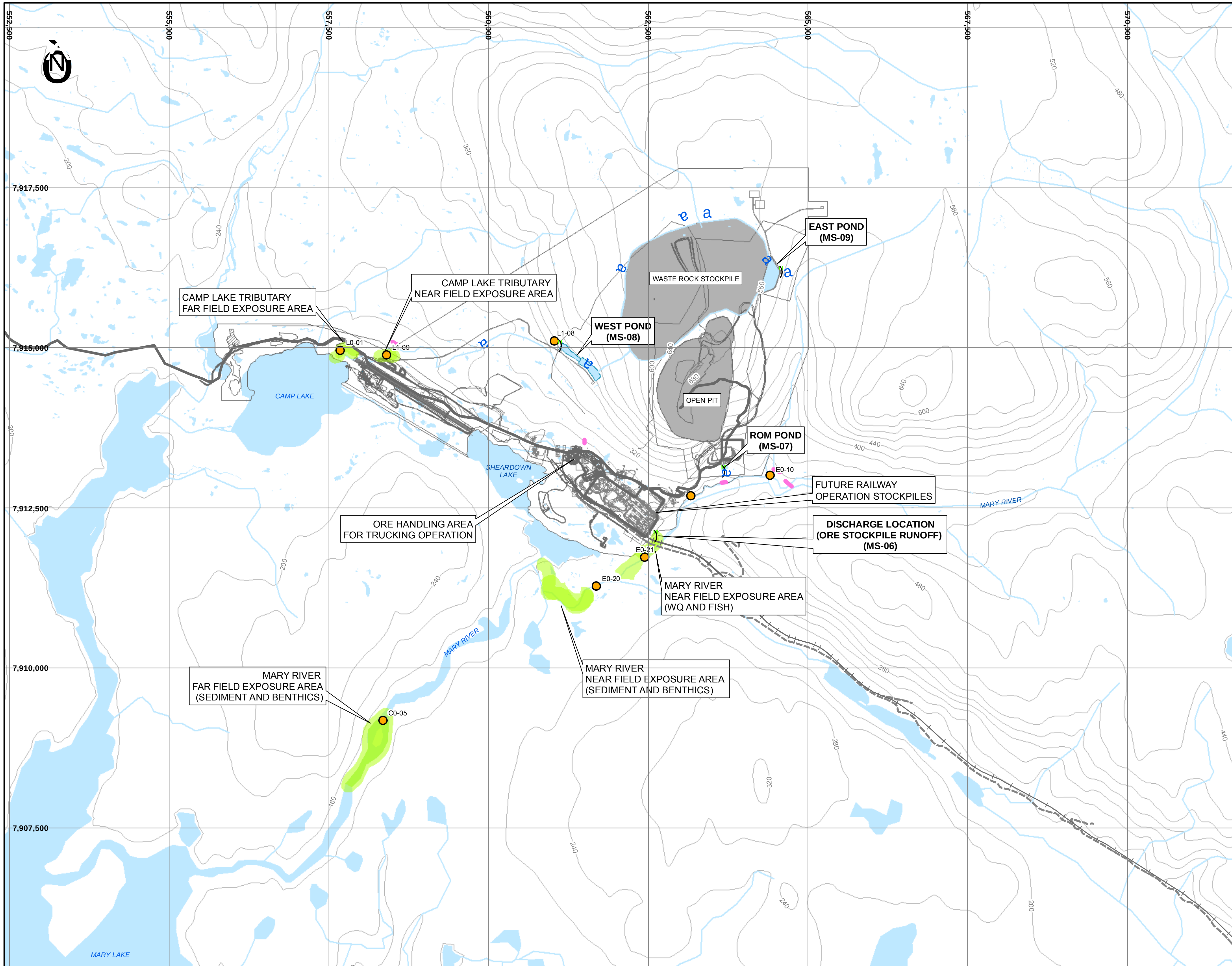
Table 1.1 Compliance Monitoring Limits Applicable to Mine Effluent Discharges

Parameter	MMER Effluent Quality Standards (Schedule 4)			Water Licence 2AM-MRY1325 Open Pit, Stockpile and Sedimentation Ponds Effluent Discharge Quality Limits
	Maximum Monthly Mean Concentration	Maximum Concentration in a Composite Sample	Maximum Concentration in a Grab Sample	Maximum Concentration of Any Grab Sample
Arsenic	0.50	0.75	1.00	0.50
Copper	0.30	0.45	0.60	0.30
Cyanide	1.00	1.50	2.00	
Lead	0.20	0.30	0.40	0.20
Nickel	0.50	0.75	1.00	0.50
Zinc	0.50	0.75	1.00	0.50
TSS	15.00	22.50	30.00	15
Radium 226 (Bq/L)	0.37	0.74	1.11	
pH (pH units)	-	-	-	Between 6.0 and 9.5
Oil and Grease	-	-	-	No visible sheen
Acute Toxicity Testing				
96-hr Rainbow Trout	$Pass_{50}$ [2]			Not acutely toxic

NOTES:
1. ALL PARAMETER CONCENTRATIONS ARE TOTAL VALUES, EXPRESSED IN MG/L UNLESS OTHERWISE SPECIFIED.
2. A PASS RESULT IS <50% MORTALITY IN 100% EFFLUENT.

The Type A Water Licence requires the development of an Aquatic Effects Monitoring Plan (AEMP). A number of component studies form the AEMP for the Mary River Project, including this EEM Program. Another component study is the Core Receiving Environment Monitoring Program (CREMP), which draws upon the same technical guidance document as the EEM Program to monitor aquatic effects due to multiple pathways (i.e., mine effluent discharges, but also sewage effluent discharges and effects due to dust deposition) within the near and far-field streams and mine site lakes: Camp, Sheardown NW and SE, and Mary Lake.

Additional details on the AEMP including the CREMP can be found in the AEMP (Baffinland, 2014).



LEGEND:

- FINAL DISCHARGE POINT
- ENVIRONMENTAL EFFECTS MONITORING STATION (EEM) (WATER, SEDIMENT, BENTHICS AND FISH)
- EEM STUDY DESIGN EXPOSURE AREA
- FISH BARRIER
- EXISTING TOTE ROAD
- PROPOSED RAILWAY ALIGNMENT
- PROPOSED CONSTRUCTION ACCESS ROAD
- PROPOSED SITE INFRASTRUCTURE
- RIVER/STREAM/DRAINAGE
- WATER

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.
5. INFRASTRUCTURE INFORMATION PROVIDED BY HATCH ON JANUARY 31, 2014.

DRAFT

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

BAFFINLAND IRON MINES CORPORATION

MARY RIVER PROJECT

PROPOSED EXPOSURE AREAS FOR THE ENVIRONMENTAL EFFECTS MONITORING (EEM) PROGRAM

Knight Piésold CONSULTING

P/A NO.	REF NO.
NB102-181/34	5

FIGURE 1.1 REV A

A	20MAY'14	ISSUED WITH REPORT	DKK	SWK	PS	RAC
REV	DATE	DESCRIPTION	DESIGNED	DRAWN	CHK'D	APP'D

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2 SITE CHARACTERIZATION

2.1 PROJECT DESCRIPTION

The Project is an iron more mine with a production rate of 21.5 Mt/a, consisting of the following major components:

- Milne Port
- Mine Site
- Railway
- Steensby Port

Each development site (excluding the railway) will have all the facilities it needs to operate effectively including maintenance and administrative buildings, warehouses and laydown areas, ore stockpiles and associated runoff management facilities, camps, water supply, wastewater treatment plants, waste management facilities including landfills, power generation, fuel depots, telecommunication facilities, and airstrips.

Baffinland is approved to mine Deposit No. 1 at the mine site by open pit mining methods. Since the Mary River iron ore is of a very high-grade, there is no need to have a process plant (or mill) on site, resulting in no tailings being generated. As such, no tailings pond will be required. This is accomplished by crushing and screening of the ore to produce two iron ore products:

- Lump ore – sized between 6.3 mm and 31.5 mm (about golf ball size), and
- Fine ore - sized less than 6.3 mm (about pea size).

Ore will be stockpiled at the mine site and transported either by truck to Milne Port or by railway to Steensby Port. Ore handling facilities at the mine site will consist of the open pit, separate ore stockpiles for the trucking and railway operations, and water management facilities to collect runoff from ore stockpiles. Waste rock will be stockpiled in a single stockpile next to the open pit, and up to two ponds will collect runoff from the stockpile. The trucking and railway operations will have separate ore stockpiles and runoff collection ponds but will otherwise share common water management facilities and final discharge points.

Mining is expected to begin in the second half of September 2014 beginning with a low-capital trucking operation involving the mining of 3.5 million tonnes per annum (Mt/a) of iron ore that will be transported year-round by truck to Milne Port, with marine shipping to market during the open water season. Ore handling facilities at Milne Port will consist of truck unloading facilities, ore stockpiles and ship-loading facilities at an ore dock. Runoff from the stockpile area at Milne Port will be collected in a pond that will discharge to the marine waters of Milne Inlet. Environment Canada has advised Baffinland that the mine effluent discharge to Milne Inlet will not be subject to the MMER, though the *Fisheries Act* still apply, including Section 36(3) regarding the prohibition of discharges of a deleterious substance in waters frequented by fish (Anne Wilson, pers.comm.)

At some point in the future when the iron ore market and economic conditions for financing capital-intensive projects improves, an 18 Mt/a railway operation will be constructed. This will involve the construction and operation of a 149-km railway to Steensby Port. Steensby Port, once constructed, will be equipped with a railway car dumper and associated conveying equipment, an ore stockpile, and ship-loading facilities to load ore onto ice-breaking ore carriers. Shipping of ore from Steensby Port will take place year-round. Runoff from the ore stockpile at Steensby Port will be collected and discharged to the marine waters in Steensby Inlet. Environment Canada similarly advised that the mine effluent discharge to marine waters from the ore stockpile at Steensby Port would not be subject to the MMER but would otherwise be subject to the *Fisheries Act*.

A number of proven mitigation measures have been included in the Project to reduce potential effects on water quality, freshwater fish, fish habitat, and other aquatic organisms. At each of the ore handling locations, crushers and screens will be installed inside buildings, and conveyors will be covered and equipped with wind ventilation hoods to reduce wind exposure and the potential for dust generation. All ventilation ducts will be routed to dust collectors which will limit dust emissions. Specific Management Plans detail the many ways that water will be protected (Baffinland, 2012).

The operational life of the Project, based on current ore reserves and a production rate of 21.5 Mt/a, is 21 years. The Closure of the facilities is expected to be carried out over a three to five year period and post-closure monitoring will follow for an additional five years. If closure objectives are not met, post closure would extend beyond five years.

2.2 FINAL DISCHARGE POINTS

Mine effluent will be discharged to two watercourses (Figure 1.1):

- Mary River
- Camp Lake Tributary 1

There will be three final discharge points will discharge mine effluent to the Mary River as follows:

- East Pond discharge collecting stormwater from the east side of the waste rock stockpile
- Run-of-mine (ROM) stockpile discharge
- The main ore stockpile at the rail load-out area

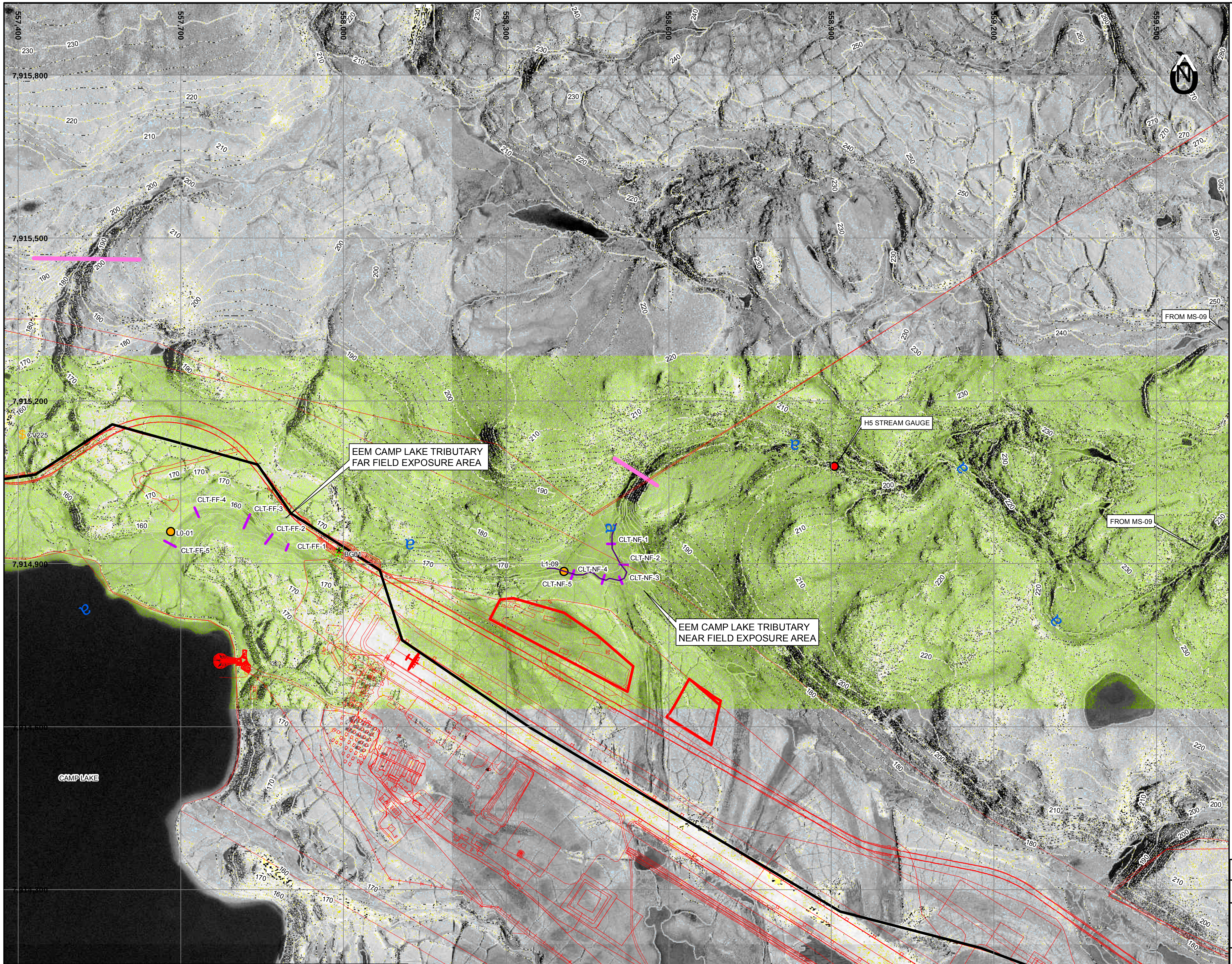
There will be one final discharge point to Camp Lake Tributary 1, from the West Pond collecting stormwater from the west side of the waste rock stockpile.

2.3 HISTORICAL DATA

In preparation for the MMER regulatory obligations, Baffinland characterized the two exposure areas (Mary River and Camp Lake Tributary 1) and several candidate reference areas in 2013.

The candidate reference areas were characterized to compare the in-situ physical and biological conditions to the conditions of the exposure areas. The candidate reference areas were identified through a series of desktop screenings and ground-truthing activities in 2012 and 2013. At least three candidate reference areas for each receiving watercourse were characterized.

The coordinates of the exposure and candidate reference areas characterized for the study design are shown in Table 2.1. The locations of the proposed exposure areas on the Camp Lake Tributary and Mary River are shown on Figure 1.1, and in greater detail on Figures 2.1 and 2.2. Reference areas for the study are shown on Figure 2.3.



LEGEND:

- ACTIVE WATER QUALITY SAMPLE LOCATION
- ACTIVE STREAM GAUGE LOCATION
- CULVERT CROSSING
- DIRECTION OF WATER FLOW
- MAJOR CONTOUR
- EXISTING TOTE ROAD
- PROPOSED SITE INFRASTRUCTURE
- RIVER/STREAM/DRAINAGE
- EEM REPLICATE TRANSECTS
- FISH BARRIER
- 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. INFRASTRUCTURE PROVIDED BY HATCH ON JANUARY 31, 2014.

DRAFT

SCALE 75 37.5 0 75 150 225 300 m

BAFFINLAND IRON MINES CORPORATION

MARY RIVER PROJECT

CAMP LAKE TRIBUTARY EEM EXPOSURE AREAS

Knight Piésold CONSULTING

P/A NO.	REF NO.
NB102-181/34	5
FIGURE 2.1	REV A

REV	DATE	DESCRIPTION	DESIGNED	DRAWN	CHK'D	APP'D
A	20MAY'14	ISSUED WITH REPORT	DKK	SWK	PS	RAC

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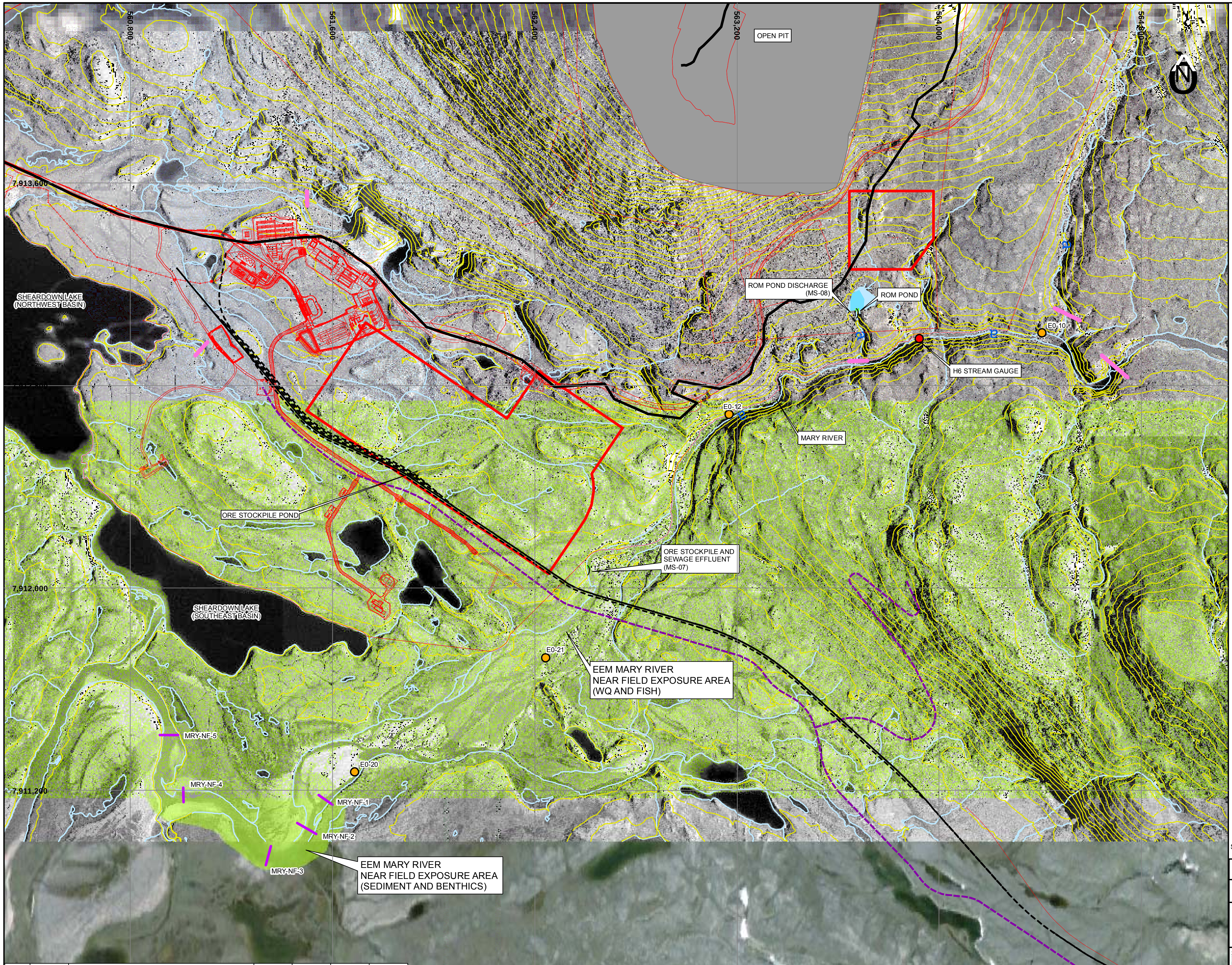

LEGEND:

- ACTIVE WATER QUALITY SAMPLE LOCATION
- ACTIVE STREAM GAUGE LOCATION
- FINAL DISCHARGE POINT
- DIRECTION OF WATER FLOW
- CONTOUR
- EXISTING TOTE ROAD
- PROPOSED RAILWAY ALIGNMENT
- PROPOSED CONSTRUCTION ACCESS ROAD
- PROPOSED SITE INFRASTRUCTURE
- RIVER/STREAM/DRAINAGE
- EEM REPLICATE TRANSECT
- FISH BARRIER
- WATER
- HIGHLIGHTED WATER FEATURE
- EEM STUDY DESIGN EXPOSURE AREA

NOTES:

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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. INFRASTRUCTURE PROVIDED BY HATCH ON JANUARY 31, 2014.

DRAFT

SCALE 200 100 0 200 400 600 800 m

BAFFINLAND IRON MINES CORPORATION

MARY RIVER PROJECT

MARY RIVER NEAR FIELD EEM EXPOSURE AREA

Knight Piésold CONSULTING

P/A NO.	REF NO.
NB102-181/34	5
FIGURE 2.2	REV A

REV	DATE	DESCRIPTION	DESIGNED	DRAWN	CHK'D	APP'D
A	20MAY'14	ISSUED WITH REPORT	DKK	SWK	PS	RAC

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A	20MAY'14	ISSUED WITH REPORT	DKK	SWK	PS	RAC
REV	DATE	DESCRIPTION	DESIGNED	DRAWN	CHK'D	APP'D

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LEGEND:

- HISTORIC WATER QUALITY SAMPLE LOCATION
- ACTIVE WATER QUALITY SAMPLE LOCATION
- b 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:

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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.

DRAFT

SCALE 200 100 0 200 400 600 800 m

BAFFINLAND IRON MINES CORPORATION

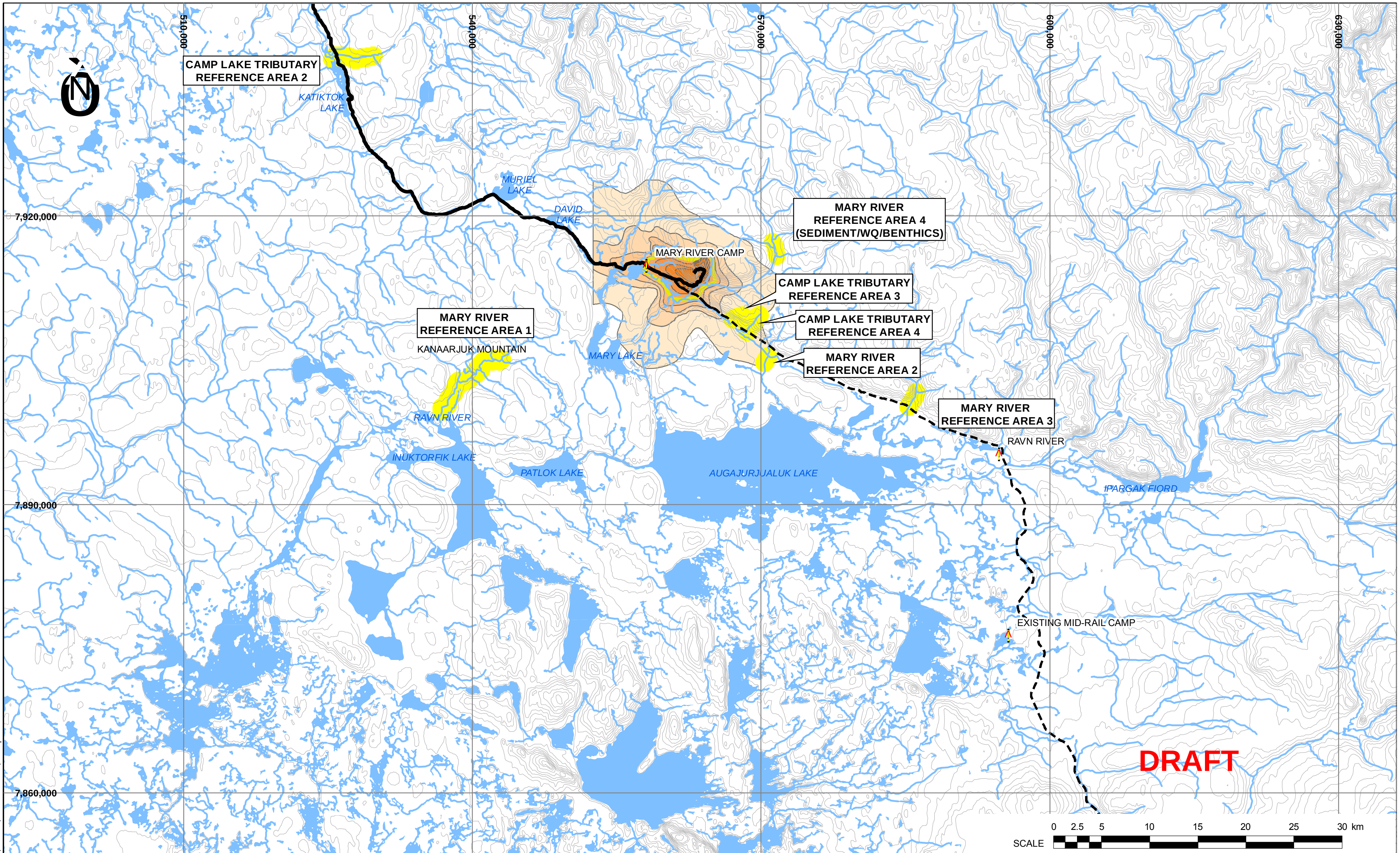
MARY RIVER PROJECT

MARY RIVER FAR FIELD EEM EXPOSURE AREA

Knight Piésold CONSULTING

P/A NO.	REF NO.
NB102-181/34	5

FIGURE 2.3 REV A



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LEGEND:

- EXISTING TOTE ROAD
- PROPOSED RAILWAY ALIGNMENT
- PROPOSED CONSTRUCTION ACCESS ROAD
- PROPOSED SITE INFRASTRUCTURE
- RIVER/STREAM/DRAINAGE
- PHOTO/VIDEO RECORD (2012-2013)
- WATER

Annual TSP Dep. (g/m^2/yr)

- 2 - 7.5
- 7.5 - 15
- 15 - 30
- 30 - 55
- 55 - 120
- 120 - 240
- 240 - 480
- > 480

NOTES:

1. BASE MAP: © HER MAJESTY THE QUEEN IN RIGHTS OF CANADA DEPARTMENT OF NATURAL RESOURCES (2009). ALL RIGHTS RESERVED.
2. COORDINATE GRID IS IN METRES. COORDINATE SYSTEM: NAD 1983 UTM ZONE 17N.
3. CONTOUR INTERVAL IS 20 METRES.
4. TOTAL SUSPENDED PARTICULATE CONTOURS PROVIDED BY RWDI AIR INC. (2011). PRESENTED IN THE FINAL ENVIRONMENT IMPACT ASSESSMENT.

REV	DATE	DESCRIPTION	DESIGNED	DRAWN	CHK'D	APP'D
A	20MAY'14	ISSUED WITH REPORT	DKK	SWK	PS	RAC

BAFFINLAND IRON MINES CORPORATION

MARY RIVER PROJECT

CANDIDATE REFERENCE AREAS FOR EEM PROGRAM

Knight Piésold CONSULTING

P/A NO. NB102-181/34

REF NO. 5

FIGURE 2.4

REV A

Baseline environmental data has been collected at the exposure and reference areas by North/South Consultants Inc. (NSC) and Knight Piésold Ltd. (KP) on behalf of Baffinland. The 2013 study area site characterization program involved:

- Identifying the in-situ habitat conditions
- In-situ and laboratory water quality sampling
- Sediment quality sampling
- Benthic invertebrate community sampling
- Fish community and population sampling

The exposure area habitat information was used to evaluate suitability of the candidate reference study areas and to position the proposed field replicate stations. Characterizing more than one reference site for each exposure area increases the ability to evaluate natural variability, ecological relevance and confounding factors, and improves the ability to evaluate the adequacy of the chosen reference site(s) (EC, 2012).

Table 2.1 Freshwater EEM Study Design Exposure and Candidate Reference Areas

Study Area ID	Latitude (Deg. Min. Sec.)	Longitude (Deg. Min. Sec.)
Camp Lake Tributary Near Field Exposure Area	71° 19’ 46” N	79° 21’ 46” W
Camp Lake Tributary Far Field Exposure Area	71° 19’ 46” N	79° 22’ 46” W
Camp Lake Tributary Reference Area 2	71° 31’ 51” N	80° 15’ 42” W
Camp Lake Tributary Reference Area 3	71° 15’ 56” N	79° 06’ 27” W
Camp Lake Tributary Reference Area 4	71° 15’ 28” N	79° 04’ 23” W
Mary River Near Field Exposure Area (Surface water & Fish at outfall)	71 17' 50" N	79° 15' 57" W
Mary River Near Field Exposure Area (Sediment & Benthos)	71° 17’ 42” N	79° 16’ 47” W
Mary River Far Field Exposure Area	71° 16’ 42” N	79° 22’ 11” W
Mary River Reference Area 1	71° 12’ 47” N	79° 56’ 17” W
Mary River Reference Area 2	71° 13’ 21” N	79° 02’ 46” W
Mary River Reference Area 3	71° 10’ 26” N	78° 39’ 31” W
Mary River Reference Area 4	71° 20' 43” N	79° 00' 04” W

NOTES:
1. AREA COORDINATES REPRESENT THE UPSTREAM EXTENT OF EACH STUDY AREA.

The habitat at each area was documented, including a description of the riparian vegetation, substrate composition and general stream morphology characteristics. A photographic record of each area is provided in Appendix A to support the habitat descriptions. Point velocity and depth measurements were taken at each replicate station and are also provided in Appendix A summary tables.

Substrate samples were collected for particle size distribution analysis and total organic carbon (TOC) content at each of the five replicate stations in each study area to characterize the habitat and as a supporting measure for the benthic invertebrate community survey data. The replicate stations were located in wadeable, erosional habitat, therefore depositional organic sediment was not available for sampling or utilized for total metals analysis. Summary figures and tables of the substrate laboratory results are provided in Appendix B.

Surface water quality samples and measurements were taken at existing monitoring stations where available. The in-situ and laboratory results are provided in Appendix C.

The benthic invertebrate community was sampled using a Hess sampler with 500 micron mesh as recommended by the technical guidance document (EC, 2012). Three grab samples were collected at each replicate station and retained in separate containers for discrete analysis for evaluation of within station variability. The benthic invertebrate community data for each replicate station, descriptions of the effects endpoints and supporting endpoint summary tables are provided in Appendix D. Discussion of the benthic community results and comparisons between exposure and candidate reference area are provided in the following sections. These results describe the community assemblages and support rationale for the selection of suitable reference areas.

Fish community and population sampling was conducted utilizing a Smith-Root backpack electrofishing unit. The collection of 100 juvenile Arctic char (*Salvelinus alpinus*) older than young-of-year (YOY) was attempted at all study areas. Subsamples of the captured fish (n=10) were retained for age verification to characterize the Arctic char population. The fish data (fork length and round weight) measured in the field and age verification data from the subsampled individuals are provided in Appendix E. Ninespine stickleback (*Pungitius pungitius*) are the only other fish species present in the mine area freshwater streams. The ninespine stickleback collected during the fall 2013 program were enumerated, but insufficient numbers were collected to perform statistical comparisons of the reference and exposure areas. Discussion of study area population composition, including age verification results are provided in the following sections.

2.4 CAMP LAKE TRIBUTARY EXPOSURE AREAS AND REFERENCE AREAS

The Camp Lake Tributary exposure area is located on the west side of Deposit No. 1 and contains the near field study area upstream of the existing Tote Road, and the far field study area located downstream of the Tote Road stream crossing as shown on Figure 2.1.

Three candidate reference areas were characterized to evaluate their suitability as EEM reference areas for the exposure area. The reference areas included one area along the Tote Road between the mine site and Milne Port, and two locations near the rail alignment, north of Angajurjualuk Lake. The locations of these reference areas are shown on Figure 2.4. Originally, a fourth candidate reference area (CLT-REF1) was selected, but this area was deemed unsuitable following a ground-truthing site visit in the summer 2013.

2.4.1 Historical Site Characterization

Prior to the 2013 fall (late August) site characterization program, various baseline aquatic data collection programs have been conducted in the exposure and some of the reference streams. A summary of the study areas, corresponding historical studies and reference to the 2013 photographs included in Appendix A are provided in Table 2.2.

Table 2.2 Camp Lake Tributary Study Areas: Historical Characterization Summary

EEM Study Area ID	CLT-NF	CLT-FF	CLT-REF2	CLT-REF3	CLT-REF4
Historical ID	L1-09	L0-01	CV-078, N1-060	CV-004-1 E2-08	CV-006-1
Study Type	**Historical Study Years**				
Water Quality	2011-2013	2005-2007, 2011-2013	2005, 2006, 2011, 2012	2005, 2012	2008
Substrate/Sediment Quality	2007, 2011-2012	2007, 2011-2012	N/A	2012	N/A
Benthic Invertebrates	2007	2007	N/A	2008	N/A
Fish Community	2007, 2010	2007, 2010	2009, 2010	2008	2008
Appendix A Photographs	1 to 4	5 to 8	9 to 12	13 to 16	17 to 20

The land immediately adjacent to these streams is typically flat, and the streams have steep vertical banks. Riparian vegetation includes grasses, mosses, and wildflowers. The streams have varying amount of undercut banks and all have boulders that provide in-stream cover.

2.4.2 Water Quality

The 2013 surface water quality data from the exposure areas (CLT-NF and CLT-FF) shows this stream is "moderately soft" with no Canadian Water Quality Guideline exceedances of criteria for the protection of freshwater aquatic life (CWQG-PAL) (CCME, 2007) as provided in Appendix C (Table C.1). The exposure areas were highly oxygenated, which is an important measure to support aquatic life. A discussion of the metal parameters of interest: aluminum, arsenic, cadmium, copper, iron and nickel are provided in the water and sediment quality review and preliminary study design report contained within the AEMP document (Baffinland, 2014).

The candidate reference areas varied in hardness with CLT-REF2 shown to have hard water and CLT-REF3 and CLT-REF4 shown to have soft water (Appendix C, Table C.1). Analytical results from reference area CLT-REF2 show a total ammonia concentration (0.83 mg/L) of from the July 2013 sample that is above the CWQG-PAL criteria. This was the only criteria exceedance documented at CLT-REF2. The laboratory results from CLT-REF3 and CLT-REF4 reference areas both show concentrations of total aluminum above the CWQG-PAL criteria (Appendix C, Table C.1). Total aluminum was the only CWQG-PAL criteria exceedance from these reference areas. All reference areas were highly oxygenated and comparable to the exposure areas.

2.4.3 Benthic Invertebrate Community Effect Endpoints

Benthic invertebrate community effect endpoints comparing the exposure and reference areas are summarized in Table 2.3. These endpoints show area CLT-REF3 was the only reference area not significantly different from CLT-NF for all effect endpoint calculations, and is the recommended reference area for use in the cycle one EEM biological monitoring study. Reference area CLT-REF4 should also be utilized in the cycle one study since family richness was the only significant difference and the use of multiple reference areas captures the natural variability of these streams, providing a less narrow comparison to a single reference area. Benthic invertebrate sample processing methods and details of the endpoint calculations are provided in Appendix D.

Table 2.3 Camp Lake Tributary Study Areas: Benthic Invertebrate Community Summary

Endpoint	Descriptor	Study Area			
		CLT-FF	CLT-REF2	CLT-REF3	CLT-REF4
Total Invertebrate Density(TID)	Different from CLT-NF (p<0.10)	N[2]	Y[2]	N[2]	N[2]
Taxa Richness	Different from CLT -NF (p<0.10)	N	N	N	Y
Simpson's Evenness Index (E)	Different from CLT -NF (p<0.10)	N[2]	Y[2]	N[2]	N[2]
Bray-Curtis Similarity Index	Different from CLT -NF (p<0.10)	-	Y	N	N

NOTES:
1. TUKEY TEST RESULTS FOR POST-HOC COMPARISON PRESENTED UNLESS OTHERWISE NOTED.
2. VARIANCE NOT HOMOGENEOUS, GAMES-HOWELL TEST RESULTS PRESENTED.
3. SEE APPENDIX D FOR CAMP LAKE TRIBUTARY STUDY AREA ENDPOINT CALCULATIONS.

Baffinland has identified the Bray-Curtis Similarity Index as one of the benthic invertebrate community effect endpoints, in accordance with EC (2012), as shown in Table 2.3. It has been acknowledged in a study commissioned by EC that this current procedure results in a highly inflated type I error rate (Borcard and Legendre, 2013). Prior to submitting the final Cycle One Study Design, Baffinland plans to seek further guidance from EC on this issue, and give due consideration to using the replacement tests identified by Borcard and Legendre (2013).

2.4.4 Supporting Benthic Invertebrate Community Measures

Reference sites must share natural habitat features with the exposure sites and represent the environmental variability of the study region. Supporting measures for the benthic invertebrate community survey were recorded to support recommendations of the appropriate reference areas. These include hydrology, stream morphology and substrate characterization.

The hydrological and morphological characteristics of the Camp Lake Tributary study areas include channel wetted width, total water depth and point velocity measurements. The wetted width was measured at each of the five replicate stations. Total water depth and point velocity measurements were recorded at ten locations per replicate station, near to where the benthic invertebrate community sampling occurred. Reference areas CLT-REF3 and CLT-REF4 are the most similar to exposure area CLT-NF, whereas CLT-REF2 is much wider and has nearly twice the mean water velocity (Table 2.4). Detailed field measurement are provided in Appendix A including the total water depths, wetted widths and water velocities in each study area.

Substrate characterization included particle size distribution analysis and determination of total organic carbon (TOC) content. Reference area CLT-REF3 had particle size fractions similar to those measured at exposure area CLT-NF. Both areas were dominated by gravel and coarse sand. Reference area CLT-REF4 was also dominated by these size classes, but had higher gravel content.

Table 2.4 Camp Lake Tributary Study Areas: Stream Characterization Summary

Measure	Units	Study Area				
		CLT-NF	CLT-FF	CLT-REF2	CLT-REF3	CLT-REF4
Mean Wetted Width	m	5.8	4.9	15.4	4.6	2.6
Mean Total Depth	m	0.16	0.14	0.20	0.17	0.13
Mean Velocity	m/s	0.28	0.38	0.51	0.20	0.37

Reference area CLT-REF2 was dominated by gravel and silt, and is not a suitable representation of exposure area habitat. TOC content at CLT-REF3 and CLT-REF4 were most similar to the TOC content of the exposure area CLT-NF. The particle size distributions and TOC results for the Camp Lake Tributary study areas are shown in Table 2.5. Detailed field measurements, laboratory results and graphs are provided in Appendix B to assist with interpretation of the supporting measures.

Table 2.5 Camp Lake Tributary Study Areas: Substrate Characterization Summary

Mean Particle Size Fraction (%)	Size (mm)	Study Area				
		CLT-NF	CLT-FF	CLT-REF2	CLT-REF3	CLT-REF4
Gravel	16.0 - 2.0	58	57	73	54	79
Coarse Sand	2.0 - 0.2	33	35	4	38	12
Fine Sand	0.2 - 0.062	0	4	2	4	5
Silt	0.062 - 0.0039	0	1	11	0	1
Clay	< 0.0039	5	5	8	4	5
Mean TOC (%)	-	0.15	0.20	0.21	0.12	0.17

2.4.5 Fish Community and Population

Backpack electrofishing during the fall 2013 program captured arctic char at all Camp Lake Tributary study areas. The fish appeared healthy, with no visible abnormalities. A summary of the fish collection results and mean measurements from the study area populations are shown in Table 2.6. Detailed collection data are presented in Appendix E.

Table 2.6 Camp Lake Tributary Study Areas: Fish Sampling Data Summary

Measure	Study Area			
	CLT-NF	CLT-REF2	CLT-REF3	CLT-REF4
Number or Arctic char collected	120	30	116	117
Number of Ninespine stickleback collected	0	0	0	1
Arctic char catch-per-unit-effort (CPUE)	8.57	1.22	9.11	5.25
Mean Arctic char fork length (mm)	148	127	90	117
Mean Arctic char round weight (g)	32	23	10	21
Mean Arctic char age (yrs), (n=10/study area)	3	4	4	4
Mean Fulton's Condition (weight at length)	1.17	1.18	1.37	1.33

The collection of 100 individuals from each area is required under the EEM program to conduct comparisons between study areas. Due to the limited capture success at reference area CLT-REF2 (n=30), only reference areas CLT-REF3 and CLT-REF4 were compared to the exposure area. Ninespine stickleback were only captured from reference area CLT-REF4 (n=1) and no further data are discussed regarding this species.

The arctic char catch-per-unit-effort (CPUE) results are shown in Table 2.5, with the highest capture rate in reference area CLT-REF3. The CLT-REF4 area had approximately half the CLT-REF3 capture success, and was lower than the CPUE recorded at the exposure area CLT-NF.

The fork lengths of the first 100 individuals from the CLT-NF, CLT-REF3 and CLT-REF4 study areas are graphically shown in Appendix E (Figure E.1). Arctic char in the exposure area were the largest and consequently the heaviest of the three study area populations. Ten individuals were retained for age verification from each study area, and ages ranged from 1 to 7 years old.

Descriptive statistics of the fork length and round weight measurements are presented in Appendix E (Table E.1). Statistical comparisons of the CLT-REF3 and CLT-REF4 length and weight data to the CLT-NF data are presented in Appendix E (Table E.2). Tests of normality show the length and weight data for all Camp Lake Tributary study areas are not normally distributed. Transforming the data did not resolve this condition. An ANOVA comparison shows length and weight data of the study areas are significantly different.

The fish population data shows both reference areas CLT-REF3 and CLT-REF4 were significantly different from the CLT-NF study area.

2.4.6 Camp Lake Tributary Exposure and Reference Area Summary

Reference areas CLT-REF3 and CLT-REF4 are the most suitable study areas for use in the EEM cycle one biological monitoring study. These areas are representative of the benthic invertebrate community seen in the near field exposure area CLT-NF, with similar water quality, substrate, hydrology and stream morphology measures.

Comparison of the fish community and population data shows CLT-REF3 and CLT-REF4 have different fish age distributions and are statistically different from CLT-NF. Additional data analysis may be performed following discussions with Environment Canada to determine an acceptable reference area for the fish component of the EEM cycle one biological monitoring study.

2.5 MARY RIVER EXPOSURE AREAS AND REFERENCE AREAS

The Mary River is located southeast of the mine site and flows in a southwest direction reporting to Mary Lake approximately 12.8 km downstream. The exposure area will receive effluent inputs from three discrete MMER final discharge points listed below in descending order, upstream to downstream as follows (Figure 1.1):

- East waste rock pond discharge (MS-10)
- Run of mine (ROM) pond discharge (MS-08)
- Ore stockpile runoff (MS-07)

The Mary River aquatic habitat between these effluent discharge points is a high energy environment dominated by a boulder substrate and steep sloping banks. The Mary River near field (MRY-NF) exposure area has two stream sections proposed for the cycle one EEM biological monitoring study as shown on Figure 2.2. During study design development, the challenges of standard biological sampling in the immediate vicinity of the final discharge points were discussed with Environment Canada. Following a site visit by Environment Canada staff, it was agreed that the benthic invertebrate and substrate sampling would take place in wadeable river habitat downstream of the dangerous, high velocity conditions. It was also decided that receiving water quality sampling will remain near the discharge locations as per the CREMP as well as the fish sampling EEM component that will take place upstream of the benthic study area, as close to the final discharge point as safely possible.

The upstream extent of the Mary River far field (MRY-FF) exposure area is located approximately 3,900 m downstream of the Sheardown Lake outlet channel confluence as shown on Figure 2.3. Existing CREMP stations are located within this study area as shown on Figure 2.3. Baseline surface water quality monitoring at station C0-05 was conducted in 2007, 2008 and 2011. Sediment quality sampling at station C0-05 was conducted in 2007 and 2011. A fish community survey had not historically been conducted at this location on the river however the barrier-free conditions between MRY-FF and MRY-NF permits fish migration through these exposure areas.

Four reference areas geographically outside of the range of anticipated mining influences were selected for comparison to the Mary River exposure areas (Figure 2.4). One of these areas (MRY-REF4) was included following a recommendation by Environment Canada to locate a study area on the Mary River. The only available areas upstream of the final discharge points and predicted dust plume are located upstream of the Mary River fish barrier (waterfall). Study area MRY-REF4 is a candidate reference area for the benthic invertebrate community EEM component. It has been shown that the Mary River is fishless upstream of the waterfall (NSC, 2008). As such, study area MRY-REF4 would not satisfy the requirements of the fish population effects endpoints.

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 (Figure 2.4).

2.5.1 Historical Site Characterization

Prior to the 2013 fall (late August) site characterization program, various baseline aquatic data collection programs have been conducted in the exposure and in some of the reference streams. A summary of the study areas, corresponding historical studies and reference to the 2013 photographs included in Appendix A are provided in Table 2.7.

The land immediately adjacent to these streams is typically flat, with steep banks on one or both sides away from the main channel. The in-streams banks are vertical with riparian vegetation including grasses, mosses, and wildflowers. The streams have varying amount of undercut banks and all have boulders that provide in-stream cover.

Table 2.7 Mary River Study Areas: Historical Characterization Summary

EEM Study Area ID	**MRY-NF**	**MRY-FF**	**MRY-REF1**	**MRY-REF2**	**MRY-REF3**	**MRY-REF4**
Historical ID	E0-20 & E0-21	C0-05	N/A	BR 011-1, S2-010	BR-025-1, S2-020	G0-09
Study Type	**Historical Study Years**					
Water Quality	2011 & 2012	2007, 2008, 2011	-	2006 & 2011	2006 & 2011	2006, 2007, 2012
Substrate/Sediment Quality	2011	2007 & 2011	-	-	-	2006, 2007, 2009, 2010 & 2012
Benthic Invertebrates	2007	-	-	-	-	2007
Fish Community	2006 & 2008	-	-	2008	2008	2006 & 2008
Appendix A Photographs	21 to 24	25 to 28	29 to 32	33 to 36	37 to 40	41 to 44

2.5.2 Water Quality

The 2013 surface water quality data from the exposure areas (MRY-NF and MRY-FF) shows these areas are "soft" (MRY-NF) and "moderately hard" (MRY-FF) with concentrations of aluminum, copper and iron measured above the CWQG-PAL criteria at the MRY-NF study areas (Appendix C, Table C.1). A discussion of the metal parameters of interest: aluminum, arsenic, cadmium, copper, iron and nickel are provided in the water and sediment quality review and preliminary study design report contained within the AEMP document (Baffinland, 2014).

The candidate reference areas were all shown to have "soft" water with the exception of MRY-REF1 that had "moderately hard" water. Laboratory results from reference areas MRY-REF3 and MRY-REF4 show concentrations of aluminum and iron above the CWQG-PAL criteria, with aluminum as the only exceedance reported from MRY-REF2. There were no CWQG-PAL criteria exceedances reported from MRY-REF1.

2.5.3 Benthic Invertebrate Community Effect Endpoints

Benthic invertebrate community effect endpoints comparing the exposure and reference areas are summarized in Table 2.8. These endpoints show three of the four reference areas are not significantly different from MRY-NF for all effect endpoint calculations. Benthic invertebrate sample processing methods and details of the endpoint calculations are provided in Appendix D.

As mentioned in Section 2.4.3, prior to submitting the final Cycle One Study Design, Baffinland plans to seek further guidance from EC on the use of the Bray-Curtis Similarity Index, and give due consideration to using the replacement tests identified by Borcard and Legendre (2013).

Table 2.8 Mary River Study Areas: Benthic Invertebrate Community Summary

Endpoint	Descriptor	Study Area				
		MRY-FF	MRY-REF1	MRY-REF2	MRY-REF3	MRY-REF4
Total Invertebrate Density (TID)	Different from MRY-NF (p<0.10)	N	N	N	Y	N
Taxa Richness	Different from MRY-NF (p<0.10)	N	N	N	N[2]	N
Simpson's Evenness Index (E)	Different from MRY-NF (p<0.10)	N	N	N	N[2]	N
Bray-Curtis Similarity Index	Different from MRY-NF (p<0.10)	-	N	N	Y	N

NOTES:
1. TUKEY TEST RESULTS FOR POST-HOC COMPARISON PRESENTED UNLESS OTHERWISE NOTED.
2. VARIANCE NOT HOMOGENEOUS, GAMES-HOWELL TEST RESULTS PRESENTED.
3. SEE APPENDIX D FOR MARY RIVER STUDY AREA ENDPOINT CALCULATIONS.

2.5.4 Supporting Benthic Invertebrate Community Measures

Reference sites must share natural habitat features with the exposure sites and represent the environmental variability of the study region. Supporting measures for the benthic invertebrate community survey were recorded to support recommendations of the appropriate reference areas. These include hydrology, stream morphology and substrate characterization.

The hydrological and morphological characteristics of the Mary River study areas include channel wetted width, total water depth and point velocity measurements. The wetted width was measured at each of the five replicate stations. Total water depth and point velocity measurements were recorded at ten locations per replicate station, near to where the benthic invertebrate community sampling occurred. Reference area MRY-REF1 and MRY-REF3 were the most similar to exposure area MRY-NF but are unlike the exposure area for other comparison criteria. The MRY-REF2 and MRY-REF4 study areas are shallower than the exposure area with higher and lower average point velocities respectively than the MRY-NF study area. Detailed field measurement are provided in Appendix A including the total water depths, wetted widths and water velocities in each study area.

Table 2.9 Mary River Study Areas: Stream Characterization Summary

Measure	Units	Study Area					
		MRY-NF	MRY-FF	MRY-REF1	MRY-REF2	MRY-REF3	MRY-REF4
Mean Wetted Width	m	36	56	37	42	38	26
Mean Total Depth	m	0.30	0.25	0.35	0.20	0.23	0.25
Mean Velocity	m/s	0.40	0.30	0.31	0.46	0.39	0.22

Substrate characterization included particle size distribution analysis and determination of total organic carbon (TOC) content. Reference areas MRY-REF2 and MRY-REF3 had particle size fractions similar to those measured at exposure area MRY-NF. These areas were dominated by gravel and coarse sand. Reference area MRY-REF4 had nearly equal fractions of gravel and coarse sand, whereas MRY-REF1 had the highest percent coarse sand fraction. TOC content at MRY-REF2 and MRY-REF4 were nearly equal to the TOC concentration at MRY-NF as shown in Table 2.10. Detailed field measurements, laboratory results and graphs are provided in Appendix B to assist with interpretation of the supporting measures.

Table 2.10 Mary River Study Areas: Substrate Characterization Summary

Mean Particle Size Fraction (%)	Size (mm)	Study Area					
		MRY-NF	MRY-FF	MRY-REF1	MRY-REF2	MRY-REF3	MRY-REF4
Gravel	16.0 - 2.0	61	46	28	63	64	42
Coarse Sand	2.0 - 0.2	31	41	64	30	29	49
Fine Sand	0.2 - 0.062	3	6	4	3	2	4
Silt	0.062 - 0.0039	0	1	1	1	0	0
Clay	< 0.0039	4	6	3	3	4	4
Mean Total Organic Carbon (%)	-	0.10	0.16	0.07	0.11	0.21	0.11

2.5.5 Fish Community and Population

Backpack electrofishing during the fall 2013 program captured arctic char at all Mary River study areas. The fish appeared healthy, with no visible abnormalities. A summary of the fish collection results and mean measurements from the study area populations are shown in Table 2.11. Detailed collection data are presented in Appendix E.

Table 2.11 Mary River Study Areas: Fish Sampling Data Summary

Measure	Study Area			
	MRY-NF	MRY-REF1	MRY-REF2	MRY-REF3
Number or Arctic char collected	108	26	22	114
Number of Ninespine stickleback collected	0	26	0	0
Arctic char catch-per-unit-effort (CPUE)	1.56	0.61	0.71	2.01
Mean Arctic char fork length (mm)	126	121	100	104
Mean Arctic char round weight (g)	23	25	11	15
Mean Arctic char age (yrs), (n=10/study area)	4	4	3	3
Mean Fulton's Condition (weight at length)	1.43	1.29	1.18	1.23

The collection of 100 individuals from each area is required under the EEM program to conduct comparisons between study areas. Due to the limited capture success at reference area MRY-REF1 and MRY-REF2, only reference area MRY-REF3 compared to the exposure area. During the field studies at MRY-REF2, weather conditions limited the fishing effort, given more time it is likely that sufficient numbers of arctic char could have been collected. Ninespine stickleback were only captured from reference area MRY-REF1 (n=26) and no further data are discussed regarding this species.

The arctic char catch-per-unit-effort (CPUE) results are shown in Table 2.11, with the highest capture rate in reference area MRY-REF3. The remaining two reference areas showed less than half the CPUE recorded at the MRY-NF study area, however MRY-REF2 received half the fishing effort that was spent at the exposure area.

The fork lengths of the first 100 individuals from the MRY-NF and MRY-REF3 study areas are graphically shown in Appendix E (Figure E.4). Arctic char in the exposure area were the largest and consequently the heaviest of the Mary River study area populations. Ten individuals were retained for age verification from each study area, and ages ranged from 1 to 7 years old.

Descriptive statistics of the fork length and round weight measurements are presented in Appendix E (Table E.1). Statistical comparisons of the MRY-REF3 length and weight data to the MRY-NF data are presented in Appendix E (Table E.3). Tests of normality show the length and weight data for the Mary River study areas are not normally distributed. Transforming the data did not resolve this condition. An ANOVA comparison shows length and weight data of the study areas are significantly different.

The fish population data shows reference area MRY-REF3 was significantly different from the MRY-NF study area.

2.5.6 Mary River Reference Area Summary

Reference areas MRY-REF2 and MRY-REF4 are the most suitable study areas for use in the EEM cycle one biological monitoring study. These areas are representative of the benthic invertebrate community seen in the near field exposure area MRY-NF, with similar water quality, substrate, hydrology and stream morphology measures.

Comparison of the fish community and population data shows MRY-REF3 has different fish age distributions and is statistically different from MRY-NF. It is possible with additional sampling, MRY-REF2 could provide sufficient numbers of arctic char for a comparison using the endpoints. Additional data analysis may be performed following discussions with Environment Canada to determine an acceptable reference area for the fish component of the EEM cycle one biological monitoring study.

3 STUDY DESIGN METHODOLOGY

3.1 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 estimated 10-year low flow conditions of the receivers are presented in Table 3.1.

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.

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.

Table 3.1 Estimated Mine Effluent and Baseline Receiving Water Flows

Effluent Source	Receiving Water	Station ID	Baseline Receiver Discharge at Station (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
		Mary River Total	**56,793,000**	**3,340,600**
West Pond (MS-08)	Camp Lake Tributary (upstream of Camp Lake)	L0-01	410,100	354,100[1]
		Camp Lake Tributary Total	**410,100**	**354,100[1]**

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

The predicted water quality of the mine effluent to be discharged into the Camp Lake Tributary and Mary River was presented in the FEIS. The predicted effluent quality from ore stockpiles was derived from lysimeter monitoring results of the bulk sample ore stockpile, whereas source terms for runoff from the waste rock stockpile was derived from geochemical testing of representative waste rock materials. Subsequently, mean ore stockpile source terms for the Mary River and the west waste rock pile source terms for Camp Lake Tributary were determined as shown in Table 3.2.

Table 3.2 Predicted Water Quality from Discharge Sources

Parameter	Unit	CWQG-PAL	West Pond	East Pond	Ore Stockpile
			Mean	Mean	95th Percentile
pH	pH	6.5 to 9.0	6.9	6.9	6.65
Arsenic	mg/L	0.005	0.006	0.003	0.002
Copper	mg/L	0.002 to 0.004[4]	0.007	0.004	0.007
Lead	mg/L	0.001 to 0.007[4]	0.0005	0.0002	0.001
Nickel	mg/L	0.025 to 0.150[4]	0.005	0.002	0.17
Zinc	mg/L	0.030	0.031	0.015	0.041

NOTES:

1. MODIFIED FROM FEIS (BAFFINLAND, 2012).
2. EFFLUENT QUALITY UNDER 10-YEAR DRY CONDITIONS PRESENTED
3. RECEIVING WATER QUALITY OBJECTIVES OBTAINED FROM THE CANADIAN COUNCIL OF MINISTERS OF THE ENVIRONMENT (CCME) CANADIAN WATER QUALITY GUIDELINES FOR THE PROTECTION OF FRESHWATER AQUATIC LIFE (CWQG-PAL).
4. CWQG-PAL GUIDELINE VALUE IS HARDNESS DEPENDENT.
5. ADDITIONAL PARAMETERS ARE PROVIDED IN THE FEIS TABLE 7-3.16 AND 7-3.20.

3.2 WATER QUALITY MONITORING

Sampling and analysis of water quality will be undertaken as part of the cycle one EEM biological monitoring 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. Field staff will follow the methods outlined in the water and sediment quality sampling protocol (KP, 2014).

The samples will be obtained by sub-surface grabs at least 15 cm below the surface directly into pre-labelled laboratory sample containers. 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 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), water temperature and stream discharge will also be recorded at each study area using portable instruments, calibrated daily with standards of known value (where applicable).

For QA/QC purposes a laboratory prepared trip blank will accompany 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. Chain of custody forms will accompany all samples for identification, tracking and transporting purposes. The level of QA/QC employed will provide confidence in the data collected.

3.3 SUPPORTING BENTHIC INVERTEBRATE COMMUNITY MEASURES

Supporting measures for the benthic invertebrate community survey will be recorded to support the appropriateness of the selected reference areas. These measures include hydrology, stream morphology and substrate characterization.

The wetted width of the channel at time of sampling will be measured at each replicate station. Water depth and point velocities at a minimum of ten locations will be recorded near to the benthic invertebrate community sampling locations at each replicate station. Substrate samples will be collected using a core-style sampler to obtain representative samples of the top 5 cm to characterize the particle size distribution and total organic carbon content at each replicate station.

3.4 BENTHIC INVERTEBRATE COMMUNITY SURVEY

A benthic invertebrate community survey will be conducted as part of the cycle one EEM biological study as required by the MMER. The results of this survey will compare the 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.

For the benthic survey, the values of and 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. The replicate stations will be positioned near to the 2013 site characterization program stations (Table A.1, Appendix A).

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 composite samples. 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, and area characterized as wadeable, erosional areas. The substrate type, stream width/depth, flow dynamics and vegetation will be evaluated prior to sample collection at all replicate stations. The benthic samples will be collected using a Hess sampler with a 500 micron mesh at all the stations.

The surficial area sampled will be recorded for each sample collected. Each benthic sample 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 a field collection record will be completed for each station. Chain of custody forms will accompany all samples for identification, tracking and transporting purposes.

3.4.1 Sample Processing

Benthic samples will be analyzed by a taxonomist. All samples will be sorted with the use of a stereo microscope (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 fourth instar 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.

3.4.2 Taxonomy

All invertebrates will be identified to the lowest practical level, usually family level. Additional identification of oligochaetes, stoneflies, mayflies, dragonflies, amphipods, 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 list of individuals collected for each sample will be included in the final interpretive report. The list will be in a standard spreadsheet format.

3.4.3 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 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 (2012). 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 to identify higher risk to the aquatic environment 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 3.3).

Table 3.3 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

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

As mentioned in Sections 2.4.3 and 2.5.3, prior to submitting the final Cycle One Study Design, Baffinland plans to seek further guidance from EC on the use of the Bray-Curtis Similarity Index, and give due consideration to using the replacement tests identified by Borcard and Legendre (2013).

3.4.4 QA/QC

A composite of three field sub-samples from each replicate station will be collected for benthic invertebrate analyses, to compensate for the within station, spatial variability encountered with benthic 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. A subset of the voucher collection will be taxonomically analysed by a second invertebrate taxonomist.

3.5 FISH COMMUNITY, POPULATION AND USABILITY SURVEY

3.5.1 Fish Community

Sufficient historical 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.

3.5.2 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 (n=100) of the proposed sentinel species (Arctic char). The absence of ninespine stickleback in suitable numbers in the exposure and proposed reference areas precludes their use as a second sentinel species. Environment Canada officials will be notified of insufficient collection numbers during the study, and an agreed upon course of action will be followed to complete the study.

Non-destructive capture methods will be employed for all fish population sampling. Backpack electrofishing will be utilized as the primary means of sampling. 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 natural or placed barriers where possible (e.g., waterfall, natural dam or block net). In this manner, all fish resident in the section of stream being sampled can be captured for measurement. 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 Arctic char older than young of the year (+YOY). Any YOY individuals collected will be measured and the proportion of fish that are YOY will be estimated from the first 100 fish collected.

Fish lengths will be measured to the nearest millimetre on a fish board. Weighs of the measured fish will be determined using a digital scale to the nearest 0.01 g. All fish captured will be released alive except for a sub-sample to be retained for aging purposes. Table 3.4 and Table 3.5 outline the fish survey measurements and effect indicators proposed for this study.

Table 3.4 Fish Survey Measurements, Expected Precision and Summary Statistics

Measurement Requirement	Expected Precision	Reporting of Summary Statistics
Length (fork and total)	+/- 1 mm	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	+/- 1 year	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

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

Table 3.5 Fish Population Effect Indicators and Endpoints

Effect Indicator	Non-lethal Effect and Supporting Endpoints
Survival	Length-frequency distribution Age-frequency distribution (if possible)
Growth	Length of YOY (age 0) at end of growth period Weight of YOY (age 0) at end of growth period Size of YOY+ (age 1+) Size at age (if possible)
Reproduction	Relative abundance of YOY (% composition of YOY) YOY survival
Condition	Body weight at length

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

Aging using fin rays will be undertaken. 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, though sex determination of small, immature fish may not be conclusive.

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).

3.5.3 Fish Usability

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.

4 SUMMARY AND SCHEDULE

The 2013 site characterization program confirmed in-situ conditions at the exposure areas and candidate reference areas. The most suitable reference areas to evaluate the benthic invertebrate community effect endpoints are as follows:

- Camp Lake Tributary Near Field (CLT-NF) : Camp Lake Tributary Reference Area 3 (CLT-REF3)
- Mary River Near Field (MRY-NF) : Mary River Reference Area 4 (MRY-REF4)

The statistical comparisons of the fish population data between the exposure and refernce areas for both receivers show significant difference within and between all groups. As such, additional data analysis may be performed following discussions with Environment Canada to determine an acceptable reference area for the fish component of the EEM cycle one biological monitoring study.

The anticipated timeline that includes milestones associated with the MMER requirements is provided below, and is subject to change based on regulatory approvals and the start of mining.

Mid-September 2014	Start of mining
June 2015	Mine is subject to MMERs once effluent discharge rate reaches 50 m^3/day
September 2015	Submission of Identifying Information & Final Discharge Points (within 60 days after date mine is subject to MMERs)
December 2015	Submission Cycle One Study Design (12 months from initial date when Mine was subject to MMERs)
	Environment Canada review of Cycle One Study Design (6 months)
August-Sept 2016	Conduct Cycle One Biological Monitoring Study (conducted no sooner than 6 months after Cycle One SD submission date)
November 2017	Submission of Cycle One Interpretive Report (within 30 months from initial date when Mine was subject to MMERs)

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Appendix B

Water and Sediment Quality CREMP

Appendix B

Water and Sediment Quality CREMP

BAFFINLAND IRON MINES CORPORATION
MARY RIVER PROJECT

WATER AND SEDIMENT QUALITY REVIEW AND CREMP STUDY DESIGN

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NB102-181/33-1
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June 25, 2014

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BAFFINLAND IRON MINES CORPORATION
MARY RIVER PROJECT

WATER AND SEDIMENT QUALITY REVIEW AND CREMP STUDY DESIGN
NB102-181/33-1

Rev	Description	Date	Approved
2	Minor Updates to Sections 2.7.8 and 3.6.8	June 25, 2014	[signature]
1	Revised Study Design to Align with freshwater biota CREMP	May 30, 2014	RAM
0	Issued in Final	March 28, 2014	RAM

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EXECUTIVE SUMMARY

Introduction

Baffinland Iron Mines Corporation (Baffinland) has conducted water and sediment quality baseline studies on the Mary River Project since 2005. This work has been completed in support of an environmental review by the Nunavut Impact Review Board (NIRB) and water licensing by the Nunavut Water Board (NWB). The Project was approved by the NIRB on December 28, 2012 (with the issuance of Project Certificate No. 005) and the NWB issued Type A Water Licence No. 2AM-MRY1325 to Baffinland on July 24, 2013. Baffinland initiated construction of the mine in the summer of 2013.

Baffinland initiated the development of an Aquatic Effects Monitoring Program (AEMP) with the development of an AEMP Framework (Baffinland, 2013a) and an updated AEMP Framework (Baffinland 2013b). A detailed AEMP Plan has been under preparation and will be submitted to the NWB prior to initiating mining in the second half of 2014.

A component study of the AEMP will be a Core Receiving Environment Monitoring Program (CREMP). The CREMP is a detailed aquatics monitoring program that is intended to complement and expand the scope of the Environmental Effects Monitoring (EEM) Program that is required under the Metal Mining Effluent Regulations (MMER). The CREMP is intended to monitor the effects of multiple stressors on the aquatic environment, including the discharge of mine effluents, the discharge of treated sewage effluent and the deposition of ore dust. The CREMP will include the monitoring of water, sediment, phytoplankton, benthic invertebrates and fish in the Project's mine site streams and lakes. Knight Piésold has prepared this baseline review and CREMP study design for the water and sediment components of the aquatic environment, in consultation with North/South Consultants Inc. who have led the freshwater biota aspects of the work and Intrinsik Inc. who have provided toxicological support in the development of the AEMP benchmarks that the monitoring results will be compared against.

A review of water and sediment quality data was undertaken to:

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

Previous Site Activities

Baffinland has been actively undertaking mineral exploration, bulk sampling and feasibility level studies at the Project site since 2004. These activities have had the potential to affect the water and sediment in the mine site area. Based on our review, limited evidence of effects from exploration activities are apparent.

Review of Baseline Water Quality

The collection of baseline water quality data began in 2005 and was carried through to 2013. Work was completed each year; although only a few samples were collected during 2009 and 2010. As such, there is about 7 to 8 years of baseline data available for the Project. To ensure consistency, all the field work was undertaken by the same small group of individuals.

Streams were typically sampled once in the spring (June), summer (July) and fall (late August/early September). The timing of spring sampling was dependent on the onset of freshet and fall sampling was carried out before the streams ran dry or froze (typically in the second half of September to early October).

Lake water quality/limnology was studied in 2006, 2007, 2008, 2011, 2012 and 2013, but not all lakes were studied in all years. Open lake water quality samples were typically collected during the fall (late August or early September). Winter sampling was carried out in select years at the mine site lakes (Camp, David, Mary and Sheardown Lakes), with sampling carried out typically in late April. Sheardown Lake has been the most studied in the area, since the lake was the receiving water for treated sewage during the open season in 2009, 2011, 2012 and 2013. Lake water quality samples were collected from both shallow depths (1 m below the waterline) and deep depths (approximately 1 m above the lake bottom).

Various graphical analysis tools were utilized to characterize the baseline water quality within the mine site area, with reference to the Canadian Council of Ministers of the Environment's Canadian Water Quality Guidelines for the Protection of Freshwater Aquatic Life (CWQG-PAL). The following lentic and lotic systems were examined: Mary River, Camp Lake Tributary, Camp Lake, Mary River and Sheardown Lake. In general, all lakes are well mixed and did not show concentration differences with depth, noting the exception of aluminum and chromium. In addition, general chemistry characteristics of the lakes and river site-wide are very similar. Within the Project area, water is characterized as circum-neutral/slightly alkaline pH and high alkalinity/low sensitivity to acidic inputs. Hardness ranges from "soft" to "moderately soft" and is almost entirely carbonate hardness. Seasonal analyses of general chemistry parameters within Mary River show a relationship between spring freshet and hardness, pH, TSS and DOC. TSS does not show distinct trends. Both pH and hardness tend to be slightly lower during spring and increase during summer, to a maximum concentration recorded in the fall. DOC is at its peak during spring and decreases substantially during summer and fall.

Site-wide, nitrate, arsenic and cadmium generally occur at detection limit, with the exception of one site in each river system that has elevated concentrations of both arsenic and cadmium (E0-02 in Mary River and L1-02 in the Camp Lake Tributary) and Mary Lake, which also has elevated concentrations of arsenic and cadmium. Due to detection limit interference, it is difficult to discern temporal and seasonal trends for these parameters.

Iron, aluminum, chromium and copper are observed to be elevated within Mary River and Camp Lake Tributary. Concentrations of these parameters are generally considerably lower in the identified lakes; however, copper remains slightly elevated in all lakes. Aluminum concentrations are slightly elevated, and close to guidelines within Mary Lake and Sheardown Lake SE. The inlets to

Mary Lake see increased concentrations of a number of metals, compared to other stations, but these concentrations generally remain below applicable guidelines. Site-wide, nickel concentrations are quite low. Site-wide, iron concentrations are slightly enriched, but always occur below guidelines.

Iron concentrations are at their peak site-wide during the summer, although elevated concentrations were noted in the Camp Lake Tributary during the spring. Iron concentrations reduce slightly, but remain elevated during the fall. Stream water quality stations consistently depict concentrations in excess of lake water quality stations.

With the exception of one large outlying value for nickel, there are relatively conserved concentrations for nickel are observed throughout the site, during different seasons. There are slightly lower nickel concentrations in the spring; however, a small sample size is also observed.

Copper concentrations increase slightly during the summer and remain slightly elevated during the fall. Some particularly high copper values have been recorded in Camp Lake, which has maximum values that exceed those observed in Mary River.

Stream aluminum concentrations are depressed in the spring, and elevated in the summer. Stream concentrations, particularly those recorded in Mary River are greater than the concentrations recorded in the lakes. Fall concentrations are elevated, when compared to fall and winter, but are less than those concentrations recorded in the summer.

Power Analysis of Water Quality

An initial power analysis was run using a paired Before-After-Control-Impact (BACI) design for each station. The goal was to assess the statistical power of various sample sizes for detecting site-specific change. The power analysis attempted to use a basic BACI design with one impact station and one control station before and after commencement of mining activity. This method was modified in two ways for water quality data: 1) in the absence of pre-mining reference data, only a Control-Impact (CI) assessment was completed, and 2) for parameters with a large amount of data below detection limits, a comparison of proportions was used.

Power analysis was completed for a subset of parameters in select areas within Camp Lake, Sheardown Lake NW, Sheardown Lake SE, Mary Lake, Mary River and Camp Lake Tributary. Key stations were selected, which often corresponded with the EEM near-field and far-field stations. Parameters that were elevated in baseline sampling and expected to be most affected during mine operation were selected to provide conservative representations of other measured parameters. Benchmarks values for water quality developed for the Project (CWQG-PAL or other; Intrinsik, 2014) were applied in the power analysis. Power analysis was completed based on all the existing data, and is expected to be revisited after completion of additional baseline sampling in 2014. The 2014 baseline sampling will occur concurrently with construction, but prior to mine-related effluent or ore dust emissions. To be conservative when creating the study design, a second effect size was added to act as an early warning flag. The second effect size was determined to be halfway between the station mean and the benchmark value.

Water Quality Study Design

The power analysis supported a monitoring program that uses the existing baseline stations, and recommended the addition of the following stations:

- Two stations within the basin at the north arm of Mary Lake, near BL0-01 (stations BL0-01-A and BL0-01-B)
- Two additional stations within the main basin of Mary Lake, near the Mary River inlet near BL0-05 (BL0-05-A and BL0-05-B)
- Sampling of an additional station within Sheardown Lake SE (existing station DL0-02-6)
- Addition of a station in vicinity of L1-09, location to be determined (L1-05)
- Addition of one or two reference stations upstream on Mary River (G0-09-A, G0-09-B)
- Sampling of identified reference lakes, consistent with EEM program

The following sampling frequencies are recommended for each of the different programs:

- Lakes - three sampling events in each available season (winter, summer and fall) during the first three years of mine operation are expected to have adequate power to detect early warning flag concentrations for lake data.
- Streams - four samples (one set of seasonal samples) per year is likely adequate for most parameters to determine significance.

Sampling will be conducted annually during the initial years of operation but sampling frequency will be evaluated regularly (i.e., each year) to determine if modifications are warranted. The sampling frequency and schedule will be evaluated after three years of monitoring.

Review of Sediment Quality

The collection of baseline sediment quality samples for the Project was carried out between 2005 and 2008 and between 2011 and 2013 in conjunction with the water quality baseline program. Sampling of sediment in streams and lakes around the mine site was typically conducted once in the fall (late August/early September) in conjunction with and at the same stations as the water quality and benthic invertebrate sampling.

Metals concentrations in sediment are positively correlated with both finer grained particles as well as higher organic carbon content (Horowitz, 1991). Smaller particles have more binding sites and a higher affinity for metals than coarser grained material. Organic carbon within sediment decreases the dissolved oxygen and creates a more anoxic environment. Depending on pH, an anoxic environment may influence metal solubility and speciation. Within depositional areas of the lake that are characterized by higher concentrations of TOC and/or greater proportions of fine grained sediment, concentrations of several metals regularly exceeded the CSQG-PAL ISQGs or the PSQG-LEL. This includes chromium, copper, iron, nickel and phosphorus, and sometimes arsenic. Iron and manganese in some instances exceeded the PSQG-SEL. Most metals correlated well; in samples where one of the metals was elevated, all others were also elevated, except arsenic and manganese.

At the mine site, depositional environments were predominantly found within the lakes. The main exception to this is the stations within the main tributary of Sheardown Lake (Tributary 1). Streams at the mine site are mostly high gradient, high energy depositional environments that are not likely to have substantial amounts of fine grained sediment or sediment with high organic carbon content.

Power Analysis of Sediment Quality

After an initial exploratory analysis of the sediment baseline data, fifty-two (52) samples were retained that fit cut-off criteria established for TOC and percent sand. Sufficient power to detect a change from baseline values was desired for each station. Baseline data not collected at reference stations and therefore, since baseline reference (control) data not available, a full BACI design was not used for the power analysis. Instead, a before-after (BA) design was used. The power analysis was carried out using a two sample t-test which assumes independence between the before and after samples. Interim area-wide benchmarks for sediment quality developed for the Project (CSQG-PAL, PSQG or other; Intrinsik, 2014) were applied in the power analysis.

After consideration of the inclusion criteria, six to twenty samples were recorded within each of the depositional area lake sampling locations. An additional year of comprehensive sediment sampling within the mine site lakes in 2014 is recommended to supplement this dataset and provide a better basis for refined power analysis.

Instead of using highly variable estimates of station means from the limited baseline data, a generic analysis was used. Power to detect a change from a baseline mean to 97.5th percentiles for a normally distributed variable was used to obtain sample size estimates which apply to all stations and metals. This analysis will be refined for specific stations and metals after 2014 samples are collected and benchmarks have been finalized.

Sediment Quality Study Design

The review of sediment quality baseline identified the need for additional sediment quality stations in the mine site lakes. Additional stations were identified in each lake, corresponding with proposed benthic invertebrate monitoring stations to be monitored under the freshwater biota CREMP (North/South, 2014).

Preliminary sediment sampling locations in each of Camp Lake, Sheardown Lake and Camp Lake are shown on Figures 3.9, 3.10 and 3.11, respectively, and are listed in Table 3.7. The lake sediment stations make use of existing and new (proposed) stations as follows:

- Camp Lake - 14 stations including three historic stations and 11 new stations
- Sheardown Lake NW - 14 stations including six historic stations and eight new stations
- Sheardown Lake SE - 10 stations including four historic stations and six new stations
- Mary Lake - 15 stations including five historic stations and 10 new stations

Lake sediment samples will be collected along transects positioned along the anticipated path of effluent (i.e., direction of inflow stream). At each station, field technicians will establish final locations for the sediment stations that are within depositional areas of the lake. This field fit of the sampling stations will likely result in some modifications to the gradient study design.

Limited stream sediment sampling is proposed for the reasons described in Section 3.5. Select existing stream sediment sampling stations will continue to be monitored as described below (see Figures 3.9, 3.10 and 3.11):

- Four sediment stations within Sheardown Tributary 1 (SDLT-1), a portion of which meet the TOC and % sand cut-offs (SDLT1-R1, D1-01, D1-05, and SDLT1-R4)
- One sediment station in each of Sheardown Tributaries 9, 12 and 13 (SDLT-9-US, SDLT-12-US, SDLT-12-DS), none of which meet the TOC and % sand cut-offs
- Three sediment stations within Camp Lake Tributaries 1 and 2 (CLT-1 and CLT-2) which do not meet the TOC and % sand cut-offs but are the lowest energy stations available (CLT-1-US, CLT-1-DS, CLT-2-DS)
- Two sediment stations on the Mary River, downstream of effluent discharges where sediment collection is possible (E0-20 and C0-05)

Additional pre-mining sediment sampling will be carried out in 2014 to increase the number of baseline sediment samples for comparison in future monitoring. It will be necessary to identify additional stations in depositional areas characterized by high TOC and fines content (or lower sand content), as the depositional areas are more sensitive to change.

In the long-term, sediment sampling under the CREMP will be conducted every three years, coinciding with biological monitoring studies. However, Baffinland will conduct sediment sampling in 2014 to collect additional pre-mining baseline data, and then annually for the first three years of mining. After monitoring three operating (mining) years, the sampling frequency will be conducted on a three year cycle provided annual sampling up to that time supports this change.

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APPENDICES

1 – INTRODUCTION

1.1 BACKGROUND

Baffinland Iron Mines Corporation (Baffinland) has conducted water and sediment quality baseline studies at the Mary River Project since 2005. This work has been completed in support of an environmental review by the Nunavut Impact Review Board (NIRB) and water licensing by the Nunavut Water Board (NWB). The water and sediment quality baseline data were utilized to support the preparation of the Final Environmental Impact Statement (FEIS) submitted to NIRB in February 2012 (Baffinland, 2012). The Project was approved by the NIRB on December 28, 2012 (with the issuance of Project Certificate No. 005; NIRB, 2012) and the NWB issued Type A Water Licence No. 2AM-MRY1325 to Baffinland on July 24, 2013 (NWB, 2013). Baffinland initiated construction of the mine in the summer of 2013.

At this stage in the Project, attention is shifting from baseline data collection to the development and execution of monitoring programs. These programs include the development of the Aquatic Effects Monitoring Program (AEMP), which is a requirement of Baffinland`s Type A Water Licence. A draft AEMP Framework was issued to the NWB and other regulators on February 26, 2013 (Baffinland, 2013a) and an updated draft AEMP Framework was distributed on December 1, 2013 (Baffinland, 2013b). A final detailed AEMP is under development from the existing framework and will be submitted to the NWB prior to initiating the operations phase of the Project in 2014.

This document presents a review of water and sediment quality data and the development of a study design for the water and sediment components of a key monitoring program referred to as the Core Receiving Environment Monitoring Program (CREMP). The CREMP will be a component program of the AEMP.

1.2 SCOPE OF REVIEW AND STUDY DESIGN

The scope of the baseline review and study design for water and sediment quality monitoring was to:

- Identify data quality issues
- Determine whether or not mineral exploration and bulk sampling activities conducted since 2004 have affected water or sediment quality in the mine site area
- Understand the seasonal, depth (for lakes) and inter-annual variability of water quality
- Understand natural enrichment of the mine site area waters and sediment
- Determine the potential to pool data from multiple sample stations to increase the statistical power of the baseline water and sediment quality dataset
- Develop study designs for monitoring water and sediment quality in mine site streams and lakes, including an a priori power analysis[1]
- Determine if changes to the existing water and sediment quality monitoring program are required to meet monitoring objectives

[1] Power analysis can be used to calculate the minimum sample size required so that one can be reasonably likely to detect an effect of a given size. A power analysis completed before data are collected is an *a priori* or prospective power analysis. *A priori* power analysis is used in estimating sufficient sample sizes to achieve adequate power.

Parameters of interest in the baseline review included water quality stressors of potential concern (SOPCs) identified on the basis of the existence of an established water quality guideline, as well as other factors such as Exposure Toxicity Modifying Factors (ETMF): pH, water hardness, dissolved organic carbon, etc., and indicator parameters (alkalinity, chloride, nitrate). Baseline water quality data was compared to Canadian Council of Ministers of the Environment (CCME) - Canadian Water Quality Guidelines for the Protection of Freshwater Aquatic Life (CWQG-PAL). The focus was on total concentrations (versus dissolved) since CWQG-PAL guidelines are developed for total concentrations. The parameters of interest are displayed graphically in box plots. The box plots are used to portray natural ranges of selected parameters. Concentration data measured for the parameters of interest has been log transformed and further analyzed to investigate the possibility of aggregating data, bearing in mind:

- Seasonal variability (between spring, summer, fall and winter samples)
- Inter-annual variability (from 2006 through 2008 and 2011 through 2013)

To assist in the development of study designs, parameter and station-specific a priori power analyses were completed in order to determine the power of the proposed sampling program to detect statistical changes. As per the Assessment Approach and Response Framework (see Section 2.7.8), management action is triggered if the mean concentrations of any parameter at selected stations reach benchmark values. Benchmark values were developed for the identified SOPCs that consider aquatic toxicology, natural enrichment in the Project area, or low concentrations below MDLs (Intrinsik, 2014; see Section 2.7.3 of the main report). Draft benchmarks were applied in the power analysis of the baseline presented in this review.

The results of the above review were used to develop preliminary study designs for the ongoing monitoring of water quality (Section 2.7) and sediment quality (Section 3.6).

1.3 PROJECT ACTIVITIES DURING BASELINE DATA COLLECTION

Baffinland has been actively undertaking mineral exploration, bulk sampling and feasibility level studies at the Project site since 2004. These activities have had the potential to affect the water and sediment in the mine site area. A description of these activities follows.

Baffinland established a camp and initiated exploration drilling at Deposit No. 1 in 2004. Drilling programs were executed most years since 2004, and some exploration was undertaken at nearby Deposit Nos. 2 and 3. Historical drillhole locations are shown in relation to historical water quality sampling stations on Figure 1.1 (mine site area including Mary Lake) and Figure 1.2 (mine site core area). Historic sediment quality sampling stations are shown on Figure 1.3.

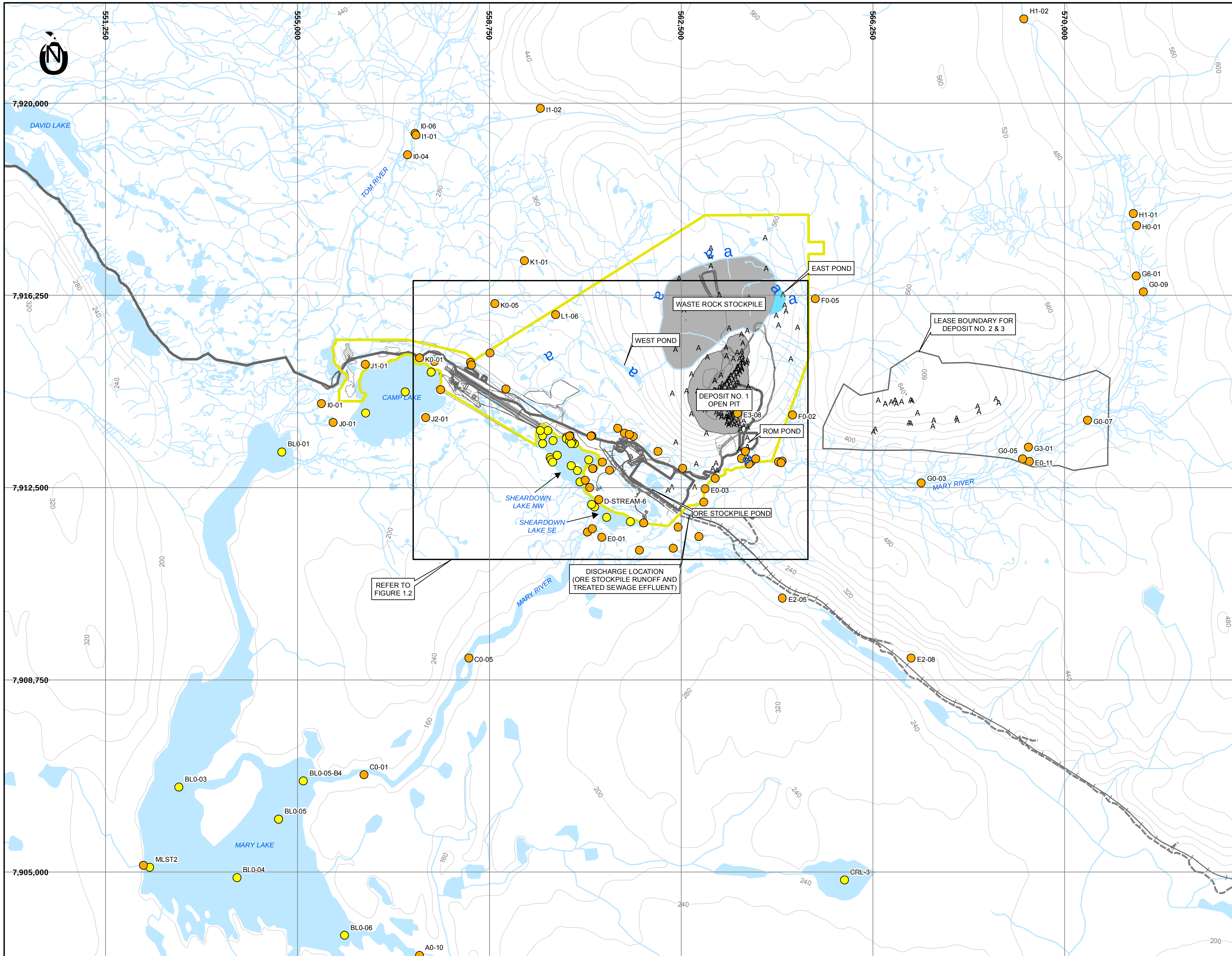
In 2007, Baffinland's operations and facilities were expanded to carry out a bulk sampling program and to accommodate expanded geotechnical investigations and environmental baseline studies. The exploration camp at the mine site was enlarged, the Milne Inlet Tote Road was upgraded, and small camps were established at Milne Port, Steensby Port and mid-way along the proposed railway alignment. With preparatory work completed in 2007, the bulk ore sample was mined in 2008. This included construction of a haul road to Deposit No. 1; mining of an 118,000 tonne bulk sample; crushing, screening and stockpiling of ore at the mine site; haulage of ore over the tote road; and stockpiling and ship loading the ore at Milne Port.

Between 2009 and the start of construction in 2013, site activities typically involved operating a summer camp to support ongoing exploration drilling at Deposits No. 1, 2 and 3; geotechnical investigations; and regional mineral exploration. A small contingent of care and maintenance staff maintained the camp and airstrip and monitored site conditions during the winter months.

The following historic activities have had the potential to affect local water and sediment quality:

- Exploration drilling on Deposits No. 1, 2 and 3 have involved the use of calcium chloride brine. Progressively sophisticated and effective measures were employed over the years to recycle and contain the brine. Monitoring of water quality in the Mary River downstream of Deposit No. 1 has confirmed that calcium chloride has reached the river.
- Treated sewage effluent has been discharged to Sheardown Lake during most open water seasons starting in 2009.
- The bulk sampling program in 2007 and 2008 involved various construction activities, the mining of the ore from the top of Deposit No. 1, as well as the crushing, stockpiling and transport of ore to Milne Port. The crushing activities resulted in the dispersion of dust in the vicinity of Sheardown Lake and its main tributary. Monitoring detected only minor changes to water and sediment quality potentially attributable to bulk sampling operations.

These activities were considered during the review of the baseline dataset.



LEGEND:

- LAKE SAMPLE LOCATION
- STREAM SAMPLE LOCATION
- A DRILLHOLE LOCATION
- EXISTING TOTE ROAD
- PROPOSED RAILWAY ALIGNMENT
- PROPOSED CONSTRUCTION ACCESS ROAD
- PROPOSED SITE INFRASTRUCTURE
- RIVER/STREAM/DRAINAGE
- WATER
- POTENTIAL DEVELOPMENT AREA (PDA)
- PROPOSED MINE INFRASTRUCTURE

NOTES:

1. BASE MAP: © HER MAJESTY THE QUEEN IN RIGHTS OF CANADA, DEPARTMENT OF NATURAL RESOURCES (2004). ALL RIGHTS RESERVED.
2. COORDINATE GRID IS IN METRES. COORDINATE SYSTEM: NAD 1983 UTM ZONE 17N.
3. CONTOURS ARE IN METRES. CONTOUR INTERVAL VARIES.
4. LAKE SAMPLE LOCATIONS VARY SLIGHTLY DURING WINTER MONTHS DUE TO ICE CONDITIONS.
5. INFRASTRUCTURE INFORMATION PROVIDED BY HATCH ON JANUARY 31, 2014.

SCALE 1 0.5 0 1 2 3 4 km

BAFFINLAND IRON MINES CORPORATION

MARY RIVER PROJECT

HISTORIC WATER QUALITY STATIONS MINE SITE AREA

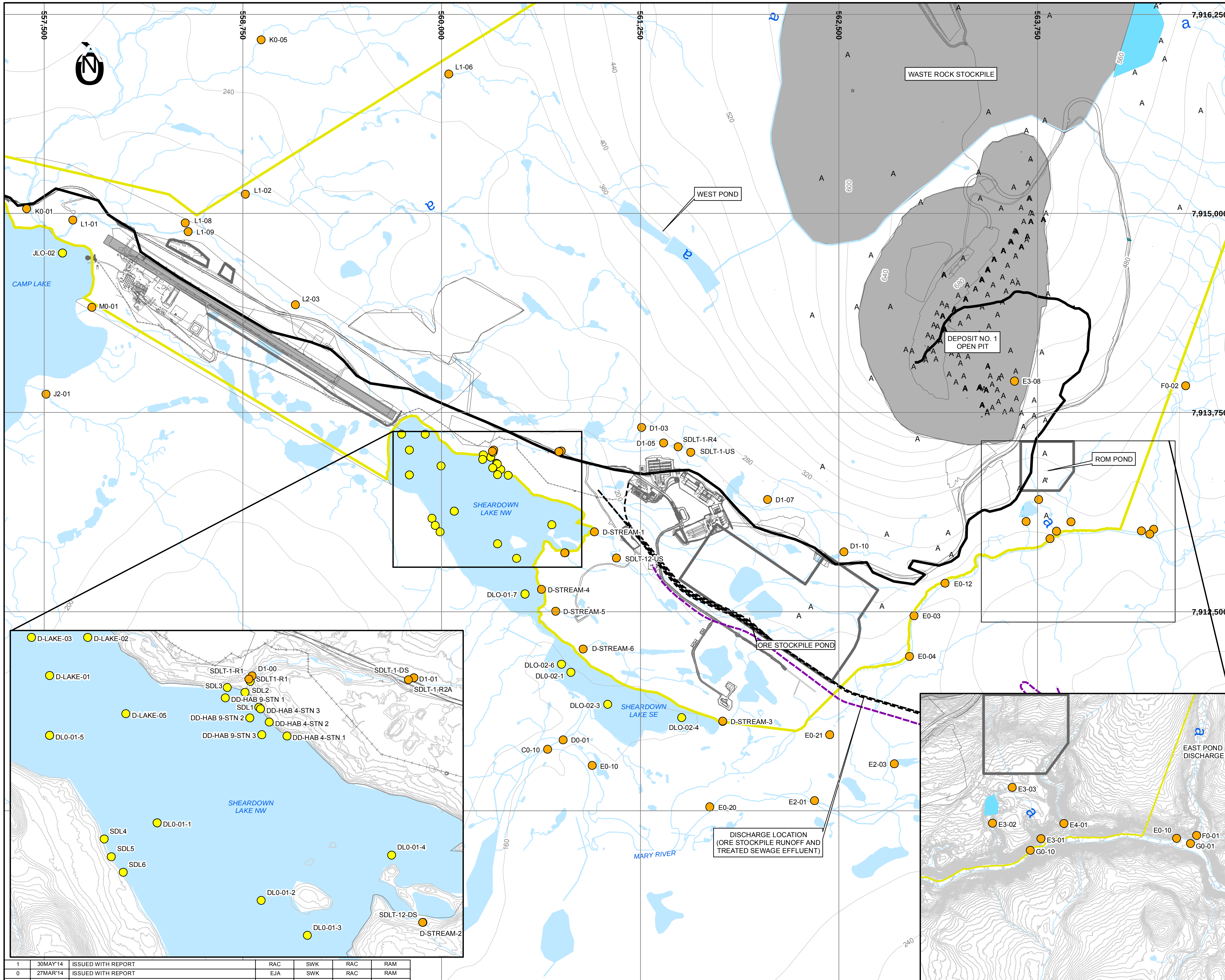
Knight Piésold CONSULTING

P/A NO.	REF NO.
NB102-181/33	1

FIGURE 1.1 REV 1

REV	DATE	DESCRIPTION	DESIGNED	DRAWN	CHK'D	APP'D
1	30MAY'14	ISSUED WITH REPORT	RAC	SWK	RAC	RAM
0	27MAR'14	ISSUED WITH REPORT	RAC	SWK	RAC	RAM

SAVED: I:\1\02\00181\33\A\GIS\Figs\B20_f1.mxd; Jun 26, 2014 4:19 PM; asimpson



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REV	DATE	DESCRIPTION	DESIGNED	DRAWN	CHK'D	APP'D
1	30MAY'14	ISSUED WITH REPORT	RAC	SWK	RAC	RAM
0	27MAR'14	ISSUED WITH REPORT	EJA	SWK	RAC	RAM

LEGEND:

- LAKE SAMPLE LOCATION
- STREAM SAMPLE LOCATION
- A DRILLHOLE LOCATION
- EXISTING TOTE ROAD
- PROPOSED RAILWAY ALIGNMENT
- PROPOSED CONSTRUCTION ACCESS ROAD
- PROPOSED SITE INFRASTRUCTURE
- RIVER/STREAM/DRAINAGE
- WATER
- POTENTIAL DEVELOPMENT AREA (PDA)
- PROPOSED MINE INFRASTRUCTURE

NOTES:

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2. COORDINATE GRID IS IN METRES. COORDINATE SYSTEM: NAD 1983 UTM ZONE 17N.
3. CONTOURS ARE IN METRES. CONTOUR INTERVAL VARIES.
4. LAKE SAMPLE LOCATIONS VARY SLIGHTLY DURING WINTER MONTHS DUE TO ICE CONDITIONS.
5. INFRASTRUCTURE INFORMATION PROVIDED BY HATCH ON JANUARY 31, 2014.

SCALE 250 125 0 250 500 750 1,000 1,250 m

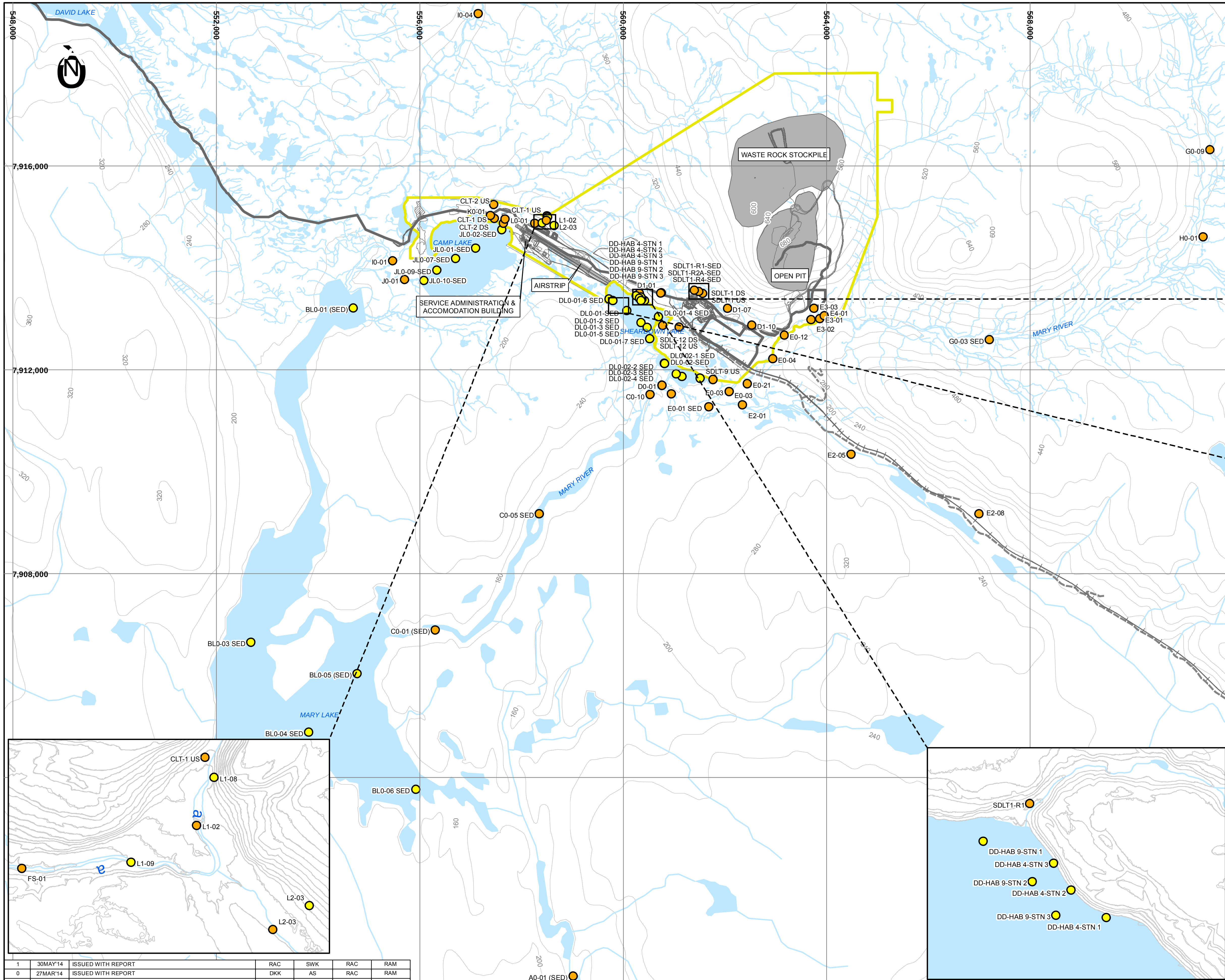
BAFFINLAND IRON MINES CORPORATION

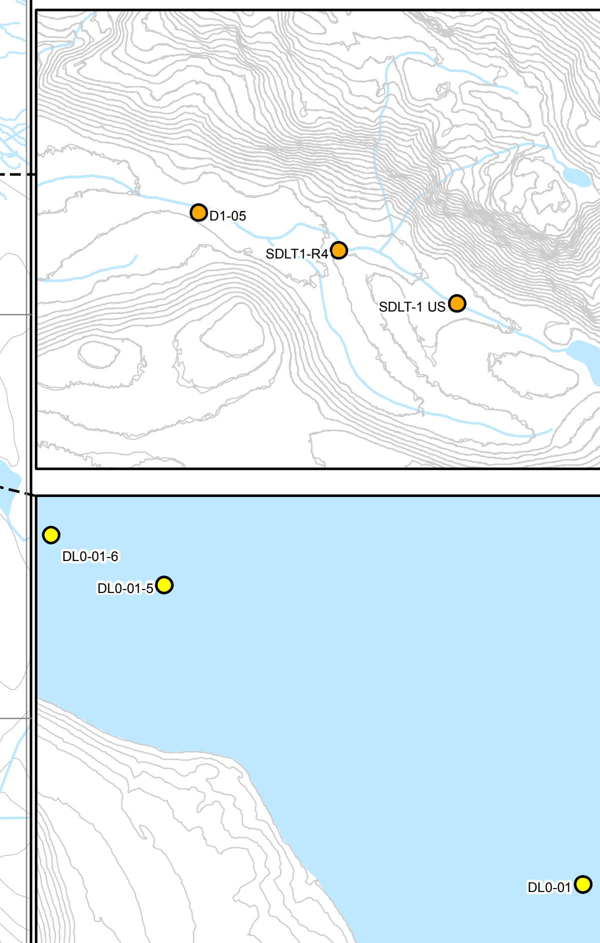
MARY RIVER PROJECT

HISTORIC WATER QUALITY STATIONS IMMEDIATE MINE SITE AREA

P/A NO.	REF NO.
NB102-181/33	1

FIGURE 1.2 REV 1





LEGEND:

- LAKE SAMPLE LOCATION
- STREAM SAMPLE LOCATION
- EXISTING TOTE ROAD
- PROPOSED RAILWAY ALIGNMENT
- PROPOSED CONSTRUCTION ACCESS ROAD
- PROPOSED SITE INFRASTRUCTURE
- RIVER/STREAM/DRAINAGE
- WATER
- POTENTIAL DEVELOPMENT AREA (PDA)
- PROPOSED MINE INFRASTRUCTURE

NOTES:

1. BASE MAP: © HER MAJESTY THE QUEEN IN RIGHTS OF CANADA, DEPARTMENT OF NATURAL RESOURCES (2004). ALL RIGHTS RESERVED.
2. COORDINATE GRID IS UTM NAD83 ZONE17.
3. CONTOUR ARE IN METRES. CONTOUR INTERVAL VARIES.
4. NOT ALL LOCATIONS WERE SAMPLED EVERY YEAR.
5. INFRASTRUCTURE INFORMATION PROVIDED BY HATCH ON JANUARY 31, 2014.

SCALE 1 0.5 0 1 2 3 4 km

BAFFINLAND IRON MINES CORPORATION

MARY RIVER PROJECT

HISTORIC SEDIMENT QUALITY STATIONS MINE SITE AREA

Knight Piésold CONSULTING

P/A NO.	REF NO.
NB102-181/33	1

FIGURE 1.3 REV 1

REV	DATE	DESCRIPTION	DESIGNED	DRAWN	CHK'D	APP'D
1	30MAY'14	ISSUED WITH REPORT	RAC	SWK	RAC	RAM
0	27MAR'14	ISSUED WITH REPORT	DKK	AS	RAC	RAM

SAVED: I:\1\02\00181\33\A\GIS\Figs\B27_r1.mxd; Jun 26, 2014 4:23 PM; asimpson

2 – WATER QUALITY REVIEW

2.1 SUMMARY OF WATER QUALITY PROGRAM

The collection of baseline water quality data began in 2005 and was carried through to 2013. Work was completed each year; however, a very limited number of samples were collected during 2009 and 2010 when the global financial crisis reduced Baffinland's project activities. As such, about 7 to 8 years of baseline data are available for the Project.

Results of the various studies are presented in a number of baseline reports prepared over the years (KP, 2007, 2008, 2010a, 2010b, 2011 and 2012; North/South Consultants Inc., 2008). Water quality data collected in 2012 and 2013 were not previously reported upon but are included within this review.

Sampling and analytical methods, and quality assurance/ quality control (QA/QC) procedures applied during the sampling period are described in the referenced baseline reports. Current sampling methods are described in Appendix A. To ensure consistency, the field work was undertaken by the same small group of individuals.

Historic water quality stations in the mine site area are shown on Figures 1.1 and 1.2. Streams were typically sampled once in the spring (June), summer (July) and fall (late August/early September). The timing of spring sampling was dependent on the onset of freshet and fall sampling was carried out before the streams ran dry or froze (typically in the second half of September to early October). The stream sampling history is presented in Table 2.1.

Lake water quality/limnology was studied in 2006, 2007, 2008, 2011, 2012 and 2013, but not all lakes were studied in all years (Table 2.2). Open lake water quality samples were typically collected during the fall (late August or early September). Winter sampling was carried out in select years at the mine site lakes (Camp, David, Mary and Sheardown Lakes), with sampling carried out typically in late April. Sheardown Lake has been the most studied in the area, since the lake was the receiving water for treated sewage during the open season in 2009, 2011, 2012 and 2013.

Table 2.1 Timing of Stream Water Quality Sampling

Year	Winter	Spring	Summer	Fall
2005	No sampling	June 9 - 11	August 9 - 12	September 9 - 11
2006	No sampling	June 18 - 26	July 2 - 30; Aug 6 - 14	Aug 20 - Sept 20
2007	No sampling	June 13 - 24	July 1 - 28; August 5 - 12	Aug 19 - 31; Sept 2 - 30
2008	No sampling	June 9 - 24	July 1 - 21; August 1 - 11	Aug 18 - Sept 16
2009	No sampling	June 29	July 6 - 20	Aug 9 - 18; Sept 2 - 14
2010	No sampling	No sampling	No sampling	Aug 13; Sept 15
2011	No sampling	No sampling	July 21 - 26	Aug 28 - Sept 1
2012	No sampling	June 18 - 23	July 22 - 24	Aug 24 - 31
2013	No sampling	June 21 - 23	July 23 - 25	Aug 20 - Sept 3

NOTES:
1. WINTER SAMPLING OCCURRED DURING APRIL AND MAY; SPRING SAMPLING OCCURRED DURING JUNE; SUMMER SAMPLING OCCURRED FROM JULY TO AUGUST 17; FALL SAMPLING OCCURRED FROM AUGUST 18 THROUGH SEPTEMBER 30.
2. DUE TO NO FLOW, NO SAMPLING OF STREAMS OCCURRED DURING THE WINTER.
3. DURING 2009 AND 2010 VERY LIMITED SAMPLING OCCURRED ONLY WITHIN MARY RIVER.

Table 2.2 Timing of Lake Water Quality Sampling

Year	Winter (Lakes)	Spring	Summer	Fall
2005	No sampling	No sampling	No Sampling	No sampling
2006	No sampling	No sampling	July 31 - Aug 2	Aug 31 - Sept 6
2007	May 6 - 8	No sampling	Aug 5 - Aug 14	Aug 13 - 20; Sept 13 - 20
2008	May 11	June 25	July 30 - 31; Aug 5 - 7	Sept 2 -14
2009	No sampling	No sampling		
2010	No sampling	No sampling		
2011	No sampling	No sampling	July 24 - 26	Sept 2 - 6
2012	April 27 - 28	No sampling	No sampling	Aug 21 - 26
2013	May 2 - 5	No sampling	July 25 - 28	Aug 24 - Sept 1

NOTES:
1. WINTER SAMPLING OCCURRED DURING APRIL AND MAY; SPRING SAMPLING OCCURRED DURING JUNE; SUMMER SAMPLING OCCURRED FROM JULY TO AUGUST 17; FALL SAMPLING OCCURRED FROM AUGUST 18 THROUGH SEPTEMBER 30TH.
2. LAKE SAMPLING GENERALLY DID NOT OCCUR DURING SPRING, DUE TO SAFETY CONCERNS OF SAMPLING OVER MELTING ICE, WITH THE EXCEPTION OF ONE SAMPLING EVENT IN 2008.
3. NO SAMPLING OCCURRED DURING 2009 AND 2010.

2.2 REVIEW OF WATER QUALITY DETECTION LIMITS

Method detection limits (MDLs; also referred to as Method Recording Limits - MRLs or Limits of Quantification - LOQs) have changed for a number of water quality parameters since baseline sampling was initiated in 2005. These changes are primarily due to improvements in laboratory instrumentation. The MDLs for key parameters are presented in Table 2.3.

Baffinland is interested in utilizing its existing baseline dataset to the maximum extent possible. The objective is to reduce the number of sampling events that would be required to detect a statistical change during project monitoring. Power analyses can be used to calculate the minimum sample size needed to reasonably detect an effect of a given size. The statistical power needed to detect change during future monitoring is a function of the number of sampling events and the spread in the results.

A number of parameters, particularly metals, are present in the water quality dataset at low concentrations (below their MDLs). For several parameters, the dataset contained different detection limits over the sampling period due to improvements in analytical laboratory tools. As such, the dataset contains a high proportion of non-detects at various MDLs.

In the interest of utilizing as many results as possible to increase the statistical power of the dataset, the baseline dataset was plotted in relation to the MDL(s) for each metal parameter. An example plot for silver is presented as Figure 2.1. Plots of this type provide a visual representation of the various MDLs and their influence on the dataset.

From review of the statistics (i.e., number and percent detects), the following actions were taken:

- For those parameters in which at least 85% of the water quality dataset was below detect limits even at the lowest MDL, the lower MDL number was adopted and replaced the higher MDL non-detect results.
- For those parameters in which less than 85% of the water quality dataset was non-detect (or conversely, more than 15% of the dataset was measured at detectable concentrations), a replacement of the lower MDL was not undertaken. Instead, the non-detect results at the higher MDL(s) were removed from the dataset. While these deletions reduce the potential statistical power of the dataset, the higher MDL non-detect results will skew the baseline results if they are left in the dataset.

Table 2.3 summarizes the yearly detection limits for each of the parameters along with any MDL adjustments that were undertaken. The MDL assessment successfully removed the occurrence of most historically elevated MDLs. In instances where 15% of the data were detectable, and below an MDL, the non-detect values at the elevated MDL were removed. In some cases, more than one MDL remained below detectable concentrations. In these instances, the MDLs were kept as is. For this reason, it is still possible to locate multiple detection limits within the data. As discussed, these lower valued MDLs are not expected to interfere with data analysis.

Knight Piésold CONSULTING

TABLE 2.3

BAFFINLAND IRON MINES CORPORATION
MARY RIVER PROJECT

WATER AND SEDIMENT QUALITY REVIEW AND PRELIMINARY CREMP STUDY DESIGN
REVIEW OF WATER QUALITY METHOD DETECTION LIMITS

Print Apr/01/14 11:25:12

Parameters	Units	Receiving Water Quality Objectives (2012)	Method Detection Limits							% Detects in the Dataset	MDL Changes to the Dataset
			2005	2006	2007	2008	2011	2012	2013		
General Parameters											
Alkalinity	mg/L CaCO3	-	2	5	5	5	5	5	5	Not reviewed	No changes
Br-	mg/L	-	0.3	0.05	0.05	0.05	0.25	0.25	0.25		
Cl-	mg/L	120	0.2	1	1	1	1	1	1		
Conductivity	uS/cm	-	1	5	5	5	5	5	5		
NH3+NH4	mg/L N	0.021-2313	0.1	0.02	0.02	0.02	0.02	0.02	0.02		
NO2-	mg/L N	0.06	0.06	0.005	0.005	0.005	0.1	0.005	0.005		
NO3-	mg/L N	13	0.05	0.1	0.1	0.1	0.1	0.1	0.1		
NO2+NO3	mg/L N	-	0.06	0.1	0.1	0.1	0.1	0.1	0.1		
Phenols	mg/L	0.004	0.001	0.001	0.001	0.001	0.001	0.001	0.001		
Chlorophyll-a	mg/m3	-					0.2				
Pheophytin-a	mg/m3	-					0.2				
SO4-	mg/L	-	0.5	1	1	1	1	3	3		
TKN	mg/L	-			0.1	0.1	0.1	0.1	0.1		
TOC	mg/L	-			0.5	0.5	0.5	0.5	0.5		
DOC	mg/L	-			0.5	0.5	0.5	0.5	0.5		
TSS	mg/L	-			2	2	2	2	2		
TDS	mg/L	-	30	5	5	5	1	1	1		
Hardness	mg/L CaCO3	-	0.5	1	1	0.5	0.5	0.5	0.5		
Phosphorus	Total	-	0.02	0.01	0.003	0.003	0.003	0.003	0.003		
Turbidity	NTU	-	0.1	0.1	0.1	0.1	0.1	0.1	0.1		
Total and Dissolved Metals											
Aluminum	mg/L	0.94	0.004	0.005	0.001	0.001	0.003	0.003	0.003	93%	
Antimony	mg/L	-	0.0004	-	0.0001	0.0001	0.0001	0.0001	0.0001	0%	
Arsenic	mg/L	0.005	0.005	0.001	0.0001	0.0001	0.0001	0.0001	0.0001	5%	Non-detects at 0.005 and 0.001 were revised to <0.0001
Barium	mg/L	-	0.01	0.01	0.00005	0.00005	0.00005	0.00005	0.00005	68%	
Beryllium	mg/L	-	0.005	-	0.0005	0.0005	0.0005	0.0001	0.00002	0%	
Bismuth	mg/L	-	0.0003	-	0.0005	0.0005	0.0005	0.0005	0.0005	0%	
Boron	mg/L	1.5	0.05	0.01	0.01	0.01	0.01	0.01	0.01	5%	
Cadmium	mg/L	0.000029	0.0001	0.0001	0.000017	0.000010	0.00001	0.00001	0.00001	8%	Non-detects at 0.0001 were revised to <0.00001
Calcium	mg/L	-	0.05	1	0.05	0.05	0.05	0.05	0.05		
Chromium	mg/L	0.0047	0.001	0.001	0.0005 0.001	0.0005	0.0005 0.001	0.0001	0.0001	16%	Non-detects from 2005 through 2011 were revised to <0.0001
(Hexavalent) Chromium	mg/L							0.001	0.001		
(Trivalent) Chromium	mg/L							0.005	0.005		
Cobalt	mg/L	-	0.0003	0.0002	0.0001	0.0001	0.0001	0.0001	0.0001	12%	
Copper	mg/L	0.002	0.0008	0.001	0.0001 0.001	0.0001	0.0005	0.0005	0.0005	72%	Non-detects at 0.001 were removed from the dataset
Iron	mg/L	0.3	0.02	0.03	0.03	0.03	0.03	0.01	0.01	64%	
Lead	mg/L	0.001	0.0002	0.001	0.00005	0.00005	0.00005	0.00005	0.00005		Non-detects at 0.001 were removed from the dataset
Lithium	mg/L	-	-	-	0.005	0.005	0.005	0.0005	0.0005	4%	
Magnesium	mg/L	-	0.005	1	0.1	0.1	0.1	0.1	0.1	100%	
Manganese	mg/L	-	0.0007	0.01	0.00005 0.01	0.00005	0.00005	0.00005	0.00005	62%	Non-detects at 0.01 were removed from the dataset
Mercury	mg/L	0.000026	0.0001	0.00005	0.00005	0.00001	0.00001	0.00001	0.00001	1%	Non-detects at 0.0001 and 0.00005 were revised to <0.00001
Molybdenum	mg/L	0.073	0.0003	0.005	0.00005 0.005	0.00005	0.00005 0.005	0.00005	0.00005	55%	Non-detects at 0.005 were removed from the dataset
Nickel	mg/L	0.083	0.001	0.005	0.0005	0.0005	0.0005	0.0005	0.0005	42%	Non-detects at 0.001 and 0.005 were removed from the dataset
Potassium	mg/L	-	0.02	0.01	2	0.05	0.05	0.05	0.05	48%	
Selenium	mg/L	0.001	0.005	0.001	0.001	0.001	0.001			1%	Non-detects at <0.001 and <0.005 were revised to <0.0001
Silicon	mg/L	-	-	-	0.05	0.05	0.05	0.05	0.05	99%	
Silver	mg/L	0.0001	0.0001	0.0001	0.00001 0.00005 0.00001	0.00001	0.000001	0.000001	0.000001	3%	Non-detects at 0.001 and 0.00005 revised to <0.000001
Sodium	mg/L	-	0.05	0.05	2	0.05	0.0012	0.0012	0.0012	86%	
Strontium	mg/L	-	0.001	0.001	0.0001	0.0001	0.0001	0.0002	0.0002	100%	
Thallium	mg/L	0.0008	0.0002	-	0.0001	0.0001	0.0001	0.00001	0.00001	0%	
Tin	mg/L	-	0.001	0.01	0.0001	0.0001	0.0001	0.0001	0.0001	10%	
Titanium	mg/L	-	0.003	-	0.01	0.01	0.01	0.01	0.01	20%	
Uranium	mg/L	0.015	-	-	0.00001	0.00001	0.00001	0.00001	0.00001	98%	
Vanadium	mg/L	0.006	0.0009	0.001	0.001	0.001	0.001	0.001	0.001	8%	
Zinc	mg/L	0.03	0.001	0.01	0.001	0.001	0.003	0.003	0.003	22%	Non-detects at 0.01 were removed from the dataset

I:\1\02\00181\33\A\Report\Report 1 - Baseline WQ Review and CREMP Design\Rev 0\Tables\[Table 2.3 MDL Review 140221 RAC.xlsx]NB Table

NOTES:

1. MDL VALUES MAY BE ELEVATED IN INDIVIDUAL SAMPLES DUE TO SAMPLE MATRICES. THE MDL VALUES ABOVE REPRESENT THE NORMAL VALUE.
2. MULTIPLE MDL VALUES ARE NOTED FOR SEVERAL PARAMETERS IN 2007 DUE TO TWO LABORATORIES DOING METALS ANALYSIS FOR COMPARISON PURPOSES.

0	28MAR'14	ISSUED WITH REPORT NB102-181/33-1	MAS	RAC	RAM
REV	DATE	DESCRIPTION	PREP'D	CHK'D	APP'D

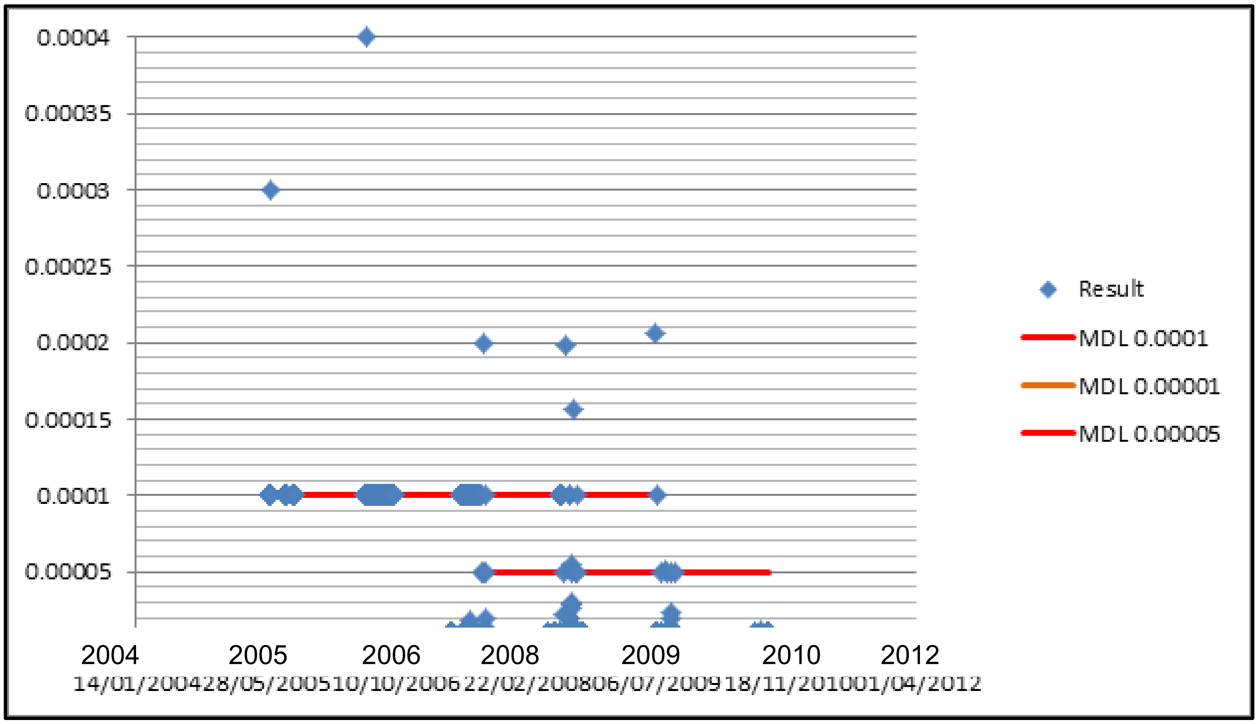


Figure 2.1 Example MDL Evaluation Graph - Silver

2.3 TREATMENT OF OUTLIERS

Once the non-detect results were modified or removed, the data were then plotted graphically and reviewed statistically in order to identify outliers. An outlier is an unusually extreme value for a variable, given the statistical model in use (Edwards, 1998). It is important to note that water quality data are among the environmental data that naturally produces extreme values. As such, outlier removal was only undertaken if there were a data entry error or if there was a quality assurance explanation that justified data removal.

2.4 WATER QUALITY PARAMETERS OF CONCERN

The parameters of concern are those metals predicted by water quality modeling to be of most concern during mine operation, and those that are currently enriched naturally. These parameters are the focus on the baseline review and include:

- Aluminum
- Arsenic
- Cadmium
- Chloride
- Chromium
- Copper
- Iron

- Nitrate
- Nickel

Aluminum, copper, iron and nickel were found to be naturally enriched in the Project Area, relative to the Water Quality Guidelines. Other parameters that have the potential to be elevated, but at a lower magnitude, due to mine site releases include the following (these parameters were not a focus of the baseline review):

- Cobalt
- Lead
- Phosphorous
- Silver
- Thallium

Not surprisingly, several of the above parameters were found to be naturally elevated in the vicinity of the mine site. In several watercourses, the mean concentrations of the above parameters occasionally exceeded the generic criteria of the Canadian Environmental Quality Guidelines for the protection of freshwater aquatic life (CWQG-PAL). As such, interim site-specific water quality objectives (SSWQOs) were initially developed by Knight Piésold (2012b) during review of the FEIS.

These Interim SSWQOs and the generic CWQG-PAL criteria are referred to in the following discussions for the above parameters.

2.5 GRAPHICAL ANALYSIS OF WATER QUALITY DATA

A detailed review of water quality was undertaken using various graphical analysis tools to characterise the baseline water quality for waterbodies expected to be most influenced by mine operations. A detailed review of the mine site area lake and stream water quality is presented in Appendix B and Appendix C, respectively. The raw data for pH, hardness, alkalinity and parameters of interest are displayed graphically in box plots and scatter plots in these two appendices. A summary of the key findings of the reviews presented in Appendices B and C is presented in the following sub-sections.

2.5.1 Lake Water Quality

Lake water quality sampling was completed in the vicinity of the mine site at Camp Lake, Sheardown Lake and Mary Lake between 2006 and 2008 and between 2011 and 2013 (Figures 1.1 and 1.2). Lake water quality samples were collected from both shallow depths (1 m below the waterline) and deep depths (approximately 1 m above the lake bottom).

The lakes in the study area are typically ice covered between October and June. As such, most of the data was collected during the summer and fall, while the least amount of data were collected during the winter.

Table 2.4 summarizes the range and median values of the general water chemistry parameters selected for evaluation. The water chemistry is similar between the three mine site lakes and is generally slightly alkaline and soft with alkalinity values similar to hardness values, suggesting that the hardness is predominantly carbonate hardness.

Table 2.4 Concentrations of Select General Chemistry Parameters in Mine Site Lakes

Parameter	Camp Lake	Sheardown L. NW	Sheardown L. SE	Mary Lake
In Situ pH (pH)	6.93 - 8.23 (7.88)	6.76 - 8.33 (7.94)	6.41 - 8.32 (7.85)	6.71 - 8.55 (7.68)
Alkalinity (mg/L $CaCO_3$)	50 - 74 (60)	47 - 72 (57)	43 - 82 (50)	25 - 126 (38)
Hardness (mg/L)	50 - 77 (59.6)	43 - 77.9 (60.5)	16 - 82 (51.75)	24.9 - 137 (39.5)
Chloride (mg/L)	<1 - 4 (1)	<1 - 4 (3)	<1 - 5 (3)	<1 - 14 (2)
Nitrate (mg/L)	<0.10	<0.10 - 0.18 (0.10)	<0.10	<0.10

NOTES:
1. MEDIAN CONCENTRATIONS IN BRACKETS.

A summary of the trends observed during the review of water quality within the individual lakes follows.

2.5.1.1 Camp Lake

The trends observed in the Camp Lake baseline data included:

- Distinct depth trends are not observed for Camp Lake, which suggests that the lake is completely mixed through much of the year. Review of data above suggests aggregation of deep and shallow stations may be appropriate.
- Geographic trends between discrete sampling stations were not observed for any parameters.
- With the exception of chloride and chromium, parameters did not show any distinct inter-annual trends/variability over the six year sampling history. Chloride and chromium concentrations in Camp Lake measured from 2011 through 2013 are elevated compared to earlier samples from 2005 to 2010.
- Parameters with MDL interference and/or that do not show seasonal trends include: cadmium, chloride, arsenic, iron and nitrate.
- Parameters that have maximum concentrations occurring in the summer: nitrate and aluminum. This is likely as a result of the spring runoff period caused by rapid melt of winter snowpack.
- Parameters that have maximum concentrations occurring in the winter: copper and nickel. Most of this concentration occurs in a dissolved form, not as particulate.
- Parameters that have maximum concentrations occurring in the fall: chromium.

2.5.1.2 Sheardown Lake

Summary of trends observed during review of Sheardown Lake NW baseline data:

- Deeper sampling stations show slightly elevated concentrations of aluminum. Distinct depth trends are not observed for other parameters within Sheardown Lake, which suggests that lake is completely mixed throughout the year, despite winter ice. As a result, aggregation of deep and shallow stations is appropriate for all parameters except aluminum.
- Detection limits decreased over the course of sampling and this decrease is particularly apparent in the copper and iron concentration data.
- Little variability was observed between geographically distinct sampling stations.
- Parameters below MDLs and/or do not show any seasonal trends: arsenic, cadmium, chloride, chromium, copper, nitrate and iron.
- Parameters with highest concentration occurring in the fall: aluminum.

- Parameters with highest concentrations occurring in the winter: nickel. The majority of the elevated nickel and copper total concentrations are in predominantly dissolved form.

Summary of trends observed during review of Sheardown Lake SE baseline data:

- Distinct depth trends are not observed for any parameters within Sheardown Lake SE. This suggests that the lake is completely mixed throughout the year, despite winter ice.
- Elevated concentrations observed at DL0-02-4 compared to other stations: copper, iron and nickel.
- Early data (2007, 2008) appears elevated when compared to more recent data: copper and nickel.
- Parameters below MDLs and/or do not show any seasonal trends: nitrate, arsenic, cadmium, chromium and copper.
- Parameters with highest concentration occurring in the summer and/or fall: aluminum and iron.
- Parameters with highest concentrations occurring in the winter: chloride and nickel.

2.5.1.3 Mary Lake

Summary of trends observed during review of Mary Lake baseline water quality data:

- Distinct depth trends were not observed for any parameters within Mary Lake, which suggests complete mixing of the lake. As a result, both deep and shallow station data have been utilized to inform baseline trends in water quality.
- Inlet sampling shows elevated concentrations for certain parameters: aluminum, chloride, copper, iron, hardness, chromium and nickel.
- Parameters that occur below MDL or do not show seasonal trends include: cadmium, copper, nitrate, and chromium.
- Parameters with the highest concentrations in the summer include: aluminum and iron.
- Parameters with the highest concentration during the fall include: arsenic.
- Parameters with the highest concentration during the winter: chloride, nickel and cadmium.
- The overall trends in the lake baseline water quality data include:
- The only parameter with distinct depth trends is aluminum in Mary Lake. The rest of the data gathered at lake stations suggests aggregations of deep and shallow stations is appropriate.
- Mary Lake inlet sampling was the only station that showed variability between geographically distinct sampling stations. In particular, slightly elevated concentrations for aluminum, chloride, copper, iron, hardness, chromium and nickel were observed (although elevated, these concentrations were below guidelines). Outlet sample locations show elevated concentrations of arsenic.
- Aluminum was noted to have high summer concentrations at all stations, with the exception of Sheardown Lake NW where highest concentrations were recorded in the fall. This would be expected given the magnitude of the spring runoff that is caused by rapid melting of the winter snowpack.
- Arsenic, cadmium and nitrate (except for some slightly elevated fall concentrations) generally occurred below MDL and seasonal affects were difficult to discern.
- Chloride, iron and copper did not show conserved seasonality trends at most stations.

- Nickel was generally high during the winter, which was not necessarily expected. One possibility is that under-ice formation concentrates solutes at depth. However, this trend would be expected to occur for all parameters. Data indicates that nickel and copper were present predominately in their dissolved form during the winter, while other parameters were present predominately in particulate form.

2.5.2 Stream Water Quality

Since 2005, a variety of watercourses have been sampled as part of the baseline monitoring program. For the purposes of the CREMP, a subset of the baseline sampling stations was selected that were deemed applicable for future monitoring. As a result, only two river/tributary systems were examined: Mary River and the Camp Lake Tributary. In general, similar station-wide and seasonal trends were noted for each parameter within rivers/tributary systems on the property. No distinct inter-annual trends were noted. Comparison of the general chemistry of the two systems indicates the general composition is quite similar: water is characterised as circum-neutral/slightly alkaline pH and high alkalinity/low sensitivity to acidic inputs. Hardness ranges from “soft” to “moderately soft” and is almost entirely carbonate hardness.

Chemical concentration trends were analysed with the knowledge that the intense spring runoff period resulting from winter snowpack melting characterizes the artic hydrologic cycle (Stewart and Lamoureux, 2011). Our data indicates highest trace metal concentrations occur during summer (and occasionally fall), and that spring concentrations are generally lowest. This indicates that the snowpack is acting as a fresh, diluting seasonal input.

Station-wide, nitrate, arsenic and cadmium general occur at detection limit. Chloride and nickel generally occur above MDL, but below guideline values. Chloride concentration increases through the seasons from the lowest recorded concentration in the spring to the highest recorded concentrations in the fall. In Mary River, the highest nickel concentrations occur in the summer; whereas, no seasonal trends are noted for nickel within the Camp Lake Tributary. Copper concentrations are consistently close to guideline value throughout the station, with highest concentrations occurring in the summer and fall.

Aluminum and iron show slightly different trends between stations within Mary River and the Camp Lake Tributary. Within Mary River, median total aluminium concentrations occur above CWQG-PAL guidelines, but below the SSWQO and are highest during the summer. Within the Camp Lake Tributary, median total aluminum concentrations are generally low and below the CWQG-PAL guideline and are highest during the spring. Total iron concentrations within Mary River are consistently close to the guideline, with maximum values exceeding guideline and highest concentrations occurring in the summer. Within the Camp Lake Tributary, iron concentrations are consistently below guidelines, with maximum values occurring during the spring.

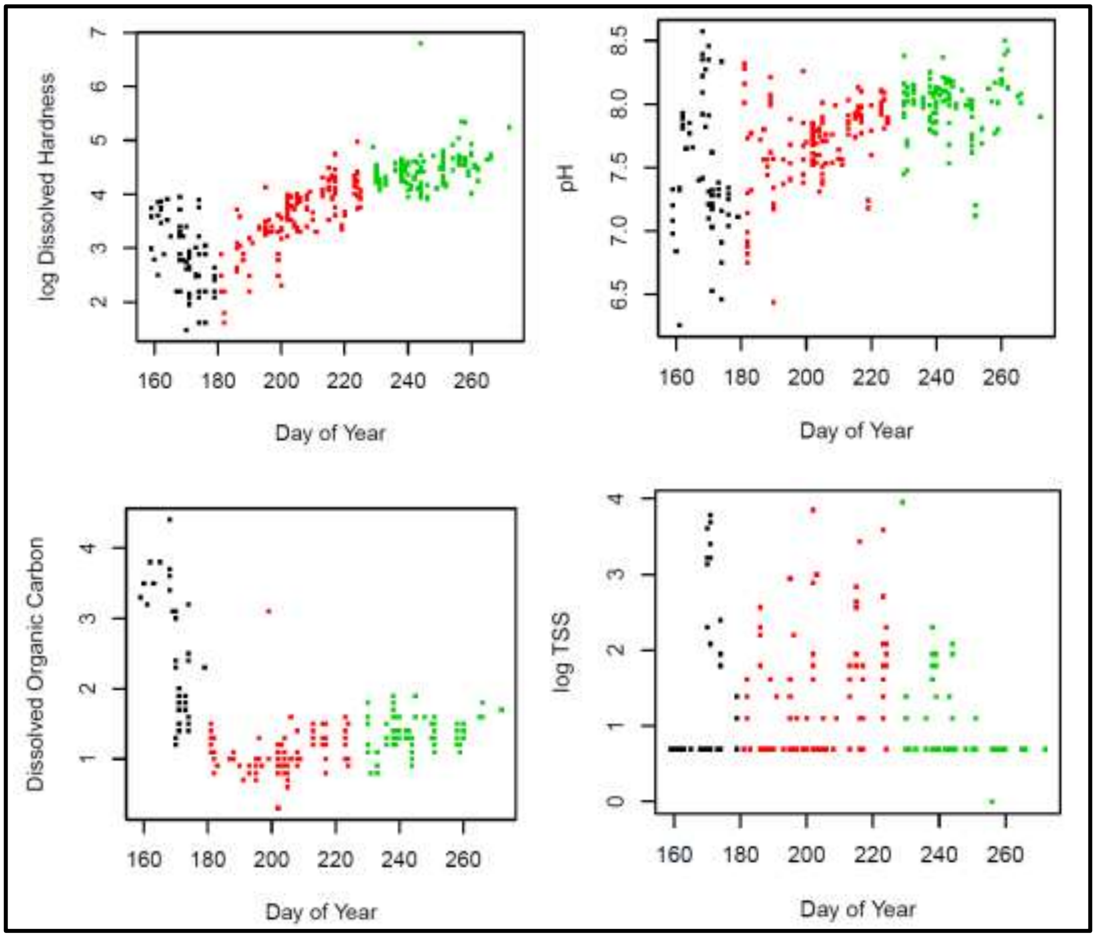
2.5.3 Site-Wide Overview of Water Quality Including Seasonal Trends

General site-wide trends were noted for the concentration of many parameters. Few inter-annual trends of significance were noted, with the exception of a general decline in detection limits. Site-wide and seasonal trends are parameter-specific and were fairly consistent for river stations. Seasonal trends for lake stations were less consistent. In general, all lakes are well mixed and did not show concentration differences with depth, with the exception of aluminum.

2.5.3.1 General Chemistry

Site-wide, general water chemistry is consistent across stations within rivers and lakes. Circum-neutral/slightly alkaline pH (7.3 through 7.8) is noted throughout the site. The water is characterized by high alkalinity, indicating low sensitive to acidic inputs and "soft" hardness and is composed almost entirely of carbonate hardness. Water within the Camp Lake tributary ranges from "moderately soft" to "soft". In general, metal concentrations within the three lakes (Camp Lake, Sheardown Lake and Mary Lake) are reduced and below guidelines, when compared to river samples from Mary River and the Camp Lake tributary, which exceed certain guidelines. High background metal concentrations are expected in an area with such a rich ore body.

Seasonal review of general chemistry shows the relationship between spring freshet and hardness, pH, TSS and DOC. TSS does not show very distinct trends. Both pH and hardness tend to be slightly lower during spring and increase during summer, to a maximum level recorded in the fall. DOC is at its peak during spring and decreases substantially during summer and fall (Figure 2.2). Geographic trends for pH are not noted within Mary River (Figure 2.3).



NOTES:

1. BLACK (SPRING); RED (SUMMER); GREEN (FALL).

Figure 2.2 Mary River - pH, TSS, DOC and Hardness

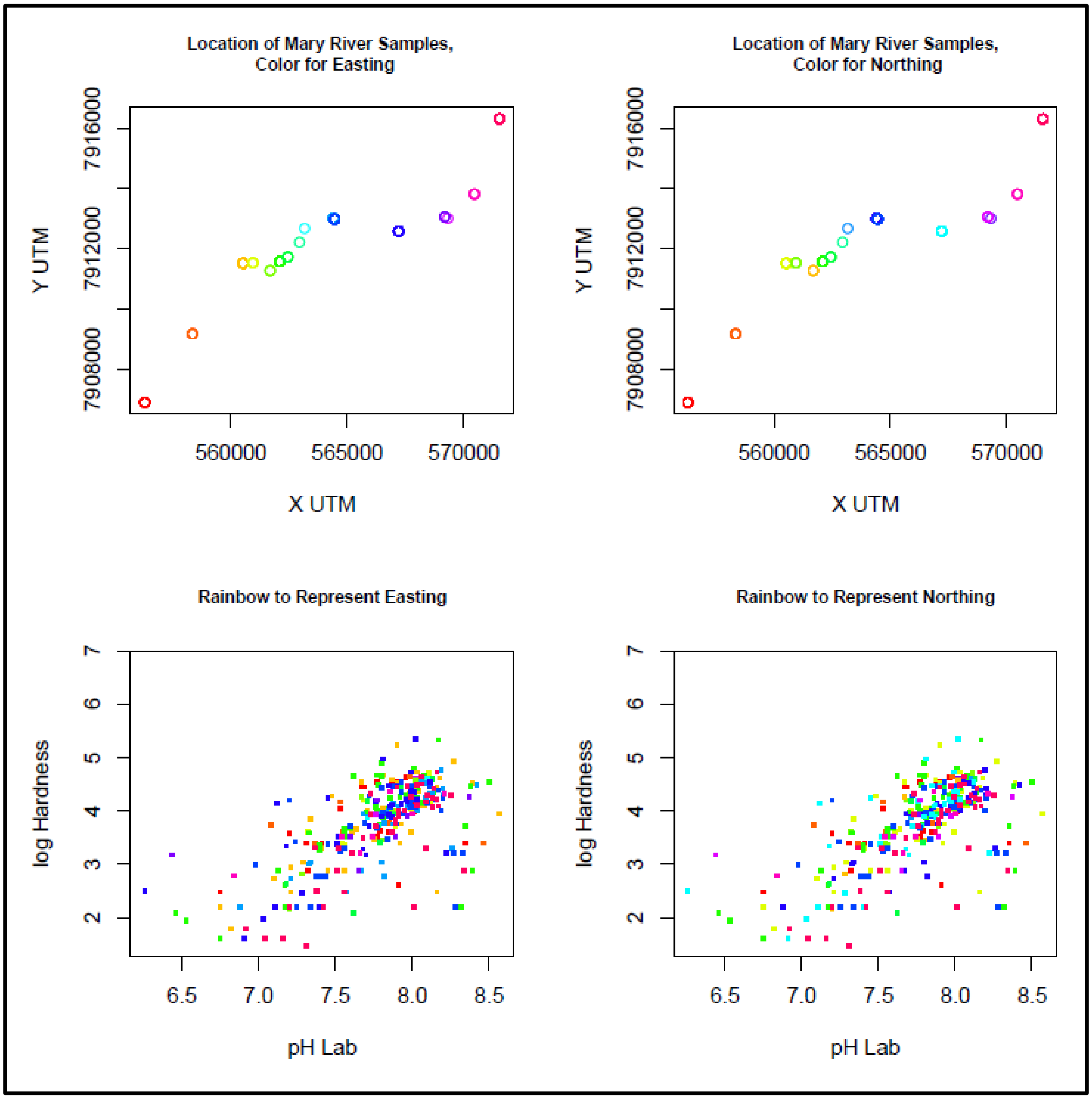


Figure 2.3 Mary River - Geographic pH Trends

2.5.3.2 Anions, Nutrients and Metals

Site-wide, nitrate, arsenic and cadmium occur at detection limit, with the exception of the Mary Lake outlet, which has slightly elevated arsenic concentrations. Due to detection limit interference, it is difficult to discern temporal and seasonal trends for these parameters.

Iron, aluminum, copper and chromium are observed to be elevated and often occur above guideline values within Mary River and Camp Lake tributary. Concentrations of these parameters are generally quite a bit lower in the identified lakes. Camp lake has high outlying iron concentrations; Mary Lake has elevated aluminum and chromium concentrations and Sheardown Lake SW has elevated aluminum and copper concentrations (Table B.9). Site-wide, iron concentrations are slightly enriched, but always occur below guidelines.

A more detailed discussion of seasonal trends site-wide for chloride, iron, nickel, copper and aluminum follows. Site-wide trends observed match closely to the trends observed for streams, but not lakes. This is simply a result of the magnitude difference between stream and lake concentrations. Lake concentrations are consistently depressed when compared to stream concentrations. Lake concentrations also have subtle differences in seasonality that can only be determined by looking at the lake in question. With the exception of chloride and nickel, site-wide the other elevated parameters are seen to increase during the summer months.

Exploration drilling on Deposits No. 1, 2 and 3 has involved the use of calcium chloride brine, as mentioned in Section 1.3. Progressively more sophisticated and effective measures were employed over the years to recycle and contain the brine. Monitoring of water quality in the Mary River in the E3 tributary, downstream of Deposit No. 1 in 2007/2008 confirmed that calcium and chloride were quite elevated downstream of this activity. Chloride concentrations reached maximum concentrations of approximately 3,000 mg/L. Detailed analysis of concentrations at E0-03 indicated that calcium and chloride concentrations were significantly reduced, but slightly elevated. Chloride concentrations reached a maximum of 73 mg/L within E0-03 and had seasonal peaks during the summer (Figure 2.4 and Figure 2.5). Despite use of the drilling salts during baseline, plots of the entire dataset indicate chloride concentrations are not distinctly elevated.

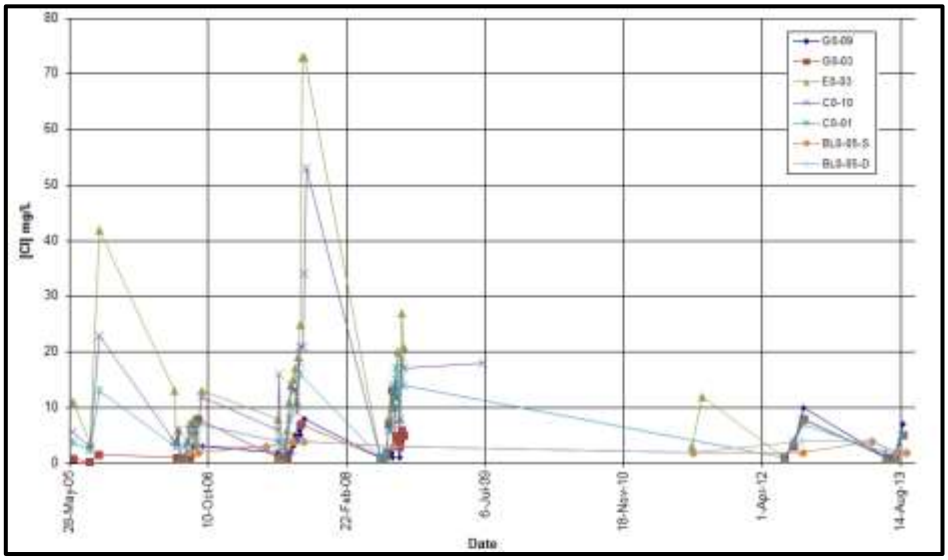
Figures 2.6 through 2.8 depict the changes in concentrations that occur during seasons in both the streams and lake in vicinity to the proposed mine site. Spring lake concentrations are never depicted and neither are winter stream concentrations. Figure 2.6 shows a small increase in chloride concentrations during the fall, with highest concentrations recorded at E0-03 and C0-01 and within the Camp Lake Tributary. In general, lake concentrations of chloride are below concentrations of chloride measured in the streams.

Iron concentrations are at their peak site-wide during the summer, although elevated concentrations were noted in the Camp Lake Tributary during the spring, as shown on Figure 2.7. Iron concentrations reduce slightly, but remain elevated during the fall. Stream water quality stations consistently depict concentrations in excess of lake water quality stations.

With the exception of one large outlying value for nickel, Figure 2.8 shows relatively conservative concentrations for nickel are observed throughout the site, during different seasons. Slightly lower nickel concentrations in the spring; however, a small sample size is also observed.

Copper concentrations increase slightly during the summer and remain slightly elevated during the fall, as depicted on Figure 2.9. Some particularly high copper values have been recorded in Camp Lake, which has maximum values that exceed those observed in Mary River.

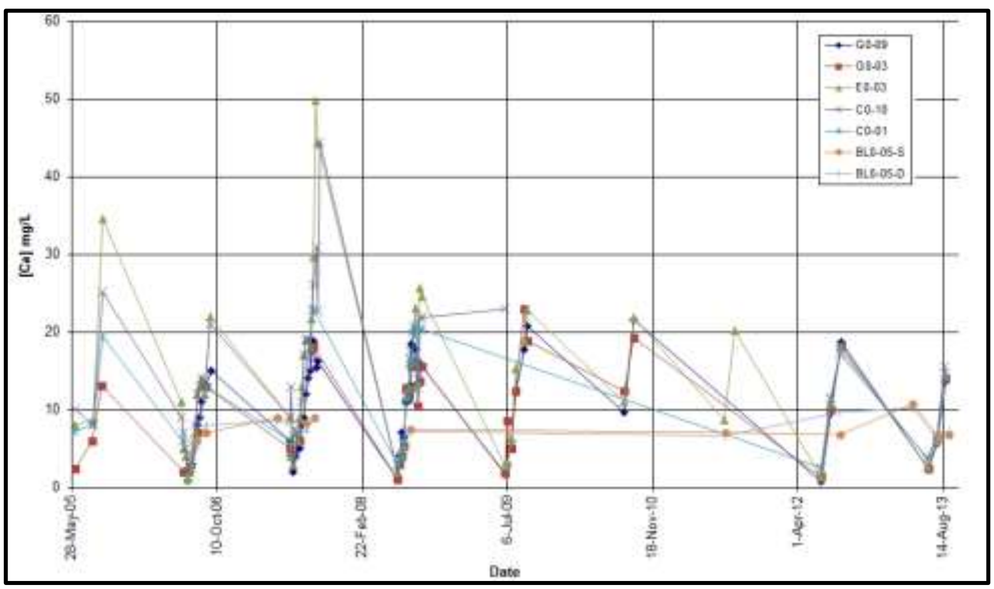
Stream aluminum concentrations are depressed in the spring, and elevated in the summer, as shown in Figure 2.10. Stream concentrations, particularly those recorded in Mary River are greater than the concentrations recorded in the lakes. Fall concentrations are elevated, when compared to fall and winter, but are less than those concentrations recorded in the summer.



NOTES:

1. G0-09 REPRESENTS BACKGROUND CONDITIONS.
2. E0-03 REPRESENTS A LOCATION DIRECTLY INFLUENCED BY DRILLING ACTIVITIES.
3. G0-03 REPRESENTS BACKGROUND IN 2005 AND 2006 (NO DRILLING AT DEPOSITS NO. 2 AND 3).

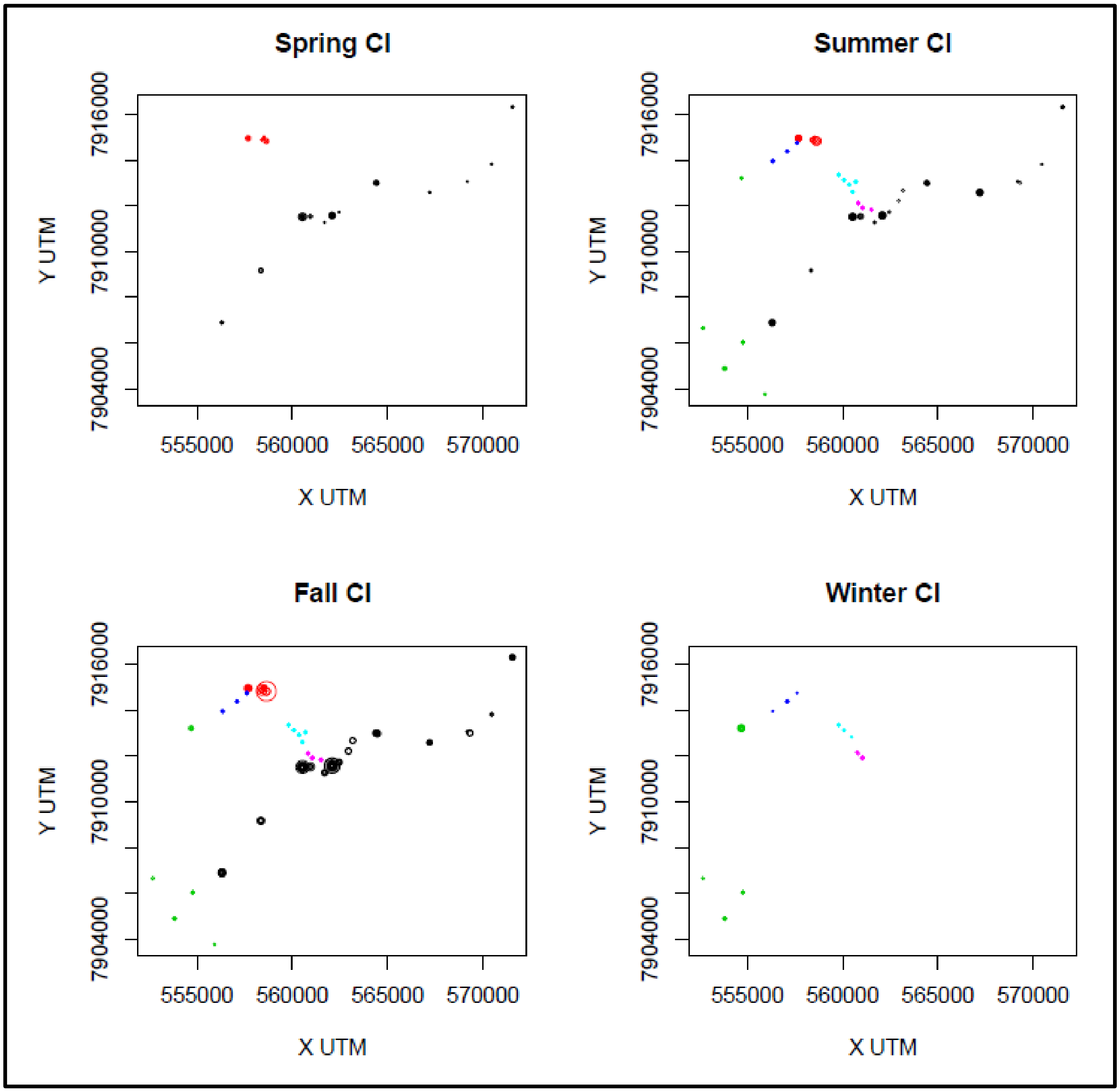
Figure 2.4 Chloride Concentrations in Mine Site Waters over the Study Period



NOTES:

1. G0-09 REPRESENTS BACKGROUND CONDITIONS.
2. E0-03 REPRESENTS A LOCATION DIRECTLY INFLUENCED BY DRILLING ACTIVITIES.
3. G0-03 REPRESENTS BACKGROUND IN 2005 AND 2006, AS THERE WAS NO DRILLING ON DEPOSITS NO. 2 AND 3.

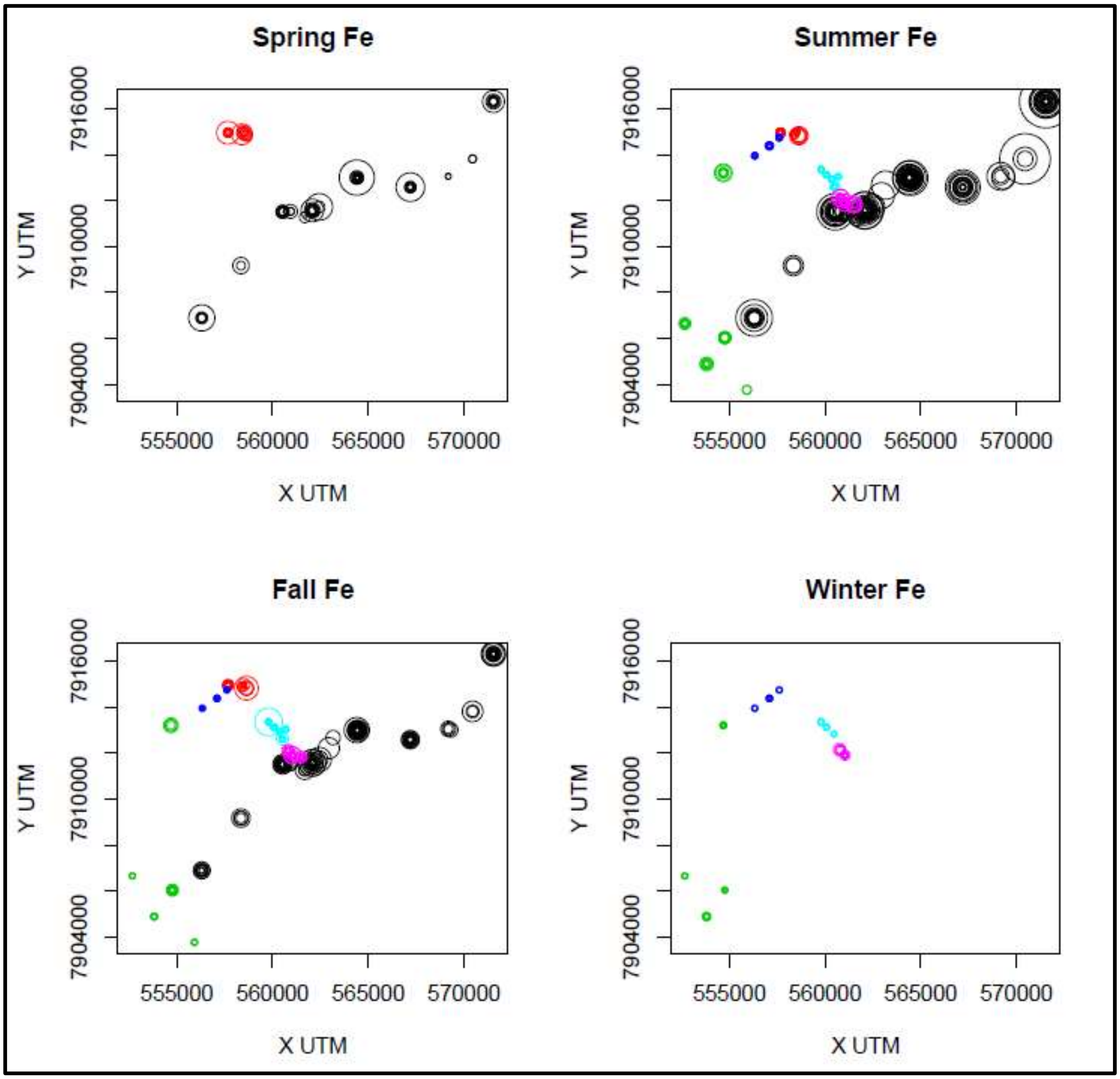
Figure 2.5 Calcium Concentrations in Mine Site Waters over the Study Period



NOTES:

1. AREA OF THE DOT IS EQUAL TO CONCENTRATION OF THE PARAMETER.
2. BLACK (MARY RIVER); RED (CAMP LAKE TRIBUTARY); GREEN (MARY LAKE); DARK BLUE (CAMP LAKE); LIGHT BLUE (SHEARDOWN LAKE NW); PINK (SHEARDOWN LAKE SE).
3. THE SITE WITH CLEARLY ELEVATED CONCENTRATIONS IS E0-03.

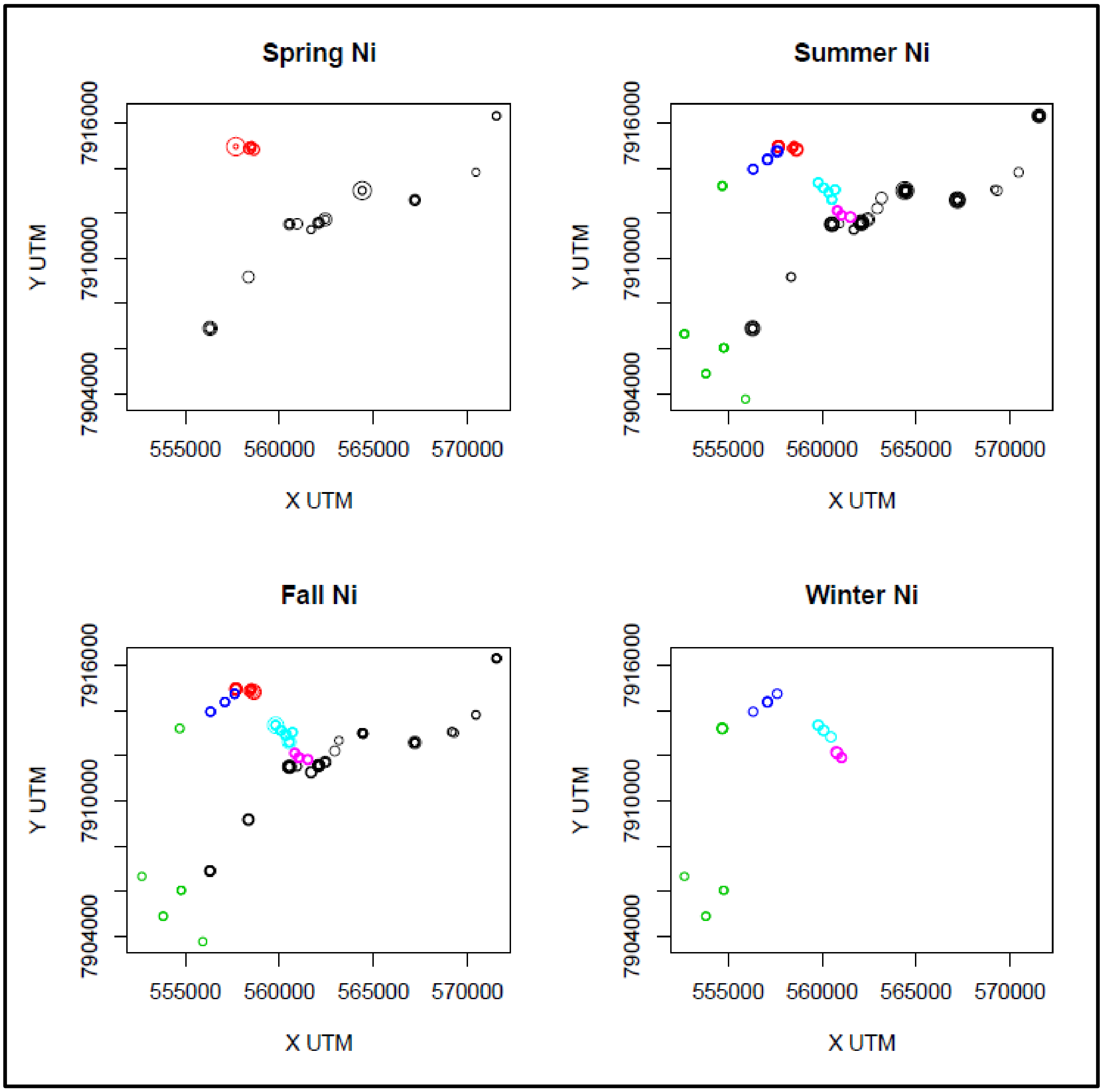
Figure 2.6 Site-Wide Seasonal Trends for Chloride



NOTES:

1. AREA OF THE DOT IS EQUAL TO CONCENTRATION OF THE PARAMETER.
2. BLACK (MARY RIVER); RED (CAMP LAKE TRIBUTARY); GREEN (MARY LAKE); DARK BLUE (CAMP LAKE); LIGHT BLUE (SHEARDOWN LAKE NW); PINK (SHEARDOWN LAKE SE).

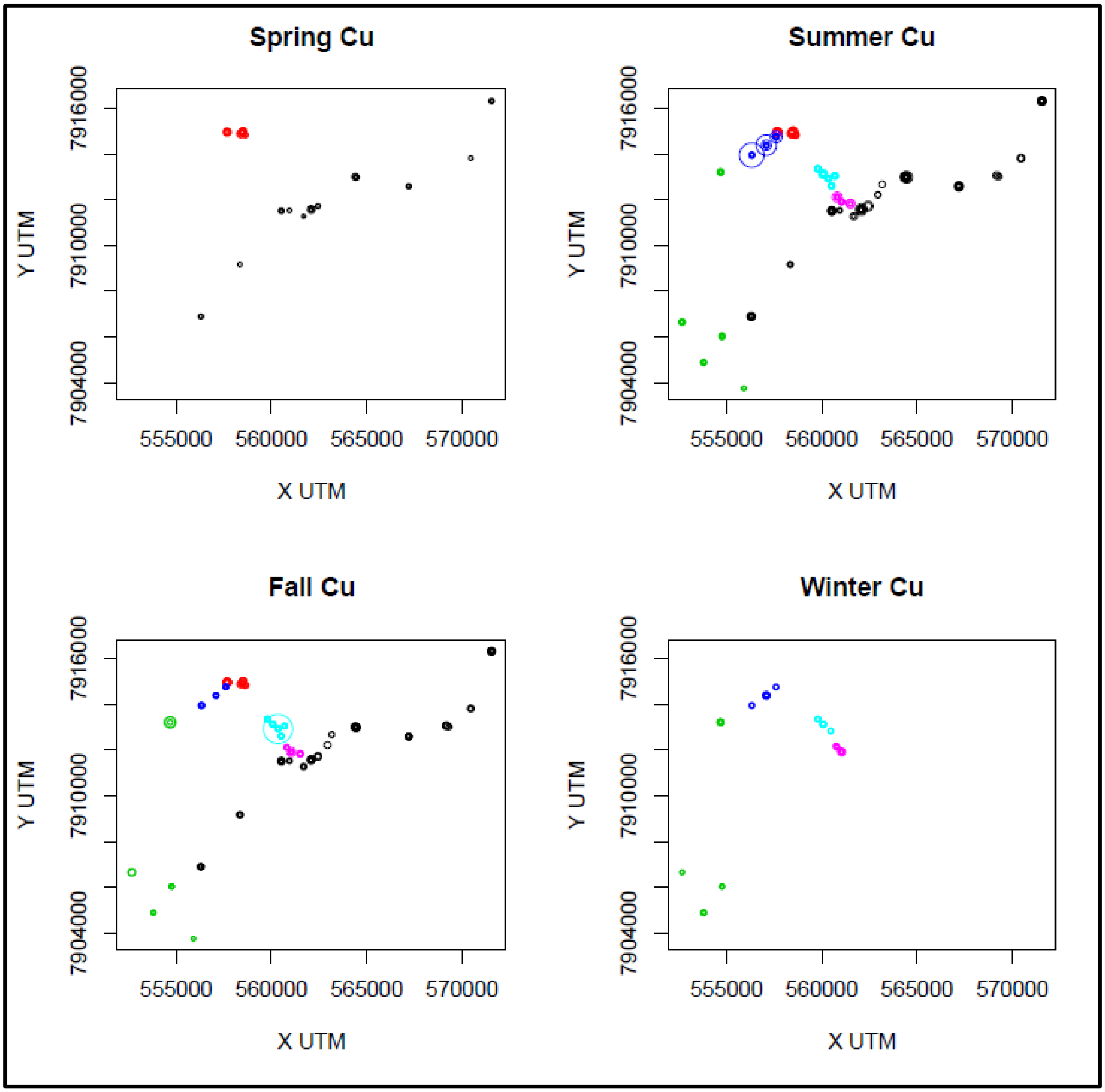
Figure 2.7 Site-Wide Seasonal Trends for Total Iron



NOTES:

1. AREA OF THE DOT IS EQUAL TO CONCENTRATION OF THE PARAMETER.
2. BLACK (MARY RIVER); RED (CAMP LAKE TRIBUTARY); GREEN (MARY LAKE); DARK BLUE (CAMP LAKE); LIGHT BLUE (SHEARDOWN LAKE NW); PINK (SHEARDOWN LAKE SE).

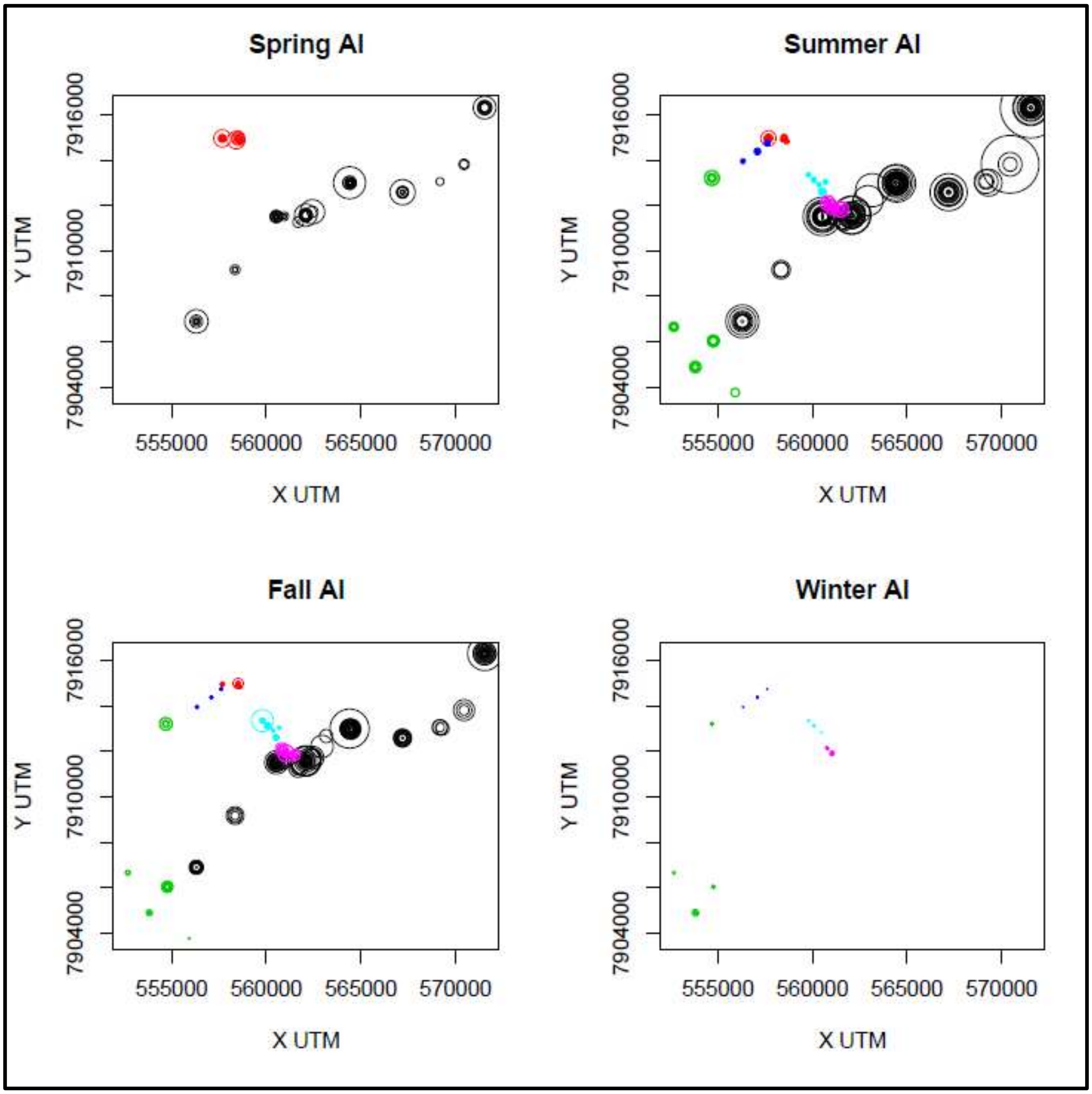
Figure 2.8 Site-Wide Seasonal Trends for Total Nickel



NOTES:

1. AREA OF THE DOT IS EQUAL TO CONCENTRATION OF THE PARAMETER.
2. BLACK (MARY RIVER); RED (CAMP LAKE TRIBUTARY); GREEN (MARY LAKE); DARK BLUE (CAMP LAKE); LIGHT BLUE (SHEARDOWN LAKE NW); PINK (SHEARDOWN LAKE SE).

Figure 2.9 Site-Wide Seasonal Trends for Total Copper



NOTES:

1. AREA OF THE DOT IS EQUAL TO CONCENTRATION OF THE PARAMETER.
2. BLACK (MARY RIVER); RED (CAMP LAKE TRIBUTARY); GREEN (MARY LAKE); DARK BLUE (CAMP LAKE); LIGHT BLUE (SHEARDOWN LAKE NW); PINK (SHEARDOWN LAKE SE).

Figure 2.10 Site-Wide Seasonal Trends for Total Aluminum

2.5.3.3 Chromium

A discussion of chromium is appropriate since most of the sampling to date has been for total chromium yet the CWQG-PAL guidelines are for two chromium species (trivalent chromium - Cr III and hexavalent chromium - Cr VI). During review of the FEIS, naturally elevated concentrations of total chromium were identified within mine site waterbodies, and as discussed in Section 2.4, an interim SSWQO of 0.0047 mg/L was established based on the 95th percentile of baseline concentration of total chromium in the Mary River upstream of the deposits.

In 2012 and 2013, analysis of chromium (III) and chromium (VI) was added to the program to understand the concentrations of these two chromium species. The generic criteria for chromium (III) and chromium (VI) is 0.0089 mg/L and 0.001 mg/L, respectively.

The majority of total chromium samples as well as chromium (III) and chromium (VI) samples were measured below MDLs. The MDLs for total chromium, chromium (III) and chromium (VI) are presented in Table 2.5.

Table 2.5 Water Quality Objectives for Chromium

Parameter	CWQG-PAL or SSWQO (mg/L)	MDL (mg/L)
Cr (total)	0.047	0.0001
Cr (III)	0.0089	0.005
Cr (VI)	0.001	0.001

The MDLs are higher for Cr (III) and Cr (VI) compared to total chromium. Total chromium was measured in 36% of samples within the Camp Lake Tributary and 38% of the samples in Mary River. There were no detectable concentrations of Cr (III) and Cr (VI) in Mary River for only 5% of Cr (III) and 2% of Cr (VI) samples were above MDLs.

Monitoring of chromium in water will likely need to focus on total chromium as a parameter of concern; however, the proportion of detectable concentrations of Cr (III) and Cr (VI) will also be monitored as an indicator of increasing concentrations over time.

2.5.3.4 Total Phosphorus and Total Kjeldahl Nitrogen

Total phosphorus was found to be elevated in the water in the streams and in the sediment in depositional areas of streams (Sheardown Lake tributary) and in the lakes (Camp, Mary and Sheardown Lakes). The distribution of total phosphorus within the Mary River system from the station furthest upstream of Deposit No. 1 (G0-09) to the station as far downstream as Mary Lake is presented in Table 2.5.

It can be seen from this table that the total phosphorus concentrations are elevated in the baseline condition throughout the Mary River system. According to Baffinland, limestone in the area is high in phosphorus up to a couple of percent by weight (Michael Zurowski, pers. comm.). This limestone outcrops to the west of Sheardown Lake and the weathered material from this limestone is found in the overburden throughout the mine site area. As such, it is possible that the concentrations of total phosphorus in the Mary River system is due to increased contact with local soils. Moss (2012) notes clay particles in soils also tend to bind tightly with phosphorus making the phosphorous resistant to simple leaching by water.

Concentrations of total phosphorus in lake sediment are high and regularly exceed the Ontario Sediment Quality Guideline`s Lower Effects Level (LEL) criterion for total phosphorus in depositional areas of the lake where metals also tend to accumulate. Sediment quality results are discussed in more detail in Appendix D, Section 3.

Monitoring of nutrients from sewage discharges to Sheardown Lake NW and the Mary River is anticipated to form a component of the AEMP. Table 2.6 suggests that total phosphorus concentrations in the mine site waters are elevated, and more importantly for monitoring, are highly variable, ranging widely from below the MDL of 0.003 mg/L (ultra-oligotrophic) to 0.035 to 0.100 mg/L (eutrophic) at each of the sampling stations in the Mary River, Mary Lake and Sheardown Lake.

Table 2.6 Total Phosphorus in the Mary River and Mary Lake

Sample Location	Total Phosphorus Concentration (mg/L)				CCME Eutrophication Scale	
	Min	Mean	Max		Category	TP (mg/L)
G0-09 (upstream)	<0.003	0.015	0.069		Ultra-oligotrophic	<0.004
G0-01	<0.003	0.010	0.032		Oligotrophic	0.004 to 0.010
E0-03	<0.003	0.014	0.060		Mesotrophic	0.010 to 0.020
Sheardown Lake NW	<0.003	0.006	0.090		Meso-eutrophic	0.020 to 0.035
C0-10	<0.003	0.014	0.060		Eutrophic	0.035 to 0.100
C0-01	<0.003	0.015	0.062		Hyper-eutrophic	>0.100
Mary Lake	<0.003	0.006	0.020			

NOTES:
1. NON-DETECT MEASUREMENTS AT OR ABOVE 0.01 MG/L WERE REMOVED BEFORE CALCULATING THE ABOVE STATISTICS.

Ongoing monitoring of total phosphorus is proposed as part of the CREMP; however, the high natural variability of total phosphorus do not allow for the measurement of statistically significant Project-related changes over time. An alternate indicator, Chlorophyll a, is proposed to monitor effects of nutrient additions to mine site waters as part of the freshwater biota CREMP being developed by North/South Consultants Inc.

The total nitrogen (TN) and total phosphorous (TP) ratio can vary with a waterbody's trophic status (Downing & McCauley, 1992). As noted above, the Mary River and Mary Lake stations show these waterbodies are oligotrophic to mesotrophic. The majority of limnological literature identifies total phosphorus as the limiting nutrient in freshwater environments that can influence phytoplankton communities. The range of TN:TP ratios for the mine area waterbodies are provided in Table 2.7.

Table 2.7 Range of Total Nitrogen : Total Phosphorus Ratios in Mine Site Lakes

Lake	TN:TP Ratio Calculation Method	Minimum TN:TP Ratio	Average TN:TP Ratio	Maximum TN:TP Ratio
Camp Lake	Mass	13	56	150
	Molar Weight	29	124	332
Sheardown Lake NW	Mass	20	65	177
	Molar Weight	44	144	391
Mary Lake	Mass	33	70	113
	Molar Weight	74	154	249

It is likely that, despite the periodically high total phosphorus concentrations measured in the mine site lakes, total phosphorus remains the limiting nutrient.

2.6 POWER ANALYSES

Parameter-specific and site-specific power analyses were completed to assess the sample size required to detect changes at individual stations. The analyses are presented in detail in Appendix C and the conclusions are presented in Section 2.7.4.

The parameters selected for power analysis include:

- Aluminum
- Arsenic
- Cadmium
- Copper
- Iron

These parameters were selected as they are expected to be the most affected parameters during mine operation. Stations were strategically selected to ensure sampling and subsequent statistical analyses would be able to provide information regarding the source of any contaminants that might be caused by mine development.

Power analyses were completed to determine the sample size required to detect changes in mean concentration with respect to the selected benchmarks, as per the AEMP Framework (Baffinland, 2013b). Also of interest was the ability to detect smaller statistically significant changes below the AEMP benchmark that would lead to low action adaptive management. Several “low-action” benchmarks were investigated for each parameter at each station.

Key sources of variation in the data were identified in the exploratory analysis:

- Spatial variability - from waterbody to waterbody and station to station, as for example from near field to far field
- Temporal variability - seasonal trends
- Within station variability - due to varying weather conditions such as rainfall effects on stream data (not shown here)

The following types of power analysis were completed, depending on the data available:

1) The power to detect a change in means was assessed for parameters with sufficient data above MDL (<15% of non-detected data). A before-after-control-impact (BACI) design was used to assess the power to detect differences in log mean concentration values (using the methods of Stroup, 1999)[2]. A BACI design is rigorous in the sense that it shows a change in the difference between impact (exposure) and control (reference) stations from before to after the commencement of a potential environmental impact. The following modifications to the complete BACI approach were taken, as dictated by the data available:
   i. Before-after (BA) design was used when control data was not available. Under this design, power analysis was carried out using a two sample t-test to compare means.
   ii. Control-impact (CI) design was assumed when very little baseline data was available. Under this design, power analysis for testing means was carried out using a paired t-test.
2) The power to detect a change in the proportion of values above MDL was assessed for parameters with a large proportion of values below MDL (>15% of non-detected data). For some parameters the baseline dataset is represented predominantly by values below MDL. This occurred for arsenic and cadmium at all stations.
   i. BA designs were assessed using a test for two independent proportions (Agresti, 1990).
   ii. McNemar's test (Agresti, 1990) was used to assess the power to detect a difference between the paired proportions at impact and control stations.

The outcome of the preliminary power analysis is provided in the preliminary study design (Section 2.8.4). Further details on the methodology used are provided in Section C.3 and D.3.

2.7 WATER QUALITY CREMP STUDY DESIGN

The water quality CREMP will monitor water quality within mine site lakes and streams with the objective of identifying project-related effects to water quality from multiple sources. The water quality CREMP applies the assessment approach and response framework identified in the AEMP that is being applied to the various components of the aquatic environment (i.e., water, sediment, biota).

The water quality CREMP study design is consistent with the requirements for the Environmental EEM Program as specified under the Metal Mining Effluent Regulations (MMER). The CREMP water quality stations overlap with those identified in the Draft EEM Cycle One Study Design (Baffinland, 2014; AEMP Appendix A).

2.7.1 Pathways of Effect and Key Questions

Key questions were developed for the CREMP to guide the review of baseline data adequacy and, ultimately, design of the monitoring program. These questions and metrics focus upon key potential

[2] Comparison of medians or log means are both supported methods to compare data sets. Median comparisons are more robust when distributions are non-normally distributed. Median or mean comparisons are equally robust when distributions are normally distributed. Log distribution of water quality data collected created a data set that was normally distributed. As a result, mean comparison was determined appropriate.

effects identified in the Final Environmental Impact Statement (FEIS) and the Early Revenue Phase (ERP) addendum, as well as metrics commonly applied for characterizing water quality.

The key pathways of potential effects of the Project on water quality include:

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

The key question related to the pathways of effect is:

- What is the estimated mine-related change in contaminant concentrations in the exposed area?

The primary issue of concern with respect to water quality is related to the combined effects on metal and TSS concentration from mine effluent discharges and ore dust deposition on water quality in lake and streams. As such, the CREMP and the baseline data review focused on waterbodies that will receive mine effluent discharges and are closest to the sources of ore dust. Camp Lake and its Tributary 1 (CLT-1), as well as the Mary River and Mary Lake, will receive mine effluent discharges. These waterbodies, along with Sheardown Lake, may also be affected by ore dust deposition and non-point sources of fugitive dust (i.e., road dust).

The discharge of treated sewage effluent also has the potential to cause eutrophication, with phosphorus being the limiting nutrient. As discussed in Section 2.5.3.4, however, TP concentrations are highly variable making it a poor indicator. While TP will continue to be monitored as part of the CREMP, Chlorophyll a will be monitored as a more reliable indicator of potential eutrophication, as part of the freshwater biota CREMP (North/South, 2014).

2.7.2 Indicators and Metrics

Water quality indicators identified for monitoring include various physical parameters, metals and nutrients. They were selected on the basis of the following:

- The potential to be naturally elevated in the environment
- The potential to become elevated in the environment as a result of future mine site activities
- Discharge limit(s) have been established for the parameter in the Type A Water Licence
- An established criterion exists for the protection of freshwater aquatic life
- Regulation under the MMER, or potential regulation as a result of the current re-evaluation of the regulations
- The parameter is an exposure toxicity modifying factor (ETMF) for other parameters of concern

The stressors of potential concern (SOPCs) and supporting parameters are listed in Table 2.8.

Table 2.8 Water Quality Parameters Selected for Monitoring

Contaminants of Potential Concern		Exploratory Data Analysis Only
Aluminum	Dissolved oxygen	Hardness
Arsenic	pH	Total Dissolved Solids
Cadmium	Total Suspended Solids	Turbidity
Chromium	Chloride	Alkalinity
Copper	Ammonia (NH3+NH4)	Calcium
Cobalt	Nitrite (NO2-)	Magnesium
Iron	Nitrate (NO3-)	Potassium
Lead	Phosphorus	Total Organic Carbon (TOC)
Nickel	Sulphate	Dissolved Organic Carbon (DOC)
Silver		
Thallium		
Vanadium		
Zinc		

2.7.3 Benchmarks

Since the mine site occurs within an area of metals enrichment, generic water quality guidelines established for all areas within Canada may naturally be exceeded near the mine site. Therefore, the selection of appropriate benchmarks must consider established water quality guidelines, such as those developed by the Canadian Council of Ministers of the Environment (CCME), as well as site-specific natural enrichment, and other factors (such as Exposure Toxicity Modifying Factors (ETMF) including pH, water hardness, dissolved organic carbon, etc.), in the selection or development of final benchmarks for monitoring data comparison (CCME, 1999, updated to 2014).

The assessment of surface water and sediment quality data over the life of the project will be ongoing, and the recommended benchmarks of comparison throughout this process may change, as more data become available. For example, a site-specific water quality guideline 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 modification of benchmarks under an AEMP is well established (MacDonald et al., 2009).

Intrinsik Environmental Sciences Inc. was retained by Baffinland to develop water and sediment quality benchmarks to be applied in the CREMP (Intrinsik, 2014; see Appendix F of the AEMP). Water quality benchmarks were identified for mine site lakes and streams individually, considering the higher of the generic water quality objective (i.e., CCME or other jurisdiction) or the 97.5^{th} percentile of baseline concentrations. For parameters that are mostly below MDL (less than 5% detected values), either the Water Quality Guideline was selected (if available), or 3 * MDL was adopted as the benchmark, as follows:

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

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

The selected benchmark development method and corresponding water quality benchmarks for the mine site lakes are presented in Table 2.9. The benchmark method and benchmark values for stream water quality are presented in Table 2.10.

Table 2.9 Selected Water Quality Benchmark Approach and Values for Mine Site Lakes

Parameter	Units	Water Quality Guideline	Camp Lake	Mary Lake	Sheardown Lake	Selected Benchmark	Benchmark Method
Metals [3]							
Aluminium	mg/L	0.1	0.026	0.137	0.179 (Shallow) 0.173 (Deep)	CL = 0.1 ML = 0.13; SDL shall/deep = 0.179/0.173	A (CL), B (ML/SDL)
Arsenic	mg/L	0.005	NC	0.00018	0.0001	0.005	A
Cadmium	mg/L	0.0001 (CL) 0.00006 (ML) 0.00009 (SDL)	NC	0.000023	0.000017	0.0001 (CL) 0.00006 (ML) 0.00009 (SDL)	A
Chromium	mg/L	NGA	NC	0.001	0.000641	0.0003 (CL) (ML) = 0.0005[8] (SDL) = 0.000642[9]	B (ML/SDL), C (CL)
Chromium +3	mg/L	0.0089	NC	0.005	NC	0.0089	A
Chromium +6	mg/L	0.001	NC	0.001	NC	0.003 – 0.015 (CL)[5] 0.003 (ML/SDL)[5]	C
Cobalt	mg/L	0.004	NC	NC	0.0002	0.004	A
Copper	mg/L	0.002	0.0113	0.00239	0.00243	(CL) = 0.004[7] (ML) = 0.0024 (SDL) = 0.0024	B
Iron	mg/L	0.3	0.0421	0.173	0.211	0.3	A
Lead	mg/L	0.001	0.000334	0.00013	0.00026	0.001	A
Nickel	mg/L	0.025	0.000941	0.00080	0.000973	0.025	A
Silver	mg/L	0.0001	NC	NC	0.0000104	0.0001	A
Thallium	mg/L	0.0008	NC	NC	0.0001	0.0008	A
Vanadium	mg/L	0.006	NC	0.00146	0.001	0.006	A
Zinc	mg/L	0.030	0.0037	0.003	0.00391	0.030	A

Parameter	Units	Water Quality Guideline	Camp Lake	Mary Lake	Sheardown Lake	Selected Benchmark	Benchmark Method
Water Quality Parameters							
Chloride (Cl^-)	mg/L	120	4	13	5	120	A
Ammonia (NH_3+NH_4)	mg N/L	0.855[4]	0.84	0.32	0.44	0.855	A
Nitrite (NO_2^-)	mg N/L	0.060	0.1[6]	0.1[6]	0.1[6]	0.060	A
Nitrate (NO_3)	mg N/L	13	NC	0.11	NC	13	A
Sulphate	mg/L	218	3	7	5	218	A

NOTES:
1. NGA = NO GUIDELINE AVAILABLE; NC = NOT CALCULATED; TBD = TO BE DETERMINED; GUIDELINE STILL UNDER DEVELOPMENT; CL = CAMP LAKE; ML = MARY LAKE; SDL = SHEARDOWN LAKE.
2. METHOD A = WATER QUALITY GUIDELINE FROM CCME/B.C. MOE; METHOD B = 97.5%ILE OF BASELINE; METHOD C = 3* MDL.
3. TOTAL METALS UNLESS OTHERWISE NOTED.
4. ASSUMES TEMPERATURE AT 10 DEGREES C, AND pH OF 8.
5. THE 2013 DETECTION LIMIT FOR Cr^{6+} INCREASED IN 2013 FROM 0.001 to 0.005, HENCE THIS AFFECTS THE 3* MDL CALCULATION FOR THE BENCHMARK IN CAMP LAKE. EFFORTS WILL BE MADE TO REDUCE THIS MDL IN 2014, AND COMPARISONS TO THE LOWER OF THE 2 BENCHMARKS WOULD THEN BE APPLIED IN CAMP LAKE. IF DETECTION LIMITS IMPROVE, METHOD A (SELECTION OF THE GUIDELINE) MAY BE IMPLEMENTED.
6. THESE VALUES ARE ELEVATED DETECTION LIMITS, AND HENCE, THE GUIDELINE HAS BEEN SELECTED AS THE BENCHMARK.
7. THE MAXIMUM VALUE OF 0.0113 MG/L COPPER WAS REMOVED TO CALCULATE THE 97.5TH PERCENTILE, AS THIS VALUE APPEARS TO BE AN OUTLIER.
8. AN ELEVATED DETECTION LIMIT OF 0.001 MG/L WAS REMOVED FROM THE DATASET AND CALCULATIONS, AND THE AEMP SELECTED WAS THE 97.5th PERCENTILE, WHICH IS 0.0005 mg/L.
9. SEVERAL DETECTED VALUES RANGING FROM 0.00079 - 0.00316 mg/L Cr HAVE BEEN REPORTED IN THE DATASET FOR SDL, AND HENCE, THESE VALUES WERE CONSIDERED TO REPRESENT BASELINE, AND WERE INCLUDED IN THE 97.5th PERCENTILE CALCULATION.

Table 2.10 Selected Water Quality Benchmark Approach and Values for Mine Site Streams

Parameter	Units	Water Quality Guideline	Camp Lake Tributary	Mary River[3]	Selected Benchmark	Benchmark Method
Metals[4]						
Aluminum	mg/L	0.1	0.179	0.97	CLT = 0.179 MR = 0.966	B
Arsenic	mg/L	0.005	0.00012	0.00013	0.005	A
Cadmium	mg/L	0.00008 (CLT) 0.00006 (MR)	NC	0.00002	CLT = 0.00008 MR = 0.00006	A
Chromium	mg/L	NGA	0.000856	0.0023	CLT = 0.000856 MR = 0.0023	B
Chromium $^{+3}$	mg/L	0.0089	NC	0.005	0.0089	A
Chromium $^{+6}$	mg/L	0.001	NC	NC	0.003[5]	C
Cobalt	mg/L	0.004	NC	0.0004	0.004	A
Copper	mg/L	0.002	0.00222	0.0024	CLT = 0.0022 MR = 0.0024	B

Parameter	Units	Water Quality Guideline	Camp Lake Tributary	Mary River[3]	Selected Benchmark	Benchmark Method
Iron	mg/L	0.3	0.326	0.874	CLT = 0.326 MR = 0.874	B
Lead	mg/L	0.001	0.000333	0.00076	0.001	A
Nickel	mg/L	0.025	0.00168	0.0018	0.025	A
Silver	mg/L	0.0001	NC	0.0001	0.0001	A
Thallium	mg/L	0.0008	0.0002	0.0002	0.0008	A
Vanadium	mg/L	0.006	NC	0.002	0.006	A
Zinc	mg/L	0.030	0.0035	0.01	0.030	A
Water Quality Parameters						
Chloride (Cl^-)	mg/L	120	23	21.55	120	A
Ammonia (NH_3+NH_4)	mg N/L	0.855[6]	0.60	0.60	0.855	A
Nitrite (NO_2^-)	mg N/L	0.060	0.095[7]	0.06	0.060	A
Nitrate (NO_3)	mg N/L	13	0.118	0.14	13	A
Sulphate	mg/L	218	6	8	218	A

NOTES:

1. NGA = NO GUIDELINE AVAILABLE; NC = NOT CALCULATED; TBD = TO BE DETERMINED; GUIDELINE STILL UNDER DEVELOPMENT; MR = MARY RIVER; CLT = CAMP LAKE TRIBUTARY.
2. METHOD A = WATER QUALITY GUIDELINE FROM CCME/B.C. MOE; METHOD B = 97.5%ILE OF BASELINE; METHOD C = 3* MDL.
3. ONE SAMPLE (OUTLIER) CONTAINING CHEMICAL CONCENTRATIONS ORDERS OF MAGNITUDE ABOVE OTHER VALUES WAS NOT INCLUDED IN THE CALCULATIONS FOR MARY RIVER.
4. TOTAL METALS UNLESS OTHERWISE NOTED.
5. EFFORTS WILL BE MADE TO REDUCE THIS MDL IN 2014, AND COMPARISONS TO THE HIGHER OF THE METHOD A OR C WOULD THEN BE APPLIED AS THE AEMP BENCHMARK.
6. ASSUMES TEMPERATURE AT 10 DEGREES C, AND pH of 8.0.
7. 97.5^{th} PERCENTILE IS BEING DRIVEN BY ELEVATED DETECTION LIMIT, THEREFORE, THE GUIDELINE WAS SELECTED.

In most cases, the recommended benchmarks are consistent between lakes and streams, with the vast majority of selected benchmarks being generic WQOs. Where natural concentrations varied, and exceeded available water quality guidelines, or < 5% of values was detected, recommended benchmarks varied.

As discussed in the baseline review in Section 2.5 and Appendices B (lakes) and C (streams), some parameters have been shown to exhibit some changes in concentrations with season. For those parameters, Step 1 of the assessment framework (see Section 2.7.8) will include an evaluation of seasonality trends relative to the benchmark and baseline. Benchmarks may need to be re-visited for these compounds, and SSWQO can be considered.

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

2.7.4 Monitoring Area and Sampling Stations

The monitoring area for water quality includes mine area lakes, specifically Camp Lake, Mary Lake, and Sheardown Lake NW and SE; selected tributaries of each lake; and the Mary River (Figure 2.11). The power analysis supported the selection of the existing baseline stations, and identified the addition of the following stations:

- Two stations within the basin at the north arm of Mary Lake, near BL0-01 (stations BL0-01-A and BL0-01-B)
- Two additional stations within the main basin of Mary Lake, near the Mary River inlet near BL0-05 (BL0-05-A and BL0-05-B)
- Sampling of an additional station within Sheardown Lake SE (existing station DL0-02-6)
- Addition of a station in vicinity of L1-09, location to be determined (L1-05)
- Addition of one or two reference stations upstream on Mary River (G0-09-A, G0-09-B)
- Sampling of identified reference lakes, consistent with EEM program and as identified by North/South (2014)

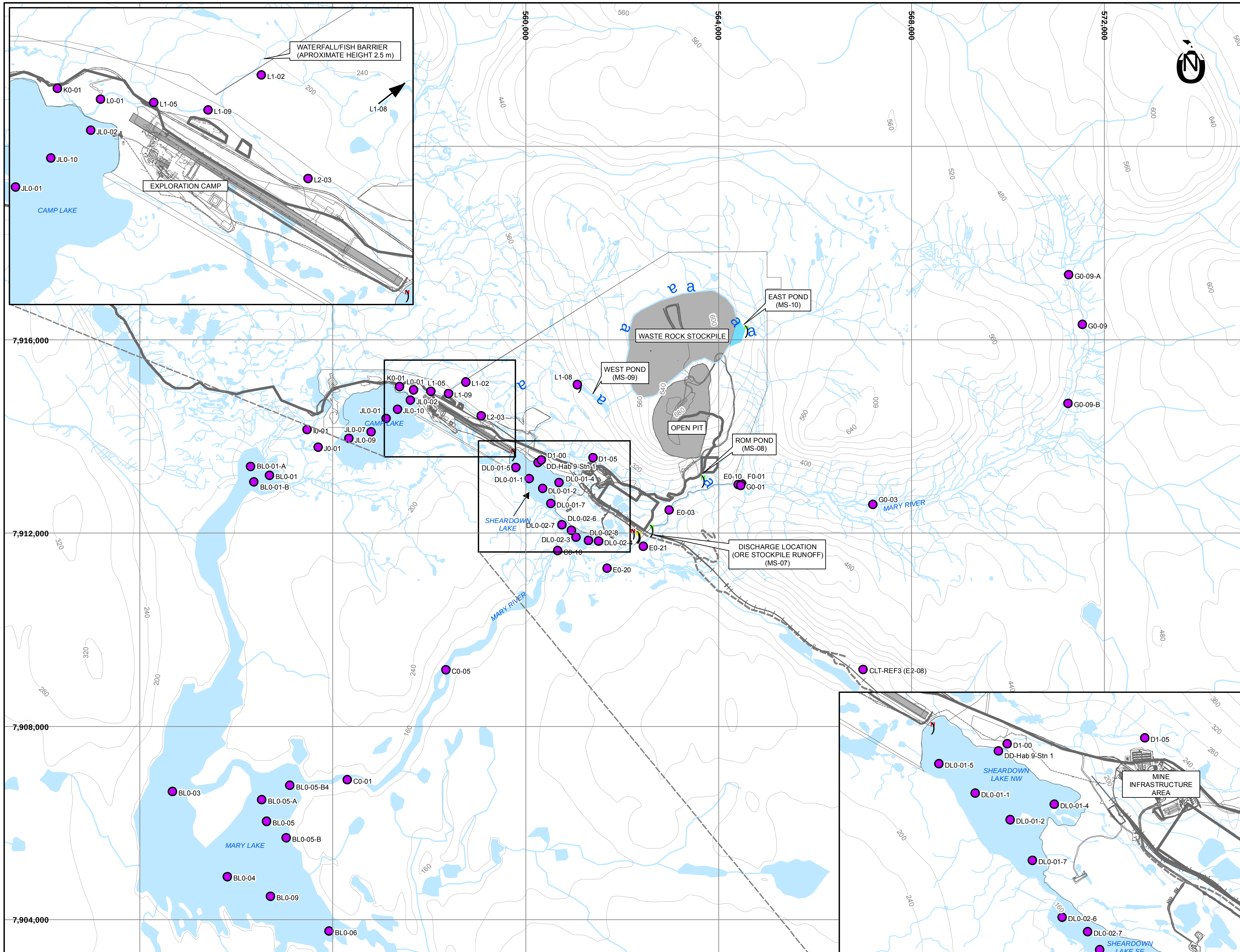
The water quality CREMP monitoring stations are presented in Table 2.11.

An initial power analysis was run using a paired BACI design for each station. The goal was to assess the statistical power of various sample sizes for detecting site-specific change. The power analysis used a basic BACI design with one impact station and one control station before and after commencement of mining activity. This method was modified in three ways:

- Simplified power analysis was used for sediment sampling
- In the absence of pre-mining reference data, only a Control-Impact (CI) assessment was completed
- For parameters with a large amount of data below detection limits, a comparison of proportions was used

Environment Canada defines statistical difference between exposure and reference stations to be a difference of a “factor of 2”, except when there are applicable WQOs, detection limit interference, water quality guidelines, changes in pH and/or locations of reference stations within different watersheds. For the Mary River Project, benchmarks were derived as summarized in Section 2.7.3. These benchmarks account for the naturally elevated metals in the Project area. As a result, the ultimate effect size used in the power analysis was the difference between the station baseline mean and the benchmark. To be conservative when creating the study design, a second effect size was added to act as an early warning flag. The second effect size was determined to be halfway between the station mean and the benchmark value.

Power analysis was completed for a subset of parameters in select areas within Camp Lake, Sheardown Lake NW, Sheardown Lake SE, Mary Lake, Mary River and Camp Lake Tributary (Appendices B and C). Key stations were selected, which corresponded with the EEM near-field and far-field stations. Parameters that were elevated in baseline sampling and expected to be most affected during mine operation were selected to provide conservative representations of other measured parameters.



LEGEND:

- WATER QUALITY CREMP STATION
- SUMMER DISCHARGE LOCATION OF TREATED SEWAGE EFFLUENT
- WINTER LAND DISCHARGE LOCATION OF TREATED SEWAGE EFFLUENT TO MARY RIVER
- MINE EFFLUENT FINAL DISCHARGE POINT
- EXISTING TOTE ROAD
- PROPOSED RAILWAY ALIGNMENT
- PROPOSED CONSTRUCTION ACCESS ROAD
- PROPOSED SITE INFRASTRUCTURE
- RIVER/STREAM/DRAINAGE
- PROPOSED SITE INFRASTRUCTURE
- WATER

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 (WGS84/NAD83) ZONE17.
3. CONTOUR ARE IN METRES. CONTOUR INTERVAL VARIES.
4. LAKE SAMPLE LOCATIONS VARY SLIGHTLY DURING WINTER MONTHS DUE TO ICE CONDITIONS.
5. INFRASTRUCTURE INFORMATION PROVIDED BY HATCH ON JANUARY 31, 2014.

SCALE 1 0.5 0 1 2 3 4 km

BAFFINLAND IRON MINES CORPORATION

MARY RIVER PROJECT

CREMP WATER QUALITY STATIONS

Knight Piésold CONSULTING

P/A NO.	REF NO.
NB102-181/33	1

FIGURE 2.11 REV 2

REV	DATE	DESCRIPTION	DESIGNED	DRAWN	CHK'D	APP'D
2	25JUN'14	ISSUED WITH REPORT	RAC	SWK	RAC	RAM
1	30MAY'14	ISSUED WITH REPORT	RAC	SWK	RAC	RAM
0	27MAR'14	ISSUED WITH REPORT	RAC	AS	RAC	RAM

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Table 2.11 Water Quality CREMP Station Details

Station ID	Easting	Northing	Winter	Spring	Summer	Fall	Description/Rationale
	NAD83, Zone 17N						
Mary Lake (North Basin)							
BL0-01	554691	7913194	2		2	2	North basin receiving water from Camp Lake
BL0-01-A	554300	7913378	2		2	2	
BL0-01-B	554369	7913058	2		2	2	
Mary Lake (South Basin)							
BL0-03	552680	7906651	2		2	2	Main basin receiving water from north basin
BL0-04	553817	7904886	2		2	2	
BL0-05	554632	7906031	2		2	2	Mary Lake, southern basin near outlet of Mary River
BL0-06	555924	7903760	2		2	2	
BL0-05-A	554530	7906478	2		2	2	
BL0-05-B	555034	7905692	2		2	2	
BL0-09	554715	7904479	2		2	2	Main basin between BL0-05 & BL0-06
Mary River (D/S of SDL)							
C0-01	556305	7906894		1	1	1	Mainstem, before outflow to Mary Lake
C0-05[1]	558352	7909170		1	1	1	Mainstem, d/s of mine
C0-10	560669	7911633		1	1	1	Mainstem, d/s Sheardown Lake outflow
SDL-Trib 1							
D1-00	560329	7913512		1	1	1	Tributary D1
D1-05	561397	7913558		1	1	1	
Sheardown Lake NW							
DD-Hab 9-Stn1	560259	7913455	2		2	2	Nearshore monitoring location
DL0-01-1	560080	7913128	2		2	2	Long-term lake monitoring
DL0-01-2	560353	7912924	2		2	2	
DL0-01-4	560695	7913043	2		2	2	
DL0-01-5	559798	7913356	2		2	2	
DL0-01-7	560525	7912609	2		2	2	
Sheardown Lake SE							
DL0-02-3	561046	7911915	2		2	2	Long-term lake monitoring
DL0-02-4	561511	7911832	2		2	2	
DL0-02-6	560756	7912167	2		2	2	
DL0-02-7	560952	7912054	2		2	2	
DL0-02-8	561301	7911846	2		2	2	
Mary River (US of SDL)							
E0-03	562974	7912472		1	1	1	Mainstem, u/s of Deposit 1
E0-10	564405	7913004		1	1	1	Mainstem, u/s of Deposits No. 2 and 3, d/s of F0-01
E0-20[1]	561688	7911272		1	1	1	Mainstem u/s of trib E2 and d/s of ore/sewage discharge
E0-21[1]	562444	7911724		1	1	1	
F0-01	564483	7913015		1	1	1	Mainstem tributary from east pond
G0-01	564459	7912984		1	1	1	Mainstem, u/s of F0-01
G0-03	567204	7912587		1	1	1	Upstream, potential reference station within anticipated dust plume
G0-09[1]	571546	7916317		1	1	1	Upstream, potential reference station beyond anticipated dust plume
G0-09-A	571264	7917344		1	1	1	
G0-09-B	571248	7914682		1	1	1	

Station ID	Easting	Northing	Winter	Spring	Summer	Fall	Description/Rationale
	NAD83, Zone 17N						
Camp Lake							
JL0-01	557108	7914369	2		2	2	Long-term lake monitoring
JL0-02	557615	7914750	2		2	2	
JL0-07	556800	7914094	2		2	2	
JL0-09	556335	7913955	2		2	2	
JL0-10	557346	7914562	2		2	2	
Camp Lake Tributaries							
I0-01	555470	7914139		1	1	1	Tom River, below tote road
J0-01	555701	7913773		1	1	1	Outlet of Camp Lake
K0-01	557390	7915030		1	1	1	Drains to north region of Camp Lake
Camp Lake Tributary 1 (CLT-1)							
L0-01	557681	7914959		1	1	1	Mainstem tributary of CLT-1
L1-02	558765	7915121		1	1	1	Northern tributary of CLT-1, upstream of L0-01
L1-05	558040	7914935		1	1	1	
L1-08	561076	7915068		1	1	1	
L1-09[1]	558407	7914885		1	1	1	Receives west pond outflow
L2-03	559081	7914425		1	1	1	Southern tributary of CLT-1
Camp Lake Tributary Reference Areas							
CLT-REF3 (E2-08)[1]	567004	7909174		1	1	1	Reference stream outside dust plume
CLT-REF4 (CV-006-1)[1]	568533	7907874		1	1	1	
Mary River Reference Areas							
MRY-REF3 (S2-020)[1]	585407	7900061		1	1	1	Reference river outside dust plume
MRY-REF2 (S2-010)[1]	570650	7905045		1	1	1	
Reference Lakes							
TBD					12	12	
Duplicates			**5**	**3**	**9**	**9**	**26**
TOTAL			**57**	**31**	**101**	**101**	**290**

NOTES:
1. STATIONS INCLUDED IN THE EEM PROGRAM.
2. LAKE STATIONS REQUIRE SHALLOW AND DEEP SAMPLES (N=2 PER SEASON).

Power analysis was completed based on all the existing data, and is expected to be revisited after completion of additional baseline sampling in 2014. The 2014 baseline sampling will occur concurrently with construction, but prior to mine-related effluent or ore dust emissions.

At certain stations, combining analysis of data from stations with similar effluent additions may be required to achieve sufficient power. Using this method, data is combined together but remains attributed to a station. In this way, variability between stations and between impact areas and reference areas can be quantified. This approach increases power, while considering the variability that might occur between stations. During statistical analysis, the following stations are expected to have similar effluent concentrations and therefore similar station mean and variability values:

- BL0-01, BL0-01-A and BL0-01-B
- BL0-05 and BL0-05-A

- L1-09 and additional station
- Stations within Camp Lake
- Stations within the Sheardown Lake SE

2.7.5 Sampling Frequency and Schedule

Environment Canada (2012) specifies that four samples collected over a 12-month period from the same exposure and reference locations is the minimum amount of sampling required to detect differences in median values between exposure and reference stations. As described above, a power analysis was completed based on the effect sizes calculated using average baseline pre-mining data and benchmarks. To ensure a conservative study design, several actions were taken. For instance, the power analyses were completed based on an early warning flag (difference between measured baseline and 50% of AEMP benchmark).

The following sampling frequencies are recommended for each of the different programs:

- Lakes - three sampling events in each available season (winter, summer and fall) during the first three years of mine operation are expected to have adequate power to detect the early warning flag concentrations for lake data.
- Streams - four samples (one set of seasonal samples) per year is likely adequate for most parameters to determine significance.

Sampling will be conducted annually during the initial years of operation but sampling frequency will be evaluated regularly (i.e., each year) to determine if modifications are warranted. The sampling frequency and schedule will be evaluated after three years of monitoring.

2.7.6 Quality Assurance/Quality Control

A strict QA/QC program is in place to ensure that high quality and representative data are obtained in a manner that is scientifically defensible, repeatable and well documented. This program aims to ensure that the highest level of QA/QC standard methods and protocols are used for the collection of all environmental media samples. Quality assurance is obtained at the project management level through organization and planning, and the enforcement of both external and internal quality control measures. The following lists summarize the QA/QC procedures and practices being followed:

- Internal Quality Control:
    - Staffing the project with experienced and properly trained individuals
    - Ensuring that representative, meaningful data are collected through planning and efficient research
    - Using standard protocols for sample collection, preservation, and documentation
    - Calibrating and maintaining all field equipment
    - Collecting duplicate, blank, filter and travel blank samples for submission for analysis (approximately 10% of overall samples)
    - External Quality Control:
    - Employing fully accredited analytical laboratories for the analysis of all samples
    - Determining analytical precision and accuracy through the interpretation of the analysis reports for the blind duplicate, blank, filter and travel blank samples

The field sampling protocols being applied to the water (and sediment) quality programs are presented in Appendix A.

The quality of the data obtained for a project is assessed via their adherence to the pre-set data quality objectives (DQOs). DQOs provide a means of assessing whether the data in question are precise, accurate, representative, and complete. The results from QA/QC samples are reviewed to determine if sample contamination occurred. These data are further used to determine if the contamination occurred during collection, handling, storage, or shipping. Upon receipt from the laboratory, the data are uploaded into EQWin® along with copies of field notes, photos, Sample Receipt Confirmations, Microsoft Excel data, and Certificates of Analysis.

2.7.7 Study Design and Data Analysis

The purpose of effluent characterization and water quality monitoring is to answer the question:

What is the estimated mine-related change in contaminant concentrations in the exposed area

To answer this question, the study has been designed to test the following three hypotheses:

- Null hypothesis: Change over time is the same for exposure and reference stations. Alternate hypothesis: Data from exposure stations is statistically different from data measured at reference stations.
- Null hypothesis: Difference between exposure and reference stations is due to natural environmental variation. Alternate hypothesis: Difference in exposure and reference station is due to mine effects.
- Null hypothesis: Magnitude of concentrations at the reference station does not exceed the benchmark. Alternate hypothesis: Magnitude of concentrations at the reference station exceeds the benchmark.

Environment Canada (2012) does not explicitly define the program design required to monitor effects to water quality. Environment Canada does specify that:

- Comparisons between reference and exposure stations should identify parameters for which there are differences. This approach is consistent with a Control-Impact (CI) approach to design.
- If logistically possible, samples of effluent and water for reference and exposure stations be collected on the same day or in as close succession as possible. This implies paired sampling.
- If there is adequate pre-mining data in the exposure area, then this data may be used a basis for comparison to determine post-mining effects. This provision suggests comparison of concentrations before and after disturbance (BA design).

With federal EEM monitoring guidance in mind, and following guidance from INAC (2009) and peer-reviewed scientific journal articles (Green, 1979; Underwood, 1992; Smith, 2002), the selected program design framework is a BACI design. The BACI design addresses each of the three points above. A BACI design compares changes over time at exposure and control stations, while considering natural variation that may occur over this same time period. With this Project, the historical pre-mining data has already been collected for exposure and reference stations. Post-mining data at the exposure stations and reference stations would then be collected during mine operations. The BACI design will be used to detect changes in mean concentration with respect to the selected benchmarks, as per the assessment framework (Section 2.7.8).

A BACI design is good for assessing large short term changes and is a natural starting point for long term monitoring. A BACI design compares the baseline mean to the post-mining mean, which ignores time trends in the post-mining data. While this is reasonable for the initial mining period, long term temporal trends require adjustments to the statistical analyses that consider the rate of change over time.

2.7.8 Assessment Framework

Monitoring data will be assessed during each year of monitoring and would follow the assessment framework as outlined in Figure 2.12 and described below.

2.7.8.1 Step 1: Initial Data Analysis

Initial data analysis will involve following specific data management and monitoring protocols in the handling and initial comparison of data. These protocols are in accordance with the conceptual sampling approach defined in Figure 2.12.

Data Input and Storage

Following data collection, and upon receipt of the laboratory reports, data will be entered into the Project EQWin® database. The EQWin® Software was developed for collecting, analyzing, storing and interpreting sample data from environmental monitoring programs. All environmental data will be stored in EQWin® to expedite quality assurance/quality control and all subsequent analyses.

Initial Data Analysis including Outlier Assessment

The initial data analysis will include the following:

- Completion of summary statistics for parameters sampled (average, median, maximum, minimum, quartiles)
- Flagging of values greater than the defined benchmark values
- Flagging of values at or exceeding the mid-point between the baseline mean and the benchmark
- Evaluating temporal changes in the data by season

The initial data analysis will include an outlier assessment after data entry and the completion of quality assurance and quality control steps. An outlier assessment is completed after each round of sampling to ensure data anomalies are identified early. If necessary, the laboratory can be contacted to re-analyze samples. Any identified outliers will be investigated to ensure no data integrity issue exists. For example, duplicate and blank samples will be assessed along with any holding time exceedances. If no evidence exists to discard data, then the data will remain in the dataset but be flagged for future consideration.

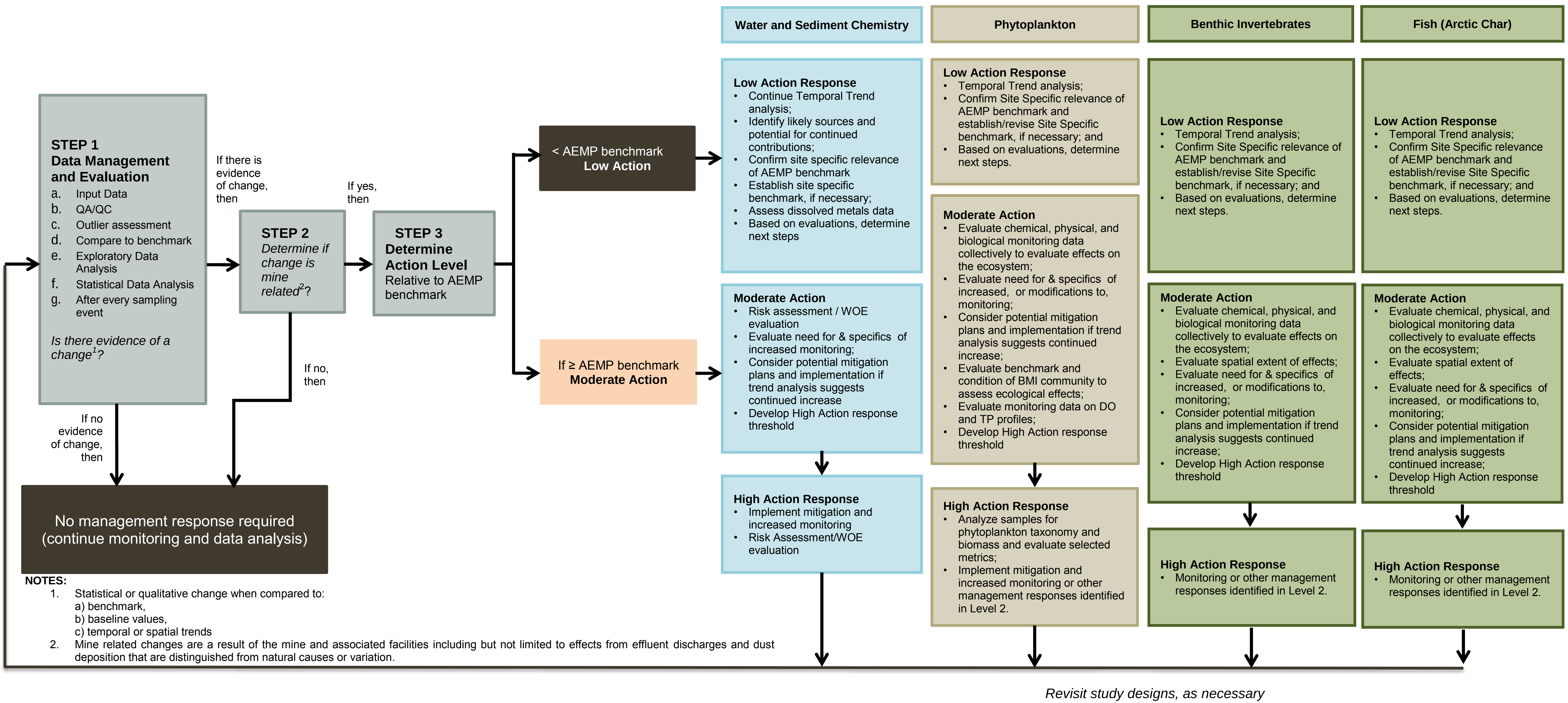


Figure 2.12 AEMP Assessment Approach and Response Framework

2.7.8.2 Step 2: Determine if Change is Mine Related

Step 2 involves determining if the changes in water quality parameters of concern are due to the Project or due to natural variability or other causes. This question will be addressed using exploratory data analysis (EDA) and subsequently using statistical data analysis (SDA), as described below.

Prior to conducting EDA and SDA, Project activities with the potential to alter water quality will be reviewed to identify potential Project-related causes or sources. This could include evaluating effluent quality, discharge regime/rates, and loading, dust deposition, and other point/non-point sources as required. Also, any evidence of potential natural causes (i.e., a major erosional event such as a slumping riverbank) will be investigated. Sampling data sheets and site personnel will be a source of this information.

Exploratory Data Analysis

Exploratory data analysis (EDA) will be completed to visualize overall data trends. This could include evaluating spatial patterns in water quality results for the Mine Area as a whole, including Mine Area lakes and streams, to evaluate if changes are widespread or specific to certain waterbodies, or proximate to mine-related sources, and to identify the spatial extent and pattern of observed changes.

Other exploratory data analyses could include comparisons of data from Mine Area streams to data from reference streams and comparisons of Mine Area Lakes to reference lake(s). This will further assist with determining whether the observed changes were due to natural variability or the Project.

Graphical analyses may be used to confirm assumptions required for statistical testing (normality, sample size, independence). Results of the EDA can be used in tandem with the Statistical Data Analysis (SDA) to evaluate the observed statistical trends and further assess whether the changes noted are mine related.

Statistical Data Analysis

Primary SDA consistent with the statistical methodology used for power analysis (BACI design) will be completed on total metals to determine the magnitude of change during post-mining. This step in the analysis tests the primary hypothesis for the effects of mine-related change and will be applied to the parameters of interest.

If the Step 2 analysis concludes that the changes in water quality parameters of concern are, or are likely, due to the Project, the assessment will proceed to Step 3. If it is concluded the observed differences relative to baseline conditions are not due to the Project, no management response will be required.

2.7.8.3 Step 3: Determine Action Level

Once EDA and primary SDA has indicated with some certainly that the measured change is project-related, Step 3 involves determination of the action level associated with the observed monitoring results through comparisons to the benchmark.

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

- Evaluate temporal trends
- Identify likely loading source(s) and potential for continued loading contributions
- Confirm the site-specific relevance of benchmark and establish a site-specific benchmark, if necessary
- Further evaluate data (for example, for water quality, review dissolved metals data and/or supporting variables)
- Based on evaluations, determine next steps

If the benchmark is exceeded and it is concluded to be Project-related, a **moderate action level response** would be undertaken and could include, in addition to analyses identified for a low action response, the following:

- Consider a weight-of-evidence (WOE) evaluation and/or risk assessment, considering other monitoring results collectively with water quality to evaluate effects on the ecosystem
- Evaluate the need for and specifics of increased monitoring
- Evaluate the need for additional monitoring (e.g., confirmation monitoring) and/or modifications to the CREMP
- Consider results of the trend analysis (i.e., trend analysis indicates an upward trend) and evaluation of potential pathways of effect (i.e., causes of observed changes) to determine if management/mitigation is required
- Identify next steps based on the above analyses. Next steps may include those identified for the high action level response.

A quantitative trigger for the **high action level response** has not been identified as the need for additional study and/or mitigation will depend on the ultimate effects of the observed increases in water quality parameters of concern on the lakes as a whole, as well as the monitoring results from the freshwater biota CREMP. Also, the benchmark may need to be revised in consideration of ongoing monitoring results. The precise relationships between water quality, sediment quality and lower trophic level changes and the collective effects on fish is difficult to predict and therefore actions undertaken under Step 3 will attempt to explore these relationships to advise on overall effects to the ecosystem. Results would be discussed with regulatory agencies and the next steps would be identified. Additional actions that may be implemented in a subsequent phase (i.e., high action level response) could include:

- Implementation of increased monitoring to further assess the potential for effects and/or define magnitude and spatial extent if warranted
- Implementation of mitigation measures or other management actions that may be identified under the moderate action level response

3 – SEDIMENT QUALITY REVIEW

3.1 SUMMARY OF SEDIMENT SAMPLING PROGRAM

The collection of baseline sediment quality samples for the Project was carried out between 2005 and 2008 and between 2001 and 2013 in conjunction with the water quality baseline program. Results up to and including 2011 were presented in the baseline reports referenced in Section 2.1. Sediment quality data collected in 2012 and 2013 are included in this review but were not previously reported.

Sampling of sediment in streams and lakes around the mine site was typically conducted once in the fall (late August/early September) in conjunction with and at the same stations as the water quality and benthic invertebrate sampling. Table 3.1 summarizes the sediment quality baseline program by year and location around the mine site. The Mine site sediment sampling locations are shown on Figure 1.3.

Table 3.1 Number of Sediment Samples by Year and Location

Grouping	2005	2006	2007	2008	2011	2012	2013
Camp Lake	0	0	6	0	0	3	3
Camp Lake Tributary	3	0	4	0	3	7	5
Mary River Downstream	2	1	5	0	10	4	3
Mary Lake	0	2	5	0	0	1	1
Sheardown Lake NW	0	0	7	12	3	4	6
Sheardown Lake SE	0	0	5	0	0	1	1
Sheardown Lake Tributary	2	0	5	3	4	3	1
Mary River Upstream	1	1	1	0	0	0	1

Sampling and analytical methods, and quality assurance/quality control (QA/QC) procedures applied during the sampling period are described in the sampling protocol included as Appendix A. In the initial years, sediment sampling was carried out using of a Petite Ponar dredge sampler to collect a maximum sample collection thickness of 5 cm. This depth is appropriate for monitoring studies where historical contamination is not a priority (Environment Canada, 2012). During the NIRB review, Baffinland agreed to a recommendation from Environment Canada that the upper 1 to 2 cm of sediment be collected as part of Project monitoring. Most infaunal organisms and the most recently introduced sediment (including any contaminants of concern) are found in the upper 2 cm of the sediment. Arctic lakes experience low sedimentation rates and therefore collection of a thinner sample on surface using a sediment core sampler should provide better resolution of changes in sediment quality. Collection of thinner (2 cm) sediment samples was implemented by Baffinland starting in 2012.

Laboratory analysis of the sediment samples included physical tests, as well as tests for nutrients, carbon and metal concentrations (Table 3.2). Specific metal parameters have been identified as parameters of interest due to their potentially toxic effects when present at defined concentrations. These are the parameters for which sediment quality criteria have been established in order to protect aquatic life. It is important to establish baseline concentrations for these parameters prior to development of the Project for post-Project comparison.

Table 3.2 Summary of Baseline Sediment Quality Analytical Parameters

Parameter Category	Analytes
Physical Tests	Moisture, Particle Size (% Sand, % Silt, % Clay)
Nutrients	Ammonia, Nitrate, Nitrite, Total Kjeldahl Nitrogen (TKN)
Carbon	Total Organic Carbon (TOC)
Metals	Aluminium, Antimony, **Arsenic**, Barium, Beryllium, Boron, Cadmium, Calcium, **Chromium**, Cobalt, **Copper**, Gold, **Iron**, Lead, Magnesium, **Manganese**, Mercury, Molybdenum, **Nickel**, Potassium, Selenium, Sodium, Strontium, Thallium, Vanadium, Zinc

NOTES:
1. THE PARAMETERS OF INTEREST ARE INDICATED IN BOLD FONT.

Baseline analytical sediment quality data were compared to relevant guidelines for the Project that include:

- Canadian Sediment Quality Guidelines for the Protection of Freshwater Aquatic Life (CSQG-PAL) established by the CCME (CCME, 2001)
- MOE Ontario Provincial Sediment Quality Guidelines (PSQG) (Fletcher et al., 2008)ss

The CSQG established Interim Sediment Quality Guidelines (ISQGs) for select parameters. These guidelines correspond to the concentration thresholds below which adverse biological effects are not expected. The Probable Effect Level (PEL) corresponds to the concentration above which adverse biological effects are frequently found (CCME, 2001).

The PSQG established a Lowest Effect Level (LEL) threshold for parameters that correspond to concentrations that can be tolerated by the majority of sediment dwelling organisms. The Severe Effect Level (SEL) corresponds with concentrations expected to be detrimental to the majority of sediment dwelling organisms (Fletcher et al., 2008).

The laboratory detection limits for many metals improved over the duration of the testing program (i.e., between 2005 and 2013). All laboratory results and their respective detection limits for each year are presented in Section 3.3.

3.2 RELATED STUDIES

Other studies that have been undertaken that provide information on sediment quality, include:

- Substrate mapping associated with aquatic biota studies
- Monitoring of water and sediment quality and benthic invertebrates in Sheardown Lake and its tributary. This work was related to dust emissions associated with an ore crushing operation in 2008 during a bulk sampling program.
- Measurements of baseline sedimentation rates in Sheardown Lake

Each of these studies is described in the following sub-sections.

3.2.1 Substrate Mapping

Bathymetry and substrate mapping of Camp Lake, Sheardown Lake and Mary Lake are shown in Figures 3.1, 3.2 and 3.3, respectively. Substrate was described by North/South (2012) as either:

- Cobble/boulder
- Gravel/pebble
- Sand
- Fine sand/silt/clay

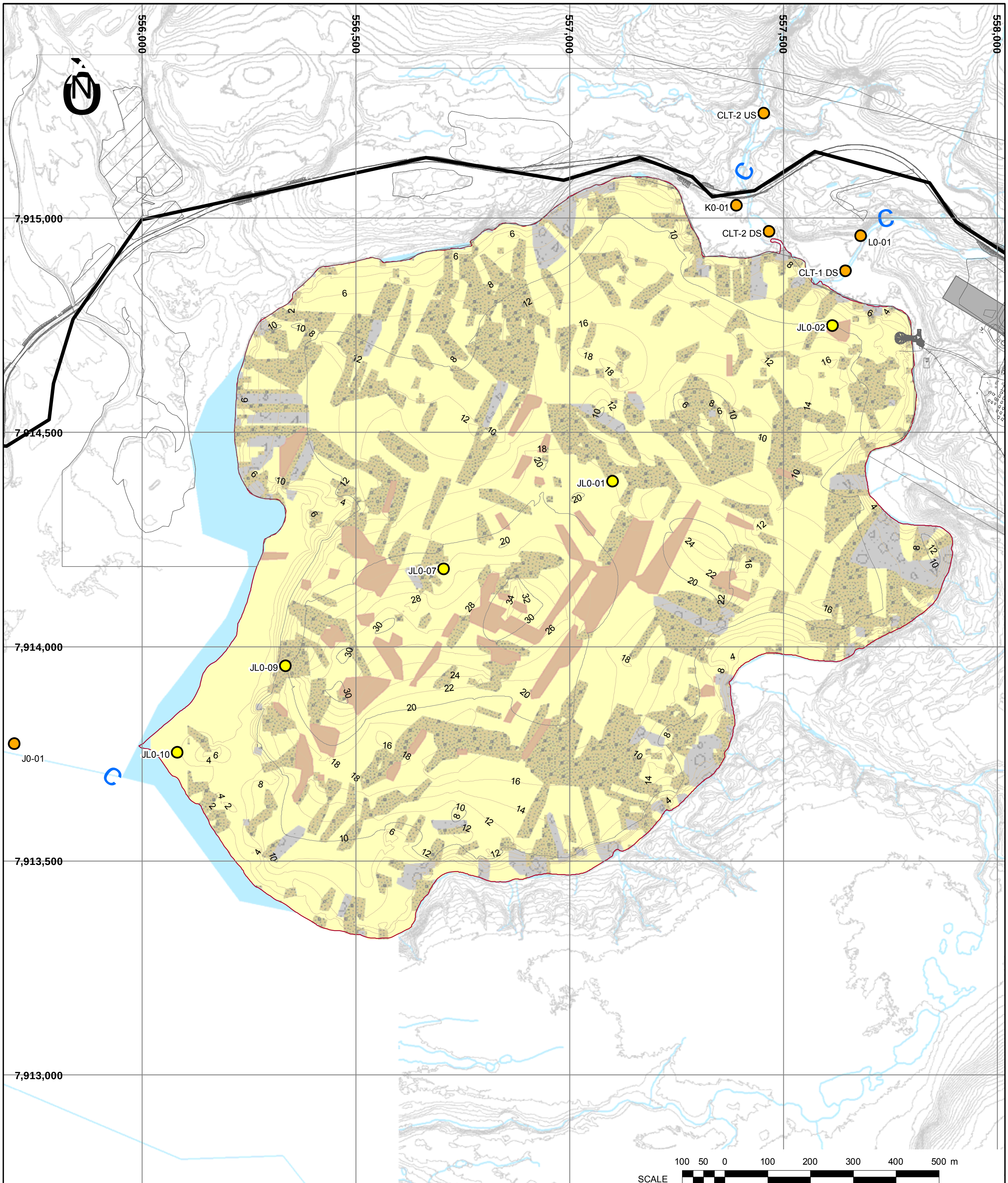
Substrate mapping provides a coarse representation of the substrate. Substrate conditions within each of the study lakes (Mary Lake, Camp Lake and Sheardown Lake), described by North/South (2012):

Camp Lake In this lake the shoreline, littoral/euphotic, and profundal zones occupy approximately 16 ha (8%), 117 ha (37%), and 78 ha (55%), respectively. Camp Lake has a maximum depth of 35.1 m and a mean depth of 13.0 m. In general, depth extends to 10 m within approximately 100 to 200 m of the shoreline with a relatively uniform depth (10 to 20 m) throughout the majority of the lake (Figure 3.1). The shoreline in Camp Lake consists primarily of gravel/pebble (or smaller-sized substrate, particularly in the southwest), with small, isolated areas of cobble/boulder shoreline in the east, southeast, and northwest sections of the lake. Sand is the dominant substrate in Camp Lake and is found throughout the near shore and offshore areas. Small patches of finer substrates are dispersed primarily in deeper, offshore areas, while patches of cobble/boulder substrate are found primarily in shallower, near shore areas (i.e., shoreline zone). Gravel/ pebble sized substrates are dispersed throughout the lake.

Sheardown Lake NW Within the northwest basin of Sheardown Lake, the shoreline, littoral/euphotic, and profundal zones occupy approximately 8 ha (12%), 28 ha (42%), and 32 ha (46%), respectively. Sheardown Lake NW is characterized by maximum and mean depths of 30.1 m and 12.1 m, respectively. This basin typically reaches depths of greater than 10 m at distances of less than 50 m from shore (Figure 3.2). The exception to this is a broad, shallow area in the southeast section of this basin. The shoreline in Sheardown Lake NW is primarily sand or gravel/pebble with a few areas of cobble/boulder. Substrate in the northwest basin consists primarily of sand or gravel/pebble with some cobble/boulder areas (usually in the littoral zone) and a few, small patches of fine substrates (typically in the profundal zone).

Sheardown Lake SE The southeast basin of Sheardown Lake is shallower than the northeast basin with maximum and mean depths of 26.7 m and 7.4 m, respectively. The shoreline, littoral/euphotic, and profundal zones occupy approximately 5 ha (19%), 16 ha (65%), and 4 ha (15%), respectively. Relatively large areas of this basin are less than 10 m in depth (Figure 3.2). This characteristic, combined with high water clarity, results in the lake being dominated by the littoral/euphotic zone.

The southeast basin has a similar proportion of sand to the northwest basin, but lacks finer substrates. An area of relatively dense aquatic macrophyte growth was observed in the southern extent of this basin. This macrophyte growth likely consists of non-vascular plants, such as macroalgae (e.g., *Chara*sp).



LEGEND:

- LAKE SEDIMENT SAMPLE STATION
- STREAM SEDIMENT SAMPLE STATION
- FLOW DIRECTION
- EXISTING TOTE ROAD
- CAMP LAKE SHORELINE
- 2 METRE INTERVAL
- 10 METRE INTERVAL
- PROPOSED INFRASTRUCTURE
- RIVER/STREAM/DRAINAGE
- WATER
- COBBLE/BOULDER
- FINE SAND/SILT/CLAY
- GRAVEL/PEBBLE
- SAND
- PROPOSED INFRASTRUCTURE

NOTES:

1. COORDINATE GRID IS IN METRES. COORDINATE SYSTEM: NAD 1983 UTM ZONE 17N.
2. CONTOUR INTERVAL IS 30 CENTIMETRES.
3. SUBSTRATE AND BATHYMETRY DATA PROVIDED BY NORTH/SOUTH CONSULTANTS INC., NOVEMBER 28, 2013.
4. DEPTHS OF BATHYMETRIC CONTOURS ARE IN METRES AND ARE RELATIVE TO SHORELINE AT TIME OF SURVEY.
5. INFRASTRUCTURE INFORMATION PROVIDED BY HATCH ON JANUARY 31, 2014.

BAFFINLAND IRON MINES CORPORATION

MARY RIVER PROJECT

SEDIMENT SAMPLE LOCATIONS CAMP LAKE

Knight Piésold CONSULTING

P/A NO.	REF NO.
NB102-181/33	1

FIGURE 3.1 REV 1

REV	DATE	DESCRIPTION	DESIGNED	DRAWN	CHK'D	APP'D
1	30MAY'14	ISSUED WITH REPORT	RAC	SWK	RAC	RAM
0	27MAR'14	ISSUED WITH REPORT	DKK	AS	RAC	RAM

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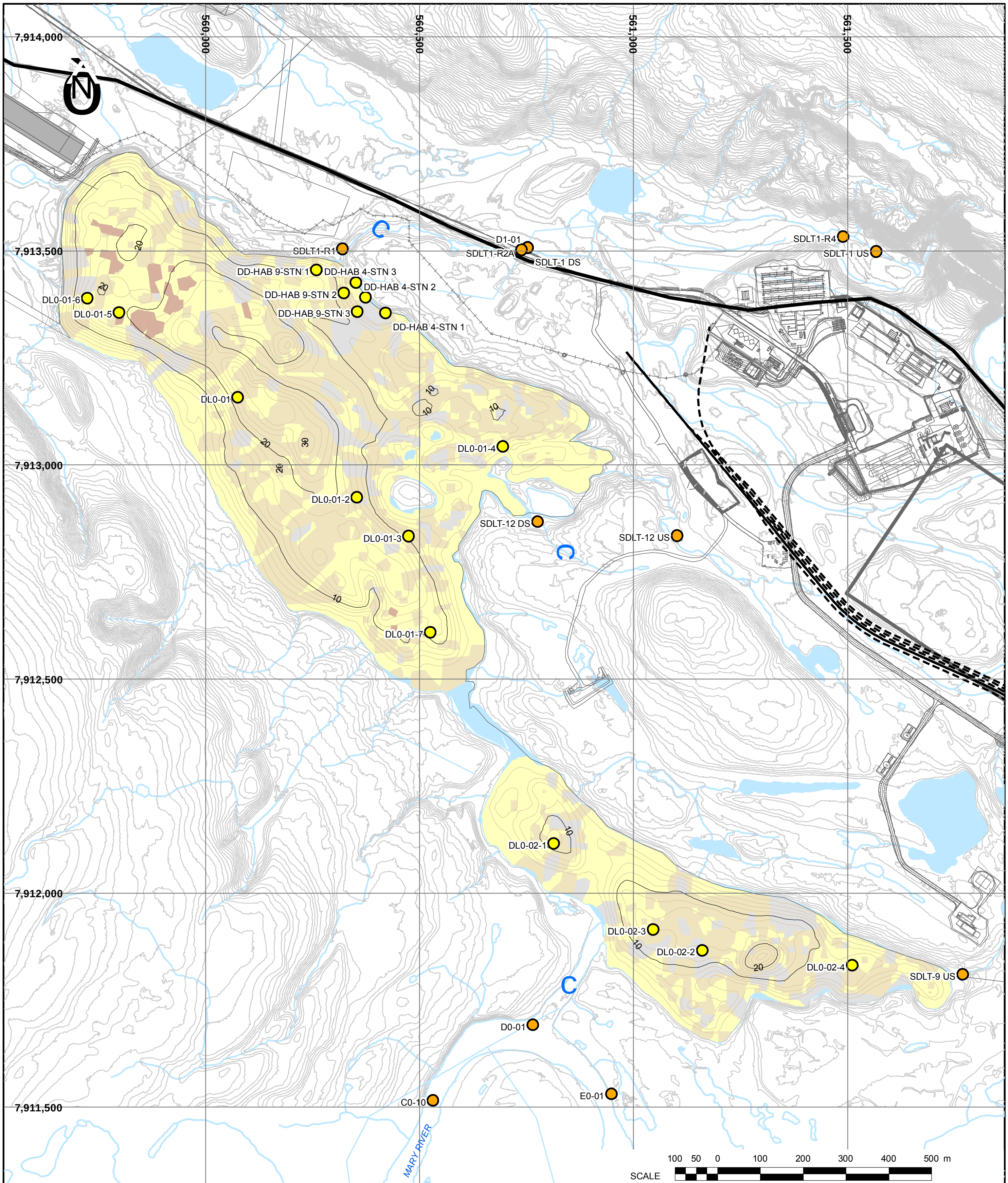

LEGEND:

- LAKE SEDIMENT SAMPLE STATION
- STREAM SEDIMENT SAMPLE STATION
- FLOW DIRECTION
- EXISTING TOTE ROAD
- CAMP LAKE SHORELINE
- 2 METRE INTERVAL
- 10 METRE INTERVAL
- PROPOSED INFRASTRUCTURE
- RIVER/STREAM/DRAINAGE
- WATER
- COBBLE/BOULDER
- FINE SAND/SILT/CLAY
- GRAVEL/PEBBLE
- SAND
- PROPOSED INFRASTRUCTURE

NOTES:

1. COORDINATE GRID IS IN METRES. COORDINATE SYSTEM: NAD 1983 UTM ZONE 17N.
2. CONTOUR INTERVAL IS 30 CENTIMETRES.
3. SUBSTRATE AND BATHYMETRY DATA PROVIDED BY NORTH/SOUTH CONSULTANTS INC., NOVEMBER 28, 2013.
4. DEPTHS OF BATHYMETRIC CONTOURS ARE IN METRES AND ARE RELATIVE TO SHORELINE AT TIME OF SURVEY.
5. INFRASTRUCTURE INFORMATION PROVIDED BY HATCH ON JANUARY 31, 2014.

BAFFINLAND IRON MINES CORPORATION

MARY RIVER PROJECT

SEDIMENT SAMPLE LOCATIONS SHEARDOWN LAKE

Knight Piésold CONSULTING

P/A NO.	REF NO.
NB102-181/33	1

FIGURE 3.2 REV 1

REV	DATE	DESCRIPTION	DESIGNED	DRAWN	CHK'D	APP'D
1	30MAY'14	ISSUED WITH REPORT	RAC	SWK	RAC	RAM
0	27MAR'14	ISSUED WITH REPORT	DKK	AS	RAC	RAM

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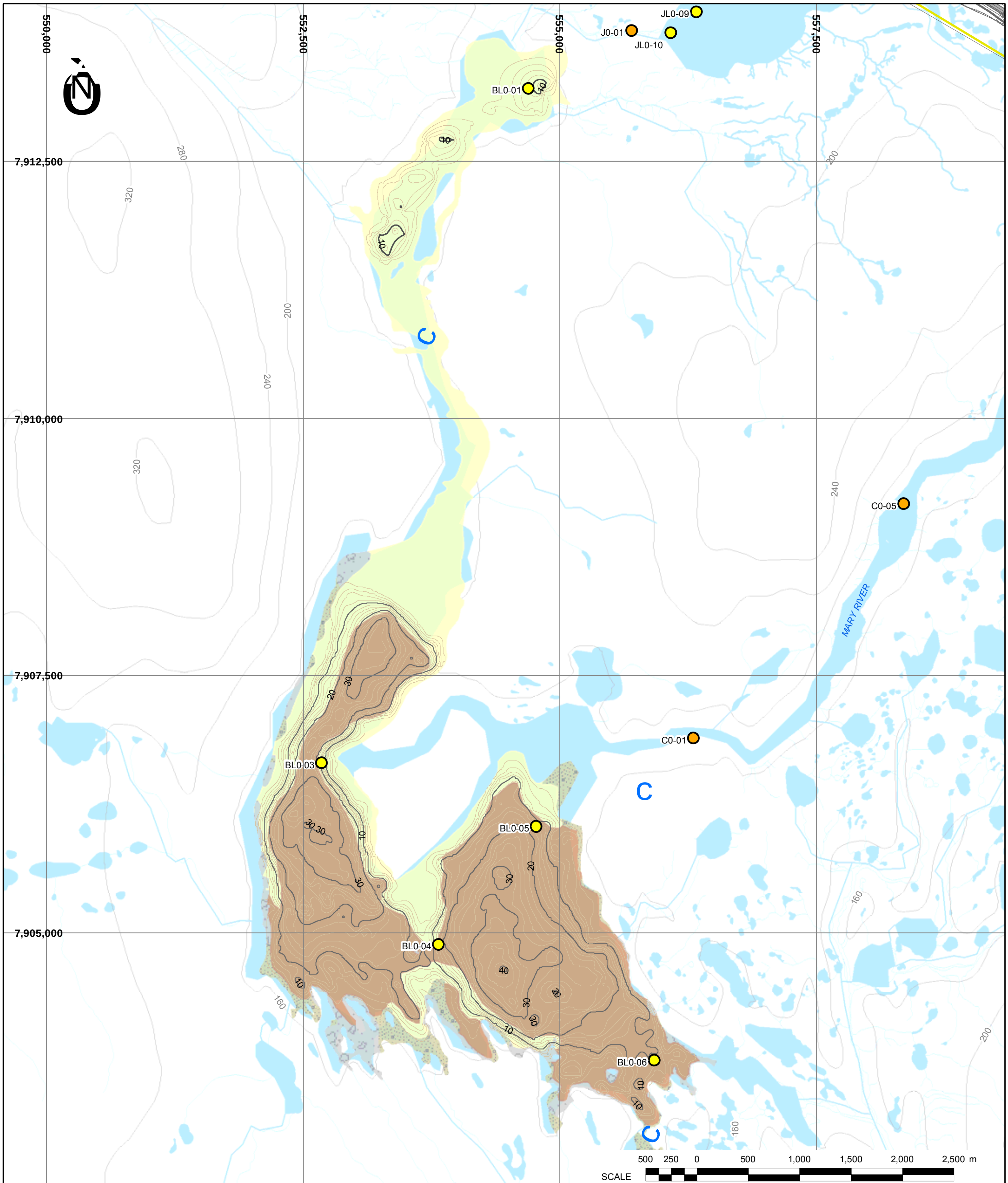


LEGEND:

- LAKE SEDIMENT SAMPLE STATION
- STREAM SEDIMENT SAMPLE STATION
- FLOW DIRECTION
- EXISTING TOTE ROAD
- CAMP LAKE SHORELINE
- 2 METRE INTERVAL
- 10 METRE INTERVAL
- PROPOSED INFRASTRUCTURE
- RIVER/STREAM/DRAINAGE
- WATER
- COBBLE/BOULDER
- FINE SAND/SILT/CLAY
- GRAVEL/PEBBLE
- SAND
- PROPOSED INFRASTRUCTURE

NOTES:

1. COORDINATE GRID IS IN METRES. COORDINATE SYSTEM: NAD 1983 UTM ZONE 17N.
2. CONTOUR INTERVAL IS 30 CENTIMETRES.
3. SUBSTRATE AND BATHYMETRY DATA PROVIDED BY NORTH/SOUTH CONSULTANTS INC., NOVEMBER 28, 2013.
4. DEPTHS OF BATHYMETRIC CONTOURS ARE IN METRES AND ARE RELATIVE TO SHORELINE AT TIME OF SURVEY.
5. INFRASTRUCTURE INFORMATION PROVIDED BY HATCH ON JANUARY 31, 2014.

BAFFINLAND IRON MINES CORPORATION

MARY RIVER PROJECT

SEDIMENT SAMPLE LOCATIONS
MARY LAKE AREA

Knight Piésold CONSULTING

P/A NO.	REF NO.
NB102-181/33	1

FIGURE 3.3 REV 1

REV	DATE	DESCRIPTION	DESIGNED	DRAWN	CHK'D	APP'D
1	30MAY'14	ISSUED WITH REPORT	RAC	SWK	RAC	RAM
0	27MAR'14	ISSUED WITH REPORT	DKK	AS	RAC	RAM

Mary Lake Similar to Camp Lake, Mary Lake is relatively deep with a maximum depth of 41.1 m in the large south basin. The mean depth of 12.0 m is shallower than Camp Lake and more similar to the NW basin of Sheardown Lake. The shoreline, littoral/euphotic, and profundal zones occupy approximately 493 ha (36%), 365 ha (26%), and 522 ha (38%), respectively. Expansive, shallow, near shore areas at the north end of the south basin (in proximity to the Mary River inlet and outlet) contribute to the comparatively shallow mean depth (Figure 3.3). Near shore substrate in Mary Lake, like the other lakes that have been surveyed for sediment quality, consists primarily of sand with patches of finer substrates and cobble/boulder. The substrata type in the shallower north arm is sand, while relatively fine sand mixed with silt/clay predominates throughout the deeper south basin.

3.2.2 Aquatic Effects Monitoring of Dust from Bulk Sample Ore Crushing

A small, single season study was completed in 2008 that sampled sediment (as well as water quality and lower trophic level components) to monitor dust emissions from ore crushing during the bulk sampling program (North/South, 2010). As part of the bulk sampling program, crushing and screening of ore occurred during the winter and spring of 2008 near Sheardown Lake NW and Tributary SDLT-1 (Tributary 1, which is a main tributary supporting the lake). The above study evaluated the water and sediment quality as well as periphyton, drifting invertebrates and benthic invertebrates within SDLT-1. The near shore environment at the mouth of SDLT-1, and control stations, were also evaluated.

Collectively, the results of the chemical and biological samples obtained did not indicate a definitive effect of dust deposition on the benthic invertebrate density or composition. Water quality monitoring results indicate that aluminum and lead may have been measurably increased in spring near the mouth of the tributary to Sheardown Lake NW, but other effects on sediment quality and lower trophic level biota were not definitive (North/South, 2010). North/South noted that the assessment was hampered by a lack of data collected in the immediately affected area prior to dust deposition and by other confounding factors such as substrate differences that limited direct comparisons.

3.2.3 AEMP Target Study on Lake Sedimentation Rates

A targeted study identified completed in the open-water season of 2013 to measure sedimentation in Sheardown Lake NW. This study was part of Baffinland's Updated AEMP Framework (Baffinland, 2013) and was designed to generate baseline information on lake sedimentation rates for post-Project comparison. Sediment traps were deployed at three stations in the lake, with five replicates at each station. This configuration was utilized to ensure adequate sediment was obtained for laboratory analysis and to provide sufficient information to evaluate variability at each station. The stations were selected to generate measurements of sedimentation rates at a deep station (where sedimentation is typically greatest) and at two shallower locations. This ongoing study may support the interpretation of results generated from CREMP sediment quality monitoring.

3.3 REVIEW OF SEDIMENT QUALITY DETECTION LIMITS

The yearly laboratory MDLs for sediment quality parameters of interest are presented in Table 3.3 and compared to the CSQG limits and PSQG criteria. In general, the detection limits were well below the relevant quality guidelines concentrations, and MDLs did not change meaningfully over the sampling period. The MDL reported for mercury is very close to the CSQG-PAL ISQG concentration. In addition, the MDL reported for cadmium is 0.1 µg/g below the CSQG-PAL ISQG and PSQG-LEL concentrations (the MDL is 0.5 µg/g compared to the guideline value of 0.6 µg/g). Increased resolution for these parameters would better define areas with concentrations above the quality guidelines.

As with the water quality, power analysis can be utilized to calculate the minimum sample size required to be reasonably sure that an effect of a given size can be detected. The ability to detect change during future monitoring is a function of the number of sampling events and the spread in results. Baffinland is interested in utilizing its existing baseline dataset to the maximum extent possible. This approach should reduce the number of monitoring events that will be required to detect a given change.

Table 3.3 Summary of Sediment Quality Laboratory Detection Limits

Parameter	**As**	**Cd**	**Cr**	**Cu**	**Fe**	**Hg**	**Mn**	**Ni**	**Pb**	**Zn**
Units	**µg/g**	**µg/g**	**µg/g**	**µg/g**	**µg/g**	**µg/g**	**µg/g**	**µg/g**	**µg/g**	**µg/g**
CSQG-PAL ISQG	5.9	0.6	37.3	35.7	--	0.17	--	--	35	123
CSQG-PEL	17	3.5	90	197	--	0.486	--	--	91.3	315
PSQG-LEL	6	0.6	26	16	20,000	0.2	460	16	31	120
PSQG-SEL	33	10	110	110	40,000	2	1100	75	250	820
Method Detection Limits (by year)										
2005	0.03	0.006	0.5	0.1	0.5	0.1	0.05	1	0.7	0.1
2006	1.0	0.5	1	1	1	0.1	1	1	1	1
2007	1	0.5	1	1	1	0.1	1	1	1	1
2008	1	0.5	1	0.1	1	0.1	1	1	1	1
2011	1	0.5	1	1	5	0.1	1	1	1	2
2012	1	0.5	1	1	5	0.1	1	1	1	2
2013	1	0.5	1	1	5	0.1	1	1	1	2

3.4 SEDIMENT QUALITY STRESSORS OF POTENTIAL CONCERN

The FEIS for the Project (Baffinland, 2012) identified the following stressors of potential concern for sediment quality given the average geochemical composition of the iron ore:

- Arsenic
- Cadmium

- Iron
- Nickel

The following metals have been noted to be naturally elevated in the sediment in the streams and lakes within the mine site area (see Section 3.5 and Table 3.4):

- Arsenic
- Cadmium
- Chromium
- Copper
- Iron
- Manganese
- Nickel

It is expected that the metals found to be naturally elevated in the sediment is due to the mineralization associated with the ore body. As such, it is possible that these same metals will accumulate in sediment during the Project. On that basis, the metals listed immediately above are the identified sediment quality stressors of potential concern.

Lead and zinc were noted at one location in Sheardown Lake in recent (2012 and 2013) sediment testing. These two metals are not consistently elevated in sediment within the mine site streams and lakes and are, therefore, not carried forward as sediment quality stressors of potential concern. Lead and zinc will still be tested for in sediment as part of the monitoring program.

3.5 REVIEW OF SEDIMENT QUALITY BASELINE

A detailed review of the available sediment quality data using various graphical analysis tools is presented in Appendix D.

3.5.1 Metals Accumulation in Sediment and Total Organic Carbon and Fines

Metals concentrations in sediment are positively correlated with both finer grained particles as well as higher organic carbon content (Horowitz, 1991). Smaller particles have more binding sites and a higher affinity for metals than coarser grained material. Organic carbon within sediment decreases the dissolved oxygen and creates a more anoxic environment. Depending on pH, an anoxic environment may influence metal solubility and speciation. Within depositional areas of the lake that are characterized by higher concentrations of TOC and/or greater proportions of fine grained sediment, concentrations of several metals regularly exceeded the CSQG-PAL ISQGs or the PSQG-LEL. This includes chromium, copper, iron, manganese, nickel and phosphorus, and sometimes arsenic. Iron in some instances exceeded the PSQG-SEL. Most metals correlated well; in samples where one of the metals was elevated, all others were also elevated, except arsenic and manganese.

At the Mary River mine site, depositional environments were predominantly found within the lakes. The main exception to this is the stations within the main tributary of Sheardown Lake (Tributary 1). Streams at the mine site are mostly high gradient, high energy depositional environments that are not likely to have substantial amounts of fine grained sediment or sediment with high organic carbon content. The accumulation of metals in the depositional environments of the lakes is observed when reviewing mean concentrations of key metals as presented in Table 3.4 (numbers have been rounded). Stream versus lake sediment sample groupings are shaded different colours.

Table 3.4 Mean Concentrations of Key Metals in Sediment at the Mine Site

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

Table 3.4 shows that the metal concentrations in depositional environments tended to be consistently higher in the same metals. In most of the mine site lakes, the mean concentrations of chromium, copper, iron, manganese and nickel exceeded the referenced guidelines.

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

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

In terms of long-term monitoring, it is recommended that sediment sampling stations in depositional environments be the focus of monitoring along with the application of the Assessment Approach and Response Framework (Figure 2.12):

- Detection of a change[3]
- Establishing if the change is mine related
- Comparison to benchmark
- Undertaking a low or moderate action depending on the result compared to the benchmark

The high level of variability within sediment samples characterized by low TOC and/or low fines (high proportion of sand) do not allow for the detection of statistically significant changes as the variability between samples is likely to be greater than any project-related changes and collection of a sufficient number of samples to obtain statistical power is likely not possible.

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

Figure 3.4 shows the entire sediment quality dataset plotted as percent clay vs percent sand with the circle size representing the proportion of silt. Figure 3.5 shows the same information in another way, plotting the proportion of clay/clay+silt versus the percent sand. The figures show the 3-way relationship between sand, silt and clay and the negative association between sand and clay.

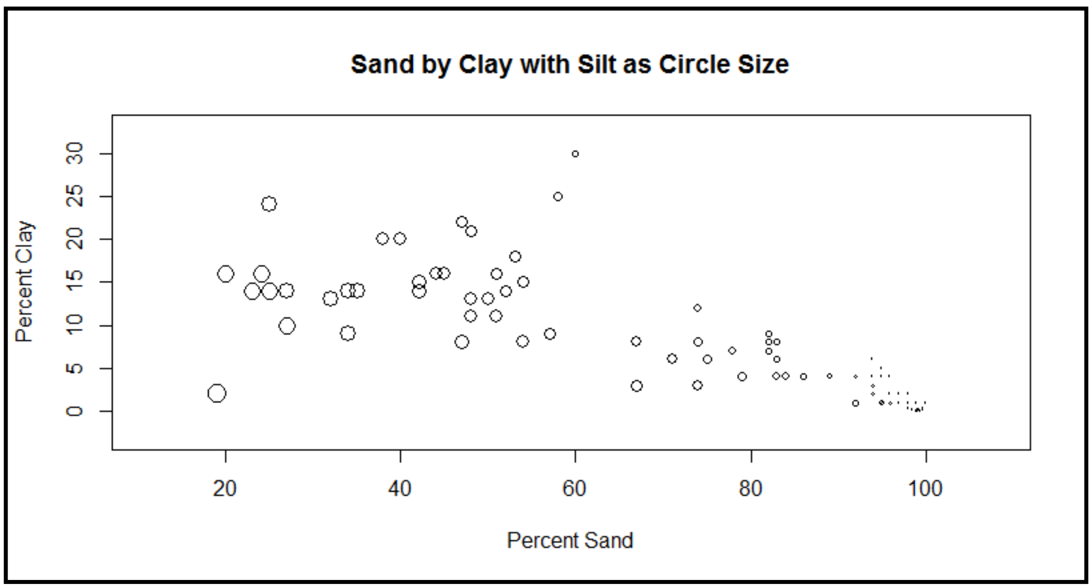


Figure 3.4 Clay by Sand with Silt as Circle Size

1. A change in this instance may be a statistical or qualitative change when compared to: a benchmark, baseline values, or temporal or spatial trends

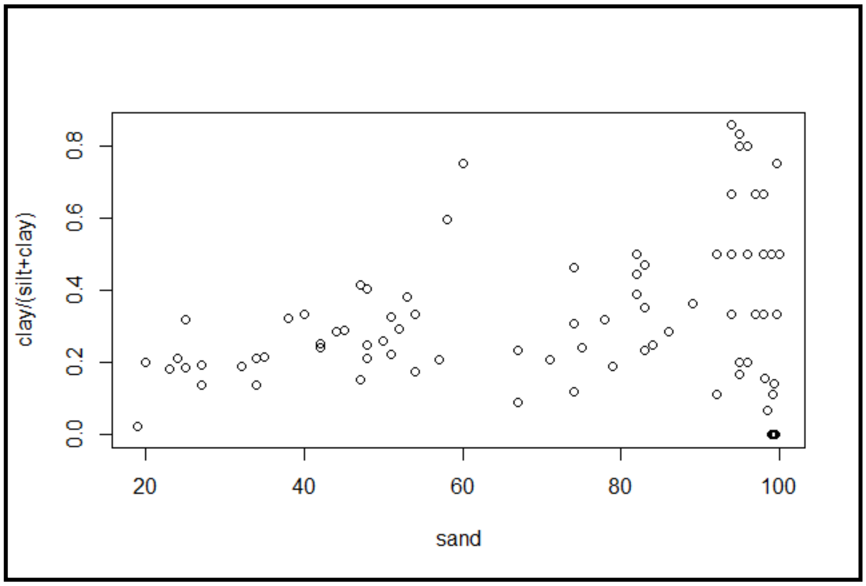


Figure 3.5 Dependent Relationship between Sand, Silt and Clay in Sediment

Colored scatter plots (Figure 3.6) show the relationship between TOC (or log TOC) and sand for lakes, streams and tributaries. Lakes are plotted using circles, streams and tributaries with triangles. Colors are used to identify the specific water bodies. Note that the x axis limits for streams and tributaries were adjusted because all the stream data is clumped at high proportions of sand (minimum of 82%). The figure shows that as expected the majority of lake sediment samples contain elevated TOC and higher proportions of fines (a lower proportion of sand), and conversely, the majority of stream samples are low in TOC and low in fines (predominantly sand).

A further evaluation was undertaken to identify cut offs in TOC and percent sand that could be applied to identify sediment samples in the baseline data. These same cut offs would be applied to sediment samples collected for monitoring.

3.5.2 Cut Point Analysis

Percent sand and TOC are generally related to metals concentrations. Deposition seems to be limited in sediment samples with a lot of sand and very little TOC. The focus of monitoring as part of the CREMP will be on identifying mine-related changes in metals concentrations. Variability due to TOC and particle size introduces extraneous noise. As such, it is generally better to control confounding factors in the study design rather than adjust for them during the data analysis. The data was reviewed to determine appropriate TOC and particle size cut-offs in order to identify sensitive depositional environments and minimize variability related to TOC and particle size. It was clear from the graphical analyses presented in Appendix D that establishing cut-offs in the vicinity of 80 to 90% sand (10 to 20% fines) and around 0.5% to 1% TOC would remove the non-depositional samples with high variability and comparatively low metals accumulation. Analyses were completed for four key parameters: arsenic, cadmium, iron and nickel.

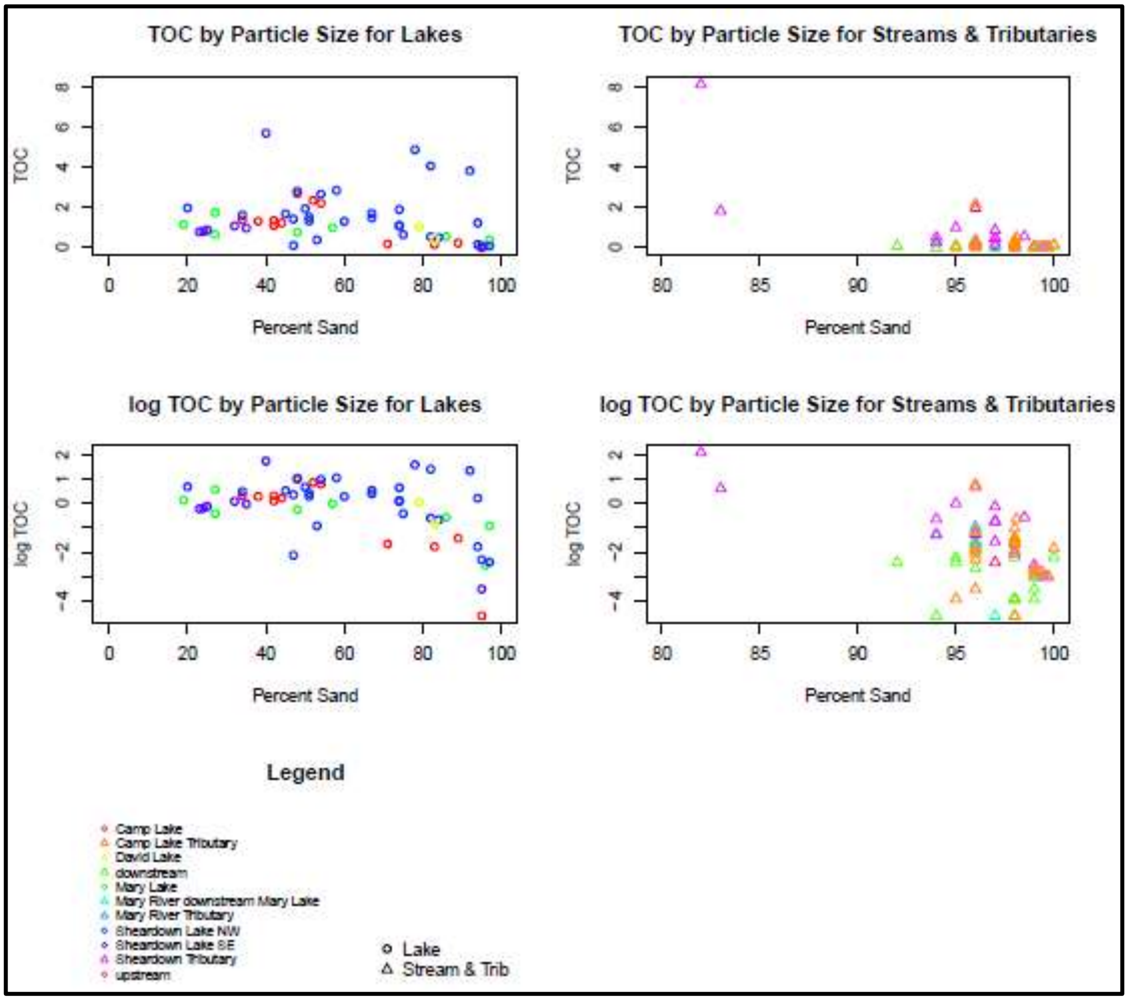


Figure 3.6 Sediment TOC versus Particle Size for Lakes and Streams

Analyses presented in Appendix D helped to identify cut points in the vicinity of inflection points on the curves. These cut points were used in subsequent linear regression analyses to explore the linear relationship above and below the cut off points.

A subset of the data was defined that excluded all samples with greater than 90% sand as well as samples with less than 0.6% TOC and greater than 80% sand (indicated in orange in Figure 3.7). Alternatively, a cut off could be established such as the sloped black line in Figure 3.7. It may be useful to carry out future research with additional data to develop such a rule.

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

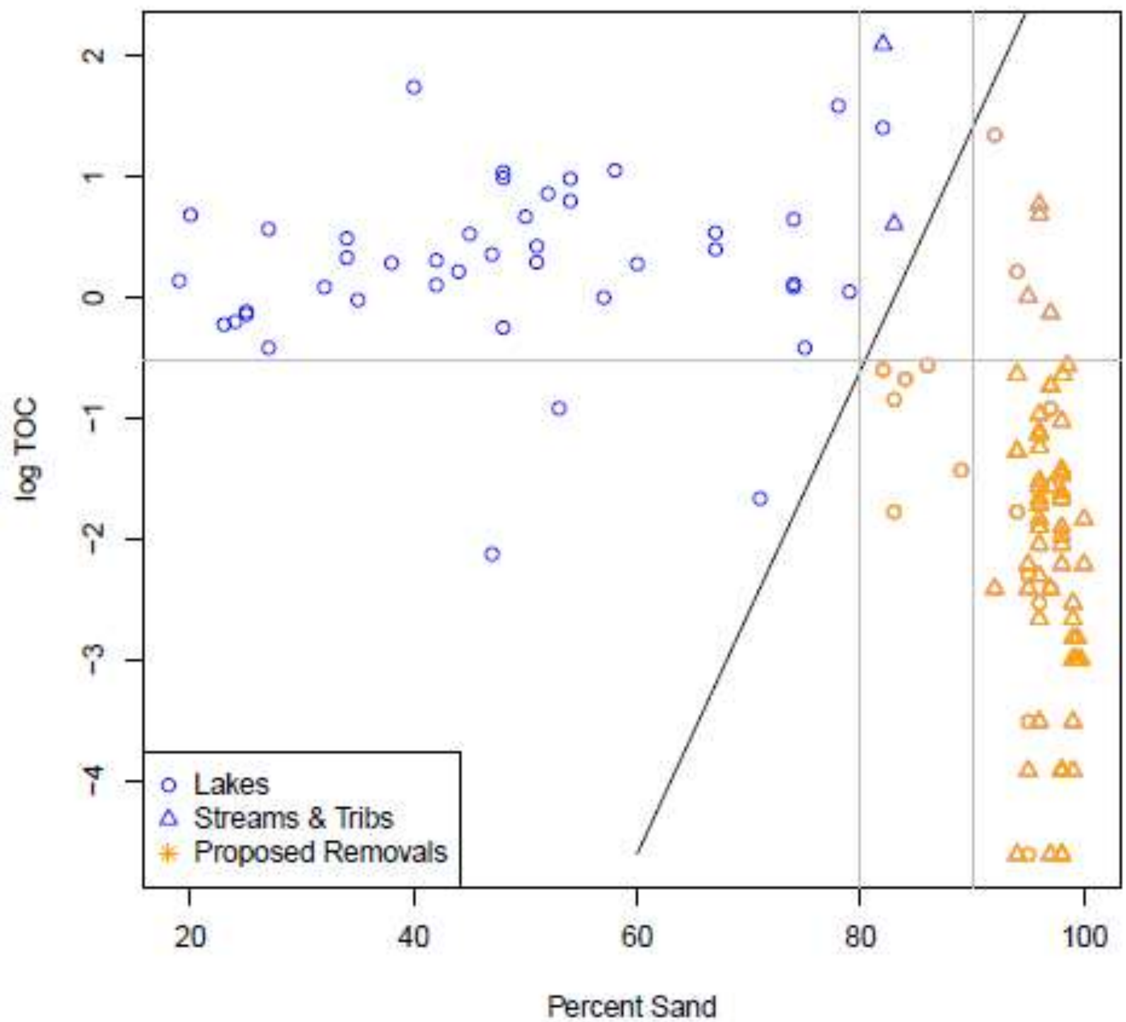


Figure 3.7 Results of Cut Point Analysis for Sediment

Environment Canada (2012) recommends that normalized metal concentrations be used to account for the effects of particle size and organic carbon. This method was considered, but it was found that the best way to minimize the relationship to organic carbon and fines involved creating data cut-offs. Additionally, normalized metals concentrations do not reflect the actual toxicity exposure in the environment.

Cut-off points have been identified for TOC and % sand based on metals accumulation in sediment in the baseline lake sediment samples. Baseline sediment samples with a TOC ≥0.6% and a minimum of 20% fines (or less than 80% sand) have been used for the development of the benchmarks and to calculate mean baseline concentrations (for "before" comparisons). Sediment samples with TOC <0.6% or with >80% sand (<20% fines) have not been included in the calculation of benchmarks, baseline means, and a priori power analyses. The same cut-off points will be applied to CREMP monitoring samples, with samples not meeting these cut-off points being excluded from exploratory and statistical analysis during monitoring.

3.5.3 Overview of Lake Sediment Results

Lakes are depositional environments that receive sediment inputs from airborne dust and surface runoff from adjacent shorelines as well as material transported into the lakes from upland areas due to seasonal stream inflows. Concentrations of metals in sediment are greatly influenced by the presence of organic carbon and/or fine sediment particle size in the substrate as described above. Substrate in depositional areas of the lake characterized by higher organic carbon content and/or higher fine sediment particle sizes are well suited for long-term monitoring since:

- These areas tend to accumulate metals due to the substrate characteristics and are therefore expected to be the most consistent with respect to elevated metals as well as the most sensitive to change (increasing accumulation of metals)
- The baseline data between lakes was similar

Each of the mine area lakes (Camp, Mary, Sheardown) showed considerable similarities in metals concentrations in sediment as well as the observed trends regarding metals accumulation at stations with high TOC and higher fines substrates. The variability in substrates that are predominantly sand and their limited TOC concentrations were also evident.

3.5.4 Overview of Stream Sediment Results

Concentrations of metals in sediments were generally highly variable within the streams, which tend to be higher energy environments with limited depositional areas. As such, these environments provide limited amounts of sediment quality data. Two sampling stations on Sheardown Lake (Tributary 1 D1-10 and D1-05) are depositional areas that show slightly higher fine sediments and elevated concentrations of cadmium, chromium, copper, iron, nickel, lead and zinc. These concentrations were above the applicable sediment quality guidelines.

Select near-field stream sediment sampling stations will continue to be monitored as described below:

- Sediment stations within Sheardown Tributary 1 that meet the TOC and % sand cut-offs will be monitored following the lake sediment monitoring program
- All other retained stream sediment stations will be monitored for comparison against previous results. These stations will be evaluated, but the higher energy, non-depositional environment may not be useful for a statistical comparison against CSQG-PAL and AEMP benchmarks. The results may support conclusions of lake samples or may trigger action using a different protocol.

3.6 SEDIMENT QUALITY CREMP STUDY DESIGN

Sediments are frequently part of environmental monitoring programs due to their importance in aquatic ecosystems. Sediments originate from particulates and precipitates that are generated from chemical and biological processes within aquatic systems. The determination of total metal concentrations in sediments is not required as part of the EEM program; however, mines are encouraged to determine total metal concentrations in sediments when completing benthic invertebrate community surveys (Environment Canada, 2012). For EEM monitoring programs where benthic invertebrate sampling is conducted in erosional habitat (e.g., streams), sediment sampling may not be possible and would not be reported. The spring freshet near the mine typically flushes fine grained sediment downstream into depositional areas (e.g., lakes). A summary of the existing baseline sediment data is provided below, in addition to the sampling plan.

The baseline sediment quality monitoring program results from the stream and lake environments surrounding the Project site show naturally elevated concentrations above the CSQG-PAL ISQGs or PSQG-LEL criteria for parameters of concern such as chromium, copper, iron, manganese and nickel (Section 3.5 and Appendix D). Iron and manganese concentrations were also occasionally above Ontario's severe effect levels in the lake environments.

The relationship between fine grained sediments and the accumulation of the parameters of concern suggests that the sediment monitoring program will focus on the depositional lake environments, since they are the end receiver of stream sediments. The proposed assessment protocol of establishing a change will be applied to lake sediment monitoring stations. Limited stream sampling will be undertaken in the Mary River and main tributaries of Camp Lake and Sheardown Lake, and the results compared to benchmarks.

3.6.1 Pathways of Effect and Key Questions

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

The key pathways of potential effects of the Project on sediment quality include:

- Sediment quality changes related to discharge of ore or stockpile runoff to freshwater systems (immediate receiving environments: Mary River and Camp Lake Tributary 1)
- Sediment quality changes (primarily nutrients and TSS) related to discharge of treated sewage effluent (immediate receiving environments: Mary River and Sheardown Lake NW)
- Sediment quality changes due to direct deposition of dust in lakes and streams (Mine Area in zone of dust deposition)
- Sediment quality changes due to dust deposition on land and subsequent runoff into lakes and streams (Mine Area in zone of dust deposition)

The key question related to the pathways of effect is:

- What is the estimated mine-related change in contaminant concentrations in the exposed area?

The primary issue of concern with respect to sediment quality is related to the effect of ore dust containing elevated metals being deposited on or running off into lakes and streams. As such, the CREMP and the baseline data review focused upon waterbodies that are closest to the sources of ore dust. Sheardown Lake and its tributaries, Camp Lake and its closest tributaries, as well as the Mary River and the north arm of Mary Lake are located within the zone of influence for ore dust deposition and non-point sources of fugitive dust (i.e., road dust). The main basin of Mary Lake receives sediment loading from the Mary River.

3.6.2 Parameters and Metrics

Sediment quality parameters identified for monitoring include various physical parameters, metals and nutrients. They were selected on the basis of the following:

- The potential to be naturally elevated in the environment
- The potential to become elevated in the environment as a result of future mine site activities
- An established criterion exists for the protection of freshwater aquatic life
- Regulation under the MMER, or potential regulation as a result of the current re-evaluation of the regulations
- The parameter affects the attenuation of metals (i.e., particle size and total organic carbon)

The contaminants of potential concern and supporting parameters are listed in Table 3.5. Those SOPCs with local enrichment are noted in the table.

Table 3.5 Sediment Quality Parameters Selected for Monitoring

Contaminants of Potential Concern	Exploratory Data Analysis Only
Arsenic	Moisture content
Cadmium	Particle Size
Chromium *	Total Organic Carbon (TOC)
Copper *	Nitrite
Iron *	Nitrate
Lead	Total Kjeldahl Nitrogen
Manganese *	
Mercury	
Nickel *	
Phosphorus *	
Zinc	

3.6.3 Benchmarks

Since the mine site occurs within an area of metals enrichment, generic sediment quality guidelines established for all areas within Canada may naturally be exceeded near the mine site. Therefore, the selection of appropriate benchmarks must consider established sediment quality guidelines, such as those developed by the Canadian Council of Ministers of the Environment (CCME) and the Ontario Ministry of the Environment (MOE), as well as site-specific natural enrichment in the selection or development of final benchmarks for monitoring data comparison (CCME, 2007).

Intrinsik Environmental Sciences Inc. was retained by Baffinland to develop water and sediment quality benchmarks to be applied in the CREMP (Intrinsik, 2014; see Appendix F of the AEMP). The sediment quality data utilized in benchmark development met the TOC and % sand cut-off points described in Section 3.5.2. The development of sediment quality benchmarks follows the same process identified for the water quality benchmarks (Section 2.7.3), considering the higher of the generic sediment quality objective (i.e., CCME or other jurisdiction) or the 97.5th percentile of baseline concentrations. For parameters that are mostly below MDL (less than 5% detected values), either the generic sediment quality guideline was selected (if available), or 3 * MDL was adopted as the benchmark, as follows:

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

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

Area-wide interim sediment quality benchmarks have been identified for mine site lakes and streams collectively (Table 3.6). Based on the available data, final sediment quality benchmarks cannot be selected at this time, as there are insufficient data within several of the lakes to adequately characterize baseline and confirm that area-wide benchmarks would not underestimate natural levels in several of the lakes (Camp Lake, Mary Lake, Tributaries of Sheardown Lake, and Sheardown Lake SE). Therefore, the area-wide interim benchmarks identified in Table 3.6 will be re-evaluated following additional sediment quality data collection in 2014.

In the case of mercury, lead and zinc, the selected benchmark is the generic sediment quality guideline, as area-wide data were less than or equal to this value. The selection of the generic guideline at this time for these substances appears reasonable. Further sediment characterization in area lakes in 2014 may result in changes to this decision. In the case of arsenic, chromium, copper, iron, manganese, nickel and phosphorus, the suggested area-wide Interim AEMP benchmark is the 97.5th percentile of baseline. The use of the area-wide percentiles as an interim benchmark appears reasonable, based on comparisons to both the existing guidelines, and characterization data for the lakes.

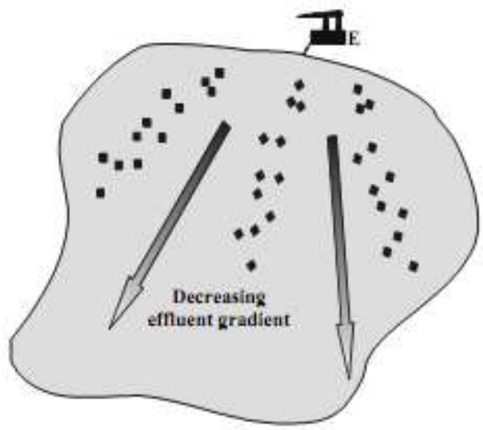
As discussed earlier, further data collection will assist in better understanding baseline within the lakes, and will assist in final benchmark development. With respect to the temporal analysis conducted for Sheardown Lake NW: chromium, copper, and nickel showed some increased trends over time in this basin (see Intrinsik, 2014; AEMP Appendix F). Based on the 97.5th percentile calculations presented in Table 3.6 for this basin, these trends are not considered to substantially influence the outcome of the recommended interim benchmark. This issue will be re-assessed with 2014 data, for final benchmark development. For cadmium, the data are largely non-detect, at an MDL of 0.5 mg/kg. The ISQG is 0.6 mg/kg, and due to the close proximity of the MDL to the ISQG, the 3 times MDL approach was applied for AEMP benchmark development.

As noted in Section 2.7.3 in regard to water quality benchmarks, the assessment of sediment quality data over the life of the project will be on-going, and the recommended benchmarks of comparison throughout this process may change, as more data become available. For example, a site-specific sediment quality guideline 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 modification of benchmarks under an AEMP is well established (MacDonald et al., 2009).

3.6.4 Monitoring Area and Sampling Stations

The monitoring area for sediment quality includes mine area lakes, specifically Camp Lake, Sheardown Lake NW and SE; selected tributaries of each lake; Mary Lake; and the Mary River.

Environment Canada (2012) recommends a Control-Impact (CI) or Gradient Sample design for detection of effects in the lake environment benthic invertebrate community (Figure 3.8). A gradient sample design has been defined for the CREMP lake sediment stations that is integrated with benthic invertebrate sampling and utilizes existing sediment sampling locations that meet the cut-off criteria (Section 3.5.2).



c) Radial gradient design for lake or coastal situations

Figure 3.8 Gradient Sampling Design to Lake Sediment Monitoring

Preliminary sediment sampling locations in each of Camp Lake, Sheardown Lake and Camp Lake are shown on Figures 3.9, 3.10 and 3.11, respectively, and are listed in Table 3.7. The lake sediment stations make use of existing and new (proposed) stations as follows:

- Camp Lake - 14 stations including three historic stations and 11 new stations
- Sheardown Lake NW - 14 stations including six historic stations and eight new stations
- Sheardown Lake SE - 10 stations including four historic stations and six new stations
- Mary Lake - 15 stations including five historic stations and 10 new stations

Lake sediment samples will be collected along transects positioned along the anticipated path of effluent (i.e., direction of inflow stream). At each station, field technicians will establish final locations for the sediment stations that are within depositional areas of the lake. This field fit of the sampling stations will likely result in some modifications to the gradient study design.

Limited stream sediment sampling is proposed for the reasons described in Section 3.5. Select existing stream sediment sampling stations will continue to be monitored as described below (see Figures 3.9, 3.10 and 3.11):

- Four sediment stations within Sheardown Tributary 1 (SDLT-1), a portion of which meet the TOC and % sand cut-offs (SDLT1-R1, D1-01, D1-05, and SDLT1-R4)
- One sediment station in each of Sheardown Tributaries 9, 12 and 13 (SDLT-9-US, SDLT-12-US, SDLT-12-DS), none of which meet the TOC and % sand cut-offs

- Three sediment stations within Camp Lake Tributaries 1 and 2 (CLT-1 and CLT-2) which do not meet the TOC and % sand cut-offs but are the lowest energy stations available (CLT-1 US, CLT-1-DS, CLT-2-DS)
- Two sediment stations on the Mary River, downstream of effluent discharges where sediment collection is possible (E0-20 and C0-05)

At least two sediment quality stations on SDLT-1 are located in depositional environments and the review has identified metals accumulation exceeding generic sediment quality guidelines. It is expected that the AEMP assessment and response framework (Section 3.6.8) can be applied to monitoring data from these stations to identify statistical change. All other retained stream sediment stations will be monitored for comparison against previous results. Stream sediment stations will be evaluated and compared to benchmarks, but statistical comparison to baseline will not be possible. The stream sediment sampling results may support conclusions of lake samples or may trigger action based on a qualitative review of the monitoring data.

3.6.5 Sampling Frequency and Schedule

Sediment quality monitoring will be conducted once each monitoring year in the fall to coincide with benthic invertebrate sampling to be conducted as part of the freshwater biota CREMP (AEMP Appendix C).

As outlined in Schedule 5, Part 2 of the MMER, biological monitoring studies are to be conducted on a three year cycle until two consecutive biological monitoring studies indicate no effect on fish populations, on fish tissue and on the benthic invertebrate community. In the long-term, sediment sampling under the CREMP will be conducted every three years, coinciding with biological monitoring studies. However, to be cautious initially, Baffinland will conduct sediment sampling in 2014 to collect additional pre-mining baseline data, and then annually for the first three years of mining. After monitoring three operating (mining) years, the sampling frequency will be re-assessed with the expectation of conducting the monitoring program on a three year cycle provided annual sampling up to that time supports this change.

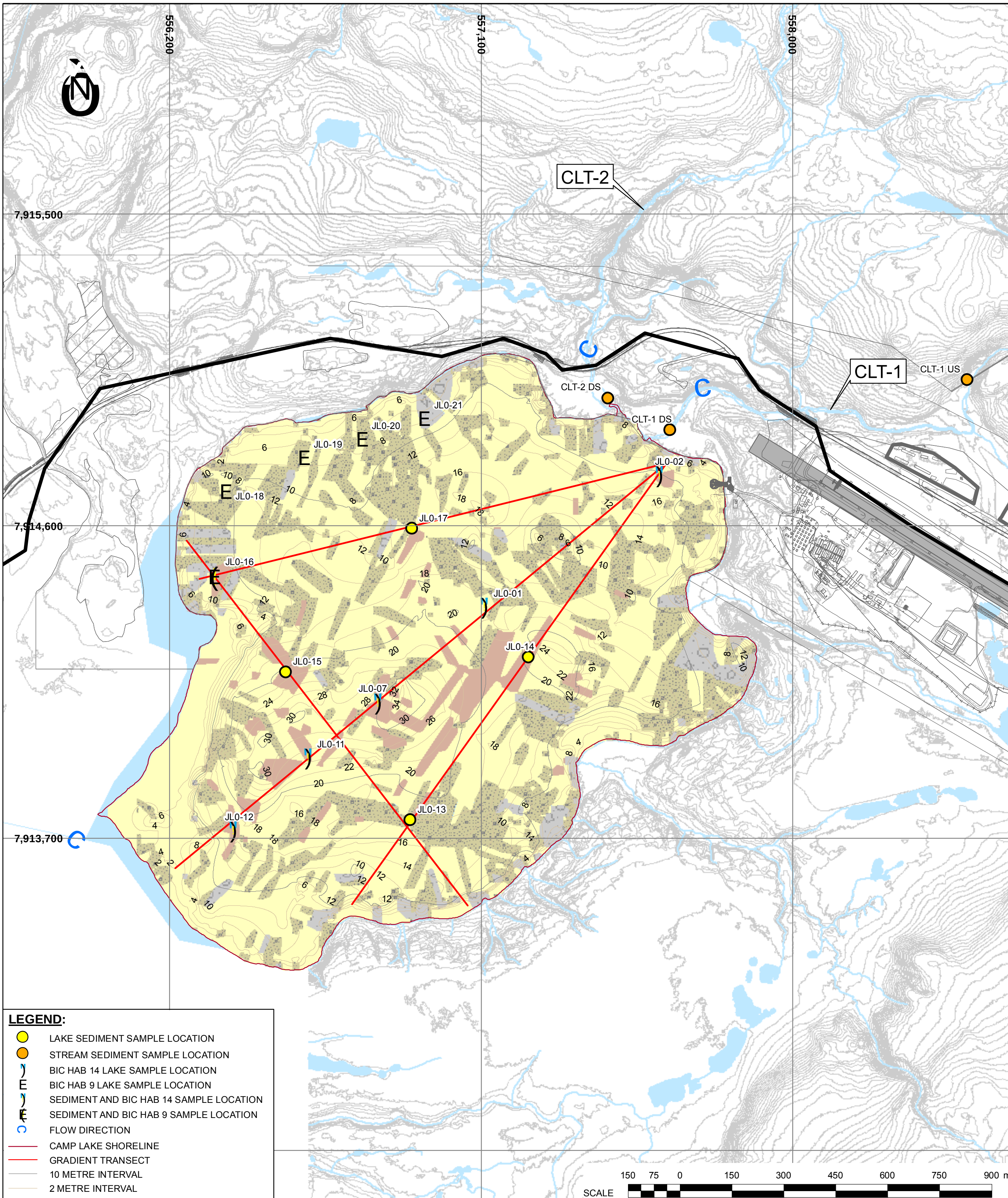
3.6.6 Quality Assurance/Quality Control

The same QA/QC program described in Section 2.6.6 will be applied to sediment quality monitoring. The field sampling protocols being applied to the sediment (and water) quality programs are presented in Appendix A.

Table 3.6 Selected Benchmark Approach and Interim Area-Wide Sediment Quality Benchmarks

Jurisdiction, Type of Guideline and Statistical Metric		Hg	As	Cd	Cr	Cu	Fe	Mn	Ni	P	Pb	Zn
CCME CSQG	**ISQG**	0.17	5.9	0.6	37.3	35.7	NGA	NGA	NGA	NGA	35	123
	PEL	0.486	17	3.5	90	197	NGA	NGA	NGA	NGA	91.3	315
Ontario PSQG	**LEL**	0.2	6	0.6	26	16	20,000	460	16	600	31	120
	SEL	2	33	10	110	110	40,000	1100	75	2,000	250	820
US EPA Sediment Quality Guidelines	**Screening**	0.18	9.8	0.99	43.4	31.6	20,000	460	22	NGA	35.8	121
97.5th Percentiles of Each Lake Area (sample size)												
Tributaries of Sheardown Lake (5)		0.1	2.95	1.9	118	106	28,370	809	115	295	52	171
Mary Lake (6)		0.1	4.95	0.5	97	38	51,463	4,305	61	1,580	28	103
Camp Lake (9)		0.1	4	0.5	83	50	40,920	1,057	74	1,480	23	69
Sheardown Lake NW (25)		0.1	7.95	0.5	96	60	56,240	5,612	81	2,310	24	92
Sheardown Lake SE (6)		0.1	2.0	0.9	80	32	32,988	547	66	1,278	18	57
95th%ile of Area-Wide Data (47)[2]		NC	5.2	0.5	93	56	50,430	3,874	76	1,565	24	91
97.5th %ile of Area-Wide Data (47)[2]		NC	6.2	0.5	97	58	52,200	4,530	77	1,958	24	94
Proposed Interim Area-Wide Benchmark		**0.17**	**6.2**	**1.5**	**97**	**58**	**52,200**	**4,530**	**77**	**1,958**	**35**	**123**
Benchmark Method		A	B	C	B	B	B	B	B	B	A	A

NOTES:
1. SHADED CELLS HAVE CONCENTRATIONS HIGHER THAN THE ISQG OR LEL; NC = NOT CALCULATED AS ALL VALUES < MDL.
2. TRIBUTARIES OF SHEARDOWN LAKE DATA ARE NOT INCLUDED DUE TO ELEVATED RESULTS IN THIS AREA.
3. GUIDELINE IS BASED ON SEDIMENT QUALITY GUIDELINE.
4. GUIDELINE IS BASED ON 97.5TH%ILE OF BASELINE DATA.
5. GUIDELINE IS BASED ON 3 TIMES MDL, THE 97.5TH%ILE IS EQUAL TO THE MDL.
6. MERCURY WAS NOT DETECTED IN ANY SAMPLES; MERCURY DETECTION LIMIT IS USED TO REPRESENT THE 95TH AND 97.5TH PERCENTILES.



LEGEND:

- LAKE SEDIMENT SAMPLE LOCATION
- STREAM SEDIMENT SAMPLE LOCATION
- BIC HAB 14 LAKE SAMPLE LOCATION
- BIC HAB 9 LAKE SAMPLE LOCATION
- SEDIMENT AND BIC HAB 14 SAMPLE LOCATION
- SEDIMENT AND BIC HAB 9 SAMPLE LOCATION
- FLOW DIRECTION
- CAMP LAKE SHORELINE
- GRADIENT TRANSECT
- 10 METRE INTERVAL
- 2 METRE INTERVAL
- EXISTING TOTE ROAD
- PROPOSED INFRASTRUCTURE
- RIVER/STREAM/DRAINAGE
- WATER
- COBBLE/BOULDER
- FINE SAND/SILT/CLAY
- GRAVEL/PEBBLE
- SAND
- PROPOSED INFRASTRUCTURE

NOTES:

1. COORDINATE GRID IS IN METRES.
   COORDINATE SYSTEM: NAD 1983 UTM ZONE 17N.
2. CONTOUR INTERVAL IS 30 CENTIMETRES.
3. SUBSTRATE AND BATHYMETRY DATA PROVIDED BY NORTH/SOUTH CONSULTANTS INC., NOVEMBER 28, 2013.
4. DEPTHS OF BATHYMETRIC CONTOURS ARE IN METRES AND ARE RELATIVE TO SHORELINE AT TIME OF SURVEY.
5. INFRASTRUCTURE INFORMATION PROVIDED BY HATCH ON JANUARY 31, 2014.

BAFFINLAND IRON MINES CORPORATION

MARY RIVER PROJECT

CAMP LAKE PROPOSED SEDIMENT LOCATIONS

Knight Piésold CONSULTING

P/A NO.	REF NO.
NB102-181/33	1

FIGURE 3.9 REV 1

REV	DATE	DESCRIPTION	DESIGNED	DRAWN	CHK'D	APP'D
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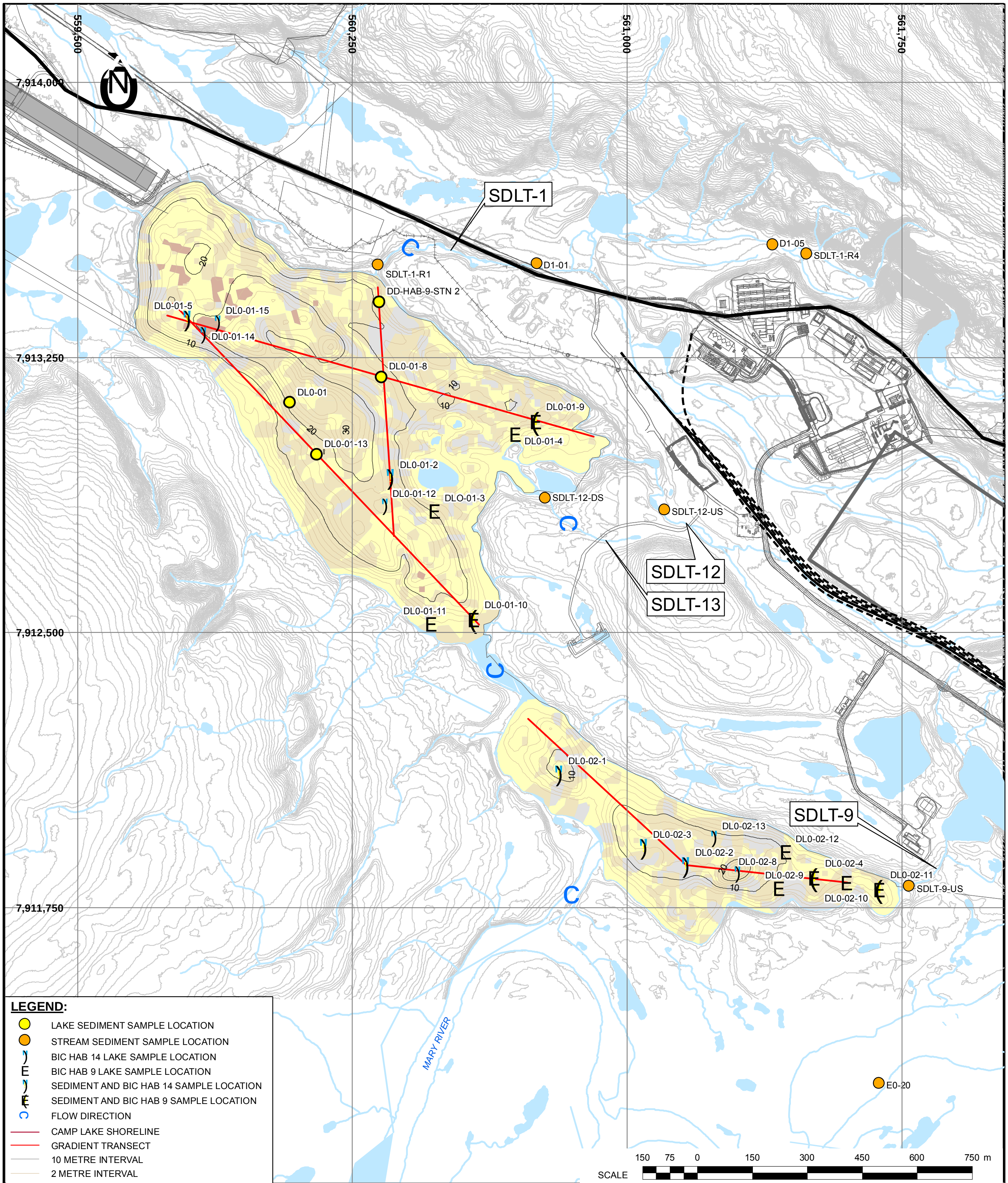

LEGEND:

- LAKE SEDIMENT SAMPLE LOCATION
- STREAM SEDIMENT SAMPLE LOCATION
- BIC HAB 14 LAKE SAMPLE LOCATION
- BIC HAB 9 LAKE SAMPLE LOCATION
- SEDIMENT AND BIC HAB 14 SAMPLE LOCATION
- SEDIMENT AND BIC HAB 9 SAMPLE LOCATION
- FLOW DIRECTION
- CAMP LAKE SHORELINE
- GRADIENT TRANSECT
- 10 METRE INTERVAL
- 2 METRE INTERVAL
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- GRAVEL/PEBBLE
- SAND
- PROPOSED INFRASTRUCTURE

NOTES:

1. COORDINATE GRID IS IN METRES.
   COORDINATE SYSTEM: NAD 1983 UTM ZONE 17N.
2. CONTOUR INTERVAL IS 30 CENTIMETRES.
3. SUBSTRATE AND BATHYMETRY DATA PROVIDED BY NORTH/SOUTH CONSULTANTS INC., NOVEMBER 28, 2013.
4. DEPTHS OF BATHYMETRIC CONTOURS ARE IN METRES AND ARE RELATIVE TO SHORELINE AT TIME OF SURVEY.
5. INFRASTRUCTURE INFORMATION PROVIDED BY HATCH ON JANUARY 31, 2014.

REV	DATE	DESCRIPTION	DESIGNED	DRAWN	CHK'D	APP'D
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BAFFINLAND IRON MINES CORPORATION

MARY RIVER PROJECT

SHEARDOWN LAKE SEDIMENT LOCATIONS

Knight Piésold CONSULTING

P/A NO. NB102-181/33

REF NO. 1

FIGURE 3.10

REV 1

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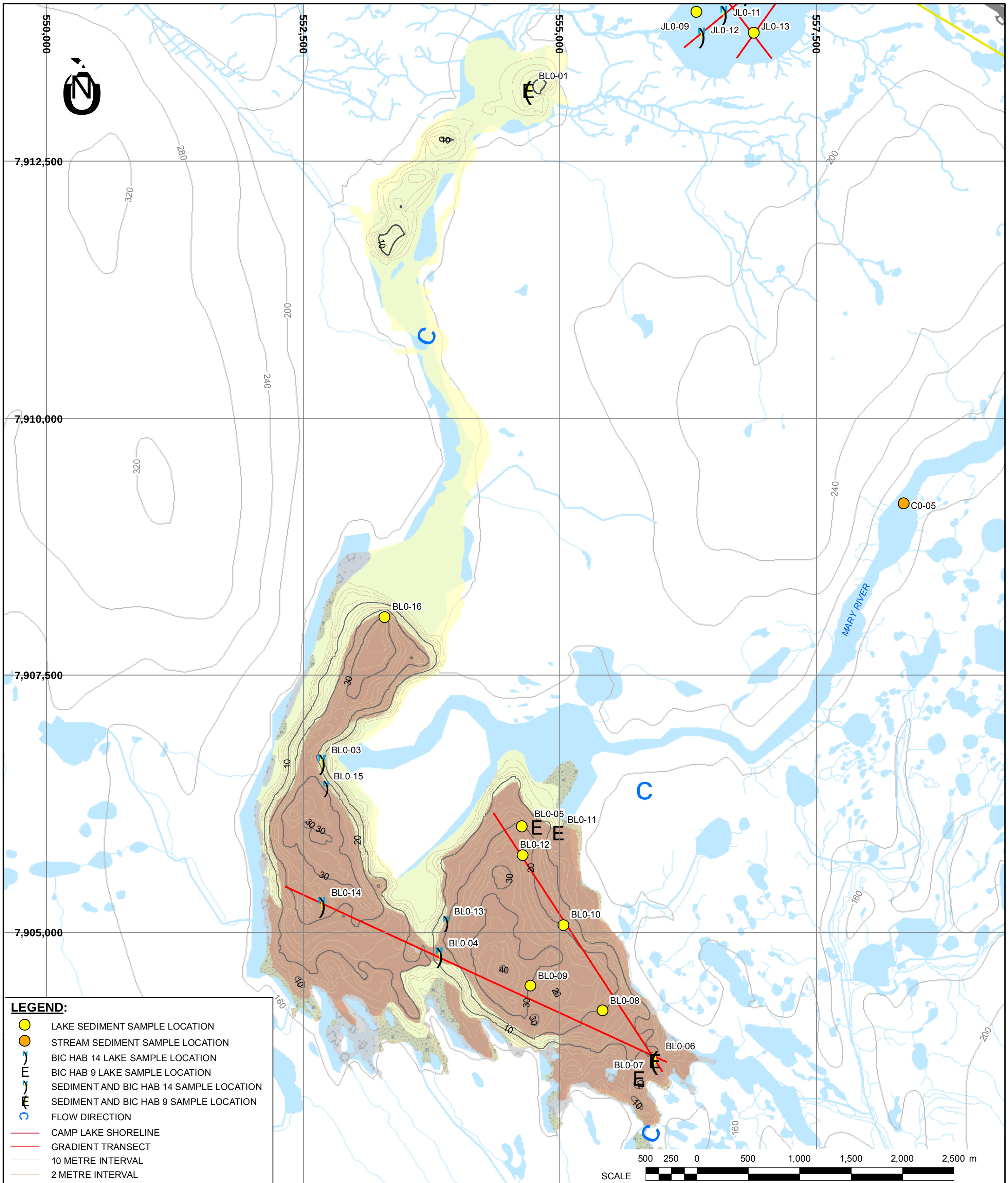

LEGEND:

- LAKE SEDIMENT SAMPLE LOCATION
- STREAM SEDIMENT SAMPLE LOCATION
- BIC HAB 14 LAKE SAMPLE LOCATION
- BIC HAB 9 LAKE SAMPLE LOCATION
- SEDIMENT AND BIC HAB 14 SAMPLE LOCATION
- SEDIMENT AND BIC HAB 9 SAMPLE LOCATION
- FLOW DIRECTION
- CAMP LAKE SHORELINE
- GRADIENT TRANSECT
- 10 METRE INTERVAL
- 2 METRE INTERVAL
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- PROPOSED INFRASTRUCTURE
- RIVER/STREAM/DRAINAGE
- WATER
- COBBLE/BOULDER
- FINE SAND/SILT/CLAY
- GRAVEL/PEBBLE
- SAND
- PROPOSED INFRASTRUCTURE

NOTES:

1. COORDINATE GRID IS IN METRES.
   COORDINATE SYSTEM: NAD 1983 UTM ZONE 17N.
2. CONTOUR INTERVAL IS 30 CENTIMETRES.
3. SUBSTRATE AND BATHYMETRY DATA PROVIDED BY NORTH/SOUTH CONSULTANTS INC., NOVEMBER 28, 2013.
4. DEPTHS OF BATHYMETRIC CONTOURS ARE IN METRES AND ARE RELATIVE TO SHORELINE AT TIME OF SURVEY.
5. INFRASTRUCTURE INFORMATION PROVIDED BY HATCH ON JANUARY 31, 2014.

BAFFINLAND IRON MINES CORPORATION

MARY RIVER PROJECT

MARY LAKE SEDIMENT LOCATIONS

Knight Piésold CONSULTING

P/A NO.	REF NO.
NB102-181/33	1

FIGURE 3.11	REV 1

REV	DATE	DESCRIPTION	DESIGNED	DRAWN	CHK'D	APP'D
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Table 3.7 Sediment Quality CREMP Stations Details

Station ID	Easting	Northing	Sediment	BIC Habitat 9	BIC Habitat 14	Description/Rationale
	NAD 83, Zone 17N					
Mary Lake (North Basin)						
BL0-01	554690	7913194	X	X		North basin receiving water from Camp Lake
Mary Lake (South Basin)						
BL0-03	552680	7906651	X		X	Main basin receiving water from north basin
BL0-04	553817	7904886	X		X	Main basin receiving water from north basin
BL0-05	554632	7906031		X		Main basin near outlet of Mary River
BL0-06	555924	7903760	X	X		Main basin near outlet of Mary River
BL0-07	555774	7903588		X		Main basin near outlet of Mary River
BL0-08	555420	7904237	X			Main basin between BL0-05 and BL0-06
BL0-09	554715	7904479	X			Main basin between BL0-05 and BL0-06
BL0-10	555038	7905069	X			Main basin between BL0-05 and BL0-06
BL0-11	554987	7905976		X		Main basin near outlet of Mary River
BL0-12	554641	7905752	X			Main basin near outlet of Mary River
BL0-13	553887	7905092			X	Main basin receiving water from north basin
BL0-14	552679	7905263	X		X	Main basin receiving water from north basin
BL0-15	552716	7906412			X	Main basin receiving water from north basin
BL0-16	553295	7908068	X			Main basin receiving water from north basin
Mary River (D/S of SDL)						
C0-01	556305	7906894	X			Mainstem, before outflow into Mary Lake
C0-05	558352	7909170	X			Mainstem, d/s of mine
SDL-Tributaries						
D1-01	560753	7913507	X			Tributary SDLT-1
D1-05	561397	7913558	X			
SDLT-1-R1	560320	7913504	X			
SDLT-1-R4	561490	7913533	X			
SDLT-9-US	561770	7911810	X			Tributary SDLT-9
SDLT-12-DS	560776	7912867	X			Tributary SDLT-12
Sheardown Lake NW						
DD-Hab 9-Stn 2	560323	7913402	X			Nearshore station
DL0-01	560079	7913128	X			Mid-lake position
DL0-01-2	560353	7912924	X		X	Mid-lake position
DL0-01-3	560474	7912833		X		Southeastern region
DL0-01-4	560695	7913043		X		Eastern region, near SDLT-9 inflow stream
DL0-01-5	559798	7913356	X		X	Near treated wastewater discharge location
DL0-01-8	560329	7913197	X			Mid-lake position
DL0-01-9	560750	7913077	X	X		Eastern region, near SDLT-9 inflow stream
DL0-01-10	560580	7912537	X	X		Near outlet channel to Southeast Basin
DL0-01-11	560464	7912525		X		Near outlet channel to Southeast Basin
DL0-01-12	560337	7912848			X	Mid-lake position
DL0-01-13	560152	7912986	X			Mid-lake position
DL0-01-14	559842	7913316			X	Near treated wastewater discharge location
DL0-01-15	559881	7913347			X	Near treated wastewater discharge location

Station ID	Easting	Northing	Sediment	BIC Habitat 9	BIC Habitat 14	Description/Rationale
	NAD 83, Zone 17N					
Sheardown Lake SE						
DL0-02-1	560813	7912116	X		X	Near inlet channel from Northwest Basin
DL0-02-2	561160	7911866	X		X	Mid-lake position
DL0-02-3	561046	7911915	X		X	Mid-lake position
DL0-02-4	561511	7911832	X	X		Eastern region
DL0-02-8	561301	7911846			X	Mid-lake position
DL0-02-9	561414	7911804		X		Eastern region
DL0-02-10	561600	7911819		X		Eastern region near SDLT-9 stream inflow
DL0-02-11	561688	7911801	X	X		Eastern region near SDLT-9 stream inflow
DL0-02-12	561434	7911904		X		Eastern region
DL0-02-13	561237	7911943			X	Mid-lake position
Mary River (US of SDL)						
E0-20	561688	7911272	X			Near EEM near field exposure area
Camp Lake						
JL0-01	557107	7914369	X		X	On gradient transect between CLT-1 and lake outlet
JL0-02	557614	7914750	X		X	
JL0-07	556800	7914094	X		X	
JL0-11	556598	7913935	X		X	
JL0-12	556382	7913724	X		X	
JL0-13	556894	7913752	X			Southern region
JL0-14	557235	7914222	X			Mid-lake position
JL0-15	556534	7914179	X			Eastern region
JL0-16	556329	7914456	X	X		Near northwest shoreline
JL0-17	556899	7914593	X			Northern region
JL0-18	556361	7914702		X		Along the northwest shoreline
JL0-19	556588	7914800		X		Along the northwest shoreline
JL0-20	556755	7914854		X		Along the northwest shoreline
JL0-21	556935	7914913		X		Along the northwest shoreline
Camp Lake Tributaries						
CLT-1 DS	557645	7914878	X			Lower reach of CLT-1 near lake outlet
CLT-1-US	558504	7915022	X			Upstream of CLT-1 near natural fish barrier
CLT-2 DS	557466	7914969	X			Lower reach of CLT-2 near lake outlet
Reference Lakes						
TBD						
Duplicates			**5**	**-**	**-**	
TOTAL			**50**	**20**	**20**	

NOTES:
1. STATION LOCATIONS PROPOSED BASED ON AVAILABLE SUBSTRATE AND WATER DEPTH DATA, SUBJECT TO CHANGE FOLLOWING IN-SITU FIELD CONFIRMATION OF CONDITIONS.

3.6.7 Study Design and Data Analysis

The purpose of sediment quality monitoring is to answer the same question posed in regard to water quality:

What is the estimated mine-related change in contaminant concentrations in the exposed area

To answer this question, the study has been designed to test the following three hypotheses:

- Null hypothesis: Change over time is the same for exposure and reference stations. Alternate hypothesis: Data from exposure stations is statistically different from data measured at reference stations.
- Null hypothesis: Difference between exposure and reference stations is due to natural environmental variation. Alternate hypothesis: Difference in exposure and reference station is due to mine effects.
- Null hypothesis: Magnitude of concentrations at the exposure station does not exceed the benchmark. Alternate hypothesis: Magnitude of concentrations at the exposure station exceeds the benchmark.

The sediment quality CREMP monitoring program will focus on sediment in lakes, since the depositional characteristics found within the lakes is the final sink for natural and project-related contributions to sediment load.

Environment Canada (2012) recommends a Control-Impact (CI) or Gradient Sample design for detection of effects in the lake environment benthic invertebrate community (Figure 3.8). A gradient sample design has been defined for the CREMP lake sediment stations that is integrated with benthic invertebrate sampling and utilizes existing sediment sampling locations that meet the cut-off criteria (Section 3.5.2). Sediment samples will be collected mainly along lake transects. Transects have been positioned along the anticipated path of effluent (i.e., direction of inflow stream). Preliminary sediment sample locations are presented on Figures 3.9, 3.10 and 3.11, and are discussed in Section 3.6.4.

Candidate reference lakes have been identified for application to the AEMP. Being located outside of the mine area, the reference lakes are expected to be unaffected by local mineralization to the extent that the mine site lakes are. Therefore, a control-impact approach to monitoring change in the mine site lakes may have limited utility in detecting Project-related changes to sediment quality.

With the exception of Sheardown Lake NW, the baseline dataset for sediment quality at the mine area is relatively limited. Additional baseline (pre-mining) sediment quality data will be collected in 2014 to supplement the baseline dataset. Nonetheless, a before-after comparison of monitoring data to baseline data will be carried out to the extent that the dataset allows.

In addition, the gradient design selected for lake sediment quality will allow for an assessment of the spatial extent of mine impacts. Since effluent discharges are fixed and dust deposition can be expected to occur in a gradient, it is expected that concentrations will decrease as the distance from the mine increases In the absence of appropriate control data, it may be necessary to use the exposure data alone to assess mine effects. Mining effects could be observed in several ways:

- Before-After: concentrations increase over time at a given station
- Gradient effect: concentrations increase with increasing proximity to the mine
- Gradient effect changes over time: concentrations are stable across the gradient during baseline but increase with increasing proximity to the mine after mining commences. That is, concentrations increase over time at stations close to the mine but remain relatively stable at far field stations (i.e., the slope of the gradient effect increases over time).

In addition, because there is a relationship between sediment SOPCs, increases in multiple parameters can be used in a weight of evidence to identify project-related changes.

3.6.8 Assessment Framework

Monitoring data will be assessed during each year of monitoring and would follow the assessment framework as outlined in Figure 2.12 and described below. The assessment framework for sediment quality monitoring closely mirrors that described for water quality in Section 2.6.8, with minor differences.

3.6.8.1 Step 1: Initial Data Analysis

Initial data analysis will involve following specific data management and monitoring protocols in the handling and initial comparison of data.

Data Input and Storage

Following data collection, and upon receipt of the laboratory reports, data will be entered into the Project EQWin® database.

Initial Data Analysis including Outlier Assessment

The initial data analysis will include a number of possible steps, such as the following:

- Completion of summary statistics (average, median, maximum, minimum, quartiles)
- Flagging of lake and stream sediment samples that do not meet the TOC and % sand cut-off values
- Flagging of values greater than the defined benchmark values
- Flagging of values at or exceeding the mid-point between the baseline mean and the benchmark
- Evaluating temporal changes in the data by season

The initial data analysis will include an outlier assessment after data entry and the completion of quality assurance and quality control steps. An outlier assessment is completed after each round of sampling to ensure data anomalies are identified early. If necessary, the laboratory can be contacted to re-analyze samples. Any identified outliers will be investigated to ensure no data integrity issue exists. For example, duplicate samples will be assessed along with any holding time exceedances. If no evidence exists to discard data, then the data will remain in the dataset but be flagged for future consideration.

3.6.8.2 Step 2: Determine if Change is Mine Related

Step 2 involves determining if the changes in sediment quality parameters of concern are due to the Project or due to natural variability or other causes. This question will be addressed using exploratory data analysis (EDA) and subsequently using statistical data analysis (SDA), as described below.

Prior to conducting EDA and SDA, Project activities with the potential to alter sediment quality will be reviewed to identify potential Project-related causes or sources. This could include evaluating effluent quality, discharge regime/rates, and loading, dust deposition, and other point/non-point sources as required. Also, any evidence of potential natural causes (i.e., a major erosional event such as a slumping riverbank) will be investigated. Sampling data sheets and site personnel will be a source of this information.

Exploratory Data Analysis

Exploratory data analysis (EDA) will be completed to visualize overall data trends. This could include evaluating spatial patterns in sediment quality results for the mine area as a whole, including mine area lakes and streams, to evaluate if changes are widespread or specific to certain waterbodies, or proximate to mine-related sources, and to identify the spatial extent and pattern of observed changes.

Data from Mine Area lakes will be compared to data from Mine Area streams to reference streams and potentially to reference lake(s) and stream(s). This will further assist with determining whether the observed changes were due to natural variability or the Project.

These graphical analyses will also confirm assumptions required for statistical testing (normality, sample size, independence). Results of the EDA will be used in tandem with the SDA to confirm the observed statistical trends and can be used to evaluate the potential for biologically relevant change.

Statistical Data Analysis

Primary SDA will be completed using methodology consistent with the before-after design used for the power analysis. This will be used to assess the potential magnitude of change during post-mining. This step in the analysis tests the primary hypothesis for the effects of mine-related change and can be applied to the parameters of interest.

If the Step 2 analysis concludes that the changes in sediment quality parameters of concern are, or are likely, due to the Project, the assessment will proceed to Step 3. If it is concluded the observed differences relative to baseline conditions are not due to the Project, no management response will be required.

3.6.8.3 Step 3: Determine Action Level

Once EDA and primary SDA has indicated with some certainly that the measured change is project-related, Step 3 involves determination of the action level associated with the observed monitoring results through comparisons to the benchmark.

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

- Evaluate temporal trends
- Identify likely source(s) and potential for continued contributions
- Confirm the site-specific relevance of benchmark and establish a site-specific benchmark, if necessary
- Based on evaluations, determine next steps

If the benchmark is exceeded and it is concluded to be due to, or likely due to, the Project, a **moderate action level response** would be undertaken and would include, in addition to analyses identified in for a low action response, the following:

- Consider a weight-of-evidence (WOE) evaluation and/or risk assessment, considering other monitoring results collectively with sediment quality to evaluate effects on the ecosystem

- Evaluate the need for and specifics of increased monitoring
- Evaluate the need for additional monitoring (e.g., confirmation monitoring) and/or modifications to the CREMP
- Consider results of the trend analysis (i.e., trend analysis indicates an upward trend) and evaluation of potential pathways of effect (i.e., causes of observed changes) to determine if management/mitigation is required
- Identify next steps based on the above analyses. Next steps may include those identified for the high action level response.

A quantitative trigger for the **high action level response** has not been identified as the need for additional study and/or mitigation will depend on the ultimate effects of the observed increases in sediment quality parameters of concern on the lakes as a whole, as well as the monitoring results from the freshwater biota CREMP. Also, the benchmark may need to be revised in consideration of ongoing monitoring results. The precise relationships between water quality, sediment quality and lower trophic level changes and the collective effects on fish is difficult to predict and therefore actions undertaken under Level 2 will attempt to explore these relationships to advise on overall effects to the ecosystem. Results would be discussed with regulatory agencies and the next steps would be identified. Additional actions that may be implemented in a subsequent phase (i.e., high action level response) include:

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

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5 – CERTIFICATION

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APPENDIX A

WATER AND SEDIMENT QUALITY SAMPLING PROTOCOL

(Pages A-1 to A-24)

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

BAFFINLAND IRON MINES CORPORATION
MARY RIVER PROJECT

WATER AND SEDIMENT QUALITY SAMPLING PROTOCOL
NB102-181/33-2

Rev	Description	Date
0	Issued in Final	March 28, 2014

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CONSULTING

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ABBREVIATIONS

AEMP	Aquatic Environment Monitoring Program
BIM	Baffinland Iron Mines Corporation
DO	dissolved oxygen
EC	Environment Canada
FEIS	Final Environmental Impact Statement
KP	Knight Piésold Ltd
Mary River Project	the project
NSC	North South Consultants
UTM	universal transverse mercator

1 – INTRODUCTION

Baseline surface water and sediment quality sampling was conducted for the Mary River Project (the Project) in support of the Final Environmental Impact Statement (FEIS) completed by Baffinland Iron Mines Corporation (BIM) in 2012. An Aquatic Environment Monitoring Program (AEMP) Framework has been developed following submission of the FEIS. This field water and sediment sampling protocol supports the AEMP.

This document is intended to provide a detailed description of the baseline surface water and sediment quality field sampling methodologies that have been applied to date and that will be applied to the Project in the future.

The baseline sampling programs are conducted during the open-water season for streams and lakes in the Project area. Stream water quality is monitored during the spring, summer and fall, whereas, lake sampling takes places only during the summer and fall. Sediment sampling is done concurrently with the surface water sampling program during the fall campaign. The sampling methodologies within this protocol include details regarding:

- Equipment and sampling
- Field measurements and observations
- Quality assurance/quality control (QA/QC)
- Sample tracking (Chain of Custody) and shipping

2 – WATER QUALITY

2.1 GENERAL

Stream and lake water quality data were collected for the Mary River Project (the Project) by Knight Piésold Ltd. (KP) every year since 2005, with the exception of 2009 and 2010. Additional sampling was conducted by North/South Consultants Inc. (NSC) in 2007. The analytical suite of parameters included nutrients, total and dissolved metals, and major ions. A detailed list of water quality parameters is provided in Appendix A.

2.2 STREAM SAMPLING METHODOLOGY

2.2.1 Sampling Strategy

Consistent sampling methods have been applied throughout the stream water sampling programs. Stream samples are collected from flowing sections of the streams (unless otherwise noted) and are obtained by either wading into the stream or by collecting the sample from the bank. Samples are collected in an upstream direction, with bottles being placed beneath the surface (when possible) to reduce the amount of surface residue collected. Bottles with no acid preservative are rinsed three times before filling. For bottles where an acid preservative is required, the samples are transferred from a clean bottle into the bottle containing preservative.

2.2.2 Equipment and Sampling

The width of the stream at the sampling location is measured using range finders. If the stream is less than 5 metres (minimum distance for range finders), the width is estimated. Photos are taken upstream, downstream and across the sampling site.

The baseline water quality monitoring program includes as suite of analytical parameters (Appendix A). The laboratory typically provides nine sample bottles for these analyses (Table 2.1).

Table 2.1 Sample Bottle Summary

Sample Bottle Volume/Description	Analytical Parameter
1 L Amber glass	Chlorophyll *a*/Pheophytin
125 mL Plastic X 2	Total and Dissolved Metals
125 mL Plastic X 2 (pre-charged)	Nutrients
1 L Plastic	General/Routine
125 mL Amber glass X 2 (one pre-charged)	TOC, phenols, COD, etc.
250 mL Plastic	Chromium

The metals bottles require nitric acid preservative (blue label) that is provided in single dose vials by the laboratory (one vial per bottle). On occasion, the chromium sample bottle will not be provided pre-charged with preservative. In this case, a chromium preservative (green label) will be provided as required.

Prior to the addition of preservative, samples for dissolved metals and the other required parameters listed on the labels (e.g., dissolved organic carbon) are field filtered using Acrodisc® 32 mm Syringe Filters with 0.45 µm Supor® membrane filter. The syringes and filters are sealed in sterile packaging and should not be rinsed prior to use. The following steps outline the basic filtration technique that will be utilized:

- Attach the filter to the syringe prior to pulling the plunger out of the syringe (Note: pulling the plunger activates the filter media).
- Pull the plunger from the syringe, fill the syringe with sample water and then replace the plunger. Dispense the first 10 mL of water to the ground (not as sample).
- Filter the remaining sample directly into the appropriate container. Repeat the process until the sample bottle is full.
- Repeat the initial two steps if the water is particularly turbid and another filter is necessary prior to the sample bottle being full

2.2.3 Field Measurements and Observations

In-situ water quality measurements will be taken during the sample collection process, provided the multi-parameter probe (e.g., Quanta Hydrolab or YSI 600Q sonde) can be positioned downstream of the sample collection area. The following in-situ parameters are recorded (when available from the multi-parameter sonde):

- Water temperature (°C)
- Dissolved oxygen (mg/L and %)
- pH (pH units)
- Conductivity (µS/cm) and/or specific conductance (µS/cm^n) (both when possible)

Field observations around the sample area include:

- Description of the landscape (e.g., hilly, mountains, marsh, etc.)
- Vegetation
- Stream substrate (e.g., sand, cobble, boulder, bedrock)
- Stream flow description (e.g., strong-turbulent, slow-calm)
- Weather conditions
- Air temperature

All measurements and observations are recorded on the field record sheets included within Appendix B.

2.2.4 QA/QC

The QA/QC protocol aims to ensure the collection of reliable and accurate data. Using standard methods as outlined in this document provides control of sample collection, handling and shipping. While collection of duplicate samples ensures the laboratory results meet defined standards of quality, in addition to the internal laboratory QA/QC protocols required for analytical accreditation. Duplicate samples will be taken for 10 percent of the total number of samples. When possible, one field blank should be taken per sampling event.

2.2.5 Chain of Custody and Sample Shipment

An essential part of the QA/QC protocol is maintaining a record of the collected samples and the corresponding list of analytical parameters reported for those samples. A chain of custody (CoC) form will be completed digitally on the BIM environmental office laptop. An example of a completed CoC form is included as Appendix C. In order to start a new entry, the previous CoC should be opened and saved as a new file name beginning with the current sample date, followed by sample type (e.g., 13_07_24_COC_BWQ.pdf). The CoC is an editable pdf document that can be found using the following folder structure:

Mary River Project (\\10.20.1.253)(M:)
Environment
FINAL File System
14.0 LABORATORY ANALYTICAL RESULTS
2014 - Open last CoC and save as "YY_MM_DD_COC_BWQ.pdf"

The waybills for shipping coolers are provided by BIM in the environment office. One of the seasonal environmental staff or environmental coordinators will provide assistance in completing the required paperwork.

All coolers must have "this side up" arrows attached to either end of the cooler. These stickers are found on a roll in the BIM environment office. The laboratory shipping labels are also in the BIM environment office. Each cooler requires one laboratory shipping label affixed to the lid.

2.3 LAKE SAMPLING METHODOLOGY

2.3.1 Sampling Strategy

Consistent sampling methods have been applied throughout the lake water sampling programs. Wherever possible, water quality samples are collected from two isolated depths (approximately 1 m below surface and approximately 1 m above the bottom) at each of the lake water quality sites. Inflatable zodiac boats are used to access the lake sample locations and are anchored at the stations for the duration of the sampling and in-situ data collection. Some boat drift is inevitable due to wind and wave influence. The general procedures to be undertaken at each lake sampling station are detailed below.

2.3.2 Equipment and Sampling

The total depth of the water at each lake station is determined either using a portable fish finder, a weighted meter tape or the pressure sensor on the multi-parameter probe. The depth is recorded on the field record sheets. Windy conditions during sampling may result in variable depth measurements. The depth range, the estimated wind speed, and the estimated wind direction are always recorded.

The baseline water quality monitoring program includes a suite of analytes (Appendix A). As above (i.e., Table 2.1), the analytical laboratory typically provides nine sample bottles for these analyses.

A 2.2 L acrylic Kemmerer bottle with a graduated line is utilized to obtain water samples at the target depths. The Kemmerer bottle is set in the open position for sampling with the bottom sample valve in the closed position. The sampler is lowered to the desired depth and the messenger weight is released down the line to trigger the closing spring of the sampler. The Kemmerer bottle is retrieved and the retained water is discarded over the side of the boat.

Following this initial rinse, the Kemmerer bottle is deployed to the sample depth to obtain the analytical sample. Upon retrieval of the Kemmerer bottle, a small amount of water is purged out of the bottom sample valve. The remaining sample is discharged into the pre-labelled, laboratory sample containers (or into a field filter) via the sample valve. The remaining water is discarded over the side of the boat. This sampling process is then repeated for the next sample depth.

Bottles with no acid preservative are rinsed three times before filling. For bottles where acid preservative is required, samples are transferred from the Kemmerer bottle into the sample bottle containing preservative. Some samples will also require field filtration before adding preservatives. The filtration process is discussed in Section 2.2.2.

2.3.3 Field Measurements and Observations

Upon collection of the shallow and deep samples, in-situ lake profiling and secchi depths are completed at each sample station.

The profiling is undertaken using a measuring tape that is secured to a multi-parameter probe (e.g., Quanta Hydrolab or YSI 600Q sonde). The probe is lowered in 1 m increments and given time to stabilize prior to recording the in-situ parameters listed in Section 2.2.2.

Secchi depths are determined by attaching the measuring tape to the secchi disk and lowering the disk over the shaded side of the boat. Two depths are recorded: the depth at which the disk disappears while lowering the disk and the depth at which it reappears while raising the disk. The secchi depth is calculated from the average of these two depths and recorded on the field record sheets.

2.3.4 QA/QC

As with the stream samples, duplicate samples are to be taken for 10 percent of the total number of samples. When possible, one field blank per sampling event will be taken.

2.3.5 Chain of Custody and Sample Shipment

Information regarding the COC's and sample shipping methods are discussed in Section 2.2.5.

2.4 METHODOLOGY ADJUSTMENTS OVER TIME

There have not been any changes to the sampling methods for streams and lakes between 2005 and 2013, unless specific circumstances required alternative methods. These exceptions would be very rare, and any changes to methodology would be recorded on field record sheets. Field record sheets used by KP were updated in 2013 and are included in Appendix B. NSC used their own field sheets.

Equipment used for field measurements and lake sample collection have varied over time, based on the equipment available at the time. For lake sampling, the following samplers have been used:

- Beta bottle
- Van Dorn sampler
- Kemmerer bottle

It was decided in 2012 that the Kemmerer bottle would be the only sampler used for future sampling events in order to maintain consistency.

3 – SEDIMENT QUALITY

3.1 GENERAL

Stream sediment quality data were collected for the Project by KP every year since 2005, with the exception of 2009 and 2010. Lake sediment quality data were collected for the Project every year since 2006, with the exception of 2009 and 2010. Parameters analysed included nutrients, metals, major ions and particle size. A detailed list of parameters is provided in Appendix A.

Sediment quality monitoring is typically conducted as part of the benthic invertebrate community surveys for mining projects. These sampling programs typically focus on total organic carbon content, metals and particle size distribution (EC, 2012). The purpose of sediment monitoring at these sites is to identify any habitat differences that may contribute to changes in the invertebrate community. As such, sediment samples will be collected concurrently with benthic invertebrate samples.

3.2 STREAM SEDIMENT SAMPLING METHODOLOGY

3.2.1 Sampling Strategy

Consistent sampling methods have been applied throughout the stream sediment sampling programs. Stream samples are collected from flowing sections of the streams (unless otherwise noted) and are obtained by wading into the stream. The sampling equipment and collection protocol is discussed in the following section.

3.2.2 Equipment and Sampling

Equipment used for stream sediment sampling includes the following:

- Stainless steel bowl
- Stainless steel spatula
- Stainless steel spoon
- 500 mL Polyethylene (PET) bottle with open ends
- Four 250 mL amber glass sample jars
- Zip-top or Whirl-pak sample bag for archived sample

Stream sediment samples are collected as near as possible to the water sample location. Wherever possible, sediment samples are collected from the wetted area of the stream at water depths between 10 cm and 40 cm. Prior to collecting the sediment samples, all of the sampling equipment is rinsed in the stream water to ensure that trace sediments do not transfer between sample stations. Samples are collected by wading downstream to upstream. Where possible, sediment is collected from the surface of the stream bed. Up to 10 sub-samples can be taken where sufficient fine sediments (particles < 2 mm diameter) are present.

The following procedure for sampling stream sediments is followed at each sub-sample location:

- Insert the open-ended PET bottle 5 cm to 10 cm into the bottom substrate
- Slide the stainless steel spatula under the bottom of the PET bottle to trap the sediments inside
- Slowly raise the spatula and PET bottle out of the stream
- Place the contents of the PET bottle into a stainless steel bowl for compositing

The stainless steel bowl and sample is allowed to settle once sufficient sample has been obtained to fill the sample containers. Any excess water that forms on the surface of the sample is either poured-off or siphoned-off using a sterile syringe. Care must be taken during this process not to lose any fines. The sample is homogenized using a stainless steel spoon. The composite sample is then created by removing any large inorganic material (e.g., cobble). The sample is transferred to laboratory provided sample jars. This transfer is completed by adding a spoonful of sample to each of the jars and repeating until all the jars they are all full. This approach provides more consistent results than what would be obtained if each jar was filled in turn. Surplus sample will be put into a labeled Zip-top or Whirl-pak bag. Samples should be kept cool and in the dark until they can be shipped to the laboratory.

The field record sheet will record the number of jars and/or sample bags obtained at each station. A note on the field record sheet should also indicate if insufficient sample is available at a station.

3.2.3 Field Measurements and Observations

Field observations made during sediment sampling include sample characteristics, such as:

- Substratum composition
- Colour
- Odour
- Vegetation presence

3.2.4 QA/QC

As with the water samples, duplicate sediment samples will be taken for 10 percent of the total number of samples.

3.2.5 Chain of Custody and Sample Shipment

The required COC's and sample shipping procedures are discussed in Section 2.2.5.

3.3 LAKE SEDIMENT SAMPLING METHODOLOGY

3.3.1 Sampling Strategy

Lake sediment samples have been collected using various methods as described in section 3.4. The methods defined below describe the collection of the lake sediment samples.

3.3.2 Equipment and Sampling

A sediment gravity core sampler (Figure 3.1) will be utilized to obtain lake sediment samples. The top two centimeters of sediment from the core samples will be retained for laboratory analysis.

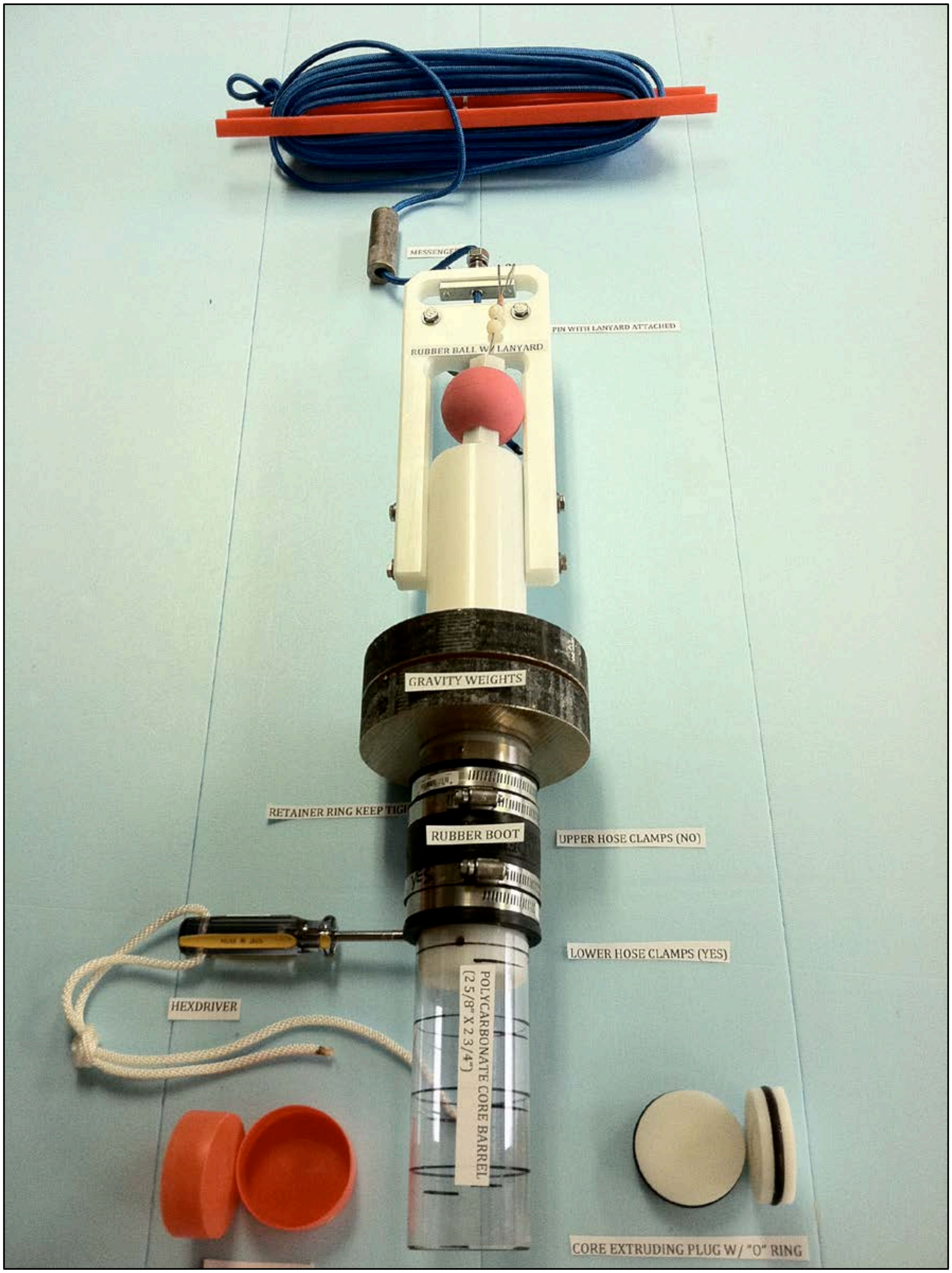

Figure 3.1 Sediment Gravity Core Sampler

3.3.3 Field Measurements and Observations

At each sampling site, the following information will be recorded during the collection of sediment samples.

- Site ID and UTM coordinates and location of any duplicate samples collected
- Sampling date and time
- Ambient weather conditions (e.g., wind speed, direction, wave action, current, air temperature)
- Sediment collection device
- General site description and observations (e.g., depth of water or ice)
- Sample properties (e.g., colour, texture, consistency, odour, presence of biota, estimate of quantity of recovered sediment)
- Deviations from standard operating procedures

Lake sediment samples will be collected using the sediment gravity corer and the following procedure.

- A clear polycarbonate core tube will be loaded into the corer and secured using a set of stainless steel hose clamps
- The corer (Figure 3.1) will be positioned perpendicular to the water surface prior to release. The penetration depth of the core tube is affected by the depth of water, angle of corer deployment and substrate type.
- Once the corer is embedded in the substrate, the stainless steel messenger will be sent down the corer rope to release the ball-type seal. This seal creates a vacuum in the core tube, retaining the sampled sediment.
- The corer will be retrieved vertically and at a constant speed to surface
- Upon retrieval, the bottom of the core tube will be plugged using an extruding plug prior to breaking the air-water interface. This procedure will prevent sample loss.
- Following placement of the core tube plugs, the hose clamps on the corer will be loosened to release the tube
- The visual characteristics of the core sample will be recorded on the field record sheets (e.g., colour, apparent horizons, aquatic vegetation, etc.)
- Overlying water within the tube will be described on field notes (e.g., clarity) prior to decanting. The decanting process should be undertaken carefully to ensure that no sediment sample is lost.

The sample is extruded out of the core tube and processed as follows:

- A suitable extruding apparatus, such as a PVC tube cut longer than core tube and with a slightly smaller outside diameter, will be used to force the extruding plug through the core tube. This process moves the sediment sample to the end. Care will be taken not to extrude the sediment, since the first two centimetres are the sample.
- The top two centimeters of sediment will be scooped out using a clean stainless steel spoon and placed in a clean stainless steel bowl
- A minimum of three core samples will be required per station. Limiting the amount of sampled sediment per tube (i.e., the top two centimeters) typically requires more sampling effort to obtain the required sample size.

- Samples within a station will be close to one another, but far enough apart to ensure that sampling disturbance from one grab does not affect another. Sampling from both sides of the boat and around the bow typically provides suitable spatial distribution within the station.
- After the top two centimeters are retained, the remaining, unused sediments within the core tube will be placed into a bucket and only released once sampling is complete at that particular station
- The core tube will be rinsed at surface and reloaded into the sampler in preparation for the next sample.

3.3.4 Sediment Sample Homogenization

Once sufficient sediments have been collected within the stainless steel bowl, the sample will be homogenized. Prior to homogenization, excess water will be decanted once the water has settled (to prevent loss of fines) and any large inorganic material (e.g., cobble) or debris will be removed. Once this step is complete, the sample will be thoroughly mixed using a newly gloved hand or stainless steel spoon until the sample has a homogeneous appearance. The sample containers will be filled by alternating aliquots between each of the containers. Once the containers are full, each sample will be transferred to an ice-packed cooler. Samples will be kept cool and in the dark until they can be shipped to the analytical laboratory.

3.3.5 QA/QC

All sampling equipment will be thoroughly cleaned between sampling stations and rinsed with ambient water prior to sampling. Duplicate samples will be taken for ten percent of the total number of samples.

3.3.6 Chain of Custody and Sample Shipment

The COC's and sample shipping methods are discussed in Section 2.2.5.

3.4 METHODOLOGY ADJUSTMENTS OVER TIME

Sediment sampling conducted prior to 2012 utilized a Petite Ponar grab sampler (231 cm^2) or an Ekman dredge sampler (523 cm^2). The sediment fraction collected for analysis was limited to the top 5 cm.

During review of the FEIS, BIM agreed to a recommendation from Environment Canada to carry out sediment sampling utilizing core in order to collect only the uppermost one to two centimetres. The rationale for this approach is that most infaunal organisms and the most recently introduced sediment (including contaminants of concern) are found in the upper two centimetres of the lake sediment. Arctic lakes experience low sedimentation rates and, therefore, collection of a thinner sample using a sediment coring instrument provides better resolution of changes in sediment quality.

Collection of thinner (1 cm to 2 cm) sediment samples was implemented by Baffinland starting in 2012. The top 2 cm of sediment from the core samples as described above will be retained for laboratory analysis.

4 – REFERENCES

Environment Canada (EC). 2012. *Environmental Effects Monitoring Technical Guidance Document*. National Environmental Effects Monitoring Office.

APPENDIX A

2014 SURFACE WATER AND SEDIMENT QUALITY PARAMETER LIST

(Pages A-1 to A-3)

Details of Quotation

Baseline - Cr III and VI

ANALYTE	METHOD REFERENCE	MDL	UNITS
Cr(VI)	Cr(VI) water M US EPA	0.05	mg/L
Cr(III)	Cr(VI) water M US EPA	0	mg/L

Baseline - Sediment

ANALYTE	METHOD REFERENCE	MDL	UNITS
Ca	Metals soil FAA - AMSFAAE2 M SM3111B-3050B	100	ug/g
Mg	Metals soil FAA - AMSFAAE2 M SM3111B-3050B	100	ug/g
Na	Metals soil FAA - AMSFAAE2 M SM3111B-3050B	100	ug/g
K	Metals soil FAA - AMSFAAE2 M SM3111B-3050B	100	ug/g
Al	ICP-MS SOIL PE6100 EPA 200.8	5	ug/g
Ba	ICP-MS SOIL PE6100 EPA 200.8	1	ug/g
Be	ICP-MS SOIL PE6100 EPA 200.8	1	ug/g
Cd	ICP-MS SOIL PE6100 EPA 200.8	0.5	ug/g
Cr	ICP-MS SOIL PE6100 EPA 200.8	1	ug/g
Co	ICP-MS SOIL PE6100 EPA 200.8	1	ug/g
Cu	ICP-MS SOIL PE6100 EPA 200.8	1	ug/g
Fe	ICP-MS SOIL PE6100 EPA 200.8	5	ug/g
Pb	ICP-MS SOIL PE6100 EPA 200.8	1	ug/g
Mn	ICP-MS SOIL PE6100 EPA 200.8	1	ug/g
Mo	ICP-MS SOIL PE6100 EPA 200.8	1	ug/g
Ni	ICP-MS SOIL PE6100 EPA 200.8	1	ug/g
Ag	ICP-MS SOIL PE6100 EPA 200.8	0.2	ug/g
Sr	ICP-MS SOIL PE6100 EPA 200.8	1	ug/g
Tl	ICP-MS SOIL PE6100 EPA 200.8	1	ug/g
V	ICP-MS SOIL PE6100 EPA 200.8	2	ug/g
Zn	ICP-MS SOIL PE6100 EPA 200.8	2	ug/g
As	ICP-MS SOIL PE6100 EPA 200.8	1	ug/g
Sb	ICP-MS SOIL PE6100 EPA 200.8	1	ug/g
Se	ICP-MS SOIL PE6100 EPA 200.8	1	ug/g
Hg	Hydride - Soil M SM3114C-3500C	0.1	ug/g
Sand (>0.050mm)	Particle Size C Ag Particle	1	%
Silt (>0.002-0.050mm)	Particle Size C Ag Particle	1	%
Clay (<=0.002mm)	Particle Size C Ag Particle	1	%
Moisture	MOISTURE C SM2540B	0.1	%
Total Kjeldahl Nitrogen	TKN soil/solids - AMTKNHX8 C SM4500-Norg-B	0.01	%
TOC	Organic matter Ag Soil	0.01	%
N-NO2	SOIL - Extractable N C 33-3 Methods of So	1	ppm
N-NO3	SOIL - Extractable N C 33-3 Methods of So	1	ppm
NO2 + NO3 as N	NO2/NO3 SKALAR - AMNOXSE1 C SM4500-NO3-F	0.1	mg/L
Boron (hot water extract)	Boron - hot water EXT Boron HWE	0.5	ug/g

Baseline - SW Chem

ANALYTE	METHOD REFERENCE	MDL	UNITS

pH	pH in water : Auto - AMAPCAE1 C SM4500-H+B	1	
Conductivity	Conductivity : Auto - AMAPCAE1 C SM2510B	5	uS/cm
Alkalinity as CaCO3	Alkalinity : Auto - AMAPCAE1 SM 2320B	5	mg/L
TDS (COND - CALC)	solids in water - AMSOLWE1 C SM2540	5	mg/L
Turbidity	Turbidity - AMTURBE1 C SM2130B	0.1	NTU
Phenols	Phenols 4-AAP - AMPHACE1 C SM5530D	0.001	mg/L
N-NH3	NH3 water low - AMNH3LE1 C SM4500-NH3D	0.02	mg/L
SO4	Anions by IC - DX-100 SM 4110C	3	mg/L
Cl	Anions by IC - DX-100 SM 4110C	1	mg/L
Br	Anions by IC - DX-100 SM 4110C	0.05	mg/L
N-NO2	Low NO2 - Technicon C SM4500-NO2-B	0.005	mg/L
N-NO3	NO2/NO3 SKALAR - AMNOXSE1 C SM4500-NO3-F	0.1	mg/L
NO2 + NO3 as N	NO2/NO3 SKALAR - AMNOXSE1 C SM4500-NO3-F	0.1	mg/L
TOC	TOC in water - AMDTOCE1 C SM5310C	0.5	mg/L
DOC	TOC in water - AMDTOCE1 C SM5310C	0.5	mg/L
Total Suspended Solids	solids in water - AMSOLWE1 C SM2540	2	mg/L
Total P	Low Total P C SM4500-PF	0.003	mg/L
Total Kjeldahl Nitrogen	TKN low water - AMTKNLE1 C SM4500-Norg-C	0.1	mg/L

Baseline Chlorophyll-Pheo

ANALYTE	METHOD REFERENCE	MDL	UNITS
Chlorophyll-a	Chlorophyll C SM10200H	0.2	mg/m3
Pheophytin-a	Chlorophyll C SM10200H	0.2	mg/m3

Baseline Dissolved Metals

ANALYTE	METHOD REFERENCE	MDL	UNITS
Ca	ALS Low Level ICP-MS TOTAL Met ALS-OUTSIDE	50	ug/L
Mg	ALS Low Level ICP-MS TOTAL Met ALS-OUTSIDE	100	ug/L
Na	ALS Low Level ICP-MS TOTAL Met ALS-OUTSIDE	50	ug/L
K	ALS Low Level ICP-MS TOTAL Met ALS-OUTSIDE	50	ug/L
Al	ALS Low Level ICP-MS TOTAL Met ALS-OUTSIDE	3	ug/L
Sb	ALS Low Level ICP-MS TOTAL Met ALS-OUTSIDE	0.1	ug/L
As	ALS Low Level ICP-MS TOTAL Met ALS-OUTSIDE	0.1	ug/L
Ba	ALS Low Level ICP-MS TOTAL Met ALS-OUTSIDE	0.05	ug/L
Be	ALS Low Level ICP-MS TOTAL Met ALS-OUTSIDE	0.5	ug/L
Bi	ALS Low Level ICP-MS TOTAL Met ALS-OUTSIDE	0.5	ug/L
B	ALS Low Level ICP-MS TOTAL Met ALS-OUTSIDE	10	ug/L
Cd	ALS Low Level ICP-MS TOTAL Met ALS-OUTSIDE	0.01	ug/L
Cr	ALS Low Level ICP-MS TOTAL Met ALS-OUTSIDE	0.5	ug/L
Co	ALS Low Level ICP-MS TOTAL Met ALS-OUTSIDE	0.1	ug/L
Cu	ALS Low Level ICP-MS TOTAL Met ALS-OUTSIDE	0.5	ug/L
Fe	ALS Low Level ICP-MS TOTAL Met ALS-OUTSIDE	30	ug/L
Pb	ALS Low Level ICP-MS TOTAL Met ALS-OUTSIDE	0.05	ug/L
Li	ALS Low Level ICP-MS TOTAL Met ALS-OUTSIDE	5	ug/L
Mn	ALS Low Level ICP-MS TOTAL Met ALS-OUTSIDE	0.05	ug/L
Mo	ALS Low Level ICP-MS TOTAL Met ALS-OUTSIDE	0.05	ug/L
Ni	ALS Low Level ICP-MS TOTAL Met ALS-OUTSIDE	0.5	ug/L
Se	ALS Low Level ICP-MS TOTAL Met ALS-OUTSIDE	1	ug/L

Si	ALS Low Level ICP-MS TOTAL Met ALS-OUTSIDE	50	ug/L
Ag	ALS Low Level ICP-MS TOTAL Met ALS-OUTSIDE	0.01	ug/L
Sr	ALS Low Level ICP-MS TOTAL Met ALS-OUTSIDE	0.1	ug/L
Tl	ALS Low Level ICP-MS TOTAL Met ALS-OUTSIDE	0.1	ug/L
Sn	ALS Low Level ICP-MS TOTAL Met ALS-OUTSIDE	0.1	ug/L
Ti	ALS Low Level ICP-MS TOTAL Met ALS-OUTSIDE	10	ug/L
U	ALS Low Level ICP-MS TOTAL Met ALS-OUTSIDE	0.01	ug/L
V	ALS Low Level ICP-MS TOTAL Met ALS-OUTSIDE	1	ug/L
Zn	ALS Low Level ICP-MS TOTAL Met ALS-OUTSIDE	3	ug/L
Hardness as CaCO3	ALS Low Level ICP-MS TOTAL Met ALS-OUTSIDE	500	ug/L
Hg	ALS Low Level ICP-MS TOTAL Met ALS-OUTSIDE	0.01	ug/L

Baseline Total Metals

ANALYTE	METHOD REFERENCE	MDL	UNITS
Ca	ALS Low Level ICP-MS TOTAL Met ALS-OUTSIDE	50	ug/L
Mg	ALS Low Level ICP-MS TOTAL Met ALS-OUTSIDE	100	ug/L
Na	ALS Low Level ICP-MS TOTAL Met ALS-OUTSIDE	50	ug/L
K	ALS Low Level ICP-MS TOTAL Met ALS-OUTSIDE	50	ug/L
Al	ALS Low Level ICP-MS TOTAL Met ALS-OUTSIDE	3	ug/L
Sb	ALS Low Level ICP-MS TOTAL Met ALS-OUTSIDE	0.1	ug/L
As	ALS Low Level ICP-MS TOTAL Met ALS-OUTSIDE	0.1	ug/L
Ba	ALS Low Level ICP-MS TOTAL Met ALS-OUTSIDE	0.05	ug/L
Be	ALS Low Level ICP-MS TOTAL Met ALS-OUTSIDE	0.5	ug/L
Bi	ALS Low Level ICP-MS TOTAL Met ALS-OUTSIDE	0.5	ug/L
B	ALS Low Level ICP-MS TOTAL Met ALS-OUTSIDE	10	ug/L
Cd	ALS Low Level ICP-MS TOTAL Met ALS-OUTSIDE	0.01	ug/L
Cr	ALS Low Level ICP-MS TOTAL Met ALS-OUTSIDE	0.5	ug/L
Co	ALS Low Level ICP-MS TOTAL Met ALS-OUTSIDE	0.1	ug/L
Cu	ALS Low Level ICP-MS TOTAL Met ALS-OUTSIDE	0.5	ug/L
Fe	ALS Low Level ICP-MS TOTAL Met ALS-OUTSIDE	30	ug/L
Pb	ALS Low Level ICP-MS TOTAL Met ALS-OUTSIDE	0.05	ug/L
Li	ALS Low Level ICP-MS TOTAL Met ALS-OUTSIDE	5	ug/L
Mn	ALS Low Level ICP-MS TOTAL Met ALS-OUTSIDE	0.05	ug/L
Mo	ALS Low Level ICP-MS TOTAL Met ALS-OUTSIDE	0.05	ug/L
Ni	ALS Low Level ICP-MS TOTAL Met ALS-OUTSIDE	0.5	ug/L
Se	ALS Low Level ICP-MS TOTAL Met ALS-OUTSIDE	1	ug/L
Si	ALS Low Level ICP-MS TOTAL Met ALS-OUTSIDE	50	ug/L
Ag	ALS Low Level ICP-MS TOTAL Met ALS-OUTSIDE	0.01	ug/L
Sr	ALS Low Level ICP-MS TOTAL Met ALS-OUTSIDE	0.1	ug/L
Tl	ALS Low Level ICP-MS TOTAL Met ALS-OUTSIDE	0.1	ug/L
Sn	ALS Low Level ICP-MS TOTAL Met ALS-OUTSIDE	0.1	ug/L
Ti	ALS Low Level ICP-MS TOTAL Met ALS-OUTSIDE	10	ug/L
U	ALS Low Level ICP-MS TOTAL Met ALS-OUTSIDE	0.01	ug/L
V	ALS Low Level ICP-MS TOTAL Met ALS-OUTSIDE	1	ug/L
Zn	ALS Low Level ICP-MS TOTAL Met ALS-OUTSIDE	3	ug/L
Hardness as CaCO3	ALS Low Level ICP-MS TOTAL Met ALS-OUTSIDE	500	ug/L
Hg	ALS Low Level ICP-MS TOTAL Met ALS-OUTSIDE	0.01	ug/L

Knight Piésold CONSULTING

APPENDIX B

FIELD RECORD SHEET

(Page B-1)

SURFACE WATER QUALITY SAMPLING FIELD FORM

Knight Piésold CONSULTING

PROJECT NO.: ______________ *(i.e. NB102-102/10)*

SITE: ______________ *(i.e. BISSETT CREEK)* **DATE:** ______________ *(i.e.12MAR2013)*

STATION ID: ______________ *(i.e. SW12-01)* **STAFF:** ______________ *(i.e. SMR / DKK)*

SITE CONDITIONS

Air Temperature ______ ºC **Wind** ______ *(direction, speed)* **Weather** ______ *(clear, o'cast, rain, etc.)*

SAMPLE DESCRIPTION/OBSERVATIONS

Sample ID: ______________ *(i.e. SW12-01)* **UTM mE** ______________ *(i.e. 558407)*

Sample Date / Time: ______________ *(i.e.12MAR2013/14:35)* **UTM mN** ______________ *(i.e. 7914885)*

No. of bottles ______________ **Zone / Datum** ______________ *(i.e. 17T / NAD83)*

Quote No. ______________ **Accuracy** ______________ *(± m)*

WATER BODY TYPE: ☐ Lake ☐ Pond ☐ Wetland ☐ Stream

FLOW: ☐ Stagnant ☐ Low ☐ Moderate ☐ High

ODOUR: ☐ None ☐ Describe: ______________ *(i.e. mineral, organic)*

COLOUR: ☐ None ☐ Describe: ______________ *(i.e. light tea, brown, black)*

TRANSPARENCY: ☐ Clear ☐ Translucent ☐ Opaque

SAMPLES FILTERED: ☐ None ☐ Yes, analytes incl.: ______________

IN-SITU WQ DATA

Water Temperature: ______ ºC **pH:** ______ pH **WQ INSTRUMENT:** *(i.e. Hanna/HI 98129, YSI 600QS)*

Conductivity: ______ µS/cm **Secchi:** ______ m ______________

Dissolved Oxygen: ______ % ______ : ______ Calibrated (Date / Time):

Dissolved Oxygen: ______ mg/L ______ : ______ ______________

Calibration Check (Date / Time):

PHOTOS: ☐ Upstream/Downstream ☐ None taken ______________

QA/QC INFORMATION

Duplicate Collected: ☐ No ☐ Yes, ID: ______________ *(i.e. SW12-01-DUP)*

Field Blank Collected: ☐ No ☐ Yes, ID: ______________ *(i.e. SW12-01-FB)*

SITE SKETCH: *(i.e. stream, flow direction, road, culvert, north arrow, beaver dams, sample location, etc.)*

NOTES: *(i.e. additional WQ instrument calibration notes, water body name, photo notes, changes in site since last visit)*

APPENDIX C

EXAMPLE CHAIN OF CUSTODY

(Page C-1)

CHAIN OF CUSTODY RECORD

ACCUTEST LABORATORIES LTD.

☑ 146 Colonnade Rd., Unit 8
Ottawa, ON K2E 7Y1
Ph: (613) 727-5692 Fax: (613) 727-5222

☐ 608 Norris Court
Kingston, ON K7P 2R9
Ph: (613) 634-9307 Fax: (613) 634-9308

LABORATORY USE ONLY
Report #: ____________

Company Name: Baffinland Iron Mines Corporation	Address: Mary River	☐ Fax Results to: ____________
Report Attention: Mr. Jim Millard/Allan Knight/Trevor Myers	City/Prov: via Iqaluit, NU Postal Code:	☑ E-mail Results to: Millard/Myers/Knight/mrsite.sd
Phone: 647-693-9447 Ext	Project # * Quotation # Baseline Water Quality	☑ Copy of Results to: salldred@knightpiesold.com
* Waterworks Name:	* Waterworks Number:	*Note that for drinking water samples, all exceedances will be reported where applicable legislation requires.*

Invoice to:
(if different from above)

____

____

SAMPLE ANALYSIS REQUIRED

⇦ Indicate: F=Filtered or P=Preserved

Sample ID	* Date/Time Collected	Sample Matrix i.e. Water, Soil, Paint	* Sample Type (see "Codes" below)	* MOE Reportable? Y = Yes N = No	# of Containers	** Service Required R=Rush S=Standard	Baseline Water Quality - Dissolved Metals Field Filtered							Criteria Required (i.e. Reg.170, Reg.153, CCME, PWQO etc.)	Laboratory Identification
BL0-05-B4	July 24, 2013, 14:35	Water	-	N	9	S	✔								
C0-01	July 24, 2013, 15:20	Water	-	N	9	S	✔								
C0-01-DUP	July 24, 2013, 15:25	Water	-	N	9	S	✔								
C0-10	July 24, 2013, 16:20	Water	-	N	9	S	✔								
C0-10-FB	July 24, 2013, 16:25	Water	-	N	9	S	✔								
E0-20	July 24, 2013, 17:10	Water	-	N	9	S	✔								
E0-21	July 24, 2013, 17:50	Water	-	N	9	S	✔								

Sample Type Codes for Drinking Water Systems: **RW** = Raw Water, **RWFC** = Raw Water For Consumption, **TW** = Treated Water at point of entry to distribution, **DW** = Distribution/Plumbing Water
"MOE Reportable" refers to the requirements under the SDWA for immediate reporting of results, which are indicators of adverse water quality, to the Owner/Operator, MOE, and MOH Medical Officer.

Sampled By: Shannon Alldred	Date/Time: July 24, 2013 19:00	Relinquished By: Allan Knight	Date/Time: July 25, 2013 08:00	Comments CN AWB 518-64071313	**Cooler Temp (°C) on Receipt**
Work Authorized By (signature):	Date/Time:	Received By Lab:	Date/Time:		

*** Indicates a required field.** If not complete, analysis will proceed only on verification of missing information. A quotation number is required, if one was provided.
**** There may surcharges applied to "Rush" service.** Please check with lab prior to submission of samples for rush analysis to confirm availability and pricing.

Copies: White – Sampler, Yellow – Laboratory, Pink – With Report
Please print and submit, to the laboratory, 2 copies of this form with your samples.

APPENDIX B

DETAILED REVIEW OF BASELINE LAKE WATER QUALITY

(Pages B-1 to B-98)

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

BAFFINLAND IRON MINES CORPORATION
MARY RIVER PROJECT

DETAILED REVIEW OF BASELINE LAKE WATER QUALITY
NB102-181/33-1B

Rev	Description	Date
1	Issued in Final	May 30, 2014

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Knight Piésold CONSULTING

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B – LAKE WATER QUALITY REVIEW

B.1 OVERVIEW

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

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

The focus of this review of lake water quality is the mine site area lakes: Camp Lake, Sheardown Lake NW, Sheardown Lake SE and Mary Lake.

Parameters of interest in the baseline review included water quality stressors of potential concern (SOPCs) identified on the basis of the existence of an established water quality guideline, as well as other factors such as Exposure Toxicity Modifying Factors (ETMF): pH, water hardness, dissolved organic carbon, etc., and indicator parameters (alkalinity, chloride, nitrate). Baseline water quality data was compared to Canadian Council of Ministers of the Environment (CCME) – Canadian Water Quality Guidelines for the Protection of Freshwater Aquatic Life (CWQG-PAL). The focus was on total concentrations (versus dissolved) since CWQG-PAL guidelines are developed for total concentrations. The parameters of interest are displayed graphically in box plots. The box plots are used to portray natural ranges of selected parameters. Concentration data measured for the parameters of interest has been log transformed and further analyzed to investigate the possibility of aggregating data, bearing in mind:

- Seasonal variability (between summer, fall and winter samples)
- Inter-annual variability (from 2006 through 2008 and 2011 through 2013)

To assist in the development of study designs, parameter and station-specific a priori power analyses were completed in order to determine the power of the proposed sampling program to detect statistical changes. As per the Assessment Approach and Response Framework in the CREMP (see Figure 2.12 in the main report), management action is triggered if the mean concentrations of any parameter at selected stations reach benchmark values. Benchmark values were developed for the identified SOPCs that consider aquatic toxicology, natural enrichment in the Project area, or low concentrations below MDLs (Intrinsik, 2014; see Section 2.7.3 of the main report). Draft benchmarks were applied in the power analysis of the baseline presented in this detailed review.

The resultant study design for the monitoring of Project-related effects to water quality is presented in Section 2.7 of the main report.

B.2 BASELINE SUMMARY

B.2.1 Camp Lake

A total of 51 lake samples were collected over the baseline sampling period. Most sampling was completed during July and August. Late winter sampling (May) was carried out in 2007, 2008 and 2013. Three stations were monitored (Figures B.1 and B.2):

- JL0-01-S and JL0-01-D - Shallow and deep; centre and deepest part of the lake
- JL0-02-S and JL0-02-D - Near two main tributaries likely to be influenced by the Project
- JL0-09-S and JL0-09-D - Near the outlet of Camp Lake

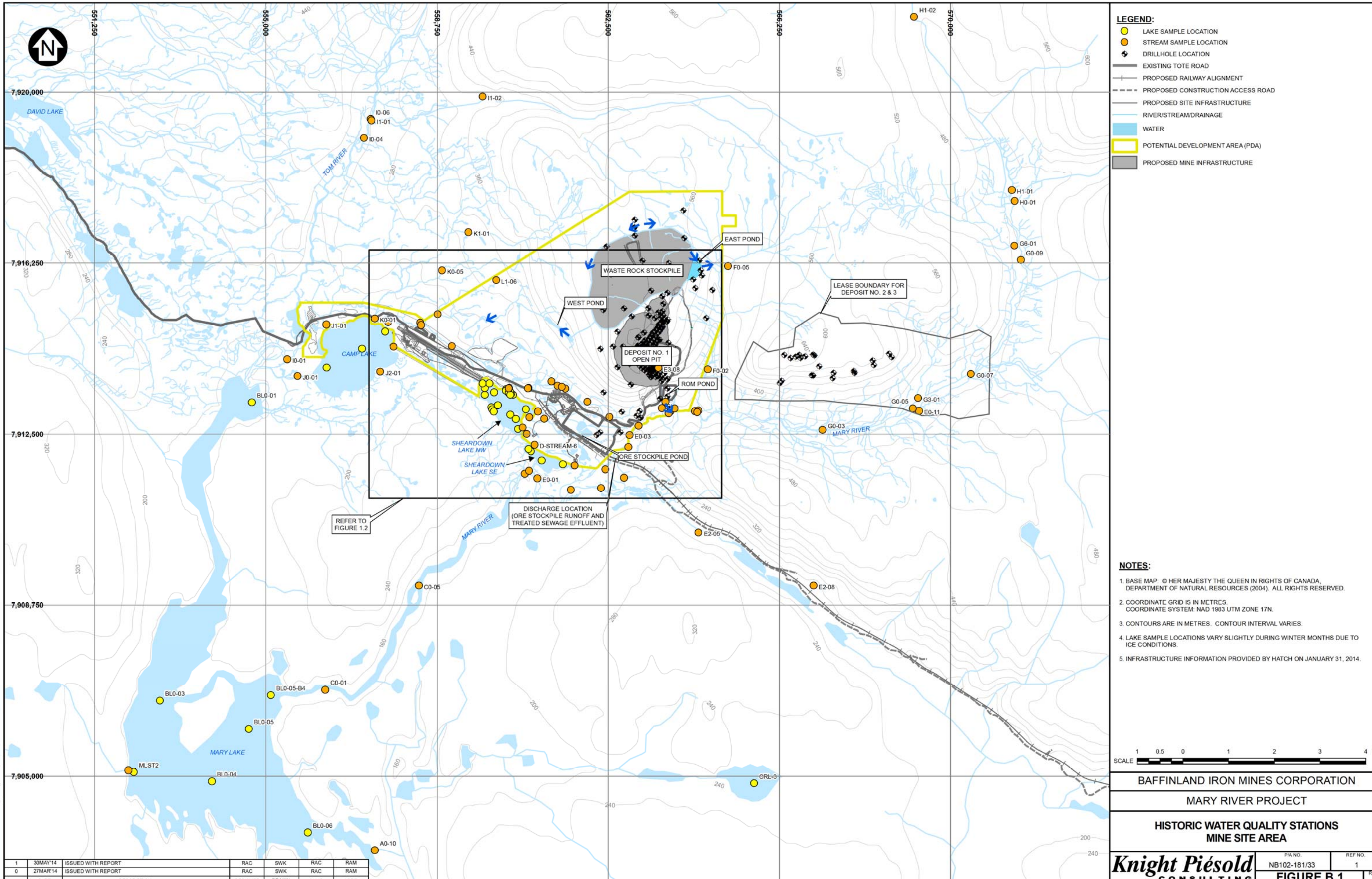
A summary of the data collected during each season are included in Table B.1. A graphical representation of the sampling events is provided in Figure B.3.

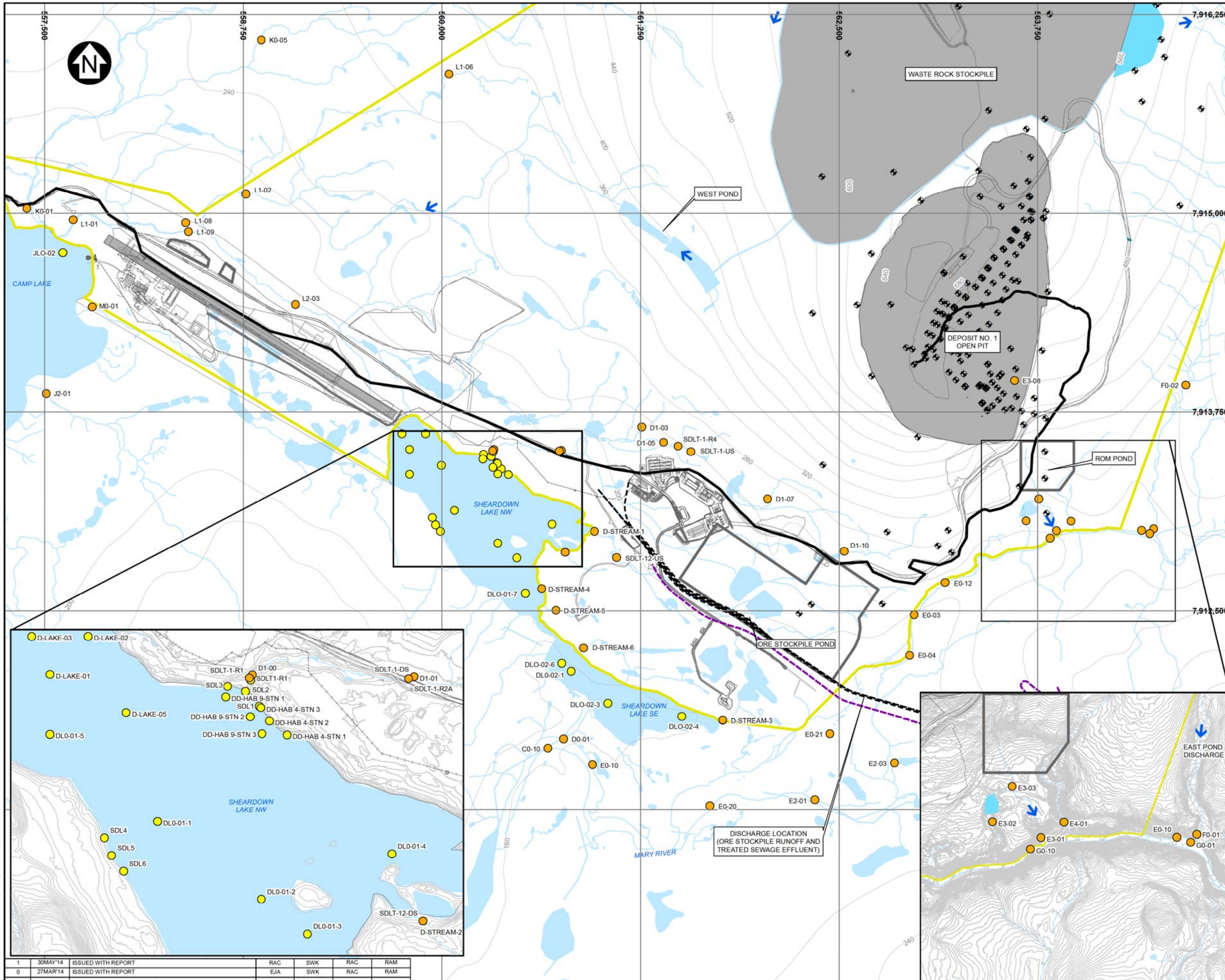
Table B.1 Camp Lake Sample Size

Year	Summer	Fall	Winter
2006	2	2	0
2007	6	6	6
2008	6	0	2
2011	4	0	0
2012	0	6	0
2013	5	6	2
Site	**Summer**	**Fall**	**Winter**
JL0-01-S	4	3	1
JL0-01-D	5	4	3
JL0-02-S	3	3	1
JL0-02-D	4	4	1
JL0-09-S	4	3	3
JL0-09-D	3	3	1

NOTES:

1. WINTER SAMPLING OCCURRED DURING APRIL AND MAY; SPRING SAMPLING OCCURRED DURING JUNE; SUMMER SAMPLING OCCURRED FROM JULY TO AUGUST 17; FALL SAMPLING OCCURRED FROM AUGUST 18 THROUGH SEPTEMBER 30.
2. LAKE SAMPLING DID NOT OCCUR DURING SPRING, DUE TO SAFETY CONCERNS OF SAMPLING OVER MELTING ICE.
3. NO SAMPLING OCCURRED DURING 2009 AND 2010.


LEGEND:
LAKE SAMPLE LOCATION
STREAM SAMPLE LOCATION
DRILLHOLE LOCATION
EXISTING TOTE ROAD
PROPOSED RAILWAY ALIGNMENT
PROPOSED CONSTRUCTION ACCESS ROAD
PROPOSED SITE INFRASTRUCTURE
RIVER/STREAM/DRAINAGE
WATER
POTENTIAL DEVELOPMENT AREA (PDA)
PROPOSED MINE INFRASTRUCTURE
N
551,250
555,000
558,750
562,500
566,250
570,000
7,920,000
7,916,250
7,912,500
7,908,750
7,905,000
DAVID LAKE
TOM RIVER
CAMP LAKE
MARY LAKE
MARY RIVER
SHEARDOWN LAKE NW
SHEARDOWN LAKE SE
WASTE ROCK STOCKPILE
EAST POND
WEST POND
DEPOSIT NO. 1 OPEN PIT
ROM POND
ORE STOCKPILE POND
LEASE BOUNDARY FOR DEPOSIT NO. 2 & 3
DISCHARGE LOCATION (ORE STOCKPILE RUNOFF AND TREATED SEWAGE EFFLUENT)
REFER TO FIGURE 1.2
H1-02
I1-02
I0-06
I1-01
I0-04
K1-01
K0-05
L1-06
F0-05
J1-01
K0-01
I0-01
J0-01
J2-01
BL0-01
E3-08
F0-02
D-STREAM-6
E0-03
E0-01
H1-01
H0-01
G6-01
G0-09
G0-07
G0-05
G3-01
E0-11
G0-03
E2-05
E2-08
C0-05
C0-01
BL0-05-B4
BL0-03
BL0-05
MLST2
BL0-04
BL0-06
A0-10
CRL-3
NOTES:
1. BASE MAP: © HER MAJESTY THE QUEEN IN RIGHTS OF CANADA, DEPARTMENT OF NATURAL RESOURCES (2004). ALL RIGHTS RESERVED.
2. COORDINATE GRID IS IN METRES. COORDINATE SYSTEM: NAD 1983 UTM ZONE 17N.
3. CONTOURS ARE IN METRES. CONTOUR INTERVAL VARIES.
4. LAKE SAMPLE LOCATIONS VARY SLIGHTLY DURING WINTER MONTHS DUE TO ICE CONDITIONS.
5. INFRASTRUCTURE INFORMATION PROVIDED BY HATCH ON JANUARY 31, 2014.
SCALE 1 0.5 0 1 2 3 4 km
BAFFINLAND IRON MINES CORPORATION
MARY RIVER PROJECT
HISTORIC WATER QUALITY STATIONS
MINE SITE AREA
Knight Piésold CONSULTING
P/A NO. NB102-181/33
REF NO. 1
FIGURE B.1
REV 1
1 30MAY'14 ISSUED WITH REPORT RAC SWK RAC RAM
0 27MAR'14 ISSUED WITH REPORT RAC SWK RAC RAM
REV DATE DESCRIPTION DESIGNED DRAWN CHK'D APP'D
SAVED: I:\102\00181\33\A\GIS\Figs\B40_r1.mxd; May 30, 2014 1:11 PM; skozmick



REV	DATE	DESCRIPTION	DESIGNED	DRAWN	CHK'D	APP'D
1	30MAY'14	ISSUED WITH REPORT	RAC	SWK	RAC	RAM
0	27MAR'14	ISSUED WITH REPORT	EJA	SWK	RAC	RAM

LEGEND:

- LAKE SAMPLE LOCATION
- STREAM SAMPLE LOCATION
- DRILLHOLE LOCATION
- EXISTING TOTE ROAD
- PROPOSED RAILWAY ALIGNMENT
- PROPOSED CONSTRUCTION ACCESS ROAD
- PROPOSED SITE INFRASTRUCTURE
- RIVER/STREAM/DRAINAGE
- WATER
- POTENTIAL DEVELOPMENT AREA (PDA)
- PROPOSED MINE INFRASTRUCTURE

NOTES:

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2. COORDINATE GRID IS IN METRES. COORDINATE SYSTEM: NAD 1983 UTM ZONE 17N.
3. CONTOURS ARE IN METRES. CONTOUR INTERVAL VARIES.
4. LAKE SAMPLE LOCATIONS VARY SLIGHTLY DURING WINTER MONTHS DUE TO ICE CONDITIONS.
5. INFRASTRUCTURE INFORMATION PROVIDED BY HATCH ON JANUARY 31, 2014.

SCALE 250 125 0 250 500 750 1,000 1,250 m

BAFFINLAND IRON MINES CORPORATION

MARY RIVER PROJECT

HISTORIC WATER QUALITY STATIONS IMMEDIATE MINE SITE AREA

Knight Piésold CONSULTING

P/A NO. NB102-181/33 | REF NO. 1

FIGURE B.2 REV 1

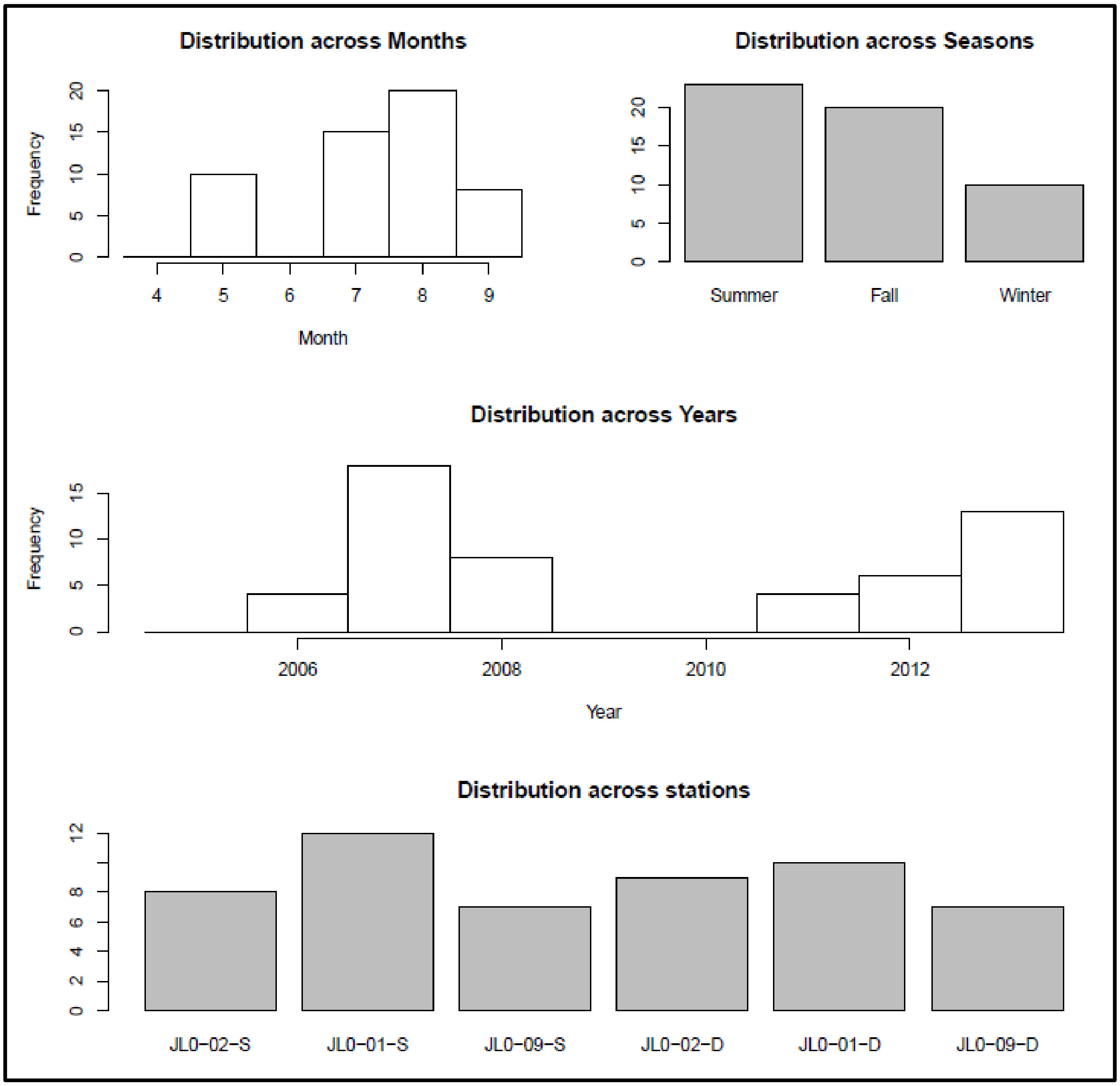


Figure B.3 Camp Lake - Graphical Summary of Sampling Events

The following summarizes the data review observations for the of the physical parameter data depicted in Figures B.4 and B.5.

pH (Figure B.4)

- Camp Lake is slightly alkaline, with total median pH of ~8.
- Measured median *In situ* pH at the deep stations (~7.6) was slightly lower compared to shallow samples (> 7.8).
- The lowest pH value was measured at the deep sample site JL0-01-D, located near the deepest portion of the lake.

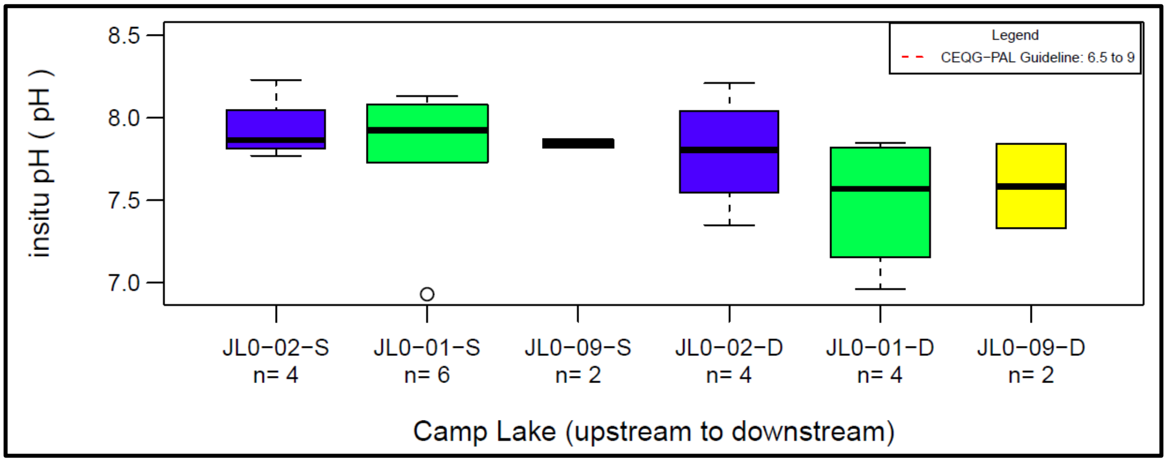


Figure B.4 Camp Lake – pH

Hardness (Figure B.5)

- Median hardness at stations within Camp Lake ranged from ~56 and 62 mg/L, classifying the lake water as “soft”. One station, JL0-02-D had a median hardness concentration that classifies the lake water as “medium hardness”.
- Hardness did not change meaningfully with depth, and portrayed trends very similar to alkalinity.
- The close range between hardness and alkalinity suggest that the hardness is almost entirely carbonate hardness with little to no non-carbonate contributions to hardness.

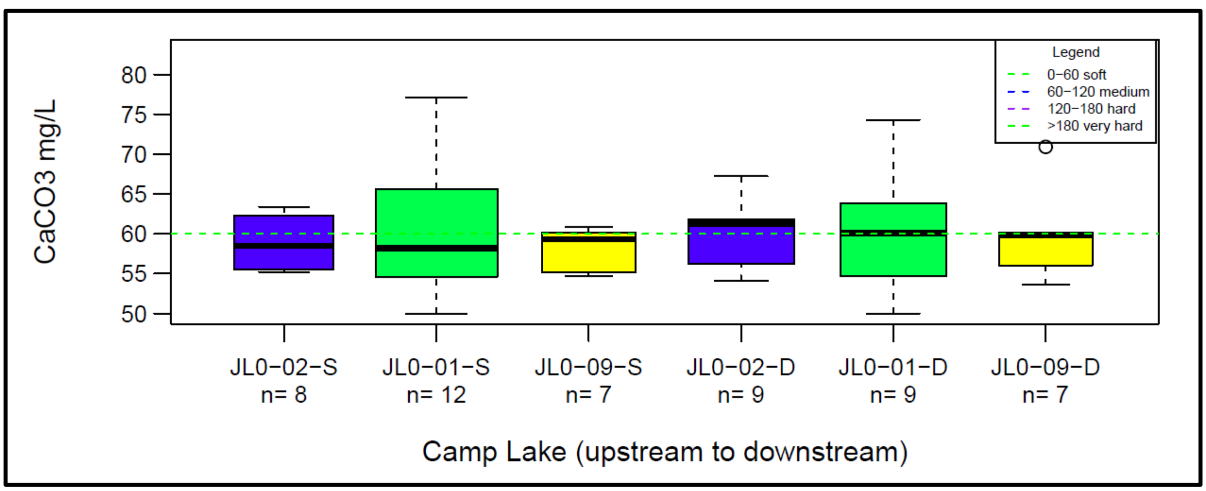
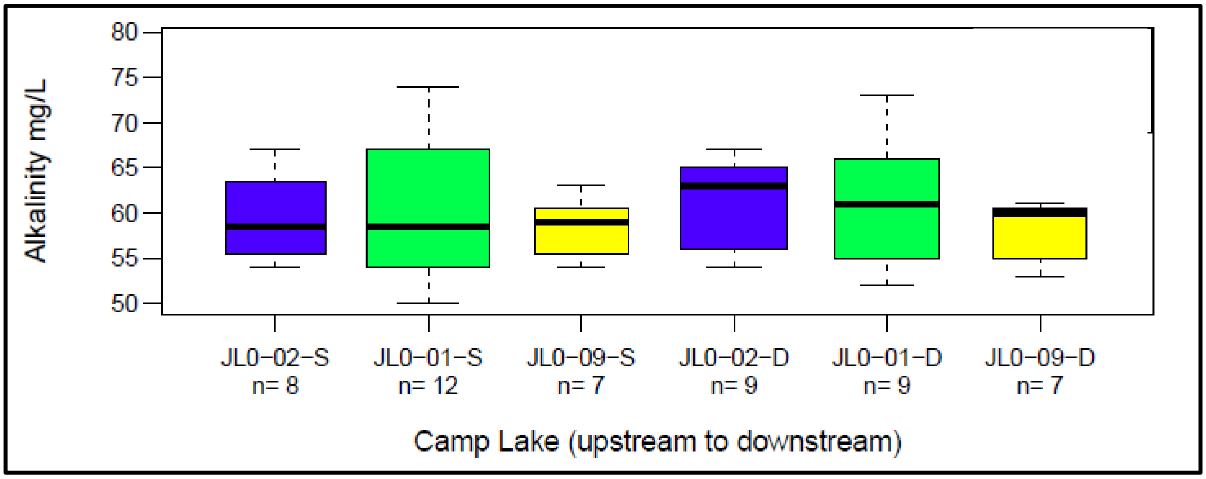


Figure B.5 Camp Lake – Hardness

Alkalinity (Figure B.6)

- Camp Lake sites have uniformly high median alkalinity values that range from 58 to 65 mg/L $CaCO_3$, classifying the lake water as having low sensitivity to acidic inputs.
- Discrete sites, regardless of depth, show similar measured alkalinity.



NOTES:

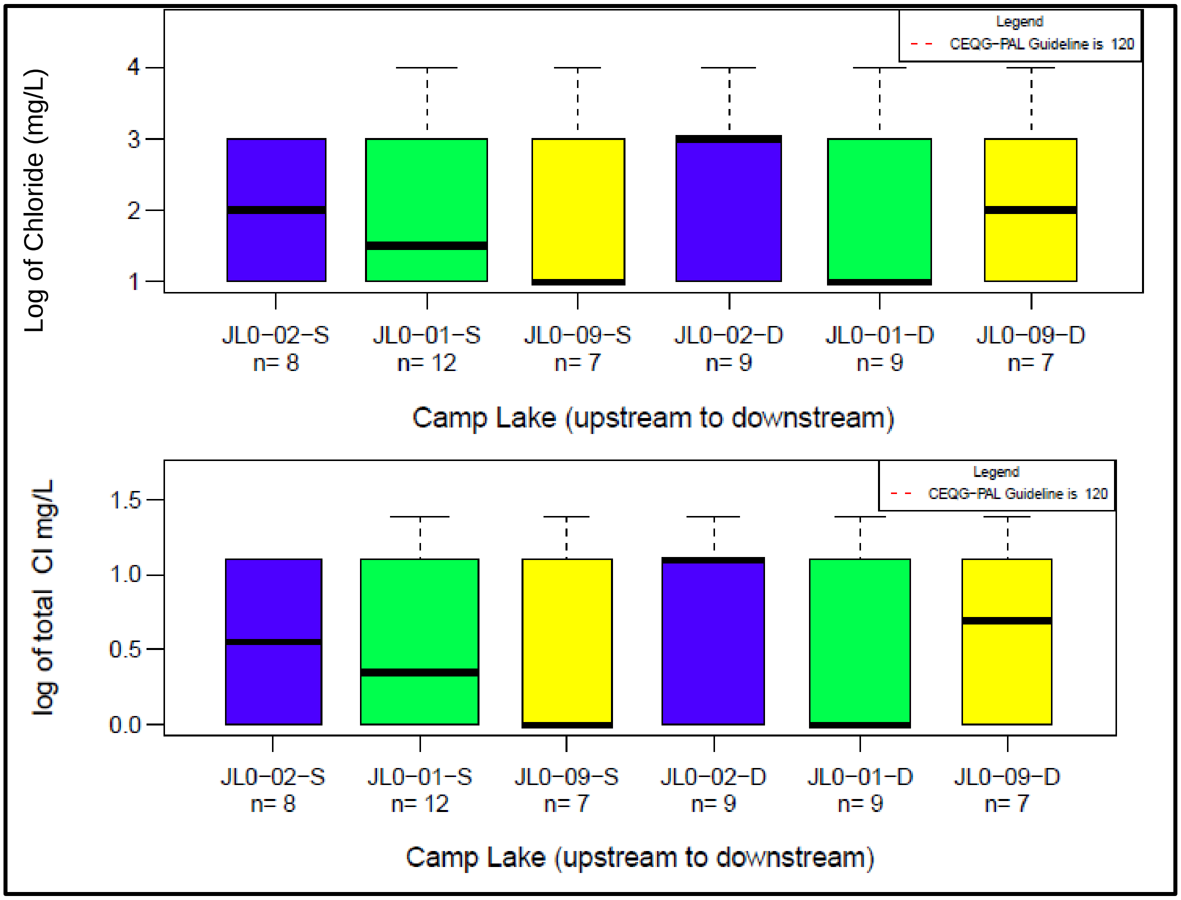
1. ALKALINITY VALUES BELOW 10 mg/L ARE HIGHLY SENSITIVE TO ACIDIC INPUTS; ALKALINITY VALUES BETWEEN 10 – 20 mg/L ARE MODERATELY SENSITIVE TO ACIDIC INPUTS AND ALKALINITY VALUES ABOVE 20 mg/L HAVE LOW SENSITIVITY TO ACIDIC INPUTS.

Figure B.6 Camp Lake – Alkalinity

The following sections summarize the results for the non-metallic inorganic parameters of interest: chloride and nitrate.

Chloride (Figures B.7 and B.8)

The total sample size for chloride concentration samples collected ranges from seven to twelve, depending on the geographically distinct sampling site. Chloride concentrations are very low and range from maximum values of 4 mg/L to detection limit values of 1 mg/L (Figure B.7). These concentrations are far below the CWQG limit of 120 mg/L. All sites within Camp Lake have median values that range from 1 mg/L to 3 mg/L. No clear trends with respect to sample location are noted (Figure B.7). Raw data and log transformed data have identical distributions and therefore, chloride distributions remain unaffected by the lognormal data transformation.

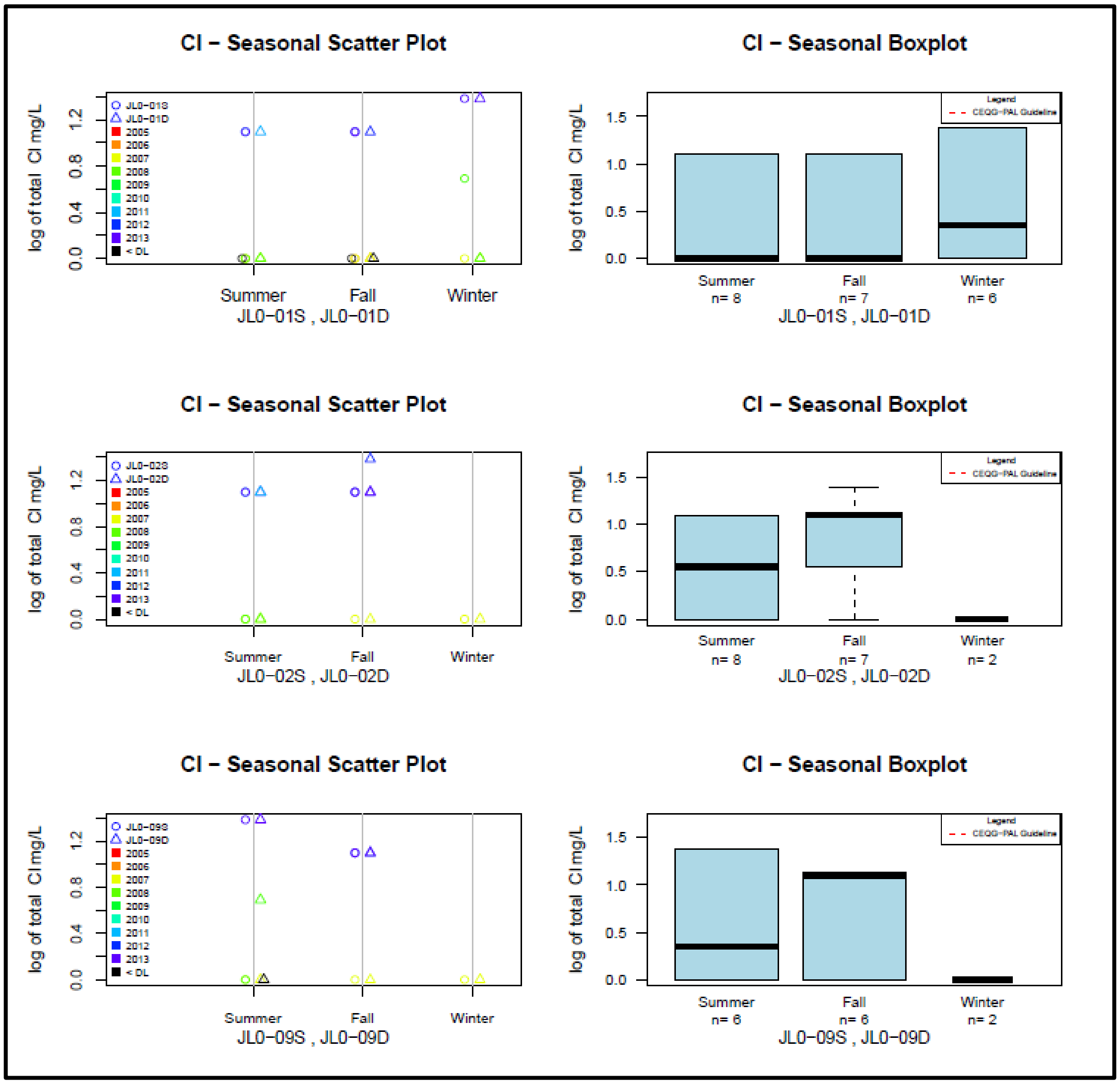


NOTES:

1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.

Figure B.7 Camp Lake – Chloride Concentrations in Water

Seasonal scatterplots and boxplots (Figure B.8) show that deep and shallow samples taken during the same year often had similar concentration values, which does not support the assumption that chloride concentration changes with depth.



NOTES:

1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.

Figure B.8 Camp Lake – Variability of Chloride in Water

The absence of greater chloride concentrations at deep sites may be explained by the very low chloride concentrations or the lack of winter under ice samples, and does not necessarily indicate the absence of stratification. The seasonal scatterplots indicate that 2011 through 2013 chloride concentrations are elevated compared to 2005 to 2010 concentrations. No distinct seasonal trends are noted.

Nitrate

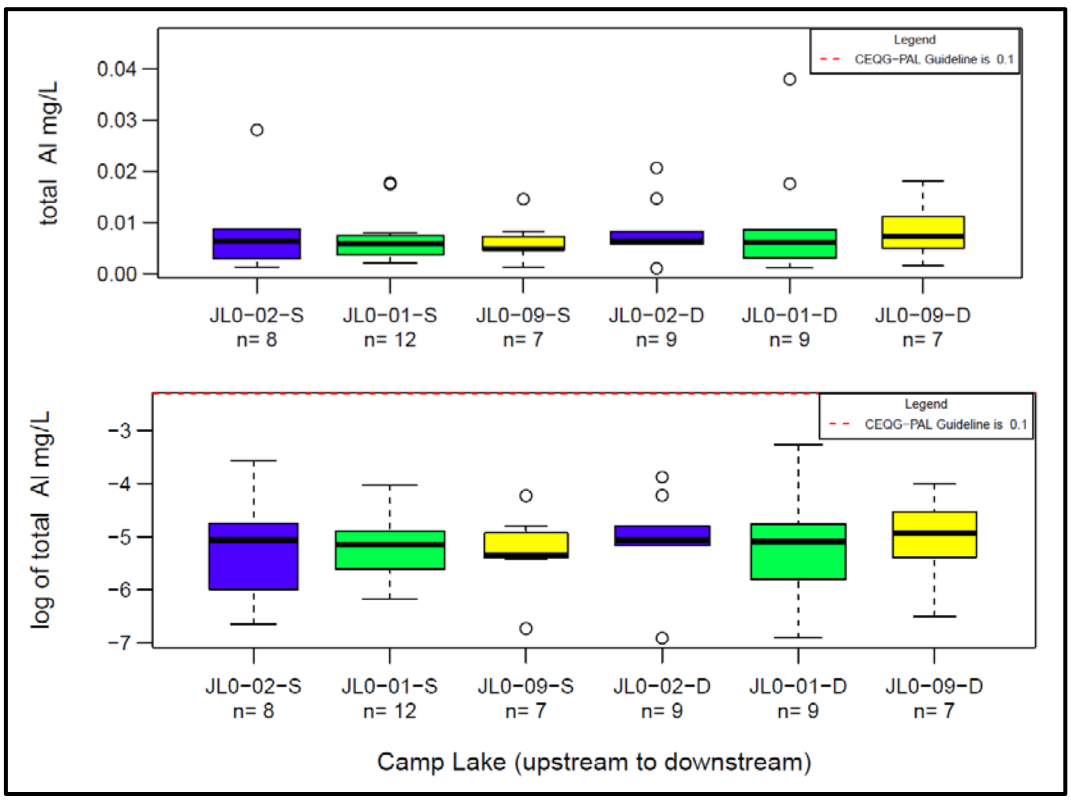
Fifty-two (52) nitrate concentration samples were collected at Camp Lake. All samples collected were at detection limit (0.10 mg/L) and occur well below the CWQG-PAL guideline (3 mg/L). Due to detection limit interference, no depth, seasonal or inter-annual variability is discernable and graphical depiction is not warranted.

The following sections summarize the results for the metal parameters of interest: aluminum, arsenic, cadmium, copper, iron, and nickel. Total metals concentrations for the parameters of interest have been presented on the basis that applicable guidelines are focused on total metals.

Total Aluminum (Figures B.9 and B.10)

Total aluminum values are uniformly above detection limits, but below the CWQG-PAL guideline across all sites in Camp Lake. Similar to nitrate and chloride, seasonal scatterplots and boxplots for aluminum show concentrations measured at deep and shallow samples taken during the same year have similar values (Figures B.9 and B.10).

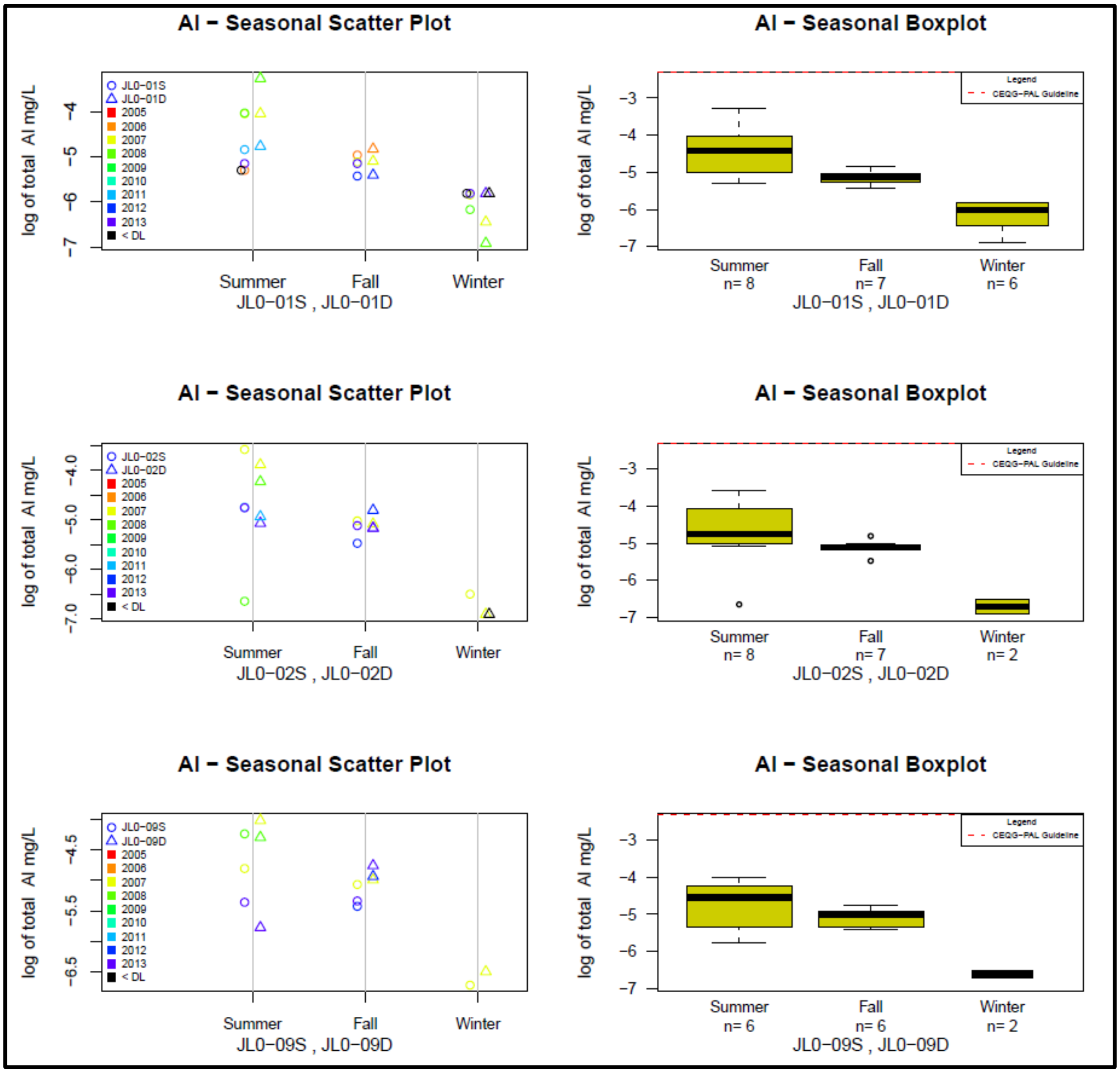
Seasonal plots show higher median values of aluminum measured during the summer, lower aluminum concentrations measured in the fall and the lowest aluminum concentrations measured in the winter. Due to the log scale of these graphs, the actual magnitude variation is small. This seasonal trend may be explained by a combination of natural and anthropogenic factors. Elevated summer concentrations may occur as result of increase summer water temperature, increased aluminum mobilization from rocks, soils and sediments by running water during summer and fall seasons or as a result of drilling activities that have occurred in vicinity to Camp Lake during the summer.



NOTES:

1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.
2. THE CWQG-PAL GUIDELINE LIMIT IS BASED ON THE TOTAL MEDIAN HARDNESS.

Figure B.9 Camp Lake – Total Aluminum Concentrations in Water



NOTES:

1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.
2. THE CWQG-PAL GUIDELINE LIMIT IS BASED ON THE TOTAL MEDIAN HARDNESS.

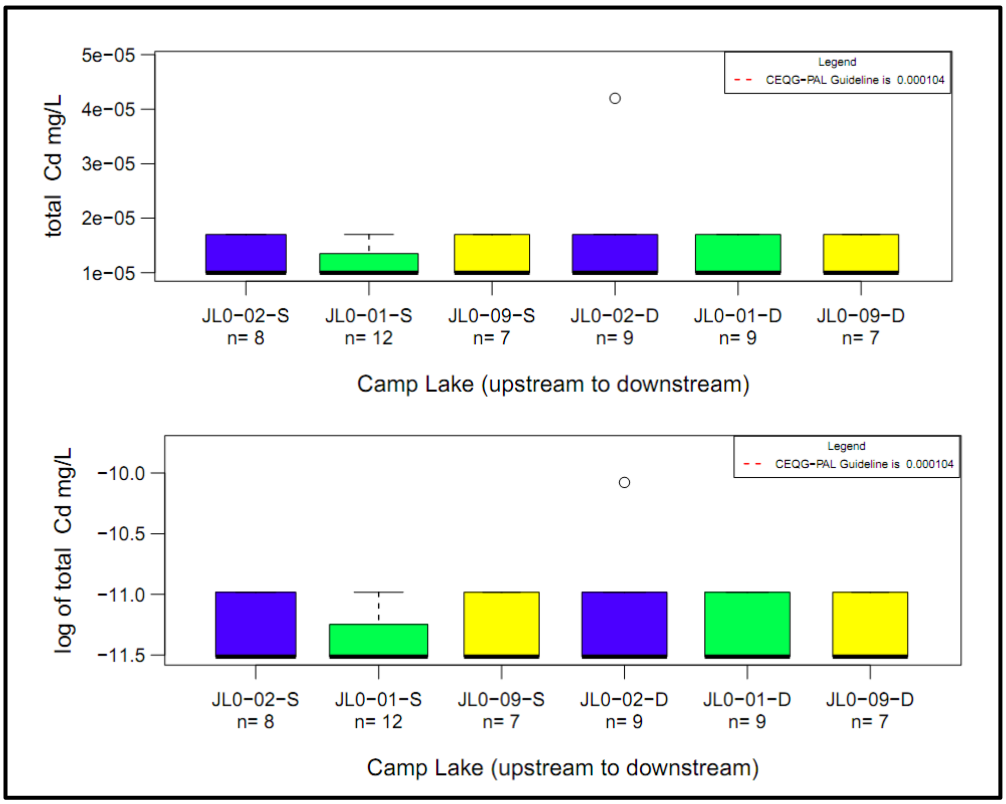
Figure B.10 Camp Lake – Variability of Total Aluminum in Water

Total Arsenic

Total arsenic concentrations were measured at the detection limit (0.0001 mg/L), consistently at all sampling locations within Camp Lake, throughout all seasons and during all years of sampling. As a result, graphical representation of data is not deemed necessary. The detection limit value is well below the appilcable CWQG-PAL guideline limit (0.005 mg/L).

Total Cadmium (Figures B.11 and B.12)

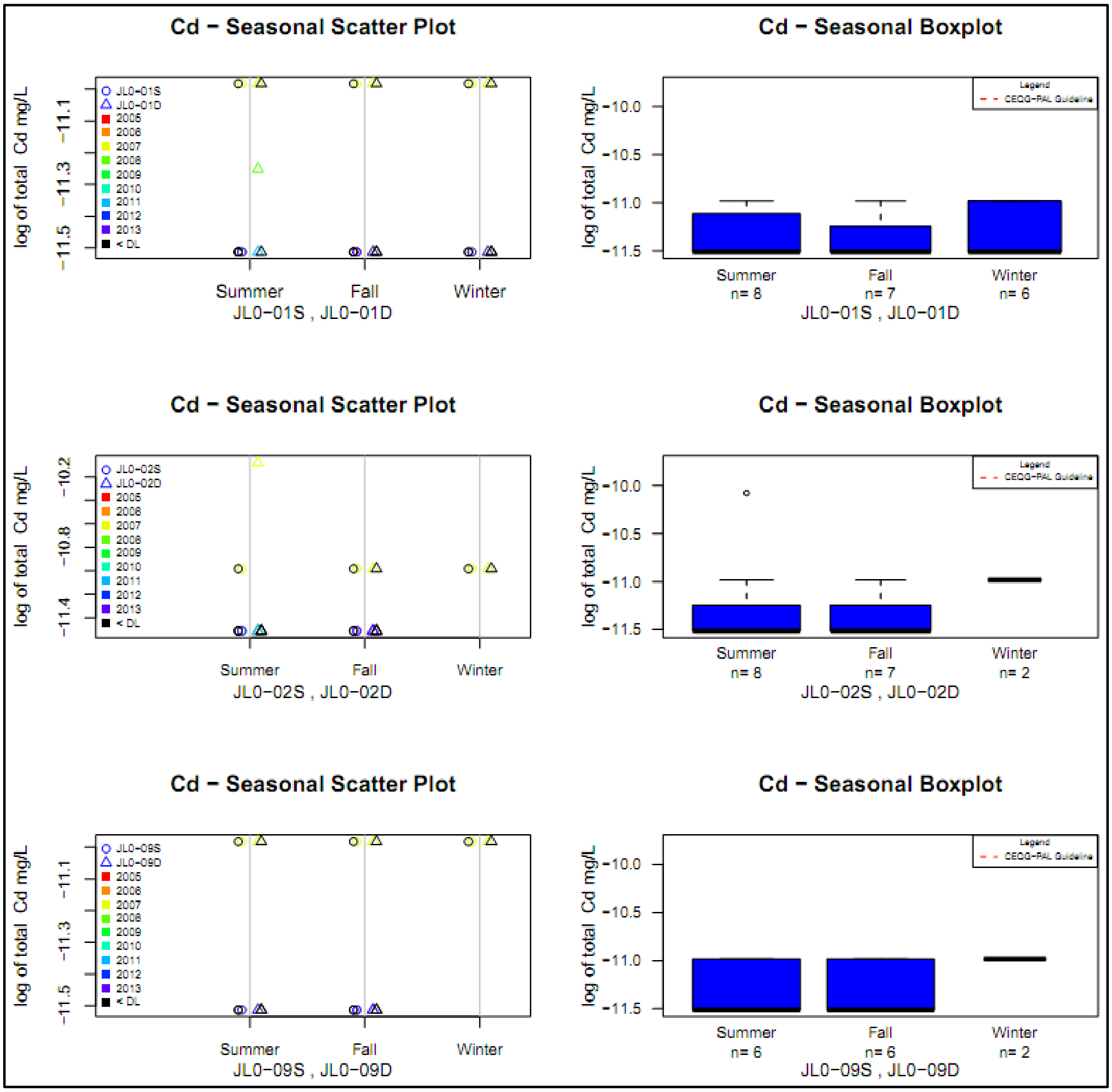
A total of 52 samples with measured cadmium concentrations were collected at Camp Lake, with seven to 12 samples collected at each of the sampling locations in Camp Lake (Figure B.11). Most total cadmium concentrations ranged from detection limit (0.00001 mg/L) to 0.00017 mg/L. One outlying value with a concentration of 0.00004 mg/L recorded in the summer, reported above the CWQG-PAL guideline (0.00018 mg/L, calculated using a median hardness of 50 mg/L $CaCO_3$). Seasonal scatter plots indicate that all measured cadmium concentrations are at a detection limit, with the exception of two data points. Seasonal box plots are obscured by artifact detection limits and do not show a consistent seasonal trend amoung the three sites sampled (Figure B.12). Definitive conclusions regarding depth and seasonal variability are obscured by artificially high detection limits.



NOTES:

1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.
2. THE CWQG-PAL GUIDELINE LIMIT IS BASED ON THE TOTAL MEDIAN HARDNESS.

Figure B.11 Camp Lake – Total Cadmium Concentrations in Water



NOTES:

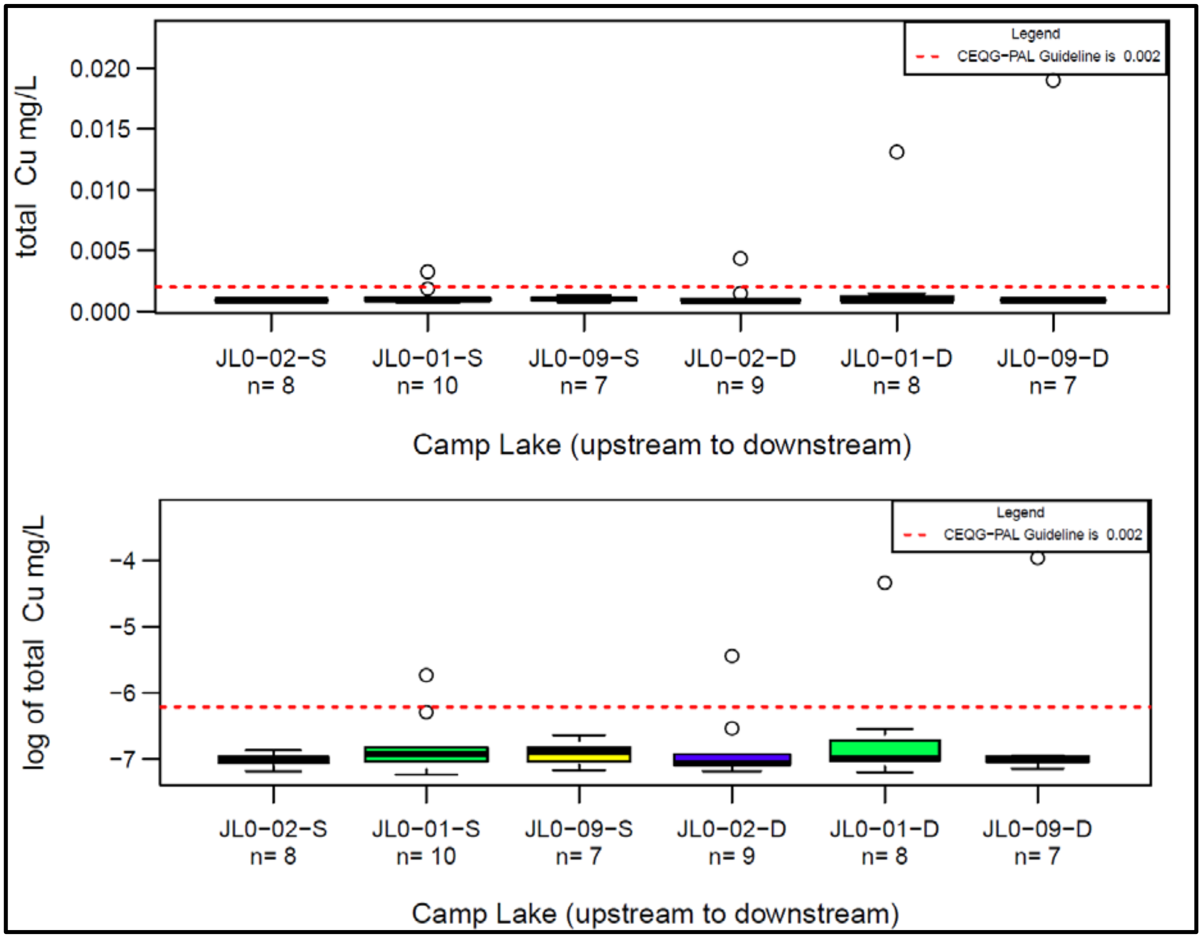
1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.
2. THE CWQG-PAL GUIDELINE LIMIT IS BASED ON THE TOTAL MEDIAN HARDNESS.

Figure B.12 Camp Lake – Variability of Total Cadmium in Water

Total Copper (Figures B.13 and B.14)

The total sample size for copper samples in Camp Lake is 49, with between seven through ten samples collected at each sampling location. Median values for total copper at all sites occur below 0.002 mg/L (Figure B.13). Log values indicate a distribution of samples with low concentrations, below the guideline limit, that are not obscured by detection limits. Outlying values occur for several sites, to a maximum concentration of approximately 0.018 mg/L. Four outlying values exceed the CWQG-PAL guideline (0.002 mg/L).

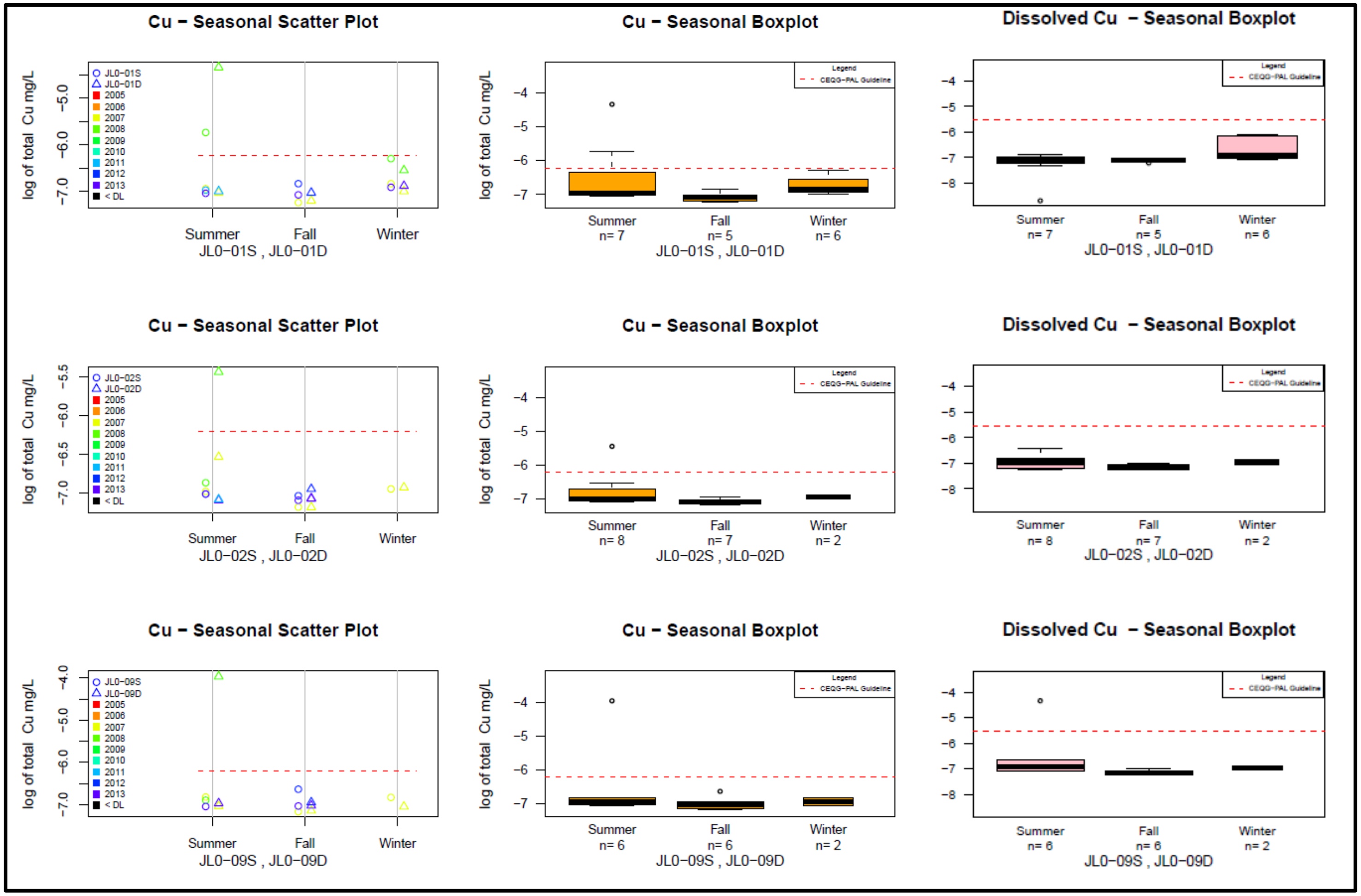
The seasonal copper scatterplot indicates that, with the exception of deep samples taken in 2008, shallow and deep concentrations are quite similar and do not show a consistent trend with depth (Figure B.14). In contrast to other parameters, seasonal trends indicates slightly higher concentrations are measured in summer and winter, when compared to fall. Further investigation into this seasonal trend revealed that winter total concentrations are almost entirely composed of the dissolved fraction, and not the particulate fraction (Figure B.14).



NOTES:

1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.
2. THE CWQG-PAL GUIDELINE LIMIT IS BASED ON THE TOTAL MEDIAN HARDNESS.

Figure B.13 Camp Lake –Total Copper Concentrations in Water



NOTES:

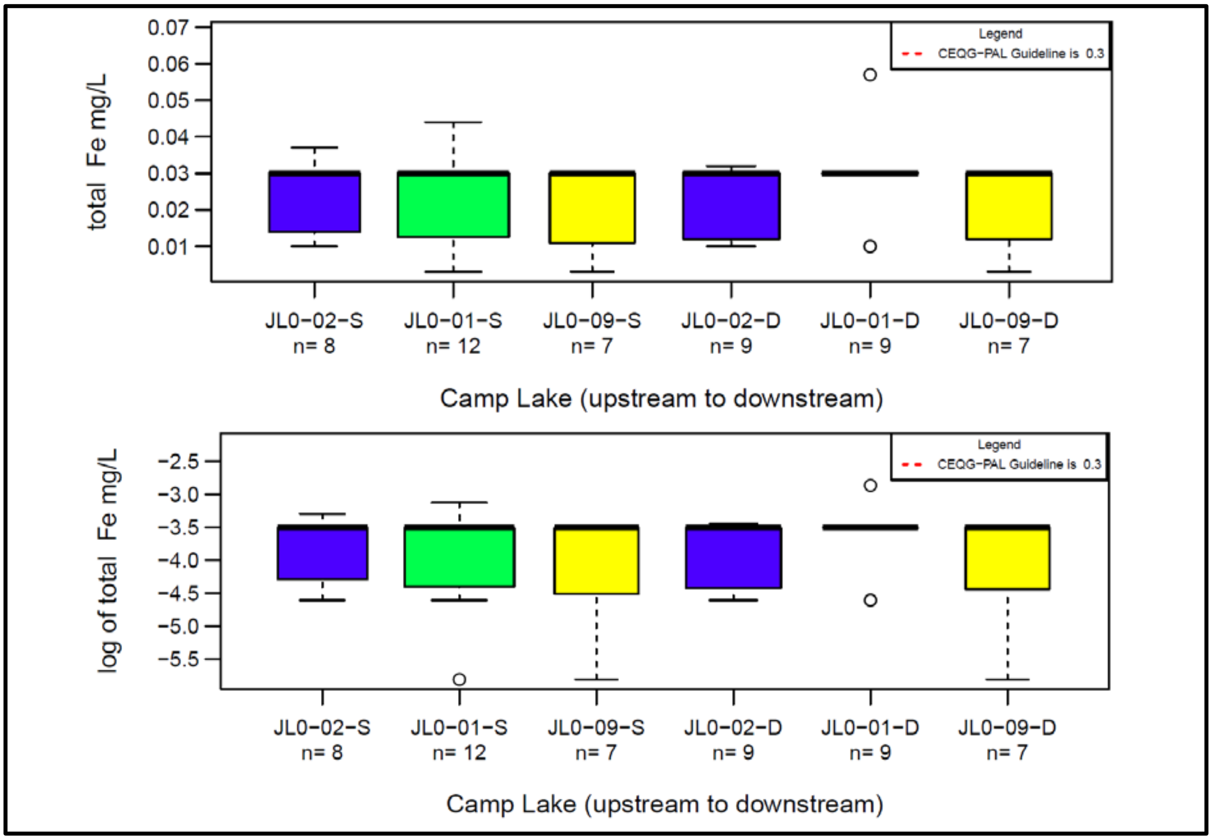
1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.
2. THE CWQG-PAL GUIDELINE LIMIT IS BASED ON THE TOTAL MEDIAN HARDNESS.

Figure B.14 Camp Lake – Variability of Copper in Water

Total Iron (Figures B.15 and B.16)

Fifty-two (52) samples of total iron were taken within Camp Lake, with between 7 to 12 samples taken at each site within Camp Lake (Figure B.15). Median total iron concentrations at all sites was 0.03 mg/L, below the most stringent water quality guideline, CWQG-PAL at 0.3 mg/L (or the Interim SSWQO of 0.77 mg/L; see Section 2.4 of the main report). Raw and lognormal data show very similar trends, indicating that transformation may not be required for statistical tests and that graphical representation of outliers is not affected. Seasonal scatterplots of iron concentrations indicate that artificially elevated detection limits may be influencing the data and no distinct seasonal trends are noted.

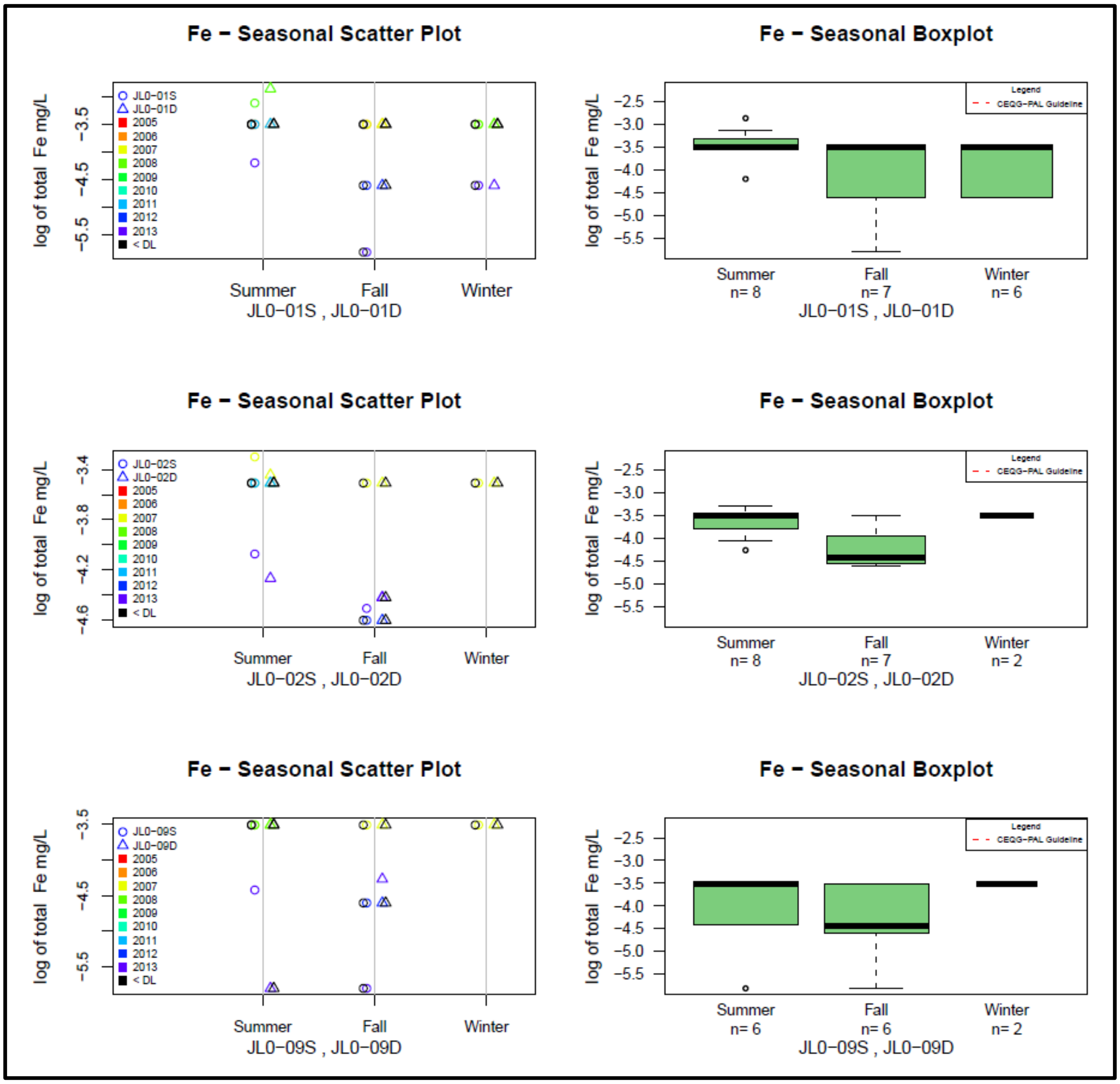
Due to interaction with detection limits during early years of sampling, definitive seasonal or depth trends are difficult to define (Figure B.16). Of note are the slightly lower iron concentrations during fall sampling events.



NOTES:

1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.
2. THE CWQG-PAL GUIDELINE LIMIT IS BASED ON THE TOTAL MEDIAN HARDNESS.

Figure B.15 Camp Lake – Total Iron Concentrations in Water



NOTES:

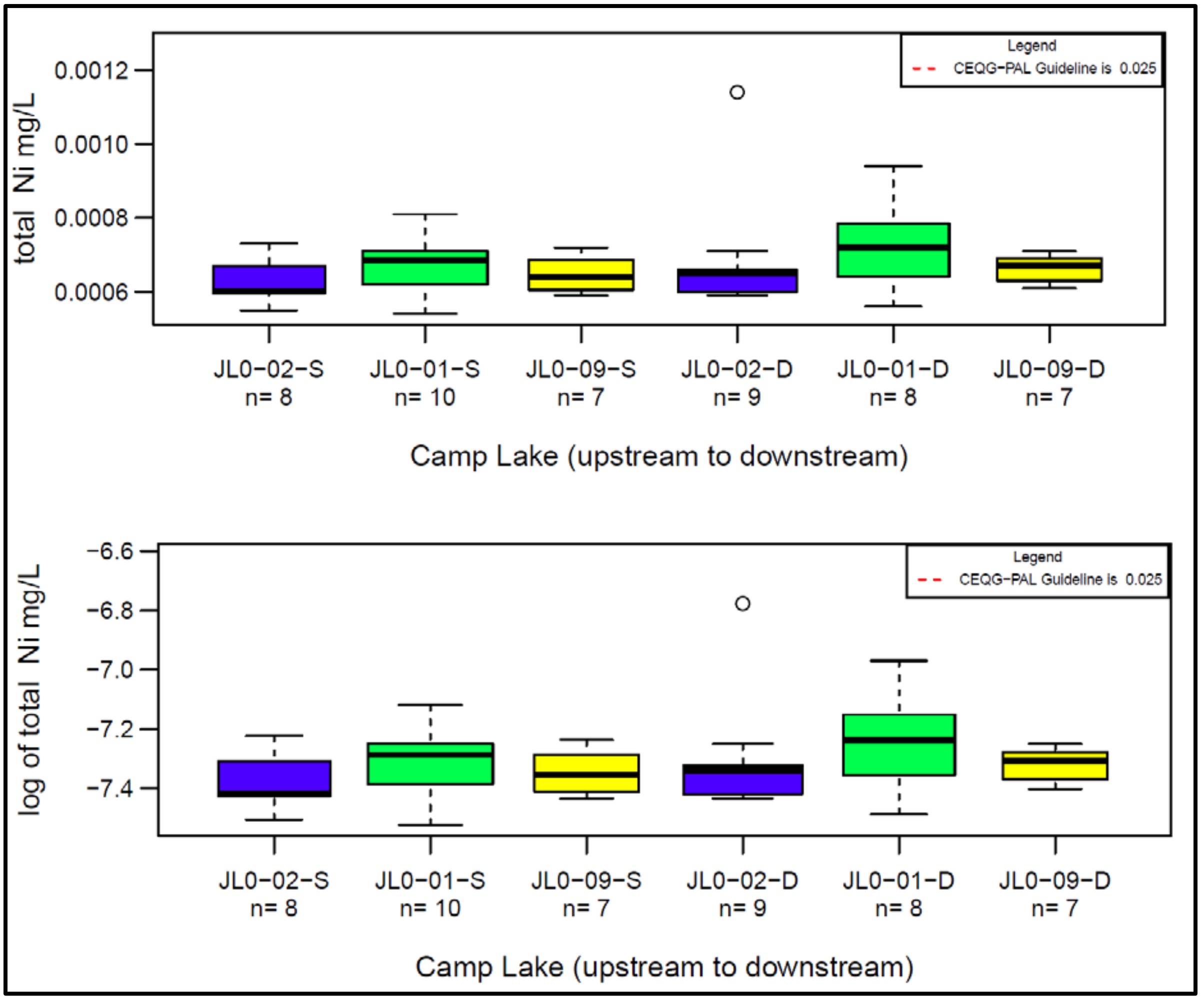
1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.
2. THE CWQG-PAL GUIDELINE LIMIT IS BASED ON THE TOTAL MEDIAN HARDNESS.

Figure B.16 Camp Lake – Variability of Total Iron in Water

Total Nickel (Figures B.17 and B.18)

Forty-nine (49) nickel samples were collected at Camp Lake, with between seven to ten samples collected at each discrete sampling location. Median total nickel concentrations at each site are low and range from 0.0006 mg/L to 0.00075 mg/L (Figure B.17). All values are well below the CWQG-PAL guideline calculated to be 0.025 mg/L based on 50 mg/L $CaCO_3$ hardness.

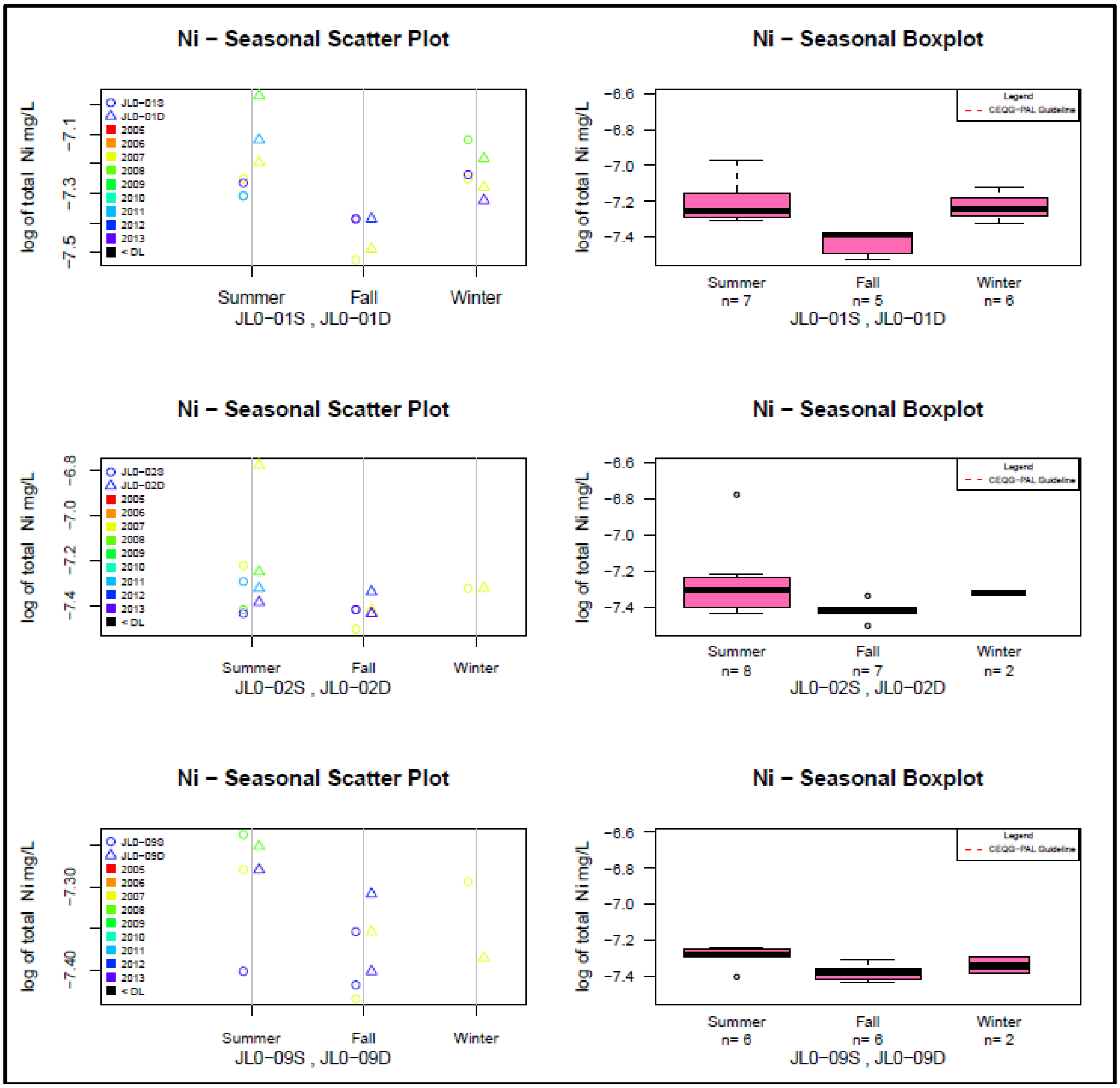
No distinct temporal trends over the course of yearly sampling are noted, although variation in site location is greater than variation as a result of depth (Figure B.18). JL0-01 has a very low magnitude elevation of nickel concentrations when compared to other sites. Seasonal trends are noted that are similar to those observed for copper, with very similar median summer and winter concentrations and lower fall sampling concentrations. Similar to copper, investigation into total versus dissolved concentration reveal that almost all total nickel is present in the dissolved form during the winter months, although summer and fall have more particulate data.



NOTES:

1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.
2. THE CWQG-PAL GUIDELINE LIMIT IS BASED ON THE TOTAL MEDIAN HARDNESS.

Figure B.17 Camp Lake – Total Nickel Concentrations in Water



NOTES:

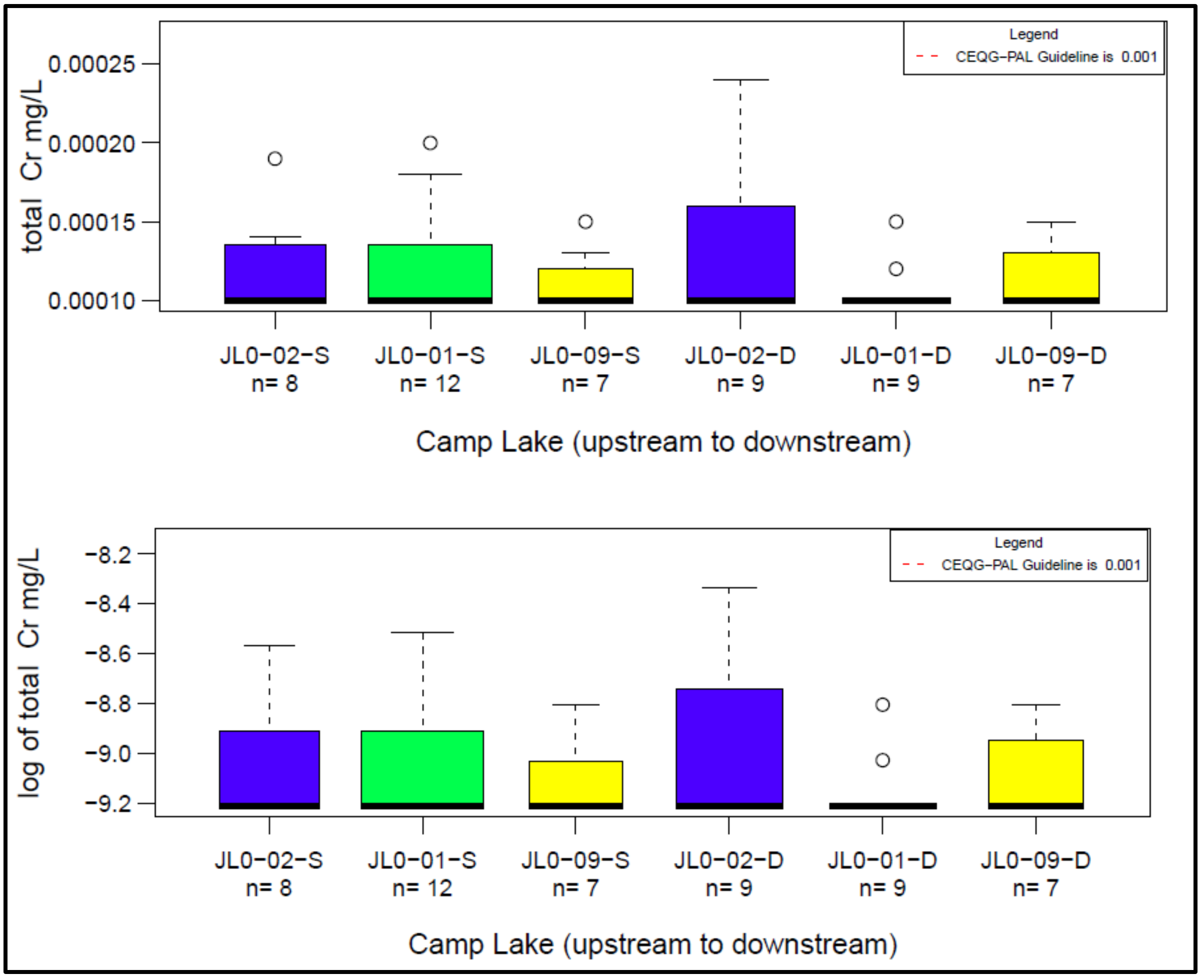
1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.
2. THE CWQG-PAL GUIDELINE LIMIT IS BASED ON THE TOTAL MEDIAN HARDNESS.

Figure B.18 Camp Lake – Variability of Total Nickel in Water

Total Chromium (Figures B.19 and B.20)

Fifty-two (52) chromium samples were collected at Camp Lake, with between seven to twelve samples collected at each discrete sampling location. Median total chromium concentrations at each site are low and range from 0.0001 mg/L to 0.00024 mg/L (Figure B.19). All values are well below the CWQG-PAL guideline (0.001 mg/L).

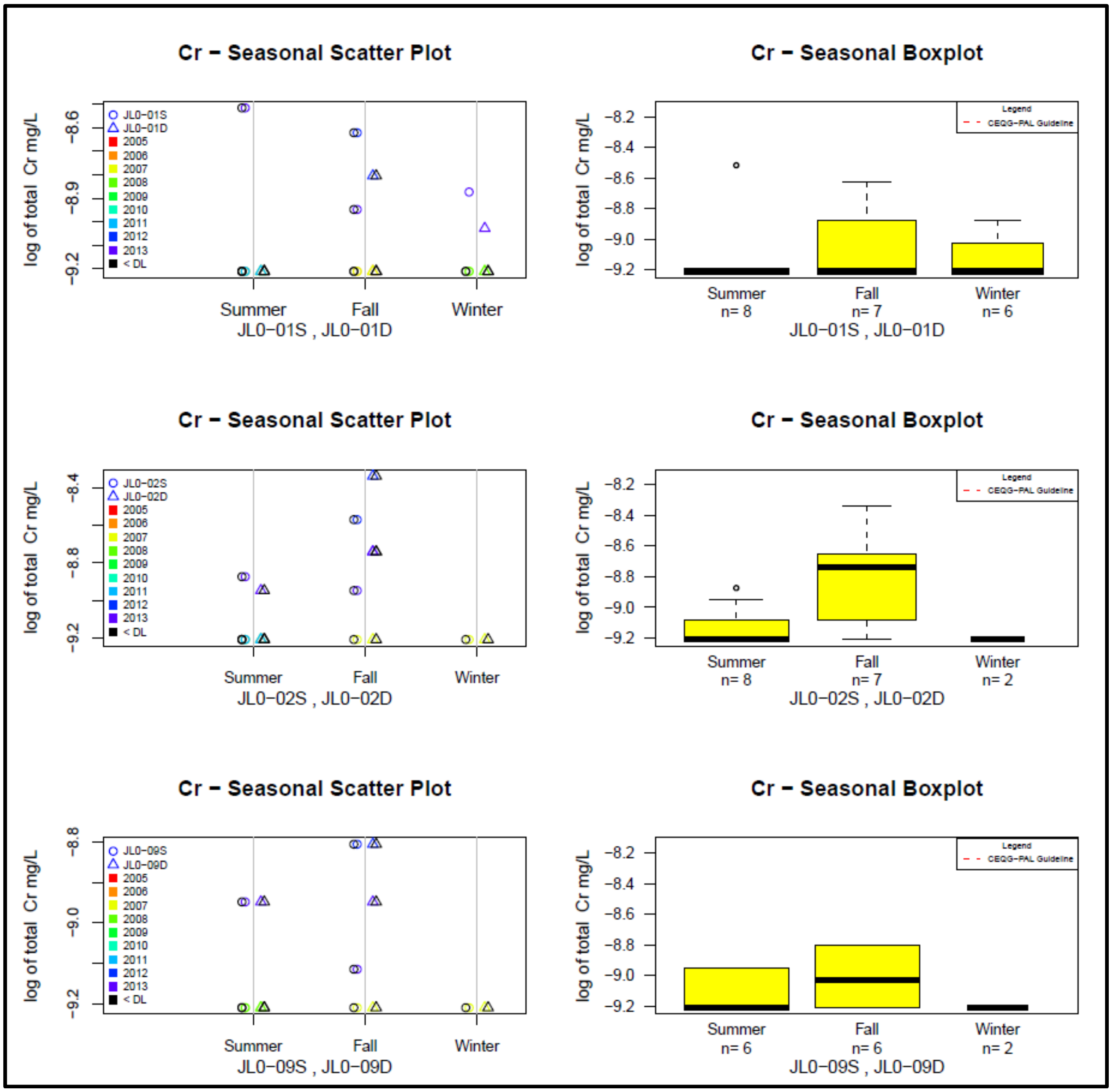
Samples from 2012 and 2013 are slightly elevated when compared to previous sampling years (Figure B.20). Slightly greater concentrations during the fall are noted for chromium



NOTES:

1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.

Figure B.19 Camp Lake – Total Chromium Concentrations in Water



NOTES:

1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.

Figure B.20 Camp Lake – Variability of Total Chromium in Water

Summary of Camp Lake Water Quality

Summary of trends observed during review of Camp Lake baseline data:

- Distinct depth trends are not observed for Camp Lake, which suggests that the lake is completely mixed through much of the year. Review of data above suggests aggregation of deep and shallow sites may be appropriate.
- Geographic trends between discrete sampling sites were not observed for any parameters.

- With the exception of chloride and chromium, parameters did not show any distinct inter-annual trends/variability over the six year sampling history. Chloride and chromium concentrations in Camp Lake measured from 2011 through 2013 are elevated compared to earlier samples from 2005 to 2010.
- Parameters with MDL interference and/or that do not show seasonal trends include: cadmium, chloride, arsenic, iron and nitrate.
- Parameters that have maximum concentrations occurring in the summer: nitrate and aluminum. This is likely as a result of the spring runoff period caused by rapid melt of winter snowpack.
- Parameters that have maximum concentrations occurring in the winter: copper and nickel. Most of this concentration occurs in a dissolved form, not as particulate.
- Parameters that have maximum concentrations occurring in the fall: chromium.

B.2.2 Sheardown Lake

Sheardown Lake is separated into two basins, referred to as the northwest basin and southeast basin. Sheardown Lake NW has been the receiving water for treated sewage from the exploration camp. In addition, stockpiling and crushing of ore occurred in 2008 near the lake and the primary tributary to the lake. As such, the concentrations within the lake may have already been affected by construction and mining activities. Findings from both lakes will be discussed in the subsequent sections.

B.2.2.1 Sheardown Lake NW

A total of 92 lake samples were collected from the northwest basin of Sheardown Lake from 10 sampling stations over the sampling period. Most sampling was completed during the open water season, from July through September (summer and fall). Late winter sampling (May) was carried out only in 2007, 2008, 2012 and 2013. Ten stations are reported in detail (Figures B.1 and B.2):

- DL0-01-1-S and DL0-01-1-D - Shallow and deep; located in the centre of Sheardown Lake NW.
- DL0-01-2-S and DL0-01-2-D - Shallow and deep; located in the south centre of Sheardown Lake NW.
- DL0-01-4-S and DL0-01-4-D - Shallow and deep; located on the northeast bay within Sheardown Lake NW.
- DL0-01-5-S and DL0-01-5-D - Shallow and deep; located near the northwest shore within Sheardown Lake NW.
- DL0-01-7-S and DL0-01-7-D - Shallow and deep; located near the southern outlet of Sheardown Lake NW.

D-Lake-01, -02, -03, -04 and -05 were also established, but each has only one sampling point. A summary of the data collected during each season, with respect to year and site are included in Table B.2. A graphical representation of the sampling events within Sheardown Lake for the ten station reported in detail is provided in Figure B.21.

Table B.2 Sheardown Lake NW Sample Size

Year	Summer	Fall	Winter
2006	2	2	0
2007	10	10	4
2008	11	10	2
2011	6	6	0
2012	0	6	2
2013	13	8	6
Site	**Summer**	**Fall**	**Winter**
DL0-01-1-S	5	6	2
DL0-01-1-D	5	6	2
DL0-01-2-S	3	3	0
DL0-01-2-D	3	3	0
DL0-01-4-S	5	2	0
DL0-01-4-D	2	3	0
DL0-01-5-S	4	5	2
DL0-01-5-D	4	5	2
DL0-01-7-S	4	5	0
DL0-01-7-D	7	4	0

NOTES:

1. WINTER SAMPLING OCCURRED DURING APRIL AND MAY; SPRING SAMPLING OCCURRED DURING JUNE; SUMMER SAMPLING OCCURRED FROM JULY TO AUGUST 17; FALL SAMPLING OCCURRED FROM AUGUST 18 THROUGH SEPTEMBER 30.
2. LAKE SAMPLING DID NOT OCCUR DURING SPRING, DUE TO SAFETY CONCERNS OF SAMPLING OVER MELTING ICE.
3. DURING WINTER 2013, SAMPLES WERE COLLECTED WITHIN SHEARDOWN LAKE AT D-LAKE-05.

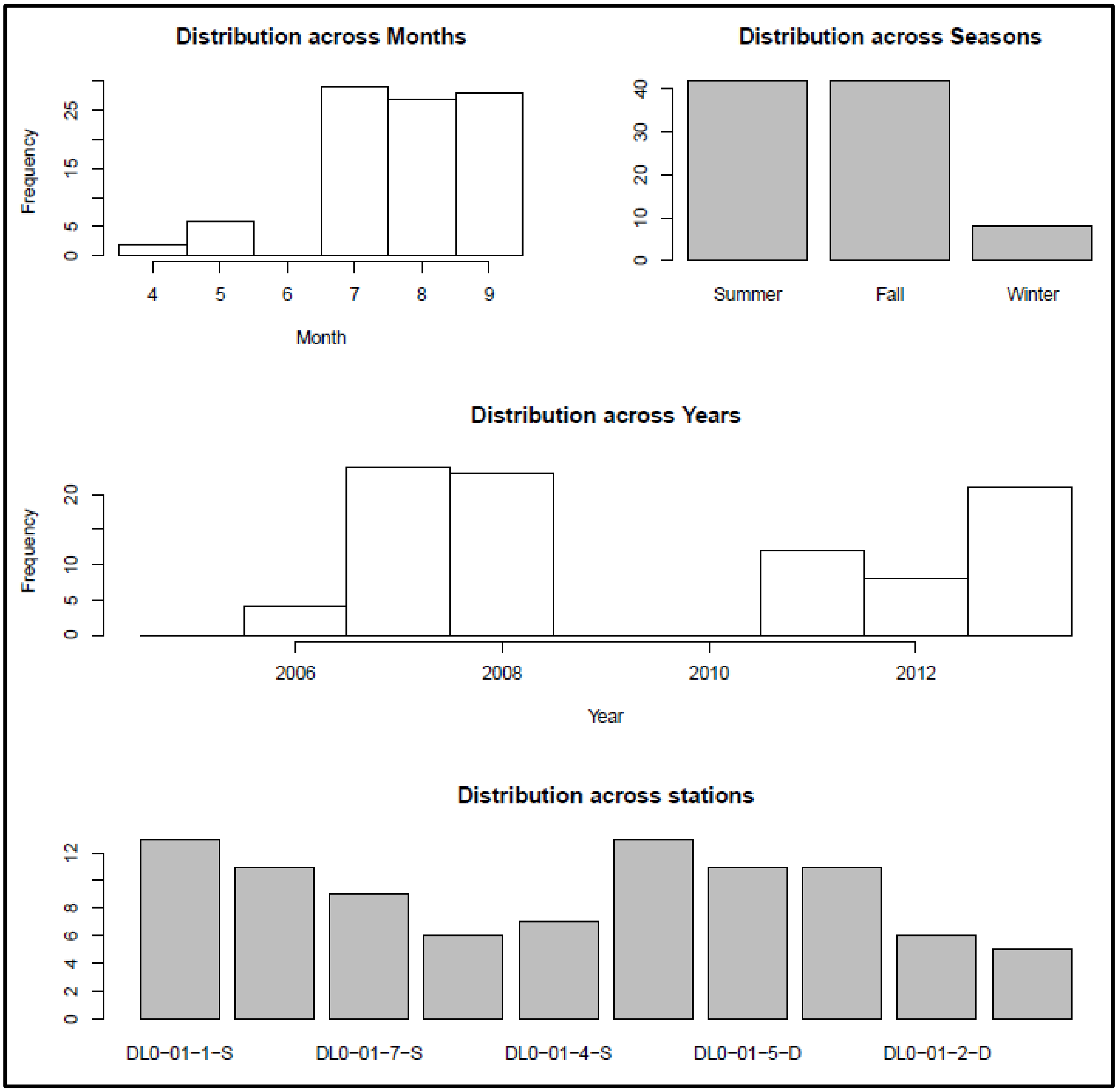


Figure B.21 Sheardown Lake NW – Graphical Summary of Sampling Events

The following summarizes the data review observations for Sheardown Lake NW.

pH (Figure B.22)

- Sheardown Lake NW is slightly alkaline with a median in-situ pH of ~7.6.
- A slight influence of depth on pH is observed with a measured median *in situ* pH at the deep stations is slightly lower compared to shallow stations.

Alkalinity (Figure B.22)

- Sheardown Lake sites are fairly uniform with median alkalinity values that range from 50 to 60 mg/L $CaCO_3$, classifying the lake water as having low sensitivity to acidic inputs.

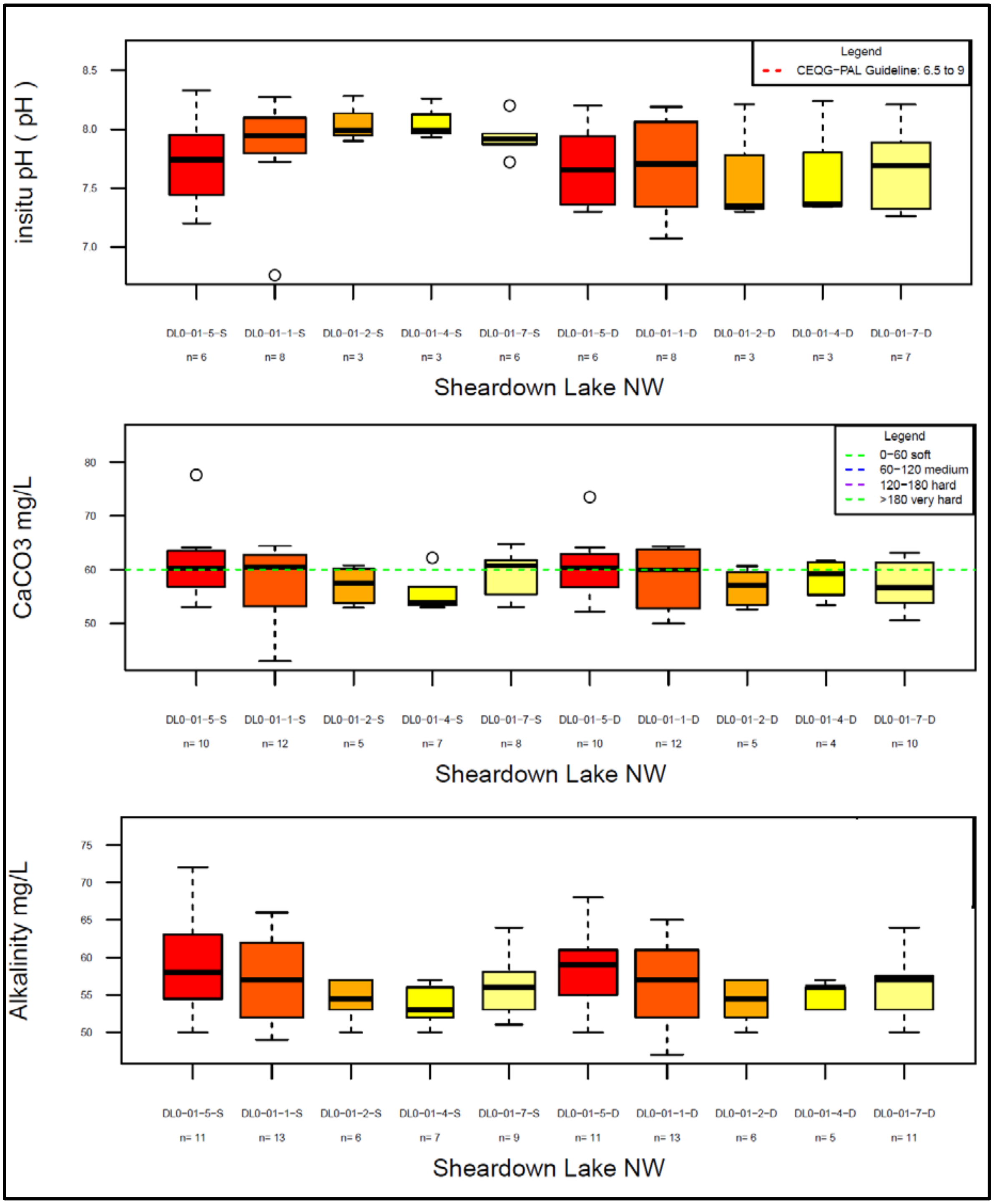


Figure B.22 Sheardown Lake NW – *In situ* pH, Alkalinity and Hardness

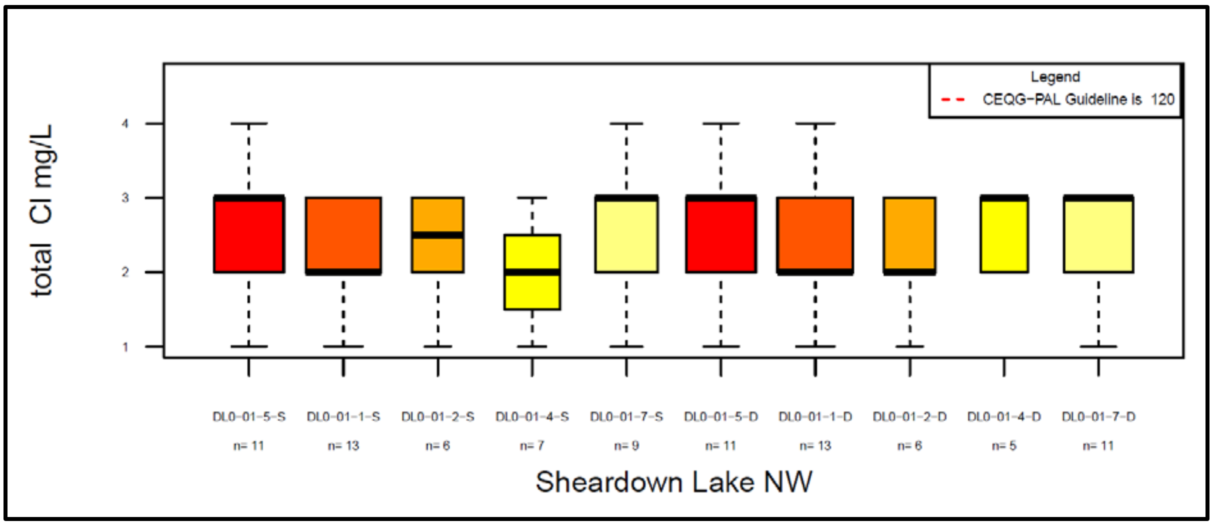
Hardness (Figure B.22)

- Median hardness ranged from 54 and 61 mg/L, putting Sheardown Lake NW right on the border of water that is considered “soft” or “medium” hardness.
- Hardness did not change meaningfully with depth, and showed more variation with station than with depth.
- The close range between hardness and alkalinity suggest that the hardness is almost entirely carbonate hardness with little to no non-carbonate contributions to hardness.

The following sections summarize the results for the non-metallic inorganic parameters of interest: chloride and nitrate.

Chloride (Figures B.23 and B.24)

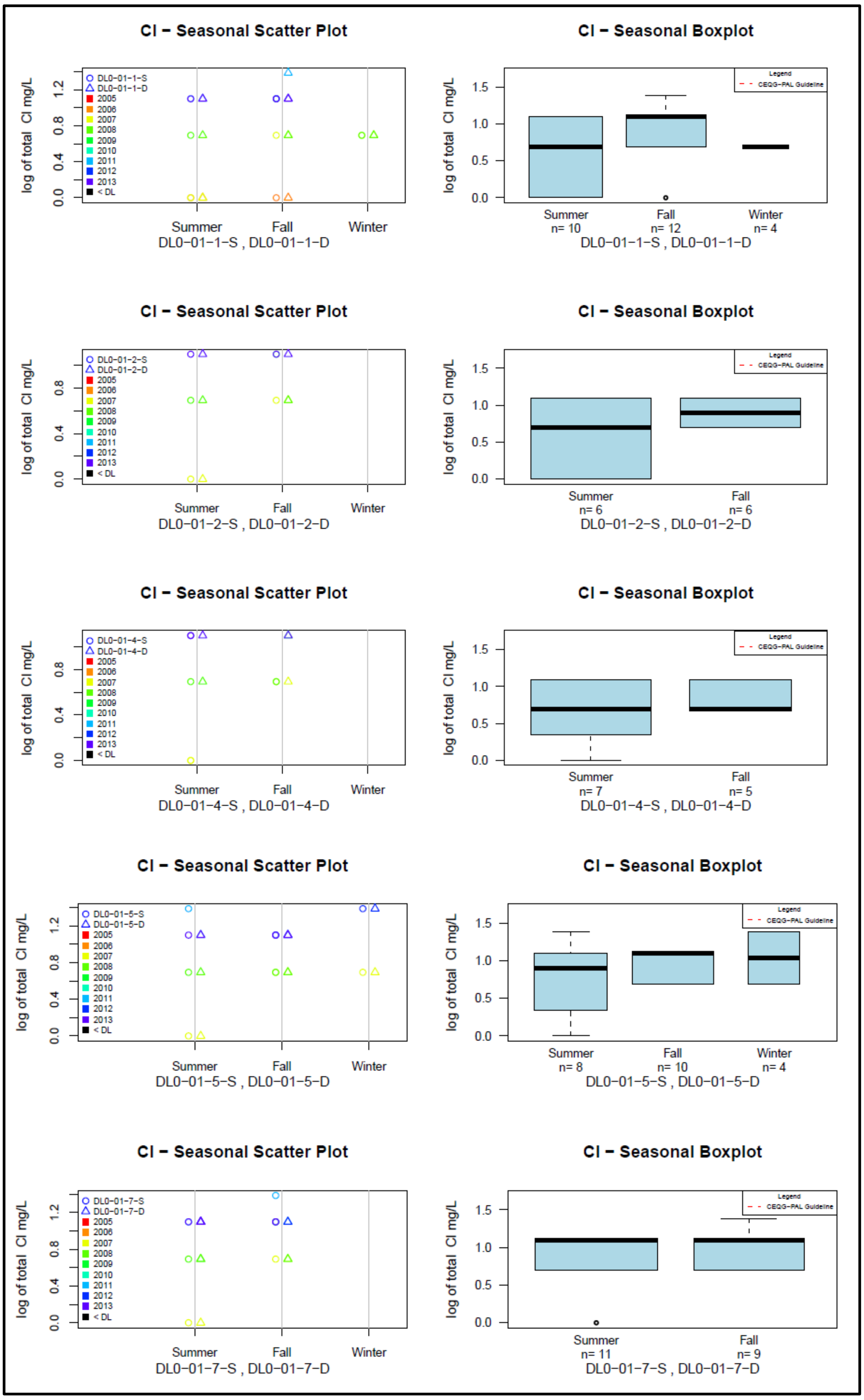
Ninety-two (92) chloride concentration samples were collected at Sheardown Lake NW. Chloride concentrations in Sheardown Lake NW are very low and have maximum values of 4 mg/L, well below the CWQG-PAL limit of 120 mg/L (Figure B.23). All sites within Sheardown Lake NW have very similar median chloride concentrations that range between 2 to 3 mg/L. Comparison of raw data and log values reveals the occurrence of low concentration outlying data, at a MDL. Seasonal scatterplots indicate that detection limit interference is occurring for chloride concentrations and that distinct trends with depth are not apparent (Figure B.24).



NOTES:

1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.

Figure B.23 Sheardown Lake NW – Chloride Concentrations in Water



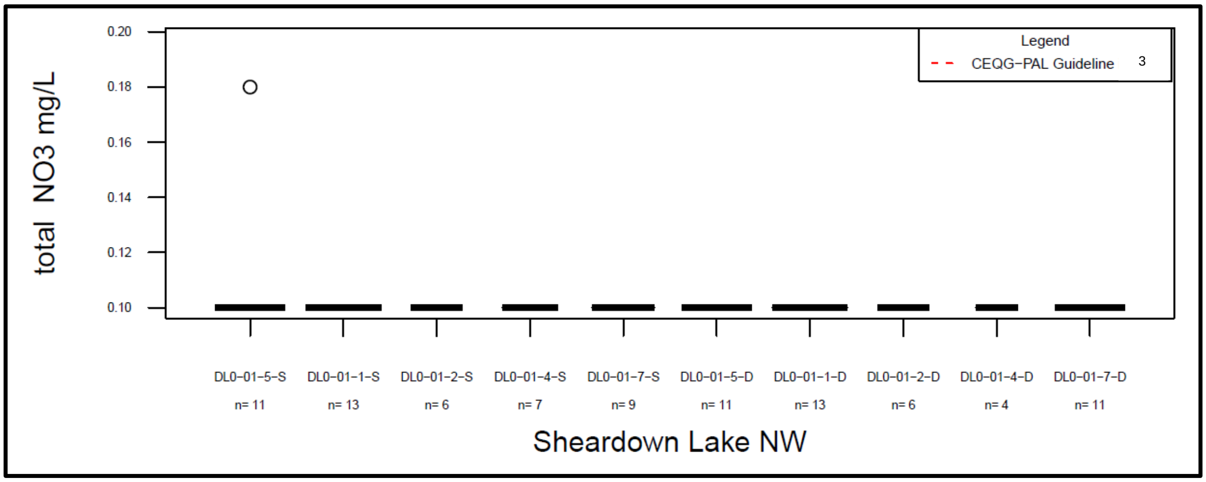
NOTES:

1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.

Figure B.24 Sheardown Lake NW – Variability of Chloride in Water

Nitrate (Figure B.25)

Eighty-seven (87) nitrate concentration samples were collected from Sheardown Lake over the course of eight years. All nitrate concentrations were measured at the detection limit (0.10 mg/L), except for one outlying concentration equal to 0.18 mg/L (Figure B.25). As a result, no seasonal, inter-annual or depth variation can be determined.



NOTES:

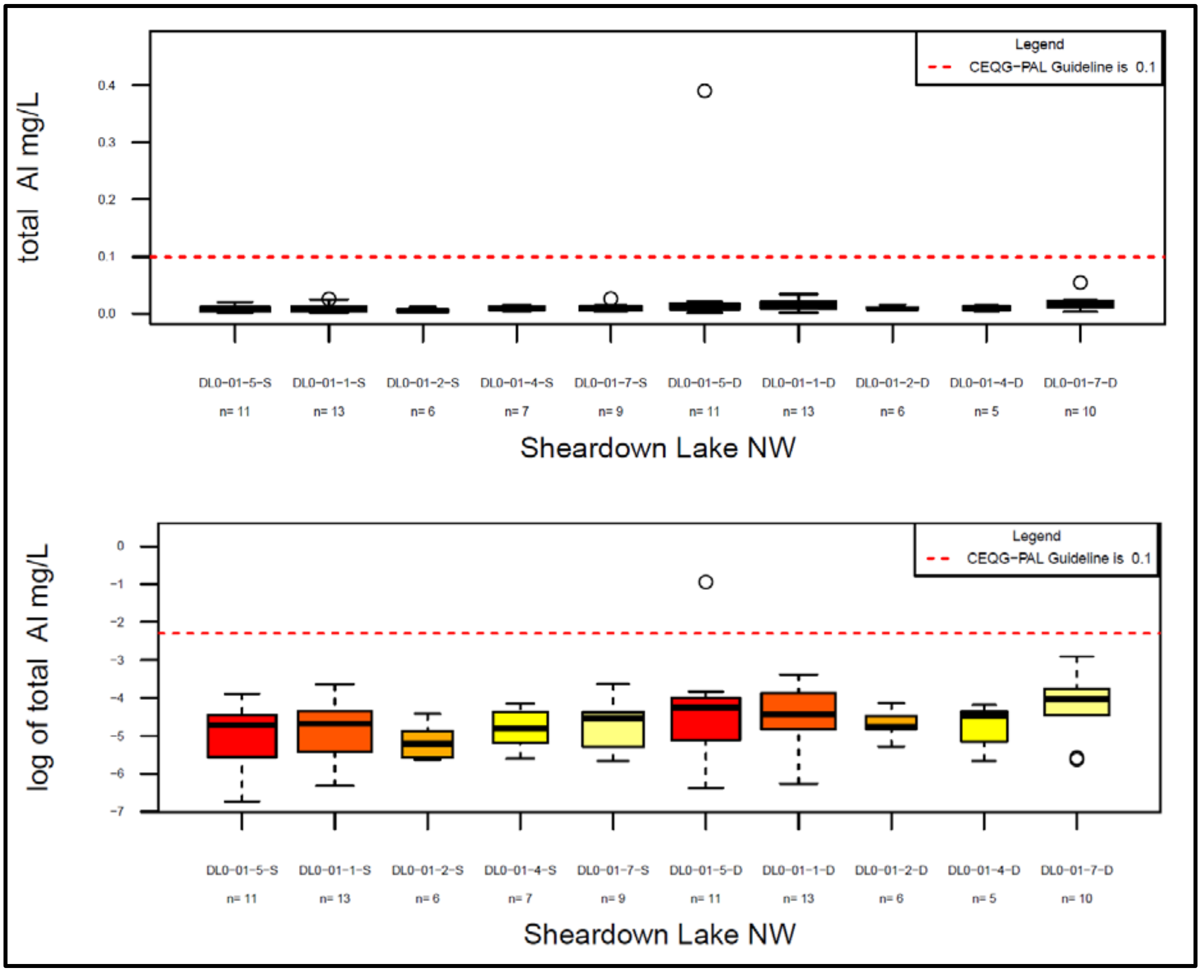
1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.

Figure B.25 Sheardown Lake NW – Nitrate Concentrations in Water

The following sections summarize the results for the metal parameters of interest: aluminum, arsenic, cadmium, copper, iron, and nickel. All metals are discussed as total concentrations to match the relevant applicable guidelines.

Total Aluminum (Figures B.26 and B.27)

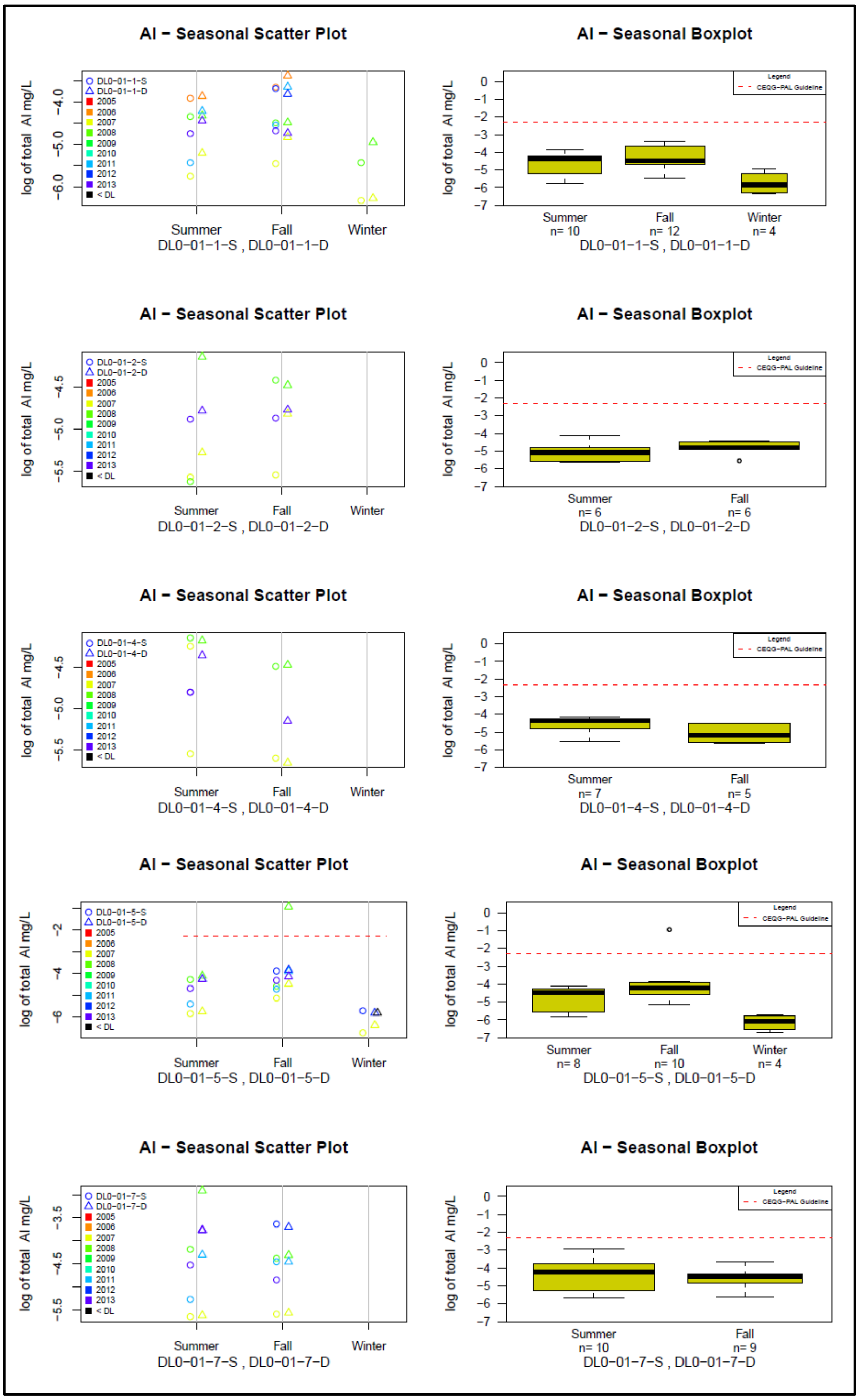
Ninety-one (91) total aluminum concentration samples were collected from Sheardown Lake NW over the course of eight years. Total aluminum concentrations consistently report above MDLs, and are consistently below the CWQG-PAL guideline, with the exception of one sample (Figure B.26). All stations within Sheardown Lake have similar median aluminum concentrations that are less than 0.05 mg/L. Deeper sampling stations show slightly elevated concentrations when compared to shallow stations. Comparison of raw data and log values reveals fewer outliers within the log transformed data, as expected. Seasonal scatterplots indicate that summer and fall concentrations of aluminum remain fairly elevated, while winter concentrations are reduced in comparison (Figure B.27).



NOTES:

1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.
2. THE CWQG-PAL GUIDELINE LIMIT IS BASED ON THE TOTAL MEDIAN HARDNESS.

Figure B.26 Sheardown Lake NW – Total Aluminum Concentrations in Water



NOTES:

1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.
2. THE CWQG-PAL GUIDELINE LIMIT IS BASED ON THE TOTAL MEDIAN HARDNESS.

Figure B.27 Sheardown Lake NW – Variability of Total Aluminum in Water

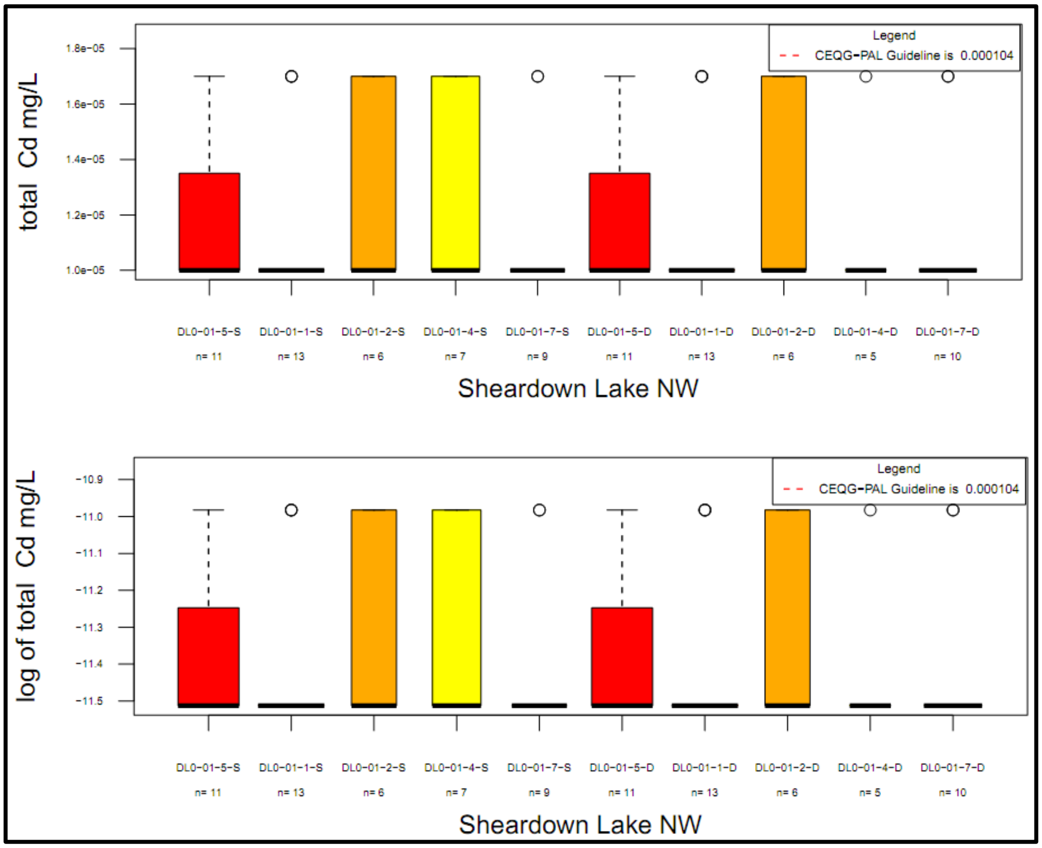
Total Arsenic

All (ninety-one) measured total arsenic levels report at detection limit and are therefore not not portrayed via graphical representation. The detection limit (0.00010 mg/L) is far below the CWQG-PAL guideline limit (0.005 mg/L).

Total Cadmium (Figures B.28 and B.29)

Ninety-one (91) total cadmium concentration samples were collected from Sheardown Lake over the course of eight years. Cadmium concentrations consistently report at or below MDLs, and are consistently below the CWQG-PAL guideline (Figure B.28). Although total boxplots of all data seem to indicate a range of values at each sampling point, this is as a result of two different detection limits. Seasonal scatterplots reveal that earlier data from 2007 had a detection limit of 0.000017 mg/L and later data from 2009 onwards had a detection limit of 0.00001 mg/L.

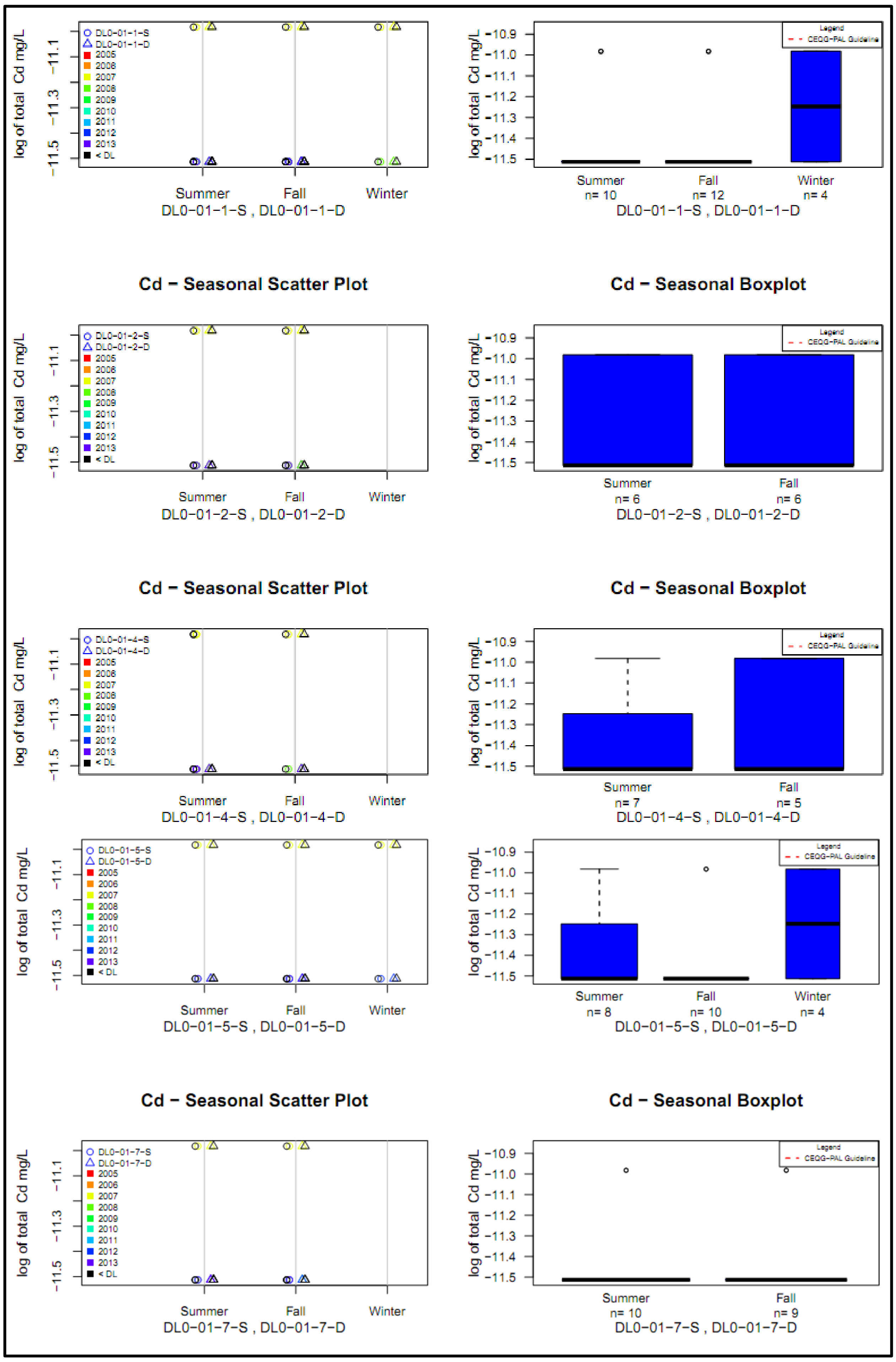
Seasonal scatterplots that combine data from deep and shallow sampling stations show no difference in values between the two stations, as a result of MDL interference (Figure B.29). Similarly, seasonal differences are not noted as a result of MDL interference.



NOTES:

1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.
2. THE CWQG-PAL GUIDELINE LIMIT IS BASED ON THE TOTAL MEDIAN HARDNESS.

Figure B.28 Sheardown Lake NW – Total Cadmium Concentrations in Water



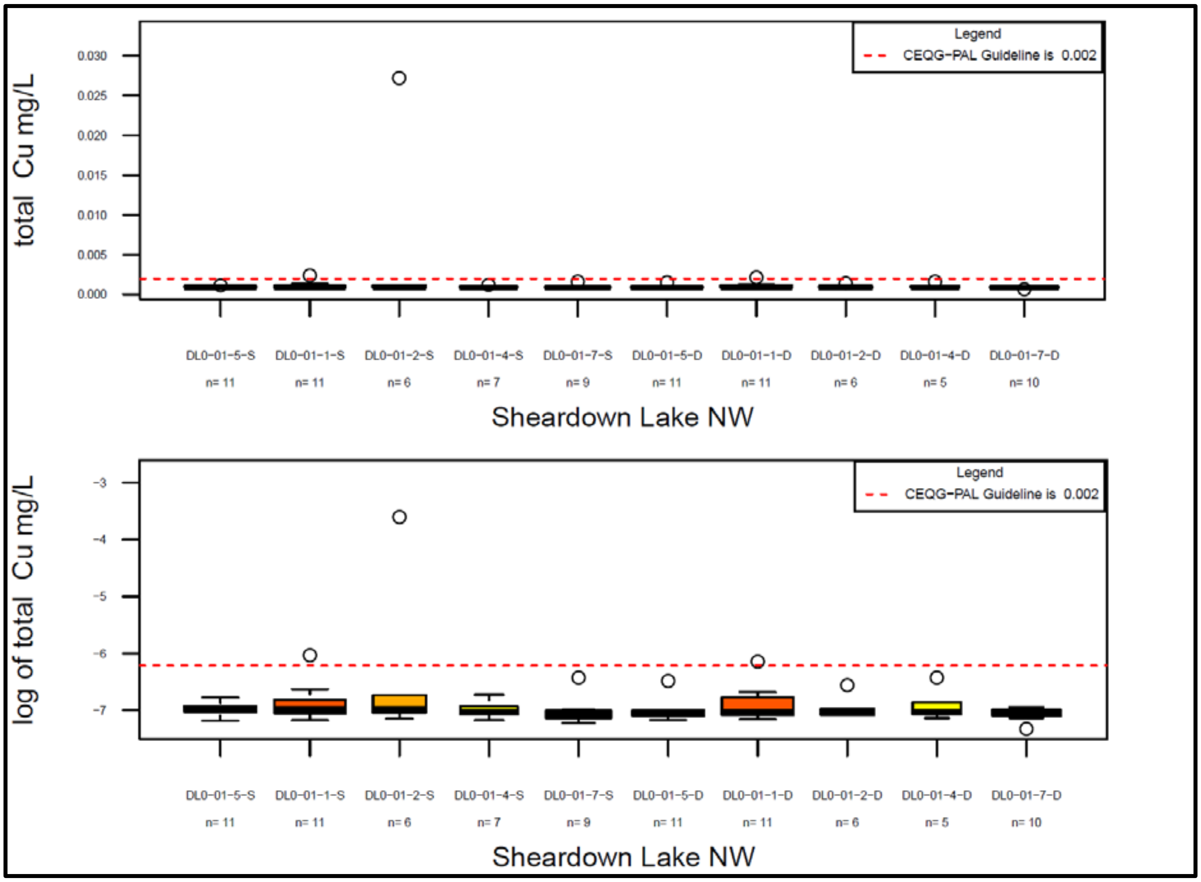
NOTES:

1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.
2. THE CWQG-PAL GUIDELINE LIMIT IS BASED ON THE TOTAL MEDIAN HARDNESS.

Figure B.29 Sheardown Lake NW – Variability of Total Cadmium in Water

Total Copper (Figures B.30 and B.31)

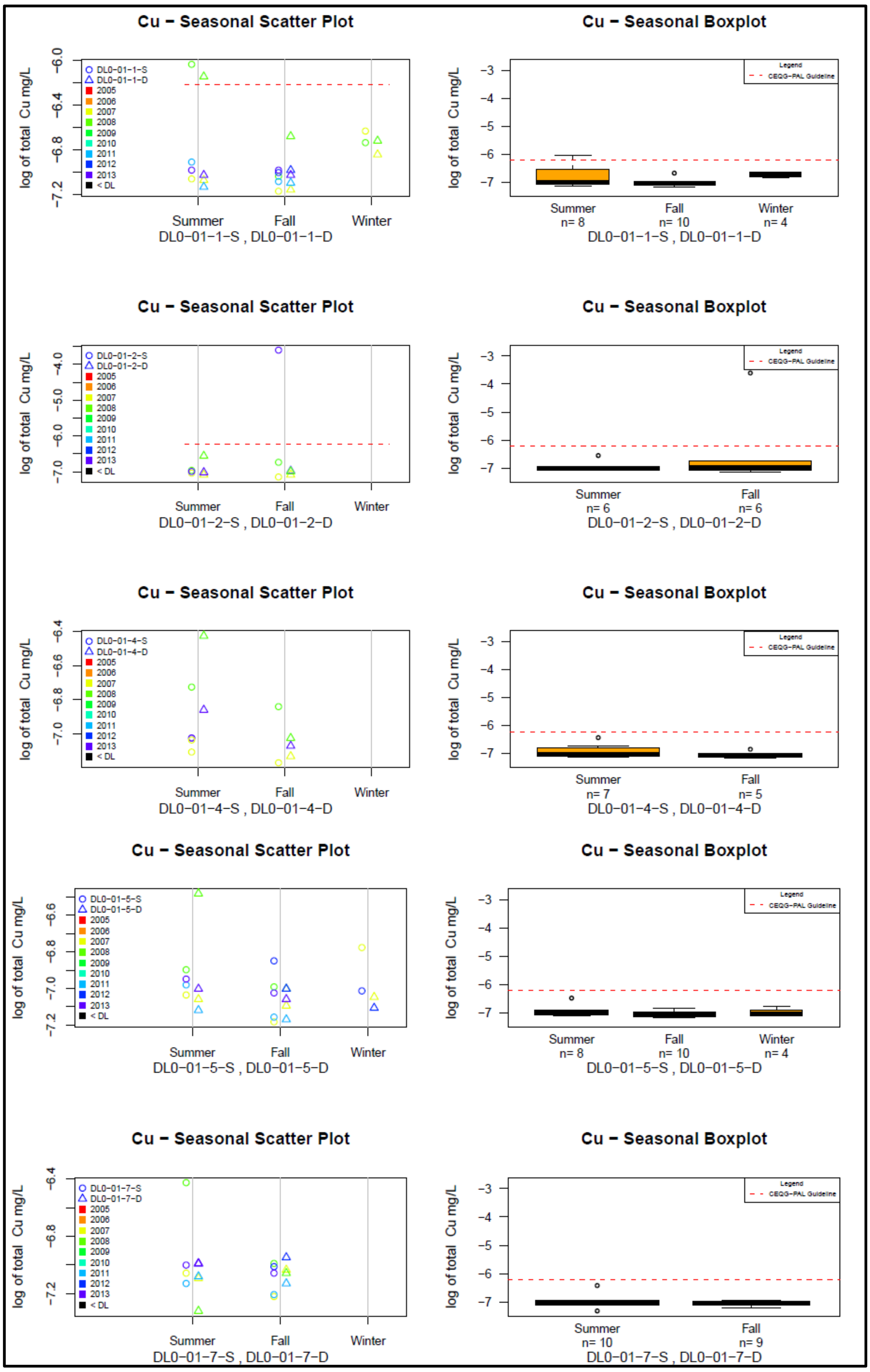
Eighty-seven (87) total copper concentration samples were collected from Sheardown Lake NW over the course of eight years. Total copper concentrations are slightly elevated, but usually below the CWQG-PAL guideline (Figure B.30). Seasonal scatterplots that combine data from deep and shallow sampling stations show little difference in values between the two stations (Figure B.31). No distinct seasonal differences are observed.



NOTES:

1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.
2. THE CWQG-PAL GUIDELINE LIMIT IS BASED ON THE TOTAL MEDIAN HARDNESS.

Figure B.30 Sheardown Lake NW – Total Copper Concentrations in Water



NOTES:

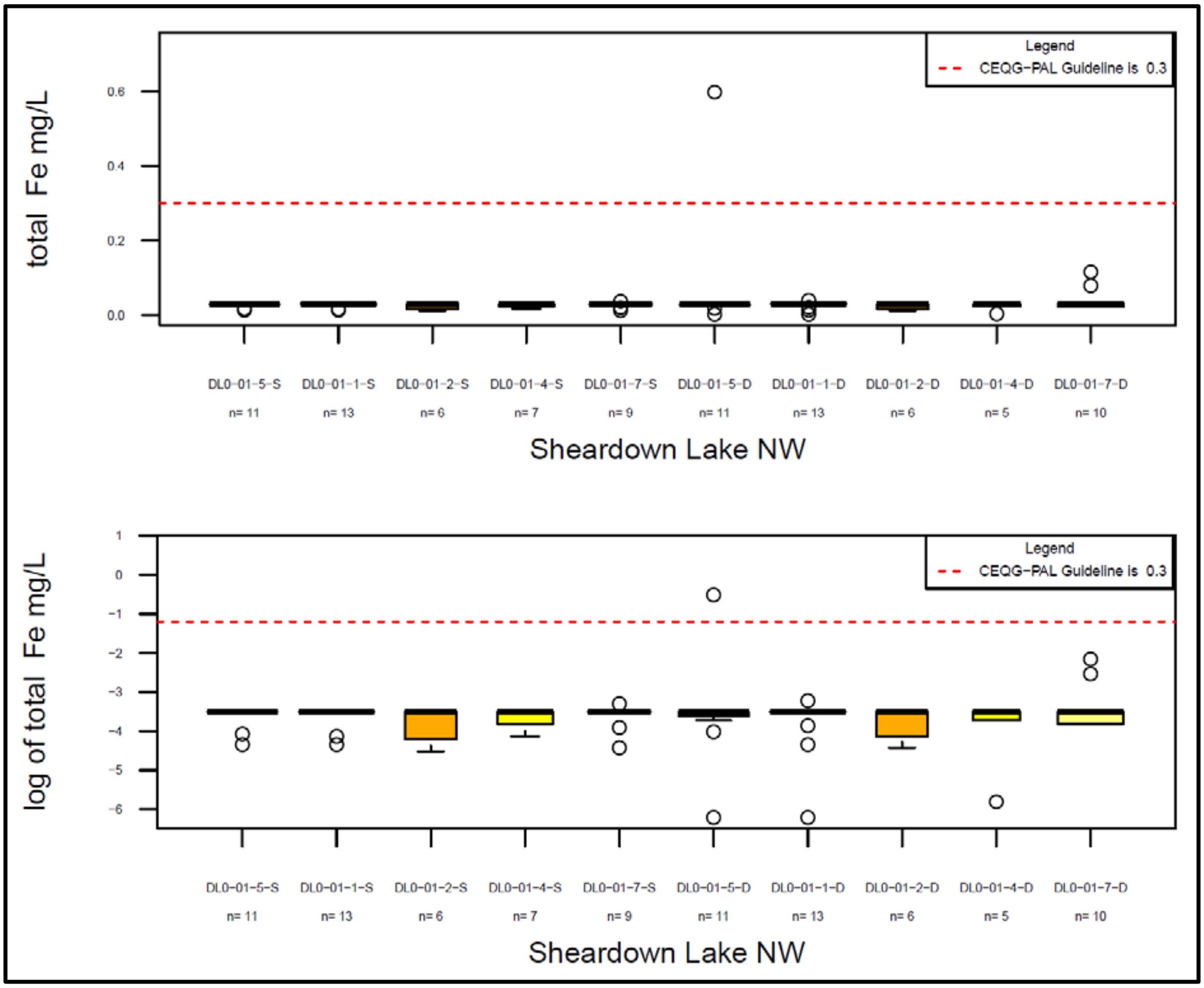
1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.
2. THE CWQG-PAL GUIDELINE LIMIT IS BASED ON THE TOTAL MEDIAN HARDNESS.

Figure B.31 Sheardown Lake NW – Variability of Total Copper in Water

Total Iron (Figures B.32 and B.33)

Ninety-one (91) total iron concentration samples were collected from Sheardown Lake NW over the course of eight years. Total iron concentrations consistently report at or below MDLs, with the exception of one outlier (Figure B.32). Only one outlying data point, from DL0-01-5-D, reports above the CWQG-PAL guideline (0.002 mg/L). Seasonal scatterplots indicate samples prior to 2010 reported at or below the MDL. During 2013, detection limits were lowered and total iron concentrations consistently occurred below the 2010 MDL.

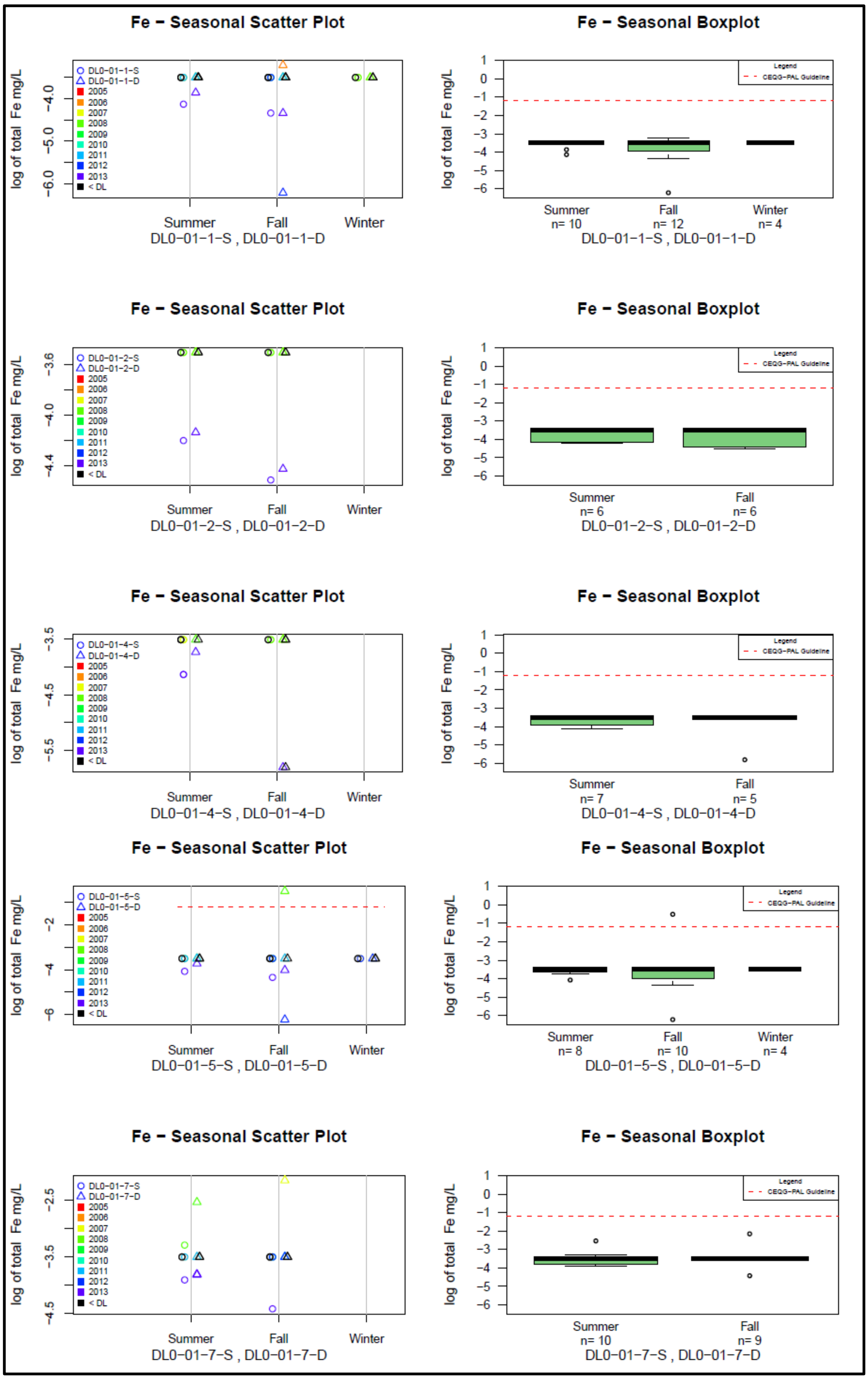
Seasonal scatterplots that combine data from deep and shallow sampling stations show no difference in values between the two stations (Figure B.33). Seasonal differences are not noted as a result of MDL interference.



NOTES:

1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.

Figure B.32 Sheardown Lake NW – Total Iron Concentrations in Water



NOTES:

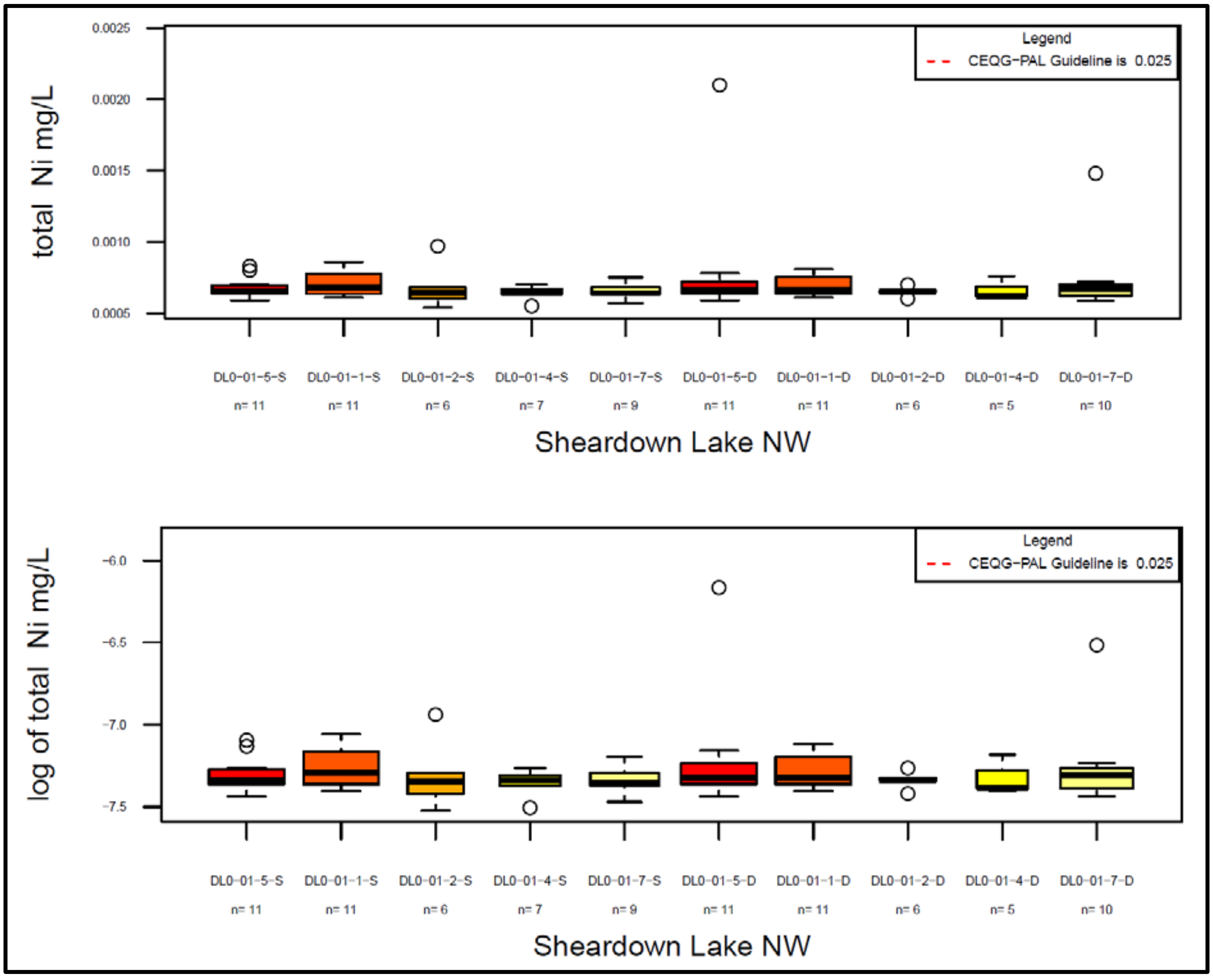
1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.

Figure B.33 Sheardown Lake NW – Variability of Total Iron in Water

Total Nickel (Figures B.34 and B.35)

Eighty-seven (87) total nickel concentration samples were collected from Sheardown Lake NW over the course of eight years. Nickel concentrations consistently report above MDLs, but below the CWQG-PAL guideline (0.025 mg/L) (Figure B.34). Median total nickel concentrations are consistent throughout the geographically distinct sampling stations, and occur around 0.0007 mg/L; however, certain stations have a greater distribution of values. DL0-01-1-S and DL0-01-1-D show the greatest range of values, but also have the largest sample size.

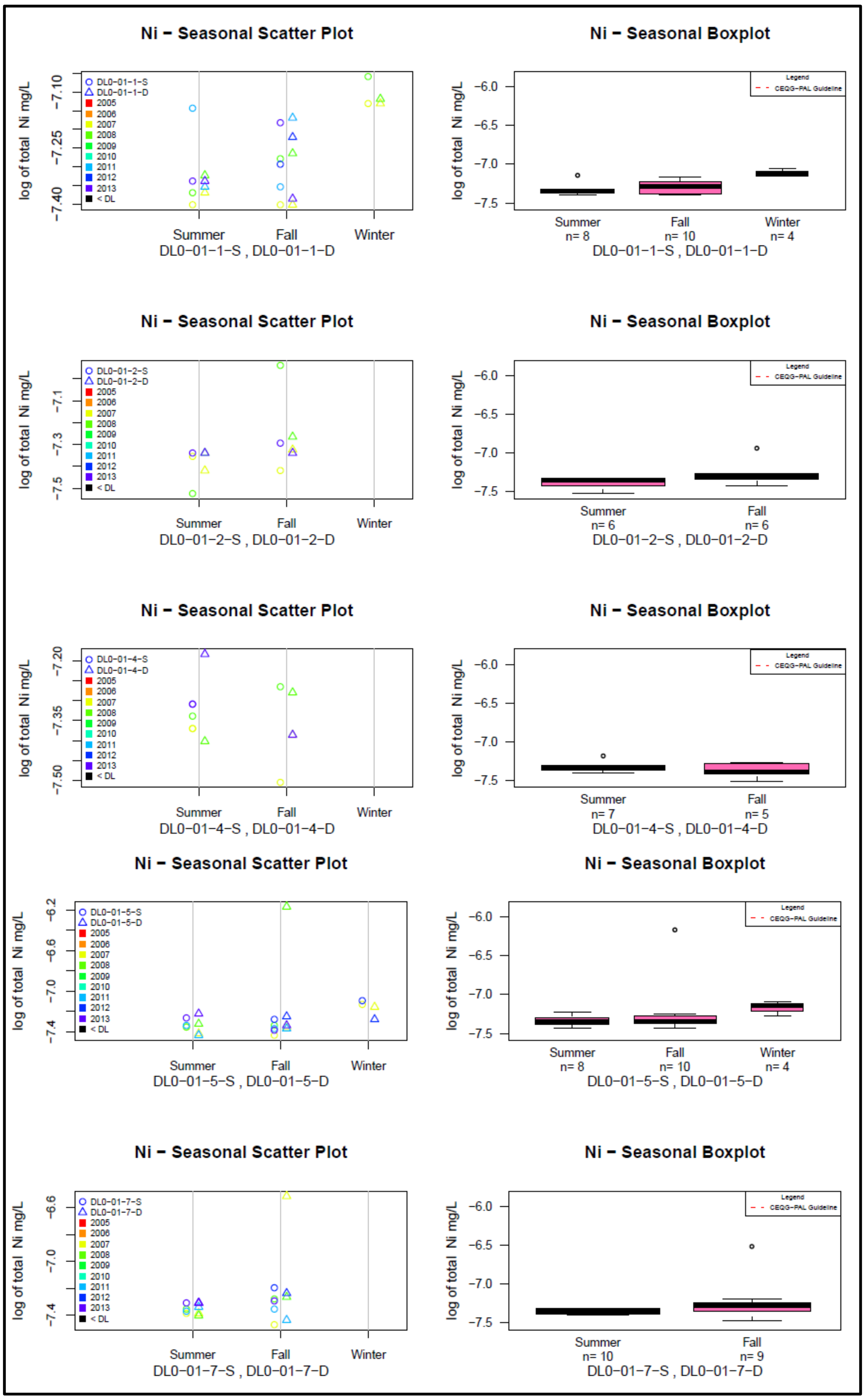
Seasonal scatterplots show that outlying data points tend to originate from sampling in 2008/2009 (Figure B.35). Seasonal boxplots show that the winter dataset for Sheardown lake nickel samples is limited. Historical summer and fall data have similar median values. The limited data collected for winter indicates winter samples have slightly higher concentrations; however, additional sampling is required to determine if this is a true trend.



NOTES:

1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.
2. THE CWQG-PAL GUIDELINE LIMIT IS BASED ON THE TOTAL MEDIAN HARDNESS.

Figure B.34 Sheardown Lake NW – Total Nickel Concentrations in Water



NOTES:

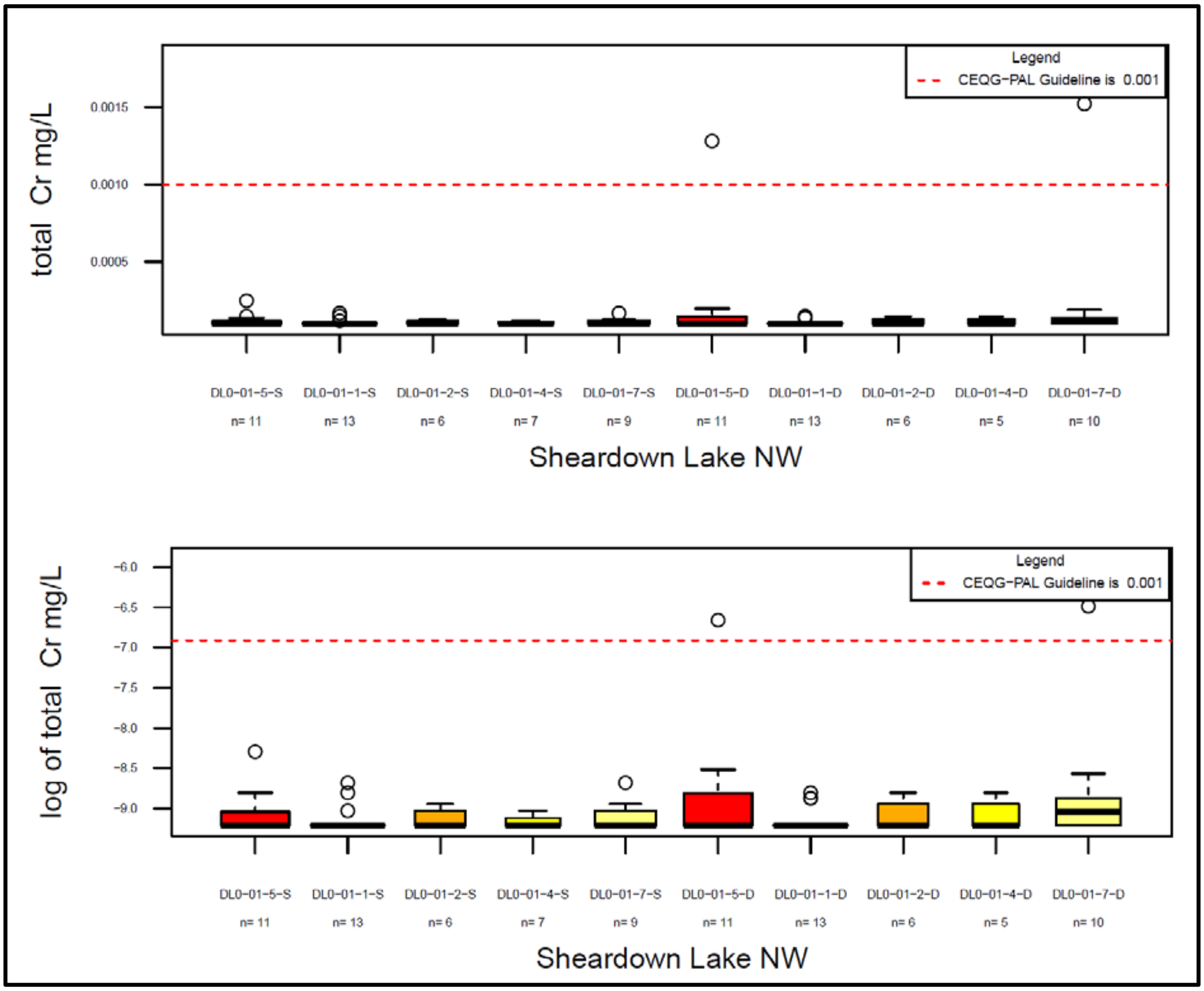
1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.
2. THE CWQG-PAL GUIDELINE LIMIT IS BASED ON THE TOTAL MEDIAN HARDNESS.

Figure B.35 Sheardown Lake NW – Variability of Total Nickel in Water

Total Chromium (Figure B.36 and Figure B.37)

Ninety-one (91) total chromium concentration samples were collected from Sheardown Lake NW over the course of eight years. Chromium concentrations are low, with the exception of one outlier sampled at DL0-05-D (Figure B.36). Deep sites showed slightly elevated concentrations when compared with shallow samples.

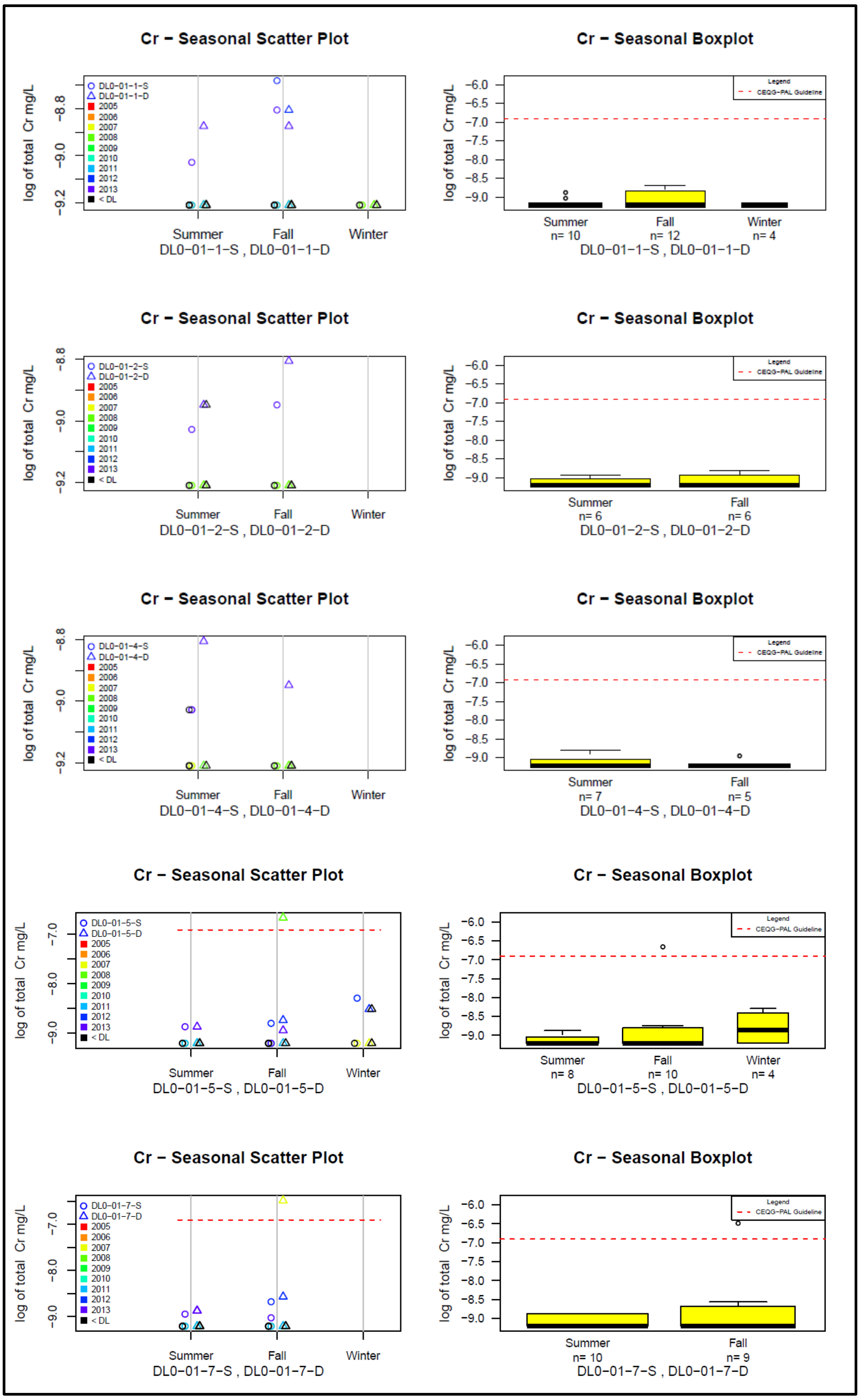
Seasonal scatterplots show 2012 and 2013 data is generally elevated when compared to older data (Figure B.37). Seasonal boxplots do not show a consistent seasonal trend.



NOTES:

1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.

Figure B.36 Sheardown Lake NW – Total Chromium Concentrations in Water



NOTES:

1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.
2. THE CWQG-PAL GUIDELINE LIMIT IS BASED ON THE TOTAL MEDIAN HARDNESS.

Figure B.37 Sheardown Lake NW – Variability of Total Chromium in Water

Summary of Sheardown Lake NW Water Quality

Summary of trends observed during review of Sheardown Lake NW baseline data:

- Deeper sampling stations show slightly elevated concentrations of aluminum. Distinct depth trends are not observed for other parameters within Sheardown Lake, which suggests that lake is completely mixed throughout the year, despite winter ice. As a result, aggregation of deep and shallow stations is appropriate for all parameters except aluminum.
- Detection limits decreased over the course of sampling and their decrease is particularly apparent in the copper and iron concentration data.
- Little variability was observed between geographically distinct sampling stations.
- Parameters below MDLs and/or do not show any seasonal trends: arsenic, cadmium, chloride, chromium, copper, nitrate and iron.
- Parameters with highest concentration occurring in the fall: aluminum.
- Parameters with highest concentrations occurring in the winter: nickel. The majority of the elevated nickel and copper total concentrations are as a result of dissolved metals.

B.2.2.2 Sheardown Lake SE

A total of forty-six (46) lake samples were collected from the southeast basin of Sheardown Lake from 8 sampling stations over the sampling period (Figures B.1 and B.2):

- DL0-02-1-S and DL0-02-1-D - Shallow and deep; located in west portion of Sheardown Lake SE.
- DL0-02-3-S and DL0-02-3-D - Shallow and deep; located in the centre of Sheardown Lake SE.
- DL0-02-4-S and DL0-02-4-D - Shallow and deep; located on the eastern lobe of Sheardown Lake SE.
- DL0-02-6-S and DL0-02-6-D - Shallow and deep; located in the most westerly portion of Sheardown Lake SE.

Most sampling was completed during the open water season, from July through September (summer and fall). Late winter sampling (May) was carried out only in 2007, 2008, 2012 and 2013. Six stations are reported in detail. Only one sample was taken at DL0-06-S and DL0-02-6-D, and therefore, these sites are excluded from graphical representation.

A summary of the data collected during each season, with respect to year and site are included in Table B.3. A graphical representation of the sampling events within Sheardown Lake for the six stations reported in detail is provided in Figure B.38.

Table B.3 Sheardown Lake SE Sample Size

Year	Summer	Fall	Winter
2006	1	1	0
2007	6	6	4
2008	8	6	2
2011	2	0	0
2012	0	2	2
2013	2	2	2
Site	**Summer**	**Fall**	**Winter**
DL0-02-1-S	3	2	1
DL0-02-1-D	5	3	1
DL0-02-3-S	3	4	3
DL0-02-3-D	3	4	3
DL0-02-4-S	3	2	0
DL0-02-4-D	2	2	0
DL0-02-6-S	0	0	1
DL0-02-6-D	0	0	1

NOTES:

1. WINTER SAMPLING OCCURRED DURING APRIL AND MAY; SPRING SAMPLING OCCURRED DURING JUNE; SUMMER SAMPLING OCCURRED FROM JULY TO AUGUST 17; FALL SAMPLING OCCURRED FROM AUGUST 18 THROUGH SEPTEMBER 30TH.
2. LAKE SAMPLING DID NOT OCCUR DURING SPRING, DUE TO SAFETY CONCERNS OF SAMPLING OVER MELTING ICE.
3. DURING WINTER 2013, SAMPLES WERE COLLECTED WITHIN SHEARDOWN LAKE AT D-LAKE-05.

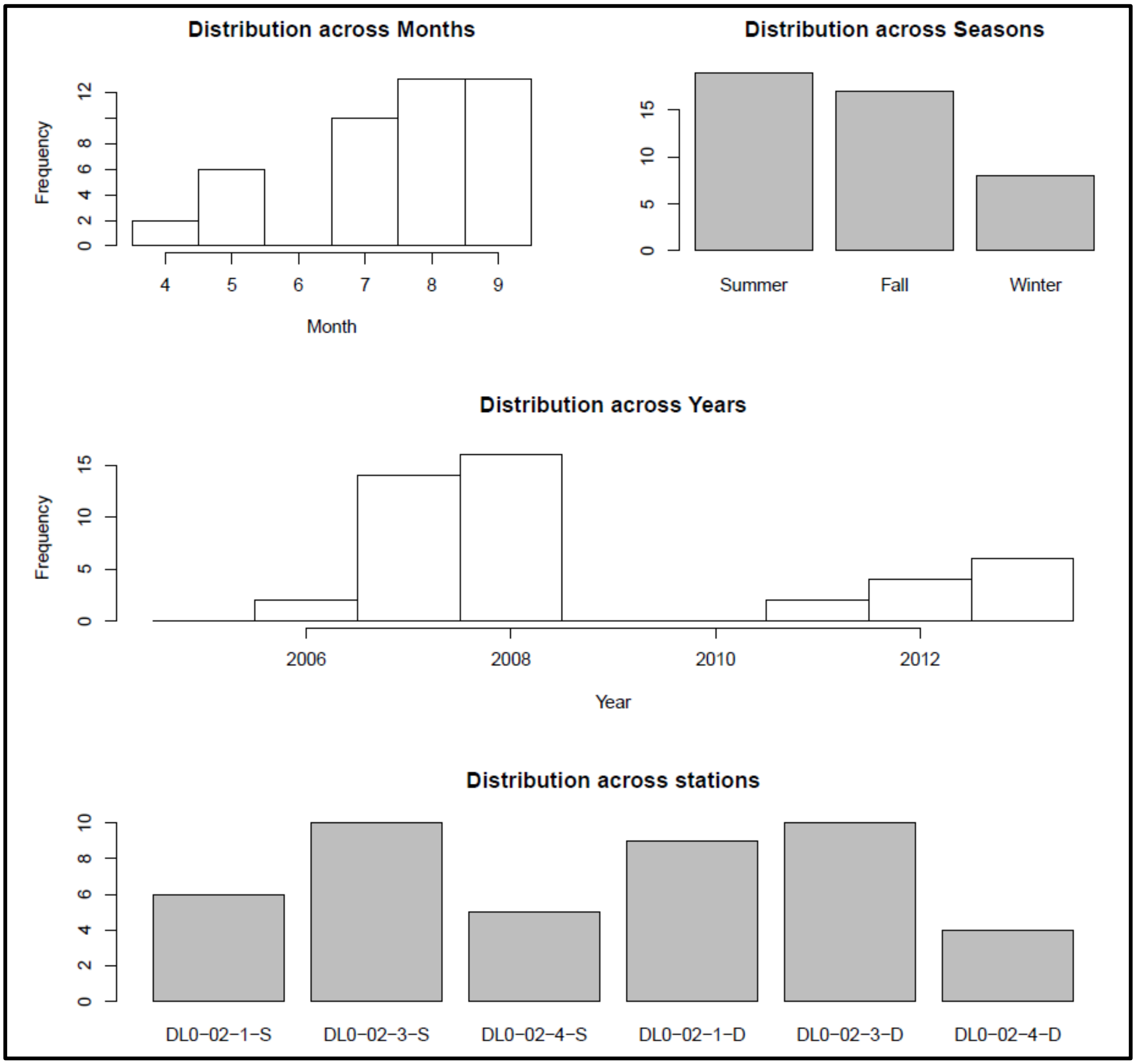


Figure B.38 Sheardown Lake SE – Graphical Summary of Sampling Events

The following summarizes the data review observations for Sheardown Lake NW.

pH (Figure B.39)

- Sheardown Lake NW is slightly alkaline with a median in-situ pH of 7.57 (range from 6.41 to 8.32).
- A slight influence of depth on pH is observed with a measured median in-situ pH at the deep stations of ~7.5, slightly lower compared to shallow samples (> 7.9).

Alkalinity (Figure B.39)

- Sheardown Lake sites are fairly uniform with median alkalinity values that range from 53 to 57 mg/L $CaCO_3$, classifying the lake water as having low sensitivity to acidic inputs.

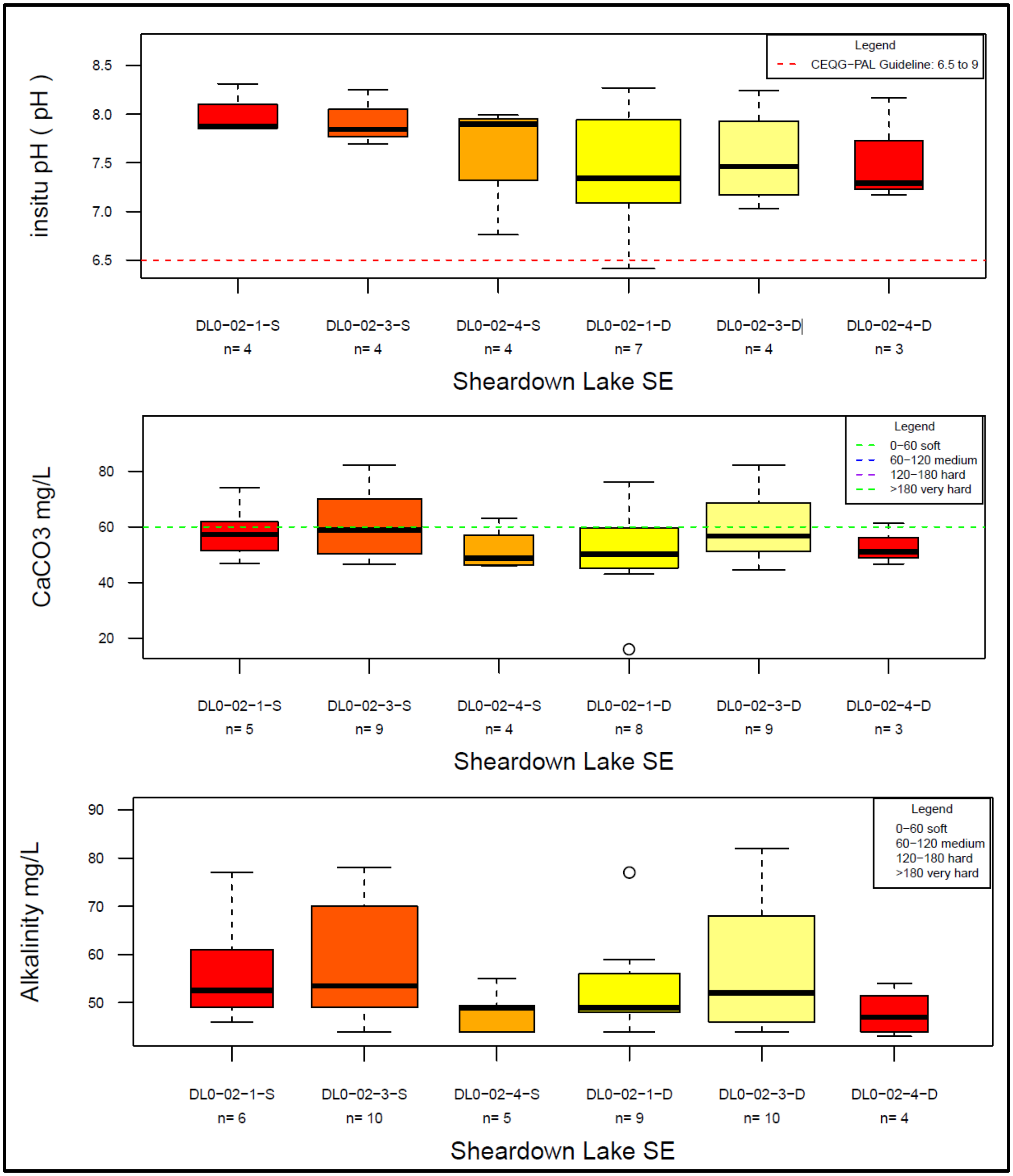


Figure B.39 Sheardown Lake SE – *In situ* pH, Alkalinity and Hardness

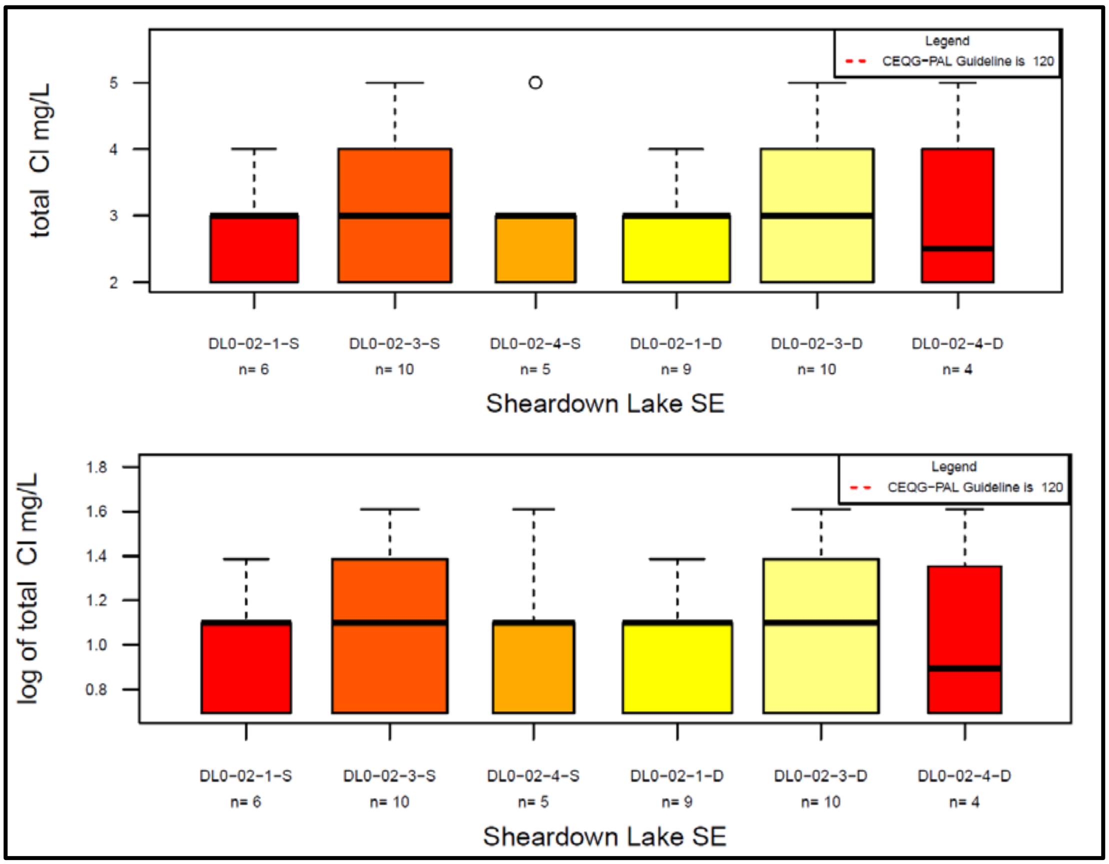
Hardness (Figure B.39)

- Median hardness ranged from 54 and 61 mg/L, classifying the lake water as “soft”.
- Hardness did not change meaningfully with depth, and portrayed trends very similar to alkalinity.
- The close range between hardness and alkalinity suggest that the hardness is almost entirely carbonate hardness with little to no non-carbonate contributions to hardness.

The following sections summarize the results for the non-metallic inorganic parameters of interest: chloride and nitrate.

Chloride (Figures B.40 and B.41)

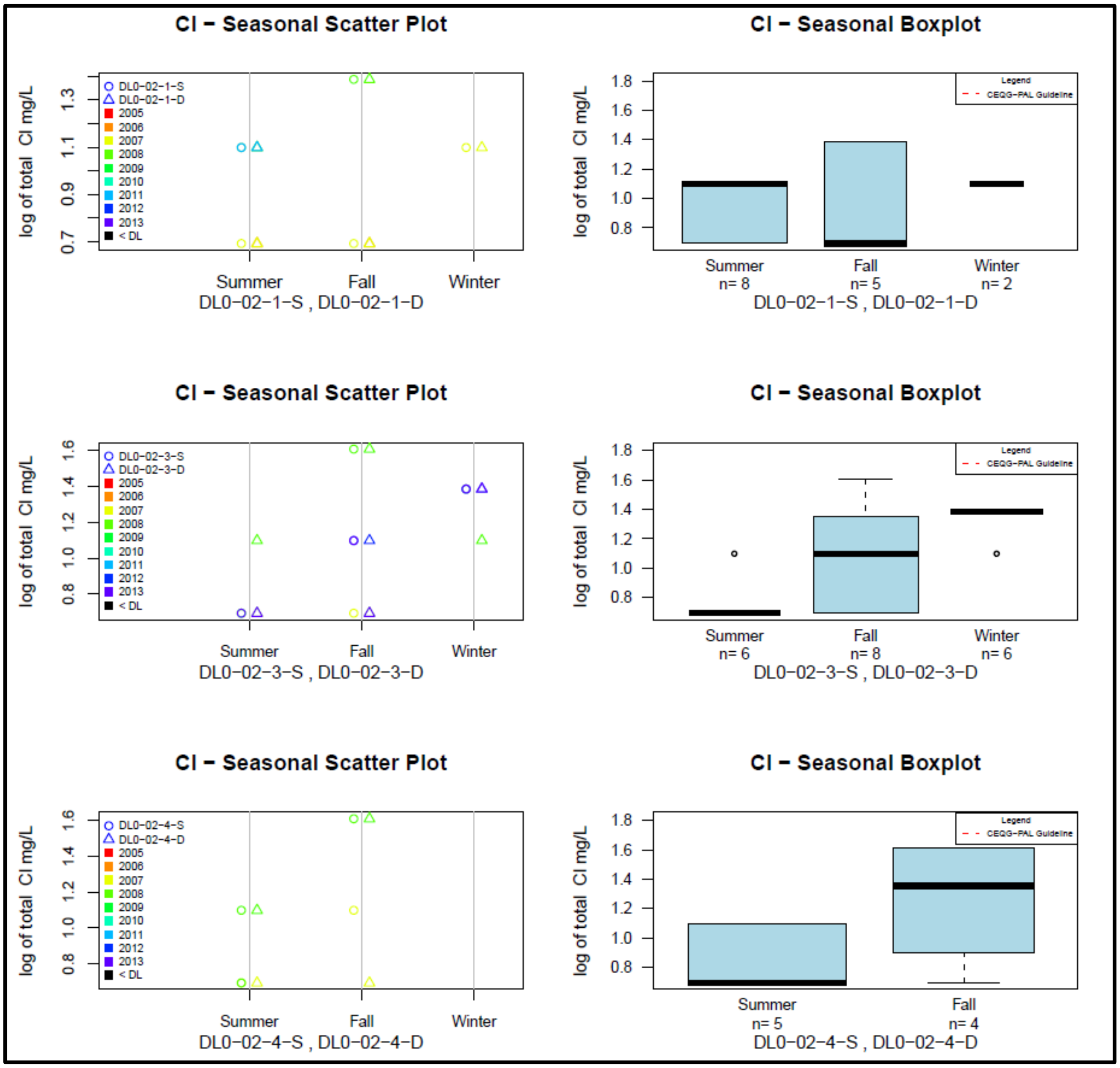
Forty-four (44) chloride concentration samples were collected at Sheardown Lake SE. Chloride concentrations in Sheardown Lake SE are very low and have maximum values of 5 mg/L, well below the CWQG-PAL limit of 120 mg/L (Figure B.40). All sites within Sheardown Lake SE have very similar median chloride concentrations that range between 0.9 mg/L to 1.1 mg/L. Log transformation does not reveal any outlying values in the data. Seasonal scatterplots indicate possible elevations of chloride concentrations in the winter. Additional baseline sampling will help to reveal this trend.



NOTES:

1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.

Figure B.40 Sheardown Lake SE – Chloride Concentrations in Water



NOTES:

1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.

Figure B.41 Sheardown Lake SE – Variability of Chloride in Water

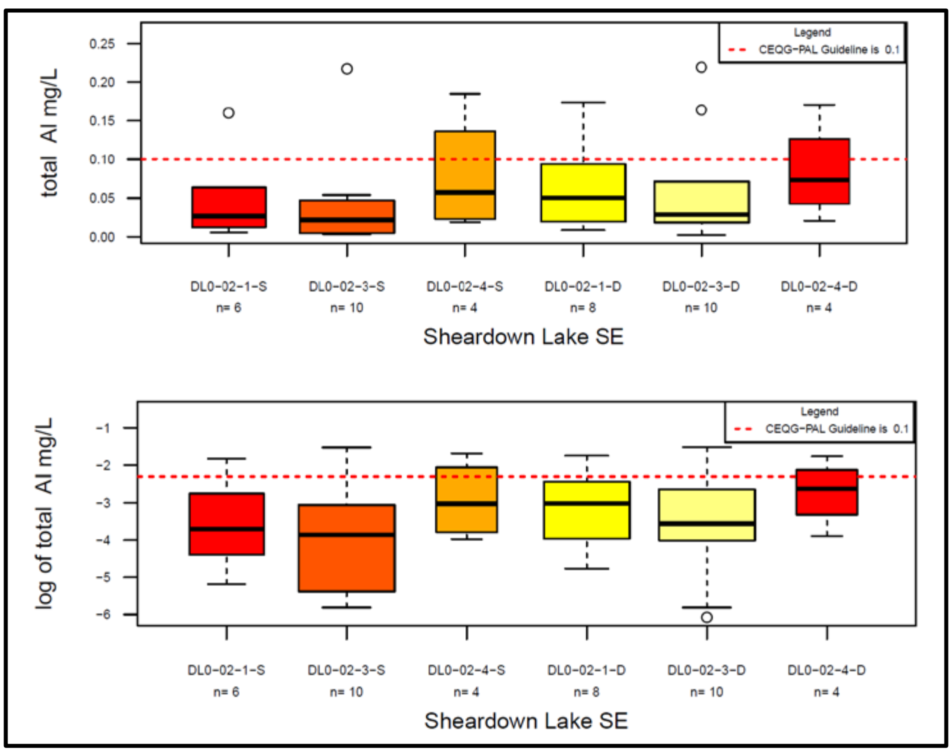
Nitrate

Forty-four (44) nitrate concentration samples were collected from Sheardown Lake SE over the course of eight years. All nitrate concentrations were measured at the detection limit (0.10 mg/L). As a result, no seasonal, inter-annual or depth variation can be determined and further graphical analyses are not warranted.

The following sections summarize the results for the metal parameters of interest: aluminum, arsenic, cadmium, copper, iron, and nickel. All metals are discussed as total concentrations to reflect the applicable guidelines.

Total Aluminum (Figures B.42 and B.43)

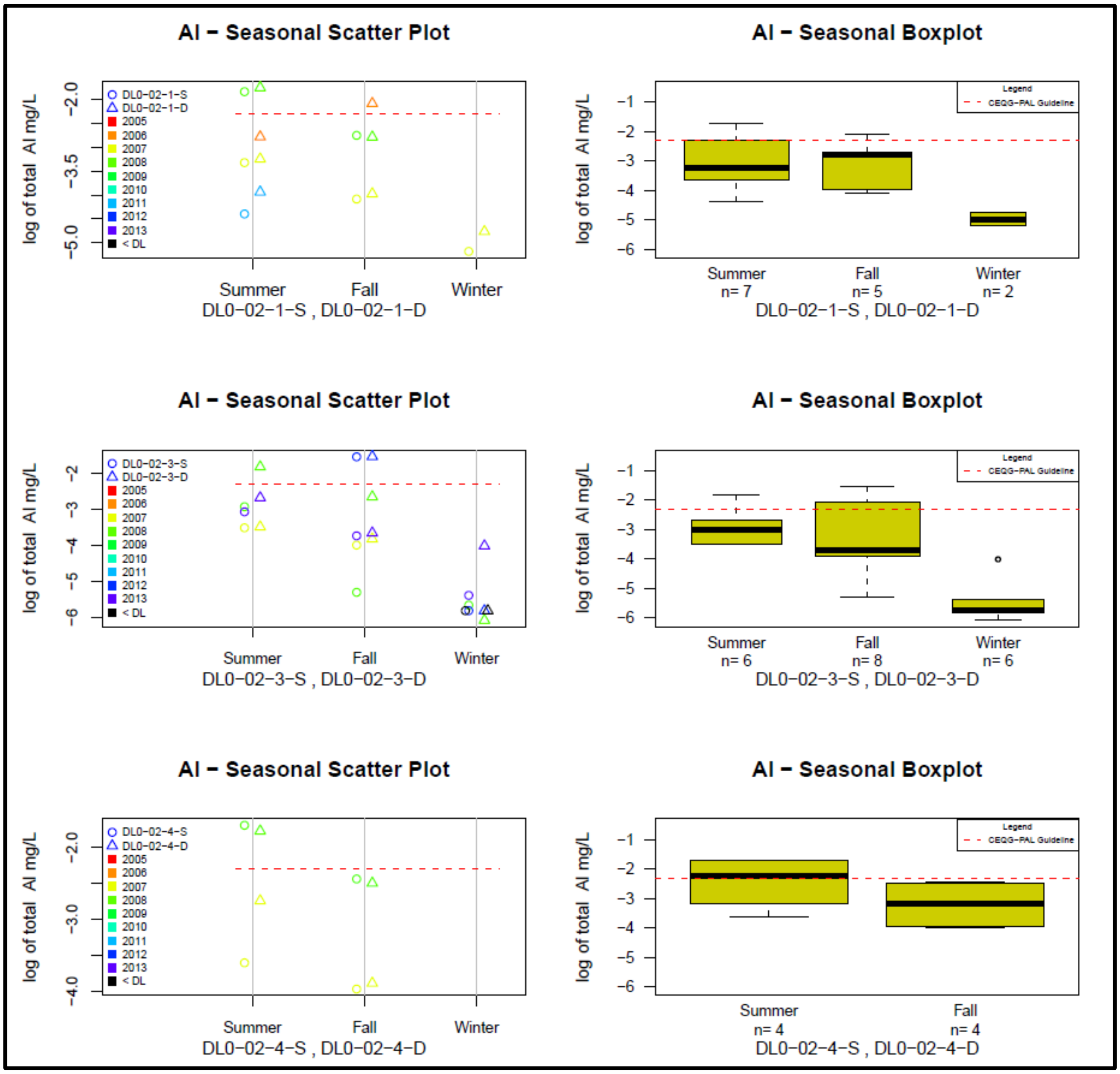
Forty-two (42) total aluminum concentration samples were collected from Sheardown Lake SE over the course of eight years. Total aluminum concentrations consistently report above MDLs and have 75th percentile values that exceed the CWQG-PAL guidelines of 0.1 mg/L (Figure B.42). All stations within Sheardown Lake have median aluminum concentrations that range from 0.02 mg/L to 0.06 mg/L. Deeper sampling stations show slightly elevated concentrations when compared to shallow stations. Comparison of raw data and log values reveals fewer outliers within the log transformed data, as expected. Similar to Sheardown NW, Sheardown SE data shows summer and fall concentrations of aluminum remain fairly elevated, while winter concentrations are reduced in comparison (Figure B.43).



NOTES:

1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.
2. THE CWQG-PAL GUIDELINE LIMIT IS BASED ON THE TOTAL MEDIAN HARDNESS.

Figure B.42 Sheardown Lake SE – Total Aluminum Concentrations in Water



NOTES:

1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.
2. THE CWQG-PAL GUIDELINE LIMIT IS BASED ON THE TOTAL MEDIAN HARDNESS.

Figure B.43 Sheardown Lake SE – Variability of Total Aluminum in Water

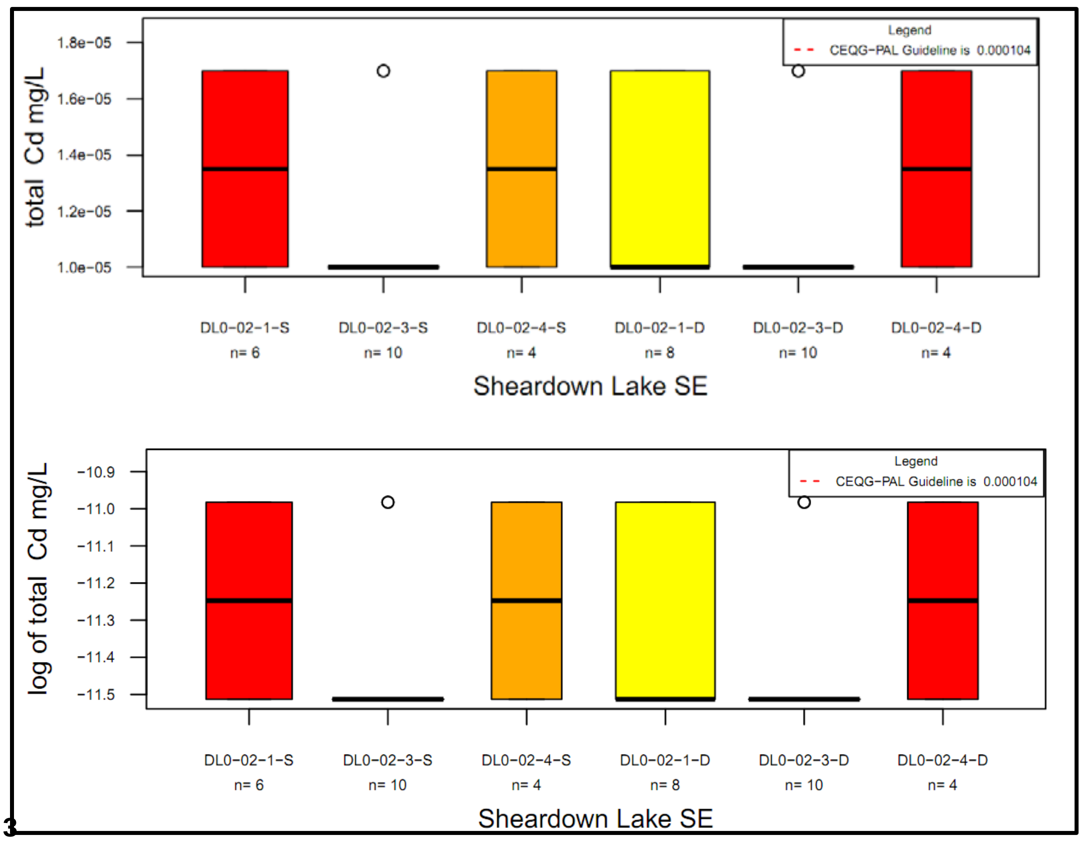
Total Arsenic

With the exception of one sample, the remaing (forty-one) measured total arsenic levels report at detection limit and are therefore not not portrayed via graphical representation. The detection limit (0.00010 mg/L) and the one outlying value (0.00011 mg/L) are far below the CWQG-PAL guideline limit (0.005 mg/L).

Total Cadmium (Figures B.44 and B.45)

Forty-two (42) total cadmium concentration samples were collected from six sites in Sheardown Lake SE over the course of eight years. Cadmium concentrations consistently report at or below MDLs, and are consistently below the CWQG-PAL guideline (Figure B.44). Although total boxplots of all data seem to indicate a range of values at each sampling point, this is as a result of two different detection limits. Seasonal scatterplots reveal that earlier data from 2007 had a detection limit of 0.000017 mg/L and later data from 2009 onwards had a detection limit of 0.00001 mg/L.

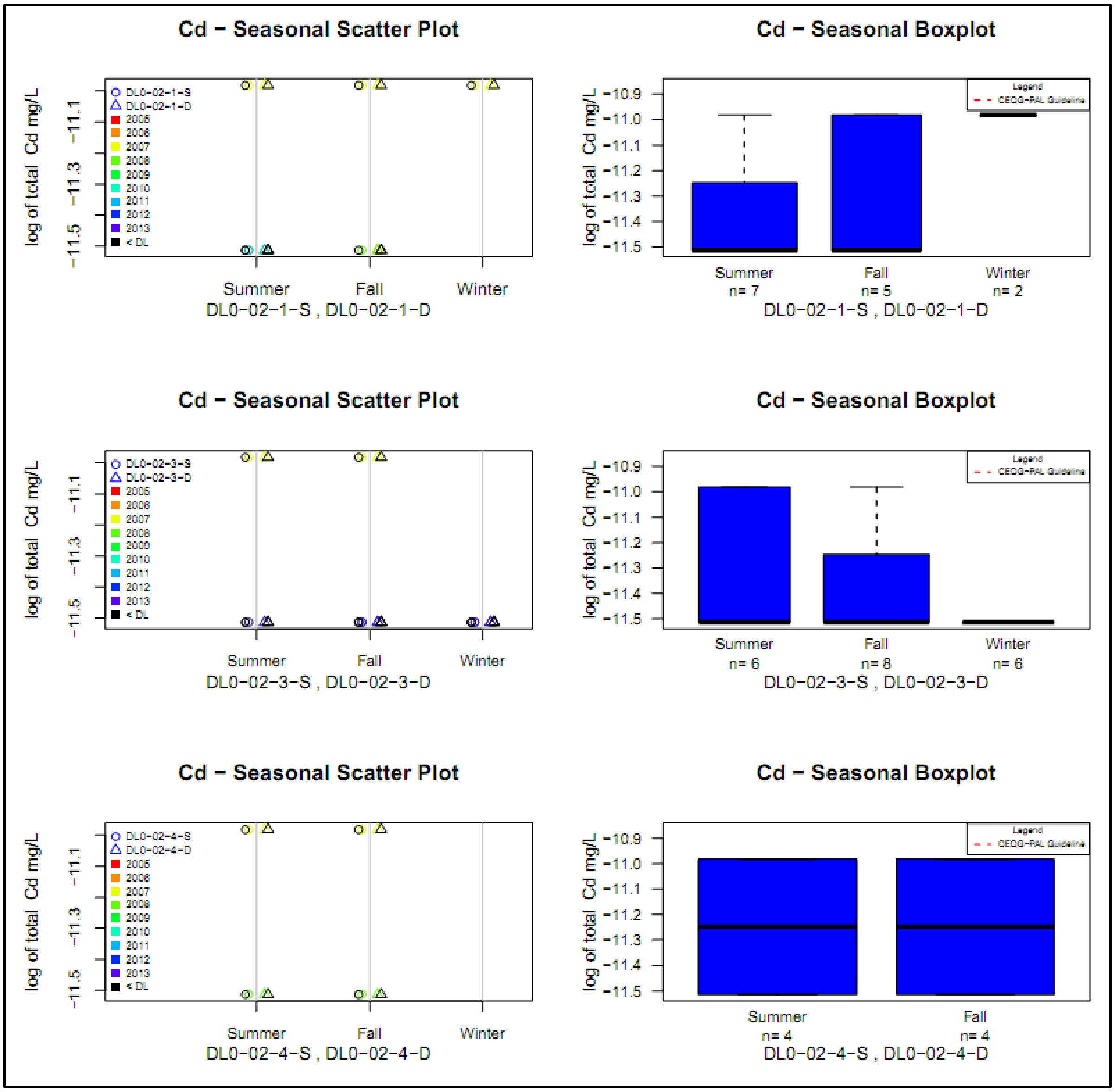
Seasonal scatterplots that combine data from deep and shallow sampling stations show no difference in values between the two stations, as a result of MDL interference (Figure B.45). Similarly, seasonal differences are not noted as a result of MDL interference.



NOTES:

1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.
2. THE CWQG-PAL GUIDELINE LIMIT IS BASED ON THE TOTAL MEDIAN HARDNESS.

Figure B.44 Sheardown Lake SE – Total Cadmium Concentrations in Water



NOTES:

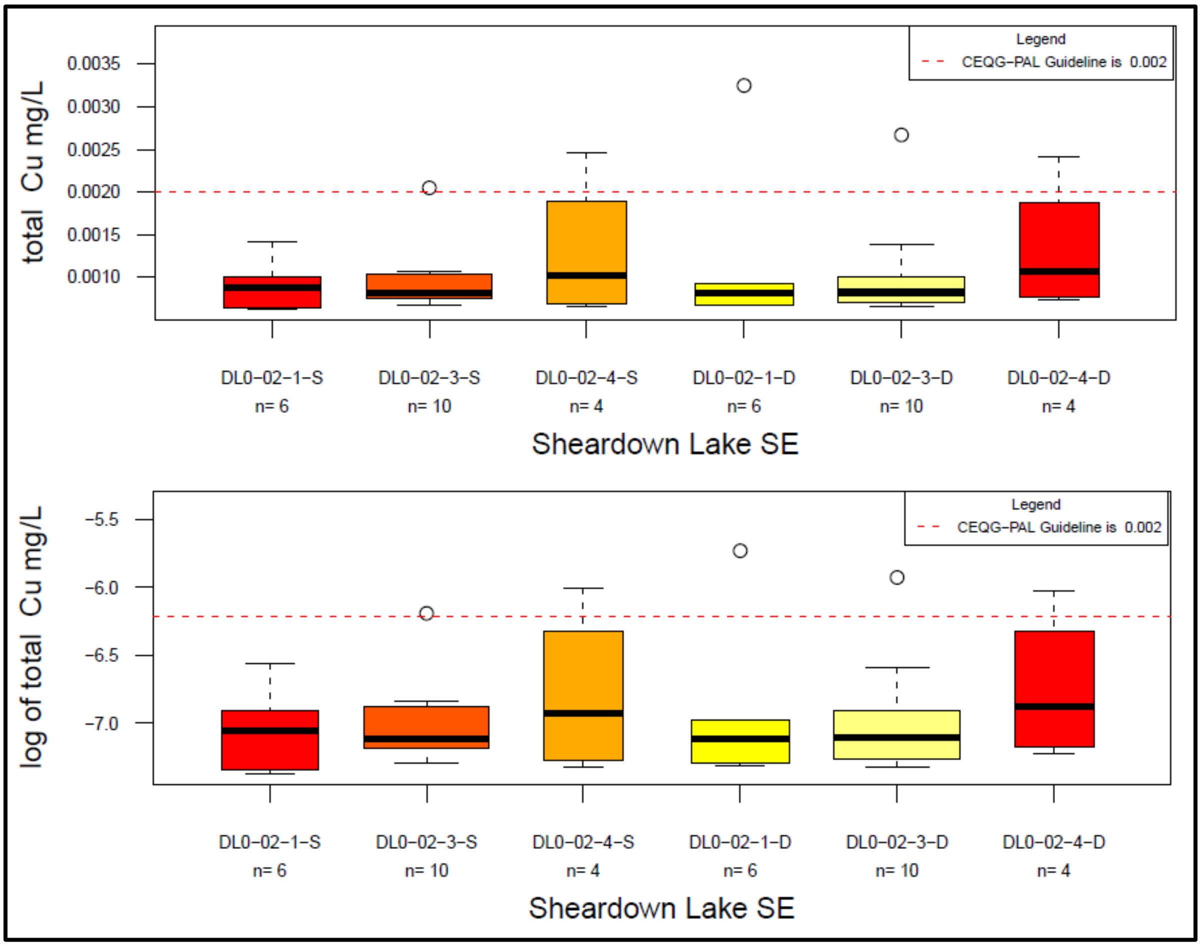
1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.
2. THE CWQG-PAL GUIDELINE LIMIT IS BASED ON THE TOTAL MEDIAN HARDNESS.

Figure B.45 Sheardown Lake SE – Variability of Total Cadmium in Water

Total Copper (Figures B.46 and B.47)

Forty (40) total copper concentration samples were collected from six stations in Sheardown Lake SE over the course of eight years. Total copper concentrations consistently report above MDLs, and, with the exception of a few outliers, below the CWQG-PAL guideline (Figure B.46). Outliers at two deep and one shallow station just exceed the CWQG-PAL guideline of 0.002 mg/L, with a maximum outlying value of 0.0032 mg/L. Concentrations at DL0-02-4 are elevated compared to the other sites, which indicates inputs from D-Stream-3 might be higher in total copper concentrations than inputs from Sheardown NW. Log transformation of the data does not remove outliers observed in data.

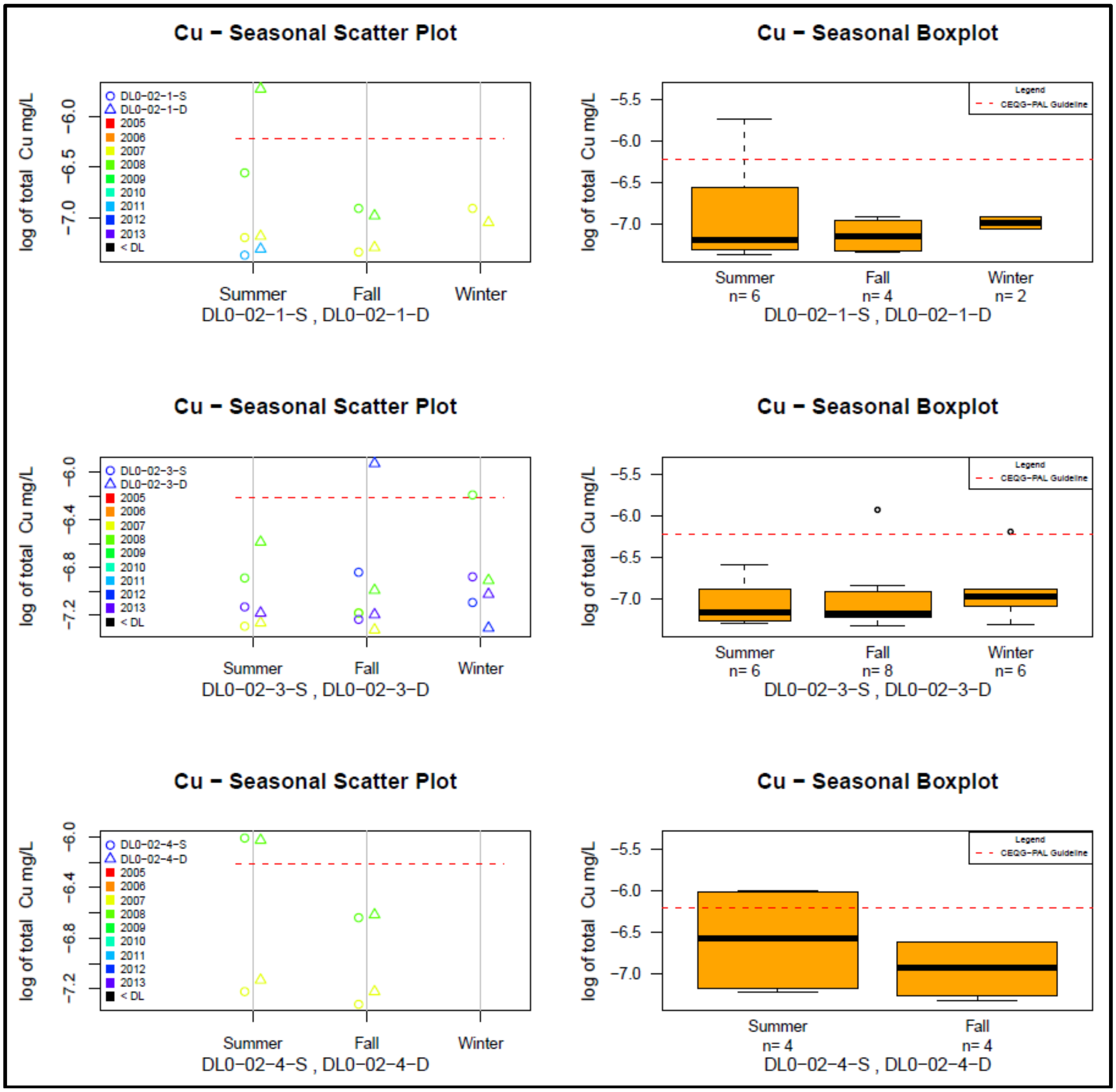
Seasonal scatterplots that combine data from deep and shallow sampling stations do not show a consistent trend across stations (Figure B.47). Data from 2008 appears to be slightly elevated when compared to later data. With the data available, distinct seasonal trends are not observed.



NOTES:

1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.
2. THE CWQG-PAL GUIDELINE LIMIT IS BASED ON THE TOTAL MEDIAN HARDNESS.

Figure B.46 Sheardown Lake SE – Total Copper Concentrations in Water



NOTES:

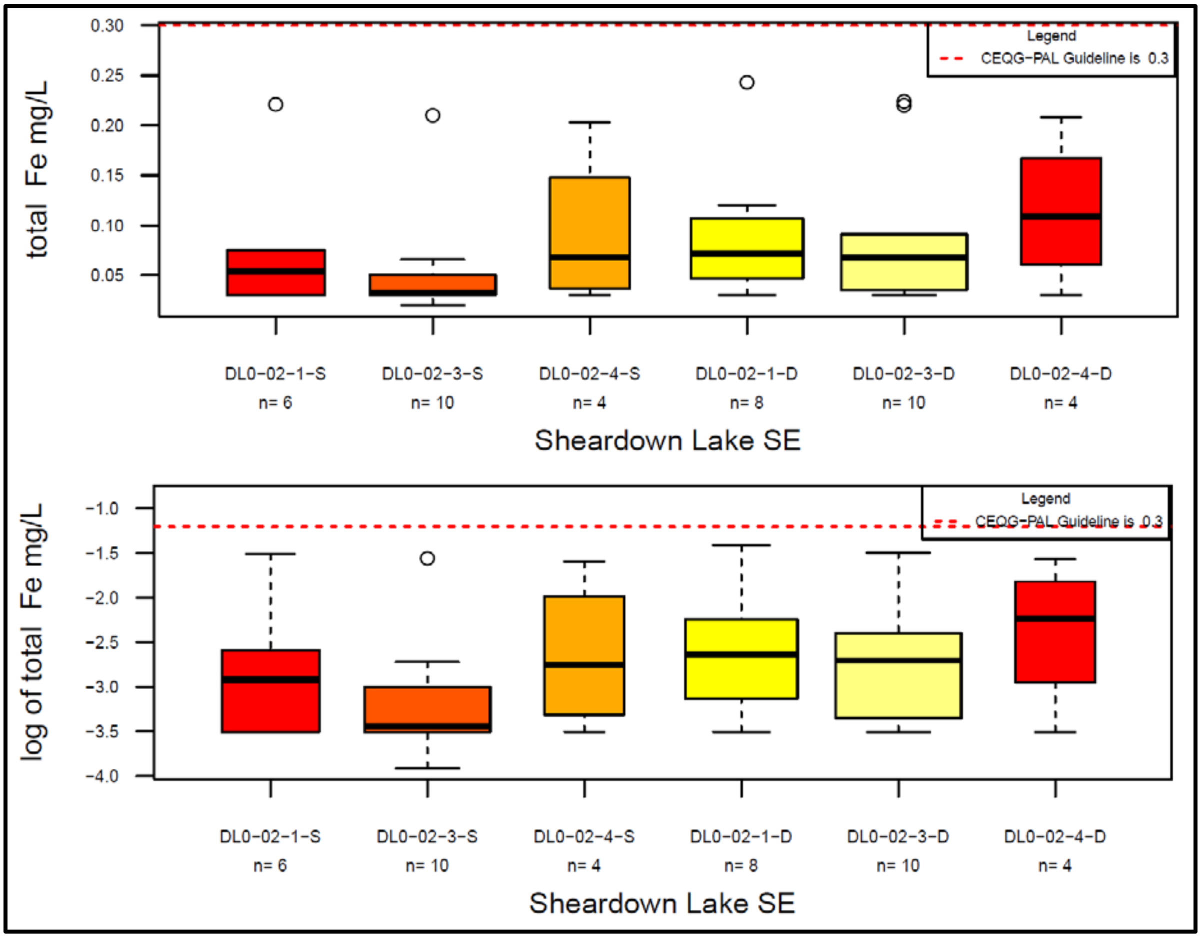
1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.
2. THE CWQG-PAL GUIDELINE LIMIT IS BASED ON THE TOTAL MEDIAN HARDNESS.

Figure B.47 Sheardown Lake SE – Variability of Total Copper in Water

Total Iron (Figures B.48 and B.49)

Forty-two (42) total iron concentration samples were collected from Sheardown Lake SE at six stations over the course of eight years. The majority of total iron concentrations report above MDLs, band all samples report below the CWQG-PAL guideline of 0.3 mg/L (Figure B.48). Similar to copper, station DL0-02-4 has slightly elevated total iron concentrations when compared to the other stations in Sheardown Lake SE.

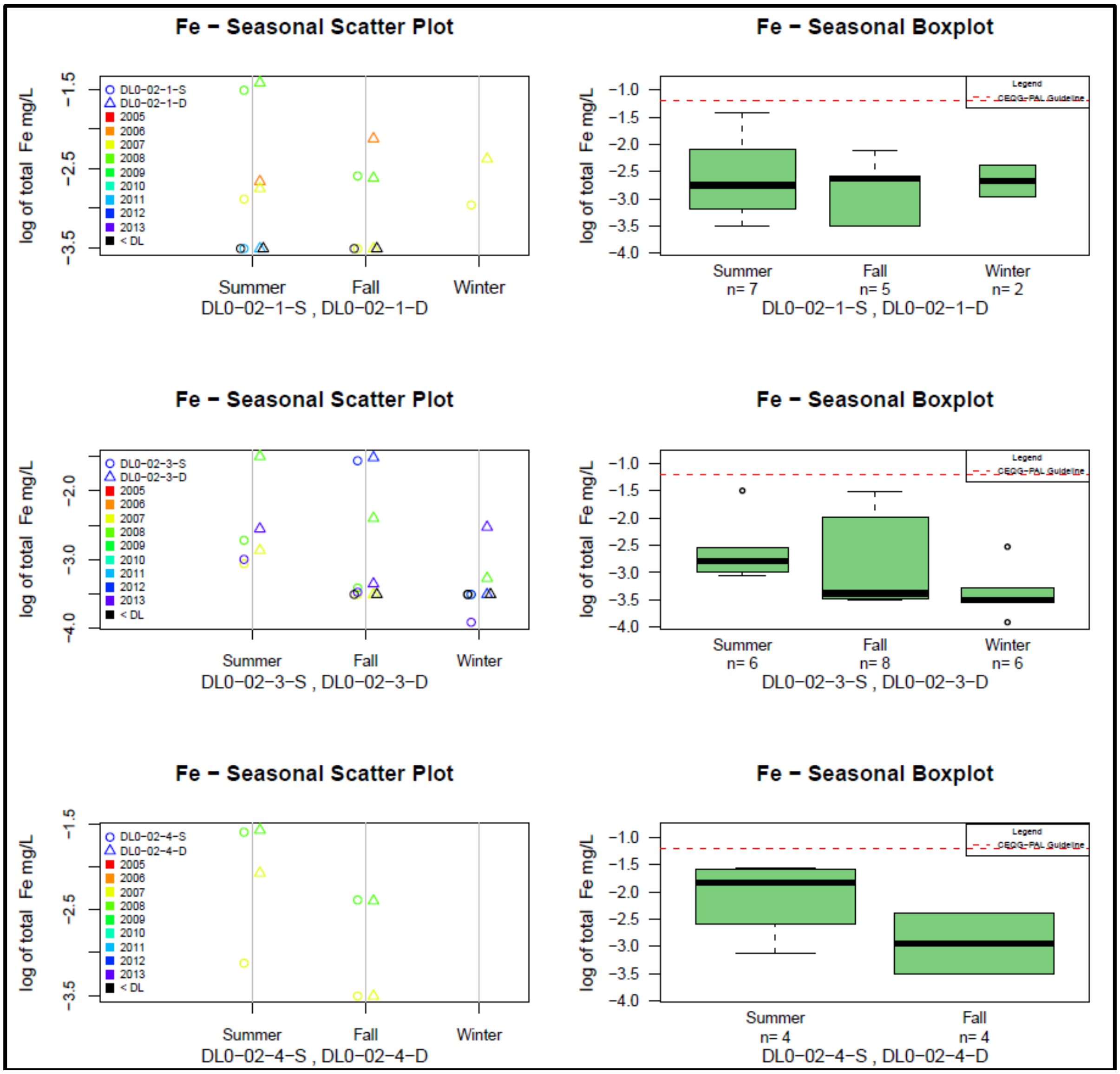
Seasonal scatterplots that combine data from deep and shallow sampling stations show no difference in values between the two stations (Figure B.49). Slightly elevated summer concentrations are noted; however, more samples are required to understand magnitude of seasonal trend.



NOTES:

1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.

Figure B.48 Sheardown Lake SE – Total Iron Concentrations in Water



NOTES:

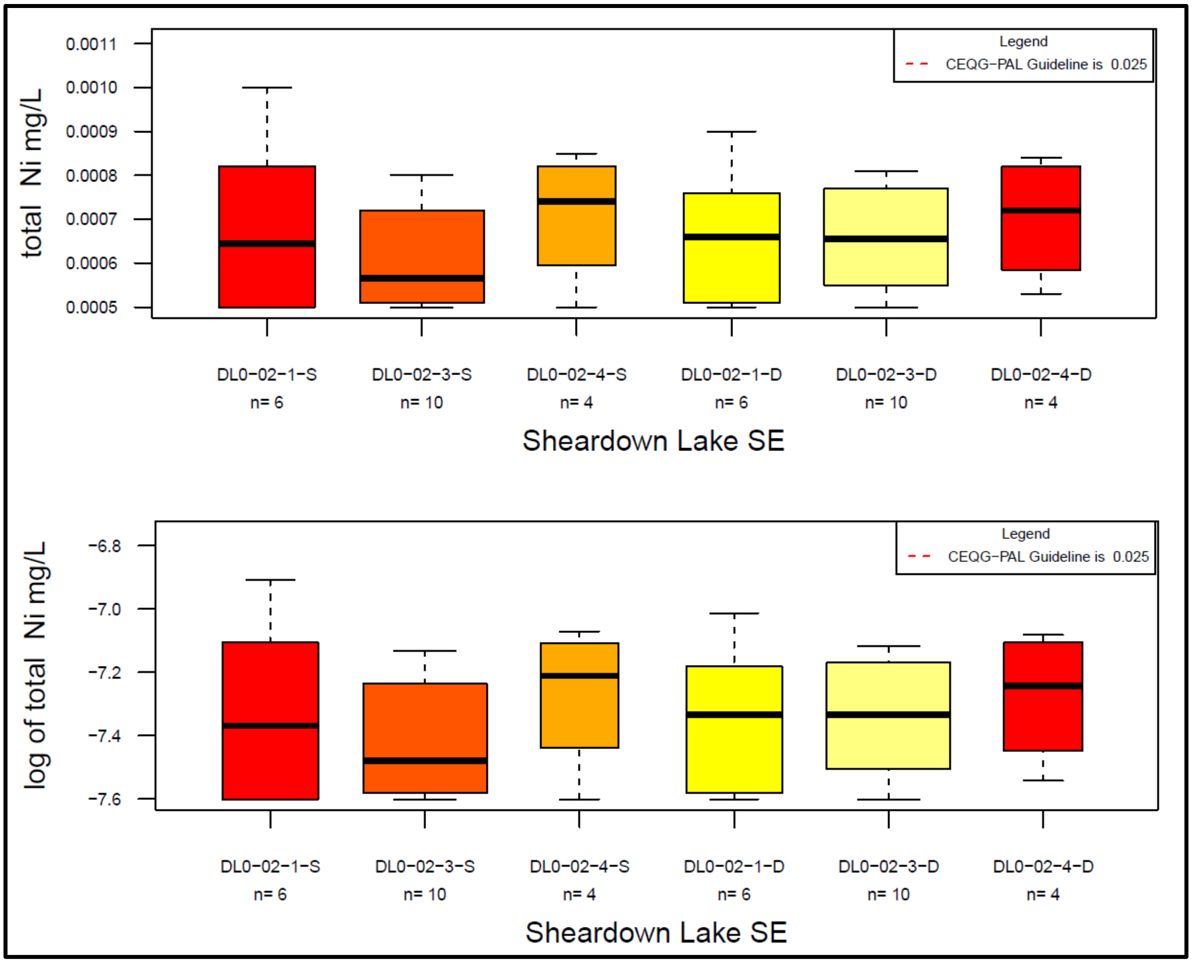
1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.

Figure B.49 Sheardown Lake SE – Variability of Total Iron in Water

Total Nickel (Figures B.50 and B.51)

Forty (40) total nickel concentration samples were collected from Sheardown Lake SE at six sample stations over the course of eight years. Nickel concentrations consistently report above MDLs, but well below the CWQG-PAL guideline (0.025 mg/L) (Figure B.50). Median total nickel concentrations are consistent throughout the geographically distinct sampling stations and range from 0.00055 mg/L through 0.00075 mg/L. Similar to other iron, nickel concentrations are slightly elevated at the DL0-02-4 station.

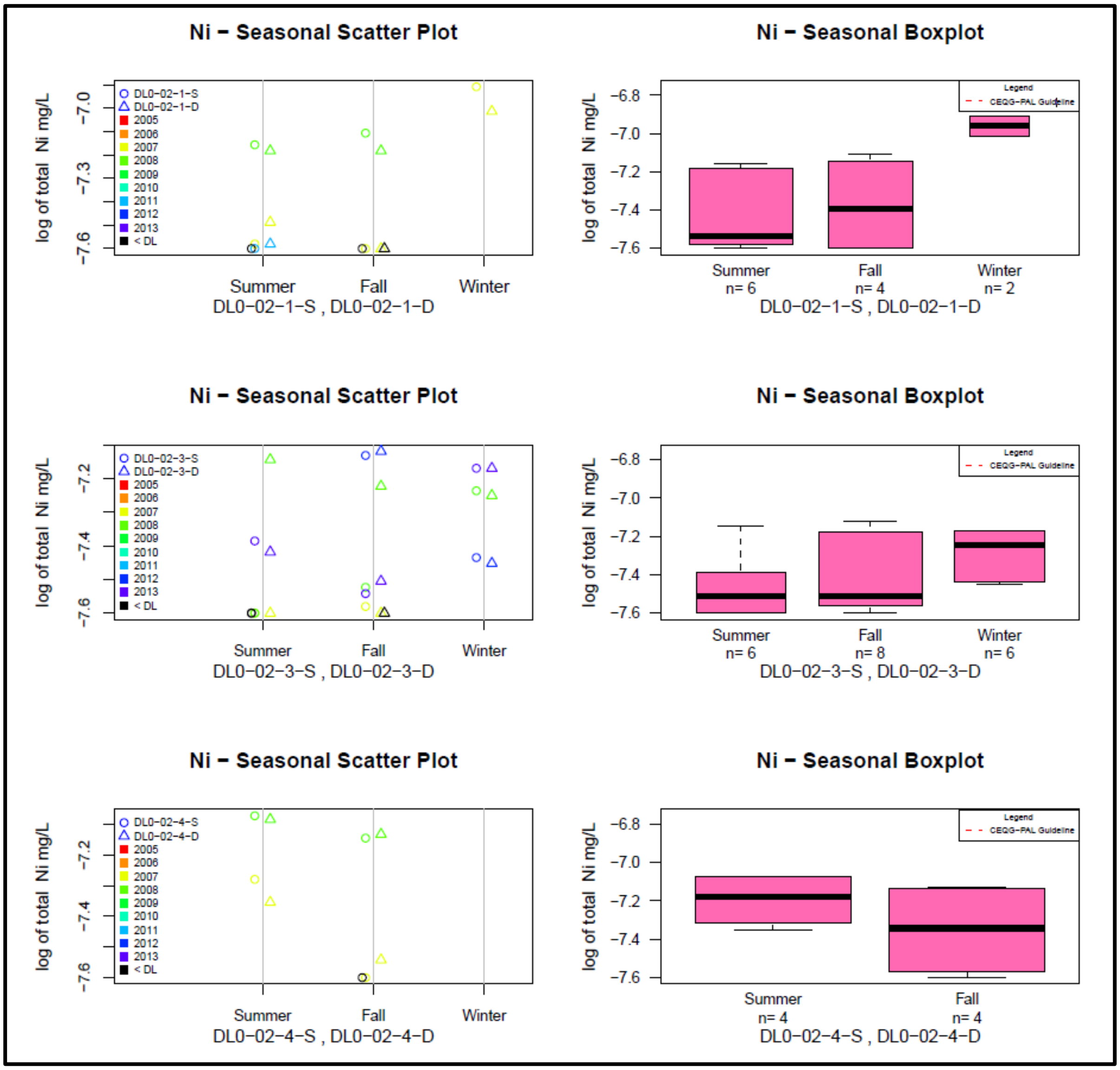
Seasonal scatterplots show that elevated concentrations are derived from early sampling (2007 and 2008), especially at DL0-02-1 and DL0-02-4 (Figure B.51). Although the winter dataset is limited, the current data indicates concentration peaks for nickel occur during the winter.



NOTES:

1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.
2. THE CWQG-PAL GUIDELINE LIMIT IS BASED ON THE TOTAL MEDIAN HARDNESS.

Figure B.50 Sheardown Lake SE – Total Nickel Concentrations in Water



NOTES:

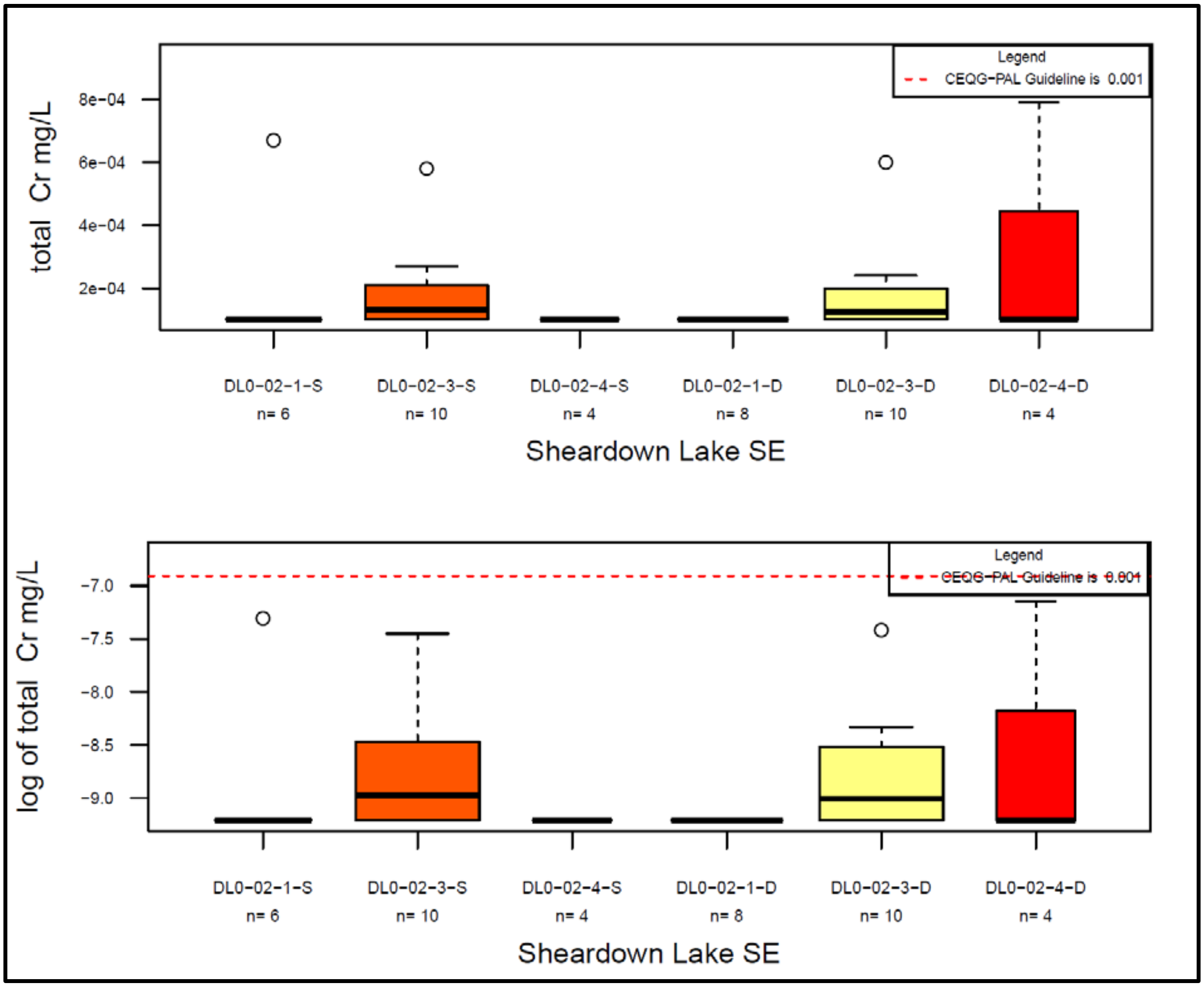
1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.
2. THE CWQG-PAL GUIDELINE LIMIT IS BASED ON THE TOTAL MEDIAN HARDNESS.

Figure B.51 Sheardown Lake SE– Variability of Total Nickel in Water

Total Chromium (Figures B.52 and B.53)

Forty-two (42) total chromium concentration samples were collected from Sheardown Lake SE at six sample stations over the course of eight years. Chromium concentrations are generally low, but concentrations are certain sites approach the CWQG-PAL guideline (0.001 mg/L) (Figure B.52). Samples from DL0-02-3/D and DL0-02-4-D are slightly elevated compared to the other stations with Sheardown Lake SE, but the trend is so muted, it is not considered important.

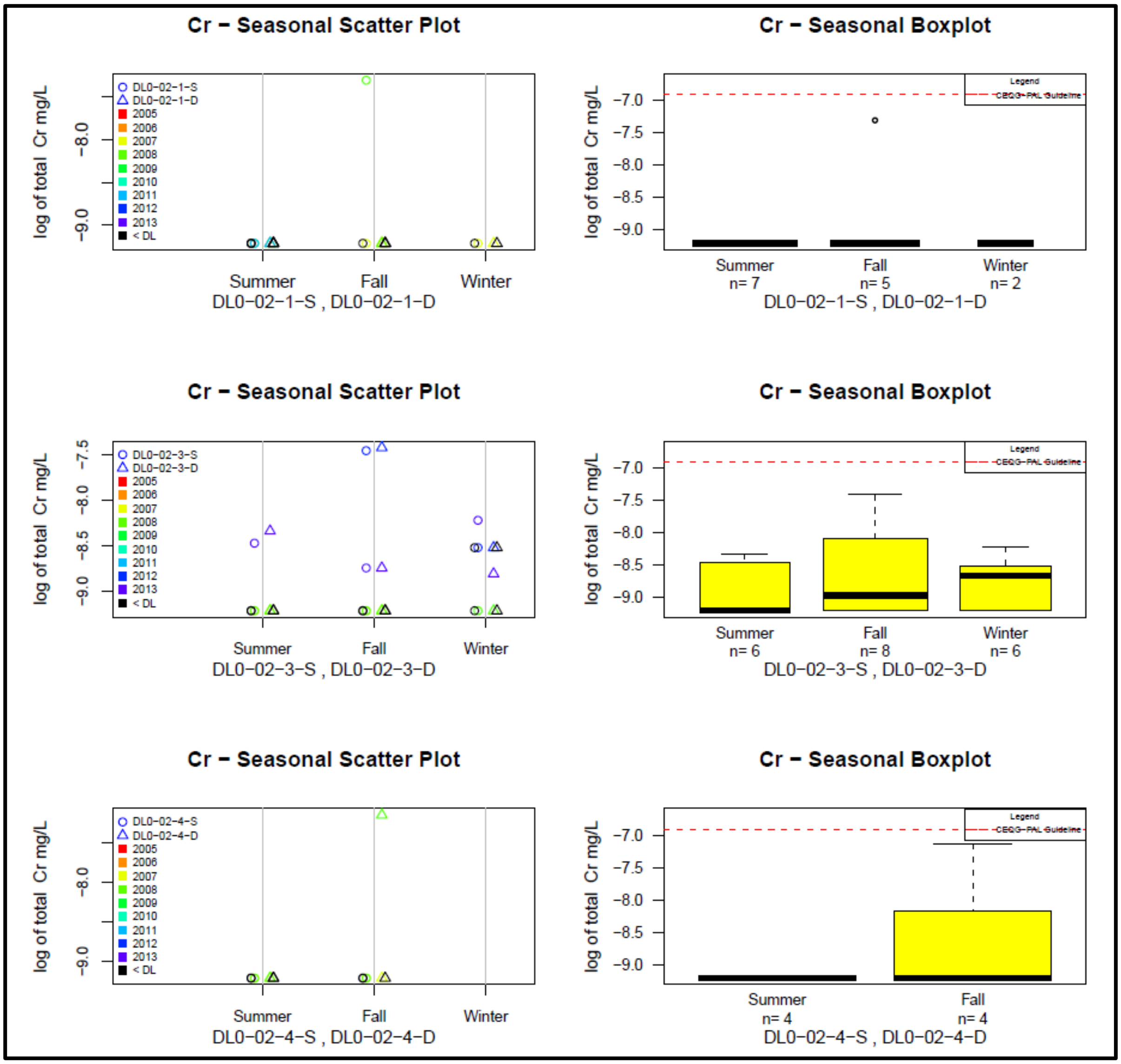
Seasonal scatterplots show that elevated concentrations at DL0-02-3-D are derived from recent sampling, during 2012 and 2013 (Figure B.53). No consistent seasonal trend was noted between sites.



NOTES:

1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.

Figure B.52 Sheardown Lake SE – Total Chromium Concentrations in Water



NOTES:

1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.
2. THE CWQG-PAL GUIDELINE LIMIT IS BASED ON THE TOTAL MEDIAN HARDNESS.

Figure B.53 Sheardown Lake SE– Variability of Total Chromium in Water

Summary of Sheardown Lake SE Water Quality

Summary of trends observed during review of Sheardown Lake SE baseline data:

- Distinct depth trends are not observed for any parameters within Sheardown Lake SE, which suggests that lake is completely mixed throughout the year, despite winter ice.
- Elevated concentrations observed at DL0-02-4 compared to other sites: copper, iron and nickel.
- Early data (2007, 2008) appears elevated when compared to more recent data: copper and nickel.

- Parameters below MDLs and/or do not show any seasonal trends: nitrate, arsenic, cadmium, chromium and copper.
- Parameters with highest concentration occurring in the summer and/or fall: aluminum and iron.
- Parameters with highest concentrations occurring in the winter: chloride and nickel.

B.2.3 Mary Lake

A total of eighty-five (85) lake samples were collected at twelve stations over the eight-year sampling history at Mary Lake (Figures B.1 and B.2):

- BL0-01-D and S - Within a small basin at the north end of the northern arm of Mary Lake to which Camp Lake drains.
- BL0-03-D and S - Located at the centre of Mary Lake.
- BL0-04-D and S - Located in the centre of the main basin of Mary Lake.
- BL0-05-D and S - Located within the main basin of Mary Lake near the mouth of the Mary River.
- BL0-05-B4-D and S - Located at the inlet of Mary Lake.
- BL0-06-D and S - Located within the southern portion of Mary Lake.

Most samples were collected in 2007 and no samples were collected during 2009 and 2010. Most samples occurred in the summer, and the least number of samples were collected in the winter.

A summary of the data collected during each season, with respect to year and site are presented in Table B.4 and a graphical representation of the sampling events is provided in Figure B.54. Note that for the purposes of graphical analysis, data from BL0-05-B4 has been pooled with data from BL0-05.

Table B.4 Mary Lake Sample Size

Year	Summer	Fall	Winter
2006	8	4	0
2007	10	14	8
2008	10	0	4
2011	4	0	0
2012	0	2	0
2013	10	6	5
Site	**Summer**	**Fall**	**Winter**
BL0-01-S	4	3	2
BL0-01-D	4	2	4
BL0-03-S	4	2	1
BL0-03-D	4	2	1
BL0-04-S	4	2	2
BL0-04-D	4	2	2
BL0-05-S	5	5	2
BL0-05-D	5	5	2
BL0-05-B4-S	1	0	0
BL0-05-B4-D	1	0	0
BL0-06-S	3	2	0
BL0-06-D	3	2	0

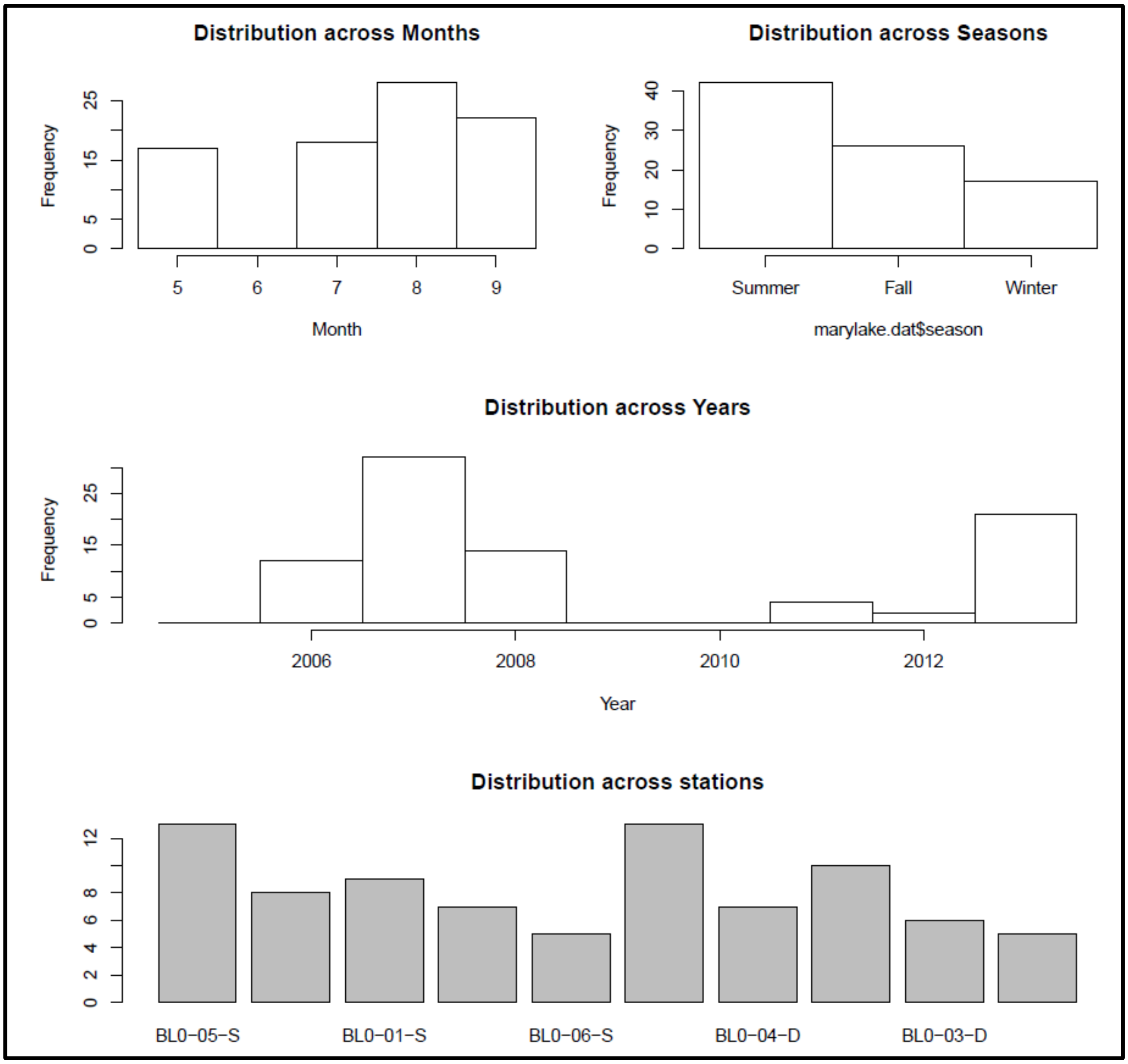


Figure B.54 Mary Lake – Graphical Summary of Sampling Events

The following summarizes the data review observations of the physical parameter data for Mary Lake.

pH (Figure B.55)

- The median pH from all samples collected in Mary Lake is ~7.5. Median values for pH at station within Mary Lake range from 6.6 to 8.3.

Alkalinity (Figure B.55)

- Mary Lake stations generally have alkalinity values that are below 40 mg/L $CaCO_3$; however, BL0-01-S/D show elevated median alkalinity values equal to approximately 70 mg/L $CaCO_3$.
- Differences between deep and shallow stations are not noted.

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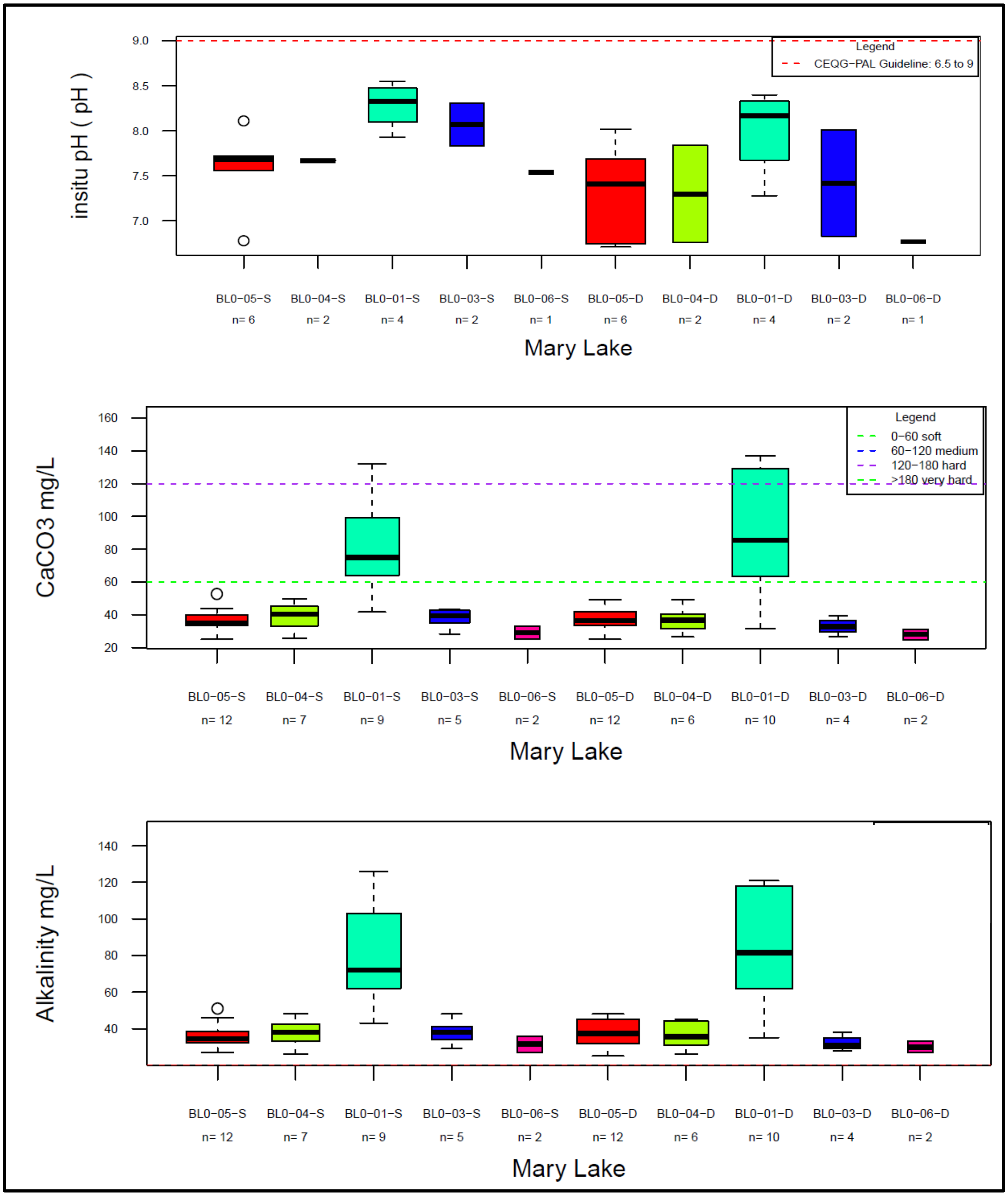


Figure B.55 Mary Lake – In-situ pH, Alkalinity and Hardness

Hardness (Figure B.55)

- Mary Lake stations have "soft water" and generally have alkalinity values that are below 40 mg/L hardness measured as $CaCO_3$, with the exception of BL0-01-S/D which has elevated median alkalinity values equal to ~80 mg/L $CaCO_3$.
- Differences between deep and shallow stations are not noted.
- Hardness portrayed trends very similar to alkalinity and suggests that the hardness is almost entirely carbonate hardness with little to no non-carbonate contributions to hardness.

The following sections summarize the results for the non-metallic inorganic parameters of interest: chloride and nitrate.

Chloride (Figures B.56 and B.57)

Sixty-nine (69) chloride concentration samples were collected from Mary Lake over the course of eight years. Chloride concentrations are consistently low, and each geographically distinct site in Mary Lake has a median than ranges from 2 to 2.5 mg/L (Figure B.56). This is well below the CWQG-PAL limit of 120 mg/L. A comparison of total data and seasonal scatterplots reveals that deep and shallow stations located at the same location vary little in reported concentrations. BL0-01-S and BL0-01-D show the greatest variability and have the largest sample size. These stations have outlying values recorded around 11 mg/L to 14 mg/L. The BL0 sampling stations are located in a small basin at the north end of the north arm of the lake, which receives flows from Camp Lake as well as the Tom River (Figure B.1).

Seasonal boxplots show lower chloride concentrations occur in the summer and higher concentrations occur in the winter (Figure B.57).

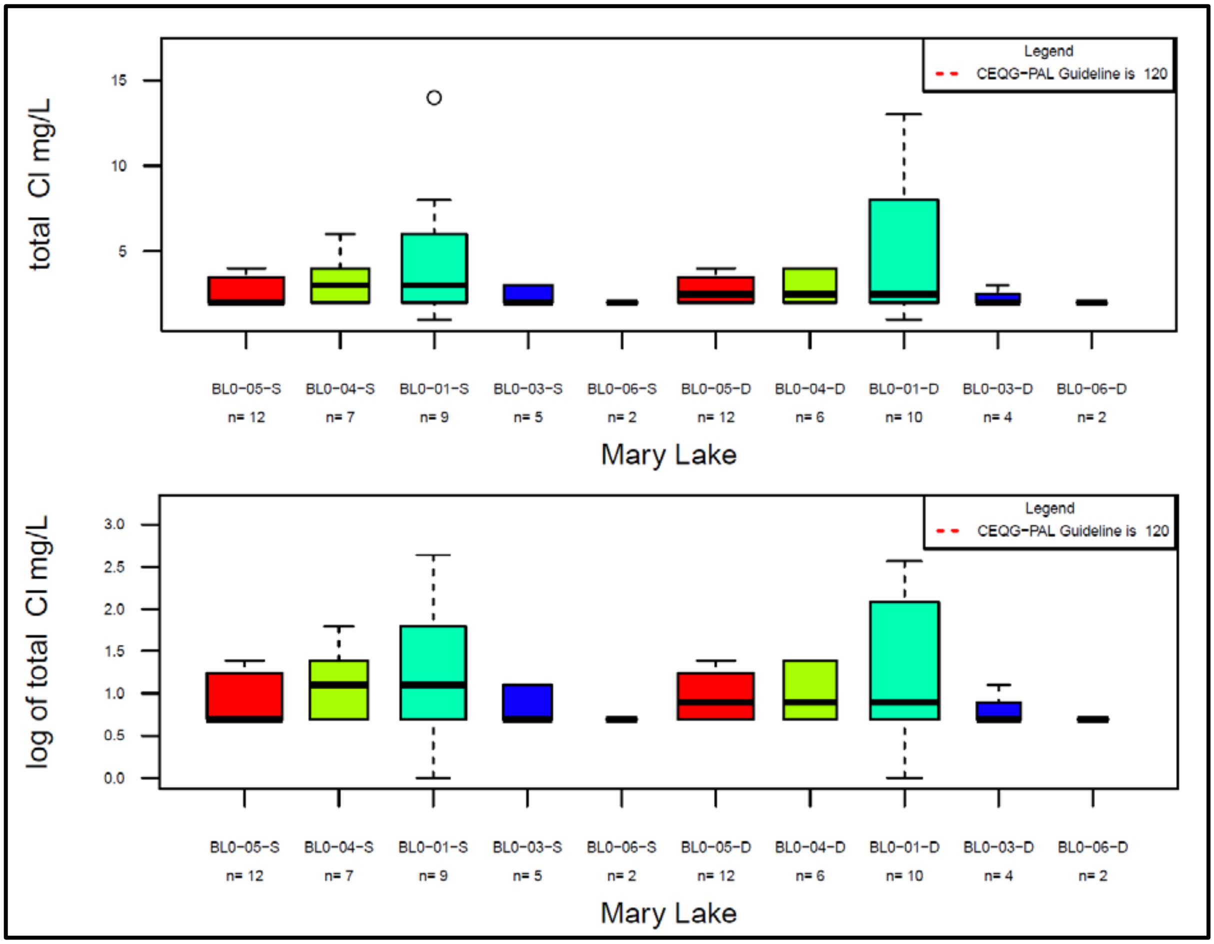
Nitrate

Sixty-nine (69) nitrate concentration samples were collected from Mary Lake over the course of eight years. All nitrate concentrations were measured at the detection limit (0.10), which is well below the CWQG-PAL limit (3 mg/L). As a result, no seasonal, inter-annual or depth variation can be determined and further graphical analyses are not warranted.

The following sections summarize the results for the metal parameters of interest: aluminum, arsenic, cadmium, copper, iron, and nickel. All metals are discussed as total concentrations instead of dissolved concentrations, to reflect both the total dissolved and particulate metal loading.

Total Aluminum (Figure B.58 and Figure B.59)

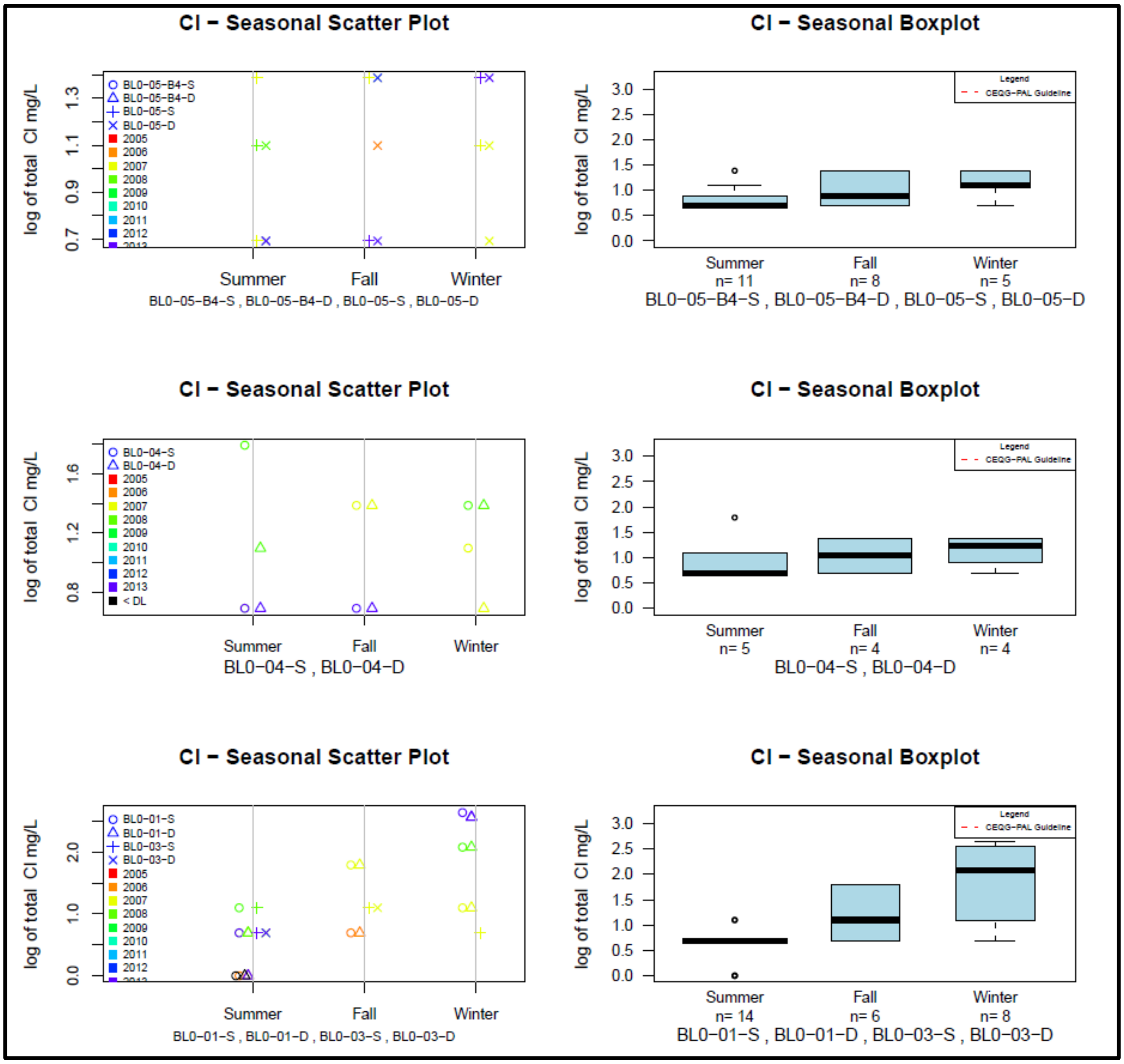
Sixty-nine (69) total aluminum concentration samples were collected from Mary Lake over the course of eight years. Total aluminum concentrations tend to occur above detection limits, and are elevated to concentrations above, or close to the CWQG-PAL limit (0.10 mg/L). Maximum aluminum concentrations exceed the CWQG-PAL limit at all sites except BL0-03-D/S and BL0-6S/D (Figure B.58). Median total aluminum concentrations at each geographically distinct sampling station in Mary Lake range from 0.03 mg/L to 0.06 mg/L. Sampling stations close to inlets, such as BL0-01 and BL0-05, show slightly higher aluminum concentrations when compared to other stations, indicating that upstream aluminum inputs may be occurring from waters flowing into the lake at these locations (the Mary River and Camp Lake). Elevated total aluminum concentrations measured in various watercourses across the mine site area.



NOTES:

1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.

Figure B.56 Mary Lake – Chloride Concentrations in Water

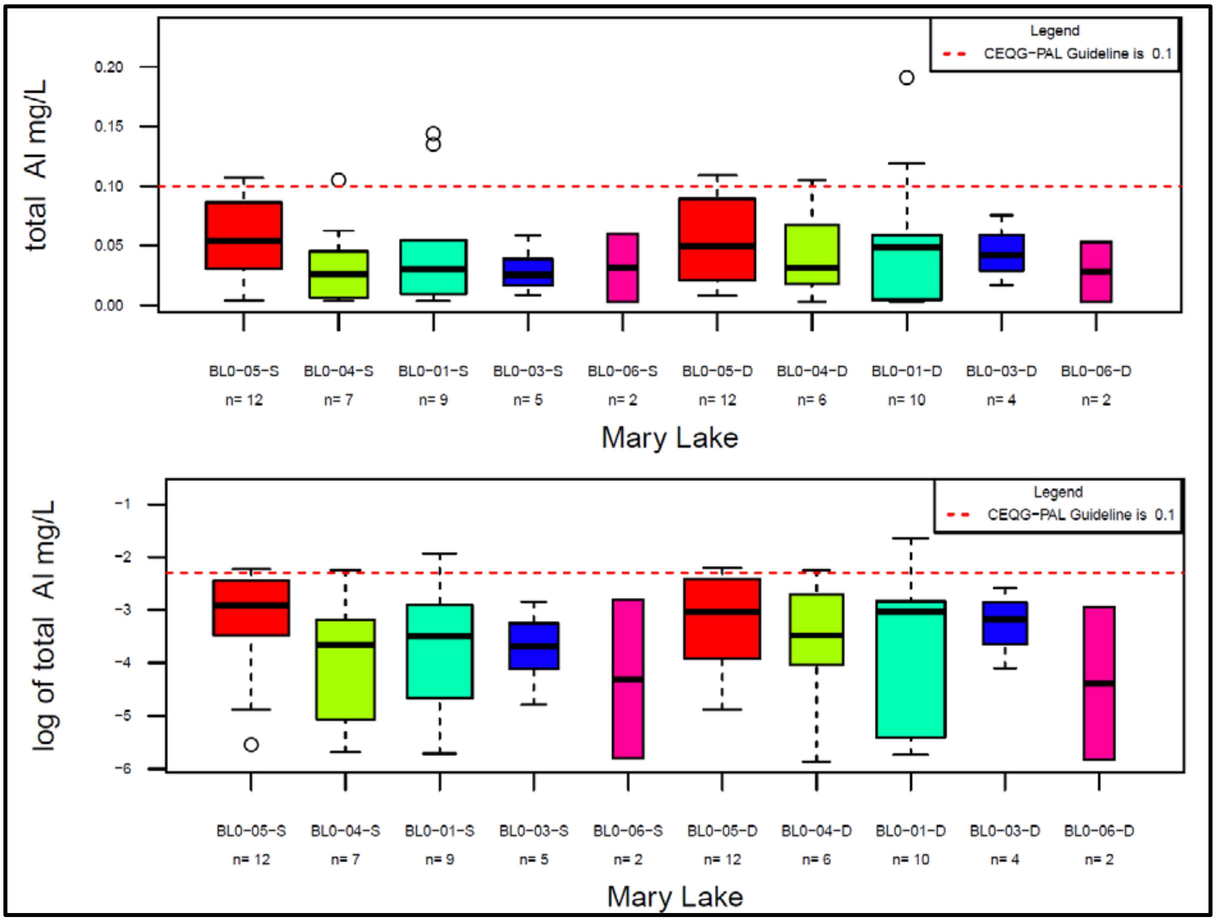


NOTES:

1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.

Figure B.57 Mary Lake – Variability of Chloride in Water

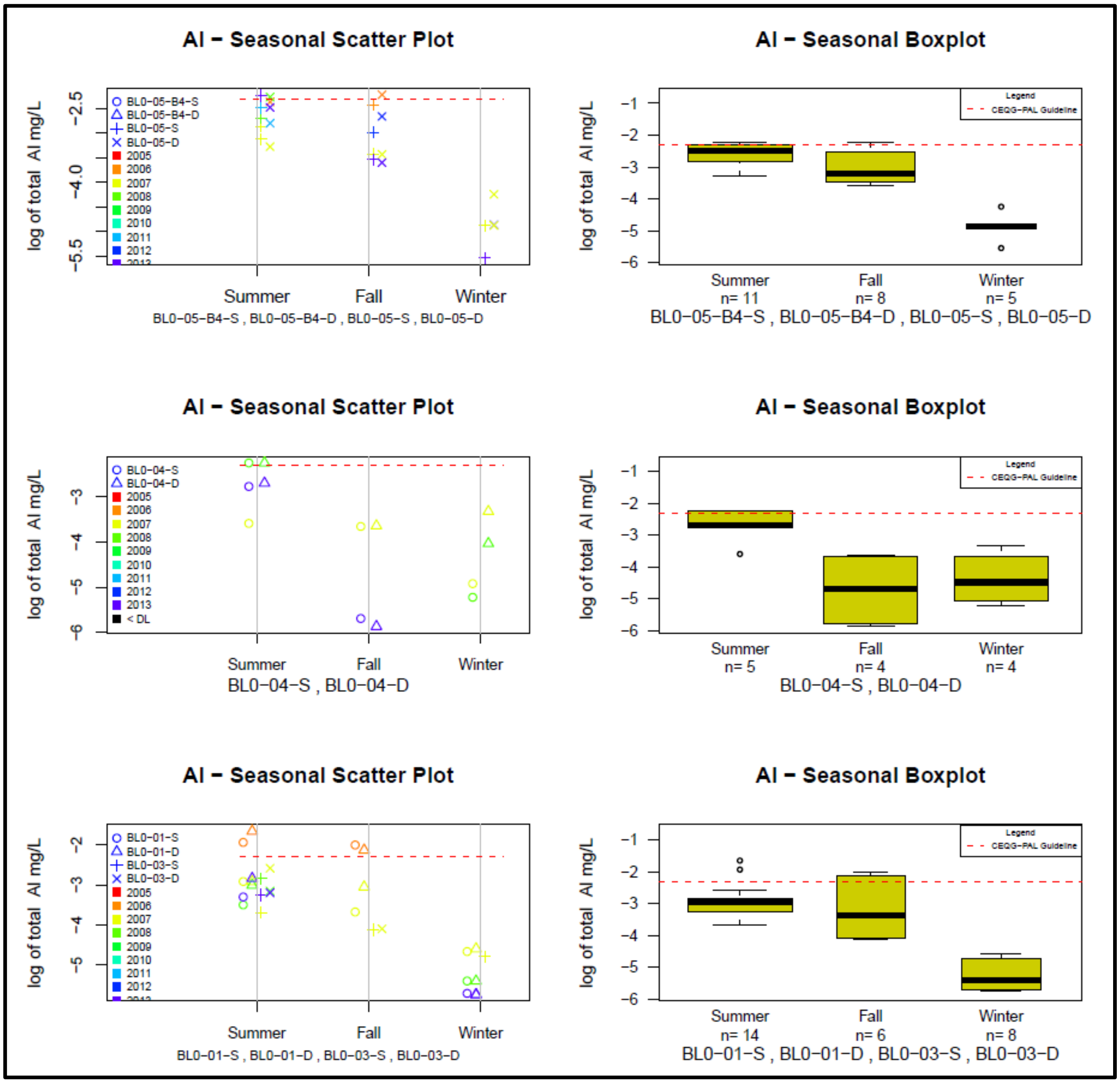
Seasonal scatterplots indicate shallow and deep sampling locations have similar data, and may be aggregated (Figure B.59). Distinct temporal trends over the eight-year sampling history are not noted.



NOTES:

1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.
2. THE CWQG-PAL GUIDELINE LIMIT IS BASED ON THE TOTAL MEDIAN HARDNESS.

Figure B.58 Mary Lake – Total Aluminum Concentrations in Water



NOTES:

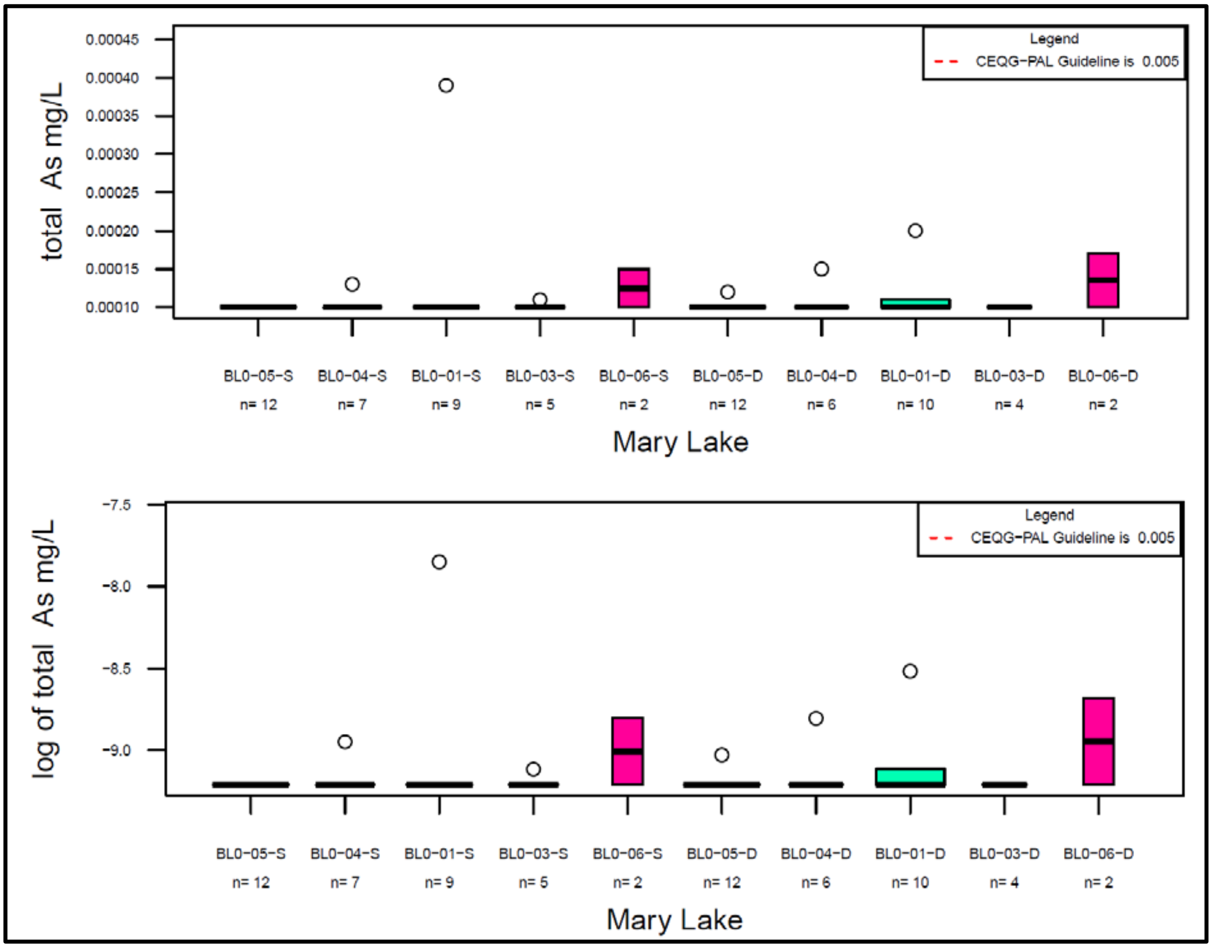
1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.
2. THE CWQG-PAL GUIDELINE LIMIT IS BASED ON THE TOTAL MEDIAN HARDNESS.

Figure B.59 Mary Lake – Variability of Total Aluminum in Water

Seasonal boxplots show aluminum concentrations tend to be at their maximum in the summer, and decrease to their minimum value in the winter, with fall concentrations occurring somewhere in between. The only stations that do not show this trend are BL0-04-S/D and BL0-06-S/D. These stations show a cluster of low concentration values below 2007-2008 winter data. Similar to other locations within the mine site, seasonal box plots indicate that aluminum concentrations are highest in the winter and lowest in the summer.

Total Arsenic (Figures B.60 and B.61)

Sixty-nine (69) total arsenic concentration samples were collected from Mary Lake over the course of eight years. Arsenic concentrations tend to occur below detection limits, and below the CWQG-PAL limit (0.005 mg/L), with the exception of several outlying values (Figure B.60). All outlying values occur during the fall at BL0-05-S, BL0-04-S/D, and BL0-06-S/D in 2013; and at BL0-01-S/D in 2007. The highest outlying value (~0.0004 mg/L) remains below the CWQG-PAL limit. Samples from BL0-06-S/D, located at the outlet of Mary Lake, have slightly elevated median arsenic concentrations when compared to other stations.

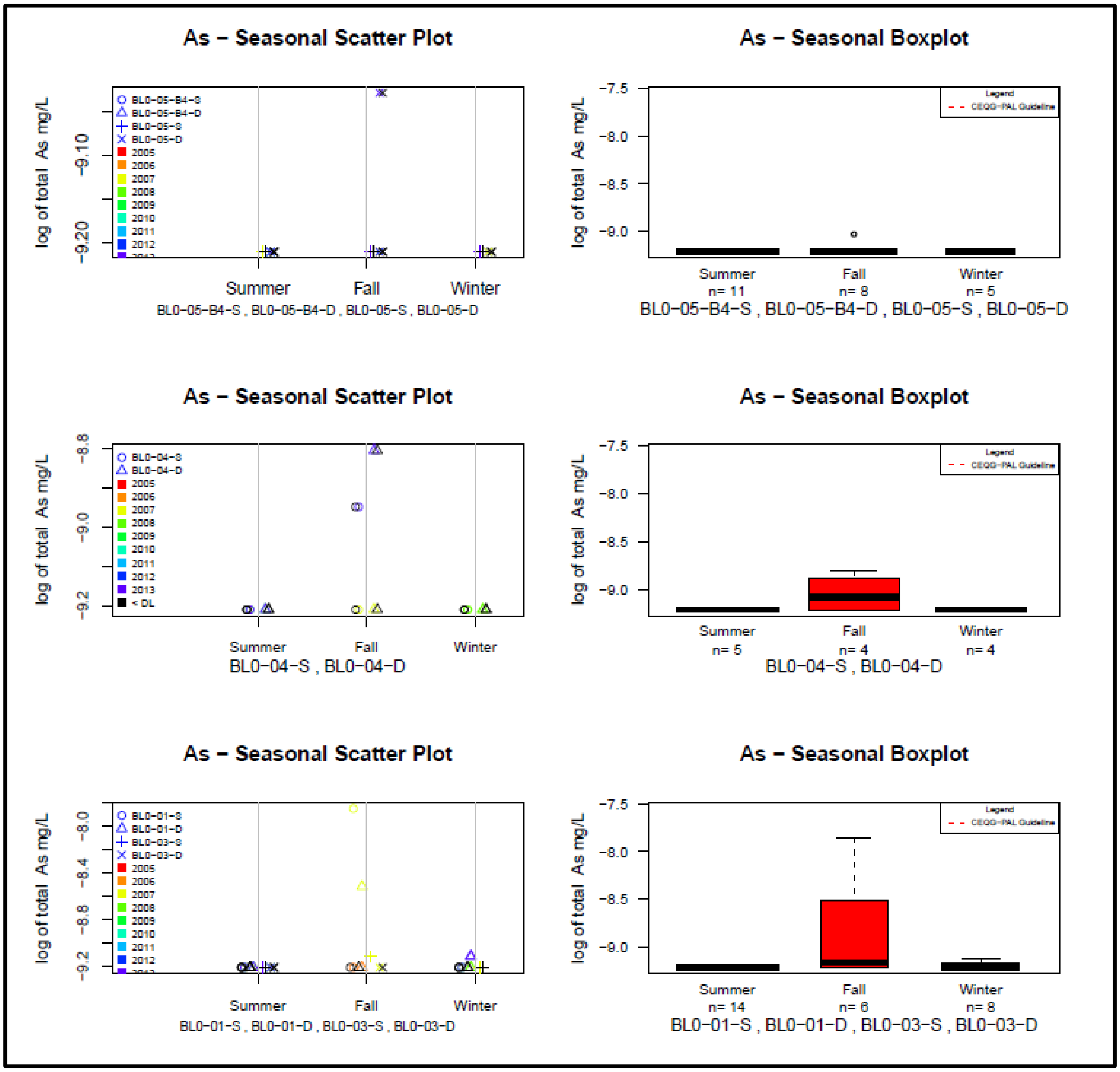


NOTES:

1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.

Figure B.60 Mary Lake – Total Arsenic Concentrations in Water

Seasonal scatterplots indicate shallow and deep sampling locations have similar data, and may be utilized together for calculation of benchmarks (Figure B.61). Seasonal boxplots show that all maximum arsenic concentration outliers occur during the fall, while summer and winter concentrations remain depressed in comparison.



NOTES:

1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.

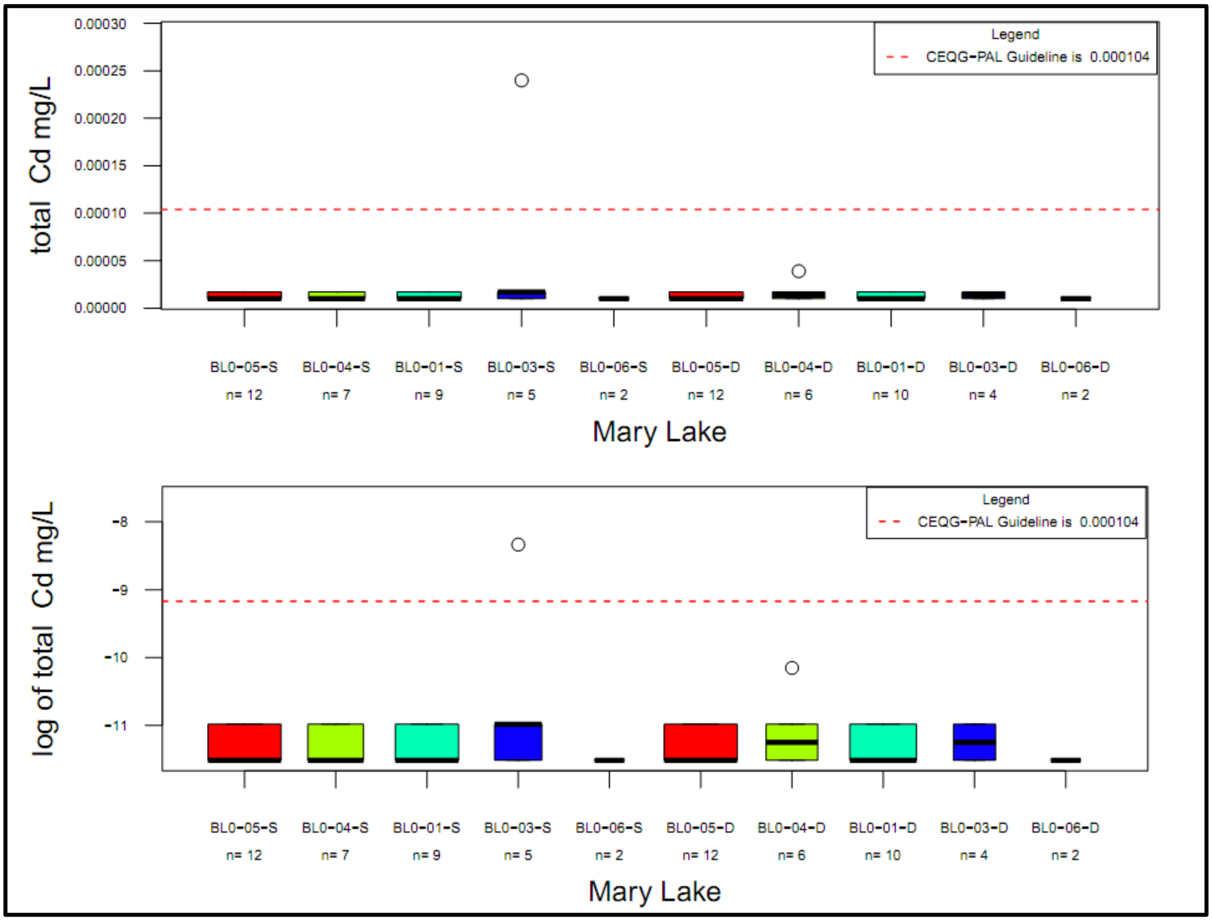
Figure B.61 Mary Lake – Variability of Total Arsenic in Water

Total Cadmium (Figures B.62 and B.63)

Sixty-nine (69) total cadmium concentration samples were collected from Mary Lake over the course of eight years. Cadmium concentrations tend to occur at or below detection limits, and just below the CWQG-PAL limit (0.000018 mg/L), with the exception of several outlying values (Figure B.62). BL0-04-D and BL0-03-S are the only stations where maximum concentrations exceed the

CWQG-PAL limit. All geographically distinct sample locations in Mary Lake have similar median values, with the exception of BL0-04-D and BL0-03-S, which have elevated median values.

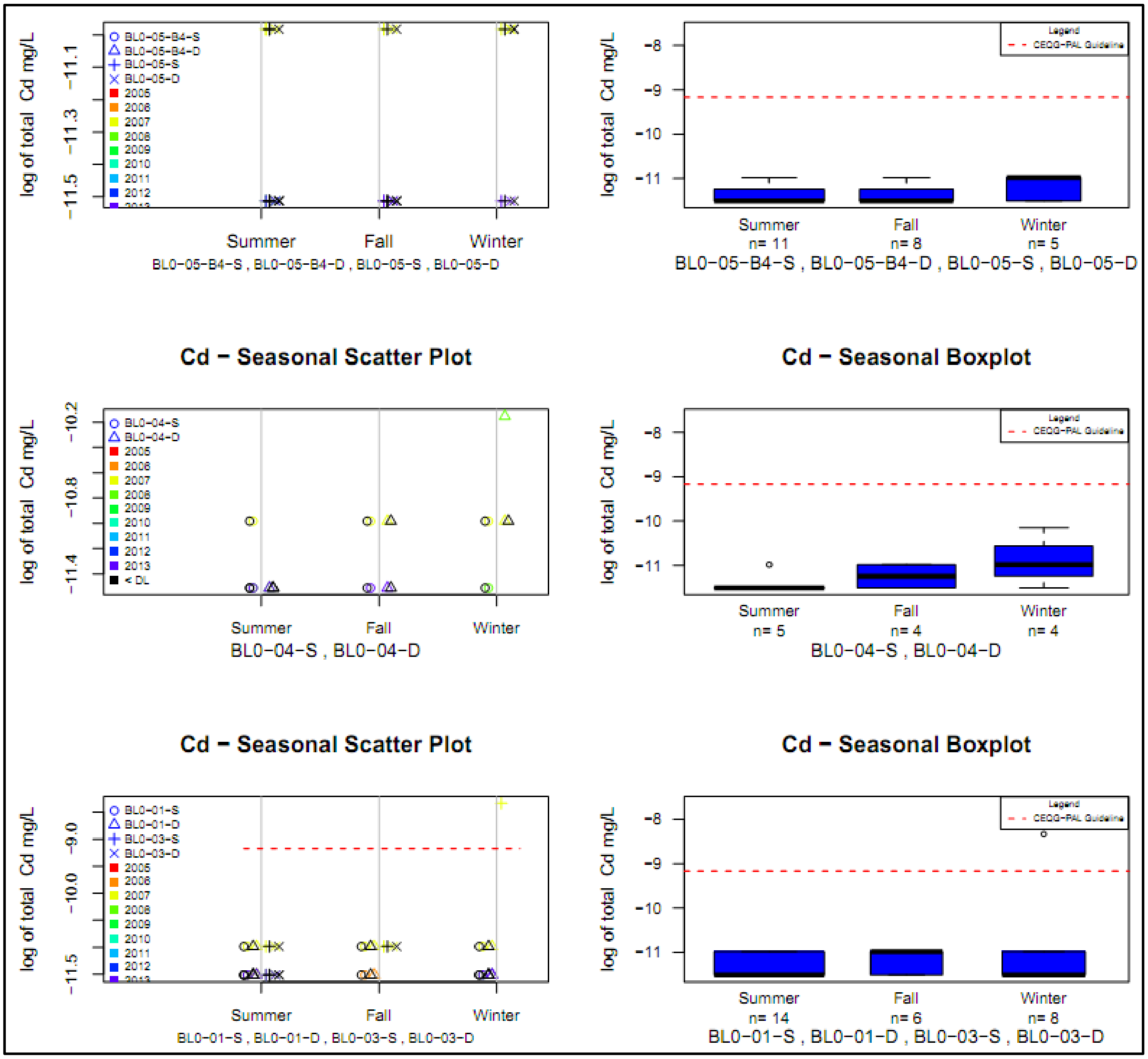
Seasonal scatterplots indicate shallow and deep sampling locations have similar data, and may be utilized together to determine baseline trends (Figure B.63). Seasonal scatterplots indicate cadmium concentrations are slightly elevated in the winter, when compared to other seasons.



NOTES:

1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.
2. THE CWQG-PAL GUIDELINE LIMIT IS BASED ON THE TOTAL MEDIAN HARDNESS.

Figure B.62 Mary Lake – Total Cadmium Concentrations in Water



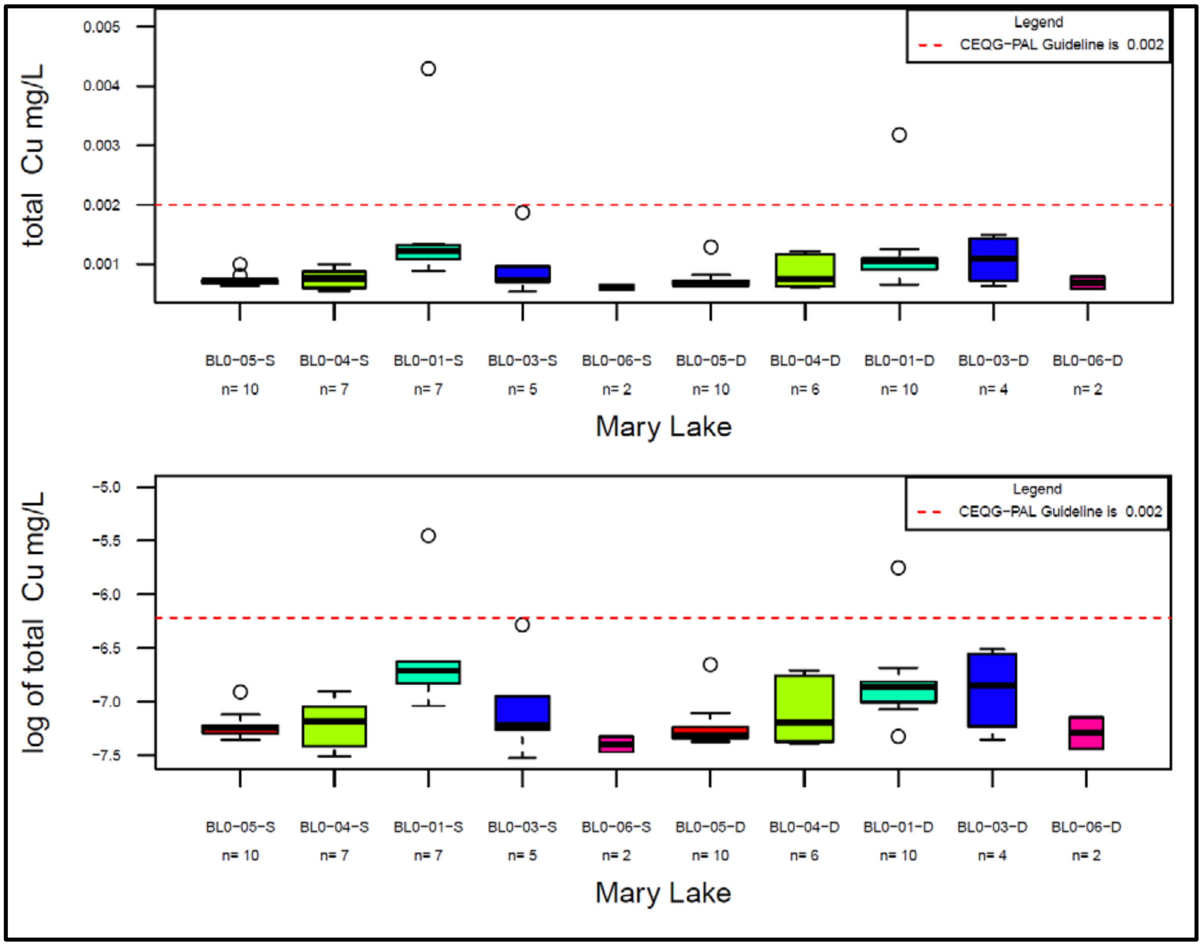
NOTES:

1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.
2. THE CWQG-PAL GUIDELINE LIMIT IS BASED ON THE TOTAL MEDIAN HARDNESS.

Figure B.63 Mary Lake – Variability of Total Cadmium in Water

Total Copper (Figures B.64 and B.65)

Sixty-three (63) total copper concentration samples were collected from Mary Lake over the course of eight years. Copper concentrations tend to occur above detection limits, and below the CWQG-PAL limit (0.0002 mg/L), with the exception of two outlying values (Figure B.64). Samples from BL0-01-S/D and BL0-03-D are elevated in comparison to other stations. This indicates possible existing copper loading via inflows from I-tributary or J-tributary.

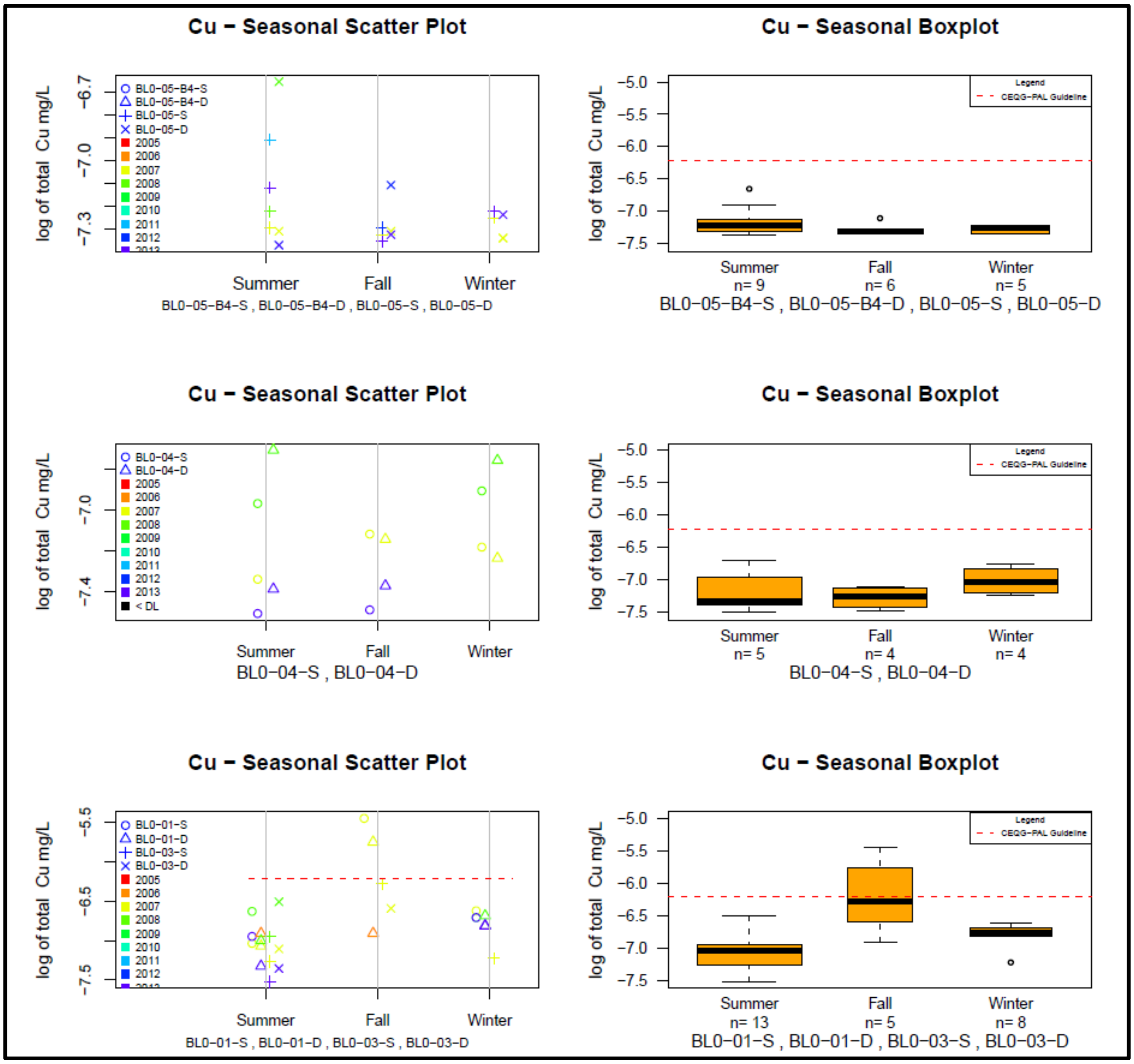


NOTES:

1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.
2. THE CWQG-PAL GUIDELINE LIMIT IS BASED ON THE TOTAL MEDIAN HARDNESS.

Figure B.64 Mary Lake – Total Copper Concentrations in Water

Seasonal scatterplots indicate shallow and deep sampling locations have similar data, and may be utilized together to obtain an understanding of baseline concentrations (Figure B.65). Seasonal boxplots do not reveal a consistent trend among stations.



NOTES:

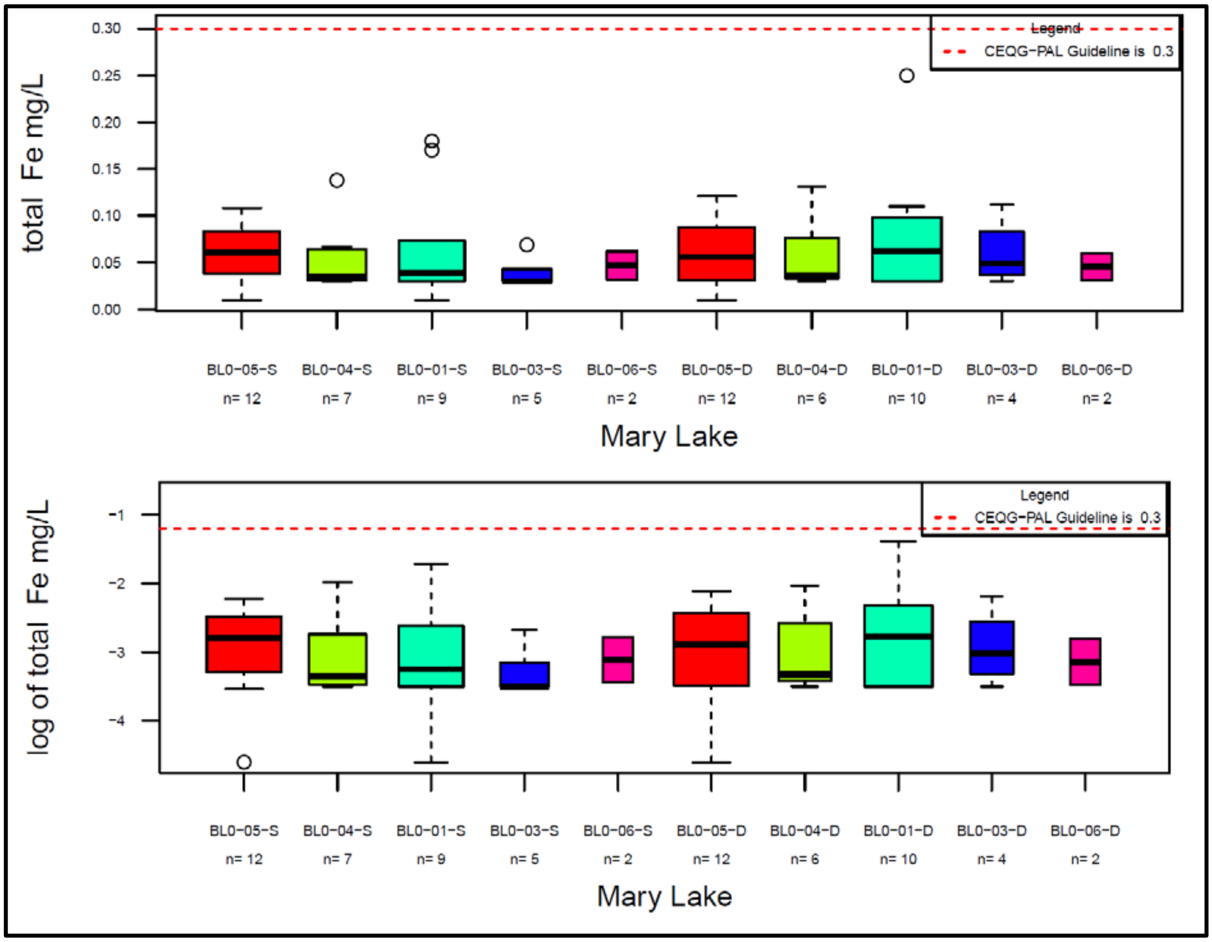
1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.
2. THE CWQG-PAL GUIDELINE LIMIT IS BASED ON THE TOTAL MEDIAN HARDNESS.

Figure B.65 Mary Lake – Variability of Total Copper in Water

Total Iron (Figures B.66 and B.67)

Sixty-nine (69) total iron concentration samples were collected from Mary Lake over the course of eight years. Iron concentrations tend to occur above detection limits, and well below the CWQG-PAL limit (0.3 mg/L) (Figure B.66). Median iron concentrations range from 0.04 mg/L to 0.06 mg/L. BL0-05-S/D and BL0-01-D, both located at Mary Lake inlet locations, have elevated median iron concentrations. This indicates some amount of existing iron loading may be occurring from upstream sources.

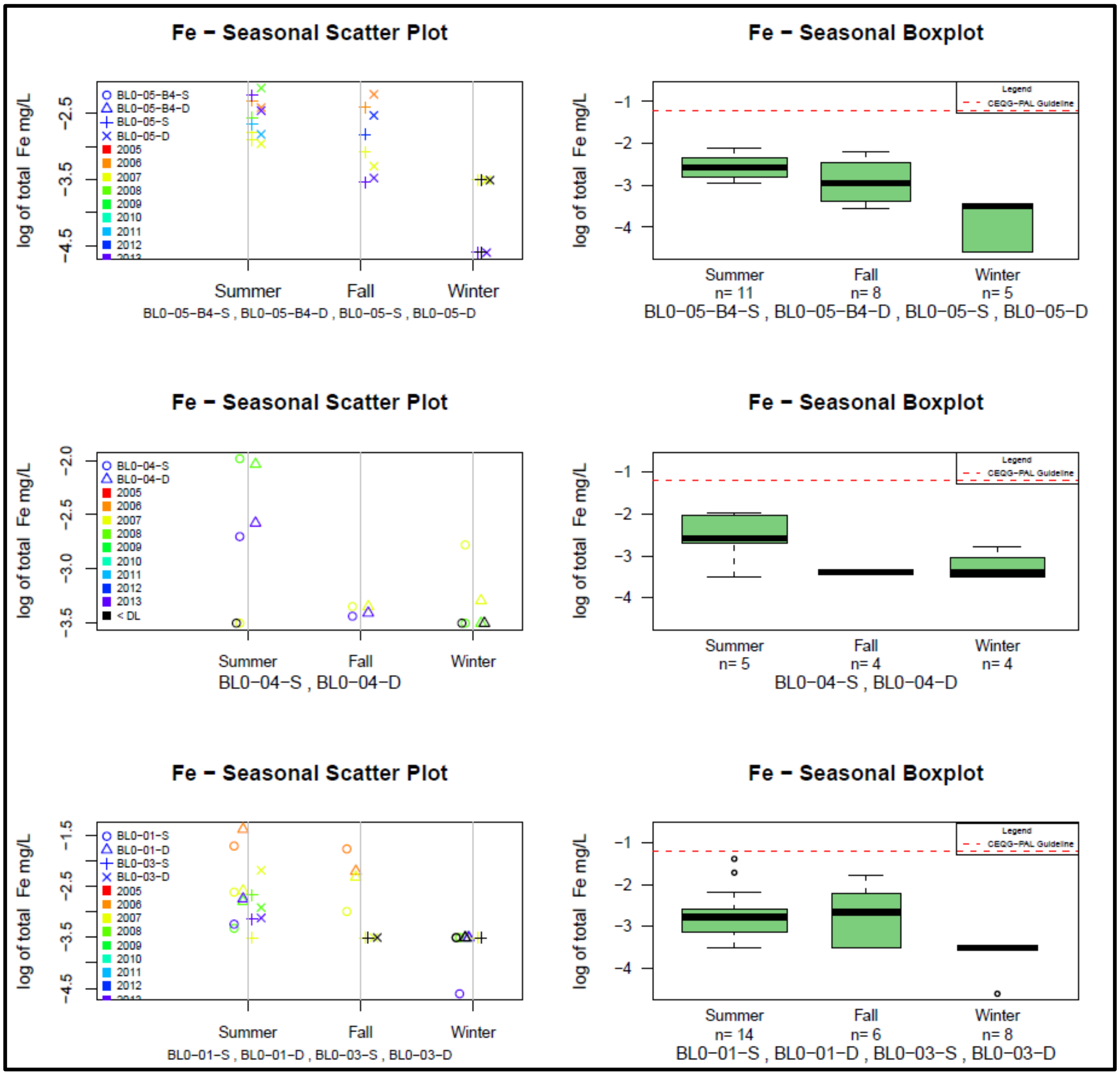
Seasonal scatterplots indicate shallow and deep sampling locations have similar data, and may be utilized together to gain an understanding of baseline conditions (Figure B.67*)*. Seasonal boxplots indicate summer concentrations are typically elevated, when compared to winter concentrations. Concentration trends for fall data are less consistent.



NOTES:

1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.

Figure B.66 Mary Lake – Total Iron Concentrations in Water



NOTES:

1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.

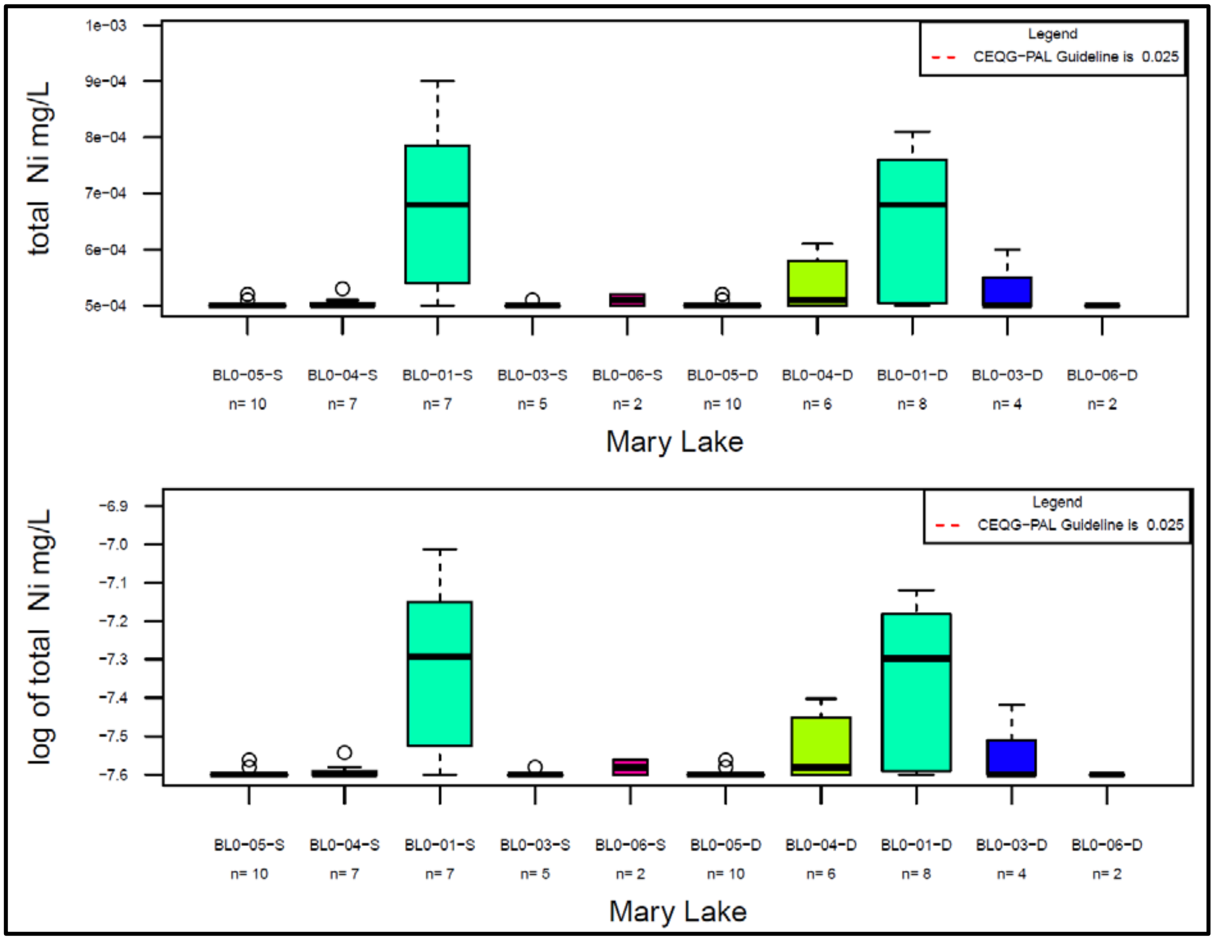
Figure B.67 Mary Lake – Variability of Total Iron in Water

Total Nickel (Figures B.68 and B.69)

Sixty-one (61) total nickel concentration samples were collected from Mary Lake over the course of eight years. Nickel concentrations are low and tend to occur at, below or slightly above detection limits, and well below the CWQG-PAL limit (0.025 mg/L) (Figure B.68). Median nickel concentrations at geographically distinct sampling stations tend to occur around 0.0005 mg/L. Samples from

BL0-01-S/D (north arm near the Camp Lake discharge) are elevated in comparison to other sample stations and have a median concentration ~0.0007 mg/L. This indicates some amount of existing nickel loading may be occurring from upstream sources.

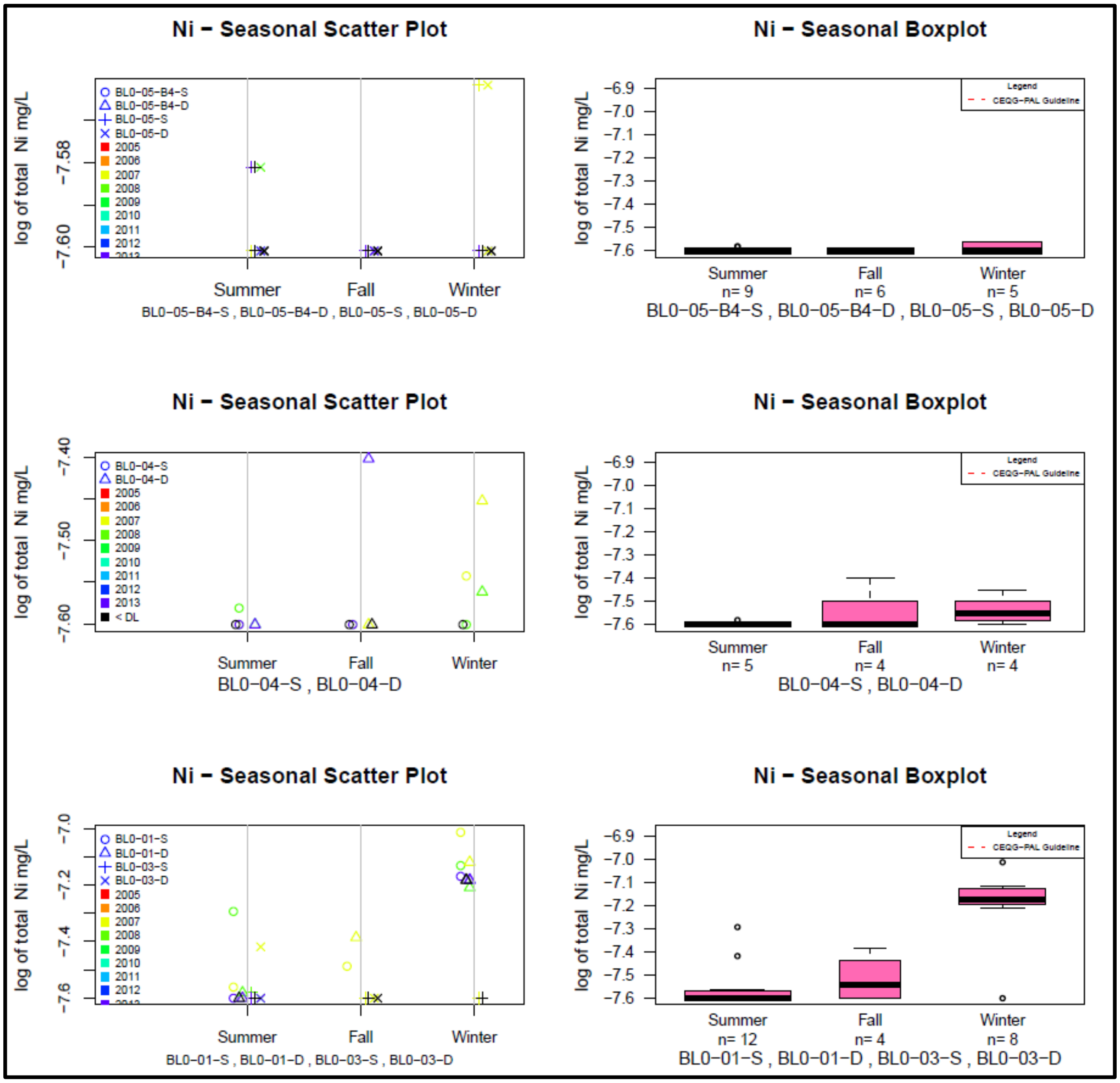
Seasonal scatterplots indicate shallow and deep sampling locations have similar data, and may be utilized en mass to determine overall baseline trends (Figure B.69). Seasonal boxplots indicate summer concentrations are typically depressed when compared to winter concentrations.



NOTES:

1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.
2. THE CWQG-PAL GUIDELINE LIMIT IS BASED ON THE TOTAL MEDIAN HARDNESS.

Figure B.68 Mary Lake – Total Nickel Concentrations in Water



NOTES:

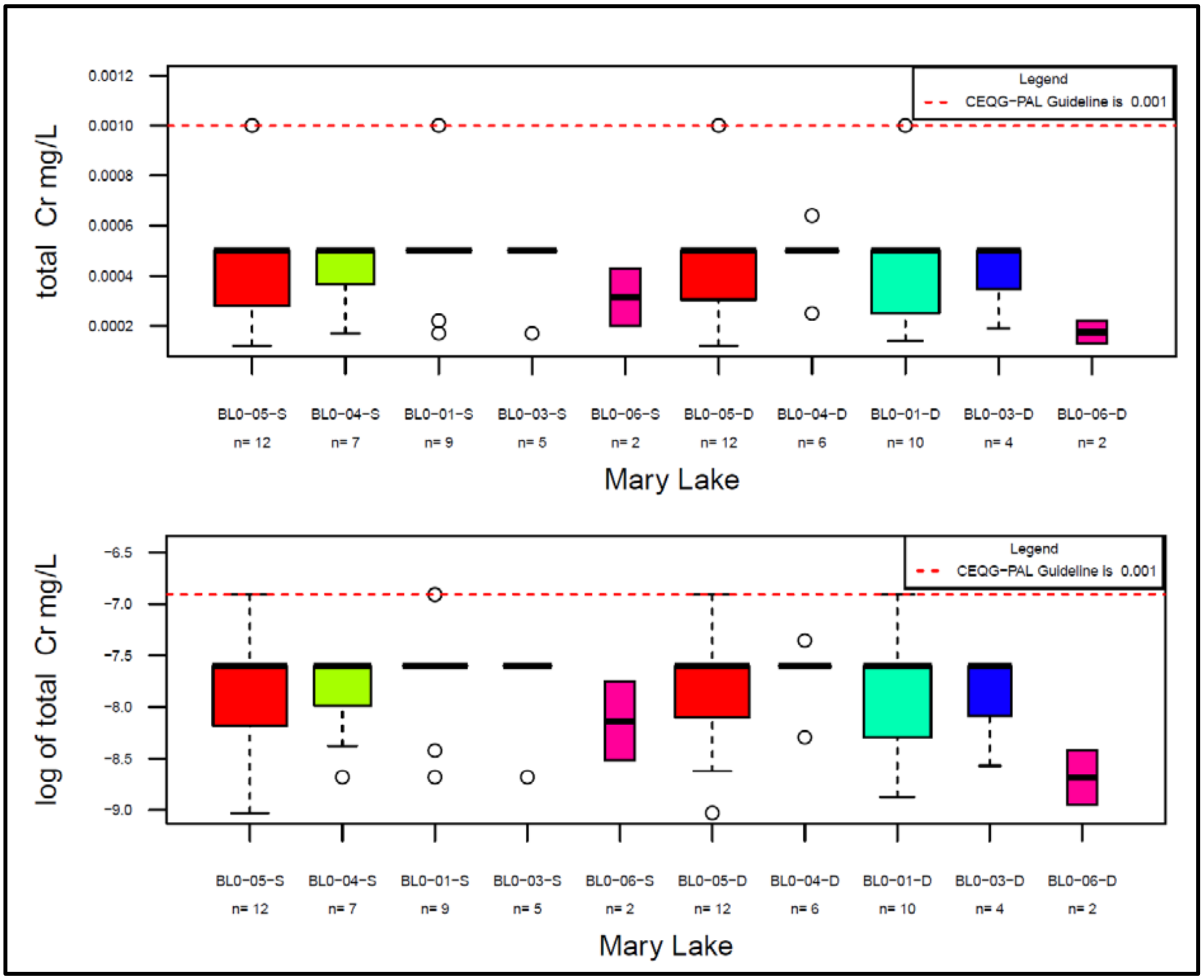
1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.
2. THE CWQG-PAL GUIDELINE LIMIT IS BASED ON THE TOTAL MEDIAN HARDNESS.

Figure B.69 Mary Lake – Variability of Total Nickel in Water

Total Chromium (Figures B.70 and B.71)

Sixty-nine (69) total chromium concentration samples were collected from Mary Lake over the course of eight years. Total chromium concentrations are low and tend to occur at, below or slightly above detection limits, and well below the CWQG-PAL limit (0.001 mg/L) (Figure B.70). Maximum and outlying concentrations at BL0-05-S/D and BL0-01-S/D reach the guideline limit.

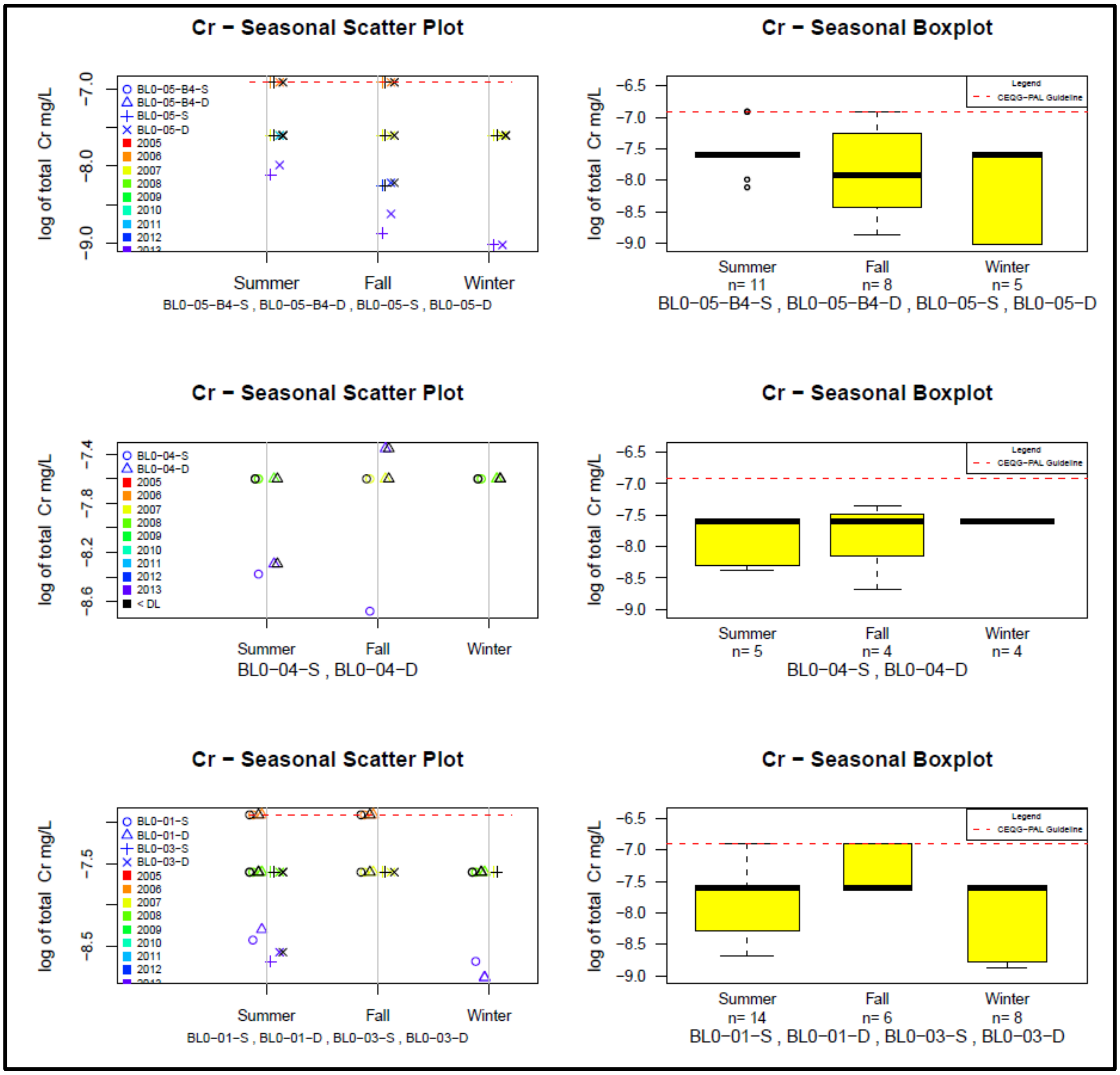
Seasonal scatterplots indicate show that detection limits are defined by applicable years (Figure B.71*)*. Seasonal boxplots do not show any conserved trend throughout sites.



NOTES:

1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.

Figure B.70 Mary Lake – Total Chromium Concentrations in Water



NOTES:

1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.

Figure B.71 Mary Lake – Variability of Total Chromium in Water

Summary of Mary Lake Water Quality

Summary of trends observed during review of Mary Lake baseline water quality data:

- Distinct depth trends were not observed for any parameters within Mary Lake, which suggests complete mixing of the lake. As a result, both deep and shallow station data has been utilized to inform baseline trends in water quality.

- Inlet sampling shows elevated concentrations for certain samples, such as aluminum, chloride, copper, iron, hardness, chromium and nickel.
- Parameters that occur below MDL or do not show seasonal trends include: cadmium, copper, nitrate, and chromium.
- Parameters with the highest concentrations in the summer include: aluminum and iron.
- Parameters with the highest concentration during the fall include: arsenic.
- Parameters with the highest concentration during the winter: chloride, nickel and cadmium.

B.3 POWER ANALYSIS

B.3.1 Methods

Parameter and station-specific power analyses were completed in order to determine the power of the proposed sampling program to detect statistical changes. As per the Assessment Approach and Response Framework in the CREMP (see Figure 2.12 in the main report), management action is triggered if the mean concentrations of any parameter at selected stations reach benchmark values. Benchmark values have been developed for water quality contaminants of potential concern (COPCs) that consider aquatic toxicology, natural enrichment in the Project area, or low concentrations below MDLs (Intrinsik, 2014; see Section 2.7.3 of the main report). Sufficient statistical power is required to ensure that management action is triggered correctly, and this has necessitated the completion of a power analysis. Inputs to the power analyses include all baseline data sampled to date and the proposed benchmark values, which were calculated using the 97.5th percentile of the baseline data. For all lakes in the sampling program, no pre-mining reference data exists; therefore, a complete Before-After-Control-Impact (BACI) analysis cannot be completed. Instead a before-after (BA) design framework was used (Smith, 2002). Once additional baseline data from 2014 and post-mining data is collected, it is anticipated that a Linear Mixed Effects model will be used to test the differences between concentrations measured for pre-mining impact data, pre-mining baseline data, post-mining impact data and post-mining reference data.

The *a priori* power analysis determines, based on a given sample size, variability and effect size[1], the number of samples required to obtain a certain power at a certain alpha value or Type I error rate. Type I error quantifies the probability that a given statistical test will incorrectly reject the null hypothesis or provide a false positive/false alarm. Conversely, type II error occurs when the null hypothesis is false, but fails to be rejected. In other words, to miss something that is actually occurring. Type I and type II error are inversely related. Since the design of the sampling program is conservative and errs on the side of false alarm vs. miss, a greater alpha value (0.10) has been selected to increase power and consequently decrease the type II error. The power analyses presented here are do not account for multiple testing or use Bonferoni or other correction to adjust for experiment wise error rates. Correcting for multiple testing would result in lower nominal type I errors and reduced power for a given sample size.

The power analyses were run based on two effect sizes: 1) the difference between the station baseline mean and benchmark and 2) halfway between the station baseline mean and benchmark.

[1] Effect size is the magnitude of an effect. In a priori power analysis, the effect size quantifies the magnitude difference between two groups that the test will be able to determine.

The following parameters were selected for power analysis as they have a large number of detected values, have elevated concentrations during baseline conditions, are expected to be the most affected parameters during mine operation and are expected to require the largest sample sizes to detect change:

- Aluminum
- Arsenic
- Copper
- Iron
- Cadmium

A short list of sites was compiled from key sites in the proposed CREMP program. The following sites were selected for targeted power analysis:

- Camp Lake:
    - JL0-02-S
    - JL0-09-S
- Sheardown Lake NW:
    - DL0-01-1-S
    - DL0-01-5-S
- Sheardown Lake SE:
    - DL0-02-3-S
- Mary Lake:
    - BL0-01-S
    - BL0-05-S

Two different types of power analysis were run, depending on the proportion of data above MDL. Several modifications to each approach were taken, depending on availability of data at a specific site.

1) The power to detect a change in means was assessed for parameters with sufficient data above MDL (<15% of non-detected data). A before-after (BA) design was used when control data was not available and power analysis was carried out using a two sample t-test to compare means. This approach is less rigorous when compared to the BACI design and does not control for natural temporal changes.

   For the purposes of analysis, for parameters with <15% non-detected data, only detected data was analyzed. This method was selected due to a variety of detection limits present in the historic data. In some cases, imputation of detection limits occurred, as discussed in Section 2.2. Although all imputation assumptions were conservative; analysis of the detected data removes the possibility that data analysis was affected by imputation or elevated detection limits. To verify the use of the detected data to inform mean values for the power analysis, the mean values estimated with detected data are compared to the mean values estimated via Regression on Order (ROS) method. The Regression on Order (ROS) statistics method is recommended by the BC Ministry of Environment as a method to calculate statistics in data sets including non-detects and especially those affected by left-censored data (Huston and Juarez-Colunga, 2009). Both of these values are provided for each key parameter examined for the sake of comparison. In general, the mean estimate based on detected data is larger than the ROS estimate. This is conservative for the power analysis as a higher baseline mean corresponds to a smaller change to be detected post mining.

2) The power to detect a change in the proportion of values above MDL was assessed for parameters with a large proportion of values below MDL (>15% of non-detected data). For some parameters the baseline dataset is represented predominantly by values below MDL. This occurred for arsenic and cadmium at all stations. For these parameters, the exact magnitude of the parameters under baseline conditions is unknown. Although a full BACI analysis will be carried out for data analysis purposes, simplified designs were assumed for the power analysis. Two approaches were utilized for the test of proportions:

   a. BA designs were assessed using a test for two independent proportions (Agresti, 1990).

   b. McNemar's test (Agresti, 1990) was used to assess the power to detect a difference between the paired proportions at impact and control stations. As for continuous data, pairing allows exploitation of the fact that the variance of the difference between paired data is smaller than the variance of the difference between independent samples (Agresti, 1990). Under a full BACI design, the baseline and post-mining paired proportions can be compared to assess whether a change is mine related.

McNemar test for the equivalence of paired proportions (each impact sample paired with a correlated control sample collected at a comparable time) is carried out using the off-diagonal elements (p01 and p10) of a 2x2 contingency table. It is helpful to reference Table B.5 for discussions related to the analysis of proportions. This is a novel approach that enables the use of data highly affected by censored data, where a meaningful comparison of means is not possible and the utility of left-censored methods is limited. To our knowledge, this approach has not been used in other projects, but is supported within scientific literature as a valid method to deal with left-censored data (Agresti, 1990).

Table B.5 Proportion Labels for 2x2 Contingency Table

Impact	Control		
	<MDL	>MDL	Total
<MDL	p_{00}	p_{01}	p_{0+}
>MDL	p_{10}	p_{11}	p_{1+}
Total	p_{+0}	p_{+1}	p_{++}

For lakes, both shallow and deep sites were sampled at the same location at the same time. Although baseline results did not indicate stratification occurs in any of the lakes, the sampling program will continue to sample deep and shallow stations separately, with the hypothesis that mine-related effects could have different depth affects. Data from two depths will be analyzed separately. The power analysis presented here considers shallow stations. Sample size, median, mean, standard deviation and power were compared power between sites for a variety of lake sites. In general, sample sets that have a lower sample size, higher variability and a small difference from station baseline mean and benchmark have low power.

B.3.2 Results

Since the power analysis was completed on a site-specific and parameter-specific basis, the results were interpreted by identifying the sites and parameters that are most constraining. Table B.6 highlights the sites and parameters that are expected to constrain analysis. It is not unexpected that aluminum is a constraining factor across a number of sites since aluminum is the most enriched metal during baseline conditions. Analysis of Figure B.3 shows that sites identified as constraining factors for aluminum concentrations are those sites where the distribution of aluminum data occurs close to the benchmark. Subsequent discussion of each parameter follows individually in Section B.3.2.1 through Section B.3.2.3.

Table B.6 Lake Power Analysis – Constraining Sites and Parameters

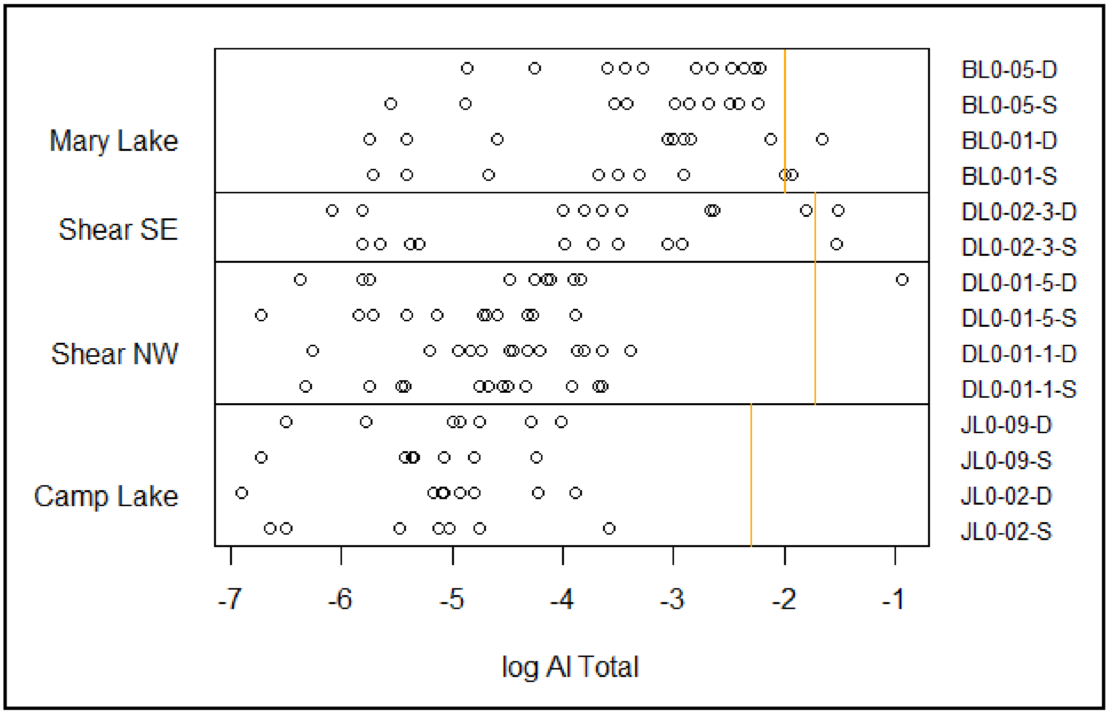
Parameter	Site	Waterbody	Power (given sample size of 10, alpha of 0.1)	Power (given sample size of 50)
Aluminum	DL0-02-3-S	Sheardown Lake SE	50%	78%
	BL0-01-S	Mary Lake	38%	58%
	BL0-05-S	Mary Lake	30%	58%
Copper	BL0-01-S	Mary Lake	30%	38%
Iron	BL0-01-S	Mary Lake	50%	75%

NOTES:

1. POWER IS CALCULATED BASED ON AN EFFECT SIZE EQUAL TO HALFWAY BETWEEN THE STATION BASELINE MEAN AND BENCHMARK.

B.3.2.1 Aluminum

Total aluminum values are elevated throughout the mine-site area and are noticeably elevated at sites within Sheardown Lake SE and Mary Lake (median aluminum ranges from 0.024 mg/L to 0.061 mg/L between individual sites) when compared to values in Camp Lake and Sheardown Lake NW (median aluminum ranges from 0.0059 mg/L to 0.0093 mg/L between individual sites). Sufficient power is expected to be obtained for sites examined within Camp Lake (JL0-1-S/D, JL0-2-S/D, JL0-09-S/D) and Sheardown Lake (DL0-01-1-S/D and DL0-01-5-S/D) with 5 samples. In contrast, approximately fifty (50) samples are expected to be required within Sheardown Lake SE and Mary Lake. Figure B.72 demonstrates that sites within Sheardown Lake and Mary Lake have a distribution of aluminum values very close to the benchmark. In contrast, Camp Lake and Sheardown Lake SW have a distribution of aluminum values further from the benchmark. Values in Table B.7 show that a higher standard deviation also characterizes data from Sheardown Lake SE and Mary Lake.



NOTES:

1. THE CAMP LAKE BENCHMARK FOR ALUMINUM IS 0.1 mg/L (LOG VALUE = -2.3).
2. THE SHEARDOWN LAKE BENCHMARK FOR ALUMINUM IS 0.179 mg/L (LOG VALUE = -1.72).
3. THE MARY LAKE BENCHMARK FOR ALUMINUM IS 0.137 mg/L (LOG VALUE = -1.99).

Figure B.72 Baseline Aluminum Values with Respect to the Benchmark

Table B.7 Results of Aluminum Power Analysis - Lakes

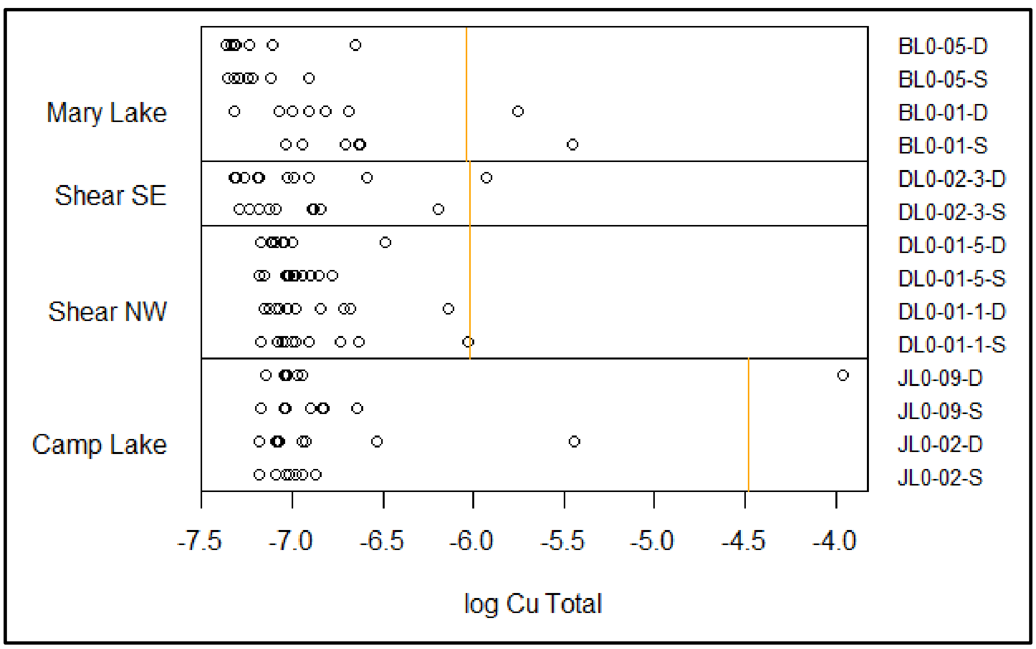
Station	Total Sample Size	Sample Size Detected	Median (mg/L)	Standard Deviation (mg/L)	Log Mean (mg/L)	Log Standard Deviation (mg/L)	ROS Log Mean (mg/L)	Benchmark Value (mg/L)	Log Benchmark Value (mg/L)	N Required	N Required (half benchmark)[1]
Camp Lake											
JL0-02-S	8	8	0.0063	0.01	-5.23	1.00	-5.23	0.1	-2.30	2.93	5
JL0-02-D	9	8	0.0068	0.01	-4.79	0.48	-4.91	0.1	-2.30	2.49	5
JL0-09-S	7	7	0.0048	0.00	-5.28	0.76	-5.28	0.1	-2.30	2.98	5
JL0-09-D	7	7	0.0072	0.01	-5.04	0.86	-5.04	0.1	-2.30	2.73	5
Sheardown Lake NW											
DL0-01-1-S	13	13	0.0093	0.01	-4.80	0.82	-4.8	0.18	-1.72	3.08	5
DL0-01-1-D	13	13	0.012	0.01	-4.47	0.76	-4.47	0.18	-1.72	2.75	5[2]
DL0-01-5-S	11	11	0.0089	0.01	-5.03	0.83	-5.03	0.18	-1.72	3.31	5
DL0-01-5-D	11	10	0.015	0.12	-4.20	1.42	-4.22	0.18	-1.72	2.48	5[2]
Sheardown Lake SE											
DL0-02-3-S	10	9	0.024	0.07	-3.89	1.36	-4.23	0.18	-1.72	2.17	50
DL0-02-3-D	10	9	0.031	0.07	-3.29	1.36	-3.40	0.18	-1.72	1.57	50[2]
Mary Lake											
BL0-01-S	9	9	0.030	0.05	-3.68	1.36	-3.68	0.14	-1.99	1.69	50
BL0-01-D	10	10	0.048	0.06	-3.71	1.53	-3.71	0.14	-1.99	1.72	50[2]
BL0-05-S	11	11	0.057	0.04	-3.21	1.09	-3.21	0.14	-1.99	1.22	50
BL0-05-D	11	11	0.061	0.04	-3.11	0.87	-3.11	0.14	-1.99	1.12	50[2]

NOTES:

1. N REQUIRED IS BASED ON A POWER EQUAL TO 80%, AN ALPHA VALUE EQUAL TO 0.1 AND AN EFFECT SIZE EQUAL TO HALFWAY BETWEEN THE STATION MEAN AND THE BENCHMARK. THIS ANALYSIS ASSUMES EQUAL STANDARD DEVIATION BEFORE AND AFTER MINE INFLUENCE.
2. VALUES ESTIMATED BASED ON SIMILAR SITES.

B.3.2.2 Copper

Total copper values are observed to be elevated site-wide and are particularly elevated within Mary River and Camp Lake tributary. Although total copper concentrations are reduced in lake sites compared to stream sites, certain sites remain elevated. The copper benchmark in Sheardown Lake and Mary is the same (0.0024 mg/L) and the Camp Lake benchmark is slightly higher (0.011 mg/L). Based on the existing baseline data, five baseline samples are expected to provide sufficient power to detect changes between baseline mean and halfway between baseline mean and the benchmark value (comparisons on log scale) at all sites within Camp Lake, at DL0-01-5-/S/D (Sheardown Lake NW) and DL0-02-3-S/D (Sheardown Lake SE) and BL0-05-S/D (Mary Lake). Ten post-mining samples are expected to be sufficient at DL0-01-1-S/D. As show on Figure B.73, the BL0-01-S/D site has a distribution of data which falls on either side of the benchmark. Due to the elevated median values and high variability, with the current baseline data it is estimated 50 samples would be required to show significance for the sites examined in Mary Lake; however, even with collection of 50 samples the power to detect change would only be 38%. With collection of additional baseline data in 2014, the power to detect change for copper is expected to increase.



NOTES:

1. THE CAMP LAKE BENCHMARK FOR COPPER IS 0.011 mg/L (LOG VALUE = -4.5).
2. THE SHEARDOWN LAKE BENCHMARK FOR COPPER IS 0.0024 mg/L (LOG VALUE = -6.0).
3. THE MARY LAKE BENCHMARK FOR COPPER IS 0.0024 mg/L (LOG VALUE = -6.0).

Figure B.73 Baseline Copper Values with respect to the Benchmark

Table B.8 Results of Copper Power Analysis - Lakes

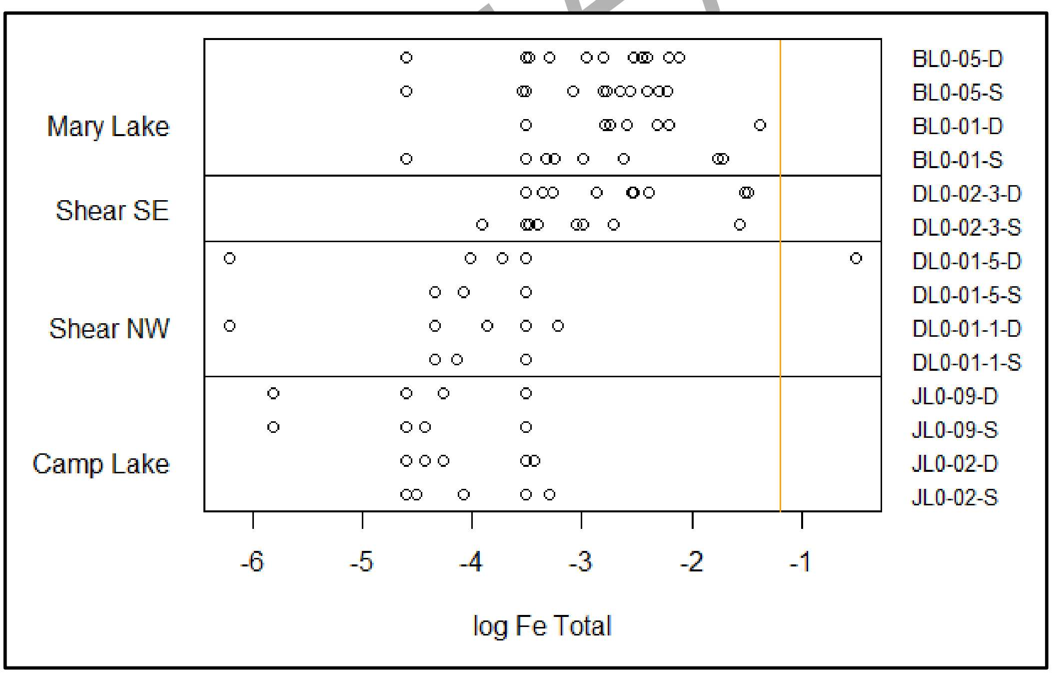
Station	Total Sample Size	Sample Size Detected	Median (mg/L)	Standard Deviation (mg/L)	Log Mean (mg/L)	Log Standard Deviation (mg/L)	Benchmark Value (mg/L)	Log <Benchmark Value (mg/L)	Difference between log mean and log benchmark (mg/L)	N Required
JL0-01-S	12	10	0	0.00076	-6.8	0.44	0.011	-4.5	2.3	5[2]
JL0-01-D	10	8	0	0.0043	-6.6	0.94	0.011	-4.5	2.1	5[2]
JL0-02-S	8	8	0	0.00008	-7.0	0.09	0.011	-4.5	2.5	5
JL0-02-D	9	9	0	0.0011	-6.8	0.55	0.011	-4.5	2.3	5[2]
JL0-09-S	7	7	0	0.00018	-6.9	0.18	0.011	-4.5	2.4	5
JL0-09-D	7	7	0	0.0068	-6.6	1.2	0.011	-4.5	2.1	5[2]
DL0-01-1-S	11	11	0	0.00046	-6.9	0.32	0.0024	-6.0	0.85	10
DL0-01-1-D	11	11	0	0.00040	-6.9	0.30	0.0024	-6.0	0.88	10[2]
DL0-01-5-S	11	11	0	0.00011	-7.0	0.12	0.0024	-6.0	0.97	5
DL0-01-5-D	11	11	0	0.00021	-7.0	0.18	0.0024	-6.0	0.99	5[2]
DL0-02-3-S	10	10	0	0.00040	-7.0	0.32	0.0024	-6.0	0.97	5
DL0-02-3-D	10	10	0	0.00061	-7.0	0.43	0.0024	-6.0	0.95	5[2]
BL0-01-S	7	7	0	0.0012	-6.6	0.53	0.0024	-6.0	0.55	50[6]
BL0-01-D	10	10	0	0.00071	-6.8	0.41	0.0024	-6.0	0.77	NA
BL0-05-S	9	9	0	0.00011	-7.2	0.13	0.0024	-6.0	1.2	5
BL0-05-D	9	9	0	0.00021	-7.2	0.23	0.0024	-6.0	1.2	5

NOTES:

1. N REQUIRED IS BASED ON A POWER EQUAL TO 80%, AN ALPHA VALUE EQUAL TO 0.1 AND AN EFFECT SIZE EQUAL TO HALFWAY BETWEEN THE STATION MEAN AND THE BENCHMARK. THIS ANALYSIS ASSUMES EQUAL STANDARD DEVIATION BEFORE AND AFTER MINE INFLUENCE.
2. VALUES ESTIMATED BASED ON SIMILAR SITES.
3. NA SITES WERE NOT ASSESSED.
4. TOTAL SAMPLE SIZE REPRESENTS THE NUMBER OF MEASURED SAMPLES AT EACH SITE (EXCLUDING NON-DETECTS).
5. THERE ARE NO NON-DETECT VALUES AT THIS SITE; THEREFORE, THE ROS LOG MEAN IS THE SAME AS THE LOG MEAN CALCULATED AND IS NOT PRESENTED.
6. SAMPLE SIZE REQUIRED FOR BL0-01-S IS AFFECTED BY OUTLIER VISIBLE IN FIGURE B.73.

B.3.2.3 Iron

Total iron concentrations are slightly elevated site-wide, but greater iron concentrations were observed in streams than rivers. There is a significant deficit of detection iron data at Camp Lake and Sheardown Lake NW. Due to the low numbers of detected samples, sample size cannot be estimated for Camp Lake and Sheardown Lake NW. Baseline sampling during 2014 is recommended to increase the sample size at these sites, or, alternately, an approach that considers non-detects is required. Approximately ten post-mining samples are expected to be sufficient to determine significant differences between baseline impact and post-mining impact sites within Sheardown Lake SE. The recommended sample size for Mary Lake is problematic, particularly for the BL0-01-S site. This site has among the highest mean and median iron values, in addition to elevated variability and relatively small sample size. Even with collection of fifty samples at BL0-01-S, power at this station does not exceed 75%. Similar to other parameters, additional baseline data from 2014 is expected to increase power for iron at this site.



NOTES:

1. THE BENCHMARK FOR IRON IN ALL LAKES IS 0.3 mg/L (LOG VALUE = -1.2).

Figure B.74 Baseline Iron Values with Respect to the Benchmark

Table B.9 Results of Iron Power Analysis - Lakes

Station	Total Sample Size	Sample Size Detected	Median (mg/L)	Standard Deviation (mg/L)	Log Mean (mg/L)	Log Standard Deviation (mg/L)	ROS Log Mean (mg/L)	Benchmark Value (mg/L)	Log Benchmark Value (mg/L)	Difference between log mean and log benchmark (mg/L)	N Required
Camp Lake											
JL0-02-S	8	3	0.017	0.014	-4.0	0.61	-4.5	0.3	-1.2	2.8	-
JL0-02-D	9	3	0.014	0.011	-4.0	0.53	-4.6	0.3	-1.2	2.8	-
JL0-09-S	7	1	0.012	NA	-4.4	NA	-4.4	0.3	-1.2	3.2	-
JL0-09-D	7	1	0.014	NA	-4.3	NA	-4.2	0.3	-1.2	3.1	-
Sheardown Lake NW											
DL0-01-1-S	13	5	0.030	0.009	-3.8	0.41	NA	0.3	-1.2	2.6	-
DL0-01-1-D	13	4	0.017	0.016	-4.4	1.3	-4.4	0.3	-1.2	3.2	-
DL0-01-5-S	11	4	0.024	0.009	-3.9	0.42	NA	0.3	-1.2	2.7	-
DL0-01-5-D	11	6	0.027	0.236	-3.6	1.8	NA	0.3	-1.2	2.4	-
Sheardown Lake SE											
DL0-02-3-S	10	7	0.047	0.066	-3.0	0.75	NA	0.3	-1.2	1.8	10
DL0-02-3-D	10	8	0.079	0.076	-2.5	0.70	-2.8	0.3	-1.2	1.3	10[2]
Mary Lake											
BL0-01-S	9	7	0.050	0.068	-2.9	1.00	NA	0.3	-1.2	1.7	50
BL0-01-D	10	8	0.070	0.071	-2.6	0.70	-3.0	0.3	-1.2	1.4	-
BL0-05-S	11	9	0.070	0.025	-2.7	0.41	-2.9	0.3	-1.2	1.5	5
BL0-05-D	11	11	0.060	0.036	-2.9	0.74	-2.9	0.3	-1.2	1.7	5[2]

NOTES:

1. N REQUIRED IS BASED ON A POWER EQUAL TO 80%, AN ALPHA VALUE EQUAL TO 0.1 AND AN EFFECT SIZE EQUAL TO HALFWAY BETWEEN THE STATION MEAN AND THE BENCHMARK. THIS ANALYSIS ASSUMES EQUAL STANDARD DEVIATION BEFORE AND AFTER MINE INFLUENCE.
2. VALUES ESTIMATED BASED ON SIMILAR SITES.
3. IF INSUFFICIENT SAMPLE SIZE IS AVAILABLE, NO VALUE FOR N WAS PROVIDED.

B.3.2.4 Cadmium, Arsenic and Iron Proportions

The proportion of data below MDL was determined for each of the target parameters at selected stations. Cadmium, Arsenic and iron were identified as requiring analysis of proportions (Figure B.10). A normal approximation has been used to estimate the width of the confidence interval on the proportion of values below (above) MDL for given sample sizes (Table B.10). For analysis purposes, when the proportion of non-detects is close to 100%, an exact test will be used.

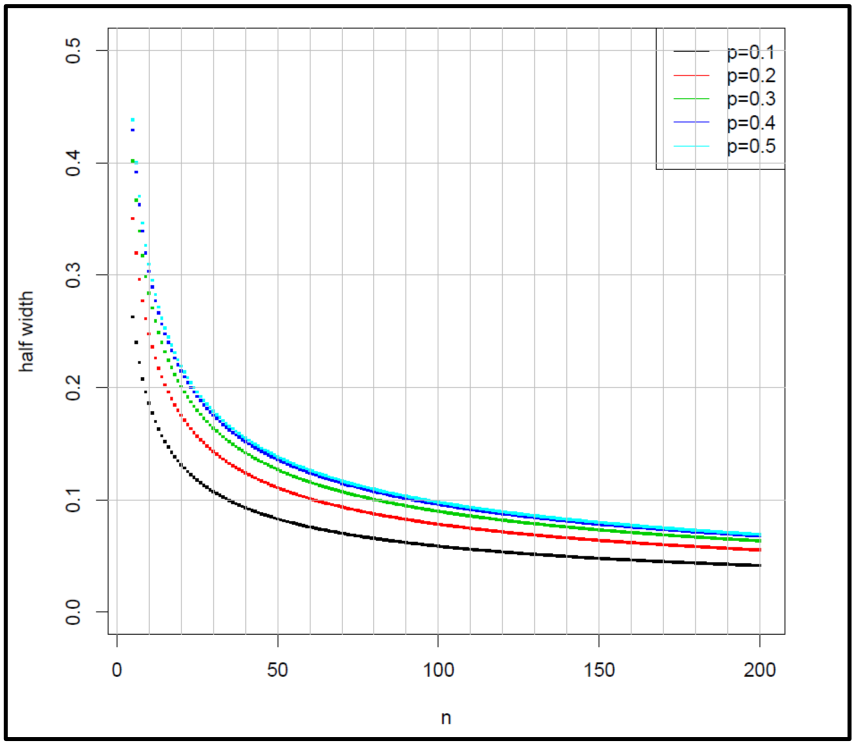
In order to assess statistical power to detect a change in the proportion of values below (or above) MDL from baseline to post-mining, we present a table of the sample sizes required. We see that a sample size of 12 is sufficient to show a change from 30% to 80%; a sample size of 8 is sufficient to show a difference between 20% and 80%.

Table B.10 Sample Size Required to Obtain 80% Power

	Proportion Above (below) MDL Post Mining				
Baseline Proportion Above (below) MDL	0.4	0.5	0.6	0.7	0.8
0.2	64	31	18	12	8
0.3	281	74	33	19	12
0.4	NA	305	77	33	18

NOTE:

1. Sample size required for baseline and post-mining to obtain 80% power with a two-sided type I error of 0.05 (or one-sided type I error of 0.05.



NOTES:

2. FOR THIS GRAPH, P = PROPORTION OF VALUES BELOW MDL/NON-DETECT.
3. THE CONFIDENCE INTERVAL WIDTHS ARE SYMMETRIC AROUND P=0.5. THERFORE P=0.1 AND 0.9; P=0.2 AND 0.8; P=0.3 AND 0.7; P=0.4 AND 0.6.

Figure B.75 Half 95% Confidence Interval Width

B.3.3 Recommendations

Power analysis completed for a subset of parameters at select areas is expected to be used to detect change at critical locations for most parameters. Parameters used here are indicator parameters, which are expected to have small effects sizes and represent the most number of samples required to be collected. There are two major factors that evidently constrain the power analysis for the lake samples. First, elevated aluminum concentrations create difficulties obtaining sufficient power, especially within Mary Lake and one site in Sheardown Lake SE. Second, the BL0-01-S site has high concentrations of aluminum, copper and iron, in addition to high variability. This site is predicted to have very low power, even with sample sizes as great as fifty.

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

1. Increase the amount of baseline data (this will occur during the 2014 season of baseline data collection that will occur concurrently with mine construction but prior to mine effluent or dust emission);
2. Collect data at one more station within Sheardown Lake SE (recommend DL0-02-6)
3. Add two sites at the inlet location of Mary Lake near BL0-01 to ensure sufficient power to detect changes at this key location.

4. Add one additional site to the inlet location of Mary Lake near BL0-05 to ensure sufficient power to detect changes at this key location.
5. Add two to three lake reference sites for post-mining data collected. Ideally these sites should be consistent with the EEM reference sites.
6. Ensure that samples collected at all locations are collected as close to the same day and time as possible.
7. Three yearly samples are recommended to be collected during the first three-years of mine operation.

B.4 CONCLUSIONS

The only distinct depth trends are noted in Sheardown Lake for aluminum. The rest of the lake data gathered a lake stations suggests aggregations of deep and shallow stations is appropriate.

Table B.11 summarizes the trends observed in the data.

B.5 REFERENCES

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Table B.11 Summary of Trend Analysis in Area Lakes

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

APPENDIX C

DETAILED REVIEW OF BASELINE STREAM WATER QUALITY

(Pages C-1 to C-70)

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

BAFFINLAND IRON MINES CORPORATION
MARY RIVER PROJECT

DETAILED REVIEW OF BASELINE STREAM WATER QUALITY
NB102-181/33-1C

Rev	Description	Date
1	Issued in Final	May 30, 2014

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C – STREAM WATER QUALITY REVIEW

C.1 OVERVIEW

A detailed review of water quality within the mine site streams was undertaken to facilitate the development of the Core Receiving Environment Monitoring Program (CREMP) for water and sediment quality. The review adopted the same approach applied to the detailed review of lake water quality presented in Appendix B. As stated in Section 1.2 of the main report, the objectives of the baseline review were as follows:

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

The focus of this review of stream water quality is the two main receiving waters of mine effluent, which are also close to the Project mining area that will be exposed to ore dust deposition: Camp Lake Tributary 1 (CLT-1) and the Mary River.

Parameters of interest in the baseline review included water quality stressors of potential concern (SOPCs) identified on the basis of the existence of an established water quality guideline, as well as other factors such as Exposure Toxicity Modifying Factors (ETMF): pH, water hardness, dissolved organic carbon, etc., and indicator parameters (alkalinity, chloride, nitrate). Baseline water quality data was compared to Canadian Council of Ministers of the Environment (CCME) – Canadian Water Quality Guidelines for the Protection of Freshwater Aquatic Life (CWQG-PAL). The focus was on total concentrations (versus dissolved) since CWQG-PAL guidelines are developed for total concentrations. The parameters of interest are displayed graphically in box plots. The box plots are used to portray natural ranges of selected parameters. Concentration data measured for the parameters of interest has been log transformed and further analyzed to investigate the possibility of aggregating data, bearing in mind:

- Seasonal variability (between spring, summer and fall samples)
- Inter-annual variability (from 2006 through 2008 and 2011 through 2013)

To assist in the development of study designs, parameter and station-specific a priori power analyses were completed in order to determine the power of the proposed sampling program to detect statistical changes. As per the Assessment Approach and Response Framework in the CREMP (see Figure 2.12 in the main report), management action is triggered if the mean concentrations of any parameter at selected stations reach benchmark values. Benchmark values were developed for the identified SOPCs that consider aquatic toxicology, natural enrichment in the Project area, or low concentrations below MDLs (Intrinsik, 2014; see Section 2.7.3 of the main report). Draft benchmarks were applied in the power analysis of the baseline presented in this detailed review.

The resultant study design for the monitoring of Project-related effects to water quality is presented in Section 2.7 of the main report.

C.2 STREAM FLOW CHARACTERISTICS

Stream water quality sampling was completed within the drainages, streams and rivers in vicinity to the mine station from 2005 through 2008 and 2011 through 2013. The most comprehensive sampling was conducted in 2007.

The streams and rivers in the study area typically flow in early June and stop flowing in the second half of September. The hydrograph developed from the H6 stream gauge on the Mary River is presented as Figure C.1. Smaller creeks typically run dry and/or freeze earlier than the Mary River. Only the largest rivers in the area such as the Ravn River or the Rowley River flow during the winter.

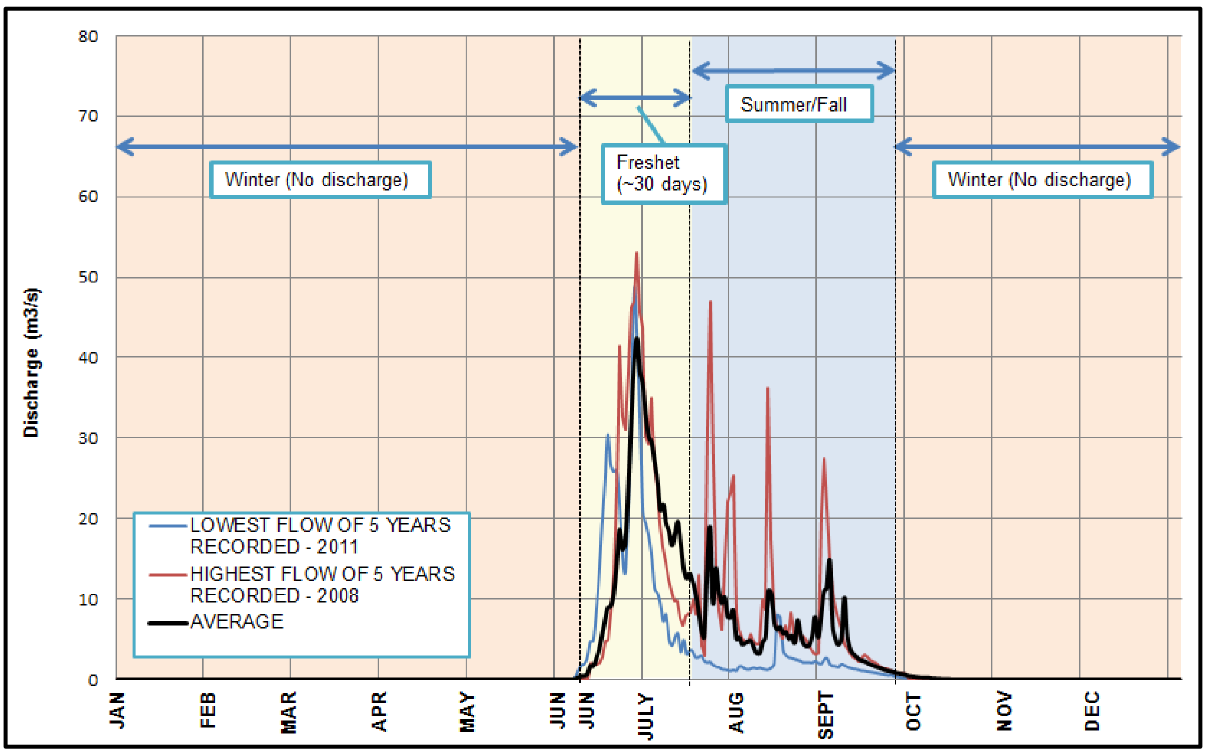


Figure C.1 Hydrograph of Stream Gauge H6 on the Mary River (2008-2011)

Understanding the flow regime at the station is an important backdrop to understanding the seasonal differences.

A review of the baseline data for each of the streams in vicinity to the mine site is provided below.

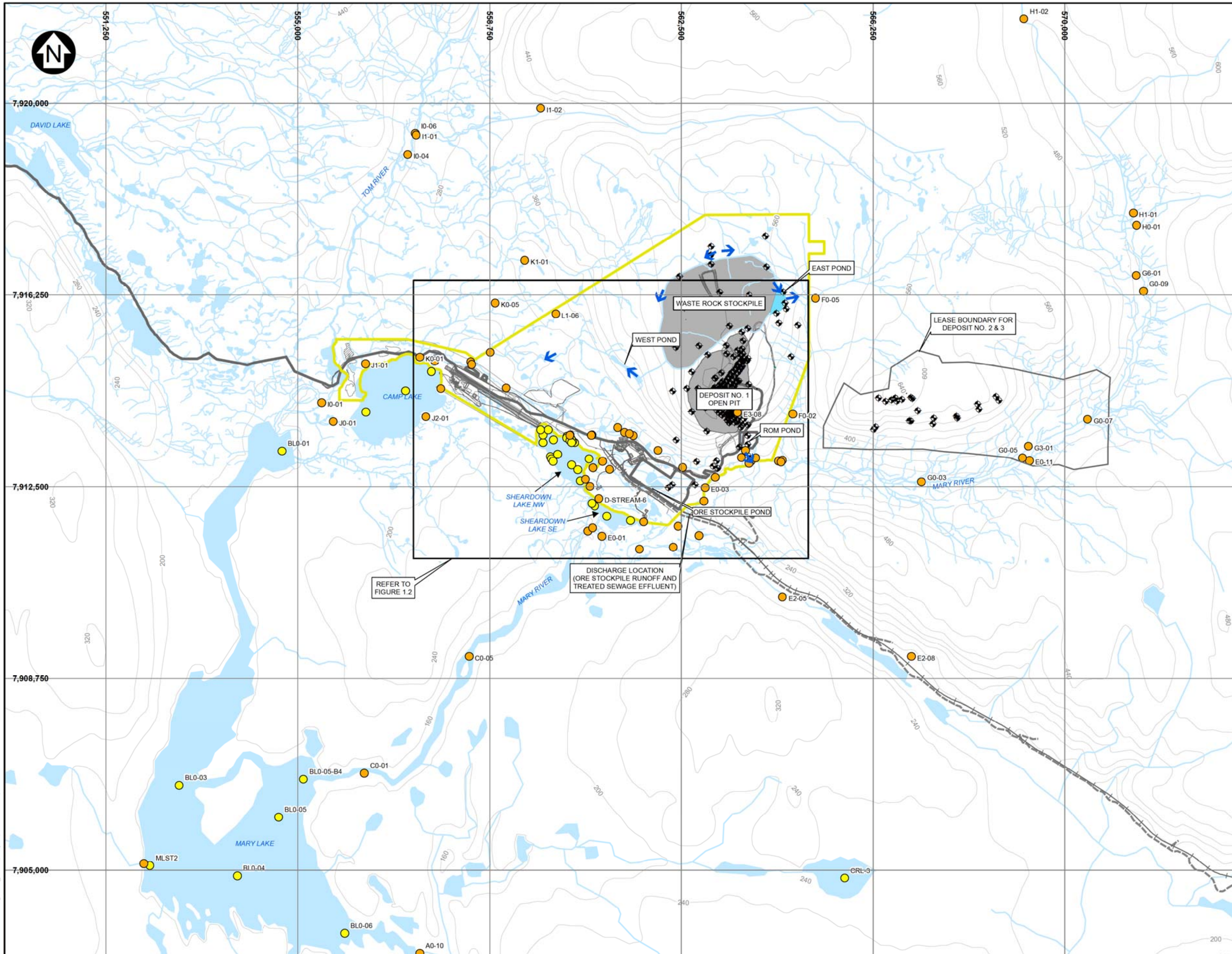
C.3 BASELINE SUMMARY

C.3.1 Mary River

Water quality samples within Mary River have been collected from 2005 through 2013, at a number of stations along the Mary River. The following 11 stations were selected as applicable for future CREMP monitoring and are discussed in detail below. A total of 351 samples from these 11 stations on Mary River were collected. Most sampling was completed during the summer season, from July through August. The greatest number of samples was collected during 2007 and 2008. Starting upstream of the mine station working downstream to Mary Lake, the sample stations are described below (Figures C.2 and C.3):

- G0-09: This is the most upstream station on the mainstem of the Mary River. This station will remain an upstream control station that will remain unaffected by mine-affected seepage or mine-affected dust particulate.
- G0-03: This station is on Mary River mainstem, downstream from G0-09, but upstream of any mine-related effluent effects.
- G0-01: This station is located on Mary River mainstem, immediately upstream of the confluence with the F-Tributary to which the east waste rock stormwater pond will discharge.
- E0-10: This station is located on the Mary River mainstem, immediately downstream of the F-tributary confluence. During operation of the proposed mine, seepage effects from the East Pond could potentially affect water quality at this station.
- E0-03: This station is located on the Mary River mainstem, downstream of the proposed ROM Pond discharge.
- E0-04: This station is located on the Mary River mainstem, downstream of the proposed ROM Pond discharge and immediately downstream of E0-03.
- E0-21: This station is located on the Mary River mainstem and is located downstream of all potential mine effects and is being considered as a “near-field” exposure station for the EEM program.
- E0-20: This station is located on the Mary River mainstem and is located downstream of all potential mine effects. The station is also located immediately downstream of station E0-21.
- C0-10: This station is located on the Mary River mainstem and is located downstream of all potential mine effects.
- C0-05: This station is located on the Mary River mainstem and is located downstream of all potential mine effects and is being considered as a “far-field” exposure station for the EEM program.
- C0-01: This station is located on the Mary River mainstem near the mouth, downstream of all potential mine effects. The station is being considered as an alternate “far-field” exposure station for the EEM program.

To simplify discussion and determine whether data aggregation would be appropriate, the stations above have been discussed in regard to seasonal and inter-annual variability, due to very similar water quality characteristics:



REV	DATE	DESCRIPTION	DESIGNED	DRAWN	CHK'D	APP'D
1	30MAY'14	ISSUED WITH REPORT	RAC	SWK	RAC	RAM
0	27MAR'14	ISSUED WITH REPORT	RAC	SWK	RAC	RAM

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LEGEND:

- LAKE SAMPLE LOCATION
- STREAM SAMPLE LOCATION
- DRILLHOLE LOCATION
- EXISTING TOTE ROAD
- PROPOSED RAILWAY ALIGNMENT
- PROPOSED CONSTRUCTION ACCESS ROAD
- PROPOSED SITE INFRASTRUCTURE
- RIVER/STREAM/DRAINAGE
- WATER
- POTENTIAL DEVELOPMENT AREA (PDA)
- PROPOSED MINE INFRASTRUCTURE

NOTES:

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2. COORDINATE GRID IS IN METRES. COORDINATE SYSTEM: NAD 1983 UTM ZONE 17N.
3. CONTOURS ARE IN METRES. CONTOUR INTERVAL VARIES.
4. LAKE SAMPLE LOCATIONS VARY SLIGHTLY DURING WINTER MONTHS DUE TO ICE CONDITIONS.
5. INFRASTRUCTURE INFORMATION PROVIDED BY HATCH ON JANUARY 31, 2014.

SCALE 1 0.5 0 1 2 3 4 km

BAFFINLAND IRON MINES CORPORATION

MARY RIVER PROJECT

HISTORIC WATER QUALITY STATIONS MINE SITE AREA

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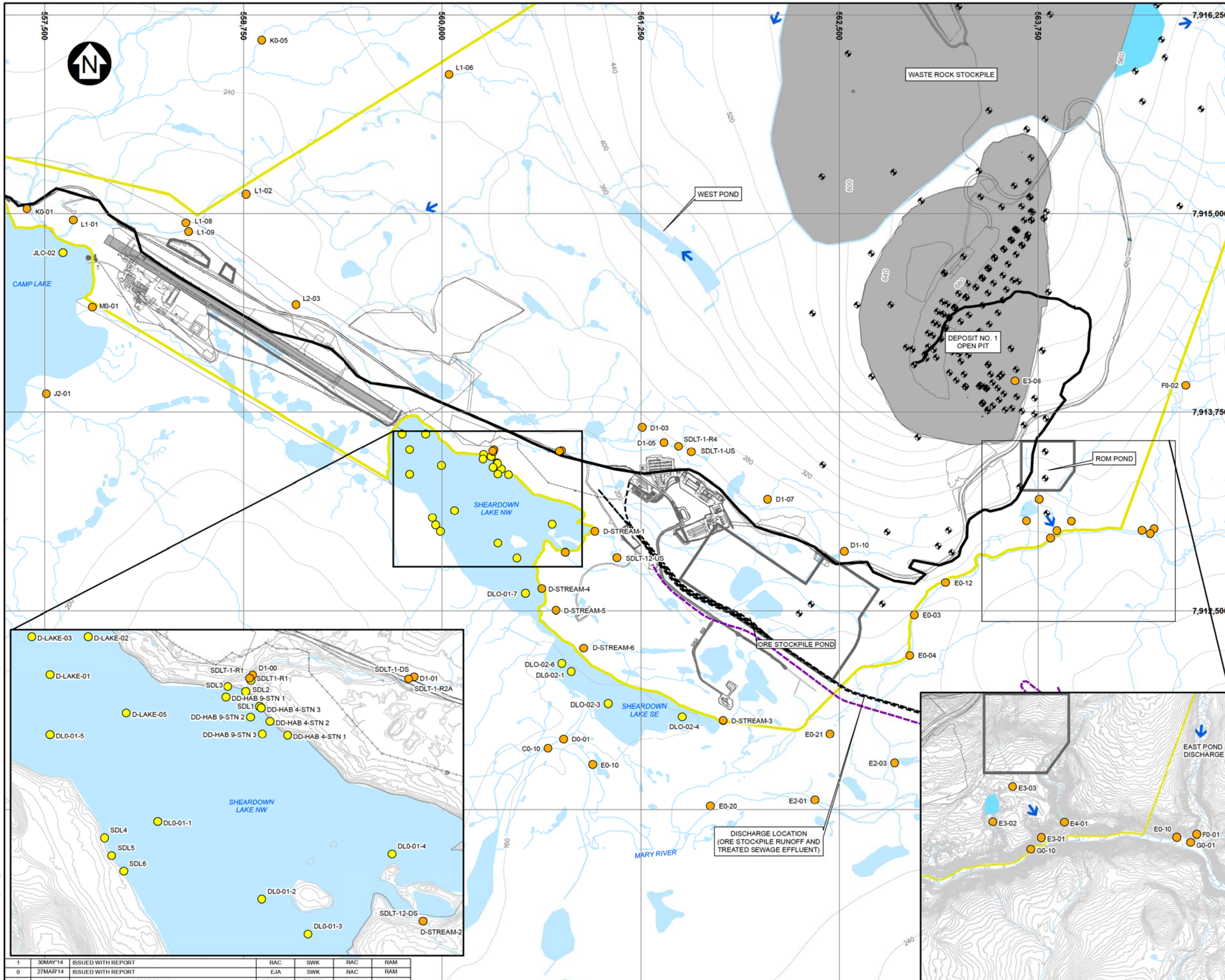
P/A NO. NB102-181/33 | REF NO. 1

FIGURE C.2 | REV 1



REV	DATE	DESCRIPTION	DESIGNED	DRAWN	CHK'D	APP'D
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0	27MAR'14	ISSUED WITH REPORT	EJA	SWK	RAC	RAM

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LEGEND:

- LAKE SAMPLE LOCATION
- STREAM SAMPLE LOCATION
- DRILLHOLE LOCATION
- EXISTING TOTE ROAD
- PROPOSED RAILWAY ALIGNMENT
- PROPOSED CONSTRUCTION ACCESS ROAD
- PROPOSED SITE INFRASTRUCTURE
- RIVER/STREAM/DRAINAGE
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NOTES:

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2. COORDINATE GRID IS IN METRES. COORDINATE SYSTEM: NAD 1983 UTM ZONE 17N.
3. CONTOURS ARE IN METRES. CONTOUR INTERVAL VARIES.
4. LAKE SAMPLE LOCATIONS VARY SLIGHTLY DURING WINTER MONTHS DUE TO ICE CONDITIONS.
5. INFRASTRUCTURE INFORMATION PROVIDED BY HATCH ON JANUARY 31, 2014.

SCALE 250 125 0 250 500 750 1,000 1,250 m

BAFFINLAND IRON MINES CORPORATION

MARY RIVER PROJECT

HISTORIC WATER QUALITY STATIONS IMMEDIATE MINE SITE AREA

Knight Piésold CONSULTING

P/A NO. NB102-181/33 | REF NO. 1

FIGURE C.3 | REV 1

- G0-09, G0-03, E0-10 and G0-01: These stations represent upstream control stations that are expected to remain relatively unaffected by mine development (except perhaps by dust deposition). All stations, except E0-10 will also act as control stations once the proposed mine commences operation.
- E0-03, E0-21, E0-20: These stations have similar water quality and represent near-field exposure stations during operation of the proposed mine.
- C0-10, C0-05, C0-01: These stations have similar water quality and represent far-field exposure stations during operation of the proposed mine.

A summary of the data collected during each season, with respect to year and station are included in Table C.1. A graphical representation of the sampling events is provided in Figure C.4.

Table C.1 Mary River Sample Size

Year	Summer	Fall	Winter
2005	5	5	5
2006	16	31	17
2007	12	39	32
2008	6	50	33
2009	5	14	10
2010	0	4	4
2011	0	5	7
2012	8	9	8
2013	8	9	9
Station	**Summer**	**Fall**	**Winter**
G0-09	8	26	18
G0-03	7	16	13
G0-01	6	23	16
E0-10	7	26	15
Station	**Summer**	**Fall**	**Winter**
E0-03	10	28	21
E0-04	0	1	1
E0-21	2	2	3
E0-20	2	2	3
C0-10	10	27	21
C0-05	2	3	4
C0-01	6	12	10

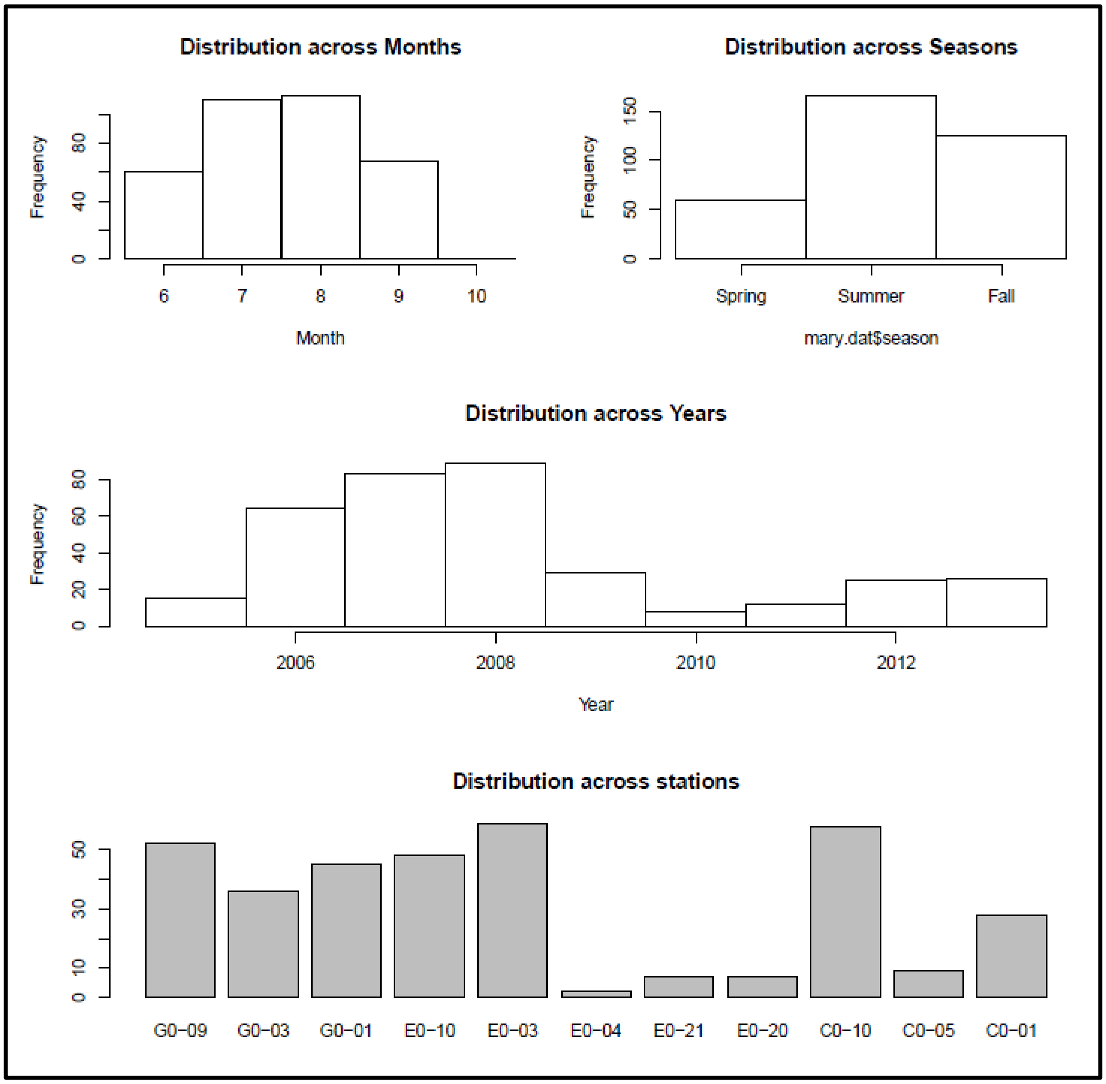


Figure C.4 Mary River – Graphical Summary of Sampling Events

The following summarizes the data review observations for the of the physical parameter data. Box plots that follow present upstream on the far left, moving downstream towards the right.

pH (Figure C.5)

- Mary River is slightly alkaline, with total median pH of 7.87 (range from 6.26 to 8.5).
- No distinct geographic trends were noted.

Alkalinity (Figure C.6)

- Mary River stations have uniformly high median alkalinity values that range from 40 to 50 mg/L $CaCO_3$, with maximum alkalinity values reaching close to 120 mg/L $CaCO_3$, classifying the lake water as having low sensitivity to acidic inputs.
- No distinct geographic trends were noted.

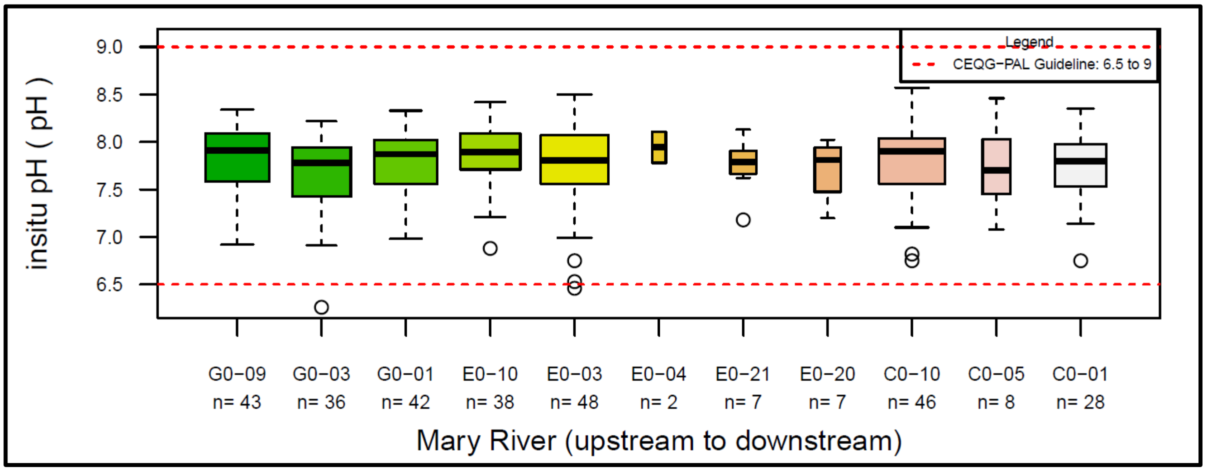


Figure C.5 Mary River – In Situ pH

Hardness (Figure C.6)

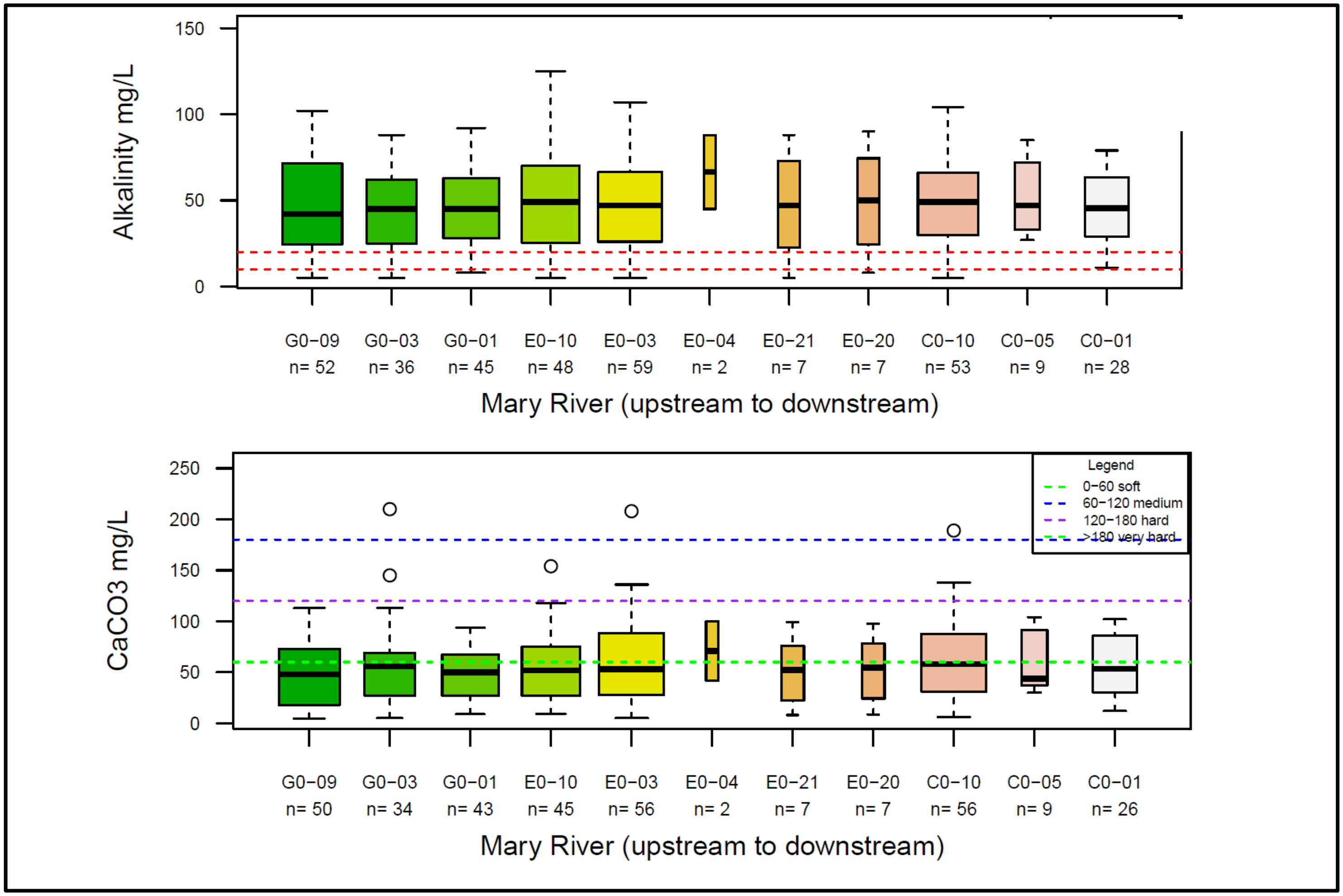
- Median hardness values at the stations in Mary River between 50 mg/L to 60 mg/L, classifying the river water as "soft". Only one station (E0-04) had median hardness values greater than 60 mg/L.
- Hardness portrayed trends very similar to alkalinity, although elevated values at E0-21 and E0-20 were reduced when compared with the alkalinity values.
- The close range between hardness and alkalinity suggest that the hardness is almost entirely carbonate hardness with little to no non-carbonate contributions to hardness.

The following sections summarize the results for the non-metallic inorganic parameters of interest: chloride and nitrate.

Chloride (Figures C.7 and C.8)

The total sample size for chloride concentration samples collected in Mary River is 315, with between 2 and 51 samples collected at each geographically distinct station. Chloride concentrations are low and range from maximum values of 8 mg/L to detection limit values of 1 mg/L (Figure C.7). These concentrations are far below the CWQG-PAL guideline of 120 mg/L. Distinct geographic trends for chloride are not observed; however, measured chloride concentrations from upstream stations (G0-09, G0-03, G0-01 and E0-10) are slightly lower than concentrations observed at stations downstream of E0-10. This is expected to be the result of drilling salts that have been used during exploration in areas in vicinity to the open pit. Log transformed data has far fewer outliers and depicts geographic trends more clearly than the normal data.

Seasonal scatterplots and boxplots show a fairly conserved seasonal trend among different stations aggregated together: lowest measured concentrations occur in the spring (with the exception of C0-10, C0-05 and C0-01 data), slightly higher measured concentrations occur in the summer and the highest measured concentrations occur during the fall (Figure C.8). Seasonal scatter plots do not show consistent temporal trends over the years sampled, although seasonal scatterplots indicate the presence of one detection limit at ~1 mg/L.



NOTES:

1. ALKALINITY VALUES BELOW 10 mg/L ARE HIGHLY SENSITIVE TO ACIDIC INPUTS; ALKALINITY VLAUES BETWEEN 10 – 20 mg/L ARE MODERATELY SENSITIVE TO ACIDIC INPUTS AND ALKALINITY VALUES ABOVE 20 mg/L HAVE LOW SENSITIVITY TO ACIDIC INPUTS.

Figure C.6 Mary River – Alkalinity and Hardness

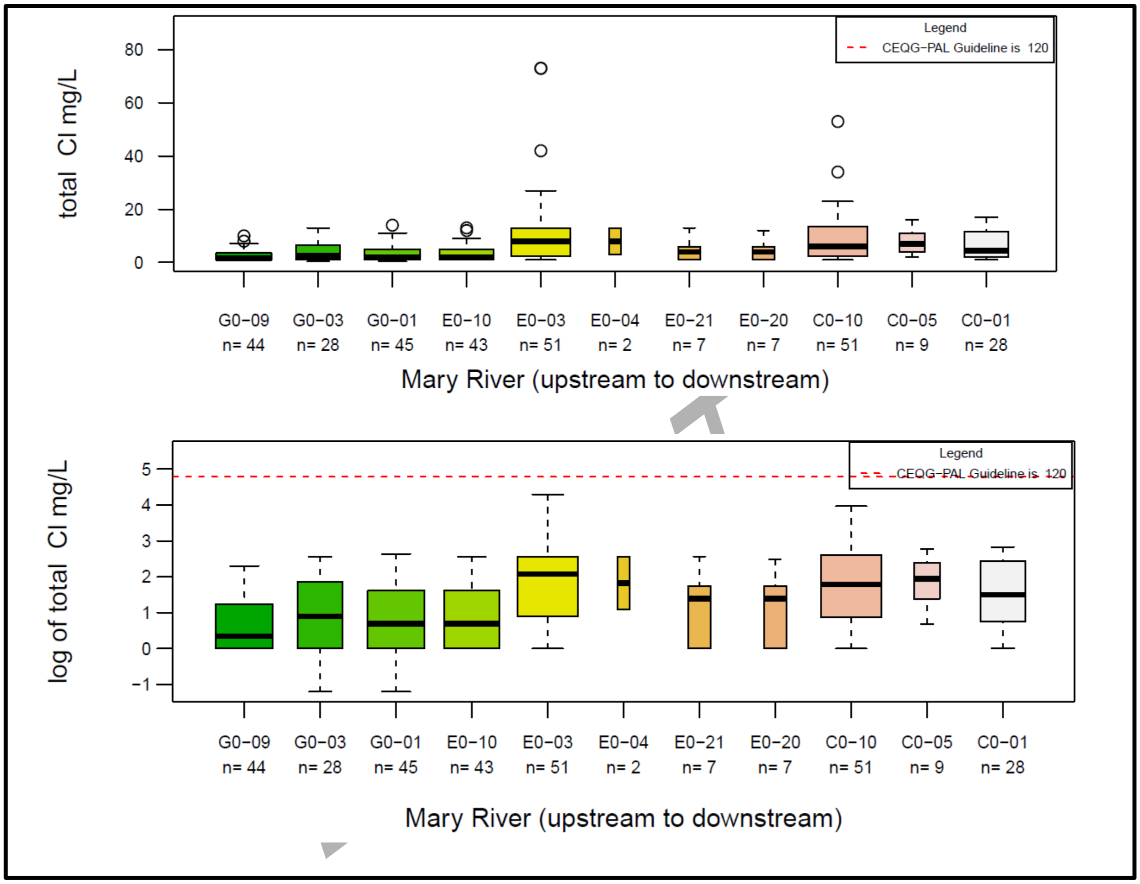
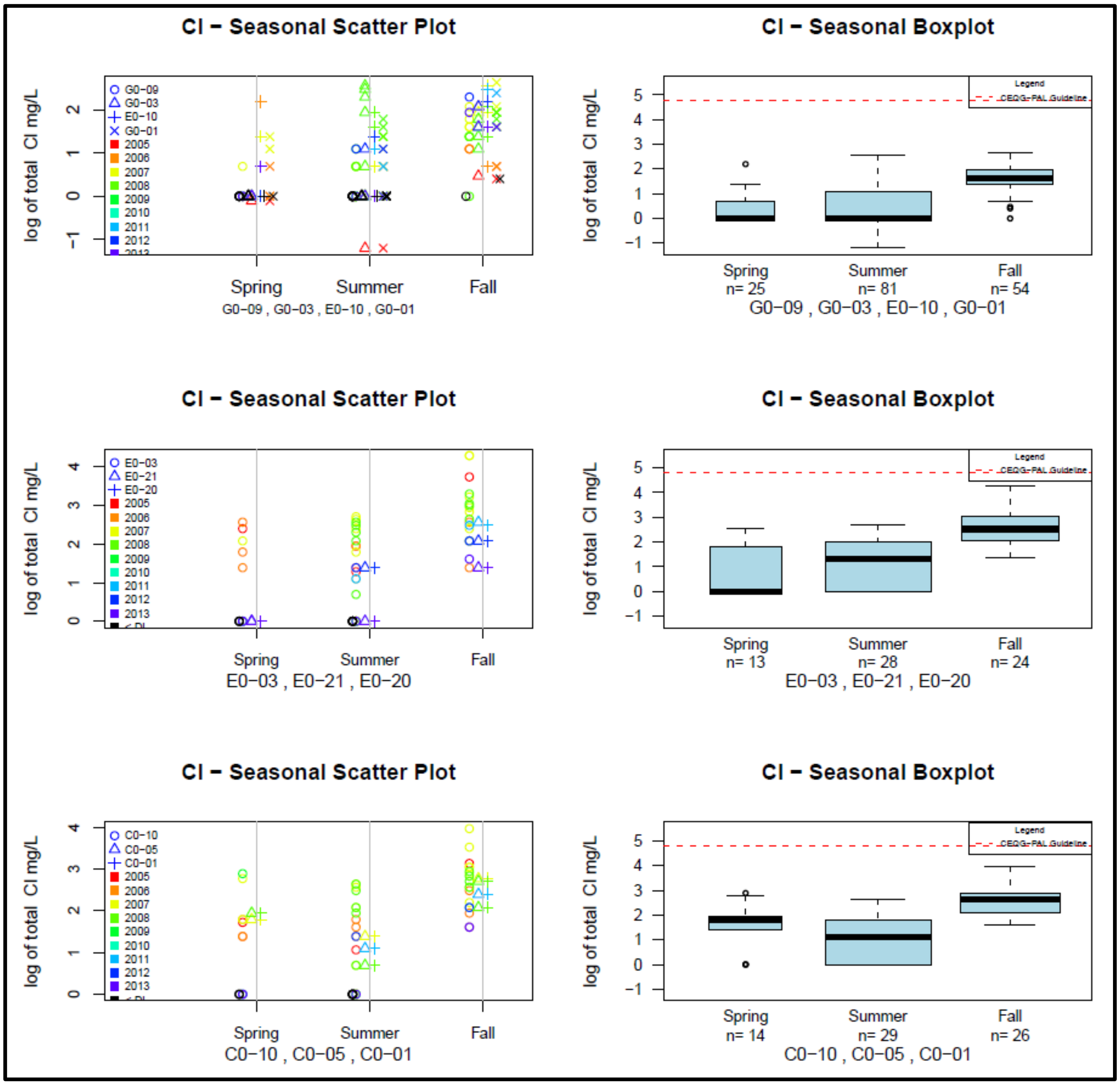


Figure C.7 Mary River – Chloride Concentrations in Water



NOTES:

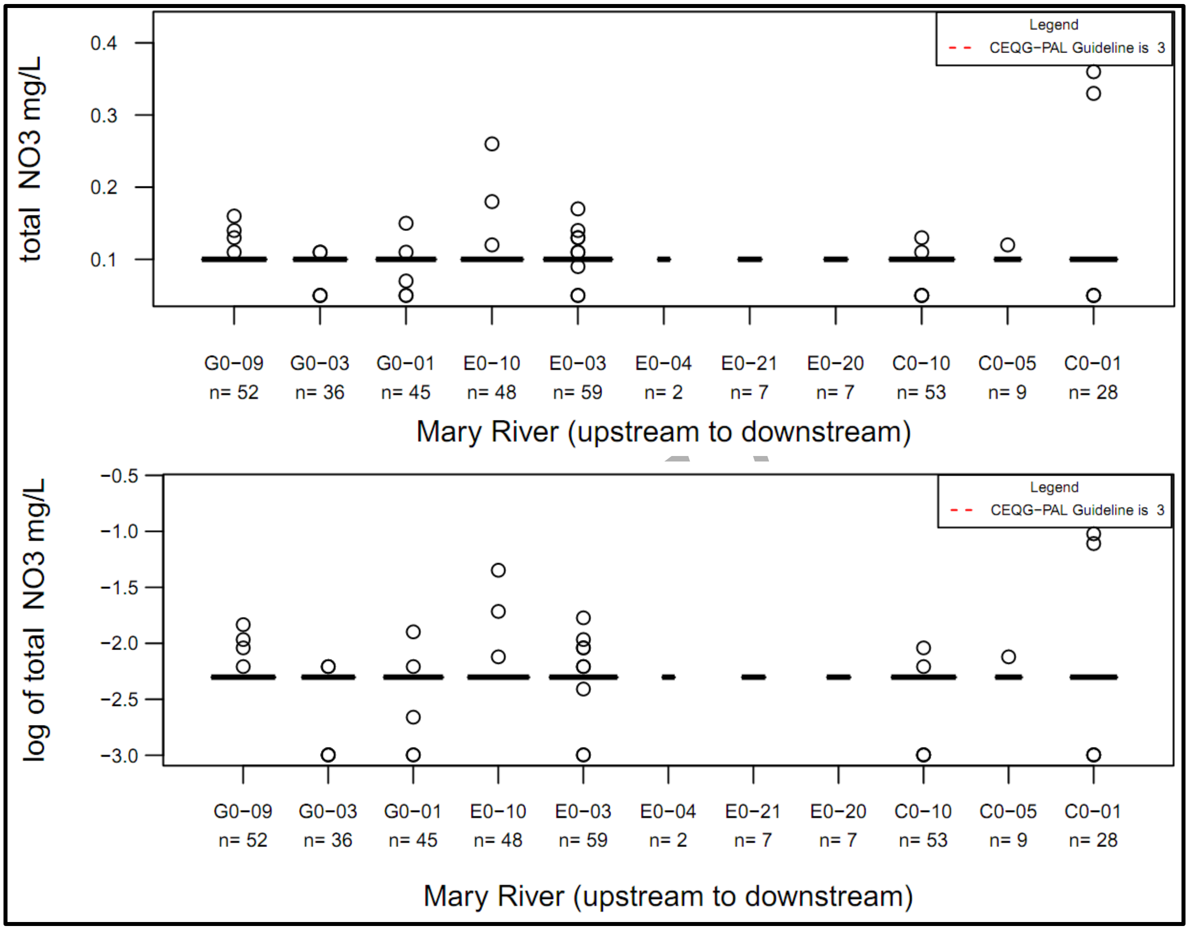
1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.

Figure C.8 Mary River – Variability of Chloride in Water

Nitrate (Figures C.9 and C.10)

The total sample size for nitrate samples collected in Mary River is 346, with between 2 and 59 samples collected at each geographically distinct station on the Mary River. Nitrate concentrations generally occur at MDL level, and well below the CWQG-PAL guideline (3 mg/L), although, frequent outliers are noted (Figure C.9).

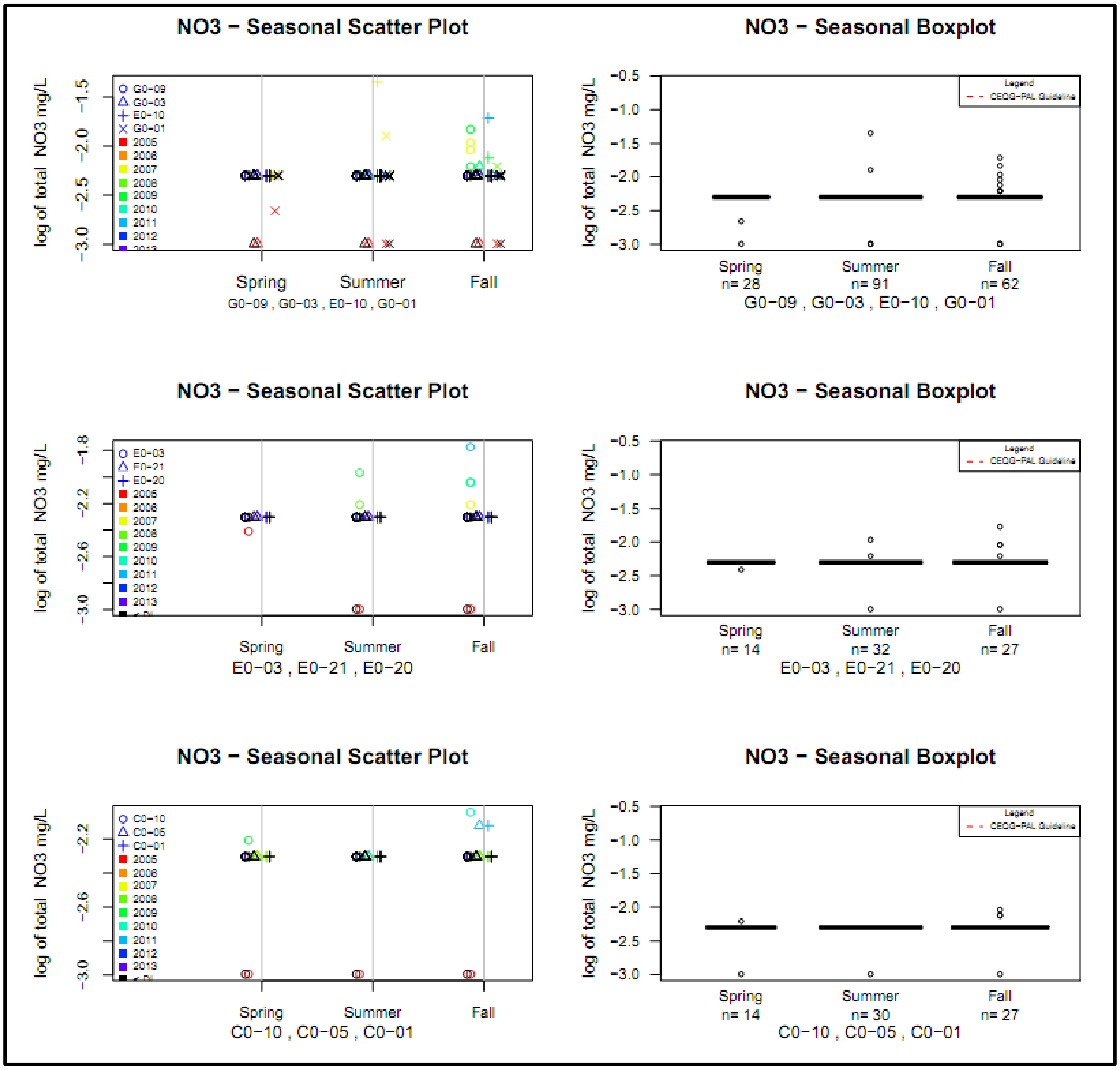
Seasonal scatterplots and boxplots show that the majority of outliers occur in the fall, and that data is subject to MDL interference. Seasonal scatterplots indicate that earlier data, from 2005, actually had a lower MDL than more recently collected data in 2012 (Figure C.10).



NOTES:

1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.
2. THE CWQG-PAL GUIDELINE LIMIT IS BASED ON THE TOTAL MEDIAN HARDNESS.

Figure C.9 Mary River – Nitrate Concentrations in Water



NOTES:

1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.

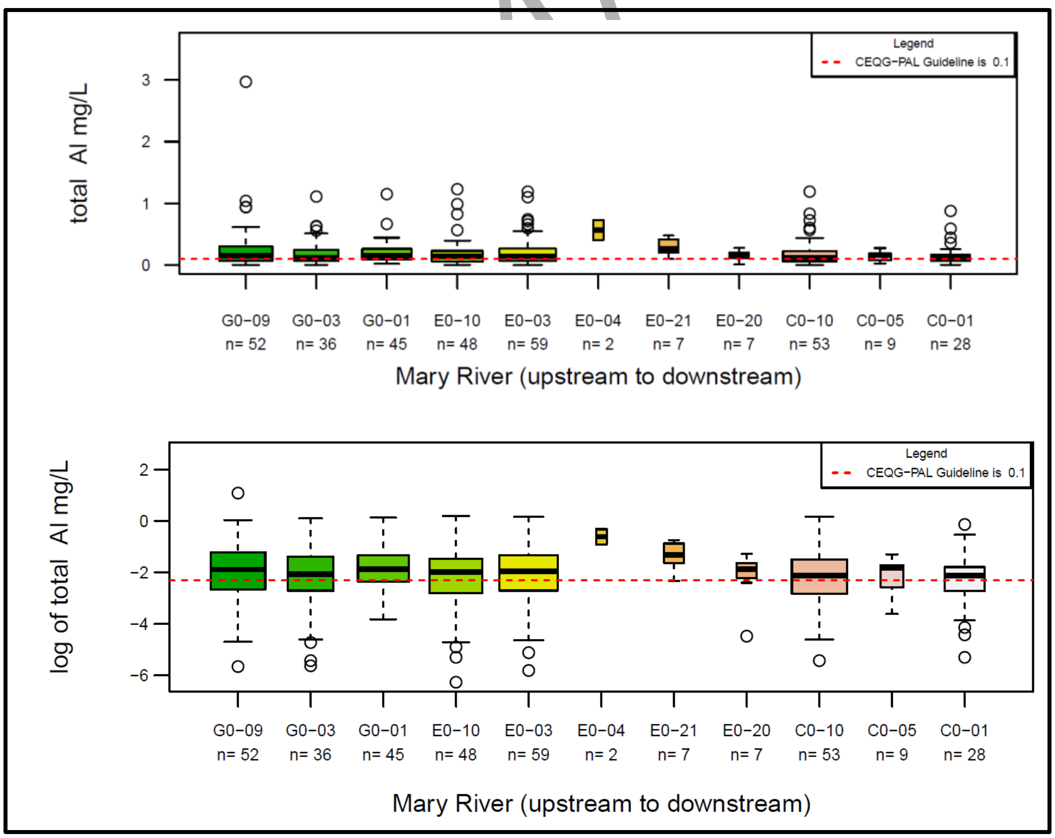
Figure C.10 Mary River – Variability of Nitrate in Water

The following sections summarize the results for the metal parameters of interest: aluminum, arsenic, cadmium, copper, iron, and nickel. All metals are discussed as total concentrations instead of dissolved concentrations, to reflect both the total dissolved and particulate metal loading.

Total Aluminum (Figures C.11 and C.12)

The total sample size for aluminum samples collected in Mary River is 346, with between one through 59 samples collected at each geographically distinct station on the Mary River (Figure C.11). Baseline total aluminum concentrations are elevated, and all stations sampled have median values greater than the CWQG-PAL guideline (0.1 mg/L) but below the Interim SSWQO[1] of 0.94 mg/L). The highest outlying value is 3 mg/L. Many outlying values are noted when box plots are created with raw data; however, when values are log transformed, fewer outliers are noted, and all occur below the calculated median value. Distinct geographic trends for aluminum are not observed, although slightly higher concentrations are noted at E0-04, E0-21 and E0-20. These observations are reliant are small amounts of data, and are therefore, not conclusive.

Seasonal scatterplots and boxplots do not show temporal effects during the eight year sampling program; however, seasonal trends are noted that are consistent between distinct Mary River stations (Figure C.12). Samples collected during summer show slightly higher seasonal concentrations, followed closely by fall concentrations, while spring concentrations occur at the lowest magnitudes.

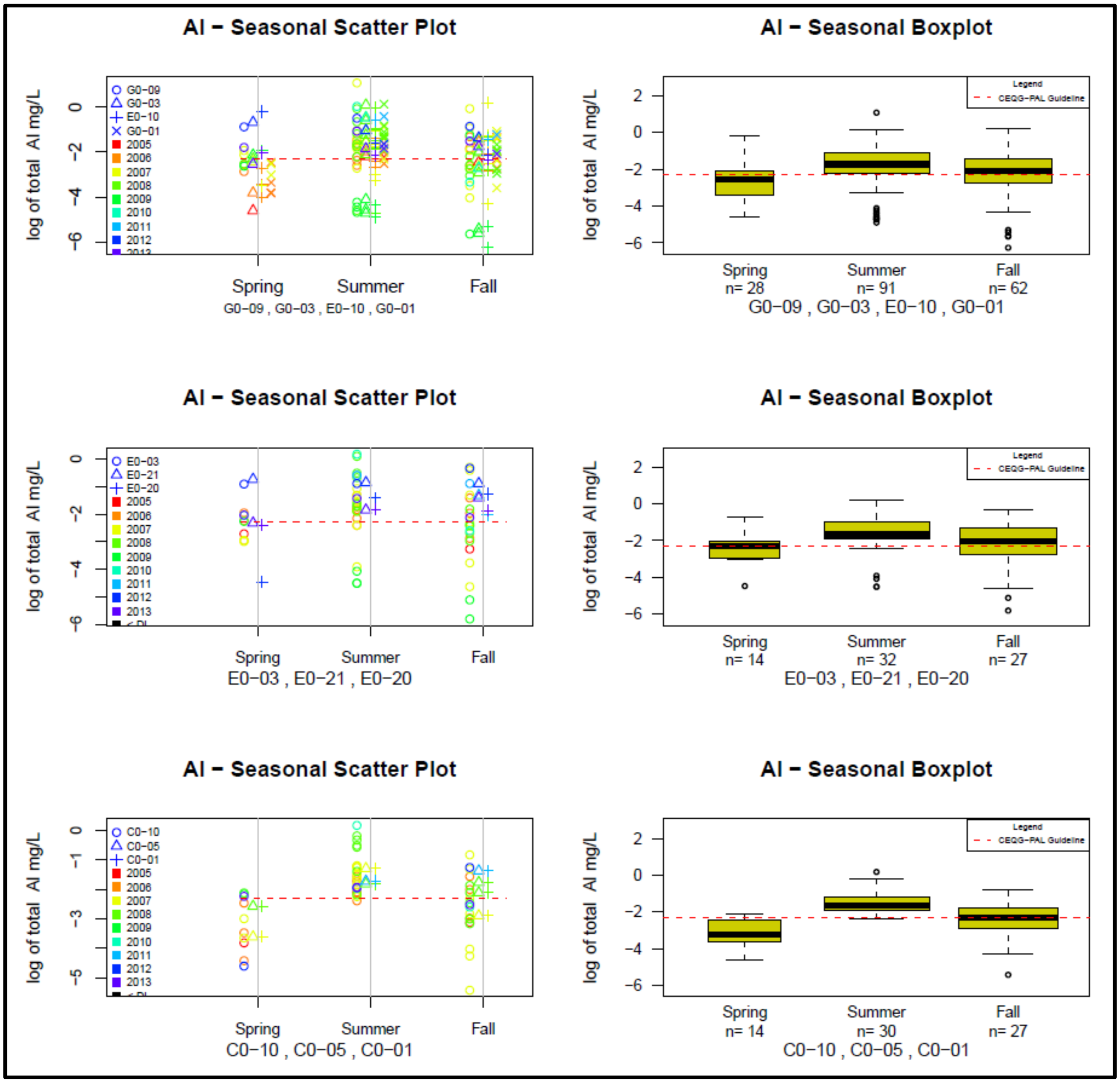


NOTES:

1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.
2. THE CWQG-PAL GUIDELINE LIMIT IS BASED ON THE TOTAL MEDIAN HARDNESS.

Figure C.11 Mary River – Total Aluminum Concentrations in Water

[1] The SSWQO was based on the 95th percentile of G0-09.



NOTES:

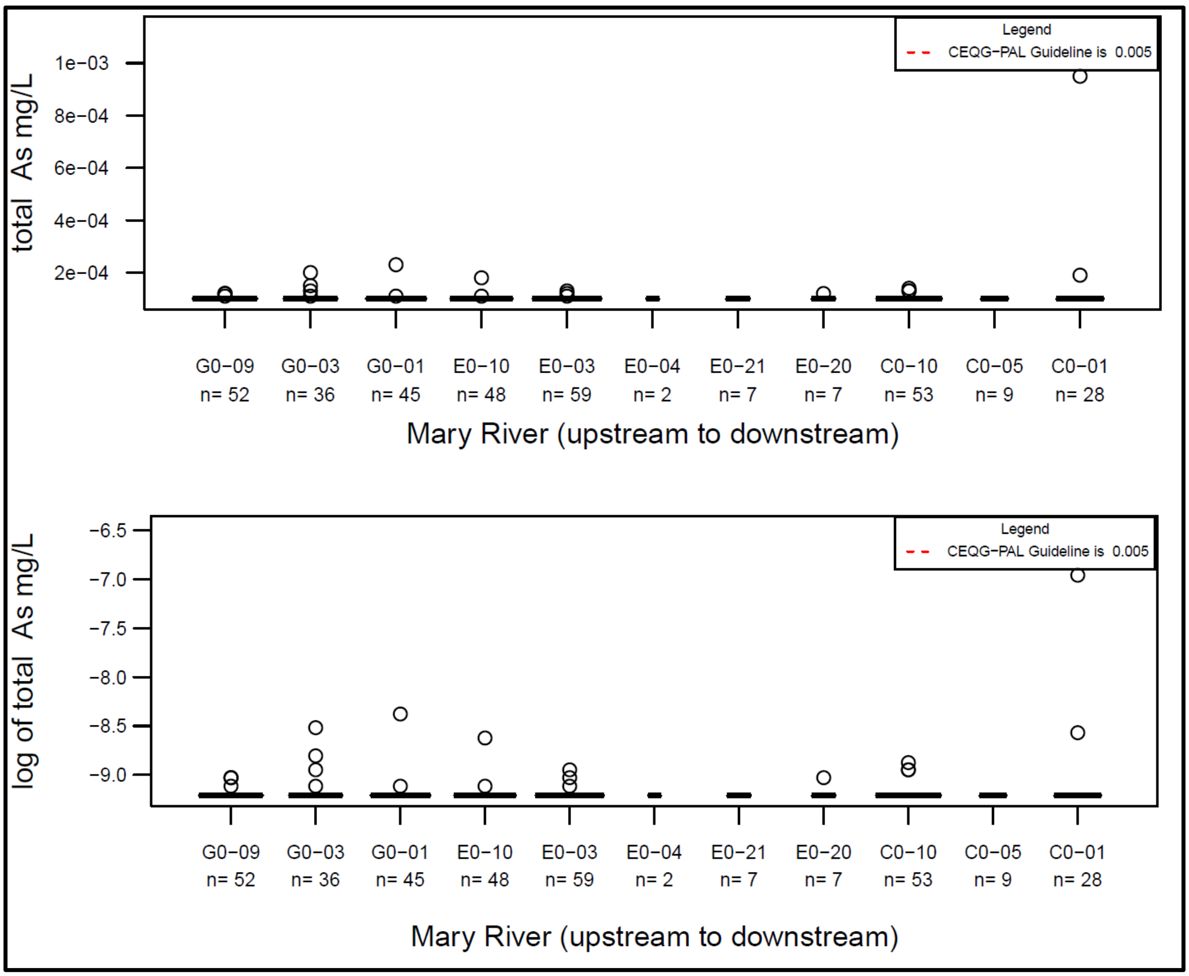
1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.
2. THE CWQG-PAL GUIDELINE LIMIT IS BASED ON THE TOTAL MEDIAN HARDNESS.

Figure C.12 Mary River – Variability of Total Aluminum in Water

Total Arsenic (Figure C.13)

Total arsenic concentrations throughout Mary River generally occur at very low values or at the the laboratory MDLs, with the exception of some outlying values. Outlying values have been recorded at all stations except E0-04, E0-21 and C0-01, which all have smaller sample sizes than other stations (Figure C.13).

Median arsenic concentrations range from 0.0001 mg/L to 0.0002 mg/L. On average, 93% of data falls below the laboratory MDL. Station E0-03 has a median concentration slightly above MDL, with the 75th percentile concentration equal to approximately 0.001 mg/L. Ninety-five percent of data points occur below MDL. Station G0-01 also has the highest outlying value, recorded at ~0.0025 mg/L.



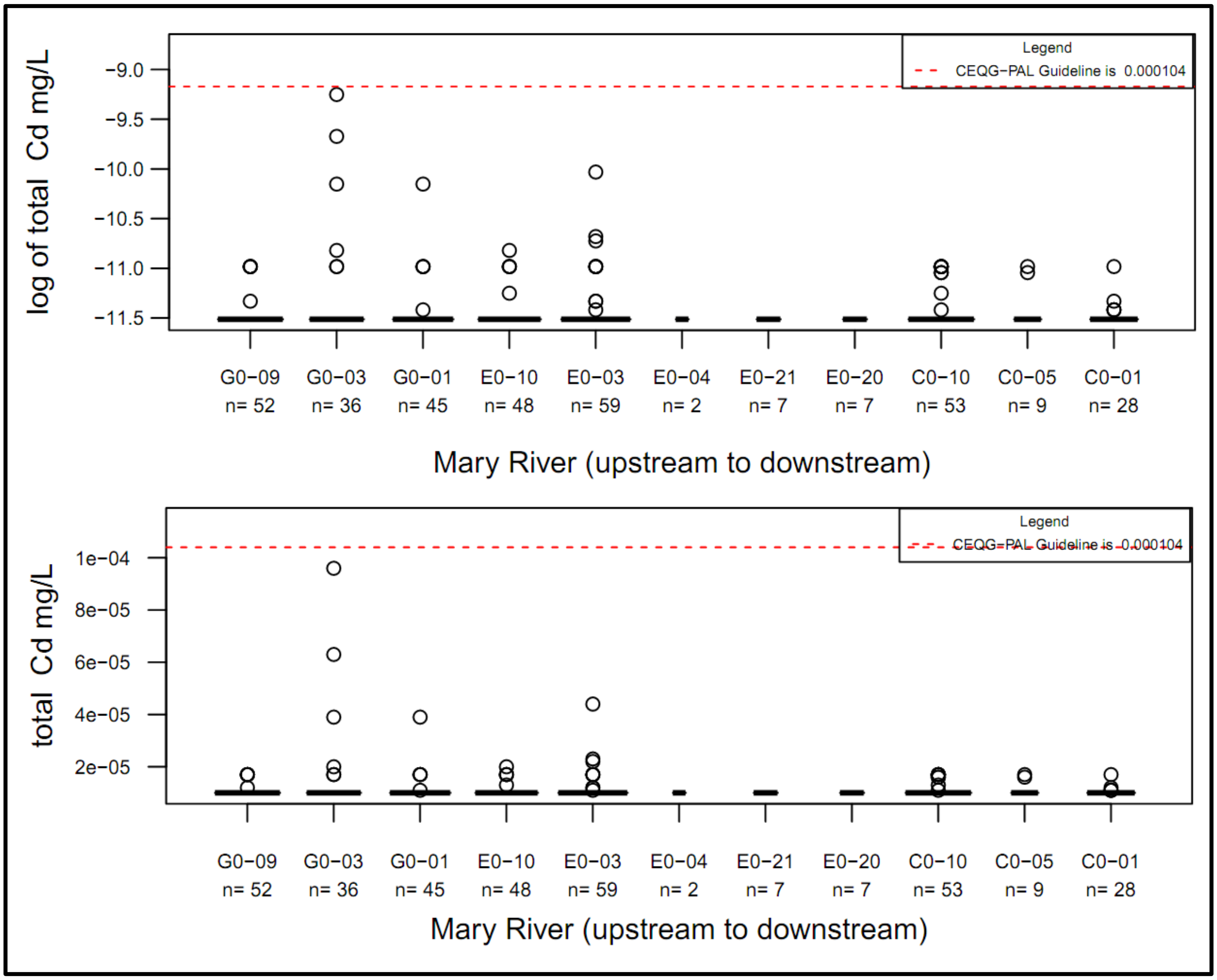
NOTES:

1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.
2. THE CWQG-PAL GUIDELINE LIMIT IS BASED ON THE TOTAL MEDIAN HARDNESS.

Figure C.13 Mary River – Total Arsenic Concentrations in Water

Total Cadmium (Figure C.14)

The total sample size for cadmium samples collected in Mary River is 346, with between two through 59 samples collected at each geographically distinct station on the Mary River. Similar to arsenic, cadmium concentrations remain low or below the laboratory MDLs at most stations (Figure C.14). Median cadmium concentrations range from 0.00001 mg/L to 0.0001 mg/L. Based on all samples in Mary River, approximately 92% of samples fall below the laboratory MDLs.



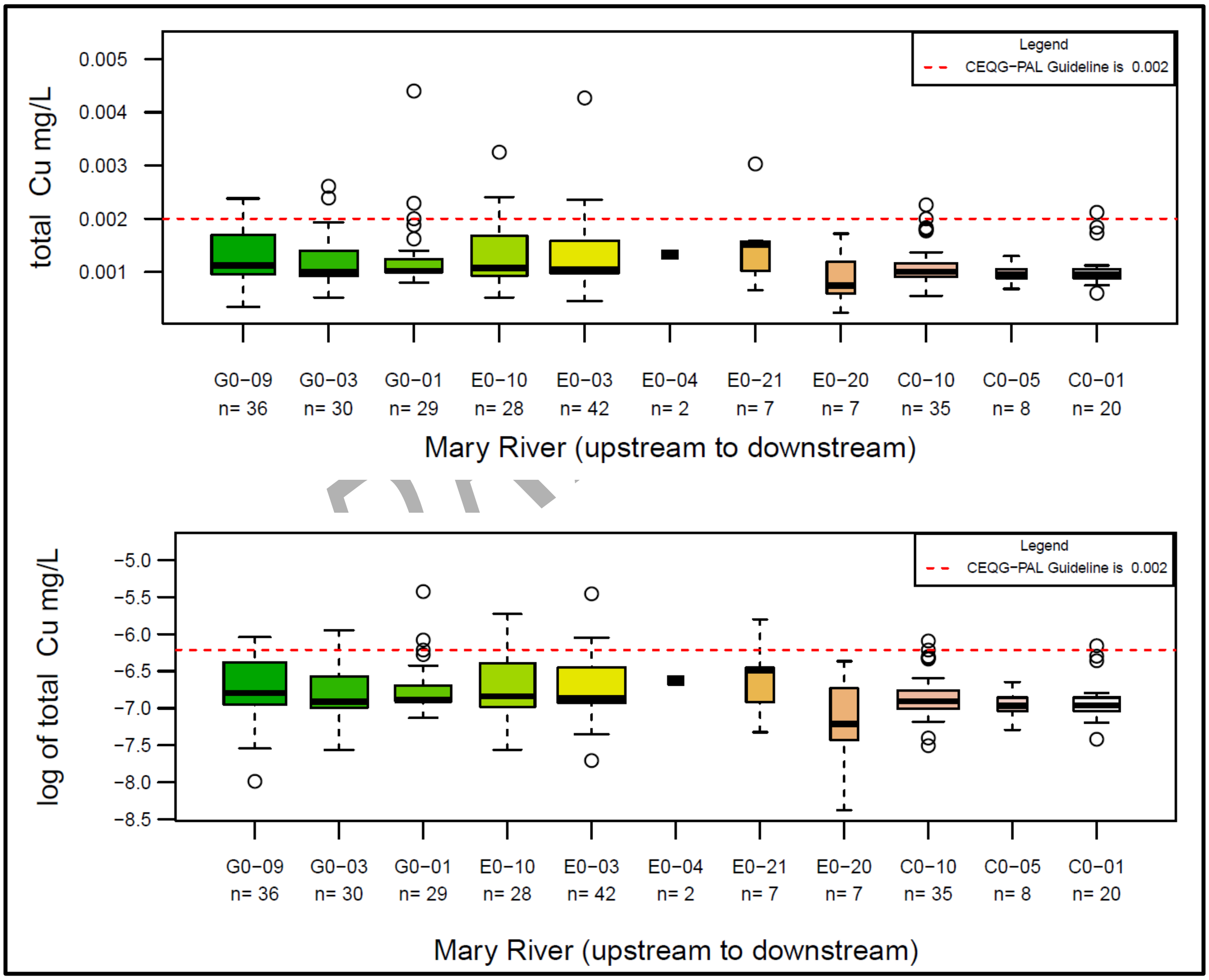
NOTES:

1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.
2. THE CWQG-PAL GUIDELINE LIMIT IS BASED ON THE TOTAL MEDIAN HARDNESS.

Figure C.14 Mary River – Total Cadmium Concentrations in Water

Total Copper (Figures C.15 and C.16)

Between two through 59 total copper samples were collected at each geographically distinct station on the Mary River, for a total of 244 copper samplesa collected from the Mary River. Baseline total copper concentrations are slightly elevated. Although no median copper concentrations surpass the CWQG-PAL guideline (0.002 mg/L), naturally occuring maximum concentrations and 75th precentile concentrations do exceed this guideline (Figure C.15). The maximum copper concentration recorded within Mary River was slightly above 0.004 mg/L, which is twice that of the CWQG-PAL guideline limit. Distinct geographic trends are not noted within Mary River, as all stations have median values that are quite similar. Log transformed data shows slightly fewer outliers, but the data transformation does not affect the spread of data to a large extent.

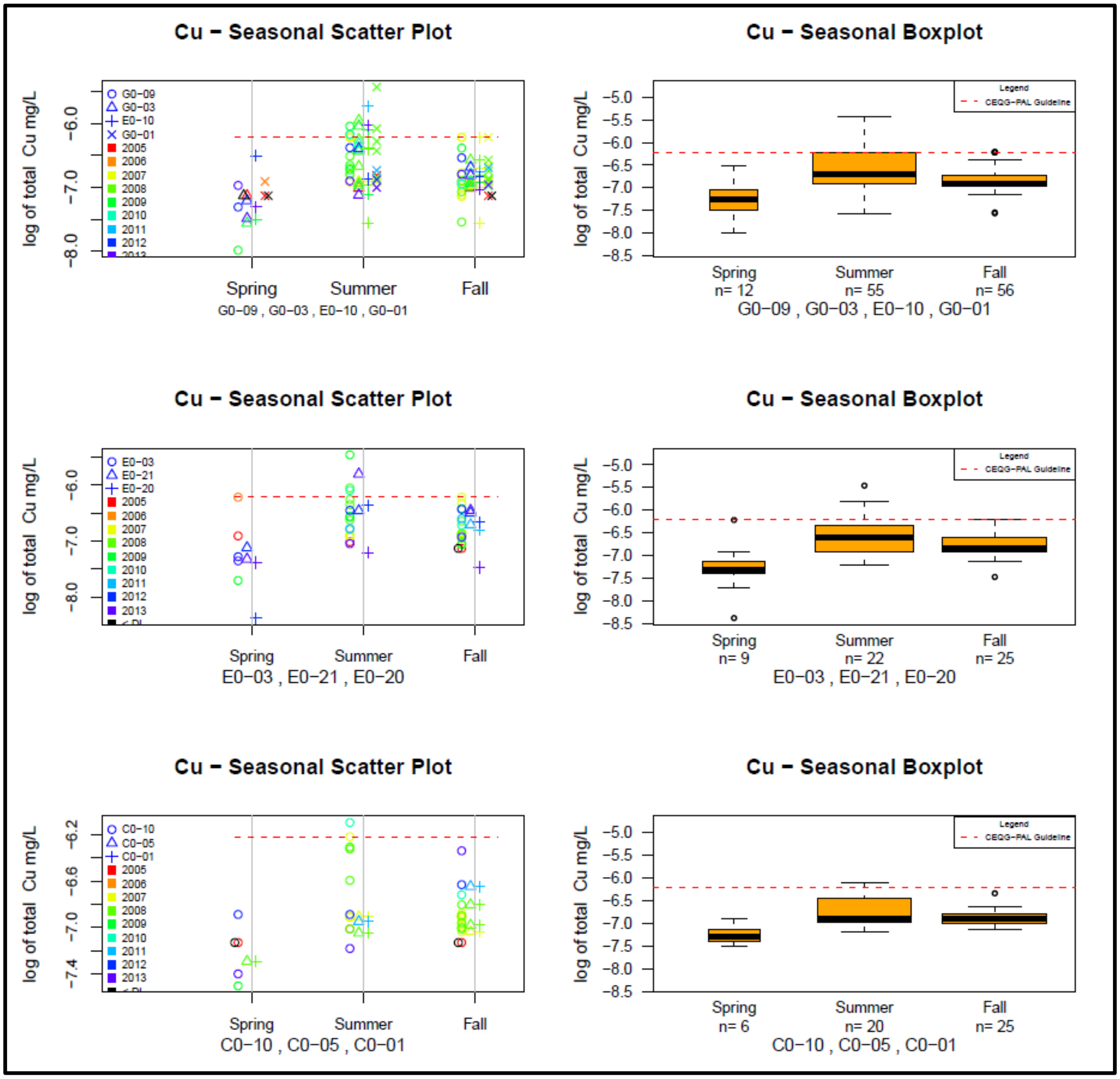


NOTES:

1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.
2. THE CWQG-PAL GUIDELINE LIMIT IS BASED ON THE TOTAL MEDIAN HARDNESS.

Figure C.15 Mary River – Total Copper Concentrations in Water

Seasonal scatterplots do not reveal a temporal trend over the eight year sampling history (Figure C.16). Seasonal scatterplots and boxplots do show, however, that all stations on Mary River show a consistent seasonal trend: with elevated, but similar concentrations occurring in summer and fall, and slightly lower concentrations occurring during spring. This trend is unique to copper.



NOTES:

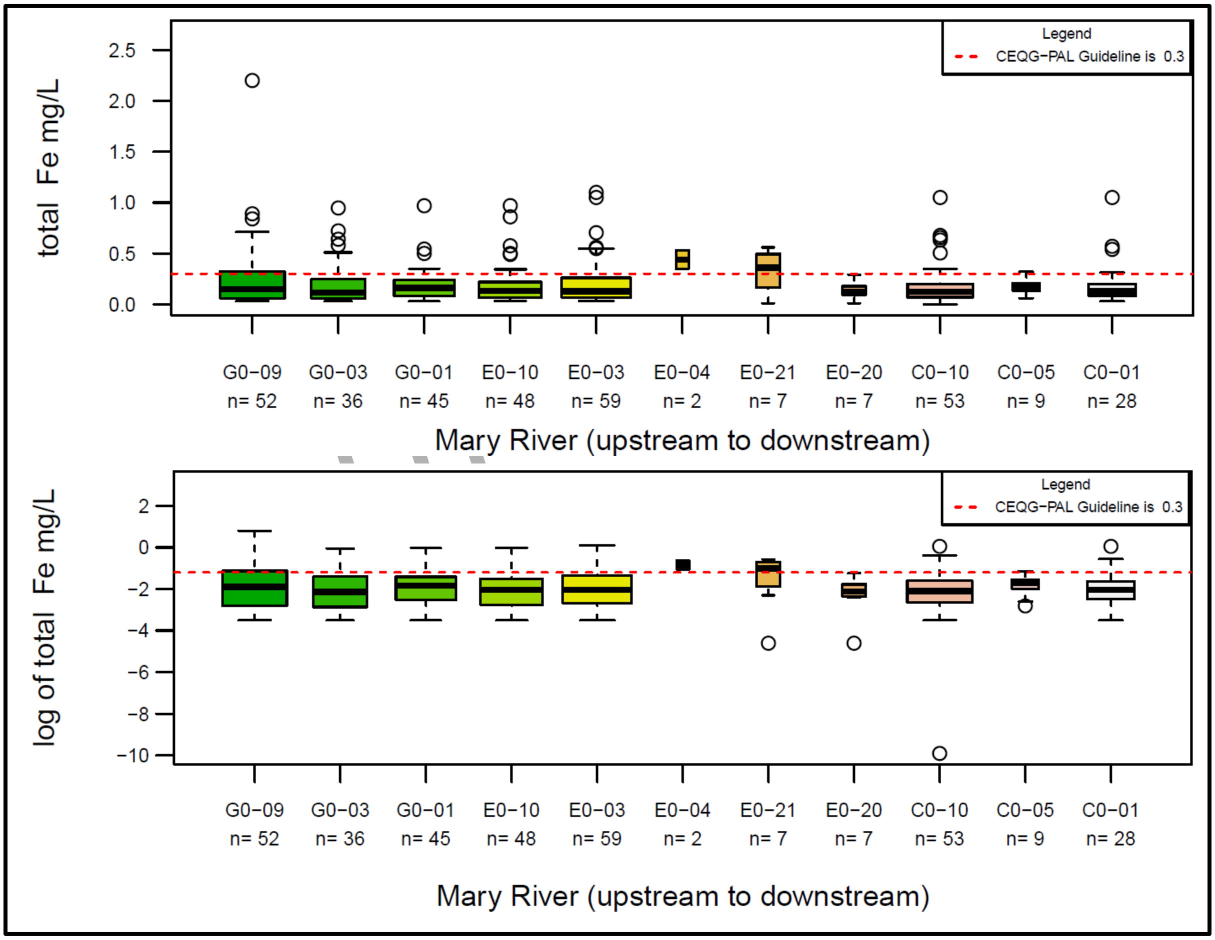
1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.
2. THE CWQG-PAL GUIDELINE LIMIT IS BASED ON THE TOTAL MEDIAN HARDNESS.

Figure C.16 Mary River – Variability of Total Copper in Water

Total Iron (Figures C.17 and C.18)

The total sample size for total iron samples collected in Mary River is 346, with between two through 53 samples collected at each geographically distinct station on the Mary River. Baseline total iron concentrations are slightly elevated (Figure C.17).

Stations E0-21 and E0-04 have median iron concentrations that exceed the CWQG-PAL guideline (0.3 mg/L), but are based on a small sample size and are therefore inconclusive. The rest of the stations on Mary River have median values that fall below this guideline. Naturally occuring maximum concentrations and 75th percentile concentrations, however, do exceed the CWQG-PAL guideline and occur at a maximum, approximately six times the gudieline value. Plots of the log data indicate reduce the frequency of outliers significantly.

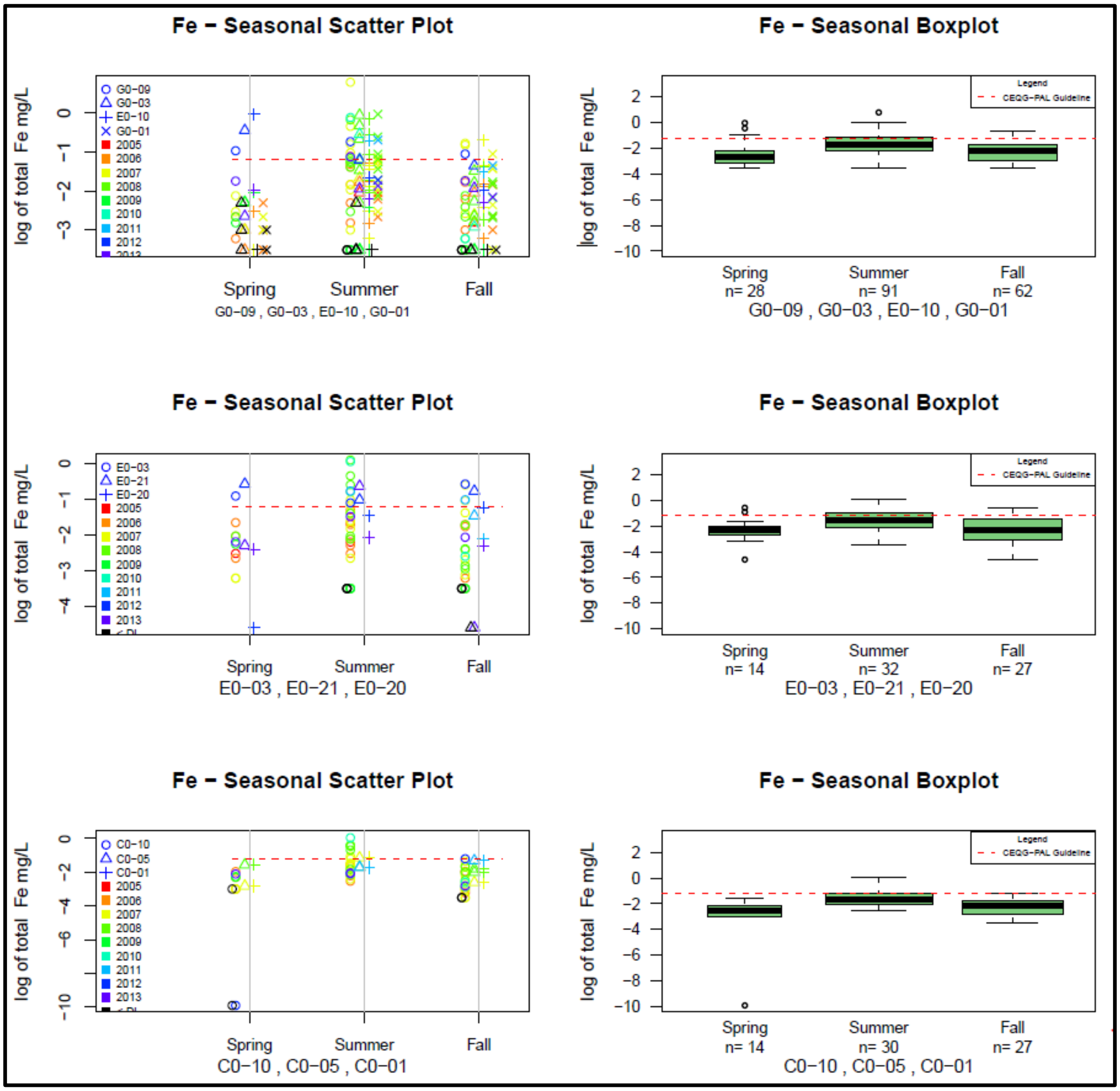


NOTES:

1. THE CWQG-PAL GUIDELINE LIMIT IS BASED ON THE TOTAL MEDIAN HARDNESS.

Figure C.17 Mary River – Total Iron Concentrations in Water

Seasonal scatterplots do not reveal a temporal trend over the eight year sampling history (Figure C.18). Seasonal scatterplots and boxplots do show, however, that all stations on Mary River show a muted seasonal trend similar to the seasonal trend observed for aluminum. Summer total iron concentrations occur at slightly higher concentrations, with fall concentrations reporting slightly below summer concentrations, but above median spring concentrations.



NOTES:

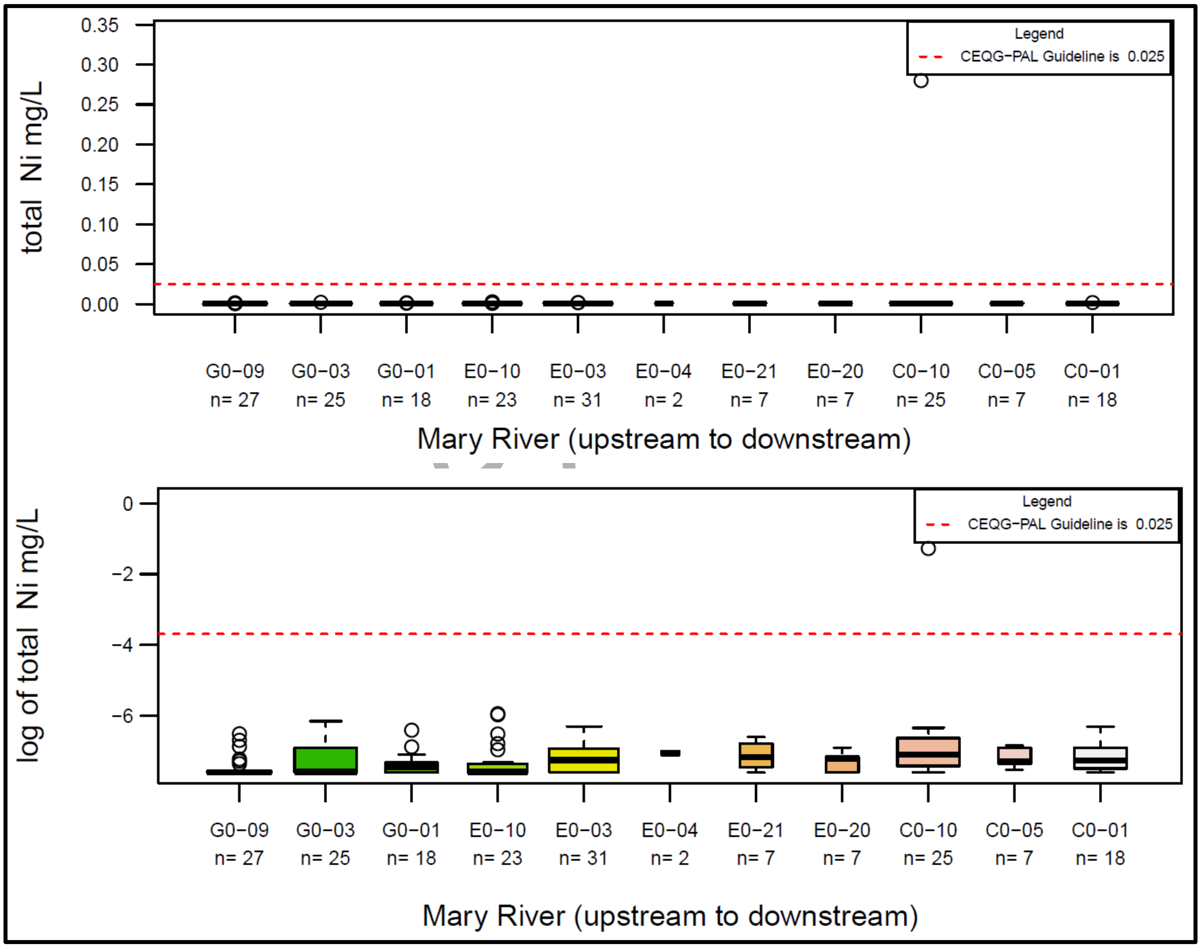
1. THE CWQG-PAL GUIDELINE LIMIT IS BASED ON THE TOTAL MEDIAN HARDNESS.

Figure C.18 Mary River – Variability of Total Iron in Water

Total Nickel (Figures C.19 and C.20)

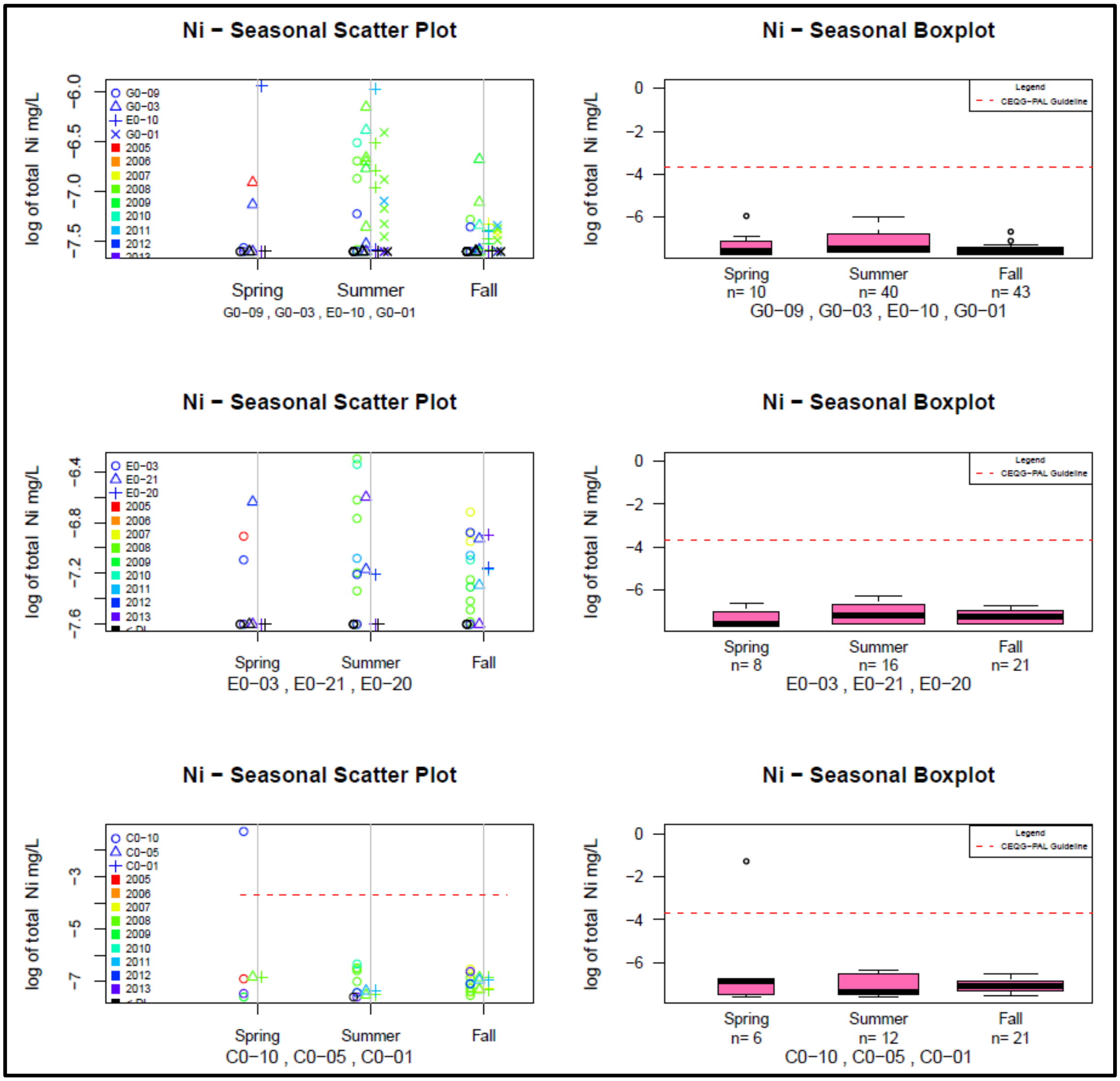
The total sample size for total nickel samples collected in Mary River is 190, with between two through 31 samples collected at each geographically distinct station on the Mary River. Baseline total nickel concentrations are low and occur consistently below the CWQG-PAL guideline (0.025 mg/L) (Figure C.19). Median values vary only slightly between stations, but do not appear to indicate any kind of geographic trend.

Seasonal scatterplots indicate data from 2008 and 2009 is slightly elevated compared to other data collected during the eight year sampling history (Figure C.20). Seasonal scatterplots and boxplots do not show any discernable seasonal trend, although it is possible summer concentrations are slightly higher than fall and spring concentrations.



NOTES:
1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.
2. THE CWQG-PAL GUIDELINE LIMIT IS BASED ON THE TOTAL MEDIAN HARDNESS.

Figure C.19 Mary River – Total Nickel Concentrations in Water



NOTES:

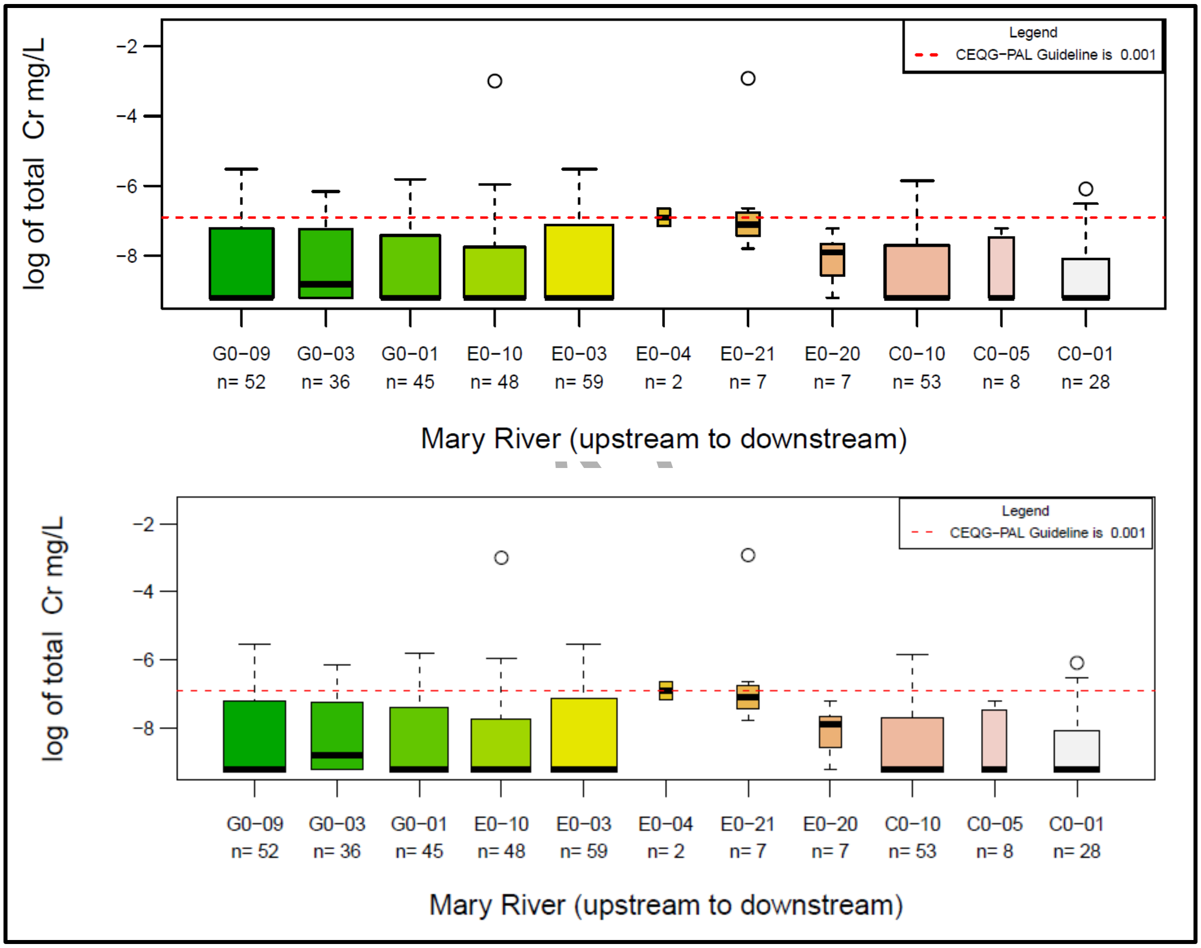
1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.
2. THE CWQG-PAL GUIDELINE LIMIT IS BASED ON THE TOTAL MEDIAN HARDNESS.

Figure C.20 Mary River – Variability of Total Nickel in Water

Total Chromium (Figure C.21 and Figure C.22*)*

The total sample size for total chromium, samples collected in Mary River is 347, with between two through 59 samples collected at each geographically distinct station on the Mary River. Baseline total chromium concentrations are generally low but occur above the CWQG-PAL guideline (0.001 mg/L) at some stations (Figure C.21). Stations E0-04, E0-21 and E0-20 have elevated median concentrations compared to other stations.

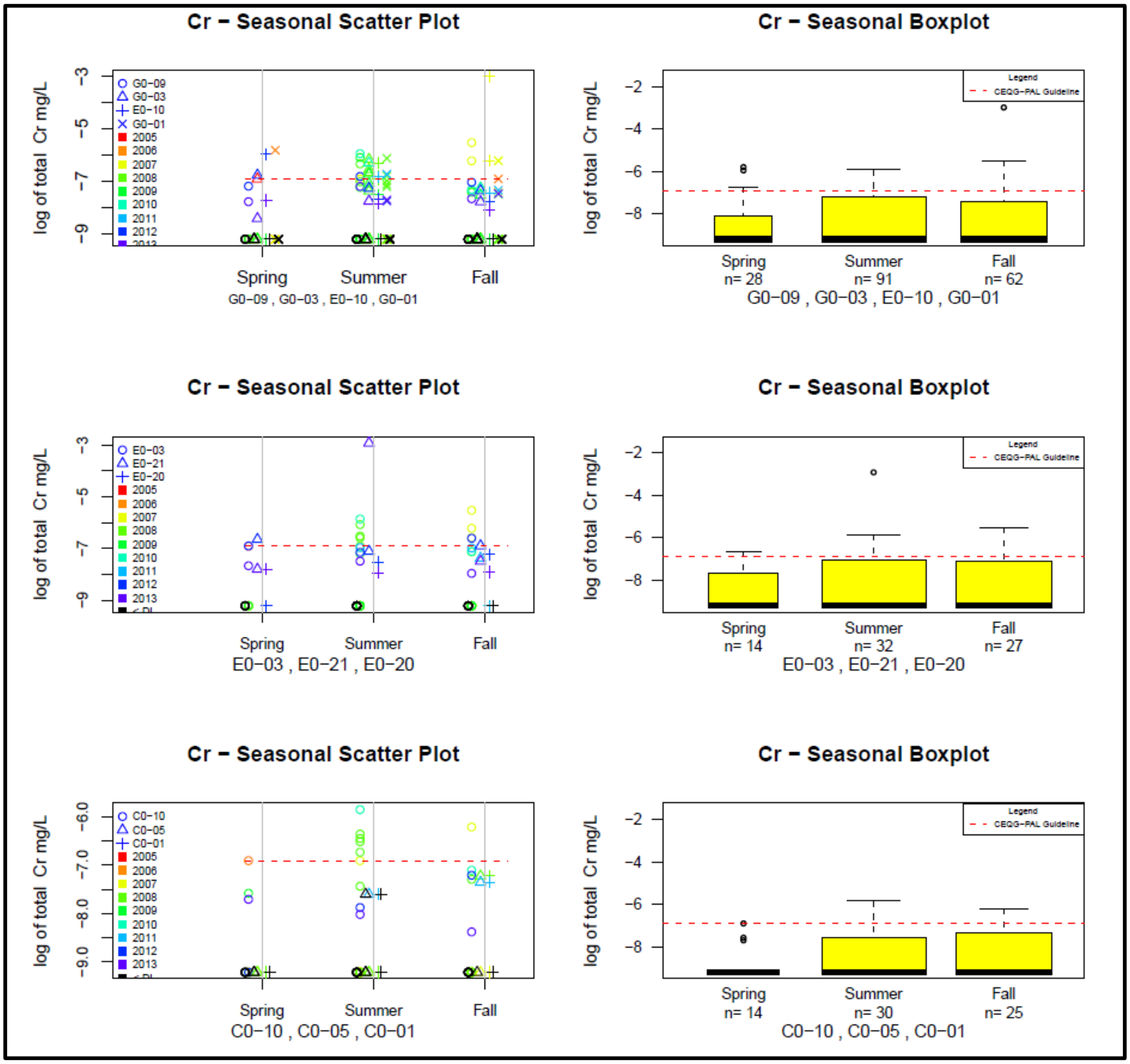
Seasonal scatterplots indicate data from summer of 2008 is slightly elevated compared to other data collected during the eight year sampling history (Figure C.22). Seasonal scatterplots and boxplots do not show any discernable seasonal trend.



NOTES:

1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.
2. THE CWQG-PAL GUIDELINE LIMIT IS BASED ON THE TOTAL MEDIAN HARDNESS.

Figure C.21 Mary River – Total Chromium Concentrations in Water



NOTES:

1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.
2. THE CWQG-PAL GUIDELINE LIMIT IS BASED ON THE TOTAL MEDIAN HARDNESS.

Figure C.22 Mary River – Variability of Total Chromium in Water

Summary of trends observed during review of Mary River baseline data:

- Geographic trends between discrete sampling stations were not observed for any parameters, with the exception of chloride, which showed slightly lower upstream concentrations. Concentrations at E0-04, E0-20 and E0-21 were often slightly elevated, but due to small sample size, this is not a conclusive trend.
- With the exception of nitrate and nickel, parameters did not show any distinct temporal trends over the sampling period.
- No seasonal trends were noted for nitrate, arsenic and cadmium due to detection limit interference. Although detection limit interference did not occur for nickel and chromium, these parameters do not also show consistent seasonal trends between sample stations.
- Aluminum, copper and iron (and muted trends observed for nickel) historically have their highest concentrations occurring during the summer.

C.3.2 Camp Lake Tributary

Water quality samples at five stations within the Camp Lake Tributary were collected from 2005 through 2013. A total of eighty-seven (87) samples were collected from the Camp Lake Tributary L0/L1 (Table C.2). Most sampling was completed during the spring and summer season, from June through August. The most number of samples were collected during 2007 and 2008. Variability in the Camp Lake Tributary samples is larger than variation observed within the other lakes samples. Although variability may be influenced by the relatively low sample size at all stations (15 to 22, with the exception of L0), variability is expected to also be as a result of sampling different tributaries.

- L0-01: Located on Tributary L0, this is the most downstream station on the Camp Lake Tributary, prior to discharge into Camp Lake and represents the most downstream point of entry of discharge from West Pond.
- L1-02: Located on Tributary L1, located immediately downstream of L1-08, prior to the confluence of Tributary L1 and L2.
- L1-08: Located on Tributary L1, within fish-bearing water, immediately below the West Pond discharge station and a large falls.
- L1-09: Located on Tributary L0, immediately downstream of the confluence of the L2 Tributary and the L1 tributary.
- L2-03: Located on Tributary L2, adjacent to the existing air strip. Tributary L2 converges with Tributary L1 to form Tributary L0.

Sampling locations are shown on Figures C.2 and C.3. A summary of the data collected during each season, with respect to year and station are included in Table C.2. A graphical representation of the sampling events is provided in Figure C.23.

Table C.2 Camp Lake Tributary Sample Size

Year	Summer	Fall	Winter
2005	4	3	3
2006	3	6	3
2007	2	7	5
2008	2	8	5
2011	0	3	3
2012	5	5	5
2013	5	5	5
Station	**Summer**	**Fall**	**Winter**
L0-01	9	23	15
L1-02	3	3	3
L1-08	4	4	4
L1-09	2	3	3
L2-03	3	4	4

The following summarizes the data review observations for the physical parameter data collected for the Camp Lake Tributary.

pH (Figure C.24)

- *In situ* pH values in the Camp Lake Tributary do not vary greatly, and slightly alkaline, with total median pH ~ 8.
- *In situ* pH is observed to increase slightly from upstream to downstream stations.

Alkalinity (Figure C.24)

- All Camp Lake Tributary stations have high alkalinity and are considered to have low sensitivity to acidic inputs. Median hardness is equal to 73 mg/L.
- The lowest alkalinity values are recorded at L1-08, the station located furthest upstream, and values increase to a maximum of approximately 95 mg/L at L2-03. This indicates the possibility that inputs may have occurred during exploration activities.

Hardness (Figure C.24)

- Median hardness for all stations within the Camp Lake tributary is 79 mg/L, classifying the river water as “moderately soft”; although, median hardness values at L1-08 and L1-02 are classified as “soft”.
- Hardness portrayed trends very similar to alkalinity, with the lowest measured concentration occurring at L1-08 (~48 mg/L) and increasing to a maximum value at L2-03 (~100 mg/L).
- The close range between hardness and alkalinity suggest that the hardness is almost entirely carbonate hardness with little to no non-carbonate contributions to hardness.

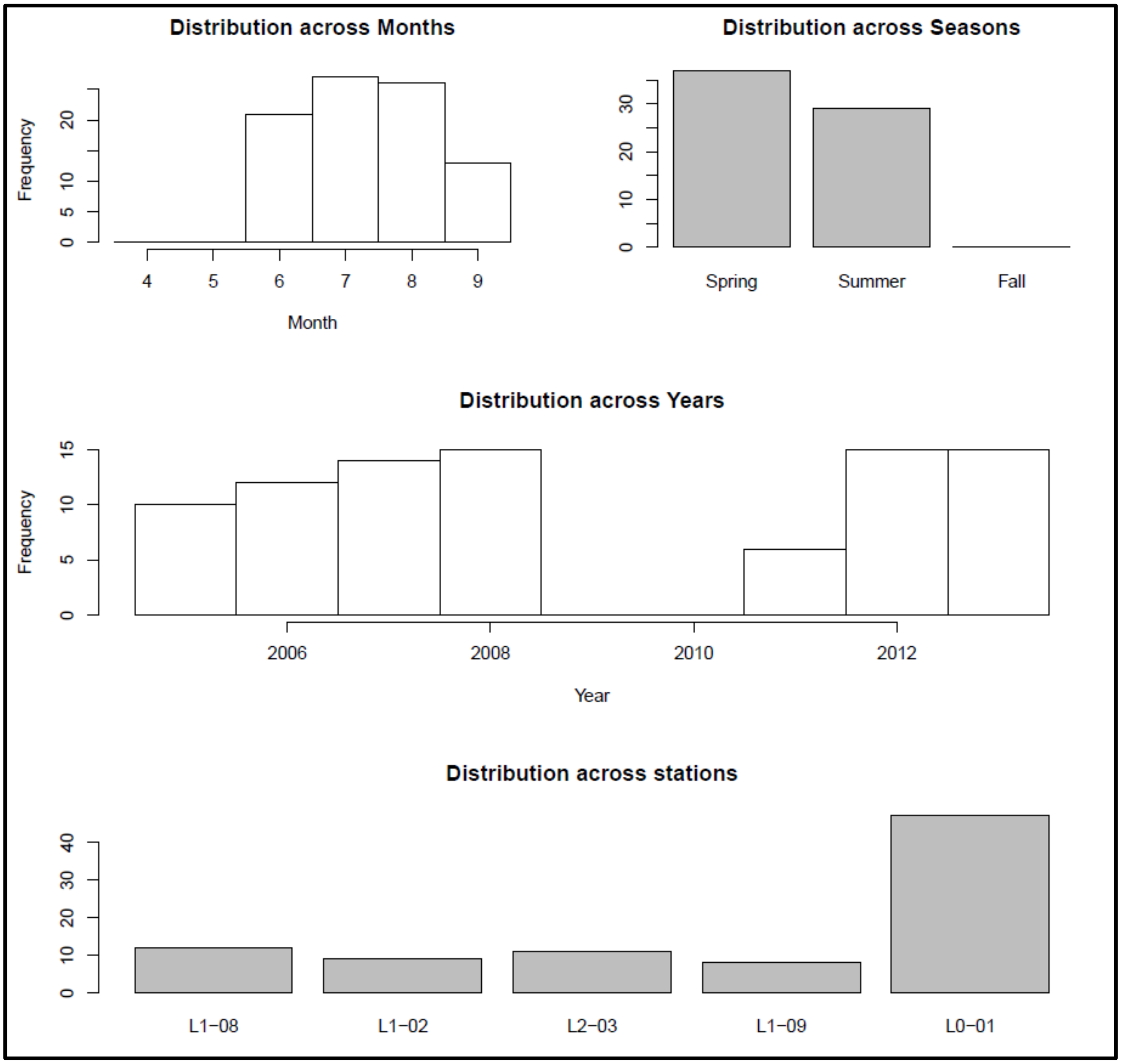
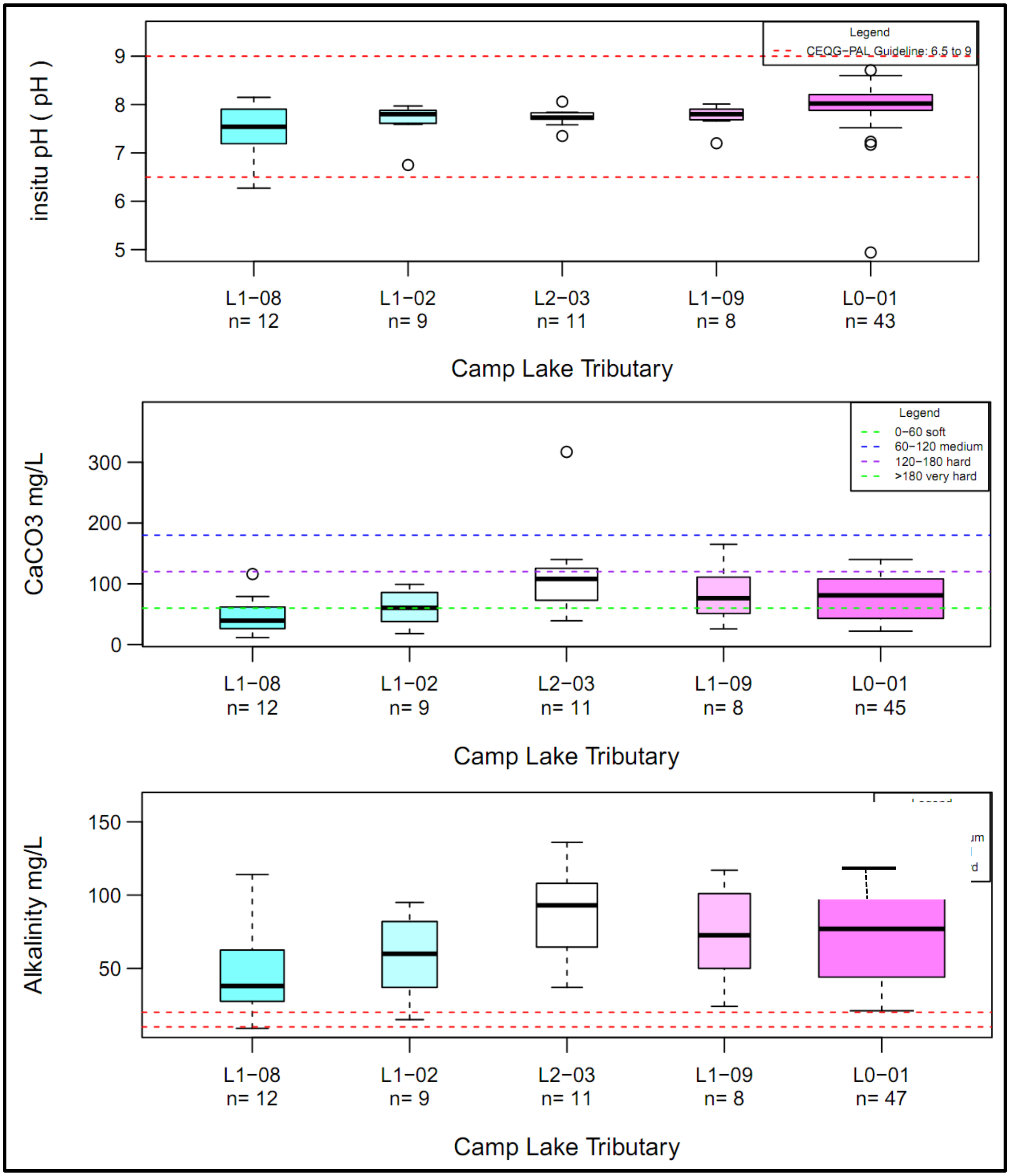


Figure C.23 Camp Lake Tributary – Graphical Summary of Sampling Events

The following sections summarize the results for the non-metallic inorganic parameters of interest: chloride and nitrate.

Chloride (Figures C.25 and C.26)

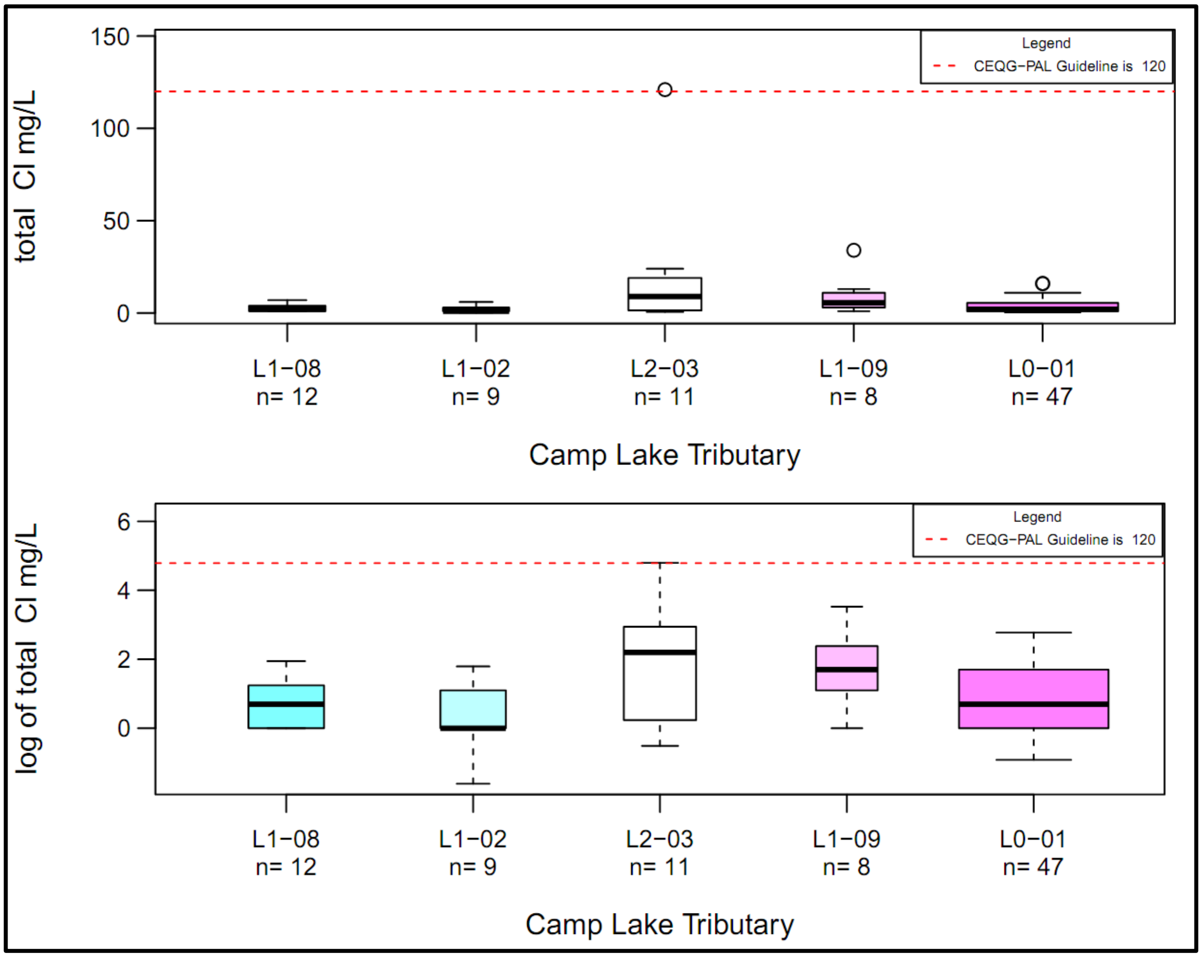
The total sample size for chloride concentration samples collected in the Camp Lake Tributary is eighty-seven (87) with 8 to 47 samples collected at each geographically distinct sampling station (Figure C.25). Chloride concentrations are low, with the exception of one outlier recorded at L2-03. Chloride concentrations generally range from the MDL to 20 mg/L, with the exception of one outlier recorded at 120 mg/L (at the CWQG limit). Chloride concentrations are marginally higher at L2-03, which samples a tributary adjcaent to the existing air strip, and are marginally lower at sampling point



NOTES:

1. ALKALINITY VALUES BELOW 10 mg/L ARE HIGHLY SENSITIVE TO ACIDIC INPUTS; ALKALINITY VLAUES BETWEEN 10 – 20 mg/L ARE MODERATELY SENSITIVE TO ACIDIC INPUTS AND ALKALINITY VALUES ABOVE 20 mg/L HAVE LOW SENSITIVITY TO ACIDIC INPUTS.

Figure C.24 Camp Lake Tributary – In-Situ pH, Alkalinity and Hardness



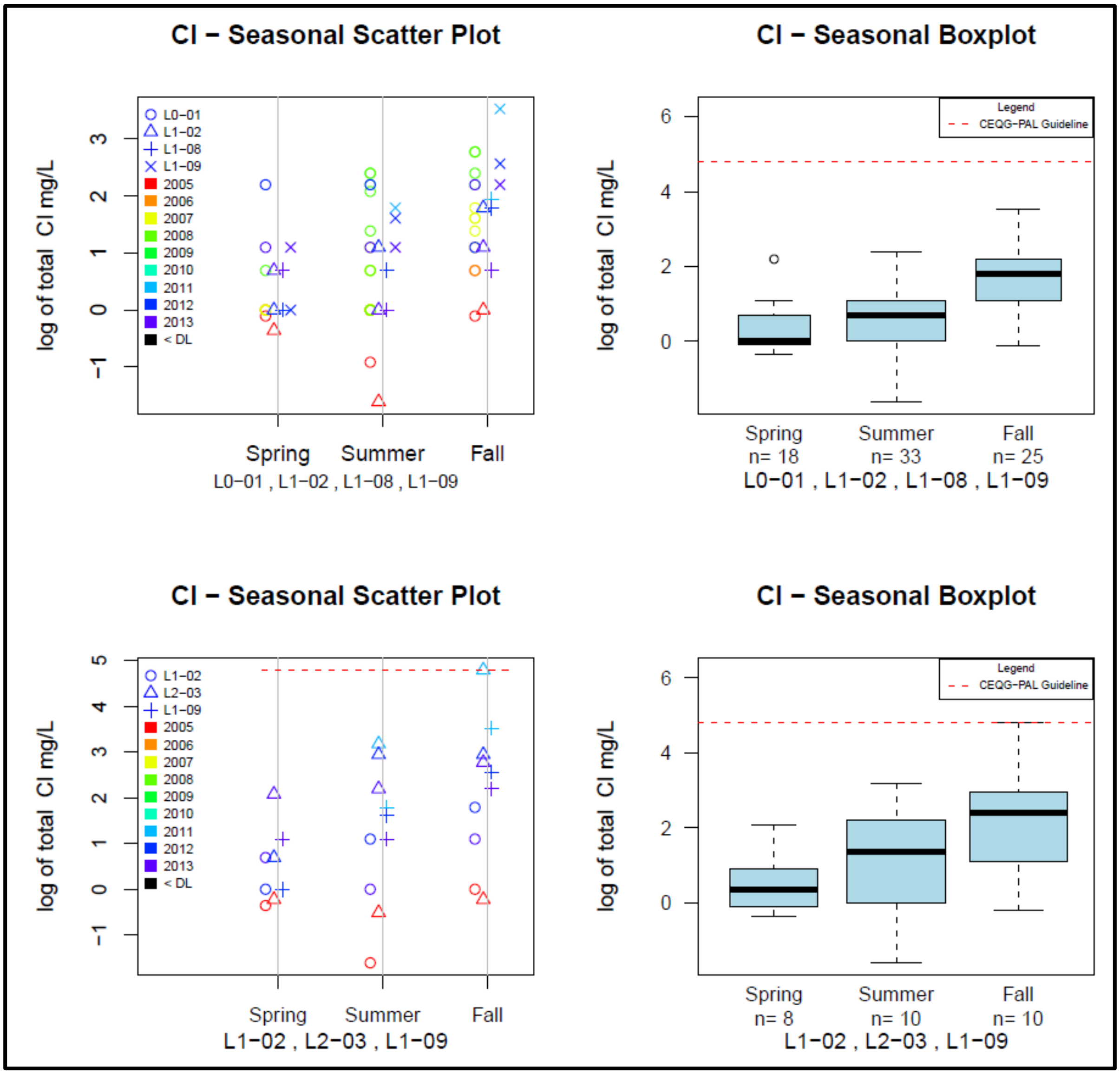
NOTES:

1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.

Figure C.25 Camp Lake Tributary – Chloride Concentrations in Water

higher upstream in the catchment: L1-08 and L1-02. The small magnitude of this change is not conclusive enough to attribute significant change to this parameter as a result of exploration activities.

Temporal trends were not observed to have occurred within the seasonal scatter plots (Figure C.26). Seasonal boxplots for data within the Camp Lake Tributary show a conserved trend of: lower spring concentrations, slightly elevated summer concentrations, and highest seasonal concentrations occurring in the fall.



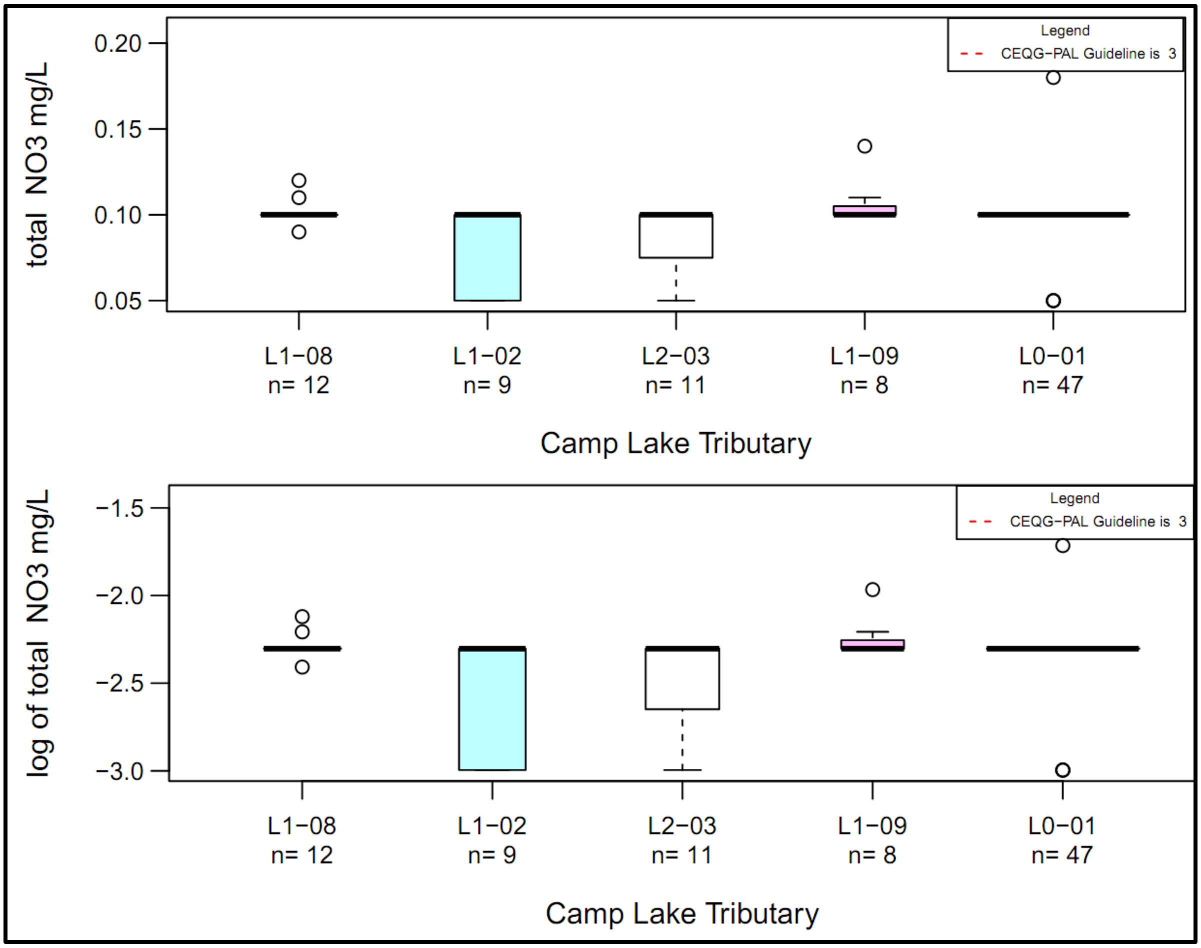
NOTES:

1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.

Figure C.26 Camp Lake Tributary – Variability of Chloride in Water

Nitrate (Figure C.27)

Eighty-seven (87) nitrate samples were collected from the Camp Lake Tributary sampling area. At each geographically distinct sampling station, between 11 to 47 samples were collected. The vast majority of samples collected for nitrate are at MDLs (Figure C.27). Two distinct MDLs are noted: at 0.05 mg/L, and 0.1 mg/L. Due to detection limit interference, distinct geographic trends are difficult to discern. Seasonal trends are not observed due to detection limit interference.



NOTES:

1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.

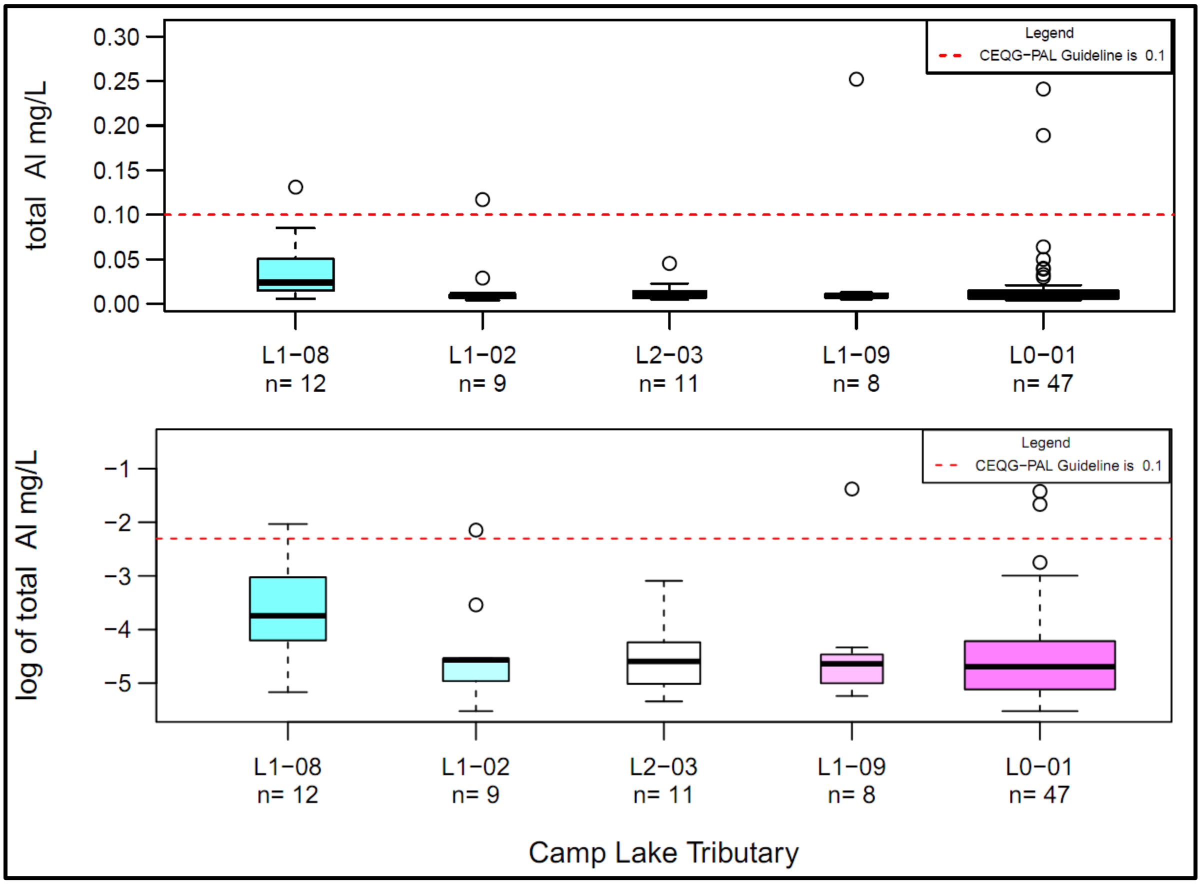
Figure C.27 Camp Lake Tributary – Nitrate Concentrations in Water

The following sections summarize the results for the metal parameters of interest: aluminum, arsenic, cadmium, copper, iron, and nickel.

Total Aluminum (Figures C.28 and C.29)

Eighty-seven (87) samples of total aluminum concentration were collected in the Camp Lake Tributary with 8 to 47 samples collected at each geographically distinct sampling station. Baseline aluminum concentrations occur consistently above MDL, but generally below the CWQG-PAL guideline (0.1 mg/L), except during the spring and summer (Figure C.28). During summer sampling, one outlying maximum aluminum concentrations occurs just above the CWQG-PAL limit and below the Interim SSWQO (0.94 mg/L). Aluminum concentrations at L1-08, the furthest upstream station, are slightly elevated when compared to other sampling stations.

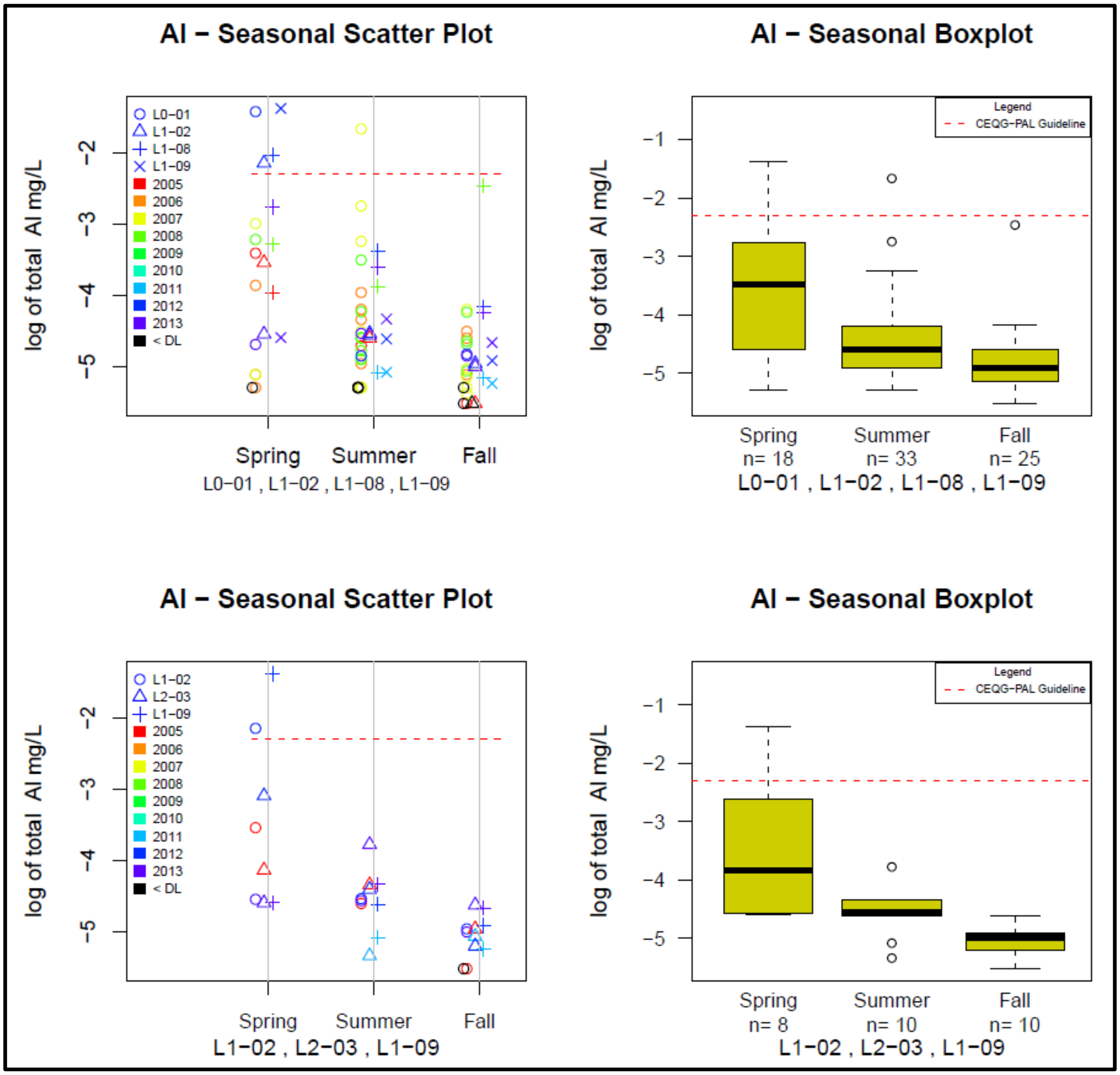
Data from 2012 and 2013 tends to be slightly elevated when compared to other years of sampling (Figure C.29). As mentioned above, seasonal boxplots for the Camp Lake Tributary area show a conserved trend of highest concentrations occurring in the spring, with slightly lower summer concentrations and slightly lower concentrations again in the fall.



NOTES:

1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.

Figure C.28 Camp Lake Tributary – Total Aluminum Concentrations in Water



NOTES:

1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.
2. THE CWQG-PAL GUIDELINE LIMIT IS BASED ON THE TOTAL MEDIAN HARDNESS.

Figure C.29 Camp Lake Tributary – Aluminum Data Aggregation

Total Arsenic

Eighty-seven (87) total arsenic samples were collected in the Camp Lake Tributary area with 8 to 61 samples collected at each geographically distinct sampling station (47 samples were collected at L0-01 and between 8 to12 samples were collected at the remaining stations). Baseline arsenic concentrations occur consistently at MDL and do not change over time. Therefore, graphical analysis is not warranted.

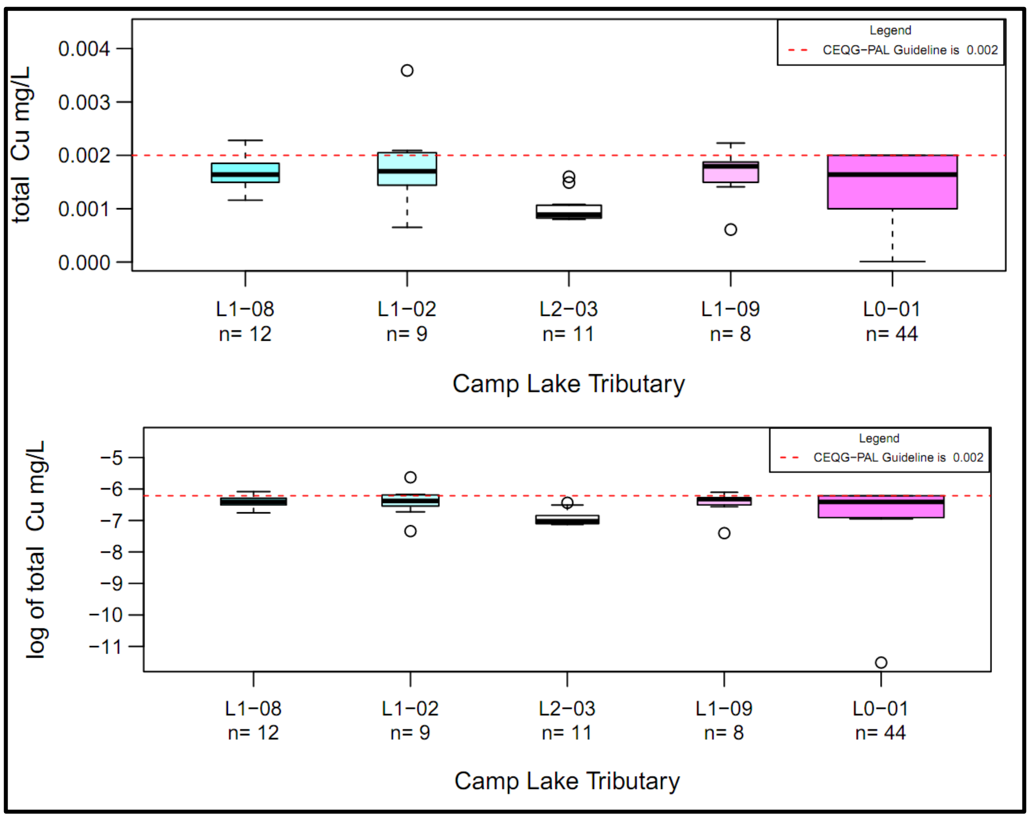
Total Cadmium

Eighty-seven (87) total cadmium samples were collected in the Camp Lake Tributary area with 8 to 47 samples collected at each geographically distinct sampling station (47 samples were collected at L0-01; 8 to 12 samples were collected at the remaining stations). Baseline cadmium concentrations occur consistently at MDL and do not warrant graphical analysis.

Total Copper (Figures C.30 and C.31)

Eight-four (84) copper samples were collected in the Camp Lake Tributary area with 8 to 44 samples collected at each geographically distinct sampling station. Baseline copper concentrations occur consistently above MDL, and close to or above the CWQG-PAL guideline (Figure C.30). Maximum and 75th percentile concentrations occur at or above the CWQG limit at L0-01, L1-02, L1-08, and L1-09. Total median copper concentrations remain at a consistent value for all stations, except L2-03, where copper concentrations are lower.

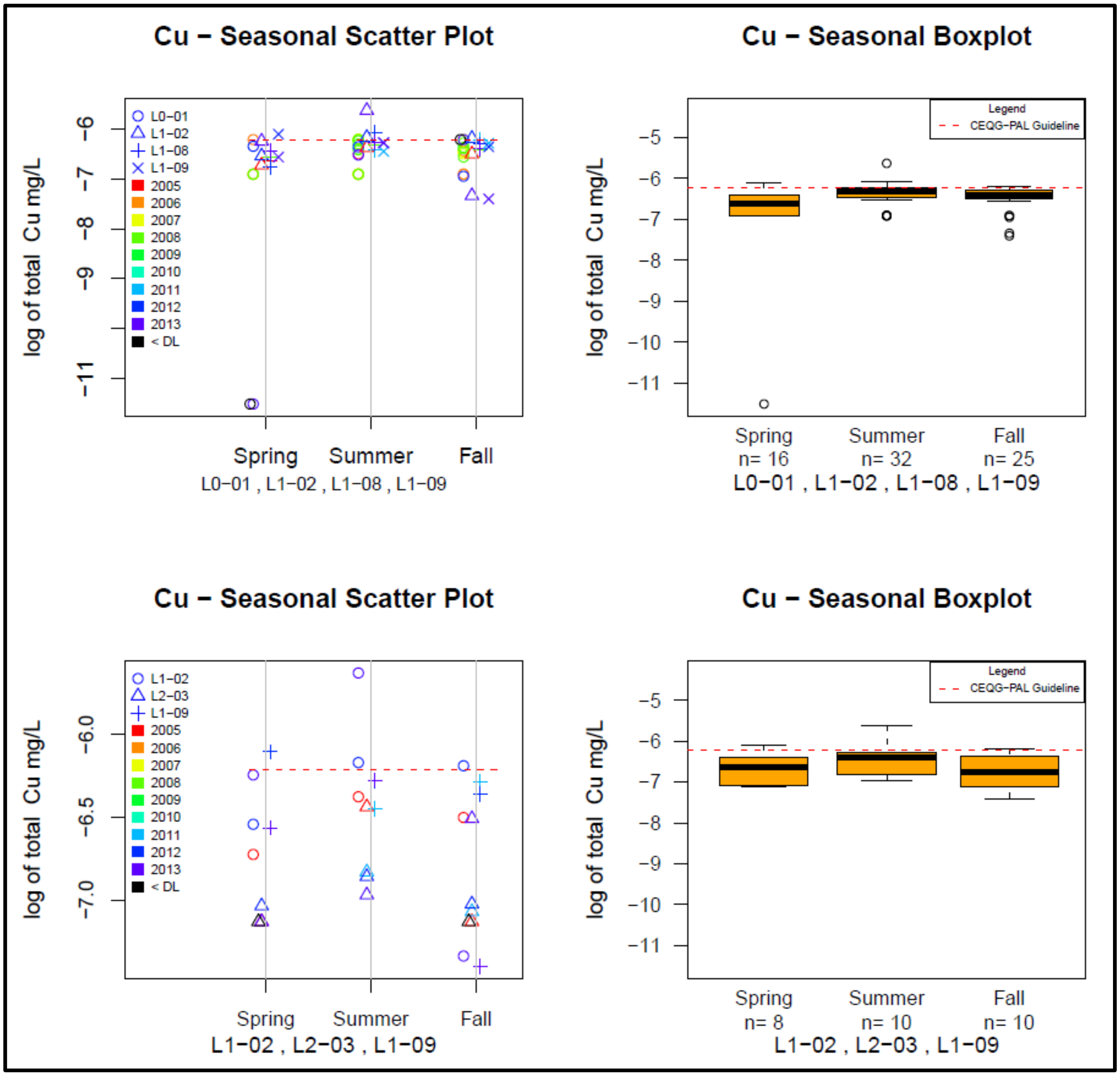
Large magnitude seasonal trends are not observed, but slightly elevated summer concentrations are observed (Figure C.31). No consistent temporal trends are noted over the eight-year sampling history.



NOTES:

1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.
2. THE CWQG-PAL GUIDELINE LIMIT IS BASED ON THE TOTAL MEDIAN HARDNESS.

Figure C.30 Camp Lake Tributary – Total Copper Concentrations in Water



NOTES:

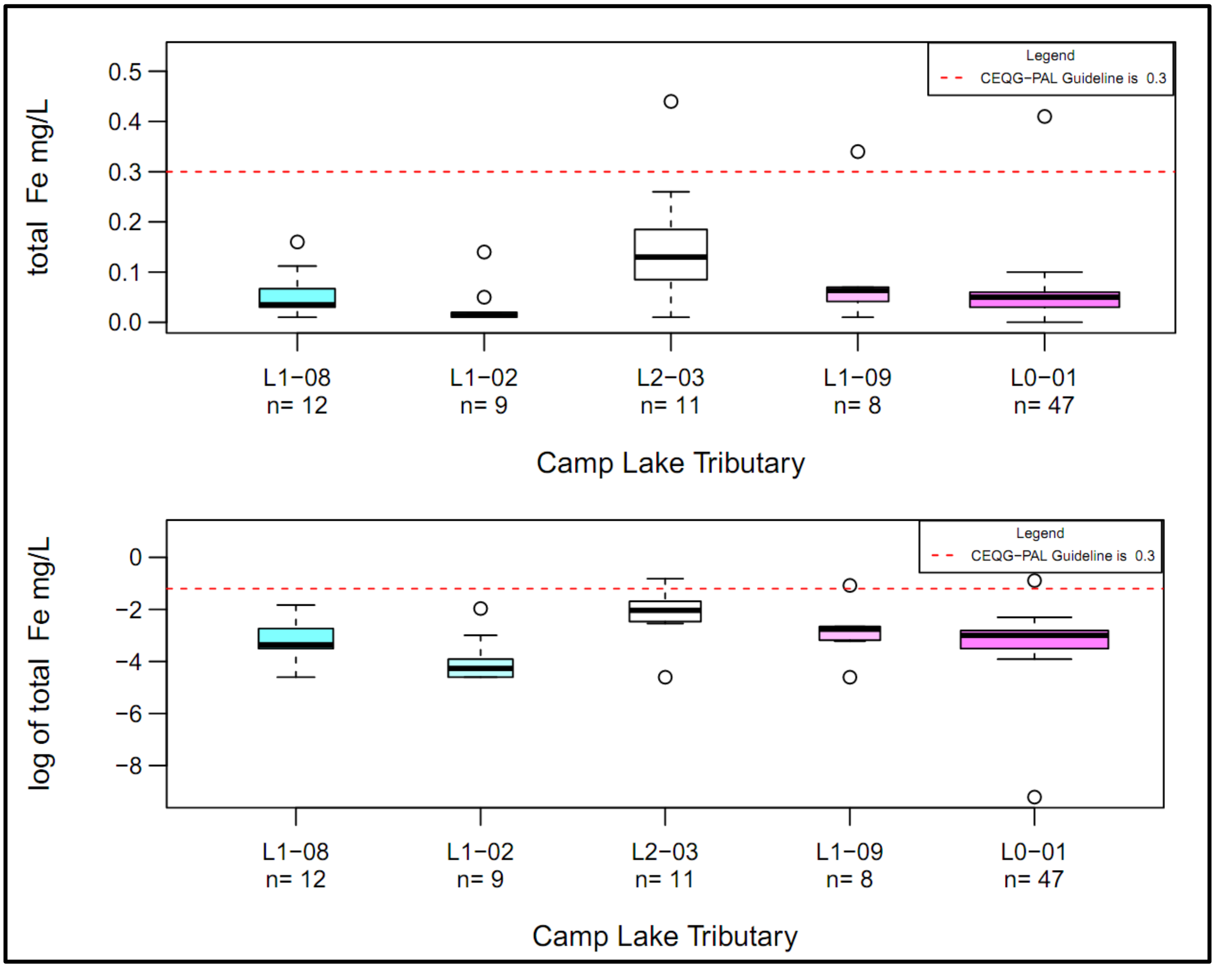
1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.
2. THE CWQG-PAL GUIDELINE LIMIT IS BASED ON THE TOTAL MEDIAN HARDNESS.

Figure C.31 Camp Lake Tributary – Copper Data Aggregation

Total Iron (Figures C.32 and C.33)

Eighty-seven (87) total iron samples were collected in the Camp Lake Tributary area with 8 to 47 samples collected at each geographically distinct sampling station. Baseline iron concentrations occur consistently above MDL, with just 25% of all data collected in the Camp Lake Tributary occuring below MDL (Figure C.32). Total and seasonal median iron values occur consistently below the CWQG-PAL guideline; however, outlying concentrations occur at or above the CWQG limit at several stations (L2-03, L1-09 and L0-01). Iron concentrations at L2-03 are slightly elevated compared to other stations.

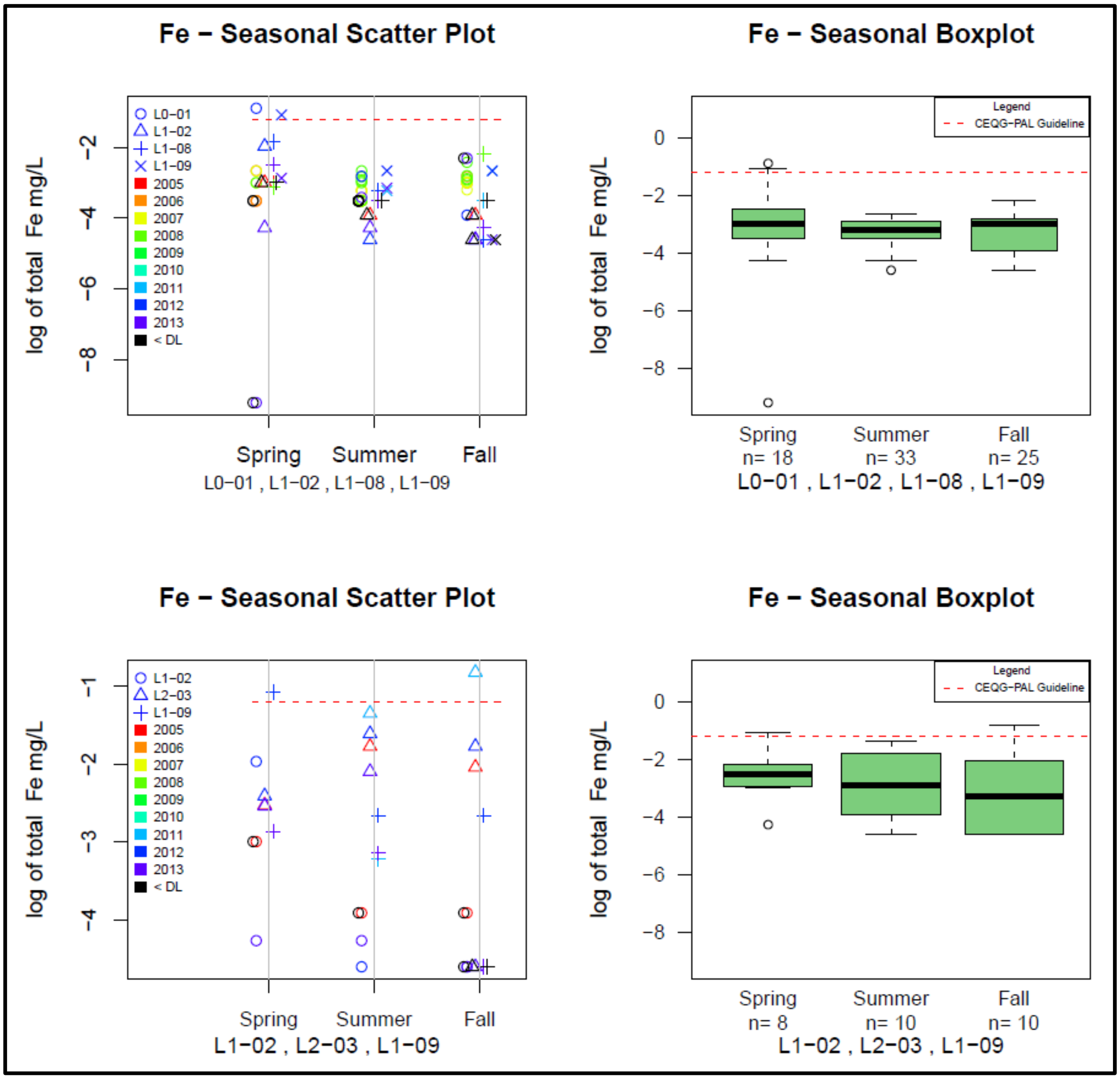
Seasonal box plots show fairly consistent median iron concentration, regardless of season (Figure C.33). In addition, no consistent temporal trends are noted over the eight-year sampling history.



NOTES:

1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.

Figure C.32 Camp Lake Tributary – Total Iron Concentrations in Water



NOTES:

1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.

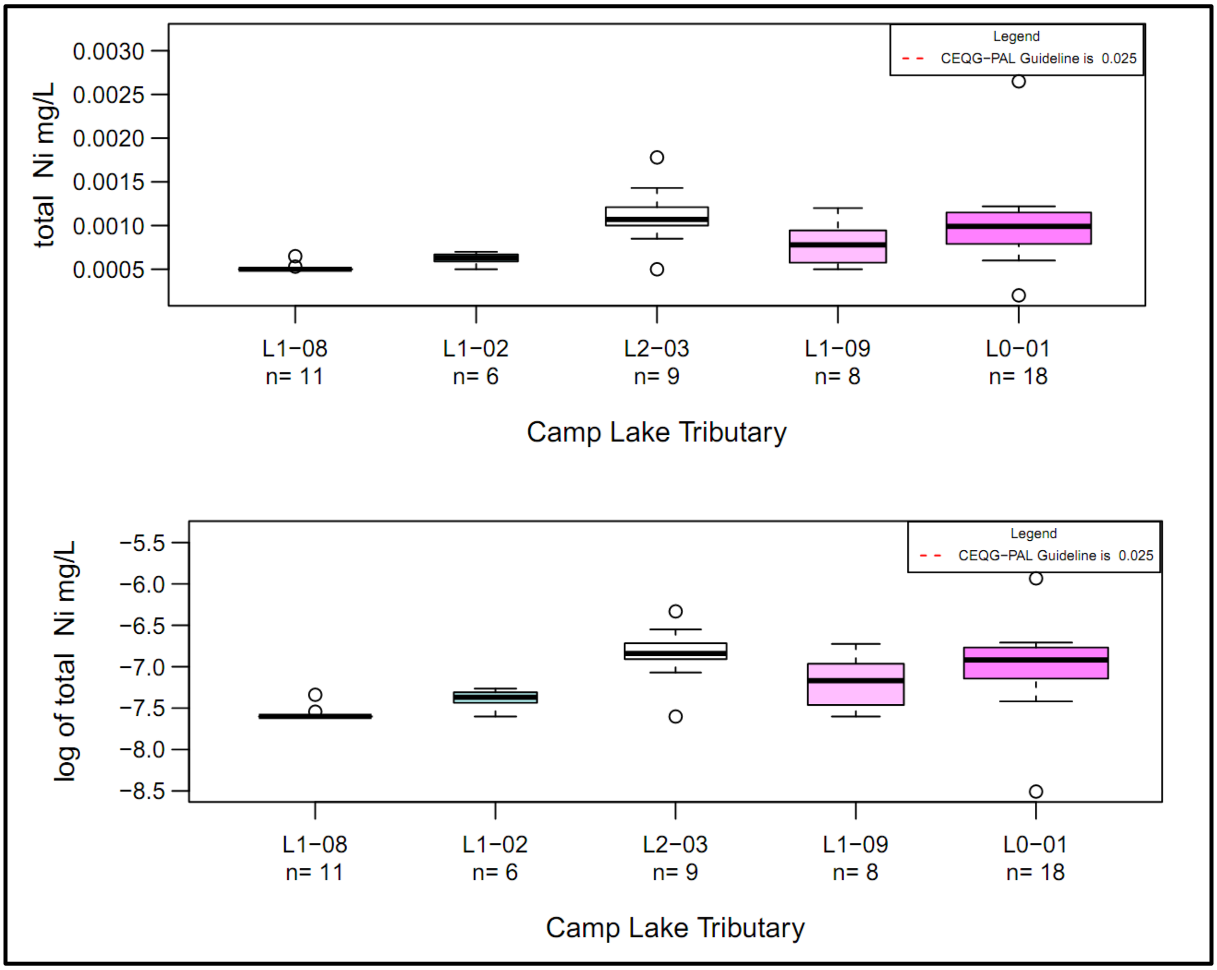
Figure C.33 Camp Lake Tributary – Variability of Total Iron in Water

Total Nickel (Figures C.34 and C.35)

Fifty-two (52) total nickel samples were collected in the Camp Lake Tributary area with 6 to 18 samples collected at each geographically distinct sampling station. Baseline nickel concentrations are consistently low, but occur above MDL (Figure C.34).

All measured concentrations of nickel occur well below the CWQG-PAL guideline, which is a hardness dependent guideline (calculated to be 0.025 mg/L with 50 mg/L $CaCO_3$). Similar to iron, nickel concentrations at L2-03 are slightly elevated compared to other stations, with concentrations at L0-01 occuring just behind those at L2-03.

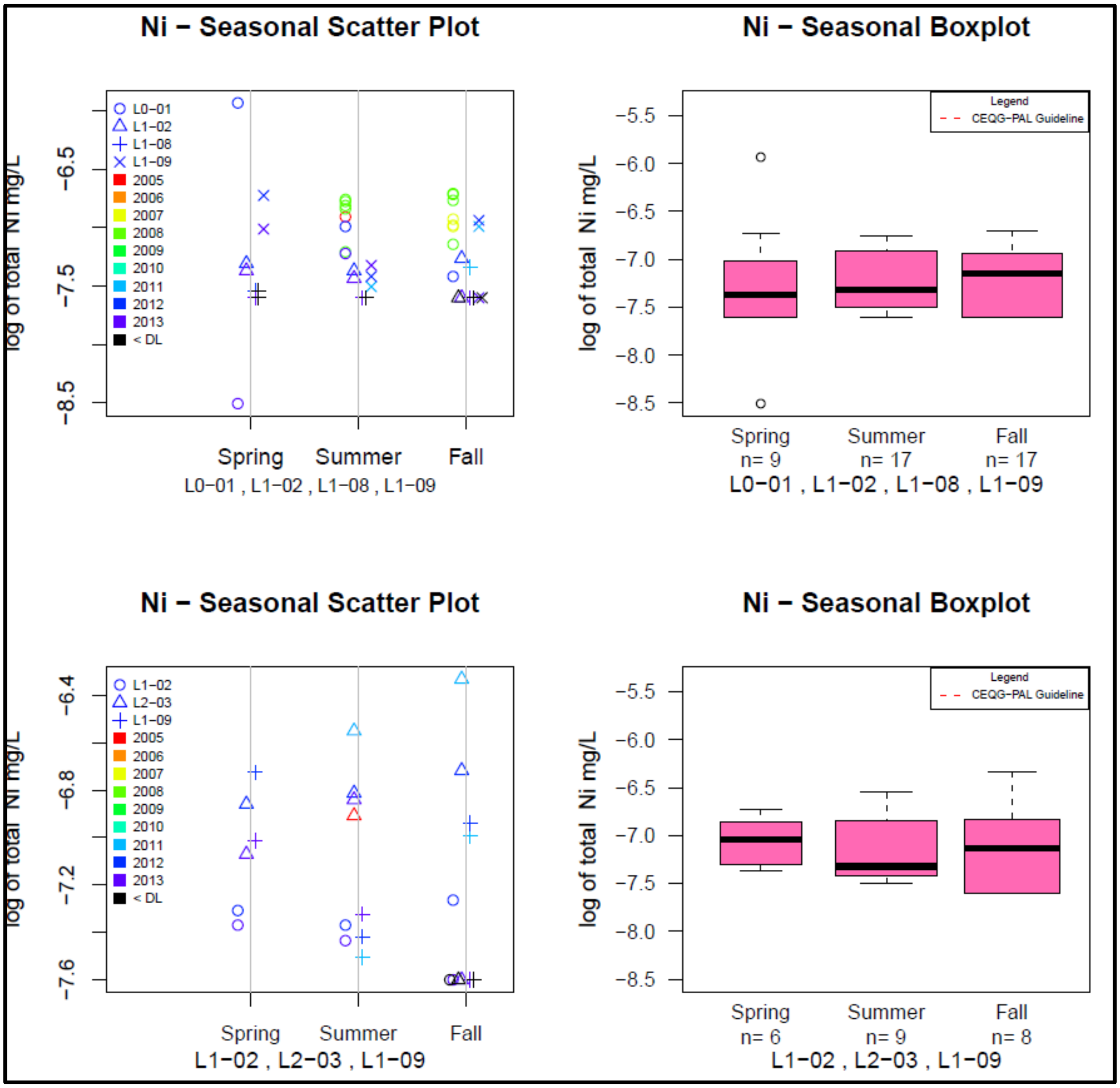
Seasonal box plots show consistent median iron concentration, regardless of season (Figure C.35). In addition, no consistent temporal trends are noted over the eight-year sampling history.



NOTES:

1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.
2. THE CWQG-PAL GUIDELINE LIMIT IS BASED ON THE TOTAL MEDIAN HARDNESS.

Figure C.34 Camp Lake Tributary – Total Nickel Concentrations in Water



NOTES:

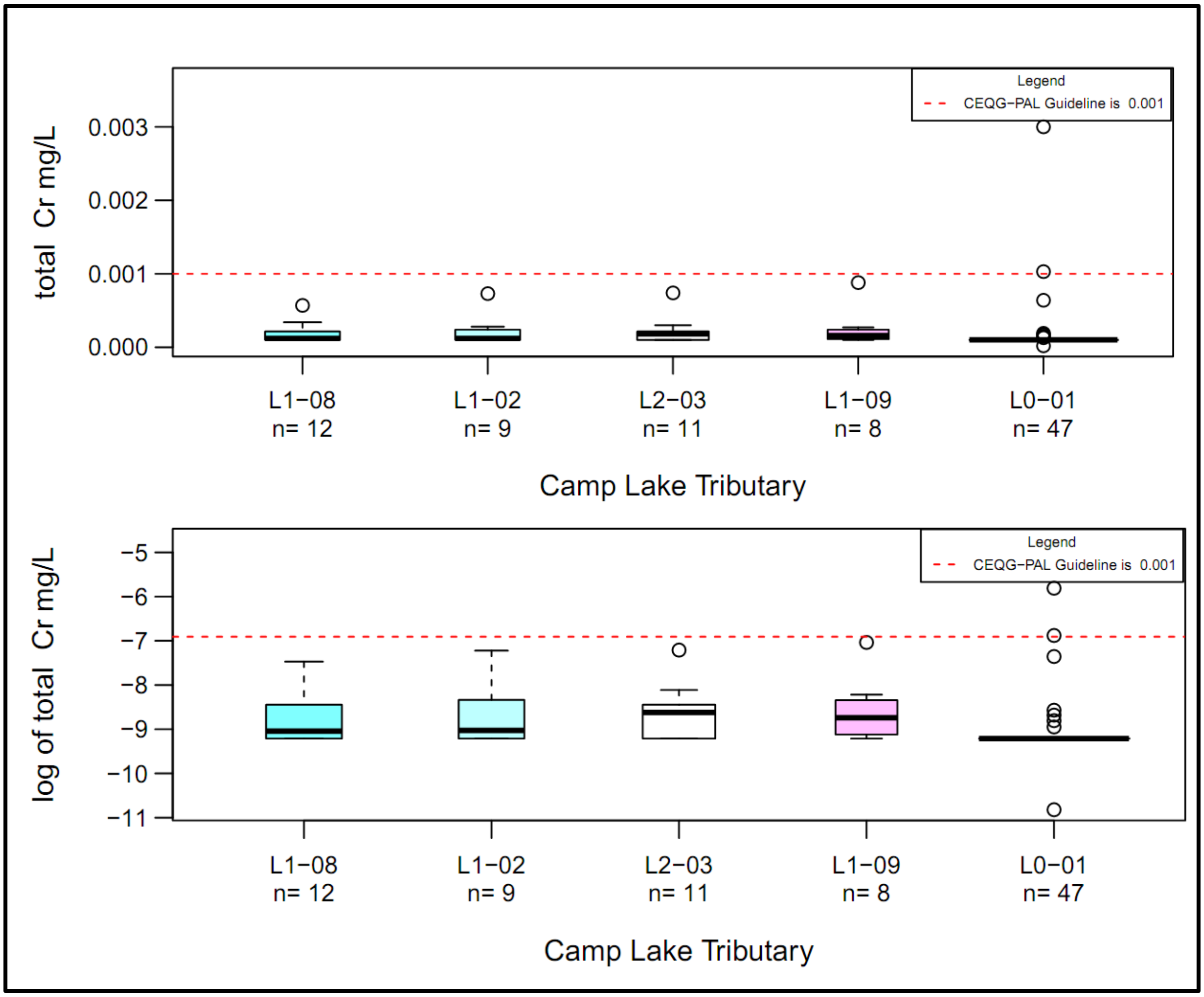
1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.
2. THE CWQG-PAL GUIDELINE LIMIT IS BASED ON THE TOTAL MEDIAN HARDNESS.

Figure C.35 Camp Lake Tributary – Nickel Data Aggregation

Total Chromium (Figures C.36 and C.37)

Eighty-seven (87) total chromium samples were collected in the Camp Lake Tributary area with six to forty-seven samples collected at each geographically distinct sampling station. Baseline chromium concentrations are consistently elevated and occur close to the CWQG-PAL guideline (Figure C.36).

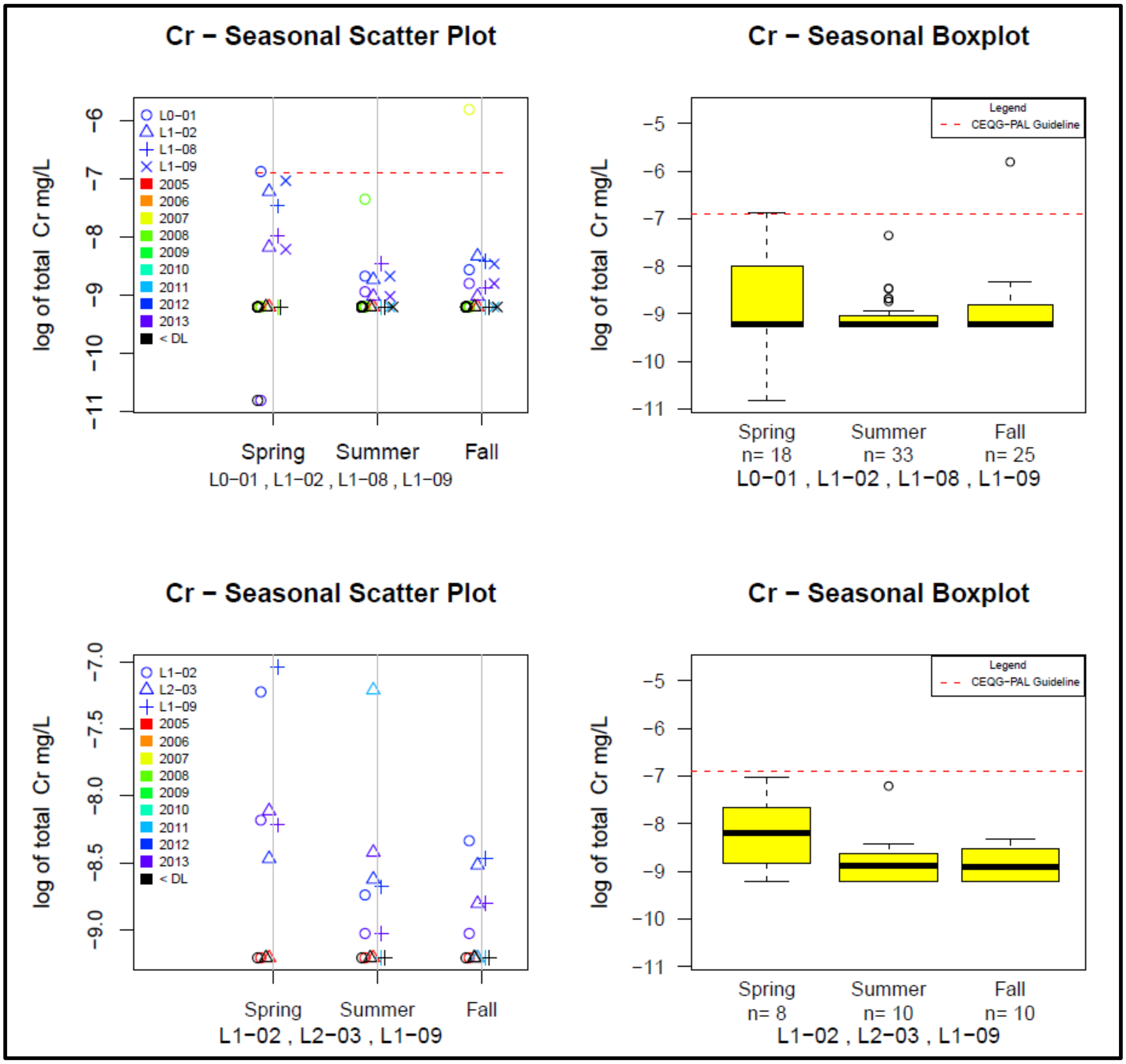
Seasonal box plots show consistent median chromium concentrations, regardless of season (Figure C.37). Data from 2012 and 2013 show slightly elevated values compared to previous years, but insufficient amount of data is avialable to prove this is the case.



NOTES:

1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.
2. THE CWQG-PAL GUIDELINE LIMIT IS BASED ON THE TOTAL MEDIAN HARDNESS.

Figure C.36 Camp Lake Tributary – Total Chromium Concentrations in Water



NOTES:

1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.
2. THE CWQG-PAL GUIDELINE LIMIT IS BASED ON THE TOTAL MEDIAN HARDNESS.

Figure C.37 Camp Lake Tributary – Chromium Data Aggregation

Summary of trends observed during review of Camp Lake Tributary baseline data:

- Station L0-01 has the greatest sample size, with sample size ranging from 30 to 61, depending on the parameter sampled.
- Aluminum and chromium data from 2012 and 2013 was observed to be slightly elevated when compared to other data.
- The L2-03 station recorded slightly higher concentrations of chloride, iron and nickel.

- Seasonal trends occurred for some parameters, and were specific to the parameter: baseline chloride concentrations were highest in the fall, lowest in the spring; aluminum concentration were highest in the spring, lowest in fall; nickel, chromium and iron had consistent median values, regardless of season and copper concentrations were highest in the summer, lowest in the spring.
- Nitrate, arsenic and cadmium were consistently measured to occur below MDLs and seasonal trends were not observed, due to detection limit interference.

C.3.3 River Summary

Since 2005, a variety of watercourses have been sampled as part of the baseline monitoring program. For the purposes of the CREMP, a subset of the total stations was selected that were deemed applicable for future monitoring. As a result, only two river/tributary systems were examined: Mary River and the Camp Lake Tributary. In general, similar station-wide and seasonal trends were noted for each parameter within rivers/tributary systems on the property. No distinct inter-annual trends were noted. Comparison of the general chemistry of the two systems indicates the general composition is quite similar: water is characterised as circum-neutral/slightly alkaline pH and high alkalinity/low sensitivity to acidic inputs. Hardness ranges from “soft” to “moderately soft” and is almost entirely carbonate hardness.

Chemical concentration trends were analysed with the knowledge that the intense spring runoff period resulting from winter snowpack melting characterizes the artic hydrologic cycle (Stewart and Lamoureux, 2011). Our data indicates highest trace metal concentrations occur during summer (and occasionally fall), and that spring concentrations are generally lowest. This indicates that the snowpack is acting as a fresh, diluting seasonal input.

Station-wide, nitrate, arsenic and cadmium general occur at detection limit. Chloride and nickel generally occur above MDL, but below guideline values. Chloride concentration increases through the seasons from the lowest recorded concentration in the spring to the highest recorded concentrations in the fall. In Mary River, the highest nickel concentrations occur in the summer; whereas, no seasonal trends are noted for nickel within the Camp Lake Tributary. Copper concentrations are consistently close to guideline value throughout the station, with highest concentrations occurring in the summer and fall.

Aluminum and iron show slightly different trends between stations within Mary River and the Camp Lake Tributary. Within Mary River, median total aluminium concentrations occur above CWQG-PAL guideline, but below the SSWQO and are highest during the summer. Within the Camp Lake Tributary, median total aluminum concentrations are generally low and below the CWQG guideline and are highest during the spring. Total iron concentrations within Mary River are consistently close to the guideline, with maximum values exceeding guideline and highest concentrations occurring in the summer. Within the Camp Lake Tributary, iron concentrations are consistently below guidelines, with maximum values occurring during the spring.

It is observed that the MDLs are higher for Cr (III) and Cr (VI) compared to total chromium. As such, 38% of samples in Mary River analyzed for total chromium were above MDL. Only 5% of Cr (III) and 2% of Cr (VI) samples were above MDLs. This supports the assumption that most chromium is in suspended particulate.

C.4 POWER ANALYSIS

Parameter and station-specific power analyses were completed in order to determine the power of the proposed sampling program to detect statistical changes. As per the AEMP Assessment Approach and Response Framework (Figure 2.12 in the main report), management action will be triggered if the mean concentrations of any parameter at selected stations reach benchmark values. Benchmarks have been developed as reference concentrations for comparison in the response framework (Intrinsik, 2014). Sufficient statistical power is required to ensure that management action is triggered correctly, and this has necessitated the completion of a power analysis. Inputs to the power analyses include all baseline data sampled to date and the benchmark values. The methodology used in the following sections follows closely the methodology used on lake water quality data in Appendix B.

The *a priori* power analysis determines, based on a given sample size, variability and effect size[2], the number of samples required to obtain a certain power at a certain alpha value or Type I error rate. The analysis utilized a two-sided alpha value of 0.10 (with an alpha of 0.05 on each side). The power analyses were run based on two effect sizes: 1) the difference between the station baseline mean and benchmark and 2) halfway between the station baseline mean and benchmark.

The following parameters were selected for power analysis as they have a large number of detected values, have elevated concentrations during baseline conditions and are expected to be the most affected parameters during mine operation:

- Aluminum
- Arsenic
- Cadmium
- Copper
- Iron

Two different types of power analysis were run, depending on the proportion of data above MDL. Several modifications to each approach were taken, depending on availability of data at a specific site.

1) The power to detect a change in means was assessed for parameters with sufficient data above MDL (<15% of non-detected data). A before-after-control-impact (BACI) design was used to assess the power to detect differences in log mean concentration values (using the methods of Stroup, 1999)[3]. A BACI design is rigorous in the sense that it shows a change in the difference between impact (exposure) and control (reference) stations from before to after the commencement of a potential environmental impact. This method accounts for background natural variation, such as seasonal trends, that may occur during the same period as the potential environmental impact. In order to utilize this design, sufficient baseline data is required at both control and impact sites.

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[2] Effect size is the magnitude of an effect. In *a priori* power analysis, the effect size quantifies the magnitude difference between two groups that the test will be able to determine.

[3] Comparison of medians or log means are both supported methods to compare data sets. Median comparisons are more robust when distributions are non-normally distributed. Median or mean comparisons are equally robust when distributions are normally distributed. Log distribution of water quality data collected created a data set that was normally distributed. As a result, mean comparison was determined appropriate.

For the purposes of analysis, for parameters with <15% non-detected data, only detected data was analyzed. This method was selected due to a variety of detection limits present in the historic data. In some cases, imputation of detection limits occurred, as discussed in Section 2.2. Although all imputation assumptions were conservative; analysis of the detected data removes the possibility that data analysis was affected by imputation or elevated detection limits. To verify the use of the detected data to inform mean values for the power analysis, the mean values estimated with detected data are compared to the mean values estimated via Regression on Order (ROS) method. The Regression on Order (ROS) statistics method is recommended by the BC Ministry of Environment as a method to calculate statistics in data sets including non-detects and especially those affected by left-censored data (Huston and Juarez-Colunga, 2009). Both of these values are provided for each key parameter examined for the sake of comparison. In general, the mean estimate based on detected data is larger than the ROS estimate. This is conservative for the power analysis as a higher baseline mean corresponds to a smaller change to be detected post mining.

The following modifications to the complete BACI approach were taken, as dictated by the data available:

a. Before-after (BA) design was used when control data was not available. Under this design, power analysis was carried out using a two sample t-test to compare means. This approach is less rigorous when compared to the BACI design and does not control for natural temporal changes.

b. Control-impact (CI) design was assumed when very little baseline data was available. Under this design, power analysis for testing means was carried out using a paired t-test. This approach is less rigorous when compared to the BACI design does not control for natural geographic differences between the control and impact sites.

2) The power to detect a change in the proportion of values above MDL was assessed for parameters with a large proportion of values below MDL (>15% of non-detected data). For some parameters the baseline dataset is represented predominantly by values below MDL. This occurred for arsenic and cadmium at all stations. For these parameters, the exact magnitude of the parameters under baseline conditions is unknown. Although a full BACI analysis will be carried out for data analysis purposes, simplified designs were assumed for the power analysis. Two approaches were utilized for the test of proportions:

a. BA designs were assessed using a test for two independent proportions (Agresti, 1990).

b. McNemar's test (Agresti, 1990) was used to assess the power to detect a difference between the paired proportions at impact and control stations. As for continuous data, pairing allows exploitation of the fact that the variance of the difference between paired data is smaller than the variance of the difference between independent samples (Agresti, 1990). Under a full BACI design, the baseline and post-mining paired proportions can be compared to assess whether a change is mine related.

McNemar test for the equivalence of paired proportions (each impact sample paired with a correlated control sample collected at a comparable time) is carried out using the off-diagonal elements (p_{01} and p_{10}) of a 2x2 contingency table. It is helpful to reference Table C.3 for discussions related to the analysis of proportions. This is a novel approach that enables the use of data highly affected by censored data, where a meaningful comparison of means is not possible and the utility of left-censored methods is limited. To our knowledge, this approach has not been used in other projects, but is supported within scientific literature as a valid method to deal with left-censored data (Agresti, 1990).

Table C.3 Proportion Labels for 2x2 Contingency Table

Impact	Control		
	<MDL	>MDL	Total
<MDL	p_{00}	p_{01}	p_{0+}
>MDL	p_{10}	p_{11}	p_{1+}
Total	p_{+0}	p_{+1}	p_{++}

Stations were strategically selected to ensure sampling, and subsequent statistical testing would provide information regarding the source of the contaminants, if any, that arise during the course of mine development. Carrying out the power analysis for each station separately ensures sufficient power to detect change at each location. This is important as pooling data from near-field and far-field stations could potentially wash out effects at near field stations. By choosing stations located at various distances from a potential contaminant source, the spatial extent of potential impacts can be identified and the impact source(s) potentially isolated. These stations are specific to the water body.

C.4.1 Camp Lake Tributary

C.4.1.1 Methods

No pre-mining reference stations were available and the analysis was run assuming no control data, using a before-after (BA) design. Three key monitoring stations within the Camp Lake tributary were assessed. These stations also correspond to the Camp Lake tributary near-field and far-field exposure areas examined as part of the EEM.

- L0-01
- L1-09
- L1-02

Very few data points exist for L1-09 and L1-02, and the most number of samples at Camp Lake tributary were collected for L0-01. By assessing these key points, that also contain the smallest sample sizes, the study design is designed conservatively.

Metrics for sample size, median, mean and standard deviation will be used as a method to compare power between stations for a variety of lakes. In general, sample sets that have a lower sample size, higher variability and a small difference between station baseline mean and benchmark have low power.

C.4.1.2 Results

Since the power analysis was completed on a station-specific and parameter-specific basis, the results were interpreted by identifying the stations and parameters that are most constraining. Table B.5 highlights the stations and parameters that are expected to constrain power. Note that this power analysis is conservative because the effect size used is equal to halfway between the station baseline mean and the benchmark. It is not unexpected that aluminum is a constraining factor across a number of stations since aluminum is the most enriched metal during baseline conditions. Analysis of Table C.4 shows that stations identified as constraining factors for aluminum concentrations are those stations where the distribution of aluminum data occurs close to the benchmark. Discussion of each parameter follows.

Table C.4 Camp Lake Tributary Power Analysis – Constraining Stations and Parameters

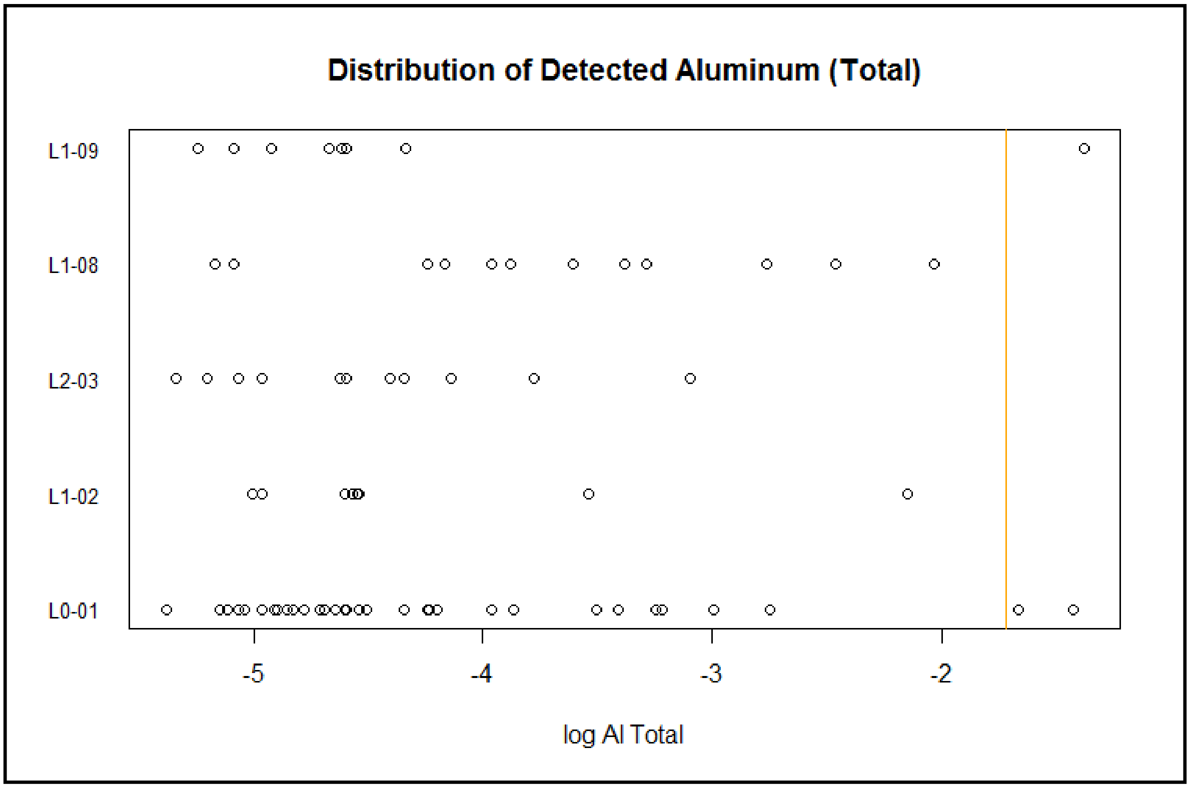
Parameter	Station	Waterbody	Power (given sample size of 10, alpha of 0.1)	Power (given sample size of 50)
Copper	L1-09	Camp Lake Tributary	58%	78%
	L1-02	Camp Lake Tributary	40%	58%
Iron	L1-09	Camp Lake Tributary	60%	80%
	L1-02	Camp Lake Tributary	65%	82%
Aluminum	L1-09	Camp Lake Tributary	70%	90%

NOTES:
1. POWER IS CALCULATED BASED ON AN EFFECT SIZE EQUAL TO HALFWAY BETWEEN THE STATION BASELINE MEAN AND BENCHMARK.

Aluminum

Total aluminum values are elevated throughout the mine site area but concentrations are significantly reduced in the Camp Lake Tributary when compared to the Mary River. Within the Camp Lake Tributary, measured baseline aluminum concentrations have several values that exceed the benchmark at L0-01 and L1-09 (Figure C.38). All measured concentrations at L1-08, L2-03 and L1-02 occur below the benchmark value. The benchmark for aluminum within the Camp Lake Tributary is 0.18 mg/L.

Five (5) samples are expected to be sufficient given an alpha value of 0.1 at all sites with the exception of L1-08 and L1-09, which are anticipated to require 5-10 and 20 samples, respectively.



NOTES:

1. THE CAMP LAKE TRIBUTARY BENCHMARK FOR ALUMINUM IS 0.18 mg/L (LOG VALUE = -1.7), DISPLAYED AS YELLOW LINE.

Figure C.38 Detected Total Aluminum Values in Camp Lake Relative to Benchmark

Table C.5 Results of Aluminum Power Analysis – Camp Lake Tributary Stations

Station	Total Sample Size	Sample Size Detected	Median (mg/L)	Standard Deviation (mg/L)	Log Mean (mg/L)	Log Standard Deviation (mg/L)	ROS Log Mean (mg/L)	Benchmark Value (mg/L)	Log Benchmark Value (mg/L)	Difference between log mean and log benchmark (mg/L)	N Required
L0-01	47	39	0.010	0.047	-4.3	0.91	-4.6	0.18	-1.7	2.6	5
L1-02	9	8	0.011	0.038	-4.2	1.0	-4.5	0.18	-1.7	2.5	5
L2-03	11	11	0.010	0.012	-4.5	0.67	-4.5	0.18	-1.7	2.8	~5[2]
L1-08	12	12	0.024	0.037	-3.7	0.96	-4.7	0.18	-1.7	1.9	~5-10[2]
L1-09	8	8	0.010	0.086	-4.4	1.2	-4.4	0.18	-1.7	2.6	20

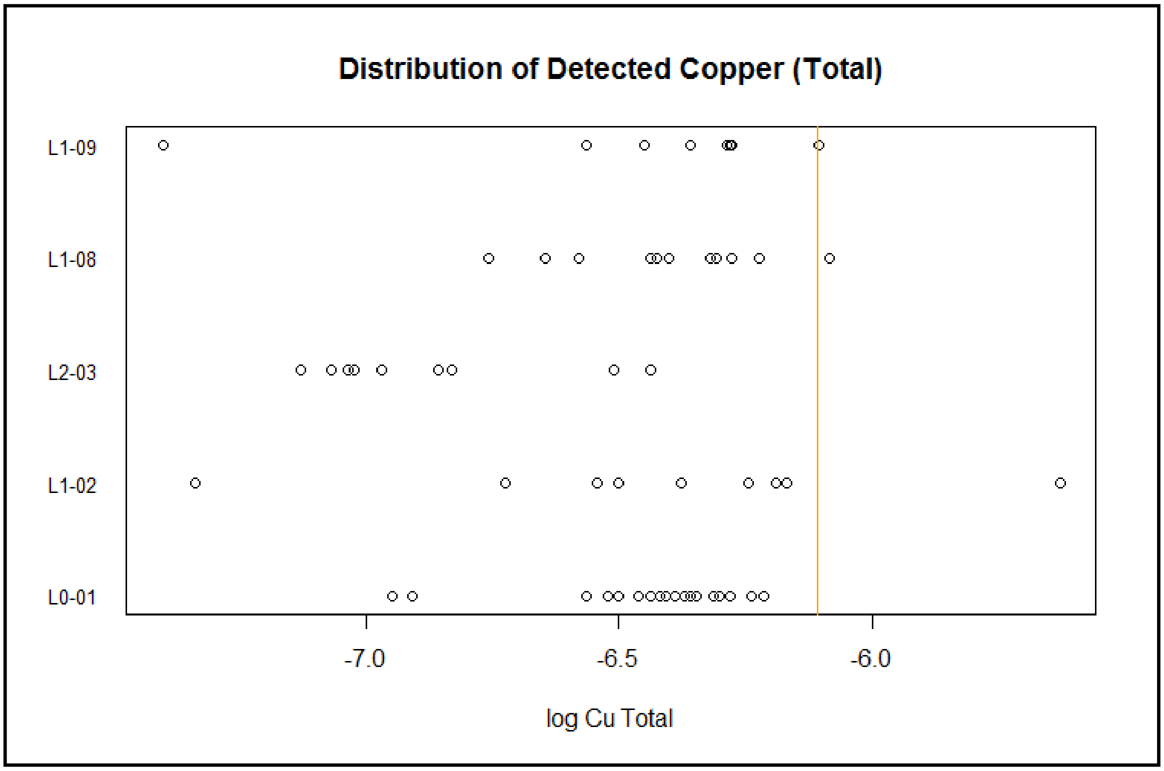
NOTES:

1. N REQUIRED IS BASED ON A POWER EQUAL TO 80%, AN ALPHA VALUE EQUAL TO 0.1 AND AN EFFECT SIZE EQUAL TO HALFWAY BETWEEN THE STATION MEAN AND THE BENCHMARK. THIS ANALYSIS ASSUMES EQUAL STANDARD DEVIATION BEFORE AND AFTER MINE INFLUENCE.
2. VALUES ESTIMATED BASED ON SIMILAR STATIONS.
3. ALL STATISTICS EXCEPT THE ROS LOG MEAN ARE CALCLUATED BASED ON DETECTED DATA. ROS LOG MEAN DATA IS CALCULATED BASED ON BOTH DETECTED AND NONDETECTED DATA.

Copper

Total copper values are observed to be elevated site-wide and are particularly elevated within Mary River and Camp Lake tributary. Median copper values for stations within the Camp Lake tributary range from 0.00094 mg/L to 0.0016 mg/L. The CWQG-PAL guideline for copper is 0.002 mg/L and the benchmark value is 0.0022 mg/L (log value of -6.1). Figure C.39 shows that even though L0-01, L1-02 and L1-9 have median copper concentrations that vary slightly, the distribution of values are quite different.

L1-02 and L1-09 stations are problematic in obtaining adequate sample size to test for pre-mining and post-mining differences in copper. Even with the collection of fifty samples at these stations, the power obtained is still less than adequate (78% for L1-02 and 58% for L1-09) (Table C.6). The power analysis is constrained by the small baseline sample size, which is expected to increase after 2014 sampling.



NOTES:

1. THE CAMP LAKE TRIBUTARY BENCHMARK FOR COPPER IS 0.0022 mg/L (-6.1), DISPLAYED AS YELLOW LINE.

Figure C.39 Detected Total Copper Values in Camp Lake Tributary Relative to Benchmark

Table C.6 Results of Copper Power Analysis – Camp Lake Tributary Stations

Station	Total Sample Size	Sample Size Detected	Median (mg/L)	Standard Deviation (mg/L)	Log Mean (mg/L)	Log Standard Deviation (mg/L)	ROS Log Mean (mg/L)	Benchmark Value (mg/L)	Log Bench mark Value (mg/L)	Difference between log mean and log benchmark (mg/L)	N Required
L0-01	44	42	0.0016	0.00041	-6.5	0.29	-6.5	0.0022	-6.1	0.40	20
L1-02	9	9	0.0017	0.0008	-6.4	0.47	-6.4	0.0022	-6.1	0.30	50
L2-03	11	9	0.00094	0.00029	-6.9	0.25	-7.0	0.0022	-6.1	0.76	NA
L1-08	12	12	0.0016	0.00031	-6.4	0.19	-6.4	0.0022	-6.1	0.30	NA
L1-09	8	8	0.0018	0.00048	-6.5	0.40	-6.5	0.0022	-6.1	0.36	50

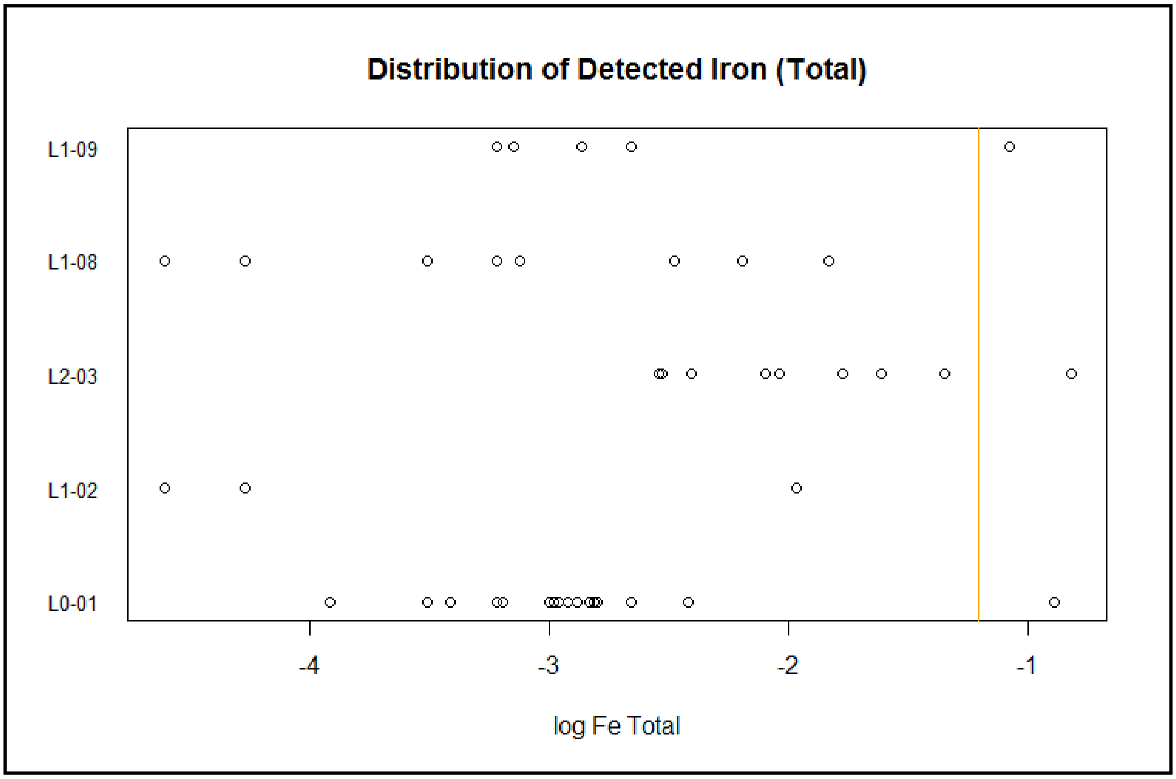
NOTES:

1. N REQUIRED IS BASED ON A POWER EQUAL TO 80%, AN ALPHA VALUE EQUAL TO 0.1 AND AN EFFECT SIZE EQUAL TO HALFWAY BETWEEN THE STATION MEAN AND THE BENCHMARK. THIS ANALYSIS ASSUMES EQUAL STANDARD DEVIATION BEFORE AND AFTER MINE INFLUENCE.
2. NA STATIONS WERE NOT ASSESSED AND CANNOT BE ESTIMATED BASED ON ASSESSED STATIONS.
3. ALL STATISTICS EXCEPT THE ROS LOG MEAN ARE CALCLUATED BASED ON DETECTED DATA. ROS LOG MEAN DATA IS CALCULATED BASED ON BOTH DETECTED AND NONDETECTED DATA.

Iron

Similar to aluminum and copper, iron concentrations are moderately elevated within the Camp Lake Tributary (Figure C.40). Median iron concentrations within the Camp Lake tributary range from 0.042 mg/L to 0.11 mg/L and the number of detectable samples ranges from 8 through 47.

As expected, the L0-01 station requires the least amount of samples post-mining to detect a statistical change (Table C.7). This is as a result of a high sample size for pre-mining data (36) and a low median iron concentration. Twenty post-mining samples are predicted to be required at L1-02, due mostly to the low sample size of pre-mining data. L1-09 proves to be a problematic station to determine significant differences for iron. This station has a low sample size and very high standard deviation. At L1-09, up to 50 samples are required to achieve 80% power. It is expected that the number of samples required at these stations will decrease after the completion of 2014 sampling; however, additional samples at L1-09 in particular key location is recommended to increase power.



NOTES:

1. THE BENCHMARK FOR IRON IN THE CAMP LAKE TRIBUTARY IS 0.3 mg/L (LOG VALUE = -1.2), DISPLAYED AS YELLOW LINE.

Figure C.40 Detected Total Iron Values in Camp Lake Tributary Relative to Benchmark

Table C.7 Results of Iron Power Analysis – Camp Lake Tributary Stations

Station	Total Sample Size	Sample Size Detected	Median (mg/L)	Standard Deviation (mg/L)	Log Mean (mg/L)	Log Standard Deviation (mg/L)	ROS Log Mean (mg/L)	Bench mark Value (mg/L)	Log Benchmark Value (mg/L)	Difference between log mean and log benchmark (mg/L)	N Required
L0-01	47	36	0.052	0.061	-2.9	0.46	-3.1	0.30	-1.2	1.7	5
L1-02	9	5	0.014	0.057	-3.9	1.1	-4.4	0.30	-1.2	2.7	20
L2-03	11	10	0.150	0.110	-1.9	0.55	-2.0	0.30	-1.2	0.7	NA
L1-08	12	8	0.042	0.053	-3.2	0.97	NA	0.30	-1.2	1.9	NA
L1-09	8	7	0.070	0.107	-2.6	0.7	-2.8	0.30	-1.2	1.4	50

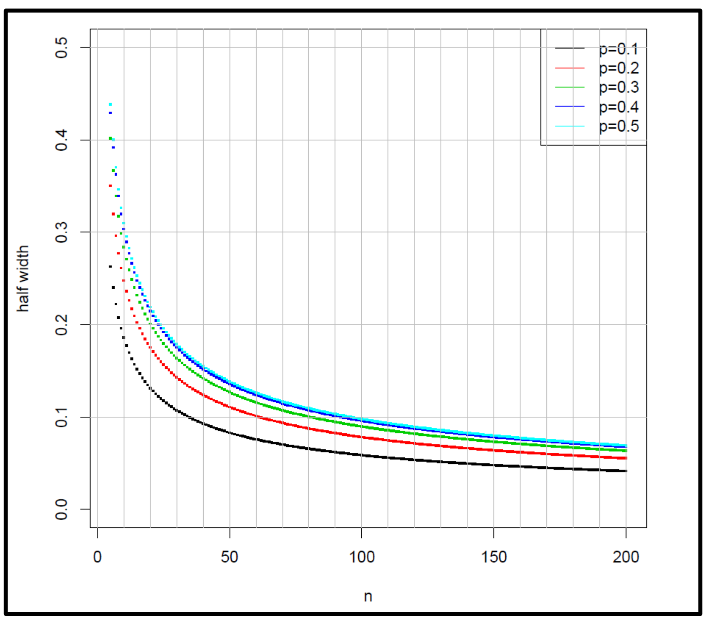
NOTES:

1. REQUIRED IS BASED ON A POWER EQUAL TO 80%, AN ALPHA VALUE EQUAL TO 0.1 AND AN EFFECT SIZE EQUAL TO HALFWAY BETWEEN THE STATION MEAN AND THE BENCHMARK. THIS ANALYSIS ASSUMES EQUAL STANDARD DEVIATION BEFORE AND AFTER MINE INFLUENCE.
2. NA STATIONS WERE NOT ASSESSED AND CANNOT BE ESTIMATED BASED ON EXISTING STATIONS.
3. ALL STATISTICS EXCEPT THE ROS LOG MEAN ARE CALCLUATED BASED ON DETECTED DATA. ROS LOG MEAN DATA IS CALCULATED BASED ON BOTH DETECTED AND NONDETECTED DATA.

Arsenic and Cadmium

More than 90% of samples at each station in the Camp Lake Tributary have arsenic and cadmium concentrations that are below detection limits. As a result, assessment of the proportion of values above MDL was used for these parameters. A normal approximation to the binomial distribution was used to obtain the estimates of the width of confidence intervals for various proportions and sample sizes (based on a normal approximation) shown in Figure C.41. A statistically significant difference between proportions is equivalent to non-overlapping confidence intervals (CI) for the baseline and post-mining proportions. Figure C.41 can be used to determine the accuracy of the proportion estimates (CI) for various proportions and samples sizes. For arsenic and cadmium, the proportion of values below detection limits is greater than 90% (10% above); therefore, the p=0.1 line (black) is selected. For example, L0-01 has a baseline sample size of 47. Thus, a 95% CI on a proportion would be 0.1+/- 0.085 or (1.5%, 18.5%). The post-mining confidence interval for 50% above MDL with 20 samples would be 0.5 +/- 0.22 or (28%, 72%) and would be sufficient to detect such a change. The normal approximation does not hold for small sample sizes and extreme proportions but an exact confidence interval can be calculated. A sample size of 10 would produce a 95% baseline CI of (2%, 40%). Thus, only a large change to approximately 65% (CI = (44%, 86%)) above MDL would differ for a sample 20.

The power to detect a difference between independent samples can also be calculated. To detect a change from 10% to 50% approximately 20 samples are required at baseline and post-mining. With only 10 baseline samples and 10 post-mining samples, 80% power can be obtained for a larger change to 68% above MDL.



NOTES:

1. P EQUALS PROPORTION OF SAMPLES BELOW DETECTION LIMIT.

Figure C.41 Half 95% Confidence Interval Width for Proportions – L0-01

C.4.2 Mary River

C.4.2.1 Methods

Similar to the methods used for the Camp Lake Tributary power analysis, parameter and station-specific power analyses were completed in order to determine the power of the proposed sampling program to detect statistical changes. In contrast to the method used for the Camp Lake Tributary power analysis, pre-mining reference and impact stations exist; therefore, a complete Before-After-Control-Impact (BACI) analysis is utilized.

The stations along the Mary River used in the power analysis were:

- E0-10
- E0-03
- E0-21 and E0-20 (pooled), and
- C0-10.

The best reference station for each impact station was considered to be the G0-09 value collected on the same day. Comparing data on the same day was considered optimal as it would minimize the effects of time. Since data from the same day was not always available, the data was infilled using the following alternatives, listed in order of priority and data proximity (0:29 with 0 indicating the best quality):

- 0-4: G0-09 same day, within 1 day, within 2 days, within 3 days, within 4 days
- 5-9: G0-03 same day, within 1 day, within 2 days, within 3 days, within 4 days
- 10-14: G0-01 same day, within 1 day, within 2 days, within 3 days, within 4 days
- 15-19: G0-09 within 5 days, within 6 days, within 7 days
- 20-24: G0-03 within 5 days, within 6 days, within 7 days, and
- 25-29: G0-01 within 5 days, within 6 days, within 7 days.

For future sampling, it is recommended that the timing of sampling for impact and control sites occur as closely as possible.

C.4.2.2 Results

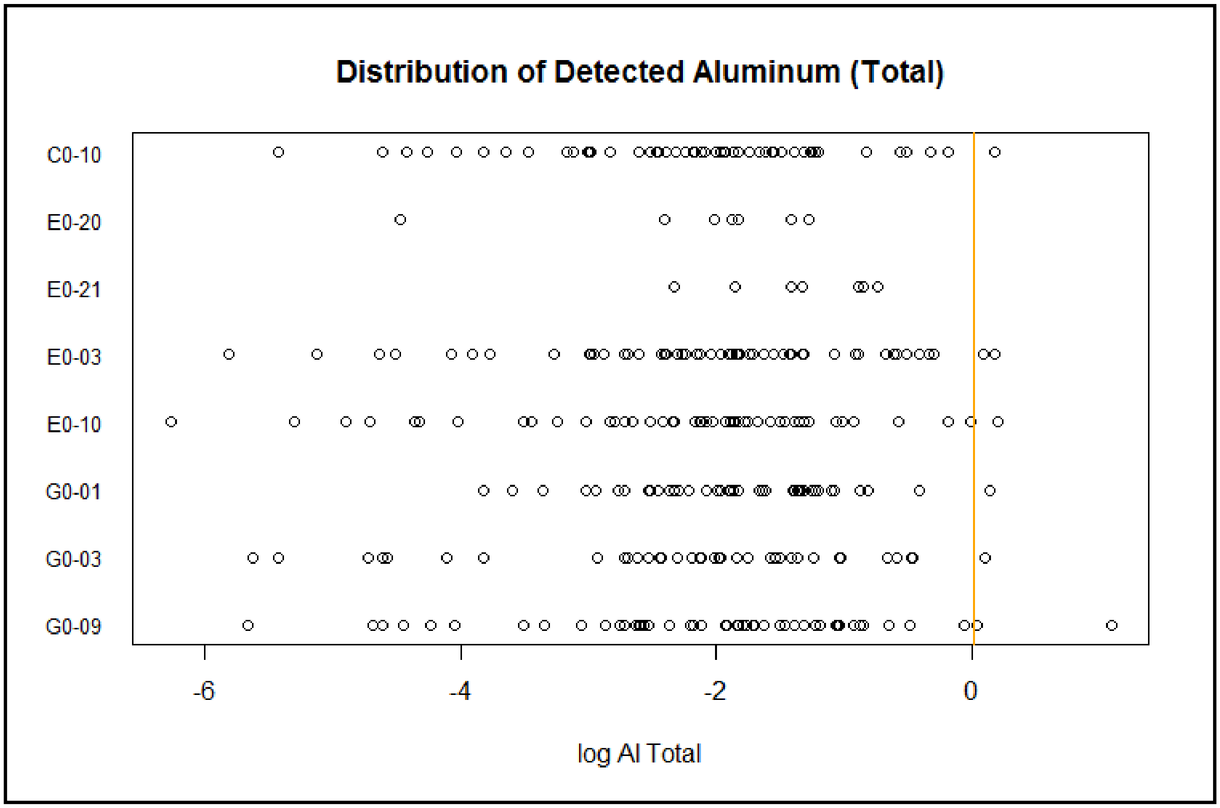
Since the power analysis was completed on a station-specific and parameter-specific basis, the results were interpreted by parameter and station. Unlike the Camp Lake Tributary, no particularly constraining stations or parameters were identified. Power analysis determined between five to ten samples are sufficient to provide 80% power at key stations within the Mary River. Discussion of each parameter individually follows.

Aluminum

Aluminum concentrations are elevated site-wide and are particularly elevated within Mary River. Median aluminum concentrations obtained from all stations in Mary River exceed the CWQG-PAL guideline (0.10 mg/L). The benchmark derived for aluminum is based on the 97.5th percentile of baseline concentrations, and is 1.01 mg/L, which is approximately one order of magnitude greater than the CWQG-PAL guideline. Median aluminum concentrations from the examined stations within Mary River range from 0.13 mg/L to 0.35 mg/L, and standard deviations range from 0.093 mg/L to

0.23 mg/L (Table C.8). Based on the existing baseline and reference data (from stations G0-09, G0-03 and G0-01), all key stations in the Mary River require between eight to ten samples to have adequate power to show significant differences in pre-mining and post-mining data. No "constraining" stations were identified, unlike the Camp Lake tributary (Section C3.1) or lakes assessment (Appendix B).

Figure C.42 shows that there is a strong correlation between aluminum concentrations at impact and control stations. For these stations, the standard deviation of the difference between the impact and control data is smaller than the standard deviation of either sample. The BACI design takes advantage of this correlation and is one of the reasons that relatively low sample sizes can achieve high power.



NOTES:

1. THE BENCHMARK FOR ALURMINUM IN MARY RIVER IS 1.01 mg/L (LOG VALUE = 0.01), DISPLAYED IN RED.

Figure C.42 Detected Total Aluminum Values in Mary River with Respect to Benchmark

Table C.8 Results of Aluminum Power Analysis – Mary River

Station	Total Sample Size	Sample Size Detected	Median (mg/L)	Standard Deviation (mg/L)	Log Mean (mg/L)	Log Standard Deviation (mg/L)	ROS Log Mean (mg/L)	Benchmark Value (mg/L)	Log Benchmark Value (mg/L)	Difference between log mean and log benchmark (mg/L)	N Required
G0-09	52	52	0.15	0.45	-2.1	-0.80	-2.1	1.01	0.01	2.1	NA
G0-03	36	36	0.13	0.23	-2.3	-1.46	-2.3	1.01	0.01	2.2	NA
G0-01	45	45	0.16	0.19	-1.9	-1.65	-1.9	1.01	0.01	1.9	NA
E0-10	48	48	0.14	0.25	-2.3	-1.40	-2.3	1.01	0.01	2.2	10
E0-03	59	59	0.14	0.25	-2.1	-1.37	-2.1	1.01	0.01	2.1	8
E0-21	7	7	0.27	0.14	-1.3	-1.93	-1.3	1.01	0.01	1.3	10
E0-20	7	7	0.15	0.09	-2.2	-2.41	-2.2	1.01	0.01	2.2	
C0-10	53	53	0.12	0.22	-2.2	-1.49	-2.2	1.01	0.01	2.2	8

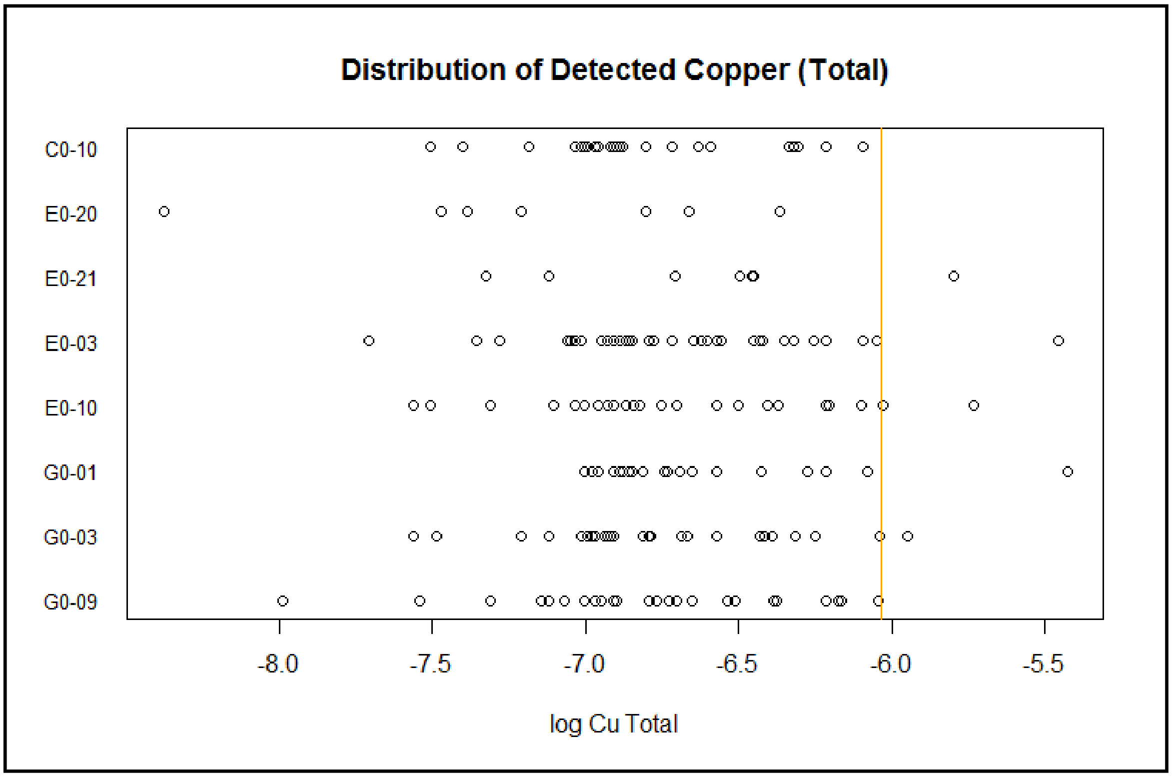
NOTES:

1. N REQUIRED IS BASED ON A POWER EQUAL TO 80%, AN ALPHA VALUE EQUAL TO 0.1 AND AN EFFECT SIZE EQUAL TO HALFWAY BETWEEN THE STATION MEAN AND THE BENCHMARK. THIS ANALYSIS ASSUMES EQUAL STANDARD DEVIATION BEFORE AND AFTER MINE INFLUENCE.
2. VALUES ESTIMATED BASED ON SIMILAR STATIONS.
3. NA STATIONS WERE NOT ASSESSED AND CAN NOT BE ESTIMATED BASED ON EXISTING STATIONS.
4. ALL STATISTICS EXCEPT THE ROS LOG MEAN ARE CALCLUATED BASED ON DETECTED DATA. ROS LOG MEAN DATA IS CALCULATED BASED ON BOTH DETECTED AND NONDETECTED DATA.

Copper

Similar to aluminum, copper is elevated throughout the site. The CWQG-PAL guideline is 0.002 mg/L and the benchmark derived for Mary River is 0.0024 mg/L, which is only slightly above the CWQG-PAL guideline. Median copper values at key stations within Mary river range from 0.00074 mg/L to 0.0015 mg/L (Table C.9). The standard deviation of the baseline copper concentrations at stations along the Mary River are quite low and range from 0.0004 mg/L to 0.00071 mg/L.

Although certain stations have median concentrations that are relatively close to the benchmark (Figure C.43), most stations have median concentrations 50% less than the benchmark and have low standard deviations. As a result, between eight to ten samples are required at the key stations in the Mary River, to achieve 80% power to detect statistical change from baseline concentrations to half of the benchmark value. E0-03 and C0-10 required the least samples (5 and 8, respectively) and E0-20 and E0-21 required the most samples.



NOTES:

1. THE BENCHMARK FOR ALUMINUM IN MARY RIVER IS 0.0024 mg/L (LOG VALUE = -6.0), DISPLAYED IN RED.

Figure C.43 Detected Total Copper Values in Mary River with Respect to Benchmark

Table C.9 Results of Copper Power Analysis – Mary River

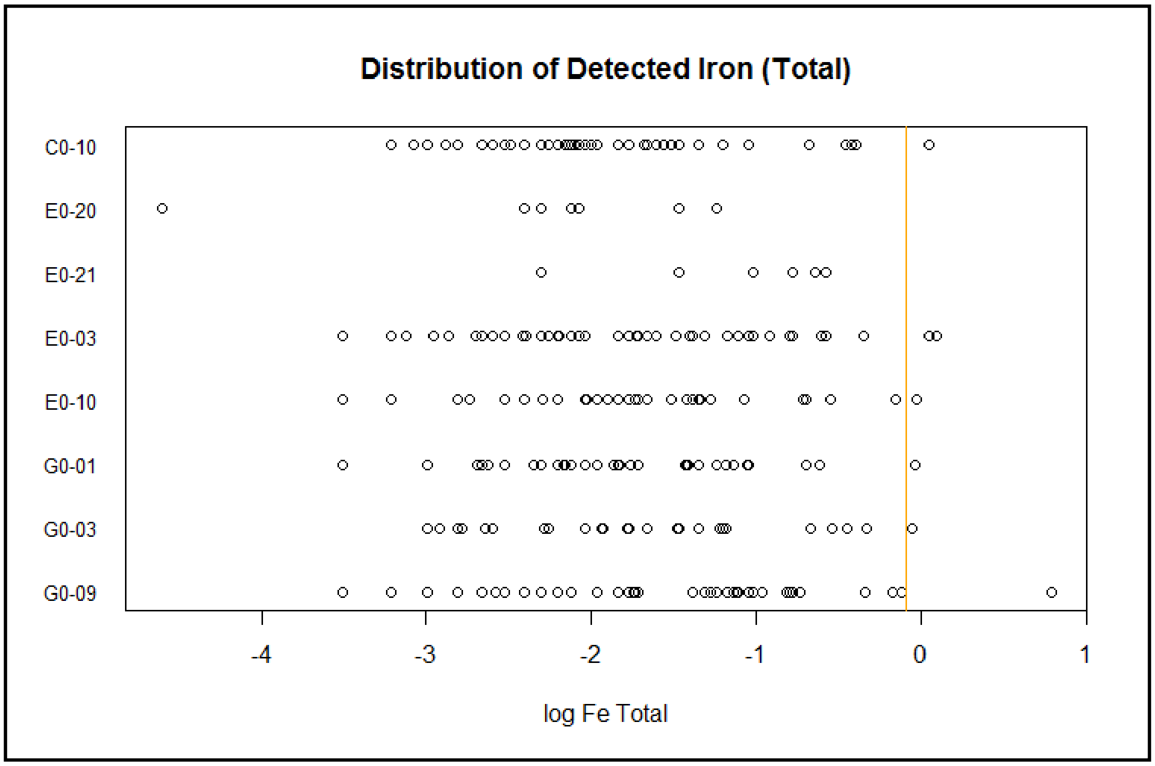
Station	Total Sample Size	Sample Size Detected	Median (mg/L)	Standard Deviation (mg/L)	Log Mean (mg/L)	Log Standard Deviation (mg/L)	ROS Log Mean (mg/L)	Benchmark Value (mg/L)	Log Benchmark Value (mg/L)	Difference between log mean and log benchmark (mg/L)	N Required
G0-09	36	36	0.0011	0.00051	-6.7	0.42	-6.7	0.0024	-6.0	0.71	NA
G0-03	30	29	0.0010	0.00050	-6.8	0.38	-6.8	0.0024	-6.0	0.76	NA
G0-01	29	27	0.0010	0.00071	-6.7	0.36	-6.8	0.0024	-6.0	0.68	NA
E0-10	28	28	0.0011	0.00065	-6.7	0.47	-6.7	0.0024	-6.0	0.71	10
E0-03	42	41	0.0011	0.00065	-6.7	0.40	-6.7	0.0024	-6.0	0.69	5
E0-21	7	7	0.0015	0.00078	-6.6	0.50	-6.6	0.0024	-6.0	0.59	10
E0-20	7	7	0.00074	0.00050	-7.2	0.66	-7.2	0.0024	-6.0	1.15	
C0-10	35	33	0.0010	0.00040	-6.8	0.32	-6.8	0.0024	-6.0	0.79	8

NOTES:

1. N REQUIRED IS BASED ON A POWER EQUAL TO 80%, AN ALPHA VALUE EQUAL TO 0.1 AND AN EFFECT SIZE EQUAL TO HALFWAY BETWEEN THE STATION MEAN AND THE BENCHMARK. THIS ANALYSIS ASSUMES EQUAL STANDARD DEVIATION BEFORE AND AFTER MINE INFLUENCE.
2. VALUES ESTIMATED BASED ON SIMILAR STATIONS.
3. NA STATIONS WERE NOT ASSESSED AND CAN NOT BE ESTIMATED BASED ON EXISTING STATIONS.
4. ALL STATISTICS EXCEPT THE ROS LOG MEAN ARE CALCLUATED BASED ON DETECTED DATA. ROS LOG MEAN DATA IS CALCULATED BASED ON BOTH DETECTED AND NONDETECTED DATA.

Iron

Iron concentrations are relatively elevated throughout the mine site area, and are particularly elevated within Mary River. Median iron levels at baseline range from 0.12 mg/L through 0.17 mg/L. The CWQG-PAL guideline for iron is 0.30 mg/L and the benchmark value (derived from the 97.5th percentile of baseline data) is 0.92 mg/L (log value of -0.088 mg/L). The power analysis was completed based on the statistical test determining a difference halfway between baseline mean and the 0.916 mg/L benchmark. Due to the high effect size, and the distribution of baseline values (Figure C.44), all key stations within Mary River only require between five to ten samples to obtain 80% power to detect the effect size required (Table C.10).



NOTES:

1. THE BENCHMARK FOR IRON IN MARY RIVER IS 0.92 mg/L (LOG VALUE = -0.880), DISPLAYED AS YELLOW LINE.

Figure C.44 Detected Total Iron Values in Mary River with Respect to Benchmark

Table C.10 Results of Iron Power Analysis – Mary River

Station	Total Sample Size	Sample Size Detected	Median (mg/L)	Standard Deviation (mg/L)	Log Mean (mg/L)	Log Standard Deviation (mg/L)	ROS Log Mean (mg/L)	Benchmark Value (mg/L)	Log Benchmark Value (mg/L)	Difference between log mean and log benchmark (mg/L)	N Required
G0-09	52	46	0.17	0.35	-1.8	0.97	-2.0	0.92	-0.088	1.7	NA
G0-03	36	27	0.17	0.23	-1.7	0.85	-2.2	0.92	-0.088	1.7	NA
G0-01	45	42	0.16	0.17	-1.9	0.70	-2.0	0.92	-0.088	1.8	~5
E0-10	48	41	0.14	0.20	-1.9	0.80	-2.2	0.92	-0.088	1.8	5
E0-03	59	52	0.17	0.23	-1.8	0.87	-2.1	0.92	-0.088	1.7	5
E0-21	7	6	0.41	0.18	-1.1	0.66	-1.3	0.92	-0.088	1.0	10
E0-20	7	7	0.12	0.093	-2.3	1.10	-2.3	0.92	-0.088	2.2	
C0-10	58	49	0.13	0.20	-2.0	0.76	-2.1	0.92	-0.088	1.9	5

NOTES:

1. N REQUIRED IS BASED ON A POWER EQUAL TO 80%, AN ALPHA VALUE EQUAL TO 0.1 AND AN EFFECT SIZE EQUAL TO HALFWAY BETWEEN THE STATION MEAN AND THE BENCHMARK. THIS ANALYSIS ASSUMES EQUAL STANDARD DEVIATION BEFORE AND AFTER MINE INFLUENCE.
2. VALUES ESTIMATED BASED ON SIMILAR STATIONS.
3. NA STATIONS WERE NOT ASSESSED AND CAN NOT BE ESTIMATED BASED ON EXISTING STATIONS.
4. ALL STATISTICS EXCEPT THE ROS LOG MEAN ARE CALCLUATED BASED ON DETECTED DATA. ROS LOG MEAN DATA IS CALCULATED BASED ON BOTH DETECTED AND NONDETECTED DATA.

Arsenic

Baseline concentrations of arsenic are very low site-wide. At each station in the Mary River, between 86% to 96% of arsenic samples at each station measured below detection limits. Median detected values for arsenic ranged from 0.00010 mg/L to 0.00017 mg/L. The benchmark for arsenic equals the CWQG-PAL guideline (0.005 mg/L). Table C.11 and Table C.12 list the proportions of samples above and below MDL at stations within the Mary River. Since baseline data was available for control sites in the Mary River, the power analysis was based on McNemar test for the difference between paired proportions. Based on a two-sided alpha value of 0.1 (0.05 on each side), for a power equal to 80%, to detect a difference in paired proportions indicated by: 10% of observations below MDL at impact and above MDL at control; 40% above MDL at impact and below MDL at control.

Table C.11 Number of Arsenic Samples Above and Below MDL at Mary River Stations

	E0-10		C0-10		E0-03	
	Control < MDL	**Control > MDL**	**Control < MDL**	**Control > MDL**	**Control < MDL**	**Control > MDL**
Impact < MDL	43	3	47	3	52	4
Impact > MDL	1	1	2	1	2	1

Table C.12 Proportion of Arsenic Samples Above and Below MDL at Mary River Stations

	E0-10		C0-10		E0-03	
	Control < MDL	**Control > MDL**	**Control < MDL**	**Control > MDL**	**Control < MDL**	**Control > MDL**
Impact < MDL	0.90	0.06	0.89	0.06	0.88	0.07
Impact > MDL	0.02	0.02	0.04	0.02	0.03	0.02

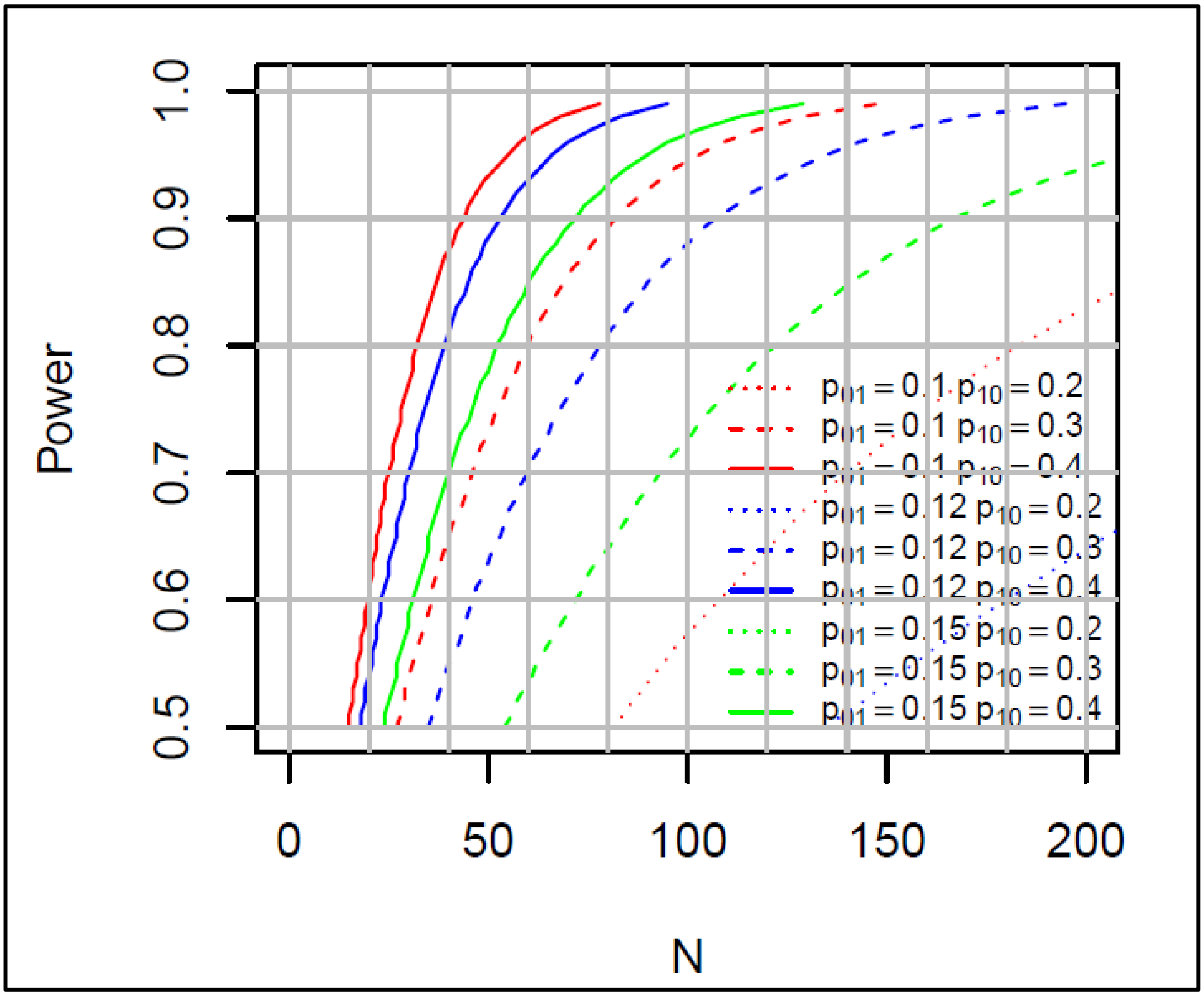


Figure C.45 Arsenic Sample Size Requirements for Equality of Proportions

Cadmium

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

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

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

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

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

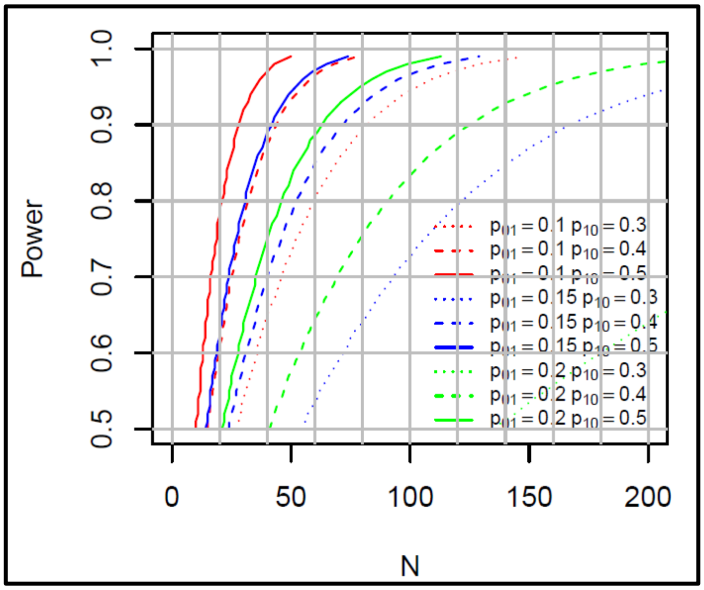


Figure C.46 Cadmium Sample Size Requirements for Equality of Proportions

C.4.3 Recommendations

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

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

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

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

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

C.5 REFERENCES

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APPENDIX D

DETAILED REVIEW OF BASELINE SEDIMENT QUALITY

(Pages D-1 to D-37)

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

BAFFINLAND IRON MINES CORPORATION
MARY RIVER PROJECT

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

Rev	Description	Date
1	Issued in Final	May 30, 2014

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D – SEDIMENT QUALITY REVIEW

D.1 OVERVIEW

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

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

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

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

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

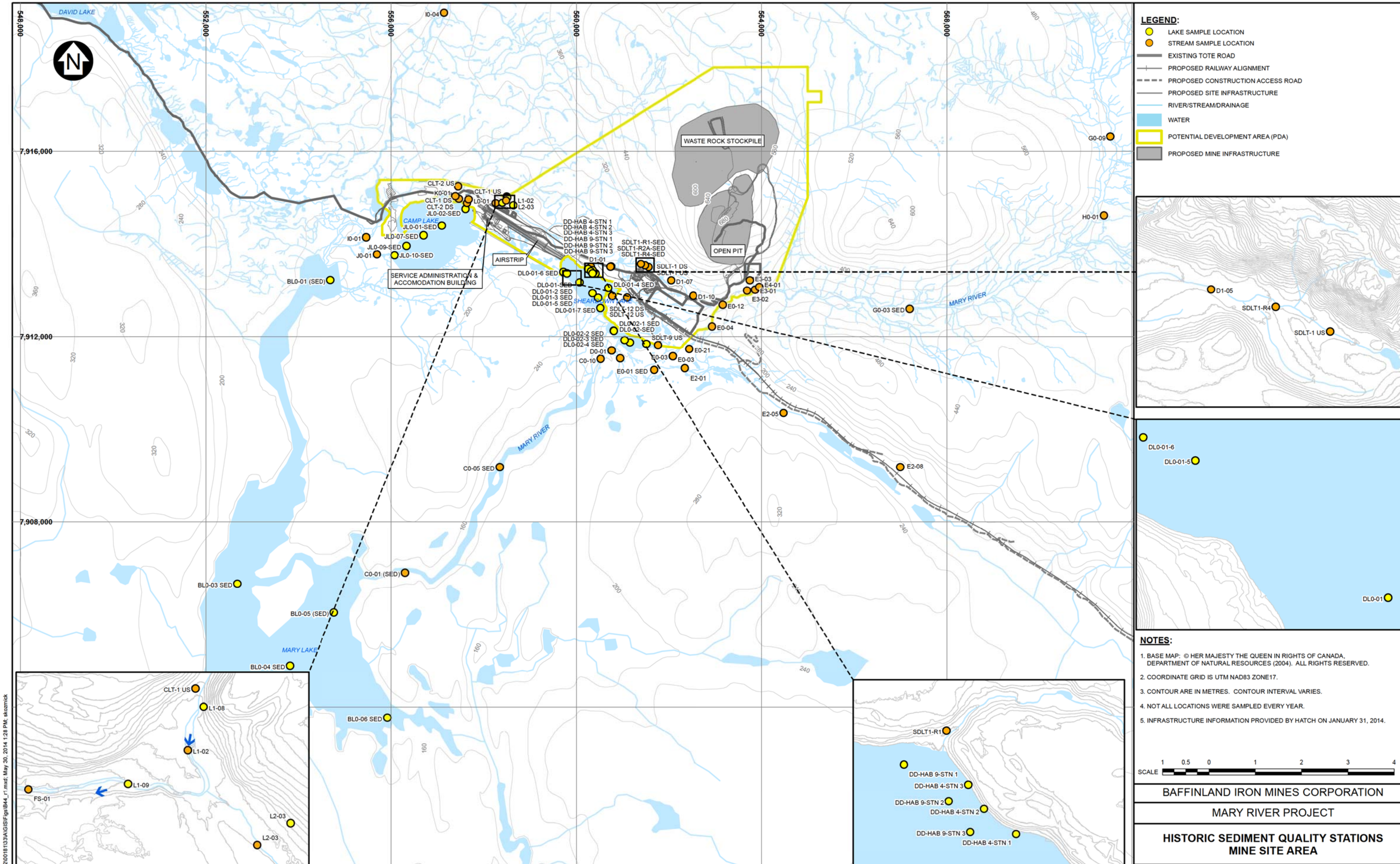
To assist in the development of study designs, parameter and station-specific a priori power analyses were completed in order to determine the power of the proposed sampling program to detect statistical changes. As per the Assessment Approach and Response Framework in the CREMP (see Figure 2.12 in the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

D.2 REVIEW OF SEDIMENT QUALITY BY PARAMETER

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

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

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



REV	DATE	DESCRIPTION	DESIGNED	DRAWN	CHK'D	APP'D
1	30MAY'14	ISSUED WITH REPORT	RAC	SWK	RAC	RAM
0	27MAR'14	ISSUED WITH REPORT	DKK	AS	RAC	RAM

BAFFINLAND IRON MINES CORPORATION

MARY RIVER PROJECT

HISTORIC SEDIMENT QUALITY STATIONS MINE SITE AREA

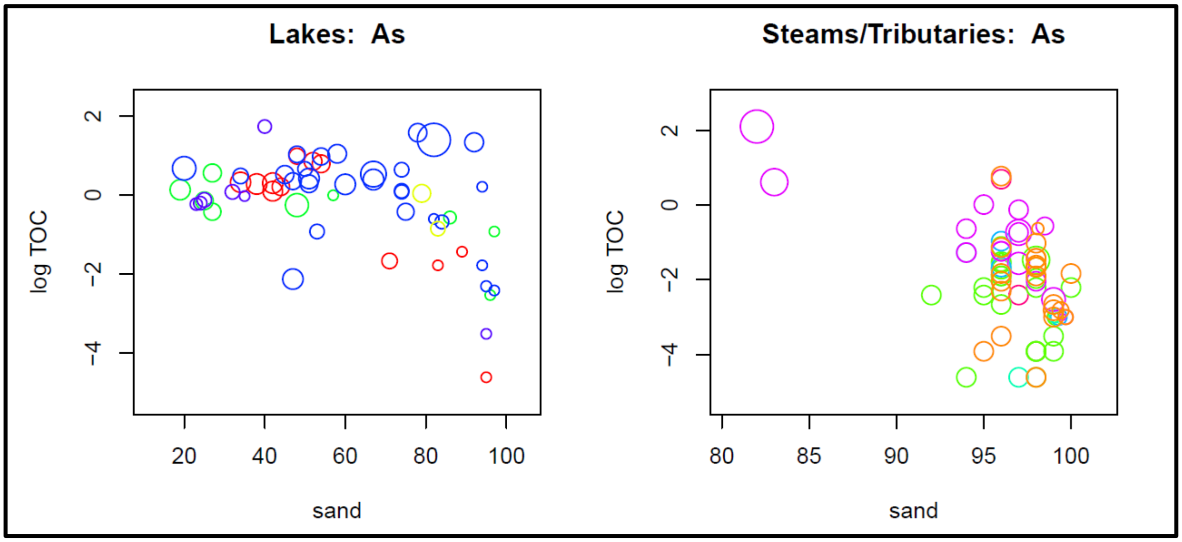
Knight Piésold CONSULTING

P/A NO. NB102-181/33 | REF NO. 1

FIGURE D.1 | REV 1

Arsenic (Figure D.2)

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



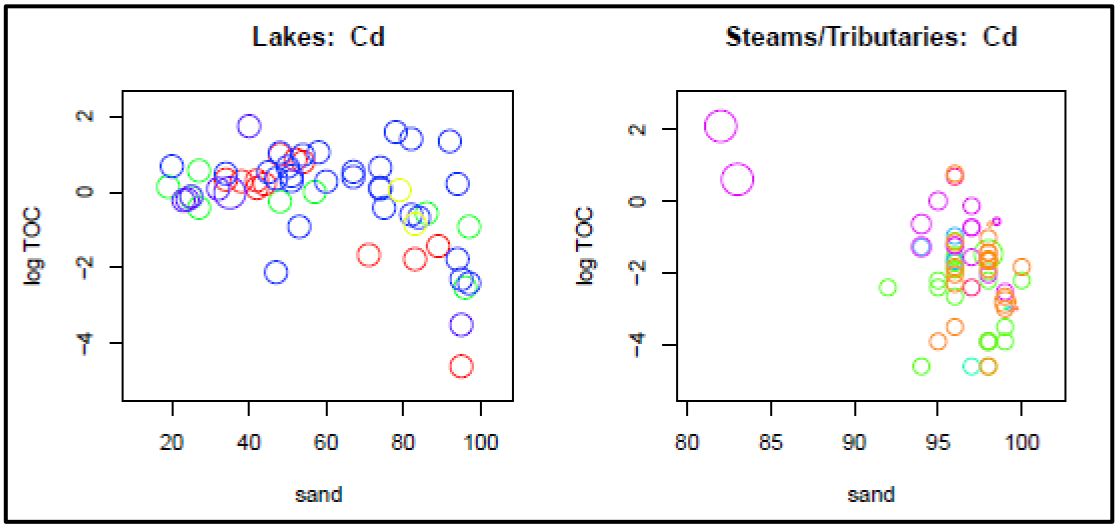
NOTES:

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

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

Cadmium (Figure D.3)

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



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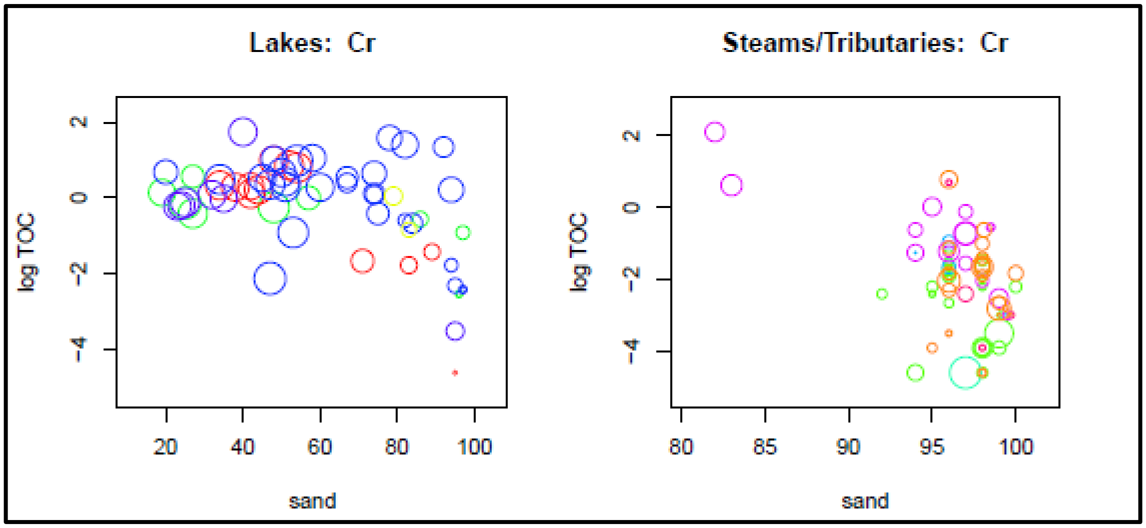
4. VALUES RECORDED AT OR BELOW DETECTION LIMIT ARE PLOTTED AT THEIR DETECTION LIMIT.

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

Chromium (Figure D.4)

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



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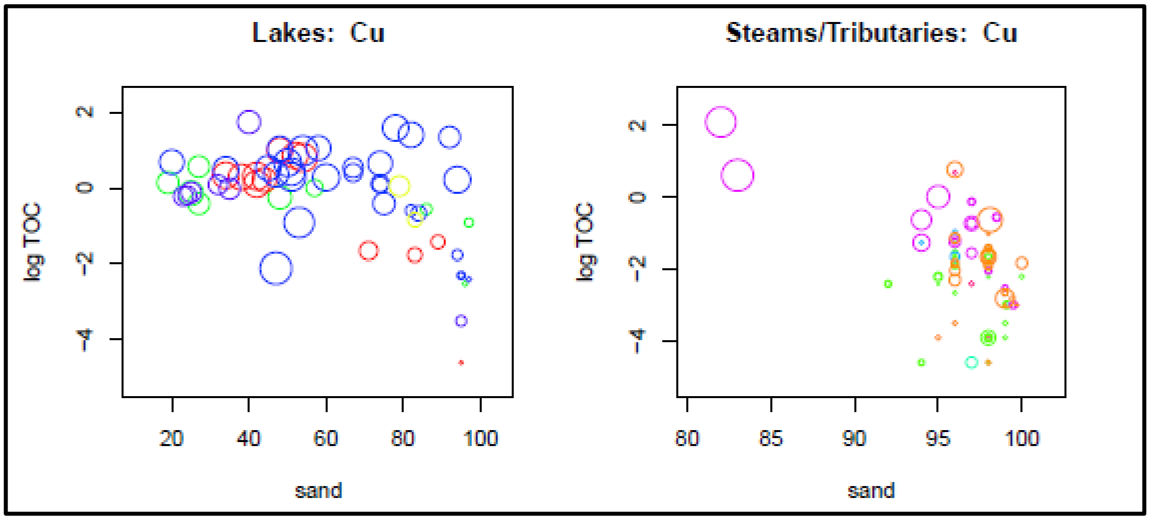
3. THE AREA OF THE DOT REPRESENTS THE CONCENTRATION OF THE METAL.
4. VALUES RECORDED AT OR BELOW DETECTION LIMIT ARE PLOTTED AT THEIR DETECTION LIMIT.

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

Copper (Figure D.5)

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



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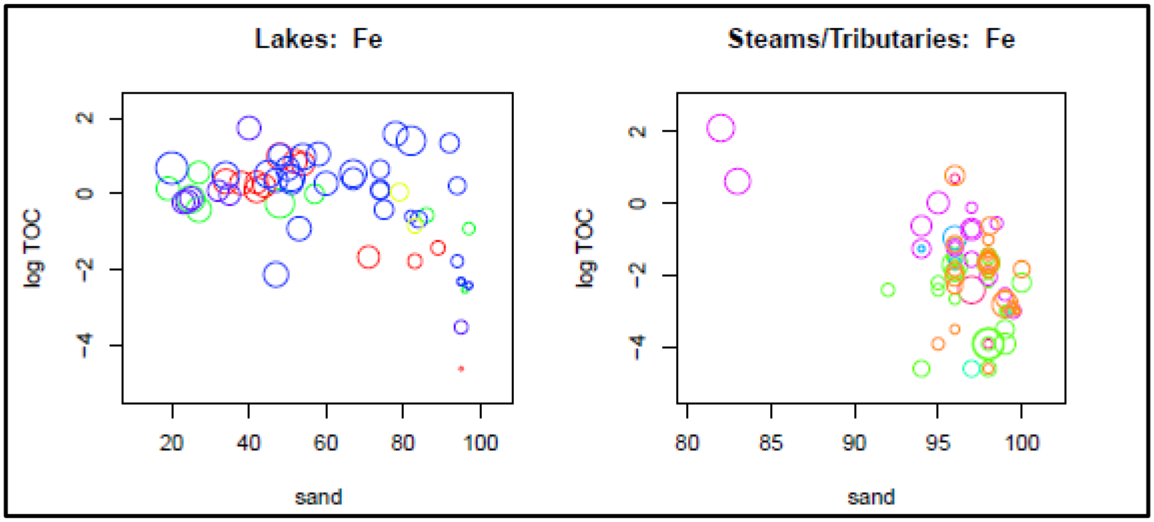
3. THE AREA OF THE DOT REPRESENTS THE CONCENTRATION OF THE METAL.
4. VALUES RECORDED AT OR BELOW DETECTION LIMIT ARE PLOTTED AT THEIR DETECTION LIMIT.

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

Iron (Figure D.6)

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



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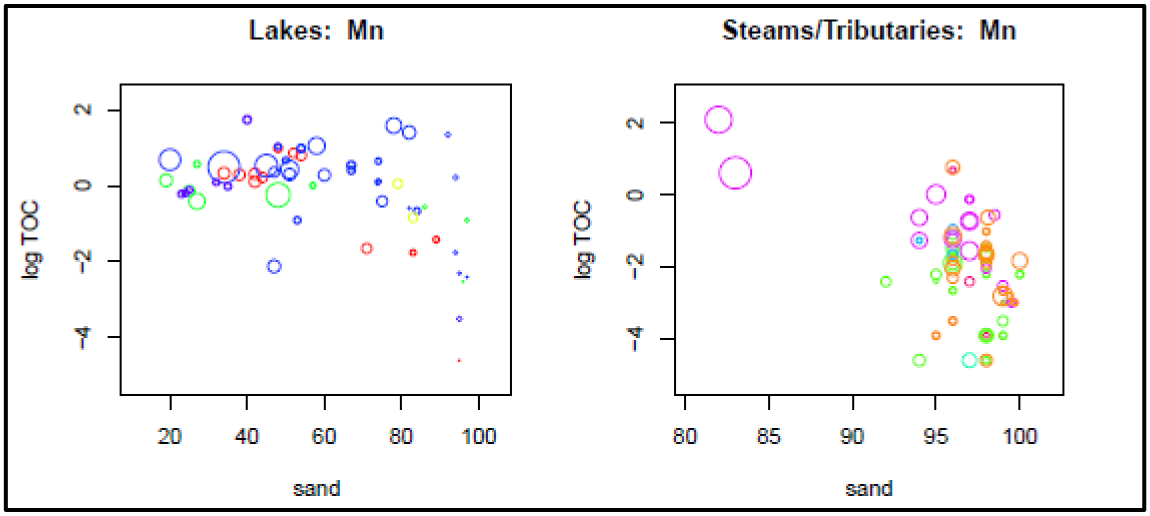
3. THE AREA OF THE DOT REPRESENTS THE CONCENTRATION OF THE METAL.
4. VALUES RECORDED AT OR BELOW DETECTION LIMIT ARE PLOTTED AT THEIR DETECTION LIMIT.

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

Manganese (Figure D.7)

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



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

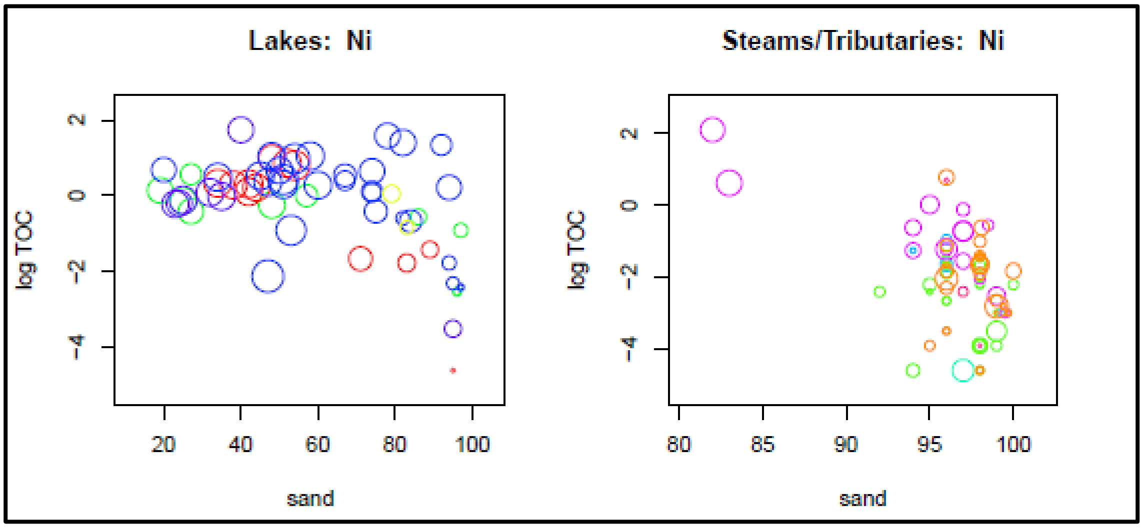
Figure D.7 Manganese in Sediment as a Function of Log TOC and Percent Sand

Mercury (no figure)

- All stream and lake concentrations were below the MDL.

Nickel (Figure D.8)

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



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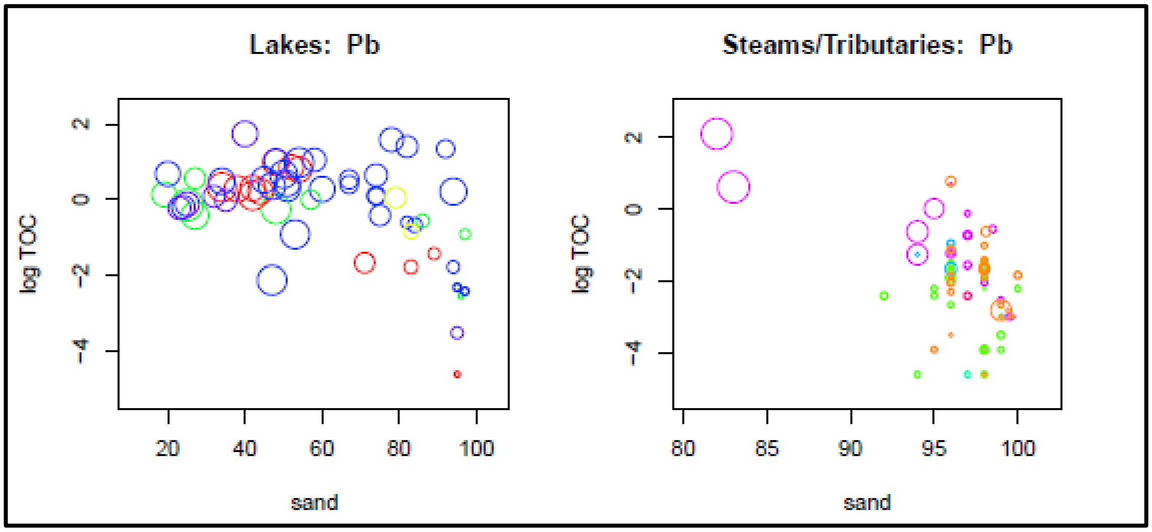
3. THE AREA OF THE DOT REPRESENTS THE CONCENTRATION OF THE METAL.
4. VALUES RECORDED AT OR BELOW DETECTION LIMIT ARE PLOTTED AT THEIR DETECTION LIMIT.

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

Lead (Figure D.9)

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



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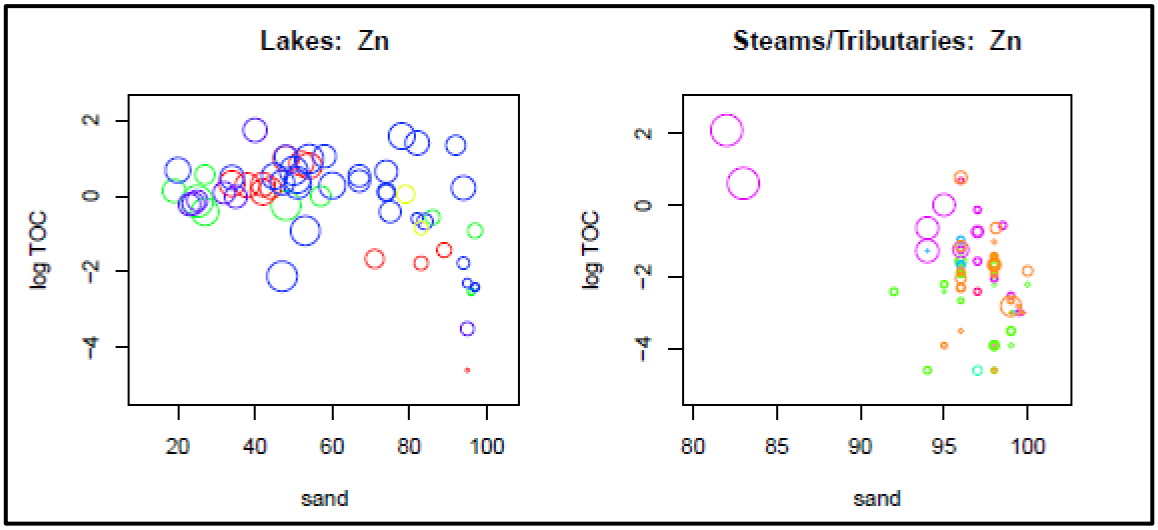
4. VALUES RECORDED AT OR BELOW DETECTION LIMIT ARE PLOTTED AT THEIR DETECTION LIMIT.

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

Zinc (Figure D.10)

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



NOTES:

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

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

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

D.3 SEDIMENT IN STREAM ENVIRONMENTS

Upstream of the Deposits

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

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

Downstream of the Deposits

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

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

Background Tributary to Mary River

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

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

Downstream of Mary Lake

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

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

Sheardown Lake Tributaries

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

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

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

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

Camp Lake Tributaries

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

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

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

D.4 SEDIMENT IN LAKE ENVIRONMENTS

Camp Lake

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

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

Sheardown Lake (NW Basin)

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

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

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

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

Sheardown Lake (SE Basin)

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

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

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

Mary Lake

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

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

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

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

David Lake

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

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

D.5 INFLUENCE OF TOC AND FINES ON METALS ACCUMULATION

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

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

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

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

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

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

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

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

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

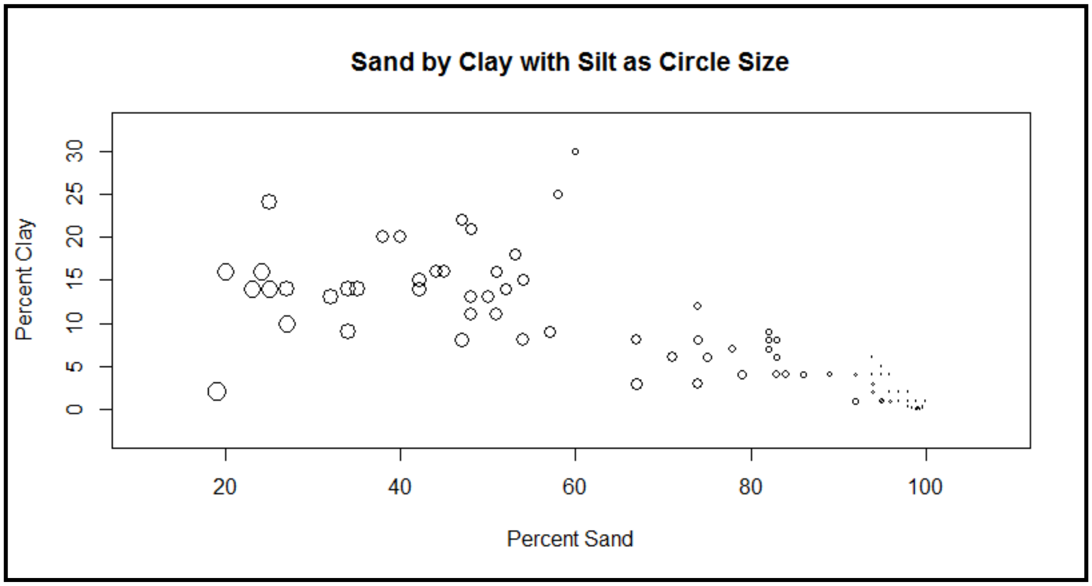


Figure D.11 Clay by Sand with Silt as Circle Size

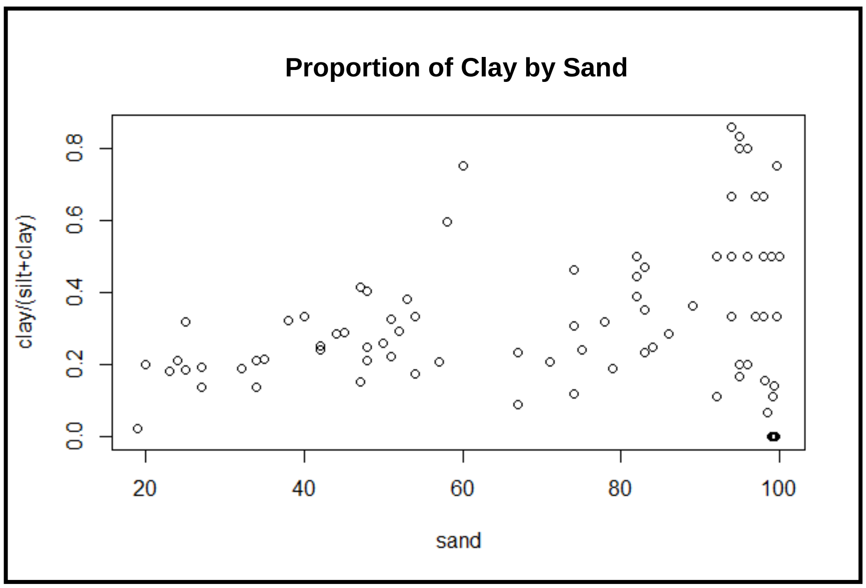


Figure D.12 Dependent Relationship between Sand, Silt and Clay in Sediment

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

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

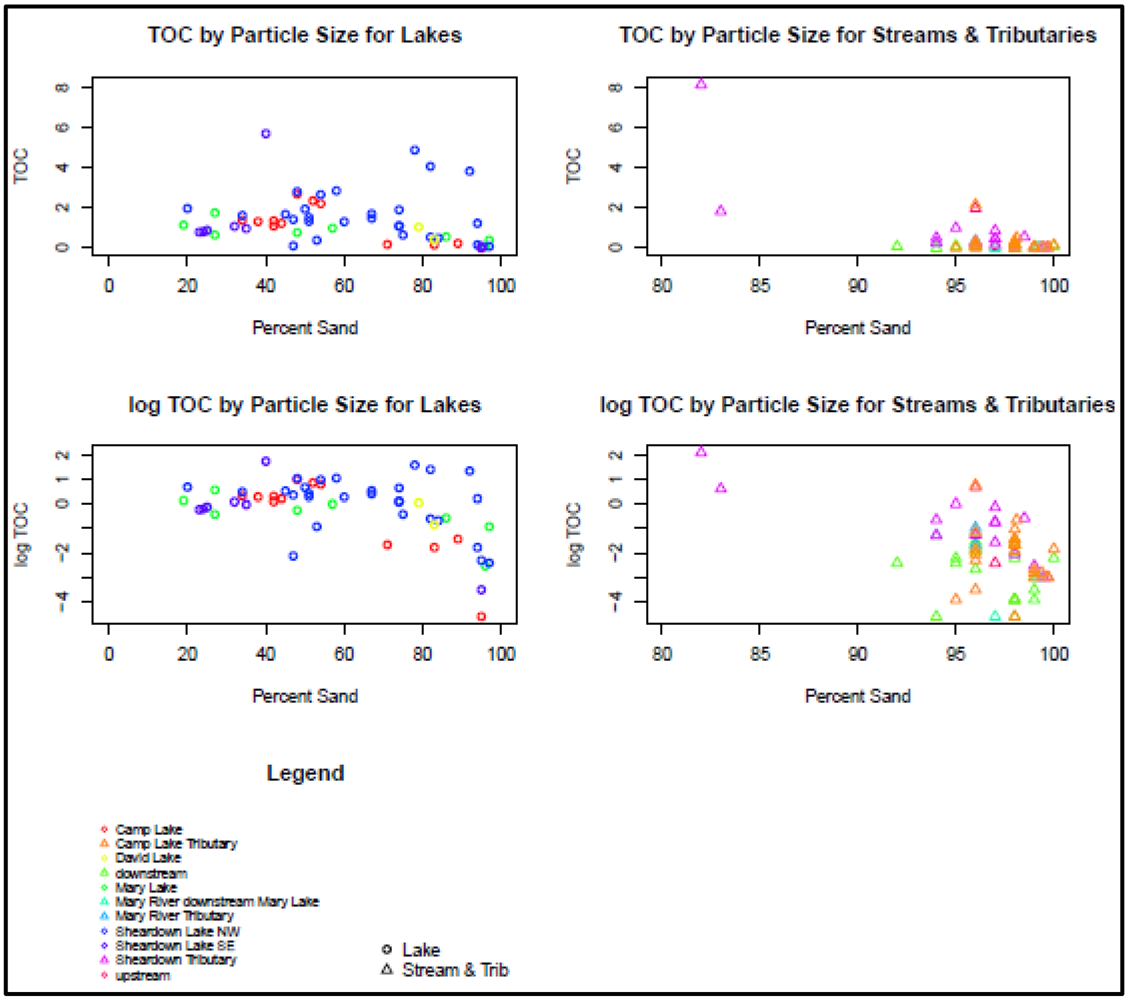


Figure D.13 Sediment TOC versus Particle Size for Lakes and Streams

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

D.6 STATISTICAL AND CUT POINT ANALYSIS

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

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

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

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

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

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

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

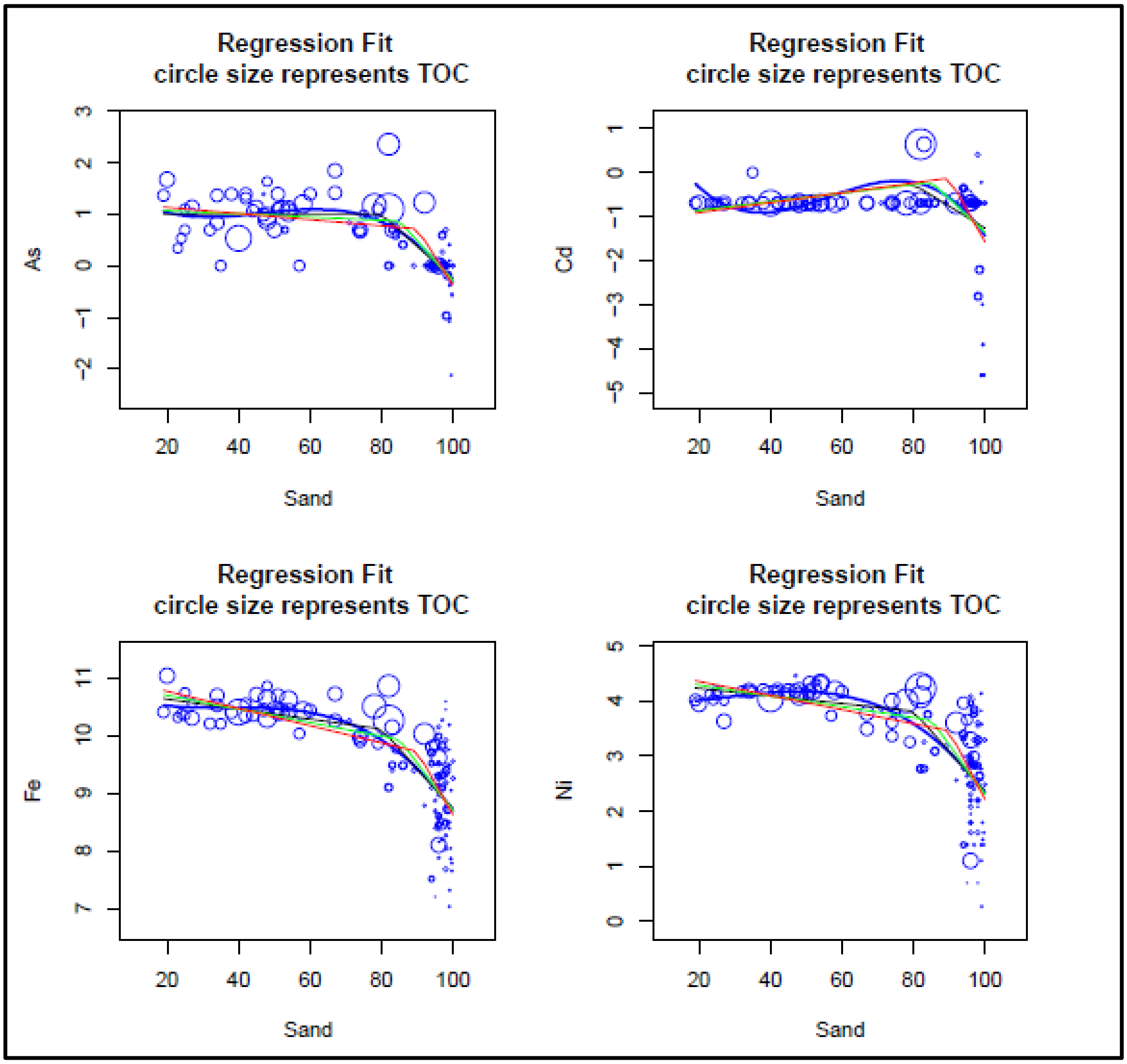


Figure D.14 Concentrations of As, Cd, Fe and Ni in Sediment Based on Percent Sand

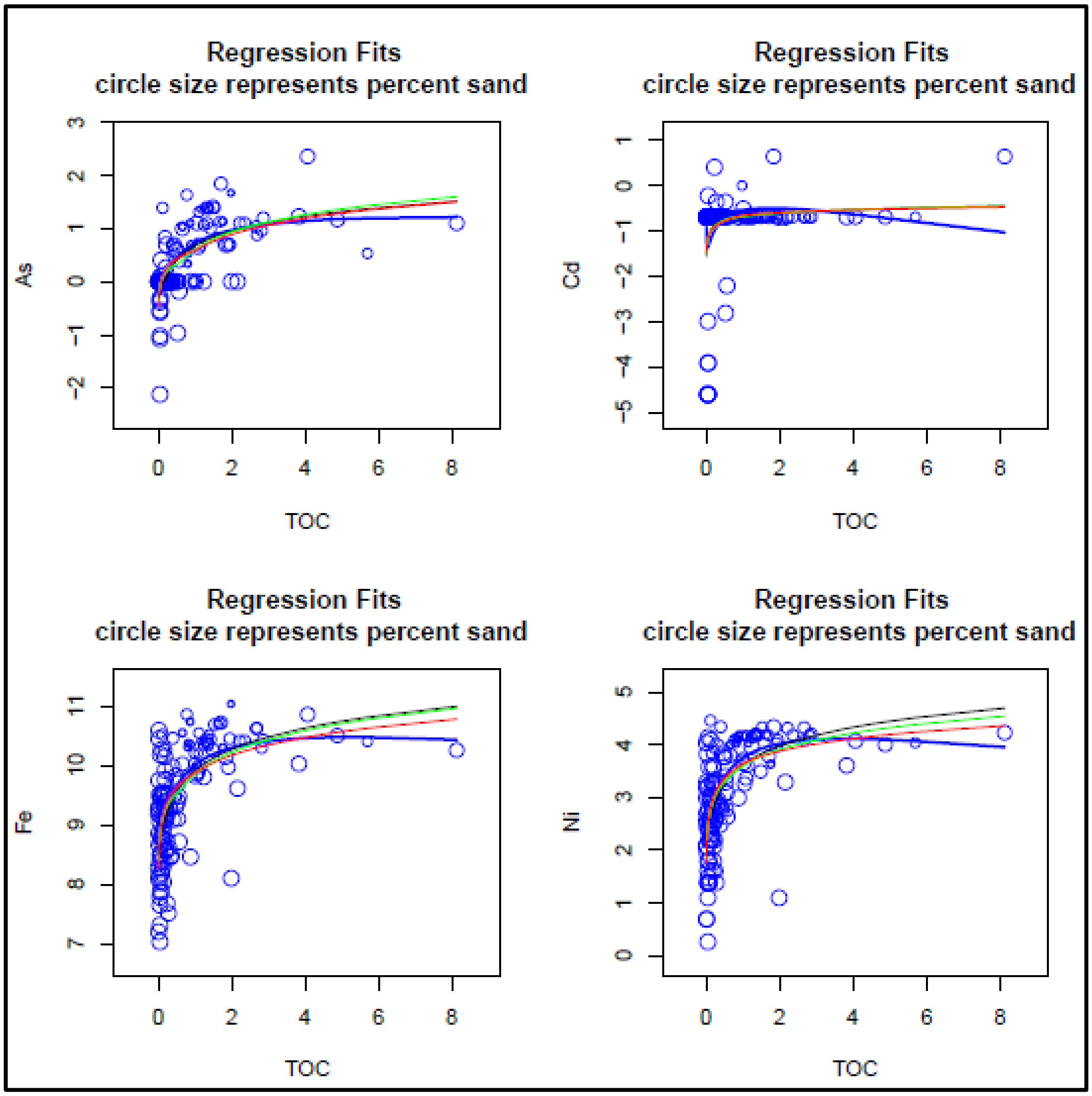


Figure D.15 Concentrations of As, Cd, Fe and Ni in Sediment Based on Percent TOC

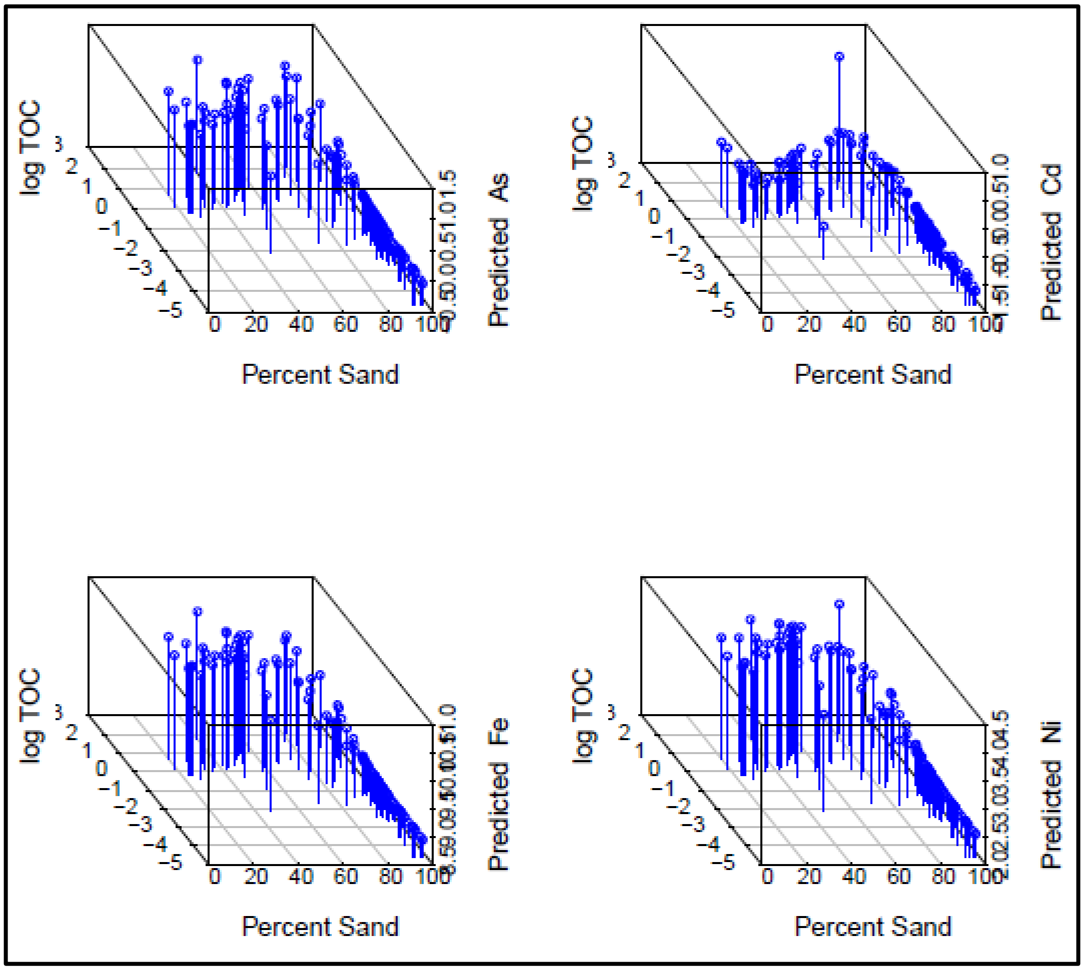


Figure D.16 Concentrations of As, Cd, Fe and Ni in Sediment Based on Log TOC and Percent Sand

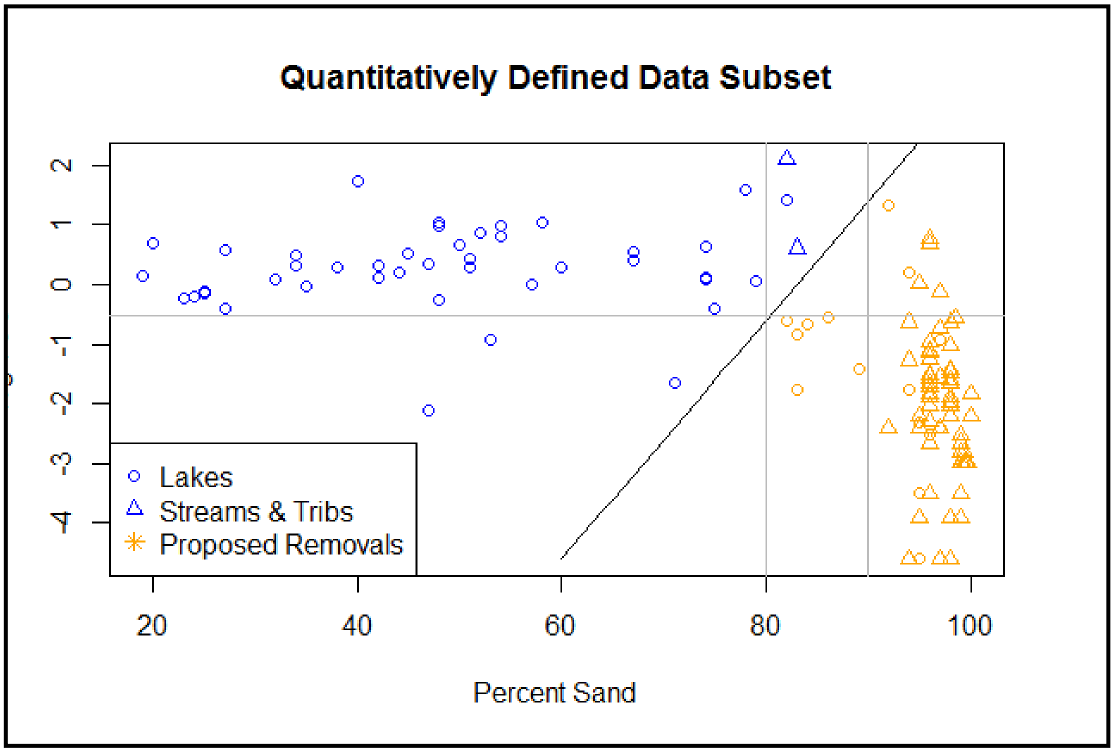


Figure D.17 Results of Cut Point Analysis for Sediment

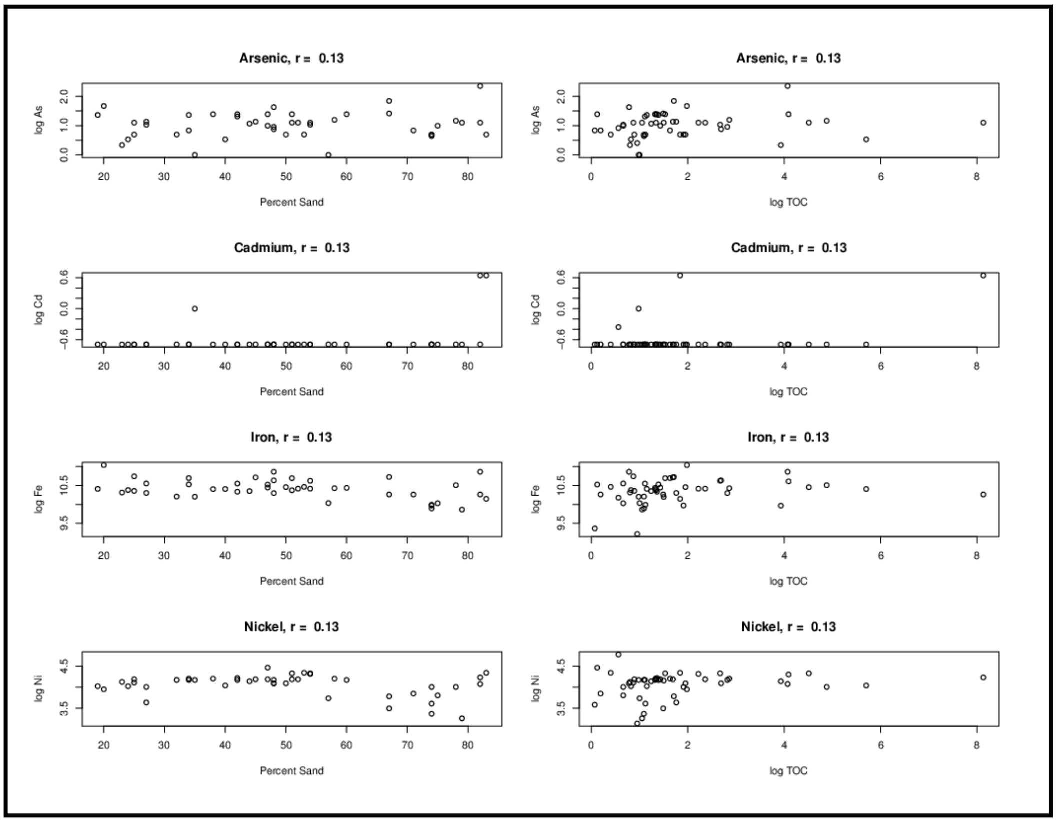


Figure D.18 Correlations between TOC and Percent Sand, and the 4 Key Parameters for the Subset Data, Second Stage Cuts in Blue

D.7 TEMPORAL AND SAMPLING EFFECTS

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

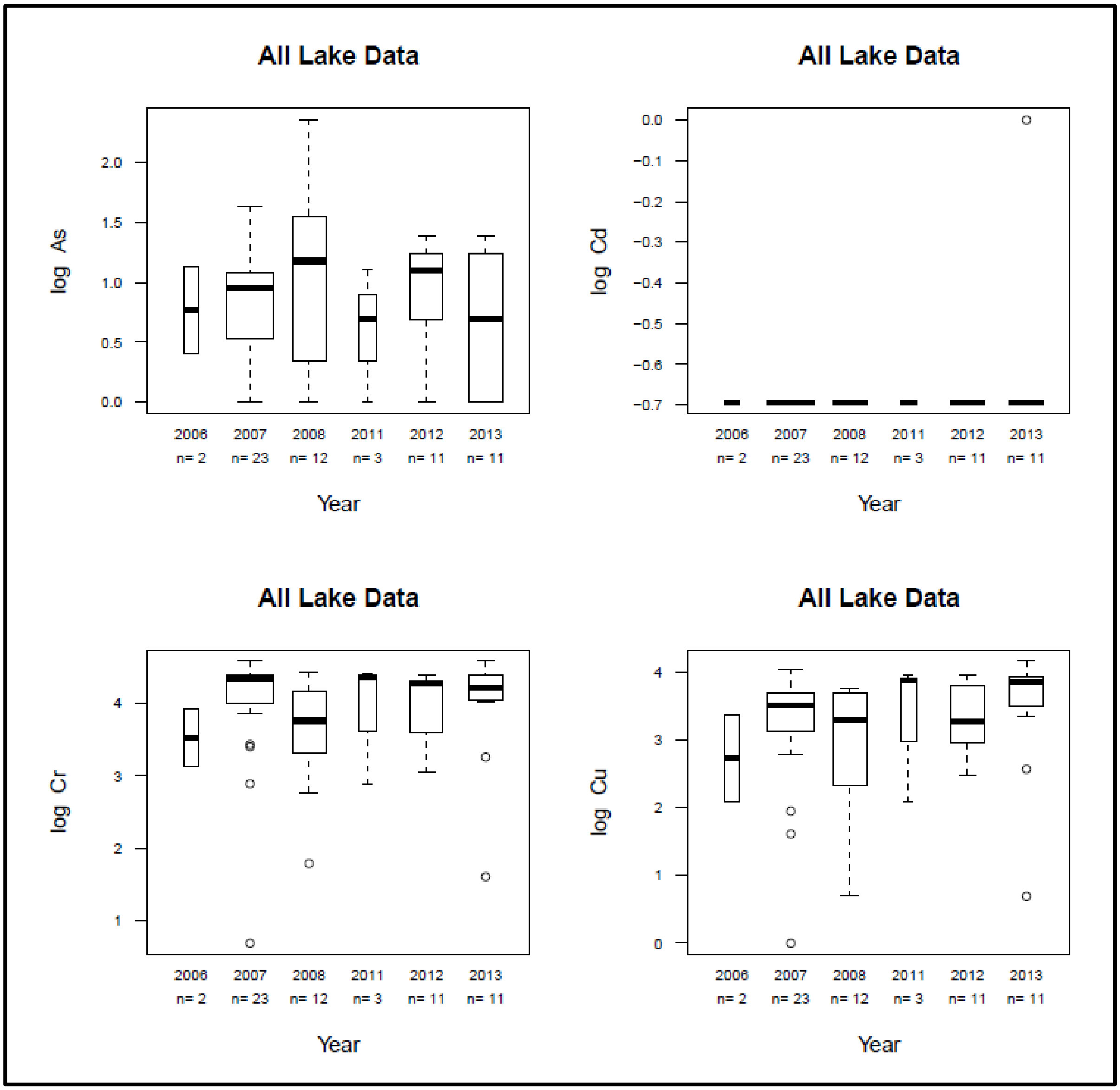


Figure D.19 Inter-Annual Variability for As, Cd, Cr and Cu in Sediment

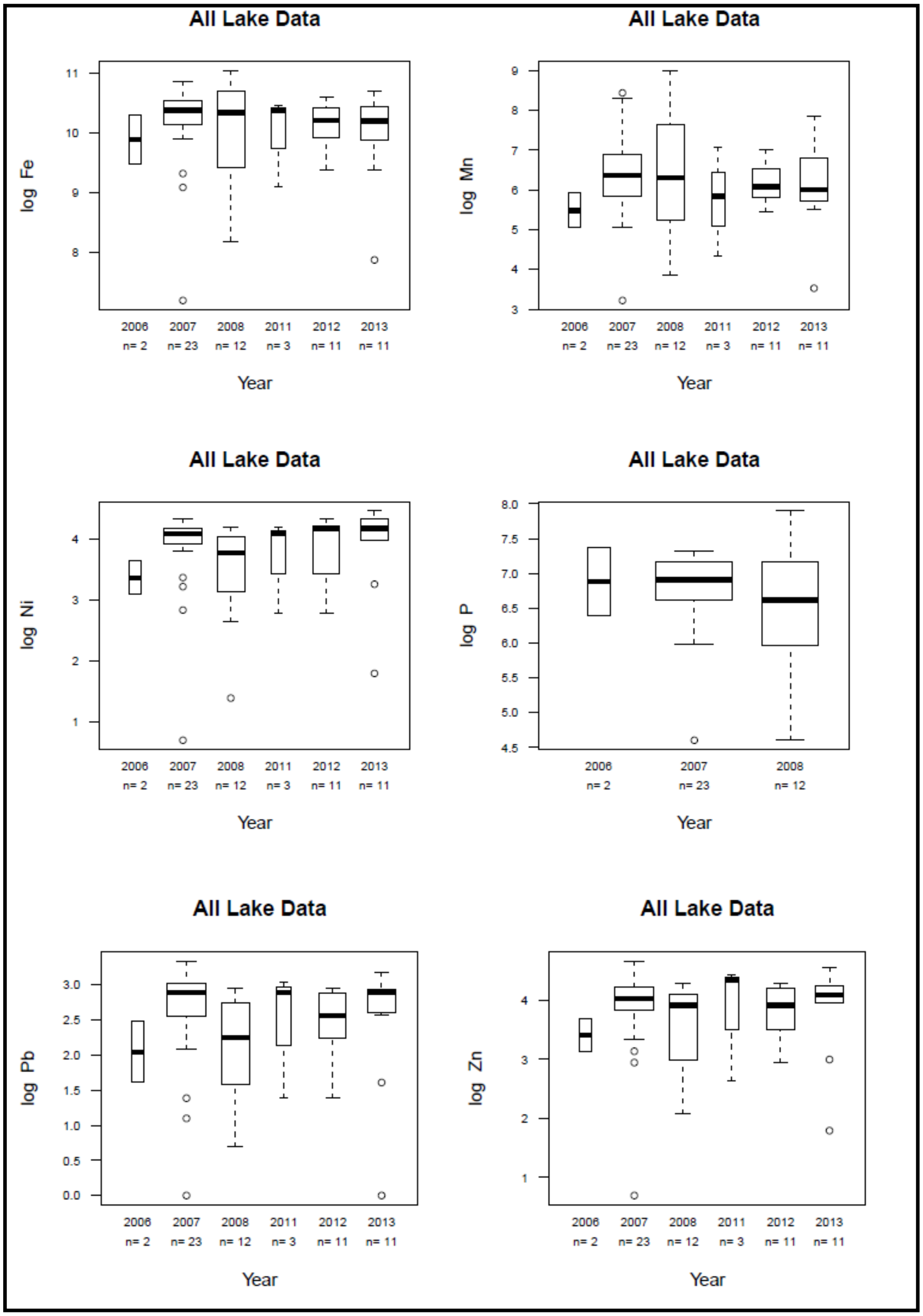


Figure D.20 Inter-Annual Variability for Fe, Mn, Ni, P, Pb and Zn in Sediment

D.8 POWER ANALYSIS

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

D.9 RECOMMENDATIONS

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

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

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

D.10 REFERENCES

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

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

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

Appendix C

Development of Water and Sediment Quality Benchmarks

Appendix C

Development of Water and Sediment Quality Benchmarks

SCIENCE INTEGRITY KNOWLEDGE

intrinsik

APPENDIX C

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

June 26, 2014

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

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

C- 1.0 INTRODUCTION

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

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

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

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

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

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

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

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

C- 2.0 SEDIMENT EVALUATION AND BENCHMARK DEVELOPMENT

C-2.1 Selection of Substances for Benchmark Development

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

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

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

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

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

C-2.2 Baseline Data Evaluation

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

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

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

C-2.2.1 Sediment Data Evaluation for Determining AEMP Benchmarks

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

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

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

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

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

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

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

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

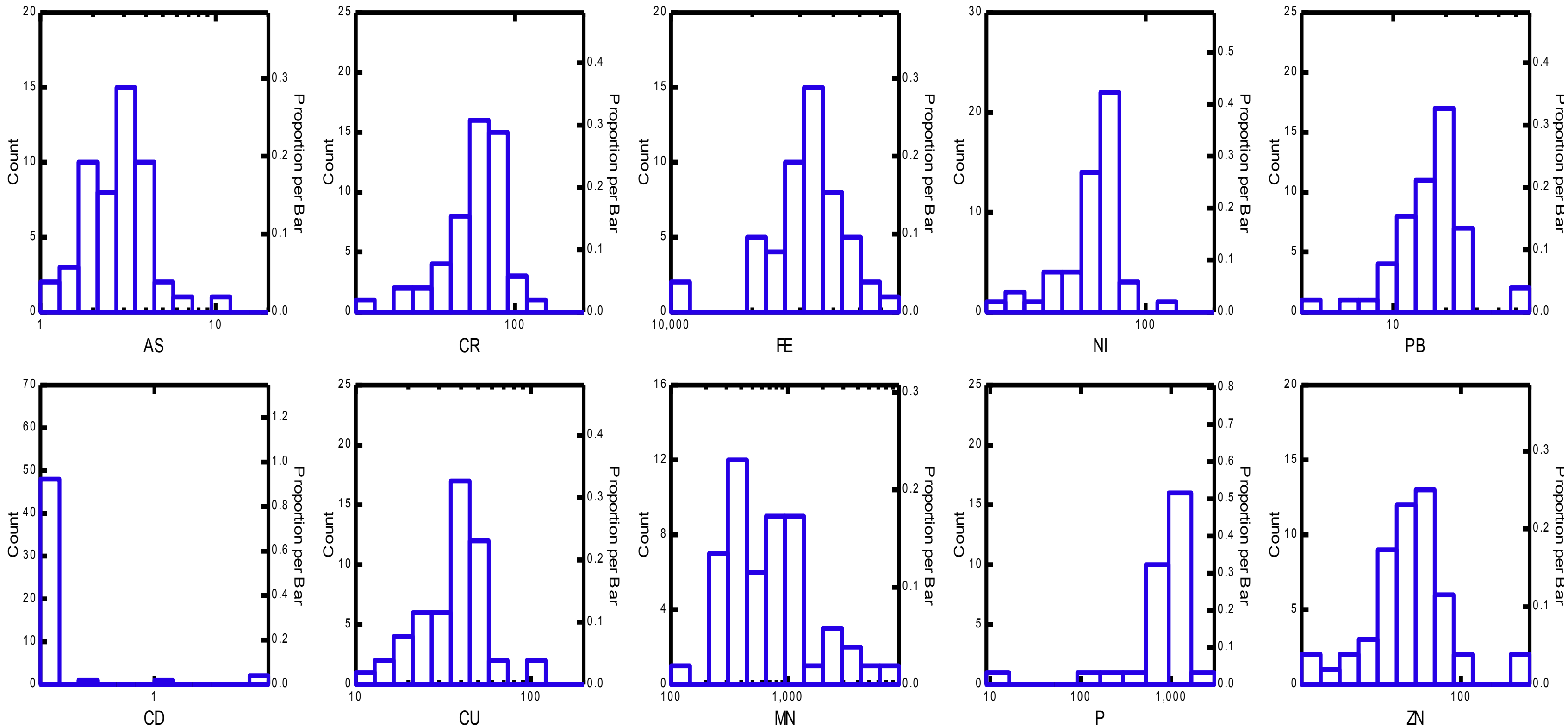

Figure 2-1 Log10 Histograms of Area-Wide Sediment Data (N=52), by Metal of Interest

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

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

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

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

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

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

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

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

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

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

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

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

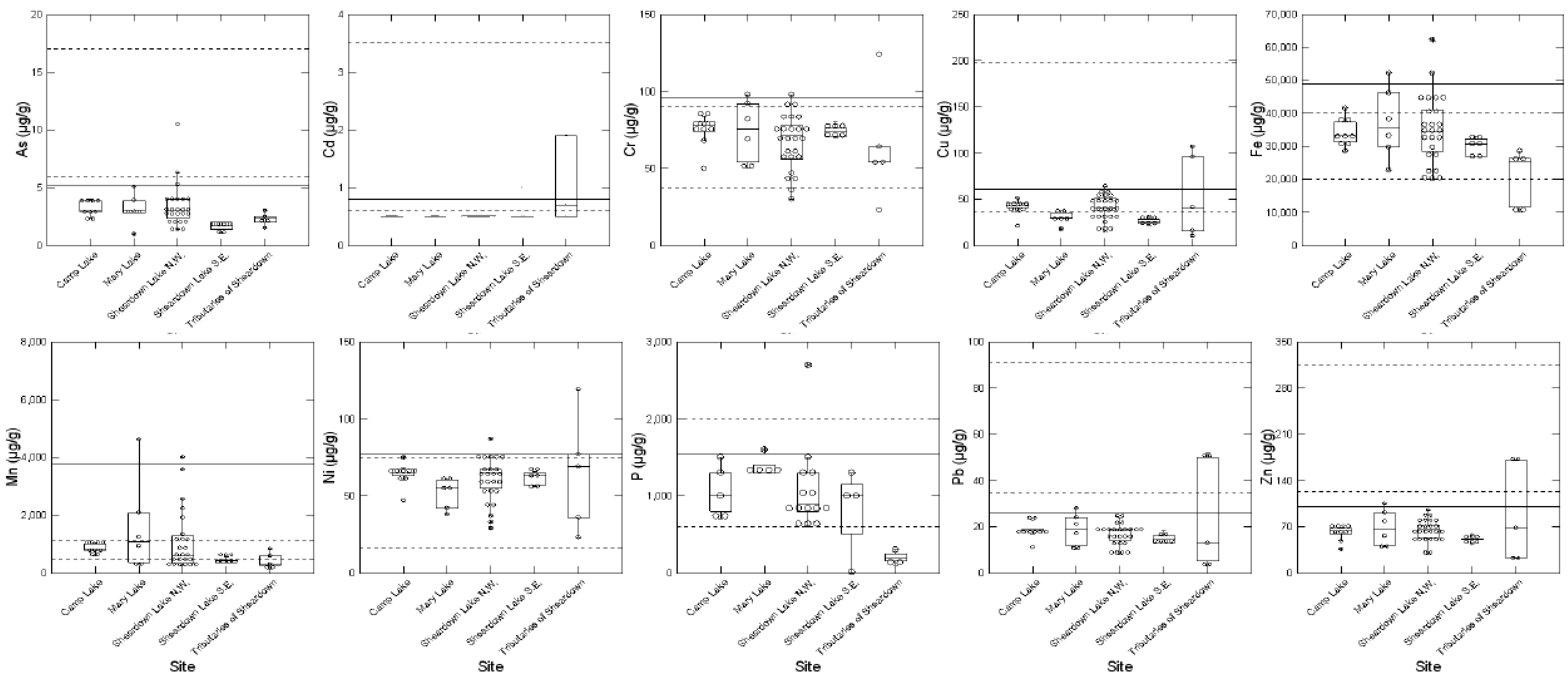

Figure 2-2 Box and Whisker Plots of Metal Concentrations by Area (Solid line represents 95th percentile of area-wide data; dotted lines represent ISQG/LEL and PEL/SEL sediment quality guidelines, respectively)

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

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

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

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

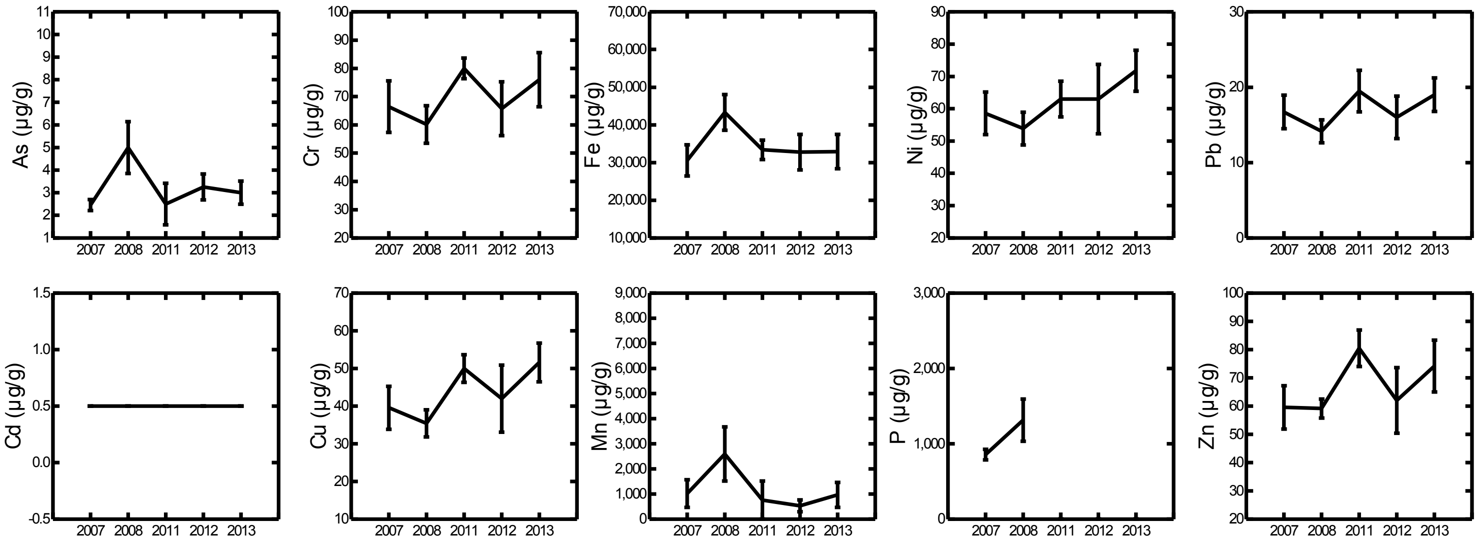

Figure 2-3 Temporal Trend Analysis for Sheardown Lake NW (n = 25) for Various Parameters (mean +/- std error)

C-2.3 AEMP Benchmark Derivation for Sediments

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

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

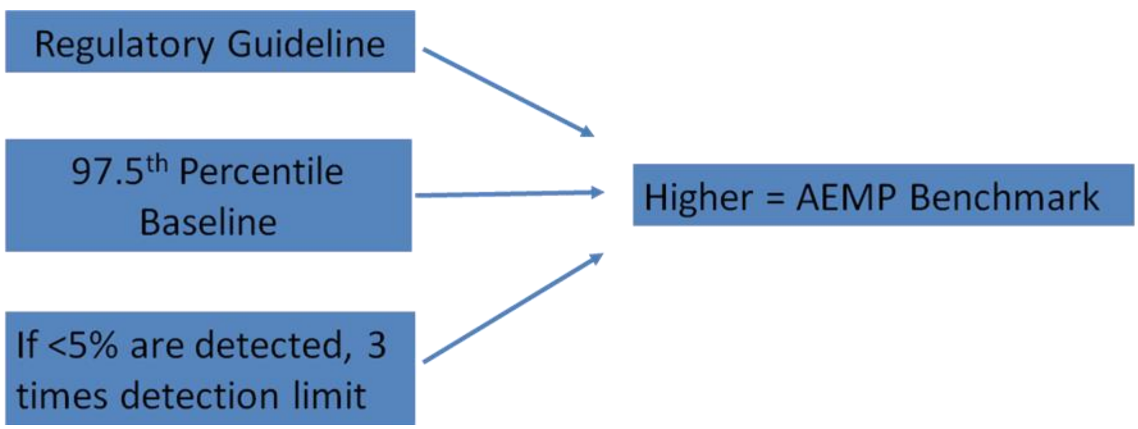

Figure 2-4 Approach for Selecting AEMP Benchmarks

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

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

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

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

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

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

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

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

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

C- 3.0 SURFACE WATER EVALUATION AND BENCHMARK DEVELOPMENT

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Table 3-5 Statistical Model Results indicating effects of Pseudoreplication

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

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

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

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

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

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

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

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

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

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

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

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

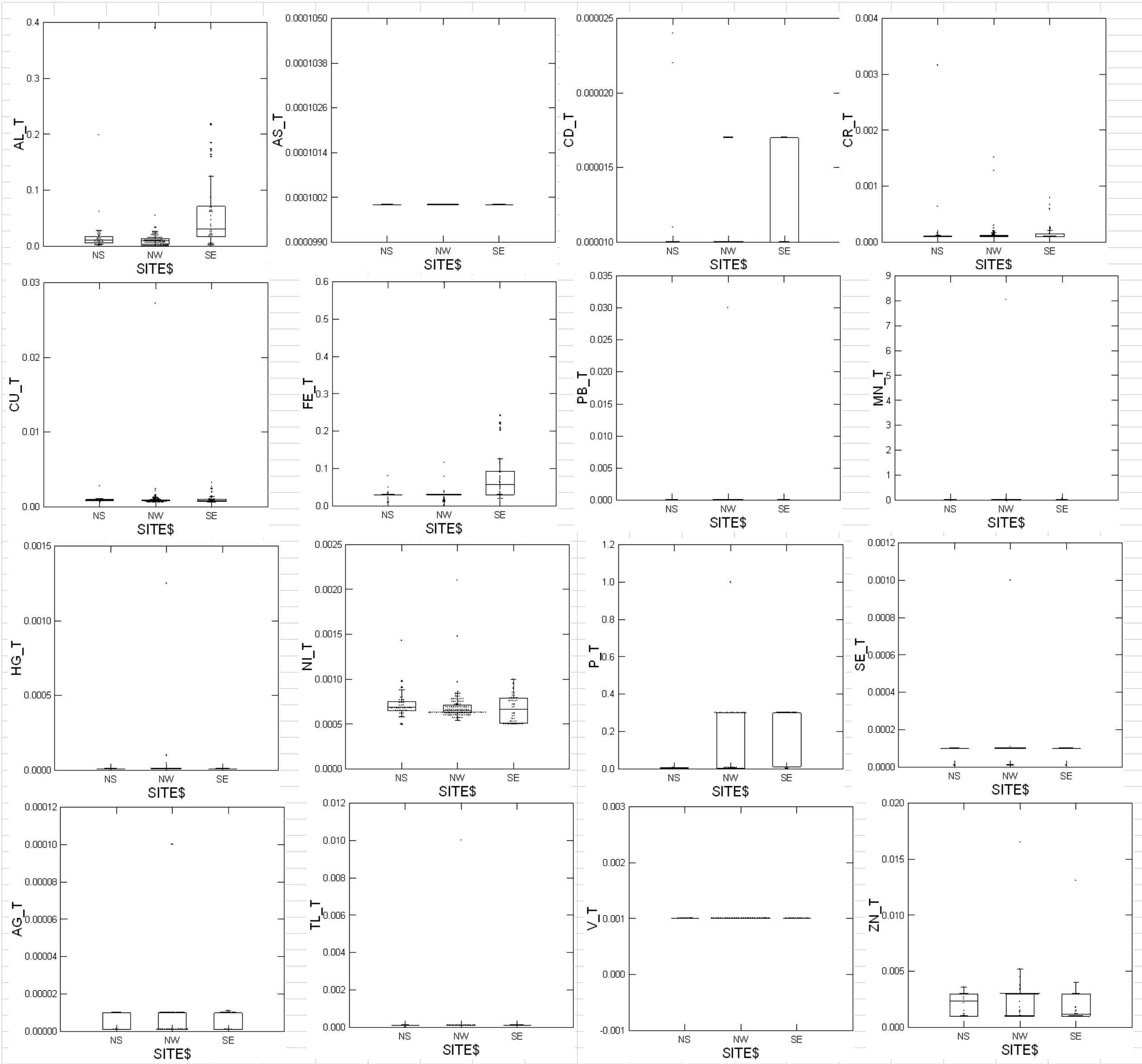

Figure 3-1 Total Metals (mg/L) Compared Between Various Sheardown Lake Sampling Locations (Nearshore (NS), Northwest (NW) and Southeast (SE)); T = total; Non-detectable values replaced with detection limit

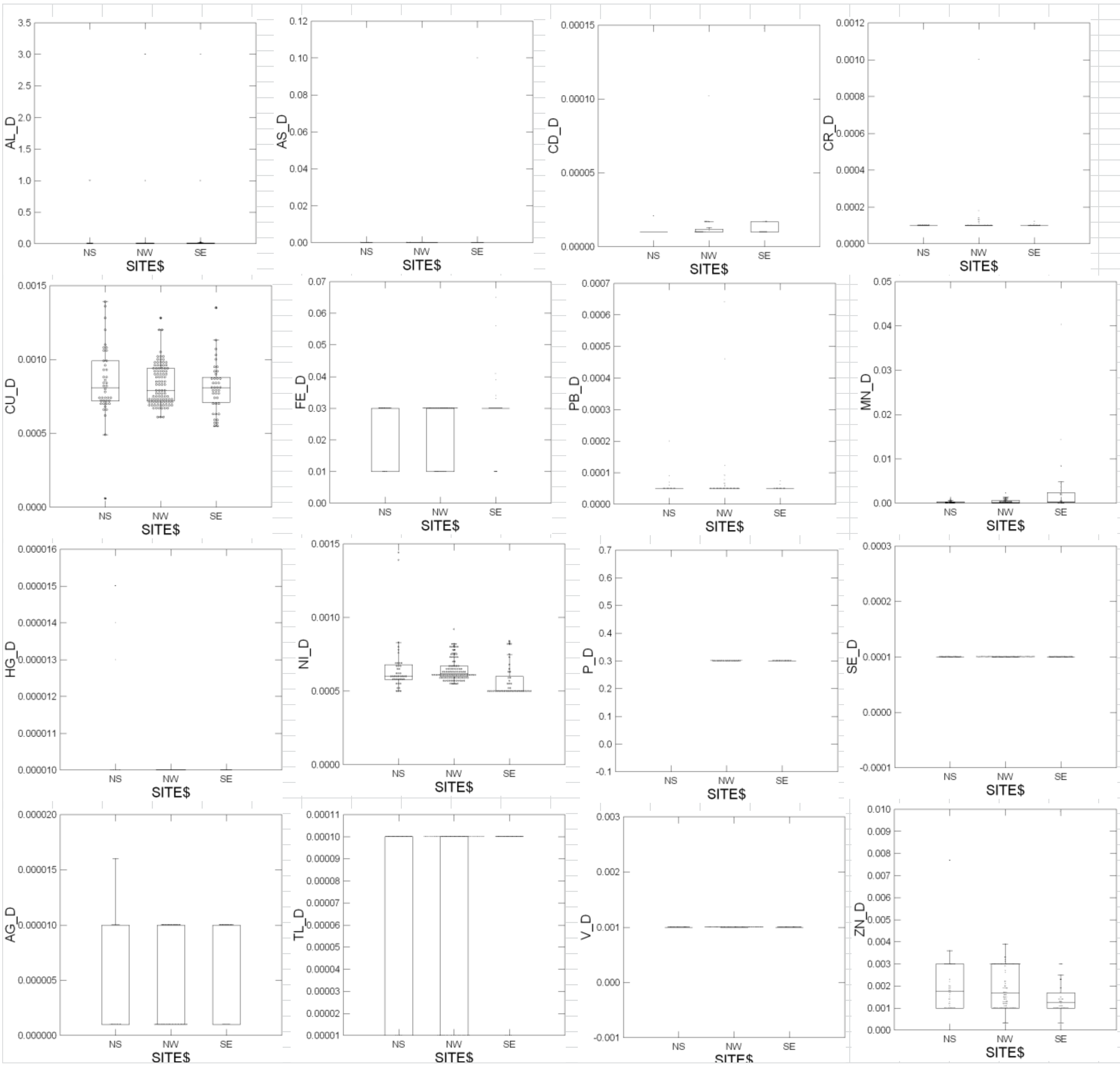

Figure 3-2 Dissolved Metals (mg/L) Compared Between Various Sheardown Lake Sampling Locations (Nearshore (NS), Northwest (NW) and Southeast (SE)); D = Dissolved; Non-detectable values replaced with detection limit

Table 3-7	**Summary of Camp Lake Surface Water Analytical Data (Total Metals; 2006 to 2013)**								
Parameter	***Units***	***N***	***% Detect***	***Min***[b]	***Max***[c]	***Median*** [d]	***95th %ILE***[d]	***97.5th %ILE***[d]	***Mean*** [d]
Metals [a]									
Aluminium	mg/L	52	92	<0.001	0.0379	0.00615	0.0192	0.0260	0.00801
Arsenic	mg/L	52	0[e]	<0.0001	<0.0001	NC	NC	NC	NC
Cadmium	mg/L	52	4[e]	<0.00001	0.000042	NC	NC	NC	NC
Chromium	mg/L	52	4[e]	<0.0001	0.00014[g]	NC	NC	NC	NC
Chromium $^{+3}$	mg/L	19	0[e]	<0.001	<0.005	NC	NC	NC	NC
Chromium $^{+6}$	mg/L	15	0[e]	<0.001	<0.005	NC	NC	NC	NC
Cobalt	mg/L	52	0[e]	<0.0001	<0.0002	NC	NC	NC	NC
Copper	mg/L	49	100	0.00072	0.019	0.00092	0.00389	0.0113	0.00169
Iron	mg/L	52	23	<0.003	0.057	0.03	0.0343	0.0421	0.0238
Lead	mg/L	49	20	<0.00005	0.000429	0.00005	0.0002	0.000334	0.000074
Nickel	mg/L	49	100	0.00054	0.00114	0.00066	0.00081	0.000914	0.000672
Silver	mg/L	52	0[e]	<0.000001	<0.00001	NC	NC	NC	NC
Thallium	mg/L	49	0[e]	<0.000001	<0.0001	NC	NC	NC	NC
Vanadium	mg/L	52	0[e]	<0.001	<0.001	NC	NC	NC	NC
Zinc	mg/L	49	18	<0.001	0.0049	0.003	0.0032	0.0037	0.0022
Water Quality Parameters									
Chloride (Cl^-)	mg/L	52	27	<1	4	1	4	4	2.02
Ammonia (NH^3+NH^4)	mg N/L	52	92	<0.02	1.41	0.02	0.560	0.84	0.101
Nitrite (NO_2^-)	mg N/L	52	12	<0.002	0.012[e]	0.005	0.1	0.1	0.012
Nitrate (NO_3)	mg N/L	52	0[e]	<0.1	<0.1	NC	NC	NC	NC
Sulphate (SO_4^{2-})	mg/L	52	62	<1	3[e]	2	3	3	2.0
Major Toxicity Modifying Factors for Guideline Development									
pH	-	52	NA	6.8	8.3	7.5	8.3	8.3	7.6
Hardness	mg/L [f]	52	NA	50	77.1	59.7	69.5	73.4	59.4
Temperature	^{o}C	36	NA	0.9	9.0	7.1	8.7	8.9	6.2

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

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

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

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

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

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

f. mg/L as $CaCO_3$

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Table 3-13 Summary of Camp Lake Tributary Surface Water Analytical Data (Total Metals; 2005 to 2013)									
Parameter	***Units***	***N***	***% Detect***	***Min***[b]	***Max***[c]	***Median*** [d]	***95th %ILE***[d]	***97.5th %ILE***[d]	***Mean*** [d]
Metals [a]									
Aluminum	mg/L	88	90	<0.004	0.252	0.01	0.106	0.179	0.0247
Arsenic	mg/L	88	6	<0.0001	0.00554	0.0001	0.0001	0.00012	0.00016
Cadmium	mg/L	88	1[e]	<0.00001	0.000096[h]	NC	NC	NC	NC
Chromium	mg/L	88	36	0.000022[g]	0.003	0.0001	0.000699	0.000856	0.00020
Chromium $^{+3}$	mg/L	30	0	<0.005	<0.005	NC	NC	NC	NC
Chromium $^{+6}$	mg/L	30	0	<0.001	<0.001	NC	NC	NC	NC
Cobalt	mg/L	87	2	<0.0001	0.00013[h]	NC	NC	NC	NC
Copper	mg/L	85	95	<0.00001	0.00359	0.0016	0.00204	0.00222	0.00152
Iron	mg/L	88	75	<0.0001	0.44	0.05	0.190	0.326	0.0684
Lead	mg/L	56	20	<0.00005	0.00025[h]	0.00005	0.000268	0.000333	0.000094
Nickel	mg/L	52	75	0.000202[g]	0.00265	0.00077	0.00131	0.00168	0.00085
Silver	mg/L	87	0	<0.000001	<0.00001	NC	NC	NC	NC
Thallium	mg/L	71	14	<0.000001	0.00909	0.0001	0.0002	0.0002	0.00021
Vanadium	mg/L	86	1	<0.0009	0.001[h]	NC	NC	NC	NC
Zinc	mg/L	61	21	<0.00033	0.0104	0.003	0.0032	0.0035	0.00240
Water Quality Parameters									
Chloride (Cl^-)	mg/L	89	100	0.2[g]	121	2	17.8	23	6.06
Ammonia (NH^3+NH^4)	mg N/L	86	52	<0.02	0.8	0.02	0.475	0.60	0.087
Nitrite (NO_2^-)	mg N/L	86	15	0.002[g]	0.014[h]	0.005	0.06	0.095	0.015
Nitrate (NO_3)	mg N/L	89	9	<0.05	0.18	0.1	0.106	0.118	0.0961
Sulphate (SO_4^{2-})	mg/L	88	73	<0.5	8	3	5.7	6	2.8
Major Toxicity Modifying Factors for Guideline Development									
pH	-	84	NA	4.94	8.71	7.88	8.42	8.52	7.80
Hardness	mg/L [f]	87	NA	0.003	317	73.7	133.8	140	76.16
Temperature	^{o}C	85	NA	-0.17	17.81	6.05	14.15	17.33	6.52

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

C-3.3 AMEP Benchmark Derivation for Surface Waters

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

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

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

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

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

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

Notes:
25^{th} percentile pH: Camp Lake 7.3; Mary Lake 6.9; Sheardown Lake 7.3; Camp Lake Tributary 7.7; Mary River 7.6
25^{th} percentile hardness (as $CaCO_3$): Camp Lake 55.3; Mary Lake 33.2; Sheardown Lake 53.5; Camp Lake Tributary 41.0; Mary River 28.0
a. pH Guideline of 0.1 mg/L selected since 25^{th}%ile pH in all lakes and rivers was ≥ 6.5
b. Cadmium guideline based on 25%ile water hardness and following equation: *CWQG (mg/L) =* $[10^{\{0.83(\log[hardness]) - 2.46\}}] / 1000$.
c. Copper guideline based on 25th%ile water hardness and following equation: *CWQG (mg/L) =* $[0.2 * e^{\{0.8545[\ln(hardness)]-1.465\}}] / 1000$.
d. Lead guideline based on 25^{th}%ile water hardness and following equation: *CWQG (mg/L)=* $[e^{\{1.273[\ln(hardness)]-4.705\}}] / 1000$
e. 30 day average; approved guideline
f. Nickel guideline based on 25^{th}%ile water hardness and following equation: *CWQG (mg/L) =* $[e^{\{0.76[\ln(hardness)]+1.06\}}] / 1000$.
g. Working guideline; reported as Ontario's water quality objective
h. Based on pH and temperature (look up table provided in CCME, on-line); calculated based on 75%ile temperature data, to be conservative, and 75%ile pH of 7.5. These values equate to a pH of 8 and a temperature of 10 degrees C, in the summary table, which yields a guideline of 0.855 mg/L total ammonia-N.
i. 30-day average (minimum of 5 evenly-spaced samples collected in 30 days); Approved guideline

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

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

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

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

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

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

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

Table 3-15 Comparison of 97.5th Percentile Concentrations in Area Lakes to Water Quality Guidelines and Selection of AEMP Benchmarks							
Parameter	***Units***	***Water Quality Guideline***	***Camp Lake***	***Mary Lake***	***Sheardown Lake***	***Selected AEMP Benchmark***	***Benchmark Method***
Nitrate (NO_3)	mg N/L	13	NC	0.11	NC	13	A
Sulphate	mg/L	218	3	7	5	218	A

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

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

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

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

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Appendix D

Freshwater Biota CREMP Study Design

Appendix D

Freshwater Biota CREMP Study Design

Mary River Project

June 2014

Core Receiving Environment Monitoring Program: Freshwater Biota

North/South Consultants Inc.
Aquatic Environment Specialists

Core Receiving Environment Monitoring Program: Freshwater Biota

June, 2014

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LIST OF ABBREVIATIONS

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

1.0 INTRODUCTION

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

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

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

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

2.0 PHYTOPLANKTON

The following section provides a description of monitoring of phytoplankton under the CREMP. The program focuses on monitoring lakes in the Mine Area, where potential for eutrophication is greatest.

2.1 PATHWAYS OF EFFECT AND KEY QUESTIONS

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

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

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

The key question related to the pathways of effect is:

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

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

2.2 PARAMETERS AND METRICS

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

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

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

2.3 BENCHMARKS

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

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

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

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

- Natural variability in existing phytoplankton community metrics;
- Limitations associated with the existing data set - specifically issues associated with chlorophyll *a* concentrations being below the analytical detection limits;
- Relationships between nutrients (notably phosphorus) and phytoplankton metrics for Mine Area lakes;
- Lake trophic categorization schemes and trophic status of the Mine Area lakes; and
- Literature in which CESs for phytoplankton have been identified or adopted, such as AEMPs for the Diavik Diamond Mine and the Meadowbank projects.

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

The benchmark for chlorophyll *a* for the Mary River Project (3.7 µg/L) is based on maintaining the trophic status (i.e., oligotrophic) of Mine Area lakes. The benchmark was derived using a similar approach and rationale as was recently applied for the DDMI Project. Specifically, the benchmark represents the average of the upper and lower ranges of trophic boundaries for lakes based on chlorophyll *a*, as designated and/or adopted in the scientific literature (Table 2-2). This value is lower than the benchmark adopted by DDMI due to some differences in the literature incorporated in this calculation. Two of the literature sources utilized for the DDMI benchmark derivation

(United States Environmental Protection Agency [USEPA] 1974 and 1988) were omitted due to the age of the documents and because the USEPA has applied a different trophic status categorization scheme in a more recent report (USEPA 2009). The values applied in USEPA (2009) were included in the calculation instead. In addition, the values presented in CCME (2004) were omitted since these values are reproductions of the Organization for Economic Cooperation and Development (OECD 1982) values, which are already included in the data set. Similarly, Alberta Environment (2013) also applies the same boundaries as the OECD (1982) but this was not included as a separate entry in the calculations for the same reason. Lastly, the trophic categorization scheme applied by the Swedish EPA (2000) was also included in the calculation.

As previously noted, the benchmark (3.7 µg/L) for Mary River lakes is lower than the recently developed benchmark for Lac de Gras in relation to the Diavik Diamond Mines Project. Lac de Gras has a similar background concentration of chlorophyll *a* than Sheardown Lake NW but a lower concentration than other Mine Area lakes (Table 2-3); the "normal range" of chlorophyll *a* in Lac de Gras (mean±2 x SD) was identified as 0.89 µg/L and the mean was 0.52 µg/L for the open-water season (Golder Associates 2014).

2.4 MONITORING AREA AND SAMPLING SITES

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

Five sites will be monitored for chlorophyll *a* in Camp, Sheardown NW and Sheardown SE lakes during each sampling period; six sites will be monitored in Mary Lake. Samples will also be collected at these same locations for phytoplankton biomass and taxonomy but will be archived following collection. Sites will be consistent with water quality sampling sites to provide supporting information for interpretation and analysis of results (e.g., nutrient concentrations and water clarity).

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

An *a priori* power analysis was conducted using existing baseline data for chlorophyll *a* for Sheardown Lake NW and Mary Lake to advise on the power of the existing dataset and to identify sample sizes for the CREMP (see Appendix 1 for details); these two lakes represent the range of baseline conditions for the Mine Area lakes as a whole. Power analyses indicate relatively high power to detect a change of the magnitude of the benchmark for each sampling season in each lake (Table 2-4). Power is greater for Sheardown Lake NW owing to the lower baseline concentrations of chlorophyll *a* than Mary Lake. A sample size of five for Sheardown Lake NW and similar lakes including Sheardown Lake SE and Camp Lake, and a sample size of six for Mary Lake, are associated with high power in relation to the benchmark. Power was also evaluated for an effects size of 2 x the mean; relatively high power (0.7 for Mary Lake and 0.8 for Sheardown Lake NW) is associated with detecting this level of change.

2.5 SAMPLING FREQUENCY AND SCHEDULE

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

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

2.6 FIELD AND LABORATORY METHODS

Chlorophyll *a* samples will be collected at a depth of approximately 1 m below the water surface with a sampling device (i.e., van Dorn or Kemmerer), transferred to sample bottles provided by the analytical laboratory, kept cool and in the dark and submitted to a laboratory accredited under the Canadian Association for Laboratory Accreditation (CALA) Inc. Additional information will be recorded at the time of sampling including:

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

- Site conditions/observations.

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

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

2.7 QUALITY ASSURANCE/QUALITY CONTROL (QA/QC)

The QA/QC program will include the following components:

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

The field QA/QC program will include:

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

2.8 STUDY DESIGN AND DATA ANALYSIS

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

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

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

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

2.9 ASSESSMENT FRAMEWORK

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

2.9.1 Step 1: Initial Data Analysis

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

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

2.9.2 Step 2: Determine if Change is Mine Related

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

- Evaluating spatial patterns in chlorophyll *a* results for the Mine Area as a whole, including Mine Area lakes and streams, to evaluate if changes are widespread or specific to certain waterbodies, and to identify the spatial extent and pattern of observed changes. This exercise would assist with identifying potential stressors/pathways of effects;
- Comparing data from Mine Area lakes to reference lake(s) and potentially data from Mine Area streams to reference streams. This would further assist with determining whether the observed changes were due to natural variability or the Project;
- Evaluating monitoring results for nutrients, notably phosphorus, in Mine Area waterbodies (lakes and streams) to assess whether nutrients have similarly changed and in the same spatial pattern/magnitude as observed for chlorophyll *a*;
- Evaluating other factors that affect phytoplankton abundance such as water clarity and temperature; and
- Evaluating Project activities with the potential to alter nutrients and/or conditions that may affect phytoplankton. This may include evaluating effluent quality, discharge regime/rates, and loading, notably in relation to sewage effluent, dust deposition, and other point/non-point sources as required.

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

2.9.3 Step 3: Determine Action Level

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

- Evaluate temporal trends: this will be a qualitative exercise and consist of graphical presentation of data over time to evaluate increasing or decreasing trends. It is important to note that several years of data will be required to begin to assess temporal trends;
- Investigate and summarize potential causes and pathways of effect of the observed changes;
- Review and summarize monitoring results for other metrics of relevance to phytoplankton (i.e., drivers) and eutrophication including nutrients, water clarity, and DO. Trend analysis results for these metrics, notably phosphorus, will also be considered in the interpretation of phytoplankton monitoring results;
- Review/assess the benchmark with acquisition of data (note: this will be undertaken over the course of monitoring). This may include updating the regression analysis relating chlorophyll *a* to TP concentrations with additional data to generate a site-specific model; and
- Based on the above evaluations, determine next steps.

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

- Evaluate indicators of nutrient enrichment (i.e., nitrogen and phosphorus) and other eutrophication response indicators (i.e., dissolved oxygen, Secchi disk depth) to assess overall trophic status and relationships between nutrients and chlorophyll *a*;
- Evaluate chemical, biological, and physical monitoring results collectively with chlorophyll *a* monitoring results to evaluate effects on the ecosystem. Key metrics would be evaluated to determine if increases in chlorophyll *a* are

adversely affecting other biota, specifically BMI and Arctic Char. It is anticipated that BMI metrics would be the most sensitive for evaluating these linkages;

- Evaluate the need for additional monitoring (e.g., confirmation monitoring) and/or modifications to the CREMP;
- Consider results of the trend analysis (i.e., trend analysis indicates an upward trend) and evaluation of potential pathways of effect (i.e., causes of observed changes) to determine if management/mitigation is required; and
- Identify next steps based on the above analyses. Next steps may include those identified for the high action level response.

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

- Analysis of phytoplankton samples collected from Mine Area lakes for biomass and taxonomy (i.e., samples will be collected and archived under the CREMP). This information would provide additional data regarding phytoplankton abundance (i.e., biomass) as well as information to characterize the community composition. Derived metrics such as diversity, richness, and evenness could be examined to evaluate shifts in the phytoplankton communities that may trigger cascading effects across trophic levels. This information may be useful in exploring causes or pathways of effects across higher trophic levels if they are observed (e.g., changes in BMI communities);
- Implementation of increased monitoring to confirm effects and/or define magnitude and spatial extent of effects if warranted; and
- Implementation of mitigation measures or other management actions that may be identified under the moderate action level response.

3.0 BENTHIC MACROINVERTEBRATES

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

3.1 PATHWAYS OF EFFECT AND KEY QUESTIONS

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

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

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

The key question related to the pathways of effect is:

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

3.2 COMMUNITY METRICS

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

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

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

3.3 BENCHMARKS

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

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

Recent and ongoing monitoring programs in northern Canada have identified effects sizes and/or benchmarks for BMI using different approaches. For the Diavik Diamond Mine, a significant adverse effect as it relates to aquatic biota was defined in the Environmental

Assessment as a change in fish population(s) that is greater than 20% (Government of Canada 1999). This effect must have a high probability of being permanent or long-term in nature and must occur throughout the receiving environment (Lac de Gras). The "Significance Thresholds" for this AEMP, therefore, are related to impacts that could result in a change in fish population(s) that is greater than 20% (Golder 2014).

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

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

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

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

3.4 MONITORING AREA AND SAMPLING SITES

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

3.4.1 Lakes

Based on habitat types identified from previous field studies, Habitat Type 9 (5 nearshore replicate stations) and Habitat Type 14 (5 offshore replicate stations) will be sampled in each of the Mine Area and reference lakes (total of 10 replicate stations per lake; Figure 3-1). Each replicate station will consist of five benthic macroinvertebrate field sub-samples/grabs. Replicate stations will be consistent with sediment quality sampling locations where feasible to provide supporting information for interpretation and analysis of results (e.g., metals concentrations).

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

3.4.2 Streams

Five replicate stations separated by approximately three wetted stream widths will be sampled in each stream reach (Figure 3-2). Each replicate station will consist of five benthic macroinvertebrate field sub-samples. Sub-samples will be collected moving in an upstream direction and, whenever possible, they will be collected from representative microhabitats across the stream.

3.5 SAMPLING FREQUENCY AND SCHEDULE

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

Timing of sampling will be concentrated within a single sampling season (i.e., late summer/fall). Benthic invertebrate sampling has been consistently conducted in the Mine Area in late summer/fall, which is an ecologically relevant time for sampling and is most appropriate considering the effluent discharge regime (i.e., discharge during the open-water season only), hydrology (i.e., streams/rivers freeze solid), and dust deposition (i.e., introduction during the open-water season).

3.6 FIELD AND LABORATORY METHODS

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

3.6.1 Lakes

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

For each field sub-sample/grab:

1. The petite Ponar (area of opening 0.23 m^2) will be slowly lowered until it rests on the bottom to prevent shock waves that could physically move or disturb organisms and sediment from beneath the sampler.

2. The petite Ponar will be closed using a messenger.

3. The petite Ponar will be slowly raised, to minimize turbulence, and the sample will be immediately placed into a pail.

4. An acceptable sample requires that the jaws be completely closed upon retrieval.

5. If the jaws are not completely closed the sample will be discarded into a bucket (and disposed of once sampling is completed) and the procedure will be repeated.

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

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

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

3.6.2 Streams

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

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

buffered formalin. Fixed and labelled samples will be shipped to the analytical laboratory for processing and archiving.

3.6.3 Supporting Environmental Variables

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

- Sample date and start/end sample time;
- UTM position (using a hand-held GPS receiver);
- Water transparency (using a Secchi disk; lakes only); and
- Water temperature (using a hand-held thermometer for water surface measurement).

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

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

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

3.7 QUALITY ASSURANCE/QUALITY CONTROL

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

3.8 STUDY DESIGN AND DATA ANALYSIS

As existing baseline data for potential reference lakes and streams are minimal, the monitoring program will focus upon before-after comparisons of key metrics within the Mine Area waterbodies. The overall objective of this program is to collect habitat-based abundance, composition, and distribution information for the BMI community across a range of habitat types in the Mine Area lakes and streams.

For Sheardown Lake NW, Sheardown Lake SE, Camp, Mary, and reference lakes, major nearshore and offshore habitat types (5 replicate stations per habitat type) will be sampled. Based on habitat types identified from previous field studies, one nearshore and one offshore habitat type would be sampled in each of the Mine Area lakes (total of 10 replicate stations per lake) to provide information on habitat-based abundance, composition, and distribution of benthos. For Sheardown Lake tributaries 1, 9, and 12, Camp Lake tributaries 1 and 2, and the Mary River, representative stream reaches (5 replicate stations per reach) will also be sampled.

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

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

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

where:

X = the sample mean

n = the number of field sub-samples

s = the sample variance

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

Inter-annual differences in macroinvertebrate metrics will be assessed statistically for each lake by habitat type and for each stream by reach (where multiple years of data are available). All data will be tested for normality prior to statistical analysis and data that are normally distributed will be assessed using parametric statistics while non-normally distributed data will be analysed using non-parametric tests. Differences between years (and before-after comparisons) will be assessed using the t-test (parametric) or Mann-Whitney U-test (non-parametric) when two years of data are available; ANOVA with Bonferroni pairwise comparison (parametric) or Kruskal-Wallis test followed by multiple pairwise comparison (Dunn's procedure) (non-parametric) will be used when three years of data are available. All tests will be assessed with a significance level of 0.05.

3.9 ASSESSMENT FRAMEWORK

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

3.9.1 Step 1: Initial Data Analysis

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

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

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

3.9.2 Step 2: Determine if Change is Mine-Related

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

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

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

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

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

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

3.9.3 Step 3: Determine Action Level

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

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

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

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

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

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

- Based on the above evaluations, determine next steps.

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

- Evaluate chemical, biological, and physical monitoring results collectively with BMI monitoring results to evaluate effects on the ecosystem. For example, key metrics would be evaluated to determine if any observed increases in chlorophyll *a* are adversely affecting other biota, specifically BMI and Arctic Char;
- Evaluate the need for additional monitoring (e.g., targeted studies to confirm monitoring results) and/or modifications to the CREMP;
- Consider results of the temporal analysis (i.e., analysis indicates a substantive change) to determine if management/mitigation is required;
- Evaluate the benchmark to determine if it should be modified, as described above; and
- Identify next steps based on the above analyses. Next steps may include those identified for a high action level response.

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

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

- Implement mitigation measures or other management actions that may be identified in a moderate action level response.

4.0 ARCTIC CHAR

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

4.1 PATHWAYS OF EFFECT AND KEY QUESTIONS

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

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

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

The key question related to the pathways of effect is:

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

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

4.2 PARAMETERS AND METRICS

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

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

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

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

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

4.3 BENCHMARKS

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

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

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

The MMER identifies CESs for a fish population as a percentage of change from the "reference mean" (Table 4-2). As noted by Indian and Northern Affairs Canada (INAC 2009), "these effect sizes do not reflect the method recommended by Environment Canada (2004); namely effect sizes that correspond with unacceptable ecological changes." INAC (2009) also notes that Environment Canada (2008) identified these CESs "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".

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

4.4 MONITORING AREA AND SAMPLING SITES

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

4.5 SAMPLING FREQUENCY AND SCHEDULE

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

4.6 FIELD METHODS

4.6.1 Lakes

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

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

Capture of smaller fish (age 0+ and 1+) will be conducted through targeted sampling in nearshore habitats. Gear will include standard gang index gill nets and nearshore backpack electrofishing to obtain the required minimum target sample size (100 fish) and range of fish ages/sizes. Small mesh nets (i.e., Swedish nets) may also be employed, but based on field programs conducted to date, are not anticipated to be a key gear type for this program.

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

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

4.7 QUALITY ASSURANCE/QUALITY CONTROL (QA/QC)

The QA/QC program will include the following components:

- Application of established sampling protocols;
- Review of data for transcription errors, omissions, and outliers; and
- QA/QC of fish ageing data.

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

4.8 STUDY DESIGN, DATA ANALYSIS, AND SAMPLE SIZE

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

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

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

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

4.9 ASSESSMENT FRAMEWORK

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

4.9.1 Step 1: Initial Data Analysis

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

4.9.2 Step 2: Determine if Change is Mine Related

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

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

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

4.9.3 Step 3: Determine Action Level

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

- Conduct a temporal trend analysis: this will be a qualitative exercise and consist of graphical presentation of data over time to evaluate increasing or decreasing trends. It is important to note that several years of data will be required to begin to assess temporal trends;
- Investigate and summarize potential causes and pathways of effect of the observed changes;

- Review and summarize monitoring results for other metrics of relevance to Arctic Char (i.e., drivers) such as water levels and flows, water temperature, and/or chemical and other biological metrics;
- Review/assess benchmarks with acquisition of data (note: this will be undertaken over the course of monitoring); and
- Based on the above evaluations, determine next steps.

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

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

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

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

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

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

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

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

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

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

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

Table 2-4. Summary of power analysis results for phytoplankton chlorophyll *a*.

Waterbody	Effect Size	Power			
		Summer		Fall	
		n = 5	n = 6	n = 5	n = 6
Sheardown Lake NW	Benchmark	1	1	1	1
	2 x Mean of Baseline	0.80	0.83	0.82	0.85
Mary Lake	Benchmark	0.94	0.68	0.77	0.67
	2 x Mean of Baseline	0.95	0.69	0.77	0.69

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

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

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

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

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

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

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

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

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

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

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

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

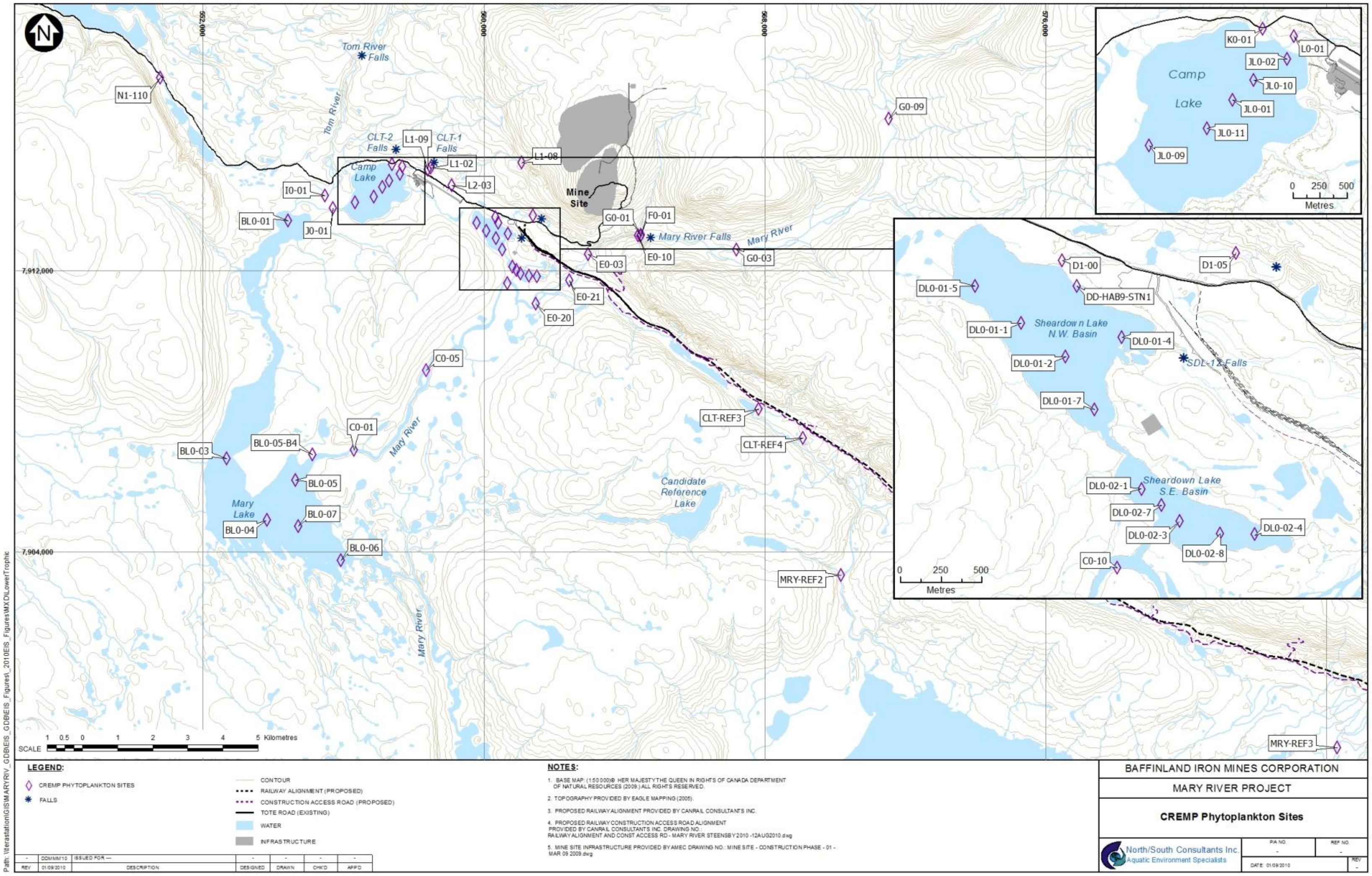
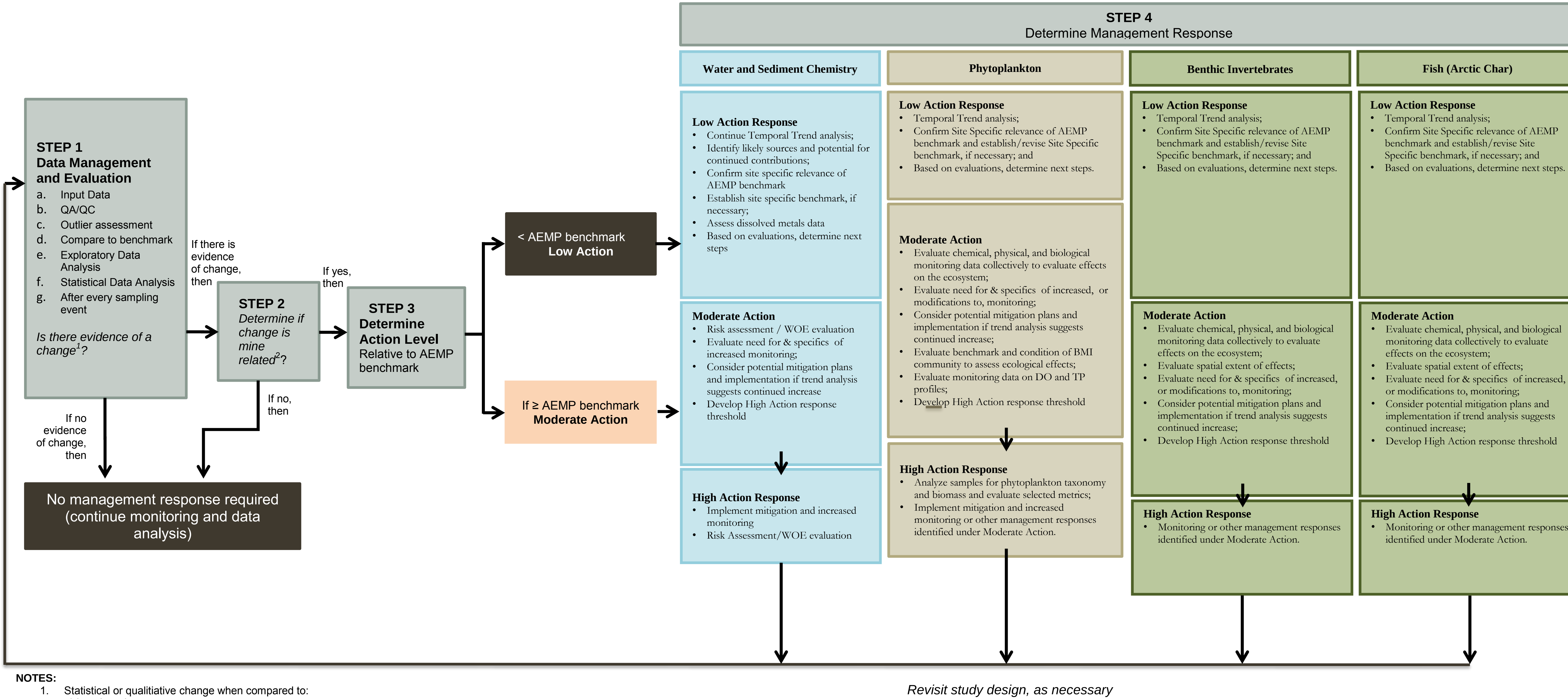


Figure 2-1. Locations of phytoplankton monitoring sites under CREMP.



NOTES:

1. Statistical or qualitative change when compared to:
   a) benchmark,
   b) baseline values,
   c) temporal or spatial trends
2. Mine related changes are a result of the mine and associated facilities including but not limited to effects from effluent discharges and dust deposition that are distinguished from natural causes or variation

Figure 2-2. Assessment approach and response framework.

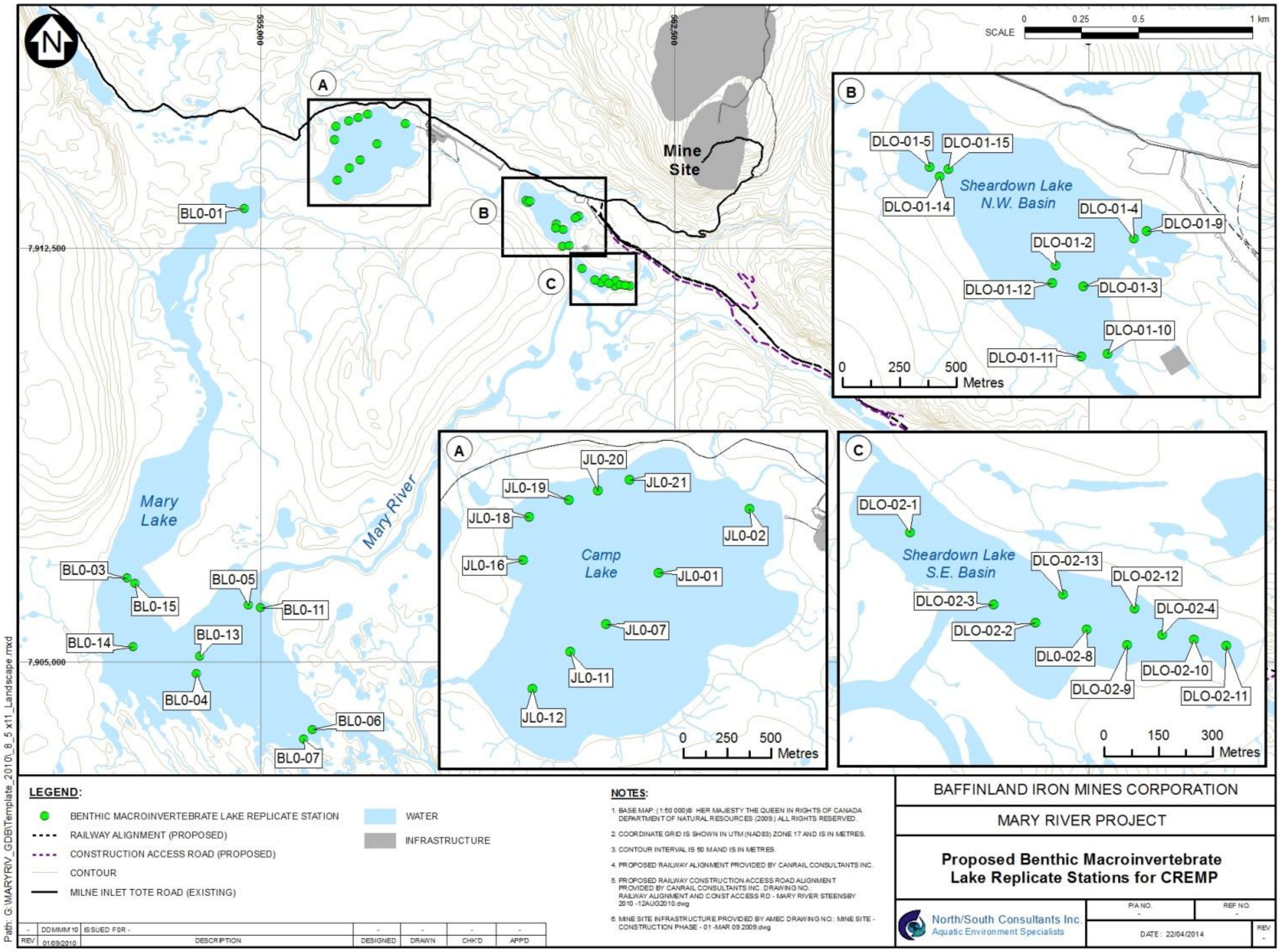


Figure 3-1. Locations of lake benthic macroinvertebrate sampling sites under the CREMP.

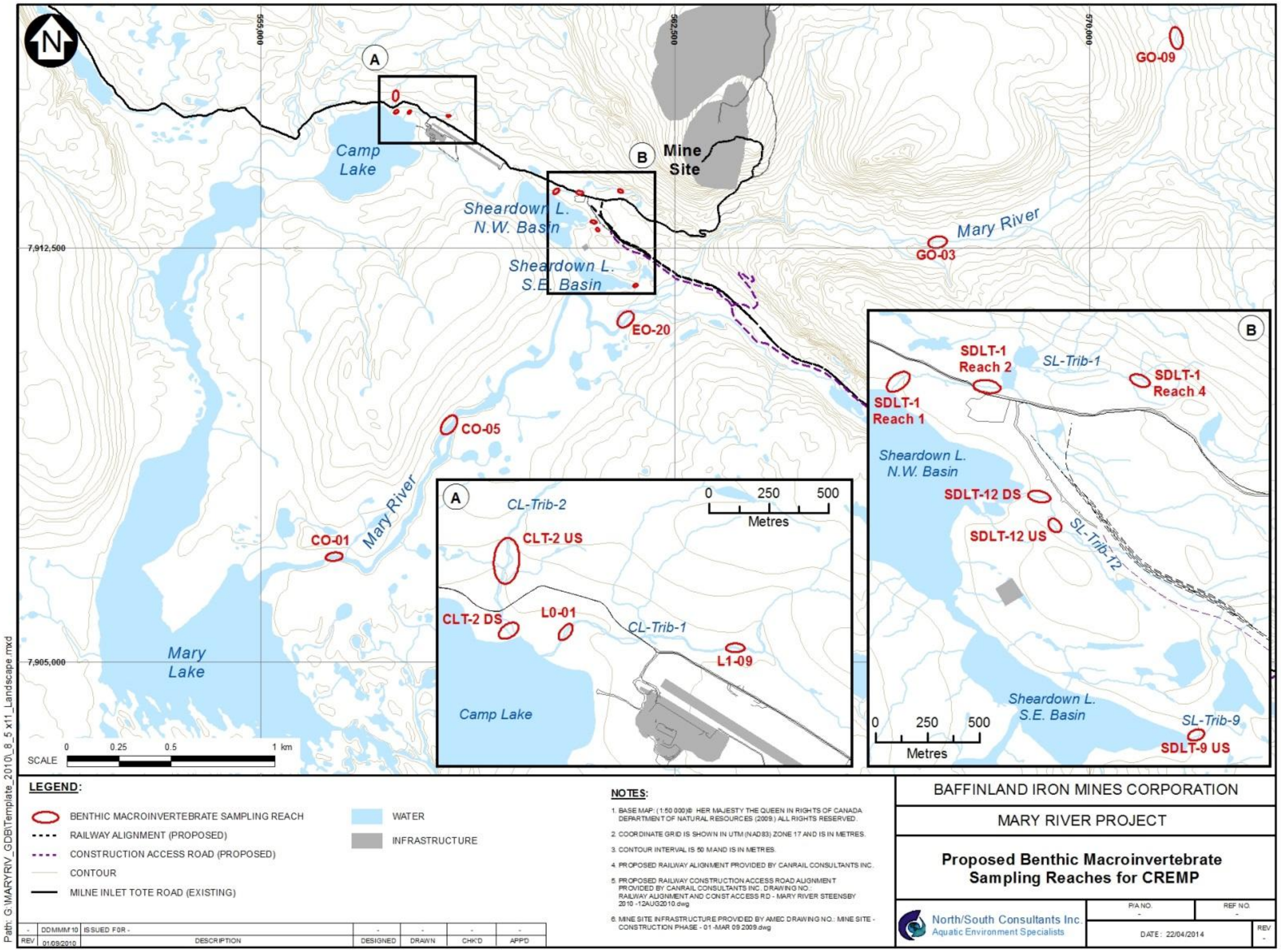


Figure 3-2. Locations of stream benthic macroinvertebrate sampling sites under the CREMP.

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

Mary River Project

June 2014

Review of Baseline Data for Freshwater Biota:

Mary River Mine Site

North/South Consultants Inc.
Aquatic Environment Specialists

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

June, 2014

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

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

1.0 INTRODUCTION

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

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

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

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

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

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

2.0 PHYTOPLANKTON

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

2.1 INVENTORY OF FRESHWATER BASELINE DATA

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

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

2.1.1 Sampling Methods

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

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

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

2.1.2 Baseline Data Inventory

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

2.1.2.1 Lakes

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

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

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

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

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

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

2.1.2.2 Streams

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

2.2 PATHWAYS OF EFFECT AND KEY QUESTIONS

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

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

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

The key question related to the pathways of effect is:

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

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

2.3 EVALUATION OF DATA FOR POST-PROJECT MONITORING

2.3.1 Description of Existing Data

2.3.1.1 Data Analysis

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

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

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

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

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

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

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

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

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

2.3.1.2 Results

Chlorophyll a

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

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

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

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

Phytoplankton Biomass

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

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

Phytoplankton Taxonomic Metrics

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

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

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

Correlations and Regressions

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

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

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

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

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

2.3.1.3 Chlorophyll *a* in Streams

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

2.3.2 Power Analysis

2.3.2.1 Methods

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

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

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

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

Phytoplankton Taxonomy and Biomass

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

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

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

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

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

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

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

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

Chlorophyll a

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

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

2.3.2.2 Results

Phytoplankton Taxonomy and Biomass

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

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

Chlorophyll a

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

2.3.3 Sampling Sites and Areas

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

2.3.4 Sampling Methods

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

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

2.3.5 Sampling Frequency

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

2.4 OVERVIEW OF 2013 SAMPLING

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

3.0 BENTHIC MACROINVERTEBRATES

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

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

3.1 INVENTORY OF FRESHWATER BASELINE DATA

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

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

3.1.1 Sampling Methods

3.1.1.1 Lakes

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

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

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

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

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

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

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

3.1.1.2 Streams

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

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

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

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

3.1.2 Baseline Data Inventory

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

3.1.2.1 Lakes

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

3.1.2.2 Streams

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

3.2 PATHWAYS OF EFFECT AND KEY QUESTIONS

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

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

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

The key question related to the pathways of effect is:

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

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

3.3 EVALUATION OF DATA FOR POST-PROJECT MONITORING

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

3.3.1 Description of Existing Data

3.3.1.1 Data Analysis

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

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

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

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

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

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

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

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

where:

X = the sample mean

n = the number of field sub-samples

s = the sample variance

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

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

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

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

3.3.1.2 Lake Results

Abundance

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

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

Composition

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

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

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

Richness

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

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

3.3.1.3 Stream Results

Abundance

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

Composition

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

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

Richness

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

3.3.2 Power Analysis

3.3.2.1 Data Analysis Methods

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

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

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

Metrics that were subject to a power analysis included:

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

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

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

3.3.2.2 Lake Results

Total Macroinvertebrate Density

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

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

Chironomidae Proportion

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

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

Shannon's Equitability

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

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

Simpson's Diversity Index

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

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

Total Taxa Richness

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

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

3.3.2.3 Streams Results

Total Macroinvertebrate Density

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

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

Chironomidae Proportion

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

Shannon's Equitability

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

Simpson's Diversity Index

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

Total Taxa Richness

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

3.3.3 Sampling Sites and Areas

3.3.3.1 Lakes

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

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

3.3.3.2 Streams

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

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

3.3.4 Sample Size

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

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

3.3.4.1 Lakes

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

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

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

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

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

3.3.4.2 Streams

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

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

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

3.3.5 Sampling Methods

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

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

3.3.6 Timing of Sampling

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

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

3.3.7 Taxonomy

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

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

3.3.8 Summary

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

3.4 OVERVIEW OF 2013 SAMPLING

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

3.4.1 Lakes

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

3.4.2 Streams

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

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

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

4.0 ARCTIC CHAR

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

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

- Fish distribution across the Mine Area streams and identification of fish barriers;
- Fish movements (Arctic Char) between waterbodies;
- Fish population characteristics and condition (catch-per-unit-effort [CPUE], age structure, length/size at age, sex and sexual maturity, condition factors, deformities, erosion, lesions, and tumours [DELTs], and internal and external parasites);
- Seasonal movement of Arctic Char from lakes into and out of streams/rivers;
- Anadromy;
- Seasonal use of various habitat types by different life history stages;
- Metals in liver and muscle; and
- Spawning areas/timing.

This review focused upon metrics that were identified for the CREMP (i.e., individual and population level metrics of growth, survival, condition and reproduction) and did not therefore discuss data regarding fish movements/anadromy or metals in fish. Information on fish movements and habitat use were considered as supporting information for the review of baseline data and in the design of the CREMP.

While this review focused upon consideration of baseline data in Mine Area lakes, for the purposes of providing a general overview of available baseline data for Arctic Char in the Mine area, and because data collected in streams could be used to augment or support lake monitoring programs, Section 4.1 provides a brief description of baseline studies programs conducted in lakes and streams.

The detailed review of baseline data was completed in 2013 prior to the open-water season (NSC 2013) in part to provide recommendations for additional baseline data collection for the 2013 field season. A field program was subsequently completed in 2013, as summarized in Section 3.4. The detailed review of baseline data provided in Section 4.3 is based on data collected from 2005 through 2012 in the Mine Area.

4.1 INVENTORY OF FRESHWATER BASELINE DATA

The following sections provide an inventory of baseline studies for Arctic Char in the Mine Area. Specifically, the following provides:

- An overview of the sampling methods employed for collection and analysis of Arctic Char in the Mine Area waterbodies; and
- An inventory of existing baseline Arctic Char data for Mine Area waterbodies.

4.1.1 Sampling Methods

4.1.1.1 Lakes

A Smith-Root Model 11A or LR-24 backpack electrofisher was used during 2007, 2008 and 2013 to assess the use of wadeable nearshore lake habitat by small fish. During summer 2007, approximately 50-100 m long sections of shoreline with a variety of substrates (e.g., sand, cobble/boulder, gravel/cobble) were electrofished to assess habitat use by small fish in most Mine Area lakes. During spring 2008, electrofishing effort was focused on substrate types (cobble/boulder) thought to be preferred Arctic Char rearing habitat. The presence of recently hatched young-of-the-year (YOY) Arctic Char in nearshore habitat during early spring would provide some evidence of nearby fall spawning. Captured fish were sampled and released. During fall 2013, rocky habitats were fished in an attempt to collect sufficient numbers of juvenile Arctic Char for AEMP analyses.

During the open-water seasons of 2006-2008 and 2013, standard gang index gill nets were used to sample fish at sites in Camp, Sheardown, and Mary lakes. Small mesh gill nets were also used in 2013. During 2006, gillnet sites were selected opportunistically. In 2007, sites were selected to achieve good spatial coverage of Camp, Sheardown, and Mary lakes. In 2008, the focus of the gillnetting program was on the identification of Arctic Char spawning habitat. In 2013, the focus of the gillnetting was to capture a sufficient number of fish (n = 100) across all size ranges of Arctic Char as part of a baseline study to support the CREMP. Standard index gillnet gangs consisted of six 22.9

m long by 1.8 m deep twisted nylon or monofilament panels of 1.5, 2.0, 3.0, 3.75, 4.25, and 5.0 inch (38, 51, 76, 95, 108, and 127 mm, respectively) stretched mesh. Small mesh gangs consisted of three 10 m long by 1.8 m deep panels of 16, 20 and 25 mm stretched mesh. Nets were set on the bottom and left in place for short periods of time (typically less than 4 hours) to minimize fish mortality. Winter gillnetting conducted in May 2007 used different gang arrangements and different methods and are not comparable with open-water gillnetting. Therefore, winter gillnetting data were excluded from the analyses presented in this report. Locations (i.e., UTMs) of all captured fish were recorded using a hand-held global positioning system (GPS) unit.

Biological data were collected for most fish captured in both gear types; however, the amount of data collected varied by year, gear type, and size and condition (i.e., live or mortalities) of fish. In all surveys, fish were identified to species, enumerated by location, and measured for fork length (± 1 mm). For fish less than 250 mm in length, round weight was measured to an accuracy of ± 1 g in 2006-2008 and 0.01 g in 2013, while larger fish were consistently weighed to an accuracy of ± 25 g. When possible (i.e., during fall), live fish were examined for sex and maturity by gently massaging the abdomen and identifying any extruded gametes. Mortalities and fish in poor condition from all years were retained and examined internally to determine sex and state of sexual maturity (i.e., had never spawned, preparing to spawn in the current year, had just completed spawning in the current year, or had spawned in a previous year but would not be spawning in the current year), where possible. Ageing structures (otoliths) were collected from a length-stratified sub-sample of gillnet-caught fish from all Mine Area lakes and from a length-stratified sub-sample of electrofishing-caught fish from Mary River from 2006-2008. In 2013, pectoral fin rays were collected from live released fish and both otoliths and fin rays were collected from incidental mortalities.

4.1.1.2 Streams

Backpack electrofishing was conducted from 2006-2008 using a Smith-Root Model 11A or LR-24 backpack electrofisher to assess the use of streams and rivers within the Mine Area by fish. Electrofishing surveys were primarily confined to reaches of streams and rivers where the results of aquatic habitat surveys suggested some potential to support fish. Stream reaches that either were ephemeral, or were cut off from lakes by impassable barriers typically were not fished. Streams and rivers electrofished in 2006 were confined to summer surveys, whereas most streams and rivers electrofished in 2007 were surveyed during spring, summer, and fall to document seasonal use of the tributaries. During 2008, several tributaries that had not been electrofished previously (particularly tributaries to Mary Lake) were fished during spring and summer.

Streams were subdivided into reaches based primarily on changes in dominant habitat types. Sections of each reach (50 m long) were isolated with barrier nets, where possible, and electrofished to estimate total fish use and compare between habitat types. Three passes were made in a downstream direction along each reach and the number of fish captured during each pass was recorded. All captured fish were released back into the reach from which they were captured at the completion of sampling.

Additional information on the fish use of selected tributaries was collected using hoop nets. Hoop nets oriented to capture fish moving downstream were installed in Camp Lake Tributary 2 (CLT2) and Sheardown Lake Tributary 1 (SDLT1) during fall 2007 to assess downstream movements of fish out of these tributaries. During 2008, hoop nets were installed during spring and fall to identify timing and magnitude of movements of fish into and out of these two streams after spring melt and prior to freeze-up. Upstream and downstream movements were monitored in CLT2 during spring and fall and in SDLT1 during spring, 2008. Low water levels during fall 2008 prevented monitoring of upstream movements in SDLT1. During fall 2013, downstream facing hoop nets were installed in Camp Lake Tributaries 1 and 2 and Sheardown Lake NW Tributary 1.

Hoop nets were constructed of fine-mesh beach seine material, were 0.6 m in diameter, and had 5 m long wings. Each hoop net was positioned as close to the confluences as possible at sufficient depths to remain submerged. Each wing and the cod end of the net were anchored so that it remained taut and spanned the width of the stream. Wings were lengthened with rock barriers, where necessary, to achieve 100% blockage of the channel in either upstream or downstream configurations. All captured fish were released into the stream on the opposite side of the hoop net in which they were caught at the completion of sampling.

Biological data were collected for most fish captured in all gear types; however, the amount of data collected varied by gear type and size of fish. Fish were identified to species, enumerated by location, and measured for fork length (± 1 mm). For hoopnet-caught fish, only the first 50 fish captured each day were measured for fork length. For fish less than 250 mm in length, round weight was measured to an accuracy of ± 1 g, while larger fish were weighed to an accuracy of ± 25 g. Fish longer than 250 mm, and in good condition, were marked with individually numbered Floy® FD-94 tags inserted at the base of the dorsal fin. During 2013, pectoral fin rays were also collected from a subsample of fish and otoliths were collected from incidental mortalities.

4.1.2 Baseline Data Inventory

4.1.2.1 Lakes

Fish were sampled in lakes in the Mine Area using angling, minnow traps, backpack electrofishing, and standard gang and small mesh index gill nets during the open-water periods of 2005 to 2008, 2010 and 2013 and using gill nets deployed under the ice in May 2007 (Figure 4-1, Table 4-1). Sampled lakes included Camp, Sheardown (northwest and southeast basins), and Mary (north and south basins) lakes.

4.1.2.2 Streams

Fish were sampled in streams within the Mine Area using angling, minnow traps, backpack electrofishing, and hoop nets during the open-water periods of 2005 to 2008 and 2013 (Figure 4-2, Table 4-1). Sampled streams and rivers included inflows to Camp Lake, Sheardown Lake (northwest and southeast basins), and Mary Lake (north and south basins), as well as the Mary and Tom rivers. The largest data sets were obtained from the hoopnetting programs conducted at the confluences of tributary streams with Camp and Sheardown lakes. These data improve robustness of the baseline database respecting YOY and age 1+ juvenile datasets for lakes.

4.2 PATHWAYS OF EFFECT AND KEY QUESTIONS

Key questions were developed to guide the review of baseline data adequacy and, ultimately, design of the monitoring program. The adequacy of baseline data to address these key questions is addressed in Section 4.3. These questions and metrics focus upon key potential residual effects identified in the FEIS (BIM 2012) and the Addendum to the FEIS for the ERP (BIM 2013), as well as metrics commonly applied for characterizing fish populations (growth, reproduction, condition and survival) and recommended by EC (2012).

The key pathways of potential residual effects of the Project on Arctic Char include:

- Water quality changes related to discharge of ore or stockpile runoff to freshwater systems (immediate receiving environments: Mary River and Camp Lake Tributary 1);

- Water quality changes related to discharge of treated sewage effluent (immediate receiving environments: Mary River and Sheardown Lake NW);
- Water quality changes due to deposition of dust in lakes and streams (Mine Area in zone of dust deposition);
- Water quality changes due to non-point sources, such as site runoff and use of ANFO explosives (Mine Area);
- Changes in water levels and/or flows due to water withdrawals, diversions, and effluent discharges (i.e., alteration or loss of aquatic habitat);
- Dust deposition (i.e., sedimentation) in Arctic Char spawning areas (habitat) and on Arctic Char eggs; and
- Effects of the Project on primary and secondary producers.

The key question related to the pathways of effect is:

- What are the combined effects of point and non-point sources, sedimentation, habitat loss or alteration, and changes in primary or secondary producers on Arctic Char in Mine Area lakes (Sheardown Lake NW and SE, Camp Lake, and Mary Lake)?

Arctic Char will be monitored downstream of discharges of ore and waste rock stockpile runoff (i.e., Camp Lake Tributary 1 and the Mary River) under the MMER EEM program. Of the remaining waterbodies, potential effects of the Project on Arctic Char populations are predicted to be greatest in the Camp Lake and Sheardown Lake drainages.

4.3 EVALUATION OF DATA FOR POST-PROJECT MONITORING

The Mine Area streams and lakes support only two fish species: land-locked Arctic Char; and, Ninespine Stickleback (*Pungitius pungitius*). Of these, abundance of Ninespine Stickleback is relatively limited and highly localized while Arctic Char are overwhelmingly the most abundant fish species in the area. As Mine Area streams freeze solid during winter, overwintering habitat is provided exclusively by lakes.

EC (2012) recommends monitoring of sexually mature individuals of a minimum of two fish species for EEM programs and use of invasive sampling (i.e., lethal) if acceptable. Alternative study designs include non-lethal sampling methods for fish populations/communities, as well as studies of juvenile fish if appropriate and/or required.

Given that there are only two fish species present in the area, fish monitoring in the Mine Area would be limited to successful capture of sufficient numbers of both of these fish species in the exposure areas. In most lakes and streams in the exposure area, Arctic Char are sufficiently abundant that successful capture of enough fish for monitoring purposes is possible. In contrast, Ninespine Stickleback are absent or uncommon in a number of waterbodies. Similar results have been observed in most waterbodies surveyed for all components of the Mary River Project. It is unlikely, even with extensive effort, that sufficient numbers of Ninespine Stickleback could be captured for monitoring purposes from either the receiving environments or from prospective reference areas. For this reason, only a single species, Arctic Char, will be monitored used for the CREMP program.

4.3.1 Description of Existing Data

The following provides a description of existing data for Arctic Char based on backpack electrofishing and open-water gillnetting data collected in Mine Area lakes in 2006-2008 and hoopnetting data collected in streams in 2006-2008.

4.3.1.1 Data Analysis

To explore the robustness of various potential metrics for Arctic Char for the CREMP, several metrics were derived as indicated in Table 4-2, using the datasets indicated in Table 4-3. The CREMP and MMER EEM programs will employ non-lethal sampling methods to minimize impacts of monitoring on the Arctic Char populations. Therefore the metrics identified and assessed for the CREMP are those that can be measured using non-lethal sampling methods. Metric data for Arctic Char were analysed where sample sizes were ≥ 10, by waterbody, year, gear type (gill net and electrofishing only), and sex. When sex could not be determined for sufficient numbers of fish (e.g., electrofishing catches), data were pooled. Age data collected from a subsample of gillnetted fish in each lake were pooled to provide a sufficient sample size. Annual gillnetting data collected from 2006-2008 and shoreline electrofishing data (Sheardown Lake NW only) collected in 2007 and 2008 were analysed. Methods for the calculation of derived metrics are described below.

All fish catch and life history data were tabulated and reviewed for transcription errors as part of routine QA/QC measures and, if warranted, outliers were eliminated from datasets. Fish catches were examined by lake, species, gear type, and year.

For Arctic Char, mean length, weight, and condition factor were calculated by lake, year, gear type, and, where possible, sex. CPUE was calculated for fish captured by electrofishing (#fish/minute of electrofishing) and in gill nets (#fish/100 m of net/24 hrs). Summary statistics (mean, median, SE, SD, minimum, maximum, n, COV, and 95th percentile) for each of these metrics were derived for each year, waterbody, gear type and, where possible, sex using data from all sites sampled concurrently in that waterbody.

COV was calculated as SD/mean x 100; COV facilitated comparisons of the variability of various datasets to assist with identifying the most robust metrics as well as to assist with advising on sampling design. The variability of the metrics examined was then described to facilitate identification of those metrics with the lowest natural variation for further consideration and statistical analysis.

Additional summary statistics were conducted on YOY and fish aged 1+, including length-frequency analyses, length-at-age and weight-at-age to provide estimates of growth and survival of these early life stages.

Some hoop net data from streams (i.e., lengths and weights for YOY and 1+ fish) were pooled with shoreline electrofishing data in Sheardown Lake NW to improve robustness of the lake dataset for analysis.

4.3.1.2 Results

Fork Length (mm)

Mean lengths of Arctic Char show variation between lake, year, and sex (Tables 4-4 to 4-6). However, there were no significant differences observed between males and females sampled within the same year in any lakes and with one exception, there were no significant differences observed between years for this metric (Table 4-7). The sole exception occurred for females captured in Camp Lake where lengths were significantly different between years.

Comparing datasets between lakes revealed that Camp Lake had the smallest mean length and highest COV while the catches from the Mary Lake basins had the highest mean length and lowest variability (Tables 4-4 and 4-6). There were no significant differences for any between-lake comparisons of datasets (Table 4-8).

Weight (g)

Mean weights of Arctic Char show even greater variation between lake, year, and sex (Tables 4-9 to 4-11) than mean fork lengths. No significant differences between sexes or years were observed for Sheardown Lake NW or Mary Lake South. Weights of females were significantly lower than males captured in 2006, 2008, and with all years combined (2006-2008) and weights of both males and females were significantly different between years in Camp Lake (Table 4-12).

Comparing datasets between lakes revealed that north basin of Mary Lake had the smallest mean weight and COV while the south basin had the highest mean weight and Camp Lake had the highest variability (Tables 4-9 to 4-11). There were no significant differences for any between-lake comparisons of datasets (Table 4-13).

Condition Factor (K)

In contrast to length and weight metrics, mean condition factor of Arctic Char showed little variation between datasets and lower COVs than fork lengths (Tables 4-14 to 4-16). Mean condition factor was similar between males and females and between years in Camp Lake with consistently low COVs (Table 4-14). Mean condition factor of Arctic Char captured in Sheardown Lake was slightly lower than for Camp Lake, but also showed consistency between sexes and across years with low COVs for the gillnetting catch (Table 4-15). Condition factors of fish captured by electrofishing in Sheardown Lake NW was greater than for fish captured with gill nets, however the electrofishing dataset also exhibited higher COVs. In the south basin of Mary Lake, mean condition factor was higher in 2006 than in 2007, but relatively consistent between sexes and variability was low (Table 4-16).

Non-parametric analysis revealed significant interannual differences for males captured in Sheardown Lake NW and between males and females from Sheardown Lake NW in 2006 (Table 4-17). There were no significant differences for any between-lake comparisons of condition factor datasets (Table 4-18).

Catch-Per-Unit-Effort

As is commonly observed, CPUE for Arctic Char showed consistently high variation among datasets (Table 4-19). The highest COV was observed in the Sheardown Lake datasets. Data for males and females were not analysed separately because sex could not be identified for all captured fish, particularly during summer sampling.

Significant interannual differences (P value < 0.05) were observed for gillnetting datasets for Camp Lake and Mary Lake south and for the electrofishing dataset from Sheardown Lake NW (Table 4-20). In addition, there were significant differences for all between-lake comparisons (Table 4-21).

Age

Summary statistics for age data from Arctic Char are presented in Table 4-22. Fish sampled from Sheardown and Mary lakes had the highest average age while those sampled from Mary River had the lowest. Variation is relatively low between individual lakes and high between lakes and rivers. Length and weight-at-age statistics show a general increase in size with increasing age (Table 4-23). Growth rates appear to be higher between the ages of 2 and 10 than in older fish. Analysis of covariance (ANCOVA) tests show a significant effect of age on both length and weight (Table 4-24).

4.3.2 Power Analysis

4.3.2.1 Methods

Selected Arctic Char metrics (Table 4-25) were subject to a power analysis to:

- Provide a preliminary analysis of the power of the existing dataset to be used as the foundation for detecting post-Project change (i.e., Before-After comparisons);
- Explore samples sizes required for detecting pre-defined levels of change; and
- Advise on the need for collection of additional baseline data and/or modifications to future sampling programs (i.e., number of sites).

The variability of selected Arctic Char metrics measured during the baseline studies program was evaluated and described in Section 4.3.1 to assist with identifying the most robust metrics for further statistical exploration and consideration under the CREMP. Metrics that were subject to a power analysis included:

- Age 0+ and 1+ Length (mm);
- Age 1+ Weight (g); and
- Age 1+ Condition Factor.

Condition factor and weight of Age 0+ (i.e., YOY) fish could not be subject to a power analysis due to the precision of the weight measurements for the existing baseline datasets.

Power analysis was conducted following general guidance provided in the EC Metal Mining EEM Guidance Document (2012). Specifically, values for α (Type I error) and β (Type II error) were set at 0.1 as advised in EC (2012). Data were evaluated for assumptions of normality and equal variance and transformed where required. Baseline data on Arctic Char populations collected in Sheardown Lake NW and Camp Lake from 2006-2010 were evaluated statistically for consideration of monitoring under the CREMP.

For non-lethal sampling, EC (2012) recommends sampling of a minimum of 100 fish older than YOY for each study site but also recommends retaining and measuring all YOY collected during the sampling for older fish. Where possible, fish older than YOY should represent the whole range of fish sizes and be representative of the population (mature and immature).

A Priori Power Analyses

Power analysis by simulation was implemented using PopTools (Hood 2010).Two types of power analyses were used; one based on a *t*-test (parametric) and one based on the Mann-Whitney (nonparametric) *U*-test.

The power of existing baseline data to be used for demonstrating changes in the various metrics was explored for a range of effects sizes (i.e., ±10%, ±20%, and ±25%). Using the dNormalDev(mean, SD) function, random data were generated for the observed baseline and hypothetical monitoring scenarios. The Excel formula for a t-test was used keeping the first row fixed. This process was iterated 1000 times by Monte Carlo simulation to determine the frequency of a realised t-probability greater than α (Type I error). This provided an estimate of β (Type II error) with the power of the test being 1-β. Both α and β were set at 0.10 for a power of 90% following the EEM Guidelines (EC 2012).

4.3.2.2 Results

The power analyses indicated that a sample size of 100 fish is sufficient to detect changes in length of 10%, in weight of 20%, and in condition factor of 10% (Table 4-25). Weights were the most variable of these three metrics and the power associated with this metric is the lowest. The power analyses indicate that relatively small samples sizes are required to detect 10% changes in length (n = 25 YOY and n = 11 for Age 1+) and condition factor (n = 9 for Age 1+).

4.3.3 Study Design

Monitoring of Arctic Char in the Mine Area under the CREMP would utilize a non-lethal sampling design. The objective of the lake monitoring programs is to examine cumulative effects of the Project on Arctic Char populations. Lakes provide critical habitat for Arctic Char, as streams freeze solid in winter and spawning and overwintering habitat is restricted to lakes. The CREMP would examine the collective Project effects through monitoring Arctic Char in Mine Area lakes as a whole.

The lake-based CREMP sampling program is focused upon obtaining measures of metrics for Age 1+ fish using standardized sampling methods (i.e., standard gang index gillnetting). The monitoring program will consist of direct before-after comparisons within a lake and, depending on the suitability of the final reference lakes incorporated into the CREMP, may also include control-impact comparisons (or, ideally, before-after-control-impact comparisons).

Gear would be primarily standard gang index gill nets, supplemented with smaller mesh nets (i.e., Swedish nets) and/or electrofishing as required to obtain the required minimum target sample size and range of fish ages/sizes.

4.3.4 Timing of Sampling

EC (2012) indicates that timing of sampling should consider the time of year, hydrology/habitat variability, stage of reproductive development, and effluent discharge regime. Fish biology also affects timing of sampling (e.g., seasonal use of exposure areas) and reference and exposure areas should be sampled as close in time as feasible and should consider water temperature explicitly.

For Arctic Char, the recommended sampling period is 4-6 weeks prior to first spawn (EC 2012). For non-lethal surveys that include collection of YOY, EC (2012) recommends that sampling be conducted when YOY are a catchable size in the gear being used. They further recommend sampling YOY in late fall where appropriate, though timing should consider variability in YOY size distributions of the population being monitored, or ideally, at the beginning and end of the growing period.

From 2006-2008, baseline sampling programs conducted in Camp, Sheardown and Mary Lakes with standard gang index gill nets typically occurred during summer (late July/early August) and covered all habitat types throughout the lake. These data were supplemented with limited fall sampling intended to identify spawning locations. Fall gillnetting was primarily restricted to areas where preferred spawning substrates were located. Sampling in streams was conducted during spring, summer and fall in all available habitat types to document seasonal use of stream habitat by both species of fish.

In 2013, the Arctic Char sampling program was conducted in late summer/fall in Mine Area lakes to target the end of the growing season prior to spawning. During Project operation, this timing would allow for sampling of Arctic Char following a prolonged period of exposure to effluent (which will be discharged in the open-water season) and other non-point sources such as dust.

4.3.5 Sampling Areas

EC (2012) provides detailed direction on identifying exposure areas for the fish monitoring component under MMER EEM. As the objective of the MMER EEM programs is to monitor for effects of metal mining effluent on fish populations, these exposure areas are intentionally selected in areas affected by effluent discharges. Reference areas are then identified with, ideally, identical features and characteristics (e.g., habitat), for comparison.

Baseline sampling of Mine Area lakes with standard gang index gill nets was designed to provide quantitative estimates of Arctic Char populations for each lake and to identify spawning areas, while backpack electrofishing in all available nearshore habitat types of the lakes was conducted to identify habitat preferences of juveniles and assist with identification of spawning areas. During 2006, gillnet sites were selected opportunistically. In 2007, sites were selected to achieve good spatial and habitat coverage of Camp, Sheardown, and Mary lakes. In 2008, the focus of the gillnetting program was on the identification of Arctic Char spawning habitat.

In 2013, the program was designed to collect 100 fish from all size classes in each lake to provide baseline information for the CREMP. The CREMP is intended to monitor the cumulative effects of the Project on Arctic Char populations in Mine Area lakes and is not intended to focus upon mining effluent or any one particular effects pathway. As such the CREMP adopts a broader spatial scope and is intended to provide information on a lake-wide basis, rather than on a focused area of each lake.

4.3.6 Sample Size

For non-lethal sampling, EC (2012) recommends sampling of a minimum of 100 fish older than YOY for each study area but also recommends retaining and measuring all YOY collected during the sampling for older fish. Where possible, fish older than YOY should represent the whole range of fish sizes and be representative of the population (mature and immature).Where abundance of YOY is “extremely high” (i.e., >80-90% of the first 100 fish captured during the program), sampling should continue until 100 non-YOY fish are captured.

Results of the power analyses conducted on the Sheardown Lake NW datasets indicates that this recommended sample size will be adequate to detect CESs between 10 and 25% on selected metrics. However, the power analyses were based on baseline data collected from a representative lake (Sheardown Lake NW) using a different study design than recommended for the CREMP. Therefore the CREMP will target a minimum of 100 individuals per lake, as recommended by EC (2012).

4.3.7 Metrics

EC (2012) recommends that non-lethal sampling should include fork length for fish with a forked caudal fin (± 1 mm), total body weight (± 1.0%), assessment of external condition (i.e., DELTs), external sex determination (if possible), and age (where possible; ± 1 year). They further recommend the use of a 3-decimal scale for measuring weights of small-sized fish.

Baseline studies included measurement of all of these metrics but some metrics were not measured to the recommended precision for all fish sampled. Future programs will employ the level of precision identified by EC (2012) for all fish captured.

Arctic Char were aged using otoliths - the preferred ageing structure for this species – during most of the baseline studies. The CREMP will employ a non-lethal design and therefore will require use of another ageing structure (i.e., pectoral fin rays) for fish that are live released. Based on the results of a comparative analysis of pectoral fin rays and otoliths for ageing Arctic Char in the Mine Area (NSC 2014), it will be necessary to sacrifice fish from a length-stratified sub-sample during the conduct of future studies. Ageing measurements will also be independently confirmed on a minimum of 10% of samples, as recommended by EC (2012).

4.3.8 Sampling Equipment

EC (2012) indicates the same gear type should be used for sampling reference and exposure areas and ideally only one gear type is used for the fish study. In nearshore areas of lakes, backpack electrofishing has been the primary method of sampling and will be used for sampling these areas during the CREMP program as needed. Standard gang index gillnetting has been used for baseline lake surveys and will continue to be used during the CREMP program as the primary sampling method. Small mesh nets may also be used to capture sufficient numbers of fish, in particular smaller size ranges. However, small mesh nets have proven relatively ineffective for capture of fish smaller than 250 mm in length and it is anticipated that backpack electrofishing will be required in future programs to obtain Arctic Char in this length range.

4.4 OVERVIEW OF 2013 SAMPLING

The Arctic Char sampling program conducted in Mine Area lakes in 2013 was designed to be non-lethal and was based upon EC's EEM survey design (EC 2012). As such, the lake-based sampling program was focused upon obtaining measures of metrics for Age 1+ fish using standardized sampling methods (i.e., standard gang index gillnetting). The program was habitat-based, with sampling effort weighted in accordance with the proportions of major habitat types in each of the lakes. Major habitat types were defined in terms of water depth and substrate as follows:

- Deep (> 12 m)/hard;
- Deep/soft;
- Shallow (2-12 m)/hard; and
- Shallow/soft.

Sites were randomly selected within these habitats in each lake. Catch rates were lower than anticipated based on gillnetting surveys conducted from 2006-2008 and sampling was enhanced by addition of sites most likely to optimize catches (e.g., probable spawning areas). Gear included standard gang index gill nets, supplemented with smaller mesh nets (i.e., Swedish nets) and nearshore backpack electrofishing to obtain the required minimum target sample size (100 fish) and range of fish ages/sizes.

Twenty-four standard index and eleven small mesh gillnet gangs were set in Camp Lake from 27-29 August, 2013 (Figure 4-3). Twelve standard index and 6 small mesh gillnet gangs were set in Sheardown NW Lake on 30 August, 2013 (Figure 4-4). A total of 26 Arctic Char were captured in Camp Lake and 28 were captured Sheardown Lake NW with gill nets.

To supplement the small gillnetting catches, backpack electrofishing was conducted at one site in Camp Lake and two sites in Sheardown Lake NW. Fifty-seven juvenile Arctic Char were captured in Camp Lake and 183 Arctic Char and one Ninespine Stickleback were captured in Sheardown Lake NW during electrofishing surveys.

As noted in Section 4.3.7, pectoral fin rays and otoliths were collected from incidental mortalities of Arctic Char during the 2013 field program to facilitate comparison of the two ageing structures. The results of this comparison are provided in NSC (2014).

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TABLES AND FIGURES

Table 2-1. Summary of number of sites sampled for analysis of chlorophyll *a* in Mine Area lakes (near surface sampling).

Sampling Period	Sheardown Lake NW	Sheardown Lake SE	Camp Lake	Mary Lake
May 2007	3	2	3	4
August 2007	5	3	3	4
September 2007	5	3	3	4
June 2008	6	0	0	0
July/August 2008	22	6	3	3
September 2008	11	3	0	0
August/September 2009	4	1	0	0
July 2013	6	1	5	6
August 2013	6	1	5	3
Total	68	20	22	24
Total: Open-water Period	65	18	19	20

Table 2-2. Summary of number of sites sampled for analysis of phytoplankton taxonomy and biomass in Mine Area lakes.

Sampling Period	Sheardown Lake NW	Sheardown Lake SE	Camp Lake	Mary Lake
August 2007	5	3	3	5
September 2007	5	3	3	5
July/August 2008	5	3	3	4
September 2008	5	3	0	0
July 2013	11	8	10	10
August 2013	6	1	10	0
Total	37	21	29	24

Table 2-3. Summary of number of sites sampled for analysis of chlorophyll *a* in Mine Area streams.

Sampling Period	Mary River	Tom River	Sheardown Lake Tributaries						Camp Lake Tributaries		Tributary to CL Trib 1	Outlet of Camp Lake	Camp Lake Reference stream s		N. Trib of Mary River	Tributaries to Mary Lake	Mary River Reference Streams		Tributary to Katiktok Lake
			SDL NW Trib 1	SDL SE Trib 9	SDL NW Trib 12	SDL NW Trib 13	Unnamed Trib A SDL NW	Unnamed Trib B SDL NW	CL Trib 1	CL Trib 2			No. 3	No. 4		Mary Lake Trib 2	No. 2	No. 3	
Jun-07	7	2	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Jul-07	8	2	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sep-07	7	2	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jun-08	3	2	3	1	1	1	1	0	0	0	0	0	0	0	0	1	0	0	0
Jul-08	8	0	3	1	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Sep-08	2	1	2	1	1	0	1	1	0	0	0	0	0	0	0	1	0	0	0
Jun-13	9	1	0	0	0	0	0	0	4	1	1	1	0	0	1	0	0	0	1
Jul-13	10	1	2	0	0	0	0	0	4	1	1	1	1	1	1	0	1	1	0
Aug-13	9	1	2	0	0	0	0	0	4	1	1	1	1	0	1	0	0	0	0
Total	**63**	**12**	**15**	**4**	**6**	**2**	**2**	**1**	**12**	**3**	**3**	**3**	**2**	**1**	**3**	**3**	**1**	**1**	**1**

Table 2-4. Phytoplankton metrics considered for CREMP.

Effect Indicator	Metric	Unit
Algal Abundance/Density	Chlorophyll *a*	(µg/L)
	Total Biomass	(mg/m^3)
	Biomass of Major Groups	(mg/m^3)
	Biomass of Major Groups	(% of total biomass)
Evenness	Simpson's evenness	-
	Shannon's evenness	-
	Hill's evenness	-
Taxa Richness	Total number of species	-
	Hill's effective richness	-
	Simpson's diversity index	-

Table 2-5. Summary statistics for chlorophyll *a* (µg/L) measured in Mine Area lakes in summer and late summer/fall: 2007, 2008, and 2013. Analytical detection limit = 0.2 µg/L. Nearshore sampling sites excluded.

	Sheardown Lake NW	Sheardown Lake SE	Camp Lake	Mary Lake	All Lakes: 2007, 2008, and 2013
Mean	0.35	0.78	0.57	1.18	0.66
Median	0.20	0.20	0.20	1.05	0.20
Minimum	<0.20	<0.20	<0.20	<0.20	<0.20
Maximum	1.50	2.30	2.10	3.50	3.50
SD	0.29	0.78	0.60	1.00	0.72
SE	0.05	0.19	0.14	0.22	0.08
n	35	17	19	20	91
95th Percentile	0.90	2.14	1.74	1.80	2.10
% Detections	43	41	53	70	51
COV (%)	83	101	105	85	110
Mean + 2 x SD	0.92	2.34	1.78	3.17	2.10
2 x Mean	0.69	1.55	1.15	2.35	1.31
Mean + 50%	0.52	1.16	0.86	1.76	0.99
Mean + 25%	0.43	0.97	0.72	1.47	0.82
Mean + 20%	0.41	0.93	0.69	1.41	0.79

Table 2-6. Summary statistics and results of Kruskal-Wallis tests for chlorophyll *a* (µg/L) measured in Sheardown Lake NW in summer and late summer/fall: 2007, 2008, and 2013. Analytical detection limit = 0.2 µg/L. Nearshore sampling sites excluded. The mean of samples collected in July and August 2008 were averaged to represent the summer sampling period.

	Summer	Late Summer/Fall	2007	2008	2013	All Data (2007, 2008, and 2013)
Mean	0.42	0.29	0.38	0.28	0.40	0.35
Median	0.30	0.20	0.20	0.20	0.35	0.20
Minimum	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Maximum	0.90	0.90	0.90	0.90	0.80	0.90
SD	0.28	0.19	0.29	0.22	0.22	0.24
SE	0.07	0.05	0.09	0.07	0.07	0.04
n	15	15	10	10	10	30
95th Percentile	0.90	0.62	0.90	0.63	0.76	0.90
% Detections	67	33	60	20	70	50
COV (%)	66	67	76	79	55	69
Mean + 2 x SD	0.97	0.67	0.96	0.72	0.84	0.84
2 x Mean	0.84	0.57	0.76	0.56	0.80	0.71
Mean + 50%	0.63	0.43	0.57	0.42	0.60	0.53
Mean + 25%	0.53	0.36	0.48	0.35	0.50	0.44
Mean + 20%	0.50	0.34	0.46	0.34	0.48	0.42
P value[1]	0.134		0.235			-

[1]Differences between two groups tested with a Kruskal-Wallis test at alpha = 0.05.

Table 2-7. Summary statistics for total phytoplankton biomass (mg/m^3) measured in Mine Area lakes in summer and late summer/fall: 2007 and 2008.

	Phytoplankton biomass (mg/m^3)			
	Sheardown Lake NW	**Sheardown Lake SE**	**Camp Lake**	**Mary Lake**
Mean	204	125	122	149
Median	160	62	109	173
Minimum	42	43	43	28
Maximum	456	336	250	415
SD	134	111	73	106
SE	30	32	24	28
n	20	12	9	14
95th Percentile	430	312	243	298
COV	66	89	60	71
Mean + 2 x SD	471	347	268	360
2 x Mean	408	250	243	298
Mean + 50%	306	188	183	223
Mean + 25%	255	157	152	186
Mean + 20%	245	150	146	179

Table 2-8. Summary statistics and results of Kruskal-Wallis tests for total phytoplankton biomass (mg/m^3) measured in Sheardown Lake NW in summer and late summer/fall: 2007 and 2008.

	Phytoplankton biomass (mg/m^3)				
	Summer	**Late Summer/Fall**	**2007**	**2008**	**All Data (2007 and 2008)**
Mean	182	226	87	321	204
Median	145	208	92	302	160
Minimum	42	88	42	183	42
Maximum	429	456	137	456	456
SD	137	134	30	79	134
SE	43	42	10	25	30
n	10	10	10	10	20
95th Percentile	378	410	129	444	430
COV	75	59	35	25	66
Mean + 2 x SD	456	493	148	479	471
2 x Mean	364	451	173	642	408
Mean + 50%	273	338	130	481	306
Mean + 25%	228	282	108	401	255
Mean + 20%	218	271	104	385	245
P value[1]	0.315		<0.0001		-

[1]Differences between two groups tested with a Kruskal-Wallis test at alpha = 0.05.

Table 2-9. Mean, SD, COV, and 95th percentiles for phytoplankton species diversity, evenness, and richness metrics measured in Mine Area lakes in summer and late summer/fall: 2007 and 2008.

	MEANS					
	Simpson's Diversity Index	Simpson's Evenness	Species Richness	Shannon's Evenness	Hill's Effective Richness	Hill's Evenness
Sheardown Lake NW	0.71	0.22	18	0.61	6.19	0.34
Sheardown Lake SE	0.71	0.29	16	0.61	6.10	0.37
Camp Lake	0.72	0.22	17	0.60	5.55	0.33
Mary Lake	0.52	0.20	15	0.47	3.84	0.28
All lakes combined	0.66	0.23	17	0.58	5.47	0.33
	SD					
	Simpson's Diversity Index	Simpson's Evenness	Species Richness	Shannon's Evenness	Hill's Effective Richness	Hill's Evenness
Sheardown Lake NW	0.12	0.08	3	0.10	1.94	0.08
Sheardown Lake SE	0.88	0.43	20	0.77	9.31	0.54
Camp Lake	0.07	0.05	3	0.04	1.18	0.04
Mary Lake	0.19	0.15	4	0.17	2.00	0.15
All lakes combined	0.17	0.11	3	0.14	2.18	0.11
	COV					
	Simpson's Diversity Index	Simpson's Evenness	Species Richness	Shannon's Evenness	Hill's Effective Richness	Hill's Evenness
Sheardown Lake NW	17	34	16	16	31	25
Sheardown Lake SE	27	42	18	26	41	34
Camp Lake	9	25	20	7	21	13
Mary Lake	36	75	28	36	52	55
All lakes combined	26	47	21	24	40	34
	95TH PERCENTILE					
	Simpson's Diversity Index	Simpson's Evenness	Species Richness	Shannon's Evenness	Hill's Effective Richness	Hill's Evenness
Sheardown Lake NW	0.84	0.34	22	0.74	8.9	0.46
Sheardown Lake SE	0.87	0.42	19	0.76	9.2	0.51
Camp Lake	0.81	0.28	23	0.66	7.5	0.37
Mary Lake	0.84	0.52	21	0.78	7.5	0.56
All lakes combined	0.87	0.42	22	0.77	9.1	0.53

Table 2-10. Summary statistics and results of Kruskal-Wallis tests for phytoplankton taxonomy metrics measured in Sheardown Lake NW in summer and late summer/fall: 2007 and 2008.

	Simpson's Diversity Index				
	Summer	**Late Summer/Fall**	**2007**	**2008**	**All Data (2007 and 2008)**
Mean	0.76	0.66	0.80	0.62	0.71
Median	0.79	0.70	0.81	0.62	0.76
Minimum	0.59	0.41	0.71	0.41	0.41
Maximum	0.87	0.81	0.87	0.78	0.87
SD	0.10	0.13	0.05	0.11	0.12
SE	0.03	0.04	0.01	0.04	0.03
n	10	10	10	10	20
95th Percentile	0.86	0.80	0.86	0.77	0.84
COV	13	20	6	18	17
Mean + 2 x SD	0.95	0.93	0.89	0.85	0.96
2 x Mean	1.52	1.32	1.60	1.24	1.42
Mean + 50%	1.14	0.99	1.20	0.93	1.07
Mean + 25%	0.95	0.83	1.00	0.78	0.89
Mean + 20%	0.91	0.79	0.96	0.75	0.85
P value[1]	0.075		<0.0005		-

	Simpson's Evenness				
	Summer	**Late Summer/Fall**	**2007**	**2008**	**All Data (2007 and 2008)**
Mean	0.27	0.18	0.27	0.18	0.22
Median	0.27	0.17	0.26	0.17	0.20
Minimum	0.15	0.13	0.17	0.13	0.13
Maximum	0.40	0.26	0.40	0.32	0.40
SD	0.08	0.05	0.07	0.06	0.08
SE	0.02	0.01	0.02	0.02	0.02
n	10	10	10	10	20
95th Percentile	0.37	0.25	0.37	0.28	0.34
COV	29	25	27	32	34
Mean + 2 x SD	0.42	0.27	0.41	0.30	0.38
2 x Mean	0.53	0.36	0.53	0.36	0.45
Mean + 50%	0.40	0.27	0.40	0.27	0.34
Mean + 25%	0.33	0.23	0.33	0.23	0.28
Mean + 20%	0.32	0.22	0.32	0.22	0.27
P value[1]	0.007		0.009		-

Table 2-10. - continued -

	Species Richness				
	Summer	Late Summer/Fall	2007	2008	All Data (2007 and 2008)
Mean	18	18	19.9	16.0	18.0
Median	17	20	20.0	15.5	18.5
Minimum	13	13	16.0	13.0	13.0
Maximum	22	22	22.0	20.0	22.0
SD	3	3	1.9	2.4	2.9
SE	1	1	0.6	0.8	0.7
n	10	10	10	10	20
95th Percentile	21	22	22.0	20.0	22.0
COV	16	17	9	15	16
Mean + 2 x SD	23	24	23.6	20.9	23.8
2 x Mean	35	37	40	32	36
Mean + 50%	26	27	30	24	27
Mean + 25%	22	23	25	20	22
Mean + 20%	21	22	24	19	22
P value[1]	0.614		0.002		-

	Shannon's Evenness				
	Summer	Late Summer/Fall	2007	2008	All Data (2007 and 2008)
Mean	0.66	0.57	0.68	0.54	0.61
Median	0.69	0.59	0.69	0.56	0.62
Minimum	0.54	0.39	0.59	0.39	0.39
Maximum	0.77	0.72	0.77	0.69	0.77
SD	0.08	0.10	0.05	0.09	0.10
SE	0.03	0.03	0.02	0.03	0.02
n	10	10	10	10	20
95th Percentile	0.75	0.69	0.75	0.65	0.74
COV	12	18	8	16	16
Mean + 2 x SD	0.82	0.78	0.79	0.72	0.81
2 x Mean	1.31	1.14	1.37	1.09	1.23
Mean + 50%	0.98	0.86	1.02	0.81	0.92
Mean + 25%	0.82	0.71	0.85	0.68	0.77
Mean + 20%	0.79	0.68	0.82	0.65	0.74
P value[1]	0.105		0.001		-

Table 2-10. - continued -

	Hill's Effective Richness				
	Summer	Late Summer/Fall	2007	2008	All Data (2007 and 2008)
Mean	6.8	5.6	7.7	4.6	6.2
Median	6.8	5.9	7.6	4.5	6.1
Minimum	4.4	2.8	5.9	2.8	2.8
Maximum	9.7	8.9	9.7	6.2	9.7
SD	1.8	2.0	1.1	1.2	1.9
SE	0.6	0.6	0.4	0.4	0.4
n	10	10	10	10	20
95th Percentile	9.2	8.2	9.3	6.1	8.9
COV	27	35	15	25	31
Mean + 2 x SD	10.5	9.5	10.0	6.9	10.1
2 x Mean	13.5	11.2	15.5	9.3	12.4
Mean + 50%	10.1	8.4	11.6	6.9	9.3
Mean + 25%	8.5	7.0	9.7	5.8	7.7
Mean + 20%	8.1	6.7	9.3	5.6	7.4
P value[1]	0.280		<0.0001		-

	Hill's Evenness				
	Summer	Late Summer/Fall	2007	2008	All Data (2007 and 2008)
Mean	0.38	0.30	0.39	0.29	0.34
Median	0.40	0.30	0.40	0.30	0.32
Minimum	0.28	0.21	0.30	0.21	0.21
Maximum	0.52	0.42	0.52	0.45	0.52
SD	0.08	0.07	0.07	0.07	0.08
SE	0.03	0.02	0.02	0.02	0.02
n	10	10	10	10	20
95th Percentile	0.49	0.39	0.49	0.39	0.46
COV	21	22	17	24	25
Mean + 2 x SD	0.55	0.43	0.53	0.43	0.51
2 x Mean	0.77	0.60	0.78	0.58	0.68
Mean + 50%	0.58	0.45	0.59	0.44	0.51
Mean + 25%	0.48	0.37	0.49	0.36	0.43
Mean + 20%	0.46	0.36	0.47	0.35	0.41
P value[1]	0.052		0.004		-

[1]Differences between two groups tested with a Kruskal-Wallis test at alpha = 0.05.

Table 2-11. Spearman rank correlation coefficients for phytoplankton metrics and total phosphorus (TP). Values in bold indicate significant correlations at α = 0.05. Correlation analysis includes data collected from all Mine Area lakes in 2007, 2008, and 2013. RA = relative abundance; > DL = detections only.

Variables	TN	TP	TN:TP	Chlorophyll *a* (>DL)	Chlorophyll *a*	Total Biomass	Diatom Biomass	Green-Algae Biomass	Chrysophyte Biomass	Cryptophyte Biomass	Blue-Green Algae Biomass	Euglenoid Biomass	Dinoflagellate Biomass	Diatom RA	Green-Algae RA	Green-Algae RA	Green-Algae RA	Green-Algae RA	Green-Algae RA	Green-Algae RA	Maximum Species Biomass	Simpson's Diversity Index	Simpson's Evenness	Species Richness	Shannon's Evenness	Hill's Effective Richness
TP	-0.099	**1**																								
TN:TP Molar Ratios	**0.679**	**-0.763**	**1**																							
Chlorophyll *a* (>DL)	0.242	**0.519**	-0.271	**1**																						
Chlorophyll *a*	0.049	**0.286**	-0.197	**1.000**	**1**																					
Total Biomass	-0.044	0.119	-0.018	0.272	-0.068	**1**																				
Diatom Biomass	0.009	0.046	0.060	0.148	-0.038	**0.957**	**1**																			
Green-Algae Biomass	0.066	-0.058	0.132	0.156	-0.224	**0.462**	**0.377**	**1**																		
Chrysophyte Biomass	-0.148	0.230	-0.186	0.130	-0.018	**0.533**	**0.457**	**0.323**	**1**																	
Cryptophyte Biomass	-0.146	0.129	-0.171	0.252	0.121	**0.318**	**0.288**	0.107	0.236	**1**																
Blue-Green Algae Biomass	-0.095	0.113	-0.102	0.204	0.007	0.224	0.091	0.045	0.159	0.059	**1**															
Euglenoid Biomass	-0.046	-0.164	0.106	-0.231	0.123	-0.244	-0.188	-0.253	**-0.310**	0.036	-0.061	**1**														
Dinoflagellate Biomass	0.063	-0.055	0.179	0.007	-0.070	**0.303**	0.223	0.218	0.120	0.157	0.195	0.017	**1**													
Diatom RA	0.070	-0.103	0.088	-0.194	0.165	0.035	**0.267**	**-0.431**	-0.085	-0.102	**-0.426**	0.079	**-0.398**	**1**												
Green-Algae RA	0.061	-0.226	0.192	-0.191	-0.256	-0.095	-0.167	**0.803**	-0.018	-0.036	-0.030	-0.074	0.053	**-0.528**	**1**											
Chrysophyte RA	-0.153	0.152	-0.192	0.022	0.032	0.001	-0.051	-0.003	**0.805**	0.032	0.075	-0.197	-0.098	-0.059	-0.067	**1**										
Cryptophyte RA	-0.145	0.134	-0.196	0.233	0.164	-0.067	-0.083	-0.110	0.009	**0.885**	-0.024	0.176	0.018	-0.131	-0.043	0.004	**1**									
Blue-Green Algae RA	-0.115	0.111	-0.125	0.183	0.028	0.140	0.000	0.028	0.096	0.032	**0.988**	-0.060	0.145	**-0.447**	0.008	0.048	-0.021	**1**								
Euglenoid RA	-0.024	-0.183	0.125	-0.258	0.112	**-0.289**	-0.237	-0.250	**-0.319**	-0.002	-0.051	**0.992**	0.026	0.048	-0.047	-0.184	0.156	-0.047	**1**							
Dinoflagellate RA	0.109	-0.093	0.230	0.003	-0.091	0.168	0.088	0.147	0.035	0.126	0.167	0.061	**0.970**	**-0.429**	0.078	-0.122	0.041	0.126	0.079	**1**						
Maximum Species Biomass	-0.012	0.142	-0.015	0.193	0.012	**0.951**	**0.957**	**0.360**	**0.513**	**0.284**	0.136	-0.227	0.181	0.184	-0.189	0.018	-0.083	0.047	**-0.274**	0.047	**1**					
Simpson's Diversity Index	-0.003	-0.244	0.126	-0.098	-0.183	**-0.595**	**-0.651**	-0.055	**-0.353**	-0.122	0.127	0.217	0.154	**-0.421**	**0.337**	-0.069	0.126	0.185	0.258	0.246	**-0.786**	**1**				
Simpson's Evenness	0.045	-0.084	0.015	0.073	-0.144	**-0.706**	**-0.781**	-0.094	**-0.282**	-0.156	0.010	0.062	-0.023	**-0.394**	**0.317**	0.077	0.115	0.083	0.109	0.089	**-0.858**	**0.901**	**1**			
Species Richness	-0.107	**-0.434**	0.269	**-0.582**	-0.170	0.008	0.061	0.023	-0.260	-0.006	0.190	**0.429**	**0.370**	-0.058	0.111	**-0.282**	-0.003	0.176	**0.417**	**0.353**	-0.108	**0.446**	0.052	**1**		
Shannon's Evenness	0.045	-0.164	0.091	-0.008	-0.099	**-0.645**	**-0.701**	-0.049	**-0.299**	-0.105	0.079	0.198	0.101	**-0.416**	**0.348**	0.019	0.156	0.137	0.241	0.192	**-0.811**	**0.969**	**0.936**	**0.307**	**1**	
Hill's Effective Richness	0.004	**-0.282**	0.169	-0.185	-0.159	**-0.551**	**-0.588**	-0.029	**-0.314**	-0.110	0.146	**0.289**	0.214	**-0.395**	**0.346**	-0.051	0.113	0.194	**0.326**	**0.294**	**-0.733**	**0.974**	**0.826**	**0.566**	**0.946**	**1**
Hill's Evenness	0.070	-0.084	0.035	0.062	-0.087	**-0.711**	**-0.770**	-0.089	**-0.276**	-0.137	0.021	0.123	0.017	**-0.386**	**0.318**	0.092	0.127	0.085	0.168	0.122	**-0.850**	**0.905**	**0.979**	0.103	**0.965**	**0.862**

Table 2-12. Summary of power analysis results for selected phytoplankton community metrics. Values represent the minimum number of samples required for achieving 90% power.

Metric	Minimum Sample Size					
	All data 2007-2008			Fall data 2007-2008		
	CES			CES		
	50%	25%	20%	50%	25%	20%
Simpson's Diversity Index	3	8	12	4	11	16
Species Richness	3	7	11	3	8	12
Shannon's Evenness	3	8	11	3	9	13
Total Biomass	8	27	99	6	22	86

Table 2-13. Overview of phytoplankton sampling conducted in Mine Area lakes: 2013.

Site ID	Sample Date	Season	Chlorophyll *a*		Biomass and Taxonomy
			No. of Replicates		No. of Replicates
			Surface	Bottom	
Camp Lake					
JL0-01	27-Jul-13	Summer	2	-	1
	26-Aug-13	Fall	2	-	1
JL0-02	27-Jul-13	Summer	1	1	3
	24-Aug-13	Fall	1	1	3
JL0-09	27-Jul-13	Summer	1	1	1
	26-Aug-13	Fall	1	1	1
JL0-10	27-Jul-13	Summer	1	-	1
	25-Aug-13	Fall	1	-	1
JL0-11	27-Jul-13	Summer	1	-	1
	26-Aug-13	Fall	1	-	1
JL0-PHYTO1	27-Jul-13	Summer	-	-	1
	25-Aug-13	Fall	-	-	1
JL0-PHYTO2	27-Jul-13	Summer	-	-	1
	25-Aug-13	Fall	-	-	1
JL0-PHYTO3	27-Jul-13	Summer	-	-	1
	26-Aug-13	Fall	-	-	1
JL0-PHYTO4	27-Jul-13	Summer	-	-	1
	26-Aug-13	Fall	-	-	1
JL0-PHYTO5	27-Jul-13	Summer	-	-	1
	27-Aug-13	Fall	-	-	1
Sheardown Lake NW					
DD-HAB9-STN1	25-Jul-13	Summer	1	1	1
DD-HAB9-STN1	28-Aug-13	Fall	1	1	1
DL0-01-1	26-Jul-13	Summer	1	1	1
	28-Aug-13	Fall	1	1	1
DL0-01-2	26-Jul-13	Summer	1	1	1
	28-Aug-13	Fall	1	1	3
DL0-01-4	26-Jul-13	Summer	1	1	1
	28-Aug-13	Fall	2	2	1
DL0-01-5	26-Jul-13	Summer	2	1	1
	27-Aug-13	Fall	1	1	1
DL0-01-7	26-Jul-13	Summer	1	1	1
	28-Aug-13	Fall	1	1	1
DL0-01-PHYTO 1	26-Jul-13	Summer	-	-	1
		Fall	-	-	NS
DL0-01-PHYTO 2	26-Jul-13	Summer	-	-	1
		Fall	-	-	NS
DL0-01-PHYTO 3	26-Jul-13	Summer	-	-	1
		Fall	-	-	NS
DL0-01-PHYTO 4	26-Jul-13	Summer	-	-	1
		Fall	-	-	NS
DL0-01-PHYTO 5	26-Jul-13	Summer	-	-	1
		Fall	-	-	NS

Table 2-13. - continued –

Site ID	Sample Date	Season	Chlorophyll *a*		Biomass and Taxonomy
			No. of Replicates		No. of Replicates
			Surface	Bottom	
Sheardown Lake SE					
DL0-02-1	26-Jul-13	Summer	NS	NS	1
		Fall	NS	NS	NS
DL0-02-3	26-Jul-13	Summer	1	1	1
	29-Aug-13	Fall	1	1	1
DL0-02-4	26-Jul-13	Summer	NS	NS	3
		Fall	NS	NS	NS
DL0-02-6	26-Jul-13	Summer	-	-	1
		Fall	-	-	NS
DL0-02-7	26-Jul-13	Summer	NS	NS	1
		Fall	NS	NS	NS
DL0-02-8	26-Jul-13	Summer	NS	NS	1
		Fall	NS	NS	NS
DL0-02-PHYTO 1		Summer	-	-	NS
		Fall	-	-	NS
DL0-02-PHYTO 2		Summer	-	-	NS
		Fall	-	-	NS
DL0-02-PHYTO 3	26-Jul-13	Summer	-	-	1
		Fall	-	-	-
DL0-02-PHYTO 4	26-Jul-13	Summer	-	-	1
		Fall	-	-	-
Mary Lake South					
BL0-03	28-Jul-13	Summer	1	1	1
		Fall	NS	1	NS
BL0-04	28-Jul-13	Summer	1	1	1
		Fall	1	1	NS
BL0-05	28-Jul-13	Summer	1	1	1
		Fall	1	1	NS
BL0-06	28-Jul-13	Summer	1	1	3
		Fall	1	1	NS
BL0-07	28-Jul-13	Summer	1	-	3
		Fall	NS	-	NS
BL0-PHYTO1	28-Jul-13	Summer	-	-	1
		Fall	-	-	NS
BL0-PHYTO2	28-Jul-13	Summer	-	-	3
		Fall	-	-	NS
BL0-PHYTO3	28-Jul-13	Summer	-	-	1
		Fall	-	-	NS
BL0-PHYTO4	28-Jul-13	Summer	-	-	1
		Fall	-	-	NS
BL0-PHYTO5		Summer	-	-	NS
		Fall	-	-	NS
Mary Lake North					
BL0-01	27-Jul-13	Summer	1	1	3
		Fall	NS	NS	NS

NS = not sampled

Table 2-14. Number of samples collected for chlorophyll *a* in Mine Area streams: 2013.

Stream	June	July	August
Mary River	9	10	9
N. Tributary of Mary River, D/S of Falls	1	1	1
Sheardown Lake Tributary 1	0	2	2
Tom River	1	1	1
Camp Lake Tributary 1	4	4	4
Stream north of airstrip - confluence with Camp Lake Tributary 1	1	1	1
Camp Lake Tributary 2	1	1	1
Outlet channel of Camp Lake	0	1	1
Proposed CLT Reference stream No. 3	0	1	0
Proposed CLT Reference stream No. 4	0	1	0
Proposed Mary River Reference stream No. 2	0	1	0
Proposed Mary River Reference stream No. 3	0	1	0

Table 3-1. Summary of benthic macroinvertebrate sampling methods for Mine Area lakes (2006-2013).

Year	Equipment	Mesh Size (µm)	Replicate Stations per Site or Habitat Type	Sub-samples per Replicate Station	Taxonomy	Description/Comments
2006	Ekman Dredge (sampling area of 0.023 m^2)	500	3	5	Genus level by qualified taxonomist (ZEAS Inc.)	Sub-samples approx. 1 m apart; replicates approx. 10 m apart
2007	Petit Ponar Dredge (sampling area of 0.023 m^2)	500	3	5 [1]	Genus level by qualified taxonomist (ZEAS Inc.)	Sub-samples approx. 1 m apart; replicates approx. 10 m apart
2008	Petit Ponar Dredge (sampling area of 0.023 m^2)	500	3-7	5	Genus level by qualified taxonomist (ZEAS Inc.)	Sub-samples approx. 1 m apart; replicates min. of 20 m apart
2009	-	-	-	-	-	-
2010	-	-	-	-	-	-
2011	Petit Ponar Dredge (sampling area of 0.023 m^2)	500	3	1, 3, 1 [2]	Genus level by qualified taxonomist (ZEAS Inc.)	Sub-samples approx. 1 m apart; replicates min. of 20 m apart
2013	Petit Ponar Dredge (sampling area of 0.023 m^2)	500	5	5	-	Sub-samples approx. 1 m apart; replicates min. of 20 m apart

[1] excepting Mary Lake where only 1 sub-sample/replicate was collected

[2] sampling occurred at one site in Sheardown Lake NW only

Table 3-2. Summary of benthic macroinvertebrate sampling methods for Mine Area streams (2005-2013).

Year	Equipment	Mesh Size (µm)	Replicate Stations per Site or Habitat Type	Sub-samples per Replicate Station	Taxonomy	Description/Comments
2005	Surber sampler (sampling area of 0.097 m^2)	250	1	5	Genus level by qualified taxonomist (ZEAS Inc.)	-
2006	Surber sampler (sampling area of 0.097 m^2)	500	3	5	Genus level by qualified taxonomist (ZEAS Inc.)	replicates separated by 3 wetted stream widths
2007	Surber sampler (sampling area of 0.097 m^2)	500	3	5	Genus level by qualified taxonomist (ZEAS Inc.)	replicates separated by 3 wetted stream widths
2008	Surber sampler (sampling area of 0.097 m^2)	500	3	5	Genus level by qualified taxonomist (ZEAS Inc.)	replicates separated by 3 wetted stream widths
2009	-	-	-	-	-	-
2010	-	-	-	-	-	-
2011	Surber sampler (sampling area of 0.097 m^2)	500	3	5	Genus level by qualified taxonomist (ZEAS Inc.)	replicates separated by 3 wetted stream widths
2013	Surber sampler (sampling area of 0.097 m^2)	500	2-3 [1]	2-5 [2]	-	replicates separated by 3 wetted stream widths

[1] KP field personnel were unable to find 3 suitable replicate stations in Sheardown Lake Tributary 12, downstream reach

[2] KP field personnel were unable to find 5 suitable locations in Sheardown Lake Tributary 1, Reach 4, and Sheardown Lake Tributary 12, downstream reach for required number of sub-samples

Table 3-3. Summary of benthic macroinvertebrate sampling periods in Mine Area lakes and streams (2005-2013).

Waterbody	Sampling Period							
	2005	2006	2007	2008	2009	2010	2011	2013
Lakes								
Mary Lake	-	Aug. 31-Sept.5	Aug. 31-Sept. 20	-	-	-	-	-
Camp Lake	-	-	Aug. 31-Sept. 20	-	-	-	-	Sept. 5-8
Sheardown Lake NW	-	-	Aug. 31-Sept. 20	Sept. 8-12	-	-	Sept. 3	Sept. 5-8
Sheardown Lake SE	-	-	Aug. 31-Sept. 20	-	-	-	-	Sept. 5-8
Streams								
Mary River	Aug. 6-17	Aug. 23-Sept. 1	Aug. 31-Sept. 5	-	-	-	Aug. 28-29	-
Tom River	-	Aug. 23-Sept. 1	Aug. 31-Sept. 5	-	-	-	-	-
Camp Lake Tributaries	Aug. 6-17	-	Aug. 31-Sept. 5	-	-	-	-	-
Sheardown Lake Tributaries	Aug. 6-17	-	Aug. 31-Sept. 5	Sept. 10-11	-	-	Sept. 4	Aug. 29-31

Table 3-4. Locations of benthic macroinvertebrate lake sampling sites in the Mine Area (2006-2013).

Waterbody	Site ID	Habitat Type	UTM			Sample Date
			Zone	Easting	Northing	
Camp Lake	JLO-10-B1	4	17W	556085	7913755	2-Sep-07
	JLO-10-B2			556085	7913753	2-Sep-07
	JLO-10-B3			556087	7913757	2-Sep-07
	JLO-10-B1			556085	7913755	7-Sep-13
	Stn 1	9	17W	556320	7914417	7-Sep-13
	Stn 2			556325	7914603	7-Sep-13
	Stn 3			556510	7914791	7-Sep-13
	Stn 4			556781	7914872	6-Sep-13
	Stn 5			557031	7914989	6-Sep-13
	JLO-01-B1	14	17W	557099	7914360	1-Sep-07
	JLO-01-B2			557105	7914375	1-Sep-07
	JLO-01-B3			557104	7914374	1-Sep-07
	JLO-01-B1			557099	7914360	7-Sep-13
	JLO-02-B1	14	17W	557617	7914749	31-Aug-07
	JLO-02-B2			557621	7914750	31-Aug-07
	JLO-02-B3			557624	7914747	31-Aug-07
	JLO-02-B1			557617	7914749	7-Sep-13
	JLO-07-B1	14	17W	556705	7914182	2-Sep-07
	JLO-07-B2			556715	7914157	2-Sep-07
	JLO-07-B3			556719	7914170	2-Sep-07
	JLO-07-B1			556705	7914182	7-Sep-13
	JLO-07-B2			556715	7914157	7-Sep-13
	JLO-09-B1	14	17W	556332	7913948	2-Sep-07
	JLO-09-B2			556342	7913946	2-Sep-07
	JLO-09-B3			556324	7913946	2-Sep-07
	JLO-09-B1			556332	7913948	7-Sep-13
Sheardown Lake NW	SDL-Hab4-Stn1	4	17W	560401	7912573	8-Sep-08
	SDL-Hab4-Stn2			560503	7912526	8-Sep-08
	SDL-Hab4-Stn3			560605	7912654	8-Sep-08
	SDL-Hab4-Stn4			560582	7912730	8-Sep-08
	SDL-Hab4-Stn5			560561	7912801	8-Sep-08
	DD-Hab4-Stn-1	4	17W	560420	7913355	12-Sep-08
	DD-Hab4-Stn-2			560374	7913391	12-Sep-08
	DD-Hab4-Stn-3			560351	7913426	12-Sep-08

Table 3-4. - continued -

Waterbody	Site ID	Habitat Type	UTM			Sample Date
			Zone	Easting	Northing	
Sheardown Lake NW continued	DD-Hab9-Stn-1	9	17W	560259	7913455	12-Sep-08
	DD-Hab9-Stn-2			560323	7913402	12-Sep-08
	DD-Hab9-Stn-3			560354	7913358	12-Sep-08
	DLO-01-3-B1	9	17W	560466	7912837	15-Sep-07
	DLO-01-3-B2			560485	7912833	15-Sep-07
	DLO-01-3-B3			560496	7912815	15-Sep-07
	DLO-01-3-B1			560474	7912833	12-Sep-08
	DLO-01-3-B1			560474	7912833	5-Sep-13
	DLO-01-4-B1	9	17W	560690	7913045	7-Sep-07
	DLO-01-4-B2			560678	7913055	7-Sep-07
	DLO-01-4-B3			560683	7913060	7-Sep-07
	DLO-01-4-B1			560695	7913043	9-Sep-08
	DLO-01-4-B2			560775	7913069	9-Sep-08
	DLO-01-4-B1			560695	7913043	6-Sep-13
	DLO-01-4-B2			560775	7913069	6-Sep-13
	DLO-01-6-B1	9	17W	559705	7913525	14-Sep-07
	DLO-01-6-B2			559721	7913526	14-Sep-07
	DLO-01-6-B3			559705	7913506	14-Sep-07
	DLO-01-6-B1			559685	7913509	11-Sep-08
	DLO-01-6-B2			559680	7913564	11-Sep-08
	DLO-01-6-B1			559685	7913509	5-Sep-13
	DLO-01-6-B2			559680	7913564	5-Sep-13
	DLO-01-7-B1	9	17W	560520	7912616	7-Sep-07
	DLO-01-7-B2			560509	7912603	7-Sep-07
	DLO-01-7-B3			560481	7912619	7-Sep-07
	DLO-01-7-B1			560525	7912609	9-Sep-08
	DLO-01-7-B2			560572	7912619	9-Sep-08
	DLO-01-2-B1	14	17W	560337	7912913	15-Sep-07
	DLO-01-2-B2			560342	7912915	15-Sep-07
	DLO-01-2-B3			560357	7912917	15-Sep-07
	DLO-01-2-B1			560353	7912924	12-Sep-08
	DLO-01-2-B2			560326	7912854	12-Sep-08
	DLO-01-2-B1			560353	7912924	5-Sep-13
	DLO-01-2-B2			560326	7912854	5-Sep-13
	DLO-01-5-B1	14	17W	559775	7913350	15-Sep-07
	DLO-01-5-B2			559788	7913335	15-Sep-07
	DLO-01-5-B3			559800	7913340	15-Sep-07
	DLO-01-5-B1			559798	7913356	9-Sep-08
	DLO-01-5-B1			559800	7913325	3-Sep-11
	DLO-01-5-B2			559867	7913325	3-Sep-11
	DLO-01-5-B3			559847	7913310	3-Sep-11
	DLO-01-5-B1			559800	7913325	5-Sep-13
	DLO-01-5-B2			559867	7913325	5-Sep-13
	DLO-01-5-B3			559847	7913310	5-Sep-13

Table 3-4. - continued -

Waterbody	Site ID	Habitat Type	UTM			Sample Date
			Zone	Easting	Northing	
Sheardown Lake SE	DLO-02-3-B1	4	17W	560950	7911919	4-Sep-07
	DLO-02-3-B2			560947	7911926	4-Sep-07
	DLO-02-3-B3			560958	7911925	4-Sep-07
	Stn 1	9	17W	561520	7911857	8-Sep-13
	Stn 2			561620	7911832	8-Sep-13
	Stn 3			561546	7911816	8-Sep-13
	Stn 4			561546	7911816	8-Sep-13
	Stn 5			561510	7911779	8-Sep-13
	DLO-02-4-B1	10	17W	561127	7911708	4-Sep-07
	DLO-02-4-B2			561133	7911717	4-Sep-07
	DLO-02-4-B3			561145	7911699	4-Sep-07
	DLO-02-1-B1	14	17W	560816	7912124	6-Sep-07
	DLO-02-1-B2			560824	7912125	6-Sep-07
	DLO-02-1-B3			560818	7912111	6-Sep-07
	DLO-02-1-B1			560816	7912124	8-Sep-13
	DLO-02-2-B1	14	17W	561161	7911866	6-Sep-07
	DLO-02-2-B2			561170	7911872	6-Sep-07
	DLO-02-2-B3			561164	7911864	6-Sep-07
	DLO-02-2-B1			561161	7911866	8-Sep-13
	Stn 3	14	17W	561082	7911929	8-Sep-13
	Stn 4			561107	7911890	8-Sep-13
	Stn 5			561229	7911868	8-Sep-13
Mary Lake	BLO-01 -B1	9	17W	554695	7913212	19-Sep-07
	BLO-01 -B2			554695	7913212	19-Sep-07
	BLO-01 -B3			554695	7913212	19-Sep-07
	BLO-05-B1	9	17W	554780	7906047	20-Sep-07
	BLO-05-B2			554769	7906066	20-Sep-07
	BLO-05-B3			554785	7906078	20-Sep-07
	BLO-06-B1	9	17W	555912	7903757	20-Sep-07
	BLO-06-B2			555913	7903734	20-Sep-07
	BLO-06-B3			555890	7903721	20-Sep-07
	BLO-01 -B1	14	17W	554695	7913212	31-Aug-06
	BLO-01-B2			554695	7913212	31-Aug-06
	BLO-01- B3			554695	7913212	31-Aug-06
	BLO-05-B1	14	17W	554771	7906033	31-Aug-06
	BLO-05-B2			554771	7906033	31-Aug-06
	BLO-05-B3			554771	7906033	31-Aug-06
	BLO-03-B1	14	17W	552387	7906645	20-Sep-07
	BLO-03-B2			552360	7906630	20-Sep-07
	BLO-03-B3			552356	7906635	20-Sep-07
	BLO-04-B1	14	17W	553799	7904897	20-Sep-07
	BLO-04-B3			553824	7904871	20-Sep-07

Table 3-5. Locations of benthic macroinvertebrate stream sampling sites in the Mine Area (2005-2013).

Waterbody	Site ID	UTM			Sample Date
		Zone	Easting	Northing	
Mary River	AO-01	17W	559019	7900094	1-Aug-05
	CO-01	17W	556305	7906894	1-Aug-05
	DO-01	17W	560765	7911692	1-Aug-05
	DO-01	17W	560765	7911692	28-Aug-11
	EO-01a (E2-01)	17W	562348	7911310	1-Aug-05
	EO-01a (E0-03)	17W	562974	7912472	1-Aug-05
	HO-01	17W	571409	7917611	1-Aug-05
	AO-01 B1	17W	559034	7900064	5-Sep-07
	AO-01 B2	17W	558997	7900112	5-Sep-07
	AO-01 B3	17W	558994	7900151	5-Sep-07
	CO-01 B1	17W	556291	7906919	3-Sep-07
	CO-01 B2	17W	-	-	3-Sep-07
	CO-01 B3	17W	556323	7906925	3-Sep-07
	CO-05 B1	17W	558364	7909231	3-Sep-07
	CO-05 B2	17W	558389	7909248	3-Sep-07
	CO-05 B3	17W	558411	7909298	3-Sep-07
	CO-05 B1	17W	-	-	28-Aug-11
	CO-05 B2	17W	558352	7909170	28-Aug-11
	CO-05 B3	17W	-	-	28-Aug-11
	CO-10 B1	17W	560490	7911370	30-Aug-06
	CO-10 B2	17W	560490	7911370	30-Aug-06
	CO-10 B3	17W	560490	7911370	30-Aug-06
	CO-10 B1	17W	560616	7911666	4-Sep-07
	CO-10 B2	17W	560661	7911687	4-Sep-07
	CO-10 B3	17W	560708	7911701	4-Sep-07
	EO-20 B1	17W	561688	7911724	29-Aug-11
	EO-20 B2	17W	561680	7911258	29-Aug-11
	EO-20 B3	17W	561649	7911241	29-Aug-11
	EO-01 B1	17W	560926	7911488	4-Sep-07
	EO-01 B2	17W	560940	7911429	4-Sep-07

Table 3-5. - continued -

Waterbody	Site ID	UTM			Sample Date
		Zone	Easting	Northing	
Mary River continued	EO-01 B3	17W	560906	7911533	4-Sep-07
	GO-03 B1	17W	567194	7912596	5-Sep-07
	GO-03 B2	17W	567220	7912598	5-Sep-07
	GO-03 B3	17W	567247	7912602	5-Sep-07
	GO-09 B1	17W	571665	7916111	1-Sep-06
	GO-09 B2	17W	571665	7916111	1-Sep-06
	GO-09 B3	17W	571665	7916111	1-Sep-06
	GO-09 B1	17W	571572	7916367	5-Sep-07
	GO-09 B2	17W	571577	7916330	5-Sep-07
	GO-09 B3	17W	571566	7916302	5-Sep-07
Tom River	IO-01 B1	17W	555441	7914175	25-Aug-06
	IO-01 B2	17W	555441	7914175	25-Aug-06
	IO-01 B3	17W	555441	7914175	25-Aug-06
	IO-01 B1	17W	555407	7914291	5-Sep-07
	IO-01 B2	17W	555449	7914160	5-Sep-07
	IO-01 B3	17W	555496	7914154	5-Sep-07
	IO-04 B1	17W	557136	7918889	23-Aug-06
	IO-04 B2	17W	557136	7918889	23-Aug-06
	IO-04 B3	17W	557136	7918889	23-Aug-06
	IO-04 B1	17W	557132	7918928	5-Sep-07
	IO-04 B2	17W	557153	7918972	5-Sep-07
	IO-04 B3	17W	557155	7918994	5-Sep-07
Camp Lake Tributaries	FS-01 (Trib.1, Reach 1)	17W	558264	7914877	Aug-05
	KO-01 (Trib.2, Reach 2)	17W	557390	7915030	Aug-05
	JO-01 (lake outlet stream)	17W	555701	7913773	Aug-05
	CLT-1 DS B1	17W	557641	7914880	2-Sep-07
	CLT-1 DS B2	17W	557648	7914888	2-Sep-07
	CLT-1 DS B3	17W	557653	7914898	2-Sep-07
	CLT-1 US B1	17W	558515	7915032	4-Sep-07
	CLT-1 US B2	17W	558509	7915020	4-Sep-07
	CLT-1 US B3	17W	558497	7914999	4-Sep-07
	L1-09	17W	558407	7914890	1-Sep-11
	L1-09	17W	558393	7914889	1-Sep-11
	L1-09	17W	558407	7914882	1-Sep-11

Table 3-5. - continued -

Waterbody	Site ID	UTM			Sample Date
		Zone	Easting	Northing	
Camp Lake Tributaries continued	L1-08	17W	558513	7914893	1-Sep-11
	L1-08	17W	558507	7914907	1-Sep-11
	L1-08	17W	558494	7914919	1-Sep-11
	L2-03	17W	558593	7914797	1-Sep-11
	L2-03	17W	558605	7914784	1-Sep-11
	L2-03	17W	554641	7914753	1-Sep-11
	CLT-2 DS B1	17W	557466	7914969	2-Sep-07
	CLT-2 DS B2	17W	557465	7914977	2-Sep-07
	CLT-2 DS B3	17W	557449	7914956	2-Sep-07
	CLT-2 US B1	17W	557448	7915324	2-Sep-07
	CLT-2 US B2	17W	557450	7915287	2-Sep-07
	CLT-2 US B3	17W	557464	7915251	2-Sep-07
Sheardown Lake Tributaries	SDLT-1 Reach 1 B1	17W	560320	7913504	10-Sep-08
	SDLT-1 Reach 1 B2	17W	560337	7913512	10-Sep-08
	SDLT-1 Reach 1 B3	17W	560346	7913525	10-Sep-08
	SDLT-1 Reach 1 B1	17W	560320	7913504	29-Aug-13
	SDLT-1 Reach 1 B2	17W	560337	7913512	29-Aug-13
	SDLT-1 Reach 1 B3	17W	560346	7913525	30-Aug-13
	SDLT-1 Reach 2a	17W	560753	7913507	Aug-05
	SDLT-1 DS Reach 2 B1	17W	560710	7913504	31-Aug-07
	SDLT-1 DS Reach 2 B2	17W	560716	7913506	31-Aug-07
	SDLT-1 DS Reach 2 B3	17W	560722	7913504	31-Aug-07
	SDLT-1 Reach 2 B1	17W	560739	7913502	10-Sep-08
	SDLT-1 Reach 2 B2	17W	560756	7913502	10-Sep-08
	SDLT-1 Reach 2 B3	17W	560774	7913598	10-Sep-08
	SDLT-1 Reach 2 B1	17W	560739	7913502	30-Aug-13
	SDLT-1 Reach 2 B2	17W	560756	7913502	30-Aug-13
	SDLT-1 Reach 2 B3	17W	560774	7913508	30-Aug-13
	SDLT-1 US Reach 4 B1	17W	561503	7913541	31-Aug-07
	SDLT-1 US Reach 4 B2	17W	-	-	31-Aug-07
	SDLT-1 US Reach 4 B3	17W	561521	7913524	31-Aug-07
	SDLT-1 Reach 4 B1	17W	561490	7913533	11-Sep-08
	SDLT-1 Reach 4 B2	17W	561506	7913538	11-Sep-08
	SDLT-1 Reach 4 B3	17W	561511	7913536	11-Sep-08
	SDLT-1 Reach 4 B1	17W	561476	7913550	4-Sep-11

Table 3-5. - continued -

Waterbody	Site ID	UTM			Sample Date
		Zone	Easting	Northing	
Sheardown Lake Tributaries continued	SDLT-1 Reach 4 B2	17W	561483	7913546	4-Sep-11
	SDLT-1 Reach 4 B3	17W	561490	7913533	4-Sep-11
	SDLT-1 Reach 4 B1	17W	561490	7913533	30-Aug-13
	SDLT-1 Reach 4 B2	17W	561506	7913538	30-Aug-13
	SDLT-1 Reach 4 B3	17W	561526	7913531	31-Aug-13
	SDLT-9 US B1	17W	561771	7911813	1-Sep-07
	SDLT-9 US B2	17W	561774	7911814	1-Sep-07
	SDLT-9 US B3	17W	561784	7911819	1-Sep-07
	SDLT-9 US B1	17W	561771	7911813	31-Aug-13
	SDLT-9 US B2	17W	561774	7911820	31-Aug-13
	SDLT-9 US B3	17W	561784	7911819	31-Aug-13
	SDLT-12 DS B1	17W	561000	7942973	1-Sep-07
	SDLT-12 DS B2	17W	561011	7912970	1-Sep-07
	SDLT-12 DS B3	17W	561027	7912966	1-Sep-07
	SDLT-12 DS B1	17W	561000	7942973	31-Aug-13
	SDLT-12 DS B2	17W	561011	7912970	31-Aug-13
	SDLT-12 US B1	17W	561091	7912833	1-Sep-07
	SDLT-12 US B2	17W	561092	7912848	1-Sep-07
	SDLT-12 US B3	17W	561097	7912837	1-Sep-07

Table 3-6. Benthic macroinvertebrate metrics considered for the CREMP.

Effect Indicator	Metric	Unit
Abundance/Density	Total Macroinvertebrate Density	(individuals/m^2)
Composition	Chironomidae Proportion	(% of total density)
	Shannon's Equitability (evenness)	-
	Simpson's Diversity Index	-
Richness	Total Taxa Richness	genus-level
	Hill's Effective Richness	genus-level

Table 3-7. Classification of lacustrine habitats in the Mine Area.

Zone	Substrata Type/ Aquatic Macrophytes		Habitat Type
Shoreline Zone (≤ 2 m water depth)	Cobble/Boulder		**1**
	Gravel/Pebble		**2**
	Sand		**3**
	Fine Sand, Silt/Clay	Macrophytes Absent	**4**
		Macrophytes Present	**5**
Littoral/Euphotic Zone (> 2-12 m water depth)	Cobble/Boulder		**6**
	Gravel/Pebble		**7**
	Sand		**8**
	Fine Sand, Silt/Clay	Macrophytes Absent	**9**
		Macrophytes Present	**10**
Profundal Zone (> 12 m water depth)	Cobble/Boulder		**11**
	Gravel/Pebble		**12**
	Sand		**13**
	Fine Sand, Silt/Clay	Macrophytes Absent	**14**

Table 3-8. Summary statistics for total macroinvertebrate density: all Mine Area lakes by aquatic habitat type.

Metric	**Total Macroinvertebrate Density (individuals/m²)**									
Habitat Type	**4**			**9**		**10**	**14**			
Lake	**Camp**	**SDL NW**	**SDL SE**	**Mary**	**SDL NW**	**SDL SE**	**Camp**	**Mary**	**SDL NW**	**SDL SE**
Year	2007	2008	2007	2007	2007, 2008	2007	2007	2006, 2007	2007, 2008, 2011	2007
n (rep. stn.)	3	8	3	9	22	3	12	11	12	6
Mean	14	829	4270	4005	3658	18562	2649	2668	1588	5042
Median	0	507	1026	3957	2165	15235	1978	2670	1665	4674
SD	25.10	782.76	6137.08	2879.22	3428.83	11312.34	1496.51	2057.11	1233.42	1350.49
SE	14.49	276.75	3543.24	959.74	731.03	6531.18	432.01	620.24	356.06	551.34
Min	0	162	435	783	250	9287	730	609	102	3548
Max	43	2129	11348	8870	10470	31165	6226	7017	4652	6730
Sub-samples (20% precision)	75	22	52	13	22	9	8	15	15	2
95th Percentile	39.1	2022.8	10315.7	8243.5	10027.8	29572.2	5250.4	5917.0	3384.8	6700.0
COV (%)	173	94	144	72	94	61	57	77	78	27
Mean + 2 x SD	64.70	2394.87	16543.73	9763.27	10515.84	41187.00	5641.58	6782.20	4054.50	7743.01
2 x Mean	28.99	1658.70	8539.14	8009.66	7316.36	37124.64	5297.10	5335.96	3175.32	10084.06
Mean +50%	21.74	1244.03	6404.36	6007.25	5487.27	27843.48	3972.83	4001.97	2381.49	7563.05
Mean -50%	7.25	414.68	2134.79	2002.42	1829.09	9281.16	1324.28	1333.99	793.83	2521.02
Mean +25%	18.12	1036.69	5336.96	5006.04	4572.73	23202.90	3310.69	3334.98	1984.58	6302.54
Mean -25%	10.87	622.01	3202.18	3003.62	2743.64	13921.74	1986.41	2000.99	1190.75	3781.52
Mean +20%	17.39	995.22	5123.48	4805.80	4389.82	22274.78	3178.26	3201.58	1905.19	6050.44
Mean -20%	11.59	663.48	3415.66	3203.86	2926.54	14849.86	2118.84	2134.38	1270.13	4033.62
Data Normally Distributed	- [1]	Yes	- [1]	Yes	No	- [1]	Yes	Yes	Yes	Yes

[1] insufficient data points to determine

Table 3-9. Summary statistics for total macroinvertebrate density: Sheardown Lake NW by aquatic habitat type and year.

Metric	Total Macroinvertebrate Density (individuals/m^2)					
Habitat Type	**4**	**9**		**14**		
Year	**2008**	**2007**	**2008**	**2007**	**2008**	**2011**
n (rep. stn.)	8	12	10	6	3	3
Mean	829	6026	817	1577	149	3048
Median	507	5887	798	1665	158	2348
SD	782.76	2970.50	448.25	218.79	42.98	1392.69
SE	276.75	857.51	141.75	89.32	24.81	804.07
Min	162	2026	250	1226	102	2145
Max	2129	10470	1677	1783	186	4652
Sub-samples (20% precision)	22	6	8	0.5	2	5
95th Percentile	2022.8	10259.1	1516.9	1769.6	183.3	4421.7
COV (%)	94	49	55	14	29	46
Mean + 2 x SD	2394.87	11967.09	1713.20	2014.39	234.66	5833.68
2 x Mean	1658.70	12052.18	1633.40	3153.62	297.40	6096.62
Mean +50%	1244.03	9039.14	1225.05	2365.22	223.05	4572.46
Mean -50%	414.68	3013.05	408.35	788.41	74.35	1524.15
Mean +25%	1036.69	7532.61	1020.88	1971.01	185.88	3810.39
Mean -25%	622.01	4519.57	612.53	1182.61	111.53	2286.23
Mean +20%	995.22	7231.31	980.04	1892.17	178.44	3657.97
Mean -20%	663.48	4820.87	653.36	1261.45	118.96	2438.65
Data Normally Distributed	Yes	No		Yes		
Significant Inter-annual Difference	-	Yes [1]		Yes - all years [2]		

[1] p-value <0.0001 (Mann-Whitney U-test)

[2] p-value 2007 vs 2008 0.015; 2007 vs 2011 0.013; 2008 vs 2011 0.001 (ANOVA with Bonferroni pairwise comparison)

Table 3-10. Summary statistics for Chironomidae proportion: all Mine Area lakes by aquatic habitat type.

Metric	**Chironomidae Proportion (% of total density)**									
Habitat Type	**4**			**9**		**10**	**14**			
Lake	**Camp**	**SDL NW**	**SDL SE**	**Mary**	**SDL NW**	**SDL SE**	**Camp**	**Mary**	**SDL NW**	**SDL SE**
Year	2007	2008	2007	2007	2007, 2008	2007	2007	2006, 2007	2007, 2008, 2011	2007
n (rep. stn.)	3	8	3	9	22	3	12	11	12	6
Mean	7	66	55	90	83	73	95	96	94	97
Median	0	64	56	96	86	68	96	99	95	98
SD	11.55	18.28	41.93	10.47	9.05	13.05	4.32	4.54	2.55	2.85
SE	6.67	6.46	24.21	3.49	1.93	7.54	1.25	1.37	0.74	1.16
Min	0	40	13	70	67	62	88	89	88	92
Max	20	88	97	99	98	87	100	100	97	100
Sub-samples (20% precision)	75	2	14	0.3	0.3	1	0.1	0.1	0.02	0.02
95th Percentile	18.0	87.7	92.5	98.8	95.3	85.3	100.0	100.0	96.6	99.7
COV (%)	173	28	76	12	11	18	5	5	3	3
Mean + 2 x SD	29.76	102.33	138.95	111.05	101.48	98.66	103.57	105.52	99.28	102.71
2 x Mean	13.33	131.54	110.18	180.22	166.76	145.12	189.87	192.88	188.36	194.02
Mean +50%	10.00	98.66	82.64	135.17	125.07	108.84	142.40	144.66	141.27	145.52
Mean -50%	3.33	32.89	27.55	45.06	41.69	36.28	47.47	48.22	47.09	48.51
Mean +25%	8.33	82.21	68.86	112.64	104.23	90.70	118.67	120.55	117.73	121.26
Mean -25%	5.00	49.33	41.32	67.58	62.54	54.42	71.20	72.33	70.64	72.76
Mean +20%	8.00	78.92	66.11	108.13	100.06	87.07	113.92	115.73	113.02	116.41
Mean -20%	5.33	52.62	44.07	72.09	66.70	58.05	75.95	77.15	75.34	77.61
Data Normally Distributed	- [1]	Yes	- [1]	No	Yes	- [1]	Yes	No	Yes	Yes

[1] insufficient data points to determine

Table 3-11. Summary statistics for Chironomidae proportion: Sheardown Lake NW by aquatic habitat type and year.

Metric	Chironomidae Proportion (% of total density)					
Habitat Type	**4**	**9**		**14**		
Year	**2008**	**2007**	**2008**	**2007**	**2008**	**2011**
n (rep. stn.)	8	12	10	6	3	3
Mean	66	83	84	95	93	93
Median	64	87	85	96	95	93
SD	18.28	10.67	7.17	1.58	4.08	1.91
SE	6.46	3.08	2.27	0.64	2.36	1.10
Min	40	67	75	92	88	91
Max	88	98	95	97	96	94
Sub-samples (20% precision)	2	0.4	0.2	0.01	0.05	0.01
95th Percentile	87.7	96.5	94.4	96.7	95.7	94.3
COV (%)	28	13	9	2	4	2
Mean + 2 x SD	102.33	104.34	98.19	98.58	101.33	96.55
2 x Mean	131.54	166.00	167.70	190.84	186.34	185.46
Mean +50%	98.66	124.50	125.78	143.13	139.76	139.10
Mean -50%	32.89	41.50	41.93	47.71	46.59	46.37
Mean +25%	82.21	103.75	104.81	119.28	116.46	115.91
Mean -25%	49.33	62.25	62.89	71.57	69.88	69.55
Mean +20%	78.92	99.60	100.62	114.50	111.80	111.28
Mean -20%	52.62	66.40	67.08	76.34	74.54	74.18
Data Normally Distributed	Yes	Yes		Yes		
Significant Inter-annual Difference	-	No [1]		No - all years [2]		

[1] p-value 0.833 (t-test)

[2] p-value 2007 vs 2008 0.224; 2007 vs 2011 0.152; 2008 vs 2011 0.828 (ANOVA with Bonferroni pairwise comparison)

Table 3-12. Summary statistics for Shannon's Equitability: all Mine Area lakes by aquatic habitat type.

Metric	**Shannon's Equitability (evenness)**									
Habitat Type	**4**			**9**		**10**	**14**			
Lake	**Camp**	**SDL NW**	**SDL SE**	**Mary**	**SDL NW**	**SDL SE**	**Camp**	**Mary**	**SDL NW**	**SDL SE**
Year	2007	2008	2007	2007	2007, 2008	2007	2007	2006, 2007	2007, 2008, 2011	2007
n (rep. stn.)	1	8	3	9	22	3	12	11	12	6
Mean	0.72	0.65	0.67	0.70	0.72	0.65	0.56	0.52	0.40	0.59
Median	-	0.64	0.61	0.76	0.74	0.69	0.57	0.56	0.41	0.59
SD	-	0.10	0.16	0.16	0.08	0.09	0.13	0.21	0.11	0.09
SE	-	0.03	0.09	0.05	0.02	0.05	0.04	0.06	0.03	0.04
Min	-	0.49	0.56	0.37	0.56	0.54	0.33	0.00	0.23	0.46
Max	-	0.79	0.86	0.86	0.84	0.71	0.82	0.81	0.57	0.68
Sub-samples (20% precision)	-	1	1	1	0.3	0	1	4	2	1
95th Percentile	0.72	0.77	0.83	0.84	0.83	0.71	0.75	0.73	0.56	0.68
COV (%)	0	15	24	22	11	14	24	40	28	15
Mean + 2 x SD	0.72	0.84	1.00	1.01	0.87	0.82	0.83	0.94	0.63	0.76
2 x Mean	1.44	1.29	1.35	1.39	1.43	1.29	1.12	1.04	0.81	1.17
Mean +50%	1.08	0.97	1.01	1.04	1.07	0.97	0.84	0.78	0.61	0.88
Mean -50%	0.36	0.32	0.34	0.35	0.36	0.32	0.28	0.26	0.20	0.29
Mean +25%	0.90	0.81	0.84	0.87	0.89	0.81	0.70	0.65	0.50	0.73
Mean -25%	0.54	0.48	0.51	0.52	0.54	0.48	0.42	0.39	0.30	0.44
Mean +20%	0.86	0.77	0.81	0.84	0.86	0.78	0.67	0.62	0.48	0.70
Mean -20%	0.58	0.52	0.54	0.56	0.57	0.52	0.45	0.42	0.32	0.47
Data Normally Distributed	- [1]	Yes	- [1]	Yes	Yes	- [1]	Yes	Yes	Yes	Yes

[1] insufficient data points to determine

Table 3-13. Summary statistics for Simpson's Diversity Index: all Mine Area lakes by aquatic habitat type.

Metric	**Simpson's Diversity Index**									
Habitat Type	**4**			**9**		**10**	**14**			
Lake	**Camp**	**SDL NW**	**SDL SE**	**Mary**	**SDL NW**	**SDL SE**	**Camp**	**Mary**	**SDL NW**	**SDL SE**
Year	2007	2008	2007	2007	2007, 2008	2007	2007	2006, 2007	2007, 2008, 2011	2007
n (rep. stn.)	1	8	3	9	22	3	12	11	12	6
Mean	0.33	0.73	0.73	0.67	0.76	0.71	0.60	0.50	0.37	0.61
Median	-	0.72	0.67	0.73	0.79	0.77	0.61	0.58	0.37	0.65
SD	-	0.09	0.12	0.12	0.08	0.12	0.12	0.23	0.14	0.15
SE	-	0.03	0.07	0.04	0.02	0.07	0.03	0.07	0.04	0.06
Min	-	0.57	0.66	0.43	0.56	0.57	0.39	0.00	0.15	0.35
Max	-	0.83	0.87	0.77	0.86	0.78	0.76	0.69	0.58	0.75
Sub-samples (20% precision)	-	0.4	1	1	0.3	1	1	5	4	1
95th Percentile	0.33	0.83	0.85	0.77	0.86	0.78	0.76	0.68	0.56	0.74
COV (%)	0	13	16	17	10	17	19	46	39	24
Mean + 2 x SD	0.33	0.91	0.97	0.90	0.92	0.95	0.83	0.96	0.65	0.90
2 x Mean	0.66	1.46	1.47	1.34	1.53	1.42	1.20	1.00	0.73	1.22
Mean +50%	0.50	1.09	1.10	1.01	1.15	1.06	0.90	0.75	0.55	0.91
Mean -50%	0.17	0.36	0.37	0.34	0.38	0.35	0.30	0.25	0.18	0.30
Mean +25%	0.41	0.91	0.92	0.84	0.96	0.89	0.75	0.63	0.46	0.76
Mean -25%	0.25	0.55	0.55	0.50	0.57	0.53	0.45	0.38	0.27	0.46
Mean +20%	0.40	0.88	0.88	0.80	0.92	0.85	0.72	0.60	0.44	0.73
Mean -20%	0.26	0.58	0.59	0.54	0.61	0.57	0.48	0.40	0.29	0.49
Data Normally Distributed	- [1]	Yes	- [1]	Yes	No	- [1]	Yes	No	Yes	Yes

[1] insufficient data points to determine

Table 3-14. Summary statistics for Shannon's Equitability: Sheardown Lake NW by aquatic habitat type and year.

Metric	**Shannon's Equitability (evenness)**					
Habitat Type	**4**	**9**		**14**		
Year	**2008**	**2007**	**2008**	**2007**	**2008**	**2011**
n (rep. stn.)	8	12	10	6	3	3
Mean	0.65	0.73	0.70	0.36	0.52	0.39
Median	0.64	0.75	0.72	0.39	0.56	0.33
SD	0.10	0.08	0.08	0.10	0.08	0.13
SE	0.03	0.02	0.03	0.04	0.05	0.07
Min	0.49	0.57	0.56	0.23	0.42	0.30
Max	0.79	0.84	0.83	0.45	0.57	0.54
Sub-samples (20% precision)	1	0.3	0.3	2	1	3
95th Percentile	0.77	0.81	0.81	0.45	0.57	0.51
COV (%)	15	10	12	27	16	33
Mean + 2 x SD	0.84	0.88	0.86	0.55	0.68	0.64
2 x Mean	1.29	1.46	1.40	0.71	1.03	0.78
Mean +50%	0.97	1.09	1.05	0.53	0.77	0.58
Mean -50%	0.32	0.36	0.35	0.18	0.26	0.19
Mean +25%	0.81	0.91	0.88	0.44	0.65	0.49
Mean -25%	0.48	0.55	0.53	0.27	0.39	0.29
Mean +20%	0.77	0.87	0.84	0.43	0.62	0.47
Mean -20%	0.52	0.58	0.56	0.28	0.41	0.31
Data Normally Distributed	Yes	Yes		Yes		
Significant Inter-annual Difference	-	No [1]		No - all years [2]		

[1] p-value 0.416 (t-test)

[2] p-value 2007 vs 2008 0.051; 2007 vs 2011 0.659; 2008 vs 2011 0.155 (ANOVA with Bonferroni pairwise comparison)

Table 3-15. Summary statistics for Simpson's Diversity Index: Sheardown Lake NW by aquatic habitat type and year.

Metric	**Simpson's Diversity Index**					
Habitat Type	**4**	**9**		**14**		
Year	**2008**	**2007**	**2008**	**2007**	**2008**	**2011**
n (rep. stn.)	8	12	10	6	3	3
Mean	0.73	0.77	0.76	0.32	0.49	0.32
Median	0.72	0.79	0.78	0.35	0.55	0.24
SD	0.09	0.07	0.09	0.13	0.12	0.15
SE	0.03	0.02	0.03	0.05	0.07	0.09
Min	0.57	0.59	0.56	0.15	0.36	0.22
Max	0.83	0.86	0.86	0.47	0.58	0.49
Sub-samples (20% precision)	0.4	0.2	0.3	4	1	5
95th Percentile	0.83	0.85	0.85	0.46	0.57	0.47
COV (%)	13	10	12	41	24	47
Mean + 2 x SD	0.91	0.92	0.94	0.59	0.73	0.62
2 x Mean	1.46	1.54	1.52	0.65	0.99	0.64
Mean +50%	1.09	1.15	1.14	0.49	0.74	0.48
Mean -50%	0.36	0.38	0.38	0.16	0.25	0.16
Mean +25%	0.91	0.96	0.95	0.40	0.62	0.40
Mean -25%	0.55	0.58	0.57	0.24	0.37	0.24
Mean +20%	0.88	0.92	0.91	0.39	0.59	0.38
Mean -20%	0.58	0.61	0.61	0.26	0.40	0.25
Data Normally Distributed	Yes	No		Yes		
Significant Inter-annual Difference	-	No [1]		No - all years [2]		

[1] p-value 0.974 (Mann-Whitney U-test)

[2] p-value 2007 vs 2008 0.103; 2007 vs 2011 0.961; 2008 vs 2011 0.140 (ANOVA with Bonferroni pairwise comparison)

Table 3-16. Summary statistics for total taxa richness: all Mine Area lakes by aquatic habitat type.

Metric	Total Taxa Richness (genus-level)									
Habitat Type	4			9		10	14			
Lake	Camp	SDL NW	SDL SE	Mary	SDL NW	SDL SE	Camp	Mary	SDL NW	SDL SE
Year	2007	2008	2007	2007	2007, 2008	2007	2007	2006, 2007	2007, 2008, 2011	2007
n (rep. stn.)	3	8	3	9	22	3	12	11	12	6
Mean	1	15	15	8	13	13	9	9	7	9
Median	0	16	15	8	14	13	9	8	8	10
SD	1.15	1.04	1.53	1.42	2.72	1.53	2.76	5.66	1.62	2.83
SE	0.67	0.37	0.88	0.47	0.58	0.88	0.80	1.71	0.47	1.15
Min	0	13	14	5	8	12	6	1	4	4
Max	2	16	17	10	20	15	14	18	9	12
Sub-samples (20% precision)	75	0.1	0.2	1	1	0.3	2	10	1	2
95th Percentile	1.8	16.0	16.8	9.2	16.0	14.8	13.5	16.5	9.0	11.8
COV (%)	173	7	10	19	20	11	31	64	22	31
Mean + 2 x SD	2.98	17.32	18.39	10.40	18.85	16.39	14.53	20.24	10.66	14.66
2 x Mean	1.33	30.50	30.67	15.11	26.82	26.67	18.00	17.82	14.83	18.00
Mean +50%	1.00	22.88	23.00	28.50	20.11	20.00	13.50	13.36	11.13	13.50
Mean -50%	0.33	7.63	7.67	9.50	6.70	6.67	4.50	4.45	3.71	4.50
Mean +25%	0.83	19.06	19.17	23.75	16.76	16.67	11.25	11.14	9.27	11.25
Mean -25%	0.50	11.44	11.50	14.25	10.06	10.00	6.75	6.68	5.56	6.75
Mean +20%	0.80	18.30	18.40	22.80	16.09	16.00	10.80	10.69	8.90	10.80
Mean -20%	0.53	12.20	12.27	15.20	10.73	10.67	7.20	7.13	5.93	7.20
Data Normally Distributed	- [1]	No	- [1]	Yes	Yes	- [1]	Yes	Yes	Yes	Yes

[1] insufficient data points to determine

Table 3-17. Summary statistics for Hill's effective richness: all Mine Area lakes by aquatic habitat type.

Metric	**Hill's Effective Richness (genus-level)**									
Habitat Type	**4**			**9**		**10**	**14**			
Lake	**Camp**	**SDL NW**	**SDL SE**	**Mary**	**SDL NW**	**SDL SE**	**Camp**	**Mary**	**SDL NW**	**SDL SE**
Year	2007	2008	2007	2007	2007, 2008	2007	2007	2006, 2007	2007, 2008, 2011	2007
n (rep. stn.)	1	8	3	9	22	3	12	11	12	6
Mean	2	6	7	4	6	5	4	3	2	4
Median	-	6	5	5	6	6	3	4	2	4
SD	-	1.63	3.06	1.05	1.47	1.23	1.24	1.31	0.66	1.15
SE	-	0.58	1.77	0.35	0.31	0.71	0.36	0.40	0.19	0.47
Min	-	4	5	2	4	4	2	1	1	2
Max	-	8	10	5	9	6	6	5	3	5
Sub-samples (20% precision)	-	2	5	2	1	1	3	4	2	2
95th Percentile	1.6	8.1	9.7	5.3	8.7	6.4	5.5	4.9	3.3	5.0
COV (%)	0	27	46	26	23	23	35	39	28	31
Mean + 2 x SD	1.65	9.25	12.78	6.21	9.40	7.89	6.03	5.96	3.65	6.01
2 x Mean	3.30	11.98	13.33	8.22	12.94	10.85	7.11	6.68	4.68	7.43
Mean +50%	2.47	8.98	10.00	6.17	9.70	8.14	5.33	5.01	3.51	5.57
Mean -50%	0.82	2.99	3.33	2.06	3.23	2.71	1.78	1.67	1.17	1.86
Mean +25%	2.06	7.49	8.33	5.14	8.09	6.78	4.44	4.18	2.92	4.65
Mean -25%	1.24	4.49	5.00	3.08	4.85	4.07	2.67	2.51	1.75	2.79
Mean +20%	1.98	7.19	8.00	4.93	7.76	6.51	4.27	4.01	2.81	4.46
Mean -20%	1.32	4.79	5.33	3.29	5.18	4.34	2.84	2.67	1.87	2.97
Data Normally Distributed	- [1]	Yes	- [1]	Yes	Yes	- [1]	Yes	Yes	Yes	Yes

[1] insufficient data points to determine

Table 3-18. Summary statistics for total taxa richness: Sheardown Lake NW by aquatic habitat type and year.

Metric	**Total Taxa Richness (genus-level)**					
Habitat Type	**4**	**9**		**14**		
Year	**2008**	**2007**	**2008**	**2007**	**2008**	**2011**
n (rep. stn.)	8	12	10	6	3	3
Mean	15	12	15	8	8	7
Median	16	13	15	9	8	6
SD	1.04	2.35	2.67	2.07	0.58	1.73
SE	0.37	0.68	0.84	0.85	0.33	1.00
Min	13	8	11	4	7	6
Max	16	15	20	9	8	9
Sub-samples (20% precision)	0.1	1	1	2	0.1	2
95th Percentile	16.0	15.0	18.2	9.0	8.0	8.7
COV (%)	7	19	18	28	8	25
Mean + 2 x SD	17.32	17.03	20.04	11.65	8.82	10.46
2 x Mean	30.50	24.67	29.40	15.00	15.33	14.00
Mean +50%	22.88	18.50	22.05	11.25	11.50	10.50
Mean -50%	7.63	6.17	7.35	3.75	3.83	3.50
Mean +25%	19.06	15.42	18.38	9.38	9.58	8.75
Mean -25%	11.44	9.25	11.03	5.63	5.75	5.25
Mean +20%	18.30	14.80	17.64	9.00	9.20	8.40
Mean -20%	12.20	9.87	11.76	6.00	6.13	5.60
Data Normally Distributed	No	Yes		Yes		
Significant Inter-annual Difference	-	Yes [1]		No - all years [2]		

[1] p-value 0.039 (t-test)

[2] p-value 2007 vs 2008 0.897; 2007 vs 2011 0.699; 2008 vs 2011 0.655 (ANOVA with Bonferroni pairwise comparison)

Table 3-19. Summary statistics for Hill's effective richness: Sheardown Lake NW by aquatic habitat type and year.

Metric	**Hill's Effective Richness (genus-level)**					
Habitat Type	**4**	**9**		**14**		
Year	**2008**	**2007**	**2008**	**2007**	**2008**	**2011**
n (rep. stn.)	8	12	10	6	3	3
Mean	6	6	7	2	3	2
Median	6	6	7	2	3	2
SD	1.63	1.38	1.60	0.51	0.56	0.86
SE	0.58	0.40	0.51	0.21	0.32	0.49
Min	4	4	4	1	2	2
Max	8	9	9	3	3	3
Sub-samples (20% precision)	2	1	1	1	1	4
95th Percentile	8.1	8.5	9.1	2.6	3.3	3.1
COV (%)	27	22	24	24	19	38
Mean + 2 x SD	9.25	9.05	9.90	3.11	4.03	3.97
2 x Mean	11.98	12.56	13.39	4.19	5.82	4.50
Mean +50%	8.98	9.42	10.04	3.15	4.37	3.38
Mean -50%	2.99	3.14	3.35	1.05	1.46	1.13
Mean +25%	7.49	7.85	8.37	2.62	3.64	2.81
Mean -25%	4.49	4.71	5.02	1.57	2.18	1.69
Mean +20%	7.19	7.54	8.04	2.52	3.49	2.70
Mean -20%	4.79	5.02	5.36	1.68	2.33	1.80
Data Normally Distributed	No	Yes		Yes		
Significant Inter-annual Difference	-	No [1]		No - all years [2]		

[1] p-value 0.520 (t-test)

[2] p-value 2007 vs 2008 0.094; 2007 vs 2011 0.729; 2008 vs 2011 0.222 (ANOVA with Bonferroni pairwise comparison)

Table 3-20. Summary statistics for total macroinvertebrate density: Sheardown Lake Tributary 1 by reach and year.

Metric	Total Macroinvertebrate Density (individuals/m^2)							
Stream Reach	**1**	**2**			**4**			
Year	**2008**	**2007**	**2008**	**All**	**2007**	**2008**	**2011**	**All**
n (rep. stn.)	3	3	3	6	3	3	3	9
Mean	299	441	647	544	4520	3042	2432	3332
Median	315	421	429	425	2043	3225	1454	2266
SD	53.49	110.73	465.01	322.72	4372.64	702.61	1711.24	2549.53
SE	30.88	63.93	268.47	131.75	2524.55	405.65	987.99	849.84
Min	239	342	332	332	1948	2266	1435	1435
Max	342	561	1181	1181	9569	3635	4408	9569
Sub-samples (20% precision)	1	2	13	9	23	1	12	15
95th Percentile	339.6	546.8	1106.2	1026.3	8816.5	3594.0	4112.8	7504.7
COV (%)	18	25	72	59	97	23	70	77
Mean + 2 x SD	405.95	662.69	1577.44	1189.78	13265.56	4447.14	5854.79	8430.56
2 x Mean	597.94	882.47	1294.85	1088.66	9040.55	6083.85	4864.60	6663.00
Mean +50%	448.45	661.86	971.13	816.49	6780.41	4562.89	3648.45	4997.25
Mean -50%	149.48	220.62	323.71	272.16	2260.14	1520.96	1216.15	1665.75
Mean +25%	373.71	551.55	809.28	680.41	5650.34	3802.41	3040.38	4164.38
Mean -25%	224.23	330.93	485.57	408.25	3390.21	2281.44	1824.23	2498.63
Mean +20%	358.76	529.48	776.91	653.20	5424.33	3650.31	2918.76	3997.80
Mean -20%	239.18	352.99	517.94	435.46	3616.22	2433.54	1945.84	2665.20
Data Normally Distributed	- [1]	No			No			
Significant Inter-annual Difference	-	No [2]			No [3]			

[1] insufficient data points to determine

[2] p-value 1.000 (Mann-Whitney U-test)

[3] p-value 0.561

Table 3-21. Summary statistics for Chironomidae proportion: Sheardown Lake Tributary 1 by reach and year.

Metric	Chironomidae Proportion (% of total density)							
Stream Reach	**1**	**2**			**4**			
Year	**2008**	**2007**	**2008**	**All**	**2007**	**2008**	**2011**	**All**
n (rep. stn.)	3	3	3	6	3	3	3	9
Mean	69	64	78	71	92	94	87	91
Median	70	74	76	75	93	93	86	92
SD	1.97	22.96	4.20	16.56	3.84	2.19	2.68	4.06
SE	1.13	13.26	2.42	6.76	2.21	1.27	1.55	1.35
Min	67	38	75	38	88	92	85	85
Max	71	81	83	83	95	96	90	96
Sub-samples (20% precision)	0.02	3	0.1	1	0.04	0.01	0.02	0.05
95th Percentile	70.5	80.1	81.9	82.1	95.3	95.7	89.4	95.7
COV (%)	3	36	5	23	4	2	3	4
Mean + 2 x SD	73.03	110.04	86.22	104.09	99.87	97.97	92.12	98.96
2 x Mean	138.19	128.24	155.64	141.94	184.41	187.16	173.50	181.69
Mean +50%	103.64	96.18	116.73	106.46	138.31	140.37	130.12	136.27
Mean -50%	34.55	32.06	38.91	35.49	46.10	46.79	43.37	45.42
Mean +25%	86.37	80.15	97.28	88.71	115.25	116.98	108.44	113.56
Mean -25%	51.82	48.09	58.37	53.23	69.15	70.19	65.06	68.13
Mean +20%	82.91	76.95	93.39	85.17	110.64	112.30	104.10	109.01
Mean -20%	55.28	51.30	62.26	56.78	73.76	74.86	69.40	72.68
Data Normally Distributed	- [1]	No			Yes			
Significant Inter-annual Difference	-	No [2]			No [3]			

[1] insufficient data points to determine

[2] p-value 0.400 (Mann-Whitney U-test)

[3] p-value 2007 vs 2008 0.592; 2007 vs 2011 0.067; 2008 vs 2011 0.031

Table 3-22. Summary statistics for Shannon's Equitability: Sheardown Lake Tributary 1 by reach and year.

Metric	Shannon's Equitability (evenness)							
Stream Reach	**1**	**2**			**4**			
Year	**2008**	**2007**	**2008**	**All**	**2007**	**2008**	**2011**	**All**
n (rep. stn.)	3	3	3	6	3	3	3	9
Mean	0.77	0.70	0.71	0.71	0.62	0.66	0.62	0.63
Median	0.77	0.70	0.72	0.71	0.67	0.68	0.65	0.67
SD	0.06	0.03	0.03	0.03	0.18	0.08	0.11	0.11
SE	0.03	0.02	0.01	0.01	0.10	0.05	0.06	0.04
Min	0.72	0.67	0.69	0.67	0.42	0.57	0.50	0.42
Max	0.83	0.73	0.74	0.74	0.76	0.72	0.71	0.76
Sub-samples (20% precision)	0.1	0.1	0.03	0.04	2	0.4	1	1
95th Percentile	0.82	0.73	0.73	0.74	0.75	0.72	0.70	0.75
COV (%)	7	5	4	4	29	12	17	18
Mean + 2 x SD	0.89	0.77	0.76	0.76	0.97	0.82	0.83	0.86
2 x Mean	1.55	1.40	1.43	1.41	1.23	1.31	1.24	1.26
Mean +50%	1.16	1.05	1.07	1.06	0.93	0.98	0.93	0.95
Mean -50%	0.39	0.35	0.36	0.35	0.31	0.33	0.31	0.32
Mean +25%	0.97	0.87	0.89	0.88	0.77	0.82	0.77	0.79
Mean -25%	0.58	0.52	0.53	0.53	0.46	0.49	0.46	0.47
Mean +20%	0.93	0.84	0.86	0.85	0.74	0.79	0.74	0.76
Mean -20%	0.62	0.56	0.57	0.56	0.49	0.52	0.50	0.50
Data Normally Distributed	- [1]	Yes			Yes			
Significant Inter-annual Difference	-	No [2]			No [3]			

[1] insufficient data points to determine

[2] p-value 0.595 (t-test)

[3] p-value 2007 vs 2008 0.732; 2007 vs 2011 0.983; 2008 vs 2011 0.747

Table 3-23. Summary statistics for Simpson's Diversity Index: Sheardown Lake Tributary 1 by reach and year.

Metric	Simpson's Diversity Index							
Stream Reach	**1**	**2**			**4**			
Year	**2008**	**2007**	**2008**	**All**	**2007**	**2008**	**2011**	**All**
n (rep. stn.)	3	3	3	6	3	3	3	9
Mean	0.82	0.77	0.76	0.76	0.69	0.74	0.73	0.72
Median	0.83	0.76	0.75	0.76	0.77	0.81	0.76	0.77
SD	0.04	0.03	0.03	0.03	0.21	0.12	0.11	0.14
SE	0.02	0.02	0.02	0.01	0.12	0.07	0.06	0.05
Min	0.78	0.73	0.73	0.73	0.45	0.61	0.62	0.45
Max	0.85	0.80	0.80	0.80	0.85	0.81	0.82	0.85
Sub-samples (20% precision)	0.05	0.04	0.1	0.04	2	1	1	1
95th Percentile	0.85	0.80	0.79	0.80	0.84	0.81	0.82	0.84
COV (%)	4	4	5	4	31	16	15	19
Mean + 2 x SD	0.90	0.83	0.83	0.82	1.12	0.98	0.95	0.99
2 x Mean	1.65	1.53	1.52	1.53	1.38	1.48	1.47	1.44
Mean +50%	1.23	1.15	1.14	1.14	1.03	1.11	1.10	1.08
Mean -50%	0.41	0.38	0.38	0.38	0.34	0.37	0.37	0.36
Mean +25%	1.03	0.96	0.95	0.95	0.86	0.93	0.92	0.90
Mean -25%	0.62	0.57	0.57	0.57	0.52	0.56	0.55	0.54
Mean +20%	0.99	0.92	0.91	0.92	0.83	0.89	0.88	0.87
Mean -20%	0.66	0.61	0.61	0.61	0.55	0.59	0.59	0.58
Data Normally Distributed	- [1]	Yes			Yes			
Significant Inter-annual Difference	-	No [2]			No [3]			

[1] insufficient data points to determine

[2] p-value 0.856 (t-test)

[3] p-value 2007 vs 2008 0.684; 2007 vs 2011 0.726; 2008 vs 2011 0.954

Table 3-24. Summary statistics for total taxa richness: Sheardown Lake Tributary 1 by reach and year.

Metric	**Total Taxa Richness (genus-level)**							
Stream Reach	**1**	**2**			**4**			
Year	**2008**	**2007**	**2008**	**All**	**2007**	**2008**	**2011**	**All**
n (rep. stn.)	3	3	3	6	3	3	3	9
Mean	12	15	13	14	16	16	17	16
Median	12	15	13	14	16	17	17	17
SD	1.00	1.00	1.00	1.41	2.52	4.58	1.53	2.74
SE	0.58	0.58	0.58	0.58	1.45	2.65	0.88	0.91
Min	11	14	12	12	14	11	15	11
Max	13	16	14	16	19	20	18	20
Sub-samples (20% precision)	0.2	0.1	0.1	0.3	1	2	0.2	1
95th Percentile	12.9	15.9	13.9	15.8	18.7	19.7	17.9	19.6
COV (%)	8	7	8	10	15	29	9	17
Mean + 2 x SD	14.00	17.00	15.00	16.83	21.37	25.17	19.72	21.81
2 x Mean	24.00	30.00	26.00	28.00	32.67	32.00	33.33	32.67
Mean +50%	18.00	22.50	19.50	21.00	24.50	24.00	25.00	24.50
Mean -50%	6.00	7.50	6.50	7.00	8.17	8.00	8.33	8.17
Mean +25%	15.00	18.75	16.25	17.50	20.42	20.00	20.83	20.42
Mean -25%	9.00	11.25	9.75	10.50	12.25	12.00	12.50	12.25
Mean +20%	14.40	18.00	15.60	16.80	19.60	19.20	20.00	19.60
Mean -20%	9.60	12.00	10.40	11.20	13.07	12.80	13.33	13.07
Data Normally Distributed	- [1]	Yes			Yes			
Significant Inter-annual Difference	-	No [2]			No [3]			

[1] insufficient data points to determine

[2] p-value 0.070 (t-test)

[3] p-value 2007 vs 2008 0.901; 2007 vs 2011 0.901; 2008 vs 2011 0.804

Table 3-25. Summary statistics for Hill's effective richness: Sheardown Lake Tributary 1 by reach and year.

Metric	Hill's Effective Richness (genus-level)							
Stream Reach	**1**	**2**			**4**			
Year	**2008**	**2007**	**2008**	**All**	**2007**	**2008**	**2011**	**All**
n (rep. stn.)	3	3	3	6	3	3	3	9
Mean	7	7	6	6	6	6	6	6
Median	7	7	6	6	6	8	6	6
SD	1.17	0.48	0.43	0.47	3.20	2.20	1.94	2.18
SE	0.68	0.28	0.25	0.19	1.85	1.27	1.12	0.73
Min	6	6	6	6	3	4	4	3
Max	8	7	7	7	9	8	8	9
Sub-samples (20% precision)	1	0.1	0.1	0.1	6	3	3	3
95th Percentile	7.8	6.9	6.6	6.9	9.1	7.8	7.6	8.8
COV (%)	17	7	7	7	51	34	32	35
Mean + 2 x SD	9.24	7.60	7.09	7.37	12.70	10.82	9.86	10.59
2 x Mean	13.80	13.28	12.45	12.87	12.59	12.83	11.95	12.46
Mean +50%	10.35	9.96	9.34	9.65	9.44	9.62	8.96	9.34
Mean -50%	3.45	3.32	3.11	3.22	3.15	3.21	2.99	3.11
Mean +25%	8.62	8.30	7.78	8.04	7.87	8.02	7.47	7.79
Mean -25%	5.17	4.98	4.67	4.82	4.72	4.81	4.48	4.67
Mean +20%	8.28	7.97	7.47	7.72	7.55	7.70	7.17	7.48
Mean -20%	5.52	5.31	4.98	5.15	5.04	5.13	4.78	4.98
Data Normally Distributed	- [1]	Yes			Yes			
Significant Inter-annual Difference	-	No [2]			No [3]			

[1] insufficient data points to determine

[2] p-value 0.331 (t-test)

[3] p-value 2007 vs 2008 0.955; 2007 vs 2011 0.881; 2008 vs 2011 0.837

Table 3-26. Critical effects sizes for select benthic macroinvertebrate community metrics from Sheardown Lake NW.

Metric	Habitat Type 4 (2008; n = 8)					
	Mean +50%	Mean -50%	Mean +25%	Mean -25%	Mean +20%	Mean -20%
Total macroinvertebrate density	1244.03	414.68	1036.69	622.01	995.22	663.48
Chironomidae proportion	98.66	32.89	82.21	49.33	78.92	52.62
Shannon's Equitability	0.97	0.32	0.81	0.48	0.77	0.52
Simpson's Diversity Index	1.09	0.36	0.91	0.55	0.88	0.58
Total taxa richness	22.88	7.63	19.06	11.44	18.30	12.20

Metric	Habitat 9 (2007 and 2008; n = 22)					
	Mean +50%	Mean -50%	Mean +25%	Mean -25%	Mean +20%	Mean -20%
Total macroinvertebrate density	5487.27	1829.09	4572.73	2743.64	4389.82	2926.54
Chironomidae proportion	125.07	41.69	104.23	62.54	100.06	66.70
Shannon's Equitability	1.07	0.36	0.89	0.54	0.86	0.57
Simpson's Diversity Index	1.15	0.38	0.96	0.57	0.92	0.61
Total taxa richness	20.11	6.70	16.76	10.06	16.09	10.73

Metric	Habitat Type 14 (2007, 2008, 2011; n = 12)					
	Mean +50%	Mean -50%	Mean +25%	Mean -25%	Mean +20%	Mean -20%
Total macroinvertebrate density	2381.49	793.83	1984.58	1190.75	1905.19	1270.13
Chironomidae proportion	141.27	47.09	117.73	70.64	113.02	75.34
Shannon's Equitability	0.61	0.20	0.50	0.30	0.48	0.32
Simpson's Diversity Index	0.55	0.18	0.46	0.27	0.44	0.29
Total taxa richness	11.13	3.71	9.27	5.56	8.90	5.93

Table 3-27. Critical effects sizes for select benthic macroinvertebrate community metrics from Sheardown Lake Tributary 1, Reach 4.

Metric	2007, 2008, 2011; n = 9					
	Mean +50%	Mean - 50%	Mean +25%	Mean - 25%	Mean +20%	Mean - 20%
Total macroinvertebrate density	4997.25	1665.75	4164.38	2498.63	3997.80	2665.20
Chironomidae proportion	136.27	45.42	113.56	68.13	109.01	72.68
Shannon's Equitability	0.95	0.32	0.79	0.47	0.76	0.50
Simpson's Diversity Index	1.08	0.36	0.90	0.54	0.87	0.58
Total taxa richness	24.50	8.17	20.42	12.25	19.60	13.07

Table 3-28. Power of existing benthic macroinvertebrate data to detect pre-defined levels of change in Sheardown Lake NW.

Metric	Habitat Type 4 (2008; n = 8)		
	Mean +/-50%	Mean +/-25%	Mean +/-20%
Total macroinvertebrate density	0.247	0.148	0.123
Chironomidae proportion	0.957	0.536	0.402
Shannon's Equitability	1.000	0.935	0.813
Simpson's Diversity Index	1.000	0.982	0.938
Total taxa richness	1.000	1.000	1.000

Metric	Habitat 9 (2007 and 2008; n = 22)		
	Mean +/-50%	Mean +/-25%	Mean +/-20%
Total macroinvertebrate density	0.807	0.387	0.282
Chironomidae proportion	1.000	1.000	1.000
Shannon's Equitability	1.000	1.000	0.999
Simpson's Diversity Index	1.000	1.000	1.000
Total taxa richness	1.000	0.992	0.943

Metric	Habitat Type 14 (2007, 2008, 2011; n = 12)		
	Mean +/-50%	Mean +/-25%	Mean +/-20%
Total macroinvertebrate density	0.441	0.170	0.154
Chironomidae proportion	1.000	1.000	1.000
Shannon's Equitability	0.990	0.681	0.495
Simpson's Diversity Index	0.892	0.446	0.317
Total taxa richness	1.000	0.866	0.712

Table 3-29. Sample sizes (i.e., number of replicate stations) required for detecting pre-defined levels of change in Sheardown Lake NW.

Metric	Habitat Type 4		
	Mean +/-50%	Mean +/-25%	Mean +/-20%
Total macroinvertebrate density	64	>180	>>180
Chironomidae proportion	6	22	37
Shannon's Equitability	3	7	10
Simpson's Diversity Index	3	5	7
Total taxa richness	<<3	<3	3

Metric	Habitat 9		
	Mean +/-50%	Mean +/-25%	Mean +/-20%
Total macroinvertebrate density	31	>60	>>60
Chironomidae proportion	2	4	6
Shannon's Equitability	2	4	6
Simpson's Diversity Index	<5	5	6
Total taxa richness	4	12	18

Metric	Habitat Type 14		
	Mean +/-50%	Mean +/-25%	Mean +/-20%
Total macroinvertebrate density	43	167	>180
Chironomidae proportion	1	1	1
Shannon's Equitability	7	22	37
Simpson's Diversity Index	12	45	70
Total taxa richness	4	13	21

Table 3-30. Power of existing benthic macroinvertebrate data to detect pre-defined levels of change in Sheardown Lake Tributary 1, Reach 4.

Metric	2007, 2008, 2011; n = 9		
	Mean +/- 50%	**Mean +/- 25%**	**Mean +/- 20%**
Total macroinvertebrate density	0.564 [1]	0.248 [2]	0.209 [3]
Chironomidae proportion	1.000	1.000	1.000
Shannon's Equitability	1.000	0.791	0.602
Simpson's Diversity Index	1.000	0.750	0.578
Total taxa richness	1.000	0.844	0.651

[1] metric not normally distributed: -50%, 0.785

[2] metric not normally distributed: -25%, 0.276

[3] metric not normally distributes: -20%, 0.109

Table 3-31. Sample sizes (i.e., number of replicate stations) required for detecting pre-defined levels of change in Sheardown Lake Tributary 1, Reach 4.

Metric	2007, 2008, 2011; n = 9		
	Mean +/- 50%	Mean +/- 25%	Mean +/- 20%
Total macroinvertebrate density	22 [1]	>61 [2]	>>61 [3]
Chironomidae proportion	2	3	3
Shannon's Equitability	4	12	18
Simpson's Diversity Index	5	13	19
Total taxa richness	4	10	16

[1] metric not normally distributed: -50%, 13

[2] metric not normally distributed: -25%, 59

[3] metric not normally distributed: -20%, 60

Table 4-1. Summary of baseline electrofishing and gillnetting Arctic Char data collections in selected Mine Area waterbodies, 2006-2008 and 2013.

Waterbody	Year	Season	Gear Type[1]	Sampling Effort[2]	Catch
Camp Lake	2006	Summer	Gill Net	2	21
	2007	Winter	Gill Net	2	3
		Summer	Gill Net	20	94
			Electrofishing	1	8
	2008	Fall	Gill Net	14	22
	2013	Fall	Gill Net	35	26
			Electrofishing	1	57
Camp Lake Tributary 1	2006	Summer	Electrofishing	3	8
	2007	Summer	Electrofishing	3	196
		Fall	Electrofishing	3	211
Sheardown Lake NW	2006	Summer	Gill Net	1	17
	2007	Winter	Gill Net	2	5
		Summer	Gill Net	12	92
			Electrofishing	5	220
	2008	Spring	Electrofishing	10	36
		Fall	Gill Net	4	5
	2013	Fall	Gill Net	18	28
			Electrofishing	2	184
Sheardown Lake SE	2007	Winter	Gill Net	2	7
		Summer	Gill Net	2	30
			Electrofishing	2	32
	2008	Spring	Electrofishing	4	4
		Fall	Gill Net	4	63

Table 4-1. - continued -

Waterbody	Year	Season	Gear Type[1]	Sampling Effort[2]	Catch
Sheardown Lake Tributary 1	2006	Summer	Electrofishing	1	5
	2007	Spring	Electrofishing	4	4
		Summer	Electrofishing	4	145
		Fall	Electrofishing	4	52
			Hoop Net	23	1240
	2008	Spring	Electrofishing	2	33
			Hoop Net[3]	18	849
		Summer	Electrofishing	2	55
		Fall	Electrofishing	2	13
			Hoop Net	17	469
Mary Lake – South	2006	Summer	Gill Net	2	62
			Electrofishing	1	
	2007	Summer	Gill Net	24	168
	2008	Spring	Electrofishing	7	2
Mary Lake – North	2007	Summer	Gill Net	8	98
	2008	Spring	Electrofishing	3	4

1 Does not include minnow trap or angling data.

2 Effort for gill nets described as the number of standard index gillnet gangs set in each lake; electrofishing effort is the number of 50-100 m sections of shoreline or stream sampled, and hoopnetting effort is the number of days traps were installed.

3 Data include two hoop nets (one facing upstream and one downstream) that each fished for 18 days.

Table 4-2. Summary of fish metrics and statistical analysis methods recommended under EEM (EC 2012). Metrics indicated with an asterisk are endpoints used for determining effects under EEM, as designated by statistically significant differences between exposure and reference areas. Other endpoints may be used to support analyses.

Effect Indicators	Fish Effect Endpoint			
	Non-Lethal Survey	**Statistical Test**	**Lethal Adult Survey**	**Statistical Test**
Growth	*Length of YOY (age 0) at end of growth period	ANOVA	-	
	*Weight of YOY (age 0) at end of growth period	ANOVA	-	
	*Size of 1+ fish if possible	ANOVA		
	*Size-at-age (body weight at age) - if possible	ANCOVA	*Size-at-age (body weight at age)	ANCOVA
	Length-at-age	ANCOVA	Length-at-age	ANCOVA
	Body Weight	ANOVA		
	Length	ANOVA		
Reproduction	*Relative abundance of YOY (% composition of YOY)	Kolmorgorov-Smirnov test performed on length-frequency distributions with and without YOY included; OR proportions of YOY can be tested using a Chi-squared test.	-	
	OR relative age-class strength		*Gonad weight at body weight	ANCOVA
	-		Gonad weight at length	
	-		Fecundity	
Condition	*Condition Factor	ANCOVA	*Condition Factor	ANCOVA
	-		*Liver size at body weight	ANCOVA
	-		Liver weight at length	
	-		Egg weight at body weight and/or age (mature females only)	
Survival	*Length-frequency-distribution	2-sample Kolmorgorov-Smirnov test[1]	Length-frequency-distribution	2-sample Kolmorgorov-Smirnov test
	*Age-frequency distribution (if possible)	2-sample Kolmorgorov-Smirnov test	*Age-frequency distribution (if possible)	2-sample Kolmorgorov-Smirnov test
	YOY Survival		*Age	ANOVA

[1] Examine YOY alone and for both sizes combined

Table 4-3. Datasets analysed for Arctic Char metrics.

Waterbody	Year	Gear Type	Sex
Camp Lake	2006	Gill Net	M, F, Total
	2007	Gill Net	M, F, Total
	2008	Gill Net	M, F, Total
	All Years	Gill Net	M, F, Total
Sheardown Lake	2006	Gill Net	M, F, Total
	2007	Electrofishing	Total
		Gill Net	M, F, Total
	2008	Electrofishing	Total
		Gill Net	M, F, Total
	All Years	Electrofishing	Total
		Gill Net	M, F, Total
Mary Lake – South	2006	Gill Net	M, F, Total
	2007	Gill Net	M, F, Total
	All Years	Gill Net	M, F, Total
Mary Lake – North	2007	Gill Net	Total

Table 4-4. Summary statistics for fork lengths (mm) of Arctic Char captured during backpack electrofishing (EF) and gillnetting surveys in Camp Lake, 2006-2008.

Statistic	2006			2007			2008			All Years		
	Males	Females	All	Males	Females	All	Males	Females	All	Males	Females	All
n	11	10	21	3	3	99	9	2	22	23	15	134
Mean	335	224	282	291	329	305	465	394	401	380	267	332
Median	265	221	230	312	338	321	430	394	368	350	236	323
SD	195	39	151	38	45	117	137	100	117	171	80	114
SE	59	12	33	22	26	12	46	71	25	36	21	10
Minimum	170	175	170	247	280	40	342	323	236	170	175	170
Maximum	751	311	751	315	368	682	745	464	745	751	464	751
95th Percentile	699	286	647	315	365	542	680	457	582	735	397	578
COV (%)	58	18	54	13	14	38	29	25	29	45	30	34

Table 4-5. Summary statistics for fork lengths (mm) of Arctic Char captured during backpack electrofishing (EF) and index gillnetting surveys in Sheardown Lake, 2006-2008.

Statistic	2006			2007				2008				All Years			
	Gillnetting			EF	Gillnetting			EF	Gillnetting			EF	Gillnetting		
	Males	Females	All		Males	Females	All		Males	Females	All		Males	Females	All
n	6	2	14	252	12	15	116	39	27	8	68	291	45	25	198
Mean	313	385	346	76	367	353	372	83	402	383	387	77	381	365	375
Median	281	385	293	65	371	335	369	87	403	380	385	66	388	364	377
SD	142	142	137	29	59	69	82	28	37	18	38	29	70	63	76
SE	58	101	37	2	17	18	8	4	7	6	5	2	10	13	5
Minimum	180	284	180	33	278	240	178	26	360	364	276	26	180	240	178
Maximum	572	485	599	180	507	508	587	140	552	420	552	180	572	508	599
95th Percentile	519	475	581	139	449	497	541	127	441	410	431	138	495	491	531
COV (%)	45	37	39	38	16	20	22	34	9	5	10	37	18	17	20

Table 4-6. Summary statistics for fork lengths (mm) of Arctic Char captured in standard index gill nets deployed in the north and south basins of Mary Lake, 2006-2007.

Statistic	South Basin									North Basin
	2006			2007			All Years			2007
	Males	Females	All	Males	Females	All	Males	Females	All	
n	26	33	62	14	12	161	40	45	223	98
Mean	386	370	384	383	375	383	385	372	384	379
Median	390	370	384	394	373	392	395	372	391	389
SD	132	116	133	74	43	71	114	102	92	41
SE	26	20	17	20	13	6	18	15	6	4
Minimum	165	181	165	266	266	197	165	181	165	198
Maximum	685	658	705	548	432	671	685	658	705	458
95^{th} Percentile	594	586	648	485	424	457	573	552	559	432
COV (%)	34	31	35	19	12	18	30	27	24	11

Table 4-7. Comparison of Arctic Char length between sexes and years. Data represent fish captured during backpack electrofishing (EF) and index gillnetting (GN) surveys in study area lakes, 2006-2008. Values in red indicate significant difference at $p < 0.05$.

Lake	Comparison			P value[1]
	Dataset 1	Dataset 2	Dataset 3	
Camp Lake	2006 GN Males	2006 GN Females	-	0.58
	2007 GN Males	2007 GN Females	-	0.38
	2008 GN Males	2008 GN Females	-	0.37
	All Years Males	All Years Females	-	0.17
	2006 GN Males	2007 GN Males	2008 GN Males	0.11
	2006 GN Females	2007 GN Females	2008 GN Females	0.04
	2006 GN All Fish	2007 GN All Fish	2008 GN All Fish	0.70
Sheardown Lake	2006 GN Males	2006 GN Females	-	0.11
	2007 GN Males	2007 GN Females	-	0.98
	2008 GN Males	2008 GN Females	-	0.47
	All Years GN Males	All Years GN Females	-	0.66
	2006 GN Males	2007 GN Males	2008 GN Males	0.91
	2006 GN Females	2007 GN Females	2008 GN Females	0.77
	2006 GN All Fish	2007 GN All Fish	2008 GN All Fish	0.98
	2007 EF All Fish	2008 EF All Fish	-	0.76
Mary Lake - S	2006 GN Males	2006 GN Females	-	0.79
	2007 GN Males	2007 GN Females	-	0.43
	All Years Males	All Years Females	-	0.72
	2006 GN Males	2007 GN Males	-	0.55
	2006 GN Females	2007 GN Females	-	0.60
	2006 GN All Fish	2007 GN All Fish	-	0.72

[1]Differences between two groups tested with a Kruskal-Wallis test at alpha = 0.05.

Table 4-8. Inter-lake comparisons of fork lengths (mm) of Arctic Char captured during index gillnetting surveys, 2006-2008.

Comparison				P value[1]
Dataset 1	**Dataset 2**	**Dataset 3**	**Dataset 4**	
Camp L. 2006 GN	Sheardown L. 2006 GN	Mary L – S 2006 GN	-	0.74
Camp L. 2007 GN	Sheardown L. 2007 GN	Mary L – S 2007 GN	Mary L – N 2007 GN	0.94
Camp L. 2008 GN	Sheardown L. 2008 GN	-	-	0.52
Camp L. All GN	Sheardown L. All GN	Mary L – S All GN	Mary L – N All GN	0.94

[1]Differences between two groups tested with a Kruskal-Wallis test at alpha = 0.05.

Table 4-9. Summary statistics for weights (g) of Arctic Char captured in Camp Lake, 2006-2008.

Statistic	2006			2007			2008			All Years		
	Males	Females	All	Males	Females	All	Males	Females	All	Males	Females	All
n	11	9	20	3	3	91	9	2	22	23	14	133
Mean	823	139	515	275	342	435	1450	625	876	997	252	520
Median	200	150	150	325	400	350	750	625	463	375	150	350
SD	1512	69	1152	109	146	509	1705	460	1181	1506	234	785
SE	456	23	258	63	85	53	568	325	252	314	62	68
Minimum	50	75	50	150	175	25	375	300	200	50	75	25
Maximum	4900	300	4900	350	450	3050	5600	950	5600	5600	950	5600
95th Percentile	3650	240	2525	348	445	1475	4320	918	2368	4650	625	1965
COV (%)	184	49	224	40	43	117	118	74	135	151	93	151

Table 4-10. Summary statistics for weights (g) of Arctic Char captured during backpack electrofishing (EF) and gillnetting surveys in Sheardown Lake, 2006-2008.

Statistic	2006			2007				2008				All Years			
	Gillnetting			EF	Gillnetting			EF	Gillnetting			EF	Gillnetting		
	Males	Females	All		Males	Females	All		Males	Females	All		Males	Females	All
n	6	2	8	230	12	15	116	36	27	8	68	266	45	25	192
Mean	479	600	509	7	435	396	494	9	698	591	604	7	599	475	533
Median	200	600	225	4	400	350	425	8	675	575	538	4	525	425	500
SD	711	566	640	9	218	209	317	6	249	101	209	8	348	227	306
SE	290	400	226	1	63	54	29	1	48	36	25	1	52	45	22
Minimum	50	200	50	1	150	125	50	1	475	450	250	1	50	125	50
Maximum	1900	1000	1900	59	1000	950	1800	28	1750	725	1750	59	1900	1000	1900
95^{th} Percentile	1538	1900	1585	27	780	828	1119	20	948	716	850	26	998	915	1086
COV (%)	148	94	126	123	50	53	64	70	36	17	35	115	58	48	57

Table 4-11. Summary statistics for weights (g) of Arctic Char captured in standard index gill nets set in the north and south basins of Mary Lake, 2006-2007.

Statistic	South Basin									North Basin
	2006			2007			All Years			2007
	Males	Females	All	Males	Females	All	Males	Females	All	
n	26	33	62	14	12	161	40	45	223	98
Mean	736	639	743	534	467	548	665	593	602	493
Median	600	525	600	513	475	525	575	450	525	500
SD	596	600	709	329	132	344	523	522	481	125
SE	117	104	90	88	38	27	83	78	32	13
Minimum	25	75	25	125	175	75	25	75	25	75
Maximum	2350	2450	3300	1425	700	3050	2350	2450	3300	850
95th Percentile	1825	2060	2348	1019	645	825	1630	1780	1590	679
COV (%)	81	94	95	62	28	63	79	88	80	25

Table 4-12. Comparison of Arctic Char weights between sexes and years. Data represent fish captured during backpack electrofishing (EF) and index gillnetting (GN) surveys in study area lakes, 2006-2008. Values in red indicate significant difference at $p < 0.05$.

Lake	Comparison			P value[1]
	Dataset 1	Dataset 2	Dataset 3	
Camp Lake	2006 GN Males	2006 GN Females	-	**< 0.01**
	2007 GN Males	2007 GN Females	-	0.32
	2008 GN Males	2008 GN Females	-	**0.02**
	All Years Males	All Years Females	-	**0.01**
	2006 GN Males	2007 GN Males	2008 GN Males	**< 0.01**
	2006 GN Females	2007 GN Females	2008 GN Females	**< 0.01**
	2006 GN All Fish	2007 GN All Fish	2008 GN All Fish	0.34
Sheardown Lake	2006 GN Males	2006 GN Females	-	0.55
	2007 GN Males	2007 GN Females	-	0.76
	2008 GN Males	2008 GN Females	-	0.29
	All Years GN Males	All Years GN Females	-	0.40
	2006 GN Males	2007 GN Males	2008 GN Males	0.42
	2006 GN Females	2007 GN Females	2008 GN Females	0.28
	2006 GN All Fish	2007 GN All Fish	2008 GN All Fish	0.92
	2007 EF All Fish	2008 EF All Fish	-	0.77
Mary Lake - S	2006 GN Males	2006 GN Females	-	0.95
	2007 GN Males	2007 GN Females	-	0.42
	All Years Males	All Years Females	-	0.85
	2006 GN Males	2007 GN Males	-	0.33
	2006 GN Females	2007 GN Females	-	0.12
	2006 GN All Fish	2007 GN All Fish	-	0.31

[1]Differences between two groups tested with a Kruskal-Wallis test at alpha = 0.05.

Table 4-13. Inter-lake comparisons of weights (g) of Arctic Char captured during index gillnetting surveys, 2006-2008.

Comparison				P value[1]
Dataset 1	Dataset 2	Dataset 3	Dataset 4	
Camp L. 2006 GN	Sheardown L. 2006 GN	Mary L – S 2006 GN	-	0.71
Camp L. 2007 GN	Sheardown L. 2007 GN	Mary L – S 2007 GN	Mary L – N 2007 GN	0.91
Camp L. 2008 GN	Sheardown L. 2008 GN	-	-	0.14
Camp L. All GN	Sheardown L. All GN	Mary L – S All GN	Mary L – N All GN	0.67

[1]Differences between two groups tested with a Kruskal-Wallis test at alpha = 0.05.

Table 4-14. Summary statistics for condition factors of Arctic Char captured in standard index gill nets set in Camp Lake, 2006-2008.

Statistic	2006			2007			2008			All Years		
	Males	Females	All	Males	Females	All	Males	Females	All	Males	Females	All
n	11	9	20	3	3	91	9	2	22	23	14	133
Mean	1.00	1.10	1.04	1.06	0.91	0.96	1.03	0.92	1.02	1.02	1.03	0.99
Median	1.01	1.06	1.02	1.04	0.90	0.98	1.01	0.92	0.95	1.01	1.01	0.99
SD	0.13	0.15	0.14	0.08	0.12	0.19	0.16	0.04	0.23	0.14	0.16	0.19
SE	0.04	0.05	0.03	0.05	0.07	0.02	0.05	0.03	0.05	0.03	0.04	0.02
Minimum	0.84	0.89	0.84	1.00	0.80	0.47	0.86	0.89	0.82	0.84	0.80	0.47
Maximum	1.23	1.35	1.35	1.15	1.04	1.43	1.35	0.95	1.67	1.35	1.35	1.67
95^{th} Percentile	1.19	1.32	1.27	1.14	1.02	1.23	1.30	0.95	1.51	1.23	1.29	1.28
COV (%)	12.77	13.39	13.69	7.62	13.11	19.45	15.93	4.66	22.03	13.28	15.00	19.25

Table 4-15. Summary statistics for condition factors of Arctic Char captured during backpack electrofishing (EF) and gillnetting surveys in Sheardown Lake, 2006-2008.

Statistic	2006			2007				2008				All Years			
	Gillnetting			EF	Gillnetting			EF	Gillnetting			EF	Gillnetting		
	Males	Females	All		Males	Females	All		Males	Females	All		Males	Females	All
n	6	2	8	230	12	15	116	36	27	8	68	266	45	25	192
Mean	0.91	0.87	0.90	0.98	0.82	0.86	0.85	1.21	1.04	1.05	1.02	1.01	0.97	0.92	0.91
Median	0.89	0.87	0.87	1.02	0.80	0.90	0.87	1.13	1.03	1.02	1.01	1.02	0.98	0.93	0.93
SD	0.08	0.00	0.07	0.24	0.07	0.11	0.13	0.29	0.09	0.11	0.13	0.26	0.13	0.13	0.15
SE	0.03	0.00	0.02	0.02	0.02	0.03	0.01	0.05	0.02	0.04	0.02	0.02	0.02	0.03	0.01
Minimum	0.83	0.87	0.83	0.44	0.70	0.59	0.54	0.72	0.86	0.93	0.49	0.44	0.70	0.59	0.49
Maximum	1.02	0.88	1.02	2.04	0.93	0.98	1.16	2.02	1.24	1.22	1.51	2.04	1.24	1.22	1.51
95^{th} Percentile	1.01	0.88	1.00	1.36	0.93	0.96	1.05	1.80	1.19	1.21	1.21	1.40	1.17	1.16	1.16
COV (%)	8.37	0.28	7.37	24.04	8.65	12.62	15.06	23.98	8.75	10.35	12.86	25.30	13.37	14.69	16.29

Table 4-16. Summary statistics for condition factors of Arctic Char captured in standard index gill nets set in the north and south basins of Mary Lake, 2006-2007.

Statistic	South Basin									North Basin
	2006			2007			All Years			2007
	Males	Females	All	Males	Females	All	Males	Females	All	
n	26	33	62	14	12	161	40	45	223	98
Mean	1.03	1.00	1.01	0.85	0.86	0.88	0.96	0.96	0.92	0.90
Median	1.02	0.99	0.99	0.86	0.87	0.88	0.88	0.96	0.90	0.91
SD	0.27	0.16	0.21	0.08	0.08	0.11	0.24	0.16	0.16	0.13
SE	0.05	0.03	0.03	0.02	0.02	0.01	0.04	0.02	0.01	0.01
Minimum	0.56	0.77	0.56	0.66	0.71	0.60	0.56	0.71	0.56	0.60
Maximum	1.93	1.64	1.93	1.01	0.98	1.41	1.93	1.64	1.93	1.20
95th Percentile	1.46	1.23	1.39	0.97	0.97	1.04	1.41	1.21	1.15	1.11
COV (%)	26.24	16.42	20.97	9.87	9.08	12.37	24.64	16.45	16.96	14.94

Table 4-17. Comparison of Arctic Char condition factors between sexes and years. Data represent fish captured during backpack electrofishing (EF) and index gillnetting (GN) surveys in study area lakes, 2006-2008. Values in red indicate significant difference at $p < 0.05$.

Lake	Comparison			P value[1]
	Dataset 1	Dataset 2	Dataset 3	
Camp Lake	2006 GN Males	2006 GN Females	-	0.44
	2007 GN Males	2007 GN Females	-	0.38
	2008 GN Males	2008 GN Females	-	0.29
	All Years Males	All Years Females	-	0.79
	2006 GN Males	2007 GN Males	2008 GN Males	0.86
	2006 GN Females	2007 GN Females	2008 GN Females	0.42
	2006 GN All Fish	2007 GN All Fish	2008 GN All Fish	0.85
Sheardown Lake	2006 GN Males	2006 GN Females	-	**< 0.01**
	2007 GN Males	2007 GN Females	-	0.60
	2008 GN Males	2008 GN Females	-	0.85
	All Years GN Males	All Years GN Females	-	0.69
	2006 GN Males	2007 GN Males	2008 GN Males	**< 0.01**
	2006 GN Females	2007 GN Females	2008 GN Females	0.19
	2006 GN All Fish	2007 GN All Fish	2008 GN All Fish	0.67
	2007 EF All Fish	2008 EF All Fish	-	0.49
Mary Lake - S	2006 GN Males	2006 GN Females	-	0.95
	2007 GN Males	2007 GN Females	-	0.42
	All Years Males	All Years Females	-	0.85
	2006 GN Males	2007 GN Males	-	0.33
	2006 GN Females	2007 GN Females	-	0.12
	2006 GN All Fish	2007 GN All Fish	-	0.31

[1]Differences between two groups tested with a Kruskal-Wallis test at alpha = 0.05.

Table 4-18. Inter-lake comparisons of condition factors of Arctic Char captured during index gillnetting surveys, 2006-2008.

Comparison				P value[1]
Dataset 1	Dataset 2	Dataset 3	Dataset 4	
Camp L. 2006 GN	Sheardown L. 2006 GN	Mary L – S 2006 GN	-	0.51
Camp L. 2007 GN	Sheardown L. 2007 GN	Mary L – S 2007 GN	Mary L – N 2007 GN	0.84
Camp L. 2008 GN	Sheardown L. 2008 GN	-	-	0.63
Camp L. All GN	Sheardown L. All GN	Mary L – S All GN	Mary L – N All GN	0.85

[1]Differences between two groups tested with a Kruskal-Wallis test at alpha = 0.05.

Table 4-19. Summary statistics for catch-per-unit-effort (#fish/24 hours/100 m net) of Arctic Char captured in standard index gill nets deployed in Mine Area lakes, 2006-2008.

Statistic	Camp Lake				Sheardown Lake				Mary Lake – South Basin			Mary Lake – North Basin
	2006	2007	2008	All	2006	2007	2008	All	2006	2007	All	Males
n	2	21	14	36	1	14	8	23	2	24	26	8
Mean	13.4	41.8	10.1	29.0	13.8	92.8	57.8	77.2	27.1	73.4	69.9	175.2
Median	13.4	34.9	10.0	18.0	-	55.6	41.8	53.9	27.1	66.2	64.4	169.1
SD	5.0	37.5	8.4	32.6	-	86.3	64.0	78.6	12.4	55.5	54.7	59.8
SE	3.5	8.2	2.2	5.4	-	23.1	22.6	16.4	8.7	11.3	10.7	21.1
Minimum	9.9	0.0	0.0	0.0	13.8	0.0	0.0	0.0	18.4	0.0	0.0	78.8
Maximum	16.9	157.2	22.9	157.2	13.8	314.4	189.9	314.4	35.9	216.7	216.7	286.3
95th Percentile	16.5	99.8	21.4	86.1	-	219.0	158.3	187.6	35.0	159.9	159.2	259.7
COV (%)	37.1	89.7	83.2	112.4	-	93.0	110.8	101.9	45.6	75.6	78.3	34.1

Table 4-20. Comparison of catch-per-unit-effort (#fish/24 hours/100 m net) of Arctic Char between years. Data represent fish captured during backpack electrofishing (EF) and index gillnetting (GN) surveys in study area lakes, 2006-2008. Values in red indicate significant difference at p < 0.05.

Lake	Comparison			P value[1]
	Dataset 1	Dataset 2	Dataset 3	
Camp Lake	2006 GN All Fish	2007 GN All Fish	2008 GN All Fish	**< 0.01**
Sheardown Lake	2007 GN All Fish	2008 GN All Fish	-	0.23
	2007 EF All Fish	2008 EF All Fish	-	**< 0.01**
Mary Lake - S	2006 GN All Fish	2007 GN All Fish	-	**< 0.01**

[1]Differences between two groups tested with a Kruskal-Wallis test at alpha = 0.05.

Table 4-21. Inter-lake comparisons of catch-per-unit-effort (#fish/24 hours/100 m net) of Arctic Char captured during index gillnetting surveys, 2006-2008. Values in red indicate significant difference at p < 0.05.

Comparison				P value[1]
Dataset 1	Dataset 2	Dataset 3	Dataset 4	
Camp L. 2006 GN	Mary L – S 2006 GN	-	-	**< 0.01**
Camp L. 2007 GN	Sheardown L. 2007 GN	Mary L – S 2007 GN	Mary L – N 2007 GN	**0.02**
Camp L. 2008 GN	Sheardown L. 2008 GN	-	-	**< 0.01**
Camp L. All GN	Sheardown L. All GN	Mary L – S All GN	Mary L – N All GN	**0.01**

[1]Differences between two groups tested with a Kruskal-Wallis test at alpha = 0.05.

Table 4-22. Summary statistics for age of Arctic Char captured during standard index gillnetting and backpack electrofishing surveys in selected mine area lakes and in the Mary River, 2006-2008.

Statistic	Camp Lake	Sheardown Lake	Mary Lake	Mary River	All Waterbodies
n	28	35	97	29	189
Mean	9.5	13.3	13.2	2.6	11.1
Median	9	13	13	2	11
SD	3.7	4.5	3.6	0.9	5.2
SE	0.7	0.8	0.4	0.2	0.4
Minimum	4	5	7	2	2
Maximum	19	22	24	5	24
95th Percentile	16.7	21	19.4	4.6	19
COV (%)	39.2	33.8	27.5	33.5	47.3

Table 4-23. Length and weight-at-age for Arctic Char pooled from all Study Area waterbodies, 2006-2008.

Age	Fork Length (mm)				Weight (g)			
	n	Mean	SD	Range	n	Mean	SD	Range
2	17	88	12	63 - 108	17	10	4	4 - 18
3	9	106	13	86 - 128	9	17	7	7 - 28
4	2	179	69	130 - 228	2	92	82	33 - 150
5	5	189	44	149 - 240	4	92	53	44 - 150
6	4	186	13	170 - 197	4	69	24	50 - 100
7	7	228	46	171 - 301	7	125	76	50 - 275
8	9	246	59	172 - 331	9	178	90	75 - 300
9	15	273	48	192 - 351	15	210	111	75 - 450
10	14	294	78	167 - 496	14	300	306	50 - 1300
11	19	337	63	181 - 465	19	400	230	75 - 1100
12	12	364	39	312 - 451	12	473	154	275 - 800
13	13	398	107	241 - 658	13	685	625	100 - 2450
14	12	404	81	315 - 615	12	756	573	325 - 2300
15	11	390	17	370 - 418	11	525	51	450 - 600
16	16	404	43	357 - 490	16	608	232	350 - 1200
17	7	488	98	354 - 647	7	1114	691	350 - 2400
18	4	385	8	373 - 391	4	494	94	375 - 600
19	5	541	143	384 - 751	5	1985	1753	525 - 4900
20	0	-	-	-	-	-	-	-
21	3	440	62	387 - 508	3	608	163	450 - 775
22	1	507	-	-	1	1000	-	-
23	3	529	93	424 - 602	3	1408	610	725 - 1900
24	1	685	-	-	1	2350	-	-
Total	189	316	136	63 - 751	188	462	570	4 - 4900

Table 4-24. Results of Analysis of Covariance (ANCOVA) tests of length and weight-at-age for Arctic Char captured in Study Area waterbodies.

Statistic	Degrees of Freedom	R^2	Sum of Squares	Mean Squares	Pr > F[1]
Length	157	0.581	1544.568	772.284	< 0.0001
Weight	156	0.351	913.208	456.604	< 0.0001

[1] Fisher's F-test significance

Table 4-25. Results of power analyses for selected Arctic Char metrics for Sheardown Lake.

Effect Indicator	Metric	Effect Size	Sample Size @ $\beta = 0.1$
Growth	Age 0+ Length	10%	25
		20%	8
		25%	6
	Age 1+ Length	10%	11
		20%	4
		25%	3
	Age 1+ Weight	10%	250
		20%	62
		25%	42
Condition	Age 1+ Condition	10%	9
		20%	3
		25%	3

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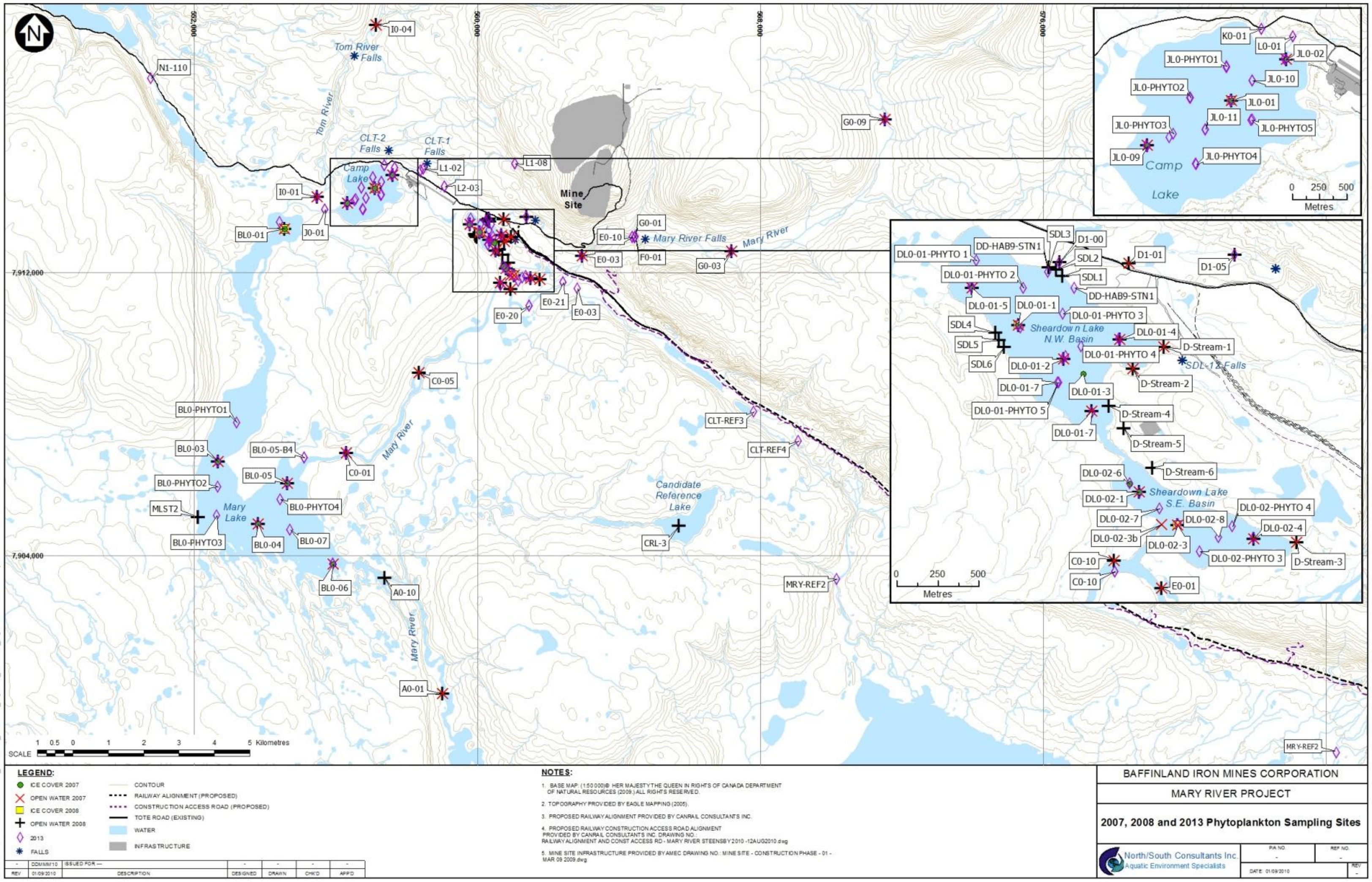
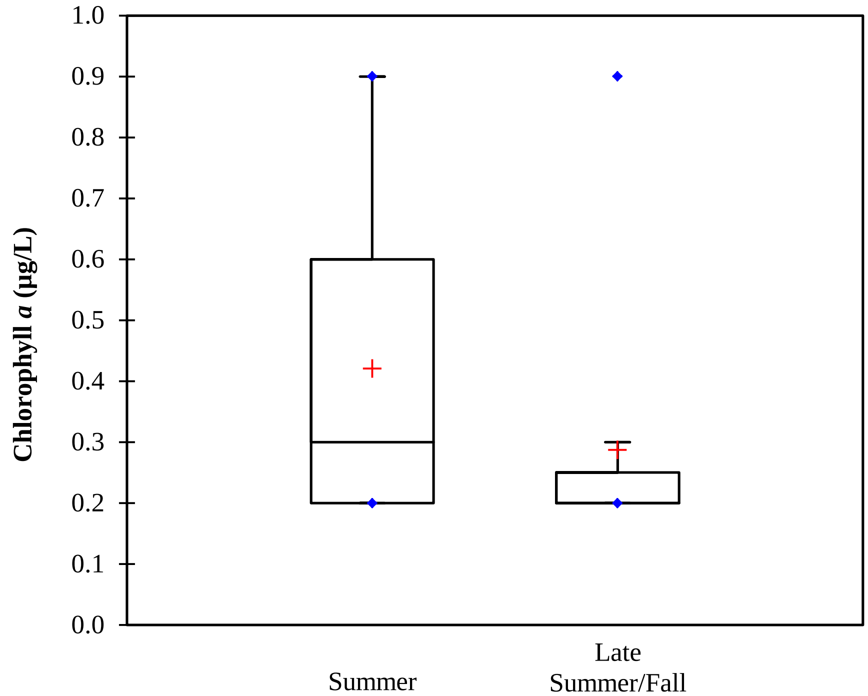


Figure 2-1. Locations of sites where phytoplankton taxonomy and biomass and/or chlorophyll *a* were measured in Mine Area lakes and streams: 2007-2013.

(A)



(B)

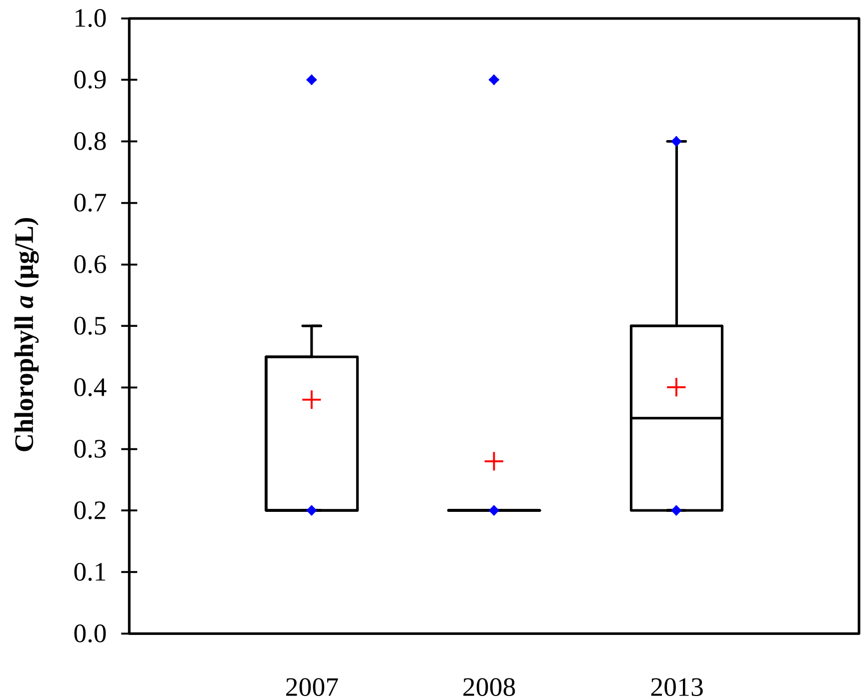


Figure 2-2. Box plots of chlorophyll *a* measured in Sheardown Lake NW by (A) sampling period and (B) sampling year. Data include offshore sampling measurements collected in summer and late summer/fall in 2007, 2008, and 2013.

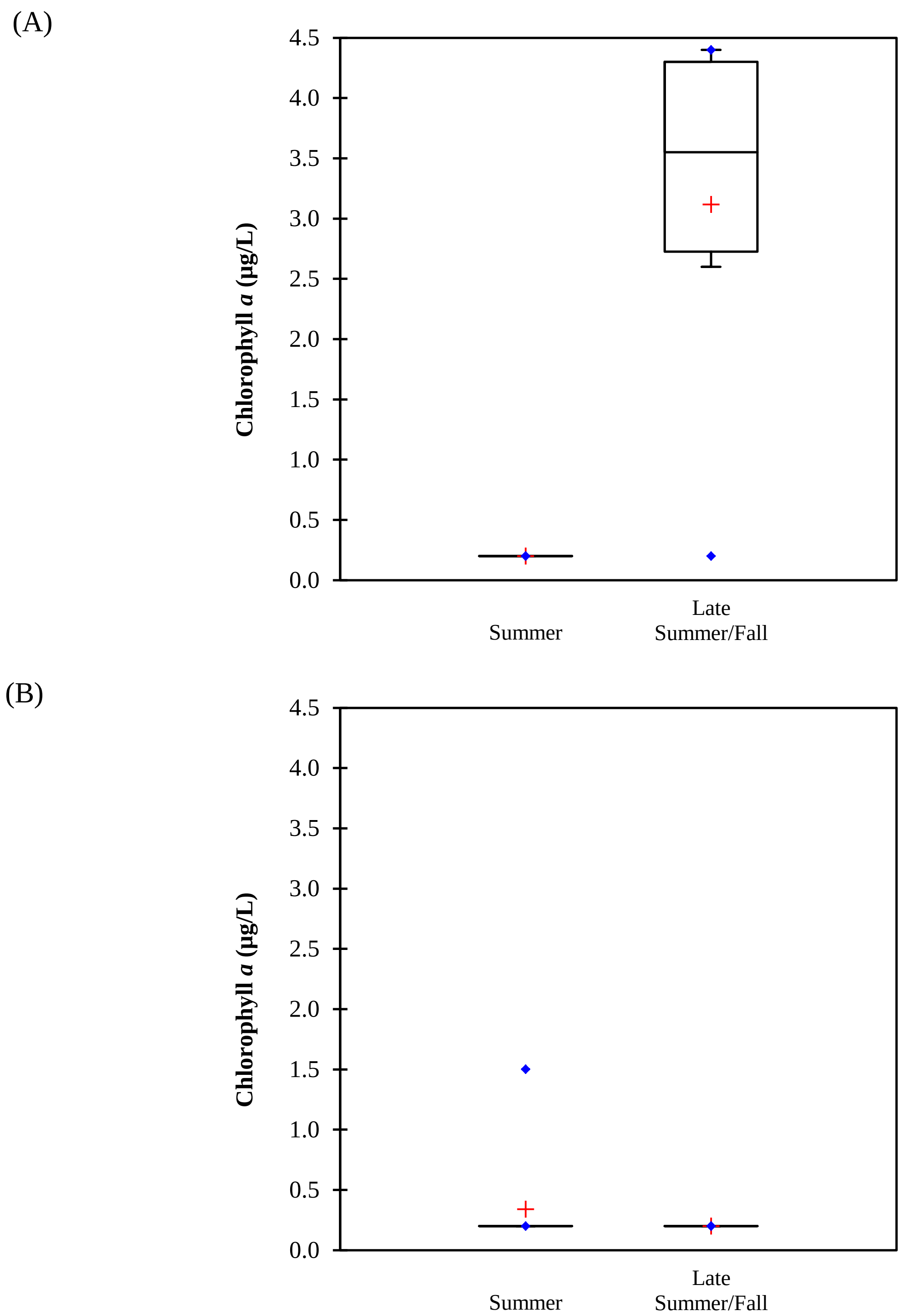


Figure 2-3. Comparisons of chlorophyll *a* measured in Sheardown Lake (A) nearshore sites and (B) offshore sites. Data include measurements collected in summer and late summer/fall in 2008.

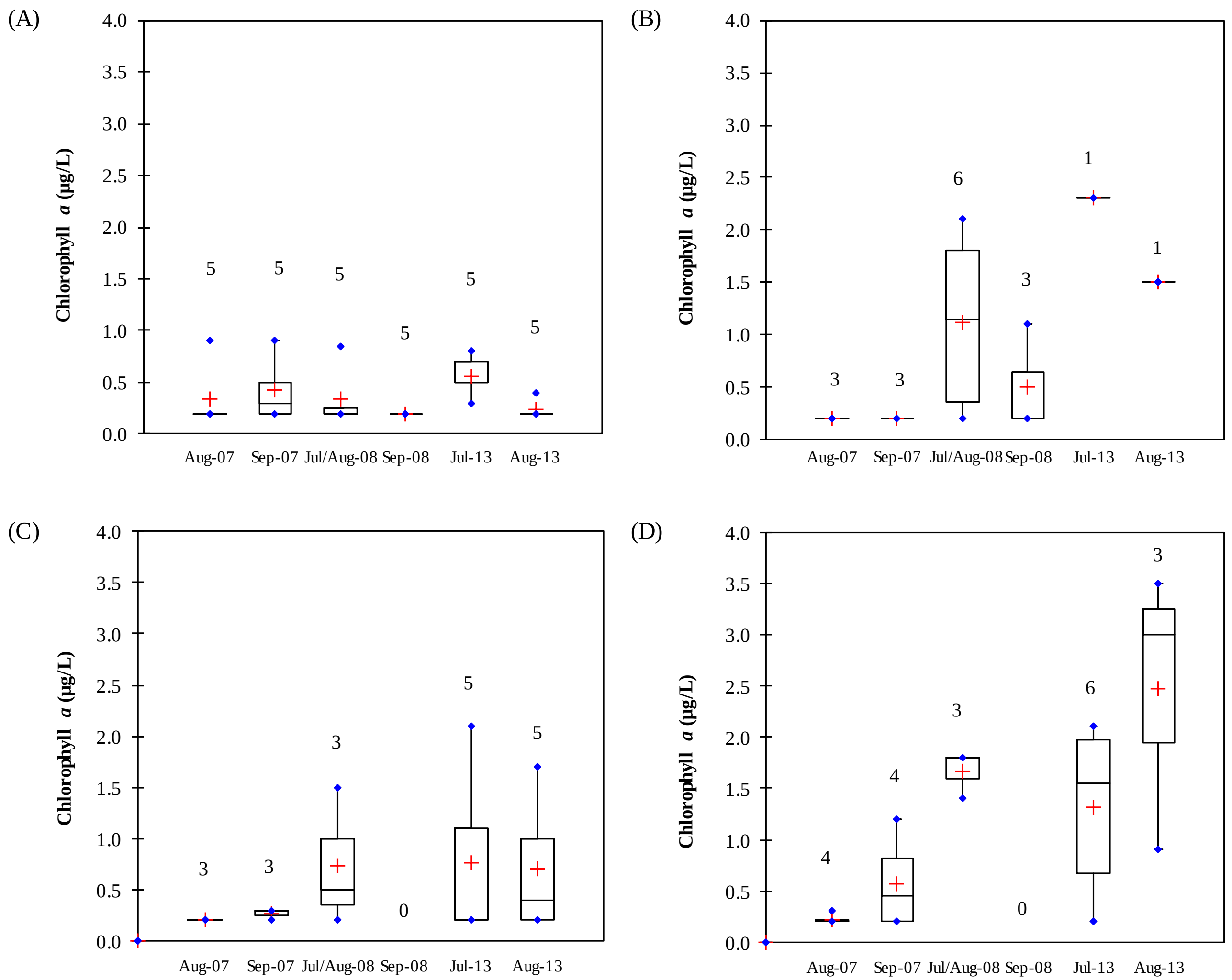


Figure 2-4. Comparisons of chlorophyll *a* measured in the open-water season of 2007, 2008, and 2013: (A) Sheardown Lake NW; (B) Sheardown Lake SE; (C) Camp Lake; and (D) Mary Lake. Where two samples were collected in summer 2008 (Sheardown Lake NW and SE), the data points were averaged to normalize sample sizes. Sample sizes are indicated above each box.

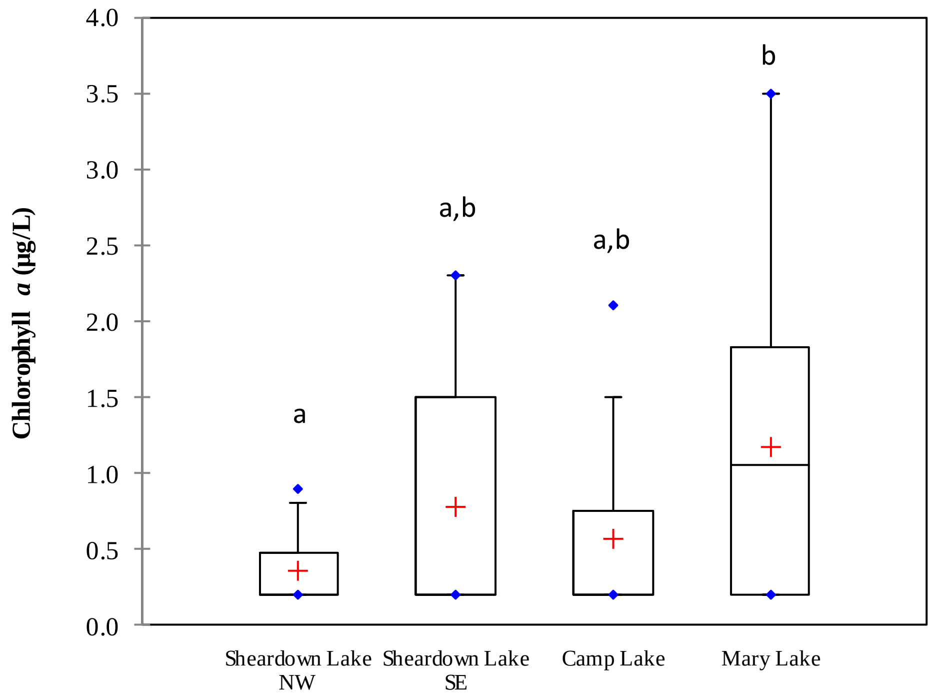


Figure 2-5. Chlorophyll *a* measured in Mine Area lakes: 2007-2013. Statistically significant spatial differences are denoted with different superscripts ($p < 0.05$).

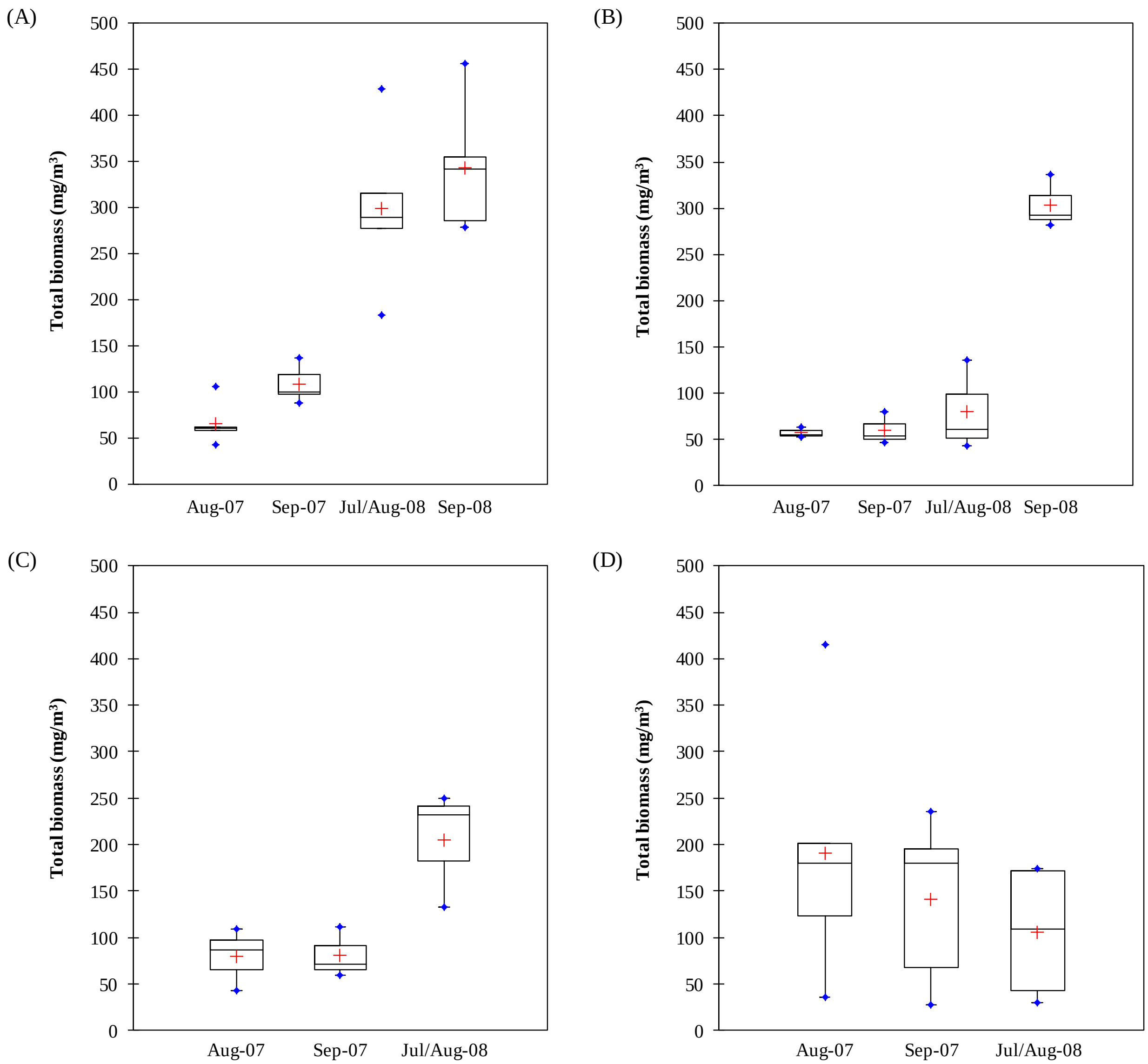


Figure 2-6. Total biomass of phytoplankton measured by sampling period in Mine Area lakes, 2007-2008: (A) Sheardown Lake NW; (B) Sheardown Lake SE; (C) Camp Lake; and (D) Mary Lake.

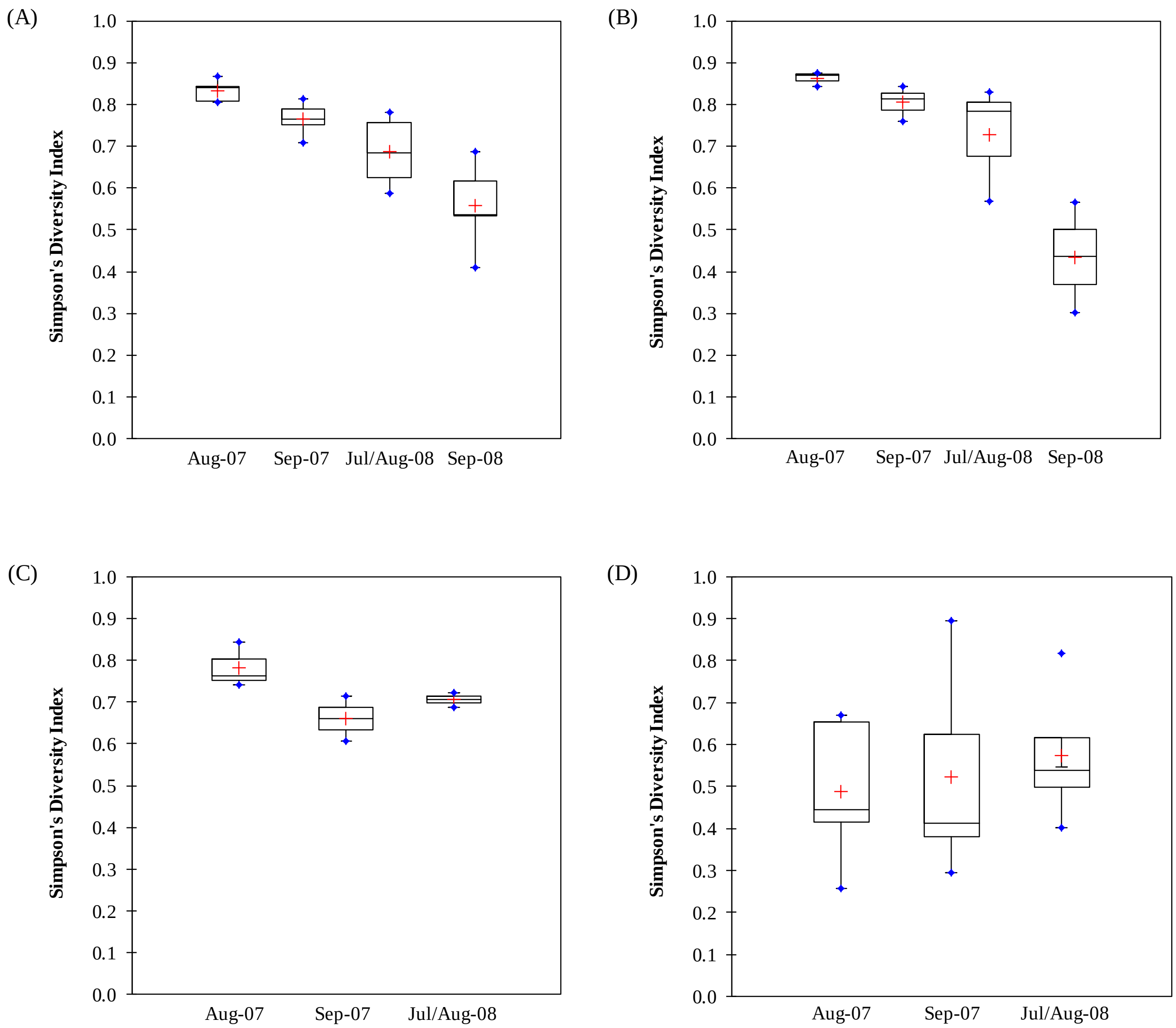


Figure 2-7. Phytoplankton Simpson's Diversity Index by sampling period in Mine Area lakes, 2007-2008: (A) Sheardown Lake NW; (B) Sheardown Lake SE; (C) Camp Lake; and (D) Mary Lake.

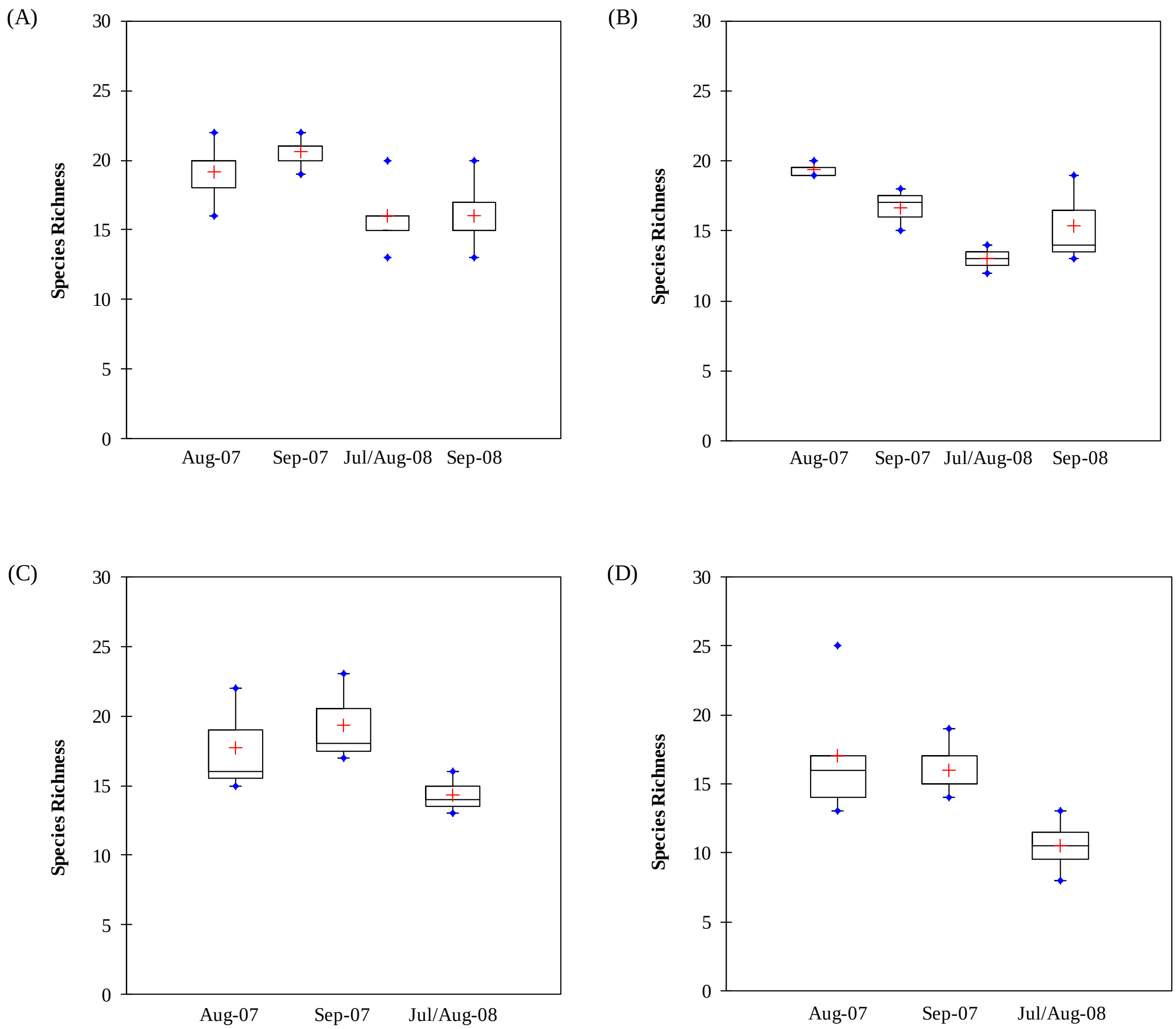


Figure 2-8. Phytoplankton species richness by sampling period in Mine Area lakes, 2007-2008: (A) Sheardown Lake NW; (B) Sheardown Lake SE; (C) Camp Lake; and (D) Mary Lake.

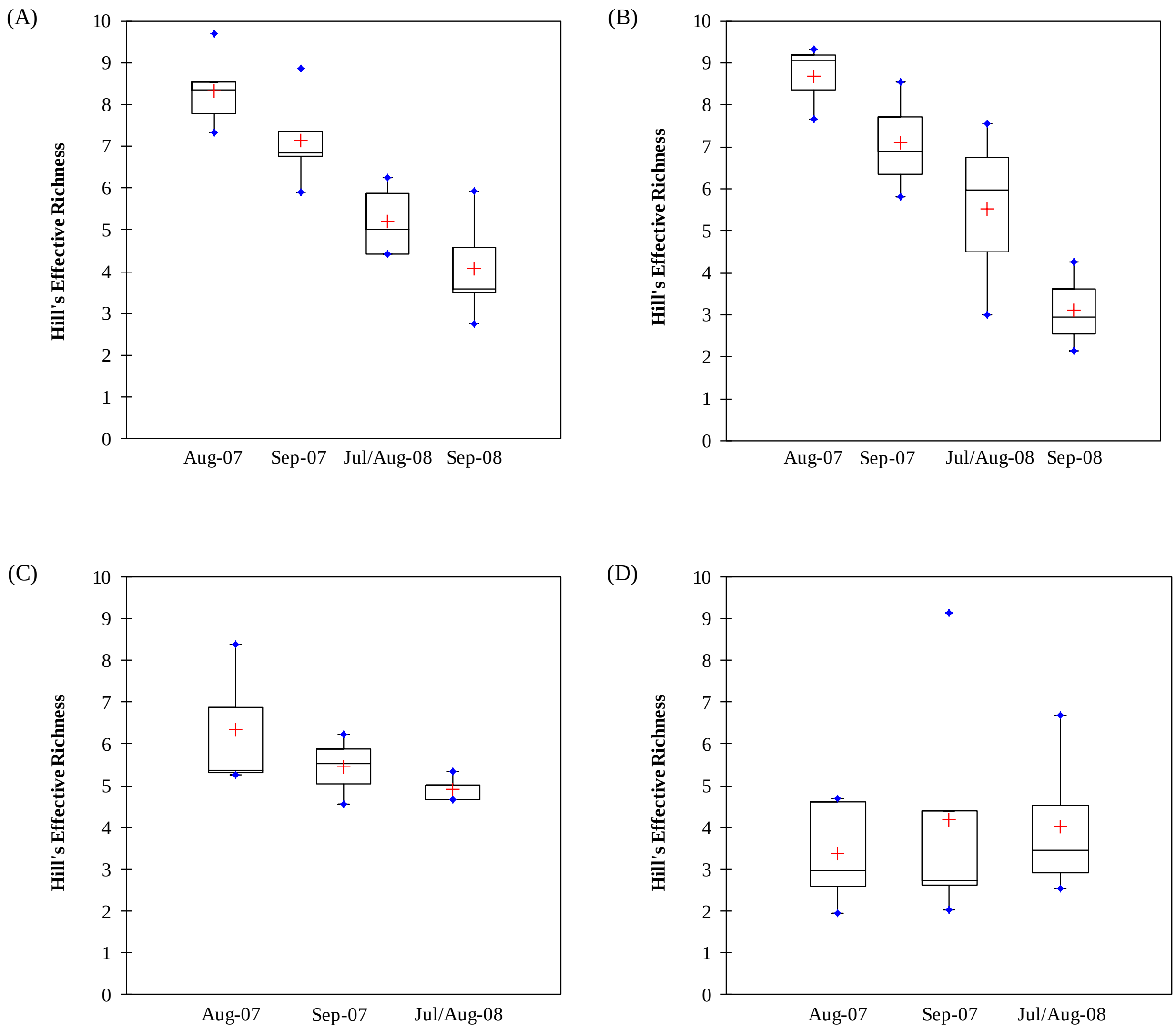
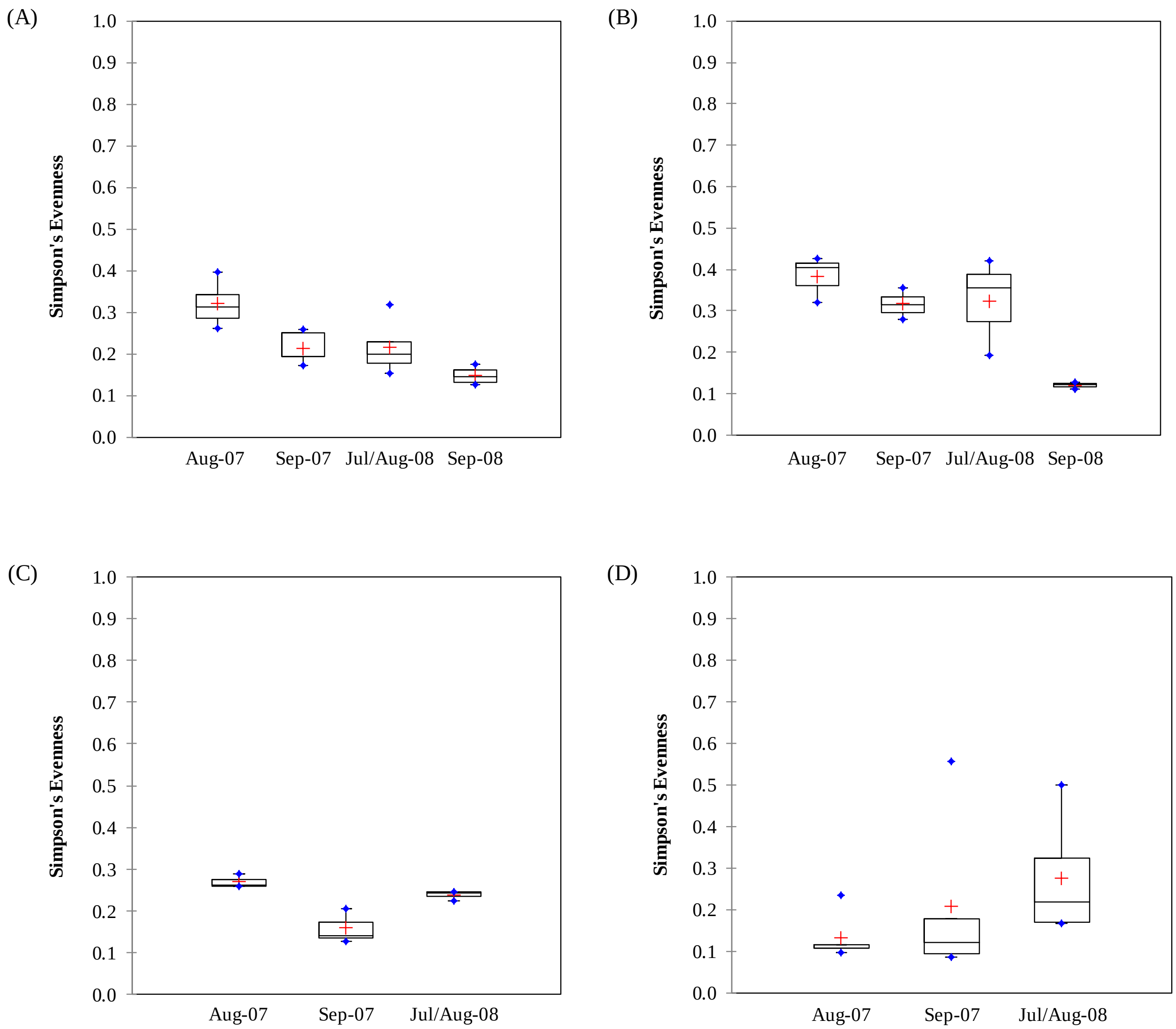


Figure 2-9. Phytoplankton Hill's effective richness by sampling period in Mine Area lakes, 2007-2008: (A) Sheardown Lake NW; (B) Sheardown Lake SE; (C) Camp Lake; and (D) Mary Lake.



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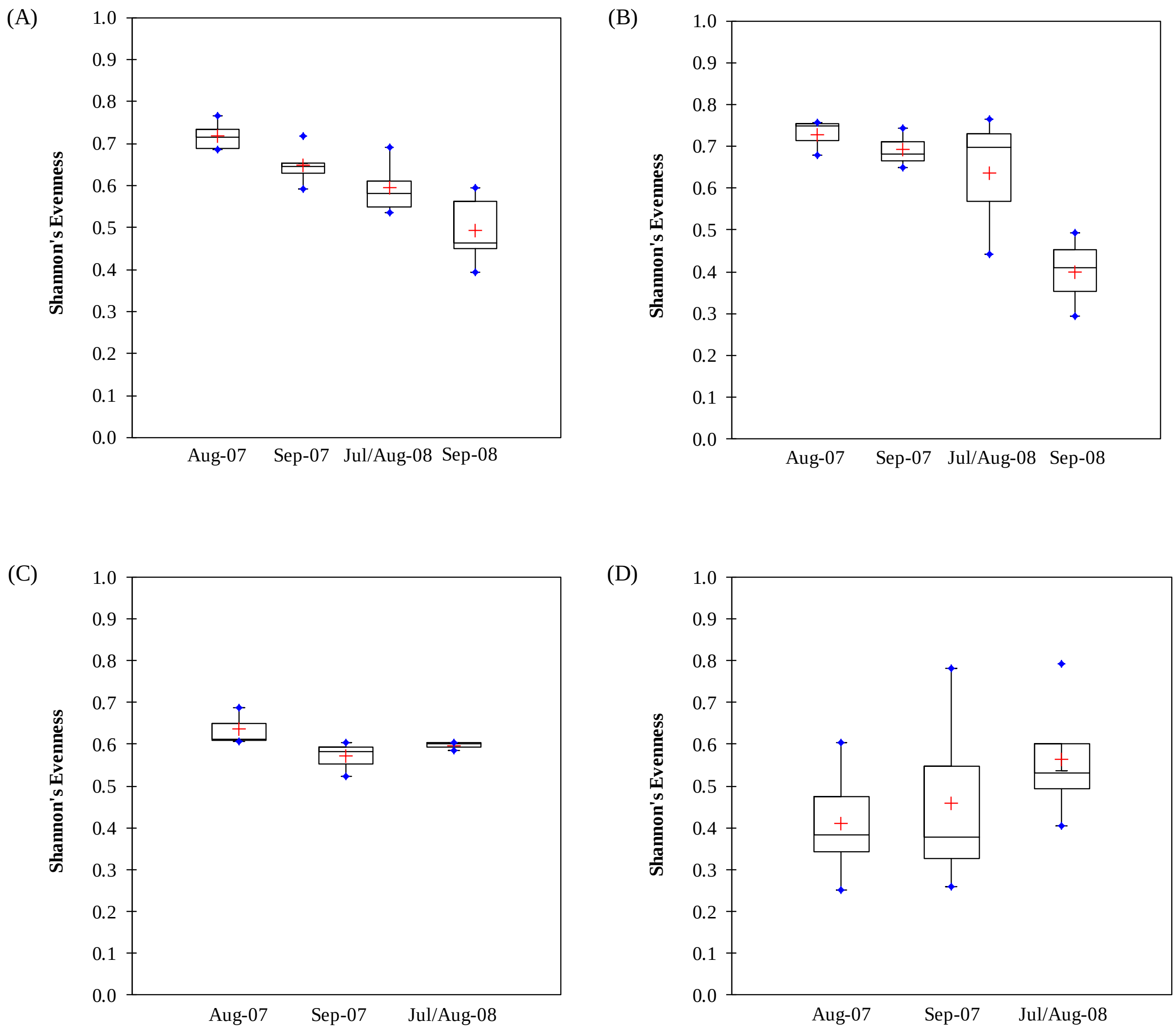

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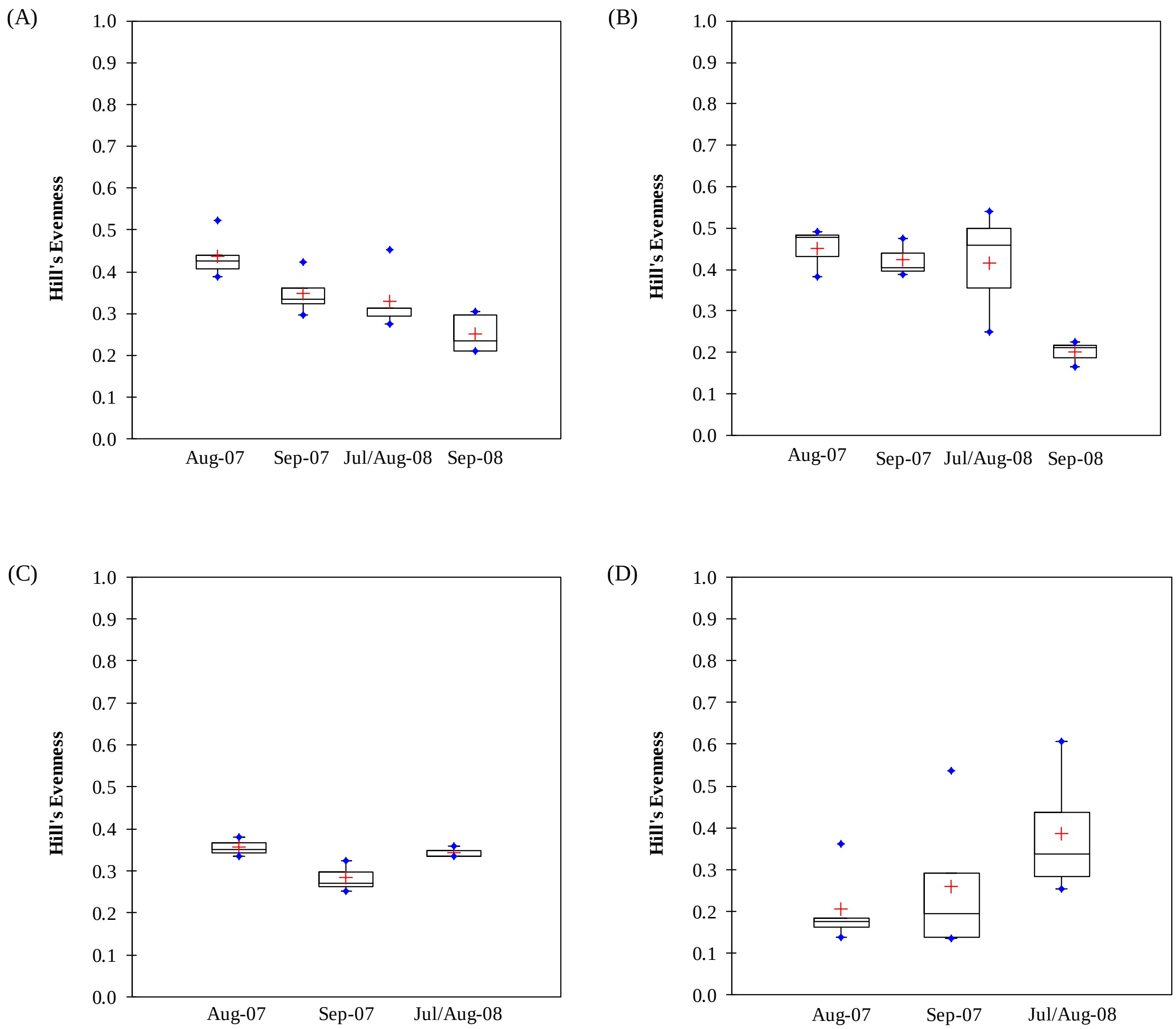

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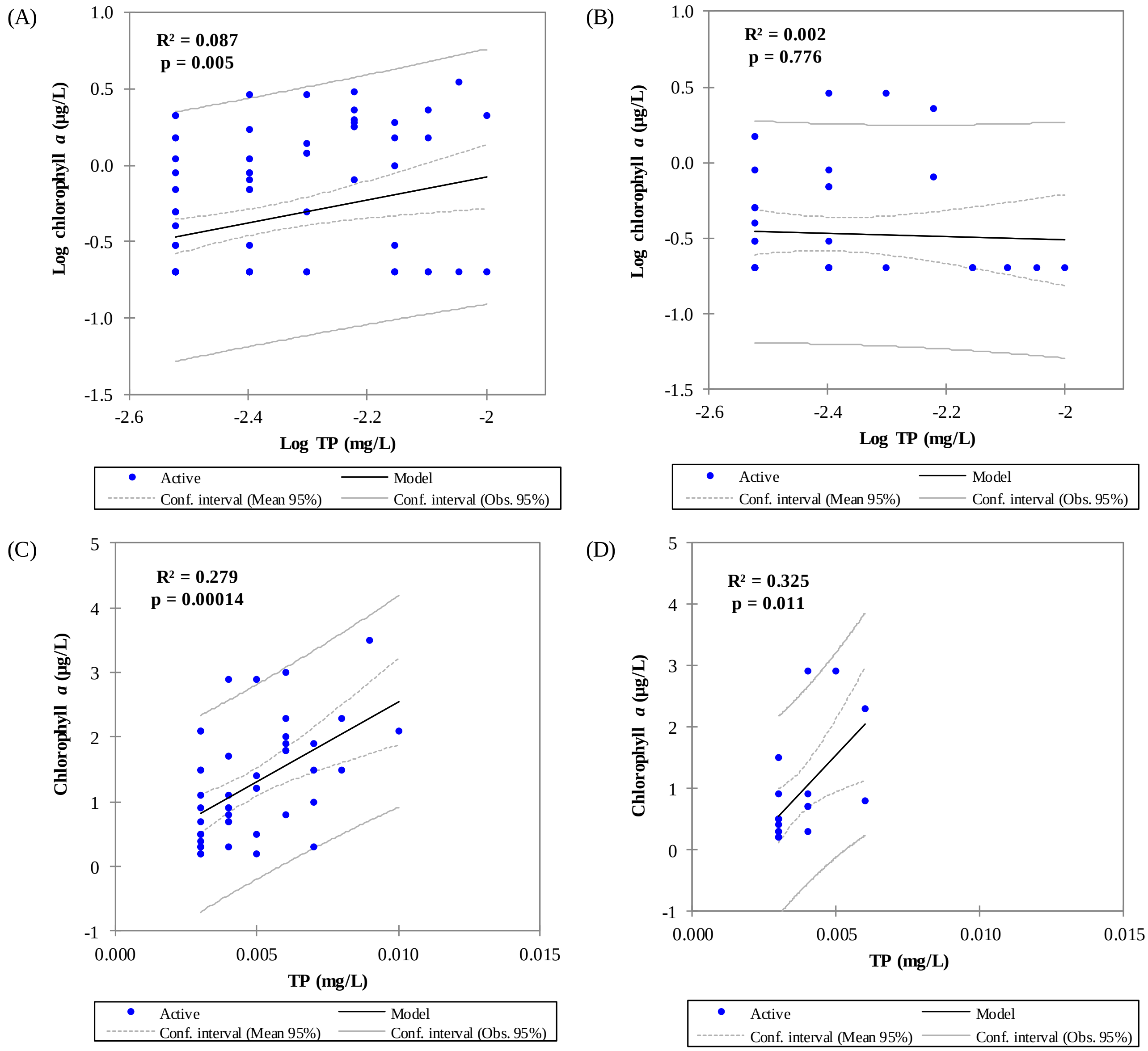

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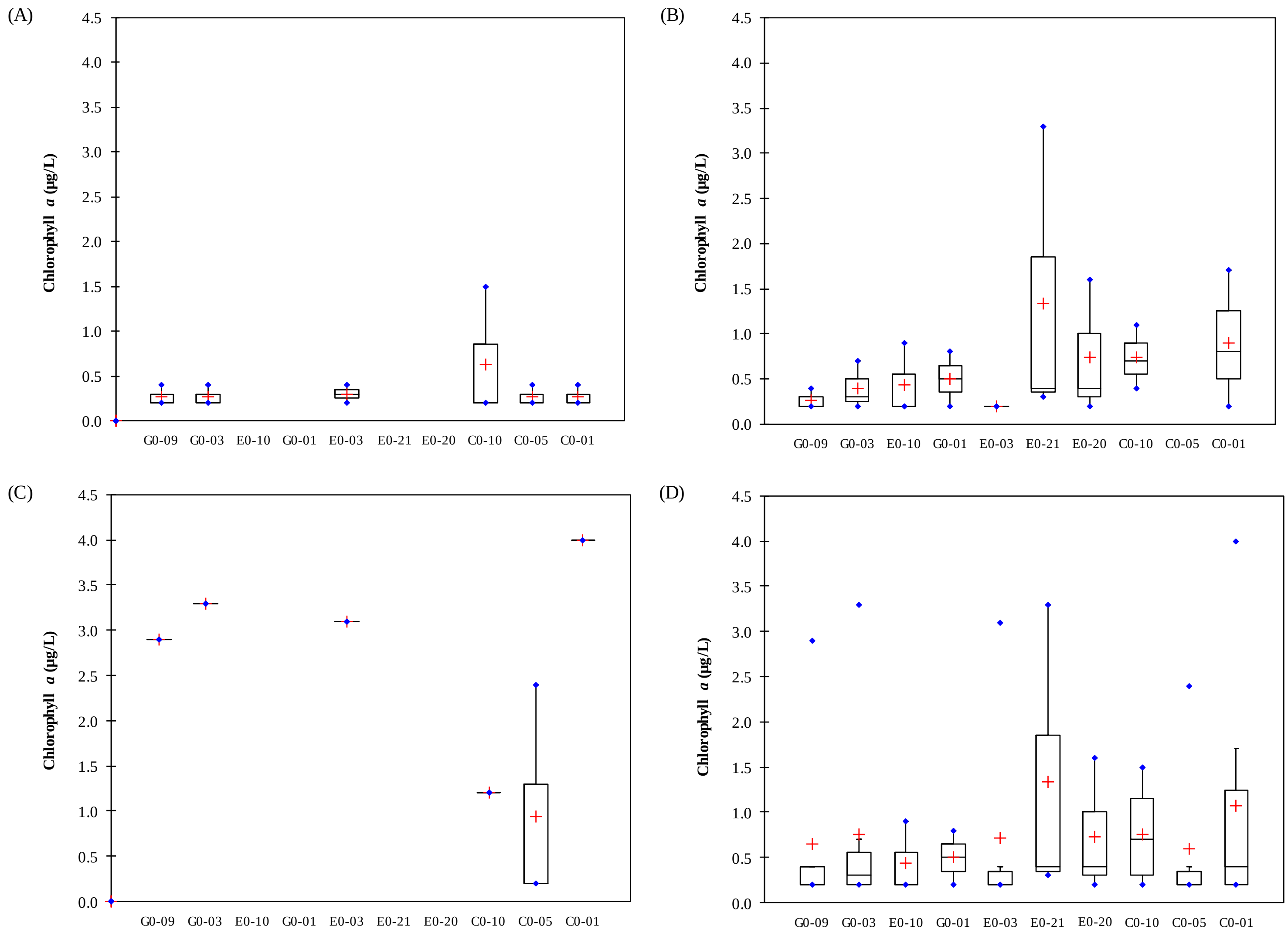

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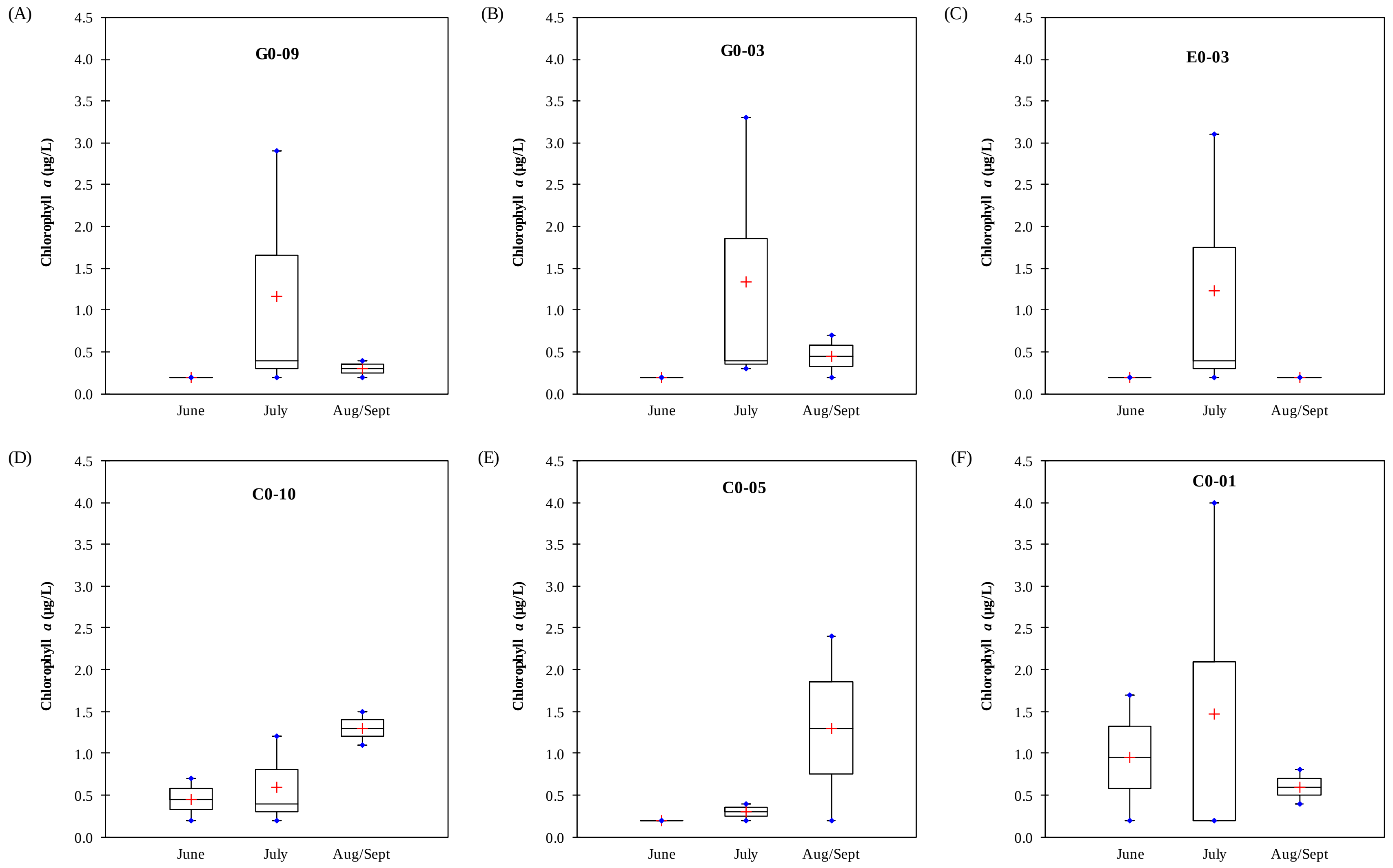

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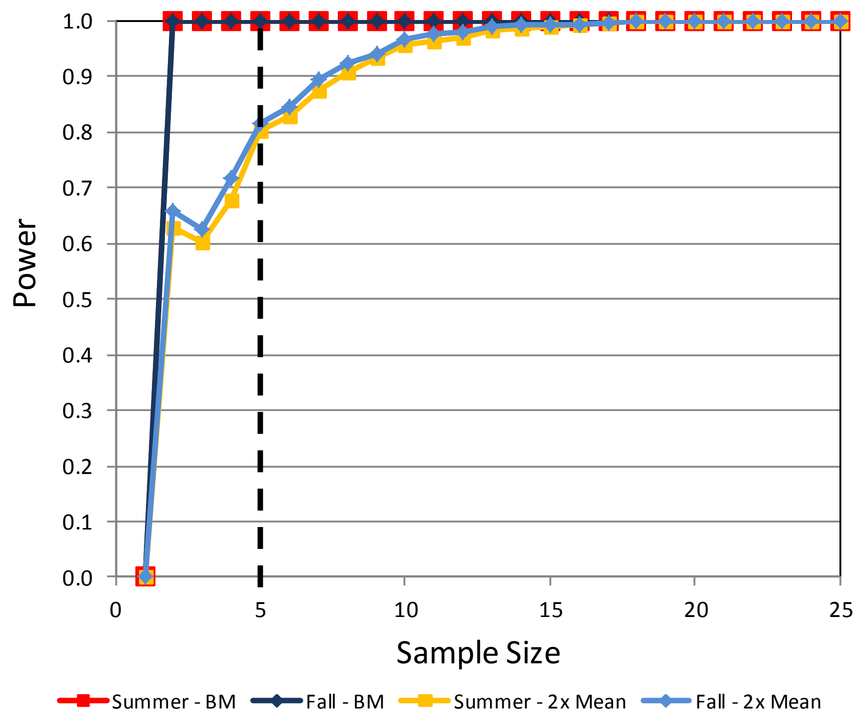
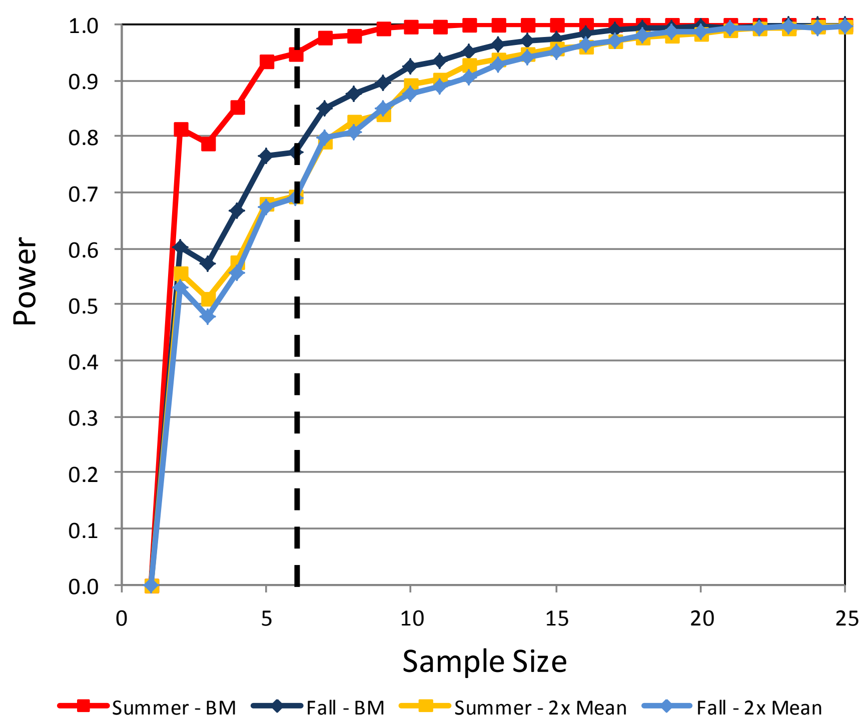
(A)



(B)



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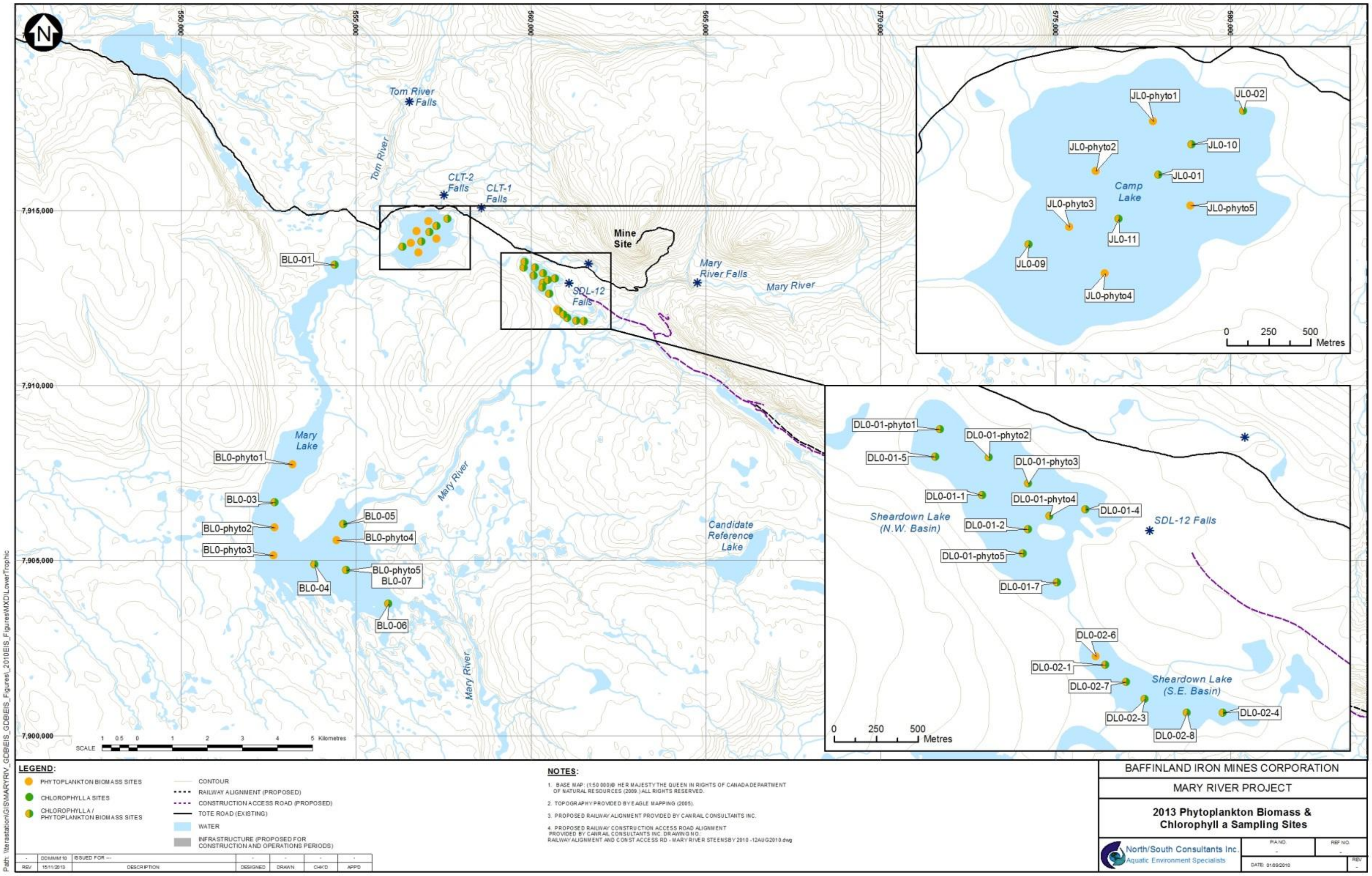

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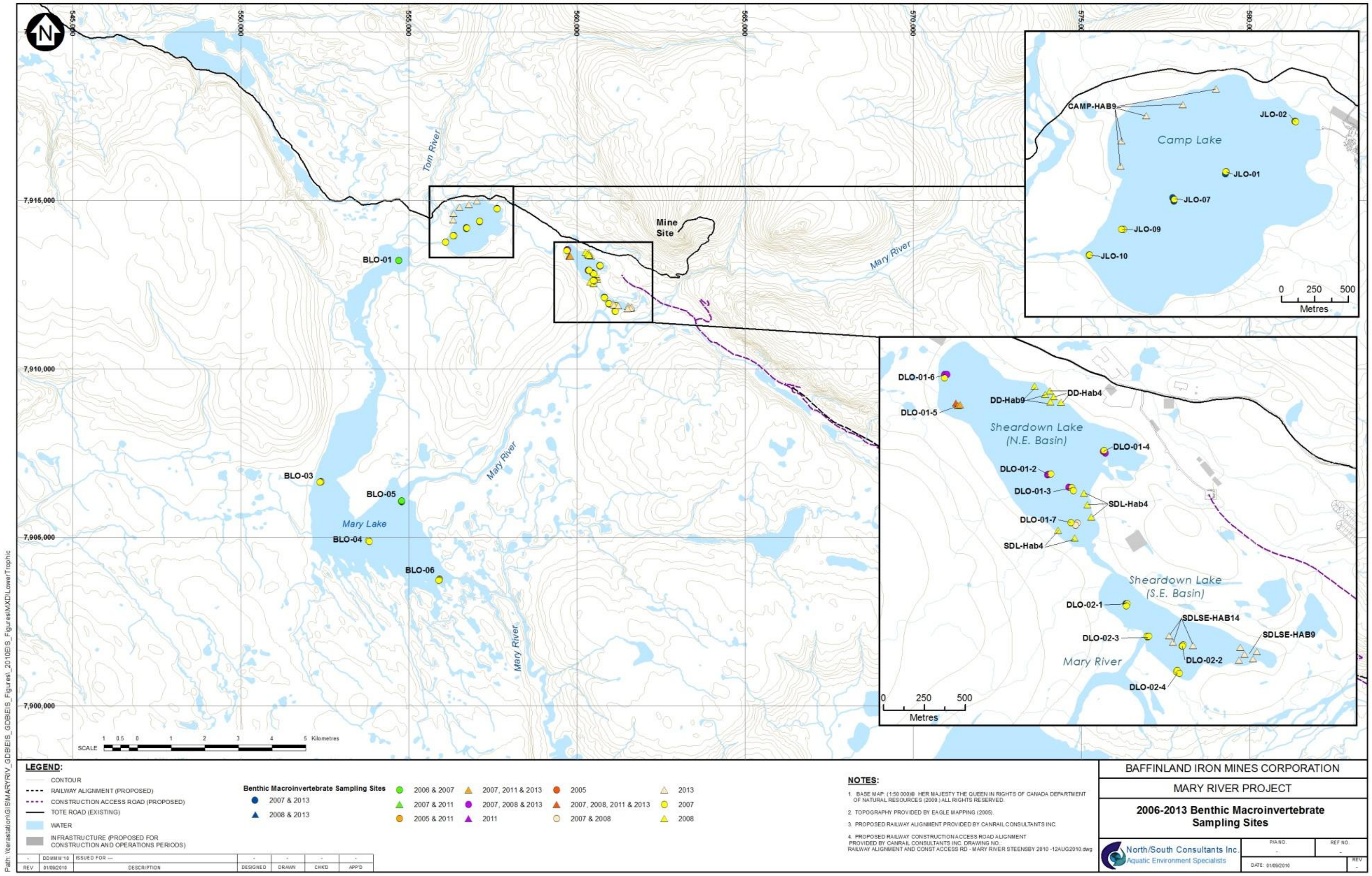
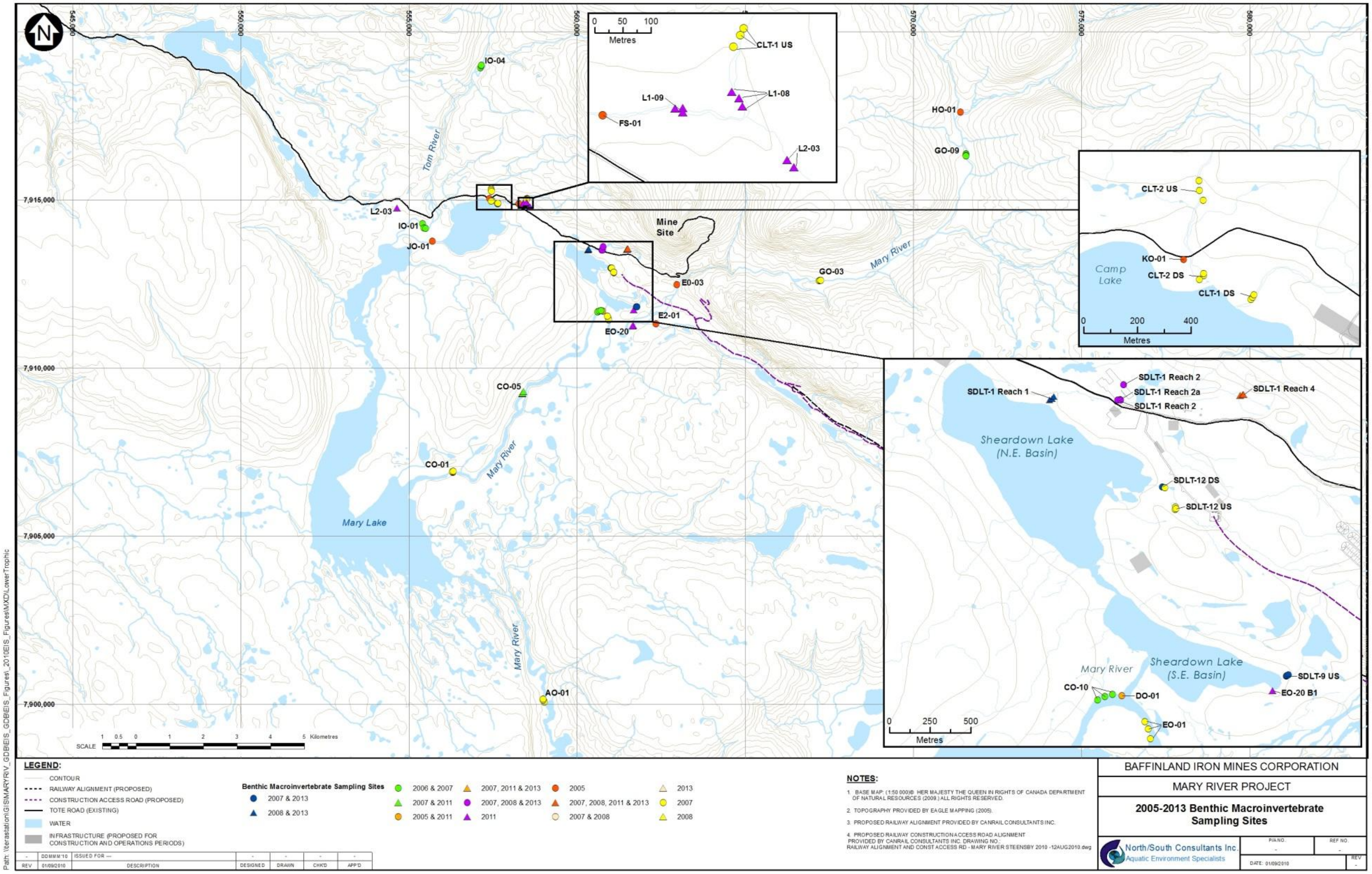


Figure 3-1. Benthic invertebrate sampling sites in Mine Area lakes.



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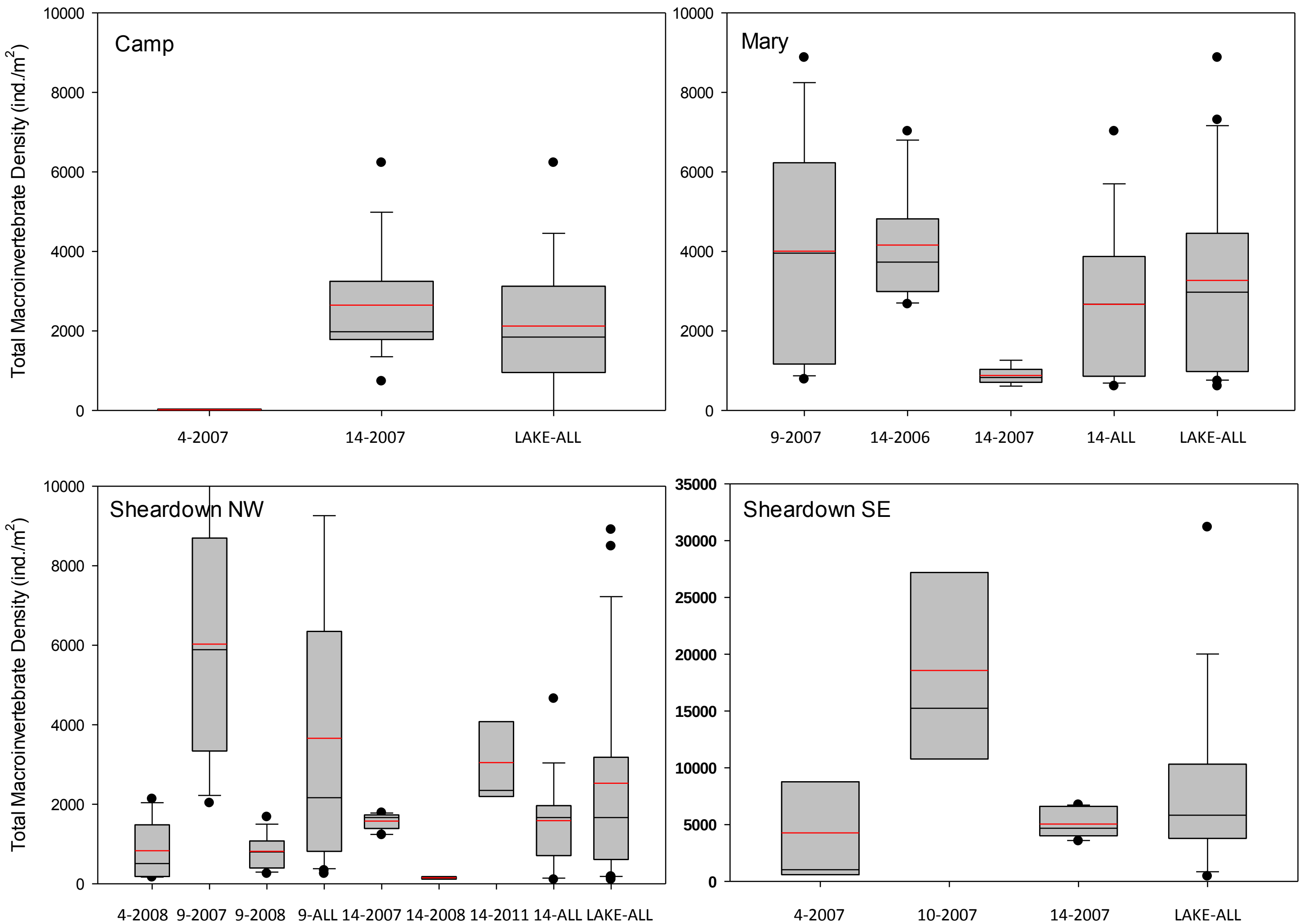

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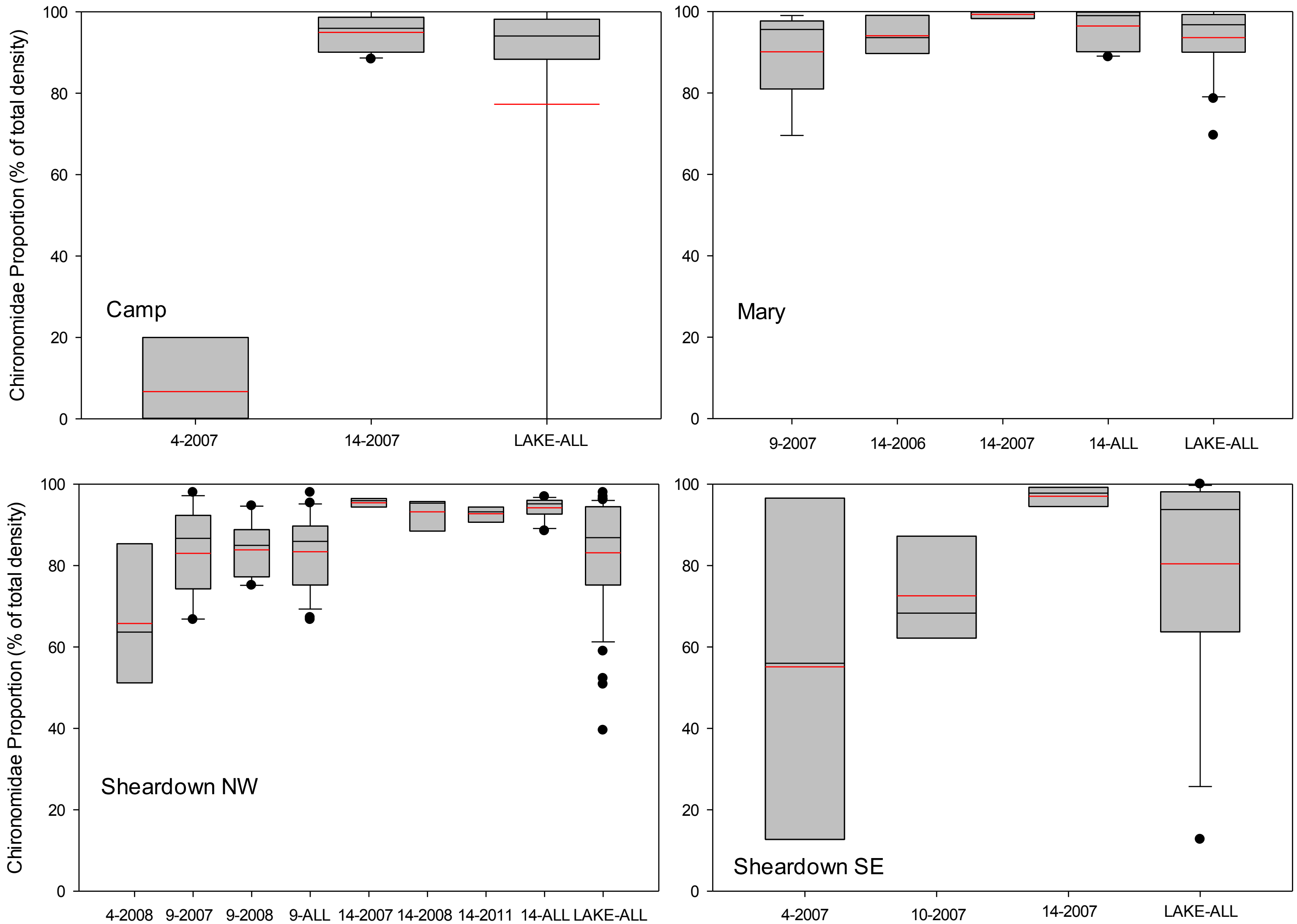

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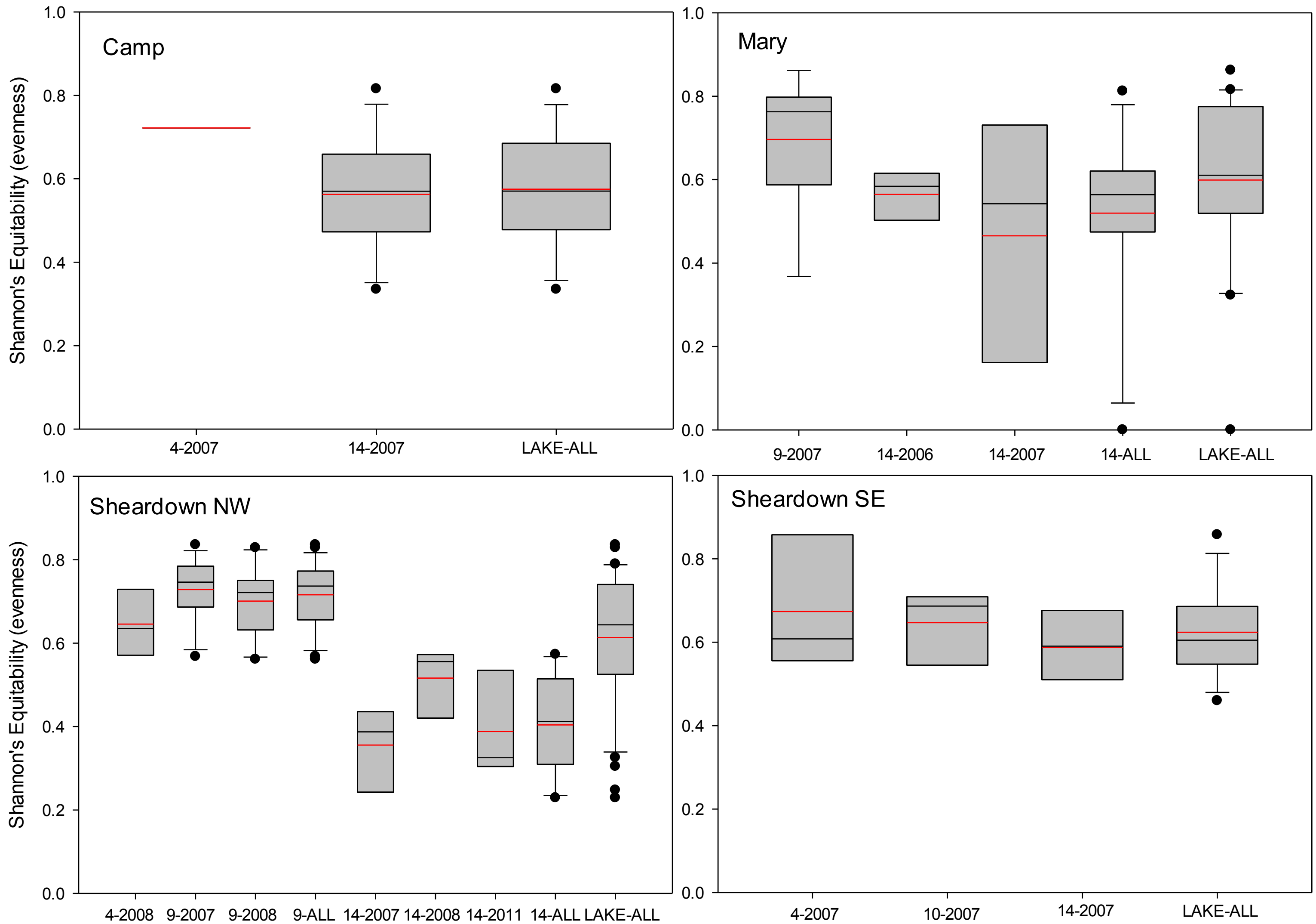

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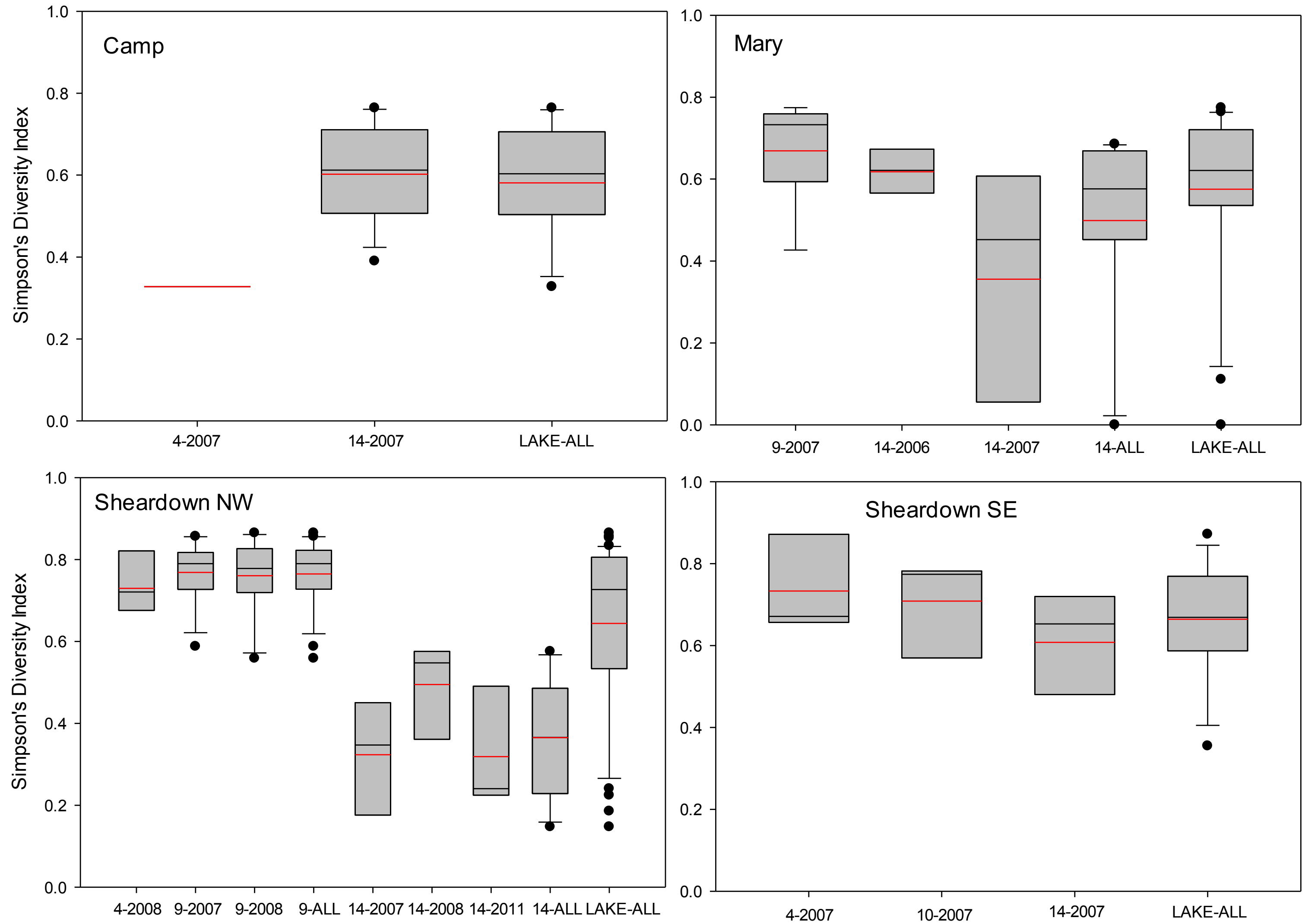

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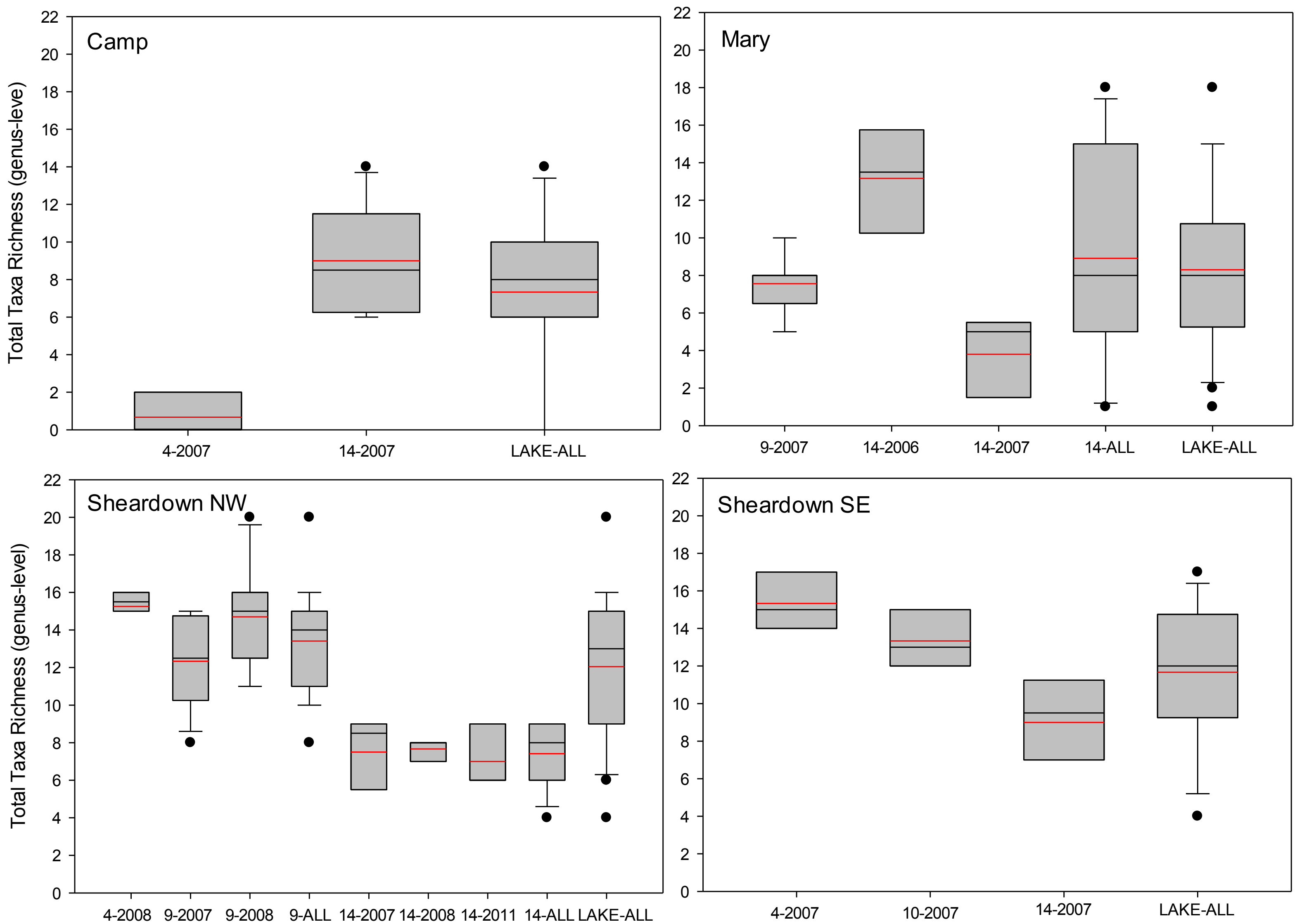

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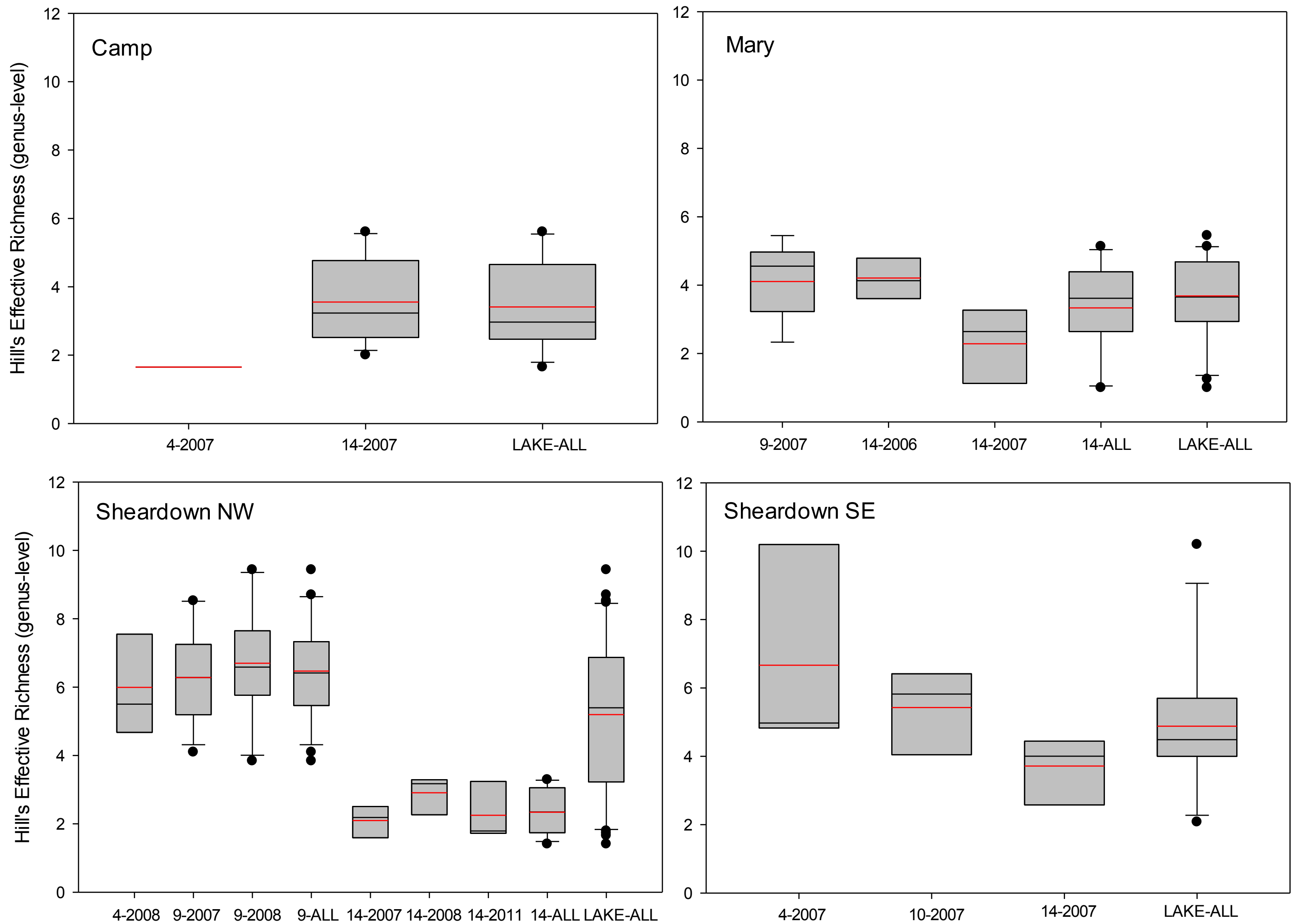

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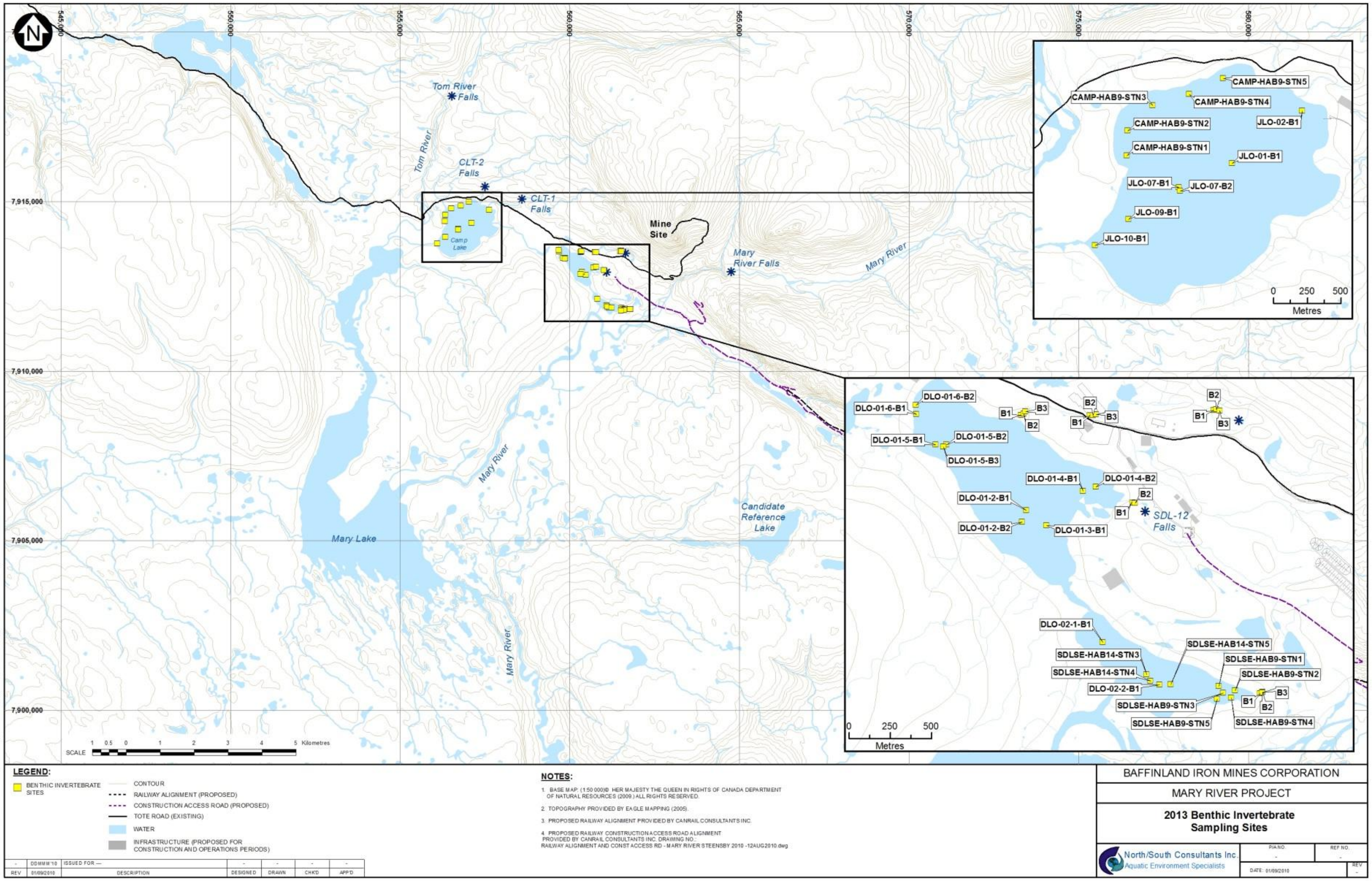
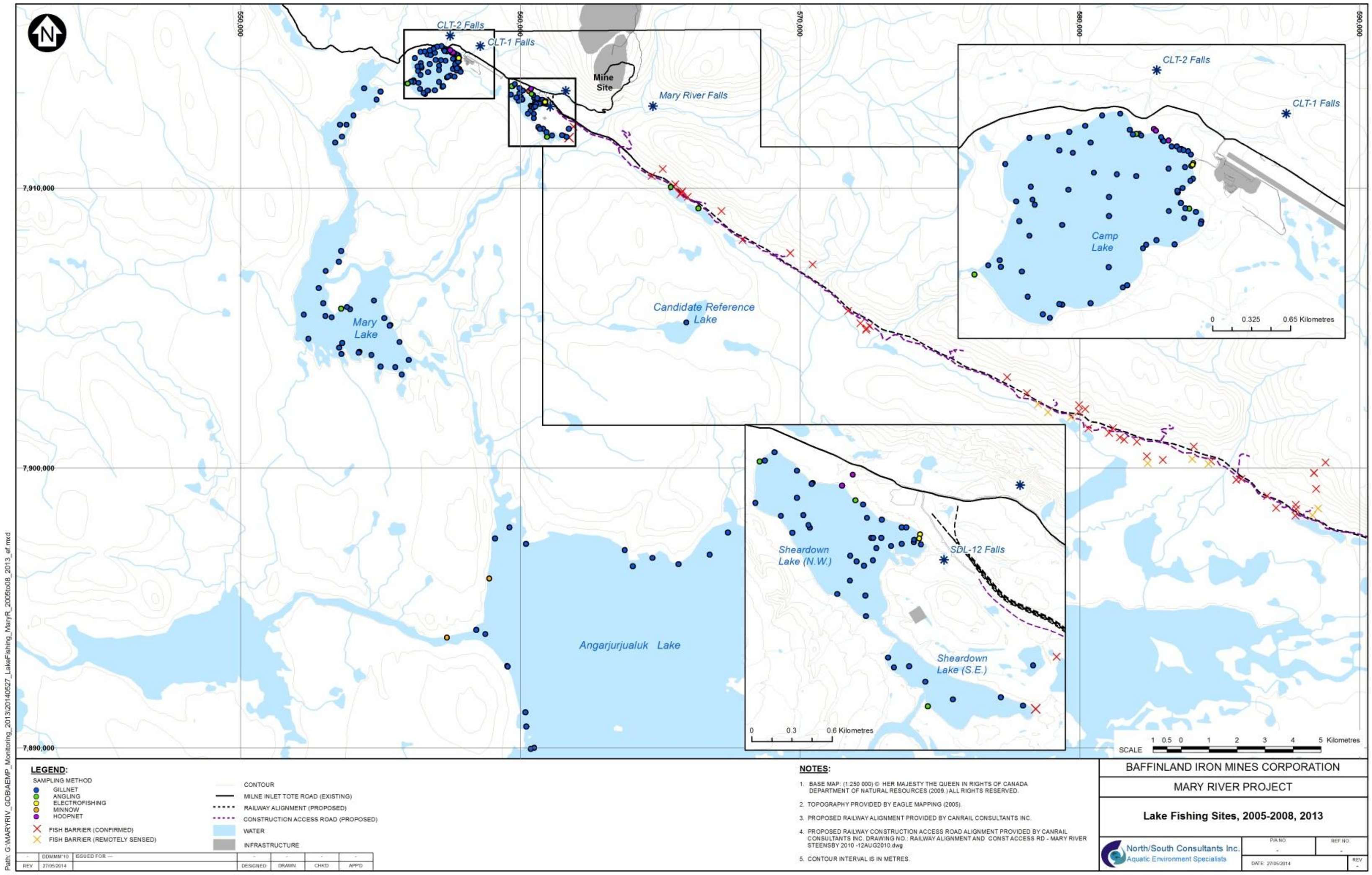


Figure 3-9. Benthic invertebrate sampling sites: 2013.



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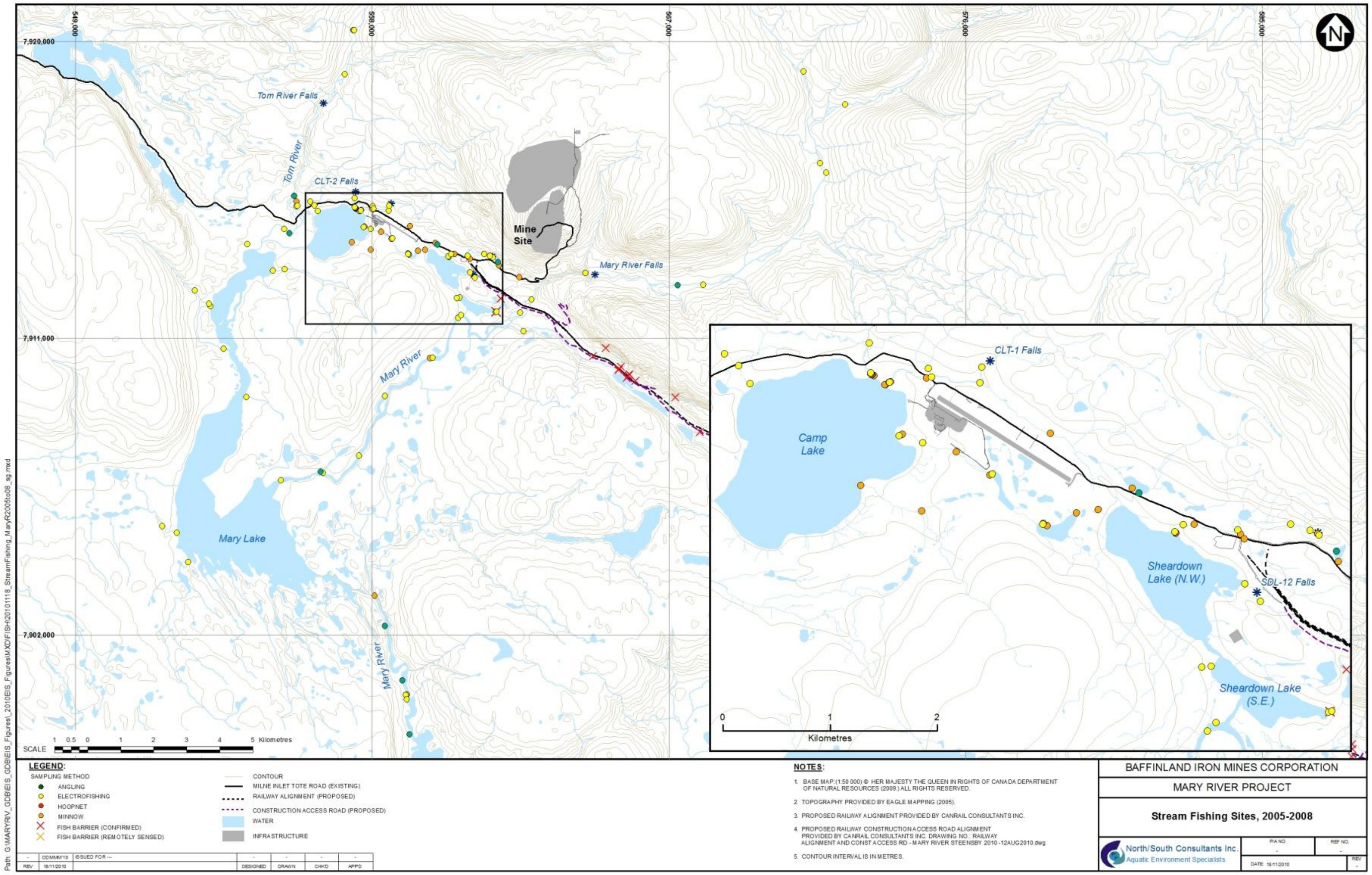

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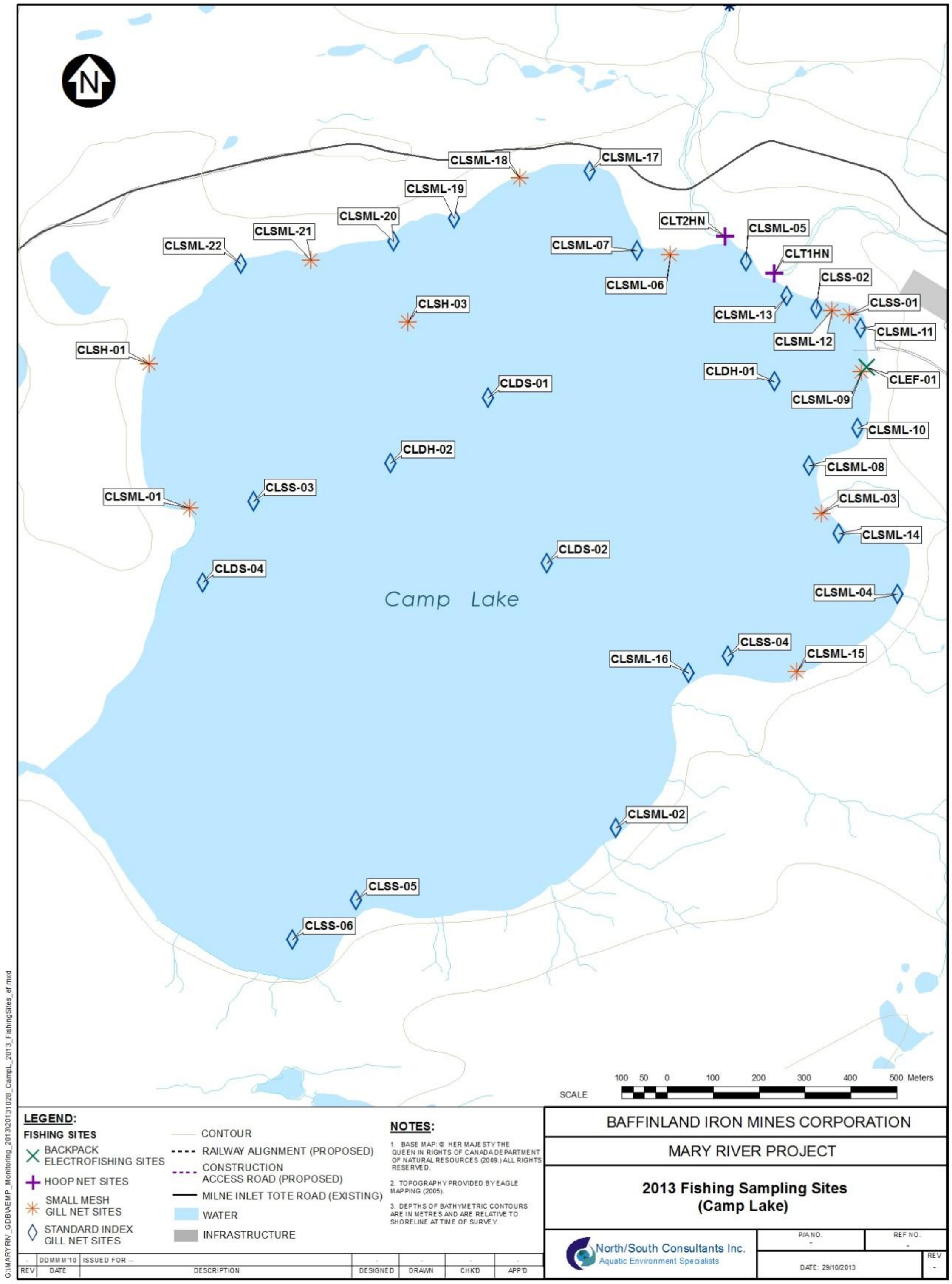

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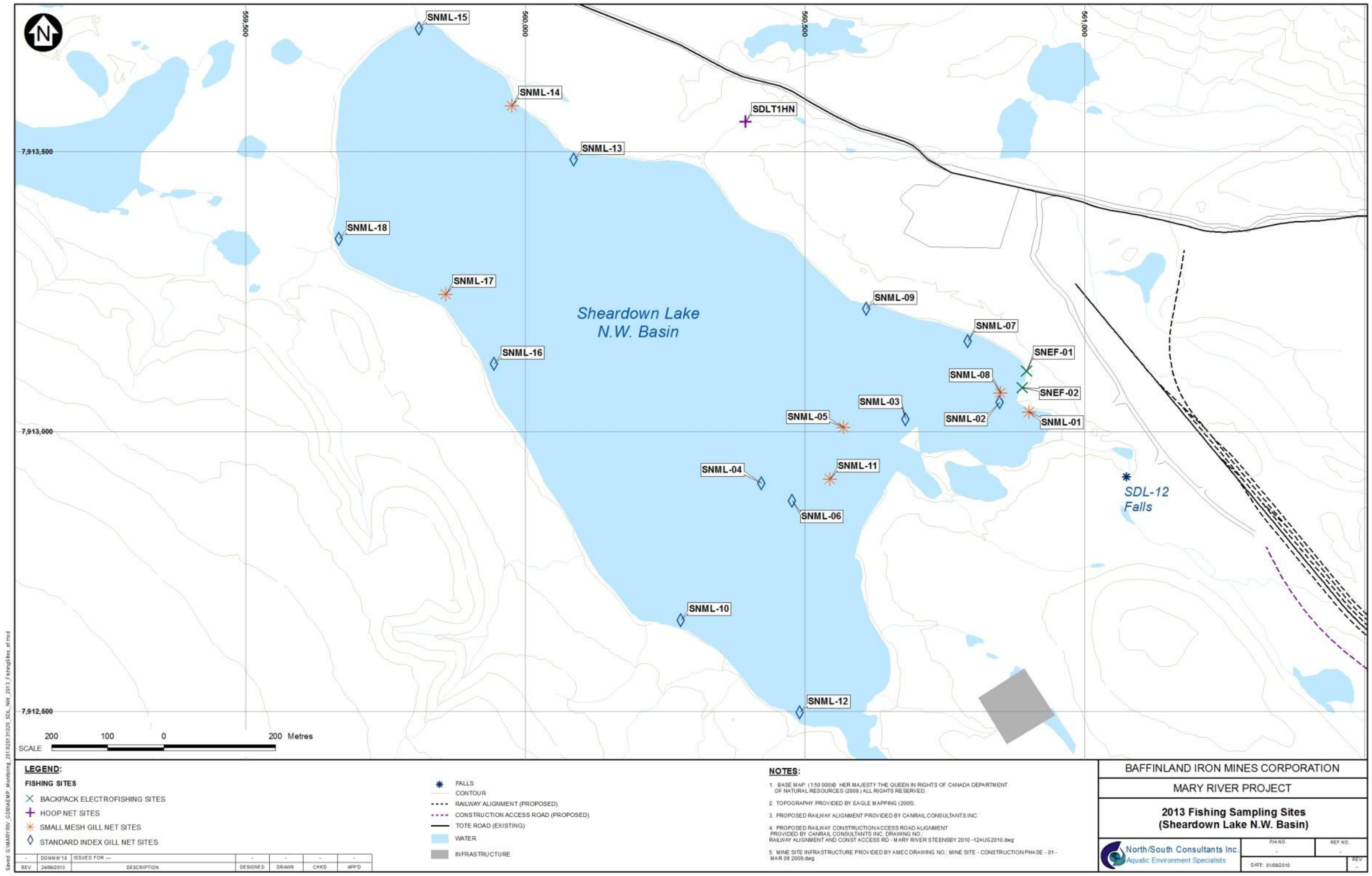

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Appendix E

Evaluation of Reference Lakes

Appendix E

Evaluation of Reference Lakes

Mary River Project

June 2014

Candidate Reference Lakes:

Preliminary Survey 2013

North/South Consultants Inc.
Aquatic Environment Specialists

Candidate Reference Lakes:
Preliminary Survey 2013

June, 2014

Prepared by

North/South Consultants Inc.

For

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AEMP	Aquatic Effects Monitoring Program
BMI	Benthic macroinvertebrate(s)
CCME	Council of Ministers of the Environment
CCREM	Canadian Council of Resource and Environment Ministers
COV	Coefficient of variation
CREMP	Core Receiving Environment Monitoring Program
DO	Dissolved oxygen
NSC	North/South Consultants Inc.
PAL	Protection of aquatic life
PRSD	Percent relative standard deviation
PSA	Particle size analysis
RPMD	Relative percent mean difference
SD	Standard deviation
SE	Standard error of the mean
TDS	Total dissolved solids
TN	Total nitrogen
TP	Total phosphorus
TOC	Total organic carbon

1.0 INTRODUCTION AND OVERVIEW

The Core Receiving Environment Monitoring Program (CREMP) of the aquatic effects monitoring program (AEMP) for the Mary River Project incorporates monitoring in reference waterbodies. The AEMP identifies that a minimum of one reference lake would be monitored for chemical and biological parameters in parallel with the CREMP which will be conducted in the Mine Area.

Preliminary identification of candidate reference lakes for the CREMP and AEMP was completed through a series of desktop screening exercises completed in 2013. This exercise, which is described in North/South Consultants Inc. (NSC) and Knight Piésold (2013), identified 12 potential reference lakes for Camp and/or Sheardown lakes within an 80 km radius of the Mary River Mine Site (Figure 1).

This interim report provides a description of reconnaissance surveys conducted in the open-water season of 2013 to identify reference lakes for Camp and Sheardown lakes at the mine site. Reconnaissance surveys were planned for the open-water season of 2013, with the objective of collecting information on the biota, physical habitat, and chemical conditions (i.e., water quality) at the three most suitable lakes as identified through an initial survey. Ultimately, the objective was to determine presence/absence of land-locked resident Arctic Char (*Salvelinus alpinus*), conduct a coarse aquatic habitat survey, and collect water quality, phytoplankton, zooplankton, and benthic macroinvertebrate (BMI) samples (all from a single site) in each of three lakes to assist with selecting the final reference lake(s).

The first reconnaissance survey conducted in summer (i.e., early August 2013) identified two potentially suitable reference lakes and these lakes were surveyed as indicated above. As the overall objective was to identify three candidate lakes, a second reconnaissance survey was completed in fall 2013 with the intent to identify additional lakes for consideration.

The following provides a description of the aerial and ground reconnaissance surveys completed for candidate reference lakes in the open-water season of 2013, a description of results of the field programs, and qualitative comparisons to Mine Area lakes.

2.0 SUMMER RECONNAISSANCE SURVEY

The first reconnaissance survey was undertaken in early August and included an initial aerial survey to identify the most suitable lakes of the 12 candidates identified through the desktop screening exercise, followed by ground surveys of the these lakes.

2.1 AERIAL SURVEYS

Twelve potential reference lakes for Camp and/or Sheardown lakes were initially identified within an 80 km radius of the Mary River Mine Site through the desktop screening exercise (Figure 1, NSC and Knight Piésold 2013). On August 3, 2013, these 12 lakes were surveyed by helicopter to identify basic suitability characteristics such as general depth, shoreline substrate and connectivity to other waterbodies. Lakes that were identified as unsuitable during the aerial survey were eliminated as potential references. Depth was the primary limiting factor identified during aerial surveys. Based on several ground-truthed surveys of other lakes in the study area, depths < 3.0 m, which are insufficient for overwintering, can be identified reliably from aerial surveys.

Table 1 provides a summary of reconnaissance survey information for the 12 candidate reference lakes surveyed in early August. Five of the lakes were eliminated as potential references due to shallow depths observed during aerial surveys. An additional three lakes remained largely frozen in early August . These three lakes are located in a mountain range to the north of the Mine Area at significantly higher altitudes than Camp and Sheardown lakes and may remain at least partially ice-covered during most summers. For this reason, these lakes were disregarded from further consideration. Aerial surveys indicated four of the 12 lakes may be suitable candidates as reference lakes.

2.2 DETAILED GROUND SURVEYS

Of the four lakes identified as potentially suitable candidates through the aerial reconnaissance survey, detailed ground surveys were conducted at lakes CR-P3-11, CR-P3-09, and CL-P2-13. Lake CR-P3-12 appeared to have nearly identical physical characteristics to the adjacent Lake CR-P3-11, including a largely sandy shoreline, and only one (Lake CR-P3-11) of these two lakes was chosen for a detailed ground survey.

Ground surveys included collection of information on shoreline characteristics (qualitative observations), an aquatic habitat reconnaissance survey (collection of bathymetric and substrate information), determination of fish presence/absence (specifically identification of land-locked resident Arctic Char), collection of water quality information (*in situ* and laboratory measurements) and collection of phytoplankton and zooplankton samples (Table 2).

3.0 FALL RECONNAISSANCE SURVEY

The second round of the reconnaissance surveys was conducted in late August and included revisiting and sampling two of the candidate lakes visited in early August (CR-P3-11 and CL-P2-13), as well as conduct of a second aerial reconnaissance survey to identify additional potential candidate lakes for consideration. The third lake (Lake CR-P3-09) that was surveyed in early August was subsequently dropped from further consideration and was not sampled in late August due to the suspected presence of a population of dwarf Arctic Char (see Section 4.1.3 for a detailed description of results).

3.1 AERIAL SURVEY

Results from aerial and ground surveys conducted on potential reference lakes in early August confirmed only two lakes as likely suitable candidates. Both lakes are smaller than Sheardown and Camp lakes and one has primarily sandy substrate (less preferred by Arctic Char for spawning and rearing). As a result, 11 alternate lakes to the south of the mine site (ALT-1 to ALT-11) were surveyed aerially in late August for general depth, shoreline substrate and connectivity to other waterbodies to expand the list of potential suitable candidates (Figure 1).

Table 1 provides a summary of reconnaissance survey information for these 11 lakes. Several lakes appeared potentially suitable as references, but four have a combination of abundant, ideal nearshore habitat (cobble), sufficient depths (estimated to be > 10 m), and sufficient size when compared with Camp and/or Sheardown NW lakes.

3.2 DETAILED GROUND SURVEYS

Detailed sampling was completed in fall at lakes CR-P3-11 and CL-P2-13 and included collection of information on water quality, phytoplankton, zooplankton and BMIs (Table 2). Detailed ground surveys of the four alternate lakes identified during the aerial reconnaissance in late August could not be completed due to inclement weather conditions and time constraints.

4.0 SUMMARY OF RESULTS

The following sections provide a brief summary of the results of the ground reconnaissance surveys completed in 2013 and qualitative comparisons to Mine Area lakes to provide an initial screening of the suitability of the lakes as reference waterbodies.

4.1 LAKE CR-P3-09

4.1.1 WATER QUALITY

In situ water quality measurements are presented in Appendix 1 and the sampling site is indicated in Figure 2. As this lake was subsequently eliminated as a candidate reference lake, detailed review of water quality for this lake was not undertaken.

4.1.2 LOWER TROPHIC LEVEL BIOTA

Samples for taxonomic analysis of phytoplankton and zooplankton were collected from Lake CR-P3-09 in summer and have been archived at the laboratory at NSC in Winnipeg, MB. BMIs were not sampled in Lake CR-P3-09 as the lake was eliminated as a candidate following the summer sampling period. Metadata associated with the summer sampling period are presented in Appendix 2 and sampling sites are presented in Figure 2.

4.1.3 FISH AND FISH HABITAT

Lake CR-P3-09 is isolated from all nearby waterbodies. Both the inflow and outflow provide insufficient depth or flows for adult or juvenile Arctic Char use. Any fish in the lake are, therefore, resident and non-migratory. The shoreline of this lake is typically cobble/boulder with a relatively steep gradient (Photo 1). Nearshore substrate (to about 5-6 m depth) is a continuation of the cobble/boulder shoreline (Photo 2). As depth increases, cobble is replaced with increasing amounts of sand and silt (Figure 3). Silt is the dominant substrate at depths greater than 10 m. Maximum observed depth in this lake was 29.81 m with a mean of 11.92 m (Figure 2).

Juvenile Arctic Char (30-70 mm fork length) were observed in nearshore rocky habitat. Five Arctic Char were captured in two standard gang index gill nets set for short duration in the lake. The captured fish ranged in size from 191-332 mm. One fish (193 mm) died in the net and was frozen and transported to the laboratory at NSC in Winnipeg for further examination of sex, maturity, diet, parasite load and age. Laboratory examination indicated this fish was a sexually mature male aged 11 years with a diet of chironomids and a parasite infracommunity that included cestode cysts (probably *Diphyllobothrium* sp.) along the exterior surface of the digestive tract. The presence of a sexually mature 11-year-old male at that size, and the lack of

Photo 1. Typical shoreline of reference lake CR-P3-09.

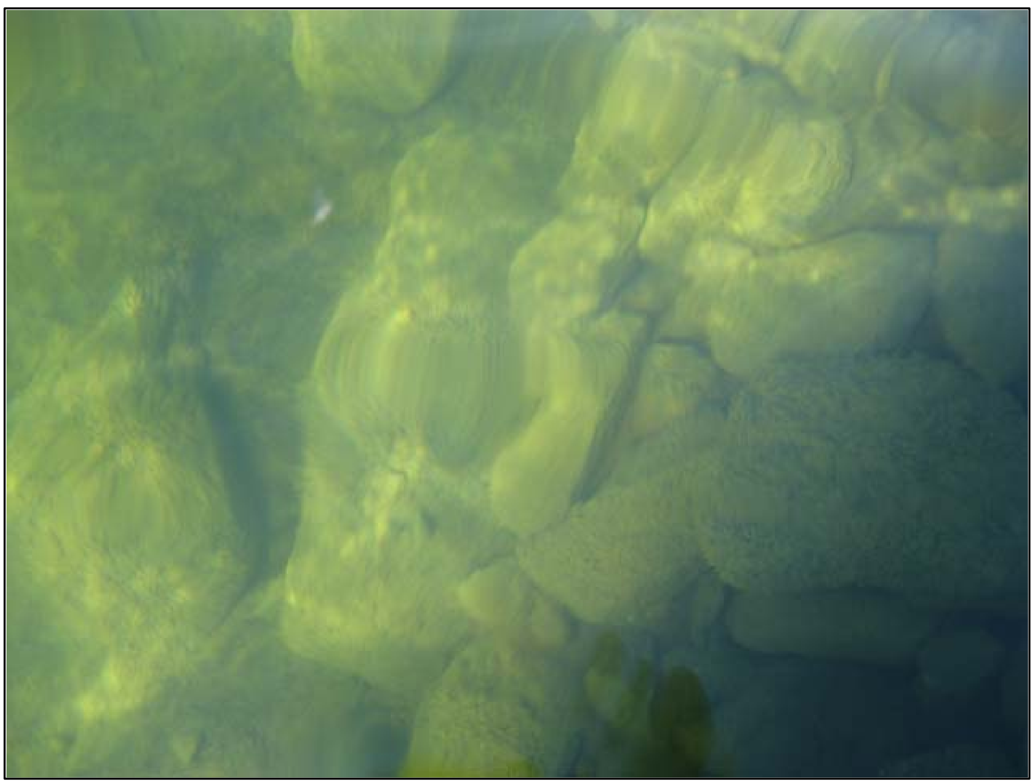

Photo 2. Typical nearshore substrate in reference lake CR-P3-09.

any fish larger than about 330 mm in the gill nets, suggest that this lake likely contains a stunted population of Arctic Char. On this basis Lake CR-P3-09 is likely not a suitable reference for Camp or Sheardown lakes. As previously noted, this lake was subsequently dropped from further consideration as a candidate reference lake based on this observation. Therefore, fall sampling was not undertaken in this lake.

4.2 LAKE CR-P3-11

4.2.1 WATER QUALITY

Laboratory and *in situ* water quality results collected in summer and fall at Lake CR-P3-11 are provided in Appendix 1 and the sampling site is indicated in Figure 4. Qualitative comparison of water quality conditions in Lake CR-P3-11 to Mine Area lakes (2013 data) indicates similarities for some parameters but differences for others (Table 3 and Figures 5-9).

Like Mine Area lakes, Lake CR-P3-11 was well-oxygenated and had a relatively high clarity. Nutrient concentrations were also relatively similar between this candidate reference lake and the Mine Area lakes (Figure 5) and the lake ranked as oligotrophic on the basis of total phosphorus (TP). Total nitrogen (TN) to TP ratios indicate this lake is strongly phosphorus limited, like Mine Area lakes (Table 3). Concentrations of many metals were also similar to Mine Area lakes, with a number of metals below detection (on average) in all of the lakes including antimony, beryllium, bismuth, boron, cadmium, cobalt, mercury, selenium, thallium, tin, titanium, and vanadium. Aluminum, iron, and copper were also similar to Mine Area lakes (Figure 6).

The primary difference between Lake CR-P3-11 and the Mine Area lakes relates to total dissolved solids (TDS)/conductivity, major cations, alkalinity, and hardness, all of which were lower in Lake CR-P3-11 (Table 3, Figure 7). Conductivity was less than half the levels measured in Sheardown Lake NW and SE and Camp Lake, but more similar to the more dilute Mary Lake (Figure 7). Lake CR-P3-11 ranked as very soft, whereas Mine Area lakes ranked as soft to moderately soft based on the Canadian Council of Resource and Environment Ministers (CCREM 1987) water hardness categories. These differences likely reflect differences in local geology.

Lake CR-P3-11 contains lower concentrations of calcium, magnesium, and potassium, but similar concentrations of sodium, than Mine Area lakes (Figure 8). Although concentrations of a number of metals were lower in Lake CR-P3-11, chromium, nickel, zinc (Figure 9) and manganese (Figure 6) were higher. Lake CR-P3-11 was not thermally stratified during the two sampling periods in 2013, whereas Mine Area lakes stratify during some sampling periods.

All water quality parameters measured in Lake CR-P3-11 in 2013 were within the Canadian Council of Ministers of the Environment (CCME) guidelines for the protection of aquatic life (PAL; CCME 1999; updated to 2014).

4.2.1 LOWER TROPHIC LEVEL BIOTA

Samples of phytoplankton, zooplankton, and BMIs were collected during summer and/or fall from Lake CR-P3-11. Metadata associated with this sampling are presented in Appendix 2 and sampling sites are presented in Figure 4.

Phytoplankton

Chlorophyll *a* concentrations measured in Lake CR-P3-11 were similar to those measured in Mine Area lakes in the open-water season of 2013 (Table 3, Figure 10), indicating similar levels of primary productivity.

Detailed phytoplankton results for samples collected in summer and fall at Lake CR-P3-11 are provided in Appendix 3. Qualitative comparisons of the phytoplankton community in Lake CR-P3-11 measured in the open-water season of 2013 to data collected in the open-water seasons of 2007 and 2008 from Mine Area lakes indicated that the community composition differs (Table 4; Figure 11). Unlike Mine Area lakes where diatoms dominated the phytoplankton community, dinoflagellates dominated the phytoplankton community and diatoms formed a small portion of the phytoplankton biomass in Lake CR-P3-11 (Figure 11). However, the dominant taxa (*Gymnodinium* and *Peridinium* sp.) were also present in Mine Area lakes in 2007 and 2008. Species diversity and richness were also higher in Lake CR-P3-11 in 2013 than in the Mine Area lakes in 2007 and 2008 (Table 4). Three phytoplankton not identified in the Mine Area lakes were observed in CR-P3-11, including: *Rhoicosphenia* sp. (Diatom), *Staurodesmus* sp. (Charophyta), and *Bitrichia* sp. (Charophyta).

During the summer, three phytoplankton replicates were collected and two of these were analysed for phytoplankton composition and biomass to assess variability (Appendix 3). The relative percent mean difference (RPMD) for biomass was high (63%) indicating that there is a high degree in variation in the phytoplankton. Variability of replicates of this order of magnitude is not uncommon for environmental monitoring programs (e.g., Coordinated Aquatic Monitoring Program 2014).

Zooplankton

Detailed zooplankton results for samples collected in summer and fall at Lake CR-P3-11 are provided in Appendix 4. Qualitative comparisons of the zooplankton community in CR-P3-11 to

Mine Area lakes (2007 and 2008 data) indicated that the communities were generally comparable (Table 5, Figure 12). A total of five crustacean zooplankton taxa were identified from vertical tows in Lake CR-P3-11, within the range of the number of taxa observed in the Mine Area lakes. As observed in Mine Area lakes, copepods, particularly cyclopoids, dominated the community and consisted of two species, *Cyclops scutifer* and *Diaptomus minutus*. The cladoceran community was primarily composed of two small-bodied taxa, *Bosmina longirostris* and *Daphnia longiremis*. The other cladoceran observed, *Holopedium gibberum*, was rare in comparison. As is typical, cladoceran density increased through the growing season and these organisms contributed to a greater proportion of the community sampled in the fall in comparison to the summer. Cyclopoid copepods and smaller-bodied cladocerans are more likely to be present in lakes with fish predators (i.e., Arctic char).

During the summer sampling period, three replicate samples of zooplankton were collected in Lake CR-P3-11 (Appendix 4). Percent relative standard deviation (PRSD) of zooplankton density for the three replicates was low (9%). Higher levels of variability were observed for individual taxa.

Benthic Macroinvertebrates

The objective of the BMI program was to sample aquatic habitat type 14 for comparison to Mine Area lakes. Habitat type 14 is characterized by water depths greater than 12 m, fine sand, silt, clay substrate, and an absence of macrophytes. While mean water depth in CR-P3-11 was only 8.8 m, it was decided that the samples represented the offshore profundal habitat based on its maximum depth of 11.65 m. Supporting variables for the BMI program (i.e., sediment total organic carbon [TOC] and particle size analysis [PSA]) were measured at each replicate station.

Detailed taxonomic results for BMI samples collected in the fall at Lake CR-P3-11 are provided in Appendix 5. Qualitative comparisons of BMI metrics in CR-P3-11 (2013; n=1) were made to the same habitat type within the Mine Area lakes using available data as follows: Sheardown Lake NW (2007, 2008, 2011, 2013; n=17); Sheardown Lake SE (2007; n=6); Camp Lake (2007; n=12); and Mary Lake (2006, 2007; n=11). Statistics for six community metrics: total density, proportion of Chironomidae, Shannon's evenness index, Simpson's diversity index, taxa richness (total number of genera), and Hill's effective richness, were graphically compared using summary statistics. Reference lake values were visually comparable to the mine site lake values for most of the metrics (Figures 13 and 14).

A total of 3,861 individuals/m^2 were collected in Lake CR-P3-11 which was in the range of BMI densities measured in all Mine Area lakes (Table 6). Chironomidae comprised 98% of the total abundance, and was compositionally similar to the Mine Area lakes. Evenness and diversity indices were also similar amongst all lake sites. Mean taxa richness and Hill's effective richness values for Lake CR-P3-11 were both within the ranges for all Mine Area lakes.

Supporting sediment analysis results for Lake CR-P3-11 (n=1) are provided in Figure 15. The benthic sediment was predominantly silt (47.8%), loam in texture; and TOC was 3.17%.

4.2.1 FISH AND FISH HABITAT

The shoreline of Lake CR-P3-11 is predominantly sandy with occasional small patches of rocks and a gradient ranging from low to high (Photos 3 and 4). Nearshore substrate (to about 5-6 m depth) is largely sand with occasional gravel or cobble (Figure 16). Silt and sand are dominant at depths greater than 5 m with occasional patches of coarser material. The most predominant substrate type in this lake is fines (i.e., fine sand, silt, and clay) but hard substrates are present at depths greater than 2 m, indicating the lake provides suitable spawning habitat for Arctic Char (Table 8). Maximum observed depth in this lake was 11.65 m with a mean of 6.10 m (Figure 4). The greatest depths were located in the northern third of the lake. There are several shallow shoals in the southern two thirds of the lake.

Lake CR-P3-11 has tributaries suitable for use by juvenile Arctic Char, but of insufficient depth for adult use. Any fish in the lake are, therefore, likely resident and non-migratory. Juvenile Arctic Char (30-70 mm fork length) were observed in tributary streams and in pools along the lake margin that had become isolated as water levels decreased. Fifteen Arctic Char were captured in two standard gang index gill nets set for short duration in the lake. The captured fish ranged in size from 313-431 mm. There were five mortalities, which were frozen and returned to the laboratory at NSC in Winnipeg for further examination of sex, maturity, diet, parasite load and age. Of the five mortalities, four were immature males (FL = 318-334 mm) and one was a resting female (FL = 355 mm). These fish were aged 10-13 years. Stomachs from all five mortalities contained chironomids and cestode cysts (probably *Diphyllobothrium* sp.) were present along the exterior surface of the digestive tracts. One fish was also infected with adult nematodes (likely *Cystidicola* sp.) in the body cavity, which may have been in the swim bladder before it was punctured during the necropsy.

Although the largely sandy nearshore substrate differs from the nearshore substrate of Camp or Sheardown lakes, which contain greater amounts of coarser substrate, and the lake is smaller and shallower than Camp or Sheardown lakes (Table 8), preliminary analysis of the fish population shows that basic meristics, growth rates, diet and parasite load are similar to populations in the Mine Area lakes. As previously noted, the lake also contains habitat that could support Arctic Char spawning.

Photo 3. Low-relief shoreline in reference lake CR-P3-11.

Photo 4. High-relief shoreline in reference lake CR-P3-11.

4.3 LAKE CL-P2-13

4.3.1 WATER QUALITY

Laboratory and *in situ* water quality results collected in summer and fall at Lake CL-P2-13 are provided in Appendix 1 and the sampling site is indicated in Figure 17. Qualitative comparison of water quality conditions in Lake CL-P2-13 to Mine Area lakes (2013 data) indicates some similarities but also a number of differences (Table 3 and Figures 5-9).

Like Mine Area lakes, Lake CL-P2-13 was well-oxygenated and had a relatively high clarity. Secchi disk depth was within the range measured at the Mine Area lakes, though was most similar to the less clear Mary Lake (Table 3). TP concentrations were also relatively similar between this candidate reference lake and the Mine Area lakes (Figure 5) and the lake ranked as oligotrophic on the basis of TP. TN to TP ratios indicate this lake is strongly phosphorus limited, like Mine Area lakes (Table 3). Concentrations of many metals were similar to Mine Area lakes, with a number of metals below detection (on average) in all of the lakes including antimony, beryllium, bismuth, boron, cadmium, cobalt, mercury, selenium, thallium, tin, titanium, and vanadium. Aluminum, iron, and copper were similar to Mine Area lakes, though the mean iron concentration was slightly higher than Mine Area lakes or Lake CR-P3-11 (Figure 6).

Like Lake CR-P3-11, the primary difference between Lake CL-P2-13 and the Mine Area lakes relates to TDS/conductivity, major cations, alkalinity, and hardness, all of which are lower in Lake CL-P2-13 (Table 3). Conductivity was less than half the levels measured in Sheardown Lake NW and SE and Camp Lake, but more similar to the more dilute Mary Lake (Figure 7). Lake CL-P2-13 ranked as very soft, whereas Mine Area lakes ranked as soft to moderately soft based on the CCREM (1987) water hardness categories. These differences likely reflect differences in local geology. Lake CL-P2-13 contains lower concentrations of calcium, magnesium, potassium, and sodium than Mine Area lakes (Figure 8). Although concentrations of a number of metals were lower in Lake CL-P2-13 than Mine Area lakes, like Lake CR-P3-11, chromium and nickel were higher (Figure 9). Lake CL-P2-13 was not thermally stratified during the two sampling periods in 2013, whereas Mine Area lakes stratify during some sampling periods.

All water quality parameters measured in Lake CL-P2-13 in 2013 were within the CCME PAL guidelines (CCME 1999; updated to 2014).

4.3.2 LOWER TROPHIC LEVEL BIOTA

Samples of phytoplankton, zooplankton, and BMIs were collected during summer and/or fall from Lake CL-P2-13. Metadata associated with this sampling are presented in Appendix 2 and sampling sites are presented in Figure 17.

Phytoplankton

Chlorophyll *a* concentrations measured in Lake CL-P2-13 were similar to those measured in Mine Area lakes and Lake CR-P3-11 in the open-water season of 2013 (Table 3, Figure 10), indicating similar levels of primary productivity.

Detailed results of phytoplankton biomass and community composition analyses of samples collected in summer and fall at Lake CR-P3-13 are provided in Appendix 3. Qualitative comparisons of the phytoplankton community in Lake CR-P3-13 to Mine Area lakes (2007 and 2008 data) indicates that the communities are different, but compared to Lake CR-P3-11, the phytoplankton community of Lake CR-P3-13 is more similar to the Mine Area lakes (Table 4; Figure 11). Unlike Mine Area lakes where diatoms dominated, dinoflagellates dominated the phytoplankton community in Lake CR-P3-13 (Figure 11).

In general, species diversity was similar to Mine Area lakes, but a greater number of species (i.e., richness) was observed in Lake CR-P3-13 in 2013 than in the Mine Area lakes in 2007 and 2008 (Table 4). The phytoplankton *Bitrichia* sp. (Charophyta) was observed in CR-P3-13, but was not identified in the Mine Area lakes.

During the fall, three phytoplankton replicates were collected and two of these were analysed for phytoplankton composition and biomass to evaluate variability (Appendix 3). The RPMD for biomass was low (8%) indicating good precision in the estimate of phytoplankton biomass.

Zooplankton

Detailed zooplankton results for samples collected in summer and fall at Lake CL-P2-13 are provided in Appendix 3. Qualitative comparisons of the zooplankton community in CL-P2-13 to Mine Area lakes (2007 and 2008 data) indicate that the communities are generally comparable (Table 5, Figure 12). Total zooplankton density in CL-P2-13 was somewhat lower than in Mine Area lakes and Lake CR-P3-11, but within the range of densities observed in the Mine Area lakes throughout the open-water season. The distribution of zooplankton is inherently patchy (i.e., these organisms are often highly aggregated). Spatial (e.g., within a lake or among lakes in the same area) and temporal (e.g., seasonal) variation in lake zooplankton density is typical and may be related to a variety of factors such as water depth, prevailing wind direction, water temperature regimes, and fish predation pressure.

A total of five crustacean zooplankton taxa were identified from vertical tows in Lake CL-P2-13, which is within the range of the number of taxa observed in the Mine Area lakes. As observed in Mine Area lakes and Lake CR-P3-11, copepods, particularly cyclopoids, dominated the community and consisted of two species, *Cyclops scutifer* and *Diaptomus minutus*. The cladoceran community was primarily composed of two small-bodied taxa, *Bosmina longirostris* and *Daphnia longiremis*. The other cladoceran observed, *Holopedium gibberum*, was rare in comparison.

During the summer, three zooplankton replicate samples were collected in CL-P2-13 (Appendix 4). PRSD for total zooplankton density was relatively low (26%) but higher variability was observed among the replicates for the various taxa.

Benthic Macroinvertebrates

BMIs were sampled in the profundal zone of Lake CL-P2-13 (i.e., aquatic habitat type 14) in the fall of 2013. Detailed taxonomic results for BMI samples are provided in Appendix 5. Qualitative comparisons of BMI metrics measured in Lake CL-P2-13 (2013; n=1) were made to the data collected from the same habitat type within the Mine Area lakes as follows: Sheardown Lake NW (2007, 2008, 2011, 2013; n=17); Sheardown Lake SE (2007; n=6); Camp Lake (2007; n=12); and Mary Lake (2006, 2007; n=11). Statistics for six community metrics: total density, proportion of Chironomidae, Shannon's evenness index, Simpson's diversity index, taxa richness (total number of genera), and Hill's effective richness, were graphically compared using summary statistics. Reference lake values were visually comparable to the mine site lake values for most of the metrics (Figures 13 and 14).

A total of 1,593 individuals/m^2 were collected in CL-P2-13 which was in the range of BMI densities for Mine Area lakes, except for Sheardown Lake SE (Table 6). Chironomidae comprised 100% of the total abundance, and was compositionally similar to the Mine Area lakes, except for Sheardown Lake NW. Evenness and diversity indices were also similar amongst all lake sites. Mean taxa richness and Hill's effective richness values for Lake CL-P2-13 were both within the ranges for all Mine Area lake sites.

Supporting sediment analysis results for Lake CL-P2-13 (n=1) are provided in Figure 15. The sediment was predominantly silt (73.0%), silt loam in texture; and TOC was 2.02%.

4.3.3 FISH AND FISH HABITAT

Lake CL-P2-13 has the smallest surface area of the three lakes that were surveyed in detail in 2013 (Figure 17). There are tributaries suitable for use by juvenile Arctic Char, but of insufficient depth for adult use. Any fish in the lake are, therefore, likely resident and non-migratory. The shoreline of this lake is predominantly rocky with a gradient ranging from low to high (Photo 5). Nearshore substrate (to about 5-6 m depth) ranged from almost 100% sand in some areas to almost 100% cobble/boulder in others (Photo 6, Figure 18). Silt and sand were dominant at depths greater than 5 m, however, the northwest section of the lake consisted of large amounts of cobble to at least 12 m depth. The predominant substrate type in this lake is fines (i.e., fine sand, silt, and clay) but hard substrates are present at depths greater than 2 m, indicating the lake provides suitable spawning habitat for Arctic Char (Table 9).The lake is characterized by steep shorelines typically reaching depths of 8-10 m within 50 m of shore tapering to a broad basin ranging from 10-15 m deep (Figure 17). Maximum observed depth in this lake was 15.34 m with a mean of 9.40 m.

Juvenile Arctic Char (30-70 mm fork length) were observed in tributary streams and in rocky nearshore areas. Two Arctic Char were captured in two standard gang index gill nets set for short duration in the lake. The captured fish ranged in size from 395-558 mm. One mortality (FL = 395 mm) was frozen and returned to the NSC laboratory in Winnipeg for further examination of sex, maturity, diet, parasite load and age. The fish was an immature male aged 17 years with chironomids in the stomach and larval cestode (likely *Diphyllobothrium* sp.) cysts along the gut and adult cestodes (possibly *Proteocephalus* sp.) in the stomach. Although this fish is older than most similarly-sized fish from Mine Area lakes, it is immature and may not necessarily be indicative of an overall slower growth rate for fish in this lake. Additional data are required to more thoroughly assess the fish population compatibility with Mine Area lakes.

Despite a smaller surface area, a higher proportion of fines, and a shallower basin than the Mine Area lakes (Table 8), preliminary surveys indicate Lake CL-P2-13 may be suitable as a reference lake.

Photo 5. Typical shoreline of reference lake CL-P2-13.

Photo 6. Typical nearshore substrate in reference lake CL-P2-13.

5.0 SUMMARY AND RECOMMENDATIONS

5.1 WATER QUALITY

Some water quality variables, notably water clarity, dissolved oxygen (DO), nutrients, and numerous metals, were similar between candidate reference lakes and Mine Area lakes. The primary differences observed relate to hardness, TDS/conductivity, and major cations – all of which were lower in candidate reference lakes than Mine Area lakes, notably Camp Lake and Sheardown Lake NW. These parameters were more similar to Mary Lake, which is softer and more dilute than other Mine Area lakes.

5.2 LOWER TROPHIC LEVEL BIOTA

5.2.1 PHYTOPLANKTON

The key findings of the phytoplankton analyses are:

- Primary productivity was similar between the candidate reference lakes and Mine Area lakes based on chlorophyll *a* concentrations; and
- Phytoplankton community composition varied between the candidate reference lakes and Mine Area lakes. The former were dominated by dinoflagellates (Dinophyceae) whereas the latter were typically dominated by diatoms.

While the differences in community composition are not ideal, the community composition of all the lakes (candidate reference lakes and Mine Area lakes) is consistent with nutrient-poor Arctic lakes. Other studies have reported high abundance of dinoflagellates, and specifically the Genus *Gymnodinium*, in other Arctic lakes (e.g., Snap Lake and a reference lake; De Beers 2002; Golder Associates 2012).

5.2.2 ZOOPLANKTON

Densities and composition of the zooplankton communities were similar between Mine Area lakes (as measured in 2007 and 2008) and the candidate reference lakes CR-P3-11 and CL-P2-13 (as measured in 2013).

5.2.3 BENTHIC MACROINVERTEBRATES

Benthic macroinvertebrate abundance and composition metrics were similar between Mine Area lakes (as measured in 2006, 2007, 2008, 2011, and 2013) and the candidate reference lakes CR-P3-11 and CL-P2-13 (as measured in 2013).

5.3 FISH AND FISH HABITAT

Available information regarding Arctic Char populations and aquatic habitat in the two candidate reference lakes indicate both lakes support what are likely land-locked resident populations and both are supplied by tributary streams that appear to provide juvenile rearing habitat (similar to Mine Area lakes). Also like Mine Area lakes, Lakes CR-P3-11 and CL-P21-13 likely provide overwintering and spawning habitat. Of the two lakes, growth rates of Arctic Char in Lake CL-P2-13 may be slower than Mine Area lakes. However, due to limited sample size this suggestion requires further investigation.

5.4 RECOMMENDATIONS

Although some differences in aquatic habitat, water quality, and lower trophic level biota were noted between the candidate reference lakes and Mine Area lakes based on the results of the 2013 survey and comparison to existing data for Mine Area lakes, it is recommended to retain one or both of these lakes for further consideration as reference lakes. However, additional sampling is required to confirm the suitability of these lakes as reference systems, in particular in relation to the Arctic Char populations.

Should additional reference lakes be desired, lakes ALT-06, ALT-07, ALT-09 and ALT-10 (Figure 1) were deemed to be the most likely suitable candidates based on aerial surveys conducted in fall 2013. These lakes have suspected depths, nearshore substrates and, in particular, surface areas that appear to suitably match Camp and Sheardown NW lakes. Surface areas of these lakes area greater than lakes CR-P3-11 and CL-P2-13 and more comparable to the surface areas of Camp and Sheardown NW lakes. If additional reference lakes are to be identified, these lakes could be subject to a ground level screening comparable to that conducted in lakes CR-P3-11 and CL-P2-13 in 2013 to evaluate physical, chemical, and biological conditions.

6.0 LITERATURE CITED

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TABLES AND FIGURES

Table 1. Summary of information collected during preliminary surveys of potential reference lakes, August 2013. Lakes highlighted in bold, blue lettering have been identified as the best possible candidates.

Lake	Date	Survey Type	Maximum Depth (m)	Dominant Substrate (0-5 m depth)	Dominant Substrate (> 5 m depth)	Fish Community	Potential Reference Lake Status	Comments
CR-P3-07	03-Aug-13	Ground	3.0	Cobble	NA	Small juveniles observed along shore	Not Suitable	Too shallow for overwintering or large adult fish use
CL-P2-05	03-Aug-13	Aerial	< 3.0	NA	NA	Unknown	Not Suitable	Too shallow for overwintering or large adult fish use
CL-P2-01	03-Aug-13	Aerial	> 5.0	Appears to be cobble	NA	Unknown	Potentially Suitable	Lake was still ~80% covered in ice and could not be surveyed in detail
CR-P3-29	03-Aug-13	Aerial	> 5.0	Appears to be cobble	NA	Unknown	Potentially Suitable	Lake was still ~90% covered in ice and could not be surveyed in detail
CL-P2-04	03-Aug-13	Aerial	> 5.0	Appears to be cobble	NA	Unknown	Potentially Suitable	Lake was still ~80% covered in ice and could not be surveyed in detail
CL-P2-13	**07-Aug-13**	**Ground**	**13.0-15.0**	**Cobble/boulder**	**Sand/silt with rocky patches**	**Small juveniles along shore and in tributary streams; large adults captured in lake**	**Potentially Suitable**	**Lake is small, but substrate is ideal and there are large, resident Arctic Char**
CL-P2-07	03-Aug-13	Aerial	~ 5.0	Appears to be cobble	NA	Unknown	Not Suitable	80-90% of the lake is < 3.0 m deep

Table 1. - continued -

Lake	Date	Survey Type	Maximum Depth (m)	Dominant Substrate (0-5 m depth)	Dominant Substrate (> 5 m depth)	Fish Community	Potential Reference Lake Status	Comments
CR-P3-09	05-Aug-13	Ground	28.0-30.0	Cobble/ boulder	Sand/silt with rocky patches	Probable isolated stunted Arctic Char population	Not Suitable if resident char are stunted	May need more studies to confirm lack of large fish, but seems unlikely as a reference
CR-P3-01	03-Aug-13	Aerial	~ 5.0-10.0	Appeared to be cobble	NA	Unknown	Not Suitable	50% of the lake is < 3.0 m deep and lake is isolated from other waterbodies
CL-03	03-Aug-13	Aerial	< 2.0	NA	NA	Unknown	Not Suitable	Too shallow for overwintering or large adult fish use
CR-P3-11	**06-Aug-13**	**Ground**	**10.0-12.0**	**Sand**	**Sand/silt**	**Small juveniles along shore and in tributary streams; large adults captured in lake**	**Potentially Suitable**	**Substrate not ideal, but resident fish population present**
CR-P3-12	03-Aug-13	Aerial	~10.0-15.0	Sand	Sand/silt	Probable juvenile and adult use	Potentially Suitable	Very similar to CR-P3-11, so only one of the two was surveyed in detail
ALT-01	31-Aug-13	Aerial	> 10	Sand	NA	Probable juvenile and adult use	Potentially Suitable	Does not have ideal nearshore habitat (larger cobble), but may qualify for more detailed survey
ALT-02	31-Aug-13	Aerial	> 10	Cobble/sand	NA	Probable juvenile and adult use	Potentially Suitable	Nearshore habitat more suitable than ALT-1

Table 1. - continued -

Lake	Date	Survey Type	Maximum Depth (m)	Dominant Substrate (0-5 m depth)	Dominant Substrate (> 5 m depth)	Fish Community	Potential Reference Lake Status	Comments
ALT-03	31-Aug-13	Aerial	~ 5.0-10.0	Cobble/sand	NA	Unknown	Not Likely Suitable	Substrate decent, but depths a little shallow
ALT-04	31-Aug-13	Aerial	> 10	Cobble/sand	NA	Probable juvenile and adult use	Not Suitable	Essentially a bay in Nina Bang Lake
ALT-05	31-Aug-13	Aerial	> 10	Mainly Cobble	NA	Probable juvenile and adult use	Potentially Suitable	Excellent nearshore habitat and depths, but lake is a little small
ALT-06	**31-Aug-13**	**Aerial**	**> 10**	**Mainly Cobble**	**NA**	**Probable juvenile and adult use**	**Potentially Suitable**	**Excellent nearshore habitat and depths and lake is larger than other reference sites**
ALT-07	**31-Aug-13**	**Aerial**	**> 10**	**Mainly Cobble**	**NA**	**Probable juvenile and adult use**	**Potentially Suitable**	**Connected to ALT-06, but even better suited as reference**
ALT-08	31-Aug-13	Aerial	> 10	Sand/Cobble	NA	Unknown	Potentially Suitable	Low shoreline slope and lower quality habitat means this is likely less suitable than others in the area
ALT-09	**31-Aug-13**	**Aerial**	**> 10**	**Mainly Cobble**	**NA**	**Probable juvenile and adult use**	**Potentially Suitable**	**Among the best nearshore habitat and depth of any ALT lakes**
ALT-10	**31-Aug-13**	**Aerial**	**> 10**	**Mainly Cobble**	**NA**	**Probable juvenile and adult use**	**Potentially Suitable**	**Shallow connection to ALT-09 with similar habitat**
ALT-11	31-Aug-13	Aerial	> 10	Sand/Cobble	NA	Probable juvenile and adult use	Potentially Suitable	Good size and depth, but nearshore habitat not as ideal as ALT-06 or ALT-09/10)

Table 2. Sampling programs completed in candidate reference lakes, summer and fall 2013.

Lake	Season	Bathymetry & Substrate	Water Quality			Phytoplankton	Zooplankton	Benthic Macroinvertebrates	Fish
			in situ	Surface Sample	Bottom Sample				
CR-P3-09	Summer	+	+	+[1]		+	+		+
	Fall								
CR-P3-11	Summer	+	+	+	+	+	+		+
	Fall		+	+	+	+	+	+	
CL-P2-13	Summer	+	+	+	+	+	+		+
	Fall		+	+	+	+	+	+	

[1] Sample was collected by not analysed.

Table 3. Water quality measured in candidate reference lakes CR-P3-11 and CL-P2-13 and Mine Area lakes in the open-water season of 2013. Values represent means of surface samples. SDL NW = Sheardown Lake northwest and SDL SE = Sheardown Lake southeast.

		Reference Lakes		Mine Area Lakes			
Parameter	**Unit**	**CR-P3-11**	**CR-P2-13**	**SDL NW**	**SDL SE**	**Camp L.**	**Mary L.**
In situ							
Temperature	ºC	Summer: 9.6 Fall: 4.4	Summer: 6.9 Fall: 3.8	Summer: 8.6 Fall: 6.9	Summer: 10.0 Fall: 6.3	Summer: 4.6 Fall: 6.9	Summer: 6.2 Fall: 5.9
Dissolved oxygen	mg/L	11.54	11.55	12.20	12.09	12.20	12.37
pH	pH units	8.01	7.83	7.87	7.62	7.54	7.53
Specific conductance	µS/cm	40.1	42.0	120	100	122	64.3
Secchi Disk Depth	m	6.13	4.30	7.48	4.17	7.15	4.56
Laboratory Routine							
Lab pH	pH units	6.70	6.73	7.44	7.35	7.42	7.02
Lab Conductivity	µS/cm	41	42	121	106	124	67
Lab Turbidity	NTU	0.60	0.90	0.43	0.65	0.27	1.30
Total Alkalinity (as $CaCO_3$)	mg/L	17	22	57	50	59	33
Bromide	mg/L	<0.25	<0.25	<0.25	<0.25	0.25	<0.25
Chloride	mg/L	2.0	<1	3.0	2.5	3.2	2.0
Dissolved Hardness	mg/L	16.0	18.8	58.7	48.7	59.1	31.0
Total Hardness	mg/L	16.7	18.7	61.1	51.2	61.2	31.7
Ammonia	mg N/L	0.03	0.52	0.08	<0.02	0.28	0.14
Nitrite	mg N/L	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Nitrite/nitrate	mg N/L	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Nitrate	mg N/L	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Sulphate	mg/L	3	<3	4	4	<3	<3
Total Dissolved Solids	mg/L	26.7	27.5	79	68.5	80.7	43.6
Total Suspended Solids	mg/L	<2	<2	<2	<2	<2	<2
Total Phosphorus	mg/L	0.005	0.005	0.005	0.006	0.004	0.005
Total Kjeldahl Nitrogen	mg/L	0.75	0.80	0.20	<0.10	0.60	0.22
Total Nitrogen	mg/L	0.85	0.90	0.30	<0.2	0.70	0.32
TN:TP Molar Ratios	-	533	556	163	101	493	144
Phenols	mg/L	<0.001	0.009	<0.001	<0.001	<0.001	<0.001
Total Organic Carbon	mg/L	2.0	1.2	1.8	1.6	1.9	1.4
Dissolved Organic Carbon	mg/L	1.9	1.1	1.7	1.4	1.8	1.3
Chlorophyll *a*	µg/L	0.45	0.90	0.59	1.90	0.73	1.70
Pheophytin *a*	µg/L	0.72	0.80	0.75	0.20	2.22	0.42

Table 3. - continued -

Parameter	Unit	Reference Lakes		Mine Area Lakes			
		CR-P3-11	CR-P2-13	SDL NW	SDL SE	Camp L.	Mary L.
Total Metals							
Al	mg/L	0.0164	0.0346	0.0090	0.0356	0.0060	0.0425
Sb	mg/L	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
As	mg/L	<0.00010	0.00012	<0.00010	<0.00010	<0.00010	<0.00010
Ba	mg/L	0.00276	0.00243	0.00502	0.00462	0.00548	0.00372
Be	mg/L	<0.00002	<0.00002	<0.00002	<0.00002	<0.00002	<0.00002
Bi	mg/L	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
B	mg/L	<0.0100	<0.0100	<0.0100	<0.0100	<0.0100	<0.0100
Cd	mg/L	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010
Ca	mg/L	3.6	3.8	12.2	10.4	12.3	6.5
Cr	mg/L	0.00077	0.00175	0.00038	0.00019	0.00014	0.00023
Cu	mg/L	0.00046	0.00179	0.00312	0.00076	0.00087	0.00066
Co	mg/L	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Fe	mg/L	0.03	0.08	0.02	0.04	0.01	0.05
Pb	mg/L	0.00007	0.00009	<0.00005	<0.00005	<0.00005	0.00007
Li	mg/L	<0.00005	<0.00005	0.00034	<0.00005	0.00082	<0.00005
Mg	mg/L	1.89	2.24	7.42	6.15	7.39	3.77
Mn	mg/L	0.00402	0.00232	0.00203	0.00276	0.00230	0.00168
Hg	mg/L	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010
Mo	mg/L	0.00006	0.00042	0.00077	0.00047	0.00022	0.00011
Ni	mg/L	0.0008	0.0010	0.0007	0.0006	0.0006	<0.00050
K	mg/L	0.355	0.310	0.873	0.706	0.881	0.471
Se	mg/L	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
Si	mg/L	0.27	0.37	0.61	0.57	0.40	0.47
Ag	mg/L	<0.000001	0.0000085	<0.000001	<0.000001	<0.000001	<0.000001
Na	mg/L	1.09	0.70	1.06	1.06	1.04	0.94
Sr	mg/L	0.00492	0.00368	0.00795	0.00706	0.00919	0.00513
Tl	mg/L	<0.000001	<0.000001	<0.000001	<0.000001	<0.000001	<0.000001
Sn	mg/L	<0.00010	0.00050	<0.00010	<0.00010	<0.00010	<0.00010
Ti	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
U	mg/L	0.000074	0.000136	0.000931	0.000695	0.000584	0.000498
V	mg/L	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Zn	mg/L	0.013	0.004	<0.0030	<0.0030	<0.0030	<0.0030

Table 3. - continued -

Paramaeter	Unit	Reference Lakes		Mine Area Lakes			
		CR-P3-11	CR-P2-13	SDL NW	SDL SE	Camp L.	Mary L.
Dissolved Metals							
Al	mg/L	0.0043	0.0039	<0.00100	0.0022	<0.00100	0.0073
Sb	mg/L	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
As	mg/L	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Ba	mg/L	0.00274	0.00220	0.00494	0.00439	0.00546	0.00349
Be	mg/L	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Bi	mg/L	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
B	mg/L	<0.0100	<0.0100	<0.0100	<0.0100	<0.0100	<0.0100
Cd	mg/L	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010
Ca	mg/L	3.44	3.83	11.73	9.81	11.97	6.38
Cr	mg/L	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Cr(VI)	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cr(III)	mg/L	-	-	<0.005	<0.005	<0.005	<0.005
Co	mg/L	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Cu	mg/L	0.00036	0.00041	0.00074	0.00059	0.00279	0.00049
Fe	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Pb	mg/L	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005
Li	mg/L	<0.00005	<0.00005	0.00090	0.00095	0.00113	0.00117
Mg	mg/L	1.81	2.24	7.16	5.85	7.08	3.66
Mn	mg/L	0.00116	0.00084	0.00041	0.00032	0.00063	0.00072
Hg	mg/L	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010
Mo	mg/L	<0.00005	0.00012	0.00072	0.00045	0.00021	0.00015
Ni	mg/L	0.00050	0.00109	0.00060	<0.00050	0.00054	<0.00050
K	mg/L	0.349	0.288	0.852	0.694	0.876	0.458
Se	mg/L	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Si	mg/L	0.23	0.32	0.59	0.49	0.36	0.36
Ag	mg/L	<0.0000010	<0.0000010	<0.0000010	<0.0000010	<0.0000010	<0.0000010
Na	mg/L	1.11	0.670	1.05	0.92	1.05	0.959
Sr	mg/L	0.00475	0.00352	0.00756	0.00667	0.00857	0.00480
Tl	mg/L	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010
Sn	mg/L	<0.00010	0.00082	<0.00010	<0.00010	<0.00010	<0.00010
Ti	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.02
U	mg/L	0.000063	0.000118	0.000897	0.000666	0.000552	0.000455
V	mg/L	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Zn	mg/L	0.00139	0.00255	0.00133	0.00092	0.00217	0.00199

Table 4. Mean, standard deviation (SD), coefficient of variation (COV), and 95th percentiles for phytoplankton species diversity, evenness, and richness metrics measured in reference lakes (summer and fall 2013) and Mine Area lakes (summer and late summer/fall, 2007 and 2008).

	MEANS					
	Simpson's Diversity Index	Simpson's Evenness	Species Richness	Shannon's Evenness	Hill's Effective Richness	Hill's Evenness
CR-P3-11	0.82	0.24	24	0.70	9.20	0.39
CL-P2-13	0.69	0.18	22	0.59	6.41	0.30
Camp Lake	0.72	0.22	17	0.60	5.55	0.33
Sheardown Lake NW	0.71	0.22	18	0.61	6.19	0.34
Sheardown Lake SE	0.71	0.29	16	0.61	6.1	0.37
Mary Lake	0.52	0.2	15	0.47	3.84	0.28
	SD					
	Simpson's Diversity Index	Simpson's Evenness	Species Richness	Shannon's Evenness	Hill's Effective Richness	Hill's Evenness
CR-P3-11	0.00	0.00	1	0.02	0.44	0.03
CL-P2-13	0.17	0.09	1	0.14	2.81	0.12
Camp Lake	0.07	0.05	3	0.04	1.18	0.04
Sheardown Lake NW	0.12	0.08	3	0.10	1.94	0.08
Sheardown Lake SE	0.88	0.43	20	0.77	9.31	0.54
Mary Lake	0.19	0.15	4	0.17	2.00	0.15
	COV					
	Simpson's Diversity Index	Simpson's Evenness	Species Richness	Shannon's Evenness	Hill's Effective Richness	Hill's Evenness
CR-P3-11	1	1	3	3	5	8
CL-P2-13	25	53	3	24	44	41
Camp Lake	9	25	20	7	21	13
Sheardown Lake NW	17	34	16	16	31	25
Sheardown Lake SE	27	42	18	26	41	34
Mary Lake	36	75	28	36	52	55
	95TH PERCENTILE					
	Simpson's Diversity Index	Simpson's Evenness	Species Richness	Shannon's Evenness	Hill's Effective Richness	Hill's Evenness
CR-P3-11	0.83	0.24	24	0.72	9.5	0.41
CL-P2-13	0.80	0.24	22	0.68	8.2	0.37
Camp Lake	0.81	0.28	23	0.66	7.5	0.37
Sheardown Lake NW	0.84	0.34	22	0.74	8.9	0.46
Sheardown Lake SE	0.87	0.42	19	0.76	9.2	0.51
Mary Lake	0.84	0.52	21	0.78	7.5	0.56

Table 5. Summary statistics for total crustacean zooplankton density (individuals/m^3) by waterbody (seasonally) for the candidate reference (2013) and Mine Area (2007 and 2008) lakes.

Waterbody	Season	n [1]	Mean	SD	Min	Max	Taxonomic Richness [2]
Lake CR-P3-11							
	Summer	3	7,942	741	7,153	8,623	5
	Fall	1	7,920	-	-	-	4
Lake CL-P2-13							
	Summer	1	1,163	-	-	-	5
	Fall	3	1,619	414	1,354	2,096	5
Camp Lake							
	Summer	6	11,772	8,442	3,244	22,619	4
	Fall	3	9,829	6,269	5,561	17,027	5
Sheardown Lake NW							
	Summer	10	11,878	8,335	2,637	26,211	7
	Fall	10	19,966	17,352	3,753	53,307	6
Sheardown Lake SE							
	Summer	6	13,127	10,132	3,303	31,074	6
	Fall	6	10,578	5,707	4,776	16,854	6
Mary Lake							
	Summer	9	2,713	2,246	750	7,811	9
	Fall	5	6,147	5,159	1,528	13,832	5

[1] number of samples collected

[2] total number of taxa observed to species-level, not the average number of taxa

Table 6. Mean, median, standard deviation (SD), standard error (SE), minimum (Min), maximum (Max), precision (20%), 95th percentile, and coefficient of variation (%COV) for BMI composition and richness metrics measured from the offshore profundal habitat of candidate reference lakes and Mine Area lakes.

Metric	Total Macroinvertebrate Density (individuals/m^2)					
Habitat Type	Offshore Profundal (14)					
Lake	CL-P2-13	CR-P3-11	SDL NW	SDL SE	Camp	Mary
Sample Year(s)	2013	2013	2007, 2008, 2011, 2013	2007	2007	2006, 2007
n (rep. stn.)	1	1	17	6	12	11
Mean	1593	3861	1871	5042	2649	2668
Median	--	--	1783	4674	1978	2670
SD	--	--	1143.36	1350.49	1496.51	2057.11
SE	--	--	277.31	551.34	432.01	620.24
Min	--	--	102	3548	730	609
Max	--	--	4652	6730	6226	7017
Sub-samples (20% precision)	--	--	9.33	1.79	7.98	14.86
95th Percentile	--	--	3603.56	6700.00	5250.43	5917.00
COV (%)	--	--	61.10	26.78	56.50	77.10

Metric	Chironomidae Proportion (% of total density)					
Habitat Type	Offshore Profundal (14)					
Lake	CL-P2-13	CR-P3-11	SDL NW	SDL SE	Camp	Mary
Sample Year(s)	2013	2013	2007, 2008, 2011, 2013	2007	2007	2006, 2007
n (rep. stn.)	1	1	17	6	12	11
Mean	100	98	91	97	95	96
Median	--	--	94	98	96	99
SD	--	--	7.68	2.85	4.32	4.54
SE	--	--	1.86	1.16	1.25	1.37
Min	--	--	70	92	88	89
Max	--	--	98	100	100	100
Sub-samples (20% precision)	--	--	0.18	0.02	0.05	0.06
95th Percentile	--	--	97.08	99.74	100.00	100.00
COV (%)	--	--	8.46	2.94	4.55	4.71

Metric	Shannon's Evenness Index					
Habitat Type	Offshore Profundal (14)					
Lake	CL-P2-13	CR-P3-11	SDL NW	SDL SE	Camp	Mary
Sample Year(s)	2013	2013	2007, 2008, 2011, 2013	2007	2007	2006, 2007
n (rep. stn.)	1	1	17	6	12	11
Mean	0.63	0.67	0.45	0.59	0.56	0.52
Median	--	--	0.43	0.59	0.57	0.56
SD	--	--	0.14	0.09	0.13	0.21
SE	--	--	0.03	0.04	0.04	0.06
Min	--	--	0.23	0.46	0.33	0.00
Max	--	--	0.68	0.68	0.82	0.81
Sub-samples (20% precision)	--	--	2.53	0.54	1.41	4.09
95th Percentile	--	--	0.66	0.68	0.75	0.73
COV (%)	--	--	31.80	14.65	23.75	40.42

Table 6. - continued -

Metric	Simpson's Diversity Index					
Habitat Type	Offshore Profundal (14)					
Lake	CL-P2-13	CR-P3-11	SDL NW	SDL SE	Camp	Mary
Sample Year(s)	2013	2013	2007, 2008, 2011, 2013	2007	2007	2006, 2007
n (rep. stn.)	1	1	17	6	12	11
Mean	0.51	0.67	0.41	0.61	0.60	0.50
Median	--	--	0.44	0.65	0.61	0.58
SD	--	--	0.16	0.15	0.12	0.23
SE	--	--	0.04	0.06	0.03	0.07
Min	--	--	0.15	0.35	0.39	0.00
Max	--	--	0.63	0.75	0.76	0.69
Sub-samples (20% precision)	--	--	4.06	1.46	0.94	5.38
95th Percentile	--	--	0.61	0.74	0.76	0.68
COV (%)	--	--	40.30	24.13	19.41	46.38

Metric	Total Taxa Richness (genus-level)					
Habitat Type	Offshore Profundal (14)					
Lake	CL-P2-13	CR-P3-11	SDL NW	SDL SE	Camp	Mary
Sample Year(s)	2013	2013	2007, 2008, 2011, 2013	2007	2007	2006, 2007
n (rep. stn.)	1	1	17	6	12	11
Mean	9 [1]	17 [1]	9	9	9	9
Median	--	--	9	10	9	8
SD	--	--	2.27	2.83	2.76	5.66
SE	--	--	0.55	1.15	0.80	1.71
Min	--	--	4	4	6	1
Max	--	--	12	12	14	18
Sub-samples (20% precision)	--	--	1.77	2.47	2.36	10.11
95th Percentile	--	--	12.00	11.75	13.45	16.50
COV (%)	--	--	26.58	31.43	30.70	63.59

[1] Total number of taxa observed to genus-level, not the average number of taxa

Metric	Hill's Effective Richness					
Habitat Type	Offshore Profundal (14)					
Lake	CL-P2-13	CR-P3-11	SDL NW	SDL SE	Camp	Mary
Sample Year(s)	2013	2013	2007, 2008, 2011, 2013	2007	2007	2006, 2007
n (rep. stn.)	1	1	17	6	12	11
Mean	3	5	3	4	4	3
Median	--	--	2	4	3	4
SD	--	--	0.88	1.15	1.24	1.31
SE	--	--	0.21	0.47	0.36	0.40
Min	--	--	1	2	2	1
Max	--	--	4	5	6	5
Sub-samples (20% precision)	--	--	2.82	2.39	3.04	3.85
95th Percentile	--	--	3.94	5.03	5.52	4.90
COV (%)	--	--	33.60	30.89	34.85	39.27

Table 7. Substrate types in Lake CR-P3-11.

Substrate Type	Shoreline Zone (0-2 m)		Euphotic Zone (2-12 m)		Total	
	(m^2)	%	(m^2)	%	(m^2)	%
Boulder / Cobble	6,687	17	36,976	8	43,663	9
Gravel/Pebble	5,843	15	2,241	0.5	8,084	2
Sand	9,623	25	167,909	37	177,532	36
Fine Sand, Silt/Clay	16,504	43	250,251	55	266,754	54
Grand Total	38,657	100	457,376	100	496,033	100

Table 8. Comparison of aquatic habitat and lake characteristics.

Lake	Drainage Basin Area (km^2)	Lake Area (km^2)	Lake Area (km^2)	Drainage Basin: Lake Area Ratio	Mean Depth (m)	Maximum Depth (m)	Volume (1,000,000 m^3)	Substrate			
								Cobble/ Boulder (%)	Gravel/ Pebble (%)	Sand (%)	Fine Sand and Silt/Clay (%)
Camp Lake	26.47	2.21	2.21	11.98	13.03	35.08	27.5	5.1	28.2	61.1	5.6
Sheardown Lake NW	6.55	0.678	0.678	9.66	12.11	30.1	8.18	10.1	41.8	46.0	2.0
CR-P3-11	2.35	0.496	0.484	4.86	6.1	11.65	3.01	8.8	1.6	35.8	53.8
CL-P2-13	3.39	0.241	0.228	14.9	9.4	15.34	2.27	18.1	12.6	8.4	60.9

Table 9. Substrate types in Lake CL-P2-13.

Substrate Type	Shoreline Zone (0-2 m)		Euphotic Zone (2-12 m)		Profundal Zone (>12 m)		Total	
	(m^2)	%	(m^2)	%	(m^2)	%	(m^2)	%
Boulder / Cobble	3,128	30.4	35,752	19.5	4,547	9.8	43,427	18.1
Gravel/Pebble	1,031	10.0	23,035	12.6	6,102	13.2	30,169	12.6
Sand	5,164	50.1	14,918	8.1	157	0.3	20,238	8.4
Fine Sand, Silt/Clay	982	9.5	109,761	59.8	35,443	76.6	146,186	60.9
Grand Total	10,305	100.0	183,466	100.0	46,250	100.0	240,021	100.0

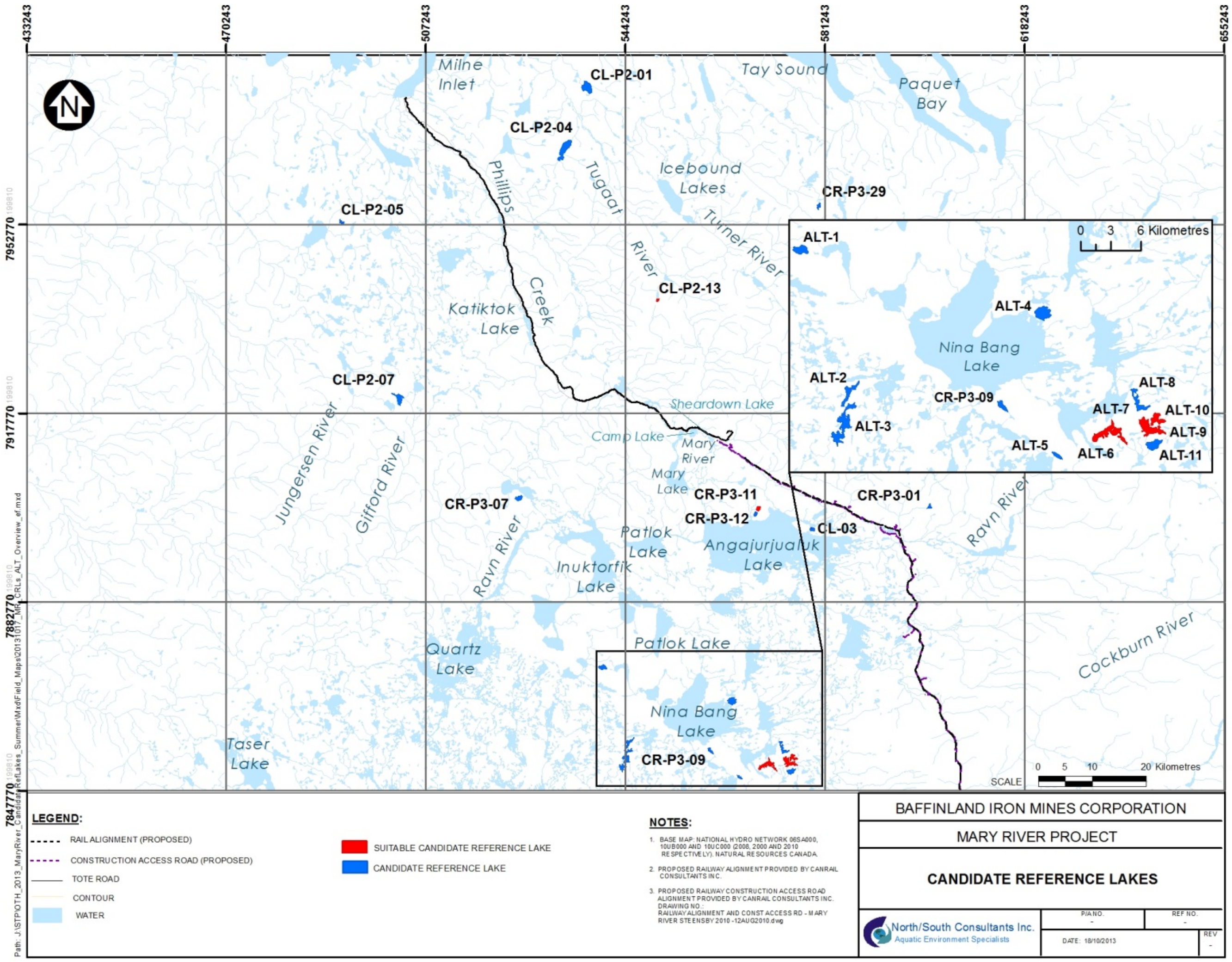


Figure 1. Proposed candidate reference lakes surveyed during summer and fall 2013. Lakes highlighted in red were identified as those most likely to be suitable as references for Camp and/or Sheardown NW lakes.

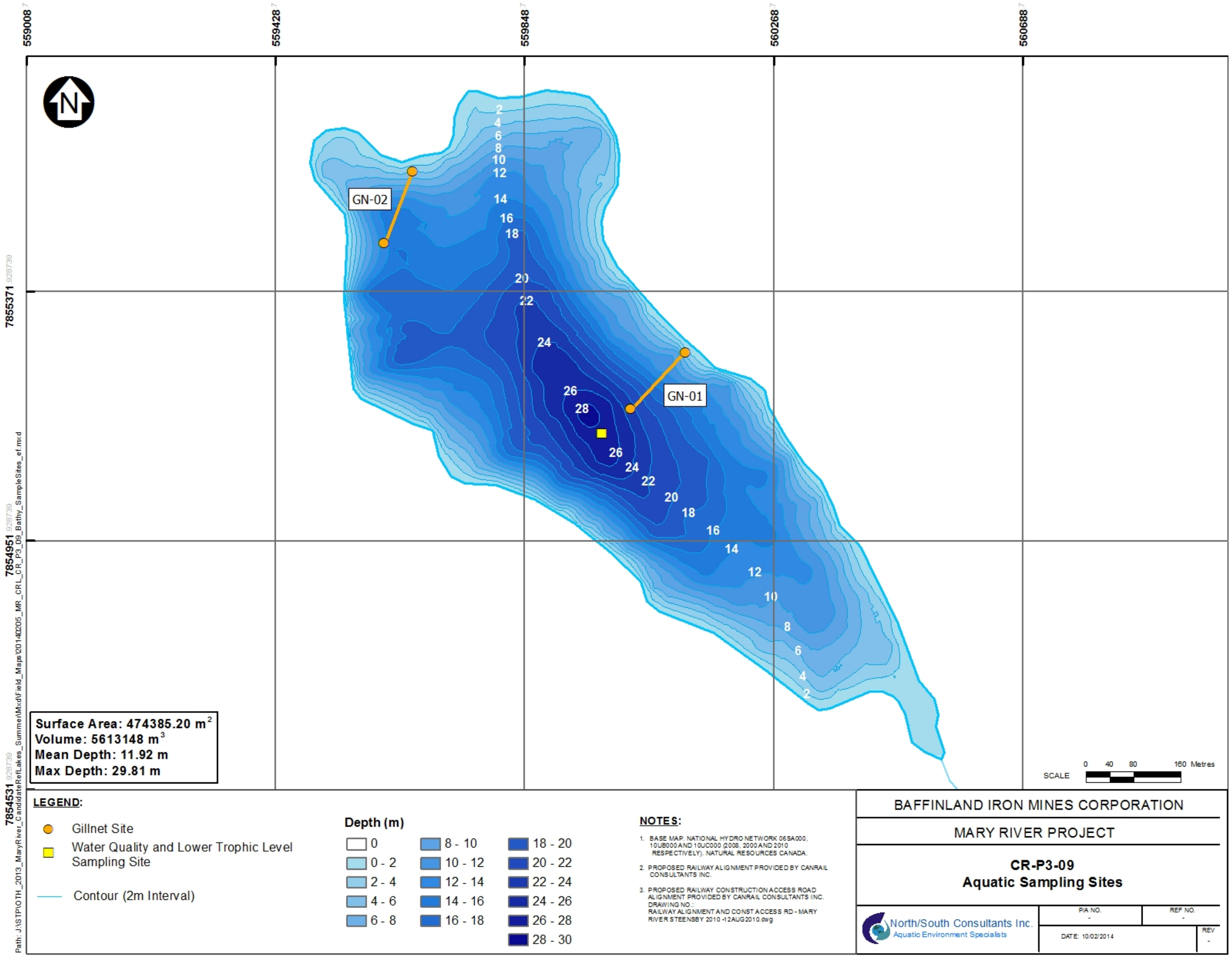


Figure 2. Bathymetry and locations of water quality, lower trophic level (phytoplankton & zooplankton), and fish sampling sites in Lake CR-P3-09.

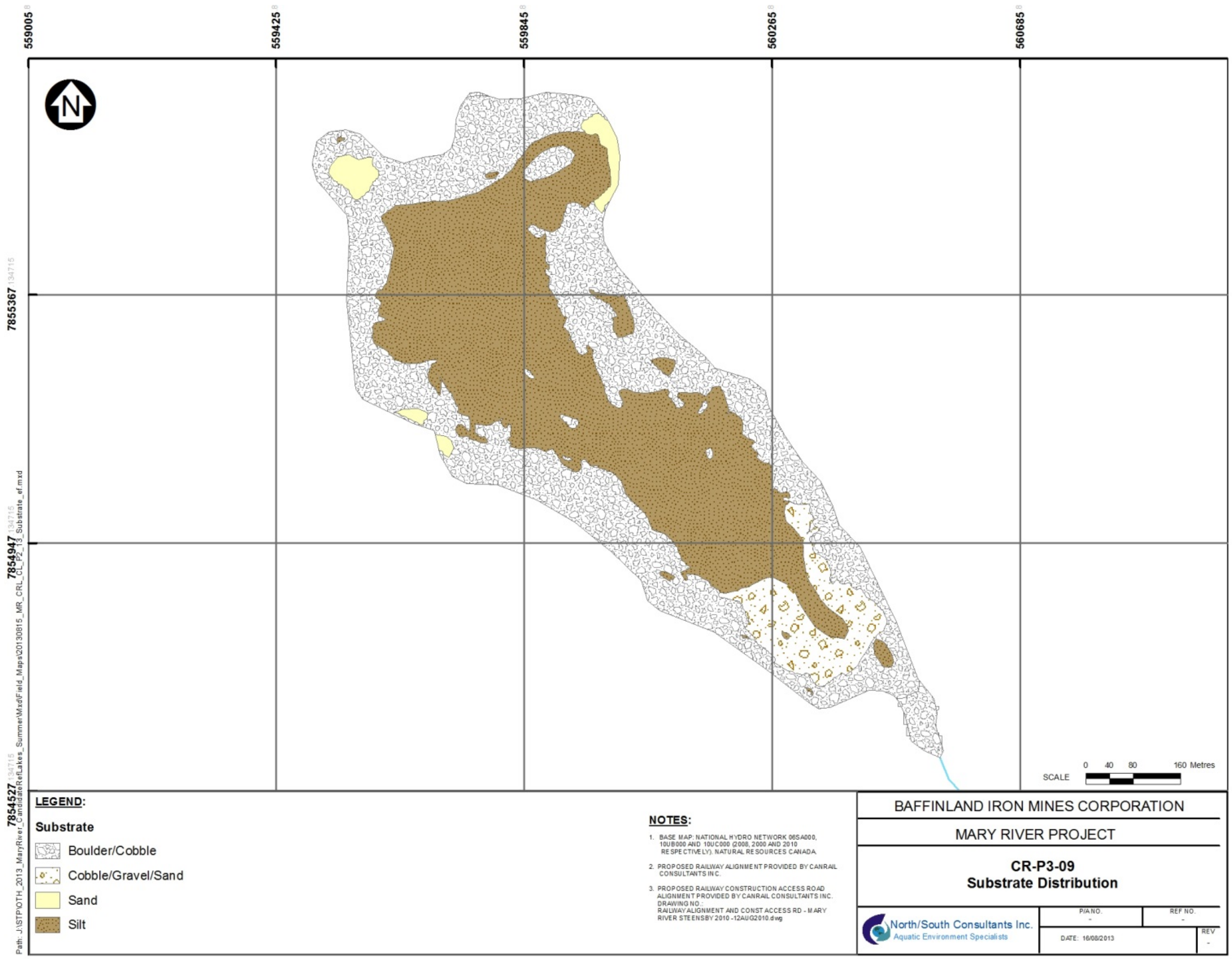


Figure 3. Substrate distribution map for Lake CR-P3-09, summer 2013.

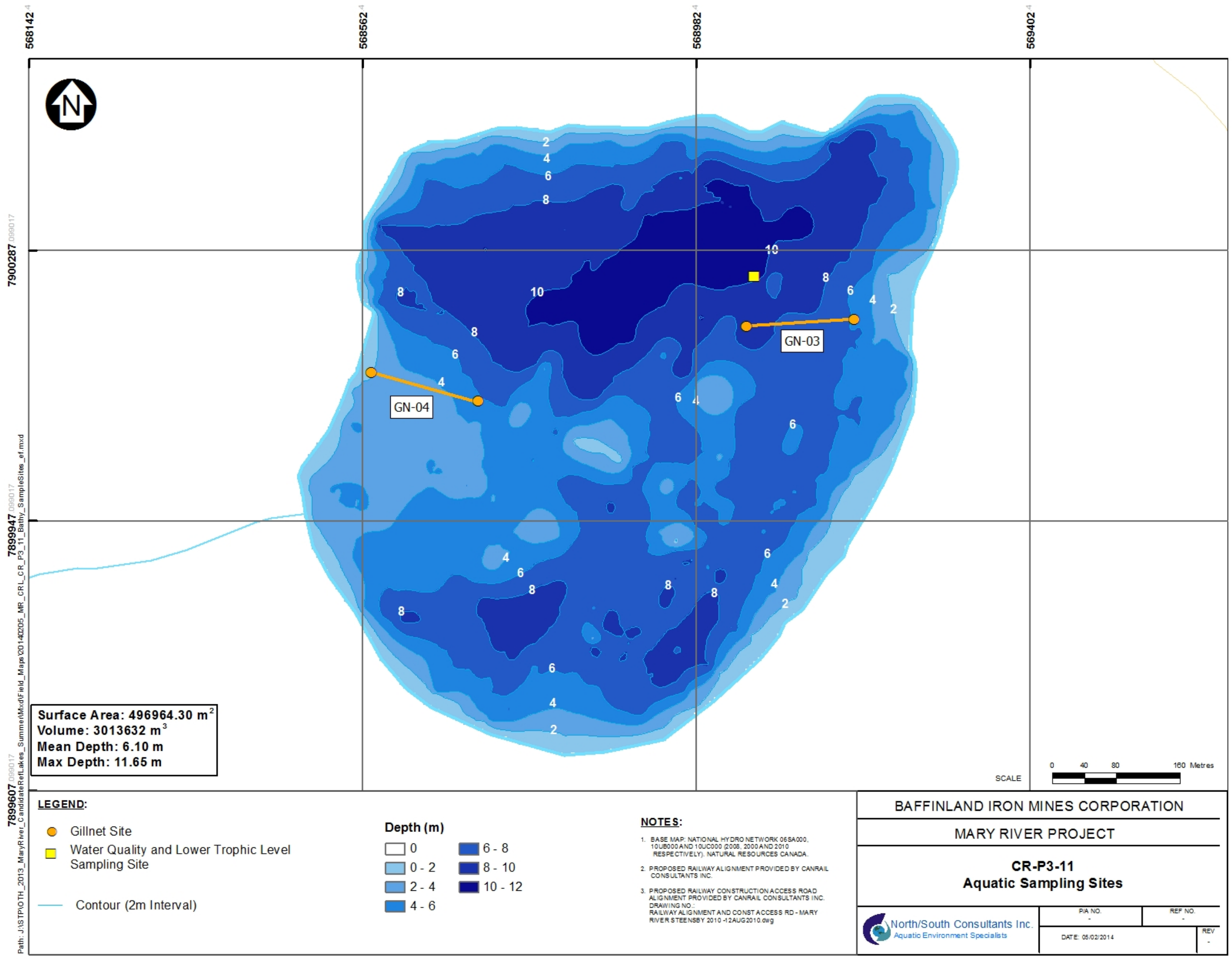
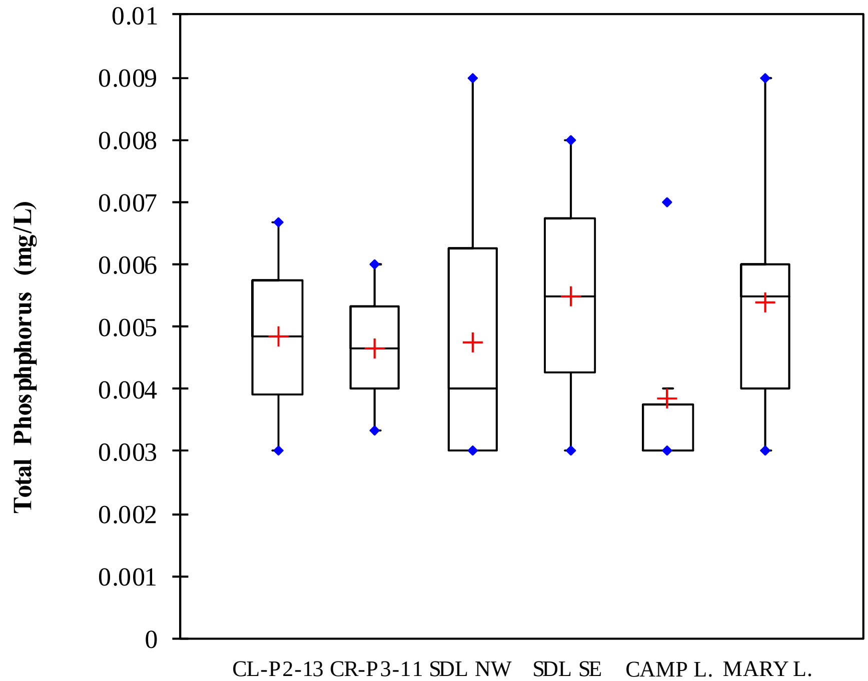


Figure 4. **Bathymetry and locations of water quality, lower trophic level (phytoplankton, zooplankton & BMI), and fish sampling sites in Lake CR-P3-11.**

(A)



(B)

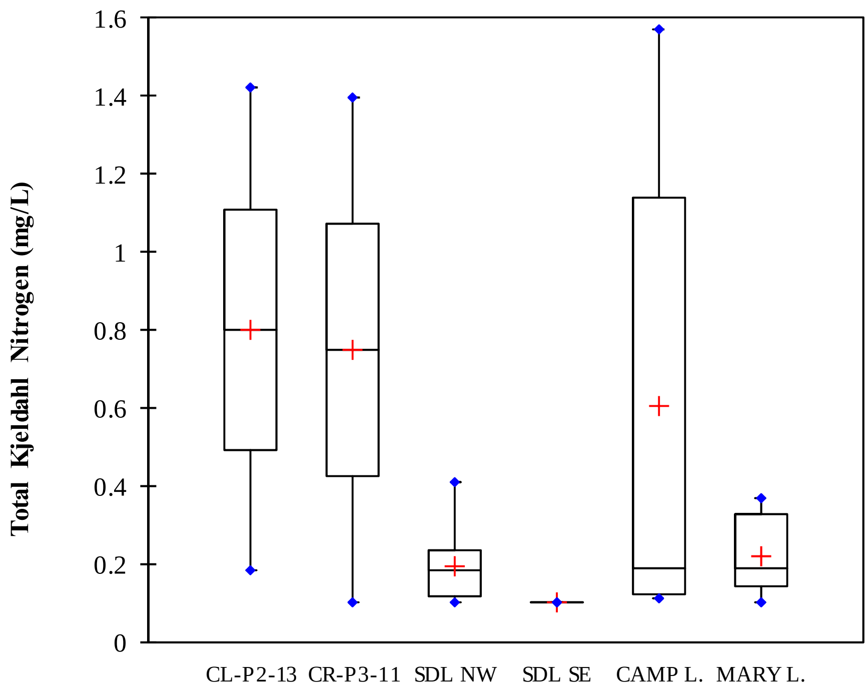


Figure 5. Total phosphorus (A) and total Kjeldahl nitrogen (B) measured in candidate reference lakes and Mine Area lakes in the open-water season, 2013.

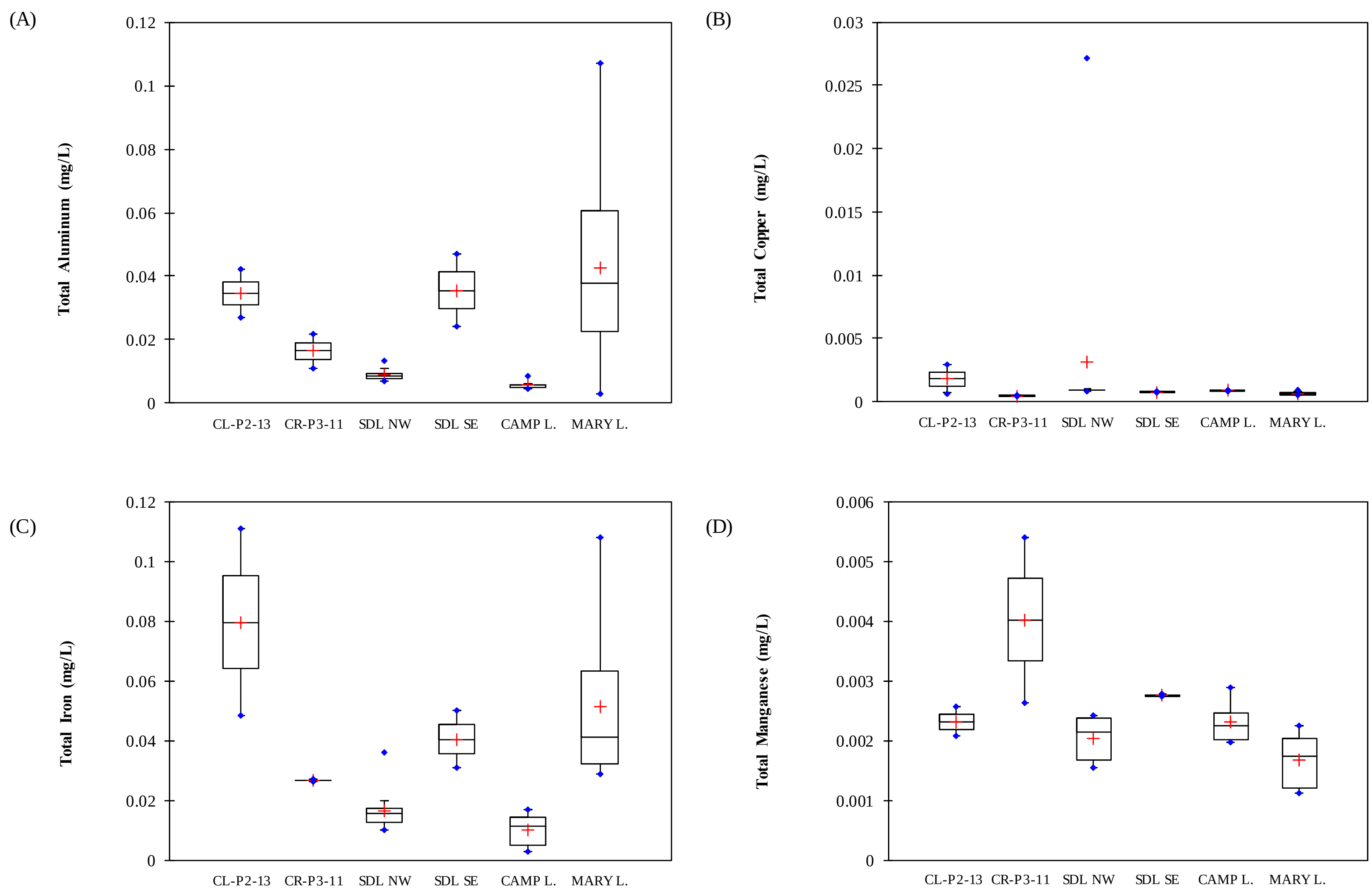


Figure 6. Total aluminum (A), total copper (B), total iron (C), and total manganese (D) measured in candidate reference lakes and Mine Area lakes in the open-water season, 2013.

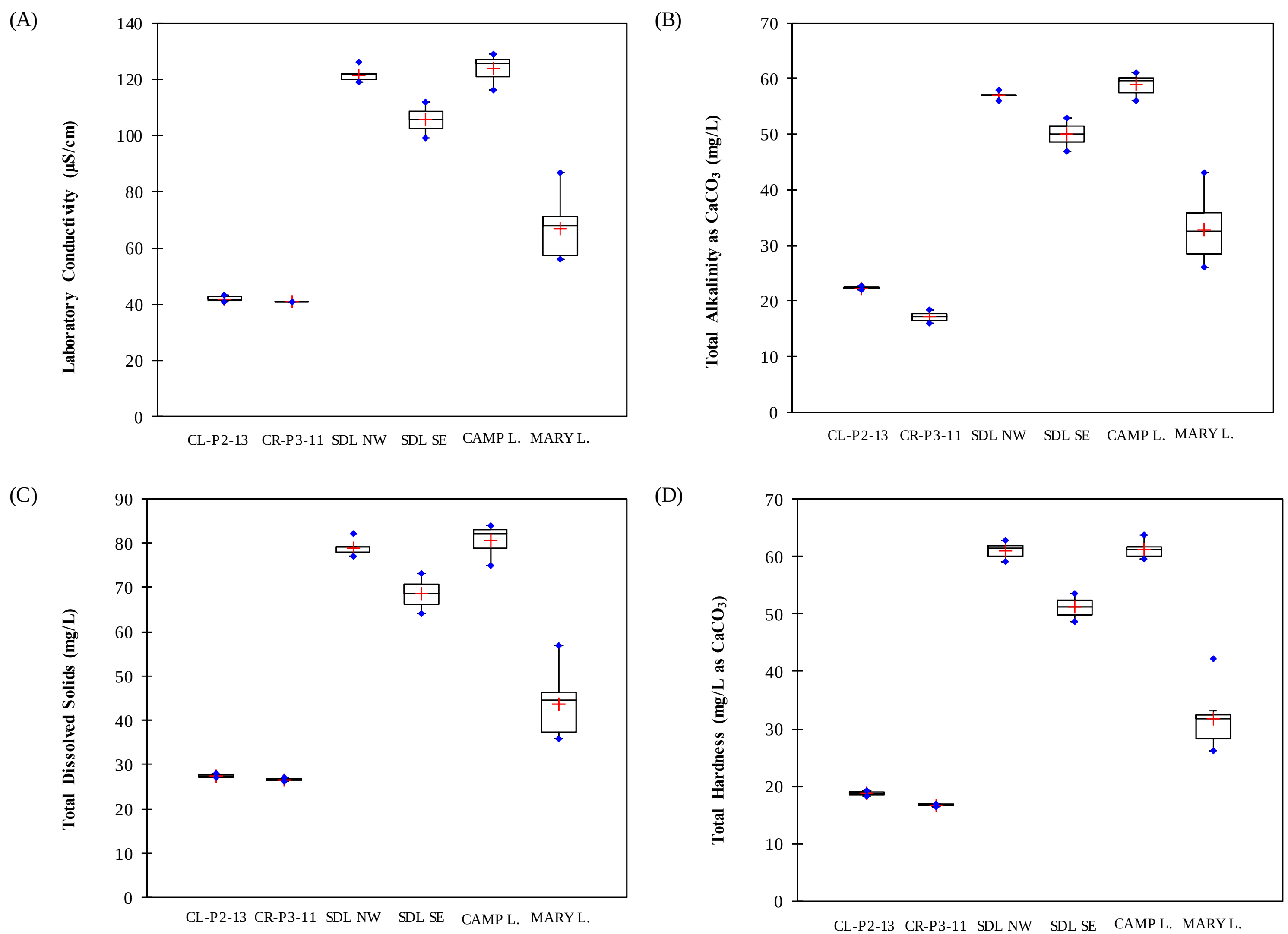


Figure 7. **Laboratory conductivity (A), total alkalinity (B), total dissolved solids (C), and hardness (D) measured in candidate reference lakes and Mine Area lakes in the open-water season, 2013.**

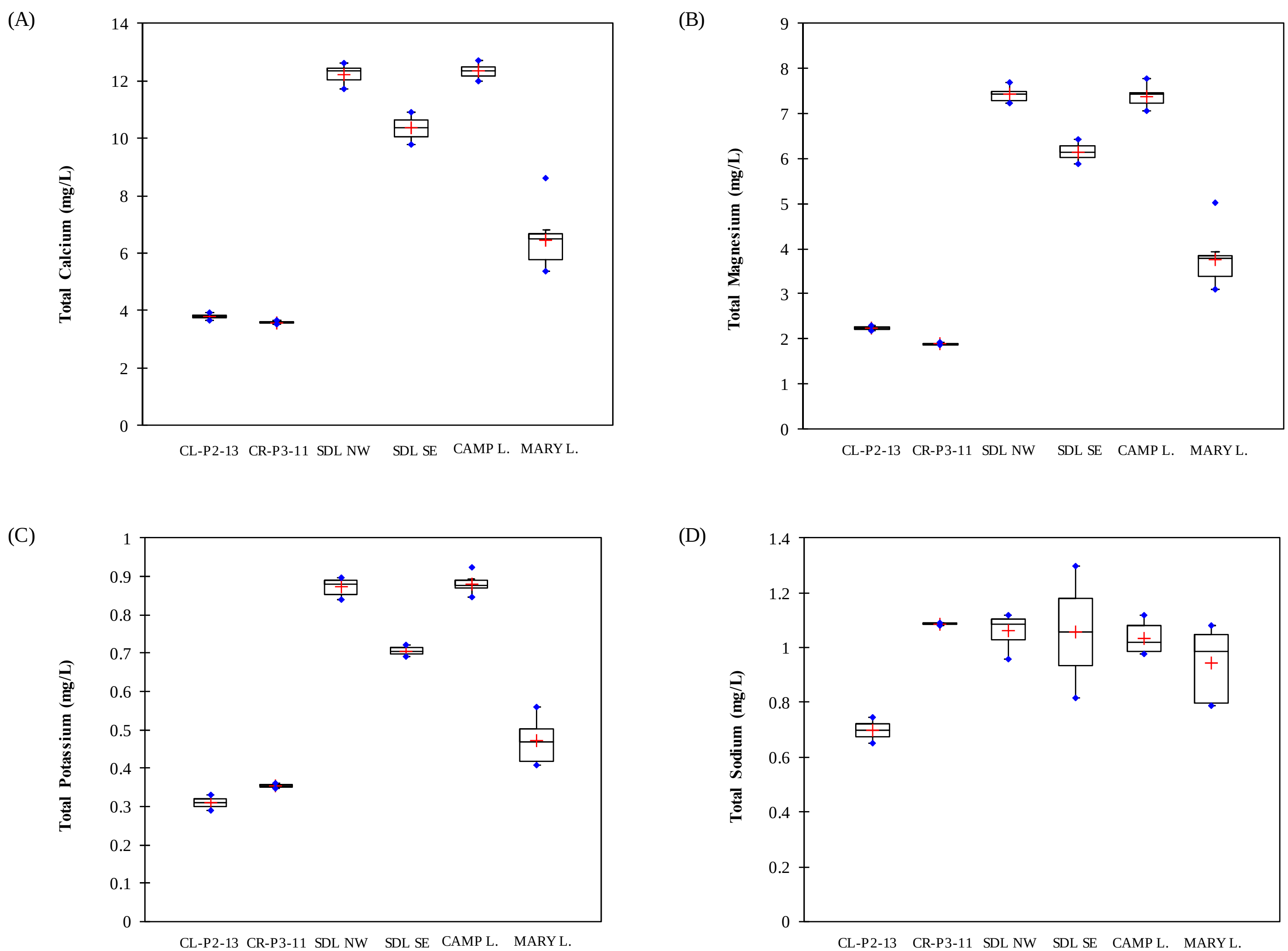


Figure 8. Total calcium (A), total magnesium (B), total potassium (C), and total sodium (D) measured in candidate reference lakes and Mine Area lakes in the open-water season, 2013.

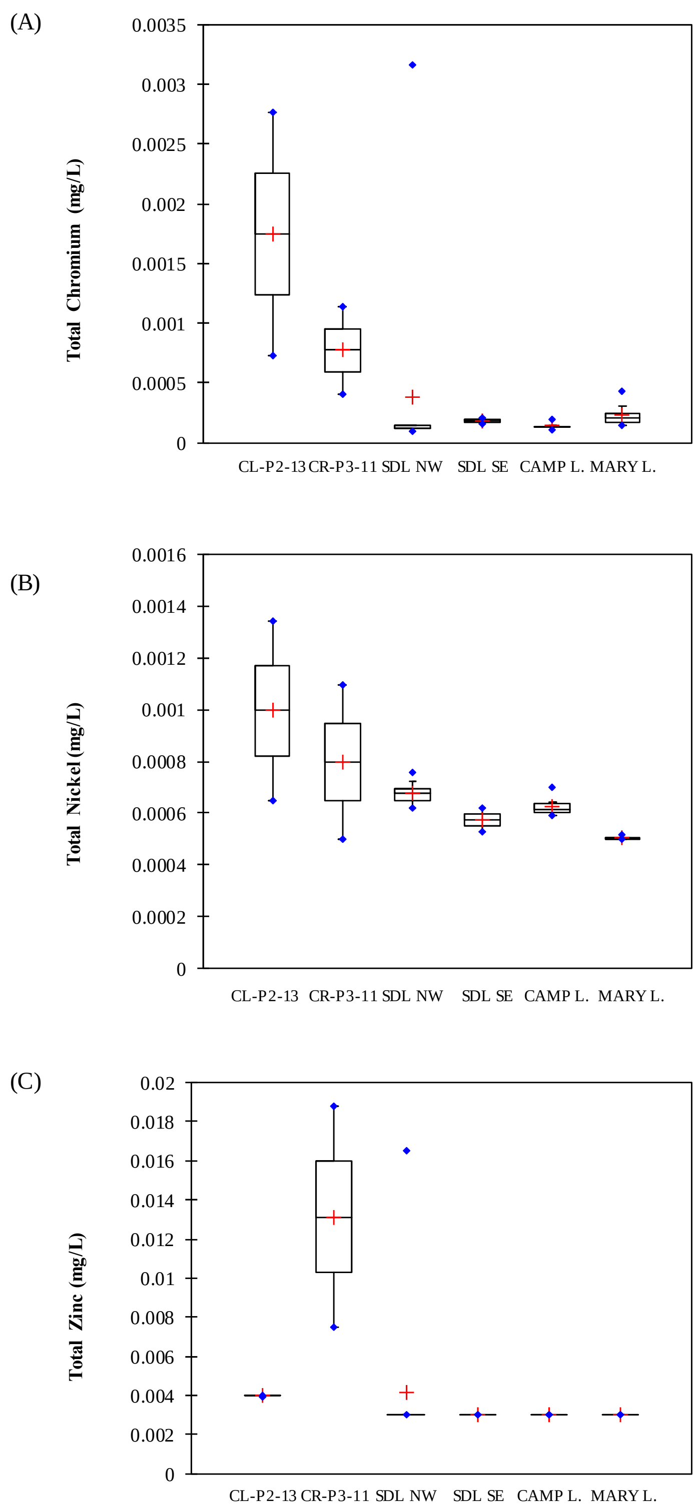


Figure 9. Total chromium (A), total nickel (B), and total zinc (C) measured in candidate reference lakes and Mine Area lakes in the open-water season, 2013.

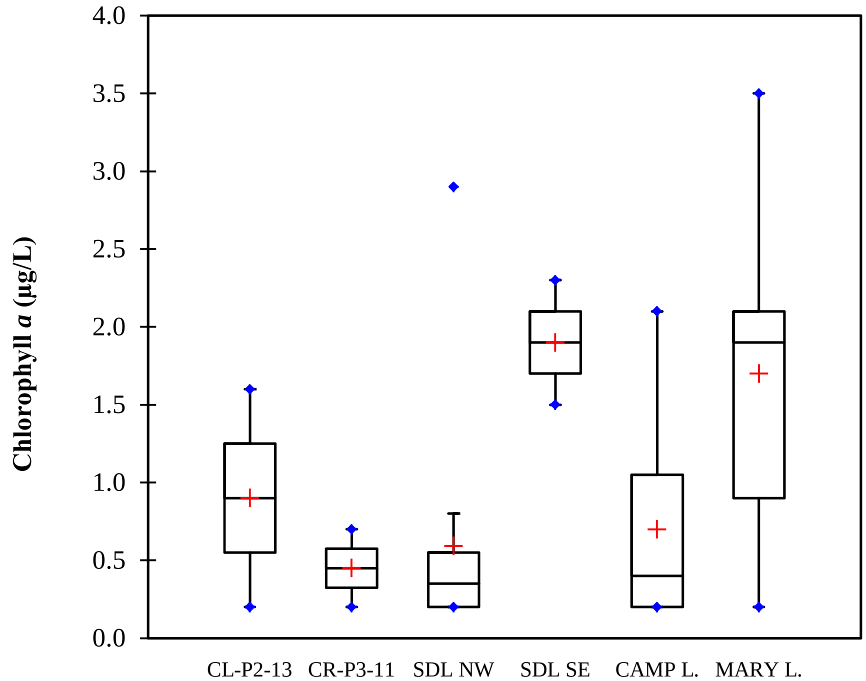


Figure 10. **Chlorophyll *a* measured in candidate reference lakes and Mine Area lakes in the open-water season, 2013.**

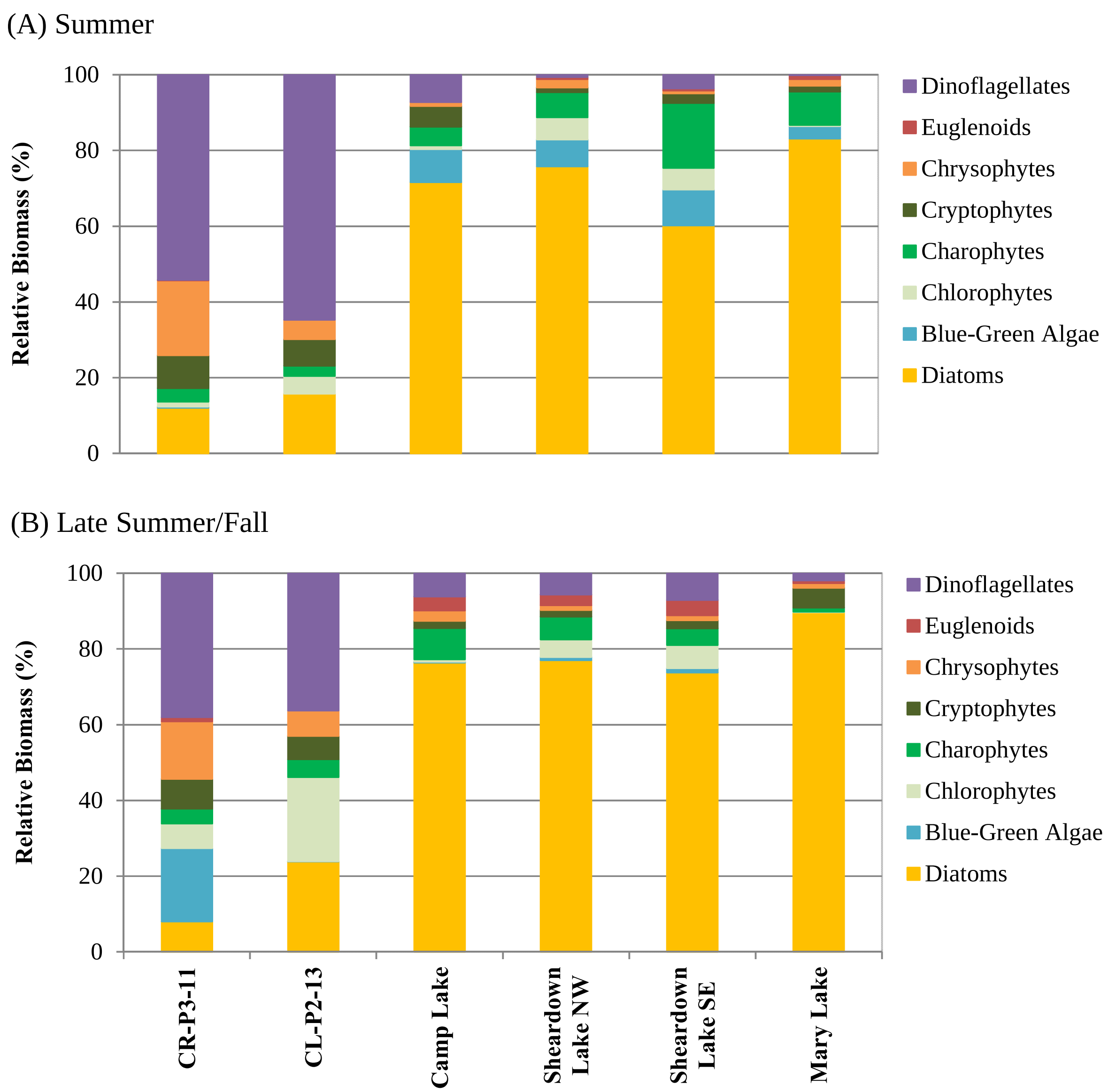


Figure 11. Percent relative biomass of major groups of phytoplankton measured in reference lakes (summer and fall 2013) and Mine Area lakes (summer and late summer/fall, 2007 and 2008).

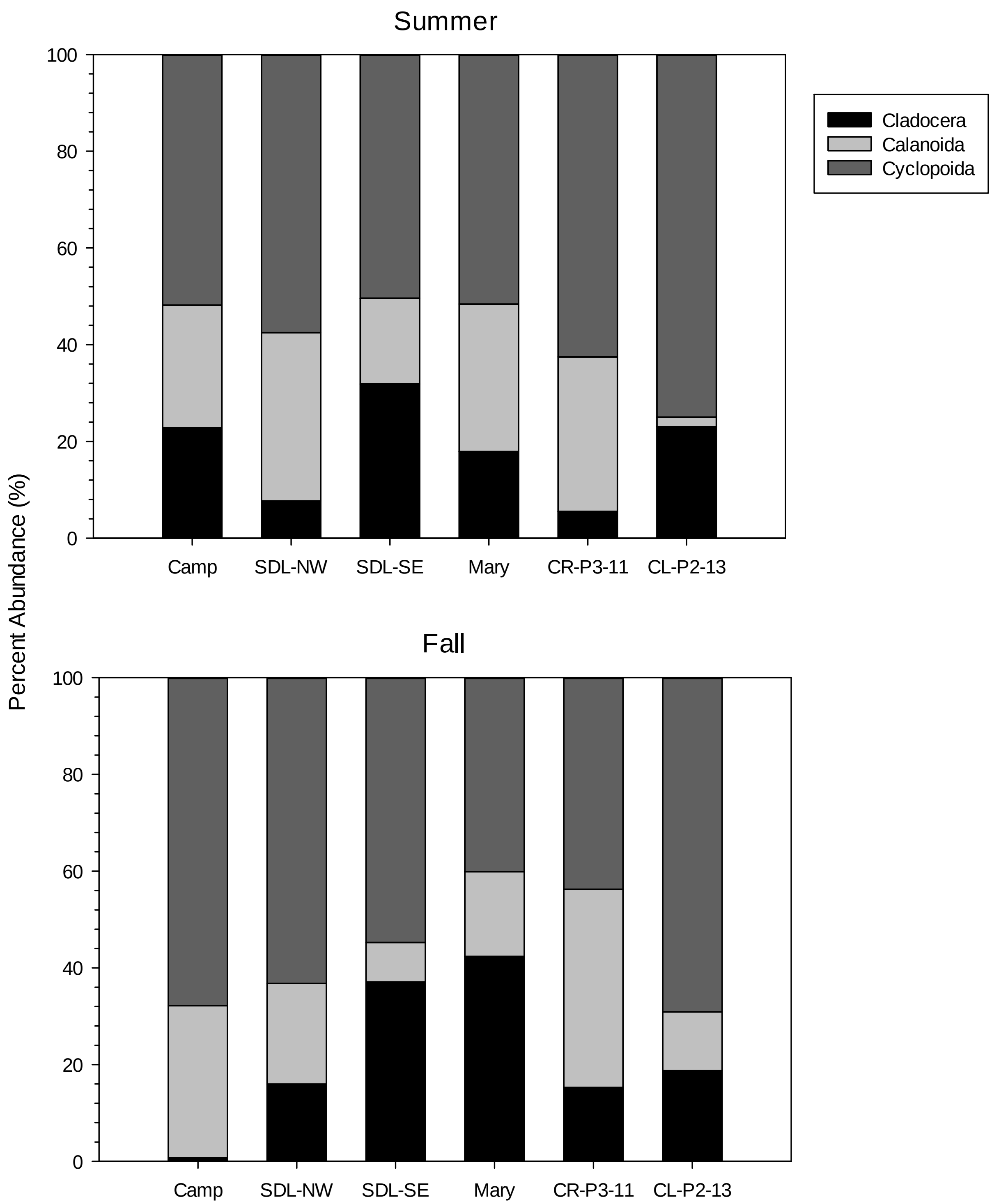


Figure 12. Seasonal relative abundance of crustacean zooplankton in Mine Area (2007 and 2008) and candidate reference (2013) lakes.

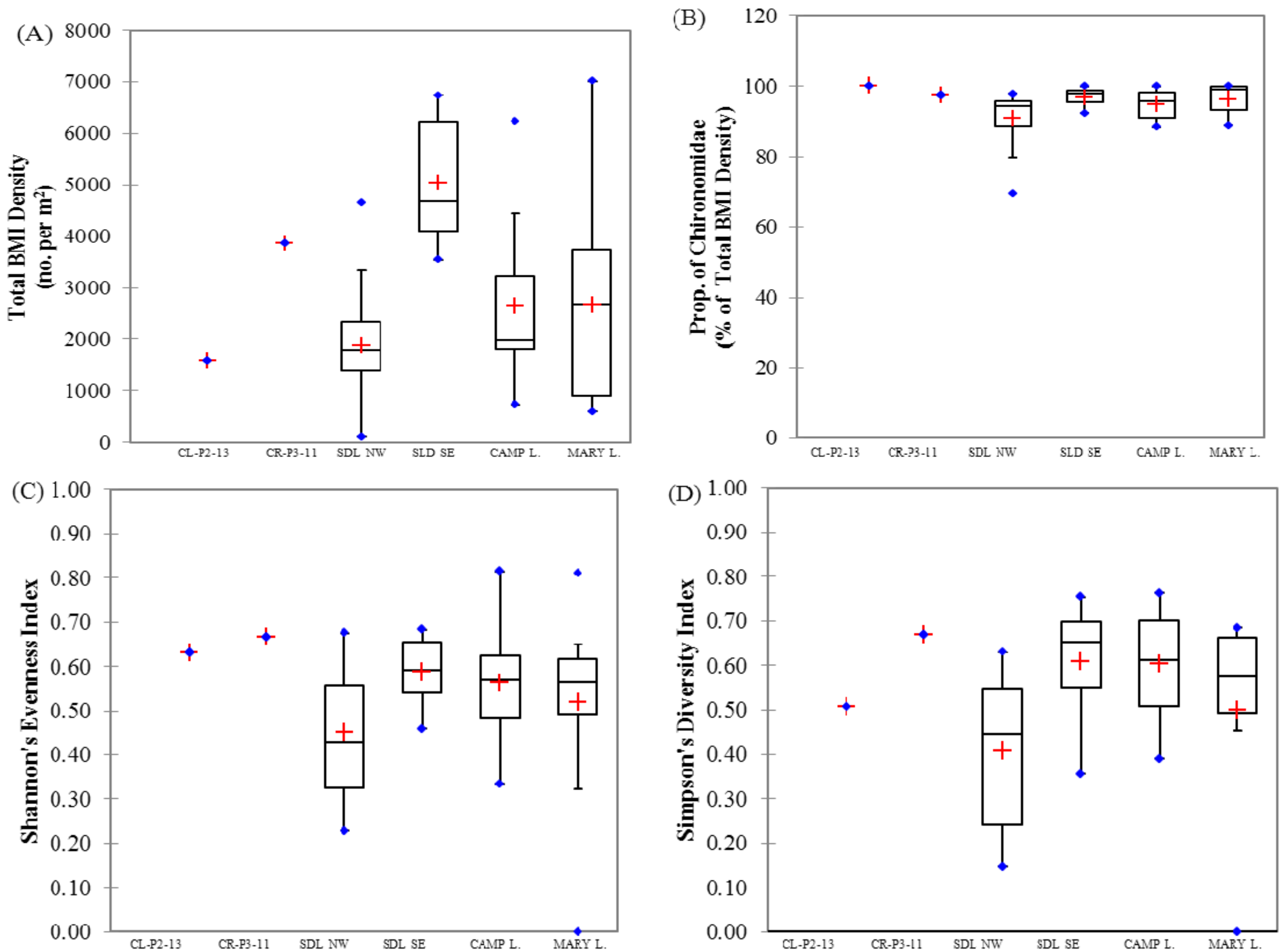


Figure 13. Total benthic macroinvertebrate (BMI) density (A), proportion of Chironomidae (B), Shannon's evenness index (C), and Simpson's diversity index (D) measures calculated from samples collected in the offshore profundal zone of candidate reference lakes (2013) and Mine Area lakes (2006, 2007, 2008, 2011, 2013).

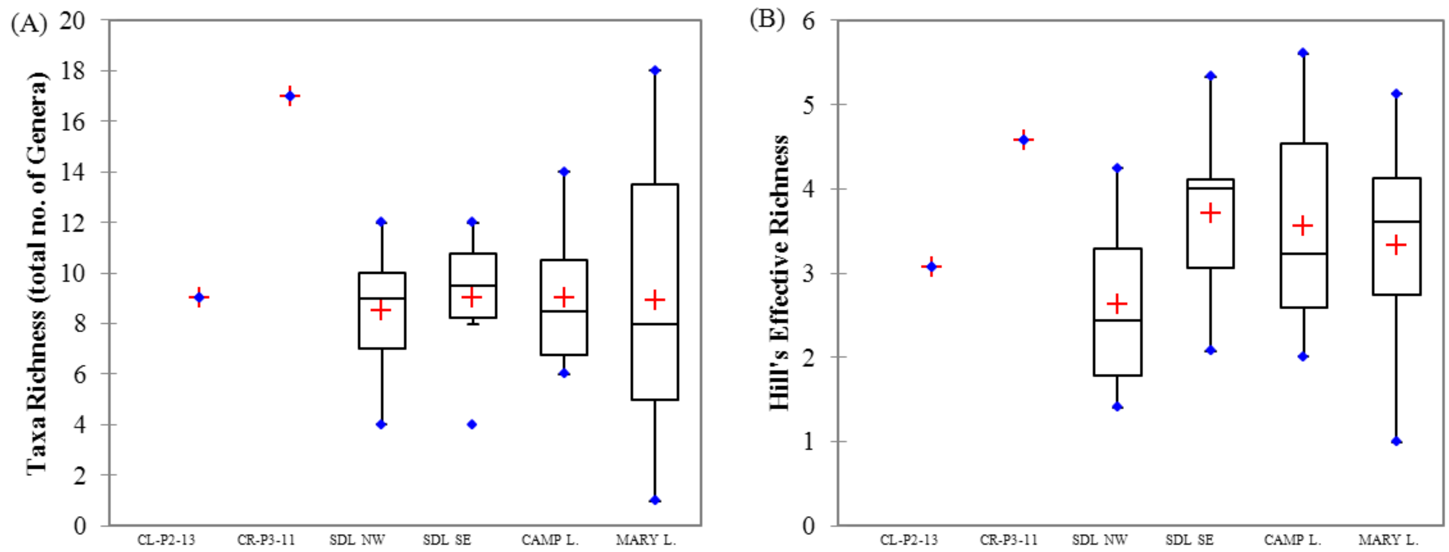


Figure 14. Total number of benthic macroinvertebrate taxa (genus-level) (A), and Hill's effective richness (B) measures calculated from samples collected in the offshore profundal zone of candidate reference lakes (CL-P2-13 and CR-P3-11; 2013) and Mine Area lakes (2006, 2007, 2008, 2011, 2013). Note: taxa richness for candidate reference lakes is the total number of taxa observed, not the average number of taxa.

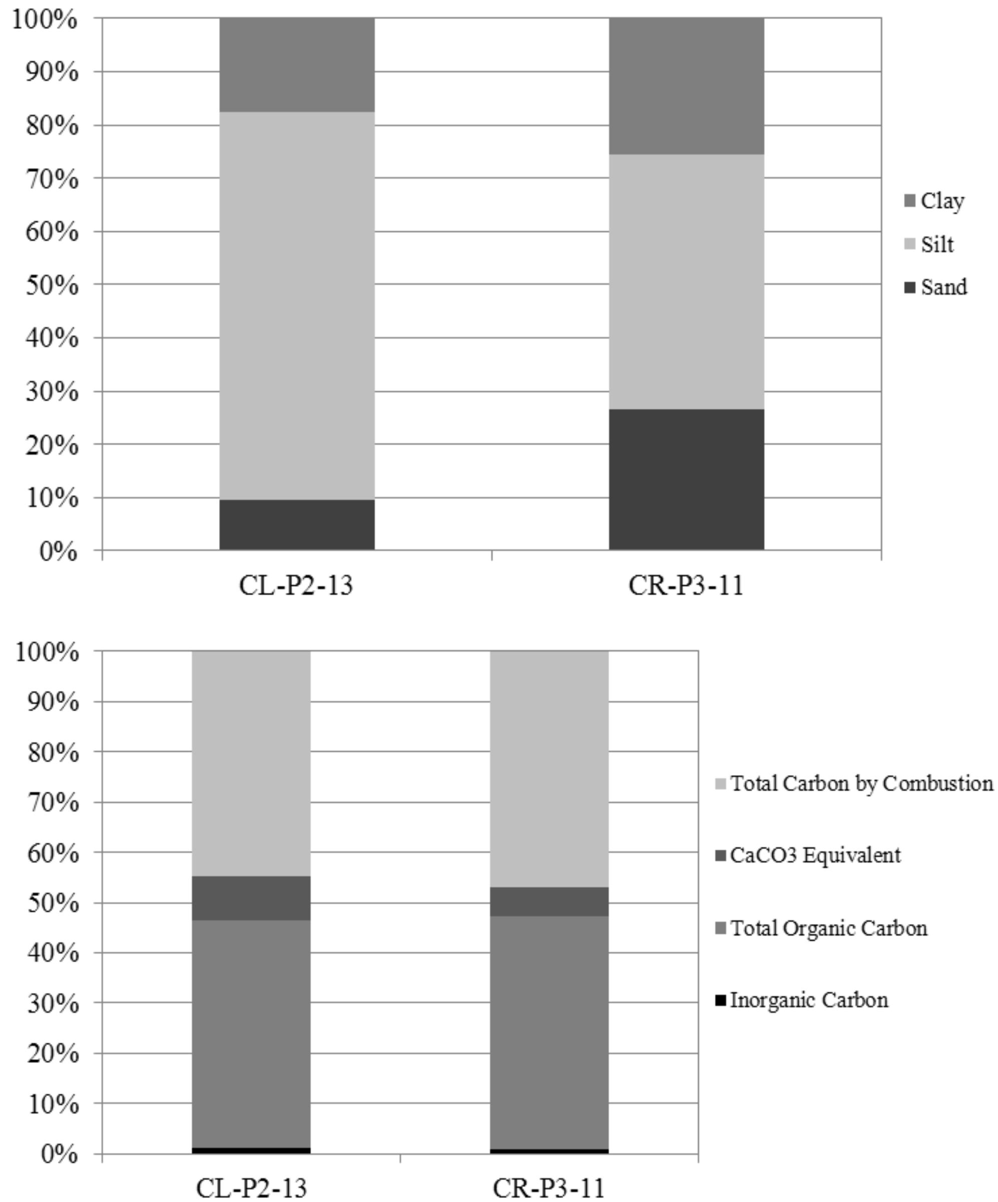


Figure 15. Particle size (% sand, % silt, % clay) (A) and organic carbon analyses (%) (B) from benthic sediment samples collected in the offshore profundal zone of candidate reference lakes (CL-P2-13 and CR-P3-11; 2013).

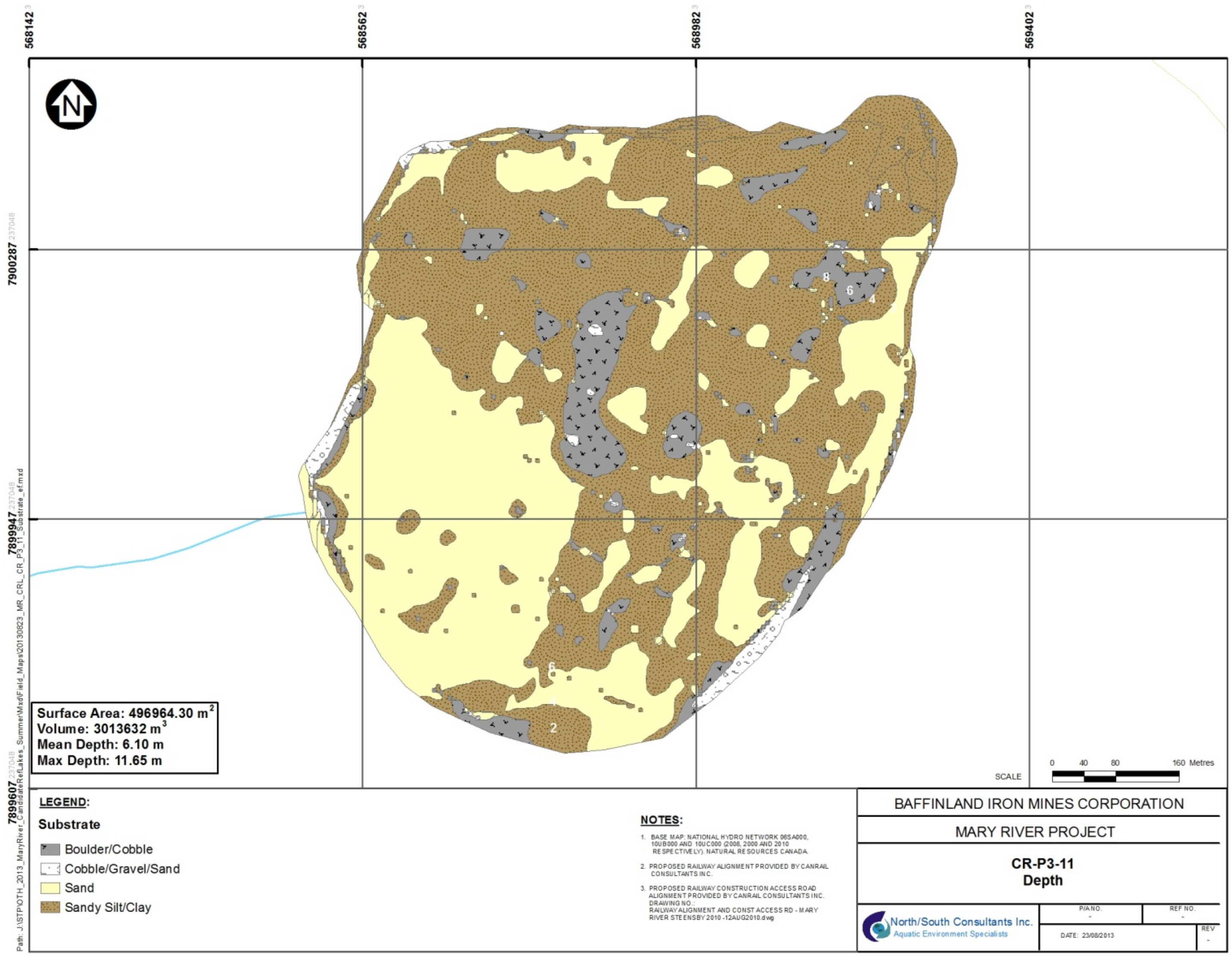


Figure 16. Substrate distribution map for Lake CR-P3-11, summer 2013.

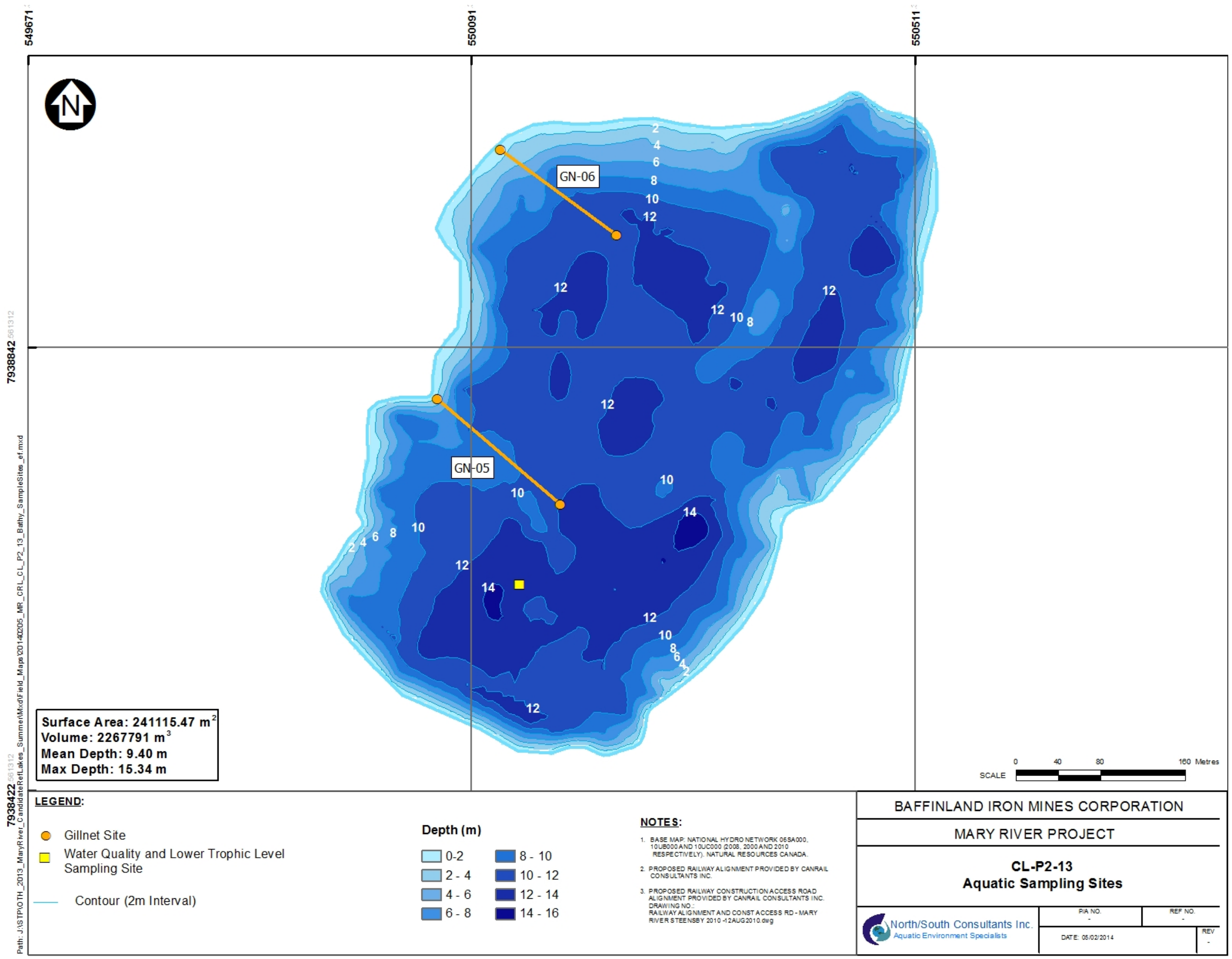


Figure 17. Bathymetry and locations of water quality, lower trophic level (phytoplankton, zooplankton & BMI), and fish sampling sites in Lake CL-P2-13.

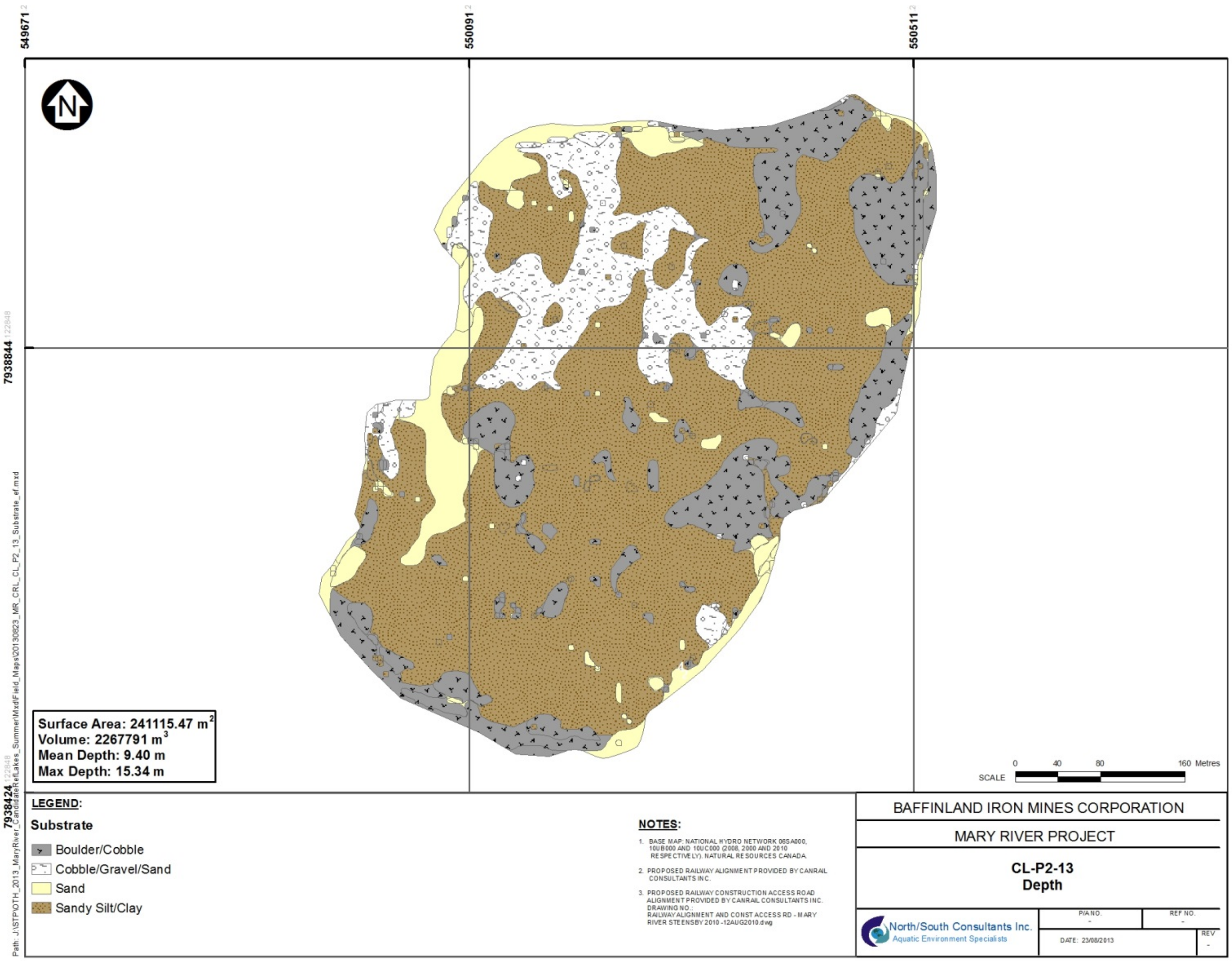


Figure 18. Substrate distribution map for Lake CL-P2-13, summer 2013.

APPENDIX 1. CANDIDATE REFERENCE LAKE WATER QUALITY DATA, 2013

Table A1-1. Summary of water quality sampling conducted in candidate reference lakes, 2013.

Waterbody	Sample ID	Site UTM (17W)		Sample Date	Sample Time	Site Depth (m)	Secchi Depth (m)	*in situ* Sample	Surface Sample	Bottom Sample
		Easting	Northing							
CR-P3-09	WQ-01	559980	7855131	05-Aug-13	15:10	28.4	9.25	Y	Y	N
CR-P3-11	WQ-02	569055	7900254	06-Aug-13	17:00	10.5	6.50	Y	Y	Y
CL-P2-13	WQ-03	550137	7938617	07-Aug-13	14:00	12.9	4.35	Y	Y	Y

Table A1-2. *In situ* water quality parameters measured in Lake CR-P3-09, summer 2013.

Depth (m)	Temperature (°C)	Specific Conductance (µS/cm)	DO (% saturation)	DO (mg/L)	pH	Turbidity (FNU)	Secchi Disk Depth (m)
1	8.5	44.9	95.8	11.30	8.11	0.04	9.25
2	8.2	44.9	96.6	11.43	8.03	0.08	
3	7.6	45.2	96.4	11.53	7.94	0.04	
4	7.6	45.2	96.8	11.58	7.88	0.05	
5	7.4	45.3	96.2	11.58	7.85	0.04	
6	7.3	45.5	96.5	11.63	7.71	0.06	
7	7.2	45.5	96.4	11.63	7.69	0.03	
8	7.2	45.5	96.2	11.64	7.68	0.05	
9	7.1	45.5	96.1	11.65	7.68	0.05	
10	7.0	45.6	96.1	11.66	7.67	0.06	
11	7.0	45.5	96.0	11.67	7.65	0.06	
12	6.9	45.6	95.9	11.67	7.66	0.04	
13	6.8	45.6	95.7	11.69	7.65	0.04	
14	6.7	45.6	95.5	11.71	7.64	0.05	
15	6.6	45.6	95.5	11.72	7.64	0.05	
16	6.5	45.6	95.3	11.73	7.63	0.05	
17	6.2	45.6	94.9	11.77	7.62	0.05	
18	6.1	45.6	95.0	11.79	7.61	0.04	
19	6.1	45.6	95.0	11.79	7.60	0.04	
20	6.0	45.6	94.8	11.80	7.59	0.05	
21	6.0	45.6	94.7	11.80	7.58	0.03	
22	5.8	45.6	94.6	11.81	7.58	0.06	
23	5.9	45.6	94.6	11.80	7.58	0.04	
24	5.9	45.6	94.6	11.81	7.57	0.05	
25	5.8	45.6	94.5	11.81	7.57	0.04	

Table A1-3. *In situ* water quality parameters measured in potential reference Lake CR-P3-11, summer and fall 2013.

Depth (m)	Temperature (°C)	Specific Conductance (µS/cm)	DO (%)	DO (mg/L)	pH	Turbidity (FNU)	Secchi Disk Depth (m)
August 6, 2013							
1	9.6	38.7	99.4	11.33	7.91	0.06	6.5
2	9.6	38.7	99.8	11.37	7.83	0.06	
3	9.6	38.7	99.9	11.39	7.77	0.06	
4	9.4	38.7	99.8	11.42	7.73	0.07	
5	9.4	38.7	99.8	11.43	7.67	0.08	
6	9.3	38.7	99.8	11.46	7.64	0.07	
7	9.3	38.7	99.7	11.45	7.61	0.08	
8	9.0	38.7	99.4	11.50	7.60	0.08	
9	8.2	38.6	98.3	11.60	7.57	0.05	
September 4, 2013							
1	4.4	41.5	90.6	11.75	8.10	0.32	5.75
2	4.4	44.1	91.8	11.90	7.82	0.29	
3	4.4	44.1	91.2	11.82	7.74	0.33	
4	4.4	44.0	91.5	11.87	7.63	0.32	
5	4.4	44.0	91.4	11.85	7.59	0.32	
6	4.4	44.0	91.2	11.84	7.52	0.30	
7	4.4	44.0	91.2	11.83	7.50	0.29	
8	4.4	43.9	90.4	11.73	7.56	0.37	
9	4.4	43.8	90.5	11.74	7.55	0.32	

Table A1-4. *In situ* water quality parameters measured in potential reference Lake CL-P2-13, summer and fall 2013.

Depth (m)	Temperature (°C)	Specific Conductance (µS/cm)	DO (%)	DO (mg/L)	pH	Turbidity (FNU)	Secchi Disk Depth (m)
August 7, 2013							
1	6.9	40.8	93.7	11..46	8.23	0.58	4.35
2	6.8	40.7	96.3	11.75	8.02	0.60	
3	6.8	40.7	97.3	11.88	7.96	0.58	
4	6.8	40.7	97.7	11.92	7.82	0.63	
5	6.7	40.7	97.6	11.93	7.73	0.57	
6	6.6	40.7	97.4	11.96	7.59	0.61	
7	6.4	40.7	97.6	12.01	7.42	0.59	
8	6.4	40.8	97.5	12.01	7.37	0.62	
9	5.8	40.6	96.8	12.08	7.29	0.59	
10	5.6	40.7	96.7	12.14	7.23	0.58	
11	5.4	40.6	96.4	12.18	7.20	0.61	
September 4, 2013							
1	3.8	43.2	87.8	11.55	7.42	0.73	4.25
2	3.8	43.2	87.5	11.52	7.66	0.74	
3	3.8	43.3	87.2	11.49	7.58	0.71	
4	3.8	43.3	87.1	11.47	7.66	0.67	
5	3.8	43.2	87.0	11.46	7.61	0.66	
6	3.8	43.3	86.9	11.45	7.48	0.70	
7	3.8	43.2	86.8	11.43	7.43	0.64	
8	3.8	43.2	86.7	11.43	7.62	0.70	
9	3.8	43.3	86.7	11.42	7.60	0.66	
10	3.8	43.2	86.6	11.41	7.51	0.70	
11	3.8	43.2	86.5	11.40	7.46	0.70	
12	3.8	43.3	86.5	11.39	7.38	0.67	

Table A1-5. Laboratory water quality results for lakes CR-P3-11 and CL-P2-13, 2013.

Waterbody	Site ID	Sampling Date	Surface/ Bottom	Notes	Chlorophyll *a*	Pheophytin *a*	pH	Conductivity	Turbidity	Alkalinity as $CaCO_3$	Bromide	Chloride	Hardness as $CaCO_3$ (Dissolved)	Hardness as $CaCO_3$ (Total)	Ammonia	Nitrite	Nitrate/nitrite	Nitrate	Sulphate	Total Dissolved Solids	Total Suspended Solids
					µg/L	µg/L		µS/cm	NTU	mg/L	mg/L	mg/L	mg/L	mg/L	mg N/L	mg N/L	mg N/L	mg N/L	mg/L	mg/L	mg/L
CP-P3-11	CP-P3-11SA	2013-08-06	Surface	Replicate 1	<0.2	0.2	6.72	39	0.3	17	<0.25	2	15.8	16.2	0.03	<0.005	<0.10	<0.10	<3	25	<2
CP-P3-11	CP-P3-11SB	2013-08-06	Surface	Replicate 2	<0.2	2.8	6.71	39	0.4	17	<0.25	2	15.9	16.5	0.04	<0.005	<0.10	<0.10	<3	25	<2
CP-P3-11	CP-P3-11SC	2013-08-06	Surface	Replicate 3	<0.2	0.7	6.86	45	0.5	21	<0.25	2	15.9	16.7	0.03	<0.005	<0.10	<0.10	<3	29	<2
CP-P3-11	CP-P3-11Bot	2013-08-06	Bottom		1.1	<0.2	6.71	39	0.5	16	<0.25	2	15.8	16.2	0.04	<0.005	<0.10	<0.10	<3	25	<2
CP-P3-11	CR-P3-11S	2013-09-04	Surface		0.7	<0.2	6.64	41	0.8	16	<0.25	2	16.2	17.0	0.03	<0.005	<0.10	<0.10	<3	27	<2
CP-P3-11	CR-P3-11Bot	2013-09-04	Bottom		1.8	<0.2	6.63	41	0.7	17	<0.25	2	16.0	16.8	0.05	<0.005	<0.10	<0.10	<3	27	<2
CL-P2-13	CL-P2-13S	2013-08-07	Surface		<0.2	1.4	6.77	41	0.8	22	<0.25	<1	18.5	18.2	1.01	<0.005	<0.10	<0.10	<3	27	<2
CL-P2-13	CL-P2-13BOT	2013-08-07	Bottom		<0.2	2.7	6.76	41	0.9	22	<0.25	<1	18.8	18.0	0.04	<0.005	<0.10	<0.10	<3	27	<2
CL-P2-13	CL-P2-13S	2013-09-04	Surface	Replicate 1	1.5	<0.2	6.69	42	0.9	23	<0.25	<1	18.7	19.1	<0.02	<0.005	<0.10	<0.10	<3	27	<2
CL-P2-13	CL-P2-13SA	2013-09-04	Surface	Replicate 2	2.3	<0.2	6.68	43	1.1	22	<0.25	<1	19.1	19.3	<0.02	<0.005	<0.10	<0.10	<3	28	<2
CL-P2-13	CL-P2-13SB	2013-09-04	Surface	Replicate 3	1.0	<0.2	6.71	44	1.0	23	<0.25	<1	19.2	19.2	<0.02	<0.005	<0.10	<0.10	<3	29	<2
CL-P2-13	CL-P2-13Bot	2013-09-04	Bottom		3.8	<0.2	6.69	43	0.8	23	<0.25	<1	18.9	19.1	0.93	<0.005	<0.10	<0.10	<3	28	<2
	CL-P2-13F	2013-08-07		Field Blank	<0.2	<0.2	5.75	<5	0.1	<5	<0.25	<1	<0.5	<0.5	0.17	<0.005	<0.10	<0.10	<3	<1	<2
	Trip Blank	2013-09-04		Trip Blank	1.5	<0.2	6.19	<5	<0.1	<5	<0.25	<1	<0.5	<0.5	<0.02	<0.005	<0.10	<0.10	<3	<1	<2
	Field Blank	2013-09-04		Field Blank	2.0	<0.2	5.72	<5	<0.1	<5	<0.25	<1	<0.5	<0.5	<0.02	<0.005	<0.10	<0.10	<3	<1	<2

Table A1-5. - continued -

Waterbody	Site ID	Sampling Date	Surface/ Bottom	Notes	Total Phosphorus	Total Kjeldahl Nitrogen	Phenols	Total Organic Carbon	Dissolved Organic Carbon	Aluminum (Dissolved)	Aluminum (Total)	Antimony (Dissolved)	Antimony (Total)	Arsenic (Dissolved)	Arsenic (Total)	Barium (Dissolved)	Barium (Total)	Beryllium (Dissolved)	Beryllium (Total)	Bismuth (Dissolved)	Bismuth (Total)
					mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
CP-P3-11	CP-P3-11SA	2013-08-06	Surface	Replicate 1	0.004	0.68	<0.001	1.7	1.7	0.0042	0.0106	<0.00010	<0.00010	<0.00010	<0.00010	0.0026	0.00260	<0.00010	<0.00002	<0.00050	<0.00050
CP-P3-11	CP-P3-11SB	2013-08-06	Surface	Replicate 2	0.003	0.14	<0.001	1.8	1.6	0.0039	0.0114	<0.00010	<0.00010	<0.00010	<0.00010	0.00261	0.00269	<0.00010	<0.00002	<0.00050	<0.00050
CP-P3-11	CP-P3-11SC	2013-08-06	Surface	Replicate 3	0.003	3.37	<0.001	2	1.7	0.0039	0.0112	<0.00010	<0.00010	<0.00010	<0.00010	0.00259	0.00274	<0.00010	<0.00002	<0.00050	<0.00050
CP-P3-11	CP-P3-11Bot	2013-08-06	Bottom		0.003	0.11	<0.001	1.8	1.7	0.0047	0.0136	<0.00010	<0.00010	<0.00010	<0.00010	0.00268	0.00263	<0.00010	<0.00002	<0.00050	<0.00050
CP-P3-11	CR-P3-11S	2013-09-04	Surface		0.006	<0.10	<0.001	2.2	2.2	0.0046	0.0218	<0.00010	<0.00010	<0.00010	<0.00010	0.00287	0.00284	<0.00010	<0.00002	<0.00050	<0.00050
CP-P3-11	CR-P3-11Bot	2013-09-04	Bottom		0.005	0.11	<0.001	2	2	0.0044	0.0237	<0.00010	<0.00010	<0.00010	<0.00010	0.00287	0.00287	<0.00010	<0.00002	<0.00050	<0.00050
CL-P2-13	CL-P2-13S	2013-08-07	Surface		<0.003	1.42	<0.001	1.1	0.8	0.0040	0.0271	<0.00010	<0.00010	<0.00010	<0.00010	0.00215	0.00233	<0.00010	<0.00002	<0.00050	<0.00050
CL-P2-13	CL-P2-13BOT	2013-08-07	Bottom		0.003	1.33	<0.001	0.9	0.8	0.0046	0.0287	<0.00010	<0.00010	<0.00010	<0.00010	0.00211	0.00218	<0.00010	<0.00002	<0.00050	<0.00050
CL-P2-13	CL-P2-13S	2013-09-04	Surface	Replicate 1	0.004	0.35	<0.001	1.4	1.2	0.0033	0.0323	<0.00010	<0.00010	<0.00010	0.00013	0.00231	0.00248	<0.00010	<0.00002	<0.00050	<0.00050
CL-P2-13	CL-P2-13SA	2013-09-04	Surface	Replicate 2	0.009	<0.10	0.021	1.1	1.3	0.0037	0.0504	<0.00010	<0.00010	<0.00010	0.00014	0.00223	0.00248	<0.00010	<0.00002	<0.00050	<0.00050
CL-P2-13	CL-P2-13SB	2013-09-04	Surface	Replicate 3	0.007	<0.10	0.029	1.2	1.4	0.0044	0.0434	<0.00010	<0.00010	<0.00010	0.00015	0.00222	0.00263	<0.00010	<0.00002	<0.00050	<0.00050
CL-P2-13	CL-P2-13Bot	2013-09-04	Bottom		0.06	1.12	<0.001	1.1	1.2	0.0042	0.3870	<0.00010	<0.00010	<0.00010	<0.00010	0.00226	0.00381	<0.00010	<0.00002	<0.00050	<0.00050
	CL-P2-13F	2013-08-07		Field Blank	<0.003	0.37	<0.001	<0.5	<0.5	<0.001	<0.001	<0.00010	<0.00010	<0.00010	<0.00010	0.000788	0.000596	<0.00010	<0.00002	<0.00050	<0.00050
	Trip Blank	2013-09-04		Trip Blank	<0.003	<0.10	<0.001	<0.5	<0.5	<0.001	<0.001	<0.00010	<0.00010	<0.00010	<0.00010	<0.000050	<0.000050	<0.00010	<0.00002	<0.00050	<0.00050
	Field Blank	2013-09-04		Field Blank	<0.003	<0.10	<0.001	<0.5	<0.5	<0.001	<0.001	<0.00010	<0.00010	<0.00010	<0.00010	<0.000050	<0.000050	<0.00010	<0.00002	<0.00050	<0.00050

Table A1-5. - continued -

Waterbody	Site ID	Sampling Date	Surface/ Bottom	Notes	Boron (Dissolved)	Boron (Total)	Cadmium (Dissolved)	Cadmium (Total)	Calcium (Dissolved)	Calcium (Total)	Chromium (Dissolved)	Chromium (Total)	Hexavalent Chromium (dissolved(	Cobalt (Dissolved)	Cobalt (Total)	Copper (Dissolved)	Copper (Total)	Iron (Dissolved)	Iron (Total)
					mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
CP-P3-11	CP-P3-11SA	2013-08-06	Surface	Replicate 1	<0.01	<0.01	<0.000010	<0.000010	3.37	3.47	<0.00010	0.00029	<0.001	<0.00010	<0.00010	0.0003	<0.00020	<0.01	0.02
CP-P3-11	CP-P3-11SB	2013-08-06	Surface	Replicate 2	<0.01	<0.01	<0.000010	<0.000010	3.4	3.53	<0.00010	0.0022	<0.001	<0.00010	<0.00010	0.00031	0.0005	<0.01	0.032
CP-P3-11	CP-P3-11SC	2013-08-06	Surface	Replicate 3	<0.01	<0.01	<0.000010	<0.000010	3.38	3.57	<0.00010	0.00092	<0.001	<0.00010	<0.00010	0.00034	0.00054	<0.01	0.027
CP-P3-11	CP-P3-11Bot	2013-08-06	Bottom		<0.01	<0.01	<0.000010	<0.000010	3.37	3.45	<0.00010	0.00951	<0.001	<0.00010	<0.00010	0.00039	0.00052	<0.01	0.059
CP-P3-11	CR-P3-11S	2013-09-04	Surface		<0.01	<0.01	<0.000010	<0.000010	3.5	3.65	<0.00010	0.00041	<0.001	<0.00010	<0.00010	0.0004	0.0005	<0.01	0.027
CP-P3-11	CR-P3-11Bot	2013-09-04	Bottom		<0.01	<0.01	<0.000010	0.000021	3.43	3.58	0.00015	0.00037	<0.001	<0.00010	<0.00010	0.00037	<0.00020	<0.01	0.03
CL-P2-13	CL-P2-13S	2013-08-07	Surface		<0.01	<0.01	<0.000010	<0.000010	3.73	3.68	<0.00010	0.00277	<0.001	<0.00010	<0.00010	0.00045	0.00292	<0.01	0.111
CL-P2-13	CL-P2-13BOT	2013-08-07	Bottom		<0.01	<0.01	<0.000010	<0.000010	3.79	3.65	<0.00010	0.00019	<0.001	<0.00010	<0.00010	0.00053	0.00053	<0.01	0.028
CL-P2-13	CL-P2-13S	2013-09-04	Surface	Replicate 1	<0.01	<0.01	<0.000010	<0.000010	3.81	3.88	0.0001	0.00037	<0.001	<0.00010	<0.00010	0.00054	0.00063	<0.01	0.038
CL-P2-13	CL-P2-13SA	2013-09-04	Surface	Replicate 2	<0.01	<0.01	<0.000010	<0.000010	3.96	3.94	<0.00010	0.0009	<0.001	<0.00010	<0.00010	0.00026	0.00071	<0.01	0.055
CL-P2-13	CL-P2-13SB	2013-09-04	Surface	Replicate 3	<0.01	<0.01	<0.000010	<0.000010	3.99	3.95	<0.00010	0.00093	<0.001	<0.00010	<0.00010	0.00031	0.00066	<0.01	0.052
CL-P2-13	CL-P2-13Bot	2013-09-04	Bottom		<0.01	<0.01	<0.000010	<0.000010	3.87	3.77	<0.00010	0.00137	<0.001	<0.00010	0.00021	0.00046	0.00133	<0.01	0.522
	CL-P2-13F	2013-08-07		Field Blank	<0.01	<0.01	<0.000010	<0.000010	0.115	0.126	<0.00010	<0.00002	<0.001	<0.00010	<0.00010	<0.00020	<0.00020	<0.01	<0.003
	Trip Blank	2013-09-04		Trip Blank	<0.01	<0.01	<0.000010	<0.000010	<0.050	<0.050	<0.00010	<0.00002	<0.001	<0.00010	<0.00010	<0.00020	<0.00020	<0.01	<0.003
	Field Blank	2013-09-04		Field Blank	<0.01	<0.01	<0.000010	<0.000010	<0.050	<0.050	<0.00010	<0.00002	<0.001	<0.00010	<0.00010	<0.00020	<0.00020	<0.01	<0.003

Table A1-5. - continued -

Waterbody	Site ID	Sampling Date	Surface/ Bottom	Notes	Lead (Dissolved)	Lead (Total)	Lithium (Dissolved)	Lithium (Total)	Magnesium (Dissolved)	Magnesium (Total)	Manganese (Dissolved)	Manganese (Total)	Mercury (Dissolved)	Mercury (Total)	Molybdenum (Dissolved)	Molybdenum (Total)	Nickel (Dissolved)	Nickel (Total)	Potassium (Dissolved)	Potassium (Total)
					mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
CP-P3-11	CP-P3-11SA	2013-08-06	Surface	Replicate 1	<0.00005	<0.00005	<0.00005	<0.00005	1.80	1.83	0.00168	0.00534	<0.000010	<0.000010	<0.000050	<0.000050	<0.00050	<0.00050	0.342	0.351
CP-P3-11	CP-P3-11SB	2013-08-06	Surface	Replicate 2	<0.00005	<0.00005	<0.00005	<0.00005	1.80	1.86	0.00154	0.00556	<0.000010	<0.000010	<0.000050	0.000072	<0.00050	0.00173	0.341	0.348
CP-P3-11	CP-P3-11SC	2013-08-06	Surface	Replicate 3	<0.00005	0.00019	<0.00005	<0.00005	1.81	1.90	0.00171	0.00532	<0.000010	<0.000010	<0.000050	0.000063	<0.00050	0.00106	0.341	0.342
CP-P3-11	CP-P3-11Bot	2013-08-06	Bottom		<0.00005	0.00006	<0.00005	<0.00005	1.80	1.83	0.00170	0.00647	<0.000010	<0.000010	0.000075	0.000216	0.00167	0.00524	0.347	0.336
CP-P3-11	CR-P3-11S	2013-09-04	Surface		<0.00005	<0.00005	<0.00005	<0.00005	1.82	1.91	0.000671	0.00263	<0.000010	<0.000010	<0.000050	0.000056	<0.00050	<0.00050	0.357	0.362
CP-P3-11	CR-P3-11Bot	2013-09-04	Bottom		<0.00005	<0.00005	<0.00005	<0.00005	1.80	1.90	0.00144	0.00257	<0.000010	<0.000010	0.052	<0.000050	<0.00050	<0.00050	0.346	0.357
CL-P2-13	CL-P2-13S	2013-08-07	Surface		<0.00005	0.00013	<0.00005	<0.00005	2.24	2.19	0.00121	0.00256	<0.000010	<0.000010	0.000181	0.00076	0.00166	0.00134	0.286	0.290
CL-P2-13	CL-P2-13BOT	2013-08-07	Bottom		<0.00005	<0.00005	<0.00005	<0.00005	2.26	2.17	0.000627	0.00192	<0.000010	<0.000010	0.000087	0.000052	0.00061	<0.00050	0.286	0.285
CL-P2-13	CL-P2-13S	2013-09-04	Surface	Replicate 1	<0.00005	0.00005	<0.00005	<0.00005	2.24	2.28	0.000505	0.00187	<0.000010	<0.000010	0.000075	0.000077	0.00051	<0.00050	0.289	0.322
CL-P2-13	CL-P2-13SA	2013-09-04	Surface	Replicate 2	<0.00005	0.00006	<0.00005	<0.00005	2.23	2.29	0.000447	0.00217	<0.000010	<0.000010	<0.000050	0.000073	<0.00050	0.00078	0.287	0.334
CL-P2-13	CL-P2-13SB	2013-09-04	Surface	Replicate 3	<0.00005	0.00006	<0.00005	<0.00005	2.24	2.28	0.000439	0.00217	<0.000010	<0.000010	<0.000050	0.000064	0.00053	0.00067	0.296	0.333
CL-P2-13	CL-P2-13Bot	2013-09-04	Bottom		<0.00005	0.00033	<0.00005	0.00061	2.25	2.35	0.000444	0.0109	<0.000010	<0.000010	0.000053	0.000056	<0.00050	0.00105	0.299	0.449
	CL-P2-13F	2013-08-07		Field Blank	<0.00005	<0.00005	<0.00005	<0.00005	<0.10	<0.10	<0.000050	0.000092	<0.000010	<0.000010	<0.000050	<0.000050	<0.00050	<0.00050	<0.050	<0.050
	Trip Blank	2013-09-04		Trip Blank	<0.00005	<0.00005	<0.00005	<0.00005	<0.10	<0.10	<0.000050	<0.000050	<0.000010	<0.000010	<0.000050	<0.000050	<0.00050	<0.00050	<0.050	<0.050
	Field Blank	2013-09-04		Field Blank	<0.00005	<0.00005	<0.00005	<0.00005	<0.10	<0.10	<0.000050	<0.000050	<0.000010	<0.000010	<0.000050	<0.000050	<0.00050	<0.00050	<0.050	<0.050

Table A1-5. - continued -

Waterbody	Site ID	Sampling Date	Surface/ Bottom	Notes	Selenium (Dissolved)	Selenium (Total)	Silicon (Dissolved)	Silicon (Total)	Silver (Dissolved)	Silver (Total)	Sodium (Dissolved)	Sodium (Total)	Strontium (Dissolved)	Strontium (Total)	Thallium (Dissolved)	Thallium (Total)	Tin (Dissolved)	Tin (Total)	Titanium (Dissolved)	Titanium (Total)
					mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
CP-P3-11	CP-P3-11SA	2013-08-06	Surface	Replicate 1	<0.0001	<0.00001	0.25	0.26	<0.0000010	<0.0000010	1.06	1.08	0.00462	0.00481	<0.000010	<0.000001	0.00031	0.00019	<0.01	<0.01
CP-P3-11	CP-P3-11SB	2013-08-06	Surface	Replicate 2	<0.0001	<0.00001	0.25	0.26	<0.0000010	<0.0000010	1.07	1.1	0.0046	0.00479	<0.000010	<0.000001	0.00023	0.00018	<0.01	<0.01
CP-P3-11	CP-P3-11SC	2013-08-06	Surface	Replicate 3	<0.0001	<0.00001	0.25	0.26	<0.0000010	<0.0000010	1.07	1.07	0.00461	0.00483	<0.000010	<0.000001	0.00039	0.0004	<0.01	<0.01
CP-P3-11	CP-P3-11Bot	2013-08-06	Bottom		<0.0001	<0.00001	0.26	0.26	<0.0000010	<0.0000010	1.12	1.12	0.00467	0.00479	<0.000010	<0.000001	0.00098	0.00098	<0.01	<0.01
CP-P3-11	CR-P3-11S	2013-09-04	Surface		<0.0001	<0.00001	0.21	0.27	<0.0000010	<0.0000010	1.15	1.09	0.00489	0.00502	<0.000010	<0.000001	0.00047	0.0003	<0.01	<0.01
CP-P3-11	CR-P3-11Bot	2013-09-04	Bottom		<0.0001	<0.00001	0.19	0.27	<0.0000010	<0.0000010	1.09	1.12	0.00475	0.00498	<0.000010	<0.000001	0.00038	0.0002	<0.01	<0.01
CL-P2-13	CL-P2-13S	2013-08-07	Surface		<0.0001	<0.00001	0.32	0.35	<0.0000010	0.000016	0.667	0.652	0.00353	0.00352	<0.000010	<0.000001	0.0014	0.00077	<0.01	<0.01
CL-P2-13	CL-P2-13BOT	2013-08-07	Bottom		<0.0001	<0.00001	0.32	0.35	<0.0000010	<0.0000010	0.656	0.636	0.00344	0.0035	<0.000010	<0.000001	0.00036	0.00021	<0.01	<0.01
CL-P2-13	CL-P2-13S	2013-09-04	Surface	Replicate 1	<0.0001	<0.00001	0.33	0.37	<0.0000010	<0.0000010	0.67	0.709	0.00357	0.00379	<0.000010	<0.000001	0.0005	0.00021	<0.01	<0.01
CL-P2-13	CL-P2-13SA	2013-09-04	Surface	Replicate 2	<0.0001	<0.00001	0.32	0.42	<0.0000010	<0.0000010	0.668	0.732	0.00351	0.00382	<0.000010	<0.000001	<0.00010	0.00019	<0.01	<0.01
CL-P2-13	CL-P2-13SB	2013-09-04	Surface	Replicate 3	<0.0001	<0.00001	0.32	0.37	<0.0000010	<0.0000010	0.679	0.791	0.00345	0.00391	<0.000010	<0.000001	<0.00010	0.00027	<0.01	<0.01
CL-P2-13	CL-P2-13Bot	2013-09-04	Bottom		<0.0001	<0.00001	0.34	1.02	<0.0000010	0.000019	0.728	0.68	0.00358	0.00381	<0.000010	<0.000001	0.00034	0.00015	<0.01	0.02
	CL-P2-13F	2013-08-07		Field Blank	<0.0001	<0.00001	<0.050	<0.050	<0.0000010	<0.0000010	<0.0012	<0.0012	<0.00040	<0.00040	<0.000010	<0.000001	<0.00010	<0.00010	<0.01	<0.01
	Trip Blank	2013-09-04		Trip Blank	<0.0001	<0.00001	<0.050	<0.050	<0.0000010	<0.0000010	<0.0012	<0.0012	<0.00040	<0.00040	<0.000010	<0.000001	<0.00010	<0.00010	<0.01	<0.01
	Field Blank	2013-09-04		Field Blank	<0.0001	<0.00001	<0.050	<0.050	<0.0000010	<0.0000010	<0.0012	<0.0012	<0.00040	<0.00040	<0.000010	<0.000001	<0.00010	<0.00010	<0.01	<0.01

Table A1-5. - continued -

Waterbody	Site ID	Sampling Date	Surface/ Bottom	Notes	Uranium (Dissolved)	Uranium (Total)	Vanadium (Dissolved)	Vanadium (Total)	Zinc (Dissolved)	Zinc (Total)
					mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
CP-P3-11	CP-P3-11SA	2013-08-06	Surface	Replicate 1	0.00006	0.00007	<0.001	<0.001	<0.00033	<0.003
CP-P3-11	CP-P3-11SB	2013-08-06	Surface	Replicate 2	0.000063	0.00007	<0.001	<0.001	<0.00033	<0.003
CP-P3-11	CP-P3-11SC	2013-08-06	Surface	Replicate 3	0.000062	0.00007	<0.001	<0.001	0.0014	0.0164
CP-P3-11	CP-P3-11Bot	2013-08-06	Bottom		0.000061	0.000071	<0.001	<0.001	0.0016	<0.003
CP-P3-11	CR-P3-11S	2013-09-04	Surface		0.000065	0.000077	<0.001	<0.001	0.0021	0.0188
CP-P3-11	CR-P3-11Bot	2013-09-04	Bottom		0.000066	0.000078	<0.001	<0.001	0.0013	<0.003
CL-P2-13	CL-P2-13S	2013-08-07	Surface		0.000113	0.000127	<0.001	<0.001	0.0018	0.004
CL-P2-13	CL-P2-13BOT	2013-08-07	Bottom		0.000121	0.000136	<0.001	<0.001	0.0014	<0.003
CL-P2-13	CL-P2-13S	2013-09-04	Surface	Replicate 1	0.000126	0.000141	<0.001	<0.001	0.0011	<0.003
CL-P2-13	CL-P2-13SA	2013-09-04	Surface	Replicate 2	0.000121	0.000142	<0.001	<0.001	0.0051	0.004
CL-P2-13	CL-P2-13SB	2013-09-04	Surface	Replicate 3	0.000124	0.000149	<0.001	<0.001	0.0037	0.0049
CL-P2-13	CL-P2-13Bot	2013-09-04	Bottom		0.000133	0.000242	<0.001	<0.001	<0.00033	<0.003
	CL-P2-13F	2013-08-07		Field Blank	<0.000010	<0.000010	<0.001	<0.001	0.0012	<0.003
	Trip Blank	2013-09-04		Trip Blank	<0.000010	<0.000010	<0.001	<0.001	<0.00033	<0.003
	Field Blank	2013-09-04		Field Blank	<0.000010	<0.000010	<0.001	<0.001	<0.00033	<0.003

APPENDIX 2. SUMMARY OF LOWER TROPHIC LEVEL SAMPLING CONDUCTED IN CANDIDATE REFERENCE LAKES, 2013

Table A2-1. Summary of phytoplankton sampling completed in candidate reference lakes, 2013.

Waterbody	Sample ID	Site UTM (17W)		Sample Date	Sample Time	Site Depth (m)	Secchi Depth (m)	Euphotic Zone Depth (m)	Sampled Depth Range (m)
		Easting	Northing						
CR-P3-09	PHYTO-01U	559980	7855131	05-Aug-13	15:10	28.4	9.25	27.75	0-10
CR-P3-09	PHYTO-01L	559980	7855131	05-Aug-13	15:10	28.4	9.25	27.75	10-27
CR-P3-11	PHYTO-02	569055	7900254	06-Aug-13	17:00	10.5	6.50	19.50	0-9
CL-P2-13	PHYTO-03	550137	7938617	07-Aug-13	14:00	12.9	4.35	13.05	0-11

Table A2-2. Summary of zooplankton sampling completed in candidate reference lakes, 2013.

Waterbody	Sample ID	Site UTM (17W)		Sample Date	Sample Time	Site Depth (m)	Secchi Depth (m)	Sampled Depth Range (m)	No. of Tows
		Easting	Northing						
CR-P3-09	ZOO-01	559980	7855131	05-Aug-13	15:10	28.4	9.25	0-27	1
CR-P3-11	ZOO-02	569055	7900254	06-Aug-13	17:00	10.5	6.50	0-9	1
CL-P2-13	ZOO-03	550137	7938617	07-Aug-13	14:00	12.9	4.35	0-11	1
CR-P3-11	ZOO-02	569055	7900254	04-Sep-13	12:05	10.6	5.75	0-9	1
CL-P2-13	ZOO-03	550137	7938617	04-Sep-13	15:40	12.5	4.25	0-11	1

Table A2-3. Summary of benthic macroinvertebrate sampling completed in candidate reference lakes, 2013.

Waterbody	Sample ID	Site UTM (17W)		Sample Date	Sample Time	Secchi Depth (m)	No. of Replicate Grabs	Depth Range of Grabs (m)	Macrophyte Abundance	Dominant Substrate(s)
		Easting	Northing							
CR-P3-11	BMI-01	569055	7900254	04-Sep-13	12:57	18:00	5	8.2 - 9.7	Absent	Sand/Silt
CL-P2-13	BMI-02	550137	7938617	04-Sep-13	18:10	6:00	5	12.1 - 13.8	Absent	Silt/Sand

APPENDIX 3. PHYTOPLANKTON COMMUNITY COMPOSITION IN CANDIDATE REFERENCE LAKES, 2013.

Table A3-1. Phytoplankton biomass and composition measured in reference lakes in 2013. Means and relative percent mean difference (RPMD) have been calculated for duplicate samples.

Waterbody	Sample ID	Sample Date	Sample Type	Major Group	Diatoms						
				Class	Bacillariophyceae					Coscinodiscophyceae	
				Genus	*Eunotia*	*Navicula*	*Nitzschia*	*Rhoicosphenia*	*Surirella*	*Cyclotella*	*Rhizosolenia*
				Species	*sp.*	*sp.*	*sp.*	*sp.*	*sp.*	*sp.*	*sp.*
CR-P3-11	CR-P3-11 A	6-Aug-13	Duplicate		1.35	10.00	0.77	-	-	4.50	-
	CR-P3-11 B	6-Aug-13	Duplicate		13.50	4.80	0.77	-	-	6.66	-
	CR-P3-11	6-Aug-13	Mean		7.43	7.40	0.77	-	-	5.58	-
			RPMD		164	70	0	-	-	39	-
	CR-P3-11	4-Sep-13	Normal		-	-	7.17	0.45	-	4.50	-
CL-P2-13	CL-P2-13	7-Aug-13	Normal		3.60	-	1.60	-	-	49.60	1.55
	CL-P2-13 REP 1	4-Sep-13	Duplicate		-	-	0.77	-	6.40	54.40	0.71
	CL-P2-13 REP 2	4-Sep-13	Duplicate		5.00	4.80	0.77	-	-	24.80	1.67
	CL-P2-13	4-Sep-13	Mean		2.50	2.40	0.77	-	3.20	39.60	1.19
			RPMD		200	200	0	-	200	75	81

Table A3-1. - continued -

Waterbody	Sample ID	Sample Date	Sample Type	Diatoms				Chlorophyta			
				Fragilariophyceae				Chlorophyceae			
				Asterionella	*Diatoma*	*Synedra*	*Tabellaria*	*Botryococcus*	*Dictyosphaerium*	*Elakatothrix*	*Tetraedron*
				formosa	*sp.*	*sp.*	*sp.*	*sp.*	*sp.*	*sp.*	*minimum*
CR-P3-11	CR-P3-11 A	6-Aug-13	Duplicate	4.70	0.96	15.07	8.80	-	-	6.25	0.20
	CR-P3-11 B	6-Aug-13	Duplicate	3.46	2.00	17.09	-	-	-	3.35	0.20
	CR-P3-11	6-Aug-13	Mean	4.08	1.48	16.08	4.40	-	-	4.80	0.20
			RPMD	30	70	13	200	-	-	60	0
	CR-P3-11	4-Sep-13	Normal	2.70	2.00	3.00	0.80	-	-	11.61	-
CL-P2-13	CL-P2-13	7-Aug-13	Normal	22.79	0.96	26.08	-	10.80	-	6.70	1.71
	CL-P2-13 REP 1	4-Sep-13	Duplicate	18.74	0.96	30.13	-	-	135.94	8.71	3.01
	CL-P2-13 REP 2	4-Sep-13	Duplicate	14.74	-	11.99	-	-	-	3.13	2.26
	CL-P2-13	4-Sep-13	Mean	16.74	0.48	21.06	-	-	67.97	5.92	2.64
			RPMD	24	200	86	-	-	200	94	29

Table A3-1. - continued -

Waterbody	Sample ID	Sample Date	Sample Type	Chlorophyta			Charophyta			Chrysophytes		
				Trebouxiophyceae			Conjugophyceae			Chrysophyceae		
				Lagerheimia sp.	*Monoraphidium sp.*	*Oocystis sp.*	*Cosmarium sp.*	*Staurastrum sp.*	*Staurodesmus sp.*	*Bitrichia sp.*	*Dinobryon bavaricum*	*Dinobryon sp.*
CR-P3-11	CR-P3-11 A	6-Aug-13	Duplicate	-	-	-	-	1.35	10.00	0.15	9.40	26.78
	CR-P3-11 B	6-Aug-13	Duplicate	-	-	-	14.40	-	2.40	0.47	20.09	22.79
	CR-P3-11	6-Aug-13	Mean	-	-	-	7.20	0.68	6.20	0.31	14.74	24.79
			RPMD	-	-	-	200	200	123	102	73	16
	CR-P3-11	4-Sep-13	Normal	-	-	5.00	-	-	10.00	0.15	4.00	12.74
CL-P2-13	CL-P2-13	7-Aug-13	Normal	0.32	9.53	2.40	18.00	-	-	0.32	0.65	16.74
	CL-P2-13 REP 1	4-Sep-13	Duplicate	0.64	1.63	-	26.65	-	-	0.15	-	1.35
	CL-P2-13 REP 2	4-Sep-13	Duplicate	0.15	8.18	-	8.05	-	-	0.15	-	14.74
	CL-P2-13	4-Sep-13	Mean	0.40	4.91	-	17.35	-	-	0.15	-	8.05
			RPMD	123	133	-	107	-	-	0	-	166

Table A3-1. - continued -

Waterbody	Sample ID	Sample Date	Sample Type	Chrysophytes	Cryptophytes		Blue-Green Algae				
				Chrysophyceae	Cryptophyceae		Cyanophyceae				
				small chrysophytes	*Cryptomonas sp.*	*Unidentified*	*Anabaena sp.*	*Aphanocapsa sp.*	*Aphanothece sp.*	*Oscillatoria sp.*	*Planktolyngbya sp.*
CR-P3-11	CR-P3-11 A	6-Aug-13	Duplicate	32.22	44.40	5.68	-	-	-	-	1.20
	CR-P3-11 B	6-Aug-13	Duplicate	42.85	14.40	3.84	-	-	-	-	1.20
	CR-P3-11	6-Aug-13	Mean	37.54	29.40	4.76	-	-	-	-	1.20
			RPMD	28	102	39	-	-	-	-	0
	CR-P3-11	4-Sep-13	Normal	21.90	14.40	5.68	0.86	18.23	29.60	0.58	0.19
CL-P2-13	CL-P2-13	7-Aug-13	Normal	16.83	44.40	2.84	-	-	-	-	-
	CL-P2-13 REP 1	4-Sep-13	Duplicate	16.03	7.20	7.60	-	-	-	-	-
	CL-P2-13 REP 2	4-Sep-13	Duplicate	17.22	14.40	16.20	-	-	-	-	0.58
	CL-P2-13	4-Sep-13	Mean	16.63	10.80	11.90	-	-	-	-	0.29
			RPMD	7	67	72	-	-	-	-	200

Table A3-1. - continued -

Waterbody	Sample ID	Sample Date	Sample Type	Blue-Green Algae	Euglenoids	Dinoflagellates		Total Biomass
				Cyanophyceae	Euglenophyceae	Dinophyceae		
				Pseudanabaena	***Euglena***	***Gymnodinium***	***Peridinium***	
				sp.	***sp.***	***sp.***	***sp.***	**(mg/m^3)**
CR-P3-11	CR-P3-11 A	6-Aug-13	Duplicate	0.10	1.20	72.90	-	258.0
	CR-P3-11 B	6-Aug-13	Duplicate	-	-	178.20	172.80	525.3
	CR-P3-11	6-Aug-13	Mean	0.05	0.60	125.55	86.40	391.6
			RPMD	200	200	84	200	68
	CR-P3-11	4-Sep-13	Normal	-	2.70	97.20	-	255.5
CL-P2-13	CL-P2-13	7-Aug-13	Normal	-	-	434.70	-	672.1
	CL-P2-13 REP 1	4-Sep-13	Duplicate	-	-	32.40	-	353.4
	CL-P2-13 REP 2	4-Sep-13	Duplicate	-	-	234.90	-	383.7
	CL-P2-13	4-Sep-13	Mean	-	-	133.65	-	365.4
			RPMD	-	-	152	-	8

APPENDIX 4. ZOOPLANKTON ABUNDANCE AND COMMUNITY COMPOSITION IN CANDIDATE REFERENCE LAKES, 2013.

Table A4-1. Crustacean zooplankton (individuals/m^3) collected in vertical net tows from reference lakes during 2013. Individual abundances may not add up to totals due to rounding.

Waterbody	**Lake CR-P3-11**										
Site ID	**Stn CR P3-11**										
Sampling Date	**6-Aug-13**							**4-Sep-13**		**Overall**	
Replicate	**A**	**B**	**C**	**Mean**	**SD [1]**	**% [2]**	**PRSD [3]**		**%**	**Mean**	**%**
water volume filtered (m^3)	0.09	0.09	0.09	-	-	-	-	0.09	-		
Cladocera (water fleas)											
Alona guttata	0	0	0	0	0	0	-	0	0	0	0
Bosmina longirostris	197	219	219	212	13	3	6	395	5	258	3
Chydorus sphaericus	0	0	0	0	0	0	-	0	0	0	0
Daphnia longiremis	132	307	176	205	91	3	45	812	10	357	4
Holopedium gibberum	44	22	0	22	22	0	*100*	0	0	16	0
Total Cladocera	**373**	**549**	**395**	**439**	**96**	**6**	**22**	**1207**	**15**	**631**	**8**
Copepoda (copepods)											
Calanoida											
Diaptomus minutus	1404	1163	1646	1404	241	18	17	2743	35	1739	22
Limnocalanus macrurus	0	0	0	0	0	0	-	0	0	0	0
Calanoida copepodite	658	1426	1316	1134	415	14	37	505	6	976	12
Total Calanoida	**2062**	**2589**	**2962**	**2538**	**452**	**32**	**18**	**3247**	**41**	**2715**	**34**
Cyclopoida											
Cyclops scutifer	2567	2194	2084	2282	253	29	11	1997	25	2210	28
Cyclopoida nauplii	2150	2721	3181	2684	517	34	19	1470	19	2381	30
Total Cyclopoida	**4717**	**4915**	**5266**	**4966**	**278**	**63**	**6**	**3467**	**44**	**4591**	**58**
Harpacticoida	0	0	0	0	0	0	-	0	0	0	0
Total Copepoda	**6780**	**7504**	**8228**	**7504**	**724**	**94**	**10**	**6714**	**85**	**7306**	**92**
OVERALL TOTAL	**7153**	**8052**	**8623**	**7942**	**741**	**100**	**9**	**7920**	**100**	**7937**	**100**
Taxonomic Richness [4]	**5**	**5**	**4**	**5**	**-**	**-**	**-**	**4**	**-**	**5**	**-**

Table A4-1. - continued -

Waterbody	Lake CL-P2-13										
Site ID	Stn CL P2-13										
Sampling Date	7-Aug-13		4-Sep-13							Overall	
Replicate		%	A	B	C	Mean	SD	%	PRSD	Mean	%
water volume filtered (m^3)	0.13		0.13	0.13	0.13	-	-		-		
Cladocera (water fleas)											
Alona guttata	0	0	0	0	0	0	0	0	-	0	0
Bosmina longirostris	214	18	260	130	84	158	91	10	***58***	172	11
Chydorus sphaericus	0	0	0	0	0	0	0	0	-	0	0
Daphnia longiremis	46	4	199	76	138	138	61	9	44	115	8
Holopedium gibberum	8	1	0	0	23	8	13	0	***173***	8	1
Total Cladocera	**268**	**23**	**459**	**207**	**245**	**303**	**136**	**19**	**45**	**294**	**20**
Copepoda (copepods)											
Calanoida											
Diaptomus minutus	23	2	444	38	8	163	243	10	***149***	128	9
Limnocalanus macrurus	0	0	0	0	0	0	0	0	-	0	0
Calanoida copepodite	0	0	31	54	15	33	19	2	***58***	25	2
Total Calanoida	**23**	**2**	**474**	**92**	**23**	**196**	**243**	**12**	***124***	**153**	**10**
Cyclopoida											
Cyclops scutifer	849	73	765	765	773	767	4	47	1	788	52
Cyclopoida nauplii	23	2	398	344	314	352	43	22	12	270	18
Total Cyclopoida	**872**	**75**	**1163**	**1109**	**1086**	**1119**	**39**	**69**	**4**	**1057**	**70**
Harpacticoida	0	0	0	0	0	0	0	0	-	0	0
Total Copepoda	**895**	**77**	**1637**	**1201**	**1109**	**1316**	**282**	**81**	**21**	**1210**	**80**
OVERALL TOTAL	**1163**	**100**	**2096**	**1407**	**1354**	**1619**	**414**	**100**	**26**	**1505**	**100**
Taxonomic Richness [4]	**5**	**-**	**4**	**4**	**5**	**5**	**-**	**-**	**-**	**5**	**-**

[1] Standard deviation
[2] Percent abundance of the overall total
[3] Percent relative standard deviation; evaluation of precision for triplicate samples
[4]Total number of taxa observed to species-level, not the average number of taxa

APPENDIX 5. BENTHIC MACROINVERTEBRATE ABUNDANCE AND COMMUNITY COMPOSITION IN CANDIDATE REFERENCE LAKES, 2013.

Table A5-1. Benthic macroinvertebrates (no. of individuals/m^2) collected in petite Ponar grab (area 0.023 m^2) samples from reference lake candidate CR-P3-11 during 2013. Individual abundances may not add up to totals due to rounding.

Waterbody				**CR-P3-11**				
Habitat Type				**Offshore Profundal (14)**				
Subsample no.				**1**	**2**	**3**	**4**	**5**
Sample ID				**CR-P3-11-1**	**CR-P3-11-2**	**CR-P3-11-3**	**CR-P3-11-4**	**CR-P3-11-5**
Number of invertebrates per m^2								
ROUNDWORMS				0	0	0	0	0
P. Nemata				0	0	0	0	43
ANNELIDS				0	0	0	0	0
P. Annelida				0	0	0	0	0
	WORMS			0	0	0	0	0
	Cl. Oligochaeta			0	0	0	0	0
		F. Naididae		0	0	0	0	0
	S.F. Tubificinae			0	0	0	0	0
			Aulodrilus limnobius	0	0	0	0	0
		F. Lumbriculidae		0	0	0	0	0
			Lumbriculus	0	0	0	0	0
ARTHROPODS				0	0	0	0	0
P. Arthropoda				0	0	0	0	0
	MITES			0	0	0	0	0
	Cl. Arachnida			0	0	0	0	0
	Subcl. Acari			43	87	43	87	43
	HARPACTICOIDS			0	0	0	0	0
	O. Harpacticoida			0	0	0	0	0
	SEED SHRIMPS			0	0	0	0	0
	Cl. Ostracoda			0	43	0	43	0
INSECTS				0	0	0	0	0
	Cl. Insecta			0	0	0	0	0
	CADDISFLIES			0	0	0	0	0
	O. Trichoptera			0	0	0	0	0
		F. Apataniidae		0	0	0	0	0
			Apatania	0	0	0	0	0
TRUE FLIES				0	0	0	0	0
	O. Diptera			0	0	0	0	0
	MIDGES			0	0	0	0	0
		F. Chironomidae		0	0	0	0	0
			chironomid pupae	0	0	0	0	0
	S.F. Chironominae			0	0	0	0	0
			Chironomus	0	0	2640	1169	1169
			Corynocera	0	0	173	0	0
			Micropsectra	87	303	0	0	0
			Paratanytarsus	0	0	0	0	0
			Sergentia	0	0	0	0	0
			Stictochironomus	173	649	0	43	0
			Tanytarsus	390	519	1342	3246	2554
	S.F. Diamesinae			0	0	0	0	0
			Protanypus	0	0	43	0	0
			Pseudodiamesa	0	0	0	0	0

Table A5-1. - continued -

Waterbody	CR-P3-11				
Habitat Type	**Offshore Profundal (14)**				
Subsample no.	**1**	**2**	**3**	**4**	**5**
Sample ID	**CR-P3-11-1**	**CR-P3-11-2**	**CR-P3-11-3**	**CR-P3-11-4**	**CR-P3-11-5**
Number of invertebrates per m²					
S.F. Orthocladiinae	0	0	0	0	0
Abiskomyia	87	87	346	260	216
Corynoneura	0	0	0	0	0
Cricotopus/Orthocladius	0	0	0	0	0
Genus "Greenland"	0	0	0	0	0
Heterotrissocladius	693	173	173	216	260
Mesocricotopus	0	0	0	0	0
Paracladius	0	0	0	0	43
Parakiefferiella	43	43	0	0	0
Psectrocladius	87	260	0	0	0
Pseudosmittia	0	0	43	0	0
Zalutschia	0	43	43	43	0
indeterminate	0	0	0	0	0
S.F. Tanypodinae	0	0	0	0	0
Procladius	390	822	0	0	0
Thienemannimyia complex	0	0	0	0	0
Total Density (no. per m²)	1991	3030	4848	5107	4328
Proportion of Chironomidae (% of total density)	98	96	99	97	98
Shannon's Evenness Index	0.82	0.82	0.58	0.53	0.58
Simpson's Diversity Index	0.79	0.83	0.62	0.54	0.57
Taxonomic Richness (genus-level) [1]	9	11	9	8	7
Hill's Effective Richness	6.01	7.21	3.60	3.01	3.07

[1] Total number of taxa observed to genus-level

Table A5-2. Benthic macroinvertebrates (no. of individuals/m^2) collected in petite Ponar grab (area 0.023 m^2) samples from reference lake candidate CL-P2-13 during 2013. Individual abundances may not add up to totals due to rounding.

Waterbody				**CL-P2-13**				
Habitat Type				**Offshore Profundal (14)**				
Subsample no.				**1**	**2**	**3**	**4**	**5**
Sample ID				**CL-P2-13-1**	**CL-P2-13-2**	**CL-P2-13-3**	**CL-P2-13-4**	**CL-P2-13-5**
Number of invertebrates per m^2								
ROUNDWORMS				0	0	0	0	0
P. Nemata				0	0	0	0	0
ANNELIDS				0	0	0	0	0
P. Annelida				0	0	0	0	0
	WORMS			0	0	0	0	0
	Cl. Oligochaeta			0	0	0	0	0
		F. Naididae		0	0	0	0	0
	S.F. Tubificinae			0	0	0	0	0
			Aulodrilus limnobius	0	0	0	0	0
		F. Lumbriculidae		0	0	0	0	0
			Lumbriculus	0	0	0	0	0
ARTHROPODS				0	0	0	0	0
P. Arthropoda				0	0	0	0	0
	MITES			0	0	0	0	0
	Cl. Arachnida			0	0	0	0	0
	Subcl. Acari			0	0	0	0	0
	HARPACTICOIDS			0	0	0	0	0
	O. Harpacticoida			0	0	0	0	0
	SEED SHRIMPS			0	0	0	0	0
	Cl. Ostracoda			0	0	0	0	0
INSECTS				0	0	0	0	0
	Cl. Insecta			0	0	0	0	0
	CADDISFLIES			0	0	0	0	0
	O. Trichoptera			0	0	0	0	0
		F. Apataniidae		0	0	0	0	0
			Apatania	0	0	0	0	0
TRUE FLIES				0	0	0	0	0
	O. Diptera			0	0	0	0	0
	MIDGES			0	0	0	0	0
		F. Chironomidae		0	0	0	0	0
			chironomid pupae	0	0	0	0	0
	S.F. Chironominae			0	0	0	0	0
			Chironomus	43	43	3333	1212	0
			Corynocera	0	0	0	0	0
			Micropsectra	0	43	43	0	0
			Paratanytarsus	0	0	0	0	0
			Sergentia	0	0	0	0	0
			Stictochironomus	0	43	0	87	0
			Tanytarsus	0	0	0	0	0
	S.F. Diamesinae			0	0	0	0	0
			Protanypus	216	0	43	43	87
			Pseudodiamesa	0	0	0	0	0

Table A5-2. - continued -

Waterbody	CL-P2-13				
Habitat Type	Offshore Profundal (14)				
Subsample no.	1	2	3	4	5
Sample ID	CL-P2-13-1	CL-P2-13-2	CL-P2-13-3	CL-P2-13-4	CL-P2-13-5
Number of invertebrates per m²					
S.F. Orthocladiinae	0	0	0	0	0
Abiskomyia	87	130	0	130	0
Corynoneura	0	0	0	0	0
Cricotopus/Orthocladius	0	0	0	0	0
Genus "Greenland"	0	0	0	0	0
Heterotrissocladius	87	0	0	43	519
Mesocricotopus	0	0	0	0	0
Paracladius	476	260	0	87	606
Parakiefferiella	0	43	0	216	0
Psectrocladius	0	0	0	0	0
Pseudosmittia	0	0	0	0	0
Zalutschia	43	0	0	0	0
indeterminate	0	0	0	0	0
S.F. Tanypodinae	0	0	0	0	0
Procladius	0	0	0	0	0
Thienemannimyia complex	0	0	0	0	0
Total Density (no. per m²)	952	563	3419	1818	1212
Proportion of Chironomidae (% of total density)	100	100	100	100	100
Shannon's Evenness Index	0.78	0.83	0.12	0.61	0.82
Simpson's Diversity Index	0.68	0.71	0.05	0.53	0.56
Taxonomic Richness (genus-level) [1]	6	6	3	7	3
Hill's Effective Richness	4.06	4.41	1.15	3.25	2.46

[1] Total number of taxa observed to genus-level

Appendix F

Lake Sedimentation Monitoring Program

Appendix F

Lake Sedimentation Monitoring Program

Mary River Project

June 2014

Aquatic Effects Monitoring Program:

Lake Sedimentation Monitoring Program

North/South Consultants Inc.
Aquatic Environment Specialists

Mary River Project

Aquatic Effects Monitoring Program: Lake Sedimentation Monitoring Program

June, 2014

Prepared by

North/South Consultants Inc.

For

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LIST OF ABBREVIATIONS

AEMP	Aquatic Effects Monitoring Program
BIM	Baffinland Iron Mines Corporation
BMI	Benthic macroinvertebrate(s)
DFO	Department of Fisheries and Oceans
ERP	Early Revenue Phase
FEIS	Final Environmental Impact Statements
NSC	North/South Consultants Inc.
QA/QC	Quality assurance/quality control
TSS	Total suspended solids
UTM	Universal Transverse Mercator

1.0 INTRODUCTION AND BACKGROUND

The Mary River Project is expected to result in increased sediment deposition in Mine Area waterbodies, including lakes, due to dust deposition and potentially due to introduction of suspended solids from various activities (e.g., wastewater discharges). Dust will be directly deposited on watercourses during the open-water season and on snow and ice during the winter. Dust will be indirectly introduced from runoff within the watersheds which will likely be greatest during the snowmelt/freshet period.

Potential effects of dust on aquatic ecosystems include effects on water quality (i.e., total suspended solids [TSS], metals, nutrients, water clarity) when suspended in the water column and effects once deposited on the lake bottom or streambed. Sedimentation of dust in lakes and streams may affect aquatic biota through changes in sediment quality (e., metals, nutrients, particle size, organic matter), through changes in habitat quality (i.e., changes in substrate composition), direct effects on benthic macroinvertebrates (BMI; i.e., smothering), and direct effects on fish eggs (i.e., smothering of eggs).

Baffinland Iron Mines Corporation (BIM) proposed a targeted study, which was subsequently recommended by the Department of Fisheries and Oceans (DFO), to measure rates of sediment deposition in Mine Area lakes. The following describes the general background, approach, and methods for this targeted study to monitor sediment deposition in Mine Area lakes during Project operation as part of the Aquatic Effects Monitoring Program (AEMP).

2.0 PATHWAYS OF EFFECT AND KEY QUESTIONS

The Project may affect sediment deposition in Mine Area lakes through airborne dust deposition and through introduction of suspended materials (i.e., TSS) to lakes via tributary streams and/or aqueous point or non-point sources. Potential pathways of effect on freshwater biota in lakes include:

- Increased sediment deposition in lakes may adversely affect BMI communities which may in turn affect Arctic Char populations;
- Increased sediment deposition in lakes may alter Arctic Char (*Salvelinus alpinus*) habitat, notably Arctic Char spawning habitat, through changes in substrate composition; and
- Increased sediment deposition in lakes during the Arctic Char egg incubation period (i.e., over winter) may adversely affect egg survival and hatching success.

The key question related to the pathways of effect is:

- What are the combined effects of point and non-point sources of suspended materials on sedimentation rates in Mine Area lakes?

The primary issue of concern in relation to Mine Area lakes is the potential effect of the Project on sediment deposition on Arctic Char eggs.

3.0 PARAMETERS

The key parameter that will be monitored under this special study is total sediment deposition, measured as total dry weight of sediment deposited in a known area over a known duration (i.e., $mg/cm^2/day$). Measurements will also allow for determination of the total mass of sediment deposited over the sampling period. Results of a baseline sampling program conducted over the open-water season of 2013 in Sheardown Lake NW indicate that sufficient volumes of sediment for laboratory analysis of total dry weight of sediment can be obtained during this period (North/South Consultants Inc. [NSC] 2014). Sediment deposition monitoring over the ice-cover season is ongoing and it is unknown whether sufficient volumes of sediments can be obtained from the lake over this period for reliable laboratory analysis. Results of the winter sedimentation program will be reviewed when available and details of this study may be modified in accordance.

If sufficient sample was collected in future lake sedimentation monitoring, bulk density would also be measured to facilitate estimates of total depth of sediment deposition in lakes (i.e., mm of sediment). However required volumes for these measurements were not realized in the open-water season of 2013 due to low rates of sedimentation (even with deployment of multiple traps and sample compositing) in the Mine Area. Therefore, it is anticipated that due to logistical restrictions, samples will only be analysed for total dry weight of sediment in the lake sedimentation monitoring program.

4.0 MONITORING AREA AND SAMPLING SITES

In the Mine Area, Arctic Char spawning habitat is restricted to lakes, as rivers and streams freeze solid in winter, and lakes provide the sole overwintering habitat for Arctic Char. The results of air quality modeling presented in the Final Environmental Impact Statement (FEIS) and the Addendum to the FEIS for the Early Revenue Phase (ERP), indicate that Sheardown Lake will experience the largest increases in sediment deposition of the Mine Area lakes. The lake sediment deposition special study is therefore focused on monitoring in Sheardown Lake NW. However, monitoring at additional Mine Area lakes may be undertaken in the future upon review of initial monitoring results collected during the ERP and/or during full production if increased effects (e.g., greater rates of dust deposition) are measured.

Increases in sedimentation rates may affect BMIs (through smothering and changes in substrate characteristics), Arctic Char habitat (notably spawning areas which are typically hard substrates), and/or Arctic Char eggs (through deposition on incubating eggs). Therefore the sampling sites will include a suspected Arctic Char spawning area, a shallow, soft substrate area, and a deep-water location. Collectively this information will provide information on sedimentation rates in different habitat types in the lake. Sites sampled during baseline studies will be retained for operation monitoring. A brief description of these sites is provided below.

Specific spawning sites have not been identified within Sheardown Lake NW and the FEIS conservatively assumed that areas of hard substrate at water depths ranging from 2-12 m in the lakes could potentially provide spawning habitat. One area in Sheardown Lake NW best matched these criteria and was selected for sediment trap deployment in 2013 to represent potential Arctic Char spawning habitat (Figure 1). A second sampling site was selected at a similar depth range (2-12 m), but with a soft substrate for comparison. A third sampling site was selected near the deepest point in the lake as these areas are typically the ultimate depositional areas in lakes and because sampling the profundal zone (i.e., depth > 12 m) would provide a measure of a dominant aquatic habitat type.

5.0 SAMPLING FREQUENCY AND SCHEDULE

Sediment traps will be deployed year-round in Sheardown Lake NW but will be retrieved and emptied in late summer/fall prior to freeze up and again in spring following ice breakup on the lake. This will provide a means for quantifying annual deposition rates in the lake as well as rates associated with the open-water and ice-cover seasons.

Baseline studies are on-going and will continue into fall 2014. Monitoring during Project operation will commence this fall and will continue for three years, following which a review of the program and results will be undertaken to advise on monitoring during full production.

6.0 FIELD AND LABORATORY METHODS

Sedimentation rates will be measured through deployment of sediment traps with an aspect ratio of > 5:1 as recommended for cylindrical sediment traps (Mudroch and MacKnight 1994). Traps will be anchored such that the trap is suspended off the bottom and secured with a buoy.

Five replicate traps (i.e., subsamples) will be deployed within close proximity at each of the three sites. The number of replicates may be modified pending the results of the ongoing baseline studies and initial results of monitoring during operation. Total water depth, substrate, date, time, and universal transverse mercator units (UTMs) will be recorded at each site.

Traps will be retrieved and emptied in late summer/fall and in spring following breakup. Trap contents will be transferred to sample bottles, kept cool and in the dark and transported to an analytical laboratory for analysis.

Samples will be analysed by filtering samples, which includes sediments and water, through a pre-weighed 0.70 µm glass fibre filter, rinsing the filter apparatus and container three times, and drying the filter at 105 ^{o}C for two hours. Samples are then allowed to cool for one hour and weighed.

7.0 QUALITY ASSURANCE/QUALITY CONTROL

Quality assurance/quality control (QA/QC) measures will include verifications that sediments are not disturbed (i.e., resupended) during sediment deployment and retrieval and inclusion of sample replicates to measure variability.

8.0 STUDY DESIGN AND DATA ANALYSIS

As the objective of this study is to monitor rates of sediment deposition in Mine Area lakes as it may affect BMIs, habitat, and Arctic Char eggs, the study is designed to provide measures of sediment deposition on a seasonal (i.e., open-water vs. ice-cover season) basis. Rates will be measured through deployment of sediment traps in Sheardown Lake NW year-round, but with retrieval of samples at the end of the open-water and ice-cover seasons to provide measures for both periods. This will facilitate examination of sedimentation rates during the Arctic Char incubation period as well as during the growing season in Sheardown Lake NW.

Measured sedimentation rates will be compared to effects predictions presented in the FEIS and the Addendum to the FEIS for the ERP, as well as to the effects threshold applied in the impact assessment (i.e., 1 mm of deposition on fish eggs). Sedimentation rates exceeding 1 mm during the egg incubation period have been identified as exerting adverse effects on fish eggs (e.g., Fudge and Bodaly 1984). The FEIS and Addendum to the FEIS indicated that sedimentation is not expected to exceed this threshold in Mine Area lakes.

The study is designed to compare results directly to the threshold rather than to demonstrate statistically significant differences. Therefore, true replicates for each habitat type are not included in the design of the monitoring program. Rather, replicates will be included to provide a measure of variability at each site (i.e., subsamples) and to provide additional contingency in the event that traps cannot be located and/or quantities of sediments collected in the traps are so low that sample compositing is required. As previously indicated, results of open-water season sampling completed in 2013 indicate that sufficient sediment volumes will likely be obtainable in the open-water season, however, it is unknown whether this can be attained for winter.

Results of the targeted study may also be compared to baseline data collected in 2013 and 2014 from Sheardown Lake NW to provide a means of identifying Project-related effects on this parameter.

This document was prepared, and the special study was designed, with baseline information available at the time of preparation of this report. It is noted that not all results of additional baseline sampling initiated in 2013 were available at the time of preparation of this report; upon receipt and analysis of these additional data, recommendations for modification to the special study may be made. Results of the baseline program completed in the open-water season of 2013 are presented in NSC (2014).

9.0 REFERENCES

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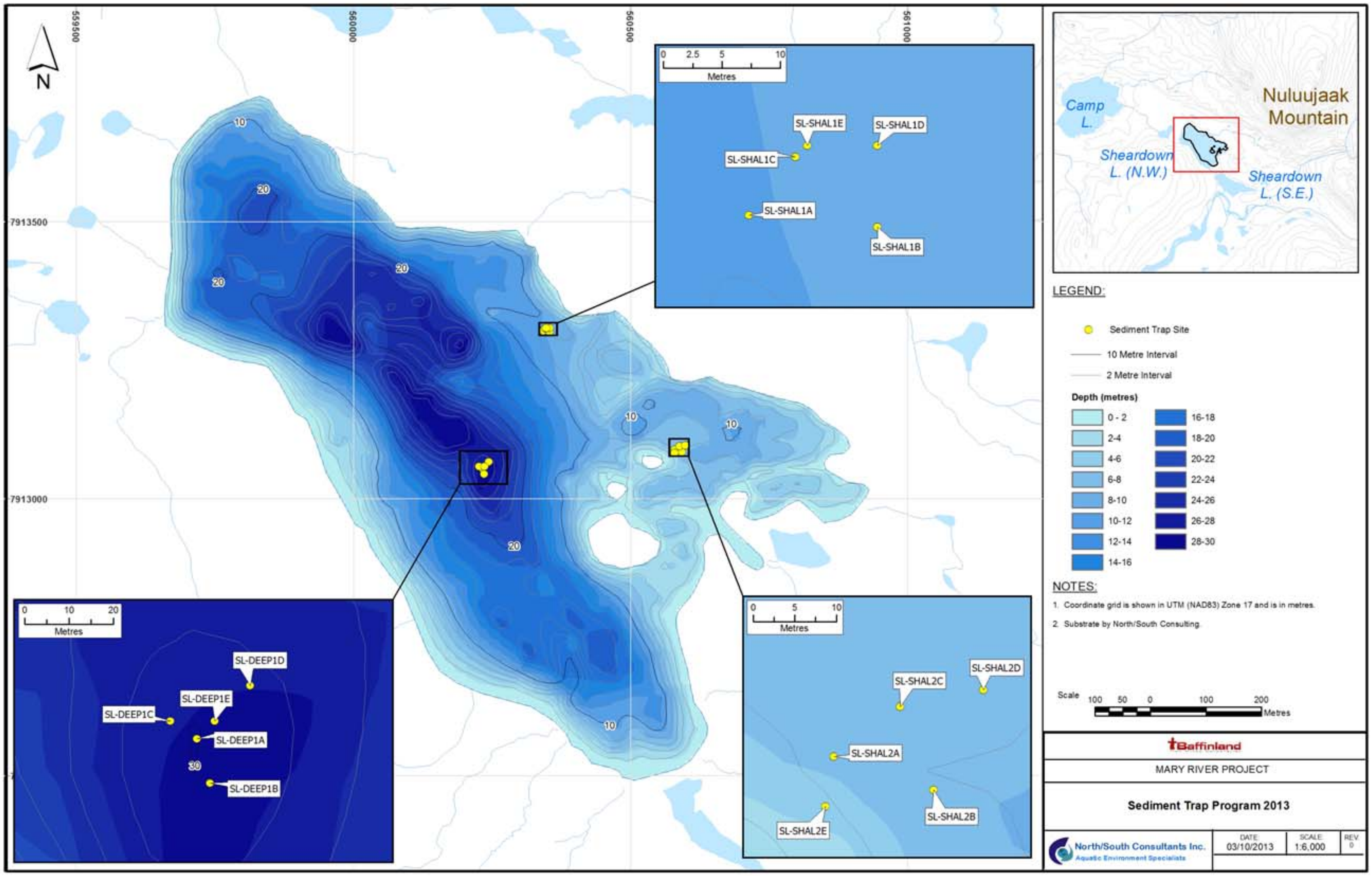

Figure 1. Sediment trap sampling sites in Sheardown Lake NW, 2013.

Appendix G

Dustfall Monitoring Program

Appendix G

Dustfall Monitoring Program

4-3 VEGETATION MONITORING: DUST FALL

The potential impacts of dust deposition on soil and vegetation has been identified as an issue of concern for the Project. In particular, other studies have shown dust deposition to have a detrimental effect on vegetation health, and dust deposition on caribou forage (i.e., lichen) has been suggested as a potential mechanism causing caribou to avoid habitat at a distance of up to 14 km (Boulager et al. 2012). The main sources of dust emissions are fugitive sources, specifically bulk handling operations, crushing, blasting, storage, and dust emissions from vehicle and equipment traffic, although natural sources of dust fall also exist (e.g. wind erosion). The largest amount of dust fall generated by the Project is expected to be associated with use of the existing Tote road linking the Mine site with the port at Milne Inlet; however, there will also be dust fall generation from the railway and from point source locations at both the Mine site and ports.

The Mary River dust fall monitoring program was initiated in the summer of 2013 with sampling stations set up at the Mine site, Milne Port, along the Tote road, and at reference sites within the RSA. At this time, the railway and Steensby port are not included in the dust fall monitoring program, due to access issues. Future construction of the railway linking Steensby port with the Mine site will initiate dust fall monitoring for the southern section of the RSA. The dust fall monitoring program was developed using knowledge gathered from other similar air monitoring programs (Ekati Mine, High Lake Project, Rescan 2006), as well as applicable caribou research. The monitoring program is in accordance with the American Society for Testing and Materials (ASTM) ASTM D1739-98 sampling method (ASTM 2004).

Objectives

There are three main objectives of the dust fall monitoring program:

2. To quantify the extent and magnitude of dust fall generated by Project activites;
3. To determine seasonal variations in dust fall at all sampling locations; and
4. To determine if annual changes in dust fall at sampling locations exceed identified thresholds associated with isopleth dispersion models.

Thresholds

There are no known dust deposition thresholds specific to effects on vegetation. Health Canada/Environment Canada's national ambient air quality objectives for particulate matter (CEPA/FPAC Working Group 1998) state that for the lack of quantitative dose-effect information, it is not possible to define a reference level for vegetation and dust deposition. In the absence of published thresholds for dust effects on vegetation, the High Lake Project (Wolfden Resources Inc. 2006), a proposed base metal mine in western Nunavut, developed thresholds in consideration of effects to vegetation health ranging from 4.6 $g/m^2/a$ for a low magnitude effect to ≥50 $g/m^2/a$ for a high magnitude effect (Table B-2). These values were based on a combination of the Alberta (AB) and Ontario (ON) ambient air quality criteria for human health purposes, and values reported by Spatt and Miller (1981) specific to effects of road dust on vegetation.

In addition to the consideration of thresholds developed by the High Lake Project, isopleth dispersion models (CALPUFF dispersion models) were used to predict deposition patterns from all sources during the operations phase of the Project. The CALPUFF dispersion model was recommended by a number of regulatory agencies and has been the *de facto* standard for environmental assessments in Canada's North. To refer to activities that are included in the assessment of the operations phase refer to the *ERP Addendum to FEIS Volume 5*.

To align with results of the isopleth dispersion models and the thresholds described above (Table B-2), the following annual TSP depositions thresholds will be used for the Mary River Project:

Low: 1–4.6 g/m²/a;

Moderate: 4.6–50 g/m²/a; and

High: ≥ 50 g/m²/a.

Table B-2 Dust (TSP) Deposition Rates and Criteria for Potential Effects on Vegetation Health.

Source of Information	Dust (TSP) deposition rate	Equivalent annual dust deposition rate ($g/m^2/a$)	Comments
High Lake Impact Assessment (Wolfden 2006)	1.0–4.6 g/m²/a	1.0–4.6	Predicted low magnitude effect on vegetation health
	4.6–50 g/m²/a	4.6–50	Predicted moderate magnitude effect on vegetation health
	50–200 g/m²/a	50–200	Predicted high magnitude effect on vegetation health
Spatt and Miller (1981)	0.07 g/ m²/ d	26	Some effects to Sphagnum species
	1.0-2.5 g/ m²/ d	365-913	Decline in Sphagnum species abundance
Alberta	5.3 g/m²/30 d	64	Alberta Guidelines for Residential and Recreational Areas (human health)
Ontario	4.6 g/m²/a	4.6	Ontario Ambient Air Quality Criteria (human health)

Methods

The Mary River dust fall monitoring program is based on passive dust fall monitoring methods. A total of 26 sampling sites were installed July 2013 at the Mine site, Milne Inlet, Tote road and reference sites within the RSA (Figure B 4.3-1). Sample site locations were chosen with consideration of the direction of prevailing winds within the RSA, excluding areas of future infrastructure development, and to represent areas of various expected dust fall concentrations based on isopleth dispersion models. The 26 dust fall sample sites include:

- Four reference sites (two located southeast and upwind of the Baffinland Mine Site; two located 14 km south and west of the road centerline with no prevalent wind direction to direct location effort).
- Three sample sites located in dust generating areas of the Baffinland Mine Site (identified via isopleth models);
- Three sample sites in Milne Inlet (two within the port area itself, and one northeast and upwind of the port); and
- Two road stations, each composed of eight sample sites located at 30 m, 100 m, 1 km and 5 km to either side of the centreline along Tote Road (prevalent wind direction roughly parallel to the roadway as opposed to perpendicular, therefore no ‘upwind’ and ‘downwind’ directions from the road are identified).

Each site is comprised of one sampling apparatus, which is made up of a hollow post (~ 2m long) and terminal bowl shaped holder for the dust collection vessel (Photo B-1). The terminal bowl is topped with bird spikes to prevent contamination by bird fecal matter. The sampling apparatus was installed by pounding 5-foot rebar into the ground, placing the post over the rebar, and then stabilizing with guy wires. Dust collection vessels are placed in the holder, pre-charged with 250 mL of algaecide in summer and 250 mL of alcohol in winter. Collection vessels are changed out every month (28–31 days) and shipped to ALS Environmental Laboratory (ALS) in Vancouver for analysis of total, fixed and volatile insoluble particulate matter.

Caribou present in the area of the Baffinland Mine site are sedentary and are present year-round. Therefore, sampling of the dust fall monitoring stations will occur on a year-round basis; however, during the winter, the sampling program will be limited to a subset of the sampling sites (at present, 14 out of 26) as access to remote sites is limiting.

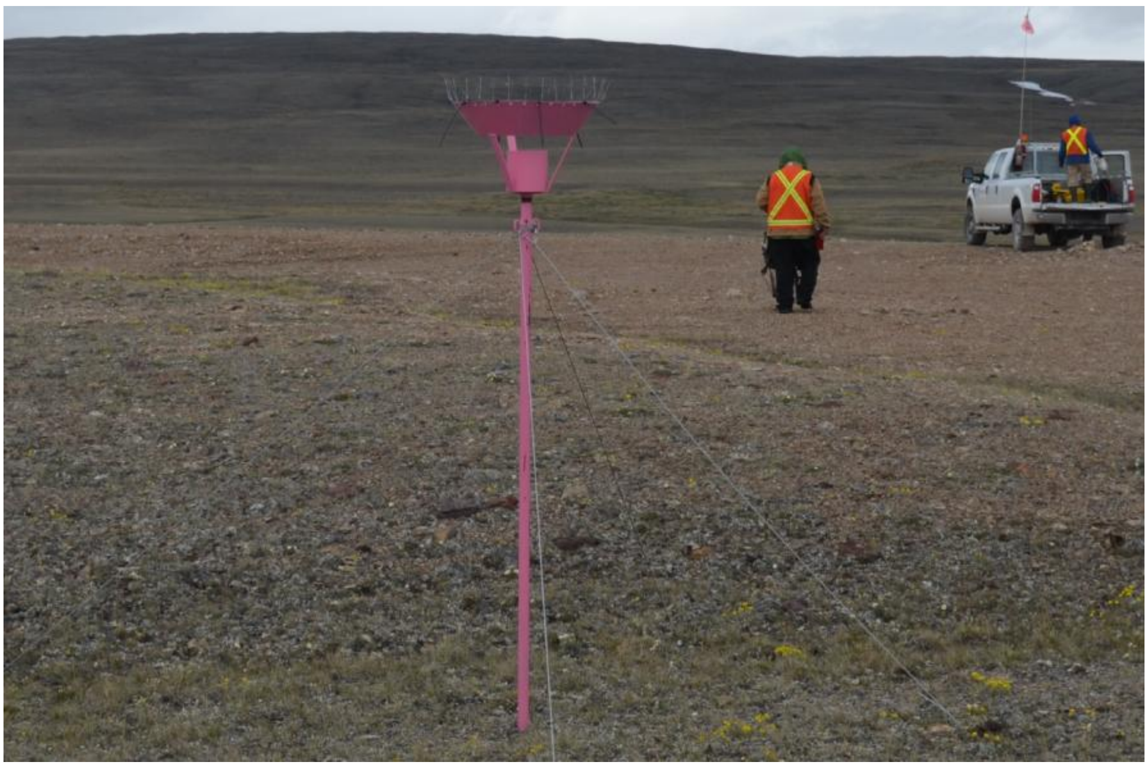

Photo B-1. Dust fall collector sampling apparatus, July 10, 2013.

Laboratory results are analyzed against the predicted dust deposition thresholds for the Project to determine if concentrations are exceeding the applicable indicator threshold. Results are also reviewed to investigate concentrations on a temporal and spatial scale relative to background concentrations with focus on seasonal differences in dust fall data. As of January 2014, three months of sampling results have been received back from the lab; in addition to the analyses described above, a power analysis is also being completed based on these results to determine the level of variability among the sampling stations and assess whether the current monitoring program is sufficient or if additional sampling stations are required to accurately capture Project effects.

References

American Society for Testing and Materials (ASTM). 2004. Standard Test Method for Collection and Measurement of Dustfall (Settleable Particulate Matter) Designation D 1739-98 Reapproved 2004, West Conshohocken, PA.

Boulanger J., Poole K.G., Gunn A., and J. Wierzchowski. 2012. Estimating the zone of influence of industrial developments on wildlife: a migratory caribou *Rangifer tarandus groenlandicus* and diamond mine case study. Wildlife Biology 18:2.

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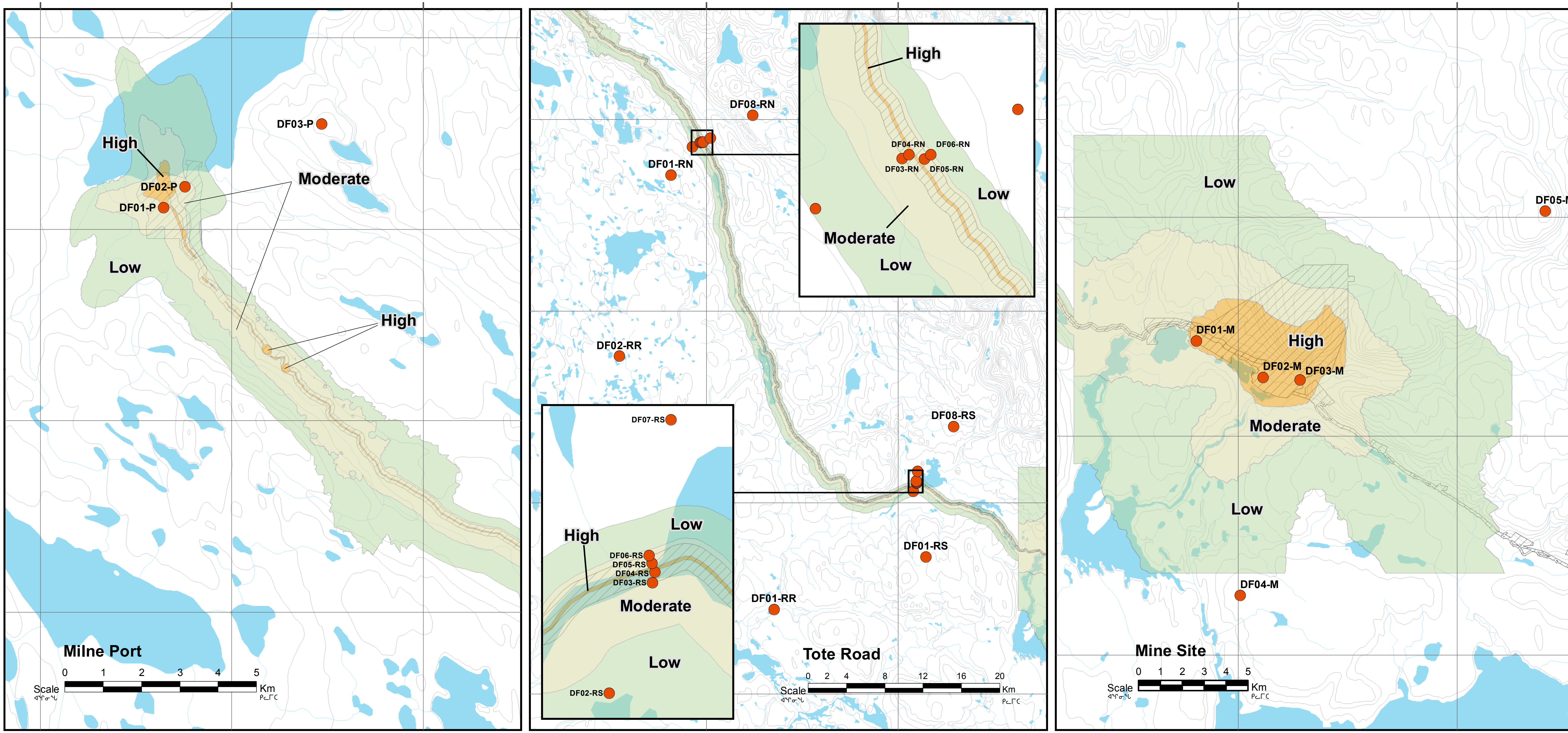
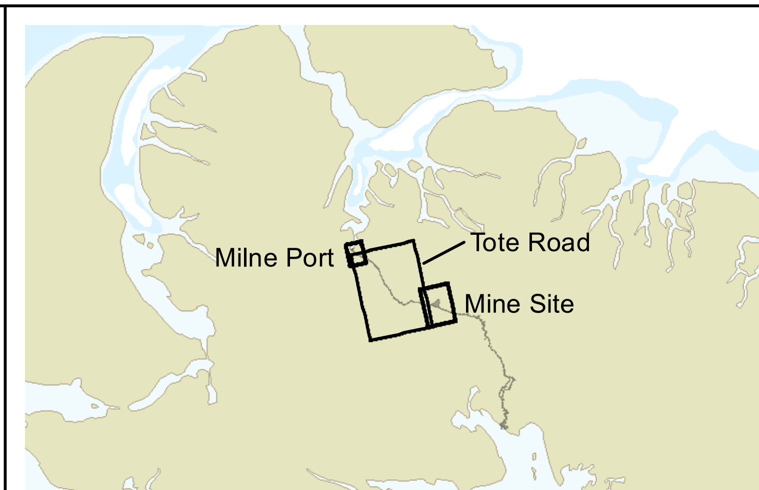


LEGEND ᑐᑦᑎᕝᓯᓐ

- Dustfall Sampling Sites
- Potential Development Area
- Topographic Contour (20m Interval)
- Watercourses
- Waterbodies

TSP Annual Deposition

- High (>50 g/m²/a.)
- Moderate (4.6–50 g/m²/a.)
- Low (1–4.6 g/m²/a.)



NOTES

TSP deposition isopleths provided by RWDI Air Inc. (2013) and modified by EDI for display purposes.

Northern Land Cover of Canada (Circa-2000) courtesy of Her Majesty the Queen in Right of Canada, Department of Natural Resources. All Rights Reserved.

Updated PDA provided by Hatch (25 April 2013).

Projection: North American Datum 1983 UTM Zone 17N.

Baffinland Iron Mines Corporation

2013 Dustfall Collector Locations within the Mary River Project Area

EDI

Date: 15/01/2014

FIGURE B4.4-1

Appendix H

Initial Stream Diversion Barrier Study

Appendix H

Initial Stream Diversion Barrier Study

MEMORANDUM

To:	Mr. Oliver Curran	Date:	June 25, 2014
Copy To:		File No.:	NB102-181/34-A.01
From:	Dale Klodnicki	Cont. No.:	NB14-00160
Re:	Initial Stream Diversion Barrier Study - Rev. 0 Mary River Project - Aquatic Effects Monitoring Program		

1 – INTRODUCTION

A stream diversion barrier study was identified as a follow-up program in the Final Environmental Impact Statement (FEIS) for the Mary River Project (Baffinland, 2012). The primary objectives of the study are to monitor the effects of both increases and reductions in streamflow at several mine site streams and to further understand how Project-related reductions in streamflow may result in the creation of fish barriers that have the potential to occur at low flows. The monitoring program may identify the need for mitigation measures to address Project-related fish stranding.

The stream diversion barrier study is a "targeted study", which forms part of Baffinland's Aquatic Effects Monitoring Program (AEMP). This memorandum describes the initial study that was focussed on obtaining a better understanding for existing flow conditions and, in particular, the frequency and duration of the occurrence of fish barriers and fish stranding that was identified in five (5) mine site streams (North/South Consultants Inc. - NSC, 2008; Knight Piésold Ltd. - KP, 2012).

Since the stream diversion barrier study was identified in the FEIS, Baffinland has developed plans that are now in the final stages of approval to initiate an Early Revenue Phase (ERP) of the Project (Baffinland, 2013). The ERP will involve mining 3.5 million tonnes per annum (Mt/a) of iron ore. The iron ore will be transported year-round by truck to Milne Port and then to market by ship during the open water season. Baffinland has contemplated a 5-year operating plan for the ERP, after which time the full-scale railway project would also be brought on-line. This development schedule is subject to a commercial decision by Baffinland to proceed and will be influenced by both market conditions and available financing.

The reduced production rate associated with the ERP will result in a considerably smaller mining footprint (open pit and waste rock stockpile) than was originally envisioned. As such, Project-related stream diversions will be negligible. The absence of diversions provides Baffinland with an opportunity to better understand existing flow conditions as it relates to fish passage. This initial study is exploratory in nature with the following objectives (which contribute to the primary objectives stated above):

- Develop an understanding of low-flow conditions that may result in barriers to fish passage within two tributaries of Camp Lake and three tributaries of Sheardown Lake (Figure 1).
- Document fish presence throughout the stream length under various flow conditions. It is important to document upstream access during spring freshet, since high water velocities in the spring can prevent fish passage. It is also important to document the downstream passage of fish in the fall, when they are returning to overwintering habitat in the lakes.

Stream gauging stations are seasonally operated on three of the five targeted streams (Figure 1). The conditions observed throughout each season and between years can be related to the calculated flows in the streams. An understanding of the relationship between flow conditions and the presence of fish barriers and fish presence, understanding that streams are dynamic systems that change over time.

2 – PROJECT EFFECTS AND PROPOSED MONITORING

2.1 GENERAL

The Project footprint (including water management features) will reduce flows in five mine site streams. The resulting flow reduction will result in a loss of fish habitat that was assessed to be minor (low magnitude) in the FEIS. The flow reductions also have the potential to affect the ability of Arctic Char (primarily juveniles) to access small tributaries in the mine site area, particularly in the spring as fish move into the streams and in fall when fish return to the lakes to overwinter. The creation of barriers (or increased frequency or changed timing of existing barriers) due to reduced flows could impede fish passage upstream or downstream in the tributaries. Although considered unlikely, mortalities are possible in the event fish became stranded in the streams in fall.

The development of the open pit, a waste rock stockpile, and associated water management facilities (ditches, berms and settling ponds) will divert and redirect runoff away from certain watercourses during the operational phase of the Mary River Project (Baffinland, 2012). Five tributary streams are anticipated to be affected by diversions in the Mine Area (Figure 1).

2.2 CAMP LAKE TRIBUTARY 1 (CLT-1)

CLT-1 provides approximately 5.7 km of probable or confirmed fish-bearing habitat within the main channel and its smaller tributaries. This habitat is generally shallow (typically < 0.5 m deep), with predominantly cobble substrates (NSC, 2012; see Figure 2). Habitat in the upper reaches of the tributaries typically consists of a shallow series of cascades and riffles, with intermittent flow that provides only small amounts of habitat for aquatic life. The L1 branch of CLT-1 extends from the north-eastern shore of Camp Lake for approximately 1,400 m before reaching an impassable barrier (waterfall). It consists predominantly of riffle/pool habitat with cobble substrata. Undercut banks, deep pools and boulders provide ample cover in this stream. The utilization of the L1 branch of CLT-1 by Arctic Char is high. During surveys by Knight Piésold and NSC, one area on the L1 branch of CLT-1 between the lake and the falls was identified as a potential fish barrier under low flow conditions (Figures 1 and 2). Baffinland has continued to operate a seasonal stream gauge on the L1 branch of CLT-1 since 2006 (Figure 1).

A secondary channel (L2, referred to in NSC (2012) as Tributary 1b), continues an additional 1.25 km from downstream of the impassable falls into a series of broad and shallow ponds. This channel runs parallel to the airstrip along the base of the mountain. This channel is a low gradient area where several large, shallow (0.5 m) pools with cobble bottoms where limited in-stream cover is present. Limited sampling in the L2 stream suggests a much lower level of fish utilization compared with the L1 branch.

The west pond will collect runoff from the west half of the waste rock stockpile area and discharge it to the L1 stream of the Camp Lake Tributary 1 (CLT-1). This will result in an overall increase in flows in the L1 stream of CLT-1 that will be not be typical of the natural hydrograph. The L2 branch (CLT-1 L2 stream) will not receive flows from the west pond and will experience a flow reduction.

Flow regimes in CLT-1 for the FEIS predicted (Page 225 in Volume 7; Baffinland, 2012):

- An 8% reduction in flows during July
- A 25 to 39% increase in flows during June, August and September during operation and closure
- A 7 to 22% increase in flows throughout the open water period during post-closure

These predictions considered the total flow of CLT-1, including the L1 and L2 streams. A section of CLT-1 L1 was identified as a potential barrier under low flow conditions. Increased flow in CLT-1 L1 has the potential to create a barrier to upstream movement during the spring.

A detailed survey of L2 stream was not conducted. Anticipated effects from flow diversion are different between these streams. The L2 stream of CLT-1 flows parallel to the airstrip, and experiences a net reduction in flow as a result of west pond discharges being directed solely into the L1 stream. The L2 stream is identified as Arctic Char habitat, though it is lower quality habitat compared with the main channel of CLT-1 (L1 stream).

Monitoring within CLT-1 will initially include the potential barrier location on the L1 branch under low flow conditions and support a better understanding of the flow conditions and fish utilization of the L2 branch under different flow conditions (i.e., in spring and fall).

2.3 CAMP LAKE TRIBUTARY 2 (CLT-2)

CLT-2 is characterized by moderate to steep gradient, coarse bed material and a channel that tends to be braided (multiple channels, split by unvegetated islands and bars). Falls are located approximately 600 m from the mouth of the tributary (Figures 1 and 2). This tributary is heavily utilized by Arctic Char. During surveys by Knight Piésold and NSC, one area between the mouth and the falls on CLT-2 was identified as a potential fish barrier under low flow conditions (KP, 2011 and 2012; NSC, 2012).

Diversion of runoff from the west waste rock stockpile area and open pit will also alter discharge to CLT-2. The reduction in mean monthly flows is predicted to be 15 to 32% throughout the open-water period during operation, closure and post-closure (Page 225 in Volume 7; Baffinland, 2012). This reduction is predicted for the fish barrier location. Due to the apparent absence of any substantial inflows between the fish barrier and Camp Lake, the 15 to 32% reduction in flows is expected to be a fairly accurate estimate at its confluence with Camp Lake. No significant depth reduction was predicted within the fish-bearing section between Camp Lake and the upstream barrier that would impede fish access to habitat in CLT-2.

Since no barriers are expected under baseline flow conditions, limited “baseline” monitoring of CLT-2 will be undertaken during this initial study to validate predictions made in the FEIS. The stream will be visited opportunistically in the spring and fall during low flow years. More detailed monitoring of the fish-bearing section of CLT-2 will be undertaken once the Project has advanced to full-scale mining and the potential flow reductions identified in the FEIS have been realized.

2.4 SHEARDOWN LAKE TRIBUTARY 1 (SLDT-1)

Only four tributaries of Sheardown Lake support fish, and, of these, only one is of substantial size (SLDT-1). Three of the four fish-bearing tributaries (SDLT 1, SLDT 9, and SLDT 12) will be affected by a combination of open pit mining, ore stockpile placement and the associated water management practices during the Project’s operations and closure phases (Page 226 in Volume 7; Baffinland, 2012).

SDLT-1 (Tributary 1) and its main branch (Tributary 1b) flow into the northwest basin of Sheardown Lake and provide approximately 3 km of fish-bearing stream channel before reaching parts of the tributary that would not be passable to fish (Figure 3). Much of the stream is riffle or riffle/pool habitat over a predominantly cobble substrate and it is shallow (<0.1 m deep). The stream depth increases in the mid-section (up to 0.5 m) and both riffles and pools are present. Further upstream, the tributary forms a series of broad shallow pools. Stream habitat upstream of these pools is limited, consisting of a shallow (<0.1 m) stream with a cobble/boulder substrate and little cover. Cover in Tributary 1 varies with position, but is provided by boulders, undercut banks, and deep pools. SDLT-1 is the largest tributary of Sheardown Lake, providing important open water habitat for juvenile Arctic Char. Two potential barriers were identified within SDLT-1 (Figure 3).

The SDLT-1 stream contains stream gauge station H11 (established in 2011). Discharge hydrographs and rating curves have been developed for this stream.

During the operating and closure phases of the Project, SDLT-1 will experience flow reductions in the range of 21 to 35%. Post-closure, SDLT-1 will continue to experience a reduction in flows of 6 to 20% throughout the open-water period due to diversion of water around the open pit.

Monitoring within SDLT-1 will include the identified potential barrier locations within the lower reach near the outlet to the northwest lake basin and the other reach near the mine access road upstream. The proposed monitoring program will improve the mine's understanding of the flow and fish utilization conditions under different flow regimes (i.e., in the spring and fall).

2.5 SHEARDOWN LAKE TRIBUTARY 9 (SDLT-9)

SDLT-9 is characterized by cascade/pool habitat over cobble with varying amounts of boulder, gravel and/or sand (NSC, 2012). SDLT-9 drains a small fish-bearing lake with sufficient depth for overwintering, but an impassable barrier prevents upstream access from Sheardown Lake. Use of Tributary 9 habitat downstream of the barrier can also be limited due to lack of connectivity to Sheardown Lake under low flow conditions.

During operation of the railway project, SDLT-9 will experience an estimated 29% reduction in open-water season flows during operation and closure. Ore stockpiles will be removed at closure, so SDLT-9 flows will only be impacted during operations and closure. No Project-related reduction in flows is anticipated in SDLT-9 during the ERP, since there are no ERP facilities within this catchment.

SDLT-9 will be monitored during this initial program to understand the frequency and duration of fish barriers between Sheardown Lake and the small lake during low flow conditions (Figure 3). The presence and/or absence of fish will also be noted during low flow conditions.

2.6 SHEARDOWN LAKE TRIBUTARY 12 (SDLT-12)

SDLT-12 is similar to SDLT-9 and characterized by cascade/pool habitat over cobble with varying amounts of boulder, gravel and/or sand. Fish use of SDLT-12 is limited by an impassable waterfall and low flows during much of the open-water season.

SDLT-12 will experience an estimated 15% reduction in open-water season flows during operation and closure. Ore stockpiles will be removed at closure, so SDLT-12 flows will only be impacted during operations and closure. No Project-related reduction in flows is anticipated in SDLT-12 during the ERP, since there are no ERP facilities within this catchment.

SDLT-12 will be monitored during this initial program to understand the frequency and duration of fish barriers between Sheardown Lake and the permanent fish barrier (waterfall) during low flow conditions. The presence and/or absence of fish will also be noted during low flow conditions.

3 – MONITORING PROGRAM METHODOLOGY

The five streams of interest will be monitored in spring and fall during the initial years of operation. Low and high flow periods will be targeted where possible. Results of this initial monitoring will be reviewed to determine whether mitigation and/or ongoing monitoring is required. In spring, all five streams will be visually assessed to monitor for potential barriers and obstructions to upstream fish passage.

Surveys will document conditions within the monitoring streams between the upstream fish barriers and their outlets into Camp Lake and Sheardown Lake. The survey will utilize a field sheet (Appendix A) to document in situ conditions, including:

- A visual inspection along the targeted stream reaches
- Measurements of total water depth and point velocities at locations that may pose barriers to fish passage
- Instantaneous flow measurements within the SDLT-9 and SDLT-12 tributaries (not currently gauged)
- Photographing the potential natural barriers (facing upstream, downstream and the left and right banks). A minimum of 4 photos will be taken at each location.
- Documenting the presence and location of fish during the stream inspections

A target of two (2) spring surveys and three (3) fall surveys has been set. The number of surveys completed will be subject to on-site resource availability.

Other monitoring programs will contribute data relevant to this study. For example, Baffinland`s hydrology monitoring program includes stream gauges on three streams monitored under this program, and the freshwater biota monitoring will be undertaken as part of the Core Receiving Environment Monitoring Program (CREMP). Monitoring data from both these programs will be used in the analysis of data from this initial stream diversion monitoring study.

4 – ANALYSIS OF MONITORING RESULTS

The proposed Initial Stream Diversion Study will be completed annually over the next three years (2014, 2015 and 2016) followed by a review at the end of 2016. At the end of the three-year initial program, a report will be produced that summarizes the monitoring data and presents an analysis of results, including:

- Hydrographs from the existing stream gauging stations - The hydrograph results for the three years will be compared to historical hydrology records to better understand how flows varied throughout the year and how the flow rates compared to historical norms.
- The flow and water depths will also be compared to the values presented in support of the FEIS (KP, 2011 and 2012).
- Presentation of fish barrier identification information - This information will be summarized in tabular format and will most likely be organized by fish barrier or transect location. Comments will be provided on how the presence of specific fish barriers relate to flow conditions. This may help identify when specific sections of the streams become barriers to fish passage.
- Fish stranding information - A discussion on the frequency, timing and duration of current fish stranding. Comments will be provided on whether these events are likely to result in fish mortalities.

The 3-year initial stream diversion study monitoring report will be presented with the AEMP Annual Monitoring Report in the first half of 2017. The report will also include recommendations on potential mitigation measures and future monitoring.

Continuation of the monitoring program will depend upon the schedule and size of the Project. The Approved Project (18 Mt/a) will result in meaningful reductions in streamflow and monitoring will be required to identify Project-related fish barriers and fish stranding. If the ERP were to continue beyond 2017 and the 3-year study has met the stated objectives, then this targeted study may be discontinued until such time as the Approved Project proceeds. If possible, monitoring for the Approved Project will start one year prior to the start of larger scale mining.

5 – POTENTIAL MITIGATION MEASURES

A number of mitigation measures have been identified in the FEIS (Baffinland, 2012) and the Updated AEMP Framework (Baffinland, 2013), including:

- Monitoring and salvage fisheries
- Channel improvements
- Exclusion of Arctic Char from streams

Since the ERP will result in minimal to no changes in flows, implementation of mitigation measures will not be required within the initial three year study period. These mitigation options will be carried forward for consideration when the Project has reached full scale and the Project-related changes in flow can be expected to occur.

6 – REFERENCES

Baffinland Iron Mines Corporation, 2012. *Mary River Project Final Environmental Impact Statement*. February 2012.

Baffinland Iron Mines Corporation, 2013. *Mary River Project - Addendum to the Final Environmental Impact Statement*. June 2013.

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Knight Piésold Ltd., 2012. Memorandum to: Richard Remnant, North/South Consultants Inc. Re: *Mary River Project - Fish Passage Barrier Assessment Support*. January 9. Ref. No. VA12-00095.

North/South Consultants Inc., 2008. *Freshwater Aquatic Environment Baseline Report: Fish and Fish Habitat 2007 DRAFT*. April 2008.

North/South Consultants Inc., 2012. *Freshwater Aquatic Biota and Habitat Baseline Synthesis Report 2005-2011*. January 2012.

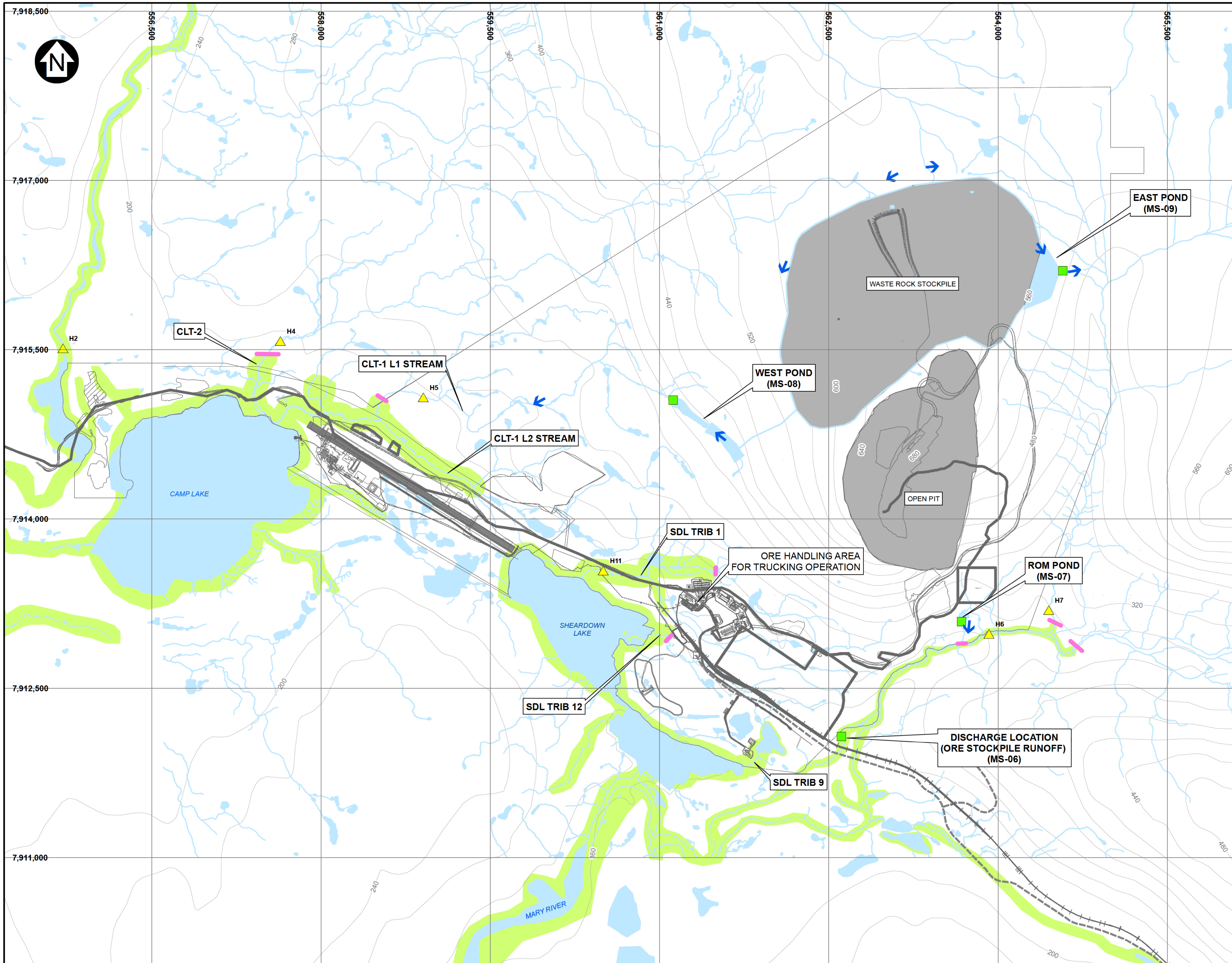
Signed: for ______________________________
Dale Klodnicki, C.E.T. - Environmental Technologist

Reviewed and Approved: ______________________________
Richard Cook, B.Sc. - Senior Scientist

Attachments:

Figure 1 Rev 0	Diversion Study Area Streams
Figure 2 Rev 0	Camp Lake Tributaries Subject to Monitoring
Figure 3 Rev 0	Sheardown Lake Tributaries Subject to Monitoring
Appendix A	Stream Diversion Field Data Sheet

/dkk



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REV	DATE	DESCRIPTION	DESIGNED	DRAWN	CHK'D	APP'D

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LEGEND:

- FINAL DISCHARGE POINT
- STREAM FLOW GAUGING STATION
- FISH BARRIER
- EXISTING TOTE ROAD
- PROPOSED RAILWAY ALIGNMENT
- PROPOSED CONSTRUCTION ACCESS ROAD
- PROPOSED SITE INFRASTRUCTURE
- RIVER/STREAM/DRAINAGE
- WATER
- CONFIRMED ARCTIC CHAR HABITAT

NOTES:

1. BASE MAP: © HER MAJESTY THE QUEEN IN RIGHTS OF CANADA, DEPARTMENT OF NATURAL RESOURCES (2004). ALL RIGHTS RESERVED.
2. COORDINATE GRID IS UTM NAD83 ZONE17.
3. CONTOURS ARE IN METRES. CONTOUR INTERVAL VARIES.
4. INFRASTRUCTURE INFORMATION PROVIDED BY HATCH ON JANUARY 31, 2014.
5. ARCTIC CHAR HABITAT (PRESENCE) FROM NSC, 2012 MARY RIVER PROJECT FRESHWATER AQUATIC BASELINE SYNTHESIS. REPORT: 2005-2011.

SCALE 250 125 0 250 500 750 1,000 1,250 1,500 m

BAFFINLAND IRON MINES CORPORATION

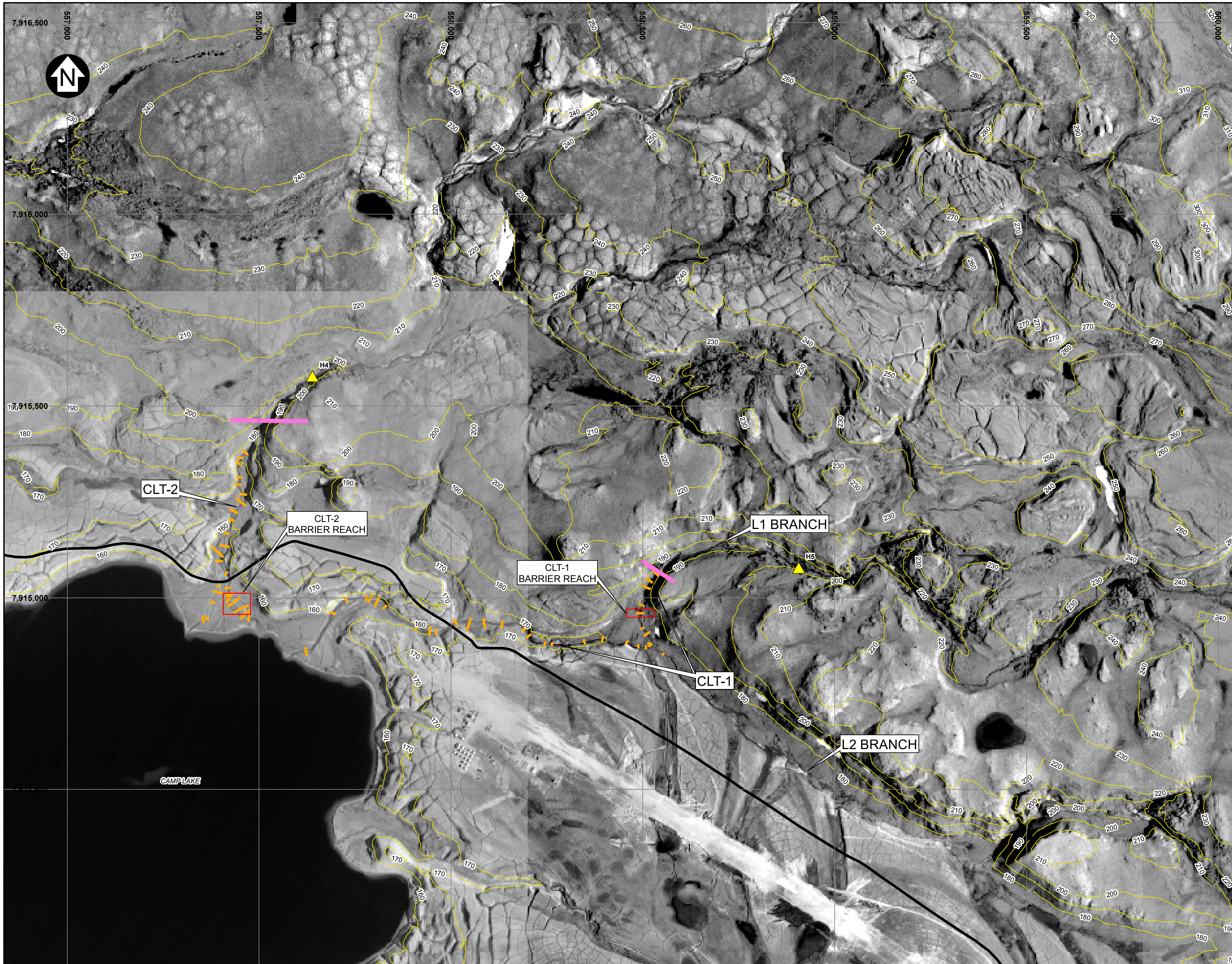
MARY RIVER PROJECT

DIVERSION STUDY AREA STREAMS

Knight Piésold CONSULTING

P/A NO.	REF NO.
NB102-181/34	NB14-00160

FIGURE 1 | REV 0



LEGEND:

- STREAM FLOW GAUGING STATION
- FISH BARRIER
- PREVIOUS TRANSECT LINE (KNIGHT PIESOLD, 2011)
- MILNE INLET TOTE ROAD
- CONTOUR

NOTES:

1. TOPOGRAPHY AND ORTHOPHOTOS PROVIDED BY EAGLE MAPPING (2005).
2. COORDINATE GRID IS IN METRES. COORDINATE SYSTEM: NAD 1983 UTM ZONE 17N.
3. CONTOUR INTERVAL IS 10 METRES.

SCALE 100 50 0 100 200 300 400 500 m

BAFFINLAND IRON MINES CORPORATION

MARY RIVER PROJECT

CAMP LAKE TRIBUTARIES SUBJECT TO MONITORING

Knight Piésold CONSULTING

P/A NO.	REF NO.
NB102-181/34	NB14-00160

FIGURE 2 REV 0

REV	DATE	DESCRIPTION	DESIGNED	DRAWN	CHK'D	APP'D
0	25JUN'14	ISSUED WITH MEMO	DKK	SWK	RAC	RAC

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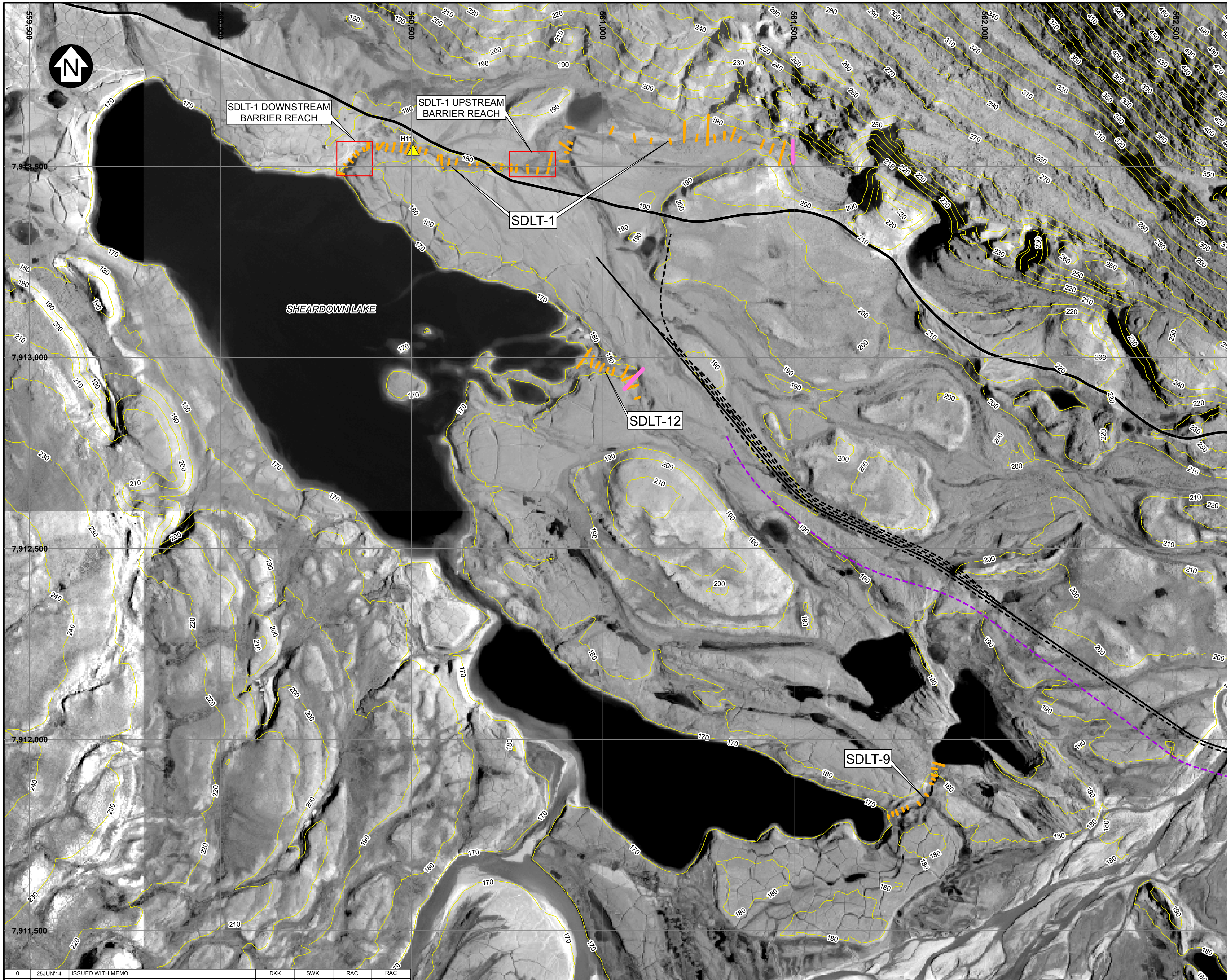


LEGEND:

- STREAM FLOW GAUGING STATION
- FISH BARRIER
- PREVIOUS TRANSECT LINE (KNIGHT PIESOLD, 2011)
- MILNE INLET TOTE ROAD
- PROPOSED RAILWAY ALIGNMENT
- PROPOSED CONSTRUCTION ACCESS ROAD
- CONTOUR

NOTES:

1. TOPOGRAPHY AND ORTHOPHOTOS PROVIDED BY EAGLE MAPPING (2005).
2. COORDINATE GRID IS IN METRES. COORDINATE SYSTEM: NAD 1983 UTM ZONE 17N.
3. CONTOUR INTERVAL IS 10 METRES.
4. RAILWAY ALIGNMENT PROVIDED BY CANARAIL CONSULTANTS INC. (AUGUST, 2010).

SCALE 100 50 0 100 200 300 400 500 m

REV	DATE	DESCRIPTION	DESIGNED	DRAWN	CHK'D	APP'D
0	25JUN'14	ISSUED WITH MEMO	DKK	SWK	RAC	RAC

SAVED: I:\102\00181\34\A\GIS\Figs\BS2_r0.mxd; Jun 25, 2014 2:44 PM; skozmick

BAFFINLAND IRON MINES CORPORATION

MARY RIVER PROJECT

SHEARDOWN LAKE TRIBUTARIES SUBJECT TO MONITORING

Knight Piésold CONSULTING

P/A NO. NB102-181/34 | REF NO. NB14-00160

FIGURE 3 | REV 0

Knight Piésold
CONSULTING

APPENDIX A

STREAM DIVERSION FIELD DATA SHEET

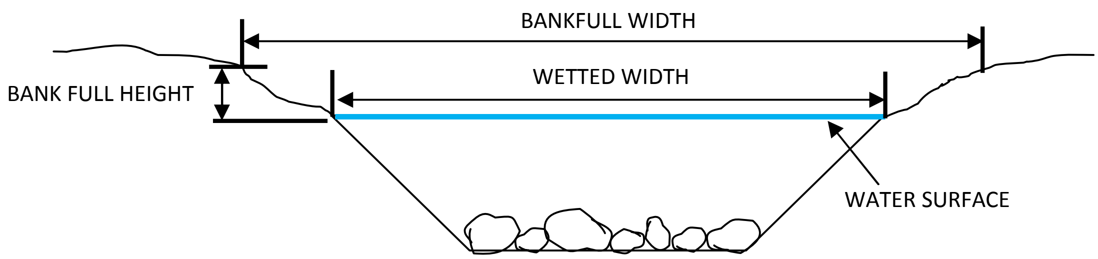
(Page A-1)

Knight Piésold CONSULTING

STREAM DIVERSION FIELD DATA SHEET

PROJECT NO: NB102-181/34	**WATER BODY:**	**DATE(ddmmmyyyy):**
FIELD CREW:	**START TIME:**	**END TIME:**
WEATHER:		

CHANNEL CHARACTERISTICS



Station ID:	**UTM Easting (m):**	**UTM Northing (m):**
Wetted Width (m):	**Bank Full Width (m):**	**Bank Full Height (m):**

Photos (check): ☐ Upstream ☐ Right Bank ☐ Downstream ☐ Left Bank

Depth/Point Velocity measurements across the stream

Total Depth (m):	m	m	m	m	m	m
Velocity (m/s):	m/s	m/s	m/s	m/s	m/s	m/s
Total Depth (m)	m	m	m	m	m	m
Velocity (m/s):	m/s	m/s	m/s	m/s	m/s	m/s

Fish Presence (circle US/DS) : US / DS >10 individuals US / DS <10 individuals US / DS No Fish Observed

Comments:

Station ID:	**UTM Easting (m):**	**UTM Northing (m):**
Wetted Width (m):	**Bank Full Width (m):**	**Bank Full Height (m):**

Photos (check): ☐ Upstream ☐ Right Bank ☐ Downstream ☐ Left Bank

Depth/Point Velocity measurements across the stream

Total Depth (m):	m	m	m	m	m	m
Velocity (m/s):	m/s	m/s	m/s	m/s	m/s	m/s
Total Depth (m)	m	m	m	m	m	m
Velocity (m/s):	m/s	m/s	m/s	m/s	m/s	m/s

Fish Presence (circle US/DS) : US / DS >10 individuals US / DS <10 individuals US / DS No Fish Observed

Comments:

Incidental Fish Observations

UTM Easting (m)	**UTM Northing (m)**	**Fish:** ☐ >10 individuals ☐ <10 individuals
UTM Easting (m)	**UTM Northing (m)**	**Fish:** ☐ >10 individuals ☐ <10 individuals
UTM Easting (m)	**UTM Northing (m)**	**Fish:** ☐ >10 individuals ☐ <10 individuals
UTM Easting (m)	**UTM Northing (m)**	**Fish:** ☐ >10 individuals ☐ <10 individuals
UTM Easting (m)	**UTM Northing (m)**	**Fish:** ☐ >10 individuals ☐ <10 individuals
UTM Easting (m)	**UTM Northing (m)**	**Fish:** ☐ >10 individuals ☐ <10 individuals
UTM Easting (m)	**UTM Northing (m)**	**Fish:** ☐ >10 individuals ☐ <10 individuals