Baffinland Iron Mines Corporation

AQUATIC EFFECTS MONITORING PLAN

BAF-PH1-830-P16-0039

Rev 2

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

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

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	Jim Millard	Part I, Item 2 of Type A Water Licence N0. 2AM-MRY1325 Amendment No.1
03/31/16	2	Andrew Vermeer	Jim Millard JM	CREMP Design Revision recommended by Minnow

Index of Major Changes/Modifications in Revision 2

Item No.	Description of Change	Relevant Section
1	Updated Table 1.2 to include final sediment quality benchmarks established in 2015 and Minnow's recommendations for modifying the CREMP Study Design.	1.0
2	Added Figure 2.1 to show locations of the different Project Sites and updated Figure 2.2 to reflect current ERP operations.	2.1
3	Updated Figure 3.2 and 3.3 as well as Table 3.2 to reflect the 2015 Surveillance Network Program (SNP).	3.4
4	Updated timeline/schedule for MMER requirements.	4.1.5
5	Updated all CREMP Study Design components to reflect the recommendations proposed by Minnow in 2016.	4.2
6	Updated to reflect current status of the Stream Diversion Barrier Study during the Early Revenue Phase (ERP) of the Project.	4.3
7	Updated Table 5.3 to reflect the final sediment quality benchmarks established in 2015.	5.3.3
8	Included Bray Curtis Index in list of metrics used to assess CREMP BMI data.	5.3.5
9	Added Inrisik's report on the establishment of final sediment quality AEMP benchmarks as Appendix D.	Appendix D

TABLE OF CONTENTS

TABLES

FIGURES

APPENDICES

ABBREVIATIONS

Project	the Mary River 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 the initial date when the Mine became 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 Interim Sediment Quality Benchmarks for Application in Aquatic Effects Monitoring at the Mary River Project	A technical document describing the development of the current water quality benchmarks and interim sediment quality benchmarks for the CREMP in 2014.
Appendix D	Development of the Final Area-Specific Sediment Quality Benchmarks for Application in Aquatic Effects Monitoring at the Mary River Project	A technical document describing the development of the current sediment quality benchmarks established for the CREMP in 2015.
Appendix E	Core Receiving Environment Monitoring Program: Freshwater Biota	Presents the freshwater biota CREMP including a review of the freshwater biota baseline
Appendix F	2014 Reference Lake Evaluation	Presents work completed on the candidate CREMP reference lakes up to and including the 2014 field program.
Appendix G	Lake Sedimentation Monitoring Program	A targeted study on baseline and project-influenced lake sedimentation rates.
Appendix H	Dustfall Monitoring Program	The dustfall monitoring program contained in the Terrestrial Environment Management and Monitoring Plan (TEMMP; Baffinland, 2014)
Appendix I	Initial Stream Diversion Barrier Study	A targeted study on monitoring the effects of Project-related Stream Diversion

In 2015, Minnow Environmental Inc. (Minnow) was contracted to assist Baffinland in completing the field work and reporting requirements of several of the AEMP component studies, including the CREMP. After completing the CREMP in 2015, Minnow proposed several modifications to the CREMP to provide greater efficiencies to the program and improve the program's ability to achieve its objectives (i.e. to evaluate short and long term effects of the Project on aquatic ecosystems). Minnow's recommendations proposed modifications to the CREMP water quality, sediment quality and benthic community monitoring programs in study lakes and streams as well as modifications to the fish population monitoring program in study lakes. This document has been revised to reflect all of the recommendations proposed by Minnow in 2016.

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.

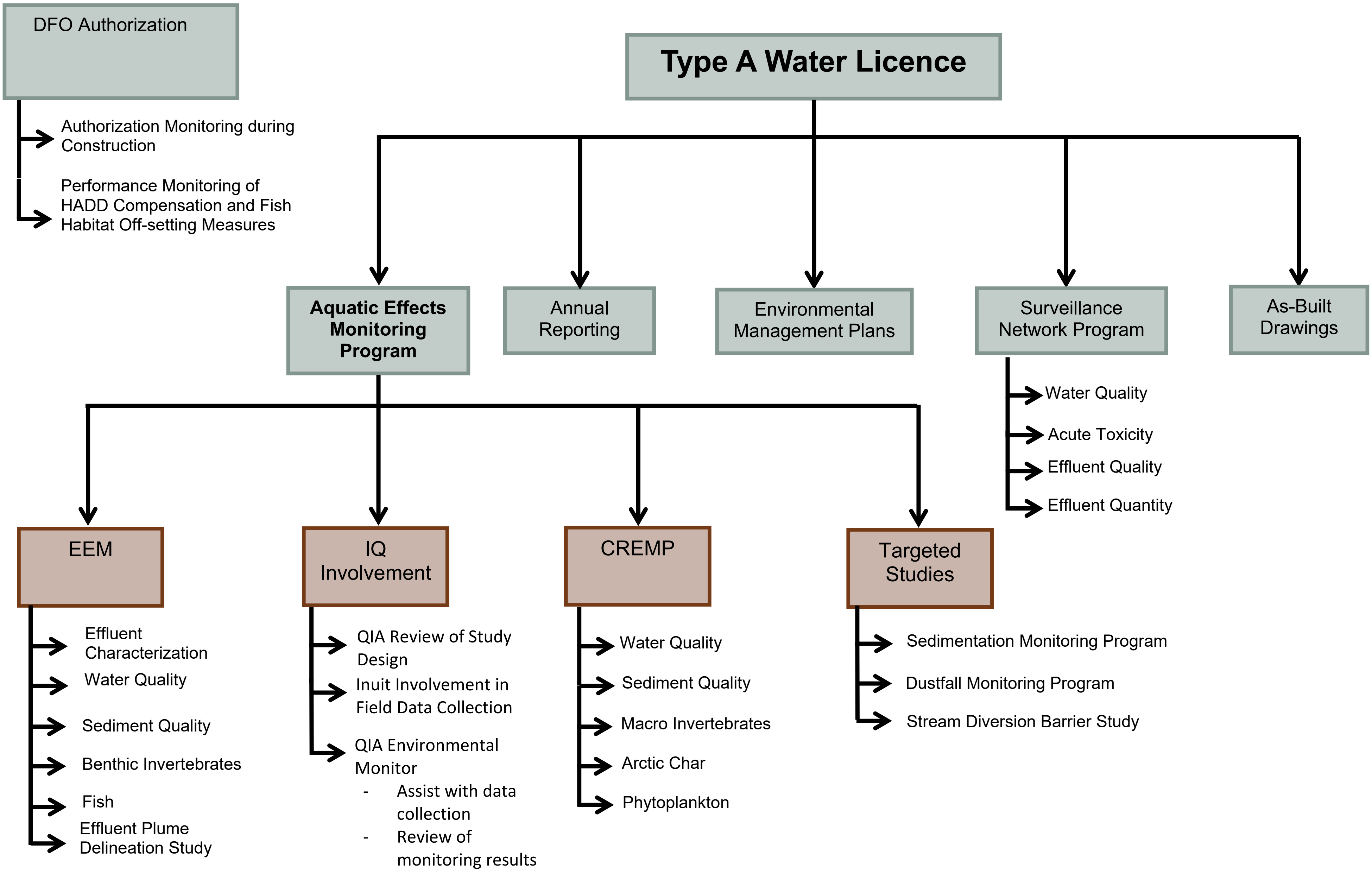
Part I of the licence outlines conditions related to general and aquatic effects monitoring. Part I (1) approved with the issuance of the water licence for the construction phase of the Project an AEMP Framework prepared in February 2013 (Baffinland, 2013b). Part I (1) also required Baffinland, upon 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.

On October 30, 2015, a revised version of the AEMP (Rev. 1) was submitted to the NWB for approval. The purpose of this submission was satisfy the condition stated in Part I, Item 2 of the Amended Type A Water Licence requiring Baffinland to submit to the board for approval in writing a revised version of the AEMP 60 days following the issuance of the Amended Licence.

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. On May 28, 2014, NIRB issued an amendment to Baffinland's Project Certificate No. 005 (Amendment No. 1) to allow for the Early Revenue Phase (ERP) of the Project. 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 (Figure 2.1):

- 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 2.2).

Mining began in 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 in ponds 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 applies, 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.

Figure 2-1 Project Sites and Location Map

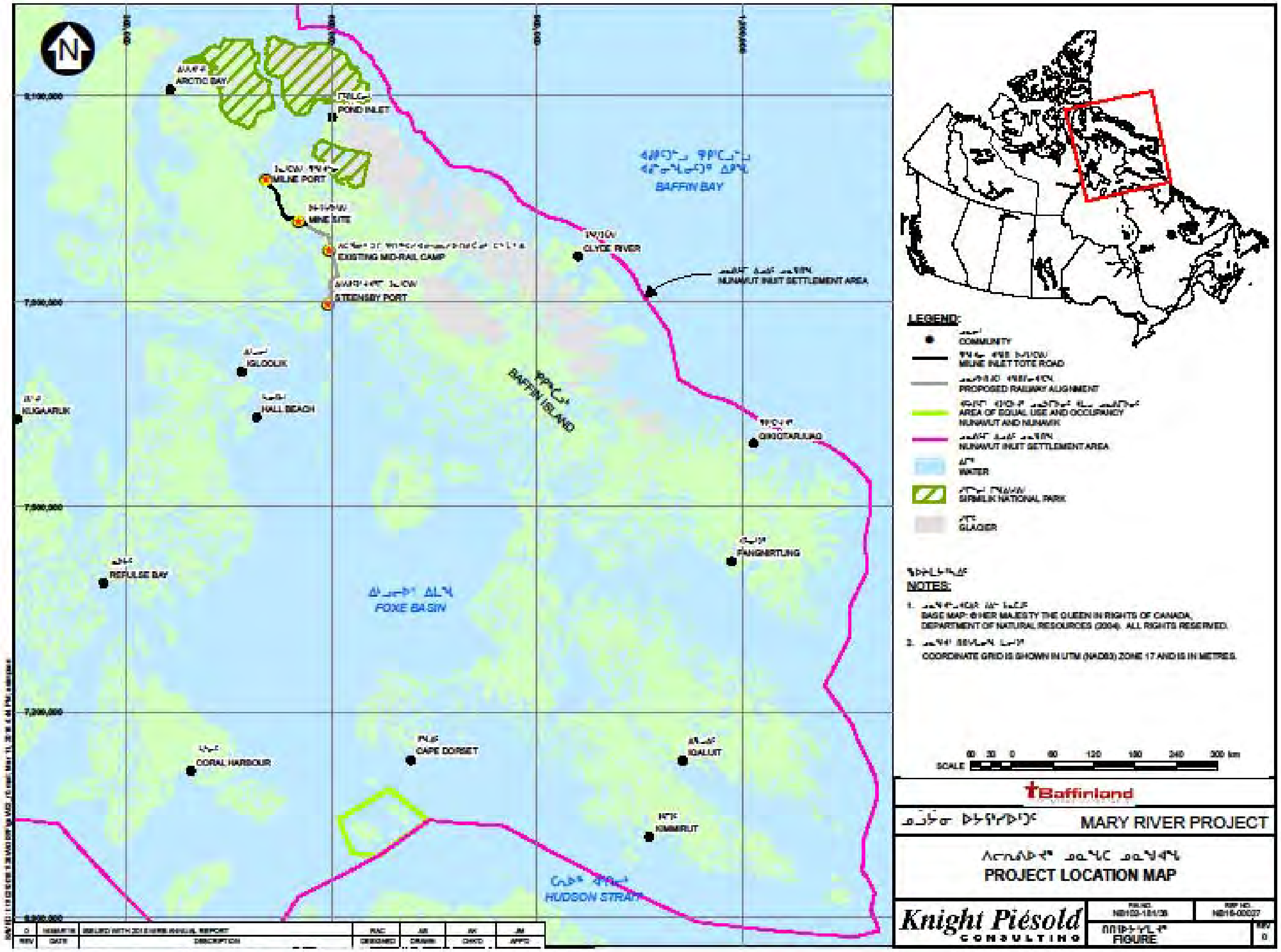
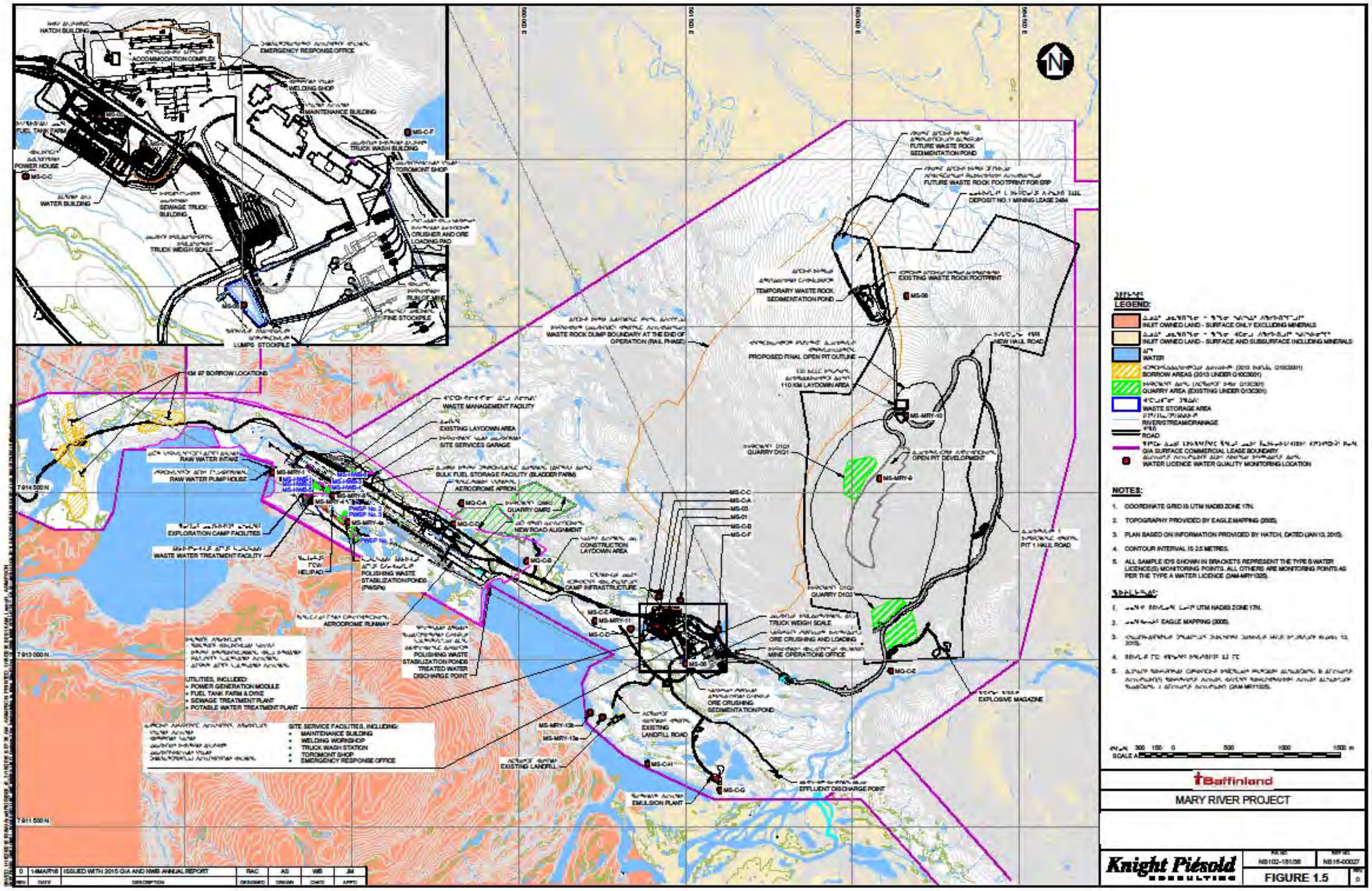


Figure 2-2 Mine Site Layout



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*.

For the 18 Mt/a operation, a number of proven mitigation measures have been proposed 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. Where practicable, ventilation ducts will be routed to dust collectors which will limit dust emissions. For the 3.5 Mt/a ERP operation, crushers and conveyors will not be fully enclosed. 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 stockpile (MS-08) runoff in an interim settling pond commenced during the summer of 2015 and coincided with the early development of the waste rock stockpile. A construction of a permanent settling/sedimentation pond commenced during 2015. It was designed for collecting runoff from the waste rock stockpile and will be completed during 2016. 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 2.2):

- Mary River (early in the Mine life); and
- Camp Lake Tributary 1 (later in the Mine life).

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 2.3).

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.

Figure 2-3 Mine Site Tributaries and Effluent Discharge Locations

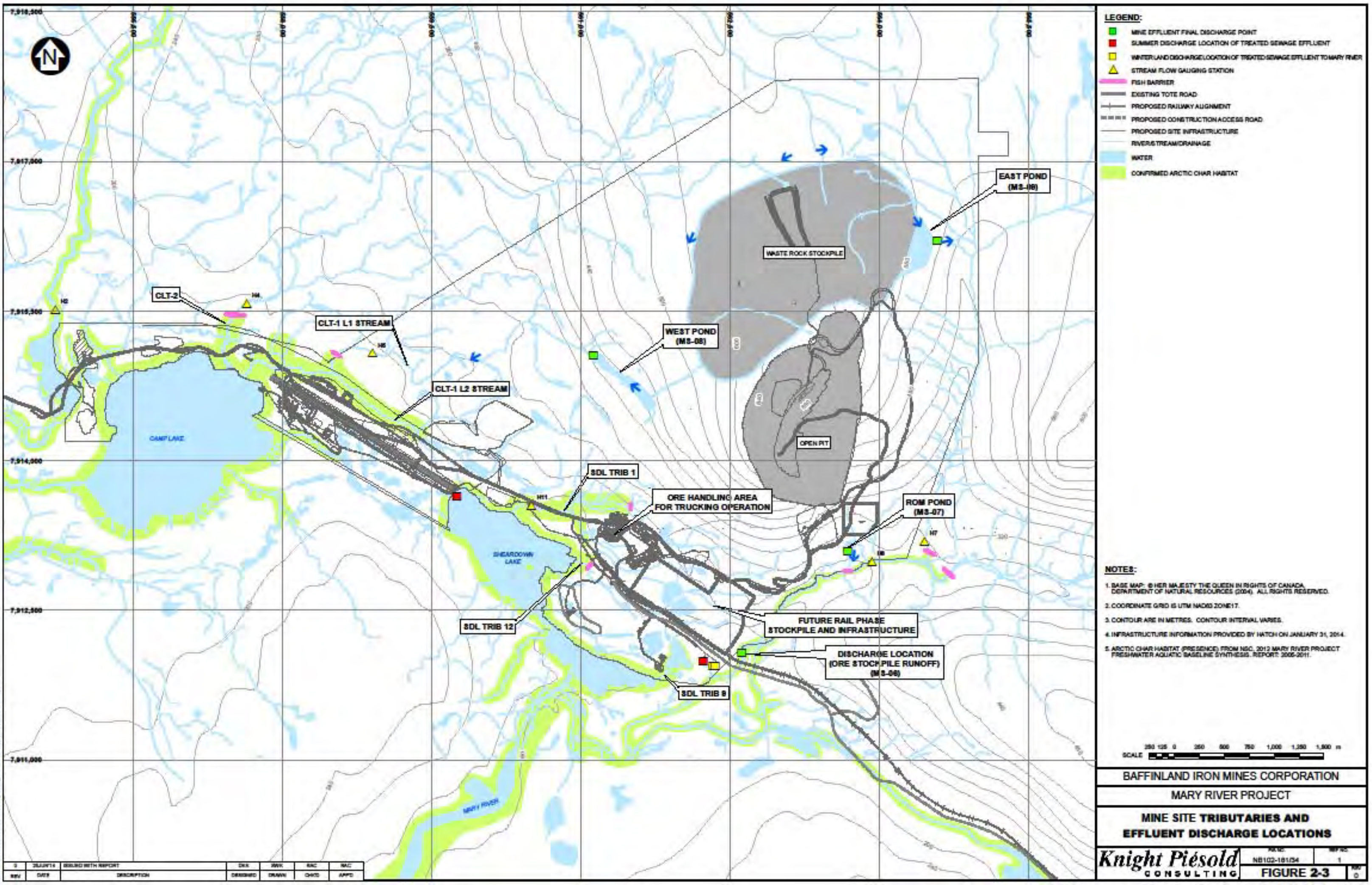


Table 2.1 Key Issues for Water and Sediment Quality at the Mine Site

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, blasting residue (ammonia, nitrate)	Mary River	Operation
Ore stockpile contact water	Metals, TSS, blasting residue (ammonia, nitrate)	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
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 2-4. 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.

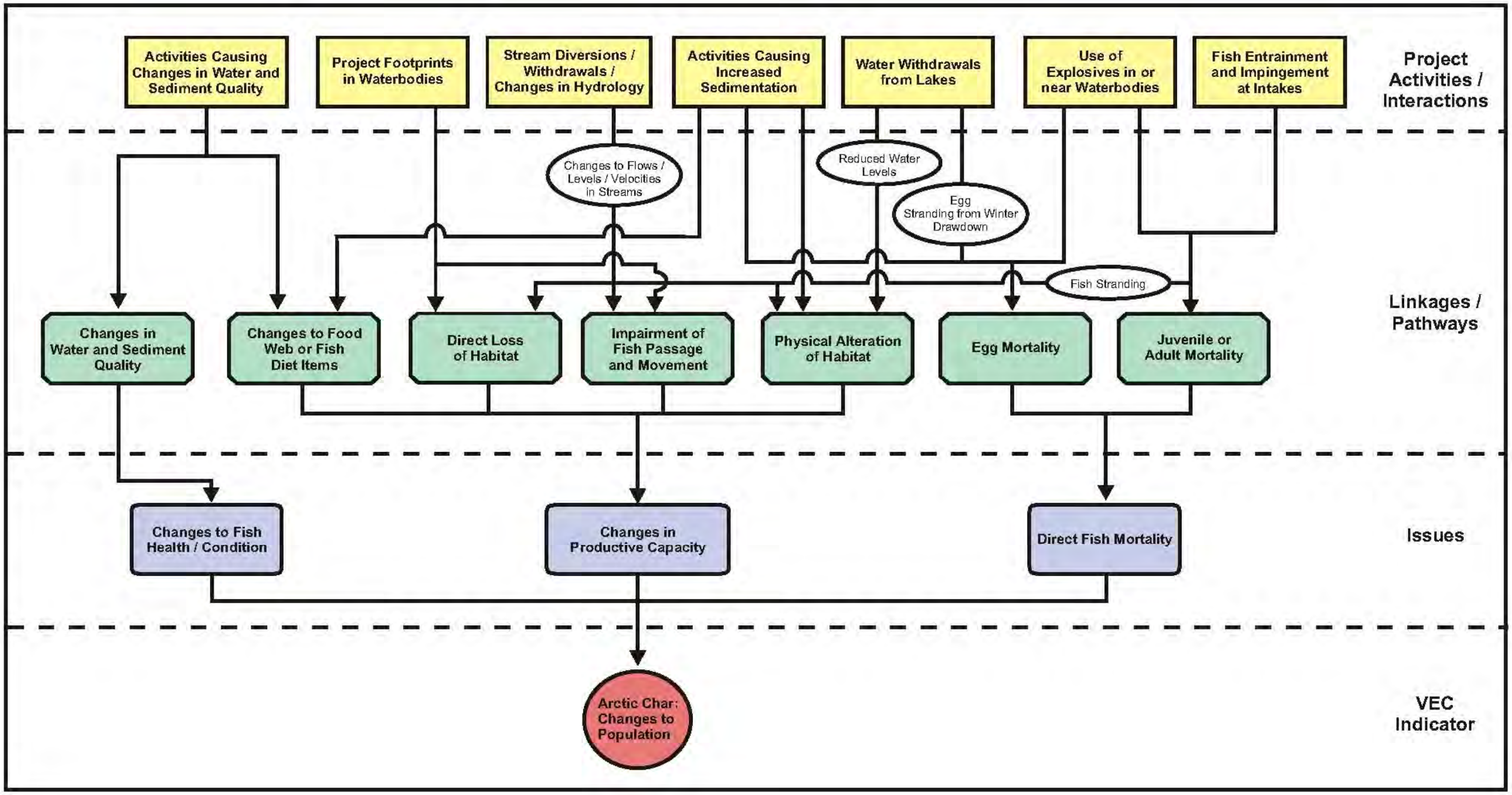
2.4.2 Potential Effects on Fish Habitat

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 2-4 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, when it eventually occurs, will be directed to the waste rock sedimentation pond or to other permitted containment structures as required.

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 I.

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. Several quarries and borrows will be developed within the Mine Site area to provide aggregate material for the site development and ongoing operations and maintenance.

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). For the longer term mining project Milne Port will serve both as the main staging areas for material and equipment required for the construction activities at the Mine Site, as well as for the sole shipping point during the ERP phase of the mine. The site includes the 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). A number of quarries will be developed near Milne Port to provide aggregate for the site development and ongoing operations and maintenance.

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, runoff from the ore stockpiles is channeled to two sedimentation ponds on the North end of the Ore Stockpile Pad. Site drainage from the Camp Pad is channeled to a series of natural swales located along the shoreline of Milne Inlet (ocean). Treated sewage and oily water effluent are discharged to a natural swale located North of the Bulk Fuel Tank Farm (refer to Figure 3.3). Both sedimentation ponds and swales along the Milne Inlet shoreline drain directly into the ocean without coming in contact with any freshwater body. As a result, site drainage and effluent discharge at Milne Port have no effects on the freshwater receiving environment.

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

Water Quantity

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

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

- 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 to support the ore transport required for the ERP phase of the Project.. Select water crossings may be rebuilt as part of the ongoing maintenance of the road and upgrades to support the ERP. 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:

Water and Sediment Quality

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

Freshwater Biota and Fish Habitat

- 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)

The longer term plans for the Project involve the transportation of iron ore 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:

<u>Water Quantity (Potable Water and Construction Activities)</u>

- Water withdrawals affecting downstream flows

<u>Water and Sediment Quality</u>

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

<u>Freshwater biota and fish habitat</u>

- 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 longer term plans for the Project involve the sizing and stockpiling of iron ore 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 meter 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 several 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.

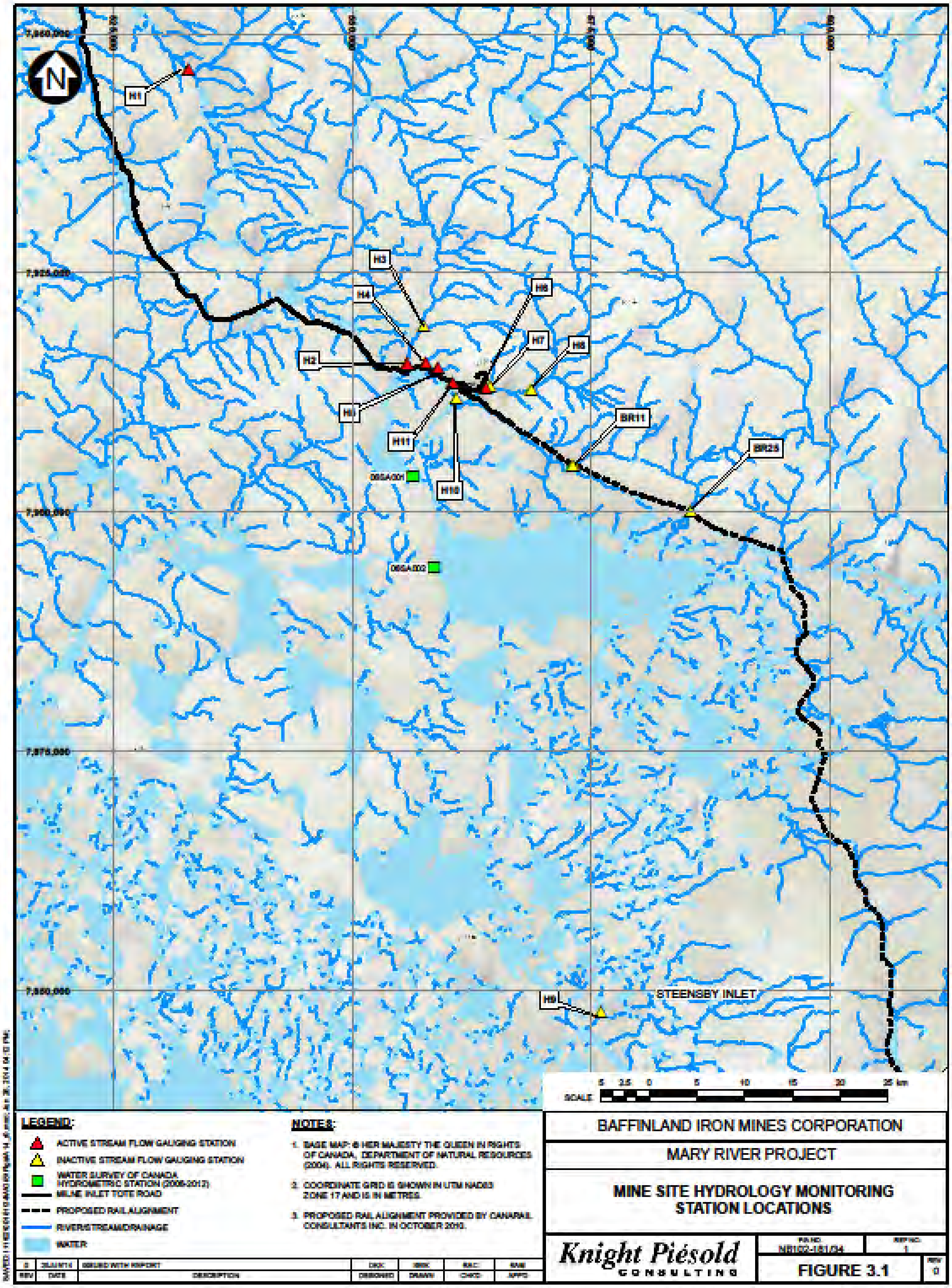
3.3 STREAMFLOW MONITORING

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. The hydrometric stations installed by the Water Survey have not been active since 2011. 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, 2011-2015	250	17W	532831	7946247
H02	Stream flow	2006-2008, 2010, 2012-2015	210	17W	555712	7915514
H03	Stream flow	2006-2008, 2010	30.5	17W	557485	7919401
H04 (CLT-2)	Stream flow	2006-2008, 2010, 2012-2015	8.3	17W	557639	7915579
H05 (CLT-1 L1)	Stream flow	2006-2008, 2010-2015	5.3	17W	558906	7915079
H06 (Mary River)	Stream flow	2006-2008, 2010-2015	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	2011-2015	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

Figure 3-1 Mine Site Hydrology Monitoring Stations



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

- 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.

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, Milne Port 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. 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 H).

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

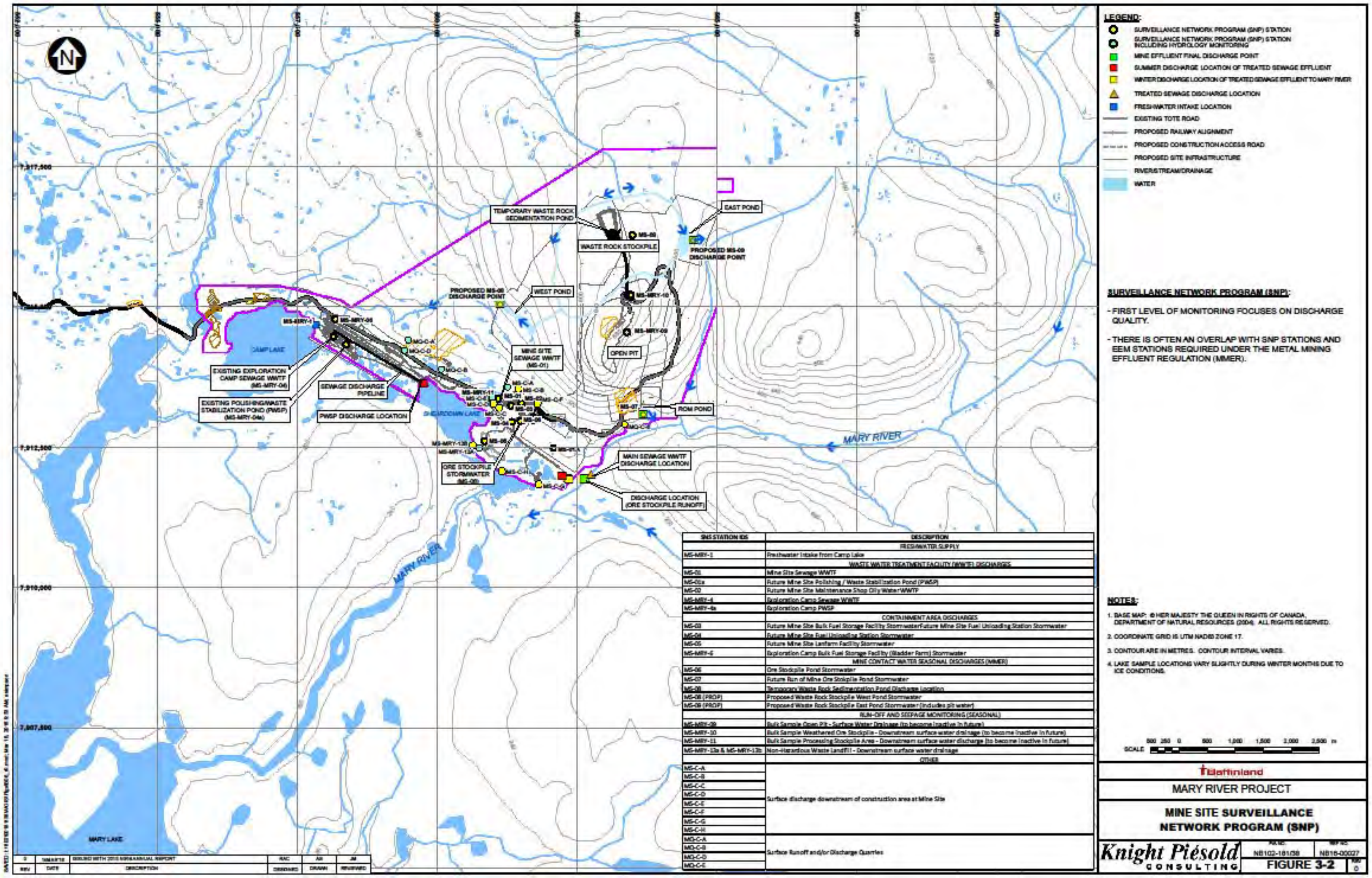
Air quality monitoring program is a supporting monitoring program to the AEMP as dustfall monitoring is required by PC Condition #21. Dustfall monitoring may be able inform the findings of monitoring of the aquatic environment under the AEMP, as well as measure changes in dustfall due to changes in the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

Table 3.2 Established SNP Monitoring Stations Associated with ERP

Monitoring Station	Description	UTM Coordinates (NAD83, Zone 17)		Status
		Easting (m)	Northing (m)	
Milne Port Site				
MP-MRY-2	Fresh Water Intake at Philips Creek (Summer)	514,503	7,964,579	Active
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	Inactive (not yet constructed)
MP-03	Milne Port Bulk Fuel Storage Facility Storm Water	503,638	7,976,272	Active
MP-04	Milne Port Landfarm Facility Storm Water	503,710	7,975,574	Active
MP-05	Milne Port Ore Stockpile Settling Pond (East)	503,469	7,976,383	Active
MP-06	Milne Port Ore Stockpile Settling Pond (West)	503,125	7,976,364	Active
MP-MRY-04	Milne Exploration Phase Sewage Treatment Facilities	503,462	7,975,764	Inactive (decommissioned)
MP-MRY-04a	Milne Exploration Phase Sewage PWSP	503,344	7,976,118	Inactive (decommissioned)
MP-MRY-7[1]	Milne Exploration Phase Bladder Farm Fuel Storage Facility Storm water	503,309	7,976,097	Inactive (decommissioned)
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	Active
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-01a	Mine Site Polishing/Waste Stabilization Pond (PWSP)	TBD	TBD	Not yet established
MS-02	Mine Site Maintenance Shop Oily Water WWTF (Truck Wash)	561,638	7,913,222	Inactive (not yet commissioned)
MS-03	Mine Site Bulk Fuel Storage Facility Storm Water	561,258	7,913,304	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-04	Mine Site Fuel Unloading Station Storm Water	561,258	7,913,304	Not yet established
MS-05	Mine Site Landfarm Facility	TBD	TBD	Not yet established
MS-MRY-6	Exploration Camp Bulk Fuel Storage Facility (Bladder Farm) Storm Water	558,186	7,914,780	Active
MS-06+	Ore Stockpile Pond Storm Water (Crusher Pad)	561,475	7,913,000	Active
MS-07	Run of Mine Ore Stockpile Pond Stormwater	TBD	TBD	Not yet established

Monitoring Station	Description	UTM Coordinates (NAD83, Zone 17)		Status
		Easting	Northing	
		(m)	(m)	
MS-08	Waste Rock Stockpile West Pond	563,492	7,916,273	Active
MS-09	Waste Rock Stockpile East Pond	562,984	7,916,316	Not yet established
MS-MRY-9	Bulk Sample Open Pit - Surface water drainage	563,246	7,914,632	Inactive
MS-MRY-10	Bulk Sample Weathered Ore Stockpile - Downstream surface water drainage	563,488	7,915,197	Inactive
MS-MRY-10A	Surface discharge downstream of km 107 on Haul Road	564531	7913652	Active
MS-MRY-11	Bulk Sample Processing - Downstream surface water discharge	560,690	7,913,350	Inactive
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
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
MQ-C-E		563351	7912902	Active

Figure 3-2 Mine Site Surveillance Network Program (SNP)



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).

SNS 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	Future Mine Site Polishing / Waste Stabilization Pond (PWSP)
MS-02	Future Mine Site Maintenance Shop Oily Water WWTP
MS-MRY-4	Exploration Camp Sewage WWTF
MS-MRY-4a	Exploration Camp PWSP
	CONTAINMENT AREA DISCHARGES
MS-03	Future Mine Site Bulk Fuel Storage Facility StormwaterFuture Mine Site Fuel Unloading Station Stormwater
MS-04	Future Mine Site Fuel Unloading Station Stormwater
MS-05	Future 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	Future Run of Mine Ore Stokpile Pond Stormwater
MS-08	Temporary Waste Rock Sedimentation Pond Discharge Location
MS-08 (PROP)	Proposed Waste Rock Stockpile West Pond Stormwater
MS-09 (PROP)	Proposed 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-Hazardous 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	
MO-C-A	Surface Runoff and/or Discharge Quarries
MO-C-B	
MO-C-D	
MO-C-E	

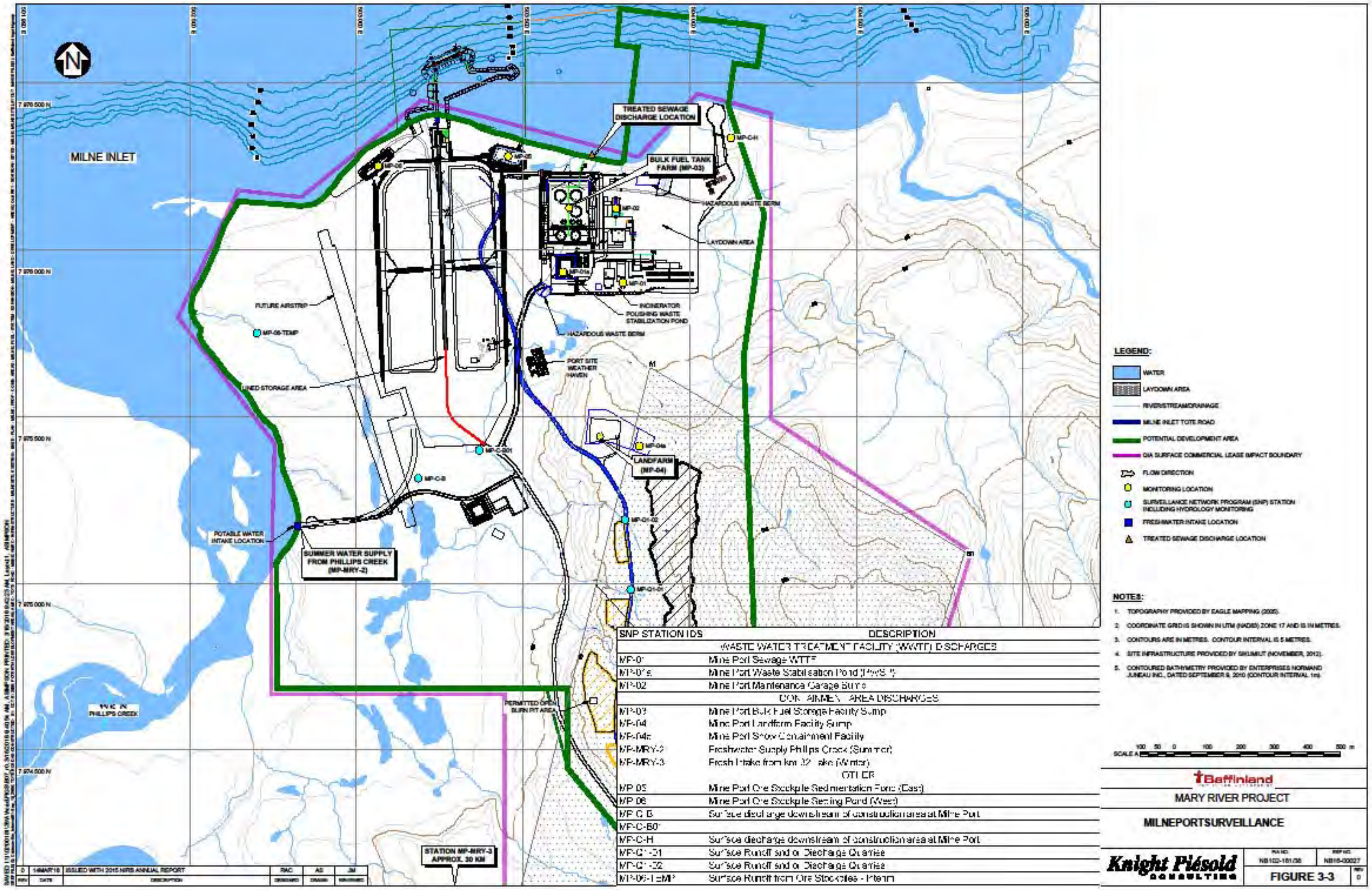
NOTES:

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
MARY RIVER PROJECT
MINE SITE SURVEILLANCE NETWORK PROGRAM (SNP)
Knight Piésold CONSULTING
P/A NO. NB102-181/38
REF NO. NB16-00027
FIGURE 3-2
REV 0

Figure 3-3 Milne Port Surveillance Network Program (SNP)

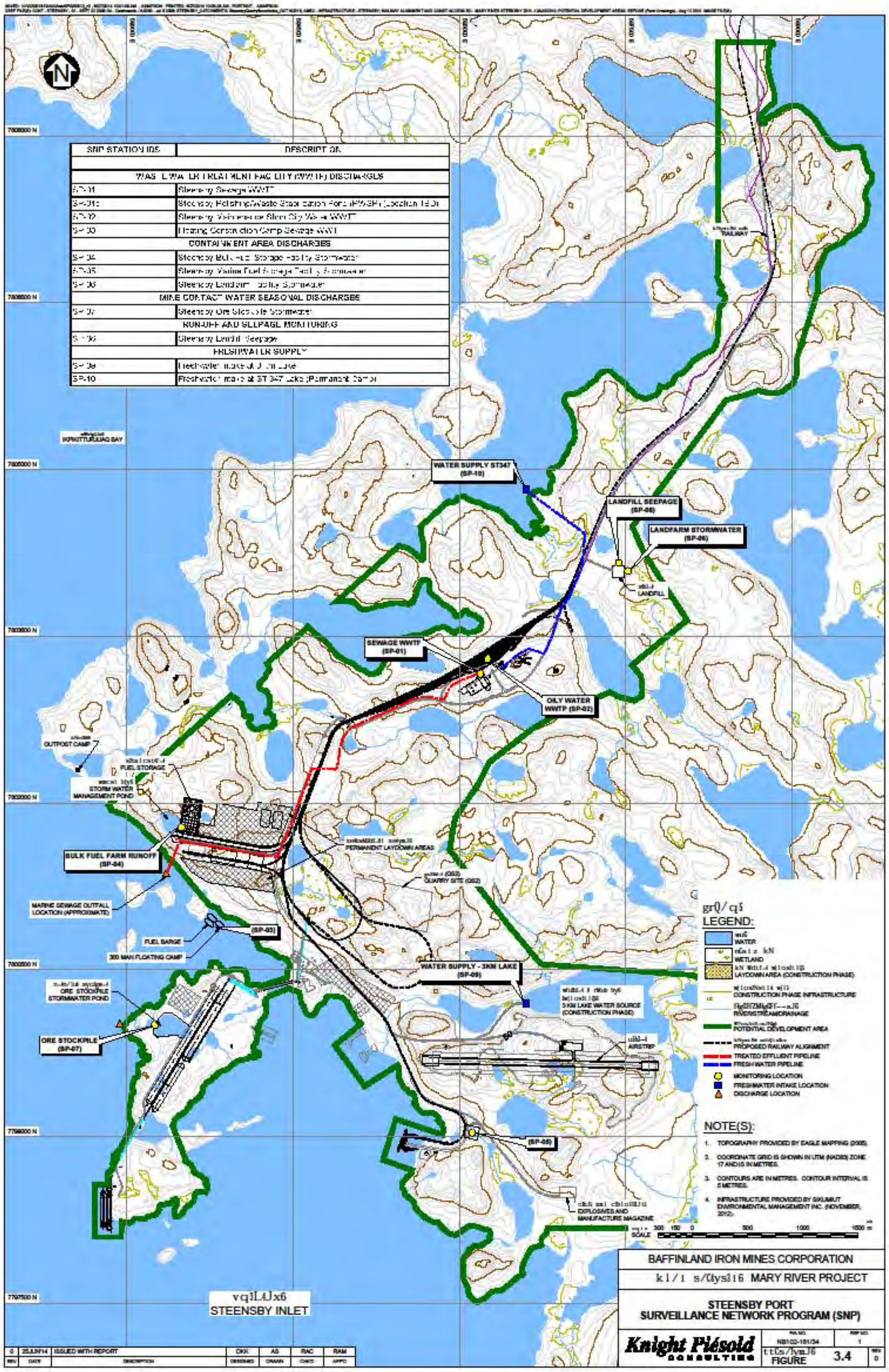


SNP STATION IDS	DESCRIPTION
	WASTE WATER TREATMENT FACILITY (WWTF) DISCHARGES
MP-01	Milne Port Sewage WWTF
MP-01a	Milne Port Waste Stabilization Pond (PWSP)
MP-02	Milne Port Maintenance Garage Sump
	CONTAINMENT AREA DISCHARGES
MP-03	Milne Port Bulk Fuel Storage Facility Sump
MP-04	Milne Port Landfarm Facility Sump
MP-04a	Milne Port Snow Containment Facility
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-B01	
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
MP-06-TEMP	Surface Runoff from Ore Stockpiles - Interim

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).

Figure 3-4 Steensby Port Surveillance Network Program (SNP)



SNP STATION IDS	DESCRIPTION
WASTEWATER TREATMENT FACILITY (WWTF) DISCHARGES	
SP-01	Steensby Sewage WWTF
SP-01b	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. NB102-181/34 REF NO. 1
FIGURE 3.4 REV 0

REV	DATE	DESCRIPTION	DESIGNED	DRAWN	CHK'D	APP'D
0	25JUN14	ISSUED WITH REPORT	DKK	AS	RAC	RAM

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 Baffinland 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 and extension/reinstalls for a large number of stream crossings. DFO has issued Letters of Advice for this work and 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.

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
- Freshwater Supply, Sewage and Wastewater Management Plan

- Waste Management Plan
- Hazardous Materials and Hazardous Waste Management Plan
- Explosives Management Plan
- Blasting Management Plan
- Waste Rock Management Plan
- Emergency Response Plan
- 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 lakes and streams within the area of the Mine Site.

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 0 °C, 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 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 (early in mine life); and
- Camp Lake Tributary 1 (later in mine life).

There will be three final discharge points where mine effluent will be discharged to the Mary River. The three discharge points are as follows:

- East Pond discharge (MS-08) collecting stormwater from the east side of the waste rock stockpile;
- Run-of-mine (ROM) and crusher 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)

.

Figure 4-1 EEM Program Exposure Areas

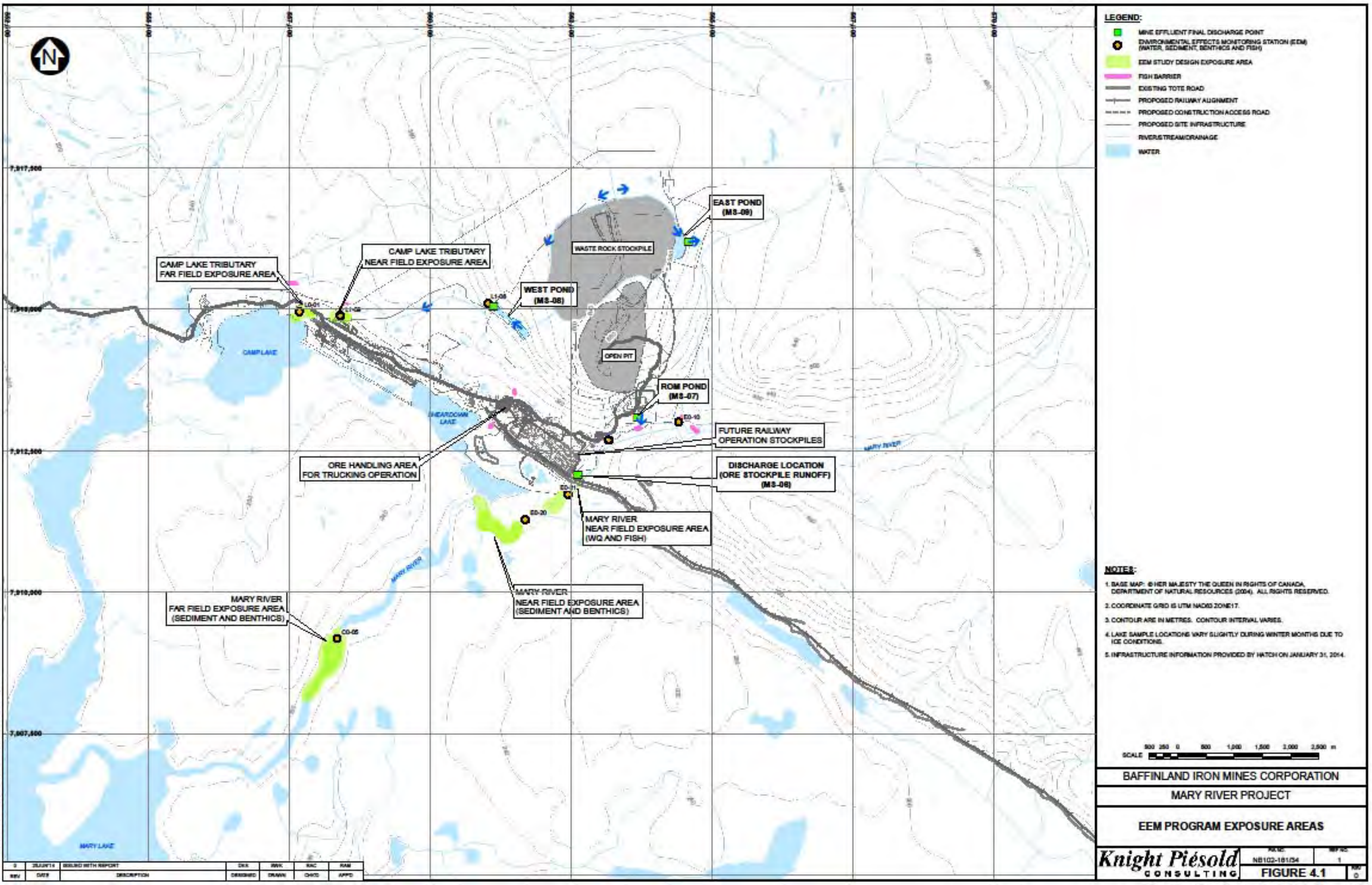


Table 4.1 Freshwater EEM Study Design Exposure and Candidate Reference Areas

Study Area ID	UTM Coordinates (NAD83, Zone 17)	
	Easting (m)	Northing (m)
Camp Lake Tributary Near Field Exposure Area	558,491	7,914,932
Camp Lake Tributary Far Field Exposure Area	557,896	7,914,916
Camp Lake Tributary Reference Area 2	526,105	7,936,762
Camp Lake Tributary Reference Area 3	567,831	7,908,076
Camp Lake Tributary Reference Area 4	569,093	7,907,247
Mary River Near Field Exposure Area (Surface water & Fish at outfall)	562057	7,911,436
Mary River Near Field Exposure Area (Sediment & Benthos)	561,567	7,911,174
Mary River Far Field Exposure Area	558,396	7,909,227
Mary River Reference Area 1	538,169	7,901,494
Mary River Reference Area 2	570,186	7,903,346
Mary River Reference Area 3	584,310	7,898,422
Mary River Reference Area 4	571,350	7,917,086

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.) It is noted that the most practical approach to plume monitoring would be to conduct a pro-rated evaluation based on a known volume of effluent released and the available hydrology data.

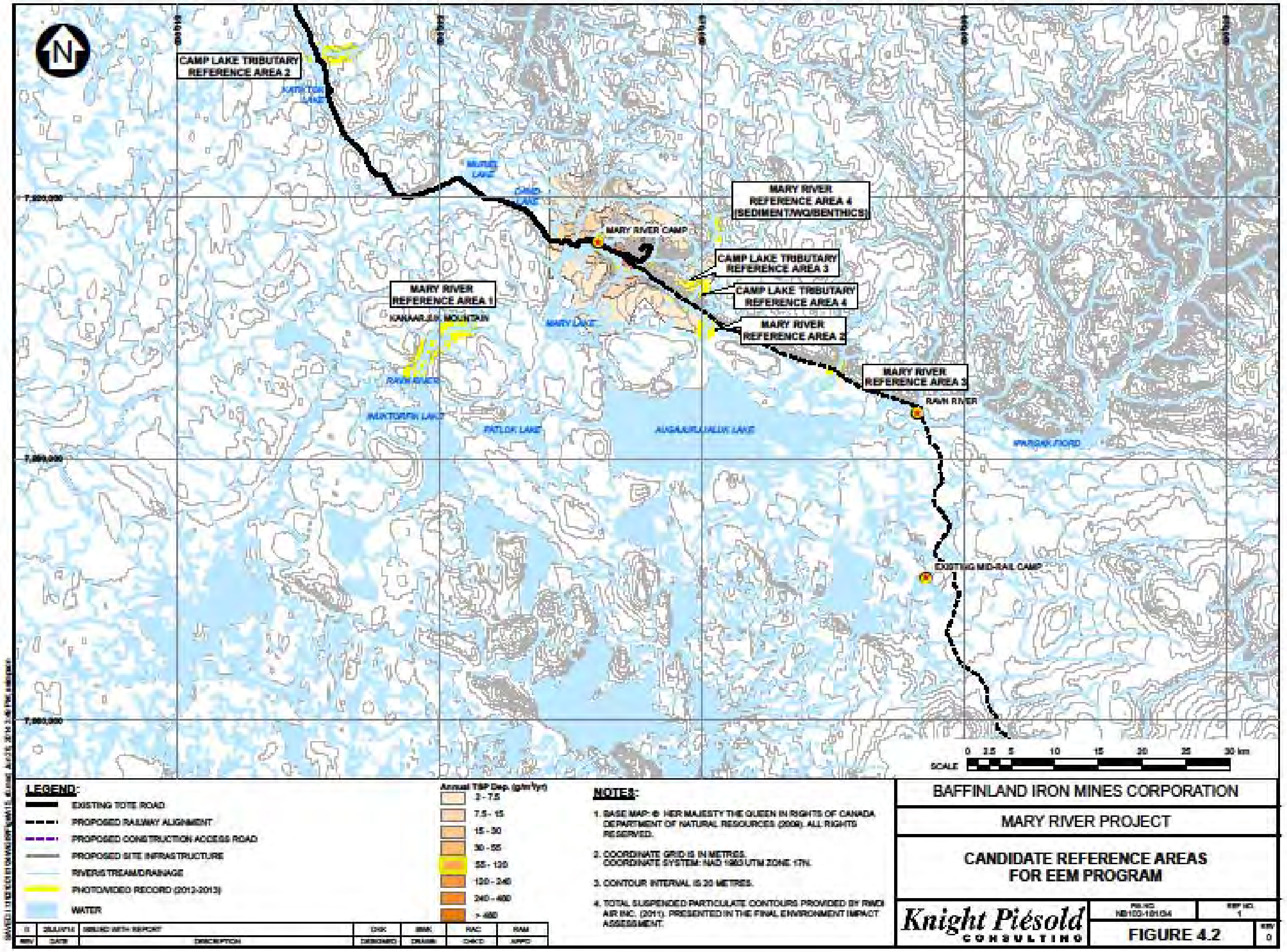
4.1.4.2 Water Quality Monitoring

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.

Figure 4-2 Candidate Reference Areas for EEM Program



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	The mine became subject to MMERs (effluent discharge rate reached 50 m^3/day)
September 9, 2015	Submission of Identifying Information & Final Discharge Points (within 60 days after date mine is subject to MMERs)
July 10, 2016	Submission of Cycle One Study Design to Environment Canada (12 months from initial date when Mine was subject to MMERs)
	Environment Canada review of Cycle One Study Design (At least 6 months prior to commencing study)
August-Sept 2017	Conduct Cycle One Biological Monitoring Study (conducted no sooner than 6 months after Cycle One SD submission date)
January 10, 2018	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.

In 2015, Reference Lake 3 was established as the reference lake for the CREMP. Reference Lake 3 will be used to assist in identifying mine influenced changes to the water, sediment and freshwater biota of mine area lakes.

After completing the CREMP in 2015, Minnow proposed several modifications to the CREMP in an effort to provide greater efficiencies to the program and improve the program’s ability to achieve its objectives.

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 E (NSC, 2014a). Both the brief descriptions of each CREMP component below and the CREMP appendices (Appendix B and E) have been revised to reflect the modifications proposed by Minnow.

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 (Appendix B) 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 total phosphorus (TP) 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).

Within the list of recommendations, Minnow noted that no consistent spatial differences in water quality/chemistry were evident in any of the study lakes in 2015, nor during any of the baseline studies, suggesting that study lakes are generally well mixed with relatively uniform water chemistry throughout the year. (Minnow, 2016). Because of this, Minnow recommended three modifications to the CREMP lake water quality sampling program:

1. Reduce the number of water quality monitoring stations to three (3) in each of Camp, Sheardown NW and SE lakes and four (4) in Mary Lake (Item 7; Minnow, 2016);
2. Collect a single water quality sample at mid-depth instead of collecting two samples, surface and bottom, at each lake water quality monitoring station (Item 9; Minnow, 2016) and;
3. Conduct water quality *in-situ* profiling at the main (i.e. deepest) basin of the study lakes to evaluate the occurrence of anoxic conditions and guide the subsequent sampling approach (Item 8; Minnow 2016).[1]

Lake water quality stations selected by Minnow for i*n-situ* profiling are listed below.

- Camp Lake Station - JL0-07
- Sheardown Lake NW Station – DL0-01-2
- Sheardown Lake SE Station – DL0-02-3
- Mary Lake (North Basin) Station – BL0-1A

---

[1] Anoxic conditions have not been observed at any of the study lakes since baseline studies began in 2005.

- Mary Lake (South Basin) Station – BL0-9
- Reference Lake 3 (NW Basin) Station – REF03-3

In addition to the recommendations pertaining to the lake water sampling program, Minnow also recommended the following modifications be made to the CREMP lotic (stream) water quality sampling program:

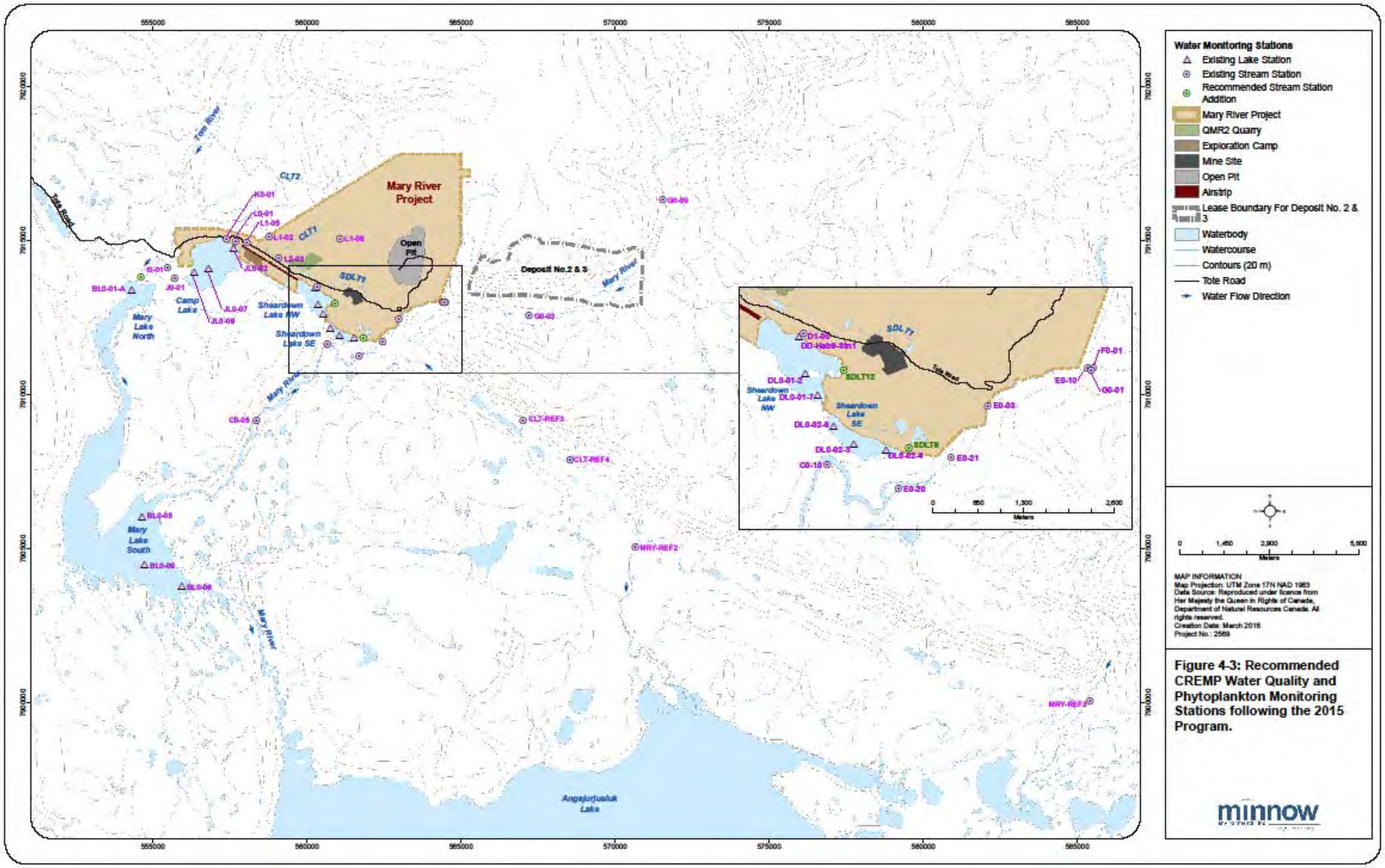
1. The addition of three stream water quality monitoring stations, including at lower Tom River, Sheardown Lake Tributary 9 and Sheardown Lake Tributary 12.
2. Discontinue water quality monitoring at stations L1-09 (Camp Lake Tributary 1) and D1-05 (Sheardown Lake Tributary 1).
3. Discontinue water quality monitoring at stations G0-09A, G0-09B and C0-01 on the Mary River.

CREMP water quality stations are monitored three (3) times per year. Stream water quality will be monitored during the spring, summer and fall, whereas, lake water quality monitoring will take place during the winter (late April), summer and fall. This sampling frequency should be adequate to detect early warning flag concentrations and determine significance for most water quality parameters. The sampling frequency and schedule will be re-evaluated after the first three years of mine operation.

This revision of the AEMP (Rev. 2) has been updated to reflect all Minnow's recommendations listed above. Additional details regarding the CREMP water quality sampling program are presented in Appendix B.

The CREMP water quality (phytoplankton) monitoring stations recommended by Minnow are shown on Figures 4.3 and 4.5.

Figure 4-3 Recommended CREMP Water Quality and Phytoplankton Monitoring Stations following the 2015 Program



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 sediment quality monitoring program has historically focused upon waterbodies (lakes and streams) closest to the sources of ore dust.

Prior to 2016, the sediment quality monitoring program did not sample sediment at each lake benthic macroinvertebrate (BMI) station. Therefore, in effort to harmonize the sediment quality and benthic macroinvertabrate monitoring programs and refocus the lake benthic macroinvertebrate program solely on littoral (shallow) habitats, Minnow proposed the following recommendations:

1. Establish five (5) sediment quality/BMI stations located in littoral (shallow) habitat at each mine exposed study lake and Reference Lake 3.
2. Continue sediment quality monitoring at three (3) existing sediment quality stations located in profundal (deep) habitat at Reference Lake 3 and each mine exposed study lake, with the exception of Sheardown Lake SE, where profundal habitat is limited to only a small proportion of the lake.

Littoral sediment sampling stations will be situated at the same locations as the littoral BMI stations. Utilizing the same littoral stations for both sediment quality and benthic macroinvertebrate community sampling will provide supporting information for interpretation and analysis of BMI results (e.g., metals concentrations) and allow the CREMP to establish potential linkages between sediment metal concentrations and their potential effects on benthic macroinvertebrates.

To the extent possible, littoral sediment quality/BMI stations proposed by Minnow were established at existing (historic) BMI stations. However, in some cases, new stations will be established to ensure sufficient coverage of the lake, and to ensure that substrate properties for sampling stations are comparable among and within lakes.

In contrast, all profundal sediment quality stations recommended by Minnow were selected from existing sediment stations. Because the majority of Sheardown Lake is less than 12 meters deep and represents primarily littoral habitat, no profundal sediment quality stations will be established in Sheardown Lake SE.

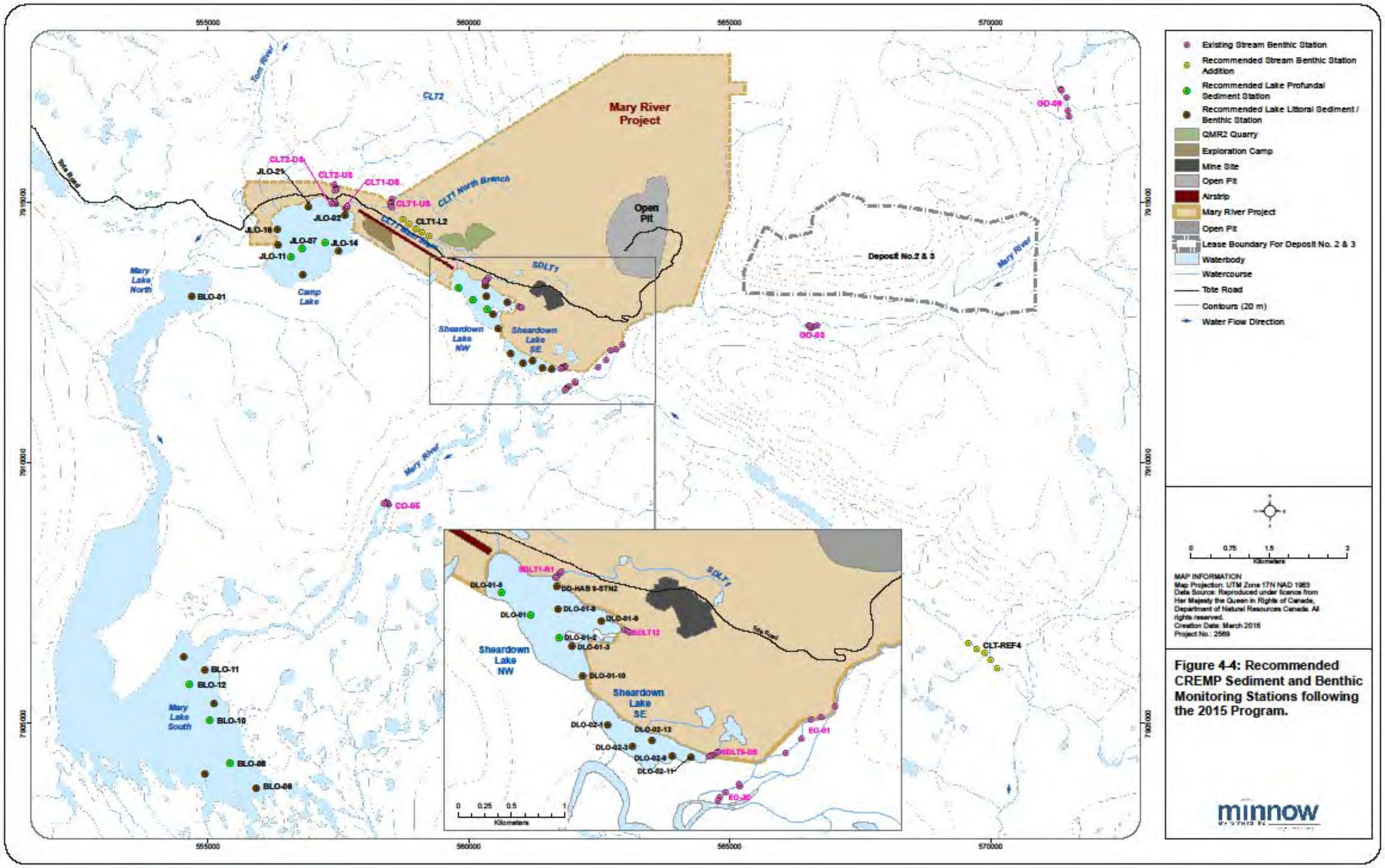
Lake sediment quality stations are positioned to allow for the evaluation of any spatial differences in sediment chemistry in order to determine potential gradients in metal concentrations associated with mine sources (i.e. mine exposed tributaries). At each station, field technicians will establish 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.

Moreover, in addition to modifications to the lake sediment quality program, Minnow also recommended that the CREMP sediment monitoring program focus solely on depositional lake environments and that CREMP sediment monitoring stations in streams and rivers be discontinued in future CREMP studies, This recommendation was based on the observation that the majority of streams and rivers in the Mary River Project local study area (LSA) contain very limited depositional habitat suitable for the collection of fine sediments. As observed during the 2015 CREMP and baseline studies (KP, 2015), the general absence of any substantial accumulation of fine sediments within these watercourses preclude any meaningful assessment of potential mine-related influences on sediment quality within, along and/or between watercourses. As a result, all sediment quality stations in streams and rivers near the Mine Site have been removed from future CREMP studies.

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 quality sampling in 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, consistent with the Environment Canada (2012) recommendations for EEM sampling.

Additional details regarding the CREMP sediment quality sampling program are presented in Appendix B. CREMP sediment quality and benthic monitoring stations recommended by Minnow are shown in Figures 4.4 and 4.5.

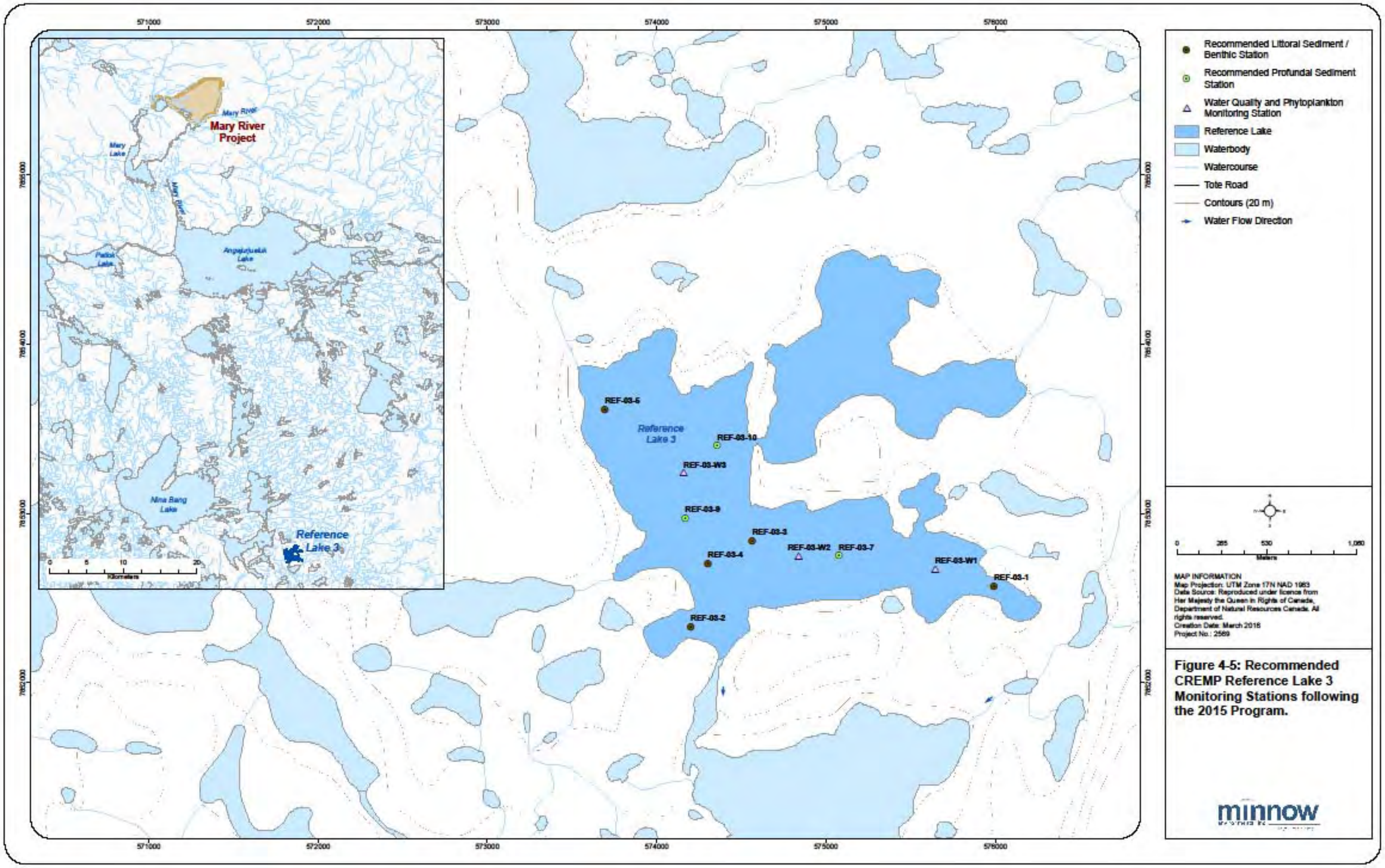
Figure 4-4 Recommended CREMP Sediment and Benthic Monitoring Stations Following the 2015 Program



MAP INFORMATION
Map Projection: UTM Zone 17N NAD 1983
Data Source: Reproduced under licence from Her Majesty the Queen in Rights of Canada, Department of Natural Resources Canada. All rights reserved.
Creation Date: March 2016
Project No.: 2569

Figure 4-4: Recommended CREMP Sediment and Benthic Monitoring Stations following the 2015 Program.

Figure 4-5 Recommended CREMP Reference Lake 3 Monitoring Stations following the 2015 Program



MAP INFORMATION
Map Projection: UTM Zone 17N NAD 1983
Data Source: Reproduced under licence from Her Majesty the Queen in Rights of Canada, Department of Natural Resources Canada. All rights reserved.
Creation Date: March 2016
Project No.: 2569

Figure 4-5: Recommended CREMP Reference Lake 3 Monitoring Stations following the 2015 Program.

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 E 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 Lake, Mary Lake and Sheardown Lake NW and SE as well as selected streams. In addition, monitoring will be conducted at Reference Lake 3. (NSC, 2014b; Appendix F). Chlorophyll-a will be sampled at all water quality stations and will coincide with water quality sampling events..

Sampling will be conducted annually during the initial three years of mine operation. However sampling frequency will be evaluated regularly (i.e., each year) to determine if modifications are warranted. Chlorophyll-a sampling in lakes will consist of two open-water periods (summer and late summer/fall) and once in late winter (April/May). Streams will be sampled three times in the open-water season (spring, summer, fall). Sampling of phytoplankton biomass and taxonomy will occur twice a year (summer and late summer/fall).

Phytoplankton data will be assessed during each year of monitoring and will 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 E.

4.2.4 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 the evaluation of mine related influences to benthic invertebrates in the Mine Area lakes and streams. The benthic invertebrate community survey is one of a main tools utilised for assessing mine-related influences on biota

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 Reference Lake 3 along with BMI reference stream station CLT-REF4.

Benthic invertebrate composition, distribution and relative abundance of dominant groups, including metal-sensitive taxa, naturally differ significantly between littoral (shallow) and profundal (deep) habitats of area lakes. The sampling of benthic invertebrates at profundal depths can confound the evaluation of mine related effects on biota due to the fact that at deeper depths natural factors, such as low oxygen and food resources, become more important drivers in shaping BMO community structure than mine-related contaminants. Because of this, Minnow has recommended that benthic invertebrate community sampling stations be established solely in littoral habitats. Five (5) replicate stations will be sampled in each lake and will coincide with each study lakes five (5) littoral sediment quality stations.. Utilizing the same littoral stations for both sediment quality and benthic invertebrate community sampling will provide supporting information for interpretation and analysis of benthic invertebrate results (e.g., metals concentrations) and allow the CREMP to establish potential linkages between sediment metal concentrations and their potential effects on benthic invertebrates. Recommended BMI community monitoring stations by Minnow are presented in Figure 4.4

Figure 4.4 has also been updated to reflect Minnow's additional recommendations of (1) discontinuing BMI monitoring on the two upper reaches of Sheardown Lake Tributary 1, (2) adding BMI monitoring station CLT1-L2 near water quality station L2-03 to monitor the effect of mine-influenced water quality changes on BMI communities and (3) establishing a stream reference BMI community station at CLT-REF4.

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 Reference Lake 3 and stream reference station CLT-REF4 are minimal the monitoring program will primarily 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 E.

4.2.5 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 Lake, Mary Lake and Sheardown Lake NW and SE. Monitoring of lakes is a key component of the CREMP because the mine area lakes provide overwintering and spawning habitat, support the full range of age classes, and because they may be affected differently than streams. In addition, monitoring will be conducted at Reference Lake 3, and potentially in one reference stream.

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 juvenile and adult fish using standardized sampling methods (i.e., standard gang index gillnetting and shoreline backpack electrofishing).

After completing the 2015 CREMP field program, Minnow recommended two (2) modifications to the CREMP adult Arctic char survey in order to reduce the amount incidental mortalities and optimize gill net capture rates.

1. Reduce the non-lethal adult Arctic char sample size to 50 fish per study lake and;
2. Standardize mesh size of gill nets used to optimize capture rates for adult Arctic char.

Based on data collected during the 2015 CREMP, power analysis conducted by Minnow indicated that total samples sizes for the adult fish survey can be reduced by half (i.e. 50 fish) while still maintaining the ability to detect changes between lakes and/or between study periods with sufficient power.

Additionally, during the 2015 CREMP the majority of adult Arctic char were captured in net mesh sizes ranging from 38 – 64 mm, which was also similar to the most efficient mesh size used to capture adult Arctic char during previous CREMP studies. As a result, the fish CREMP study design has been modified to reflect these recommendations.

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.

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 E.

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 G).

Sedimentation rates will be monitored in Sheardown Lake NW through deployment of sediment traps, as described in detail in Appendix G. 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. This sampling program was initiated in 2013 and is currently 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 char 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 H. 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 I (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.

The initial study conducted in 2013, focused on obtaining a better understanding for baseline flow conditions and, in particular, the frequency and duration of the occurrence of fish barriers and fish stranding in five (5) mine site streams (see Figure 1.1):

- CLT-1;
- CLT-2;
- SDLT-1;
- SDLT-9;
- And SDLT-12.

This initial study was 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 were monitored in the spring and fall of 2013. Low and high flow periods were targeted where possible. In spring, all five streams were visually assessed to monitor for potential barriers and obstructions to upstream fish passage. Surveys documented 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 allowed for the effective determination of whether perceived barriers resulted in the prevention of fish migration within each tributary, and thus electro fishing surveys were not deemed necessary for the assessment. During the 2013 field program, the combination of visual observations of barriers, fish presence and associated flows at the time of the survey were 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.

Since the stream diversion barrier study was identified in the FEIS, Baffinland started operating under an Early Revenue Phase (ERP) of the Project (Baffinland, 2013). The ERP involves mining 3.5 million tonnes per annum (Mt/a) of iron ore. The iron ore is 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. However, the development of the railway will be subject to a commercial decision by Baffinland to proceed and will be heavily 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 with Project-related stream diversions during the ERP being negligible. As a result, this study was discontinued for the next several years following the initial 2013 field program.

Resumption of of this monitoring program will depend upon the schedule and size of the Project. The Approved full scale Project (18 Mt/a) will result in meaningful reductions in streamflow and therefore monitoring under this program will be required to identify Project-related fish barriers and fish stranding. 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.

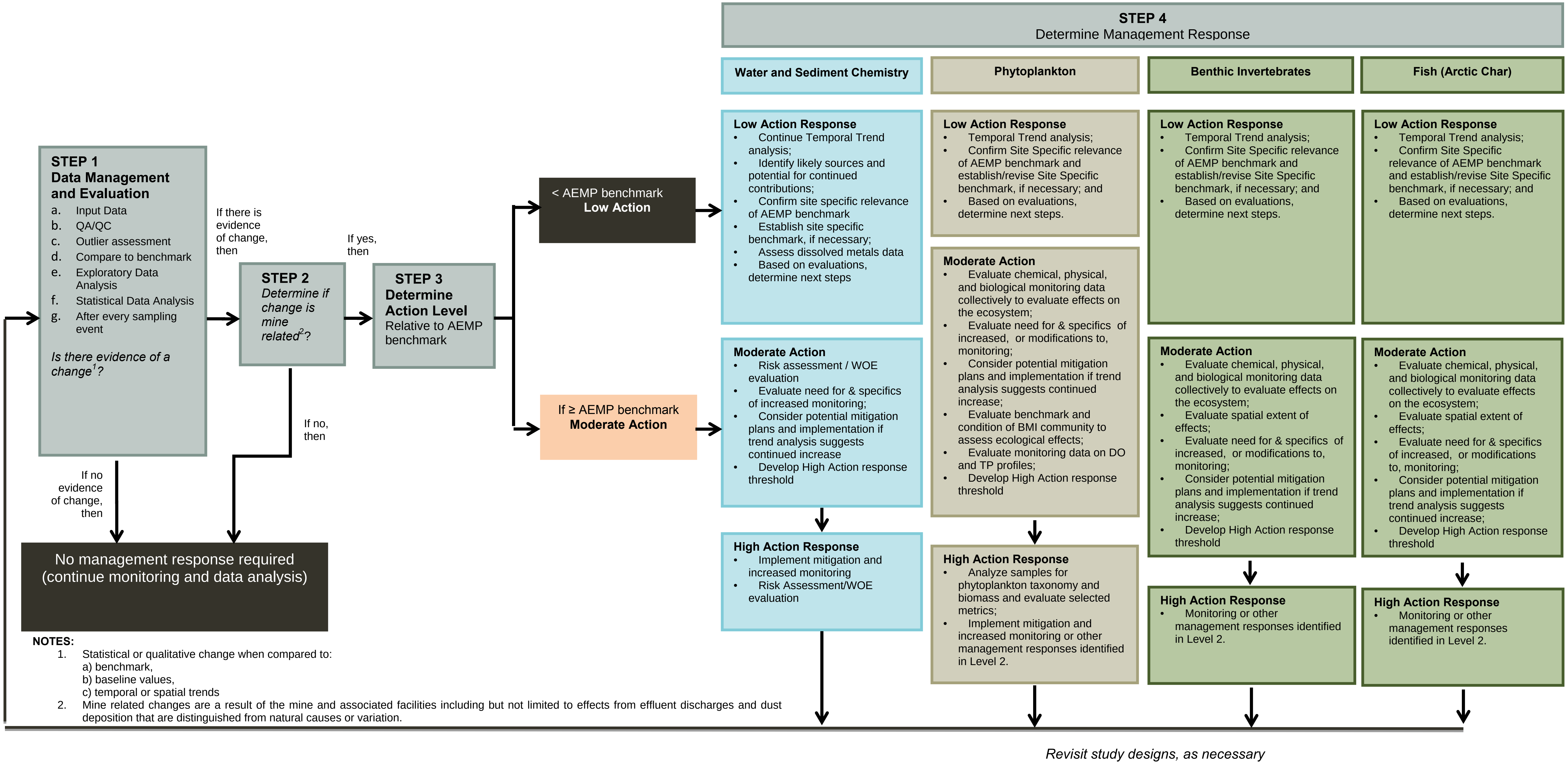
Step 2 – Determining Whether the Observed Change is Mine-Related

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



STEP 1
Data Management and Evaluation

a. Input Data
b. QA/QC
c. Outlier assessment
d. Compare to benchmark
e. Exploratory Data Analysis
f. Statistical Data Analysis
g. After every sampling event

Is there evidence of a change[1]?

If there is evidence of change, then

STEP 2
Determine if change is mine related[2]?

If yes, then

STEP 3
Determine Action Level
Relative to AEMP benchmark

< AEMP benchmark
Low Action

If ≥ AEMP benchmark
Moderate Action

STEP 4
Determine Management Response

Water and Sediment Chemistry

Low Action Response
- Continue Temporal Trend analysis;
- Identify likely sources and potential for continued contributions;
- Confirm site specific relevance of AEMP benchmark
- Establish site specific benchmark, if necessary;
- Assess dissolved metals data
- Based on evaluations, determine next steps

Moderate Action
- Risk assessment / WOE evaluation
- Evaluate need for & specifics of increased monitoring;
- Consider potential mitigation plans and implementation if trend analysis suggests continued increase
- Develop High Action response threshold

High Action Response
- Implement mitigation and increased monitoring
- Risk Assessment/WOE evaluation

Phytoplankton

Low Action Response
- Temporal Trend analysis;
- Confirm Site Specific relevance of AEMP benchmark and establish/revise Site Specific benchmark, if necessary; and
- Based on evaluations, determine next steps.

Moderate Action
- Evaluate chemical, physical, and biological monitoring data collectively to evaluate effects on the ecosystem;
- Evaluate need for & specifics of increased, or modifications to, monitoring;
- Consider potential mitigation plans and implementation if trend analysis suggests continued increase;
- Evaluate benchmark and condition of BMI community to assess ecological effects;
- Evaluate monitoring data on DO and TP profiles;
- Develop High Action response threshold

High Action Response
- Analyze samples for phytoplankton taxonomy and biomass and evaluate selected metrics;
- Implement mitigation and increased monitoring or other management responses identified in Level 2.

Benthic Invertebrates

Low Action Response
- Temporal Trend analysis;
- Confirm Site Specific relevance of AEMP benchmark and establish/revise Site Specific benchmark, if necessary; and
- Based on evaluations, determine next steps.

Moderate Action
- Evaluate chemical, physical, and biological monitoring data collectively to evaluate effects on the ecosystem;
- Evaluate spatial extent of effects;
- Evaluate need for & specifics of increased, or modifications to, monitoring;
- Consider potential mitigation plans and implementation if trend analysis suggests continued increase;
- Develop High Action response threshold

High Action Response
- Monitoring or other management responses identified in Level 2.

Fish (Arctic Char)

Low Action Response
- Temporal Trend analysis;
- Confirm Site Specific relevance of AEMP benchmark and establish/revise Site Specific benchmark, if necessary; and
- Based on evaluations, determine next steps.

Moderate Action
- Evaluate chemical, physical, and biological monitoring data collectively to evaluate effects on the ecosystem;
- Evaluate spatial extent of effects;
- Evaluate need for & specifics of increased, or modifications to, monitoring;
- Consider potential mitigation plans and implementation if trend analysis suggests continued increase;
- Develop High Action response threshold

High Action Response
- Monitoring or other management responses identified in Level 2.

If no evidence of change, then

If no, then

No management response required
(continue monitoring and data analysis)

Revisit study designs, as necessary

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. 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.

During 2014 and 2015, Intrinsik Environmental Sciences Inc. was retained by Baffinland to develop water and sediment quality benchmarks to be applied in the CREMP. The specifics of the benchmark selection process for both sediment and surface water are outlined in Appendix C and D, 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 the 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, 95th percentile, and 97.5th 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
Chromium $^{+6}$	mg/L	0.001	NC	0.001	NC	0.003 – 0.015	C

Parameter	Units	Water Quality Guideline	Camp Lake	Mary Lake	Sheardown Lake	Selected Benchmark	Benchmark Method
						(CL)[5] 0.003 (ML/SDL)[5]	
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]						
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 2014, 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 D (Intrinsik, 2015).

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=67), 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 and D (Intrinsik, 2014; Intrinsik 2015).

The outcomes of the final assessment in 2015 can be summarized as follows:

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

The approach used 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 Final AEMP benchmark. The outcome of this evaluation process is presented in Table 5.3.

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 E). 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 E).

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 Development of Area-Specific Aquatic Effects Sediment Benchmarks, based on Area-Specific Baseline Calculations and Relevant Sediment Quality Guidelines (mg/kg; dw; Intrinsik, 2015)[2]

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	20,000	460	16	600	31	120
	SEL	2	33	10	110	110	40,000	1100	75	2,000	250	820
97.5th Percentiles of Lake Areas and Lake Specific Benchmarks by Area												
Mary Lake (2007 – 2014) and Camp lake (2007 – 2014) (N=31)		<0.1	5.3	<0.5	98	50	52,400	4,370	72	1580	25	135
Proposed AEMP Benchmark – Mary Lake and Camp Lake		0.17[A]	5.9[A]	1.5[C]	98[B]	50[B]	52,400[B]	4,370[B]	72[B]	1,580[B]	35[A]	135[B]
Sheardown Lake SE (2007 – 2014) (N=11)		<0.1	2	1	79	56	34,400	657	66	1278	18	63
Proposed AEMP Benchmark – Sheardown Lake SE		0.17[A]	5.9[A]	1.5[C]	79[B]	56[B]	34,400[B]	657[B]	66[B]	1278[B]	35[A]	123[A]
Sheardown Lake NW (2007-2014, excluding 2008) (N=25)		<0.1	6.4	<0.5	96	62	53,000	4,300	84	1,100	24	107
Interim AEMP Benchmark – Sheardown Lake NW		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]

<u>**NOTES**</u>:

*=N for phosphorus is lower than other elements / parameters

A = guideline is based on sediment quality guideline (CCME or Ontario)

B = guideline is based on 97.5% percentile of baseline data

C = guideline is based on 3 times MDL

Where mercury and cadmium were not detected in any samples in a given area; the detection limit is used to represent the 97.5% percentiles.

---

[2] As recommended by Minnow, arsenic, copper and iron sediment quality benchmarks presented in Table 5.3 may be modified in the future to account for the elevated levels of these metals observed in sediments of Reference Lake 3 during the 2015 CREMP field program.

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).

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

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 Study Design 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.

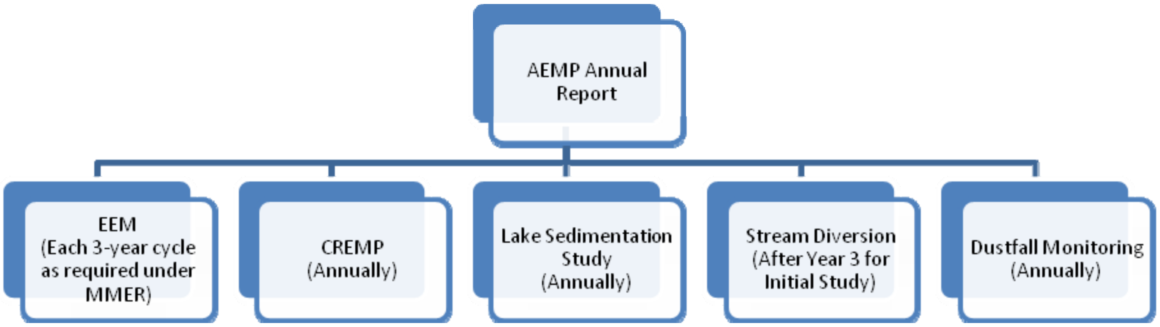
6.4 DATA EVALUATION

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, with the exception of the Stream Diversion Study. 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:

Baffinland

- Erik Madsen – Overall corporate responsibility
- Oliver Curran – Primary client contact and reviewer
- Jim Millard – technical review
- Fernand Beaulac – consultant advisor contributing to initial AEMP Framework

Knight Piésold Ltd.

- Richard Cook – Consultant Team Project Manager; contributions to the water and sediment quality CREMP; management response framework; senior review
- Dale Klodnicki – EEM Study Design; QA/QC; EEM, water and sediment quality field programs
- 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

North/South Consultants Inc.

- Megan Cooley – Freshwater biota baseline review and CREMP study design
- Richard Remnant – Freshwater biota baseline review
- Mike Johnson – Fisheries field programs
- Leanne Zrum – benthic macroinvertebrate baseline review and CREMP study design

Intrinsik Environmental Sciences Inc.

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

Minnow Environmental Inc.

Paul LePage - Consultant Team Project Manager, 2015 CREMP field program; Mary River Project CREMP Recommendations for Future Monitoring (2016)

9 REFERENCES

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

Azimuth Consulting Group Inc. 2010. *Aquatic Effects Management Program: Meadowbank Gold Project, Version 1*. Project No. AE-10-01. Prepared for Agnico-Eagle Mines Ltd., Baker Lake, Nunavut. May 2010.

Baffinland Iron Mines Corporation (Baffinland). 2012. *Final Environmental Impact Statement*. February 2012.

Baffinland. 2013a. *Addendum to the Final Environmental Impact Statement*. June 2013.

Baffinland. 2013b. *Aquatic Effects Monitoring Program Framework*. February 2013.

Baffinland. 2013c. *Updated Aquatic Effects Monitoring Program Framework*. December 2013.

Baffinland. 2014. Terrestrial Environment Management and Monitoring Plan, Version 3.0. January 2014.

British Columbia Ministry of the Environment, undated. Water Quality Guidelines (Criteria) Reports. Available at: http://www.env.gov.bc.ca/wat/wq/wq_guidelines.html. Accessed April 2014.

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

CCME. 1999. *Canadian environmental quality guidelines*. Canadian Council of Ministers of the Environment, Winnipeg, MB. Updated to 2014. Available at: http://st-ts.ccme.ca/.

CCME. 2007. *Canadian sediment quality guidelines for the protection of aquatic life: Summary tables and fact sheets. Update 2002*. In: Canadian environmental quality guidelines, 1999, Canadian Council of Ministers of the Environment, Winnipeg.

Department of Fisheries and Oceans Canada (DFO). 1995. *Freshwater Intake End-of-Pipe Fish Screen Guideline*. Ottawa: Ministry of Supply and Services Canada. Catalogue No. Fs 23-270 / 1995E.

Environment Canada. 2003. *Revised Technical Guidance on How to Conduct Effluent Plume Delineation Studies.* National EEM Office, National Water Research Institute and Environment Canada. March 2003.

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

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

Fisheries Act. R.S.C. (1985). c. F-14, June 29, 2012.

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

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

Indian and Northern Affairs Canada. 2009. *Guidelines for Designing and Implementing Aquatic Effects Monitoring Programs for Development Projects in the Northwest Territories*. Yellowknife. June 2009. Volumes 1-6.

Knight Piésold Ltd. 2014a. *Baffinland Iron Mines Corporation – Mary River Project – Water and Sediment Quality Review and CREMP Study Design*. Ref. No. NB102-181/33-1, Rev. 2, dated June 25, 2014.

Knight Piésold Ltd. 2014b. *Baffinland Iron Mines Corporation – Mary River Project – Water and Sediment Quality Sampling Protocol*. Ref. No. NB102-181/33-2, Rev.0, dated March 28, 2014.

Knight Piésold Ltd. 2014c. *Initial Stream Diversion Barrier Study - Rev. 0 - Mary River Project - Aquatic Effects Monitoring Program*. Memo Ref. No. NB14-00160, dated June 25, 2014.

Knight Piésold Ltd., 2007. *Mary River Project – Bulk Sampling Program – Fish Habitat No Net Loss and Monitoring Plan*. Ref. No. NB102-181/10-4, Rev. 0, dated August 30, 2007.

MacDonald, D.D., Clark, M.J.R., Whitfield, P.H., and Wong, M.P. (2009). Designing monitoring programs for water quality based on experience in Canada I. Theory and framework. Trends in Analytical Chemistry 28(2):204-213.

Minister of Justice (MOJ). 2012. Consolidation Metal Mining Effluent Regulations. SOR/2002-222. Current to September 12, 2012.

North/South Consultants Inc. 2008. *Mary River Project Freshwater Aquatic Environment Baseline Draft Report: Fish and Fish Habitat*. Winnipeg, MB.

North/South Consultants Inc. 2010. *Mary River Project Freshwater Aquatic Biota and Habitat Baseline Synthesis Report 2005-2010*. November 2010. Winnipeg, MB.

North/South Consultants Inc. 2014. *Preliminary review of Baseline Data for Freshwater Biota: Mary River Mine Site.* Issued in Draft August 2013.

North/South Consultants (NSC). (2013b). *Mary River Project Candidate Reference Lakes: Preliminary Survey August 3-7, 2013*. Draft Technical Memorandum.

Nürnberg, G.K. (1996). Trophic state of clear and colored, soft- and hardwater lakes with special consideration of nutrients, anoxia, phytoplankton and fish. Lake and Reservoir Management. 8: 17-30.

Nunavut Impact Review Board. 2012. In the matter of an application by Baffinland Iron Mines Corporation for development of the Mary River Project Proposal in the Qikiqtani Region of Nunavut: NIRB Project Certificate No. 005. Dated December 28, 2012.

Nunavut Impact Review Board. 2014. Nunavut Impact Review Board - Public Hearing Report - Mary River Project: Early Revenue Phase Proposal - Baffinland Iron Mines Corporation - NIRB File No. 08MN053. March 2014.

Nunavut Water Board (NWB). 2013. *Water Licence No: 2AM-MRY1325*. Motion Number 2013-10-P4-05. June 10, 2013.

Ontario Ministry of the Environment. 2011. *Soil, Ground Water and Sediment Standards for Use Under Part XV.1 of the Environmental Protection Act*. PIBS # 7382e01, dated April 15, 2011.

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

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

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

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

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

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

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

United States Environmental Protection Agency (USEPA). 2014. National Recommended Water Quality Criteria: Aquatic Life Criteria Table. Office of Water, Office of Science and Technology, USEPA, Washington, DC. Available at: http://water.epa.gov/scitech/swguidance/standards/criteria/current/index.cfm#altable. Last modified May 22, 2014.

Wetzel, R. 1983. *Limnology 2nd Ed*: Lake and River Ecosystem. Academic Press, San Diego, C

Wright, D. G. & Hopky, G. E. 1998. *Guidelines for the Use of Explosives In or Near Canadian Fisheries Waters*. Canadian Technical Report of Fisheries Aquatic Sciences 2107.

APPENDICES

Appendix A

Draft EEM Cycle One Study Design

MARY RIVER PROJECT

DRAFT – REV B
EEM CYCLE ONE STUDY DESIGN

JUNE 2014

Table of Contents

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

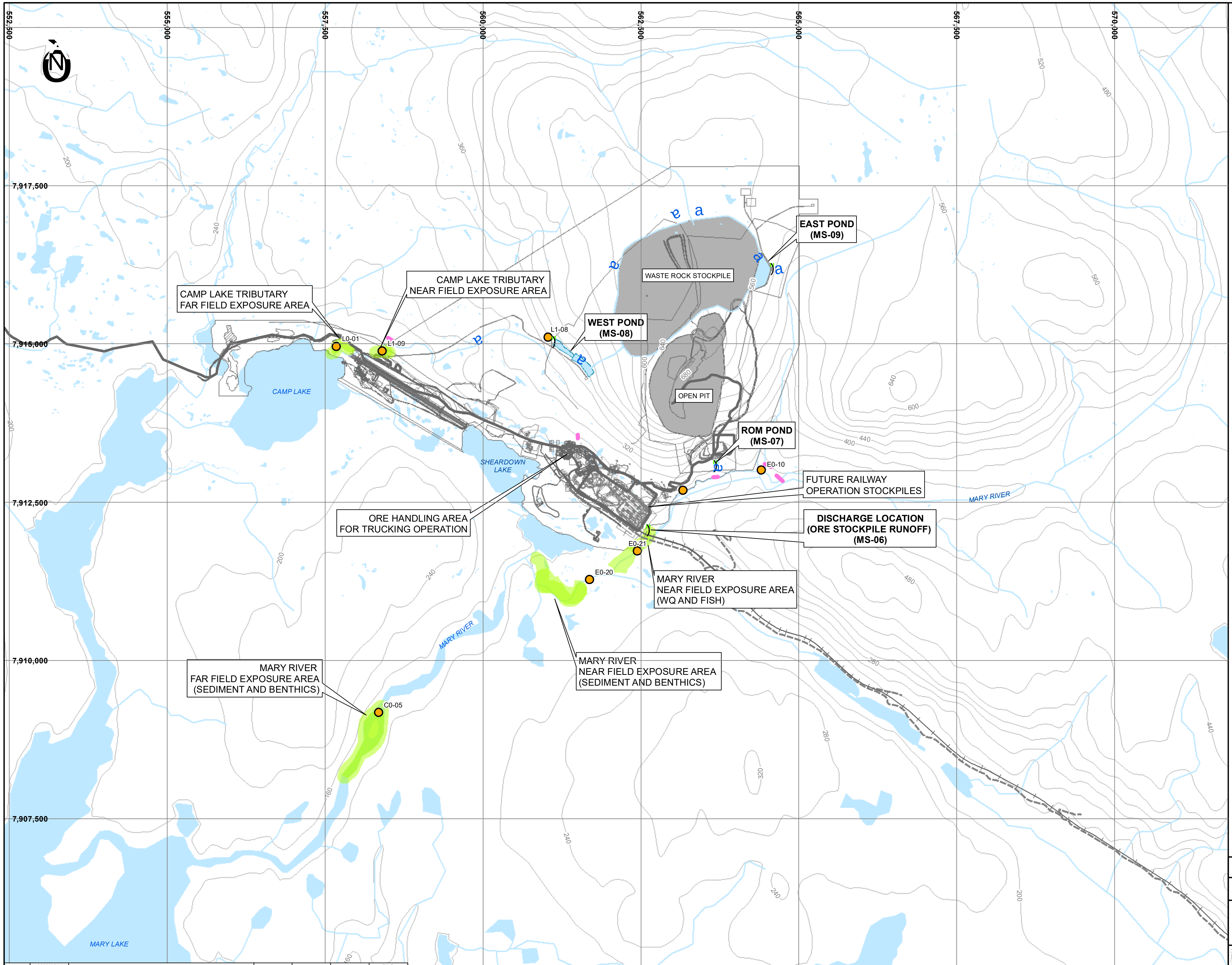
Parameter	**MMER Effluent Quality Standards (Schedule 4)**			**Water Licence 2AM-MRY1325 Open Pit, Stockpile and Sedimentation Ponds Effluent Discharge Quality Limits**
	Maximum Monthly Mean Concentration	Maximum Concentration in a Composite Sample	Maximum Concentration in a Grab Sample	Maximum Concentration 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

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

SAVED: I:\1\02\00181\34\A\GIS\Figs\B45_rA.mxd; May 21, 2014 11:45 AM; asimpson

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

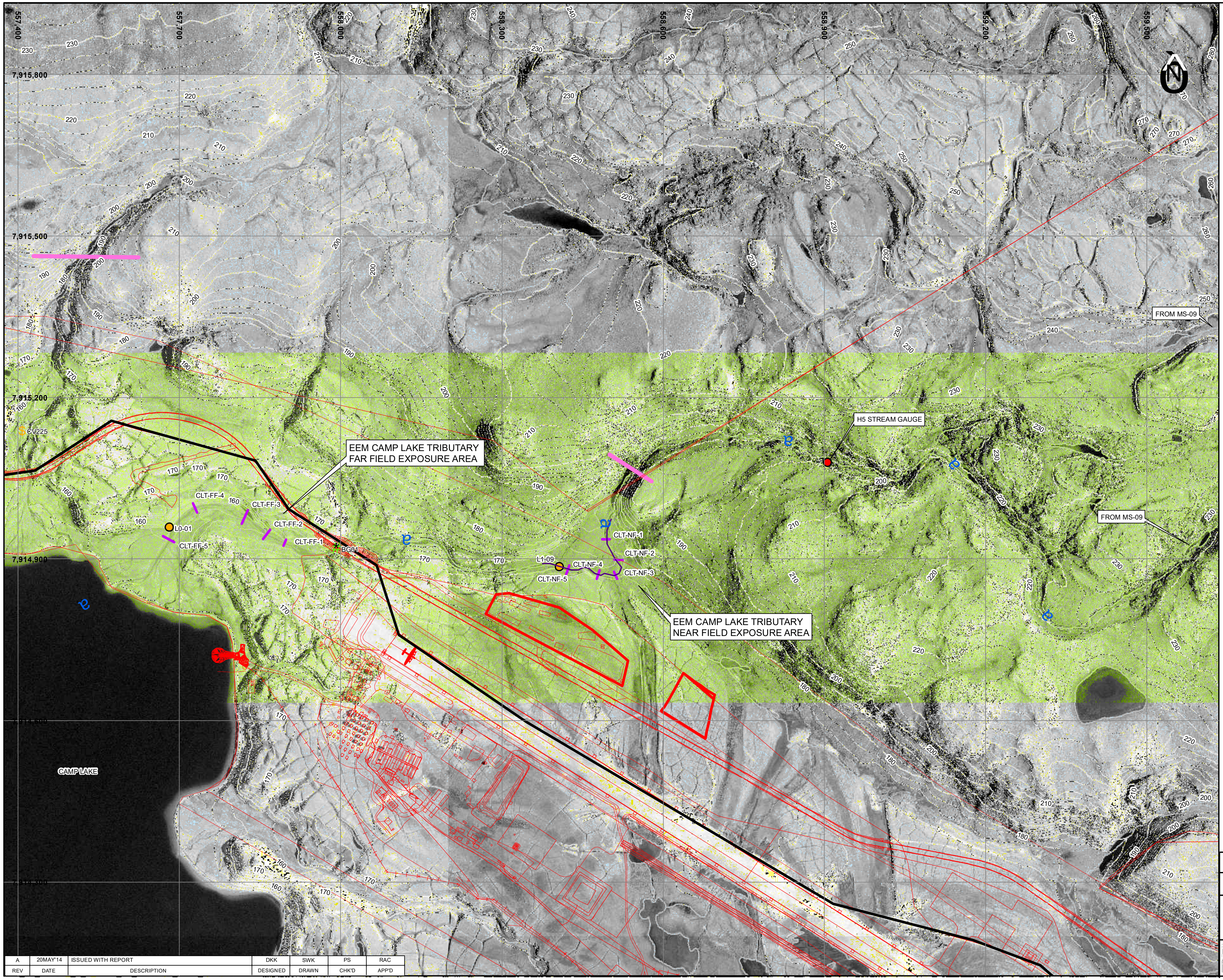
There will be one final discharge point to Camp Lake Tributary 1, from the West Pond collecting stormwater from the west side of the waste rock stockpile.

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
- b 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

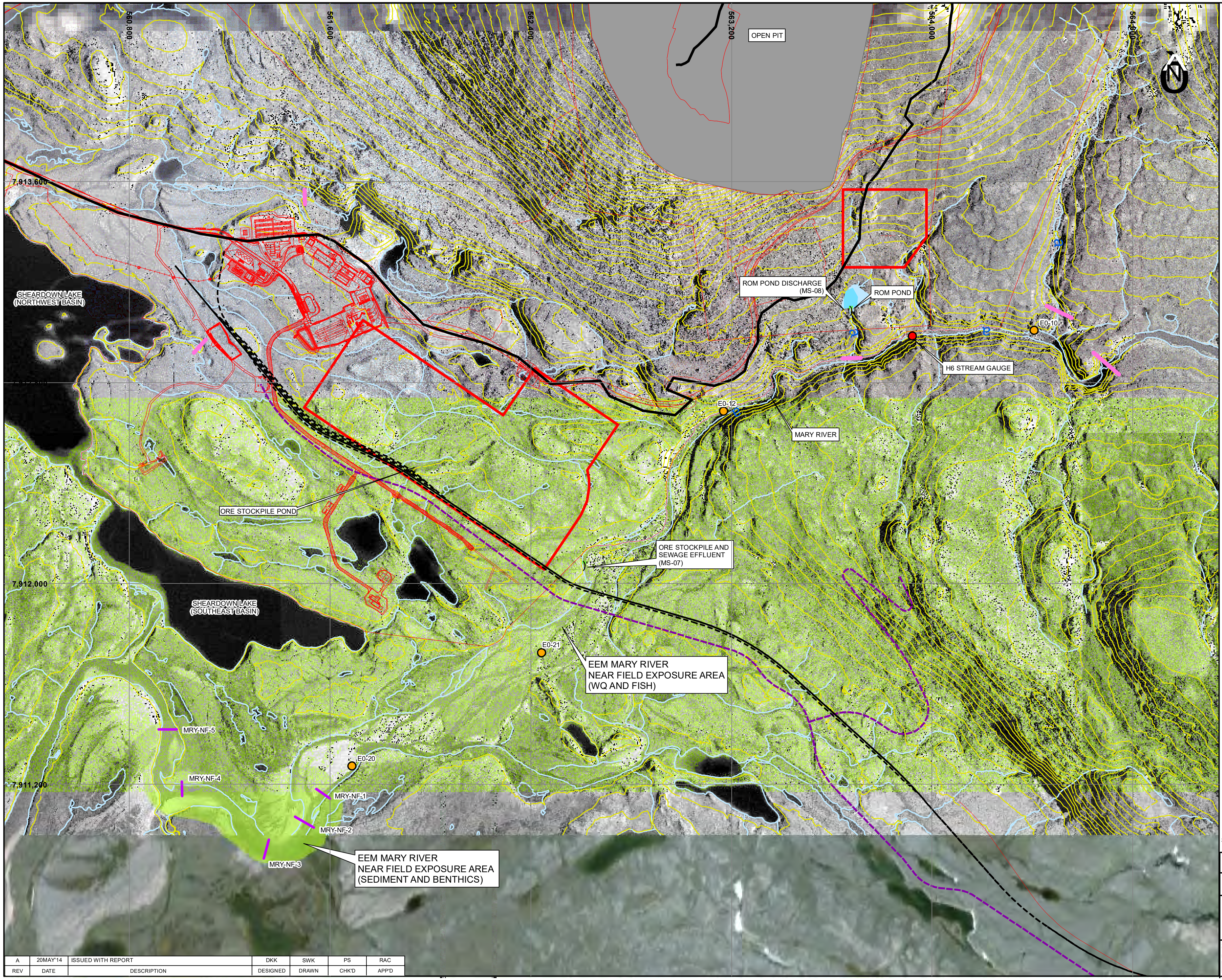
P/A NO.	REF NO.
NB102-181/34	5

FIGURE 2.1

REV A

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

SAVED: I:\1\02\00181\34\A\GIS\Figs\B47_rA.mxd; Jun 26, 2014 1:48 PM; asimpson



LEGEND:

●	ACTIVE WATER QUALITY SAMPLE LOCATION
●	ACTIVE STREAM GAUGE LOCATION
)	FINAL DISCHARGE POINT
b	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:

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 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

SAVED: I:\1\02\00181\34\A\GIS\Figs\B46_rA.mxd; Jun 26, 2014 1:46 PM; asimpson

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

SAVED: I:\1\02\00181\34\A\GIS\Figs\B48_rA.mxd; Jun 26, 2014 1:49 PM; asimpson

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:

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

DRAFT

SCALE 200 100 0 200 400 600 800 m

BAFFINLAND IRON MINES CORPORATION

MARY RIVER PROJECT

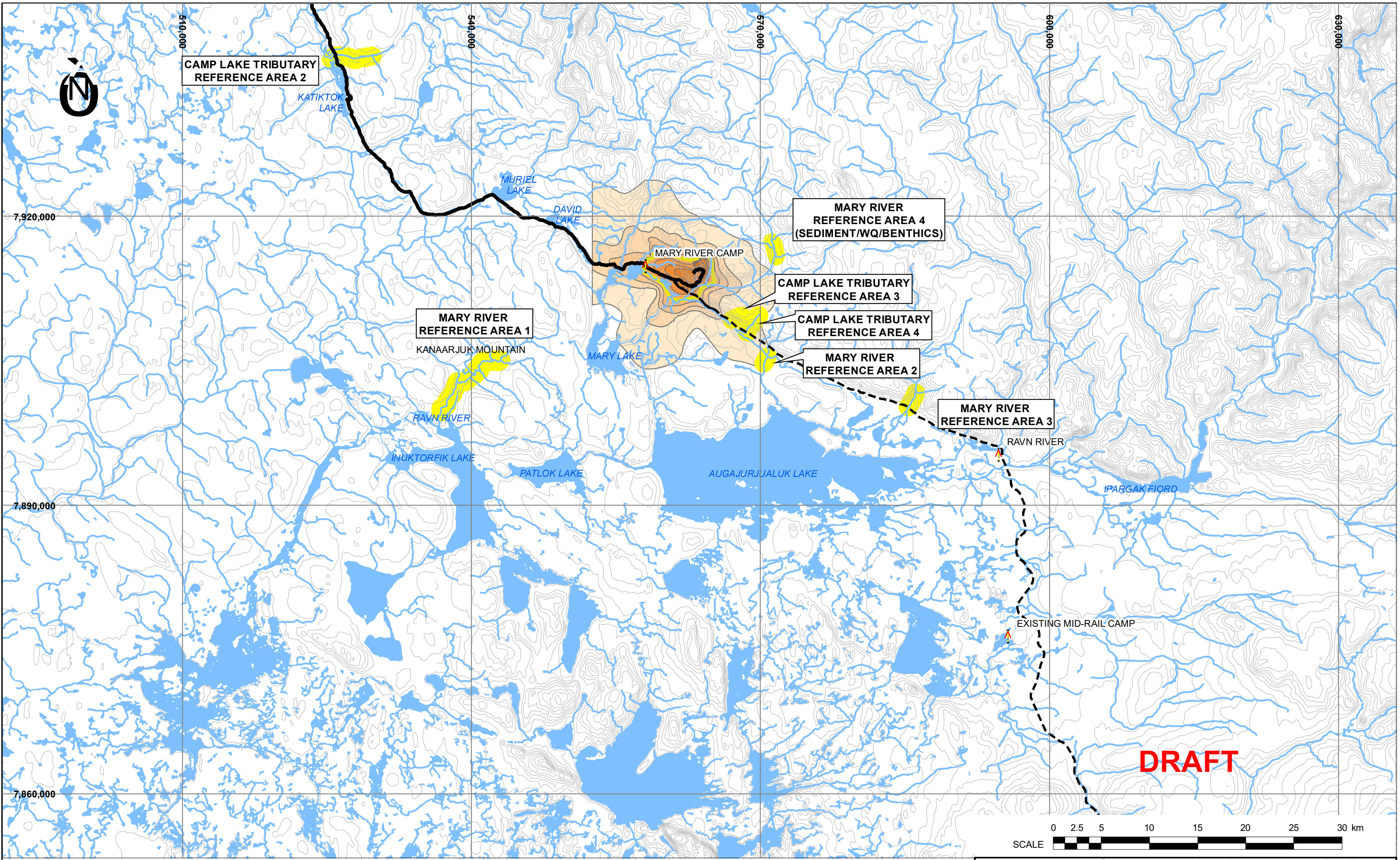
MARY RIVER FAR FIELD
EEM EXPOSURE AREA

Knight Piésold CONSULTING

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

FIGURE 2.3

REV A



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.

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

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

SAVED: I:\1\02\00181\34\A\GIS\Figs\A13_rA.mxd; Jun 26, 2014 1:32 PM; asimpson

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)

5 REFERENCES

Baffinland Iron Mines Corporation. 2014. Aquatic Effects Monitoring Program (in-progress).

Borcard, D and P. Legendre. 2013. Review of the pros and cons of available indices applicable to the Environmental Effects Monitoring (EEM) to evaluate changes in benthic invertebrate community structure in response to effluent exposure. Final Report. Project No. K2A80-12-0010. Dated March 15, 2013.

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

Environment Canada. 2003. *Revised technical guidance on how to conduct effluent plume delineation studies.* National EEM Office, National Water Research Institute and Environment Canada. March 2003.

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

Fisheries Act. R.S.C. 1985. c. F-14, June 29, 2012.

Games, P.A., Keselman, H.J., & Rogan, J.C., 1983. *A review of simultaneous pairwise multiple comparisons*. Statistica Neerlandica 37: 53–58.

Knight Piésold Ltd. 2014. *Water and Sediment Quality Review and CREMP Study Design*. Ref.No.NB102-181/33-1, Rev. 2, dated June 26. 2014.

Krebs, C. J. 2001. Ecology. San Francisco, California, Benjamin Cummings.

Minister of Justice. 2014. Consolidation Metal Mining Effluent Regulations. SOR/2002-222. Current to January 23, 2014.

North/South Consultants Inc. 2008. *Mary River Project Freshwater Aquatic Environment Baseline Draft Report: Fish and Fish Habitat*. Winnipeg, MB.

Nunavut Water Board. 2013. *Water Licence No: 2AM-MRY1325*. Motion Number 2013-10-P4-05. June 10, 2013.

Ricker, W.E., 1975. *Computation and interpretation of biological statistics of fish populations*. Ca. Bull. Fish. Aquat. Sci. 191. 382 p.

Wilson, Anne. 2014. Head, Water Quality, Expert Support and Contaminated Sites, Environment Canada. Personal Communication on April 3, 2014.

APPENDIX A

STUDY AREA CHARACTERIZATION DATA

(Pages A-1 to A-14)

TABLE A.1

BAFFINLAND IRON MINES CORPORATION
MARY RIVER PROJECT

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

Print Jun/26/14 11:25:00

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

\\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.1

NOTES:

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

TABLE A.2

BAFFINLAND IRON MINES CORPORATION
MARY RIVER PROJECT

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

Print Jun/26/14 11:26:31

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.

TABLE A.3

BAFFINLAND IRON MINES CORPORATION
MARY RIVER PROJECT

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

Print Jun/26/14 11:27:31

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	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-REF3-4	MRY-REF3-5	MRY-REF4-1	MRY-REF4-2	MRY-REF4-3	MRY-REF4-4	MRY-REF4-5
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	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	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	-	170	195	440	275	-	564	215	145	196	-	210	167	262	410	-	220	224	226	258	-	188	200	220	125	-	60	88	93	115
TOTAL DISTANCE	m	**1080**					**1120**					**1049**					**928**					**733**					**356**				
Wetted Width	m	33	32	46	38	30	98	47	52	37	46	44	38	30	35	37	31	35	52	43	50	46	34	45	26	40	22	25	27	30	24
AVERAGE WIDTH	m	**36**					**56**					**37**					**42**					**38**					**26**				
TD1	m	0.32	0.22	0.20	0.20	0.27	0.19	0.32	0.26	0.28	0.33	0.20	0.48	0.46	0.40	0.50	0.36	0.16	0.19	0.16	0.10	0.31	0.26	0.21	0.25	0.19	0.44	0.32	0.18	0.28	0.22
VEL1	m/sec	0.66	0.22	0.18	0.39	0.55	0.23	0.26	0.25	0.50	0.36	0.29	0.07	0.26	0.21	0.47	0.49	0.31	0.60	0.45	0.36	0.18	0.25	0.40	0.76	0.33	0.15	0.23	0.15	0.54	0.09
TD2	m	0.25	0.28	0.32	0.26	0.35	0.26	0.24	0.46	0.26	0.29	0.22	0.31	0.54	0.46	0.54	0.24	0.14	0.22	0.22	0.10	0.34	0.18	0.10	0.25	0.14	0.36	0.30	0.10	0.24	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	0.40	0.02	0.18	0.18	0.57	0.35	0.40	0.90	0.37	0.25	0.30	0.77	0.13	0.70	0.16	0.20	0.24	0.21	0.06	0.10
TD3	m	0.16	0.36	0.32	0.30	0.33	0.18	0.28	0.39	0.19	0.16	0.26	0.32	0.44	0.49	0.56	0.30	0.13	0.22	0.24	0.16	0.32	0.34	0.16	0.28	0.21	0.38	0.42	0.24	0.19	0.20
VEL3	m/sec	0.14	0.29	0.32	0.39	0.56	0.34	0.23	0.58	0.36	0.36	0.33	0.33	0.38	0.39	0.42	0.65	0.18	0.95	0.64	0.18	0.37	1.06	0.67	0.51	0.34	0.20	0.23	0.30	0.24	0.20
TD4	m	0.16	0.37	0.43	0.29	0.31	0.20	0.40	0.34	0.18	0.16	0.30	0.30	0.32	0.40	0.44	0.24	0.13	0.24	0.26	0.18	0.36	0.30	0.14	0.21	0.20	0.36	0.30	0.11	0.18	0.24
VEL4	m/sec	0.08	0.38	0.50	0.45	0.46	0.22	0.29	0.50	0.43	0.29	0.37	0.29	0.10	0.36	0.21	0.40	0.22	0.64	0.61	0.45	0.12	0.46	0.38	0.58	0.08	0.36	0.09	0.15	0.45	0.13
TD5	m	0.22	0.30	0.29	0.30	0.36	0.27	0.40	0.29	0.20	0.19	0.24	0.28	0.25	0.46	0.42	0.32	0.21	0.28	0.30	0.20	0.33	0.32	0.15	0.20	0.22	0.40	0.28	0.18	0.14	0.24
VEL5	m/sec	0.18	0.36	0.48	0.42	0.50	0.40	0.36	0.40	0.25	0.28	0.49	0.30	0.36	0.39	0.20	0.32	0.23	0.78	0.70	0.56	0.40	0.50	0.33	0.70	0.30	0.49	0.10	0.36	0.33	0.26
TD6	m	0.28	0.36	0.26	0.39	0.29	0.32	0.36	0.30	0.26	0.14	0.25	0.20	0.29	0.57	0.50	0.24	0.22	0.14	0.27	0.22	0.24	0.23	0.12	0.20	0.26	0.33	0.25	0.14	0.14	0.24
VEL6	m/sec	0.23	0.50	0.38	0.56	0.58	0.34	0.32	0.37	0.26	0.26	0.59	0.42	0.18	0.25	0.26	0.21	0.51	0.57	0.61	0.51	0.34	0.20	0.13	0.66	0.44	0.22	0.11	0.22	0.21	0.10
TD7	m	0.37	0.49	0.22	0.41	0.27	0.34	0.31	0.28	0.22	0.24	0.34	0.26	0.32	0.48	0.36	0.14	0.22	0.18	0.14	0.16	0.32	0.20	0.19	0.22	0.35	0.28	0.28	0.11	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	0.33	0.31	0.39	0.30	0.27	0.15	0.42	0.55	0.32	0.39	0.45	0.24	0.26	0.30	0.52	0.22	0.20	0.16	0.17	0.20
TD8	m	0.42	0.47	0.25	0.36	0.27	0.30	0.10	0.26	0.10	0.22	0.16	0.30	0.28	0.46	0.36	0.20	0.18	0.14	0.24	0.13	0.20	0.16	0.25	0.16	0.34	0.22	0.34	0.08	0.12	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	0.48	0.32	0.30	0.40	0.26	0.43	0.32	0.32	0.49	0.53	0.53	0.44	0.40	0.45	0.36	0.14	0.21	0.10	0.31	0.07
TD9	m	0.36	0.26	0.19	0.36	0.30	0.14	0.22	0.24	0.14	0.28	0.20	0.22	0.34	0.36	0.28	0.14	0.18	0.12	0.22	0.14	0.20	0.14	0.28	0.26	0.13	0.11	0.36	0.20	0.23	0.33
VEL9	m/sec	0.23	0.18	0.29	0.45	0.58	0.14	0.34	0.31	0.08	0.08	0.27	0.09	0.31	0.26	0.24	0.50	0.34	0.24	0.70	0.45	0.26	0.32	0.47	0.26	0.17	0.06	0.24	0.33	0.45	0.21
TD10	m	0.26	0.17	0.33	0.32	0.31	0.19	0.16	0.20	0.17	0.22	0.28	0.28	0.42	0.34	0.29	0.12	0.26	0.14	0.27	0.23	0.16	0.15	0.24	0.26	0.30	0.16	0.36	0.30	0.17	0.29
TD10	m/sec	0.23	0.29	0.38	0.34	0.47	0.19	0.24	0.26	0.20	0.53	0.30	0.38	0.32	0.29	0.17	0.65	0.41	0.36	0.61	0.66	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**	**0.33**	**0.28**	**0.32**	**0.31**	**0.24**	**0.28**	**0.30**	**0.20**	**0.22**	**0.25**	**0.30**	**0.37**	**0.44**	**0.43**	**0.23**	**0.18**	**0.19**	**0.23**	**0.16**	**0.28**	**0.23**	**0.18**	**0.23**	**0.23**	**0.30**	**0.32**	**0.16**	**0.19**	**0.25**
MEAN VELOCITY	m/sec	**0.32**	**0.36**	**0.35**	**0.43**	**0.54**	**0.23**	**0.29**	**0.39**	**0.28**	**0.33**	**0.39**	**0.25**	**0.28**	**0.30**	**0.31**	**0.42**	**0.33**	**0.59**	**0.55**	**0.43**	**0.34**	**0.45**	**0.34**	**0.52**	**0.28**	**0.22**	**0.18**	**0.24**	**0.30**	**0.15**
MINIMUM DEPTH	m	**0.16**					**0.10**					**0.16**					**0.10**					**0.10**					**0.08**				
MAXIMUM DEPTH	m	**0.49**					**0.46**					**0.57**					**0.36**					**0.36**					**0.44**				
MEAN TOTAL DEPTH	m	**0.30**					**0.25**					**0.35**					**0.20**					**0.23**					**0.25**				
MINIMUM VELOCITY	m/sec	**0.08**					**0.03**					**0.02**					**0.15**					**0.08**					**0.06**				
MAXIMUM VELOCITY	m/sec	**0.65**					**0.58**					**0.59**					**0.95**					**1.06**					**0.49**				
MEAN VELOCITY	m/sec	**0.40**					**0.30**					**0.31**					**0.46**					**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.

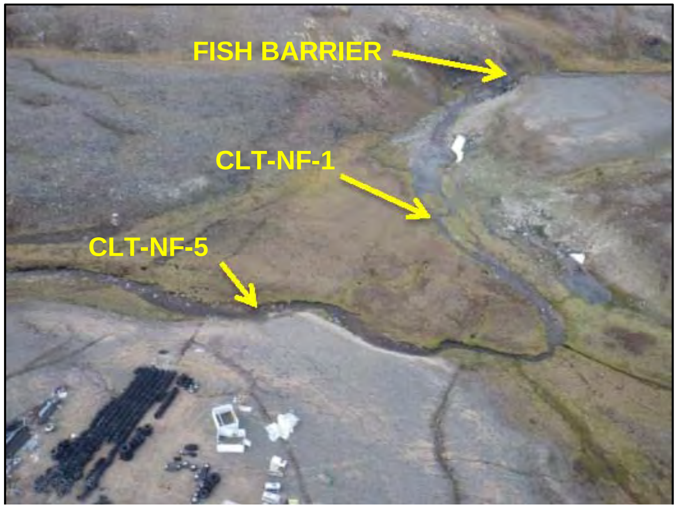


PHOTO 4 – CLT-NF aerial view including fish barrier upstream.

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.

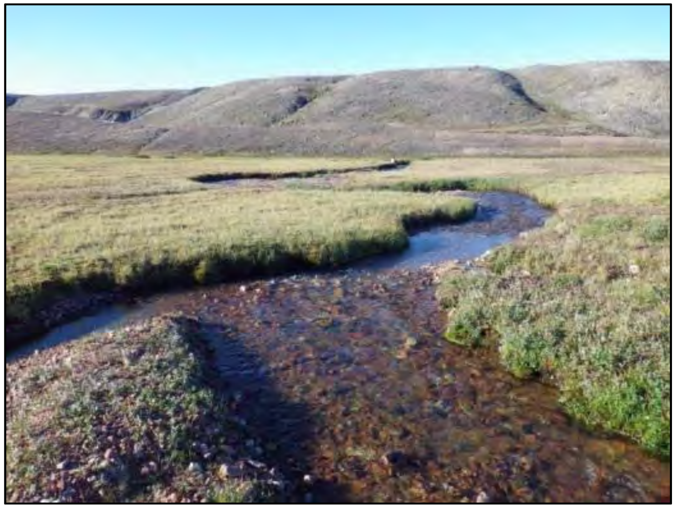


PHOTO 18 – CLT-REF4-3 facing downstream.

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.

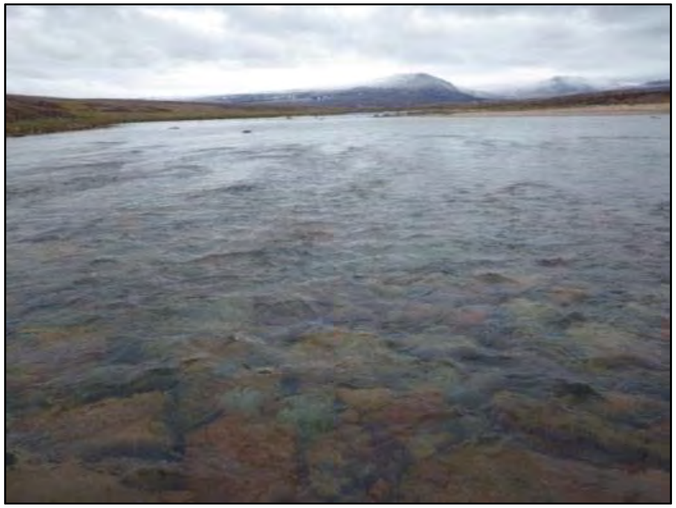


PHOTO 26 – MRY-FF-4 facing upstream.

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)

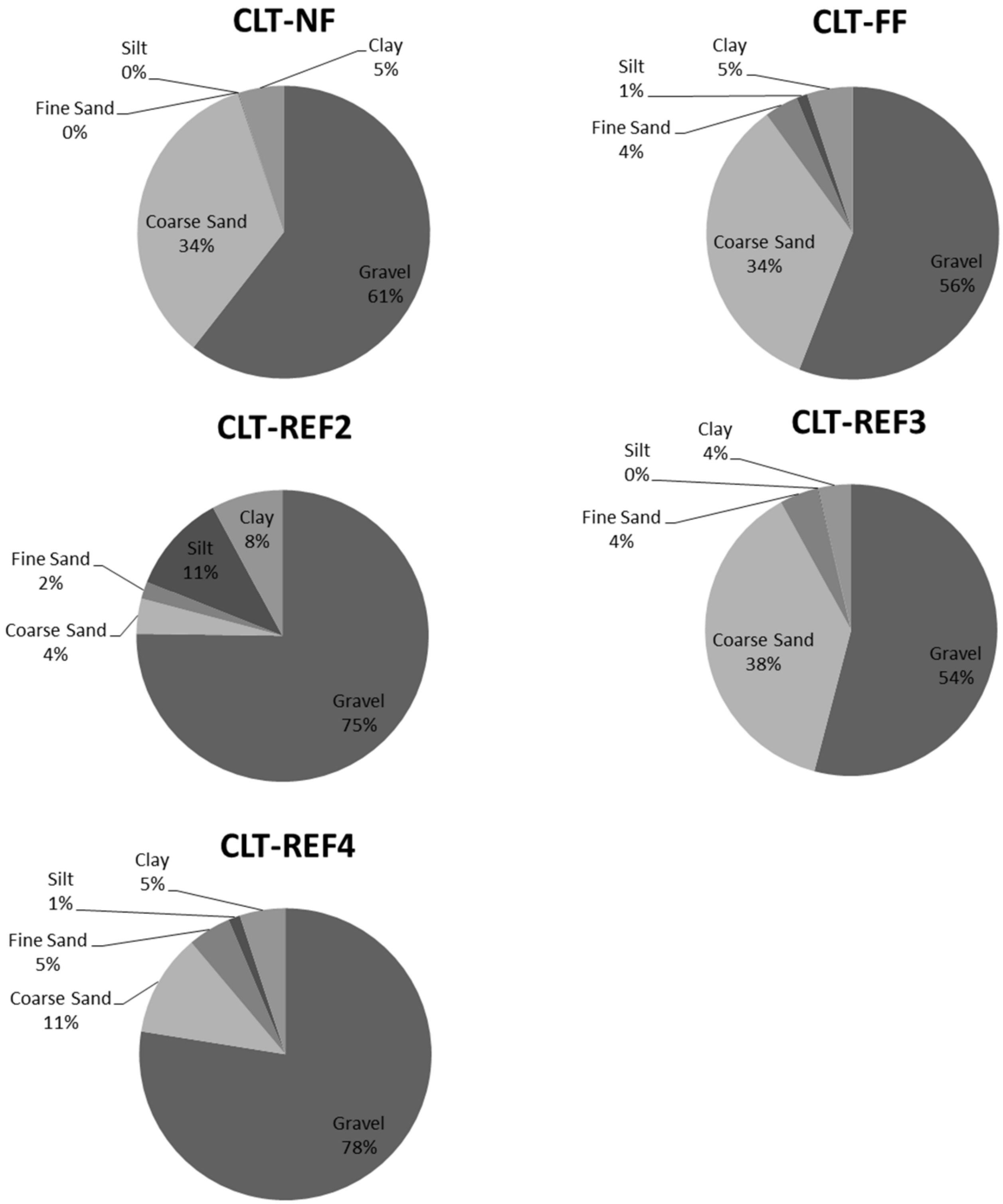


Figure B.1 Camp Lake Tributary Study Areas: Particle Size Distribution and TOC Summary

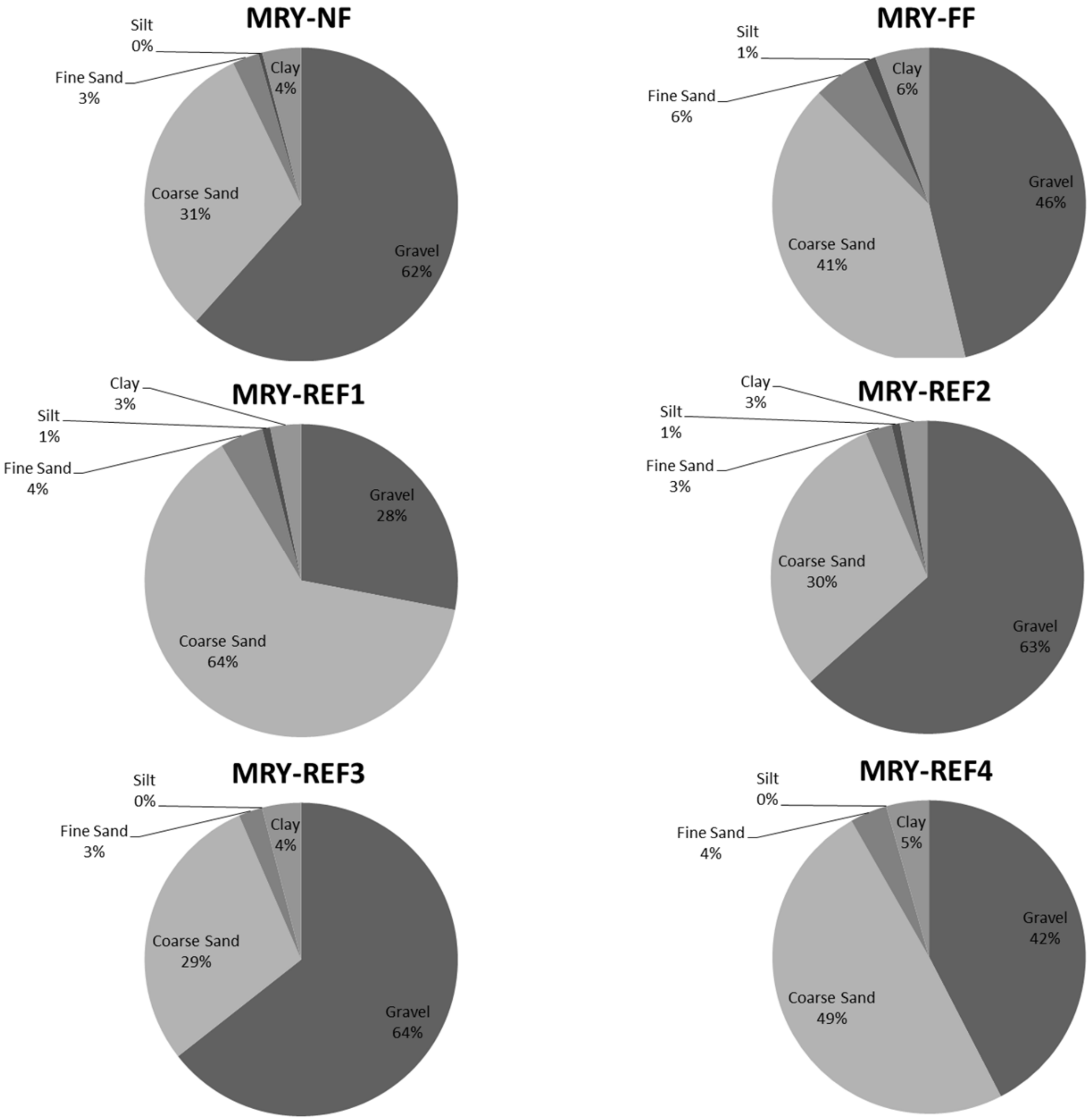


Figure B.2 Mary River Study Areas: Particle Size Distribution and TOC Summary

Appendix B

Water and Sediment Quality CREMP

April, 2016

BAFFINLAND IRON MINES CORPORATION
MARY RIVER PROJECT

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

REVISION 3

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

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

DOCUMENT REVISION RECORD

Issue Date MM/DD/YY	Revision	Prepared By	Approved By	Issue Purpose
03/28/14	0	KP	KP	Issued in Final
05/30/14	1	KP	KP	Revised Study Design to Align with freshwater biota CREMP
06/25/14	2	KP	KP	Minor Updates to Sections 2.7.8 and 3.6.8
03/31/16	3	AV	JM	Updated to reflect CREMP study design modifications proposed by Minnow in 2016

Index of Major Changes/Modifications in Revision 3

Item No.	Description of Change	Relevant Section
1	Updated background/introduction to include the ERP phase and discussed status current operations.	1.1
2	Updated CREMP water quality monitoring areas and stations to reflect Minnow's recommendations.	2.7.4
3	Clarified sampling frequency and schedule for the CREMP water quality sampling program.	2.7.5
4	Included 2014 sediment quality program in Table 3.1 and discussed final sediment quality stations established by Intrinsik in 2015.	3.1
5	Updated summary to reflect current status of the Lake Sedimentation Study in Sheardown Lake NW.	3.2.3
6	Updated the CREMP sediment quality study design to reflect the recommendations proposed by Minnow.	3.6
7	Updated the CREMP sediment quality study design to reflect the recommendations proposed by Minnow.	3.6.1
8	Updated sediment quality parameters in Table 3.5 to reflect the 2015 CREMP.	3.6.2
9	Updated sediment quality benchmarks in Table 3.6 to reflect the benchmarks established by Intrinsik in 2015. Discussed Minnow's recommendation of including reference areas in the derivation of lake sediment quality benchmarks.	3.6.3
10	Updated sediment quality monitoring areas and stations to reflect Minnow's recommendations.	3.6.4

April, 2016

PREFACE

This document was originally written by Knight Piésold Consulting in June 2014 for Baffinland Iron Mines Corporation (Baffinland). This document has since then been revised by Baffinland to reflect the recommendations proposed by Minnow Environmental Inc. in 2016 regarding modifications to the CREMP Study Design.

TABLE OF CONTENTS

PAGE

TABLES

FIGURES

APPENDICES

1 – INTRODUCTION

1.1 BACKGROUND

Baffinland Iron Mines Corporation (Baffinland) conducted water and sediment quality baseline studies at the Mary River Project from 2005 to 2014. 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).

Due to poor market conditions in 2013 and the large amount of financial resources required to complete the construction of the railway to Steensby Port, Baffinland proposed an Early Revenue Phase (ERP) of the Project to the NIRB and NWB in 2013. The ERP proposal outlined a plan that involved mining 3.5 million tonnes per annum (Mt/a) of iron ore and transporting the ore year-round by truck to Milne Port using the Tote Road. The iron ore would be stockpiled at Milne Port and transported to market by ship during the open water season.

On May 28, 2014, NIRB issued to Baffinland an amendment to the Mary River Project Certificate No. 005 to reflect modifications to the Project associated with the ERP. Baffinland initiated construction of the mine in the summer of 2013 and began ERP mine operations in September 2014.

On September 2, 2015 the NWB issued the Type A Water Licence No: 2AM-MRY1325 Amendment No.1 to Baffinland. The Amended Licence incorporates entire scope of the Type “B” Water Licences (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 and addressed many elements associated with ERP activities and facilities.

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. However, the development of the railway will be subject to a commercial decision by Baffinland to proceed and will be heavily influenced by both market conditions and available financing.

Since the beginning of mine operations in September 2014, the attention of the AEMP monitoring programs has shifted 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 amended Type A Water Licence.

This document presents a review of water and sediment quality baseline data up to 2013 and outlines the current 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 is a component program of the AEMP.

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

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

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; Intrinsik, 2015; see Section 5.3 of the AEMP). Draft benchmarks established by Intrisik in 2014 were applied in the power analysis of the baseline data reviews presented below.

---

[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.

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 the summer of 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.

Figure 1.1 Historic Water Quality Stations - Mine Site Area

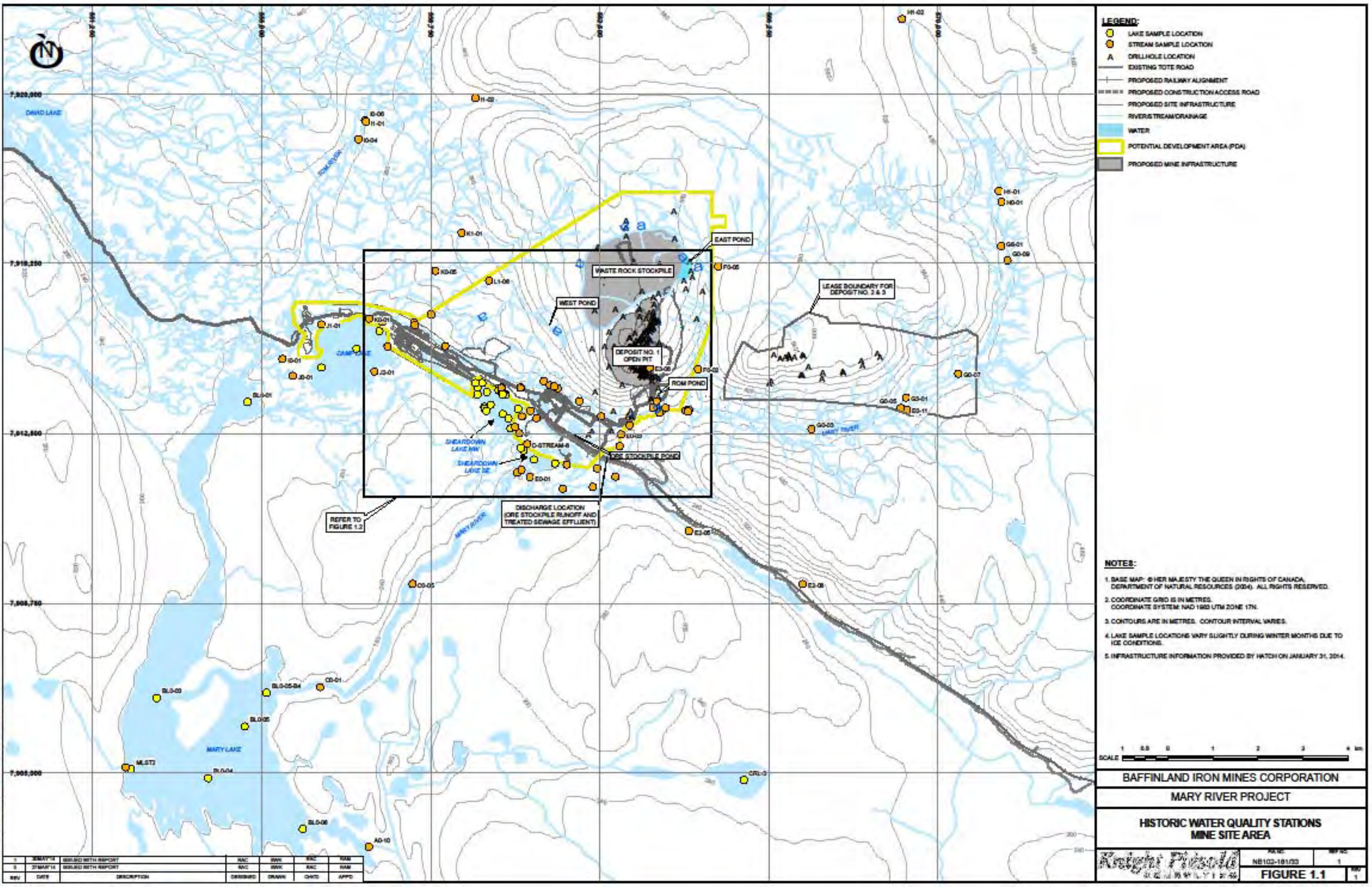


Figure 1.2 Historic Water Quality Stations - Immediate Mine Site Area

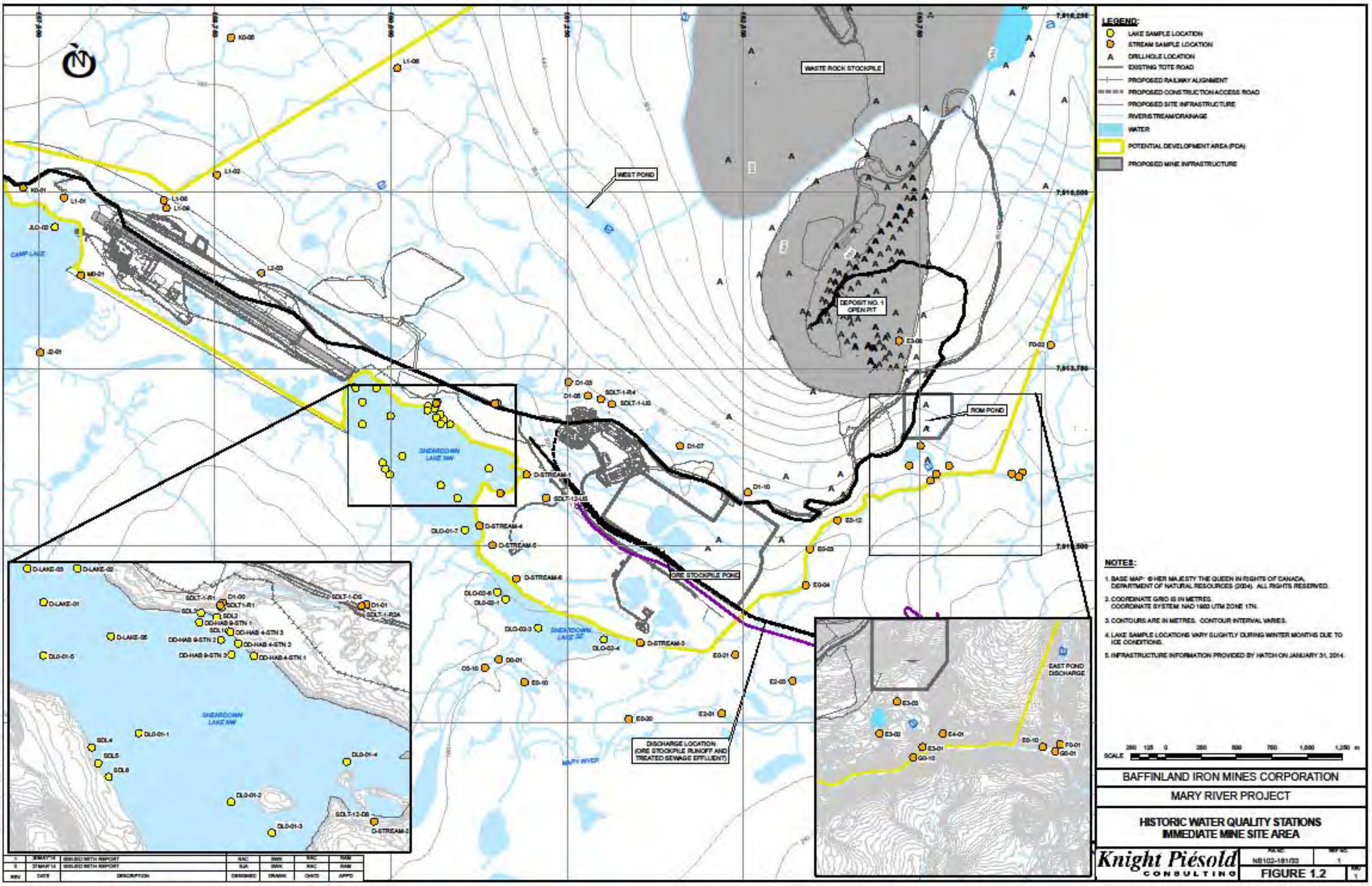
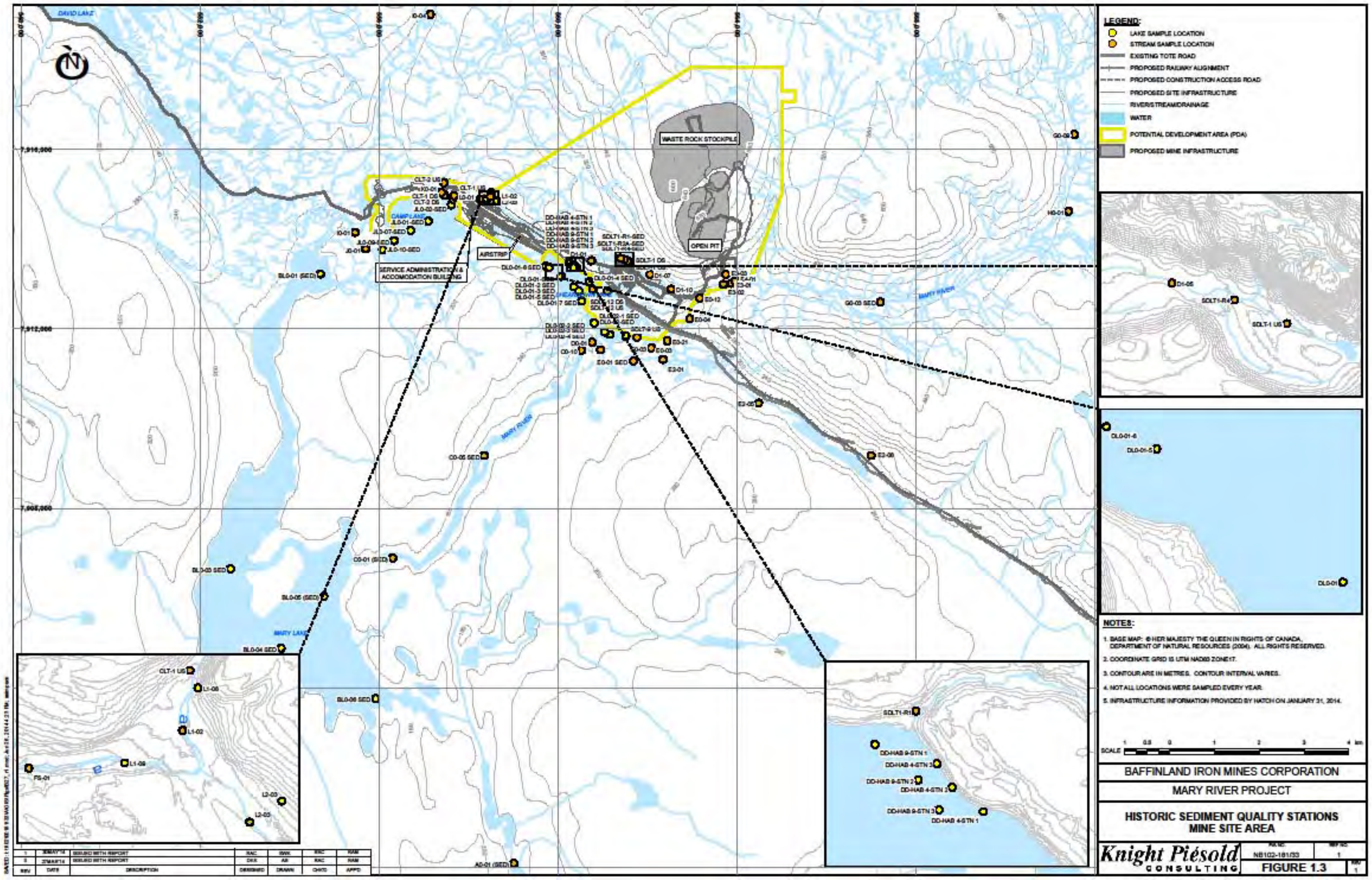


Figure 1.3 Historic Sediment Quality Stations - Mine Site Area



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.

BAFFINLAND IRON MINES CORPORATION

MARY RIVER PROJECT

HISTORIC SEDIMENT QUALITY STATIONS
MINE SITE AREA

2 – BASELINE WATER QUALITY REVIEW

2.1 SUMMARY OF BASELINE 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.

Table 2.3 Review of Water Quality Method Detection Limits

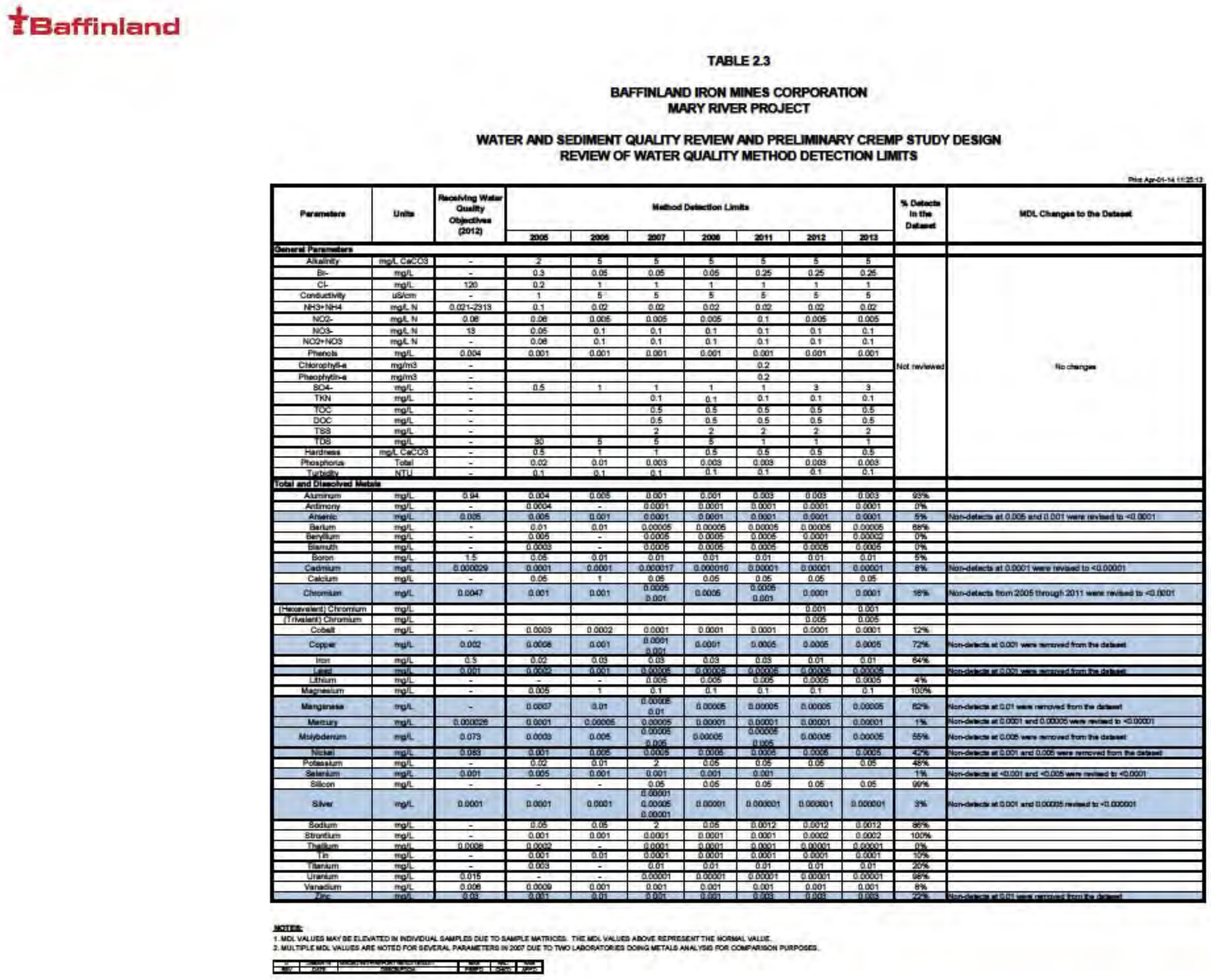


TABLE 2.3

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 11:25:13

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	6%	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	0.0006	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

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.

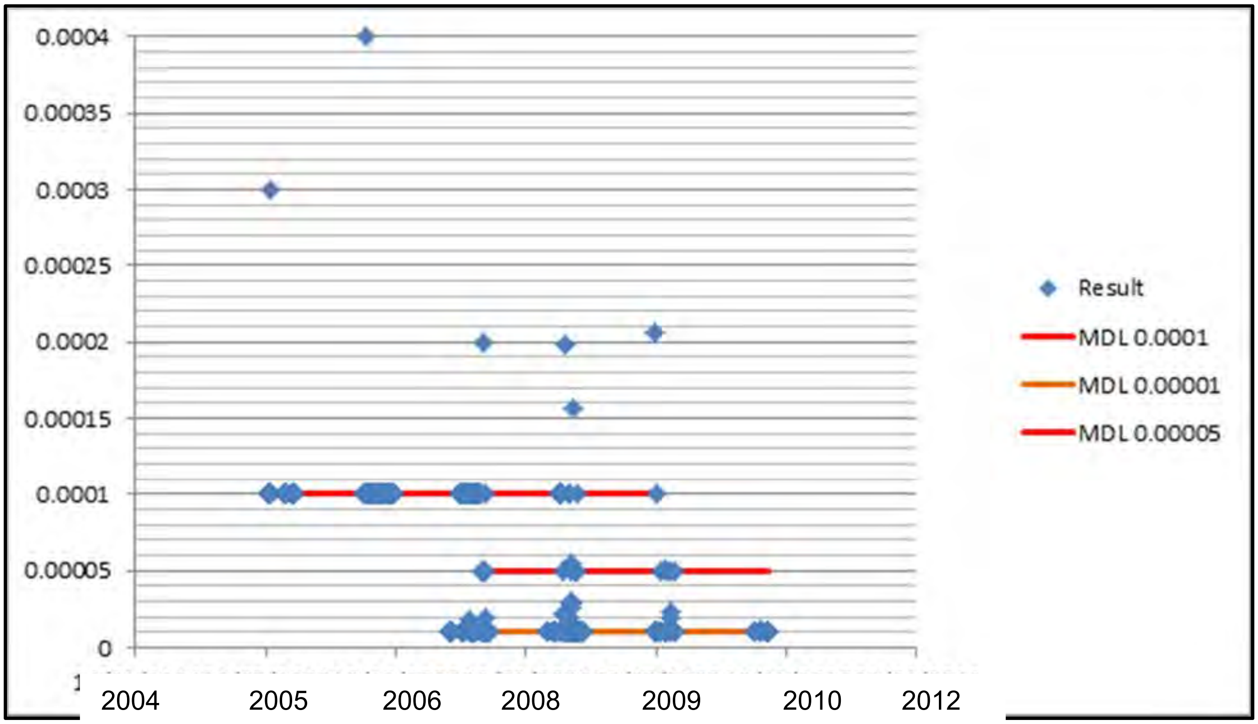


Figure 2.1 Example MDL Evaluation Graph - Silver

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 arctic 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.

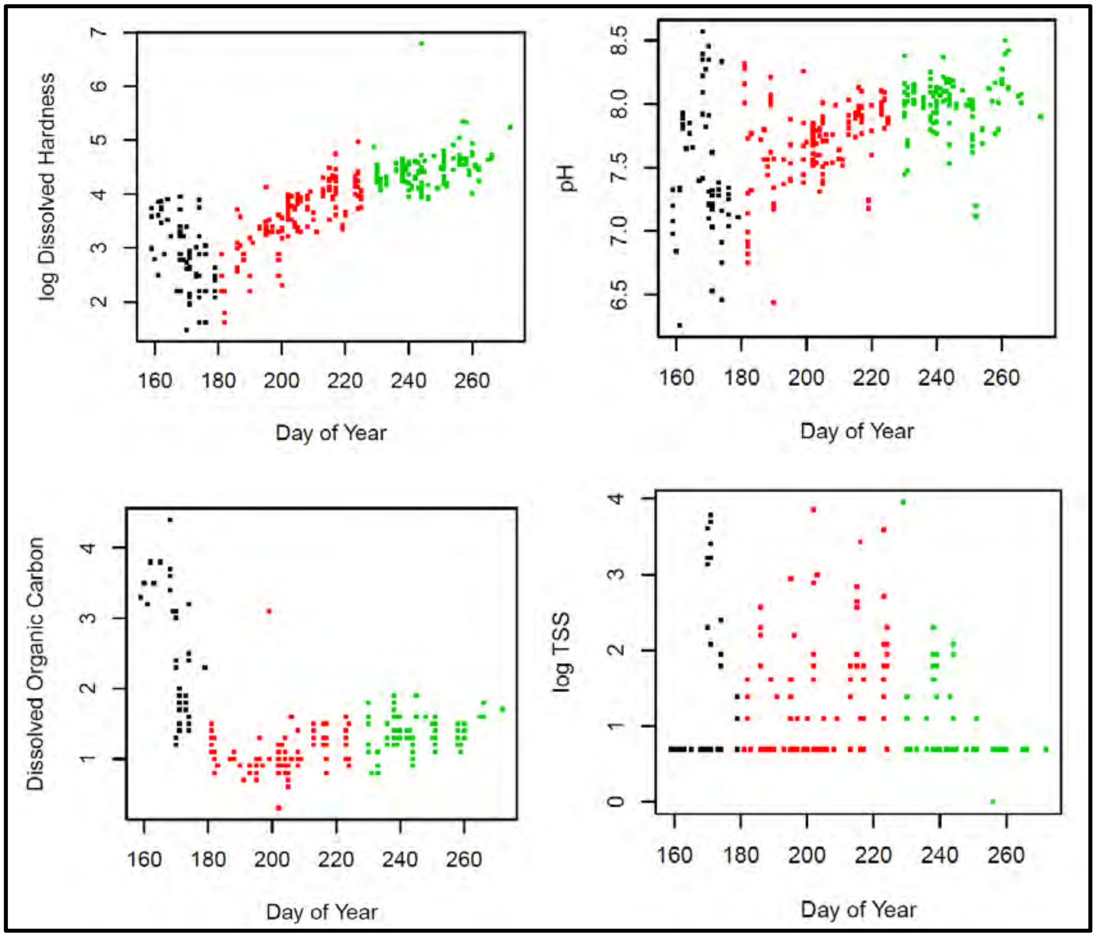
2.5.3 Site-Wide Overview of Water Quality Including Seasonal Trends

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

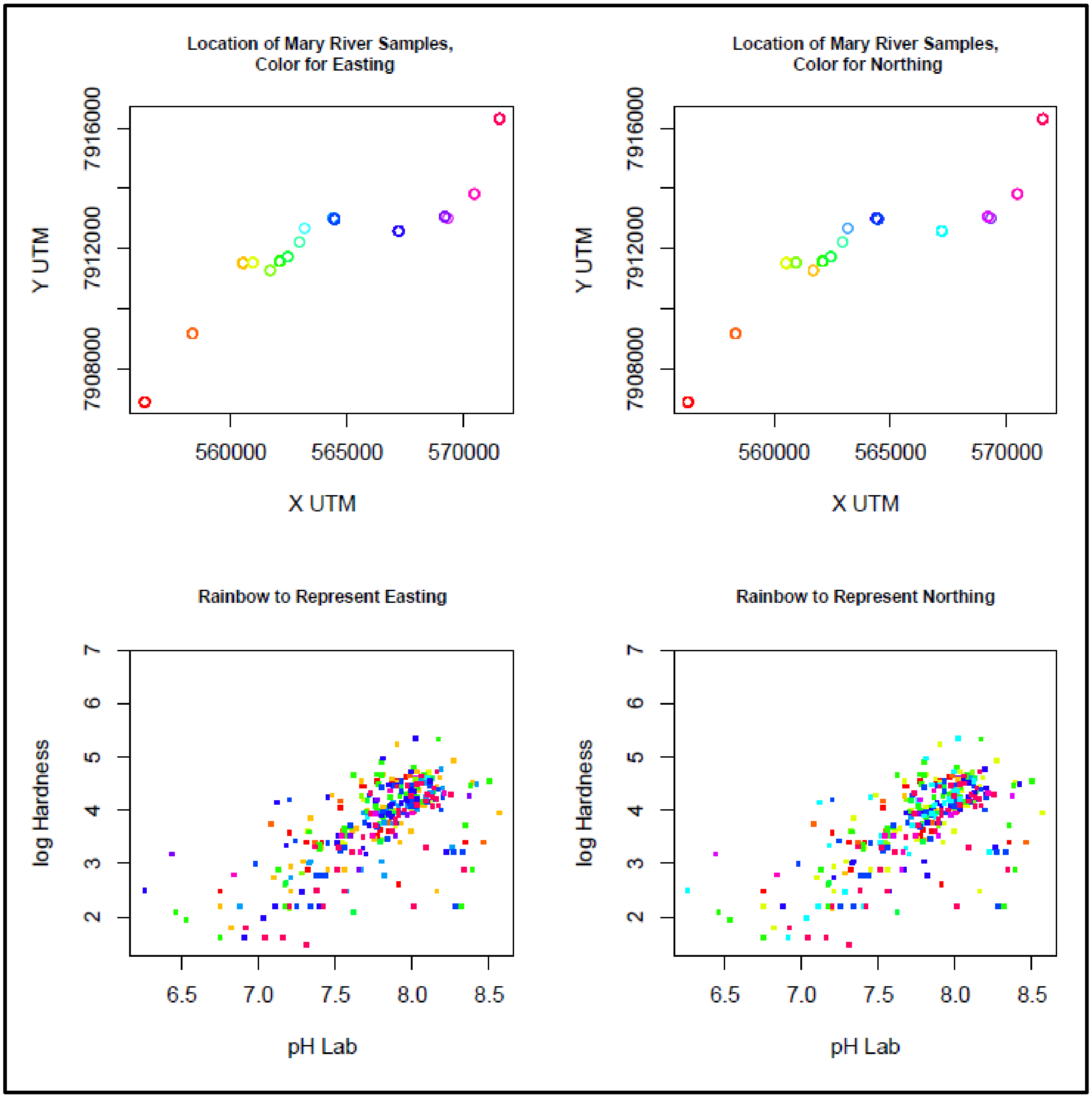


Figure 2.3 Mary River - Geographic pH Trends

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.

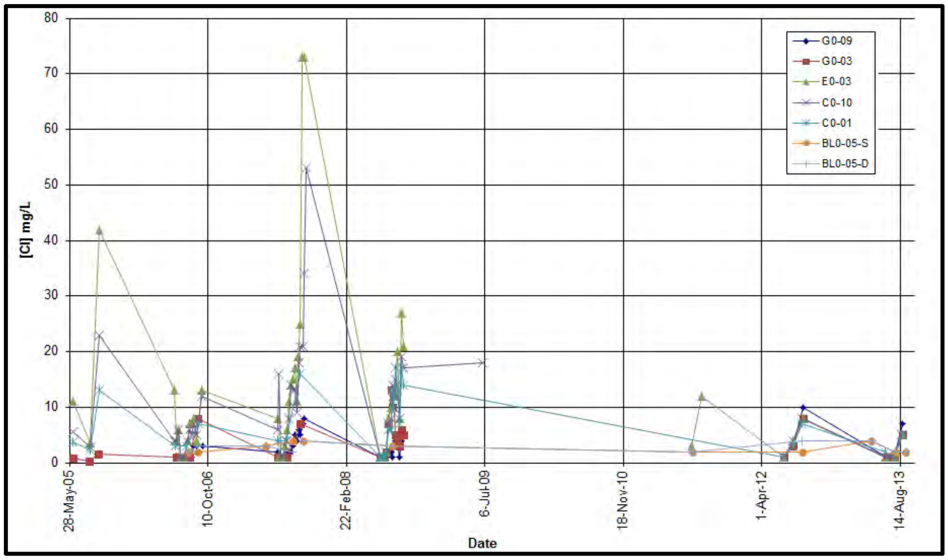
Figures 2.6 through 2.8 depict the changes in concentrations that occur during seasons in both the streams and lake in vicinity to the proposed mine site. Spring lake concentrations are never depicted and neither are winter stream concentrations. Figure 2.6 shows a small increase in chloride concentrations 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.

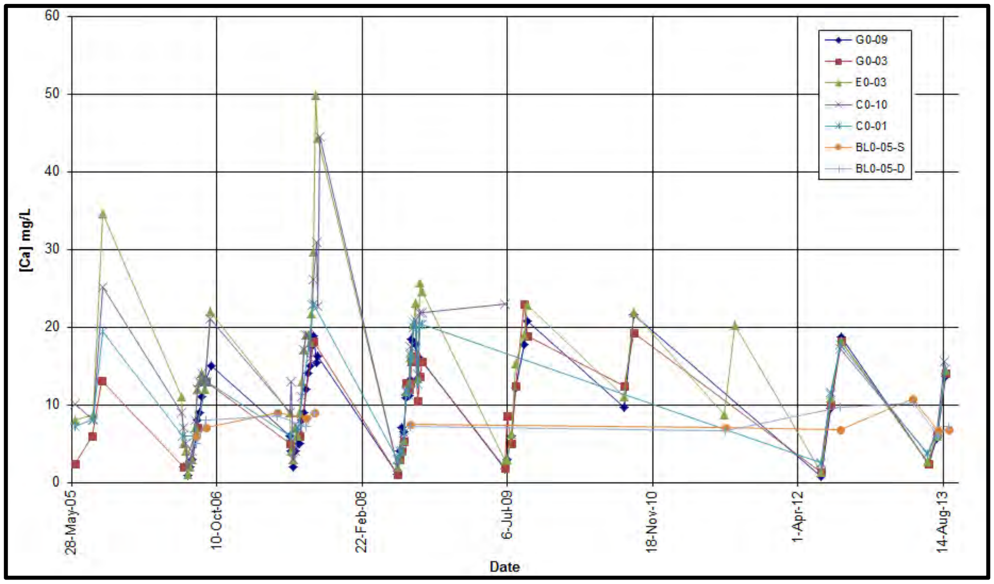
Stream aluminum concentrations are depressed in the spring, and elevated in the summer, as shown in Figure 2.10. Stream concentrations, particularly those recorded in Mary River are greater than the concentrations recorded in the lakes. Fall concentrations are elevated, when compared to fall and winter, 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).

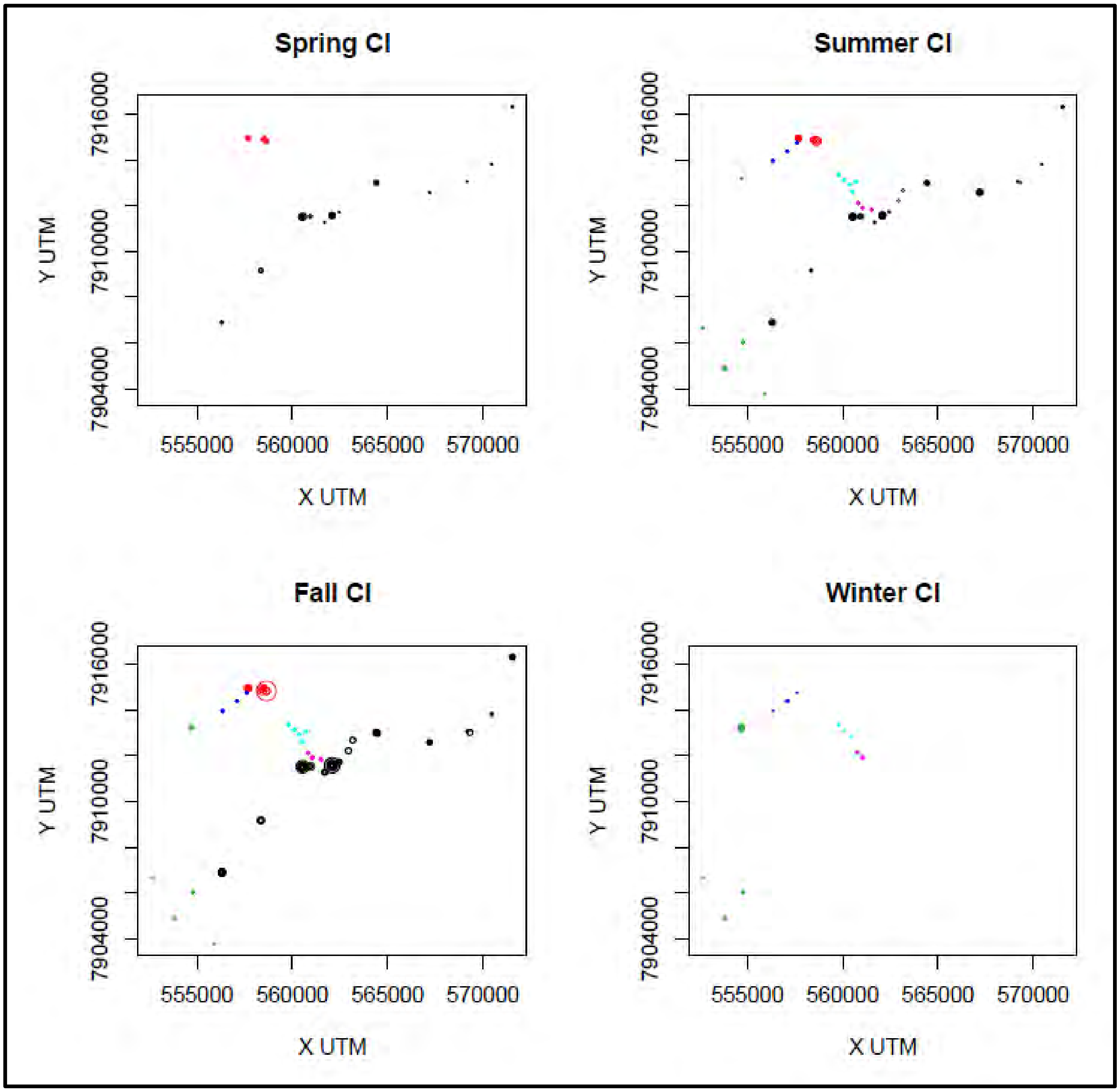
Figure 2.4 Chloride Concentrations in Mine Site Waters over the Study Period



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.

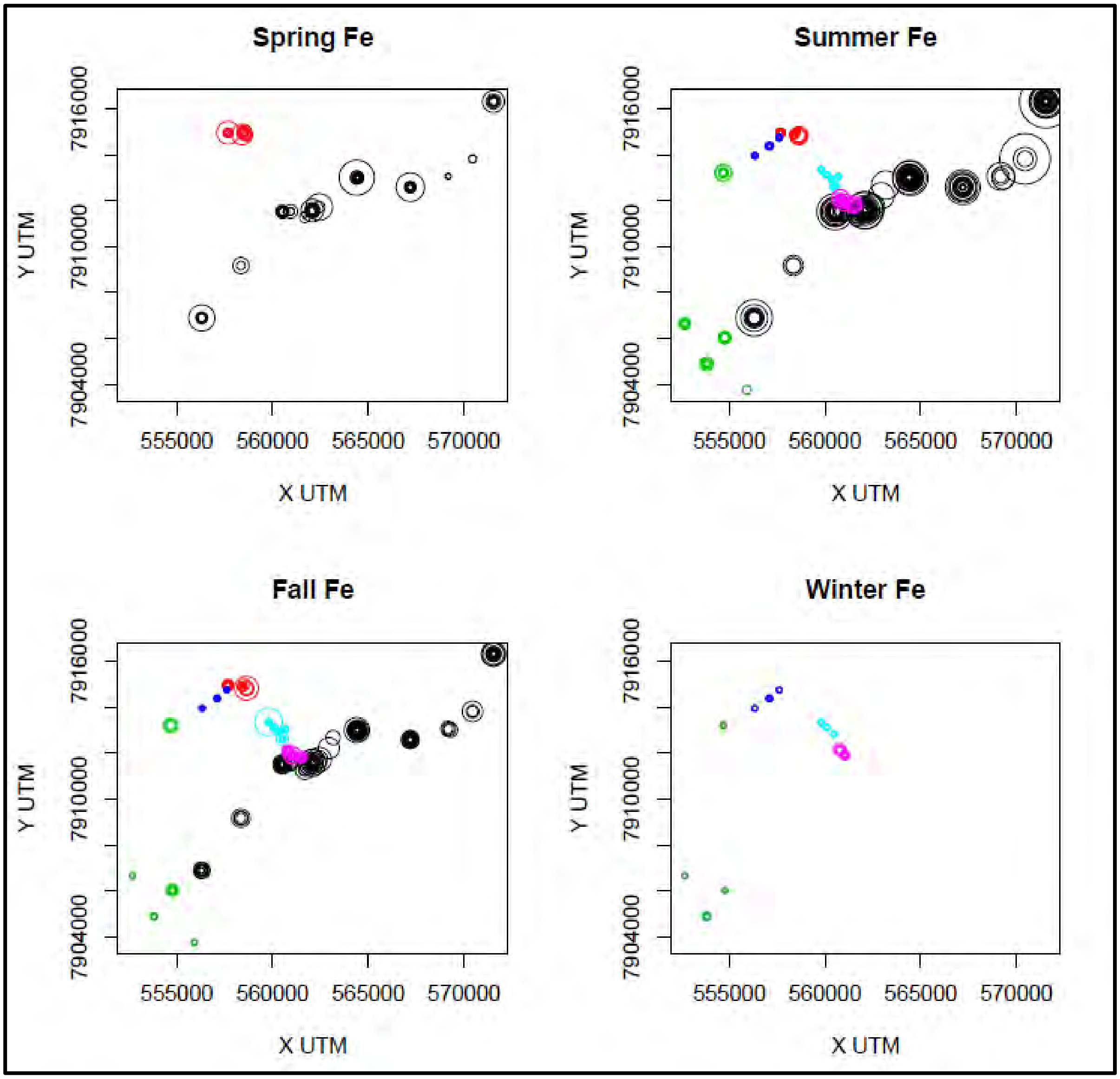
Figure 2.5 Calcium Concentrations in Mine Site Waters over the Study Period



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.

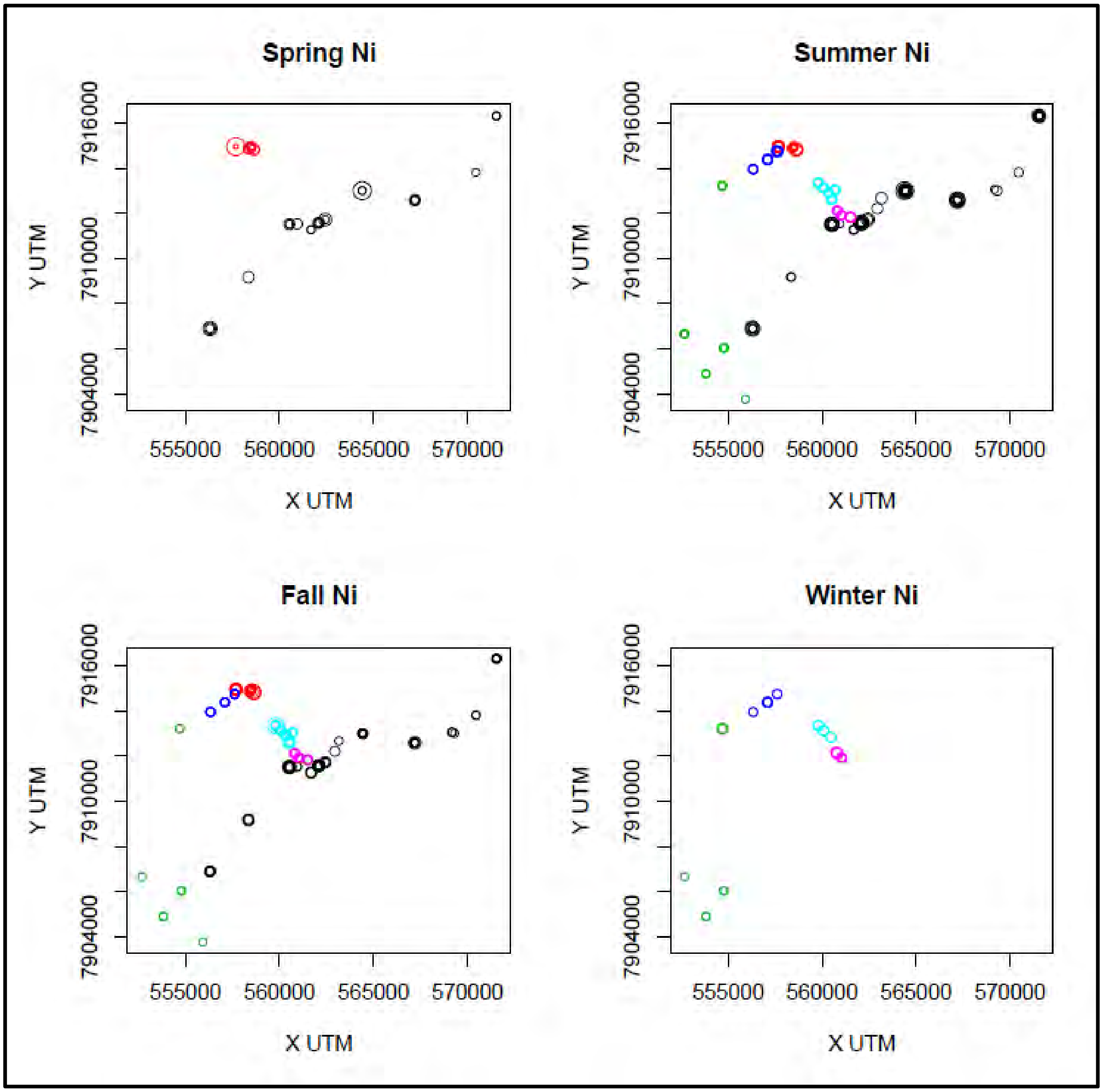
Figure 2.6 Site-Wide Seasonal Trends for Chloride



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).

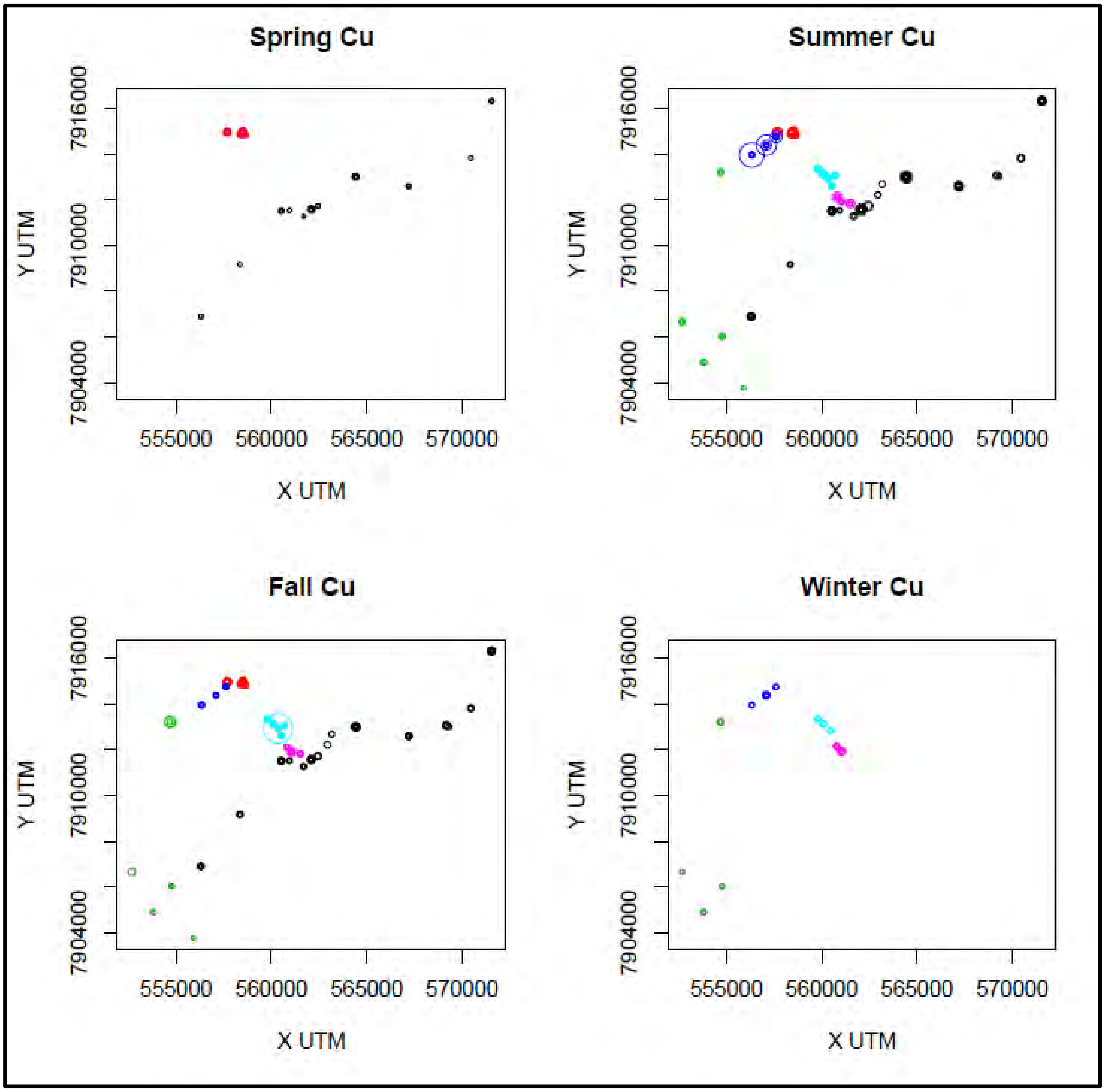
Figure 2.7 Site-Wide Seasonal Trends for Total Iron



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).

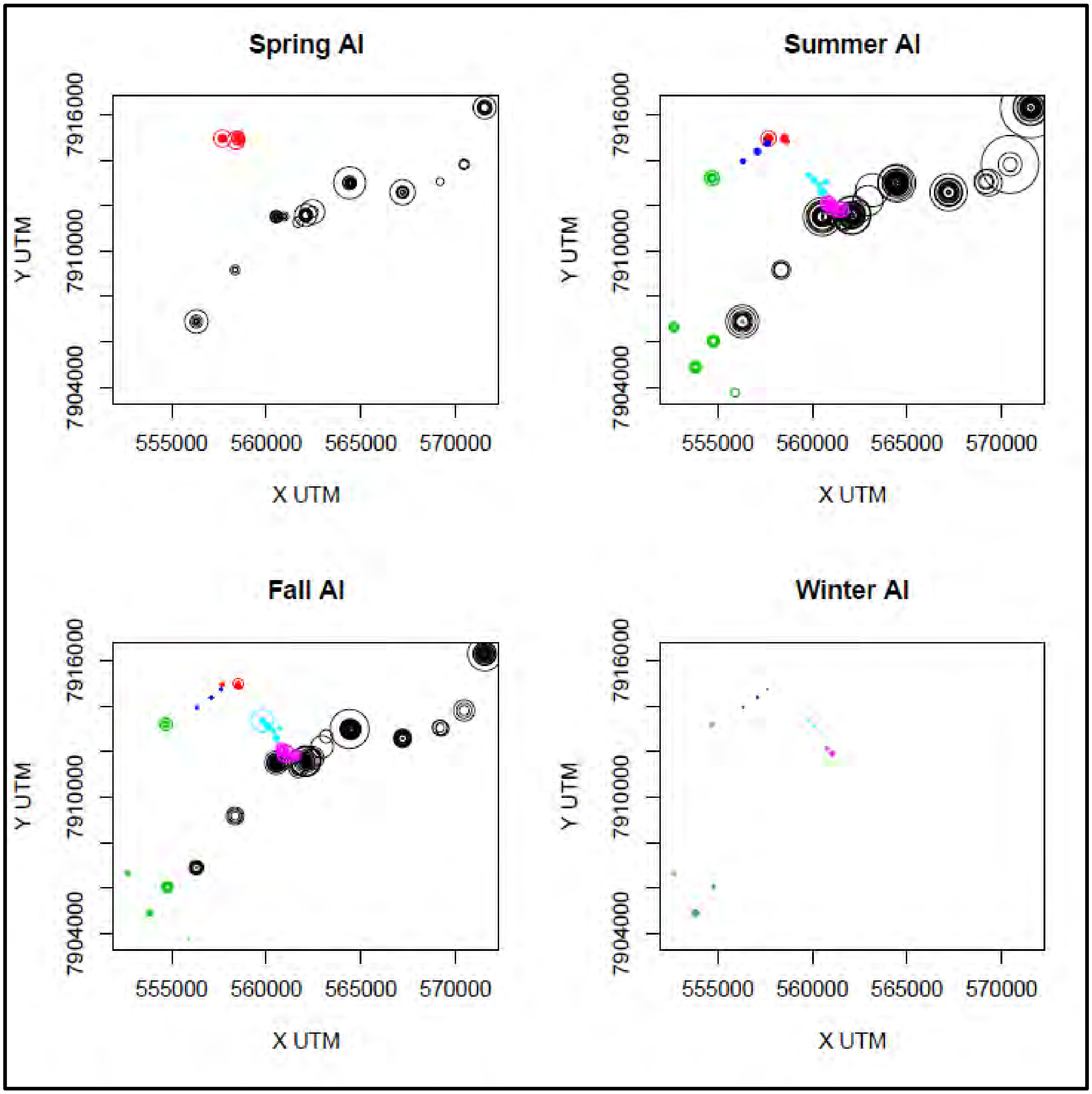
Figure 2.8 Site-Wide Seasonal Trends for Total Nickel



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 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.

The parameters selected for power analysis included:

- 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 power analysis along with further details on the methodology used are provided in Appendix B and C.

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 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.

---

[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.

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

- Water quality changes related to ore body 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 monitoring focused on waterbodies that will receive mine effluent discharges, site runoff, and are closest to the sources of mine related 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 total phosphorus (TP) being a key 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 current and 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; Intrinsik, 2015; see Appendix C and D of the AEMP). These benchmarks were designed to assist in identifying temporal changes and mine related influences on the Mine Site Area lakes and streams to inform management decisions. 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 97.5th 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
Iron	mg/L	0.3	0.326	0.874	CLT = 0.326 MR = 0.874	B

Parameter	Units	Water Quality Guideline	Camp Lake Tributary	Mary River[3]	Selected Benchmark	Benchmark Method
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 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). In addition, Reference Lake 3 was selected in 2015 as the CREMP reference lake and will be sampled concurrently with mine area lakes in the summer and fall[3].

After completing the CREMP in 2015, Minnow proposed several modifications to the program (presented in Appendix I of the AEMP) to provide greater efficiencies and improve the program's ability to achieve its objectives (i.e. to evaluate short and long term effects of the Project on aquatic ecosystems).

Within their list of recommendations, Minnow noted that no consistent spatial differences in water quality/chemistry were evident in any of the study lakes in 2015, nor during any of the baseline studies, suggesting that study lakes are generally well mixed with relatively uniform water chemistry throughout the year. (Minnow, 2016). Because of this, Minnow recommended three modifications to the CREMP lake water quality sampling program:

1. Reduce the number of water quality monitoring stations to three (3) in each of Camp, Sheardown NW and SE lakes and four (4) in Mary Lake (Item 7; Minnow, 2016);
2. Collect a single water quality sample at mid-depth instead of collecting two samples, surface and bottom, at each lake water quality monitoring station (Item 9; Minnow, 2016) and;
3. Focus water quality *in-situ* profiling to a few select stations located at the main (i.e. deepest) basin of the study lakes with the goal of identifying the occurrence of anoxic conditions to guide sampling approach (Item 8; Minnow 2016).[4]

Lake water quality stations selected by Minnow for *in-situ* profiling are listed below.

- Camp Lake Station - JL0-07
- Sheardown Lake NW Station – DL0-01-2
- Sheardown Lake SE Station – DL0-02-3
- Mary Lake (North Basin) Station – BL0-1A
- Mary Lake (South Basin) Station – BL0-9
- Reference Lake 3 (NW Basin) Station – REF03-3

In addition to the recommendations pertaining to the lake water sampling program, Minnow also recommended the following modifications to the CREMP lotic (stream) water quality sampling program:

1. The addition of three stream water quality monitoring stations to the program, including one station in each of lower Tom River,Sheardown Lake Tributary 9 and Sheardown Lake Tributary 12.

---

[3] Reference Lake 3 is located approximately 60 km south of the mine, and therefore no winter sampling is proposed during the winter months due to difficult accessibility and associated safety concerns for mine personnel.

[4] Anoxic conditions have not been observed at any of the study lakes since baseline studies began in 2005.

2. Discontinue water quality monitoring at stations L1-09 (Camp Lake Tributary 1) and D1-05 (Sheardown Lake Tributary 1).
3. Discontinue water quality monitoring at stations G0-09A, G0-09B and C0-01 on the Mary River.

This document has been revised reflect all of the recommendations listed above. Additional details regarding water quality sampling methodology for lakes and streams is presented in Appendix A.

An updated list of the CREMP water quality monitoring stations is presented in Table 2.11.

Figure 2.11 Recommended CREMP Water Quality and Phytoplankton Monitoring Stations following the 2015 Program

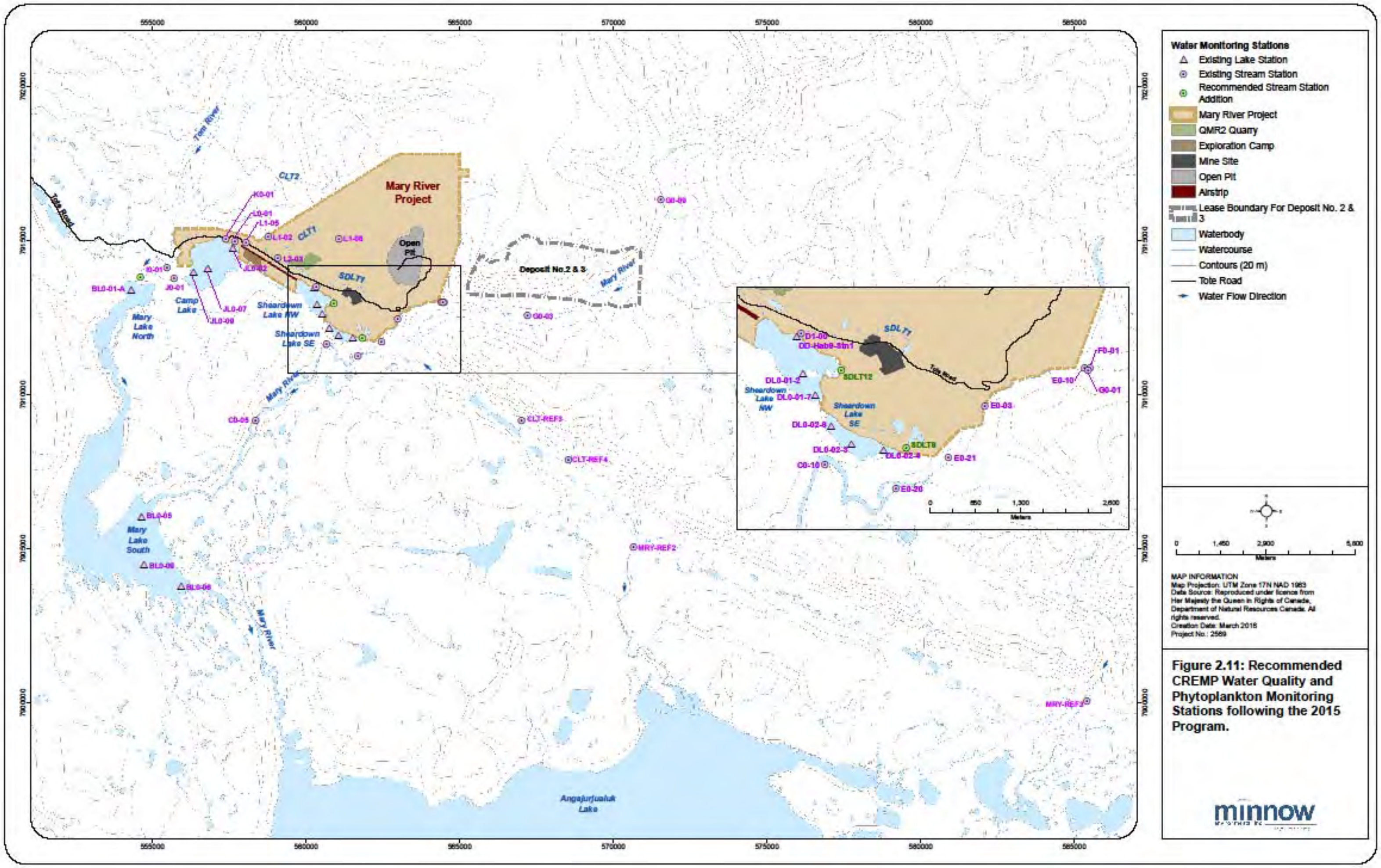


Table 2.11 Water Quality CREMP Station Details

Station ID	Easting	Northing	Winter	Spring	Summer	Fall	Description/Rationale
	NAD83, Zone 17N						
Mary Lake (North Basin)							
BL0-01-A	554300	7913378	1		1	1	North basin receiving water from Ca Lake
Mary Lake (South Basin)							
BL0-05	554632	7906031	1		1	1	Mary Lake, southern basin near ou of Mary River
BL0-06	555924	7903760	1		1	1	
BL0-09	554715	7904479	1		1	1	Main basin between BL0-05 & BL0-
Mary River (D/S of SDL)							
C0-05[1]	558352	7909170		1	1	1	Mainstem, d/s of mine
C0-10	560669	7911633		1	1	1	Mainstem, d/s Sheardown La outflow
SDL-Trib 1							
D1-00	560329	7913512		1	1	1	Tributary D1
Sheardown Lake NW							
DD-Hab 9-Stn1	560259	7913455	1		1	1	Nearshore monitoring location
DL0-01-2	560353	7912924	1		1	1	Long-term lake monitoring
DL0-01-7	560525	7912609	1		1	1	
Sheardown Lake SE							
DL0-02-3	561046	7911915	1		1	1	Long-term lake monitoring
DL0-02-4	561511	7911832	1		1	1	
DL0-02-6	560756	7912167	1		1	1	
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 an 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 statio within anticipated dust plume
G0-09[1]	571546	7916317		1	1	1	Upstream, potential reference statio beyond anticipated dust plume
Tom River							
TR-01	TBD	TBD		1	1	1	Downstream of I0-01 and J0-01
SDL-Trib 9							
SDLT-09	TBD	TBD		1	1	1	Downstream of Emulsion Plant
SDL-Trib 12							
SDLT-12	TBD	TBD		1	1	1	Downstream of Crusher Pad
Camp Lake							
JL0-02	557615	7914750	1		1	1	Littoral station near CLT1, CLT2 inl
JL0-07	556800	7914094	1		1	1	Deep basin, near centre of lake
JL0-09	556335	7913955	1		1	1	Near lake outlet
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	
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 Lake 3							
REF03-01	575642	7852666			1	1	East end of southeast basin
REF03-02	574836	7852744			1	1	Centre of southeast basin
REF03-03	574158	7853237			1	1	Centre of northeast basin
TOTAL			**13**	**26**	**42**	**42**	

NOTES:

1. STATIONS INCLUDED IN THE EEM PROGRAM.

2.7.5 Sampling Frequency and Schedule

Environment Canada (2012) specifies that four samples collected over a 12-month period, not less than one month apart, 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. Due to the short open water season (3-4 months) experienced at the Mary River Project, three sampling events will be conducted for streams and lakes under the CREMP.

Stream water quality will be monitored during the spring, summer and fall, whereas, lake water quality monitoring will take place during the winter (late April), summer and fall. This sampling frequency should be adequate to detect early warning flag concentrations and determine significance for most water quality parameters. The sampling frequency and schedule will be re-evaluated after the first three years of mine operation.

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. The use of other analyses will be considered as well (e.g. use of 97th percentile of background and regression analysis) to define trends in the short terms. 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

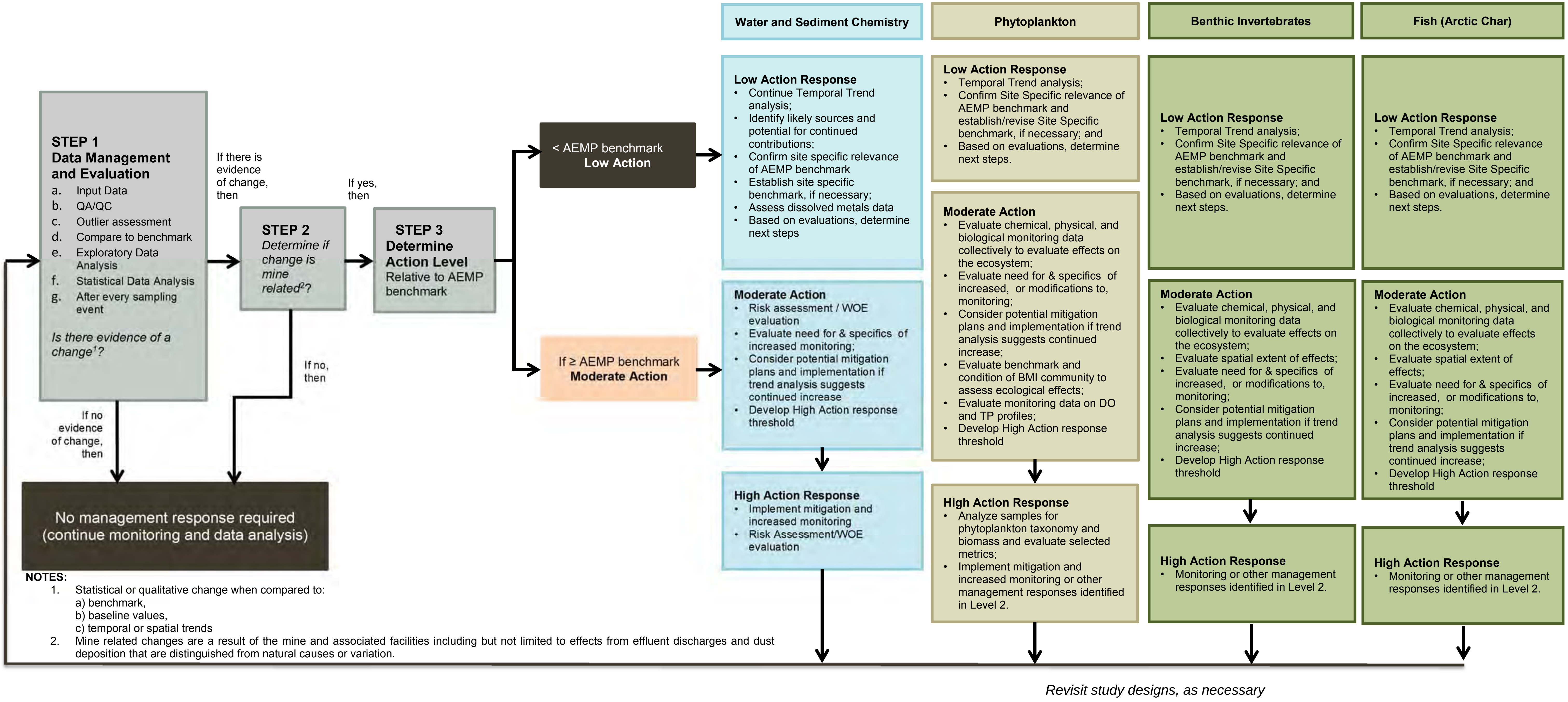
Following data collection, and upon receipt of the laboratory reports, data will be entered into the Project EQWin® database. The EQWin® Software was developed for collecting, analyzing, storing and interpreting sample data from environmental monitoring programs. All environmental data will be stored 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.



Water and Sediment Chemistry

Low Action Response
- Continue Temporal Trend analysis;
- Identify likely sources and potential for continued contributions;
- Confirm site specific relevance of AEMP benchmark
- Establish site specific benchmark, if necessary;
- Assess dissolved metals data
- Based on evaluations, determine next steps

Moderate Action
- Risk assessment / WOE evaluation
- Evaluate need for & specifics of increased monitoring;
- Consider potential mitigation plans and implementation if trend analysis suggests continued increase
- Develop High Action response threshold

High Action Response
- Implement mitigation and increased monitoring
- Risk Assessment/WOE evaluation

Phytoplankton

Low Action Response
- Temporal Trend analysis;
- Confirm Site Specific relevance of AEMP benchmark and establish/revise Site Specific benchmark, if necessary; and
- Based on evaluations, determine next steps.

Moderate Action
- Evaluate chemical, physical, and biological monitoring data collectively to evaluate effects on the ecosystem;
- Evaluate need for & specifics of increased, or modifications to, monitoring;
- Consider potential mitigation plans and implementation if trend analysis suggests continued increase;
- Evaluate benchmark and condition of BMI community to assess ecological effects;
- Evaluate monitoring data on DO and TP profiles;
- Develop High Action response threshold

High Action Response
- Analyze samples for phytoplankton taxonomy and biomass and evaluate selected metrics;
- Implement mitigation and increased monitoring or other management responses identified in Level 2.

Benthic Invertebrates

Low Action Response
- Temporal Trend analysis;
- Confirm Site Specific relevance of AEMP benchmark and establish/revise Site Specific benchmark, if necessary; and
- Based on evaluations, determine next steps.

Moderate Action
- Evaluate chemical, physical, and biological monitoring data collectively to evaluate effects on the ecosystem;
- Evaluate spatial extent of effects;
- Evaluate need for & specifics of increased, or modifications to, monitoring;
- Consider potential mitigation plans and implementation if trend analysis suggests continued increase;
- Develop High Action response threshold

High Action Response
- Monitoring or other management responses identified in Level 2.

Fish (Arctic Char)

Low Action Response
- Temporal Trend analysis;
- Confirm Site Specific relevance of AEMP benchmark and establish/revise Site Specific benchmark, if necessary; and
- Based on evaluations, determine next steps.

Moderate Action
- Evaluate chemical, physical, and biological monitoring data collectively to evaluate effects on the ecosystem;
- Evaluate spatial extent of effects;
- Evaluate need for & specifics of increased, or modifications to, monitoring;
- Consider potential mitigation plans and implementation if trend analysis suggests continued increase;
- Develop High Action response threshold

High Action Response
- Monitoring or other management responses identified in Level 2.

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

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 2011 and 2014. Because ERP mine operations started in September, 2014, sediment quality data collected after the 2014 CREMP field program were not included in this review.

Sampling of sediment in streams and lakes around the Mine Site is 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 sediment sampling locations around the Mine Site up until 2013 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	2014[1]
Camp Lake	0	0	6	0	0	3	3	9
Camp Lake Tributary	3	0	4	0	3	7	5	1
Mary River Downstream	2	1	5	0	10	4	3	0
Mary Lake	0	2	5	0	0	1	1	10
Sheardown Lake NW	0	0	7	12	3	4	6	8
Sheardown Lake SE	0	0	5	0	0	1	1	5
Sheardown Lake Tributary	2	0	5	3	4	3	1	2
Mary River Upstream	1	1	1	0	0	0	1	0

[1] Five (5) sediment samples were taken at Reference Lake 1 and 2. One (1) sediment sample was taken at Reference Lake 3.

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. Contrary to current protocols, sediment sampling in the initial years of baseline studies 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 includes 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.

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)

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 2015). All laboratory results and their respective detection limits for each year are presented in Section 3.3.

During 2014 and 2015, Intrinsik Environmental Sciences Inc. was retained by Baffinland to develop water and sediment quality benchmarks to be applied to the CREMP. In 2015, Intrinsik established area-specific benchmarks for sediment quality at mine exposed lakes, with the exception of Sheardown Lake NW. The current sediment quality benchmarks are further discussed in Section 3.6.3. The specifics of the benchmark selection process for both sediment and surface water are outlined in Appendix C and D of the AEMP. 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.

3.1.1 Substrate Mapping

Bathymetry and substrate mapping along with historic sediment monitoring stations 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).

Figure 3.1 Camp Lake – Substrate and Bathymetry

Figure 3.2 Sheardown Lake –Substrate and Bathymetry

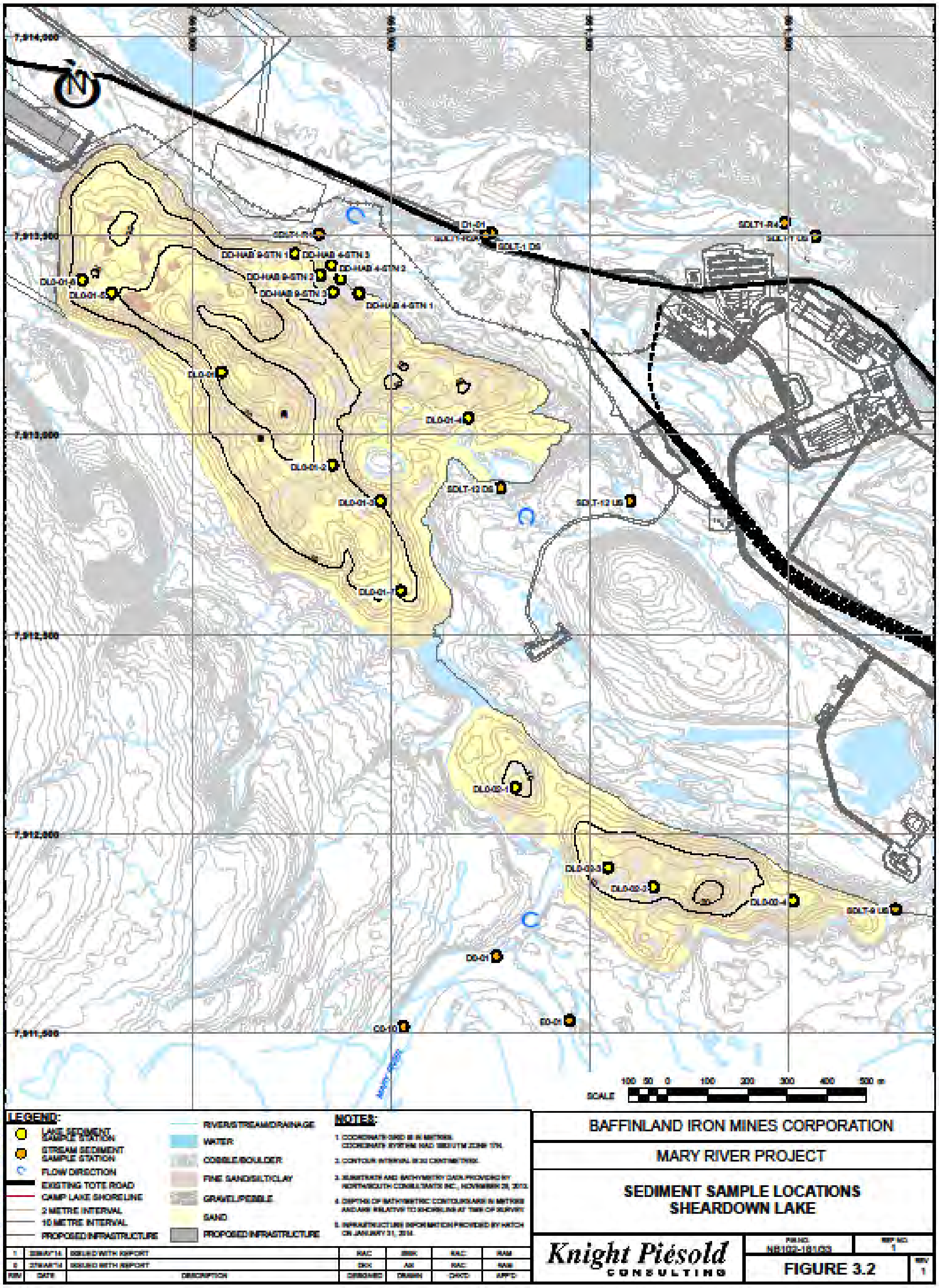
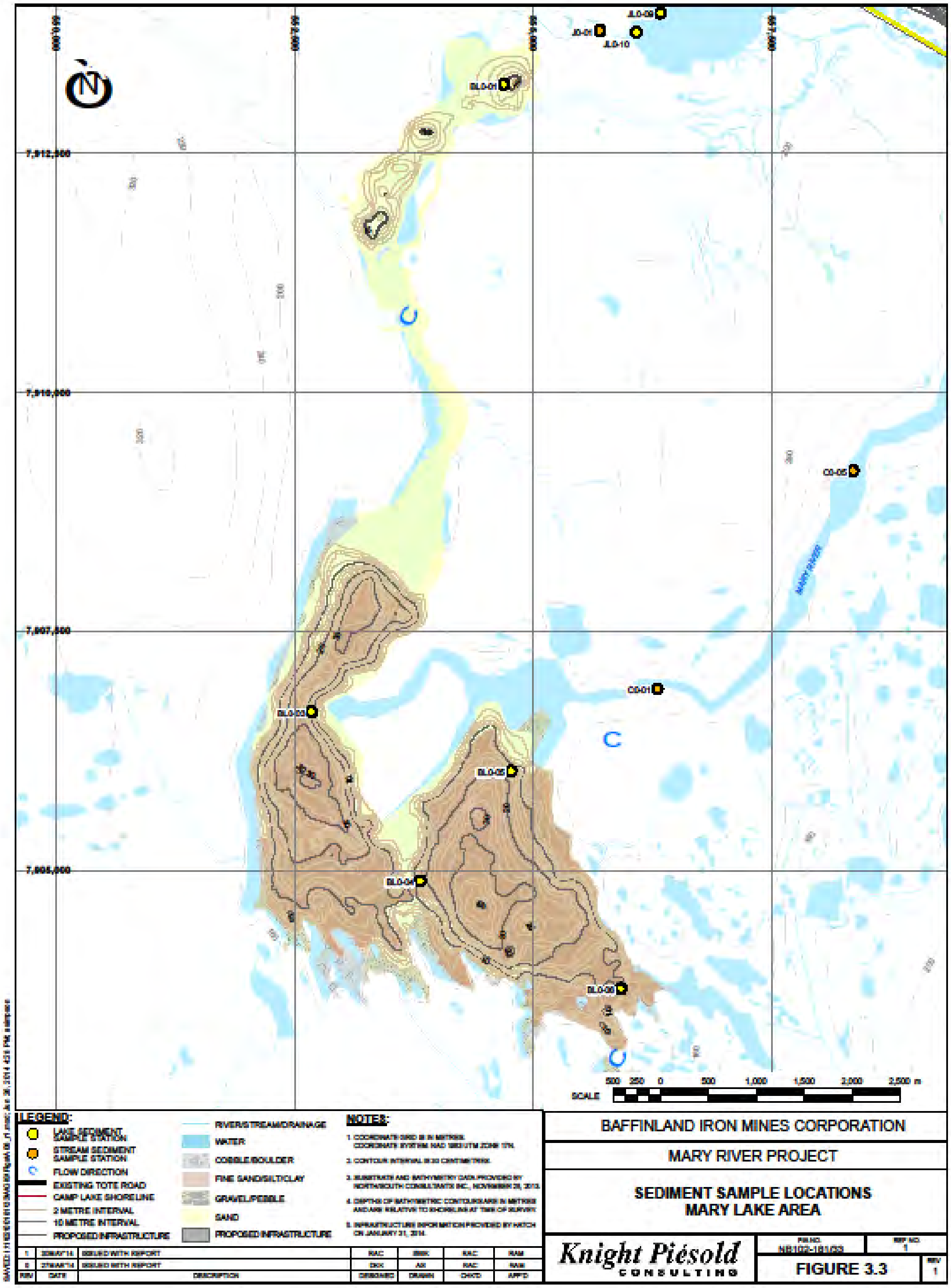


Figure 3.3 Mary Lake – Substrate and Bathymetry



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.

3.1.2 Aquatic Effects Monitoring of Dust from Bulk Sample Ore Crushing

A 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 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.

3.1.3 AEMP Target Study on Lake Sedimentation Rates (Sheardown Lake NW)

This study began in the open-water season of 2013 to measure sedimentation in Sheardown Lake NW and is currently ongoing. The study was designed to monitor the effects of dust generated by mine operations on sedimentation rates in lakes near the Mine Site with a specific focus on Sheardown Lake NW. The study involves deploying sediment traps at three stations in the lake, with five replicates at each station. This configuration is utilized to ensure adequate sediment is obtained for laboratory analysis and to provide sufficient information to evaluate variability at each station. The stations are selected to generate measurements of sedimentation rates at a deep station (where sedimentation is typically greatest) and at two shallower locations. The data from the study will be used to monitor potential influence of sedimentation on Arctic charr populations related to smothering of incubating eggs in spawning beds. This ongoing study along with the Dustfall Monitoring Program (Appendix G of AEMP) will provide supporting information for the interpretation of results generated from CREMP sediment quality monitoring.

3.2 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 (up to and including 2014).

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
2014	1	0.5	1	1	5	0.1	1	1	1	2

3.3 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.

3.4 REVIEW OF SEDIMENT QUALITY BASELINE

A detailed review of the baseline data using various graphical analysis tools is presented in Appendix D. The sediment quality baseline review presented in Appendix D and summarized below (Section 3.5) was written by Knight Piesold in early 2014 and does not include sediment quality data collected during the 2014 or 2015 CREMP field program.

3.4.1 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 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[5]
- Establishing if the change is mine related

---

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

- 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.

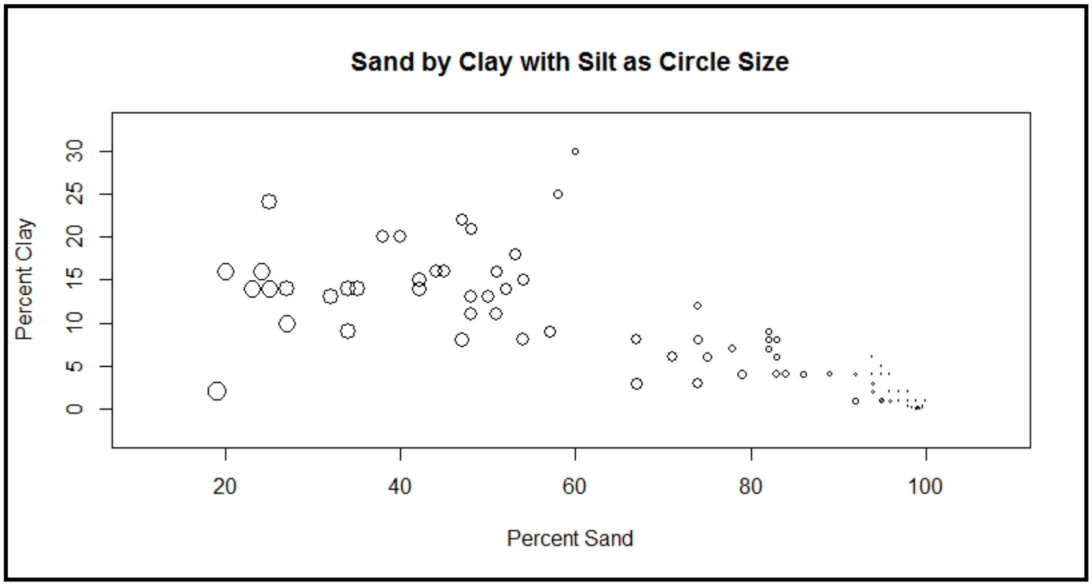


Figure 3.4 **Clay by Sand with Silt as Circle Size**

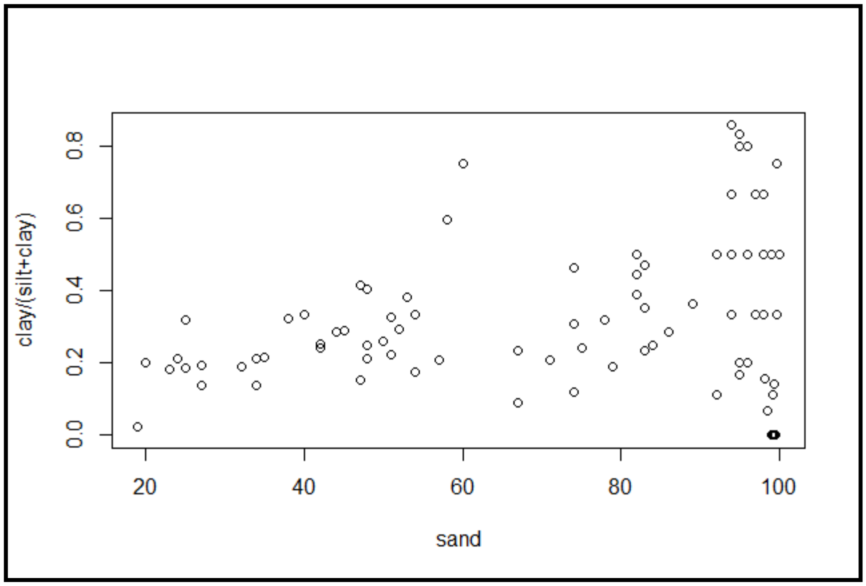


Figure 3.5 Dependent Relationship between Sand, Silt and Clay in Sediment

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.

3.4.2 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.

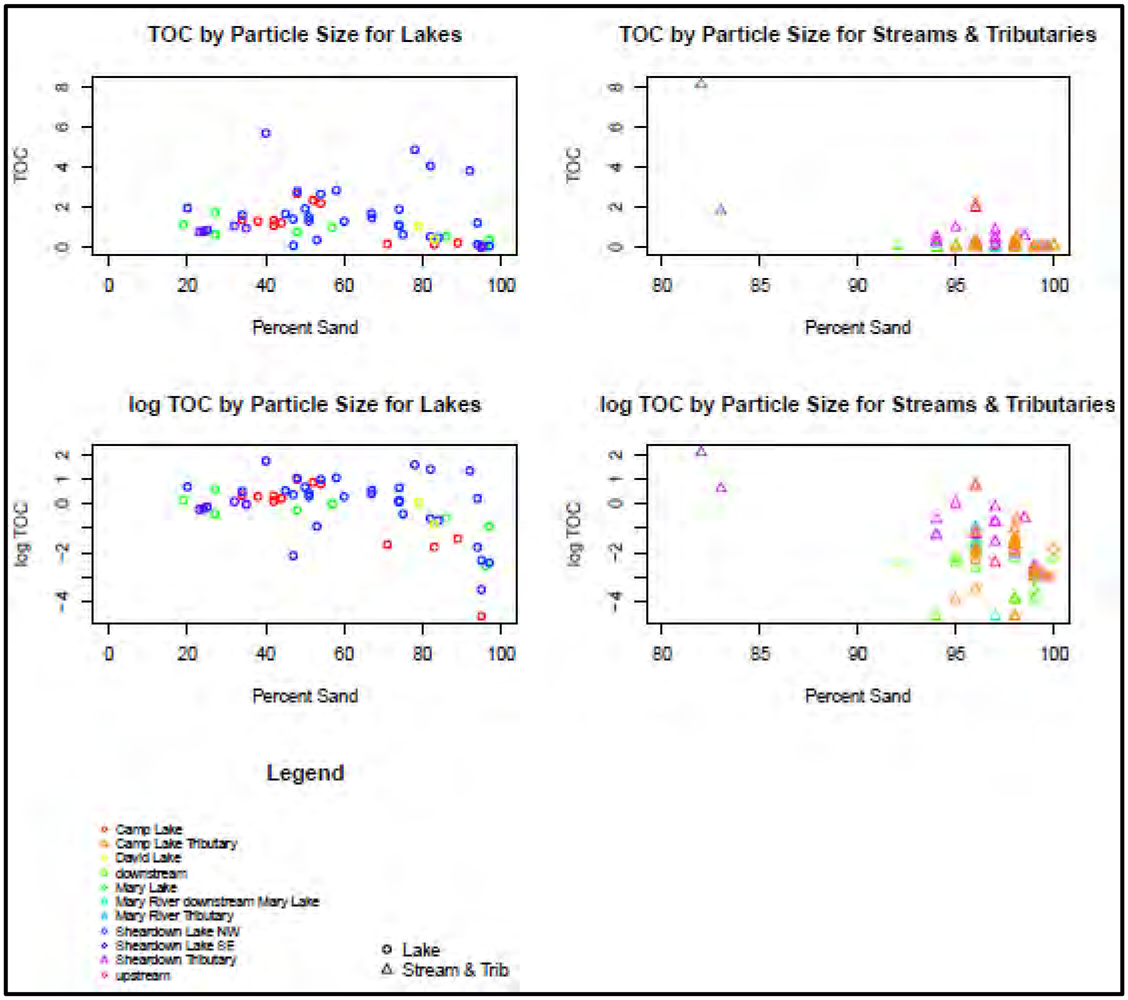


Figure 3.6 Sediment TOC versus Particle Size for Lakes and Streams

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.

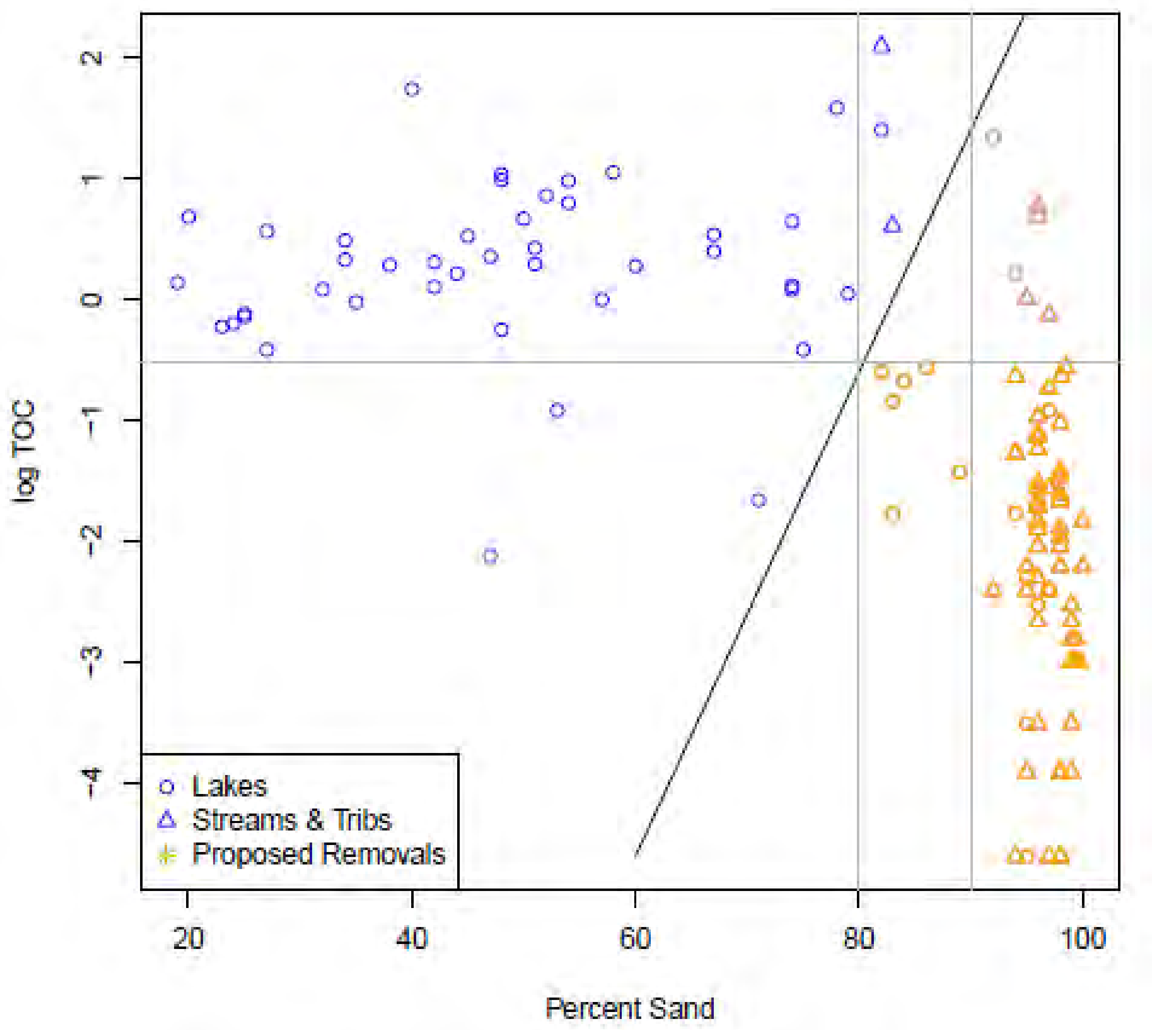


Figure 3.7 Results of Cut Point Analysis for Sediment

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.

3.4.3 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.

3.4.4 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.

3.5 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). Because of this and the very limited depositional habitat suitable for the collection of fine sediments in streams and rivers in and around the Mine Site, the CREMP sediment monitoring program focuses solely on the four (4) mine area lakes (Camp, Sheardown NW and NE, Mary Lake). In addition, Reference Lake 3 was selected in 2015 as the CREMP reference lake and will be sampled concurrently with mine area lakes in the summer and fall[6]. Further details on the CREMP sediment quality monitoring program is discussed in Section 3.6.4 and Section 3.6.5.

3.5.1 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 issues of concern with respect to sediment quality is the effect of ore dust containing elevated metals being deposited on, or running off into mine area lakes. In addition, another concern to consider is metal loads from Mine effluent influencing sediment metal concentrations over time, although limited effluent is released in the current phase of the mine. In the review of baseline sediment data presented in Appendix D, Knight Piésold 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).

Moreover, after conducting the 2015 CREMP sediment quality program, Minnow recommended that the stream sediment sampling in future CREMP studies be discontinued on the basis that very limited depositional habitat suitable for the collection of fine sediments was present in streams and rivers in and around the Mine Site. As such, CREMP sediment quality monitoring will focus solely on the four (4) mine area lakes closest to mine operations and the sources of ore dust: Sheardown Lake NW and SE, Camp Lake and Mary Lake. Sediment quality monitoring will also be conducted at Reference Lake

---

[6] The lack of accessibility to Reference Lake 3 during the winter months prevents the lake from being sampled concurrently with mine area lakes in late April.

3 to assist in identifying any sediment quality changes related to mine operations. Parameters and Metrics

Sediment quality parameters identified for monitoring include various physical parameters and metals. 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[7]

Contaminants of Potential Concern	Exploratory Data Analysis Only
Arsenic	Moisture content
Cadmium	Particle Size
Chromium *	Total Organic Carbon (TOC)
Copper *	
Iron *	
Lead	
Manganese *	
Mercury	
Nickel *	
Phosphorus *	
Zinc	

3.5.2 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; Intrinsik, 2015; see Appendix C and D 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 followed 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

---

[7] Nitrite, nitrate, phosphorus and Total Kjeldahl Nitrogen (TKN) had been monitored during CREMP sediment monitoring programs up to but not including the 2015 CREMP program.

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.

In 2015, Intrinsik established area-specific sediment quality benchmarks for all mine area lakes with the exception of Sheardown Lake NW. (Table 3.6).

In the case of mercury, lead and zinc, the selected benchmark was either a CCME or an Ontario sediment quality guideline, as area-wide data were less than or equal to this value. Lake sediment characterization during future CREMP studies may result in changes to this decision. In the case of arsenic, chromium, copper, iron, manganese, nickel and phosphorus, the established AEMP benchmark is the 97.5^{th} percentile of baseline (including 2014). The use of the area-wide percentiles as benchmarks appears to be reasonable, based on comparisons to both the existing guidelines, and characterization data for the lakes.

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 to determine an AEMP benchmark for cadmium

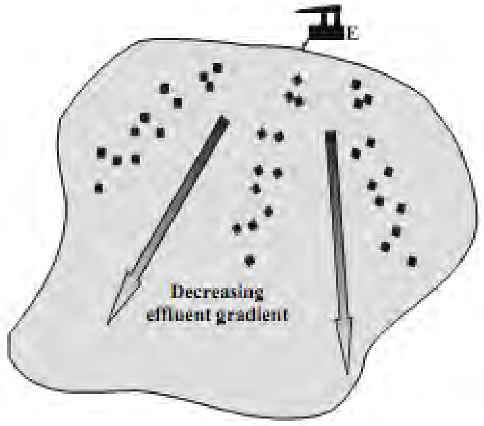
During the 2015 CREMP, it was observed that average arsenic, copper and iron concentrations in Reference Lake 3, were elevated above the AEMP sediment quality benchmarks established by Intrinsik in 2015 (Intrinsik, 2015). In turn, this suggests that the AEMP sediment benchmarks established for these metals may be overly conservative. Because reference lake information had not been available at the time of AEMP benchmark development, Minnow recommends that reference sediment quality data be factored into the derivation of AEMP benchmarks for arsenic, copper and iron in the future to improve the applicability of these benchmarks as a tool for evaluating potential mine effects for the Mary River Project CREMP.

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).

3.5.3 Monitoring Area and Sampling Stations

The monitoring area for sediment quality includes mine area lakes, including Camp Lake, Sheardown Lake NW and SE and Mary Lake as well as Reference Lake 3.

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 several historic 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

The current sediment sampling locations for the mine exposed lakes (Sheardown Lake, NW and SE, Camp Lake and Mary Lake) are shown in Figure 3.9. Sediment sampling locations for Reference Lake 3 are shown in Figure 3.10. Within each mine exposed study lake, stations are positioned to allow for the evaluation of any spatial differences in sediment chemistry in order to determine potential gradients in metal concentrations associated with mine sources (i.e. mine exposed tributaries).

Prior to 2016, the sediment quality monitoring program did not sample sediment at each lake benthic macroinvertebrate (BMI) station. Therefore, in effort to harmonize the sediment quality and benthic macroinvertabrate monitoring programs and refocus the lake benthic macroinvertebrate program solely on littoral (shallow) habitats, Minnow proposed the following recommendations in 2016:

1. Establish five (5) sediment quality/BMI stations located in littoral (shallow) habitat at each mine exposed study lake and Reference Lake 3.
2. Continue sediment quality monitoring at three (3) existing sediment quality stations located in profundal (deep) habitat at Reference Lake 3 and each mine exposed study lake, with the exception of Sheardown Lake SE where limited profundal habitat is present.

Littoral sediment sampling stations are situated at the same locations as the littoral BMI stations. Utilizing the same littoral stations for both sediment quality and benthic macroinvertebrate community sampling will provide supporting information for interpretation and analysis of BMI results (e.g., metals concentrations) and allow the CREMP to establish potential linkages between sediment metal concentrations and effects on benthic macroinvertebrates.

To the extent possible, littoral sediment quality/BMI stations proposed by Minnow were established at existing (historic) BMI stations. However, in some cases, new stations were established to ensure sufficient coverage of the lake, and to ensure that substrate properties are comparable among and within lakes.

In contrast, all profundal sediment quality stations recommended by Minnow were selected from existing sediment stations. Because the majority of Sheardown Lake is less than 12 meters deep and represents primarily littoral habitat, sediment quality will focus only on littoral habitat of this lake..

Moreover, in addition to modifications to the lake sediment quality program, Minnow also recommended that the CREMP sediment monitoring program focus solely on depositional lake environments and that CREMP sediment monitoring stations in streams and rivers be discontinued in future CREMP studies, This recommendation was based on the observation that the majority of streams and rivers in the Mary River Project local study area (LSA) contain very limited depositional habitat suitable for the collection of fine sediments. As observed during the 2015 CREMP and baseline studies (KP, 2015), the general absence of any substantial accumulation of fine sediments within these watercourses preclude any meaningful assessment of potential mine-related influences on sediment quality within, along and/or between watercourses. As a result, all sediment quality stations in streams and rivers near the Mine Site have been removed from future CREMP studies.

This document has been revised reflect all of the recommendations listed above. Additional details regarding sediment quality sampling methodology is presented in Appendix A.

An updated list of the CREMP sediment monitoring stations is presented in Table 3.7.

3.5.4 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 (Appendix D of AEMP).

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 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. Sedimentation rates at Sheardown Lake are predicted to be less than 1mm per year; therefore, a three year frequency should be sufficient to track changes in sediment metal concentrations over time.

3.5.5 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 Development of Area-Specific Aquatic Effects Sediment Benchmarks, based on Area-Specific Baseline Calculations and Relevant Sediment Quality Guidelines (mg/kg; dw; Intrinsik, 2015)

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	20,000	460	16	600	31	120
	SEL	2	33	10	110	110	40,000	1100	75	2,000	250	820
97.5th Percentiles of Lake Areas and Lake Specific Benchmarks by Area												
Mary Lake (2007 – 2014) and Camp lake (2007 – 2014) (N=31)		<0.1	5.3	<0.5	98	50	52,400	4,370	72	1580	25	135
Proposed AEMP Benchmark – Mary Lake and Camp Lake		0.17[A]	5.9[A]	1.5[C]	98[B]	50[B]	52,400[B]	4,370[B]	72[B]	1,580[B]	35[A]	135[B]
Sheardown Lake SE (2007 – 2014) (N=11)		<0.1	2	1	79	56	34,400	657	66	1278	18	63
Proposed AEMP Benchmark – Sheardown Lake SE		0.17[A]	5.9[A]	1.5[C]	79[B]	56[B]	34,400[B]	657[B]	66[B]	1278[B]	35[A]	123[A]
Sheardown Lake NW (2007-2014, excluding 2008) (N=25)		<0.1	6.4	<0.5	96	62	53,000	4,300	84	1,100	24	107
Interim AEMP Benchmark – Sheardown Lake NW		0.17[A]	6.2[B]	1.5[C]	97[B]	58[B]	52,200[B]	4,530[B]	77[B]	1958[B]	35[A]	123[A]

NOTES:

*=N for phosphorus is lower than other elements / parameters

A = guideline is based on sediment quality guideline (CCME or Ontario)

B = guideline is based on 97.5% percentile of baseline data

C = guideline is based on 3 times MDL

Where mercury and cadmium were not detected in any samples in a given area; the detection limit is used to represent the 97.5% percentiles.

Figure 3.9 Recommended CREMP Sediment and Benthic Monitoring Stations following the 2015 Program

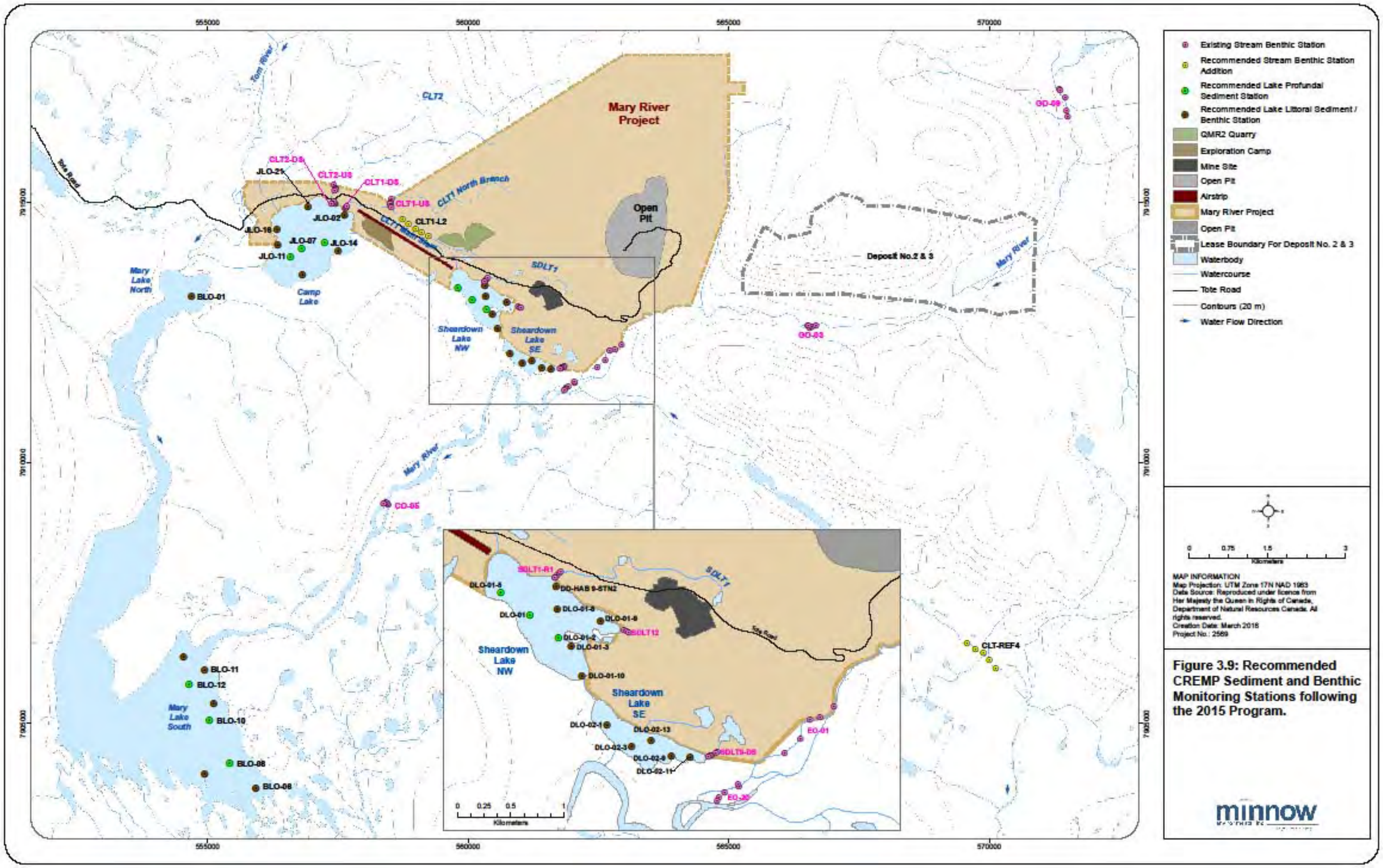
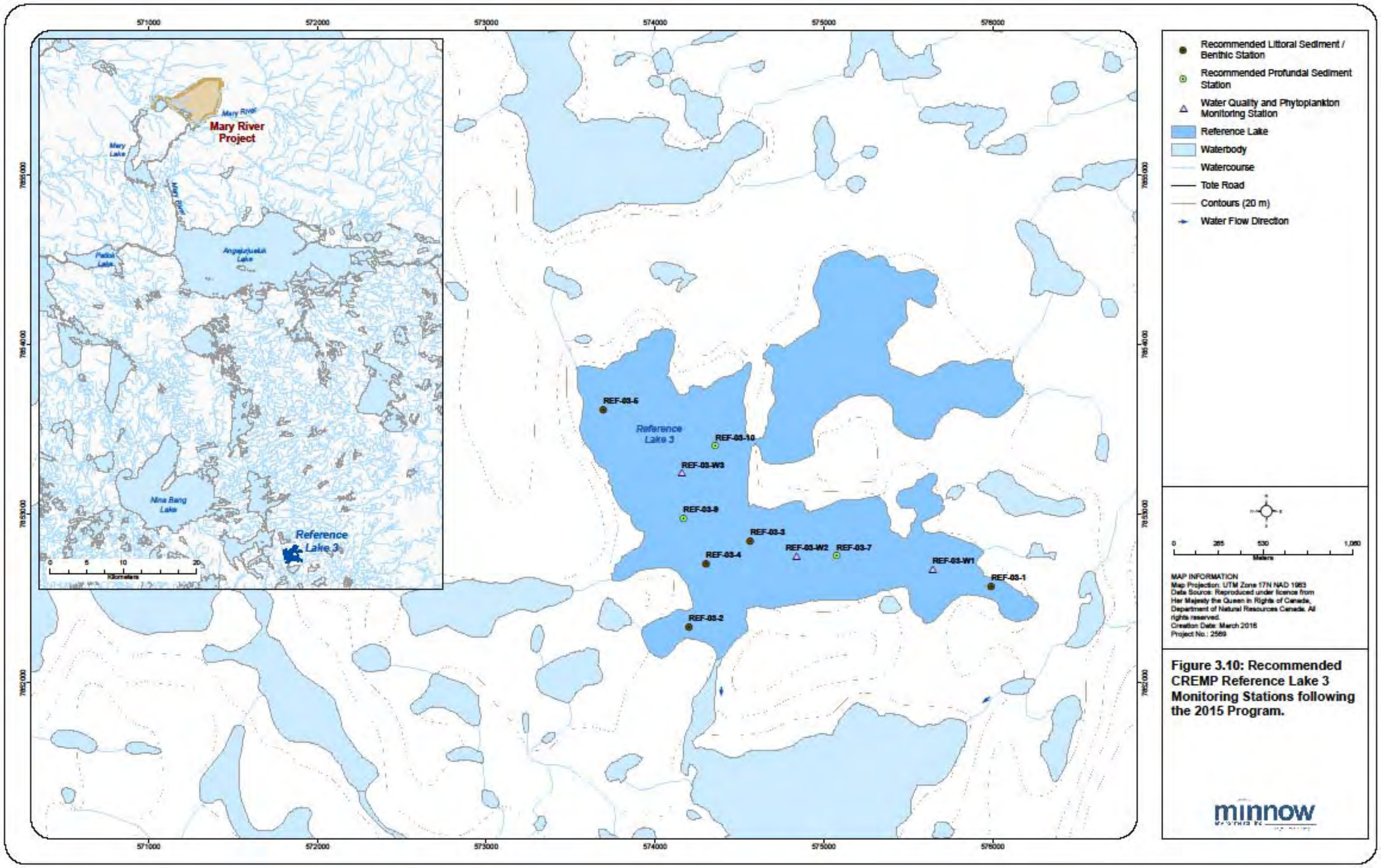


Figure 3.9: Recommended CREMP Sediment and Benthic Monitoring Stations following the 2015 Program.

Figure 3.10 Recommended CREMP Reference Lake 3 Monitoring Stations following the 2015 Program



MAP INFORMATION
Map Projection: UTM Zone 17N NAD 1983
Data Source: Reproduced under licence from Her Majesty the Queen in Rights of Canada, Department of Natural Resources Canada. All rights reserved.
Creation Date: March 2016
Project No.: 2569

Figure 3.10: Recommended CREMP Reference Lake 3 Monitoring Stations following the 2015 Program.

Table 3.7 Sediment Quality CREMP Stations Details

Station ID	Easting	Northing	Sediment	Benthic Macroinvertebrates	Description/Rationale
	NAD 83, Zone 17N				
Mary Lake (North Basin)					
BL0-01	554690	7913194	X	X	North basin receiving water from Camp La
Mary Lake (South Basin)					
BL0-06	555924	7903760	X	X	Main basin near outlet of Mary River
BL0-08	555420	7904237	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
TBD	TBD	TBD	X	X	Main basin near outlet of Mary River
TBD	TBD	TBD	X	X	Main basin nearshore between BL0-12 and BL0-10
TBD	TBD	TBD	X	X	Main basin near south shore
Mary River (D/S of SDL)					
C0-05	558352	7909170		X	Mainstem - downstream of Mine Site
SDL-Tributaries					
SDLT-1-R1	560320	7913504		X	Tributary SDLT-1
SDLT-9-DS	561770	7911810		X	Tributary SDLT-9
SDLT-12	560776	7912867		X	Tributary SDLT-12
Sheardown Lake NW					
DD-Hab 9-Stn 2	560323	7913402	X	X	Nearshore station
DL0-01	560079	7913128	X		Mid-lake position
DL0-01-2	560353	7912924	X		Mid-lake position
DL0-01-3	560474	7912833	X	X	Southeastern region
DL0-01-5	559798	7913356	X		Near treated wastewater discharge locatio
DL0-01-8	560329	7913197	X	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
Sheardown Lake SE					
DL0-02-1	560813	7912116	X	X	Near inlet channel from Northwest Basin
DL0-02-3	561046	7911915	X	X	Mid-lake position
DL0-02-9	561414	7911804	X	X	Eastern region
DL0-02-11	561688	7911801	X	X	Eastern region near SDLT-9 stream inflow
DL0-02-13	561237	7911943	X	X	Mid-lake position
Mary River (US of SDL)					
E0-20	561688	7911272		X	Near EEM near field exposure area
E0-01	562942	7912274		X	Downstream of Deposit 1 near sewage outfall
G0-03	566516	7912618		X	Upstream of Deposit 1
G0-09	571341	7917169		X	Mary River Reference Area - Upstream of Deposit 1, 2 and 3
Camp Lake					
JL0-02	557614	7914750	X	X	On gradient transect between CLT-1 and lake outlet.
JL0-07	556800	7914094	X		
JL0-11	556598	7913935	X		
JL0-14	557235	7914222	X		Mid-lake position
JL0-16	556329	7914456	X	X	Near northwest shoreline
JL0-21	556935	7914913	X	X	Along the northwest shoreline
TBD	TBD	TBD	X	X	Near northwest shoreline

Station ID	Easting	Northing	Sediment	Benthic Macroinvertebrates	Description/Rationale
	NAD 83, Zone 17N				
Camp Lake cont'd					
TBD	TBD	TBD	X	X	Near southwest shoreline
TBD	TBD	TBD	X	X	Near southeast 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
CLT-2-US	TBD	TBD		X	Upper reach of CLT-2
CLT1-L2*	TBD	TBD		X	CLT1 Upper Main Stem, DS of QMR2
Reference Tributary					
CLT-REF4*	TBD	TBD		X	Camp Lake Tributary Reference Area 4
Reference Lake					
REF-03-1	575992	7852572	X	X	Nearshore southeast shoreline
REF-03-2	574200	7852330	X	X	Nearshore south shoreline
REF-03-3	574564	7852840	X	X	Nearshore north shoreline
REF-03-4	574301	7852705	X	X	Mid-lake position
REF-03-5	573694	7853613	X	X	Nearshore northwest shoreline
REF-03-7	575076	7852750	X		East Mid-lake position
REF-03-9	574168	7852975	X		Mid-lake position
REF-03-10	574358	7853400	X		Northwest shoreline
TOTAL			**38**	**41**	

NOTES:

1. STATION LOCATIONS PROPOSED BASED ON AVAILABLE SUBSTRATE AND WATER DEPTH DATA, SUBJECT TO CHANGE FOLLOWING IN-SITU FIELD CONFIRMATION OF CONDITIONS.

3.5.6 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 solely 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).Stations are generally situated on a gradient type approach within each lake while the analysis is conducted using a CI approach. A gradient sample design has been defined for the CREMP lake sediment stations that is integrated with benthic invertebrate sampling and utilizes several historic sediment sampling locations that meet the cut-off criteria (Section 3.5.2). Within each mine exposed study lake and Reference Lake 3, stations are positioned to allow for the evaluation of any spatial differences in sediment chemistry in order to determine potential gradients in metal concentrations associated with mine sources (i.e. mine exposed tributaries).

As mentioned before, Reference 3 Lake was established as the reference lake for the CREMP in 2015. Being located outside of the mine area, Reference Lake 3 is 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 require use of various statistical approaches to assist with the detection of Project-related changes to sediment quality.

Additionally, a before-after comparison of monitoring data to baseline data will be conducted to detect Project-related changes to sediment quality.

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.

3.5.7 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.

3.5.7.1 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 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.

3.5.7.2 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 mine area lakes 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 Reference Lake 3. 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.

3.5.7.3 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

4 – REFERENCES

Agresti, A, 1990. *Categorical Data Analysis*. Wiley Series, New York.

Baffinland Iron Mines Corporation, 2012. *Mary River Project - Final Environmental Impact Statement.* February.

Baffinland Iron Mines Corporation, 2013a. *Mary River Project - Aquatic Effects Monitoring Program Framework.* February.

Baffinland Iron Mines Corporation, 2013b. *Mary River Project - Updated Aquatic Effects Monitoring Program Framework.* December.

Baffinland Iron Mines Corporation, 2014. *Mary River Project - Aquatic Effects Monitoring Plan.* In-progress.

Canadian Council of Ministers of the Environment, 2002. *Canadian sediment quality guidelines for the protection of aquatic life: Introduction*. Updated. In: Canadian environmental quality guidelines, 1999, Canadian Council of Ministers of the Environment, Winnipeg.

Canadian Council of Ministers of the Environment, 1999. *Canadian water quality guidelines for the protection of freshwater aquatic life*. Canadian Environmental Quality Guidelines Summary Table on-line, http://st-ts.ccme.ca/. Updated in 2014.

Downing, J.A. and E. McCauley, 1992. The Nitrogen : Phosphorus Relationship in Lakes, in: *Limnol. Oceanogr.* 37(5), pages 936-945. The American Society of Limnology and Oceanography, Inc.

Edwards, D., 1998. Data Quality Control/Quality Assurance, in: *Data and Information Management in the Ecological Sciences: A Resource Guide*. Michener, W.K., Porter, J.H. and Stafford, S.G. (eds.), LTER Network Office, Univ. of New Mexico, Albuquerque, NM, USA.

Environment Canada, 2012. *Metal Mining Technical Guidance for Environmental Effects Monitoring*. Available online at: https://www.ec.gc.ca/esee-eem/AEC7C481-D66F-4B9B-BA08-A5DC960CDE5E/COM-1434---Tec-Guide-for-Metal-Mining-Env-Effects-Monitoring_En_02[1].pdf

Fletcher R., P. Welsh and T. Fletcher, 2008. *Guidelines for Identifying, Assessing and Managing Contaminated Sediments in Ontario: An Integrated Approach.* Queen`s Printer for Ontario. PIBS 6658e. May 2008.

Green, R., 1979. *Sampling Design and Statistical Methods for Environmental Biologists. In 'Proceedings of the 29th Congress of the Australian Society of Limnology, Jabiru, NT, 1990*'. (Ed. R. V. Hyne.) pp. 105-23. (Office of the Supervising Scientist Alligator Rivers Region, Australian Government Publishing Service: Canberra.).

Knight Piésold Ltd., 2013*. 2013 Lake Surface Water and Sediment Quality Sampling Protocol*. North Bay, Ontario. Ref. No. NB102-181/33-2, Rev. A. July 31.

Knight Piésold Ltd., 2012a. *Compendium to Surface Water and Sediment Quality Baseline Report*. North Bay, Ontario. Ref. No. NB102-00181/30-6, Rev. 0. January 30.

Knight Piésold Ltd., 2012b. Memorandum to Oliver Curran, Baffinland Iron Mines Corporation. Re: *Response to Environment Canada IR EC-23 on Site-Specific Water Quality Objectives*. April 27. North Bay, Ontario. Ref. No. NB12-00183.

Knight Piésold Ltd., 2011. *Surface Water and Sediment Quality Baseline Report*. North Bay, Ontario. Ref. No. NB102-00181/30-5, Rev. 0. December 22.

Knight Piésold Ltd., 2010a. *Surface Water and Sediment Quality Baseline Report*. North Bay, Ontario. Ref. No. NB102-00181/25-2, Rev. 0. October 29.

Knight Piésold Ltd., 2010b. *Compendium to Surface Water and Sediment Quality Baseline Report*. North Bay, Ontario. Ref. No. NB102-00181/25-16, Rev. 0. December 31.

Knight Piésold Ltd., 2008. *2007 Baseline Water Quality Summary Report.* Ref. No. NB102-00181/7-5, Rev. A. June 6.

Knight Piésold Ltd., 2007. *2005/2006 Baseline Water Quality Summary Report.* Vancouver, BC. Vancouver, BC. Ref. No. NB102-00181/4-5, Rev. A. March 13.

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

Indian and Northern Affairs Canada, 2009. *Guidelines for Designing and Implementing Aquatic Effects Monitoring Programs for Development Projects in the Northwest Territories. Volume 6: Recommended Procedures for Evaluating, Compiling, Analyzing, Interpreting, and Reporting Data and Information Collected under the Aquatic Effects Monitoring Programs*. Available online at: http://mvlwb.com/sites/default/files/documents/INAC%20-%20AEMP%20Guidelines%20-%20Volume%206%20-%202009.pdf

Indian and Northern Affairs Canada, 2009. *Guidelines for Designing and Implementing Aquatic Effects Monitoring Programs for Development Projects in NWT: Overview Report*. Available online at: http://www.aadnc-aandc.gc.ca/DAM/DAM-INTER-NWT/STAGING/texte-text/aemp_1313792165251_eng.pdf

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.

Nunavut Impact Review Board, 2012. *NIRB Project Certificate No. 005*. In the matter of the Nunavut Land Claims Agreement, Nunavut Land Claims Agreement Act, S.C. 1993, c. 29, Article 12, Part 5 and in the matter of an application by Baffinland Iron Mines Corporation for the development of the Mary River Project Proposal in the Qikiqtani Region of Nunavut: NIRB Project Certificate No. 005.

Nunavut Water Board, 2013. Type A Water Licence No. 2AM-MRY1325. Issued on June 12, 2013.

North/South Consultants Inc., 2014. *Baffinland Iron Mines Corporation - Mary River Project - Core Receiving Environment Monitoring Program: Freshwater Biota*. Internal Draft, dated May 2014.

North/South Consultants Inc., 2012. *Baffinland Iron Mines Corporation - Mary River Project - Freshwater Aquatic Biota and Habitat Baseline Synthesis Report 2005-2011*. January 2012.

North/South Consultants Inc., 2010. Technical Memorandum Describing the Results of Monitoring for Effects of Dust Deposition from the Bulk Sampling Program: 2008. August 31, 2010.

North/South Consultants Inc., 2008. *Freshwater Aquatic Environment Baseline Report: Lake Limnology and Lower Trophic Levels: 2007*.

R Development Core Team, 2012. *R: A language and environment for statistical computing. R Foundation for Statistical Computing*. Vienna, Austria. ISBN 3-900051-07-0, URL http://www.R-project.org.

Smith, E., 2002. BACI Design. *Encyclopedia of Environmetrtics*. John Wiley and Sons. 1(141-148).

Stewart, K.A. and Lamoureux, S.F., 2011. Seasonal hydrochemical conditions and limnological response in adjacent High Arctic lakes: Cape Bounty, Melville Island, Nunavut. *Arctic* 64: 169-182.

Stroup, W.W., 1999. *Mixed Model Procedures to Assess Power, Precision, and Sample Size in the Design of Experiments*. Department of Biometry, University of Nebraska.

Underwood, A.J., and C.H. Peterson, 1992. Beyond BACI: experimental designs for detecting human environmental impacts in the real, but variable, world. *Journal of Experimental Marine Biology and Ecology*. 161: 145-178.

APPENDIX A

WATER AND SEDIMENT QUALITY SAMPLING PROTOCOL

(Pages A-1 to A-24)

APPENDIX B

DETAILED REVIEW OF BASELINE LAKE WATER QUALITY

(Pages B-1 to B-98)

APPENDIX C

DETAILED REVIEW OF BASELINE STREAM WATER QUALITY

(Pages C-1 to C-70)

APPENDIX D

DETAILED REVIEW OF BASELINE SEDIMENT QUALITY

(Pages D-1 to D-37)

APPENDIX A

WATER AND SEDIMENT QUALITY SAMPLING PROTOCOL

REVISION 1

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

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

DOCUMENT REVISION RECORD

Issue Date MM/DD/YY	Revision	Prepared By	Approved By	Issue Purpose
03/28/14	0	KP	KP	Issued in Final
03/31/16	1	AV	JM	Updated to reflect CREMP Study Design modifications proposed by Minnow in 2016

Index of Major Changes/Modifications in Revision 1

Item No.	Description of Change	Relevant Section
1	Included Baffinland's Sampling Program – Quality Assurance and Quality Control Plan (BAF-PH1-830-P16-0001) and discussed Minnow's recommendations for future CREMP monitoring.	1.0
2	Updated Table 2.1 to reflect the bottle types required in the 2015 CREMP field program.	2.2.2
3	Updated sampling handling and shipping protocols to reflect current operations.	2.2.5
4	Updated all lake sampling methodology sections to reflect recommendations proposed by Minnow.	2.3
5	Included modifications recommended by Minnow regarding water quality sampling methodology and protocols.	2.4
6	Discussed Minnow's recommendations to discontinue stream and sampling stations from future CREMP sediment sampling programs. Removed sections discussing stream and river sediment sampling methodology and protocols.	3.1, 3.3
7	Updated list of water and sediment quality analytes/parameters to reflect the parameters analyzed in the 2015 CREMP field program.	Appendix A
8	Replaced Exova COC with an ALS COC example.	Appendix C
9	Added Baffinland's Sampling Program – Quality Assurance and Quality Control Plan (BAF-PH1-830-P16-0001) as Appendix D.	Appendix D

Baffinland

April, 2016

PREFACE

This document was originally written by Knight Piésold Consulting in March 2014 for Baffinland Iron Mines Corporation (Baffinland). This document had been revised by Baffinland to reflect the recommendations proposed by Minnow Environmental Inc. in 2016 regarding modifications to the CREMP Study Design.

TABLE OF CONTENTS

PAGE

TABLES

FIGURES

APPENDICES

Appendix A – 2015 Surface Water and Sediment Quality Parameter List
Appendix B – Field Record Sheet
Appendix C – Example of Chain of Custody
Appendix D – Sampling Program – Quality Assurance and Quality Control Plan (BAF-PH1-830-P16-0001)

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

This document is intended to provide a detailed description of the surface water and sediment quality field sampling methodologies that are applied to the CREMP sampling programs and should be used in conjunction with Baffinland's Sampling Program – Quality Assurance and Quality Control Plan (QA/QC Plan) (Appendix D). Where methodology protocols differ between this document and Baffinland's QA/QC Plan, methodology protocols outlined in this document will be followed.

CREMP water quality stations are monitored three (3) times per year. Stream water quality will be monitored during the spring, summer and fall, whereas, lake water quality will take place during the winter (late April), summer and fall. Lake sediment sampling is done concurrently with the surface water sampling program during the fall sampling event.

In 2015, Minnow Environmental Inc. (Minnow) was contracted to assist Baffinland in completing the fieldwork and reporting requirements of several of the AEMP component studies, including the CREMP. After completing the CREMP in 2015, Minnow proposed several modifications to the program (presented in Appendix I of the AEMP) to provide greater efficiencies and improve the program's ability to achieve its objectives (i.e. to evaluate short and long term effects of the Project on aquatic ecosystems).

The sampling methodologies within this protocol have been revised to reflect Minnow's recommendations.

This document includes 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 has been collected for the Mary River Project (the Project) during every year since 2005, with the exception of 2009 and 2010. The analytical suite of parameters include 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 containing no acid preservative are rinsed three times before filling. For bottles already containing a preservative, the samples are transferred from a clean bottle/jug 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 measured with a tape measure. Photos are taken upstream, downstream and across the sampling site.

The water quality monitoring program includes a suite of analytical parameters (Appendix A). The laboratory typically provides eight (8) sample bottles per bottle set for these analyses (Table 2.1)

Table 2.1 - Water Quality Sample Bottle Set Summary

Sample Bottle Description/Volume	Quantity	Preservative	Analytical Parameter
125 mL HDPE	1	Add HNO_3	Total Metals/Hardness
125 mL HDPE	1	Add HNO_3 after filtering	Dissolved Metals
120 mL Square Glass	1	Add HCl	Total Mercury
120 mL Square Glass	1	Add HCl after filtering	Dissolved Mercury
250 mL Round Glass	1	Add H_2SO_4	Nutrients
1 L Rectangular HDPE	1	None	General Chemistry
1 L Amber Glass	1	None	Chlorophyll-a/Pheophytin-a

The metals and mercury sample bottles require nitric and hydrochloric acid preservative, respectively. Preservatives are provided in single dose vials (one vial per bottle) by the accredited laboratory.

Prior to the addition of preservative, samples for dissolved metals 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 is utilized in the field:

- 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., YSI 6820, ProDSS 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) (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. QA/QC samples will be taken for 10 percent of the total number of samples. At least, 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 and saved on the main Environmental server for all samples collected. The completed COC will be sent electronically to the accredited lab conducting the analysis. A hard copy of the completed COC will also be sent with the cooler containing the samples. An example of a completed CoC form is included as Appendix C.

The current on-site laboratory is operated by ALS Canada Ltd. and is located at the Mine Site (Mine Site ALS Lab). Periodically, a select set of water quality parameters may be analyzed (i.e. turbidity, TSS, pH) or processed (i.e. filtering of chlorophyll a samples) onsite at the Mine Site ALS Lab to ensure parameters (analytes) are analyzed within the required holding times. The off-site laboratory, ALS Environmental, located in Waterloo, ON, run by ALS Canada Ltd. (Waterloo ALS Lab) performs the majority of analyses required.

Samples will be packaged in coolers with ice packs to ensure the temperature of the samples remain near 4 °C during transportation to the accredited laboratory.

Samples will be shipped from the Mine Site to the Mirabel airport and then expedited to the Waterloo ALS Lab by courier. All samples shipped from the Mine Site will be considered priority cargo to ensure samples are analyzed within the necessary parameter holding times.

2.3 LAKE SAMPLING METHODOLOGY

2.3.1 Sampling Strategy

Consistent sampling methods have been applied throughout the lake water sampling programs to date. Prior to 2016, water quality samples were collected from two isolated depths (approximately 1 meter below surface and approximately 1 meter above the bottom) at each of the lake water quality sites.

In the list of recommendations proposed by Minnow (cover letter of AEMP), Minnow noted that no consistent spatial differences in water quality/chemistry were evident in any of the study lakes in 2015, nor during any of the baseline studies, concluding that sampling at two isolated depths at each lake water quality site was redundant and unnecessary (Minnow, 2016). Similarity in surface and bottom water quality was also noted in sampled lakes (with the exception of aluminum in Sheardown Lake) in the 2014 AEMP Appendix C

Therefore, at each lake water quality site one sample will be taken at mid-depth unless *in-situ* water quality measurements (using a multi-parameter probe) suggests the sediment may be under anoxic conditions (<2 mg/L DO). If the sediment at the water quality site is suspected to be under anoxic conditions, water quality samples will be collected at approximately one meter below the surface and one meter above the bottom/sediment.

Small aluminum boats are used to access the lake water quality sites and are anchored at the sites 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 water quality site 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 water quality monitoring program includes a suite of analytes (Appendix A). As discussed above (Table 2.1), the analytical laboratory provides eight (8) sample bottles per bottle set 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 bottles (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 each water quality sample taken at any of the lake water quality sites.

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

Prior to collecting water quality samples at each station, secchi depths should be recorded and *in-situ* monitoring near the water-sediment interface should be conducted to determine if sediment at the site is under anoxic conditions (<2 mg/L DO). Technicians should be extra vigilant in ensuring that sediment is not disturbed while determining the DO levels near the water-sediment interface.

As discussed in Section 2.3.1, if the sediment at the water quality site is suspected to be under anoxic conditions, water quality samples will be collected at approximately one meter below the surface and approximately one meter above the bottom/sediment. In addition to collecting two water samples at the site, *in-situ* profiling will also be conducted to further understand the degree and extent of the anoxic conditions.

In addition, *in-situ* profiling of the water column will be conducted at the main basin of each study lake, with the exception of Mary Lake where profiling with occur at both the north and south basin. These water quality sites, shown below, will have complete water column profiles completed during each sampling event regardless of the DO levels near the water-sediment interface.

Camp Lake Station - JL0-07
Sheardown Lake NW Station – DL0-01-2
Sheardown Lake SE Station – DL0-02-3
Mary Lake (North Basin) Station – BL0-1A
Mary Lake (South Basin) Station – BL0-9
Reference Lake 3 (NW Basin) Station – REF03-3

The *in-situ* profiling is undertaken using a measuring tape that is secured to a multi-parameter probe (e.g., YSI 6820, ProDSS 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 2.2.3

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 stream samples, QA/QC 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 COCs 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 2015, 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 are included in Appendix B.

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

To maintain consistency, all future sampling events after 2015 will use a Kemmerer bottle sampler to collect lake water quality samples.

As discussed in Section 2.3.1, prior to 2016, lake water quality sampling protocol involved taking water samples at two isolated depths (approximately 1 meter below surface and approximately 1 meter above the bottom) and conducting an *in-situ* water quality profile at each lake water quality site.

In 2015, Minnow Environmental Inc. (Minnow) was contracted to assist Baffinland in completing the fieldwork and reporting requirements of several of the AEMP component studies, including the CREMP. After completing the CREMP in 2015, Minnow proposed several modifications to the program (presented in Appendix I of the AEMP) to provide greater efficiencies and improve the program's ability to achieve its objectives (i.e. to evaluate short and long term effects of the Project on aquatic ecosystems).

In the list of recommendations proposed by Minnow (Appendix I of AEMP), Minnow noted that no consistent spatial differences in water quality/chemistry were evident in any of the study lakes in 2015, nor during any of the baseline studies, suggesting that study lakes are generally well mixed with relatively uniform water chemistry throughout the year. (Minnow, 2016) (Minnow, 2016). Because of this, Minnow proposed two adjustments to the water quality sampling methodology being applied to the CREMP water quality program:

1. Changing the number and depth at which water samples were taken (previously near surface and bottom) to a single sample taken at mid-depth (Item 9; Minnow, 2016)
2. Limiting water quality *in-situ* profiling to a few select stations located at the main basins of study lakes as well as any stations showing anoxic conditions (Item 8; Minnow 2016)

This document along with the CREMP study design has been modified to reflect both of these recommendations.

3 – SEDIMENT QUALITY

3.1 GENERAL

Stream sediment quality data was collected for the Project every year between 2005 to 2015, with the exception of 2009 and 2010. Lake sediment quality data was 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 current 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 changes in sediment quality from baseline data that may be attributed to mine operations and that may pose a risk to benthic macroinvertebrate communities. As such, sediment samples will be continued to be collected concurrently with benthic macroinvertebrate samples.

Following the 2015 CREMP field program, Minnow recommended that stream sediment sampling be discontinued in future CREMP studies due to the very limited amount of depositional habitat suitable for the collection of sediment in the streams and rivers located in the Mary River Project local study area. As observed during the 2015 CREMP and baseline studies, the general absence of any substantial accumulation of fine sediments within the studied watercourses preclude any meaningful assessment of potential mine-related influences on sediment quality within, along and/or between watercourses (Minnow, 2016). Because of this, historic sediment sampling sites within streams and rivers have been removed from the CREMP Study Design.

3.2 LAKE SEDIMENT SAMPLING METHODOLOGY

3.2.1 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.

3.2.2 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.

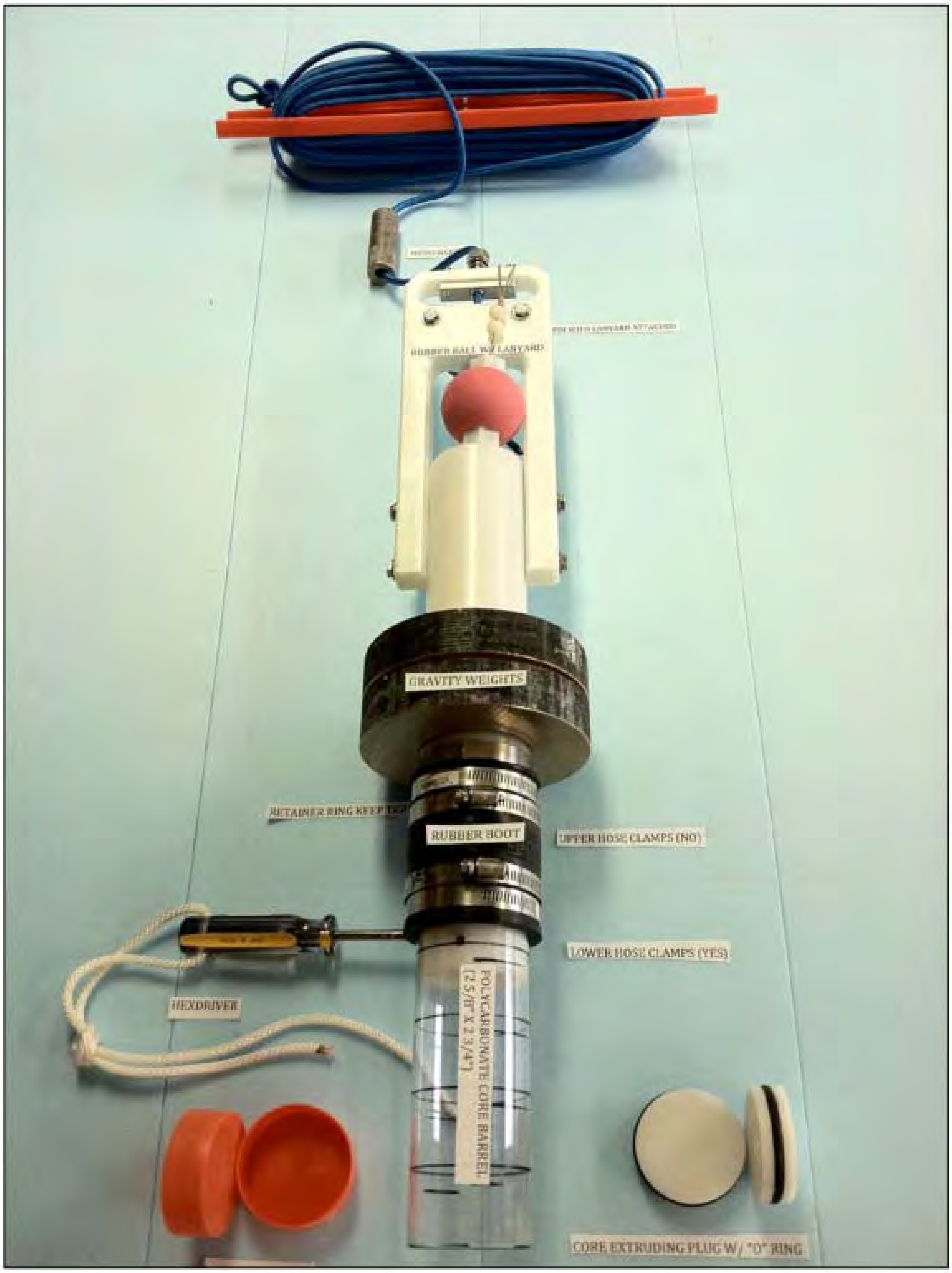


Figure 3.1 – Sediment Gravity Core Sampler

3.2.3 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 the 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 the 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 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.

3.2.4 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.

3.2.5 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.

3.2.6 Chain of Custody and Sample Shipment

The COCs and sample shipping methods are discussed in Section 2.2.5.

3.3 METHODOLOGY ADJUSTMENTS OVER TIME

Sediment sampling conducted prior to 2012 utilized a Petite Ponar grab sampler (231 cm2) or an Ekman dredge sampler (523 cm2). 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.

As discussed in Section 3.1, beginning in 2016, stream and river sediment sampling will no longer conducted as part of the CREMP sediment sampling program.

4 – REFERENCES

Environment Canada (EC). 2012. *Environmental Effects Monitoring Technical Guidance Document*. National Environmental Effects Monitoring Office.

Minnow Environmental Inc. (Minnow). 2016. *Mary River Project CREMP Recommendations for Future Monitoring*.

APPENDIX A

2015 SURFACE WATER AND SEDIMENT QUALITY PARAMETER LIST

Water Quality Parameters

Parameter	Lowest Detection Limit	Units
Physical Tests (Water)		
Conductivity	3.0	umhos/cm
Hardness (as CaCO3)	10	mg/L
pH	0.10	pH units
Total Suspended Solids	2.0	mg/L
Total Dissolved Solids	20	mg/L
Turbidity	0.10	NTU
Anions and Nutrients (Water)		
Alkalinity, Total (as CaCO3)	10	mg/L
Ammonia, Total (as N)	0.050	mg/L
Bromide (Br)	0.10	mg/L
Chloride (Cl)	0.50	mg/L
Nitrate and Nitrite as N	0.021	mg/L
Nitrate (as N)	0.020	mg/L
Nitrite (as N)	0.0050	mg/L
Total Kjeldahl Nitrogen	0.15	mg/L
Total Phosphorus	0.0030	mg/L
Sulfate (SO4)	0.30	mg/L
Organic / Inorganic Carbon (Water)		
Dissolved Organic Carbon	1.0	mg/L
Total Organic Carbon	1.0	mg/L
Total Metals (Water)		
Mercury (Hg)-Total	0.000010	mg/L
Total Metals (Undigested) (Water)		
Aluminum (Al)-Total	0.0030	mg/L
Antimony (Sb)-Total	0.00010	mg/L
Arsenic (As)-Total	0.00010	mg/L
Barium (Ba)-Total	0.000050	mg/L
Beryllium (Be)-Total	0.00050	mg/L
Bismuth (Bi)-Total	0.00050	mg/L
Boron (B)-Total	0.010	mg/L
Cadmium (Cd)-Total	0.000010	mg/L
Calcium (Ca)-Total	0.050	mg/L
Chromium (Cr)-Total	0.00050	mg/L
Cobalt (Co)-Total	0.00010	mg/L
Copper (Cu)-Total	0.00050	mg/L
Iron (Fe)-Total	0.030	mg/L
Lead (Pb)-Total	0.000050	mg/L
Lithium (Li)-Total	0.0010	mg/L
Magnesium (Mg)-Total	0.050	mg/L
Manganese (Mn)-Total	0.000070	mg/L
Molybdenum (Mo)-Total	0.000050	mg/L
Nickel (Ni)-Total	0.00050	mg/L
Potassium (K)-Total	0.20	mg/L
Selenium (Se)-Total	0.0010	mg/L
Silicon (Si)-Total	0.10	mg/L
Silver (Ag)-Total	0.000010	mg/L
Sodium (Na)-Total	0.050	mg/L

Strontium (Sr)-Total	0.00010	mg/L
Thallium (Tl)-Total	0.00010	mg/L
Tin (Sn)-Total	0.00010	mg/L
Titanium (Ti)-Total	0.010	mg/L
Uranium (U)-Total	0.000010	mg/L
Vanadium (V)-Total	0.0010	mg/L
Zinc (Zn)-Total	0.0030	mg/L

Dissolved Metals (Water)

Aluminum (Al)-Dissolved	0.00060	mg/L
Antimony (Sb)-Dissolved	0.000020	mg/L
Arsenic (As)-Dissolved	0.000020	mg/L
Barium (Ba)-Dissolved	0.000030	mg/L
Beryllium (Be)-Dissolved	0.000010	mg/L
Bismuth (Bi)-Dissolved	0.0000050	mg/L
Boron (B)-Dissolved	0.0050	mg/L
Cadmium (Cd)-Dissolved	0.0000050	mg/L
Calcium (Ca)-Dissolved	0.020	mg/L
Chromium (Cr)-Dissolved	0.00010	mg/L
Cobalt (Co)-Dissolved	0.0000050	mg/L
Copper (Cu)-Dissolved	0.00010	mg/L
Iron (Fe)-Dissolved	0.0010	mg/L
Lead (Pb)-Dissolved	0.0000090	mg/L
Lithium (Li)-Dissolved	0.00050	mg/L
Magnesium (Mg)-Dissolved	0.0050	mg/L
Manganese (Mn)-Dissolved	0.000070	mg/L
Mercury (Hg)-Dissolved	0.000010	mg/L
Molybdenum (Mo)-Dissolved	0.000050	mg/L
Nickel (Ni)-Dissolved	0.000090	mg/L
Phosphorus (P)-Dissolved	0.050	mg/L
Potassium (K)-Dissolved	0.050	mg/L
Selenium (Se)-Dissolved	0.000040	mg/L
Silicon (Si)-Dissolved	0.050	mg/L
Silver (Ag)-Dissolved	0.0000050	mg/L
Sodium (Na)-Dissolved	0.020	mg/L
Strontium (Sr)-Dissolved	0.000050	mg/L
Sulfur (S)-Dissolved	1.0	mg/L
Thallium (Tl)-Dissolved	0.0000020	mg/L
Tin (Sn)-Dissolved	0.000030	mg/L
Titanium (Ti)-Dissolved	0.00050	mg/L
Uranium (U)-Dissolved	0.0000070	mg/L
Vanadium (V)-Dissolved	0.000050	mg/L
Zinc (Zn)-Dissolved	0.00050	mg/L
Zirconium (Zr)-Dissolved	0.00010	mg/L

Aggregate Organics (Water)

Phenols (4AAP)	0.0010	mg/L

Plant Pigments (Water)

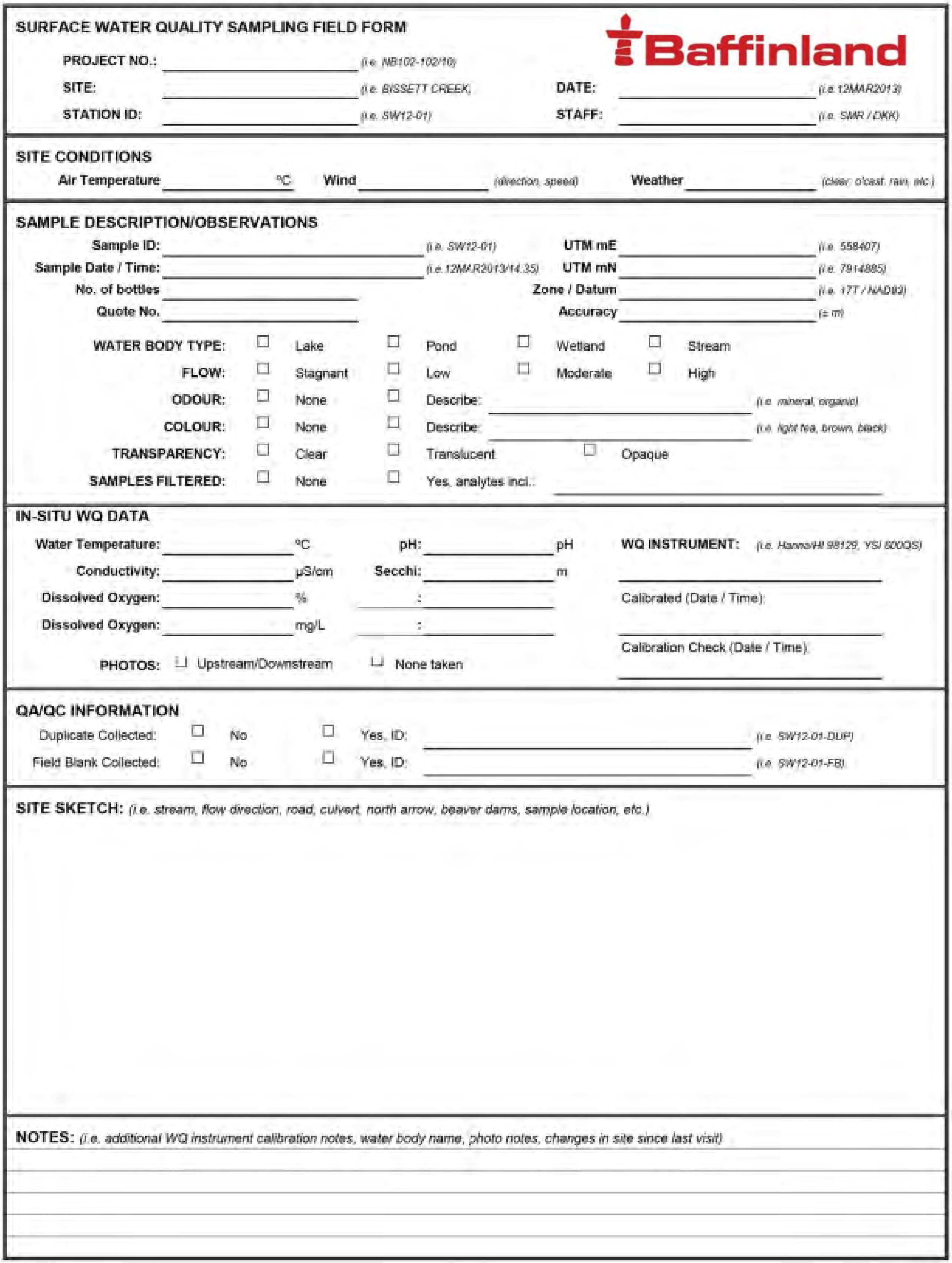
Chlorophyll a	0.10	ug/L
Phaeophytin a	0.10	ug/L

SEDIMENT QUALITY PARAMETERS

Parameter	Lowest Detection Limit	Units
Physical Tests (Sediment)		
% Moisture	0.10	%
Particle Size (Sediment)		
% Sand (2.0mm - 0.05mm)	0.10	%
% Silt (0.05mm - 2um)	0.10	%
% Clay (<2um)	0.10	%
Texture		-
Organic / Inorganic Carbon (Sediment)		
Fraction Organic Carbon	0.0010	g/g
Total Organic Carbon	0.10	%
Metals (Sediment)		
Aluminum (Al)	50	ug/g
Antimony (Sb)	0.10	ug/g
Arsenic (As)	0.10	ug/g
Barium (Ba)	0.50	ug/g
Beryllium (Be)	0.10	ug/g
Bismuth (Bi)	0.20	ug/g
Boron (B)	5.0	ug/g
Cadmium (Cd)	0.020	ug/g
Calcium (Ca)	50	ug/g
Chromium (Cr)	0.50	ug/g
Cobalt (Co)	0.10	ug/g
Copper (Cu)	0.50	ug/g
Iron (Fe)	50	ug/g
Lead (Pb)	0.50	ug/g
Lithium (Li)	2.0	ug/g
Magnesium (Mg)	20	ug/g
Manganese (Mn)	1.0	ug/g
Mercury (Hg)	0.0050	ug/g
Molybdenum (Mo)	0.10	ug/g
Nickel (Ni)	0.50	ug/g
Phosphorus (P)	50	ug/g
Potassium (K)	100	ug/g
Selenium (Se)	0.20	ug/g
Silver (Ag)	0.10	ug/g
Sodium (Na)	50	ug/g
Strontium (Sr)	0.50	ug/g
Sulfur (S)	5000	ug/g
Thallium (Tl)	0.050	ug/g
Tin (Sn)	2.0	ug/g
Titanium (Ti)	1.0	ug/g
Uranium (U)	0.050	ug/g
Vanadium (V)	0.20	ug/g
Zinc (Zn)	2.0	ug/g
Zirconium (Zr)	1.0	ug/g

APPENDIX B

FIELD RECORD SHEET



SURFACE WATER QUALITY SAMPLING FIELD FORM

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 ______ °C **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: ______ °C **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)*

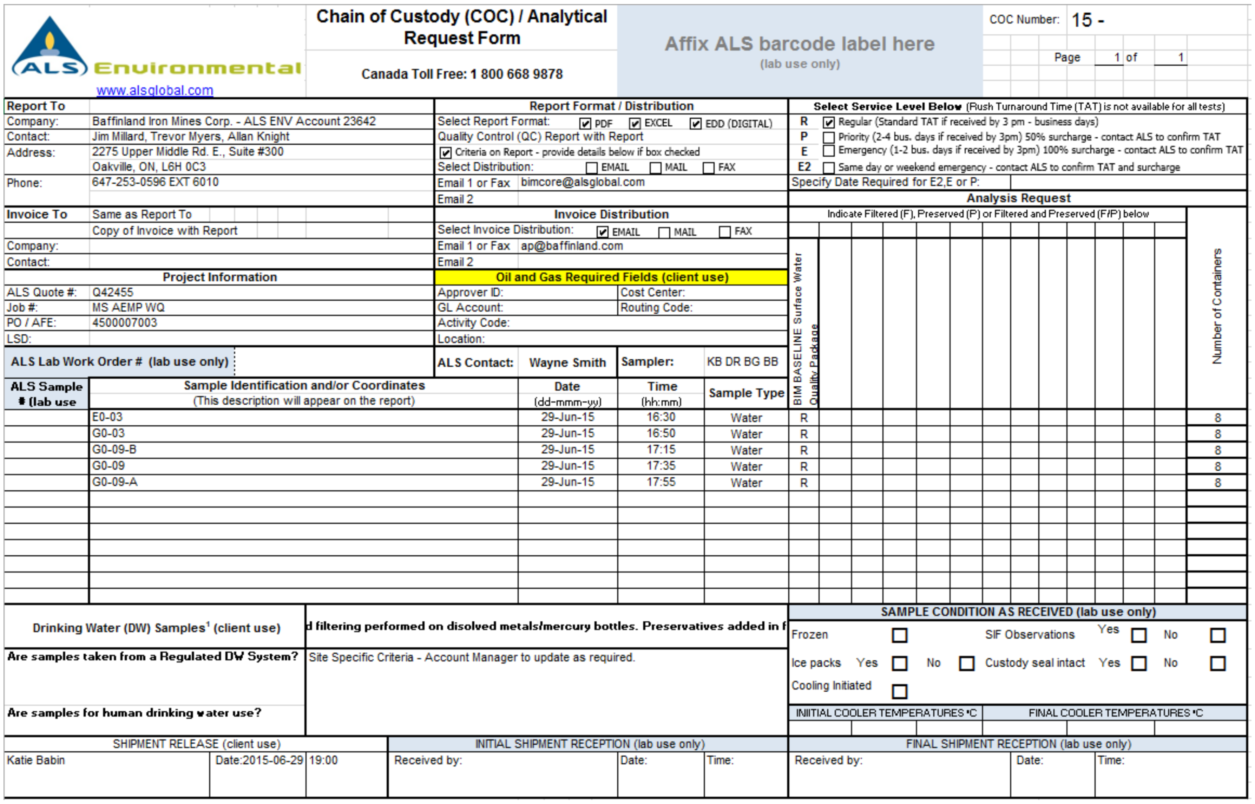
Field Blank Collected: ☐ No ☐ Yes, ID: ______ *(i.e. SW12-01-FB)*

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 OF CHAIN OF CUSTODY



ALS Environmental
www.alsglobal.com

Chain of Custody (COC) / Analytical Request Form

Canada Toll Free: 1 800 668 9878

Affix ALS barcode label here
(lab use only)

COC Number: 15 -

Page 1 of 1

Report To	
Company:	Baffinland Iron Mines Corp. - ALS ENV Account 23642
Contact:	Jim Millard, Trevor Myers, Allan Knight
Address:	2275 Upper Middle Rd. E., Suite #300 Oakville, ON, L6H 0C3
Phone:	647-253-0596 EXT 6010

Report Format / Distribution

Select Report Format: ☑ PDF ☑ EXCEL ☑ EDD (DIGITAL)
Quality Control (QC) Report with Report
☑ Criteria on Report - provide details below if box checked
Select Distribution: ☐ EMAIL ☐ MAIL ☐ FAX
Email 1 or Fax bimcore@alsglobal.com
Email 2

Select Service Level Below (Rush Turnaround Time (TAT) is not available for all tests)

- R ☑ Regular (Standard TAT if received by 3 pm - business days)
- P ☐ Priority (2-4 bus. days if received by 3pm) 50% surcharge - contact ALS to confirm TAT
- E ☐ Emergency (1-2 bus. days if received by 3pm) 100% surcharge - contact ALS to confirm TAT
- E2 ☐ Same day or weekend emergency - contact ALS to confirm TAT and surcharge

Specify Date Required for E2,E or P:

Invoice To	Same as Report To
	Copy of Invoice with Report
Company:	
Contact:	

Invoice Distribution

Select Invoice Distribution: ☑ EMAIL ☐ MAIL ☐ FAX
Email 1 or Fax ap@baffinland.com
Email 2

Project Information

ALS Quote #:	Q42455
Job #:	MS AEMP WQ
PO / AFE:	4500007003
LSD:	

Oil and Gas Required Fields (client use)

Approver ID:
Cost Center:
GL Account:
Routing Code:
Activity Code:
Location:

ALS Lab Work Order # (lab use only)

ALS Contact: Wayne Smith
Sampler: KB DR BG BB

Analysis Request

Indicate Filtered (F), Preserved (P) or Filtered and Preserved (F/P) below

ALS Sample # (lab use	Sample Identification and/or Coordinates (This description will appear on the report)	Date (dd-mmm-yy)	Time (hh:mm)	Sample Type	BIM BASELINE Surface Water Quality Package	Number of Containers
	E0-03	29-Jun-15	16:30	Water	R	8
	G0-03	29-Jun-15	16:50	Water	R	8
	G0-09-B	29-Jun-15	17:15	Water	R	8
	G0-09	29-Jun-15	17:35	Water	R	8
	G0-09-A	29-Jun-15	17:55	Water	R	8

Drinking Water (DW) Samples[1] (client use)

Are samples taken from a Regulated DW System?

Are samples for human drinking water use?

d filtering performed on disolved metals/mercury bottles. Preservatives added in f

Site Specific Criteria - Account Manager to update as required.

SAMPLE CONDITION AS RECEIVED (lab use only)

Frozen ☐ SIF Observations Yes ☐ No ☐
Ice packs Yes ☐ No ☐ Custody seal intact Yes ☐ No ☐
Cooling Initiated ☐

INIITIAL COOLER TEMPERATURES °C
FINAL COOLER TEMPERATURES °C

SHIPMENT RELEASE (client use)			INITIAL SHIPMENT RECEPTION (lab use only)			FINAL SHIPMENT RECEPTION (lab use only)		
Katie Babin	Date:2015-06-29	19:00	Received by:	Date:	Time:	Received by:	Date:	Time:

APPENDIX D

SAMPLING PROGRAM – QUALITY ASSURANCE AND QUALITY CONTROL PLAN
(BAF-PH1-830-P16-0001 r1)

Baffinland Iron Mines Corporation

Sampling Program – Quality Assurance and Quality Control Plan

BAF-PH1-830-P16-0001

Rev 1

Prepared By: William Bowden
Department: Environment
Title: Environmental Coordinator
Date: March 14, 2016
Signature:

Approved By: Erik Madsen
Department: Health, Safety and Environment
Title: Vice President – SD, Environment, Health & Safety
Date: March 14, 2016
Signature:

DOCUMENT REVISION RECORD

Issue Date MM/DD/YY	Revision	Prepared By	Approved By	Issue Purpose
01/15/2014	0	JM	EM	Approved for Use
03/14/16	1	WB	EM	Approved for Use

TRACK CHANGES TABLE

A review and update of the Surface Water Sampling Program – Quality Assurance and Quality Control Plan has been undertaken, with the following salient revisions to the January 15, 2014 version (BAF-PH1-830-P16-0001, Rev 0).

Index of Major Changes/Modifications in Revision 5

Item No.	Description of Change	Relevant Section
1	Major revision to whole document	
2		
3		
4		
5		
6		
7		
8		
9		
10		

TABLE OF CONTENTS

List of Appendix

Appendix A- Quality Assurance Assurance (QA) and Quality Control (QC) Guidelines for use by Class "A" Licensees in Meeting SNP Requirements and for Submission of a QA/QC Plan (INAC, 1996).

Appendix B- Example Forms

Appendix C- Analytical Laboratory Accreditation and Licencing

Appendix D- Laboratory Analytical Methods

Appendix E- Analytical Laboratory QA/QC Procedures

List of Table

List of Figure

1 INTRODUCTION

As required by Baffinland Iron Mines Corporation's (Baffinland) Type A Water Licence No. 2AM-MRY1325 Amendment No. 1 (Type A Water Licence) and Type B Water Licence No. 2BE-MRY1421 (Type B Water Licence) for the Mary River Project (Project), a review of Project Environmental Management and Monitoring Plans (EEMPs) was completed. This Quality Assurance and Quality Control (QA/QC) Plan was updated to meet the requirements of the Type A and B water licences. Further and continual modifications and revisions to this Plan shall be completed based on future work scope modifications, QA/QC procedures, and associated approvals. Updates to this Plan shall be completed in accordance to the terms and conditions of Baffinland's Water Licences, QIA Commercial Lease – Q13C301, issued September 6, 2013, the amended Project Certificate No. 005 issued by the Nunavut Impact Review Board (NIRB) and any subsequent requirements which may be issued.

This Quality Assurance and Quality Control (QA/QC) Plan has been reviewed to fulfill the requirement of Part I, Item 16 of License No. 2AM-MRY1325 Amendment No. 1 approved by the Nunavut Water Board to Baffinland Iron Mines Corporation (Baffinland) on July 31, 2014.

In accordance with the stipulations of the Type A Water Licence No. 2AM-MRY1325 Amendment No. 1, this Surface QA/QC Plan has been prepared following the general recommendations presented in *Quality Assurance (QA) and Quality Control (QC) Guidelines for use by Class "A" Licensees in Meeting SNP Requirements and for Submission of a QA/QC Plan* (INAC, 1996). A copy of the guidelines is included in Appendix A.

1.1 PURPOSE AND SCOPE

The purpose of this Plan is to identify Baffinland's framework for accurate and effective QA/QC management by providing instruction for standardised field sample and laboratory analytical procedures.

For the purposes of this report, QA/QC is defined as:

- ***Quality Assurance*** - System of activities used to achieve quality control.
- ***Quality Control*** - Set of best practice methods and procedures used to ensure quality of data in terms of precision, accuracy and reliability.

The QA/QC best practices outlined in this management plan are designed to provide guidance to field staff and analytical laboratories in order to maintain a high level of confidence in the water quality, soil, and benthic data generated from Project Sites.

1.1.1 2016 WORK PLAN UPDATE

To support the activities identified in the 2016 Work Plan, Baffinland is committed to following the QA/QC procedures documented within this management plan.

1.2 REGULATORY REQUIRMENTS

Baffinland's QA/QC Plan is regulated by the Nunavut Water Board (NWB) and is subject to Baffinland's Type A Water Licence No. 2AM-MRY1325 Amendment No. 1 which provides specific Terms and Conditions for the management of QA/QC procedures at the Project Sites.

Both federal and territorial legislation regulates Water and Soil Quality and Benthic communities in Nunavut. This legislation expects a professional standard and level of confidence when evaluating these Parameters and therefore apply to this QA/QC management plan

1.3 RELATIONSHIPS TO OTHER MANAGEMENT PLANS

This Plan is intended for use in conjunction with the following Plans:

- Air Quality and Noise Abatement Management Plan (BAF-PH1-830-P16-0002)
- Aquatic Effects and Monitoring Plan (BAF-PH1-830-P16-0039)
- Environmental Protection Plan (BAF-PH1-830-P16-0008)
- Fresh Water, Sewage and Wastewater Management Plan (BAF-PH1-830-P16-0010)
- Hazardous Materials and Hazardous Waste Management Plan (BHF-PH1-830-P16-0011)
- Interim Mine Closure and Reclamation Plan (BAF-PH1-830-P16-0012)
- Surface Water, Aquatic Ecosystems, Fish and Fish Habitat Management Plan (BAF-PH1-830-P16-0026)
- Terrestrial Environmental Management and Monitoring Plan (BAF-PH1-830-P16-0027)
- Waste Management Plan (BAF-PH1-830-P16-0028)

2 BAFFINLAND POLICIES

2.1 HEALTH, SAFETY AND ENVIRONMENT POLICY

This Baffinland Iron Mines Corporation Policy on Health, Safety and Environment is a statement of our commitment to achieving a safe, healthy and environmentally responsible workplace. We will not compromise this policy for the achievement of any other organizational goals.

We implement this Policy through the following commitments:

- Continual improvement of safety, occupational health and environmental performance
- Meeting or exceeding the requirements of regulations and company policies
- Integrating sustainable development principles into our decision-making processes
- Maintaining an effective Health, Safety and Environmental Management System
- Sharing and adopting improved technologies and best practices to prevent injuries, occupational illnesses and environmental impacts
- Engaging stakeholders through open and transparent communication.
- Efficiently using resources, and practicing responsible minimization, reuse, recycling and disposal of waste.
- Reclamation of lands to a condition acceptable to stakeholders.

Our commitment to provide the leadership and action necessary to accomplish this policy is exemplified by the following principles:

- As evidenced by our motto "Safety First, Always" and our actions Health and safety of personnel and protection of the environment are values not priorities.
- All injuries, occupational illnesses and environmental impacts can be prevented.
- Employee involvement and active contribution through courageous leadership is essential for preventing injuries, occupational illnesses and environmental impacts.
- Working in a manner that is healthy, safe and environmentally sound is a condition of employment.
- All operating exposures can be safeguarded.
- Training employees to work in a manner that is healthy, safe and environmentally sound is essential.
- Prevention of personal injuries, occupational illnesses and environmental impacts is good business.
- Respect for the communities in which we operate is the basis for productive relationships.

We have a responsibility to provide a safe workplace and utilize systems of work to meet this goal. All employees must be clear in understanding the personal responsibilities and accountabilities in relation to the tasks we undertake.

The health and safety of all people working at our operation and responsible management of the environment are core values to Baffinland. In ensuring our overall profitability and business success every Baffinland and business partner employee working at our work sites is required to adhere to this Policy.

Brian Penney
Chief Executive Officer
March 2016

2.2 SUSTAINABLE DEVELOPMENT POLICY

At Baffinland Iron Mines Corporation (Baffinland), we are committed to conducting all aspects of our business in accordance with the principles of sustainable development & corporate responsibility and always with the needs of future generations in mind. Baffinland conducts its business in accordance with the Universal Declaration of Human Rights and ArcelorMittal’s Human Rights Policy which applies to all employees and affiliates globally.

Everything we do is underpinned by our responsibility to protect the environment, to operate safely and fiscally responsibly and with utmost respect for the cultural values and legal rights of Inuit. We expect each and every employee, contractor, and visitor to demonstrate courageous leadership in personally committing to this policy through their actions. The Sustainable Development and Human Rights Policy is communicated to the public, all employees and contractors and it will be reviewed and revised as necessary on a regular basis. These four pillars form the foundation of our corporate responsibility strategy:

1. Health and Safety
2. Environment
3. Upholding Human Rights of Stakeholders
4. Transparent Governance

1.0 HEALTH AND SAFETY

- We strive to achieve the safest workplace for our employees and contractors; free from occupational injury and illness, where everyone goes home safe everyday of their working life. Why? Because our people are our greatest asset. Nothing is as important as their health and safety. Our motto is “Safety First, Always”.
- We report, manage and learn from injuries, illnesses and high potential incidents to foster a workplace culture focused on safety and the prevention of incidents.
- We foster and maintain a positive culture of shared responsibility based on participation, behaviour, awareness and promoting active courageous leadership. We allow our employees and contractors the right to stop any work if and when they see something that is not safe.

2.0 ENVIRONMENT

- Baffinland employs a balance of the best scientific and traditional Inuit knowledge to safeguard the environment.
- Baffinland applies the principles of pollution prevention, waste reduction and continuous improvement to minimize ecosystem impacts, and facilitate biodiversity conservation.
- We continuously seek to use energy, raw materials and natural resources more efficiently and effectively. We strive to develop more sustainable practices.
- Baffinland ensures that an effective closure strategy is in place at all stages of project development to ensure reclamation objectives are met.

3.0 UPHOLDING HUMAN RIGHTS OF STAKEHOLDERS

- We respect human rights, the dignity of others and the diversity in our workforce. Baffinland honours and respects the unique cultural values and traditions of Inuit.
- Baffinland does not tolerate discrimination against individuals on the basis of race, colour, gender, religion, political opinion, nationality or social origin, or harassment of individuals freely employed.
- Baffinland contributes to the social, cultural and economic development of sustainable communities in the North Baffin Region.
- We honour our commitments by being sensitive to local needs and priorities through engagement with local communities, governments, employees and the public. We work in active partnership to create a shared understanding of relevant social, economic and environmental issues, and take their views into consideration when making decisions.
- We expect our employees and contractors, as well as community members, to bring human rights concerns to our attention through our external grievance mechanism and internal human resources channels. Baffinland is committed to engaging with our communities of interest on our human rights impacts and to reporting on our performance.

4.0 TRANSPARENT GOVERNANCE

- Baffinland will take steps to understand, evaluate and manage risks on a continuing basis, including those that may impact the environment, employees, contractors, local communities, customers and shareholders.
- Baffinland endeavours to ensure that adequate resources are available and that systems are in place to implement risk-based management systems, including defined standards and objectives for continuous improvement.
- We measure and review performance with respect to our safety, health, environmental, socio-economic commitments and set annual targets and objectives.
- Baffinland conducts all activities in compliance with the highest applicable legal & regulatory requirements and internal standards.
- We strive to employ our shareholder's capital effectively and efficiently and demonstrate honesty and integrity by applying the highest standards of ethical conduct.

4.1 FURTHER INFORMATION

Please refer to the following policies and documents for more information on Baffinland's commitment to operating in an environmentally and socially responsible manner:

Health, Safety and Environment Policy
Workplace Conduct Policy
Inuktitut in the Workplace Policy
Site Access Policy
Hunting and Fishing (Harvesting) Policy
Annual Report to Nunavut Impact Review Board
ArcelorMittal Canada Sustainability and Corporate Responsibility Report

If you have questions about Baffinland's commitment to upholding human rights, please direct them to contact@baffinland.com.

Brian Penney
Chief Executive Officer
March 2016

3 ENVIRONMENTAL RESPONSIBILITIES

3.1 ROLES AND RESPONSIBILITIES

Baffinland's Environment Department is structured into two components; on-site personnel and off–site personnel. The Project's organisational structure is provided in Figure 1.

Baffinland's Corporate Environment Department provides coordination and oversight on environmental and community works for both on and off-site programs and activities

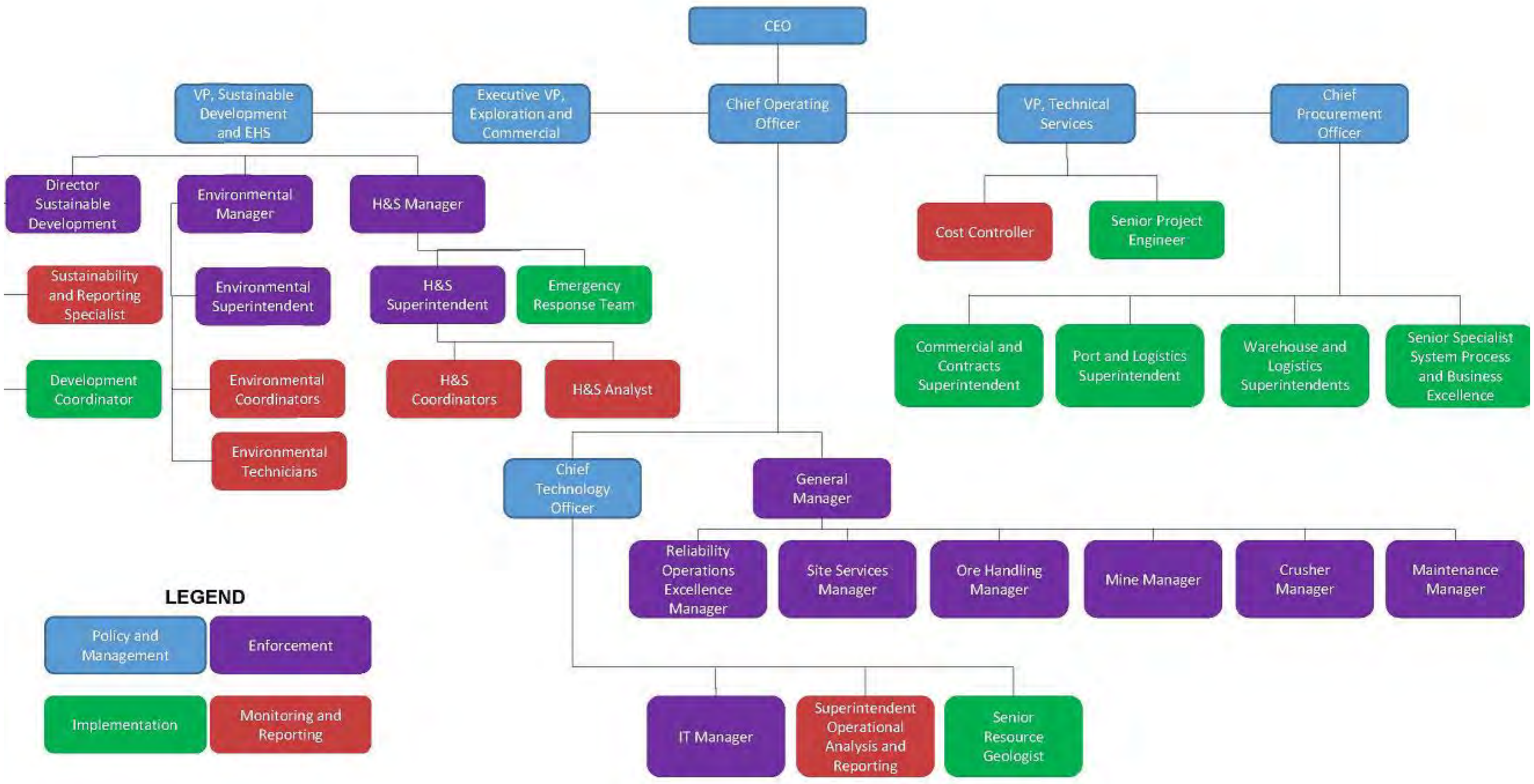
Baffinland's Project Environment Department provides direct coordination and oversight of Project environmental activities (refer to Table 1).

TABLE 1: BAFFINLAND IRON MINES CORPORATION ON-SITE ENVIRONMENTAL DEPARTMENT

Baffinland Iron Mines Corporation On-Site Environmental Team	
Position	**Responsibilities and Accountabilities**
Environmental Manager	• Reports directly to VP Sustainable Development, Health, Safety and Environment and Indirect reporting and coordination with Operations VP and Director Environment • Overall accountability for environmental staff and performance at site • Coordinates implementation and monitors the performance of the Environmental Management System at site • Liaises with the senior management, regulators and stakeholders • Ensures effective monitoring and auditing of environmental performance of departments and contractors on site and identifies opportunities for improvement • Monitors compliance with permits, licenses and authorizations • Ensures all regulatory environmental monitoring and reporting requirements (monthly, annual) are met • Leads and coordinates site permitting requirements. • Initiates and oversees environmental studies • Oversees investigations and reporting of environmental incidents to regulatory bodies, stakeholders and senior management • Reviews and updates environmental management plans
Environmental Superintendent	• Reports to Environmental Manager • Specific accountabilities for environmental monitoring and reporting • Leads investigations and reporting of environmental incidents onsite • Serves as the liaison for regulators during onsite inspections and visits • Provides ongoing environmental education and environmental awareness training to all employees and contract workers • Oversees environmental database management • Prepares updates for management plans
Environmental Coordinator	• Reports to the Environmental Superintendent and Manager • Specific accountabilities for environmental monitoring and reporting • Provides day to day direction to Environmental staff onsite • Serves as a liaison for regulators during onsite inspections and visits.

Baffinland Iron Mines Corporation On-Site Environmental Team	
Position	**Responsibilities and Accountabilities**
	• Provides ongoing environmental education and environmental awareness training to all employees and contract workers • Assists with environmental database management
Environmental Monitor and Technician	• Reports to the Environmental Superintendent or designate • Assists with environmental database management • Assists with monitoring and sampling activities as per the Project's management plans
QIA Monitor	• Works alongside the Baffinland Environment Department to ensure the proper implementation of all environmental management and monitoring plans • Acts as the QIA liaison for onsite environmental matters
Environmental Support Groups (Consultants, etc.)	• Assists with sampling, monitoring and reporting activities as required by permits, licenses and environmental management plans • Provides technical expertise to various environmental studies

Figure 1 - **MARY RIVER PROJECT ORGANIZATION CHART**



3.2 TRAINING AND AWARENESS

All site personnel (including contractors) are required to obtain a general level of environmental awareness and understanding of their obligations regarding compliance with regulatory requirements, commitments and best practices. Site personnel receive prescribed environmental training as part of Baffinland's Mary River Project Site Orientation.

Environment personnel performing environmental monitoring programs are required to understand and be proficient with the QA/QC procedures outlined in this management plan.

4 WATER SAMPLE COLLECTION

4.1 GENERAL

The samples will be collected following the general recommendations presented in *Quality Assurance (QA) and Quality Control (QC) Guidelines for use by Class "A" Licensees in Meeting SNP Requirements and for Submission of a QA/QC Plan* (INAC, 1996). A copy of the guidelines is included in Appendix A.

A summary of recommended water sample containers, sample volumes, sample preservatives and maximum sample holding times is presented in Table 3. Laboratory parameters such as pH, turbidity, BOD, nitrite, nitrate, total phosphorus, faecal coliforms, chlorophyll-a and pheophytin typically have maximum sample storage times varying from four (4) to 72 hours. Due to the remoteness of the site, it may not always be possible to get laboratory analysis done within the sample holding time window. Every effort will be made to get samples analysed within the preferred holding time window.

Every effort will be made to prevent accidental freezing of water samples (due to on-site climatic conditions) which could affect analytical results for parameters.

For a complete list of the required sample analyses at each monitoring station, please refer to Baffinland's Type A Water Licence No. 2AM-MRY1325 Amendment No. 1 (Nunavut Water Board, July 31 2014) and the Aquatic Effects Management Plan BAF-PH1-830-P16-0039 r1.

4.2 WATER QUALITY MONITORING LOCATIONS

The QA/QC Plan addresses the collection of freshwater surface water quality samples related to monitoring programs being carried out in support of Baffinland's Mary River Project, namely:

1. Collection of environmental surface water samples from area lakes, streams and rivers.
2. Collection of effluent samples from the current and future wastewater treatment facilities located at the Mine Site, Milne Port and Steensby Port.
3. Collection of drinking water samples from camp potable water sources.
4. Collection of surface water discharges from ore stockpiles and waste rock dumps.
5. Collection of surface water discharges from future bulk sample open pits.
6. Collection of water samples from fuel berms and dispensing facilities.
7. Collection of water samples from landfarm facilities and maintenance shops.
8. Collection of effluent samples from oily water treatment systems.
9. Collection of surface water discharges from landfill facilities at the Mine Site.
10. Collection of water samples representative of general site drainage before, during and after construction on Project Sites and the Tote Road.
11. Collection of water samples downstream of active Quarry locations
12. Measurement of water sample field parameters (e.g. pH, conductivity, temperature etc.).

Exact locations and sampling frequency for designated monitoring stations are presented in Baffinland's Type A Water Licence No. 2AM-MRY1325 Amendment No. 1 (Nunavut Water Board, July 31 2014) and the Aquatic Effects Management Plan BAF-PH1-830-P16-0039 r1.

4.3 WATER SAMPLING METHODS AND EQUIPMENT

Water samples specified under Baffinland's Type A Water Licence No. 2AM-MRY1325 Amendment No. 1 (Nunavut Water Board, July 31 2014) and Aquatic Effects Management Plan BAF-PH1-830-P16-0039 r1 are characterised by the following procedures.

4.3.1 GENERAL SAMPLING PROCEDURES

Generally, sampling procedures will consist of the following:

1. Sampler will wear a fresh pair of disposable nitrile gloves for each sampling event.
2. A fresh sample bottle(s) will be used at each monitoring station. Sample bottles will *not* be re-used.
3. Sampling will be carried out by either: i) rinsing the sample bottle with source water three times before immersing the sample bottle to fill it (after which preservative is added, as required), or ii) if the sample bottles are provided pre-charged with preservatives then it is generally convenient to transfer water samples from the source to the sample bottle using a 1-2L plastic jug. Plastic jugs will be rinsed in the source water three times before filling the sample bottle. A dedicated jug will be used for different sample types (e.g. sewage effluent, fuel contaminated drainage and receiving waters). Sample jugs will be replaced on a regular basis.
4. Prior to collecting the sample, the sampling jug will be rinsed in the source water three times. Rinse water will be disposed of so that it does not contaminate the source water where the sample will be collected.
5. Do not rinse bottles that are supplied certified sterile by the laboratory For samples *not requiring preservatives*, sample bottles not certified sterile will be rinsed three times with source water before filling the bottle to the top.
6. For samples *requiring preservatives*, the sample bottle will be filled to the top (or to the indicator line marked on the bottle) and securely sealed. Note that for some volatile contaminants (e.g. BTEX), the sample bottle must be filled with zero headspace.
7. Care will be taken to avoid disturbance of sediments and inclusion of disturbed suspended solids in the sample.
8. Sample details e.g. date, sample ID and analysis will be clearly marked on the bottle in indelible ink.
9. For *dissolved metals* analyses, if possible, the water sample will be filtered in the field immediately after sampling using a 0.45µm disposable filter and syringe. A fresh syringe and filters must be used at each monitoring station. Alternatively, sample filtration can be carried out by the analytical laboratory.
10. All samples will be sealed by ensuring their lids are tightly secured before placing the bottles into the coolers.
11. All samples will be placed in an iced cooler as soon as possible after collection.

4.3.1.1 SAMPLE PRESERVATION

Sample bottles and preservative will be stored under clean conditions on site. Sample bottles will have the appropriate volume of preservative added in the field immediately after sample collection to minimize chemical alterations. Alternatively, sample bottles will be supplied by the analytical laboratory with preservatives already added. Ensure that the preservative container does not come in contact with the sample or inside of the sample bottle/lid. If a water sample requires filtration (e.g., analysis of dissolved metals), preservative must be added following filtration.

4.3.2 LAKE SAMPLING

For monitoring of water quality arising from vertical stratification in lakes, a depth sampler will be used (e.g. a 'Van Dorn' or 'Kemmerer'). Generally, depth samplers consist of a clear polycarbonate sample tube with two spring mounted rubber bungs, one located at each end. The depth sampler is lowered to the correct depth attached to a cord, whereupon a metal weight is released. The weight slides down the cord and strikes a release mechanism button which releases the two bungs which then seal both ends of the tube. The water sample is then pulled back to the surface.

Regardless of the brand, water samplers that are used will be suitable for collection of water samples for ultra-low metals analyses i.e. will have acrylic or PVC construction and silicone seals.

For depth sampling, the following considerations will be taken into account to ensure sample QA/QC:

1. Sampling station locations will be dependent upon the monitoring program objectives and the lake dimensions. When sampling from a watercraft all efforts will be made to anchor the boat stationary. Map coordinates for all lake sampling station locations will be recorded using a GPS unit.
2. A vertical stratification profile (if required), profiling in-situ water quality measurements (e.g pH, temperature, dissolved oxygen, conductivity and turbidity), will be determined using a water quality multimeter (e.g. YSI Sonde) equipped with a long cord with metre intervals marked on it.
3. Depending upon the purpose of the monitoring program, water quality samples may be collected from the different stratified layers. The depth sampler must be slowly lowered in the 'open' position (i.e. to let water enter it) until it reaches the required depth.
4. The depth sampler will be held at this depth temporarily to allow flushing of water inside the apparatus.
5. The metal weight (messenger) will be released (to activate the closing mechanism) and the depth sampler will be pulled back to the surface. Field measurements can be taken at depth or by filling a bottle with the sampled water and taking measurements from that immediately after sampling.
6. When collecting samples close to the lake bed care must be taken to ensure that the depth sampler does not disturb lake bed sediments (which could contaminate the sample).
7. Depending upon the lake area and depth, multiple sampling stations will likely be required to adequately characterize lake water quality.

4.3.3 RIVER SAMPLING

Depending upon the size of the water body, river sampling methods are the same as those presented in Sections 4.3.1 and 4.3.2. To avoid inclusion of floating detritus in the sample, the sample bottle must be fully immersed in the river water. Care will be taken to ensure that disturbed sediments are not included in the sample.

For river sampling, the additional following considerations will be taken into account to ensure sample QA/QC:

1. Grasp the bottle well below the neck and remove the lid, taking care not to touch the inside of the lid.
2. Facing upstream, plunge the bottle beneath the surface of the water to a depth of 20 cm (if possible) with the opening facing downward, then tilt the bottle opening upward into the current to fill.
3. Once the bottle is full, remove the bottle from the water in one motion by forcing the opening upward and into the current and seal the bottle securely.

When selecting water quality monitoring station locations on rivers, care will be taken where a tributary joins a river, since complete mixing of the two waters may not be achieved within several hundred metres downstream of the confluence (or further). When in doubt, vertical profile monitoring across the river's width using a field parameter such as pH, temperature or conductivity will be used to assess if complete mixing has occurred.

4.3.4 SAMPLING FOR TOXICITY TESTING

Sampling for lethal toxicity testing is a condition of Baffinland's Type A Water Licence No. 2AM-MRY1325 Amendment No. 1 (Nunavut Water Board, July 31 2014) for various monitoring programs. Sub-lethal toxicity testing is a condition of Environmental Effects Monitoring (EEM) and Metal Mining Effluent Regulations (MMER). Depending on the regulatory and analysis requirements, one or more 4L effluent samples are required. Depending upon the objectives of the toxicity testing, variables that will require confirmation prior to testing include:

- Type of effluent sample to be collected e.g. instantaneous grab sample, or composite sample collected over a period of time
- Type of dilution water to be used by the testing laboratory e.g. standard synthetic laboratory dilution water, receiving water collected upstream of the discharge etc.
- Preferred test organism e.g. *Daphnia magna* and/or rainbow trout

Details concerning laboratory methods are presented in Appendix D. For further details concerning acute lethality testing refer to Environment Canada (2002) and USEPA (2002). For further details concerning sub-lethal testing refer to Environment Canada (2012)

4.3.5 IN-SITU WATER QUALITY

Measurement of field parameters (e.g. temperature, pH, conductivity, redox potential, or dissolved oxygen, etc.), where warranted, will be carried out for each sample at the time of sampling. The required set of field parameters will vary according to sample type and monitoring objectives. For a complete list of required parameters please refer to the Baffinland's Type A Water Licence No. 2AM-MRY1325 Amendment No. 1 (Nunavut Water Board, July 31 2014). The exact methods used for monitoring field parameters will depend upon the type of monitoring probes being used. Field staff will read and be familiar with the instruction manual for the equipment being used on site, and follow manufacturer's instructions for specifics on proper calibration, use, storage, and maintenance.

Field staff will rinse the monitoring probe three times with the water to be monitored before immersing the probe in the water. Generally, the user will ensure that the probe being used has had sufficient time to equilibrate in the water before the reading is taken. This is generally regarded as the point at which the reading has stabilized.

Field parameter data will be recorded in notebooks, or preferably in a custom form designed for this purpose. A copy of the data should be retained on site.

4.3.5.1 MONITORING PROBE CALIBRATION

Monitoring probes will be stored and calibrated in accordance with manufacturers' instructions. All probes will be calibrated regularly per sampling program requirements and a written record of the calibration results will be maintained on site. Field staff will ensure that calibration solutions are of the correct specification and that they have not passed their expiry date (if applicable). Monitoring probes will be stored as per manufacturers' recommendations.

5 SEDIMENT SAMPLE COLLECTION

For a complete list of the required sample analyses at pre-established monitoring station, please refer to Baffinland's Type A Water Licence No. 2AM-MRY1325 Amendment No. 1 (Nunavut Water Board, July 31 2014) and the Aquatic Effects Management Plan BAF-PH1-830-P16-0039 r1. Every effort will be made to get samples analysed within the preferred holding time window conforming to the specified protocols for sediment sampling. A summary of recommended sediment sample containers, sample volumes, and maximum sample holding times is presented in Table 3. Field observations and parameters if warranted should be recorded during the collection of sediment samples.

5.1 SEDIMENT MONITORING LOCATIONS

The QA/QC Plan addresses the collection of sediment samples related to monitoring programs being carried out in support of Baffinland's Mary River Project, namely:

1. Collection of environmental sediment samples from area lakes, streams and rivers.
2. Collection of sediment samples from fuel berms and dispensing facilities.
3. Collection of sediment samples from landfarm facilities.
4. Collection of sediment samples from remediation and reclamation projects.
5. Collection of sediment samples evaluating spills and releases.

5.2 SEDIMENT SAMPLING METHODS AND EQUIPMENT

Sediment samples specified under Baffinland's Type A Water Licence No. 2AM-MRY1325 Amendment No. 1 (Nunavut Water Board, July 31 2014) and Aquatic Effects Management Plan BAF-PH1-830-P16-0039 r1 are characterised by the following procedures.

5.2.1 GENERAL SAMPLING PROCEDURES

Generally, sampling procedures will consist of the following:

1. Sampler will wear a fresh pair of disposable nitrile gloves for each sampling event.
2. A fresh sample bottle(s) will be used at each monitoring station. Sample bottles will *not* be re-used.
3. Sample details e.g. date, sample ID and analysis will be clearly marked on the sample jar in indelible ink.
4. All samples will be sealed by ensuring their lids are tightly secured before placing the bottles into the coolers.
5. All samples will be placed in an iced cooler as soon as possible after collection.

5.2.2 RIVER AND GRAB SAMPLING

The collection of river and grab samples will follow the general procedures stated in 5.2.1 and will entail the following additional QA/QC considerations:

1. Sampling station locations will be dependent upon the monitoring program objectives and the sample location.
2. A sterile spatula or spoon will be utilized to obtain a representative sample of the sediment for analyse.
3. If composite samples are required by the monitoring program, a sterile container will be utilised to deposit and homogenize the subsamples, until the composite sample is fully mixed. The composite sample will then be transferred to the identified sample jars by alternating aliquots.
4. The quantity and holding time of samples obtained will depend on the prescribed analysis.

5.2.3 LAKE SAMPLING

For monitoring of sediment character and quality in lakes, a depth sampler will be used. The preferred sample apparatus for lake sediment samples are gravity percussion corers, since they allow for retrieval and analysis of sediment profiles. A petite Ponar can also be used but will not provide sediment profiles. Generally, forms of gravity percussion corers consist of a clear polycarbonate sample core tube attached to a weighted upper head assembly and a seal mechanism. The top two centimeters of sediment from the core samples will be retained for laboratory analysis unless sampling objectives state otherwise.

Sediment lake sampling procedures will follow the general procedures stated in 5.2.1 and the following additional QA/QC considerations for a gravity percussion corer:

1. Sampling station locations will be dependent upon the monitoring program objectives and the lake dimensions. When sampling from a watercraft all efforts will be made to anchor the boat stationary. Map coordinates for all lake sampling station locations will be recorded using a GPS unit.
2. The corer 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.
3. 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.
4. 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.
5. An extruding apparatus will be used to force the extruding plug through the core tube moving the sediment sample to the end of tube allowing the top two centimetres to be scooped out and placed in a clean stainless steel bowl for sample homogenisation.
6. Multiple core samples (generally three or more) are required per sample station to obtain the required sample volume. The multiple core samples are homogenized in the stainless steel bowl, removing any excess water or debris.
7. The sample containers will be filled by alternating aliquots between each of the containers.

8. 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 all core sampling is complete at that particular station.
9. Depending upon the lake area and depth, multiple sampling stations will likely be required to adequately characterize lake water quality.

6 BENTHIC INVERTEBRATES SAMPLE COLLECTION

For a complete list of required analyses at pre-established monitoring stations, see Baffinland's Aquatic Effects Management Plan BAF-PH1-830-P16-0039 r1. Samples will be submitted to an analytical laboratory for processing and taxonomic identification. Laboratory methods for benthic invertebrate samples will be in accordance with guidance provided by EC, 2012. Field observations and parameters if warranted should be recorded during the collection of benthic invertebrate samples

6.1 BENTHIC INVERTEBRATE MONITORING LOCATIONS

This QA/QC Plan addresses the collection of benthic invertebrate samples related to monitoring programs being carried out in support of Baffinland's Mary River Project, namely:

- Collection of benthic invertebrate samples from area lakes, streams and rivers in remote reference areas
- Collection of benthic invertebrate samples from area lakes, streams and rivers in the Project Area to determine:
    1. Water quality changes related to discharge of ore or stockpile runoff to freshwater systems
    2. Water quality changes related to discharge of treated sewage effluent
    3. Water quality changes due to deposition of dust in lakes and streams.
    4. Changes in water levels and/or flows due to water withdrawals, diversions, and effluent discharges

6.2 BENTHIC INVERTEBRATE SAMPLING METHODS AND EQUIPMENT

Benthic Invertebrate samples follow the same general procedures outlined in 5.2.1. Benthic invertebrates can be collected from either depositional (lake) or erosional (stream) sample locations. A petite Ponar is utilised when sampling depositional environments while a Surber sampler is utilised when sampling erosional environments. For a complete list of depositional and erosional sample methods see Baffinland's Aquatic Effects Management Plan BAF-PH1-830-P16-0039 r1. Benthic invertebrate samples will be carefully sieved through 500 µm mesh. All materials, including invertebrates, retained by the mesh will be transferred to labelled plastic jars and fixed with 10% buffered formalin. Fixed and labelled samples will be shipped to an analytical laboratory for processing and archiving.

7 QA/QC

For monitoring of QA/QC during sample collection and shipping, a set of QA/QC samples will be routinely submitted for analysis. Descriptions of the QA/QC samples that will be used (e.g. field blank, travel blank, equipment blank and field duplicate) are presented on Table 2. Except equipment blanks, ten percent of all samples will comprise QA/QC samples.

In the interest of transparency, the analytical laboratories will also be instructed to report the results of their own in-house QA/QC testing (e.g. results of random replicate analyses of submitted samples).

The results of QA/QC analyses will be routinely reviewed by Baffinland or their designate, and any anomalous results will be promptly investigated with the assistance of the analytical laboratory. Once the reason for the anomalous results is identified, Baffinland will ensure that operating procedures of field staff and/or the analytical laboratory will be altered in order to rectify the problem. Compliance monitoring and data management for water license sampling will be conducted by Baffinland, with the assistance of a designate as required.

TABLE 2: PURPOSE, DESCRIPTION AND FREQUENCY OF QA/QC SAMPLES

QA/QC Plan	Purpose	Description	Frequency	Prepared By
Field blank	Identification of potential contaminants arising from sample collection. The field blank bottle is prefilled with laboratory deionized water and is handled in the same way as regular sample bottles (i.e., opened and closed during the sample collection). The bottle is submitted as a routine sample.	Bottle contains prefilled deionized water. Bottle is handled the same as one would handle the samples.	Ten percent of all samples collected will be QA/QC.	Field Staff
Travel blank	Identification of potential contaminants arising from sample storage, shipping and laboratory handling. The travel blank accompanies the samples to the laboratory but is not taken out into the field, or opened.	Sealed bottle containing deionized water provided by analytical laboratory.	Ten percent of all samples collected will be QA/QC.	Analytical laboratory
Equipment blank	Assesses cross contamination from field water sampling apparatus (e.g Kemmerer). Rinse deionized water through water sampling apparatus and transfer to sample bottles.	Bottle contains dionized water that has been rinsed through the sampling apparatus.	Collected prior and after completion of sampling program (if required).	Field Staff
Field duplicate	Assesses sample variability and precision of laboratory analytical methods. Collected from a randomly selected location, split from a homogenized	Duplicate sample selected at random. A large sterile bottle is used to collect the	Ten percent of all samples collected will be QA/QC.	Field Staff

	sample and analyzed separately in the laboratory. The duplicate samples are handled and analyzed in an identical manner in the laboratory.	water. Water is then poured equally into two sets of pre-labelled bottles.		

8 SAMPLE MANAGEMENT

8.1 SAMPLE LABELING

Accurate sample labelling is essential for later interpretation of field data. Ensure that labels are legible and written with an indelible marker. For a complete list of the predetermined sample labels at monitoring station, please refer to Baffinland's Type A Water Licence No. 2AM-MRY1325 Amendment No. 1 (Nunavut Water Board, July 31 2014) and the Aquatic Effects Management Plan BAF-PH1-830-P16-0039 r1.

A consistent format for identifying samples must be followed if a predetermined sample label does not exist in order to facilitate accurate sample tracking and to ensure sample labels are interpreted in the same manner by all personnel involved in the program.

Samples must be uniquely identified with the following information:

- Sample ID
- Collection date and time
- Project identifier
- Company name

QA/QC samples will be labeled by the following conventions:

- Field Duplicate: 01 following the sample label
- Field Blank: 02 following the sample label
- Travel Blank: 03 following the sample label
- Equipment Blank: 04 following the sample label

8.2 SAMPLE STORAGE AND HANDLING

Physical, chemical and biochemical reactions may take place in the sample container between the time of sample collection and laboratory analysis Samples will be placed in iced coolers and shipped to the analytical laboratory as soon as possible after collection, consulting stipulated analytical holding times, to minimize these changes. Care will be taken to ensure that bottles are stored upright and are packed securely within the cooler. Preferably, leak-proof ice packs will be used for cooling the samples. If loose ice is used then this should be securely sealed in plastic bags to prevent leakage of melt water.

Biological samples (e.g. benthic invertebrates) preserved using formalin or Lugol's solution can be held at room temperature until submission to the analytical laboratory.

8.3 SAMPLE SUBMISSION AND CHAIN OF CUSTODY

A chain of custody (COC) form will accompany all samples being submitted to ensure that the required analyses are completed, and to confirm receipt of samples by the laboratory (see example form presented in Appendix B).Prior to shipment, samples should be carefully prepared for shipping and sample bottles listed on the COC must be reconciled with what has physically been placed in the shipping container. The collection of samples that are time sensitive needs to coincide with shipping schedules, travel time to the laboratory, and laboratory business hours. A record of all COCs submitted for analysis must be kept on site. Information on the COC form will include:

1. Project name and project assignment number.
2. Address of analytical laboratory, name of contact person and contact details.
3. Contact details and name of sampler.
4. Date and time of sampling.
5. Whether the sample has been filtered, or whether laboratory filtration is required.
6. List of sample I.D.'s, sample type (e.g. lake water, sewage effluent, etc.), number of sample bottles per sample and analysis requested.
7. Urgency of analysis (e.g. rush or normal). For rush samples the analytical laboratory should be notified ahead of time.
8. Whether sample contains preservative and if so, what preservative and when it was added.
9. Submission date and time.
10. Comments on any unusual conditions and other important information.

9 LABORATORY ANALYSIS

9.1 LABORATORY ACCREDITATION

Laboratory analysis of samples is performed by an on-site accredited analytical laboratory and an off-site accredited analytical laboratory. The on-site laboratory is operated by ALS Canada LTD. and is located at the Mine Site. A select set of basic analytical parameters (e.g. pH, TSS, Turbidity etc.), are performed by the on-site laboratory. The off-site laboratory, ALS Environmental, located in Waterloo, ON, run by ALS Canada Ltd. performs the majority of analyse required. Toxicity testing is performed by Aquatox Testing & Consulting Inc, located in Guelph, ON. Details of ALS analytical laboratory licencing and accreditation are presented in Appendices C.

9.2 ANALYTICAL DETECTION LIMITS

ALS Limits of Reporting (LORs) are established using rigorous experimental and statistical procedures that begin with the determination of the Method Detection Limit (MDL) at 99%confidence. When detected at or above the MDL, ALS test results are considered to be qualitatively accurate, and a parameter can be reported with 99% confidence as being present in the sample.

It should be noted that on occasion, a loss of analytical sensitivity can be encountered due to excessively high concentrations of parameters within a sample or lack of provided sample matrix. If this is encountered, Baffinland or their designate will work with the analytical laboratory to try and resolve the problem and new samples will be taken if taken if required. The detection limits on ALS analytical reports contains the LOR. The LOR may be the MDL as calculated, or a higher value. Required analytical laboratory detection limits are provided in Appendix D.

9.3 LABORATORY ANALYTICAL METHODS

Analytical methods used by the analytical laboratories for water analyses generally conform to the standard methods outlined in *Standard Methods for the Examination of Water and Wastewater* (APHA et al, 1989). Standard analytical methods for available analyses through ALS Environmental are provided in Appendix D.

9.4 ANALYTICAL LABORATORY QA/QC PROCEDURES

ALS Environmental adheres to a designated QA/QC Management System which includes documentation and document control, staff training and internal audits. The practices exceed accreditation requirements for high confidence in data reliability utilising but not limited to:

- Use of calibration verification standards and drift control standards.
- Use of surrogate standards and internal standards.
- Replicate analyses and blanks on submitted samples.
- Use of standard reference materials (SRM's) and matrix spikes.
- Standards Data Quality objectives are established for each QC sample, based on a combination of reference method objectives, customer requirements and historical test method performance. Where applicable, prescriptive elements of reference methods take precedence over internal

  Further details on the analytical laboratories in-house QA/QC protocols are presented in Appendix E.

9.5 SUMMARY OF ANALYTICAL PROCEDURES

TABLE 3: SUMMARY OF ANALYTES, WATER AND SOIL SAMPLE VOLUMES, PRESERVATIVES AND SAMPLE STORAGE TIME FOR ALS ENVIRONMENTAL

Inorganics	Analysis [1]	Water Container	Water Preservation	Additional Notes	Soil Container	Water / Soil Hold Time
ROUTINE INORGANICS AND PHYSICALS	Acidity and Alkalinity	0.5-1 L Plastic			125-250 mL Jar or Bag	14 Days / NA
	Anions (Br, Cl, SO4, F) and Electrical Conductivity	0.5-1 L Plastic			125-250 mL Jar or Bag	28 Days [7]/ Unlimited
	Bromate[19], Chlorate and Chlorite	125 mL Plastic	EDA (Ethylenediamine)		NA	28 Days (Chlorite 14 Days) / NA
	BOD, Colour and Turbidity	0.5-1 L Plastic			NA	2-4 Days [8] / NA
	COD and Phenols (4AAP)	125-250 mL Glass	1:1 Sulfuric Acid (H_2SO_4)		NA	28 Days / NA
	Cyanide, Total ,Weak Acid Dissociable,Free	145 mL Plastic	6N NaOH		125-250 mL Jar or Bag	14 Days / 14 Days
	Dissolved Oxygen	300 mL BOD bottle	1 each; $MnSO_4$ & alkaline iodide azide pillows		NA	8 Hours[20] / NA
	Dissolved or Total Inorganic Carbon (DIC or TIC)	125-250 mL Glass	.	Field Filter for Dissolved	125-250 mL Jar or Bag	14 Days / 28 Days
	Dissolved or Total Organic Carbon (DOC or TOC)	125-250 mL Glass	1:1 Sulfuric Acid (H_2SO_4)	Field Filter for Dissolved	125-250 mL Jar or Bag	28 Days / 28 Days
	Flashpoint	2 x 100-250 mL Amber Glass		Zero Headspace	125-250 mL Jar	7 Days / 7 Days
	pH	0.5-1 L Plastic			125-250 mL Jar or Bag	0.25 Hours / 30 Days [9]
	Solids (TS, TSS, TDS)	0.5-1 L Plastic			NA	7 Days / NA
	Sulfide	125 - 150 mL Plastic	Zinc Acetate & 6N NaOH		125-250 mL Jar or Bag	7 Days / 7 Days
	Sulfite	125 mL Plastic			NA	0.25 Hours / NA
NUTRIENTS	Ammonia Nitrogen	250 mL Glass or Plastic	1:1 Sulfuric Acid (H_2SO_4)		125-250 mL Jar or Bag	28 Days / 72 Hours
	Nitrate or Nitrite Nitrogen (and Ammonia unpreserved)	0.5-1 L Plastic			NA	2-7 Days [10] / 72 Hours
	Nitrogen, Kjeldahl, Organic, Total or Dissolved	250 mL Glass or Plastic	1:1 Sulfuric Acid (H_2SO_4)	Field Filter for Dissolved	NA	28 Days / NA
	Nutrients, Available (N,P,K,S)	NA			125-250 mL Jar or Bag	NA / 3 Days [11]
	Phosphorus, Reactive (orthophosphate)	0.5-1 L Plastic			NA	2-7 Days [12] / NA
	Phosphorus, Total Dissolved	250 mL Glass or Plastic	1:1 Sulfuric Acid (H_2SO_4)	Field Filter for Dissolved	NA	28 Days / NA
	Phosphorus, Total	250 mL Glass or Plastic	1:1 Sulfuric Acid (H_2SO_4)		NA	28 Days / NA
METALS	Chromium VI (Hexavalent)	125 mL Plastic	50 % NaOH (BC MoE) or 6N NaOH + Ammonium Buffer (OMoE)		125-250 mL Jar or Bag	28 Days / 30 Days
	Mercury, Methyl	250 mL FLPE	1:1 Hydrochloric Acid (HCl)[21]	Field Filter for Dissolved	125-250 mL Jar or Bag	6 Months / 28 Days
	Mercury, Total or Dissolved	40 mL Glass Vial	1:1 Hydrochloric Acid (HCl)	Field Filter for Dissolved	125-250 mL Jar or Bag	28 Days / 28 Days
	Metals, Total or Dissolved	125-250 mL Plastic	1:3 Nitric Acid (HNO_3) to pH<2	Field Filter for Dissolved	125-250 mL Jar or Bag	6 Months / 6 Months
Organics						
HYDRO-CARBONS	F1, Volatile Organic Compounts (VOCs), THMs, 1,4-Dioxane, Volatile Petroleum Hydrocarbons (VPH)	2 or 3 x 40 mL Glass Vials [2]	Sodium Bisulfate [4]	Zero Headspace	Field Methanol Kit [6]	14 Days / 40 Days [13]
		2 or 3 x 40 mL Glass Vials [2]	Sodium Bisulfate [4]	Zero Headspace	Hermetic Sampler kit [6]	14 Days / 48 Hours
	CCME CWS F1, BTEX	2 or 3 x 40 mL Glass Vials [2]	Sodium Bisulfate [4]	Zero Headspace	125 - 500 mL Jar	14 Days / 7 Days
	CCME CWS F2-F4	2 x 60 mL Amber Glass Vials [3]	Sodium Bisulfate		125 - 500 mL Jar	14 Days [14]/ 14 Days
	EPH or LEPH/HEPH	2 x 250 mL Amber Glass with Septa Cap	Sodium Bisulfate		125 - 500 mL Jar	14 Days / 14 Days
	Polycyclic Aromatic Hydrocarbons (PAHs)	2 x 0.25 - 1 L Amber Glass [5]	Sodium Bisulfate		125 - 500 mL Jar	14 Days / 14 Days
	Oil & Grease or Mineral Oil & Grease	2 x 0.25 - 1 L Glass	1:1 HCl or H_2SO_4		125 - 500 mL Jar	28 Days / 28 Days
TRACE ORGANICS	Alcohols	2 x 40 mL Glass Vials		Zero Headspace	125 - 500 mL Jar	7 Days / 7 Days
	Alkanolamines (MEA, DEA, DIPA)	250 mL Amber Glass			125 - 500 mL Jar	7 Days / 14 Days
	AOX	40 - 250 mL Amber Glass	1:3 Nitric Acid (HNO_3) to pH<2		125 - 500 mL Jar	6 months [15] / 28 Days
	C1 - C5 Gases	3 x 40 mL Blue Septa Vials	Sodium Bisulfate [4]	Zero Headspace	NA	14 Days / NA
	Dioxins and Furans, PBDE and PBB	2 x 1 L Amber Glass			125 - 500 mL Jar	Unlimited / Unlimited
	Formaldehyde/Aldehydes	2 x 40 mL Amber Glass Vials [2]	Ammonium Chloride+Copper Sulfate	Zero Headspace	125 - 500 mL Jar	7 Days / 5 Days
	Glycols	2 x 40 mL Amber Glass Vials			125 - 500 mL Jar	7 Days / 14 Days
	Hormones and Steroids	1 L Plastic			NA	28 Days / NA
	Naphthenic Acids	2 x 250 mL Amber Glass			125 - 500 mL Jar	14 Days / 14 Days
	Nitroaromatics and Nitrosamines (Explosives)	1 L Amber Glass			125 - 500 mL Jar	7 Days / 14 Days
	Nonylphenol & Ethoxylates, Bisphenol A (BPA)	1 L Amber Glass			125 - 500 mL Jar	28 Days / 14 Days

	PCB	2 x 0.25 - 1 L Amber Glass			125 - 500 mL Jar	Unlimited / Unlimited[16]
	Perfluorinated Chemicals (PFCs), PFOS, PFOA	1 L Plastic (PTFE free)			125-250 mL Jar or Bag	14 Days / 14 Days
	Phenolics, Chlorinated and Non-Chlorinated	2 x 0.5 - 1 L Amber Glass	Ascorbic Acid & Sodium Bisulfate[4]		125 - 500 mL Jar	14 Days / 14 Days
	Priority Pollutants (EPA 625 list) or SVOCs	2 x 1 L Amber Glass			125 - 500 mL Jar	7 Days / 14 Days[17]
	Resin Acids & Fatty Acids	2 x 0.5 - 1 L Amber Glass	Ascorbic Acid & NaOH		125 mL Jar	14 Days / 14 Days
	Sulfolane	2 x 0.5 - 1 L Amber Glass	Sodium Bisulfate[4]		125 mL Jar	14 Days / 14 Days
PESTICIDE RESIDUES	Carbamate Pesticides	1 L Amber Glass	Use Sodium Thiosulfate if chlorinated		125 - 500 mL Jar	7 Days / 14 Days
	Glyphosate / AMPA	1 L Plastic	Use Sodium Thiosulfate if chlorinated		125 - 500 mL Jar	14 Days / 14 Days
	Herbicides, Acidic	2 x 1 L Amber Glass	Sodium Bisulfate[4]		125 - 500 mL Jar	14 Days / 14 Days
	Organochlorine or Organophosphate Pesticides	2 x 1 L Amber Glass			125 - 500 mL Jar	7 Days / 14 Days
	Soil Sterilant Scan	1 L Amber Glass			250 g Poly Bag	7 Days / 14 Days
Micro						
MICRO-BIOLOGICAL	Coliforms-Fecal, Total, E-coli & HPC	100 - 300 mL Sterilized Plastic	Sodium Thiosulfate		500 mL Sterilized Jar	24-48 Hours[18] (24 - HPC) / NA
	Microtox	1 L Amber Glass			125-250 mL Jar or Bag	3 Days / 3 Days

1. Additional analyses with the same container type and preservation may be possible - consult the lab for details.

2. The number of 40 mL glass vials required (2 or 3) for BTEX & VOC varies by lab based on instrumentation. Consult the lab for details.

3. Please fill to the top of the marked line on the 60 mL Amber Glass Vials.

4. Use Sodium Thiosulfate instead of Sodium Bisulfate if sample is chlorinated.

5. OMoE has no preservation requirement for PAHs. 2 X 250 mL Amber Glass required for BC MoE and OMoE. For AB and SK and for Alkylated PAHs, ALS requires 2 x 1 L Amber Glass.

6. Soil sampling options depend on soil location and condition of soil. Field Methanol Kit consists of one 5g TerraCore® sampler or similar sampling device, two pre-weighed 40 mL glass vials with methanol preservative and a 125mL soil jar for moisture. Hermetic sampler kit consists of a T-handle, two 5g hermetic samplers and a 125mL soil jar for moisture. One additional parameter, such as metals or hydrocarbons can also be obtained from the 125mL soil jar.

7. 4 Days hold time for Electrical Conductivity only as per Ontario MISA.

8. 3 Days hold time for British Columbia as per BC Ministry of Environment (BC MoE), 4 Days hold time as per OMoE.

9. pH in water should be taken in the field as per BC MoE, 4 Days hold time for Ontario MISA and 28 Days hold time for OMoE. 30 Days hold time as received for pH in soil as per OMoE. One year hold time once soil is dried.

10. 3 Days hold time as per BC MoE, 5 Days hold time as per Ontario MISA and 7 Days hold time as per OMoE.

11. 3 Days hold time until received. Unlimited hold time once soil is dried.

12. 3 Days hold time as per BC MoE and 7 Days hold time as per OMoE.

13. 40 Days hold time as per BC MoE and 14 Days hold time as per OMoE. Recovered methanol extract from laboratory has a 40 Days hold time as per OMoE.

14. 40 Days hold time as per OMoE.

15 14 Days hold time as per Ontario MISA.

16. 14 Days hold time as per OMoE. Consult lab for container size if limited sample volume is available.

17. 14 Days hold time for water and 60 Days hold time for soil as per OMoE. Ontario labs require 2 x 250 mL Amber Glass + 500 mL Amber Glass.

18. 30 Hours hold time as per BC Drinking Water Regulation and 48 Hours as per OMoE.

19. Bromate alone does not require preservative.

20. 15 Minutes hold time as per OMoE - Field measurement by meter is recommended.

21. Use 1:1 Sulfuric Acid (H_2SO_4) for preservation of marine or brackish samples.

SEPTEMBER 2015 BACK

10 DATA MANAGEMENT AND REPORTING

10.1 DATA MANAGEMENT

All sample data collected by Baffinland or designate consultants from the various environmental programs required on Project sites will be stored electronically in a spreadsheet database (Microsoft Excel) or using alternative software designed specifically for environmental data management.

QA/QC measures relating to data validation will include the following:

1. Designation of a suitable person to act as Water Quality Database Manager (WQDM).
2. Upon receipt, laboratory analytical data will be reviewed by the WQDM to check for completeness, typos, outlying values, etc. The analytical laboratory will be immediately notified of any anomalous results.
3. At a suitable frequency (e.g. once per month) the spreadsheet database should be updated by the WQDM using: i) results provided in electronic format by the analytical laboratories, and ii) copies of the field parameter monitoring records forwarded from site
4. The WQDM will be responsible for ensuring that a third party (e.g. another staff member) carries out a QA/QC check on a minimum of ten percent of newly entered data.

10.2 REPORTING

All documents prepared by Baffinland or their designate for submission to the regulators will be reviewed by senior staff and Baffinland prior to issue, as per the company's standard practice and quality management system.

11 REFERENCES

1. APHA *et al*, 1989. Standard Methods for the Examination of Water and Wastewater; AHPA, AWWA and WPCF, 17th ed.

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

3. Environment Canada, 2002. Metal Mining Guidance Document for Aquatic Environmental Effects Monitoring. http://www.ec.gc.ca/eem/English/MetalMining/Guidance/default.cfm.

4. INAC, 1996. Quality Assurance (QA) and Quality Control (QC) Guidelines for Use by Class “A” Licenses in Meeting SNP Requirements and for Submission of a QA/QC Plan. Prepared by Department of Indian and Northern Affairs Canada Water Resources Division and the Northwest Territories Water Board, July 1996.

5. Nunavut Water Board, 2013. Baffinland Iron Mines Corp. – Class A Water License No: 2AM-MRY1325. Issued by the Nunavut Water Board, 2013.

6. USEPA, 2002. Methods for Measuring the Acute Toxicity of Effluents and Receiving Waters to Freshwater and Marine Organisms; 5th Ed., USEPA, ref. No. EPA-821-R-02-012.

Appendix A-

Quality Assurance Assurance (QA) and Quality Control (QC) Guidelines for use by Class "A" Licensees in Meeting SNP Requirements and for Submission of a QA/QC Plan (INAC, 1996).

QUALITY ASSURANCE (QA) AND QUALITY CONTROL (QC)

GUIDELINES

FOR USE BY CLASS “A” LICENSEES
IN MEETING SNP REQUIREMENTS

AND FOR SUBMISSION OF A QA/QC PLAN

JULY 1996

DEPARTMENT OF INDIAN AND NORTHERN AFFAIRS CANADA
WATER RESOURCES DIVISION
AND THE
NORTHWEST TERRITORIES WATER BOARD

Table of Contents

Appendixes

1.0 Introduction and Definitions

In order to assist Licensees in completing their Quality Assurance and Quality Control (QA/QC) Plan, the following guidelines are provided, which indicates the minimum information that should be included.

These Guidelines are divided into three sections:

1) Field Sampling
2) Lab Analysis
3) Reporting Requirements

It is recognized that there may be different interpretations as to what is covered by "Quality Assurance/Control" due to the fact that certain Licensees have their own laboratories, while others only use commercial laboratories. For licence purposes, "Quality Assurance" and "Quality Control" refer to the following:

Quality Assurance: is the system of activities designed to better ensure that quality control is done effectively; while

Quality Control: is the use of established procedures to achieve standards of measurement for the three principal components of quality: precision, accuracy and reliability.

2.0 Field Sampling

2.1 Sample Collection

2.1.1 <u>Location</u>

A QA/QC plan must identify the locations of all sampling stations and the markers used to identify the stations. If the Surveillance Network Program (SNP) of the Water Licence does not specify sampling locations, locations should be chosen with help from an Inspector.

Buoys and landmarks identify sampling stations in tailings ponds and lakes, while sign post positioning usually marks stream sample stations. Stations should be used repeatedly, with the same personnel and techniques to reduce operational error. The use of Global Positioning System (GPS) to identify Latitude and Longitude for sampling stations is recommended.

2.1.2 Sampling Equipment

The Plan must include a detailed section on the equipment used for sampling, the rationale behind the choices of equipment, and descriptions of how the equipment is maintained and calibrated. Equipment and bottles should be selected so that they do not contaminate or otherwise alter the concentrations of parameters of interest.

Sampling devices, sample bottles and filtration devices should be constructed of non-metallic material. Most samples are now collected in containers constructed of high density polyethylene plastic. However, there are some exceptions, when testing for oil and grease or phenols glass containers are to be used. When conducting a fish bioassay, plastic drums are used while hydrocarbon based containers are not to be used for the collection of organic samples.

This section should also identify whether new or used bottles are used for each sample analysis. New bottles are preferred, but sample containers may be used repeatedly with proper handling measures.

If old bottles are used, a detailed description should be included, noting how they are maintained, stored and cleaned. Usually, this will closely resemble the product manufacturer's instructions. An example of how bottles should be cleaned is outlined below:

- Rinse well with hot tap water for one minute or more.
- Empty bottle and add 30% HNO_3 to approximately 1/3 container capacity. Shake well for three to four minutes.
- Rinse vigorously with hot tap water for two minutes.
- Rinse thoroughly three times with tap water and three times with distilled water.
- Store with 0.2% HNO_3 for a minimum of one week.
- Rinse again with distilled water at least three times.

Bottles that are to be used for bacteria testing should be acid washed or autoclaved if possible.

Note: Additional information on bottle washing is also available from Water Resources Division.

2.1.3 Sampling Methods

This Section will include details on methods for sample collection and the equipment that is to be used for each station.

In lakes and ponds, regular sample bottles are used the majority of the time, but Van Dorn samples are often utilized. The sample or the sample bottle is usually lowered to mid depth and washed three times before collecting the sample on the fourth submersion. Approximately 2% of the sample container capacity should remain to provide for mixing, preservative addition and thermal expansion.

Stream water sampling is usually done by plunging a sample bottle toward the current and allowing it to fill. Once again, the bottle should be rinsed three times before filling and room should be left for preservative addition and mixing.

A glass bottle should be used when sampling for oil and grease with the sample being collected during the first submersion and not rinsed three times first.

This section should also describe how often field blanks and replicate samples will be collected. Field blanks are samples of distilled/deionized water that are to be treated in exactly the same manner as the other samples. Blanks should therefore be taken to the field and handled and preserved as part of the sample program. They indicate when a sample may be contaminated and are indicative of general sample integrity. Replicate samples (duplicates and triplicates) are two or three samples collected from the same station at the same time. They help to ensure sample precision at the laboratory.

2.2 Sample Handling

2.2.1 Preservation

After collection, most samples must be preserved in order to prevent chemical or biochemical changes to the sample. The QA/QC plan must describe how samples from each station are to be preserved.

Preservation is generally done by the addition of certain chemicals into the bottle immediately after the sample is collected. **Table 1** is a general guide to preservatives and their appropriate concentrations. The QA/QC plan should contain more detailed information on the concentrations and amount of preservatives that will be used.

2.2.2 Sample Identification

The plan should include a description of the system used to identify samples. The system must provide positive sample identification and ensure that the identification is maintained. It is advisable to keep a logbook of samples that have already been delivered.

The identification can be maintained by marking the bottle itself or a label, with a water resistant, non-smear felt pen. The information should be clear to persons uninvolved in the sampling and may include such details as company name, sample area, SNP number, time and date.

2.2.3 Transportation

The section on transportation will describe how sample integrity will be ensured from the time of collection to completion of delivery. Delivery to the lab should be done as soon as possible after the samples have been collected.

Usually, samples are sealed and stored upright in a box with other samples to provide a snug, immobile storage space during transfer. Any samples that require refrigeration for preservation should be kept cool during transport.

3.0 Lab Analysis

Because certain Class “A” Licensees have their own analytical laboratory and others rely on commercial laboratories, this section of the Guidelines is divided accordingly.

3.1 Outside Laboratories

3.1.1 Lab Accreditation

The Licensee will identify in the plan the name of the commercial laboratory that will be conducting the analyses. A letter must be provided from the commercial lab indicating that they are accredited to conduct analyses on each of the required sampling parameters. Ideally, the lab should be accredited by the Canadian Associated for Environmental Analytical Laboratories (C.A.E.A.L.) and should provide a certificate stating parameters for which they are accredited.

3.1.2 Detection Limits

Detection limits for the commercial lab should be identified for all parameters and should be reported when any SNP data is submitted.

3.1.3 Methodology

Descriptions should be included for any methods of analysis used that are not outlined in “Standard Methods for the Examination of Water and Wastewater”.

3.2 In House Laboratories

3.2.1 Identification of Analytical Laboratory/Detection Limits

Licensees using in-house labs shall identify their detection limits for all parameters and report them when any SNP data is submitted. The Licensee shall also identify the commercial lab they use to check for quality control.

3.2.2 For Overall Analytical Methods, Precision and Accuracy

The plan must describe how the Licensee will ensure precision and accuracy in their analytical methods. This includes what action will be taken if any sample results are found to be outside the appropriate ranges.

All analyses should be conducted in accordance with methods prescribed in the current edition of "Standard Methods for the Examination of Water and Wastewater" or by other approved methods. In addition, the lab should analyze standard reference material for each parameter measured. For each parameter (group) to be measured, a complete description of the sampling procedure must be documented and adhered to.

If any sample results are outside the appropriate QA/QC ranges, attempts should be made to correct the problem and the sample shall be immediately re-analyzed. If any analysis indicates a violation of a licence condition, an Inspector shall be notified of the violation, any corrective action taken, and the results of retests.

3.2.3 Accuracy Requirements

The plan should document how the Licensee will go about ensuring accuracy in the laboratory. Accuracy is the measurement of how closely a value approximates a standard, or true value. The Licensee should identify the frequency at which certified or reference standards will be analyzed during each sampling period.

3.2.4 Precision Requirements

Precision is a measure of the closeness or repeatability of a set of values. This section will describe how and when replicate samples are taken to ensure lab precision. It is recommended that the Licensee take triplicates at one SNP station during each sampling period. If daily sampling is required at only one station, a duplicate sample should be taken each time, with a triplicate sample taken one a week.

3.2.5 Methodology

Descriptions should be included of any methods of analysis that are not taken from "Standard Methods for the Examination of Waste and Wastewater." Standard methods should be referenced.

4.0 Reporting Requirements

4.1 General Submission

The QA/QC plan will contain a section outlining what information will be reported in the monthly SNP reports. Any control charts or graphs which display the precision and accuracy of the methods used to analyze the samples should be submitted with the report. This includes warning and control limits used to determine acceptability of the data.

4.2 Outside Laboratories

The Licensee shall outline the number of replicate samples that will be collected and submitted with each SNP report. It is recommended that one set of duplicates or triplicates from an assigned SNP site, as well as the results from field blanks, be submitted with each required SNP report. This would serve as an internal/external check for the Licensee and the commercial lab.

4.3 In-House Laboratories

The Licensee shall outline the number of results from replicate samples that will be included with each required SNP report. It is recommended that two duplicate sets be collected per month at an assigned SNP site, with one set being sent to a commercial lab while the other is to be analyzed by the Licensee's lab. Analytical results from both labs should be submitted with each required SNP report. This would serve as an external check for the lab. Any results from a commercial lab should be presented on the lab's letterhead.

FOR FURTHER INFORMATION, CONTACT THE WATER RESOURCES DIVISION AT:

Box 1500
Yellowknife, NWT
X1A 2R3
(867) 669-2654 Phone
(867) 669-2716 Fax

Appendix 1
Table 1: General Summary of Special Sampling or Handling Techniques

Determination	Container	Minimum Sample Size (ml)	Preservation	Maximum Storage Recommended
BOD	Sterile polyethylene	1000	Refrigerate 4°C	24 hours
Conductivity	Polyethylene	500	Refrigerate 4°C	28 days
Total Cyanide	Polyethylene	500	Add NaOH to raise pH>12 refrigerate in dark	24 hours
Hardness	Polyethylene	100	Add Conc. HNO_3 to lower pH<2 OR (*) unpreserved	6 months
Metals, General	Polyethylene	250	For dissolved metals filter immediately, add Conc. $HN0_3$ to pH<2	6 months
Mercury	Glass (rinsed with 1 + 1 HNO_3)	500	Add Conc. HNO_3 or pH<2 or H_2SO_4 + 1 ml of 5% $K_2Cr_2O_7$, refrigerate 4°C	28 days
Nitrogen:				
Ammonia	Polyethylene	500	Analyze as soon as possible or add H_2S0_4 to pH<2, refrigerate OR (*) unpreserved	7 days
Nitrate	Polyethylene	100	Analyze as soon as possible or refrigerate	48 hours
Oil and Grease	Glass or wide-mouth calibrated	1000	Add H_2S0_4 to pH<2, refrigerate	28 days
pH	Polyethylene	--	Analyze immediately	2 hours
Suspended Solids	Polyethylene	--	Refrigerate	7 days
Temperature	Polyethylene	--	Analyze immediately	0
Turbidity	Polyethylene	--	Analyze same day; store in dark up to 24 hours, refrigerate	24 hours
Bacteria	Polyethylene (sterilized)	--	None: Keep cool	6 - 48 hours

(*) Unpreserved = check with lab that will be analyzing the samples

Appendix 2

References:

Gilbert, Andrew (1993). "Echo Bay Mines Ltd. Environmental Laboratory Quality Assurance Plan".

Soniassy, R. (1980). "A Guide for the Collection of Water and Effluent Samples"; pp 1-16; INAC

"Standard Methods for the Examination of Water and Wastewater" (1989); AHPA, AWWA and WPCF, 17th edition.

Water Resources Division, Indian and Northern Affairs Canada (1990). "Generic Quality Assurance (QA) Plan Guidelines for Use by the Licensees in Meeting SNP Requirements for Submission of a QA Plan"; INAC.

Appendix- B

Example Forms

ALS Environmental

www.alsglobal.com

Chain of Custody (COC) / Analytical Request Form

Canada Toll Free: 1 800 668 9878

Affix ALS barcode label here
(lab use only)

COC Number: 15 -

Page of

Report To	Contact and company name below will appear on the final report	
Company:		
Contact:		
Phone:		
	Company address below will appear on the final report	
Street:		
City/Province:		
Postal Code:		
Invoice To	Same as Report To	☐ YES ☐ NO
	Copy of Invoice with Report	☐ YES ☐ NO
Company:		
Contact:		

Report Format / Distribution

Select Report Format: ☐ PDF ☐ EXCEL ☐ EDD (DIGITAL)

Quality Control (QC) Report with Report ☐ YES ☐ NO

☐ Compare Results to Criteria on Report - provide details below if box checked

Select Distribution: ☐ EMAIL ☐ MAIL ☐ FAX

Email 1 or Fax

Email 2

Email 3

Invoice Distribution

Select Invoice Distribution: ☐ EMAIL ☐ MAIL ☐ FAX

Email 1 or Fax

Email 2

Select Service Level Below - Please confirm all E&P TATs with your AM - surcharges will apply

	Regular [R]	☐ Standard TAT if received by 3 pm - business days - no surcharges apply			
PRIORITY (Business Days)	**4 day [P4]**	☐	EMERGENCY	**1 Business day [E1]**	☐
	3 day [P3]	☐		**Same Day, Weekend or Statutory holiday [E0]**	☐
	2 day [P2]	☐			

Date and Time Required for all E&P TATs: dd-mmm-yy hh:mm

For tests that can not be performed according to the service level selected, you will be contacted.

Analysis Request

Indicate Filtered (F), Preserved (P) or Filtered and Preserved (F/P) below

Project Information

ALS Account # / Quote #:

Job #:

PO / AFE:

LSD:

Oil and Gas Required Fields (client use)

AFE/Cost Center:	PO#
Major/Minor Code:	Routing Code:
Requisitioner:	
Location:	

ALS Lab Work Order # (lab use only)		**ALS Contact:**	**Sampler:**

ALS Sample # (lab use only)	**Sample Identification and/or Coordinates** (This description will appear on the report)	**Date** (dd-mmm-yy)	**Time** (hh:mm)	**Sample Type**														Number of Containers

Drinking Water (DW) Samples[1] (client use)

Are samples taken from a Regulated DW System?

☐ YES ☐ NO

Are samples for human drinking water use?

☐ YES ☐ NO

Special Instructions / Specify Criteria to add on report by clicking on the drop-down list below (electronic COC only)

SAMPLE CONDITION AS RECEIVED (lab use only)

Frozen	☐			SIF Observations	Yes ☐	No	☐
Ice Packs	☐	Ice Cubes	☐	Custody seal intact	Yes ☐	No	☐
Cooling Initiated	☐						

INIITIAL COOLER TEMPERATURES °C			FINAL COOLER TEMPERATURES °C		

SHIPMENT RELEASE (client use)			INITIAL SHIPMENT RECEPTION (lab use only)			FINAL SHIPMENT RECEPTION (lab use only)		
Released by:	Date:	Time:	Received by:	Date:	Time:	Received by:	Date:	Time:

REFER TO BACK PAGE FOR ALS LOCATIONS AND SAMPLING INFORMATION WHITE - LABORATORY COPY YELLOW - CLIENT COPY

OCTOBER 2015 FRONT

Failure to complete all portions of this form may delay analysis. Please fill in this form LEGIBLY. By the use of this form the user acknowledges and agrees with the Terms and Conditions as specified on the back page of the white - report copy.

[1] If any water samples are taken from a **Regulated Drinking Water (DW) System**, please submit using an **Authorized DW COC form**.

Appendix- C

Analytical Laboratory Accreditation and Licencing

Canadian Association for Laboratory Accreditation Inc.

CALA

Certificate of Accreditation

ALS Environmental (Waterloo)
ALS Canada Ltd.
60 Northland Rd. Unit 1
Waterloo, Ontario

This laboratory is accredited in accordance with the recognized International Standard ISO/IEC 17025:2005.
This accreditation demonstrates technical competence for a defined scope and the operation of a laboratory quality management system (refer to joint ISO-ILAC-IAF Communiqué dated 8 January 2009).

Accreditation No.: A3149
Issued On: July 24, 2014
Accreditation Date: January 3, 2005
Expiry Date: January 21, 2017

President & CEO

This certificate is the property of the Canadian Association for Laboratory Accreditation Inc. and must be returned on request; reproduction must follow policy in place at date of issue. For the specific tests to which this accreditation applies, please refer to the laboratory's scope of accreditation at www.cala.ca.

Ministry of the Environment and Climate Change

Safe Drinking Water Branch
Laboratory Licensing and
Compliance Program

125 Resources Rd.
Etobicoke ON M9P 3V6
Tel: (416) 235 - 6370
Fax: (416) 235 - 6519

Ministère de l'Environnement et de l'Action en matière de changement climatique

Direction du contrôle de la qualité de l'eau potable
Programme de délivrance des permis et
de conformité des laboratoires

125, Chemin Resources
Etobicoke ON M9P 3V6
Tél: (416) 235 - 6370
Téléc: (416) 235 - 6519

Ontario

Drinking-Water Testing Licence

Under the Drinking-Water Testing Services Regulation, O. Reg. 248/03 and the Safe Drinking Water Act, 2002

Licence #: 2290

This supercedes licence issued: Sep 22, 2015

Licensee: ALS Canada Ltd.

Located at:
60 Northland Rd. Unit #1
Waterloo ON N2V 2B8
Canada

The licensee is authorized to conduct the following drinking-water tests at the laboratory:

Class: Inorganic	Technique - Sub-Technique:
4AAP-phenolics **Lab Method Code:** WT-TM-1027	Colourimetry **Appendix #:** C009
Alkalinity **Lab Method Code:** WT-TM-1032	Colourimetry **Appendix #:** C094
Alkalinity **Lab Method Code:** WT-TM-1012	Titrimetry-Manual **Appendix #:** C070
Aluminum **Lab Method Code:** NA-TM-1002	ICP-MS(Total-digested) **Appendix #:** C032
Aluminum **Lab Method Code:** NA-TM-1002	ICP-MS (Total-non-digested) **Appendix #:** C005
Ammonia **Lab Method Code:** WT-TM-1013	Colourimetry **Appendix #:** C095
Antimony **Lab Method Code:** NA-TM-1002	ICP-MS (Total-non-digested) **Appendix #:** C005
Antimony **Lab Method Code:** NA-TM-1002	ICP-MS(Total-digested) **Appendix #:** C032
Arsenic **Lab Method Code:** NA-TM-1002	ICP-MS (Total-non-digested) **Appendix #:** C005

Class: Inorganic	Technique - Sub-Technique:
Calcium **Lab Method Code:** NA-TM-1002	ICP-MS (Total-non-digested) **Appendix #:** C005
Carbon; dissolved organic **Lab Method Code:** WT-TM-1024	Combustion **Appendix #:** C047
Carbon; total organic **Lab Method Code:** WT-TM-1024	Combustion **Appendix #:** C047
Chloride **Lab Method Code:** NA-TM-1001	IC **Appendix #:** C003
Chlorine; residual **Lab Method Code:** WT-TM-1021	Colourimetry **Appendix #:** C074
Chlorine; total **Lab Method Code:** WT-TM-1021	Colourimetry **Appendix #:** C074
Chromium **Lab Method Code:** NA-TM-1002	ICP-MS(Total-digested) **Appendix #:** C032
Chromium **Lab Method Code:** NA-TM-1002	ICP-MS (Total-non-digested) **Appendix #:** C005
Chromium VI **Lab Method Code:** WT-TM-1035	IC-UV/VIS **Appendix #:** C157
Cobalt **Lab Method Code:** NA-TM-1002	ICP-MS (Total-non-digested) **Appendix #:** C005
Cobalt **Lab Method Code:** NA-TM-1002	ICP-MS(Total-digested) **Appendix #:** C032
Copper **Lab Method Code:** NA-TM-1002	ICP-MS(Total-digested) **Appendix #:** C032
Copper **Lab Method Code:** NA-TM-1002	ICP-MS (Total-non-digested) **Appendix #:** C005
Cyanate **Lab Method Code:** WT-TM-1036	ISE **Appendix #:** C161

Class: Inorganic — **Technique - Sub-Technique:**

Molybdenum — ICP-MS(Total-digested)
Lab Method Code: NA-TM-1002 — **Appendix #:** C032

Molybdenum — ICP-MS (Total-non-digested)
Lab Method Code: NA-TM-1002 — **Appendix #:** C005

Nickel — ICP-MS(Total-digested)
Lab Method Code: NA-TM-1002 — **Appendix #:** C032

Nickel — ICP-MS (Total-non-digested)
Lab Method Code: NA-TM-1002 — **Appendix #:** C005

Nitrate (as nitrogen) — IC
Lab Method Code: NA-TM-1001 — **Appendix #:** C003

Nitrilotriacetic acid — Colourimetry
Lab Method Code: WT-TM-1007 — **Appendix #:** C036

Nitrite (as nitrogen) — IC
Lab Method Code: NA-TM-1001 — **Appendix #:** C003

Nitrogen; ammonia+ammonium — Colourimetry
Lab Method Code: WT-TM-1013 — **Appendix #:** C095

Nitrogen; nitrate+nitrite — Calculation-IC
Lab Method Code: NA-TM-1001 — **Appendix #:** N/A

Nitrogen; total Kjeldahl — Colourimetry-Digestion-Aquakem
Lab Method Code: WT-TM-1023 — **Appendix #:** C099

---

o-Phosphate — Colourimetry
Lab Method Code: WT-TM-1025 — **Appendix #:** C098

Organic nitrogen — Calculation-Colourimetry-Digestion-Aquakem
Lab Method Code: WT-TM-1023 — **Appendix #:** N/A

Perchlorate — LC-MS-MS
Lab Method Code: WT-TM-1505 — **Appendix #:** C168

Phosphorus — ICP-MS (Total-non-digested)
Lab Method Code: NA-TM-1002 — **Appendix #:** C005

Class: Inorganic

	Lab Method Code:	Technique - Sub-Technique:	Appendix #:
Strontium	NA-TM-1002	ICP-MS (Total-non-digested)	C005
Sulphate	NA-TM-1001	IC	C003
Sulphide	WT-TM-1003	Colourimetry	C012
Sulphur	NA-TM-1002	ICP-MS (Total-non-digested)	C005
Sulphur	NA-TM-1002	ICP-MS(Total-digested)	C032
Thallium	NA-TM-1002	ICP-MS(Total-digested)	C032
Thallium	NA-TM-1002	ICP-MS (Total-non-digested)	C005
Tin	NA-TM-1002	ICP-MS(Total-digested)	C032
Tin	NA-TM-1002	ICP-MS (Total-non-digested)	C005
Titanium	NA-TM-1002	ICP-MS (Total-non-digested)	C005
Titanium	NA-TM-1002	ICP-MS(Total-digested)	C032
Tungsten	NA-TM-1002	ICP-MS(Total-digested)	C032
Tungsten	NA-TM-1002	ICP-MS (Total-non-digested)	C005
Uranium	NA-TM-1002	ICP-MS (Total-non-digested)	C005

Class: Microbiological	Technique - Sub-Technique:	
Total coliform **Lab Method Code:** WT-TM-1200	MF-mEndo	**Appendix #:** C002
Total coliform background **Lab Method Code:** WT-TM-1200	MF-mEndo	**Appendix #:** C002

Class: Organic	Technique - Sub-Technique:	
1,1,1,2-tetrachloroethane **Lab Method Code:** NA-TM-1102	GC-MS/FID	**Appendix #:** C113
1,1,1-trichloroethane **Lab Method Code:** NA-TM-1102	GC-MS/FID	**Appendix #:** C113
1,1,2,2-tetrachloroethane **Lab Method Code:** NA-TM-1102	GC-MS/FID	**Appendix #:** C113
1,1,2-trichloroethane **Lab Method Code:** NA-TM-1102	GC-MS/FID	**Appendix #:** C113
1,1-dichloroethane **Lab Method Code:** NA-TM-1102	GC-MS/FID	**Appendix #:** C113
1,1-dichloroethene **Lab Method Code:** NA-TM-1102	GC-MS/FID	**Appendix #:** C113
1,2,4-trichlorobenzene **Lab Method Code:** WT-TM-1101/WT-TM-1300	GC-MS	**Appendix #:** C015
1,2-dibromoethane **Lab Method Code:** NA-TM-1102	GC-MS/FID	**Appendix #:** C113
1,2-dichlorobenzene **Lab Method Code:** NA-TM-1102	GC-MS/FID	**Appendix #:** C113
1,2-dichloroethane **Lab Method Code:** NA-TM-1102	GC-MS/FID	**Appendix #:** C113
1,2-dichloropropane **Lab Method Code:** NA-TM-1102	GC-MS/FID	**Appendix #:** C113
1,2-propanediol **Lab Method Code:** WT-TM-1601	GC-FID	**Appendix #:** C090

Class: Organic — **Technique - Sub-Technique:**

2,4,6-trichlorophenol	GC-MS	**Lab Method Code:** WT-TM-1101/WT-TM-1300	**Appendix #:** C015
2,4-D	GC-MS	**Lab Method Code:** WT-TM-1107/WT-TM-1302	**Appendix #:** C023
2,4-dichlorophenol	GC-MS	**Lab Method Code:** WT-TM-1101/WT-TM-1300	**Appendix #:** C015
2,4-dimethylphenol	GC-MS	**Lab Method Code:** WT-TM-1101/WT-TM-1300	**Appendix #:** C015
2,4-dinitrophenol	GC-MS	**Lab Method Code:** WT-TM-1101/WT-TM-1300	**Appendix #:** C015
2,4-dinitrotoluene	GC-MS	**Lab Method Code:** WT-TM-1101/WT-TM-1300	**Appendix #:** C015
2,6-dichlorophenol	GC-MS	**Lab Method Code:** WT-TM-1101/WT-TM-1300	**Appendix #:** C015
2,6-dinitrotoluene	GC-MS	**Lab Method Code:** WT-TM-1101/WT-TM-1300	**Appendix #:** C015
2-chloronaphthalene	GC-MS	**Lab Method Code:** WT-TM-1101/WT-TM-1300	**Appendix #:** C015
2-chlorophenol	GC-MS	**Lab Method Code:** WT-TM-1101/WT-TM-1300	**Appendix #:** C015
2-hexanone	GC-MS/FID	**Lab Method Code:** NA-TM-1102	**Appendix #:** C113
2-methyl-4,6-dinitrophenol	GC-MS	**Lab Method Code:** WT-TM-1101/WT-TM-1300	**Appendix #:** C015
2-methylnaphthalene	GC-MS	**Lab Method Code:** WT-TM-1101/WT-TM-1300	**Appendix #:** C015
2-nitrophenol	GC-MS	**Lab Method Code:** WT-TM-1101/WT-TM-1300	**Appendix #:** C015

Class: **Organic**	Technique - Sub-Technique:
Aldrin+Dieldrin	Calculation-GC-MS
Lab Method Code: WT-TM-1102/WT-TM-1302	**Appendix #:** N/A
Anthracene	GC-MS
Lab Method Code: WT-TM-1101/WT-TM-1300	**Appendix #:** C015
Aroclor 1242	GC-MS
Lab Method Code: WT-TM-1105/WT-TM-1301	**Appendix #:** C017
Aroclor 1248	GC-MS
Lab Method Code: WT-TM-1105/WT-TM-1301	**Appendix #:** C017
Aroclor 1254	GC-MS
Lab Method Code: WT-TM-1105/WT-TM-1301	**Appendix #:** C017
Aroclor 1260	GC-MS
Lab Method Code: WT-TM-1105/WT-TM-1301	**Appendix #:** C017
Atrazine	GC-MS
Lab Method Code: WT-TM-1107/WT-TM-1302	**Appendix #:** C023
Atrazine + N-dealkylated metabolites	Calculation-GC-MS
Lab Method Code: WT-TM-1107/WT-TM-1302	**Appendix #:** N/A
Azinphos-methyl	GC-MS
Lab Method Code: WT-TM-1107/WT-TM-1302	**Appendix #:** C023
b-BHC	GC-MS
Lab Method Code: WT-TM-1102/WT-TM-1302	**Appendix #:** C019
Bendiocarb	GC-MS
Lab Method Code: WT-TM-1107/WT-TM-1302	**Appendix #:** C023
Benzene	GC-MS/FID
Lab Method Code: NA-TM-1102	**Appendix #:** C113
Benzo(a)anthracene	GC-MS
Lab Method Code: WT-TM-1101/WT-TM-1300	**Appendix #:** C015
Benzo(a)pyrene	GC-MS
Lab Method Code: WT-TM-1101/WT-TM-1300	**Appendix #:** C015

Class: Organic	Technique - Sub-Technique:
Bromomethane	GC-MS/FID
Lab Method Code: NA-TM-1102	**Appendix #:** C113
Bromoxynil	GC-MS
Lab Method Code: WT-TM-1107/WT-TM-1302	**Appendix #:** C023
Camphene	GC-MS
Lab Method Code: WT-TM-1101/WT-TM-1300	**Appendix #:** C015
Carbaryl	GC-MS
Lab Method Code: WT-TM-1107/WT-TM-1302	**Appendix #:** C023
Carbofuran	GC-MS
Lab Method Code: WT-TM-1107/WT-TM-1302	**Appendix #:** C023
Carbon disulfide	GC-MS/FID
Lab Method Code: NA-TM-1102	**Appendix #:** C113
Carbon tetrachloride	GC-MS/FID
Lab Method Code: NA-TM-1102	**Appendix #:** C113
Chlordane; total	Calculation-GC-MS
Lab Method Code: WT-TM-1102/WT-TM-1302	**Appendix #:** N/A
Chlorodibromoacetic acid	GC-Derivitatization/ECD
Lab Method Code: WT-TM-1604	**Appendix #:** C163
Chloroethane	GC-MS/FID
Lab Method Code: NA-TM-1102	**Appendix #:** C113
Chloroform	GC-MS/FID
Lab Method Code: NA-TM-1102	**Appendix #:** C113
Chloromethane	GC-MS/FID
Lab Method Code: NA-TM-1102	**Appendix #:** C113
Chlorpyrifos	GC-MS
Lab Method Code: WT-TM-1107/WT-TM-1302	**Appendix #:** C023
Chrysene	GC-MS
Lab Method Code: WT-TM-1101/WT-TM-1300	**Appendix #:** C015

Class: Organic — **Technique - Sub-Technique:**

Dichloromethane — GC-MS/FID
Lab Method Code: NA-TM-1102 — **Appendix #:** C113

Diclofop-methyl — GC-MS
Lab Method Code: WT-TM-1107/WT-TM-1302 — **Appendix #:** C023

Dieldrin — GC-MS
Lab Method Code: WT-TM-1102/WT-TM-1302 — **Appendix #:** C019

Diethyl phthalate — GC-MS
Lab Method Code: WT-TM-1101/WT-TM-1300 — **Appendix #:** C015

Diethylene glycol — GC-FID
Lab Method Code: WT-TM-1601 — **Appendix #:** C090

Dimethoate — GC-MS
Lab Method Code: WT-TM-1107/WT-TM-1302 — **Appendix #:** C023

Dimethyl phthalate — GC-MS
Lab Method Code: WT-TM-1101/WT-TM-1300 — **Appendix #:** C015

---

di-n-butyl phthalate — GC-MS
Lab Method Code: WT-TM-1101/WT-TM-1300 — **Appendix #:** C015

---

di-n-octyl phthalate — GC-MS
Lab Method Code: WT-TM-1101/WT-TM-1300 — **Appendix #:** C015

Dinoseb — GC-MS
Lab Method Code: WT-TM-1107/WT-TM-1302 — **Appendix #:** C023

Diphenyl ether — GC-MS
Lab Method Code: WT-TM-1101/WT-TM-1300 — **Appendix #:** C015

Diphenylamine — GC-MS
Lab Method Code: WT-TM-1101/WT-TM-1300 — **Appendix #:** C015

Diquat — LC-MS-MS
Lab Method Code: WT-TM-1506 — **Appendix #:** C134

Diuron — LC-MS-MS
Lab Method Code: WT-TM-1502 — **Appendix #:** C135

Class: Organic — **Technique - Sub-Technique:**

Formaldehyde — GC-Derivitatization/ECD
Lab Method Code: WT-TM-1603 — **Appendix #:** C162

g-Chlordane — GC-MS
Lab Method Code: WT-TM-1102/WT-TM-1302 — **Appendix #:** C019

Glyphosate — LC-MS-MS
Lab Method Code: WT-TM-1504 — **Appendix #:** C133

Heavy hydrocarbon (F4 Gravimetric) — GC-FID
Lab Method Code: WT-TM-1307/WT-TM-1112 — **Appendix #:** C069

Heptachlor — GC-MS
Lab Method Code: WT-TM-1102/WT-TM-1302 — **Appendix #:** C019

Heptachlor epoxide — GC-MS
Lab Method Code: WT-TM-1102/WT-TM-1302 — **Appendix #:** C019

Heptachlor+Heptachlor Epoxide — Calculation-GC-MS
Lab Method Code: WT-TM-1102/WT-TM-1302 — **Appendix #:** N/A

Hexachlorobenzene — GC-MS
Lab Method Code: WT-TM-1101/WT-TM-1300 — **Appendix #:** C015

Hexachlorobutadiene — GC-MS
Lab Method Code: WT-TM-1101/WT-TM-1300 — **Appendix #:** C015

Hexachlorocyclopentadiene — GC-MS
Lab Method Code: WT-TM-1101/WT-TM-1300 — **Appendix #:** C015

Hexachloroethane — GC-MS
Lab Method Code: WT-TM-1101/WT-TM-1300 — **Appendix #:** C015

Hexane — GC-MS/FID
Lab Method Code: NA-TM-1102 — **Appendix #:** C113

Indeno(1,2,3-c,d)pyrene — GC-MS
Lab Method Code: WT-TM-1101/WT-TM-1300 — **Appendix #:** C015

Indole — GC-MS
Lab Method Code: WT-TM-1101/WT-TM-1300 — **Appendix #:** C015

Class: Organic	Technique - Sub-Technique:		
Monochloroacetic acid	GC-Derivitatization/ECD		
Lab Method Code:	WT-TM-1604	**Appendix #:**	C163
Monochlorobenzene	GC-MS/FID		
Lab Method Code:	NA-TM-1102	**Appendix #:**	C113
MTBE	GC-MS/FID		
Lab Method Code:	NA-TM-1102	**Appendix #:**	C113
Naphthalene	GC-MS		
Lab Method Code:	WT-TM-1101/WT-TM-1300	**Appendix #:**	C015
Nitrobenzene	GC-MS		
Lab Method Code:	WT-TM-1101/WT-TM-1300	**Appendix #:**	C015
n-Nitroso-di-n-propylamine	GC-MS		
Lab Method Code:	WT-TM-1101/WT-TM-1300	**Appendix #:**	C015
Nonylphenol	LC-MS-MS		
Lab Method Code:	WT-TM-1521	**Appendix #:**	C116
Nonylphenol Diethoxylate	LC-MS		
Lab Method Code:	WT-TM-1521	**Appendix #:**	C116
Nonylphenol Monoethoxylate	LC-MS		
Lab Method Code:	WT-TM-1521	**Appendix #:**	C116
o,p'-DDD	GC-MS		
Lab Method Code:	WT-TM-1102/WT-TM-1302	**Appendix #:**	C019
o,p'-DDE	GC-MS		
Lab Method Code:	WT-TM-1102/WT-TM-1302	**Appendix #:**	C019
o,p'-DDT	GC-MS		
Lab Method Code:	WT-TM-1102/WT-TM-1302	**Appendix #:**	C019
o-Cresol	GC-MS		
Lab Method Code:	WT-TM-1101/WT-TM-1300	**Appendix #:**	C015
Octylphenol	LC-MS		
Lab Method Code:	WT-TM-1521	**Appendix #:**	C116

Class: Organic | **Technique - Sub-Technique**

Phenol GC-MS
Lab Method Code: WT-TM-1101/WT-TM-1300 **Appendix #:** C015

Phorate GC-MS
Lab Method Code: WT-TM-1107/WT-TM-1302 **Appendix #:** C023

Picloram GC-MS
Lab Method Code: WT-TM-1107/WT-TM-1302 **Appendix #:** C023

p-nitrophenol GC-MS
Lab Method Code: WT-TM-1101/WT-TM-1300 **Appendix #:** C015

Polychlorinated biphenyls GC-MS
Lab Method Code: WT-TM-1105/WT-TM-1301 **Appendix #:** C017

Prometryn GC-MS
Lab Method Code: WT-TM-1107/WT-TM-1302 **Appendix #:** C023

Pyrene GC-MS
Lab Method Code: WT-TM-1101/WT-TM-1300 **Appendix #:** C015

Simazine GC-MS
Lab Method Code: WT-TM-1107/WT-TM-1302 **Appendix #:** C023

Styrene GC-MS/FID
Lab Method Code: NA-TM-1102 **Appendix #:** C113

Temephos GC-MS
Lab Method Code: WT-TM-1107/WT-TM-1302 **Appendix #:** C023

Terbufos GC-MS
Lab Method Code: WT-TM-1107/WT-TM-1302 **Appendix #:** C023

Tetrachloroethylene GC-MS/FID
Lab Method Code: NA-TM-1102 **Appendix #:** C113

Tetraethyl Lead GC-MS
Lab Method Code: WT-TM-1308 **Appendix #:** C159

Toluene GC-MS/FID
Lab Method Code: NA-TM-1102 **Appendix #:** C113

Class: Physical/Others		Technique - Sub-Technique:	
CBOD (5 Day)	**Lab Method Code:** WT-TM-1002	Meter-D.O	**Appendix #:** C001
COD	**Lab Method Code:** WT-TM-1006	Colourimetry-Reflux	**Appendix #:** C035
Conductivity	**Lab Method Code:** WT-TM-1010	Potentiometry	**Appendix #:** C048
Conductivity	**Lab Method Code:** WT-TM-1028	Potentiometry	**Appendix #:** C108
Hardness (as CaCO3)	**Lab Method Code:** NA-TM-1002	Calculation-ICP-MS	**Appendix #:** NA
Oil and Grease; mineral	**Lab Method Code:** WT-TM-1100	Gravimetry-Extraction	**Appendix #:** C033
Oil and Grease; total	**Lab Method Code:** WT-TM-1100	Gravimetry-Extraction	**Appendix #:** C033
pH	**Lab Method Code:** WT-TM-1028	Potentiometry	**Appendix #:** C106
pH	**Lab Method Code:** WT-TM-1001	Potentiometry	**Appendix #:** C026
Solids; total	**Lab Method Code:** WT-TM-1011	Gravimetry	**Appendix #:** C056
Solids; total dissolved	**Lab Method Code:** NA-TM-1004	Gravimetry	**Appendix #:** C056
Solids; total suspended	**Lab Method Code:** WT-TM-1011	Gravimetry	**Appendix #:** C010
Solids; total volatile	**Lab Method Code:** WT-TM-1011	Gravimetry	**Appendix #:** C056
Tannins and Lignins	**Lab Method Code:** WT-TM-1015	Colourimetry-Spectrophotometry	**Appendix #:** C124

2.2 The licensee is only authorized to conduct drinking-water tests at the laboratory for the class and for the parameters set out in the licence.

2.3 Subject to conditions 2.4 and 2.5, the licensee shall only conduct drinking water tests at the laboratory for parameters using the methods that were listed in the application, and approved by this licence.

[Where applicable]

2.4 Despite condition 2.3, where the licensee listed a method for a parameter in the application for this licence, but the method is not designated as an acceptable testing method for that parameter in the protocol, the licensee is not authorized to use the method listed in the application for this licence, unless the method is specifically authorized under condition 2.5.

[Where applicable]

2.5 The licensee is specifically authorized to conduct drinking-water tests for the parameters listed below using the corresponding method listed below, despite the method not being designated as an acceptable testing method for that parameter in the protocol:

None

Accreditation

2.6 Except as authorized by condition 2.7, the licensee shall only conduct a drinking-water test if the laboratory is accredited by an accreditation body for the conduct of that test.

Non-accredited Tests [Where applicable]

2.7 In accordance with section 74 of the SDWA, the licensee is authorized to conduct the following tests for which the laboratory is not accredited by an accreditation body, using the method specified.

None

Part III: Operational Requirements

3.1. A copy of this licence shall be made readily available for reference by all persons responsible for all or part of the operation of the drinking-water testing laboratory.

3.2. A copy of this licence shall be made readily available to laboratory clients and for Ministry inspection.

3.3. The Certificate of Drinking Water Testing Licence shall be conspicuously displayed in a location at the laboratory which maximizes the likelihood of a client seeing it upon entry to the laboratory's sample receiving area.

(a) Owner of the Laboratory;
(b) Laboratory Administrator;
(c) Laboratory Operator;
(d) Laboratory Director, and
(e) Laboratory Director Designate

4.8 As per section 73(6) of the SDWA this licence is not transferable without the consent of the Director.

Information

4.9 Any information requested, by the Ministry, concerning the drinking-water testing laboratory and its operation under this licence, including but not limited to any records required to be kept by this licence shall be provided to the Ministry, upon request.

4.10 Records required by or created in accordance with the SDWA, any regulations under the SDWA, or this licence shall be retained for at least 5 years in a location where a provincial officer who is inspecting the laboratory can conveniently view them.

4. 11 The receipt of any information by the Ministry or the failure of the Ministry to prosecute any person or to require any person to take any action, under this licence or under any statute, regulation or other legal requirement, in relation to the information, shall not be construed as an approval, waiver, or justification by the Ministry of any act or omission of any person that contravenes any term or condition of this approval or any statute, regulation or other legal requirement.

Part V: Special Conditions

1 . Pursuant to subsection 10(1), clause (d) of O. Reg. 248/03, the chain of custody procedures submitted by the licensee as part of the application for this licence are approved.

2. When a sample is submitted to the licensee for a drinking-water test for a microbiological parameter, the licensee shall ensure that the test is conducted in a standardized timely manner and that microbiological plates are processed and read without extended overnight refrigerated incubation.

3. The licensee is authorized to report the results of more than one parameter (such as total THMs) as an aggregate result in order to comply with reporting requirements provided that that licensee conducts a separate test for each parameter using a method otherwise authorized by this licence, and the means by which the aggregate is calculated is documented and kept available for inspection by the Ministry.

4. The licensee shall not filter drinking water samples prior to analyses unless dictated by non-routine analytical contingencies.

4.1 The licensee shall collect and handle drinking water samples in accordance with the Ministry's Protocol.

5. Licensed laboratories shall report all adverse water quality results as per the drinking water legislation without any regard to calculated uncertainty estimations.

*** Further information on the Environmental Review Tribunal's requirements for an appeal can be obtained directly from the Tribunal at: Tel: (416) 314-4600, Fax: (416) 314-4506 or www.ert.gov.on.ca**

CALA
Canadian Association for
Laboratory Accreditation Inc.

CALA Directory of Laboratories

Membership Number: 3149
Laboratory Name: ALS Environmental (Waterloo)
Parent Institution: ALS Canada Ltd.
Address: 60 Northland Rd. Unit 1 Waterloo ON N2V 2B8
Contact: Mr. Jonathan Fisher
Phone: (519) 886-6910
Fax: (519) 886-9047
Email: ALSWT.Quality@alsglobal.com; linda.neimor@ALSGlobal.com

---

Standard: Conforms with requirements of ISO/IEC 17025
Clients Served: All Interested Parties
Revised On: August 7, 2015
Valid To: January 21, 2017

Scope of Accreditation

Air (Inorganic)
Fixed Gases - Air (180)
WT-TM-1703; modified from EPA 3C and ASTM D1946-90
GC/FID & TCD
- Carbon Dioxide
- Carbon Monoxide
- Methane
- Nitrogen
- Oxygen

Biosolids (Microbiology)
Escherichia coli (E. coli) - Biosolids (087)
WT-TM-1200; modified from MOE/LSB-E3433
MEMBRANE FILTRATION (mFC-BCIG)
- Escherichia coli (E. coli)

Biosolids (Organic)
Nonylphenol and Nonylphenol Ethoxylates - Biosolids (165)
WT-TM-1554; modified from JOURNAL OF CHROMATOGRAPHY A.849 (1999) 467-482
LC/MS - EXTRACTION
- Bisphenol A
- Nonylphenol Diethoxylate
- Nonylphenol Monoethoxylates
- Nonylphenols
- Nonylphenols Ethoxylates
- Octylphenol
- Octylphenol Diethoxylate
- Octylphenol Monoethoxylate

† "OSDWA" indicates the appendix is used for the analysis of Ontario drinking water samples, which is subject to the rules and related regulations under the Ontario "Safe Drinking Water Act" (2002).

The list of tests and measurement capabilities for which a laboratory is accredited can change at any time due to circumstances such as scope extensions, voluntary withdrawal of tests by the laboratory and suspension. Scopes are published by the CALA via the Internet at http://www.cala.ca/cala_directories.html

C1-Dibenzothiopenes
C1-Fluoranthenes/Pyrenes
C1-Fluorenes
C1-Naphthalenes
C1-Phenanthrenes/Anthracene
C2-Benzofluoroanthenes/Benzo(a)pyrenes
C2-Biphenyl
C2-Chrysenes
C2-Dibenzothiopenes
C2-Fluoranthenes/Pyrenes
C2-Fluorenes
C2-Naphthalenes
C2-Phenanthrenes/Anthracene
C3-Chrysenes
C3-Dibenzothiopenes
C3-Fluoranthenes/Pyrenes
C3-Fluorenes
C3-Naphthalenes
C3-Phenanthrenes/Anthracene
C4-Dibenzothiopenes
C4-Fluoranthenes/Pyrenes
C4-Naphthalenes
C4-Phenanthrenes/Anthracene
Chrysene
Dibenzo (a,h) anthracene
Dibenzothiopene
Fluoranthene
Fluorene
Indeno (1,2,3 - cd) pyrene
Naphthalene
Perylene
Phenanthrene
Pyrene
Quinoline
Retene

Solids (Inorganic)
Ammonia - Soil (096)
WT-TM-1013; modified from EPA 350.1
COLORIMETRIC
Ammonia

Solids (Inorganic)
Anions - Soil, Sludge (041)
NA-TM-1001, WT-TP-2013; modified from EPA 300
ION CHROMATOGRAPHY
Bromide
Chloride
Fluoride
Nitrate
Nitrite
Sulphate

† "OSDWA" indicates the appendix is used for the analysis of Ontario drinking water samples, which is subject to the rules and related regulations under the Ontario "Safe Drinking Water Act" (2002).

The list of tests and measurement capabilities for which a laboratory is accredited can change at any time due to circumstances such as scope extensions, voluntary withdrawal of tests by the laboratory and suspension. Scopes are published by the CALA via the Internet at http://www.cala.ca/cala_directories.html

Nickel
Phosphorus
Potassium
Selenium
Silver
Sodium
Strontium
Sulphur
Thallium
Tin
Titanium
Uranium
Vanadium
Zinc

Solids (Inorganic)
Metals - Solid Waste (138)
NA-TM-1700, NA-TM-1002; EPA 1311 (LEACH) and modified from EPA 6020A (ANALYSIS)
ICP/MS - TCLP

Antimony
Arsenic
Barium
Beryllium
Bismuth
Boron
Cadmium
Calcium
Chromium
Iron
Lead
Lithium
Magnesium
Manganese
Potassium
Selenium
Silver
Sodium
Strontium
Sulphur
Thallium
Tin
Uranium
Zinc
Zirconium

Solids (Inorganic)
Oil and Grease - Soil, Sludge (031)
WT-TM-1100; modified from SM 5520 B, D, E, F and EPA 8015
GRAVIMETRIC - EXTRACTION

Mineral Oil and Grease
Total Oil and Grease (Solvent Extractables)

---

† "OSDWA" indicates the appendix is used for the analysis of Ontario drinking water samples, which is subject to the rules and related regulations under the Ontario "Safe Drinking Water Act" (2002).

The list of tests and measurement capabilities for which a laboratory is accredited can change at any time due to circumstances such as scope extensions, voluntary withdrawal of tests by the laboratory and suspension. Scopes are published by the CALA via the Internet at http://www.cala.ca/cala_directories.html

2-Nitrophenol
2,3,4-Trichlorophenol
2,3,4,5-Tetrachlorophenol
2,3,4,6-Tetrachlorophenol
2,3,5-Trichlorophenol
2,3,5,6-Tetrachlorophenol
2,4-Dichlorophenol
2,4-Dimethylphenol
2,4-Dinitrophenol
2,4-Dinitrotoluene
2,4,5-Trichlorophenol
2,4,6-Trichlorophenol
2,6-Dichlorophenol
2,6-Dinitrotoluene
3,3'-Dichlorobenzidene
4-Bromophenyl Phenyl Ether
4-Chloro-3-Methylphenol
4-chloroaniline
4-Chlorophenyl Phenyl Ether
4-Nitrophenol
4,6-Dinitro-o-Cresol
5-Nitroacenaphthylene
Acenaphthene
Acenaphthylene
Acridine
Anthracene
Benzo (a) anthracene
Benzo (a) pyrene
Benzo (b) fluoranthene
Benzo (g,h,i) perylene
Benzo (k) fluoranthene
Benzyl Butyl Phthalate
Biphenyl
Bis (2-Chlorethoxy) Methane
Bis (2-Chloroethyl) Ether
Bis (2-Chloroisopropyl) Ether
Bis (2-ethylhexyl) Phthalate
Camphene
Chrysene
Di-n-Butylphthalate
Di-n-Octylphthalate
Dibenzo (a,h) anthracene
Diethyl Phthalate
Dimethyl Phthalate
Diphenyl Ether
Fluoranthene
Fluorene
Hexachlorobenzene
Hexachlorobutadiene
Hexachlorocyclopentadiene
Hexachloroethane
Indeno (1,2,3 - cd) pyrene
Indole

† "OSDWA" indicates the appendix is used for the analysis of Ontario drinking water samples, which is subject to the rules and related regulations under the Ontario "Safe Drinking Water Act" (2002).

The list of tests and measurement capabilities for which a laboratory is accredited can change at any time due to circumstances such as scope extensions, voluntary withdrawal of tests by the laboratory and suspension. Scopes are published by the CALA via the Internet at http://www.cala.ca/cala_directories.html

beta-BHC
Chlordane
delta-BHC
Dieldrin
Endosulfan I
Endosulfan II
Endosulfan Sulfate
Endrin
Endrin Aldehyde
gamma-Chlordane
Heptachlor
Heptachlor Epoxide
Lindane
Mirex
o,p'-DDD
o,p'-DDE
o,p'-DDT
Oxychlordane
p,p'-DDD
p,p'-DDE
p,p'-DDT
p,p'-Methoxychlor

Solids (Organic)
Pesticides - Soil (150)
WT-TM-1107, WT-TM-1302; modified from EPA SW-846 8270 and SW-846 3500 C

GC/MS - EXTRACTION
2,4-D
2,4,5-T
2,4,5-TP
Alachlor
Ametryn
Atrazine
Atrazine Desethyl
Azinphos-methyl
Bendiocarb
Bromoxynil
Carbaryl
Carbofuran
Chlorpyrifos
Cyanazine
Diazinon
Dicamba
Diclofop-methyl
Dimethoate
Dinoseb
Malathion
MCPA
Mecoprop
Metolachlor
Metribuzin
Parathion
Phorate
Picloram

---

† "OSDWA" indicates the appendix is used for the analysis of Ontario drinking water samples, which is subject to the rules and related regulations under the Ontario "Safe Drinking Water Act" (2002).

1,1,2,2-Tetrachloroethane
1,1,2,2-Tetrachloroethane
1,2-Dibromomethane
1,2-Dichlorobenzene
1,2-Dichloroethane
1,2-Dichloropropane
1,3-Dichlorobenzene
1,4-Dichlorobenzene
2-Hexanone
Acetone (2-Propanone)
Benzene
Bromodichloromethane
Bromoform
Bromomethane
Carbon Disulfide
Carbon Tetrachloride
Chlorobenzene
Chlorodibromomethane
Chloroethane
Chloroform
Chloromethane
cis-1,2-Dichloroethylene
cis-1,3-Dichloropropene
Dibromochloromethane
Dibromomethane
Dichlorodifluoromethane
Dichloromethane
Ethylbenzene
Ethylene Dibromide
Hexane
m/p-xylene
Methyl ethyl ketone
Methyl isobutyl ketone
Methyl t-butyl ether
Methylene Chloride
o-xylene
Styrene
Tetrachloroethane
Tetrachloroethylene
Toluene
trans-1,2-Dichloroethylene
trans-1,3-Dichloropropene
Trichloroethylene
Trichlorofluoromethane
Vinyl chloride

Solids (Organic)

Volatile Organic Compounds (VOC) - Solid Waste (182)
WT-TM-1017, NA-TM-1002; EPA 1311 (LEACH) and modified from EPA SW-846 8260 (ANALYSIS)
GC/MS - HEADSPACE - TCLP
1,2-Dichlorobenzene
1,4-Dichlorobenzene
Benzene
Carbon tetrachloride

---

† "OSDWA" indicates the appendix is used for the analysis of Ontario drinking water samples, which is subject to the rules and related regulations under the Ontario "Safe Drinking Water Act" (2002).

The list of tests and measurement capabilities for which a laboratory is accredited can change at any time due to circumstances such as scope extensions, voluntary withdrawal of tests by the laboratory and suspension. Scopes are published by the CALA via the Internet at http://www.cala.ca/cala_directories.html

Water (Inorganic) OSDWA †
Alkalinity - Water (070)
WT-TM-1012; modified from SM 2320 B
MANUAL TITRATION
Alkalinity (pH 4.5)

Water (Inorganic) OSDWA †
Alkalinity - Water (094)
WT-TM-1032; modified from EPA 310.2
COLORIMETRIC
Alkalinity (pH 4.5)

Water (Inorganic) OSDWA †
Ammonia - Water (095)
WT-TM-1013; modified from EPA 350.1
COLORIMETRIC
Ammonia
Ammonia + ammonium

Water (Inorganic) OSDWA †
Anions - Water, Wastewater (003)
NA-TM-1001; modified from EPA 300.0
ION CHROMATOGRAPHY
Bromide
Chloride
Fluoride
Nitrate
Nitrite
Sulfate

Water (Inorganic) OSDWA †
Biochemical Oxygen Demand (BOD) - Water (001)
WT-TM-1002; modified from SM 5210B
D.O. METER
BOD (5 day)
CBOD (5 day)

Water (Inorganic) OSDWA †
Bromate - Water (114)
WT-TM-1503, WT-TM-1505; modified from EPA 6850
LC-MS/MS - EXTRACTION
Bromate

Water (Inorganic) OSDWA †
Carbon - Water (047)
WT-TM-1024; modified from SM 5310 B
IR - COMBUSTION
Organic Carbon

Water (Inorganic) OSDWA †
Chemical Oxygen Demand (COD) - Water (035)
WT-TM-1006; modified from SM 5220 D
REFLUX - COLORIMETRIC
COD

Water (Inorganic) OSDWA †
Chlorine - Water (074)
WT-TM-1021; modified from SM 4500-CL G and EPA 330.5
COLORIMETRIC
Free Chlorine

---

† "OSDWA" indicates the appendix is used for the analysis of Ontario drinking water samples, which is subject to the rules and related regulations under the Ontario "Safe Drinking Water Act" (2002).

Phosphorus
Potassium
Selenium
Silicon
Silver
Sodium
Strontium
Sulphur
Thallium
Tin
Titanium
Tungsten
Uranium
Vanadium
Zinc
Zirconium

Water (Inorganic) OSDWA †
Hexavalent Chromium - Water (157)
WT-TM-1035; modified from EPA 1636 and EPA 7199
ION CHROMATOGRAPHY
Chromium (Hexavalent)

Water (Inorganic) OSDWA †
Hydrogen Sulphide - Water (012)
WT-TM-1003; modified from SM 4500-S2, D, E, F
COLORIMETRIC
Hydrogen Sulfide

Water (Inorganic) OSDWA †
Mercury - Water, Wastewater (049)
WT-TM-1018; modified from EPA 7470A and EPA 245.2
COLD VAPOUR AA - SPECTROMETRIC
Mercury

Water (Inorganic) OSDWA †
Oil and Grease - Water (033)
WT-TM-1100; modified from SM 5520 B, D, E, F and EPA 1664
GRAVIMETRIC - EXTRACTION
Mineral Oil and Grease
Total Oil and Grease

Water (Inorganic) OSDWA †
Perchlorate - Water (168)
WT-TM-1505; modified from EPA 6850
LC-MS/MS - EXTRACTION
Perchlorate

Water (Inorganic) OSDWA †
pH - Water (026)
WT-TM-1001; modified from SM 4500-H B
pH - METER
pH

Water (Inorganic) OSDWA †
pH - Water (106)
WT-TM-1028; modified from SM 4500-H B
PC TITRATE
pH

† "OSDWA" indicates the appendix is used for the analysis of Ontario drinking water samples, which is subject to the rules and related regulations under the Ontario "Safe Drinking Water Act" (2002).

Cobalt
Copper
Iron
Lead
Lithium
Magnesium
Manganese
Molybdenum
Nickel
Phosphorus
Potassium
Selenium
Silicon
Silver
Sodium
Strontium
Sulphur
Thallium
Tin
Titanium
Tungsten
Uranium
Vanadium
Zinc
Zirconium

Water (Inorganic) OSDWA †
Total Phosphorus - Water (011)
WT-TM-1020; modified from SM 4500-P E, F
AUTO COLOR - DIGESTION
Total Phosphorus

Water (Inorganic) OSDWA †
Turbidity - Water (024)
WT-TM-1004; modified from SM 2130 B
TURBIDIMETRIC
Turbidity

Water (Microbiology) OSDWA †
Coliforms - Water (155)
WT-TM-1200; modified from MOE/LSB MICROMFDC-E3407
MEMBRANE FILTRATION (DC)
Escherichia coli (E. coli)
Total Coliforms

Water (Microbiology) OSDWA †
Escherichia coli (E. coli) - Water (052)
WT-TM-1200; modified from ONTARIO MOE COMPARISON EVALUATION and SM 9222D
MEMBRANE FILTRATION (mFC-BCIG)
Escherichia coli (E. coli)

Water (Microbiology) OSDWA †
Fecal (Thermotolerant) Coliforms - Water (051)
WT-TM-1200; modified from SM 9222 D
MEMBRANE FILTRATION (m FC)
Fecal (Thermotolerant) Coliforms

† "OSDWA" indicates the appendix is used for the analysis of Ontario drinking water samples, which is subject to the rules and related regulations under the Ontario "Safe Drinking Water Act" (2002).

C1-Chrysenes
C1-Dibenzothiopenes
C1-Fluoranthenes/Pyrenes
C1-Fluorenes
C1-Naphthalenes
C1-Phenanthrenes/Anthracene
C2-Benzofluoroanthenes/Benzo(a)pyrenes
C2-Biphenyl
C2-Chrysenes
C2-Dibenzothiopenes
C2-Fluoranthenes/Pyrenes
C2-Fluorenes
C2-Naphthalenes
C2-Phenanthrenes/Anthracene
C3-Chrysenes
C3-Dibenzothiopenes
C3-Fluoranthenes/Pyrenes
C3-Fluorenes
C3-Naphthalenes
C3-Phenanthrenes/Anthracene
C4-Dibenzothiopenes
C4-Fluoranthenes/Pyrenes
C4-Naphthalenes
C4-Phenanthrenes/Anthracene
Chrysene
Dibenzo (a,h) anthracene
Dibenzothiopene
Fluoranthene
Fluorene
Indeno (1,2,3 - cd) pyrene
Naphthalene
Perylene
Phenanthrene
Phenanthrene
Pyrene
Quinoline
Retene

Water (Organic) OSDWA †
Base Neutral Acid Extractables (BNA) - Water, Wastewater (015)
WT-TM-1101/WT-TM-1300; modified from EPA SW-846-8270 and EPA SW-846 3500C
GC/MS - EXTRACTION
1-Chloronaphthalene
1-Methylnaphthalene
1,2,3-Trichlorobenzene
1,2,4-Trichlorobenzene
1,3-Dichlorobenzene
2-Chloronaphthalene
2-Chlorophenol
2-Methylnaphthalene
2-Nitrophenol
2,3,4-Trichlorophenol
2,3,4,5-Tetrachlorophenol
2,3,4,6-tetrachlorophenol

---

† "OSDWA" indicates the appendix is used for the analysis of Ontario drinking water samples, which is subject to the rules and related regulations under the Ontario "Safe Drinking Water Act" (2002).

Nitrobenzene
o-Cresol
p-chloroaniline
Pentachlorophenol
Perylene
Phenanthrene
Phenol
Pyrene
Quinoline
Total Diphenylamine

Water (Organic) OSDWA †
Diquat and Paraquat - Water (134)
WT-TM-1506; modified from MDS SCIEX APPLICATION NOTE DIQUAT and PARAQUAT
LC-MS/MS - EXTRACTION
Diquat
Paraquat

Water (Organic) OSDWA †
Formaldehyde - Water (162)
WT-TM-1603; modified from EPA 556.1
GC/ECD
Formaldehyde

Water (Organic) OSDWA †
Glycols - Water (090)
WT-TM-1601; modified from EPA 8015B - MODIFIED
GC/FID
1,2 - Propylene Glycol
1,3 - Propylene Glycol
Diethylene Glycol
Ethylene Glycol
Triethylene Glycol

Water (Organic) OSDWA †
Glyphosate - Water (133)
WT-TM-1504; modified from MOE-GLYMS-E3500
LC-MS/MS - EXTRACTION
Glyphosate

Water (Organic) OSDWA †
Haloacetic Acids - Water (163)
WT-TM-1604; modified from EPA 552.3
GC/ECD
Bromoacetic Acid (BAA)
Bromochloroacetic Acid
Bromodichloroacetic Acid
Chloroacetic Acid (CAA)
Chlorodibromoacetic Acid
Dalapon (2,2-Dichloropropionic Acid)
Dibromoacetic Acid (DBAA)
Dichloroacetic Acid (DCAA)
Tribromoacetic acid (TBAA)
Trichloroacetic Acid (TCAA)

---

† "OSDWA" indicates the appendix is used for the analysis of Ontario drinking water samples, which is subject to the rules and related regulations under the Ontario "Safe Drinking Water Act" (2002).

The list of tests and measurement capabilities for which a laboratory is accredited can change at any time due to circumstances such as scope extensions, voluntary withdrawal of tests by the laboratory and suspension. Scopes are published by the CALA via the Internet at http://www.cala.ca/cala_directories.html

Water (Organic)
Perfluorooctanoic Acid (PFOA) and Perfluorooctane Sulfonate (PFOS) - Water (174)
WT-TM-1557; modified from JOURNAL OF CHROMATOGRAPHY A.1093 (2005), 89-97
LC-MS/MS
Perfluorooctane Sulfonate (PFOS)
Perfluorooctanoic Acid (PFOA)

Water (Organic) OSDWA †
Pesticides - Water (023)
WT-TM-1107/WT-TM-1109-/WT-TM-1302; modified from EPA SW-846 8270 and EPA SW-846 3500C
GC/MS - EXTRACTION
2,4-dichlorophenoxyacetic acid
2,4,5-trichlorophenoxyacetic acid
Alachlor
Atrazine
Azinphos-methyl
Bendiocarb
Bromoxynil
Carbaryl
Carbofuran
Chlorpyrifos (ethyl)
Cyanazine
De-ethylated atrazine
Diazinon
Dicamba
Diclofop-methyl (as free acid)
Dimethoate
Dinoseb
Malathion
Metolachlor
Metribuzin
Parathion (ethyl)
Phorate
Picloram
Prometryne
Simazine
Temephos
Terbufos
Triallate
Trifluralin

Water (Organic) OSDWA †
Petroleum Hydrocarbons (PHC) - Water (068)
WT-TM-1307/WT-TM-1112; modified from MOE:DECPH E3421
GC/FID - EXTRACTION
F2 (C10-C16)
F3 (C16-C34)
F4 (C34-C50)

Water (Organic) OSDWA †
Petroleum Hydrocarbons (PHC) - Water (069)
WT-TM-1307/WT-TM-1112; modified from MOE:DECPH E3421
GRAVIMETRIC
F4G (C34-C50)

---

† "OSDWA" indicates the appendix is used for the analysis of Ontario drinking water samples, which is subject to the rules and related regulations under the Ontario "Safe Drinking Water Act" (2002).

The list of tests and measurement capabilities for which a laboratory is accredited can change at any time due to circumstances such as scope extensions, voluntary withdrawal of tests by the laboratory and suspension. Scopes are published by the CALA via the Internet at http://www.cala.ca/cala_directories.html

Water (Organic) OSDWA †

Volatile Organic Compounds - Water (113)

NA-TM-1102; modified from EPA 8260C and EPA 5021A

GC/MS - HEADSPACE

1,1-Dichloroethane
1,1-Dichloroethylene
1,1-Dichloropropene
1,1,1-Trichloroethane
1,1,1,2- Tetrachloroethane
1,1,2-Trichloroethane
1,1,2,2-Tetrachloroethane
1,2-Dibromo-3-Chloropropane
1,2-Dichlorobenzene
1,2-Dichloroethane
1,2-Dichloropropane
1,2,3-Trichlorobenzene
1,2,3-Trichloropropane
1,2,4-Trichlorobenzene
1,2,4-Trimethylbenzene
1,3-Dichlorobenzene
1,3-Dichloropropane
1,3,5-TrimethylBenzene
1,4-Dichlorobenzene
2-Chlorotoluene
2-Hexanone
2,2-Dichloropropane
4-Chlorotoluene
Acetone (2-Propanone)
Benzene
Bromobenzene
Bromochloromethane
Bromodichloromethane
Bromoform
Bromomethane
Carbon disulfide
Carbon Tetrachloride
Chlorobenzene
Chlorodibromomethane
Chloroethane
Chloroform
Chloromethane
cis-1,2-Dichloroethylene
cis-1,3-Dichloropropene
Dichlorodifluoromethane
Dichloromethane
Ethylbenzene
Ethylene Dibromide
Hexachlorobutadiene
Hexane
Isopropylbenzene
Isopropyltoluene
Isopropyltoluene
m/p-xylene

---

† "OSDWA" indicates the appendix is used for the analysis of Ontario drinking water samples, which is subject to the rules and related regulations under the Ontario "Safe Drinking Water Act" (2002).

The list of tests and measurement capabilities for which a laboratory is accredited can change at any time due to circumstances such as scope extensions, voluntary withdrawal of tests by the laboratory and suspension. Scopes are published by the CALA via the Internet at http://www.cala.ca/cala_directories.html

Canadian Association for Laboratory Accreditation Inc.

Certificate of Accreditation

AquaTox Testing & Consulting Inc.
11B Nicholas Beaver Road
Guelph, Ontario

This laboratory is accredited in accordance with the recognized International Standard ISO/IEC 17025:2005. This accreditation demonstrates technical competence for a defined scope and the operation of a laboratory quality management system (refer to joint ISO-ILAC-IAF Communiqué dated 8 January 2009).

Accreditation No.: A2803
Issued On: November 10, 2014
Accreditation Date: January 3, 2005
Expiry Date: May 10, 2017

President & CEO

This certificate is the property of the Canadian Association for Laboratory Accreditation Inc. and must be returned on request; reproduction must follow policy in place at date of issue For the specific tests to which this accreditation applies, please refer to the laboratory's scope of accreditation at www.cala.ca.

CALA
Canadian Association for
Laboratory Accreditation Inc.

CALA Directory of Laboratories

Membership Number:	2803
Laboratory Name:	AquaTox Testing & Consulting Inc.
Parent Institution:	
Address:	11B Nicholas Beaver Road Guelph ON N1H 6H9
Contact:	Ms. Stephanie Folz
Phone:	(519) 763-4412
Fax:	(519) 763-4419
Email:	sfolz@aquatox.ca

Standard:	Conforms with requirements of ISO/IEC 17025
Clients Served:	
Revised On:	November 10, 2014
Valid To:	May 10, 2017

Scope of Accreditation

Solids (Toxicology)
Chironomids - Sediment (011)
SOP 391, 271; EPS 1/RM/32
SURVIVAL AND GROWTH
Chironomus dilutus (formerly Chironomus tentans)
Chironomus riparius

Solids (Toxicology)
Hyalella azteca - Sediment (010)
SOP 390, 270; EPS 1/RM/33
SURVIVAL AND GROWTH
Hyalella azteca

Solids (Toxicology)
Marine Amphipods - Sediment (015)
SOP 387; EPS 1/RM/26, EPS 1/RM/35
ACUTE LETHALITY (SURVIVAL)
Amphipods

Solids (Toxicology)
Microtox - Solid Phase - Sediment (021)
SOP 375; EPS 1/RM/42
BIOLUMINESCENCE
Microtox Solid Phase IC-50

Solids (Toxicology)
Polydora cornuta - Sediment (030)
SOP 361; EPS 1/RM/41
SURVIVAL AND GROWTH
Polydora cornuta

---

† "OSDWA" indicates the appendix is used for the analysis of Ontario drinking water samples, which is subject to the rules and related regulations under the Ontario "Safe Drinking Water Act" (2002).

The list of tests and measurement capabilities for which a laboratory is accredited can change at any time due to circumstances such as scope extensions, voluntary withdrawal of tests by the laboratory and suspension. Scopes are published by the CALA via the Internet at http://www.cala.ca/cala_directories.html

Water (Toxicology)
Rainbow Trout - Water (001)
SOP 330, 308, 240; EPS 1/RM/9, EPS 1/RM/13
ACUTE LETHALITY (SURVIVAL)
Trout LC50 (96 h)
Trout Single Concentration (96h)

Water (Toxicology)
Silverside - Water (009)
SOP 371; modified from EPA - 821-R-02-014, METHOD 1006.0
GROWTH AND SURVIVAL
Silverside

---

† "OSDWA" indicates the appendix is used for the analysis of Ontario drinking water samples, which is subject to the rules and related regulations under the Ontario "Safe Drinking Water Act" (2002).

The list of tests and measurement capabilities for which a laboratory is accredited can change at any time due to circumstances such as scope extensions, voluntary withdrawal of tests by the laboratory and suspension. Scopes are published by the CALA via the Internet at http://www.cala.ca/cala_directories.html

Appendix- D

Laboratory Analytical Methods

Quoted Parameters with Detection Limits

Parameter	Method Reference	Report D.L.	Units
Misc.-Field Tests			
Air volume	HYGIENE METHOD	0	
Waste-Sample Preparation			
Final pH	EPA 1311	0.10	pH units
Initial pH	EPA 1311	0.10	pH units
Water-Physical Tests			
Color, Apparent	APHA 2120	1.0	C.U.
Conductivity	APHA 2510 B	3.0	umhos/ cm
Hardness (as CaCO3)	APHA 2340 B	10	mg/L
pH	APHA 4500 H-Electrode	0.10	pH units
Total Dissolved Solids	APHA 2540C	20	mg/L
Total Suspended Solids	APHA 2540 D-Gravimetric	2.0	mg/L
Turbidity	APHA 2130 B	0.10	NTU
Soil-Physical Tests			
% Moisture	Gravimetric: Oven Dried	0.10	%
Soil-Particle Size			
% Clay (<2um)	Forestry Canada (1991) p. 46-53	0.10	%
% Sand (2.0mm - 0.05mm)	Forestry Canada (1991) p. 46-53	0.10	%
% Silt (0.05mm - 2um)	Forestry Canada (1991) p. 46-53	0.10	%
Texture	Forestry Canada (1991) p. 46-53		
Filter-Particulates			
Particulates Analysis	SEE SUBLET LAB'S REPORT		
Dustfall-Particulates			
Fixed Insoluble Dustfall	BCMOE DUSTFALLS	0.10	mg/ dm2.day
Total Insoluble Dustfall	BCMOE DUSTFALLS	0.10	mg/ dm2.day
Volatile Insoluble Dustfall	BCMOE DUSTFALLS	0.10	mg/ dm2.day
Air-Asbestos/Quartz/Other Fibres			
Cristobalite	NIOSH 7500		
Soil-Leachable Anions & Nutrients			
Nitrate-N	EPA 300.0	1.0	ug/g
Nitrite-N	EPA 300.0	1.0	ug/g
Total Kjeldahl Nitrogen	APHA 4500-N	200	mg/kg
Water-Anions and Nutrients			
Alkalinity, Bicarbonate (as CaCO3)	EPA 310.2	10	mg/L

Quoted Parameters with Detection Limits

Parameter	Method Reference	Report D.L.	Units
Alkalinity, Carbonate (as CaCO3)	EPA 310.2	10	mg/L
Alkalinity, Hydroxide (as CaCO3)	EPA 310.2	10	mg/L
Alkalinity, Total (as CaCO3)	EPA 310.2	10	mg/L
Ammonia, Total (as N)	EPA 350.1	0.050	mg/L
Bromide (Br)	EPA 300.0 (IC)	0.10	mg/L
Chloride	EPA 300.0 (IC)	2.0	mg/L
Chloride (Cl)	EPA 300.0 (IC)	2.0	mg/L
Fluoride	EPA 300.0 (IC)	0.10	mg/L
Nitrate and Nitrite as N	APHA 4110 B	0.10	mg/L
Nitrate-N (NO3-N)	EPA 300.0 (IC)	0.10	mg/L
Nitrite-N	EPA 300.1 (Modified)	0.0010	mg/L
Sulphate	EPA 300.0 (IC)	2.0	mg/L
Sulphate (SO4)	EPA 300.0 (IC)	2.0	mg/L
Total Kjeldahl Nitrogen	APHA 4500-N	0.15	mg/L
Total Phosphorus	APHA 4500-P B E	0.0030	mg/L
Soil-Anions and Nutrients			
Nitrate and Nitrite as N	APHA 4110 B	1.0	ug/g
Water-Cyanides			
Cyanide, Free	ASTM 7237	0.0050	mg/L
Water-Organic / Inorganic Carbon			
Dissolved Organic Carbon	APHA 5310 B-INSTRUMENTAL	1.0	mg/L
Total Organic Carbon	APHA 5310B	1.0	mg/L
Soil-Organic / Inorganic Carbon			
Fraction Organic Carbon	CARTER 21.2	0.0010	g/g
Total Organic Carbon	CARTER 21.2	0.10	%
Water-Bacteriological Tests			
E. Coli	SM 9222D	0	CFU/100 mL
Fecal Coliforms	SM 9222D	0	CFU/100 mL
Total Coliforms	SM 9222B	0	CFU/100 mL
Soil-Metals			
Aluminum (Al)	EPA 200.2/6020A	50	ug/g
Arsenic (As)	EPA 200.2/6020A	0.2	ug/g
Arsenic (As)	EPA 200.2/6020A	1	ug/g
Barium (Ba)	EPA 200.2/6020A	1	ug/g
Cadmium (Cd)	EPA 200.2/6020A	0.5	ug/g
Calcium (Ca)	EPA 200.2/6020A	100	ug/g

Quoted Parameters with Detection Limits

Parameter	Method Reference	Report D.L.	Units
Chromium (Cr)	EPA 200.2/6020A	1	ug/g
Copper (Cu)	EPA 200.2/6020A	1	ug/g
Iron (Fe)	EPA 200.2/6020A	50	ug/g
Lead (Pb)	EPA 200.2/6020A	1	ug/g
Magnesium (Mg)	EPA 200.2/6020A	20	ug/g
Manganese (Mn)	EPA 200.2/6020A	1	ug/g
Mercury (Hg)	SW846 3050B/7471	0.010	ug/g
Sodium (Na)	EPA 200.2/6020A	100	ug/g
Uranium (U)	EPA 200.2/6020A	1	ug/g
Zinc (Zn)	EPA 200.2/6020A	5	ug/g
Dustfall-Metals			
Aluminum (Al)-Total	EPA 6020A	0.0030	mg/ dm2.day
Antimony (Sb)-Total	EPA 6020A	0.00010	mg/ dm2.day
Arsenic (As)-Total	EPA 6020A	0.00010	mg/ dm2.day
Barium (Ba)-Total	EPA 6020A	0.000050	mg/ dm2.day
Beryllium (Be)-Total	EPA 6020A	0.00050	mg/ dm2.day
Bismuth (Bi)-Total	EPA 6020A	0.00050	mg/ dm2.day
Boron (B)-Total	EPA 6020A	0.010	mg/ dm2.day
Cadmium (Cd)-Total	EPA 6020A	0.000050	mg/ dm2.day
Calcium (Ca)-Total	EPA 6020A	0.020	mg/ dm2.day
Chromium (Cr)-Total	EPA 6020A	0.00050	mg/ dm2.day
Cobalt (Co)-Total	EPA 6020A	0.00010	mg/ dm2.day
Copper (Cu)-Total	EPA 6020A	0.00050	mg/ dm2.day
Interval	EPA 245.7	1	days
Interval	EPA 6020A	1	days
Lead (Pb)-Total	EPA 6020A	0.000050	mg/ dm2.day
Lithium (Li)-Total	EPA 6020A	0.0050	mg/ dm2.day
Magnesium (Mg)-Total	EPA 6020A	0.0050	mg/ dm2.day
Manganese (Mn)-Total	EPA 6020A	0.000050	mg/ dm2.day
Mercury (Hg)-Total	EPA 245.7	0.000050	mg/ dm2.day

Quoted Parameters with Detection Limits

Parameter	Method Reference	Report D.L.	Units
Molybdenum (Mo)-Total	EPA 6020A	0.000050	mg/ dm2.day
Nickel (Ni)-Total	EPA 6020A	0.00050	mg/ dm2.day
Potassium (K)-Total	EPA 6020A	0.050	mg/ dm2.day
Selenium (Se)-Total	EPA 6020A	0.0010	mg/ dm2.day
Silver (Ag)-Total	EPA 6020A	0.000010	mg/ dm2.day
Sodium (Na)-Total	EPA 6020A	0.050	mg/ dm2.day
Strontium (Sr)-Total	EPA 6020A	0.00010	mg/ dm2.day
Thallium (Tl)-Total	EPA 6020A	0.00010	mg/ dm2.day
Tin (Sn)-Total	EPA 6020A	0.00010	mg/ dm2.day
Uranium (U)-Total	EPA 6020A	0.000010	mg/ dm2.day
Vanadium (V)-Total	EPA 6020A	0.0010	mg/ dm2.day
Zinc (Zn)-Total	EPA 6020A	0.0030	mg/ dm2.day

Water-Total Metals

Aluminum (Al)-Total	APHA 3030 B&E / EPA SW-846 6020A	0.003	mg/L
Aluminum (Al)-Total	APHA 3030 B&E / EPA SW-846 6020A	0.01	mg/L
Aluminum (Al)-Total	EPA 200.8	0.01	mg/L
Antimony (Sb)-Total	APHA 3030 B&E / EPA SW-846 6020A	0.0001	mg/L
Arsenic (As)-Total	APHA 3030 B&E / EPA SW-846 6020A	0.0001	mg/L
Arsenic (As)-Total	EPA 200.8	0.001	mg/L
Barium (Ba)-Total	APHA 3030 B&E / EPA SW-846 6020A	0.00005	mg/L
Barium (Ba)-Total	EPA 200.8	0.002	mg/L
Beryllium (Be)-Total	APHA 3030 B&E / EPA SW-846 6020A	0.0001	mg/L
Bismuth (Bi)-Total	APHA 3030 B&E / EPA SW-846 6020A	0.0005	mg/L
Boron (B)-Total	APHA 3030 B&E / EPA SW-846 6020A	0.01	mg/L
Cadmium (Cd)-Total	APHA 3030 B&E / EPA SW-846 6020A	0.00001	mg/L
Cadmium (Cd)-Total	EPA 200.8	0.00009	mg/L
Calcium (Ca)-Total	EPA 200.8	0.5	mg/L
Calcium (Ca)-Total	EPA SW-846 3005A/6010B	0.05	mg/L
Chromium (Cr)-Total	APHA 3030 B&E / EPA SW-846 6020A	0.0001	mg/L
Chromium (Cr)-Total	EPA 200.8	0.0005	mg/L
Cobalt (Co)-Total	APHA 3030 B&E / EPA SW-846 6020A	0.0001	mg/L
Copper (Cu)-Total	APHA 3030 B&E / EPA SW-846 6020A	0.0005	mg/L
Copper (Cu)-Total	EPA 200.8	0.001	mg/L

Quoted Parameters with Detection Limits

Parameter	Method Reference	Report D.L.	Units
Iron (Fe)-Total	APHA 3030 B&E / EPA SW-846 6020A	0.01	mg/L
Iron (Fe)-Total	EPA 200.8	0.05	mg/L
Lead (Pb)-Total	APHA 3030 B&E / EPA SW-846 6020A	0.00005	mg/L
Lead (Pb)-Total	EPA 200.8	0.0005	mg/L
Lithium (Li)-Total	APHA 3030 B&E / EPA SW-846 6020A	0.0005	mg/L
Magnesium (Mg)-Total	EPA 200.8	0.5	mg/L
Magnesium (Mg)-Total	EPA SW-846 3005A/6010B	0.1	mg/L
Manganese (Mn)-Total	APHA 3030 B&E / EPA SW-846 6020A	0.00005	mg/L
Manganese (Mn)-Total	EPA 200.8	0.001	mg/L
Mercury (Hg)-Total	EPA SW846 7470A	0.000010	mg/L
Molybdenum (Mo)-Total	APHA 3030 B&E / EPA SW-846 6020A	0.00005	mg/L
Nickel (Ni)-Total	APHA 3030 B&E / EPA SW-846 6020A	0.0005	mg/L
Phosphorus (P)-Total	EPA SW-846 3005A/6010B	0.3	mg/L
Potassium (K)-Total	APHA 3030 B&E / EPA SW-846 6020A	0.05	mg/L
Selenium (Se)-Total	APHA 3030 B&E / EPA SW-846 6020A	0.0001	mg/L
Silicon (Si)-Total	EPA SW-846 3005A/6010B	0.05	mg/L
Silver (Ag)-Total	APHA 3030 B&E / EPA SW-846 6020A	0.00001	mg/L
Sodium (Na)-Total	APHA 3030 B&E / EPA SW-846 6020A	0.05	mg/L
Sodium (Na)-Total	EPA 200.8	0.5	mg/L
Strontium (Sr)-Total	APHA 3030 B&E / EPA SW-846 6020A	0.0002	mg/L
Thallium (Tl)-Total	APHA 3030 B&E / EPA SW-846 6020A	0.00001	mg/L
Tin (Sn)-Total	APHA 3030 B&E / EPA SW-846 6020A	0.0001	mg/L
Titanium (Ti)-Total	EPA SW-846 3005A/6010B	0.01	mg/L
Uranium (U)-Total	APHA 3030 B&E / EPA SW-846 6020A	0.00001	mg/L
Uranium (U)-Total	EPA 200.8	0.001	mg/L
Vanadium (V)-Total	APHA 3030 B&E / EPA SW-846 6020A	0.001	mg/L
Zinc (Zn)-Total	APHA 3030 B&E / EPA SW-846 6020A	0.003	mg/L
Zinc (Zn)-Total	EPA 200.8	0.003	mg/L
Water-Dissolved Metals			
Aluminum (Al)-Dissolved	APHA 3030 B&E / EPA SW-846 6020A	0.001	mg/L
Antimony (Sb)-Dissolved	APHA 3030 B&E / EPA SW-846 6020A	0.0001	mg/L
Arsenic (As)-Dissolved	APHA 3030 B&E / EPA SW-846 6020A	0.0001	mg/L
Barium (Ba)-Dissolved	APHA 3030 B&E / EPA SW-846 6020A	0.00005	mg/L
Beryllium (Be)-Dissolved	APHA 3030 B&E / EPA SW-846 6020A	0.0001	mg/L
Bismuth (Bi)-Dissolved	APHA 3030 B&E / EPA SW-846 6020A	0.0005	mg/L
Boron (B)-Dissolved	APHA 3030 B&E / EPA SW-846 6020A	0.01	mg/L
Cadmium (Cd)-Dissolved	APHA 3030 B&E / EPA SW-846 6020A	0.00001	mg/L
Calcium (Ca)-Dissolved	EPA 200.8	0.5	mg/L
Chromium (Cr)-Dissolved	APHA 3030 B&E / EPA SW-846 6020A	0.0001	mg/L

Quoted Parameters with Detection Limits

Parameter	Method Reference	Report D.L.	Units
Cobalt (Co)-Dissolved	APHA 3030 B&E / EPA SW-846 6020A	0.0001	mg/L
Copper (Cu)-Dissolved	APHA 3030 B&E / EPA SW-846 6020A	0.0002	mg/L
Dissolved Metals Filtration Location	EPA 200.8		
Iron (Fe)-Dissolved	APHA 3030 B&E / EPA SW-846 6020A	0.01	mg/L
Lead (Pb)-Dissolved	APHA 3030 B&E / EPA SW-846 6020A	0.00005	mg/L
Lithium (Li)-Dissolved	APHA 3030 B&E / EPA SW-846 6020A	0.0005	mg/L
Magnesium (Mg)-Dissolved	EPA 200.8	0.5	mg/L
Manganese (Mn)-Dissolved	APHA 3030 B&E / EPA SW-846 6020A	0.00005	mg/L
Molybdenum (Mo)-Dissolved	APHA 3030 B&E / EPA SW-846 6020A	0.00005	mg/L
Nickel (Ni)-Dissolved	APHA 3030 B&E / EPA SW-846 6020A	0.0005	mg/L
Potassium (K)-Dissolved	EPA SW-846 3005A/6020A	0.05	mg/L
Selenium (Se)-Dissolved	APHA 3030 B&E / EPA SW-846 6020A	0.0001	mg/L
Silver (Ag)-Dissolved	APHA 3030 B&E / EPA SW-846 6020A	0.00001	mg/L
Sodium (Na)-Dissolved	APHA 3030 B&E / EPA SW-846 6020A	0.05	mg/L
Strontium (Sr)-Dissolved	APHA 3030 B&E / EPA SW-846 6020A	0.0002	mg/L
Thallium (Tl)-Dissolved	APHA 3030 B&E / EPA SW-846 6020A	0.00001	mg/L
Tin (Sn)-Dissolved	APHA 3030 B&E / EPA SW-846 6020A	0.0001	mg/L
Titanium (Ti)-Dissolved	APHA 3030 B&E / EPA SW-846 6020A	0.01	mg/L
Uranium (U)-Dissolved	APHA 3030 B&E / EPA SW-846 6020A	0.00001	mg/L
Vanadium (V)-Dissolved	APHA 3030 B&E / EPA SW-846 6020A	0.001	mg/L
Zinc (Zn)-Dissolved	APHA 3030 B&E / EPA SW-846 6020A	0.001	mg/L
Waste-TCLP Metals			
Arsenic (As)	EPA 200.8	0.001	mg/L
Barium (Ba)	EPA 200.8	0.01	mg/L
Cadmium (Cd)	EPA 200.8	0.0001	mg/L
Chromium (Cr)	EPA 200.8	0.001	mg/L
Lead (Pb)	EPA 200.8	0.001	mg/L
Mercury (Hg)	SW846 7470A	0.00010	mg/L
Water-Aggregate Organics			
BOD	APHA 5210 B	2.0	mg/L
COD	APHA 5220 D	10	mg/L
Oil and Grease, Total	APHA 5520 B	2.0	mg/L
Mineral Oil and Grease	APHA 5520 B	1.0	mg/L
Phenols (4AAP)	EPA 9066	0.0010	mg/L
Soil-Aggregate Organics			
Oil and Grease, Total	APHA 5520 B	500	mg/kg
Water-Volatile Organic Compounds			
1,4-Difluorobenzene	SW846 8260 (HEADSPACE)	1	

Quoted Parameters with Detection Limits

Parameter	Method Reference	Report D.L.	Units
4-Bromofluorobenzene	SW846 8260 (HEADSPACE)	1	
Benzene	SW846 8260 (HEADSPACE)	0.5	ug/L
Ethyl Benzene	SW846 8260 (HEADSPACE)	0.5	ug/L
Toluene	SW846 8260 (HEADSPACE)	0.5	ug/L
Water-Hydrocarbons			
2-Bromobenzotrifluoride	MOE DECPH-E3421/CCME TIER 1	1	
3,4-Dichlorotoluene	E3421/CCME (HS)	1	
Chrom. to baseline at nC50	MOE DECPH-E3421/CCME TIER 1		
F2-Naphth	CCME CWS-PHC DEC-2000 - PUB# 1310-L	100	ug/L
F3-PAH	CCME CWS-PHC DEC-2000 - PUB# 1310-L	250	ug/L
F2 (C10-C16)	MOE DECPH-E3421/CCME TIER 1	100	ug/L
F3 (C16-C34)	MOE DECPH-E3421/CCME TIER 1	250	ug/L
F4 (C34-C50)	MOE DECPH-E3421/CCME TIER 1	250	ug/L
Total Hydrocarbons (C6-C50)	CCME CWS-PHC DEC-2000 - PUB# 1310-L	250	ug/L
F1 (C6-C10)	E3421/CCME (HS)	100	ug/L
F1-BTEX	CCME CWS-PHC DEC-2000 - PUB# 1310-L	100	ug/L
Soil-Hydrocarbons			
2-Bromobenzotrifluoride	MOE DECPH-E3398/CCME TIER 1	1	
3,4-Dichlorotoluene	E3398/CCME TIER 1-HS	1	
Chrom. to baseline at nC50	MOE DECPH-E3398/CCME TIER 1		
F2-Naphth	CCME CWS-PHC DEC-2000 - PUB# 1310-S	10	ug/g
F3-PAH	CCME CWS-PHC DEC-2000 - PUB# 1310-S	50	ug/g
F2 (C10-C16)	MOE DECPH-E3398/CCME TIER 1	10	ug/g
F3 (C16-C34)	MOE DECPH-E3398/CCME TIER 1	50	ug/g
F4 (C34-C50)	MOE DECPH-E3398/CCME TIER 1	50	ug/g
Total Hydrocarbons (C6-C50)	CCME CWS-PHC DEC-2000 - PUB# 1310-S	50	ug/g
F1 (C6-C10)	E3398/CCME TIER 1-HS	5.0	ug/g
F1-BTEX	CCME CWS-PHC DEC-2000 - PUB# 1310-S	10	ug/g
Water-Organic Parameters			
Chlorophyll a	EPA 445.0 ACET	0.10	ug/L
Phaeophytin a	EPA 445.0 ACET	0.10	ug/L
Misc.-Miscellaneous			
Special Request	SEE SUBLET LAB RESULTS		

Methodology

<table>
<tr><th>Product</th><th>Matrix</th><th>Product Description</th><th>Analytical Method Reference</th></tr>
<tr><td>AIR VOLUME-ED</td><td>Misc.</td><td>Air volume (L)</td><td>HYGIENE METHOD</td></tr>
<tr><td colspan="4">NOTE: When air concentrations of analytes are reported, they are based on air sampling information (air volume, sampling time, sampling flow rate) supplied by the client.</td></tr>
<tr><td>ALK-SPEC-WT</td><td>Water</td><td>Speciated Alkalinity</td><td>EPA 310.2</td></tr>
<tr><td>ALK-WT</td><td>Water</td><td>Alkalinity, Total (as CaCO3)</td><td>EPA 310.2</td></tr>
<tr><td>ANIONS3-WT</td><td>Water</td><td>Cl, F, SO4</td><td>EPA 300.0 (IC)</td></tr>
<tr><td>BOD-WT</td><td>Water</td><td>BOD</td><td>APHA 5210 B</td></tr>
<tr><td colspan="4">Diluted and seeded samples are filled in an airtight bottle and incubated at a specified temperature for 5 days.</td></tr>
<tr><td>BR-WT</td><td>Water</td><td>Bromide</td><td>EPA 300.0 (IC)</td></tr>
<tr><td>BTX-HS-WT</td><td>Soil</td><td>BTEX by Headspace</td><td>SW846 8260 (HEADSPACE)</td></tr>
<tr><td colspan="4">BTX is determined by extracting a soil or sediment sample as received with methanol, then analyzing by headspace-GC/MS.</td></tr>
<tr><td>BTX-HS-WT</td><td>Water</td><td>BTEX by Headspace</td><td>SW846 8260 (HEADSPACE)</td></tr>
<tr><td colspan="4">BTX is determined by analyzing by headspace-GC/MS.</td></tr>
<tr><td>C-DIS-ORG-WT</td><td>Water</td><td>Dissolved Organic Carbon</td><td>APHA 5310 B-INSTRUMENTAL</td></tr>
<tr><td colspan="4">Sample is filtered through a 0.45um filter, sample is then injected into a heated reaction chamber which is packed with an oxidative catalyst. The water is vaporized and the organic cabon is oxidized to carbon dioxide. The carbon dioxide is transported in a carrier gas and is measured by a non-dispersive infrared detector.</td></tr>
<tr><td>CHL/A-ACET-FLUORO-WP</td><td>Water</td><td>Chlorophyll a by fluorometry</td><td>EPA 445.0 ACET</td></tr>
<tr><td colspan="4">This analysis is done using procedures modified from EPA method 445.0. Chlorophyll a is determined by a 90 % acetone extraction followed with analysis by fluorometry using the non-acidification procedure. This method is not subject to interferences from chlorophyll b.</td></tr>
<tr><td>CL-WT</td><td>Water</td><td>Chloride</td><td>EPA 300.0 (IC)</td></tr>
<tr><td>CN-FREE-CFA-WT</td><td>Water</td><td>Free Cyanide in water by CFA</td><td>ASTM 7237</td></tr>
<tr><td colspan="4">This analysis is carried out using procedures adapted from ASTM Method 7237 "Free Cyanide with Flow Injection Analysis (FIA) Utilizing Gas Diffusion Separation and Amperometric Detection". Free cyanide is determined by in-line gas diffusion at pH 6 with final determination by colourimetric analysis.</td></tr>
<tr><td>COD-BF</td><td>Water</td><td>Chemical Oxygen Demand</td><td>APHA 5220 D</td></tr>
<tr><td colspan="4">The dichromate ion oxidizes COD material when the sample is digested and after digestion the sample is then analyzed on a spectrophotometer.</td></tr>
<tr><td>COD-WT</td><td>Water</td><td>Chemical Oxygen Demand</td><td>APHA 5220 D</td></tr>
<tr><td colspan="4">The dichromate ion oxidizes COD material when the sample is digested and after digestion the sample is then analyzed on a spectrophotometer.</td></tr>
</table>

Methodology

<table>
<tr><th>Product</th><th>Matrix</th><th>Product Description</th><th>Analytical Method Reference</th></tr>
<tr><td>COLOUR-WT</td><td>Water</td><td>Colour</td><td>APHA 2120</td></tr>
<tr><td colspan="4">Apparent colour is determined by analysis of the decanted sample using the platinum-cobalt colourimetric method.</td></tr>
<tr><td>DUSTFALLS-INS.DM2-VA</td><td>Dustfall</td><td>Dustfalls Insoluble (mg/dm2.day)</td><td>BCMOE DUSTFALLS</td></tr>
<tr><td colspan="4">Dustfall analysis is carried out in accordance with procedures published by the B.C. Ministry of Environment Laboratory.</td></tr>
<tr><td>EC-BF</td><td>Water</td><td>Conductivity</td><td>APHA 2510 B</td></tr>
<tr><td colspan="4">Water samples can be measured directly by immersing the conductivity cell into the sample.</td></tr>
<tr><td>EC-MF-WT</td><td>Water</td><td>E. coli</td><td>SM 9222D</td></tr>
<tr><td colspan="4">A 100mL volume of sample is filtered through a membrane, the membrane is placed on mFC-BCIG agar and incubated at @44.5±0.2°C for 24±2h. Method ID: WT-TM-1200</td></tr>
<tr><td>EC-WT</td><td>Water</td><td>Conductivity</td><td>APHA 2510 B</td></tr>
<tr><td colspan="4">Water samples can be measured directly by immersing the conductivity cell into the sample.</td></tr>
<tr><td>ETL-HARDNESS-CALC-WT</td><td>Water</td><td>Hardness (as CaCO3)</td><td>APHA 2340 B</td></tr>
<tr><td>ETL-N2N3-WT</td><td>Water</td><td>Calculate from NO2 + NO3</td><td>APHA 4110 B</td></tr>
<tr><td>F-WT</td><td>Water</td><td>Fluoride</td><td>EPA 300.0 (IC)</td></tr>
<tr><td>F1-F4-CALC-WT</td><td>Soil</td><td>CCME Total Hydrocarbons</td><td>CCME CWS-PHC DEC-2000 - PUB# 1310-S</td></tr>
</table>

Analytical methods used for analysis of CCME Petroleum Hydrocarbons have been validated and comply with the Reference Method for the CWS PHC.

Hydrocarbon results are expressed on a dry weight basis.

In cases where results for both F4 and F4G are reported, the greater of the two results must be used in any application of the CWS PHC guidelines and the gravimetric heavy hydrocarbons cannot be added to the C6 to C50 hydrocarbons.
In samples where BTEX and F1 were analyzed , F1-BTEX represents a value where the sum of Benzene, Toluene, Ethylbenzene and total Xylenes has been subtracted from F1.

In samples where PAHs, F2 and F3 were analyzed, F2-Naphth represents the result where Naphthalene has been subtracted from F2. F3-PAH represents a result where the sum of Benzo(a)anthracene, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k) fluoranthene, Dibenzo(a,h)anthracene, Fluoranthene, Indeno(1,2,3-cd)pyrene, Phenanthrene, and Pyrene has been subtracted from F3.

Unless otherwise qualified, the following quality control criteria have been met for the F1 hydrocarbon range:
1. All extraction and analysis holding times were met.
2. Instrument performance showing response factors for C6 and C10 within 30% of the response factor for toluene.
3. Linearity of gasoline response within 15% throughout the calibration range.

Unless otherwise qualified, the following quality control criteria have been met for the F2-F4 hydrocarbon ranges:
1. All extraction and analysis holding times were met.
2. Instrument performance showing C10, C16 and C34 response factors within 10% of their average.
3. Instrument performance showing the C50 response factor within 30% of the average of the C10, C16 and C34 response factors.
4. Linearity of diesel or motor oil response within 15% throughout the calibration range.

Methodology

Product	Matrix	Product Description	Analytical Method Reference
F1-F4-CALC-WT	Water	CCME Total Hydrocarbons	CCME CWS-PHC DEC-2000 - PUB# 1310-L

Analytical methods used for analysis of CCME Petroleum Hydrocarbons have been validated and comply with the Reference Method for the CWS PHC.

In cases where results for both F4 and F4G are reported, the greater of the two results must be used in any application of the CWS PHC guidelines and the gravimetric heavy hydrocarbons cannot be added to the C6 to C50 hydrocarbons.
In samples where BTEX and F1 were analyzed , F1-BTEX represents a value where the sum of Benzene, Toluene, Ethylbenzene and total Xylenes has been subtracted from F1.

In samples where PAHs, F2 and F3 were analyzed, F2-Naphth represents the result where Naphthalene has been subtracted from F2. F3-PAH represents a result where the sum of Benzo(a)anthracene, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k) fluoranthene, Dibenzo(a,h)anthracene, Fluoranthene, Indeno(1,2,3-cd)pyrene, Phenanthrene, and Pyrene has been subtracted from F3.

Unless otherwise qualified, the following quality control criteria have been met for the F1 hydrocarbon range:
1. All extraction and analysis holding times were met.
2. Instrument performance showing response factors for C6 and C10 within 30% of the response factor for toluene.
3. Linearity of gasoline response within 15% throughout the calibration range.

Unless otherwise qualified, the following quality control criteria have been met for the F2-F4 hydrocarbon ranges:
1. All extraction and analysis holding times were met.
2. Instrument performance showing C10, C16 and C34 response factors within 10% of their average.
3. Instrument performance showing the C50 response factor within 30% of the average of the C10, C16 and C34 response factors.
4. Linearity of diesel or motor oil response within 15% throughout the calibration range.

F1-HS-WT	Soil	F1 (O.Reg.153/04)	E3398/CCME TIER 1-HS

Fraction F1 is determined by extracting a soil or sediment sample as received with methanol, then analyzing by headspace-GC/FID.

F1-HS-WT	Water	F1 (O.Reg.153/04)	E3421/CCME (HS)

Fraction F1 is determined by analyzing by headspace-GC/FID.

F2-F4-WT	Soil	F2-F4 (O.Reg.153/04)	MOE DECPH-E3398/CCME TIER 1

A sub-sample of the solid sample is extracted with a solvent mixture. Following extraction, the sample extract is treated in situ with Silica Gel analyzed by GC/FID.

The F2 fraction is determined by integrating the area in the chromatogram from the apex of nC10 to the apex nC16 and quantitating using external calibration using a standard mix containing nC10, nC16 and nC34. Similarly, the F3 fraction extends from the apex of nC16 to the apex nC34 and the F4 fraction covers the area from the apex nC34 to the apex nC50. If the chromatogram does not return to the baseline by the time nC50 elutes, a gravimetric determination of the F4 is performed.

Methodology

<table>
<tr><th>Product</th><th>Matrix</th><th>Product Description</th><th>Analytical Method Reference</th></tr>
<tr><td>F2-F4-WT</td><td>Water</td><td>F2-F4 (O.Reg.153/04)</td><td>MOE DECPH-E3421/CCME TIER 1</td></tr>
<tr><td colspan="4">The petroleum hydrocarbons are extracted from the aqueous samples using solvent partition. The extracts are treated with silica gel to remove polar contaminants. The final concentrated extract is analyzed by gas chromatography (GC) using flame ionization detection (FID) and a 100% polydimethylsiloxane column.

The F2 fraction is determined by integrating the area in the chromatogram from the apex of nC10 to the apex nC16 and quantitating using external calibration using a standard mix containing nC10, nC16 and nC34. Similarly, the F3 fraction extends from the apex of nC16 to the apex nC34 and the F4 fraction covers the area from the apex nC34 to the apex nC50. If the chromatogram does not return to the baseline by the time nC50 elutes, a gravimetric determination of the F4 is performed.</td></tr>
<tr><td>FILTER-NC-WT</td><td>Water</td><td>Lab Filtered and Preserved (as required)</td><td></td></tr>
<tr><td>HG-DUST(DM2-CVAFS-VA</td><td>Dustfall</td><td>Total Mercury in Dustfalls by CVAFS</td><td>EPA 245.7</td></tr>
<tr><td colspan="4">This analysis is carried out using procedures adapted from "Standard Methods for the Examination of Water and Wastewater" published by the American Public Health Association, and with procedures adapted from "Test Methods for Evaluating Solid Waste" SW-846 published by the United States Environmental Protection Agency (EPA). Instrumental analysis is by cold vapour atomic fluorescence spectrophotometry or atomic absorption spectrophotometry (EPA Method 245.7).</td></tr>
<tr><td>HG-R511-WT</td><td>Soil</td><td>Mercury-O.Reg 153/04 (July 2011)</td><td>SW846 3050B/7471</td></tr>
<tr><td colspan="4">Solid sample is digested with a heated, strong, mixed acid solution to convert all forms of mercury to divalent mercury. The divalent mercury is then reduced to elemental mercury, sparged from solution and analyzed by CVAAS.

Analysis conducted in accordance with the Protocol for Analytical Methods Used in the Assessment of Properties under Part XV.1 of the Environmental Protection Act (July 1, 2011).</td></tr>
<tr><td>HG-T-L-CVAA-WT</td><td>Water</td><td>Total Mercury in Water by CVAAS (Low)</td><td>EPA SW846 7470A</td></tr>
<tr><td colspan="4">Liquid sample is digested with a heated, strong, mixed acid solution to convert all forms of mercury to divalent mercury. The divalent mercury is then reduced to elemental mercury, sparged from solution and analyzed by CVAAS.</td></tr>
<tr><td>HG-TCLP-WT</td><td>Waste</td><td>Mercury (CVAA) for O.Reg 347</td><td>SW846 7470A</td></tr>
<tr><td>LEACH-TCLP-WT</td><td>Waste</td><td>Leachate Procedure for Reg 347</td><td>EPA 1311</td></tr>
<tr><td>MET-D-CCMS-VA</td><td>Water</td><td>Dissolved Metals in Water by CRC ICPMS</td><td>APHA 3030 B&E / EPA SW-846 6020A</td></tr>
<tr><td colspan="4">This analysis is carried out using procedures adapted from "Standard Methods for the Examination of Water and Wastewater" published by the American Public Health Association, and with procedures adapted from "Test Methods for Evaluating Solid Waste" SW-846 published by the United States Environmental Protection Agency (EPA). The procedures may involve preliminary sample treatment by acid digestion, using hotblock, or filtration (APHA 3030B&E). Instrumental analysis is by collision cell inductively coupled plasma - mass spectrometry (modified from EPA Method 6020A).</td></tr>
<tr><td>MET-D-MS-WT</td><td>Water</td><td>Dissolved Metals in Water by ICPMS</td><td>EPA 200.8</td></tr>
<tr><td colspan="4">The metal constituents of a non-acidified sample that pass through a membrane filter prior to ICP/MS analysis.

Analysis conducted in accordance with the Protocol for Analytical Methods Used in the Assessment of Properties under Part XV.1 of the Environmental Protection Act (July 1, 2011).</td></tr>
<tr><td>MET-DIS-MS-VA</td><td>Water</td><td>Dissolved Metals by ICPMS</td><td>EPA SW-846 3005A/6020A</td></tr>
<tr><td colspan="4">This analysis is carried out using procedures adapted from "Standard Methods for the Examination of Water and Wastewater" published by the American Public Health Association, and with procedures adapted from "Test Methods for Evaluating Solid Waste" SW-846 published by the United States Environmental Protection Agency (EPA). The procedure involves filtration (EPA Method 3005A) and analysis by inductively coupled plasma - mass spectrometry (EPA Method 6020A).</td></tr>
</table>

Methodology

<table>
<tr><th>Product</th><th>Matrix</th><th>Product Description</th><th>Analytical Method Reference</th></tr>
<tr><td>MET-DUST(DM2)-MS-VA</td><td>Dustfall</td><td>Total Metals in Dustfalls by ICPMS</td><td>EPA 6020A</td></tr>
<tr><td colspan="4">This analysis is carried out using procedures adapted from "Standard Methods for the Examination of Water and Wastewater" published by the American Public Health Association, and with procedures adapted from "Test Methods for Evaluating Solid Waste" SW-846 published by the United States Environmental Protection Agency (EPA). Instrumental analysis is by inductively coupled plasma - mass spectrometry (EPA Method 6020A).</td></tr>
<tr><td>MET-T-CCMS-VA</td><td>Water</td><td>Total Metals in Water by CRC ICPMS</td><td>APHA 3030 B&E / EPA SW-846 6020A</td></tr>
<tr><td colspan="4">This analysis is carried out using procedures adapted from "Standard Methods for the Examination of Water and Wastewater" published by the American Public Health Association, and with procedures adapted from "Test Methods for Evaluating Solid Waste" SW-846 published by the United States Environmental Protection Agency (EPA). The procedures may involve preliminary sample treatment by acid digestion, using hotblock, or filtration (APHA 3030B&E). Instrumental analysis is by collision cell inductively coupled plasma - mass spectrometry (modified from EPA Method 6020A).</td></tr>
<tr><td>MET-T-MS-WT</td><td>Water</td><td>Total Metals in Water by ICPMS</td><td>EPA 200.8</td></tr>
<tr><td colspan="4">This analysis involves preliminary sample treatment by hotblock acid digestion (APHA 3030E). Instrumental analysis is by inductively coupled plasma - mass spectrometry (EPA Method 6020A).</td></tr>
<tr><td>MET-TCLP-WT</td><td>Waste</td><td>O.Reg 347 TCLP Leachable Metals</td><td>EPA 200.8</td></tr>
<tr><td>MET-TOT-ICP-VA</td><td>Water</td><td>Total Metals in Water by ICPOES</td><td>EPA SW-846 3005A/6010B</td></tr>
<tr><td colspan="4">This analysis is carried out using procedures adapted from "Standard Methods for the Examination of Water and Wastewater" published by the American Public Health Association, and with procedures adapted from "Test Methods for Evaluating Solid Waste" SW-846 published by the United States Environmental Protection Agency (EPA). The procedures may involve preliminary sample treatment by acid digestion, using either hotblock or microwave oven (EPA Method 3005A). Instrumental analysis is by inductively coupled plasma - optical emission spectrophotometry (EPA Method 6010B).</td></tr>
<tr><td>MET-UG/G-CCMS-WT</td><td>Soil</td><td>Metal Scan Collision Cell ICPMS</td><td>EPA 200.2/6020A</td></tr>
<tr><td colspan="4">Sample is vigorously digested with nitric and hydrochloric acid. Analysis is conducted by ICP/MS.
Analysis conducted in accordance with the Protocol for Analytical Methods Used in the Assessment of Properties under Part XV.1 of the Environmental Protection Act (July 1, 2011), unless a subset of the Analytical Test Group (ATG) has been requested (the Protocol states that all analytes in an ATG must be reported).</td></tr>
<tr><td>MOISTURE-WT</td><td>Soil</td><td>% Moisture</td><td>Gravimetric: Oven Dried</td></tr>
<tr><td>NH3-WT</td><td>Water</td><td>Ammonia, Total as N</td><td>EPA 350.1</td></tr>
<tr><td colspan="4">Sample is measured colorimetrically. When sample is turbid a distillation step is required, sample is distilled into a solution of boric acid and measured colorimetrically.</td></tr>
<tr><td>NO2-L-IC-WP</td><td>Water</td><td>Nitrite as N by Ion Chromatography</td><td>EPA 300.1 (Modified)</td></tr>
<tr><td colspan="4">Anions in aqueous matrices are analyzed using ion chromatography with conductivity and/or UV absorbance detectors.</td></tr>
<tr><td>NO2-WT</td><td>Soil</td><td></td><td>EPA 300.0</td></tr>
<tr><td>NO3-WT</td><td>Soil</td><td>Nitrate in Soil</td><td>EPA 300.0</td></tr>
<tr><td>NO3-WT</td><td>Water</td><td>Nitrate-N</td><td>EPA 300.0 (IC)</td></tr>
<tr><td colspan="4">A filtered water sample (drinking waters-unfiltered) is analyzed by ion chromatography.</td></tr>
</table>

Methodology

<table>
<tr><th>Product</th><th>Matrix</th><th>Product Description</th><th>Analytical Method Reference</th></tr>
<tr><td>OGG-SPEC-CALC-WT</td><td>Water</td><td>Speciated Oil and Grease A/V Calculation</td><td>CALCULATION</td></tr>
<tr><td colspan="4">Sample is extracted with hexane, sample speciation into mineral and animal/vegetable fractions is achieved via silica gel separation and is then determined gravimetrically.</td></tr>
<tr><td>OGG-SPEC-WT</td><td>Water</td><td>Speciated Oil and Grease-Gravimetric</td><td>APHA 5520 B</td></tr>
<tr><td colspan="4">Sample is extracted with hexane, sample speciation into mineral and animal/vegetable fractions is achieved via silica gel separation and is then determined gravimetrically.</td></tr>
<tr><td>OGG-TOT-WT</td><td>Soil</td><td>Oil and Grease, Total</td><td>APHA 5520 B</td></tr>
<tr><td colspan="4">Sample is extracted with an acetone:hexane mixture followed, extract is then evaporated and residue is weighed to determine total oil and grease.</td></tr>
<tr><td>OGG-TOT-WT</td><td>Water</td><td>Oil and Grease, Total</td><td>APHA 5520 B</td></tr>
<tr><td colspan="4">Sample is extracted with hexane, extract is then evaporated and the residue is weighed to determine total oil and grease.</td></tr>
<tr><td>P-TOTAL-LOW-WT</td><td>Water</td><td>Phosphorus, Total, Low Level</td><td>APHA 4500-P B E</td></tr>
<tr><td colspan="4">This analysis is carried by out an discrete colorimetric auto-analyzer using procedures adapted from APHA Method 4500-P "Phosphorus".</td></tr>
<tr><td>PARTICULATE-0.10-SLT</td><td>Filter</td><td>Respirable Dust N0600</td><td>SEE SUBLET LAB'S REPORT</td></tr>
<tr><td>PH-BF</td><td>Water</td><td>pH</td><td>APHA 4500 H-Electrode</td></tr>
<tr><td colspan="4">Water samples are analyzed directly by a calibrated pH meter.
Analysis conducted in accordance with the Protocol for Analytical Methods Used in the Assessment of Properties under Part XV.1 of the Environmental Protection Act (July 1, 2011).</td></tr>
<tr><td>PH-WT</td><td>Water</td><td>pH</td><td>APHA 4500 H-Electrode</td></tr>
<tr><td colspan="4">Water samples are analyzed directly by a calibrated pH meter.
Analysis conducted in accordance with the Protocol for Analytical Methods Used in the Assessment of Properties under Part XV.1 of the Environmental Protection Act (July 1, 2011).</td></tr>
<tr><td>PHENOLS-4AAP-WT</td><td>Water</td><td>Phenol (4AAP)</td><td>EPA 9066</td></tr>
<tr><td colspan="4">An automated method is used to distill the sample. The distillate is then buffered to pH 9.4 which reacts with 4AAP and potassium ferricyanide to form a red complex which is measured colorimetrically.</td></tr>
<tr><td>PHEOA-ACET-FLUORO-WP</td><td>Water</td><td>Pheophytin a by fluorometry</td><td>EPA 445.0 ACET</td></tr>
<tr><td colspan="4">This analysis is done using procedures modified from EPA method 445.0. Pheopigments present in the sample are determined collectively as Pheophytin a by a 90% (v/v) acetone extraction followed with analysis by fluorometry using the acidification procedure.</td></tr>
<tr><td>PREP-DUSTFALL-VA</td><td>Dustfall</td><td>Dustfall Sample Preparation</td><td></td></tr>
</table>

Methodology

<table>
<tr><th>Product</th><th>Matrix</th><th>Product Description</th><th>Analytical Method Reference</th></tr>
<tr><td>PSA-3-SK</td><td>Soil</td><td>Particle size - Pipette removal OM & CO3</td><td>Forestry Canada (1991) p. 46-53</td></tr>
<tr><td colspan="4">Dry, < 2 mm soil is treated hydrochloric acid top remove carbonates, then hydrogen peroxide to remove organic matter. The remaining soil is treated with sodium hexametaphosphate to ensure complete dispersion of primary soil particles. The homogenized suspension is allowed to settle in accordance with Stoke's Law so that only clay particles remain in suspension.To determine the clay fraction, an aliquot of the clay suspension is removed, then dried and weighed. The sand fraction is determined by wet sieving the remaining suspension, then drying and weighing the sand retained on the sieve. The silt fraction is determined by calculation where % Silt = 100 - (%Sand+%Clay)

Reference:
Burt, R. (2009). Soil Survey Field and Laboratory Methods Manual. Soil Survey Investigations Report No. 5. Method 3.2.1.2.2. United States Department of Agriculture Natural Resources Conservation Service.</td></tr>
<tr><td>SAMPLE-DISPOSAL-WT</td><td>Misc.</td><td>Sample Handling and Disposal Fee</td><td></td></tr>
<tr><td>SHIPPING-WT</td><td>Misc.</td><td>Shipping Charge</td><td></td></tr>
<tr><td>SO4-WT</td><td>Water</td><td>Sulphate</td><td>EPA 300.0 (IC)</td></tr>
<tr><td>SOLIDS-TDS-BF</td><td>Water</td><td>Total Dissolved Solids</td><td>APHA 2540C</td></tr>
<tr><td colspan="4">A well-mixed sample is filtered though glass fibres filter. A known volume of the filtrate is evaporated and dried at 105±5°C overnight and then 180±10°C for 1hr.</td></tr>
<tr><td>SOLIDS-TDS-WT</td><td>Water</td><td>Total Dissolved Solids</td><td>APHA 2540C</td></tr>
<tr><td colspan="4">A well-mixed sample is filtered though glass fibres filter. A known volume of the filtrate is evaporated and dried at 105±5°C overnight and then 180±10°C for 1hr.</td></tr>
<tr><td>SOLIDS-TSS-BF</td><td>Water</td><td>Suspended solids</td><td>APHA 2540 D-Gravimetric</td></tr>
<tr><td colspan="4">A well-mixed sample is filtered through a weighed standard glass fibre filter and the residue retained is dried in an oven at 105±5°C for a minimum of four hours or until a constant weight is achieved.</td></tr>
<tr><td>SOLIDS-TSS-WT</td><td>Water</td><td>Suspended solids</td><td>APHA 2540 D-Gravimetric</td></tr>
<tr><td colspan="4">A well-mixed sample is filtered through a weighed standard glass fibre filter and the residue retained is dried in an oven at 105±5°C for a minimum of four hours or until a constant weight is achieved.</td></tr>
<tr><td>SPECIAL REQUEST-SLT</td><td>Misc.</td><td>Special Request Datachem Salt Lake</td><td>SEE SUBLET LAB RESULTS</td></tr>
<tr><td>TC-MF-WT</td><td>Water</td><td>Total Coliforms</td><td>SM 9222B</td></tr>
<tr><td colspan="4">A 100mL volume of sample is filtered through a membrane, the membrane is placed on mENDO LES agar and incubated at 35±0.5°C for 24±2h. Method ID: WT-TM-1200</td></tr>
<tr><td>TKN-WT</td><td>Soil</td><td>Total Kjeldahl Nitrogen</td><td>APHA 4500-N</td></tr>
<tr><td colspan="4">A homogenized soil sample is digested to convert the TKN to ammonium sulphate. The ammonia ions are heated to produce a colour complex. The absorbance measured by the instrument is proportional to the concentration of ammonium sulphate in the sample and is reported as TKN.</td></tr>
<tr><td>TKN-WT</td><td>Water</td><td>Total Kjeldahl Nitrogen</td><td>APHA 4500-N</td></tr>
<tr><td colspan="4">Sample is digested to convert the TKN to ammonium sulphate. The ammonia ions are heated to produce a colour complex. The absorbance measured by the instrument is proportional to the concentration of ammonium sulphate in the sample and is reported as TKN.</td></tr>
</table>

Methodology

<table>
<tr><th>Product</th><th>Matrix</th><th>Product Description</th><th>Analytical Method Reference</th></tr>
<tr><td>TOC-WT</td><td>Soil</td><td>TOC & FOC in Solids</td><td>CARTER 21.2</td></tr>
<tr><td>TOC-WT</td><td>Water</td><td>Total Organic Carbon</td><td>APHA 5310B</td></tr>
<tr><td colspan="4">Sample is injected into a heated reaction chamber which is packed with an oxidative catalyst. The water is vaporized and the organic cabon is oxidized to carbon dioxide. The carbon dioxide is transported in a carrier gas and is measured by a non-dispersive infrared detector.</td></tr>
<tr><td>TURBIDITY-BF</td><td>Water</td><td>Turbidity</td><td>APHA 2130 B</td></tr>
<tr><td colspan="4">Sample result is based on a comparison of the intensity of the light scattered by the sample under defined conditions with the intensity of light scattered by a standard reference suspension under the same conditions. Sample readings are obtained from a Nephelometer.</td></tr>
<tr><td>TURBIDITY-WT</td><td>Water</td><td>Turbidity</td><td>APHA 2130 B</td></tr>
<tr><td colspan="4">Sample result is based on a comparison of the intensity of the light scattered by the sample under defined conditions with the intensity of light scattered by a standard reference suspension under the same conditions. Sample readings are obtained from a Nephelometer.</td></tr>
<tr><td>XYLENES-SUM-CALC-WT</td><td>Soil</td><td>Sum of Xylene Isomer Concentrations</td><td>CALCULATION</td></tr>
<tr><td colspan="4">Total xylenes represents the sum of o-xylene and m&p-xylene.</td></tr>
<tr><td>XYLENES-SUM-CALC-WT</td><td>Water</td><td>Sum of Xylene Isomer Concentrations</td><td>CALCULATION</td></tr>
<tr><td colspan="4">Total xylenes represents the sum of o-xylene and m&p-xylene.</td></tr>
</table>

Appendix- E

Analytical Laboratory QA/QC Procedures

ALS Quality Management System Summary

ALS is a global diversified testing services organization with a presence on every continent, offering a broad range of services to leading global companies.

The following report summarizes standard practices routinely employed by the ALS Environmental Division in Canada. Our practices exceed accreditation requirements and have been built to meet the needs of our customers and to give them confidence in the reliability of our test data.

Additional information is available on request from the Quality Department. Customers are invited to audit or tour ALS facilities at their convenience.

Services to Customers

ALS cooperates closely with its customers to ensure their testing needs are understood, and allows them reasonable access to relevant work areas of the laboratories to audit the management system or to witness test work undertaken on their behalf.

All client issues are logged into our tracking system to ensure each issue is addressed completely and appropriately. Local and national oversight and initiatives ensure that identified improvements are incorporated in the Canadian laboratories so that customers receive the same level of service regardless of which location performs the testing.

Documentation and Document Control

Test methods and support procedures are documented in detail to ensure consistency of application, repeatability of test results and traceability of analyses.

Test method requirements include but are not limited to sample handling, sample storage, minimizing interference, sample preparation, reagent and standard specifications, equipment, supplies, calibration requirements, instrumental measurement procedures, quality control requirements, data quality objectives and corrective actions, calculations, reporting requirements, reference information, hazards and their preventive measures.

Administrative support procedures are also documented where needed to ensure quality system procedures and customer services are provided in a controlled, approved manner consistent with ALS policies and client needs.

All procedures are authorized prior to use by the signing authority, ensuring adequate technical and quality oversight.

Distribution of documents is controlled to ensure only the most recent version is available for use. Authorized documents are reviewed periodically by the signing authority to ensure they continue to meet ALS requirements and customer needs.

Test methods and support procedures are available for client viewing on-site.

Internal Audits

Internal audits are scheduled and performed by qualified Quality and Technical staff for all routine analytical procedures and Quality System elements. Such audits ensure that procedures are implemented as intended, that test methods are scientifically defensible and technically sound, and that policies, procedures and records continue to meet the Quality System objectives.

Quality staff may periodically initiate unscheduled audits in response to proficiency testing program results, client feedback, requests from managers or any other circumstance that warrants investigation.

Quality Control (QC)

ALS has established QC procedures for monitoring the validity of tests performed by its laboratories. Individual test methods specify quality control requirements, frequency of use, and Data Quality Objectives (DQOs).

The type of quality control elements used for process monitoring is dependent on the test performed, but typically includes (as appropriate): Calibration Verification Standards, Continuing Calibration Verifications, Instrument Blanks, Method Blanks, Laboratory Control Samples, Reference Materials, Matrix Spikes, Surrogate Spikes, and Internal Standards.

DQOs are established for each QC sample, based on a combination of reference method objectives, customer requirements and historical test method performance. Where applicable, prescriptive elements of reference methods take precedence over internal DQOs.

Test results for selected QC samples are available on test reports. Please contact your Account Manager for more information.

Control Charts

Control charts are used to provide a graphical representation of QC results and test method performance over time. Control charts graphically display DQOs as well as the statistically derived mean and ± 2 and 3 standard deviations ("sigma") around the mean, calculated from recent historical QC results. ALS applies advanced trend monitoring algorithms to identify outliers and non-random data distributions (trends) that may indicate undesirable changes in test method performance. The trend monitoring process has been automated within our LIMS. Upon data entry, each QC result is checked against programmed limits and trends. If a trend is identified, a notification is e-mailed to the analyst and their supervisor, so that it can be investigated and corrected.

Continuous Improvement

ALS is committed to continuously improving its processes and services. The Quality System feeds into a continuous cycle of review, implementation, and monitoring so that improvements are actively sought and adopted where needed.

Data Validation

ALS analytical data proceeds through several reviews prior to the release of final reports. The ALS data validation process includes test result validation, inter-parameter validation and report validation. Test result validation involves an independent peer review of raw and calculated test results. Inter-parameter validation occurs when all department specific parameters for a sample are completed, and involves an overall review of test results within each sample for consistency among any related test parameters. Report validation occurs when all the requested test results for a work order are completed, and involves a review of the final report before it is sent to the customer.

ALS maintains laboratory records in a traceable manner for five years.

Method Validation

Customers rely on ALS to select test methods that are appropriate to meet their needs. Wherever possible, ALS references the latest versions of published standard methods developed by organizations such as American Public Health Association, United States Environmental Protection Agency, NIOSH, Environment Canada, and other international, regional or regulatory organizations, or equipment manufacturers.

Method validations are conducted to confirm that our test methods are fit for their intended use. The validations are as extensive as necessary to meet the needs of the given application. The extent depends on the source of the method. Test methods are revalidated periodically to ensure continued suitability and fitness for purpose.

Method Detection Limits and Limits of Reporting

ALS Limits of Reporting (LORs) are established using rigorous experimental and statistical procedures that begin with the determination of the Method Detection Limit (MDL) at 99% confidence. The MDL takes into account several factors, like long term Method Blanks, low level Sample Duplicates, and low level Spiked Samples. When detected at or above the MDL, ALS test results are considered to be qualitatively accurate, and a parameter can be reported with 99% confidence as being present in the sample.

$$\boxed{\mathbf{MDL = (s_0 \times t_{n-1}) + |MBlk|}}$$

Where:
- s_0 = the standard deviation derived from the analysis of blank or low level samples, whichever gives a higher standard deviation,
- t_{n-1} = the Student's t-distribution with n-1 degrees of freedom for the one-sided 99% confidence interval.
- |MBlk|= the absolute value of the mean method blank.

ALS takes a conservative approach to detection limits. Our goal is to minimize false positives, because we recognize that any false positive results can be damaging for our clients. Where possible, we establish LORs at levels well-above the statistical MDL, and ideally at the LOQ_5. This improves the accuracy and precision of results near the detection limit, and reduces the chance of false positives due to sample-specific issues. At or above the LOQ_5, test results are considered to be quantitatively accurate. A reported parameter at the LOQ_5 is considered to be within 40% of the true value 95% of the time.

$$\boxed{\mathbf{LOQ_5 = 5s_0 + |MBlk|}}$$

Where:
- s_0 = the standard deviation used in the MDL calculation,
- |MBlk| = the absolute value of the mean method blank.

The D. L. column on ALS analytical reports contains the LOR. The LOR may be the MDL as calculated above, or a higher value. ALS does not report LORs that are less than the calculated MDL.

Measurement Uncertainty (MU)

ALS procedures for calculating measurement uncertainty are based on accepted practices of identifying components contributing to uncertainty, compiling data that represents or includes these components, evaluating the data using appropriate statistical calculations, and reporting in a manner that prevents misunderstanding of the result. The Type A method of calculating measurement uncertainty is followed, however additional factors are considered to ensure the best and most complete information is derived from our evaluation of test method performance.

The ALS model describes the dependency of uncertainty on three factors. The first is a constant contribution to uncertainty attributable to s_0, the standard deviation of the method for concentrations that approach zero. The second is a constant relative uncertainty associated with higher parameter concentrations. The third is a constant contribution to uncertainty attributable to the mean long-term method blank value where it is significant. The following is the ALS equation for measurement uncertainty, using an expansion factor of k=2:

Expanded 95% Uncertainty as a Function of Concentration

$$U(c) = 2 * [\sqrt{\{ s_0^2 + (\Theta c)^2 \}}] + |MBlk_{LT}|$$

Where:
- **U(c)** = The expanded uncertainty at concentration c. The range c ± U(c) represents approximately the 95% confidence interval (two standard deviations).
- **c** = Measured concentration of parameter in the sample.
- $\mathbf{s_0}$ = A constant contribution to standard uncertainty represented by the standard deviation at zero concentration, which is related to the method detection limit.
- $\boldsymbol{\Theta}$ = Combined relative standard uncertainty, excluding MDL and Method Blank contributions. Theta has no units.
- $|\mathbf{MBlk_{LT}}|$ = Absolute value of the mean long-term Method Blank value, where significant (i.e. if > 1/5 s_0). [Note that the Method Blank term is not expanded because it represents a constant bias, not a variance.]

Uncertainty values obtained from this procedure must be regarded as estimates. Primarily, this is because all environmental samples are different, especially with regard to matrix effects and heterogeneity. It is our intent with this procedure to arrive at an estimate of a 95% confidence level uncertainty value that can be assumed to apply to 95% (or more) of the samples that a laboratory receives for a given test. It follows that for samples where undetected matrix effects or interferences occur, or for samples that are atypically heterogeneous, uncertainty estimates may be low.

Another aspect of reporting MU is the reporting of test method bias. Bias occurs in a small number of test methods that cannot recover 100% of a parameter from a sample. In these cases ALS reports bias along with the MU to aid with the interpretation of the test result.

Participation in Interlaboratory Proficiency Testing (PT) Programs

ALS locations participate in an extensive variety of proficiency testing programs. Where available, formal programs operated by outside agencies are used. When not available, ALS utilizes less formal proficiency testing studies. Root cause analysis is initiated and corrective action plans are developed when PT program results indicate a decline in test method performance.

Staff Training

Formal training procedures are in place to ensure all staff are trained in ALS polices and analytical procedures prior to performing analyses. A staff orientation program communicates ALS polices to newly hired staff. Task specific training is performed, and analyst proficiency is demonstrated and documented before staff are authorized to work independently. On-going analyst proficiency is monitored using proficiency testing programs. Records are maintained in training logs issued to staff upon hiring.

As well, ALS Canada promotes continuing education and learning by offering advanced courses covering technical and quality functions.

Employee Agreements

ALS protects its customers' confidential information and proprietary rights. We require all employees to review and sign a Code of Conduct policy that communicates the ALS confidentiality policy. It is ALS practice to never disclose information about a client's analysis to a third party without prior consent of the client, or unless compelled to by law. If we are obligated by law to disclose such information, we will inform the client prior to doing so.

Our employees avoid involvement in activities that would diminish confidence in their competence, impartiality, judgment, or integrity by complying with the ALS Code of Conduct and Data Integrity Policy.

Sample Tracking

Procedures are in place to track samples from receipt at the lab through to final reporting. A data management system (LIMS – Laboratory Information Management System) is used to generate a work order number for each sample submission, and a unique identification number is generated for each sample within the work order. The system is then used to assign specific analyses for the samples, to identify methods to be used, and to assign due dates for the results. The system is used to manage analytical workloads and track the status of all samples in-house. LIMS is a secure system that can only be accessed using login passwords. Controlling the level of access according to staff needs provides additional security.

When requested by the client, legal sample protocols are implemented to ensure chain of custody defensibility in a court of law. Contact the lab for legal sampling and transportation instructions if this service is needed.

Equipment Calibration

Measuring and testing equipment used by ALS laboratories that can have a significant effect on the accuracy or validity of test results is calibrated using established procedures. The procedures ensure traceability through an unbroken chain of calibrations or comparisons to national measurement standards. Where traceability of measurements to SI units is not possible and/or not relevant, traceability is provided by the use of certified reference materials and/or consensus standards.

Management Reviews (MR)

Management conducts a review at least annually to ensure the management system is effective, and continues to be suitable for its operations, and to identify necessary changes or improvements. Senior management is included in the review process for all locations.

ALS Quality Control Protocols

08 May, 2012

Quality control samples are introduced into batches of samples at critical points of sample handling, preparation and analysis to demonstrate the processes are performing as expected. In general, quality control samples are considered either Instrument QC or Method QC.

Instrument QC:

Instrument QC samples demonstrate control for the instrumental portion of a method. Instrument QC requirements must be successfully met before the analysis of Method QC or samples may proceed.

- Verification of initial calibration - criteria varies with each test.
- 2nd source Calibration Verification Standard (CVS) – at minimum, with each initial calibration.
- Continuing Calibration Verification (CCV) – frequency varies by test.
- Instrument Blanks – usage and frequency varies by test.

Method QC:

Method QC samples encompass the entire method and are initiated at the earliest point of the method where appropriate. Refer to the QC Definitions below. One set of Method QC is included for each batch of up to 20 client samples. Each set includes:

- 1 Method Blank.
- 1 Sample Duplicate. *
- 1 Lab Control Sample.
- 1 Reference Material or Matrix Spike. **
- Surrogate Compounds.

* Duplicate analyses are not performed where sub-sampling is not possible – e.g. most tests for organics in water.
** Spikes and Reference Materials are unavailable for Microbiology tests.

Method QC must be successfully analyzed before sample results are approved. Method QC results are normally reported to ALS clients with data reports.

Data Quality Objectives (DQOs):

DQOs are established for each QC sample, based on a combination of reference method objectives, customer requirements and historical test method performance. Where applicable, prescriptive elements of reference methods take precedence over internal DQOs. Current DQOs are available upon request.

Detailed descriptions of how DQOs are evaluated for different types of Quality Control samples are described on the following pages.

Types of Quality Control – Definitions and Evaluation Protocols

Method Blank (MB) - A blank sample prepared to represent the sample matrix as closely as possible and analyzed exactly like the calibration standards, samples, and quality control (QC) samples. Results of Method Blanks provide an estimate of the within batch variability of the blank response and an indication of bias introduced by the analytical procedure.

Except in special cases (as outlined in ALS DQO summary documents) the ALS DQO for Method Blanks is for all results to lie below the Limit of Reporting (LOR).

Laboratory Sample Duplicate (DUP) - A second portion of sample taken from the same container as the sub-sample used for the primary analysis, that is analyzed independently through all steps of the laboratory's sampling and analytical procedures. Duplicate samples are used to assess variance of the total method including sampling and analysis.

Duplicate precision is normally measured as Relative Percent Difference (RPD), where RPD = |(Result2 - Result1) / Mean| * 100. Duplicate samples should normally agree to within the ALS Precision DQO for the test and parameter (expressed as RPD), or within ± 2 x the LOR (for low level results). Refer to the ALS DQOs for Precision for specific limits for any given test.

ALS does not establish DQOs for Field Sample Duplicates. However, it is generally understood and accepted that the variability of Field Sample Duplicates is significantly more than what is observed with Laboratory Sample Duplicates.[1]

Laboratory Control Sample (LCS) - A known matrix spiked with compound(s) representative of the target analytes. An LCS is used to verify the accuracy of the laboratory's performance of the test.

LCS accuracy is calculated as the measured amount divided by the target concentration, and is normally expressed as percent recovery. LCS recoveries should normally lie within the ALS Accuracy DQOs for the test and parameter. For a low level LCS, the result should lie within ± 1 x the LOR of the target concentration. Refer to the ALS Accuracy DQOs for specific limits for any given test.

Reference Material (RM) – A material or substance, one or more of whose property values are sufficiently homogeneous and well established to be used for the calibration of an apparatus, the assessment of a measurement method, or for assigning values to materials. An RM is similar to an LCS, but encompasses a representative sample matrix. Similar to an LCS, an RM is used to verify the accuracy of the laboratory's performance of the test, but including the challenges of a complex sample matrix.

RM accuracy is calculated, expressed, and evaluated similarly to LCS accuracy. Refer to ALS Accuracy DQOs for specific limits for any given test.

Matrix Spike (MS) - A sample prepared by adding a known amount of a target analyte to a specified amount of a sample for which an independent estimate of the target analyte concentration is available. Spiked samples are used, for example, to determine the effect of the sample matrix on a method's recovery efficiency.

Matrix Spike results are calculated and expressed as percent recovery, by dividing the measured result (minus any analyte contribution from the unspiked sample) by the target analyte concentration. Matrix Spike results should normally lie within the ALS Accuracy DQOs for Matrix

---

[1] Depending on the type of Field Sample Duplicates being evaluated (e.g. Co-located versus Split Sample Duplicates), ALS recommends DQOs for Field Sample Duplicates that are between 1.5 – 2.0 times higher than our Laboratory Sample Duplicate DQOs. Co-located Sample Duplicates generally require higher DQOs than Split Sample Duplicates.

Spikes. Matrix Spike results cannot be calculated or reported in cases where the background concentration of the test parameter in the sample is too high relative to the spike level.

Surrogate Compounds (SURR) – Surrogate Compounds are added to every sample where applicable (organics tests only). They are substances with properties that mimic the analyte of interest, and which are unlikely to be found in environmental samples. They are added at known concentration to samples to establish that the analytical method has been properly performed.

Surrogate results are calculated and expressed as percent recovery, by dividing the measured result against the expected target concentration. Refer to ALS Accuracy DQOs for specific limits for any given test.

Automated Relational Checks

In addition to all our standard Quality Control checks, ALS also employs dozens of "Relational Checks", which are programmed into our Laboratory Information Systems (LIMS) to automatically highlight any situations where the expected relationships between different test parameters are violated, which can often point to errors. Such errors may originate with field sampling, or from laboratory processes, but should always be identified and pro-actively investigated.

Total versus Dissolved Metals ("D > T" Check) – One of the most important and common relational checks we do is a check for situations where Dissolved Metal concentrations significantly exceed Total Metal concentrations. By definition, this situation should not occur. However, there are a few reasons why this can occur:

i) Circumstances where Dissolved Metals slightly exceed Total Metals are expected in a small percentage of samples, simply due to normal random variability. In fact, when all metals in a test sample exist in the dissolved form, we expect that Dissolved Metals measurements will numerically exceed Total Metals measurements exactly half the time (by a small margin), simply due to random chance.

ii) Samples to be analyzed for Dissolved Metals must be filtered, which is normally done in the field. Filtration processes are a common source of low level metals contaminants. Contamination of a sample during filtration is the most common source of significant D > T issues.

iii) Field samples for Dissolved and Total Metals are normally collected independently, so variability of the sampling process is another common cause of D > T issues.

If none of the above causes can explain a situation where Dissolved Metals exceed Total Metals, then another type of error may be indicated, either with the collection of the sample in the field, or with sample containers or preservatives, or with the laboratory testing process.

ALS automatically highlights and investigates all circumstances where a Dissolved Metal result exceeds the Total Metal result by 20% RPD or more, but only if the absolute difference between the two results is greater than the sum of the Limits of Reporting (Detection Limits) of the two results.

The mechanism of this relational check is derived from the ALS Duplicate DQOs for Metals in Water.

All D > T relational checks that violate the rule above are flagged internally, and are investigated by ALS before sample results will be released to our clients. In most cases, results will be re-analyzed to confirm or correct the anomalous relationship. If results are confirmed by re-analysis, the following data qualifier is applied:

DTC: Dissolved concentration exceeds total. Results were confirmed by re-analysis.

Other Important Relational Checks Conducted by ALS

ALS employs dozens of other relational checks to highlight anomalous relationships between test parameters. Some of more common checks include the following:

- *Total Ammonia should not exceed Total Kjeldahl Nitrogen*
- *Weak Acid Dissociable Cyanide should not exceed Total Cyanide*
- *E. coli should not exceed Fecal Coliforms*
- *Nitrate + Nitrite should not exceed Total Nitrogen*
- *Hexavalent Chromium should not exceed Total Chromium*
- *True Colour should not exceed Apparent Colour*
- *Mineral Oil and Grease should not exceed Total Oil and Grease*
- *Reactive Phosphorus should not exceed Total Phosphorus*

ALS Environmental

Quality Control Report Guide

Matrix is the substance type of the QC sample.

Common matrices are water, soil, and tissue.

The **Reference** column contains:

a) Lab sample number (L#) or work group number (WG#) of samples that were used for duplicates or matrix spikes - this information is for internal tracking purposes.

b) Test results for actual samples that were duplicated for QC purposes.

Result from analyzing the QC sample.

% Recovery is calculated for QC samples with known target values (e.g. Spikes or CRMs).

Actual (absolute) test results are reported for the second aliquot of a duplicate pair and method blanks.

A **Qualifier** is used to communicate important information about the QC sample test results.

Sample parameter qualifiers used in the report are defined near the end of the Quality Control Report.

Also refer to the *Sample Parameter Qualifier Definitions* on the next page.

Units of the QC sample test results.

Test results are reported in % recovery for samples with known target values.

Actual (absolute) concentration units are used for reporting duplicate sample and Method Blank test results.

The calculated **Relative % Difference** between duplicate pairs.

RPD is calculated as follows:
|{(Sample Result - Duplicate Result) / [Mean]}| x 100

Duplicate pairs with test results that are < 5 x LOR are reported in sample concentration units (absolute units) and are accompanied by a J qualifier.

The Control **Limit** for the QC sample (ALS Data Quality Objective (DQO)).

QC samples must fall within Control Limits or appropriate action is taken, such as reanalysis where possible, or the data is qualified.

QC samples with known target values have a range for % recovery (eg) 85-115%.

Duplicates have a ± RPD range (e.g. ± 20 RPD). The RPD is reported as an absolute value (e.g. 20 RPD).

Method Blank control limit is the parameter Detection Limit (DL), also known as the Limit of Reporting (LOR).

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
SO4-IC-WP	Water							
Batch R2179887								
WG1269694-3 DUP		L997018-4						
Sulfate		60.1	62.0		mg/L	3.1	20	21-APR-11
WG1269674-2 LCS								
Sulfate			100		%		85-115	21-APR-11
VG1269674-1 MB								
ulfate			<0.50		mg/L		0.5	21-APR-11
/G1269674-4 MS		L997018-4						
ulfate			N/A	MS-B	%		-	21-APR-11
G1269674-5 CVS								
lfate			103		%		85-115	21-APR-11
G1269674-6 CRM								
lfate			95		%		80-120	21-APR-11

Test Code: Sulfate (SO4), analyzed by Ion Chromatography (IC), in ALS Winnipeg (WP).

DUP: **Laboratory Sample Duplicate** - a second portion of sample taken from the same container as the sub-sample used for the primary analysis. Assesses variance of the total method including lab sub-sampling and analysis.

The results for this duplicate pair are 60.1 and 62.0 mg/L. The RPD is 3.1 and the control limits are ± 20 RPD.

LCS: Laboratory Control Sample – a known matrix spiked with target analytes. Verifies the accuracy of the performance of the test.

The recovery for this LCS is 100%, with control limits of 85 to 115% recovery.

MB: **Method Blank** – a blank matrix taken through the entire test method. Monitors variability of the blank response and bias of the test method.

The result for this MB is less than 0.50 mg/L. The control limit for the MB is equal to the LOR.

MS: **Matrix Spike** – a known amount of target analytes are added to a client sample. Measures the effect of the sample matrix on a method's recovery efficiency.

In this example, the recovery of the MS could not be calculated. The qualifier explains why – refer to the *Sample Parameter Qualifier Definitions.*

CVS: Calibration Verification Standard - a second source reference standard containing known concentrations of target analytes. Confirms the accuracy and stability of the calibration standards.

This CVS has a recovery of 103% and control limits of 85 to 115% recovery.

CRM/IRM: Certified or Internal Reference Material – a homogeneous sample whose analyte values have been well characterized.

This CRM has a 95% recovery and control limits of 80 to 120% recovery.

Quality Control Report Guide

Legend:

Limit ALS Control Limit (Data Quality Objectives)
DUP Duplicate RPD Relative Percent Difference
N/A Not Available
LCS Laboratory Control Sample
SRM Standard Reference Material
MS Matrix Spike
MSD Matrix Spike Duplicate
ADE Average Desorption Efficiency
MB Method Blank
IRM Internal Reference Material
CRM Certified Reference Material
CCV Continuing Calibration Verification
CVS Calibration Verification Standard
LCSD Laboratory Control Sample Duplicate

Legend: explains acronyms that may be used in the QC Report.

Sample Parameter Qualifier Definitions:

Qualifier	Description
J	Duplicate results and limits are expressed in terms of absolute difference.
MS-B	Matrix Spike recovery could not be accurately calculated due to high analyte background in sample.
RPD-NA	Relative Percent Difference Not Available due to result(s) being less than detection limit.

Qualifiers: QC sample qualifiers are listed and explained here.

The three examples are common qualifiers. They explain unusual or special circumstances that pertain to the QC sample results.

Quality Control Report Guide

Parameters and sample numbers that had Hold Time exceedances are listed in this table.

Hold Times are tracked from sampling date and time to the date and time when the sample was processed in the lab.

The recommended Hold Times.

See the Notes* section for sources of recommendations.

Hold time exceedance Qualifiers are explained in the *Legend and Qualifiers Definitions* section below.

Hold Time Exceedances:

ALS Product Description	Sample ID	Sampling Date	Date Processed	Rec. HT	Actual HT	Units	Qualifier
Physical Tests							
Transmittance, UV (254 nm)	1	19-APR-11 14:00	25-APR-11 08:16	48	38	hours	EHTL
pH	1	19-APR-11 14:00	10-MAY-11 09:32	0.25	499	hours	EHTR-FM

Legend & Qualifier Definitions:

EHTR-FM: Exceeded ALS recommended hold time prior to sample receipt. Field Measurement recommended.
EHTR: Exceeded ALS recommended hold time prior to sample receipt.
EHTL: Exceeded ALS recommended hold time prior to analysis. Sample was received less than 24 hours prior to expiry.
EHT: Exceeded ALS recommended hold time prior to analysis.
Rec. HT: ALS recommended hold time (see units).

Explanations for the Qualifiers listed above.

See also the additional Notes below.

Notes*:
Where actual sampling date is not provided to ALS, the date (& time) of receipt is used for calculation purposes.
Where actual sampling time is not provided to ALS, the earlier of 12 noon on the sampling date or the time (& date) of receipt is used for calculation purposes. Samples for L997206 were received on 21-APR-11 07:30.

ALS recommended hold times may vary by province. They are assigned to meet known provincial and/or federal government requirements. In the absence of regulatory hold times, ALS establishes recommendations based on guidelines published by the US EPA, APHA Standard Methods, or Environment Canada (where available). For more information, please contact ALS.

The ALS Quality Control Report is provided to ALS clients upon request. ALS includes comprehensive QC checks with every analysis to ensure our high standards of quality are met. Each QC result has a known or expected target value, which is compared against predetermined data quality objectives to provide confidence in the accuracy of associated test results.

Please note that this report may contain QC results from anonymous Sample Duplicates and Matrix Spikes that do not originate from this Work Order.

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

Knight Piésold Ltd.
1650 Main Street West
North Bay,Ontario Canada P1B8G5
Telephone: (705) 476-2165
Facsimile: (705) 474-8095
www.knightpiesold.com

Knight Piésold
CONSULTING

TABLE OF CONTENTS

PAGE

TABLES

FIGURES

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

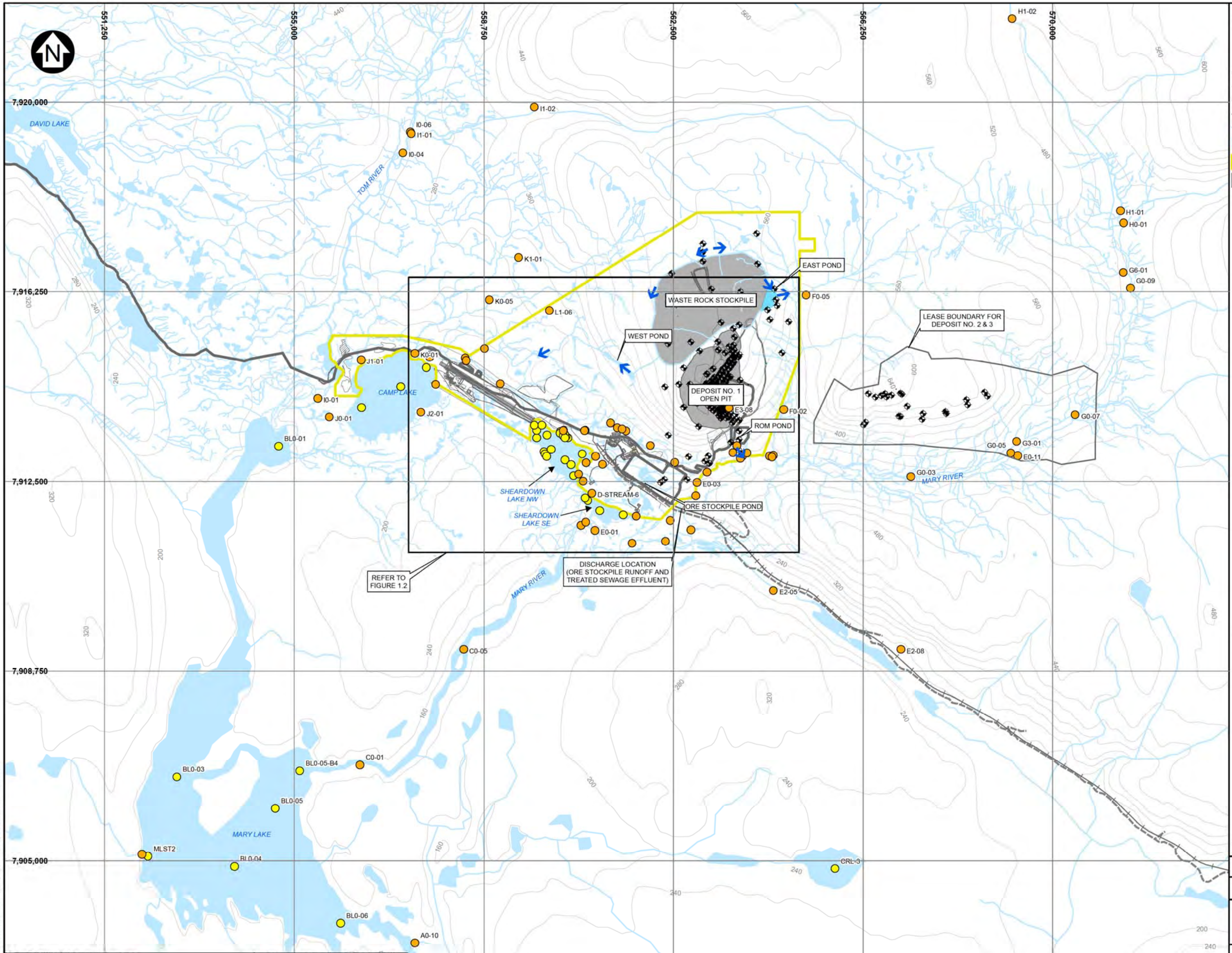
A summary of the data collected during each season are included in Table B.1. A graphical representation of the sampling events is provided in Figure B.3.

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.



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: J:\1\102\00181\33\A\GIS\Figs\B40_r1.mxd; May 30, 2014 1:11 PM; skozmick

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:

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

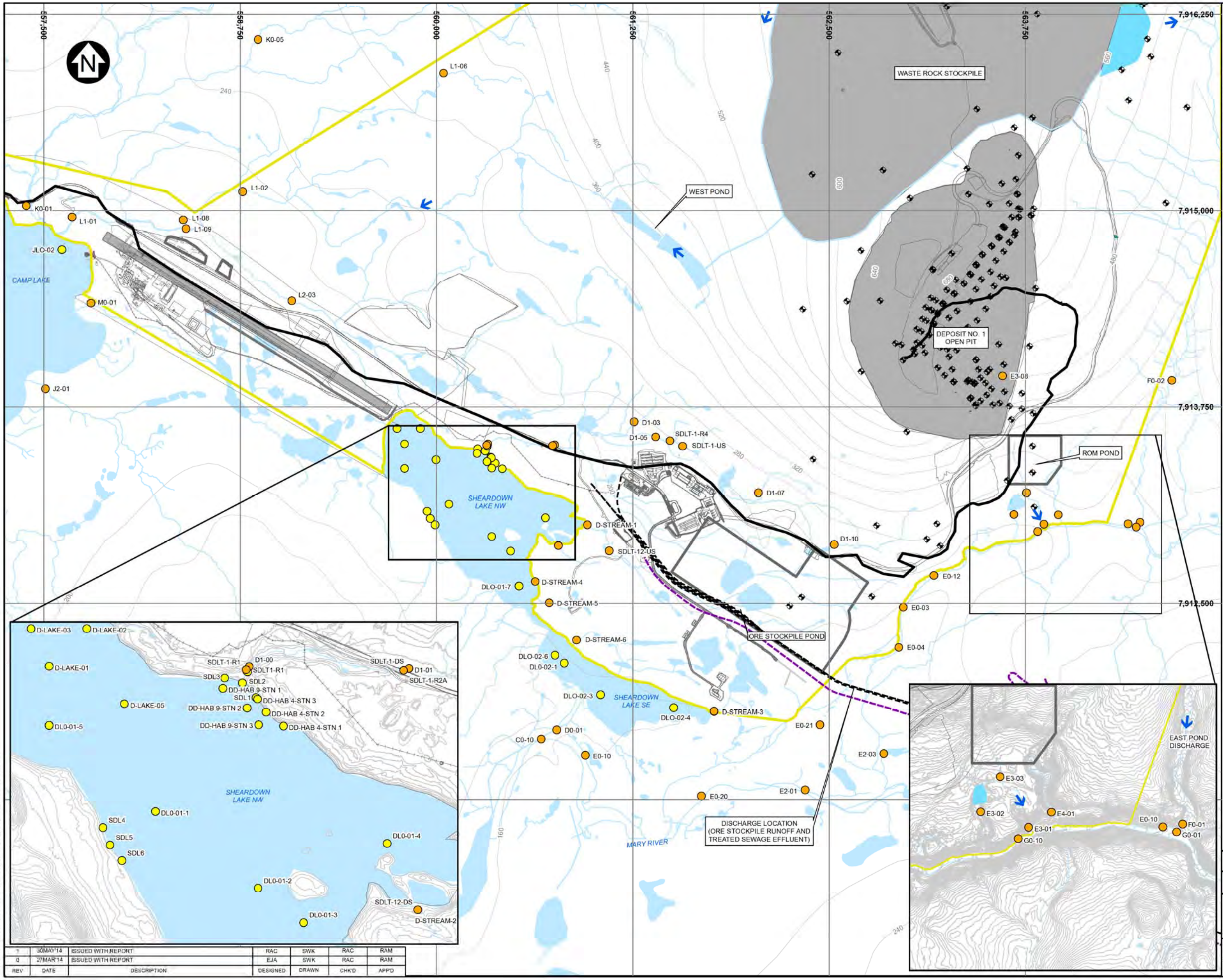
MARY RIVER PROJECT

HISTORIC WATER QUALITY STATIONS MINE SITE AREA

Knight Piésold CONSULTING

P/A NO.	REF NO.
NB102-181/33	1

FIGURE B.1	REV 1



SAVED: I:\102\00181\33\A\GIS\Figs\B41_r1.mxd; May 30, 2014 1:19 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:

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 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

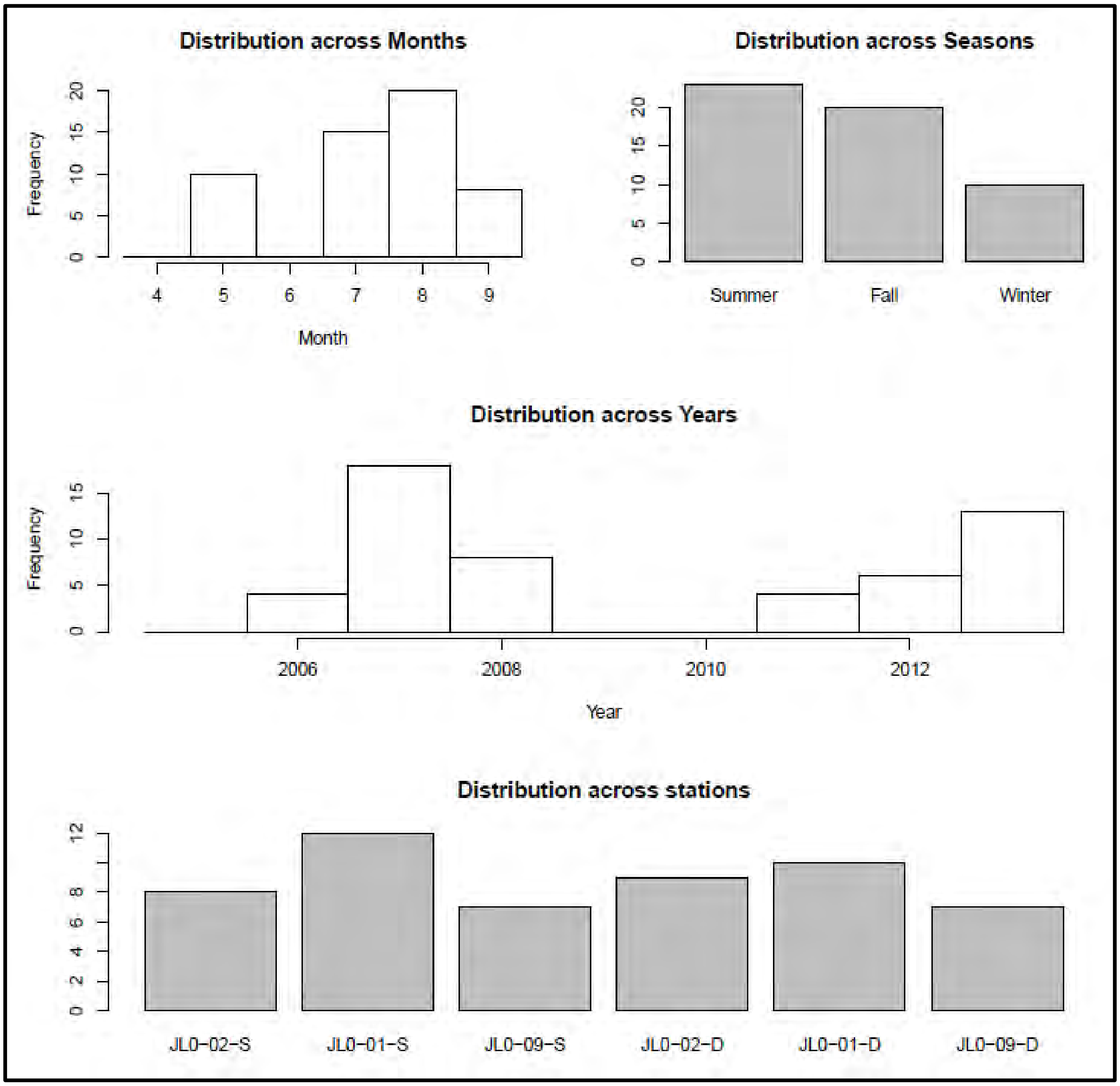


Figure B.3 Camp Lake - Graphical Summary of Sampling Events

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.

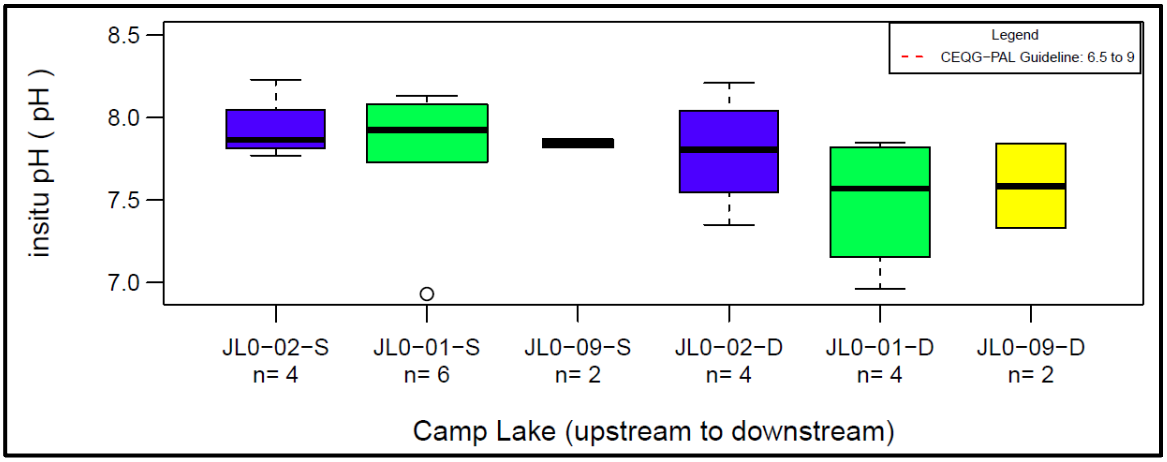


Figure B.4 Camp Lake – pH

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.

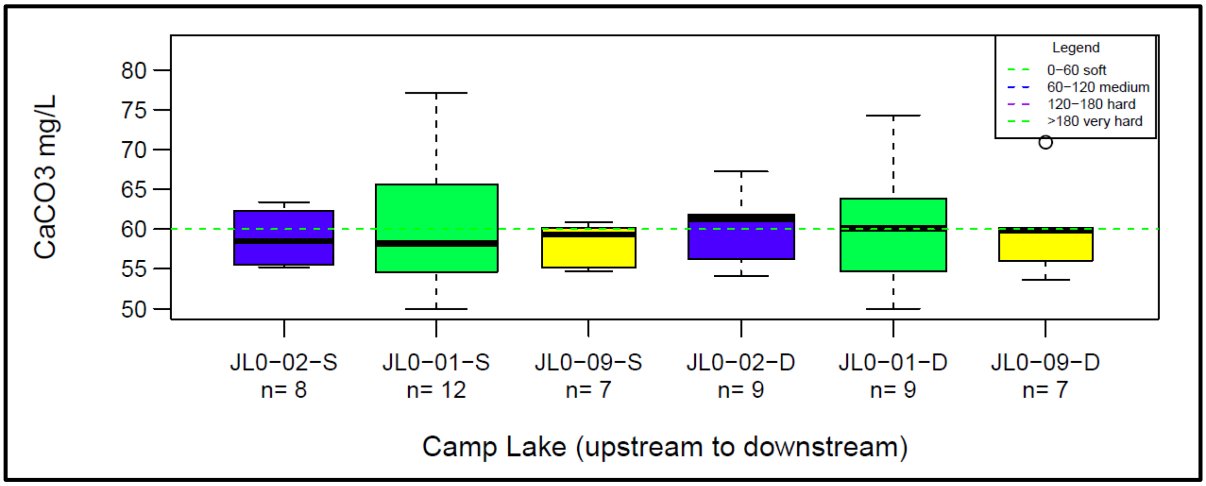
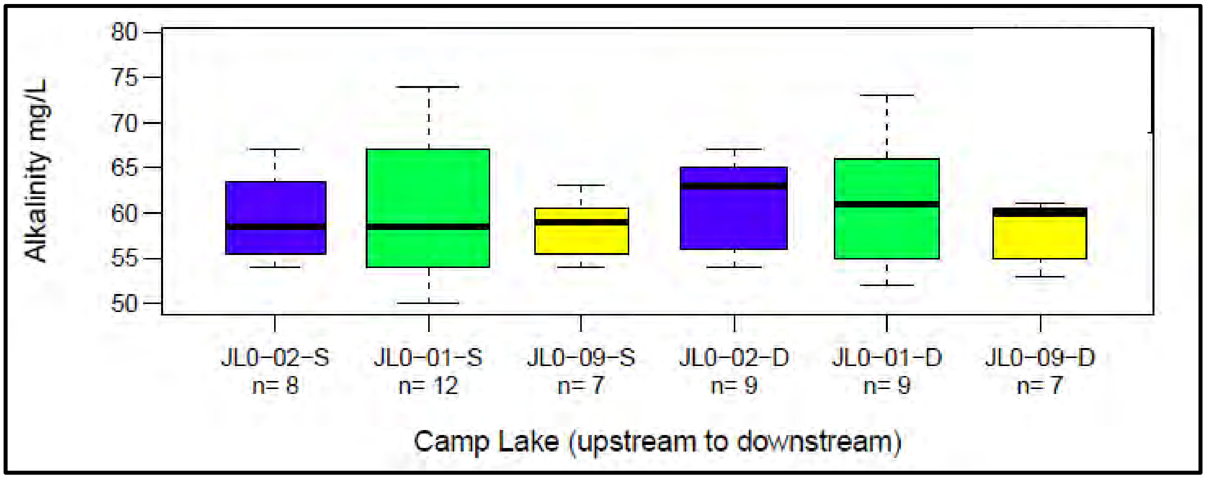


Figure B.5 Camp Lake – Hardness

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:

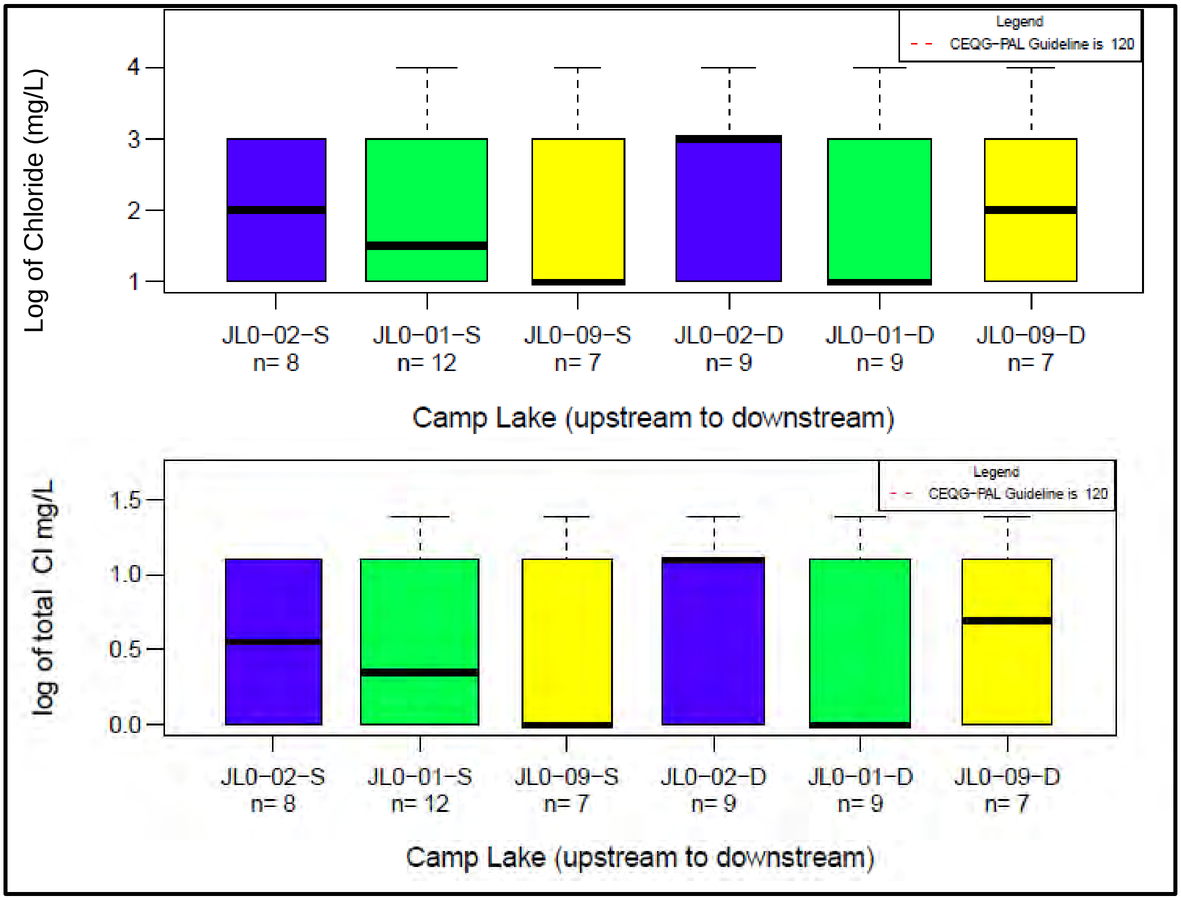
1. ALKALINITY VALUES BELOW 10 mg/L ARE HIGHLY SENSITIVE TO ACIDIC INPUTS; ALKALINITY VALUES BETWEEN 10 – 20 mg/L ARE MODERATELY SENSITIVE TO ACIDIC INPUTS AND ALKALINITY VALUES ABOVE 20 mg/L HAVE LOW SENSITIVITY TO ACIDIC INPUTS.

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.

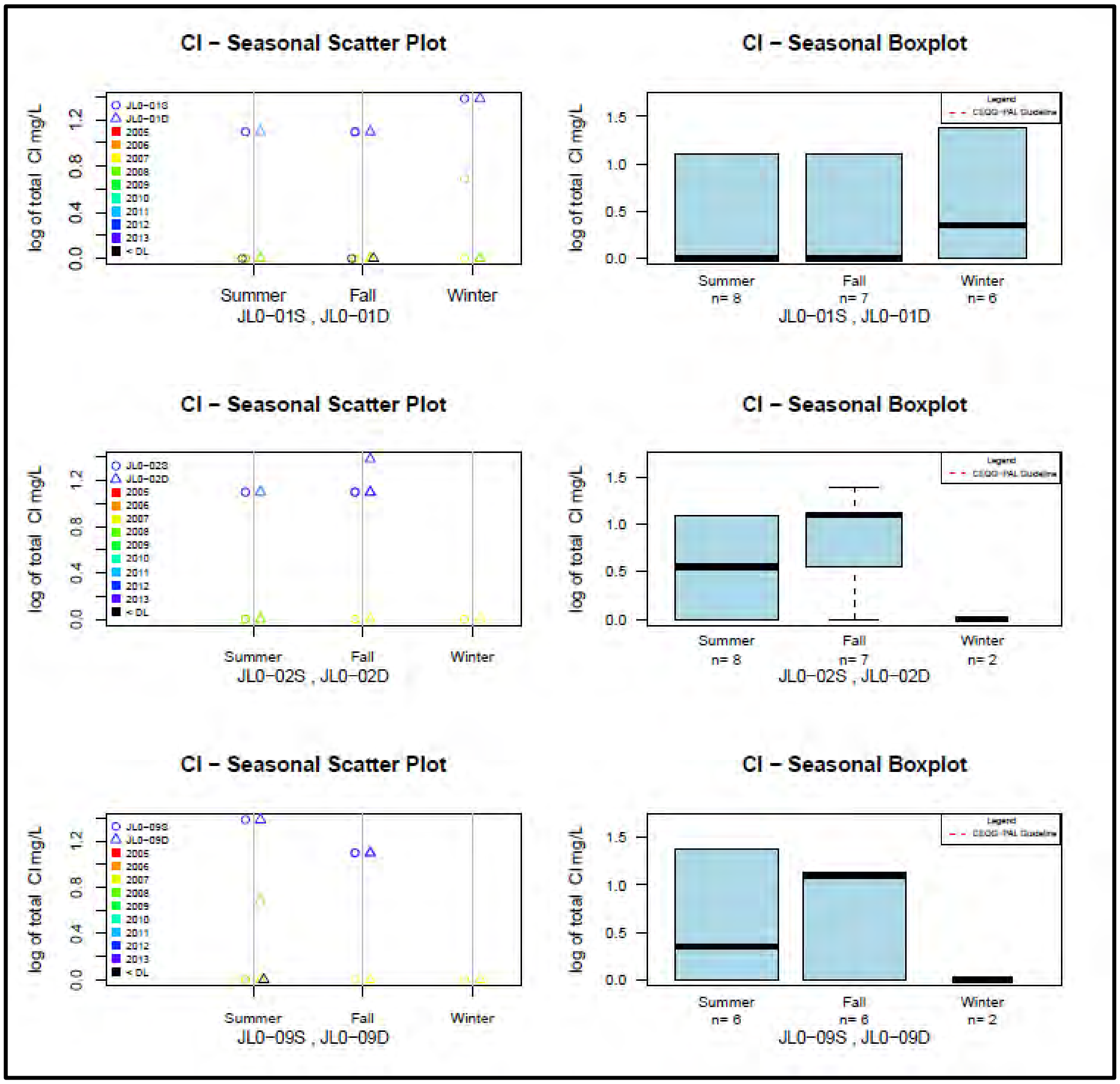


NOTES:

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

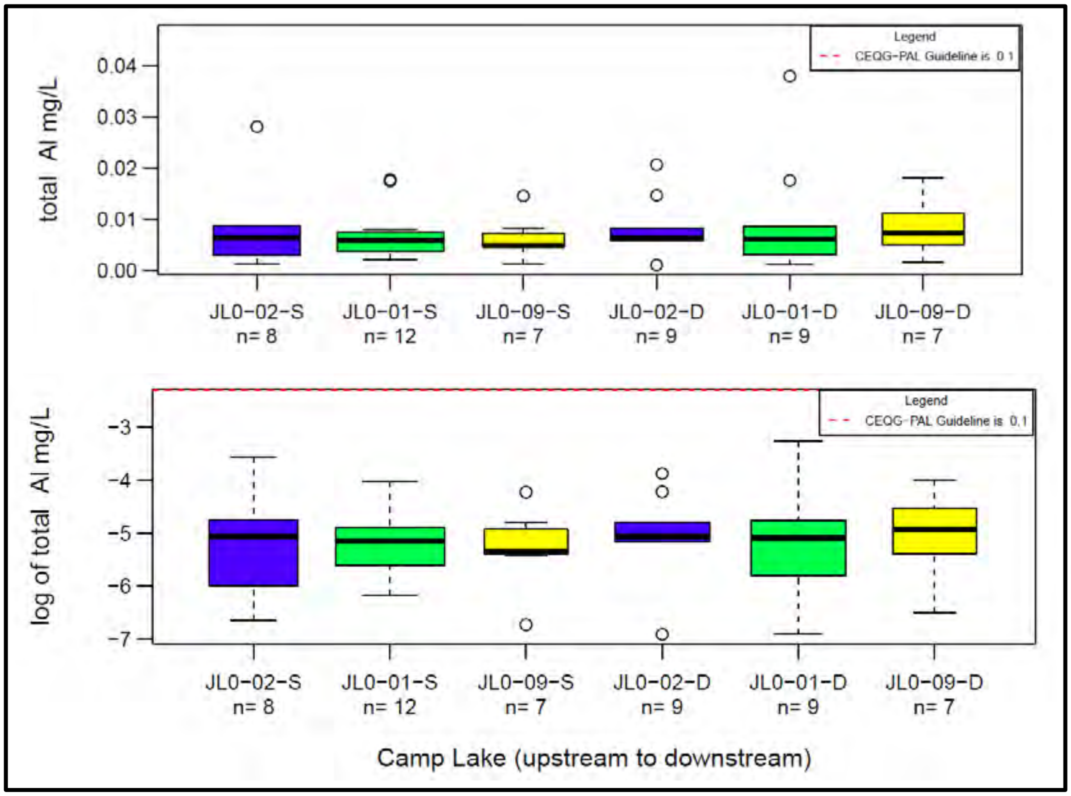
Fifty-two (52) nitrate concentration samples were collected at Camp Lake. All samples collected were at detection limit (0.10 mg/L) and occur well below the CWQG-PAL guideline (3 mg/L). Due to detection limit interference, no depth, seasonal or inter-annual variability is discernable and graphical depiction 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).

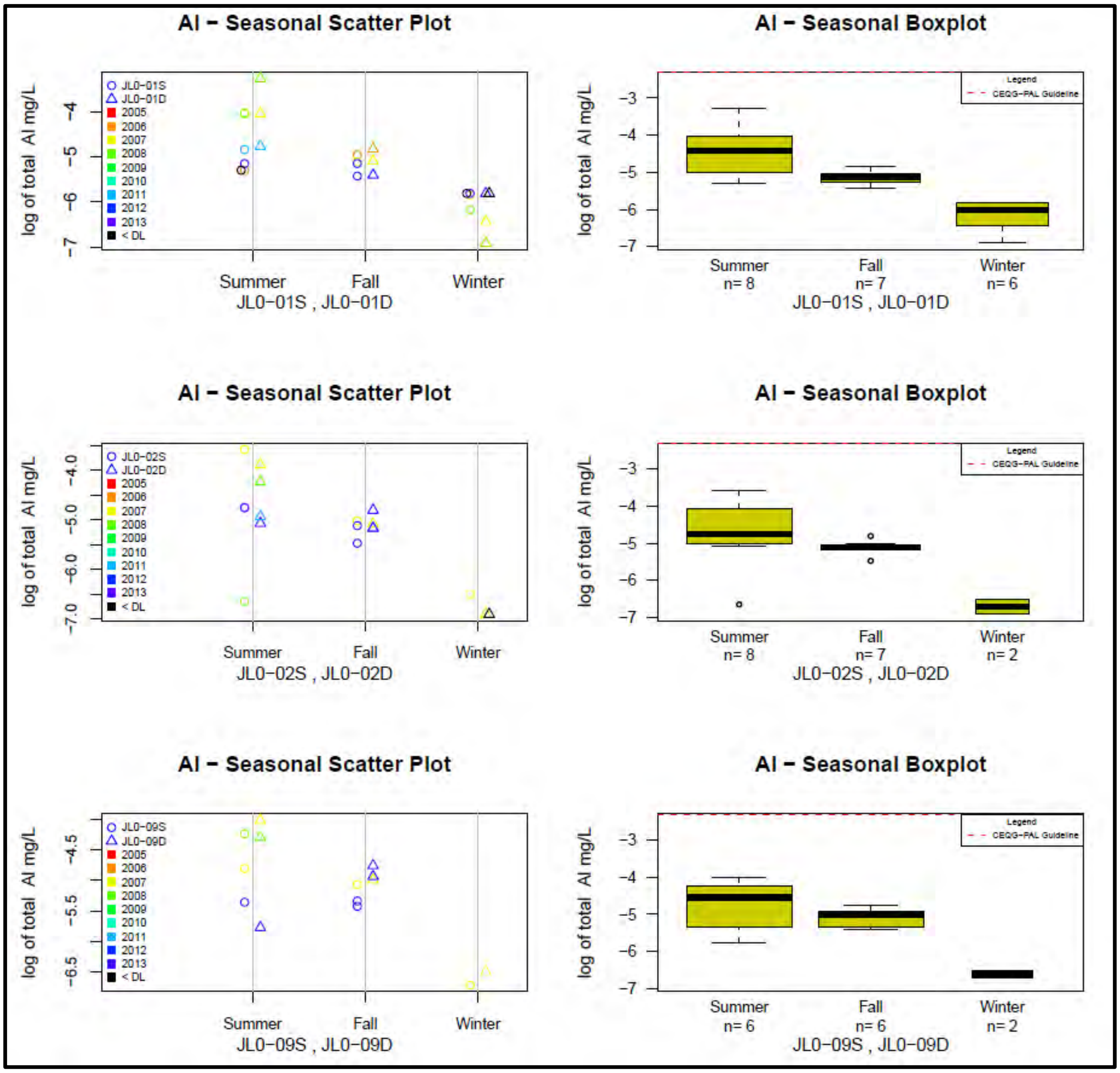
Seasonal plots show higher median values of aluminum measured during the summer, lower aluminum concentrations measured in the fall and the lowest aluminum concentrations measured in the winter. Due to the log scale of these graphs, the actual magnitude variation is small. This seasonal trend may be 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.

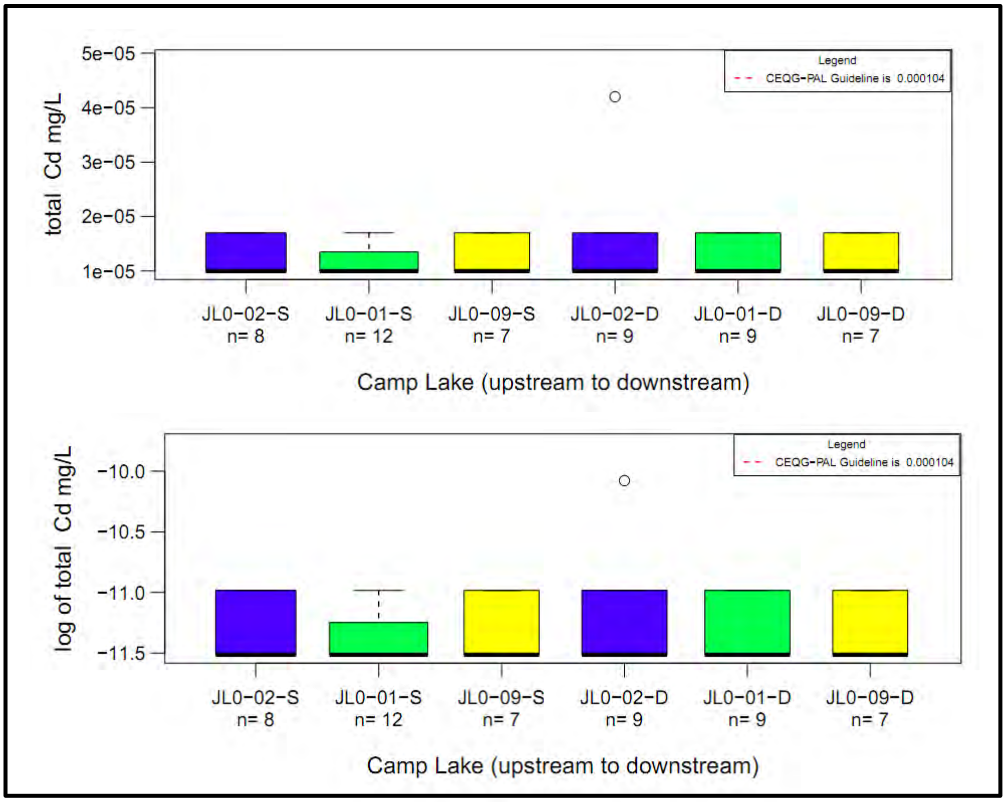
Figure B.10 Camp Lake – Variability of Total Aluminum in Water

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)

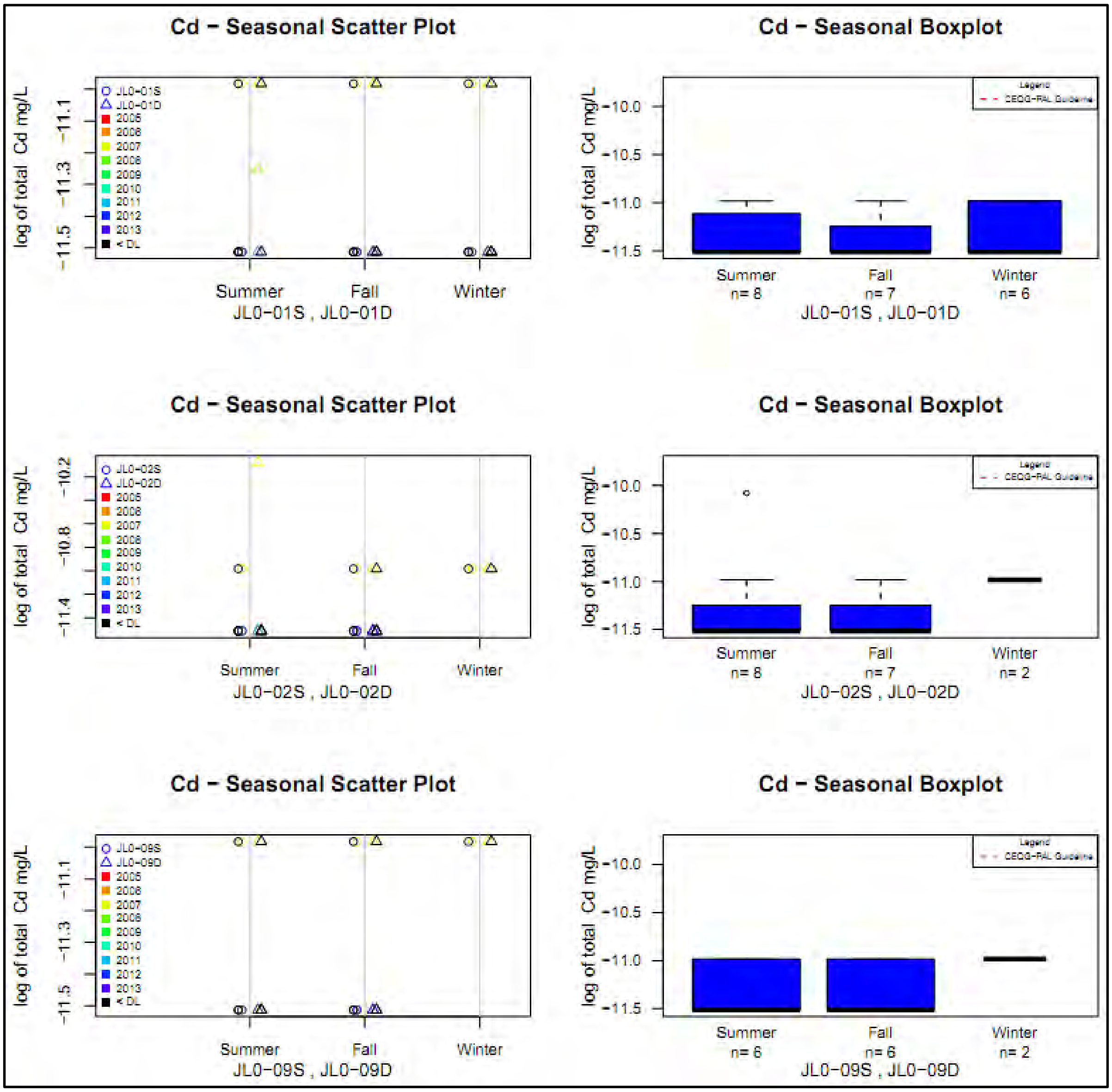
A total of 52 samples with measured cadmium concentrations were collected at Camp Lake, with seven to 12 samples collected at each of the sampling locations in Camp Lake (Figure B.11). Most total cadmium concentrations ranged from detection limit (0.00001 mg/L) to 0.00017 mg/L. One outlying value with 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:

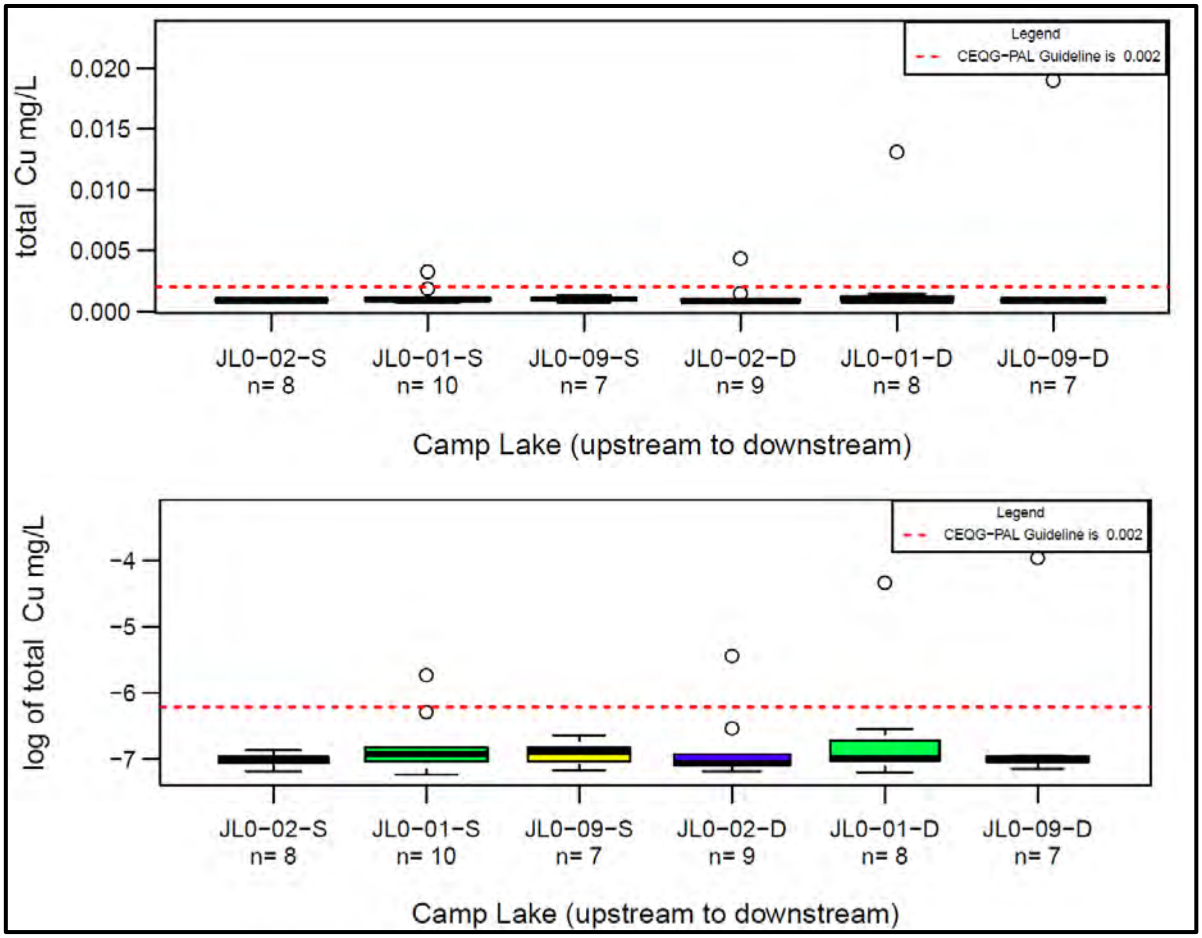
1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.
2. THE CWQG-PAL GUIDELINE LIMIT IS BASED ON THE TOTAL MEDIAN HARDNESS.

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).

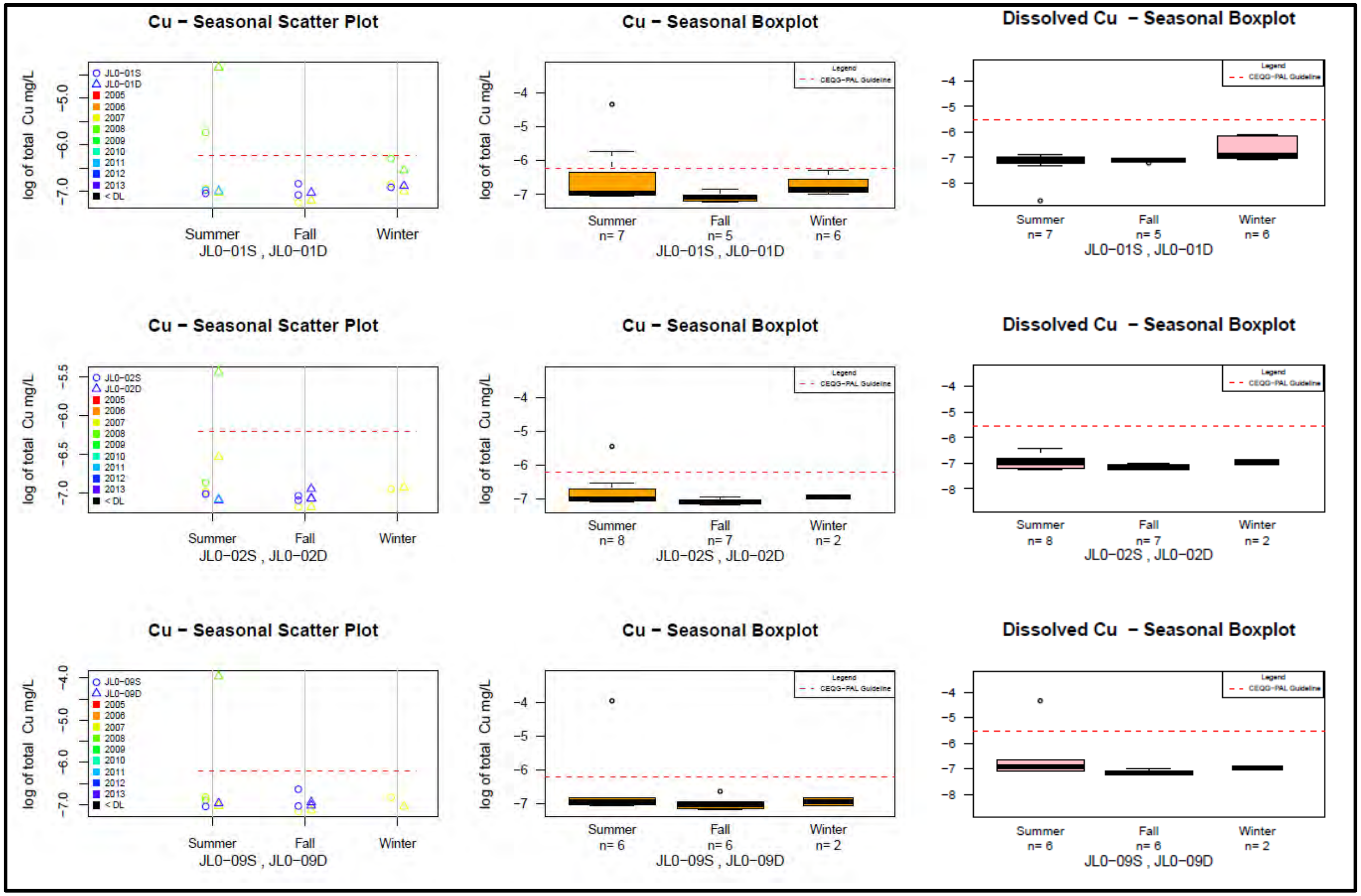
The seasonal copper scatterplot indicates that, with the exception of deep samples taken in 2008, shallow and deep concentrations are quite similar and do not show a consistent trend with depth (Figure B.14). In contrast to other parameters, seasonal trends indicates slightly higher concentrations are 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:

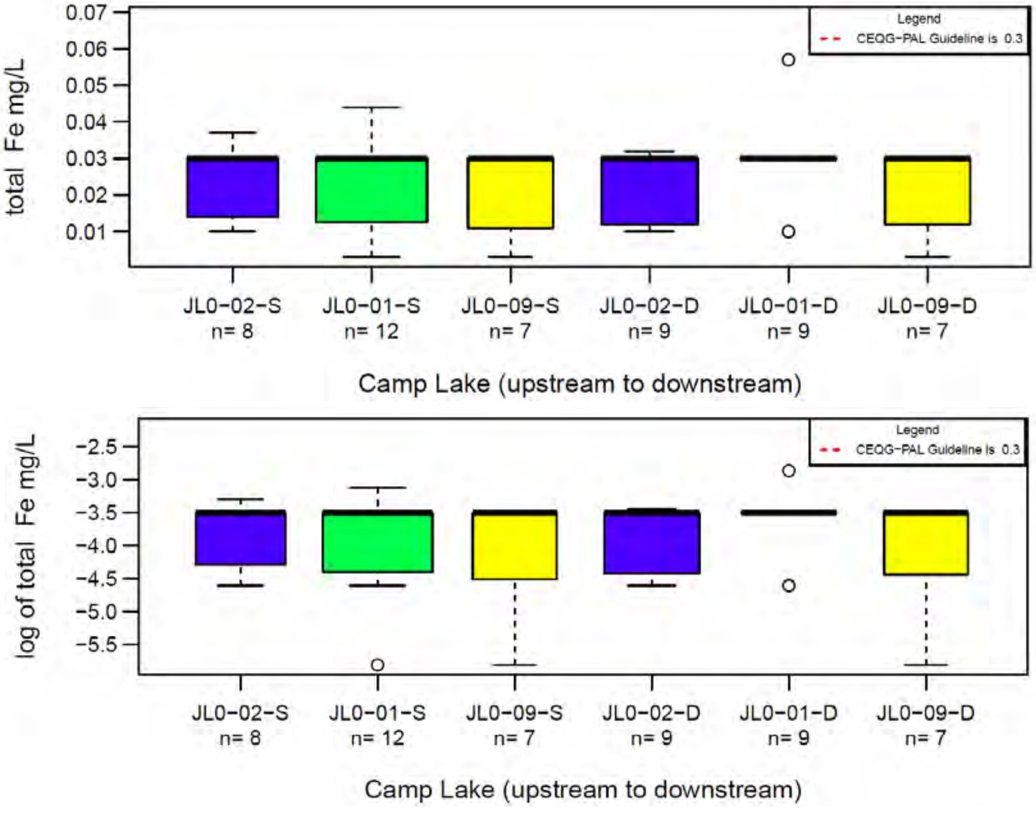
1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.
2. THE CWQG-PAL GUIDELINE LIMIT IS BASED ON THE TOTAL MEDIAN HARDNESS.

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.

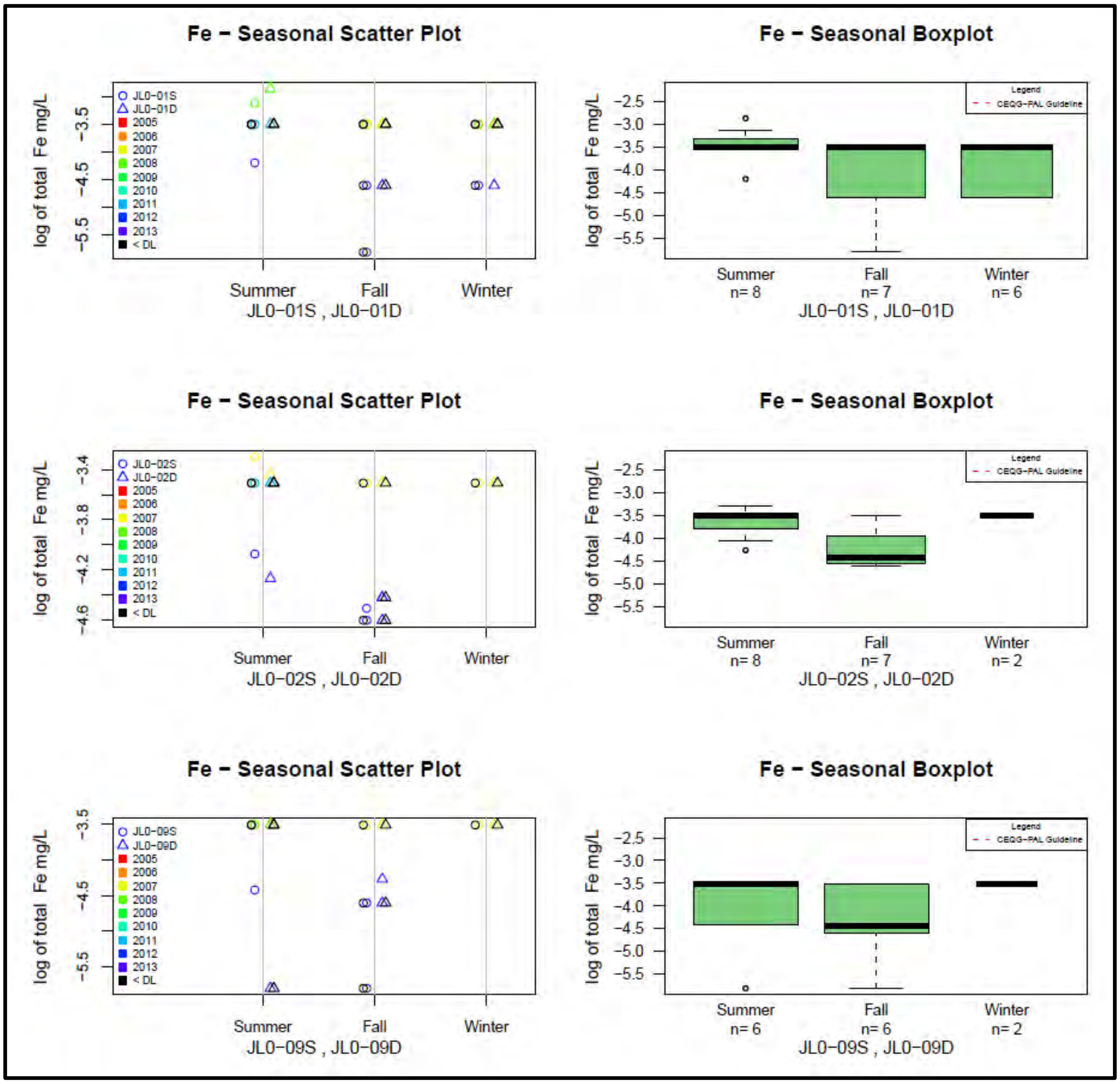
Due to interaction with detection limits during early years of sampling, definitive seasonal or depth trends are difficult to define (Figure B.16). Of note are the slightly lower iron concentrations during fall sampling events.



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:

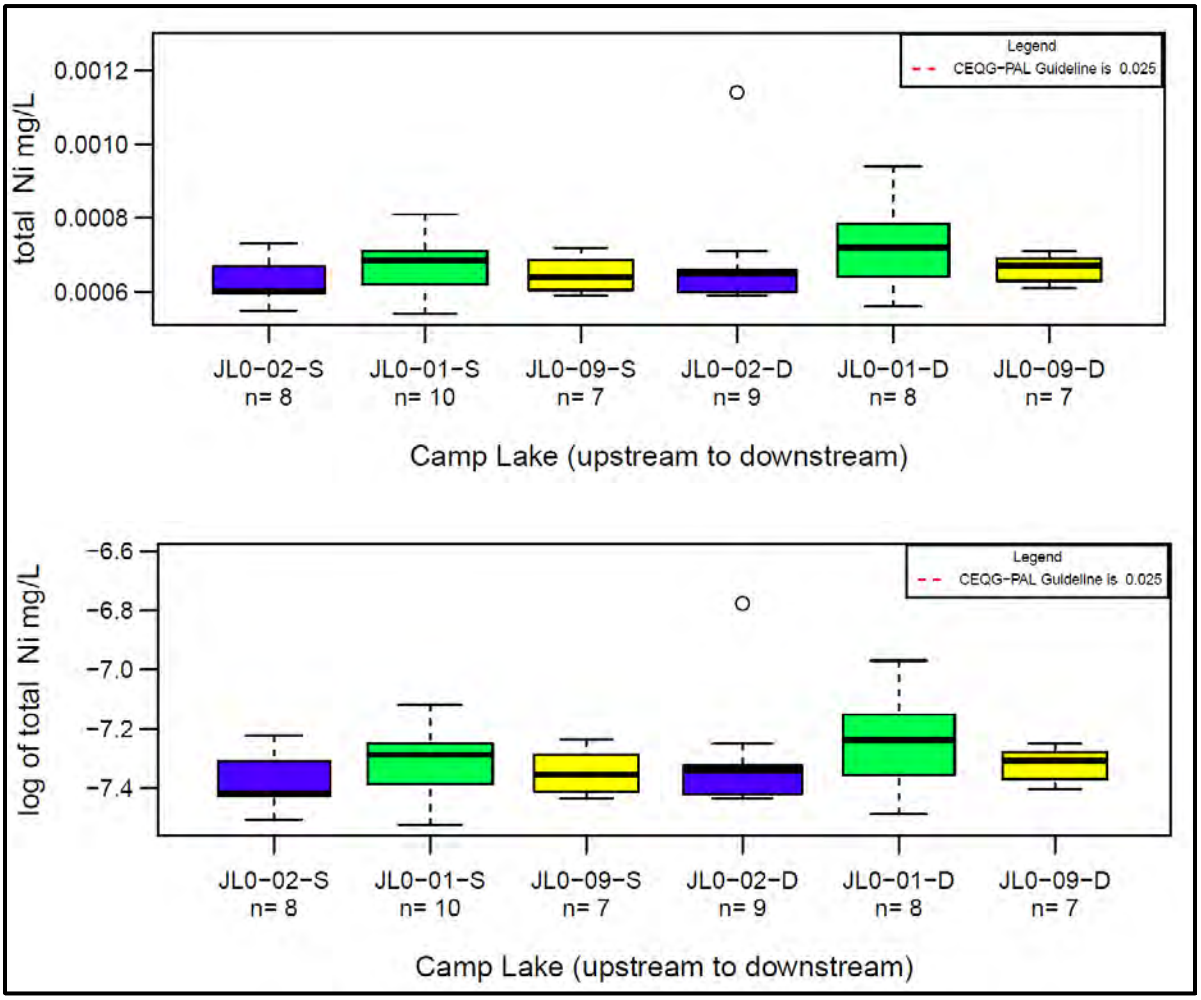
1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.
2. THE CWQG-PAL GUIDELINE LIMIT IS BASED ON THE TOTAL MEDIAN HARDNESS.

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.

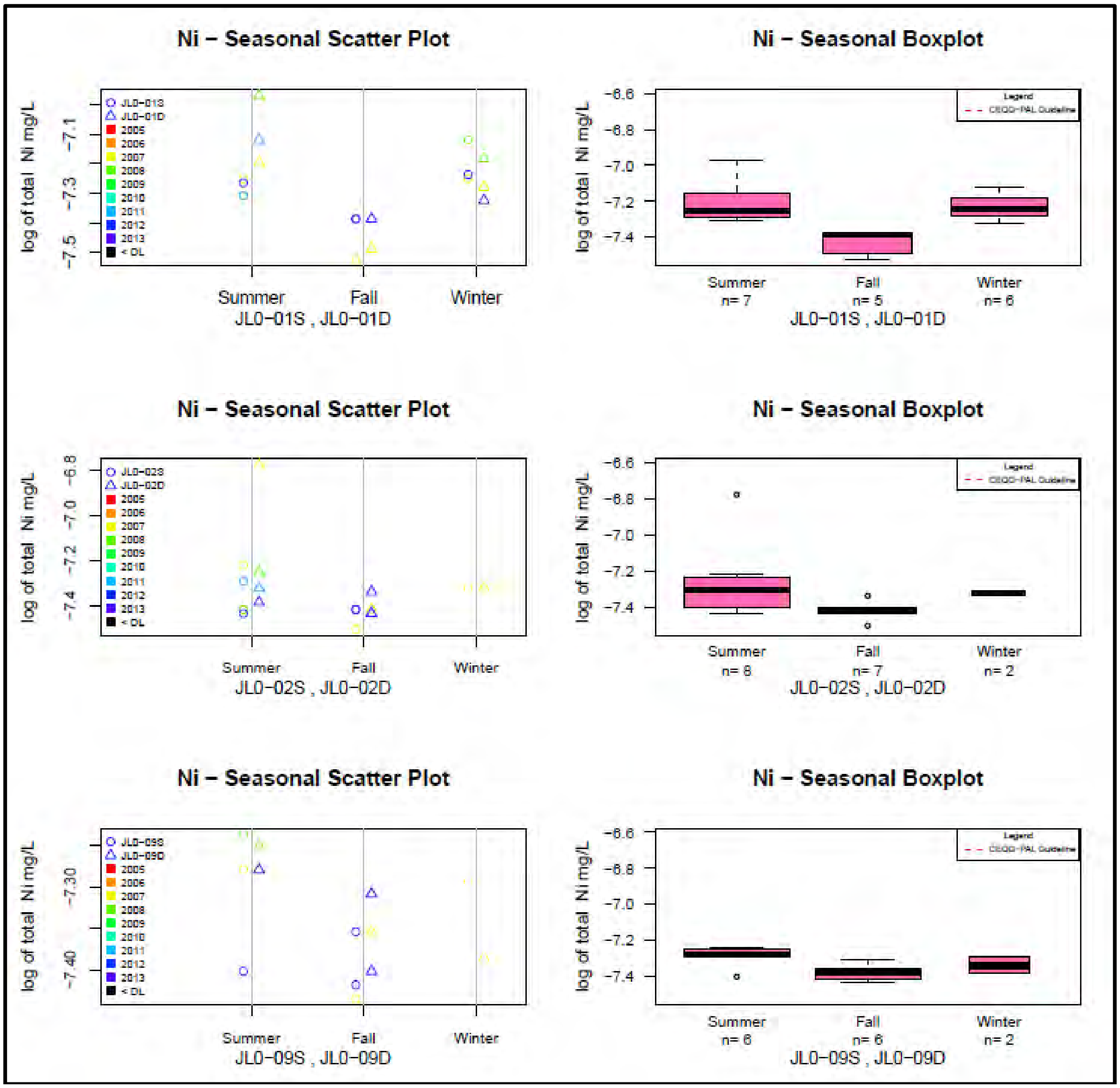
No distinct temporal trends over the course of yearly sampling are noted, although variation in site location is greater than variation as a result of depth (Figure B.18). JL0-01 has a very low magnitude elevation of nickel concentrations when compared to other sites. Seasonal trends are noted that are 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:

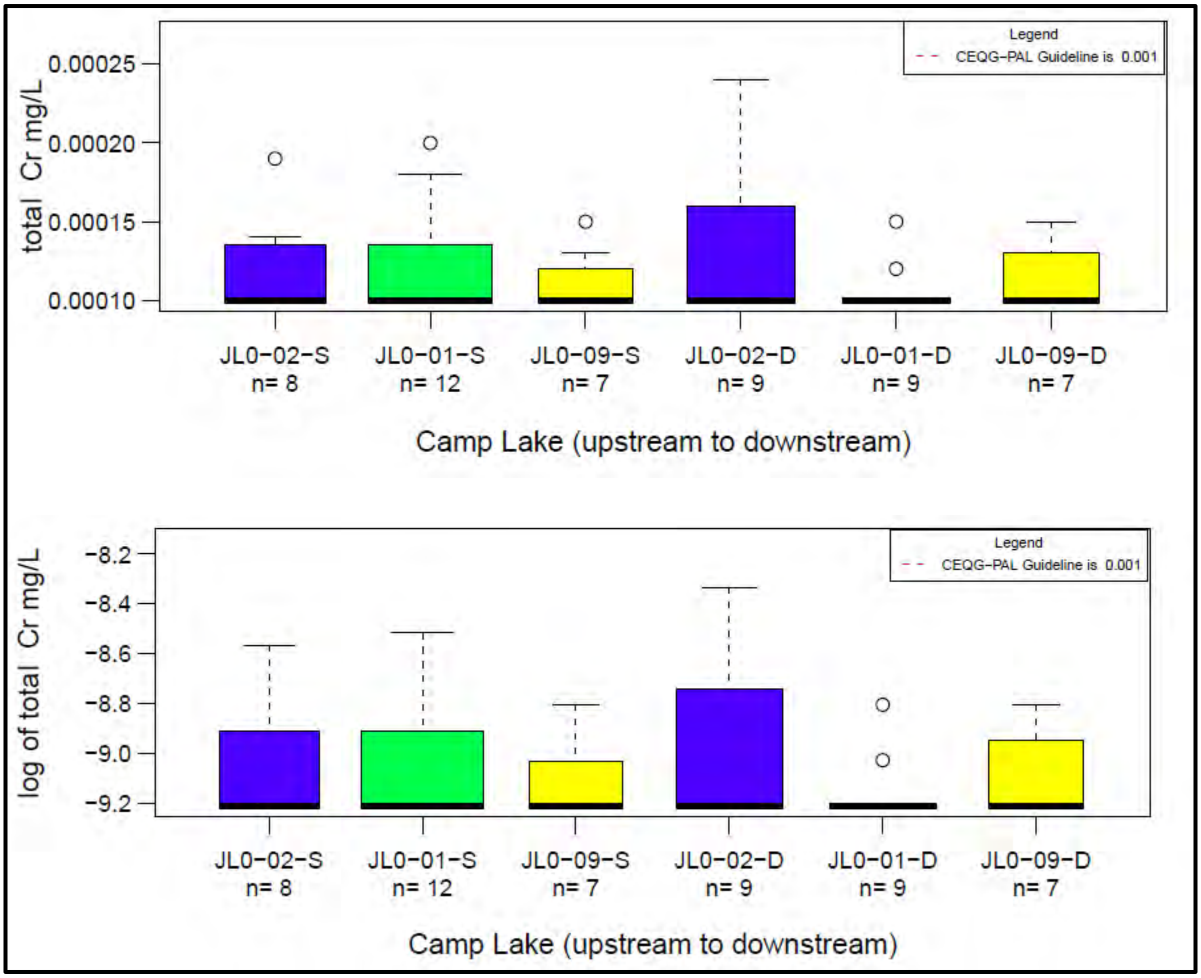
1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.
2. THE CWQG-PAL GUIDELINE LIMIT IS BASED ON THE TOTAL MEDIAN HARDNESS.

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).

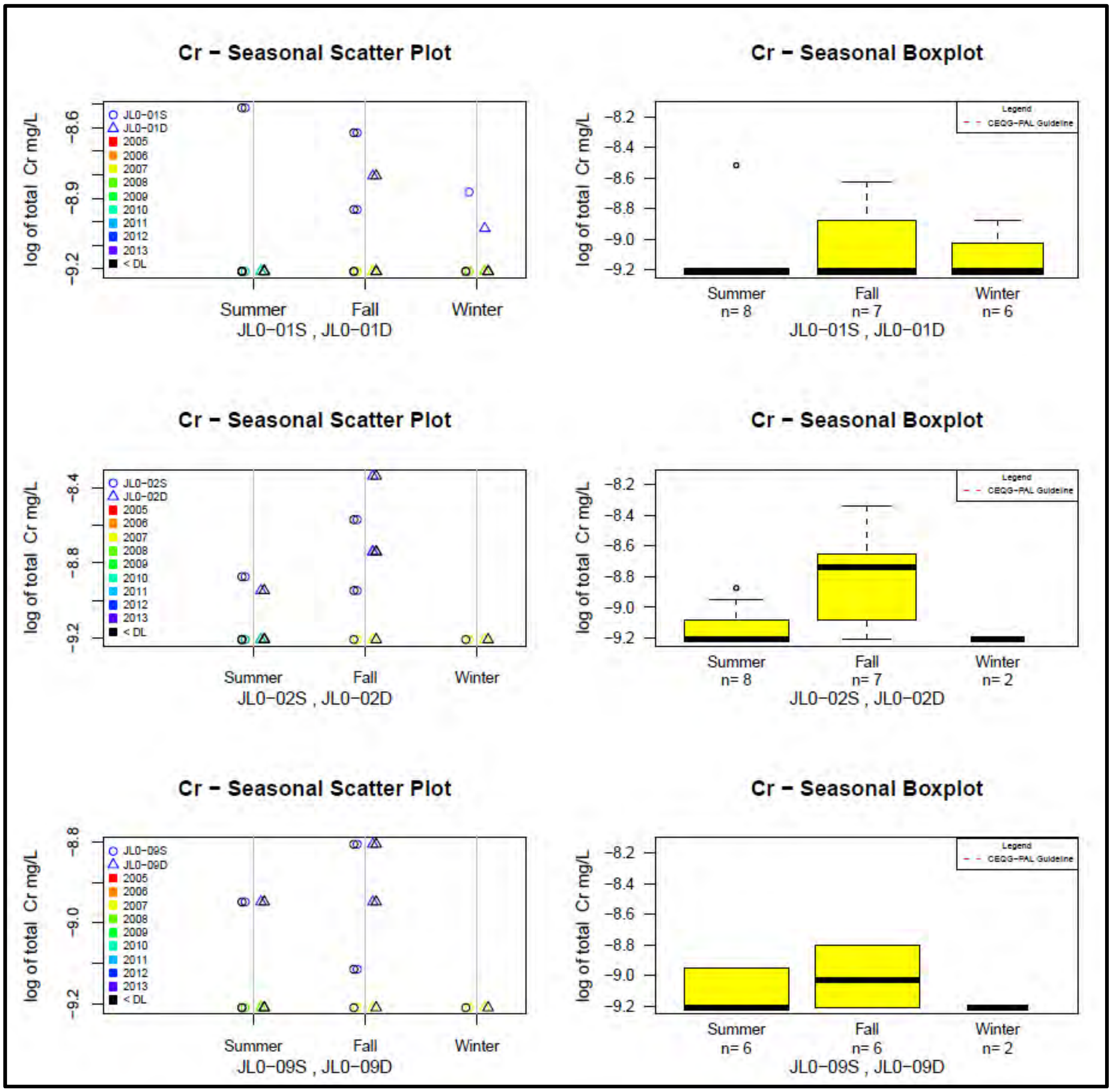
Samples from 2012 and 2013 are slightly elevated when compared to previous sampling years (Figure B.20). Slightly greater concentrations during the fall are noted for chromium



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.

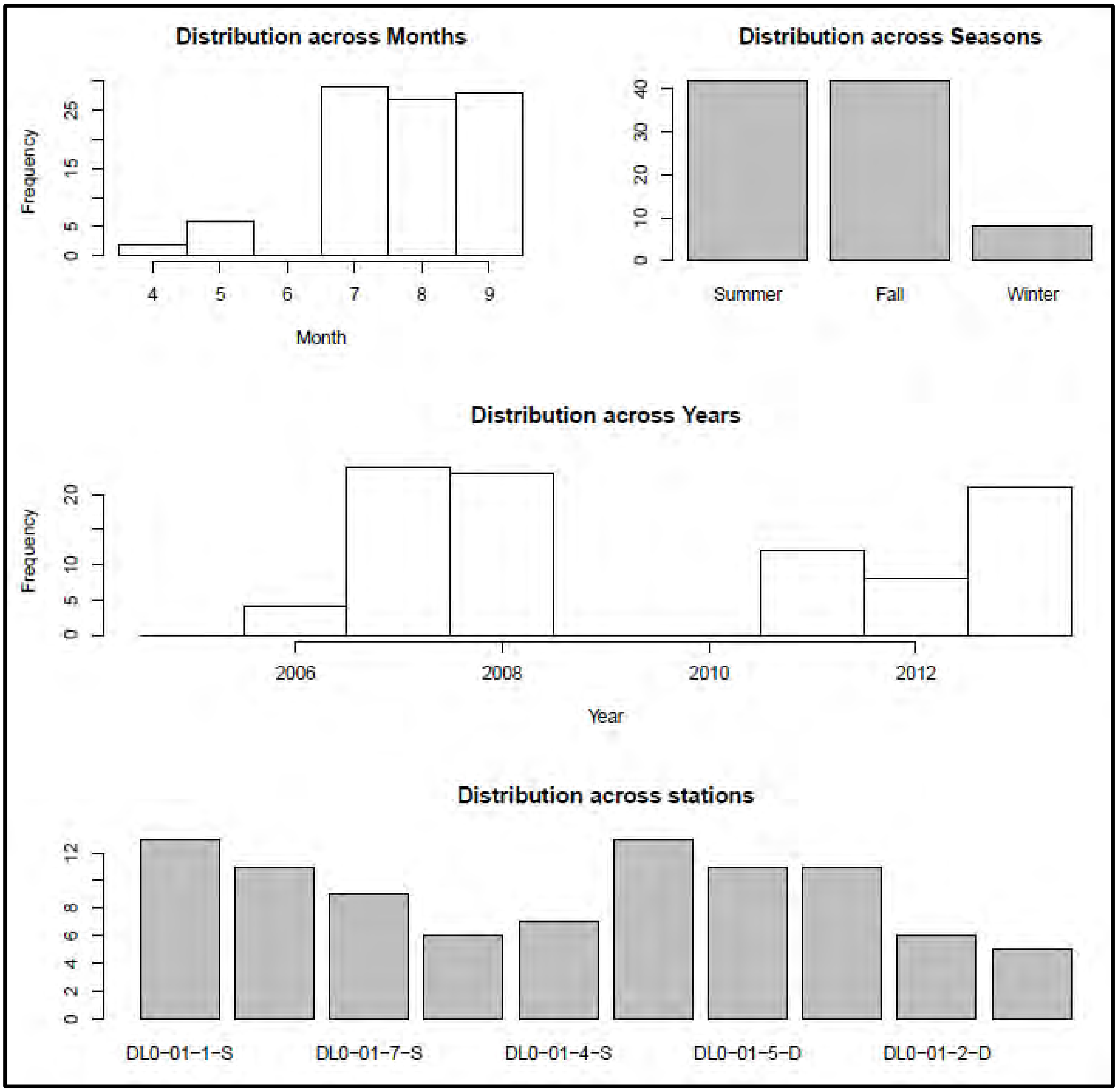


Figure B.21 Sheardown Lake NW – Graphical Summary of Sampling Events

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.

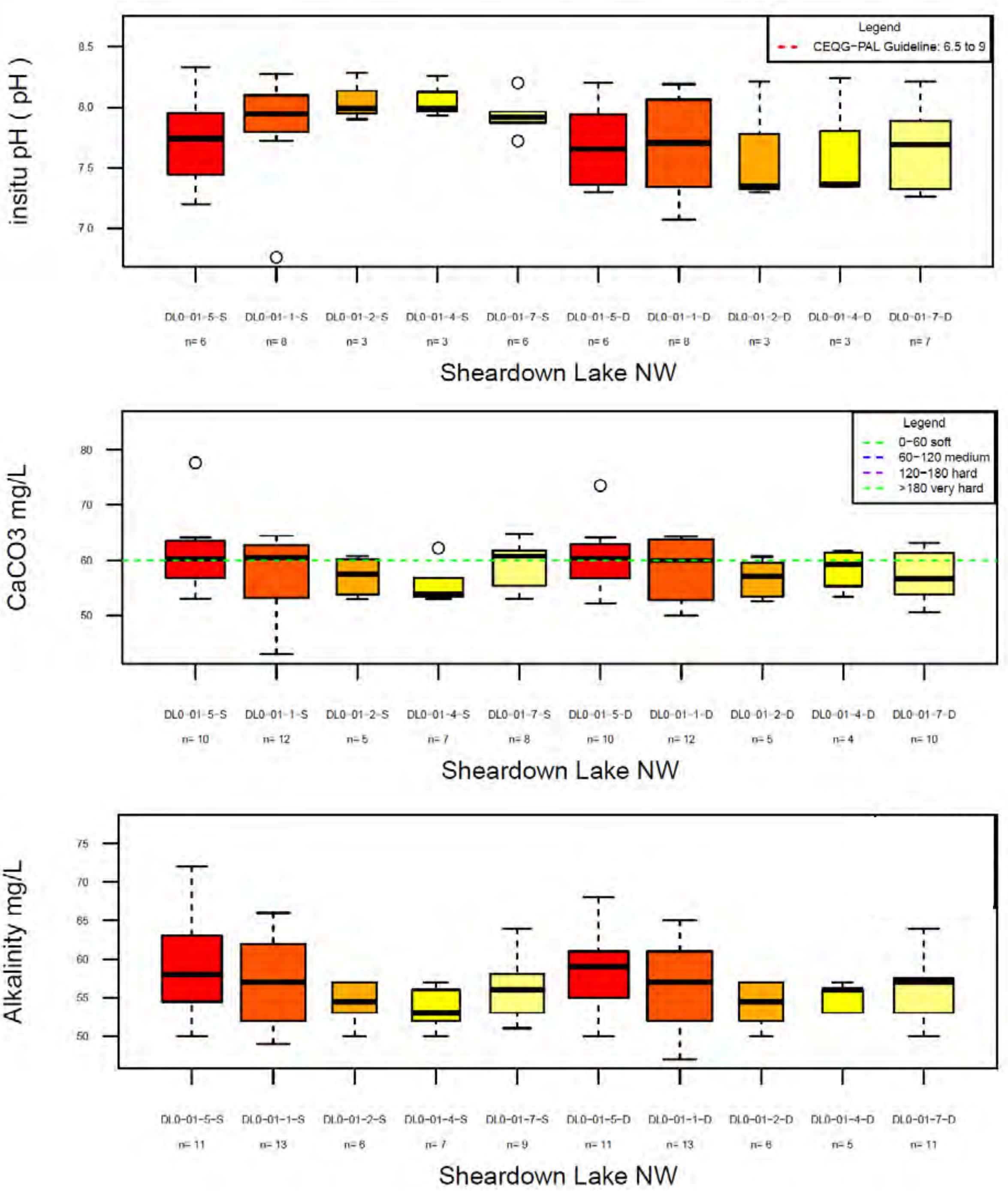


Figure B.22 Sheardown Lake NW – *In situ* pH, Alkalinity and Hardness

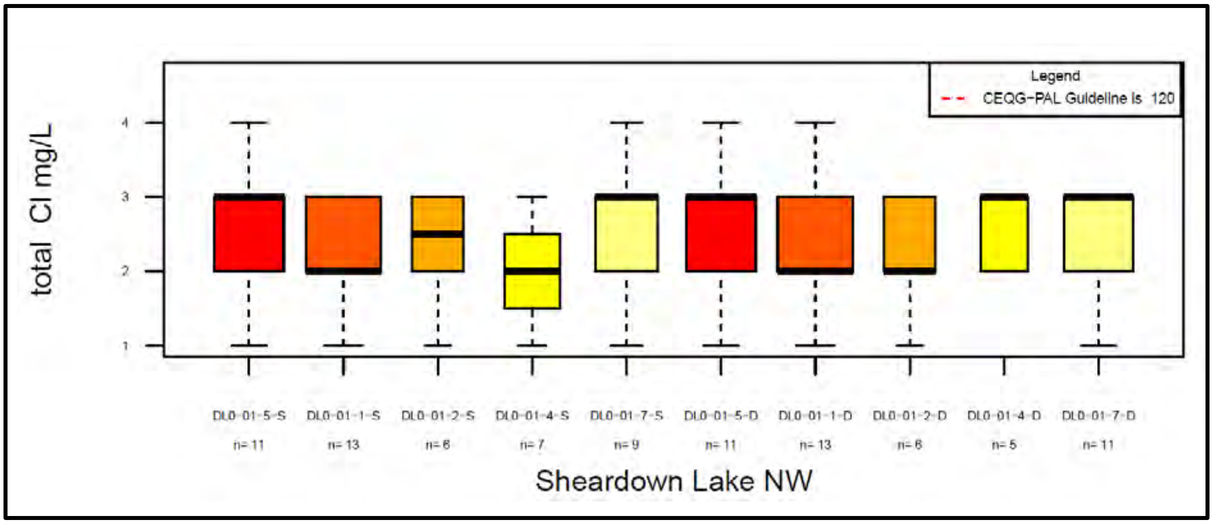
Hardness (Figure B.22)

- 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)

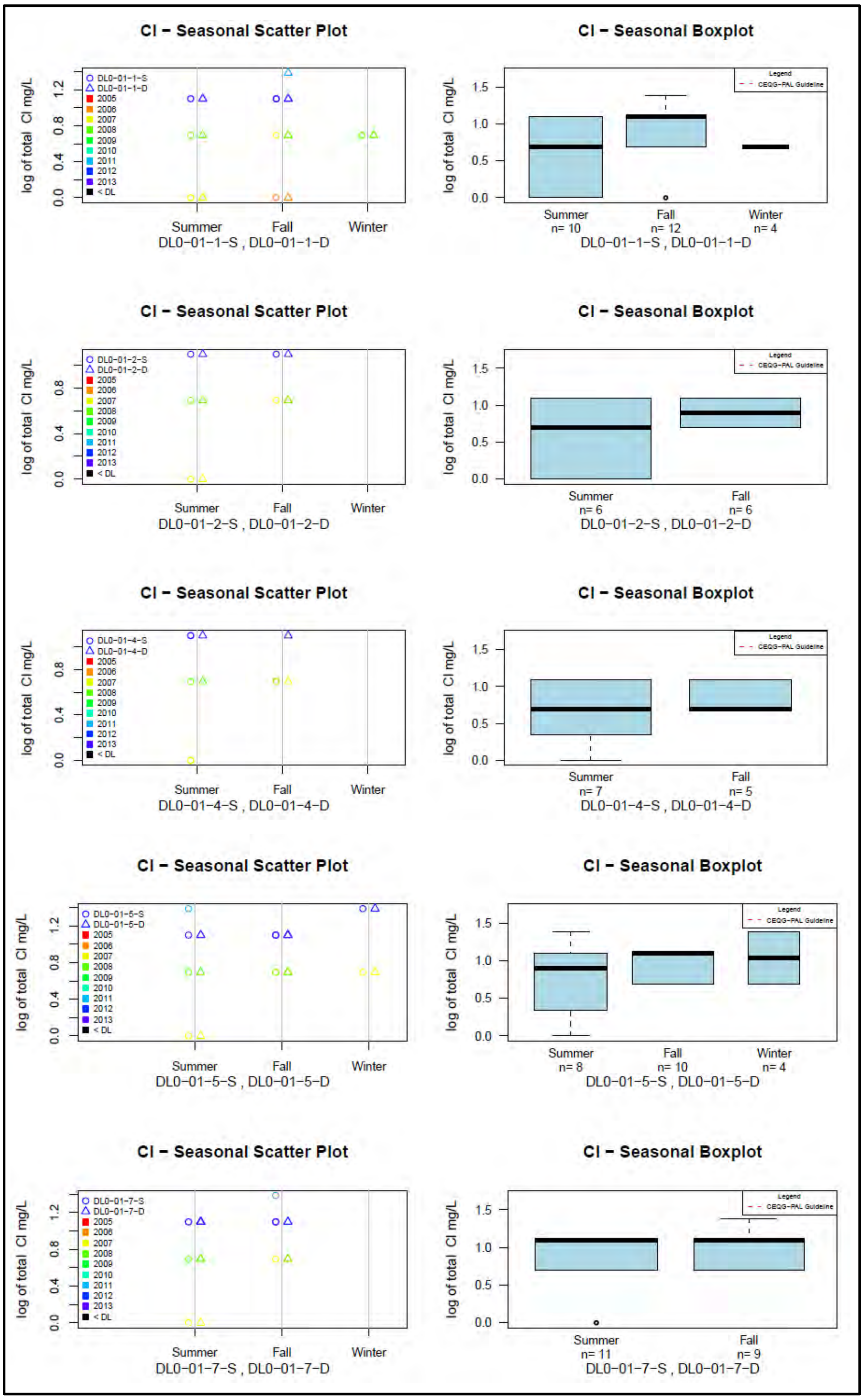
Ninety-two (92) chloride concentration samples were collected at Sheardown Lake NW. Chloride concentrations in Sheardown Lake NW are very low and have maximum values of 4 mg/L, well below the CWQG-PAL limit of 120 mg/L (Figure B.23). All sites within Sheardown Lake NW have very similar median chloride 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



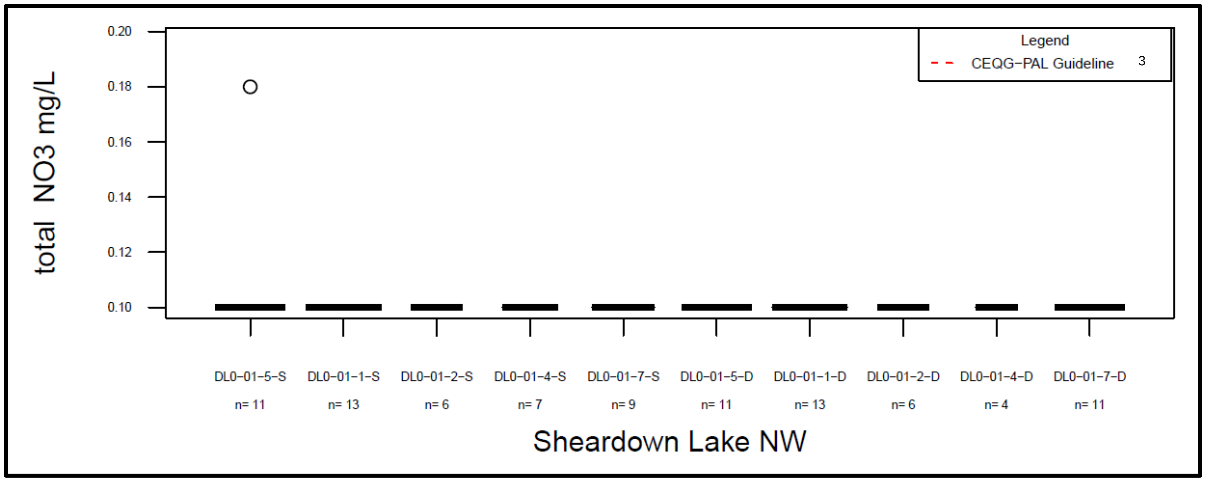
NOTES:

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:

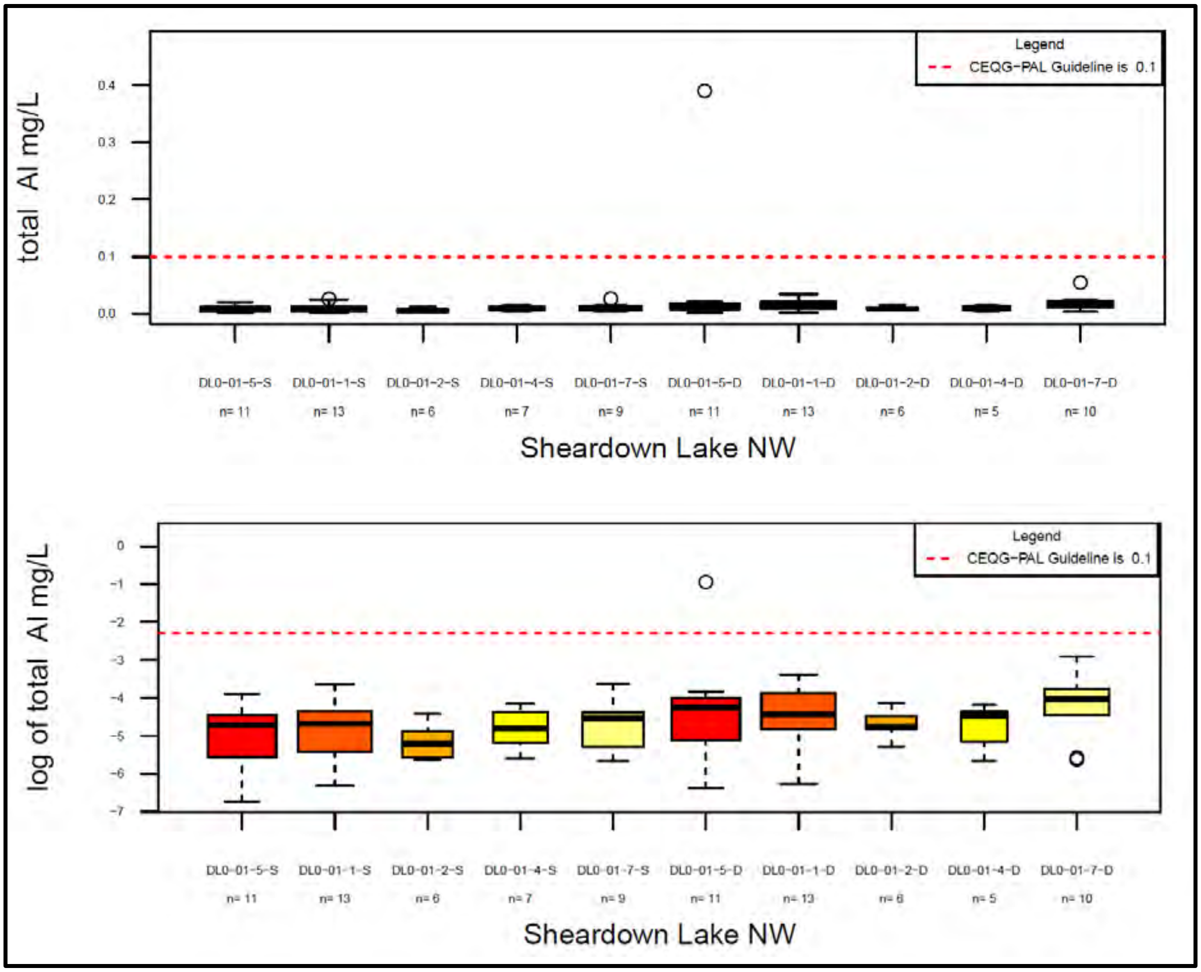
1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.

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)

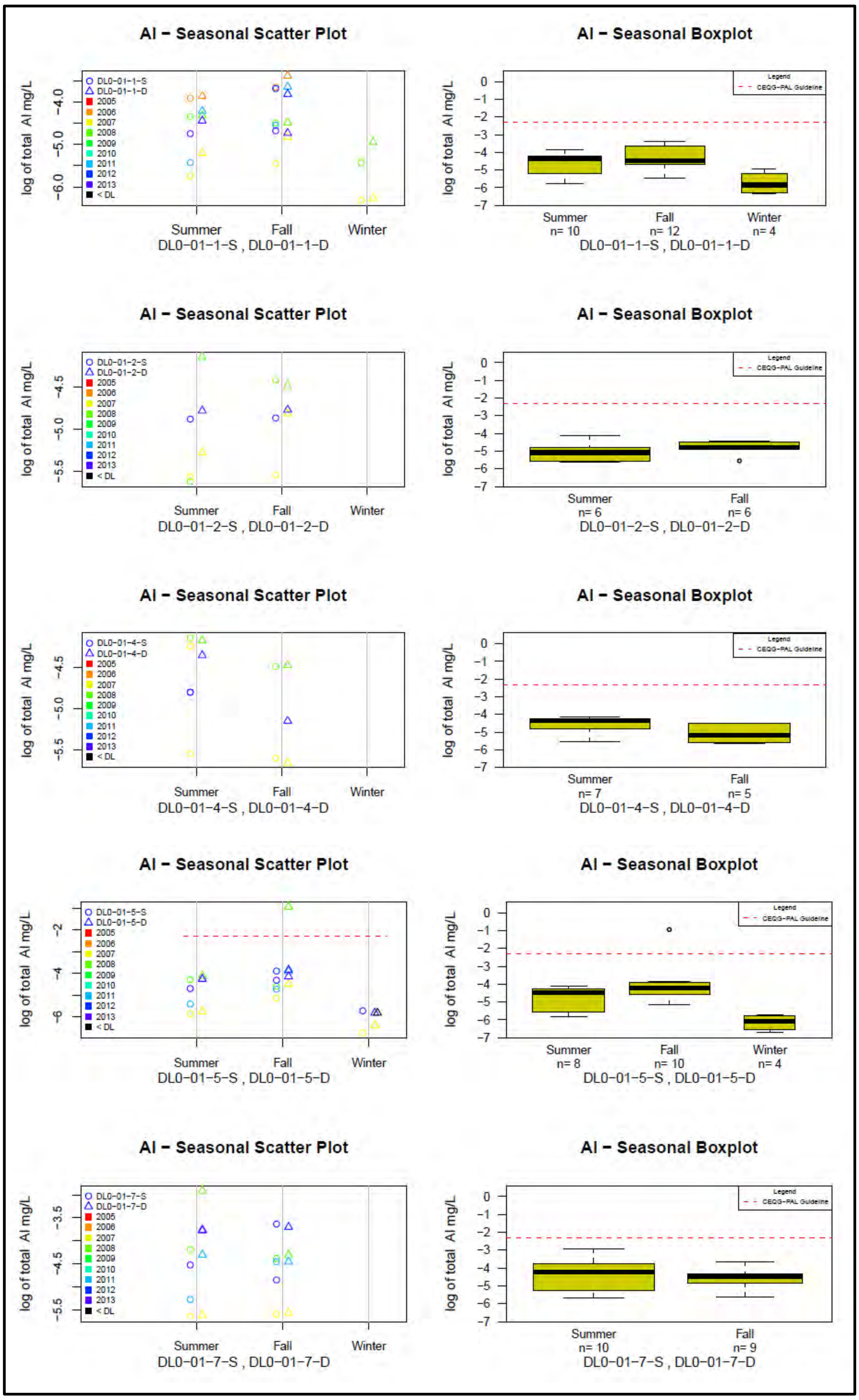
Ninety-one (91) total aluminum concentration samples were collected from Sheardown Lake NW over the course of eight years. Total aluminum concentrations consistently report above MDLs, and are consistently below the CWQG-PAL guideline, with the exception of one sample (Figure B.26). All stations within 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

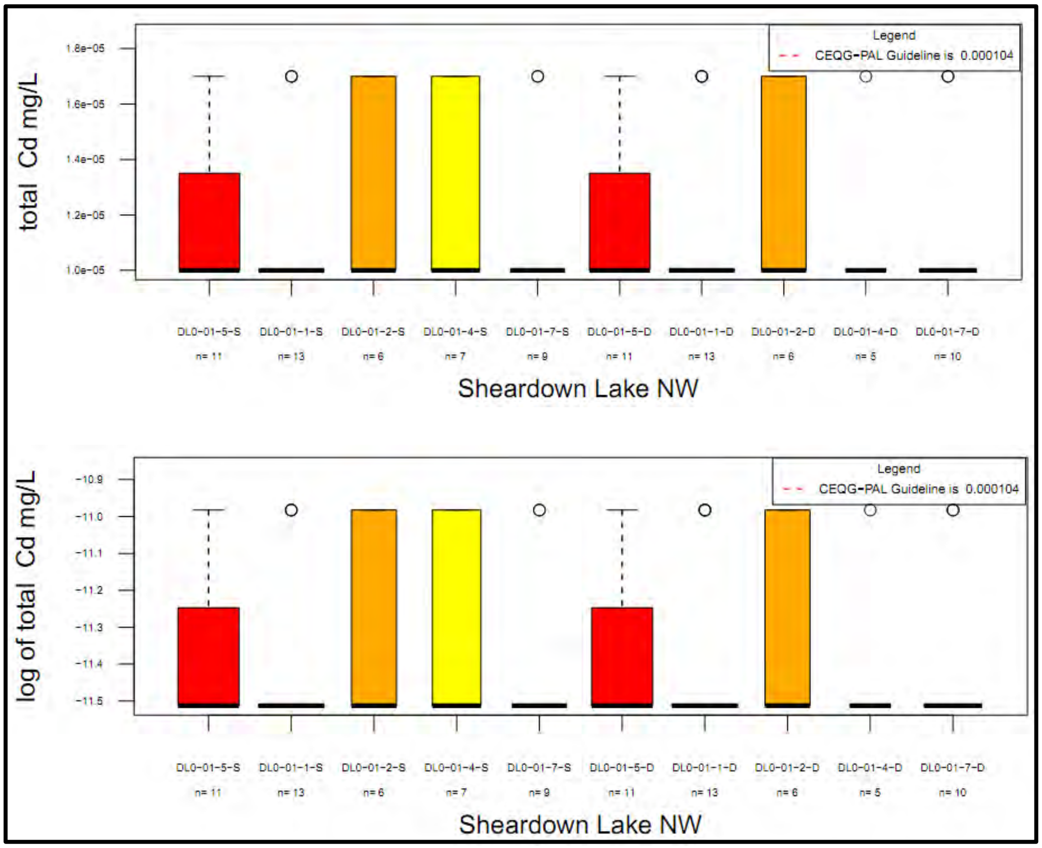
Total Arsenic

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.

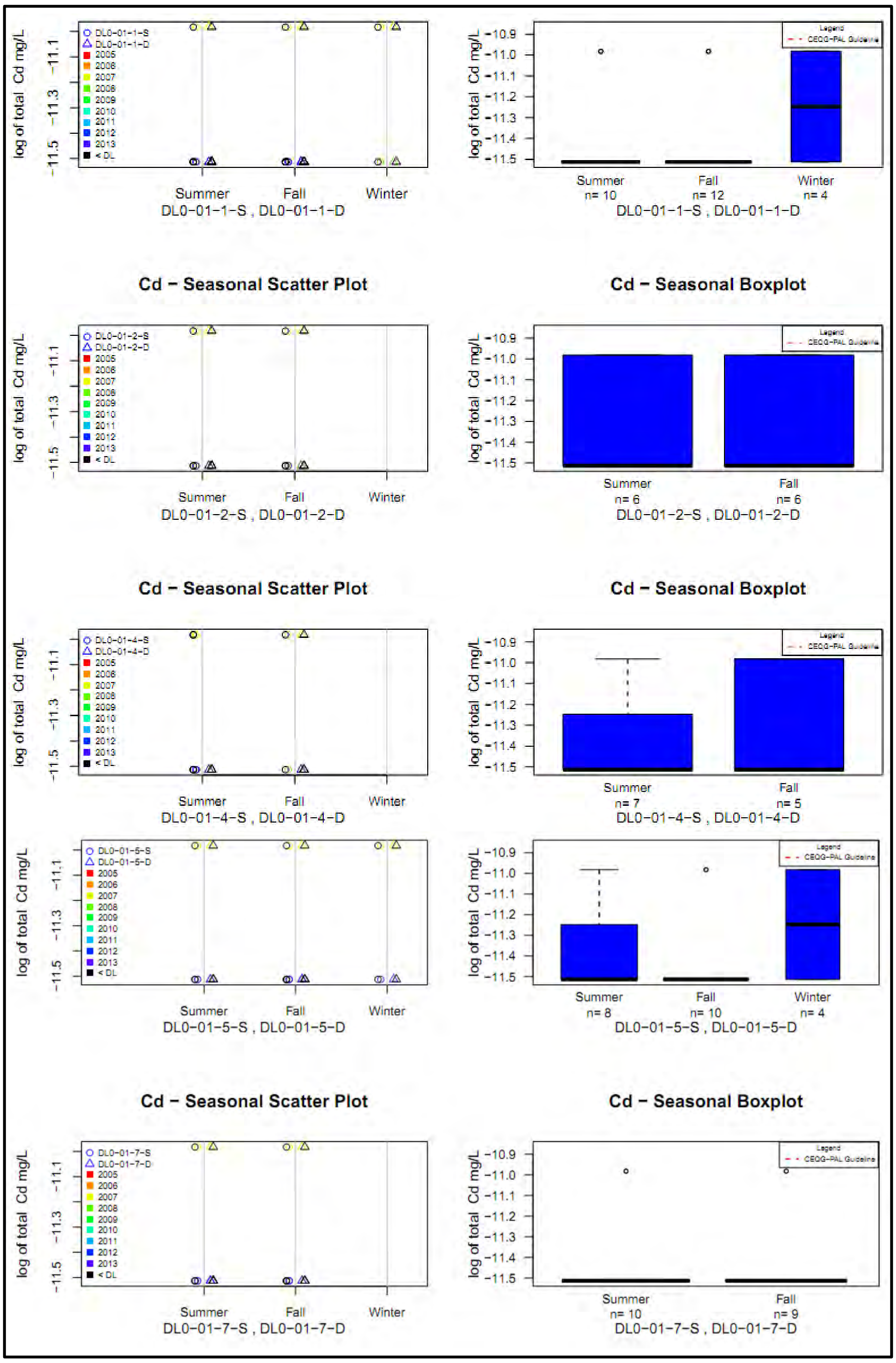
Seasonal scatterplots that combine data from deep and shallow sampling stations show no difference in values between the two stations, as a result of MDL interference (Figure B.29). Similarly, seasonal differences are not noted as a result of MDL interference.



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



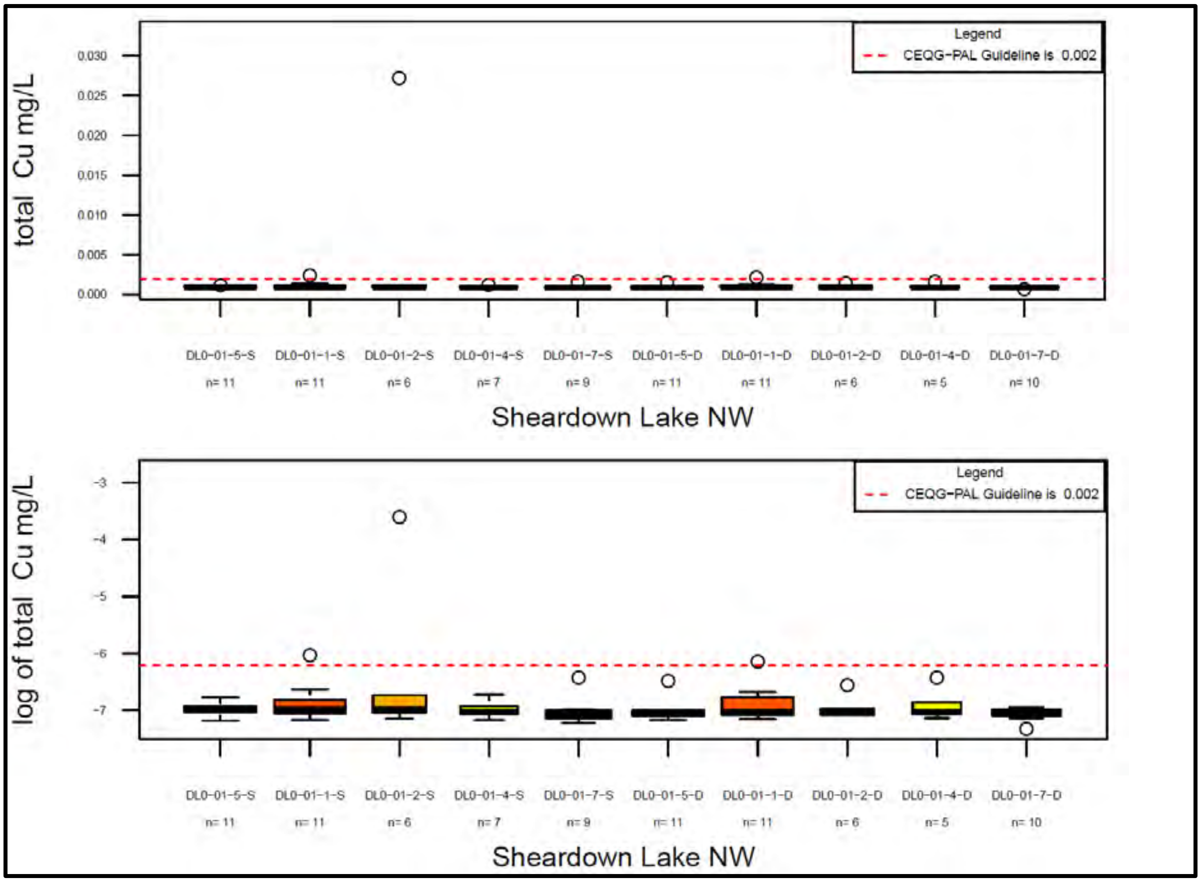
NOTES:

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)

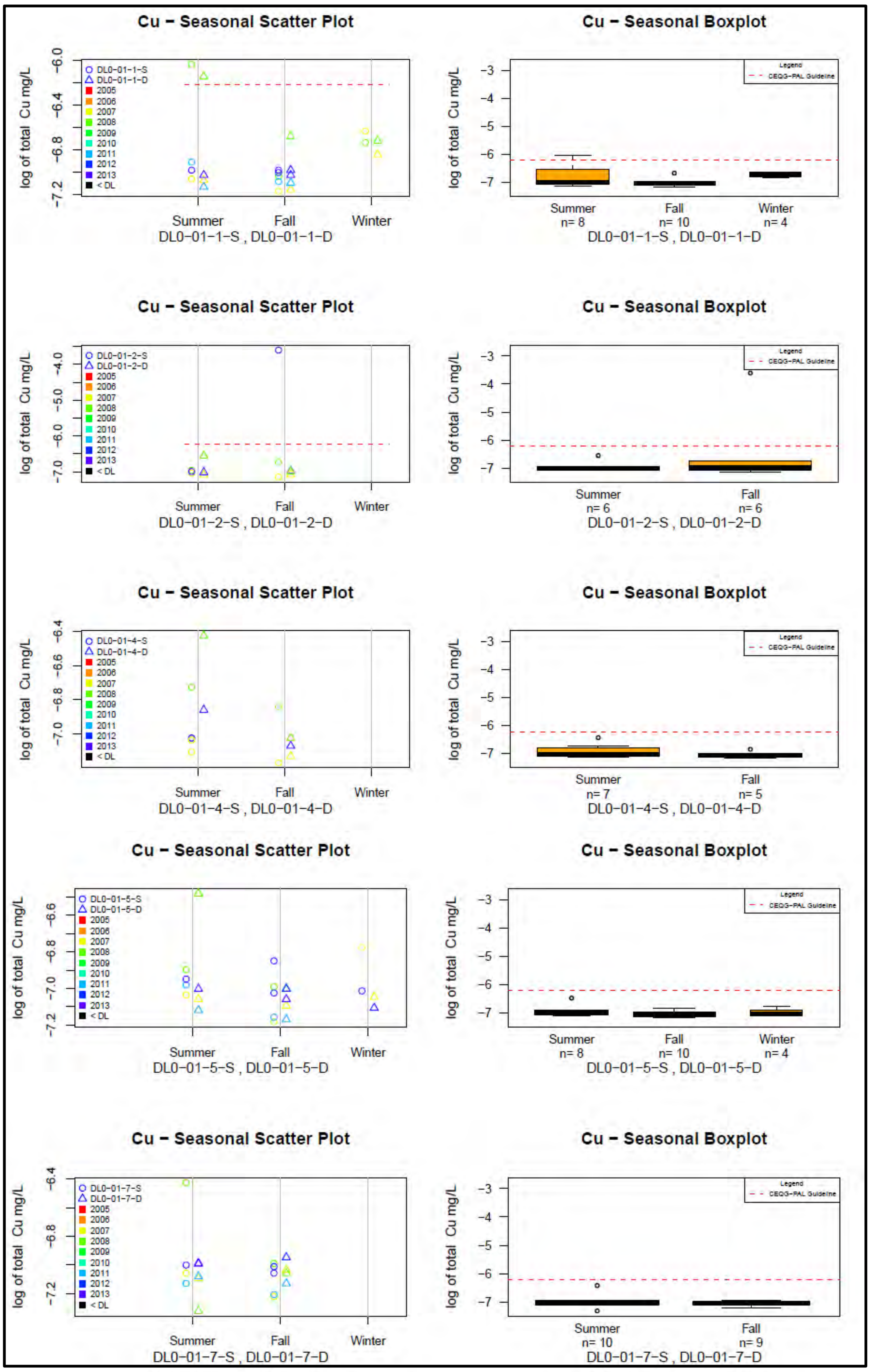
Eighty-seven (87) total copper concentration samples were collected from Sheardown Lake NW over the course of eight years. Total copper concentrations are slightly elevated, but usually below the CWQG-PAL guideline (Figure B.30). Seasonal scatterplots that combine data from deep and shallow sampling 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:

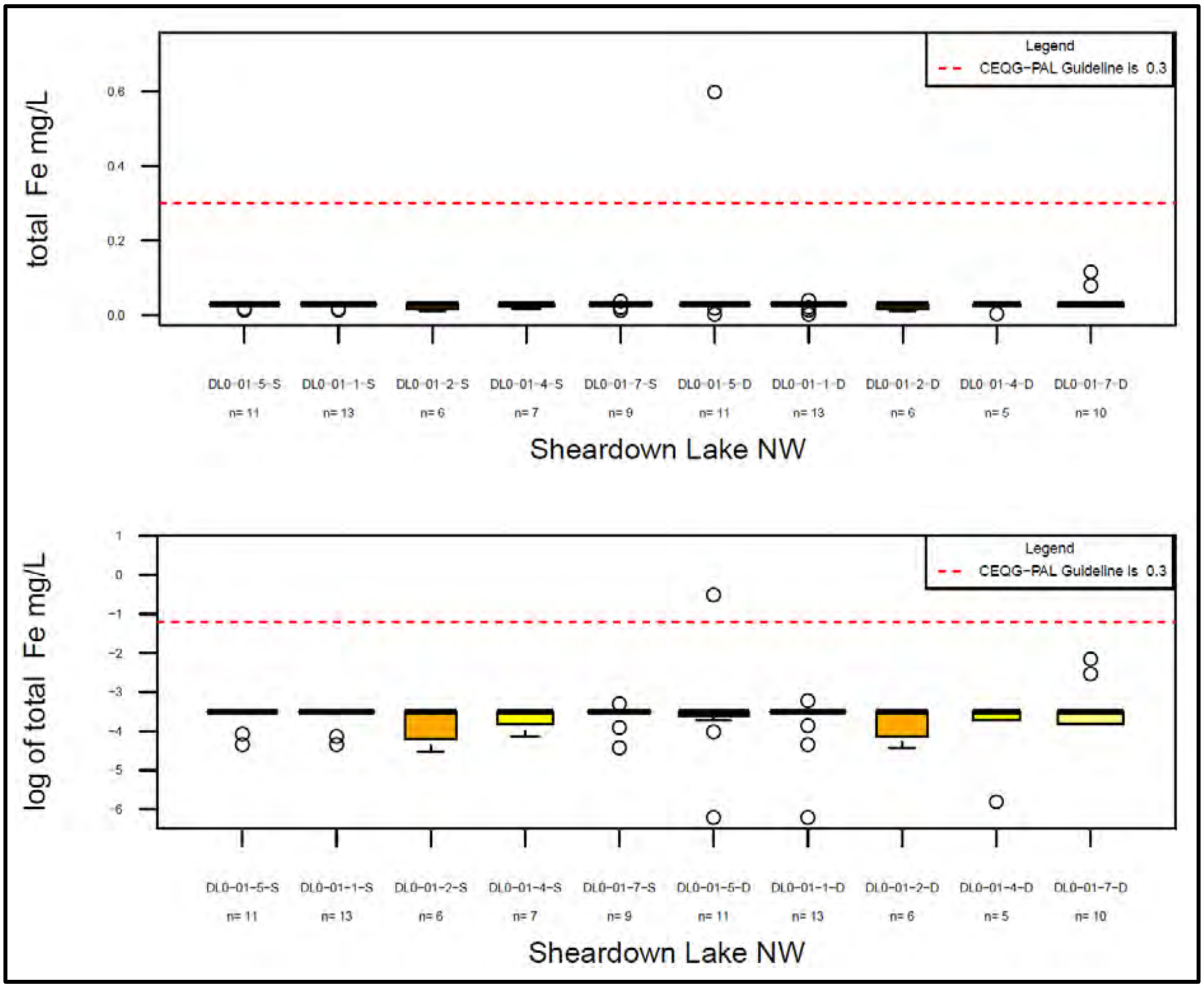
1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.
2. THE CWQG-PAL GUIDELINE LIMIT IS BASED ON THE TOTAL MEDIAN HARDNESS.

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.

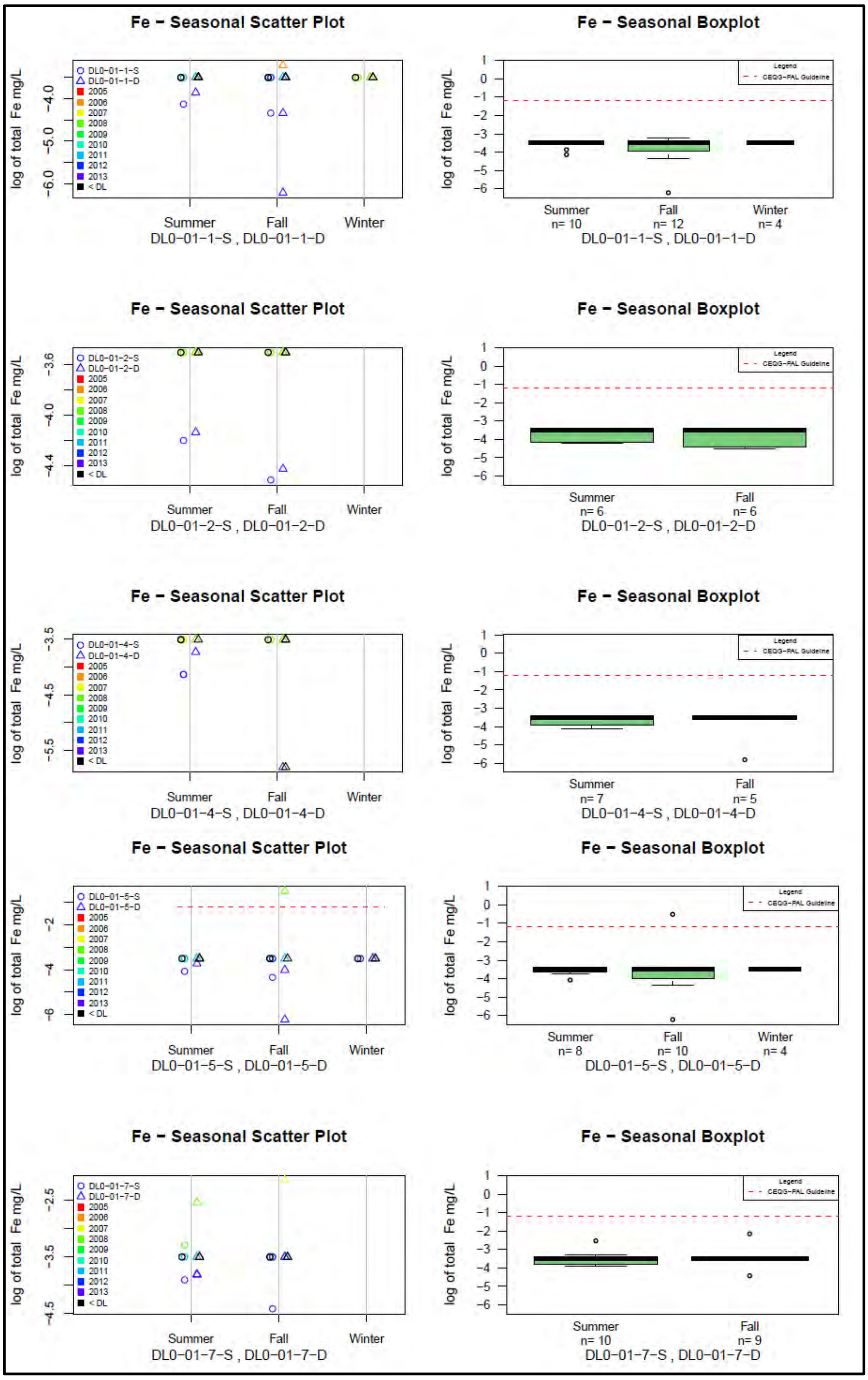
Seasonal scatterplots that combine data from deep and shallow sampling stations show no difference in values between the two stations (Figure B.33). Seasonal differences are not noted as a result of MDL interference.



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:

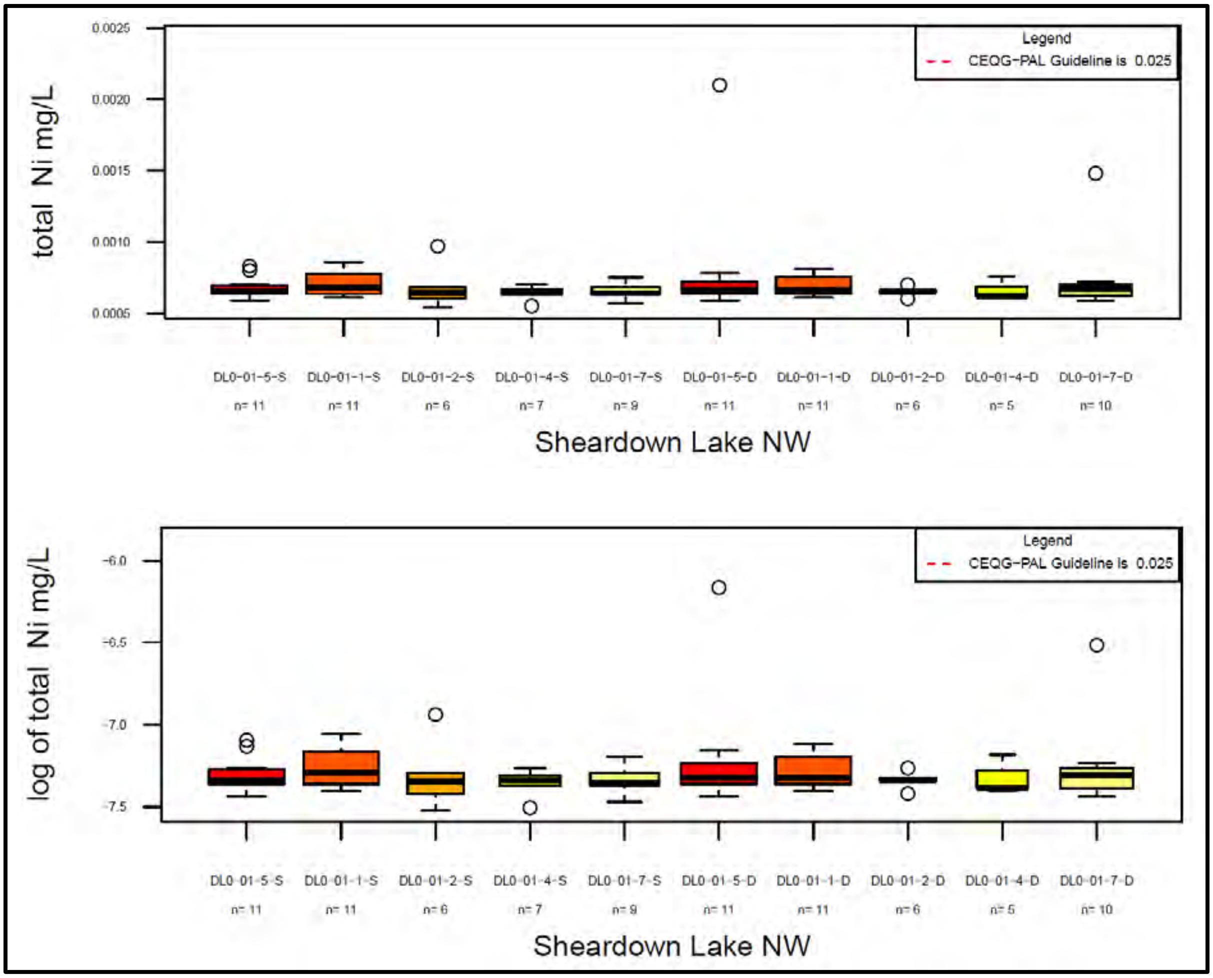
1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.

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.

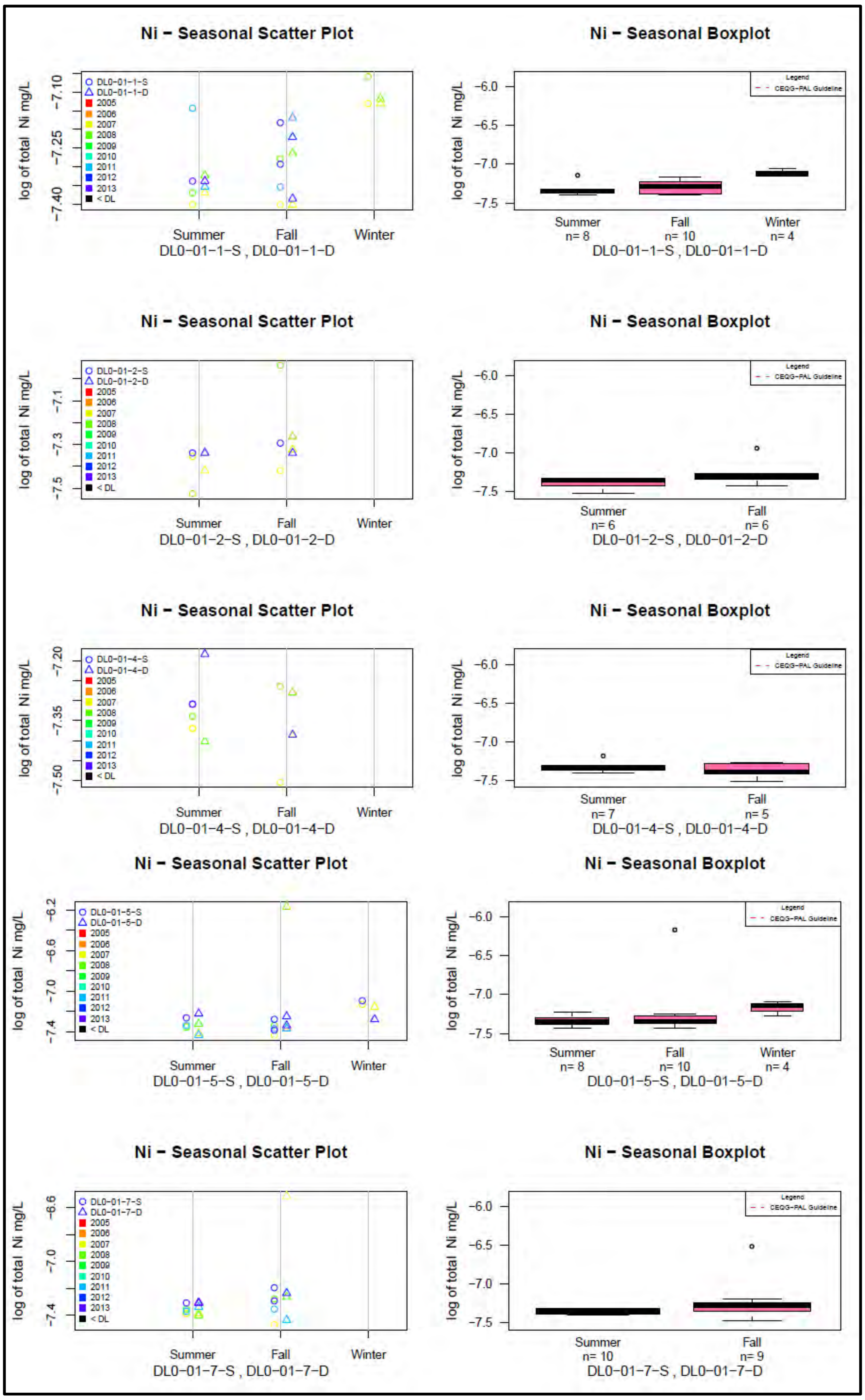
Seasonal scatterplots show that outlying data points tend to originate from sampling in 2008/2009 (Figure B.35). Seasonal boxplots show that the winter dataset for Sheardown lake nickel samples is limited. Historical summer and fall data have similar median values. The limited data collected for winter 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:

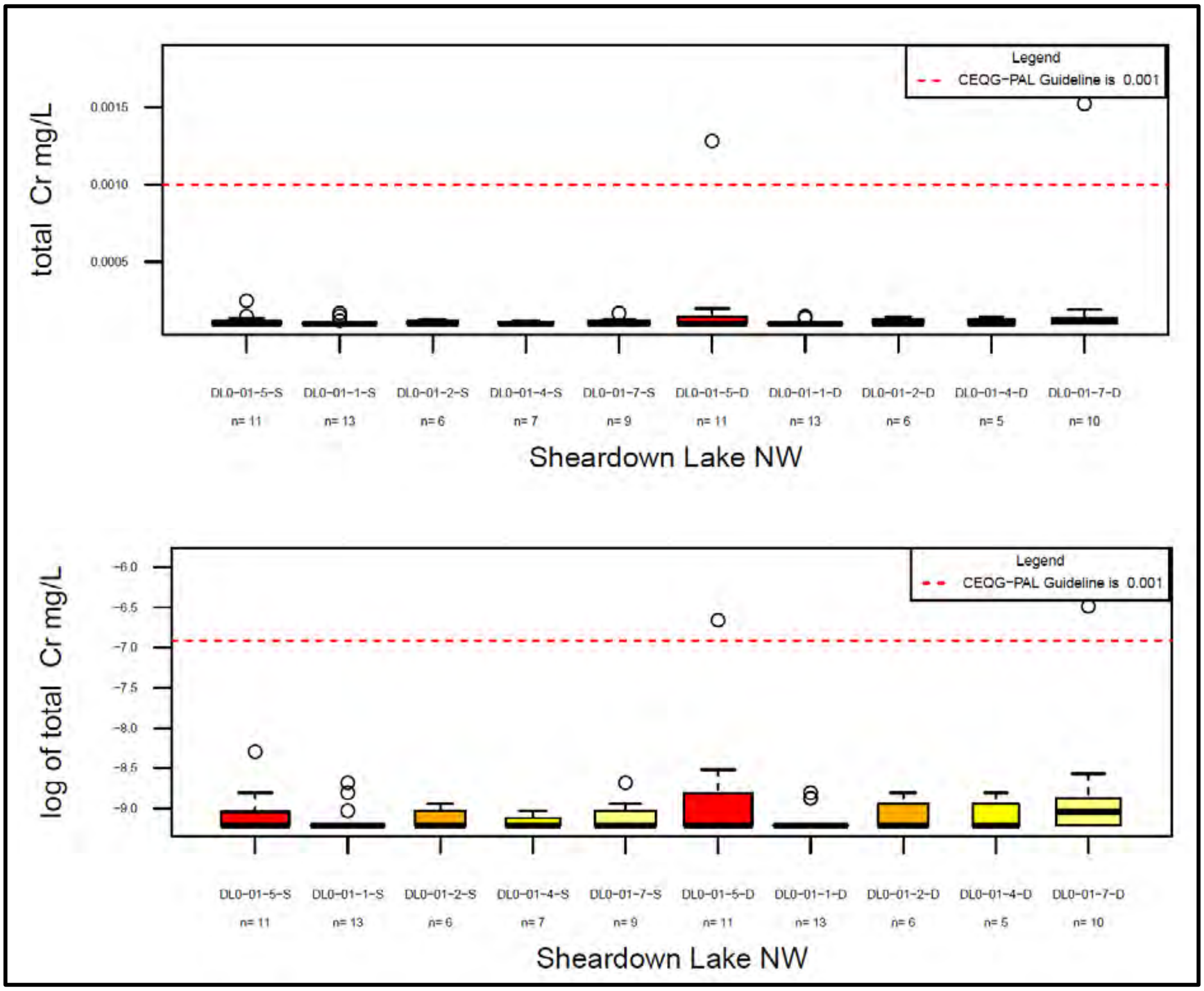
1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.
2. THE CWQG-PAL GUIDELINE LIMIT IS BASED ON THE TOTAL MEDIAN HARDNESS.

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.

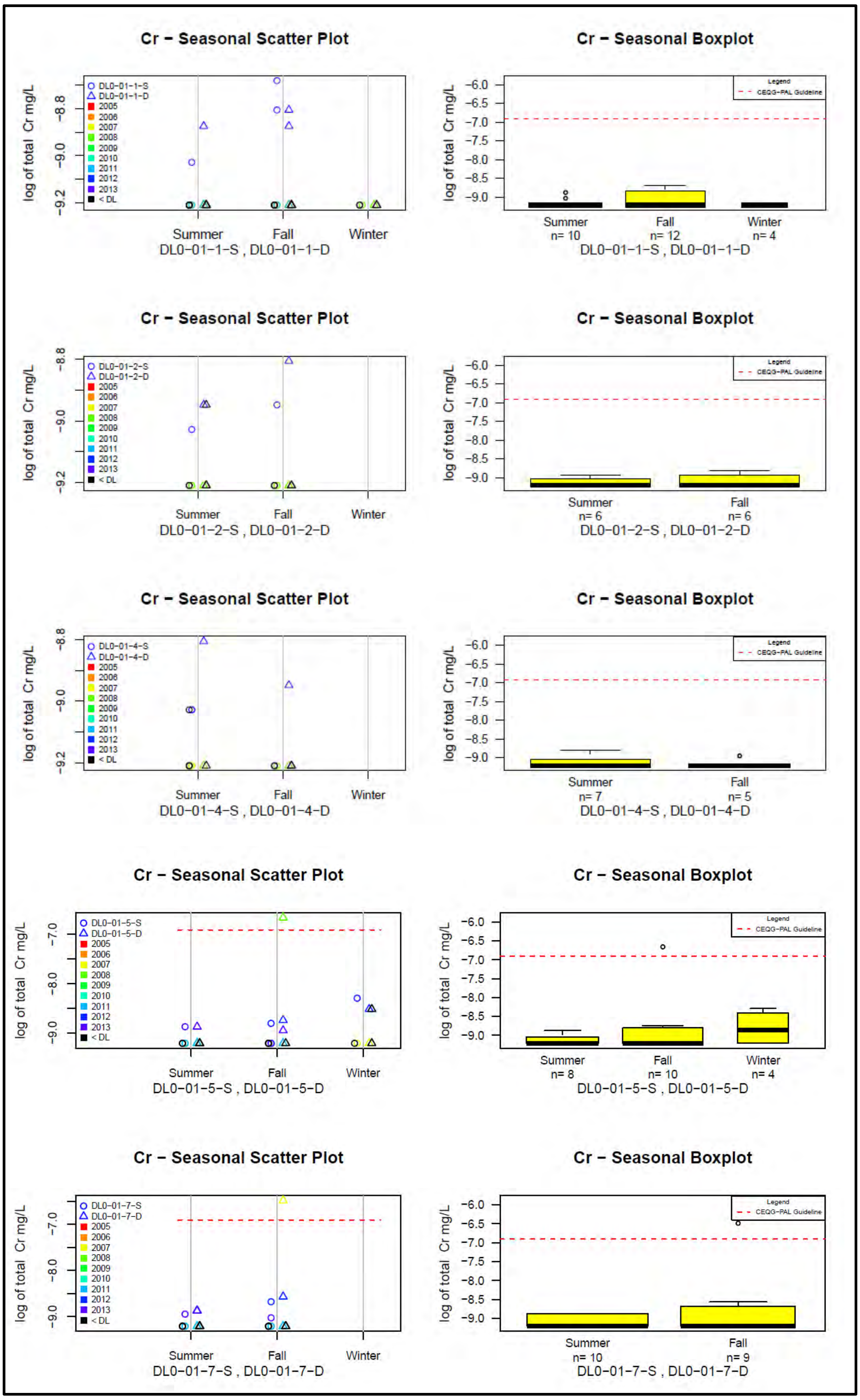
Seasonal scatterplots show 2012 and 2013 data is generally elevated when compared to older data (Figure B.37). Seasonal boxplots do not show a consistent seasonal trend.



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.

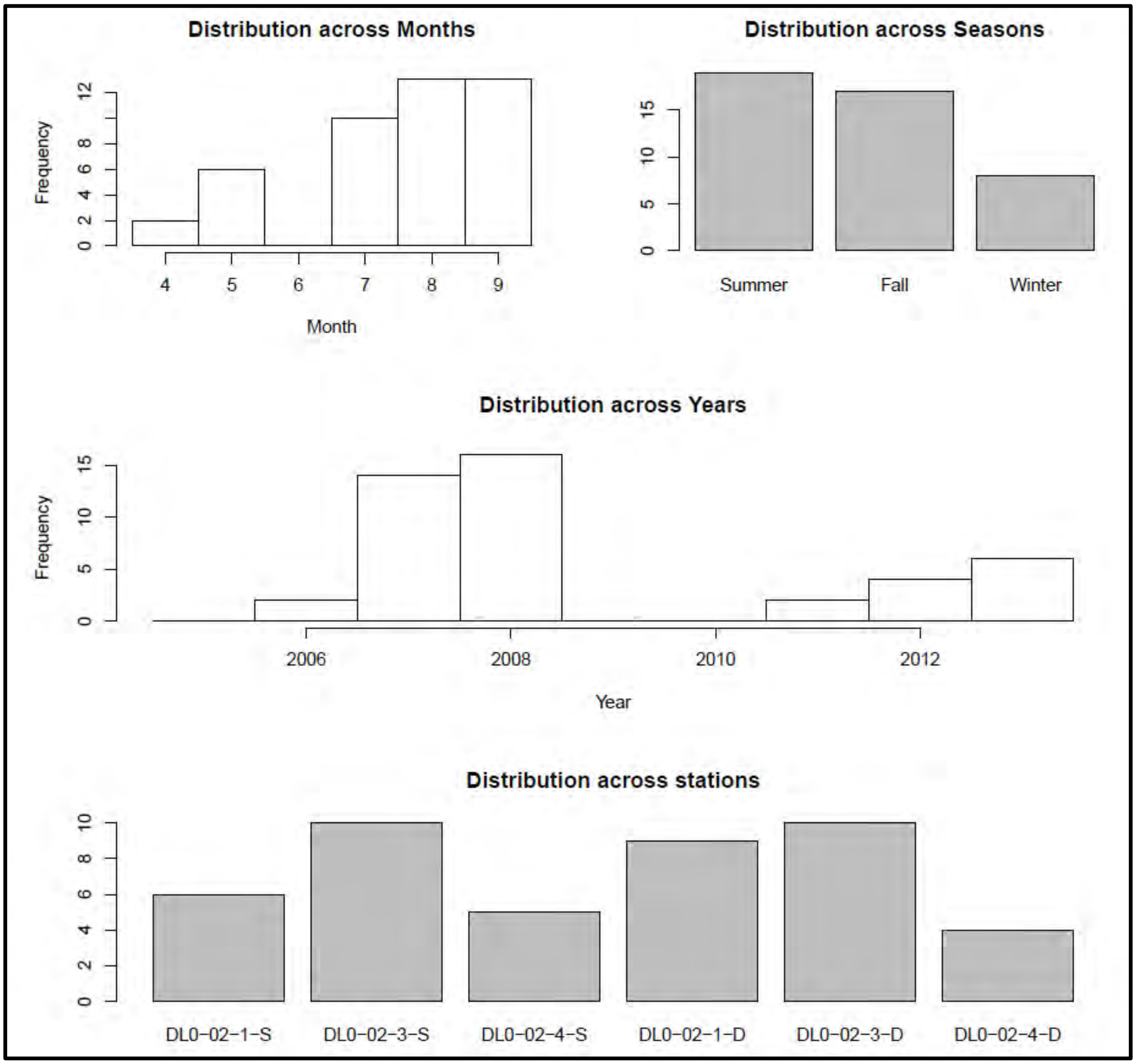


Figure B.38 Sheardown Lake SE – Graphical Summary of Sampling Events

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.

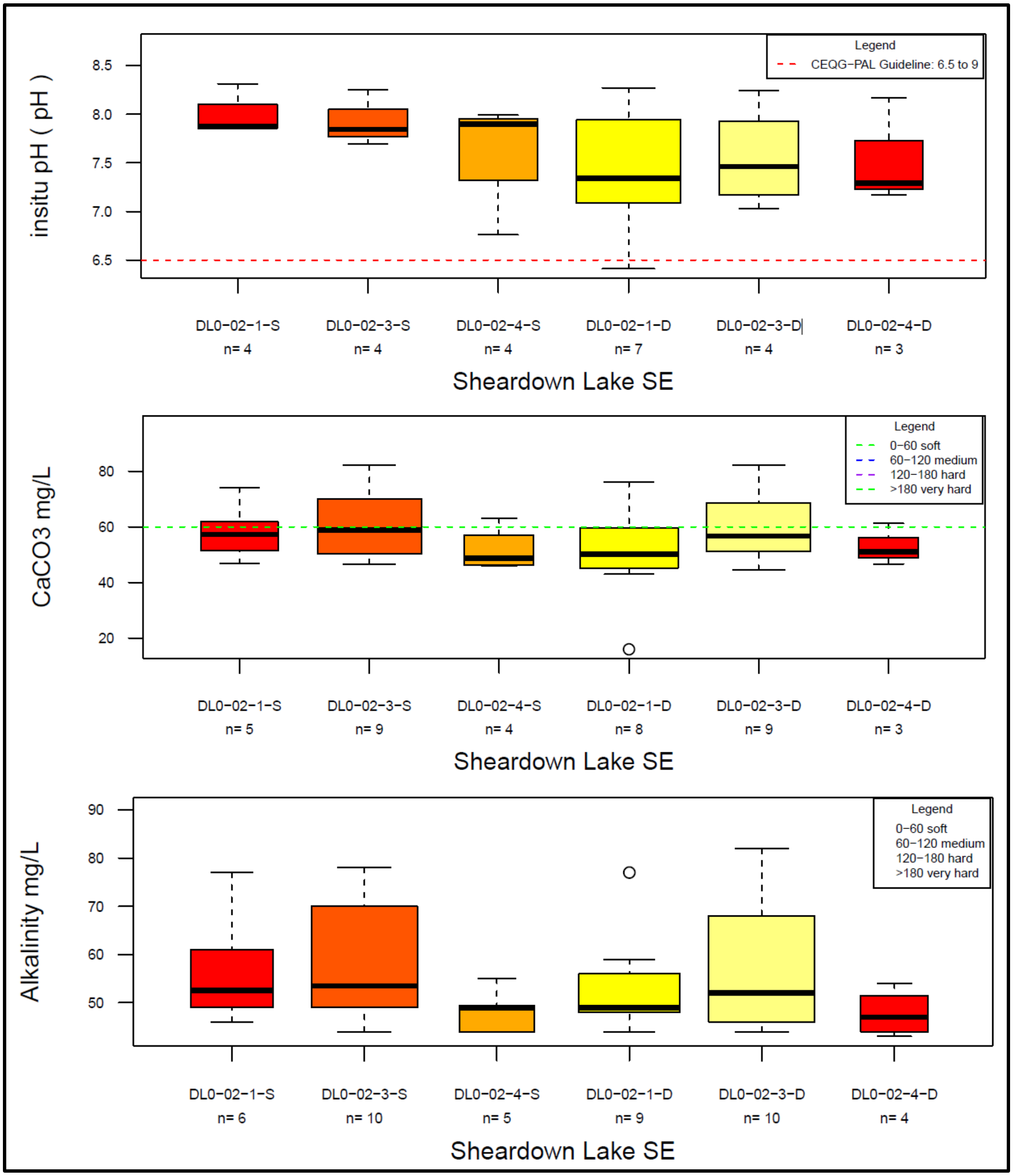


Figure B.39 Sheardown Lake SE – *In situ* pH, Alkalinity and Hardness

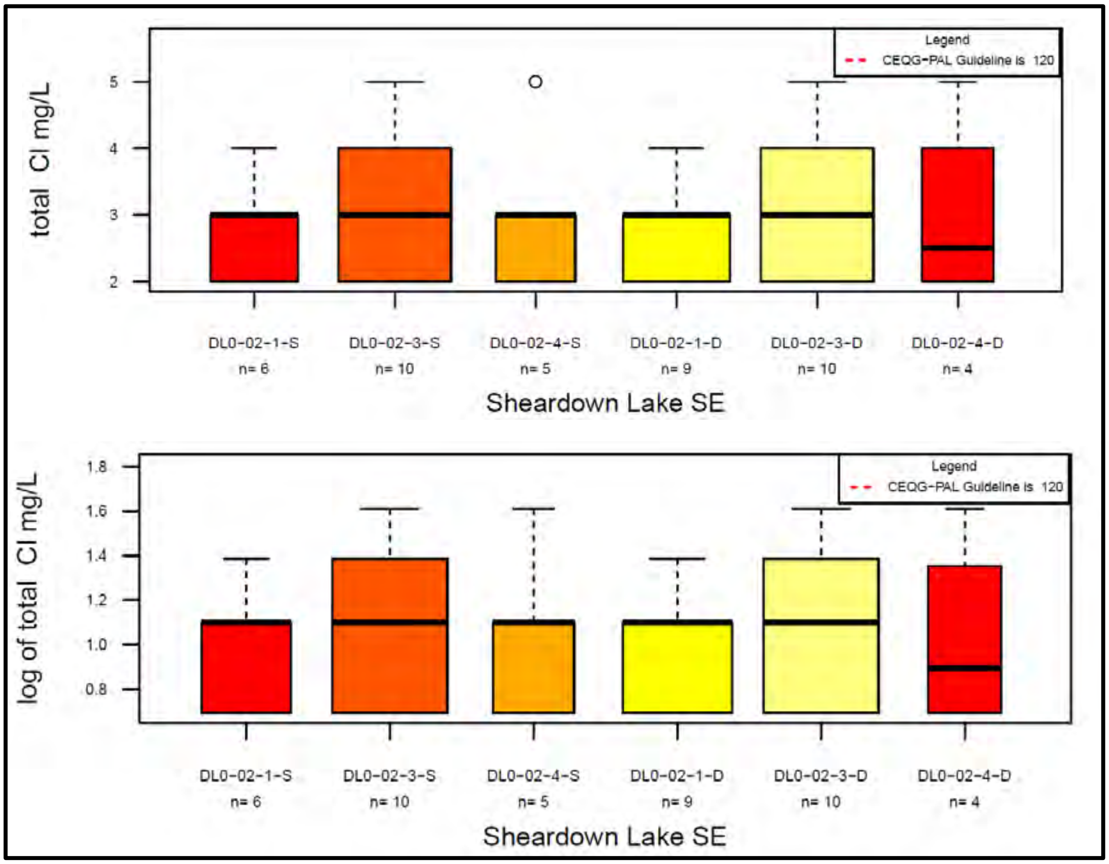
Hardness (Figure B.39)

- 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)

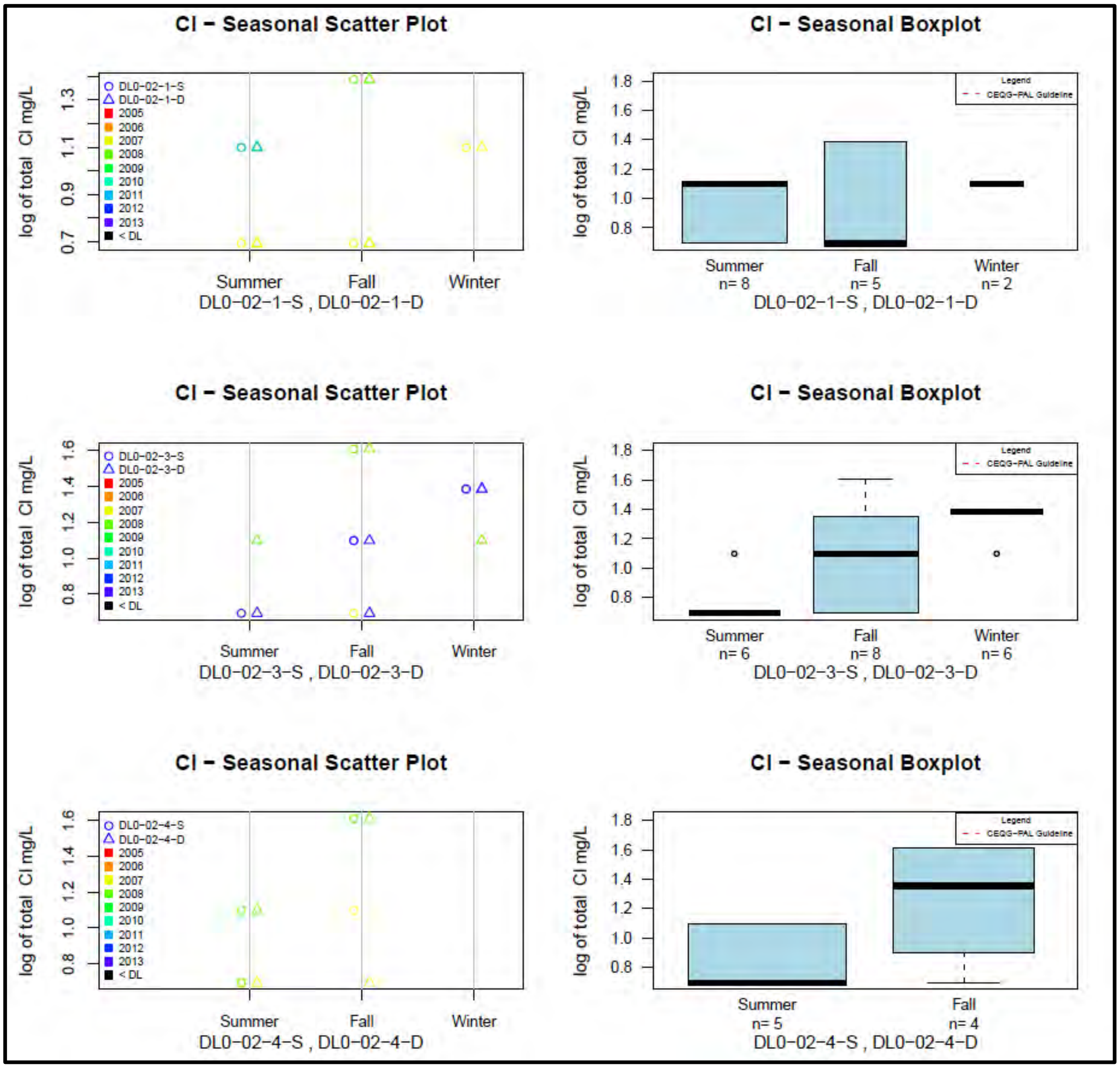
Forty-four (44) chloride concentration samples were collected at Sheardown Lake SE. Chloride concentrations in Sheardown Lake SE are very low and have maximum values of 5 mg/L, well below the CWQG-PAL limit of 120 mg/L (Figure B.40). All sites within Sheardown Lake SE have very similar median chloride 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

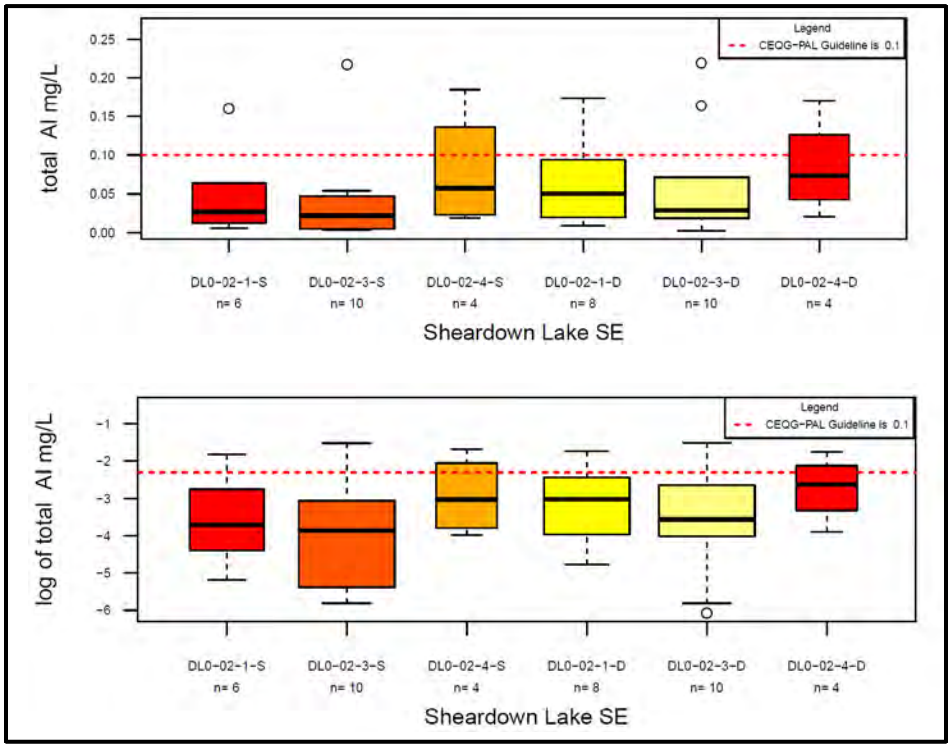
Nitrate

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)

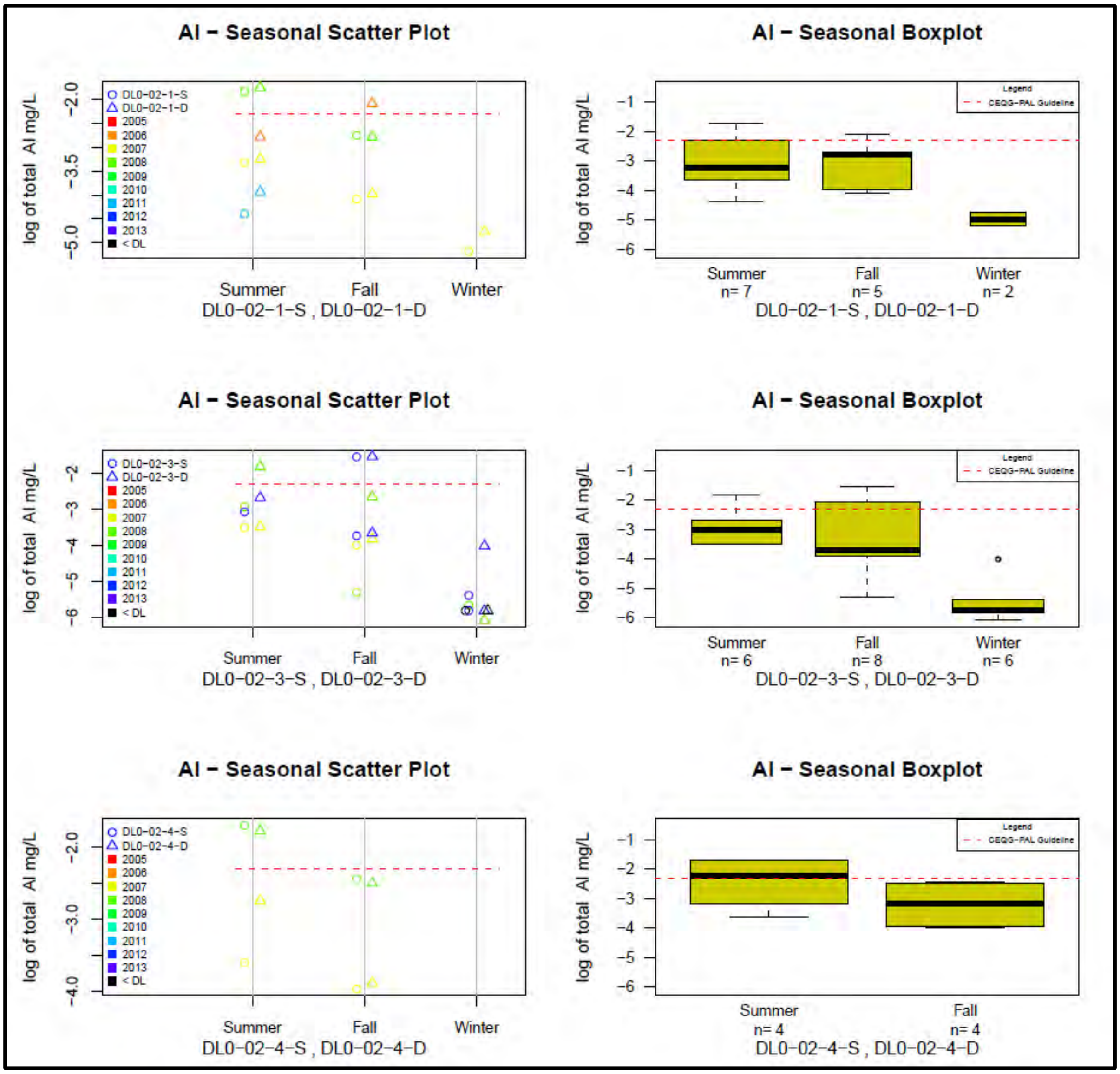
Forty-two (42) total aluminum concentration samples were collected from Sheardown Lake SE over the course of eight years. Total aluminum concentrations consistently report above MDLs and have 75th percentile values that exceed the CWQG-PAL guidelines of 0.1 mg/L (Figure B.42). All stations within Sheardown 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

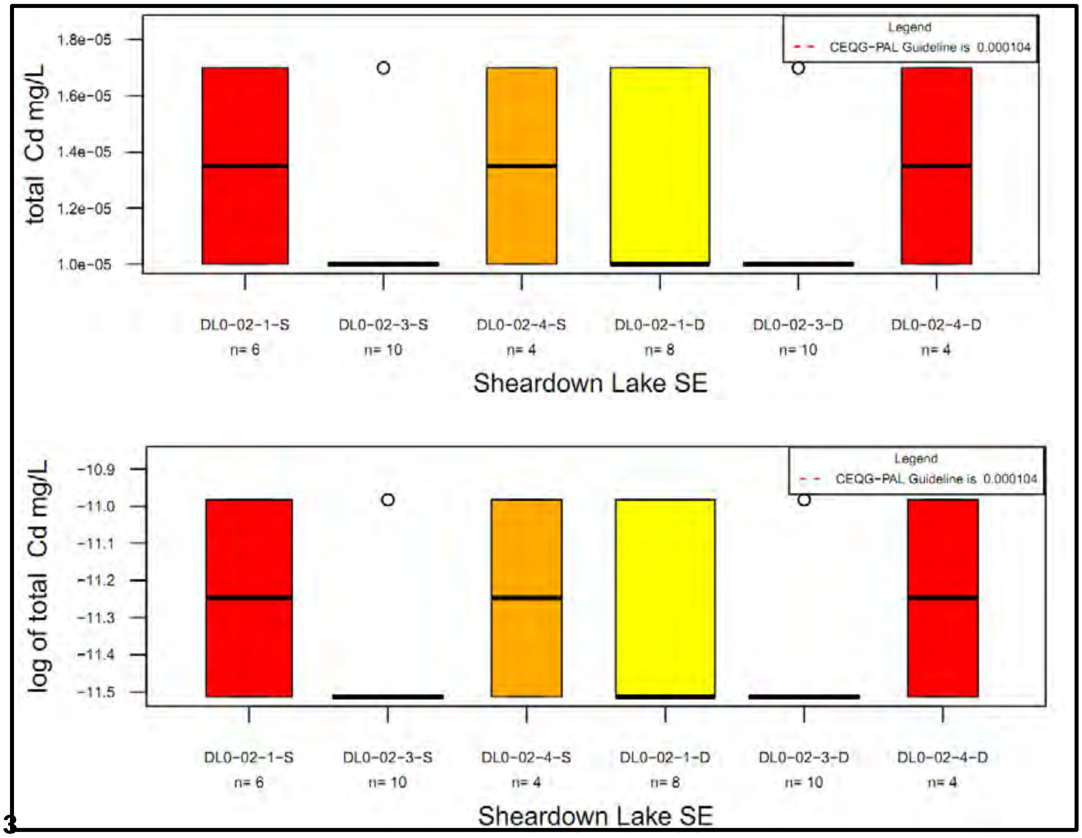
Total Arsenic

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.

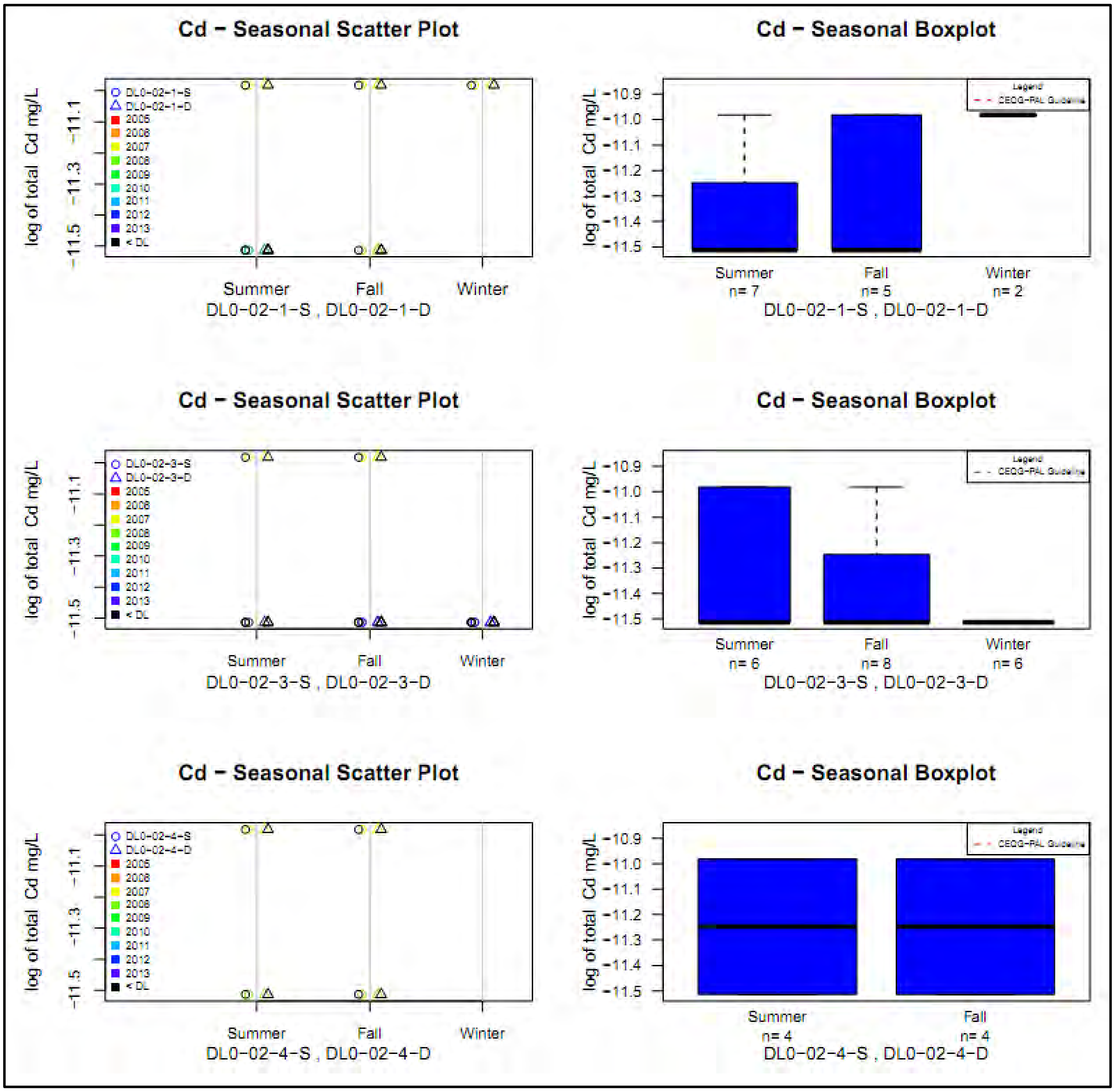
Seasonal scatterplots that combine data from deep and shallow sampling stations show no difference in values between the two stations, as a result of MDL interference (Figure B.45). Similarly, seasonal differences are not noted as a result of MDL interference.



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:

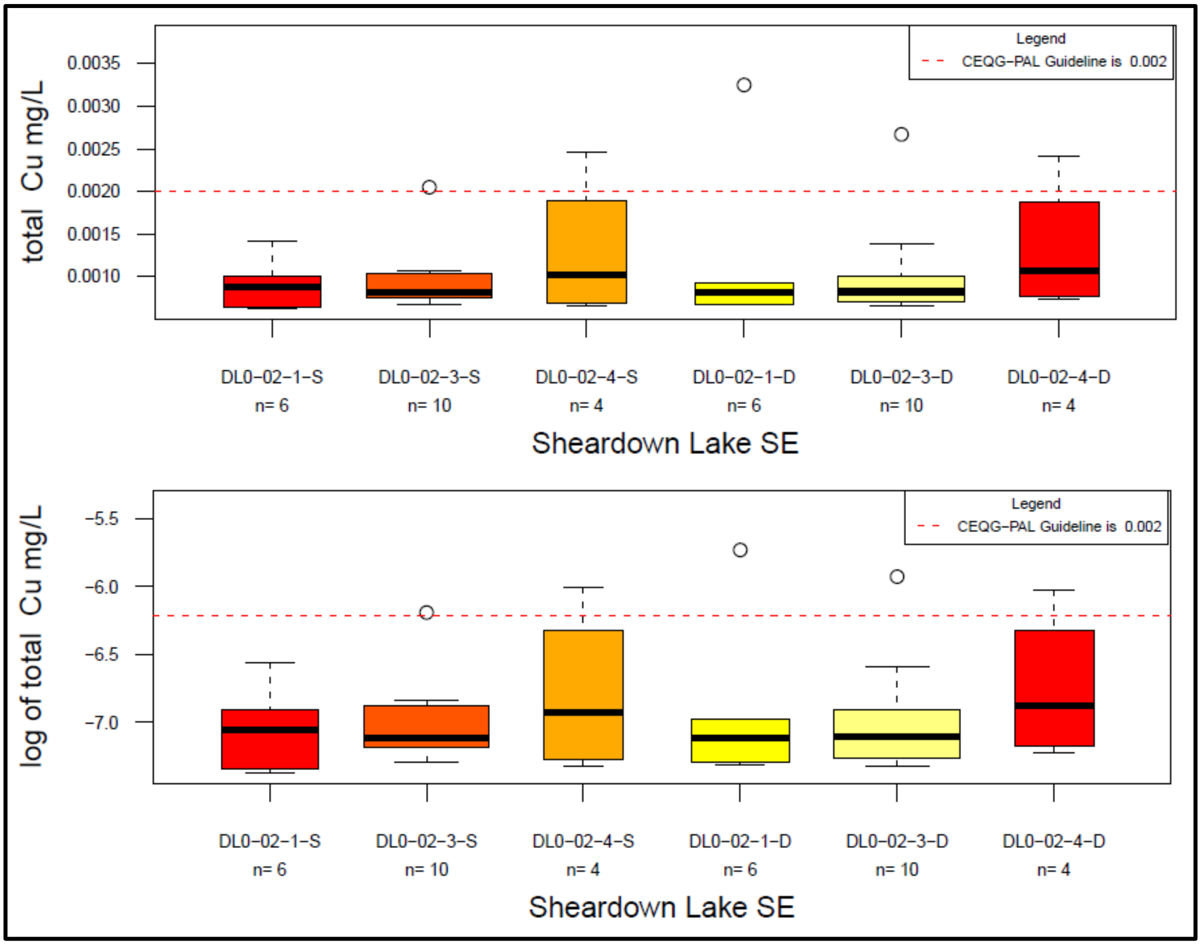
1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.
2. THE CWQG-PAL GUIDELINE LIMIT IS BASED ON THE TOTAL MEDIAN HARDNESS.

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.

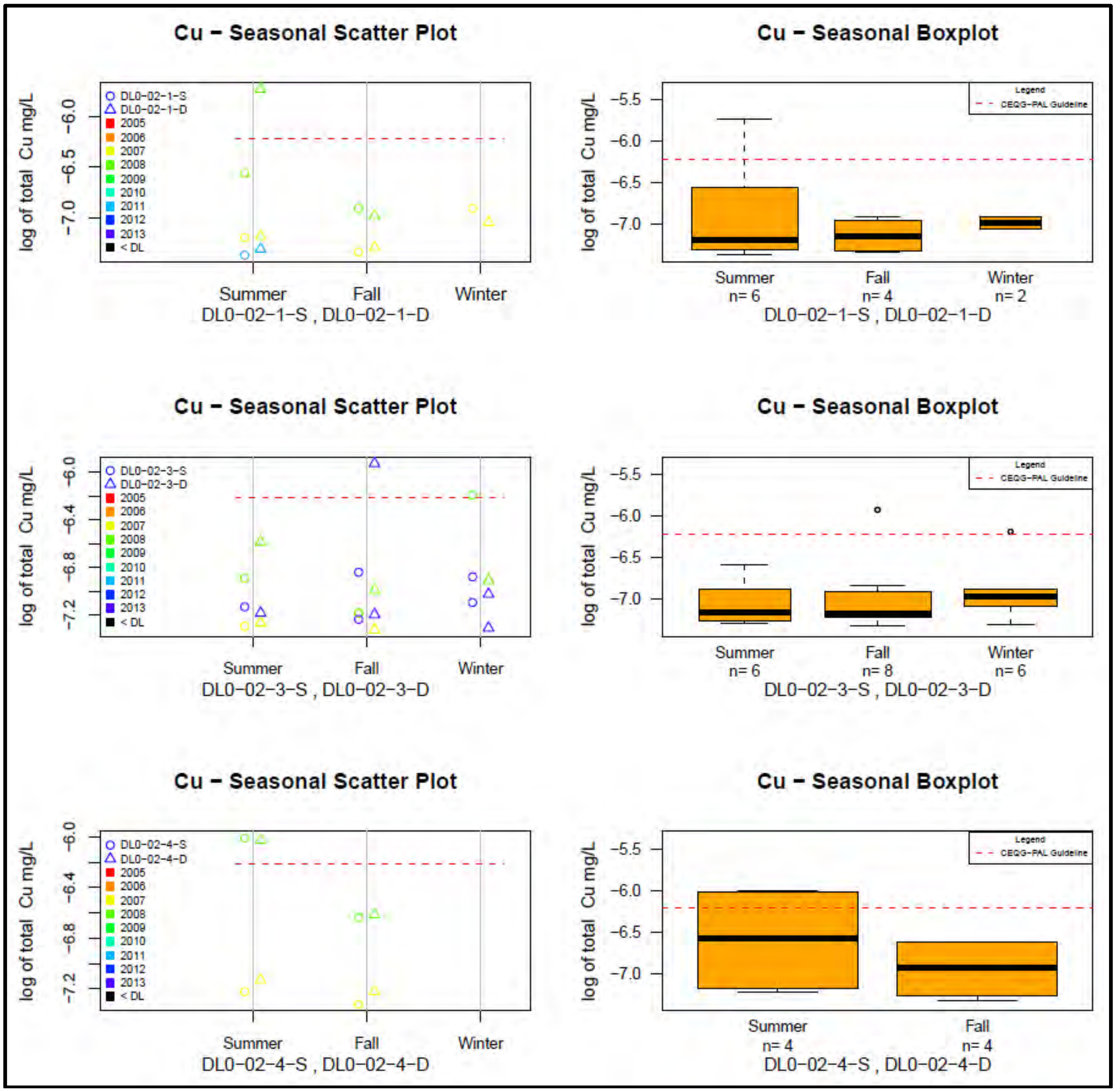
Seasonal scatterplots that combine data from deep and shallow sampling stations do not show a consistent trend across stations (Figure B.47). Data from 2008 appears to be slightly elevated when compared to later data. With the data available, distinct seasonal trends are not observed.



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:

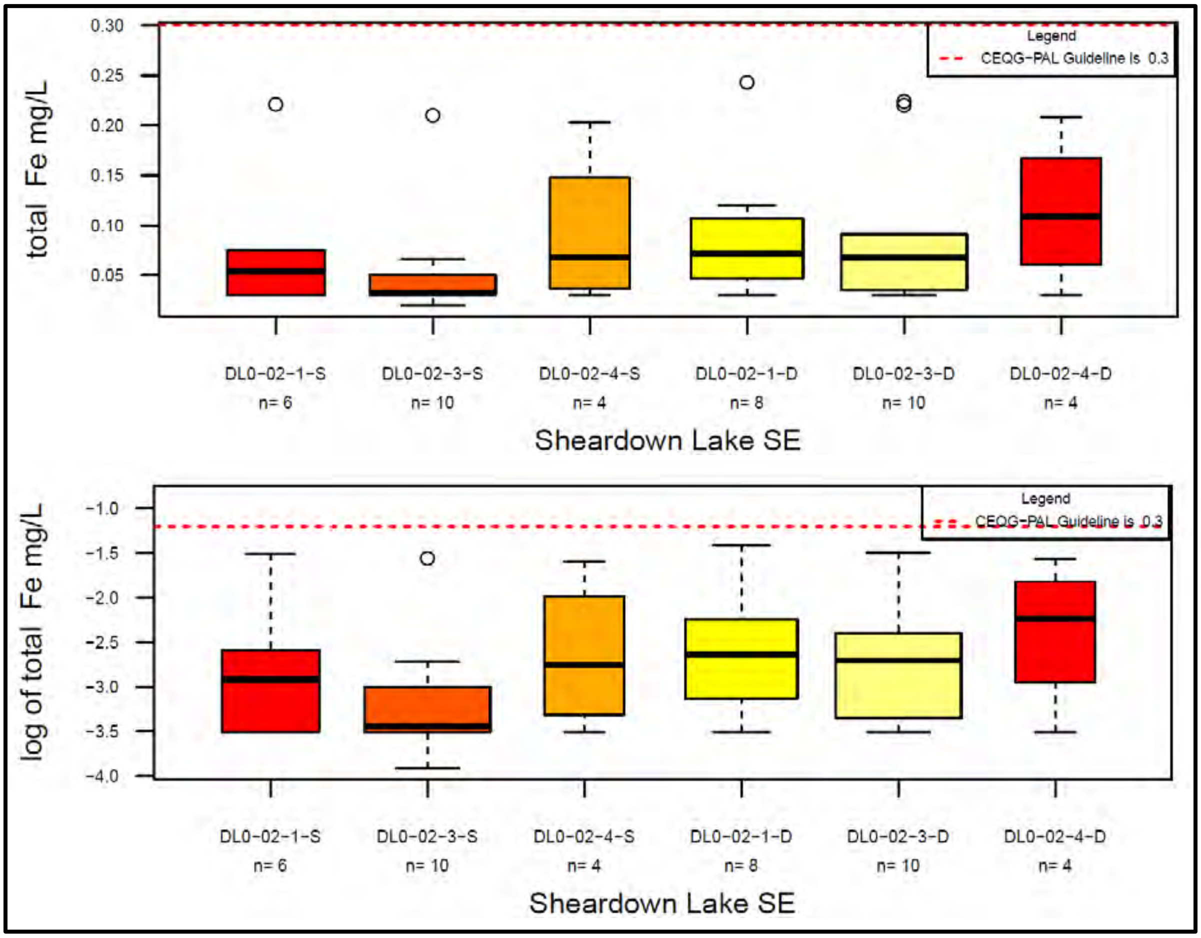
1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.
2. THE CWQG-PAL GUIDELINE LIMIT IS BASED ON THE TOTAL MEDIAN HARDNESS.

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.

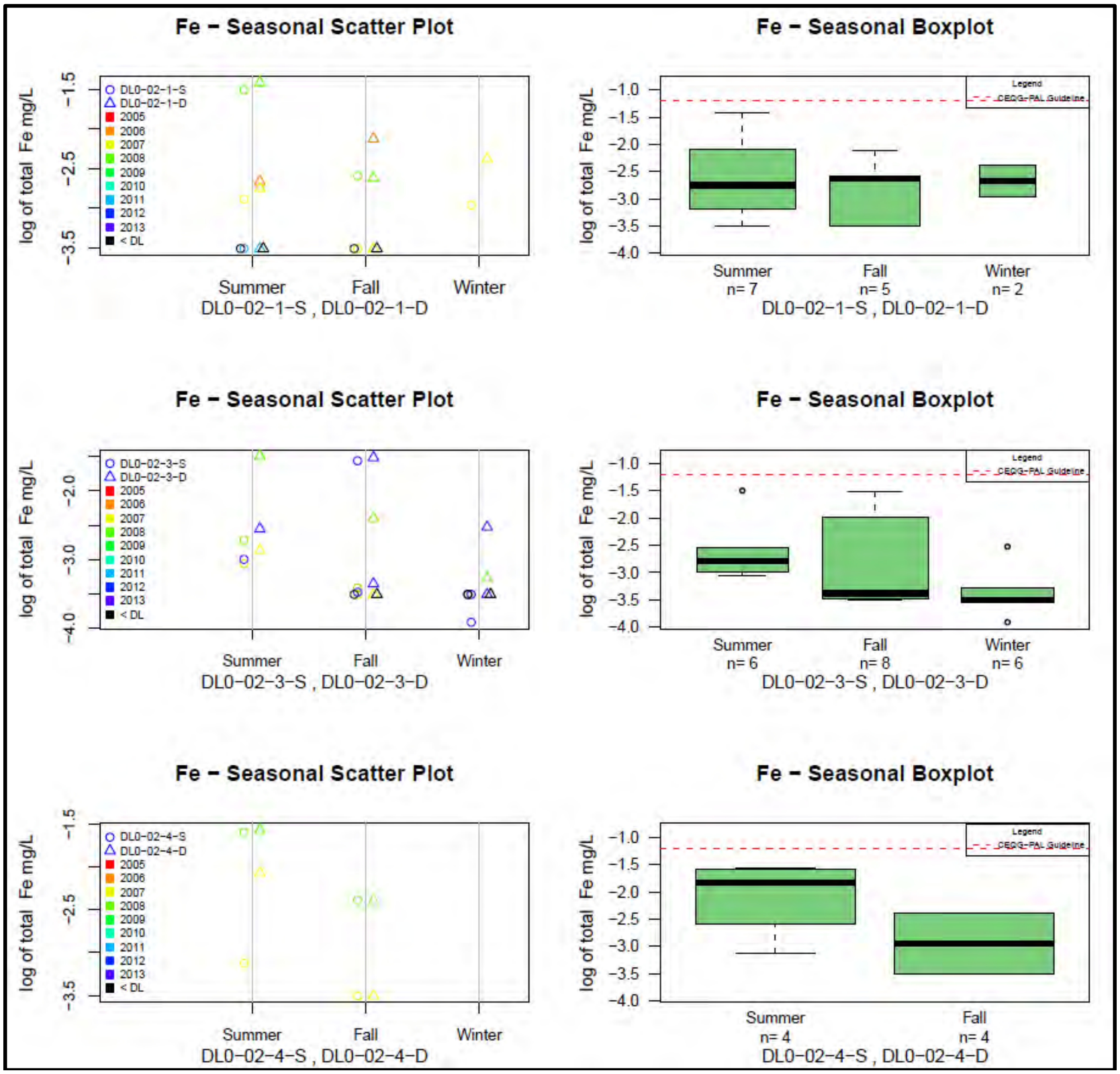
Seasonal scatterplots that combine data from deep and shallow sampling stations show no difference in values between the two stations (Figure B.49). Slightly elevated summer concentrations are noted; however, more samples are required to understand magnitude of seasonal trend.



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:

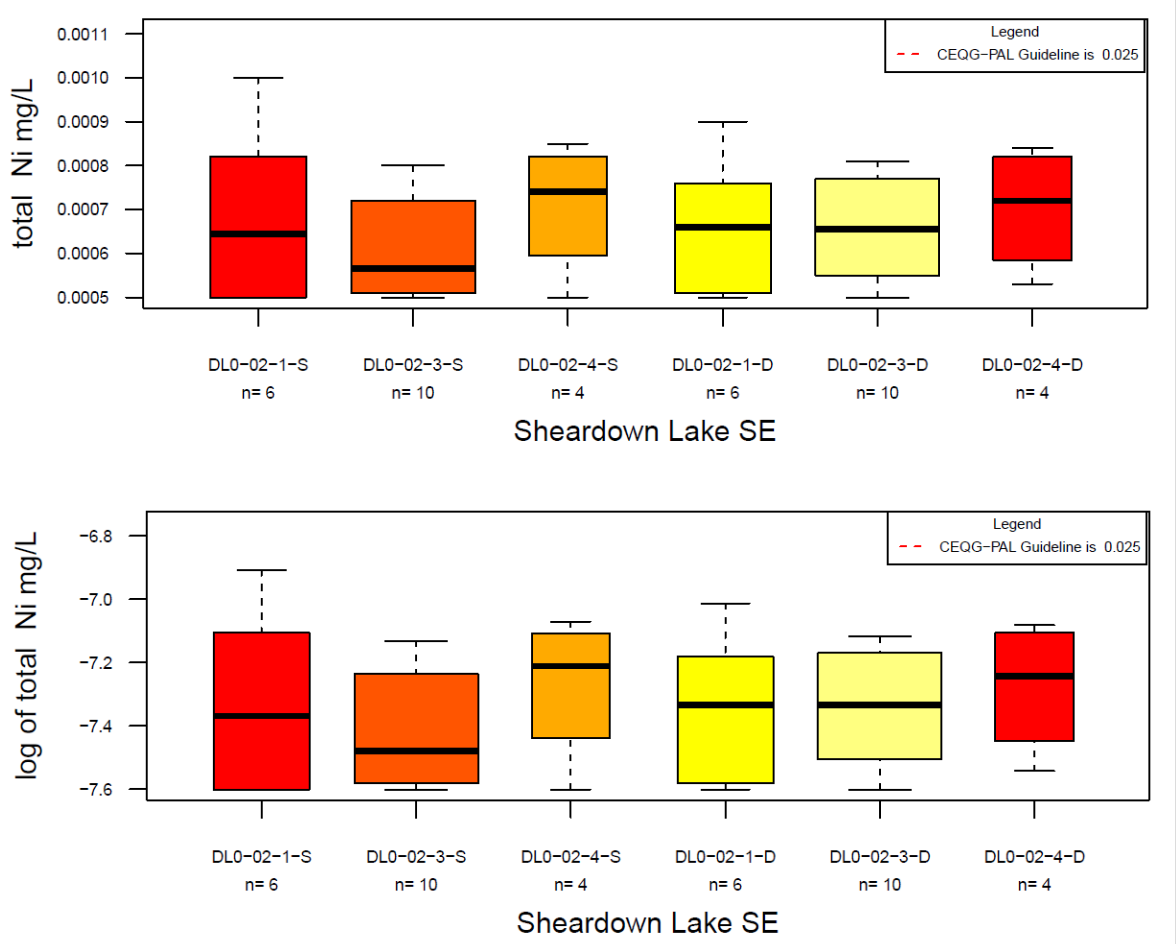
1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.

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.

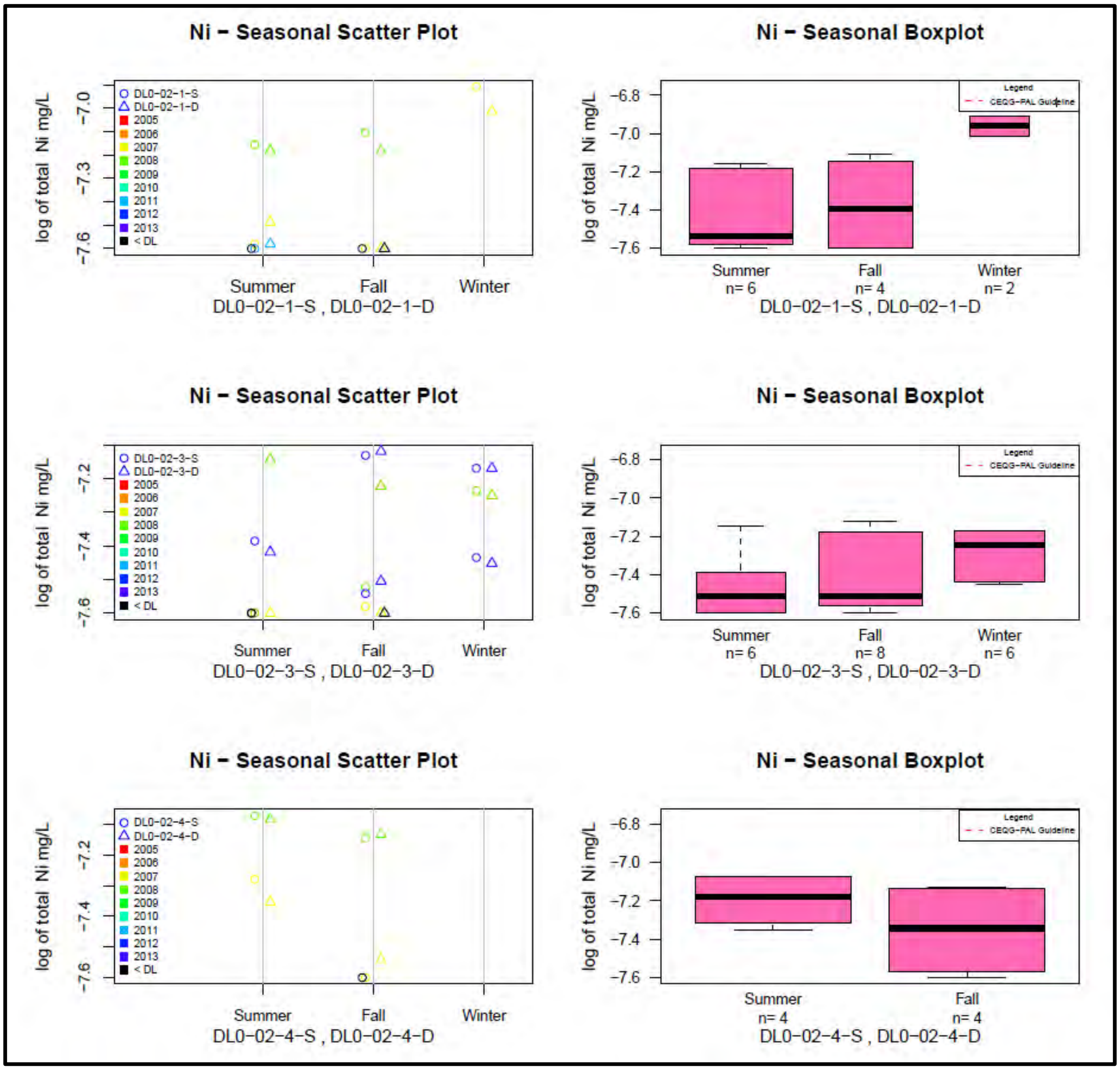
Seasonal scatterplots show that elevated concentrations are derived from early sampling (2007 and 2008), especially at DL0-02-1 and DL0-02-4 (Figure B.51). Although the winter dataset is limited, the current data indicates concentration peaks for nickel occur during the winter.



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:

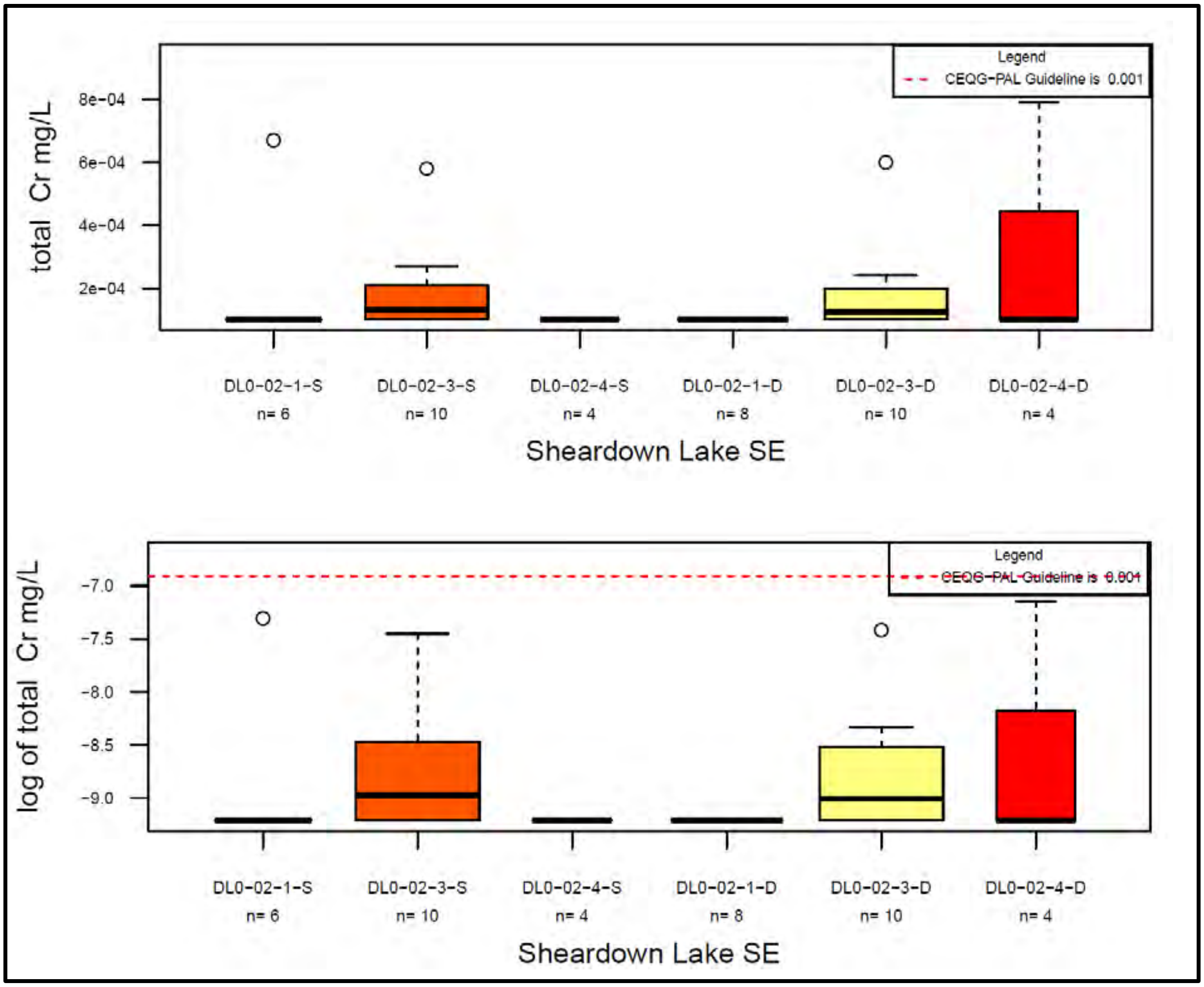
1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.
2. THE CWQG-PAL GUIDELINE LIMIT IS BASED ON THE TOTAL MEDIAN HARDNESS.

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.

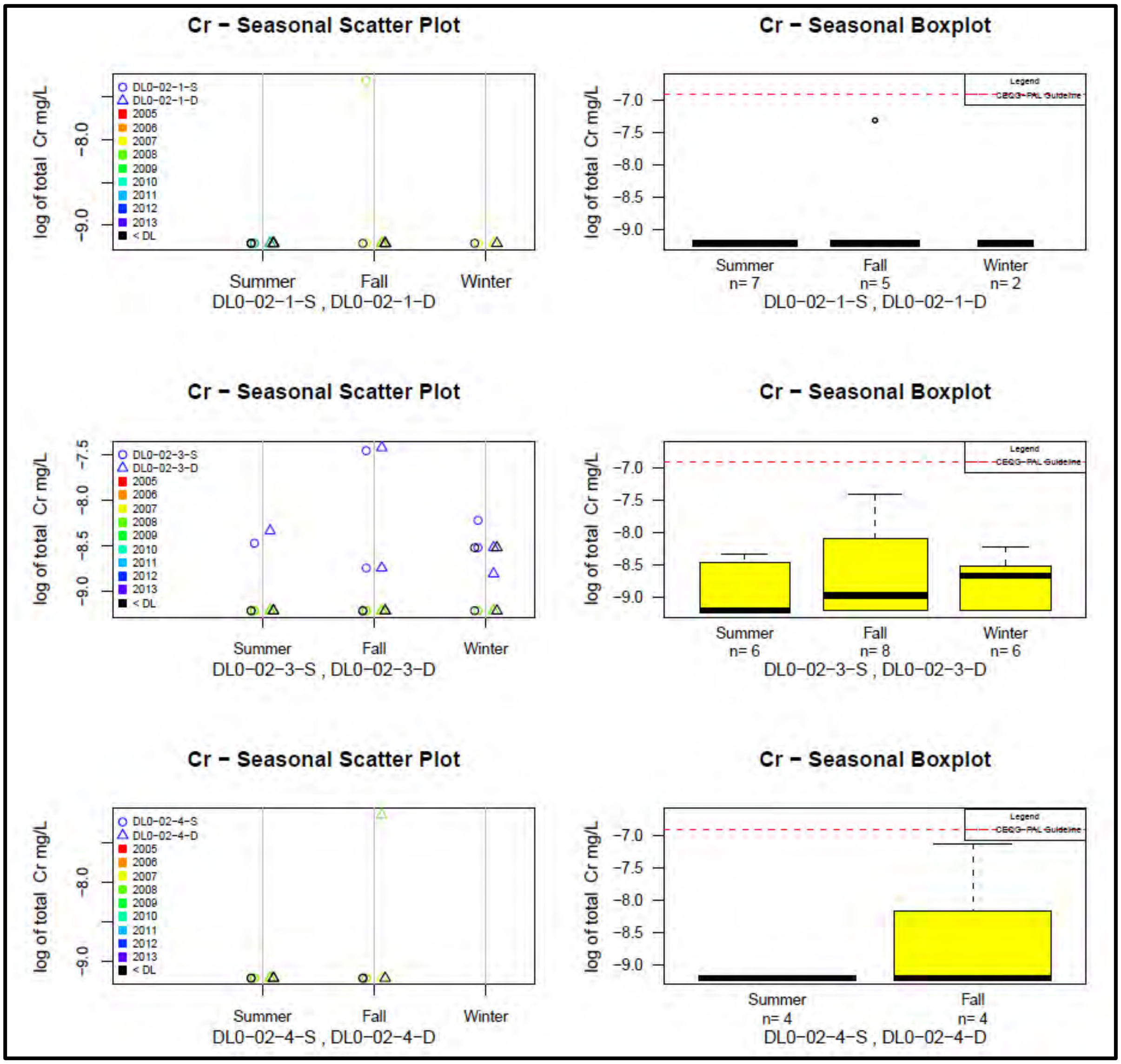
Seasonal scatterplots show that elevated concentrations at DL0-02-3-D are derived from recent sampling, during 2012 and 2013 (Figure B.53). No consistent seasonal trend was noted between sites.



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

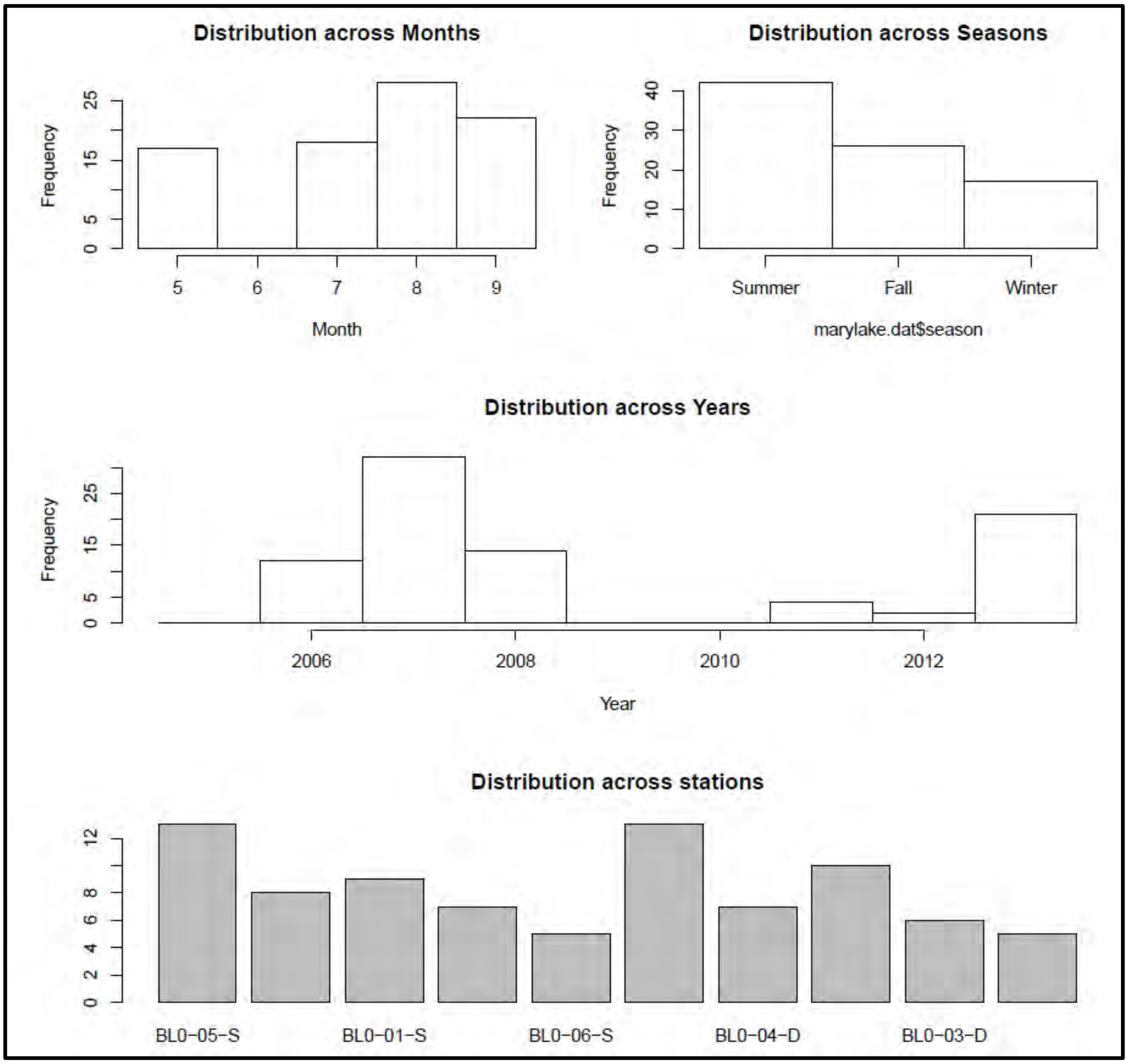


Figure B.54 Mary Lake – Graphical Summary of Sampling Events

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.

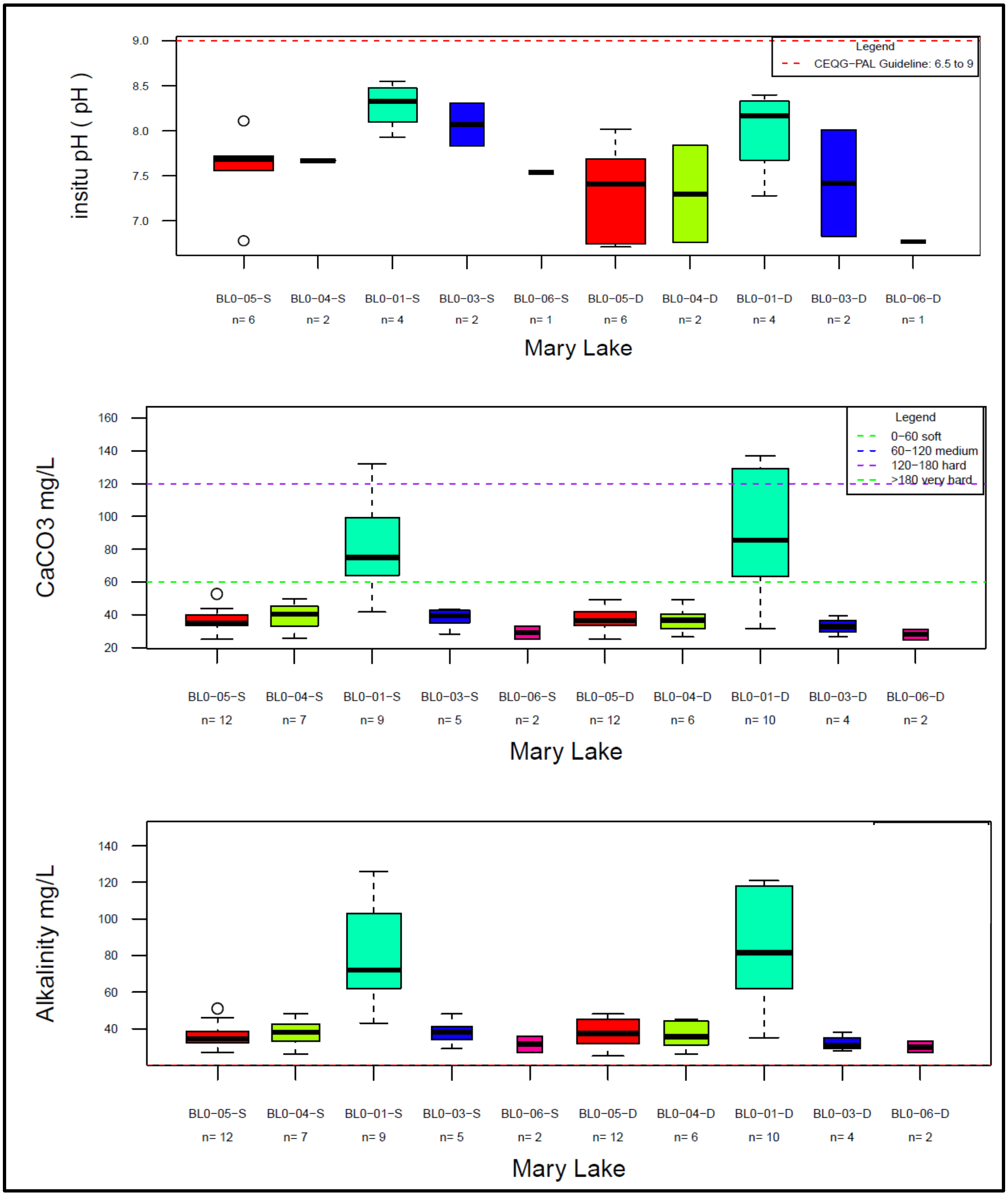


Figure B.55 Mary Lake – In-situ pH, Alkalinity and Hardness

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).

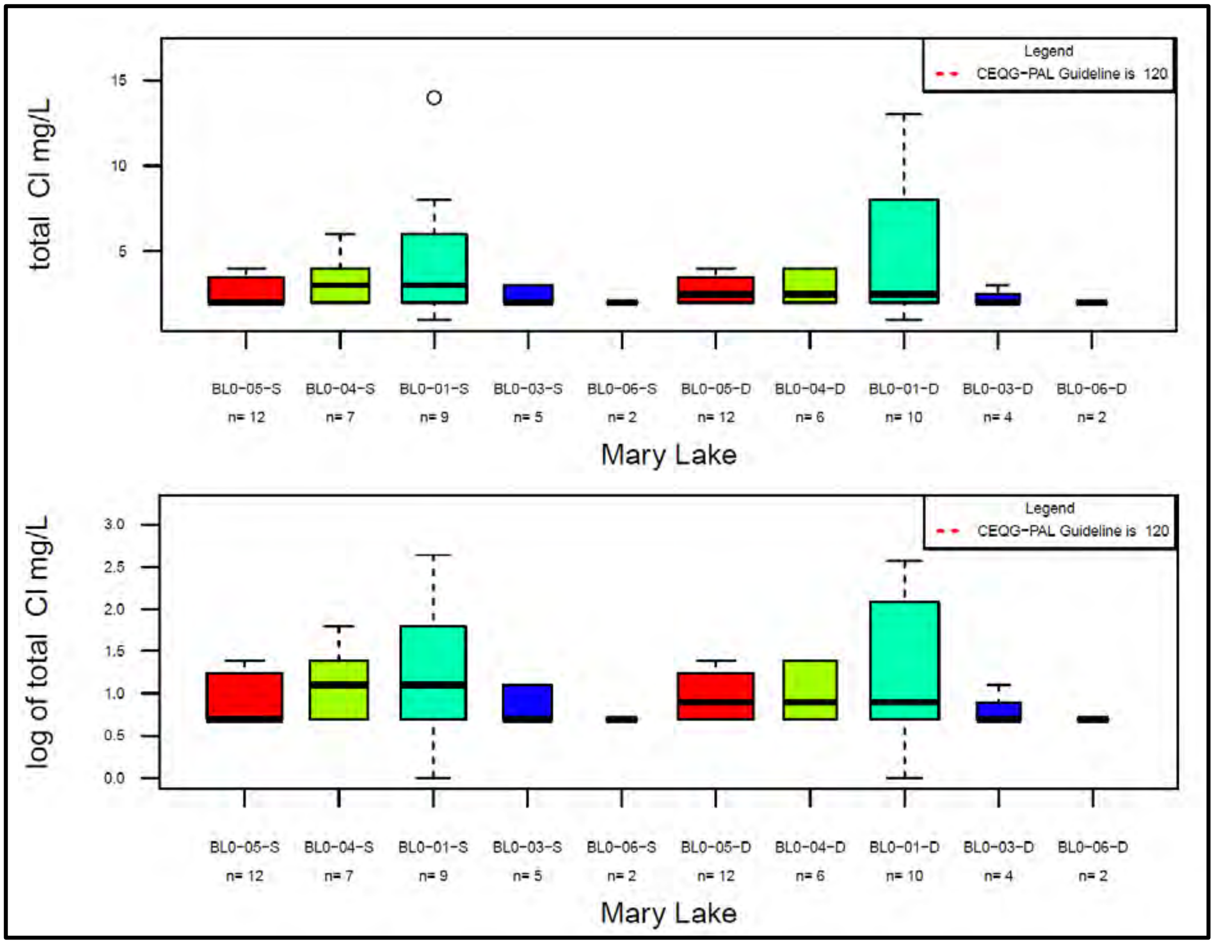
Nitrate

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)

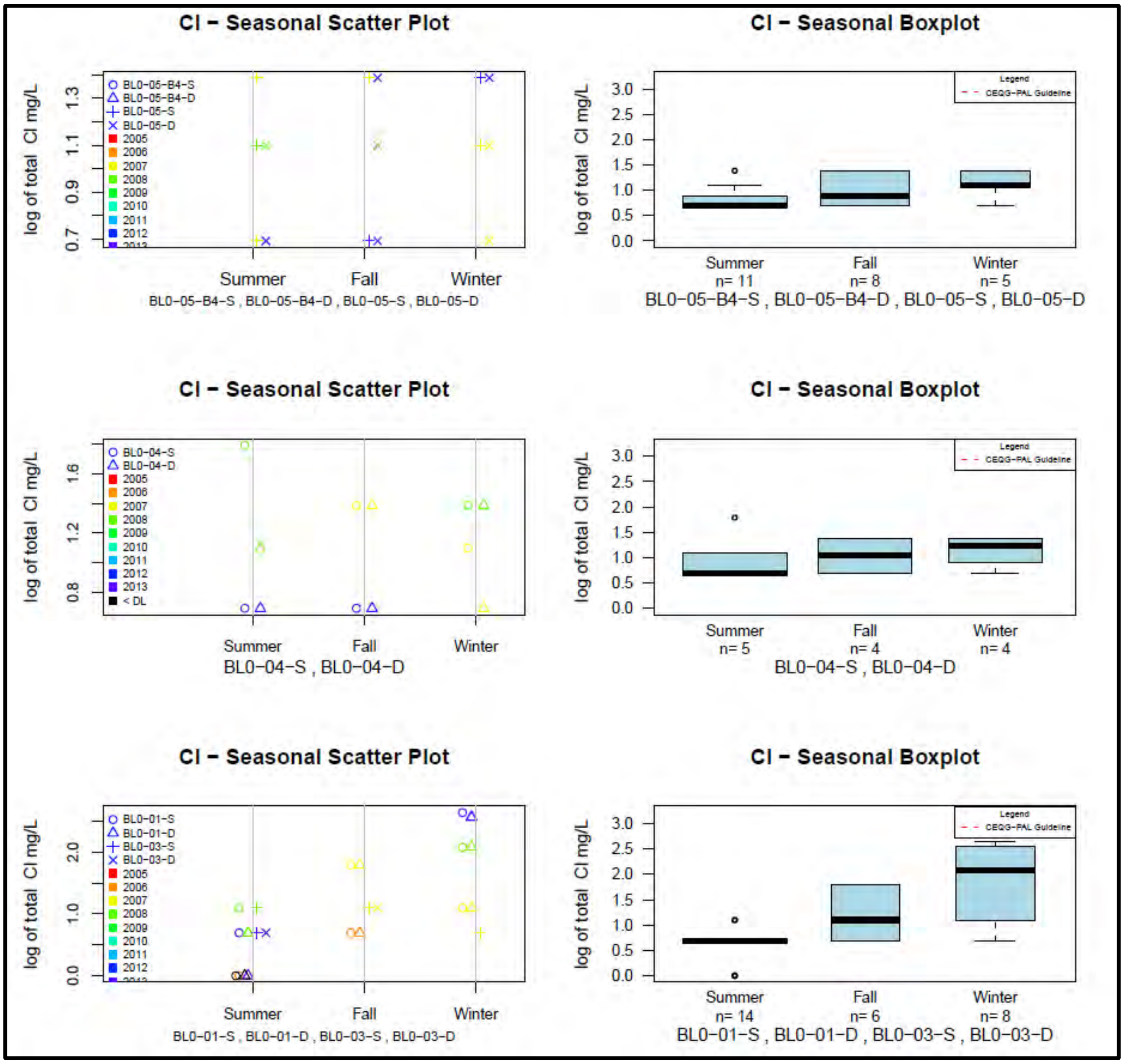
Sixty-nine (69) total aluminum concentration samples were collected from Mary Lake over the course of eight years. Total aluminum concentrations tend to occur above detection limits, and are elevated to concentrations above, or close to the CWQG-PAL limit (0.10 mg/L). Maximum aluminum concentrations 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

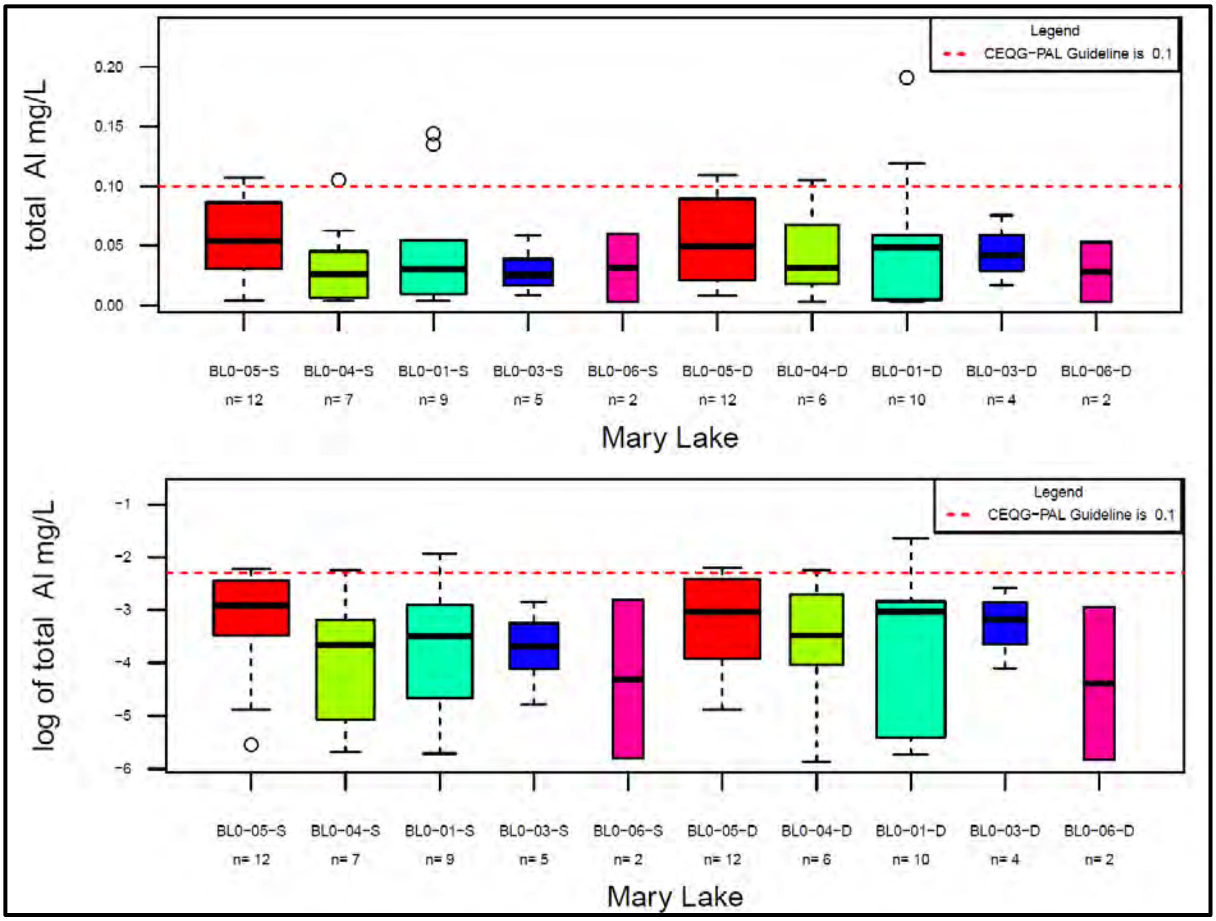


NOTES:

1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.

Figure B.57 Mary Lake – Variability of Chloride in Water

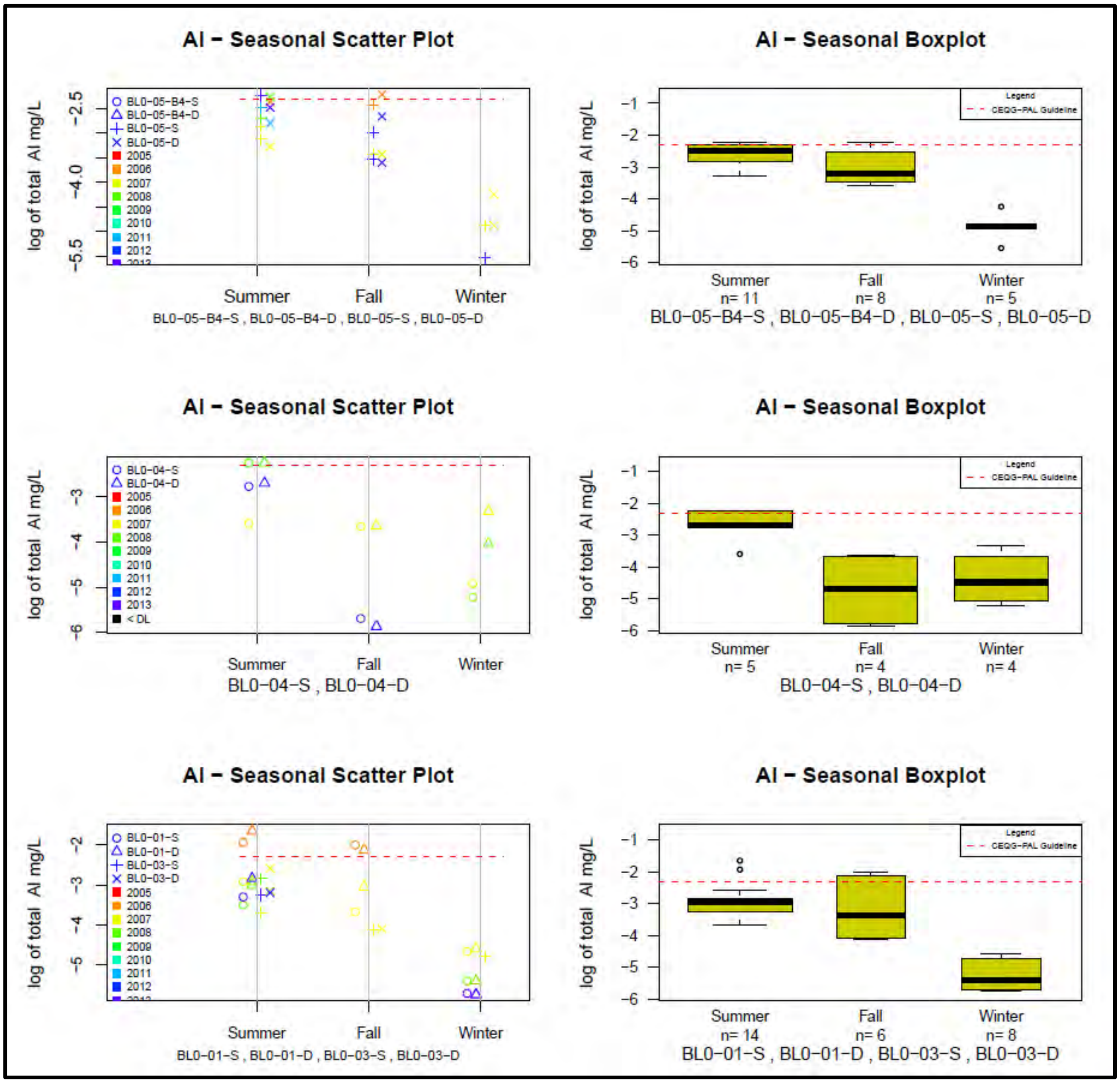
Seasonal scatterplots indicate shallow and deep sampling locations have similar data, and may be aggregated (Figure B.59). Distinct temporal trends over the eight-year sampling history are not noted.



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:

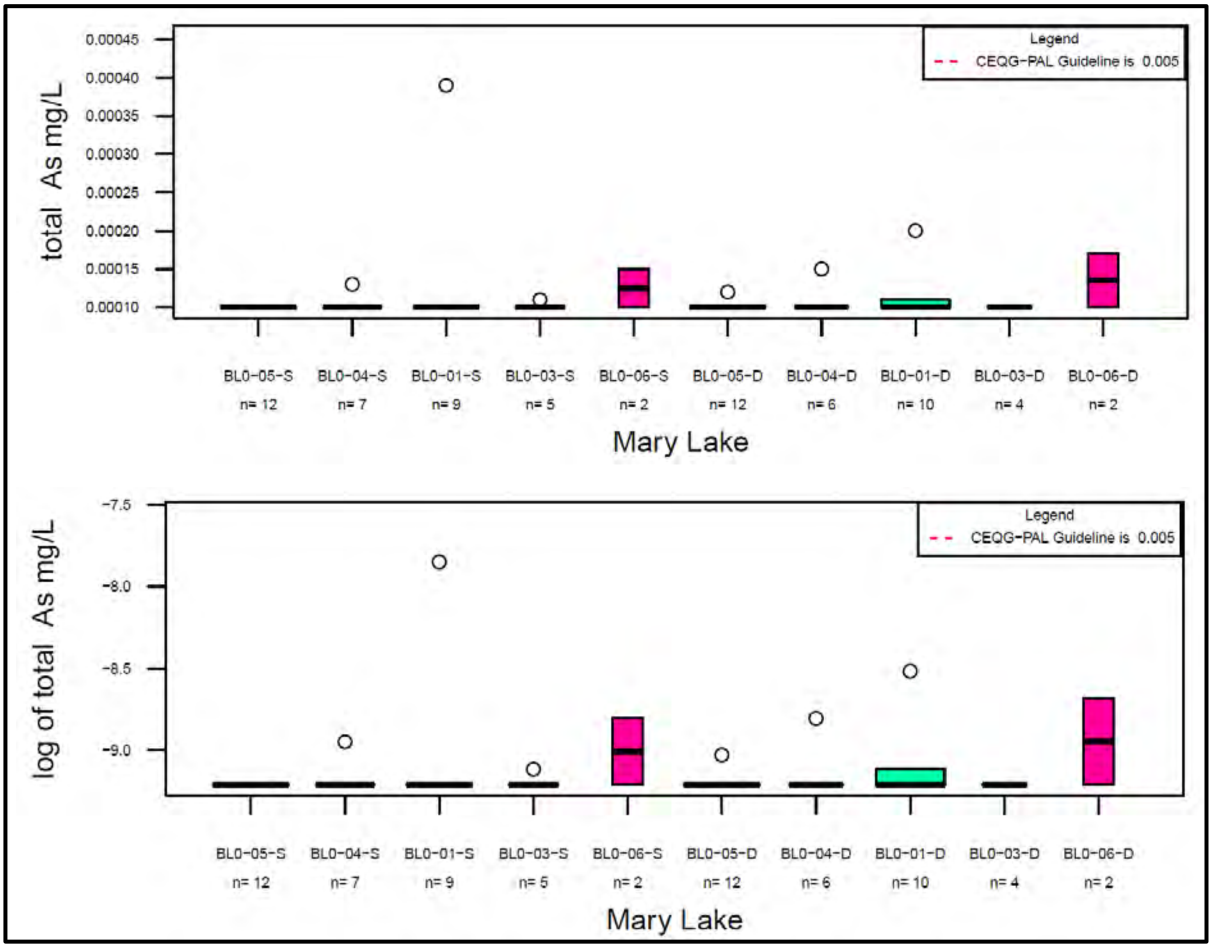
1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.
2. THE CWQG-PAL GUIDELINE LIMIT IS BASED ON THE TOTAL MEDIAN HARDNESS.

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.

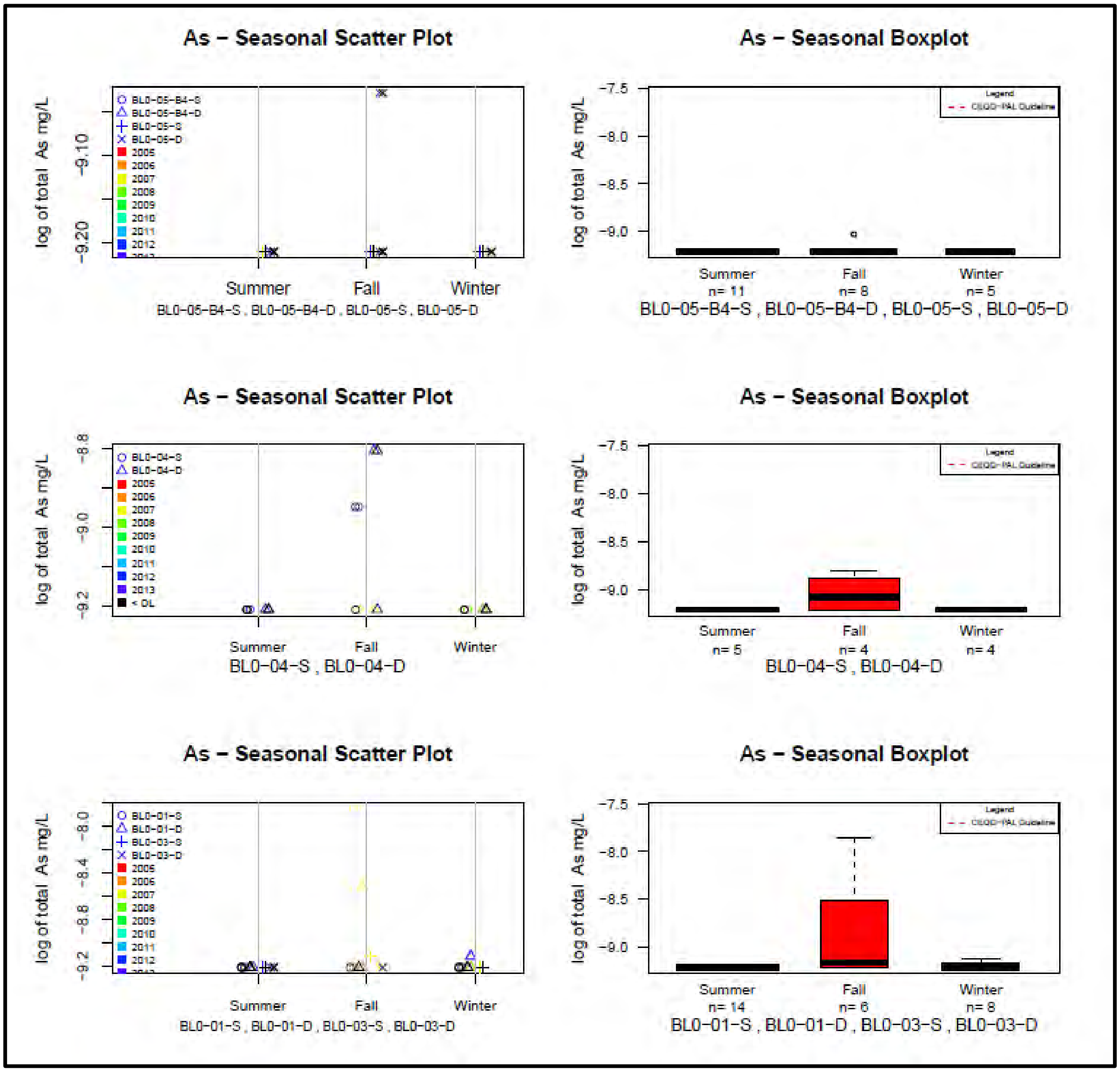


NOTES:

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.

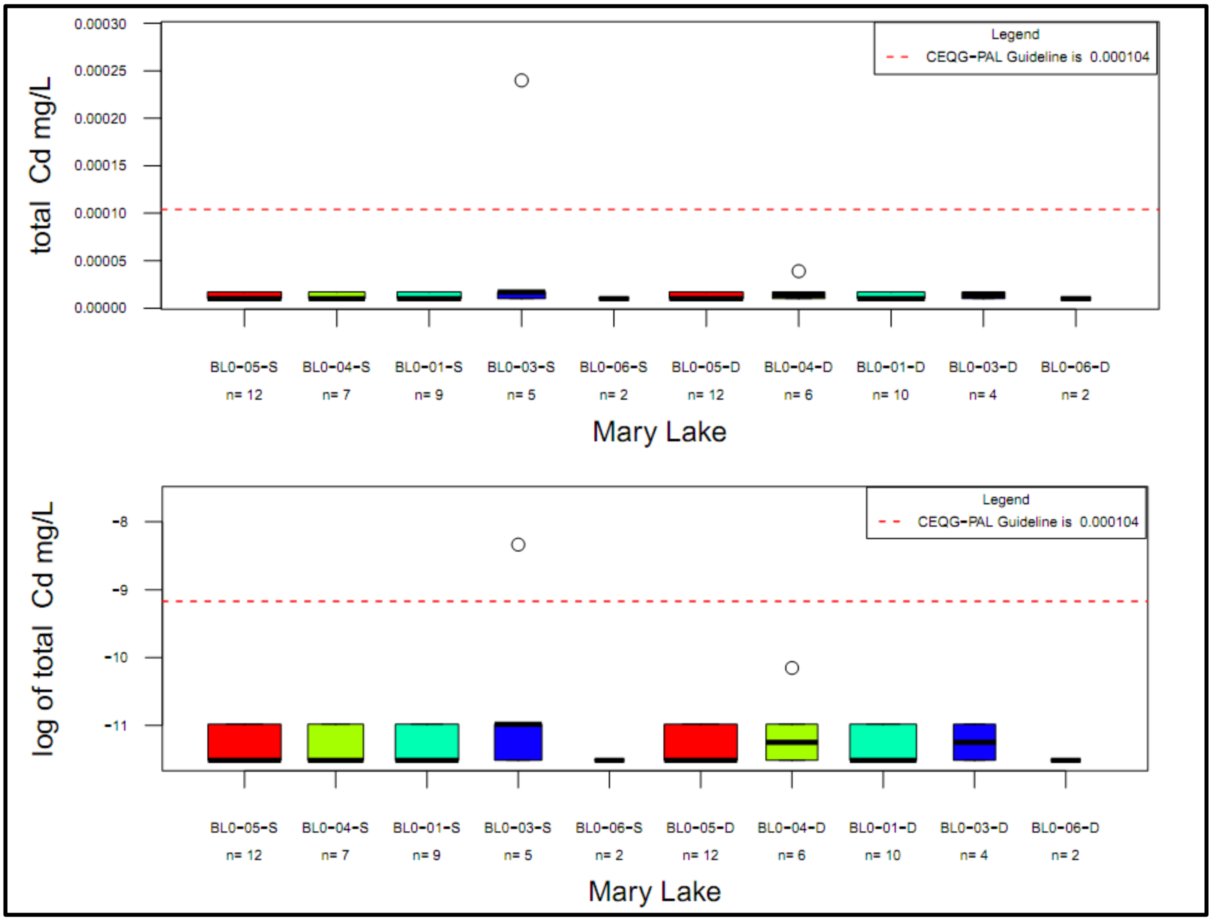
Figure B.61 Mary Lake – Variability of Total Arsenic in Water

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.

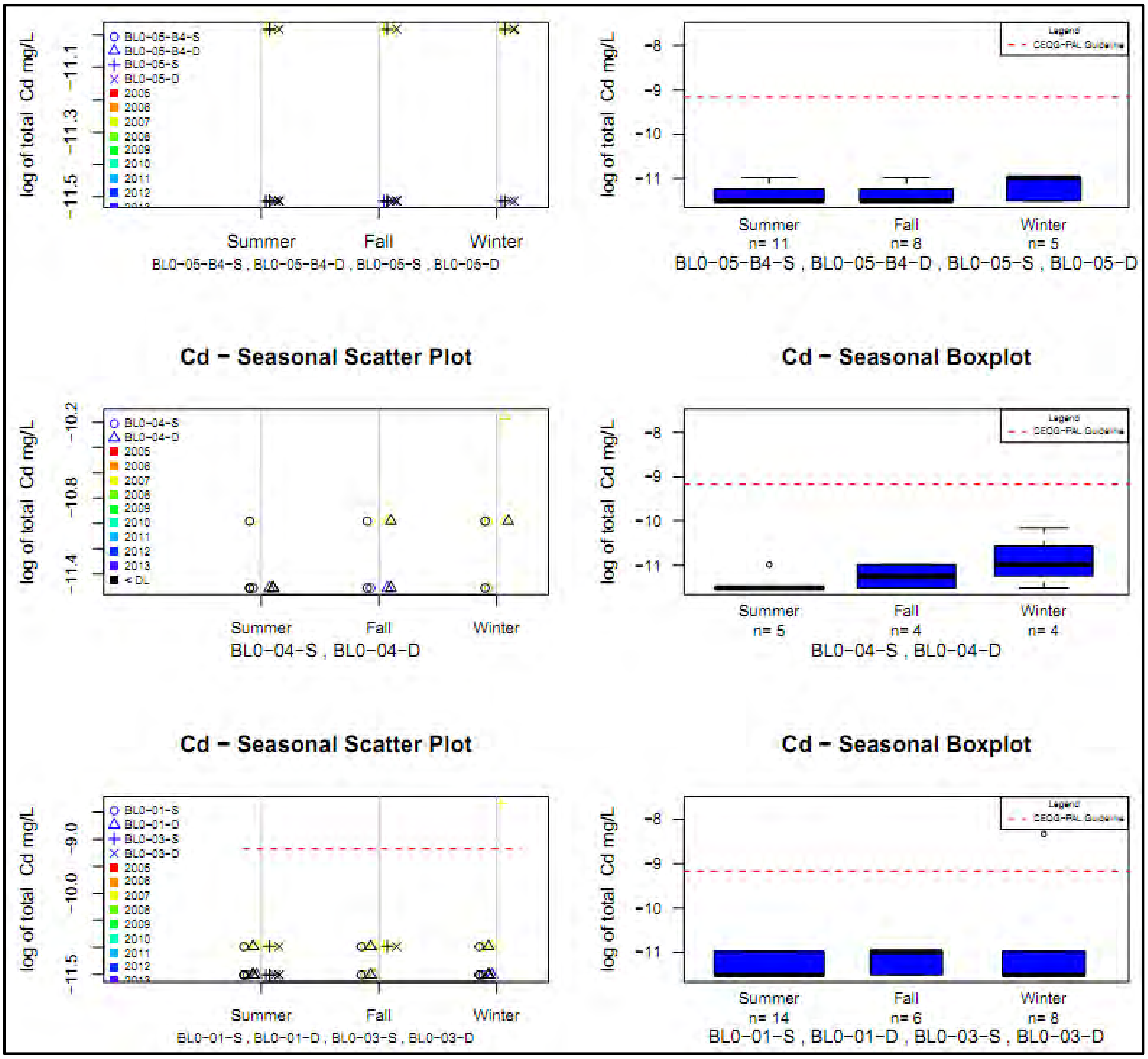
Seasonal scatterplots indicate shallow and deep sampling locations have similar data, and may be utilized together to determine baseline trends (Figure B.63). Seasonal scatterplots indicate cadmium concentrations are slightly elevated in the winter, when compared to other seasons.



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



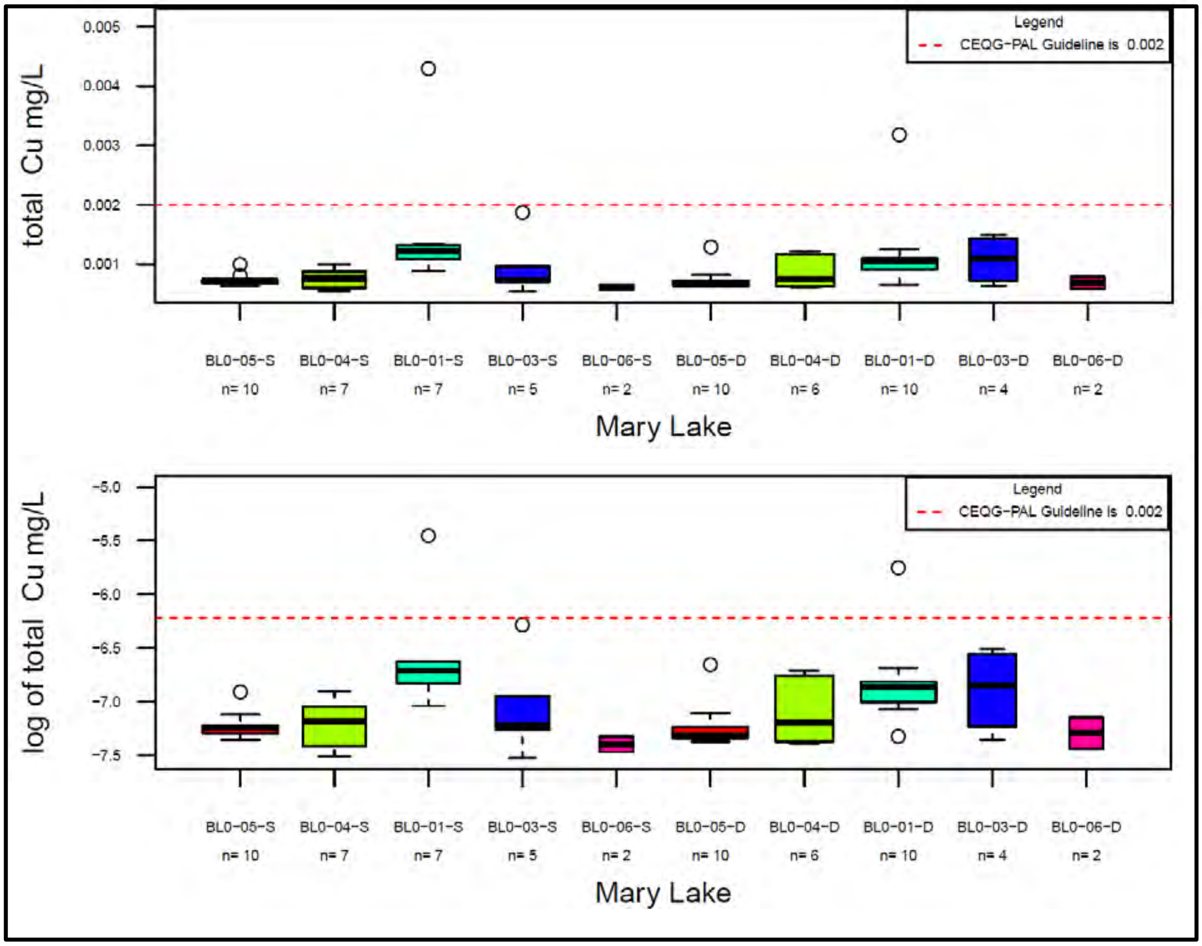
NOTES:

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.

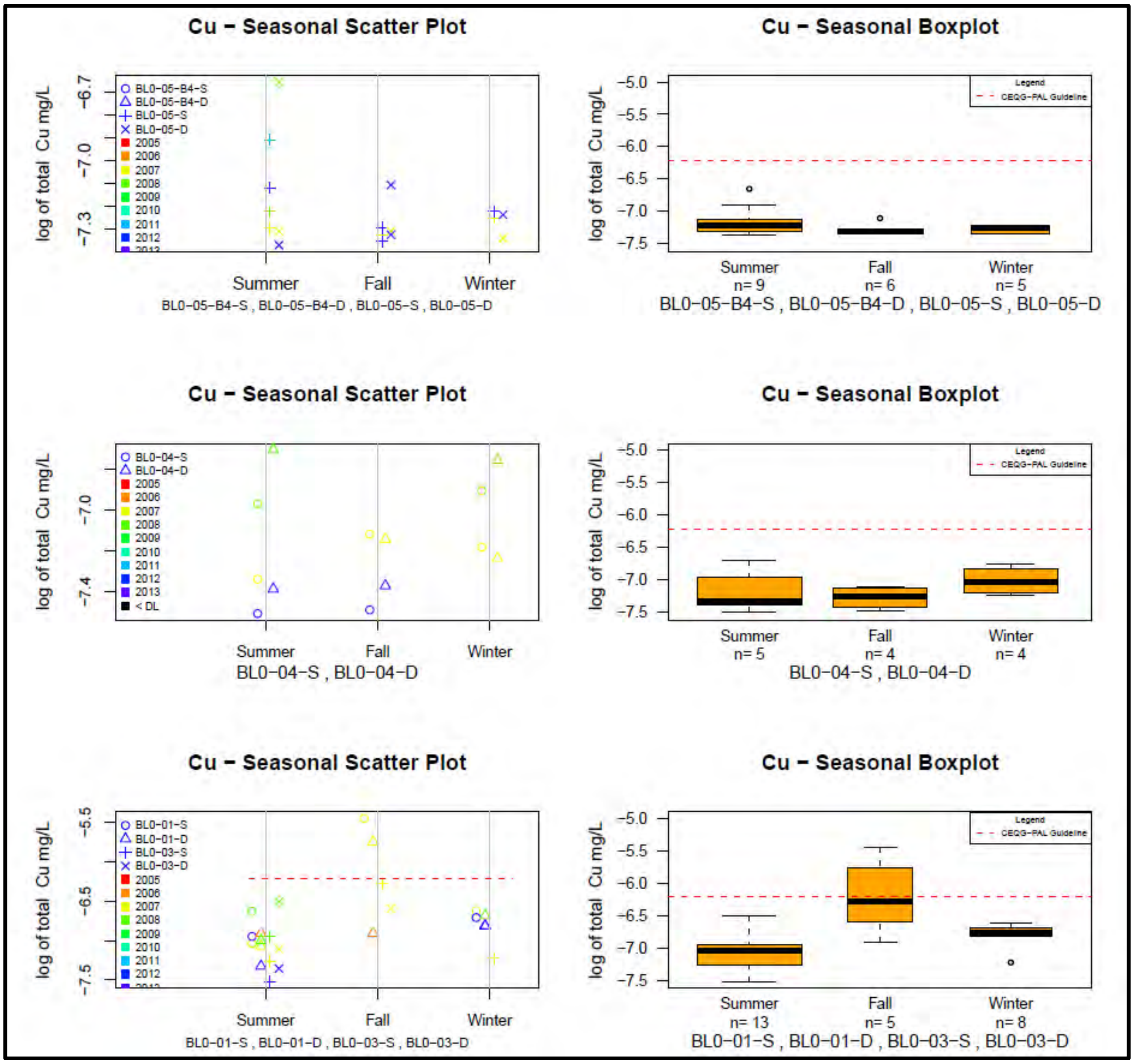


NOTES:

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:

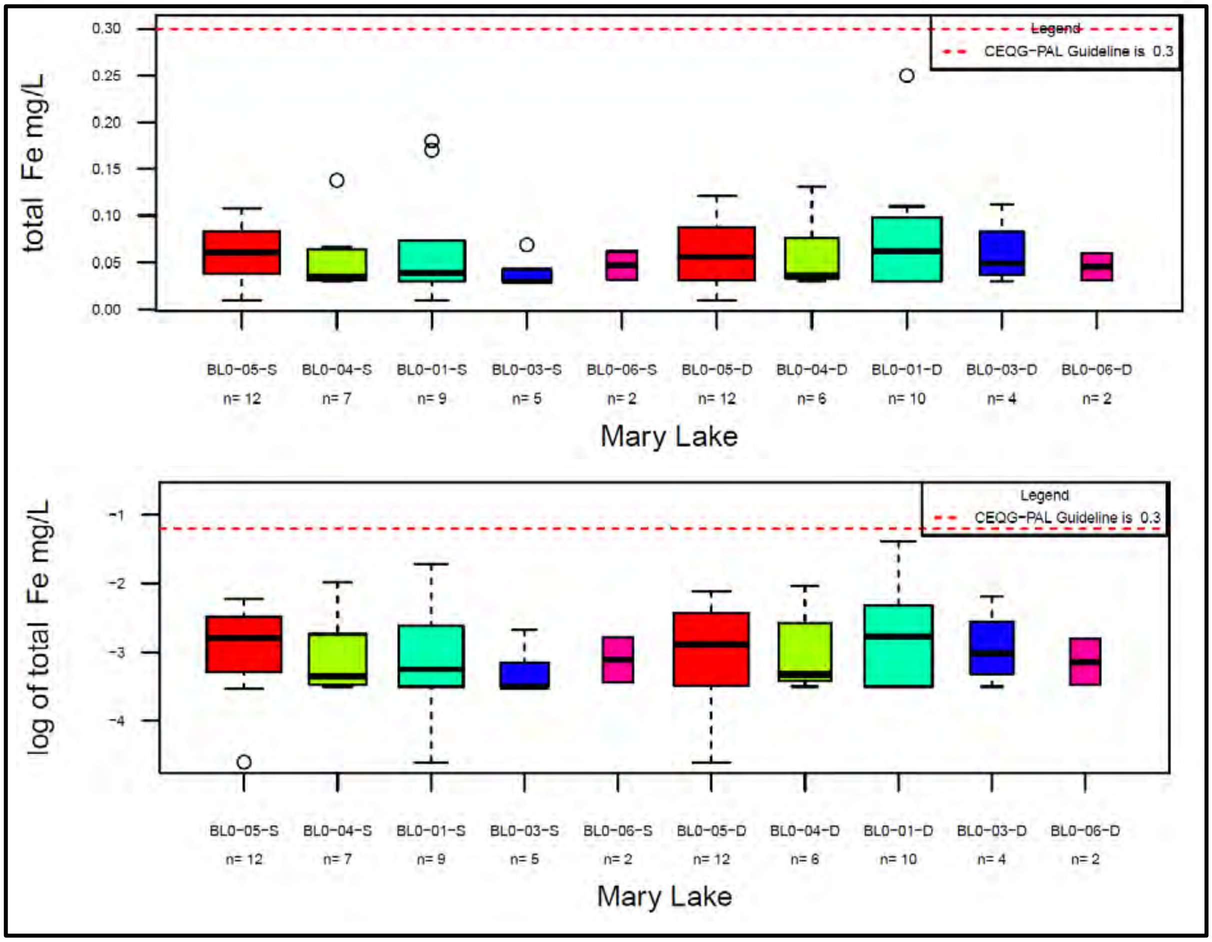
1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.
2. THE CWQG-PAL GUIDELINE LIMIT IS BASED ON THE TOTAL MEDIAN HARDNESS.

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.

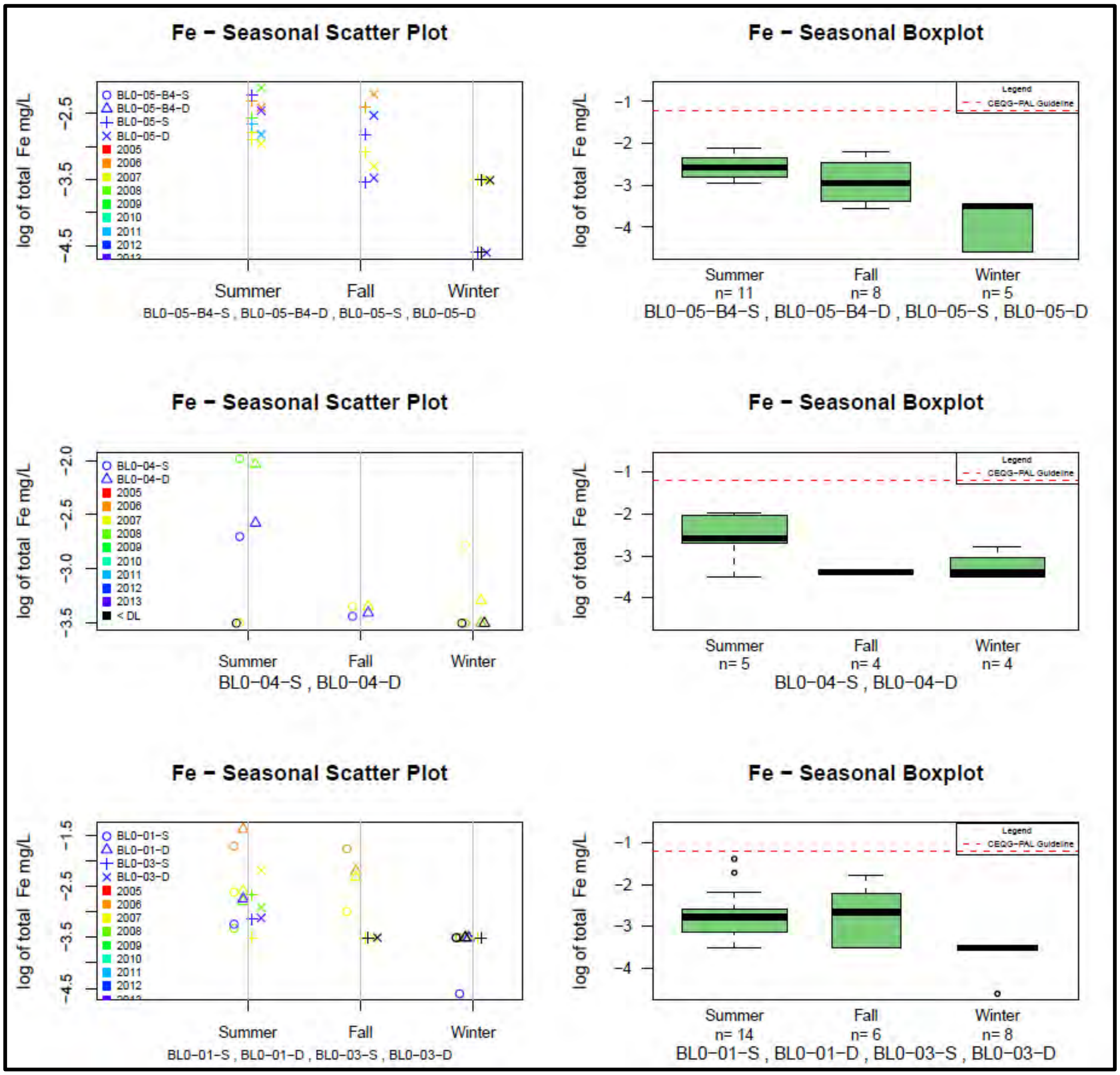
Seasonal scatterplots indicate shallow and deep sampling locations have similar data, and may be utilized together to gain an understanding of baseline conditions (Figure B.67*)*. Seasonal boxplots indicate summer concentrations are typically elevated, when compared to winter concentrations. Concentration 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.

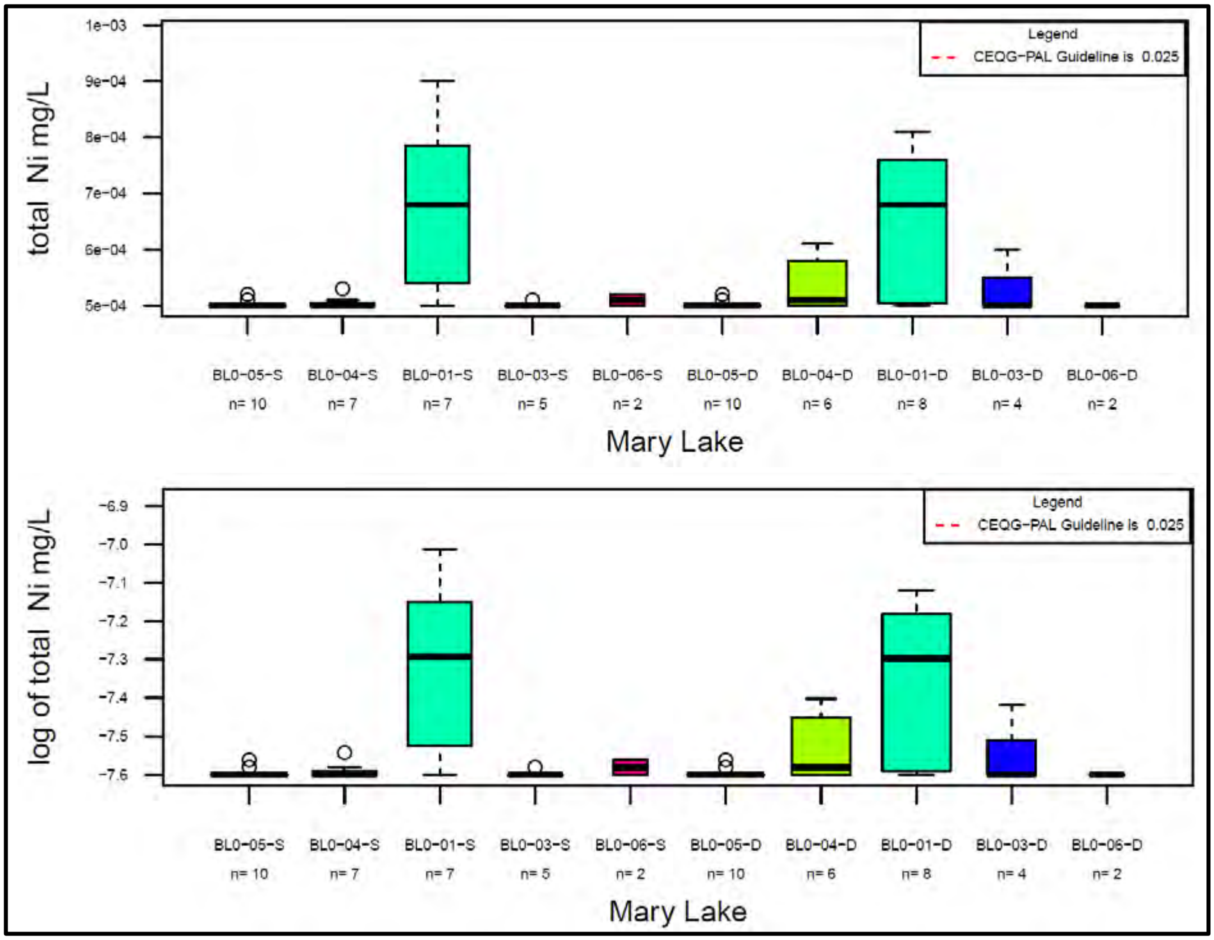
Figure B.67 Mary Lake – Variability of Total Iron in Water

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.

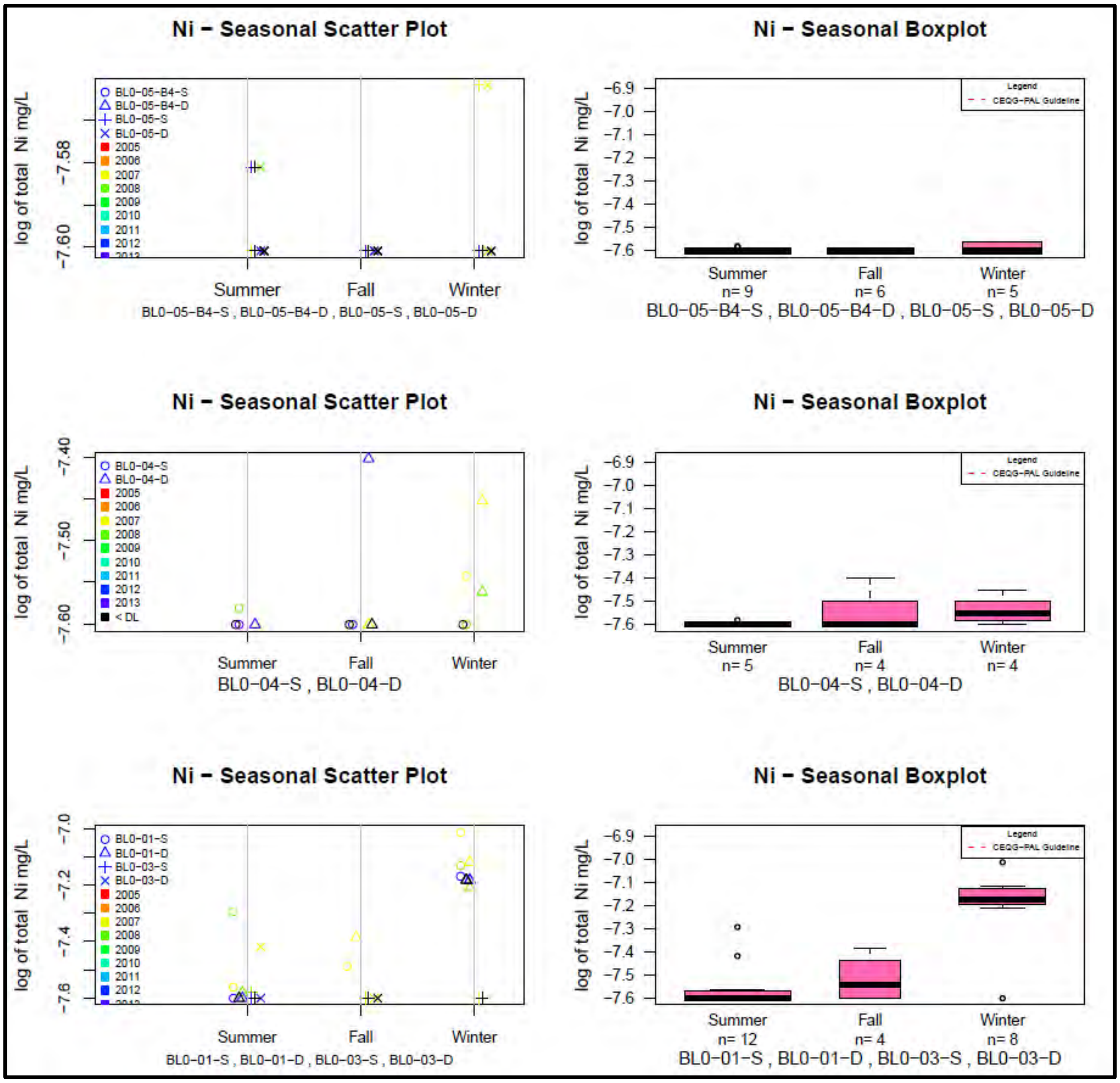
Seasonal scatterplots indicate shallow and deep sampling locations have similar data, and may be utilized en mass to determine overall baseline trends (Figure B.69). Seasonal boxplots indicate summer concentrations are typically depressed when compared to winter concentrations.



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:

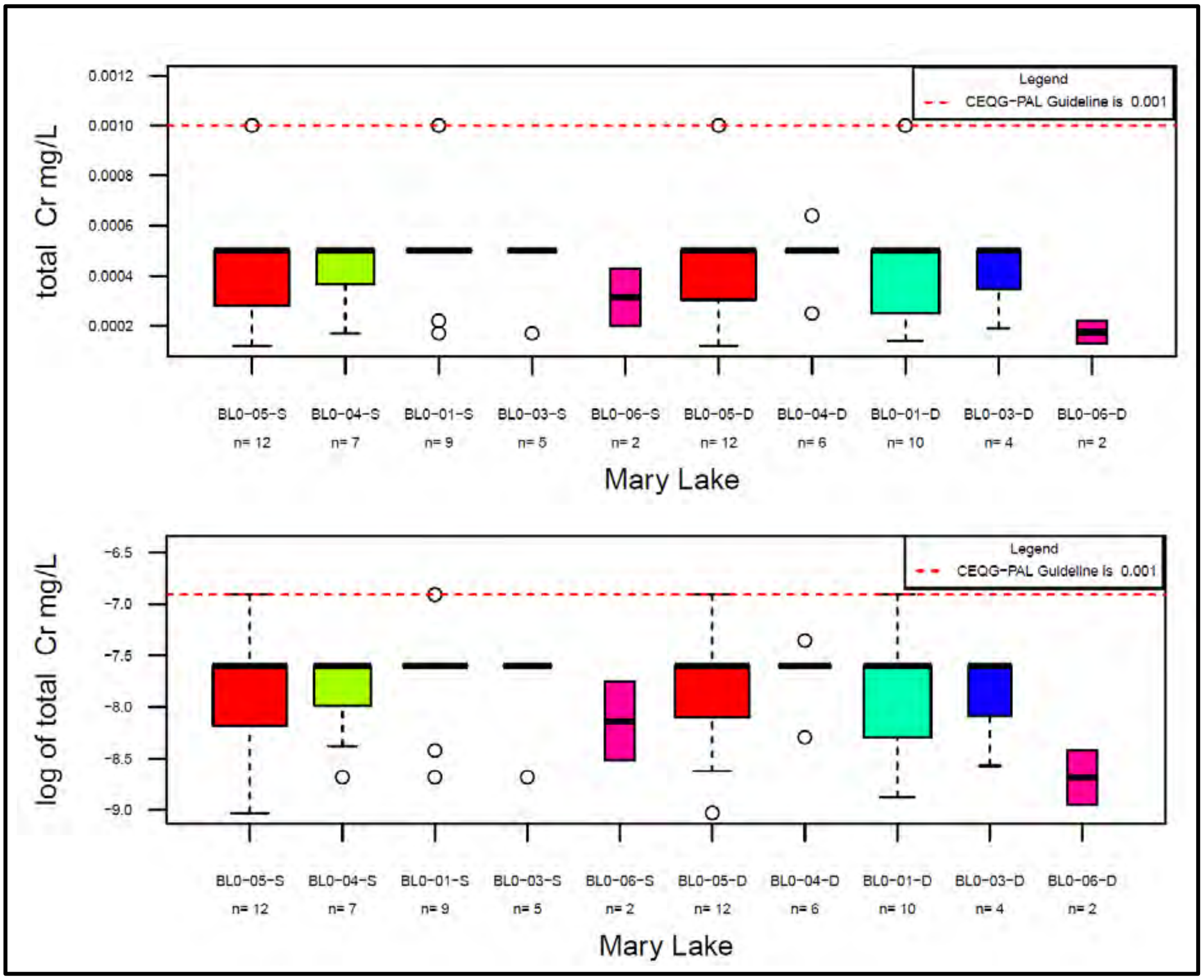
1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.
2. THE CWQG-PAL GUIDELINE LIMIT IS BASED ON THE TOTAL MEDIAN HARDNESS.

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.

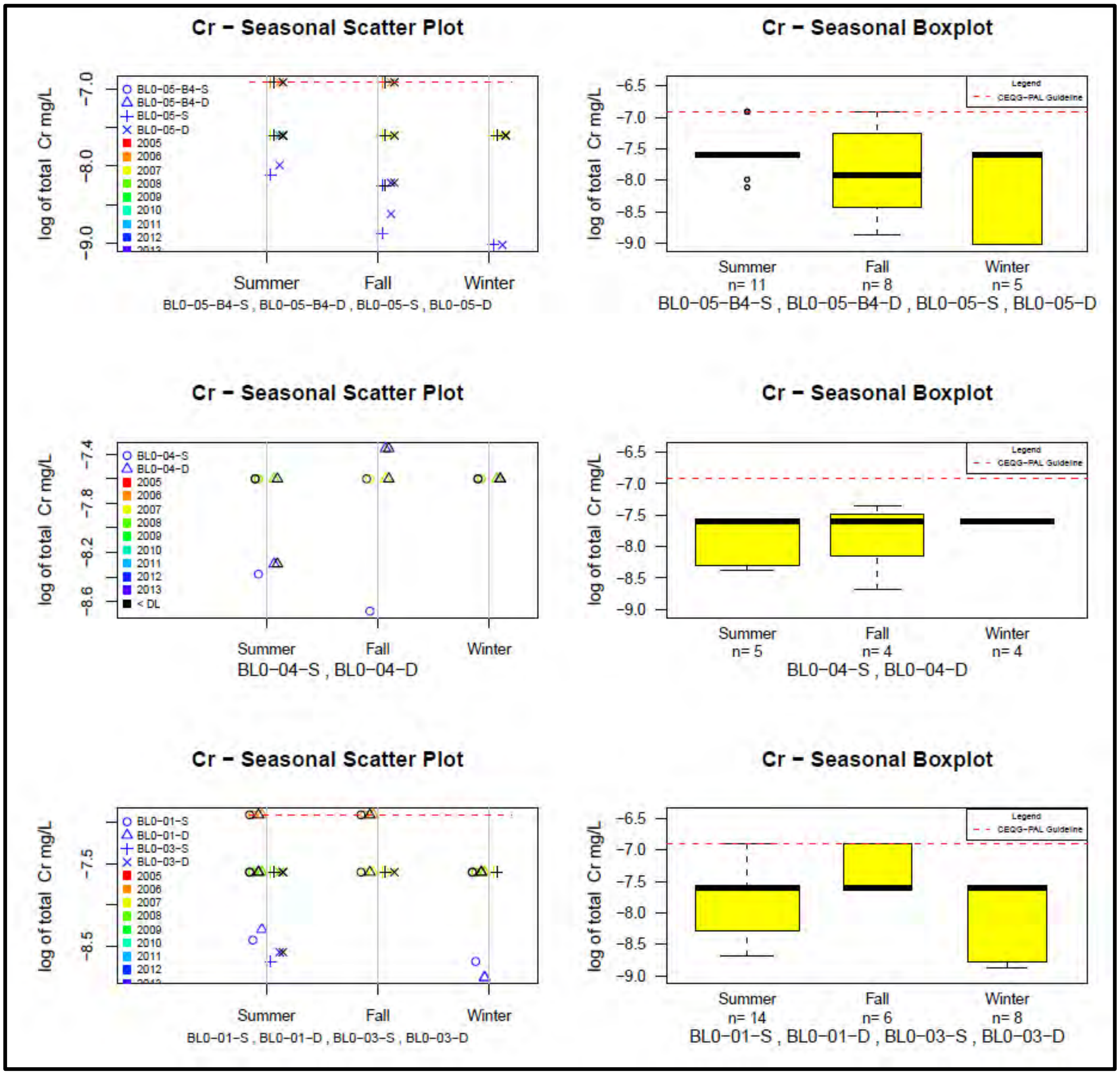
Seasonal scatterplots indicate show that detection limits are defined by applicable years (Figure B.71*)*. Seasonal boxplots do not show any conserved trend throughout sites.



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

	Control		
Impact	<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

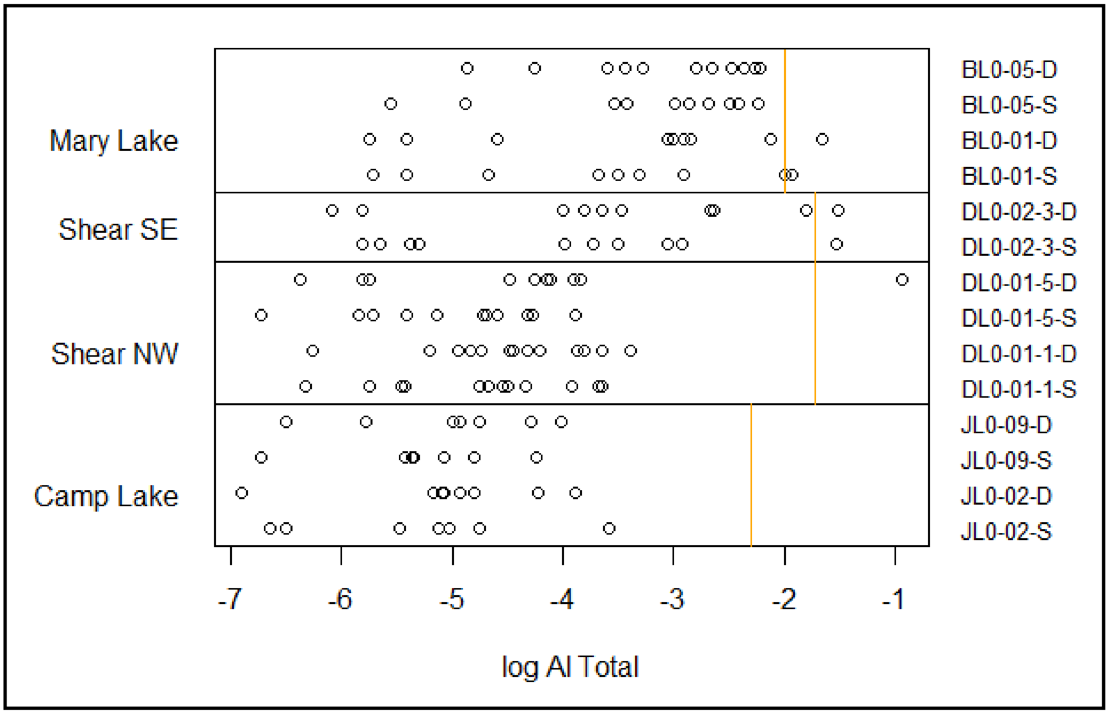
Parameter	Site	Waterbody	Power (given sample size of 10, alpha of 0.1)	Power (given sample size of 50)
Aluminum	DL0-02-3-S	Sheardown Lake SE	50%	78%
	BL0-01-S	Mary Lake	38%	58%
	BL0-05-S	Mary Lake	30%	58%
Copper	BL0-01-S	Mary Lake	30%	38%
Iron	BL0-01-S	Mary Lake	50%	75%

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

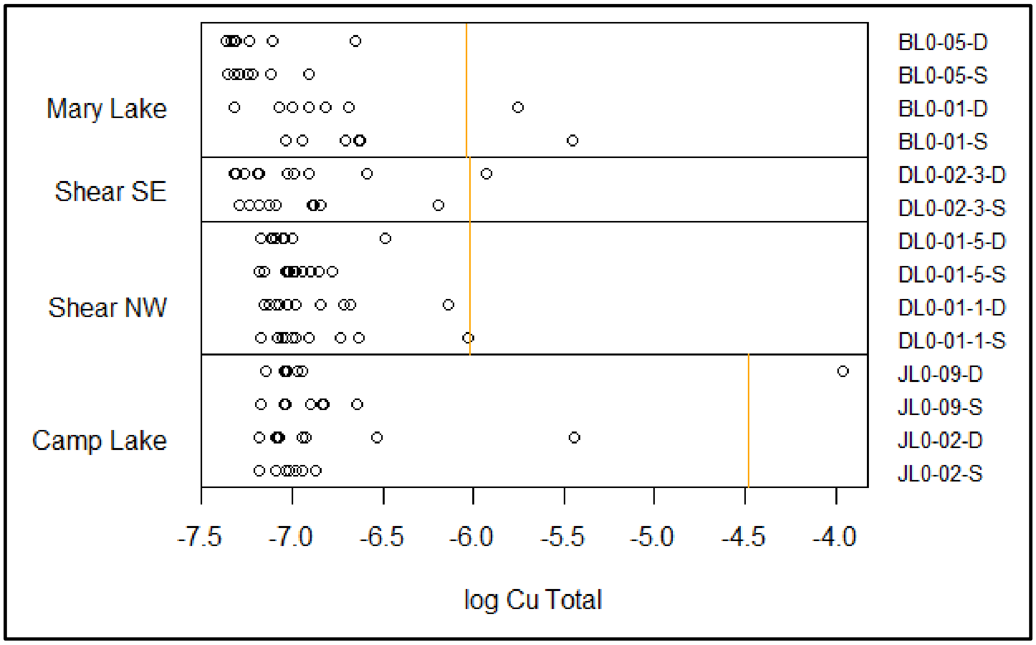
Station	Total Sample Size	Sample Size Detected	Median (mg/L)	Standard Deviation (mg/L)	Log Mean (mg/L)	Log Standard Deviation (mg/L)	ROS Log Mean (mg/L)	Benchmark Value (mg/L)	Log Benchmark Value (mg/L)	N Required	N Required (half benchmark)[1]
Camp Lake											
JL0-02-S	8	8	0.0063	0.01	-5.23	1.00	-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

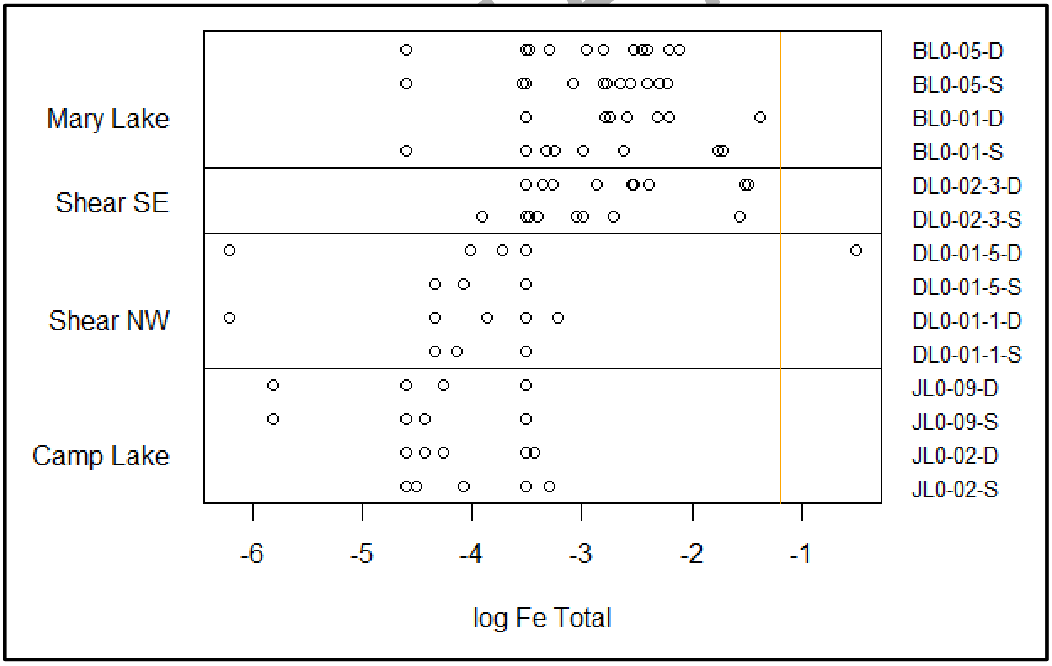
Station	Total Sample Size	Sample Size Detected	Median (mg/L)	Standard Deviation (mg/L)	Log Mean (mg/L)	Log Standard Deviation (mg/L)	Benchmark Value (mg/L)	Log <Benchmark Value (mg/L)	Difference between log mean and log benchmark (mg/L)	N Required
JL0-01-S	12	10	0	0.00076	-6.8	0.44	0.011	-4.5	2.3	5[2]
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.

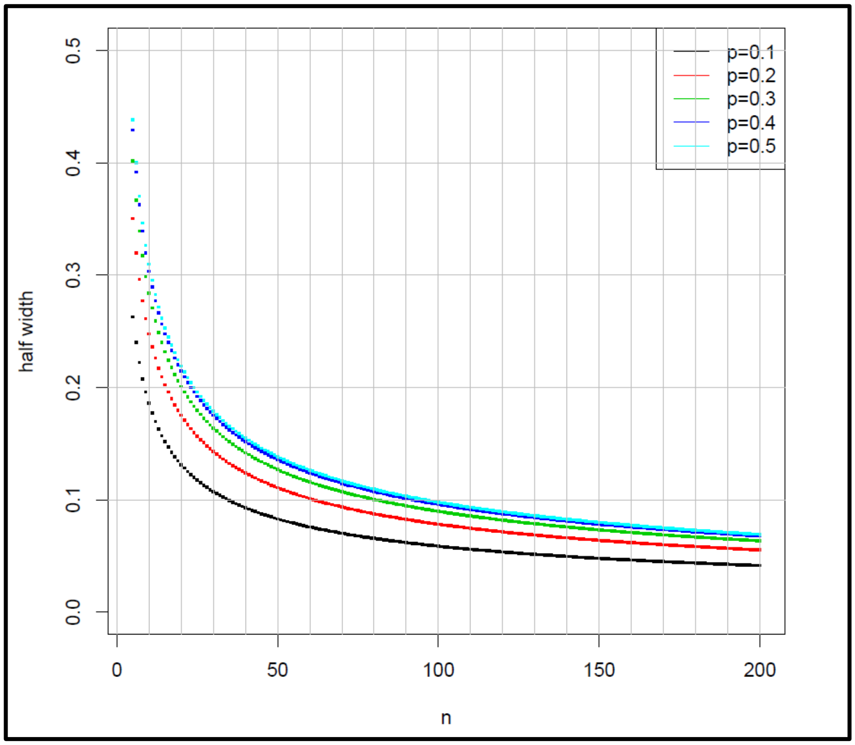
In order to assess statistical power to detect a change in the proportion of values below (or above) MDL from baseline to post-mining, we present a table of the sample sizes required. We see that a sample size of 12 is sufficient to show a change from 30% to 80%; a sample size of 8 is sufficient to show 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

Agresti, A, 1990. *Categorical Data Analysis*. Wiley Series, New York.

Huston, C. and Juarez-Colunga, E. 2009. Guidelines for computing summary statistics for data-sets containing non-detects. Written for the Bulkley Valley Research Center with assistance from the B.C. Ministry of Environment.

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.

Smith, E. 2002. BACI Design. Encyclopedia of Environmetrics. John Wiley and sons.1(141-148).

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

Knight Piésold Ltd.
1650 Main Street West
North Bay,Ontario Canada P1B8G5
Telephone: (705) 476-2165
Facsimile: (705) 474-8095
www.knightpiesold.com

Knight Piésold
CONSULTING

TABLE OF CONTENTS

PAGE

TABLE

FIGURES

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.

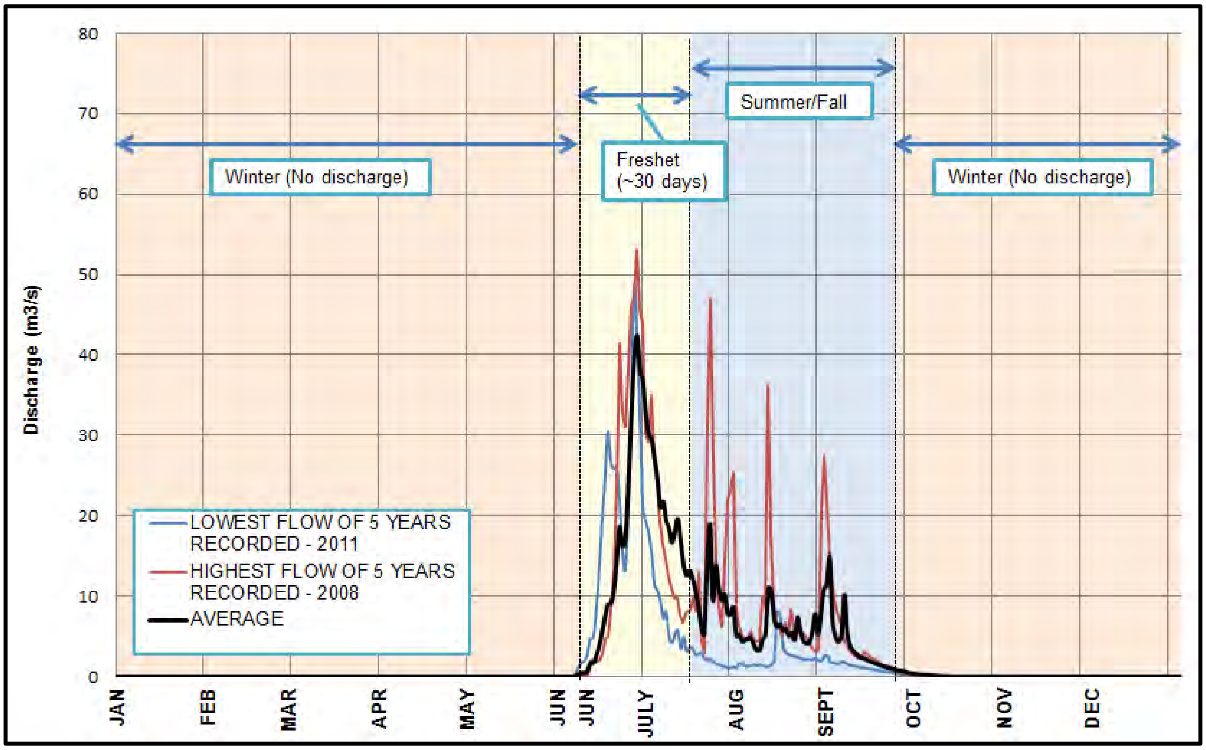


Figure C.1 Hydrograph of Stream Gauge H6 on the Mary River (2008-2011)

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.

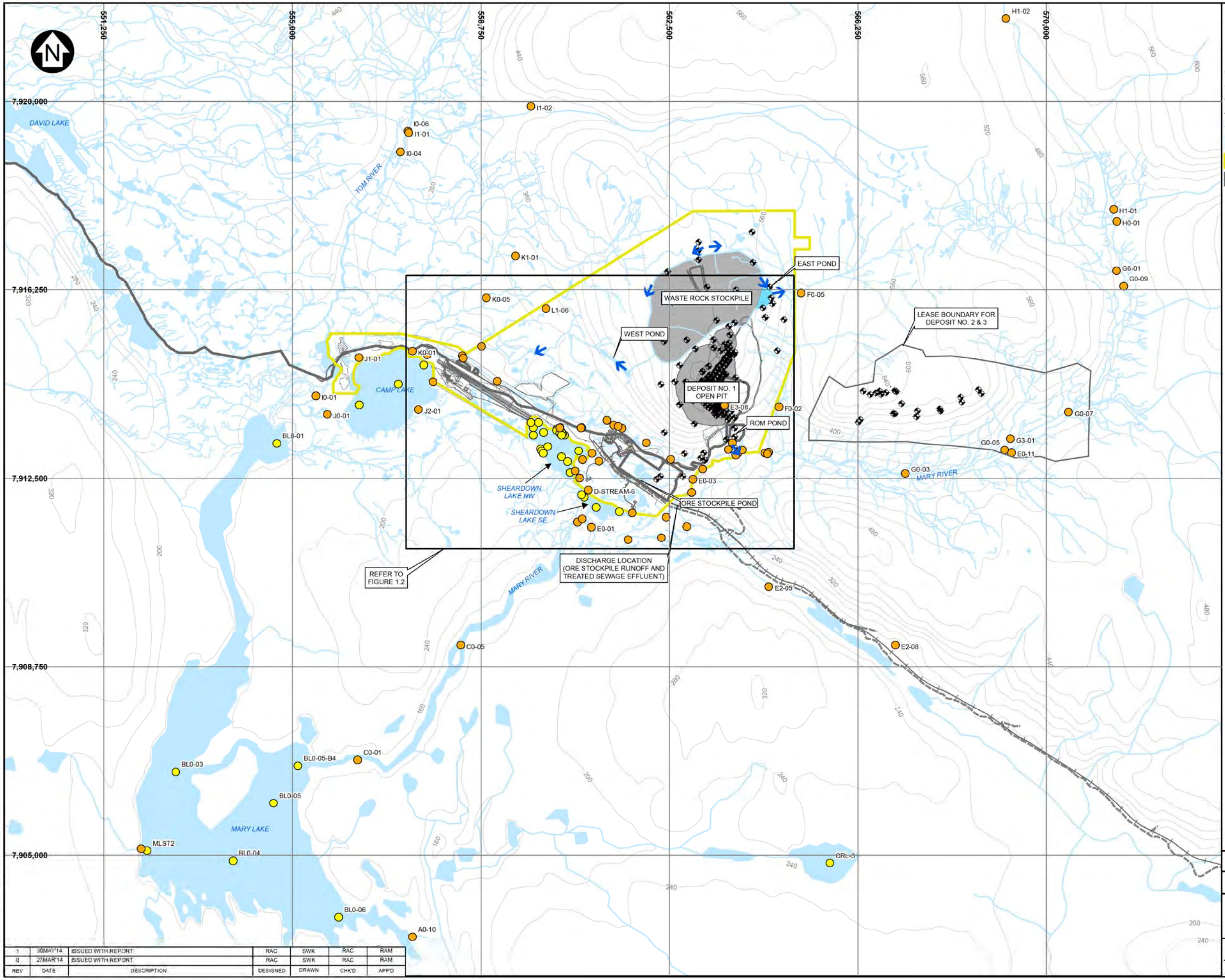
C.3 BASELINE SUMMARY

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:



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:

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

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:\102\00181\33\A\GIS\Figs\B42_r1.mxd; May 30, 2014 1:15 PM; skozmick

BAFFINLAND IRON MINES CORPORATION

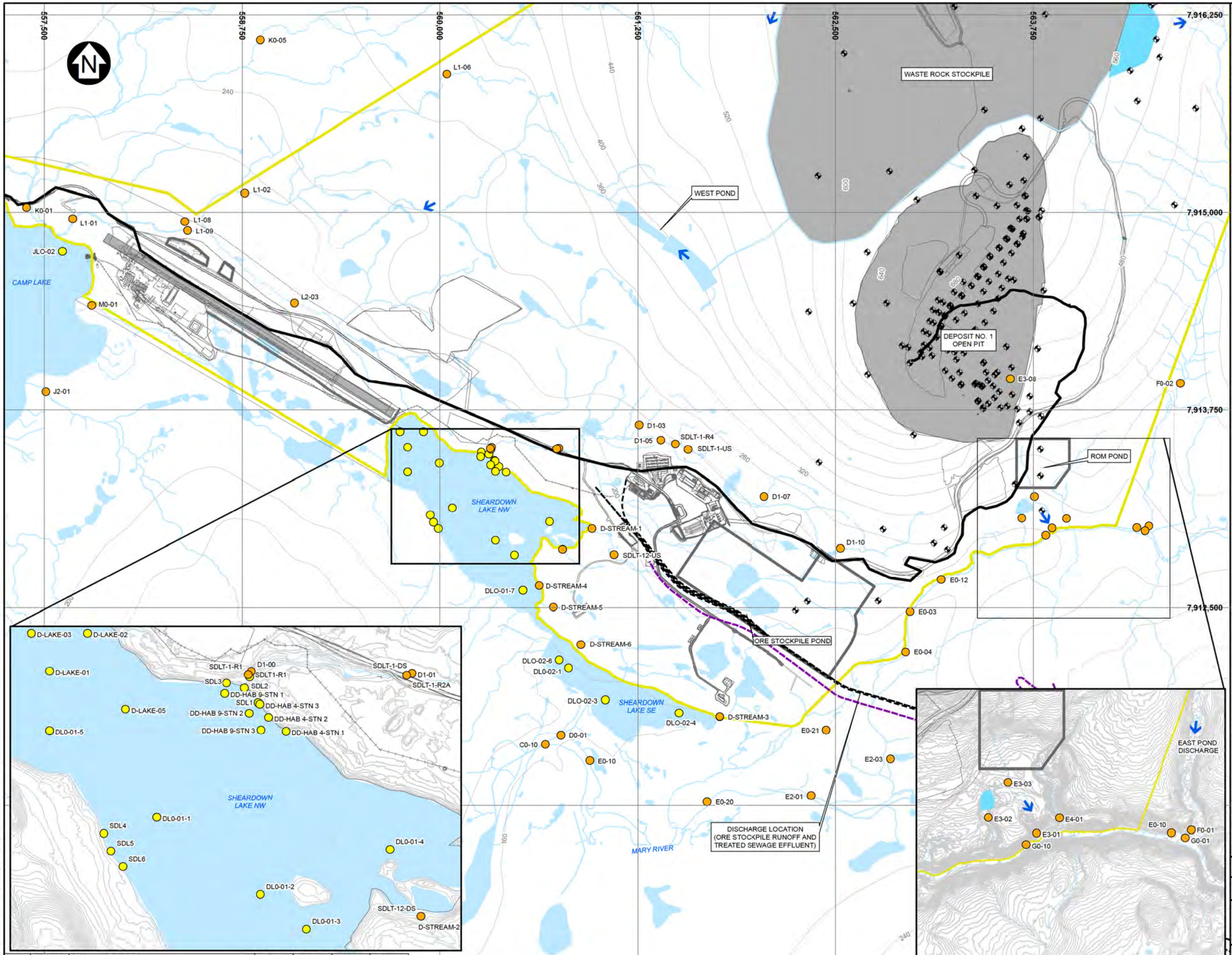
MARY RIVER PROJECT

HISTORIC WATER QUALITY STATIONS
MINE SITE AREA

Knight Piésold CONSULTING

P/A NO.	REF NO.
NB102-181/33	1

FIGURE C.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	EJA	SWK	RAC	RAM

SAVED: I:\1\02\00181\33\A\GIS\Figs\B43_r1.mxd; May 30, 2014 1:21 PM; skozmick

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:

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 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.	REF NO.
NB102-181/33	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

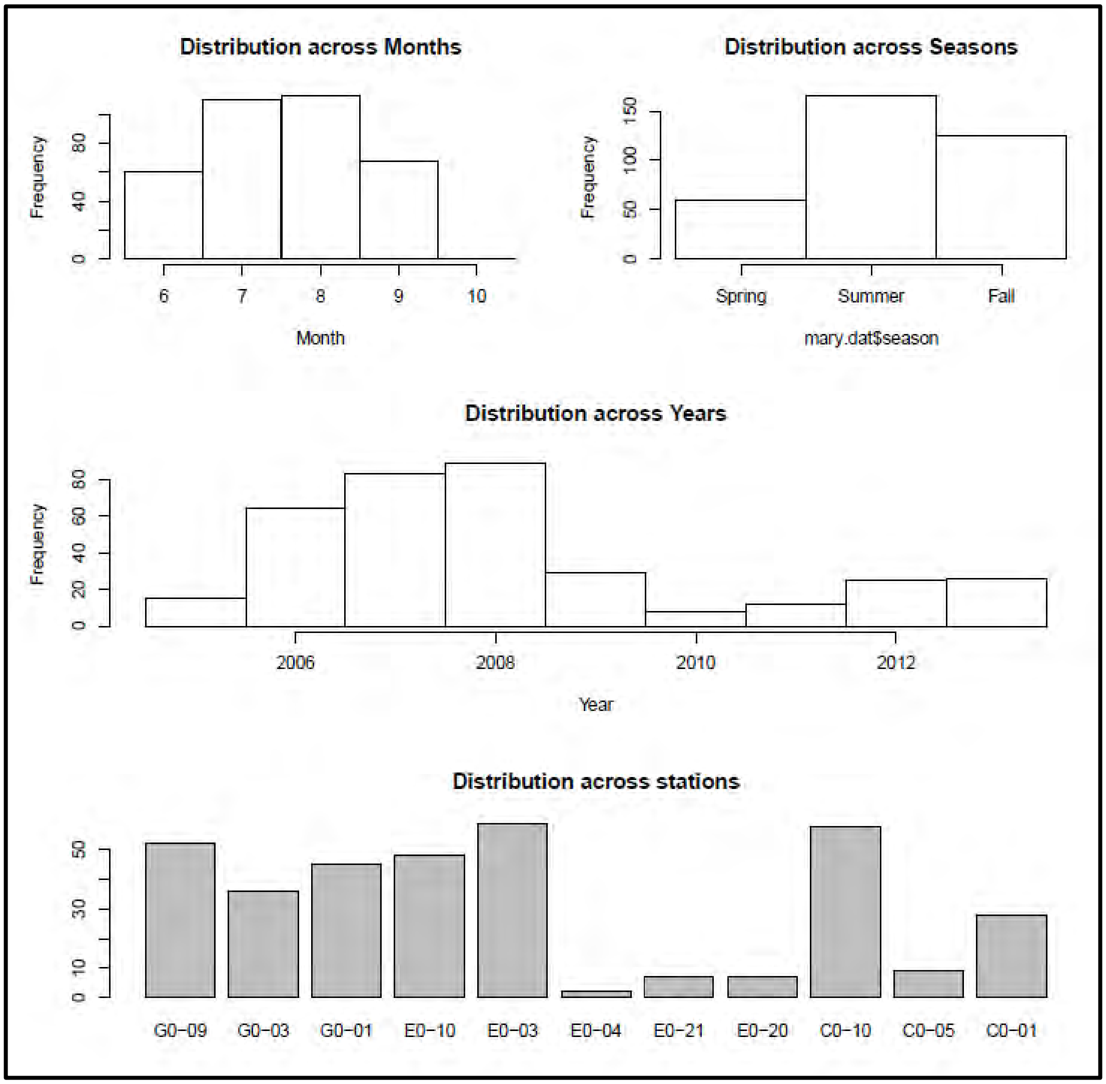


Figure C.4 Mary River – Graphical Summary of Sampling Events

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.

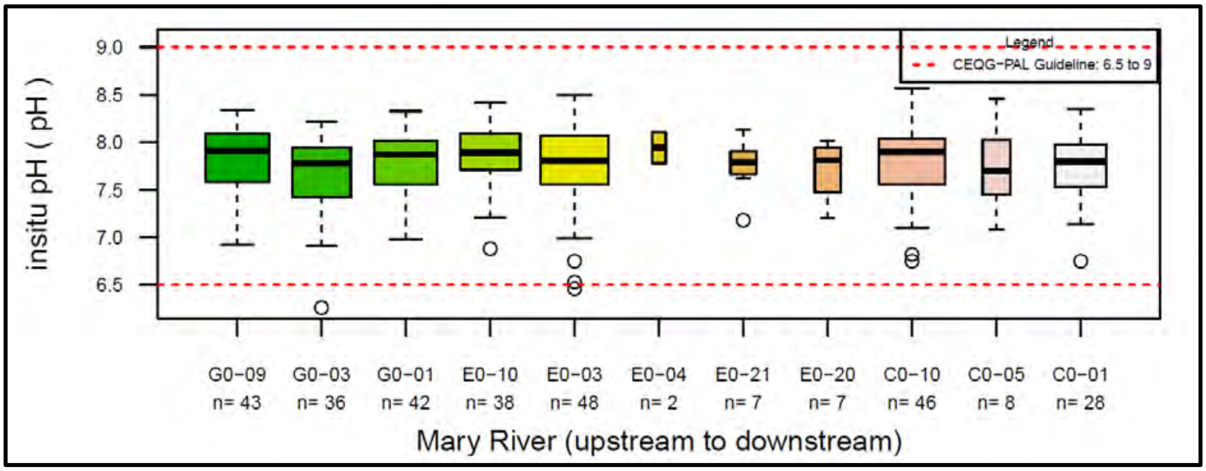


Figure C.5 Mary River – In Situ pH

Hardness (Figure C.6)

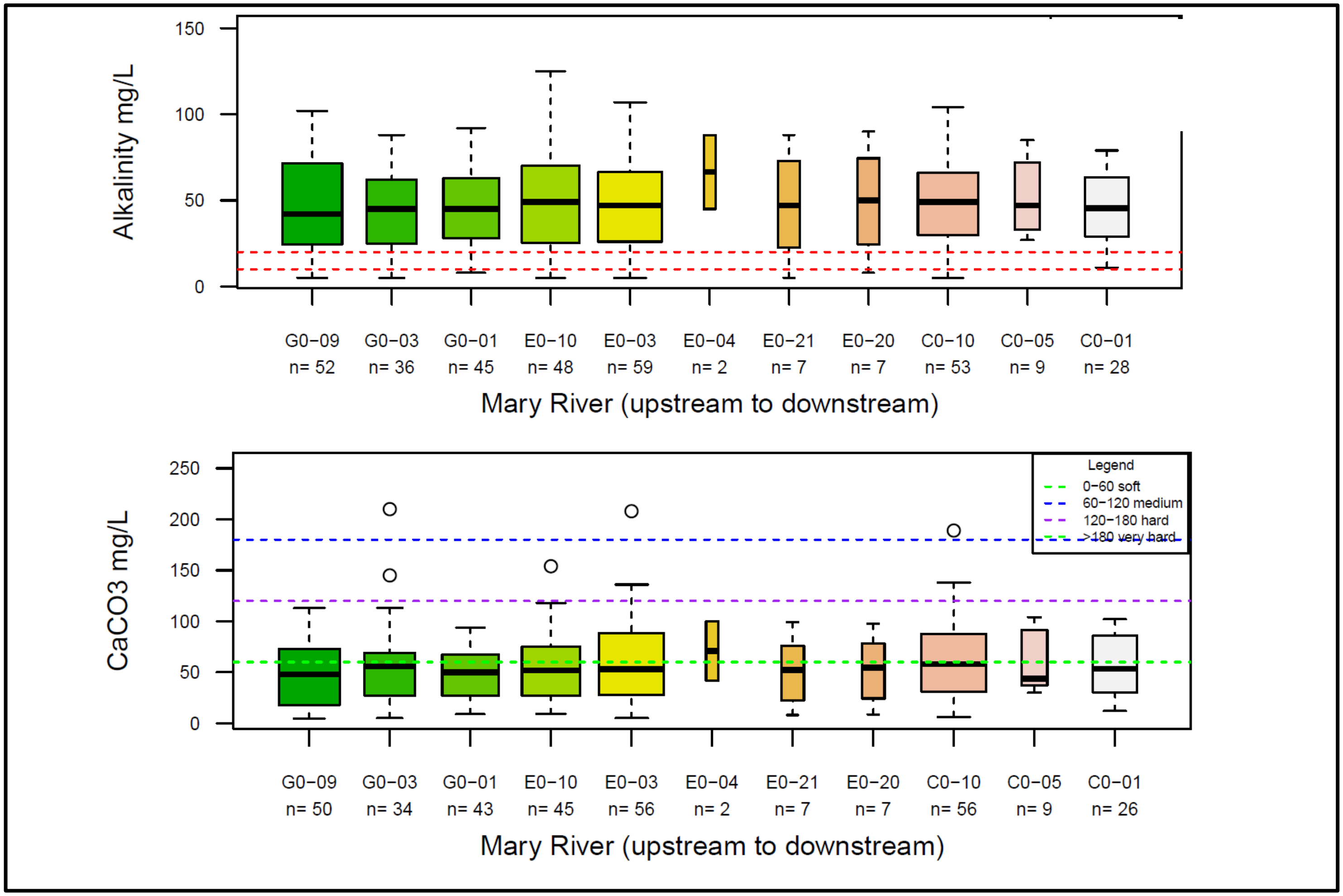
- Median hardness values at the stations in Mary River between 50 mg/L to 60 mg/L, classifying the river water as “soft”. Only one station (E0-04) had median hardness values greater than 60 mg/L.
- Hardness portrayed trends very similar to alkalinity, although elevated values at E0-21 and E0-20 were 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

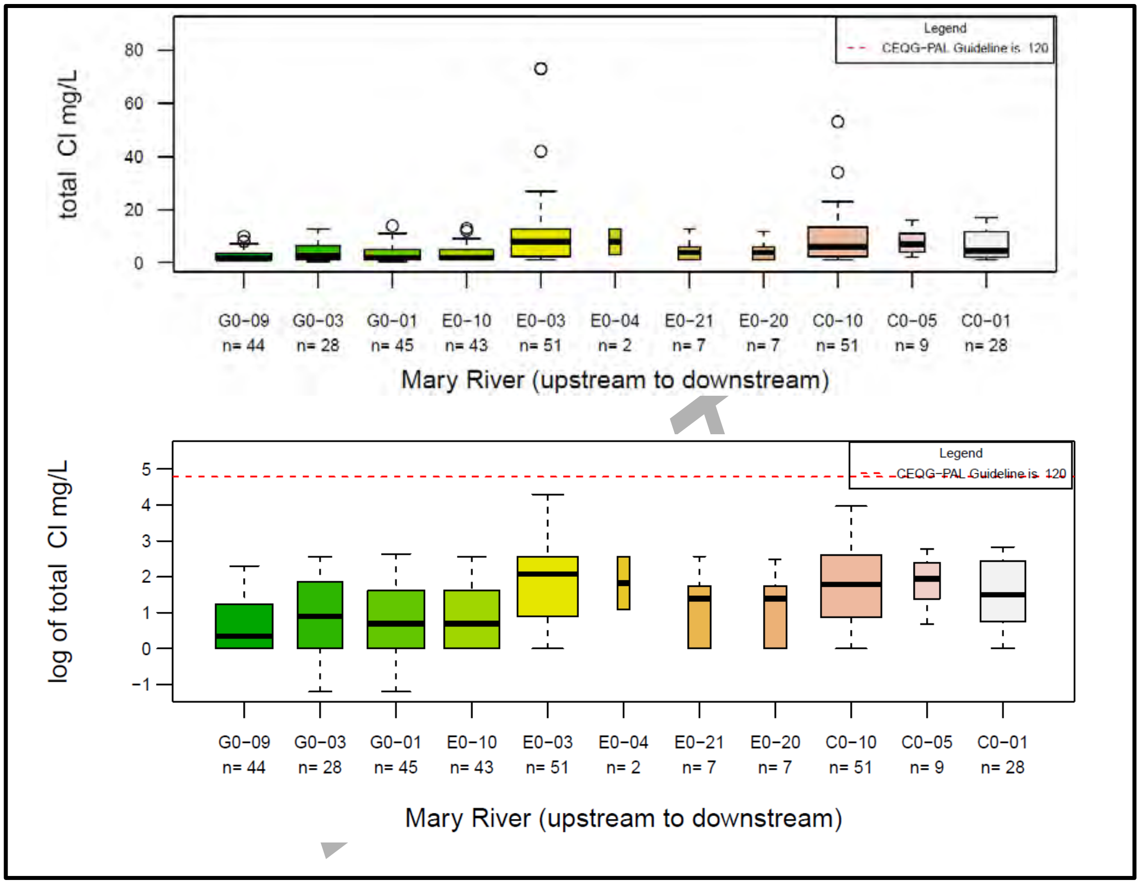
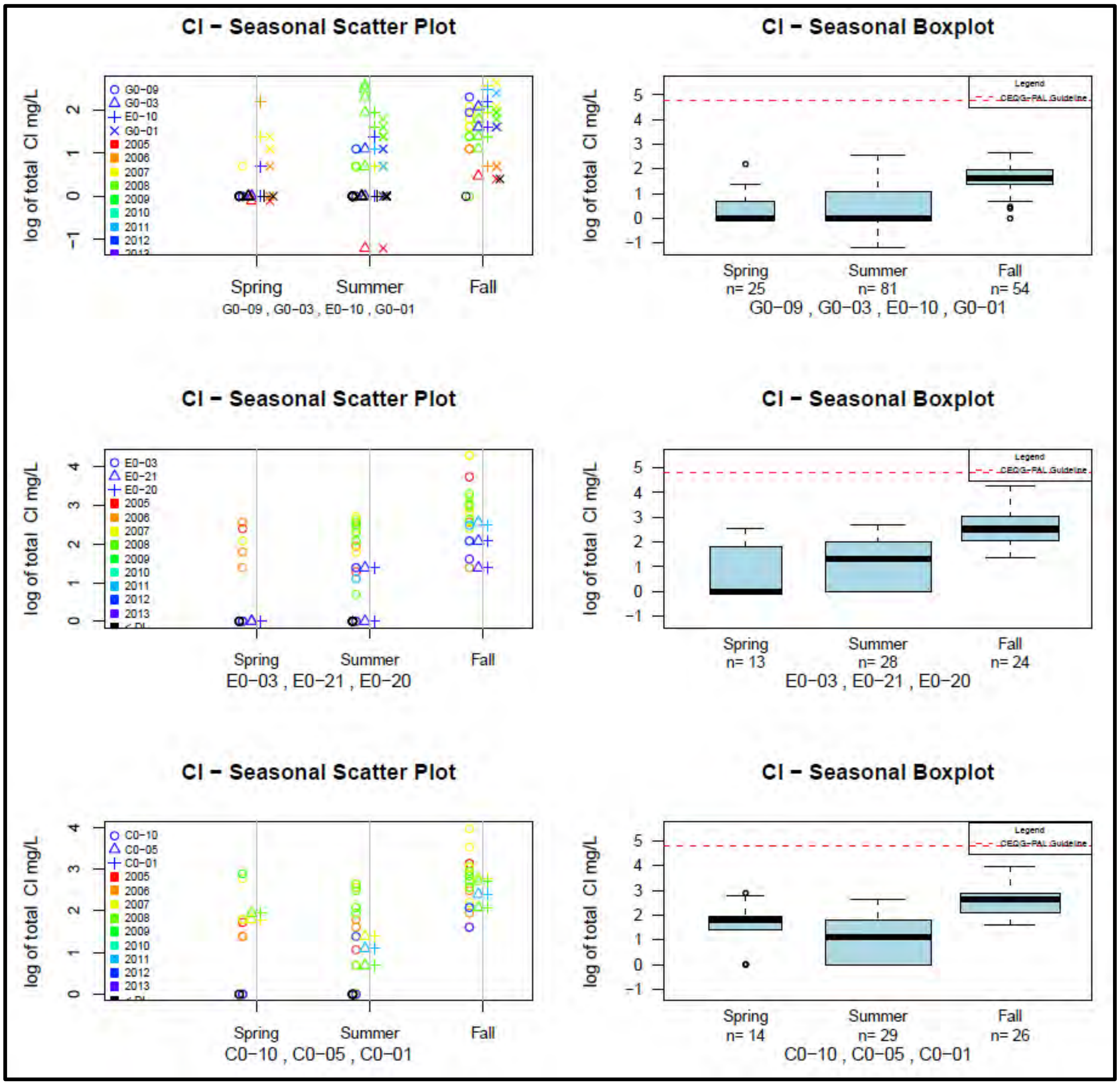


Figure C.7 Mary River – Chloride Concentrations in Water



NOTES:

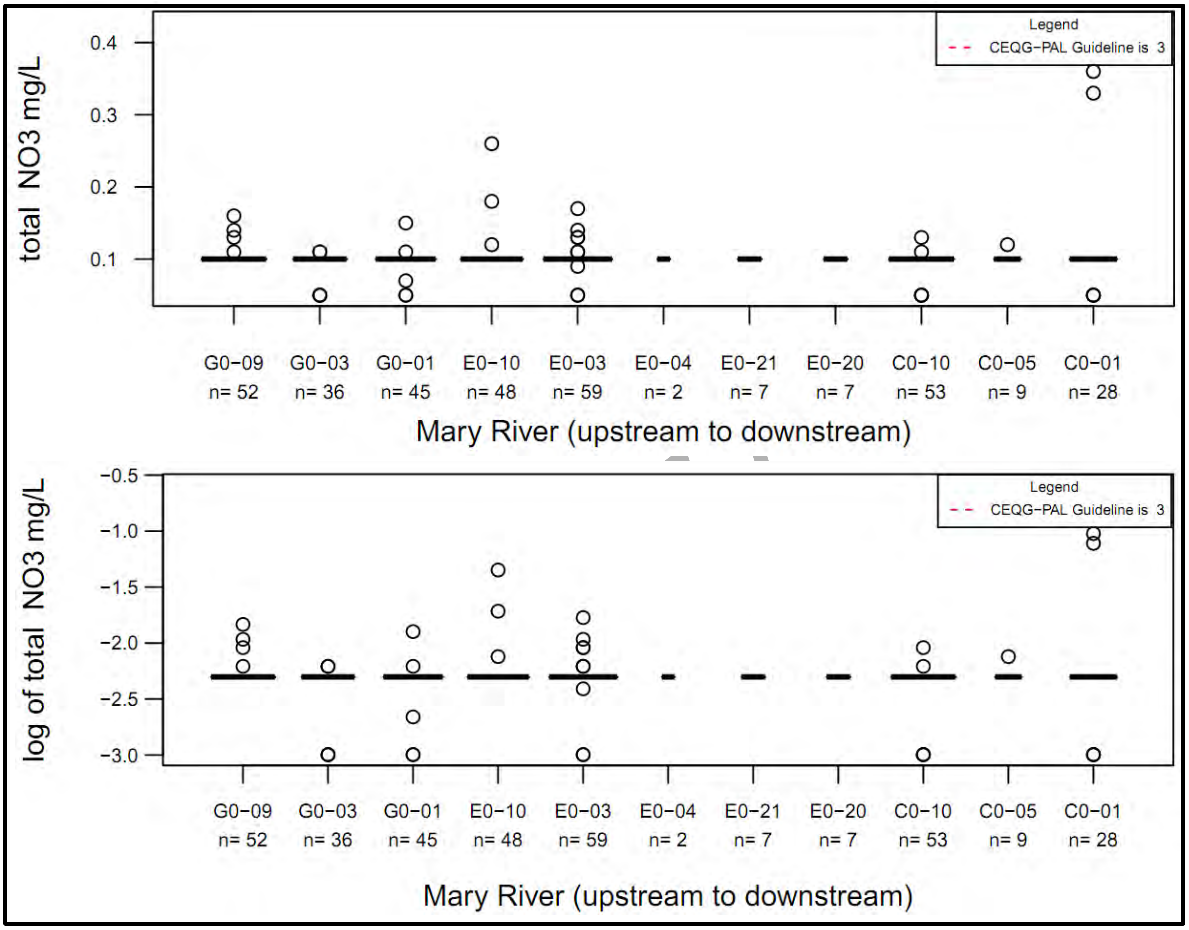
1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.

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).

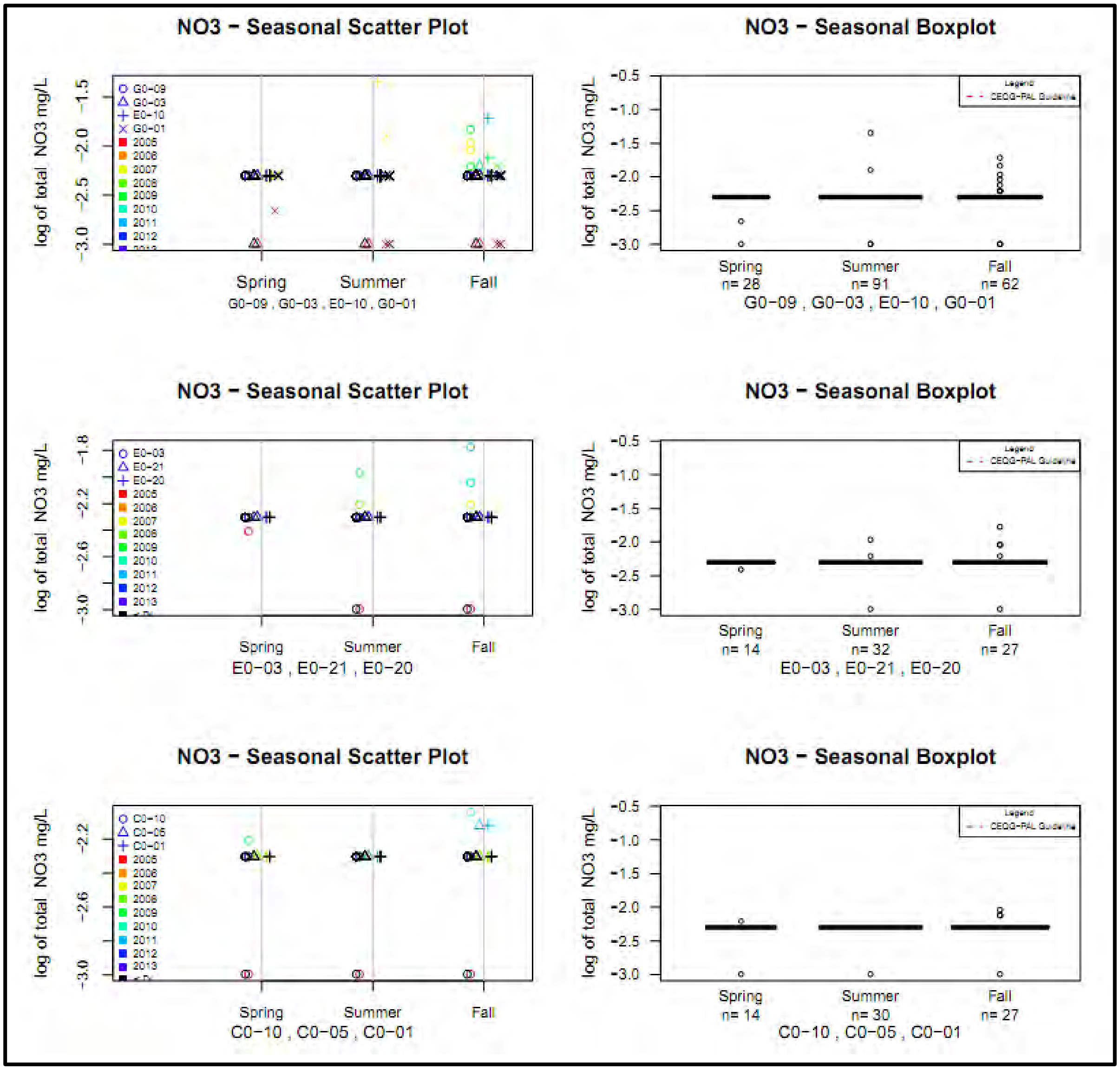
Seasonal scatterplots and boxplots show that the majority of outliers occur in the fall, and that data is subject to MDL interference. Seasonal scatterplots indicate that earlier data, from 2005, actually had a lower MDL than more recently collected data in 2012 (Figure C.10).



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.

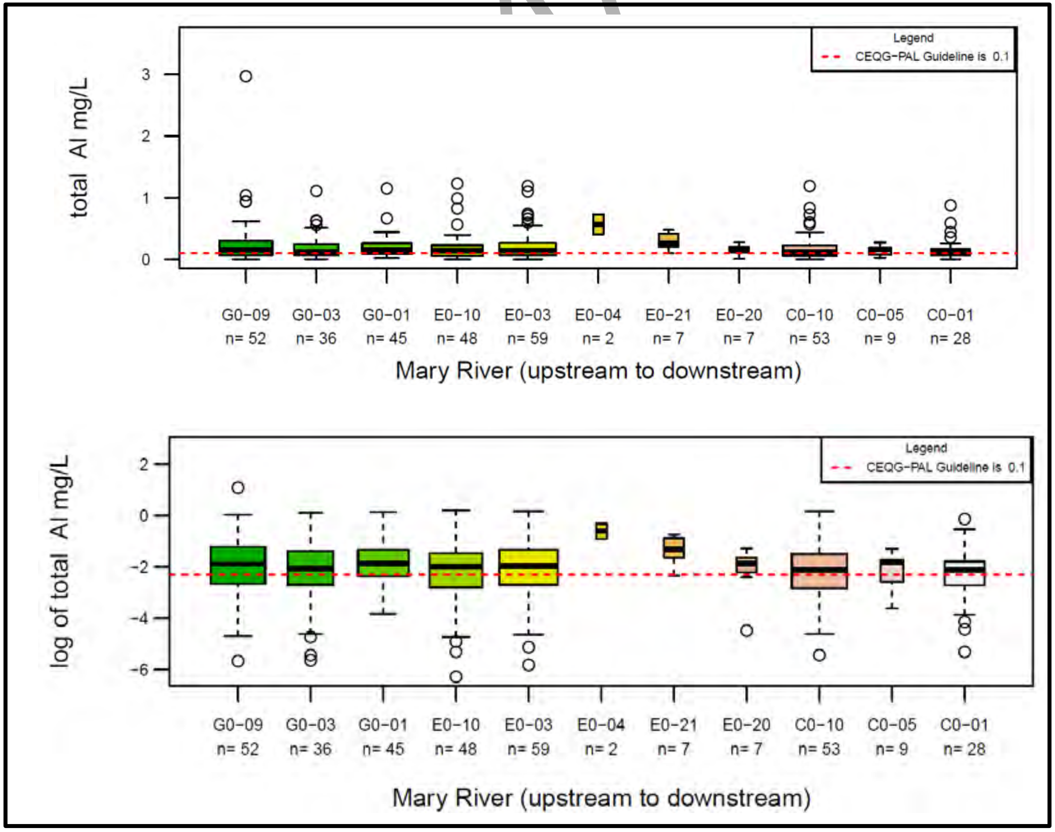
Figure C.10 Mary River – Variability of Nitrate in Water

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.



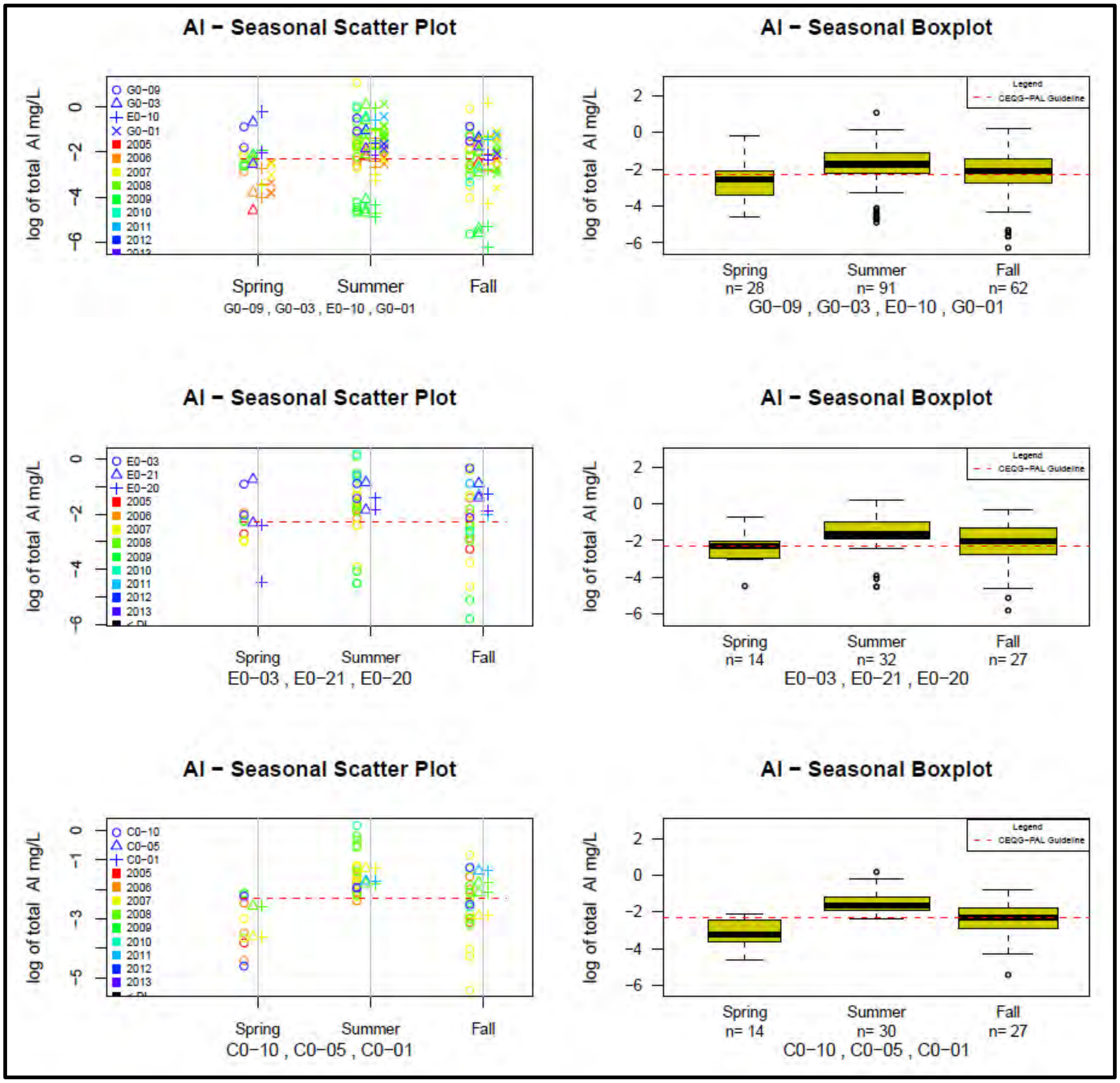
NOTES:

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:

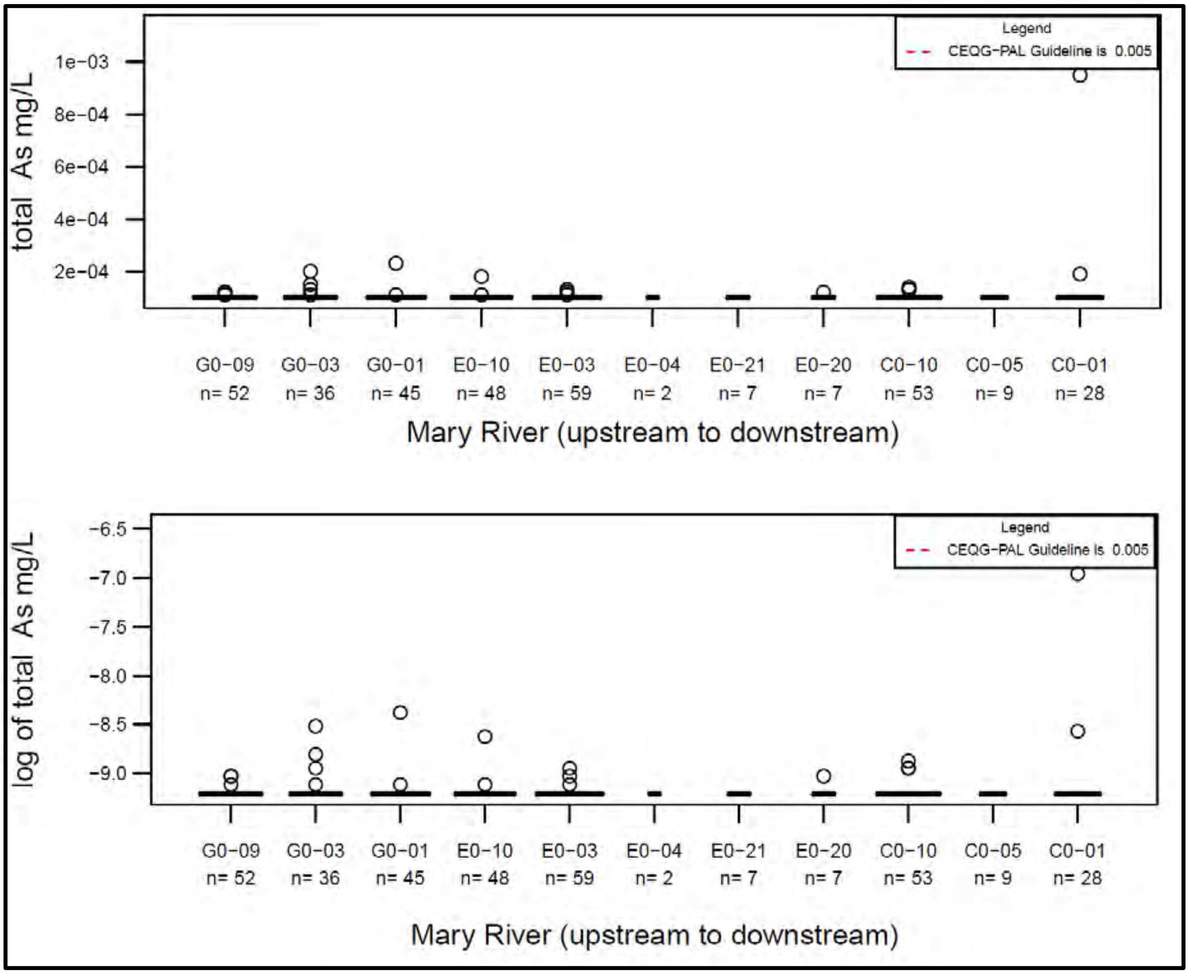
1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.
2. THE CWQG-PAL GUIDELINE LIMIT IS BASED ON THE TOTAL MEDIAN HARDNESS.

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.



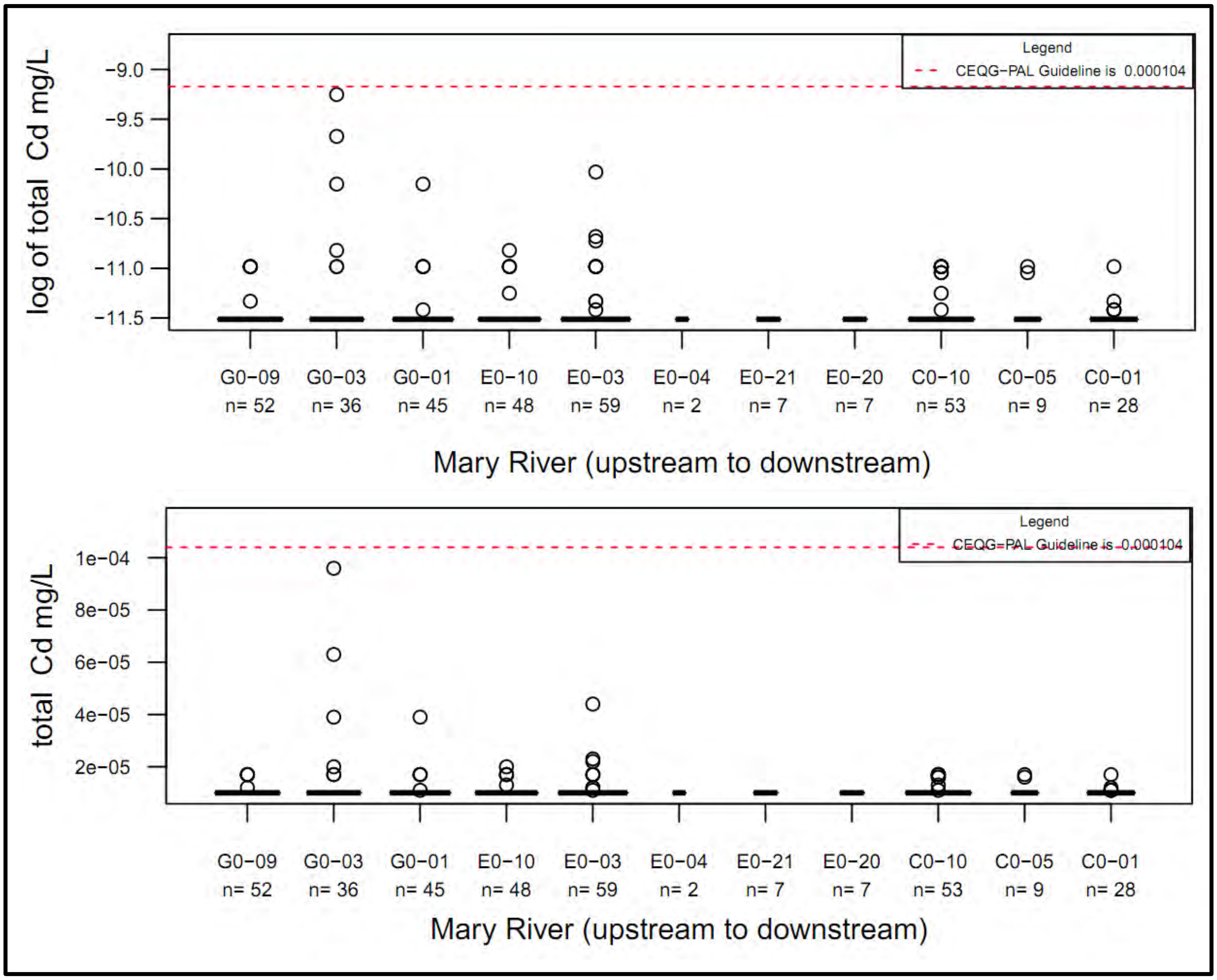
NOTES:

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.



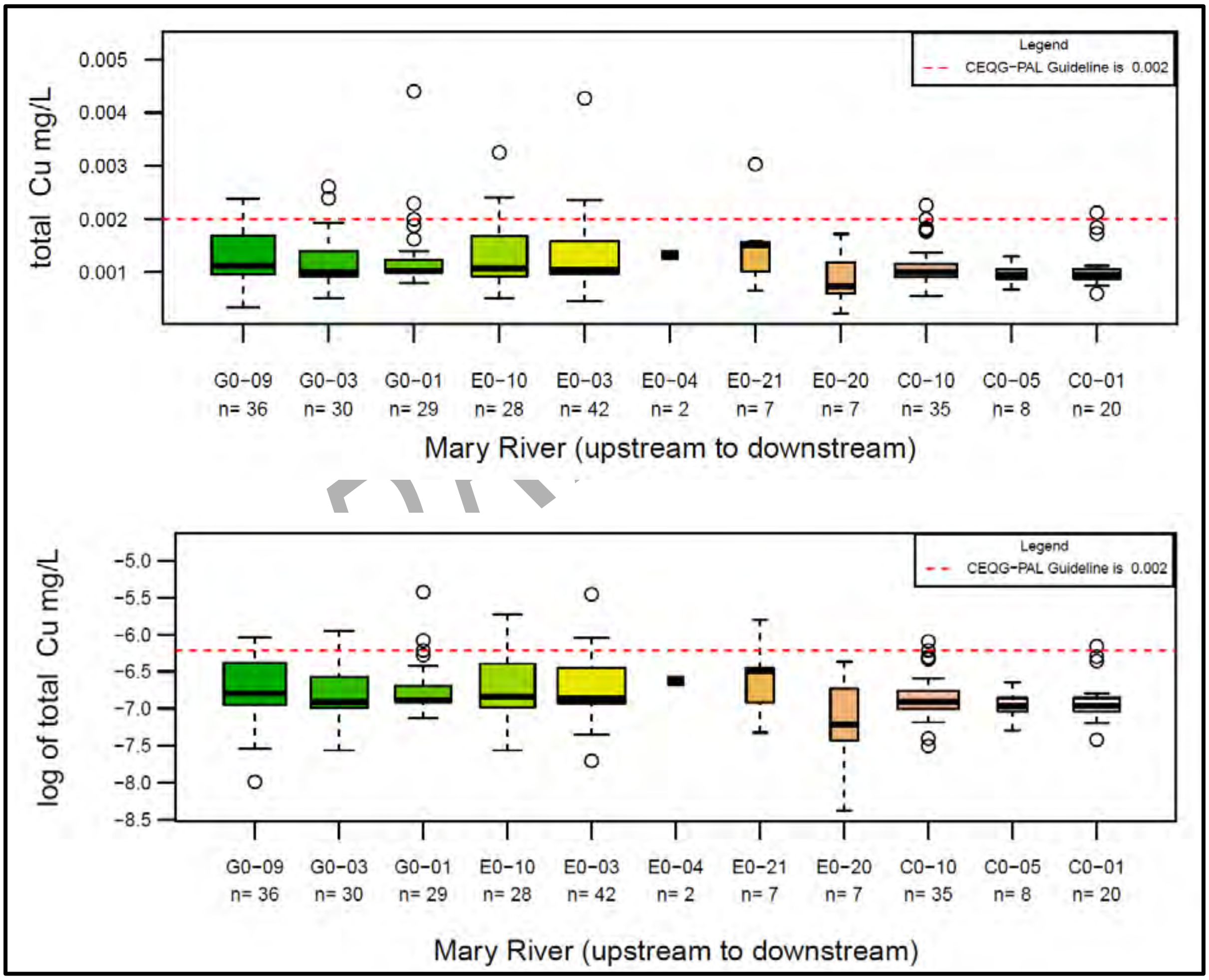
NOTES:

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.

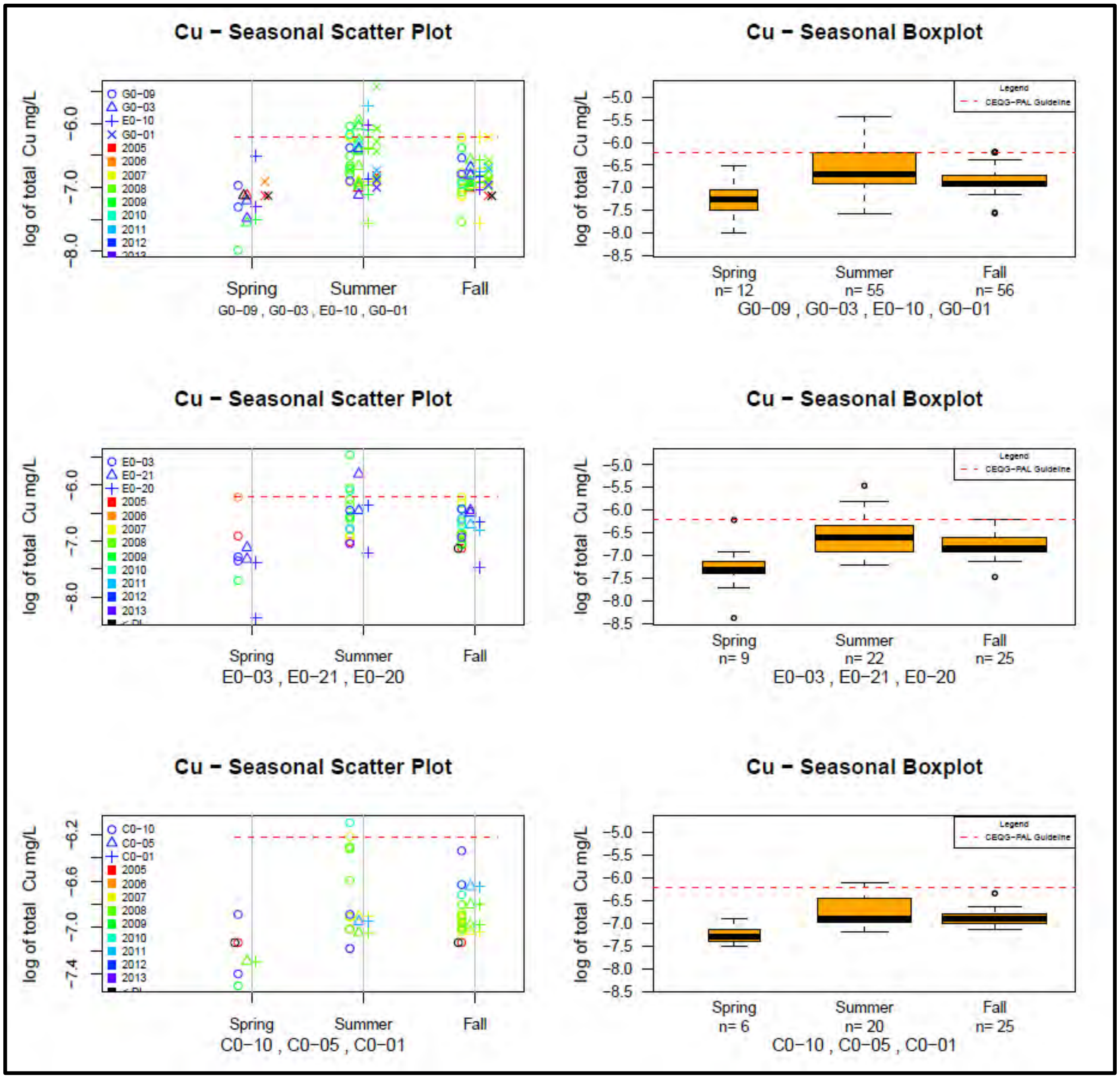


NOTES:

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:

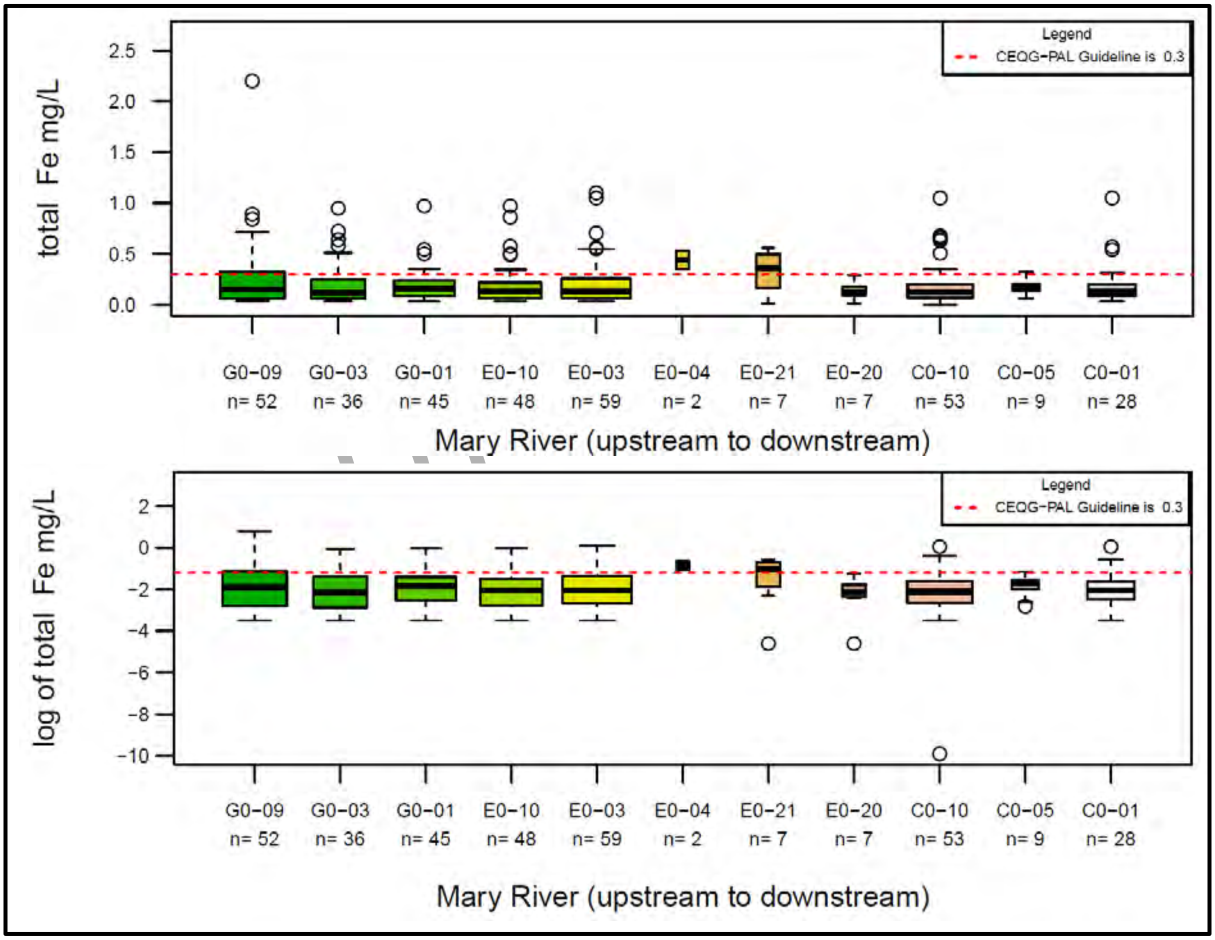
1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.
2. THE CWQG-PAL GUIDELINE LIMIT IS BASED ON THE TOTAL MEDIAN HARDNESS.

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.

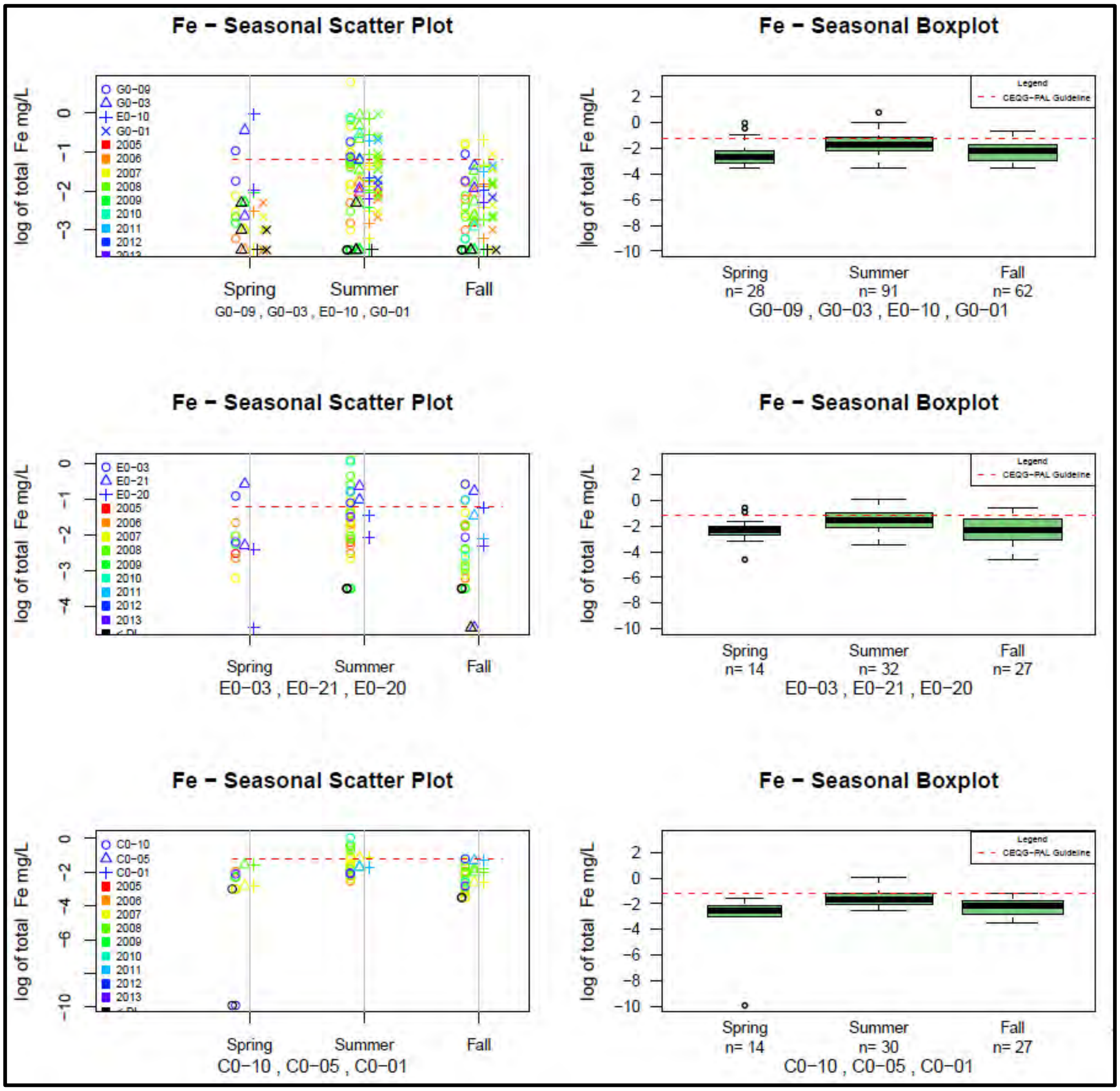


NOTES:

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:

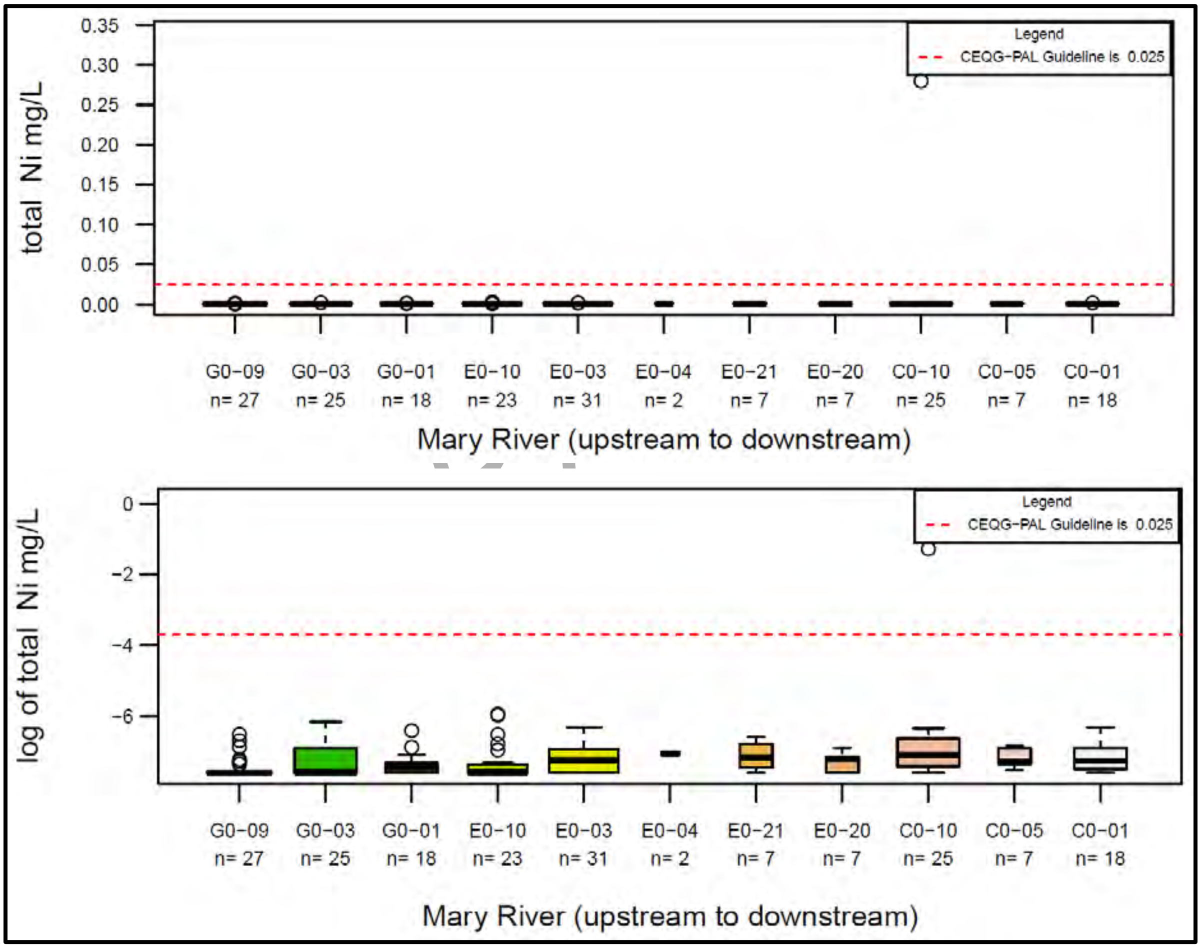
1. THE CWQG-PAL GUIDELINE LIMIT IS BASED ON THE TOTAL MEDIAN HARDNESS.

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.

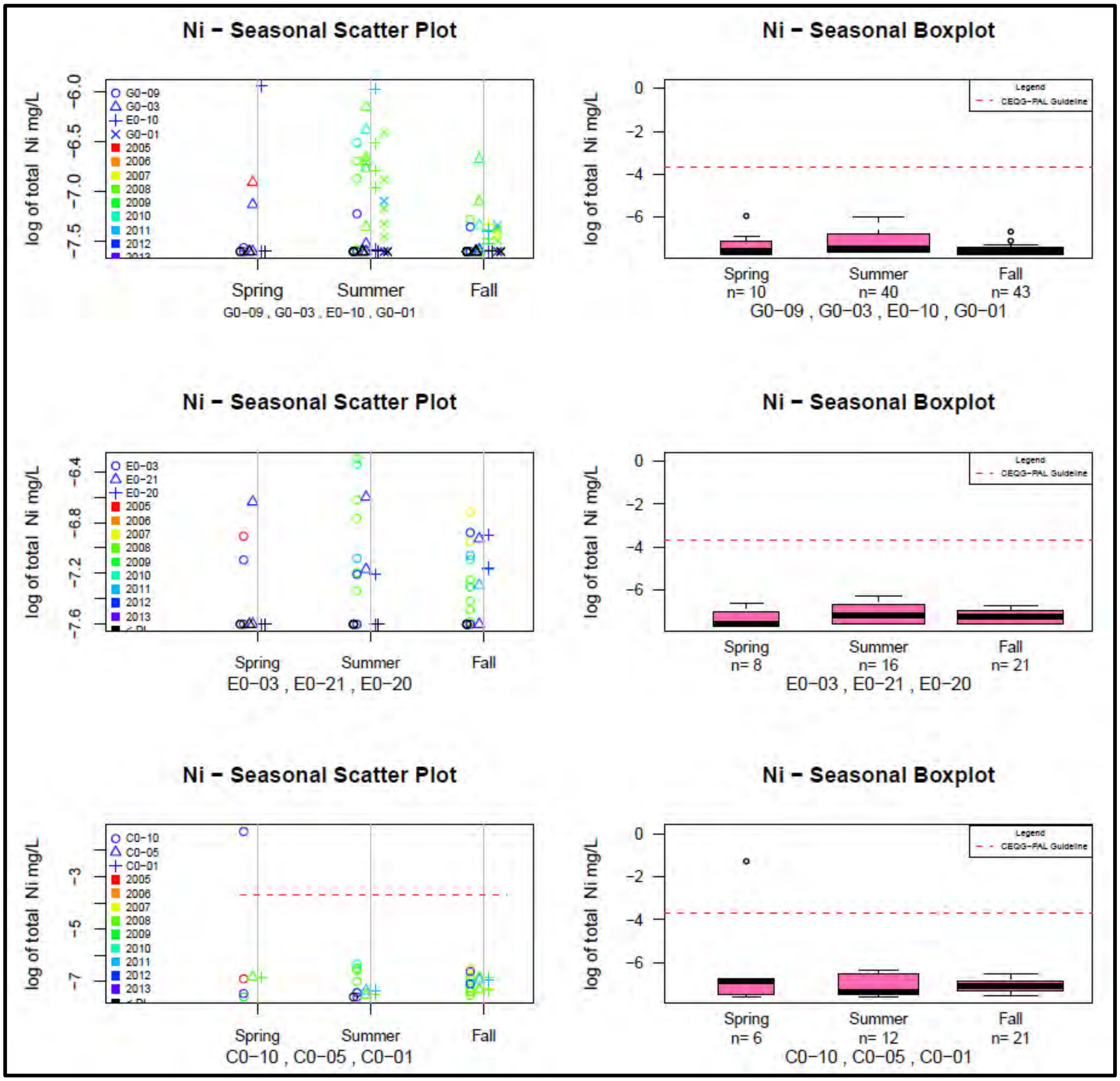
Seasonal scatterplots indicate data from 2008 and 2009 is slightly elevated compared to other data collected during the eight year sampling history (Figure C.20). Seasonal scatterplots and boxplots do not show any discernable seasonal trend, although it is possible summer concentrations are slightly 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:

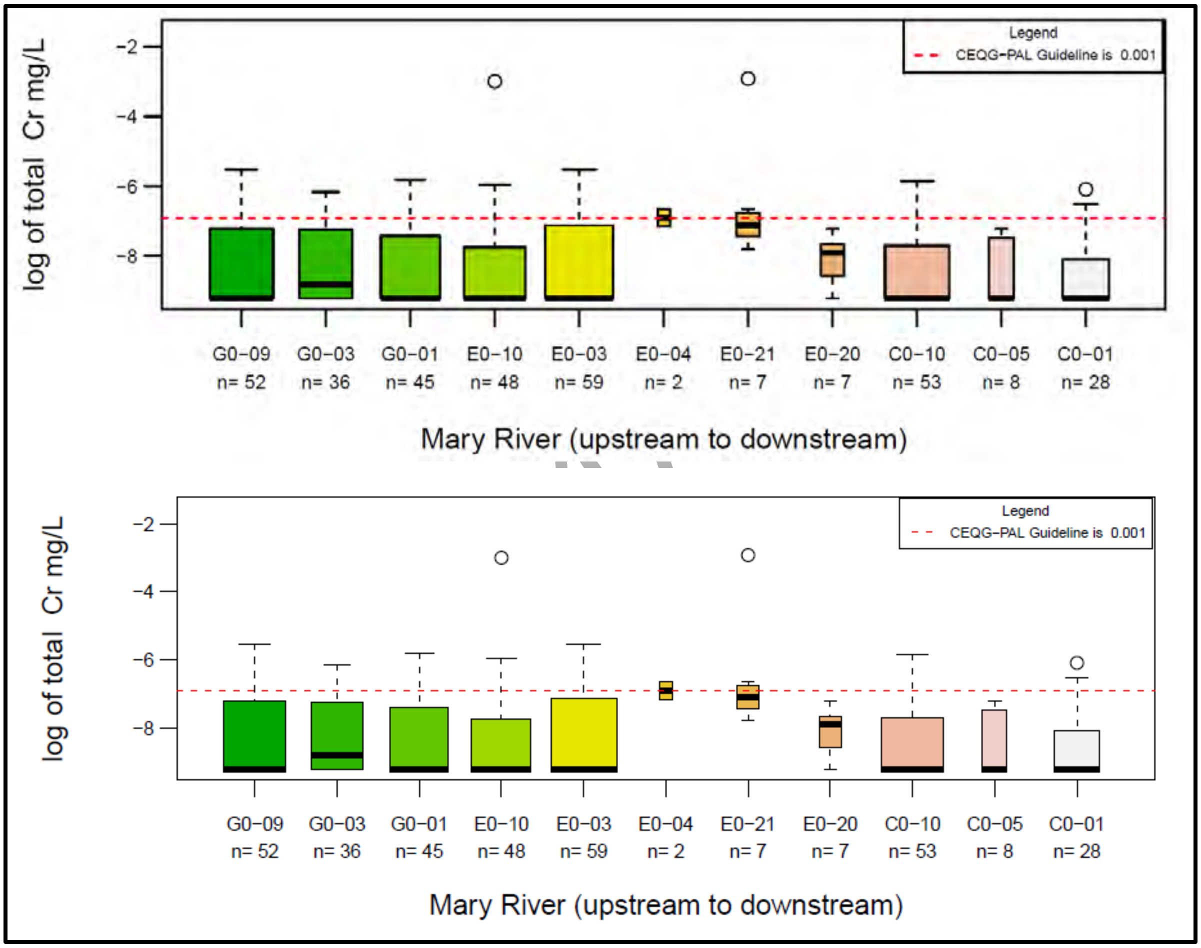
1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.
2. THE CWQG-PAL GUIDELINE LIMIT IS BASED ON THE TOTAL MEDIAN HARDNESS.

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.

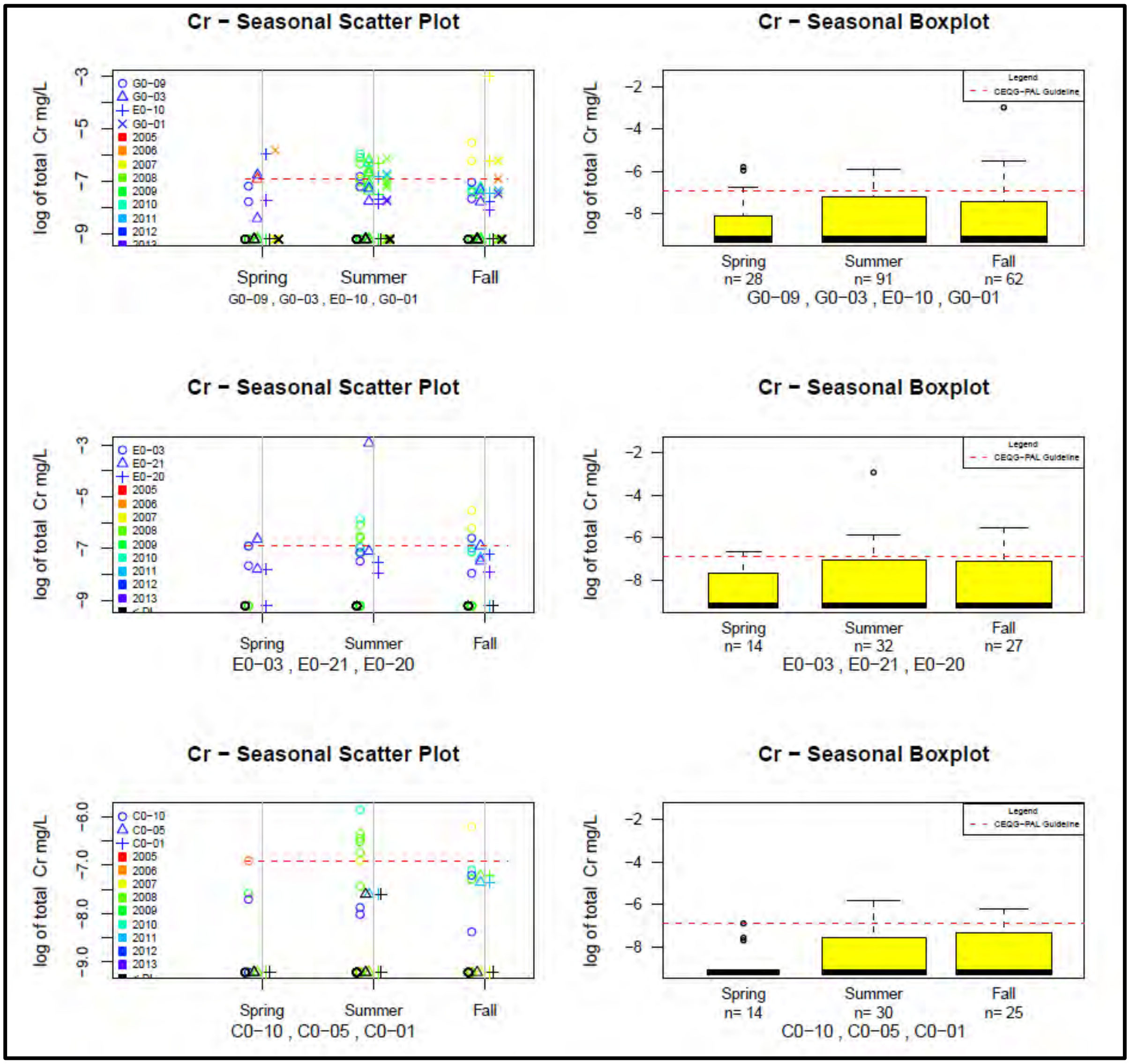
Seasonal scatterplots indicate data from summer of 2008 is slightly elevated compared to other data collected during the eight year sampling history (Figure C.22). Seasonal scatterplots and boxplots do not show any discernable seasonal trend.



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.

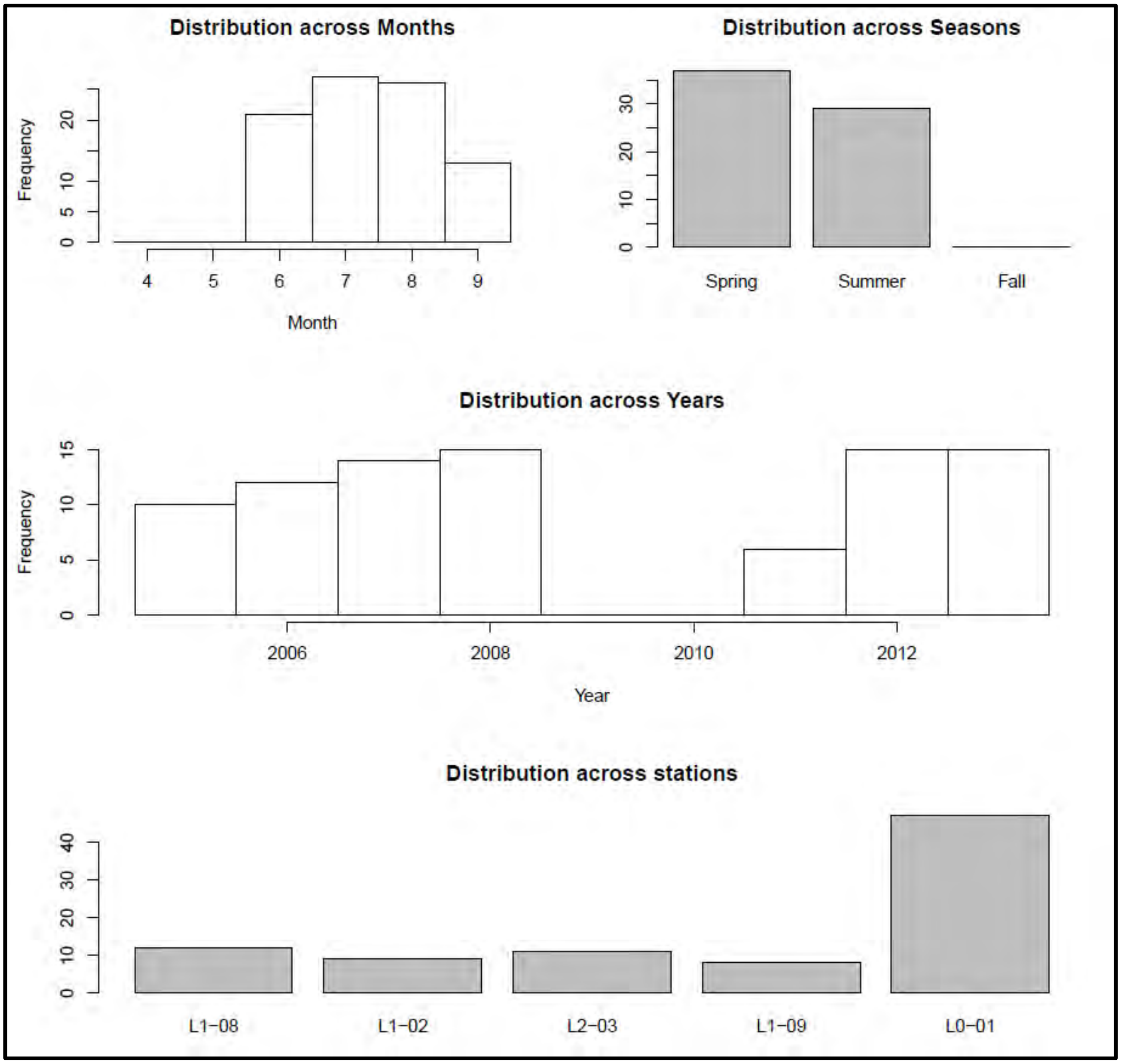
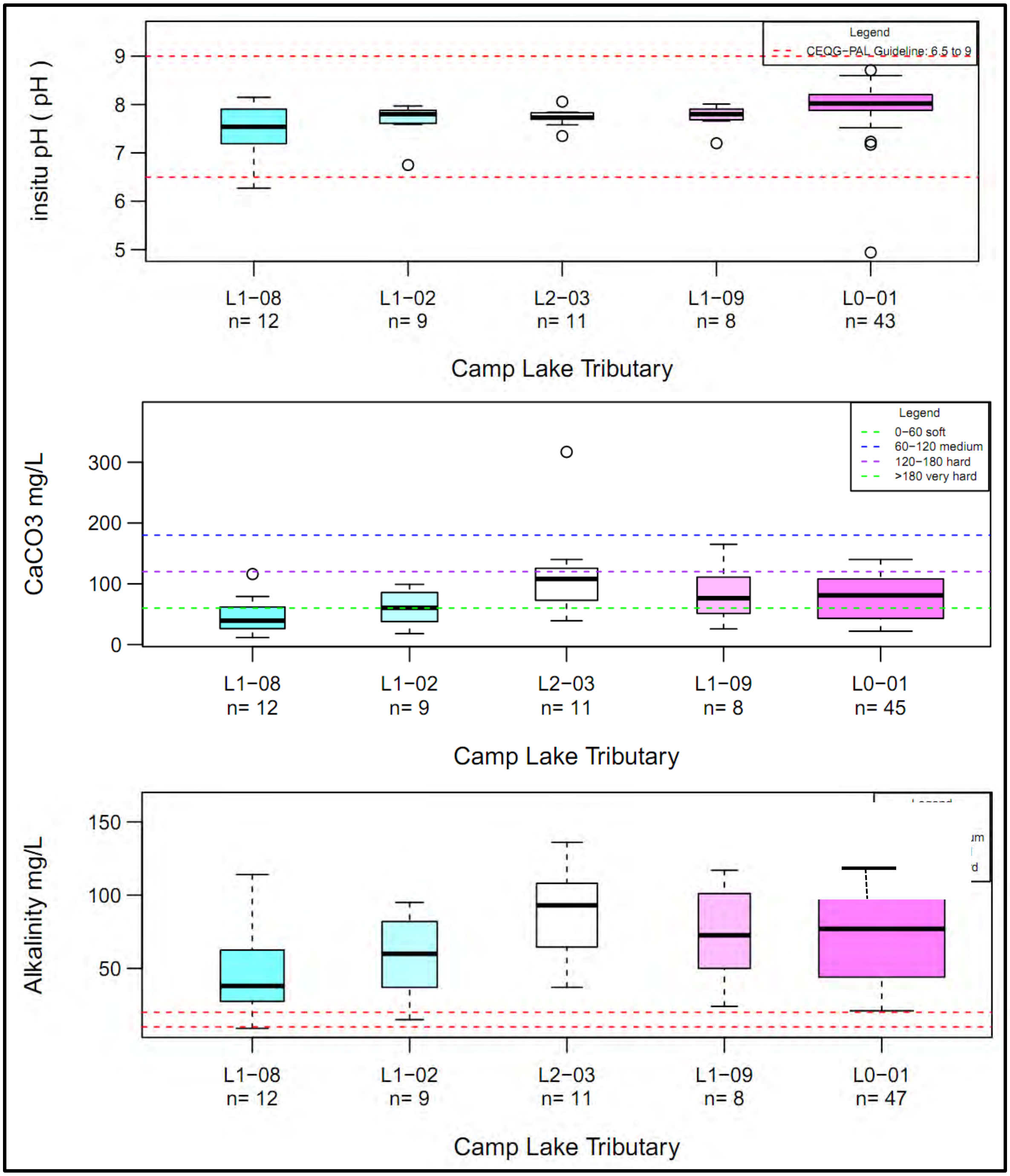


Figure C.23 Camp Lake Tributary – Graphical Summary of Sampling Events

The following sections summarize the results for the non-metallic inorganic parameters of interest: chloride and nitrate.

Chloride (Figures C.25 and C.26)

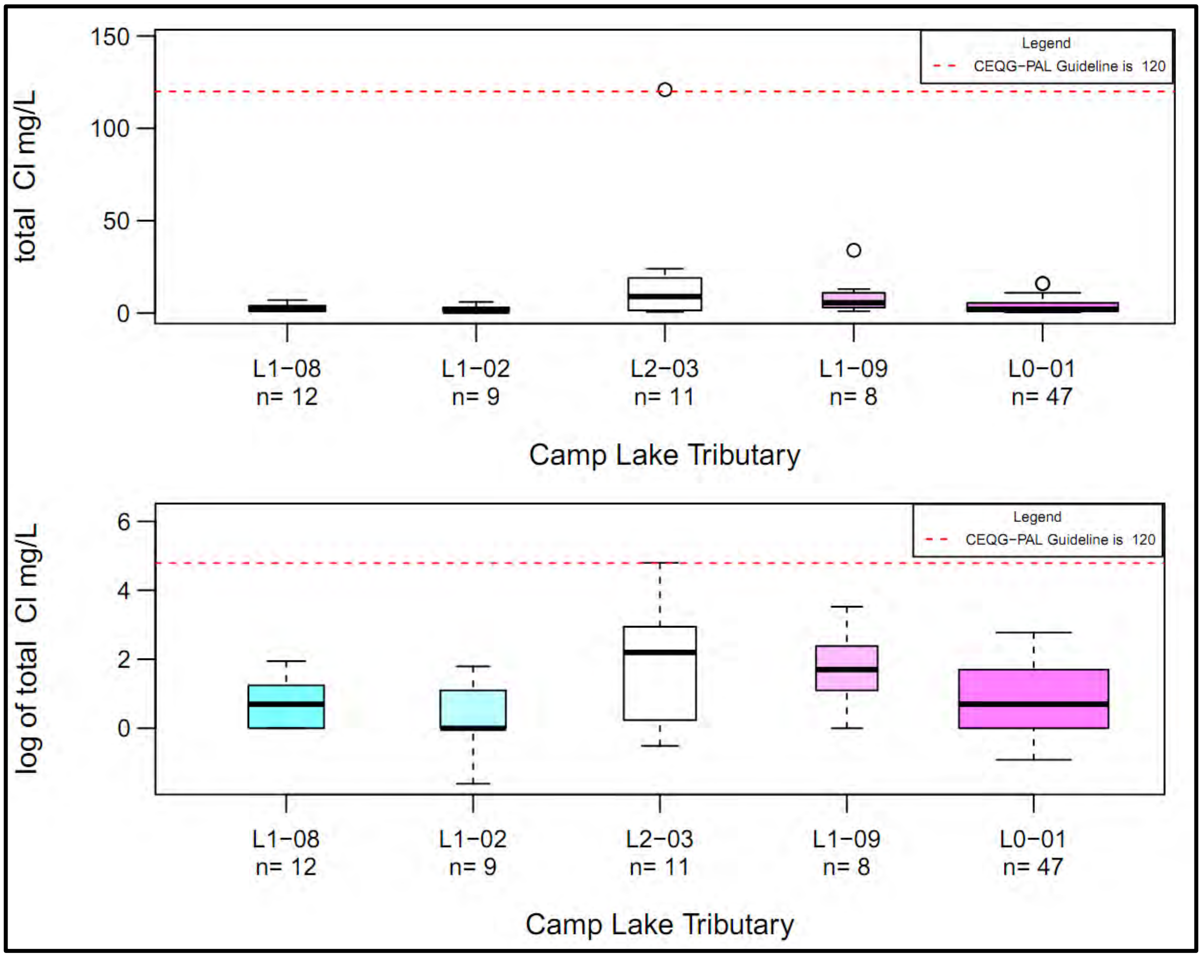
The total sample size for chloride concentration samples collected in the Camp Lake Tributary is eighty-seven (87) with 8 to 47 samples collected at each geographically distinct sampling station (Figure C.25). Chloride concentrations are low, with the exception of one outlier recorded at L2-03. Chloride 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



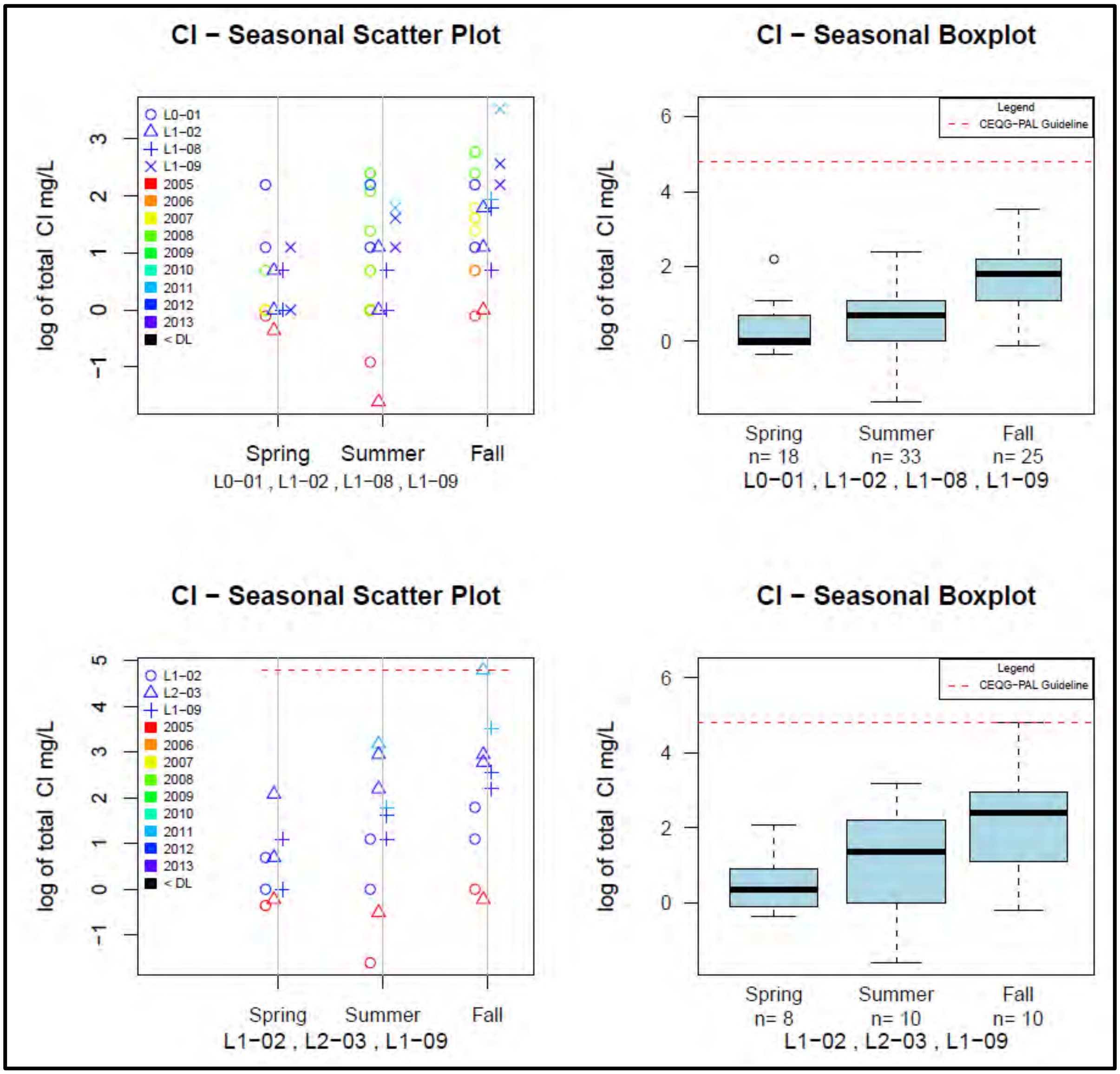
NOTES:

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.



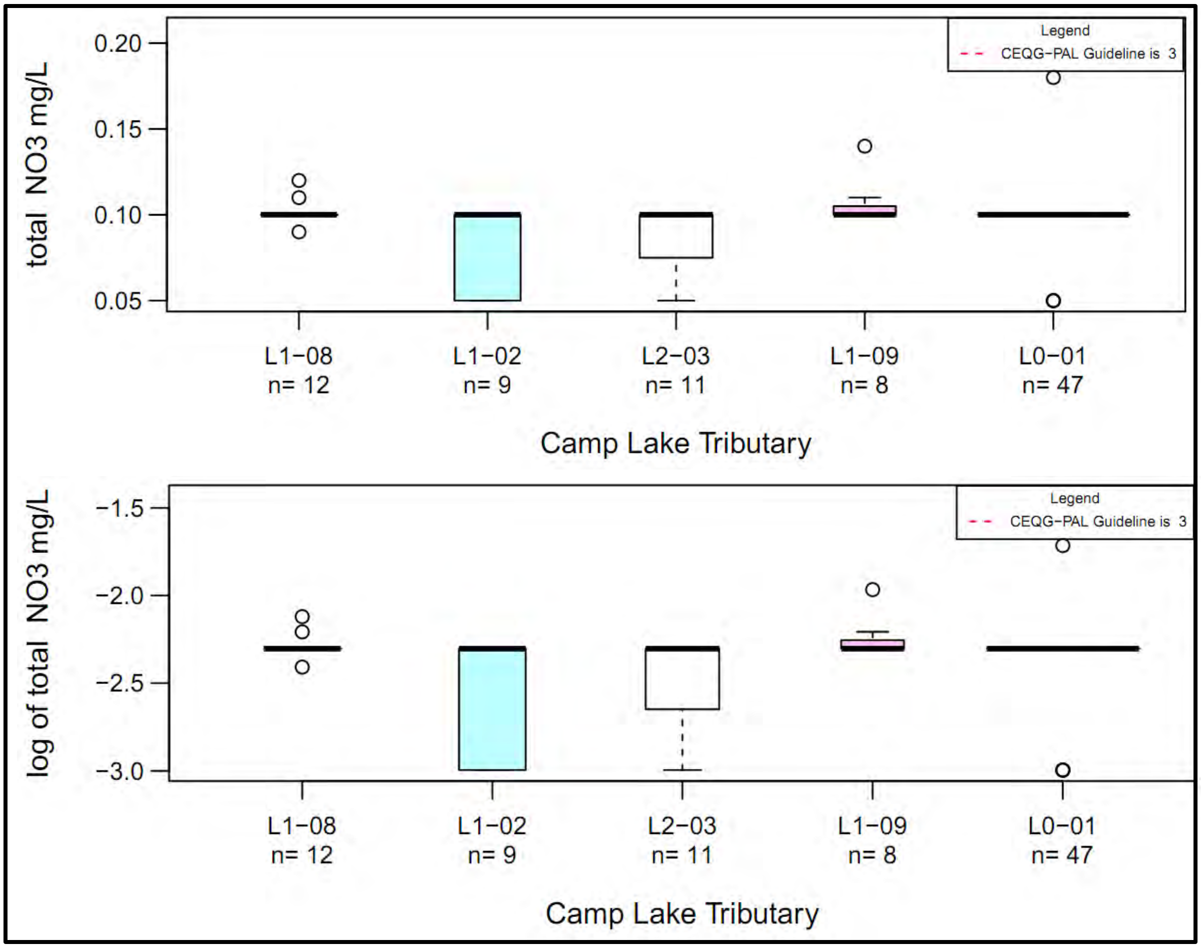
NOTES:

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.

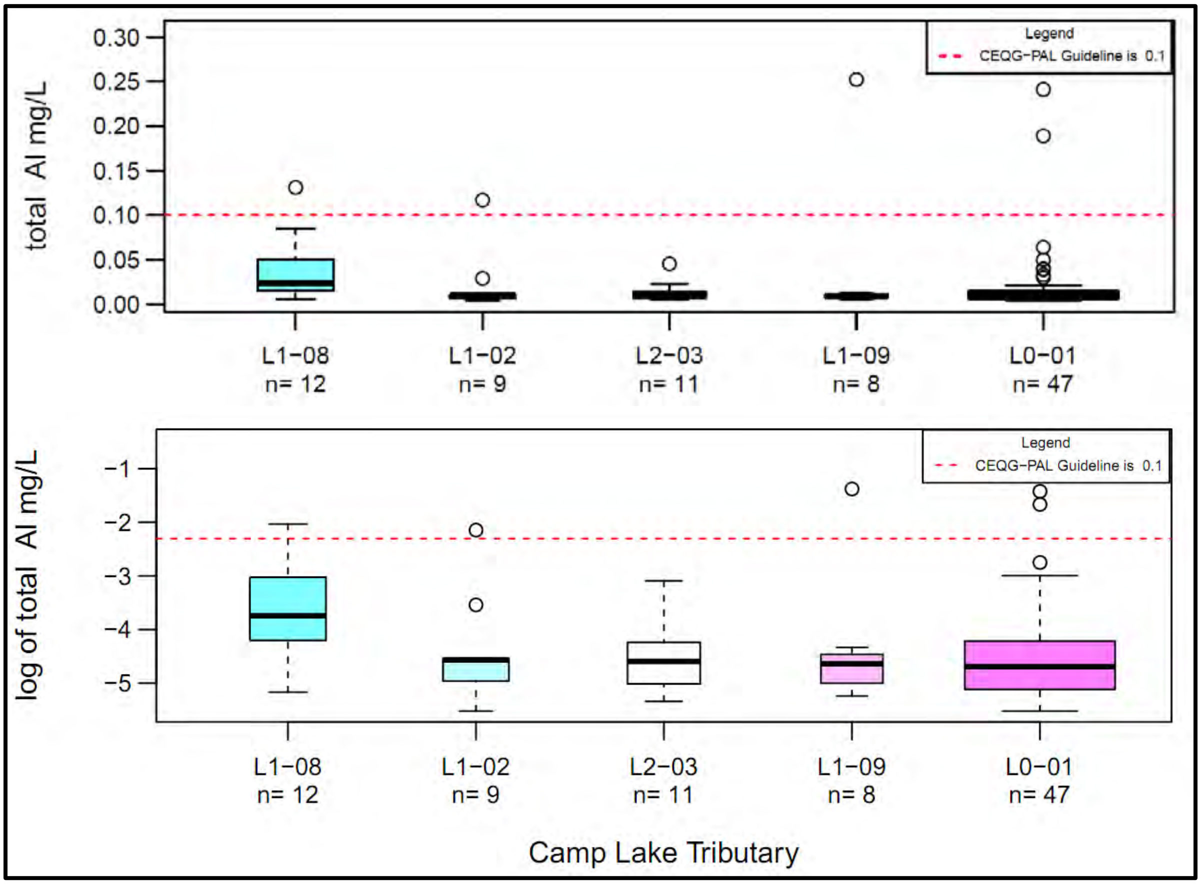
Figure C.27 Camp Lake Tributary – Nitrate Concentrations in Water

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.

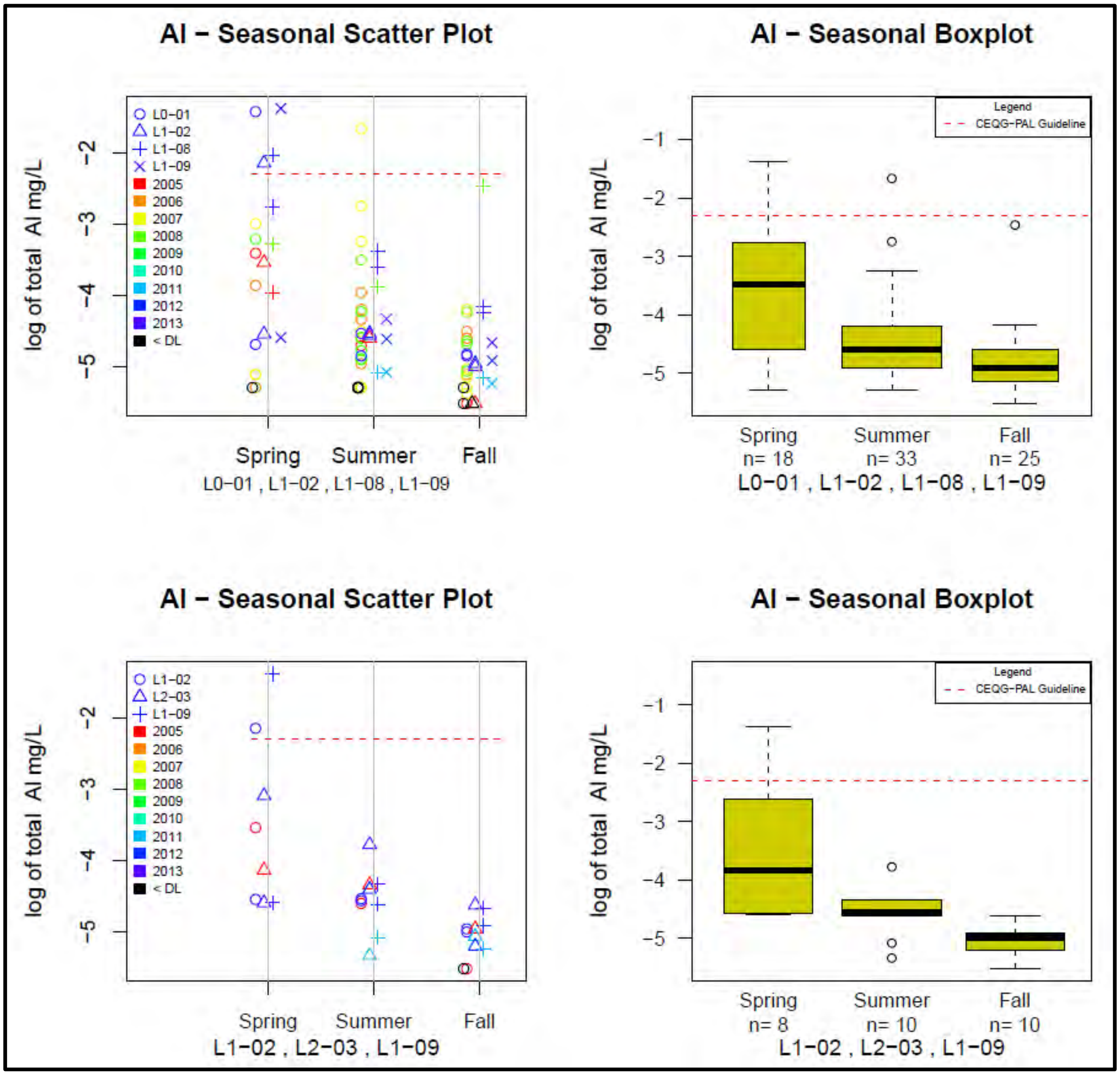
Data from 2012 and 2013 tends to be slightly elevated when compared to other years of sampling (Figure C.29). As mentioned above, seasonal boxplots for the Camp Lake Tributary area show a conserved trend of highest concentrations occurring in the spring, with slightly lower summer concentrations and 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.

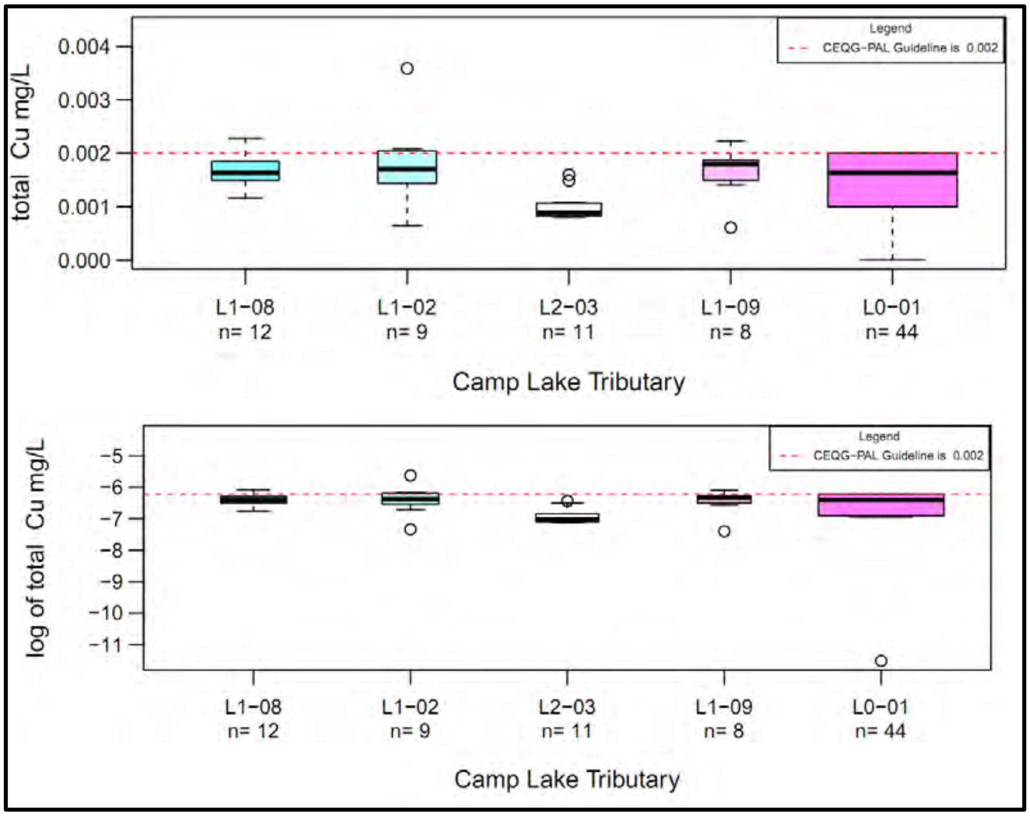
Total Cadmium

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.

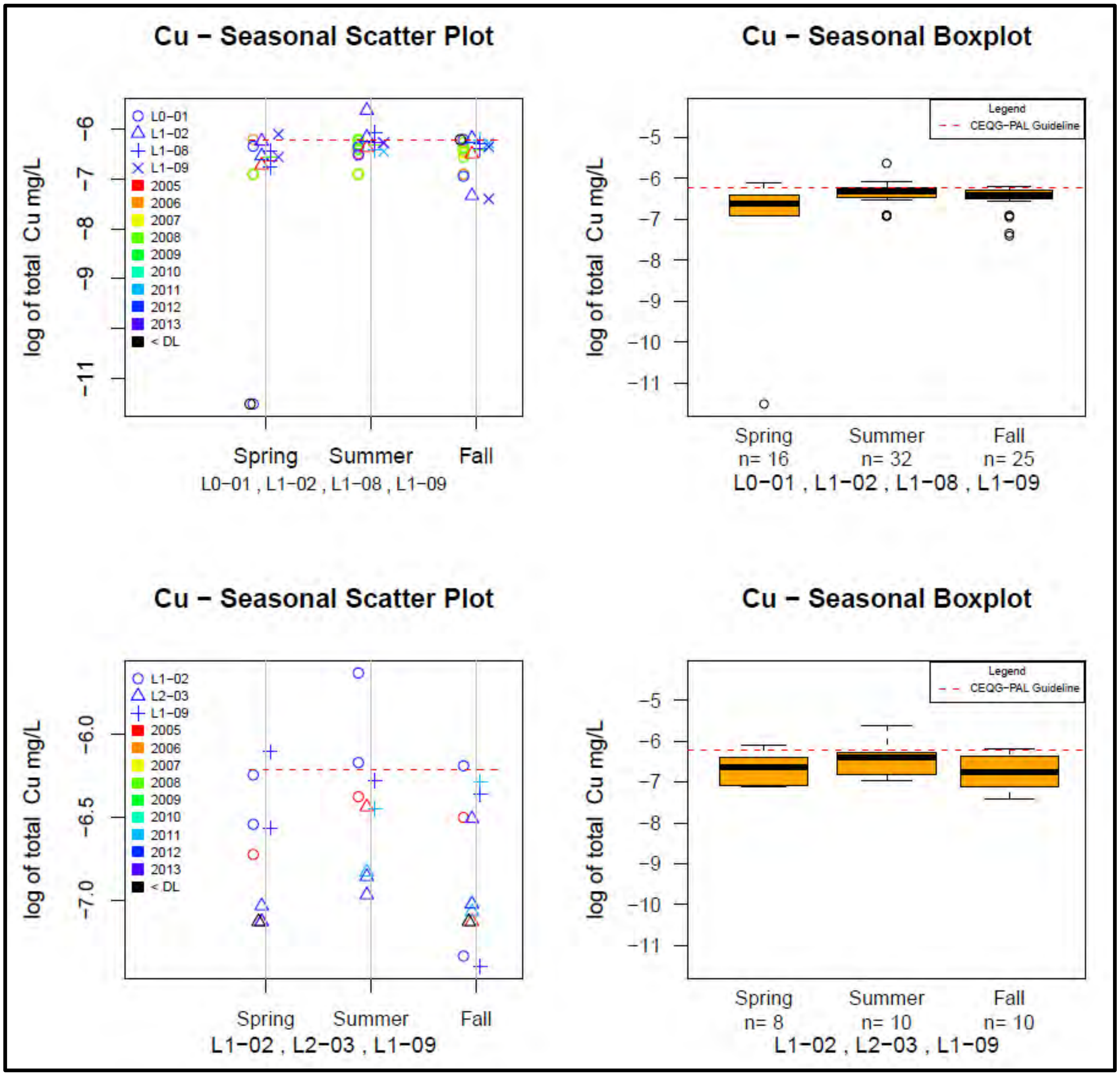
Large magnitude seasonal trends are not observed, but slightly elevated summer concentrations are observed (Figure C.31). No consistent temporal trends are noted over the eight-year sampling history.



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:

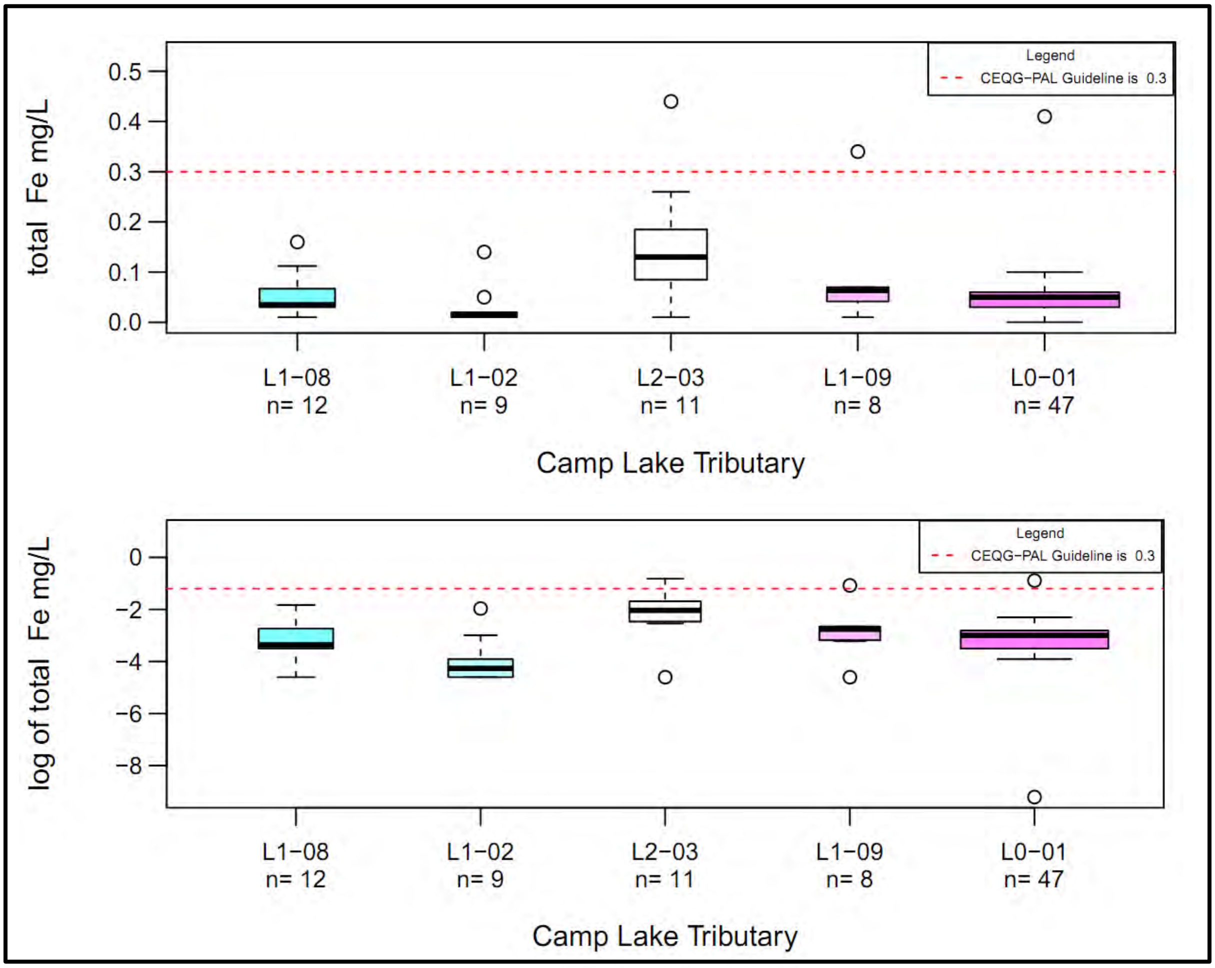
1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.
2. THE CWQG-PAL GUIDELINE LIMIT IS BASED ON THE TOTAL MEDIAN HARDNESS.

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.

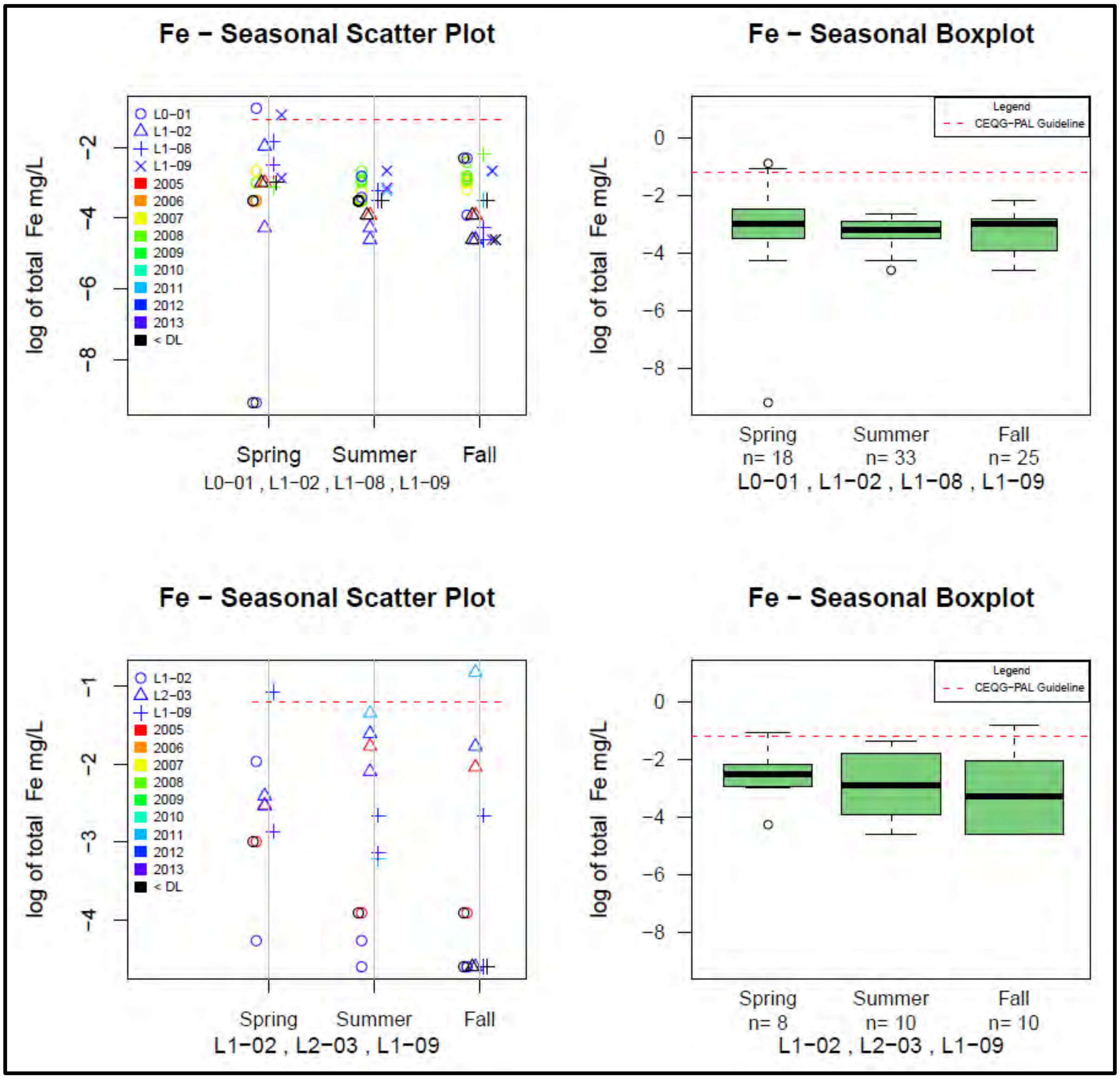
Seasonal box plots show fairly consistent median iron concentration, regardless of season (Figure C.33). In addition, no consistent temporal trends are noted over the eight-year sampling history.



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.

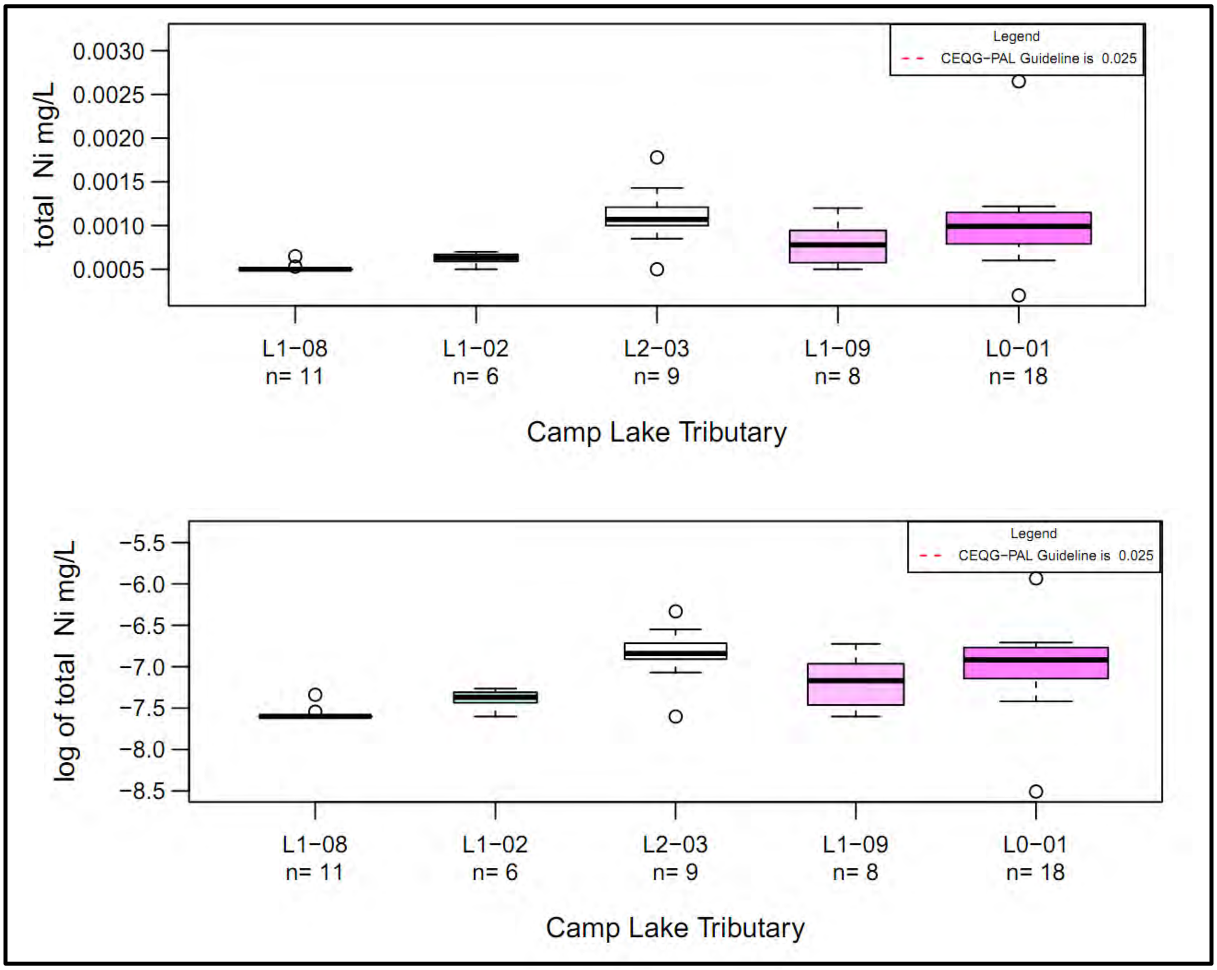
Figure C.33 Camp Lake Tributary – Variability of Total Iron in Water

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.

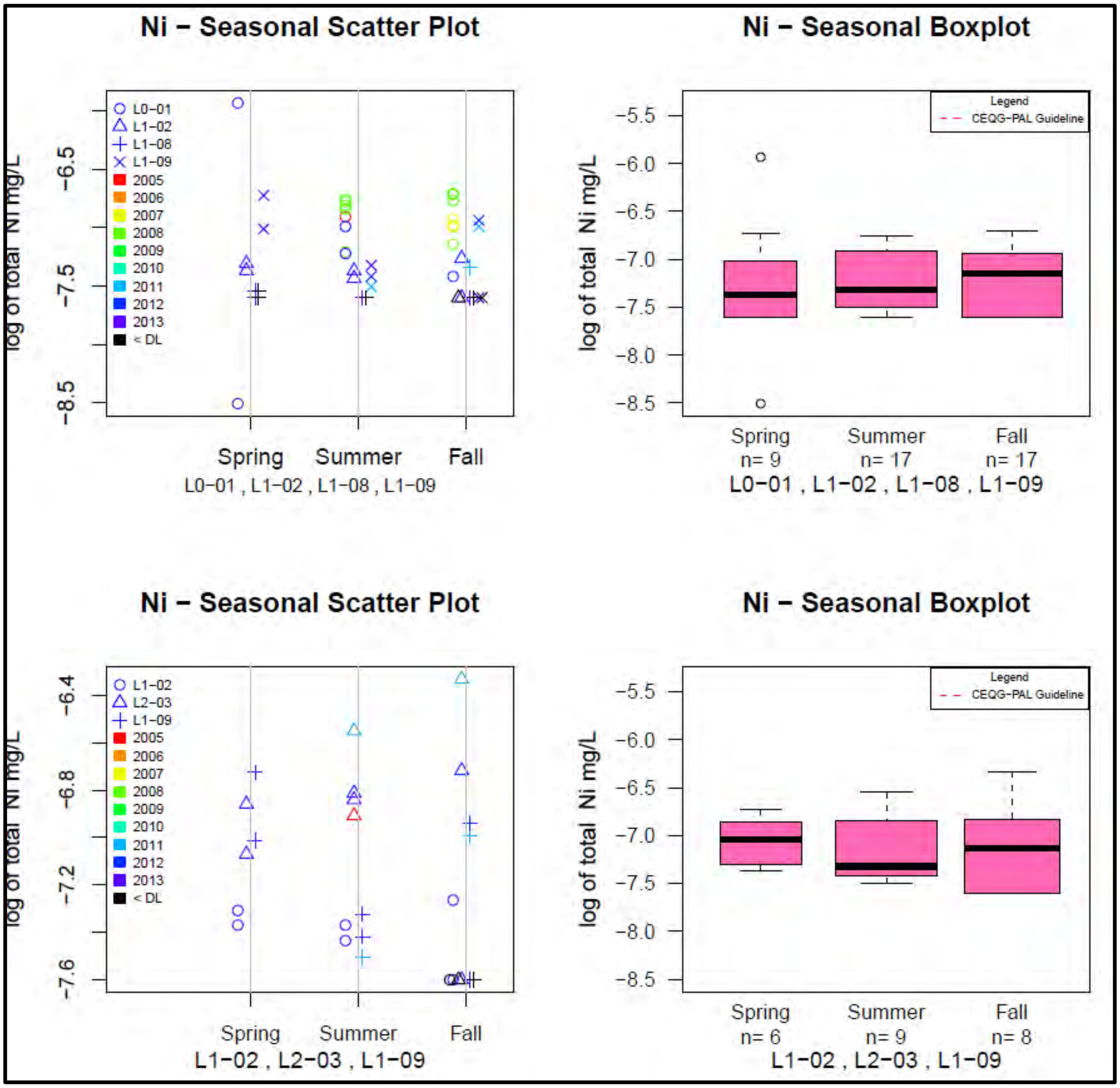
Seasonal box plots show consistent median iron concentration, regardless of season (Figure C.35). In addition, no consistent temporal trends are noted over the eight-year sampling history.



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:

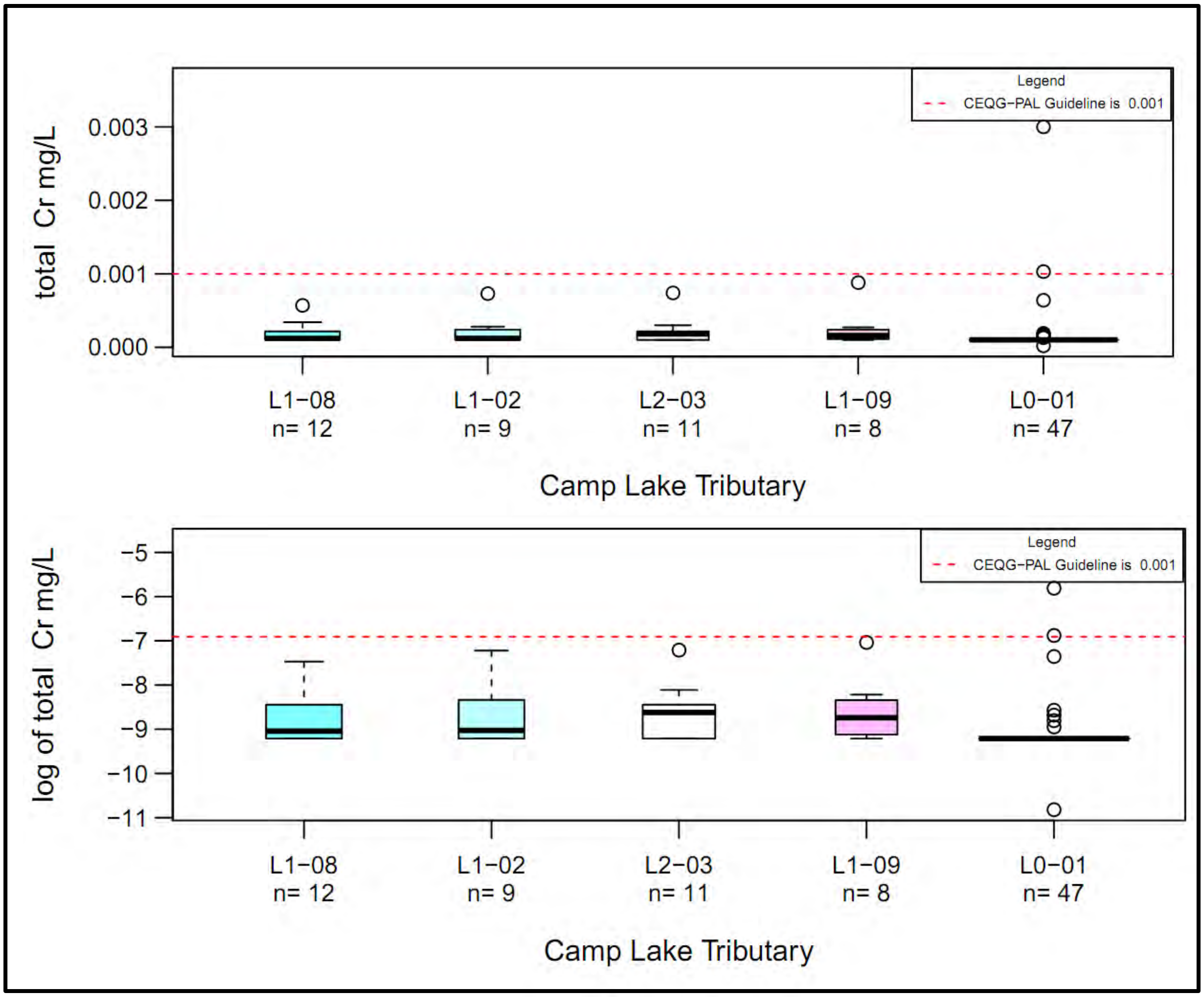
1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.
2. THE CWQG-PAL GUIDELINE LIMIT IS BASED ON THE TOTAL MEDIAN HARDNESS.

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).

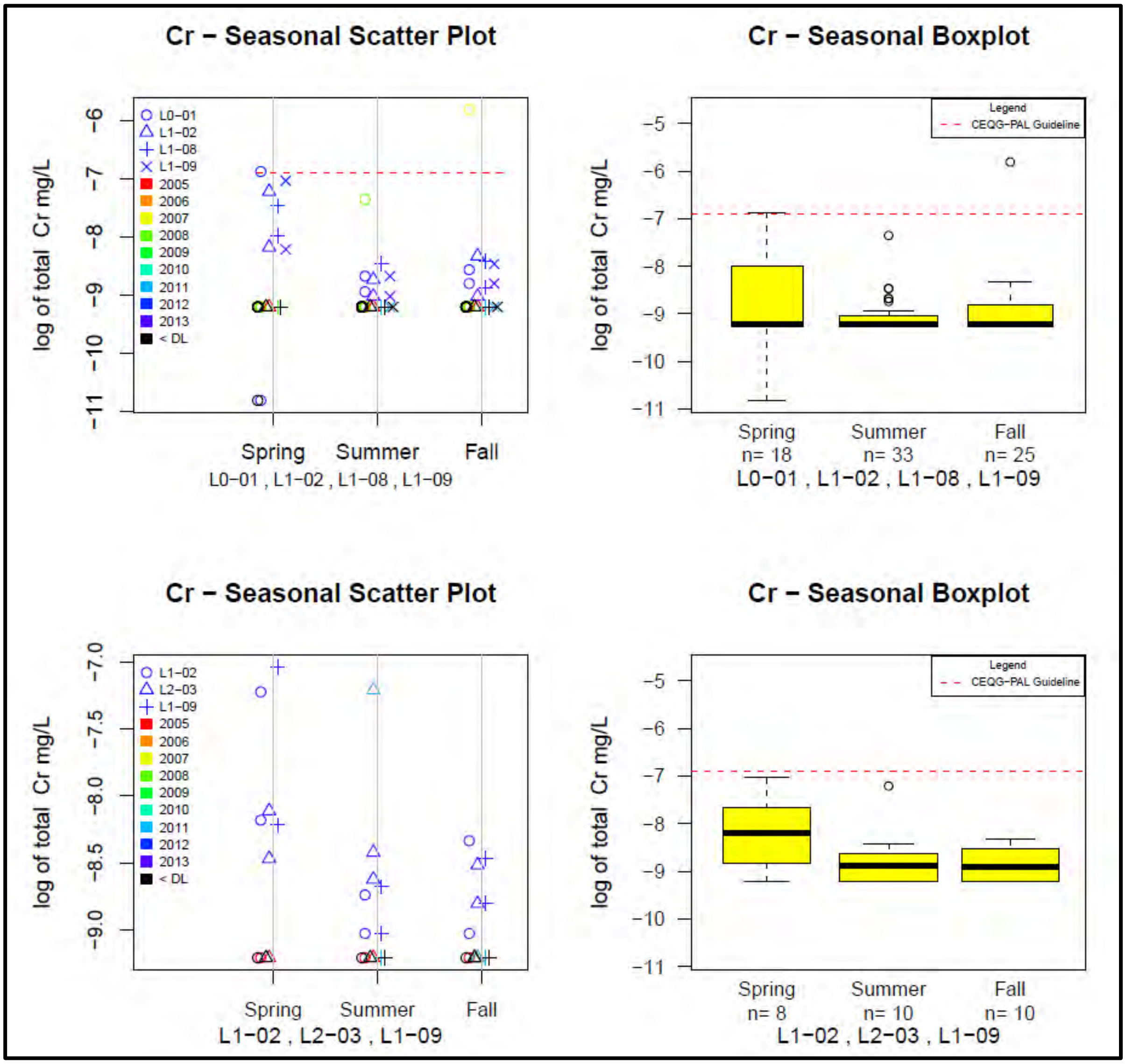
Seasonal box plots show consistent median chromium concentrations, regardless of season (Figure C.37). Data from 2012 and 2013 show slightly elevated values compared to previous years, but insufficient amount of data is avialable to prove this is the case.



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.

---

[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%

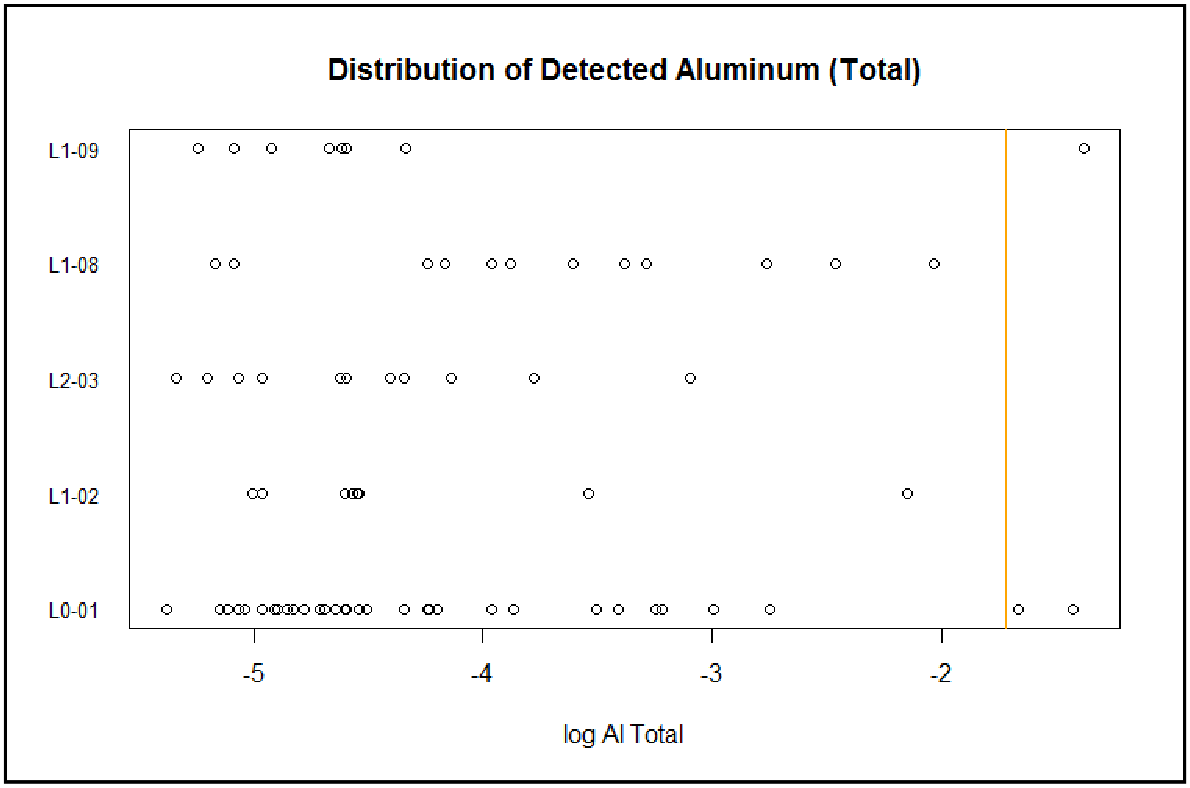
NOTES:

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

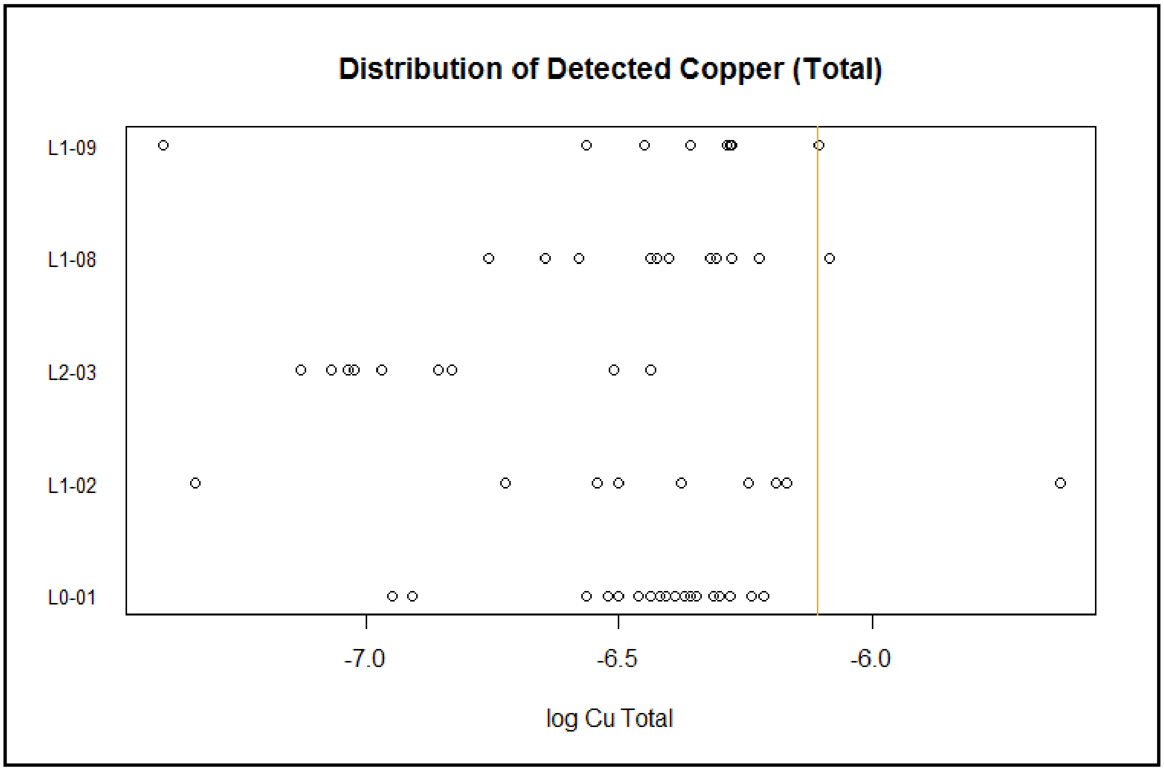
NOTES:

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

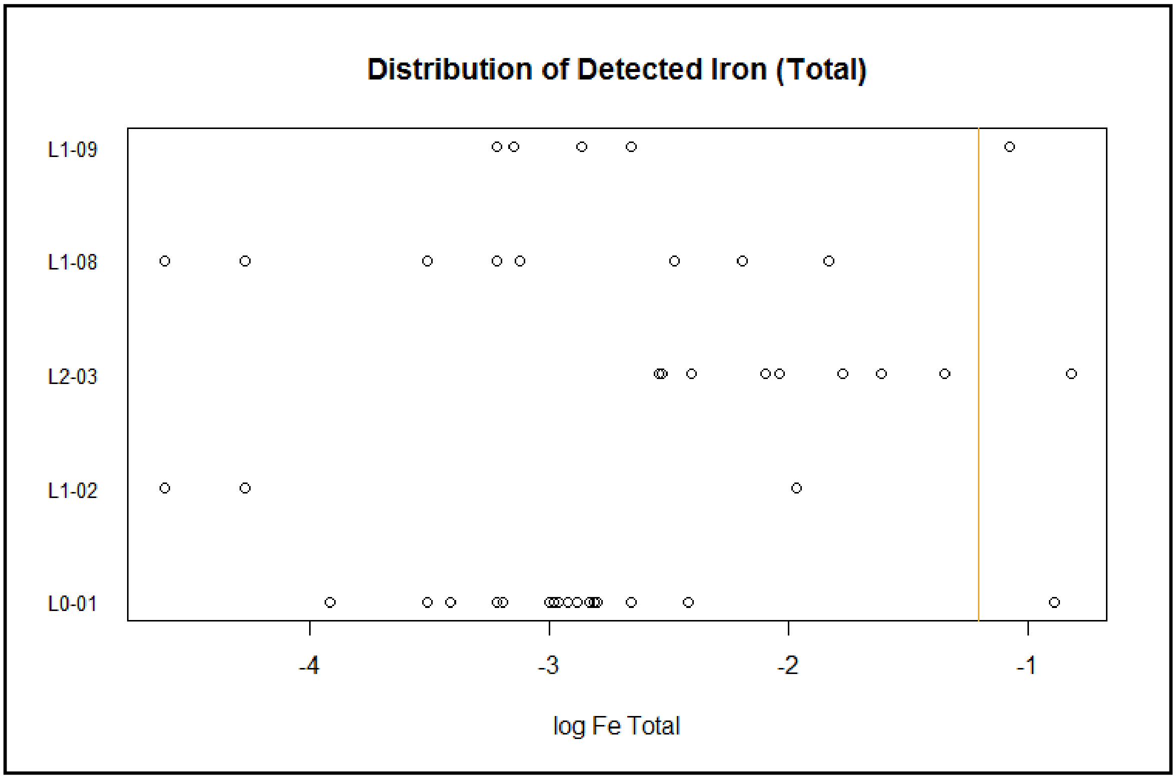
NOTES:

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

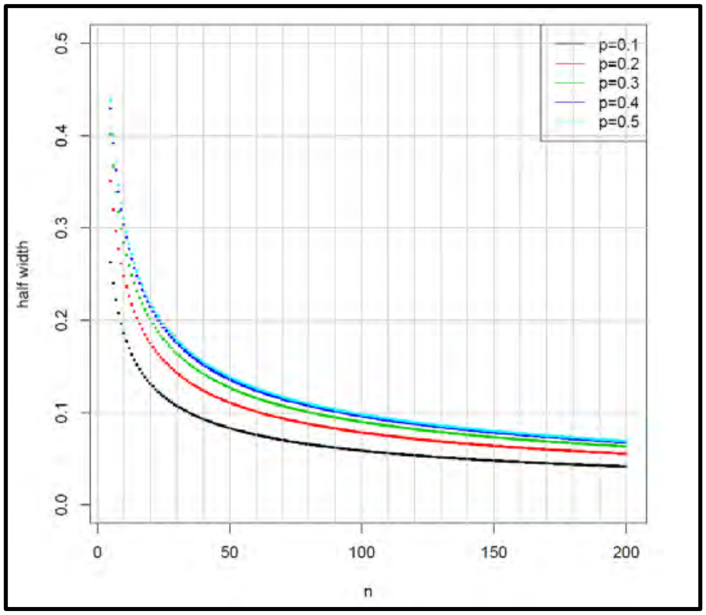
NOTES:

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

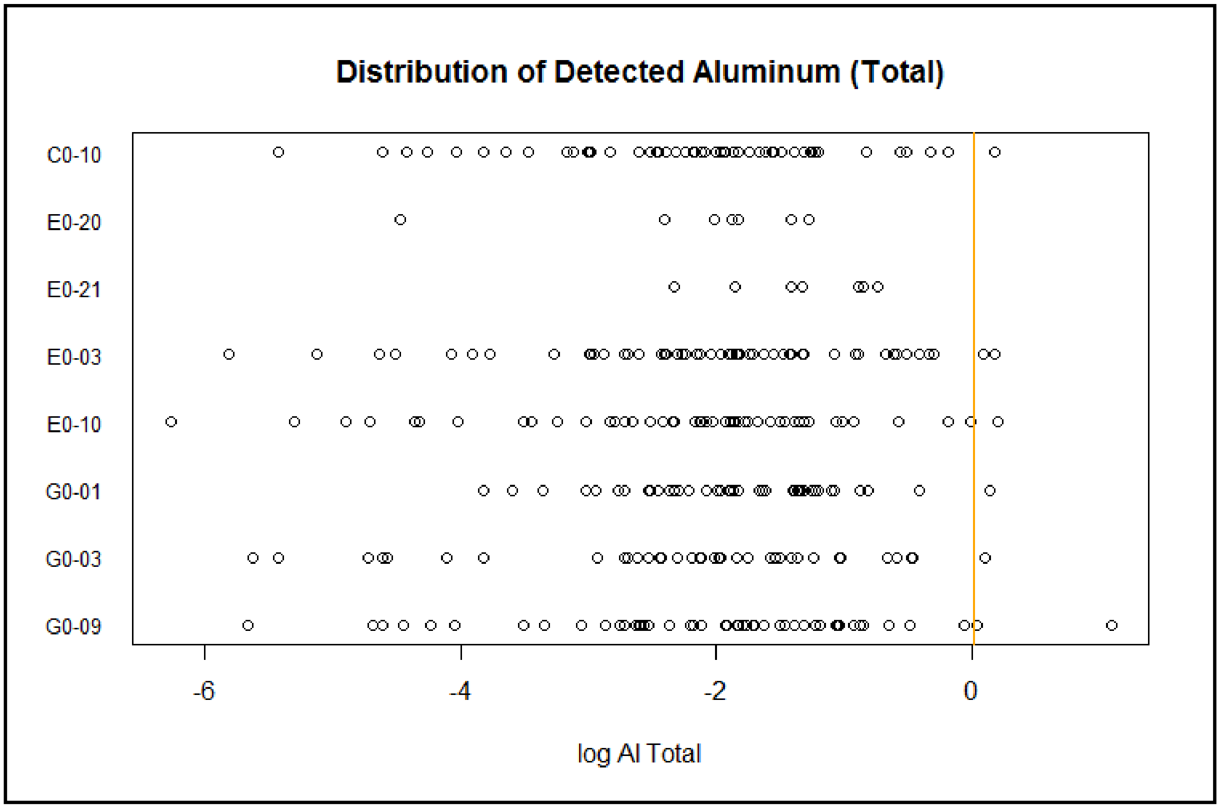
Since the power analysis was completed on a station-specific and parameter-specific basis, the results were interpreted by parameter and station. Unlike the Camp Lake Tributary, no particularly constraining stations or parameters were identified. Power analysis determined between five to ten samples 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

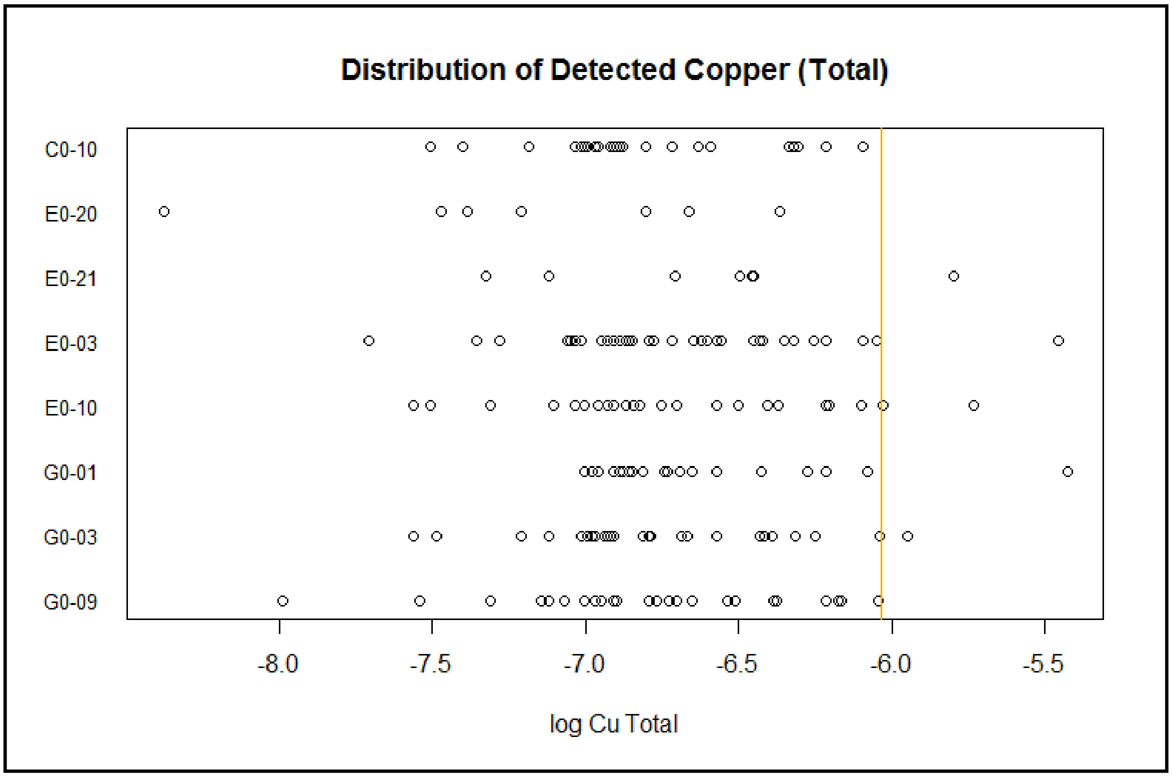
NOTES:

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

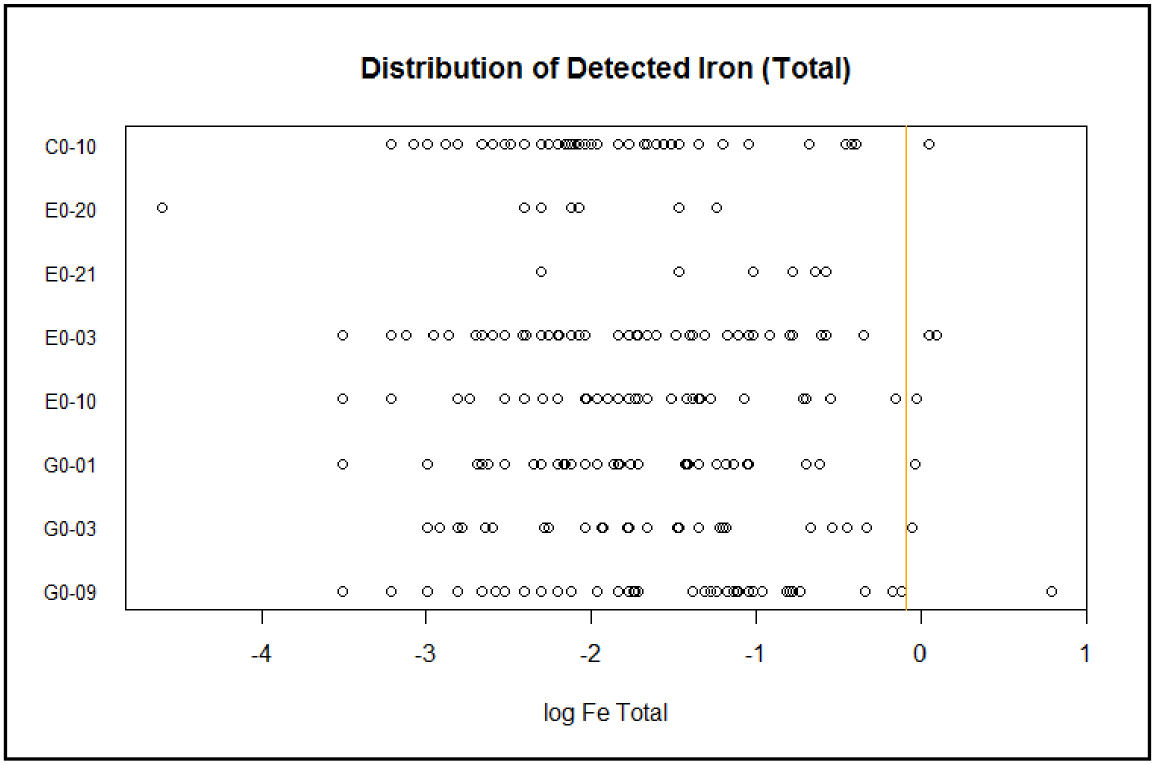
Station	Total Sample Size	Sample Size Detected	Median (mg/L)	Standard Deviation (mg/L)	Log Mean (mg/L)	Log Standard Deviation (mg/L)	ROS Log Mean (mg/L)	Benchmark Value (mg/L)	Log Benchmark Value (mg/L)	Difference between log mean and log benchmark (mg/L)	N Required
G0-09	36	36	0.0011	0.00051	-6.7	0.42	-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

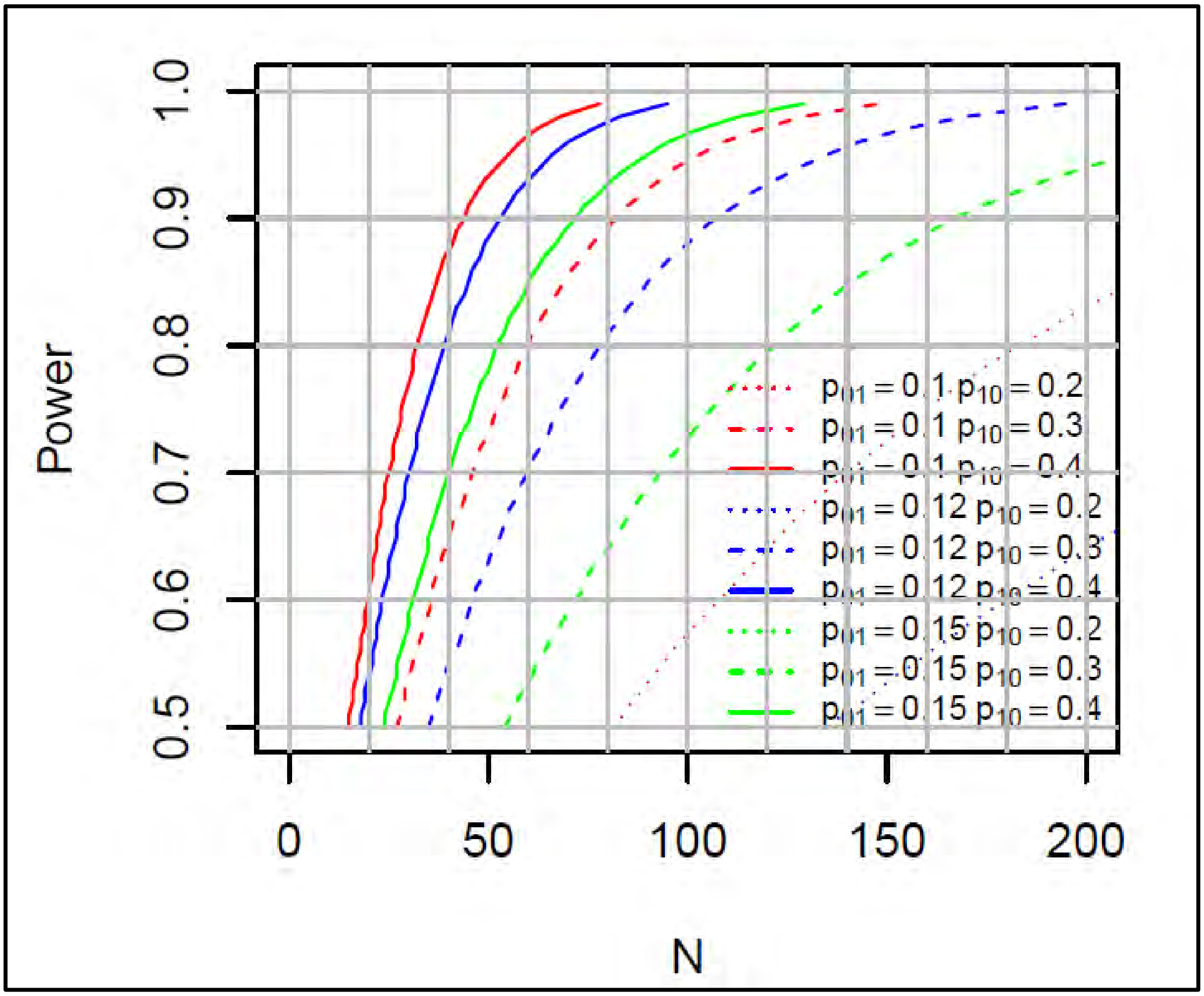


Figure C.45 Arsenic Sample Size Requirements for Equality of Proportions

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

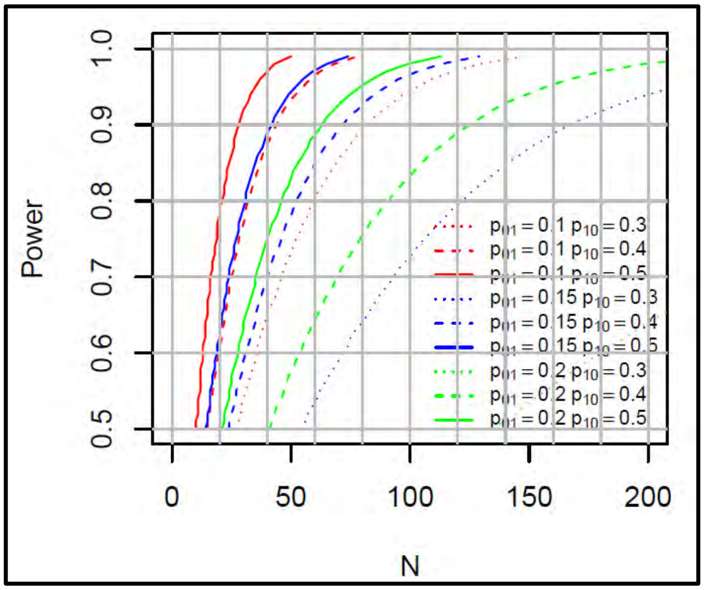


Figure C.46 Cadmium Sample Size Requirements for Equality of Proportions

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

Agresti, A, 1990. Categorical Data Analysis. Wiley Series, New York.

Baffinland Iron Mines Corporation. 2013. *Mary River Project – Updated Aquatic Effects Monitoring Program Framework.* December 2013.

Huston, C. and Juarez-Colunga, E. 2009. Guidelines for computing summary statistics for data-sets containing non-detects. Written for the Bulkley Valley Research Center with assistance from the B.C. Ministry of Environment.

Smith, E. 2002. BACI Design. Encyclopedia of Environmetrics. John Wiley and Sons.1(141-148).

Stewart, K.A. and Lamoureux, S.F., 2011. Seasonal hydrochemical conditions and limnological response in adjacent High Arctic lakes: Cape Bounty, Melville Island, Nunavut. *Arctic* 64: 169-182.

Stroup, W.W., 1999. *Mixed Model Procedures to Assess Power, Precision, and Sample Size in the Design of Experiments*. Department of Biometry, University of Nebraska.

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

Knight Piésold Ltd.
1650 Main Street West
North Bay, Ontario Canada P1B8G5
Telephone: (705) 476-2165
Facsimile: (705) 474-8095
www.knightpiesold.com

Knight Piésold
CONSULTING

TABLE OF CONTENTS

TABLES

FIGURES

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.

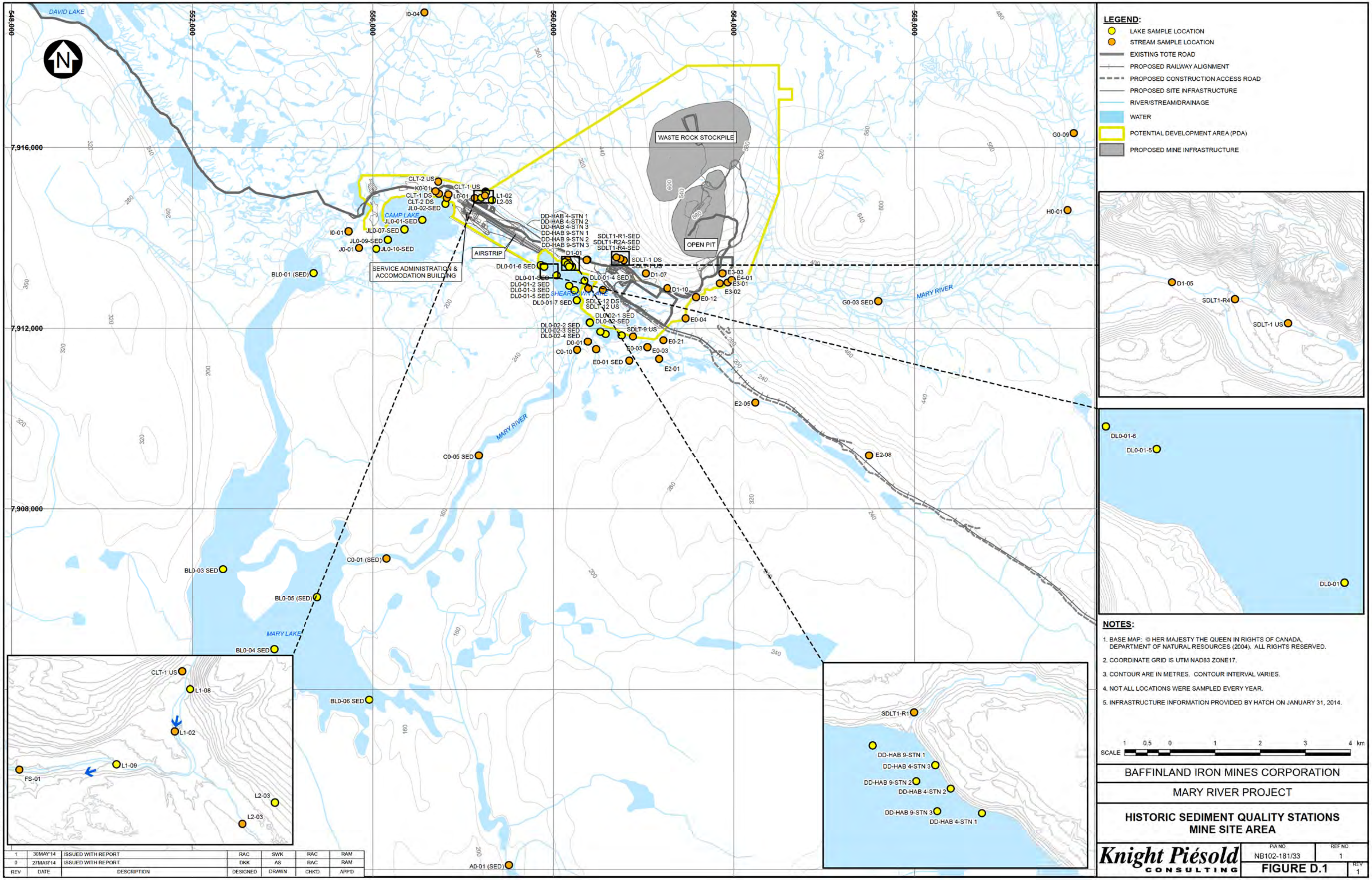
To assist in the development of study designs, parameter and station-specific a priori power analyses were completed in order to determine the power of the proposed sampling program to detect statistical changes. As per the Assessment Approach and Response Framework in the CREMP (see Figure 2.12 in the 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.



SAVED: I:\1\02\00181\33\A\GIS\Figs\B44_r1.mxd; May 30, 2014 1:28 PM; skozmick

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.

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

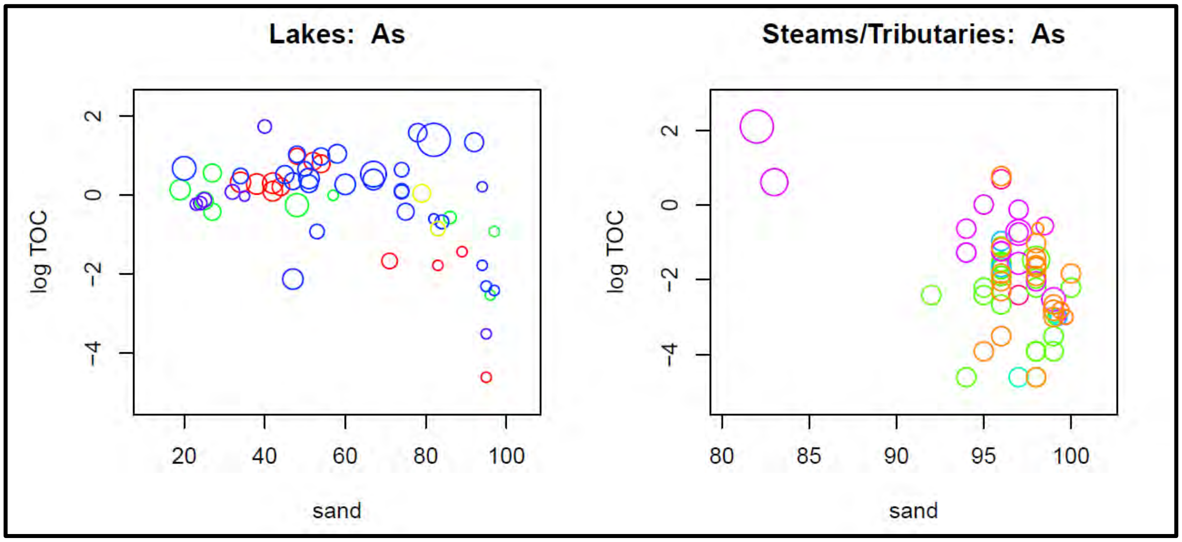
P/A NO.	REF NO.
NB102-181/33	1

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.



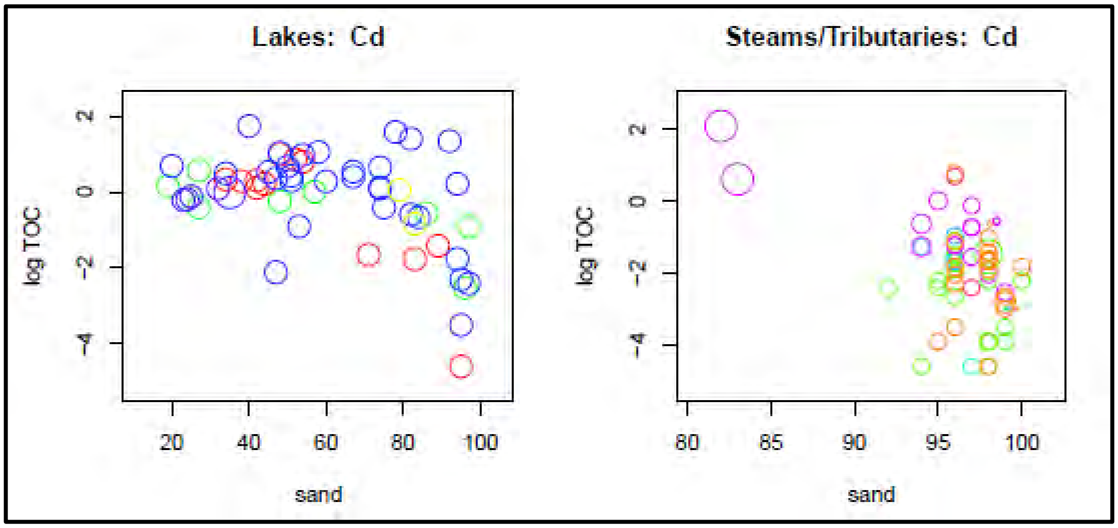
NOTES:

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).



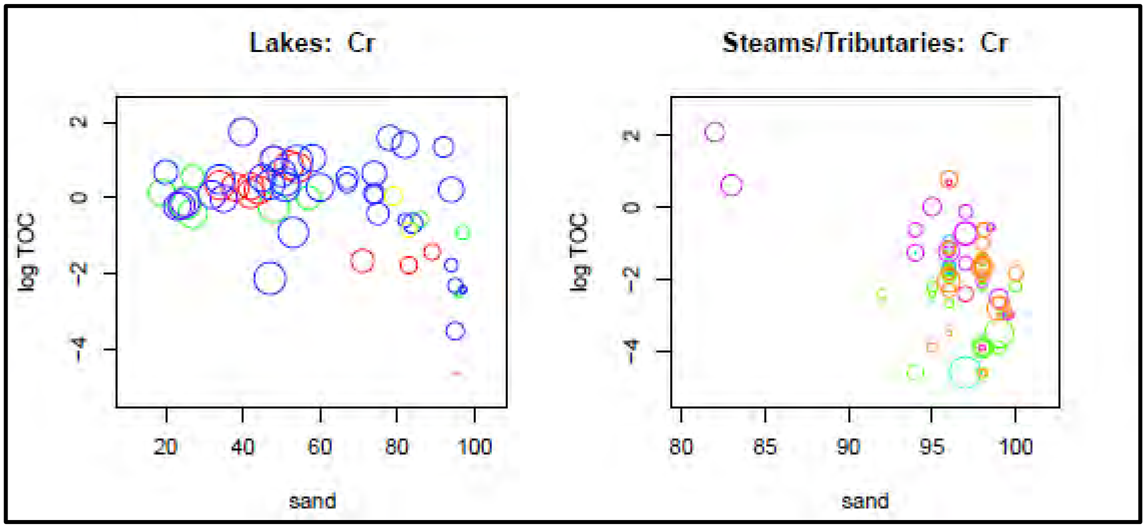
NOTES:

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.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.



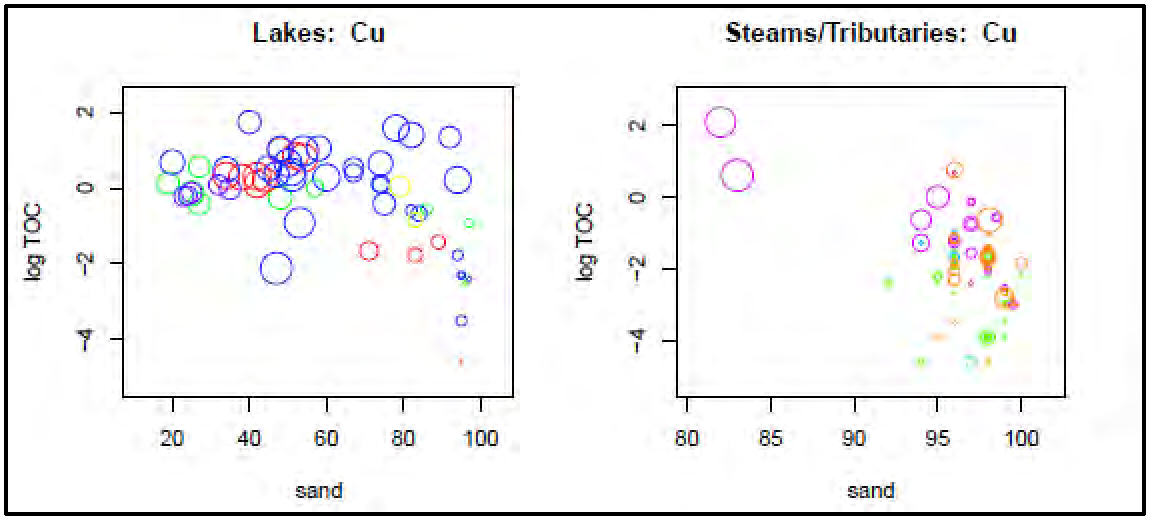
NOTES:

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.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.



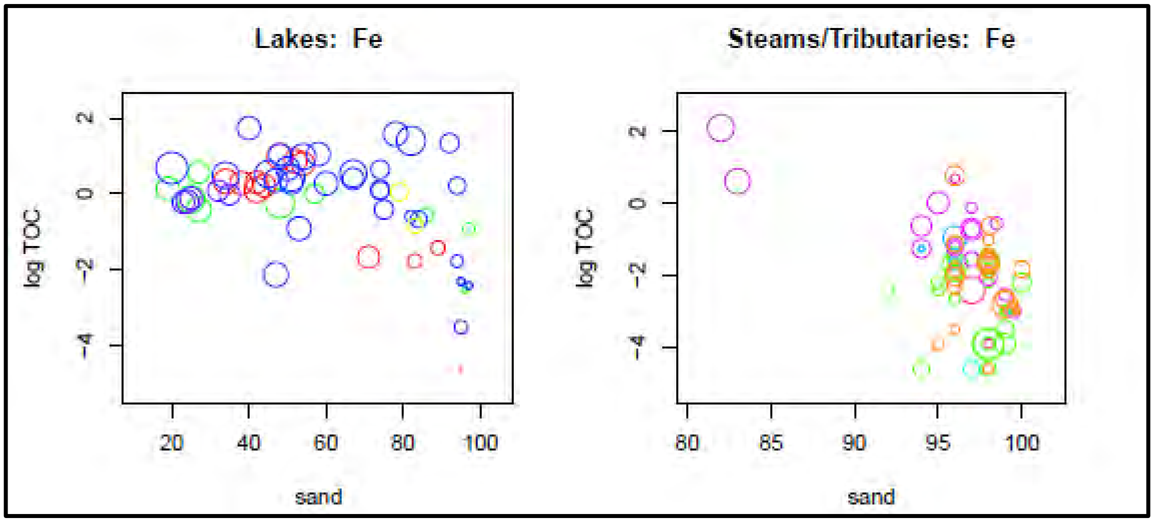
NOTES:

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.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.



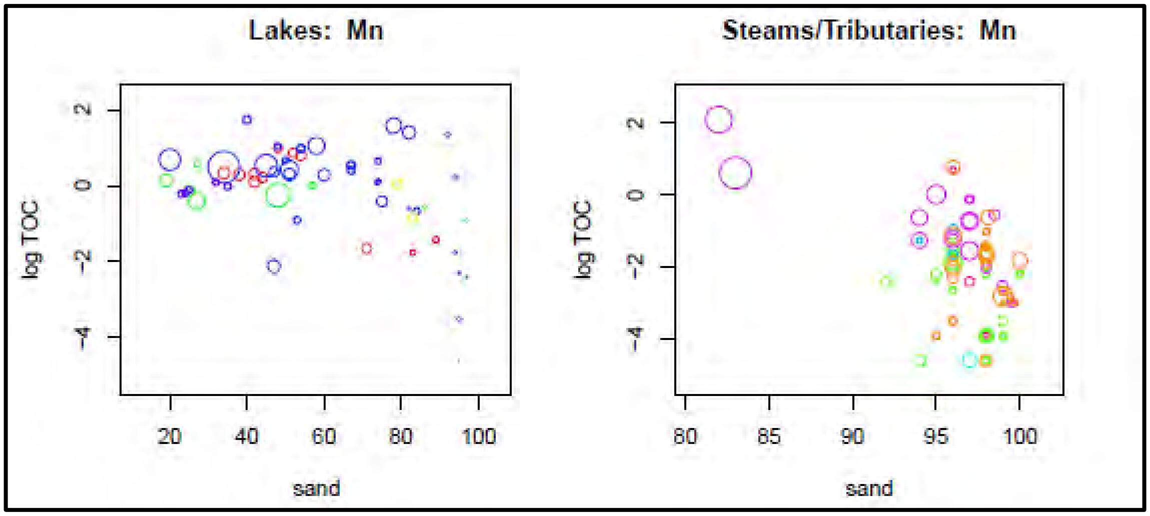
NOTES:

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.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).



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.

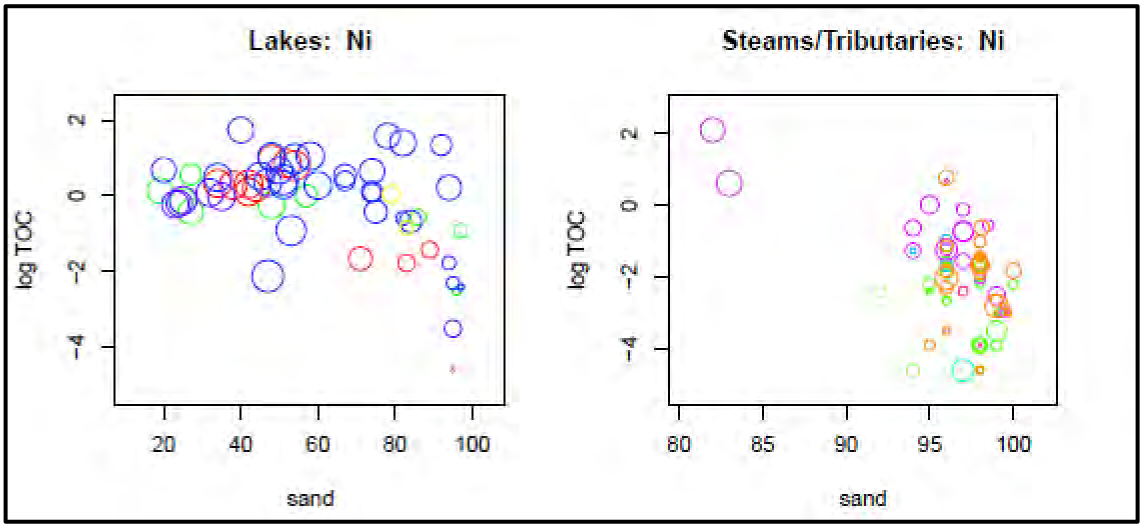
Figure D.7 Manganese in Sediment as a Function of Log TOC and Percent Sand

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.



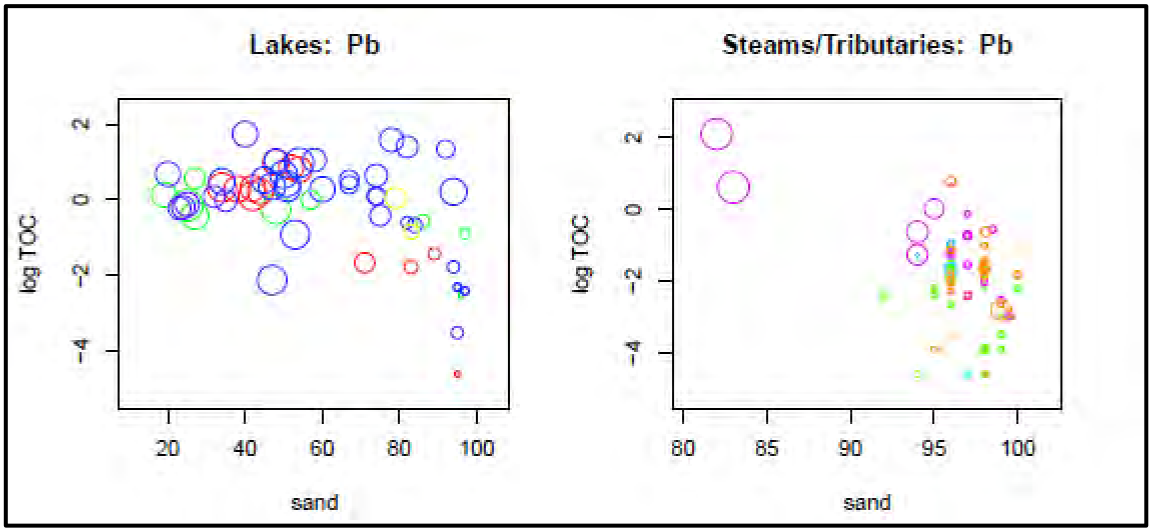
NOTES:

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.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).



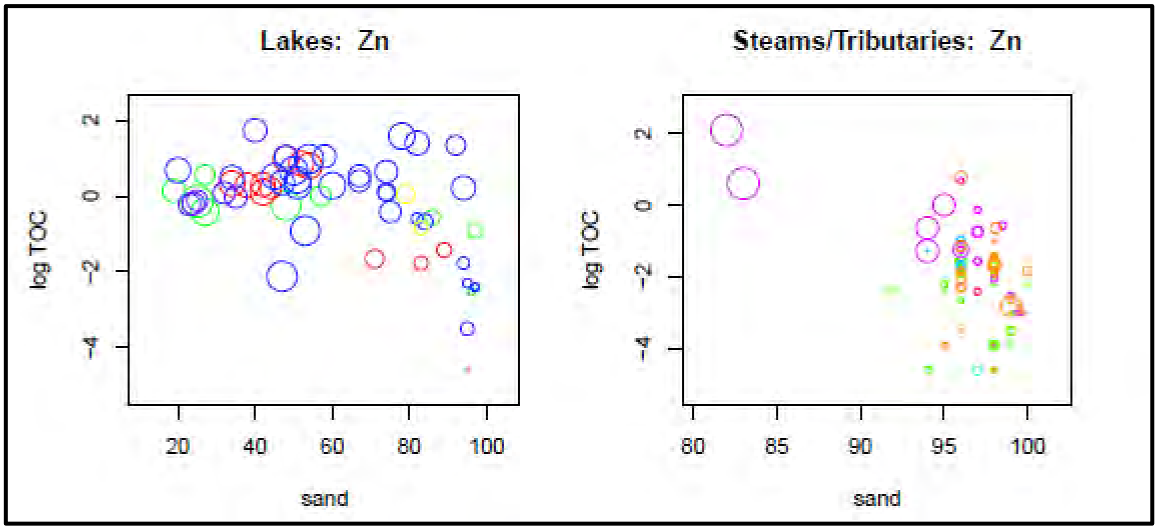
NOTES:

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.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.

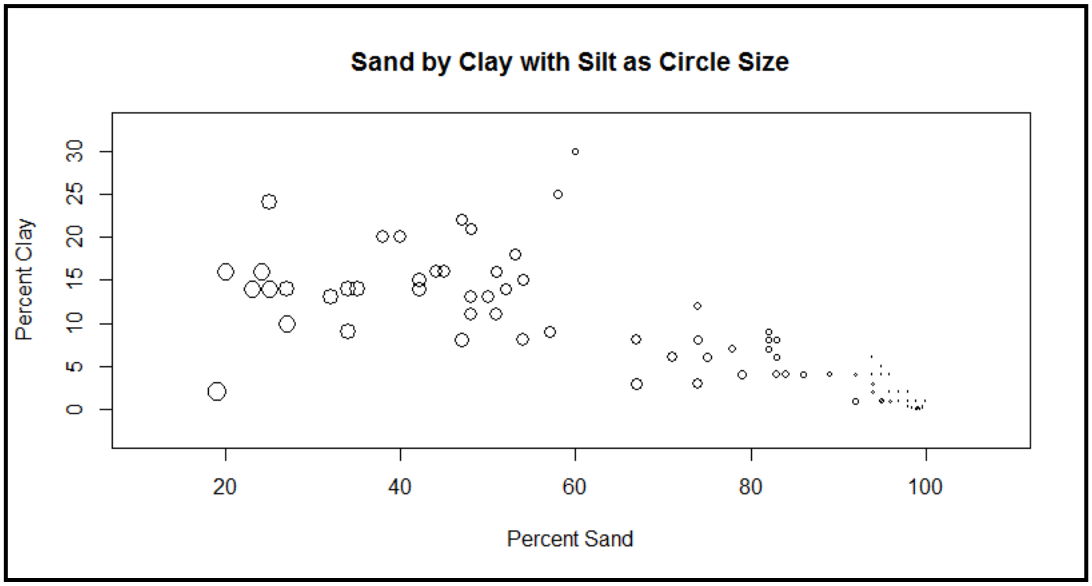


Figure D.11 Clay by Sand with Silt as Circle Size

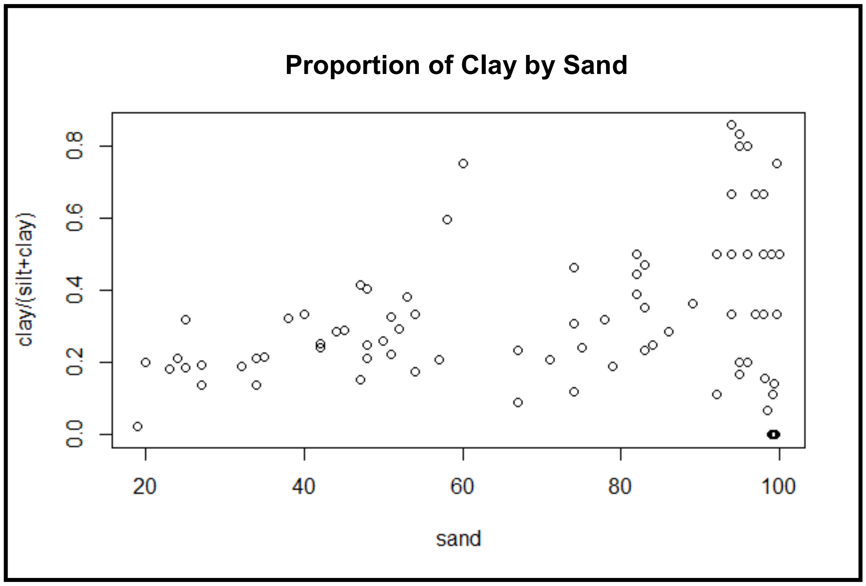


Figure D.12 Dependent Relationship between Sand, Silt and Clay in Sediment

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).

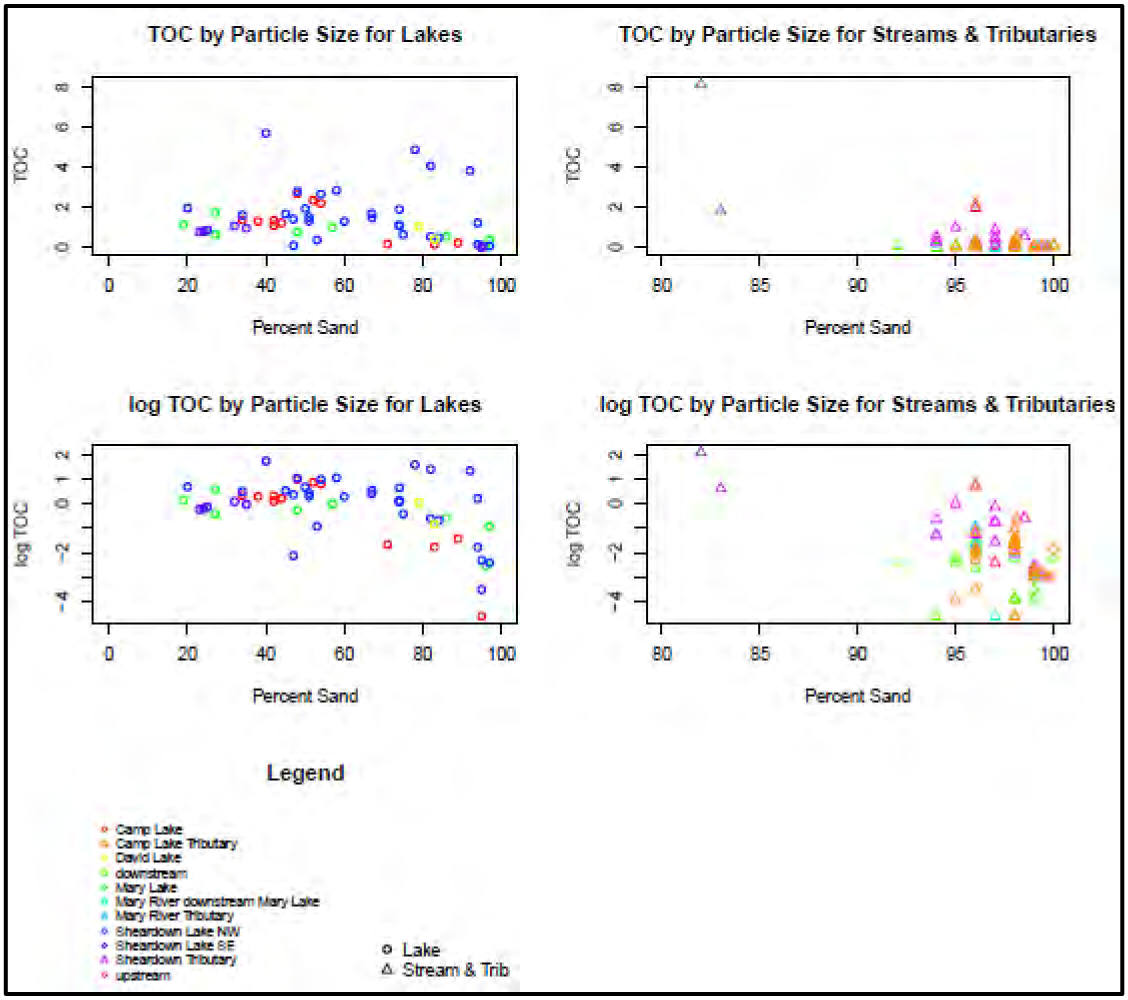


Figure D.13 Sediment TOC versus Particle Size for Lakes and Streams

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.

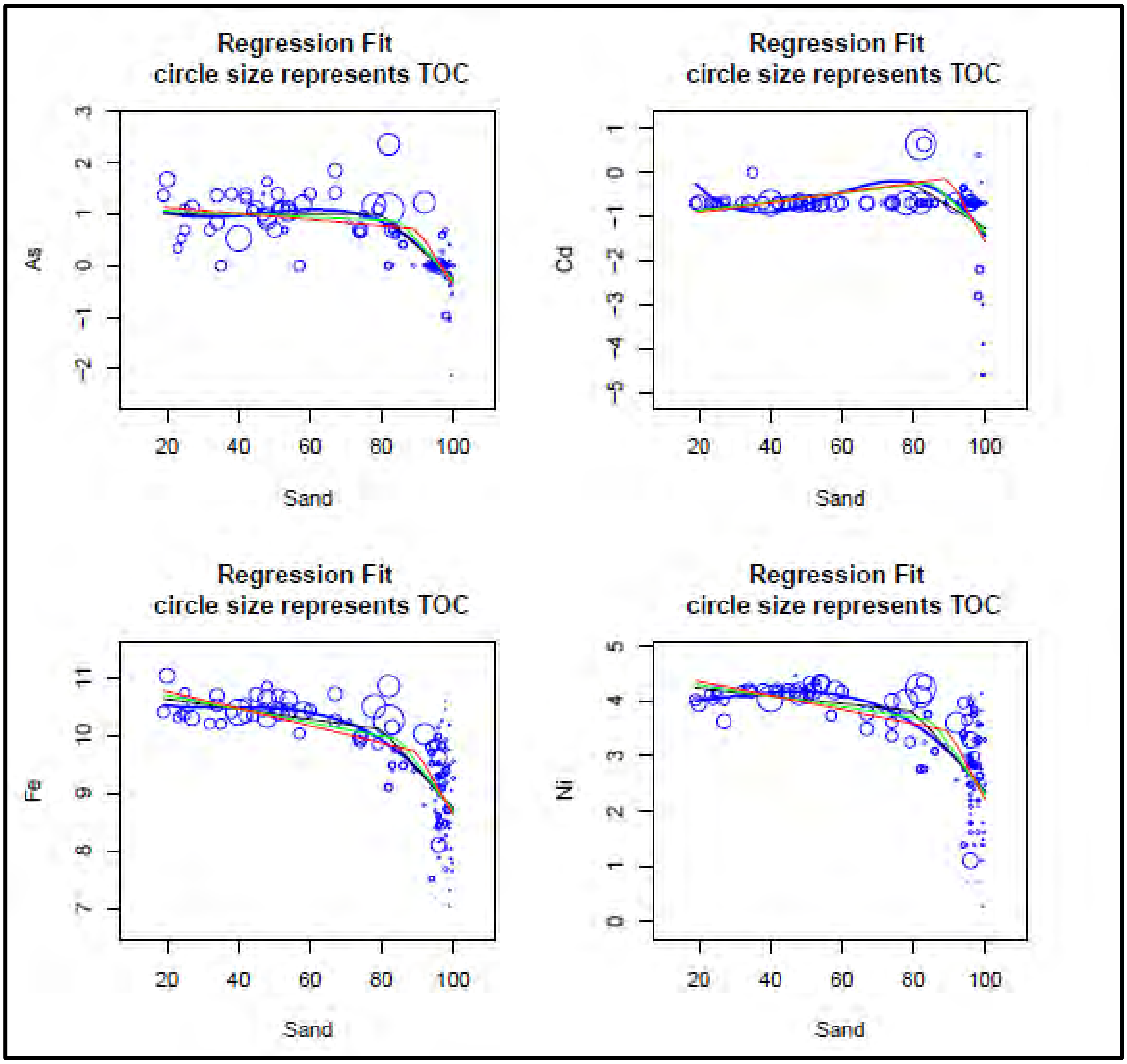


Figure D.14 Concentrations of As, Cd, Fe and Ni in Sediment Based on Percent Sand

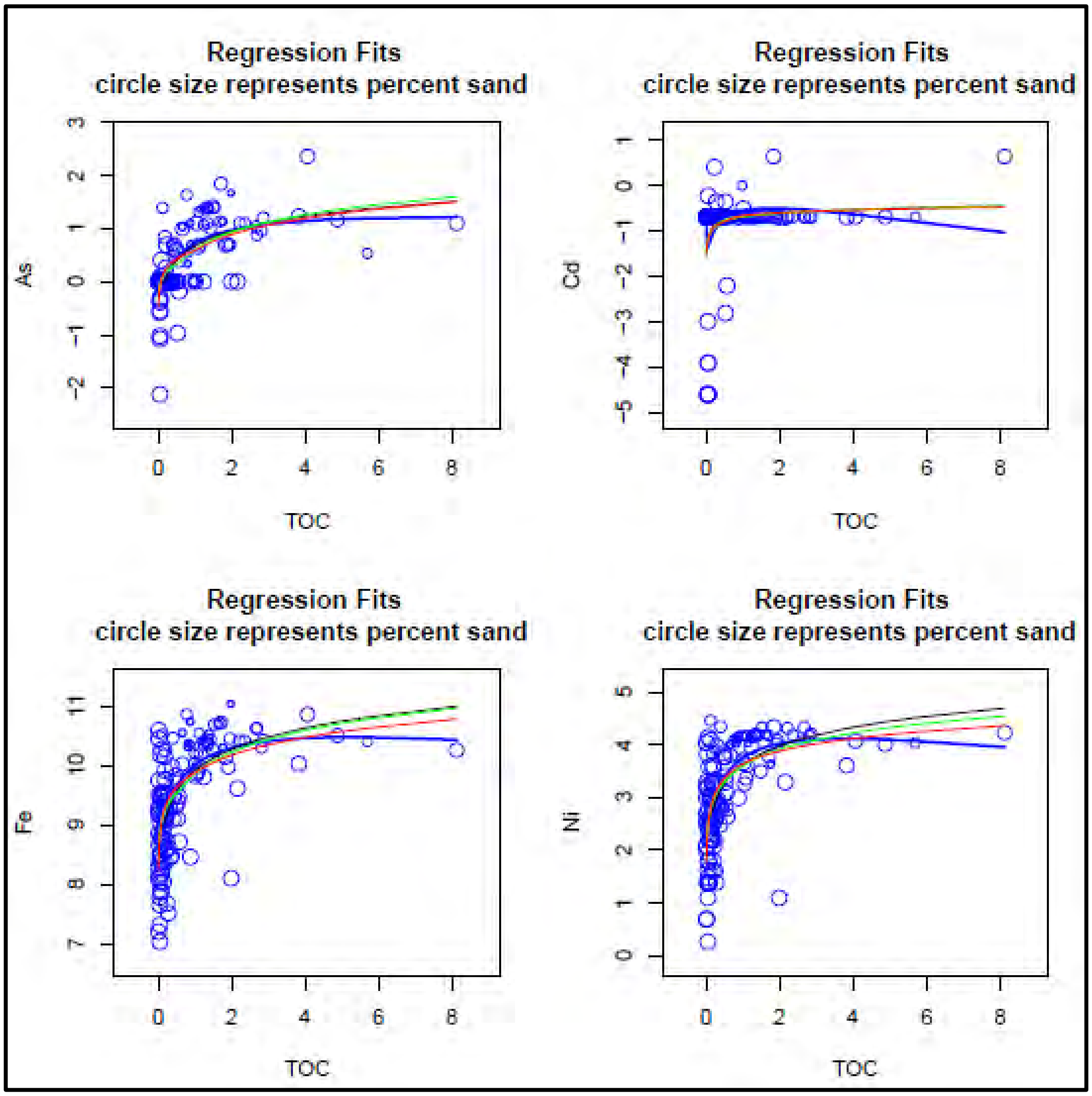


Figure D.15 **Concentrations of As, Cd, Fe and Ni in Sediment Based on Percent TOC**

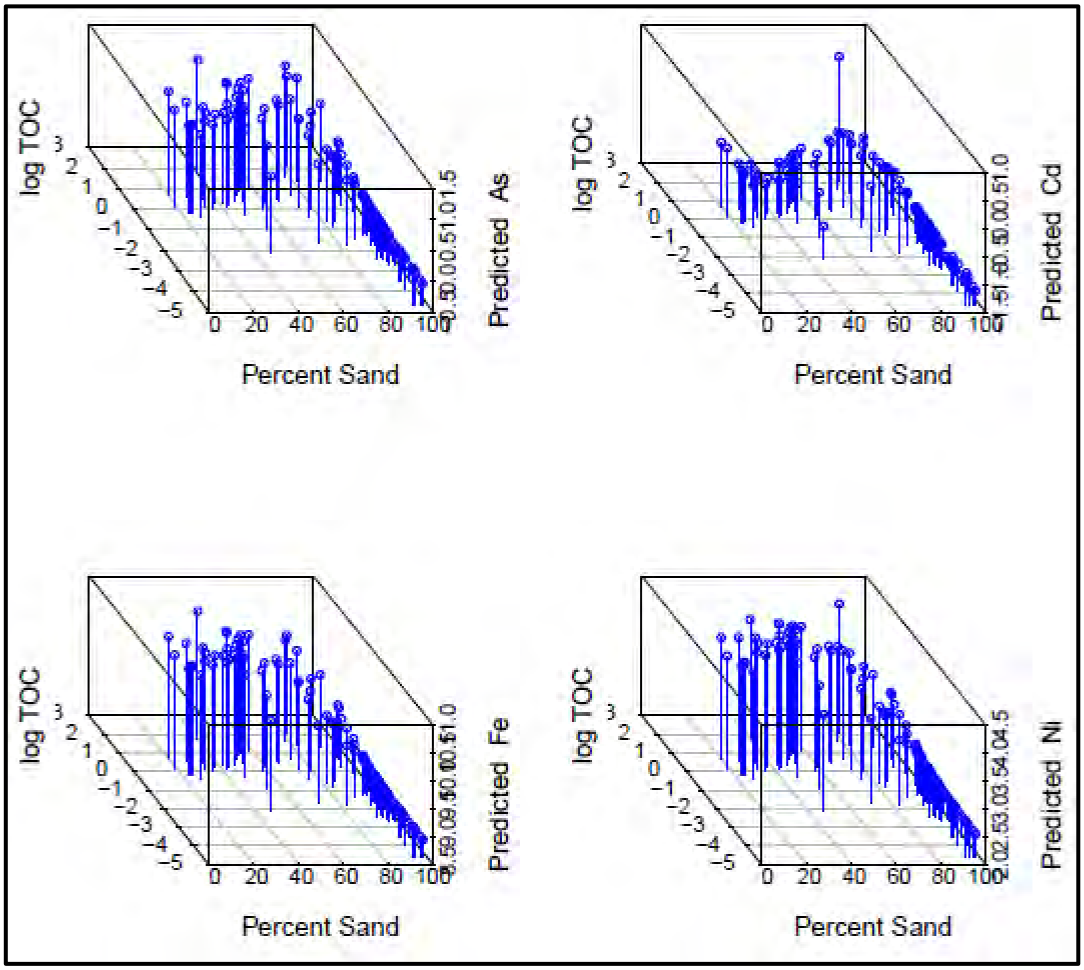


Figure D.16 Concentrations of As, Cd, Fe and Ni in Sediment Based on Log TOC and Percent Sand

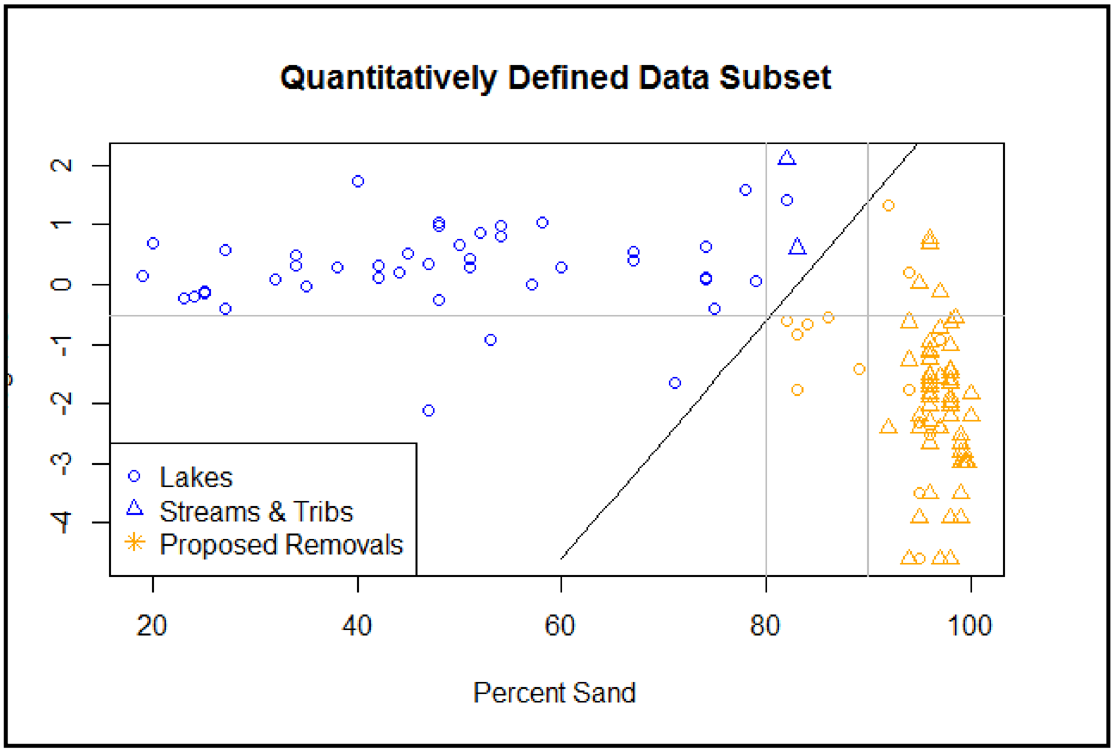


Figure D.17 Results of Cut Point Analysis for Sediment

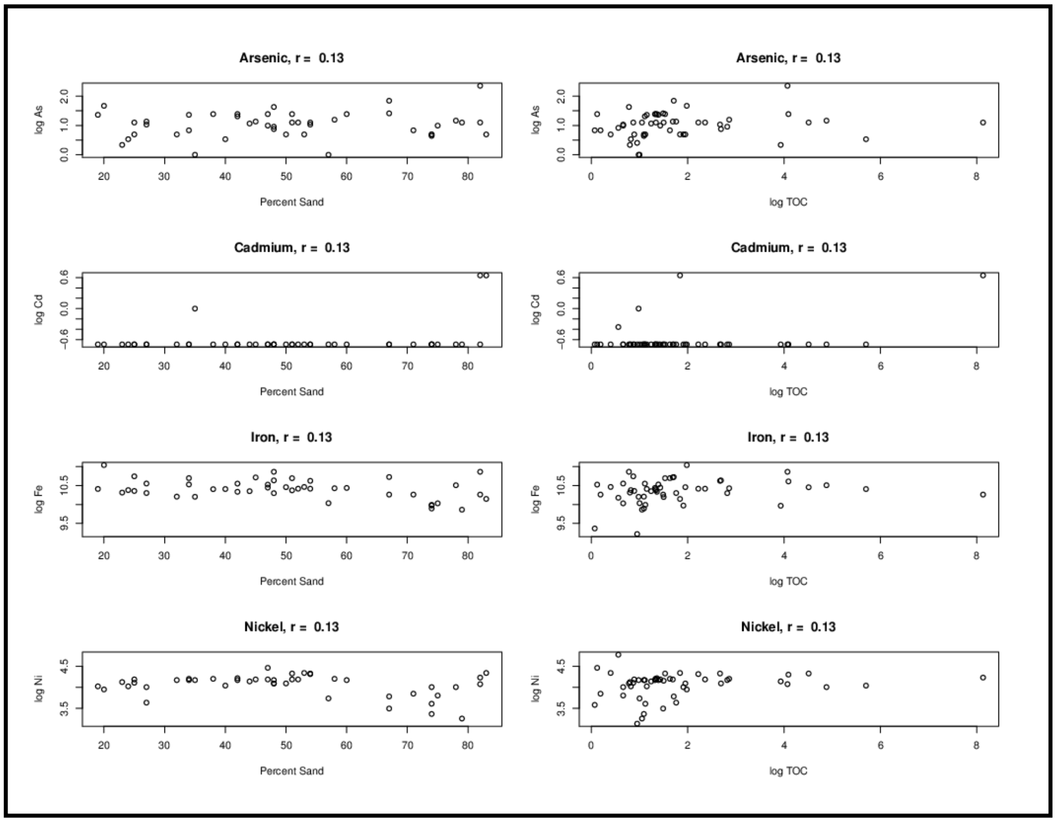


Figure D.18 Correlations between TOC and Percent Sand, and the 4 Key Parameters for the Subset Data, Second Stage Cuts in Blue

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.

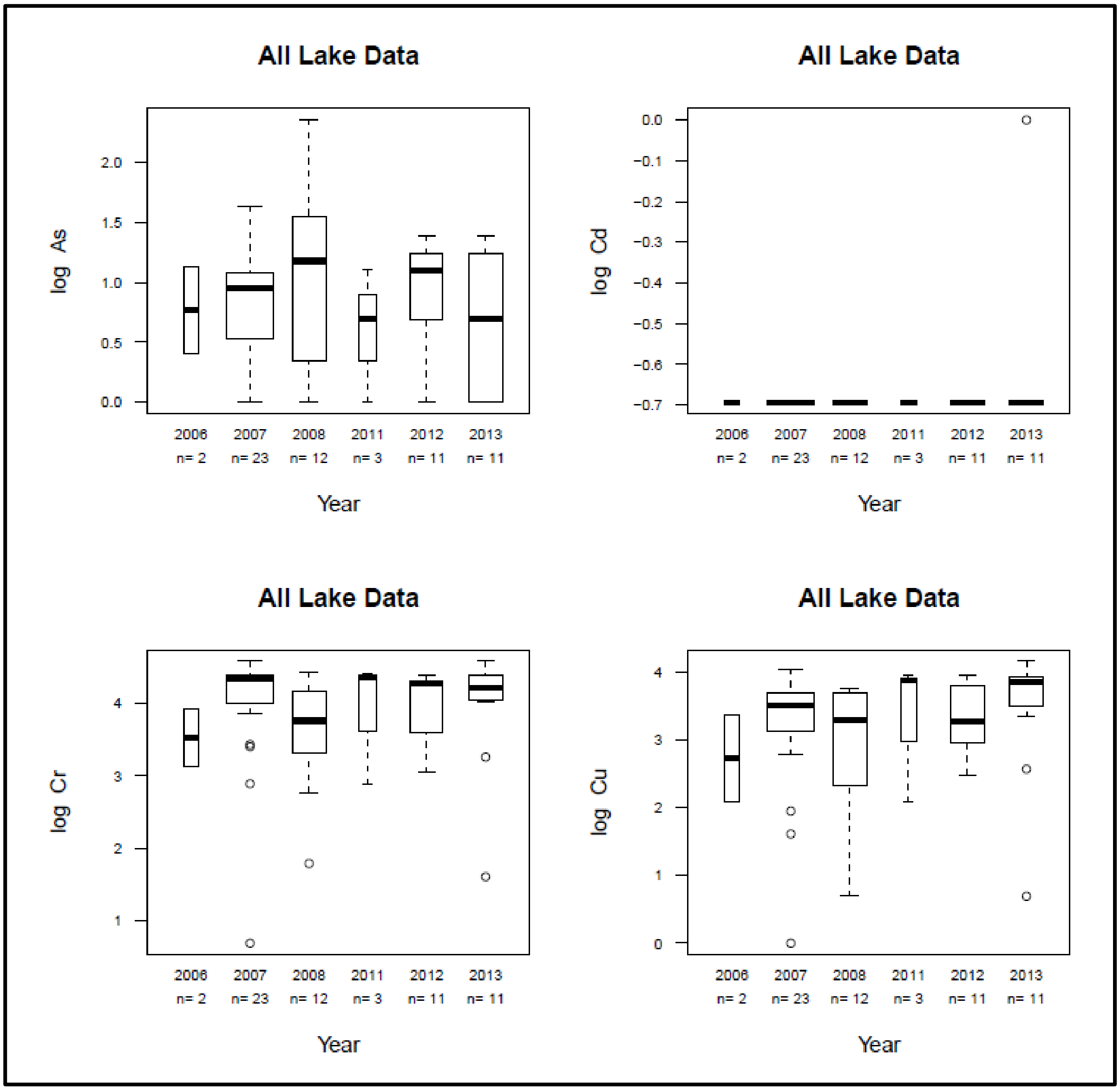


Figure D.19 Inter-Annual Variability for As, Cd, Cr and Cu in Sediment

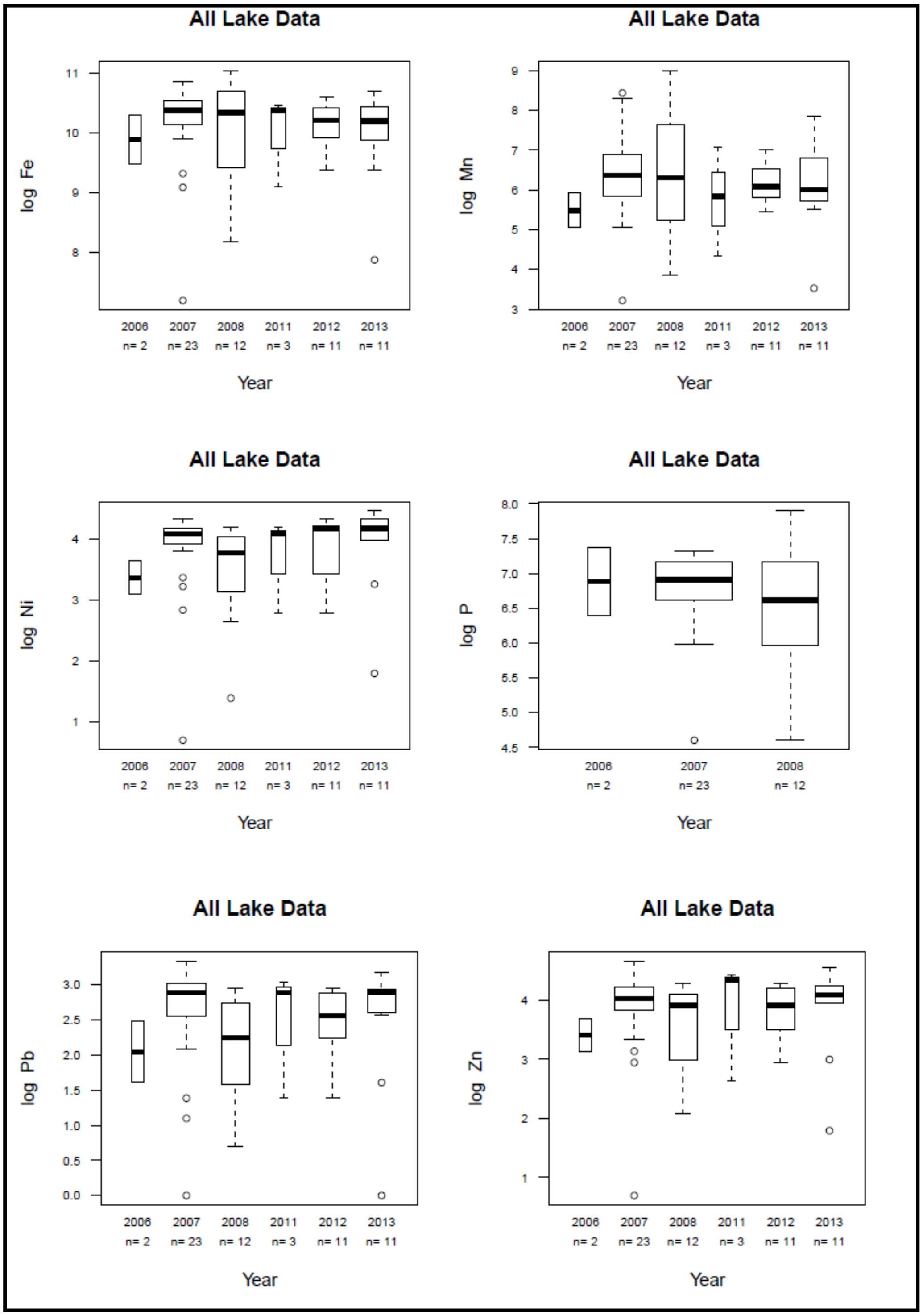


Figure D.20 Inter-Annual Variability for Fe, Mn, Ni, P, Pb and Zn in Sediment

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

WATER QUALITY DATA

(Pages C-1 to C-6)

TABLE C.1

BAFFINLAND IRON MINES CORPORATION
MARY RIVER PROJECT

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

Print Jun/26/14 11:47:26

			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

TABLE C.1

BAFFINLAND IRON MINES CORPORATION
MARY RIVER PROJECT

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

Print Jun/26/14 11:47:26

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

TABLE C.1

BAFFINLAND IRON MINES CORPORATION
MARY RIVER PROJECT

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

Print Jun/26/14 11:47:26

			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.

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**													
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

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**													
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

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.

1.3 TAXONOMIC REFERENCES

Allen, R.K., and G.F. Edmunds, Jr. (1963). A revision of the genus *Ephemerella* (Ephemeroptera: Ephemerellidae). VII. The subgenus *Eurylophella*. The Canadian Entomologist 95: 597-623.

Allen, R.K., and G.F. Edwards, Jr. (1965). A review of the genus *Ephemerella* (Ephemeroptera: Ephemerellidae) VIII. The subgenus *Ephemerella* in North America. Misc. Publ. Ent. Soc. Am. 4:243-282.

Archangelsky, M. (1997). *Studies on the Biology, Ecology, and Systematics of the Immature Stages of New World Hydrophiloidea (Coleoptera: Staphyliniformia)*. Ohio Biological Survey, Columbus, Ohio. 207pp.

Bednarik, A.F., and W.P. McCafferty. (1979). Biosystematic Revision of the Genus *Stenonema* (Ephemeroptera: Heptageniidae). Canadian Bulletin of Fisheries and Aquatic Sciences, Bulletin 201, Department of Fisheries and Oceans.

Bousfield, E.L., (1967). *Freshwater amphipod crustaceans of glaciated North America*. The Canadian Field-Naturalist. Vol. 72, No. 2, pp. 55-113.

Brinkhurst, R.O. (1986). *Guide to the Freshwater Aquatic Microdrile Oligochaetes of North America.* Department of Fisheries and Oceans, Ottawa.

Brown, H.P. (1972). *Aquatic Dryopoid Beetles (Coleoptera) of the United States.* Biota of Freshwater Ecosystems Identification Manual No. 6, Water Pollution Control Research Series, Environmental Protection Agency.

Burch, J.G. (1989). *North American Freshwater Snails.* Malacological Publications, Hamburg, Michigan.

Clarke, A.H. (1981). *The freshwater molluscs of Canada*. National Museum of Natural Sciences. Ottawa.

Crocker, D.W., and D.W. Barr. (1968). *Handbook of the Crayfishes on Ontario*. University of Toronto Press.

Edmunds, G.F., Jr., Jensen, S.L., and L. Berner. (1976). *The Mayflies of North and Central America*. University of Minnesota Press., Minneapolis.

Epler, J.H. (2001). *Identification Manual for the Larval Chironomidae (Diptera) of North and South Carolina North Carolina Department of Environment and Natural Resources.* 526 pp.

Frest, T.J. and E.J. Johannes. (1999). *Field Guide to Survey and Manage Freshwater Mollusk Species*. U.S. Fish and Wildlife Service.

Fullington, K.E., and K.W. Stewart. (1980). Nymphs of the stonefly genus *Taeniopteryx* (Plecoptera: Taeniopterygidae) of North America. *Journal of the Kansas Entomological Society,* 53(2): 237-259.

Harper, P.P., and H.B.N. Hynes. (1971a). *The Leuctridae of Eastern Canada (Insecta: Plecoptera)*. Can. J. Zool. 49:915-920.

Harper, P.P., and H.B.N. Hynes. (1971b). *The nymphs of the Nemouridae of Eastern Canada (Insecta: Plecoptera).* Can. J. Zool. 49:1129-1142.

Harper, P.P., and H.B.N. Hynes. (1971c). *The nymphs of the Taeniopterygidae of Eastern Canada (Insecta: Plecoptera)*. Can J. Zool. 49: 941-947.

Hilsenhoff, W.L. (1995). *Aquatic Insects of Wisconsin: Keys to Wisconsin genera and notes on biology, distribution and species*. Publication Number 3 of the Natural History Museums Council, University of Wisconsin-Madison 79 pp.

Hilsenhoff, W.L., and K.L. Schmude. (1992). *Riffle beetles of Wisconsin (Coleoptera: Dryopidae, Elmidae, Lutrochidae, Psephenidae) with notes on distribution, habitat, and identification*. The Great Lakes Entomologist 25(3): 191-213.

Hitchcock, S.W. (1974). *Guide to the Insects of Connecticut*. Part VII. The Plecoptera or Stoneflies of Connecticut. State Geological and Natural History Survey of Connecticut, Bulletin No. 107, 262pp.

Holsinger, J.R. (1976). *The Freshwater Amphipod Crustaceans (Gammaridae) of North America*. Biota of Freshwater Ecosystems Identification Manual No. 5, Water Pollution Control Research Series, U.S. Environmental Protection Agency.

Ide, F.P. (1937). *Descriptions of eastern North American species of Baetine mayflies with particular reference to the nymphal stages*. The Canadian Entomologist 11: 217-243.

Jackson, G.A. (1977). *Nearctic and Palaerarctic Paracladopelma Harnisch and Saetheria n. gen. (Diptera: Chironomidae)*. J. Fish. Res. Board Canada. 34: 1321-1359.

Jokinen, E.H. (1992). *The freshwater snails (Mollusca: Gastropoda) of New York State*. New York State Museum Bulletin 482, Albany, New York. 112pp.

Kathman, R.D. and R.O. Brinkhurst. (1999). *Guide to the Freshwater Oligochaetes of North America*. Aquatic Resources Center, Tennessee.264pp.

Klemm, D.J. (1991). *Taxonomy and Pollution Ecology of the Great Lakes Region.* Leeches (Annelida:Hirudinea). Michigan Academician 24:37-103.

Larson, D.J., Alarie, Y. and R.E. Roughley. (2000). *Predaceous Diving Beetles (Coleoptera: Dytiscidae) of the Nearctic Region, with emphasis on the fauna of Canada and Alaska*. NRC Research Press. 982 pp.

Lee, T. and Foighil, D. (2003). *Phylogenetic Structure of the Sphaeriinae, a Global Clade of Freshwater Bivalve Molluscs, inferred from Nuclear IITS-1) and Mitochondrial (16S) Ribosomal Gene Sequences*. Zoological Journal of the Linnean Society 137: 245-260.

Mackie, G.L., and D.G. Huggins. (1983). *Sphaeriacean Clams of Kansas*. Technical Publications of the State Biological Survey of Kansas, University of Kansas, No. 14. 92pp.

Maschwitz, D.E. and E.F. Cook. (2000). *Revision of the Nearctic Species of the Genus Polypedilum Kieffer (Diptera: Chironomidae) in the Subgenera P. (Polypedilum) Kieffer and P. (Uresipedilum) Oyewo and Saether*. Ohio Biological Survey, Ohio State University. 135pp.

McCafferty, W.P. (2000). *The Mayflies of North America: Species List.*

McCafferty, W.P. (1976). *The burrowing mayflies of the United States (Ephemeroptera: Ephemeroidea)*. Trans. Amer. Ent. Soc., 101:447-504.

McCafferty, W.P., and R.D. Waltz. (1990). *Revisionary synopsis of the Baetidae (Ephemeroptera) of North and middle America*. Transactions of the American Entomological Society. 116(4): 769-799.

Merritt, R.W., Cummins, K.W. & M.B. Berg (eds.). (2008). *An Introduction to the Aquatic Insects of North America*. 4th edition. Kendall/Hunt Publishing Co. Dubuque, Iowa. 1158 pp.

Morihara, D.K., and W.P. McCafferty. (1979). T*he Baetis larvae of North America (Ephemeroptera: Baetidae)*. Trans. Amer. Ent. Soc. 105:139-219.

Oliver, D.R. and M.E. Dillon. (1990). *A Catalog of Nearctic Chironomidae*. Research Branch Agriculture Canada. 89pp.

Oliver, D.R. and M.E. Roussel. (1983). *Redescription of Brillia Dieffer (Diptera: Chironomidae) with descriptions of nearctic species*. The Canadian Entomologist 115:257-279.

Pennak, R.W. (1989). *Freshwater invertebrates of the United States*. 3rd edition. Protozoa to Mullusca. John Wiley and Son, Inc. New York, Toronto.

Schefter, P.W., and G.B. Wiggins. (1986). *A Systematic Study of the Nearctic Larvae of the Hydropsyche morosa Group (Trichoptera: Hydropsychidae)*. Miscellaneous Publication of the Royal Ontario Museum, Toronto. 94pp.

Schuster, G.A. and D.A. Etnier. (1978). *A manual for the identification of the larvae of the caddisfly genera Hydropsyche Pictet and Symphitopsyche Ulmer in eastern and central North America (Trichoptera : Hydropsychidae)*. United States Environmental Protection Agency Report 600/ 4-78-060. 129pp.

Simpson, K.W., R.W. Bode and P. Albu. (1983). *Keys for the Genus Cricotopus*. New York State Museum Bulletin No. 450. 133pp.

Simpson, K.W. and R.W. Bode. (1980). *Common Larvae of Chironomidae (Diptera) From New York State Streams and Rivers*. New York State Museum, Bulletin No. 439. 105 pp.

Stewart, K.W., and B.P. Stark. (1988). *Nymphs of North American Stonefly Genera (Plecoptera)*. Thomas Say Foundation, Entomol. Soc. Amer. 12:1-460.

Thorp, J.H., and A.P. Covich (eds.). (1991). *Ecology and Classification of North American Freshwater Invertebrates*. Academic Press, Inc., San Diego, California 911 pp.

Walker, E.M. (1953). *The Odonata of Canada and Alaska*. Vol. 1: Part I: General. Part II: The Zygoptera - Damselflies. University of Toronto Press. Toronto, Ontario. 292 pp.

Walker E.M. (1958). *The Odonata of Canada and Alaska*. Vol. 2: Part III: The Anisoptera - Four Families. University of Toronto Press. Toronto, Ontario. 318 pp.

Walker, E.M. and P.S. Corbet. (1978) *The Odonata of Canada and Alaska*. Vol. 3: Part III: The Anisoptera - Three Families. University of Toronto Press. Toronto, Ontario. 308 pp.

Waltz, R.D. (1994). *Key to the larvae of Baetid genera known east of the Mississippi River (Ephemeroptera: Baetidae)*. Indiana Department of Natural Resources, unpublished.

Westfall, M.J. Jr. and M.L. May. (1996). Damselflies of North America. Scientific Publishers. Washington. 649pp.

Wetzel, M.J., Kathman, R.D., Fend, S.V. and K.A. Coates. (2000). *Taxonomy, Systematics, and Ecology of Freshwater Oligochaeta*. Workbook prepared for North American Benthological Society Technical Information Workshop, 48th Annual Meeting, Keystone Resort, CO. 120p. + app.

Waltz, R.D. (1994). *Key to the larvae of Baetid genera known east of the Mississippi River (Ephemeroptera: Baetidae*). Indiana Department of Natural Resources, unpublished.

Wiederhom, T. (Ed.). (1983). *Chironomidae of the Holarctic Region: Keys and Diagnoses*. Part 1. Larvae. Entomologica Scandinavica Supplement No. 19.

Wiggins, G.B. (1996). *Larvae of North American Caddisfly Genera (Trichoptera)*. Second Edition. University of Toronto Press, Toronto, Ont. 457p.

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.

1.5 REFERENCES

Environment Canada (EC). (2011). *Environmental Effects Monitoring Technical Guidance Document*. National Environmental Effects Monitoring Office.

Krebs CJ. (1985). *Ecology: the experimental analysis of distribution and abundance*. 3rd edition. New York (NY): Harper and Row.

Legendre L, Legendre P. (1983). *Numerical ecology*. Amsterdam (NL): Elsevier.

Smith B, Wilson JB. (1996). *A consumer's guide to evenness indices*. Oikos 76:70-82.

Knight Piésold
CONSULTING

TABLE D.1

BAFFINLAND IRON MINES CORPORATION
MARY RIVER PROJECT

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

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.

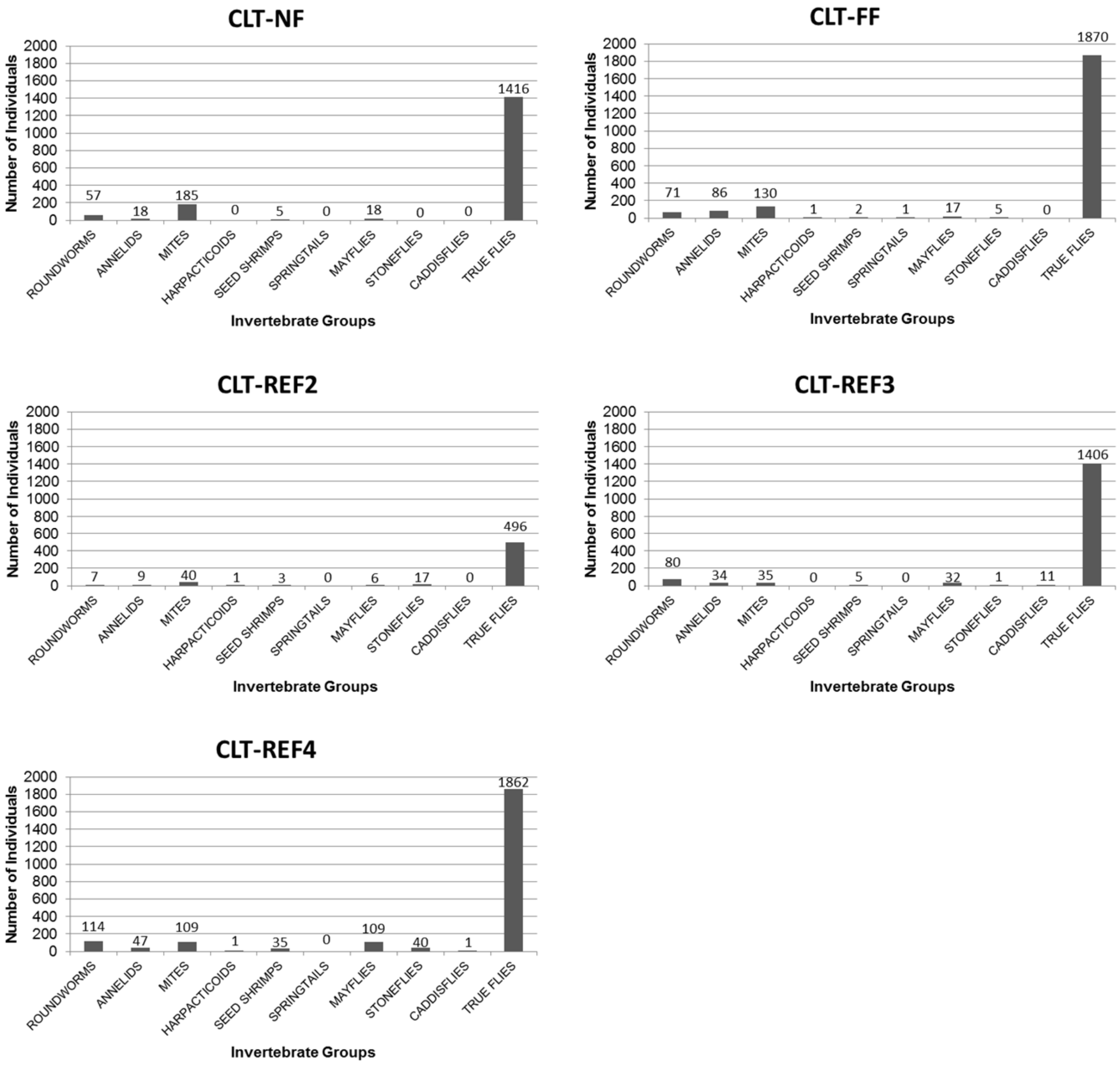


Figure D.1 Camp Lake Tributary Study Areas: Benthic Invertebrate Community Summary

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.

TABLE D.9

BAFFINLAND IRON MINES CORPORATION
MARY RIVER PROJECT

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

Print Jun/26/14 12:09:21

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.

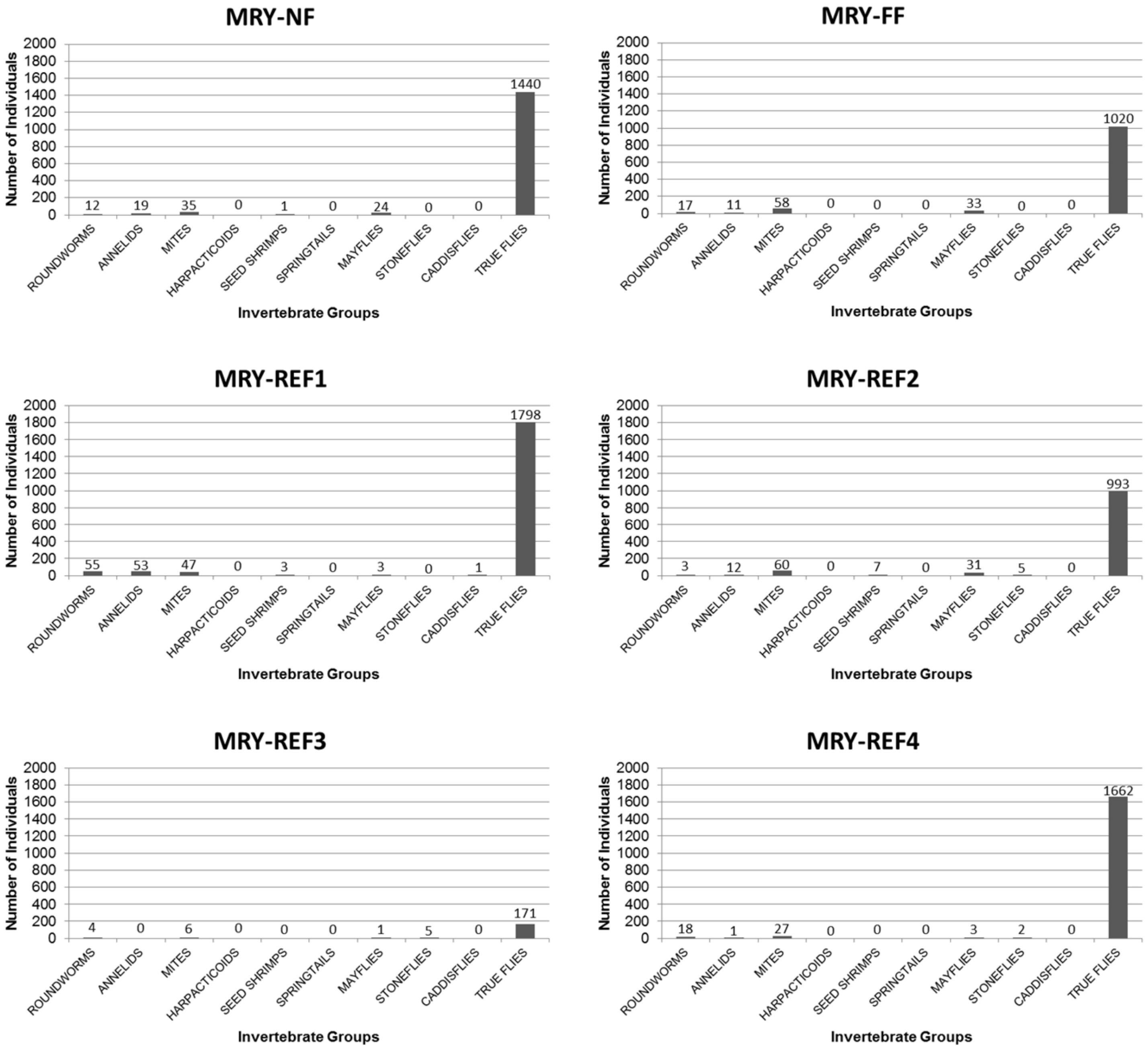


Figure D.2 Mary River Study Areas: Benthic Invertebrate Community Summary

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.

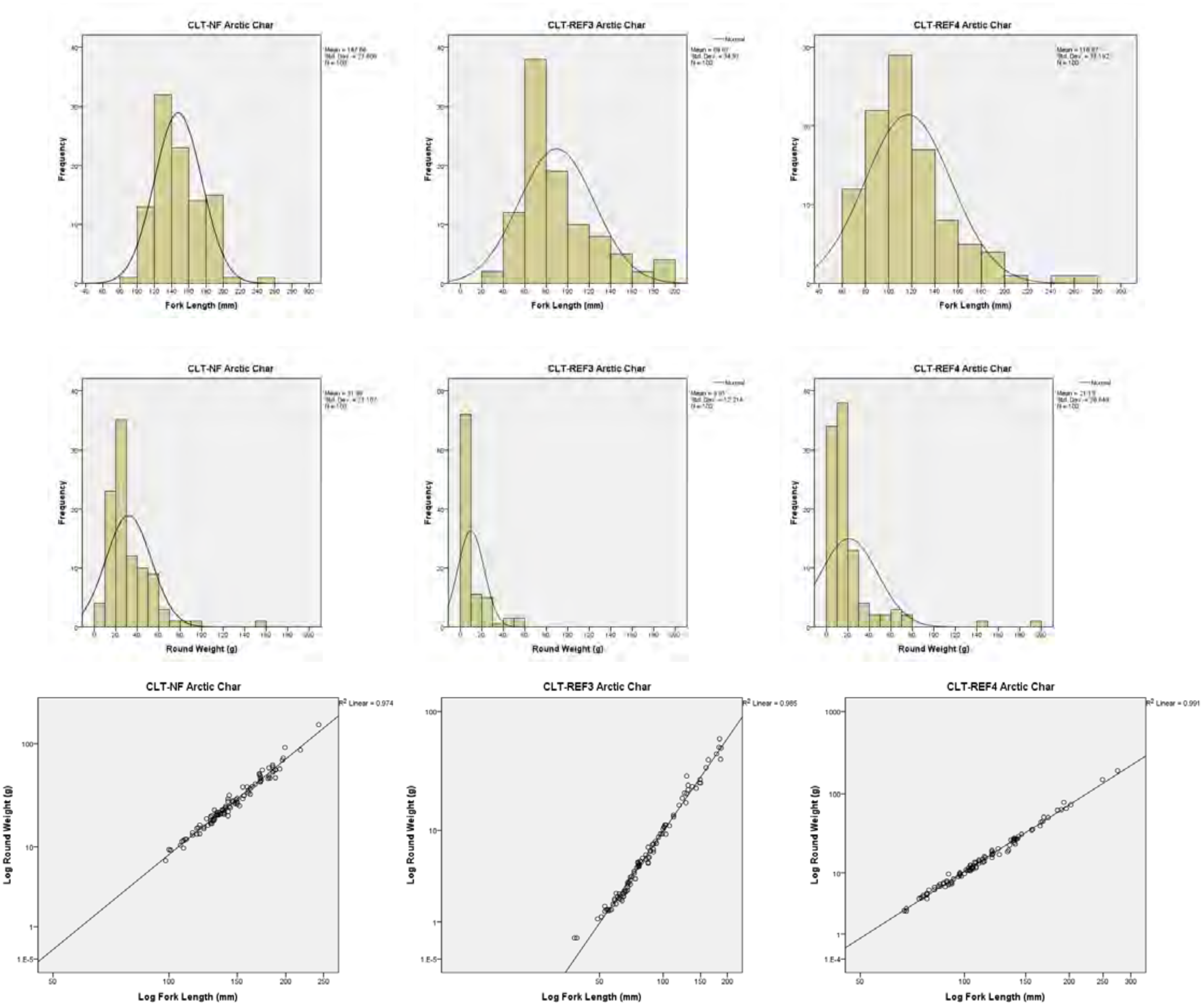


Figure E.1 Camp Lake Tributary Study Areas: Arctic Char Round Weight to Fork Length Data and Comparison

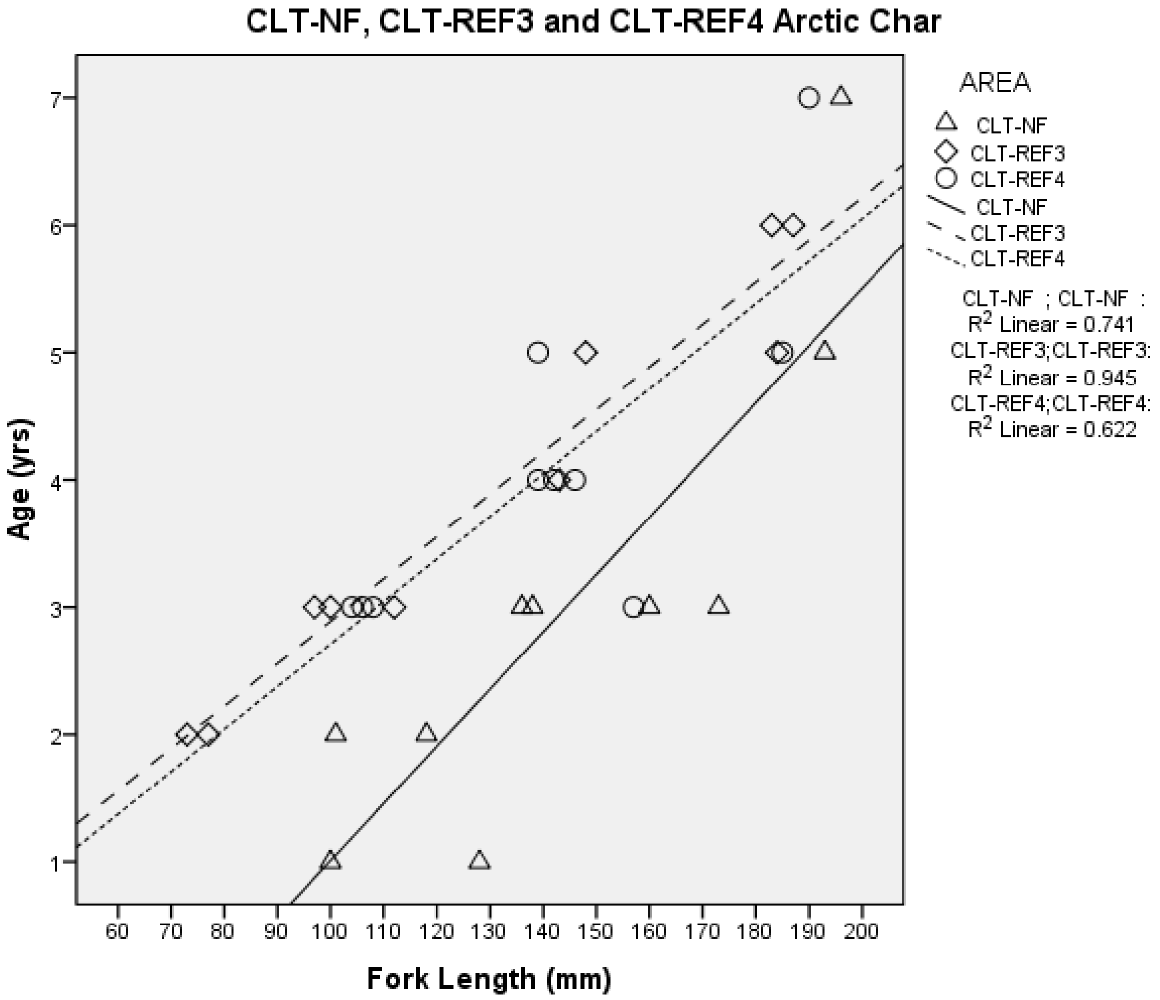


Figure E.2 Camp Lake Tributary NF, REF3 and REF4 Study Areas: Relationship between Arctic Char Age and Fork Length

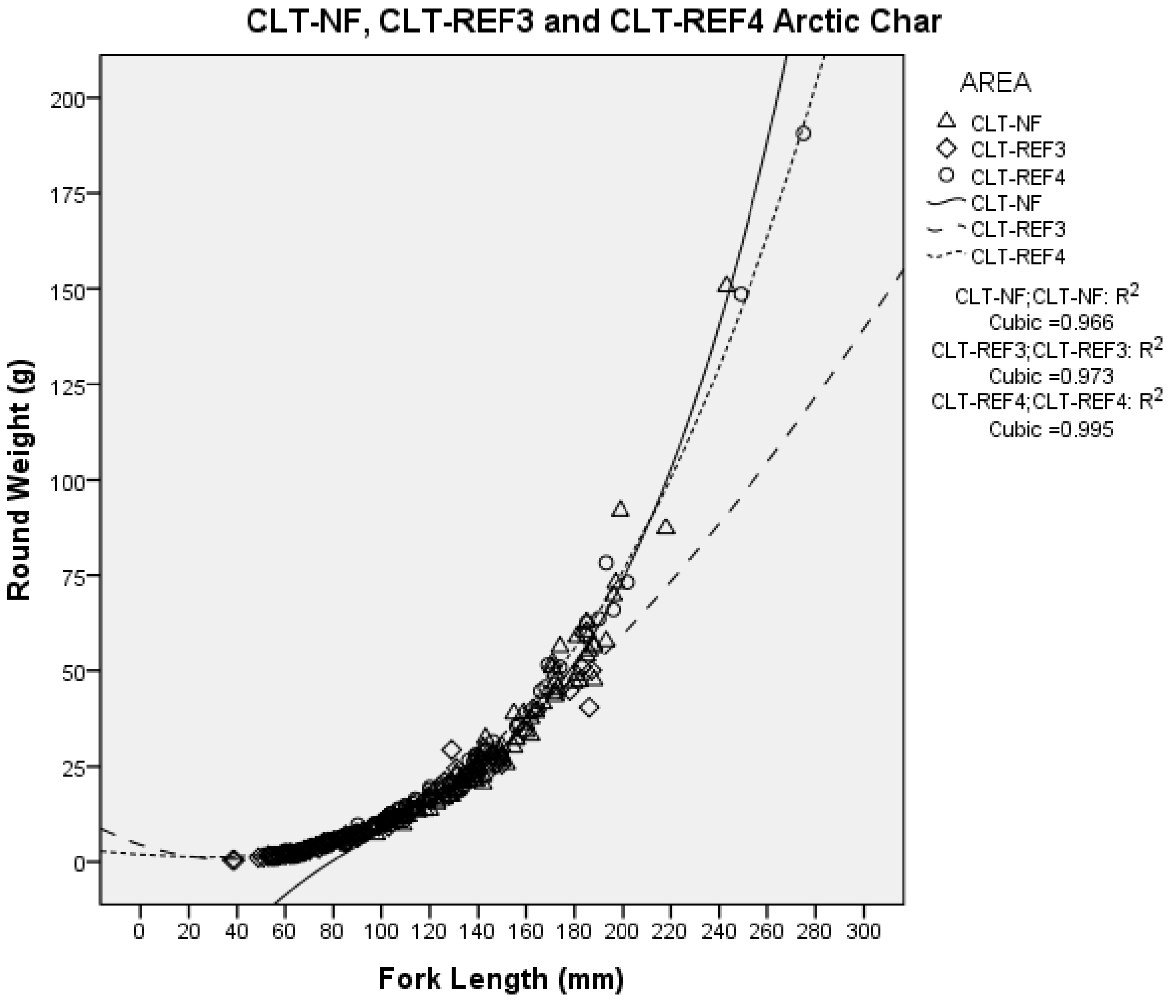


Figure E.3 Camp Lake Tributary NF, REF3 and EF4 Study Areas: Relationship between Arctic Char Round Weight and Fork Length

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.

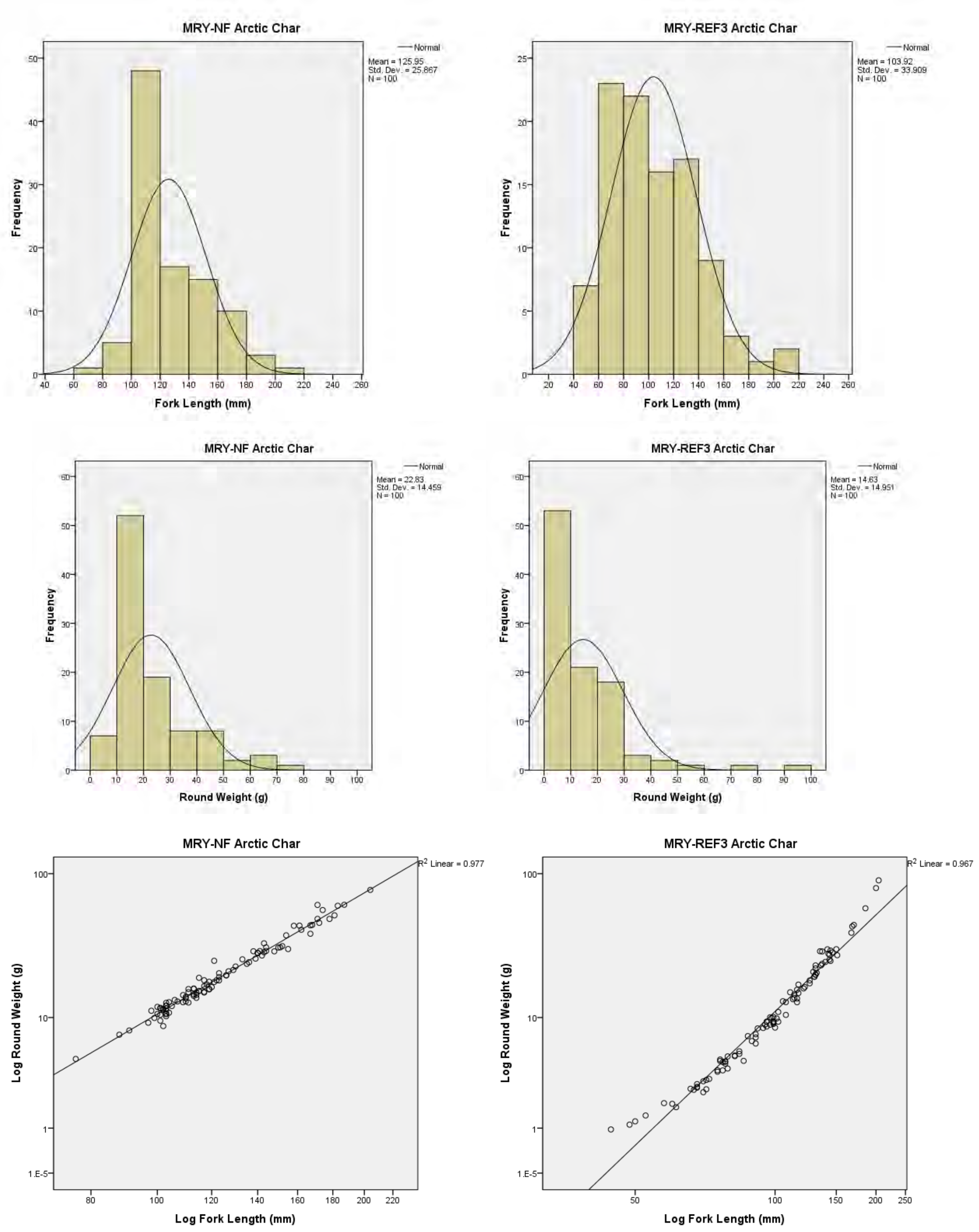


Figure E.4 Mary River NF and REF3 Study Areas: Arctic Char Round Weight to Fork Length Data and Comparison

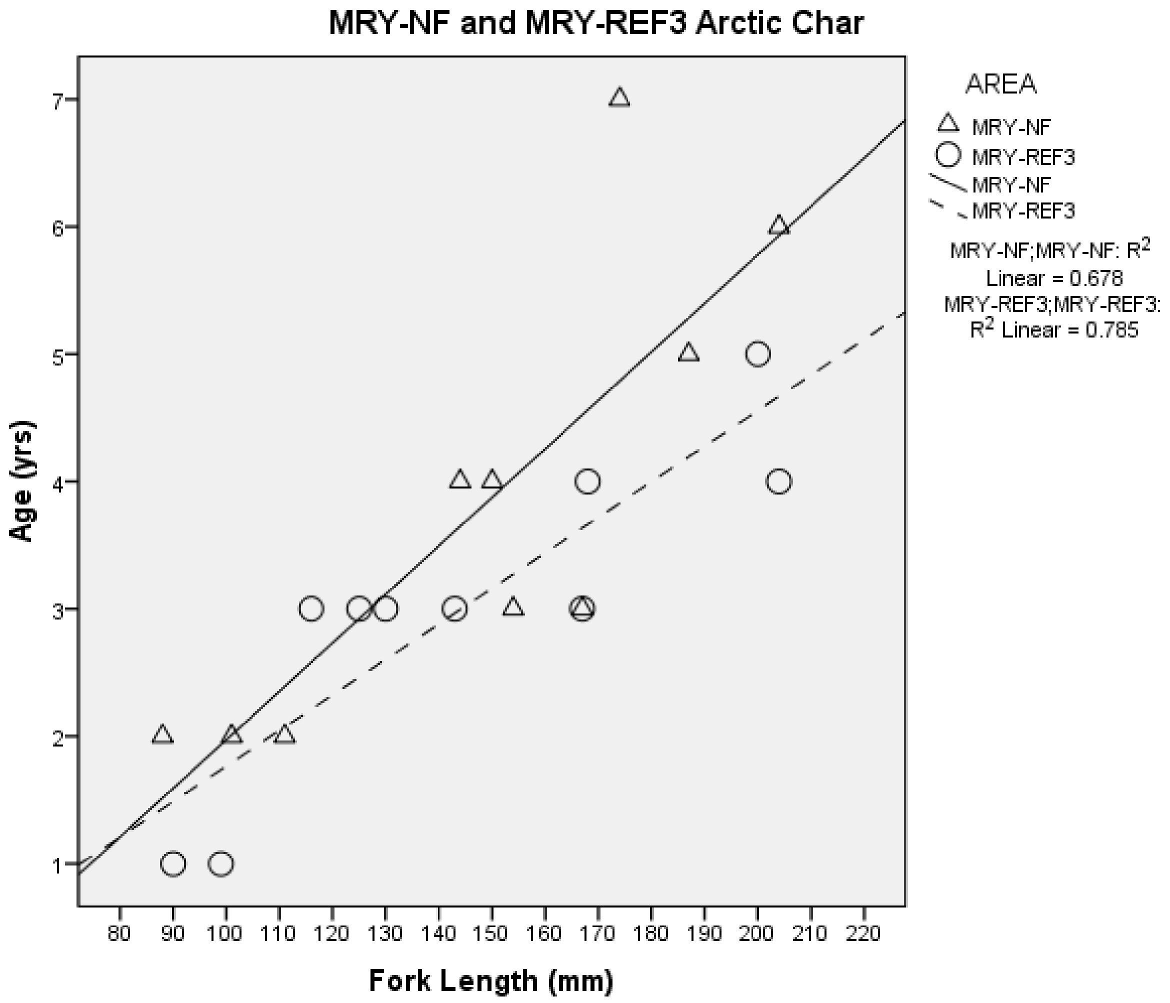


Figure E.5 Mary River NF and REF3 Study Areas: Relationship between Arctic Char Age and Fork Length

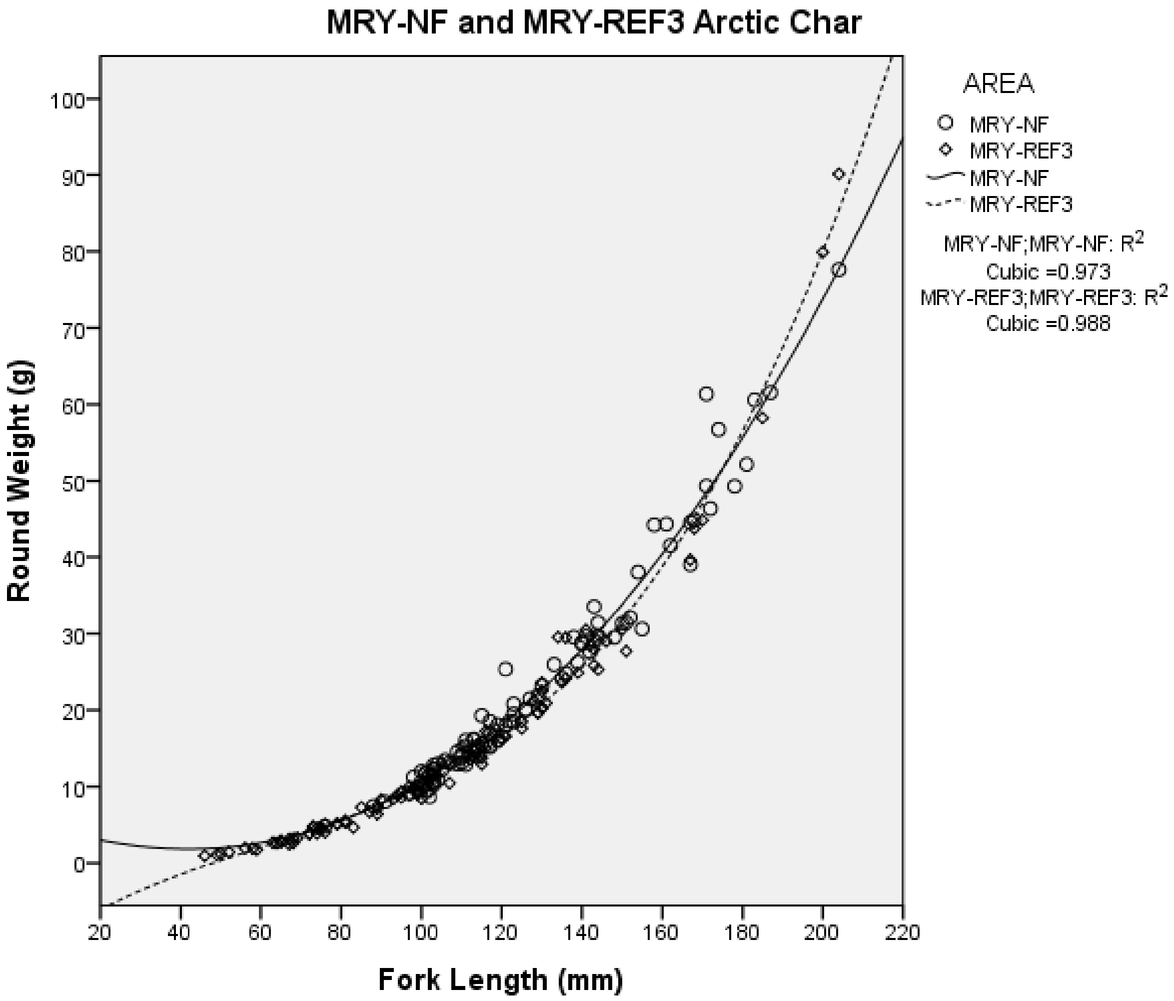


Figure E.6 Mary River NF and REF3 Study Areas: Relationship between Arctic Char Weight and Fork Length

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.