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28 March 2014

Dear Ms. Camsell-Blondin:

Subject: 2013 Annual AEMP Report – Part K Item 10

The Annual Aquatic Effects Monitoring Plan (AEMP) Report for 2013 is attached as specified under W2007-0003 Part K Item 10.

Following analysis of the 2013 AEMP, Golder recommended that modifications be made to two components of the AEMP:

- Plankton: To be consistent with the eutrophication indicators component, plankton should be sampled every three years at the reference areas (FF1, FFA, FFB). Action levels would be based on the most recent reference area data.

- Benthic invertebrates: Collect composite benthic invertebrate samples (i.e., pool the six individual grabs) at all stations based on the low variability among replicate sub-samples (i.e., grabs) observed in 2013 and previous studies.

We request that the plankton sampling recommendation be implemented for the 2014 open-water sampling period, which is scheduled to begin August 15, 2014. As such, we will be proceeding with submitting an updated AEMP Study Design Version 3.5, which reflects these recommendations. The AEMP Study Design Version 3.5 will be submitted to the WLWB no later than May 1, 2014. We would respectfully request WLWB consideration of the AEMP Study Design Version 3.5 prior to the 2014 open-water sampling effort.

If you have any questions regarding the above, please contact the undersigned at your convenience.

Yours sincerely

David Wells
Superintendent - Environment

DIAVIK DIAMOND MINES (2012) INC.

AQUATIC EFFECTS MONITORING PROGRAM 2013 ANNUAL REPORT

Submitted to:
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Distribution:

1 Copy – Diavik Diamond Mines Inc., Yellowknife, NT
1 Copy – Golder Associates Ltd., Calgary, AB
3 Copies – Wek'èezhìi Land and Water Board

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Executive Summary

Diavik Diamond Mines (2012) Inc. (DDMI). conducts environmental monitoring programs under the terms and conditions of the Territorial Water Licence (W2007L2-0003) issued for the Diavik Diamond Mine (Mine) and the Fisheries Authorization (SC98001) issued by Fisheries and Oceans Canada. The Aquatic Effects Monitoring Program (AEMP) is the primary program specified in the Water Licence for monitoring the aquatic environment of Lac de Gras.

The central purpose of the AEMP is "to determine the short and long-term effects in the aquatic environment resulting from the project, test impact predictions, measure the performance of operations and evaluate the effectiveness of impact mitigation". The particular focus of the AEMP is in relation to the primary valued ecosystem components of Lac de Gras, which includes water chemistry, sediment chemistry, lake productivity, planktonic and benthic invertebrate communities, fish, fish habitat, and the use of fisheries resources in Lac de Gras.

To accomplish these objectives, aquatic effects monitoring conducted by DDMI has included an east island-based monitoring program for source waters, as represented by the Surveillance Network Program (SNP), and a lake-based monitoring program. The lake monitoring program includes the following components:

- a water chemistry program in Lac de Gras;
- an aquatic biota monitoring program in Lac de Gras (including fish surveys, planktonic and benthic invertebrate community studies, and supporting sediment and water chemistry data collection);
- a dust deposition monitoring program; and
- special effects studies required as part of the Class A Water Licence and the Fisheries Authorization.

The lake monitoring program generally occurs in four areas within Lac de Gras:

- the near-field (NF) exposure area located near the effluent diffuser;
- the mid-field (MF) areas, generally surrounding the east island;
- the far-field (FF) exposure area, FF2; and
- the far-field (FF) reference areas.

This report is intended to communicate the 2013 results of the AEMP. A similar document is produced each March, reporting on the previous year's results. The focus of the assessment for the annual report is a spatial analysis, whereby areas of the lake exposed to effluent are compared to areas of the lake that are not exposed to effluent (i.e., reference areas). Temporal analyses and an assessment of trends over time will be provided in the next three-year summary report (to be submitted by October 15, 2014). The importance of an effect was compared to Action Levels, which are part of a Response Framework. The goal of having a Response framework is to ensure that significant adverse effects never occur.

To better communicate the results to the range of technical and non-technical parties who are interested in the results, we have provided information in two ways. First, the main body of the report provides a non-technical summary of the most important results from the 2013 studies. Second, technical appendices have been included that provide a full description of analyses conducted and results obtained. These appendices are intended for parties with more technical interests.

Key findings from the 2013 AEMP include the following:

- Dust deposition rates in 2013 were generally lower than in previous years, whereby deposition rates were highest immediately adjacent to the project infrastructure and decreased with distance from the Mine. Snow chemistry analyte concentrations were less than the effluent concentration limits in the Water License.
- Mine effluent had an effect on 15 water quality variables (conductivity, total dissolved solids, dissolved calcium, chloride, dissolved sodium, sulphate, ammonia, nitrate, aluminum, barium, chromium, molybdenum, silicon, strontium, and uranium). The median concentrations of these variables in the near-field area were greater than two times the reference area median concentrations. As a result, these variables demonstrated an effect equivalent to Action Level 1. Each of the 15 variables also reached Action Level 2, which was applicable because the 75th percentile concentration in the Near-field exposure area exceeded the normal range for Lac de Gras.
- Results relating to eutrophication indicators suggest that the Mine is causing a nutrient enrichment effect. Statistically greater concentrations of chlorophyll *a*, total phosphorus, total nitrogen, and zooplankton biomass were observed in the near-field exposure area relative to reference areas. Concentrations of chlorophyll *a* exceeded the upper boundary of the normal range of the reference areas over an area representing greater than 20% of the lake. Consequently, the magnitude of the eutrophication effect is equivalent to Action Level 2 of the Response Framework.
- Effects of the Mine discharge on bottom sediments in the exposure area of Lac De Gras were evident for 13 metals (aluminum, bismuth, boron, calcium, chromium, lead, lithium, magnesium, potassium, sodium, tin, titanium, and uranium), which had near-field area mean concentrations significantly greater than reference area concentrations. Of these 13 variables, bismuth, lead and uranium had near-field area mean concentrations that were greater than their respective normal ranges. Compared to sediment quality guidelines and information in the primary literature,

concentrations of bismuth, lead, and uranium encountered in exposure area sediments are considered unlikely to pose a toxicological risk to biota.

- The 2013 monitoring results suggest that plankton communities in Lac de Gras are exhibiting a Mine-related nutrient enrichment effect. Statistical differences in phytoplankton biomass and community structure, and zooplankton community structure were observed between the exposure and reference areas. The 2013 results provided no evidence for toxicological impairment. Overall, the plankton biomass and taxonomic richness data indicate that an Action Level 1 for plankton has not been reached.
- Statistically differences in total benthic invertebrate density and *Procladius* density were observed between the exposure and reference areas indicating a nutrient enrichment effect. Since the effects indicate nutrient enrichment rather than toxicity, an Action Level was not reached.
- Statistical differences in Slimy Sculpin body size (length and weight), condition factor, relative liver size, and relative gonad size were observed between the exposure and reference areas, indicating a potential toxicological response. These observations are not consistent with the results of previous fish surveys in Lac de Gras and with the findings of the other biological components of the AEMP, which have all indicated a nutrient enrichment response. Overall, the fish data indicate that an Action Level 1 has been reached.

List of Acronyms

AEMP	Aquatic Effects Monitoring Program
DDMI	Diavik Diamond Mines Inc.
EA	environmental assessment
EOI	Evidence of Impact
EQC	Effluent Quality Criteria
FF	far-field
Golder	Golder Associates Ltd.
LOE	Lines of Evidence
Maxxam	Maxxam Analytics Inc.
MF	mid-field
NF	near-field
NIWTP	North Inlet Water Treatment Plant
SD	standard deviation
SES	special effects study
SNP	Surveillance Network Program
SOI	substance of interest
sp.	species
Mine	Diavik Diamond Mine
TOC	total organic carbon
TN	total nitrogen
TP	total phosphorus
WOE	weight-of-evidence
WLWB	Wek’eezhii Land and Water Board

List of Units

+	plus
%	percent
>	greater than
±	plus or minus
µg/L	micrograms per litre
µm	micrometre
cm	centimetre
km^2	square kilometre
L	litre
m	metre
$mg/dm^2/y$	milligrams per square decimetre per year

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1 INTRODUCTION

1.1 BACKGROUND INFORMATION

Diavik Diamond Mines (2012) Inc. (DDMI) conducts environmental monitoring programs under the terms and conditions of Territorial Water Licence W2007L2 0003 (hereafter, the Water Licence) issued for the Diavik Diamond Mine (Mine). The Aquatic Effects Monitoring Program (AEMP) is the primary program specified in the Water Licence for monitoring the aquatic environment of Lac de Gras.

As per the Water Licence, an update to the design of the AEMP is done every three years so that the AEMP can be adjusted to consider the findings of the previous three years. The third version of the AEMP was submitted as Study Design Version 3.0 in October 2011 (Golder 2011a). Following three rounds of revisions, the AEMP study design was approved by the Wek'èezhìi Land and Water Board (WLWB) on February 19, 2014 (WLWB 2014). The most current AEMP is described in the document titled: "Diavik Diamond Mines Inc. - Aquatic Effects Monitoring Program - Study Design Version 3.3", hereafter referred to as the AEMP Study Design Version 3.3 (Golder 2014). That document describes the updated AEMP design and provides a summary of effects and trends from all aquatic monitoring programs conducted by DDMI from baseline conditions (1996) to 2010. As such, the AEMP Study Design Version 3.3 is an important reference when considering ongoing monitoring results. The reader is encouraged to review the document for specifics regarding the basis for the current AEMP design and information regarding past studies.

As summarized in the AEMP Study Design Version 3.3 (Golder 2014), Mine water discharge represents the main concern for Lac de Gras. Therefore, mine water discharge (also called effluent), and its potential impact on the lake ecosystem, is the principal focus of the AEMP. The AEMP has also been designed to include the results of other sources of information on potential effects to the lake, specifically the results of Traditional Knowledge studies.

1.2 PURPOSE AND OBJECTIVES

As defined in the Water License, objectives of the AEMP are "to determine the short and long-term effects in the aquatic environment resulting from the project, test impact predictions, measure the performance of operations, and evaluate the effectiveness of impact mitigation". The AEMP is focussed on the primary valued ecosystem components of Lac de Gras. The valued ecosystem components have been evaluated in previous site investigations, including the Environmental Assessment (EA), and they consist of fish, fish habitat, water quality, sediment quality, lake productivity, planktonic, and benthic invertebrate communities, and the use of fisheries resources in Lac de Gras (DDMI 1998).

An objective of the AEMP is to monitor the Mine water discharge and assess its potential ecological risks so that appropriate actions can be taken in the Mine operations that will prevent adverse effects from occurring. The AEMP is subject to adaptive management; meaning it will be updated as necessary, as new information and findings become available. The AEMP will compare the effluent quality to the discharge limits stipulated in the Water License, and it will assess compliance monitoring and the effectiveness of operational management (e.g., mitigation) measures.

The AEMP is comprised of the following components:

- a water and sediment chemistry program in Lac de Gras;
- an aquatic biota monitoring program in Lac de Gras (including fish surveys, benthic invertebrate surveys, and plankton studies);
- a dust deposition monitoring program; and
- special effects studies (SES) required as part of the Class A Water Licence and the Fisheries Authorization.

Lake monitoring is carried out in four general areas of Lac de Gras:

- the near-field (NF) exposure area located near the effluent diffuser;
- the mid-field (MF) exposure areas (MF1, MF2, MF3);
- the far-field (FF) exposure area (FF2); and
- the far-field (FF) reference areas (FF1, FFA and FFB).

The objective of this annual report is to communicate the results of monitoring conducted as part of the AEMP in 2013. A similar document is produced each March, reporting on the previous year’s results. The results from 2007 through to 2012 were reported by DDMI (2008, 2009, 2010, 2011, 2012 and 2013). In addition, every third year, AEMP results from the previous three years are integrated into a summary report, which includes a comparison of results to impacts predicted during the EA. The last three-year summary report was completed in 2011 (Golder 2011b).

1.3 AEMP ANNUAL REPORT CONTENT AND ORGANIZATION

The organization of this report follows the outline provided in Section 7.2-1 of the AEMP Study Design Version 3.3 (Golder 2014). To better communicate the results to the range of technical and non-technical parties who are interested in the results, we have provided information in two ways. First, this main body of the report provides a summary of the most important results from the 2013 studies, presented in a non-technical way. Second, the appendices provide a full technical description of analyses conducted and results obtained. These appendices are intended for parties with more technical interests. The technical appendices prepared for the 2013 annual report are:

- Appendix I –Dust Deposition Report;
- Appendix II –Water Chemistry Report;
- Appendix III – Sediment Report;
- Appendix IV – Benthic Invertebrate Report;
- Appendix V – Fish Report;
- Appendix XI –Plankton Report;
- Appendix XIII –Eutrophication Indicators Report; and
- Appendix XV – WOE Report.

These technical appendices were prepared by Golder Associates Ltd. (Golder), with the exception of Appendix I, which was prepared by ERM Rescan.

The order in which the appendices appear in the annual report and the appendix number for a given component is the same, even though there may not be a technical report for a given component in each year. This was done to meet reporting commitments stated in the AEMP Study Design Version 3.3 (Golder 2014) and as a means of tracking available information. The technical report “place holder” appendices which do not contain a technical report for 2013 consist of:

- Appendix VI – Plume Delineation Survey;
- Appendix VII – Dike Monitoring Study;
- Appendix VIII – Fish Salvage Program;
- Appendix IX – Fish Habitat Compensation Monitoring;
- Appendix X – Fish Palatability, Fish Health, and Fish Tissue Chemistry Survey;
- Appendix XII – Special Effects Study Reports; and
- Appendix XIV – Traditional Knowledge.

Since there is not a technical report for these components in 2013, a note has been inserted in the appropriate appendix place holder stating that the component was not monitored in that year.

2 DUST DEPOSITION

2.1 INTRODUCTION AND OBJECTIVES

Many of the mining-associated activities at the Mine site generate dust, in particular, trucks travelling on roads, the dumping of Mine rock on the waste rock piles, and activities associated with construction. The dust in the air can be transported by wind, but eventually it settles onto the ground or surface waters. The objective of the dust monitoring program is to measure the amount of dustfall at various distances from the Mine project footprint and to determine the chemical characteristics of the dustfall that may be deposited onto, and subsequently into, Lac de Gras.

A detailed technical report prepared by DDMI on the findings from the 2013 dust deposition monitoring program is provided in Appendix I. The following section provides an overview of the dust deposition monitoring program and a summary of the 2013 results.

2.2 METHODS

Two methods are used to monitor dustfall: snow core surveys and dust collection gauges. In a snow core survey, a cylindrical section of snow is collected by drilling into the snow pack with a hollow tube (Photo 2-1). The collected snow is then allowed to melt in the laboratory, and the melt water is analyzed for total suspended solids. This measures the amount of solid particles, which are presumably mostly from dust blown onto the snow. An additional core collected at snow core collection sites on Lac de Gras is analyzed for various chemicals such as nutrients and metals. This is not done for cores collected at sites on land.

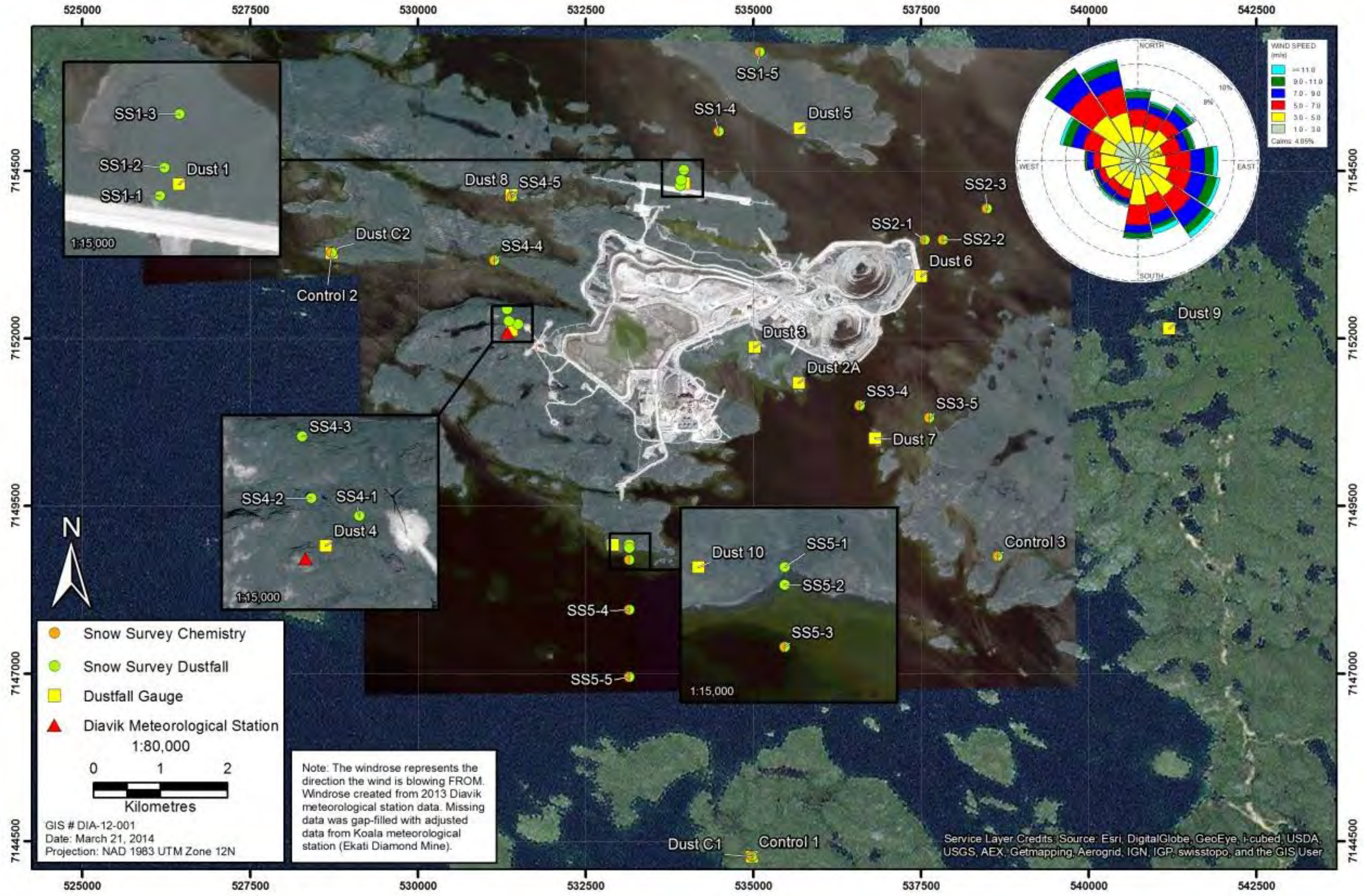
Snow survey samples were collected along 5 transects at 24 predetermined survey stations, including 3 control stations (Figure 2-1). On average for the 24 sampling locations, the total sampling period was 182 days in 2013 for stations on land and over water (ice). Sampling started on Oct. 27, 2012, which corresponds to the first snowfall for land stations, and the first freeze-up for lake stations.

Passive sampling of airborne particles is done with dust collection gauges. Dust gauges were located at several sampling points around the Mine site in 2013. A dust gauge is a hollow cylinder, 52 cm in length and 12.5 cm in diameter, surrounded by a fibreglass shield with the shape of an inverted bell (Photo 2-2). The dust gauges used in 2013 were located around the Mine site as well as at control stations located away from the Mine site, as shown in Figure 2-1.

Photo 2-1 Photo of Snow Sampling

Photo 2-2 Dust Gauge

Figure 2-1 2013 Dust Gauge and Snow Survey Sampling Stations



GIS # DIA-12-001
Date: March 21, 2014
Projection: NAD 1983 UTM Zone 12N

Note: The windrose represents the direction the wind is blowing FROM. Windrose created from 2013 Diavik meteorological station data. Missing data was gap-filled with adjusted data from Koala meteorological station (Ekati Diamond Mine).

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User

In 2013, dust was collected from 12 gauges, which collected dustfall from December 2012 to December 2013. Each gauge collected dustfall year-round, and samples were collected every three months. The dry weight of the material collected in the gauges was recorded.

Estimated dustfall rates were compared to the British Columbia (BC) dustfall objective (which ranges from 621 to 1,059 mg/dm^2/y) for the mining, smelting, and related industries. This objective is used for comparison purposes only as there are no standards or objectives for the Northwest Territories. It is also used by other mines in the region. Snow water chemistry results were compared to effluent quality criteria outlined in DDMI's Water Licence. Snow chemistry analytes of interest included aluminium, ammonia, arsenic, cadmium, chromium, copper, lead, nickel, nitrite, and zinc.

2.3 RESULTS AND DISCUSSION

The total dustfall collected from each dustfall gauge and snow survey station is summarized in Table 2-1. As expected, measured dustfall levels generally decreased with distance from the Mine site, and areas that were predominantly downwind of the mine site received more dustfall than areas that were not downwind (Figure 2-2). Dustfall levels were generally lower in 2013 compared to previous years except at the four snow survey stations closest to the airstrip (SS1-1, SS1-2, SS1-3 and SS1-4) and at a single station located southwest of the mine (Dust 7). At these five stations, dustfall levels were within the range of results from all previous years, but were higher than levels measured over the last two years.

The annual dustfall estimated from each of the 12 dustfall gauges ranged from 49 to 315 mg/dm^2/y. The annualized dustfall estimated from gauges at each station was below the British Columbia objective for the mining industry (621 to 1,059 mg/dm^2/y). The annual dustfall estimated from each of the 24 snow survey locations ranged from 10 to 1,576 mg/dm^2/y. Two results estimated from snow core samples were above the British Columbia objective. These two samples were collected at stations SS1-1 and SS1-2, which are located close to the mine footprint (30 m and 115 m north of the airstrip, respectively). Dustfall rates at these locations were 1,576 mg/dm^2/y and 772 mg/dm^2/y. The airstrip is one of the primary sources of dust at the Mine site due to ground-level air turbulence generated by aircraft during takeoff and landing.

In general, analyte concentrations in snow melt water decreased with distance from the Mine site. The majority of concentrations were lower than in previous years with the exception of nickel, which was within the range of concentrations from previous years, but higher than the last two years. Concentrations of metals in snow melt water were below their associated effluent discharge limits. The full laboratory analysis of snow water chemistry for each station is included in Appendix 1.

Table 2-1 2013 Dustfall Deposition Results

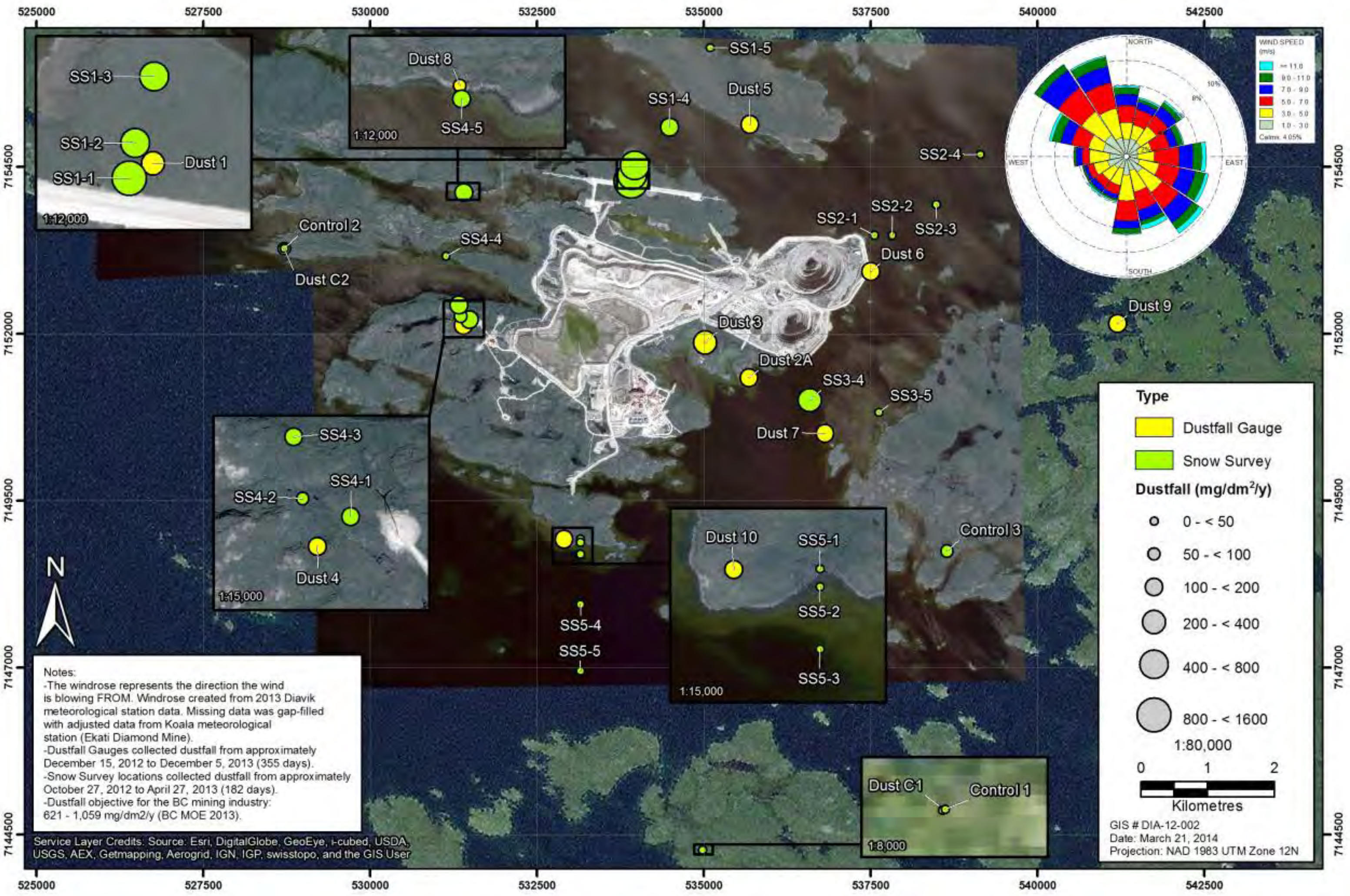
Zone	Station	Approximate Distance from 2013 Project Footprint (m)	Dustfall (mg/dm^2/y)
0 to 100 m	Dust 1	75	262
	Dust 3	30	315
	Dust 6	25	175
	SS1-1	30	1,576
	SS4-1	100	174
	Mean		**500**
	Standard Deviation		**604**
	95% Confidence Interval (Mean +/-)		**750**
	Upper Limit of 95% Confidence Interval		**1,251**
	Lower Limit of 95% Confidence Interval		**0**
101 to 250 m	Dust 4	200	122
	SS1-2	115	772
	SS2-1	180	49
	SS4-2	245	52
	Mean		**249**
	Standard Deviation		**350**
	95% Confidence Interval (Mean +/-)		**557**
	Upper Limit of 95% Confidence Interval		**806**
	Lower Limit of 95% Confidence Interval		**0**
251 to 1,000 m	Dust 2A	435	155
	Dust 10	670	122
	SS1-3	275	460
	SS1-4	920	178
	SS2-2	445	42
	SS3-4	615	388
	SS4-3	350	168
	SS5-1	665	17
	SS5-2	710	23
	SS5-3	885	18
	Mean		**157**
	Standard Deviation		**155**
	95% Confidence Interval (Mean +/-)		**111**
	Upper Limit of 95% Confidence Interval		**268**
	Lower Limit of 95% Confidence Interval		**46**

Table 2-1 2013 Dustfall Deposition Results

Zone	Station	Approximate Distance from 2013 Project Footprint (m)	Dustfall (mg/dm^2/y)
1,001 to 2,500 m	Dust 5	1,195	121
	Dust 7	1,155	192
	Dust 8	1,220	95
	Dust 9	3,810	102
	SS1-5	2,180	28
	SS2-3	1,220	44
	SS2-4	2,180	41
	SS3-5	1,325	33
	SS4-4	1,065	42
	SS4-5	1,220	132
	SS5-4	1,635	12
	SS5-5	2,635	10
	Mean		**71**
	Standard Deviation		**57**
	95% Confidence Interval (Mean +/-)		**36**
	Upper Limit of 95% Confidence Interval		**107**
	Lower Limit of 95% Confidence Interval		**35**
Control	Dust C1	5,655	49
	Dust C2	3,075	67
	CONTROL 1	5,655	22
	CONTROL 2	3,075	13
	CONTROL 3	3,570	52
	Mean		**40**
	Standard Deviation		**23**
	95% Confidence Interval (Mean +/-)		**28**
	Upper Limit of 95% Confidence Interval		**68**
	Lower Limit of 95% Confidence Interval		**13**
Reference Levels[(a)]			**621–1,059**

a) BC MOE (2013) for dustfall.

Figure 2-2 Dust Deposition Rates ($mg/dm^2/d$) at Dust Gauge and Snow Survey Stations Sampled in 2013



Notes:
-The windrose represents the direction the wind is blowing FROM. Windrose created from 2013 Diavik meteorological station data. Missing data was gap-filled with adjusted data from Koala meteorological station (Ekati Diamond Mine).
-Dustfall Gauges collected dustfall from approximately December 15, 2012 to December 5, 2013 (355 days).
-Snow Survey locations collected dustfall from approximately October 27, 2012 to April 27, 2013 (182 days).
-Dustfall objective for the BC mining industry:
621 - 1,059 mg/dm2/y (BC MOE 2013).

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User

GIS # DIA-12-002
Date: March 21, 2014
Projection: NAD 1983 UTM Zone 12N

3 EFFLUENT AND WATER CHEMISTRY

3.1 INTRODUCTION AND OBJECTIVES

Substances released from the Mine must enter the water of Lac de Gras before aquatic organisms can become exposed to the material and, consequently, potentially be affected by this material. Water quality represents a valuable early warning measurement endpoint to identify potential effects to aquatic organisms in Lac de Gras. The objective of the water quality monitoring component of the AEMP is to assess the effects of Mine effluent on water quality in Lac de Gras.

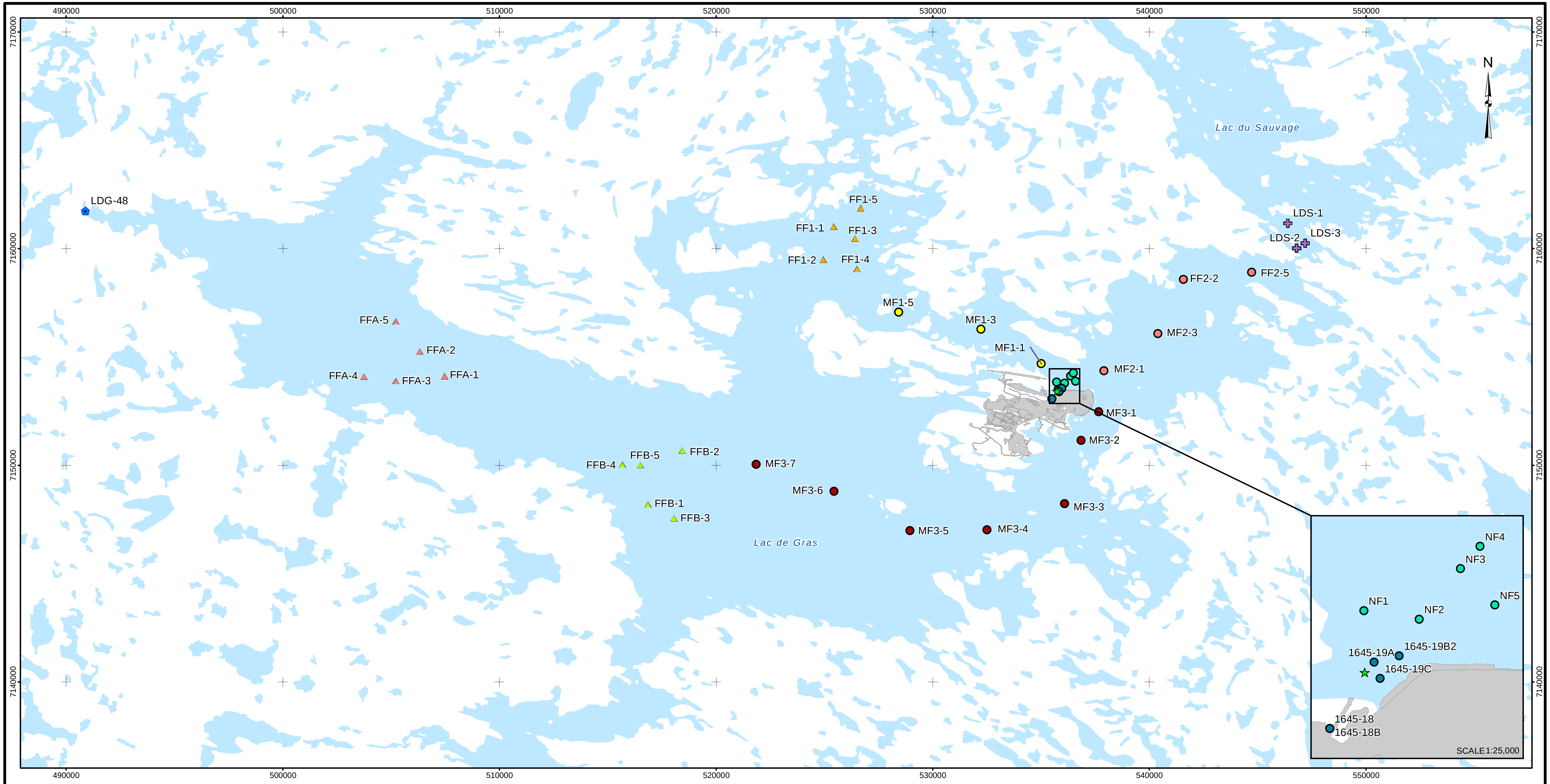
A detailed technical report prepared by Golder on the findings from the 2013 effluent and water chemistry monitoring program is included in Appendix II. The following section provides an overview of the effluent and water chemistry program and a summary of the 2013 results.

3.2 METHODS

Water quality sampling at AEMP stations in 2013 was carried out according the comprehensive monitoring program, which is undertaken every three years (Golder 2014). Water quality samples were collected from the three general areas (NF, MF, and FF) of Lac de Gras, as well as at the outlet of Lac de Gras, and at one area located near the outflow of Lac du Sauvage (Figure 3-1). The AEMP water quality sampling was carried out over two monitoring periods: ice-cover and open-water. Ice-cover season (late winter) sampling was completed from April 10 to April 19, 2013. Open-water sampling was completed from August 18 to September 7, 2013.

Data from the Surveillance Network Program (SNP) were incorporated into the 2013 AEMP report. Effluent samples were collected once every six days from the North Inlet Water Treatment Plant (NIWTP) final discharge point (stations SNP 1645-18a and SNP 1645-18b) and on a monthly basis at the edge of the mixing zone boundary (Stations SNP 1645-19a, SNP 1645-19b2, and SNP 1645-19c). The SNP sampling period summarized in this report included information collected from November 1, 2012 to October 31, 2013.

Water samples were sent to Maxxam Analytics Inc. (Maxxam) in Burnaby, British Columbia, for chemical analysis. Field measurements of water quality were also made at AEMP stations by lowering a specialized electronic device (Hydrolab water quality meter; Photo 3-1) slowly down to the bottom of the lake while recording the measurements of temperature, dissolved oxygen, conductivity, turbidity, and pH.



LEGEND

★ DIFFUSER

EXPOSURE

● NEAR-FIELD
● MID-FIELD 3
● MID-FIELD 1
● FAR-FIELD 2; MID-FIELD 2
● SURVEILLANCE NETWORK PROGRAM

REFERENCE

▲ FAR-FIELD 1
▲ FAR-FIELD A
▲ FAR-FIELD B

✚ LAC DU SAUVAGE
⬟ LDG 48
▨ DIAVIK FOOTPRINT
▨ WATERBODY

5 0 5

SCALE 1:175,000 KILOMETRES

REFERENCE

HYDROGRAPHY DATA OBTAINED FROM CANVEC © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 12 DATUM: NAD 83

PROJECT

DIAVIK DIAMOND MINES INC.

TITLE

WATER QUALITY SAMPLING STATIONS, 2013 AEMP

Golder Associates

PROJECT		13-1328-0001	FILE No.	
DESIGN	LJ	28 Jan. 2014	SCALE AS SHOWN	REV. 0
GIS	JC	20 Mar. 2014	FIGURE: 3-1	
CHECK	TD	20 Mar. 2014		
REVIEW	CF	20 Mar. 2014		

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Photo 3-1 Hydrolab Water Quality Meter

Initial data analyses with all chemical analytes were conducted to identify substances of interest (SOIs), which are a subset of variables with the potential to show Mine-related effects. The intent of defining SOIs was to identify a meaningful set of variables that will undergo further analyses, while limiting analyses on variables that were less likely to be affected. The process of developing the list of SOIs considered concentrations in the final effluent (SNP 1645 18 and SNP 1645 18B) as well as in the fully-mixed exposure area of Lac de Gras:

i. Effluent chemistry data collected at stations SNP 1645 18 and SNP 1645 18B were first compared to Water License discharge limits (Section 3.3.1). Variables that exceeded limits were considered SOIs.

ii. Water quality variables were assessed according to the Action Level framework (Section 3.3.4). Variables that triggered Action Level 1 were added to the SOI list.

The following analyses were conducted on SOIs identified in 2013:

- Examination of effluent chemistry and resulting loads;
- Examination of water chemistry at the edge of the mixing zone;
- Assessment of magnitude and extent of effects, as defined by the Action Levels; and,
- Statistical testing between the NF and FF reference areas to determine whether concentrations in the NF area were significantly greater than those in reference areas.

Water quality variables were assessed for a Mine-related effect according to the Action Level Framework for water chemistry (Table 3-1). Magnitude of effects to water quality variables were determined by comparing analyte concentrations between exposure areas and reference areas, background values or benchmark values. Background values for Lac de Gras are those that fall within the normal range, which is defined as the historical reference area mean ± 2 standard deviations.

The Effects Benchmarks adopted for the AEMP are consistent with those used in the Project Environmental Assessment (Government of Canada 1999) and are based on the Canadian Water Quality Guidelines for the protection of aquatic life (CCME 1999), the Canadian Drinking Water Quality Guidelines (Health Canada 1996, 2006) and adaptations of general guidelines to site-specific conditions at Lac de Gras (Appendix IV.1 in DDMI 2007).

The full suite of water chemistry variables analyzed in 2013 was initially evaluated in the Action Level assessment, with the exception of pH (which is assessed qualitatively in Section 3.4) and nutrients such as phosphorus and nitrogen (which are evaluated in the Eutrophication Indicators Report [Section 4; Appendix XIII]). Variables measured in the field (conductivity, dissolved oxygen, temperature and pH) are discussed qualitatively in Section 3.4.3, and were not considered for inclusion as SOIs. Effects were assessed separately for the ice-cover and open-water seasons.

Table 3-1 Action Levels for Water Chemistry, Excluding Indicators of Eutrophication

Action Level	**Magnitude of Effect[(a)]**	**Extent of Effect**	**Action/Notes**
1	Median of NF greater than 2X median of reference areas (open water or ice cover) and strong evidence of link to Mine	NF	Early warning.
2	75th percentile of NF values greater than normal range	NF	Establish *Effects Benchmark* if one does not exist.
3	75th percentile of MZ values greater than normal range plus 25% of Effects Benchmark[b]	MZ	Confirm site-specific relevance of Effects Benchmark. Establish *Effects Threshold*. Define the Significance Threshold if it does not exist. The WLWB to consider developing an Effluent Quality Criteria (EQC) if one does not exist
4	75th percentile of MZ values greater than normal range plus 50% of Effects Threshold[b]	MZ	Investigate mitigation options.
5	95th percentile of MZ values greater than Effects Threshold	MZ	The WLWB to re-assess EQC. Implement mitigation required to meet new EQC if applicable.
6	95th percentile of NF values greater than Effects Threshold + 20%	NF	The WLWB to re-assess EQC. Implement mitigation required to meet new EQC if applicable.
7	95th percentile of MF values greater than Effects Threshold + 20%	MF	The WLWB to re-assess EQC. Implement mitigation required to meet new EQC if applicable.
8	95th percentile of FFB values greater than Effects Threshold + 20%	FFB	The WLWB to re-assess EQC. Implement mitigation required to meet new EQC if applicable.
9	95th percentile of FFA values greater than Effects Threshold + 20%	FFA	Significance Threshold.

a) Calculations are based on pooled data from all depths and stations.

b) Indicates 25% or 50% of the difference between the benchmark/threshold and the top of the normal range

3.3 RESULTS AND DISCUSSION

The following SOIs were identified based on the selection procedure described in Section 3.2.2:

- Specific Conductivity (Laboratory Measured)
- Total Dissolved Solids (Calculated)
- Calcium
- Chloride
- Sodium
- Sulphate
- Ammonia (as Nitrogen)
- Nitrate (as Nitrogen)
- Aluminum
- Barium
- Chromium
- Molybdenum
- Silicon
- Strontium
- Uranium

Each of the variables included as SOIs reached an Action Level 1 or greater in 2013. Since all variables in effluent with Water License discharge criteria and AEMP Effects Benchmarks were within applicable limits, effluent chemistry did not contribute to the SOI list.

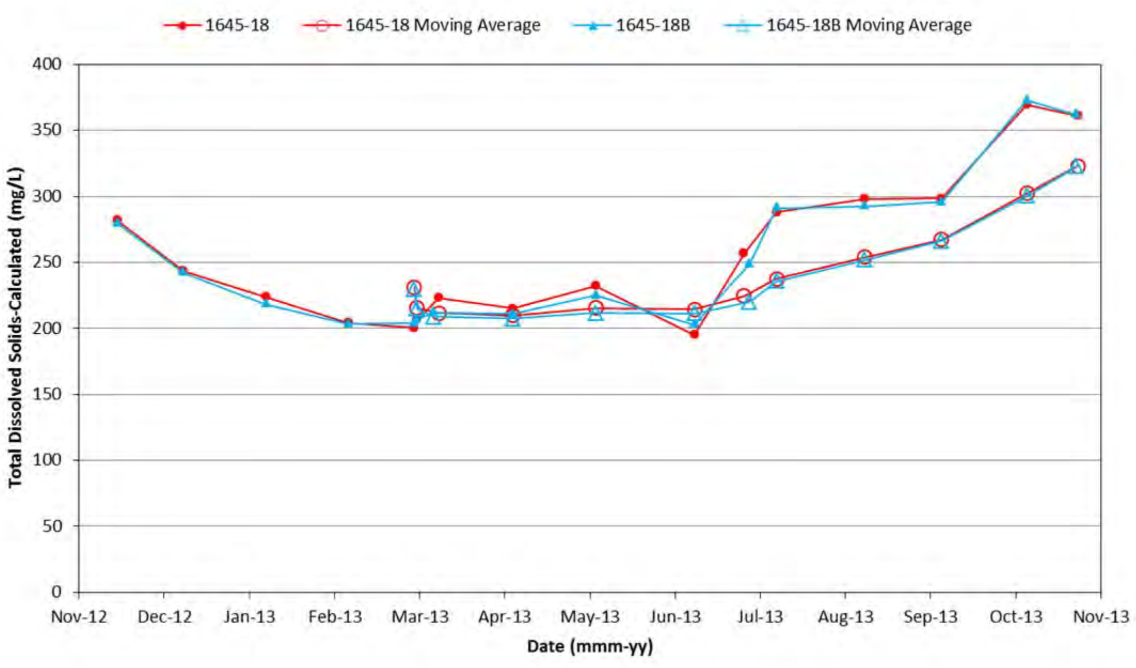
3.3.1 Effluent Quality

The water chemistry monitoring data collected from the NIWTP final discharge (SNP 1645 18 and 18B) were compared to the effluent quality criteria in the Water Licence. The 12 month period from November 2013 to October 2013 was used to describe the NIWTP discharge. Concentrations of SOIs in effluent were well below discharge criteria.

The discharge data for variables on the SOI list were visually assessed for temporal trends. The seasonal patterns observed for many variables (e.g., dissolved calcium, dissolved sodium, sulphate, strontium, molybdenum) reflected that of total dissolved solids which increased in the effluent through the open-water season into early-ice cover. (Figure 3-2). The concentrations of ammonia in the effluent were lower during the open-water season compared to in ice-cover. In contrast, nitrate increased from May to August. Seasonal trends for chloride followed a similar pattern, though concentrations in the early open-water were lower than under ice-cover. Chromium, silicon, and uranium concentrations were generally lower in the open-water season compared to in ice-cover. The only analyte that did not exhibit a seasonal tendency was aluminum.

Toxicity testing results in 2013 indicated that all effluent samples passed the relevant acute or chronic lethality and sublethal toxicity tests. The results in 2013 are consistent with test results in previous years (2002 and 2012) which indicated that the effluent was generally not toxic to aquatic test organisms.

Figure 3-2 Total Dissolved Solids Concentration (Calculated) at SNP 1645-18 and 1645-18B, November 2012 to October 2013



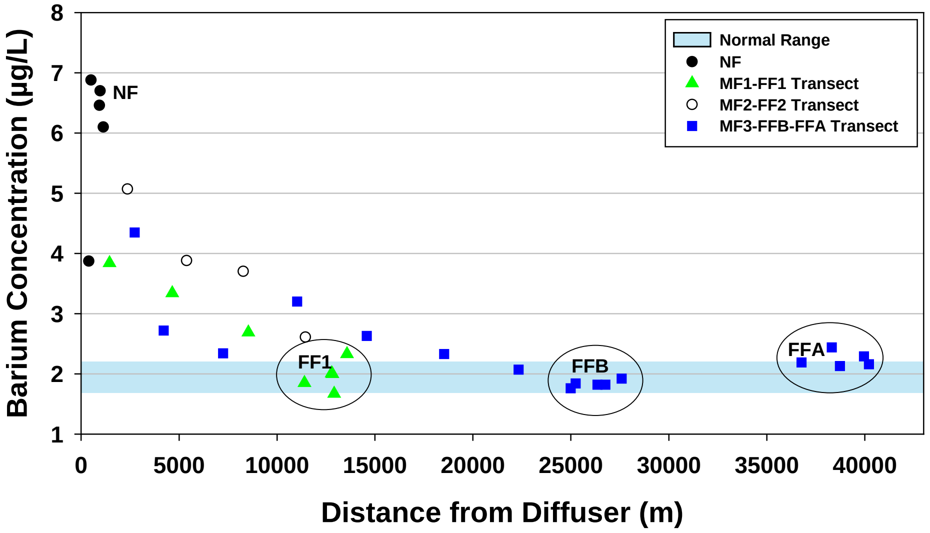
Note: mg/L = milligrams per litre

3.3.2 Effluent Distribution

The dilution and distribution of effluent from the NIWTP was estimated based on the concentration of total barium measured at the SNP and AEMP sampling locations. The background concentration of barium in Lac de Gras was evaluated in terms of the normal range, which was defined as the historic (2007-2010) reference area mean concentration ± 2 standard deviations. During the ice-cover season, the upper limit of the normal range for barium was 2.2 µg/L. During the 2013 monitoring period, barium concentrations measured in the Mine discharge at stations SNP 1645-18 and SNP 1645-18B ranged from 48.2 to 76.7 µg/L. Barium concentrations measured at the mixing zone boundary ranged from 2.3 to 7.93 µg/L.

The distribution of barium concentrations at AEMP stations indicated that the effluent was spreading throughout the exposure area (Figure 3-3). In the reference areas, barium concentrations exceeded the normal range in at least one station in two of the three FF reference areas. Among the reference areas, the highest barium concentrations were measured in the FFA area. Given that the FFA area is farthest from the Mine and that this pattern has been observed in previous years, it is not possible to confirm that concentrations above the normal range represent Mine effluent exposure. The AEMP Summary Report (to be submitted in October 2014) will include updates to the temporal trend analyses which have been established for barium in reference areas FF1, FFB and FFA. This analysis will help determine if concentrations of barium above the normal range are indicative of effluent having reached these areas.

Figure 3-3 Spatial Variation in Barium Concentration with Distance from the Mine-effluent Diffuser, Ice-cover Season, 2013 AEMP



Notes: µg/L = micrograms per litre; m = meter.
The NF area data shown are from the sampling depth representing the maximum average concentration (mid depth). MF area values represent the maximum concentration of three depths (top, middle bottom) sampled at each station.

3.3.3 Depth Profiles

Depth profiles were prepared for conductivity, dissolved oxygen, water temperature and pH data collected at AEMP stations. Specific conductivity increased with depth in the NF area during the ice-cover season to about mid-depth (approximately 10 m) and then declined with increasing depth. The greater density of the effluent compared to the water in Lac de Gras combined with the absence of wind and wave-driven mixing during ice-cover conditions resulted in elevated conductivity at mid-depth. Peak conductivity occurred between about 10 and 15 m depth, indicating the point where the effluent plume was most concentrated. A similar, but less defined pattern was observed under ice-cover at stations located closest to the diffuser along the MF2 and MF3 transects, which extend to the northeast of the Mine and to the west of the Mine, respectively. This pattern, however, was not observed in the MF1 area, which extends northwest of the Mine.

Temperature profiles in Lac de Gras were vertically homogeneous at most stations during both the ice cover and open water seasons. Dissolved oxygen concentrations were typically uniform throughout the water column during the open-water season. During the ice-cover season, dissolved oxygen concentrations were greatest just below the ice-water interface and declined with increasing depth. The pH values measured in Lac de Gras in 2013 showed a slight tendency to decrease with depth in both seasons, Also, somewhat greater pH values observed in the NF area likely indicated the presence of Mine effluent, which has a pH typically greater than 7.

3.3.4 Assessment of Effects and Action Levels

Water quality variables were assessed for a Mine-related effect according to Action Levels (Table 3-1). Fifteen variables reached Action Level 1. These variables, considered as SOIs, had NF area median concentrations that were greater than two times the median concentrations of reference areas. Each of the SOIs had detectable concentrations in the NIWTP effluent, indicating that the increase seen in the NF area could be linked to the Mine.

All 15 variables that reached Action Level 1 also reached Action Level 2 (Table 3-2), which was attained because the 75th percentile concentration in the NF exposure area was greater than the normal range for Lac de Gras. Variables that reached Action Level 2 were evaluated for an effect at a magnitude of Action Level 3, provided they had existing AEMP Effects Benchmarks. None of the variables reached the Action Level 3 criterion).

Each of the 15 SOIs that reached Action Levels 1 and 2 in 2013 had NF area mean concentrations that were statistically greater than reference area concentrations in one or both sampling seasons (i.e., ice-cover or open-water). Spatial trends of decreasing concentrations with distance from the Mine-effluent diffuser were evident for each of these variables based on a graphical evaluation of the data. The results of these analyses provided confirmation that that the changes observed in the NF area for these variables (i.e., at Action Levels 1 and 2) were related to the Mine-water discharge.

Table 3-2 Action Level Summary for Water Quality, 2013 AEMP

Variable	Action Level Classification
Conventional Parameters	
Specific Conductivity	2
Total Dissolved Solids (Calculated)	2
Major Ions	
Calcium	2
Chloride	2
Sodium	2
Sulphate	2
Nutrients	
Ammonia (as Nitrogen)	2
Nitrate (as Nitrogen)	2
Metals (Total)	
Aluminum	2
Barium	2
Chromium	2
Molybdenum	2
Silicon	2
Strontium	2
Uranium	2

4 EUTROPHICATION INDICATORS

4.1 INTRODUCTION AND OBJECTIVES

One of the more important predictions from the EA was that operation of the Mine would release nutrients (nitrogen and phosphorus) into Lac de Gras. Phosphorus naturally occurs in the groundwater that seeps into the Mine workings. Nitrogen gets into the Mine water as a residue from ammonium nitrate used as an explosive during mining. While phosphorus is reduced to the lowest levels practical in the NIWTP, and nitrogen is managed to the extent practical through blasting and water management practices, both phosphorus and nitrogen exist in substantially higher concentrations in the NIWTP effluent than in Lac de Gras under baseline conditions (see Section 3).

Lac de Gras is a nutrient-poor lake (oligotrophic). The aquatic organisms (algae, invertebrates, and fish) survive with limited nutrient availability. It is expected, and was predicted, that increasing the nutrient levels in Lac de Gras would affect aquatic organisms (Government of Canada 1999). The primary effect of this nutrient enrichment on Lac de Gras was expected to be an increase in primary productivity, also referred to as eutrophication.

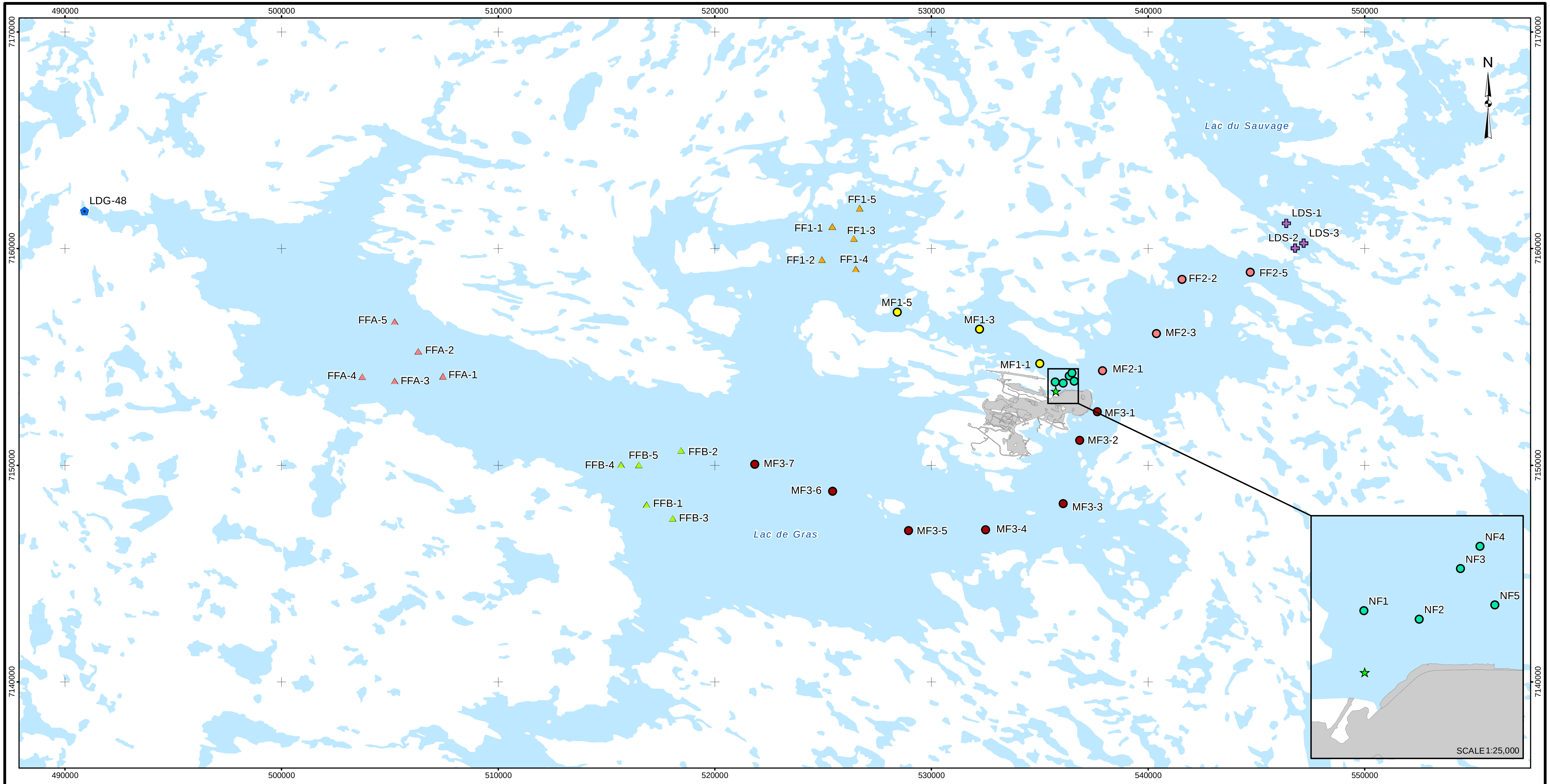
The objective of this section is to describe the AEMP results for nutrients, chlorophyll *a*, and zooplankton biomass, which are monitored as indicators of eutrophication. Chlorophyll *a* is the green colour in plants, and is a measure of the amount of phytoplankton or algae (microscopic plants) in the water. Algae are the first aquatic organisms to respond to a change in nutrient levels. Zooplankton biomass is a measure of the total amount of tiny animals that live in the water and feed on algae.

The following is a summary of the 2013 analysis of eutrophication indicators conducted by Golder. Appendix XIII provides a more complete analysis and presents detailed results for eutrophication indicators.

4.2 METHODS

In 2013, the AEMP eutrophication indicators program was completed over two sampling periods. The ice-cover sampling period was conducted between April 10 and April 19, 2013, and the open-water sampling period was conducted between August 18 and September 7, 2013. Nutrient samples were taken during both ice-cover and open water conditions from the three general areas (NF, MF, and FF) of Lac de Gras, at the outlet of Lac de Gras, and at one area in Lac du Sauvage (Figure 4 1). Chlorophyll *a* and zooplankton biomass were only collected during the open-water period, when biological activity is greatest.

Chlorophyll *a* and nutrient data were collected using a depth-integrated sampler. This device collects lake water over a range of sample depths. The top section of the water column (i.e., the top 10 m) was sampled for chlorophyll *a* and nutrients during the open-water, since this is where most of the algae is found. The ice-covered nutrient samples were collected from three depths: near the bottom, at the middle depth and near the surface (or top depth). Zooplankton samples were collected using a specially designed fine mesh net that was towed up through the entire water column (i.e., from 1 m above the bottom to the top of the water column). Methods used to collect water profile data are described in Section 3.



LEGEND

★ DIFFUSER

⬟ LDG 48

✚ LAC DU SAUVAGE

▨ DIAVIK FOOTPRINT

▨ WATERBODY

EXPOSURE

● NEAR-FIELD

● MID-FIELD 3

● MID-FIELD 1

● FAR-FIELD 2; MID-FIELD 2

REFERENCE

▲ FAR-FIELD 1

▲ FAR-FIELD A

▲ FAR-FIELD B

REFERENCE

HYDROGRAPHY DATA OBTAINED FROM CANVEC © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 12 DATUM: NAD 83

5 0 5
SCALE 1:175,000 KILOMETRES

PROJECT

DIAVIK DIAMOND MINES INC.

TITLE

EUTROPHICATION INDICATORS SAMPLING STATIONS, 2013 AEMP

Golder Associates

PROJECT	13-1328-0001	FILE No.	
DESIGN	LJ	28 Jan. 2014	SCALE AS SHOWN REV. 0
GIS	JC	20 Mar. 2014	FIGURE: 4-1
CHECK	TD	20 Mar. 2014	
REVIEW	CF	20 Mar. 2014	

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The 2013 AEMP results were analyzed to identify and understand patterns in the data collected. A specific focus was assessing the magnitude of effects according to the Action Levels (Table 4-1).

Table 4-1 Action Levels for Chlorophyll a

Action Level	Magnitude of Effect	Extent of Effect	Action/Notes
1	95th percentile of MF values greater than normal range(a)	Mid-field (MF) station	Early warning.
2	Near-field (NF) and MF values greater than normal range	20% of lake area or more	Establish *Effects Benchmark*.
3	NF and MF values greater than normal range plus 25% of Effects Benchmark(b)	20% of lake area or more	Confirm site-specific relevance of existing benchmark. Establish *Effects Threshold*.
4	NF and MF values greater than normal range plus 50% of Effects Threshold(b)	20% of lake area or more	Investigate mitigation options.
5	NF and MF values greater than Effects Threshold	20% of lake area or more	The WLWB to re-assess EQC for phosphorus. Implement mitigation required to meet new EQC if applicable.
6	NF and MF values greater than Effects Threshold +20%	20% of lake area or more	The WLWB to re-assess EQC for phosphorus. Implement mitigation required to meet new EQC if applicable.
7	95th percentile of MF values greater than Effects Threshold +20%	All MF stations	The WLWB to re-assess EQC for phosphorus. Implement mitigation required to meet new EQC if applicable.
8	95th percentile of FFB values greater than Effects Threshold +20%	Far-field B (FFB)	The WLWB to re-assess EQC for phosphorus. Implement mitigation required to meet new EQC if applicable.
9	95th percentile of FFA values greater than Effects Threshold+20%	Far-field A (FFA)	Significance Threshold.

a = The normal range is based on AEMP Version 2.0 data, from the August 15 to September 15 sampling period only.

b = Indicates 25% or 50% of the difference between the benchmark and the top of the normal range.

4.4 RESULTS AND DISCUSSION

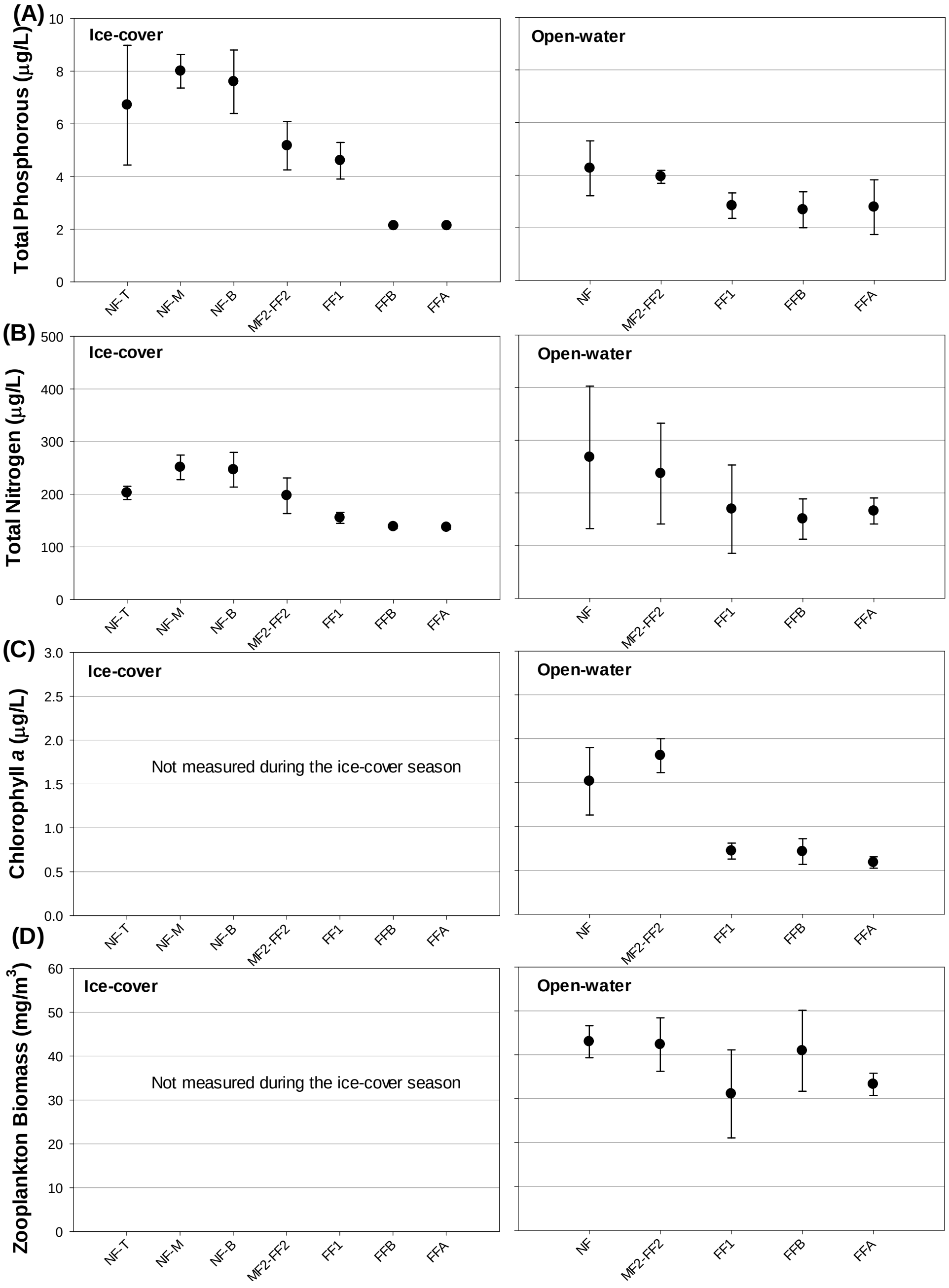
The following text summarizes the key findings from the 2013 AEMP related to total phosphorus, total nitrogen, chlorophyll a, and zooplankton. Appendix XIII contains more information and a detailed analysis of results.

The 2013 AEMP results showed a very clear nutrient enrichment effect in the NF area compared to the FF reference areas. The levels of the nutrients (total phosphorus and total nitrogen), chlorophyll *a* and zooplankton biomass in the NF exposure areas, and the FF1, FFA and FFB reference areas is shown in Figure 4-2. Results are shown for the ice-cover and open-water periods.

Under ice-cover and open-water conditions total phosphorus concentrations were significantly greater in the NF exposure areas compared to the reference areas (Figure 4-2). Total nitrogen concentrations were significantly greater in the NF exposure area compared to the reference areas during the ice-cover sampling periods. There were issues with the integrity of 2013 open-water total nitrogen data from the laboratory. Although the open-water nitrogen data are present in Figure 4-2, all Mine-related conclusions were based on the ice-cover total nitrogen data.

Chlorophyll *a* concentrations were significantly greater in the NF exposure area than in the reference areas, reflecting the increased levels of dissolved nutrients discharged from the Mine. The mean chlorophyll *a* concentrations in the NF exposure area during the open-water was 1.5 µg/L, compared to a maximum mean value of 0.72 µg/L in the reference areas (Figure 4-2). Zooplankton biomass in the NF exposure area was also significantly greater than the reference areas of Lac de Gras

Figure 4-2 Concentration (Mean ± SD) of Total Phosphorus, Total Nitrogen, Chlorophyll a and Biomass (Mean ± SD) of Zooplankton in Lac de Gras in 2013



Notes: NF = near-field; MF = mid-field; FF = far-field; µg/L = micrograms per litre; Ice-cover = ice-cover sampling from top (T), middle (M) or bottom (B) depths; samples analyzed by the University of Alberta (U of A). OW= open-water season, depth-integrated samples collected and analyzed by Maxxam. Soluble reactive P was analyzed by Maxxam as ortho-phosphorus during the OW (see text for details). Standard deviation at MF2-FF2 calculated from four samples, at all other stations, standard deviation based on five samples. The detection limits for total phosphorous differed between the open-water and under-ice seasons, due to differences between labs. For samples collected during the ice-cover season the detection limit was 3.0 µg/L, in the open-water season the detection limit was 2.0 µg/L.

The MF area results were used to determine the extent of the zone of nutrient enrichment. Mean concentrations of total phosphorus (TP), total nitrogen (TN), and chlorophyll *a*, and zooplankton biomass from the NF area and each MF exposure area were compared with the upper bound of the normal ranges (i.e., pooled mean of the reference areas for 2007-2010 plus 2 standard deviations [SD]). Since only open-water samples were collected for chlorophyll *a* and zooplankton biomass, the open-water data were used for determining the extent of spatial effects. For TN and TP, the ice-cover period was selected since that period demonstrated the greatest effects on nutrients. The bottom and top depths, respectively, were chosen since they showed the greatest extent of effects.

For chlorophyll *a*, the extent of effects during the open-water season encompassed all stations to the northeast (MF2-FF2 transect) of the Mine and to a location between station MF1-1 and MF1-3 to the northwest (MF1-FF1 transect). The boundary of effects on chlorophyll *a* to the south of the Mine extended to a location between stations MF3-4 and MF3-5. Based on these results, the extent of effects on chlorophyll *a*, was calculated to be 143 km^2. Compared to the total surface area of the lake (573 km^2), the affected area based on chlorophyll *a* represents 24.9% of the lake (Figure 4-3A).

For zooplankton biomass, the extent of effects during the open-water season encompassed all stations to the northeast (MF2-FF2 transect) of the Mine and to a location between station MF1-3 and MF1-5 to the northwest (MF1-FF1 transect). The boundary of effects on zooplankton biomass to the south of the Mine extended to a location between stations MF3-6 and MF3-7. The extent of effects on zooplankton biomass was calculated to be 212 km^2. Compared to the total surface area of the lake (573 km^2), the affected area based on zooplankton biomass represents 37.1% of the lake (Figure 4-3B).

The extent of effects on TN during the ice-cover season to the northeast of the Mine extended to a location between station MF2-1 and MF2-3 (MF2-FF2 transect). The boundary of effects on TN south of the Mine extended to between stations MF3-1 and MF3-2. The resulting TN affected area of the lake was calculated to be 15 km^2, or 2.6% of the lake (Figure 4-4A).

The extent of effects on TP was limited to the NF area of Lac de Gras and to the northeast (MF2-FF2 transect). The boundary of effects on TP to the northwest extended to station MF1-1 (MF1-FF1 transect) and the boundary of effects south of the Mine extended to station MF3-2 (MF3-FFB-FFA transect). The resulting TP affected area of the lake was calculated as 8 km^2, or 1.5% of the lake (Figure 4-4B).

The magnitude of the eutrophication effect is equivalent to Action Level 2 of the Response Framework (Table 4-1). Action Level 2 is identified when chlorophyll *a* concentrations in the NF and MF exposure areas representing more than 20% of the lake area are greater than the normal range. In 2013, 24.9% of the lake area had chlorophyll *a* concentrations uniformly greater than the normal range (normal range upper limit = 0.82 µg/L).

Figure 4-3 Chlorophyll a Concentrations (A) and Zooplankton Biomass (B) in Lac de Gras According to Distance from the Effluent Discharge during the Open-Water Period, 2013

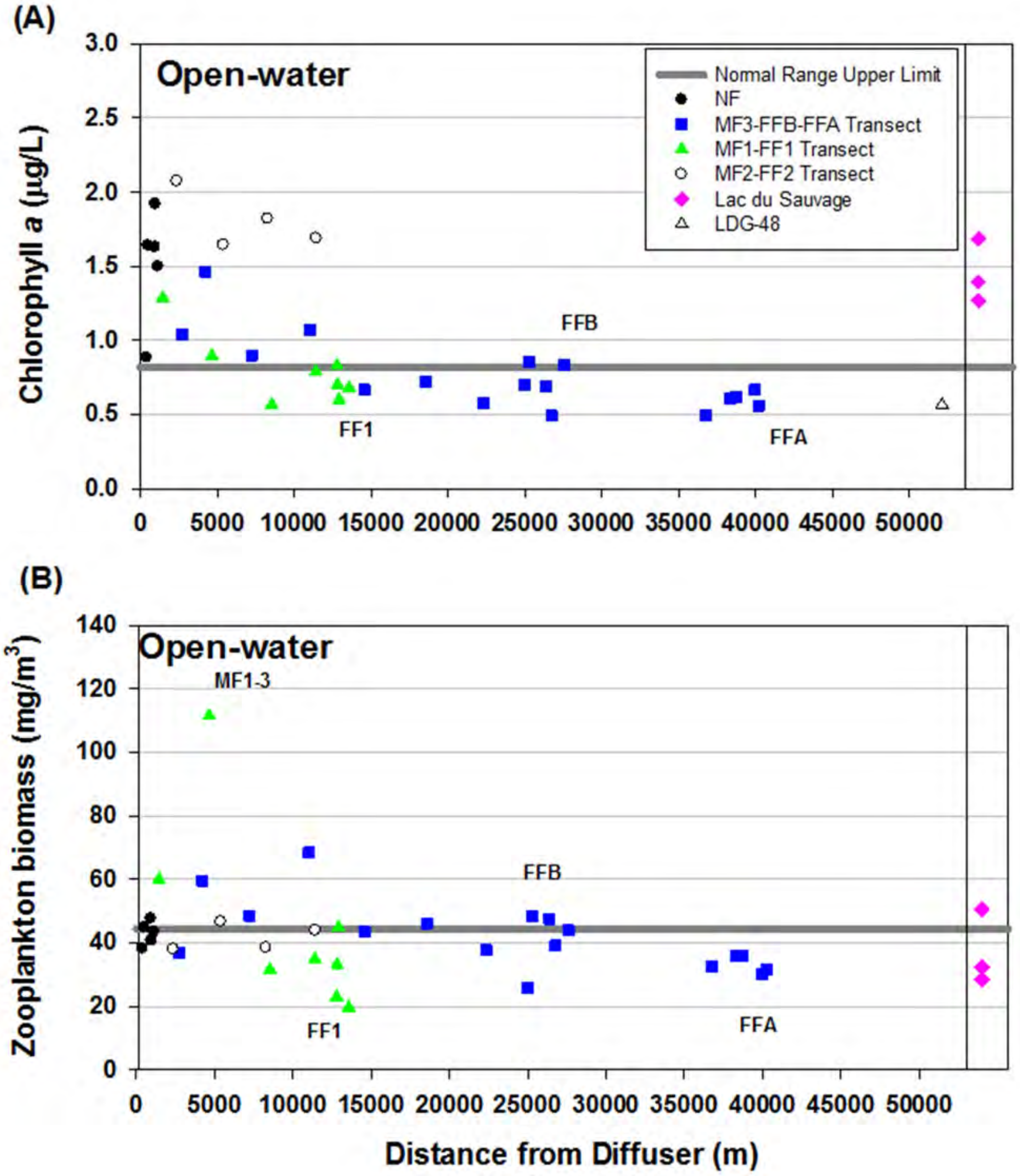
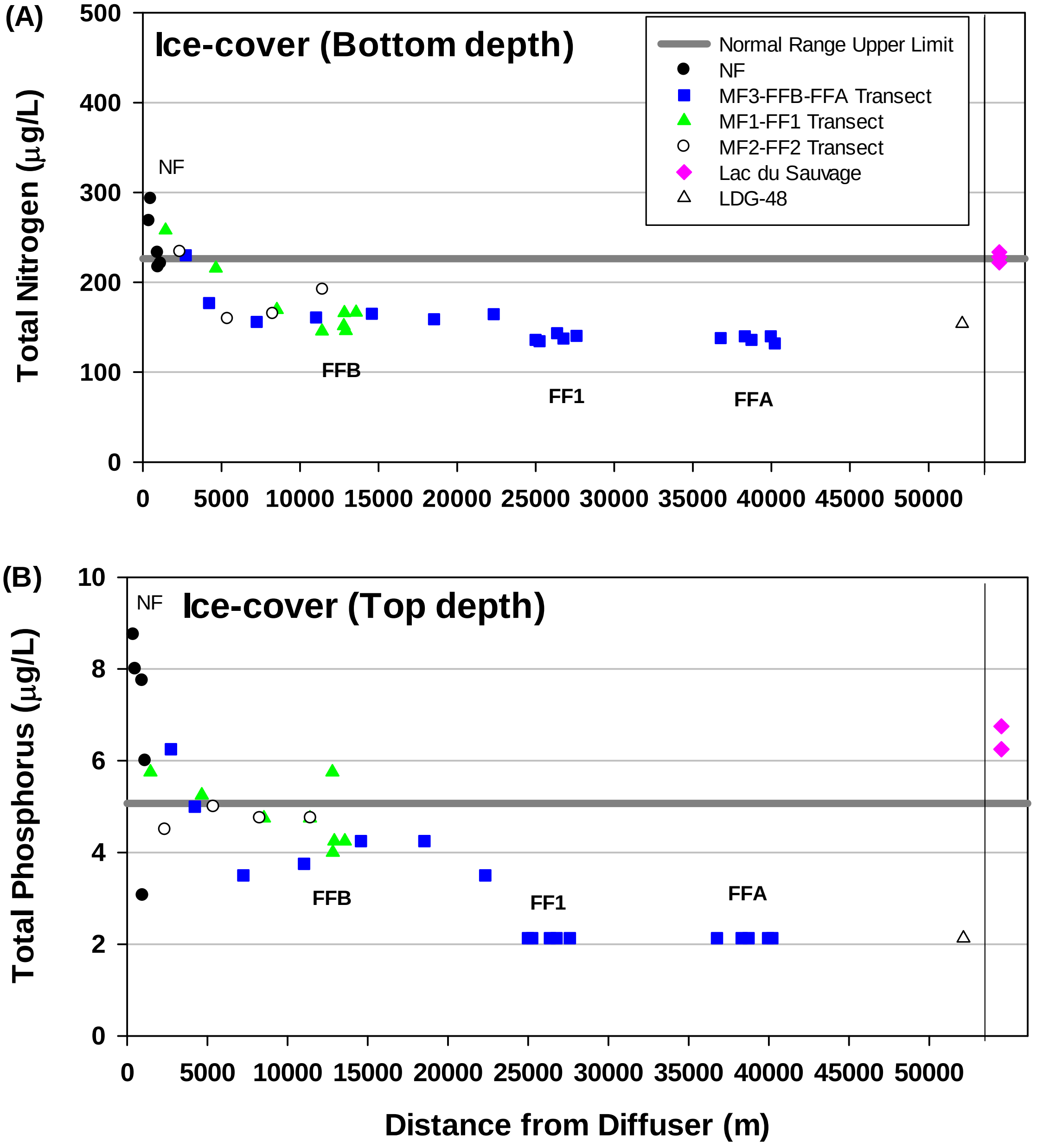


Figure 4-4 Total Nitrogen Concentration (Bottom depth) (A) and Total Phosphorus Concentration (Top Depth) (B) on Lac de Gras According to Distance from the Effluent Discharge during the Ice-Cover Period of 2013



5 SEDIMENT CHEMISTRY

5.1 INTRODUCTION AND OBJECTIVES

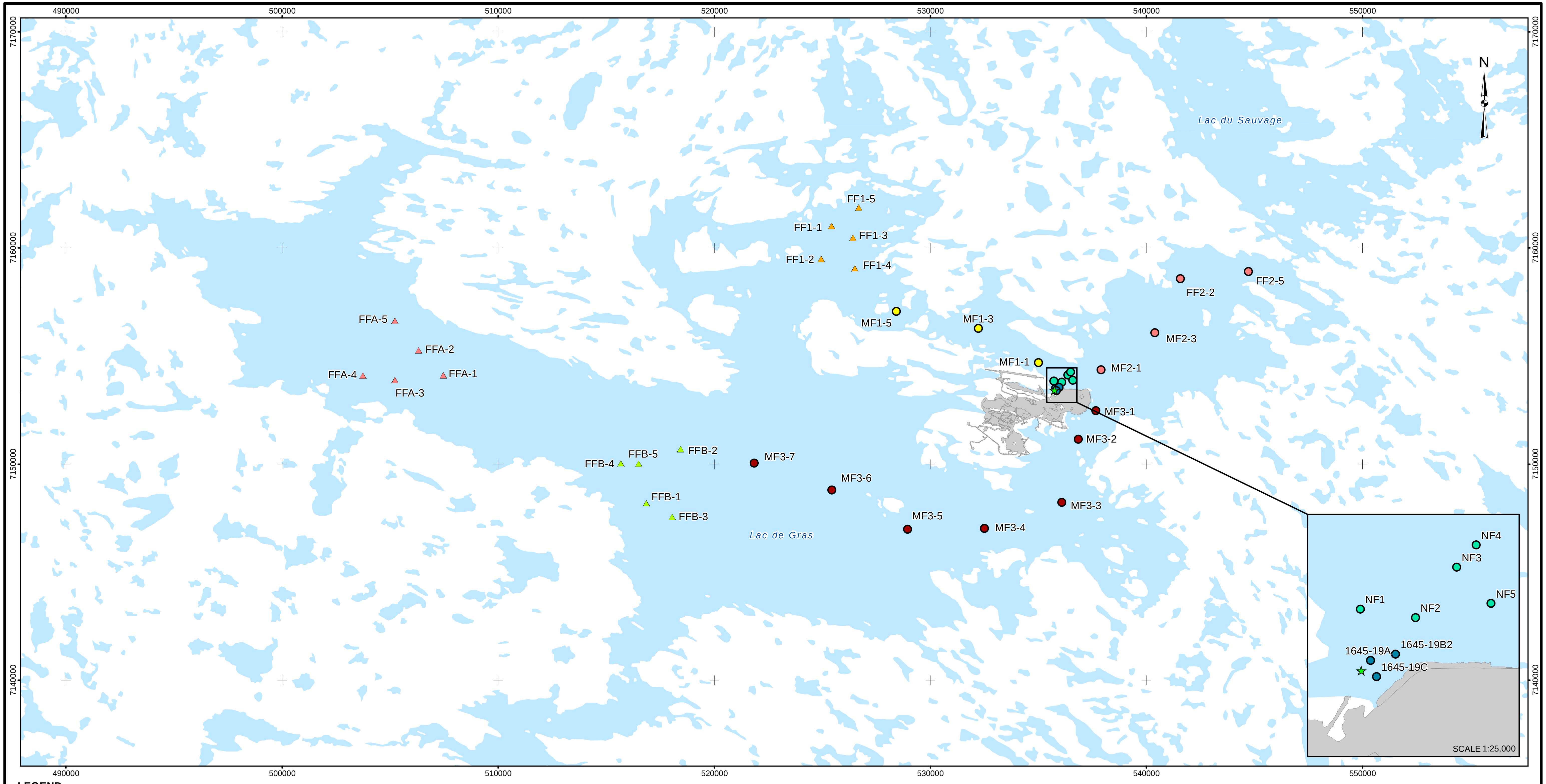
The objective of the sediment survey is to assess the effects of Mine effluent on sediment quality. Sediment data were analyzed to determine whether there are any differences in sediment quality between exposure and reference areas.

The amount of metals in sediments provides information regarding the presence of chemical stressors and may help explain effects, should they occur, in the benthic invertebrates. Substrate size is an important factor influencing the benthic community structure, and organic carbon can indicate if metals are more or less likely to be taken up by benthic invertebrate organisms. Therefore, a secondary objective of the sediment survey was to provide such supporting environmental information to help interpret findings from the AEMP benthic invertebrate community survey.

A detailed technical report prepared by Golder on the findings from the 2013 sediment monitoring program is included in Appendix III. The following section provides an overview of the sediment program and a summary of the 2013 results.

5.2 METHODS

Sample collection for the AEMP sediment quality component took place between August 18 and September 7, 2013, at the same time that benthic invertebrate sampling took place. Sediment samples were taken during both ice-cover and open-water conditions from the three general areas (NF, MF, and FF) of Lac de Gras (Figure 5-1). Sediment samples were also collected at the location where effluent mixes with lake water (called the mixing zone boundary). The specific sampling location is called Station SNP-1645-19, also referred to as SNP-19. Data from SNP-19 were incorporated into the 2013 AEMP report. Sediment samples were analyzed by Maxxam.



LEGEND

★ DIFFUSER

EXPOSURE

- ● NEAR-FIELD
- ● MID-FIELD 3
- ● MID-FIELD 1
- ● FAR-FIELD 2; MID-FIELD 2
- ● SURVEILLANCE NETWORK PROGRAM

REFERENCE

- ▲ FAR-FIELD 1
- ▲ FAR-FIELD A
- ▲ FAR-FIELD B
- ▨ DIAVIK FOOTPRINT
- ▨ WATERBODY

5 0 5

SCALE 1:175,000 KILOMETRES

REFERENCE

HYDROGRAPHY DATA OBTAINED FROM CANVEC © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 12 DATUM: NAD 83

PROJECT

DIAVIK DIAMOND MINES INC.

TITLE

SEDIMENT QUALITY SAMPLING STATIONS, 2013 AEMP

Golder Associates

PROJECT	13-1328-0001		FILE No.
DESIGN	LJ	24 Dec. 2013	SCALE AS SHOWN REV. 0
GIS	JC	20 Mar. 2014	
CHECK	TD	20 Mar. 2014	FIGURE: 5-1
REVIEW	CF	20 Mar. 2014	

I:\2011\11-1328\11-1328-0038\Mapping\MXD\2013AEMP\FINAL\Fig5-1_2013_AEMP_Sediment_Sampling_Locations_20140219_Final.mxd

Sediment samples were collected with two sampling devices, which allowed for sampling at different sediment depths. The first method used a bulk sampling device called an Ekman grab (Photo 5-1). The Ekman grab was lowered to the bottom, and the top 10 to 15 cm of the sediments brought to the surface. This was done three times at each location. Sediments from the three "grabs" were combined to form a single composite sample. The sample was analyzed for particle size (i.e., percentages of sand, silt and clay) and the amount of total organic carbon (TOC) and total organic matter.

The second method for collecting sediment samples used a gravity-feed core sampling device which was used to obtain a thin (1 cm) slice of the top layer of the sediment (Photo 5-2). If changes are occurring in the sediment due to mining activities, it is expected that the changes would be most noticeable closest to the surface. The top 1-cm layer from a minimum of three cores was collected at each AEMP station and combined to form a single sample that was analyzed for metals, total nitrogen, total phosphorus and TOC.

Photo 5-1 Photo of Ekman Grab Sediment Sampling Device

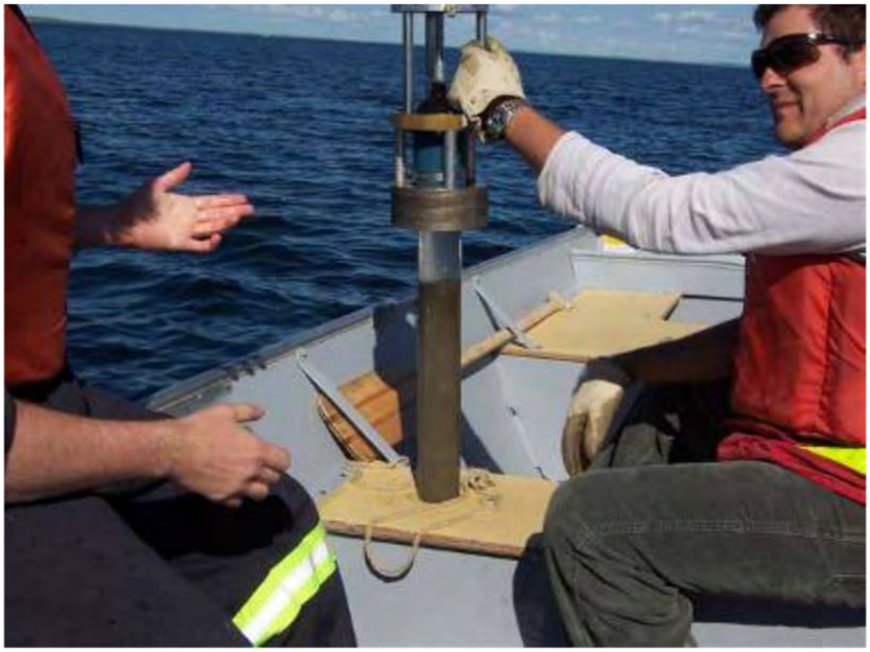


Photo 5-2 Photo of Sediment Coring Device

The full suite of sediment chemistry variables (consisting of nutrients, total metals, TOC, and organic matter) analyzed from the top 1 cm of the core samples was examined to identify variables that exhibited greater concentrations in the NF exposure area compared to the reference areas. Variables were then analyzed statistically to determine whether the differences were significant. All variables with significantly greater concentrations in the Near-field exposure area relative to the reference areas were referred to as SOIs.

The magnitude of the effect on SOIs was assessed by comparing analyte concentrations in exposure areas to the *normal range*, which is defined as the historical reference area mean ± 2 SD. Values that exceed the normal range are exceeding what would be considered natural levels for Lac de Gras. Although unnatural for this lake, these values do not necessarily represent levels that are harmful.

Differences in physical characteristics of sediments that are unrelated to the Mine discharge (i.e., particle size and TOC) have the potential to influence sediment chemistry in Lac de Gras. To address this source of uncertainty, correlation analysis was used to determine if sediment chemistry is correlated to physical variables.

Elevated metal concentrations do have the potential to impact the benthic invertebrate community; therefore, the importance of effects observed on SOIs was determined by screening SOI concentrations against sediment quality guidelines (CCME 2002; OMOEE 1993). Exceeding guidelines does not imply that toxicity will occur. By design, these are conservative guidelines and are considered intentionally overprotective of the aquatic environment (O'Connor 2004).

5.3 RESULTS AND DISCUSSION

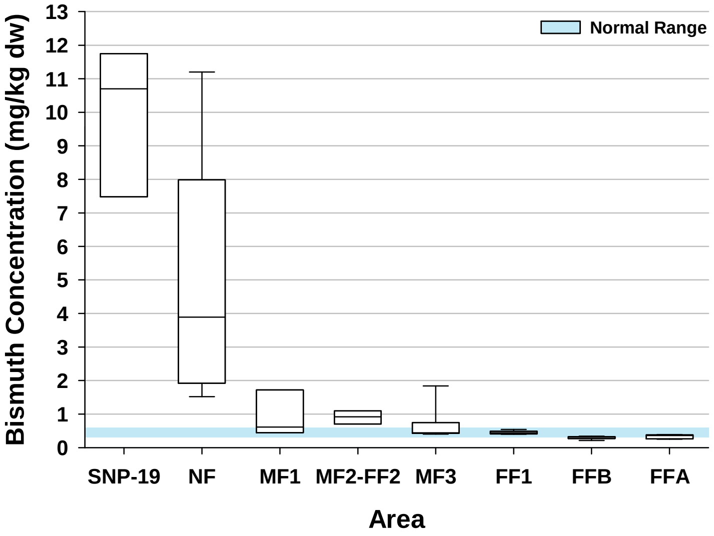
Effects of the Mine discharge on bottom sediments in the NF area of Lac De Gras were evident for 13 SOIs (aluminum, bismuth, boron, calcium, chromium, lead, lithium, magnesium, potassium, sodium, tin, titanium, and uranium), which had NF area mean concentrations that were significantly greater than reference area concentrations. Three of the SOIs (bismuth, lead and uranium) had NF area mean concentrations that were greater than their normal ranges. Pronounced spatial patterns related to the diffuser were apparent for each of these three variables (Figures 5-2 to 5-4).

Results of the most recent dike monitoring study reported similar elevations of bismuth, lead and uranium in the vicinity of the A154 and A418 dikes. Sediment results indicated that effluent discharge is likely the primary source of these metals in the exposure area, although other factors, such as dike construction and seepage from the dike may have also contributed to the observed pattern.

Results of the Effluent and Water Quality Reports have indicated clear mine-related spatial and temporal trends in water for uranium; however, effluent-related patterns for bismuth and lead have not been identified. Lead is, however, regularly detected in the effluent. Bismuth is typically not detected in the effluent or at AEMP water quality sampling stations.

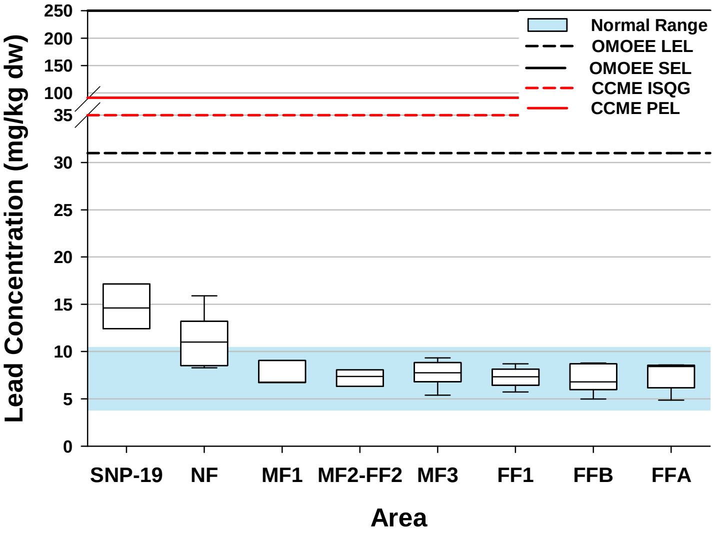
The toxicological risks associated with elevated bismuth concentrations in exposure area sediments are unknown (no guidelines exist and no sediment toxicity data were found); however, lead and uranium concentrations are unlikely to pose a toxicological risk to biota based on comparisons to sediment quality guidelines and information from the primary literature. Benthic invertebrate data collected to date in Lac de Gras do not suggest a toxic effect.

Figure 5-2 Box and Whisker Plots of Bismuth Concentrations at Mixing Zone (SNP-19) and AEMP Stations, 2013



Note: Box and whisker plots represent the minimum, 25th percentile, median, 75th percentile and maximum values in each area. Blue shaded area represents mean of reference area (FFA, FFB, FF1) data from 2007 to 2010, plus or minus two standard deviations.

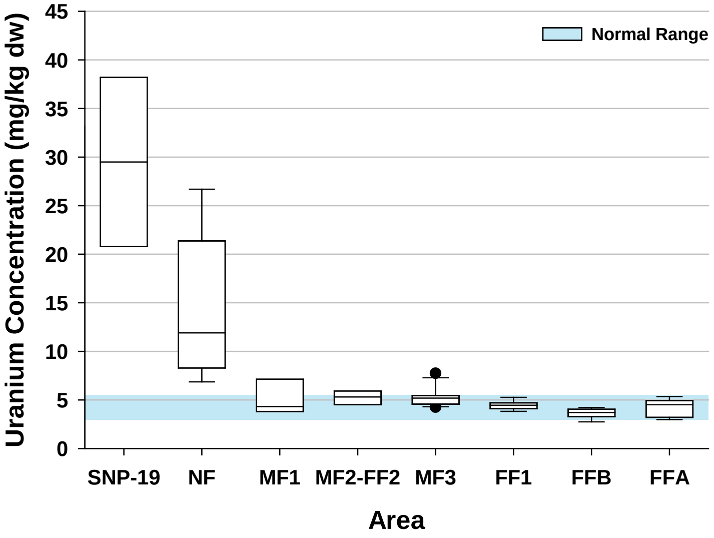
Figure 5-3 Box and Whisker Plots of Lead Concentrations at Mixing Zone (SNP-19) and AEMP Stations, 2013



Note: OMOEE = Ontario Ministry of the Environment and Energy; LEL = Lowest Effect Level; SEL = Severe Effect Level; CCME = Canadian Council of Minister of the Environment; ISQG = Interim Sediment Quality Guideline; PEL = Probable Effect Level

Box and whisker plots represent the minimum, 25th percentile, median, 75th percentile and maximum values in each area. Blue shaded area represents mean of reference area (FFA, FFB, FF1) data from 2007 to 2010, plus or minus two standard deviations.

Figure 5-4 Box and Whisker Plots of Uranium Concentrations at Mixing Zone (SNP-19) and AEMP Stations, 2013



Note: Box and whisker plots represent the minimum, 25th percentile, median, 75th percentile and maximum values in each area. Blue shaded area represents mean of reference area (FFA, FFB, FF1) data from 2007 to 2010, plus or minus two standard deviations.

Confounding variables such as TOC and percent fine sediment explained much of the variability in the concentrations of metals and nutrients that had no clear Mine-related patterns in 2013. These confounding variables, however, did not impair our ability to detect effects on these chemicals.

Only one SOI (chromium) exceeded guideline concentrations; however, concentrations in the exposure area were within the normal range for Lac de Gras, indicating that the observed exceedances fall within the range of concentrations considered natural for Lac de Gras. Concentrations of several other nutrients and metals in sediments in Lac de Gras were above sediment quality guidelines. In general, variables that exceeded guidelines did so throughout the lake, and they reflected patterns in TOC content of bottom sediments and had no clear spatial trends related to the Mine.

6 PLANKTON

6.1 INTRODUCTION AND OBJECTIVES

The term “plankton” is a general term referring to small, usually microscopic organisms that live suspended in the open-water. For the purpose of this study, the term “phytoplankton” refers to the open-water, algal (small plants) component of the plankton. There are five major ecological groups of phytoplankton: Cyanobacteria, Chlorophytes, Microflagellates, dinoflagellates and diatoms. The term “zooplankton” refers to the very small animals in the plankton, ranging from microscopic to visible with the naked eye, and includes crustaceans (i.e., Cladocera [cladocerans], Cyclopoida [cyclopoids], Calanoida [calanoids]), and Rotifera (rotifers).

The main goal of the plankton component is to monitor phytoplankton and zooplankton communities (i.e., abundance, biomass, and taxonomic composition) as indicators of effects of the Mine on the Lac de Gras ecosystem. Plankton data were collected during the 2013 AEMP field program, which was carried out by DDMI according to the AEMP Study Design Version 3.0 (Golder 2011a).

6.2 METHODS

Thirty-four stations located within five general areas of Lac de Gras and three stations located in one general area in Lac du Sauvage were sampled by DDMI during the 2013 plankton program. Sampling areas consisted of the near-field (NF) exposure area, three mid-field areas (MF1, MF3, and FF2), three far-field reference areas (FF1, FFA, and FFB) and the Lac du Sauvage area located in the narrows separating the two lakes (Figure 6-1).

A depth-integrated sampler, which collected water from the surface to a depth of 10 m, was used to collect phytoplankton samples. A Wisconsin plankton net with a 75-µm mesh and a 30.5-cm mouth diameter was used to collect duplicate zooplankton samples at each station. Phytoplankton samples were sent to Eco-Logic Ltd. (Vancouver, BC), and zooplankton samples were sent to Salki Consultants Inc. (Winnipeg, MB), for analysis of taxonomic composition.

Effects were assessed by comparing areas of the lake exposed to effluent to areas of the lake that are not exposed to effluent (i.e., reference areas). Plankton community endpoints were statistically tested to establish whether the differences seen among areas were related to the Mine (i.e., demonstrated a statistically-significant difference) or whether they may have occurred by chance.

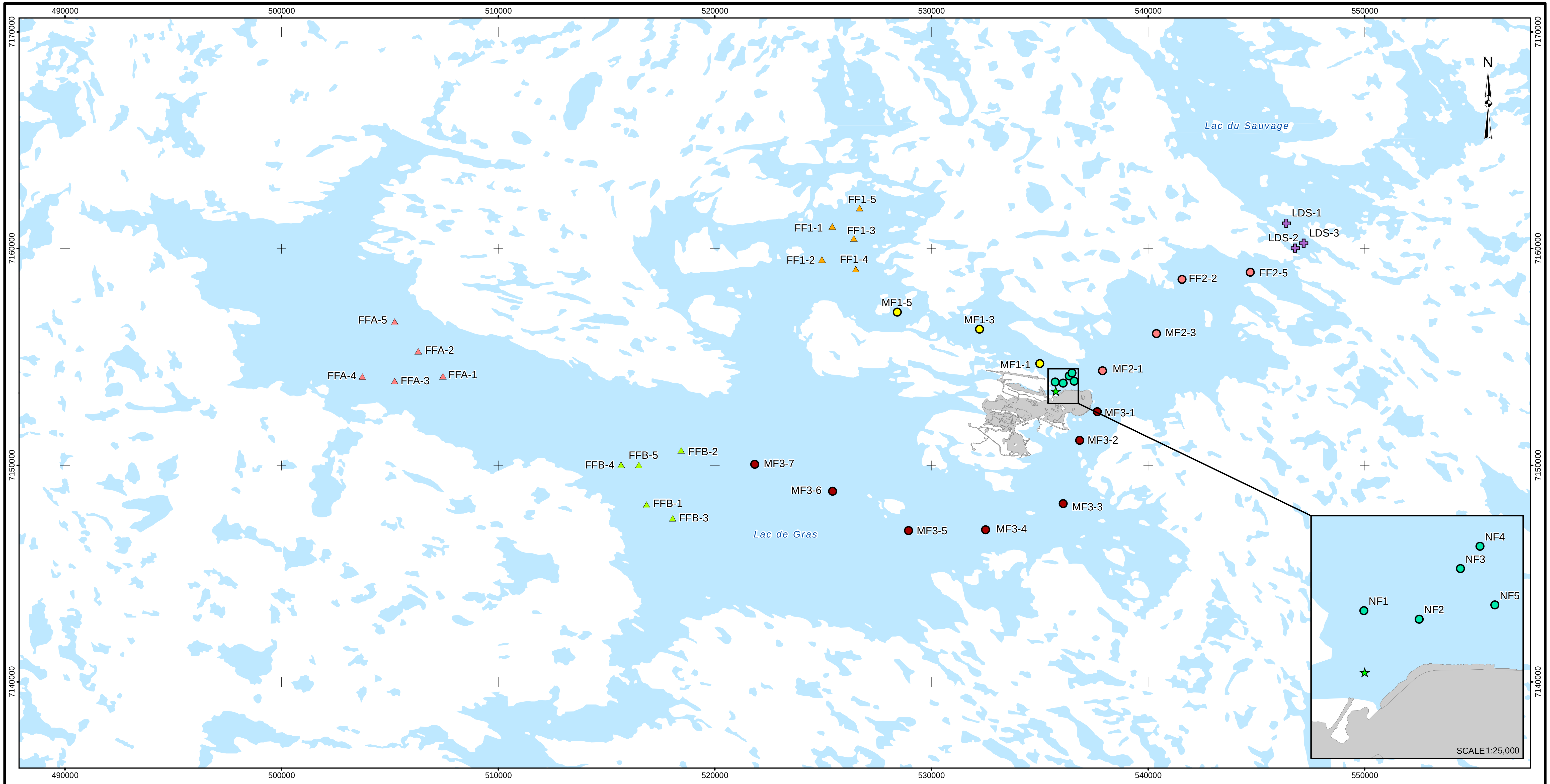
The importance of effects to a phytoplankton or zooplankton assessment endpoint (i.e., biomass or taxonomic richness) has been categorized according to Action Levels, which are summarized in Table 6-1. The magnitude of effect was assessed by comparing community endpoints in exposure areas to background values. Background values for Lac de Gras are those that fall within the *normal range*, which is defined as the historical reference area mean ± 2 SD. Values that are beyond the normal range are exceeding what would be considered natural levels for Lac de Gras.

Table 6-1 Action Levels for Plankton Effects

Action Level	Plankton	Extent	Action
1	Mean biomass or richness significantly less than reference area means	Near-field	Confirm effect
2	Mean biomass or richness significantly less than reference area means	Nearest Mid-field station	Investigate cause
3	Mean richness less than normal range	Near-field	Examine ecological significance Set Action Level 4 Identify mitigation options
4	TBD[a]		Define conditions required for the Significance Threshold
5	Decline in biomass or richness likely to cause a >20% change in fish population(s)	Far-field A (FFA)	Significance Threshold

Notes: >= greater than;% = percent.

a) To be determined if Action Level 3 is reached.



LEGEND

★ DIFFUSER

EXPOSURE

● NEAR-FIELD

● MID-FIELD 3

● MID-FIELD 1

● FAR-FIELD 2; MID-FIELD 2

REFERENCE

▲ FAR-FIELD 1

▲ FAR-FIELD A

▲ FAR-FIELD B

✚ LAC DU SAUVAGE

▨ DIAVIK FOOTPRINT

▨ WATERBODY

5 0 5

SCALE 1:175,000 KILOMETRES

REFERENCE

HYDROGRAPHY DATA OBTAINED FROM CANVEC © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 12 DATUM: NAD 83

PROJECT

DIAVIK
DIAMOND MINES INC.

TITLE

PLANKTON SAMPLING STATIONS, 2013 AEMP

Golder Associates

PROJECT		13-1328-0001	FILE No.	
DESIGN	LJ	28 Jan. 2014	SCALE AS SHOWN	REV. 0
GIS	JC	20 Mar. 2014		
CHECK	TD	20 Mar. 2014	FIGURE: 6-1	
REVIEW	CF	20 Mar. 2014		

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6.3 RESULTS

Overall, phytoplankton biomass was greater at stations exposed to effluent than at more distant stations. Biomass at stations along the MF2-FF2 transect (MF2-1, FF2-2, and FF2-5) were above the normal range, and the biomass at station MF3-1 to the southeast of the Mine was at the upper limit of the normal range (Figure 6-2). Phytoplankton biomass at one of the Lac du Sauvage stations was greater than that observed in the three reference areas in Lac de Gras (Figure 6-2).

In 2013, phytoplankton community structure in Lac de Gras was characterized by a dominance of cyanobacteria by abundance and a dominance of chlorophytes by biomass (Figure 6-3). The contribution of cyanobacteria to total phytoplankton community biomass was less than abundance because of the relatively small size of most cyanobacteria cells. The relative biomass of chlorophytes was greater than abundance because of their large cell size. Phytoplankton community structure in Lac du Sauvage differed from that in Lac de Gras in terms of relative abundance; however, relative biomass was similar among the Lac du Sauvage stations and the FF reference area stations (Figure 6-3).

Figure 6-2 Total Phytoplankton Biomass in Lac de Gras According to Distance from the Effluent Diffuser, Open 1 Period of 2013

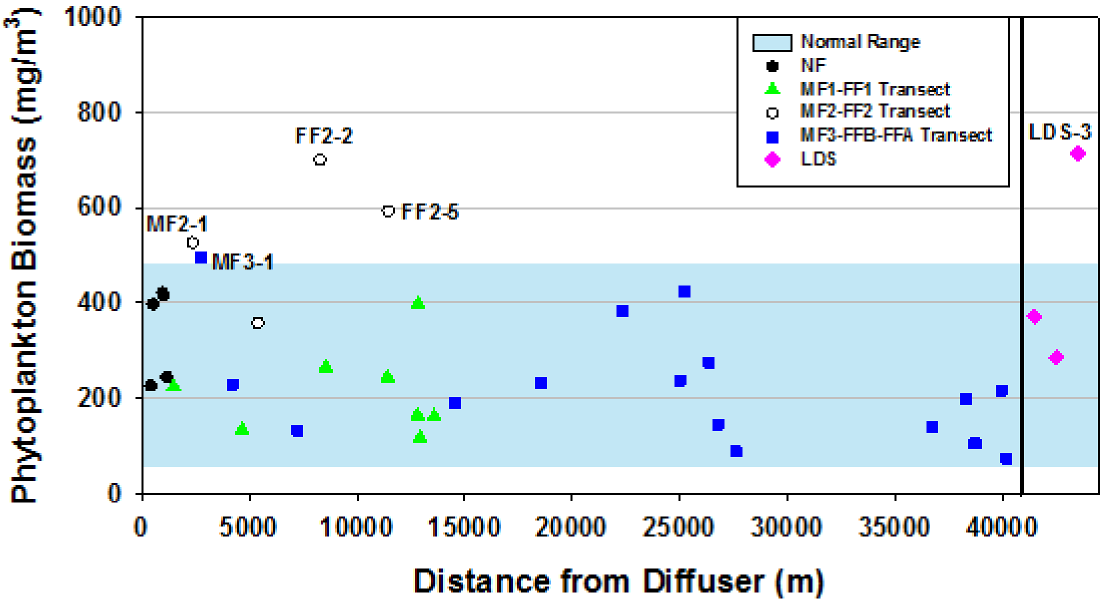
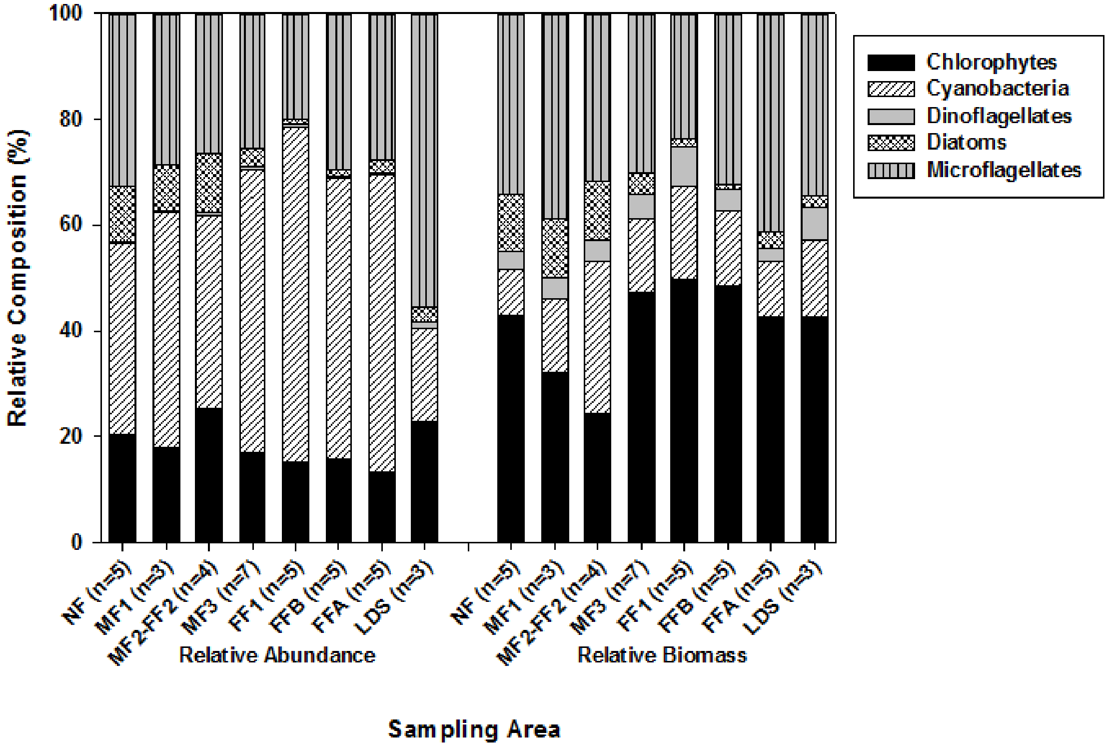


Figure 6-3 Mean Relative Phytoplankton Biomass by Sampling Ares in Lac de Gras in 2013



Zooplankton biomass in the NF exposure area was generally similar to that in the reference areas in 2013. All stations were within the normal range based on the 2008 to 2010 pooled reference area data, with the exception of MF1-3 (Figure 6-4).

Zooplankton community structure in Lac de Gras was characterized by a dominance of rotifers by abundance, ranging from 52% to 84% (Figure 6-5). Despite accounting for a large proportion of the relative abundance, rotifers accounted for a small proportion (1% to 5%) of the zooplankton biomass, reflective of their small size. While cladocerans were trivial in abundance (1% to 3%), they contributed a large proportion to the overall biomass (25% to 92%), reflective of their large size. Zooplankton biomass in Lac de Gras was not dominated by any particular group; rather it was co-dominated by cladocerans, calanoid copepods, and cyclopoid copepods (Figure 6-5). Differences in the community composition among stations in Lac de Gras was still noticeable. Zooplankton community structure in Lac du Sauvage was different from that in Lac de Gras in terms of relative abundance and biomass (Figure 6-5). Greater abundances of cladocerans were observed at the Lac du Sauvage stations (26% to 39%) compared to stations in Lac de Gras (1% to 3%) (Figure 6-5). By biomass, the Lac du Sauvage stations were dominated by cladocerans (88% to 94%), with minimal biomasses accounted for by the other groups (calanoids, cyclopoids, and rotifers) (Figure 6-5).

Sufficient differences in phytoplankton biomass and community structure, and zooplankton community structure were observed between the exposure and reference areas to indicate that the Mine is having an effect on the plankton community. These observations are consistent with the findings of the Eutrophication Indicators component of the AEMP. The 2013 monitoring results suggest that plankton communities in Lac de Gras are exhibiting a Mine-related nutrient enrichment effect and provided no evidence for toxicological impairment. Overall, the plankton biomass and taxonomic richness data indicate that an Action Level 1 for plankton has not been reached.

Figure 6-4 Total Zooplankton Biomass in Lac de Gras According to Distance from the Diffuser in 2013

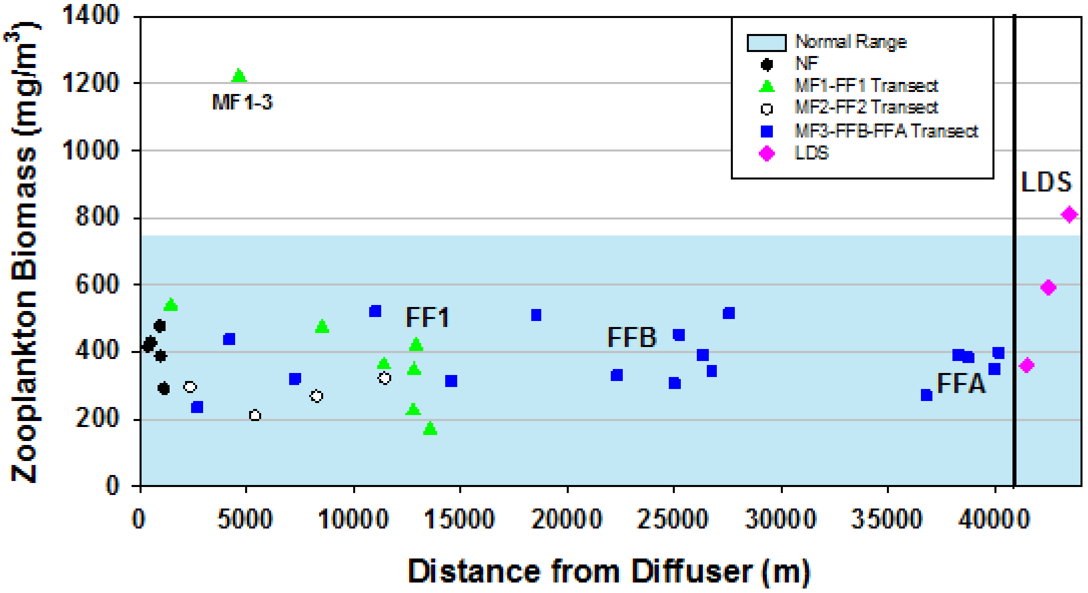
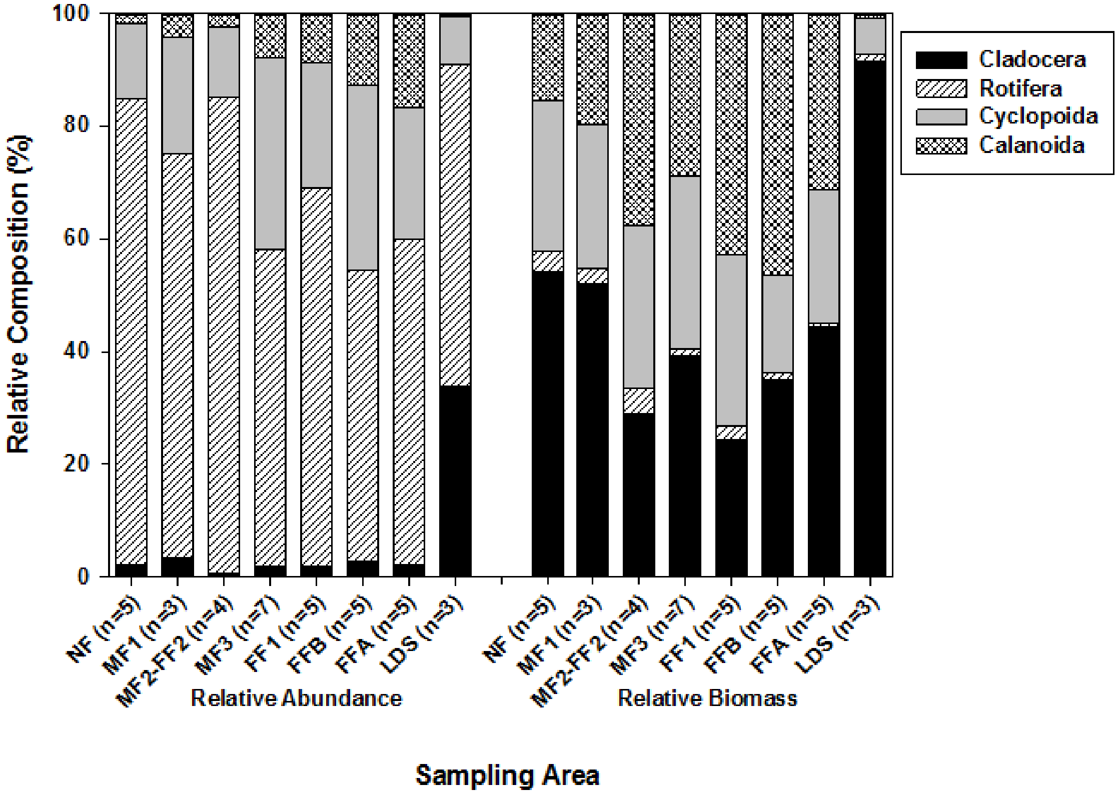


Figure 6-5 Mean Relative Zooplankton Abundance and Biomass (calculated) by Sampling Area in Lac de Gras and Lac du Sauvage, 2013



7 BENTHIC INVERTEBRATES

7.1 INTRODUCTION AND OBJECTIVES

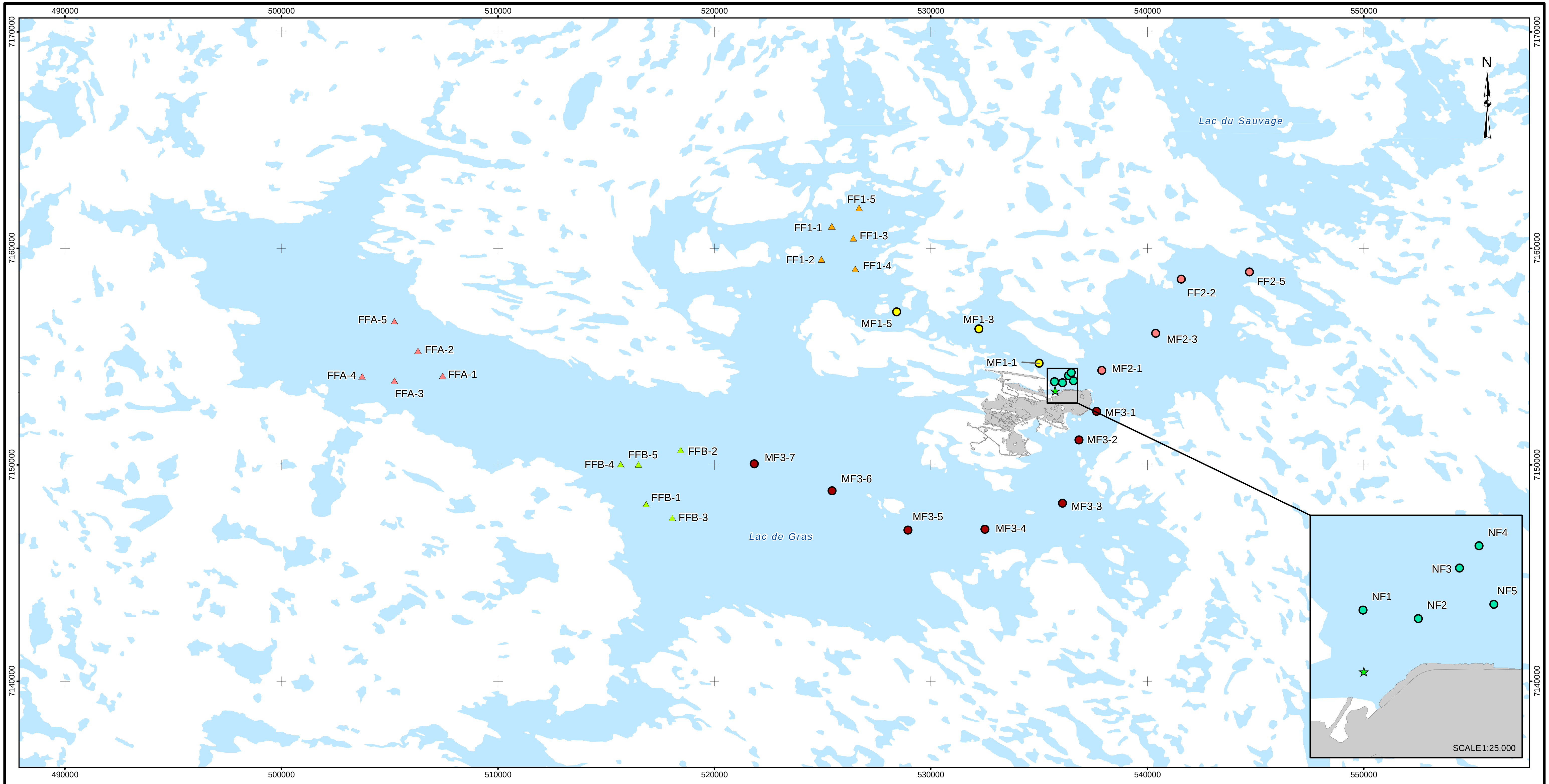
Benthic invertebrates are very small organisms without backbones (*e.g.*, insect larvae, snails, clams, worms) that spend at least part of their life living in or on the bottoms of rivers and lakes. Many different types of benthic invertebrates live within the lake bottom. The types of benthic invertebrates found at any particular location in Lac de Gras can provide information on changes or effects due to the Mine operations. The objective of this component of the AEMP was to determine if an effect is occurring on the benthic invertebrate communities of Lac de Gras due to the Mine operation.

A detailed technical report prepared by Golder on the findings of the 2013 benthic invertebrate monitoring program is included in Appendix IV. The following section provides an overview of the benthic invertebrate program and a summary of the 2013 results.

7.2 METHODS

Benthic invertebrate samples were collected at AEMP stations from August 18 to September 5, 2013, at the same time as the plankton and water chemistry monitoring. Benthic invertebrate samples were collected from each of the 34 sampling locations illustrated in Figure 7-1.

Six sub-samples, each consisting of a single Ekman grab, were collected at each location. At 26 of the stations these 6 sub-samples were composited into 1 sample. The remaining sub-samples from the eight other stations were analyzed separately to allow an evaluation of within-station variability. Each sample was sieved, and material retained in the mesh was placed into a separate bottle. The types of invertebrates present in each sample were identified (a process called taxonomic identification). The number of individual organisms of each type was counted (a process called enumeration).



LEGEND

★ DIFFUSER

▨ DIAVIK FOOTPRINT

🟦 WATERBODY

EXPOSURE

● NEAR-FIELD

● MID-FIELD 3

● MID-FIELD 1

● FAR-FIELD 2; MID-FIELD 2

REFERENCE

▲ FAR-FIELD 1

▲ FAR-FIELD A

▲ FAR-FIELD B

REFERENCE

HYDROGRAPHY DATA OBTAINED FROM CANVEC © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 12 DATUM: NAD 83

5 0 5

SCALE 1:175,000 KILOMETRES

PROJECT

DIAVIK DIAMOND MINES INC.

TITLE

BENTHIC INVERTEBRATE SAMPLING STATIONS, 2013 AEMP

Golder Associates

PROJECT		13-1328-0001	FILE No.	
DESIGN	LJ	18 Feb. 2014	SCALE AS SHOWN	REV. 0
GIS	JC	20 Mar. 2014	FIGURE: 7-1	
CHECK	TD	20 Mar. 2014		
REVIEW	CF	20 Mar. 2014		

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From the taxonomic identifications and enumeration, a number of variables were selected that describe various aspects of the benthic community at each sampling location. These variables were:

- total invertebrate density (number of organisms per square metre);
- richness (total number of taxa per station at the lowest level of taxonomic identification);
- Simpson's Diversity Index (a means of measuring taxonomic diversity);
- evenness index (a means of measuring the balance among numbers of different invertebrates present at a location);
- dominance (percentage of the dominant organism at a station);
- Bray-Curtis distance (a means of determining change compared to a reference condition);
- densities of dominant taxa:
  - *Procladius* sp. (29% of total abundance across all stations);
  - Pisidiidae (23%);
  - *Heterotrissocladius* sp. (14%); and
  - Microtendipes sp. (7%).

Mine-related effects were assessed by comparing these variables in exposure areas to those in reference areas. The influence of sediment particle size on the composition of the benthic invertebrate community was assessed. The importance of a Mine-related effect was categorized according to the Action Levels, which are listed in Table 7-1.

Table 7-1 Action Levels for Benthic Invertebrate Effects

Action Level	Benthic Invertebrates	Extent	Action
1	The mean of a community index [(a)] significantly less than reference area means.	Near-field	Confirm effect
2	The mean of a community index [(a)] significantly less than reference area means.	Nearest Mid-field station	Investigate cause
3	The mean of any measurement endpoint [(a)] less than normal range.	Near-field	Examine ecological significance Set Action Level 4 Identify mitigation options
4	TBD [(b)]	-	Define conditions required for the Significance Threshold
5	Decline of community indices [(a)] likely to cause a >20% change n fish populations(s).	Far-field A (FFA)	Significance Threshold

a) Refers to indices such as total density, richness, Simpson's diversity index, Bray-Curtis index and densities of dominant taxa; the criterion for the Bray-Curtis index is a significantly higher mean value compared to the reference areas.

b) To be determined if an Action Level 3 effect is reached.

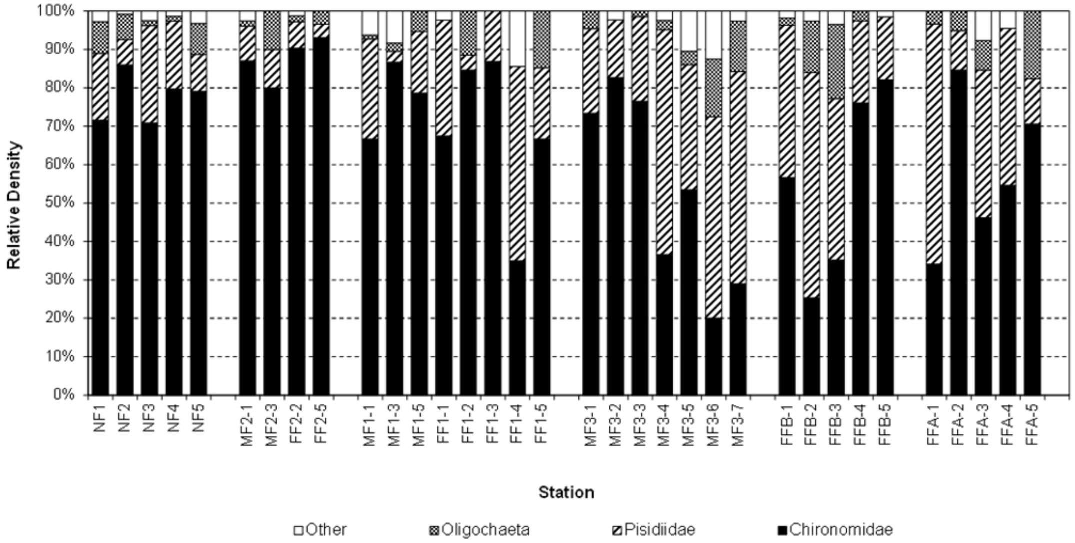
7.3 RESULTS AND DISCUSSION

The following is a summary of key findings from the benthic invertebrate program. More detailed analysis and results are described in Appendix IV.

There was no overall correlation between habitat variables and biological variables for benthic invertebrates. This means that habitat variables were not influencing the evaluation of the Mine's potential effects.

Figure 7-2 shows the composition of the benthic invertebrate community, by major group of invertebrates (taxa), based on data collected during the 2013 AEMP. The benthic invertebrate community of Lac de Gras was dominated by midges (Chironomidae), which accounted for 20% to 93% of total invertebrate density at all stations. Midges accounted for 70% or more of the total density at the exposure stations nearest the Mine. Fingernail clams (Pisidiidae) formed a large proportion of the total density at most reference area stations, with the largest relative abundance of 63% at Station FFA-1. At this coarse level of evaluation, exposure area communities had generally higher and less variable proportions of midges, and lower proportions of fingernail clams compared to the reference areas.

Figure 7-2 Composition of the Benthic Community at Sampling Areas in Lac de Gras in 2013



Statistically-significant differences were detected between the reference areas (FFA, FFB, and FF1) and the NF exposure area for 3 of the 11 benthic invertebrate community variables analyzed. Total density (Figure 7-3) and *Procladius* density (Figure 7-4) in the NF area were greater than in the reference areas, suggesting potential Mine-related effects. Near-field area means were within the estimated normal ranges (pooled means ± 2 SD for 2007-2010). Spatial trends in total density and *Procladius* density and *Heterotrissocladius* density (Figure 7-5) were consistent with nutrient enrichment resulting from the discharge of Mine effluent to Lac de Gras. Results of multivariate analysis indicated a slight difference in the benthic invertebrate community in the exposure areas compared to the reference areas. Given that there was no evidence of toxicity to the benthic invertebrate community, an effect equivalent to Action Level 1 was not reached (Table 5-1).

Figure 7-3 Total Invertebrate Density at Sampling Areas in Lac de Gras, 2013

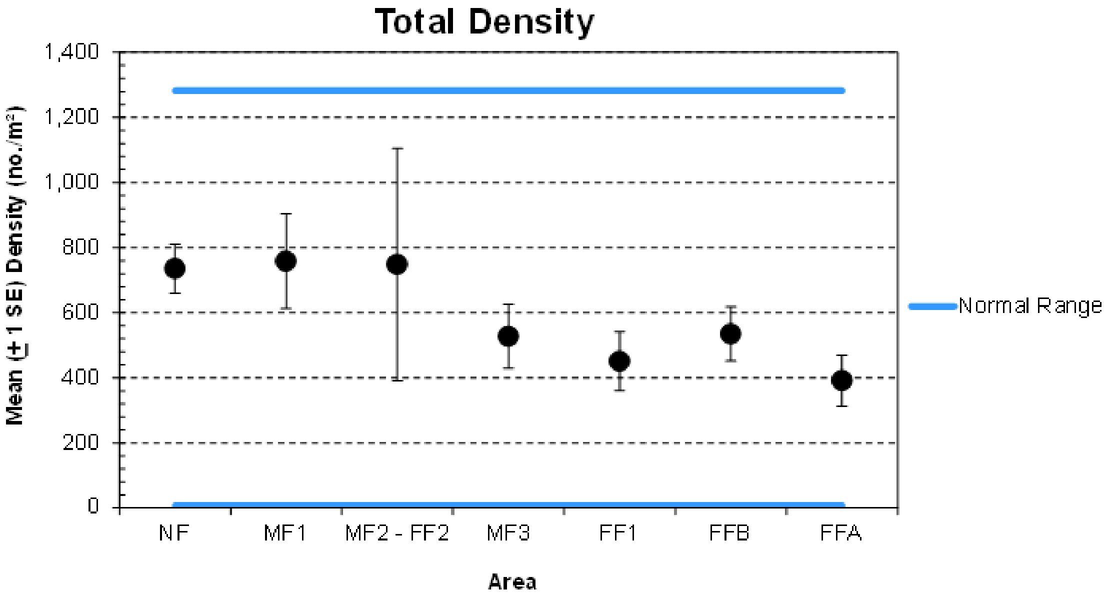


Figure 7-4 Densities of *Procladius sp.* at Sampling Areas in Lac de Gras, 2013

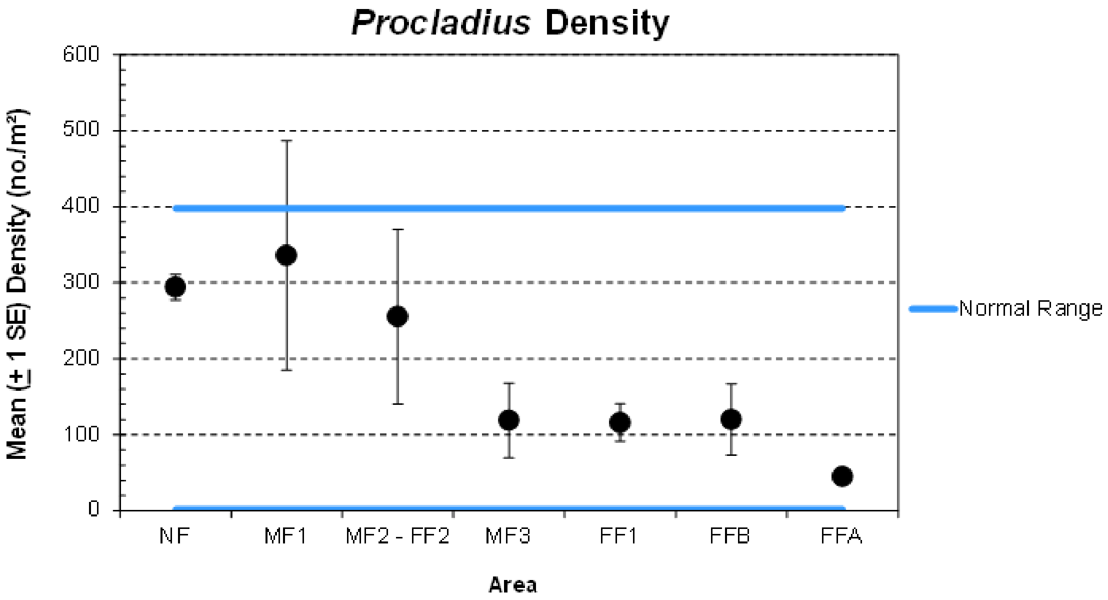
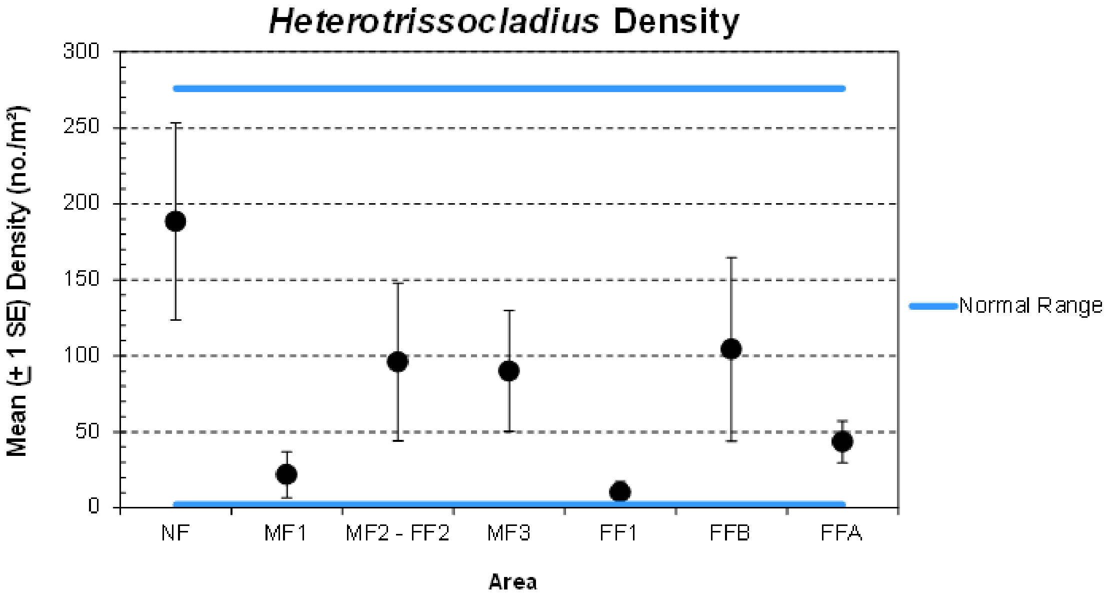


Figure 7-5 Densities of Procladius sp. at Sampling Areas in Lac de Gras, 2013



8 FISH

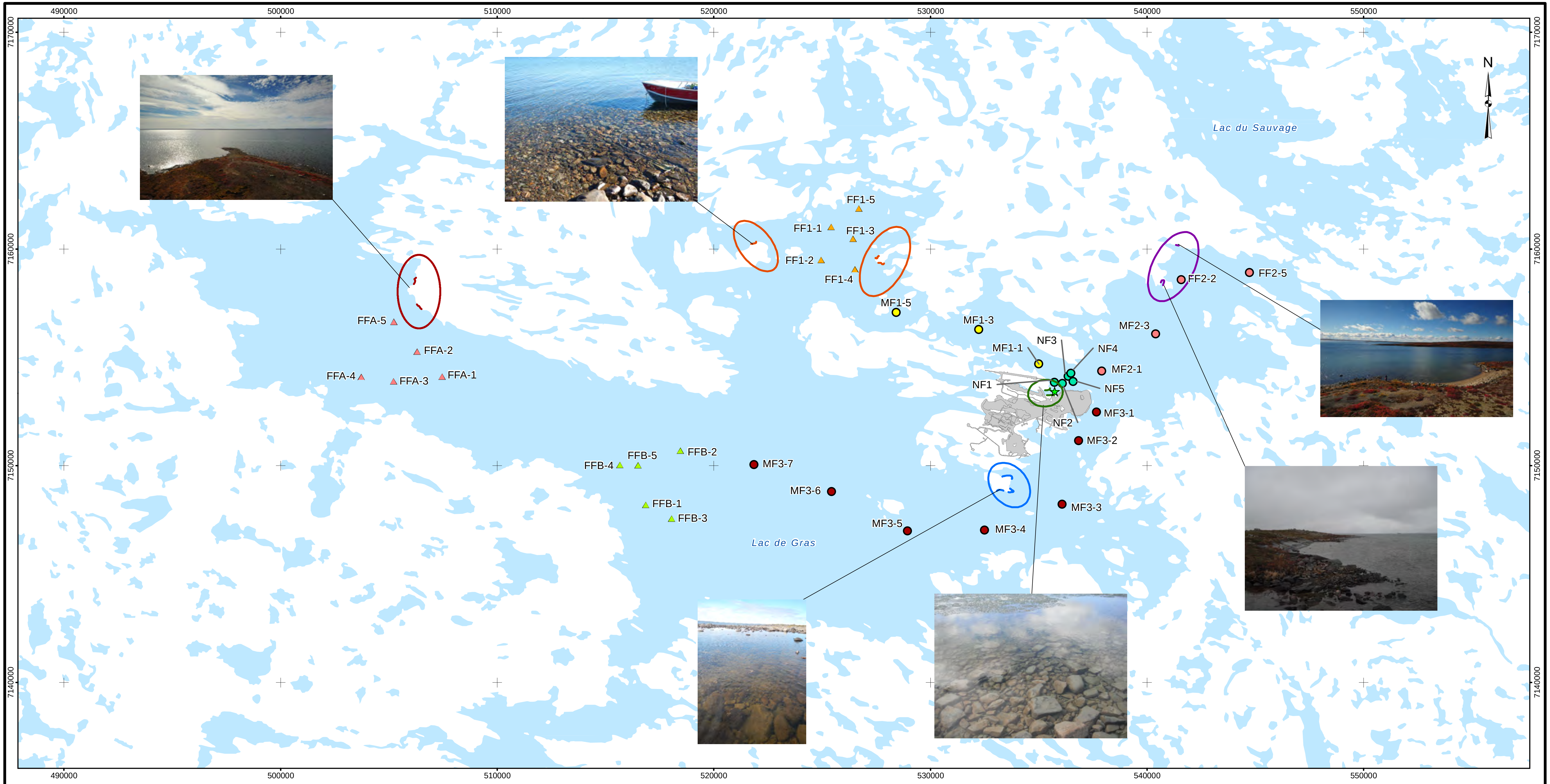
8.1 INTRODUCTION AND OBJECTIVES

The objective of sampling the small-bodied fish called Slimy Sculpin (*Cottus cognatus*) in Lac de Gras was to determine if the Mine is having an effect on the fish of Lac de Gras. Slimy sculpin were selected for this program because they can be found in most areas of Lac de Gras, but unlike Lake Trout (*Salvelinus namaycush*) or Round Whitefish (*Prosopium cylindraceum*), Slimy Sculpin stay in one area for their entire lives and do not travel throughout the lake. This is an important consideration because it means that the sediment, food, and water quality conditions in which those fish are found are likely the conditions in which they spend most of their lives. In this way, fish collected near the Mine site can be compared with fish collected far from the Mine site to evaluate whether changes to the health of the fish population are occurring. Also, since small-bodied fish are usually more abundant than bigger fish such as Lake Trout, there is less worry that the population will be harmed by the sampling itself.

To assess Mine-related effects on Slimy Sculpin, indicators of fish health and metal concentrations in fish from the exposure area were compared to fish health and metal concentrations in Slimy Sculpin from the reference areas. The following is a summary of the 2013 fish program results. A detailed report can be found in Appendix V.

8.2 METHODS

Slimy Sculpin were collected from five areas in Lac de Gras: NF, FF2, MF3, FFA and FF1 (Figure 8-1) between August 27 and September 10, 2013. The fish were collected by stunning them with electricity and then collecting them when they stopped moving. The electrical current was provided by a backpack shocker (Photo 8-1). Shocking the fish in this way is a common method for collecting fish in shoreline areas. .



LEGEND

★ DIFFUSER

EXPOSURE

● NEAR-FIELD
● MID-FIELD 3
● MID-FIELD 1
● FAR-FIELD 2; MID-FIELD 2

REFERENCE

▲ FAR-FIELD 1
▲ FAR-FIELD A
▲ FAR-FIELD B

SHORELINE BACKPACK ELECTROFISHING

— FAR-FIELD 1
— FAR-FIELD 2
— FAR-FIELD A
— NEAR-FIELD
— MID-FIELD 3

▨ DIAVIK FOOTPRINT
🟦 WATERBODY

5 0 5
SCALE 1:175,000 KILOMETRES

REFERENCE

HYDROGRAPHY DATA OBTAINED FROM CANVEC © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 12 DATUM: NAD 83

PROJECT

DIAVIK DIAMOND MINES INC.

TITLE

SMALL-BODIED FISH SURVEY SAMPLING AREAS, 2013 AEMP

PROJECT		13-1328-0001	FILE No.
DESIGN	TD	18 Feb. 2010	SCALE AS SHOWN REV. 0
GIS	JC	20 Mar. 2014	FIGURE: 8-1
CHECK	TD	20 Mar. 2014	
REVIEW	CF	20 Mar. 2014	

Golder Associates

I:\2011\11-1328\11-1328-0038\Mapping\MXD\2013AEMP\FINAL\Fig8-1_2013_AEMP_ Small_Bodied_Fish_Health_Sampling_Areas_20140225_Final.mxd

Photo 8-1 Electrofishing for Slimy Sculpin in Lac de Gras, October 2013

At each of the 5 sampling areas the goal was to collect 100 or more fish. This number was determined based on the number of fish measurements that are required to find differences among locations. There has to be enough replication so that the results could be interpreted statistically. Some tests could be done on live fish and once completed these fish were released back to Lac de Gras. About 40 fish per area were required for sampling on live fish (non-lethal sampling). Sampling on sacrificed fish (lethal sampling) required of 60 fish.

The following summarizes the different measurements that were taken:

- external examination: length, weight and any observations of wounds, parasites, lesions, etc.;
- internal examination: sex, state of maturity, abnormalities in liver, spleen, gall bladder, kidney and gonads. Parasites were removed and body cavity weight was recorded along with gonad, liver, and carcass weight. Stomach contents were assessed; and
- Fish tissue chemistry: whole fish tissue metals analyzed by ALS Laboratories, Vancouver, BC.

From these measurements additional metrics were calculated, including catch-per-unit-effort (a measure of number of fish in an area relative to sampling efforts), biological indices that help describe fish health , energy stores (condition and liver weight) and reproductive potential.

Mine-related effects were assesses by comparing measurements in fish from the exposure areas to those in reference areas. The importance of a Mine-related effect was categorized according to the Action Levels, which are listed in Table 8-1

Table 8-1 Action Levels for Fish Health Effects

Action Level	Fish Health	Extent	Action
1	Statistical difference from reference indicative of toxicological response(a)	Near-field	Confirm effect
2	Statistical difference from reference indicative of toxicological response(a)	Nearest Mid-field station	Investigate cause
3	A measurement endpoint beyond the normal range	Near-field	Examine ecological significance Set Action Level 4 Identify mitigation options
4	TBD(b)		Define conditions required for the Significance Threshold
5	Indications of severely impaired reproduction or unhealthy fish likely to cause a >20% change in fish population(s)	Far-field A (FFA)	Significance Threshold

Notes: >= greater than;% = percent.

a) Such a response could include a decrease in recruitment (fewer young fish), smaller gonads, reduced fecundity, changes to liver size, changes in condition, increased incidence of pathology, reduced growth, reduced survival.

b) To be determined if Action Level 3 is reached.

8.3 RESULTS AND DISCUSSION

The findings indicated that there was a decrease in body size (length and weight) and liver size in the three groups of fish (adult males, adult females, and juveniles) from both the NF and FF2 exposure areas. There was also a decrease in condition factor (a measure of the plumpness of the fish) in juvenile fish captured in the NF exposure area. Finally, there was a decrease in the size of the ovaries (reproductive organ) in adult females captured in the NF exposure area. These findings were different from what had been observed in three previous studies, which all demonstrated nutrient enrichment effects. Differences in environmental factors, such as water temperature, could account for some the differences observed in Slimy Sculpin in 2013.

The fish tissue chemistry results indicated that concentrations of bismuth, lead, strontium, thallium and uranium were greater in the NF exposure fish compared to the reference fish. The concentrations of these metals were looked at in the water, and were not found to be at concentrations known to cause effects in fish since they were all well below guideline values. There was no evidence that the amount of metals in fish were sufficiently high to negatively impact fish health.

Since the statistical differences observed between exposure and reference fish may reflect a toxicological effect, the Mine is considered to be having an effect equivalent to that at Action Level 1. However, given that there was no indication as to why this response was observed, the Slimy Sculpin survey will be repeated again in 2016 to confirm the response. It is necessary to confirm the effect observed in 2013 before we can decide whether a toxicological response has indeed occurred.

9 FISHERIES AUTHORIZATION AND SPECIAL EFFECTS STUDIES

9.1 PLUME DELINEATION SURVEY

Plume delineation surveys did not take place in 2013. Consequently, Appendix VI is a place holder in this AEMP Annual Report.

9.2 FISHERIES AUTHORIZATION STUDIES

9.2.1 Dike Monitoring Studies

Dike monitoring did not take place in 2013. Consequently, Appendix VII is a place holder in this AEMP Annual Report.

9.2.2 Fish Salvage Programs

A fish salvage program did not occur in 2013. Consequently, Appendix VIII is a place holder in this AEMP Annual Report.

9.2.3 Fish Habitat Compensation Monitoring

Fish habitat compensation monitoring was not conducted in 2013. Consequently, Appendix IX is a placeholder appendix in this annual report.

9.2.4 Fish Palatability, Fish Health, and Fish Tissue Chemistry Survey

A fish palatability survey was not conducted in 2013. As per the AEMP Study Design Version 3.3, the fish palatability surveys will be incorporated into the Traditional Knowledge program. Consequently, Appendix X will remain a placeholder appendix in annual reports, and information relating to the fish palatability surveys will appear in the Traditional Knowledge appendix report.

9.3 AEMP SPECIAL EFFECTS STUDY REPORTS

There were no special effects studies in 2013. Consequently, Appendix XII is a place holder in this AEMP Annual Report.

10 TRADITIONAL KNOWLEDGE STUDIES

Traditional Knowledge Studies did not take place in 2013. Consequently, Appendix XIV is a place holder in this AEMP Annual Report.

11 WEIGHT-OF-EVIDENCE

11.1 INTRODUCTION AND OBJECTIVES

The objective of the Weight-of-Evidence (WOE) analysis is to bring together all of the key findings from the 2013 AEMP to make conclusions as to the overall effects observed and whether there is a strong link between the effects and the Mine. WOE analyses considered two types of impacts for Lac de Gras:

- **Nutrient Enrichment:** Enrichment could occur due to the release of nutrients (phosphorus and nitrogen) to Lac de Gras.
- **Toxicological Impairment:** Toxicity to aquatic organisms could occur due to chemical contaminants (primarily metals) released to Lac de Gras.

All of the components discussed in this report were used in the WOE analysis. For each type of impact, the WOE analysis integrated the results of exposure (e.g., water and sediment chemistry) and biological effects (e.g., on plankton, benthic invertebrates or fish). The WOE provides a ranking of the strength of evidence. A higher rank represents a higher strength of evidence for a Mine-related impact.

Appendix XV contains a report by Golder that provides the standardized approach and assessment results for the WOE analysis. The following section is a brief summary of the results.

11.2 METHODS

The WOE analysis was conducted according to the methods described in the updated Version 3.3 Study Design (Golder 2014). The WOE analysis begins by summarizing the key findings from each of the 2013 AEMP component results. These are referred to as endpoints, and the endpoints are organized into groups called Lines of Evidence (LOE). Two types of evidence were assessed for each AEMP component to integrate exposure and effects in the WOE:

- **Exposure:** Measures the amount of Mine-related substances of interest (SOIs), in surface water, sediment and fish tissue; and
- **Biological Response:** Measures the changes in natural communities in Lac de Gras, including measures of primary productivity, zooplankton biomass, benthic invertebrate community structure, and fish population health.

Within each LOE group, multiple endpoints have been measured in Lac de Gras. Results that demonstrate a high degree of agreement between several endpoints or among LOE groups provide a stronger WOE regarding potential ecological effects than reliance on a single endpoint. The results from individual AEMP components were rated according to a series of decision criteria, and weighted to reflect the strength and relevance of the evidence they brought to the assessment.

The effect *rating* and the before and after *weighting* were then combined in the calculation of an overall evidence of impact (EOI) ranking. The EOI ranking provides an indication of the strength of evidence associated with apparent impacts to a particular ecosystem component.

The following summarizes the EOI ranking scheme used:

- EOI Rank 0 – Negligible EOI;
- EOI Rank 1 – Low EOI;
- EOI Rank 2 – Moderate EOI; and
- EOI Rank 3 – Strong EOI.

A full description of the process used to integrate the findings from the different AEMP endpoints and the weightings applied can be found in Section 2.3.4 of Appendix XV.

11.3 RESULTS AND DISCUSSION

The results of the WOE assessments are summarized in Table 9-1.

Table 9-1 Weight-of-Evidence Results, 2013 AEMP

Ecosystem Component	EOI Ranking
Toxicological Impairment	
Lake Productivity	**0**
Benthic Invertebrates	**0**
Fish Population Health	**1**
Nutrient Enrichment	
Lake Productivity	**3**
Benthic Invertebrates	**3**
Fish Population Health	**1**

11.3.1 Nutrient Enrichment Impacts

The endpoint results relevant to nutrient enrichment support the interpretation that Mine activities and discharges are resulting in effects to lake productivity and the benthic invertebrate community that are consistent with nutrient enrichment. In the NF area, a consistent relationship was found between release of nutrients from the Mine, increases in the amount of plankton, and increases in density and richness of the benthic invertebrate community. The area of effect for increases in nutrients and primary productivity extended into the MF areas.

In contrast to this consistent response for the plankton community and benthic invertebrate community, none of the fish health responses were consistent with enrichment. Thus, although the increased primary productivity in NF and MF areas suggested the potential for increased food supply to fish, the results for 2013 did not indicate a response to this increased food supply.

The following EOI ranks were determined for a nutrient enrichment impact:

Lake Productivity – EOI Rank 3 (Strong):

- The average total phosphorus and total nitrogen concentrations exceeded the reference normal range in NF and some MF areas but these elevated concentrations did not extend over greater than 20% of the lake area.
- Chlorophyll *a* concentration exhibited a statistically significant increase exceeding the normal range, which extended over greater than 20% of the lake area.
- The strong linkage of elevated nutrient concentrations to the Mine combined with a clear indication of responses in primary and secondary productivity provided strong evidence for an enrichment effect on Lake Productivity.

Benthic Invertebrates – EOI Rank 3 (Strong):

- There was a statistically significant increase exceeding the reference normal range in chlorophyll *a* in NF areas compared to reference areas (representing increased food supply for benthic invertebrates), which extended beyond 20% of the lake area. This increased food supply has a clear linkage to the Mine as a result of corresponding increases in nutrients (nitrogen and phosphorous) in NF areas.
- There was a statistically significant increase in total invertebrate density, in NF areas compared to reference areas. Increases in dominant taxa and a shift in community composition were also evident as a result of nutrient enrichment.
- The strong linkage to elevated food supply to nutrient releases from the Mine combined with a clear indication of increased biomass of the benthic community provide strong evidence for an enrichment effect on Benthic Invertebrates.

Fish Population Health – EOI Rank 1 (Low):

- There was a statistically significant increase exceeding the normal range in chlorophyll *a* in NF compared to reference areas, which extended beyond 20% of the lake area. This increased primary productivity is indicative of a potential corresponding increase in zooplankton and/or benthic invertebrate food supply for slimy sculpin.
- Based on the pattern of response in fish health, none of the responses were indicative of nutrient enrichment. The overall low EOI Rank was entirely due to the high rating for chlorophyll *a* (which indicates nutrient exposure only) rather than actual biological responses in fish health. There was no evidence that this exposure was causing an enrichment response in the fish health endpoints in 2013.

11.3.2 Toxicological Impairment Impacts

The endpoint results relevant to toxicological impairment support the interpretation that Mine activities and discharges are not having a toxicological effect on lake productivity and the benthic invertebrate community. Potential toxicological impairment effects to fish health were observed. The pattern of response included decreases in body size, energy reserves and reproductive investment for some groups (i.e., male, female and juvenile) of fish. There was uncertainty as to the cause of the apparent changes to fish health observed in 2013 and it remains inconclusive if a true toxicological effect has occurred.

The following EOI ranks were determined for a toxicological impairment impact:

Lake Productivity – EOI Rank 0 (Negligible):

- There was a statistically significant increase in water column concentrations of multiple SOIs in the NF area relative to reference areas. These findings were linked to effluent release from the Mine.
- The observed responses in all plankton biomass endpoints (chlorophyll *a*, phytoplankton biomass and zooplankton biomass (increases in exposed areas relative to reference areas) were not consistent with toxicological impairment, resulting in negligible support for this hypothesis. Although a shift in community structure of both phytoplankton and zooplankton was apparent, the most likely cause was enrichment, not toxicity.

Benthic Invertebrates – EOI Rank 0 (Negligible):

- Multiple sediment quality parameters were significantly higher in the NF area relative to reference area. Of these, bismuth, lead and uranium also exceeded the normal range in the NF area. However, none of the parameters that had statistical differences exceeded available sediment quality guidelines indicating generally that the differences were of low toxicological concern.
- Based on the pattern of response in benthic invertebrates, none of the responses were indicative of toxicological impairment.

Fish Population Health – EOI Rank 1 (Low):

- Bismuth and uranium concentrations in fish from the NF area were greater than the reference normal range, with the difference being statistically significant. However, there was uncertainty as to whether bismuth levels in fish were related to effluent release from the Mine.
- Concentrations of these metals in fish or the surrounding environment (water and sediment) were not at levels known to cause toxicity.

- The pattern of response in fish health endpoints was similar among all groups of fish. The patterns included decreases in body size, energy reserves and reproductive investment in exposure area fish. The lack of similar responses in previous years, in which similar metals concentrations in exposure fish were found, and the lack of toxic impairment responses in the plankton and benthic communities suggests that the fish health responses for 2013 may be due to random fluctuations or other factors. Based on these considerations', the EOI Rank of 1 (Low) was considered appropriate.

11.4 CONCLUSIONS

The evidence for nutrient enrichment in Lac de Gras is much stronger than the evidence for toxicological impairment. For 2013, there continued to be a relatively clear link between nutrient releases to Lac de Gras from the Mine, increases in nutrient concentrations in exposed areas, and increases in lake productivity in exposed areas. There was also a consistent response of increases in invertebrate density and a mild community shift in the benthic invertebrate community that can be linked to the observed enrichment.

The magnitude and type of response in Lac de Gras appears to be increased lake productivity as a result of nutrient enrichment. Although there are statistically significant changes to indicators of enrichment in the near-field area (and in some cases mid-field areas), the severity with respect to the ecological integrity of Lac de Gras associated with these changes is considered to be low.

Responses for fish health were in the direction of a toxicological impairment response. However, such responses have not been observed in previous years and there was a lack of toxic impairment responses in the plankton and benthic communities. Moreover, the body burdens of metals in fish and the concentrations of metals in water are well below levels known to cause toxicity in fish. Therefore, it remains inconclusive if a true toxicological effect has occurred. The response may simply reflect random fluctuations within a normal range of variability and/or it could have been caused by other ecological or abiotic factors such as the colder water encountered in exposure areas.

12 ADAPTIVE MANAGEMENT RESPONSE ACTIONS

Part K, Item 10d of Water Licence W2007L2-0003 requires that the Annual AEMP include an evaluation of any adaptive management response actions implemented during the year. In 2013 there were no specific adaptive management responses to evaluate.

13 CONCLUSIONS AND RECOMMENDATIONS

13.1 CONCLUSIONS

The following conclusions were made based on the results of the 2013 AEMP:

- Following the general trend of a reduction in dust levels over the past several years, dustfall levels were generally lower in 2013 than in previous years. Snow water chemistry analytes of interest included aluminum, ammonia, arsenic, cadmium, chromium, copper, lead, nickel, nitrite, phosphorous, and zinc. All 2013 sample values were below the effluent discharge criteria. As expected, measured dustfall levels and snow chemistry variable concentrations generally decreased with distance from the mine site.
- Mine effluent had an effect on fifteen water quality variables analyzed in 2013 (conductivity, total dissolved solids [calculated], dissolved calcium, chloride, dissolved sodium, sulphate, ammonia, nitrate, aluminum, barium, chromium, molybdenum, silicon, strontium, and uranium). The median concentrations of these 15 variables were greater than two times the reference area median concentrations. As a result, these variables demonstrated an effect equivalent to Action Level 1, and they comprised the list of SOIs. Each of the 15 SOIs that reached Action Level 1 also reached Action Level 2, which was applicable because the 75th percentile concentration in the near-field exposure area exceeded the normal range for Lac de Gras.
- Results from the 2013 AEMP relating to eutrophication indicators showed that an Action Level 2 was reached within Lac de Gras for chlorophyll *a*. An Action Level 2 is identified when chlorophyll *a* concentrations in the NF and MF exposure areas representing more than 20% of the lake area are greater than the normal range. In 2013, 24.9% of the lake area had chlorophyll *a* concentrations uniformly greater than the normal range. The Mine operations are a significant contributor to this nutrient enrichment effect. This conclusion is based on statistical differences in the NF area relative to reference areas for TP, TN, zooplankton biomass and chlorophyll *a*.
- Effects of the Mine discharge on bottom sediments in the NF area of Lac De Gras were evident for 13 SOIs (aluminum, bismuth, boron, calcium, chromium, lead, lithium, magnesium, potassium, sodium, tin, titanium, and uranium), which had NF area mean concentrations significantly greater than reference area concentrations. Three of the SOIs (bismuth, lead, and uranium) had NF area mean concentrations that were greater than their normal ranges. Compared to sediment quality guidelines and information in the primary literature, the concentrations of these three variables in exposure area sediments are considered unlikely to pose a toxicological risk to biota.
- The 2013 monitoring results suggest that plankton communities in Lac de Gras are exhibiting a Mine-related nutrient enrichment effect. Phytoplankton richness and biomass and zooplankton richness were statistically greater in the Near-field exposure area relative to the reference areas. There were differences in zooplankton community

composition between the ,near-field exposure area and the reference areas, with greater proportions of rotifers and cladocerans, and fewer calanoids in the near-field area compared to the reference areas. Given that the differences observed within the plankton community are not indicative of toxicological impairment, an Action Level 1 was not reached for the plankton component in 2013.

- Overall, differences in the benthic invertebrate community in the NF area relative to the reference areas were consistent with nutrient enrichment. Statistically greater total density and *Procladius* density in the NF area compared to reference areas suggested mild nutrient enrichment. *Heterotrissocladius* density was also greater in the NF area compared to reference areas, though the difference was not statistically significant. Results of multivariate analysis indicated a slight difference in the benthic invertebrate community in the exposure areas compared to the reference areas. Given that the differences observed within the benthic invertebrate community were indicative of a nutrient enrichment response and not a toxicological response, Action Level 1 was not applied for benthic invertebrates in 2013.
- The 2013 fish survey results suggest that small-bodied fish in Lac de Gras are exhibiting a Mine-related toxicological effect, as opposed to a nutrient enrichment effect. Significant differences were observed between the exposure and reference areas for slimy sculpin body size (length and weight), condition factor, relative liver size, and relative gonad size. Since these differences can be indicative of a toxicological response, the effects observed in 2013 are at a magnitude equivalent to Action Level 1. These findings are in contrast to those of the previous three fish surveys and with other AEMP components, which have demonstrated responses typical of nutrient enriched environments.

13.2 RECOMMENDATIONS

The following recommendations were made for future aquatic effects monitoring of Lac de Gras:

- The laboratory detection limits for water quality samples collected at the mixing zone boundary should be the same as those requested for the AEMP dataset, given that the mixing zone data are incorporated into the Action Level framework.
- The criteria used to classify an effect at Action Levels 1 and 2 for water chemistry should be re-evaluated so that Action Levels 1 and 2 are applied sequentially.
- The data quality objective used to identify notable differences between field duplicate samples collected during the water quality and sediment quality sampling programs should be adjusted so that it is less stringent than the objectives used by Maxxam to identify unacceptable differences between laboratory duplicate samples. Laboratory duplicate samples consist of two independently analyzed portions of the same sample. They would be expected to have lower variability than field duplicates, which consist

of two completely separate grab samples collected from the water column or lake bottom.

- To be consistent with the eutrophication indicator endpoints, plankton should be sampled every three years at reference areas (FF1, FFA, FFB), as opposed to every year. Action levels would be based on the most recent reference area data. This recommendation should be implemented for the 2014 open-water sampling period.
- Composite benthic invertebrate samples should be collected at all stations due to the low variability among replicate samples observed in 2013 and previous studies.
- Since 2013 was the first study to report effects in slimy sculpin equivalent to Action Level 1, it will be important to confirm the response pattern during the next fish survey, which is scheduled to occur in 2016. It will be necessary to confirm the effect before we can conclude that a toxicological effect has occurred. The effects patterns from the three previous fish surveys should also be examined for temporal trends that may signal a shift in the overall health of the slimy sculpin population in the Near-Field exposure area.

14 CONTRIBUTORS

This document has been prepared by DDMI in association with Golder Calgary AB, Mississauga ON, and Burnaby BC.

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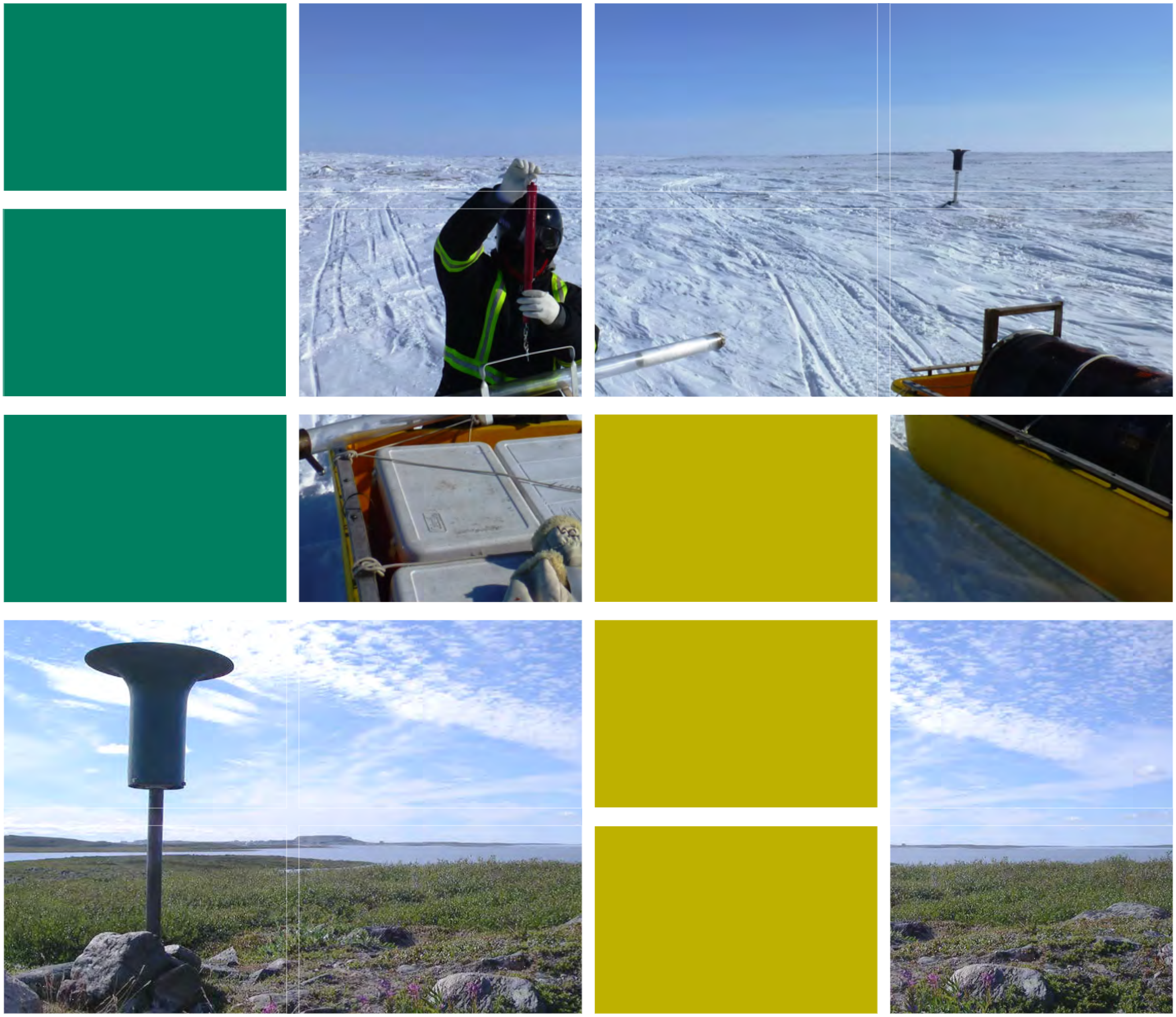
APPENDIX I

DUST DEPOSITION REPORT



Prepared for:

Rio Tinto

DOMINION
DIAMOND
CORPORATION

Diavik Diamond Mine

Diavik Diamond Mine

2013 Dust Deposition Report

March 2014

ERM

The world's leading sustainability consultancy

Diavik Diamond Mines (2012) Inc.

DIAVIK DIAMOND MINE
2013 Dust Deposition Report

March 2014

Project #0207514-0002

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EXECUTIVE SUMMARY

Air and water quality concerns associated with airborne fugitive dust, a result of mining activities, were identified in the Diavik Diamond Mine Environmental Assessment (DDMI 1998), and thereby required inclusion in DDMI environmental monitoring.

DDMI, in accordance with the Environmental Assessment and as required for the AEMP, initiated a dust monitoring program in 2001 designed and implemented to identify:

- dust deposition (dustfall) rates at various distances from the mine project footprint; and
- the chemical characteristics of dustfall that may be deposited onto, and subsequently into, Lac de Gras from mining activities in support of DDMI's Aquatic Effects Monitoring Program (AEMP).

Monitoring in 2013 incorporated three monitoring components, with sampling completed at varying distances around the mine from 25 to 5,655 m away from infrastructure:

1. Dustfall collected with dustfall gauges at 12 locations (including two control locations).
2. Dustfall sampled from snow surveys at 24 locations (including three control locations).
3. Snow water chemistry sampled from snow surveys at 16 locations (including three control locations).

Following the general trend of a reduction in dust levels over the past several years, dustfall levels were generally lower in 2013 than previous years, with the exception of stations SS1-1, SS1-2, SS1-3, SS1-4 and to a lesser extent Dust 7, all of which were within the range of concentrations from all previous years, but higher than the last two years.

The calculated annual dustfall collected from each of the 12 dustfall gauges ranged from 49 to 315 mg/dm^2/y. The calculated annual dustfall collected from each of the 24 snow survey locations ranged from 10 to 1,576 mg/dm^2/y. Only two samples were above the BC mining dustfall objective[1] range of 621–1,059 mg/dm^2/y:

- 1,576 mg/dm^2/y calculated from the snow survey at station SS1-1, 30 m north of the airstrip; and
- 772 mg/dm^2/y calculated from the snow survey at station SS1-2, 115 m north of the airstrip.

As expected, measured dustfall levels generally decreased with distance from the mine site, and areas that were predominantly downwind of the mine site received more dustfall than areas that were not downwind.

Snow water chemistry analytes of interest included aluminum, ammonia, arsenic, cadmium, chromium, copper, lead, nickel, nitrite, phosphorous and zinc. All 2013 sample values were below their associated reference levels as specified by the "maximum concentration of any grab sample"

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[1] The BC mining dustfall objective is used for comparison purposes only as there are no standards or objectives for the Northwest Territories. It is also used by other mines in the region.

outlined in DDMI's Type "A" Water Licence (W2007L2-0003). In general, analyte concentrations decreased with distance from the mine site. The majority of concentrations were lower than in previous years with the exception of nickel which was within the range of concentrations from previous years, but higher than the last two years.

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DIAVIK DIAMOND MINE

2013 Dust Deposition Report

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GLOSSARY AND ABBREVIATIONS

Terminology used in this document is defined where it is first used. The following list will assist readers who may choose to review only portions of the document.

AEMP	Aquatic Effects Monitoring Program
BC	British Columbia
BC MOE	British Columbia Ministry of Environment
d	Day
DDMI	Diavik Diamond Mines Inc.
dm^2	Square decimetre
Dustfall	Dust deposition
ERM Rescan	ERM Consultants Canada Ltd.
L	Litre
m	Metre
mg	Milligram
RPD	Relative Percent Difference
SOP	Standard Operating Procedure
µg	Microgram
y	Year

1. INTRODUCTION

Air and water quality concerns associated with airborne fugitive dust, a result of mining activities, were identified in the Diavik Diamond Mine Environmental Assessment (DDMI 1998), and thereby required inclusion in DDMI environmental monitoring.

DDMI, in accordance with the Environmental Assessment and as required for the Aquatic Effects Monitoring Program (AEMP), initiated a dust monitoring program in 2001 designed and implemented to identify:

- Dust deposition (dustfall) rates at various distances from the mine project footprint; and
- The chemical characteristics of dustfall that may be deposited onto, and subsequently into, Lac de Gras from mining activities in support of DDMI's AEMP.

Since 2001, the dust monitoring program has gone through various changes, such as increasing the number of sampling locations, relocating some sampling locations and improving the dustfall sampling methodology. A description of annual changes is provided in Appendix A.

Historical dustfall monitoring results have been presented each year in the *Diavik Diamond Mine Dust Deposition* reports from 2001 to 2012 (DDMI 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2012, 2013). Historical information on dustfall is summarized in these reports.

2. METHODOLOGY

The dustfall monitoring in 2013 incorporated three monitoring components, with sampling completed at varying distances around the mine, including three control locations (Table 2-1, Figure 2-1):

1. Dustfall collected with dustfall gauges at 12 locations (including two control locations).
2. Dustfall sampled from snow surveys at 24 locations (including three control locations).
3. Snow water chemistry sampled from snow surveys at 16 locations (including three control locations).

2.1 DUSTFALL GAUGES

During the 2013 monitoring period, dustfall gauges were used at 12 stations (including two control stations) located around the mine site and ranged in distance from approximately 25 to 5,655 m away from mining operations (Table 2-1). Each gauge collected dustfall year-round and samples were collected every three months. On average for the 12 sampling locations, the total sampling period was 355 days in 2013. Station Dust 5 was found to be dismantled upon arrival in September; the sample was compromised and not used.

A dustfall gauge consists of a hollow brass cylinder (52 cm length, 12.5 cm inner diameter) housed in a Nipher snow gauge (Plate 2.1-1). The cylinder collects dustfall and the Nipher snow gauge is used to reduce the amount of air turbulence around the gauge and therefore increase the dustfall catch efficiency. For sample collection the cylinder is exchanged with an empty clean cylinder. The content of the retrieved cylinder is then processed in the DDMI environment lab to determine the mass of collected dustfall. This processing involves filtration, drying and weighing of samples as specified in the standard operating procedures (SOPs) ENVR-508-0112 and ENVI-403-0112 (see Appendix E).

Once the mass of collected dustfall at a station is measured, the following formula is used to calculate the mean daily dustfall rate over the collection period:

$$D = \frac{M}{A * T}$$

where:

D = mean daily dustfall rate (mg/dm^2/d) during time period T
M = mass of dustfall collected (mg) during time period T
A = surface area of dustfall gauge collection cylinder orifice (dm^2); approximately 1.227 dm^2
T = number of days of dustfall collection (d)

The mean daily dustfall rate (mg/dm^2/d) is multiplied by 365 days to estimate the mean annual dustfall rate (mg/dm^2/y).

Table 2-1. Dustfall and Snow Water Chemistry Sampling Locations in 2013

Transect Line	Station ID	2013 Sampling Dates	Total Sample Exposure Duration (days)	UTM Coordinates[1]		Approx. Distance from Mining Operations (m)	Surface Description	Snow Water Chemistry Sampled
				Easting (m)	Northing (m)			
Dustfall Gauges								
	Dust 1	Mar. 27, Jun. 2, Sep. 24, Dec. 4	353	533964	7154321	75	Land	
	Dust 2A	Mar. 12, Jun. 3, Sep. 19, Dec. 6	356	535678	7151339	435	Land	
	Dust 3	Mar 12., Jun. 2, Sep. 24, Dec. 6	359	535024	7151872	30	Land	
	Dust 4	Mar 27., Jun. 2, Sep. 23, Dec. 4	353	531397	7152127	200	Land	
	Dust 5	Mar 27., Jun. 3, Sep. 19[2], Dec. 4	246[2]	535696	7155138	1,195	Land	
	Dust 6	Mar 28., Jun. 2, Sep. 24, Dec. 6	355	537502	7152934	25	Land	
	Dust 7	Mar 12., Jun. 3, Sep. 19, Dec. 4	354	536819	7150510	1,155	Land	
	Dust 8	Mar 27., Jun. 3, Sep. 19, Dec. 6	356	531401	7154146	1,220	Land	
	Dust 9	Mar 12., Jun. 3, Sep. 19, Dec. 4	354	541204	7152154	3,810	Land	
	Dust 10	Mar 12., Jun. 3, Sep. 19, Dec. 4	354	532908	7148924	670	Land	
	Dust C1	Mar 12., Jun. 3, Sep. 19, Dec. 4	354	534979	7144270	5,655	Land	
	Dust C2	Mar 27., Jun. 3, Sep. 19, Dec. 6	356	528714	7153276	3,075	Land	
Snow Surveys								
1	SS1-1	Apr. 27	182	533911	7154288	30	Land	
	SS1-2[3]	Apr. 27	182	533924	7154367	115	Land	
	SS1-3	Apr. 27	182	533966	7154517	275	Land	
	SS1-4	Apr. 27	182	534485	7155094	920	Ice	✓
	SS1-5	Apr. 27	182	535099	7156279	2,180	Ice	✓
2	SS2-1	Apr. 27	182	537553	7153473	180	Ice	✓
	SS2-2[3,4]	Apr. 27	182	537829	7153476	445	Ice	✓
	SS2-3	Apr. 27	182	538484	7153939	1,220	Ice	✓
	SS2-4	Apr. 27	182	539151	7154685	2,180	Ice	✓

(continued)

Table 2-1. Dustfall and Snow Water Chemistry Sampling Locations in 2013 (completed)

Transect Line	Station ID	2013 Sampling Dates	Total Sample Exposure Duration (days)	UTM Coordinates[1] Easting (m)	Northing (m)	Approx. Distance from Mining Operations (m)	Surface Description	Snow Water Chemistry Sampled
Snow Surveys (cont'd)								
3	SS3-4	Apr. 26	181	536585	7151002	615	Ice	✓
	SS3-5	Apr. 26	181	537623	7150817	1,325	Ice	✓
4	SS4-1[3]	Apr. 28	183	531491	7152211	100	Land	
	SS4-2	Apr. 28	183	531356	7152261	245	Land	
	SS4-3	Apr. 28	183	531331	7152434	350	Land	
	SS4-4[5]	Apr. 28	183	531141	7153167	1,065	Ice	✓
	SS4-5	Apr. 28	183	531405	7154116	1,220	Ice	✓
5	SS5-1	Apr. 26	181	533150	7148925	665	Land	
	SS5-2	Apr. 26	181	533150	7148875	710	Land	
	SS5-3	Apr. 26	181	533150	7148700	885	Ice	✓
	SS5-4	Apr. 26	181	533150	7147950	1,635	Ice	✓
	SS5-5[3,4]	Apr. 26	181	533150	7146950	2,635	Ice	✓
	Control 1	Apr. 26	181	534983	7144271	5,655	Land	✓[6]
	Control 2	Apr. 28	183	528714	7153281	3,075	Land	✓[6]
	Control 3	Apr. 28	183	538650	7148750	3,570	Land	✓[6]

[1] *UTM Zone 12W, NAD83*

[2] *September sample was compromised and not used.*

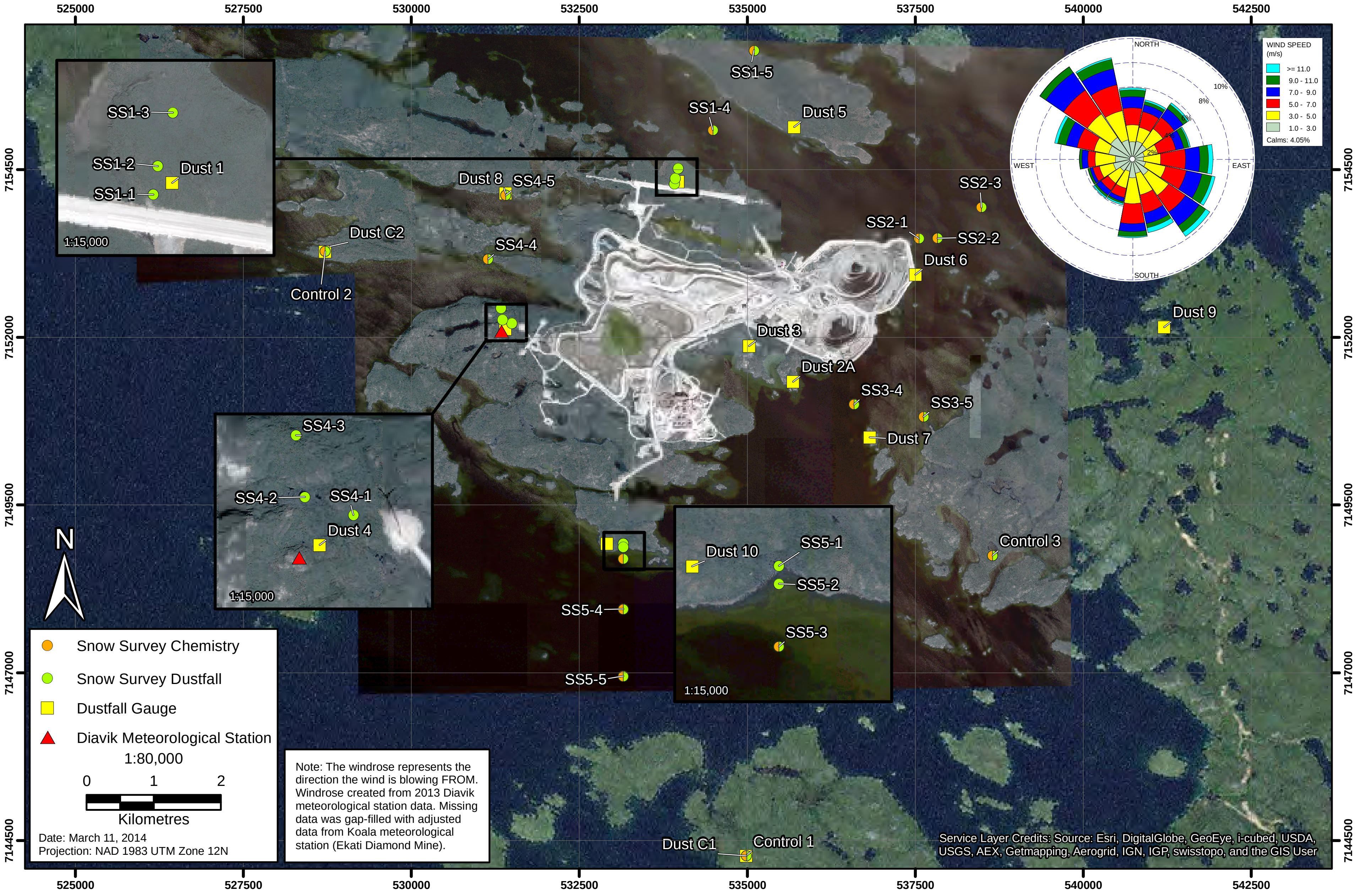
[3] *Duplicate sample taken for dustfall.*

[4] *Duplicate sample taken for snow water chemistry.*

[5] *Blank sample taken for dustfall and snow water chemistry.*

[6] *Snow water chemistry was sampled over ice, adjacent to the on-land control station.*

Figure 2-1
Dustfall Gauge and Snow Survey Locations



Date: March 11, 2014
Projection: NAD 1983 UTM Zone 12N

Note: The windrose represents the direction the wind is blowing FROM. Windrose created from 2013 Diavik meteorological station data. Missing data was gap-filled with adjusted data from Koala meteorological station (Ekati Diamond Mine).

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User

Plate 2.1-1. Dustfall gauge during sample collection. The dustfall gauge consists of a hollow brass cylinder (centre) housed inside a Nipher snow gauge (right).

Estimated dustfall rates are compared to the BC dustfall objective for the mining, smelting and related industries (Table 2.1-1), for comparison purposes only. This objective is also used by other mines in the region. It is the first time that this objective is being used in this annual report.

Table 2.1-1. Dustfall and Snow Water Chemistry Reference Values

Parameter	Value	Unit	Comment	Source
Dustfall Rate	1.7–2.9 (621–1,059)	mg/dm²/day (mg/dm²/y)	Objective for the mining, smelting, and related industries	BC MOE (2013)
Aluminum-Total	3,000	µg/L	Max. grab sample concentration	W2007L2-0003
Ammonia-N	12,000	µg/L	Max. grab sample concentration	W2007L2-0003
Arsenic-Total	100	µg/L	Max. grab sample concentration	W2007L2-0003
Cadmium-Total	3	µg/L	Max. grab sample concentration	W2007L2-0003
Chromium-Total	40	µg/L	Max. grab sample concentration	W2007L2-0003
Copper-Total	40	µg/L	Max. grab sample concentration	W2007L2-0003
Lead-Total	20	µg/L	Max. grab sample concentration	W2007L2-0003
Nickel-Total	100	µg/L	Max. grab sample concentration	W2007L2-0003
Nitrite-N	2,000	µg/L	Max. grab sample concentration	W2007L2-0003
Zinc-Total	20	µg/L	Max. grab sample concentration	W2007L2-0003

2.2 DUSTFALL SNOW SURVEYS

During the 2013 monitoring period, dustfall snow surveys were performed at 24 stations (including three control stations) located around the mine site, grouped into five different transects (Table 2-1). Each station ranged in distance from approximately 30 to 5,655 m away from mining operations. On average for the 24 sampling locations, the total sampling period was 182 days in 2013 for stations on land and over water (ice). The start dates correspond to the first snowfall for land stations, and the first ice freeze up for ice stations, which was the same for both: Oct. 27, 2012.

At each snow survey station, a snow corer was used to drill into the snow pack to retrieve a cylindrical snow core (6.1 cm inner diameter; Plate 2.2-1). Multiple cores were extracted at each station and composited in the field to ensure a representative snow sample was obtained for the station. Composited samples were bagged and brought to the DDMI environment lab for processing as specified in SOP ENVR-512-0213 and ENVI-403-0112 (see Appendix F). Similar to the dustfall gauge samples, the processing of snow cores also involves filtration, drying and weighing. For quality assurance and control, duplicate samples were taken at stations SS1-2, SS2-2, SS4-1 and SS5-5, and a blank sample was taken at station SS4-4.

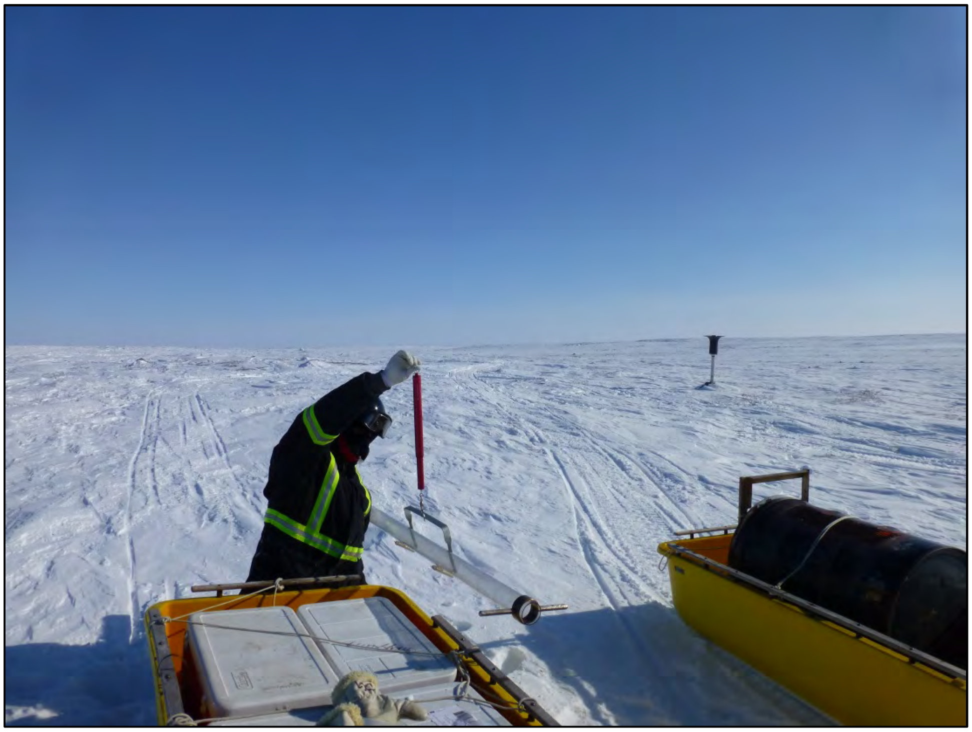


Plate 2.2-1. Snow core sample being weighed, with dustfall gauge in background.

Once the mass of collected dustfall was measured for a snow survey station, the mean daily dustfall rate (mg/dm^2/d) over the collection period was calculated using the same formula presented in Section 2.1. Only the surface area (equation variable A) was adjusted to that of the surface area of the snow corer tube orifice (approximately 0.2922 dm^2) multiplied by the number of snow cores used for the composited sample at the station. The mean annual dustfall rate (mg/dm^2/y) was estimated by multiplying the mean daily dustfall rate by 365 days.

The dustfall rates in Table 2.1-1 are compared to the BC dustfall objective for the mining, smelting and related industries, for comparison purposes only.

2.3 SNOW WATER CHEMISTRY

Snow water chemistry analysis was performed on snow cores extracted from 16 locations, including three control locations (Table 2-1). These locations included the 13 dustfall snow survey stations on ice, as well as samples taken on ice adjacent to the three control stations. Stations ranged in their distance away from mining operations from approximately 180 to 5,655 m. On average for the 12 sampling locations, the total sampling period was 182 days in 2013, after the ice freeze up date (Oct. 27, 2012). At each station, cores taken for chemistry analysis were taken immediately after the dustfall snow cores were extracted.

Similar to the dustfall snow survey core extraction, snow water chemistry cores were extracted using a snow corer. If needed, multiple cores were extracted and composited to obtain the necessary 3 L of snow water required for the laboratory chemical analysis (see Appendix F). These snow cores were then processed and prepared for shipment to Maxxam laboratory where the chemical analysis is performed. For quality assurance and control purposes, duplicate samples were taken at stations SS2-2 and SS5-5, and a blank sample was taken at station SS4-4. The complete snow water chemistry sampling methodology is detailed in SOP ENVR-512-0213 (see Appendix F).

DDMI's Water Licence W2007L2-0003 sets effluent quality criteria ("maximum average concentration" and "maximum concentration of any grab sample") for aluminium, ammonia, arsenic, cadmium, chromium, copper, lead, nickel, nitrite, and zinc (Table 2.1-1). The snow water chemistry results for these variables are compared to the "maximum concentration of any grab sample" in Section 3 of this report. These results are also presented as part of DDMI's Aquatic Effects Monitoring Program (AEMP) report.

3. RESULTS

Dustfall and snow water chemistry results were grouped into zones based on their relative distance from the mine footprint (see Table 3.1-1). Although station groupings into zones were first established at the outset of the program, these groupings were re-established using the most current 2013 satellite image of the site. The following stations have been grouped into different zones compared to previous dust deposition reports:

- SS1-2 changed from zone 0–100 m to zone 101–250 m;
- SS1-3 changed from zone 101–250 m to zone 251–1,000 m;
- SS2-1 changed from zone 0–100 m to zone 101–250 m;
- SS2-2 changed from zone 101–250 m to zone 251–1,000 m;
- SS2-3 changed from zone 251–1,000 m to zone 1,001–2,500 m;
- SS4-2 changed from zone 0–100 m to zone 101–250 m;
- SS4-3 changed from zone 101–250 m to zone 251–1,000 m; and
- SS4-4 changed from zone 251–1,000 m to zone 1,001–2,500 m.

3.1 DUSTFALL GAUGES

In 2013, the primary sources of fugitive dust were associated with unpaved road and airstrip usage. To supress dust generation, roads were watered during the summer as needed, and EK35 was applied to the airport apron (tarmac) and helipad during the spring. The mine production rate was steady throughout the year, and all mining was underground. There was an increase in construction activity related to the tailings impoundment between April and September. Fugitive dust generation is expected to be highest during snow-free periods where and when there is site activity. Therefore it is expected that the highest fugitive dust generation and resulting dustfall occurred in areas closest to the mine footprint between April and September.

The total dustfall collected from each dustfall gauge throughout the year is summarized in Table 3.1-1. Figure 3.1-1 presents the annual 2013 dustfall for each station at its geographic location relative to the mine site, and Figures 3.1-2 and 3.1-3 graph the annual dustfall for 2013 and historical years for each station. A comparison of 2013 dustfall versus distance from the mine footprint is presented in Figure 3.1-4. Boxplots summarizing the dustfall measured in each year are presented in Figure 3.1-5. The detailed 2013 measurements and calculations for each station are included in Appendix A. The gauge at Dust 5 was found to be dismantled upon arrival in September; the sample was compromised and not used.

Table 3.1-1. 2013 Dustfall and Snow Water Chemistry Results

Zone	Station	Approx. Distance from 2013 Project Footprint (m)	Dustfall (mg/dm^2/y)	Snow Water Chemistry (µg/L)										
				Aluminum	Ammonia	Arsenic	Cadmium	Chromium	Copper	Lead	Nickel	Nitrite	Phosphorous	Zinc
0-100 m	Dust 1	75	262	-	-	-	-	-	-	-	-	-	-	-
	Dust 3	30	315	-	-	-	-	-	-	-	-	-	-	-
	Dust 6	25	175	-	-	-	-	-	-	-	-	-	-	-
	SS1-1	30	1,576	-	-	-	-	-	-	-	-	-	-	-
	SS4-1	100	174	-	-	-	-	-	-	-	-	-	-	-
	Mean		**500**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**
	Standard Deviation		**604**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**
	95% Confidence Interval (Mean +/-)		**750**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**
	Upper Limit of 95% Confidence Interval		**1,251**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**
	Lower Limit of 95% Confidence Interval		**0**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**
101-250 m	Dust 4	200	122	-	-	-	-	-	-	-	-	-	-	-
	SS1-2	115	772	-	-	-	-	-	-	-	-	-	-	-
	SS2-1	180	49	153	39	0.12	<0.005	1.14	0.46	0.24	2.5	3.3	17.5	2.0
	SS4-2	245	52	-	-	-	-	-	-	-	-	-	-	-
	Mean		**249**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**
	Standard Deviation		**350**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**
	95% Confidence Interval (Mean +/-)		**557**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**
	Upper Limit of 95% Confidence Interval		**806**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**
	Lower Limit of 95% Confidence Interval		**0**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**

(continued)

Table 3.1-1. 2013 Dustfall and Snow Water Chemistry Results (continued)

		Approx. Distance from 2013 Project Footprint (m)	Dustfall (mg/dm^2/y)	Snow Water Chemistry (µg/L)										
Zone	**Station**			**Aluminum**	**Ammonia**	**Arsenic**	**Cadmium**	**Chromium**	**Copper**	**Lead**	**Nickel**	**Nitrite**	**Phosphorous**	**Zinc**
251-1,000 m	Dust 2A	435	155	-	-	-	-	-	-	-	-	-	-	-
	Dust 10	670	122	-	-	-	-	-	-	-	-	-	-	-
	SS1-3	275	460	-	-	-	-	-	-	-	-	-	-	-
	SS1-4	920	178	531	83	0.20	0.011	2.75	1.56	0.79	6.5	10.3	139.0	4.3
	SS2-2	445	42	146	27	0.07	<0.005	0.81	0.36	0.20	2.2	3.7	20.2	1.9
	SS3-4	615	388	862	120	0.44	0.015	10.10	2.71	2.53	30.5	7.9	98.2	9.4
	SS4-3	350	168	-	-	-	-	-	-	-	-	-	-	-
	SS5-1	665	17	-	-	-	-	-	-	-	-	-	-	-
	SS5-2	710	23	-	-	-	-	-	-	-	-	-	-	-
	SS5-3	885	18	69	49	0.06	0.007	1.48	0.52	0.13	5.0	<2.0	9.5	1.2
	Mean		**157**	**402**	**70**	**0.19**	**0.010**	**3.79**	**1.29**	**0.91**	**11.0**	**6.0**	**66.7**	**4.2**
	Standard Deviation		**155**	**367**	**41**	**0.18**	**0.004**	**4.29**	**1.09**	**1.12**	**13.1**	**3.8**	**62.3**	**3.7**
	95% Confidence Interval (Mean +/-)		**111**	**584**	**65**	**0.28**	**0.007**	**6.82**	**1.73**	**1.78**	**20.9**	**6.1**	**99.2**	**5.9**
	Upper Limit of 95% Confidence Interval		**268**	**986**	**134**	**0.48**	**0.017**	**10.60**	**3.02**	**2.69**	**31.9**	**12.0**	**165.9**	**10.1**
	Lower Limit of 95% Confidence Interval		**46**	**0**	**5**	**0.00**	**0.002**	**0.00**	**0.00**	**0.00**	**0.0**	**0.0**	**0.0**	**0.0**
1,001-2,500 m	Dust 5	1,195	121	-	-	-	-	-	-	-	-	-	-	-
	Dust 7	1,155	192	-	-	-	-	-	-	-	-	-	-	-
	Dust 8	1,220	95	-	-	-	-	-	-	-	-	-	-	-
	Dust 9	3,810	102	-	-	-	-	-	-	-	-	-	-	-
	SS1-5	2,180	28	130	34	0.08	<0.005	0.80	0.27	0.22	1.8	3.2	9.1	1.5
	SS2-3	1,220	44	94	32	0.11	<0.005	0.53	0.35	0.16	1.3	<2.0	17.4	1.2

(continued)

Table 3.1-1. 2013 Dustfall and Snow Water Chemistry Results (continued)

				Snow Water Chemistry (µg/L)										
Zone	Station	Approx. Distance from 2013 Project Footprint (m)	Dustfall (mg/dm^2/y)	Aluminum	Ammonia	Arsenic	Cadmium	Chromium	Copper	Lead	Nickel	Nitrite	Phosphorous	Zinc
1,001-2,500 m *(cont'd)*	SS2-4	2,180	41	108	52	0.18	<0.005	0.41	13.10	0.72	0.9	<2.0	11.2	2.0
	SS3-5	1,325	33	72	55	0.06	<0.005	0.74	0.38	0.11	2.5	2.5	14.3	1.2
	SS4-4	1,065	42	103	50	0.10	<0.005	1.15	3.34	0.23	3.5	<2.0	8.1	1.4
	SS4-5	1,220	132	240	76	0.09	0.005	3.96	0.60	0.47	12.9	4.6	51.4	2.5
	SS5-4	1,635	12	61	25	0.08	<0.005	1.06	0.47	0.15	3.6	2.2	13.9	1.7
	SS5-5	2,635	10	44	20	0.04	<0.005	0.82	0.28	0.10	3.0	2.3	6.5	1.0
	Mean		**71**	**106**	**43**	**0.09**	**0.005**	**1.18**	**2.35**	**0.27**	**3.7**	**2.6**	**16.5**	**1.6**
	Standard Deviation		**57**	**61**	**19**	**0.04**	**0.000**	**1.15**	**4.47**	**0.22**	**3.9**	**0.9**	**14.6**	**0.5**
	95% Confidence Interval (Mean +/-)		**36**	**51**	**16**	**0.03**	**n/a**	**0.96**	**3.73**	**0.18**	**3.2**	**0.8**	**12.2**	**0.4**
	Upper Limit of 95% Confidence Interval		**107**	**157**	**59**	**0.13**	**n/a**	**2.14**	**6.08**	**0.45**	**6.9**	**3.4**	**28.7**	**2.0**
	Lower Limit of 95% Confidence Interval		**35**	**56**	**27**	**0.06**	**n/a**	**0.23**	**0.00**	**0.09**	**0.4**	**1.8**	**4.3**	**1.2**
Control	Dust C1	5,655	49	-	-	-	-	-	-	-	-	-	-	-
	Dust C2	3,075	67	-	-	-	-	-	-	-	-	-	-	-
	CONTROL 1	5,655	22	28	19	0.03	<0.005	0.49	0.30	0.06	1.1	2.0	6.2	1.5
	CONTROL 2	3,075	13	57	22	0.06	<0.005	0.68	0.24	0.09	2.0	3.9	7.0	1.3
	CONTROL 3	3,570	52	139	15	0.13	0.005	2.17	0.57	0.24	6.8	<2.0	19.0	3.3
	Mean		**40**	**75**	**19**	**0.08**	**0.005**	**1.11**	**0.37**	**0.13**	**3.3**	**2.6**	**10.7**	**2.0**
	Standard Deviation		**23**	**58**	**4**	**0.05**	**0.000**	**0.92**	**0.17**	**0.09**	**3.1**	**1.1**	**7.2**	**1.1**
	95% Confidence Interval (Mean +/-)		**28**	**143**	**9**	**0.13**	**n/a**	**2.29**	**0.43**	**0.23**	**7.6**	**2.7**	**17.8**	**2.7**

(continued)

Table 3.1-1. 2013 Dustfall and Snow Water Chemistry Results (completed)

Zone	Station	Approx. Distance from 2013 Project Footprint (m)	Dustfall (mg/dm^2/y)	Snow Water Chemistry (µg/L)										
				Aluminum	Ammonia	Arsenic	Cadmium	Chromium	Copper	Lead	Nickel	Nitrite	Phosphorous	Zinc
Control *(cont'd)*	**Upper Limit of 95% Confidence Interval**		**68**	**218**	**27**	**0.21**	**n/a**	**3.40**	**0.80**	**0.36**	**10.9**	**5.4**	**28.5**	**4.7**
	Lower Limit of 95% Confidence Interval		**13**	**0**	**10**	**0.00**	**n/a**	**0.00**	**0.00**	**0.00**	**0.0**	**0.0**	**0.0**	**0.0**
Reference Levels[1]			**621–1,059**	**3,000**	**12,000**	**100**	**3**	**40**	**40**	**20**	**100**	**2,000**	**n/a**	**20**

Notes:

- = not available.

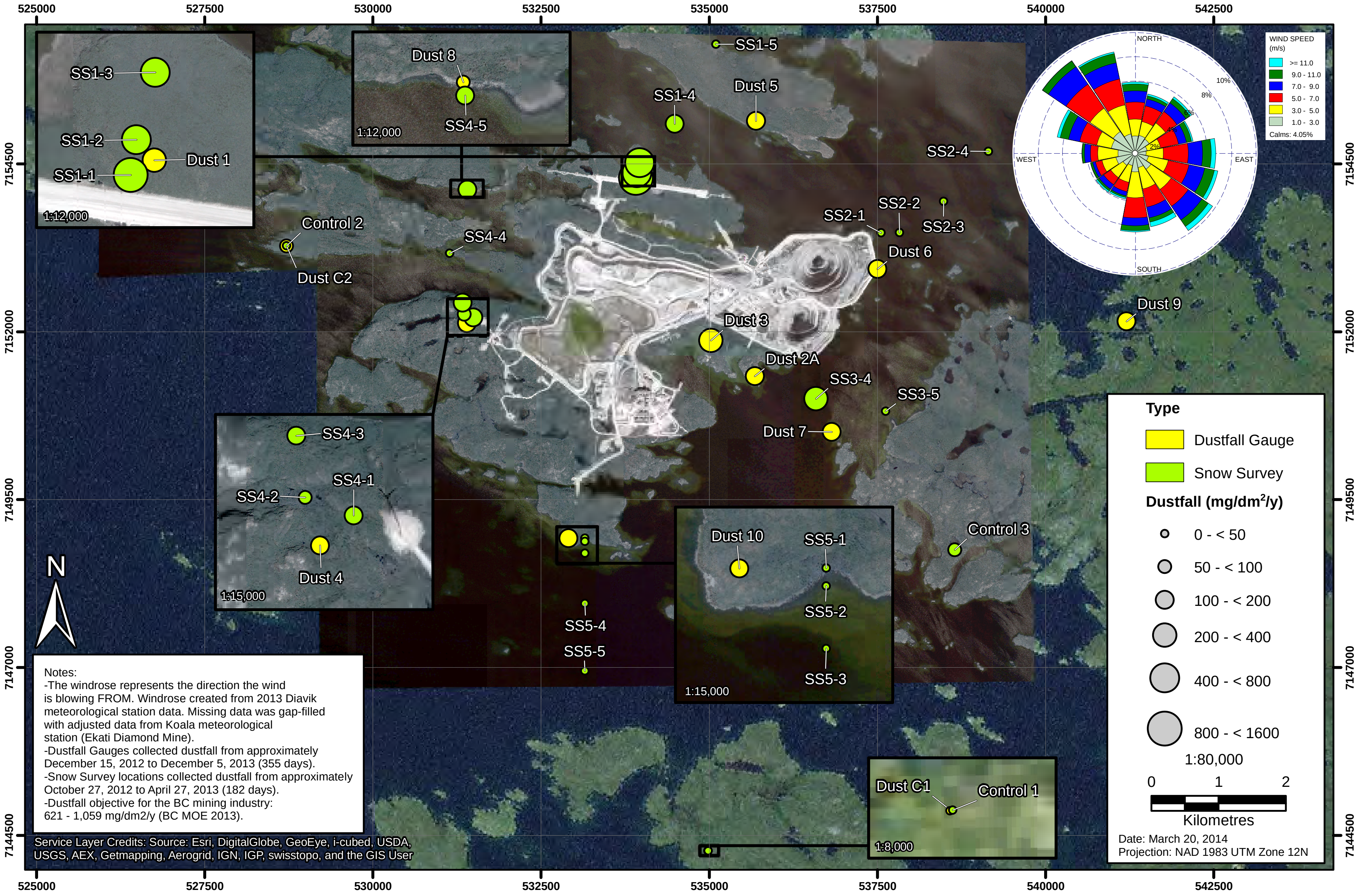
n/a = not applicable.

For measurements that were under the detection limit, the detection limit value was used for statistical calculations.

See Table 2.1-1 for reference level descriptions.

[1] *BC MOE (2013) for dustfall and Water Licence W2007L2-0003 for snow water chemistry.*

Figure 3.1-1
Dustfall Results



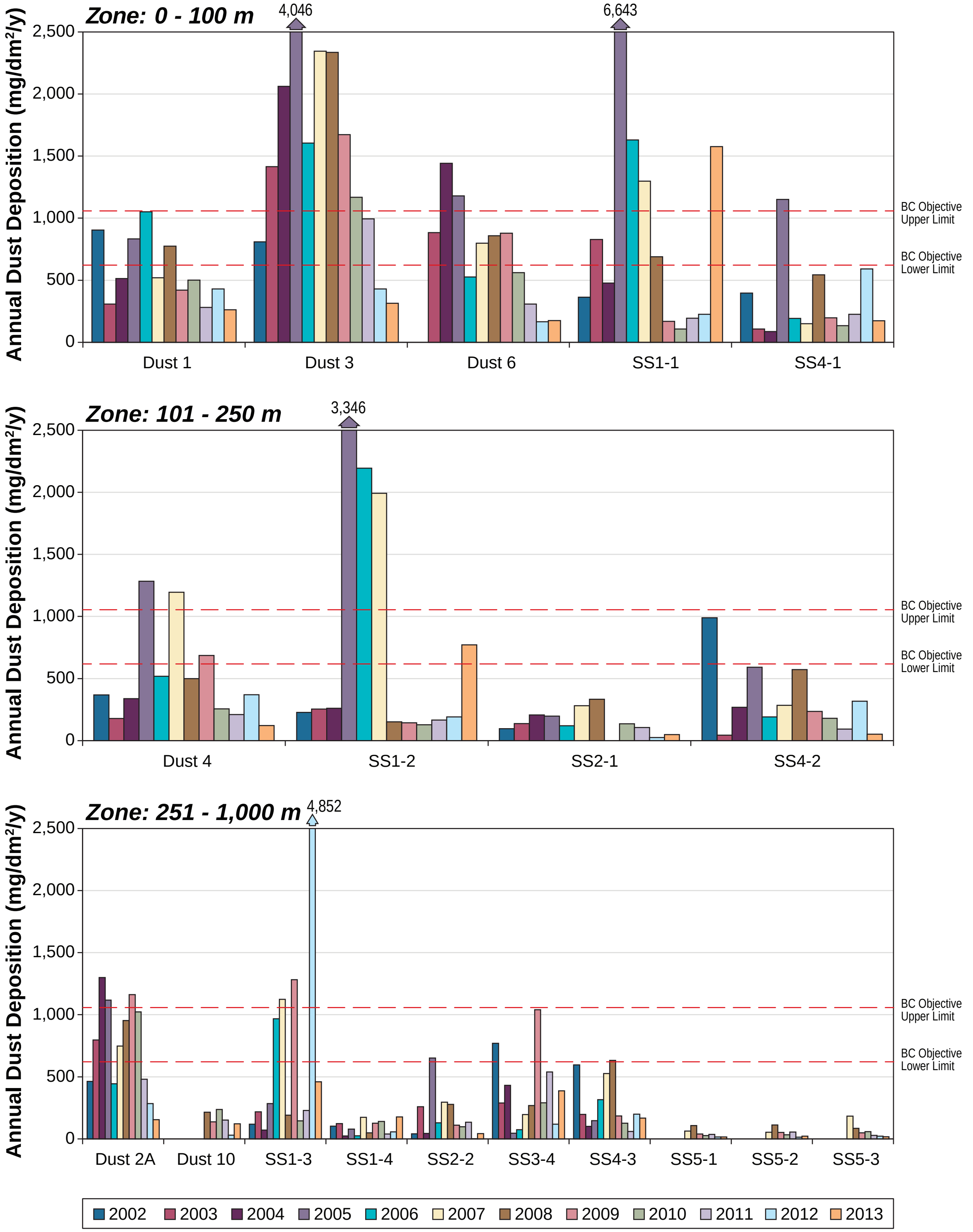
Notes:
-The windrose represents the direction the wind is blowing FROM. Windrose created from 2013 Diavik meteorological station data. Missing data was gap-filled with adjusted data from Koala meteorological station (Ekati Diamond Mine).
-Dustfall Gauges collected dustfall from approximately December 15, 2012 to December 5, 2013 (355 days).
-Snow Survey locations collected dustfall from approximately October 27, 2012 to April 27, 2013 (182 days).
-Dustfall objective for the BC mining industry: 621 - 1,059 mg/dm2/y (BC MOE 2013).

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User

Date: March 20, 2014
Projection: NAD 1983 UTM Zone 12N

Figure 3.1-2

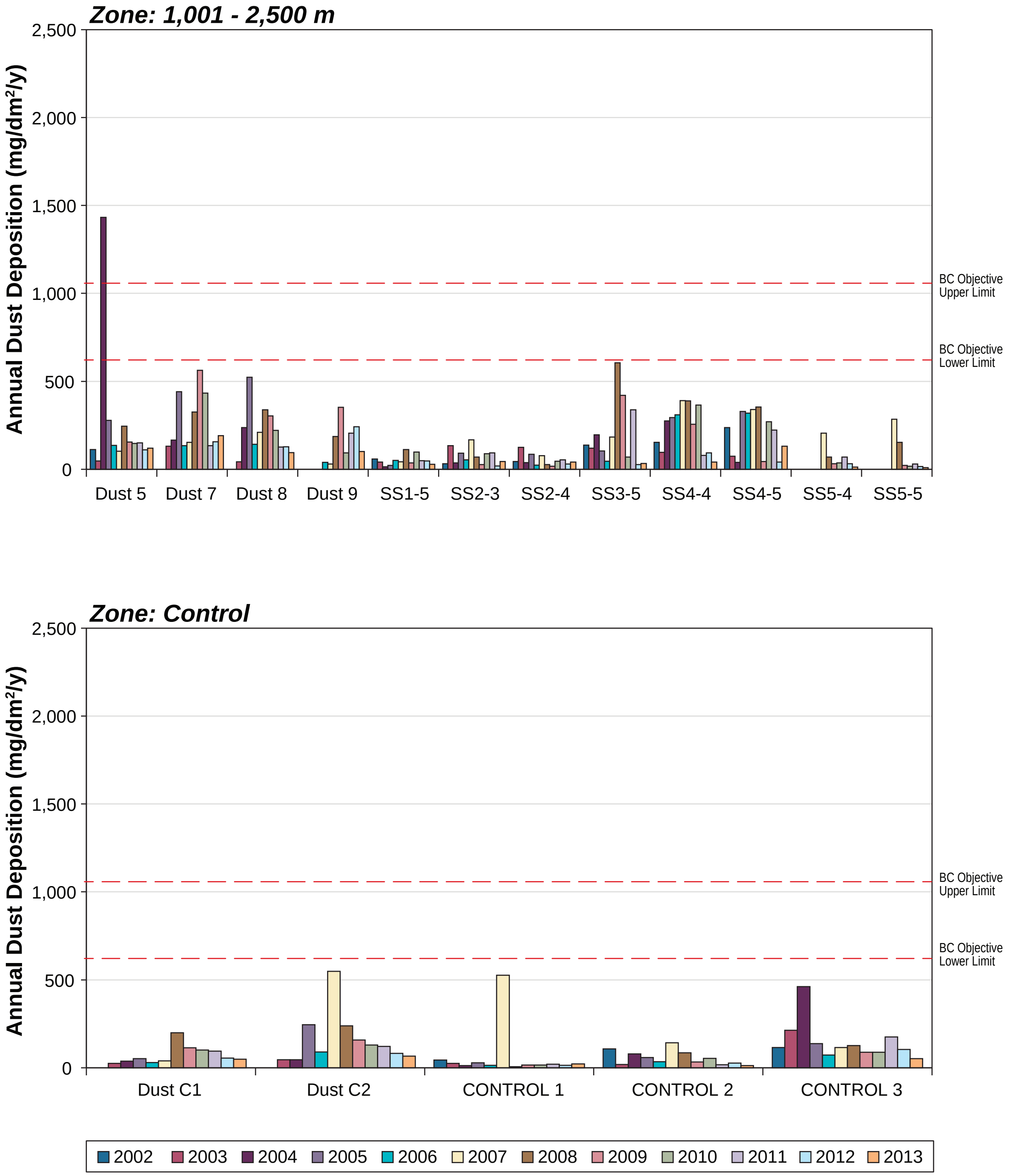
Calculated Annual Dust Deposition Rates at Dustfall Gauges and Snow Survey Locations up to 1,000 m from the Project Footprint, 2002 to 2013



Notes: BC Objective Source: BC MOE (2013).
Annual deposition is calculated using the methodology described in Section 2. See Table 2-1 for actual 2013 sample exposure times.
Station locations have been grouped into zones based on their distance from the 2013 Project footprint. Some stations have historically been grouped in different zones based on their distance from the Project footprint when they were first established.

Figure 3.1-3

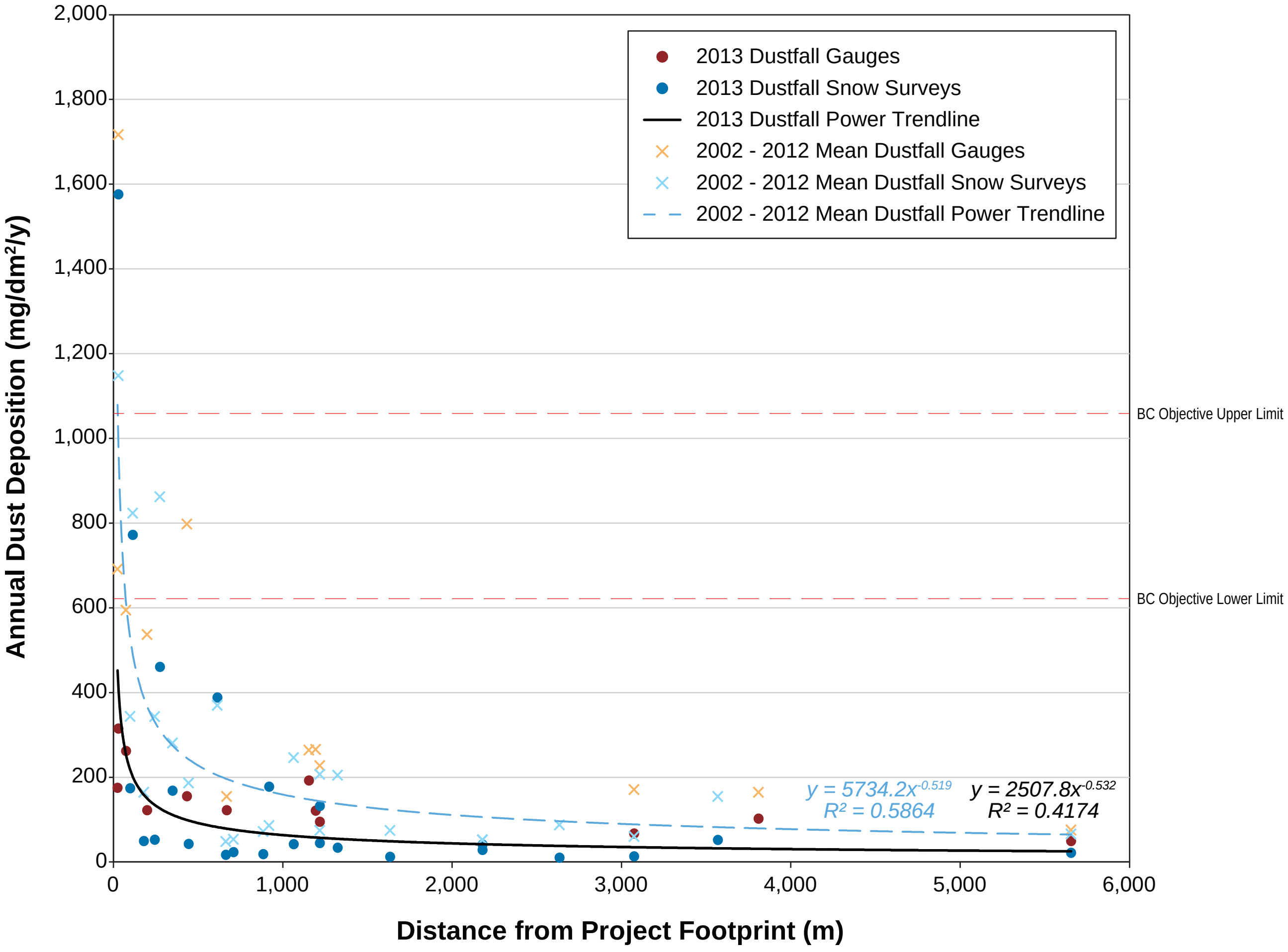
Calculated Annual Dust Deposition Rates at Dustfall Gauges and Snow Survey Locations over 1,000 m from the Project Footprint, 2002 to 2013



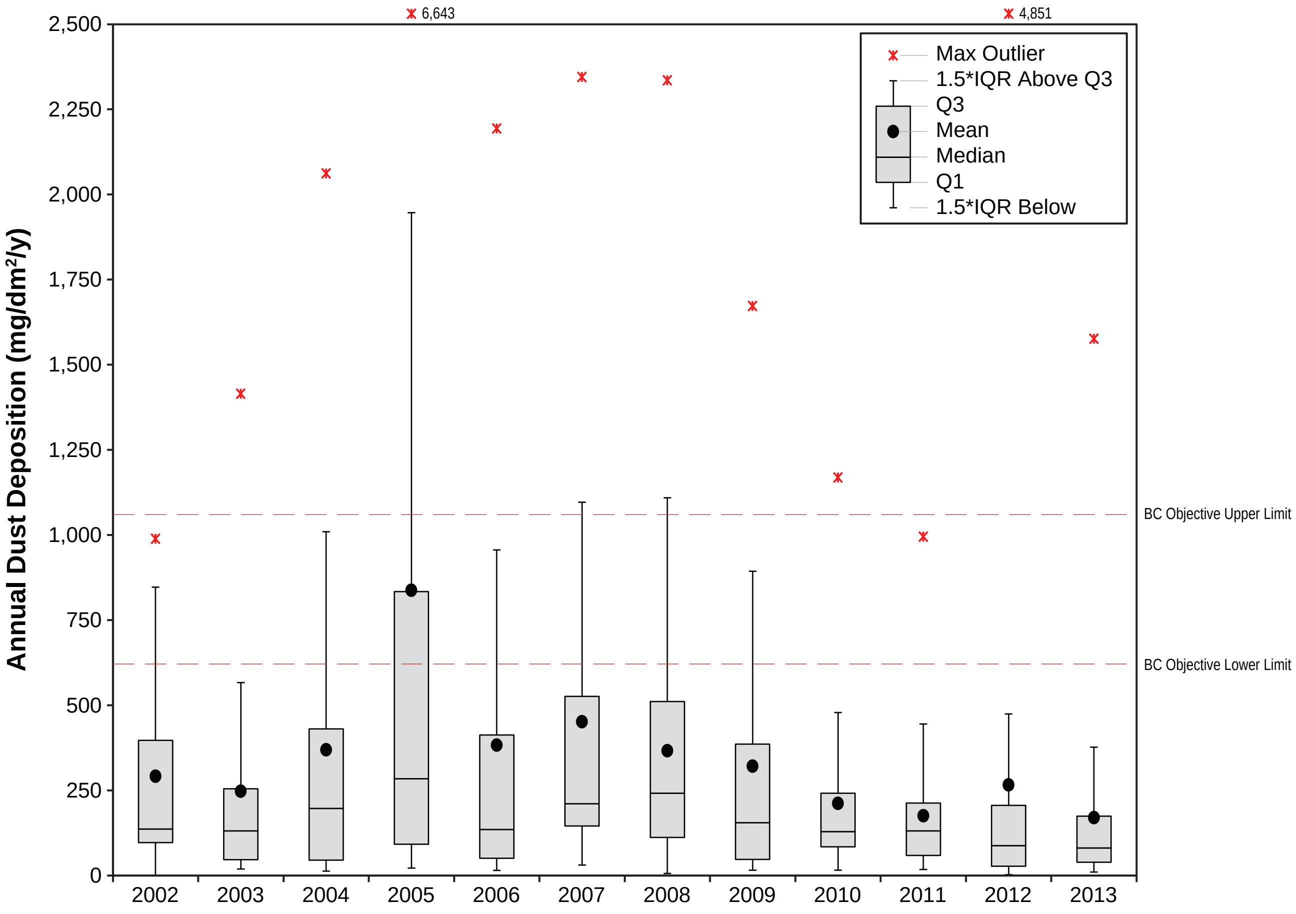
Notes: BC Objective Source: BC MOE (2013).
Annual deposition is calculated using the methodology described in Section 2. See Table 2-1 for actual 2013 sample exposure times.
Station locations have been grouped into zones based on their distance from the 2013 Project footprint. Some stations have historically been grouped in different zones based on their distance from the Project footprint when they were first established.

Figure 3.1-4

Dust Deposition Versus Distance from Project Footprint, 2013



Notes: BC Objective Source: BC MOE (2013)
Annual deposition is calculated using the methodology described in Section 2. See Table 2-1 for actual 2013 sample exposure times.



Notes: BC Objective Source: BC MOE (2013)
Annual deposition is calculated using the methodology described in Section 2. See Table 2-1 for actual 2013 sample exposure times.

The annualized dustfall estimated from gauges at each station was below the BC objective for the mining industry (621–1,059 mg/dm^2/y). This objective is used for comparison purposes only as there are no standards or objectives for the Northwest Territories. It is also used by other mines in the region.

The highest estimated dustfall rate measured using gauges occurred at station Dust 3 (315 mg/dm^2/y), and the second highest at Dust 1 (262 mg/dm^2/y). This result is expected as both stations are close to the mine footprint (within 75 m). Dust 3 is downwind of the footprint (Figure 3.1-1) and Dust 1 is located close to the airstrip which is one of the primary sources of dust due to ground-level air turbulence generated by aircraft during takeoff and landing. Although Dust 6 is the closest station to the footprint (25 m away), it collected only the fourth highest amount of dust (175 mg/dm^2/y) because it is downwind of a relatively small area of the mine footprint. In general, dustfall decreases with increasing distance away from the mine site (Figure 3.1-4). The lowest dustfall rate was estimated for the two control stations; Dust C1 (49 mg/dm^2/y) and Dust C2 (67 mg/dm^2/y).

As depicted in Figures 3.1-2 and 3.1-3, dustfall rates estimates from gauges at each station in 2013 were lower compared to the majority of previous years, with the exception of station Dust 7 which was in the range of historical values. Figures 3.1-4 and 3.1-5 also depict how dustfall (including dustfall measured from snow surveys) measured in 2013 was generally lower than all previous years, with the mean, median and third quartile dustfall values being lower than all other years.

3.2 DUSTFALL SNOW SURVEYS

Table 3.1-1 and Figure 3.1-1 summarize the annual dustfall collected from each snow survey in 2013. Figures 3.1-2 and 3.1-3 graph the 2013 annual dustfall compared to historical years for each station, and Figure 3.1-4 plots the annual dustfall versus distance from the mine footprint. Boxplots summarizing the dustfall measured in each year are presented in Figure 3.1-5. The detailed 2013 snow survey field datasheets and laboratory results are included in Appendix B. Duplicate samples were taken at stations SS1-2, SS2-2, SS4-1 and SS5-5, and a blank sample was taken at station SS4-4. These sample results are discussed in Section 3.4.

The annualized dustfall rates estimated from the 2013 snow survey data ranged from 10 to 1,576 mg/dm^2/y. Stations SS1-1 (1,576 mg/dm^2/y) and SS1-2 (772 mg/dm^2/y) were the only stations to have dustfall over the BC objective for the mining industry (621–1,059 mg/dm^2/y). Both of these stations are within 115 m of the airstrip (Figure 3.1-1).

As depicted in Figures 3.1-2 and 3.1-3, dustfall estimated from each snow survey station in 2013 was lower compared to the majority of previous years, with the exception of stations SS1-1, SS1-2, SS1-3 and SS1-4 all of which were within the range of results from all previous years, but higher than the last two years. Stations SS1-1 to SS1-4 are closest to the airstrip. Figures 3.1-4 and 3.1-5 also depict how dustfall (including dustfall measured from dustfall gauges) measured in 2013 was generally lower than all previous years, with the mean, median and third quartile dustfall values being lower than all other years.

The mean dustfall rates measured from both dustfall gauges and snow surveys within the 0–100, 101–250, 251–1,000, 1,001–2,500 and Control zones were 500, 249, 157, 71 and 40 mg/dm^2/y, respectively (Table 3.1-1). In general, dustfall decreases with increasing distance away from the mine site (Figure 3.1-4), and the lowest dustfall was recorded at station SS5-5.

Dustfall stations Dust 5, Dust 7, SS1-1, SS1-3, SS3-4 and SS4-5 all exceeded the upper limit of the 95% confidence interval for their respective zones in 2013 (Table 3.1-1).

Because dustfall gauges continuously collect dust throughout the year, and the snow surveys are only representative of dustfall accumulated over the snow cover period, the reported annual dustfall results from the dustfall gauges are expected to better estimate annual dustfall compared to snow survey results for similar geographic areas.

3.3 SNOW WATER CHEMISTRY

The full laboratory analysis of snow water chemistry for each station is included in Appendix C and a summary for each variable of interest is provided in the following sections. Duplicate samples were taken at stations SS2-2 and SS5-5, and a blank sample was taken at station SS4-4. These sample results are discussed in Section 3.4.

The annual predominant wind directions at the site are from the northwest and southeast, and the expectation is that airborne material will be deposited primarily northwest and southeast of the mine as seen in Figure 3.1-1. As expected, station S3-4, located approximately 615 m south-southeast of the A418 dike, recorded the highest concentrations of each variable of interest except for nitrite and phosphorous which were highest at station S1-4.

3.3.1 Aluminum

Aluminum concentrations measured in 2013 ranged from a low of 28 µg/L in the control zone, to a high of 862 µg/L in the 251–1,000 m zone (Table 3.1-1). All values were well below the value of 3,000 µg/L specified in the Water Licence for grab sample concentrations.

Compared to previous years, the 2013 median concentration in each zone was relatively low (Figure 3.3-1). In general, concentrations also decreased with distance from the mine.

3.3.2 Ammonia

Ammonia concentrations measured in 2013 ranged from a low of 15 µg/L in the control zone, to a high of 120 µg/L in the 251–1,000 m zone (Table 3.1-1). All values were well below the the value of 12,000 µg/L specified in the Water Licence for grab sample concentrations.

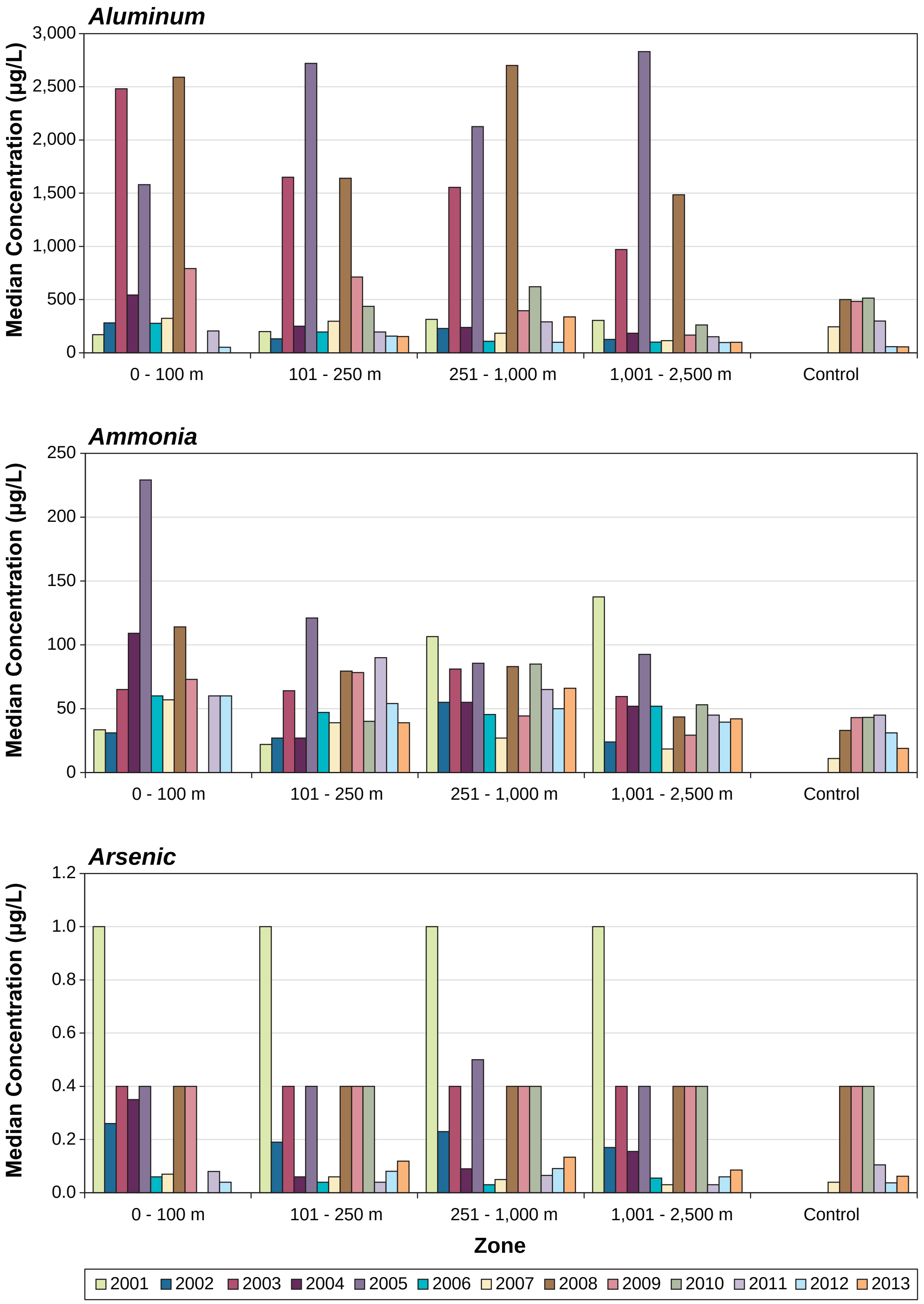
Compared to previous years, the 2013 median concentration in each zone was relatively low (Figure 3.3-1). In general, concentrations also decreased with distance from the mine.

3.3.3 Arsenic

Arsenic concentrations measured in 2013 ranged from a low of 0.03 µg/L in the control zone, to a high of 0.44 µg/L in the 251–1,000 m zone (Table 3.1-1). All values were below the value of 100 µg/L specified in the Water Licence for grab sample concentrations.

Figure 3.3-1

Snow Water Chemistry Results: Aluminum, Ammonia and Arsenic, 2001 to 2013



Notes: See Table 2.1-1 for Water Licence max grab sample concentrations.

Compared to previous years, the 2013 median concentration in each zone was relatively low (Figure 3.3-1). In general, concentrations also decreased with distance from the mine.

3.3.4 Cadmium

Cadmium concentrations measured in 2013 ranged from a low of <0.005 µg/L (below the detection limit) in all zones, to a high of 0.015 µg/L in the 251–1,000 m zone (Table 3.1-1). All values were below the value of 3 µg/L specified in the Water Licence for grab sample concentrations.

Compared to previous years, the 2013 median concentration in each zone was relatively low (Figure 3.3-2). In general, concentrations also decreased with distance from the mine.

3.3.5 Chromium

Chromium concentrations measured in 2013 ranged from a low of 0.41 µg/L in the 1,001–2,500 m zone, to a high of 10.1 µg/L in the 251–1,000 m zone (Table 3.1-1). All values were below the value of 40 µg/L specified in the Water Licence for grab sample concentrations.

Compared to previous years, the 2013 median concentration in each zone was relatively low (Figure 3.3-2). In general, concentrations also decreased with distance from the mine.

3.3.6 Copper

Copper concentrations measured in 2013 ranged from a low of 0.24 µg/L in the control zone, to a high of 13.1 µg/L in the 251–1,000 m zone (Table 3.1-1). All values were below the value of 40 µg/L specified in the Water Licence for grab sample concentrations.

Compared to previous years, the 2013 median concentration in each zone was relatively low (Figure 3.3-2). In general, concentrations also decreased with distance from the mine.

3.3.7 Lead

Lead concentrations measured in 2013 ranged from a low of 0.06 µg/L in the control zone, to a high of 2.5 µg/L in the 251–1,000 m zone (Table 3.1-1). All values were below the value of 20 µg/L specified in the Water Licence for grab sample concentrations.

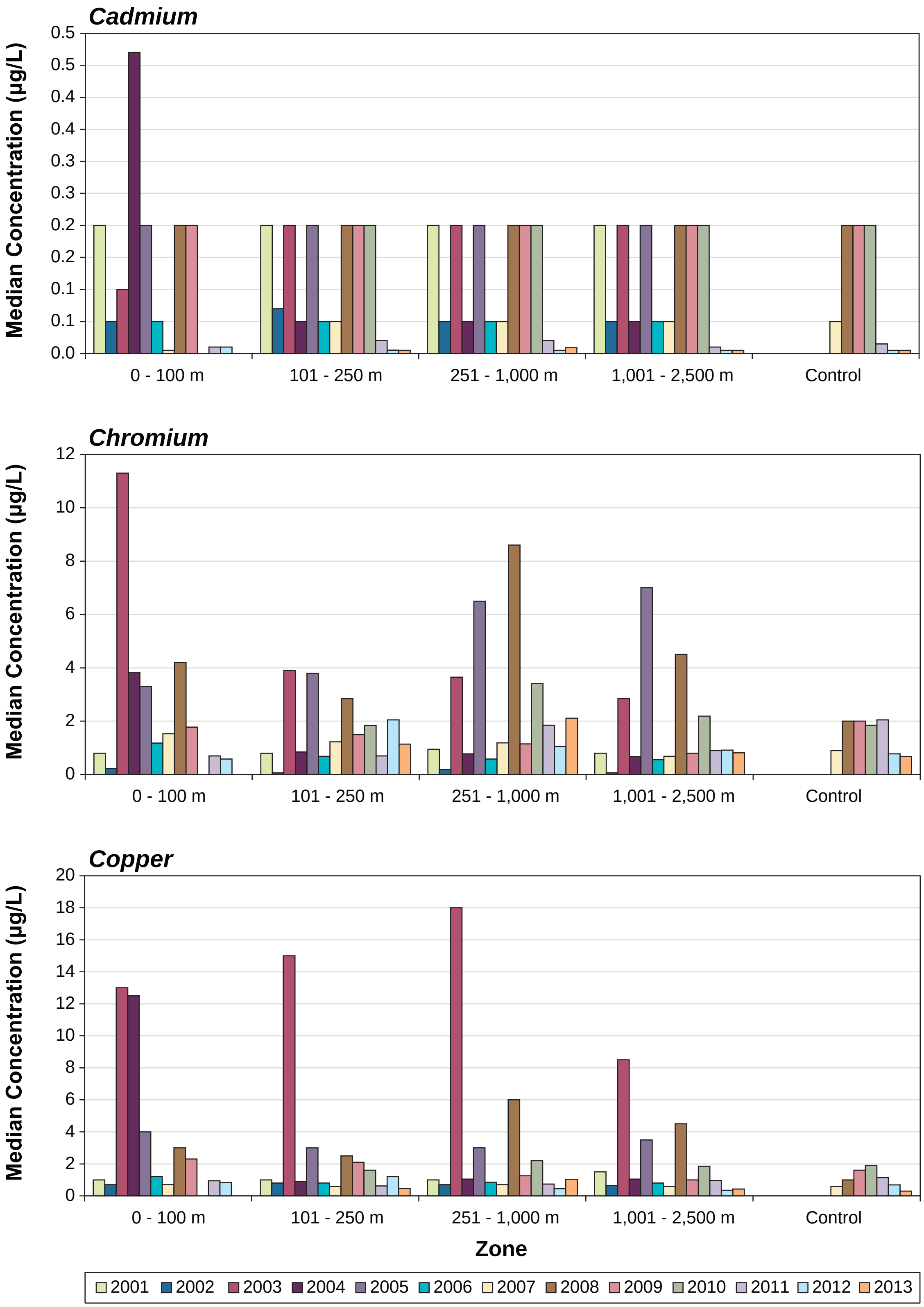
Compared to previous years, the 2013 median concentration in each zone was relatively low (Figure 3.3-3). In general, concentrations also decreased with distance from the mine.

3.3.8 Nickel

Nickel concentrations measured in 2013 ranged from a low of 0.89 µg/L in the 1,001–2,500 m zone, to a high of 30.5 µg/L in the 251–1,000 m zone (Table 3.1-1). All values were below the value of 100 µg/L specified in the Water Licence for grab sample concentrations.

Figure 3.3-2

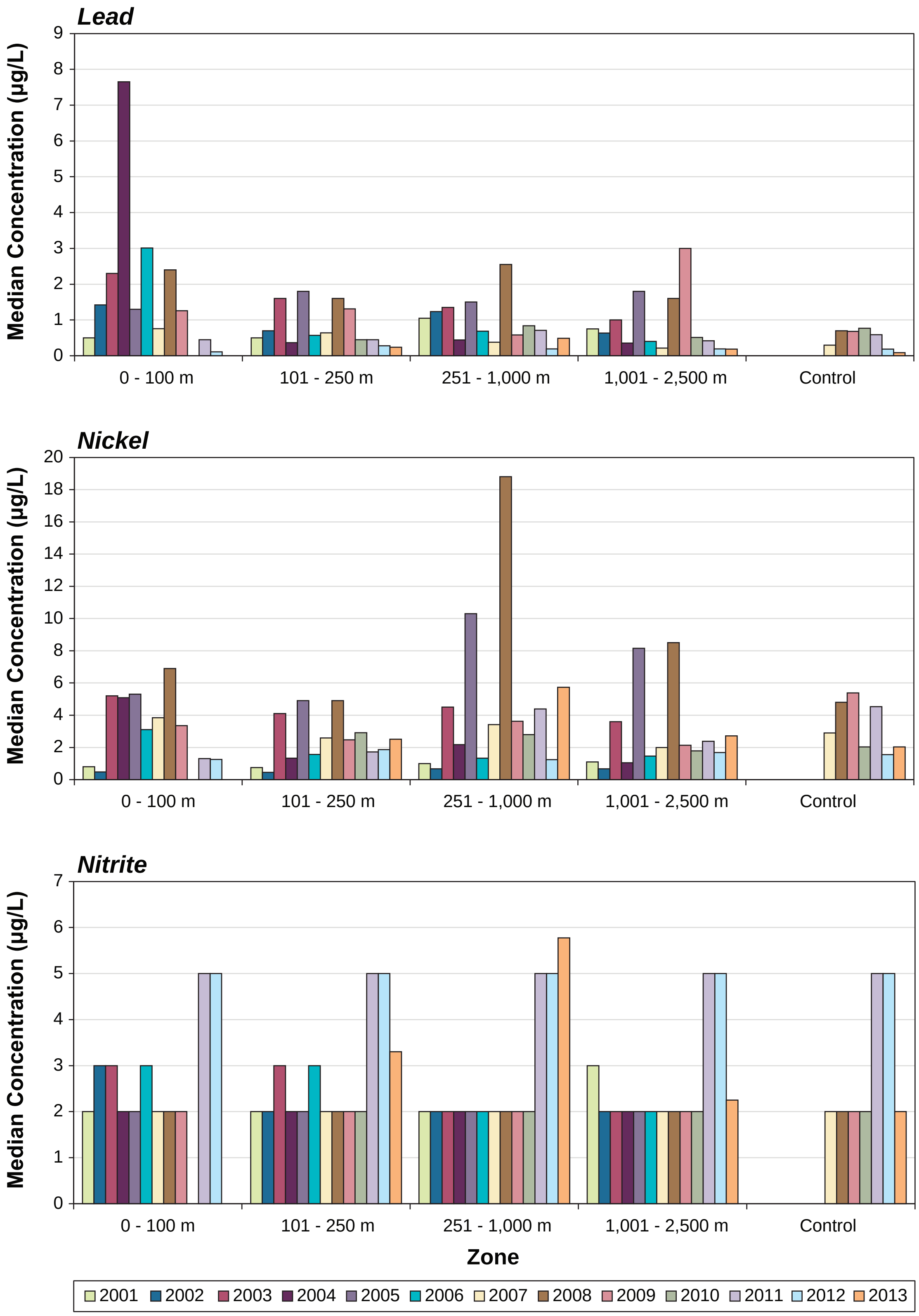
Snow Water Chemistry Results: Cadmium, Chromium and Copper, 2001 to 2013



Notes: Median concentrations are below the Water Licence max grab sample concentration threshold, unless presented otherwise. See Table 2.1-1 for Water Licence max grab sample concentrations.

Figure 3.3-3

Snow Water Chemistry Results: Lead, Nickel and Nitrite, 2001 to 2013



Notes: Median concentrations are below the Water Licence max grab sample concentration threshold, unless presented otherwise. See Table 2.1-1 for Water Licence max grab sample concentrations.

The 2013 median concentration in each zone was higher than the two previous years (except for the control location which had a higher 2011 value), and mid-range compared to all other years (Figure 3.3-3). In general, concentrations also decreased with distance from the mine.

3.3.9 Nitrite

Nitrite concentrations measured in 2013 ranged from a low of <2.0 µg/L (below the detection limit) in the 251–1,000 m, 1,001–2,500 m and control zones, to a high of 10.3 µg/L in the 251–1,000 m zone (Table 3.1-1). All values were below the value of 2,000 µg/L specified in the Water Licence for grab sample concentrations.

Nitrite measured in previous years were below analytical detection limits. These detection limits have changed over time and it is not possible to form accurate conclusions regarding Nitrite's increase or decrease over time (Figure 3.3-3).

3.3.10 Phosphorous

Phosphorous concentrations measured in 2013 ranged from a low of 6.2 µg/L in the control zone, to a high of 139 µg/L in the 251–1,000 m zone (Table 3.1-1). Although the Water Licence has a load limit for phosphorous, there is no concentration criterion under the licence.

Compared to previous years, the 2013 median concentration in each zone was relatively low (Figure 3.3-4). In general, concentrations also decreased with distance from the mine.

3.3.11 Zinc

Zinc concentrations measured in 2013 ranged from a low of 1.0 µg/L in the 1,001–2,500 m zone, to a high of 9.4 µg/L in the 251–1,000 m zone (Table 3.1-1). All values were below the value of 20 µg/L specified in the Water Licence for grab sample concentrations.

Compared to previous years, the 2013 median concentration in each zone was relatively low (Figure 3.3-4). In general, concentrations also decreased with distance from the mine.

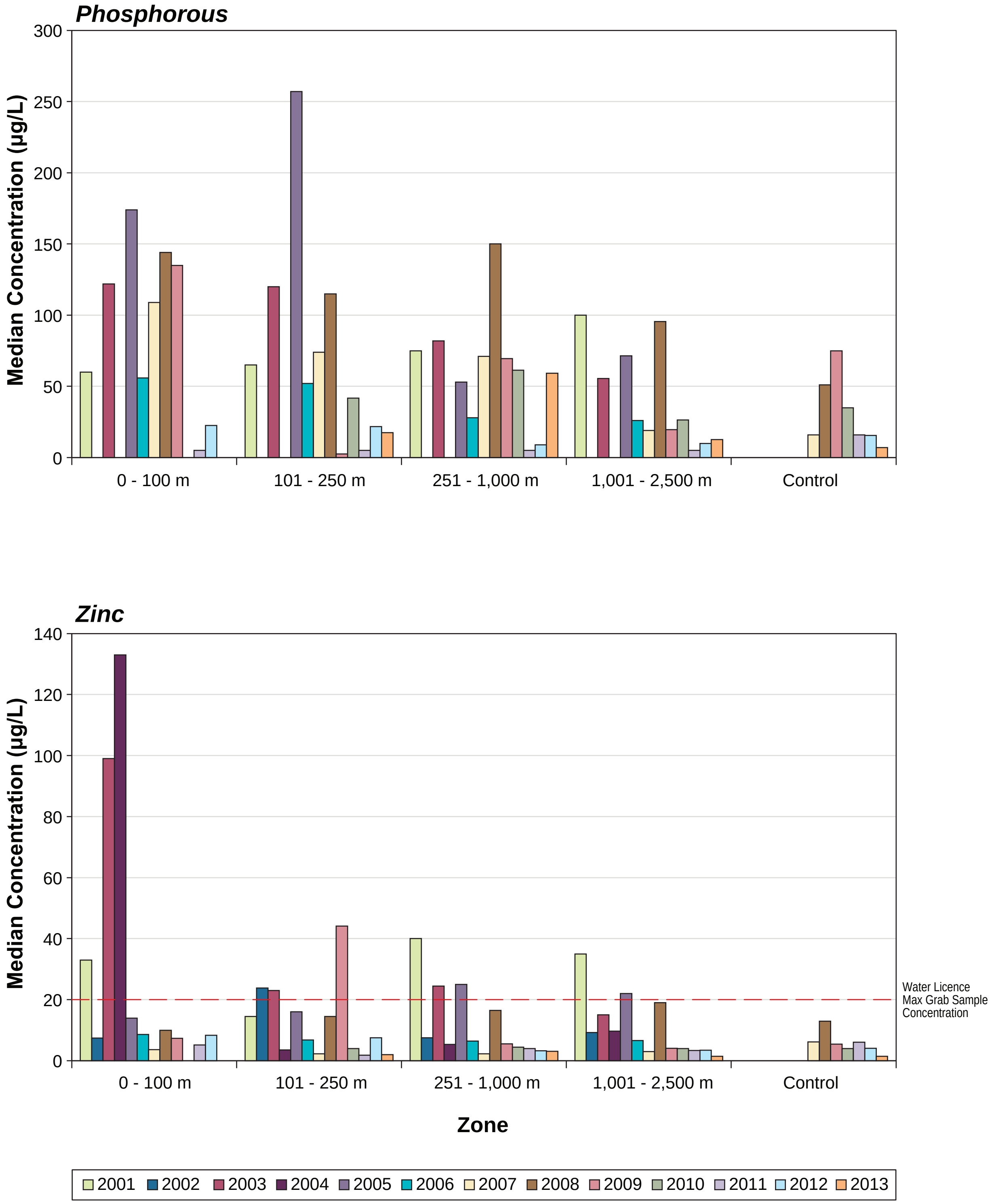
3.4 QUALITY ASSURANCE AND CONTROL

Dustfall gauge, dustfall snow surveys and snow water chemistry sampling and analysis were conducted by experienced technicians following SOPs ENVR-508-0112, ENVR-512-0213 and ENVI-403-0112 to ensure proper field sampling and laboratory analysis. As part of SOP ENVR-512-0213, duplicate and blank samples were taken for some snow survey and snow water chemistry sample sites (Table 2-1). The results from these samples are summarized in Table 3.4-1 below.

The relative percent difference (RPD) of duplicate samples from a site represents the amount of variation between each duplicate. Generally, RPD values greater than 40% may indicate *in situ* variation and more samples may be required to adequately characterize the site. Because each measured aluminum duplicate for station SS5-5 was well below the applicable reference level, it is expected that a well characterized sample would have also been below the aluminum reference level.

Figure 3.3-4

Snow Water Chemistry Results: Phosphorus and Zinc, 2001 to 2013



Notes: Median concentrations are below the Water Licence max grab sample concentration threshold, unless presented otherwise.

All blank sample parameters from station SS4-4 were well below those from the non-blank sample, with the exception of nitrite which was higher for the blank sample (2.5 μg/L) than the non-blank sample (<2.0 μg/L, below detection limit). Nitrate samples from all snow water chemistry sites were either below detection limits or far below the 2,000 μg/L Water Licence threshold. For all sampling locations it is expected that a well characterized nitrite sample would also be far below the threshold value.

Table 3.4-1. Sample Duplicates and Blanks

Parameter	Relative Percent Difference[1] (%)				SS4-4 Blank Sample (μg/L)	Percent Below Non-blank SS4-4 Sample
	SS1-2	SS2-2	SS4-1	SS5-5		
Dustfall	36	7	20	6	0.0 $mg/dm^2/y$	100
Aluminum	n/a	28	n/a	22	1.8	98
Ammonia	n/a	7	n/a	56	<5[2]	90
Arsenic	n/a	15	n/a	29	<0.02[2]	80
Cadmium	n/a	n/a[2]	n/a	n/a[2]	<0.005[2]	0[3]
Chromium	n/a	21	n/a	27	0.19	84
Copper	n/a	27	n/a	2	0.48	86
Lead	n/a	20	n/a	3	0.02	93
Nickel	n/a	11	n/a	1	0.05	99
Nitrite	n/a	n/a[4]	n/a	n/a[4]	2.5	-25[5]
Phosphorous	n/a	40	n/a	28	<2[2]	75
Zinc	n/a	3	n/a	~0	0.4	73

n/a = not applicable

[1] *Relative difference between duplicates, with respect to their mean:* $RPD = 100 \times |rep1 - rep2| / [(rep1 + rep2)/2]$

[2] *Both duplicates were below detection limit.*

[3] *Both blank and non-blank samples were below detection limit.*

[4] *One of the two duplicates was below detection limit (<2.0 μg/L).*

[5] *The non-blank sample was below detection limit (<2.0 μg/L).*

4. SUMMARY

In 2013, dustfall around the mine was monitored using 12 dustfall gauges and 24 snow survey stations located at varying distances around the mine. Snow water chemistry was also sampled at 16 of these snow survey stations.

Dustfall levels were generally lower in 2013 than previous years except at the four snow survey stations closest to the airstrip (SS1-1, SS1-2, SS1-3 and SS1-4) and one station southwest of the mine (Dust 7). For these five stations, dustfall levels were within the range of results from all previous years, but higher than the last two years.

The annual dustfall estimated from each of the 12 dustfall gauges ranged from 49 to 315 mg/dm^2/y. The annual dustfall estimated from each of the 24 snow survey locations ranged from 10 to 1,576 mg/dm^2/y. Only two samples were above the BC mining dustfall objective range of 621-1,059 mg/dm^2/y:

- 1,576 mg/dm^2/y estimated from the snow survey conducted 30 m north of the airstrip (station SS1-1); and
- 772 mg/dm^2/y estimated from the snow survey conducted 115 m north of the airstrip (station SS1-2).

Overall, as expected, dustfall rates decreased with distance from the mine site, and areas that were predominantly downwind of the mine site received more dustfall than upwind areas. Snow water chemistry variables of interest included aluminum, ammonia, arsenic, cadmium, chromium, copper, lead, nickel, nitrite, phosphorous and zinc. All 2013 sample values were below their associated reference values as specified by the "maximum concentration of any grab sample" outlined in DDMI's Type "A" Water Licence. In general, concentrations decreased with distance from the mine site. The majority of concentrations were lower than in previous years with the exception of nickel which was within the historical range.

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Definitions of the acronyms and abbreviations used in this reference list can be found in the Glossary and Abbreviations section.

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W2007L2-0003. Class A Water Licence Issued to Diavik Diamond Mines (2012) Inc. by Wek'éezhìi Land and Water Board.

Appendix A

Annual Changes to Dustfall Program

APPENDIX A. ANNUAL CHANGES TO DUSTFALL PROGRAM

2001

The 2001 dust monitoring program was based entirely upon snow survey samples collected along four radial transects emanating from the project footprint outward to a distance of approximately 1,000 meters. All sample locations were analyzed for dust deposition, while only those locations on Lac de Gras were analyzed for snow water chemistry.

2002

DDMI amended the dust monitoring program, in response to recommendations made by the Mackenzie Valley Land and Water Board, to include two snow survey control locations. In addition, five dust gauges (passive dust collectors) were deployed, one along each of the snow survey transects and one at a control location, in efforts to enhance the monitoring program.

2003

In response to further recommendations, the dust monitoring program was modified. All four snow survey transects were extended in length to a distance of approximately 2,000 meters from the project footprint. An additional five dust gauges, including a second control, were deployed.

2004

Increased construction activity necessitated further changes to the dust monitoring program. One dust gauge (Dust 02) was removed from its location to accommodate project footprint expansion, and subsequently relocated and redeployed (Dust 2A).

2005

Dust deposition monitoring was carried out with no modifications to either the snow survey or the dust gauge portion of the program.

2006

An additional dust gauge was deployed bringing the total to eleven (including two controls). Testing of Mini-Vol portable air samplers were conducted to determine feasibility of incorporation into the dust monitoring program. Preliminary findings proved the inclusion of the Mini-Vol samplers would be impractical.

2007

The snow survey portion of the program was amended with an additional snow survey transect being incorporated bringing the total number of transects to five. As well, snow water chemistry samples were collected adjacent to the pre-existing control locations as background references.

Two additional dust gauges (temporary) were deployed adjacent to two pre-existing dust gauges. The intent of the temporary gauges was to compare results from the same location when sample collection frequency is altered.

DDMI initiated contact with Environment Canada and Golder Associates with regards to remodeling dust deposition with the intent of revising predictions made in the 1998 environmental effects report.

In light of dust deposition monitoring results from previous years, several control measures were adopted to reduce dust generation on site, including the utilization of EK-35 (suppressant) on the airport apron, taxiway and helipad, and fitting a second 830E haul truck with tank for haul road watering.

2008

All of the dust gauges were modified to accommodate the replacement of the polyacrylic dust gauge inserts with brass Nipher gauge inserts, to minimize loss associated with damage during the collection and handling of the dust gauges.

An additional dust gauge was added to the program bringing the total to twelve permanently deployed (including two control), and two temporary (reference) dust gauges.

Three snow survey sample points were not sampled as they had become overtaken by construction activity and expansion of the project footprint.

Additional preparations for dust deposition modelling were completed including data collection, identification of point source inputs, selection of a modelling program and inputs (with regulator input) and discussion of cumulative effects.

2009

The two temporary dust gauges deployed in 2007 were decommissioned. All twelve permanent gauges were collected quarterly. An error in collection/deployment resulted in “No Data” being collected for Dust 03 between July 11 and September.

Snow survey sampling was conducted in April. An error in collection/analysis resulted in the Dust Deposition sample for SS2-1 being compromised; as such “No Dust Deposition Data” was available for this location.

2010

All twelve permanent dust gauges were collected quarterly during 2010. Overall, there was a reduction of observed dustfall deposition from 2009 to 2010, with the exception of Dust 1 and Dust 10.

Snow survey sampling was conducted throughout the month of April. An error in collection/ processing resulted in two missing stations for the water quality analysis. SS2-1 field results were collected; however, the sample was compromised during processing in the lab. An error also resulted with the collection of SS5-2; data collection for water quality analysis was missed in the field. No data for these two stations resulted in Zone 1 having no data for the various water chemistry results and SS5-2 was not represented in Zone 3 data for 2010.

2011

All twelve permanent dust gauges were collected quarterly during 2011. During collection and repair to Station Dust 5 in September, the sample was compromised and therefore not processed, which resulted in data loss.

Snow survey sampling was conducted throughout the month of April. Due to an internal error shipping samples, water quality samples for stations SS1-4, SS1-5, SS2-1, SS2-2, SS2-3, SS2-4, and SSC-3 arrived at the Maxxam laboratory past the recommended holding time.

2012

All twelve permanent dust gauges were collected quarterly during 2012. During collection in June repairs were conducted on Station Dust 9 as it was found on its side, the sample was compromised, which resulted in data loss. Overall in 2012, 8 of the 12 dust gauges reported lower deposition rates compared to 2011.

Snow survey sampling was conducted on April 30 and on May 4 and 5.

2013

All twelve permanent dust gauges were collected quarterly during 2013. Station Dust 5 was dismantled upon arrival in September and the sample was compromised, which resulted in data loss for that quarter.

Snow survey sampling was conducted at 24 locations from April 26 to 28.

Appendix B

Dustfall Gauge Analytic Results

Appendix B. Dustfall Gauge Analytic Results

Sample Date	Dust Gauge ID	Filter #	Weight of Filter (mg)	Filter + Residue (mg)	Weight of Residue (mg)	Cumulative (filters, mg)	Dust Deposition (mg/dm²)	Days Deployed	Dust Deposition (mg/dm²/d)	Dust Deposition (mg/dm²/y)
16-Dec-12	Initial Deployment Date									
27-Mar-13	Dust 1	1	124.6	189.2	64.6	64.6	52.67	101.00	0.52	190.3
2-Jun-13	Dust 1	1	116.9	232.4	115.5	115.5	94.17	67.00	1.41	513.0
24-Sep-13	Dust 1	1	112.3	190.8	78.5	78.5	64.00	114.00	0.56	204.9
4-Dec-13	Dust 1	1	121.5	173.6	52.1	52.1	42.48	71.00	0.60	218.4
					Totals	**310.7**	**253.31**	**353.00**	**0.72**	**261.9**
15-Dec-12	Initial Deployment Date									
12-Mar-13	Dust 2A	1	116	226.9	110.9	110.9	90.42	87.00	1.04	379.3
3-Jun-13	Dust 2A	1	115.6	157.1	41.5	41.5	33.83	83.00	0.41	148.8
19-Sep-13	Dust 2A	1	114.3	127.7	13.4	13.4	10.92	108.00	0.10	36.9
6-Dec-13	Dust 2A	1	117.6	137.2	19.6	19.6	15.98	78.00	0.20	74.8
					Totals	**185.4**	**151.15**	**356.00**	**0.42**	**155.0**
12-Dec-12	Initial Deployment Date									
12-Mar-13	Dust 3	1	119.8	194.2	74.4	74.4	60.66	90.00	0.67	246.0
2-Jun-13	Dust 3	1	115.2	205.2	90	90	73.38	82.00	0.89	326.6
24-Sep-13	Dust 3	1	114.2	283.8	169.6	169.6	138.27	114.00	1.21	442.7
6-Dec-13	Dust 3	1	121.9	167.7	45.8	45.8	37.34	73.00	0.51	186.7
					Totals	**379.8**	**309.65**	**359.00**	**0.86**	**314.8**
16-Dec-12	Initial Deployment Date									
27-Mar-13	Dust 4	1	122.4	154.7	32.3	32.3	26.33	101.00	0.26	95.2
2-Jun-13	Dust 4	1	115.5	161	45.5	45.5	37.10	67	0.55	202.1
23-Sep-13	Dust 4	1	114.4	168.9	54.5	54.5	44.43	113	0.39	143.5
4-Dec-13	Dust 4	1	122.2	134.7	12.5	12.5	10.19	72	0.14	51.7
					Totals	**144.8**	**118.05**	**353**	**0.33**	**122.1**

Appendix B. Dustfall Gauge Analytic Results

Sample Date	Dust Gauge ID	Filter #	Weight of Filter (mg)	Filter + Residue (mg)	Weight of Residue (mg)	Cumulative (filters, mg)	Dust Deposition (mg/dm²)	Days Deployed	Dust Deposition (mg/dm²/d)	Dust Deposition (mg/dm²/y)
15-Dec-12	Initial Deployment Date									
27-Mar-13	Dust 5	1	116.4	148.8	32.4	32.4	26.42	102.00	0.26	94.5
3-Jun-13	Dust 5	1	117.5	152.2	34.7	34.7	28.29	68.00	0.42	151.9
19-Sep-13[a]	Dust 5	1	117.7	145.1	27.4	27.4	22.34	108.00	0.21	75.5
4-Dec-13	Dust 5	1	120.5	153.2	32.7	32.7	26.66	76.00	0.35	128.0
					Totals[b]	**99.8**	**81.37**	**246.00**	**0.33**	**120.7**
16-Dec-12	Initial Deployment Date									
28-Mar-13	Dust 6	1	116.4	168.3	51.9	51.9	42.31	102.00	0.41	151.4
2-Jun-13	Dust 6	1	116.8	195.7	78.9	78.9	64.33	66.00	0.97	355.7
24-Sep-13	Dust 6	1	112.8	147.5	34.7	34.7	28.29	114.00	0.25	90.6
6-Dec-13	Dust 6	1	120.3	163.6	43.3	43.3	35.30	73.00	0.48	176.5
					Totals	**208.8**	**170.23**	**355**	**0.48**	**175.0**
15-Dec-12	Initial Deployment Date									
12-Mar-13	Dust 7	1	122.3	216	93.7	93.7	76.39	87.00	0.88	320.5
3-Jun-13	Dust 7	1	115.7	180.7	65	65	52.99	83.00	0.64	233.0
19-Sep-13	Dust 7	2	229.8	273.5	43.7	43.7	35.63	108.00	0.33	120.4
4-Dec-13	Dust 7	1	122.4	148.7	26.3	26.3	21.44	76.00	0.28	103.0
					Totals	**228.7**	**186.46**	**354**	**0.53**	**192.2**
15-Dec-12	Initial Deployment Date									
27-Mar-13	Dust 8	1	122.6	158.2	35.6	35.6	29.02	102.00	0.28	103.9
3-Jun-13	Dust 8	1	115.2	140.8	25.6	25.6	20.87	68.00	0.31	112.0
19-Sep-13	Dust 8	3	346.5	371.8	25.3	25.3	20.63	108.00	0.19	69.7
6-Dec-13	Dust 8	1	120.3	147.3	27	27	22.01	78.00	0.28	103.0
					Totals	**113.5**	**92.54**	**356**	**0.26**	**94.9**

Appendix B. Dustfall Gauge Analytic Results

Sample Date	Dust Gauge ID	Filter #	Weight of Filter (mg)	Filter + Residue (mg)	Weight of Residue (mg)	Cumulative (filters, mg)	Dust Deposition (mg/dm²)	Days Deployed	Dust Deposition (mg/dm²/d)	Dust Deposition (mg/dm²/y)
15-Dec-12	Initial Deployment Date									
12-Mar-13	Dust 9	1	116.6	155	38.4	38.4	31.31	87.00	0.36	131.3
3-Jun-13	Dust 9	1	115.9	137.5	21.6	21.6	17.61	83.00	0.21	77.4
19-Sep-13	Dust 9	1	113.7	157.3	43.6	43.6	35.55	108.00	0.33	120.1
4-Dec-13	Dust 9	1	121.3	139.2	17.9	17.9	14.59	76	0.19	70.1
					Totals	**121.5**	**99.06**	**354**	**0.28**	**102.1**
15-Dec-12	Initial Deployment Date									
12-Mar-13	Dust 10	1	125.4	151.8	26.4	26.4	21.52	87.00	0.25	90.3
3-Jun-13	Dust 10	1	113.8	131.6	17.8	17.8	14.51	83.00	0.17	63.8
19-Sep-13	Dust 10	1	110.9	160	49.1	49.1	40.03	108.00	0.37	135.3
4-Dec-13	Dust 10	1	119.9	171.6	51.7	51.7	42.15	76.00	0.55	202.4
					Totals	**145**	**118.22**	**354**	**0.33**	**121.9**
15-Dec-12	Initial Deployment Date									
12-Mar-13	Dust C1	1	125.1	151.9	26.8	26.8	21.85	87.00	0.25	91.7
3-Jun-13	Dust C1	1	116	122.6	6.6	6.6	5.38	83.00	0.06	23.7
19-Sep-13	Dust C1	1	116.6	127.2	10.6	10.6	8.64	108.00	0.08	29.2
4-Dec-13	Dust C1	1	118.4	132.9	14.5	14.5	11.82	76.00	0.16	56.8
					Totals	**58.5**	**47.69**	**354**	**0.13**	**49.2**
15-Dec-12	Initial Deployment Date									
27-Mar-13	Dust C2	1	125.7	140.3	14.6	14.6	11.90	102.00	0.12	42.6
3-Jun-13	Dust C2	1	115.3	129.6	14.3	14.3	11.66	68.00	0.17	62.6
19-Sep-13	Dust C2	1	114.1	122.1	8	8	6.52	108.00	0.06	22.0
6-Dec-13	Dust C2	1	122.9	166.1	43.2	43.2	35.22	78.00	0.45	164.8
					Totals	**80.1**	**65.30**	**356**	**0.18**	**67.0**

Note:

[a] *Station was dismantled upon arrival, sample was compromised.*

[b] *Does not include September sample.*

Appendix C

Dustfall Snow Survey Fieldsheets and Analytic Results

Rio Tinto

Snow Sampling Field Sheet

		No:	ENVI-177-0312
Area:	8000	**Revision:**	R0
Effective Date:	26-MAR-2012	**By:**	Dianne Dul
Task:	Snow Sampling Field Sheet		
		Page:	1 of 2

GENERAL

LOCATION NAME: SS1-1 **DATE (dd-mmm-yyyy):** 27 Apr 2013 **TIME (24:00):** 1545

SAMPLED BY: DD1 DG **TYPE OF SAMPLE:** [✓ Dust] Water Quality **QAQC** /

GPS COORDINATES (UTM): 533911 **E** 7154288 **N (Zone)** 12 NAD 83

DESCRIPTION: Diavik 2.18 Km SE

CLIMATE CONDITIONS (if sampling outside)

Air Temp: -16 °C **Wind Direction:** S **Wind Speed (knots):** 13

Precipitation: rain / mist / snow / [✓ n/a] **Cloud Cover:** 0%, 10%, 25%, 50%, 75%, [✓ 100%]

Dust in area: [✓ Visible], Not Visible **Snow Condition:** Crystallized, Packed, Wet, Dry

Has boulder Bottom

Core Number	Depth of Snow (cm)	Length of Snow Core (cm)	Weight of Tube & Core (g)	Weight of Empty Tube	Water Content (cm)	Density (%)	Dust Present Yes No	Comments
1	62	62	58	39	19		Y	Throughout
2	70	63	58		19		Y	Loose Packed
3	75	56	55		16/54		Y	
4								

Total Volume of Water After Melting : 1675 (mL) Bag 1 = 1675

1								
2								
3								
4								
5								
6								
7								
9								
10								
11								
12								

Total Volume of Water After Melting : ______ (mL)

Snow Sampling Field Sheet

Area:	8000	**No:**	ENVI-177-0312
Effective Date:	26-MAR-2012	**Revision:**	R0
Task:	Snow Sampling Field Sheet	**By:**	Dianne Dul
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Dust Sample Filters

Filter #	Weight of Filter	Filter + Residue	Residue Weight	Comments
1	125.1	179.0	53.9	Sieved- only a few twigs.
2	123.5	758.6	635.1	fine looking gravel.
3				
4				
Totals			689.0	

Water Quality Bottles

Analysis	Bottle Type	Triple Rinse	Preserve	Sample Type	Sample Type	Sample Type	Preserved (circle when added)	Sample Comments (location preserved if not in field, label changes)
Routine	1000 mL plastic	Y	N	☐	☐	☐	N/A	
Nutrients	120 mL plastic	Y	Y	☐	☐	☐	1mL - H_2SO_4	
Metals – Total	120 mL plastic	Y	Y	☐	☐	☐	1mL - $HN0_3$	
Other				☐	☐	☐		
Other				☐	☐	☐		

Revision History

Revision	Revision Description	Date of Revision	Author
0	Initial Release	16-Mar-2012	D. Dul
1	First Revision	13-May-2012	D. Dul
2	Revised Table 1	27-April-2013	D. Dul

Snow Sampling Field Sheet

		No:	ENVI-177-0312
Area:	8000	**Revision:**	R0
Effective Date:	26-MAR-2012	**By:**	Dianne Dul
Task:	Snow Sampling Field Sheet		
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GENERAL

LOCATION NAME: SS1-2-4 **DATE (dd-mmm-yyyy):** 27 Apr 2013 **TIME (24:00):** 1530

SAMPLED BY: DD/DG **TYPE OF SAMPLE:** [✓ Dust] Water Quality **QAQC** DuA1

GPS COORDINATES (UTM): 533924 **E** 7154361 **N (Zone)** 12 NAD83

DESCRIPTION: Diavik 2.21 Km SE

CLIMATE CONDITIONS (if sampling outside)

Air Temp: -16 °C **Wind Direction:** S **Wind Speed (knots):** 13

Precipitation: rain / mist / snow / [✓ n/a] **Cloud Cover:** 0%, 10%, 25%, 50%, 75%, [✓ 100%]

Dust in area: [✓ Visible], Not Visible **Snow Condition:** Crystallized, Packed, Wet, Dry

Core Number	Depth of Snow (cm)	Length of Snow Core (cm)	Weight of Tube & Core (g)	Weight of Empty Tube	Water Content (cm)	Density (%)	Dust Present Yes No	Comments
1	45	35	52	39	13		Y	Surface
2	46	42	55		16		Y	"
3	42	38	54		14/43		Y	"
4								
Total Volume of Water After Melting : 1365 (mL) Bag 1 = 1365								
1								
2								
3								
4								
5								
6								
7								
9								
10								
11								
12								
Total Volume of Water After Melting : ______ (mL)								

Rio Tinto

Snow Sampling Field Sheet

		No:	ENVI-177-0312
Area:	8000	**Revision:**	R0
Effective Date:	26-MAR-2012	**By:**	Dianne Dul
Task:	Snow Sampling Field Sheet		
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Dust Sample Filters

Filter #	Weight of Filter	Filter + Residue	Residue Weight	Comments
1	124.5	183.3	58.8	Lots of twigs - Sieved
2	118.8	457.8	339.0	
3				
4				
Totals			397.8	

Water Quality Bottles

Analysis	Bottle Type	Triple Rinse	Preserve	Sample Type	Sample Type	Sample Type	Preserved (circle when added)	Sample Comments (location preserved if not in field, label changes)
Routine	1000 mL plastic	Y	N	☐	☐	☐	N/A	
Nutrients	120 mL plastic	Y	Y	☐	☐	☐	1mL - H_2SO_4	
Metals – Total	120 mL plastic	Y	Y	☐	☐	☐	1mL - $HN0_3$	
Other				☐	☐	☐		
Other				☐	☐	☐		

Revision History

Revision	Revision Description	Date of Revision	Author
0	Initial Release	16-Mar-2012	D. Dul
1	First Revision	13-May-2012	D. Dul
2	Revised Table 1	27-April-2013	D. Dul

Rio Tinto

Snow Sampling Field Sheet

		No:	ENVI-177-0312
Area:	8000	**Revision:**	R0
Effective Date:	26-MAR-2012	**By:**	Dianne Dul
Task:	Snow Sampling Field Sheet		
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GENERAL

LOCATION NAME: SS1-2-5 **DATE (dd-mmm-yyyy):** 27 Apr 2013 **TIME (24:00):** 1539

SAMPLED BY: DD/DG **TYPE OF SAMPLE:** [✓ Dust] Water Quality [✓ QAQC] Dup2

GPS COORDINATES (UTM): 533924 **E** 7154367 **N (Zone)** 12 NAD 83

DESCRIPTION: Diavik 2.21 Km SE

CLIMATE CONDITIONS (if sampling outside)

Air Temp: -16 °C **Wind Direction:** S **Wind Speed (knots):** 13

Precipitation: ~~rain~~ / mist / snow / [✓ n/a] **Cloud Cover:** 0%, 10%, 25%, 50%, 75%, [✓ 100%]

Dust in area: [✓ Visible], Not Visible **Snow Condition:** Crystallized, Packed, Wet, Dry

Core Number	Depth of Snow (cm)	Length of Snow Core (cm)	Weight of Tube & Core (g)	Weight of Empty Tube	Water Content (cm)	Density (%)	Dust Present Yes No	Comments
1	49	42	56	39	17		Y	Surface
2	47	40	56		17		Y	"
3	42	36	53.5		14/48		Y	"
4								

Total Volume of Water After Melting : 1500 (mL) Bag 1 = 1500

1								
2								
3								
4								
5								
6								
7								
9								
10								
11								
12								

Total Volume of Water After Melting : ____________ (mL)

Snow Sampling Field Sheet

		No:	ENVI-177-0312
Area:	8000	**Revision:**	R0
Effective Date:	26-MAR-2012	**By:**	Dianne Dul
Task:	Snow Sampling Field Sheet		
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Dust Sample Filters

Filter #	Weight of Filter	Filter + Residue	Residue Weight	Comments
1	124.2	185.2	61.0	fairly Clean - Not Sieved
2	119.5	335.5	216.0	
3				
4				
Totals			277.0	

Water Quality Bottles

Analysis	Bottle Type	Triple Rinse	Preserve	Sample Type	Sample Type	Sample Type	Preserved (circle when added)	Sample Comments (location preserved if not in field, label changes)
Routine	1000 mL plastic	Y	N	☐	☐	☐	N/A	
Nutrients	120 mL plastic	Y	Y	☐	☐	☐	1mL - H_2SO_4	
Metals – Total	120 mL plastic	Y	Y	☐	☐	☐	1mL - $HN0_3$	
Other				☐	☐	☐		
Other				☐	☐	☐		

Revision History

Revision	Revision Description	Date of Revision	Author
0	Initial Release	16-Mar-2012	D. Dul
1	First Revision	13-May-2012	D. Dul
2	Revised Table 1	27-April-2013	D. Dul

Rio Tinto

Snow Sampling Field Sheet

Area:	8000	**No:**	ENVI-177-0312
Effective Date:	26-MAR-2012	**Revision:**	R0
Task:	Snow Sampling Field Sheet	**By:**	Dianne Dul
		Page:	1 of 2

GENERAL

LOCATION NAME: SS1-3

DATE (dd-mmm-yyyy): 27 Apr 2013

TIME (24:00): 1517

SAMPLED BY: DD, DG

TYPE OF SAMPLE: [✓ Dust] Water Quality QAQC

GPS COORDINATES (UTM): 533966 **E** 7154577 **N (Zone)** 12 NAD 83

DESCRIPTION: Diavik 2.27m SE

CLIMATE CONDITIONS (if sampling outside)

Air Temp: -16 °C

Wind Direction: S

Wind Speed (knots): 13

Precipitation: ~~rain / mist~~ / snow / [✓ n/a]

Cloud Cover: 0%, 10%, 25%, 50%, 75%, [✓ 100%]

Dust in area: [✓ Visible] Not Visible

Snow Condition: Crystallized, Packed, Wet, Dry

Core Number	Depth of Snow (cm)	Length of Snow Core (cm)	Weight of Tube & Core (g)	Weight of Empty Tube	Water Content (cm)	Density (%)	Dust Present Yes No	Comments
1	44	30	48	39	9		Y	Surface
2	46	29	47.5		8.5		Y	"
3	35	30	47.0		8/ 25.5		Y	surface
4								
Total Volume of Water After Melting : 790 (mL) Bag 1 = 790								
1								
2								
3								
4								
5								
6								
7								
9								
10								
11								
12								
Total Volume of Water After Melting : _______ (mL)								

Rio Tinto

Snow Sampling Field Sheet

		No:	ENVI-177-0312
Area:	8000	**Revision:**	R0
Effective Date:	26-MAR-2012	**By:**	Dianne Dul
Task:	Snow Sampling Field Sheet		
		Page:	2 of 2

Dust Sample Filters

Filter #	Weight of Filter	Filter + Residue	Residue Weight	Comments
1	118.7	320.0	201.3	grass - sieved
2				
3				
4				
Totals			201.3	

Water Quality Bottles

Analysis	Bottle Type	Triple Rinse	Preserve	Sample Type	Sample Type	Sample Type	Preserved (circle when added)	Sample Comments (location preserved if not in field, label changes)
Routine	1000 mL plastic	Y	N	☐	☐	☐	N/A	
Nutrients	120 mL plastic	Y	Y	☐	☐	☐	1mL - H_2SO_4	
Metals – Total	120 mL plastic	Y	Y	☐	☐	☐	1mL - $HN0_3$	
Other				☐	☐	☐		
Other				☐	☐	☐		

Revision History			
Revision	**Revision Description**	**Date of Revision**	**Author**
0	Initial Release	16-Mar-2012	D. Dul
1	First Revision	13-May-2012	D. Dul
2	Revised Table 1	27-April-2013	D. Dul

Rio Tinto

Snow Sampling Field Sheet

Area:	8000	**No:**	ENVI-177-0312
Effective Date:	26-MAR-2012	**Revision:**	R0
Task:	Snow Sampling Field Sheet	**By:**	Dianne Dul
		Page:	1 of 2

GENERAL

LOCATION NAME: SSI-4 **DATE (dd-mmm-yyyy):** 27 Apr 2013 **TIME (24:00):** 1500

SAMPLED BY: DD/DG **TYPE OF SAMPLE:** [✓ Dust] [✓ Water Quality] **QAQC**

GPS COORDINATES (UTM): 53436463 **E** 7155036 **N (Zone)** 12 NAD 83

DESCRIPTION: Diavik 2.37 km SE

CLIMATE CONDITIONS (if sampling outside)

Air Temp: -16 °C **Wind Direction:** S **Wind Speed (knots):** 13

Precipitation: rain / ~~mist / snow~~ / [✓ n/a]

Dust in area: Visible, [✓ Not Visible]

Cloud Cover: 0%, 10%, 25%, 50%, 75%, [✓ 100%]

Snow Condition: Crystallized, Packed, Wet, Dry

Core Number	Depth of Snow (cm)	Length of Snow Core (cm)	Weight of Tube & Core (g)	Weight of Empty Tube	Water Content (cm)	Density (%)	Dust Present Yes No	Comments
1	30	30	50	39	11 ~~39~~		N	Hard Packed
2	31	31	51		12		N	
3	31	31	51		12 / 35		N	
4								
Total Volume of Water After Melting : 1045 (mL) Bag 1 = 1045								
1	30	30	51	39	12		N	
2	31	31	51		12		N	
3	32	32	51.5		12.5		N	
4	31	31	50.5		11.5/48		N	
5	32	31	50.5	39	11.5/59.5		N	
6	32	32	51		12/71.5		N	
7	33	32	51		12/83.5		N	
9								
10								
11								
12								
Total Volume of Water After Melting : 2495 (mL) Bag 1 = 1435 Bag 2 = 1060								

Rio Tinto

Snow Sampling Field Sheet

		No:	ENVI-177-0312
Area:	8000	**Revision:**	R0
Effective Date:	26-MAR-2012	**By:**	Dianne Dul
Task:	Snow Sampling Field Sheet		
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Dust Sample Filters

Filter #	Weight of Filter	Filter + Residue	Residue Weight	Comments
1	123.3	200.9	77.6	Not Sieved.
2				
3				
4				
Totals			77.6	

Water Quality Bottles

Analysis	Bottle Type	Triple Rinse	Preserve	Sample Type GW	Sample Type	Sample Type	Preserved (circle when added)	Sample Comments (location preserved if not in field, label changes)
Routine	1000 mL plastic	[✓ Y]	[✓ N]	☑	☐	☐	N/A	
Nutrients	120 mL plastic	[✓ Y]	[✓ Y]	☑	☐	☐	[✓ 1mL - H_2SO_4]	
Metals – Total	120 mL plastic	[✓ Y]	[✓ Y]	☑	☐	☐	[✓ 1mL - HNO_3]	
Other-TSS, Turb pH	1L	[✓ Y]	[✓ N]	☑	☐	☐		
Other Perchlorate	60mL	[✓ Y]	[✓ N]	☑	☐	☐		

Revision History

Revision	Revision Description	Date of Revision	Author
0	Initial Release	16-Mar-2012	D. Dul
1	First Revision	13-May-2012	D. Dul
2	Revised Table 1	27-April-2013	D. Dul

RioTinto

Snow Sampling Field Sheet

Area:	8000	**No:**	ENVI-177-0312
Effective Date:	26-MAR-2012	**Revision:**	R0
Task:	Snow Sampling Field Sheet	**By:**	Dianne Dul
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GENERAL

LOCATION NAME: SS1-5

DATE (dd-mmm-yyyy): 27 Apr 2013

TIME (24:00): 1438

SAMPLED BY: DD/DW

TYPE OF SAMPLE: [✓ Dust] [✓ Water Quality]

QAQC ____

GPS COORDINATES (UTM): 535099 **E** 7156279 **N (Zone)** 12 NAD83

DESCRIPTION: Diavik 3.28 km S

CLIMATE CONDITIONS (if sampling outside)

Air Temp: -16 °C

Wind Direction: S

Wind Speed (knots): 13

Precipitation: rain / mist / snow / [✓ n/a]

Cloud Cover: 0%, 10%, 25%, 50%, 75%, [✓ 100%]

Dust in area: Visible, [✓ Not Visible]

Snow Condition: Crystallized, Packed, Wet, Dry

Core Number	Depth of Snow (cm)	Length of Snow Core (cm)	Weight of Tube & Core (g)	Weight of Empty Tube	Water Content (cm)	Density (%)	Dust Present Yes No	Comments
1	53	52	58	39	19		N	Loose Pack
2	64	62	59		20		N	
3	64	61	58		19/58		N	
4								
Total Volume of Water After Melting : 1765 (mL) Bag 1= 1765								
1	64	64	59	39	20		N	
2	63	62	58.5		19.5		N	
3	61	59	57		18/57.5		N	
4	60	59	57		18/75.5		N	
5	61	61	59	39	20/95.5		N	
6								
7								
9								
10								
11								
12								
Total Volume of Water After Melting : 2935 (mL) Bag 1= 1180 Bag 2= 1755								

Snow Sampling Field Sheet

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Dust Sample Filters

Filter #	Weight of Filter	Filter + Residue	Residue Weight	Comments
1	125.0	137.3	12.3	fairly clean - Not Sieved.
2				
3				
4				
Totals			12.3	

Water Quality Bottles

Analysis	Bottle Type	Triple Rinse	Preserve	Sample Type GW	Sample Type	Sample Type	Preserved (circle when added)	Sample Comments (location preserved if not in field, label changes)
Routine	1000 mL plastic	[✓ Y]	[✓ N]	☑	☐	☐	N/A	
Nutrients	120 mL plastic	[✓ Y]	[✓ Y]	☑	☐	☐	[✓ 1mL - H_2SO_4]	
Metals – Total	120 mL plastic	[✓ Y]	[✓ Y]	☑	☐	☐	[✓ 1mL - HNO_3]	
Other TSS, Turb, pH	1L	[✓ Y]	[✓ N]	☑	☐	☐		
Other perchlorate	60ml	[✓ Y]	[✓ N]	☑	☐	☐		

Revision History			
Revision	**Revision Description**	**Date of Revision**	**Author**
0	Initial Release	16-Mar-2012	D. Dul
1	First Revision	13-May-2012	D. Dul
2	Revised Table 1	27-April-2013	D. Dul

Rio Tinto

Snow Sampling Field Sheet

Area:	8000	**No:**	ENVI-177-0312
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GENERAL

LOCATION NAME: SS2-1 **DATE (dd-mmm-yyyy):** 27 Apr 2013 **TIME (24:00):** 1255

SAMPLED BY: DD/DG **TYPE OF SAMPLE:** [✓ Dust] [✓ Water Quality] **QAQC**

GPS COORDINATES (UTM): 537553 **E** 7153473 **N (Zone)** 12 NAD83

DESCRIPTION: Diavik 1.88 Km W

CLIMATE CONDITIONS (if sampling outside)

Air Temp: -16 °C **Wind Direction:** S **Wind Speed (knots):** 13

Precipitation: rain / mist / snow / [✓ n/a] **Cloud Cover:** 0%, 10%, 25%, 50%, 75%, [✓ 100%]

Dust in area: [✓ Visible], Not Visible **Snow Condition:** Crystallized, Packed, Wet, [✓ Dry]

Core Number	Depth of Snow (cm)	Length of Snow Core (cm)	Weight of Tube & Core (g)	Weight of Empty Tube	Water Content (cm)	Density (%)	Dust Present Yes No	Comments
1	43	42	52.5	39	13.5		N	Loose Pack on Top
2	43	43	53.		14		N	
3	44	43	62		23/60.5		N	
4								
Total Volume of Water After Melting : 1195 (mL) Bag 1 = 1195								
1	42	41	53	39	14		N	
2	43	42	53		14/28		N	
3	43	42	53		14/42		N	
4	44	43	53		14/56		N	
5	45	44	53	39	14/70		N	
6	45	45	54		15/85		N	
7								
9								
10								
11								
12								
Total Volume of Water After Melting : 2540 (mL) Bag 1 = 1295 Bag 2 = 1245								

Snow Sampling Field Sheet

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Dust Sample Filters

Filter #	Weight of Filter	Filter + Residue	Residue Weight	Comments
1	118.7	140.1	21.4	fairly clean - Not Sieved.
2				
3				
4				
Totals			21.4	

Water Quality Bottles

Analysis	Bottle Type	Triple Rinse	Preserve	Sample Type GW	Sample Type	Sample Type	Preserved (circle when added)	Sample Comments (location preserved if not in field, label changes)
Routine	1000 mL plastic	[✓ Y]	[✓ N]	☑	☐	☐	N/A	
Nutrients	120 mL plastic	[✓ Y]	[✓ Y]	☑	☐	☐	[✓ 1mL - H_2SO_4]	
Metals – Total	120 mL plastic	[✓ Y]	[✓ Y]	☑	☐	☐	[✓ 1mL - $HN0_3$]	
Other TSS, Turb, pH	1L	[✓ Y]	[✓ N]	☑	☐	☐		
Other perchlorate	60ml	[✓ Y]	[✓ N]	☑	☐	☐		

Revision History

Revision	Revision Description	Date of Revision	Author
0	Initial Release	16-Mar-2012	D. Dul
1	First Revision	13-May-2012	D. Dul
2	Revised Table 1	27-April-2013	D. Dul

Rio Tinto

Snow Sampling Field Sheet

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GENERAL

LOCATION NAME: SS2-2-4 **DATE (dd-mmm-yyyy):** 27 Apr 2013 **TIME (24:00):** 1310
SAMPLED BY: DD/DG **TYPE OF SAMPLE:** [✓ Dust] [✓ Water Quality] [✓ QAQC] DUP1
GPS COORDINATES (UTM): 537829 **E** 7155347 6 **N (Zone)** 12 NAD83
DESCRIPTION: Diavik 2.15 ~~xt~~ km W

CLIMATE CONDITIONS (if sampling outside)

Air Temp: -16 °C **Wind Direction:** S **Wind Speed (knots):** 13
Precipitation: rain / mist / snow / [✓ n/a] **Cloud Cover:** 0%, 10%, 25%, 50%, 75%, [✓ 100%]
Dust in area: Visible, [✓ Not Visible] **Snow Condition:** Crystallized, [✓ Packed], Wet, Dry

Core Number	Depth of Snow (cm)	Length of Snow Core (cm)	Weight of Tube & Core (g)	Weight of Empty Tube	Water Content (cm)	Density (%)	Dust Present Yes No	Comments
1	36	36	49	39	10		N	packed Snow
2	36	36	49.5		10.5		N	
3	35	34	49		10 / 30.5		N	
4								

Total Volume of Water After Melting : 925 (mL) Bag 1 = 925

1	37	36	49.5	39	10.5		N	Packed Snow
2	37	36	49		10		N	
3	37	36	49		10		N	
4	35	34	50		11/41.5		N	
5	37	36	50	39	11/52.5		N	
6	35	34	49.5		10.5/63		N	
7	36	36	50		11/74		N	
9	36	36	49.5		10.5/84.5		N	
10								
11								
12								

Total Volume of Water After Melting : 2495 (mL) Bag 1 = 1235 Bag 2 = 1260

Snow Sampling Field Sheet

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Dust Sample Filters

Filter #	Weight of Filter	Filter + Residue	Residue Weight	Comments
1	123.1	142.3	19.2	fairly clean - Not Sieved
2				
3				
4				
Totals			192	

✓

Water Quality Bottles

Analysis	Bottle Type	Triple Rinse	Preserve	Sample Type	Sample Type	Sample Type	Preserved (circle when added)	Sample Comments (location preserved if not in field, label changes)
				Dupwl				
Routine	1000 mL plastic	[✓ Y]	[✓ N]	☑	☐	☐	N/A	
Nutrients	120 mL plastic	[✓ Y]	[✓ Y]	☑	☐	☐	[✓ 1mL - H_2SO_4]	
Metals – Total	120 mL plastic	[✓ Y]	[✓ Y]	☑	☐	☐	[✓ 1mL - HNO_3]	
Other TSS, Turb pH	1L	[✓ Y]	[✓ N]	☑	☐	☐		
Other: perchlorate	60mL	[✓ Y]	[✓ N]	☑	☐	☐		

Revision History

Revision	Revision Description	Date of Revision	Author
0	Initial Release	16-Mar-2012	D. Dul
1	First Revision	13-May-2012	D. Dul
2	Revised Table 1	27-April-2013	D. Dul

Rio Tinto

Snow Sampling Field Sheet

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GENERAL

LOCATION NAME: SS2-2-5
DATE (dd-mmm-yyyy): 27 Apr 2013
TIME (24:00): 1322
SAMPLED BY: DG / DD
TYPE OF SAMPLE: [✓ Dust] [✓ Water Quality] [✓ QAQC] Dup 2
GPS COORDINATES (UTM): 537829 **E** 7155376 **N (Zone)** 12 NAD 83
DESCRIPTION: Diavik 2.15 Km W

CLIMATE CONDITIONS (if sampling outside)

Air Temp: -16 °C
Wind Direction: S
Wind Speed (knots): 13
Precipitation: rain / mist / snow / [✓ n/a]
Cloud Cover: 0%, 10%, 25%, 50%, 75%, [✓ 100%]
Dust in area: Visible, [✓ Not Visible]
Snow Condition: Crystallized, Packed, Wet, [✓ Dry]

Core Number	Depth of Snow (cm)	Length of Snow Core (cm)	Weight of Tube & Core (g)	Weight of Empty Tube	Water Content (cm)	Density (%)	Dust Present Yes No	Comments
1	34	34	49	39	10		N	
2	36	35	48		9		N	
3	36	34	48.5		9.5/28.5		N	
4							|	
Total Volume of Water After Melting : 860 (mL) Bag 1 = 860								
1	36	35	49	39	10		N	
2	37	35	49.5		10.5		N	
3	37	36	50		10		N	
4	37	36	50		11/42.5		N	
5	37	36	50	39	11		N	
6	37	37	50		11/64.5		N	
7	37	37	49.5		10.5/75		N	
9	37	36	49.5		10.5/85.5		N	
10								
11								
12								
Total Volume of Water After Melting : 2515 (mL) Bag 1 = 1255 Bag 2 = 1260								

Snow Sampling Field Sheet

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Area:	8000	**Revision:**	R0
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Dust Sample Filters

Filter #	Weight of Filter	Filter + Residue	Residue Weight	Comments
1	124.0	141.9	17.9	fairly clean - Not Sieved
2				
3				
4				
Totals			17.9	

Water Quality Bottles

Analysis	Bottle Type	Triple Rinse	Preserve	Sample Type DupW2	Sample Type	Sample Type	Preserved (circle when added)	Sample Comments (location preserved if not in field, label changes)
Routine	1000 mL plastic	[✓ Y]	[✓ N]	☑	☐	☐	N/A	
Nutrients	120 mL plastic	[✓ Y]	[✓ Y]	☑	☐	☐	[✓ 1mL - H_2SO_4]	
Metals – Total	120 mL plastic	[✓ Y]	[✓ Y]	☑	☐	☐	[✓ 1mL - $HN0_3$]	
Other TSS, Turb pH	1L	[✓ Y]	[✓ N]	☑	☐	☐		
Other Perchlorate	60ml	[✓ Y]	[✓ N]	☑	☐	☐		

Revision History

Revision	Revision Description	Date of Revision	Author
0	Initial Release	16-Mar-2012	D. Dul
1	First Revision	13-May-2012	D. Dul
2	Revised Table 1	27-April-2013	D. Dul

Rio Tinto

Snow Sampling Field Sheet

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GENERAL

LOCATION NAME: 552-3 **DATE (dd-mmm-yyyy):** 27 Apr 2013 **TIME (24:00):** 1340
SAMPLED BY: DD/DG **TYPE OF SAMPLE:** [✓ Dust] [✓ Water Quality] QAQC
GPS COORDINATES (UTM): 538484 **E** 7153939 **N (Zone)** 12 NAD83
DESCRIPTION: Diavik 2.90 km W

CLIMATE CONDITIONS (if sampling outside)

Air Temp: -16 °C **Wind Direction:** S **Wind Speed (knots):** 13
Precipitation: rain / mist / snow / [✓ n/a]
Dust in area: Visible, [✓ Not Visible]
Cloud Cover: 0%, 10%, 25%, 50%, 75%, [✓ 100%]
Snow Condition: Crystallized, [✓ Packed], Wet, Dry

Core Number	Depth of Snow (cm)	Length of Snow Core (cm)	Weight of Tube & Core (g)	Weight of Empty Tube	Water Content (cm)	Density (%)	Dust Present Yes No	Comments
1	37	36	52	39	13	N	N	Hard Packed
2	37	37	53		12		N	
3	38	38	53		12/37		N	
4								
Total Volume of Water After Melting : 1230 (mL) Bag 1 = 1230								
1	39	38	53	39	12		N	
2	40	39	53		12		N	
3	40	40	54		13/37		N	
4	40	40	53		12/49		N	
5	41	41	54	39	13/62		N	
6	41	41	54		13/75		N	
7	41	40	53		12/87		N	
9								
10								
11								
12								
Total Volume of Water After Melting : 3095 (mL) Bag1 = 1765 Bag2 = 1330								

RioTinto

Snow Sampling Field Sheet

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Dust Sample Filters

Filter #	Weight of Filter	Filter + Residue	Residue Weight	Comments
1	123.4	142.8	19.4	fairly Clean - Not Sieved
2				
3				
4				
Totals			19.4	

Water Quality Bottles

Analysis	Bottle Type	Triple Rinse	Preserve	Sample Type	Sample Type	Sample Type	Preserved (circle when added)	Sample Comments (location preserved if not in field, label changes)
				GW				
Routine	1000 mL plastic	[✓ Y]	[✓ N]	☑	☐	☐	N/A	
Nutrients	120 mL plastic	[✓ Y]	[✓ Y]	☑	☐	☐	[✓ 1mL - H_2SO_4]	
Metals – Total	120 mL plastic	[✓ Y]	[✓ Y]	☑	☐	☐	[✓ 1mL - HNO_3]	
Other TSS, Turb, pH	1L	[✓ Y]	[✓ N]	☑	☐	☐		
Other Perchlorate	60ml	[✓ Y]	[✓ N]	☑	☐	☐		

Revision History			
Revision	**Revision Description**	**Date of Revision**	**Author**
0	Initial Release	16-Mar-2012	D. Dul
1	First Revision	13-May-2012	D. Dul
2	Revised Table 1	27-April-2013	D. Dul

Rio Tinto

Snow Sampling Field Sheet

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GENERAL

LOCATION NAME: SS2-4

DATE (dd-mmm-yyyy): 27 Apr 2013

TIME (24:00): 1400

SAMPLED BY: DN / DG

TYPE OF SAMPLE: [✓ Dust] [✓ Water Quality] QAQC

GPS COORDINATES (UTM): 539151 **E** 7154685 **N (Zone)** 12 NAD 83

DESCRIPTION: Diavik 3.79 km SW

CLIMATE CONDITIONS (if sampling outside)

Air Temp: -16 °C

Wind Direction: S

Wind Speed (knots): 13

Precipitation: rain / mist / snow / [✓ n/a]

Cloud Cover: 0%, 10%, 25%, 50%, 75%, [✓ 100%]

Dust in area: Visible, [✓ Not Visible]

Snow Condition: Crystallized, Packed, Wet, [✓ Dry]

Core Number	Depth of Snow (cm)	Length of Snow Core (cm)	Weight of Tube & Core (g)	Weight of Empty Tube	Water Content (cm)	Density (%)	Dust Present Yes No	Comments
1	51	51	56	39	17		N	
2	51	50	56		17		N	
3	50	48	55		16 150		N	
4								
Total Volume of Water After Melting : 1515 (mL) Bag 1 = 1515								
1	49	49	56	39	17		N	
2	49	49	56		17		N	
3	50	49	55		16		N	
4	49	48	55		16 166		N	
5	49	47	55	39	16/82		N	
6	47	47	56		17/99			
7								
9								
10								
11								
12								
Total Volume of Water After Melting : 2945 (mL) Bag 1 = 1500 Bag 2 = 1445								

Snow Sampling Field Sheet

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Dust Sample Filters

Filter #	Weight of Filter	Filter + Residue	Residue Weight	Comments
1	124.8	142.6	17.8	fairly clean - Not Sieved
2				
3				
4				
Totals			17.8	

Water Quality Bottles

Analysis	Bottle Type	Triple Rinse	Preserve	Sample Type	Sample Type	Sample Type	Preserved (circle when added)	Sample Comments (location preserved if not in field, label changes)
				GW				
Routine	1000 mL plastic	[✓ Y]	[✓ N]	☑	☐	☐	N/A	
Nutrients	120 mL plastic	[✓ Y]	[✓ Y]	☑	☐	☐	[✓ 1mL - H_2SO_4]	
Metals – Total	120 mL plastic	[✓ Y]	[✓ Y]	☑	☐	☐	[✓ 1mL - $HN0_3$]	
Other TSS, Turb, pH	1L	[✓ Y]	[✓ N]	☑	☐	☐		
Other Perchlorate	60ml	[✓ Y]	[✓ N]	☑	☐	☐		

Revision History			
Revision	**Revision Description**	**Date of Revision**	**Author**
0	Initial Release	16-Mar-2012	D. Dul
1	First Revision	13-May-2012	D. Dul
2	Revised Table 1	27-April-2013	D. Dul

RioTinto

Snow Sampling Field Sheet

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GENERAL

LOCATION NAME: SS3-4 **DATE (dd-mmm-yyyy):** 26 Apr. 2013 **TIME (24:00):** 1835

SAMPLED BY: DD / DG **TYPE OF SAMPLE:** [✓ Dust] [✓ Water Quality] **QAQC**______

GPS COORDINATES (UTM): 536585 **E** 7151002 **N (Zone)** 12 NAD 83

DESCRIPTION: Diavik 2.23 Km N

CLIMATE CONDITIONS (if sampling outside)

Air Temp: -23 °C **Wind Direction:** SE **Wind Speed (knots):** 4

Precipitation: rain / mist / snow / [✓ n/a] **Cloud Cover:** 0%, 10%, [✓ 25%], 50%, 75%, 100%

Dust in area: Visible, [✓ Not Visible] **Snow Condition:** Crystallized, [✓ Packed], Wet, Dry

Core Number	Depth of Snow (cm)	Length of Snow Core (cm)	Weight of Tube & Core (g)	Weight of Empty Tube	Water Content (cm)	Density (%)	Dust Present Yes No	Comments
1	51	42	52	39	13		N	Hard Packed
2	53	50	59		20		N	
3	57	48	58		19/52		N	
4								
Total Volume of Water After Melting : 1700 (mL) Bag 1 = 1700								
1	64	58	63	39	24		N	Hard Packed
2	64	58	63		24		N	
3	69	69	64		25		N	
4	68	61	64		25 /98		N	
5								
6								
7								
8								
9								
10								
11								
12								
Total Volume of Water After Melting : 3005 (mL) Bg 1=1485 Bag 2 = 1520 mL								

Snow Sampling Field Sheet

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Dust Sample Filters

Filter #	Weight of Filter	Filter + Residue	Residue Weight	Comments
1	123.7	187.2	635	fairly Clean - Not sieved
2	125.6	230.7	1051	
3			~~1686~~	
4				
Totals			1686	

Water Quality Bottles

Analysis	Bottle Type	Triple Rinse	Preserve	Sample Type RW	Sample Type	Sample Type	Preserved (circle when added)	Sample Comments (location preserved if not in field, label changes)
Routine	1000 mL plastic	[✓ Y]	[✓ N]	☑	☐	☐	N/A	
Nutrients	120 mL plastic	[✓ Y]	[✓ Y]	☑	☐	☐	[✓ 1mL - H_2SO_4]	
Metals – Total	120 mL plastic	[✓ Y]	[✓ Y]	☑	☐	☐	[✓ 1mL - $HN0_3$]	
Other TSS, Turb, pH	1L	[✓ Y]	[✓ N]	☑	☐	☐		
Other Perchlorate	60ml	[✓ Y]	[✓ N]	☑	☐	☐		

Revision History			
Revision	**Revision Description**	**Date of Revision**	**Author**
0	Initial Release	16-Mar-2012	D. Dul
1	First Revision	13-May-2012	D. Dul
2	Revised Table 1	27-April-2013	D. Dul

Rio Tinto

Snow Sampling Field Sheet

Area: 8000
Effective Date: 26-MAR-2012
Task: Snow Sampling Field Sheet
No: ENVI-177-0312
Revision: R0
By: Dianne Dul
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GENERAL

LOCATION NAME: SS3-5 **DATE (dd-mmm-yyyy):** 26 Apr 2013 **TIME (24:00):** 1812
SAMPLED BY: DD / DG **TYPE OF SAMPLE:** [✓ Dust] [✓ Water Quality] **QAQC**
GPS COORDINATES (UTM): 537652 **E** 7150789 **N (Zone)** 12 NAD 83
DESCRIPTION: move off coordinates as they were in middle of ice road. Diavik 2.94 km NW

CLIMATE CONDITIONS (if sampling outside)

Air Temp: -23 °C **Wind Direction:** SE **Wind Speed (knots):** 4
Precipitation: rain / mist / snow / [✓ n/a] **Cloud Cover:** 0%, 10%, [✓ 25%], 50%, 75%, 100%
Dust in area: Visible, [✓ Not Visible] **Snow Condition:** Crystallized, Packed, Wet, Dry

Core Number	Depth of Snow (cm)	Length of Snow Core (cm)	Weight of Tube & Core (g)	Weight of Empty Tube	Water Content (cm)	Density (%)	Dust Present Yes No	Comments
1	38	38	52	39	13		N	
2	37	37	52		13		N	
3	37	37	52		13 / 39		N	
4								
Total Volume of Water After Melting : 1220 (mL) Bag 1 = 1220								
1	41	40	53	39	14			
2	41	40	52		13			
3	41	40	53		14/41			
4	40	40	53		14			
5	41	40	53	39	14			
6	38	37	51		12/81			
7	36	35	51		12/93			
8								
9								
10								
11								
12								
Total Volume of Water After Melting : 2885 (mL) Bag 1 = 1250 Bag 2 = 1635								

Snow Sampling Field Sheet

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Dust Sample Filters

Filter #	Weight of Filter	Filter + Residue	Residue Weight	Comments
1	117.3	131.8	14.50	fairly clean - Not filtered
2				
3				
4				
Totals			14.50	

Water Quality Bottles

Analysis	Bottle Type	Triple Rinse	Preserve	Sample Type GW	Sample Type	Sample Type	Preserved (circle when added)	Sample Comments (location preserved if not in field, label changes)
Routine	1000 mL plastic	[✓ Y]	[✓ N]	☑	☐	☐	N/A	
Nutrients	120 mL plastic	[✓ Y]	[✓ Y]	☑	☐	☐	[✓ 1mL - H_2SO_4]	
Metals – Total	120 mL plastic	[✓ Y]	[✓ Y]	☑	☐	☐	[✓ 1mL - $HN0_3$]	
Other TSS, Turb, pH	1L	[✓ Y]	[✓ N]	☑	☐	☐		
Other perchlorate	60mL	[✓ Y]	[✓ N]	☑	☐	☐		

Revision History

Revision	Revision Description	Date of Revision	Author
0	Initial Release	16-Mar-2012	D. Dul
1	First Revision	13-May-2012	D. Dul
2	Revised Table 1	27-April-2013	D. Dul

Rio Tinto

Snow Sampling Field Sheet

Area: 8000
Effective Date: 26-MAR-2012
Task: Snow Sampling Field Sheet

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By: Dianne Dul

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GENERAL

LOCATION NAME: SS4-1-4 **DATE (dd-mmm-yyyy):** 28 Apr 2013 **TIME (24:00):** 1435
SAMPLED BY: DD/DG **TYPE OF SAMPLE:** [✓ Dust] Water Quality **QAQC** DUP 1
GPS COORDINATES (UTM): 531491 **E** 7152211 **N (Zone)** 12 NAD 83
DESCRIPTION: Diavik 2.38 km SE

CLIMATE CONDITIONS (if sampling outside)

Air Temp: -25 °C **Wind Direction:** N **Wind Speed (knots):** 3
Precipitation: rain / mist / snow / [✓ n/a] **Cloud Cover:** [✓ 0%], 10%, 25%, 50%, 75%, 100%
Dust in area: [✓ Visible], Not Visible **Snow Condition:** Crystallized, Packed, Wet, Dry

Core Number	Depth of Snow (cm)	Length of Snow Core (cm)	Weight of Tube & Core (g)	Weight of Empty Tube	Water Content (cm)	Density (%)	Dust Present Yes No	Comments
1	52	41	51.5	39	12.5		Y	ON Top
2	55	45	54		15		Y	On Top
3	57	49	55		16 /43.5		Y	ON Top
4								
Total Volume of Water After Melting : 1330 (mL) Bag 1 = 1330								
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								
Total Volume of Water After Melting : ______ (mL)								

Snow Sampling Field Sheet

No: ENVI-177-0312
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Task: Snow Sampling Field Sheet
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Dust Sample Filters

Filter #	Weight of Filter	Filter + Residue	Residue Weight	Comments
1	124.8	193.5	68.7	few twigs - sieved
2				
3				
4				
Totals			68.7	

Water Quality Bottles

Analysis	Bottle Type	Triple Rinse	Preserve	Sample Type	Sample Type	Sample Type	Preserved (circle when added)	Sample Comments (location preserved if not in field, label changes)
Routine	1000 mL plastic	Y	N	☐	☐	☐	N/A	
Nutrients	120 mL plastic	Y	Y	☐	☐	☐	1mL - H_2SO_4	
Metals – Total	120 mL plastic	Y	Y	☐	☐	☐	1mL - $HN0_3$	
Other				☐	☐	☐		
Other				☐	☐	☐		

Revision History

Revision	Revision Description	Date of Revision	Author
0	Initial Release	16-Mar-2012	D. Dul
1	First Revision	13-May-2012	D. Dul
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GENERAL

LOCATION NAME: SS4-1-5 **DATE (dd-mmm-yyyy):** 28 Aug 2013 **TIME (24:00):** 1440

SAMPLED BY: DD/DG **TYPE OF SAMPLE:** [✓ **Dust**] **Water Quality** **QAQC** Dup 2

GPS COORDINATES (UTM): 531491 **E** 7152211 **N (Zone)** 12 NAD83

DESCRIPTION: Diavik 2.38 km SE

CLIMATE CONDITIONS (if sampling outside)

Air Temp: -25 °C **Wind Direction:** N **Wind Speed (knots):** 3

Precipitation: rain / mist / snow / [✓ n/a] **Cloud Cover:** [✓ 0%], 10%, 25%, 50%, 75%, 100%

Dust in area: Visible, [✓ Not Visible] **Snow Condition:** Crystallized, Packed, Wet, Dry

Core Number	Depth of Snow (cm)	Length of Snow Core (cm)	Weight of Tube & Core (g)	Weight of Empty Tube	Water Content (cm)	Density (%)	Dust Present Yes No	Comments
1	50	42	52	39	13		N	
2	61	52	55.5		16.5		N	
3	61	53	55		16/45.5		N	
4								
Total Volume of Water After Melting : 1430 (mL) Bag 1 = 1430								
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								
Total Volume of Water After Melting : ____ (mL)								

Snow Sampling Field Sheet

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Dust Sample Filters

Filter #	Weight of Filter	Filter + Residue	Residue Weight	Comments
1	117.8	202.0	84.2	few twigs - ~~filtered~~ sieved.
2				
3				
4				
Totals			84.2	

Water Quality Bottles

Analysis	Bottle Type	Triple Rinse	Preserve	Sample Type	Sample Type	Sample Type	Preserved (circle when added)	Sample Comments (location preserved if not in field, label changes)
Routine	1000 mL plastic	Y	N	☐	☐	☐	N/A	
Nutrients	120 mL plastic	Y	Y	☐	☐	☐	1mL - H_2SO_4	
Metals – Total	120 mL plastic	Y	Y	☐	☐	☐	1mL - $HN0_3$	
Other				☐	☐	☐		
Other				☐	☐	☐		

Revision History

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Snow Sampling Field Sheet

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GENERAL

LOCATION NAME: SS 4 -2 **DATE (dd-mmm-yyyy):** 28 Apr 2013 **TIME (24:00):** 1450

SAMPLED BY: DD / DG **TYPE OF SAMPLE:** [✓ Dust] Water Quality QAQC

GPS COORDINATES (UTM): 531356 **E** 7152261 **N (Zone)** 12 NAD 83

DESCRIPTION: Diavik 4.42 km E.

CLIMATE CONDITIONS (if sampling outside)

Air Temp: -25 °C **Wind Direction:** N **Wind Speed (knots):** 3

Precipitation: rain / mist / snow / [✓ n/a] **Cloud Cover:** [✓ 0%], 10%, 25%, 50%, 75%, 100%

Dust in area: Visible, [✓ Not Visible] **Snow Condition:** Crystallized, Packed, Wet, Dry

Core Number	Depth of Snow (cm)	Length of Snow Core (cm)	Weight of Tube & Core (g)	Weight of Empty Tube	Water Content (cm)	Density (%)	Dust Present Yes No	Comments
1	34	25	45	39	6		N	
2	44	29	47		7		N	
3	36	27	46		7		N	
4	40	28	48		8 / 28		N	

Total Volume of Water After Melting : 946 (mL) Bag = 946

Core Number	Depth of Snow (cm)	Length of Snow Core (cm)	Weight of Tube & Core (g)	Weight of Empty Tube	Water Content (cm)	Density (%)	Dust Present Yes No	Comments
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								

Total Volume of Water After Melting : ______________(mL)

Snow Sampling Field Sheet

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Dust Sample Filters

Filter #	Weight of Filter	Filter + Residue	Residue Weight	Comments
1	119.4	150.1	30.7	few twigs - sieved.
2				
3				
4				
Totals			30.7	

Water Quality Bottles

Analysis	Bottle Type	Triple Rinse	Preserve	Sample Type	Sample Type	Sample Type	Preserved (circle when added)	Sample Comments (location preserved if not in field, label changes)
Routine	1000 mL plastic	Y	N	☐	☐	☐	N/A	
Nutrients	120 mL plastic	Y	Y	☐	☐	☐	1mL - H_2SO_4	
Metals – Total	120 mL plastic	Y	Y	☐	☐	☐	1mL - $HN0_3$	
Other				☐	☐	☐		
Other				☐	☐	☐		

Revision History			
Revision	**Revision Description**	**Date of Revision**	**Author**
0	Initial Release	16-Mar-2012	D. Dul
1	First Revision	13-May-2012	D. Dul
2	Revised Table 1	27-April-2013	D. Dul

Snow Sampling Field Sheet

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GENERAL

LOCATION NAME: SS4-3 **DATE (dd-mmm-yyyy):** 28 Apr 2013 **TIME (24:00):** 1510

SAMPLED BY: DD / DG **TYPE OF SAMPLE:** [✓ **Dust**] **Water Quality** **QAQC**

GPS COORDINATES (UTM): 531331 **E** 7152434 **N (Zone)** 12 NAD83

DESCRIPTION: Diavik 4.42 Km E

CLIMATE CONDITIONS (if sampling outside)

Air Temp: -25 °C **Wind Direction:** N **Wind Speed (knots):** 3

Precipitation: rain / mist / snow / [✓ n/a] **Cloud Cover:** [✓ 0%], 10%, 25%, 50%, 75%, 100%

Dust in area: Visible, [✓ Not Visible] **Snow Condition:** Crystallized, Packed, Wet, Dry

Core Number	Depth of Snow (cm)	Length of Snow Core (cm)	Weight of Tube & Core (g)	Weight of Empty Tube	Water Content (cm)	Density (%)	Dust Present Yes No	Comments
1	78	70	63½	39	24½		N	
2	~~72~~60	52	55		16		N	
3	62	55	53		14 / 54.5		N	
4								
Total Volume of Water After Melting : 1815 (mL)				Bag 1 = 1815				
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								
Total Volume of Water After Melting : ______ (mL)								

Rio Tinto

Snow Sampling Field Sheet

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Dust Sample Filters

Filter #	Weight of Filter	Filter + Residue	Residue Weight	Comments
1	117.7	191.5	738	grass/twigs - sieved
2				
3				
4				
Totals			738	

✓

Water Quality Bottles

Analysis	Bottle Type	Triple Rinse	Preserve	Sample Type	Sample Type	Sample Type	Preserved (circle when added)	Sample Comments (location preserved if not in field, label changes)
Routine	1000 mL plastic	Y	N	☐	☐	☐	N/A	
Nutrients	120 mL plastic	Y	Y	☐	☐	☐	1mL - H_2SO_4	
Metals – Total	120 mL plastic	Y	Y	☐	☐	☐	1mL - $HN0_3$	
Other				☐	☐	☐		
Other				☐	☐	☐		

Revision History			
Revision	**Revision Description**	**Date of Revision**	**Author**
0	Initial Release	16-Mar-2012	D. Dul
1	First Revision	13-May-2012	D. Dul
2	Revised Table 1	27-April-2013	D. Dul

RioTinto

Snow Sampling Field Sheet

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GENERAL

LOCATION NAME: SS4- 4 **DATE (dd-mmm-yyyy):** 28Apr 2013 **TIME (24:00):** 1555

SAMPLED BY: DD / DG **TYPE OF SAMPLE:** [✓ Dust] [✓ Water Quality] **QAQC** EBW on seperate Sheet ✓

GPS COORDINATES (UTM): 531141 **E** 7153167 **N (Zone)** 12 NAD 83

DESCRIPTION: ~~Sampled~~ Diavik 4.56 Km E

CLIMATE CONDITIONS (if sampling outside)

Air Temp: -25 °C **Wind Direction:** N **Wind Speed (knots):** 3

Precipitation: rain / mist / snow / [✓ n/a] **Cloud Cover:** [✓ 0%], 10%, 25%, 50%, 75%, 100%

Dust in area: Visible, [✓ Not Visible] **Snow Condition:** Crystallized, Packed, Wet, Dry

Core Number	Depth of Snow (cm)	Length of Snow Core (cm)	Weight of Tube & Core (g)	Weight of Empty Tube	Water Content (cm)	Density (%)	Dust Present Yes No	Comments
1	84	82	67	39	28		N	
2	86	84	67		28		N	
3	86	84	66.5		27.5		N	
4								
Total Volume of Water After Melting : 2520 (mL) Bag 1 = 1475 Bag 2 = 1045								
1	82	79	65	39	26		N	
2	84	82	66		27		N	
3	82	81	66		27		N	
4	82	81	65		26/106		N	
5								
6								
7								
8								
9								
10								
11								
12								
Total Volume of Water After Melting : 3200 (mL) Bag 1 = 1605 Bag 2 = 1595								

Rio Tinto

Snow Sampling Field Sheet

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Dust Sample Filters

Filter #	Weight of Filter	Filter + Residue	Residue Weight	Comments
1	116.2	134.5	18.3	fairly clean - Not Sieved
2				
3				
4				
Totals			18.3	

Water Quality Bottles

Analysis	Bottle Type	Triple Rinse	Preserve	Sample Type	Sample Type	Sample Type	Preserved (circle when added)	Sample Comments (location preserved if not in field, label changes)
				GW				
Routine	1000 mL plastic	[✓ Y]	[✓ N]	☑	☐	☐	N/A	
Nutrients	120 mL plastic	[✓ Y]	[✓ Y]	☑	☐	☐	[✓ 1mL - H_2SO_4]	
Metals – Total	120 mL plastic	[✓ Y]	[✓ Y]	☑	☐	☐	[✓ 1mL - $HN0_3$]	
Other TSS, Turb, pH	1L	[✓ Y]	[✓ N]	☑	☐	☐		
Other perchlorate	60mL	[✓ Y]	[✓ N]	☑	☐	☐		

Revision History

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0	Initial Release	16-Mar-2012	D. Dul
1	First Revision	13-May-2012	D. Dul
2	Revised Table 1	27-April-2013	D. Dul

Rio Tinto

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GENERAL

LOCATION NAME: SS4-4-1
DATE (dd-mmm-yyyy): 29-APR-2013 **TIME (24:00):** 19:00
SAMPLED BY: DG/DD
TYPE OF SAMPLE: Dust [✓ Water Quality] [✓ QAQC] EBW
GPS COORDINATES (UTM): ______ E ______ N (Zone) ______

DI Batch: 031313-0313

DESCRIPTION: equipment Blank Ran through Snowcore back @ Lab, Last Station Sampled SS4-4

CLIMATE CONDITIONS (if sampling outside)

Air Temp: ______ °C **Wind Direction:** ______ **Wind Speed (knots):** ______
Precipitation: rain / mist / snow / n/a **Cloud Cover:** 0%, 10%, 25%, 50%, 75%, 100%
Dust in area: Visible, Not Visible **Snow Condition:** Crystallized, Packed, Wet, Dry

Core Number	Depth of Snow (cm)	Length of Snow Core (cm)	Weight of Tube & Core (g)	Weight of Empty Tube	Water Content (cm)	Density (%)	Dust Present Yes No	Comments
1								
2				N/A				
3								
4								

Total Volume of Water After Melting : 4000 (mL)

1	EBW	—		4L	DI BATCH #			031313-0313
2					expired 13-APR-2013			
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								

Total Volume of Water After Melting : 4000 (mL)

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Dust Sample Filters

Filter #	Weight of Filter	Filter + Residue	Residue Weight	Comments
1				
2				
3				
4				
Totals				

Water Quality Bottles

Analysis	Bottle Type	Triple Rinse	Preserve	Sample Type EBW	Sample Type	Sample Type	Preserved (circle when added)	Sample Comments (location preserved if not in field, label changes)
Routine	1000 mL plastic	[✓ Y]	[✓ N]	☑	☐	☐	N/A	
Nutrients	120 mL plastic	[✓ Y]	[✓ Y]	☑	☐	☐	[✓ 1mL - H_2SO_4]	
Metals – Total	120 mL plastic	[✓ Y]	[✓ Y]	☑	☐	☐	[✓ 1mL - $HN0_3$]	
Other TSS Turb pH	1L	[✓ Y]	[✓ N]	☑	☐	☐		
Other Perchbrate	60ml	[✓ Y]	[✓ N]	☑	☐	☐		

Revision History

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Rio Tinto

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GENERAL

LOCATION NAME: 594-5 **DATE (dd-mmm-yyyy):** 28 Apr 2013 **TIME (24:00):** 1535

SAMPLED BY: DD/DG **TYPE OF SAMPLE:** [✓ Dust] [✓ Water Quality] QAQC

GPS COORDINATES (UTM): 531405 **E** 715 **N (Zone)** 12 NAD83

DESCRIPTION: Diavik 4.43 km E

CLIMATE CONDITIONS (if sampling outside)

Air Temp: -25 °C **Wind Direction:** N **Wind Speed (knots):** 3

Precipitation: rain / mist / snow / [✓ n/a] **Cloud Cover:** [✓ 0%], 10%, 25%, 50%, 75%, 100%

Dust in area: Visible, [✓ Not Visible] **Snow Condition:** Crystallized, Packed, Wet, Dry

Core Number	Depth of Snow (cm)	Length of Snow Core (cm)	Weight of Tube & Core (g)	Weight of Empty Tube	Water Content (cm)	Density (%)	Dust Present Yes No	Comments
1	51	50	56.5	39	17.5		N	
2	50	47	56		17		N	
3	49	46	55		16/40.5		N	
4								
Total Volume of Water After Melting : 1525 (mL) Bag 1 = 1525								
1	49	46	55	39	16		N	
2	49	46	55		16		N	
3	49	46	55.5		16.5/48.5		N	
4	50	47	56		17		N	
5	50	46	56	39	17		N	
6	50	46	56		17/49.5		N	
7								
8								
9								
10								
11								
12								
Total Volume of Water After Melting : 2990 (mL) Bag 1 = 1465 Bag 2 = 1525								

Rio Tinto

Snow Sampling Field Sheet

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Dust Sample Filters

Filter #	Weight of Filter	Filter + Residue	Residue Weight	Comments
1	125.3	183.4	58.1	Fairly clean - Not Sieved
2				
3				
4				
Totals			58.1	

✓

Water Quality Bottles

✓

Analysis	Bottle Type	Triple Rinse	Preserve	Sample Type	Sample Type	Sample Type	Preserved (circle when added)	Sample Comments (location preserved if not in field, label changes)
				GW				
Routine	1000 mL plastic	[✓ Y]	[✓ N]	☑	☐	☐	N/A	
Nutrients	120 mL plastic	[✓ Y]	[✓ Y]	☑	☐	☐	[✓ 1mL - H_2SO_4]	
Metals – Total	120 mL plastic	[✓ Y]	[✓ Y]	☑	☐	☐	[✓ 1mL - $HN0_3$]	
Other TSS, Turb, pH	1L	[✓ Y]	[✓ N]	☑	☐	☐		
Other perchlorate	60mL	[✓ Y]	[✓ N]	☑	☐	☐		

Revision History			
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0	Initial Release	16-Mar-2012	D. Dul
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Rio Tinto

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GENERAL

LOCATION NAME: SS5-1
DATE (dd-mmm-yyyy): 26 Apr 2013
TIME (24:00): 1328
SAMPLED BY: DD | DG
TYPE OF SAMPLE: [✓ Dust] Water Quality QAQC
GPS COORDINATES (UTM): 533150 **E** 7149925 **N (Zone)** NAD83 - 12
DESCRIPTION: South of Diavik 2.1 Km NE.

CLIMATE CONDITIONS (if sampling outside)

Air Temp: -23 °C
Wind Direction: SE
Wind Speed (knots): 4
Precipitation: rain / mist / snow / [✓ n/a]
Cloud Cover: 0%, 10%, 25%, 50%, 75%, [✓ 100%]
Dust in area: Visible, [✓ Not Visible]
Snow Condition: Crystallized, Packed, Wet, Dry

Core Number	Depth of Snow (cm)	Length of Snow Core (cm)	Weight of Tube & Core (g)	Weight of Empty Tube	Water Content (cm)	Density (%)	Dust Present Yes No	Comments
1	45	35	50	39.0	11		N	Looks Clean
2	42	28	46		7		N	Hard Packed &
3	43	25	45		6		N	Crystally
4	45	39	49		10/34		N	same. A little more
5								Condensed
6								
7								
8								
9								
10								
11								

Total Volume of Water After Melting : 1140 (mL)

Bag 1 = 1140

Snow Sampling Field Sheet

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Dust Sample Filters

Filter #	Weight of Filter	Filter + Residue	Residue Weight	Comments
1	124.8	134.4	9.6	Little grass - sieved
2				
3				
4				
Totals			9.6	

Water Quality Bottles

Analysis	Bottle Type	Triple Rinse	Preserve	Sample Type	Sample Type	Sample Type	Preserved (circle when added)	Sample Comments (location preserved if not in field, label changes)
Routine	1000 mL plastic	Y	N	☐	☐	☐	N/A	
Nutrients	120 mL plastic	Y	Y	☐	☐	☐	1mL - H_2SO_4	
Metals – Total	120 mL plastic	Y	Y	☐	☐	☐	1mL - $HN0_3$	
Other				☐	☐	☐		
Other				☐	☐	☐		

Revision History			
Revision	**Revision Description**	**Date of Revision**	**Author**
0	Initial Release	16-Mar-2012	D. Dul
1	First Revision	13-May-2012	D. Dul

Snow Sampling Field Sheet

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GENERAL

LOCATION NAME: SS5-2 **DATE (dd-mmm-yyyy):** 26 Apr 2013 **TIME (24:00):** 1553

SAMPLED BY: DD / DG **TYPE OF SAMPLE:** [✓ Dust] Water Quality QAQC

GPS COORDINATES (UTM): 533150 **E** 7148875 **N (Zone)** 12 NAD83

DESCRIPTION: Diavik 4.90 km NE

CLIMATE CONDITIONS (if sampling outside)

Air Temp: -23 °C **Wind Direction:** SE **Wind Speed (knots):** 4

Precipitation: rain / mist / snow / [✓ n/a] **Cloud Cover:** 0%, 10%, 25%, 50%, 75%, [✓ 100%]

Dust in area: Visible, [✓ Not Visible] **Snow Condition:** Crystallized, Packed, Wet, Dry

Core Number	Depth of Snow (cm)	Length of Snow Core (cm)	Weight of Tube & Core (g)	Weight of Empty Tube	Water Content (cm)	Density (%)	Dust Present Yes No	Comments
1	44.0	40.0	51	39.0	12		N	Hard Packed Crystal
2	44.0	42.0	50		11		N	
3	48.0	47.0	51		12/35		N	
4								
5								
6								
7								
8								
9								
10								
11								

Total Volume of Water After Melting : 1260 (mL)

Bag1 = 1260

Snow Sampling Field Sheet

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Dust Sample Filters

Filter #	Weight of Filter	Filter + Residue	Residue Weight	Comments
1	117.8	127.7	9.9	fairly Clean-Not Sieved.
2				
3				
4				
Totals			9.9	

Water Quality Bottles

Analysis	Bottle Type	Triple Rinse	Preserve	Sample Type	Sample Type	Sample Type	Preserved (circle when added)	Sample Comments (location preserved if not in field, label changes)
Routine	1000 mL plastic	Y	N	☐	☐	☐	N/A	
Nutrients	120 mL plastic	Y	Y	☐	☐	☐	1mL - H_2SO_4	
Metals – Total	120 mL plastic	Y	Y	☐	☐	☐	1mL - HNO_3	
Other				☐	☐	☐		
Other				☐	☐	☐		

Revision History

Revision	Revision Description	Date of Revision	Author
0	Initial Release	16-Mar-2012	D. Dul
1	First Revision	13-May-2012	D. Dul

Rio Tinto

Snow Sampling Field Sheet

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GENERAL

LOCATION NAME: SS5-3 **DATE (dd-mmm-yyyy):** 26 Apr 2013 **TIME (24:00):** 1408

SAMPLED BY: DD/DG **TYPE OF SAMPLE:** [✓ Dust] [✓ Water Quality] **QAQC**____

GPS COORDINATES (UTM): 533150 **E** 7148700 **N (Zone)** 12 NAD83

DESCRIPTION: Diavik 5.05 km NE

CLIMATE CONDITIONS (if sampling outside)

Air Temp: -23 °C **Wind Direction:** SE **Wind Speed (knots):** 4

Precipitation: rain / mist / snow / [✓ n/a] **Cloud Cover:** 0%, 10%, 25%, 50%, 75%, [✓ 100%]

Dust in area: Visible, [✓ Not Visible] **Snow Condition:** Crystallized, Packed, Wet, Dry

Core Number	Depth of Snow (cm)	Length of Snow Core (cm)	Weight of Tube & Core (g)	Weight of Empty Tube	Water Content (cm)	Density (%)	Dust Present Yes No	Comments
1	25	25	47	39	8		N	Hard Packed
2	26	25	47		8		N	Crystally
3	29	29	47		8/24		N	
4								
Total Volume of Water After Melting : 820 (mL) Bag 1= 820								
1	30	29	50	39	11		N	
2	27	27	48		9		N	
3	30	36	49		10/30		N	
4	47	36	47		8		N	
5	38	38	52	39	13		N	
6	38	38	52		13		N	
7	38	37	52		13		N	
8	38	38	52		13/90		N	
9								
10								
11								
12								
Total Volume of Water After Melting : 2860 (mL) Bag 1=1260 Bag 2= 1600								

Rio Tinto

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Dust Sample Filters

Filter #	Weight of Filter	Filter + Residue	Residue Weight	Comments
1	118.6	126.5	7.9	fairly clean - Not Sieved
2				
3				
4				
Totals			7.9	

Water Quality Bottles

Analysis	Bottle Type	Triple Rinse	Preserve	Sample Type GW	Sample Type	Sample Type	Preserved (circle when added)	Sample Comments (location preserved if not in field, label changes)
Routine	1000 mL plastic	[✓ Y]	[✓ N]	☑	☐	☐	N/A	
Nutrients	120 mL plastic	[✓ Y]	[✓ Y]	☑	☐	☐	[✓ 1mL - H_2SO_4]	
Metals – Total	120 mL plastic	[✓ Y]	[✓ Y]	☑	☐	☐	[✓ 1mL - HNO_3]	
Other TSS, Turb, pH	1L	[✓ Y]	[✓ N]	☑	☐	☐		
Other Perchlorate	60mL	[✓ Y]	[✓ N]	☑	☐	☐		

Revision History			
Revision	**Revision Description**	**Date of Revision**	**Author**
0	Initial Release	16-Mar-2012	D. Dul
1	First Revision	13-May-2012	D. Dul
2	Revised Table 1	27-April-2013	D. Dul

Snow Sampling Field Sheet

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GENERAL

LOCATION NAME: SS5-4
DATE (dd-mmm-yyyy): 26 Apr 2013
TIME (24:00): 1435
SAMPLED BY: DD/DG
TYPE OF SAMPLE: [✓ Dust] [✓ Water Quality] QAQC
GPS COORDINATES (UTM): 533150 E 7147950 N (Zone) 12 NAD 83
DESCRIPTION: Diavik 5.71 km NE

CLIMATE CONDITIONS (if sampling outside)

Air Temp: -23 °C
Wind Direction: S/E
Wind Speed (knots): 4
Precipitation: rain / mist / snow / [✓ n/a]
Cloud Cover: 0%, 10%, 25%, 50%, 75%, [✓ 100%]
Dust in area: Visible, [✓ Not Visible]
Snow Condition: Crystallized, Packed, Wet, Dry

Core Number	Depth of Snow (cm)	Length of Snow Core (cm)	Weight of Tube & Core (g)	Weight of Empty Tube	Water Content (cm)	Density (%)	Dust Present Yes No	Comments
1	34	34	50	40	10		N	
2	35	35	51		11		N	
3	37	36	51		10 /31		N	
4								
Total Volume of Water After Melting : 1040 (mL) Bag 1 = 1040								
1	34	32	49	40	9		N	
2	35	33	49		9		N	
3	35	35	50		10/28		N	
4	36	35	50		10		N	
5	37	36	49	40	10		N	
6	36	35	50		11/59		N	
7	35	34	49		10		N	
8	35	35	50		11		N	
9	35	35	49	39	10		N	
10	35	35	49		10/100		N	
11								
12								
Total Volume of Water After Melting : 2155 (mL) Bag 1 = 1200 Bag 2 = 915 Bag 3 = 955								

Rio Tinto

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Dust Sample Filters

Filter #	Weight of Filter	Filter + Residue	Residue Weight	Comments
1	125.3	130.6	5.3	fairly Clean - Not Sieved.
2				
3				
4				
Totals			5.3	

✓

Water Quality Bottles

✓

Analysis	Bottle Type	Triple Rinse	Preserve	Sample Type GW	Sample Type	Sample Type	Preserved (circle when added)	Sample Comments (location preserved if not in field, label changes)
Routine	1000 mL plastic	[✓ Y]	[✓ N]	☑	☐	☐	N/A	
Nutrients	120 mL plastic	[✓ Y]	[✓ Y]	☑	☐	☐	[✓ 1mL - H_2SO_4]	
Metals – Total	120 mL plastic	[✓ Y]	[✓ Y]	☑	☐	☐	[✓ 1mL - HNO_3]	
Other TSS, Turb, pH	1L	[✓ Y]	[✓ N]	☑	☐	☐		
Other perchlorate	60mL	[✓ Y]	[✓ N]	☑	☐	☐		

Revision History			
Revision	**Revision Description**	**Date of Revision**	**Author**
0	Initial Release	16-Mar-2012	D. Dul
1	First Revision	13-May-2012	D. Dul
2	Revised Table 1	27-April-2013	D. Dul

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Snow Sampling Field Sheet

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GENERAL

LOCATION NAME: SS5-5-4 **DATE (dd-mmm-yyyy):** 26 Apr 2013 **TIME (24:00):** 1504

SAMPLED BY: DD/DG **TYPE OF SAMPLE:** [✓ Dust] [✓ Water Quality] [✓ QAQC] Dup 1

GPS COORDINATES (UTM): 533150 **E** 7146950 **N (Zone)** 12 NAD83

DESCRIPTION: Diavik 6.61 km NE

CLIMATE CONDITIONS (if sampling outside)

Air Temp: -23 °C **Wind Direction:** SE **Wind Speed (knots):** 4

Precipitation: rain / mist / snow / [✓ n/a] **Cloud Cover:** 0%, 10%, 25%, 50%, 75%, [✓ 100%]

Dust in area: Visible, [✓ Not Visible] **Snow Condition:** Crystallized, Packed, Wet, Dry

Core Number	Depth of Snow (cm)	Length of Snow Core (cm)	Weight of Tube & Core (g)	Weight of Empty Tube	Water Content (cm)	Density (%)	Dust Present Yes No	Comments
1	35	34	51	40	11		N	
2	35	34	50		10		N	
3	34	33	49		9/30		N	
4								
Total Volume of Water After Melting : 1070 (mL) Bag 1 = 1070								
1	31	30	48	39	9		N	
2	30	29	47		8		N	
3	30	29	47		8/25		N	
4	30	29	47		8		N	
5	32	30	47	39	8		N	
6	30	29	48		9/50		N	
7	30	30	48		9		N	
8	30	29	47		8		N	
9	31	29	48	39	9/76		N	
10	32	30	49		10		N	
11	30	30	48		9		N	
12	31	30	48		9/104		N	
Total Volume of Water After Melting : 3330 (mL) Bag 1 = 1390 Bag 2 = 1060 Bag 3 = 880								

Rio Tinto

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Dust Sample Filters

Filter #	Weight of Filter	Filter + Residue	Residue Weight	Comments
1	118.5	122.8	4.3	Fairly Clean- Not Sieved.
2				
3				
4				
Totals			4.3	

✓

Water Quality Bottles

✓

Analysis	Bottle Type	Triple Rinse	Preserve	Sample Type	Sample Type	Sample Type	Preserved (circle when added)	Sample Comments (location preserved if not in field, label changes)
				DupW)				
Routine	1000 mL plastic	[✓ Y]	[✓ N]	☑	☐	☐	N/A	
Nutrients	120 mL plastic	[✓ Y]	[✓ Y]	☑	☐	☐	[✓ 1mL - H_2SO_4]	
Metals – Total	120 mL plastic	[✓ Y]	[✓ Y]	☑	☐	☐	[✓ 1mL - $HN0_3$]	
Other TSS, Turb, pH	1L	[✓ Y]	[✓ N]	☑	☐	☐		
Other Perchlorate	60mL	[✓ Y]	[✓ N]	☑	☐	☐		

Revision History			
Revision	**Revision Description**	**Date of Revision**	**Author**
0	Initial Release	16-Mar-2012	D. Dul
1	First Revision	13-May-2012	D. Dul
2	Revised Table 1	27-April-2013	D. Dul

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Snow Sampling Field Sheet

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GENERAL

LOCATION NAME: SS5-5-5 **DATE (dd-mmm-yyyy):** 26 Apr 2013 **TIME (24:00):** 1532

SAMPLED BY: DD/DG **TYPE OF SAMPLE:** [✓ **Dust**] [✓ **Water Quality**] **QAQC** DUP2

GPS COORDINATES (UTM): 533150 **E** 7146950 **N (Zone)** 12 NAD 83

DESCRIPTION: Diavik 6.61 km NE

CLIMATE CONDITIONS (if sampling outside)

Air Temp: -22 °C **Wind Direction:** SE **Wind Speed (knots):** 4

Precipitation: rain / mist / snow / [✓ n/a] **Cloud Cover:** 0%, 10%, 25%, 50%, 75%, [✓ 100%]

Dust in area: Visible, [✓ Not Visible] **Snow Condition:** Crystallized, Packed, Wet, Dry

Core Number	Depth of Snow (cm)	Length of Snow Core (cm)	Weight of Tube & Core (g)	Weight of Empty Tube	Water Content (cm)	Density (%)	Dust Present Yes No	Comments
1	34	33	50	39	11		N	
2	34	34	51		12		N	
3	33	32	50		11/34		N	
4								
Total Volume of Water After Melting : 1050 (mL) Bag 1 = 1050								
1	30	30	48	40	8		N	
2	30	30	47		7		N	
3	32	31	49		9/24		N	
4	30	29	47		7		N	
5	30	29	48	39	9		N	
6	30	30	49		10/50		N	
7	30	29	48		9		N	
8	30	29	48		9		N	
9	30	28	48	39	9		N	
10	30	28	47		8/85		N	
11								
12								
Total Volume of Water After Melting : 2720 (mL) Bag 1 = 1110 Bag 2 = 1080 Bag 3 = 530								

Snow Sampling Field Sheet

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Dust Sample Filters

Filter #	Weight of Filter	Filter + Residue	Residue Weight	Comments
1	124.5	129.0	4.5	fairly clean-Not Sieved
2				
3				
4				
Totals			4.5	

Water Quality Bottles

Analysis	Bottle Type	Triple Rinse	Preserve	Sample Type	Sample Type	Sample Type	Preserved (circle when added)	Sample Comments (location preserved if not in field, label changes)
				PapW2				
Routine	1000 mL plastic	[✓ Y]	[✓ N]	☑	☐	☐	N/A	
Nutrients	120 mL plastic	[✓ Y]	[✓ Y]	☑	☐	☐	[✓ ~~1mL - H_2SO_4~~]	
Metals – Total	120 mL plastic	[✓ Y]	[✓ Y]	☑	☐	☐	[✓ 1mL - HNO_3]	
Other TSS, Turb, PH	1L	[✓ Y]	[✓ N]	☑	☐	☐		
Other perchlorate	60ml	[✓ Y]	[✓ N]	☑	☐	☐		

Revision History

Revision	Revision Description	Date of Revision	Author
0	Initial Release	16-Mar-2012	D. Dul
1	First Revision	13-May-2012	D. Dul
2	Revised Table 1	27-April-2013	D. Dul

Rio Tinto

Snow Sampling Field Sheet

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GENERAL

LOCATION NAME: SSC-1 **DATE (dd-mmm-yyyy):** 26 Apr 2013 **TIME (24:00):** 1650

SAMPLED BY: DD/DG **TYPE OF SAMPLE:** [✓ Dust] [✓ Water Quality] QAQC____

GPS COORDINATES (UTM): 534983 **E** 7144271 **N (Zone)** 12 NAD83

DESCRIPTION: Diavik 8.81 km N

CLIMATE CONDITIONS (if sampling outside)

Air Temp: -23 °C **Wind Direction:** SE **Wind Speed (knots):** 4

Precipitation: rain / mist / snow / [✓ n/a] **Cloud Cover:** 0%, 10%, 25%, 50%, 75%, [✓ 100%]

Dust in area: Visible, Not Visible **Snow Condition:** Crystallized, Packed, Wet, Dry

Core Number	Depth of Snow (cm)	Length of Snow Core (cm)	Weight of Tube & Core (g)	Weight of Empty Tube	Water Content (cm)	Density (%)	Dust Present Yes No	Comments
1	86	67	62	39	23		Y	Top - Hard on top the crystals
2	75	67	63		24		N	
3	67	60	59		20/67		N	
4								
Total Volume of Water After Melting : 2030 (mL) Bag 1 = 2030								
1	45	45	54	39	15		N	
2	48	41	53		14		N	
3	35	34	51		12/41		N	
4	41	40	53		14		N	
5	63	53	55	39.5	15.5		N	
6	53	42	53		13.5/84		N	
7								
8								
9								
10								
11								
12								
Total Volume of Water After Melting : 2625 (mL) Bag 1 = 1215 Bag 2 = 1410								

Snow Sampling Field Sheet

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Dust Sample Filters

Filter #	Weight of Filter	Filter + Residue	Residue Weight	Comments
1	124.6	134.0	9.4	some Twigs - sieved
2				
3				
4				
Totals			9.4	

Water Quality Bottles

Analysis	Bottle Type	Triple Rinse	Preserve	Sample Type	Sample Type	Sample Type	Preserved (circle when added)	Sample Comments (location preserved if not in field, label changes)
				GW				
Routine	1000 mL plastic	[✓ Y]	[✓ N]	☑	☐	☐	N/A	
Nutrients	120 mL plastic	[✓ Y]	[✓ Y]	☑	☐	☐	[✓ 1mL - H_2SO_4]	
Metals – Total	120 mL plastic	[✓ Y]	[✓ Y]	☑	☐	☐	[✓ 1mL - HNO_3]	
Other TSS, Turb, PH	1L	[✓ Y]	[✓ N]	☑	☐	☐		
Other perchlorate	60mL	[✓ Y]	[✓ N]	☑	☐	☐		

Revision History			
Revision	**Revision Description**	**Date of Revision**	**Author**
0	Initial Release	16-Mar-2012	D. Dul
1	First Revision	13-May-2012	D. Dul
2	Revised Table 1	27-April-2013	D. Dul

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Snow Sampling Field Sheet

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GENERAL

LOCATION NAME: SSC-2 **DATE (dd-mmm-yyyy):** 28 Apr 2013 **TIME (24:00):** 13 50

SAMPLED BY: DD/DG **TYPE OF SAMPLE:** [✓ Dust] [✓ Water Quality] QAQC

GPS COORDINATES (UTM): 528714 **E** 7153281 **N (Zone)** 12 NAD 83

DESCRIPTION: Diavik 6.99 km E

CLIMATE CONDITIONS (if sampling outside)

Air Temp: -23 °C **Wind Direction:** SE **Wind Speed (knots):** 4

Precipitation: rain / mist / snow [✓ n/a] **Cloud Cover:** 0%, 10%, 25%, 50%, 75%, [✓ 100%]

Dust in area: Visible, Not Visible **Snow Condition:** Crystallized, Packed, Wet, Dry

Core Number	Depth of Snow (cm)	Length of Snow Core (cm)	Weight of Tube & Core (g)	Weight of Empty Tube	Water Content (cm)	Density (%)	Dust Present Yes No	Comments
1	33	26	48	39	9		N	Hard Packed.
2	23	23	47		8		N	
3	25	24	47		8		N	
4	32	26	48		9/34			
Total Volume of Water After Melting : 1040 (mL) Bag 1 = 1040								
1	24	23	46	39	7		N	Hard Packed
2	33	27	48		9		N	Crystal @ bottom
3	29	25	47.5		8.5/24.5		N	
4	23	22	46		7		N	
5	23	22	46	39	7		N	
6	25	23	47		8 / 46.5		N	
7	26	25	46		7		N	
8	29	27	47		8		N	
9	31	26	47.5	39	8.5/70		N	
10	25	24	47		8		N	
11	25	23	46		7 / 85		N	
12								
Total Volume of Water After Melting : 2640 (mL) Bag 1 = 1445 Bag 2 = 1195								

Snow Sampling Field Sheet

		No:	ENVI-177-0312
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Dust Sample Filters

Filter #	Weight of Filter	Filter + Residue	Residue Weight	Comments
1	118.7	126.2	7.5	Twigs ~ Sieved
2				
3				
4				
Totals			7.5	

Water Quality Bottles

Analysis	Bottle Type	Triple Rinse	Preserve	Sample Type GW	Sample Type	Sample Type	Preserved (circle when added)	Sample Comments (location preserved if not in field, label changes)
Routine	1000 mL plastic	[✓ Y]	[✓ N]	☑	☐	☐	N/A	
Nutrients	120 mL plastic	[✓ Y]	[✓ Y]	☑	☐	☐	[✓ 1mL - H_2SO_4]	
Metals – Total	120 mL plastic	[✓ Y]	[✓ Y]	☑	☐	☐	[✓ 1mL - $HN0_3$]	
Other TSS, Turb, pH	1L	[✓ Y]	[✓ N]	☑	☐	☐		
Other Perchlorate	60ml	[✓ Y]	[✓ N]	☑	☐	☐		

Revision History

Revision	Revision Description	Date of Revision	Author
0	Initial Release	16-Mar-2012	D. Dul
1	First Revision	13-May-2012	D. Dul
2	Revised Table 1	27-April-2013	D. Dul

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Snow Sampling Field Sheet

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GENERAL

LOCATION NAME: SSC - 3 **DATE (dd-mmm-yyyy):** 26 Apr 2013 **TIME (24:00):** 1739

SAMPLED BY: DD/DG **TYPE OF SAMPLE:** [✓ Dust] [✓ Water Quality] **QAQC**

GPS COORDINATES (UTM): 538650 **E** 7148750 **N (Zone)** 12 NAD 83

DESCRIPTION: Diavik 5.20km NW

CLIMATE CONDITIONS (if sampling outside)

Air Temp: -23 °C **Wind Direction:** SE **Wind Speed (knots):** 4

Precipitation: rain / mist / snow / [✓ n/a] **Cloud Cover:** 0%, 10%, 25%, 50%, 75%, [✓ 100%]

Dust in area: Visible, [✓ Not Visible] **Snow Condition:** Crystallized, Packed, Wet, [✓ Dry]

Core Number	Depth of Snow (cm)	Length of Snow Core (cm)	Weight of Tube & Core (g)	Weight of Empty Tube	Water Content (cm)	Density (%)	Dust Present Yes No	Comments
1	79	54	55	39	16		N	
2	82	64	58		19		N	
3	82	70	61		22/57		N	
4								

Total Volume of Water After Melting : 1770 (mL) Bag 1 = 1770

1	80	61	58	39	19		N	
2	75	70	60		21		N	
3	80	72	60		21/61		N	
4	78	68	59		20		N	
5	80	67	59	39	20/101		N	
6								
7								
8								
9								
10								
11								
12								

Total Volume of Water After Melting : 3065 (mL) Bag 1 = 1195 Bag 2 = 1870

Snow Sampling Field Sheet

		No:	ENVI-177-0312
Area:	8000	**Revision:**	R0
Effective Date:	26-MAR-2012	**By:**	Dianne Dul
Task:	Snow Sampling Field Sheet		
		Page:	2 of 2

Dust Sample Filters

Filter #	Weight of Filter	Filter + Residue	Residue Weight	Comments
1	123.8	146.6	22.8	Twigs - sieved
2				
3				
4				
Totals			22.8	

Water Quality Bottles

Analysis	Bottle Type	Triple Rinse	Preserve	Sample Type GW	Sample Type	Sample Type	Preserved (circle when added)	Sample Comments (location preserved if not in field, label changes)
Routine	1000 mL plastic	Y	N	☑	☐	☐	N/A	
Nutrients	120 mL plastic	Y	Y	☑	☐	☐	[✓ 1mL - H_2SO_4]	
Metals – Total	120 mL plastic	Y	Y	☑	☐	☐	[✓ 1mL - HNO_3]	
Other TSS, Turb, pH	1L	Y	N	☑	☐	☐		
Other Perchlorate	60mL	Y	N	☑	☐	☐		

Revision History			
Revision	**Revision Description**	**Date of Revision**	**Author**
0	Initial Release	16-Mar-2012	D. Dul
1	First Revision	13-May-2012	D. Dul
2	Revised Table 1	27-April-2013	D. Dul

Appendix D

Snow Water Chemistry Analytic Results

Your P.O. #: K00909
Your Project #: AEMP
Your C.O.C. #: 08344534, 08370438

Attention: DDMI Environment
DIAVIK DIAMOND MINES INC.
P.O. BOX 2498
5007 - 50 AVE.
YELLOWKNIFE, NT
CANADA X1A 2P8

Report Date: 2013/05/09

CERTIFICATE OF ANALYSIS

MAXXAM JOB #: B334547
Received: 2013/05/02, 09:25

Sample Matrix: GROUND WATER
Samples Received: 19

Analyses	Quantity	Date Extracted	Date Analyzed	Laboratory Method	Analytical Method
Acidity pH 4.5 & pH 8.3 (as CaCO3)	19	N/A	2013/05/03	BBY6SOP-00037	SM-2310B
Alkalinity - Water	19	2013/05/03	2013/05/04	BBY6SOP-00026	SM2320B
Chloride by Automated Colourimetry	19	N/A	2013/05/03	BBY6SOP-00011	SM-4500-Cl-
Conductance - water	19	N/A	2013/05/04	BBY6SOP-00026	SM-2510B
Fluoride - Mining Clients	19	N/A	2013/05/06	BBY6SOP-00038	SM - 4500 F C
Hardness Total (calculated as CaCO3)	8	N/A	2013/05/06	BBY7SOP-00002	EPA 6020A
Hardness Total (calculated as CaCO3)	11	N/A	2013/05/07	BBY7SOP-00002	EPA 6020A
Na, K, Ca, Mg, S by CRC ICPMS (total)	8	N/A	2013/05/06	BBY7SOP-00002	EPA 6020A
Na, K, Ca, Mg, S by CRC ICPMS (total)	11	N/A	2013/05/07	BBY7SOP-00002	EPA 6020A
Elements by ICPMS Low Level (total)	19	N/A	2013/05/06	BBY7SOP-00002	EPA 6020A
Nitrogen (Total)	13	2013/05/03	2013/05/06	BBY6SOP-00022	SM-4500N C
Nitrogen (Total)	6	2013/05/07	2013/05/08	BBY6SOP-00022	SM-4500N C
Ammonia-N (Preserved)	13	N/A	2013/05/03	BBY6SOP-00009	SM-4500NH3G
Ammonia-N (Preserved)	6	N/A	2013/05/07	BBY6SOP-00009	SM-4500NH3G
Nitrate+Nitrite (N) (low level)	19	N/A	2013/05/03	BBY6SOP-00010	EPA 353.2
Nitrite (N) (low level)	19	N/A	2013/05/03	BBY6SOP-00010	SM 4500NO3-I
Nitrogen - Nitrate (as N)	19	N/A	2013/05/06	BBY6SOP-00010	SM 4500NO3-I
pH Water	19	N/A	2013/05/04	BBY6SOP-00026	SM-4500H+B
Orthophosphate by Konelab (low level)	19	N/A	2013/05/04	BBY6SOP-00013	SM 4500 P E
Sulphate by Automated Colourimetry	19	N/A	2013/05/03	BBY6SOP-00017	SM4500-SO42- E
Total Dissolved Solids (Filt. Residue)	19	N/A	2013/05/03	BBY6SOP-00033	SM 2540C
TKN (Calc. TN, N/N) total	14	N/A	2013/05/06	BBY6SOP-00022	SM 4500N-C
TKN (Calc. TN, N/N) total	5	N/A	2013/05/08	BBY6SOP-00022	SM 4500N-C
Phosphorus-P (Total, dissolved)	19	2013/05/04	2013/05/04	BBY6SOP-00013	SM-4500 PE
Total Phosphorus	19	N/A	2013/05/04	BBY6SOP-00013	SM 4500 P E
Total Suspended Solids-Low Level	19	2013/05/03	2013/05/03	BBY6SOP-00034	SM-2540 D
Turbidity	19	N/A	2013/05/04	BBY6SOP-00027	SM - 2130B

* Results relate only to the items tested.

Maxxam Job #: B334547
Report Date: 2013/05/09

DIAVIK DIAMOND MINES INC.
Client Project #: AEMP

Your P.O. #: K00909

Encryption Key

Maxxam

09 May 2013 11:47:50 -07:00

Please direct all questions regarding this Certificate of Analysis to your Project Manager.

Tabitha Rudkin, Burnaby Project Manager
Email: TRudkin@maxxam.ca
Phone# (604) 638-2639

==

This report has been generated and distributed using a secure automated process.
Maxxam has procedures in place to guard against improper use of the electronic signature and have the required "signatories", as per section 5.10.2 of ISO/IEC 17025:2005(E), signing the reports. For Service Group specific validation please refer to the Validation Signature Page.

Total cover pages: 2

RESULTS OF CHEMICAL ANALYSES OF GROUND WATER

Maxxam ID		GH2694	GH2695	GH2696	GH2697	GH2698	GH2699		GH2700		
Sampling Date		2013/04/27	2013/04/27	2013/04/27	2013/04/27	2013/04/27	2013/04/27		2013/04/27		
	UNITS	**SS1-4**	**SS1-5**	**SS2-1**	**SS2-2-4**	**SS2-2-5**	**SS2-3**	**QC Batch**	**SS2-4**	**RDL**	**QC Batch**
Misc. Inorganics											
Acidity (pH 4.5)	mg/L	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	6787689	<0.50	0.50	6787689
Acidity (pH 8.3)	mg/L	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	6787689	<0.50	0.50	6787689
Fluoride (F)	mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	6791260	<0.010	0.010	6791260
Calculated Parameters											
Nitrate (N)	mg/L	0.100	0.0871	0.0699	0.0633	0.0610	0.116	6787487	0.121	0.0020	6787487
Misc. Inorganics											
Alkalinity (Total as CaCO3)	mg/L	2.49	0.86	1.26	1.30	1.36	1.11	6789680	0.59	0.50	6789680
Alkalinity (PP as CaCO3)	mg/L	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	6789680	<0.50	0.50	6789680
Bicarbonate (HCO3)	mg/L	3.04	1.05	1.54	1.59	1.66	1.35	6789680	0.72	0.50	6789680
Carbonate (CO3)	mg/L	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	6789680	<0.50	0.50	6789680
Hydroxide (OH)	mg/L	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	6789680	<0.50	0.50	6789680
Anions											
Orthophosphate (P)	mg/L	0.013(1)	0.0027(1)	0.0034(1)	0.0039(1)	0.0055(1)	0.0023(1)	6789889	0.0028(1)	0.0010	6789889
Dissolved Sulphate (SO4)	mg/L	0.70	0.55	0.61	0.67	<0.50	0.54	6789783	0.57	0.50	6789783
Dissolved Chloride (Cl)	mg/L	0.99	0.61	0.73	0.95	0.77	<0.50	6789739	0.64	0.50	6789739
Nutrients											
Ammonia (N)	mg/L	0.083	0.034	0.039	0.026	0.028	0.032	6789692	0.052	0.0050	6795724
Dissolved Phosphorus (P)	mg/L	0.0502	0.0066	0.0133	0.0108	0.0167	0.0161	6790027	0.0103	0.0020	6790027
Total Total Kjeldahl Nitrogen (Calc)	mg/L	0.104	0.036	0.050	0.049	0.042	0.045	6787302	0.128	0.020	6787302
Nitrate plus Nitrite (N)	mg/L	0.111(1)	0.0903(1)	0.0732(1)	0.0633(1)	0.0663(1)	0.116(1)	6789731	0.121(1)	0.0020	6789731
Nitrite (N)	mg/L	0.0103(1)	0.0032(1)	0.0033(1)	<0.0020(1)	0.0053(1)	<0.0020(1)	6789732	<0.0020(1)	0.0020	6789732
Total Nitrogen (N)	mg/L	0.214	0.126	0.123	0.113	0.108	0.160	6789715	0.249	0.020	6795028
Total Phosphorus (P)	mg/L	0.139	0.0091	0.0175	0.0162	0.0242	0.0174	6790031	0.0112	0.0020	6790031
Physical Properties											
Conductivity	uS/cm	6.2	3.2	3.7	3.0	2.9	2.7	6789687	3.6	1.0	6789687
pH	pH Units	6.56	5.39	6.05	5.98	6.00	5.75	6789683	5.34		6789683
Physical Properties											
Total Suspended Solids	mg/L	40.7	7.1	7.3	20.2	7.5	9.1	6787398	10.8	1.0	6787398
Total Dissolved Solids	mg/L	8.4	3.2	<1.0	3.2	<1.0	6.8	6789055	5.2	1.0	6789055
Turbidity	NTU	11.3(1)	1.95(1)	4.76(1)	4.10(1)	7.59(1)	3.56(1)	6789621	1.55(1)	0.10	6789621

RDL = Reportable Detection Limit
(1) - Sample arrived to laboratory past recommended hold time.

RESULTS OF CHEMICAL ANALYSES OF GROUND WATER

Maxxam ID		GH2701		GH2702	GH2703		GH2704		GH2705	GH2706		
Sampling Date		2013/04/26		2013/04/26	2013/04/28		2013/04/29		2013/04/28	2013/04/26		
	UNITS	**SS3-4**	**QC Batch**	**SS3-5**	**SS4-4**	**QC Batch**	**SS4-4-1**	**QC Batch**	**SS4-5**	**SS5-3**	**RDL**	**QC Batch**
Misc. Inorganics												
Acidity (pH 4.5)	mg/L	<0.50	6787689	<0.50	<0.50	6787689	<0.50	6787689	<0.50	<0.50	0.50	6787689
Acidity (pH 8.3)	mg/L	<0.50	6787689	<0.50	<0.50	6787689	<0.50	6787689	<0.50	<0.50	0.50	6787689
Fluoride (F)	mg/L	0.010	6791260	<0.010	<0.010	6791260	<0.010	6791260	<0.010	<0.010	0.010	6791260
Calculated Parameters												
Nitrate (N)	mg/L	0.134	6787487	0.0875	0.0509	6787487	0.0064	6787487	0.127	0.0895	0.0020	6787487
Misc. Inorganics												
Alkalinity (Total as CaCO3)	mg/L	13.0	6789680	1.24	1.54	6789680	0.78	6789680	3.35	1.37	0.50	6789680
Alkalinity (PP as CaCO3)	mg/L	0.68	6789680	<0.50	<0.50	6789680	<0.50	6789680	<0.50	<0.50	0.50	6789680
Bicarbonate (HCO3)	mg/L	14.2	6789680	1.51	1.88	6789680	0.95	6789680	4.09	1.67	0.50	6789680
Carbonate (CO3)	mg/L	0.82	6789680	<0.50	<0.50	6789680	<0.50	6789680	<0.50	<0.50	0.50	6789680
Hydroxide (OH)	mg/L	<0.50	6789680	<0.50	<0.50	6789680	<0.50	6789680	<0.50	<0.50	0.50	6789680
Anions												
Orthophosphate (P)	mg/L	0.013(1)	6789889	0.0035(1)	0.0034(1)	6789889	0.0028(1)	6789889	0.0073(1)	0.0076(1)	0.0010	6789889
Dissolved Sulphate (SO4)	mg/L	1.25	6789783	0.54	0.52	6789783	<0.50	6789783	1.35	0.68	0.50	6789783
Dissolved Chloride (Cl)	mg/L	0.55	6789739	0.61	0.68	6789739	0.52	6789739	0.84	0.62	0.50	6789739
Nutrients												
Ammonia (N)	mg/L	0.12	6789692	0.055	0.050	6795724	<0.0050	6789692	0.076	0.049	0.0050	6795724
Dissolved Phosphorus (P)	mg/L	0.0443	6790027	0.0062	0.0078	6790027	<0.0020	6790027	0.0192	0.0082	0.0020	6790027
Total Total Kjeldahl Nitrogen (Calc)	mg/L	0.147	6787302	0.100	0.045	6787302	<0.020	6787302	0.130	0.051	0.020	6787302
Nitrate plus Nitrite (N)	mg/L	0.142(1)	6789731	0.0900(1)	0.0509(1)	6789731	0.0089(1)	6789731	0.132(1)	0.0895(1)	0.0020	6789731
Nitrite (N)	mg/L	0.0079(1)	6789732	0.0025(1)	<0.0020(1)	6789732	0.0025(1)	6789732	0.0046(1)	<0.0020(1)	0.0020	6789732
Total Nitrogen (N)	mg/L	0.289	6789715	0.190	0.096	6795028	0.023	6789715	0.262	0.141	0.020	6795028
Total Phosphorus (P)	mg/L	0.0982	6790031	0.0143	0.0081	6790031	<0.0020	6790031	0.0514	0.0095	0.0020	6790031
Physical Properties												
Conductivity	uS/cm	28.8	6789687	3.2	3.0	6789687	<1.0	6789687	9.1	3.5	1.0	6789687
pH	pH Units	8.44	6789683	6.10	5.99	6789683	5.44	6789683	6.85	6.07		6789683
Physical Properties												
Total Suspended Solids	mg/L	47.4	6787398	10.9	8.7	6787398	<1.0	6787398	22.3	6.5	1.0	6787398
Total Dissolved Solids	mg/L	22.0	6789055	6.4	4.4	6789055	1.2	6789055	10.4	6.0	1.0	6789055
Turbidity	NTU	14.4(1)	6789621	1.90(1)	1.01(1)	6789621	0.12(2)	6789621	2.88(1)	2.40(1)	0.10	6789621

RDL = Reportable Detection Limit
(1) - Sample arrived to laboratory past recommended hold time.
(2) - Sample analysed past recommended hold time.

RESULTS OF CHEMICAL ANALYSES OF GROUND WATER

Maxxam ID		GH2707		GH2708	GH2709	GH2710	GH2711	GH2712		
Sampling Date		2013/04/26		2013/04/26	2013/04/26	2013/04/26	2013/04/28	2013/04/26		
	UNITS	**SS5-4**	**QC Batch**	**SS5-5-4**	**SS5-5-5**	**SSC-1**	**SSC-2**	**SSC-3**	**RDL**	**QC Batch**
Misc. Inorganics										
Acidity (pH 4.5)	mg/L	<0.50	6787689	<0.50	<0.50	<0.50	<0.50	<0.50	0.50	6787689
Acidity (pH 8.3)	mg/L	<0.50	6787689	<0.50	<0.50	<0.50	<0.50	<0.50	0.50	6787689
Fluoride (F)	mg/L	<0.010	6791260	<0.010	<0.010	<0.010	<0.010	<0.010	0.010	6791260
Calculated Parameters										
Nitrate (N)	mg/L	0.0465	6787487	0.104	0.123	0.107	0.103	0.104	0.0020	6787487
Misc. Inorganics										
Alkalinity (Total as CaCO3)	mg/L	0.89	6789680	1.09	0.85	0.65	0.84	1.53	0.50	6789680
Alkalinity (PP as CaCO3)	mg/L	<0.50	6789680	<0.50	<0.50	<0.50	<0.50	<0.50	0.50	6789680
Bicarbonate (HCO3)	mg/L	1.09	6789680	1.33	1.04	0.79	1.03	1.87	0.50	6789680
Carbonate (CO3)	mg/L	<0.50	6789680	<0.50	<0.50	<0.50	<0.50	<0.50	0.50	6789680
Hydroxide (OH)	mg/L	<0.50	6789680	<0.50	<0.50	<0.50	<0.50	<0.50	0.50	6789680
Anions										
Orthophosphate (P)	mg/L	0.0069(1)	6789889	0.0028(1)	0.0030(1)	0.0031(1)	0.0042(1)	0.0053(1)	0.0010	6789889
Dissolved Sulphate (SO4)	mg/L	<0.50	6789783	0.51	0.64	<0.50	0.53	0.57	0.50	6789783
Dissolved Chloride (Cl)	mg/L	0.60	6789739	<0.50	<0.50	0.70	0.60	0.58	0.50	6789739
Nutrients										
Ammonia (N)	mg/L	0.025	6796804	0.014	0.025	0.019	0.022	0.015	0.0050	6789692
Dissolved Phosphorus (P)	mg/L	0.0094	6790027	0.0056	0.0040	0.0044	0.0081	0.0183	0.0020	6790027
Total Total Kjeldahl Nitrogen (Calc)	mg/L	0.036	6787302	0.031	0.031	0.031	0.033	0.109	0.020	6787302
Nitrate plus Nitrite (N)	mg/L	0.0487(1)	6789731	0.104(1)	0.125(1)	0.109(1)	0.107(1)	0.104(1)	0.0020	6789731
Nitrite (N)	mg/L	0.0022(1)	6789732	<0.0020(1)	0.0026(1)	0.0020(1)	0.0039(1)	<0.0020(1)	0.0020	6789732
Total Nitrogen (N)	mg/L	0.084	6795028	0.135	0.157	0.139	0.140	0.213	0.020	6789715
Total Phosphorus (P)	mg/L	0.0139	6790031	0.0074	0.0056	0.0062	0.0070	0.0190	0.0020	6790031
Physical Properties										
Conductivity	uS/cm	2.3	6789687	2.7	2.9	3.1	2.9	3.8	1.0	6789687
pH	pH Units	5.88	6789683	5.59	5.41	5.23	5.49	6.22		6789683
Physical Properties										
Total Suspended Solids	mg/L	5.9	6787398	2.6	6.3	4.4	9.2	14.5	1.0	6787398
Total Dissolved Solids	mg/L	8.0	6789055	6.4	6.4	5.2	6.0	7.6	1.0	6789055
Turbidity	NTU	1.78(1)	6789621	1.52(1)	1.70(1)	2.08(1)	2.28(1)	2.95(1)	0.10	6789621

RDL = Reportable Detection Limit
(1) - Sample arrived to laboratory past recommended hold time.

LOW LEVEL TOTAL METALS IN WATER (GROUND WATER)

Maxxam ID		GH2694	GH2695	GH2696		GH2697	GH2698		GH2699	GH2700		
Sampling Date		2013/04/27	2013/04/27	2013/04/27		2013/04/27	2013/04/27		2013/04/27	2013/04/27		
	UNITS	**SS1-4**	**SS1-5**	**SS2-1**	**QC Batch**	**SS2-2-4**	**SS2-2-5**	**QC Batch**	**SS2-3**	**SS2-4**	**RDL**	**QC Batch**
Calculated Parameters												
Total Hardness (CaCO3)	mg/L	6.60	1.77	2.52	6787232	2.06	1.84	6787232	1.28	1.22	0.50	6787232
Total Metals by ICPMS												
Total Aluminum (Al)	ug/L	531	130	153	6791105	166	125	6791109	93.9	108	0.20	6791105
Total Antimony (Sb)	ug/L	0.033	<0.020	<0.020	6791105	<0.020	<0.020	6791109	<0.020	0.023	0.020	6791105
Total Arsenic (As)	ug/L	0.195	0.079	0.119	6791105	0.078	0.067	6791109	0.112	0.177	0.020	6791105
Total Barium (Ba)	ug/L	11.5	3.89	5.16	6791105	5.03	4.50	6791109	3.09	3.00	0.020	6791105
Total Beryllium (Be)	ug/L	0.017	<0.010	<0.010	6791105	<0.010	<0.010	6791109	<0.010	<0.010	0.010	6791105
Total Bismuth (Bi)	ug/L	0.112	0.0170	0.0130	6791105	0.0110	0.0140	6791109	0.0100	0.0060	0.0050	6791105
Total Boron (B)	ug/L	<5.0	<5.0	<5.0	6791105	<5.0	<5.0	6791109	<5.0	<5.0	5.0	6791105
Total Cadmium (Cd)	ug/L	0.0110	<0.0050	<0.0050	6791105	<0.0050	<0.0050	6791109	<0.0050	<0.0050	0.0050	6791105
Total Chromium (Cr)	ug/L	2.75	0.804	1.14	6791105	0.897	0.730	6791109	0.529	0.411	0.050	6791105
Total Cobalt (Co)	ug/L	0.869	0.164	0.212	6791105	0.210	0.178	6791109	0.114	0.106	0.0050	6791105
Total Copper (Cu)	ug/L	1.56	0.270	0.461	6791105	0.406	0.309	6791109	0.348	13.1	0.050	6791105
Total Iron (Fe)	ug/L	858	219	273	6791105	269	199	6791109	147	142	1.0	6791105
Total Lead (Pb)	ug/L	0.785	0.218	0.237	6791105	0.218	0.179	6791109	0.157	0.717	0.0050	6791105
Total Lithium (Li)	ug/L	2.24	<0.50	0.95	6791105	0.56	<0.50	6791109	<0.50	<0.50	0.50	6791105
Total Manganese (Mn)	ug/L	15.0	3.57	4.55	6791105	4.48	3.79	6791109	2.93	2.84	0.050	6791105
Total Mercury (Hg)	ug/L	<0.010	<0.010	<0.010	6791105	<0.010	<0.010	6791109	<0.010	<0.010	0.010	6791105
Total Molybdenum (Mo)	ug/L	0.067	<0.050	0.084	6791105	0.130	0.062	6791109	<0.050	<0.050	0.050	6791105
Total Nickel (Ni)	ug/L	6.50	1.79	2.51	6791105	2.27	2.04	6791109	1.27	0.885	0.020	6791105
Total Selenium (Se)	ug/L	<0.040	<0.040	<0.040	6791105	<0.040	<0.040	6791109	<0.040	<0.040	0.040	6791105
Total Silicon (Si)	ug/L	1080	234	305	6791105	342	252	6791109	163	157	50	6791105
Total Silver (Ag)	ug/L	0.0080	<0.0050	<0.0050	6791105	<0.0050	<0.0050	6791109	<0.0050	<0.0050	0.0050	6791105
Total Strontium (Sr)	ug/L	4.87	1.27	2.12	6791105	1.76	1.71	6791109	1.50	1.14	0.050	6791105
Total Thallium (Tl)	ug/L	0.0180	0.0030	0.0030	6791105	0.0050	0.0040	6791109	0.0020	0.0020	0.0020	6791105
Total Tin (Sn)	ug/L	0.075	0.055	0.089	6791105	0.029	0.092	6791109	0.046	0.059	0.010	6791105
Total Titanium (Ti)	ug/L	44.0	11.0	13.2	6791105	14.5	11.4	6791109	7.55	7.07	0.50	6791105
Total Uranium (U)	ug/L	0.850	0.0740	0.101	6791105	0.108	0.0910	6791109	0.0890	0.0780	0.0020	6791105
Total Vanadium (V)	ug/L	1.22	0.37	0.38	6791105	0.45	0.37	6791109	0.22	0.22	0.10	6791105
Total Zinc (Zn)	ug/L	4.26	1.48	1.99	6791105	1.89	1.83	6791109	1.23	2.04	0.10	6791105
Total Zirconium (Zr)	ug/L	0.082	<0.050	<0.050	6791105	<0.050	<0.050	6791109	<0.050	<0.050	0.050	6791105
Total Calcium (Ca)	mg/L	1.01	0.183	0.355	6787551	0.296	0.295	6787551	0.226	0.224	0.050	6787551
Total Magnesium (Mg)	mg/L	0.988	0.319	0.398	6787551	0.320	0.267	6787551	0.175	0.160	0.050	6787551
Total Potassium (K)	mg/L	0.362	0.110	0.133	6787551	0.132	0.103	6787551	0.066	0.085	0.050	6787551
Total Potassium (K)	ug/L	362	110	133	6791105	132	103	6791109	66	85	10	6791105

RDL = Reportable Detection Limit

LOW LEVEL TOTAL METALS IN WATER (GROUND WATER)

Maxxam ID		GH2694	GH2695	GH2696		GH2697	GH2698		GH2699	GH2700		
Sampling Date		2013/04/27	2013/04/27	2013/04/27		2013/04/27	2013/04/27		2013/04/27	2013/04/27		
	UNITS	**SS1-4**	**SS1-5**	**SS2-1**	**QC Batch**	**SS2-2-4**	**SS2-2-5**	**QC Batch**	**SS2-3**	**SS2-4**	**RDL**	**QC Batch**
Total Sodium (Na)	mg/L	0.083	0.099	0.124	6787551	0.087	0.082	6787551	0.051	0.098	0.050	6787551
Total Sulphur (S)	mg/L	<0.50	<0.50	<0.50	6787551	<0.50	<0.50	6787551	<0.50	<0.50	0.50	6787551

RDL = Reportable Detection Limit

LOW LEVEL TOTAL METALS IN WATER (GROUND WATER)

Maxxam ID		GH2701	GH2702	GH2703	GH2704		GH2705	GH2706	GH2707	GH2708		
Sampling Date		2013/04/26	2013/04/26	2013/04/28	2013/04/29		2013/04/28	2013/04/26	2013/04/26	2013/04/26		
	UNITS	**SS3-4**	**SS3-5**	**SS4-4**	**SS4-4-1**	**QC Batch**	**SS4-5**	**SS5-3**	**SS5-4**	**SS5-5-4**	**RDL**	**QC Batch**
Calculated Parameters												
Total Hardness (CaCO3)	mg/L	32.7	2.24	2.76	<0.50	6787232	10.3	3.40	2.39	2.04	0.50	6787232
Total Metals by ICPMS												
Total Aluminum (Al)	ug/L	862	71.6	103	1.75	6791109	240	69.3	60.7	49.4	0.20	6791105
Total Antimony (Sb)	ug/L	0.119	<0.020	<0.020	<0.020	6791109	0.036	<0.020	<0.020	<0.020	0.020	6791105
Total Arsenic (As)	ug/L	0.443	0.058	0.102	<0.020	6791109	0.092	0.061	0.075	0.051	0.020	6791105
Total Barium (Ba)	ug/L	41.9	4.39	4.60	0.192	6791109	21.9	6.65	5.44	4.28	0.020	6791105
Total Beryllium (Be)	ug/L	0.019	<0.010	<0.010	<0.010	6791109	<0.010	<0.010	<0.010	<0.010	0.010	6791105
Total Bismuth (Bi)	ug/L	0.182	0.0100	0.0120	<0.0050	6791109	0.0260	0.0050	0.0060	<0.0050	0.0050	6791105
Total Boron (B)	ug/L	<5.0	<5.0	<5.0	<5.0	6791109	<5.0	<5.0	<5.0	<5.0	5.0	6791105
Total Cadmium (Cd)	ug/L	0.0150	<0.0050	<0.0050	<0.0050	6791109	0.0050	0.0070	<0.0050	<0.0050	0.0050	6791105
Total Chromium (Cr)	ug/L	10.1	0.741	1.15	0.188	6791109	3.96	1.48	1.06	0.933	0.050	6791105
Total Cobalt (Co)	ug/L	1.76	0.128	0.254	0.0060	6791109	0.663	0.249	0.180	0.163	0.0050	6791105
Total Copper (Cu)	ug/L	2.71	0.376	3.34	0.484	6791109	0.602	0.522	0.468	0.281	0.050	6791105
Total Iron (Fe)	ug/L	1810	132	226	15.3	6791109	577	195	160	124	1.0	6791105
Total Lead (Pb)	ug/L	2.53	0.106	0.229	0.0150	6791109	0.467	0.133	0.151	0.0970	0.0050	6791105
Total Lithium (Li)	ug/L	2.14	<0.50	<0.50	<0.50	6791109	0.63	<0.50	<0.50	<0.50	0.50	6791105
Total Manganese (Mn)	ug/L	31.8	2.86	4.02	0.744	6791109	11.2	4.02	3.09	2.57	0.050	6791105
Total Mercury (Hg)	ug/L	<0.010	<0.010	<0.010	<0.010	6791109	<0.010	<0.010	<0.010	<0.010	0.010	6791105
Total Molybdenum (Mo)	ug/L	0.243	0.061	0.055	<0.050	6791109	0.266	<0.050	0.067	<0.050	0.050	6791105
Total Nickel (Ni)	ug/L	30.5	2.48	3.45	0.050	6791109	12.9	4.97	3.64	2.96	0.020	6791105
Total Selenium (Se)	ug/L	0.040	<0.040	<0.040	<0.040	6791109	<0.040	<0.040	<0.040	<0.040	0.040	6791105
Total Silicon (Si)	ug/L	2780	189	270	<50	6791109	782	239	189	152	50	6791105
Total Silver (Ag)	ug/L	0.0110	<0.0050	<0.0050	<0.0050	6791109	<0.0050	<0.0050	<0.0050	<0.0050	0.0050	6791105
Total Strontium (Sr)	ug/L	21.4	2.04	2.09	<0.050	6791109	10.4	2.80	1.98	1.49	0.050	6791105
Total Thallium (Tl)	ug/L	0.0220	0.0020	0.0030	<0.0020	6791109	0.0060	<0.0020	<0.0020	<0.0020	0.0020	6791105
Total Tin (Sn)	ug/L	0.096	0.108	0.060	0.024	6791109	0.062	0.035	0.126	0.019	0.010	6791105
Total Titanium (Ti)	ug/L	64.4	5.82	10.4	<0.50	6791109	19.4	5.51	4.80	5.74	0.50	6791105
Total Uranium (U)	ug/L	1.27	0.0850	0.0740	<0.0020	6791109	0.235	0.0420	0.0490	0.0310	0.0020	6791105
Total Vanadium (V)	ug/L	2.23	0.20	0.30	<0.10	6791109	0.73	0.23	0.20	0.18	0.10	6791105
Total Zinc (Zn)	ug/L	9.41	1.18	1.37	0.36	6791109	2.48	1.19	1.74	1.03	0.10	6791105
Total Zirconium (Zr)	ug/L	0.149	<0.050	<0.050	<0.050	6791109	<0.050	<0.050	<0.050	<0.050	0.050	6791105
Total Calcium (Ca)	mg/L	6.17	0.383	0.274	<0.050	6787551	1.12	0.306	0.247	0.189	0.050	6787551
Total Magnesium (Mg)	mg/L	4.20	0.312	0.504	<0.050	6787551	1.83	0.640	0.430	0.380	0.050	6787551
Total Potassium (K)	mg/L	0.515	0.061	0.109	<0.050	6787551	0.277	0.065	<0.050	<0.050	0.050	6787551
Total Potassium (K)	ug/L	515	61	109	<10	6791109	277	65	48	40	10	6791105

RDL = Reportable Detection Limit

LOW LEVEL TOTAL METALS IN WATER (GROUND WATER)

Maxxam ID		GH2701	GH2702	GH2703	GH2704		GH2705	GH2706	GH2707	GH2708		
Sampling Date		2013/04/26	2013/04/26	2013/04/28	2013/04/29		2013/04/28	2013/04/26	2013/04/26	2013/04/26		
	UNITS	**SS3-4**	**SS3-5**	**SS4-4**	**SS4-4-1**	**QC Batch**	**SS4-5**	**SS5-3**	**SS5-4**	**SS5-5-4**	**RDL**	**QC Batch**
Total Sodium (Na)	mg/L	0.175	0.058	0.111	<0.050	6787551	0.134	0.068	<0.050	0.053	0.050	6787551
Total Sulphur (S)	mg/L	<0.50	<0.50	<0.50	<0.50	6787551	<0.50	<0.50	<0.50	<0.50	0.50	6787551

RDL = Reportable Detection Limit

LOW LEVEL TOTAL METALS IN WATER (GROUND WATER)

Maxxam ID		GH2709		GH2710	GH2711		GH2712		
Sampling Date		2013/04/26		2013/04/26	2013/04/28		2013/04/26		
	UNITS	**SS5-5-5**	**QC Batch**	**SSC-1**	**SSC-2**	**QC Batch**	**SSC-3**	**RDL**	**QC Batch**
Calculated Parameters									
Total Hardness (CaCO3)	mg/L	1.76	6787232	0.83	1.68	6787232	5.87	0.50	6787232
Total Metals by ICPMS									
Total Aluminum (Al)	ug/L	39.5	6791105	28.2	56.9	6791109	139	0.20	6791105
Total Antimony (Sb)	ug/L	<0.020	6791105	<0.020	<0.020	6791109	0.024	0.020	6791105
Total Arsenic (As)	ug/L	0.038	6791105	0.029	0.062	6791109	0.134	0.020	6791105
Total Barium (Ba)	ug/L	4.50	6791105	2.12	4.70	6791109	12.9	0.020	6791105
Total Beryllium (Be)	ug/L	<0.010	6791105	<0.010	<0.010	6791109	<0.010	0.010	6791105
Total Bismuth (Bi)	ug/L	<0.0050	6791105	<0.0050	0.0060	6791109	0.0140	0.0050	6791105
Total Boron (B)	ug/L	<5.0	6791105	<5.0	<5.0	6791109	<5.0	5.0	6791105
Total Cadmium (Cd)	ug/L	<0.0050	6791105	<0.0050	<0.0050	6791109	0.0050	0.0050	6791105
Total Chromium (Cr)	ug/L	0.710	6791105	0.493	0.676	6791109	2.17	0.050	6791105
Total Cobalt (Co)	ug/L	0.142	6791105	0.0650	0.120	6791109	0.391	0.0050	6791105
Total Copper (Cu)	ug/L	0.276	6791105	0.301	0.242	6791109	0.565	0.050	6791105
Total Iron (Fe)	ug/L	105	6791105	77.8	108	6791109	316	1.0	6791105
Total Lead (Pb)	ug/L	0.0940	6791105	0.0620	0.0890	6791109	0.235	0.0050	6791105
Total Lithium (Li)	ug/L	<0.50	6791105	<0.50	<0.50	6791109	<0.50	0.50	6791105
Total Manganese (Mn)	ug/L	2.29	6791105	1.33	7.32	6791109	27.7	0.050	6791105
Total Mercury (Hg)	ug/L	<0.010	6791105	<0.010	<0.010	6791109	<0.010	0.010	6791105
Total Molybdenum (Mo)	ug/L	<0.050	6791105	0.144	<0.050	6791109	<0.050	0.050	6791105
Total Nickel (Ni)	ug/L	2.94	6791105	1.09	2.03	6791109	6.81	0.020	6791105
Total Selenium (Se)	ug/L	<0.040	6791105	<0.040	<0.040	6791109	<0.040	0.040	6791105
Total Silicon (Si)	ug/L	123	6791105	63	130	6791109	421	50	6791105
Total Silver (Ag)	ug/L	<0.0050	6791105	<0.0050	<0.0050	6791109	<0.0050	0.0050	6791105
Total Strontium (Sr)	ug/L	1.55	6791105	0.727	1.44	6791109	4.05	0.050	6791105
Total Thallium (Tl)	ug/L	<0.0020	6791105	<0.0020	0.0020	6791109	0.0060	0.0020	6791105
Total Tin (Sn)	ug/L	0.221	6791105	0.115	0.031	6791109	0.033	0.010	6791105
Total Titanium (Ti)	ug/L	3.53	6791105	1.98	3.65	6791109	11.3	0.50	6791105
Total Uranium (U)	ug/L	0.0250	6791105	0.0150	0.0450	6791109	0.109	0.0020	6791105
Total Vanadium (V)	ug/L	0.14	6791105	<0.10	0.15	6791109	0.43	0.10	6791105
Total Zinc (Zn)	ug/L	1.03	6791105	1.49	1.29	6791109	3.28	0.10	6791105
Total Zirconium (Zr)	ug/L	<0.050	6791105	<0.050	<0.050	6791109	0.063	0.050	6791105
Total Calcium (Ca)	mg/L	0.178	6787551	0.124	0.252	6787551	0.770	0.050	6787551
Total Magnesium (Mg)	mg/L	0.320	6787551	0.127	0.255	6787551	0.958	0.050	6787551
Total Potassium (K)	mg/L	<0.050	6787551	<0.050	0.066	6787551	0.149	0.050	6787551
Total Potassium (K)	ug/L	33	6791105	22	66	6791109	149	10	6791105

RDL = Reportable Detection Limit

LOW LEVEL TOTAL METALS IN WATER (GROUND WATER)

Maxxam ID		GH2709		GH2710	GH2711		GH2712		
Sampling Date		2013/04/26		2013/04/26	2013/04/28		2013/04/26		
	UNITS	**SS5-5-5**	**QC Batch**	**SSC-1**	**SSC-2**	**QC Batch**	**SSC-3**	**RDL**	**QC Batch**
Total Sodium (Na)	mg/L	<0.050	6787551	<0.050	0.059	6787551	<0.050	0.050	6787551
Total Sulphur (S)	mg/L	<0.50	6787551	<0.50	<0.50	6787551	<0.50	0.50	6787551

RDL = Reportable Detection Limit

Package 1	4.3°C
Package 2	4.7°C
Package 3	5.0°C

Each temperature is the average of up to three cooler temperatures taken at receipt

General Comments

Sample GH2694-01: The BC-MOE and APHA Standard Method require pH to be analysed within 15 minutes of sampling and therefore field analysis is required for compliance. All Laboratory pH analyses in this report are reported past the BC-MOE/APHA Standard Method holding time.

Sample GH2695-01: The BC-MOE and APHA Standard Method require pH to be analysed within 15 minutes of sampling and therefore field analysis is required for compliance. All Laboratory pH analyses in this report are reported past the BC-MOE/APHA Standard Method holding time.

Sample GH2696-01: The BC-MOE and APHA Standard Method require pH to be analysed within 15 minutes of sampling and therefore field analysis is required for compliance. All Laboratory pH analyses in this report are reported past the BC-MOE/APHA Standard Method holding time.

Sample GH2697-01: The BC-MOE and APHA Standard Method require pH to be analysed within 15 minutes of sampling and therefore field analysis is required for compliance. All Laboratory pH analyses in this report are reported past the BC-MOE/APHA Standard Method holding time.

Sample GH2698-01: The BC-MOE and APHA Standard Method require pH to be analysed within 15 minutes of sampling and therefore field analysis is required for compliance. All Laboratory pH analyses in this report are reported past the BC-MOE/APHA Standard Method holding time.

Sample GH2699-01: The BC-MOE and APHA Standard Method require pH to be analysed within 15 minutes of sampling and therefore field analysis is required for compliance. All Laboratory pH analyses in this report are reported past the BC-MOE/APHA Standard Method holding time.

Sample GH2700-01: The BC-MOE and APHA Standard Method require pH to be analysed within 15 minutes of sampling and therefore field analysis is required for compliance. All Laboratory pH analyses in this report are reported past the BC-MOE/APHA Standard Method holding time.

Sample GH2701-01: The BC-MOE and APHA Standard Method require pH to be analysed within 15 minutes of sampling and therefore field analysis is required for compliance. All Laboratory pH analyses in this report are reported past the BC-MOE/APHA Standard Method holding time.

Sample GH2702-01: The BC-MOE and APHA Standard Method require pH to be analysed within 15 minutes of sampling and therefore field analysis is required for compliance. All Laboratory pH analyses in this report are reported past the BC-MOE/APHA Standard Method holding time.

Sample GH2703-01: The BC-MOE and APHA Standard Method require pH to be analysed within 15 minutes of sampling and therefore field analysis is required for compliance. All Laboratory pH analyses in this report are reported past the BC-MOE/APHA Standard Method holding time.

Sample GH2704-01: The BC-MOE and APHA Standard Method require pH to be analysed within 15 minutes of sampling and therefore field analysis is required for compliance. All Laboratory pH analyses in this report are reported past the BC-MOE/APHA Standard Method holding time.

Sample GH2705-01: The BC-MOE and APHA Standard Method require pH to be analysed within 15 minutes of sampling and therefore field analysis is required for compliance. All Laboratory pH analyses in this report are reported past the BC-MOE/APHA Standard Method holding time.

Sample GH2706-01: The BC-MOE and APHA Standard Method require pH to be analysed within 15 minutes of sampling and therefore field analysis is required for compliance. All Laboratory pH analyses in this report are reported past the BC-MOE/APHA Standard Method holding time.

Sample GH2707-01: The BC-MOE and APHA Standard Method require pH to be analysed within 15 minutes of sampling and therefore field analysis is required for compliance. All Laboratory pH analyses in this report are reported past the BC-MOE/APHA Standard Method holding time.

Sample GH2708-01: The BC-MOE and APHA Standard Method require pH to be analysed within 15 minutes of sampling and therefore field analysis is required for compliance. All Laboratory pH analyses in this report are reported past the BC-MOE/APHA Standard Method holding time.

Sample GH2709-01: The BC-MOE and APHA Standard Method require pH to be analysed within 15 minutes of sampling and therefore field analysis is required for compliance. All Laboratory pH analyses in this report are reported past the BC-MOE/APHA Standard Method holding time.

Sample GH2710-01: The BC-MOE and APHA Standard Method require pH to be analysed within 15 minutes of sampling and therefore field analysis is required for compliance. All Laboratory pH analyses in this report are reported past the BC-MOE/APHA Standard Method holding time.

Sample GH2711-01: The BC-MOE and APHA Standard Method require pH to be analysed within 15 minutes of sampling and therefore field analysis is required for compliance. All Laboratory pH analyses in this report are reported past the BC-MOE/APHA Standard Method holding time.

Sample GH2712-01: The BC-MOE and APHA Standard Method require pH to be analysed within 15 minutes of sampling and therefore field analysis is required for compliance. All Laboratory pH analyses in this report are reported past the BC-MOE/APHA Standard Method holding time.

QUALITY ASSURANCE REPORT

			Matrix Spike		Spiked Blank		Method Blank		RPD	
QC Batch	**Parameter**	**Date**	**% Recovery**	**QC Limits**	**% Recovery**	**QC Limits**	**Value**	**UNITS**	**Value (%)**	**QC Limits**
6787398	Total Suspended Solids	2013/05/03			101	80 - 120	<1.0	mg/L		
6787689	Acidity (pH 8.3)	2013/05/03			101	80 - 120	<0.50	mg/L	NC	20
6787689	Acidity (pH 4.5)	2013/05/03					<0.50	mg/L	NC	20
6789055	Total Dissolved Solids	2013/05/03	NC	80 - 120	106	80 - 120	<1.0	mg/L	20.0	20
6789621	Turbidity	2013/05/04			102	80 - 120	<0.10	NTU	15.5	20
6789680	Alkalinity (Total as CaCO3)	2013/05/04	NC	80 - 120	100	80 - 120	0.90, RDL=0.50	mg/L	NC	20
6789680	Alkalinity (PP as CaCO3)	2013/05/04					<0.50	mg/L	NC	20
6789680	Bicarbonate (HCO3)	2013/05/04					1.10, RDL=0.50	mg/L	NC	20
6789680	Carbonate (CO3)	2013/05/04					<0.50	mg/L	NC	20
6789680	Hydroxide (OH)	2013/05/04					<0.50	mg/L	NC	20
6789687	Conductivity	2013/05/04			100	N/A	<1.0	uS/cm	2.1	20
6789692	Ammonia (N)	2013/05/03	104	80 - 120	94	80 - 120	<0.0050	mg/L	3.4	20
6789715	Total Nitrogen (N)	2013/05/06	NC	80 - 120	102	80 - 120	<0.020	mg/L	0.9	20
6789731	Nitrate plus Nitrite (N)	2013/05/03	112	80 - 120	103	80 - 120	<0.0020	mg/L	0.4	25
6789732	Nitrite (N)	2013/05/03	108	80 - 120	93	80 - 120	<0.0020	mg/L	NC	25
6789739	Dissolved Chloride (Cl)	2013/05/03	NC	80 - 120	101	80 - 120	<0.50	mg/L	NC	20
6789783	Dissolved Sulphate (SO4)	2013/05/03	NC	80 - 120	96	80 - 120	0.67, RDL=0.50	mg/L	NC	20
6789889	Orthophosphate (P)	2013/05/04	88	80 - 120	100	80 - 120	0.0016, RDL=0.0010	mg/L	6.2	20
6790027	Dissolved Phosphorus (P)	2013/05/04	95	80 - 120	103	80 - 120	<0.0020	mg/L	NC	20
6790031	Total Phosphorus (P)	2013/05/04	98	80 - 120	112	80 - 120	<0.0020	mg/L	NC	20
6791105	Total Aluminum (Al)	2013/05/06	NC	80 - 120	97	80 - 120	<0.20	ug/L	0.2	20
6791105	Total Antimony (Sb)	2013/05/06	99	80 - 120	97	80 - 120	<0.020	ug/L	NC	20
6791105	Total Arsenic (As)	2013/05/06	98	80 - 120	97	80 - 120	<0.020	ug/L	NC	20
6791105	Total Barium (Ba)	2013/05/06	NC	80 - 120	94	80 - 120	<0.020	ug/L	3.3	20
6791105	Total Beryllium (Be)	2013/05/06	97	80 - 120	92	80 - 120	<0.010	ug/L	NC	20
6791105	Total Bismuth (Bi)	2013/05/06	94	80 - 120	95	80 - 120	<0.0050	ug/L	14.3	20
6791105	Total Cadmium (Cd)	2013/05/06	97	80 - 120	95	80 - 120	<0.0050	ug/L	NC	20
6791105	Total Chromium (Cr)	2013/05/06	91	80 - 120	98	80 - 120	<0.10	ug/L	2.4	20
6791105	Total Cobalt (Co)	2013/05/06	91	80 - 120	97	80 - 120	<0.0050	ug/L	7.8	20
6791105	Total Copper (Cu)	2013/05/06	91	80 - 120	96	80 - 120	<0.050	ug/L	7.4	20
6791105	Total Iron (Fe)	2013/05/06	NC	80 - 120	106	80 - 120	<1.0	ug/L	2.1	20
6791105	Total Lead (Pb)	2013/05/06	92	80 - 120	94	80 - 120	<0.0050	ug/L	1.1	20
6791105	Total Lithium (Li)	2013/05/06	91	80 - 120	93	80 - 120	<0.50	ug/L	NC	20
6791105	Total Manganese (Mn)	2013/05/06	NC	80 - 120	99	80 - 120	<0.050	ug/L	2.9	20
6791105	Total Mercury (Hg)	2013/05/06	99	80 - 120	94	80 - 120	<0.010	ug/L	NC	20
6791105	Total Molybdenum (Mo)	2013/05/06	96	80 - 120	93	80 - 120	<0.050	ug/L	15.6	20
6791105	Total Nickel (Ni)	2013/05/06	NC	80 - 120	97	80 - 120	<0.020	ug/L	0.7	20
6791105	Total Selenium (Se)	2013/05/06	107	80 - 120	102	80 - 120	<0.040	ug/L	NC	20
6791105	Total Silver (Ag)	2013/05/06	95	80 - 120	93	80 - 120	<0.0050	ug/L	NC	20

QUALITY ASSURANCE REPORT

			Matrix Spike		Spiked Blank		Method Blank		RPD	
QC Batch	Parameter	Date	% Recovery	QC Limits	% Recovery	QC Limits	Value	UNITS	Value (%)	QC Limits
6791105	Total Strontium (Sr)	2013/05/06	NC	80 - 120	95	80 - 120	<0.050	ug/L	1.4	20
6791105	Total Thallium (Tl)	2013/05/06	96	80 - 120	100	80 - 120	<0.0020	ug/L	NC	20
6791105	Total Tin (Sn)	2013/05/06	90	80 - 120	94	80 - 120	<0.20	ug/L	13.5	20
6791105	Total Titanium (Ti)	2013/05/06	NC	80 - 120	105	80 - 120	<0.50	ug/L	2.4	20
6791105	Total Uranium (U)	2013/05/06	92	80 - 120	94	80 - 120	<0.0020	ug/L	1.7	20
6791105	Total Vanadium (V)	2013/05/06	92	80 - 120	97	80 - 120	<0.20	ug/L	10.9	20
6791105	Total Zinc (Zn)	2013/05/06	100	80 - 120	102	80 - 120	<0.10	ug/L	2.8	20
6791105	Total Boron (B)	2013/05/06					<50	ug/L	NC	20
6791105	Total Silicon (Si)	2013/05/06					<100	ug/L	0.7	20
6791105	Total Zirconium (Zr)	2013/05/06					<0.10	ug/L	NC	20
6791105	Total Potassium (K)	2013/05/06					<10	ug/L	3.2	20
6791109	Total Aluminum (Al)	2013/05/06	NC	80 - 120	99	80 - 120	<0.20	ug/L	0.8	20
6791109	Total Antimony (Sb)	2013/05/06	103	80 - 120	100	80 - 120	<0.020	ug/L	1.2	20
6791109	Total Arsenic (As)	2013/05/06	104	80 - 120	95	80 - 120	<0.020	ug/L	0.9	20
6791109	Total Barium (Ba)	2013/05/06	NC	80 - 120	96	80 - 120	<0.020	ug/L	0.8	20
6791109	Total Beryllium (Be)	2013/05/06	99	80 - 120	94	80 - 120	<0.010	ug/L	NC	20
6791109	Total Bismuth (Bi)	2013/05/06	93	80 - 120	97	80 - 120	<0.0050	ug/L	NC	20
6791109	Total Cadmium (Cd)	2013/05/06	99	80 - 120	98	80 - 120	<0.0050	ug/L	NC	20
6791109	Total Chromium (Cr)	2013/05/06	95	80 - 120	98	80 - 120	<0.10	ug/L	NC	20
6791109	Total Cobalt (Co)	2013/05/06	92	80 - 120	96	80 - 120	<0.0050	ug/L	8.0	20
6791109	Total Copper (Cu)	2013/05/06	90	80 - 120	98	80 - 120	<0.050	ug/L	18.9	20
6791109	Total Iron (Fe)	2013/05/06	100	80 - 120	105	80 - 120	<1.0	ug/L	3.2	20
6791109	Total Lead (Pb)	2013/05/06	93	80 - 120	97	80 - 120	<0.0050	ug/L	NC	20
6791109	Total Lithium (Li)	2013/05/06	NC	80 - 120	94	80 - 120	<0.50	ug/L	0.03	20
6791109	Total Manganese (Mn)	2013/05/06	NC	80 - 120	98	80 - 120	<0.050	ug/L	0.6	20
6791109	Total Mercury (Hg)	2013/05/06	104	80 - 120	102	80 - 120	<0.010	ug/L	NC	20
6791109	Total Molybdenum (Mo)	2013/05/06	NC	80 - 120	96	80 - 120	<0.050	ug/L	1.1	20
6791109	Total Nickel (Ni)	2013/05/06	NC	80 - 120	99	80 - 120	<0.020	ug/L	3.8	20
6791109	Total Selenium (Se)	2013/05/06	108	80 - 120	106	80 - 120	<0.040	ug/L	NC	20
6791109	Total Silver (Ag)	2013/05/06	98	80 - 120	99	80 - 120	<0.0050	ug/L	NC	20
6791109	Total Strontium (Sr)	2013/05/06	NC	80 - 120	96	80 - 120	<0.050	ug/L	0.6	20
6791109	Total Thallium (Tl)	2013/05/06	98	80 - 120	103	80 - 120	<0.0020	ug/L	NC	20
6791109	Total Tin (Sn)	2013/05/06	101	80 - 120	98	80 - 120	<0.20	ug/L	NC	20
6791109	Total Titanium (Ti)	2013/05/06	102	80 - 120	94	80 - 120	<0.50	ug/L	NC	20
6791109	Total Uranium (U)	2013/05/06	101	80 - 120	97	80 - 120	<0.0020	ug/L	1.4	20
6791109	Total Vanadium (V)	2013/05/06	96	80 - 120	96	80 - 120	<0.20	ug/L	NC	20
6791109	Total Zinc (Zn)	2013/05/06	101	80 - 120	104	80 - 120	<0.10	ug/L	NC	20
6791109	Total Boron (B)	2013/05/06					<50	ug/L	NC	20
6791109	Total Silicon (Si)	2013/05/06					<100	ug/L	0.2	20

QUALITY ASSURANCE REPORT

			Matrix Spike		Spiked Blank		Method Blank		RPD	
QC Batch	Parameter	Date	% Recovery	QC Limits	% Recovery	QC Limits	Value	UNITS	Value (%)	QC Limits
6791109	Total Zirconium (Zr)	2013/05/06					<0.10	ug/L	NC	20
6791109	Total Potassium (K)	2013/05/06					<10	ug/L	0.02	20
6791260	Fluoride (F)	2013/05/06	100	80 - 120	100	80 - 120	<0.010	mg/L	NC	20
6795028	Total Nitrogen (N)	2013/05/08	NC	80 - 120	105	80 - 120	0.021, RDL=0.020	mg/L	2.0	20
6795724	Ammonia (N)	2013/05/07	NC	80 - 120	101	80 - 120	<0.0050	mg/L	6.4	20
6796804	Ammonia (N)	2013/05/07	NC	80 - 120	99	80 - 120	<0.0050	mg/L	NC	20

N/A = Not Applicable
RDL = Reportable Detection Limit
RPD = Relative Percent Difference
Duplicate: Paired analysis of a separate portion of the same sample. Used to evaluate the variance in the measurement.
Matrix Spike: A sample to which a known amount of the analyte of interest has been added. Used to evaluate sample matrix interference.
Spiked Blank: A blank matrix sample to which a known amount of the analyte, usually from a second source, has been added. Used to evaluate method accuracy.
Method Blank: A blank matrix containing all reagents used in the analytical procedure. Used to identify laboratory contamination.
NC (Matrix Spike): The recovery in the matrix spike was not calculated. The relative difference between the concentration in the parent sample and the spiked amount was not sufficiently significant to permit a reliable recovery calculation.
NC (RPD): The RPD was not calculated. The level of analyte detected in the parent sample and its duplicate was not sufficiently significant to permit a reliable calculation.

Validation Signature Page

Maxxam Job #: B334547

The analytical data and all QC contained in this report were reviewed and validated by the following individual(s).

Andy Lu, Data Validation Coordinator

==

Maxxam has procedures in place to guard against improper use of the electronic signature and have the required "signatories", as per section 5.10.2 of ISO/IEC 17025:2005(E), signing the reports. For Service Group specific validation please refer to the Validation Signature Page.

05/025 43

08370438

RioTinto

Diavik Diamond Mines Inc. - Chain of Custody

Maxxam
30-Apr-13 08344534

Diavik Diamond Mines Inc.
P.O.Box 2498
5007-50 Ave
Yellowknife NT
X1A 2P8

Contact Information - Sample Inquiry
DDMI ENVIRONMENT
DDMI.ENVIRONMENT@RIOTINTO.COM
Site Env. Supervisor: Kristin Moore/Dwight Grabke (867) 766-5403

REPORT TO
DDMI ENVIRONMENT
DDMI.ENVIRONMENT@RIOTINTO.COM
REFERENCE LAB ID #: Maxxam

REPORT DISTRIBUTION
Electronic PDF ☑
Electronic Excel ☑
Hard Copy ☐

SERVICE REQUESTED
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Priority (50% Surcharge) ☐
Emergency (100% Surcharge) ☐

INVOICE TO
DDMI ACCOUNTS PAYABLE
DDMI.AP@RIOTINTO.COM
Reference PO #: K00909

SAMPLE INFORMATION / **ANALYSIS REQUESTED**

Identification	Project	Collected By	Date	Type	Routine Parameters: (pH, EC, Acidity, Alkalinity, Fl, K, Cl, SO4, PO4, NO2, NO3, Dissolved Phosphorus, TDS	Nutrients: (Ammonia, Total Phosphorus, TKN) PRESERVED	TOC (Total Organic Carbon) - analysis to be taken from the 120mL Nutrients bottle	DOC (Dissolved Organic Carbon) UNFILTERED & UNPRESERVED	TotalMetals Low Level: +Hg,Sb,Se PRESERVED	Dissolved Metals Low Level: +Hg, Sb,Se UNFILTERED & UNPRESERVED	Oil & Grease PRESERVED	Biochemical Oxygen Demand (BOD)	Fecal Coliforms:	BTEX	Hardness: +Na, S	TSS, Turbidity, pH - analysis to be taken from the 1L bottle	Gross Alpha	Reactive Silica		EH (2 bottles)
SS5-5-4 GH2708	AEMP	DG/DD	26-Apr-2013	GW	☑	☑	☐	☐	☑	☐	☐	☐	☐	☐	☐	☑	☐	☐		
SS5-5-5 GH2709	AEMP	DG/DD	26-Apr-2013	GW	☑	☑	☐	☐	☑	☐	☐	☐	☐	☐	☐	☑	☐	☐		
SSC-1 GH2710	AEMP	DG/DD	26-Apr-2013	GW	☑	☑	☐	☐	☑	☐	☐	☐	☐	☐	☐	☑	☐	☐		
SSC-2 GH2711	AEMP	DG/DD	28-Apr-2013	GW	☑	☑	☐	☐	☑	☐	☐	☐	☐	☐	☐	☑	☐	☐		
SSC-3 GH2712	AEMP	DG/DD	26-Apr-2013	GW	☑	☑	☐	☐	☑	☐	☐	☐	☐	☐	☐	☑	☐	☐		
					☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐		
					☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐		
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					☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐		

SAMPLE CONDITION (Shipped)
TEMP°C: 5.0
FROZEN ☐
COLD ☑
AMBIENT ☐

SPECIAL INSTRUCTIONS
Final Destination Burnaby, BC. **Note: Bottles state TOC analysis please disregard - NO TOC analysis required.**

SAMPLE CONDITION (Re
TEMP°C
FROZEN
COLD
AMBIENT

RELINQUISHED BY:	DATE / TIME:	RECEIVED BY:	DATE / TIME:	PAGE
DG	30-Apr-2013		2013/05/02 9:25	2 of 2

Doc # ENVI-140-0112 R0

3,4,6/6,4,4/5,4,6.

CS-yes.

Relinquished by Bo Su
Bo 2013/05/01 16:30

B334547

Appendix E

Dust Gauge Collection Standard Operating Procedure

ENVIRONMENT
STANDARD OPERATING PROCEDURE

Area No.: **8000**

Document #: **ENVR-508-0112**

Revision: **0**

Task Title: **SOP – Dust Gauge Collection**

Supersedes ENV SOP 508

FOR DOCUMENT CONTROL USE ONLY:

Next Review: **1 year from Area Manager Authorized Signature Date below**

Effective Date: **See Area Manager Authorized Signature Date below**

1 REFERENCES/RELATED DOCUMENTS

1.1 ENVI-178-0312 - Dust Gauge Collection Field Sheet – Located in: P:\DDMIEnvironment\10.0 Operational Control\10.2 Forms\2012 Active Forms

1.2 ENVI-403-0112 R0 - SOP Total Suspended Solids - Located in: Diavik Intranet - SOPs – Environment Folder

1.3 ENVR-301-0112 – SOP General Laboratory Safety - Located in: Diavik Intranet – SOPs – Environment Folder

1.4 ENVR-605-0112 R0 - SOP Snowmobiles – Located in: Diavik Intranet – SOPs – Environment Folder

1.5 ENVR-602-0112 R0 - SOP Watercraft – Located in: Diavik Intranet – SOPs – Environment Folder

1.6 ENVR-504-0112 R0- SOP Remote Field Safety – Located in: Diavik Intranet – SOPs – Environment Folder

1.7 ENVR-601-0112 R0 – SOP Aircraft - Located in: Diavik Intranet – SOPs – Environment Folder

1.8 ENVI-135-0112 R0 - Remote Field Safety Permit Form – Located in: P:\DDMIEnvironment\10.0 Operational Control\10.2 Forms\2012 Active Forms

Revision History

Revision	Revision Description	Date of Revision	Author
0	Initial Release	11-Jan-12	D. Meredith

Authorized By:

Area Superintendent:	D. Wells	**Date:**
Area Manager:	S. Bourn	**Date:**

(Document owners will be prompted annually to update content, however, changes may or may not result.)

Dust5

Description

Dust gauge collections involves twelve dust gauge stations including two control stations. Dust gauges are monitored quarterly; in order to measure dust deposition at stations surrounding Diavik Mine site.

2 PURPOSE

The purpose of this Standard Operating Procedure is to outline the methodology for collecting dust gauges. This program is aimed at understanding dust deposition rates associated with project activities. Results collected for this program are complied and placed in the Appendix for the annual AEMP report.

3 SCOPE

3.1 Scope of Procedure

There are 12 dust gauges (10 stations, plus 2 control), established on and around East Island for monitoring airborne dust particles. All dust gauges should be collected quarterly during both summer and winter. . Before heading out, be sure to check the clean replacement tubes for leakage by filling them with water and placing them in the sink. If they leak, they must be repaired with acrylic epoxy before use. A map illustrating coordinates and where the gauges are located is on the last page of this SOP.

STATION	EASTING	NORTING		STATION	EASTING	NORTING
Dust 01	533964	7154321		**Dust 7**	536819	7150510
Dust 2A	535678	7151339		**Dust 8**	531401	7154146
Dust 3	535024	7151872		**Dust 9**	541204	7152154
Dust 4	531397	7152127		**Dust 10**	532908	7148924
Dust 5	535696	7155138		**Dust C1**	534979	7144270
Dust 6	537502	7152934		**Dust C2**	528714	7153276

4 DEFINITIONS

N/A

5 RESPONSIBILITIES

5.1 Environment Superintendant

It is the responsibility of the superintendent to ensure that satisfactory provisions for safety and health are made for remote field activities by:

- Instituting, maintaining and communicating this procedure and ensuring technical best practice requirements are properly incorporated;
- Ensuring that the responsibilities for safety and health are communicated to all participants;
- Ensuring that the risks associated with remote field activities are managed effectively;
- Providing appropriate information, instruction and training to all participants

5.2 Environment Supervisor

The Environment Supervisor has a responsibility to ensure that:

- All personnel have read and understand the appropriate SOPs
- Ensuring proper tools are used for risk management (JHAs, Take5s, Hazard IDs)
- All legal requirements are followed
- All equipment and PPE required for the sampling program are available and have had the scheduled maintenance and repair completed
- The appropriate quality control/quality assurance practices are followed
- All personnel have completed the required training before completing the tasks assigned

5.3 Technicians and Contractors

Each staff member, student and contractor has a moral and legal responsibility for ensuring that his or her work environment is conductive to good health, safety and environment practices by:

- Complying with all standard operating procedures;
- Undertaking relevant safety and health training;
- Reviewing and becoming familiar with all related documents and reference material;
- Taking action to eliminate, minimize, avoid and report hazards of which they are aware;
- Making proper use of all safety devices and PPE;
- Not placing at risk the safety and health of themselves or any others;
- Ensuring all equipment is maintained and in a safe working condition;
- Ensuring samples are obtained using proper quality assurance and control procedures;
- Attending and participating in daily Field Work Planning sessions;
- Documenting any safety or procedural issues that occur during the program
- Ensuring all field equipment is in good repair and ready to work

6 PROCEDURE

6.1 Key HSEQ Aspects

6.1.1 Remote field work/Environmental Exposure

When travelling further in to the field, the completion of a detailed Remote Field Work Permit ENVI-135-0112 , is mandatory. The plan must be signed by all field personnel as well as the on-site supervisor, and a copy made available to the field crew as well as on-site staff. Environmental exposure can be a significant risk for those who are unprepared. Risks are seasonal, and winter time considerations include frost nip/frostbite, hypothermia, dehydration, windburn, sunburn and snow blindness. Summer time risks include heat exhaustion/heat stroke, insect bites, dehydration, sunburn, windburn and hypothermia (due to cold water exposure/submersion). During winter it is extremely important to dress appropriately for the conditions and bring extra clothing and winter gear with you. Conditions can quickly change in this area; be prepared and continuously monitor the weather while you work. If you notice a front moving in, ensure you allow enough time to get back to site. If you do not think that you can get back to site, consider alternative areas for shelter. The waypoint file GPS_Essentials on the p-drive should be uploaded into all GPS's; this file contains coordinates for many alternative shelters around Lac de Gras. If you must wait out the storm at your present location, prepare your survival kit and erect a temporary, make-shift shelter. Always be sure to communicate your plans to your on-site designate so that they are aware of the situation and can begin to coordinate a response as required. Environment staff are the first choice for on-site designate. If they are not available, a Safety representative would be assigned this role.

6.1.2 Equipment Operation and Break Downs

Operating equipment in this environment can involve risks such as: collision with rocks or other equipment, rollovers, spinning out/loss of control, machine fire, exhaust inhalation, vibration impacts, hearing damage, muscle sprains/strains, spills, cold water submersion (due to man-overboard, boat accident, aircraft crash or falling through the ice), aircraft crash, getting lost and becoming stranded in unfavourable conditions. In order to control these risks, it is important to conduct all required mechanical inspections prior to using equipment for field work. Ensure all field equipment is well maintained throughout the season, and that you are familiar with machine operation and basic field maintenance. Also ensure that you have and use the correct PPE for the equipment you are using. A survival kit must be carried for work farther afield; know the contents of this kit and wilderness survival skills.

6.2 Tools Required

Clean Replacement Cylinders		Glass Beakers (1000 mL)
Large/Clear/Heavy-duty Plastic Bags		TSS Filters
Duct Tape		High Temp Oven
Permanent Marker		Fire Proof Gloves/Tongs
Map/GPS With Coordinates		Tweezers
Multi-tool (Leatherman)		Boat/Snowmobile (Seasonal)
Spot Locator / Satellite Phone		Survival Kit
XL Latex Gloves		

6.3 Procedural Steps

6.3.1 Sample Collection

- Samples are collected through various methods, depending on location. You can walk, drive, boat, snowmobile or use helicopter to access the various sites. Be sure to bring clean tubes with you to replace the ones you will be collecting. Clean tubes are stored in the Environment field lab.
- Pull the copper tube out of the center of the fiberglass shield, keeping it upright. If the tube is stuck or frozen to the bottom, try wiggling it from the top, or tapping it with a multi-tool near the bottom. If it will not come free, you can remove the shield and then pop the tube out. Be sure to replace the shield and insert a new copper tube afterwards.

- Once you retrieve the tube, cover it right-side-up with a sampling glove and then with a large, heavy-duty plastic bag. Fold the bag around the tube and secure it to the tube using duct tape. Label the bag with the station number, date and time collected. Keep the tube upright and secure at all times during transport. If it is going to be a rough boat or sled ride, you may want to consider double-bagging the tube with one bag on top and another from below.
- (Summer Samples) Once sample tubes are back in the lab, the sample is transferred into a labeled glass beaker. Clear as much of the dried-on algae, dust, etc. that is found on the inside of the tube with distilled water and add it to the beaker. Run the water through the TSS analysis (ENVI-403-0112 R0). It may take multiple filters to complete one sample.
- (Winter Samples) Once sample tubes are back in the lab, let the snow melt within the tube by leaving them at room temperature secured in a cooler. Once all the snow has melted, transfer the sample into a labelled glass beaker. From here, follow the same procedures as those outlined above in summer collection.
- The resulting filter(s) with the dust particles are put into ceramic crucibles (1 filter per crucible) and dried in DDMI's high temperature oven at 650˚C for 1 hour. This will burn off any organic materials from the filter. You are required to wear heavy-duty fire-proof gloves and use a long set of tongs designed to hold the crucibles. The high temperature oven should be set up within the fume hood and be sure to turn on the fume hood fan. Ensure that you record the sample number on the crucibles <u>in</u> <u>pencil</u> before they are put into the oven.
- When samples are removed from the oven, Let the Crucibles initially cool, and then place the crucibles into the labeled tin tray that the filter originally came in. Place this combination into the dessicator to allow the sample to cool off for an hour at minimum.
- Once cooled, remove the filter from the crucible using tweezers and weigh only the filter according to the procedure outlined in the TSS analysis SOP ENVI-403-0112 R0 If any of the dust has fallen into the crucible during drying in the oven, be sure to tip the crucible and add this dust to the top of the filter prior to weighing.
- Record the results on the Dust Gauge Data Form (ENVI-178-0312).
- To determine the dustfall deposition rate, use the equation below:

Daily Dustfall Deposition (mg/dm$_2$/d) = (TP (mg) / SA (dm$_2$)) / TDD (d)

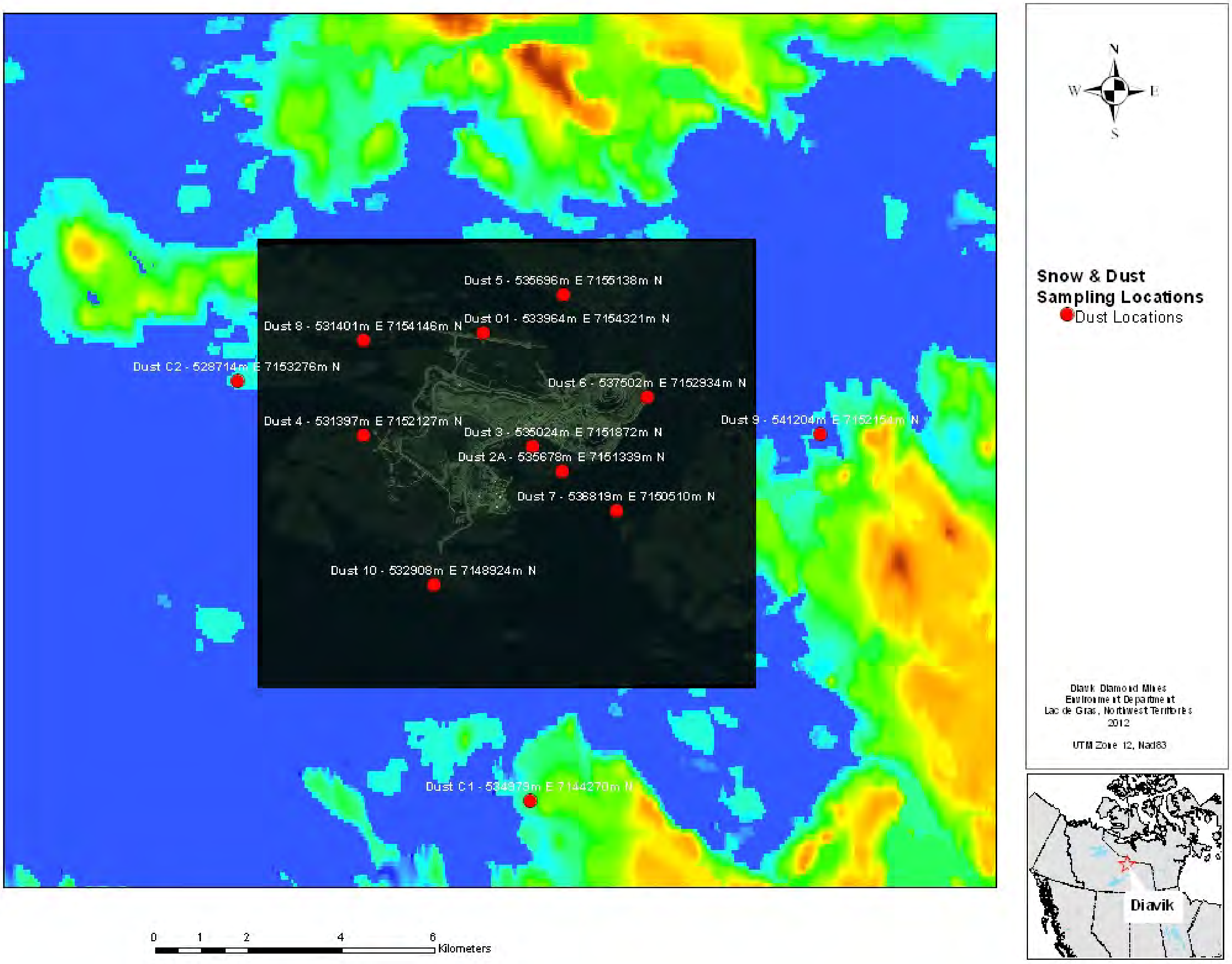
Where:
TP (mg) = Total Particulate
SA (dm$_2$) = Surface Area of Dust Gauge Collection Tube
TDD = Total Days Gauge was Deployed

7 QUALITY OUTCOMES AND EXPECTATIONS

7.1 This SOP will allow procedures to be conducted safely in order to avoid injury.

7.2 Adherence to this SOP as well as reference to the related documents will ensure successful retrieval of the dust samples for analysis.

7.3 It is also expected that all employees and contractors adhere to this SOP.


Dust 5 - 535696m E 7155138m N
Dust 8 - 531401m E 7154146m N
Dust 01 - 533964m E 7154321m N
Dust C2 - 528714m E 7153276m N
Dust 6 - 537502m E 7152934m N
Dust 4 - 531397m E 7152127m N
Dust 3 - 535024m E 7151872m N
Dust 9 - 541204m E 7152154m N
Dust 2A - 535678m E 7151339m N
Dust 7 - 536819m E 7150510m N
Dust 10 - 532908m E 7148924m N
Dust C1 - 534879m E 7144270m N
0
1
2
4
6
Kilometers
N
W
E
S
Snow & Dust Sampling Locations
● Dust Locations
Diavik Diamond Mines
Environment Department
Lac de Gras, Northwest Territories
2012
UTM Zone 12, Nad83
Diavik

Appendix F

Snow Survey Standard Operating Procedure

ENVIRONMENT
STANDARD OPERATING PROCEDURE

Area No.: **8000**
Document #: **ENVR-512-0213**
Revision: **0**
Task Title: **Snow Survey**
supersedes ENV SOP 512

FOR DOCUMENT CONTROL USE ONLY:
Next Review: **1 year from Area Manager Authorized Signature Date below**
Effective Date: **See Area Manager Authorized Signature Date below**

1 REFERENCES/RELATED DOCUMENTS

1.1 ENVR-501-0112 – SOP Remote Field Safety - Located in: Diavik Intranet – SOPs – Environment Folder

1.2 ENVR-602-0112 - SOP Snowmobile Operation - Located in: Diavik Intranet – SOPs – Environment Folder

1.3 ENVR-301-0112 - SOP General Laboratory Safety - Located in: Diavik Intranet – SOPs – Environment Folder

1.4 ENVR-303-0112 - SOP Quality assurance and Quality Control - Located in: Diavik Intranet – SOPs – Environment Folder

1.5 ENVR-206-0112 - SOP Chain of Custody and Sample Shipment - Located in: Diavik Intranet – SOPs – Environment Folder

1.6 ENVR-403-0112 - SOP Total Suspended Solids Analysis - Located in: Diavik Intranet – SOPs – Environment Folder

1.7 ENVI-099-1011- Snowmobile Inspection Checklist - Located in: P:\DDMI Environment\10.0 Operational Control\10.2 Forms\2012 Active Forms

1.8 ENVI-135-0112 R0 – Remote Field Safety Permit - Located in: P:\DDMI Environment\10.0 Operational Control\10.2 Forms\2012 Active Forms

1.9 ENVI-177-0312 R0 – Snow Sampling Field Sheet - Located in: P:\DDMI Environment\10.0 Operational Control\10.2 Forms\2012 Active Forms

Revision History

Revision	Revision Description	Date of Revision	Author
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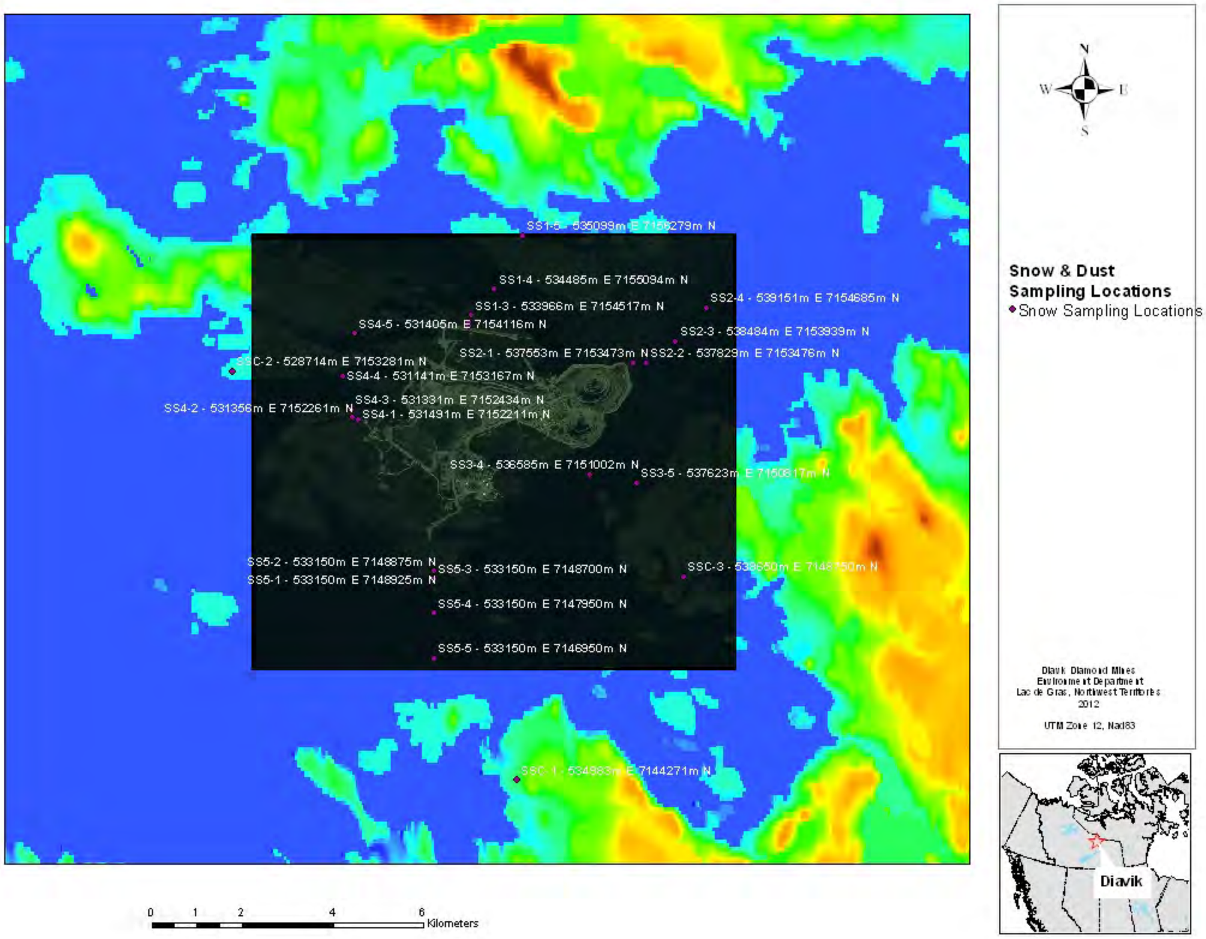
(Document owners will be prompted annually to update content, however, changes may or may not result.)



Snow Survey Sample Program Map

Description

Snow sampling at the Diavik Diamond Mine consists of snow core sampling to monitor dust deposition rates relative to predictions outlined in the DDMI Environmental Effects Report (1998), and snow water quality sampling in support of the DDMI Aquatic Effects Monitoring Program (AEMP).

2 PURPOSE

The purpose of this guide is to promote efficient and accurate snow surveying and to establish uniform sampling procedures.

3 SCOPE

3.1 Scope of Procedure

This standard operating procedure (SOP) describes the responsibilities and processes for collecting, documenting, and processing snow samples from at the Diavik mine site a surrounding Lac de Gras area (during ice cover). This procedure applies to all Diavik Diamond Mines personnel and contractor personnel authorized to collect samples under the current years Aurora Research Institute – Aquatic Effects Monitoring Program (AEMP) Research Permit.

3.2 Scope of Activities

This procedure has been developed to be consistent with the requirements of the AEMP design document and Environmental Effects Monitoring.

4 DEFINITIONS

4.1 QA/QC

- quality assurance/quality control. Methods undertaken to ensure sampling procedures and handling are accurate and precise. QA/QC can also refer to a type of sample used to assess field and laboratory performance, e.g. duplicate samples.

5 RESPONSIBILITIES

5.1 Environment Superintendent

It is the responsibility of the superintendent to ensure that satisfactory provisions for safety and health are made for remote field activities by:

- Instituting, maintaining and communicating this procedure and ensuring technical best practice requirements are properly incorporated;
- Ensuring that the responsibilities for safety and health are communicated to all participants;
- Ensuring that the risks associated with remote field activities are managed effectively;
- Providing appropriate information, instruction and training to all participants;

5.2 Environment Supervisor

The Environment Supervisor has a responsibility to ensure that:

- All personnel have read and understand the appropriate SOPs

- Ensuing proper tools are used for risk management (JHAs, Take5s, Hazard IDs)
- All legal requirements are followed
- All equipment and PPE required for the sampling program are available and have had the scheduled maintenance and repair completed
- The appropriate quality control/quality assurance practices are followed
- All personnel have completed the required training before completing the tasks assigned

5.3 Environment Technicians and contractors:

Each staff member, student and contractor has a moral and legal responsibility for ensuring that his or her work environment is conductive to good health, safety and environment practices by:

- Complying with all standard operating procedures;
- Undertaking relevant safety and health training;
- Reviewing and becoming familiar with all related documents and reference material;
- Taking action to eliminate, minimize, avoid and report hazards of which they are aware;
- Making proper use of all safety devices and PPE;
- Not placing at risk the safety and health of themselves or any others;
- Ensuring all equipment is maintained and in a safe working condition;
- Ensuring samples are obtained using proper quality assurance and control procedures;
- Attending and participating in daily Field Work Planning sessions;
- Documenting any safety or procedural issues that occur during the program.

6 PROCEDURE

6.1 Key HSEQ Aspects

Sampling requires physical labour in a cold environment with potentially inclement weather. All field personnel must be trained to recognize signs of frostbite, hypothermia, fatigue and heat stress; and avoid these symptoms with proper hydration, dress, and work schedules.

Due to the remote nature of sampling locations, all field personnel are to use extreme caution, and must be equipped with appropriate personal protective equipment. This may include cut resistant & latex gloves, hearing protection, safety glasses and emergency survival kits.

Field personnel must be competent, with appropriate training, skills and experience required to carry out the activities safely. Fieldwork requires an awareness of potential hazards and common sense. Under no circumstances should field work be conducted alone, and participants must always be aware of changing weather conditions.

Completion of a detailed Field Work Permit is mandatory prior to undertaking any off-site activities. The plan must be signed by all field personnel as well as the on-site supervisor, and a copy made available to the field crew as well as on-site staff.

Prior to initiating any off-site sampling programs, personnel must be familiar with the Remote Field Safety ENVR-501-0112

6.2 Planning

6.2.1 Program Management

The sampling snow survey will be completed annually in April. The survey design consists of 24 sample stations, including 3 control areas established along 5 transect lines originating from East Island and extending onto Lac de Gras.

Table 1 - Snowcore Sampling Locations

Transect Line	Station	UTM E (NAD 83)	UTM W (NAD 83)	Description
1	SS1-1	533911	7154288	Land
	SS1-2	533924	7154367	Land
	SS1-3	533966	7154517	Land
	SS1-4	534485	7155094	Ice
	SS1-5	535099	7156279	Ice
2	SS2-1	537553	7153473	Ice
	SS2-2	537829	7153476	Ice
	SS2-3	538484	7153939	Ice
	SS2-4	539151	7154685	Ice
3	SS3-4	536585	7151002	Ice
	SS3-5	537623	7150817	Ice
4	SS4-1	531491	7152211	Land
	SS4-2	531356	7152261	Land
	SS4-3	531331	7152434	Land
	SS4-4	531141	7153167	Ice
	SS4-5	531405	7154116	Ice
5	SS5-1	533150	7148925	Land
	SS5-2	533150	7148875	Land
	SS5-3	533150	7148700	Ice
	SS5-4	533150	7147950	Ice
	SS5-5	533150	7146950	Ice
	Control 1	534983	7144271	Land
	Control 2	528714	7153281	Land
	Control 3	538650	7148750	Land

6.2.2 Sampling Requirements – Dust Deposition

Dust deposition will be measured in-house using standard DDMI Total Suspended Solids laboratory procedures ENVR-403-0112. To facilitate this analysis, a composite sample comprised of a minimum of 3 snow cores will be collected at **ALL** (land and Ice) of the snow sampling stations. In areas with low snow pack a minimum of 35 SWE should be collected to a sufficient volume of water is available for processing. This may require more than the minimum 3 cores.

6.2.3 Sampling Requirements – Snow Water Quality

Snow water quality samples are required for all sample stations on Lac de Gras identified as **on-ice** locations, as well as at the **three control** areas Table 1 - Snowcore Sampling Locations. Snow chemistry analysis will be conducted by Maxxam Analytics. To facilitate the required analysis Table 2- Snow Water Quality Sample Requirements, a composite sample comprised of a minimum of 3 snow cores will be collected at all of the snow water quality stations.

Table 2- Snow Water Quality Sample Requirements

Maxxam Bottle	Analysis	Minimum Volume of Sample Required (ml)	Preservative
Metals	Total ICP Metals (Ultra Low)	120	1ml Nitric Acid – HNO_3
Nutrients	Ammonia	120	0.5 ml Sulfuric Acid
Routine	Sulfates, Nitrates, and Nitrites	1000	None Required
TSS, Turbidity & pH (Routine, 2nd Bottle)	TSS, Turbidity & pH	1000	None Required
Total Sample Volume Required		2240ml + 30% Triple Rinse	**3000ml = 100SWE**

Determining anticipated sample volume from Snow Water Equivalent (SWE)

Sample Water (ml) = SWE (cm) x 30(cm^2)

3000ml /30cm^2 = SWE = 100cm SWE

Therefore the aggregate SWE collected at a sample site must be at lease 100cm to ensure sufficient volume for water quality analysis.

6.3 Quality Assurance and Quality Control

Quality Control will be achieved through the use of duplicate and blank samples.

- Duplicate samples will be collected for a minimum 10% of the total samples (both Dust and Water Quality).

- At least **two** duplicate samples for the **dust** deposition samples
- At least **two** duplicate samples for the **water quality** samples
- One **equipment blank** will be collected and processed by Maxxam for water quality chemical analysis. Maxxam DI water batch number will be recorded on the field sheet. Equipment blank will be completed from a single batch of DI water. Ensure that information from the DI water is recorded on the field sheet. Batch ID and Expiry date.

Quality assurance will be achieved via the following processes;

- Field data sheets will be utilized to document any and all observations, or occurrences that may impact the integrity of the samples, as well as corrective actions implemented to deal with those occurrences.
- If a sample becomes compromised, it will be recorded on the field data sheet, the sample will be discarded and a new sample collected.
- Individuals collecting the samples will take precautions to eliminate sample contamination during handling. Avoid touching insides of sample bags, avoid contacting the snow samples with anything other than the sampling corer.

Steps will be taken prior to, during, and after sampling to ensure all samples are correctly labeled with the sample date, sample ID, and sample type.

6.4 Equipment Inspection & Preparation

Prior to commencing the sampling program, inspect all sampling equipment for fouling, contamination, or damage. All of the polyacrylic tubes that will be utilized will be rinsed with a 10% Nitric Acid solution to ensure they are clean prior to the initiation of the program.

Snow Corer – Inspect the core tube to ensure measurement etchings are legible. Check the cutting edge to ensure blade is not deformed or damaged. Inspect the handles and threads to ensure they will assemble and disassemble without binding. Ensure the corer has been de-contaminated (acid rinsed) prior to commencing the program.

Weighing Scale and Cradle – Inspect the scale and cradle for deformity or damage

Snowmobiles – Inspection and use of snowmobiles will be in accordance with ENVR-603-0112

Communication – Inspect all communication equipment (Radios/Sat Phones, Spot Personal Locator) to ensure they are operational and functional. Ensure batteries (including spares) are fully charged. Ensure check-in times and procedures are clearly identified on the Field Work Permit.

Navigation – Inspect GPS and spare batteries to ensure equipment is functioning correctly. Verify that all sample locations are present and correct, and that the GPS Essentials file is loaded. Ensure an appropriate map is present to allow navigation back to site should the GPS fail.

Personnel Gear – In addition to winter survival equipment, each individual participating in off-site activities is expected to carry appropriate personal gear and equipment as is deemed necessary for the individual well being in an emergency situation.

Survival Kit – Inspect survival kit and Ice Rescue kits to ensure that they are complete and all items are functional and ready for use.

Misc – Individual core samples will be compiled into plastic bags (soil sampling bags) and sealed with zip-ties until they are ready for processing. Prior to the program commencing bags must be inspected to ensure they are new and clean.

6.5 Tools Required

Table 3 - Tools and Gear Required

	Snow Corer & Handles		Snow Survey Map
	Transport Case		GPS & Waypoints
	Weighing Scale & Cradle		Satellite Phone
	Sample Collection Bags & Zip Ties		Spot Personal Locator
	Black Permanent Marker		Survival Kit
	Field Data Sheets (Pens/Pencils) & Clipboard		Ice Rescue Kit

6.6 Procedural Steps

6.6.1 Sample Collection

Navigate to the sampling locations – If the sample point falls on or immediately adjacent to the winter road adjusts your location to the nearest area with natural snow coverage (ie not impacted by the road or snow clearing).

Assemble the corer by threading the handles onto the tube, and re-inspect the snow corer for fouling and/or damage that may have occurred during transportation.

Fill in station location and weather information on the field data sheet. Identify snow conditions and dust observations in the comments section.

Prior to collecting a sample re-inspect the tube to check for cleanliness.
- **Take the weight of the empty snowcorer at each station prior to collecting any samples.**
- **For all station requiring snow water chemistry, collect the dust sample first – this will effectively rinse the corer with ambient snow minimizing cross contamination from locations.**

Hold the corer vertically (cutter end down) and drive it through the snow to the ground/ice surface below. Be sure the cutter contacts the ground/ice as compacted snow/ice may feel like the ground and result in an incomplete core.

Before raising the corer, read the depth of the snow (nearest cm) and record on the field datasheet.

Turn the corer at least one full turn to cut the core loose from the ground/ice surface. Carefully raise the corer and record the length of the core extracted. [Note: this could potentially be different from the depth of snow, see next]

Inspect the cutter end of the tube for dirt or litter, with gloves on carefully remove soil and litter from the core. If need be correct the length of the core extracted by subtracting the depth of the soil or litter (plug). Record adjusted core length and litter/soil observations on the field data sheet.

Carefully balance the corer containing the core on the weighing cradle.

- **Suspend the corer (like a pendulum) do not hold the corer tube or handles**

To ensure and accurate reading, gently tap the scale to be sure it is not sticking or binding.

Read the weight of the tube and core from the graduations on the scale. The scale is marked in cm of water.

Record the weight of the corer and the core to the nearest one-half cm.

To collect the core, lift the tube from the cradle and turn cutter und up. Gently tap the corer and the extracted core will slide out the top end. Be sure to use a clean/new sample bag to catch the core sample.

- **Ensure all sample bags are clearly labelled with the station ID, sample type, date, and number of cores included in the composite**
- **Ensure all bags are sealed using a clean zip-tie**

Weigh the empty sampling tube following the first and at least every fourth sample as the weight will change as small particle of water or snow accumulate/cling to the inside and outside of the tube and checking will make the data more accurate. Record the weight of the empty corer on the field data sheet.

Subtract the weight of the empty tube from the weight of the tube and core to obtain the water content of the sample.

Density calculations can be completed back in the lab following the completion of the program.

Density (g/cm^3) = Total SWE Collected (g/cm^{2*}) / Total Snow Core Length Collected (cm)

***assumes pure water density 1g/cm^3**

Prior to moving to the next sampling location ensure the field datasheet is complete.

6.6.2 Sample Processing

Prior to processing, all samples must be kept in a frozen state to minimize sample degradation.

When preparing the samples for decanting and analysis, remove the sample bags from the freezer. Check to ensure that the top of the bag is well twisted and the zip-tie is tight. Place the sample bag into a new (clean) sample bag and affix a zip-tie to seal the second bag. This double bagging will help to ensure no sample is lost during the melting process. To process samples, they will require anywhere from 12-36 hours to thaw at room temperature.

Place the sealed sample bags upright in clean coolers in the lab to thaw overnight.

Once a sample is completely melted it is ready for processing.

Sample volume can be determined using a scale accurate to 1g, set up scale, tare the sampling basin with two bags and 2 zip-ties. Place sample bags in the basin and record the weight of each of the bags on the field sheet.

Dust deposition samples will be processed in the DDMI Lab for TSS.

- **The entire volume of sample must be processed – this may require the use of multiple filters.**
- **For samples with large quantities of organics (twigs/leaves etc.) it may be necessary to sieve the sample through a course filter prior to processing.**
- **Given the possibility of the samples containing organic matter, sample filters will be dried in the high temperature oven (650°F) for 1hr to burn off any organics on the filter.**
- **Allow Samples to cool in the desiccator prior to weighing the filters.**

Snow Water Quality samples will be decanted to fill the appropriate (pre-labelled) Maxxam sample bottles as per standard water sampling procedures. Any excess sample water can be discarded.

6.6.3 Sample Chain of Custody

For all samples collected, a complete, accurate and clearly legible field data sheet must be filled out.

All samples collected must be logged in the Environment Sample Bible immediately following return to the office.

Results from DDMI Lab TSS analysis are to be recorded on the field sheet and electronically input into the MP5 database.

Prior to placing any field samples into the lab refrigerator or freezer for storage, field personnel must recheck all bag labels to ensure accuracy.

Prior to placing any Maxxam samples into the lab refrigerator for storage, personnel must recheck all bottle labels to ensure accuracy.

Samples will be shipped to Maxxam Analystics as per ENVR-206-0112 – CHAIN OF CUSTODY & SAMPLE SHIPPING – and accompanied by CoC documentation.

7 QUALITY OUTCOMES AND EXPECTATIONS

- Successful completion of the Snow Sampling program
- No safety or environmental incidents for the duration of the program
- No errors in sample labelling, shipping and analysis
- Thorough documentation on field datasheets, COCs and program sample schedule

APPENDIX II

EFFLUENT AND WATER CHEMISTRY REPORT

EFFLUENT AND WATER CHEMISTRY REPORT IN SUPPORT OF THE 2013 AEMP ANNUAL REPORT FOR THE DIAVIK DIAMOND MINE, NORTHWEST TERRITORIES

Submitted to:

Diavik Diamond Mines (2012) Inc.
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DISTRIBUTION

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EXECUTIVE SUMMARY

In 2013, Diavik Diamond Mines (2012) Inc. (DDMI) performed the field component of its Aquatic Effects Monitoring Program (AEMP) in Lac de Gras, Northwest Territories, as required by Water Licence W2007L2-0003 and according to the AEMP Study Design Version 3.0 approved by the Wek’èezhìi Land and Water Board (WLWB). This report presents the analyses of effluent and water chemistry data collected during the 2013 AEMP field sampling and from relevant stations in the Surveillance Network Program. Objectives of the water quality monitoring component of the AEMP were to assess effects of the Mine effluent on water quality in Lac de Gras.

Water quality variables were assessed for a Mine-related effect according to Action Levels in the response framework. Fifteen variables demonstrated an effect equivalent to Action Level 1. These consisted of conductivity, total dissolved solids [calculated], dissolved calcium, chloride, dissolved sodium, sulphate, ammonia, nitrate, aluminum, barium, chromium, molybdenum, silicon, strontium, and uranium. With near-field (NF) exposure area median concentrations greater than two times the median concentrations in reference areas, these 15 variables were identified as substances of interest (SOIs).

Each of the 15 SOIs that reached Action Level 1 also reached Action Level 2, which was applicable because the 75th percentile concentration in the NF exposure area exceeded the normal range for Lac de Gras. None of the SOIs reached Action Level 3, which is triggered when the 75th percentile concentration at the mixing zone is greater than the normal range plus 25% of the distance between the top of the normal range.

Statistically significant differences between the NF exposure area and far-field (FF) reference areas were detected for all 15 SOIs in one or both sampling seasons (ice-cover or open-water). Each of the SOIs had spatial patterns of decreasing concentration with distance from the Mine-effluent diffuser. These results indicate that that the effects observed in the NF area were related to the Mine water discharge.

Effluent toxicity testing indicated that the effluent was non-toxic, and regulated effluent variables were below applicable water licence discharge criteria for the 2013 monitoring period (November 2012 to October 2013).

LIST OF ACRONYMS AND ABBREVIATIONS

AL	Action Level
AEMP	Aquatic Effects Monitoring Program
ALS	ALS Laboratory Group
ANOVA	analysis of variance
CWQG	Canadian Water Quality Guidelines
CCME	Canadian Council of Ministers of the Environment
CFU	colony forming units
DDMI	Diavik Diamond Mines (2012) Inc.
DO	dissolved oxygen
DL	Detection Limit
EA	environmental assessment
EQC	effluent quality criteria
FF	far-field
HSD	honestly significant difference
HydroQual	HydroQual Laboratories
IC	inhibition concentration
KW	Kruskal Wallis
LC	lethal concentration
LDG	Lac de Gras
LDS	Lac du Sauvage
Maxxam	Maxxam Analytics Inc.
MF	mid-field
Mine	Diavik Diamond Mine
NF	near-field
NIWTP	North Inlet Water Treatment Plant
NTU	nephelometric turbidity unit
P	Probability
QA	quality assurance
QC	quality control
RPD	relative percent difference
SD	standard deviation
SNP	Surveillance Network Program
SOI	substance of interest
SOP	Standard Operating Procedure
TDS	total dissolved solids
TOC	total organic carbon
TP	total phosphorus
TSS	total suspended solids

US EPA	United States Environmental Protection Agency
UTM	Universal Transverse Mercator
WLWB	Wek'èezhìi Land and Water Board
WOE	weight-of-evidence

LIST OF UNITS

%	percent
<	less than
>	greater than
hr	hour
kg	kilogram
/month	per month
/yr	per year
km^2	square kilometre
m	metre
m^3/m	Cubic metres per month
mg/L	milligrams per litre
mg-NL	milligrams nitrogen per litre
mL	millilitre
µg/L	micrograms per litre
NTU	Nephelometric Turbidity Units
µS/cm	microSiemens per centimetre

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1 INTRODUCTION AND OBJECTIVES

1.1 BACKGROUND

In 2013, Diavik Diamond Mines (2012) Inc. (DDMI) completed the field component of its Aquatic Effects Monitoring Program (AEMP), as required by Water License W2007L2-0003 (WLWB 2007). This report presents the analysis of effluent and water chemistry data collected during the 2013 field program, which was carried out by DDMI according to the AEMP Study Design Version 3.0 (Golder 2011a). Details on methodology are provided in Section 2.

The assessment of effects was based on the updated Version 3.3 Study Design (Golder 2014a), which was approved by the Wek'èezhìi Land and Water Board (WLWB) on February 19, 2014 (WLWB 2014). Section 3 provides results of the assessment, while Section 4 provides a discussion of the results. Conclusions, together with recommendations for program changes or enhancements, are provided in Section 5.

1.2 OBJECTIVES

Substances released from the Diavik Diamond Mine (Mine) must enter the water of Lac de Gras before aquatic organisms can become exposed to the material and, consequently, potentially be affected by this material. Water quality represents a valuable early warning measurement endpoint to identify potential effects to aquatic biota in Lac de Gras. The objective of the water quality monitoring component of the AEMP is to assess the effects of Mine effluent on water quality in Lac de Gras. Water chemistry data were analyzed to determine whether there were differences in water quality between areas exposed to Mine effluent and reference areas.

1.3 SCOPE AND APPROACH

The focus of the assessment for the annual report is a spatial analysis, whereby areas of the lake exposed to effluent are compared to areas of the lake that are not exposed to effluent (i.e., reference areas). Temporal analyses and an assessment of trends over time will be provided in the next three-year summary report (to be submitted by October 15, 2014).

Water quality variables were assessed for a Mine-related effect according to the Action Level framework described for water chemistry in the AEMP Study Design Version 3.3 (Golder 2014a). The magnitude, extent, and importance of an effect are defined in the Action Level categories. The full suite of water quality variables analyzed in 2013 was included in the Action Level screening. Field measurements (i.e., depth profile data) are discussed qualitatively, and nutrients (phosphorus and nitrogen) are evaluated in the Eutrophication Indicators report (Golder 2014b).

The results of the Action Level screening were used in combination with an assessment of chemicals in effluent to identify a subset of variables with potential Mine-related effects. These variables are called Substances of interest (SOIs). The intent of defining SOIs was to identify a meaningful set of variables that will undergo further analyses, while limiting analyses on variables that were less likely to be affected.

Substances of interest were evaluated for the presence of spatial differences over the lake. Greater concentrations in exposure areas relative to reference areas was confirmation that the changes observed in the NF area were likely related to the Mine water discharge. Substances of interest were compared statistically between the near-field (NF) exposure area and far-field (FF) reference areas to determine whether concentration increases seen in the NF area were related to the Mine (i.e., demonstrated a statistically-significant difference) or whether they may have occurred by chance.

2 METHODS

2.1 FIELD SAMPLING

The water quality field sampling program included the collection of *in situ* water quality measurements and of water samples for chemical analysis. Water column profile measurements were collected at all AEMP stations using multi-parameter water quality meters (Hydrolab and YSI) following the methods described in DDMI's Standard Operating Procedure (SOP), ENVR-608-0112 "Hydrolab Calibration, Deployment and Download." Collection of water samples followed the protocols described in ENVR-014-0311 "AEMP Sampling – Ice Cover" and ENVR-003-0702 "AEMP Monitoring Program (Open Water)". Water samples were handled according to ENVR-303-0112 "Laboratory Quality Assurance/Quality Control" and ENVR-206-0112 "Processing Maxxam Samples and Tracking Documentation."

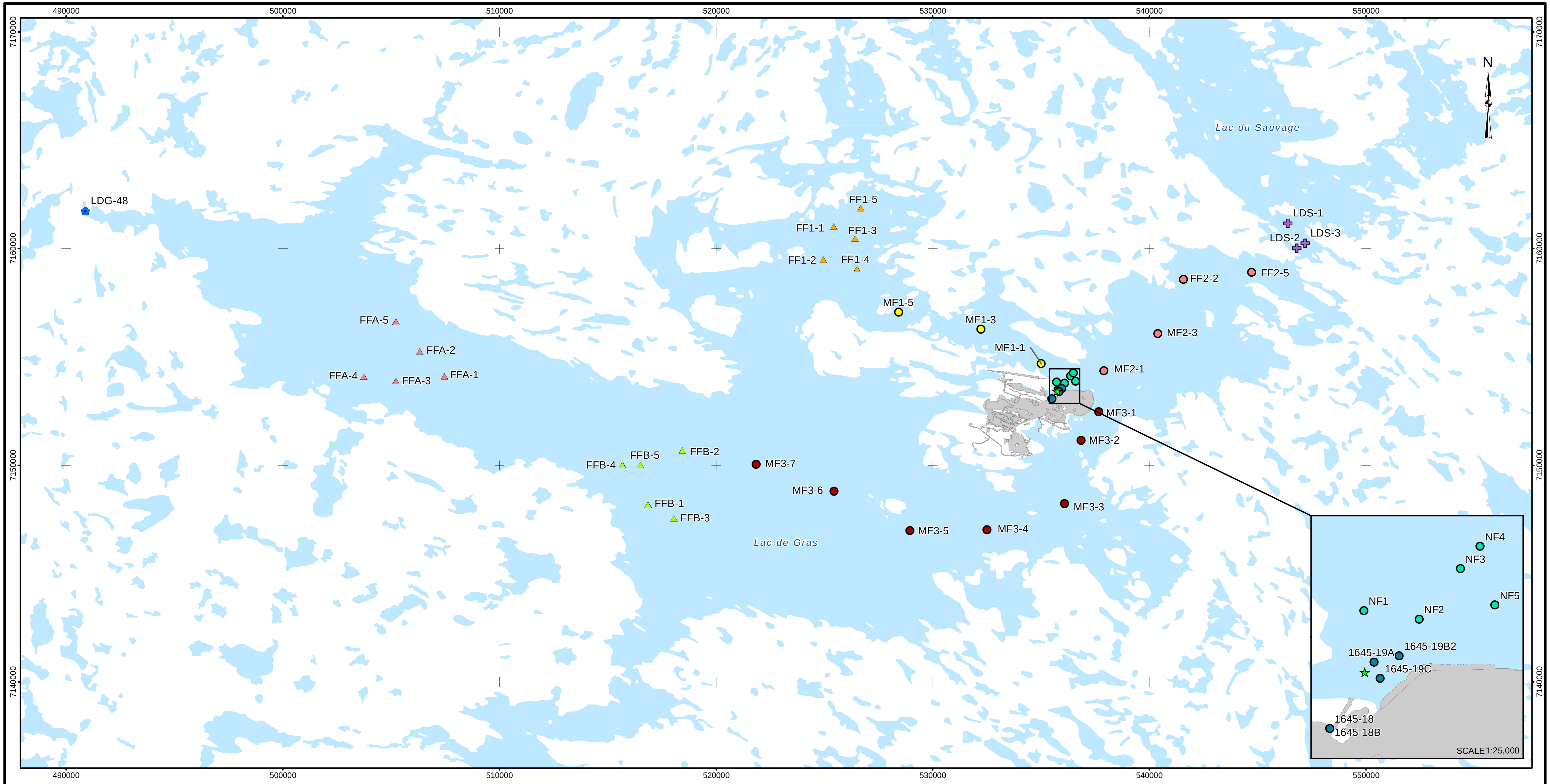
Data from the Surveillance Network Program (SNP) were incorporated into the 2013 AEMP report. The SNP included the sampling of treated effluent approximately every six days. Sampling is conducted at the discharge point from the North Inlet Water Treatment Plant (NIWTP; SNP 1645-18), which discharged continuously to Lac de Gras throughout the 2013 monitoring period. An additional discharge monitoring Station (SNP 1645-18B) provided data for the second diffuser in Lac de Gras, which became operational on September 13, 2009. Discharge records are available for this station at the same frequency as for Station SNP 1645-18. The period of effluent discharge summarized in this report included information collected from November 1, 2012 to October 31, 2013 at stations SNP 1645-18 and SNP 1645-18B.

Stations SNP 1645-19a, 1645-19b2, and 1645-19c represent the mixing zone boundary of NIWTP effluent in Lac de Gras, and are located along a semicircle defined by a 60-m radius from the diffusers. Station 1645-19b2 was established to replace Station 1645-19b after the second diffuser became active in Lac de Gras. It maintains the 60-m radius from the diffusers. Samples were collected monthly at these stations, as required by the water license, for the duration of the 2013 monitoring period (November 1, 2012 to October 31, 2013).

Water quality sampling at AEMP stations in 2013 was carried out during the comprehensive monitoring program, which is undertaken every third year (Golder 2011a). Sampling areas consisted of the near-field exposure area (NF), the far-field exposure area (FF2), and three reference areas (FF1, FFA, and FFB) (Table 2-1, Figure 2-1). In addition, three mid-field areas (MF1, MF2, and MF3) were located along three transects between the NF and FF study areas. The study design incorporated clusters of replicate stations in each area of the lake (Golder 2011a). Five stations were sampled in the NF exposure area and in each of the three FF reference areas. Two stations were located in each of the FF2 and MF2 exposure areas, three stations within the MF1 area, and seven stations within the larger MF3 area. The AEMP stations were located where water depths were approximately 20 m. Three stations located near the outflow of Lac du Sauvage (LDS-1. LDS2, LDS-3) were also sampled in 2013 (Figure 2-1). One additional station located at the Lac de Gras outflow to the Coppermine River (LDG48) was also sampled. Coordinates of the AEMP stations, and their approximate distance from the diffuser by flow path, are provided in Table 2-1.

The AEMP water quality sampling was carried out over two monitoring periods: ice-cover and open-water. Ice-cover season (late winter) sampling was completed from April 10 and April 19, 2013. Open-water sampling was completed from August 18 September 7, 2013. The same sampling locations were sampled in each sampling season. In total, water quality samples were collected from 19 exposure area stations and at 15 reference area stations. Depth profile sampling was completed at each exposure and reference station. A detailed sampling schedule for the 2013 AEMP is provided in Appendix A, Table A-1.

The exposure stations (NF, MF, and FF2 areas) were sampled at three depths (top, middle, and bottom) during each season, as these were the stations most likely to have vertical gradients in water quality as a result of the Mine discharge. Near-surface water samples (top) were collected at a depth of 2 m below the water surface, and bottom samples were collected at 2 m above the lake bottom. Mid-depth samples were collected from the mid-point of the total water column depth. Far-field reference stations (FF1, FFA, and FFB areas), station LDG-48, and stations LDS-1, LDS-2, and LDS-3 were sampled at mid-depth only.



LEGEND

★	DIFFUSER
EXPOSURE	
●	NEAR-FIELD
●	MID-FIELD 3
●	MID-FIELD 1
●	FAR-FIELD 2; MID-FIELD 2
●	SURVEILLANCE NETWORK PROGRAM
REFERENCE	
▲	FAR-FIELD 1
▲	FAR-FIELD A
▲	FAR-FIELD B
✚	LAC DU SAUVAGE
⬟	LDG 48
▨	DIAVIK FOOTPRINT
▨	WATERBODY

5 0 5

SCALE 1:175,000 KILOMETRES

REFERENCE

HYDROGRAPHY DATA OBTAINED FROM CANVEC © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 12 DATUM: NAD 83

I:\2011\11-1328\11-1328-0038\Mapping\MXD\2013AEMP\FINAL\Fig2_1_2013_AEMP_WaterQualitySampling_20140221_Final.mxd

PROJECT

DIAVIK DIAMOND MINES INC.

TITLE

WATER QUALITY SAMPLING STATIONS, 2013 AEMP

Golder Associates

PROJECT		13-1328-0001	FILE No.	
DESIGN	LJ	28 Jan. 2014	SCALE AS SHOWN	REV. 0
GIS	JC	20 Mar. 2014	FIGURE: 2-1	
CHECK	TD	20 Mar. 2014		
REVIEW	CF	20 Mar. 2014		

Table 2-1 Locations of the 2013 AEMP Water Quality Monitoring Stations

Area Type	Area	Station	Easting (UTM)	Northing (UTM)	Distance from Diffuser$^{(a)}$ (m)
Exposure	Near-field	NF1	535740	7153854	394
		NF2	536095	7153784	501
		NF3	536369	7154092	936
		NF4	536512	7154240	1,131
		NF5	536600	7153864	968
	Mid-field 1	MF1-1	535008	7154699	1,452
		MF1-3	532236	7156276	4,650
		MF1-5	528432	7157066	8,535
	Mid-field 2	MF2-1	538033	7154371	2,363
		MF2-3	540365	7156045	5,386
	Mid-field 3	MF3-1	537645	7152432	2,730
		MF3-2	536816	7151126	4,215
		MF3-3	536094	7148215	7,245
		MF3-4	532545	7147011	11,023
		MF3-5	528956	7146972	14,578
		MF3-6	525427	7148765	18,532
		MF3-7	521859	7150039	22,330
	Far-field 2	FF2-2	541588	7158561	8,276
		FF2-5	544724	7158879	11,444
Reference	Far-field 1	FF1-1	525430	7161043	13,571
		FF1-2	524932	7159476	12,915
		FF1-3	526407	7160492	12,788
		FF1-4	526493	7159058	11,399
		FF1-5	526683	7161824	12,823
	Far-field A	FFA-1	506453	7154021	36,769
		FFA-2	506315	7155271	38,312
		FFA-3	505207	7153887	38,734
		FFA-4	503703	7154081	40,211
		FFA-5	505216	7156657	39,956
	Far-field B	FFB-1	516831	7148207	26,355
		FFB-2	518473	7150712	24,991
		FFB-3	518048	7147557	25,245
		FFB-4	515687	7150036	27,591
		FFB-5	516533	7150032	26,761
Lac du Sauvage		LDS-1	546398	7161179	-
		LDS-2	546807	7160027	-
		LDS-3	547191	7160256	-
Outlet of Lac de Gras		LDG-48	490900	7161750	-

Notes: UTM = Universal Transverse Mercator, NAD83, Zone 12V; m = metre.

a) Approximate distance from the diffuser along the most direct path of effluent flow.

2.2 LABORATORY ANALYSES

Water samples were shipped to Maxxam Analytics, Burnaby, British Columbia (Maxxam) for analysis of general parameters, major ions, nutrients and total metals. A list of the variables analyzed and the analyte-specific DLs used by Maxxam in 2013 are provided in Table 2-2.

Table 2-2 Detection Limits for Water Quality Analysis, 2013 AEMP

Variable	Unit	DL	Variable	Unit	DL
Conventional Parameters			**Metals (Total)**		
Acidity (pH 4.5)	mg/L	0.5	Aluminum	µg/L	0.2
Acidity (pH 8.3)	mg/L	0.5	Antimony	µg/L	0.02
Total Alkalinity	mg/L	0.5	Arsenic	µg/L	0.02
Alkalinity (PP as CaCO3)	mg/L	0.5	Barium	µg/L	0.02
Specific Conductivity	µS/cm	1	Beryllium	µg/L	0.01
Dissolved Hardness (CaCO3)	mg/L	0.5	Bismuth	µg/L	0.005
Hardness	mg/L	0.5	Boron	µg/L	5
pH	pH Units	0.01	Cadmium	µg/L	0.005
Total Dissolved Solids (Calculated)	mg/L	0.5	Calcium	mg/L	0.01
Total Dissolved Solids (Measured)	mg/L	1	Chromium	µg/L	0.05
Total Suspended Solids	mg/L	1	Cobalt	µg/L	0.005
Total Organic Carbon	mg/L	0.2	Copper	µg/L	0.05
Turbidity	NTU	0.1	Iron	µg/L	1
Major Ions			Lead	µg/L	0.005
Bicarbonate	mg/L	0.5	Lithium	µg/L	0.5
Calcium	mg/L	0.01	Magnesium	mg/L	0.01
Carbonate	mg/L	0.5	Manganese	µg/L	0.05
Chloride	mg/L	0.5	Mercury	µg/L	0.01
Fluoride	mg/L	0.01	Molybdenum	µg/L	0.05
Hydroxide	mg/L	0.5	Nickel	µg/L	0.02
Magnesium	mg/L	0.01	Potassium	mg/L	0.01
Potassium	mg/L	0.01	Selenium	µg/L	0.04
Sodium	mg/L	0.01	Silicon	µg/L	50
Sulphate	mg/L	0.5	Silver	µg/L	0.005
Nutrients			Sodium	mg/L	0.01
Ammonia (as Nitrogen)	µg/L	5	Strontium	µg/L	0.05
Nitrate (as Nitrogen)	µg/L	2	Sulphur	mg/L	0.1
Nitrite (as Nitrogen)	µg/L	2	Thallium	µg/L	0.002
Nitrate + Nitrite (as Nitrogen)	µg/L	2	Tin	µg/L	0.01
Nitrogen - Kjeldahl	µg/L	20	Titanium	µg/L	0.5
Total Nitrogen	µg/L	20	Uranium	µg/L	0.002
Orthophosphate	µg/L	1	Vanadium	µg/L	0.1
Phosphorus - Dissolved	µg/L	2	Zinc	µg/L	0.1
Phosphorus - Total	µg/L	2	Zirconium	µg/L	0.05

Notes: DL = detection limit; mg/L = milligrams per litre; µS/cm = microSiemens per centimetre; NTU = nephelometric turbidity units; µg/L = micrograms per litre; - = not available.

2.3 QUALITY ASSURANCE/QUALITY CONTROL

The Quality Assurance Project Plan (QAPP) outlines the quality assurance (QA) and quality control (QC) procedures employed to support the collection of scientifically-defensible and relevant data addressing the objectives of the AEMP (Golder 2013a). The QAPP represents an expansion of the SNP QA/QC plan. It helps with the creation of a technically-sound and scientifically-defensible report by standardizing field sampling methods, laboratory analysis methods, data entry and storage, data analysis and report preparation activities.

2.3.1 2013 Open-water Sample contamination

In 2013, DDMI identified abnormal results in effluent and lake water samples. A detailed investigation of laboratory and site-based procedures revealed that a batch of nitric acid preservative issued by Maxxam was contaminated. Samples found to be contaminated had elevated concentrations of seven total metals (chromium, molybdenum, nickel, cadmium, cobalt, iron, and manganese). The anomalous values were first identified for SNP samples which are screened against various QA/QC checks performed by DDMI's internal database. These abnormal values, however, would have also been detected by QC analyses required under the QAPP had these initial screening tools not been in place. The SNP and AEMP samples that were affected by the contamination included 36% (*n* = 21 of 55) of effluent samples (SNP 1645-18 and SNP1645-18b), 47% (*n* = 24 of 51) of mixing zone samples (SNP 1645-19A, 1645-19B2 and 1645-19C) and 82% (*n* = 69 of 84) of AEMP samples collected during the open-water season in 2013. Samples collected during the ice-cover season were not affected. These seven metals were removed from the 2013 AEMP and SNP datasets for samples identified as contaminated. The methods used to identify and remove the metals data affected by the contamination are discussed in Appendix B.

2.3.2 Quality Control Review

A description of QA/QC practices applied to the water quality component of the 2013 AEMP and an evaluation of the QC data are provided in Appendix C. A brief summary of the QA/QC review is provided here. Quality assurance and quality control procedures specific to water quality included collection of field blanks, trip blanks, equipment blanks and duplicate samples at selected stations during the ice-cover and open-water sampling seasons. These samples constituted about 11% (*n* = 16) of the total number of samples collected during the 2013 AEMP (*n* = 152 samples) and were analyzed for the full suite of water quality variables listed in Table 2-2.

An initial review of the ice-cover dataset indicated that the sample collected at the top depth at station NF1 (sample NF1T) for dissolved metals analysis had likely been interchanged with the equipment blank prepared at that location (sample NF1T-1).

The results for these two samples were substituted in the interest of retaining the data. An additional sample collected at station MF1-T during the ice-cover season was clearly contaminated and was removed from the dataset. A review of the analytical data and discussion with the laboratory suggested that sample bottles intended for specific analyses may have been preserved with the wrong types of preservative. The exact cause of the issue, however, remains unclear. Several other analytical results were identified as visual outliers and were not used in the data analyses or the development of figures. A list of visual outliers and the methods used to identify these values are provided in Appendix C.

Possible contamination occurred with six analytes measured in blank samples (total dissolved solids [TDS], total Kjeldahl nitrogen [TKN], total nitrogen [TN], ammonia, aluminum and zinc), which had concentrations greater than five times the DL in at least one blank sample (Table C-1). Of the six analytes that exceeded the data quality objective (DQO) for blank samples, four variables (TDS, TKN, TN and aluminum) had concentrations in the blanks that were generally 5 to 10 times lower than values reported in 2013 for Lac de Gras. Two variables (zinc and ammonia) were present at similar concentrations in the blank samples and in the lake water samples. Of these, only ammonia was clearly elevated both in the blanks and in the AEMP data. This is consistent with the QC analyses completed over the previous two years of the AEMP (2011 and 2012). In all three years (2011, 2012, and 2013), ammonia concentrations in blank samples analyzed by Maxxam were at or above levels in Lac de Gras, while the concentrations reported for lake water samples were elevated compared to historic values. The quality of the ammonia data provided by Maxxam was improved in 2013 when compared with the results reported in 2011 and 2012, since there were fewer QC failures and lake water concentrations were generally not as high as those reported in 2011 and 2012; however, the concentrations at many stations remained well above historical values, particularly during the open-water season. The 2013 data reported by Maxxam were retained in all SNP and AEMP analyses; however, the ammonia results were interpreted with the understanding that the reported concentrations are likely greater than the true concentrations.

All five duplicate samples had relative percent differences (RPDs) in the concentration of one or more analyte that were greater than 20% (Appendix C, Table C-2). Eleven different analytes (total alkalinity, TDS [measured], bicarbonate, nitrate, TN, TKN, copper, nickel, sulphur, tin, and zinc) exceeded this criterion; however, with the exception of zinc, they did so in only one of the five duplicates. Zinc had RPDs of greater than 20% in three of the duplicate samples. Given that QC objective values used by Maxxam to identify unacceptable differences between laboratory duplicate samples are RPDs ranging from 20% to 25%, differences between duplicate field samples were only considered notable when RPDs were greater than 50%. One set of duplicates had two variables (TN and TKN) with RPDs >50%, and two sets of duplicates had one variable each (tin or zinc) with RPDs greater than 50%.

2.4 DATA ANALYSIS AND INTERPRETATION

2.4.1 Overview and Substances of Interest

Initial data analyses with all chemical analytes were conducted to identify Substances of Interest (SOIs), which are a subset of variables with the potential to show Mine-related effects. The intent of defining SOIs was to identify a meaningful set of variables that will undergo further analyses, while limiting analyses on variables that were less likely to be affected. The process of developing the list of SOIs considered concentrations in the final effluent (SNP 1645 18 and SNP 1645 18B), as well as in the fully-mixed exposure area of Lac de Gras:

- Effluent chemistry data collected at stations SNP 1645 18 and SNP 1645 18B were first compared to Water License discharge limits (Section 2.4.3). Variables that exceeded limits were considered SOIs.
- Water quality variables were assessed according to the Action Level framework (Section 2.4.7). Variables that triggered Action Level 1 were added to the SOI list.

The following analyses were conducted on SOIs:

- Examination of effluent loads (Section 2.4.3);
- Examination of water chemistry at the edge of the mixing zone (Section 2.4.6);
- Assessment of magnitude and extent of effects, as defined by the Action Levels (Section 2.4.7); and
- Statistical testing between the NF and FF reference areas to determine whether concentrations in the NF area were significantly greater than those in reference areas (Section 2.4.8).

2.4.2 Data Handling

As part of our QA/QC procedures, raw effluent and water quality data were screened for inaccurate entries, missing information, and potential outliers. Outlier values were identified based on a visual assessment of plots prepared for each variable. Outliers deemed to be errors were removed from the data set. Additional information about the outlier detection method and handling is provided in Appendix C. Results from duplicate samples were averaged prior to data analysis.

Values below the DL were assumed to follow the distribution of the data that were above the limit of detection. A reasonable assumption regarding the location of the non-detect data along the distribution curve would be at the location demarcating 50% of the area of the curve to the left of the DL; this value was estimated by multiplying the limit of detection by 0.71 (Roger Green, University of Western Ontario, personal communication). Guidance provided by the United States Environmental Protection Agency (US EPA 2000) for replacing non-detectable data were considered; however, most of their recommended approaches, such as trimmed mean, Cohen's adjustment or Winsorized mean, were not suitable for this data set. Therefore, the 0.71 × DL approach was applied to all non-detect values.

2.4.3 Effluent Quality and Quantity

The effluent discharge from the NIWTP to Lac de Gras was evaluated in terms of quality and quantity. The quality of the effluent was assessed by comparing water chemistry results with the discharge criteria defined in the Water Licence (Table 2-3). The comparison of phosphorus to discharge criteria is discussed in the Eutrophication Indicators Report (Golder 2014b). Analytes with maximum average and maximum grab sample concentrations greater than Water Licence discharge limits were included as SOIs. Variables with effluent concentrations that exceeded AEMP Effects Benchmarks (defined in Section 2.4.7.2) were also included in the SOI list, provided there was not a high percentage (>90%) of values below the DL.

Effluent quantity was evaluated graphically by plotting total monthly loads of SOIs as bar charts. The daily load was calculated by multiplying the discharge rate by the concentration for each effluent diffuser station (SNP 1645-18 and SNP 1645-18B) separately. Linear interpolation was used to estimate the concentrations between sampling events. The total load was calculated as the sum of loads from the two diffusers. Mean daily loads for each month and year were estimated from the daily results. The period of effluent discharge summarized in this report included information collected from November 1, 2012, to October 31, 2013, at stations SNP 1645-18 and SNP 1645-18B.

Table 2-3 Effluent Quality Criteria for the North Inlet Water Treatment Plant Discharge to Lac de Gras

Variable	Units	Maximum Average Concentration	Maximum Sample Concentration
Total ammonia	µg/L	6000	12000
Total aluminum	µg/L	1500	3000
Total arsenic	µg/L	50	100
Total copper	µg/L	20	40
Total cadmium	µg/L	1.5	3
Total chromium	µg/L	20	40
Total lead	µg/L	10	20
Total nickel	µg/L	50	100
Total zinc	µg/L	10	20

Table 2-3 Effluent Quality Criteria for the North Inlet Water Treatment Plant Discharge to Lac de Gras

Variable	Units	Maximum Average Concentration	Maximum Sample Concentration
Nitrite	µg/L	1000	2000
Total suspended solids	mg/L	15	25
Turbidity	NTU	10	15
Biochemical oxygen demand	mg/L	15	25
Oil and grease	mg/L	3	5
Fecal coliforms	CFU/100 mL	10	20

Notes: mg/L = milligrams per litre; NTU = nephelometric turbidity unit; CFU = colony forming unit; mL = millilitre.

2.4.4 Effluent Toxicity

Part H, Item 7 of the Water Licence (W2007L2-0003) requires a determination of the toxicity of effluent discharged to Lac de Gras. The following testing is required on a quarterly basis:

- acute lethality to Rainbow Trout, *Oncorhynchus mykiss*, as per Environment Canada’s Environmental Protection Series Biological Test Method EPS/1/RM/1 3;
- acute lethality to the crustacean *Daphnia magna* as per Environment Canada’s Environmental Protection Series Biological Test Method EPS/1/RM/1 4;
- chronic toxicity to the amphipod *Hyalella azteca* as per a water-only protocol approved by the WLWB;
- sub-lethal toxicity to Rainbow Trout, *Oncorhynchus mykiss*, as per Environment Canada’s Environmental Protection Series Biological Test Method EPS/1/RM/28;
- sub-lethal toxicity to the freshwater alga *Pseudokirchneriella subcapitata* as per Environment Canada’s Environmental Protection Series Biological Test Method EPS/1/RM/25; and
- sub-lethal toxicity to the crustacean *Ceriodaphnia dubia* as per Environment Canada’s Environmental Protection Series Biological Test Method EPS/1/RM/12.

Acute lethality and sub-lethal toxicity tests were conducted by HydroQual Laboratories Ltd. (HydroQual) in Calgary, AB. Chronic lethality testing using the amphipod *Hyalella azteca* was conducted by Maxxam Analytics, Yellowknife, NT.

2.4.5 Effluent Distribution

Barium has been used as a tracer element of the Mine effluent for many years. Barium was selected as a tracer because it is a relatively conservative water quality variable (meaning it is not degraded in the environment and tends to remain in solution, once dissolved) and its concentration in the NIWTP effluent is relatively high compared to the background concentration in Lac de Gras. Barium concentrations in Lac de Gras were used to verify and better define the exposure of each area to Mine effluent.

Barium concentrations at exposure and reference stations during the ice-cover sampling program in 2013 were plotted against distance from the diffusers to illustrate the spatial pattern of effluent exposure in Lac de Gras. Barium concentrations were compared to the historical normal range, which is defined as the 2007-2010 reference area mean concentration plus or minus (±) two standard deviations (SD; see Section 2.4.7.1). Areas with barium concentrations that exceeded the normal range were considered to be exposed to effluent from the Mine.

2.4.6 Water Chemistry at the Edge of the Mixing Zone

Water quality samples were collected monthly at the edge of the mixing zone, as per the conditions of the Water Licence, using the methods described in Section 2.1. The mixing zone sampling program included three stations that were monitored as part of the SNP; SNP 1645-19a, SNP 1645-19b2 and SNP 1645-19c. The Water Licence requires that samples be collected at the surface and at 5-m intervals to depth (i.e., greatest depth rounded to 5-m intervals) at each station. The concentrations of SOIs and key indicators of eutrophication (Golder 2014b) at the mixing zone were plotted according to sample depth. Water chemistry results at the edge of the mixing zone were also evaluated in the screening for Action Levels (Section 2.4.7).

2.4.7 Magnitude of Effect and Action Levels

Water quality variables were assessed for a Mine-related effect according to the Action Level Framework described for water chemistry in the AEMP Study Design Version 3.3 (Golder 2014a). The Action Level classifications were developed to meet the goals of the Response Framework for Aquatic Effects Monitoring which was drafted by the WLWB (WLWB 2010; Racher et al. 2011). The main goal of the Response Framework is to ensure that significant adverse effects never occur. This is accomplished by requiring proponents to take actions at predefined Action Levels, which are triggered well before significant adverse effects could occur. A significant adverse effect, as it pertains to water quality, was defined in the Environmental Assessment as a concentration that exceeds an established guideline by more than 20% (Government of Canada 1999). This effect must have a high probability of being permanent or long-term in nature and must occur throughout Lac de Gras.

Water quality is assessed annually to evaluate effects according to the Action Levels for Water Chemistry (Golder 2014a). Magnitude of effects will be determined by comparing analyte concentrations between exposure areas and reference areas, background values or benchmark values. Background values for Lac de Gras are those that fall within the normal range, which is defined as the historical reference area mean ± 2 SD. The magnitude of the effect was classified according to the appropriate Action Level (Table 2-4), with Action Level 9 representing a significant adverse effect.

The full suite of water chemistry variables analyzed in 2013 was initially evaluated, with the exception of pH (which is assessed qualitatively in Section 3.4) and nutrients such as phosphorus and nitrogen (which are evaluated in the Eutrophication Indicators Report [Golder 2014b]). Effects were assessed separately for the ice-cover and open-water seasons. The open water and ice-cover seasons for the mixing zone dataset were based on conditions in a typical year. The ice-cover season for the mixing zone was from November to June, while the open-water season was from July to October. The results for all depths and stations sampled both at the mixing zone and at AEMP stations were included in the calculation of the exposure area values considered at each Action Level (Table 2-4). Variables with effects that reached Action Level 1 or greater in either sampling season were classified as a SOI.

Box and whisker plots were created for SOIs to illustrate spatial variation in water quality variable concentrations within Lac de Gras. Box and whisker plots show the minimum value, 25th percentile, median, 75th percentile, and maximum values in each area. The 5th and 95th percentile concentrations are also shown. The box and whisker plots also show results relative to Action Level values.

2.4.7.1 Background Values and the Normal Range

The background values used in the Action Level assessment were based on reference area concentrations within Lac de Gras. The reference area criterion used at Action Level 1 was defined in terms of the FF reference area median concentration (Table 2-4). Background concentrations at Action Levels 2, 3 and 4, are those that fall within the normal range for Lac de Gras. Owing to the potential for effluent to reach the FF reference areas, background values (i.e., reference area median concentrations and normal ranges) were calculated using reference area data collected during the AEMP Version 2.0 (2007-2010) when those data were available. For some variables, the normal range had to be calculated from more recent data. Improvements to the analytical DLs since the AEMP Version 2.0 required that some normal ranges and reference area median values be calculated using more recent data. This was necessary only when the FF reference area data from the AEMP Version 2.0 consisted of a large proportion of non-detect values (typically >50% of values) and the DL used during that period was greater than the concentrations reported in 2013. Other variables that used reference criteria based on more recent AEMP data included variables that were analyzed for the first time in 2011 or in 2013 (Appendix D, Table D-1). In general, these variables were added as a result of the change in analytical laboratories in 2011 from ALS Environmental, Edmonton, Alberta, to Maxxam.

Background values were calculated separately for open-water and ice-cover sampling seasons. Calculations for the open-water season used data collected during the sample dates that correspond with the open-water period for the AEMP Version 3.3 (i.e., August 15 to September 15).

Table 2-4 Action Levels for Water Chemistry, Excluding Indicators of Eutrophication

Action Level	**Magnitude of Effect**[(a)]	**Extent of Effect**	**Action/Notes**
1	Median of NF greater than 2X median of reference areas (open water or ice cover) and strong evidence of link to Mine	NF	Early warning.
2	75th percentile of NF values greater than normal range	NF	Establish *Effects Benchmark* if one does not exist.
3	75th percentile of mixing zone (MZ) values greater than normal range plus 25% of Effects Benchmark[b]	MZ	Confirm site-specific relevance of Effects Benchmark. Establish *Effects Threshold*. Define the Significance Threshold if it does not exist. The WLWB to consider developing an Effluent Quality Criteria (EQC) if one does not exist
4	75th percentile of MZ values greater than normal range plus 50% of Effects Threshold(b)	MZ	Investigate mitigation options.
5	95th percentile of MZ values greater than Effects Threshold	MZ	The WLWB to re-assess EQC. Implement mitigation required to meet new EQC if applicable.
6	95th percentile of NF values greater than Effects Threshold + 20%	NF	The WLWB to re-assess EQC. Implement mitigation required to meet new EQC if applicable.
7	95th percentile of MF values greater than Effects Threshold + 20%	MF	The WLWB to re-assess EQC. Implement mitigation required to meet new EQC if applicable.
8	95th percentile of FFB values greater than Effects Threshold + 20%	FFB	The WLWB to re-assess EQC. Implement mitigation required to meet new EQC if applicable.
9	95th percentile of FFA values greater than Effects Threshold + 20%	FFA	Significance Threshold.

a) Calculations are based on pooled data from all depths and stations.

b) Indicates 25% or 50% of the difference between the benchmark/threshold and the top of the normal range.

2.4.7.2 Effects Benchmarks

The water quality benchmark values used in the Action Level screening (i.e., at Action Level 3) are the AEMP Effects Benchmarks presented in the Version 3.3 Study Design (Table 5.4-1 in Golder 2014a). The Effects Benchmarks adopted for the AEMP are consistent with those used in the Project Environmental Assessment (Government of Canada 1999) and are based on the Canadian Water Quality Guidelines (CWQGs) for the protection of aquatic life (CCME 1999), the Canadian Drinking Water Quality Guidelines (Health Canada 1996, 2006) and adaptations of general guidelines to site-specific conditions at Lac de Gras (Appendix IV.1 in DDMI 2007). These benchmarks represent concentrations intended to protect human health or aquatic life. The benchmarks for individual water chemistry variables were updated in the AEMP Version 3.3 Study Design, and a summary of the benchmarks is presented in Table 2-5.

The CWQG are intended to provide protection of freshwater life from anthropogenic stressors such as chemical inputs or physical changes (CCME 1999). These guidelines are based on current, scientifically-defensible toxicological data and are intended to protect all forms of aquatic life and all aquatic life cycles, including the most sensitive life stage of the most sensitive species over the long-term. They are based on the lowest concentration shown to have an adverse effect (Lowest Observable Effects Level [LOEL]) on the most sensitive aquatic organism. A ten-fold safety factor is then applied to the LOEL, to provide added assurance that the guideline will protect aquatic life.

The Canadian Drinking Water Quality Guidelines are based on published scientific research related to health effects, aesthetic effects and operational considerations (Health Canada 1996, 2006). Health-based guidelines are established on the basis of comprehensive review of the known health effects associated with each chemical, exposure levels, and availability of treatment and analytical technologies. Aesthetic effects (e.g., taste, odour) are taken into account when these play a role in determining whether consumers will consider the water drinkable.

Table 2-5 Effects Benchmarks for Water Quality Variables

Variable	Units	Effects Benchmarks(i)	
		Protection of Aquatic Life	Drinking Water
Conventional Parameters			
pH	pH Units	6.5 to 9.0	6.5 to 8.5
Dissolved oxygen	mg/L	Cold water:	-
		early life stages = 9.5;	
		other life stages = 6.5	
Total dissolved solids	mg/L	500(a)	500
Total Alkalinity	mg/L	n/a(b)	
Total suspended solids	mg/L	+5 (24 h to 30 days);	-
		+25 (24-h period)(c)	

Table 2-5 Effects Benchmarks for Water Quality Variables

Variable	Units	Effects Benchmarks[(i)]	
		Protection of Aquatic Life	Drinking Water
Major Ions			
Chloride	mg/L	120	250
Sodium	mg/L	-	200
Fluoride	mg/L	0.12	1.5
Sulphate	mg/L	100(d)	500
Nutrients			
Ammonia as nitrogen	µg/L	4730(e)	-
Nitrate as nitrogen	µg/L	3000	10000
Nitrite as nitrogen	µg/L	60	1000
Total Metals			
Aluminum (total)	µg/L	-	100/200(f)
Aluminum (dissolved)	µg/L	Variable with pH; median = 88 (range = 12 to 32,000)(e)	-
Antimony	µg/L	-	6
Arsenic	µg/L	5	10
Barium	µg/L	1000(d)	1000
Boron	µg/L	1500	5000
Cadmium	µg/L	0.1(e)	5
Chromium	µg/L	1 (Cr VI)(g)	50
Copper	µg/L	2	1000
Iron	µg/L	300	300
Lead	µg/L	1	10
Manganese	µg/L	-	50
Mercury	µg/L	0.026 (inorganic); 0.004 (methyl)	1
Molybdenum	µg/L	73	-
Nickel	µg/L	25	-
Selenium	µg/L	1	10
Silver	µg/L	0.1	-
Strontium	µg/L	30000(h)	-
Thallium	µg/L	0.8	-
Uranium	µg/L	15	20
Zinc	µg/L	30	5000

Notes: mg/L = milligrams per litre; µg/L = micrograms per litre; - = benchmark not available

a) Adopted from Alaska DEC (2012).

b) Alkalinity should be no lower than 25% of natural background level. There is no maximum guideline (US EPA 1998).

c) Average increase of 5 (24 hours to 30 days) or maximum increase of 25 mg/L in a 24 h-period).

d) British Columbia Ministry of Environment (2013).

e) Site specific benchmark - see Appendix IV.1 in DDMI (2007) for description.

f) 100 µg/L for conventional treatment and 200 µg/L for other treatment types.

g) Measurements of total chromium will be compared to the benchmark for chromium VI.

h) Based on results from HydroQual (2009) and Pacholski (2009). See text for more information.

i) Unless noted, benchmarks are derived from current CWQGs and Canadian Drinking Water Quality Guidelines. The Effects Benchmark shall be the lower of the two values.

2.4.8 Statistical Analysis

2.4.8.1 Approach

The objective of the statistical comparisons was to compare the NF exposure area to the three reference areas (FFA, FFB, and FF1). Statistical testing was conducted by analysis of variance (ANOVA), the Kruskal-Wallis test and a one-sample T-test. During the ice-cover and open-water seasons, water samples were collected at three depths in the NF area (top, middle, and bottom) and at a single depth in the FF reference areas (middle). Although data from all three sampling depths were evaluated in the Action Level assessment, data from only one depth was used in statistical comparisons. The NF data from the depth showing the highest average concentration of each SOI were used in the statistical comparisons to provide the most conservative evaluation of effects (Table 2-6). All statistical analyses were conducted with SYSTAT, version 13.0 for Windows (SYSTAT Software Inc. Chicago, IL.), with the exception of the Kruskal-Wallis tests, which were completed in Statistix, version 8.0 for Windows (Analytical Software, Tallahassee, FL).

2.4.8.2 Testing Assumptions for Analysis of Variance

Like other parametric tests, ANOVA assumes that the data fit the normal distribution (since the residuals [or error terms of the variates] are assumed to fit the normal distribution). If a measurement variable is not normally distributed, there is an increased chance of a false positive result (Type I error). Fortunately, an ANOVA is not sensitive to moderate deviations from normality, because when a large number of random samples are taken from a population, the means of those samples are approximately normally distributed even when the population is not normal (Sokal and Rohlf 1995).

The goodness-of-fit of the data to the normal distribution were tested with the Kolmogorov-Smirnov test. Many data sets that are significantly non-normal will still be appropriate for an ANOVA; therefore, issues with non-normality were only addressed with a P value less than 0.01. Another important assumption in ANOVA is that group variances are equal. When variances differ markedly, various data transformations will typically remedy the problem. As with normality, the consequences of moderate deviations from the assumption of equal variances do not compromise the overall test of significance. The results of tests to assess the goodness-of-fit of the data to the normal distribution (the Kolmogorov-Smirnov test) and to test the homogeneity of variance of the data (Bartlett's and Levene's test) are provided in Appendix B, Table B-1.

Table 2-6 Near-field Area Data Used for Statistical Analysis by SOI and Season, 2013 AEMP

Variable	Season	Near-Field Area Depth
Conventional Parameters		
Specific conductivity	Ice-cover	M
	Open-water	B
Total Dissolved Solids (Calculated)	Ice-cover	M
	Open-water	M
Major Ions		
Calcium	Ice-cover	M
	Open-water	M
Chloride	Ice-cover	M
	Open-water	B
Sodium	Ice-cover	M
	Open-water	B
Sulphate	Ice-cover	M
	Open-water	B
Nutrients		
Ammonia (as Nitrogen)	Ice-cover	M
	Open-water	T
Nitrate (as Nitrogen)	Ice-cover	M
	Open-water	M
Metals (Total)		
Aluminum	Ice-cover	M
	Open-water	T
Barium	Ice-cover	M
	Open-water	B
Chromium	Ice-cover	B
	Open-water	(a)
Molybdenum	Ice-cover	M
	Open-water	(a)
Silicon	Ice-cover	M
	Open-water	B
Strontium	Ice-cover	M
	Open-water	B
Uranium	Ice-cover	B
	Open-water	B

Notes: M = middle-depth; B = bottom; T = top of water column.

The greatest mean concentration was used to determine the depth used in the statistical analyses. When all mean concentrations for each depth were the same, the bottom data were used as the default.

a) Molybdenum and chromium were not analyzed statistically in open-water due to sample contamination.

2.4.8.3 Analysis of Variance

The means of the four areas (NF, FF1, FFA and FFB) were compared to one another in an overall ANOVA. Within the overall ANOVA, an *a priori* comparison (planned contrast) was then conducted to test the differences of means among specific areas (e.g., NF exposure area versus the FF reference areas). This same approach has been used in the other components of the AEMP.

Multiple comparison techniques (*a posteriori*) are frequently used with environmental assessment data; however, these techniques are not always appropriate for testing hypotheses (Hoke et al. 1990). The preferred approach is to analyze the data using planned, linear orthogonal contrasts by formulating meaningful comparisons among treatments (sampling areas) prior to conducting the study and outlining these in a study design. This preferred approach was used to help answer the question of whether effluent is having an effect in the exposure area of Lac de Gras.

In some cases, there were unforeseen differences observed among reference areas. To assess this natural variability, comparisons were also made among reference areas, thereby quantifying “natural” differences among different areas of Lac de Gras. Such comparisons, which suggested themselves as a result of the completed survey and analysis, are considered unplanned (*a posteriori*) comparisons. The procedure used for these comparisons was *Tukey’s honestly significant difference (HSD) method*, also known as the *T-method*. This test adopts a conservative approach by employing experiment-wise error rates for the Type I error (Day and Quinn 1989). Therefore, the *P* value used for these tests was 0.1, the same *P* value used for the planned contrasts.

2.4.8.4 Kruskal-Wallis Test

For SOIs that did not meet parametric test assumptions, the Kruskal-Wallis test was used to test for differences among sampling areas. The same approach was taken as described for ANOVA. Upon finding a significant overall difference, planned contrasts were conducted to test differences between the NF exposure area and the pooled reference areas (Gibbons 1976). To assess natural variability, the three reference areas were compared to one another (FF1 vs. FFA vs. FFB). The multiple-comparison procedure employed followed Dunn (1964) and is the nonparametric analogue to the unplanned tests using Tukey’s HSD method described under ANOVA. Kruskal-Wallis tests were considered significant at $P < 0.1$. The multiple-comparison procedure controls the experiment wise error rates for the Type I error and, therefore, holds the probability of correctly finding no difference at $1 - \alpha$. However, under this scenario, the task of correctly detecting differences that are significant (i.e., $1 - \beta$) is more difficult (Daniel 1990). To maintain a sufficiently small Type II error (β) with the multiple comparisons, a larger α (or P value) was used. The contrasts were tested at $P = 0.1$, and the multiple comparisons were conducted with $P = 0.15$.

2.4.8.5 One Sample T-Test

In instances where SOIs had concentrations below the DL at most of the reference area stations ($n = 15$), estimating an average reference area concentration was problematic. Without a good estimate of the reference area mean, the statistical comparisons described above could not be conducted. In this situation, the median SOI concentration in the reference area must be less than the DL. If the data are assumed to follow a normal distribution, then the mean would also be less than the DL in that area. Therefore, by testing that the NF exposure area mean is greater than the DL would provide statistical evidence that the exposure and reference areas are different in terms of SOI concentration. This comparison was made with a one-sample T-test. One-tailed critical values were used because the alternative hypothesis for the test was that the NF area mean was *greater* than the DL. One sample T-tests were considered significant at $P < 0.1$.

2.5 WEIGHT OF EVIDENCE INPUT

Results of the water quality survey feed into the Weight of Evidence (WOE) assessment, which is described in the Weight of Evidence Report (Golder 2014c). The WOE integrates results from the AEMP components to help understand the underlying cause(s) of biological responses. Whereas the annual report for each AEMP component assesses the effects separately to determine if changes in individual components are meaningful, the WOE approach integrates measures of exposure (e.g., water quality, sediment quality) with measures of biological response (e.g., plankton, benthos, fish) to assess the underlying causes of biological changes. These biological changes can reflect either nutrient enrichment or toxicological impairment effects. Thus, the WOE will provide the strength of evidence for toxicological impairment or nutrient enrichment associated with observed changes. It is not intended to reflect the ecological significance or level of concern associated with a given change.

The WOE assessment is undertaken by applying a rating scheme to determine the degree of change in individual AEMP components. It then proceeds to integrate the individual component ratings into an overall score. The methods as applied to water quality are described in Section 2 of the Weight of Evidence Report.

3 RESULTS

3.1 SUBSTANCES OF INTEREST

Substances of interest were identified based on the selection procedure described in Section 2.4.1. The following variables met the criteria for inclusion as SOIs in 2013:

- Specific Conductivity (Laboratory Measured)
- Total Dissolved Solids (Calculated)
- Calcium
- Chloride
- Sodium
- Sulphate
- Ammonia (as Nitrogen)
- Nitrate (as Nitrogen)
- Aluminum
- Barium
- Chromium
- Molybdenum
- Silicon
- Strontium
- Uranium

Each of the variables included as SOIs reached an Action Level 1 or greater in 2013. Since all variables in effluent with Water License discharge criteria and AEMP Effects Benchmarks were within applicable limits, effluent chemistry did not contribute to the SOI list.

Substances of interest in 2013 are similar to those identified during the AEMP Version 2.0 (Golder 2011b). Several variables, however, were included as SOIs for the first time in 2013. Specific conductivity (herein referred to as conductivity) was included as an SOI in 2013 because it is used as a proxy for evaluating toxicity associated with dissolved salts (US EPA 2011). Nitrate is typically evaluated in the Eutrophication Indicators Report; however, elevated concentrations of nitrate can cause toxicity to aquatic biota. Therefore, nitrate was retained as an SOI in 2013. Silicon was not analyzed prior to 2011 but met the criteria for inclusion as an SOI for the first time in 2013.

Results for nutrients that are generally not toxic to aquatic organisms (i.e., bicarbonate, nitrogen and phosphorus) are summarized in the Eutrophication Indicators Report (Golder 2014b) and are not assessed in this report. Variables measured in the field (conductivity, dissolved oxygen, temperature and pH) were not considered for inclusion as SOIs.

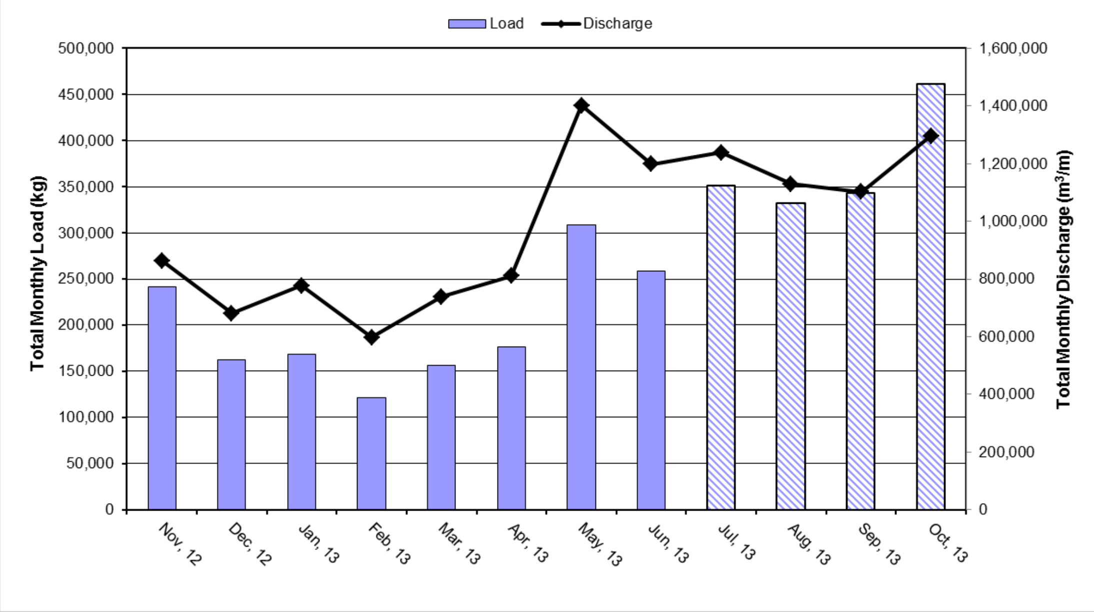
3.2 EFFLUENT

3.2.1 Loads of Substances of Interest

Monthly loading rates to Lac de Gras for SOIs identified in Section 3.1 were calculated for the 2013 reporting period (Figures 3-1 to 3-14). The loads represent inputs from both effluent streams (stations SNP 1646-18 and SNP 1646-18B). Conductivity was not included in this assessment because load is not a relevant measure for conductivity. The loads shown for chromium and molybdenum during the open-water season (July to October) were calculated based on a reduced sample size (*n* = 21 of 55 open-water season effluent samples) due to sample contamination (Appendix B).

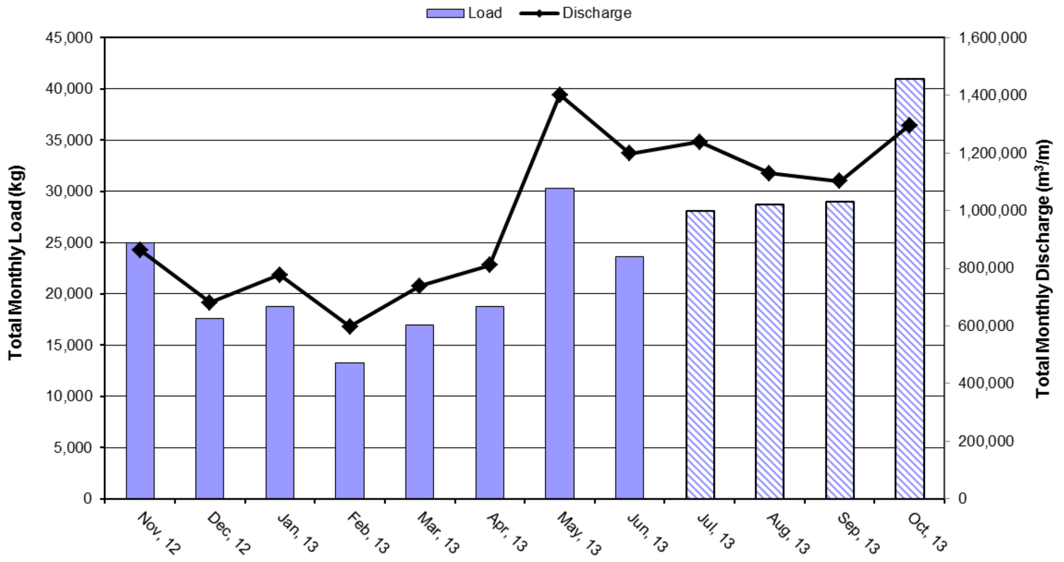
The monthly loads of many SOIs (TDS, dissolved calcium, chloride, dissolved sodium, sulphate, nitrate, barium, molybdenum and strontium) generally followed a similar pattern, with greater loads observed during the open-water season compared to the ice-cover season. The monthly loads of ammonia to Lac de Gras increased throughout the ice-cover period and were generally lower during the open water season (Figure 3-6). The month with the greatest load of most SOIs was October, with ammonia being the main exception. Loads of chromium decreased from November 2012 to September 2013, and then increased in October 2013 (Figure 3-10). Aluminum and silicon loadings were greatest in May and October 2013, and were similar in other months (Figures 3-8 and 3-12, respectively). Uranium loading was greatest in fall and decreased in winter (Figure 3-14.

Figure 3-1 **Total Monthly Loads of Total Dissolved Solids (Calculated) from the North Inlet Water Treatment Plant, 2013**



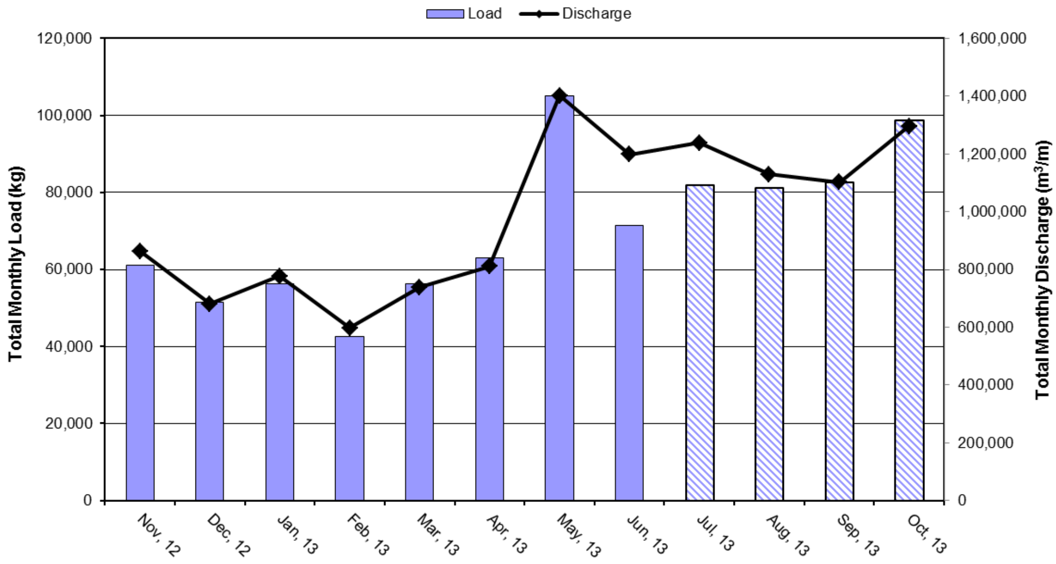
Notes: kg = kilograms; m^3/m = cubic metres per month; solid bars = typical ice-cover season; striped bars = typical open-water season.

Figure 3-2 **Total Monthly Loads of Dissolved Calcium from the North Inlet Water Treatment Plant, 2013**



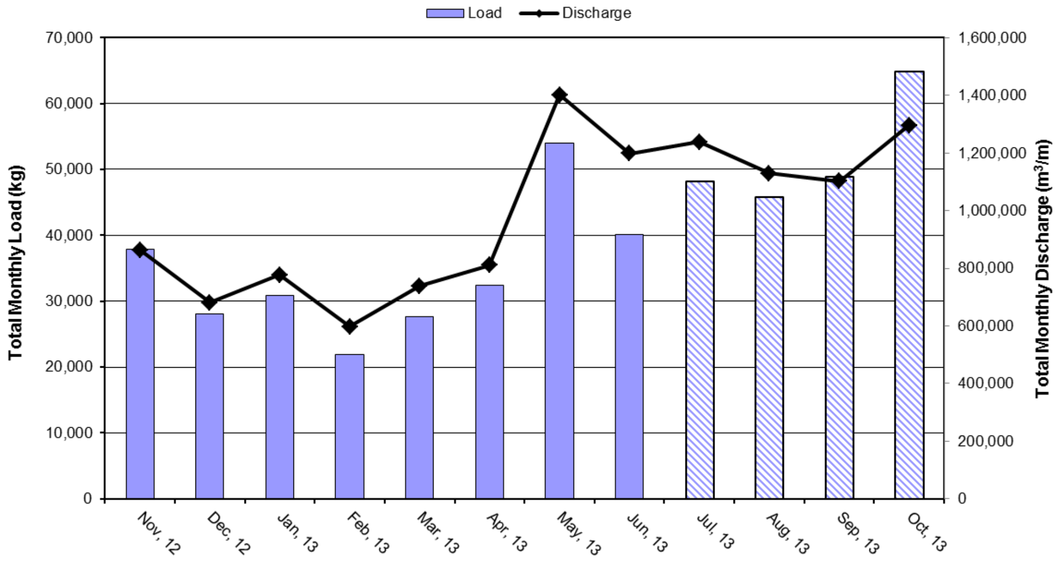
Notes: kg = kilograms; m^3/m = cubic metres per month; solid bars = typical ice-cover season; striped bars = typical open-water season.

Figure 3-3 Total Monthly Loads of Chloride from the North Inlet Water Treatment Plant, 2013



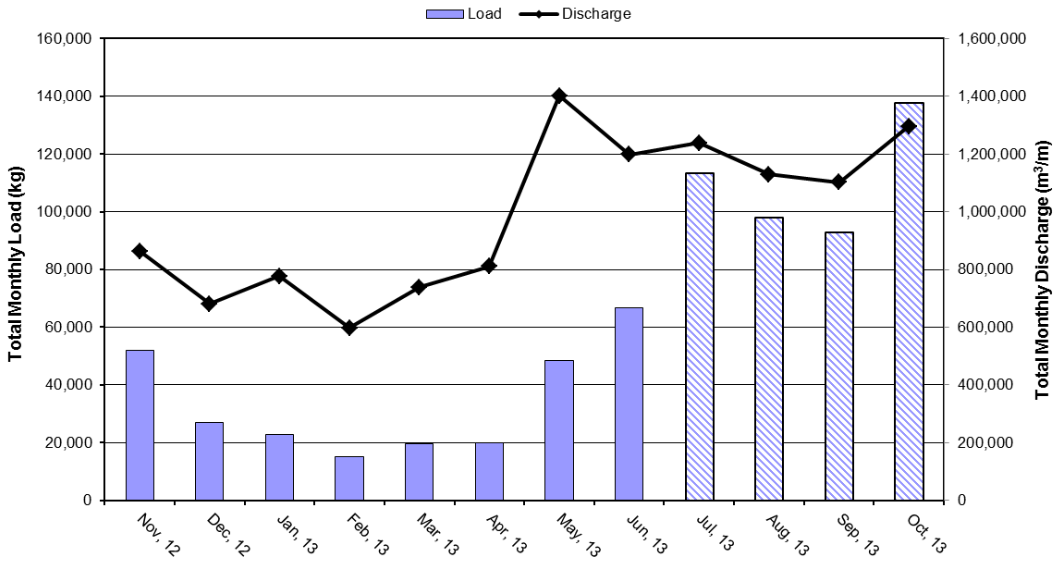
Notes: kg = kilograms; m^3/m = cubic metres per month; solid bars = typical ice-cover season; striped bars = typical open-water season.

Figure 3-4 Total Monthly Loads of Dissolved Sodium from the North Inlet Water Treatment Plant, 2013



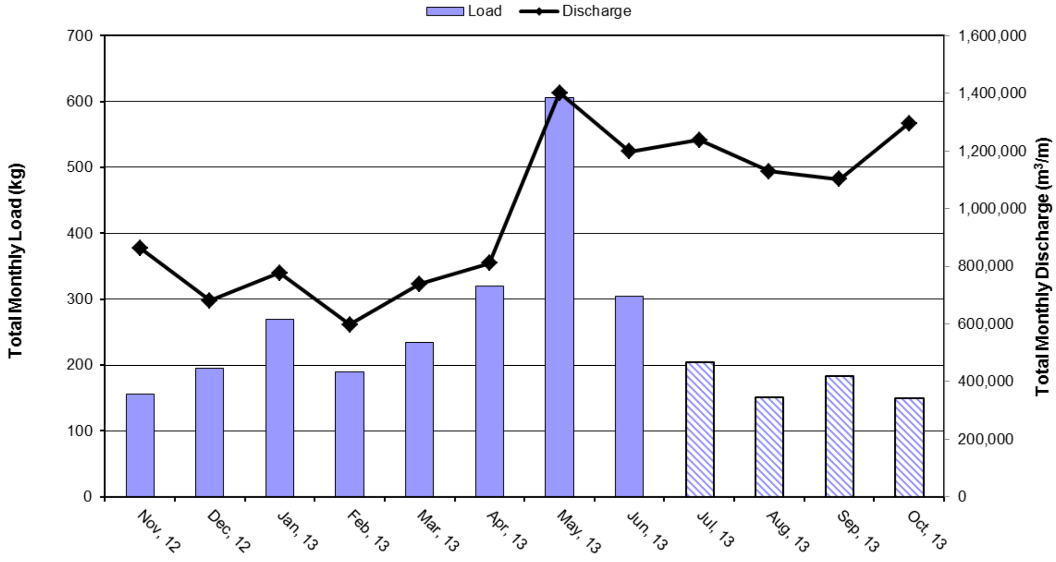
Notes: kg = kilograms; m^3/m = cubic metres per month; solid bars = typical ice-cover season; striped bars = typical open-water season.

Figure 3-5 Total Monthly Loads of Sulphate from the North Inlet Water Treatment Plant, 2013



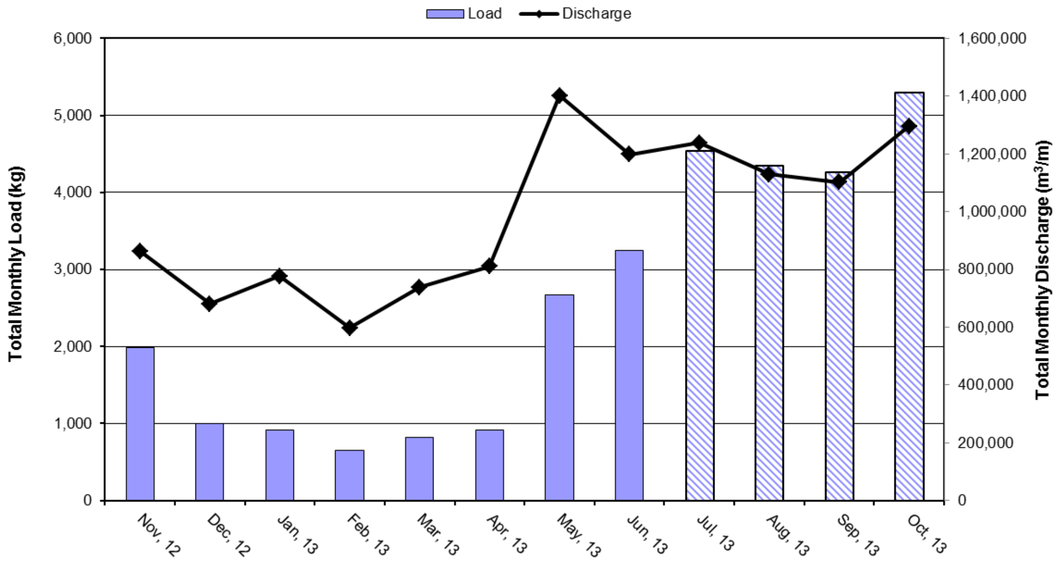
Notes: kg = kilograms; m^3/m = cubic metres per month; solid bars = typical ice-cover season; striped bars = typical open-water season.

Figure 3-6 Total Monthly Loads of Ammonia (as Nitrogen) from the North Inlet Water Treatment Plant, 2013



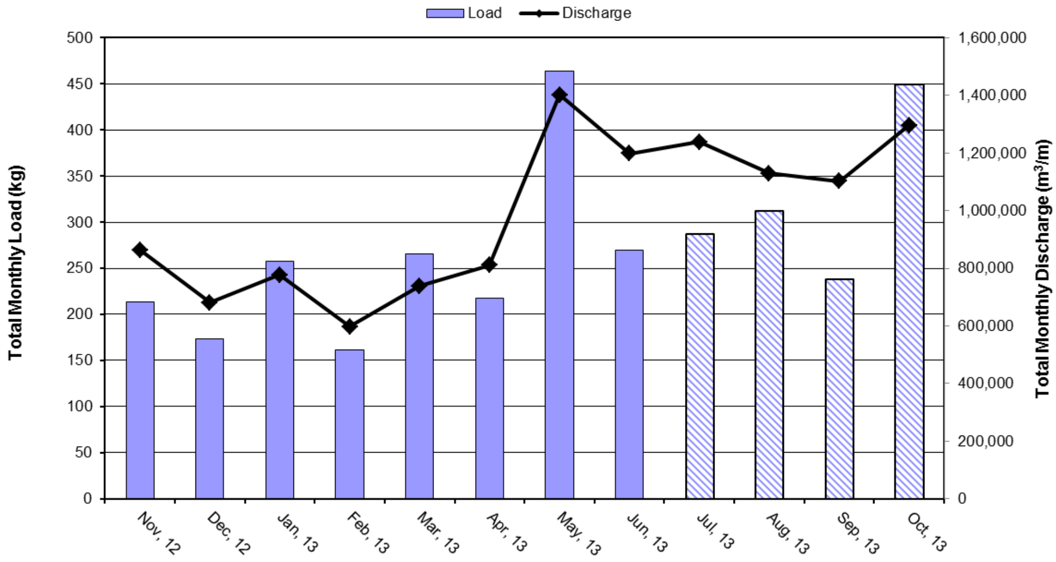
Notes: kg = kilograms; m^3/m = cubic metres per month; solid bars = typical ice-cover season; striped bars = typical open-water season

Figure 3-7 Total Monthly Loads of Nitrate (as Nitrogen) from the North Inlet Water Treatment Plant, 2013



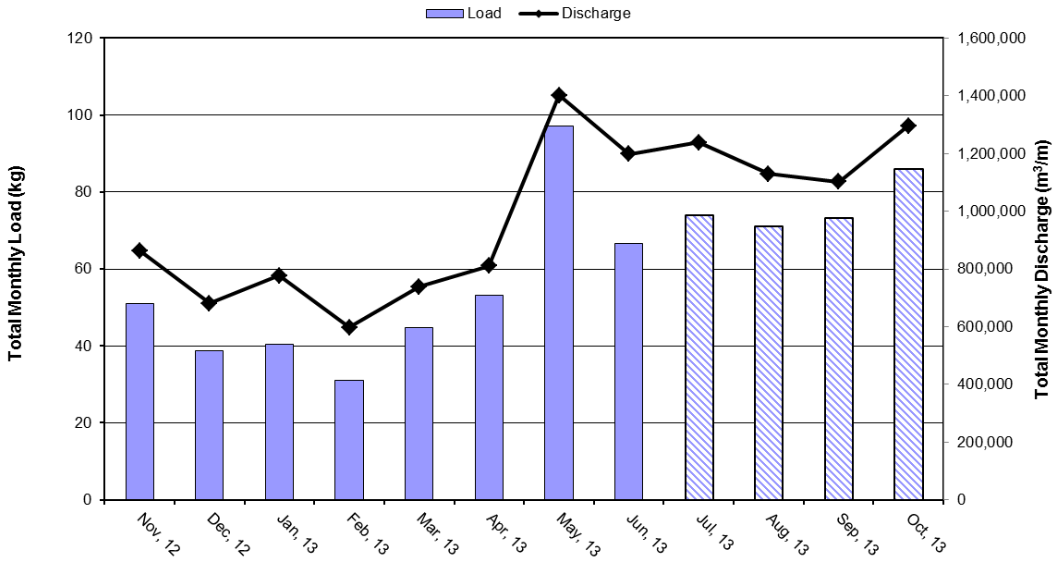
Notes: kg = kilograms; m^3/m = cubic metres per month; solid bars = typical ice-cover season; striped bars = typical open-water season.

Figure 3-8 Total Monthly Loads of Aluminum from the North Inlet Water Treatment Plant, 2013



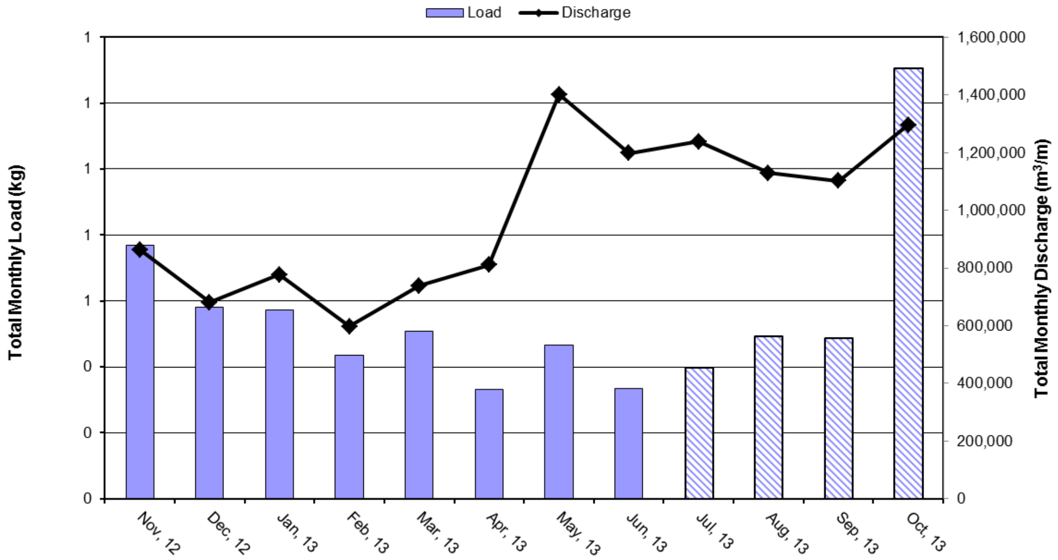
Notes: kg = kilograms; m^3/m = cubic metres per month; solid bars = typical ice-cover season; striped bars = typical open-water season.

Figure 3-9 Total Monthly Loads of Barium from the North Inlet Water Treatment Plant, 2013



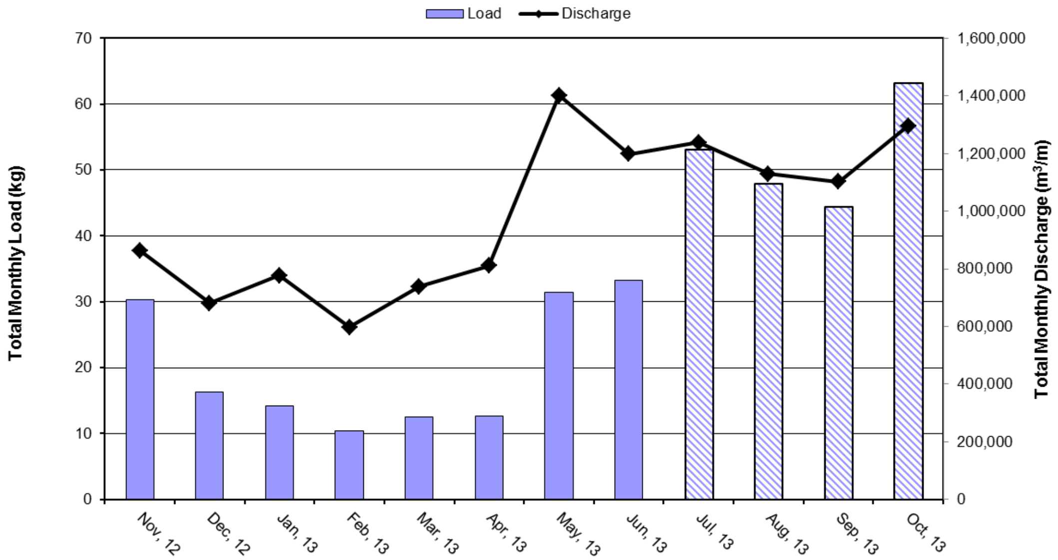
Notes: kg = kilograms; m^3/m = cubic metres per month; solid bars = typical ice-cover season; striped bars = typical open-water season.

Figure 3-10 Total Monthly Loads of Chromium from the North Inlet Water Treatment Plant, 2013



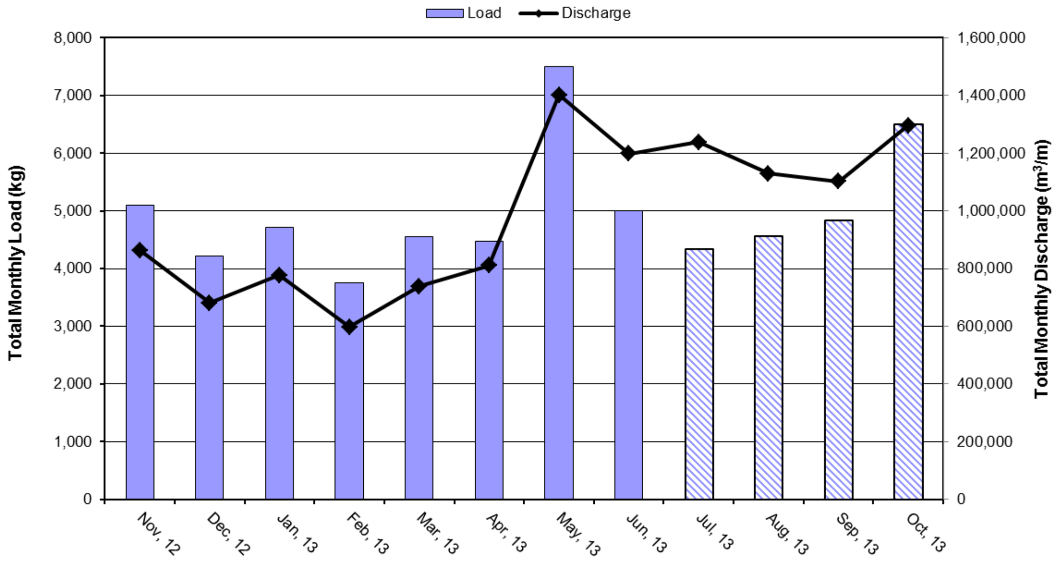
Notes: kg = kilograms; m^3/m = cubic metres per month; solid bars = typical ice-cover season; striped bars = typical open-water season. The monthly loads shown for the open-water season (July to October) were calculated based on a reduced sample size due to sample contamination (Appendix B).

Figure 3-11 Total Monthly Loads of Molybdenum from the North Inlet Water Treatment Plant, 2013



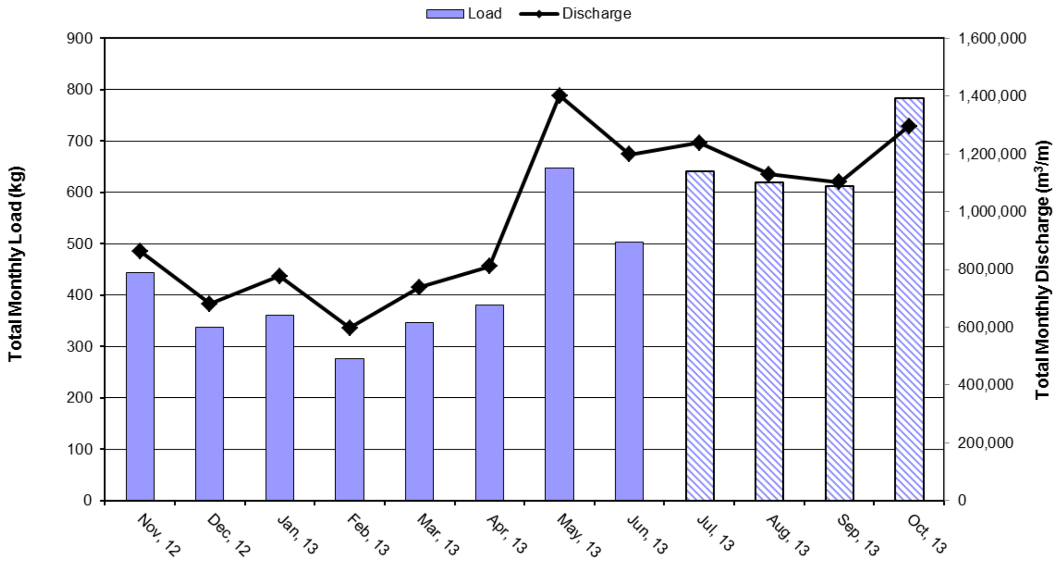
Notes: kg = kilograms; m^3/m = cubic metres per month; solid bars = typical ice-cover season; striped bars = typical open-water season. The monthly loads shown for the open-water season (July to October) were calculated based on a reduced sample size due to sample contamination (Appendix B).

Figure 3-12 Total Monthly Loads of Silicon from the North Inlet Water Treatment Plant, 2013



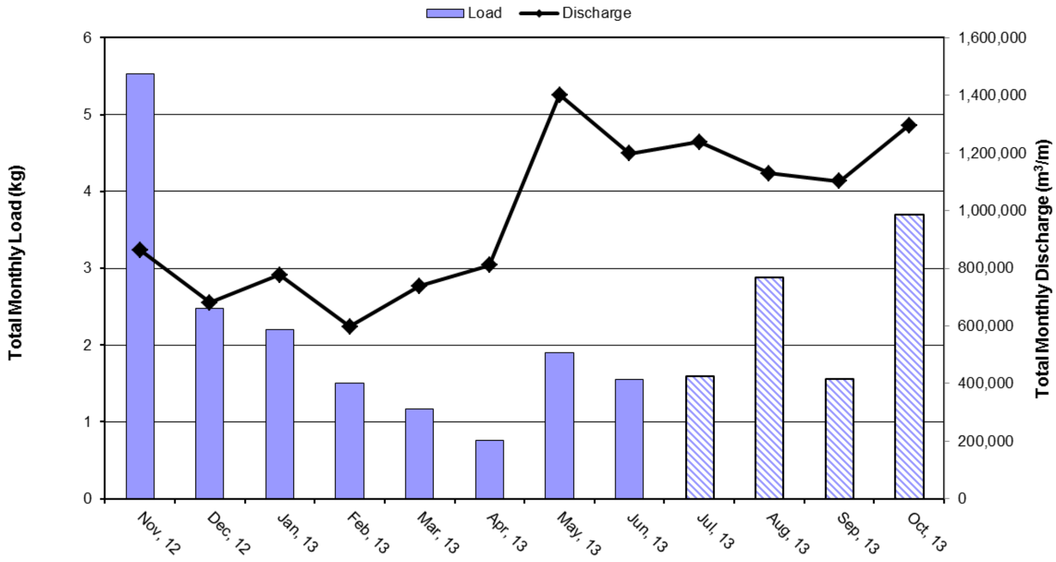
Notes: kg = kilograms; m^3/m = cubic metres per month; solid bars = typical ice-cover season; striped bars = typical open-water season.

Figure 3-13 Total Monthly Loads of Strontium from the North Inlet Water Treatment Plant, 2013



Notes: kg = kilograms; m^3/m = cubic metres per month; solid bars = typical ice-cover season; striped bars = typical open-water season.

Figure 3-14 Total Monthly Loads of Uranium from the North Inlet Water Treatment Plant, 2013



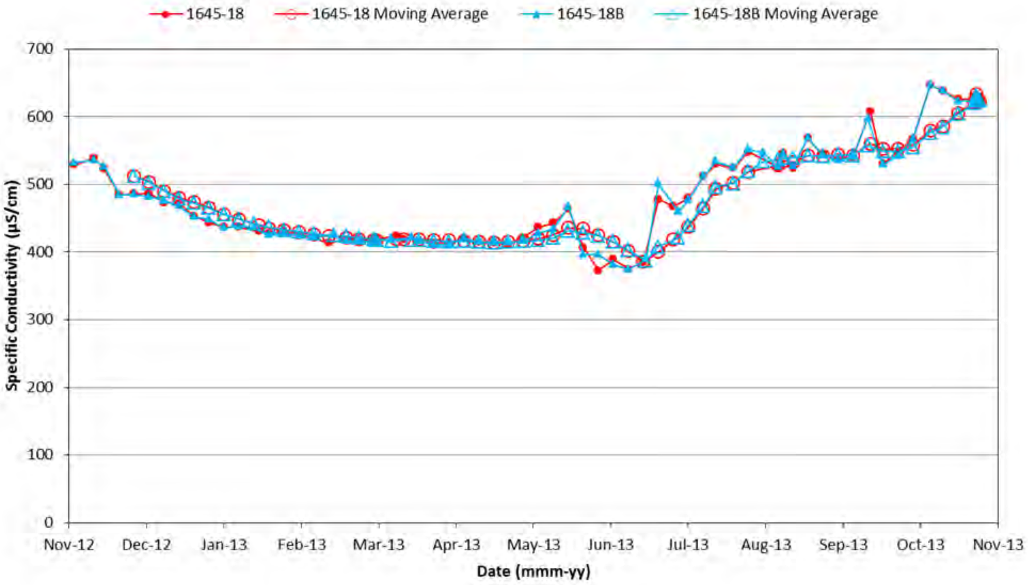
Notes: kg = kilograms; m^3/m = cubic metres per month; solid bars = typical ice-cover season; striped bars = typical open-water season.

3.2.2 Comparison of Effluent Chemistry to Water Licence Discharge Criteria

Plots showing trends in concentrations of SOIs over the 2013 reporting period are shown in Figures 3-15 to 3-28. Individual measurements and 5-day moving averages from November 2012 to October 2013 are shown. The discharge criteria (as maximum and maximum 5-day average concentrations) for SOIs with such limits are also shown. Concentrations of SOIs in effluent were well below discharge criteria. Effluent quality data for barium, which is used as the effluent tracer in Lac de Gras, are discussed in Section 3.2.4. The effluent chemistry results presented for a subset of SOIs (chromium and molybdenum) during the open-water season (July to October) were based on a reduced sample size (n = 21 of 55 effluent samples) due to sample contamination (Appendix B).

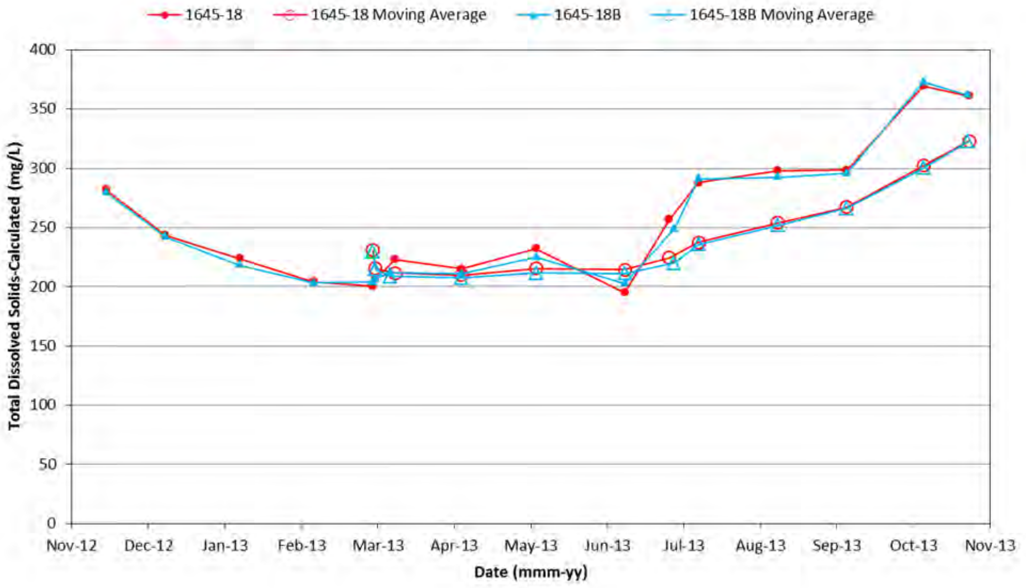
The concentrations of ammonia in effluent were lower during the open-water season compared to the ice-cover period (Figures 3-21). In contrast, nitrate increased from May to August (Figure 3-23). The seasonal patterns observed for many variables (e.g., dissolved calcium, dissolved sodium, sulphate, strontium, molybdenum and TDS) was an increase in effluent concentrations through the open-water season into early-ice cover. Seasonal trends for chloride followed a similar pattern, though concentrations in the early open-water were lower than under ice-cover (Figures 3-18). Chromium, silicon, and uranium concentrations were generally lower in the open-water season compared to in ice-cover (Figures 3-24, 3-26 and 3-28). The only analyte that did not exhibit a seasonal tendency was aluminum (Figure 3-23).

Figure 3-15 Conductivity at SNP 1645-18 and 1645-18B, November 2012 to October 2013



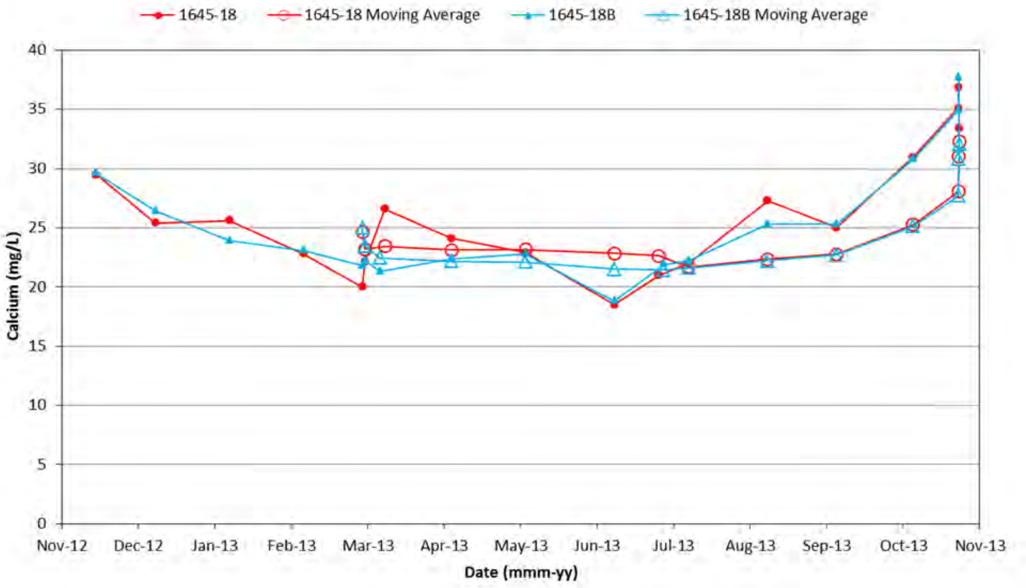
Note: µS/cm = microSiemens per centimeter.

Figure 3-16 Total Dissolved Solids Concentration (Calculated) at SNP 1645-18 and 1645-18B, November 2012 to October 2013



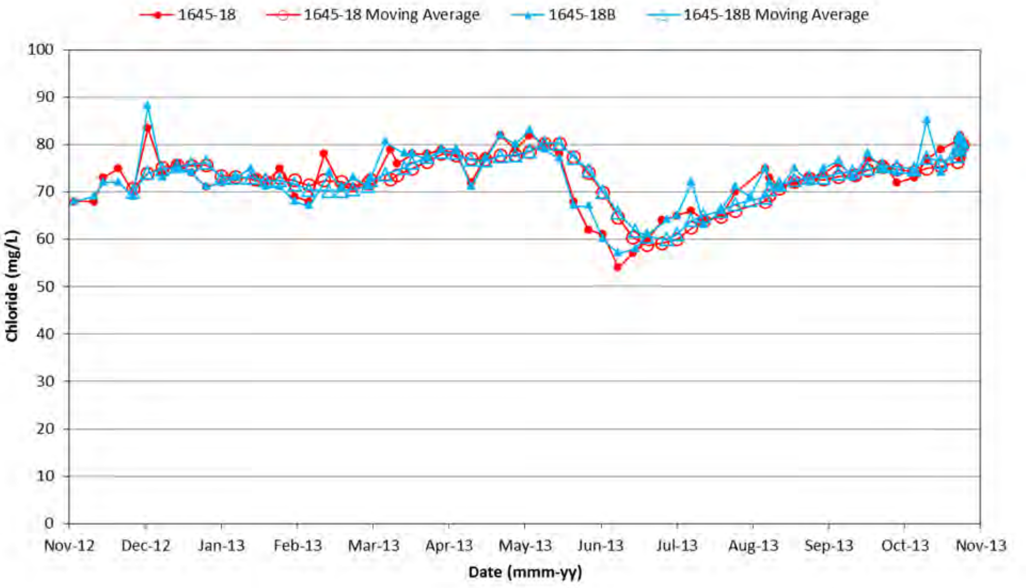
Note: mg/L = milligrams per litre.

Figure 3-17 Dissolved Calcium Concentration at SNP 1645-18 and 1645-18B, November 2012 to October 2013



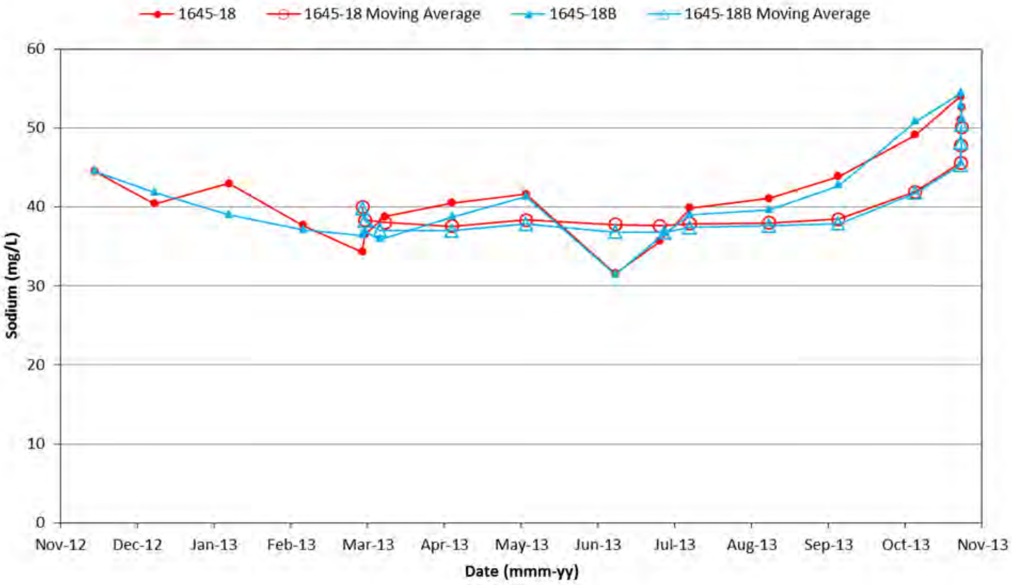
Note: mg/L = milligrams per litre; Water Licence discharge criteria are shown in text box.

Figure 3-18 Chloride Concentration at SNP 1645-18 and 1645-18B, November 2012 to October 2013



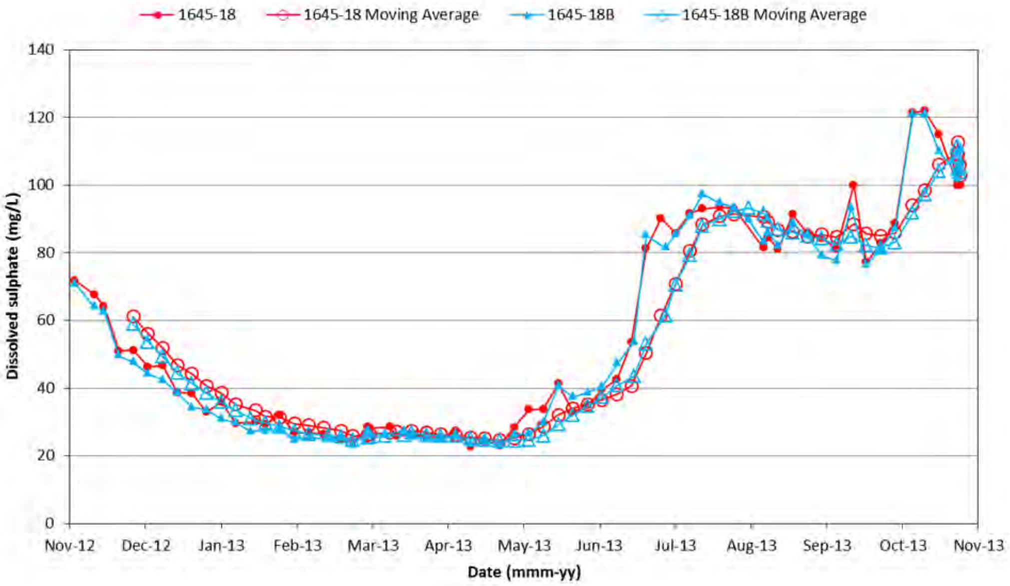
Notes: mg/L = milligrams per litre; Water Licence discharge criteria are shown in text box.

Figure 3-19 Dissolved Sodium Concentration at SNP 1645-18 and 1645-18B, November 2012 to October 2013



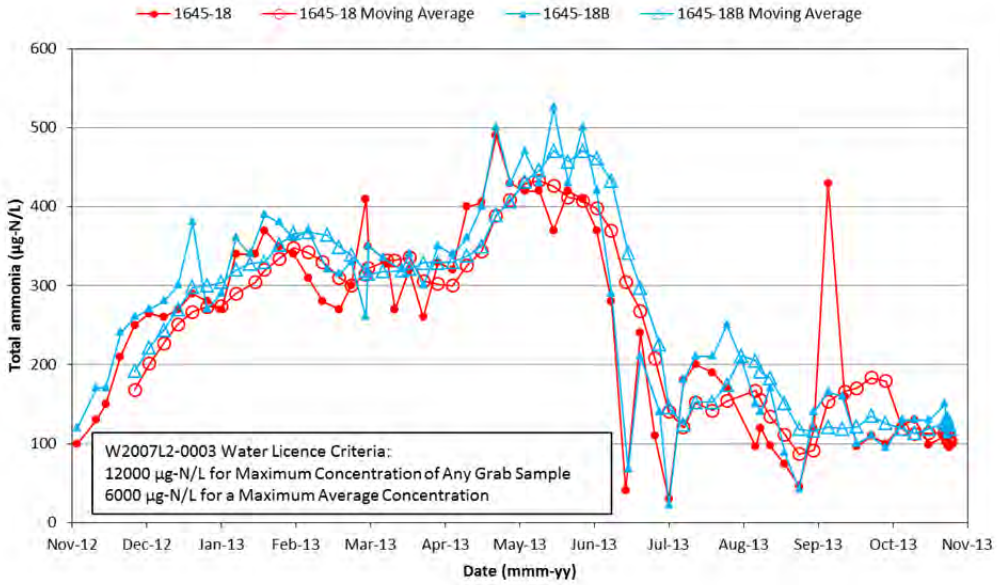
Notes: mg/L = milligrams per litre; Water Licence discharge criteria are shown in text box.

Figure 3-20 Sulphate Concentration at SNP 1645-18 and 1645-18B, November 2012 to October 2013



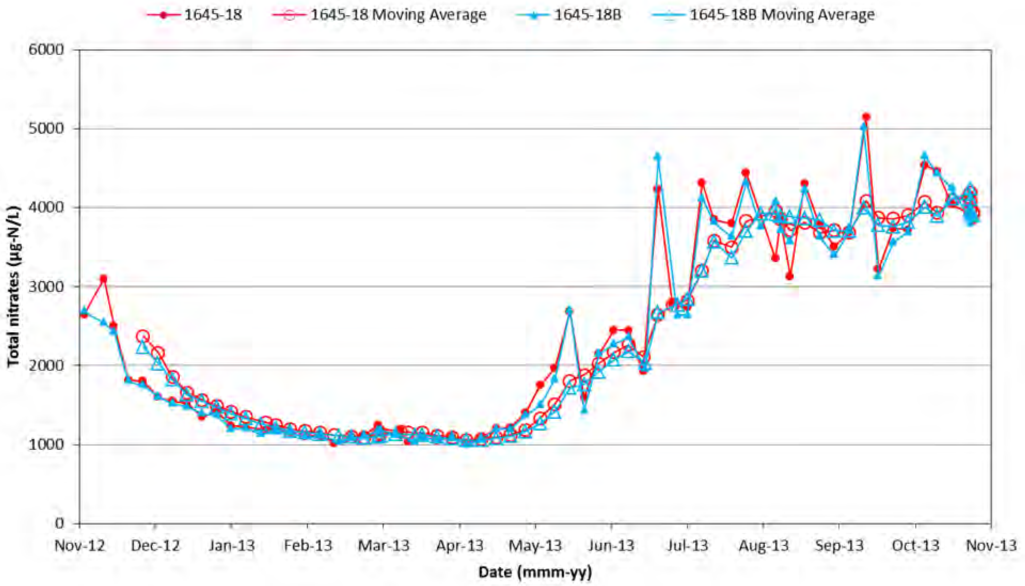
Notes: mg/L = milligrams per litre; Water Licence discharge criteria are shown in text box.

Figure 3-21 Ammonia (as Nitrogen) Concentration Measured at SNP 1645-18 and 1645-18B, November 2012 to October 2013



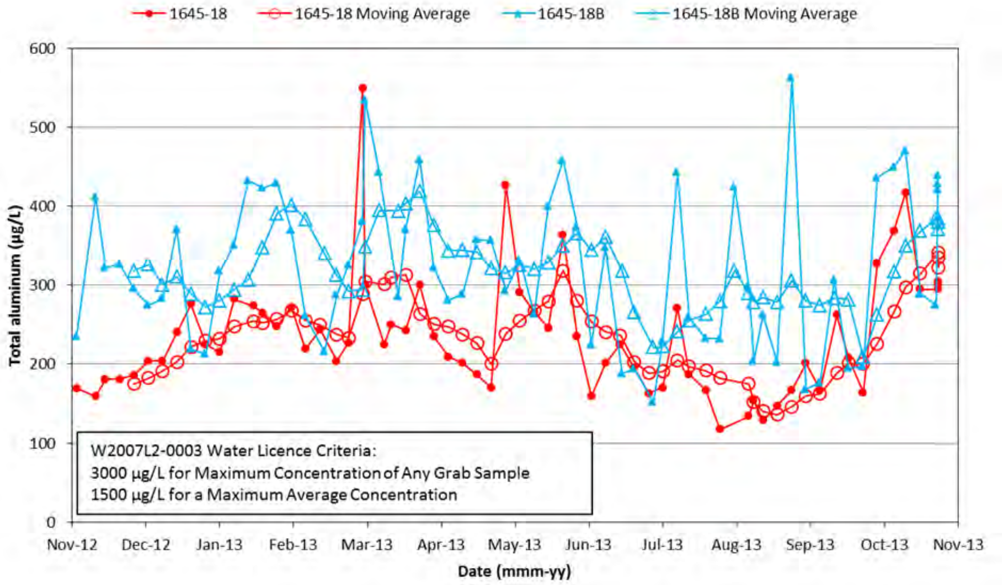
Notes: µg/L = micrograms per litre; Water Licence discharge criteria are shown in text box.

Figure 3-22 Nitrate Concentration Measured at SNP 1645-18 and 1645-18B, November 2012 to October 2013



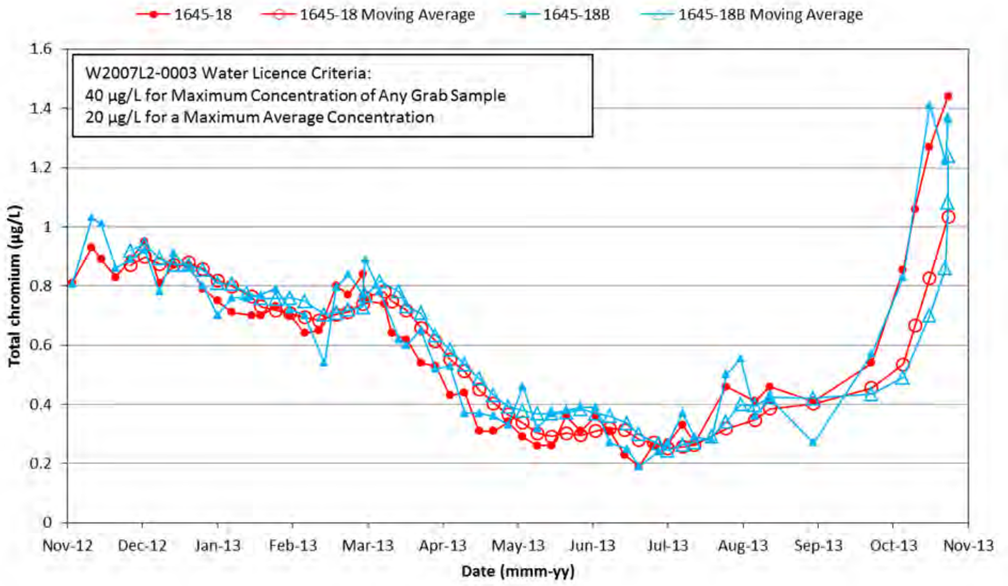
Note: µg/L = micrograms per litre.

Figure 3-23 Total Aluminum Concentration at SNP 1645-18 and 1645-18B, November 2012 to October 2013



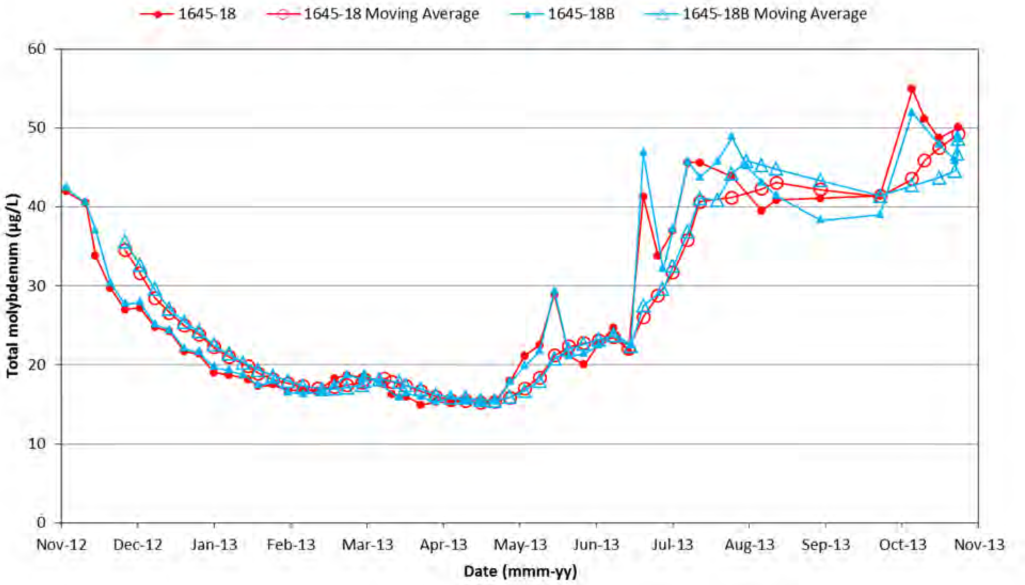
Notes: µg/L = micrograms per litre; Water Licence discharge criteria are shown in text box.

Figure 3-24 Total Chromium Concentration at SNP 1645-18 and 1645-18B, November 2012 to October 2013



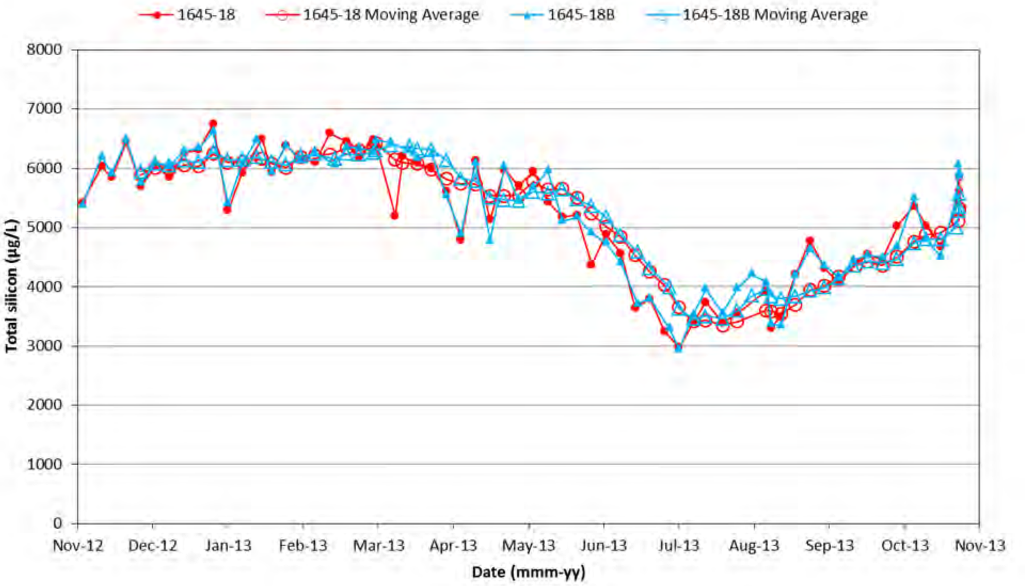
Notes: µg/L = micrograms per litre; Water Licence discharge criteria are shown in text box. A reduced sample size is shown for the open-water season (July to October) due to sample contamination (Appendix B).

Figure 3-25 Total Molybdenum Concentration at SNP 1645-18 and 1645-18B, November 2012 to October 2013



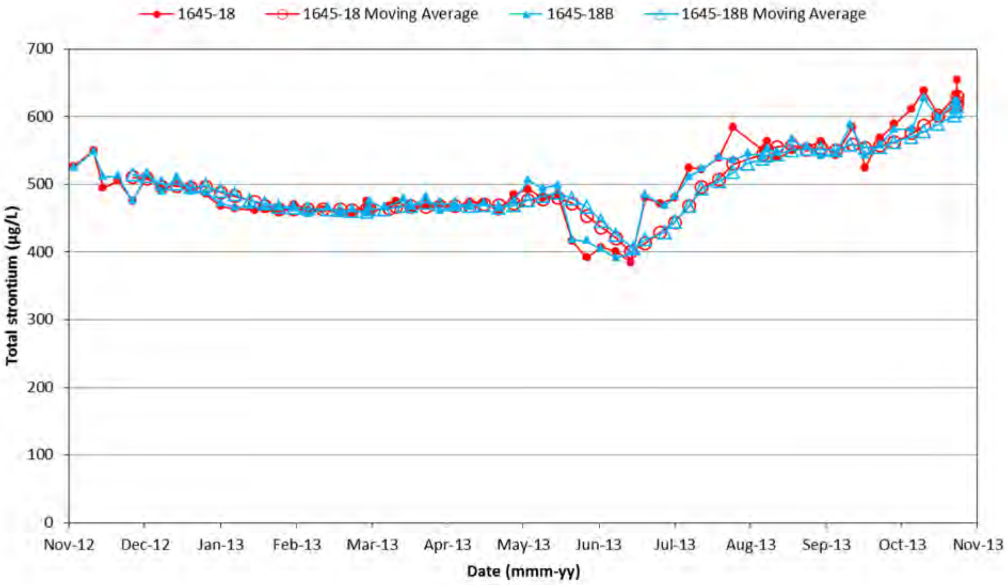
Notes: µg/L = micrograms per litre; Water Licence discharge criteria are shown in text box.

Figure 3-26 Total Silicon Concentration at SNP 1645-18 and 1645-18B, November 2012 to October 2013



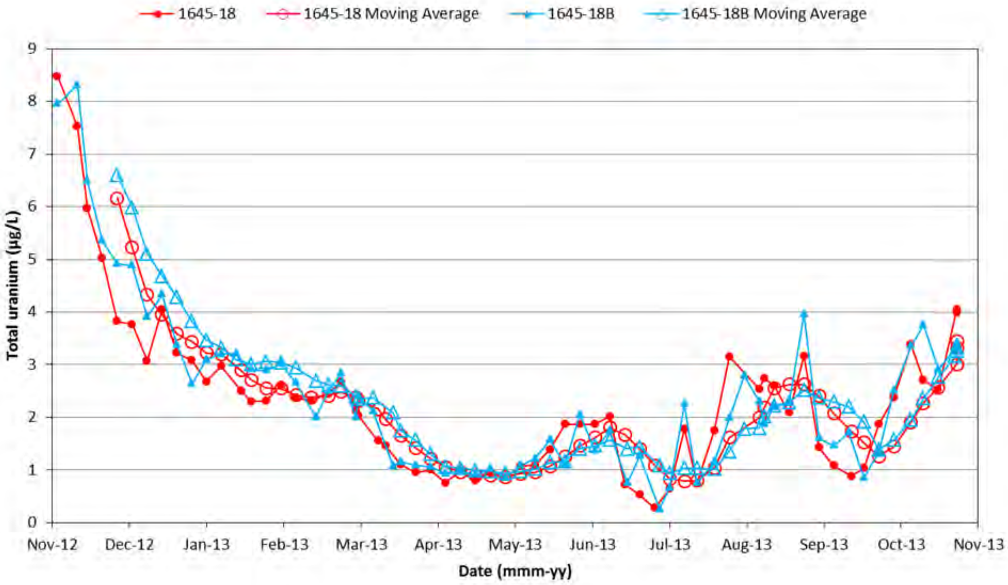
Notes: µg/L = micrograms per litre; Water Licence discharge criteria are shown in text box. A reduced sample size is shown for the open-water season (July to October) due to sample contamination (Appendix B).

Figure 3-27 Total Strontium Concentration at SNP 1645-18 and 1645-18B, November 2012 to October 2013



Notes: µg/L = micrograms per litre; Water Licence discharge criteria are shown in text box.

Figure 3-28 Total Uranium Concentration at SNP 1645-18 and 1645-18B, November 2012 to October 2013



Notes: µg/L = micrograms per litre; Water Licence discharge criteria are shown in text box.

3.2.3 Effluent Toxicity

Toxicity testing results in 2013 indicated that all effluent samples passed the relevant acute or chronic lethality and sublethal toxicity tests (Tables 3-1 and 3-2). Results are presented as a “pass” or “fail” to be consistent with the laboratory procedures and standards. The results in 2013 are consistent with test results in previous years (2002 and 2012) which indicated that the effluent was generally not toxic to aquatic test organisms (Golder 2011b, 2012, 2013b). Results were not reported for the September 10-day *Hyalella* chronic lethality test, because the effluent sample collected for toxicity testing was misplaced in transit from the Mine to the analytical laboratory.

Table 3-1 Acute and Chronic Lethality Toxicity Testing Results, North Inlet Water Treatment Plant Effluent, 2013

Test Organism	Month	Station	
		SNP 1645-18 100% Effluent	SNP 1645-18B 100% Effluent
Rainbow Trout[(a)]	January	Pass	Pass
	March	Pass	Pass
	June	Pass	Pass
	September	Pass	Pass
Ceriodaphnia dubia[(a)]	December	Pass	Pass
	March	Pass	Pass
	June	Pass	Pass
	September	Pass	Pass
Daphnia magna[(a)]	December	Pass	Pass
	March	Pass	Pass
	June	Pass	Pass
	September	Pass	Pass
Hyalella azteca[(a)]	December	Pass	Pass
	March	Pass	Pass
	June	Pass	Pass
	September	[(b)]	[(b)]

a) Test is considered a "fail" if mortality is ≥50%.

b) The effluent sample collected in September for *H. azteca* testing was misplaced in transit from the Mine to the analytical laboratory.

Table 3-2 Sub-lethal Toxicity Testing Results, North Inlet Water Treatment Plant Effluent, 2013

Test Organism	Month	Station	
		SNP 1645-18	SNP 1645-18B
Rainbow Trout[(a)]	January	Pass	Pass
	March	Pass	Pass
	July	Pass	Pass
	September	Pass	Pass
Pseudokirchneriella subcapitata[(b)]	December	Pass	Pass
	March	Pass	Pass
	June	Pass	Pass
	September	Pass	Pass
Ceriodaphnia dubia[(b)]	December	Pass	Pass
	March	Pass	Pass
	June	Pass	Pass
	September	Pass	Pass

a) Trout embryo (Early Life Stage) survival test is considered a “fail” if reduction in viable embryos is ≥50% compared to controls.

b) Test is considered a “fail” if reduction in growth compared to controls is ≥50%.

3.2.4 Effluent Distribution

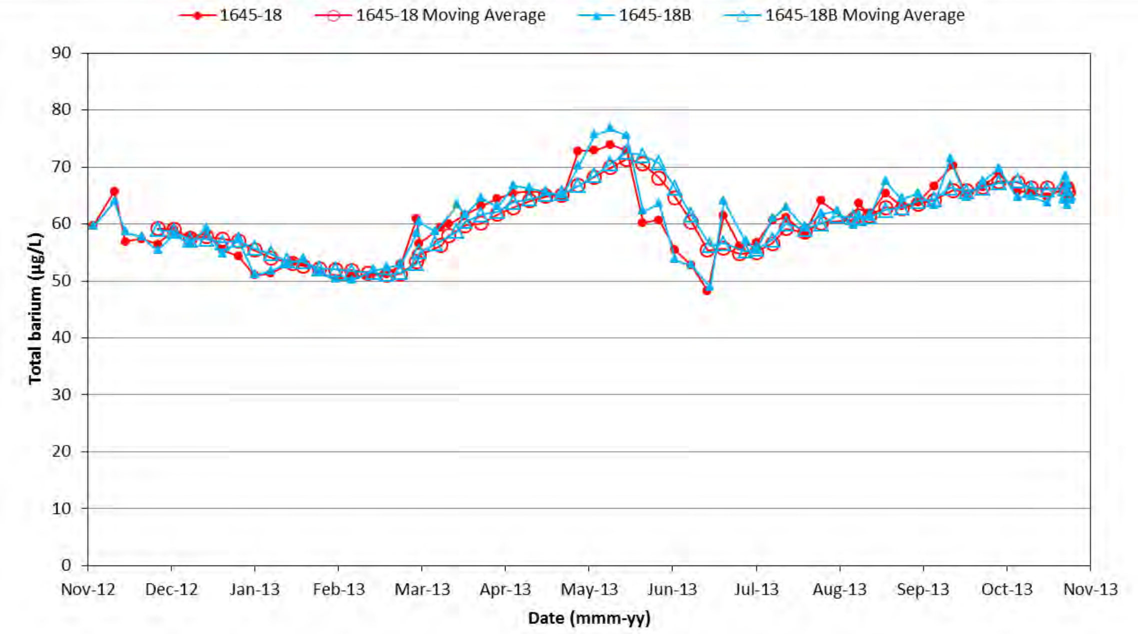
The dilution and distribution of effluent from the NIWTP was estimated based on the concentration of total barium measured at the SNP and AEMP sampling locations. The background concentration of barium in Lac de Gras was evaluated in terms of the normal range, which was defined as the historic (2007-2010) reference area mean concentration ± 2 SD. During the ice-cover season, the upper limit of the normal range for barium was 2.2 µg/L.

Barium concentrations measured in the Mine discharge at stations SNP 1645-18 and SNP 1645-18B ranged from 48.2 to 76.7 µg/L during the 2013 monitoring period (Figure 3-29). The peak in barium concentration in the effluent occurred during the late ice-cover season. At the mixing zone boundary, barium concentrations ranged from 2.3 to 7.93 µg/L (Figure 3-30).

The distribution of barium concentrations in 2013 indicated that the effluent was mixing throughout the exposure area of Lac de Gras (Figure 3-31). Barium concentrations at all five NF area stations, and at all three sampling depths, were greater than the normal range (i.e., 2.2 µg/L). Concentrations in the MF and FF2 areas were greater than the normal range at one or more depths at each station sampled, with the exception of station MF3-7, which is the exposure area station located farthest away from the Mine.

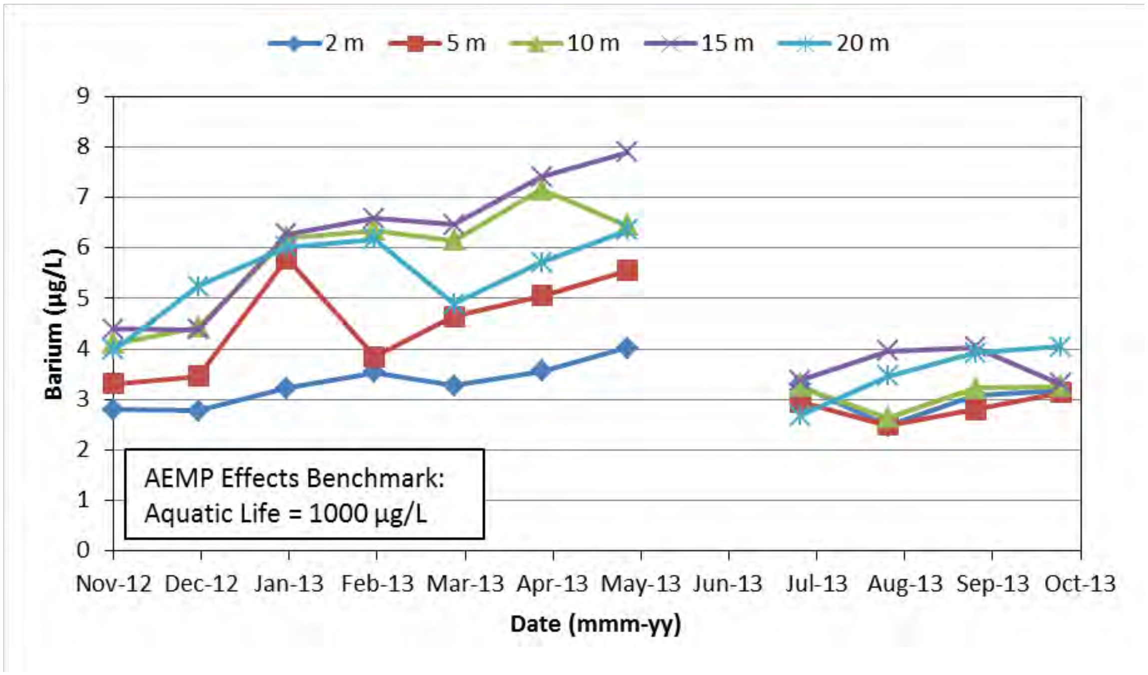
During the ice-cover season, barium concentration was greater than the normal range at one or more stations in reference areas FF1 and FFA (Figure 3-31). The mean value in the FFA area was also greater than the normal range (Table 3-3). Among the reference areas, the highest barium concentrations were measured in the FFA area. Given that the FFA area is farthest from the Mine and that this pattern has been observed in previous years, it is not possible to confirm that concentrations above the normal range represent Mine effluent exposure. The AEMP Summary Report (to be submitted in October 2014) will include updates to the temporal trend analyses which have been established for barium in reference areas FF1, FFB, and FFA. This analysis will help determine if concentrations of barium above the normal range are indicative of effluent having reached these areas.

Figure 3-29 Barium Concentration at SNP 1645-18 and 1645-18B, November 2012 to November 2013



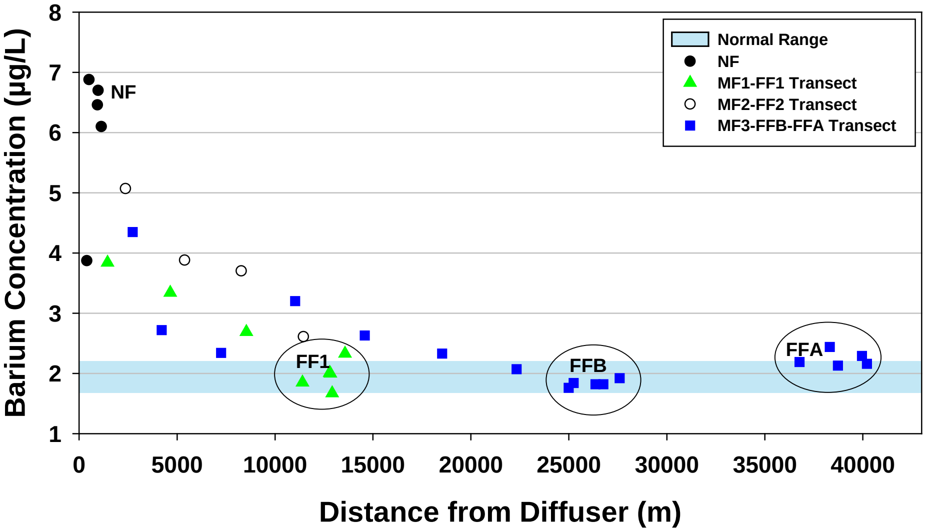
Note: µg/L = micrograms per litre.

Figure 3-30 Barium Concentration at the Mixing Zone Boundary, November 2012 to October 2013



Notes: µg/L = milligrams per litre; m = metre.

Figure 3-31 Spatial Variation in Barium Concentration with Distance from the Mine-effluent Diffuser, Ice-cover Season, 2013 AEMP



Notes: µg/L = micrograms per liter; m = meter.

The NF area data shown are from the sampling depth representing the maximum average concentration (mid depth). MF area values represent the maximum concentration of three depths (top, middle bottom) sampled at each station.

Table 3-3 Summary of Barium Concentration in the Far-field Reference Areas, Ice-cover Season, 2013

Variable	Top of Normal Range	Value	Area		
			FF1 (n = 5)	FFB (n = 5)	FFA (n = 5)
Barium (µg/L)	2.2	Min	1.67	1.76	2.13
		Max	**2.33**	1.92	**2.44**
		Median	2	1.82	2.19
		Mean	1.97	1.83	**2.24**
		Standard Deviation	0.24	0.06	0.13

Notes: µg/L = micrograms per litre.

Bolded values exceeded the normal range for barium, which is defined as the 2007 to 2010 reference area mean concentration plus 2 standard deviations.

3.3 WATER CHEMISTRY AT THE EDGE OF THE MIXING ZONE

Water quality sampling at the mixing zone was conducted monthly at 5-m depth intervals at three stations (SNP 1645-19a, SNP 1645-19b2 and SNP 1645-19c). These three stations are located 60 m from the Mine-effluent diffusers and represent the edge of the mixing zone, which has an area of approximately 0.01 km^2 (DDMI 2007). Plots showing concentrations of SOIs at the mixing zone boundary are provided in Appendix E, Figures E-1 to E-16. Water chemistry results collected at the edge of the mixing zone were evaluated against the Action Levels for water quality. Results of this assessment are described in Section 3.5.

3.4 DEPTH PROFILES

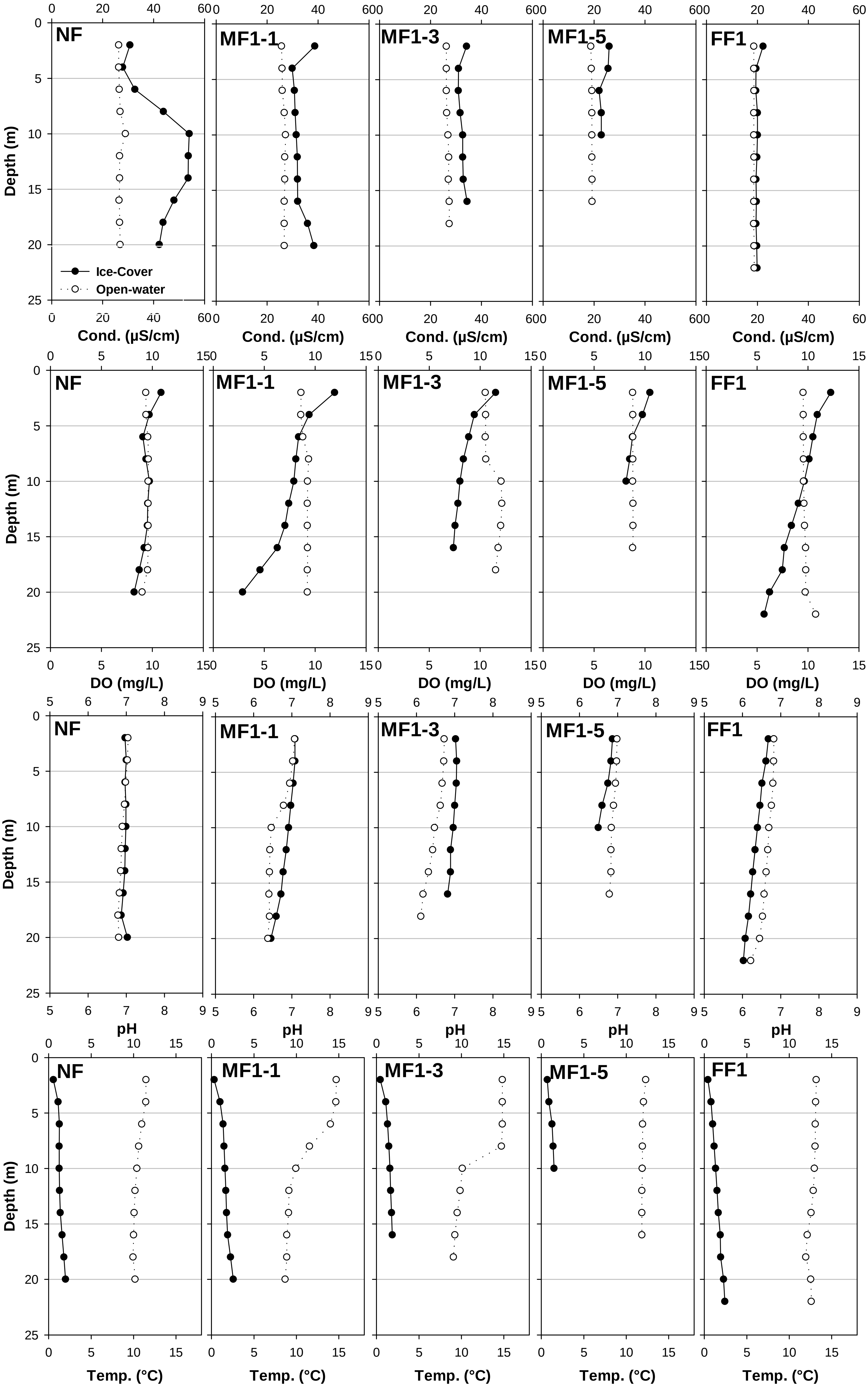
This section describes the *in-situ* (i.e., field measured) water quality measurements for conductivity, dissolved oxygen, water temperature and pH recorded at the AEMP stations. Depth profiles for specific conductivity, dissolved oxygen (DO), pH and temperature are presented for exposure and reference areas of Lac de Gras, during the ice-cover and open-water seasons (Figures 3-32 to 3-34).

Specific conductivity increased with depth in the NF area during the ice-cover season to about mid-depth (approximately 10 m) and then declined with increasing depth (Figures 3-32 to 3-34). The greater specific gravity of the effluent combined with the absence of wind and wave-driven mixing during ice-cover conditions, resulted in elevated conductivity at mid-depth. Peak conductivity occurred between about 10 and 15 m depth, indicating the point where the effluent plume was most concentrated. A similar, but less defined pattern was observed under ice-cover at stations located closest to the diffuser along the MF2 and MF3 transects, which extend to the northeast of the Mine and to the west of the Mine, respectively (Figures 3-33 and 3-34). This pattern, however, was not observed in the MF1 area, which extends northwest of the Mine (Figures 3-32). Complete vertical mixing of the effluent along the MF2 and MF3 transects was observed at stations MF2-3 and MF3-4, which are located at about half the total distance covered by each transect.

Temperature profiles in Lac de Gras were vertically homogeneous at most stations during both the ice cover and open water seasons (Figures 3-32 to 3-34). A lense of warmer water, 5 to 10 m deep, did overlie cooler water in the more sheltered MF1-1 and MF1-3 stations. During the open-water season, DO concentrations were typically uniform throughout the water column. During the ice-cover season, DO concentrations were greatest just below the ice-water interface and declined with increasing depth. There was no evidence of a DO sag at any station, though a decrease to just below 5 mg/L was encountered at MF3-5.

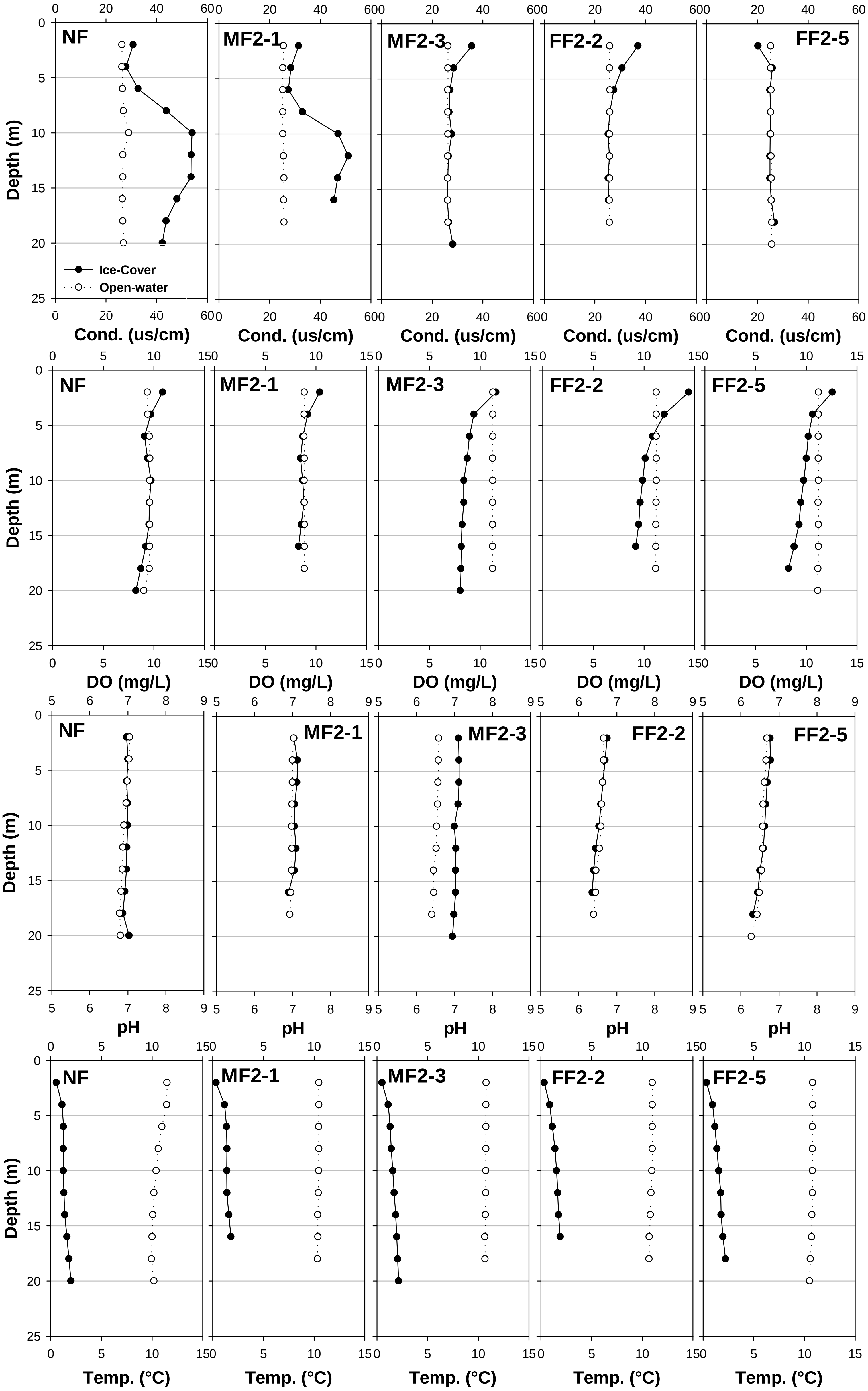
The pH values measured in Lac de Gras in 2013 showed a slight tendency to decrease with depth in both seasons (Figures 3-32 to 3-34). Slightly greater near-surface pH values observed at some stations likely reflect the removal of dissolved carbon dioxide through photosynthesis. Also, the somewhat greater pH values observed in the NF area likely reflect the presence of Mine effluent, which has a pH typically greater than 7.

Figure 3-32 Specific Conductivity, Dissolved Oxygen, pH and Temperature Profiles at MF1 Transect Stations, 2013 AEMP



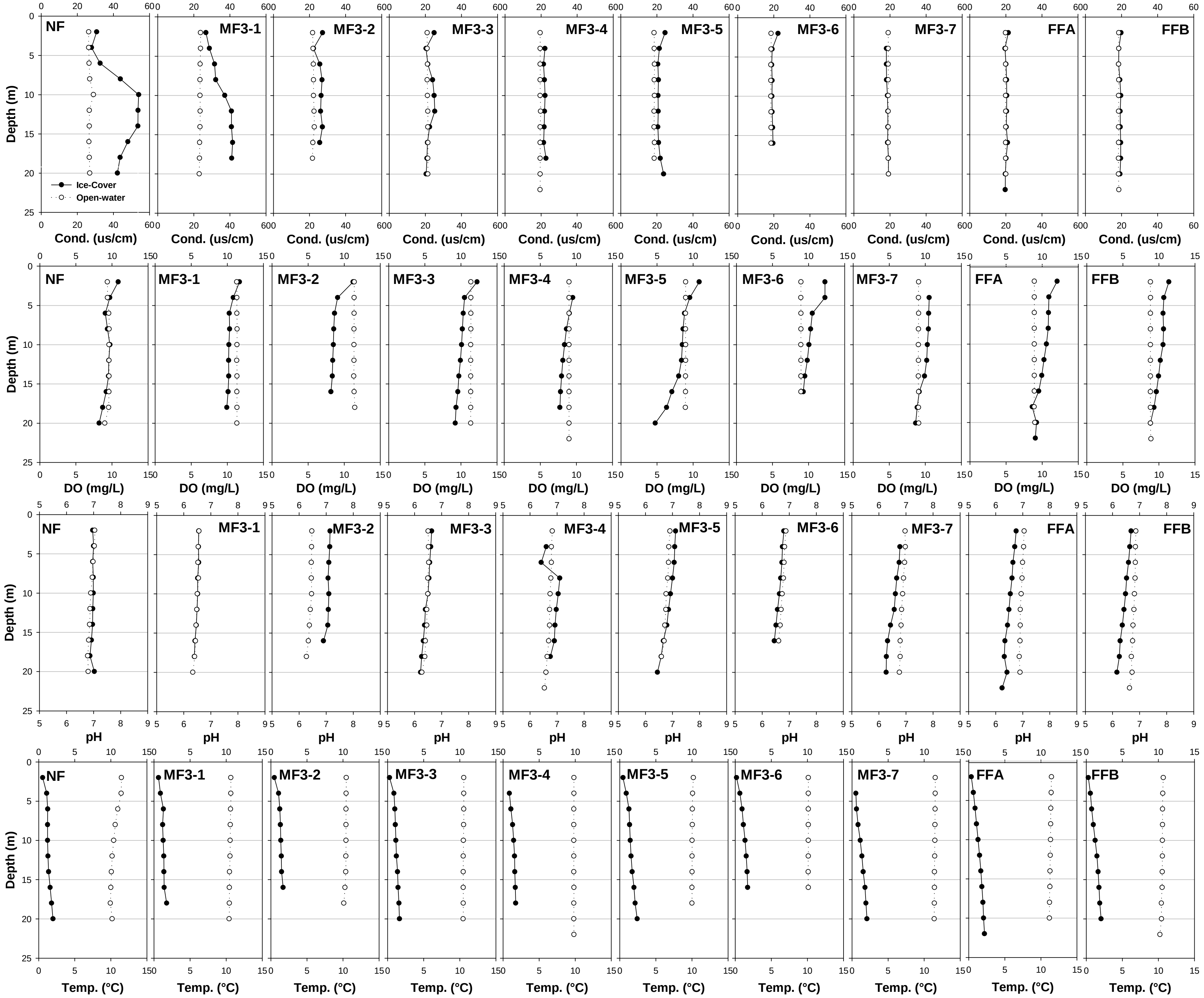
Notes: NF and FF1 area values represent the average of 5 stations; m = meters; Cond. = specific conductivity; µS/cm = microSiemens per centimetre; DO = dissolved oxygen; mg/L = milligrams per litre; Temp. = temperature; ˚C = degrees Celsius.

Figure 3-33 Conductivity, Dissolved Oxygen, pH and Temperature Profiles at MF2 Transect Stations, 2013 AEMP



Notes: NF area values represent the average of 5 stations; m = meters; Cond. = specific conductivity; µS/cm = microSiemens per centimetre; DO = dissolved oxygen; mg/L = milligrams per litre; Temp. = temperature; ˚C = degrees Celsius.

Figure 3-34 Conductivity, Dissolved Oxygen, pH and Temperature Profiles at MF3 Transect Stations, 2013 AEMP



Notes: NF, FFA and FFB area values represent the average of 5 stations; m = meters; Cond. = specific conductivity; µS/cm = microSiemens per centimetre; DO = dissolved oxygen; mg/L = milligrams per litre; Temp. = temperature; ˚C = degrees Celsius.

3.5 ASSESSMENT OF EFFECTS AND ACTION LEVELS

Mine-related effects on water quality were categorized according to the Action Levels (Table 2-4). Results of the Action Level screening are organized sequentially for each Action Level. Spatial variation in the concentrations of water quality variables that reached Action Level 1 or greater in 2013 is shown relative to Action Level values in Figures 3-35 to 3-49.

3.5.1 Action Level 1

Action Level 1 was applied for variables that had a twofold difference between the NF area median concentration and the reference area median concentration. In addition, the increase in concentration in the NF area had to be linked to the Mine (i.e., present in the effluent) for it to reach Action Level 1. A total of 15 of the 59 water quality variables assessed had NF area median concentrations that were greater than two times the reference area median value (Table 3-4). All variables that triggered Action Level 1 also had detectable concentrations in the NIWTP effluent, indicating that the elevated concentrations seen in the water column for each of these variables can be linked to the Mine (Appendix E, Figures E-1 to E-10). As described in Section 3.1, these 15 variables were retained as SOIs and underwent further analyses evaluating effects of the Mine on water quality in Lac de Gras.

Seven SOIs (TDS [calculated], sodium [dissolved], ammonia, nitrate, molybdenum, strontium, and uranium) had NF area median concentrations that exceeded the two times reference area median criterion both during the ice-cover and open-water seasons. The other eight SOIs (conductivity, calcium [dissolved], chloride, sulphate, aluminum, barium, silicon, and chromium) reached Action Level 1 during the ice-cover season only. Chromium was not evaluated in open-water due to a lack of suitable historical reference area data. Detection limits used for chromium prior to 2013 were greater than many NF area values in 2013, and most of the reference area samples collected in 2013 (*n* = 12 of 15 samples) were contaminated (Appendix B).

Given that nitrite was primarily non-detect in lake water samples (>95% of AEMP samples were non-detect [DL = 2 µg/L]) and that the results for nitrate plus nitrite were identical to those for nitrate, Action Level 1 was applied to nitrate only. The results for nitrate plus nitrite were not carried forward to Action Level 2. The total fractions of calcium and sodium reached Action Level 1 in 2013; however, Action Level 1 was applied to the dissolved values only to reduce the number of variables considered and to be consistent with previous AEMP reports, which have typically reported the dissolved results for calcium and sodium.

3.5.2 Action Level 2

Variables that reached Action Level 1 were carried forward to Action Level 2. Action Level 2 was applied when the 75th percentile concentration in the NF exposure area was greater than the normal range for Lac de Gras. Each of the 15 water quality variables that reached Action Level 1 in 2013 also reached Action Level 2 in one or both sampling seasons (Table 3-5). In general, Action Level 2 was reached during both the ice-cover and open-water seasons. Exceptions included silicon, which reached Action Level 2 during the ice-cover season only, and chromium, which reached Action Level 2 during ice-cover.

3.5.3 Action Level 3

Variables that reached Action Level 2 were carried forward to Action Level 3. An Action Level 3 was applied if the 75th percentile concentration at the mixing zone boundary was greater than the normal range plus 25% of the distance between the top of the normal range and the Effects Benchmark. Therefore, only water quality variables that have existing AEMP Effects Benchmarks were screened against Action Level 3.

Aluminum is typically evaluated based on the total concentration in Lac de Gras; however, for the purpose of Action Level 3 aluminum concentrations at the mixing zone were assessed in terms of the dissolved values to allow for comparison with the Effects Benchmark, which is specific to dissolved aluminum. Because dissolved metals results were available at the mixing zone, but not for the AEMP dataset, the normal range for aluminum was estimated using the relationship between total and dissolved values at the mixing zone. Relationships were calculated separately for open-water and ice-cover seasons.

None of the water quality variables reached an effect equivalent to Action Level 3 (Table 3-6). The 75th percentile concentrations at the mixing zone were one to two orders of magnitude lower than the Action Level 3 criterion for ammonia, barium, molybdenum, strontium and uranium. Other variables (TDS [calculated], chloride, sulphate, nitrate, dissolved aluminum, and chromium) had 75th percentile concentrations that were between three and ten times lower than the Action Level 3 criterion.

Higher detection limits used at the mixing zone boundary (compared to those for the AEMP dataset) resulted in several non-detect values reported for two variables: chromium (mixing zone DL = 0.1 µg/L vs AEMP DL = 0.05 µg/L) and nitrate (mixing zone DL = 20 µg/L vs AEMP DL = 2 µg/L). Although the higher DLs used for these variables did not affect the outcome at Action Level 3, the DLs used for the two datasets (mixing zone and AEMP) should be the same so that the results can be compared. For example, the spatial trend for chromium in Figure 3-45 appears more pronounced than it might otherwise be if the DL used at SNP-19 matched the AEMP dataset.

Table 3-4 Comparison of 2013 Data to Action Level 1

Variable	Unit	2013 Detection Li mit	Action Level 1					
			Magnitude of Effect		2013 AEMP		Action Level 1 Applied (Yes/No)	
			2 x Median of Reference Areas[(a)]		Median of NF Values[(b)]			
			Ice-cover	Open-water	Ice-cover	Open-water	Ice-cover	Open-water
Conventional Parameters								
Acidity (pH 4.5)	mg/L	0.5	0.7	0.7	<0.5	<0.5	No	No
Acidity (pH 8.3)	mg/L	0.5	0.7	0.7	0.56	<0.5	No	No
Total alkalinity	mg/L	0.5	8.8	8.1	7.4	5.3	No	No
Alkalinity (PP as CaCO3)	mg/L	0.5	0.7	0.7	<0.5	<0.5	No	No
Specific Conductivity	µS/cm	1	34	31	43	29	**Yes**	No
Dissolved Hardness (CaCO3)	mg/L	0.5	13.8	12.2	11.1	7.7	No	No
Hardness	mg/L	0.5	11.5	10.6	10.9	7.8	No	No
pH	pH Units	-	(c)	(c)	(c)	(c)	(c)	(c)
Total Dissolved Solids (Calculated)	mg/L	-	11.0	10.0	20.5	13.4	**Yes**	**Yes**
Total Dissolved Solids (Measured)	mg/L	1	30	20	28	20	No	No
Total Suspended Solids	mg/L	1	1.4	1.4	<1	<1	No	No
Total Organic Carbon	mg/L	0.2	5.4	4.4	2.3	2.3	No	No
Turbidity	NTU	0.1	0.2	0.4	0.1	0.3	No	No
Major Ions								
Bicarbonate	mg/L	0.5	(d)	(d)	(d)	(d)	(d)	(d)
Calcium	mg/L	0.0	2.20	2.02	2.34	1.48	**Yes**	No
Carbonate	mg/L	0.5	0.7	0.7	<0.5	<0.5	No	No

Table 3-4 Comparison of 2013 Data to Action Level 1

Variable	Unit	2013 Detection Li mit	Action Level 1					
			Magnitude of Effect		2013 AEMP		Action Level 1 Applied (Yes/No)	
			2 x Median of Reference Areas[(a)]		Median of NF Values[(b)]			
			Ice-cover	Open-water	Ice-cover	Open-water	Ice-cover	Open-water
Chloride	mg/L	0.5	2.0	2.6	4.5	2.2	**Yes**	No
Fluoride	mg/L	0.01	0.05	0.04	0.03	0.02	No	No
Hydroxide	mg/L	0.5	0.7	0.7	<0.5	<0.5	No	No
Magnesium	mg/L	0.01	1.40	1.38	1.35	0.99	No	No
Potassium	mg/L	0.01	1.26	1.20	1.10	0.89	No	No
Sodium	mg/L	0.01	1.42	1.42	3.20	1.67	**Yes**	**Yes**
Sulphate	mg/L	0.5	4.3	4.0	4.5	3.0	**Yes**	No
Nutrients								
Ammonia (as Nitrogen)	µg/L	5	34	8	42	18	**Yes**	**Yes**
Nitrate (as Nitrogen)	µg/L	2	7	3	70	12	**Yes**	**Yes**
Nitrite (as Nitrogen)	µg/L	2	3	3	<2	<2	No	No
Nitrate + Nitrite (as Nitrogen)	µg/L	2	7	3	70	12	(e)	(e)
Nitrogen - Kjeldahl	µg/L	20	(d)	(d)	(d)	(d)	(d)	(d)
Total Nitrogen	µg/L	20	(d)	(d)	(d)	(d)	(d)	(d)
Orthophosphate	µg/L	1	(d)	(d)	(d)	(d)	(d)	(d)
Phosphorus - Dissolved	µg/L	2	(d)	(d)	(d)	(d)	(d)	(d)
Phosphorus - Total	µg/L	2	(d)	(d)	(d)	(d)	(d)	(d)

Table 3-4 Comparison of 2013 Data to Action Level 1

Variable	Unit	2013 Detection Limit	Action Level 1					
			Magnitude of Effect		2013 AEMP		Action Level 1 Applied (Yes/No)	
			2 x Median of Reference Areas(a)		Median of NF Values(b)			
			Ice-cover	Open-water	Ice-cover	Open-water	Ice-cover	Open-water
Metals (Total)								
Aluminum	µg/L	0.2-0.5	5.9	8.8	12.1	5.5	**Yes**	No
Antimony	µg/L	0.02	0.03	0.03	0.03	<0.02	No	No
Arsenic	µg/L	0.02	0.37	0.34	0.30	0.26	No	No
Barium	µg/L	0.02	3.86	3.62	4.38	2.59	**Yes**	No
Beryllium	µg/L	0.01	0.01	0.01	<0.01	<0.01	No	No
Bismuth	µg/L	0.005	0.007	0.007	<0.005	<0.005	No	No
Boron(i)	µg/L	5	3	3	<5	<5	No	No
Cadmium	µg/L	0.005	0.07	0.07	<0.005	<0.005(f)	No	No(e)
Calcium	mg/L	0.01	2.12	1.95	2.22	1.46	(g)	(g)
Chromium	µg/L	0.05	0.07	(h)	0.08	0.054(f)	**Yes**	(h)
Cobalt	µg/L	0.005	0.022	0.030	0.014	0.012(f)	No	No(e)
Copper	µg/L	0.05	1.15	1.10	0.64	0.58	No	No
Iron	µg/L	1	4	10	2	7(f)	No	No(e)
Lead	µg/L	0.005	0.007	0.007	0.005	0.005	No	No
Lithium	µg/L	0.5	2.7	2.4	2.0	1.6	No	No
Magnesium	mg/L	0.01	1.37	1.29	1.30	1.01	No	No
Manganese	µg/L	0.05	2.60	4.84	1.78	4.01(f)	No	No(e)
Mercury	µg/L	0.01	0.03	0.03	<0.01	<0.01	No	No

Table 3-4 Comparison of 2013 Data to Action Level 1

Variable	Unit	2013 Detection Limit	Action Level 1					
			Magnitude of Effect		2013 AEMP		Action Level 1 Applied (Yes/No)	
			2 x Median of Reference Areas[a]		Median of NF Values[b]			
			Ice-cover	Open-water	Ice-cover	Open-water	Ice-cover	Open-water
Metals (Total) (Continued)								
Molybdenum	µg/L	0.05	0.16	0.19	1.25	0.67[f]	**Yes**	**Yes**[e]
Nickel	µg/L	0.02	1.95	1.90	1.01	0.74[f]	No	No[e]
Potassium	mg/L	0.01	1.18	1.09	1.15	0.97	No	No
Selenium	µg/L	0.04	0.142	0.142	<0.04	<0.04	No	No
Silicon	µg/L	50	71	104	239	<50	**Yes**	No
Silver	µg/L	0.005	0.142	0.142	<0.005	<0.005	No	No
Sodium	mg/L	0.01	1.32	1.31	2.90	1.68	[g]	[g]
Strontium	µg/L	0.05	15.58	14.90	32.30	17.90	**Yes**	**Yes**
Sulphur	mg/L	0.1	2.0	1.8	1.5	1.6	No	No
Thallium	µg/L	0.002	0.003	0.003	<0.002	<0.002	No	No
Tin	µg/L	0.01-0.2	0.038	0.05	0.036	0.038	No	No
Titanium	µg/L	0.5	0.7	0.7	<0.05	<0.05	No	No
Uranium	µg/L	0.002	0.057	0.054	0.187	0.086	**Yes**	**Yes**
Vanadium[i]	µg/L	0.1	0.07	0.07	<0.1	<0.1	No	No
Zinc	µg/L	0.1	1.9	1.5	0.9	1.0	No	No
Zirconium	µg/L	0.05	0.14	0.11	<0.05	<0.05	No	No

Notes: mg/L = milligrams per litre; µS/cm = microSiemens per centimeter; NTU = nephelometric turbidity units; µg/L= micrograms per liter

a) the 2 x median of reference areas criterion was calculated using the historic reference area data pooled across all sample dates and stations (FFA, FFB, and FF1). Sampling dates and years included in the reference area median value are described in Section 2.4.6.3 and Table IV-1 of Appendix D.

b) the median of NF area values was calculated from the NF area data pooled across all sample depths, dates and stations.

c) pH is evaluated qualitatively in Section 3.4.

d) nutrients that are generally not toxic to aquatic organisms were evaluated in the Eutrophication Indicators Report (Golder 2014b)

e) the screening results for nitrate + nitrite were identical to nitrate. Action Level 1 was applied for nitrate only given that nitrite is primarily non-detect at AEMP stations.

f) the NF area median value during the open-water season for cadmium, chromium, cobalt, iron, manganese, molybdenum and nickel was calculated based on a reduced sample size (n = 5 of 15 NF area samples) due to sample contamination (Appendix B).

g) the total fractions of calcium and sodium reached Action Level 1 in 2013; however, Action Level 1 was applied for the dissolved results only.

h) the 2x median of reference areas was not calculated for chromium because suitable reference area data were not available. Detection limits used prior to 2013 were greater than many NF area values in 2013 (i.e., which were analyzed used a lower DL), and reference area samples collected in 2013 were mostly contaminated (n= 12 of 15 samples; Appendix BI).

i) the 2x median of reference areas for boron and vanadium was based on a lower DL than that used in 2013.

Table 3-5 Comparison of 2013 Data to Action Level 2

Variable	Unit	2013 Detection Limit	Action Level 2					
			Magnitude of Effect		2013 AEMP		Action Level 2 Applied (Yes/No)	
			Top of Normal Range[(a)]		75th Percentile of Near-field Values[(b)]			
			Ice-cover	Open-water	Ice-cover	Open-water	Ice-cover	Open-water
Conventional Parameters								
Specific Conductivity	µS/cm	1	20	16	55	29	**Yes**	**Yes**
Total Dissolved Solids (Calculated)	mg/L	-	8.4	6.2	26.8	14.1	**Yes**	**Yes**
Major Ions								
Calcium	mg/L	0.01	1.4	1.2	2.9	1.6	**Yes**	**Yes**
Chloride	mg/L	0.5	1.7	1.9	6.8	2.3	**Yes**	**Yes**
Sodium	mg/L	0.01	1.94	0.71	3.89	1.76	**Yes**	**Yes**
Sulphate	mg/L	0.5	3.3	2.6	4.8	3.2	**Yes**	**Yes**
Nutrients								
Ammonia (as Nitrogen)	µg/L	5	32	11	49	24	**Yes**	**Yes**
Nitrate (as Nitrogen)	µg/L	2	11.3	2.45	95.2	13.2	**Yes**	**Yes**
Metals (Total)								
Aluminum	µg/L	0.2-0.5	4.3	6.3	16.8	6.4	**Yes**	**Yes**
Barium	µg/L	0.02	2.19	2.2	6.28	2.72	**Yes**	**Yes**
Chromium	µg/L	0.05	0.05	(c)	0.08	0.08(d)	**Yes**	(c)
Molybdenum	µg/L	0.05	0.14	0.25	1.61	0.79(d)	**Yes**	**Yes**
Silicon	µg/L	50	121	89	378	51	**Yes**	No
Strontium	µg/L	0.05	8.97	8.59	45.35	18.5	**Yes**	**Yes**
Uranium	µg/L	0.002	0.035	0.036	0.208	0.091	**Yes**	**Yes**

Notes: mg/L = milligrams per litre; µS/cm = microSiemens per centimeter; µg/L= micrograms per liter.

a) the normal range upper limit was calculated as the reference area mean plus 2 standard deviations. Sampling dates and years included in the determination of the normal range for each season and variable are provided in Section 2.4.6.3 and Table IV-1 of Appendix E.

b) the 75th percentile of NF area values was calculated from values pooled across all sample depths, dates and stations

c) the normal range for chromium was not calculated because suitable reference area data were not available. Detection limits used prior to 2013 were greater than many NF area values in 2013 (i.e., which were analyzed using a lower DL), and reference area samples collected in 2013 were mostly contaminated (n= 12 of 15 samples).

d) The NF area 75th percentile value for chromium and molybdenum during the open-water season was calculated based on a reduced sample size (n = 5 of 15 NF area samples) due to sample contamination (Appendix B).

Table 3-6 Comparison of 2013 Data to Action Level 3

Variable	Unit	2013 Mixing Zone Detection Limit	AEMP Effects Benchmark(a)	Action Level 3				Action Level 3 Applied (Yes/No)	
				Magnitude of Effect		2013 AEMP			
				Normal Range(b) + 25% of Effects Benchmark		75th Percentile of Mixing Zone Values(c)			
				Ice-cover	Open-water	Ice-cover	Open-water	Ice-cover	Open-water
Conventional Parameters									
Total Dissolved Solids (Calculated)	mg/L	-	500	131.3	129.7	29.4	20.2	No	No
Major Ions									
Chloride	mg/L	0.5	120	31.3	31.4	7.1	3.5	No	No
Sodium	mg/L	0.01	200	51.46	50.53	4.23	2.54	No	No
Sulphate	mg/L	0.5	100	27.4	27	5.5	5.1	No	No
Nutrients									
Ammonia (as Nitrogen)	µg/L	5	4730	1206	1190	51	23	No	No
Nitrate (as Nitrogen)	µg/L	20	3000	758	752	106	81	No	No
Metals									
Aluminum (dissolved)(d)	µg/L	0.2	Variable with pH; median = 88 (range = 12 to 32,000)	Variable with pH median = 24.6 (range = 5.6 to 8002.7)(d)	Variable with pH median = 24.6 (range =5.6 to 8002.6)(d)	9.9(d)	6.1(d)	No	No
Barium	µg/L	0.02	1000	251.64	251.65	6.42	3.52	No	No
Chromium	µg/L	0.1	1	0.29	(e)	0.08	<0.1	No	(e)
Molybdenum	µg/L	0.05	73	18.35	18.44	1.88	1.53(f)	No	No(f)
Strontium	µg/L	0.05	30000	7506.73	7506.44	49.78	26.73	No	No
Uranium	µg/L	0.002	15	3.776	3.777	0.298	0.123	No	No

Notes: mg/L = milligrams per litre; µg/L= micrograms per liter.

a) the AEMP Effects Benchmarks are the Aquatic Life and/or Drinking Water Benchmarks (whichever was applicable or more conservative) described in the AEMP Study Design Version 3.3 (Golder 2014a) and in Section 2.4.6.3, Table 2-5.

b) the normal range upper limit was calculated as the reference area mean plus 2 standard deviations. Sampling dates and years included in the determination of the normal range for each season and variable are provided in Section 2.4.6.3 and Table IV-1 of Appendix E.

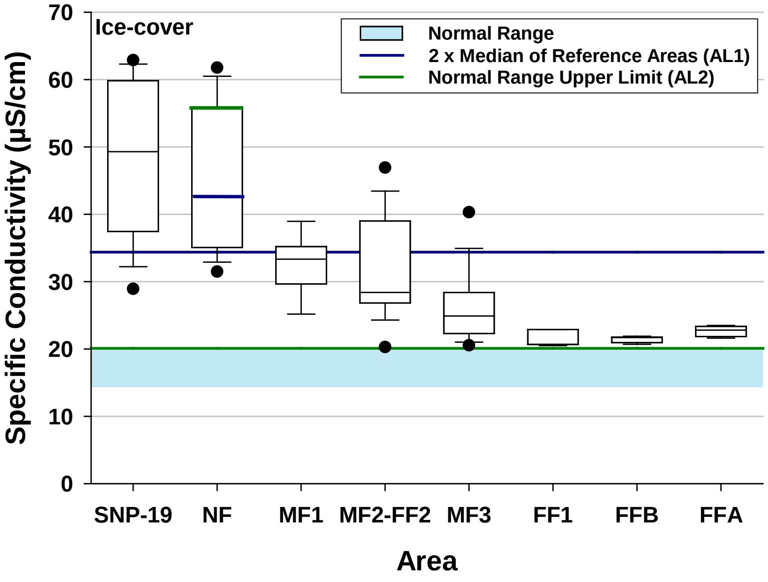
c) the 75th percentile of mixing zone values was calculated from the 2013 data pooled across all sample depths, dates and stations. The ice-cover season for the mixing zone was from November 2012 to June 2013. The open water season was from July 2013 to October 2013.

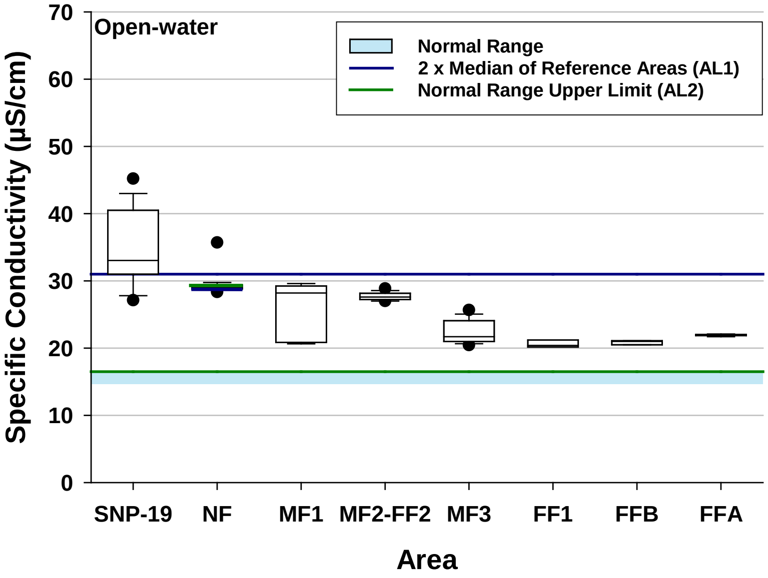
d) the 75th percentile value for aluminum at the mixing zone was calculated using dissolved values to allow for comparison with the Effects Benchmark, which is specific to dissolved aluminum (Table 2-5). The normal range for dissolved aluminum was calculated based on the relationship between total and dissolved aluminum at the mixing zone (dissolved data were not available for the AEMP dataset which comprise the normal range).

e) the normal range for chromium was not calculated because suitable reference area data were not available. Detection limits used prior to 2013 were greater than many NF area values in 2013 (i.e., which were analyzed using a lower DL), and reference area samples collected in 2013 were mostly contaminated (n= 12 of15 samples).

f) the mixing zone 75th percentile values for chromium and molybdenum during the open-water season were calculated based on a reduced sample size (n = 26 of 49 mixing zone samples) due to sample contamination (Appendix B).

Figure 3-35 Spatial Variation in Specific Conductivity Relative to Action Level Values, 2013

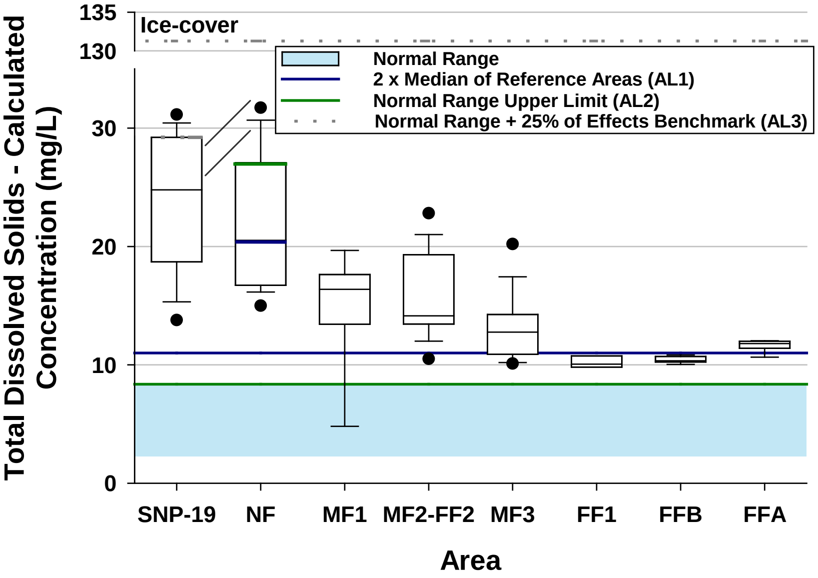


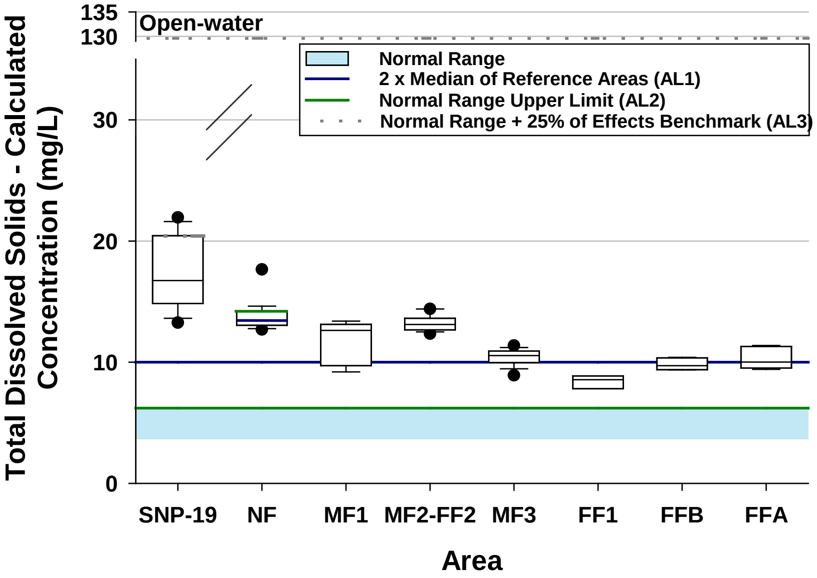


Notes: µS/cm= microSiemens per centimetre; AL = Action Level; SNP-19 = Mixing Zone.

Boxplots represent the 10th, 25th, 50th (median), 75th, and 90th percentile concentrations in each sampling area. Black circles represent the 5th and 95th percentile concentrations. Action Level threshold values were calculated from the 2007-2010 reference area data. The normal range was defined as the reference area mean ± 2 standard deviations.

Figure 3-36 Spatial Variation in Total Dissolved Solids (Calculated) Concentration Relative to Action Level Values, 2013

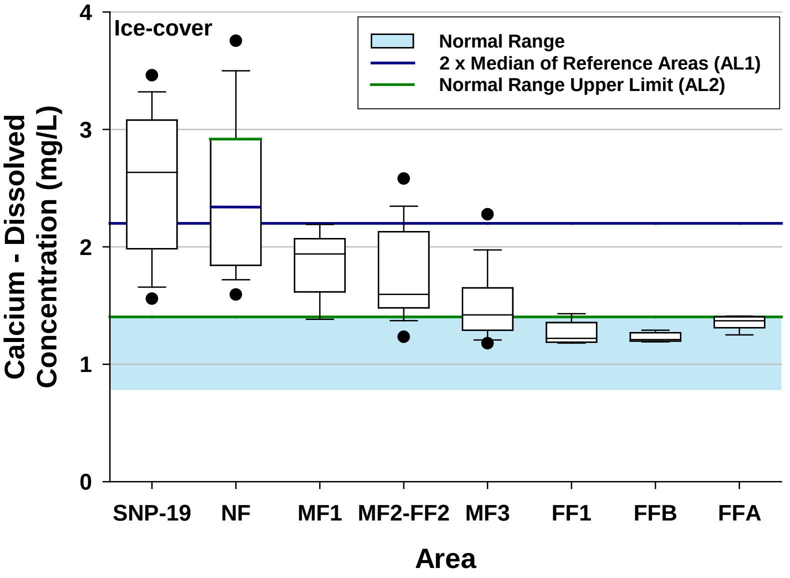


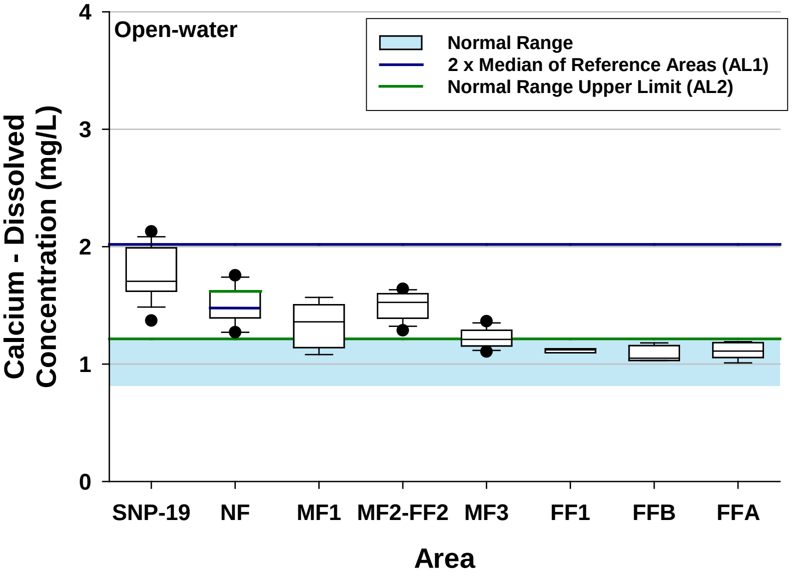


Notes: mg/L = milligrams per litre; AL = Action Level; SNP-19 = Mixing Zone.

Boxplots represent the 10th, 25th, 50th (median), 75th, and 90th percentile concentrations in each sampling area. Black circles represent the 5th and 95th percentile concentrations. Action Level threshold values were calculated from the 2007-2010 reference area data. The normal range was defined as the reference area mean ± 2 standard deviations. AEMP Effects Benchmarks used at Action Level 3 are provided in Section 2.4.6.3, Table 2-5.

Figure 3-37 Spatial Variation in Calcium (Dissolved) Concentration Relative to Action Level Values, 2013

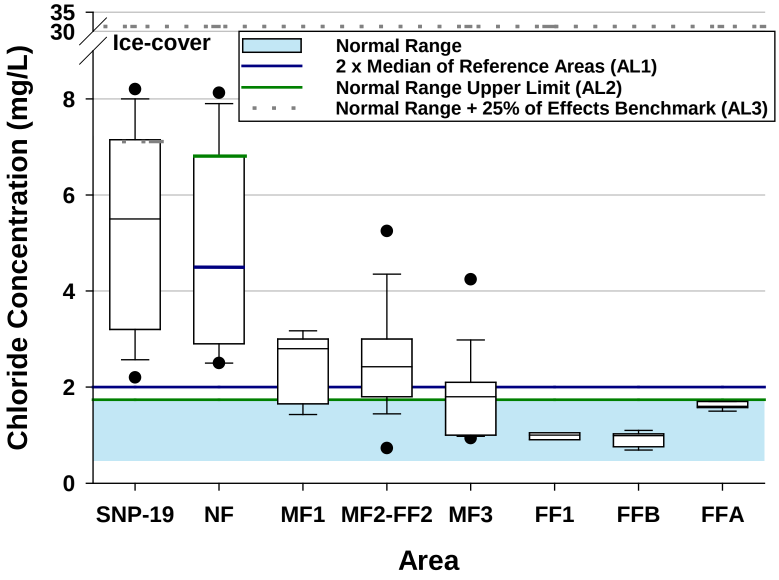


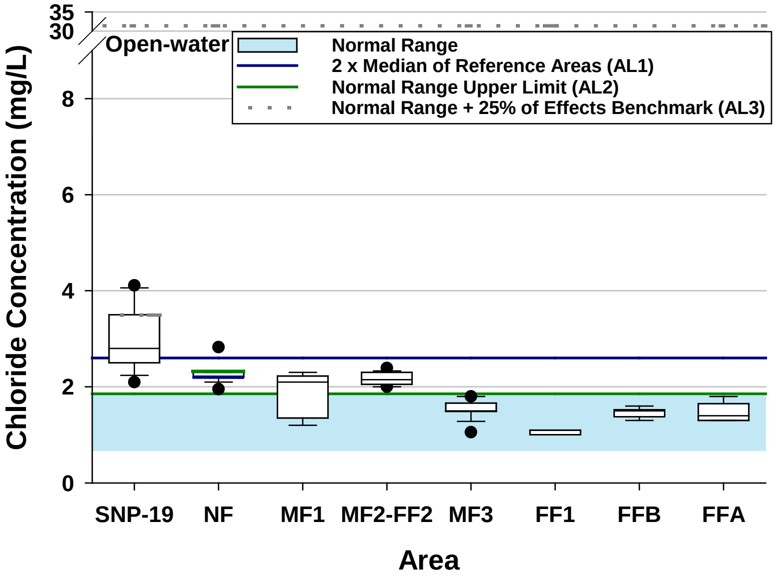


Notes: mg/L = milligrams per litre; AL = Action Level; SNP-19 = Mixing Zone.

Boxplots represent the 10th, 25th, 50th (median), 75th, and 90th percentile concentrations in each sampling area. Black circles represent the 5th and 95th percentile concentrations. Action Level threshold values were calculated from the 2007-2010 reference area data. The normal range was defined as the reference area mean ± 2 standard deviations.

Figure 3-38 Spatial Variation in Chloride Concentration Relative to Action Level Values, 2013

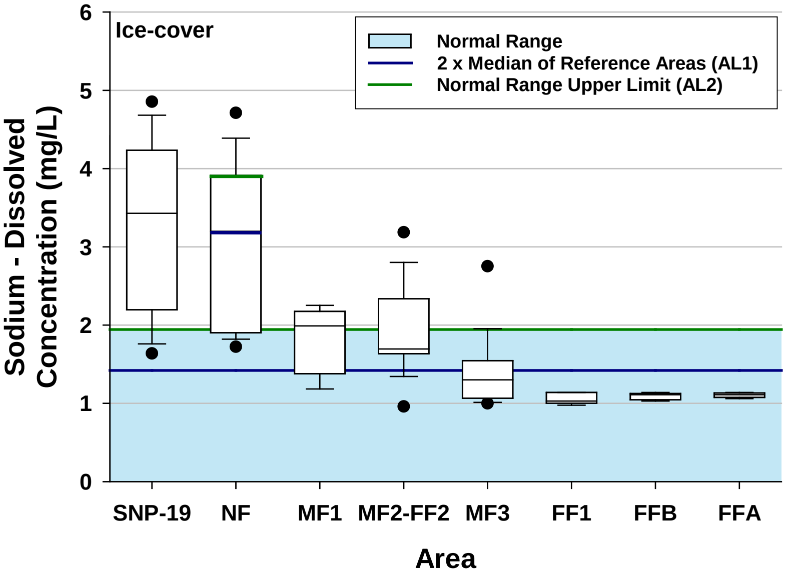


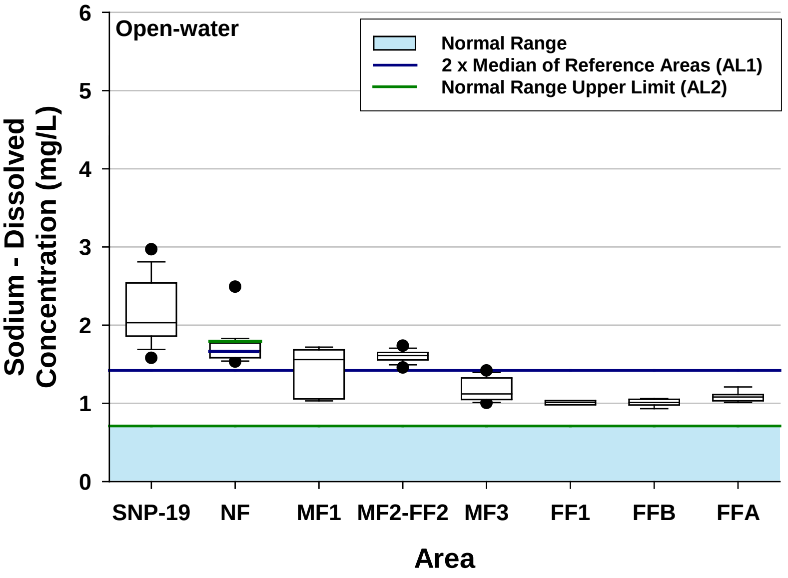


Notes: mg/L = milligrams per litre; AL = Action Level; SNP-19 = Mixing Zone.

Boxplots represent the 10th, 25th, 50th (median), 75th, and 90th percentile concentrations in each sampling area. Black circles represent the 5th and 95th percentile concentrations. Action Level threshold values were calculated from the 2011 and 2013 reference area data. The normal range was defined as the reference area mean ± 2 standard deviations. AEMP Effects Benchmarks used at Action Level 3 are provided in Section 2.4.6.3, Table 2-5.

Figure 3-39 Spatial Variation in Sodium (Dissolved) Concentration Relative to Action Level Values, 2013

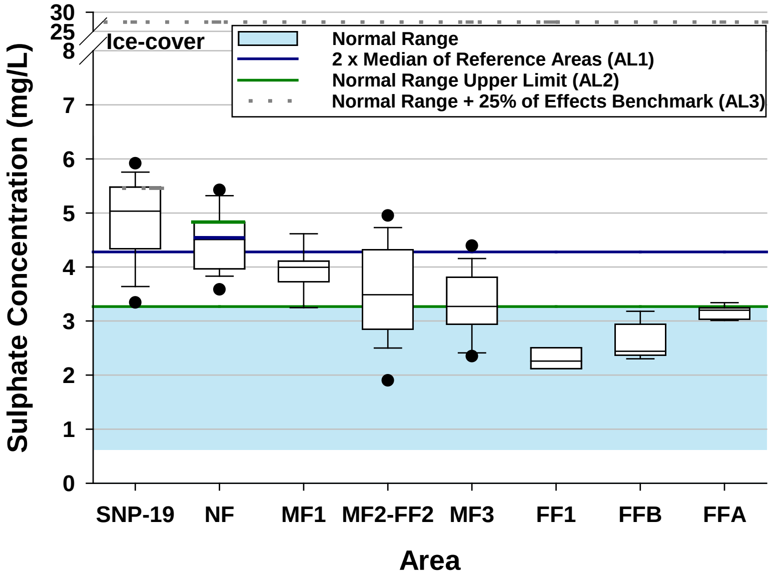


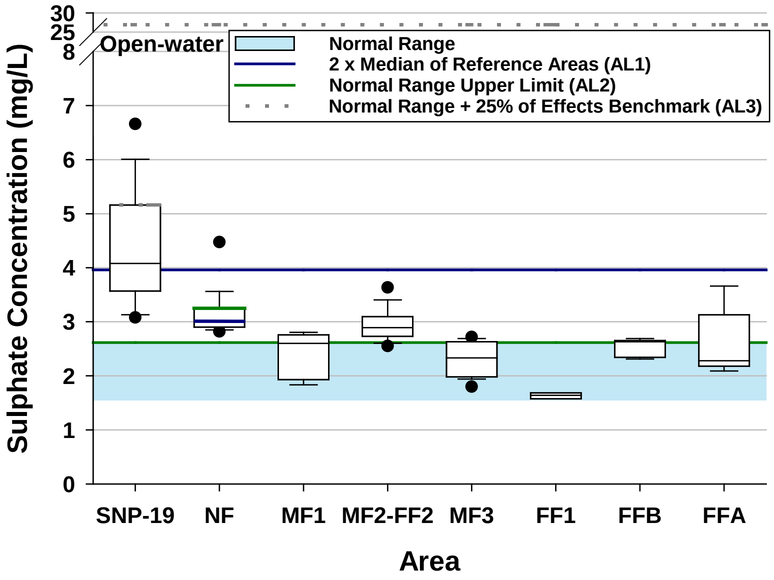


Notes: mg/L = milligrams per litre; AL = Action Level; SNP-19 = Mixing Zone

Boxplots represent the 10th, 25th, 50th (median), 75th, and 90th percentile concentrations in each sampling area. Black circles represent the 5th and 95th percentile concentrations. Action Level threshold values were calculated from the 2007-2010 reference area data. The normal range was defined as the reference area mean ± 2 standard deviations.

Figure 3-40 Spatial Variation in Sulphate Concentration Relative to Action Level Values, 2013

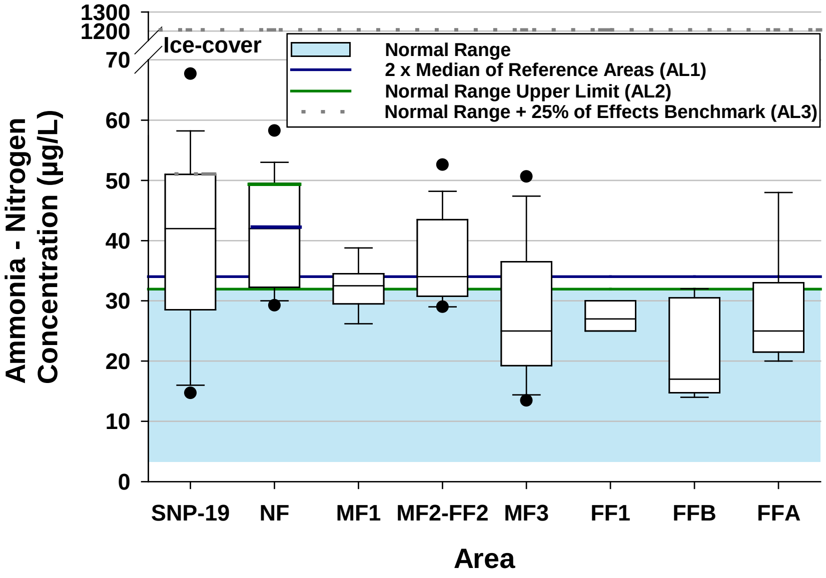


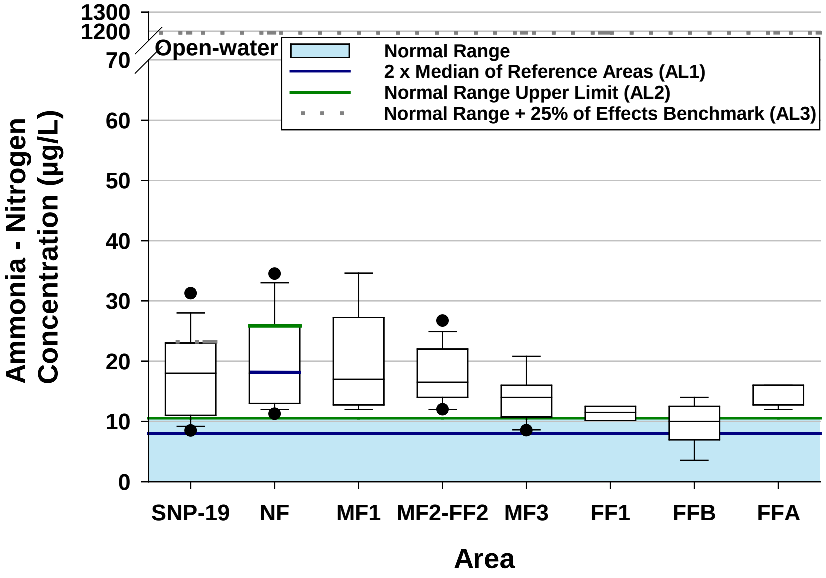


Notes: mg/L = milligrams per litre; AL = Action Level; SNP-19 = Mixing Zone

Boxplots represent the 10th, 25th, 50th (median), 75th, and 90th percentile concentrations in each sampling area. Black circles represent the 5th and 95th percentile concentrations. Action Level threshold values were calculated from the 2007-2010 reference area data. The normal range was defined as the reference area mean ± 2 standard deviations. AEMP Effects Benchmarks used at Action Level 3 are provided in Section 2.4.6.3, Table 2-5.

Figure 3-41 Spatial Variation in Ammonia (as Nitrogen) Concentration Relative to Action Level Values, 2013

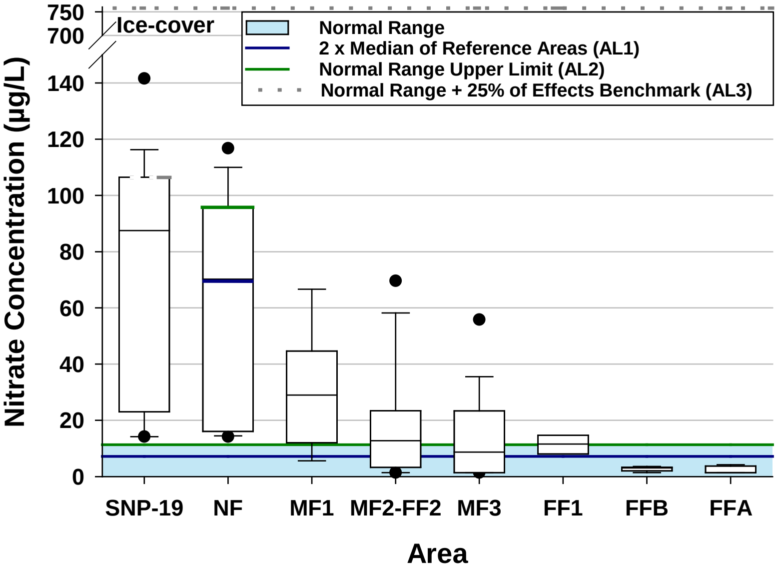


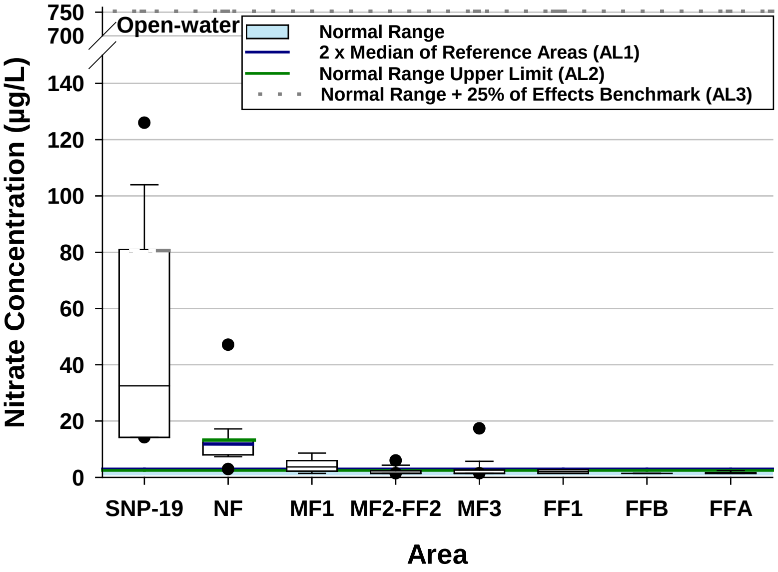


Notes: µg/L = milligrams per litre; AL = Action Level; SNP-19 = Mixing Zone

Boxplots represent the 10th, 25th, 50th (median), 75th, and 90th percentile concentrations in each sampling area. Black circles represent the 5th and 95th percentile concentrations. Action Level threshold values were calculated from the 2007-2010 reference area data. The normal range was defined as the reference area mean ± 2 standard deviations. AEMP Effects Benchmarks used at Action Level 3 are provided in Section 2.4.6.3, Table 2-5.

Figure 3-42 Spatial Variation in Nitrate Concentration Relative to Action Level Values, 2013

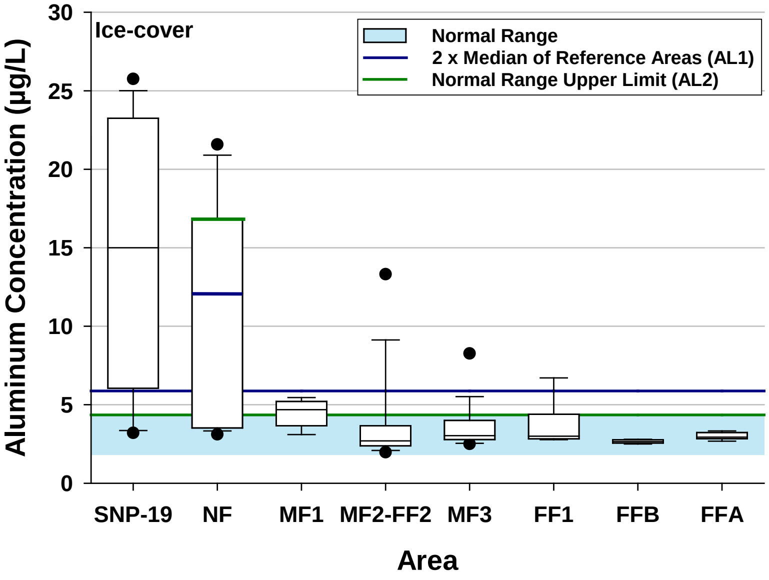


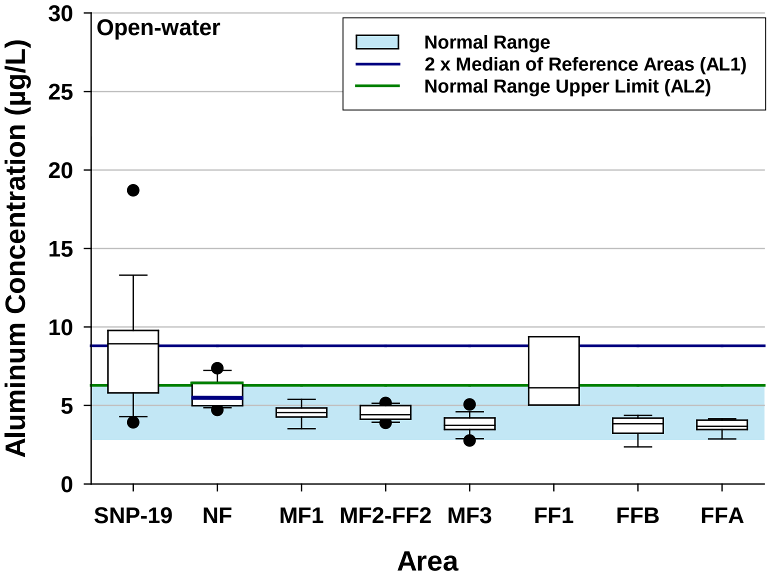


Notes: µg/L = milligrams per litre; AL = Action Level; SNP-19 = Mixing Zone.

Boxplots represent the 10th, 25th, 50th (median), 75th, and 90th percentile concentrations in each sampling area. Black circles represent the 5th and 95th percentile concentrations. Action Level threshold values were calculated from the 2013 reference area data. The normal range was defined as the reference area mean ± 2 standard deviations. AEMP Effects Benchmarks used at Action Level 3 are provided in Section 2.4.6.3, Table 2-5. The DL for nitrate at the Mixing Zone (20 µg/L) was greater than that used at AEMP stations (2 µg/L).

Figure 3-43 Spatial Variation in Aluminum (Total) Concentration Relative to Action Level Values, 2013

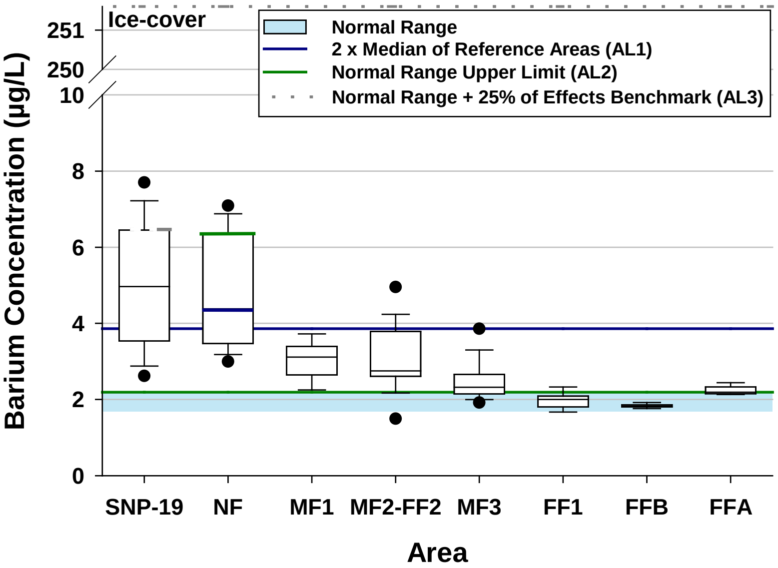


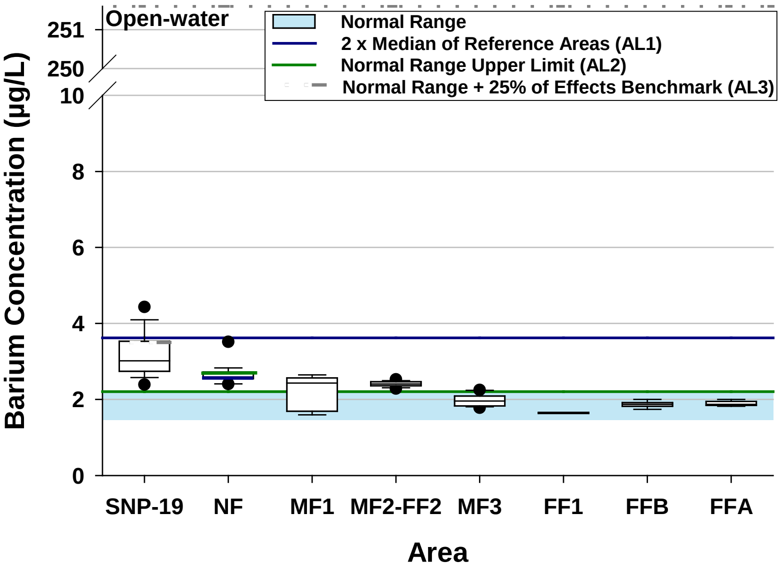


Notes: µg/L = milligrams per litre; AL = Action Level; SNP-19 = Mixing Zone

Boxplots represent the 10th, 25th, 50th (median), 75th, and 90th percentile concentrations in each sampling area. Black circles represent the 5th and 95th percentile concentrations. Action Level threshold values were calculated from the 2007-2010 reference area data. The normal range was defined as the reference area mean ± 2 standard deviations. Action Level 3 is not shown for Aluminum because the Effects Benchmark is specific to dissolved aluminum.

Figure 3-44 Spatial Variation in Barium Concentration Relative to Action Level Values, 2013

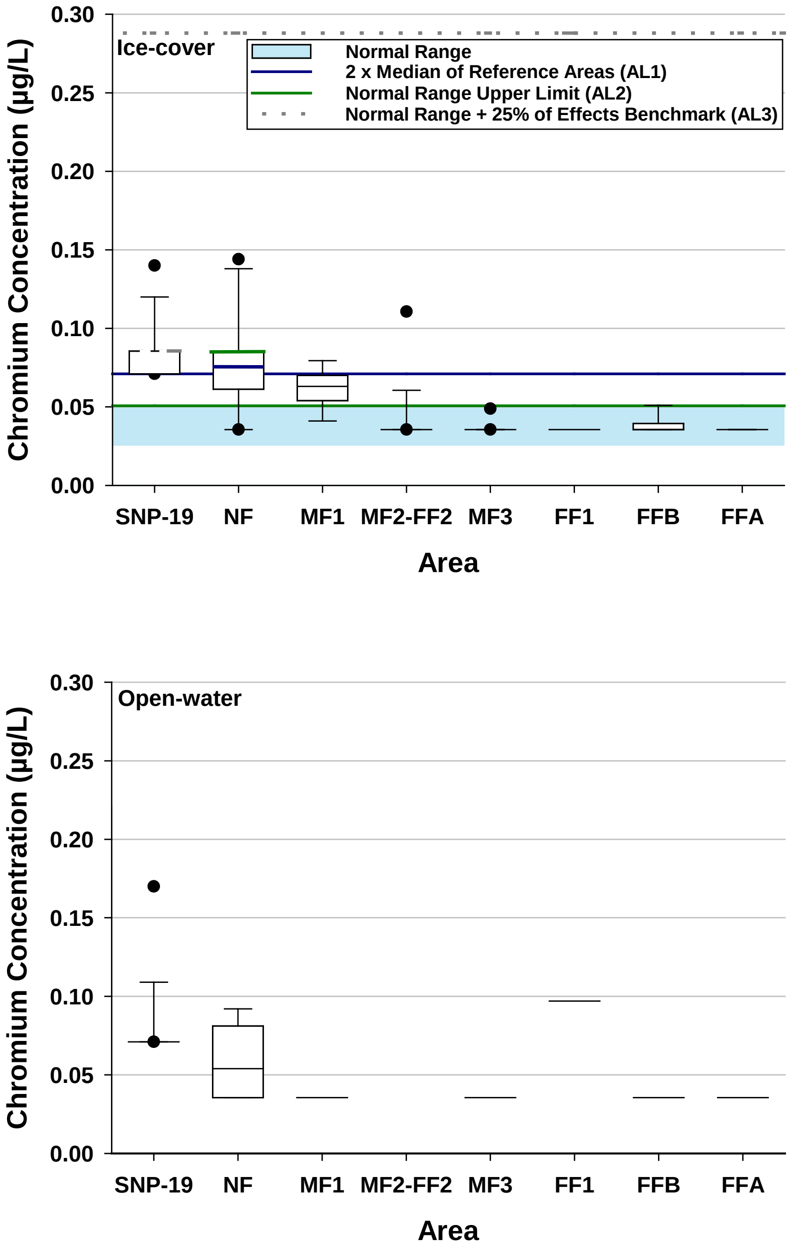




Notes: µg/L = milligrams per litre; AL = Action Level; SNP-19 = Mixing Zone.

Boxplots represent the 10th, 25th, 50th (median), 75th, and 90th percentile concentrations in each sampling area. Black circles represent the 5th and 95th percentile concentrations. Action Level threshold values were calculated from the 2007-2010 reference area data. The normal range was defined as the reference area mean ± 2 standard deviations. AEMP Effects Benchmarks used at Action Level 3 are provided in Section 2.4.6.3, Table 2-5.

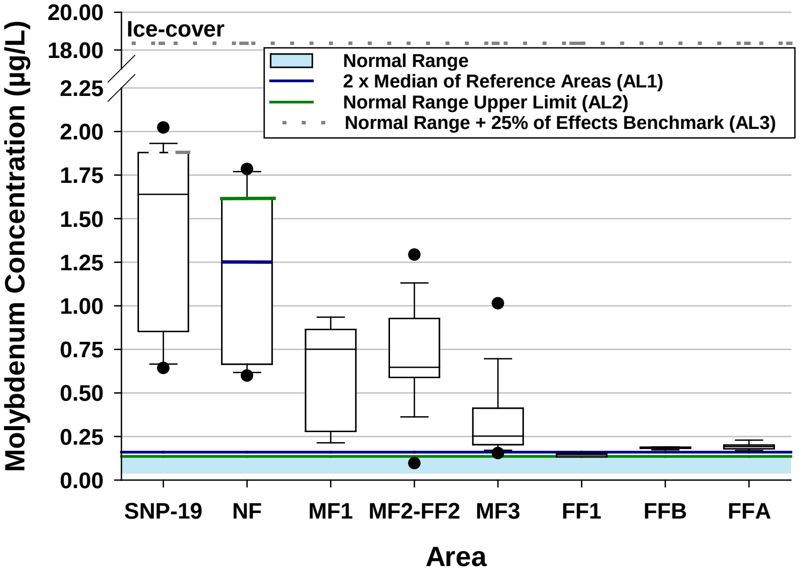
Figure 3-45 Spatial Variation in Chromium Concentration Relative to Action Level Values, 2013

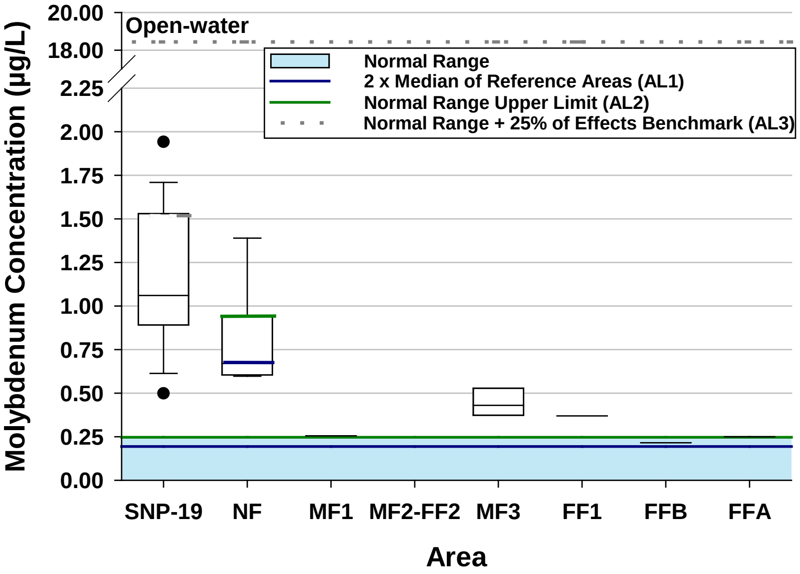


Notes: µg/L = milligrams per litre; SNP-19 = Mixing Zone.

Boxplots represent the 10th, 25th, 50th (median), 75th, and 90th percentile concentrations in each sampling area. Black circles represent the 5th and 95th percentile concentrations. Action Level threshold values for the ice-cover season were calculated from the 2013 reference area data. The normal range was defined as the reference area mean ± 2 standard deviations. AEMP Effects Benchmarks used at Action Level 3 are provided in Section 2.4.6.3, Table 2-5. Open-water boxplots for chromium were based on a reduced sample size season due to sample contamination (Appendix B). The DL for chromium at the Mixing Zone (0.1 µg/L) was greater than for AEMP stations (0.05 µg/L).

Figure 3-46 Spatial Variation in Molybdenum Concentration Relative to Action Level Values, 2013

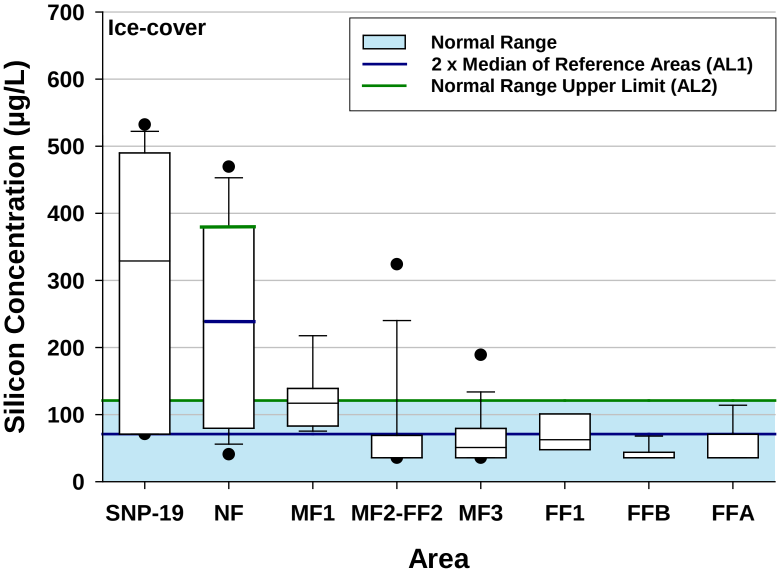


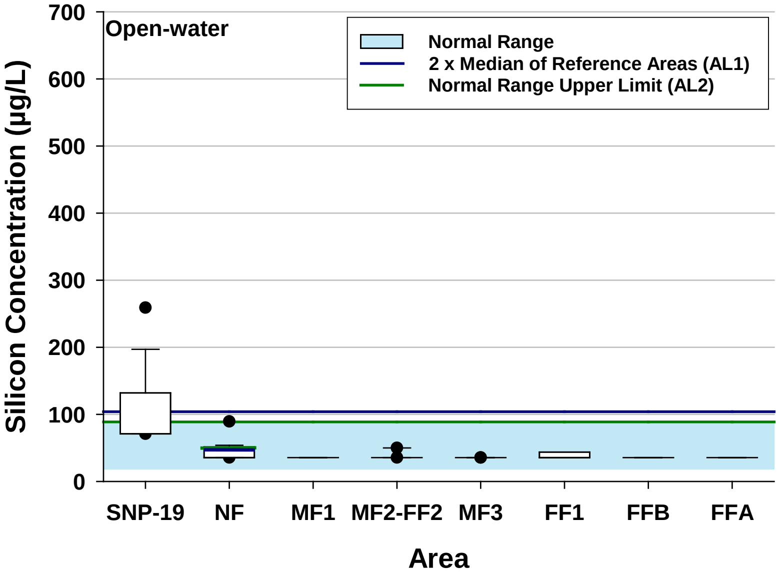


Notes: µg/L = milligrams per litre; AL = Action Level; SNP-19 = Mixing Zone.

Boxplots represent the 10th, 25th, 50th (median), 75th, and 90th percentile concentrations in each sampling area. Black circles represent the 5th and 95th percentile concentrations. Action Level threshold values were calculated from the 2007-2010 reference area data. The normal range was defined as the reference area mean ± 2 standard deviations. AEMP Effects Benchmarks used at Action Level 3 are provided in Section 2.4.6.3, Table 2-5. Open-water boxplots for molybdenum were based on a reduced sample size due to sample contamination (Appendix B).

Figure 3-47 Spatial Variation in Silicon Concentration Relative to Action Level Values, 2013

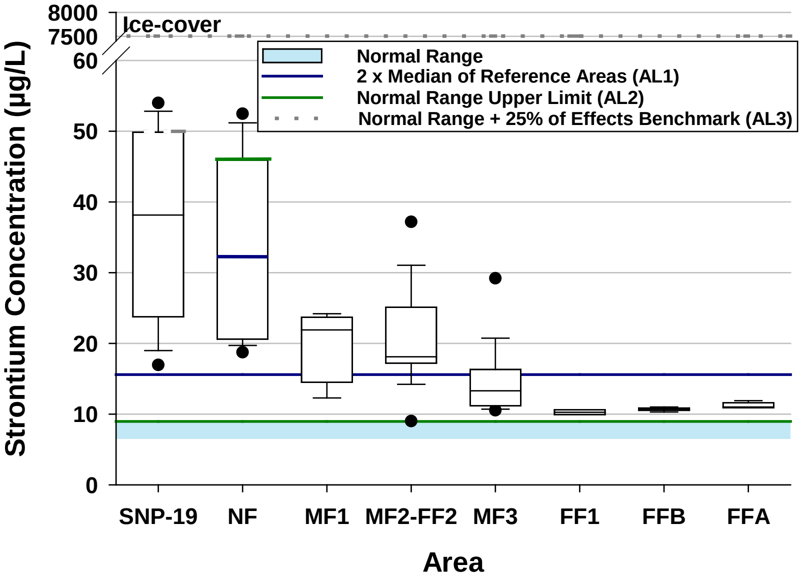


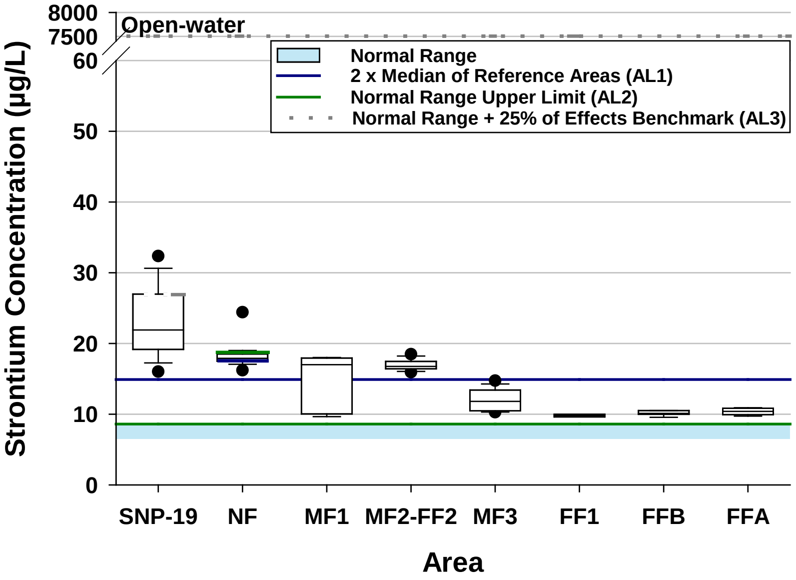


Notes: µg/L = milligrams per litre; AL = Action Level; SNP-19 = Mixing Zone.

Boxplots represent the 10th, 25th, 50th (median), 75th, and 90th percentile concentrations in each sampling area. Black circles represent the 5th and 95th percentile concentrations. Action Level threshold values were calculated from the 2013 reference area data. The normal range was defined as the reference area mean ± 2 standard deviations.

Figure 3-48 Spatial Variation in Strontium Concentration Relative to Action Level Values, 2013

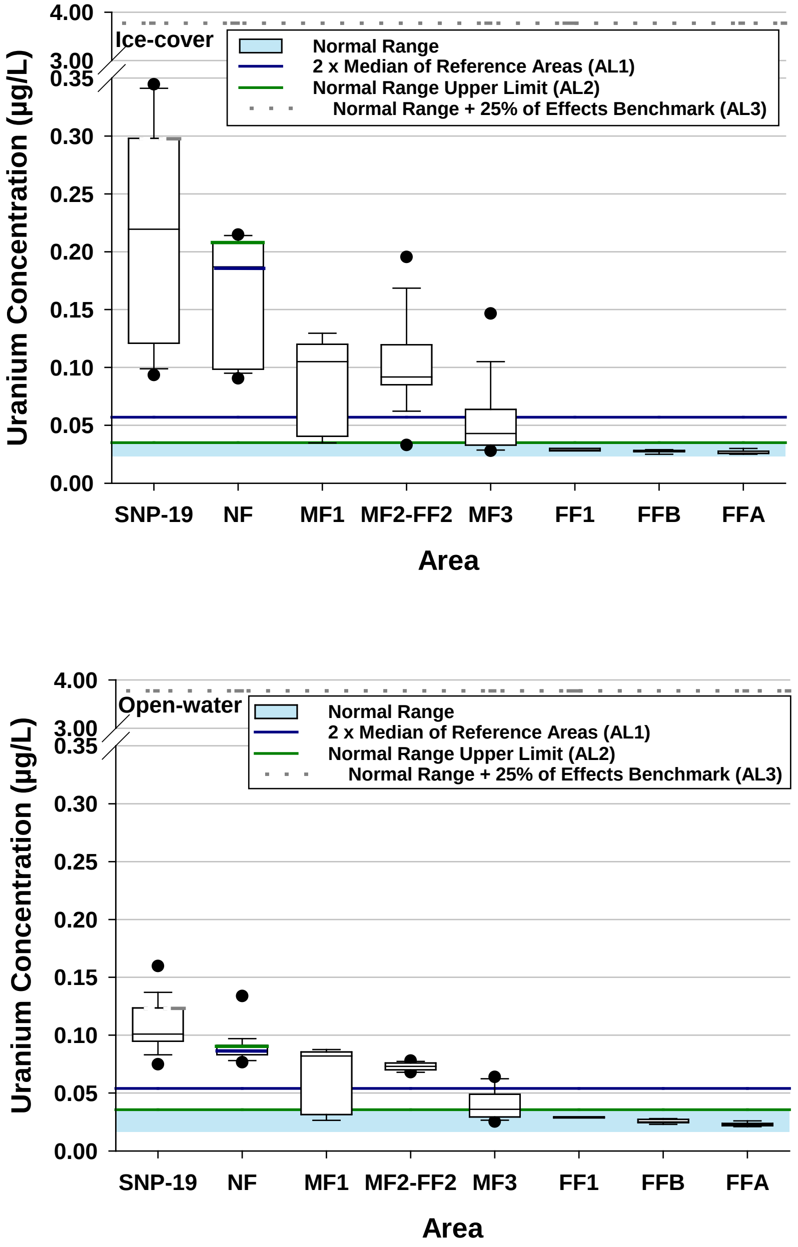




Notes: µg/L = milligrams per litre; AL = Action Level; SNP-19 = Mixing Zone.

Boxplots represent the 10th, 25th, 50th (median), 75th, and 90th percentile concentrations in each sampling area. Black circles represent the 5th and 95th percentile concentrations. Action Level threshold values were calculated from the 2007-2010 reference area data. The normal range was defined as the reference area mean ± 2 standard deviations. AEMP Effects Benchmarks used in Action Level 3 are provided in Section 2.4.6.3, Table 2-5.

Figure 3-49 Spatial Variation in Uranium Concentration Relative to Action Level Values, 2013



Notes: µg/L = milligrams per litre; AL = Action Level; SNP-19 = Mixing Zone.

Boxplots represent the 10th, 25th, 50th (median), 75th, and 90th percentile concentrations in each sampling area. Black circles represent the 5th and 95th percentile concentrations. Action Level threshold values were calculated from the 2011 and 2013 reference area data. The normal range was defined as the reference area mean ± 2 standard deviations. The normal range was defined as the reference area mean ± 2 standard deviations. AEMP Effects Benchmarks used in Action Level 3 are provided in Section 2.4.6.3, Table 2-5.

3.6 STATISTICAL ANALYSIS

Substances of interest identified in Section 3.1 were evaluated statistically to determine whether the increases seen the NF area were significantly greater relative to the reference areas. Statistical analyses compared the NF area data from the sampling depth representing the greatest effluent exposure to the mid-depth data from the FF reference areas (Table 2-6). Results for normality and homogeneity of variances tests conducted for these variables prior to making statistical comparisons are summarized in Appendix F, Table F-1.

Each of the 15 SOIs tested had NF mean concentrations significantly greater than reference area mean concentrations in one or both sampling seasons (ice-cover or open-water; Tables 3-7 and 3-8). Generally, comparisons were significant during both the ice-cover and open-water seasons. An exception occurred for silicon, which had a significant difference during the ice-cover season, but not during the open-water season. Silicon was primarily non-detect (DL = 50 µg/L) at AEMP stations during the open-water season. Chromium and molybdenum were not analyzed statistically during in the open-water season due to contamination of NF and FF area samples Appendix B). The available data for uncontaminated samples in the NF and FF reference areas are provided in Table 3-7.

Significant differences among reference areas occurred during the ice cover season for several major ions (calcium, chloride, and sulphate) as well as for nitrate and molybdenum (Table 3-8). During the open-water season, significant differences among reference areas were noted for chloride, aluminum, and uranium. The difference between individual reference area means for most of these variables, however, was small when compared with the overall difference between the NF and reference area means (Table 3-7).

Table 3-7 Substance of Interest Concentrations in the NF and FF Reference Areas, 2013 AEMP

Variable	Season	Unit	Detection Limit	NF[(a)]	FF1	FFB	FFA
Specific Conductivity	Ice-cover	µS/cm	1	53.7 ± 7.9	21.5 ± 1.2	21.4 ± 0.5	22.6 ± 0.8
	Open-Water			30.7 ± 3.9	20.6 ± 0.82	20.8 ± 0.31	21.9 ± 0.1
Total Dissolved Solids (Calculated)	Ice-cover	mg/L	0.5	26.1 ± 3.8	10.7 ± 1.2	10.4 ± 0.3	11.6 ± 0.6
	Open-Water			14.6 ± 2.3	8.4 ± 0.7	9.8 ± 0.5	10.3 ± 0.9
Calcium	Ice-cover	mg/L	0.01	2.86 ± 0.42	1.27 ± 0.11	1.23 ± 0.04	1.35 ± 0.06
	Open-Water			1.52 ± 0.15	1.11 ± 0.02	1.09 ± 0.07	1.11 ± 0.08
Chloride	Ice-cover	mg/L	0.5	6.6 ± 1.4	1.1 ± 0.2	0.9 ± 0.2	1.6 ± 0.1
	Open-Water			2.4 ± 0.3	1.1 ± 0.1	1.5 ± 0.1	1.5 ± 0.2
Sodium	Ice-cover	mg/L	0.01	3.79 ± 0.66	1.06 ± 0.08	1.09 ± 0.05	1.1 ± 0.03
	Open-Water			1.88 ± 0.47	1.01 ± 0.03	1.01 ± 0.05	1.08 ± 0.08

Table 3-7 Substance of Interest Concentrations in the NF and FF Reference Areas, 2013 AEMP

Variable	Season	Unit	Detection Limit	NF[(a)]	FF1	FFB	FFA
Sulphate	Ice-cover	mg/L	0.5	4.8 ± 0.4	2.4 ± 0.3	2.6 ± 0.4	3.2 ± 0.1
	Open-Water			3.4 ± 0.8	1.6 ± 0.1	2.5 ± 0.2	2.6 ± 0.7
Ammonia (as Nitrogen)	Ice-cover	µg/L	5	49 ± 8	28 ± 3	22 ± 9	29 ± 11
	Open-Water			23 ± 10	11 ± 1	10 ± 4	15 ± 2
Nitrate (as nitrogen)	Ice-cover	µg/L	2	92 ± 15	13 ± 5	3 ± 1	2 ± 1
	Open-Water			21 ± 20	2 ± 0.7	1 ± 0	2 ± 0.4
Aluminum	Ice-cover	µg/L	0.2-0.5	16.4 ± 5.4	3.8 ± 1.7	2.7 ± 0.1	3 ± 0.3
	Open-Water			5.8 ± 0.8	6.6 ± 3	3.6 ± 0.8	3.7 ± 0.5
Barium	Ice-cover	µg/L	0.02	6 ± 1.23	1.97 ± 0.24	1.83 ± 0.06	2.24 ± 0.13
	Open-Water			2.86 ± 0.5	1.65 ± 0.03	1.87 ± 0.09	1.89 ± 0.07
Chromium[(b)]	Ice-cover	µg/L	0.05	0.09 ± 0.027	<0.05 ± 0.009	<0.05 ± 0.007	<0.05 ± 0
	Open-Water			0.06 ± 0.025	0.1	0.04	0.04
Molybdenum[(b)]	Ice-cover	µg/L	0.05	1.54 ± 0.27	0.14 ± 0.01	0.19 ± 0.01	0.19 ± 0.02
	Open-Water			0.81 ± 0.33	0.37	0.22	0.25
Silicon	Ice-cover	µg/L	50	366 ± 105	76 ± 38	<50 ± 15	55 ± 34
	Open-Water			51.9 ± 28.4	<50 ± 7.4	<50 ± 0	<50 ± 0
Strontium	Ice-cover	µg/L	0.05	43.72 ± 8.99	10.53 ± 0.74	10.68 ± 0.26	11.24 ± 0.44
	Open-Water			19.72 ± 3.65	9.8 ± 0.22	10.15 ± 0.39	10.37 ± 0.5
Uranium	Ice-cover	µg/L	0.002	0.201 ± 0.014	0.031 ± 0.004	0.028 ± 0.002	0.027 ± 0.002
	Open-Water			0.1 ± 0.026	0.029 ± 0.001	0.026 ± 0.002	0.023 ± 0.002

Notes: mg/L = milligrams per litre; µS/cm = micro Siemens per centimetre; µg/L = micrograms per litre.

a) the sampling depth representing the greatest average NF area concentration (top, middle or bottom) is shown (Table 2-6).

b) the NF average area values provided for chromium and molybdenum were based on available results for uncontaminated samples in the NF area (n = 5 of 15 samples). The average concentrations shown include values from top, middle and bottom depths. A single uncontaminated sample was available in each reference area.

Table 3-8 Summary of Significant Differences in Water Quality, 2013 AEMP

Variable	Season	Statistical Test(a)	Exposure vs. Reference Comparison(b)	Reference vs. Reference Comparison
			NF vs. FFA+FFB+FF1	FFA vs. FFB vs. FF1
			P(c)	*P*(c)
Specific Conductivity	Ice-cover	KW	**	ns
	Open-water	KW	**	ns
Total Dissolved Solids (Calculated)	Ice-cover	ANOVA^{log}	****	ns
	Open-water	ANOVA^{log}	****	*([FFA=FFB])≠FF1
Calcium	Ice-cover	ANOVA^{log}	****	*([FFA≠FFB])=FF1
	Open-water	ANOVA^{log}	****	ns
Chloride	Ice-cover	ANOVA^{log}	****	**([FF1=FFB])≠FFA
	Open-water	ANOVA^{log}	****	**([FFA=FFB])≠FF1
Sodium	Ice-cover	KW	**	ns
	Open-water	KW	**	ns
Sulphate	Ice-cover	ANOVA	****	*([FFB≠FF1])=FFA
	Open-water	KW	**	ns
Ammonia (as Nitrogen)	Ice-cover	ANOVA	****	ns
	Open-water	ANOVA^{log}	**	ns
Nitrate (as Nitrogen)	Ice-cover	ANOVA^{log}	****	****([FFA=FFB])≠FF1
	Open-water	KW	**	ns
Aluminum	Ice-cover	KW	**	ns
	Open-water	ANOVA^{log}	**	*([FFA=FFB])≠FF1
Barium	Ice-cover	KW	**	ns
	Open-water	KW	**	ns
Chromium	Ice-cover	KW	**	ns
	Open-water	(d)	(d)	(d)
Molybdenum	Ice-cover	ANOVA^{log}	****	**([FFA=FFB])≠FF1
	Open-water	(d)	(d)	(d)
Silicon	Ice-cover	ANOVA^{log}	****	ns
	Open-water	One Sample T-test	ns	-
Strontium	Ice-cover	KW	**	ns
	Open-water	KW	**	ns
Uranium	Ice-cover	ANOVA^{log}	****	ns
	Open-water	KW	**	*([FFA≠FF1])=FFB

Notes: ANOVA = Analysis of Variance (log-transformed data indicated by superscript); KW = Kruskal-Wallis test; n/d = not determined

a) Results of normality and homogeneity of variances tests are provided in Appendix F.

b) the sampling depth representing the greatest average NF area concentration (top, middle or bottom) is shown (Table 2 6)

c) probability of Type 1 Error for Planned Comparisons (ANOVA and KW Test; NF vs. reference comparison): * = <0.1, ** = <0.01, *** = <0.001, **** = <0.0001. Probability of Type 1 Error for unplanned comparisons (ANOVA [Tukey's HSD Method]; reference vs. reference comparison): * = <0.1, ** = <0.01, *** = <0.001, **** = <0.0001. Probability of Type 1 Error for unplanned Comparisons (KW Test; reference vs reference comparisons) * = <0.15, ** = <0.01, *** = <0.001. Probability of Type 1 Error (one tailed) for One Sample T-test = * = <0.1, ** = <0.01, *** = <0.001, **** = <0.0001

d) Chromium and molybdenum were not analyzed statistically during the open-water season due to sample contamination (n = 10 of 15 NF area samples were contaminated, and n = 12 of 15 FF area samples were contaminated; Appendix B).

3.7 SPATIAL GRADIENTS

Substances of interest were evaluated for the presence of spatial trends with distance from the Mine-effluent diffuser. A pattern of decreasing concentration (i.e., in a variable that is elevated in the effluent) with increasing distance from the diffuser was confirmation that the changes observed in the NF area were related to the Mine-water discharge. Trends were identified based on a graphical (i.e., visual) evaluation of the exposure and reference area data arranged by distance from the diffuser (Figures 3-35 to 3-49). Clear spatial trends of decreasing concentration with distance from the Mine-effluent diffuser were evident for each of the variables that reached Action Level 1 or greater. Spatial trends were generally more pronounced during the ice-cover season.

3.8 LAC DU SAUVAGE AND LDG-48 STATIONS

The results for water quality samples collected at stations LDS-1, LDS-2 and LDS-3 which are located at the outflow of Lac du Sauvage to Lac de Gras, and at station LDG-48 which is located at the Lac de Gras outflow to the Coppermine River are provided in Appendix G. Concentrations at these stations were below the AEMP Effects Benchmarks (Table 2-5) for aquatic life and/or drinking water in all samples collected in 2013.

3.9 WEIGHT OF EVIDENCE INPUT

The results described in the preceding sections also feed into the WOE approach described in the Weight of Evidence Report (Golder 2014c). The results of the Weight of Evidence relevant to water quality and related components are described in Section 3.1.1 of the Weight of Evidence Report.

4 DISCUSSION

Water quality variables were assessed for a Mine-related effect according to Action Levels. Fifteen variables reached Action Level 1. These variables, termed substances of interest (SOIs), had NF area median concentrations that were greater than two times the median concentrations of reference areas. Each of the SOIs had detectable concentrations in the NIWTP effluent, indicating that the increase seen in the NF area could be linked to the Mine. All 15 variables that reached Action Level 1 also reached Action Level 2, which was attained because the 75th percentile concentration in the NF exposure area was greater than the normal range for Lac de Gras. Variables that reached Action Level 2 were evaluated for an effect at a magnitude of Action Level 3, provided they had existing AEMP Effects Benchmarks. None of the variables evaluated at Action Level 3 had 75th percentile concentrations at the mixing zone that were greater than the normal range plus 25% of the distance between the top of the normal range and the Effects Benchmark (i.e., the Action Level 3 criterion).

Each of the 15 SOIs that reached Action Level 1 or greater in 2013 had NF area mean concentrations that were significantly greater than reference area concentrations in one or both sampling seasons (i.e., ice-cover or open-water). Spatial trends of decreasing concentrations with distance from the Mine-effluent diffuser were evident for each of these variables based on a graphical evaluation of the data. The results of these analyses provided confirmation that that the changes observed in the NF area for these variables (i.e., at Action Levels 1 and 2) were related to the Mine-water discharge.

Results of the screening at Action Levels 1 and 2 indicated that Action Level 2 was generally not sequential to Action Level 1, as was expected based on the examples provided in Section 5.3.2 of the AEMP Study Design Version 3.3 (Golder 2014a). In general, the reference area criterion value used to classify an effect at Action Level 1 (two times the reference area median) was greater than the criterion used at Action Level 2 (the normal range upper limit [mean of reference areas plus 2 standard deviations]). This occurred because the variability in reference area data used to define the normal range was generally small compared to the reference area median value. As a result, water quality variables typically reached Action Level 2 before reaching Action Level 1. The box and whisker plots generated for a subset of SOIs (conductivity, TDS calcium, chloride, sodium and sulphate, aluminum, barium, molybdenum, strontium and uranium) in Section 3.5 show how the reference and exposure area criteria used to define an effect at Action Levels 1 and 2 are generally not sequential. This is especially apparent during the ice-cover period. The criteria used to classify an effect at Action Levels 1 and 2 should be re-evaluated so that Action Levels are applied sequentially.

In 2013, DDMI identified a QA/QC issue that had compromised the results of some metals analyzed during the 2013 open-water SNP and AEMP sampling. An investigation determined that a batch of nitric acid preservative used to acidify samples for total metals analysis had been contaminated. Samples that were acidified with the affected preservative had elevated concentrations of several metals. Although this issue affected a large number of samples, the interpretation of the results from the water quality survey was not impeded. The effects observed on the metals in question were sufficient to be detectable with the smaller sample size available for analysis.

Results of QC analyses completed from 2011 to 2013 have indicated ongoing data quality issues related to ammonia. In all three years, ammonia concentrations in blank samples analyzed by Maxxam were at or above levels in Lac de Gras, while the concentrations reported for lake water samples were higher than historic values. The ammonia data provided by Maxxam in 2013 were retained in all SNP and AEMP data analyses included in this report; however, concentrations at many stations were greater than historical values, particularly in the MF and FF areas during the open-water season. Hence, the magnitude of mine-related effects reported for ammonia (at an Action Level 2) is made with some scepticism given the inflated nature of ammonia concentrations in the exposure areas. The other analyses with 2013 data only (i.e., visual trends of decreasing concentration with distance from the diffuser and corresponding statistical differences), however, do suggest that the Mine is having an effect on ammonia, consistent with findings in previous years.

Effluent quality was similar to that observed in previous years. Toxicity testing results in 2013 indicated that all effluent samples passed the relevant acute or chronic lethality and sublethal toxicity tests. The results in 2013 are consistent with test results in previous years, which have indicated that the Mine effluent is non-toxic to aquatic test organisms. Concentrations of all variables with Water License discharge criteria were within applicable limits in all samples collected in 2013.

The distribution of barium concentrations at AEMP stations indicated that the effluent was spreading throughout the exposure area. In the reference areas, barium concentrations exceeded the normal range in at least one station in two of the three FF reference areas. Although it not possible to conclude that these exceedances represent the presence of Mine effluent, similar results observed with calculated TDS and conductivity do support the presence of effluent in these areas. A confounding observation with all these data is that the greatest concentrations of these effluent tracers occurred at the farthest reference area (FFA). It is also possible that the results are confounded by the fact that data in 2013 (which were provided by Maxxam) are being compared to historical data provided by ALS. The possibility of having Mine effluent in the reference areas will be evaluated in the next three year summary report (to be submitted October 15, 2014), which will include updates to the temporal trends that have been established for barium in the reference areas.

5 CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

- Mine effluent had an effect on 15 variables (conductivity, TDS [calculated], dissolved calcium, chloride, dissolved sodium, sulphate, ammonia, nitrate, aluminum, barium, chromium, molybdenum, silicon, strontium, and uranium).
- Effects were categorized according to Action Levels. The median concentrations of these 15 variables were greater than two times the reference area median concentrations. As a result, these variables demonstrated an effect equivalent to Action Level 1, and they comprised the list of substances of interest (SOIs) in 2013.
- Each of the 15 SOIs that reached Action Level 1 also reached Action Level 2, which was applicable because the 75th percentile concentration in the Near-field exposure area exceeded the normal range for Lac de Gras (Table 5-1).
- None of the SOIs had 75th percentile concentrations at the mixing zone that were greater than the normal range plus 25% of the distance between the top of the normal range and the Effects Benchmark; hence, Action Level 3 was not attained. Three SOIs (conductivity, calcium, and silicon) that reached Action Level 2 in 2013 were not assessed at Action Level 3 because they do not have existing Effects Benchmarks.
- Statistically significant differences between the NF area and FF reference areas were detected for all 15 SOIs. Each of the SOIs had spatial patterns of decreasing concentration with distance from the Mine-effluent diffuser in one or both sampling seasons. These results provided confirmation that the increased concentrations of these variables in the NF area were related to the Mine water discharge.
- The 2013 effluent toxicity results indicated that the effluent is non-toxic. Regulated effluent parameters were below applicable water licence discharge criteria.

Table 5-1 Action Level Summary for Water Quality, 2013 AEMP

Variable	Action Level Classification
Conventional Parameters	
Specific Conductivity	2
Total Dissolved Solids (Calculated)	2
Major Ions	
Calcium	2
Chloride	2
Sodium	2
Sulphate	2
Nutrients	
Ammonia (as Nitrogen)	2
Nitrate (as Nitrogen)	2
Metals (Total)	
Aluminum	2
Barium	2
Chromium	2
Molybdenum	2
Silicon	2
Strontium	2
Uranium	2

5.2 RECOMMENDATIONS

The following recommendations are made for future AEMPs at Lac de Gras:

- The analyte-specific DLs requested for samples collected at the mixing zone boundary should be the same as those requested for the AEMP dataset, given that the mixing zone data are incorporated into the Action Level framework.
- The criteria used to classify an effect at Action Levels 1 and 2 should be re-evaluated so that Action Levels 1 and 2 are applied sequentially.
- The data quality objective used to identify notable differences between field duplicate samples (i.e., RPD >20%) should be adjusted so that it is less stringent than the objectives used by Maxxam to identify unacceptable differences between laboratory duplicate samples (i.e., RPD >20% to 25%, depending on the analyte). Laboratory duplicate samples consist of two independently analyzed portions of the same sample. They would be expected to have lower variability than field duplicates, which consist of two completely separate grab samples collected from the water column.

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7 CLOSURE

We trust the information in this report meets your requirements at this time. If you have any questions relating to the information contained in this report, please do not hesitate to contact the undersigned.

GOLDER ASSOCIATES LTD.

Report prepared by:	**Report reviewed by:**
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APPENDIX A

2013 AEMP SAMPLING SCHEDULE

Table A-1 2013 AEMP Sampling Schedule

Sites	Ice-Cover										Open-water																				
	April										August														September						
	10	11	12	13	14	15	16	17	18	19	18	19	20	21	22	23	24	25	26	27	28	29	30	31	01	02	03	04	05	06	07
NF1										An	Anpbs																				
NF2										An										Anpbs											
NF3	An																			Anpbs											
NF4	An																			Anpbs											
NF5	An																			Anpbs											
MF1-1		An												Anpbs																	
MF1-3		An												Anpbs																	
MF1-5		An																Anpbs													
MF2-1			An																	Anpbs											
MF2-3			An																Anpbs												
FF2-2								An											Anpbs												
FF2-5								An											Anpbs												
MF3-1										An								Anpbs													
MF3-2			An															Anpbs													
MF3-3				An		An												Anpbs													
MF3-4				An																									Anpbs		
MF3-5				An																											Anpbs
MF3-6							An																								Anpbs
MF3-7							An											Anpbs													
FF1-1							Mn										Mnpbs														
FF1-2							Mn								Mnpbs																
FF1-3							Mn										Mnpbs														
FF1-4							Mn										Mnpbs														
FF1-5							Mn								Mnpbs																
FFA-1					Mn																	Mnpbs									
FFA-2					Mn																	Mnpbs									
FFA-3					Mn																	Mnpbs									
FFA-4					Mn																		Mnpbs								
FFA-5					Mn																						Mnpbs				
FFB-1						Mn																							Mnpbs		
FFB-2						Mn																			Mnpbs						
FFB-3						Mn																							MMnpbs		
FFB-4						Mn																			Mnpbs						
FFB-5						Mn																			Mnpbs						
LDS-1								Mn											Mn												
LDS-2								Mn											Mn												
LDS-3								Mn											Mn												
LDG-48					Mn																			Mn							

Notes: M = Water Quality mid-depth sample only; A = Water Quality surface, mid-depth and bottom samples collected; n = Nutrient sample collected, s = sediment sample collected, b = benthic sample collected, p = plankton sample collected.

QAQC Samples color coded = GW, EBW, FBW, TBW, DUP1/DUP2, DUPSP1/DUPSP2

APPENDIX B

ASSESSMENT OF CONTAMINATED SAMPLES

INTRODUCTION

In 2013, Diavik Diamond Mine (DDMI) identified a quality assurance/quality control (QA/QC) issue affecting total metals results for a subset of effluent and water quality samples collected during the 2013 open-water Aquatic Effects Monitoring Program (AEMP) and Surveillance Network Program (SNP) sampling in Lac de Gras. An investigation of laboratory and site-based QA/QC procedures determined that a batch of nitric acid preservative used to acidify samples intended for total metals analysis had been contaminated during laboratory preparation. This appendix describes the methods and results of the procedures undertaken to identify and remove values (i.e., metals and samples) that were affected by the preservative based contamination.

OBJECTIVES

The purpose of this assessment was to identify water samples that were preserved with contaminated nitric acid preservative used during the 2013 open-water SNP and AEMP sampling. A second objective was to determine which total metals were present in the contaminated preservative, and to remove these results from the 2013 AEMP and SNP datasets.

The approach used to identify samples and metals that were affected by the contaminated preservative incorporated the following steps:

- Results for blank samples analyzed in 2013 were first evaluated to identify metals that were likely present in the contaminated preservative. This involved a comparison of total metals data for contaminated and uncontaminated blank samples submitted by Diavik Diamond Mine Inc. (DDMI) to the analytical lab (i.e., following initial identification of the preservative as a likely source of contamination), as well as from quality control (QC) blanks collected during the open-water AEMP in 2013.
- Metals that had notably high concentrations both in the contaminated blank samples as well as in the presumably contaminated samples collected during the open-water SNP and AEMP sampling in 2013, were used to identify samples were likely acidified with contaminated preservative.
- Results for metals that were identified in contaminated blanks (i.e., from preservative test samples and from QC blank samples collected in 2013) were compared between contaminated and uncontaminated AEMP and SNP samples to determine if concentrations were greater the contaminated samples. This information was used to arrive at a final list of metals that likely contributed to the contamination present in the preservative.

BLANK SAMPLE EVALUATION

Maxxam Preservative Test

Sample bottles filled with deionized (DI) water supplied by Maxxam Analytics [Maxxam] were spiked with contaminated nitric acid preservative (preservative batch number 130430A [herein called contaminated samples]) and preservative from seven other batches that were presumably not contaminated (preservative batch numbers 130618B, 130819A, 121102A, 120622A, 120810B, 120223A, 130301A [herein called blank samples]). All preparations were made in duplicate and sent to Maxxam for analysis of total metals. Results for the set of duplicate contaminated samples were compared with results from the seven sets of duplicate blank samples.

Results provided by Maxxam indicated that concentrations of several metals were elevated in contaminated samples compared to blank samples (Table B-1). Cadmium, chromium and cobalt were detected in both contaminated samples but not in the blank samples. Manganese and molybdenum were detected in both contaminated samples and in one blank sample, but concentrations were generally greater in contaminated samples compared to blank samples. Nickel was detected in all but two samples, though concentrations were considerably greater in the contaminated samples. Aluminum, copper, iron and zinc were present in at least one of two replicate contaminated samples but were generally detected at similar concentrations to those in the blank samples. The exception here was for blank samples spiked with preservative batch 120810B which had concentrations of zinc an order of magnitude greater than other samples. Concentrations of nickel in the contaminated samples were three orders of magnitude greater than the detection limits (DL), while concentrations of molybdenum and chromium were two orders of magnitude greater than the DLs (Table B-1).

2013 Open-water AEMP and SNP Blank Samples

Five quality control blank samples were collected during the 2013 open-water AEMP sampling period (Table B-2). These included three trip blanks, one equipment blank and one field blank. Total metals results for two trip blanks and one field blank were comparable to those of the duplicate contaminated blank samples analyzed in the preservative test (Section 2.1). This indicates that these three samples were likely acidified with contaminated preservative. Chromium, molybdenum and nickel concentrations were also much greater than the DL in each of the three contaminated AEMP blank samples (Table B-2). Total aluminum, cadmium, cobalt, copper, iron, manganese, sulphur, tin and zinc were also detected in one or more blanks that were likely contaminated; however, a few of these metals were also detected in the two uncontaminated blank samples. Sulphur, tin and zinc were present at similar concentrations in the uncontaminated blanks, while concentrations of nickel in the contaminated samples were three to five orders of magnitude greater than in the uncontaminated blanks (Table 2).

Blank samples from the effluent dataset were not used to evaluate contamination related to the preservative because each of the blanks collected in 2013 were determined to not be contaminated based on their nickel, molybdenum and chromium concentrations. Blank samples collected at the mixing zone in 2013 consisted of two equipment blanks. One of these blanks was determined to have been contaminated based on elevated chromium, molybdenum, and nickel concentrations. The results, however, were not included in the contamination assessment, because the metals with concentrations above DLs in this sample was quite different than those identified in the contaminated AEMP field and trip blanks, as well as in the Maxxam preservative blanks. This may be due to the potential for increased contamination resulting from the equipment used to collect samples (i.e., relative to field and trip blanks which are directly filled with DI water).

Summary of Blank Sample Results

Variables detected in contaminated blank samples from the preservative test (Section 2.1) and from the 2013 open-water AEMP (Section 2.3) consisted of the following 12 metals: aluminum, cadmium, chromium, cobalt, copper, manganese, molybdenum, nickel, iron, sulphur, tin and zinc. Of these, six metals (cadmium, chromium, cobalt, manganese, molybdenum, and nickel) were clearly elevated in the contaminated blank samples compared to the uncontaminated blanks. Six other metals that were detected in contaminated blanks occurred at similar concentrations to those found in one or more of the uncontaminated blanks. These metals included aluminum, copper, iron, sulphur, tin and zinc.

Table B-1 Analytical Results for Total Metals with Concentrations Above the Detection Limit in Deionized Water Samples Spiked with Contaminated and Uncontaminated Nitric Acid Preservative

Analyte	Units	Contaminated Preservative[a]		Uncontaminated Preservative[a]															
		LL-130430A		LL-130618B		LL-130819A		LL-121102A		LL-120622A		LL-120810B		LL-120223A		LL-130301A		082913-0829	
		Dup 1	Dup 2	Dup 1	Dup 2	Dup 1	Dup 2	Dup 1	Dup 2	Dup 1	Dup 2	Dup 1	Dup 2	Dup 1	Dup 2	Dup 1	Dup 2	Dup 1	Dup 2
Aluminum	µg/L	0.63	0.90	0.64	1.66	<0.50	0.59	1.33	<0.50	0.55	0.61	0.94	0.95	1.01	0.81	0.55	0.55	0.75	<0.50
Cadmium	µg/L	0.0110	0.0190	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Chromium	µg/L	2.93	8.66	<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	<0.10	<0.10	<0.10
Cobalt	µg/L	0.0310	0.0920	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Copper	µg/L	<0.050	0.066	<0.050	0.050	<0.050	<0.050	0.219	<0.050	0.264	<0.050	<0.050	0.052	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Iron	µg/L	<1.0	1.3	<1.0	1.4	<1.0	<1.0	2.0	<1.0	<1.0	<1.0	1.2	12.4	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Manganese	µg/L	0.057	0.222	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	0.090	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Molybdenum	µg/L	4.56	15.1	0.138	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Nickel	µg/L	19.3	61.1	0.116	<0.020	0.258	0.139	0.036	0.059	0.083	0.117	0.037	0.034	0.126	0.069	0.031	0.039	<0.020	0.026
Zinc	µg/L	<0.10	0.29	<0.10	0.13	<0.10	0.15	0.32	<0.10	0.23	<0.10	1.59	1.85	0.86	<0.10	<0.10	<0.10	0.16	<0.10

Notes: Shading indicates concentrations that were less than the detection limit; Dup = Duplicate sample.

a) sample identification numbers represent preservative batch numbers used during the 2013 SNP and AEMP sampling.

Table B-2 Analytical Results for Total Metals with Concentrations Above the Detection Limit in Contaminated and Uncontaminated AEMP Blank Samples

Analyte	Unit	Contaminated Blanks			Uncontaminated Blanks	
		FF1-2M Field Blank	**FFB-3M Equipment Blank**	**NF4B Field Blank**	**FFB-3M Trip Blank**	**MF2-1B Equipment Blank**
		22-Aug-13	**6-Sep-13**	**27-Aug-13**	**5-Sep-13**	**27-Aug-13**
Aluminum	mg/L	0.00053	<0.0005	<0.0005	<0.0005	<0.0005
Cadmium	mg/L	0.000008	<0.000005	0.000012	<0.000005	<0.000005
Chromium	mg/L	0.00188	0.000716	0.00257	<0.00005	<0.00005
Cobalt	mg/L	0.000023	0.000007	0.000026	<0.000005	<0.000005
Copper	mg/L	0.00008	<0.00005	<0.00005	<0.00005	<0.00005
Iron	mg/L	0.0058	<0.001	<0.001	<0.001	<0.001
Manganese	mg/L	0.000057	<0.00005	0.000066	<0.00005	0.00009
Molybdenum	mg/L	0.00296	0.00102	0.00423	<0.00005	0.000199
Nickel	mg/L	0.0132	0.00503	0.0183	0.000033	0.000058
Sulphur	mg/L	0.27	<0.1	0.43	0.3	0.46
Tin	mg/L	0.000018	0.000013	0.00002	0.000017	0.000038
Zinc	mg/L	<0.0001	0.0003	0.00012	<0.0001	0.00113

Notes: mg/L = milligrams per litre; Shading indicates concentrations that were less than the detection limit.

IDENTIFICATION OF CONTAMINATED SAMPLES

Results from the 2013 open-water AEMP and SNP effluent (SNP Stations 1645-18 and 18B) and mixing zone samples (SNP Stations 1645-19 A, B2 and C) were evaluated to identify samples that may have been acidified with contaminated preservative. Samples were determined to be contaminated by comparing the 2013 results with historical values for metals that were detected in contaminated blanks (Section 2.0). The concentrations of three metals (chromium, molybdenum, and nickel) were the primary variables used to screen the 2013 samples. These metals were used because they were detected at high concentrations relative their DLs in contaminated blank samples (Section 2.0). In addition, their concentrations in the effluent, at the mixing zone and at AEMP stations were generally greater during the open-water season in 2013 than would be expected based on historical data. Although molybdenum was identified as a major contaminant in the preservative, historical concentrations in effluent were greater than or similar to those observed in the contaminated blank samples (Section 2.0). Therefore, molybdenum was not used in the sample screening for the effluent dataset.

Maximum concentrations identified for chromium, molybdenum and nickel were used to classify the 2013 AEMP and SNP samples as either contaminated or not contaminated (Table B-3). These values are based on historical data collected from 2007 to 2012 and represent approximate maximum concentrations that would be expected at effluent, mixing zone and AEMP stations. Concentrations that exceed these values were considered anomalous due to contamination. Following an initial screening of the data using the maximum concentrations in Table B-3, the results were evaluated on a sample by sample basis to confirm individual sample classifications (i.e., contaminated or not contaminated).

Table B-3 Historical Maximum Concentrations of Chromium, Molybdenum and Nickel Used to Identify Contamination of 2013 AEMP and SNP Samples

Variable	Unit	Approximate Maximum from 2007 to 2012 Open-water Dataset		
		SNP 18	SNP 19	AEMP
Chromium	(µg/L)	2	0.2	0.1
Molybdenum	(µg/L)	(a)	2	1
Nickel	(µg/L)	10	2	1

Note: µg/L = micrograms per litre

a) molybdenum was not used in the sample screening for the effluent dataset.

Given that dissolved metals are analyzed in addition to total metals in SNP samples, and that dissolved metal samples are not preserved, the ratio of total to dissolved concentrations for chromium, molybdenum and nickel was used as an additional screening tool for SNP sample contamination. A high total to dissolved ratio, relative to expected values, would reflect contamination within a sample. Dissolved metals are not analyzed in the AEMP samples; therefore, this approach was only applicable to SNP samples.

Sample Screening Results

Results of the screening for contamination in effluent, mixing zone and AEMP samples are provided in Tables B-4, B-5 and B-6, respectively. The corresponding chromium, molybdenum and nickel concentrations for each sample are provided as a reference. In general, contaminated AEMP and SNP samples had chromium, molybdenum and nickel concentrations that were well above identified maximum values for all variables considered in the screening. For SNP samples, the total to dissolved ratio for chromium, molybdenum, and nickel was also greater in contaminated samples than in uncontaminated samples (Tables B-4 and B-5). The exception here was for molybdenum in the effluent, which had generally comparable total and total to dissolved concentrations in contaminated and uncontaminated samples.

During the open-water season, a total of 36% (n = 21 of 55) effluent samples (i.e., those that were analyzed for total metals) was determined to be contaminated. A total of 47% (n = 24 of 51) and 82% (n = 69 of 84) of samples collected from the mixing zone and at AEMP stations were also determined to be contaminated based on their chromium, molybdenum, and nickel concentrations. Samples collected during the ice-cover season for both the SNP and AEMP datasets were not contaminated and are not included in the screening results. This corresponds with the estimated timing of when the contaminated preservative batch was first used (July 2013).

The concentrations of other metals that were present at greater concentrations in contaminated blanks relative to uncontaminated blanks (Section 2.0; cadmium, cobalt, manganese) also typically had greater concentrations in the contaminated AEMP and SNP samples (i.e., relative to uncontaminated samples). The pattern for manganese, however, was generally less clear. Figure B-1 illustrates the difference in concentrations observed for each of these metals in contaminated and uncontaminated AEMP samples collected during the open-water sampling season in 2013.

Metals that were detected in contaminated blanks, but that had similar concentrations in uncontaminated blanks (Section 2.0; aluminum, copper, iron, sulphur, tin and zinc) typically also had comparable concentrations between contaminated and uncontaminated SNP and AEMP samples. One exception was iron which had a greater total to dissolved ratio in contaminated mixing zone samples collected during the open-water season in 2013 (12.9:1.4 µg/L) compared to uncontaminated samples (6.6:1.8 µg/L). The average total iron concentration in contaminated AEMP samples was also elevated relative to uncontaminated samples. This indicates that iron may contribute to the contamination present in the preservative.

CONCLUSIONS

A total of seven metals that were detected in contaminated blank samples in 2013 (cadmium, chromium, cobalt, iron, manganese, molybdenum, and nickel) were generally associated with greater concentrations in contaminated SNP and AEMP samples relative to uncontaminated samples. This indicates that these metals likely constituted the contamination present in the nitric acid preservative used in the 2013 open-water SNP and AEMP sampling. As a result, these seven metals were removed from the AEMP and SNP datasets for samples that are identified as contaminated in Tables B-4 to B-6. These values are likewise excluded from relevant analyses presented in the 2013 Effluent and Water Chemistry Report.

Figure B-1 **Total concentrations of (A) nickel, molybdenum and chromium; (B), cadmium and cobalt; (C) manganese and iron at AEMP stations during open-water, 2013**

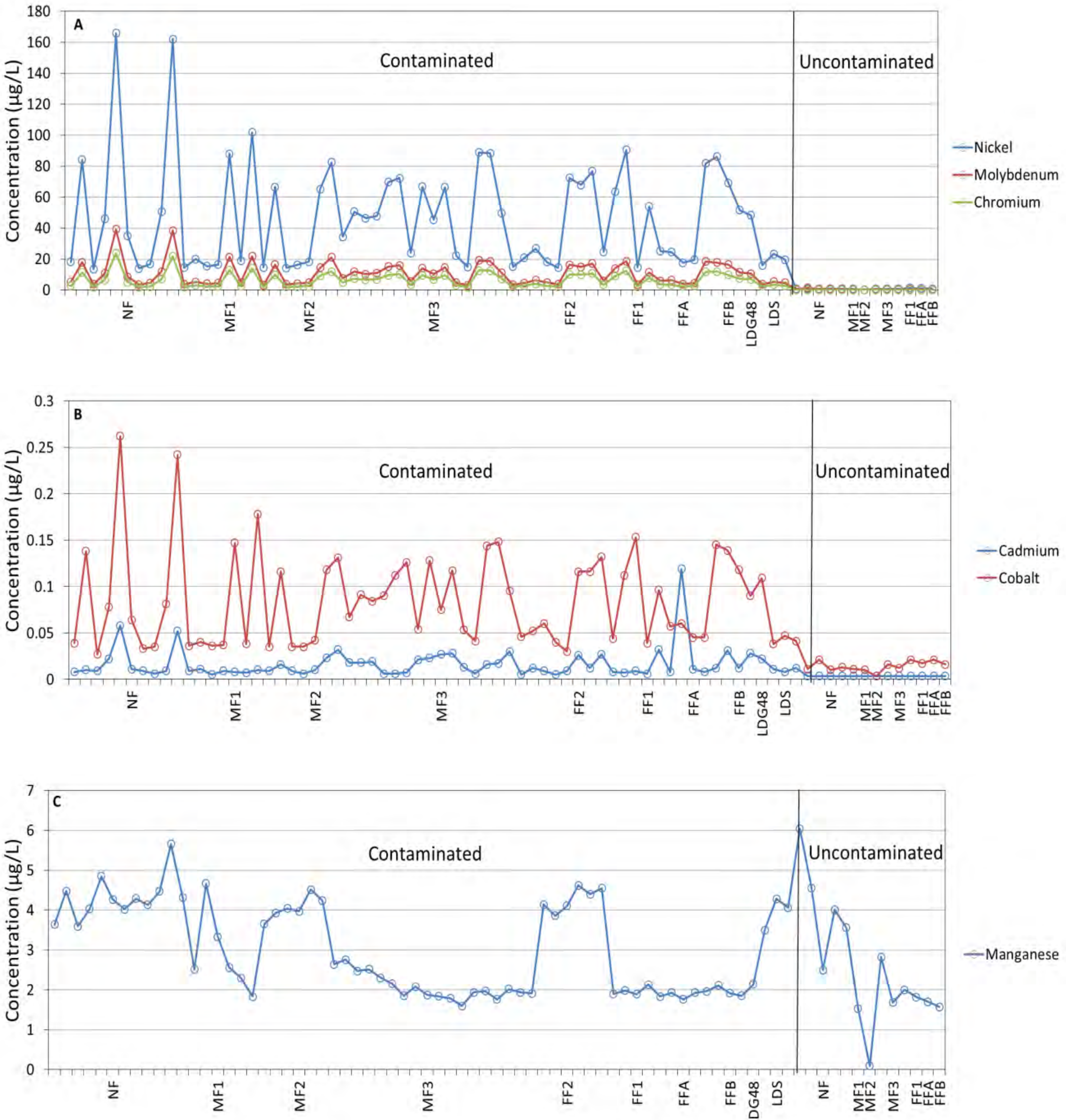


Table B-4 Total and Dissolved Chromium, Molybdenum and Nickel Concentrations for Contaminated (grey shading) and Uncontaminated (no shading) SNP Effluent Samples (Stations 18 and 18B) during the Open-water Season, 2013

					Concentration (µg/L)								
					Chromium			Molybdenum			Nickel		
Station	**Date**	**Reference Number**	**Sample Type**	**Sample Classification**	**Total**	**Dissolved**	**Ratio**	**Total**	**Dissolved**	**Ratio**	**Total**	**Dissolved**	**Ratio**
1645-18	7/1/2013	GU9287	Grab Water	Uncontaminated	0.26	0.3	0.87	33.8	32.4	1.04	3.11	2.87	1.08
1645-18	7/2/2013	GU9288	Field Blank	Uncontaminated	0.1	0.1	1.00	0.05	0.05	1.00	0.02	0.07	0.29
1645-18B	7/3/2013	GU9289	Grab Water	Uncontaminated	0.24	0.26	0.92	32.1	32.2	1.00	3.47	3.41	1.02
1645-18	7/7/2013	GW4400	Grab Water	Uncontaminated	0.27	-	-	37	-	-	3.2	-	-
1645-18B	7/7/2013	GW4401	Grab Water	Uncontaminated	0.27	-	-	37.2	-	-	3.29	-	-
1645-18	7/13/2013	GX8592	Grab Water	Uncontaminated	0.33	0.32	1.03	45.6	46.2	0.99	4.11	3.84	1.07
1645-18B	7/13/2013	GX8593	Grab Water	Uncontaminated	0.37	0.34	1.09	45.7	45.9	1.00	4.15	3.71	1.12
1645-18	7/18/2013	GZ9736	Grab Water	Uncontaminated	0.27	-	-	45.6	-	-	4.43	-	-
1645-18B	7/18/2013	GZ9737	Grab Water	Uncontaminated	0.29	-	-	43.7	-	-	4.51	-	-
1645-18	7/25/2013	HB4186	Grab Water	Contaminated	4.65	-	-	52.6	-	-	33.8	-	-
1645-18B	7/25/2013	HB4187	Grab Water	Uncontaminated	0.28	-	-	45.7	-	-	4.78	-	-
1645-18	7/31/2013	HC8506	Grab Water	Uncontaminated	0.46	-	-	43.9	-	-	5.52	-	-
1645-18B	7/31/2013	HC8507	Grab Water	Uncontaminated	0.5	-	-	48.8	-	-	5.71	-	-
1645-18B	8/6/2013	HE9271	Duplicate 1	Uncontaminated	0.62	-	-	44.4	-	-	5.51	-	-
1645-18B	8/6/2013	HE9272	Duplicate 2	Uncontaminated	0.49	-	-	45.9	-	-	5.35	-	-
1645-18	8/12/2013	HE9706	Grab Water	Uncontaminated	0.41	-	-	39.5	-	-	4.75	-	-
1645-18B	8/12/2013	HE9707	Grab Water	Uncontaminated	0.36	-	-	43.1	-	-	4.7	-	-
1645-18	8/14/2013	HG6774	Grab Water	Contaminated	9.29	0.47	19.77	58.8	43.8	1.34	63.4	4.39	14.44
1645-18B	8/14/2013	HG6775	Grab Water	Contaminated	4.02	0.31	12.97	49	41.6	1.18	29.8	4.48	6.65
1645-18	8/18/2013	HG6915	Grab Water	Uncontaminated	0.46	-	-	40.9	-	-	5.13	-	-
1645-18B	8/18/2013	HG6917	Grab Water	Uncontaminated	0.42	-	-	41.4	-	-	4.95	-	-
1645-18	8/18/2013	HG6916	Field Blank	Uncontaminated	0.1	-	-	0.05	-	-	0.035	-	-
1645-18	8/24/2013	HI6227	Grab Water	Contaminated	2.97	-	-	51.8	-	-	22.1	-	-
1645-18B	8/24/2013	HI6228	Grab Water	Contaminated	12.2	-	-	67.8	-	-	85	-	-
1645-18	8/30/2013	HK0711	Grab Water	Contaminated	4.31	-	-	50.1	-	-	30.9	-	-
1645-18B	8/30/2013	HK0712	Grab Water	Contaminated	2.29	-	-	46.6	-	-	16.5	-	-
1645-18	9/5/2013	HL9429	Grab Water	Uncontaminated	0.41	-	-	41.1	-	-	5.19	-	-
1645-18B	9/5/2013	HL9430	Grab Water	Uncontaminated	0.27	-	-	38.3	-	-	4.02	-	-
1645-18B	9/11/2013	HN0268	Duplicate 2	Contaminated	4.81	0.25	19.24	47.1	42.8	1.10	36.5	4.4	8.30
1645-18B	9/11/2013	HN0269	Duplicate 1	Contaminated	7.5	0.26	28.85	54.6	43.4	1.26	56	4.76	11.76
1645-18	9/11/2013	HN0270	Grab Water	Contaminated	2.97	0.28	10.61	44.5	41.3	1.08	23.8	4.83	4.93
1645-18B	9/17/2013	HP6519	Grab Water	Contaminated	6.94	-	-	61.4	-	-	49.5	-	-
1645-18	9/18/2013	HP6518	Grab Water	Contaminated	13	-	-	73.4	-	-	95.4	-	-
1645-18	9/23/2013	HP9089	Grab Water	Contaminated	2.3	-	-	40	-	-	18.8	-	-
1645-18B	9/23/2013	HP9090	Grab Water	Contaminated	9.32	-	-	51.5	-	-	64.8	-	-
1645-18	9/29/2013	HR7850	Grab Water	Uncontaminated	0.54	-	-	41.4	-	-	6.33	-	-
1645-18B	9/29/2013	HR7851	Grab Water	Uncontaminated	0.57	-	-	39	-	-	5.72	-	-
1645-18	10/5/2013	HT7328	Grab Water	Contaminated	4.15	-	-	43.2	-	-	31.2	-	-
1645-18B	10/5/2013	HT7329	Grab Water	Contaminated	3.04	-	-	44.4	-	-	24.5	-	-
1645-18	10/12/2013	HV6161	Duplicate 1	Uncontaminated	0.81	0.88	0.92	54.9	55.9	0.98	8.07	8.08	1.00
1645-18	10/12/2013	HV6162	Duplicate 2	Uncontaminated	0.9	0.8	1.13	54.9	55	1.00	8.03	7.36	1.09
1645-18B	10/12/2013	HV6163	Grab Water	Uncontaminated	0.83	0.82	1.01	51.9	56	0.93	8.03	7.56	1.06
1645-18B	10/17/2013	HX0757	Grab Water	Contaminated	2.68	-	-	56.9	-	-	18	-	-
1645-18	10/17/2013	HX0756	Grab Water	Uncontaminated	1.06	-	-	51.2	-	-	7.21	-	-
1645-18B	10/17/2013	HX0758	Field Blank	Uncontaminated	0.1	-	-	0.505	-	-	0.181	-	-
1645-18	10/23/2013	HY5874	Grab Water	Uncontaminated	1.27	-	-	48.7	-	-	6.43	-	-
1645-18B	10/23/2013	HY5875	Grab Water	Uncontaminated	1.41	-	-	47.9	-	-	6.66	-	-
1645-18B	10/29/2013	IA2691	Grab Water	Uncontaminated	1.22	-	-	45.8	-	-	5.71	-	-

Table B-4 Total and Dissolved Chromium, Molybdenum and Nickel Concentrations for Contaminated (grey shading) and Uncontaminated (no shading) SNP Effluent Samples (Stations 18 and 18B) during the Open-water Season, 2013

					Concentration (µg/L)								
					Chromium			Molybdenum			Nickel		
Station	**Date**	**Reference Number**	**Sample Type**	**Sample Classification**	**Total**	**Dissolved**	**Ratio**	**Total**	**Dissolved**	**Ratio**	**Total**	**Dissolved**	**Ratio**
1645-18	10/29/2013	IA2689	Grab Water	Contaminated	7.73	-	-	11.3	-	-	52.9	-	-
1645-18	10/29/2013	IA2690	Field Blank	Uncontaminated	0.5	0.1	5.00	0.25	0.05	5.00	0.1	0.027	3.70
1645-18B	10/30/2013	IA2694	Grab Water	Contaminated	4.15	1.36	3.05	52.6	47.7	1.10	23.2	5.54	4.19
1645-18	10/30/2013	IA2693	Grab Water	Contaminated	3.59	1.32	2.72	52.4	45.7	1.15	20.8	5.59	3.72
1645-18B	10/30/2013	IA2697	Grab Water	Uncontaminated	1.37	1.26	1.09	49.1	49.9	0.98	5.75	5.24	1.10
1645-18	10/30/2013	IA2696	Grab Water	Contaminated	3.35	1.33	2.52	50.6	47.7	1.06	19.4	5.46	3.55
1645-18	10/30/2013	IA2699	Grab Water	Uncontaminated	1.44	1.25	1.15	50.1	50.2	1.00	5.82	5.38	1.08
1645-18B	10/30/2013	IA2700	Grab Water	Uncontaminated	1.36	1.28	1.06	48.5	48.2	1.01	5.89	5.29	1.11

Notes: µg/L = micrograms per litre.

a) value indicates the total to dissolved ratio. Samples that had concentrations below the DL were multiplied by 0.71.

Table B-5 Total and Dissolved Chromium, Molybdenum and Nickel Concentrations for Contaminated (grey shading) and Uncontaminated (no shading) Samples Collected at the Mixing Zone (Stations 19A, 19B2, and 19C) during the Open-water Season, 2013

				Concentration (µg/L)								
				Chromium			Molybdenum			Nickel		
Station	Date	Sample Type	Sample Classification	Total	Dissolved	Ratio$^{(a)}$	Total	Dissolved	Ratio$^{(a)}$	Total	Dissolved	Ratio$^{(a)}$
1645-19A-10	15-Jul-13	Grab Water	Contaminated	2.89	0.19	15.21	5.93	1.53	3.88	20	0.768	26.04
1645-19A-15	15-Jul-13	Grab Water	Contaminated	2.49	<0.1	35.07	5.57	1.44	3.87	17.2	0.961	17.90
1645-19A-20	15-Jul-13	Grab Water	Contaminated	2.99	<0.1	42.11	5.8	0.659	8.80	21	0.735	28.57
1645-19B2-2	15-Jul-13	Grab Water	Contaminated	7.71	<0.1	108.59	13.6	0.895	15.20	54.1	0.728	74.31
1645-19B2-5	15-Jul-13	Grab Water	Uncontaminated	<0.1	<0.1	1.00	1.03	0.842	1.22	0.76	0.678	1.12
1645-19B2-10	15-Jul-13	Grab Water	Contaminated	8.89	<0.1	125.21	15.1	0.845	17.87	61.8	0.674	91.69
1645-19B2-15	15-Jul-13	Equipment Blank	Contaminated	2.15	<0.1	30.28	4.01	0.894	4.49	15.2	0.68	22.35
1645-19B2-15	15-Jul-13	Grab Water	Uncontaminated	<0.1	<0.1	1.00	<0.1	<0.05	1.00	0.12	<0.02	8.59
1645-19C-2	15-Jul-13	Grab Water	Contaminated	16.5	<0.1	232.39	25.8	0.871	29.62	116	0.675	171.85
1645-19C-5	15-Jul-13	Grab Water	Contaminated	2.92	<0.1	41.13	5.4	0.922	5.86	20.4	0.694	29.39
1645-19C-10	15-Jul-13	Grab Water	Contaminated	6.86	<0.1	96.62	11.6	0.932	12.45	47.9	0.742	64.56
1645-19C-15	15-Jul-13	Grab Water	Uncontaminated	<0.1	<0.1	1.00	1.11	1.03	1.08	0.81	0.792	1.02
1645-19A-2	14-Aug-13	Grab Water	Uncontaminated	0.17	0.31	0.55	0.44	0.493	0.89	1.2	1.3	0.92
1645-19A-10	14-Aug-13	Grab Water	Contaminated	4.6	0.43	10.70	9.12	0.72	12.67	32.2	0.639	50.39
1645-19A-15	14-Aug-13	Grab Water	Contaminated	3.22	<0.1	45.35	7.43	2.02	3.68	23.3	0.754	30.90
1645-19A-20	14-Aug-13	Grab Water	Uncontaminated	0.11	0.31	0.35	1	0.776	1.29	1.07	0.612	1.75
1645-19C-2	14-Aug-13	Grab Water	Contaminated	2.65	<0.1	37.32	5.38	0.466	11.55	19.7	0.639	30.83
1645-19C-5	14-Aug-13	Grab Water	Uncontaminated	<0.1	0.33	0.22	0.64	0.517	1.24	0.95	0.61	1.56
1645-19C-10	14-Aug-13	Grab Water	Uncontaminated	<0.1	<0.1	1.00	0.61	0.625	0.97	0.69	0.606	1.14
1645-19C-15	14-Aug-13	Grab Water	Uncontaminated	<0.1	<0.1	1.00	0.86	0.852	1.01	1.08	0.627	1.72
1645-19C-20	14-Aug-13	Grab Water	Uncontaminated	<0.1	0.32	0.22	1.67	1.57	1.06	0.85	0.852	1.00
1645-19B2-2	15-Aug-13	Grab Water	Uncontaminated	<0.1	0.12	0.59	0.51	0.537	0.95	0.67	0.64	1.05
1645-19B2-5	15-Aug-13	Grab Water	Uncontaminated	<0.1	<0.1	1.00	0.67	0.595	1.12	0.67	0.746	0.90
1645-19B2-10	15-Aug-13	Grab Water	Contaminated	2.74	<0.1	38.59	5.26	0.801	6.57	19.1	0.627	30.46
1645-19B2-15	15-Aug-13	Grab Water	Uncontaminated	0.1	0.19	0.53	1.93	1.7	1.14	1.29	0.649	1.99
1645-19B2-20	15-Aug-13	Grab Water	Uncontaminated	<0.1	<0.1	1.00	1.2	1.12	1.07	0.71	0.695	1.02
1645-19A-2	11-Sep-13	Grab Water	Uncontaminated	<0.1	<0.1	1.00	1.53	1.47	1.04	1.01	0.662	1.53
1645-19A-10	11-Sep-13	Grab Water	Contaminated	4.93	<0.1	69.44	9.25	1.47	6.29	34.2	0.743	46.03
1645-19A-15	11-Sep-13	Grab Water	Contaminated	2.19	<0.1	30.85	4.69	1.62	2.90	14.7	0.862	17.05
1645-19A-20	11-Sep-13	Grab Water	Contaminated	2.27	<0.1	31.97	4.84	1.68	2.88	16.5	0.789	20.91
1645-19A-20	11-Sep-13	Equipment Blank	Uncontaminated	<0.1	<0.1	1.00	<0.1	<0.05	1.00	0.2	0.025	8.00
1645-19B2-2	11-Sep-13	Grab Water	Contaminated	4.82	<0.1	67.89	7.98	0.739	10.80	33	0.692	47.69
1645-19B2-5	11-Sep-13	Grab Water	Uncontaminated	<0.1	<0.1	1.00	0.87	0.741	1.18	0.73	0.607	1.20
1645-19B2-10	11-Sep-13	Grab Water	Uncontaminated	0.17	<0.1	2.39	0.94	0.77	1.22	1.6	0.555	2.88
1645-19B2-15	11-Sep-13	Grab Water	Contaminated	0.74	<0.1	10.42	1.42	0.773	1.84	3.18	0.603	5.27
1645-19C-2	11-Sep-13	Grab Water	Contaminated	2.98	<0.1	41.97	5.34	0.79	6.76	21.6	0.621	34.78
1645-19C-5	11-Sep-13	Grab Water	Uncontaminated	<0.1	<0.1	1.00	0.95	0.847	1.12	0.95	0.725	1.31
1645-19C-10	11-Sep-13	Grab Water	Contaminated	3.66	<0.1	51.55	6.97	0.85	8.20	26.5	0.599	44.24
1645-19C-15$^{(b)}$	11-Sep-13	Grab Water	Contaminated	<0.5	3.95	0.09	1.29	7.7	0.17	0.86	28	0.03
1645-19A-2	12-Oct-13	Grab Water	Uncontaminated	<0.1	<0.1	1.00	1.35	0.924	1.46	1.35	0.682	1.98
1645-19A-10	12-Oct-13	Grab Water	Contaminated	4.07	<0.1	57.32	7.24	1.46	4.96	27.8	0.904	30.75
1645-19A-15	12-Oct-13	Grab Water	Uncontaminated	<0.1	<0.1	1.00	1.53	1.38	1.11	0.75	0.673	1.11
1645-19A-20	12-Oct-13	Grab Water	Uncontaminated	<0.1	0.11	0.65	2.01	1.98	1.02	0.88	0.867	1.02
1645-19B2-2	12-Oct-13	Grab Water	Uncontaminated	<0.1	<0.1	1.00	0.99	1.03	0.96	0.7	0.68	1.03
1645-19B2-5	12-Oct-13	Grab Water	Uncontaminated	<0.1	0.11	0.65	0.98	1.13	0.87	0.61	0.601	1.01

Table B-5 Total and Dissolved Chromium, Molybdenum and Nickel Concentrations for Contaminated (grey shading) and Uncontaminated (no shading) Samples Collected at the Mixing Zone (Stations 19A, 19B2, and 19C) during the Open-water Season, 2013

				Concentration (µg/L)								
				Chromium			Molybdenum			Nickel		
Station	**Date**	**Sample Type**	**Sample Classification**	**Total**	**Dissolved**	**Ratio(a)**	**Total**	**Dissolved**	**Ratio(a)**	**Total**	**Dissolved**	**Ratio(a)**
1645-19B2-10	12-Oct-13	Grab Water	Uncontaminated	<0.1	<0.1	1.00	1.06	0.948	1.12	0.97	0.637	1.52
1645-19B2-15	12-Oct-13	Grab Water	Contaminated	1.71	<0.1	24.08	3.58	1.05	3.41	12.4	0.824	15.05
1645-19C-2	12-Oct-13	Grab Water	Uncontaminated	<0.1	<0.1	1.00	1.48	1.44	1.03	0.86	0.766	1.13
1645-19C-5	12-Oct-13	Grab Water	Contaminated	8.57	<0.1	120.70	14.3	1.47	9.73	59.2	0.768	77.08
1645-19C-10	12-Oct-13	Grab Water	Uncontaminated	<0.1	<0.1	1.00	1.56	1.66	0.94	0.75	0.665	1.12
1645-19C-15	12-Oct-13	Grab Water	Uncontaminated	<0.1	<0.1	1.00	1.54	1.57	0.98	0.77	0.511	1.51

Notes: µg/L = micrograms per litre.

a) value indicates the total to dissolved ratio. Samples that had concentrations below the DL were multiplied by 0.71.

b) results for sample 1645-19c-15 collected on 11-Sep-13 indicate that sample bottles intended for analysis of total versus dissolved metals were likely interchanged.

Table B-6 Chromium, Molybdenum and Nickel Concentrations for Contaminated (grey shading) and Uncontaminated (no shading) AEMP Samples Collected during the Open–water Season, 2013

Area	Sample	Date	Sample Classification	Concentration (µg/L)		
				Chromium	Nickel	Molybdenum
Near-Field	NF1B-4	18-Aug-13	Uncontaminated	0.054	0.595	0.743
	NF1B-5	18-Aug-13	Uncontaminated	0.101	0.618	0.728
	NF1M	18-Aug-13	Uncontaminated	0.092	1.39	0.801
	NF1T	18-Aug-13	Uncontaminated	0.054	0.597	0.704
	NF2B	27-Aug-13	Contaminated	2.66	5.27	18.1
	NF2M	27-Aug-13	Contaminated	11.4	18	84.1
	NF2T	27-Aug-13	Contaminated	1.95	3.76	13.5
	NF3B	27-Aug-13	Contaminated	6.64	10.8	46
	NF3M	27-Aug-13	Uncontaminated	<0.1	0.793	0.856
	NF3T	27-Aug-13	Uncontaminated	<0.1	0.67	0.647
	NF4B	27-Aug-13	Contaminated	23.8	39.3	166
	NF4B-2	27-Aug-13	Contaminated	2.57	4.23	18.3
	NF4M	27-Aug-13	Contaminated	4.88	8.65	35
	NF4T	27-Aug-13	Contaminated	1.93	3.62	14
	NF5B	26-Aug-13	Contaminated	2.14	4.55	16.8
	NF5M	26-Aug-13	Contaminated	7.15	11.9	50.8
	NF5T	26-Aug-13	Contaminated	21.8	38.4	162
Mid-field 1	MF1-1B	21-Aug-13	Contaminated	1.95	3.79	14.4
	MF1-1M	21-Aug-13	Contaminated	2.98	5.19	19.9
	MF1-1T	21-Aug-13	Contaminated	2.15	4.11	15.5
	MF1-3B	21-Aug-13	Contaminated	2.43	4.42	16.5
	MF1-3M	21-Aug-13	Contaminated	13	21.4	88
	MF1-3T	21-Aug-13	Contaminated	2.6	4.87	18.8
	MF1-5B	25-Aug-13	Contaminated	14.1	21.8	102
	MF1-5M	25-Aug-13	Contaminated	2.05	3.13	14.6
	MF1-5T	25-Aug-13	Uncontaminated	<0.05	0.255	0.725
Mid-field 2	MF2-1B	27-Aug-13	Contaminated	10	16.5	66.6
	MF2-1B-1	27-Aug-13	Uncontaminated	<0.1	0.199	0.058
	MF2-1M	27-Aug-13	Contaminated	1.99	3.76	14.2
	MF2-1T	27-Aug-13	Contaminated	2.2	4.3	16.3
	MF2-3B	27-Aug-13	Contaminated	2.52	4.71	18.3
	MF2-3M	27-Aug-13	Contaminated	9.29	14.4	65.2
	MF2-3T	27-Aug-13	Contaminated	12	21.2	82.5

Table B-6 Chromium, Molybdenum and Nickel Concentrations for Contaminated (grey shading) and Uncontaminated (no shading) AEMP Samples Collected during the Open–water Season, 2013

Area	Sample	Date	Sample Classification	Concentration (µg/L)		
				Chromium	Nickel	Molybdenum
Mid-field 3	MF3-1B	25-Aug-13	Contaminated	4.83	7.58	34.4
	MF3-1M	25-Aug-13	Uncontaminated	<0.05	0.561	0.771
	MF3-1T	25-Aug-13	Contaminated	7.48	12	50.7
	MF3-2B	25-Aug-13	Contaminated	6.54	10.3	46.5
	MF3-2M	25-Aug-13	Contaminated	6.88	10.9	47.8
	MF3-2T	25-Aug-13	Uncontaminated	<0.05	0.354	0.767
	MF3-3B	25-Aug-13	Contaminated	9.59	15.2	69.8
	MF3-3M	25-Aug-13	Uncontaminated	<0.05	0.43	0.78
	MF3-3T	25-Aug-13	Contaminated	10.3	16	72.3
	MF3-4B	5-Sep-13	Contaminated	3.4	5.64	24
	MF3-4M	5-Sep-13	Contaminated	9.52	14.1	66.8
	MF3-4T	5-Sep-13	Contaminated	6.67	10.4	45.4
	MF3-5B	7-Sep-13	Contaminated	9.56	14.6	66.4
	MF3-5M	7-Sep-13	Contaminated	3.08	4.79	22.1
	MF3-5T-4	7-Sep-13	Contaminated	1.95	3.24	14.9
	MF3-5T-5	7-Sep-13	Contaminated	5.94	9.36	43
	MF3-6B	7-Sep-13	Contaminated	12.6	19.2	88.8
Mid-field 3	MF3-6M	7-Sep-13	Contaminated	12.6	18.6	88.3
	MF3-6T	7-Sep-13	Contaminated	7.22	11.1	49.7
	MF3-7B-4	25-Aug-13	Contaminated	1.99	3.47	15.2
	MF3-7B-5	25-Aug-13	Contaminated	1.98	3.34	13.8
	MF3-7M	25-Aug-13	Contaminated	2.87	4.63	20.8
	MF3-7T	25-Aug-13	Contaminated	3.88	6.48	26.9
Far-field 2	FF2-2B	26-Aug-13	Contaminated	2.51	4.91	18.1
	FF2-2M	26-Aug-13	Contaminated	2.14	3.72	14.4
	FF2-2T	26-Aug-13	Contaminated	10.1	16.3	72.4
	FF2-5B	26-Aug-13	Contaminated	10	15	67.9
	FF2-5M	26-Aug-13	Contaminated	10.8	17.2	76.7
	FF2-5T	26-Aug-13	Contaminated	3.46	5.83	24.6
Far-field 1	FF1-1M	24-Aug-13	Contaminated	9.01	13.9	63.4
	FF1-2M	22-Aug-13	Contaminated	12.5	18.7	90.6
	FF1-2M-2	22-Aug-13	Contaminated	1.88	2.96	13.2
	FF1-3M	24-Aug-13	Uncontaminated	0.097	0.369	1.44
	FF1-4M	24-Aug-13	Contaminated	2.23	3.53	14.6

Table B-6 Chromium, Molybdenum and Nickel Concentrations for Contaminated (grey shading) and Uncontaminated (no shading) AEMP Samples Collected during the Open–water Season, 2013

Area	Sample	Date	Sample Classification	Concentration (µg/L)		
				Chromium	Nickel	Molybdenum
	FF1-5M	22-Aug-13	Contaminated	7.94	11.5	54
Far-field A	FFA-1M	29-Aug-13	Contaminated	3.53	5.83	25.2
	FFA-2M	30-Aug-13	Contaminated	3.37	6.4	24.5
	FFA-3M	29-Aug-13	Uncontaminated	<0.1	0.25	1.07
	FFA-4M	30-Aug-13	Contaminated	2.46	3.93	17.6
	FFA-5M	3-Sep-13	Contaminated	2.7	4.36	19.4
Far-field B	FFB-1M	5-Sep-13	Contaminated	11.7	18.5	81.8
	FFB-2M	1-Sep-13	Contaminated	11.9	17.8	86.1
	FFB-3M	5-Sep-13	Uncontaminated	<0.05	0.215	0.943
	FFB-3M-1	6-Sep-13	Contaminated	0.716	1.02	5.03
	FFB-3M-3	5-Sep-13	Uncontaminated	<0.05	<0.05	0.033
	FFB-4M	1-Sep-13	Contaminated	9.83	16.5	69.1
	FFB-5M	1-Sep-13	Contaminated	7.42	11.4	51.7
Lac du Sauvage	LDS-1M	31-Aug-13	Contaminated	2.37	3.69	16
	LDS-2M	26-Aug-13	Contaminated	3.41	5.36	23.3
	LDS-3M	26-Aug-13	Contaminated	2.88	4.67	19.6
Outlet of Lac de Gras	LDG48	26-Aug-13	Contaminated	6.91	10.6	48.3

Note: µg/L = micrograms per litre.

APPENDIX C

QUALITY ASSURANCE AND QUALITY CONTROL METHODS AND RESULTS

INTRODUCTION

Quality assurance (QA) and quality control (QC) practices determine data integrity and are relevant to all aspects of a study, from sample collection to data analysis and reporting. Quality assurance encompasses management and technical practices designed to generate consistent, high quality data. Quality control is an aspect of QA and includes the techniques used to assess data quality and the corrective actions to be taken when the data quality objectives are not met. This appendix describes QA/QC practices applied during the 2013 Aquatic Environment Monitoring Program (AEMP), evaluates QC data, and describes the implications of QC results to the interpretation of study results.

2013 OPEN-WATER SAMPLE CONTAMINATION

In 2013, DDMI determined that a batch of nitric acid preservative used to preserve total metals samples collected during the 2013 open-water SNP and AEMP sampling had been contaminated during laboratory production. Samples that were acidified with the contaminated preservative had elevated concentrations of a subset of total metals analyzed in 2013 (cadmium, chromium, cobalt, iron, manganese, molybdenum, nickel). The QA/QC methods used to identify the metals and samples that were affected by the contaminated preservative are discussed in a separate appendix (Appendix B). Given that the concentrations reported for the identified metals were clearly anomalous both in the contaminated effluent samples and in the lake water samples (i.e., relative to historical values; Appendix B, Tables B-4 to B-6), affected values had to be removed from all data analyses, figures and data summary tables prepared in support of the 2013 AEMP report. This included the removal of all affected values in contaminated QC samples (i.e., blank samples and duplicate samples) which are discussed in the following sections.

To mitigate a similar experience from occurring, DDMI will complete testing of all preservatives supplied by the laboratory to ensure that contamination does not exist. In addition, only one batch of preservative will be used at any given time (for a maximum shelf life of six months), and the batch identification numbers will be recorded on a sample by sample basis so that any potential contamination resulting from a preservative based source can be tracked.

QUALITY ASSURANCE

Field Staff Training and Operations

Diavik Diamond Mines Inc. (DDMI) field staff are trained to be proficient in standardized field sampling procedures, data recording, and equipment operations applicable to water quality sampling. Field work was completed according to specified instructions and standard operating procedures (SOP). The procedures are described in:

- ENVR-003-0702 R9 AEMP Monitoring Program (Open Water)
- ENVR-014-0311 R3 AEMP Sampling – Ice Cover
- ENVR-303-0112 R0 Laboratory Quality Assurance/Quality Control
- ENVR-206-0112 R0 Processing Maxxam Samples and Tracking Documentation
- ENVR-402-0112 R0 DDMI Lab – Dissolved Oxygen
- ENVR-404-0112 R0 DDMI Lab – pH
- ENVR-405-0112 R0 DDMI Lab – Turbidity
- ENVR-403-0112 R0 DDMI Lab – Total Suspended Solids
- ENVR-604-0112 R0, ENVR-608-0112 R0 Field Meter Calibration
- ENVR-608-0112 R0, ENVR-014-0311 R3, ENVR-003-0702 R8 Biophysical Measuring
- ENVR-608-0112 R0 Hydrolab Calibration, Deployment and Download

These SOPs include guidelines for field record-keeping and sample tracking, guidance for use and calibration of sampling equipment, relevant technical procedures, and sample labelling, shipping and tracking protocols.

Laboratory

Samples were sent for analysis to Maxxam Analytics Inc. (Maxxam), Burnaby, British Columbia, a laboratory accredited by the Canadian Association of Laboratory Accreditation. Under the accreditation program, performance assessments are conducted annually for laboratory procedures, analytical methods, and internal quality control.

Quality assurance at the DDMI Environmental Laboratory encompasses all quality-related activities related to aquatic testing and analysis, and relevant technical support (SOPENV-LAB-12).

DDMI's QA places an emphasis on four aspects:

- infrastructure (instruments, testing capabilities, calibrations, SOPs);
- control measures (internal/external);
- personnel (competence, ethics and integrity); and
- data management.

Office Operations

A data management system was set in place as an organized system of data control, analysis and filing. Relevant elements of this system are as follows:

- pre-field meetings to discuss specific work instructions with field crews;
- field crew check-in with task managers every 24 to 48 hours to report work completed during that period;
- designating two crew members responsible for:
  - collecting all required samples;
  - immediate download and storage of electronic data;
  - completing chain-of-custody and analytical request forms; labelling and documentation; and
  - processing, where required, and delivering samples to analytical laboratory in a timely manner;
- cross-checking chain-of-custody forms and analysis request forms by the task manager to verify that the correct analysis packages had been requested;
- review of field sheets by the task manager for completeness and accuracy;
- reviewing laboratory data as they are received from the analytical laboratory;
- creating backup files before data analysis; and
- completing appropriate logic checks for accuracy of calculations.

QUALITY CONTROL

Quality control is a specific aspect of QA and includes the techniques used to assess data quality and the remedial measures to be taken when the data quality objectives are not met. The field QC program included collection of field blanks, trip blanks, equipment blanks, and duplicate samples to assess potential sample contamination, and within-station variation/sampling precision. Quality control samples were submitted to Maxxam for analysis of the full list of variables.

Field blanks consisted of samples prepared in the field using laboratory-provided de-ionized water to fill a set of sample bottles, which were then submitted to the appropriate laboratory for the same analyses as the original water samples. Trip blanks consisted of sample bottles filled with high-grade de-ionized water from the laboratory. They accompanied the other samples through sample collection, handling, shipping and analysis, but remained sealed. Equipment blanks consisted of de-ionized water exposed to all aspects of sample collection and analysis, using the same procedures used in the field, including contact with all sampling devices and other equipment (filters, tubing). Equipment blanks provide information regarding potential cross-contamination between samples and field equipment.

The field, trip and equipment blanks were used to detect potential sample contamination during collection, shipping and analysis. Although concentrations should be below DLs in these blanks, their concentrations were considered notable if they were greater than five times the corresponding DL. This threshold is based on the Practical Quantitation Limit (PQL) defined by the United States Environmental Protection Agency (US EPA 1985), which takes into account the potential for data accuracy errors when variable concentrations approach or are below DLs. This criterion was not applied to pH, which is expected to be above the laboratory-reported DL in the de-ionized water used to prepare the blanks.

Notable results observed in the blanks were evaluated relative to variable concentrations observed in the lake water samples to determine whether sample contamination was limited to the QC sample. If, based on this comparison, sample contamination was not isolated to the QC sample; the field data were flagged and all further interpretations were made with this limitation in mind.

Duplicate samples consisted of two samples collected from the same location at the same time, using the same sampling and sample handling procedures. They were labelled and preserved individually and submitted separately to the analytical laboratory for identical analyses. Duplicate samples are used to check within-station variation and the precision of field sampling and analytical methods. Differences between concentrations measured in duplicate water samples were calculated as the Relative Percent Difference (RPD) for each variable. Before calculating the RPD, concentrations below the DL were replaced with 0.71 times the DL value. The RPD was calculated using the following formula:

$$RPD = (|\text{difference in concentration between duplicate samples}| \,/\, \text{mean concentration}) \times 100$$

The RPD value for a given variable was considered notable if:

- it was greater than 20 percent (%); and
- concentrations in one or both samples were greater than or equal to five times the DL.

These criteria are similar to those used by Maxxam for internal QC of laboratory duplicate samples, and take into account the potential for data accuracy error as variable concentrations approach DLs.

The number of variables which exceeded the assessment criteria was compared to the total number of variables analyzed to evaluate analytical precision. The analytical precision was rated as follows:

- high, if less than 10% of the total number of variables were notably different from one another;
- moderate, if 10% to 30% of the total number of variables were notably different from one another; and
- low, if more than 30% of the total number of variables were notably different from one another.

Quality Control Results

Detection Limits

Maxxam used analyte-specific detection limits (DLs) to report results for water quality variables analyzed in 2013 (*i.e.,* the same DL was used for all samples for a particular analyte, unless matrix interference necessitated the use of a higher DL). The DLs used by Maxxam in 2013 are listed in Section 2.2 Table 2-2 of the 2013 Effluent and Water Chemistry Report. These DLs were compared with those originally requested by DDMI to determine the reason(s) for any differences in DLs and whether this difference would affect data quality. Several variables were initially identified as having DLs not matching the requested values. These issues, however, either did not affect data quality (i.e., sample concentrations were greater than the adjusted DL) or the DL was corrected by re-running the affected samples.

Blank and Duplicate Samples

A total of three variables (ammonia, aluminum and zinc) measured in blank sampled collected during the ice-cover season had concentrations that exceeded the data quality objective (DQO) of five times the DL (Table C-1). A value of five times the DL was used to define the background concentration of a blank sample. An exceedance of five times the background concentration was used to identify potential contamination. Among the six blank samples collected during the ice-cover season, one variable (ammonia [as nitrogen]), exceeded background concentrations in a single trip blank collected at station MF-1M on April 11, 2013. The total fractions of zinc and aluminum exceeded background concentrations in two or more of the blanks collected in ice-cover. During the open-water season, a total of five variables (total dissolved solids [TDS], total Kjeldahl nitrogen [TKN], total nitrogen, ammonia, and zinc) measured in blanks had concentrations that were greater than five times the DL (Table C-1). Total dissolved solids exceeded the DQO in the field blank collected at FF1-2M, while TKN and total nitrogen exceeded the criterion in the equipment blank collected at FFB-3M. Exceedances of the DQO for ammonia and zinc occurred in the trip blank collected at FFB-3M and in the field blank collected at MF2-1B.

A total of 11 out of 66 water quality variables analyzed in 2013 (17%; total alkalinity, total dissolved solids [measured], bicarbonate, nitrate, total nitrogen, TKN, copper, nickel, sulphur, tin, and zinc) exceeded both the 20% RPD and 5 times DL criteria set for duplicate samples (Table C-2). As described above, this indicates a moderate level of analytical precision for duplicate samples in 2013. Of the 11 variables that exceeded the DQOs for duplicate samples, 4 variables (total nitrogen, TKN, tin and zinc) had RPD values that were greater than 50%. These results were considered notable because the differences in concentrations between duplicate samples for these analytes were appreciably higher than the QC objective values used by Maxxam to identify unacceptable differences between laboratory duplicate samples (RPD of 20 to 25%). Laboratory duplicates consist of two independently analyzed portions of the same sample and would therefore be expected to have lower variability among paired duplicate samples than field duplicates which consist of two completely separate grab samples collected from the lake bottom. During the ice-cover season, two variables (total nitrogen and TKN) had RPD values that were greater than 50% in a single duplicate sample pair (NF3B). During the open-water season concentrations of zinc and tin were also greater the 50% RPD and 5 times DL criteria a single sample each (samples MF3-7B and NF1B, respectively). Of the four variables that had RPD values exceeding the DQO for duplicate samples, three variables (total nitrogen, TKN and zinc) also had elevated concentrations in blank samples analyzed in 2013. The combination of high blank values and inconsistent concentrations between the duplicate samples imply a non-systematic error that should be investigated by Maxxam.

Results of QC analyses completed in 2013 and over the last two cycles of the AEMP (i.e., in 2011 and 2012) have indicated ongoing data quality issues for ammonia. In all three years, ammonia concentrations reported in blank samples analyzed by Maxxam were at or above levels in Lac de Gras, while the concentrations reported in lake water samples were appreciably higher than historic values, which were analyzed by ALS. In addition, concentrations reported by Maxxam were consistently greater than the values reported by the University of Alberta (UofA), which is the laboratory contracted for analysis of the depth integrated nutrient samples collected in support of the Eutrophication Indicators report. In all three years, ammonia concentrations in the trip blanks (i.e., which are prepared in the laboratory and taken into the field unopened) were similar to or greater than the values reported for equipment blanks and field blanks (which are opened and filled with DI water during field sampling). The combination of elevated concentrations in the blank samples and in the field data suggest a systematic error that should be investigated by Maxxam.

Table C-1 Blank Sample Results, 2013 AEMP

Variable	DL	Unit	Ice-cover						Open-water				
			NF1T-1	MF1-1M-3	MF2-1M-2	FF2-2M-3	FF1-5M-1	FFB-4M-2	NF4B-2	MF2-1B-1	FF1-2M-2	FFB-3M-1	FFB-3M-3
			Equipment Blank	Trip Blank	Field Blank	Trip Blank	Equipment Blank	Field Blank	Field Blank	Equipment Blank	Field Blank	Equipment Blank	Trip Blank
			4/19/2013	4/11/2013	4/2/2013	4/17/2013	4/16/2013	4/15/2013	8/27/2013	8/27/2013	8/22/2013	9/6/2013	9/5/2013
Conventional Parameters													
Acidity (pH 4.5)	0.5	mg/L	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Acidity (pH 8.3)	0.5	mg/L	<0.5	<0.5	<0.5	<0.5	0.52	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Total Alkalinity	0.5	mg/L	1.15	1.23	1.13	0.89	0.8	0.81	0.6	<0.5	<0.5	<0.5	0.7
Alkalinity (PP as CaCO3)	0.5	mg/L	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Specific Conductivity	1	µS/cm	1.1	1.3	1.3	1.1	<1	1	<1	1	1.1	1	1.1
Dissolved Hardness (CaCO3)	0.5	mg/L	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Total Hardness	0.5	mg/L	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
pH		-	5.6	5.49	5.96	5.4	5.5	5.48	5.07	4.87	4.98	4.67	4.95
Total Dissolved Solids (Calculated)	0.5-1	mg/L	<1	1.2	<1	<1	<1	1.6	<0.5	<0.5	<0.5	<0.5	1
Total Dissolved Solids (Measured)	1	mg/L	<1	1	1	1	<0.5	1	<1	<1	**10.8**	<1	<1
Total Suspended Solids	1	mg/L	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Total Organic Carbon	0.2	mg/L	0.4	<0.2	0.22	0.32	0.39	0.32	0.22	0.23	0.22	0.23	<0.2
Turbidity	0.1	NTU	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Major Ions													
Bicarbonate	0.5	mg/L	1.4	1.5	0.5	1.09	0.98	0.99	0.73	<0.5	<0.5	<0.5	0.85
Calcium	0.01	mg/L	<0.01	<0.01	<0.05	<0.05	<0.05	<0.05	<0.01	<0.01	<0.01	<0.01	<0.01
Carbonate	0.5	mg/L	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Chloride	0.5	mg/L	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	0.52
Fluoride	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Hydroxide	0.5	mg/L	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Magnesium	0.01	mg/L	<0.01	<0.01	<0.05	<0.05	<0.05	<0.05	<0.01	<0.01	<0.01	<0.01	<0.01
Potassium	0.01	mg/L	0.0019	<0.01	<0.05	<0.05	<0.05	<0.05	0.015	0.011	<0.01	<0.01	<0.01
Sodium	0.01	mg/L	<0.01	<0.01	<0.05	<0.05	<0.05	<0.05	0.01	<0.01	<0.01	<0.01	<0.01
Sulphate	0.5	mg/L	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Nutrients													
Nitrogen - Ammonia (Total)	5	µg/L	7.9	**36**	16	8.2	6.3	15	13	22	8.1	9.9	**35**
Nitrate	2	µg/L	<20	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Nitrite	2	µg/L	<20	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Nitrate + nitrite	2	µg/L	<20	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Nitrogen - Kjeldahl	20	µg/L	41	65	<20	43	25	23	<20	82	<20	**175**	42
Total Nitrogen	20	µg/L	41	65	<20	43	25	23	<20	82	<20	**175**	42
Orthophosphate	1	µg/L	<1	<1	<1	<1	1.3	<1	<1	<1	2.5	<1	<1
Phosphorus - dissolved	2	µg/L	<20	<2	<2	<2	<2	<2	2.4	<2	2.7	<2	<2
Phosphorus - total	2	µg/L	<20	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Total Metals													
Aluminum	0.2	µg/L	**1.27**	0.98	**2.32**	0.76	0.78	0.42	<0.5	<0.5	0.53	<0.5	<0.5
Antimony	0.02	µg/L	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Arsenic	0.02	µg/L	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Barium	0.02	µg/L	0.037	<0.02	<0.02	<0.02	0.065	0.055	<0.02	<0.02	<0.02	<0.02	0.039
Beryllium	0.01	µg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Bismuth	0.005	µg/L	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Boron	5	µg/L	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Cadmium	0.005	µg/L	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	(b)	<0.005	(b)	(b)	<0.005
Calcium	0.01	mg/L	<0.05	<0.01	<0.01	<0.01	<0.05(a)	<0.05(a)	<0.01	0.02	<0.01	<0.01	<0.01

Table C-1 Blank Sample Results, 2013 AEMP

Variable	DL	Unit	Ice-cover						Open-water				
			NF1T-1	MF1-1M-3	MF2-1M-2	FF2-2M-3	FF1-5M-1	FFB-4M-2	NF4B-2	MF2-1B-1	FF1-2M-2	FFB-3M-1	FFB-3M-3
			Equipment Blank	Trip Blank	Field Blank	Trip Blank	Equipment Blank	Field Blank	Field Blank	Equipment Blank	Field Blank	Equipment Blank	Trip Blank
			4/19/2013	4/11/2013	4/2/2013	4/17/2013	4/16/2013	4/15/2013	8/27/2013	8/27/2013	8/22/2013	9/6/2013	9/5/2013
Total Metals (Continued)													
Chromium	0.05	µg/L	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	(b)	<0.05	(b)	(b)	<0.05
Cobalt	0.005	µg/L	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	(b)	<0.005	(b)	(b)	<0.005
Copper	0.05	µg/L	0.074	<0.05	<0.05	0.064	<0.05	<0.05	<0.05	<0.05	0.08	<0.05	<0.05
Iron	1	µg/L	<1	<1	<1	<1	<1	<1	(b)	<1	(b)	(b)	<1
Lead	0.005	µg/L	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Lithium	0.5	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Magnesium	0.01	mg/L	<0.05	<0.01	0.0071	<0.01	<0.05(a)	<0.05(a)	<0.01	<0.01	<0.01	<0.01	<0.01
Manganese	0.05	µg/L	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	(b)	0.09	(b)	(b)	<0.05
Mercury	0.01	µg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Molybdenum	0.05	µg/L	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	(b)	0.199	(b)	(b)	<0.05
Nickel	0.02	µg/L	0.044	<0.02	<0.02	<0.02	<0.02	<0.02	(b)	0.058	(b)	(b)	0.033
Potassium	0.01	mg/L	<0.05	<0.01	<0.01	<0.01	<0.05(a)	<0.05(a)	<0.01	<0.01	<0.01	<0.01	0.011
Selenium	0.04	µg/L	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Silicon	50	µg/L	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
Silver	0.005	µg/L	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Sodium	0.01	mg/L	<0.05	<0.01	<0.01	<0.01	<0.05(a)	<0.05(a)	<0.01	<0.01	<0.01	<0.01	<0.01
Strontium	0.05	µg/L	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Sulphur	0.1	mg/L	<0.5	0.101	<0.1	<0.1	<0.5	<0.5	0.43	0.46	0.27	<0.1	0.3
Thallium	0.002	µg/L	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Tin	0.01	µg/L	0.028	<0.01	<0.01	<0.01	<0.01	0.043	0.02	0.038	0.018	0.013	0.017
Titanium	0.5	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Uranium	0.002	µg/L	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Vanadium	0.1	µg/L	<0.1	<0.1	<0.1	<0.1	0.18	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Zinc	0.1	µg/L	**1.72**	0.28	<0.1	0.22	**0.56**	**0.52**	0.12	**1.13**	<0.1	0.3	<0.1
Zirconium	0.05	µg/L	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05

Notes: mg/L = milligrams per litre; NTU = nephelometric turbidity units; µS/cm = microSiemens per centimetre; µg/L = micrograms per litre.

Bolded values an exceedance of the data quality objective for blanks samples (concentration greater than 5 times the DL).

a) Incorrect DL reported, however, all AEMP sample concentrations were greater than the adjusted DL.

b) Values for cadmium, chromium, cobalt, iron, manganese, molybdenum, and nickel were removed for select open-water samples due to the contamination described in Appendix B.

Table C-2 Duplicate Sample Results, 2013 AEMP

Variable	Unit	DL	Ice-cover						Open-water								
			NF3B-4			MF2-3B-4			MF3-5T			MF3-7B			NF1B		
			Duplicate 1	Duplicate 2	RPD	Duplicate 1	Duplicate 2	RPD	Duplicate 1	Duplicate 2	RPD	Duplicate 1	Duplicate 2	RPD	Duplicate 1	Duplicate 2	RPD
			10-Apr-13	10-Apr-13		12-Apr-13	12-Apr-13		7-Sep-13	7-Sep-13		25-Aug-13	25-Aug-13		18-Aug-13	18-Aug-13	
Conventional Parameters																	
Acidity (pH 4.5)	mg/L	0.5	<0.5	<0.5	-	<0.5	<0.5	-	<0.5	<0.5	-	<0.5	<0.5	-	<0.5	<0.5	-
Acidity (pH 8.3)	mg/L	0.5	1.73	0.86	-	<0.5	<0.5	-	<0.5	<0.5	-	0.53	<0.5	-	<0.5	0.83	-
Total Alkalinity	mg/L	0.5	8.17	7.09	14.2%	5.51	4.22	**26.5%**	4.24	4.42	4%	4.7	4.23	11%	6.15	6.16	0%
Alkalinity (PP as CaCO3)	mg/L	0.5	<0.5	<0.5	-	<0.5	<0.5	-	<0.5	<0.5	-	<0.5	<0.5	-	<0.5	<0.5	-
Specific Conductivity	µS/cm	1	49.8	51.6	3.6%	27.3	26.8	1.8%	20.4	20.8	2%	21.6	20.7	4%	29.7	29.8	0%
Dissolved Hardness (CaCO3)	mg/L	0.5	11.8	12.2	3.3%	8.04	7.68	4.6%	6.19	6.43	4%	6.17	6.18	0%	8.43	7.93	6%
Total Hardness	mg/L	0.5	11.3	12	6.0%	7.9	7.46	5.7%	6.16	6.12	1%	6.19	6.32	2%	7.83	7.92	1%
pH	pH Units	0	7.03	7	6.9%	6.83	6.8	6.9%	6.53	6.53	0%	6.73	6.79	1%	6.93	6.97	1%
Total Dissolved Solids (Calculated)	mg/L	0.5	24	24	0.0%	15	13	14.3%	10	10	0%	10	10	0%	15	15	0%
Total Dissolved Solids (Measured)	mg/L	1	46	38	19.0%	20	22	9.5%	14	12	15%	34	30	13%	24	18	**29%**
Total Suspended Solids	mg/L	1	<1	<1	-	<1	<1	-	<1	<1	-	<1	<1	-	<1	1.6	-
Total Organic Carbon	mg/L	0.2	2.3	2.3	0.0%	2	2.1	4.9%	2.2	2.2	0%	2.2	2.1	5%	2.3	2.2	4%
Turbidity	NTU	0.1	0.11	0.1	-	<0.1	0.1	-	0.17	0.16	-	0.15	0.16	-	0.3	0.38	-
Major Ions																	
Bicarbonate	mg/L	0.5	9.97	8.65	14.2%	6.72	5.15	**26.5%**	5.17	5.39	4%	5.73	5.16	10%	7.5	7.52	0%
Calcium	mg/L	0.01	2.33	2.52	7.8%	1.59	1.41	12.0%	1.15	1.16	1%	1.1	1.14	4%	1.73	1.48	16%
Carbonate	mg/L	0.5	<0.5	<0.5	-	<0.5	<0.5	-	<0.5	<0.5	-	<0.5	<0.5	-	<0.5	<0.5	-
Chloride	mg/L	0.5	6.1	6.1	0.0%	2.4	2.3	-	1.4	1.5	-	1.3	2	-	2.1	2.1	-
Fluoride	mg/L	0.01	0.03	0.03	-	0.025	0.025	-	0.024	0.024	-	0.022	0.022	-	0.029	0.029	-
Hydroxide	mg/L	0.5	<0.5	<0.5	-	<0.5	<0.5	-	<0.5	<0.5	-	<0.5	<0.5	-	<0.5	<0.5	-
Magnesium	mg/L	0.01	1.32	1.37	3.7%	0.954	0.955	0.1%	0.805	0.861	7%	0.83	0.807	3%	1	1.03	3%
Potassium	mg/L	0.01	1.06	1.09	2.8%	0.865	0.813	6.2%	0.64	0.712	11%	0.628	0.648	3%	0.68	0.818	18%
Sodium	mg/L	0.01	3.3	3.46	4.7%	1.56	1.51	3.3%	1.03	1.03	0%	1.11	1.06	5%	1.73	1.76	2%
Sulphate	mg/L	0.5	4.75	4.53	4.7%	3.65	3.37	8.0%	2.64	2.59	2%	2.13	1.69	-	3.45	3.46	0%
Nutrients																	
Nitrogen - Ammonia (Total)	µg/L	5	41	45	9.3%	32	34	6.1%	130	130	0%	15	11	-	26	30	14%
Nitrate	µg/L	2	80.1	90.6	12.3%	16.8	13.3	**23.3%**	<2	<2	-	<2	<2	-	6.5	8.3	-
Nitrite	µg/L	2	2.5	<2	-	<2	2.5	-	<2	<2	-	<2	<2	-	<2	<2	-
Nitrate + nitrite	µg/L	2	82.6	90.6	9.2%	16.8	15.8	6.1%	<2	<2	-	<2	<2	-	6.5	8.3	-
Nitrogen - Kjeldahl	µg/L	20	396	156	**87.0%**	158	168	6.1%	130	115	12%	131	120	9%	175	155	12%
Nitrogen - total	µg/L	20	479	247	**63.9%**	175	184	5.0%	130	115	12%	131	120	9%	181	163	10%
Orthophosphate	µg/L	1	2.5	2.4	-	<1	<1	-	<1	<1	-	<1	<1	-	<1	<1	-
Phosphorus - dissolved	µg/L	2	5.4	3.9	-	<2	<2	-	<2	<2	-	2.5	2.4	-	<2	<2	-
Phosphorus - total	µg/L	2	8	6	-	2.7	2.5	-	<2	<2	-	2.3	<2	-	3	2.7	-
Total Metals																	
Aluminum	µg/L	0.2 - 0.5	15.2	16.3	7.0%	2.58	2.79	7.8%	2.87	3.06	6%	4.01	3.48	14%	5.22	5.21	0%
Antimony	µg/L	0.02	0.028	0.035	-	<0.02	<0.02	-	<0.02	<0.02	-	<0.02	<0.02	-	<0.02	<0.02	-
Arsenic	µg/L	0.02	0.343	0.357	4.0%	0.236	0.249	5.4%	0.179	0.176	2%	0.172	0.17	1%	0.264	0.275	4%
Barium	µg/L	0.02	5.28	5.71	7.8%	2.59	2.43	6.4%	1.8	1.81	1%	1.86	1.76	6%	2.59	2.5	4%
Beryllium	µg/L	0.01	<0.01	<0.01	-	<0.01	<0.01	-	<0.01	<0.01	-	<0.01	<0.01	-	<0.01	<0.01	-
Bismuth	µg/L	0.005	<0.005	<0.005	-	<0.005	<0.005	-	<0.005	<0.005	-	<0.005	<0.005	-	<0.005	<0.005	-

Table C-2 Duplicate Sample Results, 2013 AEMP

Variable	Unit	DL	Ice-cover						Open-water								
			NF3B-4			MF2-3B-4			MF3-5T			MF3-7B			NF1B		
			Duplicate 1	Duplicate 2	RPD	Duplicate 1	Duplicate 2	RPD	Duplicate 1	Duplicate 2	RPD	Duplicate 1	Duplicate 2	RPD	Duplicate 1	Duplicate 2	RPD
			10-Apr-13	10-Apr-13		12-Apr-13	12-Apr-13		7-Sep-13	7-Sep-13		25-Aug-13	25-Aug-13		18-Aug-13	18-Aug-13	
Total Metals (Continued)																	
Boron	µg/L	5	<5	<5	-	<5	<5	-	<5	<5	-	<5	<5	-	<5	<5	-
Cadmium	µg/L	0.005	<0.005	<0.005	-	<0.005	<0.005	-	(a)	(a)	-	(a)	(a)	-	<0.005	<0.005	-
Calcium	mg/L	0.01	2.46	2.54	3.2%	1.55	1.41	9.5%	1.12	1.11	1%	1.17	1.17	0%	1.47	1.47	0%
Chromium	µg/L	0.05	0.091	0.083	-	<0.05	<0.05	-	(a)	(a)	-	(a)	(a)	-	0.054	0.101	-
Cobalt	µg/L	0.005	0.015	0.015	-	0.01	0.008	-	(a)	(a)	-	(a)	(a)	-	0.011	0.013	-
Copper	µg/L	0.05	0.599	0.505	17.0%	0.552	0.536	2.9%	0.627	0.574	9%	0.549	0.551	0%	0.503	0.665	**28%**
Iron	µg/L	1	2.2	2	-	<1	<1	-	(a)	(a)	-	(a)	(a)	-	8.3	8.3	0%
Lead	µg/L	0.005	0.01	0.005	-	<0.005	<0.005	-	0.006	<0.005	-	<0.005	<0.005	-	<0.005	<0.005	-
Lithium	µg/L	0.5	2.25	2.32	-	1.48	1.44	-	1.27	1.17	-	1.39	1.41	-	1.39	1.37	-
Magnesium	mg/L	0.01	1.37	1.43	4.3%	1.01	1.01	0.0%	0.814	0.813	0%	0.793	0.824	4%	1.01	1.03	2%
Manganese	µg/L	0.05	1.93	2.06	6.5%	0.702	0.743	5.7%	(a)	(a)	-	(a)	(a)	-	6.04	6.18	2%
Mercury	µg/L	0.01	<0.01	<0.01	-	<0.01	<0.01	-	<0.01	<0.01	-	<0.01	<0.01	-	<0.01	<0.01	-
Molybdenum	µg/L	0.05	1.44	1.49	3.4%	0.61	0.573	6.3%	(a)	(a)	-	(a)	(a)	-	0.595	0.618	4%
Nickel	µg/L	0.02	0.887	1.01	13.0%	0.567	0.738	**26.2%**	(a)	(a)	-	(a)	(a)	-	0.743	0.728	2%
Potassium	mg/L	0.01	1.13	1.17	3.5%	0.871	0.872	0.1%	0.654	0.666	2%	0.653	0.602	8%	0.83	0.873	5%
Selenium	µg/L	0.04	<0.04	<0.04	-	<0.04	<0.04	-	<0.04	<0.04	-	<0.04	<0.04	-	<0.04	<0.04	-
Silicon	µg/L	50	310	342	9.8%	<50	<50	-	<50	<50	-	<50	<50	-	63	<50	-
Silver	µg/L	0.005	<0.005	<0.005	-	<0.005	<0.005	-	<0.005	<0.005	-	<0.005	<0.005	-	<0.005	<0.005	-
Sodium	mg/L	0.01	3.43	3.64	5.9%	1.62	1.6	1.2%	1.06	1.06	0%	1.05	1.08	3%	1.74	1.78	2%
Strontium	µg/L	0.05	38.9	42	7.7%	17.2	16.4	4.8%	10.2	10.5	3%	10.5	10.1	4%	17.2	16.9	2%
Sulphur	mg/L	0.1	1.89	1.4	**29.8%**	1.15	1.31	13.0%	<0.1	0.34	-	0.89	0.92	3%	1.35	1.62	18%
Thallium	µg/L	0.002	<0.002	<0.002	-	<0.002	<0.002	-	<0.002	<0.002	-	<0.002	<0.002	-	0.002	0.002	-
Tin	µg/L	0.01	0.03	0.042	-	0.038	0.04	-	0.013	0.019	-	0.063	0.014	<u>**127%**</u>	0.012	0.025	-
Titanium	µg/L	0.5	<0.5	<0.5	-	<0.5	<0.5	-	<0.5	<0.5	-	<0.5	<0.5	-	<0.5	<0.5	-
Uranium	µg/L	0.002	0.204	0.211	3.4%	0.092	0.085	7.9%	0.029	0.03	3%	0.025	0.024	4%	0.085	0.087	2%
Vanadium	µg/L	0.1	0.11	<0.1	-	<0.1	<0.1	-	<0.1	<0.1	-	<0.1	<0.1	-	<0.1	<0.1	-
Zinc	µg/L	0.1	1.03	0.64	**46.7%**	0.47	0.39	-	0.59	0.42	**34%**	0.7	0.6	15%	1.96	0.95	<u>**69%**</u>
Zirconium	µg/L	0.05	<0.05	<0.05	-	<0.05	<0.05	-	<0.05	<0.05	-	<0.05	<0.05	-	<0.05	<0.05	-

Notes: - = not applicable; mg/L = milligrams per litre; NTU = nephelometric turbidity units; µS/cm = microSiemens per centimetre; µg/L = micrograms per litre.

Bolded values indicate duplicate samples that had RPD values greater than 20%, and concentrations in one or both samples that were greater than or equal to five times the DL. Values that are <u>**bolded and underlined**</u> indicate an RPD greater than 50% and concentrations in one or both samples that were greater than or equal to five times the DL.

a) Values for cadmium, chromium, cobalt, iron, manganese, molybdenum, and nickel were removed for select open-water samples due to the contamination described in Appendix B.

Other QC Issues

Results of the QC analysis of the ice-cover dataset in 2013 indicated that two sample bottles collected for analysis of low level dissolved metals at station NF1 were likely interchanged. The sample collected at the top depth at station NF1 (sample NF1T) had likely been interchanged with the equipment blank prepared at that location (sample NF1T-1). Major ion concentrations (dissolved hardness, turbidity, calcium, magnesium, potassium, and sodium) reported for the equipment blank (NF1T-1) were similar to those at nearby NF stations, whereas the concentrations measured in the primary sample (NF1T) were mostly non-detect, suggesting the two bottles were likely mislabelled in the field or in the lab. In the interest of retaining the NF1-T sample, the results for the two samples were substituted (Table C-3)

Table C-3 Initial and corrected values for Samples NF1T and NF1T-1, Ice-cover Season, 2013 AEMP

Station	Season	Variable	Sample NF1T Primary Sample		Sample NF1T-1 Equipment Blank		Unit
			Initial Value	Corrected Value	Initial Value	Corrected Value	
NF1T	Ice-cover	Dissolved Hardness	<0.5	9.15	9.15	<0.5	mg/L
NF1T	Ice-cover	Turbidity	<0.1	0.15	0.15	<0.1	NTU
NF1T	Ice-cover	Calcium	<0.01	1.79	1.79	<0.01	mg/L
NF1T	Ice-cover	Magnesium	<0.01	1.13	1.13	<0.01	mg/L
NF1T	Ice-cover	Potassium	0.0019	1.09	1.09	0.0019	mg/L
NF1T	Ice-cover	Sodium	<0.01	1.97	1.97	<0.01	mg/L

Notes: mg/L = milligrams per litre, NTU = nephelometric turbidity units.

Elevated values for several nutrients, major ions and total metals in the sample collected at MF1-3T suggested that the sample had likely been contaminated (Table C-4). A request to re-run the sample was made to Maxxam, but sample reanalysis indicated that the results were confirmed. A review of the analytical data, and discussion with the lab suggested that sample bottles intended for specific analyses may have been preserved with the wrong types of preservative. The exact cause of the issue, however, remains unclear. The full suite of results for station MF1-3T was therefore conservatively removed from the dataset.

Table C-4 Sample Values at Station MF1-3T, Ice-cover Season, 2013 AEMP

Variable	Unit	Result	Variable	Unit	Result
Acidity (pH 4.5)	mg/L	<0.5	Total Arsenic	µg/L	0.321
Acidity (pH 8.3)	mg/L	<0.5	Total Barium	µg/L	3.93
Total alkalinity	mg/L	8.29	Total Beryllium	µg/L	<0.01
Alkalinity (PP as CaCO3)	mg/L	<0.5	Total Bismuth	µg/L	<0.005
Specific Conductivity	µS/cm	38	Total Boron	µg/L	<5
Dissolved Hardness (CaCO3)	mg/L	11.0	Total Cadmium	µg/L	<0.005
Hardness	mg/L	17.2	Total Antimony	µg/L	0.04
pH	pH Units	7.02	Total Calcium	mg/L	4.38
Total Dissolved Solids (Calculated)	mg/L	19.0	Total Chromium	µg/L	0.134
Total Dissolved Solids (Measured)	mg/L	42.0	Total Cobalt	µg/L	0.0160
Total Suspended Solids	mg/L	<1	Total Copper	µg/L	0.991
Total Organic Carbon	mg/L	2.9	Total Iron	µg/L	7.1
Turbidity	NTU	0.11	Total Lead	µg/L	0.0320
Bicarbonate	mg/L	10.1	Total Lithium	µg/L	2.41
Calcium	mg/L	2.06	Total Magnesium	mg/L	1.51
Carbonate	mg/L	<0.5	Total Manganese	µg/L	2.84
Chloride	mg/L	2.6	Total Mercury	µg/L	<0.01
Fluoride	mg/L	0.029	Total Molybdenum	µg/L	0.770
Hydroxide	mg/L	<0.5	Total Nickel	µg/L	1.05
Magnesium	mg/L	1.42	Total Potassium	mg/L	1.35
Potassium	mg/L	1.25	Total Selenium	µg/L	0.048
Sodium	mg/L	2.10	Total Silicon	µg/L	96
Sulphate	mg/L	4.58	Total Silver	µg/L	<0.005
Ammonia (as nitrogen)	µg/L	42	Total Sodium	mg/L	2.29
Nitrate (as nitrogen)	µg/L	13.7	Total Strontium	µg/L	24.3
Nitrite (as nitrogen)	µg/L	<2	Total Sulphur	mg/L	21.4
Nitrate + nitrite (as nitrogen)	µg/L	13.7	Total Thallium	µg/L	<0.002
Nitrogen - Kjeldahl	µg/L	304	Total Tin	µg/L	0.104
Total Nitrogen	µg/L	317	Total Titanium	µg/L	<0.5
Orthophosphate	µg/L	<1	Total Uranium	µg/L	0.101
Phosphorus - dissolved	µg/L	<2	Total Vanadium	µg/L	0.17
Phosphorus - total	µg/L	<2	Total Zinc	µg/L	10.4
Total Aluminum	µg/L	21.4	Total Zirconium	µg/L	<0.05

Notes: mg/L = milligrams per litre, µS/cm = microSiemens per centimetre; NTU = nephelometric turbidity units; µg/L = micrograms per litre.

Outlier Identification

A number of analytical results were identified as visual outliers in 2013 and were not used in data analyses or the development of the figures included in the 2013 Effluent and Water Chemistry Report. Values that were removed from the AEMP dataset are summarised in Table III-5. The QA protocols did not identify issues with the results described below; however, the concentrations of specific variables were determined to be anomalous after review of data plots and comparisons with nearby stations. Generally, outlier values were at least 4 to 5 times greater than those observed at other relevant stations.

Table C-5 List of Data Outliers, 2013 AEMP

Station	Season	Variable	Unit	Result
NF5-1M	Ice-cover	Tin	µg/L	0.424
MF1-1B	Ice-cover	Nitrate	µg/L	135
MF1-1B	Ice-cover	Nitrate+Nitrite	µg/L	135
MF1-3B	Ice-cover	Nitrogen - Kjeldahl	µg/L	602
MF1-3B	Ice-cover	Total Nitrogen	µg/L	674
MF1-5T	Ice-cover	Nitrogen - Kjeldahl	µg/L	443
MF2-1M	Ice-cover	Nitrogen - Ammonia	µg/L	120
MF3-3T	Ice-cover	Nitrogen - Ammonia	µg/L	84
MF3-3M	Ice-cover	Nitrogen - Ammonia	µg/L	89
MF3-6T	Ice-cover	Lead	µg/L	68
FF1-1M	Ice-cover	Lead	µg/L	0.058
FF1-1M	Ice-cover	Manganese	µg/L	6.35
FF1-3M	Ice-cover	Lead	µg/L	0.128
NF1T	Open-water	Titanium	µg/L	4.61
MF1-3M	Open-water	Total Phosphorus	µg/L	14
MF3-5M	Open-water	Acidity (pH 8.3)	mg/L	1.4
MF3-5T	Open-water	Nitrogen - Ammonia	µg/L	130
FF1-4M	Open-water	Nitrate	µg/L	142
FF1-4M	Open-water	Lead	µg/L	0.813
FF1-4M	Open-water	Tin	µg/L	0.211
FF1-5M	Open-water	Nitrate	µg/L	801
FF1-5M	Open-water	Nitrate+Nitrite	µg/L	801
FF1-5M	Open-water	Nitrogen - Kjeldahl	µg/L	748
FF1-5M	Open-water	Total Nitrogen	µg/L	1550
FF1-5M	Open-water	Lead	µg/L	1.54
FF1-5M	Open-water	Mercury	µg/L	0.035
FF1-5M	Open-water	Tin	µg/L	0.171
FF1-5M	Open-water	Zinc	µg/L	14.9

Notes: - = multiple values were removed; mg/L = milligrams per litre; µg/L = micrograms per litre.

APPENDIX D

ACTION LEVEL SCREENING

REFERENCE AREA VALUES

Table D-1 Reference Area Threshold Values Used in the Action Level Screening for Water Chemistry

	Unit	Action Level 1 2 x Median of Reference Areas(a)		Action Level 2 Normal Range(b)				Source(g)	Comment
		Ice-cover	Open-water(c)	Ice-cover		Open-water(c)			
				Upper Limit	Lower Limit	Upper Limit	Lower Limit		
Conventional Parameters									
Acidity (pH 4.5)	mg/L	0.7	0.7	-	-	-	-	2011 and 2013 AEMP (Maxxam)	Not analyzed from 2007 to 2010
Acidity (pH 8.3)	mg/L	0.7	0.7	-	-	-	-	2011 and 2013 AEMP (Maxxam)	Not analyzed from 2007 to 2010
Total alkalinity	mg/L	8.8	8.1	-	-	-	-	2011 and 2013 AEMP (Maxxam)	DL used from 2007-2010 >2013 exposure area data
Alkalinity (PP as CaCO3)	mg/L	0.7	0.7	-	-	-	-	2011 and 2013 AEMP (Maxxam)	Not analyzed from 2007 to 2010
Specific Conductivity	µS/cm	34	31	20	14	16	15	2007-2010 AEMP (ALS)	
Dissolved Hardness (CaCO3)	mg/L	13.8	12.2	-	-	-	-	2013 AEMP (Maxxam)	Not analyzed from 2007 to 2011
Hardness	mg/L	11.5	10.6	-	-	-	-	2007-2010 AEMP (ALS)	
pH	pH Units	(d)	(d)	(d)	(d)	(d)	(d)	-	
Total Dissolved Solids (Calculated)	mg/L	11	10	8.4	2.2	6.2	3.6	2007-2010 AEMP (ALS)	
Total Dissolved Solids (Measured)	mg/L	30	20	-	-	-	-	2007-2010 AEMP (ALS)	
Total Suspended Solids	mg/L	1.4	1.4	-	-	-	-	2007-2010 AEMP (ALS)	
Total Organic Carbon	mg/L	5.4	4.4	-	-	-	-	2007-2010 AEMP (ALS)	
Turbidity	NTU	0.2	0.4	-	-	-	-	2013 AEMP (Maxxam)	Not analyzed from 2007 to 2011
Major Ions									
Bicarbonate	mg/L	(e)	(e)	(e)	(e)	(e)	(e)	-	
Calcium	mg/L	2.2	2.02	1.4	0.8	1.2	0.8	2007-2010 AEMP (ALS)	
Carbonate	mg/L	0.7	0.7	-	-	-	-	2007-2010 AEMP (ALS)	
Chloride	mg/L	2	2.6	1.7	0.5	1.9	0.7	2011 and 2013 AEMP (Maxxam)	DL used from 2007-2010 >2013 exposure area data
Fluoride	mg/L	0.05	0.04	-	-	-	-	2011 and 2013 AEMP (Maxxam)	DL used from 2007-2010 >2013 exposure area data
Hydroxide	mg/L	0.7	0.7	-	-	-	-	2007-2010 AEMP (ALS)	
Magnesium	mg/L	1.4	1.38	-	-	-	-	2007-2010 AEMP (ALS)	
Potassium	mg/L	1.26	1.2	-	-	-	-	2007-2010 AEMP (ALS)	
Sodium	mg/L	1.42	1.42	1.94	0	0.71	0	2007-2010 AEMP (ALS)	
Sulphate	mg/L	4.3	4	3.3	0.6	2.6	1.5	2007-2010 AEMP (ALS)	
Nutrients									
Ammonia (as Nitrogen)	µg/L	34	8	32	3	11	0	2007-2010 AEMP - U of A	
Nitrate (as Nitrogen)	µg/L	7	3	11.3	0	2.45	0.7	2013 AEMP (Maxxam)	DL used from 2007-2011 >2013 exposure area data
Nitrite (as Nitrogen)	µg/L	3	3	-	-	-	-	2007-2010 AEMP (ALS)	
Nitrate + Nitrite (as Nitrogen)	µg/L	7	3	-	-	-	-	2013 AEMP (Maxxam)	DL used from 2007-2011 >2013 exposure area data
Nitrogen - Kjeldahl	µg/L	(e)	(e)	(e)	(e)	(e)	(e)	-	
Total Nitrogen	µg/L	(e)	(e)	(e)	(e)	(e)	(e)	-	
Orthophosphate	µg/L	(e)	(e)	(e)	(e)	(e)	(e)	-	
Phosphorus - Dissolved	µg/L	(e)	(e)	(e)	(e)	(e)	(e)	-	
Phosphorus - Total	µg/L	(e)	(e)	(e)	(e)	(e)	(e)	-	
Metals (Total)									
Aluminum	µg/L	5.9	8.8	4.3	1.8	6.3	2.8	2007-2010 AEMP (ALS)	
Antimony	µg/L	0.03	0.03	-	-	-	-	2011 and 2013 AEMP (Maxxam)	DL used from 2007-2011 >2013 exposure area data
Arsenic	µg/L	0.37	0.34	-	-	-	-	2007-2010 AEMP (ALS)	
Barium	µg/L	3.86	3.62	2.19	1.7	2.2	1.5	2007-2010 AEMP (ALS)	
Beryllium	µg/L	0.01	0.01	-	-	-	-	2007-2010 AEMP (ALS)	

Table D-1 Reference Area Threshold Values Used in the Action Level Screening for Water Chemistry

	Unit	Action Level 1 2 x Median of Reference Areas[a]		Action Level 2 Normal Range[b]				Source[g]	Comment
		Ice-cover	Open-water[c]	Ice-cover		Open-water[c]			
				Upper Limit	Lower Limit	Upper Limit	Lower Limit		
Metals (Total) (Continued)									
Bismuth	µg/L	0.007	0.007	-	-	-	-	2011 and 2013 AEMP (Maxxam)	Not analyzed from 2007 to 2010
Boron	µg/L	3	3	-	-	-	-	2007-2010 AEMP (ALS)	
Cadmium	µg/L	0.07	0.07	-	-	-	-	2007-2010 AEMP (ALS)	
Calcium	mg/L	2.12	1.95	-	-	-	-	2007-2010 AEMP (ALS)	
Chromium	µg/L	0.07	[f]	0.05	0.03	[f]	[f]	2013 AEMP (Maxxam)	DL used from 2007-2011 >2013 exposure area data
Cobalt	µg/L	0.022	0.03	-	-	-	-	2011 and 2013 AEMP (Maxxam)	DL used from 2007-2010 >2013 exposure area data
Copper	µg/L	1.15	1.1	-	-	-	-	2011 and 2013 AEMP (Maxxam)	DL used from 2007-2010 >2013 exposure area data
Iron	µg/L	4	10	-	-	-	-	2011 and 2013 AEMP (Maxxam)	DL used from 2007-2010 >2013 exposure area data
Lead	µg/L	0.007	0.007	-	-	-	-	2011 and 2013 AEMP (Maxxam)	DL used from 2007-2010 >2013 exposure area data
Lithium	µg/L	2.7	2.4	-	-	-	-	2011 and 2013 AEMP (Maxxam)	Not analyzed from 2007 to 2010
Magnesium	mg/L	1.37	1.29	-	-	-	-	2007-2010 AEMP (ALS)	
Manganese	µg/L	2.6	4.84	-	-	-	-	2007-2010 AEMP (ALS)	
Mercury	µg/L	0.03	0.03	-	-	-	-	2007-2010 AEMP (ALS)	
Molybdenum	µg/L	0.16	0.19	0.14	0.04	0.25	0	2007-2010 AEMP (ALS)	
Nickel	µg/L	1.95	1.9	-	-	-	-	2007-2010 AEMP (ALS)	
Potassium	mg/L	1.18	1.09	-	-	-	-	2007-2010 AEMP (ALS)	
Selenium	µg/L	0.142	0.142	-	-	-	-	2007-2010 AEMP (ALS)	
Silicon	µg/L	71	104	121	0	89	18	2013 AEMP (Maxxam)	Not analyzed from 2007 to 2010; DL used in 2011 >2013 exposure area data
Silver	µg/L	0.142	0.142	-	-	-	-	2007-2010 AEMP (ALS)	
Sodium	mg/L	1.32	1.31	-	-	-	-	2007-2010 AEMP (ALS)	
Strontium	µg/L	15.58	14.9	8.97	6.49	8.59	6.46	2007-2010 AEMP (ALS)	
Sulphur	mg/L	2	1.8	-	-	-	-	2013 AEMP (Maxxam)	Not analyzed from 2007 to 2010; DL used in 2011 >2013 exposure area data
Thallium	µg/L	0.003	0.003	-	-	-	-	2011 and 2013 AEMP (Maxxam)	Not analyzed from 2007 to 2010
Tin[h]	µg/L	0.038	0.05	-	-	-	-	2013 AEMP (Maxxam)	[h]
Titanium	µg/L	0.7	0.7	-	-	-	-	2011 and 2013 AEMP (Maxxam)	Not analyzed from 2007 to 2010
Uranium	µg/L	0.057	0.054	0.035	0.023	0.036	0.016	2011 and 2013 AEMP (Maxxam)	DL used from 2007-2010 >2013 exposure area data
Vanadium	µg/L	0.07	0.07	-	-	-	-	2007-2010 AEMP (ALS)	
Zinc	µg/L	1.9	1.5	-	-	-	-	2011 and 2013 AEMP (Maxxam)	DL used from 2007-2010 >2013 exposure area data
Zirconium	µg/L	0.14	0.11	-	-	-	-	2011 and 2013 AEMP (Maxxam)	Not analyzed from 2007 to 2010

Notes: mg/L = milligrams per litre; µS/cm = microSiemens per centimeter; NTU = nephelometric turbidity units; µg/L= micrograms per liter; Maxxam = Maxxam Analytics, Burnaby, BC; ALS = ALS Laboratories, Edmonton, AB; DL = detection limit; >= greater than

a) The 2 x median of reference areas criterion was calculated based on the pooled reference area data (FFA, FFB, FF1).

b) The normal range upper limit was calculated as the pooled reference area mean ± 2 standard deviations. Normal ranges were calculated only variables that reached Action Level 1 in 2013.

c) Reference area threshold values for the open-water season were calculated based on samples collected from August 15 to September 15.

d) pH is evaluated qualitatively in Section 3.4.

e) Nutrients that are generally not toxic to aquatic organisms were evaluated in the Eutrophication Indicators Report (Golder 2014b)

f) Reference area threshold values for chromium were not calculated because suitable reference area data were not available. Detection limits used prior to 2013 were greater than most NF area values in 2013 (i.e., which used a lower DL), and reference area samples collected in 2013 were mostly contaminated (n= 12 of15 samples).

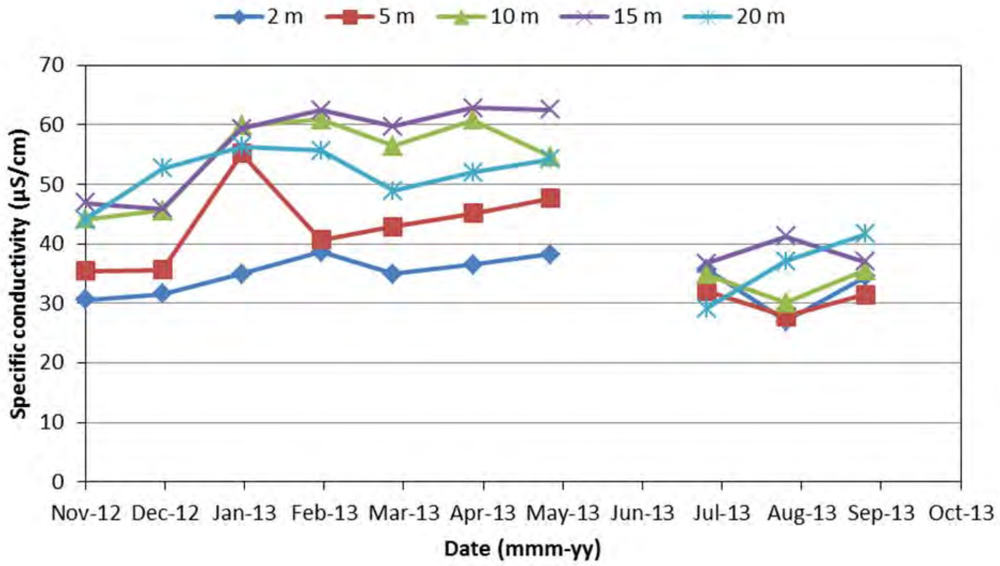
g) Reference areas were not sampled in 2012.

h) Tin was not analyzed prior to 2011; however, reported values for tin in that year were much lower than the concentrations reported in 2012 and 2013, which were generally similar to each other. In general, tin concentrations in 2012 and 2013, were between 5 and 15 times greater than values reported in 2011 which were primarily less than the DL (>90% of values; DL = 0.01 µg/L). Given the inconsistency between the 2011 results for tin and the 2012 and 2013 data, the 2011 results were not considered in the determination of the reference area threshold criteria for tin.

APPENDIX E

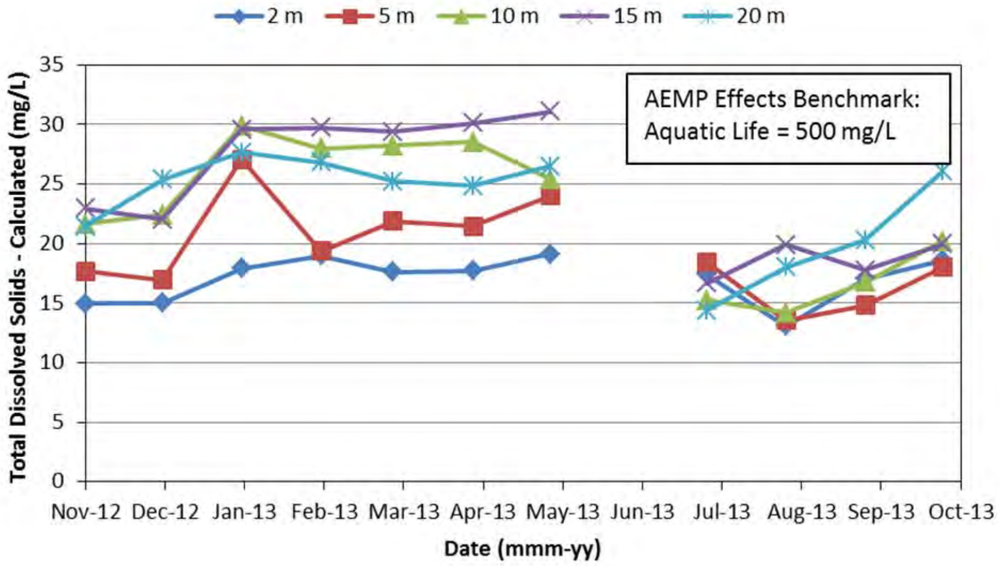
SUPPLEMENTAL FIGURES

Figure E-1 Specific Conductivity at the Mixing Zone Boundary, November 2012 to October 2013



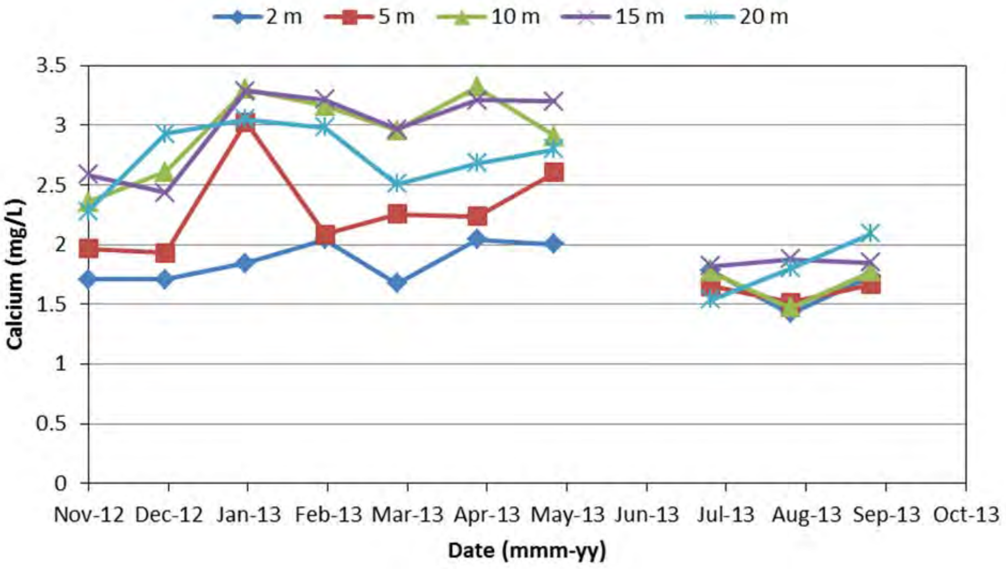
Notes: µS/cm = microSiemens per centimeter; m = meter.

Figure E-2 Total Dissolved Solids (Calculated) Concentration at the Mixing Zone Boundary, November 2012 to October 2013



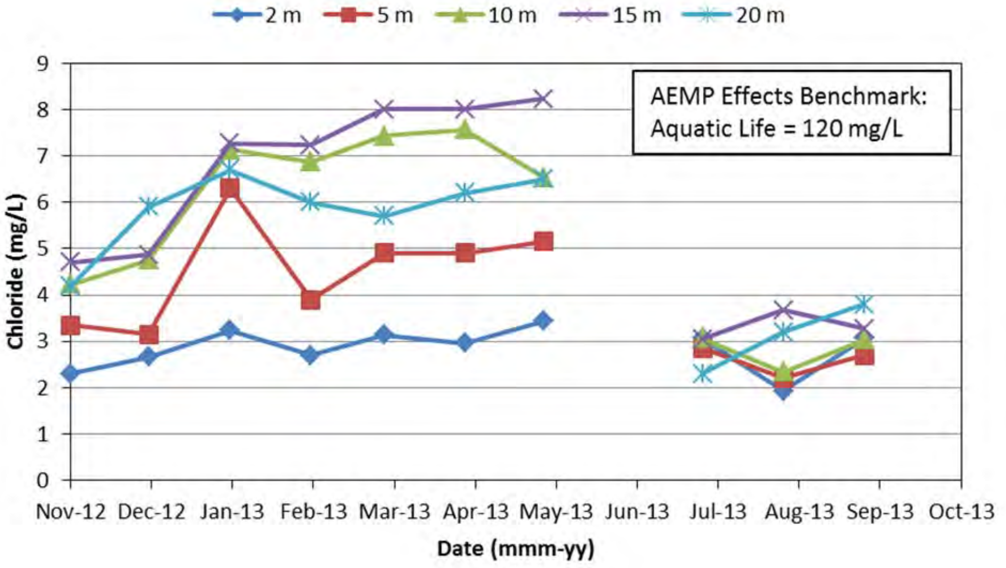
Notes: mg/L = milligrams per litre; m = metre.

Figure E-3 Dissolved Calcium Concentration at the Mixing Zone Boundary, November 2012 to October 2013



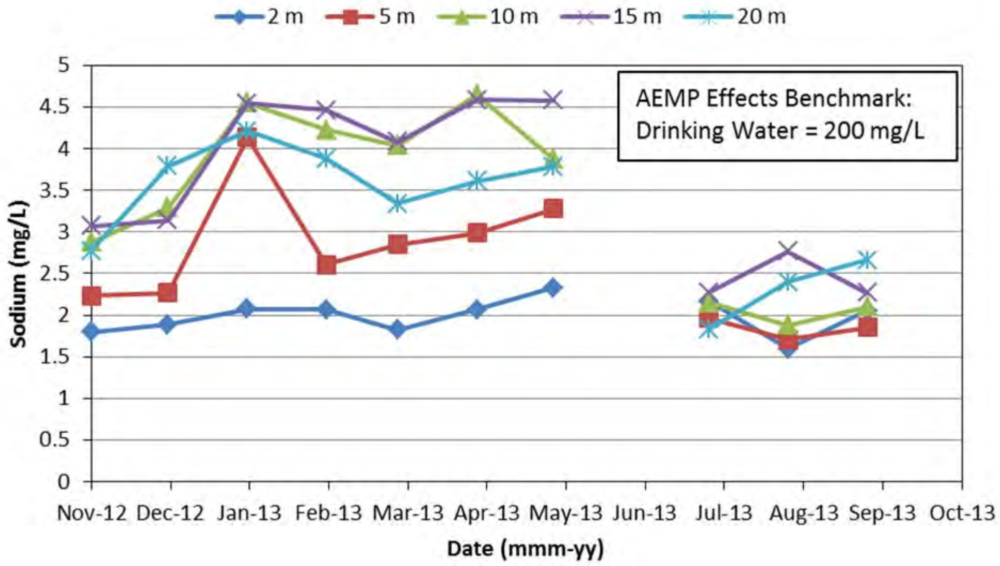
Notes: mg/L = milligrams per litre; m = metre.

Figure E-4 Chloride Concentration at the Mixing Zone Boundary, November 2012 to October 2013



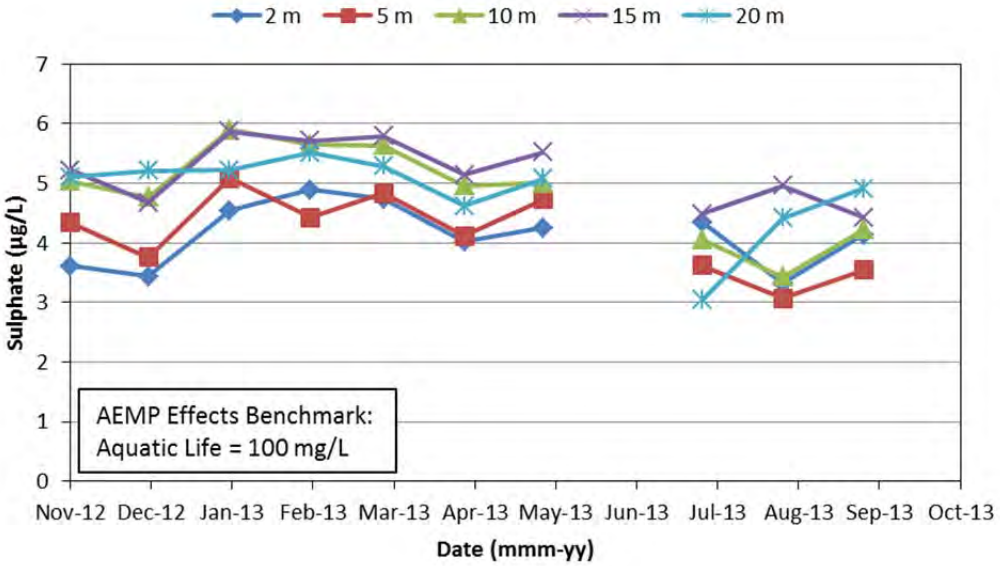
Notes: mg/L = milligrams per litre; m = metre.

Figure E-5 Dissolved Sodium Concentration at the Mixing Zone Boundary, November 2012 to October 2013



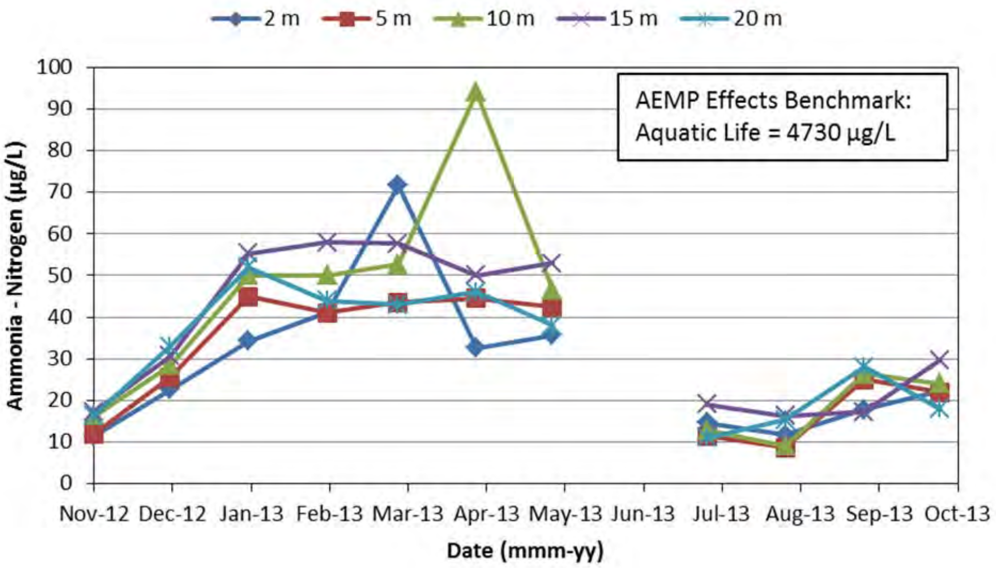
Notes: mg/L = milligrams per litre; m = metre.

Figure E-6 Sulphate Concentration at the Mixing Zone Boundary, November 2012 to October 2013



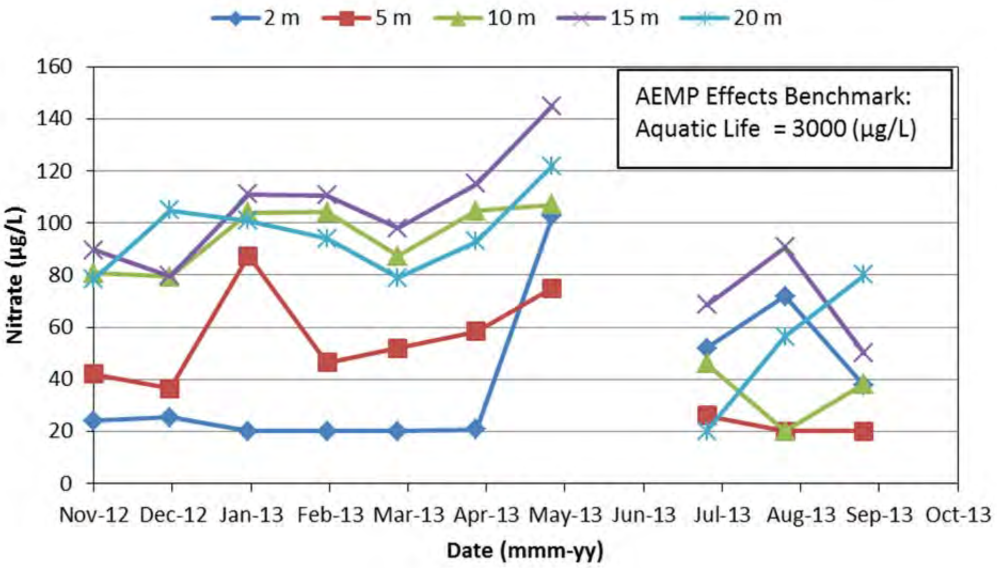
Notes: mg/L = milligrams per litre; m = metre.

Figure E-7 Ammonia (as Nitrogen) Concentration at the Mixing Zone Boundary, November 2012 to October 2013



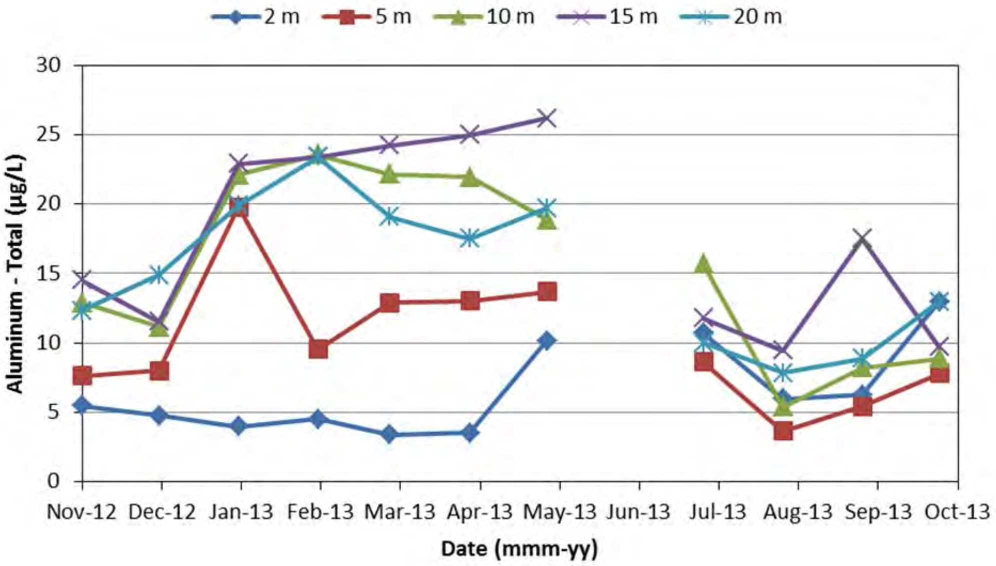
Notes: µg/L = milligrams per litre; m = metre.

Figure E-8 Nitrate (as Nitrogen) Concentration at the Mixing Zone Boundary, November 2012 to October 2013



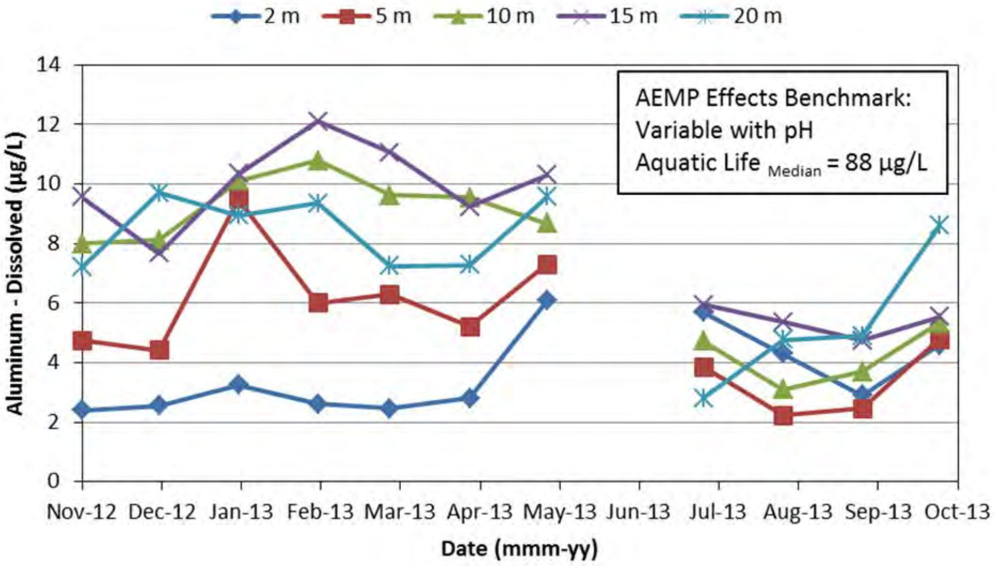
Notes: µg/L = milligrams per litre; m = metre.

Figure E-9 Total Aluminum Concentration at the Mixing Zone Boundary, November 2012 to October 2013



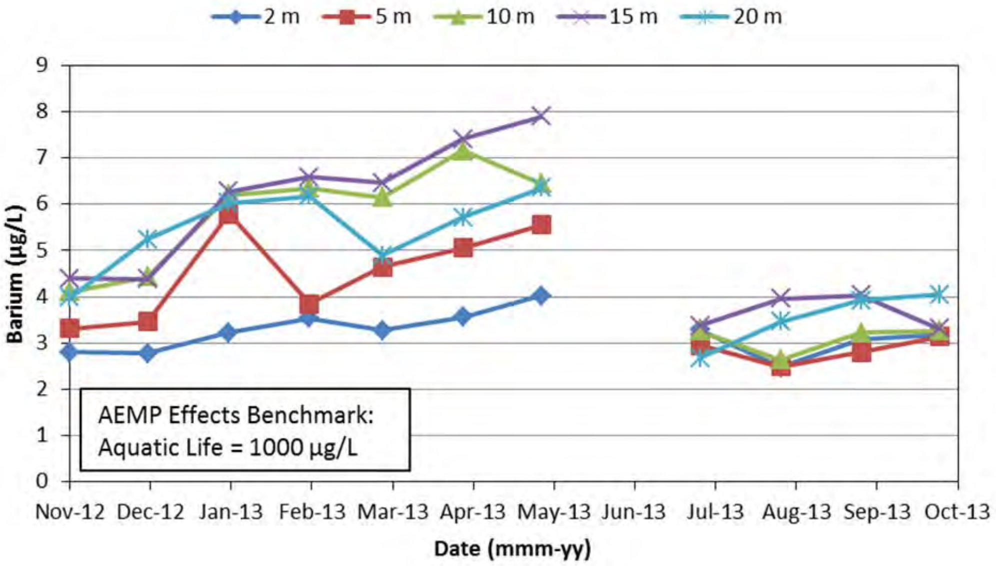
Notes: mg/L = milligrams per litre; m = metre.

Figure E-10 Dissolved Aluminum Concentration at the Mixing Zone Boundary, November 2012 to October 2013



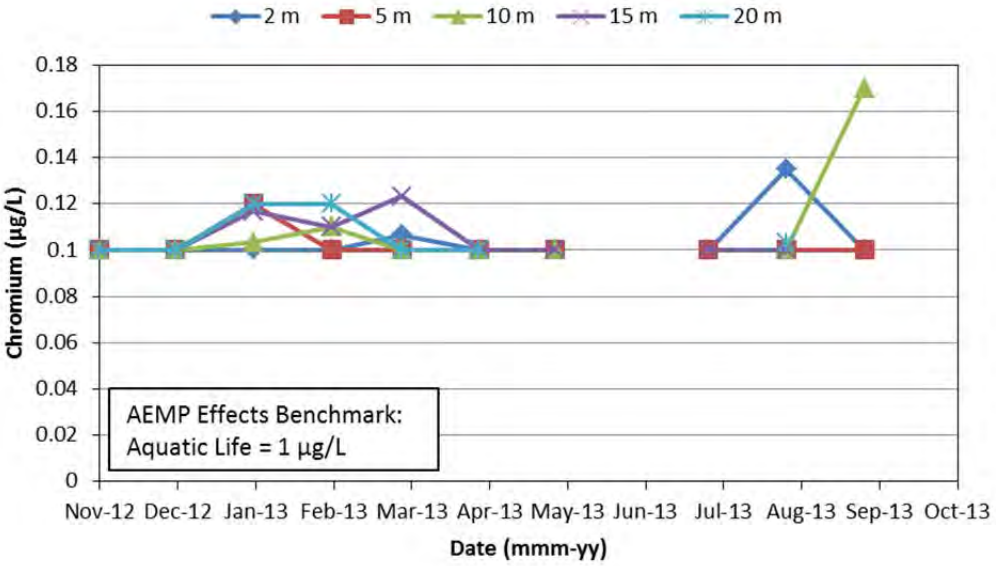
Notes: mg/L = milligrams per litre; m = metre.

Figure E-11 Barium Concentration at the Mixing Zone Boundary, November 2012 to October 2013



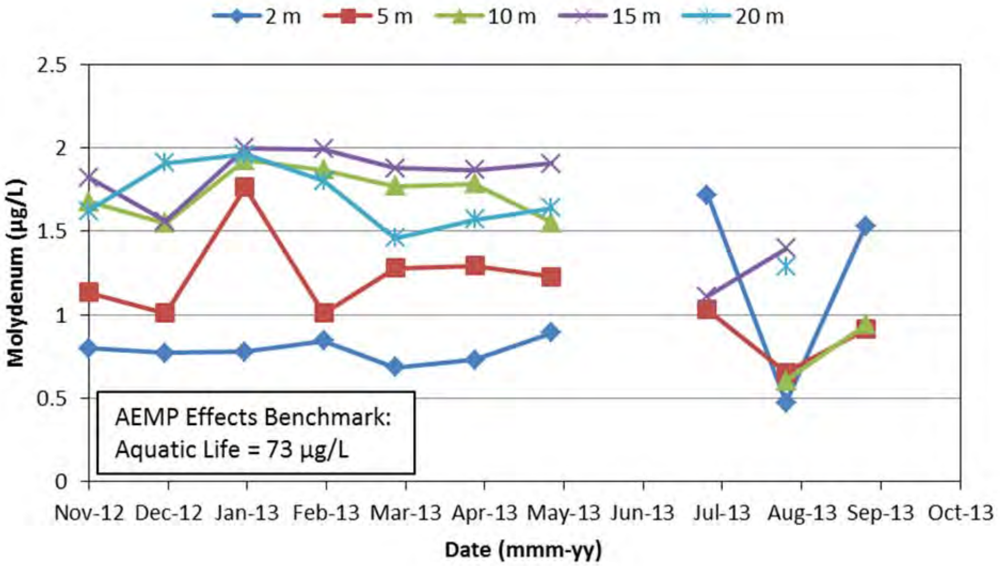
Notes: mg/L = milligrams per litre; m = metre.

Figure E-12 Chromium Concentration at the Mixing Zone Boundary, November 2012 to October 2013



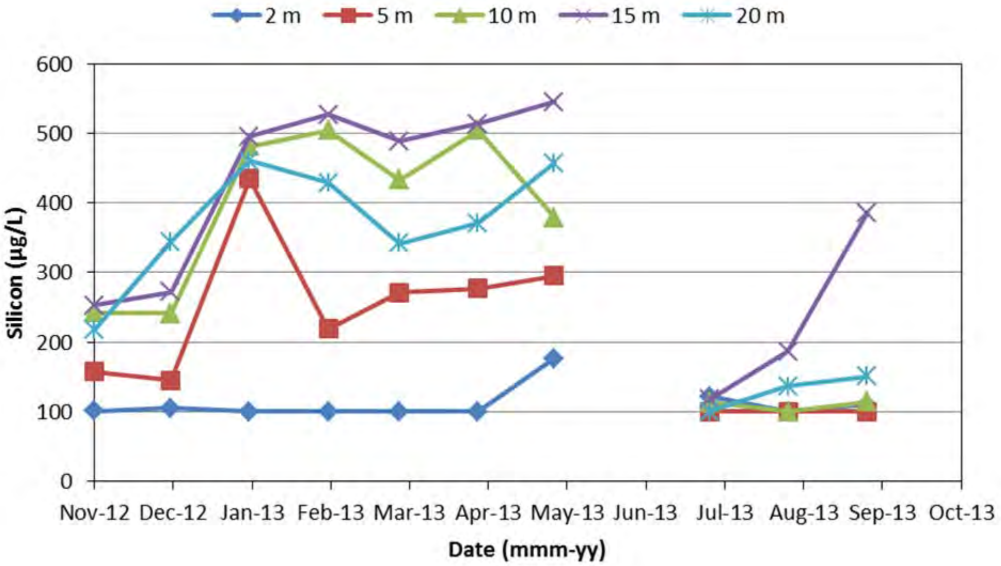
Notes: mg/L = milligrams per litre; m = metre.

Figure E-13 Molybdenum Concentration at the Mixing Zone Boundary, November 2012 to October 2013



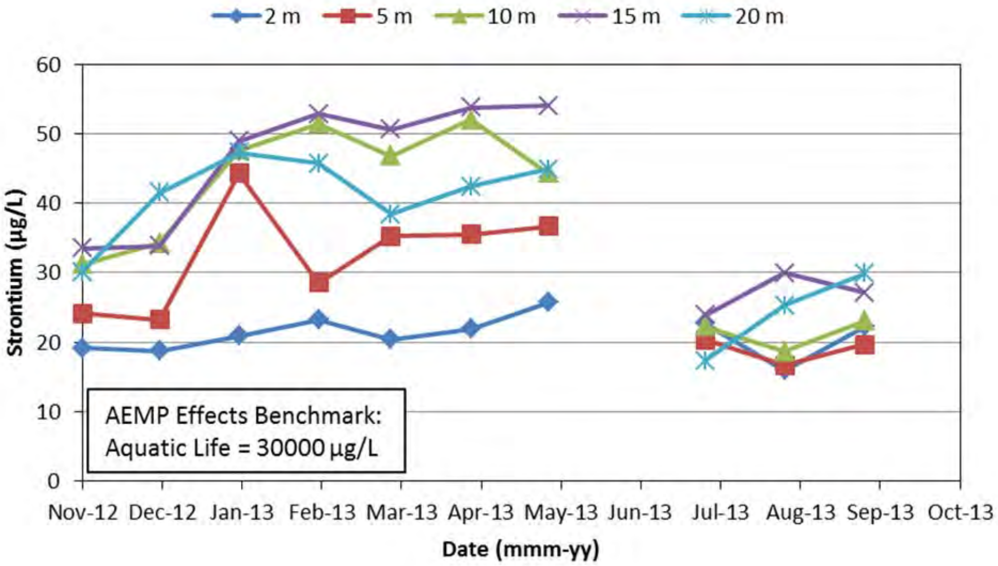
Notes: mg/L = milligrams per litre; m = metre.

Figure E-14 Silicon Concentration at the Mixing Zone Boundary, November 2012 to October 2013



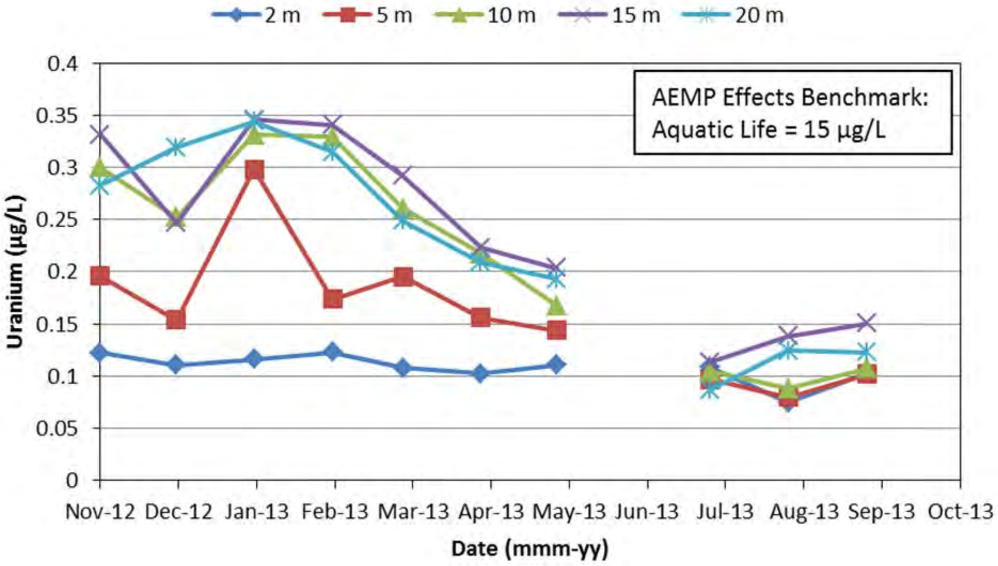
Notes: mg/L = milligrams per litre; m = metre.

Figure E-15 Strontium Concentration at the Mixing Zone Boundary, November 2012 to October 2013



Notes: mg/L = milligrams per litre; m = metre.

Figure E-16 Uranium Concentration at the Mixing Zone Boundary, November 2012 to October 2013



Notes: mg/L = milligrams per litre; m = metre.

APPENDIX F

NORMALITY AND HOMOGENEITY OF VARIANCES TEST RESULTS

Table F-1 Results of Normality and Homogeneity of Variances Tests, 2013 AEMP

Substance of Interest	Ice-cover								Open-water							
	Normality - Kolmogorov-Smirnov Test					Equality of Variances			Normality - Kolmogorov-Smirnov Test					Equality of Variances		
	Error Terms	Observations				Bartlett’s Test	Levene’s Test		Error Terms	Observations				Bartlett’s Test	Levene’s Test	
		NF	FFA	FFB	FF1		Means	Medians		NF	FFA	FFB	FF1		Means	Medians
Specific Conductivity	****	*	ns	ns	*	****	ns	ns	****	**	ns	ns	*	****	**	ns
Log Specific Conductivity	**	*	ns	ns	*	**	*	ns	****	**	ns	ns	*	****	*	ns
Total Dissolved Solids (Calculated)	****	ns	ns	ns	ns	****	ns	*	ns	*	ns	ns	ns	*	*	ns
Log Total Dissolved Solids (Calculated)	ns	ns	*	ns	ns	*	ns	ns	ns	*	ns	ns	ns	ns	ns	ns
Calcium	**	ns	ns	ns	ns	****	*	*	ns	ns	ns	ns	ns	*	**	ns
Log Calcium	ns	ns	ns	ns	ns	*	ns	ns	ns	ns	ns	ns	ns	*	*	ns
Chloride	****	ns	ns	ns	ns	****	*	ns	*	**	ns	ns	**	*	ns	ns
Log Chloride	ns	*	ns	ns	ns	*	ns	ns	ns	**	ns	ns	**	ns	ns	ns
Sodium	****	ns	ns	ns	ns	****	*	*	****	*	ns	ns	ns	****	*	ns
Log Sodium	*	*	ns	ns	ns	****	*	ns	*	ns	ns	ns	ns	****	*	ns
Sulphate	ns	ns	ns	ns	ns	ns	ns	ns	*	*	ns	*	ns	****	*	ns
Log Sulphate	ns	ns	ns	ns	ns	ns	*	ns	*	*	ns	*	ns	**	*	ns
Ammonia (as Nitrogen)	ns	ns	ns	ns	ns	ns	ns	ns	*	ns	*	ns	ns	**	****	*
Log Ammonia (as Nitrogen)	ns	ns	ns	ns	ns	ns	*	ns	ns	ns	*	ns	ns	*	*	ns
Nitrate (as Nitrogen)	***	ns	*	ns	ns	****	*	*	****	**	**	****	ns	n/d	*	ns
Log Nitrate (as Nitrogen)	ns	ns	*	ns	ns	ns	ns	ns	****	ns	**	****	ns	n/d	*	ns
Aluminum	****	ns	ns	ns	*	ns	*	*	**	ns	ns	ns	ns	*	*	ns
Log Aluminum	*	*	ns	ns	ns	**	*	ns	ns	ns	ns	ns	ns	ns	ns	ns
Barium	****	*	ns	ns	ns	****	*	ns	****	*	ns	ns	ns	****	*	ns
Log Barium	*	*	ns	ns	ns	**	*	ns	**	*	ns	ns	ns	**	*	ns
Chromium	****	*	****	**	**	n/d	*	ns	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)
Log Chromium	****	*	****	**	**	n/d	ns	ns	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)
Molybdenum	****	ns	*	ns	ns	****	**	*	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)
Log Molybdenum	ns	ns	ns	ns	ns	*	ns	ns	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)
Silicon	**	*	ns	**	ns	**	ns	ns	****	ns	****	****	**	n/d	*	ns
Log Silicon	ns	*	*	**	ns	ns	ns	ns	****	*	****	****	**	n/d	**	ns
Strontium	****	ns	ns	ns	ns	****	*	ns	****	**	ns	ns	ns	****	*	ns
Log Strontium	****	*	ns	ns	ns	****	*	ns	*	**	ns	ns	ns	**	*	ns
Uranium	**	ns	ns	**	ns	****	****	*	****	*	ns	ns	ns	****	**	ns
Log Uranium	ns	ns	ns	**	ns	ns	ns	ns	**	ns	ns	ns	ns	**	*	ns

Notes: Probability of Type 1 Error: * = <0.1, ** = <0.01, *** <0.001, **** = <0.0001, ns = not significant; LOG = logarithmic data transformation; n/d = not determined due to a lack of variance in reference areas.

a) chromium and molybdenum were not analyzed in open-water because due to sample contamination (Appendix B).

APPENDIX G

2013 WATER QUALITY RAW DATA – AEMP AND SNP (SNP 1645-18 AND SNP 1645-19)

These data are provided as an Excel file in a "Raw Data Folder" on the compact disc, rather than in hard copy form.

APPENDIX III

SEDIMENT REPORT

SEDIMENT QUALITY REPORT
IN SUPPORT OF THE
2013 AEMP ANNUAL REPORT
FOR THE DIAVIK DIAMOND MINE, NT

Submitted to:

Diavik Diamond Mines (2012) Inc.
P.O. Box 2498
5007 – 50th Avenue
Yellowknife, Northwest Territories
X1A 2P8

DISTRIBUTION

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March 2014
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EXECUTIVE SUMMARY

In 2013, Diavik Diamond Mines (2012) Inc. (DDMI) performed the field component of its Aquatic Effects Monitoring Program (AEMP) in Lac de Gras, Northwest Territories, as required by Water Licence W2007L2-0003 and according to the AEMP Study Design Version 3.0 approved by the Wek’èezhìi Land and Water Board (WLWB). This report presents the analysis and interpretation of sediment chemistry data collected during the 2013 field program. Objectives of the sediment monitoring component of the AEMP were to assess effects of the Mine effluent on sediment quality in Lac de Gras and to provide supporting environmental information to help interpret findings from the AEMP benthic invertebrate community survey.

Sediment samples were collected from 34 stations in Lac de Gras. Samples were analyzed for moisture content, soluble pH, particle size (sand, silt, clay), total organic carbon (TOC), total organic matter, total nitrogen, total phosphorus, and total metals.

Thirteen metals (aluminum, bismuth, boron, calcium, chromium, lead, lithium, magnesium, potassium, sodium, tin, titanium, and uranium) had mean concentrations that were statistically greater in the near-field (NF) exposure area than in reference areas. Of these 13 variables, which were identified as Substances of Interest (SOIs), bismuth, lead and uranium had NF area mean concentrations that were greater than their respective normal ranges.

Results of the most recent dike monitoring study reported similar elevations of bismuth, lead and uranium in the vicinity of the A154 and A418 dikes. Sediment results indicated that effluent discharge is likely the primary source of these metals in the exposure area, although other factors, such as dike construction and seepage from the dike may have also contributed to the observed pattern.

Compared to sediment quality guidelines and information in the primary literature, concentrations of bismuth, lead, and uranium encountered in exposure area sediments are considered unlikely to pose a toxicological risk to biota. Benthic invertebrates collected in Lac de Gras do not demonstrate toxicological effects as a result of exposure to SOIs.

Although one SOI (chromium) had concentrations greater than sediment quality guidelines, the concentrations were still considered normal for Lac de Gras. Concentrations of several other nutrients and metals in sediments in Lac de Gras were above sediment quality guidelines. In general, variables that exceeded guidelines did so throughout the lake, and they reflected patterns in TOC content of bottom sediments and had no clear spatial trends related to the Mine.

LIST OF ACRONYMS

AEMP	Aquatic Effects Monitoring Program
ANOVA	analysis of variance
CCME	Canadian Council of Ministers of the Environment
DDMI	Diavik Diamond Mines (2012) Inc.
DL	detection limit
DQO	data quality objective
dw	dry weight
FF	far-field
HSD	honestly significant difference
ISQG	Interim Sediment Quality Guideline
LEL	lowest effect level
Max	maximum
Maxxam	Maxxam Analytics
MF	mid-field
Mine	Diavik Diamond Mine
NF	near-field
OMOEE	Ontario Ministry of the Environment and Energy
P	probability
PCA	principal components analysis
PEL	probable effect level
QA/QC	quality assurance/quality control
QAPP	quality assurance project plan
RPD	relative percent difference
r^s	Spearman’s Rank-order correlation coefficient (*Rho*)
SD	standard deviation
SEL	severe effect level
SNP	Surveillance Network Program
SOI	substance of interest
SOP	Standard Operating Procedure
SQG	sediment quality guideline
TN	total nitrogen
TOC	total organic carbon
TP	total phosphorus
WLWB	Wek’èezhìi Land and Water Board
WOE	weight-of-evidence

LIST OF UNITS

±	plus or minus
%	percent
°C	degrees Celsius
<	less than
>	greater than
cm	centimetre
m	metre
mg/L	milligrams per litre
mg/kg dw	milligrams per kilogram dry weight
mL	millilitre
mm	millimetre
µg/L	micrograms per litre

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1 INTRODUCTION

1.1 BACKGROUND

In 2013, Diavik Diamond Mines (2012) Inc. (DDMI) completed the field component of its Aquatic Effects Monitoring Program (AEMP), as required by Water License W2007L2-0003 (WLWB 2007). This report presents the analysis of sediment chemistry data collected during the 2013 field program, which was carried out by DDMI according to the AEMP Study Design Version 3.0 (Golder 2011a). Details on methodology are provided in Section 2.

The assessment of effects was based on the updated Version 3.3 Study Design (Golder 2014a), which was approved by the Wek'èezhìi Land and Water Board (WLWB) on February 19, 2014 (WLWB 2014). Section 3 provides results of the assessment, while Section 4 provides a discussion of the results. Conclusions, together with recommendations for program changes or enhancements, are provided in Section 5.

1.2 OBJECTIVES

The objective of the sediment survey is to assess the effects of Mine effluent on sediment quality. Sediment data were analyzed to determine whether there are any differences in sediment quality between exposure and reference areas.

The amount of metals in sediments provides information regarding the presence of chemical stressors and may help explain effects observed in the benthic invertebrates. Substrate size is an important factor influencing the benthic community structure, and organic carbon aids in assessing the occurrence and potential bioavailability of metals in sediment. Therefore, a secondary objective of the sediment survey was to provide supporting environmental information to help interpret findings from the AEMP benthic invertebrate community survey.

1.3 SCOPE AND APPROACH

The focus of the assessment for the annual report is a spatial analysis, whereby areas of the lake exposed to effluent are compared to areas of the lake that are not exposed to effluent (i.e., reference areas). Temporal analyses and an assessment of trends over time will be provided in the next three-year summary report (to be submitted by October 15, 2014).

The spatial analysis commenced with a graphical assessment of differences that may exist between concentrations of analytes in exposure and reference areas. Those variables that demonstrated spatial differences were then statistically tested to establish whether the differences seen were related to the Mine (i.e., demonstrated a statistically-significant difference) or whether they may have occurred by chance.

All variables that were significantly elevated in the near-field exposure area relative to the reference areas were referred to as Substances of Interest (SOIs). The intent of defining SOIs is to arrive at a meaningful set of variables that will undergo additional analysis while preventing analysis of variables that have limited potential to be affected.

The magnitude of the effect on SOIs was assessed by comparing analyte concentrations in exposure areas to background values. Background values for Lac de Gras are those that fall within the *normal range*, which is defined as the historical reference area mean plus or minus (±) 2 standard deviations (SD). Values that exceed the normal range are exceeding what would be considered natural levels for Lac de Gras. Although unnatural for this lake, these values do not necessarily represent levels that are harmful.

Elevated metal concentrations do have the potential to impact the benthic invertebrate community; therefore, the importance of effects observed on SOIs was determined by screening SOI concentrations against sediment quality guidelines (CCME 2002; OMOEE 1993). The sediment quality guidelines represent concentrations that could be toxic to less than 5% of the sediment-dwelling fauna. By design, these are conservative guidelines and generally considered intentionally overprotective of the aquatic environment (O’Connor 2004).

2 METHODS

2.1 FIELD SAMPLING

Sediment sampling at AEMP stations in 2013 was carried out during the comprehensive monitoring program, which is undertaken every third year (Golder 2011a). Sample collection for the AEMP sediment quality component took place between August 18 and September 7, 2013, concurrently with benthic invertebrate sampling. Relevant sediment quality data from the Mine's Surveillance Network Program (SNP) were also incorporated into the 2013 AEMP report.

The AEMP evaluated five general areas of Lac de Gras defined by distance from the diffuser. Sampling areas consisted of the near-field (NF) exposure area, the far-field (FF) exposure area (FF2), and three reference areas (FF1, FFA, and FFB) (Table 2-1, Figure 2-1). In addition, three mid-field (MF) areas (MF1, MF2, and MF3) were located along three transects between the NF and FF study areas. The study design incorporated clusters of replicate stations in each area of the lake (Golder 2011a). Five stations were sampled in the NF exposure area and in each of the three FF reference areas. Two stations were located in each of the FF2 and MF2 exposure areas, three stations within the MF1 area, and seven stations within the larger MF3 area. The AEMP stations were located where water depths were approximately 20 m.

Sediment samples were collected with two sampling devices, which allowed for sampling at different sediment depths:

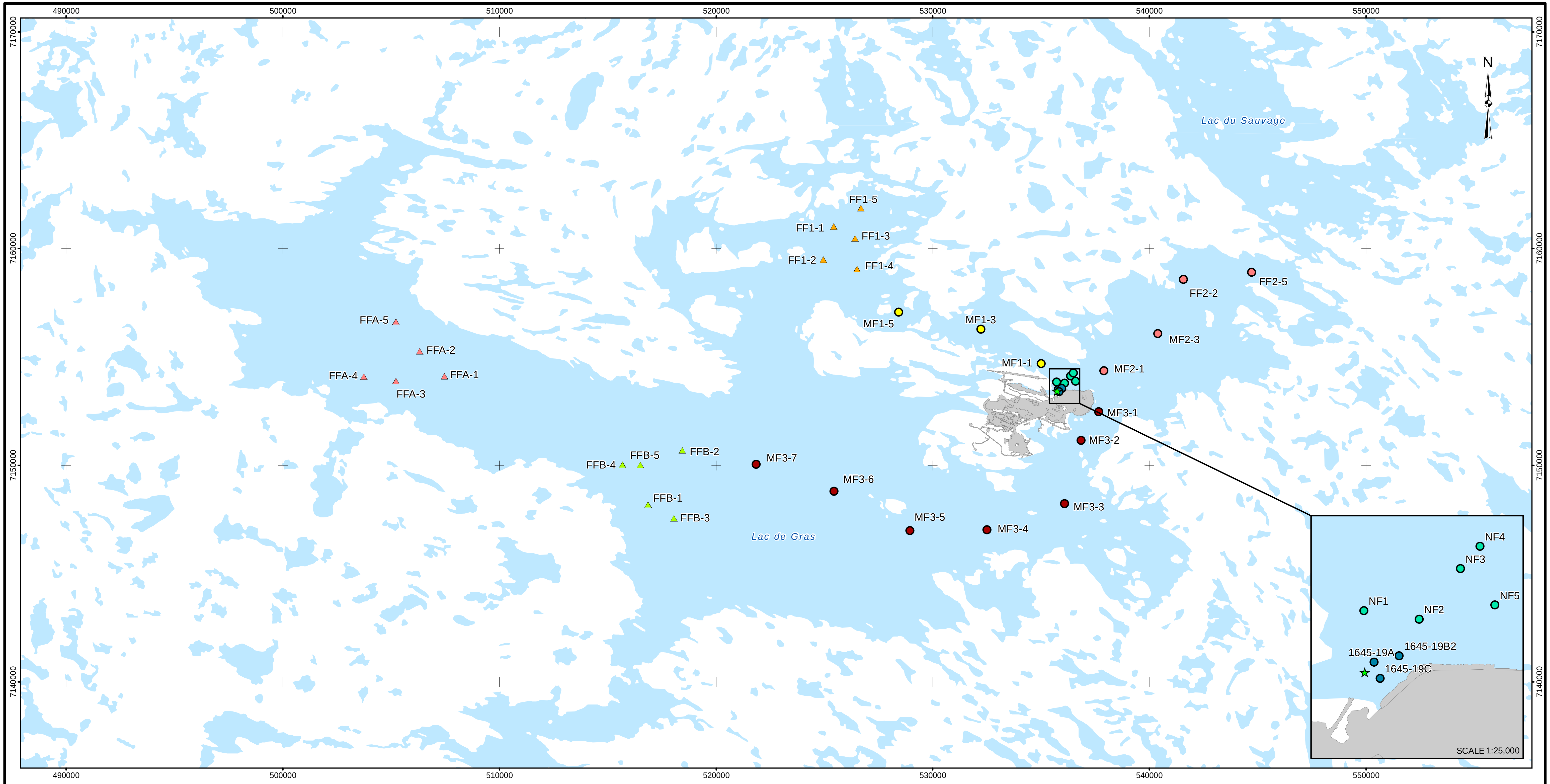
- An Ekman grab (described in DDMI Standard Operating Procedure [SOP]: SOP-ENVR-003-0702 R9) was used at the AEMP stations to collect sediment samples for analyses of particle size, total organic carbon (TOC), and total organic matter. A composite sample, consisting of the top 10 to 15 cm of sediment from at least three Ekman grabs, was collected at each station during benthic invertebrate sampling. The material from each of the three grabs was placed in a pre-cleaned plastic bucket and mixed thoroughly. The composite sample was transferred to two pre-labeled 532-mL WhirlPak™ bags and then refrigerated at 4°C for storage and shipping.

Table 2-1 UTM Coordinates (NAD83 Zone 12) for the 2013 AEMP Sediment Sampling Stations

Area	Station[a]	Easting	Northing	Area	Station	Easting	Northing
Near-field (exposure)	NF1	535740	7153854	Far-field 2 (exposure)	FF2-1	541588	7158561
	NF2	536095	7153784		FF2-2	544724	7158879
	NF3	536369	7154092	Far-field 1 (reference)	FF1-1	525430	7161043
	NF4	536512	7154240		FF1-2	524932	7159476
	NF5	536600	7153864		FF1-3	526407	7160492
Mid-field 1 (exposure)	MF1-1	535008	7154699		FF1-4	526493	7159058
	MF1-2	532280	7156268		FF1-5	526683	7161824
	MF1-5	528432	7157066	Far-field A (reference)	FFA-1	506453	7154021
Mid-field 2 (exposure)	MF2-1	538033	7154371		FFA-2	506315	7155271
	MF2-3	540365	7156045		FFA-3	505207	7153887
Mid-field 3 (exposure)	MF3-1	537645	7152432		FFA-4	503703	7154081
	MF3-2	536816	7151126		FFA-5	505216	7156657
	MF3-3	536094	7148215	Far-field B (reference)	FFB-1	516831	7148207
	MF3-4	532545	7147011		FFB-2	518473	7150712
	MF3-5	528956	7146972		FFB-3	518048	7147557
	MF3-6	525427	7148765		FFB-4	515687	7150036
	MF3-7	521859	7150039		FFB-5	516533	7150032

Note: UTM = Universal Transverse Mercator; AEMP = Aquatic Effects Monitoring Program.

a) Stations are shown in Figure 2-1.



LEGEND

- ★ DIFFUSER

EXPOSURE

- ● NEAR-FIELD
- ● MID-FIELD 3
- ● MID-FIELD 1
- ● FAR-FIELD 2; MID-FIELD 2
- ● SURVEILLANCE NETWORK PROGRAM

REFERENCE

- ▲ FAR-FIELD 1
- ▲ FAR-FIELD A
- ▲ FAR-FIELD B
- ▨ DIAVIK FOOTPRINT
- ▨ WATERBODY

5 0 5

SCALE 1:175,000 KILOMETRES

PROJECT

DIAVIK DIAMOND MINES INC.

TITLE

SEDIMENT QUALITY SAMPLING STATIONS, 2013 AEMP

Golder Associates

PROJECT		13-1328-0001	FILE No.	
DESIGN	LJ	24 Dec. 2013	SCALE AS SHOWN	REV. 0
GIS	JC	20 Mar. 2014	FIGURE: 2-1	
CHECK	TD	20 Mar. 2014		
REVIEW	CF	20 Mar. 2014		

REFERENCE

HYDROGRAPHY DATA OBTAINED FROM CANVEC © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 12 DATUM: NAD 83

I:\2011\11-1328\11-1328-0038\Mapping\MXD\2013AEMP\FINAL\Fig2-1_2013_AEMP_Sediment_Sampling_Locations_20140219_Final.mxd

- A gravity-feed core sampling device (described in DDMI SOP SOP-ENVR-003-0702 R9) was used to collect sediment samples for analyses of metals, total nitrogen, total phosphorus and TOC. The top 1-cm layer from a minimum of three cores was collected at each AEMP station and placed into a pre-labeled 532-mL WhirlPak™ bag. Samples were massaged until the content was uniform in colour and texture (to provide a homogeneous composite sample). Samples were stored at 4°C until they were shipped to the laboratory.

Stations SNP 1645-19a, 1645-19b2, and 1645-19c represent the mixing zone boundary of the North Inlet Water Treatment Plant effluent within Lac de Gras, and are located along the semicircle defined by a 60-m radius from the diffusers. Station 1645-19b2 was established to replace Station 1645-19b after the second diffuser became active in Lac de Gras, and maintains the 60-m radius from the diffusers. Composite sediment samples were collected once at each SNP mixing zone station (top 5 cm from each of three core samples), on August 14 and 15, 2013. Hereafter, data from these SNP mixing zone stations are collectively referred to as Station SNP-19 in this report.

2.2 LABORATORY ANALYSES

Sediment samples were shipped to Maxxam Analytics (Maxxam), Burnaby, British Columbia, for analysis of physical and chemical variables (Table 2-2). Composite samples collected by Ekman grab were analyzed for moisture content, TOC, total organic matter, and particle size distribution (sand: 0.063 to 2 mm; silt: 0.004 to 0.063 mm; and, clay: less than 0.004 mm). Composite sediment core samples were analyzed for moisture content, nutrients (total phosphorus and total nitrogen), TOC, and total metals. Laboratory analytical methods used in these analyses are provided in the Study Design (Golder 2011a). Detection limits (DLs) used by Maxxam in 2013 are provided in Table 2-2.

Table 2-2 Detection Limits for Sediment Chemistry Analyses, 2013 AEMP

Analyte	Units	Detection Limit	Analyte	Units	Detection Limit
Moisture	%	0.3	Total iron	mg/kg dw	100
Soluble (2:1) pH	pH Units	0.01	Total lead	mg/kg dw	0.1
Sand Content	% dw	0.1	Total lithium	mg/kg dw	0.5
Silt Content	% dw	0.1	Total magnesium	mg/kg dw	20
Clay Content	% dw	0.1	Total manganese	mg/kg dw	0.2
Total organic carbon	% dw	0.02-0.11	Total mercury	mg/kg dw	0.05
Total organic matter	% dw	1	Total molybdenum	mg/kg dw	0.1
Total nitrogen	% dw	0.2-0.3	Total nickel	mg/kg dw	0.5
Total aluminum	mg/kg dw	50	Total phosphorus	mg/kg dw	10

Table 2-2 Detection Limits for Sediment Chemistry Analyses, 2013 AEMP

Analyte	Units	Detection Limit	Analyte	Units	Detection Limit
Total antimony	mg/kg dw	0.1	Total potassium	mg/kg dw	20
Total arsenic	mg/kg dw	0.2-0.5	Total selenium	mg/kg dw	0.5
Total barium	mg/kg dw	0.1	Total silver	mg/kg dw	0.05
Total beryllium	mg/kg dw	0.2	Total sodium	mg/kg dw	100
Total bismuth	mg/kg dw	0.1	Total strontium	mg/kg dw	0.1
Total boron	mg/kg dw	1	Total thallium	mg/kg dw	0.05
Total cadmium	mg/kg dw	0.05	Total tin	mg/kg dw	0.1
Total calcium	mg/kg dw	100	Total titanium	mg/kg dw	1
Total chromium	mg/kg dw	0.5	Total uranium	mg/kg dw	0.05
Total cobalt	mg/kg dw	0.1	Total vanadium	mg/kg dw	2
Total copper	mg/kg dw	0.5	Total zinc	mg/kg dw	1

Notes: mg/kg = milligrams per kilogram; dw = dry weight; % = percent.

2.3 DATA ANALYSES

2.3.1 Data Handling

As part of our quality assurance and quality control (QA/QC) procedures, raw sediment quality data were screened for inaccurate entries, missing information, and potential outliers. Outlier values were identified based on a visual assessment of plots prepared for each sediment quality variable. Outliers deemed to be errors were removed from the data set. Additional information about the outlier detection method and handling is provided in Section 2.4 and in Appendix A. Results from duplicate samples were averaged prior to data analysis.

Values below the DL were assumed to follow the distribution of the data that were above the limit of detection. A reasonable assumption regarding the location of the non-detect data along the distribution curve would be at the location demarcating 50% of the area of the curve to the left of the DL; this value was estimated by multiplying the limit of detection by 0.71 (Roger Green, University of Western Ontario, personal communication). Guidance provided by the United States Environmental Protection Agency (USEPA 2000) for replacing non-detectable data were considered; however, most of their recommended approaches, such as trimmed mean, Cohen’s adjustment, or Winsorized mean, were not suitable for this data set. Therefore, the 0.71 × DL approach was applied to all non-detect values.

2.3.2 Spatial Analysis

The first step in the evaluation of effects on sediment chemistry was a graphical comparison of analyte concentrations in the NF exposure area relative to the reference areas (FF1, FFA, FFB). Visual comparisons were made on the full suite of sediment chemistry variables (consisting of nutrients, total metals, TOC, and organic matter) analyzed from the top 1 cm of the core samples. This initial visual comparison was used to identify variables that exhibited greater concentrations in the NF area compared to the reference areas. Variables were then analyzed statistically to determine whether visual differences were significant (see Section 2.3.3).

All variables with significantly greater concentrations in the Near-field exposure area relative to the reference areas were referred to as Substances of Interest (SOIs). All further analyses were restricted to SOIs. Box and whisker plots were created for each SOI to illustrate spatial variation in sediment variable concentrations within Lac de Gras. Box and whisker plots show the minimum value, 25th percentile, median, 75th percentile and maximum values in each area. Sediment chemistry data collected at the mixing zone (SNP-19) were included in these plots to allow comparisons between mixing zone (SNP-19) concentrations and those in the rest of the lake. Since the SNP data were collected from a deeper sediment layer (top 5 cm) than the AEMP samples (top 1 cm), the SNP data will be less representative of recent conditions.

2.3.3 Statistical Analysis

2.3.3.1 Approach

The objective of the statistical comparisons was to compare the NF exposure area to the three reference areas (FFA, FFB, and FF1). Statistical testing was conducted by analysis of variance (ANOVA).

Spatial variation in physical characteristics of sediments that are unrelated to the Mine discharge (i.e., particle size and TOC) have the potential to influence sediment chemistry in Lac de Gras. To address this source of uncertainty, correlation analysis was used to investigate potential inter-relationships between physical variables (e.g., percent fines) and sediment chemistry variables (nutrients, total metals, and TOC).

To evaluate patterns of correlation among sediment chemistry variable concentrations in relation to major environmental factors that may influence their spatial distribution (i.e., physical characteristics of sediment, exposure to Mine effluent), multivariate principal components analysis (PCA) was conducted. This procedure was used to help establish a link between spatial patterns of concentrations and the Mine effluent.

All statistical analyses were conducted with SYSTAT, version 13.0 for Windows (SYSTAT Software Inc. Chicago, IL.).

2.3.3.2 Testing Assumptions for Analysis of Variance

Like other parametric tests, ANOVA assumes that the data fit the normal distribution (since the residuals [or error terms of the variates] are assumed to fit the normal distribution). If a measurement variable is not normally distributed, there is an increased chance of a false positive result (Type I error). Fortunately, an ANOVA is not sensitive to moderate deviations from normality, because when a large number of random samples are taken from a population, the means of those samples are approximately normally distributed even when the population is not normal (Sokal and Rohlf 1995).

The goodness-of-fit of the data to the normal distribution were tested with the Kolmogorov-Smirnov test. Many data sets that are significantly non-normal will still be appropriate for an ANOVA; therefore, issues with non-normality were only addressed with a *P* value less than 0.01. Another important assumption in ANOVA is that group variances are equal. When variances differ markedly, various data transformations will typically remedy the problem. As with normality, the consequences of moderate deviations from the assumption of equal variances do not compromise the overall test of significance. The results of tests to assess the goodness-of-fit of the data to the normal distribution (the Kolmogorov-Smirnov test) and to test the homogeneity of variance of the data (Bartlett’s and Levene’s test) are provided in Appendix B, Table B-1.

2.3.3.3 Analysis of Variance

The means of the four areas (NF, FF1, FFA and FFB) were compared to one another in an overall ANOVA. Within the overall ANOVA, an *a priori* comparison (planned contrast) was then conducted to test the differences of means among specific areas (e.g., NF exposure area versus the FF reference areas). This same approach has been used in the other components of the AEMP.

Multiple comparison techniques (*a posteriori*) are frequently used with environmental assessment data; however, these techniques are not always appropriate for testing hypotheses (Hoke et al. 1990). The preferred approach is to analyze the data using planned, linear orthogonal contrasts by formulating meaningful comparisons among treatments (sampling areas) prior to conducting the study and outlining these in a study design. This preferred approach was used to help answer the question of whether effluent is having an effect in the exposure area of Lac de Gras.

In some cases, there were unforeseen differences observed among reference areas. To assess this natural variability, comparisons were also made among reference areas, thereby quantifying “natural” differences among different areas of Lac de Gras. Such comparisons, which suggested themselves as a result of the completed survey and analysis, are considered unplanned (*a posteriori*) comparisons. The procedure used for these comparisons was *Tukey’s honestly significant difference (HSD) method*, also known as the *T-method*. This test adopts a conservative approach by employing experiment-wise error rates for the Type I error (Day and Quinn 1989). Therefore, the *P* value used for these tests was 0.1, the same *P* value used for the planned contrasts.

2.3.3.4 Correlation Between Physical and Chemical Variables

Several variables did not follow the normal distribution when considered across all sampling stations. Since the data did not meet normality assumptions of parametric correlation analysis (i.e., Pearson’s product-moment correlation) the analysis was conducted with Spearman’s coefficient of rank correlation, r_s. Spearman’s r_s values were compared to critical values at the appropriate n value to determine the level of statistical significance associated with the observed correlation (Zar 1974). Correlations were considered significant at $P < 0.1$.

2.3.3.5 Multivariate Analysis

Variables included in the PCA were total metals, nutrients, TOC, percent fines (silt plus clay particle size fractions), and distance from the Mine effluent diffuser. Log transformation of a subset of variables (i.e., those that did not fit a normal distribution) was used to improve normality of the observations and/or linearity of pairwise relationships. The PCA was run with a correlation matrix and varimax rotation, and it included factors that accounted for greater than 10% of the total variance. A component loading cutoff value of 0.40 was used in selecting variables for inclusion into factors. Tabachnick and Fidell (1996) suggest using a cutoff of at least 0.32, though component loadings of greater than 0.45 represent a better fit.

2.3.4 Normal Range

Magnitude of effects to sediment chemistry were determined by comparing SOI concentrations in exposure areas to the *normal range*, which is defined as the historical pooled reference area mean ± 2 SD (Golder 2014a). Owing to the potential for North Inlet Water Treatment Plant effluent to reach the reference areas of Lac de Gras, normal ranges for most SOIs were calculated using reference area data collected from 2007 to 2010, during the AEMP Version 2.0 (DDMI 2007a). The normal ranges for two variables (lithium and tin), however, were calculated from more recent data. The normal range for lithium was calculated using reference area data collected in 2010 and 2013. This was done because lithium had not been analyzed prior to 2010. The normal range for tin was re-calculated due to differences in the DLs used between the AEMP Version 2.0 and AEMP Version 3.2. Reference area data from 2007 to 2010 were primarily below the DL used during that period (2 mg/kg dw), which was 20 times greater than that used in 2013 (0.1 mg/kg dw). Consequently, the 2013 data were not comparable to the historical data. Therefore, the normal range for tin was calculated using 2013 reference area data only (sediment was not sampled in 2011 or 2012).

2.3.5 Comparison of Sediment Chemistry to Sediment Quality Guidelines

Elevated metal concentrations have the potential to influence the benthic invertebrate community. Therefore, sediment variables were screened against Canadian Council of Ministers of the Environment (CCME) and Ontario Ministry of the Environment and Energy (OMOEE) sediment quality guidelines (SQGs) (CCME 2002; OMOEE 1993). The OMOEE guidelines were used in the assessment because they provide a broader set of guidelines for inorganic contaminants. The CCME and OMOEE SQGs represent concentrations that could be toxic to less than 5% of the sediment-dwelling fauna. By design, these are conservative guidelines and are generally considered intentionally overprotective of the aquatic environment (O’Connor 2004). Thus, if concentrations are below SQGs, then there is likely negligible ecological risk.

Effects of the Mine on the incidence of SQG exceedances in Lac de Gras were evaluated to determine whether the Mine discharge has resulted in a greater number of SQG exceedances in areas of Lac de Gras that are exposed to effluent. This was done by comparing the percentage of exceedances observed in the exposure areas with that of the reference area.

2.4 QUALITY ASSURANCE/QUALITY CONTROL

The Quality Assurance Project Plan (QAPP) outlines the quality assurance (QA) and quality control (QC) procedures employed to support the collection of scientifically-defensible and relevant data addressing the objectives of the AEMP (Golder 2013a). The QAPP represents an expansion of the SNP QA/QC plan. It helps with the creation of a technically-sound and scientifically-defensible report by standardizing field sampling methods, laboratory analysis methods, data entry and storage, data analysis and report preparation activities.

A description of QA/QC practices applied to the sediment quality component of the 2013 AEMP and an evaluation of the QC data are provided in Appendix A. A brief summary of the QA/QC review is provided here. All samples were collected, and all requested analyses were performed within specified holding time limits, except that there was insufficient sample volume to measure total organic matter in three samples. Low-level concentrations of arsenic and manganese were detected in one or more method blanks, but at concentrations well below those reported for the AEMP sediment samples.

Results for laboratory duplicates and laboratory-spiked blanks were within the limits defined by Maxxam. Field duplicate samples were collected at four of the 34 stations (representing 12% of total samples). A total of 12 sediment quality variables (organic matter, total organic carbon, nitrogen, arsenic, bismuth, cadmium, cobalt, iron, manganese, molybdenum, uranium, moisture content) had relative percent differences (RPDs) greater than 20% in one or more duplicate samples. Of these, four variables (arsenic, cobalt, iron and manganese) had RPDs greater than 50%. Each of these four variables had RPDs greater than 20% in two or three of the four duplicate samples collected. In general, the coefficients of variation calculated for these variables (i.e., based on sediment data at all 34 AEMP stations) were about 3 to 5 times greater than those calculated for other sediment variables analyzed in 2013, indicating that their concentrations were highly variable throughout Lac de Gras. This pattern was documented in previous AEMP years, as well as in Dike Monitoring studies that included a sediment monitoring component.

2.5 WEIGHT OF EVIDENCE INPUT

Results of the sediment survey feed into the Weight of Evidence (WOE) assessment, which is described in the Weight of Evidence Report (Golder 2014b). The WOE integrates results from the AEMP components to help understand the underlying cause(s) of biological responses. Whereas the annual report for each AEMP component assesses the effects separately to determine if changes in individual components are meaningful, the WOE approach integrates measures of exposure (e.g., water quality, sediment quality) with measures of biological response (e.g., plankton, benthos, fish) to assess the underlying causes of biological changes. These biological changes can reflect either nutrient enrichment or toxicological impairment effects. Thus, the WOE will provide the strength of evidence for toxicological impairment or nutrient enrichment associated with observed changes. It is not intended to reflect the ecological significance or level of concern associated with a given change.

The WOE assessment is undertaken by applying a rating scheme to determine the degree of change in individual AEMP components. It then proceeds to integrate the individual component ratings into an overall score. The methods as applied to sediment quality are described in Section 2 of the Weight of Evidence Report.

3 RESULTS

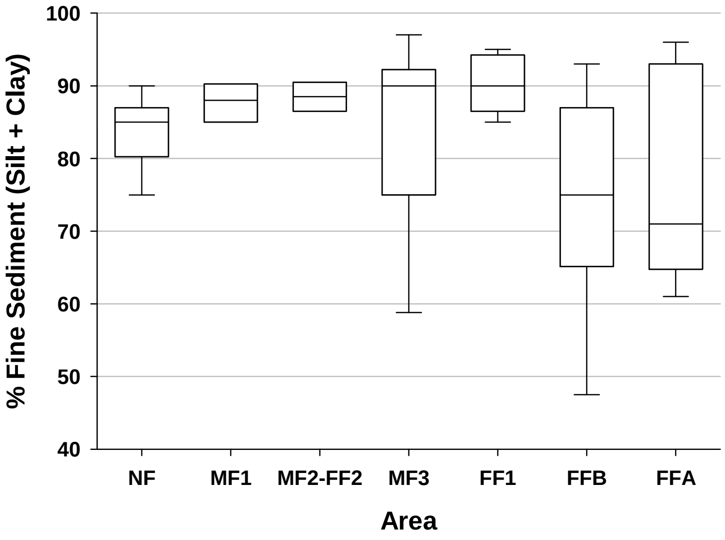
3.1 PHYSICAL CHARACTERISTICS OF SEDIMENTS

The amount of fine sediment (reported as percent fines) ranged from a median of 71% in the FFA area sediments to 90% in both the MF3 and FF1 areas (Figure 3-1). In the exposure areas, stations in the NF area (median of 85% fines) and along the MF1 and MF2-FF2 transects (medians of 88% fines for both transects) were generally similar in terms of percent fines. Although stations along the MF3 transect had greater variability, the median for the MF3 area (90% fines) was similar to other exposure areas. The percent fines varied considerably within and among reference areas, with medians ranging from 71% (FFA) to 90% (FF1). The sediments in the reference areas to the west (i.e., FFA and FFB) were coarser, with percent fine values 10% to 20% lower than other areas of Lac de Gras (Figure 3-1).

The TOC content in the top 1-cm portion of the core samples ranged from a median of 2.4% in the MF2-FF2 transect sediments to 4.4% in FFA area sediments (Figure 3-2). The pattern of variability for TOC was similar to that described for percent fines. Total organic carbon content at stations in the NF, MF1 and MF2-FF2 areas was generally similar, whereas stations in the MF3, FFA and FFB areas had greater variability in TOC content. Overall, the amount of TOC in exposure areas (ranging from 2.4% in the MF2-FF2 area to 3% in the MF3 area) was lower than that observed in reference areas (ranging from 3.5% in the FFB area to 4.4% in the FFA area) (Figure 3-2).

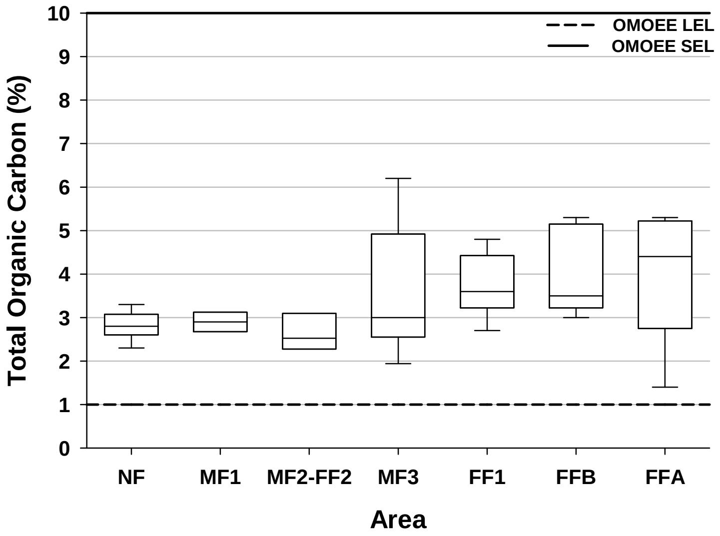
A qualitative evaluation of TOC in sediments relative to distance from the mine effluent diffuser indicates that the Mine is not having an organic carbon enrichment effect in Lac de Gras (Figure 3-2). This result is the same as for previous AEMP sediment quality surveys (Golder 2008a; 2009a; 2010a, 2011b).

Figure 3-1 Percent Fine Sediments (sum of percent silt + percent clay) in Lac de Gras, 2013 AEMP



Note: Box plots and whisker plots represent the minimum, 25th percentile, median, 75th percentile and maximum values in each area.

Figure 3-2 Total Organic Carbon Content of Lac de Gras Sediments, 2013 AEMP



Notes: OMOEE = Ontario Ministry of the Environment and Energy; LEL = Lowest Effect Level; SEL = Severe Effect Level. Box plots and whisker plots represent the minimum, 25th percentile, median, 75th percentile and maximum values in each area. Total organic carbon results are those analyzed from top 1 cm of the core samples.

3.2 SPATIAL VARIATION IN SEDIMENT QUALITY

A total of 35 sediment chemistry variables analyzed from the top 1 cm of core samples were assessed. Mercury was undetected (<0.5 mg/kg dw) in all sediment samples analyzed in 2013 and was not evaluated further. Visual evaluation of sediment chemistry data for the remaining 34 variables indicated that 16 variables had greater concentrations in the NF exposure area compared to reference areas. These variables, consisting of aluminum, bismuth, beryllium, boron, calcium, chromium, lead, lithium, magnesium, potassium, sodium, strontium, tin, titanium, uranium and vanadium, were subjected to statistical comparisons to determine whether their concentrations were significantly greater in the NF area relative to FF reference areas. The results of tests conducted to evaluate normality and homogeneity of variances for these variables are summarized in Appendix B, Table B-1.

Thirteen of the 16 variables tested had NF mean concentrations significantly greater than reference area mean concentrations (Table 3-1; Table 3-2). These consisted of aluminum, bismuth, boron, calcium, chromium, lead, lithium, magnesium, potassium, sodium, tin, titanium and uranium. These variables were retained as SOIs and were the focus of spatial analyses evaluating effects of the Mine discharge on bottom sediment quality in Lac de Gras. The SOIs identified in 2013 were similar to those identified during previous AEMP cycles (Golder 2008a; 2009a; 2010a, 2011b), with two exceptions. Lithium was added to the SOI list in 2013 (lithium was not analyzed prior to 2010), and vanadium, which had previously been a SOI, was removed from the SOI list for 2013.

Spatial variations in the concentrations of SOIs in Lac de Gras sediments are shown in box and whisker plots (Figures 3-3 to 3-15). Sediment metals data collected at the mixing zone boundary (SNP-19) in 2013 are included in these plots. The SNP data for these variables are summarized in Appendix C, Table C-1. Differences in sediment collection methods between the AEMP and SNP sampling should be considered when making comparisons between the two sets of results. The SNP data were collected from a deeper sediment layer (top 5 cm) than the AEMP samples (top 1 cm) and, therefore, may be less representative of recent depositional conditions.

Table 3-1 Mean Concentrations (± Standard Deviation) of Metals in Near-Field and Reference Area (FF1, FFA, FFB) Sediments in Lac de Gras, 2013

Variable	**Unit**	**Normal Range(a) Upper Limit**	**NF**	**FF1**	**FFB**	**FFA**
			_n_ = 5	**_n_ = 5**	**_n_ = 5**	**_n_ = 5**
Aluminum	mg/kg dw	19861	16950 ± 2086	17280 ± 3708	12817 ± 2820	15760 ± 2337
Beryllium	mg/kg dw	n/a	0.55 ± 0.06	0.67 ± 0.12	0.43 ± 0.09	0.58 ± 0.12
Bismuth	mg/kg dw	0.6	**5.1** ± 4	0.5 ± 0.1	0.3 ± 0.1	0.3 ± 0.1
Boron	mg/kg dw	7.8	5.7 ± 0.5	5.6 ± 0.4	2.5 ± 0.4	3 ± 0.7
Calcium	mg/kg dw	2071	2012 ± 86	1714 ± 289	1426 ± 239	1320 ± 408
Chromium	mg/kg dw	67	50.3 ± 8.4	56.3 ± 6.3	32.9 ± 6.6	42 ± 7.6
Lead	mg/kg dw	10.5	**11.2** ± 3.1	7.3 ± 1.1	7.1 ± 1.6	7.4 ± 1.6
Lithium	mg/kg dw	55.8	44 ± 2.6	43.7 ± 2.6	24.5 ± 6	31.7 ± 5.7
Magnesium	mg/kg dw	9150	7035 ± 773	7456 ± 1165	4670 ± 990	6002 ± 1029
Potassium	mg/kg dw	5082	4286 ± 244	4188 ± 576	2357 ± 466	2852 ± 476
Sodium	mg/kg dw	300	218 ± 12	196 ± 27	108 ± 28	132 ± 25
Strontium	mg/kg dw	n/a	18.9 ± 3.4	17.4 ± 4.3	14.6 ± 6.3	13.1 ± 5.08
Tin	mg/kg dw	0.75	0.7 ± 0.1	0.6 ± 0.1	0.3 ± 0.1	0.4 ± 0.1
Titanium	mg/kg dw	1060	665 ± 73	705 ± 81	339 ± 98	453 ± 85
Uranium	mg/kg dw	5.5	**14.76** ± 8.25	4.45 ± 0.54	3.62 ± 0.57	4.18 ± 1.01
Vanadium	mg/kg dw	n/a	41.6 ± 7.3	46.4 ± 4.9	29.3 ± 6.5	35.2 ± 6.7

Notes: SD = standard deviation; *n* = number; mg/kg dw = milligrams per kilogram dry weight; n/a = not applicable.
Bolded values represent mean concentrations that were greater than the normal range.

a) Normal range upper limit is the reference area mean plus 2 standard deviations. Normal ranges were calculated only for variables that were SOIs. Data sources and normal ranges for 2013 sediment SOIs are provided in Appendix D, Table D-1.

Table 3-2 Results of Statistical Comparisons of Mean Sediment Chemistry Concentrations, 2013 AEMP

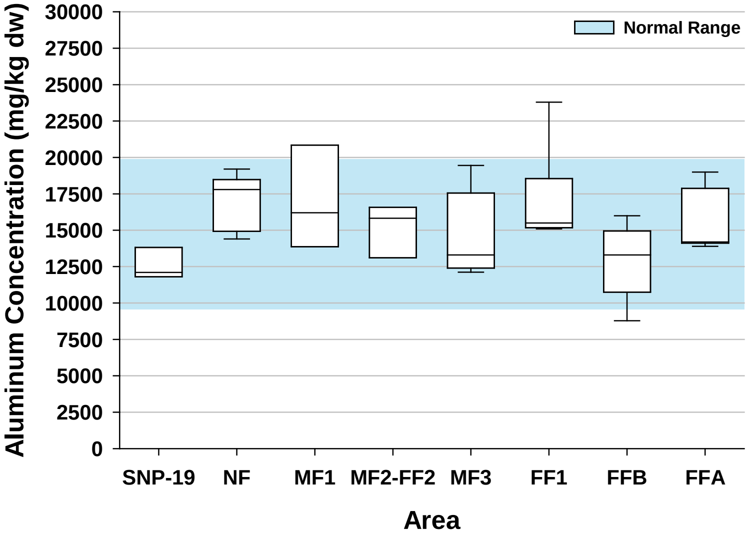
Variable	**Statistical Test[a]**	**Exposure vs. Reference Comparisons[a]**		**Reference vs. Reference Comparison**
		NF vs. FFA+FFB+FF1		**FFA vs. FFB vs. FF1**
		***P*[b]**	**NF>Normal Range[c] Upper Limit**	***P*[b]**
Aluminum	ANOVA	*	No	ns
Bismuth	ANOVA^{log}	****	Yes	ns
Beryllium	ANOVA	ns	n/a	n/a
Boron	ANOVA	****	No	****([FFA=FFB])≠FF1
Calcium	ANOVA	**	No	ns
Chromium	ANOVA	*	No	*([FFA=FFB])≠FF1
Lead	ANOVA	**	Yes	ns
Lithium	ANOVA	****	No	*FFA≠FFB≠FF1
Magnesium	ANOVA	*	No	**[(FFB≠FF1])=FFA
Potassium	ANOVA	****	No	**([FFA=FFB])≠FF1
Sodium	ANOVA	****	No	**([FFA=FFB])≠FF1
Strontium	ANOVA	ns	n/a	n/a
Tin	ANOVA^{log}	****	No	*FFA≠FFB≠FF1
Titanium	ANOVA	**	No	**([FFA=FFB])≠FF1
Uranium	ANOVA^{log}	****	Yes	ns
Vanadium	ANOVA	ns	n/a	n/a

a) ANOVA = Analysis of Variance (log-transformed data indicated by superscript)

b) Probability of Type 1 Error for planned and unplanned comparisons:* = <0.1, ** = <0.01, *** <0.001, **** = <0.0001, ns = not significant, n/a = not applicable since the NF vs reference comparison was non-significant.

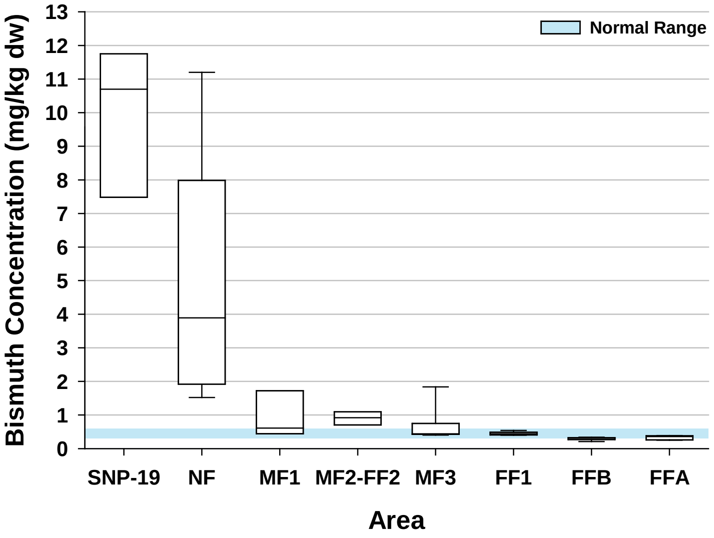
c) Normal range upper limit is the reference area mean plus 2 standard deviations. Data sources and normal ranges for 2013 sediment SOIs are provided in Appendix D, Table D-1.

Figure 3-3 Box and Whisker Plots of Aluminum Concentrations at Mixing Zone (SNP-19) and AEMP Stations, 2013



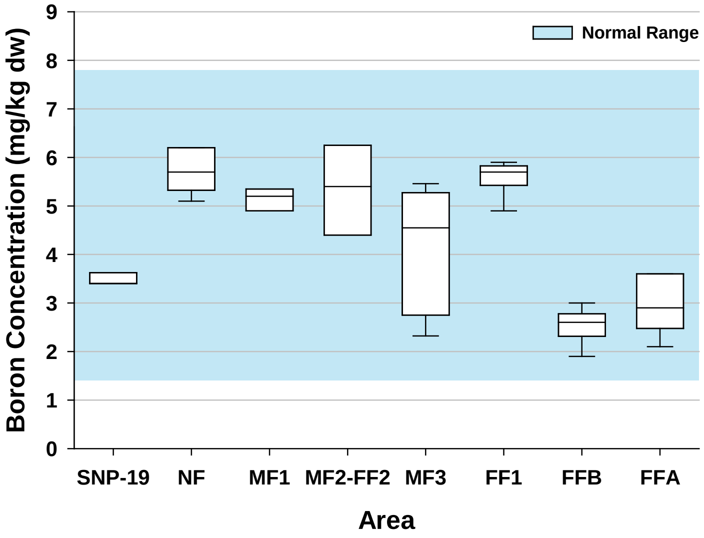
Notes: Box and whisker plots represent the minimum, 25th percentile, median, 75th percentile and maximum values in each area. Blue shaded area represents mean of reference area (FFA, FFB, FF1) data from 2007 to 2010, plus or minus two standard deviations.

Figure 3-4 Box and Whisker Plots of Bismuth Concentrations at Mixing Zone (SNP-19) and AEMP Stations, 2013



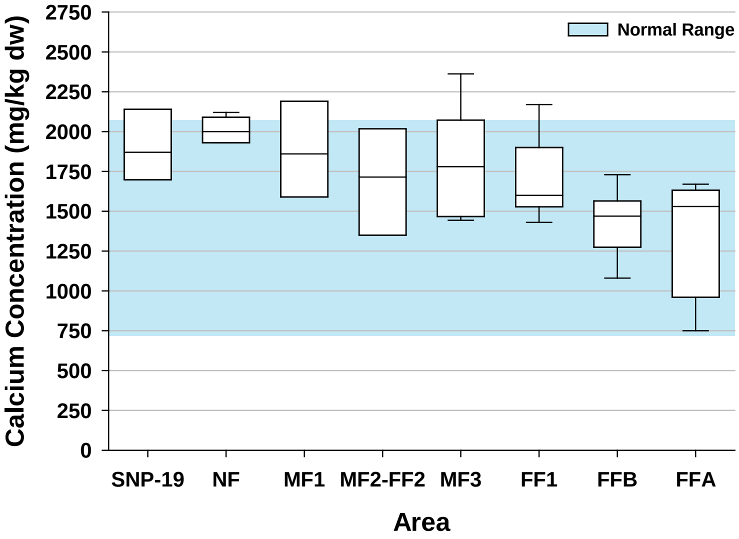
Notes: Box and whisker plots represent the minimum, 25th percentile, median, 75th percentile and maximum values in each area. Blue shaded area represents mean of reference area (FFA, FFB, FF1) data from 2007 to 2010, plus or minus two standard deviations.

Figure 3-5 Box and Whisker Plots of Boron Concentrations at Mixing Zone (SNP-19) and AEMP Stations, 2013



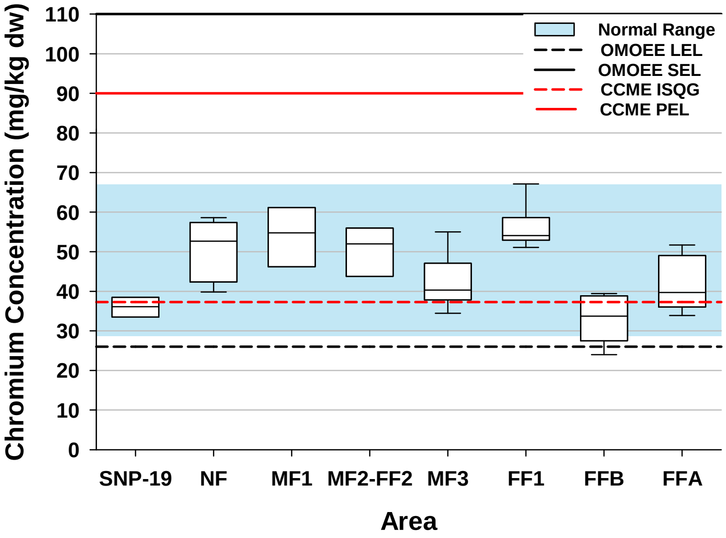
Notes: Box and whisker plots represent the minimum, 25th percentile, median, 75th percentile and maximum values in each area. Blue shaded area represents mean of reference area (FFA, FFB, FF1) data from 2007 to 2010, plus or minus two standard deviations.

Figure 3-6 Box and Whisker Plots of Calcium Concentrations at Mixing Zone (SNP-19) and AEMP Stations, 2013



Notes: Box and whisker plots represent the minimum, 25th percentile, median, 75th percentile and maximum values in each area. Blue shaded area represents mean of reference area (FFA, FFB, FF1) data from 2007 to 2010, plus or minus two standard deviations.

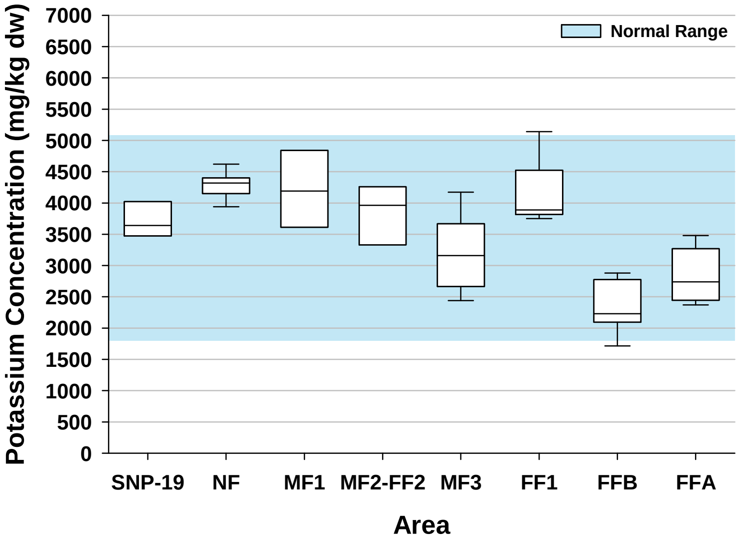
Figure 3-7 Box and Whisker Plots of Chromium Concentrations at Mixing Zone (SNP-19) and AEMP Stations, 2013



Notes: OMOEE = Ontario Ministry of the Environment and Energy; LEL = Lowest Effect Level; SEL = Severe Effect Level; CCME = Canadian Council of Minister of the Environment; ISQG = Interim Sediment Quality Guideline; PEL = Probable Effect Level

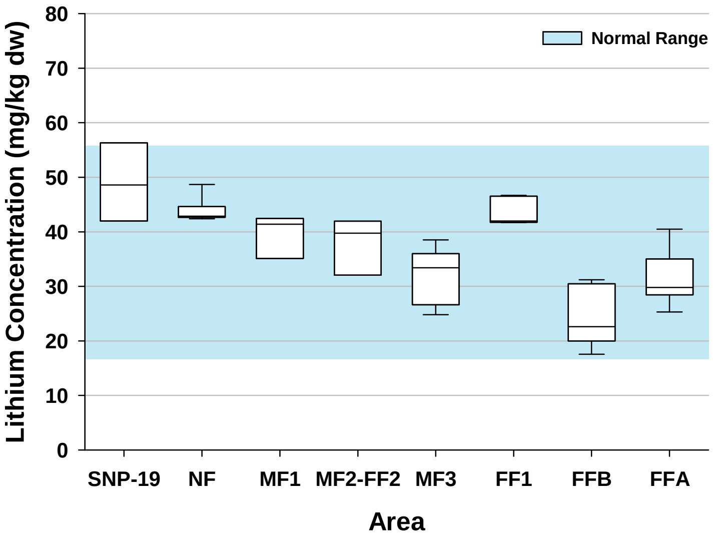
Box and whisker plots represent the minimum, 25th percentile, median, 75th percentile and maximum values in each area. Blue shaded area represents mean of reference area (FFA, FFB, FF1) data from 2007 to 2010, plus or minus two standard deviations.

Figure 3-8 Box and Whisker Plots of Potassium Concentrations at Mixing Zone (SNP-19) and AEMP Stations, 2013



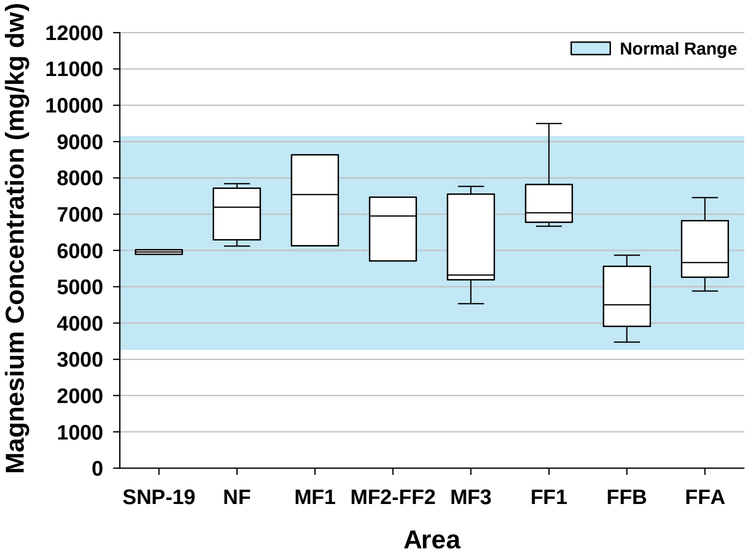
Notes: Box and whisker plots represent the minimum, 25th percentile, median, 75th percentile and maximum values in each area. Blue shaded area represents mean of reference area (FFA, FFB, FF1) data from 2007 to 2010, plus or minus two standard deviations.

Figure 3-9 Box and Whisker Plots of Lithium Concentrations at Mixing Zone (SNP-19) and AEMP Stations, 2013



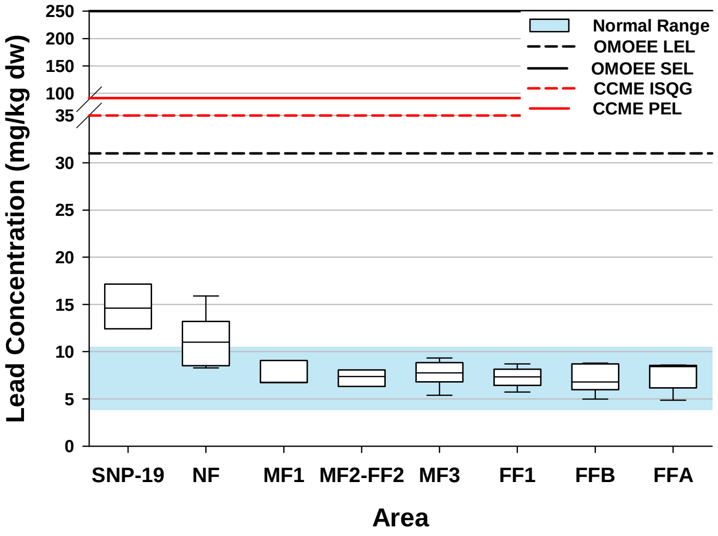
Notes: Box and whisker plots represent the minimum, 25th percentile, median, 75th percentile and maximum values in each area. Blue shaded area represents mean of reference area (FFA, FFB, FF1) data from 2010 and 2013, plus or minus two standard deviations. Lithium was not analyzed from 2007 to 2009.

Figure 3-10 Box and Whisker Plots of Magnesium Concentrations at Mixing Zone (SNP-19) and AEMP Stations, 2013



Notes: Box and whisker plots represent the minimum, 25th percentile, median, 75th percentile and maximum values in each area. Blue shaded area represents mean of reference area (FFA, FFB, FF1) data from 2007 to 2010, plus or minus two standard deviations.

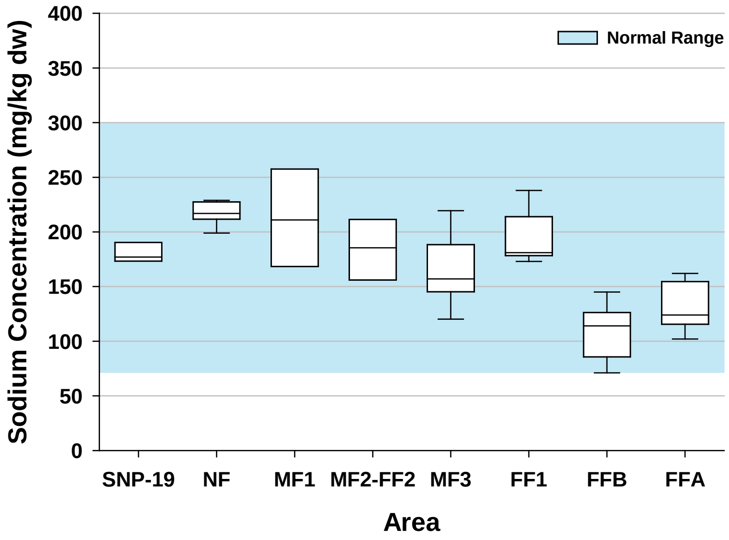
Figure 3-11 Box and Whisker Plots of Lead Concentrations at Mixing Zone (SNP-19) and AEMP Stations, 2013



Notes: OMOEE = Ontario Ministry of the Environment and Energy; LEL = Lowest Effect Level; SEL = Severe Effect Level; CCME = Canadian Council of Minister of the Environment; ISQG = Interim Sediment Quality Guideline; PEL = Probable Effect Level

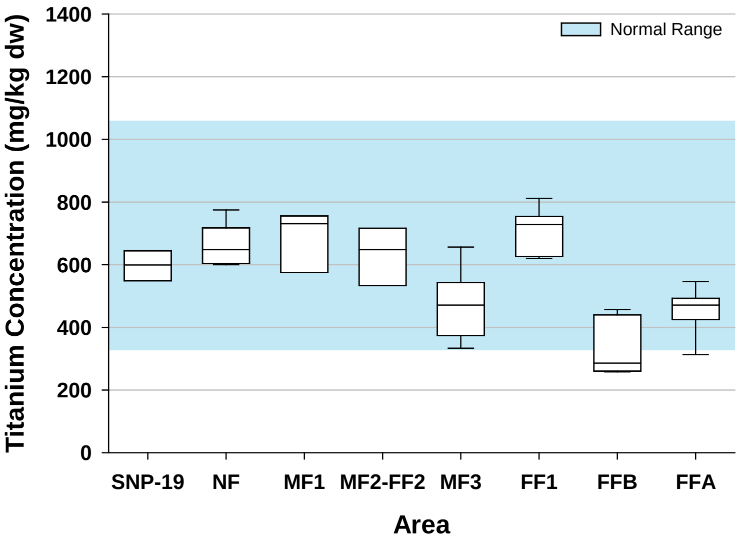
Box and whisker plots represent the minimum, 25th percentile, median, 75th percentile and maximum values in each area. Blue shaded area represents mean of reference area (FFA, FFB, FF1) data from 2007 to 2010, plus or minus two standard deviations.

Figure 3-12 Box and Whisker Plots of Sodium Concentrations at Mixing Zone (SNP-19) and AEMP Stations, 2013



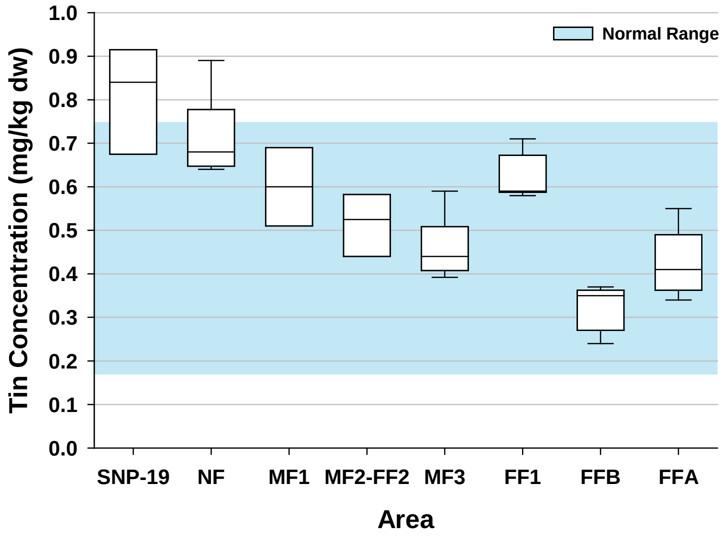
Notes: Box and whisker plots represent the minimum, 25th percentile, median, 75th percentile and maximum values in each area. Blue shaded area represents mean of reference area (FFA, FFB, FF1) data from 2007 to 2010, plus or minus two standard deviations.

Figure 3-13 Box and Whisker Plots of Titanium Concentrations at Mixing Zone (SNP-19) and AEMP Stations, 2013



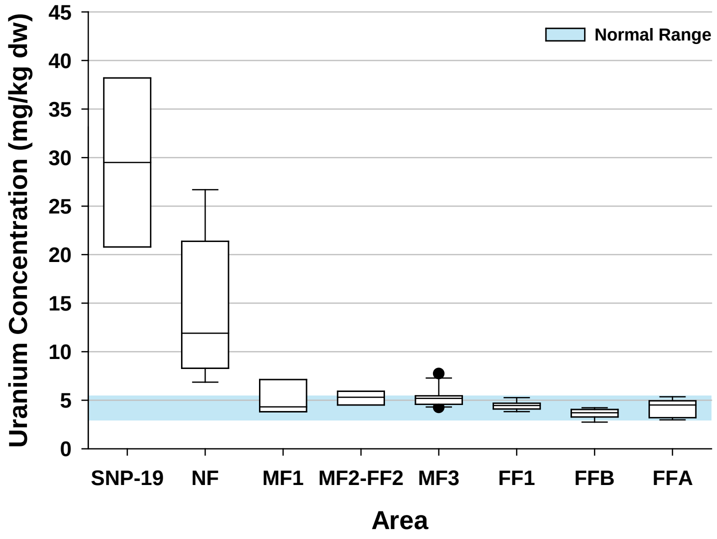
Notes: Box and whisker plots represent the minimum, 25th percentile, median, 75th percentile and maximum values in each area. Blue shaded area represents mean of reference area (FFA, FFB, FF1) data from 2007 to 2010, plus or minus two standard deviations.

Figure 3-14 Box and Whisker Plots of Tin Concentrations at Mixing Zone (SNP-19) and AEMP Stations, 2013



Notes: Box and whisker plots represent the minimum, 25th percentile, median, 75th percentile and maximum values in each area. Blue shaded area represents mean of reference area (FFA, FFB, FF1) data from 2013, plus or minus two standard deviations.

Figure 3-15 Box and Whisker Plots of Uranium Concentrations at Mixing Zone (SNP-19) and AEMP Stations, 2013



Notes: Box and whisker plots represent the minimum, 25th percentile, median, 75th percentile and maximum values in each area. Blue shaded area represents mean of reference area (FFA, FFB, FF1) data from 2007 to 2010, plus or minus two standard deviations.

Normal ranges for the SOIs shown in Figures 3-3 to 3-15 are summarized in Appendix D; Table D-1. Of the 13 SOIs identified in 2013, three variables (bismuth, lead and uranium) had NF area mean concentrations greater than the normal range (Table 3-1). Spatial patterns of decreasing concentrations with distance from the Mine effluent diffuser were evident for each of these variables (Figures 3-4, 3-11, and 3-15). In addition, the concentrations of these variables in reference areas were statistically the same (Table 3-2).

3.3 CORRELATIONS WITH PHYSICAL VARIABLES

Correlation analysis between sediment chemistry variables and percent fine sediment indicated significant positive relationships for 5 of 33 sediment variables (total phosphorus, organic matter, barium, iron, and strontium; Table 3-3). A significant negative correlation was also observed between percent fine sediment and thallium concentration. Although the significant correlations with percent fines indicate that substrate composition is associated with the concentrations of these metals and nutrients, in most cases the relationships were relatively weak. Correlations between percent fines and concentrations of SOIs were not significant (Table 3-3). These results suggest that substrate composition was not an influential factor in the assessment of Mine-related effects.

Spearman Rank correlations between sediment chemistry variables and TOC indicated significant positive relationships with several metals and nutrients (Table 3-3). The strength of the relationships with TOC was generally either moderate (r_s value from 0.3 to 0.5) or strong (r_s value greater than 0.5), indicating that the concentrations of these variables is associated with the amount of TOC in Lac de Gras (Table 3-3). Most of the analytes positively correlated with TOC were not SOIs. Lead was the only SOI with a significant positive correlation with TOC.

Given that TOC content in sediment was greater in the reference areas (Figure 3-2), it was possible that Mine-related effects on non-SOI variables were subdued due to greater TOC-related concentrations in the reference areas. To assess this influence of TOC, analyte concentrations were standardized to TOC content in the sample, and the spatial variation was then assessed. Based on TOC-standardized concentrations, none of these non-SOI analytes demonstrated significant differences among areas. Although TOC was clearly influential on the sediment chemistry, it did not confound the assessment of effects.

Table 3-3 Results of Spearman Rank Correlations between Sediment Quality Variables and Percent Fine Sediment and Total Organic Carbon

Analyte		Sample Size	Correlation Coefficient (r_s)	
			Total Organic Carbon (%)	Fine Sediment (%)
Substances of Interest	Bismuth	37	-0.125	-0.041
	Boron	37	-0.093	0.022
	Aluminum	37	0.165	0.029
	Calcium	37	0.212	0.213
	Chromium	37	-0.037	0.211
	Lead	37	**0.41***	-0.029
	Lithium	37	-0.137	0.033
	Magnesium	37	-0.033	0.138
	Potassium	37	-0.161	0.071
	Sodium	37	-0.156	0.107
	Tin	37	-0.114	0.051
	Titanium	37	**-0.325***	0.062
	Uranium	37	0.104	-0.095
Other Analytes	Total Nitrogen	37	**0.65*****	0.197
	Total Phosphorus	37	**0.327***	**0.394***
	Organic Matter	35	**0.448****	**0.406***
	Antimony	37	**0.76*****	0.231
	Arsenic	37	**0.339***	0.271
	Barium	37	**0.366***	**0.443****
	Beryllium	37	0.126	0.064
	Cadmium	37	**0.412***	-0.149
	Cobalt	37	**0.363***	-0.122
	Copper	37	**0.768*****	-0.004
	Iron	37	**0.531*****	**0.327***
	Manganese	37	0.104	0.107
	Molybdenum	37	0.17	0.181
	Nickel	37	**0.565*****	-0.027
	Selenium	37	**0.734*****	0.175
	Silver	37	**0.684*****	0.252
	Strontium	37	**0.398***	**0.351***
	Thallium	37	0.088	**-0.283***
	Vanadium	37	-0.003	0.201
	Zinc	37	**0.598*****	0.059

Notes: *n* = number of samples; r_s = Spearman Rank-order Correlation Coefficient;% = percent.

Bolded values indicate significant correlations between sediment chemistry variables and percent fines or TOC. Percent fine substrate is calculated as the sum of percent clay and silt in a sediment sample. Critical values were obtained using tables for Spearman Rank Correlation as recommended by Zar (1974).

3.4 MULTIVARIATE ANALYSIS

Principal components analysis was conducted to investigate patterns of co-variance among sediment variable concentrations in Lac de Gras. Of the 34 sediment variables included in the PCA, 29 (or 85%) were associated with the first three principal component (PC) axes generated in the analysis (Table 3-4). Collectively these three PCs accounted for greater than 60% of the total variance in the sediment chemistry dataset. This implies that the concentrations of the majority of sediment variables were inter-correlated and varied among stations in a similar manner in response to major environmental factors. Additional PC axes (i.e., those beyond the first three) generated in the PCA explained less than 10% of the overall variance within the dataset and were, therefore, not included in the PCA interpretation.

Variables with strong positive loadings onto PC-1 were metals that showed a pattern of decreasing concentration with distance from the Mine and most (10 of 12) were SOIs (Table 3-4). The “Distance from Diffuser” variable had a moderate-strength negative loading onto PC-1, indicating that metals with positive loadings on PC-1 generally have decreasing trends with distance from the diffuser. Additional variables that were associated with PC-1 were cobalt and arsenic. Spatial patterns in the concentrations of these metals did not appear to be Mine-related; rather, their concentrations were highly variable throughout Lac de Gras.

With the exception of thallium, sediment variables that were correlated with TOC (Table 3-3) were associated with PC-2 (Table 3-4), and all were non-SOIs. The results of the PCA corroborate the correlation analysis, which demonstrated that the concentrations of these metals were strongly associated with TOC and independent of the distance from Mine effluent.

Metals with loadings onto PC-3 were SOIs and, similar to PC-1, had a moderate strength negative association with distance from the Mine effluent diffuser. Variables with strong positive loadings onto PC-3 (i.e., loading values of greater than 0.85 [bismuth, lead and uranium]) were associated with pronounced Mine-related spatial trends in 2013 (Section 2.3.2; Figures 3-4, 3-11 and 3-15).

Results of the PCA indicated that about 40% of the total variability in the 2013 sediment quality data set was explained collectively by PC-1 and PC-3, which were associated both with distance from the Mine effluent diffuser and with the concentrations of the 13 SOIs in 2013. Principal component 2, which reflected TOC patterns, explained an additional 20% of the overall variability. The remaining unexplained variance may be related to such factors as substrate composition and natural variability.

Table 3-4 Principal Components Loadings for Sediment Quality Data, 2013 AEMP

Variable	**Principal Components Axis**		
	1	**2**	**3**
Chromium	**0.991**	-0.015	-0.002
Vanadium	**0.985**	0.013	-0.022
Magnesium	**0.953**	0.035	0.046
Potassium	**0.924**	-0.188	0.292
Titanium	**0.921**	-0.276	0.103
Sodium	**0.890**	-0.173	0.337
Aluminum	**0.871**	0.343	0.076
Lithium	**0.860**	-0.139	0.360
Beryllium	**0.795**	0.209	-0.056
Tin	**0.755**	-0.120	**0.592**
Boron	**0.714**	-0.387	0.356
Calcium	**0.619**	0.096	**0.479**
Copper	0.024	**0.946**	-0.218
Cadmium$_{\text{Log}}$	-0.059	**0.783**	0.160
Nickel$_{\text{Log}}$	-0.144	**0.762**	-0.084
Selenium	-0.014	**0.761**	-0.054
Zinc	0.321	**0.756**	0.190
Antimony	-0.131	**0.699**	-0.002
Cobalt$_{\text{Log}}$	**-0.453**	**0.667**	-0.279
Distance from Diffuser	***-0.478***	***0.642***	***-0.431***
Silver	0.090	**0.632**	0.209
Thallium$_{\text{Log}}$	0.152	**0.616**	0.065
Total Organic Carbon $_{\text{Log}}$	*-0.092*	***0.582***	*0.040*
Uranium	0.096	-0.115	**0.950**
Bismuth$_{\text{Log}}$	0.323	-0.283	**0.874**
Lead$_{\text{Log}}$	0.252	0.328	**0.868**
Total Nitrogen	-0.116	0.220	-0.058
Manganese$_{\text{Log}}$	-0.066	0.220	-0.001
Barium$_{\text{Log}}$	-0.039	0.340	-0.062
Molybdenum$_{\text{Log}}$	-0.201	0.263	0.182
Strontium	0.346	0.167	0.215
Total Phosphorus$_{\text{Log}}$	-0.119	0.099	0.156
Percent Fine Sediment	*0.368*	*-0.081*	*-0.048*
Arsenic	**-0.442**	0.081	-0.145
Iron$_{\text{Log}}$	-0.329	**0.445**	-0.201

Notes: **bolded** values represent a principal component loading of greater than 0.4. Boxes indicate the major environmental variables considered in the PCA. The subscript “log” indicates that variables were log transformed prior to analysis to improve normality and or linearity of pairwise relationships.

3.5 COMPARISON TO SEDIMENT QUALITY GUIDELINES

Concentrations of SOIs were screened against SQGs to assess the potential for ecological effects. Only two SOIs have CCME or OMOEE guidelines (chromium and lead), and SQG exceedances for these in the exposure and reference areas of Lac de Gras are summarized in Table 3-5. Screening results for all sediment variables at individual stations and sampling areas are presented in Appendix E; Tables E-1 and E-2.

Chromium was the only SOI with concentrations above a SQG, and it never exceeded the OMOEE Severe Effect Level (SEL) or CCME Probable Effect Level (PEL; Table 3-5). The frequency of SQG exceedances was slightly greater in the exposure area; however, chromium concentrations in both the NF and MF exposure areas were within the normal range, indicating that the observed concentrations in the exposure area were within what would be considered natural levels for Lac de Gras.

Table 3-5 Sediment Quality Guideline Exceedances in Exposure and Reference Areas of Lac de Gras, 2013

Substance of Interest[(a)]	Unit	Guideline Value (mg/kg dw)			Percentage of Samples Exceeding Guideline	
					Exposure Areas	Reference Areas
					n = 19	*n* = 15
Chromium	mg/kg dw	OMOEE	LEL	26	**100%**	**93%**
			SEL	110	0%	0%
		CCME	ISQG	37.3	**89%**	**67%**
			PEL	90	0%	0%
Lead	mg/kg dw	OMOEE	LEL	31	0%	0%
			SEL	250	0%	0%
		CCME	ISQG	35	0%	0%
			PEL	91.3	0%	0%

Notes: *n* = number of samples; OMOEE = Ontario Ministry of the Environment and Energy; CCME = Canadian Council of Ministers of the Environment; LEL = lowest effect level; SEL = severe effect level; ISQG = Interim Sediment Quality Guideline; PEL = probable effect level; mg/kg = milligrams per kilogram; dw = dry weight.

Duplicate samples were averaged prior to screening. Exposure areas included the NF, MF1, MF2, MF3 and FF2 areas. Reference areas included the FF1, FFA and FFB areas. Areas that had sediment chemistry guideline exceedances are bolded.

a) The substances of interest shown are those that have sediment quality guidelines.

3.6 WEIGHT OF EVIDENCE

As described in Section 2.5, the results described in the preceding sections also feed into the WOE approach described in the Weight of Evidence Report (Golder 2014b). The results of the WOE approach relevant to sediment quality and related components are described in Section 3.1.2 of the Weight of Evidence Report.

4 DISCUSSION

Effects of the Mine discharge on bottom sediments in the NF area of Lac De Gras were evident for 13 SOIs (aluminum, bismuth, boron, calcium, chromium, lead, lithium, magnesium, potassium, sodium, tin, titanium, and uranium), which had NF area mean concentrations significantly greater than reference area concentrations. Three of the SOIs (bismuth, lead and uranium) had NF area mean concentrations that were greater than their normal ranges. Pronounced spatial patterns related to the diffuser were apparent for each of these three variables.

Patterns identified for bismuth, lead, and uranium in 2013 were consistent with the results of dike monitoring studies (DDMI 2003, DDMI 2005, DDMI 2007b and DDMI 2011), which showed similar elevations in these metals in the vicinity of the diffuser and the A154 and A418 dikes. Results of the most recent dike monitoring study indicated that bismuth, lead, and uranium concentrations were greatest along the two transects closest to the diffusers. Concentrations decreased with distance along each of these transects, indicating effluent-related patterns. This suggests that the Mine discharge is likely a primary source of these metals in the exposure area. Gradual decreases in concentration with distance away from the dikes at transects located away from the diffuser were also apparent, suggesting that the dikes are also a potential source of these metals. Concentrations in sediments at these locations, however, were less than in sediments at stations closest to the diffuser. These results indicate that Mine effluent has caused an increase in sediment concentrations of bismuth, uranium and lead to levels that are beyond the normal range for Lac de Gras, although other factors, such as dike construction and possible seepage from the dike may also have contributed to this finding.

Results of the Effluent and Water Quality Reports have indicated clear mine-related spatial and temporal trends in water for uranium (Golder 2008b, Golder 2009c, Golder 2010c, Golder 2011d, Golder 2012, Golder 2013b and Golder 2014c); however, effluent-related patterns for bismuth and lead have not been identified. In 2013, lead concentrations in water in the NF area were below values used to designate a Mine-related effect. Lead is, however, regularly detected in the effluent. At the standard DL of 0.0002 µg/L, bismuth is typically not detected in the effluent or at AEMP water quality sampling stations. However, bismuth was detected in a few effluent samples in 2010 that were analyzed using an ultra-low DL of 0.00005 µg/L. At this DL, bismuth concentrations were either non-detect or were just above the ultra-low DL.

The following generalizations can be made regarding the likelihood of toxic effects resulting from elevated concentrations of these three SOIs:

- Sediment quality guidelines for bismuth are not known to exist and information regarding bismuth toxicity in aquatic sediments has not been published. Results of the 2010 dike monitoring study (DDMI 2011), and the past four AEMP benthic invertebrate surveys (Golder 2008b, 2009b, 2010b, 2011c) detected no toxicity-related effect on the benthic community in areas of Lac de Gras with bismuth concentrations above the background range.
- In 2013, the mean and maximum concentrations observed for lead in the NF area were 11.2 and 15.9 mg/kg dw, respectively. These concentrations were well below the OMOEE LEL for lead of 31 mg/kg dw and the CCME ISQG of 35 mg/kg dw. Therefore, sediment toxicity to benthic invertebrates in the NF area due to lead is unlikely.
- Sediment quality guidelines for uranium do not exist in Canada, although Sheppard et al. (2005) reported a predicted no-effect level for freshwater benthos of 100 mg/kg dw. Uranium, at an average concentration of 14.6 mg/kg dw (maximum of 26.7 mg/kg dw) in the NF area, and ranging up to 8.07 mg/kg dw at stations in the MF area, is thus unlikely to pose a toxicological risk to aquatic life in exposed areas.
- Only one SOI (chromium) exceeded SQGs; however, concentrations in the exposure area were within the normal range for Lac de Gras, indicating that the observed exceedances fall within the range of concentrations considered natural for Lac de Gras.
- Consistent with the above information, the 2013 AEMP benthic invertebrate survey did not detect toxicity-related effects on the benthic community in areas of Lac de Gras exposed to Mine effluent (Golder 2014d).

Confounding variables such as TOC and percent fine sediment explained much of the variability in the concentrations of metals and nutrients that had no clear Mine-related patterns in 2013. These confounding variables, however, did not impair our ability to detect effects on these chemicals. With the exception of one SOI (chromium), all variables with SQG exceedances reflected patterns in TOC content of bottom sediments and had no clear spatial trends related to the Mine, even if their concentrations were normalized to TOC content.

5 CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

- Thirteen metals (aluminum, bismuth, boron, calcium, chromium, lead, lithium, magnesium, potassium, sodium, tin, titanium, and uranium) had NF area mean concentrations that were statistically greater than reference area mean concentrations. These variables comprised the list of SOIs in 2013.
- Ten SOIs (aluminum, boron, calcium, chromium, lithium, magnesium, potassium, sodium, tin, titanium) had NF area mean concentrations that were within their respective normal ranges, whereas three SOIs (bismuth, uranium, and lead) had NF area concentrations that were greater than their respective normal ranges.
- Results of the most recent dike monitoring study reported similar elevations of bismuth, lead and uranium in the vicinity of the A154 and 418 dikes. Sediment results indicated that effluent discharge is likely the primary source of these metals in the exposure area, although other factors, such as construction of, and seepage from, the dike may also contribute to the observed patterns.
- The toxicological risks associated with elevated bismuth concentrations in exposure area sediments are unknown (no guidelines exist and no sediment toxicity data were found); however, lead and uranium concentrations are unlikely to pose a toxicological risk to biota based on comparisons to sediment quality guidelines and information from the primary literature. Benthic invertebrate data collected to date in Lac de Gras do not suggest a toxic effect.
- Only one SOI (chromium) exceeded SQGs; however, chromium concentrations never exceeded the normal range for Lac de Gras
- Concentrations of several nutrients and metals in sediments throughout Lac de Gras were above SQGs. These variables reflected patterns in TOC content of bottom sediments and had no clear spatial trends related to the Mine.
- Confounding variables (TOC and percent fine sediment) explained much of the variability in the concentrations of metals and nutrients that had no clear mine-related trends in 2013; however, these confounding variables did not interfere with the interpretation of Mine-related effects.

5.2 RECOMMENDATIONS

The following recommendation was made for future aquatic effects monitoring of Lac de Gras:

- The data quality objective (DQO) used to identify notable differences between field duplicate samples (i.e., RPD > 20%) should be adjusted so that it is less stringent than the objectives used by Maxxam to identify unacceptable differences between laboratory duplicate samples (i.e., RPD > 30 to 35%, depending on the analyte). Laboratory duplicate samples consist of two independently analyzed portions of the same sample. They would be expected to have lower variability than field duplicates, which consist of two completely separate grab samples collected from the lake bottom. The adjustment to the DQO for duplicate samples will be included in next version of the QAPP (Version 3.0), which will updated in 2015.

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7 CLOSURE

We trust that the information in this report meets your requirements at this time. If you have any questions relating to the information contained in this document please do not hesitate to contact us.

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APPENDIX A

QUALITY ASSURANCE/QUALITY CONTROL METHODS AND RESULTS

INTRODUCTION

Quality assurance (QA) and quality control (QC) practices determine data integrity and are relevant to all aspects of a study, from sample collection to data analysis and reporting. Quality assurance encompasses management and technical practices designed to generate consistent, high quality data. Quality control is an aspect of QA and includes the techniques used to assess data quality and the corrective actions to be taken when the data quality objectives (DQOs) are not met. This appendix describes QA/QC practices applied to the sediment quality component of the 2013 Aquatic Environment Monitoring Program (AEMP), evaluates the associated QC data, and describes the implications of QC results to the interpretation of AEMP study results.

QUALITY ASSURANCE

Field Staff Training and Operations

Diavik Diamond Mine Inc. (DDMI) field staff are trained to conduct standardized field sampling procedures, data recording, and equipment operations applicable to sediment quality sampling. Field work was completed according to specified instructions and standard operating procedures (SOPs) described in:

- ENVR-003-0702 R9 AEMP Monitoring Program (Open Water)
- ENVR-303-0112 R0 Laboratory Quality Assurance/Quality Control
- ENVR-206-0112 R0 Processing Maxxam Samples and Tracking Documentation

These SOPs contain guidance for field record-keeping and sample tracking, use of sampling equipment, relevant technical procedures, and sample labelling, shipping, and tracking protocols.

Laboratory

Sediment samples were sent for analyses to Maxxam Analytics, Burnaby, British Columbia (Maxxam). Maxxam is a laboratory accredited by the Canadian Association for Laboratory Accreditation for specific analyses defined in their scope of accreditation. Under the accreditation program, performance assessments are conducted annually for laboratory procedures, analytical methods and internal quality control, and laboratories undergo site assessments every two years. Maxxam used state-of-the-art equipment and instrumentation for the preparation and analyses of the Diavik AEMP samples, and they incorporated a quality assurance protocol in all testing procedures.

Office Operations

A data management system was set in place as an organized system of data control, analysis and filing. Relevant elements of this system were:

- pre-field meetings to discuss specific work instructions with field crews;
- field crew check-in with task managers every 24 to 48 hours to report work completed during that period;
- designating two crew members responsible for:
  - collecting all required samples;
  - immediate download and storage of electronic data;
  - completing chain-of-custody and analytical request forms;
  - labelling and documentation; and,
  - processing, where required, and delivering samples to the analytical laboratory in a timely manner;
- cross-checking analysis request forms by the task manager to verify that the correct analysis packages had been requested;
- review of field sheets by the task manager for completeness and accuracy;
- reviewing laboratory data as they are received from the analytical laboratory;
- creating backup files before data analysis; and,
- completing appropriate logic checks for accuracy of calculations.

QUALITY CONTROL

Quality control is a specific aspect of QA that includes techniques used to assess data quality, as well as any remedial measures that are undertaken when DQOs are not met. Quality control techniques employed for the sediment component of the 2013 AEMP consisted of both field- and laboratory-based methods.

The field component of the QC program involved the collection of field duplicate samples, which were used to assess within-station variation and sampling precision. These samples were analyzed for the full suite of sediment chemistry variables assessed in the AEMP.

Maxxam’s internal QC procedures were applied in the chemical analyses of the 2013 AEMP sediment samples. Sediment grab samples and core samples were analyzed in up to three separate batches, depending on the analyte group and submission date. Each batch included specific laboratory QC samples (e.g., method blanks, laboratory duplicates, reference materials or spiked samples). Sediment sample results were evaluated relative to the QC samples that accompanied the corresponding batch of samples.

Results of field- and laboratory-based QC procedures employed in 2013 are discussed in the following subsections. All sediment concentrations are expressed on a dry weight (dw) basis, except for moisture content.

Data Completeness

A total of 38 sediment samples were collected in 2013, representing 34 AEMP stations in Lac de Gras and 4 field duplicate samples. All of the 2013 AEMP sediment samples submitted to Maxxam were analyzed for the target analytes listed in Table 2-2 of the Sediment Quality Report, except that there was insufficient sample volume to measure total organic matter in three samples (MF3-5, FFA-3, and FFB-1-5). Because of limited sample volumes, some repeat analyses that were requested in order to verify original results could not be performed.

Sample Holding Times

All sediment sample analyses were performed within the recommended sample holding times for each target analyte.

Detection Limits

Maxxam used analyte-specific detection limits (DLs) to report results for each analyte (i.e., the same DL was used for all samples for a particular analyte, unless some factor such as matrix interference necessitated the use of a higher DL). The DLs used by Maxxam in 2013 are listed in Table 2-2 of the Sediment Quality Report. These DLs were compared with those originally requested by DDMI to determine the reason(s) for any difference in DLs and whether this difference would affect data quality.

The DLs for four analytes were higher than those requested: moisture content (0.3% versus 0.1%); particle size (0.1% versus 0.01% dw); TOC (0.02 to 0.11% versus 0.02% dw), and vanadium (2 versus 1 mg/kg dw). However, concentrations of these analytes in all AEMP sediment samples were well above the higher DLs and, therefore, data quality was not affected.

One of two batches of samples was initially analyzed for total nitrogen using a DL of 0.5% dw, which resulted in a large percentage of non-detect values being reported for total nitrogen in the AEMP samples. Therefore samples in the affected batch were re-analyzed at a lower DL (0.2% to 0.3%), which returned values that were above the adjusted DL.

Laboratory Method Blanks

A method blank is a clean sample matrix that undergoes processing identical to that carried out on the AEMP samples. Its purpose is to assess method contamination control, to determine whether any laboratory contamination might have entered into the analytical procedure. In 2013, Maxxam included method blanks in each batch for all parameters. The DQO for method blanks is that no target parameters should be detected; however, low-level concentrations of arsenic and manganese were detected in one or more method blanks in 2013: 0.58 (DL = 0.50 and 0.64 (DL = 0.20) mg/kg dw for arsenic; and 0.22 (DL = 0.20) mg/kg dw for manganese. Concentrations of these metals in method blanks, however, were two to five orders of magnitude lower than those measured in the AEMP sediment samples and, therefore, were unlikely to affect data quality.

Laboratory Duplicates

Laboratory duplicates or replicates consist of two or more independently subsampled portions of the same homogenized sample, separately prepared and processed by the identical method. Their purpose is to evaluate the precision of analysis on samples of unknown characteristics. Maxxam analyzed at least one laboratory replicate for each type of analysis performed. Maxxam’s DQO for the original sample and the laboratory replicate was that the RPD was less than or equal to 30% or 35%, depending on the analyte. The RPD was calculated using the following formula:

RPD = (|difference in concentration between duplicate samples| / mean concentration) x 100.

In those cases where concentrations were near the DL, the RPD was not calculated, since the concentrations are not sufficiently high to permit a reliable determination. The RPDs for laboratory duplicate samples analyzed in 2013 met the DQOs set by Maxxam for all sediment analytes.

Laboratory Spiked Blanks

A laboratory spiked blank is a blank matrix sample to which with a known quantity of an analyte of interest, usually from a second source, has been added prior to undergoing sample processing. The results of this analysis provide information on matrix effects and/or any losses incurred during sample preparation. In 2013, Maxxam included at least one laboratory spiked blank in each sample batch. The DQO for analyses of metals in laboratory spiked blank samples was that percent recovery be 75% to 125%; this was met for all analytes.

Field Duplicates

Field duplicate samples consisted of two samples collected from the same location at the same time, using the same sampling and sample handling procedures. They were labelled and preserved individually and submitted separately to Maxxam for identical analyses. Field duplicate samples were used to check within-station variation and the precision of field sampling. Differences between concentrations measured in field duplicate sediment samples were calculated as the RPD for each analyte, using the same formula as for laboratory duplicates. Before calculating the RPD, concentrations below the DL were replaced with values equal to 0.71 times the DL value. The RPD was calculated using the following formula:

RPD = (|difference in concentration between duplicate samples| / mean concentration) x 100.

The RPD value for a given variable was considered notable if:

- it was greater than 20 percent (%); and
- concentrations in one or both samples were greater than or equal to five times the DL.

Since these criteria are more stringent than those used by Maxxam for internal QC of laboratory duplicate samples, duplicate samples with a RPD of 50% were noted as requiring additional follow-up. Laboratory duplicates consist of two independently analyzed portions of the same sample and would therefore be expected to have lower variability than field duplicates, which consist of two completely separate grab samples collected from the lake bottom.

In 2013, field duplicate samples were collected from 4 of 34 AEMP stations (NF3, MF3-6, FF2-2 and FFB-1), representing 12% of the total number of sediment samples submitted to the laboratory (Table A-1). A total of 12 sediment quality variables analyzed in 2013 (organic matter, total organic carbon, nitrogen, arsenic, bismuth, cadmium, cobalt, iron, manganese, molybdenum, uranium, moisture content) exceeded both the 20% RPD and 5 times DL criteria set for duplicate samples in at least one sample (Table A-2). Of the 12 variables that exceeded the DQOs set for duplicate samples, four variables (arsenic, cobalt, iron and manganese) had RPD values that were greater than 50% (Table A-1). Metals that had RPD values greater than 50% exceeded the DQOs set for duplicate samples in at least two of the four duplicate samples. In other words, these four metals showed a tendency for being more variable. Moreover, these four metals generally had highly variable concentrations throughout Lac de Gras in 2013. In general, these four variables had coefficients of variation that were about 3 to 5 times greater than other sediment variables analyzed in 2013. This pattern was documented in previous AEMP years, as well as in Dike Monitoring studies that included a sediment monitoring component.

A repeat analysis of field duplicate samples by Maxxam was requested for analytes with RPDs that exceeded the DQO. The results for these metals were confirmed in one of two batches. Re-analysis of the second batch could not be completed due to insufficient sample volume. A check of the calculations used by Maxxam to generate the final data set for these metals was requested, and the results were confirmed for all variables (i.e., no errors were detected). Overall, the inconsistent concentrations observed in the field duplicate samples do not likely imply a systematic error in sample collection or analysis, but rather, that sediment concentrations are naturally highly variable throughout Lac de Gras, as demonstrated by their relatively high coefficients of variation.

Table A-1 Results for Sediment Quality Field Duplicate Samples, 2013 AEMP

			NF3-4	NF3-5		MF3-6-4	MF3-6-5		FF2-2-4	FF2-2-5		FFB-1-4	FFB-1-5	
Variable	Units	Detection Limit	Duplicate 1	Duplicate 2	RPD (%)	Duplicate 1	Duplicate 2	RPD (%)	Duplicate 1	Duplicate 2	RPD (%)	Duplicate 1	Duplicate 2	RPD (%)
Physical Properties														
Moisture	%	0.3	79.0	79.0	0	91.0	91.0	0	74.0	76.0	3.0	82.0	79.0	4.0
Soluble (2:1) pH	pH Units	0.01	5.72	5.83	1.90	5.68	5.68	0	5.74	5.78	0.7	5.92	6.26	5.6
Total Organic Carbon (Core)	% dw	0.04	2.80	3.20	13.3	6.10	6.90	12.3	2.00	2.70	**28.8**	3.50	3.10	12.1
Total Organic Carbon (Grab)	% dw	0.02-0.11	1.50	1.30	14.3	4.00	4.30	7.2	1.60	1.60	0	1.70	1.70	0
Organic Matter	% dw	1	16	10	**44**	16	18	12	9	13	**36**	8	-	-
Nutrients														
Nitrogen	% dw	0.2-0.3	0.6	0.4	**36.2**	0.6	0.7	**24.2**	0.5	0.6	**31.2**	0.6	0.9	-
Total Phosphorus	mg/kg dw	10	811	941	14.8	818	887	8.1	781	870	10.8	586	500	15.8
Total Metals														
Aluminum	mg/kg dw	50	17500	19000	8	18400	17700	4	17300	15600	10	9380	8190	14
Antimony	mg/kg dw	0.1	0.1	0.1	-	0.2	0.2	-	<0.1	<0.1	-	<0.1	<0.1	-
Arsenic	mg/kg dw	0.2	77.9	24.3	**105**	15.2	13.0	15.6	18.6	20.0	7.3	44.8	18.8	**81.8**
Barium	mg/kg dw	0.1	138.0	116.0	17.3	114.0	108.0	5.4	118.0	111.0	6.1	60.9	48.9	**21.9**
Beryllium	mg/kg dw	0.2	0.6	0.6	-	0.6	0.5	-	0.7	0.6	-	0.3	0.4	-
Bismuth	mg/kg dw	0.1	1.6	2.5	**42.0**	0.4	0.5	-	0.8	0.9	18.2	0.2	0.2	-
Boron	mg/kg dw	1	6	6	6	5	5	-	6	6	3	3	2	-
Cadmium	mg/kg dw	0.05	0.39	0.34	13.9	0.45	0.35	**23.9**	0.33	0.32	1.9	0.26	0.29	10.1
Calcium	mg/kg dw	100	1760	2100	17.6	2390	2440	2.1	2150	2040	5.3	1110	1050	5.6
Chromium	mg/kg dw	0.5	53.6	60.4	11.9	49.7	48.3	2.9	56.3	55.8	0.9	25.7	22.3	14.2
Cobalt	mg/kg dw	0.1	42.1	24.3	**53.6**	16.4	14.6	11.6	25.1	23.3	7.4	90.7	58.9	**42.5**
Copper	mg/kg dw	0.5	45.7	47.1	3.0	65.4	64.7	1.1	39.4	39.7	0.8	41.8	34.5	19.1
Iron	mg/kg dw	100	43900	27400	**46**	24900	23500	6	25400	23700	7	34700	20700	**51**
Lead	mg/kg dw	0.1	7.9	9.3	17.2	9.6	9.3	3.2	7.0	7.3	4.2	5.5	4.5	19.1
Lithium	mg/kg dw	0.5	39.9	45.6	13.3	37.5	35.0	6.9	41.6	42.9	3.1	18.5	16.6	10.8
Magnesium	mg/kg dw	20	7210	8140	12	7850	7470	5	7640	7290	5	3700	3240	13
Manganese	mg/kg dw	0.2	18600	2750	**148**	290	264	9	12400	2570	**131**	4030	2720	**39**
Mercury	mg/kg dw	0.05	<0.05	<0.05	-	<0.05	<0.05	-	<0.05	<0.05	-	<0.05	<0.05	-
Molybdenum	mg/kg dw	0.1	6.4	5.7	12.7	2.6	2.4	7.6	4.0	3.7	6.2	2.3	1.7	**29.7**
Nickel	mg/kg dw	0.5	59.4	52.6	12.1	56.1	53.1	5.5	47.8	45.0	6.0	57.1	49.4	14.5
Phosphorus	mg/kg dw	10	811	941	15	818	887	8	781	870	11	586	500	16
Potassium	mg/kg dw	20	4150	4510	8	3490	3370	3	4400	4060	8	1790	1640	9
Selenium	mg/kg dw	0.5	<0.5	<0.5	-	0.6	<0.5	-	<0.5	<0.5	-	<0.5	<0.5	-
Silver	mg/kg dw	0.05	0.10	0.11	-	0.12	0.12	-	0.08	0.08	-	0.09	0.06	-
Sodium	mg/kg dw	100	201	231	-	196	199	-	221	211	-	110	<100	-
Strontium	mg/kg dw	0.1	20.7	20.5	1.0	17.3	18.3	5.6	16.6	16.1	3.1	9.0	7.7	14.9
Thallium	mg/kg dw	0.05	0.32	0.34	4.6	0.27	0.22	20	0.30	0.28	7.6	0.22	0.20	-
Tin	mg/kg dw	0.1	0.6	0.7	15.6	0.5	0.5	9.9	0.6	0.6	5.1	0.3	0.2	-
Titanium	mg/kg dw	1	670	727	8	487	444	9	766	747	3	265	251	5
Uranium	mg/kg dw	0.05	7.52	10.00	**28.3**	5.08	5.30	4.2	5.27	5.53	4.8	2.94	2.56	13.8
Vanadium	mg/kg dw	2	47	50	6	40	38	4	48	47	2	22	19	15
Zinc	mg/kg dw	1	91	91	0	91	81	12	78	77	1	48	41	16
Particle Size														

Table A-1 Results for Sediment Quality Field Duplicate Samples, 2013 AEMP

Variable	Units	Detection Limit	NF3-4 Duplicate 1	NF3-5 Duplicate 2	RPD (%)	MF3-6-4 Duplicate 1	MF3-6-5 Duplicate 2	RPD (%)	FF2-2-4 Duplicate 1	FF2-2-5 Duplicate 2	RPD (%)	FFB-1-4 Duplicate 1	FFB-1-5 Duplicate 2	RPD (%)
Moisture, Percent	%	1	-	-	-	82	82	0	-	-	-	67	86	**25**
Sand Content	%	0.1	14.0	-	-	2.4	2.4	0	10.0	12.0	18.2	51.0	54.0	5.7
Silt Content	%	0.1	59.0	-	-	41.0	37.0	10.3	62.0	62.0	0.0	34.0	32.0	6.1
Clay Content	%	0.1	27.0	-	-	57.0	61.0	6.8	28.0	26.0	7.4	15.0	14.0	6.9

Notes: “-“ = not measured or relative percent difference (RPD) was not calculated because the concentration in one or both the duplicate samples was below the detection limit or less than five times the corresponding detection limit;

mg/kg dw = milligrams per kilogram dry weight; % = percent; < = less than.

Bolded values indicate duplicate samples that had RPD values greater than 20%, and concentrations in one or both samples that were greater than or equal to five times the DL.

Values that are **<u>bolded and underlined</u>** indicate an RPD greater than 50% and concentrations in one or both samples that were greater than or equal to five times the DL.

OUTLIER IDENTIFICATION

A number of analytical results were identified as visual outliers in 2013 and were not used in data analyses or the development of the figures presented in the 2013 Sediment Quality Report. Values that were removed from the AEMP data set are shown in Table A-2. The QA protocols did not identify issues with the results described below; however, the concentrations of specific variables were determined to be anomalous after review of data plots and comparisons. Generally, outlier values were at least 4 to 5 times greater than those observed at nearby stations. In 2013, a total of four data points were identified as outliers using graphical methods and were removed from the sediment data set. These included values for iron, total phosphorus, barium and molybdenum.

Table A-2 List of Sediment Data Outliers, 2013 AEMP

Station	Sampling Date	Analyte	Result	Unit
MF3-7	25-Aug-13	Iron	196,000	mg/kg dw
FF2-5	26-Aug-13	Total Phosphorus	2,360	mg/kg dw
FFB-2	1-Sep-13	Barium	583	mg/kg dw
FFB-2	1-Sep-13	Molybdenum	16.5	mg/kg dw

Note: mg/kg dw = milligrams per kilogram dry weight.

APPENDIX B

TESTS FOR NORMALITY AND EQUALITY OF VARIANCE

Table B-1 Results of the Kolmogorov-Smirnov Test for Normality, and Bartlett's and Levene's Tests for Homogeneity of Variance

Analyte	Normality - Kolmogorov-Smirnov Test					Equality of Variances		
	Error Terms	Observations				Bartlett's Test	Levene's Test	
		NF	FFA	FFB	FF1		Means	Medians
Aluminum	*	ns	*	ns	*	ns	ns	ns
Log Aluminum	*	ns	*	ns	*	ns	ns	ns
Bismuth	****	ns	ns	ns	ns	****	****	**
Log Bismuth	*	ns	ns	ns	ns	**	ns	**
Beryllium						ns	ns	ns
Log Beryllium						ns	ns	ns
Boron	ns	ns	ns	ns	ns	ns	ns	ns
Log Boron	ns	ns	ns	ns	*	ns	ns	ns
Calcium	ns	ns	ns	ns	ns	*	ns	ns
Log Calcium	ns	ns	ns	ns	ns	*	ns	ns
Chromium	ns	ns	ns	ns	*	ns	ns	ns
Log Chromium	ns	ns	ns	ns	ns	ns	ns	ns
Lead	ns	ns	*	ns	ns	ns	ns	ns
Log Lead	ns	ns	*	ns	ns	ns	ns	ns
Lithium	*	**	ns	ns	*	ns	ns	ns
Log Lithium	*	**	ns	ns	*	*	ns	*
Magnesium	ns	ns	ns	ns	*	ns	ns	ns
Log Magnesium	ns	ns	ns	ns	*	ns	ns	ns
Potassium	ns	ns	ns	ns	ns	ns	ns	ns
Log Potassium	ns	ns	ns	ns	ns	ns	ns	ns
Sodium	ns	ns	ns	ns	ns	ns	ns	ns
Log Sodium	ns	ns	ns	ns	ns	*	ns	ns
Strontium	ns	ns	ns	ns	ns	ns	ns	ns
Log Strontium	ns	ns	ns	ns	ns	ns	ns	ns
Tin	*	ns	ns	ns	*	ns	ns	ns
Log Tin	ns	ns	ns	ns	*	ns	ns	ns
Titanium	ns	ns	*	ns	ns	ns	ns	ns
Log Titanium	ns	ns	*	ns	ns	ns	ns	ns
Uranium	****	ns	ns	ns	ns	****	ns	*
Log Uranium	ns	ns	ns	ns	ns	*	ns	*
Vanadium	**	ns	ns	ns	ns	ns	ns	ns
Log Vanadium	**	ns	ns	ns	ns	ns	ns	ns

Notes = Probability of Type 1 Error: * = <0.1, ** = <0.01, *** <0.001, **** = <0.0001, ns = not significant; LOG = logarithmic data transformation.

APPENDIX C

2013 SURVEILLANCE NETWORK PROGRAM (SNP) DATA FOR SELECTED SEDIMENT QUALITY VARIABLES

Table C-1 Total Metals Results at the Mixing Zone, 2013 SNP

Analyte	**Unit**	**Detection Limit (DL)**	**1645-19A**	**1645-19C**	**1645-19B2**
Aluminum	mg/kg dw	100	14400	11700	12100
Antimony	mg/kg dw	0.10	<0.10	0.10	<0.10
Arsenic	mg/kg dw	0.50	26.9	283	33.1
Barium	mg/kg dw	0.10	72.5	179	100
Beryllium	mg/kg dw	0.40	0.44	<0.40	0.45
Bismuth	mg/kg dw	0.10	12.1	6.41	10.7
Boron	mg/kg dw	1.0	3.4	3.7	3.4
Cadmium	mg/kg dw	0.050	0.315	0.350	0.260
Calcium	mg/kg dw	100	2230	1640	1870
Chromium	mg/kg dw	1.0	32.6	39.3	36.1
Cobalt	mg/kg dw	0.30	13.7	72.3	31.9
Copper	mg/kg dw	0.50	26.5	35.8	32.0
Iron	mg/kg dw	100	21400	70100	30300
Lead	mg/kg dw	0.10	18.0	11.7	14.6
Lithium	mg/kg dw	5.0	58.9	39.8	48.6
Magnesium	mg/kg dw	100	5960	6040	5870
Manganese	mg/kg dw	0.20	2500	16900	6750
Mercury	mg/kg dw	0.050	<0.050	<0.050	<0.050
Molybdenum	mg/kg dw	0.10	5.77	7.78	4.43
Nickel	mg/kg dw	0.80	36.2	59.7	39.2
Phosphorus	mg/kg dw	10	1340	1170	888
Potassium	mg/kg dw	100	4150	3420	3640
Selenium	mg/kg dw	0.50	<0.50	<0.50	<0.50
Silver	mg/kg dw	0.050	0.145	0.122	0.130
Sodium	mg/kg dw	100	195	177	172
Strontium	mg/kg dw	0.10	11.5	18.7	15.5
Thallium	mg/kg dw	0.050	0.348	0.390	0.344
Tin	mg/kg dw	0.10	0.94	0.62	0.84
Titanium	mg/kg dw	1.0	660	532	599
Uranium	mg/kg dw	0.050	41.1	17.9	29.5
Vanadium	mg/kg dw	2.0	23.1	33.1	28.7
Zinc	mg/kg dw	1.0	80.9	75.9	76.8

Notes: dw = dry weight; mg/kg = milligrams per kilogram.

APPENDIX D

NORMAL RANGES FOR SUBSTANCES OF INTEREST

Table D-1 Normal Ranges for Substances of Interest, 2013 AEMP

Substance of Interest	Unit	Normal Range (mean ± 2 standard deviation)		Source	Comment
		Lower Limit	Upper Limit		
Aluminum	mg/kg dw	9528.5	19861.1	2007 to 2010 AEMP	—
Bismuth	mg/kg dw	0.3	0.6	2007 to 2010 AEMP	—
Boron	mg/kg dw	1.4	7.8	2007 to 2010 AEMP	—
Calcium	mg/kg dw	715.3	2071.3	2007 to 2010 AEMP	—
Chromium	mg/kg dw	28.6	67	2007 to 2010 AEMP	—
Lead	mg/kg dw	3.8	10.5	2007 to 2010 AEMP	—
Lithium	mg/kg dw	16.6	55.8	2010 and 2013 AEMP	Variable not analyzed from 2007 to 2009
Magnesium	mg/kg dw	3260.5	9150.3	2007 to 2010 AEMP	—
Potassium	mg/kg dw	1795.3	5082.3	2007 to 2010 AEMP	—
Sodium	mg/kg dw	71	300	2007 to 2010 AEMP	—
Tin	mg/kg dw	0.17	0.75	2013 AEMP	DL used in 2007-2010 is greater than 2013 data
Titanium	mg/kg dw	326.1	1060.3	2007 to 2010 AEMP	—
Uranium	mg/kg dw	2.9	5.5	2007 to 2010 AEMP	—

Notes: SOI = substance of interest; DL = detection limit; mg/kg = milligrams per kilogram; dw = dry weight; % = percent; <= less than; cm = centimeter ± = plus or minus

APPENDIX E

2013 AEMP SEDIMENT QUALITY DATA AND COMPARISONS TO SEDIMENT QUALITY GUIDELINES

Table E-1 Sediment Chemistry Results, 2013 AEMP

Variable			OMOEE(a)		CCME(d)																					
		Detection Limit	Guidelines		Guidelines																					
	Units		LEL(b)	SEL(c)	ISQG(e)	PEL(f)	NF1	NF2	NF3-4 (DUP)	NF3-5 (DUP)	NF4	NF5	MF1-1	MF1-3	MF1-5	MF2-1	MF2-3	MF3-1	MF3-2	MF3-3	MF3-4	MF3-5	MF3-6-4 (DUP)	MF3-6-5 (DUP)	MF3-7	FF2-2-4 (DUP)	FF2-2-5 (DUP)
Physical Properties																										
Moisture	%	0.3	-	-	-	-	80	74	79	79	81	78	79	80	80	69	79	78	77	76	71	89	91	91	87	74	76
Soluble (2:1) pH	pH Units	0.01	-	-	-	-	5.84	5.75	5.72	5.83	5.66	5.97	5.8	5.65	5.61	5.95	5.76	5.74	5.78	5.79	6.03	5.83	5.68	5.68	5.62	5.74	5.78
Total Organic Carbon(g)	%	0.04	1	10	-	-	*3.3*	*2.3*	*2.8*	*3.2*	*2.7*	*2.8*	*3.2*	*2.6*	*2.9*	*2.2*	*3.5*	*2.5*	*3*	*2.7*	*1.8*	*4.7*	*6.1*	*6.9*	*5*	*2*	*2.7*
Total Organic Carbon(h)	%	0.03-0.09	1	10	-	-	*2.3*	*2*	*1.5*	*1.3*	*1.8*	*1.6*	*1.7*	*2*	*1.6*	*1.3*	*1.8*	*1.7*	*2*	*1.1*	*1.1*	*2.7*	*4*	*4.3*	*3.1*	*1.6*	*1.6*
Organic Matter(i)	%	1	-	-	-	-	15.3	7.1	16	10.2	10.4	14.9	18.8	16	13.8	10	11	15.2	9.4	12.9	4.6	-	15.9	17.9	19.9	8.7	12.5
Nutrients																										
Total Nitrogen(j)	%	0.2-0.3	0.055	0.48	-	-	*0.71*	*0.61*	*0.62*	*0.43*	*0.51*	*0.53*	*0.65*	*0.4*	*0.43*	*0.25*	*0.54*	*0.55*	*0.63*	*0.58*	*0.72*	*0.67*	*0.58*	*0.74*	*0.76*	*0.46*	*0.63*
Total Phosphorus	mg/kg dw	10	600	2000	-	-	*870*	*964*	*811*	*941*	*647*	*914*	*890*	*635*	*903*	*730*	*896*	*601*	*967*	*751*	*779*	*833*	*818*	*887*	*1050*	*781*	*870*
Total Metals																										
Aluminum	mg/kg dw	50	-	-	-	-	17800	15100	17500	19000	19200	14400	22400	16200	13100	15200	16700	12200	19800	12100	16100	13000	18400	17700	13300	17300	15600
Antimony	mg/kg dw	0.1	-	-	-	-	0.13	<0.1	0.11	0.12	0.12	<0.1	0.11	<0.1	0.12	<0.1	<0.1	0.11	0.1	<0.1	<0.1	0.19	0.18	0.16	0.28	<0.1	<0.1
Arsenic	mg/kg dw	0.2	6	33	5.9	17	***32.9***	***20.7***	***77.9***	***24.3***	***38.2***	***19.8***	***31.6***	***17.5***	***381***	***28.7***	***22.5***	***32.8***	***24.7***	***19.1***	***22.1***	***209***	*15.2*	*13*	***789***	***18.6***	***20***
Barium	mg/kg dw	0.1	-	-	-	-	115	94.3	138	116	236	92.1	138	115	246	101	111	158	98	80.9	80.4	296	114	108	232	118	111
Beryllium	mg/kg dw	0.2	-	-	-	-	0.62	0.47	0.61	0.56	0.51	0.59	0.65	0.72	0.56	0.52	0.73	0.56	0.64	0.53	0.51	0.5	0.55	0.51	0.61	0.66	0.64
Bismuth	mg/kg dw	0.1	-	-	-	-	3.89	11.2	1.62	2.48	1.52	6.91	2.09	0.61	0.39	1.01	1.18	2.1	0.79	0.63	0.4	0.44	0.43	0.45	0.42	0.75	0.9
Boron	mg/kg dw	1	-	-	-	-	6.2	5.4	6	6.4	5.1	5.7	5.4	5.2	4.8	4.6	6.2	5.5	5.2	5.3	2.4	2.3	4.5	4.6	3.8	6.2	6.4
Cadmium	mg/kg dw	0.05	0.6	10	0.6	3.5	0.434	0.393	0.385	0.335	0.556	0.393	*0.641*	0.263	0.326	0.289	0.355	*0.784*	0.26	0.249	0.224	*0.651*	0.449	0.353	*0.607*	0.325	0.319
Calcium	mg/kg dw	100	-	-	-	-	2080	2120	1760	2100	1930	2000	2300	1860	1500	1490	1940	1440	2150	1490	1460	1840	2390	2440	1780	2150	2040
Chromium	mg/kg dw	0.5	26	110	37.3	90	*52.7*	*39.8*	*53.6*	*60.4*	*58.6*	*43.2*	*63.3*	*54.8*	*43.3*	*48.1*	*55.9*	*40*	*56.5*	*40.3*	*41.3*	*33.8*	*49.7*	*48.3*	*37.1*	*56.3*	*55.8*
Cobalt	mg/kg dw	0.1	50	-	-	-	26.5	19.3	42.1	24.3	*59.8*	18.9	31.9	22.7	*77.1*	32	24.2	25.6	31.5	28.3	29.6	*149*	16.4	14.6	*211*	25.1	23.3
Copper	mg/kg dw	0.5	16	110	35.7	197	*43.2*	*33.2*	*45.7*	*47.1*	*45.7*	*35.1*	*52.3*	*38.9*	*39.3*	*38.3*	*45.4*	*38.1*	*55*	*44*	*44.3*	*62.3*	*65.4*	*64.7*	*66.3*	*39.4*	*39.7*
Iron	mg/kg dw	100	20000	40000	-	-	*29100*	*22700*	*43900*	*27400*	*39000*	*21200*	*35500*	*24200*	*70900*	*23600*	*25300*	*21100*	*29600*	19100	*25800*	*81400*	*24900*	*23500*	*196000*	*25400*	*23700*
Lead	mg/kg dw	0.1	31	250	35	91.3	11	15.9	7.86	9.34	8.28	12.3	9.81	6.72	6.77	7.62	8.52	8.55	7.69	6.52	5.12	7.77	9.58	9.28	8.94	6.97	7.27
Lithium	mg/kg dw	0.5	-	-	-	-	42.9	48.7	39.9	45.6	42.4	43.3	42.8	41.4	33	37.8	41.7	35.2	39.1	32.1	33.4	24.8	37.5	35	24.8	41.6	42.9
Magnesium	mg/kg dw	20	-	-	-	-	7190	6120	7210	8140	7840	6350	9000	7540	5660	6440	7470	5220	7790	5180	7240	5320	7850	7470	4370	7640	7290
Manganese	mg/kg dw	0.2	460	1100	-	-	*13100*	*9100*	*18600*	*2750*	*44600*	*2420*	*13400*	*21100*	*25100*	*5090*	*3100*	*35900*	*2640*	*2100*	*2140*	*51100*	290	264	*26700*	*12400*	*2570*
Mercury	mg/kg dw	0.05	0.2	2	0.17	0.49	<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	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Molybdenum	mg/kg dw	0.1	-	-	-	-	5.74	5.3	6.43	5.66	6.26	6.08	5.82	3.13	9.12	4.7	3.62	5.84	2.52	2.14	2.36	7.32	2.59	2.4	12.3	3.98	3.74
Nickel	mg/kg dw	0.5	16	75	-	-	*52.1*	*42.9*	*59.4*	*52.6*	*84.6*	*50.7*	*96.1*	*42.1*	*78.9*	*42.7*	*50.5*	*114*	*48.8*	*37.5*	*38.1*	*189*	*56.1*	*53.1*	*128*	*47.8*	*45*
Potassium	mg/kg dw	20	-	-	-	-	4320	4220	4150	4510	4620	3940	5060	4190	3420	3700	4290	3750	4280	2980	3160	2560	3490	3370	2410	4400	4060
Selenium	mg/kg dw	0.5	-	-	-	-	0.51	<0.5	<0.5	<0.5	<0.5	<0.5	0.69	<0.5	<0.5	<0.5	<0.5	<0.5	0.51	<0.5	<0.5	0.63	0.56	<0.5	0.95	<0.5	<0.5
Silver	mg/kg dw	0.05	0.5	-	-	-	0.118	0.123	0.102	0.109	0.112	0.096	0.121	0.088	0.106	0.072	0.111	0.078	0.117	0.09	<0.05	0.102	0.124	0.122	0.181	0.084	0.08
Sodium	mg/kg dw	100	-	-	-	-	227	199	201	231	229	217	273	211	154	164	207	157	225	146	161	145	196	199	114	221	211
Strontium	mg/kg dw	0.1	-	-	-	-	19.6	14.6	20.7	20.5	23.1	16.5	21.9	17.3	18.7	12	16.6	18	14.6	11.4	8.85	24	17.3	18.3	20.8	16.6	16.1
Thallium	mg/kg dw	0.05	-	-	-	-	0.325	0.353	0.32	0.335	0.49	0.347	0.46	0.318	0.366	0.437	0.296	0.493	0.313	0.253	0.246	0.367	0.269	0.22	0.36	0.301	0.279
Tin	mg/kg dw	0.1	-	-	-	-	0.68	0.89	0.59	0.69	0.65	0.74	0.72	0.6	0.48	0.47	0.58	0.51	0.61	0.44	0.43	0.39	0.53	0.48	0.4	0.57	0.6
Titanium	mg/kg dw	1	-	-	-	-	648	605	670	727	775	600	764	731	523	619	677	542	685	471	543	331	487	444	343	766	747
Uranium	mg/kg dw	0.05	-	-	-	-	11.9	26.7	7.52	10	6.86	19.6	8.07	4.31	3.65	5.21	6.44	7.73	5.51	4.8	4.25	4.5	5.08	5.3	5.24	5.27	5.53
Vanadium	mg/kg dw	2	-	-	-	-	43.2	32.9	46.8	49.6	48.6	35.1	51.8	45.8	36.9	40.8	47.1	34.2	47.6	34.3	34.9	29.6	40	38.3	31.4	47.6	46.8
Zinc	mg/kg dw	1	120	820	123	315	86.5	94	90.8	90.6	93.1	84	103	74.7	78.3	68.4	82.2	88	84	64.2	63.3	112	90.8	80.8	95.6	77.9	77.4
Particle Size																										
Sand Content	%	0.1	-	-	-	-	26	18	14	-	9.7	15	12	16	8.8	12	15	44	25	9.9	9.9	22	2.4	2.4	7.2	10	12
Silt Content	%	0.1	-	-	-	-	53	58	59	-	51	62	60	56	59	61	62	42	57	62	58	48	41	37	57	62	62
Clay Content	%	0.1	-	-	-	-	22	24	27	-	39	23	28	28	32	27	23	13	17	28	32	30	57	61	36	28	26

Table E-1 Sediment Chemistry Results, 2013 AEMP (Continued)

			OMOEE$^{(a)}$ Guidelines		CCME$^{(d)}$ Guidelines																						
Variable	**Units**	**Detection Limit**	**LEL$^{(b)}$**	**SEL$^{(c)}$**	**ISQG$^{(e)}$**	**PEL$^{(f)}$**	**FF2-5**	**FF1-1**	**FF1-2**	**FF1-3**	**FF1-4**	**FF1-5**	**FFA-1**	**FFA-2**	**FFA-3**	**FFA-4**	**FFA-5**	**FFB-1-4 (DUP)**	**FFB-1-5 (DUP)**	**FFB-2**	**FFB-3**	**FFB-4**	**FFB-5**	**LDS1**	**LDS2**	**LDS3**
Physical Properties																										
Moisture	%	0.3	-	-	-	-	79	83	81	85	77	84	63	86	89	81	88	82	79	87	89	81	82	78	71	77
Soluble (2:1) pH	pH Units	0.01	-	-	-	-	5.56	5.7	5.84	5.78	5.79	5.65	5.87	6.01	5.77	5.94	5.8	5.92	6.26	5.68	5.62	5.96	5.78	5.87	5.63	5.59
Total Organic Carbon(g)	%	0.04	1	10	-	-	*2.7*	*3.6*	*4.3*	*3.4*	*2.7*	*4.8*	*1.4*	*4.4*	*5.3*	*3.2*	*5.2*	*3.5*	*3.1*	*5.1*	*5.3*	*3*	*3.5*	*2.4*	*1.4*	*2.4*
Total Organic Carbon(h)	%	0.03-0.09	1	10	-	-	*1.4*	*2.1*	*2.3*	*2.1*	0.66	*2.1*	0.88	*1.3*	*4.2*	*2.8*	*4.5*	*1.7*	*1.7*	*4.3*	*3.7*	*1.6*	*2.1*	*1.2*	0.92	*1.1*
Organic Matter(i)	%	1	-	-	-	-	25.7	16.2	21.9	13.4	19.6	24.8	5.5	13.3	-	9.5	13.2	8	-	17.1	14.6	10.5	9.9	8.6	15	11.4
Nutrients																										
Total Nitrogen(j)	%	0.2-0.3	0.055	0.48	-	-	*0.76*	*0.78*	*1*	*0.9*	*0.49*	*0.75*	*0.29*	*0.56*	*0.62*	*0.55*	*0.73*	*0.56*	*0.94*	*1*	*0.7*	*0.48*	*0.85*	*0.54*	*0.42*	*0.52*
Total Phosphorus	mg/kg dw	10	600	2000	-	-	*2360*	*909*	587	*610*	*619*	*905*	571	*866*	*862*	*772*	*1200*	586	500	*1110*	*1340*	*682*	*913*	*893*	*653*	*2860*
Total Metals																										
Aluminum	mg/kg dw	50	-	-	-	-	11000	23800	15500	16800	15100	15200	14200	19000	14200	13900	17500	9380	8190	11400	13300	14600	16000	19200	12000	14100
Antimony	mg/kg dw	0.1	-	-	-	-	<0.1	0.18	0.12	0.1	<0.1	0.1	<0.1	0.16	0.22	<0.1	0.18	<0.1	<0.1	0.17	0.21	<0.1	0.13	<0.1	<0.1	<0.1
Arsenic	mg/kg dw	0.2	6	33	5.9	17	***396***	***102***	***32.6***	***24.1***	***18.5***	***50.7***	***28.2***	***50.3***	***68.6***	***205***	***224***	***44.8***	***18.8***	***960***	***308***	***25.7***	***73.6***	***24.9***	***55.1***	***441***
Barium	mg/kg dw	0.1	-	-	-	-	144	206	117	196	102	101	78.2	139	276	79.8	172	60.9	48.9	583	202	82.6	183	123	124	160
Beryllium	mg/kg dw	0.2	-	-	-	-	0.44	0.73	0.53	0.76	0.79	0.55	0.51	0.71	0.48	0.48	0.72	0.32	0.36	0.33	0.48	0.46	0.54	0.63	0.57	0.48
Bismuth	mg/kg dw	0.1	-	-	-	-	0.58	0.54	0.41	0.44	0.4	0.47	0.26	0.38	0.36	0.25	0.39	0.22	0.2	0.31	0.34	0.29	0.32	0.38	0.26	0.28
Boron	mg/kg dw	1	-	-	-	-	4.2	4.9	5.8	5.7	5.6	5.9	2.1	3.6	2.9	2.6	3.6	2.8	2.1	1.9	2.7	3	2.6	5.2	4.8	4.2
Cadmium	mg/kg dw	0.05	0.6	10	0.6	3.5	0.247	*0.612*	0.364	0.589	0.277	0.167	0.559	*1.35*	*0.756*	0.257	*0.604*	0.262	0.29	0.593	*0.697*	0.38	*1.45*	0.448	0.286	0.219
Calcium	mg/kg dw	100	-	-	-	-	1210	2170	1430	1810	1600	1560	750	1530	1670	1030	1620	1110	1050	1730	1510	1340	1470	2280	1420	1390
Chromium	mg/kg dw	0.5	26	110	37.3	90	*39.4*	*67.1*	*51.1*	*55.8*	*53.5*	*54.1*	*33.9*	*51.7*	*36.7*	*39.7*	*48.1*	25.7	22.3	*28.7*	*33.7*	*38.7*	*39.4*	*64.8*	*46.2*	*45.9*
Cobalt	mg/kg dw	0.1	50	-	-	-	36.3	*72.5*	31.2	40.9	24	13.6	*99.3*	*183*	*285*	*60.9*	*98*	*90.7*	*58.9*	*154*	*161*	*62.1*	*208*	23.1	19.3	38.7
Copper	mg/kg dw	0.5	16	110	35.7	197	*28.1*	*65.8*	*52.4*	*53.7*	*46.7*	*48.2*	*47.9*	*83.6*	*72.7*	*49*	*79.7*	*41.8*	*34.5*	*55.1*	*70*	*53.1*	*72.3*	*35.8*	*24.3*	*25.4*
Iron	mg/kg dw	100	20000	40000	-	-	*61900*	*68500*	*27000*	*26500*	*22600*	*33200*	*22900*	*41100*	*80400*	*64500*	*93200*	*34700*	*20700*	*158000*	*135000*	*26200*	*48600*	*31600*	*25300*	*101000*
Lead	mg/kg dw	0.1	31	250	35	91.3	5.53	8.7	6.68	7.35	5.73	7.96	6.61	8.43	8.6	4.87	8.54	5.46	4.51	6.8	8.79	6.32	8.67	6.92	4.88	4.94
Lithium	mg/kg dw	0.5	-	-	-	-	26.3	46.7	41.7	46.5	41.8	42	29.8	40.5	25.3	29.5	33.2	18.5	16.6	20.8	22.6	31.2	30.2	42.9	34.3	30.4
Magnesium	mg/kg dw	20	-	-	-	-	4980	9500	6670	7260	6810	7040	5390	7460	4880	5670	6610	3700	3240	4050	4500	5870	5460	10600	6230	5970
Manganese	mg/kg dw	0.2	460	1100	-	-	*18200*	*29600*	*15700*	*34800*	*2160*	*526*	*7560*	*13000*	*50400*	*3020*	*9630*	*4030*	*2720*	*59500*	*14500*	*3830*	*31200*	*10400*	*20100*	*13000*
Mercury	mg/kg dw	0.05	0.2	2	0.17	0.49	<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	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Molybdenum	mg/kg dw	0.1	-	-	-	-	8.56	7.57	4.52	3.79	1.8	2.97	8.08	5.75	5.46	4.04	6.1	2.28	1.69	16.5	6.86	3.18	6.77	2.5	3.44	9.15
Nickel	mg/kg dw	0.5	16	75	-	-	*39.2*	*131*	*74*	*115*	*50.9*	*43.8*	*72.1*	*185*	*158*	*48.5*	*119*	*57.1*	*49.4*	*175*	*131*	*66.6*	*211*	*77.9*	*51.1*	*44*
Potassium	mg/kg dw	20	-	-	-	-	2960	5140	3750	4320	3890	3840	2370	3480	2470	2740	3200	1790	1640	2220	2230	2880	2740	4700	3450	3480
Selenium	mg/kg dw	0.5	-	-	-	-	<0.5	0.84	0.55	0.55	<0.5	<0.5	<0.5	0.65	0.98	<0.5	0.79	<0.5	<0.5	0.7	0.64	<0.5	0.63	<0.5	<0.5	<0.5
Silver	mg/kg dw	0.05	0.5	-	-	-	0.097	0.156	0.093	0.084	0.096	0.106	0.063	0.157	0.136	0.086	0.165	0.094	0.058	0.147	0.156	0.074	0.088	0.087	0.062	0.089
Sodium	mg/kg dw	100	-	-	-	-	148	238	173	206	181	180	102	162	124	120	152	110	<100	<100	114	145	120	239	171	158
Strontium	mg/kg dw	0.1	-	-	-	-	15.9	22.5	15.3	21.4	12.8	14.9	6.94	14.7	19.1	8.82	16	8.97	7.73	24.4	15.6	9.76	14.8	15.6	13	12.8
Thallium	mg/kg dw	0.05	-	-	-	-	0.248	0.519	0.313	0.461	0.297	0.205	0.649	1.15	0.413	0.279	0.362	0.222	0.196	0.362	0.333	0.371	0.816	0.314	0.248	0.248
Tin	mg/kg dw	0.1	-	-	-	-	0.41	0.71	0.59	0.66	0.59	0.58	0.34	0.55	0.41	0.37	0.47	0.26	0.22	0.28	0.36	0.35	0.37	0.66	0.48	0.49
Titanium	mg/kg dw	1	-	-	-	-	447	812	628	728	735	620	475	546	313	471	462	265	251	261	286	457	434	858	671	533
Uranium	mg/kg dw	0.05	-	-	-	-	3.81	5.27	4.18	4.51	3.82	4.46	2.98	4.79	4.51	3.28	5.35	2.94	2.56	3.44	3.99	3.71	4.23	3.43	2.38	2.83
Vanadium	mg/kg dw	2	-	-	-	-	33.9	54.7	42	46.6	43.7	45.1	28.4	43.7	31.4	31.5	41.1	22.2	19.1	25.2	30.3	33.5	37	52.4	39	40
Zinc	mg/kg dw	1	120	820	123	315	58.8	*127*	92.1	109	77.7	80.5	66.1	*127*	105	60.5	112	48.3	41.3	101	101	67	*126*	77.9	65.4	60.6
Particle Size																										
Sand Content	%	0.1	-	-	-	-	8.2	6	13	9.7	14	5.7	34	39	8.2	29	4.2	51	54	7	15	29	24	10	4.3	3.6
Silt Content	%	0.1	-	-	-	-	67	59	54	53	46	44	33	31	48	43	43	34	32	49	46	38	45	54	67	61
Clay Content	%	0.1	-	-	-	-	25	35	33	37	39	51	33	30	44	28	53	15	14	44	39	33	30	36	29	35

Notes: dw = dry weight; mg/kg = milligrams per kilogram; % = percent; <= less than; DUP = field duplicate sample.

Total metals and nutrient analyses were conducted on top 1-cm core samples; particle size analyses were conducted on top 10-15 cm Ekman grab samples.

Table E-1 Sediment Chemistry Results, 2013 AEMP (Continued)

a) = Ontario Ministry of Environment and Energy (OMOEE), "Guidelines for the Protection and Management of Aquatic Sediment Quality in Ontario" (OMOEE 1993).

b) = Lowest Effect Level.

c) = Severe Effect Level.

d) = Canadian Council of Ministers of the Environment (CCME), "Canadian Sediment Quality Guidelines for the Protection of Aquatic Life", (CCME 2002).

f) = Probable effect level.

g) = total organic carbon results for core samples (top 1 cm)

h) = total organic carbon results for Ekman grab samples (top 10-15 cm)

i) = results for organic matter for a subset of samples were not reported by the analytical lab. Samples could not be run due to insufficient volume.

Value	Values greater than or equal to the OMOEE LEL guidelines are italicized.
Value	Values greater than or equal to the OMOEE SEL guidelines are underlined.
Value	Values greater than or equal to the CCME ISQG guidelines are shaded.
Value	Values greater than or equal to the CCME PEL guidelines are bolded.

Table E-2 Percentage and Number of Samples Exceeding Sediment Quality Guideline in Exposure and References Areas of Lac de Gras, 2013 AEMP

Variable	Unit	Guideline		Percentage and Number of Samples Exceeding Guideline Value									
				NF **n = 5**	**MF1** **n = 3**	**MF2-FF2** **n = 4**	**MF3** **n = 7**	**FF1** **n = 5**	**FFA** **n = 5**	**FFB** **n = 5**	**Exposure Areas** **n = 19**	**Reference Areas** **n = 15**	**Total** **n = 34**
Nitrogen	% dw	OMOEE LEL	0.055	100% n = 5	100% n = 3	100% n = 4	100% n = 7	100% n = 5	100% n = 5	100% n = 5	100% n = 19	100% n = 15	100% n = 34
		OMOEE SEL	0.480	100% n = 5	33% n = 1	75% n = 3	100% n = 7	100% n = 5	80% n = 4	100% n = 5	84% n = 16	93% n = 14	88% n = 30
Total Phosphorus	mg/kg dw	OMOEE LEL	600	100% n = 5	100% n = 3	100% n = 4	100% n = 7	80% n = 4	80% n = 4	80% n = 4	100% n = 19	80% n = 12	91% n = 31
		OMOEE SEL	2,000	0% n = 0	0% n = 0	25% n = 1	0% n = 0	0% n = 0	0% n = 0	0% n = 0	5% n = 1	0% n = 0	3% n = 1
Total Organic Carbon (Cores)	% dw	OMOEE LEL	1	100% n = 5	100% n = 3	100% n = 4	100% n = 7	100% n = 5	100% n = 5	100% n = 5	100% n = 19	100% n = 15	100% n = 34
		OMOEE SEL	10	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0
Total Organic Carbon (Grabs)	% dw	OMOEE LEL	1	100% n = 5	100% n = 3	100% n = 4	100% n = 7	80% n = 4	80% n = 4	100% n = 5	100% n = 19	87% n = 13	94% n = 32
		OMOEE SEL	10	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0
Arsenic	mg/kg dw	OMOEE LEL	6	100% n = 5	100% n = 3	100% n = 4	100% n = 7	100% n = 5	100% n = 5	100% n = 5	100% n = 19	100% n = 15	100% n = 34
		OMOEE SEL	33	40% n = 2	33% n = 1	25% n = 1	29% n = 2	40% n = 2	80% n = 4	60% n = 3	32% n = 6	60% n = 9	44% n = 15
		CCME ISQG	5.9	100% n = 5	100% n = 3	100% n = 4	100% n = 7	100% n = 5	100% n = 5	100% n = 5	100% n = 19	100% n = 15	100% n = 34
		CCME PEL	17	100% n = 5	100% n = 3	100% n = 4	86% n = 6	100% n = 5	100% n = 5	100% n = 5	95% n = 18	100% n = 15	97% n = 33

Table E-2 Percentage and Number of Samples Exceeding Sediment Quality Guideline in Exposure and References Areas of Lac de Gras, 2013 AEMP

Variable	Unit	Guideline		Percentage and Number of Samples Exceeding Guideline Value									
				NF n = 5	MF1 n = 3	MF2-FF2 n = 4	MF3 n = 7	FF1 n = 5	FFA n = 5	FFB n = 5	Exposure Areas n = 19	Reference Areas n = 15	Total n = 34
Cadmium	mg/kg dw	OMOEE LEL	0.6	0% n = 0	33% n = 1	0% n = 0	43% n = 3	20% n = 1	60% n = 3	40% n = 2	21% n = 4	40% n = 6	29% n = 10
		OMOEE SEL	10	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0
		CCME ISQG	0.6	0% n = 0	33% n = 1	0% n = 0	43% n = 3	20% n = 1	60% n = 3	40% n = 2	21% n = 4	40% n = 6	29% n = 10
		CCME PEL	3.5	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0
Chromium	mg/kg dw	OMOEE LEL	26	100% n = 5	100% n = 3	100% n = 4	100% n = 7	100% n = 5	100% n = 5	80% n = 4	100% n = 19	93% n = 14	97% n = 33
		OMOEE SEL	110	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0
		CCME ISQG	37.3	100% n = 5	100% n = 3	100% n = 4	71% n = 5	100% n = 5	60% n = 3	40% n = 2	89% n = 17	67% n = 10	79% n = 27
		CCME PEL	90	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0
Cobalt	mg/kg dw	OMOEE LEL	50	20% n = 1	33% n = 1	0% n = 0	29% n = 2	20% n = 1	100% n = 5	100% n = 5	21% n = 4	73% n = 11	44% n = 15
Copper	mg/kg dw	OMOEE LEL	16	100% n = 5	100% n = 3	100% n = 4	100% n = 7	100% n = 5	100% n = 5	100% n = 5	100% n = 19	100% n = 15	100% n = 34
		OMOEE SEL	110	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0
		CCME ISQG	35.7	60% n = 3	100% n = 3	75% n = 3	100% n = 7	100% n = 5	100% n = 5	100% n = 5	84% n = 16	100% n = 15	91% n = 31
		CCME PEL	197	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0

Table E-2 Percentage and Number of Samples Exceeding Sediment Quality Guideline in Exposure and References Areas of Lac de Gras, 2013 AEMP

Variable	Unit	Guideline		Percentage and Number of Samples Exceeding Guideline Value									
				NF n = 5	MF1 n = 3	MF2-FF2 n = 4	MF3 n = 7	FF1 n = 5	FFA n = 5	FFB n = 5	Exposure Areas n = 19	Reference Areas n = 15	Total n = 34
Iron	mg/kg dw	OMOEE LEL	20,000	100% n = 5	100% n = 3	100% n = 4	86% n = 6	100% n = 5	100% n = 5	100% n = 5	95% n = 18	100% n = 15	97% n = 33
		OMOEE SEL	40,000	0% n = 0	33% n = 1	25% n = 1	29% n = 2	20% n = 1	80% n = 4	60% n = 3	21% n = 4	53% n = 8	35% n = 12
Lead	mg/kg dw	OMOEE LEL	31	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0
		OMOEE SEL	250	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0
		CCME ISQG	35	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0
		CCME PEL	91.3	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0
Manganese	mg/kg dw	OMOEE LEL	460	100% n = 5	100% n = 3	100% n = 4	86% n = 6	100% n = 5	100% n = 5	100% n = 5	95% n = 18	100% n = 15	97% n = 33
		OMOEE SEL	1,100	100% n = 5	100% n = 3	100% n = 4	86% n = 6	80% n = 4	100% n = 5	100% n = 5	95% n = 18	93% n = 14	94% n = 32
Mercury	mg/kg dw	OMOEE LEL	0.2	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0
		OMOEE SEL	2	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0
		CCME ISQG	0.17	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0
		CCME PEL	0.486	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0

Table E-2 Percentage and Number of Samples Exceeding Sediment Quality Guideline in Exposure and References Areas of Lac de Gras, 2013 AEMP

Variable	Unit	Guideline		Percentage and Number of Samples Exceeding Guideline Value									
				NF n = 5	MF1 n = 3	MF2-FF2 n = 4	MF3 n = 7	FF1 n = 5	FFA n = 5	FFB n = 5	Exposure Areas n = 19	Reference Areas n = 15	Total n = 34
Nickel	mg/kg dw	OMOEE LEL	16	100% n = 5	100% n = 3	100% n = 4	100% n = 7	100% n = 5	100% n = 5	100% n = 5	100% n = 19	100% n = 15	100% n = 34
		OMOEE SEL	75	20% n = 1	67% n = 2	0% n = 0	43% n = 3	40% n = 2	60% n = 3	60% n = 3	32% n = 6	53% n = 8	41% n = 14
Silver	mg/kg dw	OMOEE LEL	0.5	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0
Zinc	mg/kg dw	OMOEE LEL	120	0% n = 0	0% n = 0	0% n = 0	0% n = 0	20% n = 1	20% n = 1	20% n = 1	0% n = 0	20% n = 3	9% n = 3
		OMOEE SEL	820	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0
		CCME ISQG	123	0% n = 0	0% n = 0	0% n = 0	0% n = 0	20% n = 1	20% n = 1	20% n = 1	0% n = 0	20% n = 3	9% n = 3
		CCME PEL	315	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0

Notes: n = number of samples; OMOEE = Ontario Ministry of the Environment and Energy; CCME = Canadian Council of Ministers of the Environment; LEL = lowest effect level; SEL = severe effect level; ISQG = Interim Sediment Quality Guideline; PEL = probable effect level; mg/kg = milligrams per kilogram; dw = dry weight; % = percent.

Duplicate samples were averaged prior to screening.

APPENDIX IV

BENTHIC INVERTEBRATE REPORT

BENTHIC INVERTEBRATE REPORT IN SUPPORT OF THE 2013 AEMP ANNUAL REPORT FOR THE DIAVIK DIAMOND MINE, NORTHWEST TERRITORIES

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EXECUTIVE SUMMARY

In 2013, Diavik Diamond Mines (2012) Inc. completed the field component of an Aquatic Effects Monitoring Program (AEMP) in Lac de Gras, Northwest Territories, as required by Water Licence W2007L2-0003, and the Terms of Reference and Approval Conditions provided by the Wek’èezhìi Land and Water Board. The 2013 AEMP benthic invertebrate survey was conducted in Lac de Gras during the late open-water season using methods consistent with those used during previous AEMP field programs. As outlined in the updated AEMP Study Design Version 3.0, the design of the 2013 benthic invertebrate survey was similar to AEMP surveys since 2007; however, some of the sampling effort was re-allocated to better allow estimation of the spatial extent of potential effects. This report presents the results of the 2013 benthic invertebrate community survey.

The 2013 monitoring results suggest that the benthic invertebrate community in Lac de Gras was exhibiting a Mine-related nutrient enrichment effect and not a toxicological effect. The conclusion was based on the following results:

- Statistically greater total invertebrate density and *Procladius* density were observed in the Near-field exposure area compared to the reference areas. *Heterotrissocladius* density was also higher in the Near-field exposure area, but the difference was not statistically significant after the removal of an outlier in the Near-field area.
- Results of multivariate analysis (NMDS ordination) indicated a slight difference in the benthic invertebrate community in the Near-field exposure area compared to the reference area communities.

No action levels were triggered for the benthic invertebrate community component, because total density and *Procladius* density were significantly greater in the Near-field exposure area compared to the reference areas, which indicate nutrient enrichment rather than toxicity.

LIST OF ACRONYMS

AEMP	Aquatic Effects Monitoring Program
ANOVA	analysis of variance
DDMI	Diavik Diamond Mines (2012) Inc.
DO	dissolved oxygen
EEM	Environmental Effects Monitoring
FF	far-field
GPS	global positioning system
HSD	honestly significant difference
MF	mid-field
Mine	Diavik Diamond Mine
NF	near-field
NMDS	non-metric multidimensional scaling
P	probability
PCA	principal components analysis
RPD	relative percent difference
QAPP	quality assurance protection plan
QA/QC	quality assurance/quality control
SD	standard deviation
SE	standard error
SOP	Standard Operating Procedure
UTM	Universal Transverse Mercator
WLWB	Wek’èezhìi Land and Water Board
i.e.	that is
e.g.	for example
et al.	and others (authors)
sp.	species (singular)
vs.	versus

LIST OF UNITS

>	greater than
<	less than
≤	greater than or equal to
%	percent
m	metre
mg/L	milligrams per litre
L	litre
mm	millimetre
no./m^2	number of organisms per square metre
µm	micrometre
µS/cm	microSiemens per centimetre

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1 INTRODUCTION

1.1 BACKGROUND

In 2013, Diavik Diamond Mines (2012) Inc. (DDMI) completed the field component of its Aquatic Effects Monitoring Program (AEMP), as required by Water Licence W2007L2-0003 (WLWB 2007). This report presents the analysis of benthic invertebrate data collected during the 2013 field program, which was carried out by DDMI according to the AEMP Study Design Version 3.0 (Golder 2011a). Details on methodology are provided in Section 2.

The assessment of effects was based on the updated Version 3.3 Study Design (Golder 2014a), which was approved by the Wek’èezhìi Land and Water Board (WLWB) on February 19, 2014 (WLWB 2014). Section 3 provides results of the assessment, while Section 4 provides a discussion of the results. Conclusions, together with recommendations for program changes or enhancements, are provided in Section 5.

Supporting environmental data (i.e., limnology profiles, water samples, and sediment quality samples) were collected concurrently with benthic invertebrate sampling.

1.2 OBJECTIVES

The principal goal of the AEMP is to monitor the Mine water discharge and other stressors from the Mine, and to assess potential ecological effects. The objective of the benthic invertebrate component of the AEMP is to evaluate whether the benthic invertebrate community of Lac de Gras is affected by effluent discharged from the Diavik Diamond Mine (Mine) and, if so, to estimate the type, magnitude, and spatial extent of the effect.

1.3 SCOPE AND APPROACH

The benthic invertebrate component is designed to monitor both spatial and temporal changes in the benthic invertebrate community. As described in Study Design Version 3.3 (Golder 2014a), the objective of the annual report and the comprehensive sampling report (current document) is to assess the spatial extent of Mine-related effects.

Effects were assessed by comparing areas of the lake exposed to effluent to areas of the lake that are not exposed to effluent (i.e., reference areas). Benthic invertebrate community endpoints were statistically tested to establish whether the differences seen among areas were related to the Mine (i.e., demonstrated a statistically-significant difference) or whether they may have occurred by chance.

The magnitude of effect was assessed by comparing community endpoints in exposure areas to background values. Background values for Lac de Gras are those that fall within the normal range, which is defined as the historical reference area mean ± 2 standard deviations. Values that are beyond the normal range are exceeding what would be considered natural levels for Lac de Gras. The importance of effects observed on community endpoints was determined according to the Action Level classification defined in the Study Design Version 3.3 (Golder 2014a).

2 METHODS

2.1 FIELD PROGRAM

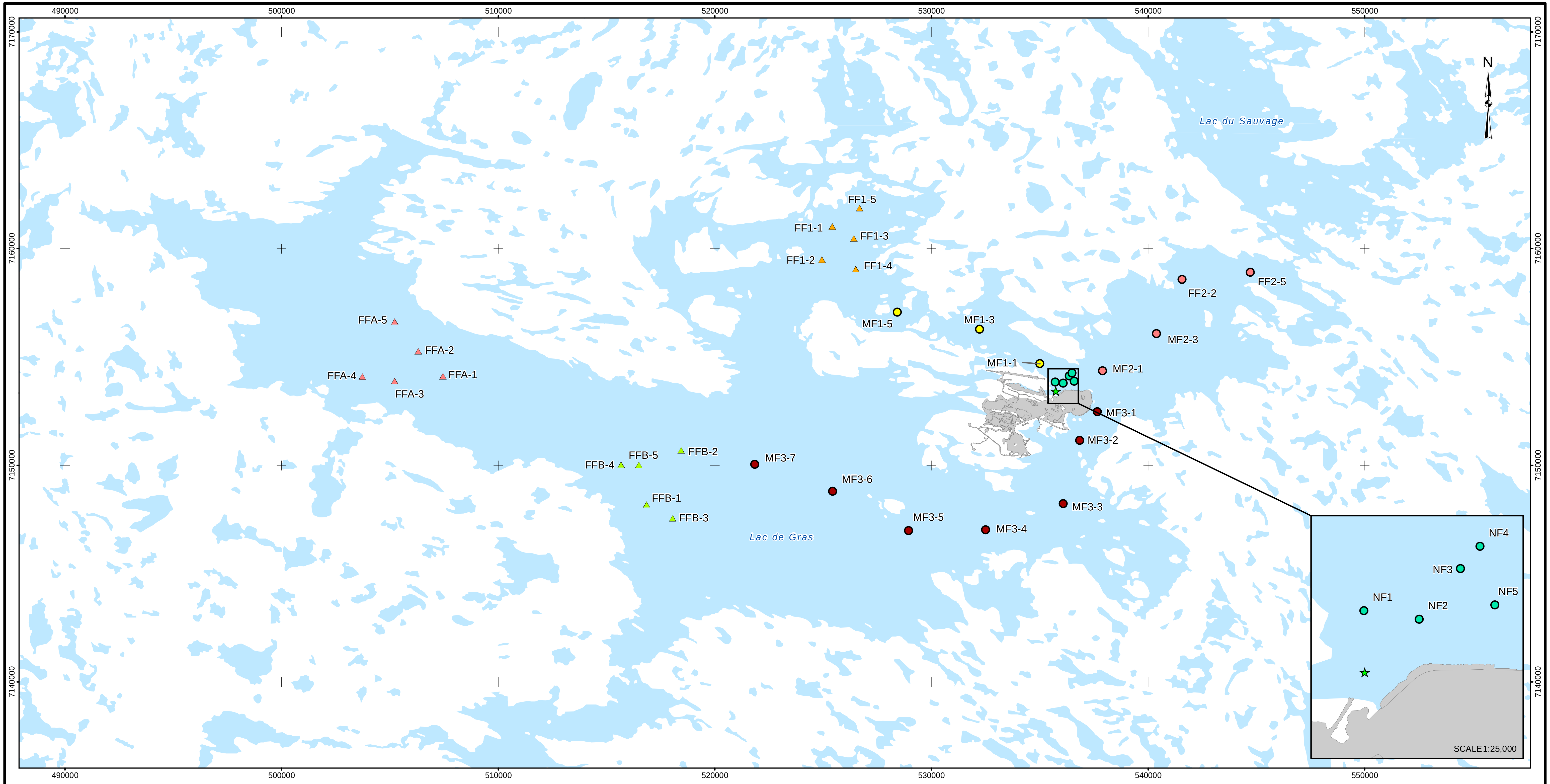
Benthic invertebrate samples were collected by DDMI personnel according to DDMI Standard Operating Procedures (SOPs) provided as appendices to the AEMP Study Design Version 3.0 (Golder 2011a). Sampling dates, station locations, water depth and field water quality data are summarized in Table 2-1. Areas exposed to Mine effluent (i.e., exposure areas) included the near-field (NF), mid-field 1 (MF1), mid-field 2 (MF2), mid-field 3 (MF3) and far-field 2 (FF2) areas; reference areas included the Far-field 1 (FF1), far-field A (FFA) and far-field B (FFB) areas.

Benthic invertebrate samples were collected and analyzed from the following replicate stations in Lac de Gras during open-water conditions in 2013 (Figure 2-1):

- five stations in the NF exposure area, and in each of the three far-field reference areas (FF1, FFA, FFB);
- three stations in the MF-1 exposure area;
- two stations in the MF-2 exposure area;
- seven stations in the MF-3 exposure area; and
- two stations in the FF2 exposure area.

Station selection was constrained by water depth, which was kept as close to 20 m as possible to prevent confounding of the study by depth, which has been demonstrated to influence the benthic community in Lac de Gras (Golder 1997).

Six subsamples, each consisting of a single Ekman grab with a sampling area of 0.023 m^2, were collected at each station. Each subsample was sieved through a 500 µm mesh Nitex screen, and material retained in the mesh was placed in a separate 1-litre plastic bottle and preserved in 10% buffered formalin. Samples were shipped to J. Zloty, PhD (independent consultant), for enumeration and taxonomic identification of invertebrates.



LEGEND

★ DIFFUSER

▨ DIAVIK FOOTPRINT

🟦 WATERBODY

EXPOSURE

● NEAR-FIELD

● MID-FIELD 3

● MID-FIELD 1

● FAR-FIELD 2; MID-FIELD 2

REFERENCE

▲ FAR-FIELD 1

▲ FAR-FIELD A

▲ FAR-FIELD B

REFERENCE

HYDROGRAPHY DATA OBTAINED FROM CANVEC © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 12 DATUM: NAD 83

5 0 5
SCALE 1:175,000 KILOMETRES

PROJECT

DIAVIK DIAMOND MINES INC.

TITLE

BENTHIC INVERTEBRATE SAMPLING STATIONS, 2013 AEMP

Golder Associates

PROJECT		13-1328-0001	FILE No.	
DESIGN	LJ	18 Feb. 2014	SCALE AS SHOWN	REV. 0
GIS	JC	20 Mar. 2014	FIGURE: 2-1	
CHECK	TD	20 Mar. 2014		
REVIEW	CF	20 Mar. 2014		

I:\2011\11-1328\11-1328-0038\Mapping\MXD\2013AEMP\FINAL\Fig2-1_2013_AEMP_Benthic_Invertebrate_Sampling_Locations_20140319_Final.mxd

Table 2-1 Benthic Invertebrate Station Locations and Sampling Dates, 2013

Area Type	Area	Station	Benthos Sampling Date	UTM Coordinates		Distance From Diffuser[a] (m)	Water Depth (m)
				Easting (m)	Northing (m)		
Exposure	Near-Field	NF1	18-Aug-13	535725	7153839	394	19
		NF2	27-Aug-13	536098	7153779	501	21
		NF3	27-Aug-13	536385	7154101	936	19
		NF4	27-Aug-13	536513	7154250	1,131	22
		NF5	27-Aug-13	536625	7153873	968	20
	Mid-Field 1	MF1-1	21-Aug-13	535014	7154690	1,452	21
		MF1-3	21-Aug-13	532225	7156295	4,650	20
		MF1-5	25-Aug-13	528214	7157050	8,535	18
	Mid-Field 2	MF2-1	27-Aug-13	538000	7154296	2,363	20
		MF2-3	26-Aug-13	540379	7156096	5,386	20
	Mid-Field 3	MF3-1	25-Aug-13	537664	7152454	2,730	21
		MF3-2	25-Aug-13	536833	7151142	4,215	19
		MF3-3	25-Aug-13	536090	7148108	7,245	21
		MF3-4	5-Sep-13	532516	7147026	11,023	22
		MF3-5	7-Sep-13	528946	7146978	14,578	20
		MF3-6	7-Sep-13	525445	7148819	18,532	18
		MF3-7	25-Aug-13	521921	7150017	22,330	22
	Far-field 2	FF2-2	26-Aug-13	541599	7158552	8,276	19
		FF2-5	26-Aug-13	544734	7158898	11,444	22
Reference	Far-Field 1	FF1-1	24-Aug-13	525404	7161022	13,571	21
		FF1-2	22-Aug-13	524896	7159441	12,915	19
		FF1-3	24-Aug-13	526424	7160477	12,788	20
		FF1-4	24-Aug-13	526334	7159076	11,399	22
		FF1-5	22-Aug-13	526553	7161775	12,823	18
	Far-Field A	FFA-1	29-Aug-13	506436	7153999	36,769	19
		FFA-2	29-Aug-13	506264	7155278	38,312	18
		FFA-3	29-Aug-13	505220	7153924	38,734	22
		FFA-4	30-Aug-13	503734	7154088	40,211	21
		FFA-5	3-Sep-13	505204	7156639	39,956	19
	Far-Field B	FFB-1	5-Sep-13	516846	7148237	26,355	19
		FFB-2	1-Sep-13	518496	7150693	24,991	18
		FFB-3	5-Sep-13	518058	7147573	25,245	22
		FFB-4	1-Sep-13	515687	7150045	27,591	20
		FFB-5	1-Sep-13	516543	7150025	26,761	22

Notes: UTM = Universal Transverse Mercator; m = metre.

a) Approximate distance from the diffuser along the most direct path of effluent flow.

UTM coordinates are North American Datum (NAD) 83, Zone 12 V.

Supporting variables collected at each station were:

- sampling date;
- global positioning system (GPS) coordinates, recorded as Universal Transverse Mercator (UTM);
- water depth;
- detailed water quality, and vertical profiles of water temperature, dissolved oxygen (DO), pH and specific conductivity, collected as part of the water quality component; field measurements taken at the lake bottom are summarized in this document and water quality data are described in detail in the 2013 Effluent and Water Chemistry Report (Golder 2014b);
- detailed sediment quality, consisting of total organic carbon (TOC) and particle size distribution in one composite sediment sample from the top 10 to 15 cm of sediments, and total metals, total nitrogen, total phosphorus, and TOC in the top 1 cm of a composite core sample; sediment quality results are described in detail in the 2013 Sediment Quality Report (Golder 2014c).

2.2 SAMPLE SORTING AND TAXONOMIC IDENTIFICATION

Benthic invertebrate samples collected at 26 of 34 stations sampled in 2013 were analyzed as a single composite sample per station (i.e., after pooling the six subsamples). Six individual subsamples were analyzed separately from eight stations (NF-1, NF-4, MF1-5, MF2-3, MF3-3, MF3-5, FF1-1, and FF1-5) to allow an evaluation of within-station variability and the adequacy of the number of subsamples collected at a station. Previous benthic invertebrate studies in Lac de Gras, including a baseline study (Golder 1997), and the 2007 to 2011 AEMPs (Golder 2008, 2009, 2010, 2011b, 2012) demonstrated that six subsamples are typically sufficient to collect representative benthic community data from a station in Lac de Gras.

Benthic invertebrate samples (subsamples and composite samples) were processed according to standard protocols based on Environment Canada (2002) and Gibbons et al. (1993). Samples were first washed through a 500 µm mesh sieve to remove the preservative and fine sediments remaining after field sieving. Organic material was separated from inorganic material using elutriation (i.e., separation of the lighter organic material from the heavier inorganic material in a water-filled pan). The inorganic material was checked for remaining shelled or cased invertebrates, which were removed and added to the organic material. The organic material was split into coarse and fine fractions using a set of nested sieves of 1 mm and 500 µm mesh size. Because samples were generally small, containing less than 300 organisms, laboratory subsampling was not necessary.

Invertebrates were identified to the lowest practical taxonomic level, typically genus, using recognized taxonomic keys (Brinkhurst 1986; Clifford 1991; Coffman and Ferrington 1996; Epler 2001; Maschwitz and Cook 2000; McAlpine et al. 1981; Merritt and Cummins 1996; Oliver and Roussel 1983; Pennak 1989; Soponis 1977; Wiederholm 1983). Organisms that could not be identified to the desired taxonomic level (e.g., immature or damaged specimens) were reported as a separate category at the lowest taxonomic level possible, typically family. Organisms that required detailed microscopic examination for identification (e.g., Chironomidae and Oligochaeta) were mounted on microscope slides using an appropriate mounting medium. The most common taxa were distinguishable based on gross morphology and required only a few slide mounts (five to ten) for verification. All rare or less common taxa were slide-mounted for identification. The biomass of each composite sample or subsample was estimated as a total wet weight, by weighing preserved organisms on an analytical balance after blotting off excess preservative on a paper towel.

A reference collection was prepared that contained preserved representative specimens of each taxon identified from the AEMP samples. Invertebrates removed from the samples have been stored for potential future taxonomic analysis.

2.3 DATA ANALYSES

2.3.1 Data Preparation and Variable Selection

To prepare the data for analysis, non-benthic invertebrates (Copepoda, Cladocera, pupae), benthic meiofauna (Nematoda), which were not quantitatively sampled, and terrestrial invertebrates were deleted, and mean abundances were calculated for stations where individual samples were collected. In addition, abundances per sample were converted to densities (number of organisms per square metre [no./m^2]) based on the bottom area of the sampling device and the number of subsamples collected.

The following variables were included in the statistical analysis:

- total invertebrate density;
- richness (total taxa per station at the lowest level of identification);
- Simpson’s diversity index;
- evenness index (evenness);
- dominance (percentage of the dominant taxon at a station);
- Bray-Curtis distance;
- densities of dominant taxa:
    - *Procladius* sp. (29% across all stations);

- Pisidiidae (23%);
- *Heterotrissocladius* sp. (14%); and
- *Microtendipes* sp. (7%).

Additional aspects of benthic community structure examined visually included presence-absence by each invertebrate taxon and community composition by major taxonomic group.

2.3.2 Evaluation of Effects of Habitat Variation

Spearman rank correlations were run between habitat variables (sediment TOC, percent fine sediments, water depth) and the biological variables selected for analysis. Before this analysis, the range of variation in habitat variables was evaluated and only those with sufficient variation to influence the benthic community were included in this analysis. Results of this analysis were used to evaluate whether habitat variation had the potential to influence the results of statistical comparisons of sampling areas.

2.3.3 Statistical Analysis

2.3.3.1 Approach

The statistical approach was developed in consideration of the guidance provided in the interpretive framework for the spatial analysis section of the AEMP Study Design version 3.3 (Golder 2014a; Section 6.3.4.6). The objective of the statistical comparisons was to compare the NF exposure area to the three reference areas (FFA, FFB, and FF1). This section describes the approach used for the statistical comparisons.

Before statistical testing, the data were screened for outliers or inaccurate entries. Calculations and statistical summaries were conducted in Excel 2010 for Windows (Microsoft Corporation, Cambridge, MA). Statistical tests were run using SYSTAT 13.1 for Windows (SYSTAT Software, San Jose, CA).

Analysis of Variance

The means of all four areas were compared to one another in an overall analysis of variance (ANOVA). Within the overall ANOVA, *a priori* comparisons (planned contrasts) were then conducted to compare means among specific areas (e.g., NF exposure area versus the FF reference areas). This approach was used throughout the AEMP; for example, the ANOVA models used for the benthic invertebrate analysis were the same models used for the analysis of water chemistry, sediment chemistry and eutrophication indicators. This level of consistency among all disciplines was necessary for the overall and weight-of-evidence interpretations.

At the study design stage, the probability of a Type I error (α) was set to the same level (i.e., 0.1) as a Type II error (β) because the probability of missing important effects was deemed to be as important as the probability of finding an effect when none exist (Environment Canada 2012). This approach resulted in a power of 90% for the study as designed.

Multiple comparison techniques (*a posteriori*) are frequently used with environmental assessment data; however, these techniques cannot always answer the main hypothesis of the study (Hoke et al. 1990). The preferred approach is to analyze the data using planned, linear orthogonal contrasts by formulating meaningful comparisons among treatments (sampling areas) before conducting the study and outlining these in a study design. Planned contrasts applied during the analysis of AEMP data were formulated to help answer the question of whether effluent is having an effect in the exposure area of Lac de Gras.

Planned, linear orthogonal contrasts are a method of partitioning the ANOVA treatment sum of squares into a series of uncorrelated (orthogonal) comparisons of sets of treatment means or totals (Hoke et al. 1990; Sokal and Rohlf 1995).

To demonstrate the contrasts used in the analysis of the 2013 AEMP data, a complete ANOVA table for total density of benthic invertebrates from the 2013 AEMP is presented in Table 2-2.

Table 2-2 Example of Detailed ANOVA Results for Total Richness of Benthic Invertebrates from the 2013

Source of Variation	*df*	*SS*	*MS*	*P*
Among groups (among areas)	3	337,310.96	113,436.99	0.046
Near-field vs. reference (NF vs. FFA + FFB + FF1)	1	285,340.09	285,340.09	0.010
Within groups (error: within areas)	16	539,109.43	33,694.34	-

Notes: *df* = degrees of freedom; *SS* = sum of squares; *MS* = mean square; *P* = probability; - = not applicable.

In some cases, unforeseen differences were observed among reference areas. To assess this natural variability, comparisons were also made among reference areas, thereby quantifying natural differences among different areas of Lac de Gras. Such comparisons, which suggested themselves as a result of the completed survey and analysis, are considered unplanned (*a posteriori*) comparisons. The procedure used for these comparisons was *Tukey's honestly significant difference (HSD) method*, also known as the *T-method*. This test adopts a conservative approach by employing experiment-wise error rates for the Type I error (Day and Quinn 1989). Therefore, a *P* value of 0.1 was used for these tests.

In the example in Table 2-2, an overall significant difference was detected in total richness among sampling areas, and the NF exposure area was significantly different from the reference areas. Comparisons made with Tukey's honestly significant difference test indicated that the reference areas (FFA, FFB, and FF1) were similar, as no significant differences were detected among reference areas (P>0.1 for all pair-wise comparisons).

2.3.3.2 Bray Curtis Distance Calculation

During the 2007 to 2010 AEMP, benthic invertebrate data analyses, Bray-Curtis distance values were calculated by comparing the benthic community of each station to the median reference area community calculated based on the pooled reference area data, as recommended by the technical guidance document for metal mining environmental effects monitoring (EEM) (Environment Canada 2012).

In 2013, Bray-Curtis distance values were calculated using the "all pair-wise comparisons" method as described in the 2011 AEMP Benthic Invertebrate Report (Golder 2012). Huebert et al. (2011) pointed out that using the reference median value as the basis for calculating Bray-Curtis distance values, as used in AEMP reports prior to 2011, results in misinterpretation of study results. The issues identified by Huebert et al. (2011) would result in frequently finding effects where none exist, referred to as a Type I error. To correctly calculate Bray-Curtis distance, Huebert et al. (2011) recommended (1) sampling multiple reference areas and (2) conducting pairwise, among-area comparisons of individual reference and exposure stations, to generate Bray-Curtis distance values for statistical comparisons.

2.3.3.3 Testing Assumptions for Statistical Analysis

The assumptions of parametric statistical tests were verified using the Shapiro-Wilk test (normality) and Levene's test (homogeneity of variances) on untransformed, log-transformed (base 10 and natural [ln]) and square-root-transformed data for density variables. Data were transformed where significant violations were found and the effectiveness of the transformations was verified.

For community variables (dominance, Simpson's diversity index, and evenness) and Bray-Curtis distance, the assumptions of parametric statistical tests were verified using the Shapiro-Wilk test and Levene's test on untransformed data. Evenness violated parametric test assumptions and was evaluated using a Kruskal-Wallis test with untransformed data. Other community variables did not violate parametric test assumptions and an ANOVA was used for statistical analysis. The transformations applied, and type of statistical test used for each variable, are shown in Table 2-3.

Table 2-3 Summary of Data Transformations and Statistical Tests, 2013

Variable	Transformation	Type of Test
Total density	none	parametric
Total richness	none	parametric
Dominance	none	parametric
Simpson's diversity index	none	parametric
Evenness	none	non-parametric
Bray-Curtis index	none	parametric
Procladius density	none	parametric
Pisidiidae density	none	parametric
Heterotrissocladius density	none	parametric
Microtendipes density	none	non-parametric

2.3.3.4 Statistical Comparisons

An overall ANOVA was initially performed to compare the four sampling areas. If a significant difference was found, the NF area was compared with the pooled reference areas (FFA, FFB, and FF1). This comparison was performed to test for Mine-related effects close to the diffuser.

The magnitude of differences among sampling areas was calculated by expressing the difference as a percentage of the pooled reference area mean, as follows:

Percent difference = [(exposure area mean – pooled reference area mean)/pooled reference area mean] x 100

Reference areas were compared using Tukey’s honestly significant difference test for all pair-wise comparisons (i.e., FF1 vs. FFA; FF1 vs. FFB; FFA vs. FFB) to investigate natural variation in benthic community variables within Lac de Gras. The magnitude of differences between means in the pair-wise reference area comparisons was calculated as the relative percent difference, by dividing the absolute value of the difference by the mean of the two areas, and then multiplying the quotient by 100.

2.3.3.5 Multivariate Analysis

Non-metric multidimensional scaling (NMDS; Kruskal 1964; Cox and Cox 2001) was run on the benthic invertebrate data set to summarize community structure and allow evaluation of potential changes in community structure along the Mine effluent concentration gradient in Lac de Gras. Non-metric multidimensional scaling is a nonparametric ordination method that allows reduction of a data set consisting of a large number of variables (taxa in this case) to typically two or three new dimensions (referred to as ordination axes), based on a station-by-station distance matrix (Clarke 1993).

A Bray-Curtis distance matrix was generated from natural log (x+1) transformed density data and was used as the input for the ordination. Three dimensions were selected for the ordination, after confirming that the stress of the two-dimensional configuration was reasonably low (<0.2). Ordination results were presented as a two-dimensional scatter-plot of the sampling stations in ordination space.

2.4 ACTION LEVELS FOR BENTHIC INVERTEBRATES

The importance of effects to benthic invertebrate assessment endpoints was categorized according to Action Levels described by Golder (2014a). The Action Level classifications were developed to meet the goals of the Response Framework for Aquatic Effects Monitoring that was drafted by the WLWB (WLWB 2010; Racher et al. 2011). The goal of the Response Framework is to ensure that significant adverse effects never occur. A significant adverse effect, as it pertains to aquatic biota, was defined in the Environmental Assessment as a change in fish population(s) that is greater than 20% (Government of Canada 1999). This effect must have a high probability of being permanent or long-term in nature and must occur throughout Lac de Gras. The Significance Thresholds for all aquatic biota, including benthic invertebrates, are therefore related to impacts that could result in a change in fish population(s) that is greater than 20%.

Although the AEMP addresses two broad impact hypotheses for Lac de Gras, the toxicological impairment hypothesis and the nutrient enrichment hypothesis (Golder 2014d), the Action Levels for benthic invertebrates address the toxicological impairment hypothesis. The nutrient enrichment hypothesis is assessed in the Eutrophication Indicators component (Golder 2014e).

Benthic invertebrates are assessed at three-year intervals to evaluate effects as described in the Action Levels for Biological Effects (Golder 2014a). This involves testing benthic invertebrate variables in the NF exposure area against those in the three FF reference areas (FFA, FFB, and FF1). The occurrence of an Action Level 1 will be determined by finding significantly lower mean value in the exposure area compared to those in the reference areas. Conditions required for Action Levels 1 to 3 are defined in Table 2-4. Action Level 4 will be defined if Action Level 3 is reached. Defining higher Action Levels after initial effects are encountered is consistent with the draft guidelines for preparing a response framework in AEMPs (WLWB 2010; Racher et al. 2011).

Table 2-4 Action Levels for Benthic Invertebrate Effects

Action Level	Benthic Invertebrates	Extent	Action
1	The mean of a community index [(a)] significantly less than reference area means.	Near-field	Confirm effect
2	The mean of a community index [(a)] significantly less than reference area means.	Nearest Mid-field station	Investigate cause
3	The mean of any measurement endpoint [(a)] less than normal range.	Near-field	Examine ecological significance Set Action Level 4 Identify mitigation options
4	To be determined [(b)]	-	Define conditions required for the Significance Threshold
5	Decline of community indices [(a)] likely to cause a >20% change n fish populations(s).	Far-field A (FFA)	Significance Threshold

a) Refers to indices such as total density, richness, Simpson’s diversity index, Bray-Curtis index and densities of dominant taxa; the criterion for the Bray-Curtis index is a significantly higher mean value compared to the reference areas.

b) To be determined if an Action Level 3 effect is reached.

2.5 QUALITY ASSURANCE/QUALITY CONTROL

The Quality Assurance Project Plan (QAPP) Version 2.0 (Golder 2013) outlined the quality assurance/quality control (QA/QC) procedures employed to support the collection of scientifically-defensible and relevant data required to meet the objectives of the AEMP (Golder 2014a). The QAPP served to ensure that field sampling, laboratory analysis, data entry, data analysis, and report preparation activities produced technically-sound and scientifically-defensible results.

Results of the QC program are provided in Appendix A. Benthic invertebrate sample processing included re-sorting by a separate individual of 10% of the total number of samples collected to evaluate invertebrate removal efficiency, and preparation of a reference collection. Subsampling was not done in the laboratory because all samples were small enough to be sorted in their entirety. Re-sorted samples satisfied the data quality objective of at least 90% invertebrate removal.

2.6 WEIGHT OF EVIDENCE INPUT

Results of the benthic invertebrate survey feed into the Weight of Evidence (WOE) assessment, which is described in the Weight of Evidence Report (Golder 2014d). The WOE integrates results from the AEMP components to help understand the underlying cause(s) of biological responses. Whereas the annual report for each AEMP component assesses the effects separately to determine if changes in individual components are meaningful, the WOE approach integrates measures of exposure (e.g., water quality, sediment quality) with measures of biological response (e.g., plankton, benthos, fish) to assess the underlying causes of biological changes. These biological changes can reflect either nutrient enrichment or toxicological impairment effects. Thus, the WOE will provide the strength of evidence for toxicological impairment or nutrient enrichment associated with observed changes. It is not intended to reflect the ecological significance or level of concern associated with a given change.

The WOE assessment is undertaken by applying a rating scheme to determine the degree of change in individual AEMP components. It then proceeds to integrate the individual component ratings into an overall score. The methods as applied to benthic invertebrates are described in Section2 of the Weight of Evidence Report.

3 RESULTS

3.1 FIELD WATER QUALITY

Field water quality measurements taken at the lake bottom at benthic invertebrate stations indicate that pH was typically slightly acidic to neutral in bottom waters of Lac de Gras (Table 3-1). Water temperature was similar among sampling areas with some slightly lower temperatures observed in the exposure areas compared to the reference areas. Near-bottom DO concentration ranged from 8.7 to 11.4 mg/L in the reference areas, and ranging from 8.8 to 11.7 mg/L in the exposure areas. Bottom conductivity reflected effluent exposure, ranging from 18 to 20 µS/cm at all reference stations. Stations in the NF area had the highest bottom conductivity values, ranging from 26 to 28 µS/cm. Conductivity in the MF areas and the FF2 area were variable and indicated some effluent exposure, with the exception of stations MF1-5, MF3-4, MF3-5 and MF3-6, which had conductivity values within the range of the reference areas.

Table 3-1 Water Depth, Field Water Quality and Sediment Quality Data for Benthic Invertebrate Stations, 2013

Area Type	Area	Station	Benthos Sampling Date	Water Depth (m)	pH	Water Temperature (°C)	Dissolved Oxygen (mg/L)	Specific Conductivity (µS/cm)	Total Organic Carbon (%)	Sediment Particle Size			
										Sand (%)	Silt (%)	Clay (%)	Fines (silt + clay) (%)
Exposure	Near-Field	NF1	18-Aug-13	19	6.5	8.4	11.7	26.7	2.3	26	53	22	75
		NF2	27-Aug-13	21	6.9	10.3	8.8	26.1	2.0	18	58	24	82
		NF3	27-Aug-13	19	6.8	10.4	9.1	26.1	1.5	14	59	27	86
		NF4	27-Aug-13	22	6.7	10.1	9.2	27.5	1.8	10	51	39	90
		NF5	27-Aug-13	20	6.8	10.1	8.8	26.5	1.6	15	62	23	85
	Mid-Field 1	MF1-1	21-Aug-13	21	6.4	8.7	9.2	26.7	1.7	12	60	28	88
		MF1-3	21-Aug-13	20	6.1	9.1	11.5	27.3	2.0	16	56	28	84
		MF1-5	25-Aug-13	18	6.8	11.9	8.8	19.2	1.6	9	59	32	91
	Mid-Field 2	MF2-1	27-Aug-13	20	6.9	10.3	8.8	25.6	1.3	12	61	27	88
		MF2-3	26-Aug-13	20	6.4	10.7	11.2	26.2	1.8	15	62	23	85
	Mid-Field 3	MF3-1	25-Aug-13	21	6.3	10.4	11.3	23.0	1.7	44	42	13	55
		MF3-2	25-Aug-13	19	6.3	10.1	11.5	21.6	2.0	25	57	17	74
		MF3-3	25-Aug-13	21	6.3	10.5	11.3	21.3	1.1	10	62	28	90
		MF3-4	5-Sep-13	22	6.5	9.8	9.0	19.4	1.1	10	58	32	90
		MF3-5	7-Sep-13	20	6.6	10.0	8.9	18.5	2.7	22	48	30	78
		MF3-6	7-Sep-13	18	6.6	10.1	9.0	18.5	4.0	2	41	57	98
		MF3-7	25-Aug-13	22	6.8	11.4	9.1	19.2	3.1	7	57	36	93
	Far-Field 2	FF2-2	26-Aug-13	19	6.4	10.7	11.1	25.7	1.6	10	62	28	90
		FF2-5	26-Aug-13	22	6.3	10.5	11.1	25.6	1.6	8	67	25	92

Table 3-1 Water Depth, Field Water Quality and Sediment Quality Data for Benthic Invertebrate Stations, 2013 (continued)

Area Type	Area	Station	Benthos Sampling Date	Water Depth (m)	pH	Water Temperature (°C)	Dissolved Oxygen (mg/L)	Specific Conductivity (µS/cm)	Total Organic Carbon (%)	Sediment Particle Size			
										Sand (%)	Silt (%)	Clay (%)	Fines (silt + clay) (%)
Reference	Far-Field 1	FF1-1	24-Aug-13	21	6.6	12.5	8.7	18.5	2.1	6	59	35	94
		FF1-2	22-Aug-13	19	6.5	10.9	9.3	18.5	2.3	13	54	33	87
		FF1-3	24-Aug-13	20	6.9	12.3	8.8	18.4	2.1	10	53	37	90
		FF1-4	24-Aug-13	22	6.2	12.6	10.7	18.7	0.7	14	46	39	85
		FF1-5	22-Aug-13	18	6.3	11.4	11.4	18.5	2.1	6	44	51	95
	Far-Field A	FFA-1	29-Aug-13	19	6.8	11.2	9.0	19.9	0.9	34	33	33	66
		FFA-2	29-Aug-13	18	7.0	11.3	9.0	19.9	1.3	39	31	30	61
		FFA-3	29-Aug-13	22	7.0	11.5	8.9	20.0	4.2	8	48	44	92
		FFA-4	30-Aug-13	21	6.9	11.4	8.9	19.9	2.8	29	43	28	71
		FFA-5	3-Sep-13	19	6.8	10.8	8.8	19.8	4.5	4	43	53	96
	Far-Field B	FFB-1	5-Sep-13	19	6.8	10.2	8.9	18.3	1.7	51	34	15	49
		FFB-2	1-Sep-13	18	6.7	10.8	8.8	18.5	4.3	7	49	44	93
		FFB-3	5-Sep-13	22	6.6	10.2	8.9	18.5	3.7	15	46	39	85
		FFB-4	1-Sep-13	20	6.6	10.7	8.8	18.4	1.6	29	38	33	71
		FFB-5	1-Sep-13	22	6.8	10.6	8.8	18.2	2.1	24	45	30	75

Notes: NF= near-field; MF = mid-field; FF = far-field; m = metre; n/a = not applicable; °C = degree Celsius; mg/L = milligrams per litre; µS/cm = microSiemens per centimetre;% = percent.

Near-bottom field water quality data are shown.

3.2 EFFECTS OF HABITAT VARIATION

Water depth varied little across stations and areas, with mean values per area between 19.2 and 20.3 m (Table 3-2). The overall range in water depth was about 4 m. Mean sediment TOC values were between 1.6% to 2.7%, with an overall range of variation of about 4%. Percent fine sediments was more variable, with mean values per area between 74.6% to 90.2% and an overall range of variation of about 50%. Only percent fine sediments varied over a sufficient range to influence the benthic invertebrate community and potentially interfere with the analysis of Mine-related effects.

Using data pooled for all stations (n=34), a weak relationship was detected between Percent fine sediments and *Heterotrissocladius* density (Table 3-3). However, no consistent relationships were apparent within individual sampling areas (Figure 3-1), suggesting the overall correlation is not indicative of an overriding influence of fine sediment content that could influence the evaluation of the Mine’s potential effect on this variable.

Table 3-2 Summary of Habitat Variables in Benthic Invertebrate Sampling Areas, 2013

Area Type	Area	Number of Stations	Water Depth (m)				TOC (%)				% Fine Sediments (silt+clay)			
			Minimum	Maximum	Mean	SE	Minimum	Maximum	Mean	SE	Minimum	Maximum	Mean	SE
Exposure	NF	5	18.7	22.0	20.1	0.6	1.5	2.3	1.8	0.1	75.0	90.0	83.6	2.5
	MF1	3	17.5	20.5	19.2	0.9	1.6	2.0	1.8	0.1	84.0	91.0	87.7	2.0
	MF2-FF2	4	19.0	22.0	20.3	0.6	1.3	1.8	1.6	0.1	85.0	92.0	88.8	1.5
	MF3	7	18.0	22.1	20.1	0.6	1.1	4.0	2.2	0.4	55.0	98.0	82.6	5.6
Reference	FF1	5	18.3	22.2	20.0	0.7	0.7	2.3	1.9	0.3	85.0	95.0	90.2	1.9
	FFA	5	18.0	21.9	19.6	0.8	0.9	4.5	2.7	0.7	61.0	96.0	77.2	7.1
	FFB	5	18.1	22.1	20.0	0.8	1.6	4.3	2.7	0.6	49.0	93.0	74.6	7.5

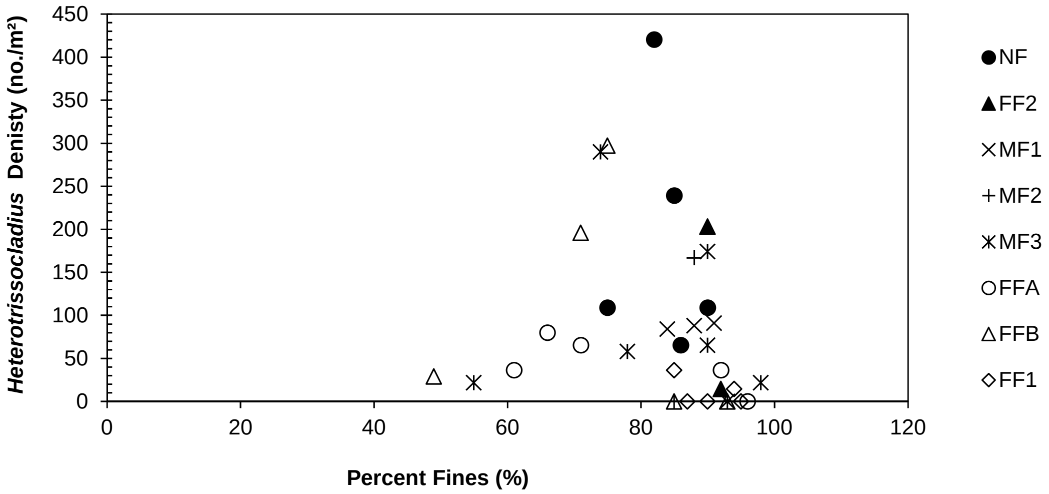
Notes: SE = standard error; TOC = total organic carbon; m = metre;% = percent; NF = near-field; MF = mid-field; FF = far-field.

Table 3-3 Spearman Rank Correlations between Biological Variables and Percent Fine Sediments, 2013

Variable	Fine Sediments (silt + clay)
Total density	-0.331
Total richness	-0.093
Dominance	-0.182
Simpson's diversity index	0.123
Evenness	0.194
Bray-Curtis index	0.138
Procladius density	-0.280
Pisidiidae density	-0.148
Heterotrissocladius density	**-0.450**
Microtendipes density	0.252

Note: **Bolded** values indicate significant correlations (n=34, *P*<0.05, r_s = 0.340).

Figure 3-1 Statistically Significant Relationships Between Fine Sediment Content and *Heterotrissocladius* Density



3.3 EXPOSURE TO MINE EFFLUENT

Exposure of benthic invertebrate sampling stations to the Mine effluent can be evaluated based on barium concentration measured in lake water (see Effluent and Water Chemistry Report; Golder 2014b). Open-water barium concentrations at exposure stations measured between August 18 and September 7, 2013, were above the upper limit of background concentrations estimated as 0.002 mg/L with the exception of stations MF1-4, MF3-3, MF3-4, MF3-5, MF3-6 and MF3-7 (Figure 3-2). Barium concentrations at reference stations were within the background range with the exception of stations FFA-5 and FFB-4, which were at 0.002 mg/L. Bottom conductivity measurements made at benthic invertebrate stations during sample collection between August 18 to September 7, 2013 show a very similar pattern, and suggest that the DDMI effluent was present at all exposure stations with the exception of MF1-5, MF3-4, MF3-5, MF3-6 and MF3-7 (Figure 3-3).

Further details regarding distribution of DDMI effluent in Lac de Gras are provided in the 2013 Effluent and Water Chemistry Report (Golder 2014b).

Figure 3-2 **Open-Water Barium Concentrations at the Benthic Invertebrate Sampling Areas in Lac de Gras, 2013**

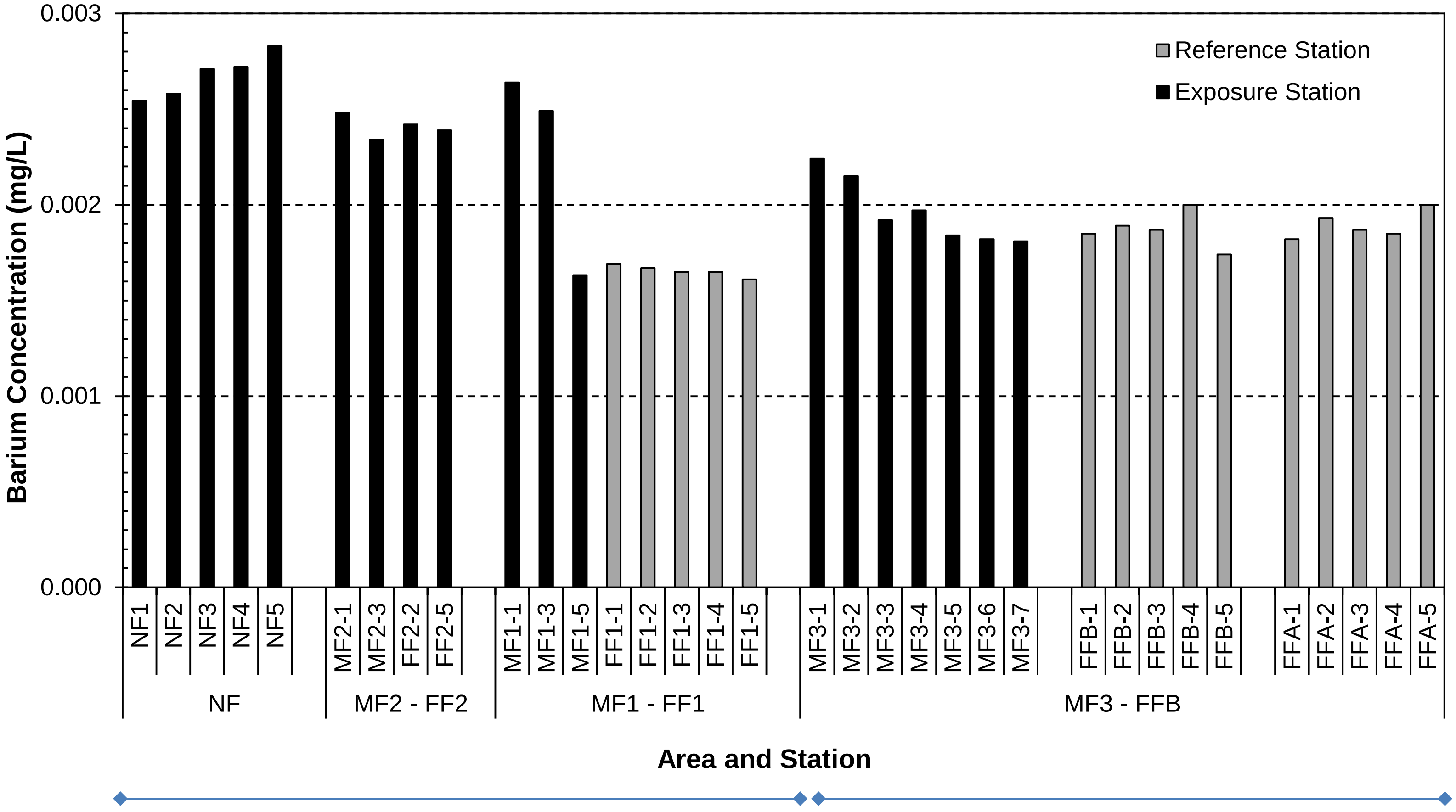
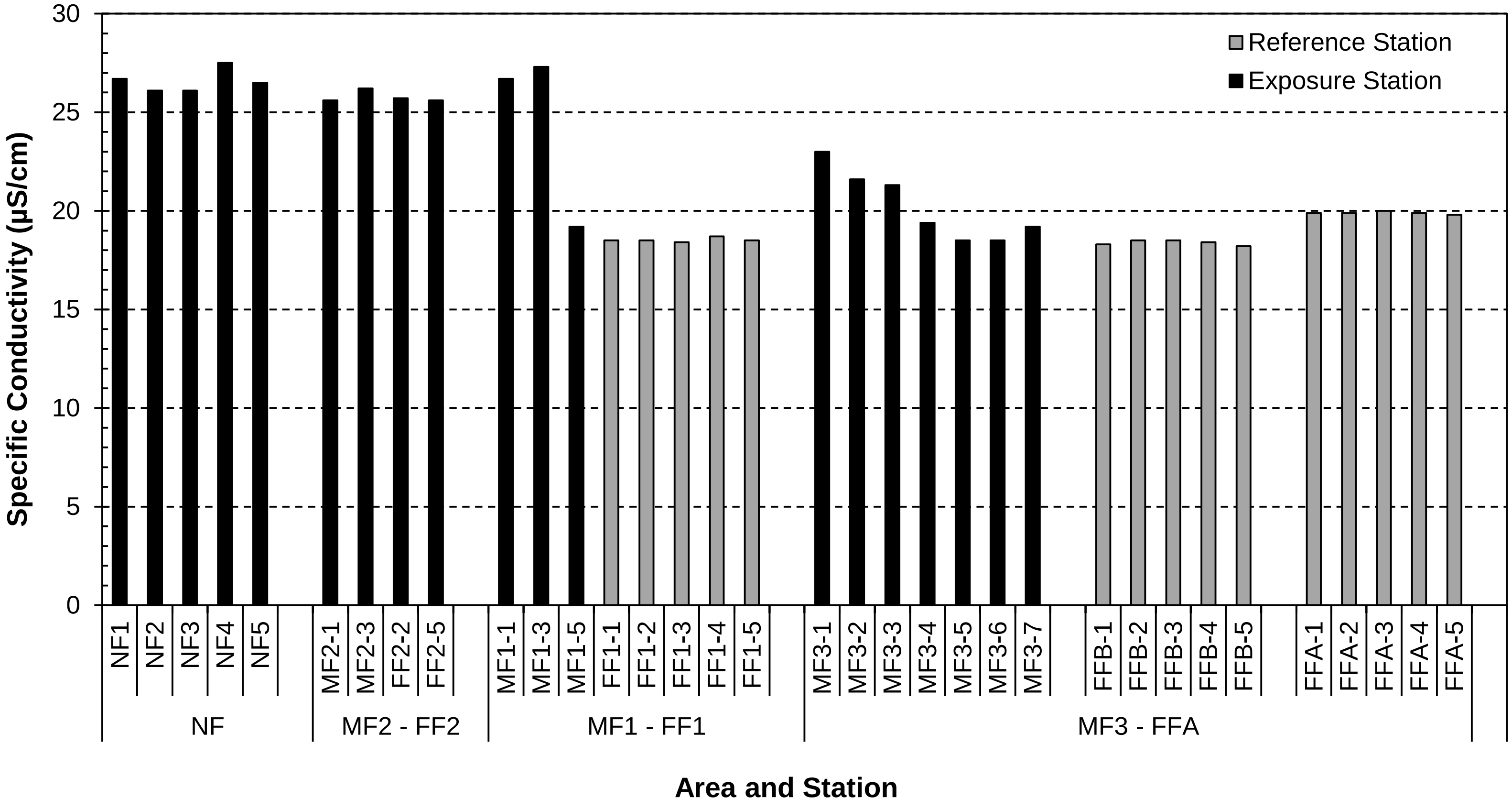


Figure 3-3 Specific Conductivity Measured at the Lake Bottom at the Benthic Invertebrate Sampling Areas in Lac de Gras, 2013

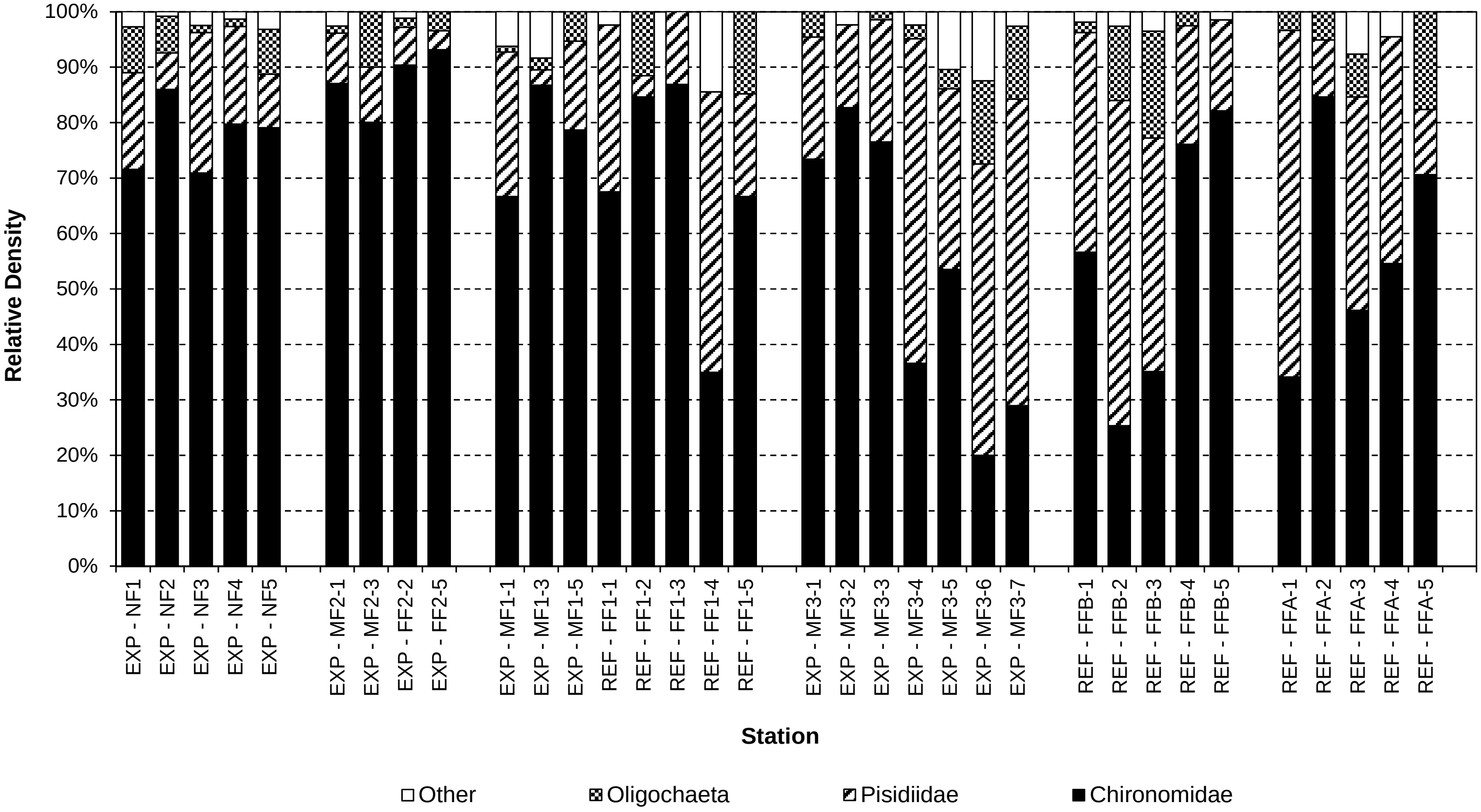


3.4 COMMUNITY COMPOSITION

The benthic invertebrate community of Lac de Gras was dominated by midges (Chironomidae), which accounted for 20% to 93% of total invertebrate density per station, with more than 50% of the total density consisting of midges at the majority of stations (Figure 3-4; raw abundance data are provided in Appendix B). The Pisidiidae (fingernail clams) also contributed a large proportion of the total density at most stations, with the largest relative abundance of 63% at Station FFA-1. At this coarse level of evaluation, exposure area communities had generally higher and less variable proportions of midges, and lower proportions of fingernail clams compared to the reference areas.

A summary of presence/absence of invertebrate taxa by area provided no clear indication of an effect on the composition of the benthic community. The invertebrates present and ranges in total number of taxa were generally similar in the exposure and reference areas (Table 3-4). The MF3 area had the greatest number of taxa (25 taxa/area) in 2013, which likely resulted from the larger number of stations in this area (7 stations) compared to other sampling areas (2 to 5 stations).

Figure 3-4 Composition of the Benthic Community at Sampling Areas in Lac de Gras, 2013



Note: REF = Reference Station, EXP = Exposure Station.

Table 3-4 Presence-Absence of Benthic Invertebrates at Sampling Areas in Lac de Gras, 2013

Major Group	Family	Subfamily	Tribe	Genus	Exposure Area					Reference Area		
					NF (n=5)	**MF1 (n=3)**	**MF2 (n=2)**	**MF3 (n=7)**	**FF2 (n=2)**	**FF1 (n=5)**	**FFA (n=5)**	**FFB (n=5)**
Microturbellaria	-	-	-	-		X		X				
Oligochaeta	Lumbriculidae	-	-	-	X	X	X	X	X	X	X	X
	Naididae	Naidinae	-	-				X				
		Tubificinae	-	-	X	X	X	X	X	X	X	X
Pelecypoda	Pisidiidae	-	-	*Sphaerium*	X	X	X	X	X	X	X	X
		-	-	*Pisidium*				X		X	X	X
Gastropoda	Valvatidae	-	-	*Valvata sincera*				X		X		X
Hydracarina	-	-	-	-	X	X	X	X		X	X	X
Notostraca	-	-	-	*Lepidurus*	X	X		X	X			
Ostracoda	-	-	-	-	X	X	X	X	X		X	X
Plecoptera	Capniidae	-	-	-						X		
Diptera	Chironomidae	Tanypodinae	Pentaneurini	*Ablabesmyia*				X		X		
				Thienemannimyia sp. group				X		X	X	X
			Procladiini	*Procladius*	X	X	X	X	X	X	X	X
		Diamesinae	Diamesini	*Potthastia longimana* group				X				
				Pseudodiamesa							X	
			Protanypini	*Protanypus*	X		X	X		X	X	X
		Prodiamesinae	-	*Monodiamesa*	X	X	X	X	X	X	X	X
		Orthocladiinae	-	*Abiskomyia*	X	X		X	X	X	X	X
			-	*Heterotrissocladius*	X	X	X	X	X	X	X	X
			-	*Psectrocladius*	X		X	X		X	X	X
			-	*Thienemanniella*				X				
			-	*Zalutschia*	X							
		Chironominae	Chironomini	*Dicrotendipes*								
				Microtendipes	X	X	X		X	X		X
				Polypedilum								
				Sergentia						X		
				Stictochironomus	X	X	X	X	X	X	X	X
			Tanytarsini	*Corynocera*								
				Micropsectra	X	X	X	X	X	X	X	X
				Micropsectra / Tanytarsus								
				Paratanytarsus	X	X	X	X	X	X	X	X
				Stempellinella		X		X		X		
				Tanytarsus	X	X	X	X	X	X	X	
Total Taxa					**18**	**17**	**15**	**25**	**14**	**22**	**18**	**18**

Note: X = taxon present.

3.5 COMPARISONS OF SAMPLING AREAS

Statistical tests detected overall significant differences among areas for four of 11 benthic community variables analyzed, which included total density, evenness, *Procladius* density and *Microtendipes* density (Table 3-5; mean values in each sampling area are shown in Figures 3-5 to 3-9). *Heterotrissocladius* density was non-significant after the removal of an outlier identified during analysis. No significant differences among areas were detected for the other benthic invertebrate community variables. Planned contrasts comparing the NF exposure area to the reference areas were statistically significant for total density, *Procladius* density and *Heterotrissocladius* density before removal of an outlier. Pair-wise comparisons of reference areas only detected statistically significant differences between the FFA and FF1 areas, and between FFB and FF1 areas for *Microtendipes* density.

Evaluation of statistical test results relative to spatial trends in sampling area means suggested potential Mine-related effects for total density and *Procladius* density, which were statistically greater in the NF exposure area compared to the reference areas (Table 3-5). *Heterotrissocladius* density was not statistically different in the NF exposure area compared to the pooled reference areas after the removal of an outlier of high density, however, there was overall trend of higher *Heterotrissocladius* density in the NF exposure area. The spatial trends in these variables were consistent with nutrient enrichment resulting from the discharge of Mine effluent to Lac de Gras (Figures 3-5 to 3-9).

Near-field area means were within the estimated normal ranges based on 2007 to 2010 data for all benthic invertebrate summary variables with available normal ranges (Table 3-6). In terms of percentage of the reference area mean, the 2 SD value based on 2007 to 2010 data was smallest for Simpson’s diversity index (22%). The values of 2 SD based on 2007 to 2010 for total richness, dominance, and evenness were between 58% and 60% of the reference area mean; for density variables, 2 SDs were greater than 100%. These results suggest that, even if statistical power is adequate to detect the chosen critical effect size of 2 SD, sensitivity of among-area statistical comparisons tends to be low for density variables, because 2 SD tends to be large, suggesting the significant differences detected by statistical tests are also large.

Table 3-5 Results of Statistical Tests Comparing Sampling Areas in Lac de Gras, 2013

			Exposure Area vs. Reference Area Comparison (NF vs. FFA + FFB + FF1)		Reference Area Comparisons					
					FF1 vs FFA		FF1 vs FFB		FFA vs FFB	
Variable	**Test**	**Overall Comparison *P* (a)**	**% (b)**	***P* (a)**	**% (c)**	***P* (d)**	**% (c)**	***P* (d)**	**% (c)**	***P* (d)**
Total density	ANOVA	*	60	*	14	ns	17	ns	31	ns
Total richness	ANOVA	ns	8	-	6	-	6	-	0	-
Dominance	ANOVA	ns	17	-	12	-	28	-	39	-
Simpson's diversity index	ANOVA	ns	-6	-	3	-	12	-	15	-
Evenness	K-W	*	-30	ns	20	ns	27	ns	46	ns
Bray-Curtis index	ANOVA	ns	-1	-	2	- (e)	7	- (e)	4	- (e)
Procladius density	ANOVA	****	214	****	88	ns	4	ns	91	ns
Pisidiidae density	ANOVA	ns	-31	-	15	-	35	-	20	-
Heterotrissocladius density	ANOVA	** / ns	258	* / -	124	ns / -	165	ns / -	82	ns / -
Microtendipes density	K-W	****	-48	ns	n/a	*	192	*	n/a	ns

Notes: NF = near-field; FF = far-field;% = percent; no./m² = number of organisms per square metre; P = probability of Type I error; ns = not significant; ANOVA = analysis of variance; - = not applicable, K-W = Kruskal-Wallis test.

a) Probability of Type 1 Error: * = <0.1; ** = <0.01; *** = <0.005; **** = <0.001.

b) Percent difference between sampling area means (i.e., exposure area mean compared to pooled mean of the FFA, FFB and FF1 areas).

c) Relative percent difference (RPD) between reference area means (e.g., RPD for FF1 vs. FFA = [(│FF1-FFA│)/(FF1+FFA)/2]*100).

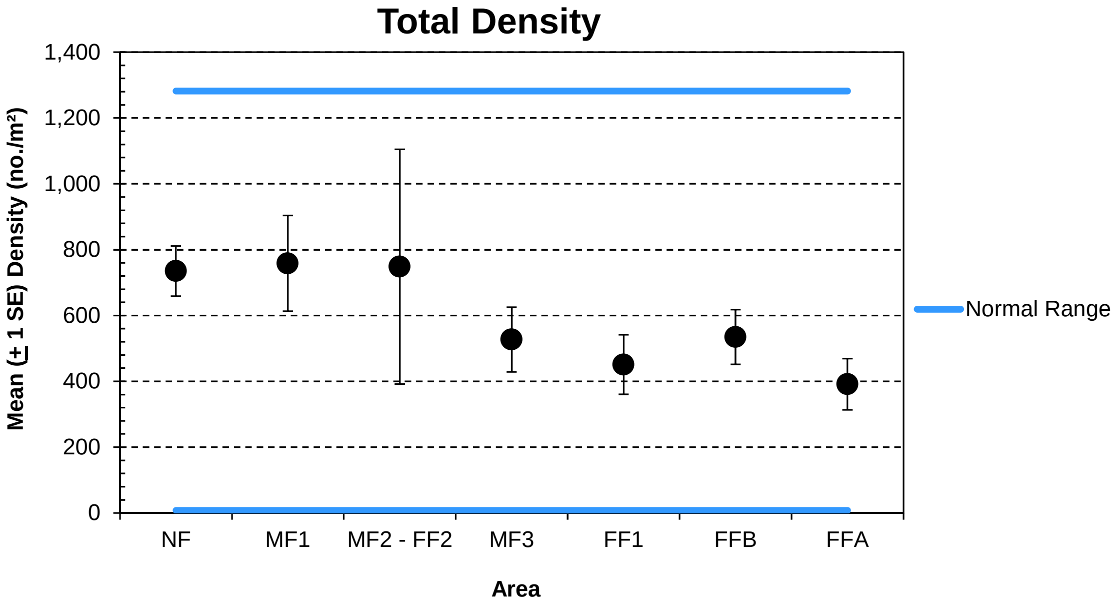
d) Differences between reference areas were considered significant at P<0.1 (Tukey's Honestly Significant Difference test).

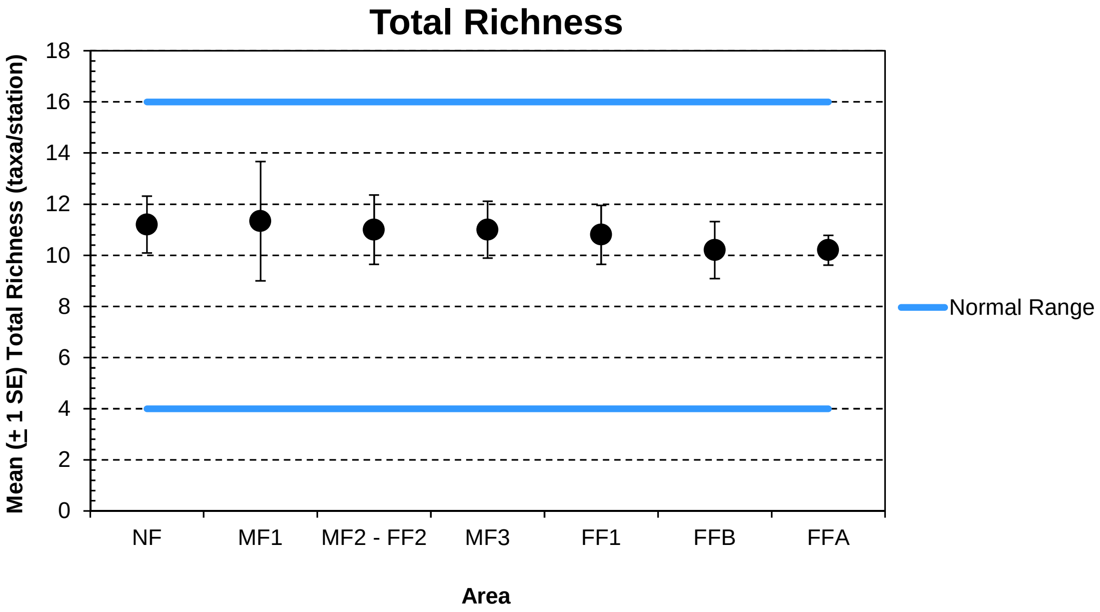
e) Not applicable because Bray-Curtis data already represent differences between reference areas.

Data separated by a "/" indicate changes in significance after the removal of a high outlier from the NF area at station NF-2 identified during analysis.

n/a = not applicable because density value for FFA is zero.

Figure 3-5 Total Invertebrate Density and Richness at Sampling Areas in Lac de Gras, 2013



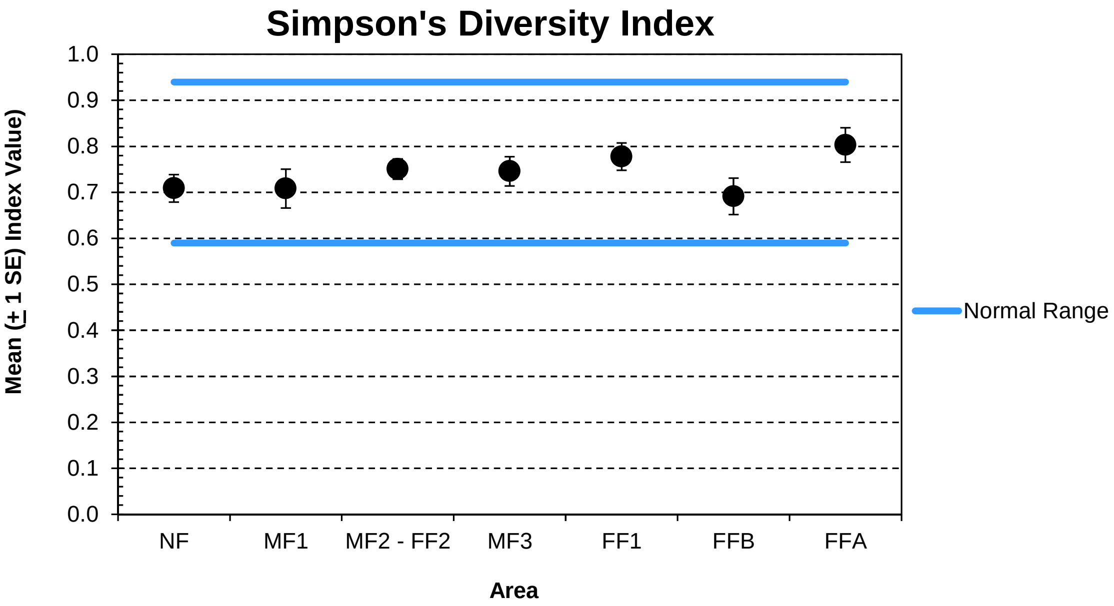


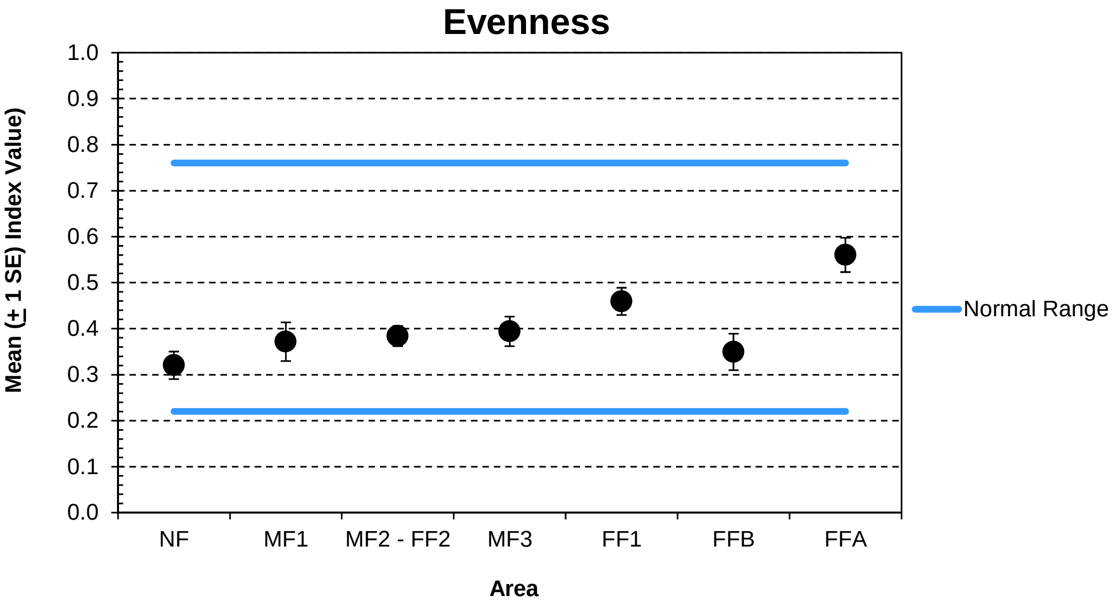
Note:

SE = standard error; no./m² = number per square metre.

Normal range is based on reference area data from the 2007 to 2010 AEMP sampling period.

Figure 3-6 Simpson’s Diversity Index and Evenness at Sampling Areas in Lac de Gras, 2013



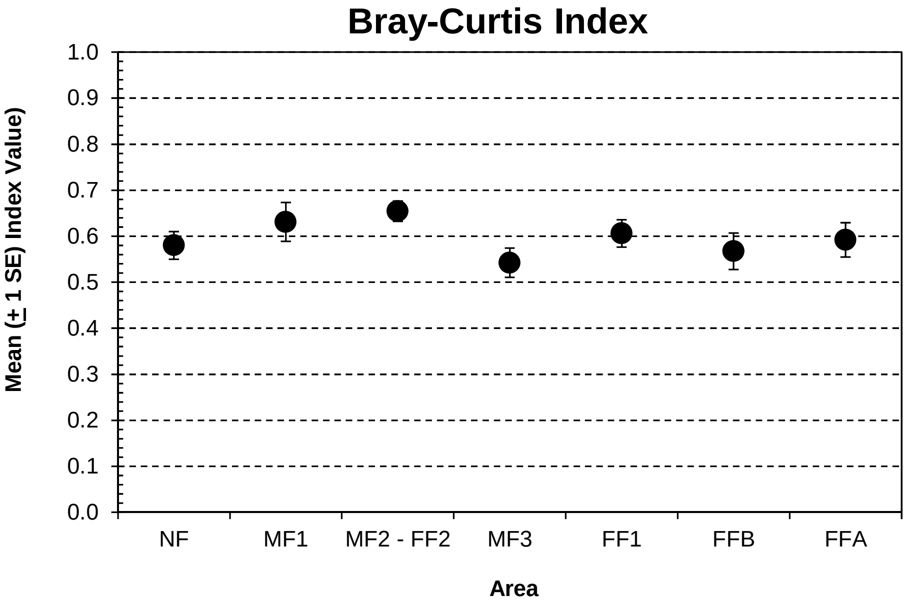


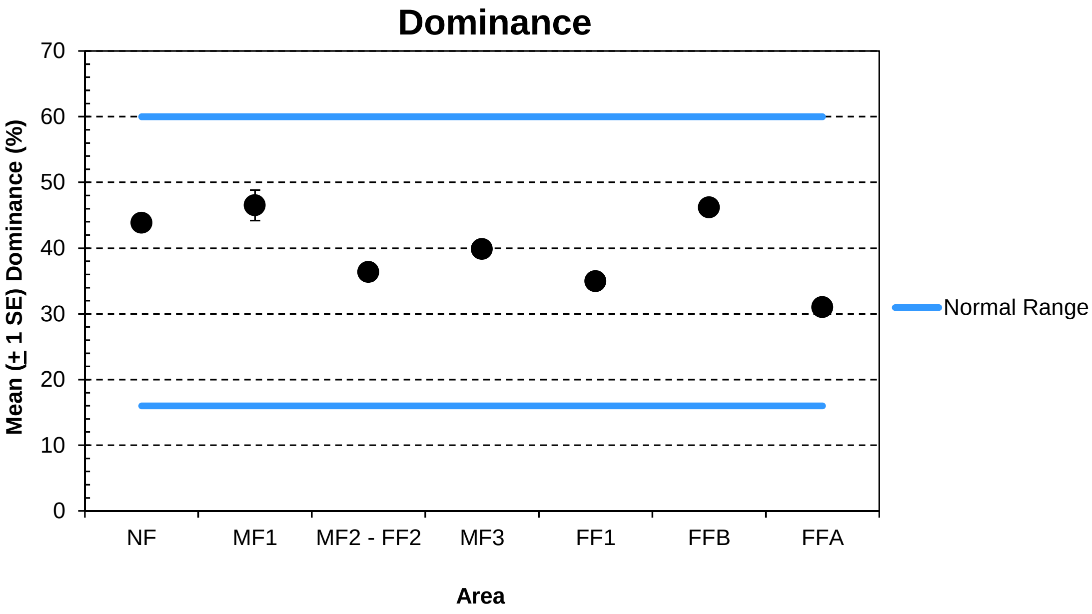
Note:

SE = standard error; no./m² = number per square metre.

Normal range is based on reference area data from the 2007 to 2010 AEMP sampling period.

Figure 3-7 Bray-Curtis Index and Dominance at Sampling Areas in Lac de Gras, 2013





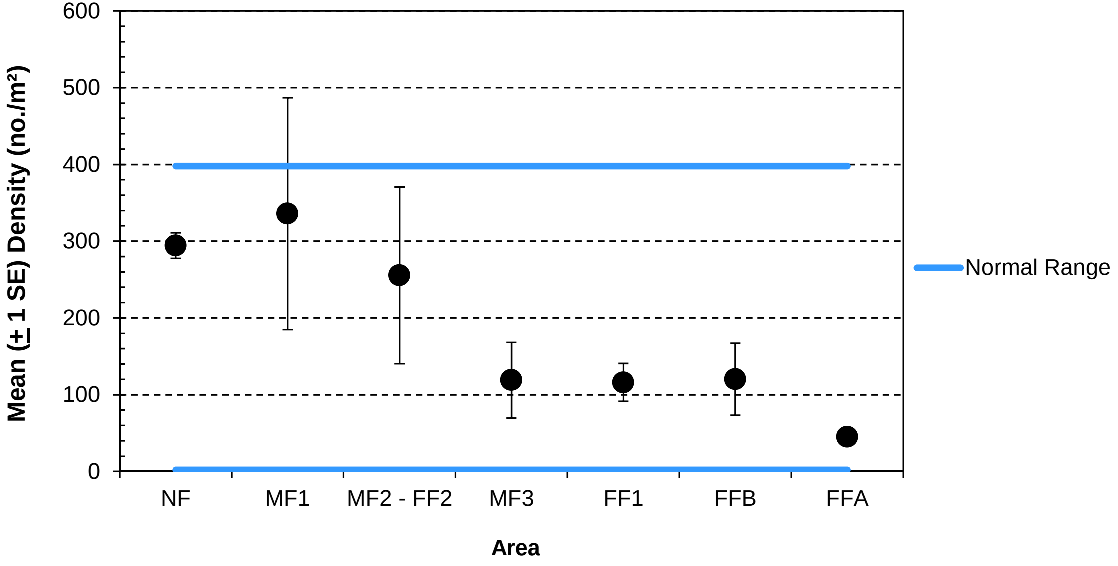
Note:

SE = standard error; no./m² = number per square metre.

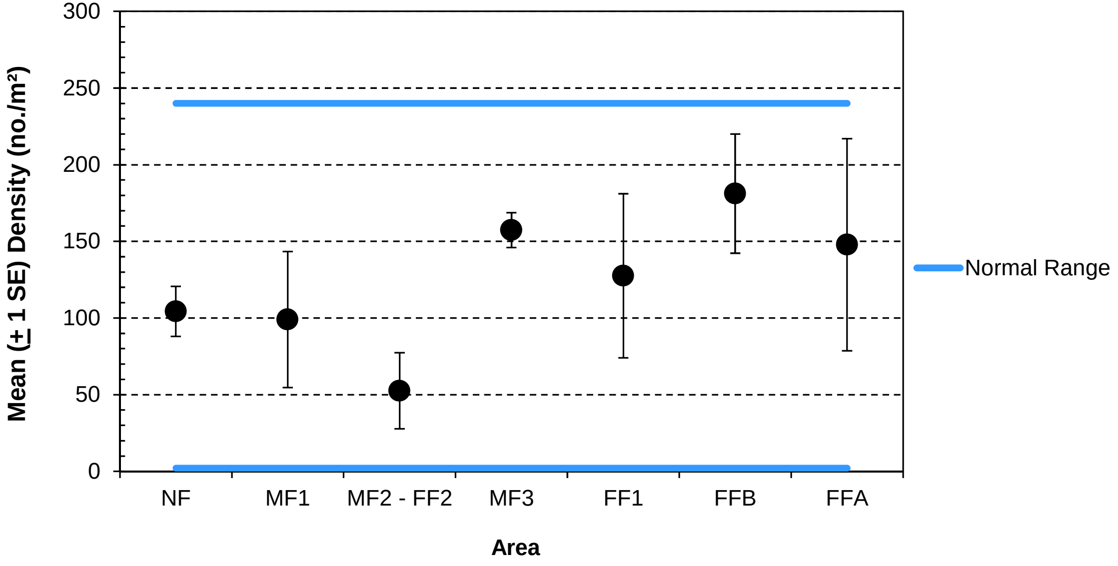
Normal range is based on reference area data from the 2007 to 2010 AEMP sampling period.

No normal range is presented for Bray-Curtis index, because the calculation method differs from the 2007 to 2010 AEMP.

Figure 3-8 Densities of *Procladius* sp. and Pisidiidae at Sampling Areas in Lac de Gras, 2013



***Procladius* Density**



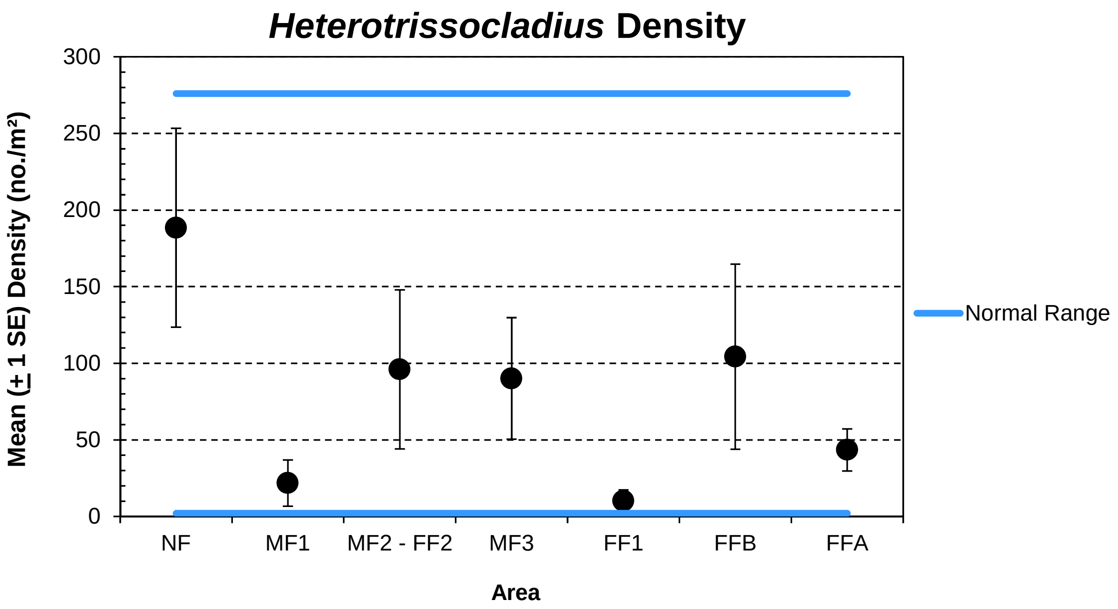
Pisidiidae Density

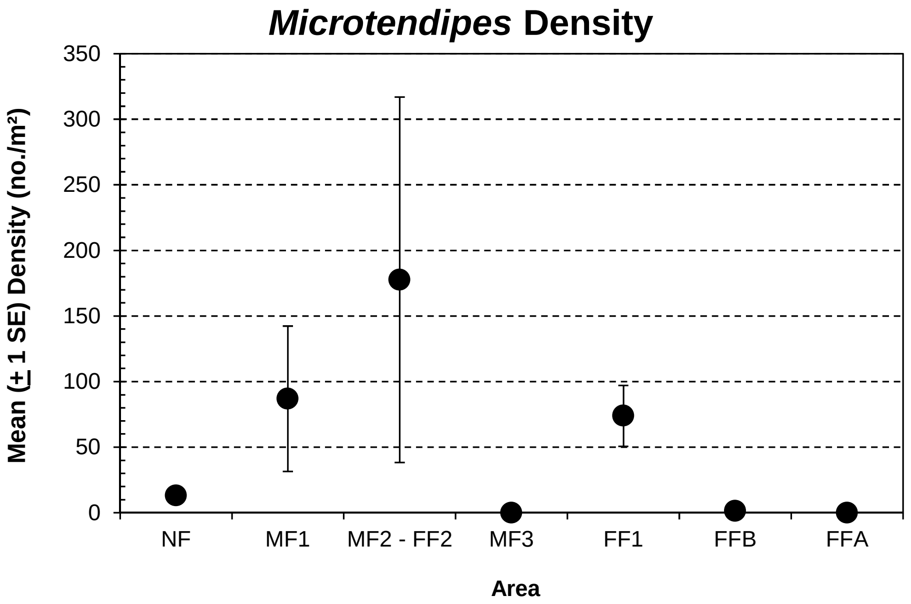
Note:

SE = standard error; no./m² = number per square metre.

Normal range is based on reference area data from the 2007 to 2010 AEMP sampling period.

Figure 3-9 Densities of *Heterotrissocladius* sp. and *Microtendipes* sp. at Sampling Areas in Lac de Gras, 2013





Note:

SE = standard error; no./m² = number per square metre.

Normal range is based on reference area data from the 2007 to 2010 AEMP sampling period.

No normal range is presented for *Microtendipes* density, because it was not included in the AEMP 3 year summary report.

Table 3-6 Comparison of Exposure Area Means to the Normal Ranges for Benthic Invertebrate Variables, 2013

Variable	Pooled Reference Areas (FF1 + FFA +FFB) [(a)]			NF Area
	Mean[(a)]	Normal Range[(b)] (Mean ± 2 SD)	2 SD as% of Mean[(c)]	Mean ± 1 SD[(d)]
Total density (no./m²)	459	0 - 1,282	165	735 ± 170
Total richness (no./taxa)	10	4 - 16	58	11 ± 2
Dominance (%)	37	16 - 60	60	44 ± 6
Simpson's diversity index	0.76	0.59 - 0.94	22	0.71 ± 0.07
Evenness	0.46	0.22 - 0.76	59	0.32 ± 0.02
Bray-Curtis index	0.59	-	-	0.58 ± 0.06
Procladius Density (no./m²)	94	0 - 398	327	294 ± 37
Pisidiidae Density(no./m²)	152	0 - 240	94	104 ± 36
Heterotrissocladius Density (no./m²)	53	0 - 276	355	188 ± 145
Microtendipes Density (no./m²)	25	-	-	13 ± 12

Notes: SD = standard deviation;% = percent; no./m² = number of organisms per square metre.

a) mean calculated using pooled FF1, FFA and FFB data for 2013 (n=15).

b) normal range based on historical reference area data from 2007 to 2010.

c) 2 SD based on 2007 to 2010 as percent of 2013 mean.

d) Near-field area mean ± 1 SD based on 2013 data.

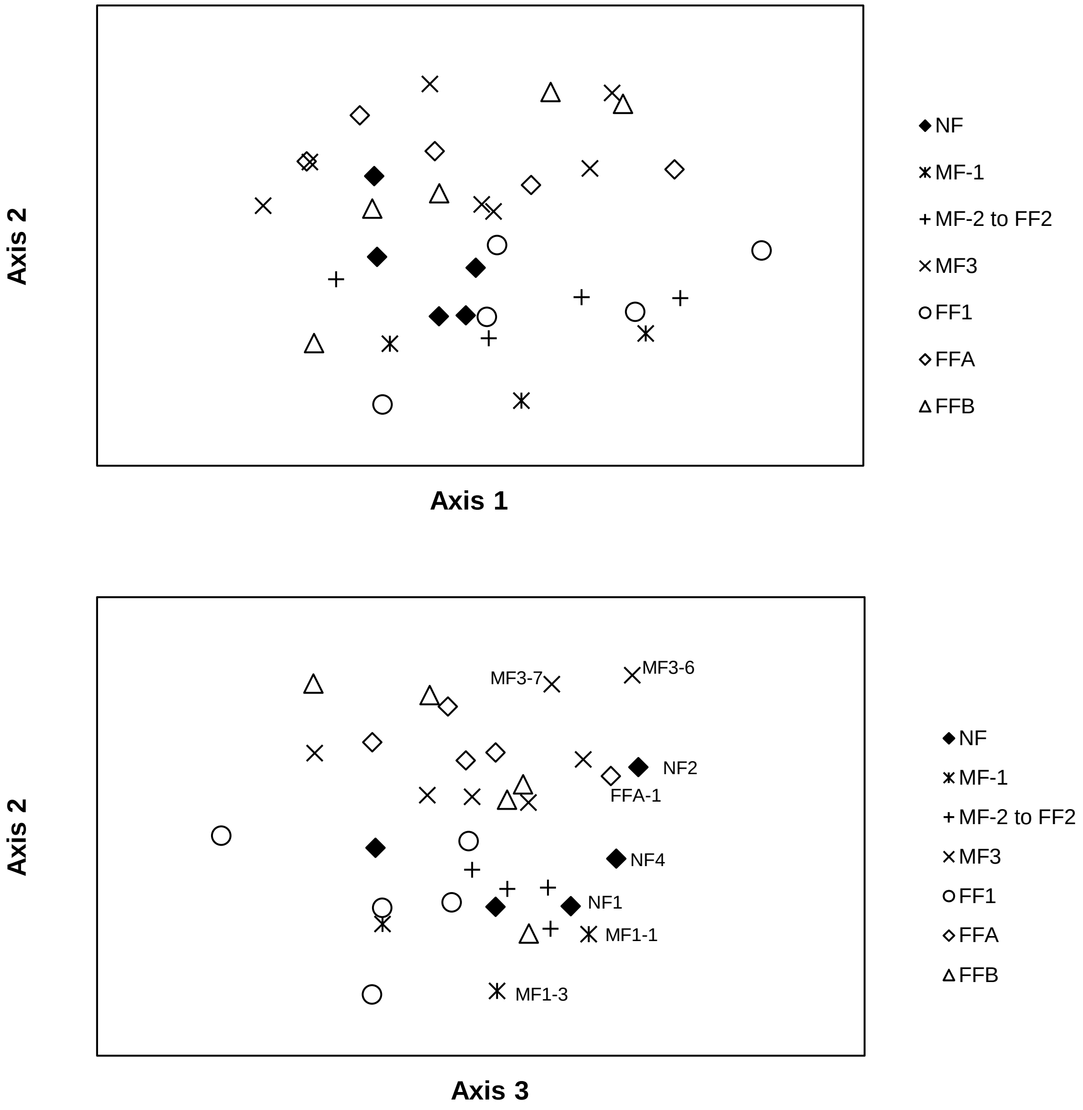
- = normal range not calculated as part of 2007 to 2010 3-year AEMP summary report.

3.6 MULTIVARIATE ANALYSIS

The three-dimensional configuration produced by NMDS run on the 2013 benthic invertebrate data set had a stress value of 0.16, indicating a “fair” fit to the distance matrix based on species abundances, according to stress categories provided by Clarke (1993).

Overall, the results of the multivariate analysis indicate that exposure area benthic invertebrate communities differed slightly from those of the reference areas. The Axis 1 vs. Axis 2 ordination plot showed that reference and exposure areas largely overlapped in terms of community structure (Figure 3-10). The Axis 2 vs. Axis 3 ordination plot showed minor separation of some exposure area stations from the reference area stations, with stations in the NF, MF1 and MF3 areas differing from the reference area stations. Stations NF-2, NF-4, MF1-1, MF1-3, MF3-6 and MF3-7 had communities that were outside the range of reference stations on the ordination plot, in most cases due to higher scores on Axis 3 compared to the reference stations. These results provide some evidence of Mine-related effects on the benthic community; however, the separation of exposure and reference area stations in 2013 was not as pronounced as in previous years.

Figure 3-10 NMDS Ordination Plots of Benthic Invertebrate Stations, 2013



Note: NF = near-field; FF = far-field; MF = mid-field.

3.7 STATISTICAL POWER

The AEMP was designed to detect minimum differences of ±2 SD in benthic community variables among sampling areas, with Type I and II error rates of 0.1, corresponding to a power of 0.9. Retrospective power analysis was done for ANOVA tests that did not detect a significant difference (i.e., total richness, dominance, SDI, Bray-Curtis index, Pisidiidae density and *Heterotrissocladius* density) to evaluate the ability to detect the chosen effect size by statistical tests comparing sampling areas. In the power analysis, Type I and II error rates were set at 0.1, the effect size was set at 2 SD based on the pooled reference area data, and the pooled SD (i.e., square-root of the mean square error term in the ANOVA) was used as the within-group SD. Sample size per area was set at five, which was the number of stations included for each area in the ANOVA analyses.

Results of the power analyses indicate that the level of power achieved by statistical tests was 0.95 for total richness, 0.97 for SDI, 0.90 for Bray-Curtis index, 0.95 for Pisidiidae density and 0.86 for *Heterotrissocladius* density, with the high outlier from the NF removed. As noted previously, even if a power of 0.9 is achieved by among-area comparisons, sensitivity of tests comparing density variables is likely to remain low in terms of the magnitude of differences detected. Nevertheless, results of the retrospective power analyses do not indicate levels of statistical power that would be of serious concern regarding the analysis of AEMP data.

3.8 WITHIN-STATION VARIATION

During the 2013 AEMP program composite samples (six individual Ekman grab samples placed into a single container and processed as a single sample by the taxonomist) were collected at the majority of stations, with discrete samples (i.e., six individual Ekman grabs placed in separate containers and processed separately by the taxonomist). Discrete samples were collected at the following stations:

- Near-field: NF1, NF4;
- Mid-field: MF1-5, MF2-3, MF3-3, MF3-5; and
- Far-field: FF1-1, FF1-5.

The number of subsamples was based on analysis of within-station variation of baseline data, which indicated that variance estimates based on subsample data tended to stabilize at about six subsamples in deep areas of Lac de Gras (Golder 1997).

Within-station variation in a benthic community variable can be summarized by expressing the standard error (SE) of the mean as a percentage (%SE), based on data collected for individual subsamples. A value of the %SE at or below 20% for major benthic community variables (e.g., total abundance and richness) is usually considered a reasonable goal for benthic invertebrate sampling (Elliott 1977). Achieving a %SE of ≤20% is the guideline for number of subsamples to be collected during EEM benthic invertebrate surveys (Environment Canada 2002). A range in %SE of 10% to 40% is considered typical in benthic studies (Merritt and Cummins 1996).

Data for individual subsamples collected in 2013 at eight AEMP stations in Lac de Gras were summarized as the mean, SE and %SE for total abundance and richness (Table 3-7). The range in %SE values for total density (11% to 37%) was similar to the range for richness (8% to 36%), which is atypical of benthic invertebrate data. Usually the range in %SE for density is larger than the range for richness, which has been the case in previous years for the Diavik AEMP. Mean %SE values were 25% and 18% for total density and richness, respectively. This level of within-station variation is indicative of reasonable precision, considering that Lac de Gras is an unproductive sub-Arctic lake, characterized by low benthic invertebrate density and richness. This level of precision suggests that collecting composite samples for benthic invertebrates is sufficient for the needs of this project.

Table 3-7 Within-station Variation in Benthic Community Variables, 2013

Station	Total Density (density/replicate)[a]			Total Richness (taxa/replicate)		
	Mean	SE	% SE	Mean	SE	% SE
NF1	790	175	22	6.5	1.0	15
NF4	536	120	22	4.0	0.4	11
MF1-5	543	161	30	4.3	0.3	8
MF2-3	217	55	25	2.7	0.7	27
MF3-3	493	103	21	4.0	0.6	14
MF3-5	623	205	33	5.8	1.4	24
FF1-1	601	69	11	5.5	0.6	11
FF1-5	587	215	37	4.2	1.5	36
Mean	-	-	25	-	-	18
Median	-	-	24	-	-	15
Minimum	-	-	11	-	-	8
Maximum	-	-	37	-	-	36

- = not applicable; SE = standard error.

% SE = standard error of the mean expressed as the percentage of the mean.

a) Abundance data (no./sample) was converted to density data (no./m²) for each replicate prior to calculation of mean and SE for each station.

3.9 ACTION LEVELS FOR BENTHIC INVERTEBRATES

No action levels were triggered for the benthic invertebrate component of the 2013 Diavik AEMP.

3.10 WEIGHT OF EVIDENCE INPUT

As described in Section 2.5, the results described in the preceding sections also feed into the WOE approach described in the Weight of Evidence report (Golder 2014d). The results of the WOE approach relevant to the benthic invertebrate and related components are described in Section 3.1.6 of the Weight of Evidence report.

4 SUMMARY AND DISCUSSION

The 2013 AEMP benthic invertebrate survey was conducted in Lac de Gras during the late open-water season using methods consistent with those used during previous AEMP field programs. Benthic invertebrate sampling locations changed from previous years based on the updated AEMP Study Design version 3.3 (Golder 2014a). Quality control results indicate that data quality objectives for the benthic invertebrate data were met.

Statistical comparisons among sampling areas detected significant differences between reference areas and the NF exposure area for total density, *Procladius* density and *Microtendipes* density. Total density and *Procladius* density were both statistically greater in the NF area compared to the reference areas. *Microtendipes* density in the NF area was within the range observed in the reference areas and did not differ significantly between the reference areas and NF area. *Heterotrissocladius* density was not significantly different in the NF area compared to the pooled reference areas after the removal of an outlier of high density in the NF area, however, there was an overall trend of higher *Heterotrissocladius* density in the NF area. The spatial trends in these variables acre consistent with nutrient enrichment resulting from discharge of Mine effluent to Lac de Gras.

Multivariate analysis indicated that reference area benthic invertebrate communities differed slightly from those of exposure areas. The results indicate increased densities of some common invertebrates in areas exposed to the Mine effluent. Sediment chemistry variables identified as potentially affected by the Mine do not appear to affect the benthic invertebrate community in the NF exposure area.

The magnitude and type of effects on the benthic community detected during the 2013 AEMP are mostly consistent with effects detected in 2010 and 2011 with benthic invertebrate community variables showing effects consistent with mild nutrient enrichment. None of the potentially toxic water substances of interest with increased concentrations related to the Mine discharge have reached AEMP benchmarks or known toxicity thresholds in 2013 (Golder 2014b), also suggesting that effects in the form of chemical toxicity are unlikely.

In 2013 the three reference areas (FFA, FFB, and FF1) were statistically similar for all benthic invertebrate variables with the exception of *Microtendipes* density, which was statistically greater in FF1 area compared to the FFA and FFB areas. This differs from 2011, when FF1 area supported a benthic community of higher richness, total density, *Procladius* sp. density and Pisidiidae density, and lower dominance, *Heterotrissocladius* sp. and *Abiskomyia* sp. density compared to the FFA and FFB areas.

5 CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

This report presents the analysis of benthic invertebrate data collected during the 2013 AEMP field program. Results of this analysis indicate that no action levels were triggered for the benthic invertebrate component of the 2013 Diavik AEMP. Overall, differences in the benthic invertebrate community in the NF area are consistent with nutrient enrichment.

The above conclusions are based on the following findings:

- Statistically greater total density and *Procladius* density in the NF area compared to reference areas, which suggest mild nutrient enrichment. *Heterotrissocladius* density was also higher in the NF area compared to reference areas, which was not statistically significant after the removal of a high outlier in the NF area.
- Results of multivariate analysis, which indicate a slight difference in the benthic invertebrate community in the exposure areas compared to the reference areas.

5.2 RECOMMENDATIONS

The following recommendation is provided:

- Collect composite samples at all stations based on the low variability among replicate samples observed in 2013 and previous studies. This recommendation will be implemented during the next benthic invertebrate community survey, which is scheduled to occur in 2016.

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7 CLOSURE

We trust the information in this report meets your requirements at this time. If you have any questions relating to the information contained in this report please do not hesitate to contact the undersigned.

GOLDER ASSOCIATES LTD.

Report prepared by:	**Report reviewed by:**
Original Signed	*Original Signed*
André Bachteram, M.Sc. Aquatic Biologist	Zsolt Kovats, M.Sc, Associate, Senior Aquatic Ecologist

AMB/ZK/xx

APPENDIX A

QUALITY ASSURANCE AND QUALITY CONTROL METHODS AND RESULTS

Introduction

The quality assurance (QA) and quality control (QC) program for the Diavik Diamond Mines Inc. (DDMI) Aquatic Effects Monitoring Program (AEMP) is described in the Quality Assurance Project Plan (QAPP) version 2.0 submitted to the Wek’èezhìi Land and Water Board (Golder 2013). This appendix provides a summary of QA/QC information relevant to the 2013 AEMP benthic invertebrate survey.

Field and Laboratory Operations

Field operations during the 2013 benthic invertebrate program incorporated QA/QC functions required by the QAPP (Section 2.7 in Golder 2013).

In the laboratory, benthic invertebrate samples were processed according to standard protocols consistent with those required for metal mining environmental effects monitoring (Environment Canada 2002). Benthic invertebrate sample processing included re-sorting 10% of the total number of samples collected to evaluate invertebrate removal efficiency, as well as preparation of a reference collection. Subsampling was not necessary because all samples were small and were thus entirely sorted. Therefore, subsampling QC requirements described in the QAPP do not apply to the 2013 benthic invertebrate data set. The reference collection is maintained by the taxonomist (J Zloty, Summerland, British Columbia) and will be updated each year, as new invertebrate taxa are identified from Lac de Gras.

Invertebrates were re-sorted in 8 of 74 samples collected during the 2013 field program. The data quality objective for benthic invertebrate sample sorting under the AEMP is a minimum sorting efficiency of 90% (Golder 2013). If this level of sorting efficiency is not achieved, all samples must be re-sorted until such a level is attained. Invertebrate sorting efficiency ranged from 98.7% to 100% in all re-sorted samples (Table A-1), which satisfies the data quality objective. Therefore, the quality of the 2013 benthic invertebrate data was considered acceptable.

Data Management and Analysis

Data were received from the taxonomist in electronic format (Excel spreadsheet) and were added to the project data management system. The raw data were reviewed upon receipt to identify any unusual invertebrate sample labels, or abundances identified as extreme values based on initial visual assessment of the raw abundance data. As a result of this step, the taxonomist was contacted regarding one unusual sample label and the appropriate correction was made.

Table A-1 Quality Control Data for Re-sorted Samples, 2011 AEMP

Sample	Total Missed	Total in Sample	Percent Missed	Sorting Efficiency
MF1-4-B	0	11	0	100
MF1-2	1	116	0.9	99.1
MF3-1-E	0	16	0	100
MF3-4	0	69	0	100
FFB-4-A	0	5	0	100
FFB-5	0	73	0	100
FF2-3-F	0	19	0	100
FFA-3-E	2	149	1.3	98.7

During data analysis and manipulation, a backup worksheet was generated before each major operation to prevent loss of data and allow re-tracing of analysis steps. Accuracy of calculations was verified by running appropriate logic checks. Benthic invertebrate data and results of data analysis are stored in printed and electronic format with appropriate documentation, to allow the analysis to be reproduced, if necessary.

APPENDIX B

BENTHIC INVERTEBRATE DATA (RAW DATA)

These data are provided as an Excel file in a "Raw Data Folder" on the compact disc, rather than in hard copy form.

APPENDIX V

FISH REPORT

FISH REPORT
IN SUPPORT OF THE
2013 AEMP ANNUAL REPORT
FOR THE DIAVIK DIAMOND MINE, NT

Submitted to:
Diavik Diamond Mines (2012) Inc.
P.O. Box 2498
5007 – 50th Avenue
Yellowknife, Northwest Territories
X1A 2P8

Distribution:
1 Copy – Diavik Diamond Mines (2012) Inc., Yellowknife, NT
1 Copy – Golder Associates Ltd., Calgary, AB
3 Copies - Wek'èezhìi Land and Water Board, Yellowknife, NT

March 2014
13-1328-0001

Doc. No. RPT-1300 Ver. 0
PO No. DO2614 Line 1

EXECUTIVE SUMMARY

In 2013, Diavik Diamond Mines (2012) Inc. (DDMI) completed the field component of its Aquatic Effects Monitoring Program (AEMP), as required by Water Licence W2007L2-0003. The small-bodied fish survey is a component of the AEMP that is to be conducted every three years. The main goal of the fish survey is to assess the effects of effluent released from the Diavik Diamond Mine (Mine) on fish health and body burdens of metals. This report presents results of the 2013 fish survey.

The 2013 monitoring results suggest that small-bodied fish in Lac de Gras may be exhibiting a Mine-related toxicological effect. This is contrast to a nutrient enrichment effect seen in previous surveys. This conclusion is based on the following findings:

- juvenile (age-1+) Slimy Sculpin were significantly shorter and lighter in the near-field (NF) and far-field (FF2) exposure areas, and they had a significantly lower condition factor and a significantly smaller relative liver size in the NF area, relative to the reference areas;
- adult male Slimy Sculpin were significantly shorter and lighter in the NF and FF2 exposure areas, and they displayed the pattern of smaller livers (though not statistically significant); and
- adult female Slimy Sculpin were significantly shorter and lighter in the NF exposure area, exhibited a similar pattern of smaller livers (though not statistically significant), and had relative gonad sizes that were significantly smaller in the NF exposure area relative to the reference areas.

Metals found to be elevated in Slimy Sculpin in the NF exposure area relative to the reference areas included bismuth, lead, uranium, thallium, and strontium. Neither body burdens of metals nor water concentrations of these metals are near levels known to cause toxicity. Although sufficient differences in fish health endpoints were observed between the exposure and reference areas to indicate that the Mine is having a toxicological effect on sculpin in the NF exposure area, the same response could be expected in a low-nutrient environment. In addition, the colder water found in the exposure areas could have accounted for the smaller fish observed. The response observed in the NF and FF2 exposure areas did not extend to the mid-field (MF) exposure area.

The responses observed in fish health endpoints are not consistent with the findings of the other biological components of the AEMP and are not consistent with what was observed during previous fish surveys. It will be necessary to confirm the response before we can conclude that a toxicological effect has occurred. The fish data indicate that an effect equivalent to Action Level 1 of the Response Framework has been reached, and as such the effects should be confirmed during the next fish survey in three years' time.

LIST OF ACRONYMS

AEMP	Aquatic Effects Monitoring Program
ALS	ALS Environmental Laboratories
ANCOVA	analysis of covariance
ANOVA	analysis of variance
CPUE	catch-per-unit-effort
DDMI	Diavik Diamond Mines (2012) Inc.
DFO	Fisheries and Oceans Canada
DL	detection limit
FF	far-field
GSI	gonadosomatic index
K	Condition Factor
LSI	liversomatic index
Mine	Diavik Diamond Mine
n	number of fish samples for each parameter
NF	near-field
NT	Northwest Territories
QA/QC	quality assurance/quality control
SD	standard deviation
SOP	Standard Operating Procedure
SR	studentized residuals
USEPA	United States Environmental Protection Agency
UTM	Universal Transverse Mercator
vs.	Versus
WLWB	Wek’èezhìi Land and Water Board
WOE	weight-of-evidence
YOY	young-of-the-year

LIST OF UNITS

<	less than
>	greater than
%	Percent
°C	degrees Celsius
µg/g	micrograms per gram
µs/cm	microSiemens per centimetre
µg/L	micrograms per litre
g	Gram
m	Metre
mg/L	milligrams per litre
mL	Millilitre
mm	Millimetre

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1 INTRODUCTION AND OBJECTIVES

1.1 BACKGROUND

In 2013, Diavik Diamond Mines Inc. (DDMI) completed the field component of its Aquatic Effects Monitoring Program (AEMP), as required by Water Licence W2007L2-0003 (WLWB 2007). This report presents the analysis of the fish survey data collected during the 2013 field program, which was carried out by Golder Associates Ltd. (Golder) according to the AEMP Study Design Version 3.0 (Golder 2011a). Details on methodology are provided in Section 2.

The assessment of effects was based on the updated Version 3.3 Study Design (Golder 2014a), which was approved by the Wek'èezhìi Land and Water Board (WLWB) on February 19, 2014 (WLWB 2014). Section 3 provides results of the assessment, while Section 4 provides a discussion of the results. Conclusions, together with recommendations for program changes or enhancements, are provided in Section 5.

1.2 OBJECTIVES

The objective of the fish survey was to assess the effects of effluent released from the Diavik Diamond Mine (Mine) on fish in Lac de Gras. Fish data were analyzed to determine whether there were any differences in fish population health and body burdens of metals between exposure and reference areas.

1.3 SCOPE AND APPROACH

The fish survey was focused on Slimy Sculpin (*Cottus cognatus*). Surveys of Slimy Sculpin have been conducted on three occasions: in 2004 (Gray et al. 2005), in 2007 (Golder 2008a) and in 2010 (Golder 2011b). This report presents the results of the fourth Slimy Sculpin survey conducted under DDMI's AEMP.

The fish survey for the annual report is based on a control-impact design using statistical analysis to detect differences among sampling areas. Multiple locations within an area were sampled. Temporal analyses and an assessment of trends over time will be provided in the next three-year summary report (to be submitted by October 15, 2014).

Fish population health effects were determined by comparing selected endpoints used to assess the status of fish populations (i.e., size-structure, size, growth, energy stores) in areas influenced by mine effluent (i.e., exposure areas) to fish in reference areas. Metal concentrations in fish from the exposure area were compared to metal concentrations in fish from the reference area to assess the exposure of fish to metals.

The magnitude of the effect on fish population health will be assessed by comparing fish population health endpoints and metal concentrations in exposure areas to background values. Background values for Lac de Gras are those that fall within the *normal range*, which is defined as the reference area mean ± 2 standard deviations. Values that exceed the normal range are exceeding what would be considered natural levels for Lac de Gras. Although unnatural for this lake, these values do not necessarily represent levels that are harmful. The importance of effects observed on fish health endpoints was determined according to the Action Level classification defined in Golder (2014a).

2 METHODS

2.1 SPECIES

Slimy Sculpin was selected as the sentinel fish species for the AEMP. Based on previous fish inventory results and the 2007 and 2010 AEMP small bodied fish survey (Golder 2008, Golder 2011b), Slimy Sculpin is the only small-bodied fish species present in Lac de Gras in sufficient numbers to be captured with a reasonable amount of effort. Rationale for the use of Slimy Sculpin as a sentinel species consists of the following:

- Slimy Sculpin are a bottom-dwelling species that feed on aquatic invertebrates. They are a primary food source for species such as Lake Trout. Effects caused by changes to the benthic invertebrates or direct effects as a result of effluent exposure are more likely to be detected early in bottom-dwelling small fish such as sculpin than in larger predatory fish that move throughout the lake.
- Slimy Sculpin have very small home ranges, thereby increasing the probability that the measured responses in sculpin reflect the environmental conditions where they were captured.
- Slimy Sculpin are relatively simple to collect and sufficiently abundant that mortality as a result of the surveys is not expected to adversely affect the sustainability of the Slimy Sculpin population.
- Slimy Sculpin are recognized by Fisheries and Oceans Canada to be a useful sentinel fish species for monitoring northern Canadian lakes (Arciszewski et al. 2010).

2.2 TIMING

The field sampling portion of the fish survey was conducted from August 27 to September 10, 2013. The fish survey was conducted in late-summer to allow time for fish gonads to develop following the spring spawning event. This timing is similar to that of the 2007 fish field survey. In 2010, the fish field survey was conducted at the beginning of July, immediately after ice-off, in an attempt to capture fish prior to spawning. Pre-spawning fish are more suitable for fish health investigations because they have larger reproductive organs (gonads) that make identification of sex and state-of-maturity easier to determine. The fish survey in 2010 found that the Slimy Sculpin had already spawned, implying that they spawn under ice. Post-spawning fish have very small and at times underdeveloped gonads. Moreover, the small gonads of post-spawning fish increase the risk of measurement error, making differences between populations more difficult to detect. As such, the timing of the 2013 fish survey returned to the fall to allow as much time as possible for gonads to develop (regenerate) following the spring spawning.

2.3 SAMPLING AREAS

The fish survey was conducted along the shorelines of five general areas of Lac de Gras. These areas, which were defined by distance from the diffuser, consisted of the near-field (NF) exposure area, mid-field (MF) exposure area (MF3), the far-field (FF) exposure area (FF2), and two reference areas (FFA and FF1) (Figure 2-1; Table 2-1). The selection of fishing sites within each area was based on:

- the proximity of Slimy Sculpin habitat to the designated AEMP water quality, sediment quality, plankton, and benthic invertebrate sampling locations;
- Slimy Sculpin abundance; and
- health and safety concerns (e.g., shoreline not suitable for wading, limited boat access to safe locations, relative exposure to wind and wave action).

Table 2-1 Fish Sampling Locations, 2013

Sampling Area	UTM coordinates (NAD 83, Zone 12W)				Length of Shoreline (m)
	Start		End		
	Easting	Northing	Easting	Northing	
NF	535820	7152308	535384	7153267	375
	535298	7153445	535539	7153541	290
FF2	541334	7160178	541609	7160079	305
	540719	7158385	540692	7158300	115
MF3	533323	7149510	533641	7149200	295
	533300	7148840	533050	7148835	840
FF1	522009	7160323	521968	7160319	165
	527549	7159328	527730	7159293	215
FFA	506271	7157312	506297	7157355	60
	505782	7158193	506129	7158449	493

UTM = Universal Transverse Mercator; NAD = North American Datum; m= metre; NF = near-field; MF = mid-field; FF = far-field.

LEGEND

★ DIFFUSER

EXPOSURE

- ● NEAR-FIELD
- ● MID-FIELD 3
- ● MID-FIELD 1
- ● FAR-FIELD 2; MID-FIELD 2

REFERENCE

- ▲ FAR-FIELD 1
- ▲ FAR-FIELD A
- ▲ FAR-FIELD B

SHORELINE BACKPACK ELECTROFISHING

- — FAR-FIELD 1
- — FAR-FIELD 2
- — FAR-FIELD A
- — NEAR-FIELD
- — MID-FIELD 3

▨ DIAVIK FOOTPRINT

🟦 WATERBODY

REFERENCE

HYDROGRAPHY DATA OBTAINED FROM CANVEC © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 12 DATUM: NAD 83

5 0 5
SCALE 1:175,000 KILOMETRES

PROJECT

DIAVIK DIAMOND MINES INC.

TITLE

SMALL-BODIED FISH SURVEY SAMPLING AREAS, 2013 AEMP

Golder Associates

PROJECT		13-1328-0001	FILE No.	
DESIGN	TD	18 Feb. 2010	SCALE AS SHOWN	REV. 0
GIS	JC	20 Mar. 2014	FIGURE: 2-1	
CHECK	TD	20 Mar. 2014		
REVIEW	CF	20 Mar. 2014		

I:\2011\11-1328\11-1328-0038\Mapping\MXD\2013AEMP\FINAL\Fig2-1_2013_AEMP_ Small_Bodied_Fish_Health_Sampling_Areas_20140225_Final.mxd

2.4 SAMPLE SIZE

For the lethal assessment (which includes a detailed external and internal examination of the sacrificed fish), the target sample size was between 20 to 30 adult male, 20 to 30 adult female and 20 to 30 juvenile Slimy Sculpin at each of the sampling areas. An additional 50 Slimy Sculpin from each study area were targeted for a non-lethal assessment (which involved measuring length and weight).

Sculpin collected from various sites in Lac de Gras have been found to be infested with the parasite *Ligula intestinalis* (Golder 2008a, 2011b). Parasitized fish may have less energy available to allocate to reproduction[1]; therefore, inclusion of these fish could increase the variability within a given population. Additionally, by removing this source of variability, the power of the study to detect mine-related effects could be increased. Golder (2011b) demonstrated that fish infested with *L. intestinalis* can typically be distinguished from those that are parasite-free using a visual external assessment; therefore, an attempt was made to target uninfected fish only. Since many fish were infected with *L. intestinalis*, the number of fish captured and processed to provide the foregoing target sample size was considerably greater.

2.5 FIELD METHODS

2.5.1 Supporting Environmental Information

Supporting environmental information recorded at all sampling areas included a detailed habitat description and *in situ* field water quality variables. A YSI Professional Plus handheld multi-parameter meter was used to measure the following water quality variables: water temperature, dissolved oxygen and specific conductivity. Dissolved oxygen data were compared to water quality guidelines (CCME 1999 with updates).

Temperature data loggers (Onset HOBO Data Loggers Tidbit V2 Water Temperature Data Logger – UTBI-001) were deployed at each sampling area to assess differences in water temperature regimes among the sampling areas. Temperature data loggers were set to measure water temperature on an hourly basis (i.e., 24 hourly readings per day). Water temperatures were recorded from May 2, 2013, to September 9, 2013, which is the time encompassing the temperature range of the principal period of growth for fish in this area (Coker et al. 2001). Differences in temperatures at each area were assessed by evaluating the change in temperature (delta, Δ) between the average reference area temperature, and each of the exposure area temperatures.

---

[1] Golder (unpublished) has found that parasitized Slimy Sculpin (*Cottus cognatus*) have significantly smaller gonads for a given age and/or size.

2.5.2 Fish Collection

Within the littoral zone of lakes, Slimy Sculpin are usually found in areas with coarse gravel or cobble substrate (McPhail 2007). Therefore, fishing took place in shallow shoreline habitat dominated by small rock substrate (Photograph 2-1; Figure 2-1). Slimy Sculpin were captured by backpack electrofishing (Smith-Root LR-24 and 12B, Vancouver, Washington, USA) by certified field staff, following the detailed methods set out in the Golder Technical Procedure TP 8.1-3, Fish Inventory Procedure (Golder, unpublished file information) and TP 8.16-0, Fish Health Assessment (Golder, unpublished file information). Large anode rings (18-inch diameter) were used to mitigate the effects of low conductivity in Lac de Gras on electrofishing efficiency. The fishing effort was conducted while adhering to the conditions set out in the Fisheries and Oceans Canada (DFO) Licence to Fish for Scientific Purposes (Licence #S-1314-3039-YK).

The following sampling details were recorded during each sampling event:

- sampling date
- start and end times;
- Universal Transverse Mercator (UTM) co-ordinates for start and end positions;
- length of shoreline sampled and depth of sampling;
- fishing effort (seconds);
- backpack electrofishing settings;
- general habitat descriptions; and
- number and species of fish captured and observed.

Fish were held in buckets filled with ambient, well-oxygenated water before processing. Non-target species and Slimy Sculpin determined to be infected with *L. intestinalis* were enumerated and released at the area of capture unharmed. Slimy Sculpin retained for the health assessment were transported live in aerated buckets from the field back to the Diavik laboratory for processing.

Photo 2-1 Electrofishing at Area MF3 in Lac de Gras, September 2013

2.5.3 Fish Processing

Captured fish were enumerated by species and examined externally. Length (± 1 mm) and total fresh body weight (± 0.001 g wet weight) were recorded on all captured Slimy Sculpin. External observations of fish features (i.e., eyes, gills, pseudobranchs, thymus, skin, body form, fins and opercula) were recorded. Any feature that appeared abnormal (e.g., wounds, tumours, fin fraying, gill parasites or lesions) were noted and photographed.

Following the enumeration and external observations, Slimy Sculpin to be included in the lethal survey were sacrificed by blunt force trauma to the head followed by cervical dislocation. Sex and state of maturity were recorded, and the following internal organs were examined for abnormalities: spleen, gall bladder, kidney and gonads (Photo 2-2). The percent estimate of mesenteric fat covering the gastrointestinal tract of the fish was recorded as well as the occurrence of any visible parasites. Gonads and liver were removed, and their wet weight was recorded (± 0.001 g). The stomach was removed and an estimate of stomach fullness (as a percentage of the stomach that was filled) was made. Once the dissection was complete, the eviscerated weight (i.e., carcass weight) was recorded.

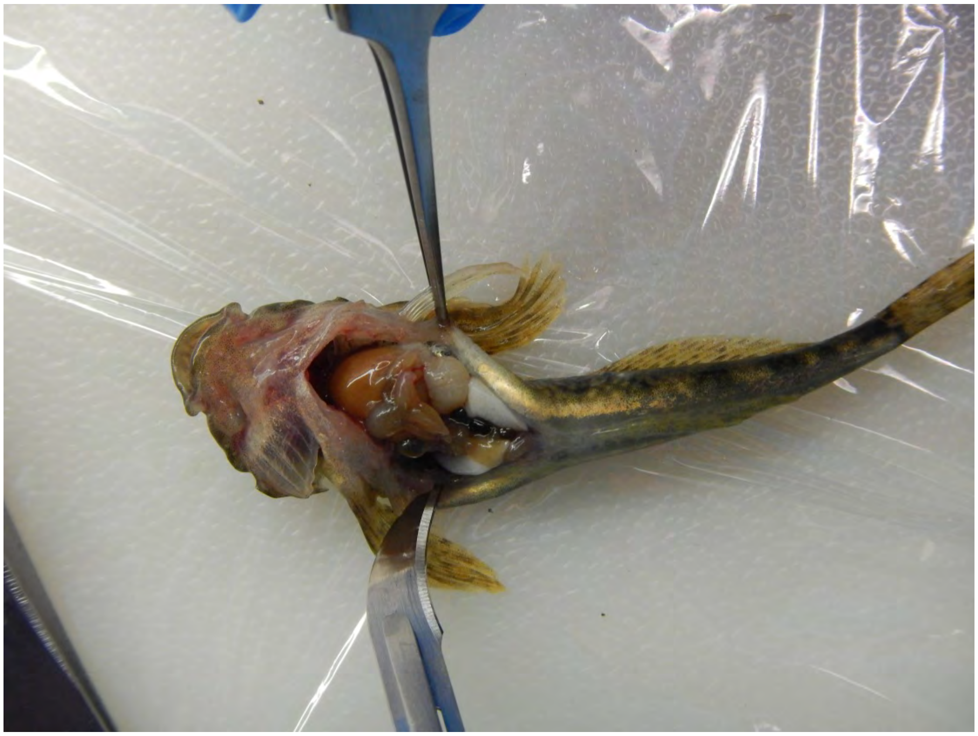


Photo 2-2 Slimy Sculpin Internal Organ Examination, September 2013

The gonads of males (testes) and of females (ovaries) were preserved in 10% buffered formalin for laboratory analysis. A subset of gonad samples preserved in formalin was sent for histopathological analysis to confirm the stage of development of the fish and to assess pathology. Stomach contents were collected and preserved in 10% buffered formalin and a subset were sent for stomach content analysis. As Slimy Sculpin lack scales, sagittal otoliths were collected as the primary aging structure. Otoliths were not examined for this survey and, therefore, were archived for possible future use. Following the internal examination, the carcass, which included the liver, was wrapped in plastic wrap and placed in a pre-labelled Zip Lock bag and frozen for shipment to the analytical laboratory.

2.6 LABORATORY METHODS

2.6.1 Histology

Gonads for which maturity was difficult to assess were placed in individually-labelled 5-mL cryovials and preserved in 10% buffered formalin. Samples were shipped to Dr. Mac Law at North Carolina State University (Raleigh, North Carolina, USA) for sectioning and histological analysis. Gender, level of sexual maturity and visible abnormalities in relation to reproductive development of Slimy Sculpin were assessed and photographed (Photograph 2-3). The gonad development categories utilized are outlined in Appendix A.

In instances where histology results were inconclusive, the size of the gonad was used to help estimate the maturity of the fish. For example, fish developing to spawn during the next spawning period would have relatively large gonads, whereas immature fish would have relatively smaller gonads.

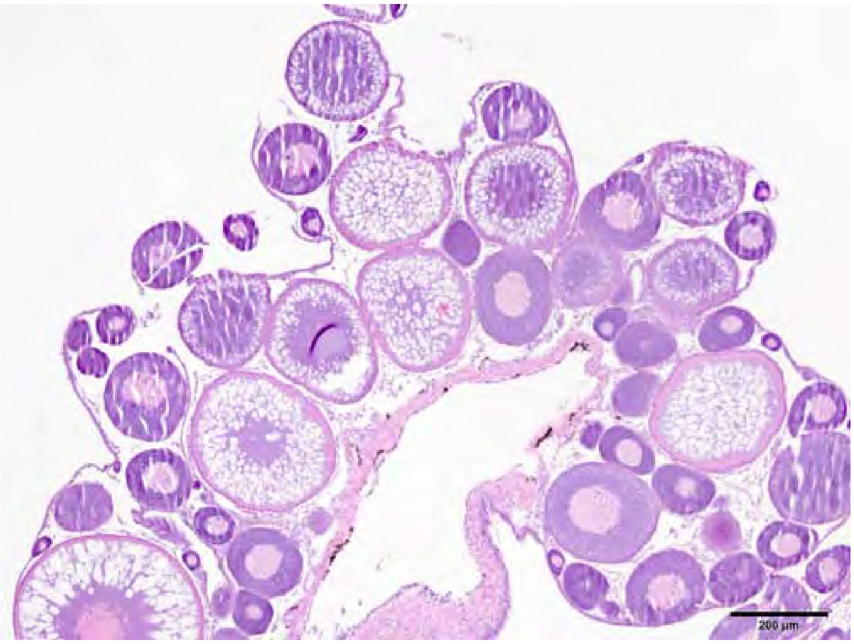


Photo 2-3 Histology Slide from a Stage 3 Slimy Sculpin Female, 2013

2.6.2 Stomach Content

Slimy Sculpin stomachs with an estimated fullness greater than or equal to (≥) 50% were sent to Dr. Jack Zloty (Summerland, BC), for enumeration and taxonomic identification of contents. Organisms within the stomach were identified to the genus level using recognized taxonomic keys. Organisms that could not be identified to the desired taxonomic level were reported as ‘other’. An estimate of taxon composition within each individual stomach was also determined. From these estimates, the relative percent density of each taxon in stomachs from fish for each area was calculated.

2.6.3 Fish Tissue Chemistry

Eight composite samples of fish captured at each of the four study areas were submitted for the analysis of metals. The samples were composed of fish carcasses from the health assessment. Therefore, gonads and stomachs were not included with the carcasses as they were required for separate analyses (Sections 2.6.1 and 2.6.2). The fish making up a composite sample were of the same sex and size class (Table 2-2). Four male and four female composite samples from each area were submitted for analysis. Samples were composited to meet the minimum sample volume requirement of 5 g wet weight (g ww) from each area. Samples were analyzed by ALS Canada Ltd. (ALS), Burnaby, British Columbia, for metals[2] listed in Table 2-3. In addition, five of the samples were randomly selected after the initial ALS analysis and sent to Flett Research Ltd., Winnipeg, Manitoba, for quality control (QC) of the mercury results.

---

[2] In the 2013 Fish Report, “metal” includes metalloids such as arsenic, and non-metals such as selenium.

Table 2-2 Slimy Sculpin Samples Used in the Fish Tissue Chemistry Analysis, 2013

Sampling Area	Sex	Sample Number	Number of Fish in Sample	Mean Total Weight (g)	Mean Length (mm)
NF	Male	1	3	2.558	69
		2	4	1.943	62
		3	4	1.427	57
		4	5	0.816	48
	Female	5	3	2.025	63
		6	5	1.567	58
		7	4	1.275	53
		8	5	0.867	49
FF2	Male	1	3	2.303	66
		2	3	1.900	62
		3	4	1.427	57
		4	6	0.903	49
	Female	5	3	2.143	66
		6	4	1.844	60
		7	4	1.199	55
		8	5	0.838	48
MF3	Male	1	3	4.759	83
		2	3	3.252	74
		3	4	2.224	67
		4	5	0.906	49
	Female	5	3	3.361	76
		6	3	2.585	70
		7	4	1.577	58
		8	5	0.852	48
FF1	Male	1	2	3.141	73
		2	3	1.870	61
		3	4	1.450	58
		4	5	1.120	53
	Female	5	2	3.915	77
		6	3	1.850	60
		7	4	1.302	56
		8	6	0.767	46
FFA	Male	1	3	3.617	75
		2	3	2.012	65
		3	4	1.380	59
		4	5	1.043	51
	Female	5	3	3.300	74
		6	3	2.177	65
		7	4	1.452	57
		8	5	1.002	51

Note: NF = near-field; MF = mid-field, FF = far -field; g = gram; mm = millimetre.

Table 2-3 Variables Analyzed in Slimy Sculpin Tissue Samples from Lac de Gras, 2013

Variable	Detection Limit (µg/g ww)	Variable	Detection Limit (µg/g ww)
% Moisture	0.10	Molybdenum (Mo)	0.0040
Aluminum (Al)	0.40	Nickel (Ni)	0.010
Antimony (Sb)	0.0020	Phosphorus (P)	50[(a)]
Arsenic (As)	0.0040	Potassium (K)	200[(a)]
Barium (Ba)	0.010	Rhenium (Re)	0.0020
Beryllium (Be)	0.0020	Rubidium (Rb)	0.010
Bismuth (Bi)	0.0020	Selenium (Se)	0.020
Boron (B)	0.20	Silver (Ag)	0.0010
Cadmium (Cd)	0.0020	Sodium (Na)	200
Calcium (Ca)	5.0[(a)]	Strontium (Sr)	0.010
Cesium (Cs)	0.0010	Tellurium (Te)	0.0040
Chromium (Cr)	0.010	Thallium (Tl)	0.00040
Cobalt (Co)	0.0040	Thorium (Th)	0.0020
Copper (Cu)	0.010	Tin (Sn)	0.020
Gallium (Ga)	0.0040	Titanium (Ti)	0.01
Iron (Fe)	0.20	Uranium (U)	0.00040
Lead (Pb)	0.0040	Vanadium (V)	0.020[(a)]
Lithium (Li)	0.020	Yttrium (Y)	0.0020
Magnesium (Mg)	10[(a)]	Zinc (Zn)	0.10
Manganese (Mn)	0.0040	Zirconium (Zr)	0.040
Mercury (Hg)	0.0010		

Note: µg/g ww = microgram per gram wet weight.

a) laboratory detection limit differed from that originally provided by the lab and listed in the AEMP Study Design Version 3.3 (Golder 2014a).

2.7 DATA AND STATISTICAL ANALYSES

2.7.1 Catch-per-Unit-Effort

The number of fish captured was standardized as catch-per-unit-effort (CPUE = number of fish per 100 seconds of effort). CPUE provides an estimate of relative abundance among sampling areas by standardizing the catch data according to the fishing effort.

2.7.2 Data Handling

2.7.2.1 Fish Population Health

Slimy Sculpin were grouped according to age, maturity and sex, and then screened and analyzed as separate groups. Maturity and sex determination were based on field observations and confirmed by lab histology data, where available. Fish that were developing reproductive organs for the first time (i.e., fish that were becoming adults and considered “maturing” [see Appendix A for maturity descriptions]) were excluded from the adult fish group since their state of development can differ from adult fish. Since parasitism by *L. intestinalis* can affect gonad size, fish infected with this parasite were not assigned to a group for analysis.

Length-frequency histograms and fish weight were used to differentiate young-of-the-year (YOY) sculpin from older fish. The separation of YOY, juvenile and adult fish was important because the different energetic requirements associated with reproduction result in differences in the rate of growth and body weight gain.

2.7.2.2 Fish Tissue Chemistry

Prior to summarizing and performing statistical analyses on the fish tissue chemistry data, values below the limit of detection, or non-detects, were estimated. Values below the detection limit (DL) were assumed to follow the distribution of the data that were above the limit of detection. A reasonable assumption regarding the location of the non-detect data along the distribution curve would be at the location demarcating 50% of the area of the curve to the left of the DL; this value was estimated by multiplying the limit of detection by 0.71 (Hornung and Reed 1990; Roger Green, University of Western Ontario, personal communication). Guidance provided by the United States Environmental Protection Agency (USEPA 2000) for replacing non-detectable data was considered; however, most of their recommended approaches, such as trimmed mean, Cohen’s adjustment, or Winsorized mean, were not suitable for this data set. Therefore, the 0.71 × DL approach was applied to all non-detect values.

2.7.3 Data Screening

Untransformed data were screened for potential outliers by visual examination of box-and-whisker plots (Appendix B) and linear regression plots. Extreme values, as detected by the visual screening techniques, were removed from the data set if they were determined to be the result of sampling, measurement, or data entry errors. This was confirmed by an additional review of the field notes to ensure no data transcription errors were incurred. Otherwise, the influence of true or statistical outliers (confirmed by analysis of residuals, Section 2.7.5) on the results was determined by analyzing the data with and without these extreme data. Studentized residuals and leverage values from liner regression analyses were also used as screening tools. Observations that were more than three studentized residuals from the mean, or had high leverage, were considered to be statistical outliers. Statistical outliers were identified and data were analyzed with and without the outliers to determine their influence on the analysis. If the removal of these outliers influenced the conclusion, then the analysis was conducted with the outlier removed (Appendix C, Table C-1). It is important to examine the data with and without outliers because many statistical procedures are not robust against outliers (Daniel 1960), and hence, the presence of outliers may influence the conclusions of the statistical tests.

2.7.4 Descriptive Statistics

Summary statistics (i.e., sample size, arithmetic mean and standard deviation [SD]) were calculated by sex, maturity and sampling area for each biological variable. Common fish indices describing relationships between body metrics were also calculated. The Indices, consisting of Fulton's condition factor (*K*), liversomatic index (LSI) and gonadosomatic index (GSI), were calculated as follows:

Condition Factor (age-1+) $K = \left(\frac{total\ body\ weight}{fork\ length^3}\right) \times 100{,}000;$

Condition Factor (adults) $K = \left(\frac{\text{carcass}\ weight}{fork\ length^3}\right) \times 100{,}000;$

Liversomatic Index $LSI = \left(\frac{liver\ weight}{carcass\ weight}\right) \times 100;$ and

Gonadosomatic index $GSI = \left(\frac{gonad\ weight}{carcass\ weight}\right) \times 100.$

Carcass weight (i.e., eviscerated) was used in the calculations of GSI and LSI because of possible differences in organ weight among sampling areas. Using carcass weight instead of body weight eliminated possible confounding effects of altered organ weight (e.g., gonad weight, liver weight) on the interpretation of these variables related to body weight. In addition to these indices, total weight adjusted to the mean length, liver weight adjusted for size (carcass weight), and gonad weight adjusted for size (carcass weight) were also provided as summary statistics. Since the ages of individual fish could not be determined with sufficient accuracy (see Section 4.5.1), mean age as an endpoint was not evaluated.

2.7.5 Statistical Comparisons

2.7.5.1 Approach

The objective of the statistical comparisons was to compare the three exposure areas (NF, FF2 and MF3) to the two reference areas (FFA and FF1). Statistical testing of differences among areas was conducted for the following parameters:

- incidence of pathology;
- size structure (length frequency distribution);
- size (weight and length) by age class;
- reproduction (gonad weight);

- abundance of young (age-1+ fish)
- energy stores (condition, liver weight); and
- metal concentrations.

Differences in the length-frequency distributions between sampling areas were assessed using the non-parametric, two-sample Kolmogorov-Smirnov (KS) test. The chi-square test was used to test differences in the abundance of young fish (i.e., one year old fish that were born the previous year [herein called age-1+ fish]) among areas. Differences among areas for all other parameters were assessed by either analysis of variance (ANOVA), analysis of covariance (ANCOVA) or the nonparametric equivalent (i.e., the Kruskal-Wallace test). Because infection by *L. intestinalis* can affect the endpoints of interest, only fish not parasitized by *L. intestinalis* were used in statistical analyses. Statistical analyses were carried out for each sex and state of maturity (i.e., age-1+ fish, adult males and adult females). The age-1+ group included all the fish that were captured (i.e., those that were processed lethally and non-lethally).

Statistical differences in the concentrations of most metals in Slimy Sculpin were determined by ANOVA or the Kruskal-Wallis test. Mercury and selenium biomagnify (i.e., accumulate via food up three or more trophic levels to a greater degree at each trophic level); therefore, if the concentration of these metals was related to fish size, comparisons among areas was conducted by ANCOVA.

Calculations and statistical summaries were conducted in Excel 2010 for Windows (Microsoft Corporation, Cambridge, Massachusetts). Statistical analyses were conducted with Systat 13 for Windows (Systat Software, San Jose, California) and Minitab 17 for Windows (Minitab Inc., State College, Pennsylvania).

2.7.5.2 Testing Assumptions for Statistical Analysis

Like other parametric tests, ANOVA and ANCOVA assume that the data fit the normal distribution (i.e., the residuals of the statistical models are assumed to fit a normal distribution). If a measurement variable is not normally distributed, there is an increased chance of committing a Type 1 error (false positive) using parametric tests. To test the data for normality, a KS test was carried out. Since many data sets that are highly non-normal are still suitable for analysis with ANOVA or ANCOVA (Sokal and Rohlf 2012), strong evidence of non-normality (e.g., $P < 0.01$) was required to justify the use of non-parametric equivalents in place of these parametric tests. Another assumption of these parametric tests is that there is homogeneity of variance (i.e., the variances among areas are equal). The Levene’s test was used to test for violations of this assumption (e.g., $P < 0.01$). A table outlining the results of the tests to assess the goodness-of-fit of the data to the normal distribution (the KS test) and to test the homogeneity of variance of the data (Levene’s test) is provided in Appendix C, Table C-2).

If the data were clearly non-normal and/or the assumption of homogeneity of variance was violated, the data were then log-transformed in an attempt to meet these assumptions. If the transformed data did not meet the assumptions, the non-parametric equivalent was used (i.e., Kruskal-Wallis test). In addition, if a variable consisted of a high percentage of non-detect values (e.g., fish tissue chemistry data), the non-parametric Kruskal-Wallis test was used since it would be impossible to test for assumptions, and it is a more appropriate approach for highly censored data (Helsel 2005).

2.7.5.3 Analysis of Variance

The means of all five areas were compared to one another in an overall ANOVA. An overall difference was considered statistically significant at P <0.1. If a significant difference was found (P <0.1), an *a priori* comparison (planned contrasts) within the overall ANOVA was conducted to test the following four contrasts: NF exposure area versus the FF reference areas, FF2 exposure area versus the FF reference areas, MF3 exposure area versus the FF reference areas, FF1 reference area versus FFA reference area. Alpha (α) and beta (β) were initially set to 0.1 for all statistical analyses resulting in a statistical power (i.e., 1-β) of 0.9 (i.e., 90%).

Multiple comparison techniques (*a posteriori*) are frequently used with environmental assessment data; however, these techniques are not always appropriate for testing hypotheses (Hoke et al. 1990). The preferred approach is to analyze the data using planned, linear orthogonal contrasts by formulating meaningful comparisons among treatments (sampling areas) prior to conducting the study and outlining these in a study design. This preferred approach was used to help answer the question of whether effluent is having an effect in the exposure area of Lac de Gras.

Planned, linear orthogonal contrasts are a method of partitioning the ANOVA treatment sum of squares into a series of uncorrelated (orthogonal) comparisons of sets of treatment means or totals (Hoke et al. 1990; Sokal and Rohlf 2012). The planned contrasts presented here are not completely uncorrelated since there are three exposure areas compared individually to the reference (unexposed) areas. An orthogonal set of comparisons could have been made, but this would have precluded the independent comparison of each of the three exposure areas to the reference areas. Independent comparison was important because each exposure area represented a different level of exposure.

To maintain the benefits of planned, linear orthogonal contrasts, and avoid the shortfalls of multiple comparison tests (Day and Quinn 1989), we conducted the planned contrasts within the overall ANOVA; however, the Type I error P value was adjusted to maintain the overall experiment-wise error probability of 0.1. The P value was adjusted by the Dunn-Šidák method to 0.026 (Sokal and Rohlf 2012).

An analysis of residuals was conducted to detect outlier data that could strongly influence the results. Studentized residuals (SR) were used because it is convenient to reference them against a *t* distribution and, thus, affords an opportunity to detect "significant" outliers. When outliers were detected by this method, the ANOVAs were recomputed after the outliers had been omitted.

The magnitude of the difference between exposure and reference areas was calculated by expressing the difference as a percentage of the pooled mean of the two reference areas:

$$Magnitude\ \mathrm{of}\ Difference\ (\%) = \frac{(Exposure\ Mean - Pooled\ Reference\ Mean)}{Pooled\ Reference\ Mean} \times 100$$

The magnitude of the difference between reference areas was calculated as the relative percent difference:

$$Relative\ Percent\ Difference\ (\%) = \frac{|(Ref1\ Mean - Ref2\ Mean)|}{Pooled\ Reference\ Mean} \times 100.$$

2.7.5.4 Analysis of Covariance

Analysis of Covariance was used to assess the area differences in variables that are dependent (or vary) on other variables (e.g., condition, which examines the relationship of weight to length). An overall area difference was considered statistically significant at *P* <0.1. One of the assumptions of ANCOVA is that the dependant variable is linearly related to the covariate. Regression analyses were carried out to test this assumption. For relative liver and relative gonad size, regressions were performed using both carcass weight and length as covariates. The variable that explained most of the variation in liver weight and gonad weight was used for the ANCOVA model.

To determine the best covariate for fish size in the comparison of mercury and selenium concentrations among areas, a regression analysis for mercury and selenium concentration against each weight and length was performed. The covariate with the strongest regression relationship (i.e., smallest *P*-value) was used as the covariate for the ANCOVA analysis. Overall, neither length nor weight was a significant predictor of selenium concentrations in Slimy Sculpin among areas (i.e., the regression relationship was not significant); therefore, differences among areas in selenium concentrations were by ANOVA. There was a significant linear relationship between mercury and total length among areas; therefore, ANCOVA with mercury was performed using length as the covariate

The data were screened for outliers and influential observations using plots of the regression, leverage, Cooks distance and Studentized Residuals. Outliers and influential observations were removed, and the statistical analysis proceeded without them (Appendix C, Table C-1).

Another assumption of ANCOVA is that the slopes of the regressions among areas are parallel. A test for homogeneity of slopes among areas was carried out. If the slopes were parallel (P >0.05 for test of interaction term in the ANCOVA model), then ANCOVA was performed, and adjusted (least-square) means were calculated. The adjusted means are the mean values of the dependent variable, adjusted to the mean value of the independent variable. If the slopes were not parallel, then ANOVA was used to compare Slimy Sculpin endpoints by study area without accounting for the influence of the covariate.

The planned comparisons among sampling areas were conducted in the same manner as for the ANOVAs. The magnitude of the differences among areas for ANCOVAs was calculated with the adjusted means (i.e., least squared means [LSM]):

$$Magnitude\ \text{of}\ Difference\ (\%) = \frac{(Exposure\ LSM - Reference\ LSM)}{Reference\ LSM} \times 100$$

The magnitude of the difference between reference areas for ANCOVAs was calculated as the relative percent difference of the least squared means:

$$Relative\ Percent\ Difference\ (\%) = \frac{|(Ref1\ LSM - Ref2\ LSM)|}{Pooled\ Reference\ LSM} \times 100.$$

2.7.5.5 Kruskal-Wallis Test

For data that did not meet the assumptions of ANOVA, the non-parametric Kruskal-Wallis test was used to assess differences among areas. The same approach was taken as described for ANOVA. Differences were considered significant at P <0.1, while the P value was adjusted by the Dunn-Šidák method to 0.026 for the contrasts (Sokal and Rohlf 2012).

2.7.5.6 Kolmogorov-Smirnov Test

Differences in the length-frequency distributions between areas were evaluated using the non-parametric, two sample KS test (Sokal and Rohlf 2012). The KS test is best suited for testing differences in distributions (based on continuous data) because it measures differences in the entire distribution, as opposed to tests based on ranks, such as the Kruskal-Wallis test. All fish, with the exception of those infected with L. intestinalis, were included in this analysis.

2.7.5.7 Chi-Square Test

Differences in incidences of parasitism and age-1+ abundance (a potential indicator of reproductive success or survival of young fish) among areas were evaluated using the chi-square test (Sokal and Rohlf 2012). The chi-square test is best suited for testing differences in frequency or proportion data, such as incidence of pathology. All fish (i.e., including fish assessed non-lethally) were included in this analysis. The magnitude of the difference between exposure and reference areas are the absolute differences in the rate of parasitism and the proportion of age-1+ Slimy Sculpin.

2.7.5.8 Power Analysis

Both *Post ho*c and *a priori* power analyses were conducted. The *post hoc* power analysis was carried out to assess the power achieved by the statistical test. This is important in the case of non-significant differences. The goal here is to determine if the study design had sufficient power to detect the differences observed. *A priori* power analysis was conducted to evaluate the adequacy of current sample sizes for detecting differences of a given magnitude (or effect size) in the fish endpoints. Since the biologically-relevant effect size, or difference to be detected, is not easily defined, the power analysis was designed to provide results for a number of possible effect sizes (e.g., 20% decrease in fish length). The results are presented as the power achieved for a given effect size (either a 10%, 20% or 30% decrease). This will indicate whether the study was capable of detecting relatively small differences among areas. Since we are interested in detecting difference that would exceed the normal range for samples collected at the reference areas, a 30% decrease provided a conservative estimate of effect size as a normal range is likely much larger than 30%. If a power of approximately 90% or greater was not achieved, then the sample size required to attain 90% power was calculated.

Since the study design consisted of five areas, simple power equations comparing two samples could not be used. Cohen (1988) provides methods for power analyses with more than two groups, for a variety of statistical tests (e.g., ANOVA, ANCOVA). The relevant background information employed in the power calculations may be found in Cohen (1988). Power analyses for the Kruskal-Wallis test were conducted by adjusting the results obtained for its corresponding parametric test (i.e., one-way ANOVA) with the appropriate asymptotic relative efficiency value of 0.95 (Lehmann 1975; Gibbons 1976).

A Type I error (α) is the probability of finding a significant difference when none exists (i.e., a false positive). A Type II error (β) is the probability of not finding a significant difference when there is a true difference of some specified magnitude (i.e., a false negative). The power of a statistical test ($1 - \beta$) is the probability of detecting a true difference. Since both types of error are considered to have equal importance, for this study α and β were set to 0.1 (giving a power of 0.9). The mean squared error term from the ANOVA or ANCOVA statistical model provided the estimate of variability for each endpoint. Power analyses were carried out using the program G*Power (Faul et al. 2007).

2.7.6 Normal Range

Potential effects were evaluated by comparing the fish population health parameters and fish tissue chemistry in the NF exposure area to the normal range of the reference areas (FF1 and FFA). The normal range is defined as the pooled reference area mean ± 2 standard deviations. For fish health parameters the normal range was calculated by pooling the 2007 and 2013 data to form a reference mean. Normal range calculations for fish health endpoints do not include 2010 data, as the 2010 survey was conducted at a different time of the season compared to the 2007 and 2013 surveys (see Section 2.2). The normal range for fish tissue chemistry did include 2010 data, in addition to the 2007 and 2013 data. The 2010 data could be included in the fish tissue chemistry normal range, as metal concentrations are not expected to vary in small-bodied fish tissue within a season (i.e., between July and September).

2.8 ACTION LEVELS FOR FISH

The importance of effects to a fish health endpoint has been categorized according to Action Levels described in Golder (2014a). The Action Level classifications were developed to meet the goals of the Response Framework for Aquatic Effects Monitoring that was drafted by the WLWB (WLWB 2010; Racher et al. 2011). The goal of the Response Framework is to ensure that significant adverse effects never occur. A significant adverse effect, as it pertains to aquatic biota, was defined in the Environmental Assessment as a change in fish population(s) that is greater than 20% (Government of Canada 1999). This effect must have a high probability of being permanent or long-term in nature and must occur throughout Lac de Gras. The Significance Thresholds for all aquatic biota are therefore related to impacts that could result in a change in fish population(s) that is greater than 20%.

Although the AEMP addresses two broad impact hypotheses for Lac de Gras, the toxicological impairment hypothesis and the nutrient enrichment hypothesis (Golder 2014b), the Action Levels for fish health address the toxicological impairment hypothesis.

Fish health responses are assessed every three years to evaluate effects as described in the Action Levels for Biological Effects (Golder 2014a). This involves measuring responses in the NF exposure area against those in the two FF reference areas (FF1 and FFA). The occurrence of an Action Level 1 will be determined by finding significantly lower fish health responses in the exposure area compared to those in the reference areas. Conditions required for Action Levels 1 to 3 are defined in Table 2-4. Action Level 4 will be defined if Action Level 3 is reached. Defining higher Action Levels after initial effects are encountered is consistent with the draft guidelines for preparing a response framework in AEMPs (WLWB 2010; Racher et al. 2011).

Table 2-4 Action Levels for Fish Health Effects

Action Level	Fish Health	Extent	Action
1	Statistical difference from reference indicative of toxicological response(a)	Near-field	Confirm effect
2	Statistical difference from reference indicative of toxicological response(a)	Nearest Mid-field station	Investigate cause
3	The mean of a measurement endpoint beyond the normal range	Near-field	Examine ecological significance Set Action Level 4 Identify mitigation options
4	To be determined(b)		Define conditions required for the Significance Threshold
5(c)	Indications of severely impaired reproduction or unhealthy fish likely to cause a >20% change in fish population(s)	Far-field A (FFA)	Significance Threshold

Notes: >= greater than;% = percent.

a) Such a response could include a decrease in recruitment (fewer young fish), smaller gonads, reduced fecundity, changes to liver size, changes in condition, increased incidence of pathology, reduced growth, reduced survival.

b) To be determined if Action Level 3 is reached.

c) Significance Threshold.

2.9 QUALITY ASSURANCE/QUALITY CONTROL

The field and laboratory quality assurance/quality control (QA/QC) procedures, as outlined by the Golder TPs and the DDMI Quality Assurance Project Plan Ver. 2.0 (Golder 2013), were implemented at all stages of the fish survey. Quality Assurance/quality control procedures were conducted to confirm the field sampling, data entry, data analysis and report preparation produced technically-sound and scientifically defensible results.

Detailed specific work instructions outlining each field task were provided to the field personnel prior to the field programs. Samples were collected by experienced personnel and were collected, labelled, preserved and shipped according to Golder TPs. Field equipment was regularly calibrated according to manufacturer’s recommendations. Data sheets and labels were checked at the end of each field day for completeness and accuracy, and they were scanned into electronic copies at the completion of the field program. Chain-of-custody forms were used to track the shipment of samples. Individual QA/QC procedures were undertaken by the laboratories performing analyses for the fish survey (e.g., metals analysis).

All data entered electronically were verified by a second person to identify any transcription errors. Results of statistical data analyses were independently reviewed by an independent biologist with appropriate technical qualifications. Tables containing data summaries and statistical results were reviewed and values were verified by a second, independent individual.

2.10 WEIGHT OF EVIDENCE INPUT

Results of the fish survey feed into the Weight of Evidence (WOE) assessment, which is described in the Weight of Evidence Report (Golder 2014b). The WOE integrates results from the AEMP components to help understand the underlying cause(s) of biological responses. Whereas the annual report for each AEMP component assesses the effects separately to determine if changes in individual components are meaningful, the WOE approach integrates measures of exposure (e.g., water quality, sediment quality) with measures of biological response (e.g., plankton, benthos, fish) to assess the underlying causes of biological changes. These biological changes can reflect either nutrient enrichment or toxicological impairment effects. Thus, the WOE will provide the strength of evidence for toxicological impairment or nutrient enrichment associated with observed changes. It is not intended to reflect the ecological significance or level of concern associated with a given change.

The WOE assessment is undertaken by applying a rating scheme to determine the degree of change in individual AEMP components. It then proceeds to integrate the individual component ratings into an overall score. The methods as applied to fish are described in Sections 2 of the Weight of Evidence Report.

3 RESULTS

3.1 SUPPORTING ENVIRONMENTAL INFORMATION

3.1.1 Field Measurements

In situ water quality measurements were collected during the fish survey at all five sample areas from August 27 to September 11, 2013. Specific conductivity was greatest at the NF exposure area and was somewhat greater than reference at exposure area FF2 (Table 3-1). Conductivity at exposure area MF3 was similar to that at the reference areas. Dissolved oxygen levels were similar among all areas, and were above the Canadian Council of the Ministry of Environment (CCME) water quality guideline of a minimum 6.5 mg/L (CCME 1999).

Table 3-1 Water Quality Information Collected During the Fish Survey, 27 August to September 11, 2013

Area	Sampling Date	UTM Co-ordinates[a]		Depth (m)	Water Temperature (°C)	Dissolved Oxygen (mg/L)	Specific Conductivity (µS/cm)
		Easting	Northing				
NF	27-Aug-13	535662	7153249	0.2	11.2	11.1	37
	02-Sep-13	535724	7153261	0.4	8.6	10.2	33
	08-Sep-13	535263	7153438	0.5	9.5	10.2	34
	01-Sep-13	535776	7153226	0.2	10.3	8.9	33
FF2	7-Sep-13	541336	7160180	0.5	9.7	10.2	30
MF3	4-Sep-13	533101	7148879	0.5	10.7	11.6	25
FF1	28-Aug-13	527649	7159335	0.2	11.0	10.1	23
	29-Aug-13	529288	7162641	0.2	10.9	9.7	23
	05-Sep-13	521968	7160319	0.3	11.1	10.4	23
FFA	28-Aug-13	506271	7157312	0.3	10.1	10.6	25
	31-Aug-13	506274	7157348	0.2	11.1	10.3	24
	11-Sep-13	505878	7158312	0.3	11.6	12.5	24

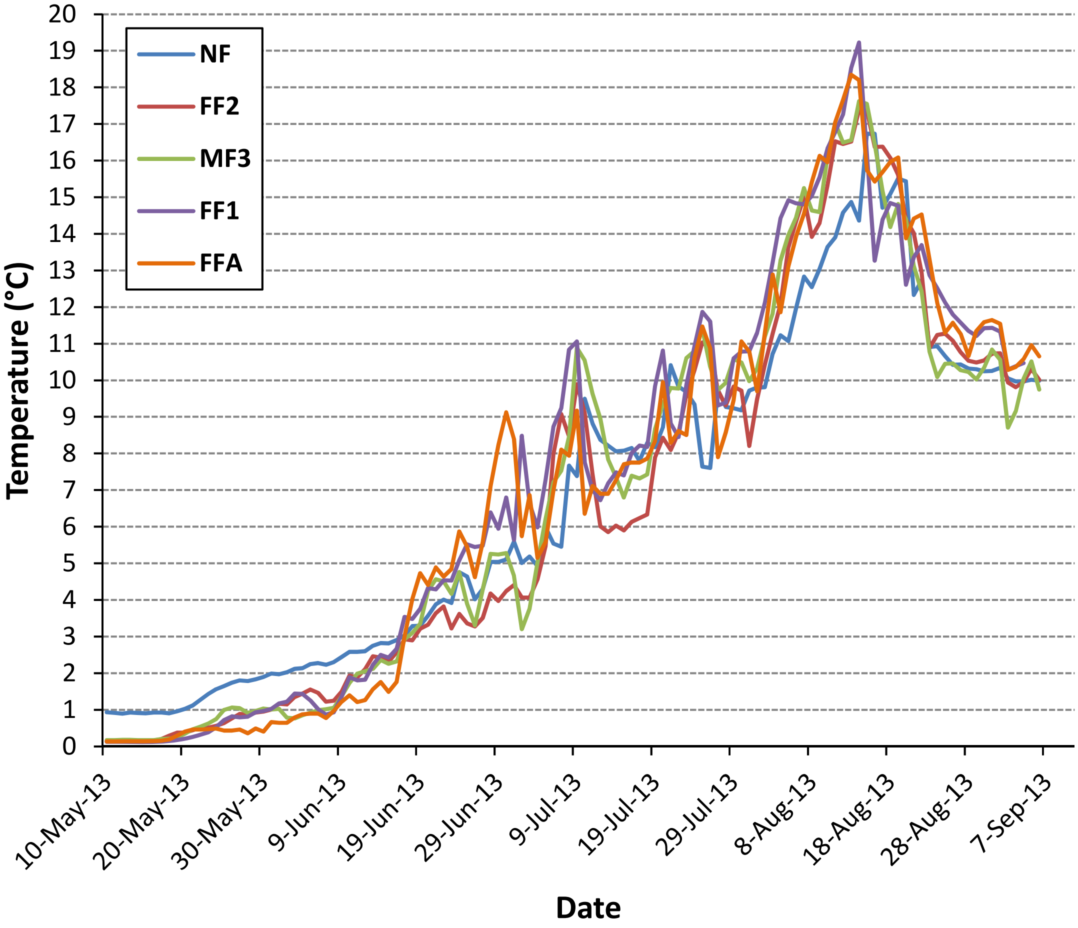
Notes: UTM = Universal Transverse Mercator; °C = degrees Celsius; m = metre; mg/L - milligrams per litre; µS/cm = microSiemens per centimeter.

a) All UTM Coordinates were recorded in NAD (North American Datum) 83 Zone 12.

3.1.2 Seasonal Water Temperature

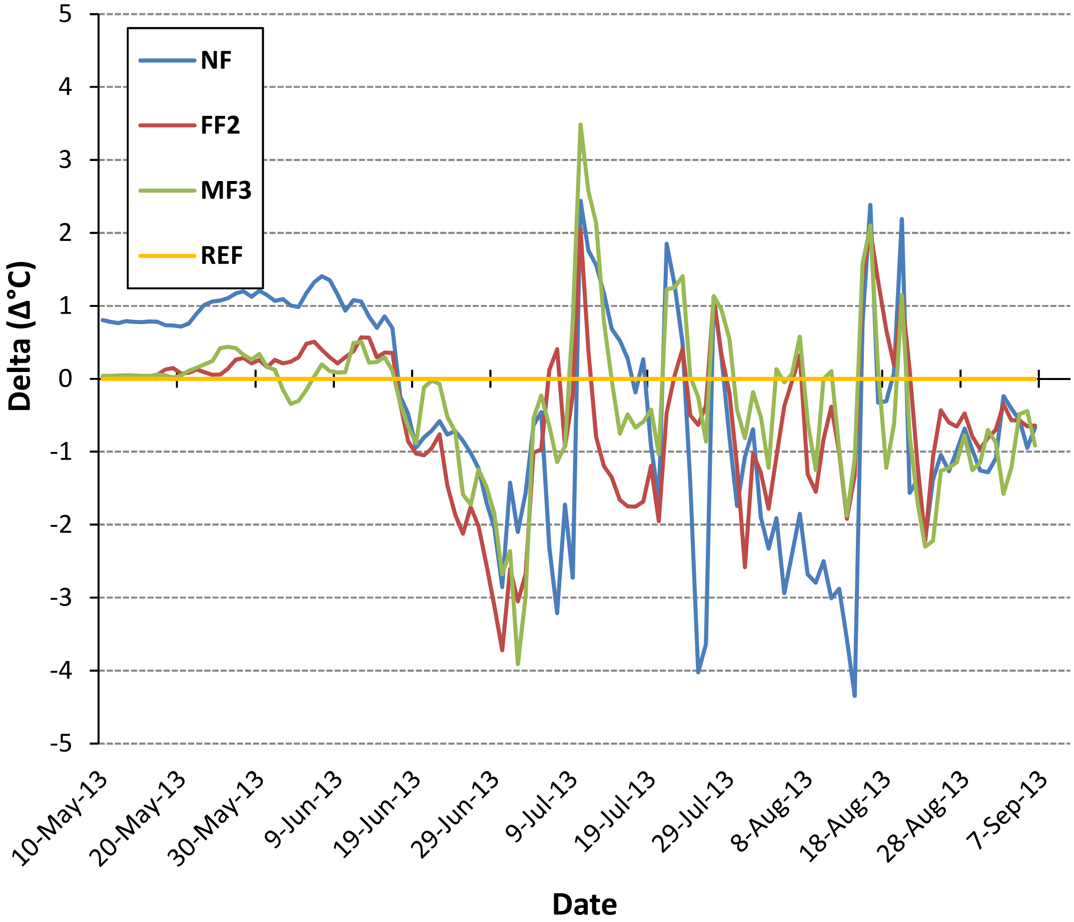
Temperature profiles as recorded by the *in situ* data loggers between May 10 and September 6, 2013, followed expected season trends in all areas (Figure 3-1). Overall, temperatures recorded over the course of the growing season (from mid-June through to July) were typically cooler at the exposure areas compared to the reference areas (Figure 3-2).

Figure 3-1 Mean Daily Water Temperature in Lac de Gras, May 10 to September 6, 2013



Notes: NF = near-field; MF = mid-field; FF = far-field; °C = degrees Celsius.

Figure 3-2 Change in Exposure Area Temperature Relative to the Reference Areas



Notes: NF = near-field; MF = mid-field; FF = far-field; ref = reference areas FF1 and FFA; Δ = delta; °C = degrees Celsius.

3.2 FISH CAPTURE

The number of fish captured by backpack electrofishing was standardized as CPUE (number of fish per 100 seconds of effort). The relative abundance (as determined using CPUE) of sculpin in exposure area FF2 was highest of all the sampling areas, while reference area FF1 was the lowest of all the sampling areas (Table 3-2). When the CPUE of all fish captured was considered, exposure area FF2 again had the highest relative abundance of fish. The CPUEs at exposure areas NF and MF3 were intermediate to those in reference areas in terms of both sculpin and all species.

Table 3-2 Catch-Per-Unit-Effort for Fish Captured in Lac de Gras, 2013

Sampling Area	Sampling Effort (s)	Slimy Sculpin[(a)]		Lake Trout		Burbot		Ninespine Stickleback		Round Whitefish		Northern Pike		All Species	
		Total Fish	CPUE (# fish/ 100 s)	Total Fish	CPUE (# fish/ 100 s)	Total Fish	CPUE (# fish/ 100 s)	Total Fish	CPUE (# fish/ 100 s)	Total Fish	CPUE (# fish/ 100 s)	Total Fish	CPUE (# fish/ 100 s)	Total Fish	CPUE (# fish/ 100 s)
NF	14,731	138	0.937	13	0.088	6	0.041	0	0.000	4	0.027	0	0.000	161	1.120
FF2	16,531	255	1.543	6	0.036	6	0.036	0	0.000	0	0.000	0	0.000	267	1.615
MF3	13,713	153	1.116	2	0.015	9	0.066	1	0.007	1	0.007	1	0.007	167	1.218
FF1	19,161	151	0.788	0	0.000	6	0.031	1	0.005	0	0.000	0	0.000	158	0.825
FFA	13,152	199	1.513	1	0.008	10	0.076	1	0.008	0	0.000	0	0.000	211	1.604

Notes: NF = near-field; MF = mid-field; FF = far-field; s = seconds; CPUE = catch-per-unit-effort; # fish/100 s = number of fish captured per 100 seconds of active electrofishing.

a – Total numbers included lethally and non-lethally and infected Slimy Sculpin.

Several other fish species were captured during the fish survey, and these were juvenile Lake Trout (*Salvelinus namaycush*), juvenile Burbot (*Lota lota*), Ninespine Stickleback (*Pungitius pungitius*), Round Whitefish (*Prosopium cylindraceum*), and one Northern Pike (*Esox lucius*) (Table 3-2). The greatest CPUE of Lake Trout occurred in the exposure areas, with the greatest CPUE occurring in the NF area. Raw catch data, including length and weight, are provided in Appendix D.

3.3 FISH POPULATION HEALTH

3.3.1 Sample Size

A total of 896 Slimy Sculpin were captured during this study (Table 3-3). Of these fish, 257 were determined to be infected with the parasitic tapeworm *L. intestinalis* and were excluded from any of the analyses. Of the remaining 639 fish captured, 444 (or between 64 and 116 fish per area) were sacrificed and underwent a full internal examination. The remaining 195 individuals (between 9 to 84 fish per area) were measured for total length and wet weight, examined for external abnormalities, and released back in the area from which they were captured. Raw Slimy Sculpin survey data are provided in Appendix E.

Table 3-3 Total Number of Slimy Sculpin Sampled During the 2013 Fish Survey

Area	Sex/Stage				Adult Non-lethal[c]	Undetermined Age[d]	Infected Fish[e]	Total
	Male	Female	Adult Unknown[a]	Age-1+[b]				
NF	33	23	1	22	7	0	52	138
FF2	48	27	0	73	50	1	55	255
MF3	44	16	3	55	12	0	23	153
FF1	24	12	0	37	12	1	65	151
FFA	33	25	1	42	35	2	62	199
Total	182	103	5	229	116	4	257	896

Notes: NF = near-field; MF = mid-field; FF= far-field.

a) adult fish whose sex could not be determined.

b) includes fish that were lethally and non-lethally sampled.

c) fish that were not sacrificed for the study, and were not included in the age-1+ category.

d) fish whose ages could not be determined, and one young-of-the-year fish from FFA.

e) fish determined to be infected with *L. intestinalis*.

3.3.2 Assessment of Abnormalities

Overall, there were very few external and internal abnormalities observed. Of the 639 Slimy Sculpin assessed externally, 5 fish exhibited external abnormalities (Table 3-4). These abnormalities consisted of spine deformities (two observations) and pale gills (three observations). The external abnormalities were observed at all areas, with the exception of FFA.

A total of 444 Slimy Sculpin were assessed for internal abnormalities (Table 3-4), and 43 of these exhibited internal abnormalities. These abnormalities consisted of fatty, enlarged or discoloured livers (26 observations), enlarged spleens (10 observations), enlarged gall-bladders (2 observations) and swollen kidneys (5 observations). Internal abnormalities were observed at all areas and the proportion of internal abnormalities observed at the NF exposure area was within the range observed in the reference areas.

3.3.3 Parasites

The incidence of external parasites was very low, with six fish from four different areas infected. The parasitic tapeworm *L. intestinalis* was observed in 257 Slimy Sculpin (Photograph 3-1). The proportion of Slimy Sculpin infected with *L. intestinalis* was not significantly different between the NF exposure area and the reference areas (Table 3-5).

Photo 3-1 External Observation of *L. intestinalis* in a Slimy Sculpin from Lac de Gras, September 2013

Table 3-4 External and Internal Abnormalities Observed in Slimy Sculpin from Lac de Gras, 2013

Assessment Type	Category	NF					FF2					MF3					FF1					FFA				
		Age-1+	**Male**	**Female**	**Non-lethal/UN**	**Total**	**Age-1+**	**Male**	**Female**	**Non-lethal/UN**	**Total**	**Age-1+**	**Male**	**Female**	**Non-lethal/UN**	**Total**	**Age-1+**	**Male**	**Female**	**Non-lethal/UN**	**Total**	**Age-1+**	**Male**	**Female**	**Non-lethal/UN**	**Total**
External	*n*	22	33	23	8	**86**	73	48	27	51	**199**	55	44	16	15	**130**	37	24	12	13	**86**	42	33	25	38	**138**
	Body Deformities	0	0	0	**0**	**0**	0	0	0	0	**0**	0	1	0	0	**1**	0	1	0	0	**1**	0	0	0	0	**0**
	Eyes	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**
	Gills	1	0	0	**0**	**1**	1	0	0	0	**1**	0	0	0	0	**0**	0	1	0	0	**1**	0	0	0	0	**0**
	Pseudobranchs	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**
	Thymus	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**
	Skin	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**
	Fins	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**
	Opercula	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**
	Hindgut	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**
Internal	*n*	20	33	23	1	**77**	40	48	27	-	**115**	47	44	16	3	**110**	28	24	12	-	**64**	19	33	25	1	**78**
	Liver - fatty	1	0	0	0	**1**	2	4	1	-	**7**	2	2	1	0	**5**	1	3	0	-	**4**	0	2	0	0	**2**
	Liver – enlarged	0	0	0	0	**0**	0	0	0	-	**0**	0	0	0	0	**0**	0	0	0	-	**0**	0	0	1	0	**1**
	Liver – focal discolouration	0	0	0	0	**0**	0	0	2	-	**2**	0	1	0	0	**1**	1	1	1	-	**3**	0	0	0	0	**0**
	Spleen – enlarged	0	0	0	0	**0**	1	2	0	-	**3**	2	2	0	0	**4**	1	1	0	-	**2**	0	0	1	0	**1**
	Gallbladder - enlarged	0	0	0	0	**0**	0	1	0	-	**1**	0	0	0	0	**0**	1	0	0	-	**1**	0	0	0	0	**0**
	Kidney - swollen	1	0	0	0	**1**	0	0	0	-	**0**	1	1	1	0	**3**	1	0	0	-	**1**	0	0	0	0	**0**

Notes: *n* = sample size; NF = near-field; MF = mid-field; FF = far-field; “-“ = not analyzed; UN = Unknown.

Table 3-5 Proportion of Slimy Sculpin Infected with *L. intestinalis* from Lac de Gras, 2013

Parameter	**Statistical Test**	**Area**	**NF vs. References**		**FF2 vs. References**		**MF3 vs. References**		**FF1 vs FFA**	
		***P*-value**	***P*-value**	**%**	***P*-value**	**%**	***P*-value**	**%**	***P*-value**	**%**
Proportion of Slimy Sculpin infected with *L. intestinalis*	Chi-square	***	ns	1.6	***	-14.0	***	-21.0	*	33.1

Notes:% = percent; vs. = versus; NF = near-field; FF2 = far-field; MF = mid-field; * = *P* <0.1; *** = *P* <0.001.

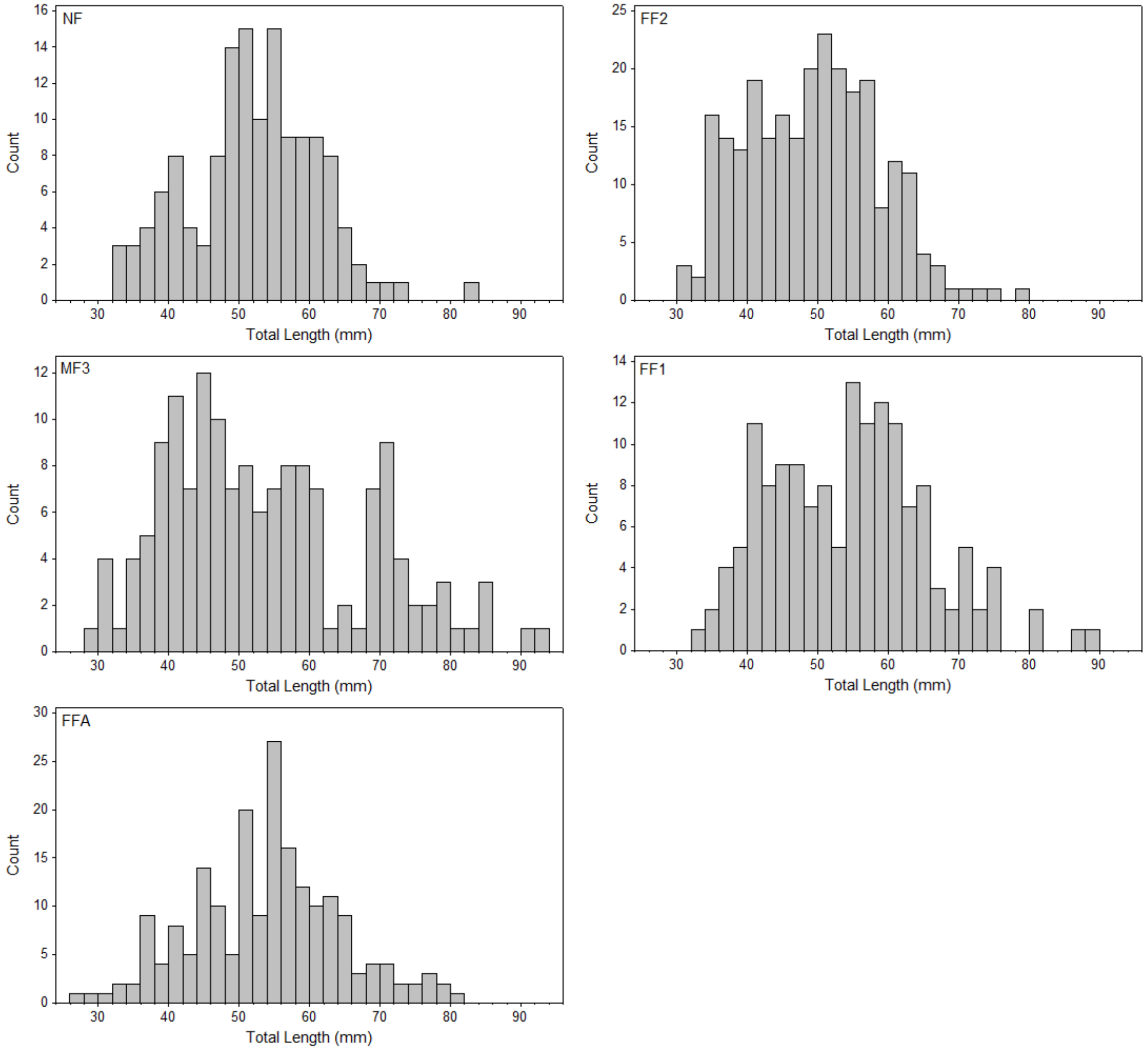
a) The percent magnitude of the difference between exposure and reference areas are the absolute differences between the proportion of Slimy Sculpin infected with *L. intestinalis*.

3.3.4 Age

Given that ages derived from otolith sections have been found to be unreliable (Golder 2011b), age data for this study were derived using length-frequency analysis. The length modes corresponding to age-1+ fish were most readily identifiable and distinct using length-frequency mode analysis; modes for fish older than age-1+ were more difficult to discern (Figure 3-3). Consequently, the length modes were not extrapolated past age-2 fish. The year of age represents the number of years since they were born. For example, fish categorized as age-1+ signifies that the fish was born in spring of the previous year (or 2012) and has now begun its second year of life.

A single young-of-the-year (YOY) fish was captured at area FFA (length = 19 mm), and, as age-0+ fish, it was not included in the comparison. There were three other fish that were identified as potential YOY through statistical analyses, and as such were excluded as outliers (Appendix C, Table C-1). There were no juvenile fish over age-1+, illustrating that there was no delayed sexual maturity in the fish examined. As it was difficult to age fish older than age-1+, there was no means of determining whether there was difference among areas in the mean age of adult fish.

Figure 3-3 Length-Frequency Histograms for Slimy Sculpin Captured in Lac de Gras, 2013



Notes: NF = near-field; MF = mid-field; FF = far-field; mm = millimetres.

3.3.5 Length-Frequency Analysis

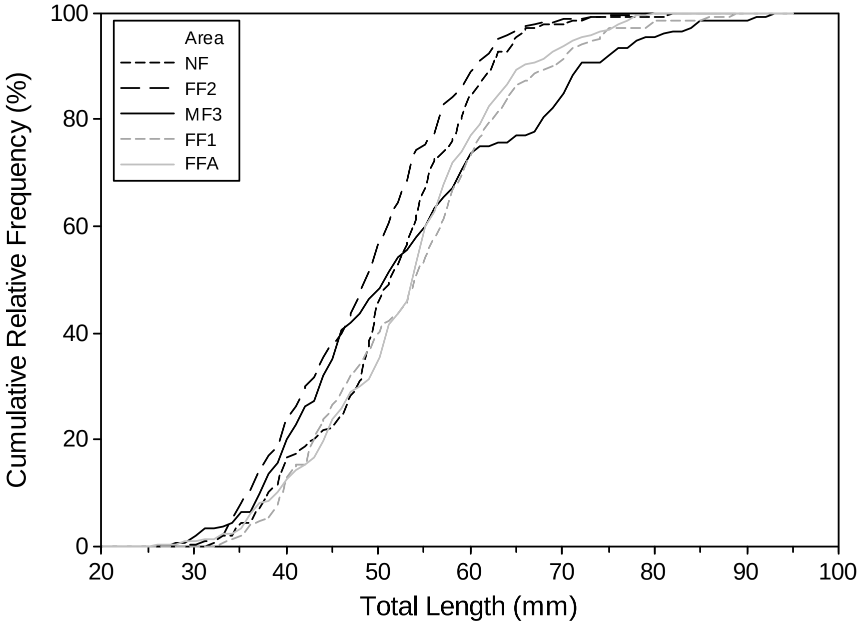
The length-frequency distributions for Slimy Sculpin were compared using the two-sample KS Test (Table 3-6, Figures 3-3 and 3-4). The length-frequency distribution at the NF and MF3 exposure areas was significantly different from one of the two reference areas, while the length-frequency distribution for Slimy Sculpin from the FF2 exposure area was significantly different from both reference areas FF1 and FFA. The comparison of length-frequency distributions between reference areas indicated that FF1 and FF2 were not significantly different from each other (Figure 3-4). The different distributions suggested that, compared to reference areas, there were fewer large fish at NF and FF2, and more large fish at MF3.

Table 3-6 Two-Sample Kolmogorov-Smirnov Test for Length-Frequency Distribution in Slimy Sculpin from Lac de Gras, 2013

Parameter	Exposure vs. Reference Comparisons						Reference vs. Reference Comparisons
	NF vs		FF2 vs		MF3 vs		FF1 vs
	FF1	FFA	FF1	FFA	FF1	FFA	FFA
Length	*	ns	***	***	ns	*	ns

Notes: NF = near-field; FF = far-field; MF = mid-field; * = *P* <0.1; *** = *P* <0.001.

Figure 3-4 Cumulative Length-Frequency for Slimy Sculpin in Lac de Gras, 2013



Notes: NF = near-field; MF = mid-field; FF = far-field; mm = millimetres;% = percent.

3.3.6 Size

Age-1+ and adult male and female Slimy Sculpin from the exposure areas were generally smaller than those from the reference area. Mean length of age-1+ Slimy Sculpin from all three exposure areas (NF, FF2, and MF3) was significantly lower than from the reference areas, while weight was significantly lower at the NF and FF2 exposure areas (Tables 3-7 and 3-8). Age-1+ mean weight was also significantly different between the two reference areas. Adult male and female Slimy Sculpin from the NF exposure area were significantly shorter and lighter than those from the reference areas (Tables 3-7 and 3-8).

3.3.7 Condition

The condition factor of age-1+ sculpin from the NF exposure area was significantly lower than that of fish from the reference areas (Tables 3-7 and 3-8). Condition factor was not different in adult male or female Slimy Sculpin from exposure areas when compared to reference areas or between the reference areas.

Table 3-7 Summary Statistics of Slimy Sculpin from Lac de Gras, 2013

Sex/Stage	Response[(a)]	Mean Covariate	NF			FF2			MF3			FF1			FFA		
			n	Mean	SD	N	Mean	SD	n	Mean	SD	n	Mean	SD	n	Mean	SD
Age-1+	Length (mm)	-	22	38.0	3.2	73	39.0	3.9	55	40.2	4.8	37	43.7	4.9	42	40.9	5.4
	Total Weight (g)	-	21	0.3988	0.0925	73	0.4877	0.15	53	0.5279	0.1625	37	0.6485	0.1937	36	0.5410	0.2036
	Condition, *K*	-	21	0.7229	0.0741	73	0.80	0.1079	53	0.79	0.1032	37	0.76	0.0751	36	0.79	0.1011
	Log total body weight adjusted for length (g)	40.0	21	0.4500	-0.0411/+0.0452	73	0.5020	-0.0635/+0.0726	53	0.4990	-0.0522/+0.0583	37	0.4942	-0.0394/+0.0428	36	0.4997	-0.0575/+0.0649
	LSI (%)	-	20	1.64	0.58	39	2.07	0.62	47	2.05	0.84	29	2.37	0.77	19	2.16	0.86
	Log liver weight adjusts for carcass weight (g)	0.4110	20	0.0064	-0.0020/0.0030	39	0.0081	-0.0023/+0.0032	47	0.0079	-0.685714286	29	0.0089	-0.0029/+0.0043	19	0.0084	-0.0025/+0.0035
Adult Male	Length (mm)	-	33	56.5	6.22	48	54.7	5.47	44	64.0	10.74	24	61.3	8.11	33	59.8	6.71
	Total Weight (g)	-	33	1.4457	0.5157	48	1.2967	0.4343	43	2.2070	1.217	24	1.8980	0.871	33	1.7300	0.721
	Carcass weight (g)	-	33	1.2451	0.4533	48	1.1295	0.3869	44	1.9670	1.134	24	1.6560	0.788	33	1.5160	0.616
	Condition, *K*	-	33	0.6650	0.0508	48	0.6665	0.0491	44	0.6765	0.0663	24	0.6786	0.0858	33	0.6832	0.0775
	Log total body weight adjusted for length (g)	58.5	33	1.5435	-0.1061/+0.1139	48	1.5382	-0.1078/+0.1159	43	1.5431	-0.1374/+0.1508	24	1.5364	-0.1595/+0.178	33	1.5314	-0.1523/+0.1691
	LSI (%)	-	33	2.11	0.73	48	2.24	0.63	44	2.62	0.99	24	2.48	0.67	33	2.34	0.63
	Log liver weight adjusted for carcass weight (g)	1.3421	33	0.0273	-0.0076/+0.0106	48	0.0299	-0.0067/+0.0087	44	0.0317	-0.0101/+0.0149	24	0.0316	-0.0077/+0.0101	33	0.0300	-0.007/+0.0091
	GSI (%)	-	32	1.78	0.51	45	1.77	0.48	41	1.80	0.51	24	2.05	0.58	32	1.71	0.59
	log(Gonad weight) (g)	1.3753	32	0.0244	-0.0066/+0.009	45	0.0251	-0.0054/+0.0069	41	0.0219	-0.0052/+0.0069	24	0.0264	-0.0064/+0.0084	32	0.0219	-0.0061/+0.0085
Adult Female	Length (mm)	-	23	53.4	5.4	27	55.2	6.0	16	61.1	10.5	12	61.5	10.6	25	57.2	8.2
	Total body weight (g)	-	23	1.2440	0.4557	27	1.3270	0.4991	16	1.9090	0.9610	12	1.9900	1.218	25	1.5570	0.8080
	Carcass weight (g)	-	23	1.0765	0.4019	27	1.1318	0.4101	16	1.6070	0.7660	12	1.6850	1.001	25	1.3600	0.7340
	Condition, *K*	-	23	0.6779	0.0766	27	0.6507	0.0529	16	0.6614	0.0443	12	0.6729	0.0753	25	0.6740	0.0525
	Log total body weight adjusted for length (g)	56.4	23	1.4041	-0.1459/+0.1628	27	1.3627	-0.1132/+0.1234	16	1.3900	-0.0974/+0.1047	12	1.3896	-0.0800/+0.0849	25	1.3900	-0.0974/+0.1047
	LSI (%)	-	23	2.81	1.03	27	2.89	0.85	16	2.77	0.77	11	3.40	0.89	25	3.35	1.23
	Log liver weight adjusted for carcass weight (g)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	NF vs Refs	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	FF2 vs Refs	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	MF3 vs Refs	1.3505	-	-	-	-	-	-	16	0.0358	-0.0094/+0.0128	-	-	-	-	-	-
	FF1 vs FFA	1.3101	-	-	-	-	-	-	-	-	-	11	0.0433	-0.0099/+0.0129	25	1.1047	-0.0120/+0.0169
	GSI (%)	-	23	1.71	0.63	26	2.18	0.52	16	2.37	0.55	12	2.26	0.65	25	2.02	0.58
	Gonad weight adjusted for length (g)	56.9	23	0.0272	0.0055	26	0.0300	0.0062	16	0.0305	0.0087	12	0.0282	0.0105	25	0.0280	0.0074

Notes: NF = near-field; MF = mid-field; FF = far-field; mm = millimetre; g = gram; LSI = liversomatic index;% = percent; n = sample size; SD = standard deviation; *K* = condition factor; - = not applicable.

a) Means of log-transformed data were back transformed. Standard deviations of log-transformed data are presented as (log-mean – log-standard deviation) and (log-mean + log-standard deviation), then back transformed.

Table 3-8 Statistical comparisons of Parameters Measured in Slimy Sculpin from Lac de Gras, 2013

Sex/Maturity Stage	Parameter	Statistical Test$^{(a)}$	Slopes	Area	Exposure vs. Reference Comparisons						Reference vs. Reference Comparisons		Power to detect decrease $^{(f)}$		
					NF		FF2		MF3		FF1 vs FFA				
			P-value$^{(b)}$	P-value$^{(b)}$	P-value$^{(c)}$	% $^{(d)}$	P-value$^{(c)}$	% $^{(d)}$	P-value$^{(c)}$	% $^{(d)}$	P-value$^{(c)}$	% $^{(e)}$	10% decrease	20% decrease	30% decrease
Age-1+	Length	KW	-	***	***	-10.0	***	-7.6	*	-4.8	ns	6.7	-	-	-
	Total body weight	ANOVA^{log}	-	***	***	-33.0	**	-18.1	ns	-11.3	**	18.1	-	-	-
	Condition (*K*)	KW	-	**	**	-6.7	ns	3.7	ns	1.8	ns	-4.2	-	-	-
	Total weight adjusted for length	ANCOVA^{log}	ns	**	**	-9.4	ns	1.0	ns	0.4	ns	-1.1	-	-	-
	LSI	ANOVA^{log}	-	*	***	-28.3	ns	-9.4	ns	-10.1	ns	9.2	-	-	-
	Liver weight adjusted for carcass weight	ANCOVA^{log}	ns	*	**	-26.3	ns	-6.6	ns	-9.6	ns	6.0	-	-	-
Adult Male	Length	KW	-	***	*	-6.6	***	-9.5	ns	5.9	ns	2.5	-	-	-
	Total body weight	KW	-	***	*	-20.0	***	-28.0	ns	22.6	ns	9.3	-	-	-
	Carcass weight	KW	-	***	*	-21.0	***	-28.0	ns	24.9	ns	8.8	-	-	-
	Condition, *K*	ANOVA	-	ns	-	-2.4	-	-2.2	-	-0.7	-	-0.7	0.92	1.00	1.00
	Total weight adjusted for length	ANCOVA^{log}	ns	ns	-	0.7	-	0.3	-	0.6	-	0.3	1.00	1.00	1.00
	LSI	ANOVA^{log}	-	*	ns	-12.0	ns	-6.8	ns	9.43	ns	5.8	-		-
	Liver weight adjusted for carcass weight	ANCOVA^{log}	ns	ns	-	-11.0	-	-2.3	-	3.45	-	5.1	-		-
	GSI	ANOVA	-	ns	-	-4.2	-	-4.7	-	-3.0	-	18.0	0.38	0.90	1.00
	Gonad weight adjusted for carcass weight	ANCOVA^{log}	ns	*	ns	2.6	ns	5.5	ns	-7.7	*	19.0	-	-	-
Adult Female	Length	KW	-	*	ns	-8.9	ns	-5.9	ns	4.3	ns	7.2	-	-	-
	Total body weight	KW	-	*	*	-27.0	ns	-22.0	ns	12.5	ns	24.0	-	-	-
	Carcass weight	KW	-	*	*	-27.0	ns	-23.0	ns	9.7	ns	21.0	-	-	-
	Condition, *K*	ANOVA	-	ns	-	0.6	-	-3.4	-	-1.8	-	-0.2	0.98	1.00	1.00
	Total weight adjusted for length	ANCOVA^{log}	ns	ns	-	0.54	-	-2.4	-	-0.5	-	1.5	0.99	1.00	1.00
	LSI	ANOVA	-	ns	-	-17.0	-	-14.0	-	-18.0	-	1.5	0.25	0.67	0.95
	Liver weight adjusted for carcass weight	ANCOVA^{log}	**	-	-	-	-	-	-	-	-	-	-	-	-
	NF vs Refs	ANCOVA	*	-	-	-	-	-	-	-	-	-	-	-	-
	FF2 vs Refs	ANCOVA	**	-	-	-	-	-	ns	6.11	-	-1.0	-	-	-
	MF3 vs Refs	ANCOVA	ns	ns	-	-	-	-	-	-	ns	-1.4	0.25	0.67	0.96
	FF1 vs FFA	ANCOVA	ns	ns	-	-	-	-	-	-	-	-	-	-	-
	GSI	ANOVA	-	**	**	-19.0	ns	4.1	ns	13.3	-	11.0	-	-	-
	Gonad weight adjusted for length	ANCOVA	ns	ns	-	-0.2	-	0.4	-	0.6	-	0.0	0.29	0.76	0.97

Notes: NF = near-field; MF = mid-field; FF = far-field;% = percent; K = condition factor; LSI = liversomatic index; GSI = gonadosomatic index; - = not determined as overall P not significant or interaction term of ANCOVA significant.

a) ANOVA = Analysis of Variance (log-transformed data indicated by superscript); KW = Kruskal Wallis test; ns = not significant; - = not applicable.

b) Overall ANOVA Probability of Type 1 Error: * = <0.1; ** = <0.01; *** = <0.001; ns = *P* >0.1

c) Probability of Type 1 Error (adjusted α of 0.026 [Dunn-Šidák method] for 4 comparisons: * = P <0.026; ** = P <0.01; *** = P <0.001; ns = *P* >0.026. Probability of Type 1 Error for KW Test: * = 0.1; ** = <0.01; *** = <0.001; ns = *P* >0.1.

d) The percent difference between exposure area mean and the reference area means.

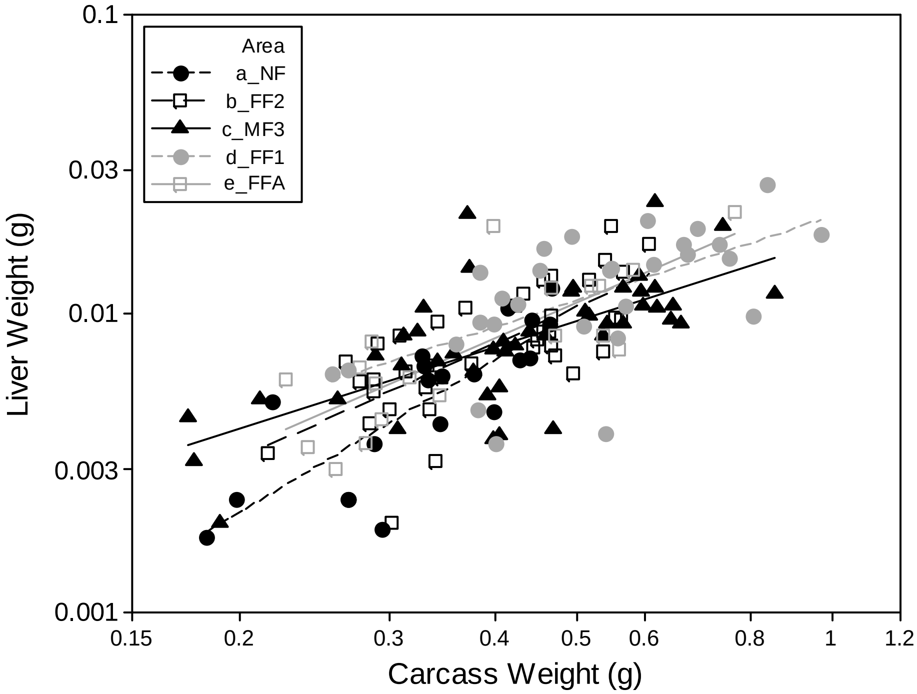
e) The relative percent difference between the reference area means.

f) Power achieved to detect a significant decrease of 10%, 20% and 30%.

3.3.8 Relative Liver Size

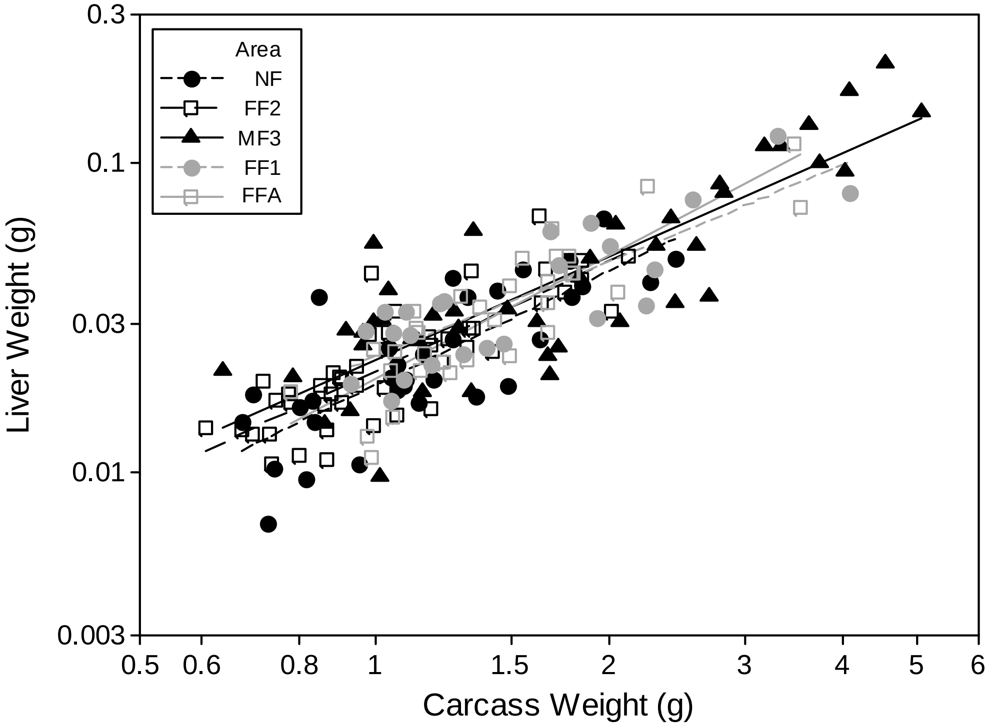
Age-1+ LSI and liver weight adjusted for carcass weight was 26% and 28% lower, respectively, in the NF exposure area when compared to the reference areas (Table 3-7, Table 3-8; Figure 3-5). There was no difference in age-1+ liver size between the other two exposure areas, FF2 and MF3, and the references. Although the LSI in adult male and female fish from the NF area was smaller than in reference area fish, the difference was not statistically significant (Table 3-8, Figure 3-6, Figure 3-7).

Figure 3-5 Liver Weight Over Carcass Weight of Age-1+ Slimy Sculpin from Lac de Gras, 2013



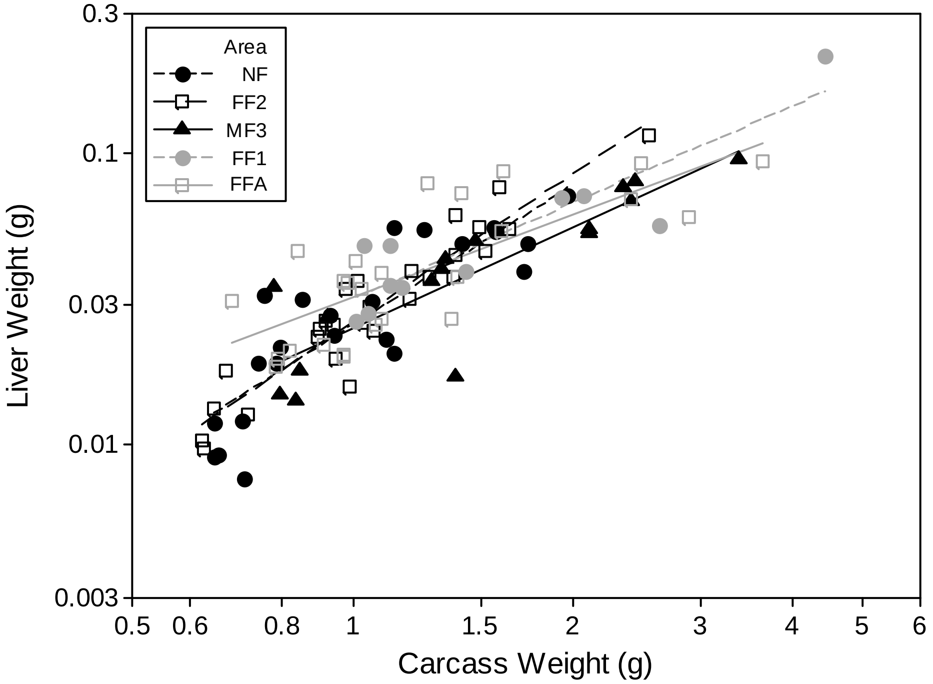
Notes: NF = near-field; MF = mid-field; FF = far-field; M = male; F = female; g = gram.

Figure 3-6 Liver Weight Over Carcass Weight of Male Slimy Sculpin from Lac de Gras, 2013



Notes: NF = near-field; MF = mid-field; FF = far-field; M = male; F = female; g = gram.

Figure 3-7 Liver Weight Over Carcass Weight of Female Slimy Sculpin from Lac de Gras, 2013

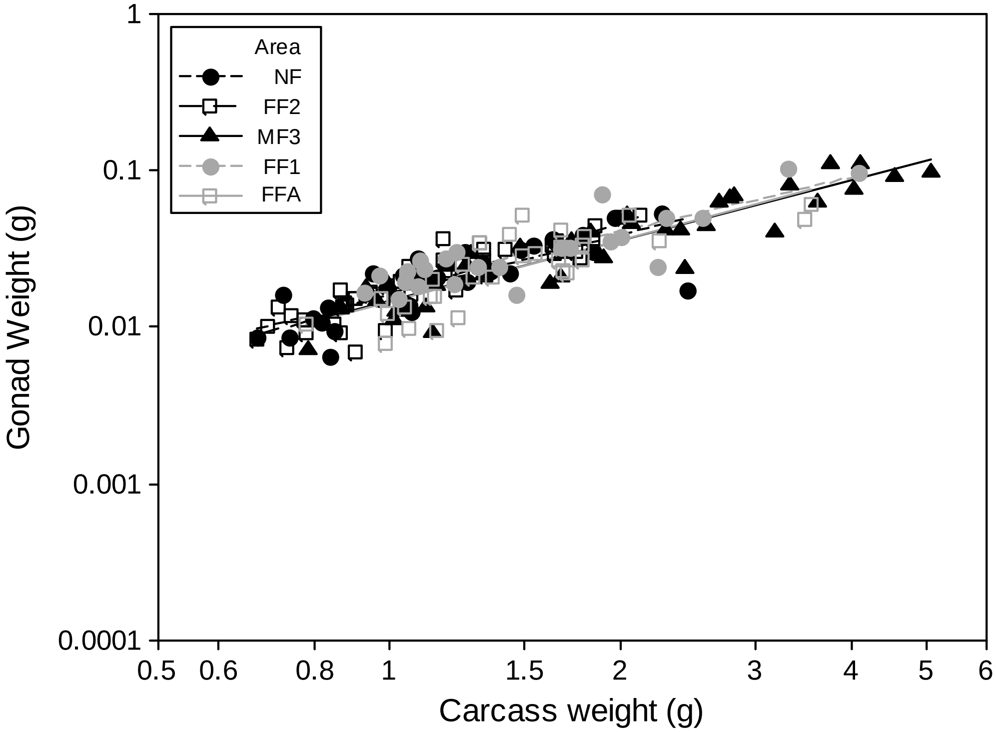


Notes: NF = near-field; MF = mid-field; FF = far-field; M = male; F = female; g = gram.

3.3.9 Relative Gonad Size

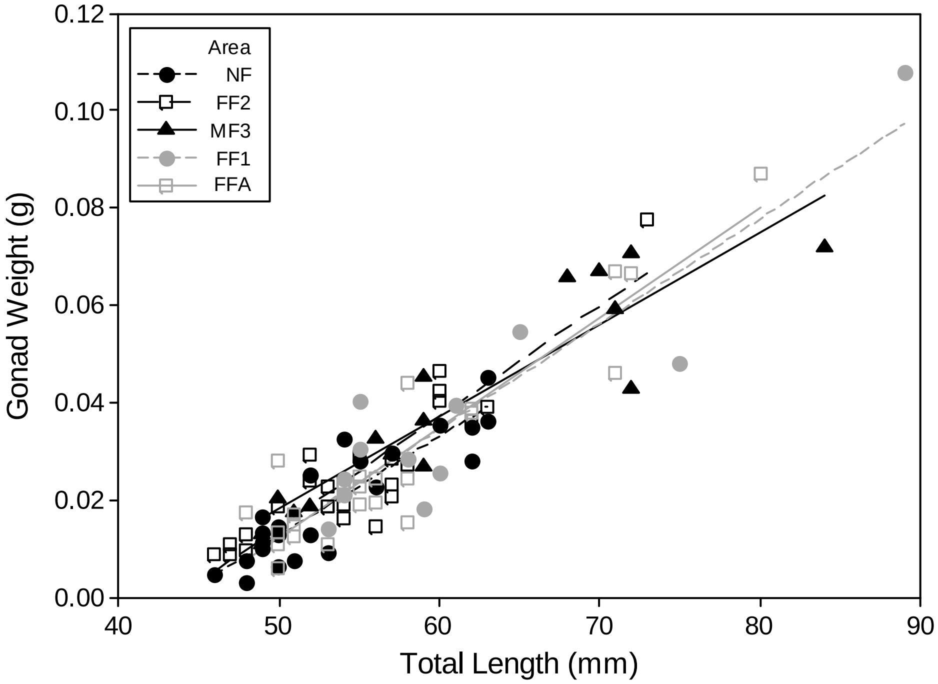
There was no significant difference among areas in either GSI or gonad size adjusted for body size in adult males (Table 3-7, Table 3-8; Figure 3-8). Adult females from the NF exposure area had significantly smaller GSIs than those from the reference areas (19% lower), and the difference was larger than that between the two reference areas (Table 3-7; Table 3-8; Figure 3-9). There was a significant difference among the slopes for gonad size adjusted for carcass weight, as such the statistical testing proceeded using body length. There was no statistical difference in female gonad size adjusted for length; however, the significant difference in slopes using carcass weight as a covariate may have been indicative of a significant effect.

Figure 3-8 Gonad Weight Over Carcass Weight of Male Slimy Sculpin from Lac de Gras, 2013



Notes: NF = near-field; MF = mid-field; FF = far-field; M = male; F = female; g = gram.

Figure 3-9 Gonad Weight Over Length of Female Slimy Sculpin from Lac de Gras, 2013



Notes: NF = near-field; MF = mid-field; FF = far-field; M = male; F = female; g = gram.

3.3.10 Relative Reproductive Success

Relative reproductive success can be assessed by observing the abundance of YOY; however, only one confirmed YOY Slimy Sculpin was captured. It is likely that YOY sculpin would have been too small to be captured by electrofishing. Given the abundance of sculpin in the exposure areas (Table 3-2), reproductive success is likely similar at exposure areas compared to the reference areas.

Chi-squared analysis on the proportion of age-1+ to adult fish (Table 3-9) revealed that the relative proportion of age-1+ Slimy Sculpin captured at NF was 10% lower than that at the reference areas (Table 3-10). However, the proportion of age-1+ Slimy Sculpin from the two reference areas were similarly different from one another, suggesting this magnitude of difference is within natural variability. The proportions of age-1+ Slimy Sculpin captured from the other exposure areas were not different from that of the reference area.

Table 3-9 Number of Age-1+ and Adult Slimy Sculpin, by Study Area, from Lac de Gras, 2013

Group	NF	FF2	MF3	FF1	FFA
Age-1+	22	73	55	37	42
Adult (>age-1+)	67	127	75	48	93
Proportion of Age-1+ fish	0.33	0.57	0.73	0.77	0.45

Notes: NF = near-field; MF = mid-field; FF = far-field.

Table 3-10 Proportion of Age-1+ Slimy Sculpin from Lac de Gras by Study Area, 2013

Parameter	Statistical Test	Area	Exposure vs. Reference Comparisons						Reference vs. Reference Comparisons	
			NF		FF2		MF3		FF1 vs FFA	
		P-value	*P*-value	% (a)	*P*-value	% (a)	*P*-value	% (a)	*P*-value	% (a)
Proportion of Age-1+ fish	Chi-square	*	*	-10.0	ns	0.6	ns	6.4	*	12.4

Notes:% = percent; NF = near-field; MF = mid-field; FF = far-field; * = <0.1; ns = not significant.

a – The percent magnitude of the difference between exposure and reference areas are the absolute differences between the proportion of age-1+ Slimy Sculpin.

3.3.11 Normal Range

Normal range can provide perspective about the biological significance of differences observed among populations, as well as a measure of natural variability. The normal range for fish health endpoints (Section 2.7.6), the area mean, and the total percent of individual results outside of the normal range are presented in Table 3-11. There were no fish health endpoints where the mean was found to be outside of the normal range.

Table 3-11 Normal Range of Fish Health Parameters in Slimy Sculpin from Reference Areas and Mean Concentrations from all Areas in Lac de Gras

Sex/ Stage	Response	Reference n	Transformation	Normal Range(a)	Exposure Areas												Reference Areas							
					NF				FF2				MF3				FF1				FFA			
					n	Mean	% below	% above	n	Mean	% below	% above	n	Mean	% below	% above	n	Mean	% below	% above	n	Mean	% below	% above
Age-1+	Length	235	-	32.5 to 50.7	22	38	4.5	-	73	38.986	2.7	-	55	40.2	9.1	-	37	43.73	-	8.1	42	40.881	7.1	-
	Total Weight	229	log	0.2832 to 1.0613	21	0.3988	14.3	-	73	0.4877	5.5	-	53	0.5279	3.8	-	37	0.6485	-	-	36	0.541	8.3	-
	Condition, *K*	110	-	0.5927 to 0.9781	21	0.7229	-	-	73	0.8029	2.7	5.5	53	0.7889	-	5.6	37	0.7586	-	-	36	0.791	2.8	2.8
	LSI	110	-	0.76 to 3.94	20	1.637	5.0	-	39	2.0695	2.6	-	47	2.054	-	2.1	29	2.366	3.4	-	19	2.158	-	5.3
Adult Male	Length	99	log	46.5 to 82.5	33	56.45	-	-	48	54.688	2.1	-	44	63.98	-	4.5	24	61.33	-	4.2	33	59.79	-	-
	Total Weight	99	log	0.7377 to 4.8831	33	1.4457	-	-	48	1.2967	2.1	-	43	2.207	-	2.3	24	1.898	-	-	33	1.73	-	-
	Carcass weight	99	log	0.6292 to 4.1343	33	1.2451	-	-	48	1.1295	2.1	-	44	1.967	-	4.5	24	1.656	-	-	33	1.516	-	-
	Condition, *K*	99	log	0.5331 to 0.8604	33	0.66497	-	-	48	0.66649	-	-	44	0.67652	-	-	24	0.6786	-	4.2	33	0.6832	3.0	3.0
	LSI	98	log	1.14 to 5.40	33	2.105	6.1	-	48	2.2357	-	-	44	2.624	2.3	2.3	24	2.479	-	-	33	2.339	3.0	-
	GSI	99	-	0.39 to 3.16	33	1.7352	3.0	-	48	1.6785	6.3	-	44	1.6911	6.8	-	24	2.052	-	8.3	33	1.666	3.0	3.0
Adult Female	Length	63	log	43.5 to 86.8	23	53.39	-	-	27	55.15	-	-	16	61.13	-	-	12	61.5	-	8.3	25	57.24	-	-
	Total body weight	63	log	0.6136 to 5.4992	23	1.244	-	-	27	1.327	-	-	16	1.909	-	-	12	1.99	-	-	25	1.557	-	-
	Carcass weight	63	log	0.5283 to 4.6270	23	1.0765	-	-	27	1.1318	-	-	16	1.607	-	-	12	1.685	-	-	25	1.36	-	-
	Condition, *K*	63	-	0.5517 to 0.8021	23	0.6779	-	-	27	0.6507	-	-	16	0.6614	-	-	12	0.6729	-	8.3	25	0.674	-	4.0
	LSI	62	log	1.51 to 7.66	23	2.807	13.0	-	27	2.894	-	-	16	2.766	6.3	-	11	3.401	-	-	25	3.35	-	-
	GSI	62	-	0.87 to 3.29	23	1.706	17.4	-	26	2.18	-	3.7	16	2.374	-	-	12	2.256	-	8.3	25	2.017	4.0	-

Notes: NF = near-field; MF = mid-field; FF = far-field; n = samples size; log = logarithm base 10;% above = percent of individuals that are above the normal range;% below = percent of individuals that are below the normal range; - = no data.
a – Normal range for fish health parameters determined as mean ± 2SD of the reference area (FFA and FF1) values from the 2007 and 2013 fish surveys.

3.3.12 Power Analysis

For an effect size of 30%, a power of 90% or more was achieved for all parameters that were found to be not significant. Parameters with the lowest power were those related to gonad size in adult male and female Slimy Sculpin (Table 3-8). Study results were not affected by parameters with low power since the study had sufficient power to detect a 30% difference in all parameters.

3.3.13 Stomach Contents

A comparison of the major taxa present in Slimy Sculpin stomachs by sex/life stage was conducted for all areas (Table 3-12). For all areas, the taxonomist also provided an estimate of the major taxon percent composition for each individual stomach. These results are summarized in Figures 3-10 and 3-11. Detailed stomach content results are presented in Appendix F.

Chironomids (predominantly Orthocladiinae; Figure 3-10; Figure 3-11) and Cladocera were commonly found in the stomachs of fish from all areas, and they were the most dominant taxa in sculpin stomachs (Table 3-12; Figure 3-10). Notable differences in the stomach contents among populations were the large numbers of other Diptera in fish from mid-field area MF3 and reference area FFA, whereas Trichoptera and terrestrial organisms (primarily Chironomidae and Trichoptera adults) were a major food item in fish from exposure area NF and reference area FF1. There were also relatively fewer Cladocera in the stomachs of NF fish, and relatively more Cladocera in the stomachs of FF2 fish, as compared to all other areas. Finally, fewer taxa made up the large proportion of stomach contents of age-1+ sculpin captured in reference areas FF1 and FFA, as compared to adult fish in the same areas.

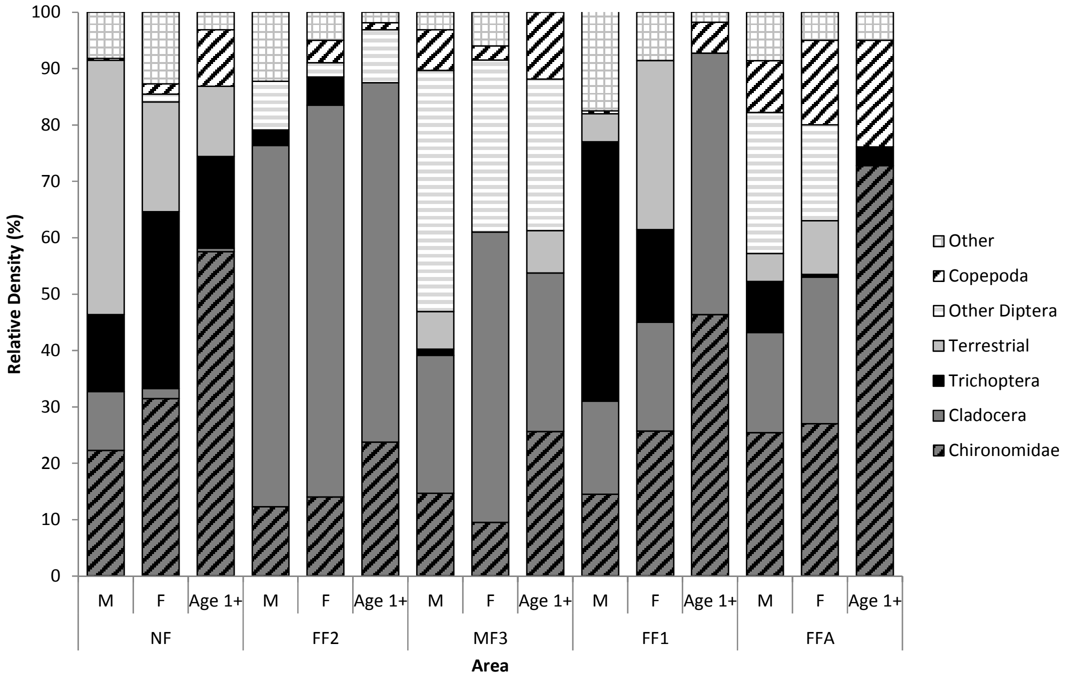
Table 3-12 Presence-Absence of Major Taxonomic Groups in Stomach Contents of Slimy Sculpin Captured in Lac de Gras, 2013

Major Group	**NF**			**FF2**			**MF3**			**FF1**			**FFA**		
	M	**F**	**Age-1+**	**M**	**F**	**Age-1+**	**M**	**F**	**Age-1+**	**M**	**F**	**Age-1+**	**M**	**F**	**Age-1+**
Sample Size (n)	11	11	8	11	10	8	9	10	8	10	7	11	10	10	9
Inorganic material	-	X	-	-	-	X	-	X	-	X	-	-	-	-	-
Terrestrial	X	X	X	-	-	-	X	-	X	X	X	-	X	X	-
Algae	-		-	X	-	-	-	-	-	-	-	-	-	-	-
Chironomidae Chiromoninae	-		-	X	X	-	X	X	-	X	-	-	-	X	X
Chironomidae Tanytarsini	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Chironomidae Orthocladiinae	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Chironomidae Tanypodinae	X		-	-	X	-	X	X	-	X	X	X	X	X	-
Chironomidae Diamesinae	X	X	-	X	X	X	X	X	X	X	-	-	-	-	-
Chironomidae Pupa	-		-	X	-	-	-	-	-	X	X	X	X	X	-
Ostracoda	-		X	-	X	X	X	-	-	-	-	X	X	-	-
Cladocera	X	X	X	X	X	X	X	X	X	X	X	X	X	X	-
Copepoda	X	X	X	-	X	X	X	X	X	X	-	X	X	X	X
Other Diptera	-	X	-	X	X	X	X	X	X	-	-	-	X	X	-
Hemiptera	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-
Nematoda	X	-	-	-	-	-	-	-	-	X	X	-	-	-	-
Coleoptera	X	X	-	-	X	-	-	X	-	X	-	-	X	X	-
Plecoptera	X	X	X	X	-	-	X	-	-	X	-	-	X	-	X
Trichoptera	X	X	X	X	X	-	X	-	-	X	X	-	X	X	X
Other	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-
TOTAL TAXA	11	11	8	10	11	8	12	10	7	16	8	7	12	11	6

Notes: NF = near-field; MF = mid-field; FF = far-field; M = male; F = female; n = sample size; X = taxon present; "-" = taxon absent.

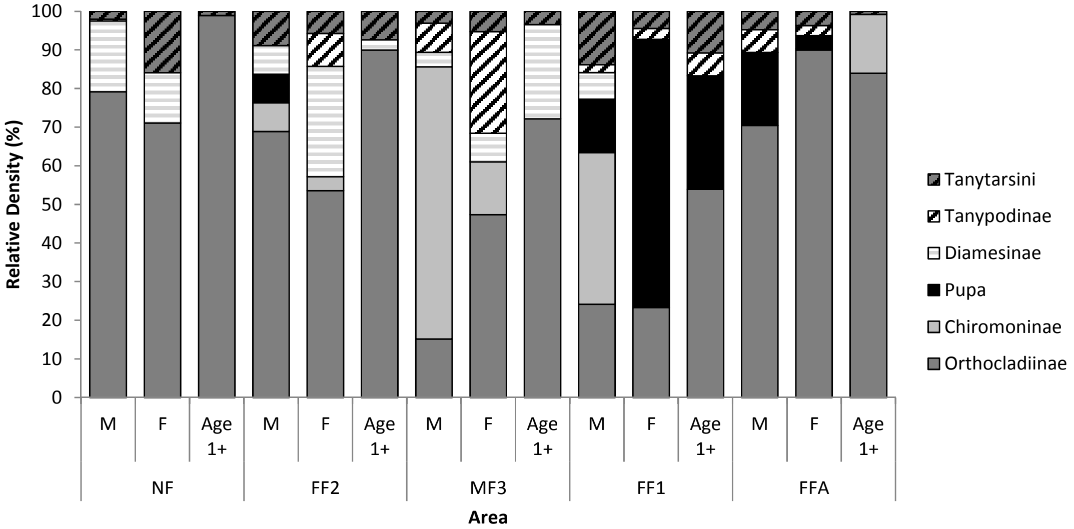
a) Terrestrial taxa includes Chironomidae and Trichoptera adults, and other unspecified material.

Figure 3-10 Composition of the Major Taxonomic Groups in Slimy Sculpin Stomach Contents, 2013



Notes: NF = near-field; MF = mid-field; FF = far-field; M = male; F = female;% = percent.

Figure 3-11 Chironomidae Composition in Slimy Sculpin Stomachs Captured in Lac de Gras, 2013



Notes: NF = near-field; MF = mid-field; FF = far-field; M = male; F = female;% = percent.

3.4 FISH TISSUE CHEMISTRY

3.4.1 Detection Limits

A few laboratory detection limits were higher than listed in the AEMP Design Document (Golder 2014a): calcium; magnesium; phosphorus; potassium; and vanadium. Of these variables, only one sample result was reported as being below the detection limit (sample FF1-5 vanadium); therefore, the increases in detection limits for these metals did not have an effect on the interpretation of the results.

3.4.2 Statistical Comparisons

A total of 40 composite samples were analyzed for percent moisture content and metals (Appendix G). The mean concentrations of uranium was significantly greater in Slimy Sculpin from exposure areas NF, FF2 and MF3 compared to sculpin in the reference areas (Table 3-13; Table 3-14). Bismuth was significantly greater at the NF and MF3 exposure areas. Three other metals (lead, strontium, and thallium) were significantly greater at the NF area only. Four metals (arsenic, iron, manganese, and molybdenum) were found in greater concentration in fish from exposure area FF2 compared to fish from the reference areas. Both copper and vanadium were significantly greater at the MF3 exposure area only. Additional, significant differences were detected between the two reference areas for arsenic, cadmium, copper, nickel, thallium, and zinc.

Table 3-13 Concentration (Mean ± SD, µg/g wet weight) of Metals in Slimy Sculpin from Lac de Gras, 2013

Variable	DL	NF	FF2	MF3	FF1	FFA
Sample Size (a)	-	8	8	8	8	8
% Moisture	0.1	73.8 ± 0.9	73.8 ± 0.9	75.5 ± 1.8	73.2 ± 1.0	74.5 ± 0.6
Aluminum (Al)	0.4	1.8 ± 0.3	2.4 ± 1.2	2.6 ± 1.6	1.9 ± 0.6	2.6 ± 1.3
Antimony (Sb)	0.002	<DL(b)	<DL(b)	<DL(b)	<DL(b)	<DL(b)
Arsenic (As)	0.004	0.049 ± 0.008	0.079 ± 0.018	0.050 ± 0.010	0.037 ± 0.012	0.056 ± 0.011
Barium (Ba)	0.01	4.23 ± 1.10	4.10 ± 1.12	5.64 ± 2.82	3.36 ± 1.08	5.09 ± 1.75
Beryllium (Be)	0.002	<DL(b)	<DL(b)	<DL(b)	<DL(b)	<DL(b)
Bismuth (Bi)	0.002	0.004 ± 0.005 (4 <DL)(c)	0.002 ± 0.001 (5 <DL)(c)	0.003 ± 0.002 (3 <DL)(c)	<DL(b)	<DL(b)
Boron (B)	0.2	<DL(b)	<DL(b)	<DL(b)	<DL(b)	<DL(b)
Cadmium (Cd)	0.002	0.011 ± 0.002	0.014 ± 0.005	0.012 ± 0.004	0.013 ± 0.004	0.025 ± 0.008
Calcium (Ca)	5	11063 ± 2044	10886 ± 2212	11545 ± 3142	9715 ± 2605	12499 ± 4233
Cesium (Cs)	0.001	0.023 ± 0.004	0.021 ± 0.005	0.024 ± 0.007	0.026 ± 0.005	0.035 ± 0.012
Chromium (Cr)	0.01	0.02 ± 0.01 (1 <DL)(c)	0.03 ± 0.02 (1 <DL)(c)	0.04 ± 0.03 (1 <DL)(c)	0.03 ± 0.01 (1 <DL)(c)	0.03 ± 0.02 (1 <DL)(c)
Cobalt (Co)	0.004	0.025 ± 0.007	0.042 ± 0.011	0.034 ± 0.003	0.021 ± 0.006	0.119 ± 0.052
Copper (Cu)	0.01	0.51 ± 0.03	0.54 ± 0.06	0.56 ± 0.05	0.49 ± 0.02	0.54 ± 0.04
Gallium (Ga)	0.004	<DL(b)	<DL(b)	<DL(b)	<DL(b)	<DL(b)
Iron (Fe)	0.2	9.6 ± 1.4	14.7 ± 4.0	13.7 ± 4.2	10.3 ± 2.7	10.8 ± 2.5
Lead (Pb)	0.004	0.012 ± 0.003	0.004 ± 0.001 (3 <DL)(c)	0.008 ± 0.002	0.006 ± 0.006 (5 <DL)(c)	0.004 ± 0.002 (3 <DL)(c)
Lithium (Li)	0.02	<DL(b)	<DL(b)	<DL(b)	<DL(b)	<DL(b)
Magnesium (Mg)	10	394 ± 34	389 ± 46	378 ± 42	370 ± 43	413 ± 55
Manganese (Mn)	0.004	12.145 ± 2.829	27.045 ± 15.574	8.185 ± 5.026	14.024 ± 8.691	11.204 ± 3.536
Mercury (Hg)	0.001	0.015 ± 0.003	0.019 ± 0.006	0.021 ± 0.008	0.021 ± 0.007	0.020 ± 0.009
Molybdenum (Mo)	0.004	0.038 ± 0.008	0.050 ± 0.026	0.035 ± 0.011	0.027 ± 0.006	0.031 ± 0.019
Nickel (Ni)	0.01	0.09 ± 0.01	0.10 ± 0.02	0.15 ± 0.03	0.10 ± 0.01	0.27 ± 0.06
Phosphorus (P)	50	7143 ± 1010	7046 ± 1142	7276 ± 1684	6496 ± 1302	7828 ± 2047
Potassium (K)	200	3781 ± 181	3723 ± 260	3599 ± 145	3868 ± 326	3788 ± 240
Rhenium (Re)	0.002	<DL(b)	<DL(b)	<DL(b)	<DL(b)	<DL(b)
Rubidium (Rb)	0.01	3.19 ± 0.51	3.68 ± 0.87	3.81 ± 0.76	3.32 ± 0.75	2.86 ± 0.29
Selenium (Se)	0.02	0.26 ± 0.04	0.25 ± 0.04	0.25 ± 0.05	0.29 ± 0.05	0.32 ± 0.04
Silver (Ag)	0.001	0.002 ± 0.0004	0.002 ± 0.0009	0.001 ± 0.0004 (6 <DL) (c)	0.002 ± 0.001 (2 <DL) (c)	0.001 ± 0.0002 (7 <DL)(c)
Sodium (Na)	200	1265 ± 96	1214 ± 85	1335 ± 43	1223 ± 98	1288 ± 57
Strontium (Sr)	0.01	46.38 ± 8.94	40.34 ± 8.21	37.86 ± 10.50	30.14 ± 7.20	39.60 ± 12.44

Table 3-13 Concentration (Mean ± SD, µg/g wet weight) of Metals in Slimy Sculpin from Lac de Gras, 2013 (continued)

Variable	DL	NF	FF2	MF3	FF1	FFA
Tellurium (Te)	0.004	<DL(b)	<DL(b)	<DL(b)	<DL(b)	<DL(b)
Thallium (Tl)	0.0004	0.006 ± 0.001	0.005 ± 0.001	0.004 ± 0.001	0.004 ± 0.001	0.005 ± 0.001
Thorium (Th)	0.002	0.002 ± 0.002 (7 <DL) (c)	<DL(b)	<DL(b)	0.002 ± 0.001 (6 <DL) (c)	<DL(b)
Tin (Sn)	0.02	0.07 ± 0.03	0.08 ± 0.03	0.06 ± 0.02	0.07 ± 0.04	0.05 ± 0.03
Titanium (Ti)	0.01	0.11 ± 0.17	0.10 ± 0.07	0.11 ± 0.10	0.06 ± 0.04	0.05 ± 0.04
Uranium (U)	0.0004	0.108 ± 0.064	0.030 ± 0.008	0.024 ± 0.006	0.011 ± 0.003	0.016 ± 0.006
Vanadium (V)	0.02	0.04 ± 0.01	0.05 ± 0.01	0.07 ± 0.02	0.03 ± 0.01 (1 <DL) (c)	0.04 ± 0.02
Yttrium (Y)	0.002	0.002 ± 0.001 (2 <DL) (c)	0.002 ± 0.001 (2 <DL) (c)	0.003 ± 0.002 (3 <DL) (c)	0.002 ± 0.001 (4 <DL) (c)	0.002 ± 0.001 (3 <DL) (c)
Zinc (Zn)	0.1	32.0 ± 4.4	29.4 ± 2.9	32.3 ± 4.1	28.0 ± 5.0	35.0 ± 2.9
Zirconium (Zr)	0.04	<DL(b)	<DL(b)	0.04 ± 0.03 (7 <DL) (c)	<DL(b)	<DL(b)

Note: NF = near-field; MF = mid-field; FF = far-field; DL = detection limit; SD = standard deviation; µg/g = microgram per gram; <= less than; ± = plus minus.

a) Refers to the number of composite whole-fish samples (excluding stomach, gonad and otoliths). The composition of each sample is summarized in Table 2-2.

b) All samples had concentrations below the detection limit (DL).

c) DLs were replaced with 0.71 × DL (see text) (number of samples <DL shown in brackets).

Table 3-14 Statistical Comparisons of Slimy Sculpin Tissue Metal Concentrations Among Sampling Areas in Lac de Gras, 2013

Variable	Statistical Test(a)	Area	Exposure vs. Reference Comparisons						Reference vs. Reference Comparisons	
			NF		FF2		MF3		FF1 vs. FFA	
		P(b)	*P*(c)	%(d)	*P*(c)	%(d)	*P*(c)	%(d)	*P*(c)	%(e)
Aluminum (Al)	ANOVA^{log}	ns	nd	-20.32	nd	6.41	nd	13.99	nd	35.37
Arsenic (As)	ANOVA	***	ns	6.41	***	69.57	ns	7.73	**	50.12
Barium (Ba)	ANOVA^{log}	ns	nd	0.19	nd	-2.95	nd	33.46	nd	51.56
Bismuth (Bi)	KW	*	*	194.72	ns	61.97	**	138.20	ns	0.00
Cadmium (Cd)	ANOVA	***	***	-43.76	*	-28.31	***	-35.58	***	90.12
Calcium (Ca)	ANOVA	ns	nd	-0.40	nd	-1.99	nd	3.94	nd	28.65
Cesium (Cs)	ANOVA^{log}	**	ns	-24.45	**	-31.78	ns	-22.23	ns	36.63
Chromium (Cr)	ANOVA	ns	nd	-23.78	nd	-9.27	nd	11.29	nd	5.81
Cobalt (Co)	KW	****	ns	-64.31	ns	-40.46	ns	-52.16	ns	455.97
Copper (Cu)	ANOVA	*	ns	0.64	ns	6.36	*	8.86	*	10.07
Iron (Fe)	ANOVA^{log}	*	ns	-8.97	**	39.66	ns	29.94	ns	4.32
Lead (Pb)	KW	**	***	117.48	ns	-23.85	ns	42.99	ns	32.26
Magnesium (Mg)	ANOVA	ns	nd	0.64	nd	-0.70	nd	-3.35	nd	11.70
Manganese (Mn)	ANOVA^{log}	**	ns	-3.72	**	114.41	ns	-35.11	ns	20.11
Mercury (Hg)	ANCOVA	ns	nd	-19.77	nd	-2.95	nd	-2.63	nd	9.76
Molybdenum (Mo)	ANOVA^{log}	*	ns	31.52	**	72.61	ns	19.15	ns	16.95
Nickel (Ni)	ANOVA^{log}	***	***	-49.27	***	-43.29	ns	-18.44	***	181.48
Phosphorus (P)	ANOVA	ns	nd	-0.27	nd	-1.61	nd	1.60	nd	20.49
Potassium (K)	ANOVA	ns	nd	-1.21	nd	-2.74	nd	-5.98	nd	2.07
Rubidium (Rb)	ANOVA^{log}	ns	nd	3.18	nd	19.16	nd	23.16	nd	13.89
Selenium (Se)	ANOVA	*	*	-16.27	*	-17.70	**	-19.47	ns	7.36
Silver (Ag)	KW	**	ns	27.98	ns	44.24	ns	-25.24	ns	52.18
Sodium (Na)	ANOVA	ns	nd	0.80	nd	-3.29	nd	6.37	nd	5.32
Strontium (Sr)	ANOVA	ns	**	33.00	nd	15.68	nd	8.59	nd	31.40
Thallium (Tl)	ANOVA^{log}	**	*	22.92	ns	9.09	ns	-9.68	*	30.34
Tin (Sn)	ANOVA^{log}	ns	nd	4.30	nd	29.13	nd	-6.31	nd	26.86
Titanium (Ti)	ANOVA^{log}	ns	nd	92.68	nd	78.90	nd	92.47	nd	14.57
Uranium (U)	ANOVA^{log}	***	***	719.13	***	123.91	***	83.62	ns	45.64
Vanadium (V)	ANOVA	***	ns	4.24	ns	45.20	***	95.09	ns	37.49
Yttrium (Y)	ANOVA^{log}	ns	nd	7.75	nd	3.79	nd	30.50	nd	28.29
Zinc (Zn)	ANOVA^{log}	**	ns	0.00	ns	0.00	ns	31.07	***	0.00

Note: NF = near-field; MF = mid-field; FF = far-field; nd = not determined as overall *P* not significant; ns = not significant.

a) ANOVA = Analysis of Variance (log-transformed data indicated by superscript); ANCOVA = Analysis of Covariance; KW = Kruskal Wallis test.

b) Overall ANOVA Probability of Type 1 Error: * = <0.1, ** = <0.01, *** = <0.001, **** = <0.0001, ns = non-significant.

c) Probability of Type 1 Error (adjusted α of 0.026 [Dunn-Šidák method]): * = <0.026, ** = <0.01, *** <0.001, **** = <0.0001, ns = non-significant. Probability of Type 1 Error for KW Test: * = <0.1, ** = <0.01, *** <0.001, **** = <0.0001, ns = non-significant.

d) Percent difference between group means.

e) Relative percent difference between group means.

3.4.3 Normal Range

Both bismuth and uranium concentrations were greater than the normal range from the NF exposure area (Table 3-15). Manganese was above normal range at the FF2 exposure area only.

Table 3-15 Normal Range Observed for Slimy Sculpin Tissue Chemistry Parameters in Reference Areas and Mean of Observed Data in Exposure Areas, 2013

Variable	Reference Areas FF1+FFA	NF	FF2	MF3
	Normal Range[(a)] (µg/g ww)	Mean (µg/g ww)	Mean (µg/g ww)	Mean (µg/g ww)
Aluminum (Al)	0 to 37.6	1.8	2.4	2.6
Arsenic (As)	0 to 0.204	0.049	0.079	0.05
Barium (Ba)	2.06 to 7.02	4.23	4.10	5.64
Bismuth (Bi)	<DL	0.004	0.002	0.003
Cadmium (Cd)	0 to 0.068	0.011	0.014	0.012
Calcium (Ca)	4,193 to 15,298	11,063	10,886	11,545
Cesium (Cs)	0 to 0.098	0.023	0.021	0.024
Chromium (Cr)	0 to 1.988	0.02	0.03	0.04
Cobalt (Co)	0 to 0.43	0.025	0.042	0.034
Copper (Cu)	0.31 to 1.22	0.51	0.54	0.56
Iron (Fe)	0 to 82.8	9.6	14.7	13.7
Lead (Pb)	0 to 0.043	0.012	0.004	0.008
Lithium (Li)	0 to 0.07[(b, c)]	nd[(c)]	nd[(c)]	nd[(c)]
Magnesium (Mg)	257 to 478	394	389	378
Manganese (Mn)	1.702 to 26.146	12.145	27.045	8.185
Mercury (Hg)	0 to 0.084	0.015	0.019	0.021
Molybdenum (Mo)	0.001 to 0.088	0.038	0.050	0.035
Nickel (Ni)	0 to 1.56	0.09	0.10	0.15
Phosphorus (P)	4,232 to 9,285	7,143	7,046	7,276
Potassium (K)	2,466 to 4,221	3,781	3,723	3,599
Rubidium (Rb)	1.45 to 7.97	3.19	3.68	3.81
Selenium (Se)	0.21 to 0.54	0.26	0.25	0.25
Silver (Ag)	0 to 0.006[(d)]	0.002	0.002	0.001
Sodium (Na)	872 to 1412	1,265	1,214	1,335
Strontium (Sr)	14.32 to 47.41	46.38	40.34	37.86
Thallium (Tl)	0.0012 to 0.0135[(d)]	0.006	0.005	0.004
Thorium (Th)	0 to 0.0049[(b, c)]	0.002	nd[(c)]	nd[(c)]
Tin (Sn)	0 to 0.17[(d)]	0.07	0.08	0.06
Titanium (Ti)	0 to 1.07	0.11	0.10	0.11
Uranium (U)	0.002 to 0.043	0.108	0.030	0.024
Vanadium (V)	0 to 0.28	0.04	0.05	0.07
Yttrium (Y)	0 to 0.008	0.002	0.002	0.003
Zinc (Zn)	17.2 to 50.0	32.0	29.4	32.3

Notes: NF = near-field; MF = mid-field; FF = far-field; DL = detection limit; SD = standard deviation; µg/g ww = micrograms per gram wet weight; nd = no data; **Bolded** values were those greater than normal range.

a) Normal range defined as Mean ± 2SD of the FFA and FF1 reference area data from 2007, 2010, 2013. Normal range was not calculated for parameters with more than half the results less than the DL in one year; Values <DL were replaced with 0.71 × DL (see text).

b) No data available in 2007.

c) Removed 2013 data from analysis as more than half the values were <DL.

d) Removed 2007 data from analysis as more than half the values were <DL.

3.4.4 QA/QC

Initial data screening of the ALS metals analysis revealed two outlier values for uranium concentrations in the NF-1 and NF-2 composite samples. As a QC measure, the tissue samples NF-1 and NF-2 were re-run by ALS and the original results were confirmed (Amber Springer, 2014, email communication).

Laboratory quality control samples were within acceptable limits for duplicate, laboratory blanks, control samples, spikes and reference materials for all metals, except for tin. Three duplicate samples for each metal were tested and only tin was above the relative percent difference (RPD) limit accepted by ALS for all three samples, suggesting that the distribution of tin in the samples was not homogeneous. Laboratory blanks, controls, spikes and reference materials were all within ALS standard acceptable limits or results were adjusted individually to reflect QC results (Amber Springer 2014, personal communication).

3.4.4.1 Mercury QC Analysis

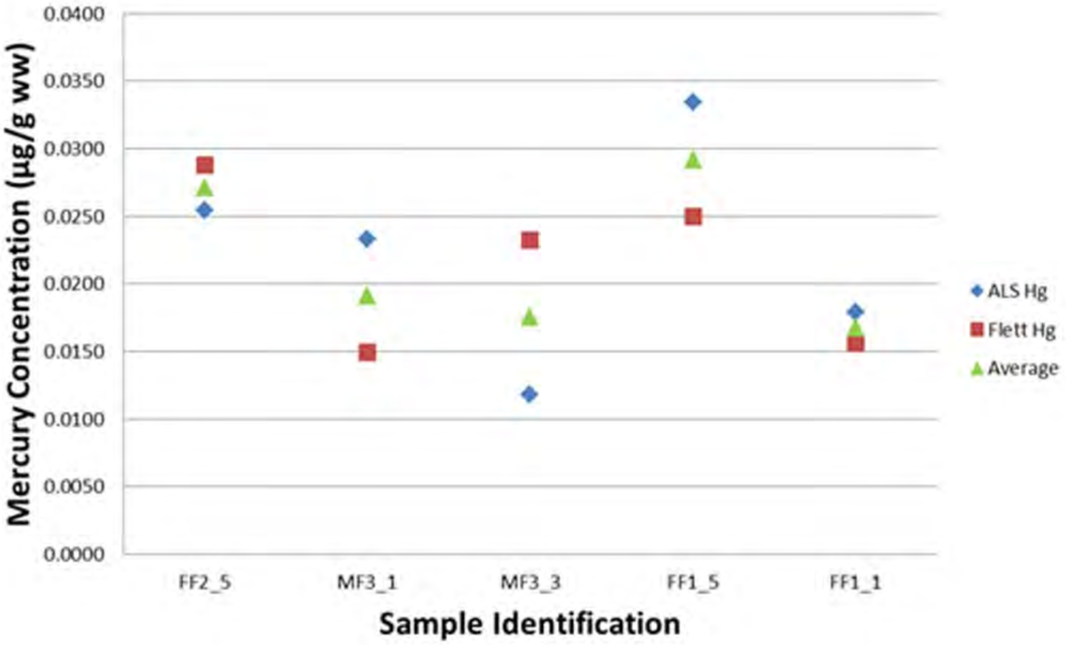
Mercury tissue concentrations were found to vary between analytical laboratories 2010 (Golder 2011b). As a QC measure, five randomly selected composites were sent to Flett Research Ltd. (Flett, Winnipeg, Manitoba) for a second determination of mercury concentration. None of the results from Flett or ALS were consistently higher than the other, and the relative differences among corresponding samples ranged from approximately 13% to 65% (Table 3-16). Regardless of the laboratory, the relative mercury concentrations between study areas is similar (Figure 3-12); therefore, statistical analysis was applied to the complete data set (n = 8) from ALS.

Table 3-16 Concentration of Mercury as analyzed by ALS Environmental Laboratories and Flett Research Ltd. in Slimy Sculpin from Lac de Gras, 2013

Sample	Hg (µg/g ww)		% Difference	% Moisture
	ALS	Flett		
FF1 Composite 1	0.0179	0.0156	13.73	73.3
FF1 Composite 5	0.0334	0.0250	28.90	75.1
FF2 Composite 5	0.0254	0.0288	12.55	72.3
MF3 Composite 1	0.0233	0.0149	43.98	73.8
MF3 Composite 3	0.0118	0.0232	65.14	76.1

Notes: FF = far-field; MF = mid-field; Hg = mercury; µg/g ww = microgram per gram wet weight;% = percent.

Figure3-12 Concentration of Mercury as Analyzed by ALS Environmental Laboratories and Flett Research Ltd. in Slimy Sculpin from Lac de Gras, 2013



Notes: NF = near-field; MF = mid-field; FF = far-field; M = male; F = female; µg/g ww = microgram per gram wet weight; Hg = mercury.

3.5 ACTION LEVELS

The Action Levels for fish health address the toxicological impairment hypothesis. There was a statistically significant decrease in length, weight, condition factor and LSI in age-1+ fish. In addition, the decreasing trend in size and LSI in adult male and female fish from the NF and FF2 exposure areas, as well as the significantly smaller gonads in NF female fish, indicate that an Action Level 1 for fish health has been reached. The fish health responses observed in the MF3 population indicate that an Action Level 2 has not been reached.

3.6 WEIGHT OF EVIDENCE INPUT

As described in Section 2.5, the results described in the preceding sections also feed into the WOE approach described in the Weight of Evidence Report (Golder 2014b). The results of the Weight of Evidence approach relevant to fish and related components are described in Section 3.17 of the Weight of Evidence Report.

4 DISCUSSION

4.1 FISH POPULATION HEALTH

There were differences in the population structure of Slimy Sculpin. However, a comparison of the length frequency modes from each population indicated that Slimy Sculpin of similar size ranges were captured at each area. Length frequency did not indicate an effect on survival.

Smaller age-1+ and adult Slimy Sculpin in the exposure areas indicate a possible nutrient limitation or toxicological effect. Nutrient limitation may be characterized by decreased condition factor, liver and gonad size, while toxicological effects may be characterized by increased or decreased liver weight, and decreased condition factor and gonad weight (Environment Canada 2012). There was no indication of nutrient limitation based on stomach contents, which provide an indication of the food ingested just prior to capture, or based on the findings of the eutrophication indicators, plankton or benthic invertebrate components of the AEMP (Golder 2014c, d, e).

The patterns of decreased size, decreased liver size and decreased gonad size in female fish are opposite to what was reported in 2010 where a nutrient enrichment pattern was observed (Golder 2011b). Given this difference in the direction of the response seen in previous surveys, non-mine related factors may be influencing the local differences in Slimy Sculpin biological endpoints. Although not considered a “nutrient limitation,” water temperature is influential on fish development and growth (Moyle and Cech 2004), and so it is important to consider the temperature regimes in the different areas that are being compared. Temperature logger data from the study areas indicate that the exposure areas were cooler than the reference areas throughout the open-water season. As such, sculpin growth may well have been slower due to cooler local temperatures during the growing season in 2013.

Condition factor index is a measure of the energy stores of a fish. This index describes the weight of a fish for a given length, and is often seen as a measure of the relative plumpness of the fish. Fish with greater mass than their counterparts of similar length are often considered to be in better ‘condition’. Fish store excess energy in two main compartments; fatty tissue and the liver. The liver stores energy primarily in the form of glycogen, which is a rapidly mobilized form of energy that can be used to power short-term bursts of activity. Fat is typically used for longer-term storage of energy reserves. Therefore, decreases in condition factor and liver size are consistent with either a toxicological or nutrient limitation effect. Juvenile fish tend to be more sensitive to toxicants, and most of the decreased responses in the age-1+ fish were statistically significant, were as many of those observed in adults were not. In addition, relative gonad size was smaller in female Slimy Sculpin from NF compared to the reference areas, indicating that less energy was allocated to reproduction in these sculpin. This can reflect the allocation of energy elsewhere, such as growth; however, there was no indication that female fish in the NF area were growing at a faster rate.

4.2 FISH TISSUE CHEMISTRY

Slimy Sculpin from the NF area had relatively greater concentrations of bismuth, lead, strontium, thallium, and uranium. In 2010, considerably more metals (consisting of aluminum, barium, bismuth, lead, lithium, molybdenum, silver, strontium, thorium, titanium, uranium, and yttrium) were elevated in NF fish (Golder 2011b). Of the metals identified in 2010 that were not greater in 2013, aluminum, lithium, molybdenum, silver and titanium were at least an order of magnitude lower in NF Slimy Sculpin in 2013 than in 2010. Differences between 2010 and 2013 my reflect variability of biological samples or seasonal patterns. Seasonality has been shown to significantly influence kidney and liver metal concentrations to the point that differences among populations are only seen in certain seasons (Couture and Pyle 2008).

Metals that were significantly elevated in the NF samples in both 2010 and 2013 were bismuth, lead, strontium, and uranium. Bismuth and uranium tissue concentrations were similar between 2010 and 2013, while 2013 lead concentrations were approximately half of those in 2010. Strontium concentrations were about a third higher in 2013 compared to 2010. Thallium was elevated in Slimy Sculpin from NF compared to reference in 2013 but not in 2010.

Similar to 2010 (Golder 2011b), tissue bismuth concentrations were low in samples from the near and far field exposure areas while they were below the detection limit for every reference area sample. The normal range for bismuth at the reference areas is, therefore; below the detection limit while mean bismuth in all exposure areas was above that. Values very near to the detection limit may have some uncertainty associated with them. Statistical differences were detected using the conservative, non-parametric, ranked, Kruskal Wallis test and most values were near or below the method detection limit while the NF values were near but above the detection limit. Baseline and reference lake data collected from smaller lakes near Lac de Gras report bismuth below the detection limit in most Slimy Sculpin tissue, but also report values similar to those measured in 2013 Slimy Sculpin from the exposure areas of Lac de Gras (range from below detection to 0.0108 µg/g; Rescan 2008, 2013). Considering that there is no guideline for the Protection of Aquatic Life for bismuth (CCME 1999) and the low concentrations at which it is found in exposure area Slimy Sculpin, it is unlikely that bismuth poses a health risk to these fish.

High levels of lead in body and organ tissues of fish can lead to reduced growth and survival (Jarvinen and Ankley 1998) and can lead to adverse effects such as scale loss, spinal curvature and caudal fin degeneration (Peplow and Edmonds 2002). For Brook Trout (*Salvelinus fontinalis*), these have been at whole body concentrations of 4.0 to 8.8 µg/g and visceral organ concentrations of 26.8 to 65.2 µg/g. Whole body concentrations found in near field exposure samples were two to three orders of magnitude lower than associated with reduced growth and an order of magnitude lower than those that were associated with reduced growth or egg hatchability in Brook Trout (0.4 µg/g); thus, they are not likely to impact fish health (Jarvinen and Ankley 1998). Baseline and reference lake data collected from smaller lakes near Lac de Gras report Slimy Sculpin lead body burdens from below detection limit to 0.335 µg/g (Rescan 2008, 2013) while the mean NF from Lac de Gras in 2013 was 0.012.

Strontium concentrations in Slimy Sculpin from the NF exposure area ranged from 37.3 to 60.2 µg/g ww. Strontium has properties that resemble calcium, and hypocalcaemia (i.e., a decrease in calcium concentration) has been identified as a possible mechanism of toxicity (Chowdhury and Blust 2012). Although Slimy Sculpin from NF and FF2 had significantly higher strontium body burdens than the reference areas, there was no corresponding significant decrease in the calcium concentration in Slimy Sculpin samples from 2013. The mean strontium body burden for 2013 Slimy Sculpin was within the range reported in baseline and reference lake data collected from smaller lakes near Lac de Gras (12.3 to 63.0 µg/g; Rescan 2008, 2013). Additionally, the range of strontium concentrations observed at the NF exposure area is overlapping, though lower than, the range of concentrations seen in other small-bodied fish (i.e., Lake Chub [*Couesius plumbeus*]) exposed to diamond mining activities (26.7 to 77.1 µg/g ww; De Beers 2013).

While thallium is known to be highly toxic to humans and animals in industrial settings, information linking thallium body burdens to potential toxicity to fish is limited. Thallium was elevated in Slimy Sculpin tissue from the near field area as well as both far field areas (FF2 and MF3) compared to the reference area in 2013. The mean thallium body burden for 2013 Slimy Sculpin was within the range reported in baseline and reference lake data collected from smaller lakes near Lac de Gras (below detection to 0.0120 µg/g) (Rescan 2008, 2013). Compared to 2010, the exposure area samples had similar thallium concentrations while the reference area thallium concentrations were less than half in 2013 (Golder 2011b). This decrease in the mean reference area thallium body burden lead to statistical differences between the exposure and reference areas in 2013. It is unclear what lead to the variability in reference thallium concentrations and it is recommended that thallium continue to be monitored for increases in exposure area fish tissue in Lac de Gras.

While MF exposure and reference area Slimy Sculpin tissue uranium concentrations fall within background concentrations, the tissue uranium concentrations in Slimy Sculpin from the NF area are about an order of magnitude above background concentrations reported from small lakes near Lac de Gras (0.0029 to 0.0477 µg/g; Rescan 2008, 2013). 2013 uranium body burdens were similar to those previously measured in Slimy Sculpin from Lac de Gras (Golder 2008a, 2011b) and they are considerably lower than those seen in other small-bodied fish (Lake Chub) exposed to uranium mining activities (0.39 to 1.65 µg/g) (Golder 2006, 2008b). The mechanism of toxicity of chronic uranium to fish is not well known (Goulet et al. 2012). In mammals, uranium is nephrotoxic, and proximal tubule necrosis has been observed in Lake Whitefish fed a high uranium diet (Cooley et al. 2000). The potential nutrient limitation or toxicological effect pattern seen in the biological endpoints has not been linked to uranium exposure, nor can it be ignored as a possible contributor; however, the concentration of uranium in water is well below levels known to cause toxicity.

Because of their potential for bioaccumulation and toxicity, mercury is often a metal of concern associated with mining activity. In 2013, mercury body burdens increased with total length of Slimy Sculpin, indicating that it bio-accumulated, but did not differ significantly between exposure and reference area fish. Mercury levels in Slimy Sculpin at the NF exposure area were similar in 2013 to 2010, and were within the range of concentrations reported in 2005 (Gray et al. 2005; Golder 2011b). Also consistent with 2010, mercury body burdens were not greater in exposure area NF in 2013. From a human health perspective, mercury levels found in the NF exposure area Slimy Sculpin were well below Health Canada's maximum acceptable levels in the edible portion of retail fish (0.5 µg/g). Excessive levels of mercury can also adversely affect fish health; however, adverse effects are typically not seen at tissue concentration of less than 1.0 µg/g (Jarvinen and Ankley 1998; Scheuhammer et al. 2007). Thus, current tissue mercury concentrations in sculpin are not expected to affect fish health.

5 CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

The conclusions of the fish survey are as follows:

- There was a decrease in body size (length and weight) in age-1+ fish and adult males at all exposure areas.
- There was a decrease in body size (length and weight) in adult females at the NF exposure area.
- There was a decrease in condition factor and relative liver weight in age-1+ fish from the NF exposure area.
- There was a decrease in relative gonad size in adult females from the NF exposure area.
- These findings are in contrast to those of the previous three surveys, which demonstrated population responses typical of nutrient enriched environments.
- Concentrations of bismuth, lead, strontium, thallium, and uranium were elevated in NF exposure area fish compared to reference fish. Concentrations of these metals in water are not at concentrations known to cause effects in fish and are well below guideline values.
- The responses observed in Slimy Sculpin are not consistent with those in the other AEMP components, which all indicate a nutrient enrichment response.
- Differences in environmental factors in 2013 (such as temperature) may account for some of the responses observed in Slimy Sculpin in 2013.
- Since the differences observed between exposure and reference fish can be indicative of a toxicological response, the effects observed in 2013 are at a magnitude equivalent to Action Level 1.
- Given the uncertainty related to the reasons for the particular response in 2013, the Slimy Sculpin Survey will be repeated in 2016 to confirm the effect.

5.2 RECOMMENDATIONS

Since 2013 was the first study to report effects in Slimy Sculpin equivalent to Action Level 1, it will be important to confirm the response pattern during the next fish survey, which is scheduled to occur in 2016. It will be necessary to confirm the effect before we can conclude that a toxicological effect has occurred. The effects patterns from the three previous fish surveys should also be examined for temporal trends that may signal a shift in the overall health of the Slimy Sculpin population in the NF exposure area. Temporal trends will be evaluated in the three year AEMP summary report, which will be submitted to the WLWB on October 31, 2014.

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7 CLOSURE

We trust that the information in this report meets your requirements at this time. If you have any questions relating to the information contained in this document please do not hesitate to contact the undersigned.

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APPENDIX A

GONAD DEVELOPMENT CATEGORIES

Table A-1 Gonad Development Categories for Male Fish

Stage	Male Macro (Phase)	Male Micro (Stage)
11. Immature	Small testes, often clear and threadlike.	Primary spermatogonia (Sg1) only. No lumen in lobules.
12. Early developing	Small testes but easily identified.	Sg1, Sg2 and primary spermatocytes (Sc1) only. Sc2 may appear here.
13. Developing	Small testes but easily identified.	Spermatocysts along lobules. Sg2, Sc1, Sc2, spermatids (St) and Spermatozoa (Sz) within the spermatocysts – No Sz in lumen or sperm ducts. Germinal epithelium (GE) continuous throughout.
14. Pre-spawning	Large and firm testes.	Advanced gamete development such that Spermatozoa release will occur – So will be able to spawn. Sz in lumen of lobules and/or spem ducts. All stages of spermatogenesis (Sg2, Sc, St, Sz) can be present. Spermatocysts throughout testis, active spermatogenesis. GE continuous or discontinuous.
15. Ripe	Imminent release of gametes. Milt released (spermiation) with gentle pressure on abdomen	Based on macroscopic observation only
16. Spent	Small and flaccid testes, no milt release with pressure.	depleted stores of Sz in sperm ducts and lumen of the lobules, cessation of spermatogenesis and a decreased number of spermatocysts. Spermatocysts widely scattered near periphery contain Sc2, St, Sz. Spermatogonial proliferation and regeneration of GE commom in periphery of testes.
17. Regenerating	Small testes, often threadlike.	gonadotropin-indepent mitotic proliferation (Sg1). No spermatocysts. Lumen of lobule often nonexistent. Compared to “Immature fish”, occasional presence of Sg1 and residual Sz in sperm ducts and lumen of lobules. Distinguishable lumen in most lobules. GE continuous throughout.

Table A-2 Gonad Histopathology Categories for Female Fish

Stage	Female Macro (Phase)	Female Micro (Stage)
1. Immature	Small ovaries, often clear, blood vessels indistinct.	Only oogonia and Primary growth oocytes (PG) present. No atresia or muscle bundles. Scarce connective tissue between follicles. Thin ovarian wall and little space between oocytes.
2. Early developing	Enlarging ovaries, blood vessels becoming more distinct.	PG oocytes and Cortical alveolar oocytes (CA), with CA being the most advanced oocyte type – this stage could last >1 year
3. Developing	Enlarging ovaries, blood vessels becoming more distinct.	CA oocytes, Primary vitellogenic (Vtg1) oocytes, Vtg2 oocytes – no Vtg3 oocytes and no postovulatory follicle complexes (POFs)
4. Pre-spawning	Large ovaries, blood vessels prominent. Individual oocytes visible macroscopically. Fecundity can be estimated at this phase since all oocytes to be released for that year have been recruited into vitellogenesis and since downregulation of fecundity due to atresia occurs in this phase.	Advanced gamete development such that oocytes are capable of receiving hormonal signals for Oocyte maturation (OM) – So will be able to spawn. Vtg3 oocytes are leading oocyte type. POFs present in batch spawners. Early stages of OM (Meiosis) can be present.
5. Ripe	Imminent release of gametes	oocytes undergoing late OM (germinal vesicle migration [GVM], germinal vesicle breakdown [GVBD], hydration) or ovulation. Presence of newly collapsed POFs (i.e., fish have just completed spawning).
6. Spent	Flaccid ovaries, blood vessels prominent. Capture of numerous females in the ‘Spent’ phase indicates end of spawning season for that population.	Presence of oocyte atresia and, in some species, POFs. Few if any Vtg2 or Vtg3 oocytes.
7. Regenerating	Small ovaries, blood vessels reduced but present.	Gonadotropin-independent mitotic proliferation (oogonia) and growth (PG oocytes). Compared to “Immature fish”, has muscle bundles, enlarged blood vessels, late-stage atresia, more space and a thicker ovarian wall. May have old, degenerating POFs (hard to differentiate from late-stage atresia).

APPENDIX B

BOX AND WHISKER PLOTS

Figure B-1 Box and Whisker Plot for Total Length of Male Slimy Sculpin from Lac de Gras, 2013

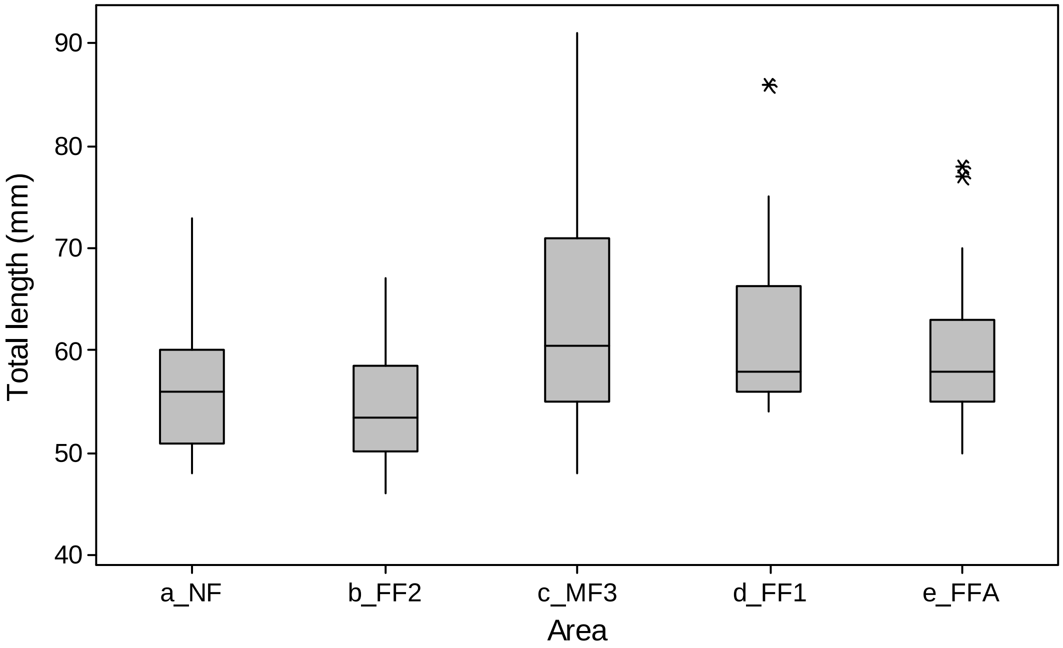


Figure B-2 Box and Whisker Plot for Total Wet Weight of Male Slimy Sculpin from Lac de Gras, 2013

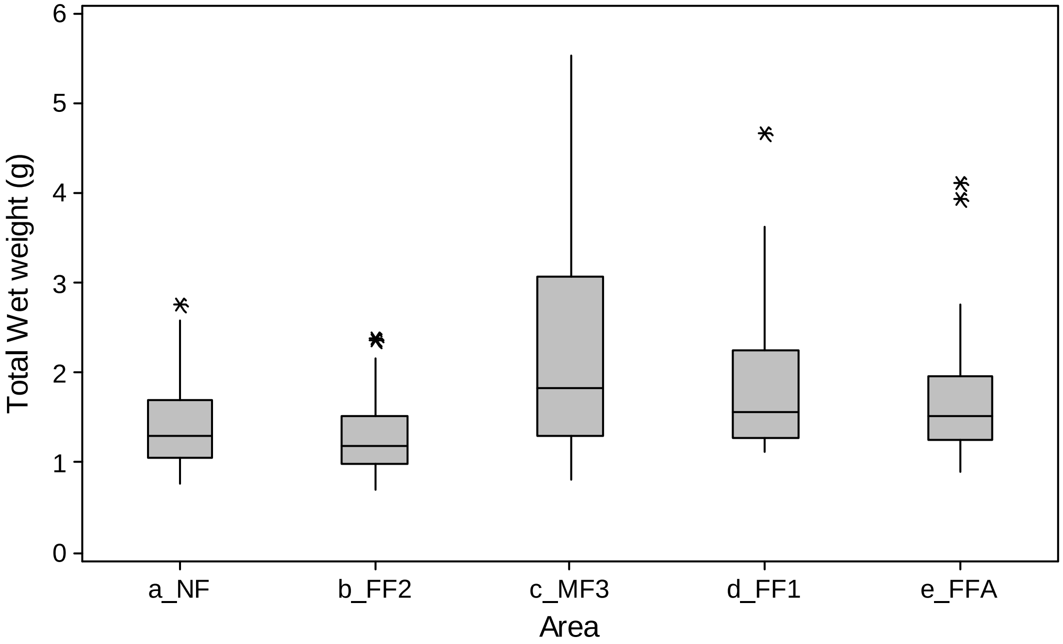


Figure B-3 Box and Whisker Plot for Carcass Weight of Male Slimy Sculpin from Lac de Gras, 2013

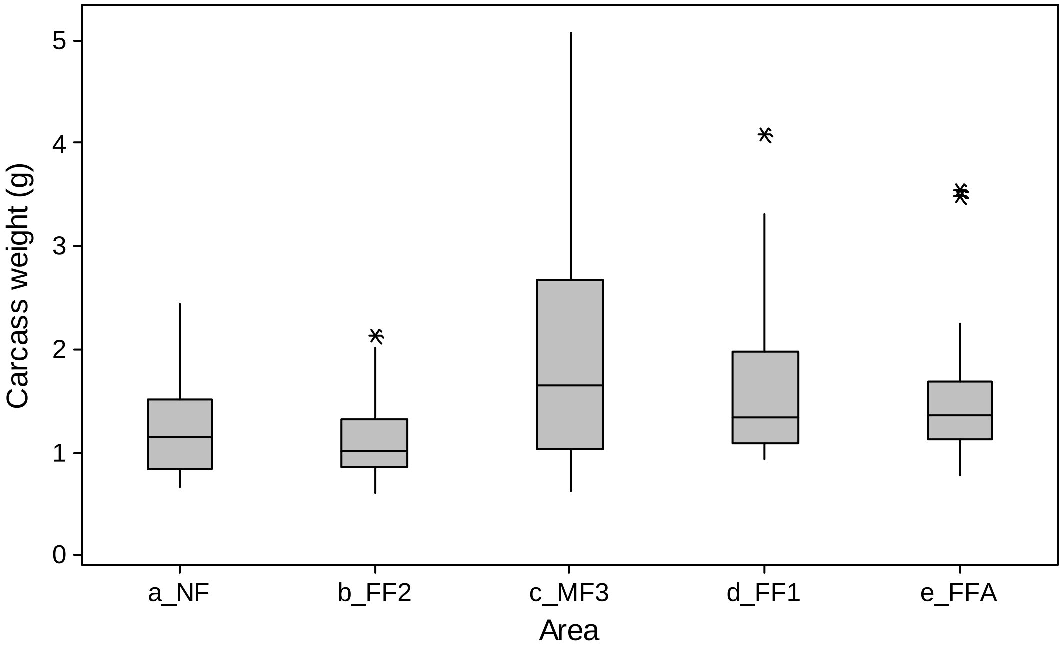


Figure B-4 Box and Whisker Plot for Condition (*K*) of Male Slimy Sculpin from Lac de Gras, 2013

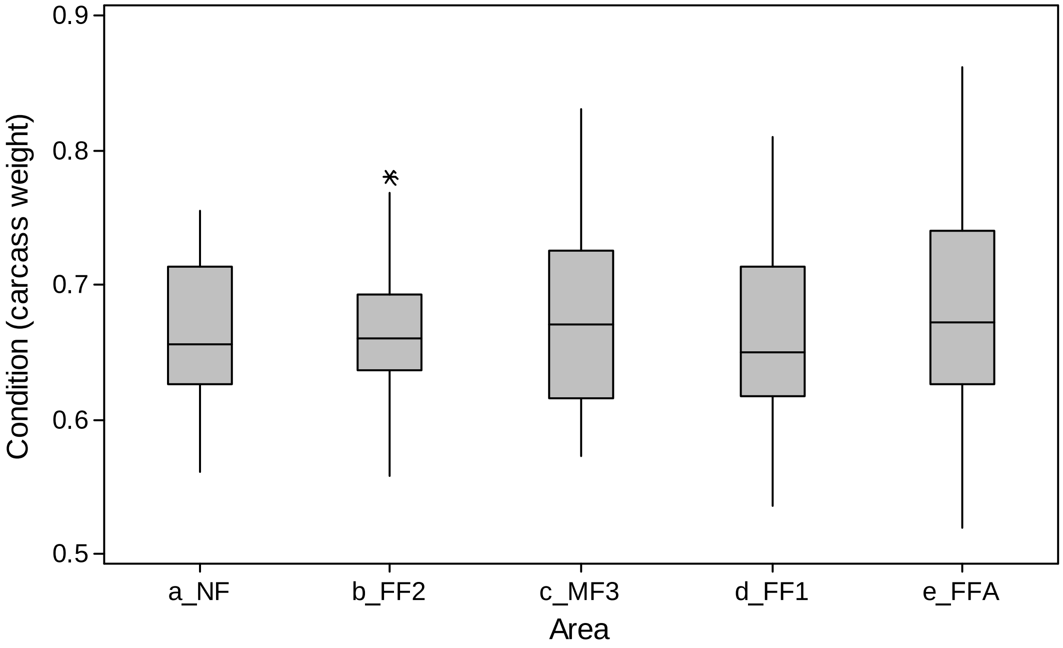


Figure B-5 Box and Whisker Plot for Liversomatic Index (LSI) of Male Slimy Sculpin from Lac de Gras, 2013

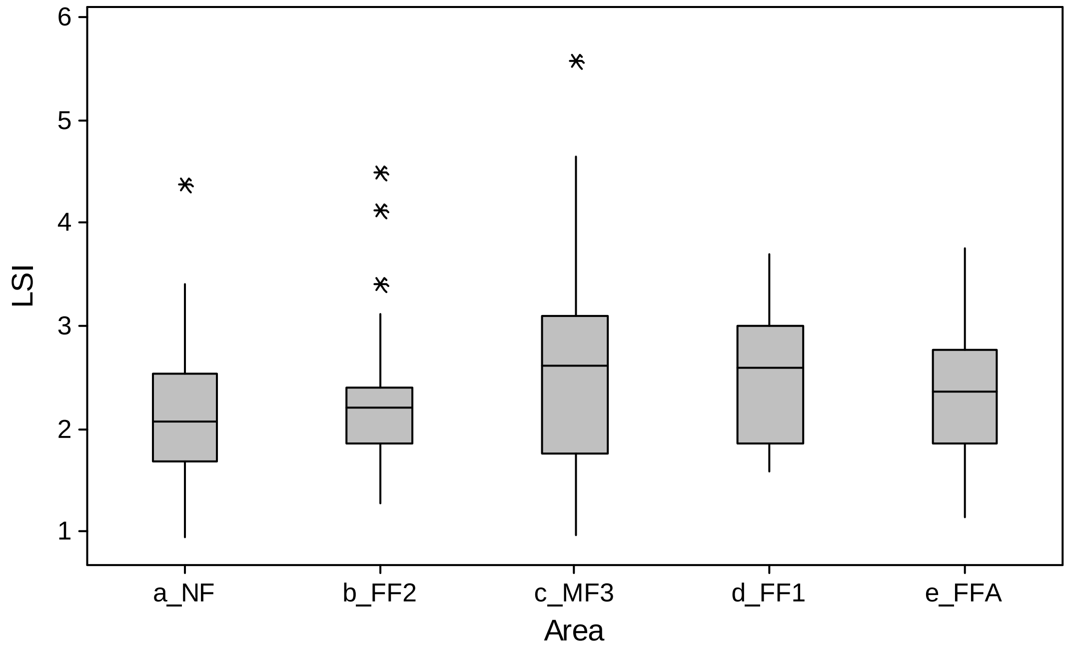


Figure B-6 Box and Whisker Plot for Gonadosomatic Index (GSI) of Male Slimy Sculpin from Lac de Gras, 2013

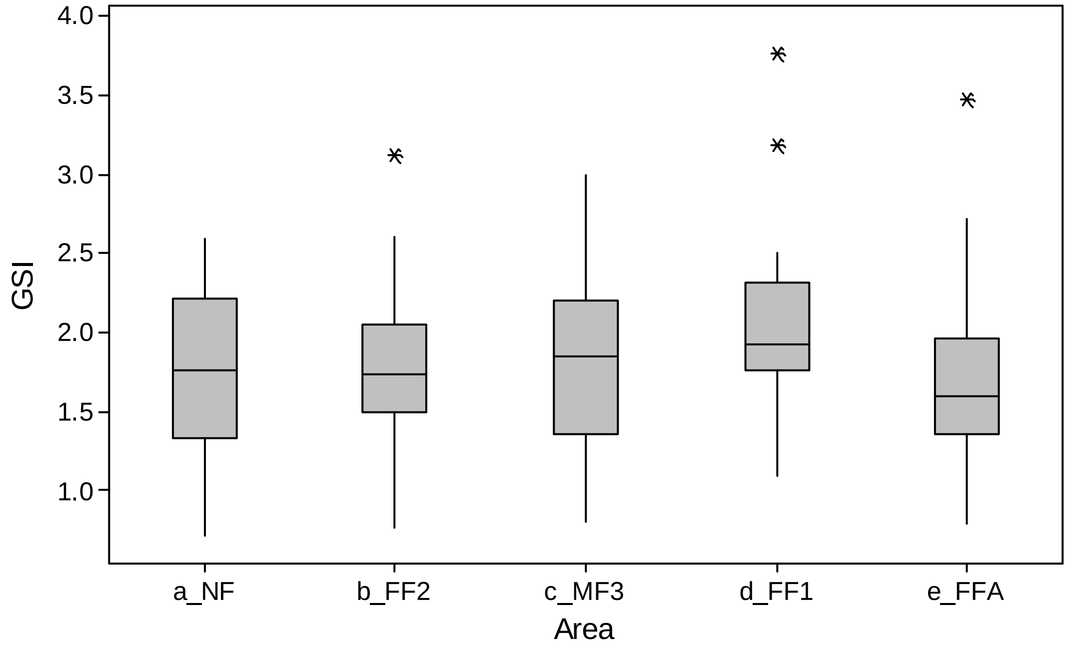


Figure B-7 Box and Whisker Plot for Total Length of Female Slimy Sculpin from Lac de Gras, 2013

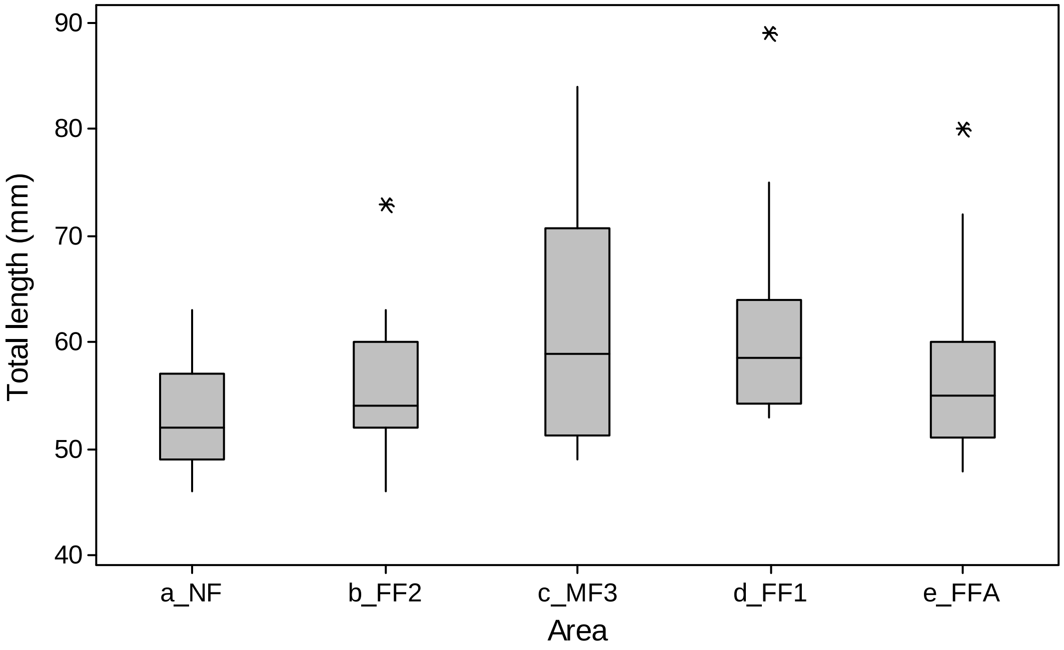


Figure B-8 Box and Whisker Plot for Total Body Weight of Female Slimy Sculpin from Lac de Gras, 2013

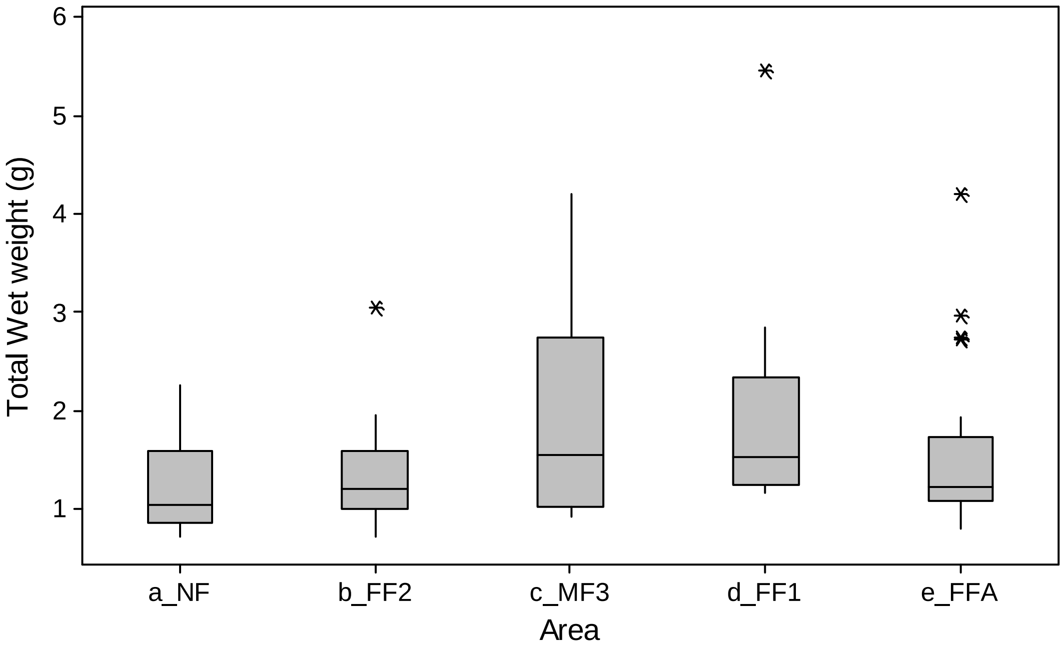


Figure B-9 **Box and Whisker Plot for Carcass Weight of Female Slimy Sculpin from Lac de Gras, 2013**

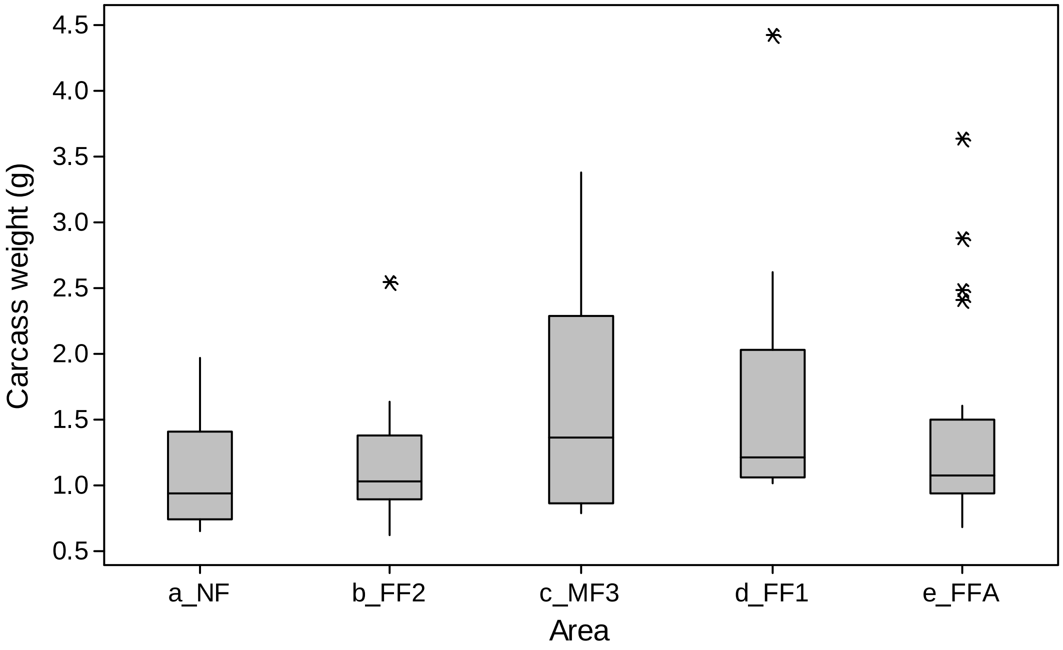


Figure B-10 **Box and Whisker Plot for Condition (*K*) of Female Slimy Sculpin from Lac de Gras, 2013**

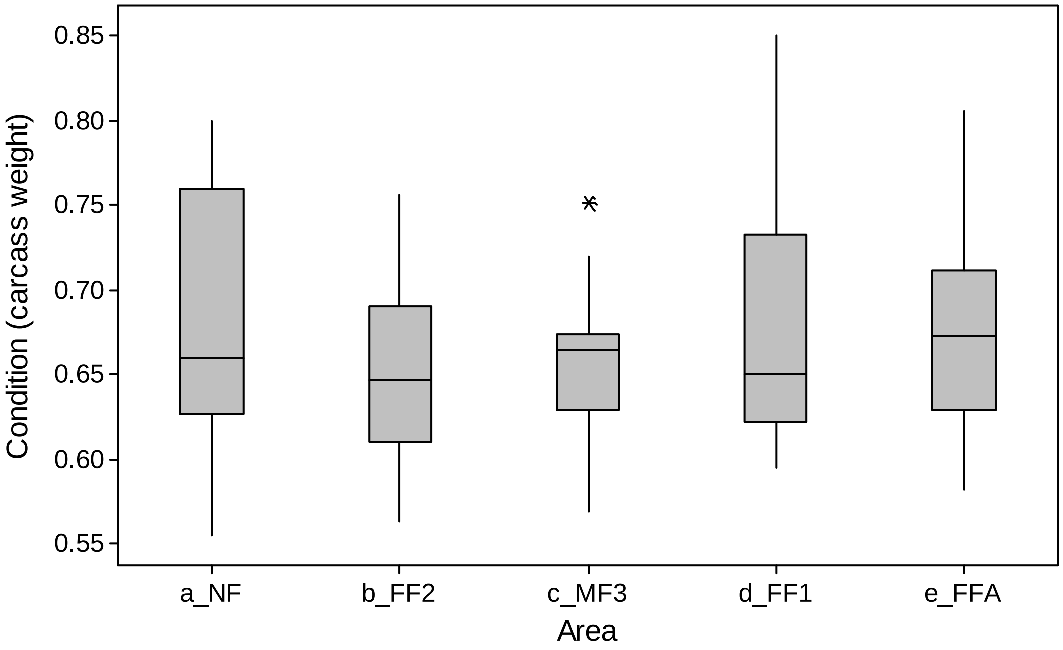


Figure B-11 Box and Whisker Plot for Liversomatic Index (LSI) of Female Slimy Sculpin from Lac de Gras, 2013

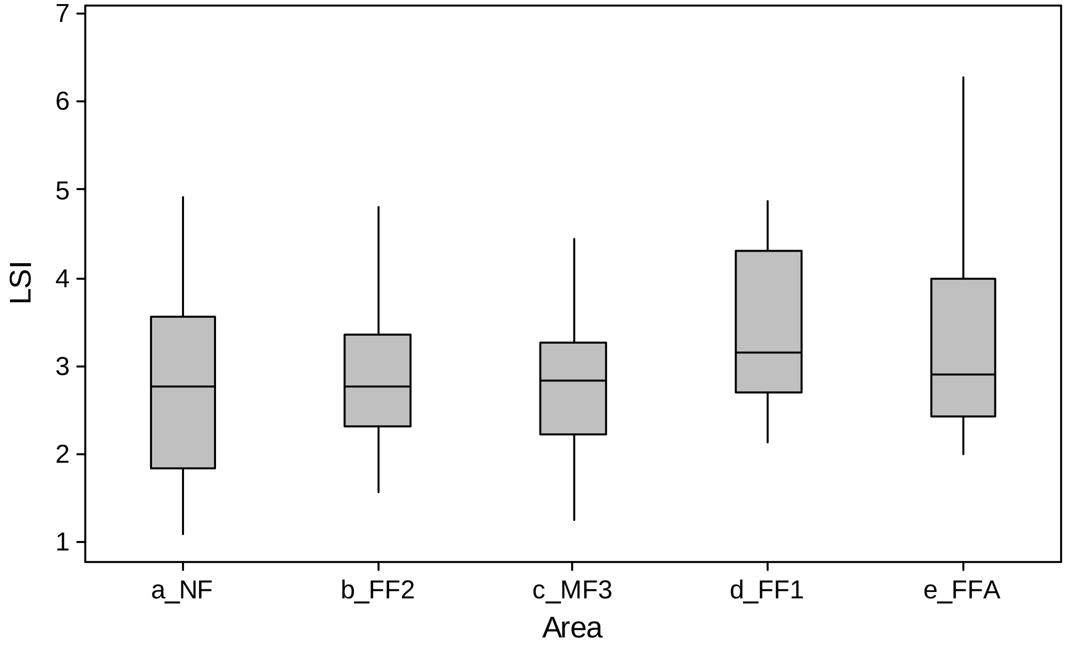


Figure B-12 Box and Whisker Plot for Gonadosomatic Index (GSI) of Female Slimy Sculpin from Lac de Gras, 2013

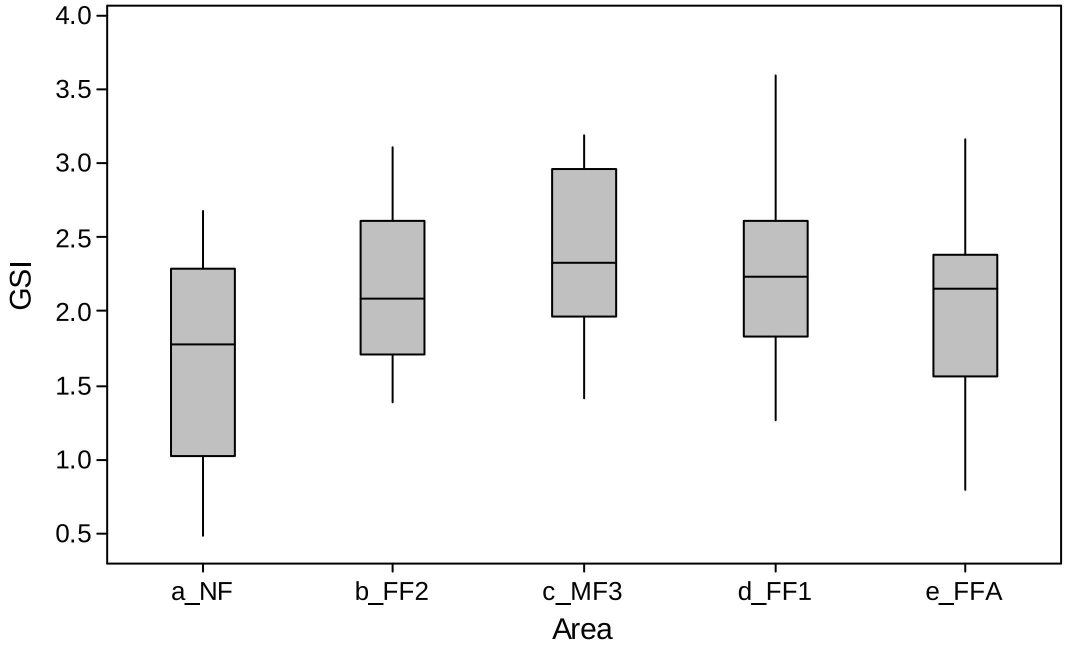


Figure B-13 Box and Whisker Plot for Total Length of Age-1+ Slimy Sculpin from Lac de Gras, 2013

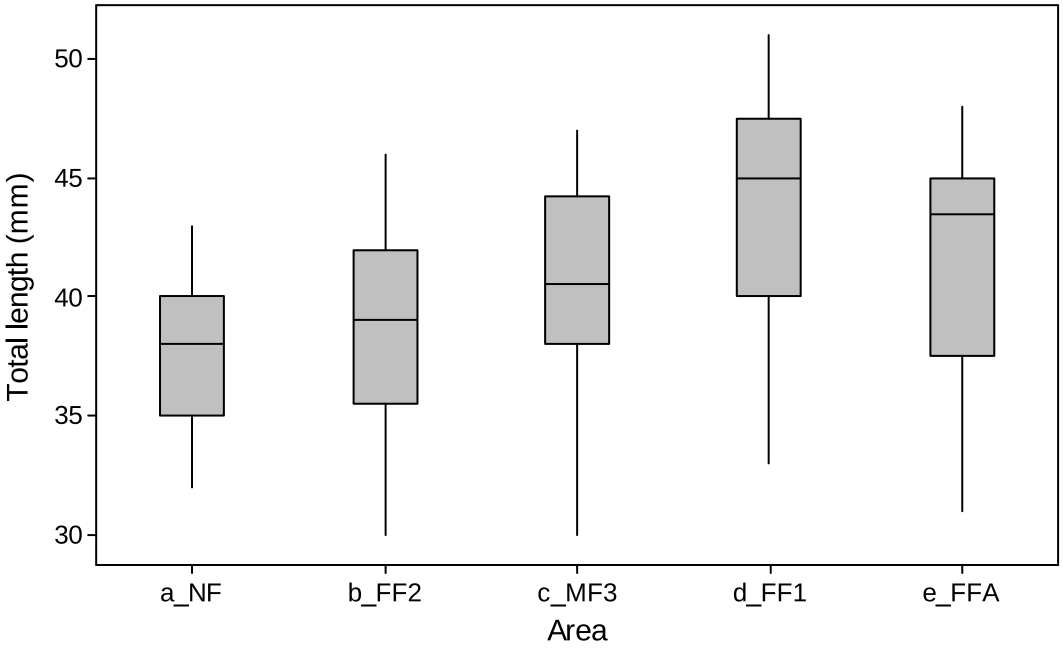


Figure B-14 Box and Whisker Plot for Total Body Weight of Age-1+ Slimy Sculpin from Lac de Gras, 2013

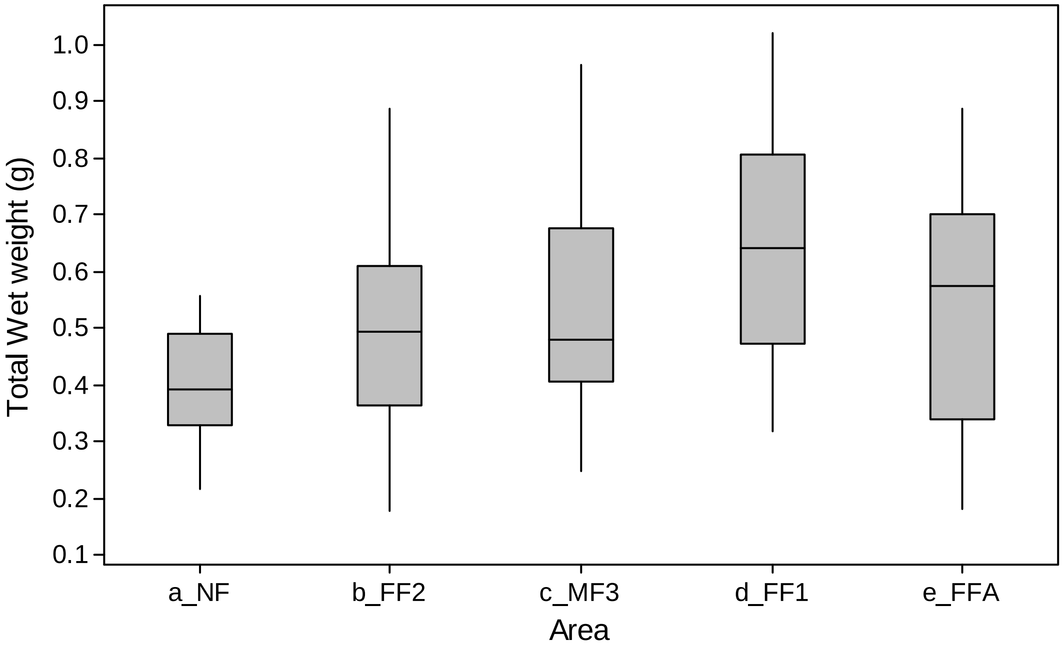


Figure B-15 Box and Whisker Plot for Condition (*K*) of Age-1+ Slimy Sculpin from Lac de Gras, 2013

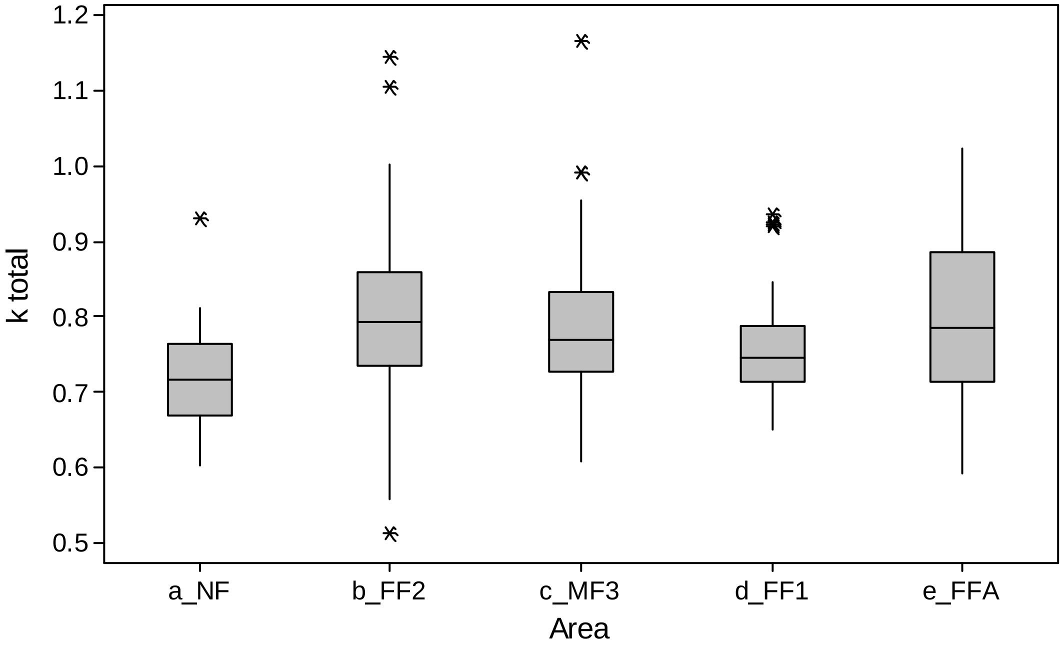
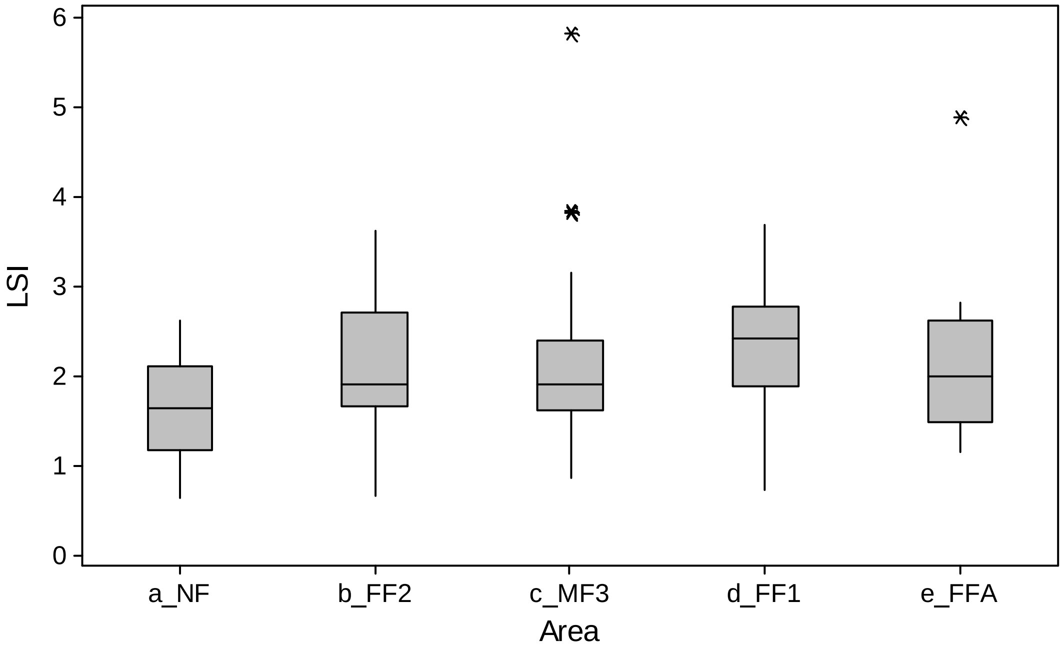


Figure B-16 Box and Whisker Plot for Liversomatic Index (LSI) of Age-1+ Slimy Sculpin from Lac de Gras, 2013



APPENDIX C

SUPPLEMENTAL STATISTICS

Table C-1 Statistical Outliers

Group	Parameter	Outlier (Fish ID number)	Rationale
Age-1+	Length	3 fish <30 mm	Potential YOY fish
	Total weight adjusted for length	35 mm fish from FF2	statistical outlier
Adult Male	Condition	3004	Studentized Residual = 4.1
	Total weight adjusted for length	3086	Studentized Residual = 4.3
	GSI	2 1025 1062 1077 2017 2023 4070	very small gonads that likely had inaccurate weights due to the size
	Gonad weight adjusted for carcass weight	2 22 1025 1062 1077 2017 2023 4070	very small gonads that likely had inaccurate weights due to the size Fish #22 was identified as a statistical outlier
Adults Female	GSI	1053	statistical outlier
	Gonad weight adjusted for carcass weight	1053	statistical outlier

Notes: GSI = gonadosomatic index; ID = identification; < = greater than; YOY = young-of-the-year.

Table C-2 Summary of Results of the Kolmogorov-Smirnov Test of Normal Distributions and Levene's Test of Means for Homogeneity of Variance Between Samples - Fish Health, 2013

Sex/Maturity Stage	Parameter	Statistical Test	Tests on untransformed data		NF	FF2	MF3	FF1	FFA	Tests on log transformed data		NF	FF2	MF3	FF1	FFA
			Levene's Test	Normality	Normality	Normality	Normality	Normality	Normality	Levene's Test	Normality	Normality	Normality	Normality	Normality	Normality
Age-1+	Length	KW	ns	**	ns	ns	ns	ns	***	ns	**	ns	ns	*	*	***
	Total body weight	ANOVA^{log}	**	ns	ns	*	*	ns	ns	*	*	ns	ns	ns	ns	*
	Condition (based on total weight)	KW	ns	**	ns	ns	*	**	ns	ns	**	ns	ns	ns	*	ns
	Total weight adjusted for length	ANCOVA^{log}	-	-	-	-	-	-	-	ns	**	ns	**	ns	ns	ns
	LSI	ANOVA^{log}	ns	*	ns	ns	***	ns	ns	ns	ns	ns	ns	ns	**	ns
	Liver weight adjusted for carcass weight	ANCOVA^{log}	-	-	-	-	-	-	-	ns	ns	ns	ns	ns	**	ns
Adult Male	Length (mm)	KW	**	**	ns	**	**	**	ns	**	**	ns	*	ns	**	ns
	Total weight (mm)	KW	***	**	ns	***	**	*	**	**	**	ns	ns	ns	ns	ns
	Carcass weight (g)	KW	***	**	ns	**	**	*	**	***	*	ns	ns	ns	ns	ns
	Total weight adjusted for length	ANCOVA^{log}	-	-	-	-	-	-	-	ns	ns	ns	ns	ns	ns	ns
	Condition, *K*	ANOVA	*	*	ns	*	ns	ns	ns	-	-	-	-	-	-	-
	Liver weight adjusted for carcass weight	ANCOVA^{log}	-	-	-	-	-	-	-	ns	ns	ns	ns	ns	*	ns
	LSI (%)	ANOVA^{log}	*	**	**	***	ns	*	ns	ns	ns	ns	*	ns	ns	ns
	Gonad weight adjusted for carcass weight	ANCOVA^{log}	-	-	-	-	-	-	-	ns	ns	ns	ns	*	*	ns
	GSI (%) less 8 small gonads	ANOVA	ns	ns	ns	ns	ns	ns	ns	-	-	-	-	-	-	-
Adult Female	Length (mm)	KW	ns	**	ns	ns	ns	*	**	ns	**	ns	ns	ns	ns	*
	Total weight (mm)	KW	ns	*	*	ns	ns	*	***	ns	**	ns	ns	ns	ns	*
	Carcass weight (g)	KW	ns	**	ns	ns	ns	*	***	ns	**	ns	ns	ns	ns	**
	Total weight adjusted for length	ANCOVA^{log}	-	-	-	-	-	-	-	ns	ns	ns	ns	ns	ns	ns
	Condition, *K*	ANOVA	ns	ns	ns	ns	ns	ns	ns	-	-	-	-	-	-	-
	Liver weight adjusted for carcass weight	ANCOVA^{log}	-	-	-	-	-	-	-	ns	ns	ns	-	-	ns	ns
	NF vs Refs	ANCOVA^{log}	-	-	-	-	-	-	-	ns	ns	ns	ns	ns	ns	ns
	FF2 vs Refs	ANCOVA^{log}	-	-	-	-	-	-	-	*	ns	-	ns	-	ns	ns
	MF3 vs Refs	ANCOVA^{log}	-	-	-	-	-	-	-	ns	ns	-	-	ns	ns	ns
	FF1 vs FFA	ANCOVA^{log}	-	-	-	-	-	-	-	ns	ns	-	-	-	ns	ns
	LSI (%)	ANOVA	ns	ns	ns	ns	ns	ns	*	-	-	-	-	-	-	-
	Gonad weight adjusted for length	ANCOVA	-	-	-	-	-	-	-	ns	ns	ns	ns	ns	ns	ns
	GSI (%)	ANOVA	-	-	ns	****	ns	ns	ns	-	-	-	-	-	-	-

Notes: Probability of Type 1 Error: * = <0.05, ** = <0.01, *** = <0.001; **** = <0.0001, ns = not significant; “-‘ = not applicable; LSI = liversomatic index; GSI =gonadosomatic index; % = percent

Table C-3 Summary of Results of the Kolmogorov-Smirnov Test of Normal Distributions and Levene’s Test of Means for Homogeneity of Variance Between Samples - Fish Tissue Chemistry, 2013

Variable	Non-Transformed Data						Log-Transformed Data					
	Kolmogorov-Smirnov Normality Test					Levene’s Test	Kolmogorov-Smirnov Normality Test					Levene’s Test
	NF	FF2	MF3	FF1	FFA		NF	FF2	MF3	FF1	FFA	
Aluminum (Al)	ns	ns	ns	ns	ns	**	ns	ns	ns	ns	ns	*
Arsenic (As)	ns	ns	ns	ns	ns	ns	-	-	-	-	-	-
Barium (Ba)	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Cadmium (Cd)	**	ns	ns	ns	ns	*	-	-	-	-	-	-
Calcium (Ca)	ns	ns	ns	ns	ns	ns	-	-	-	-	-	-
Cesium (Cs)	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Chromium (Cr)	ns	ns	ns	ns	ns	ns	-	-	-	-	-	-
Cobalt (Co)	ns	ns	ns	ns	ns	****	ns	ns	ns	ns	ns	**
Copper (Cu)	ns	ns	ns	ns	ns	*	-	-	-	-	-	-
Iron (Fe)	ns	ns	ns	ns	ns	**	ns	ns	ns	ns	ns	ns
Magnesium (Mg)	ns	ns	ns	ns	ns	ns	-	-	-	-	-	-
Manganese (Mn)	ns	ns	ns	ns	ns	*	ns	ns	ns	ns	ns	ns
Mercury (Hg)	ns	ns	ns	*	*	ns	-	-	-	-	-	-
Molybdenum (Mo)	ns	*	ns	ns	*	ns	ns	ns	ns	ns	ns	ns
Nickel (Ni)	ns	ns	*	ns	ns	*	ns	ns	ns	ns	ns	ns
Phosphorus (P)	ns	ns	ns	ns	ns	ns	-	-	-	-	-	-
Potassium (K)	ns	ns	**	*	ns	ns	-	-	-	-	-	-
Rubidium (Rb)	ns	ns	ns	ns	ns	ns	ns	ns	ns	*	ns	ns
Selenium (Se)	ns	ns	ns	ns	ns	ns	-	-	-	-	-	-
Sodium (Na)	ns	ns	ns	ns	ns	ns	-	-	-	-	-	-
Strontium (Sr)	ns	ns	*	ns	ns	ns	-	-	-	-	-	-
Thallium (Tl)	***	ns	ns	ns	ns	ns	***	ns	ns	ns	ns	ns
Tin (Sn)	ns	ns	ns	ns	***	ns	ns	ns	ns	ns	**	ns
Titanium (Ti)	**	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Uranium (U)	*	ns	ns	ns	ns	**	ns	ns	ns	ns	ns	ns
Vanadium (V)	ns	ns	ns	ns	ns	*	ns	ns	ns	*	ns	-
Yttrium (Y)	ns	**	ns	*	ns	*	ns	*	ns	*	ns	ns
Zinc (Zn)	ns	ns	ns	*	ns	ns	ns	ns	ns	ns	ns	ns

Notes: Probability of Type 1 Error: * = <0.05, ** = <0.01, *** = <0.001; **** = <0.0001, ns = not significant.

APPENDIX D

TOTAL FISH CATCH (RAW DATA)

These data are provided as an Excel file in a "Raw Data Folder" on the compact disc, rather than in hard copy form.

APPENDIX E

FISH POPULATION HEALTH (RAW DATA)

These data are provided as an Excel file in a "Raw Data Folder" on the compact disc, rather than in hard copy form.

APPENDIX F

SLIMY SCULPIN STOMACH CONTENT (RAW DATA)

These data are provided as an Excel file in a "Raw Data Folder" on the compact disc, rather than in hard copy form.

APPENDIX G

FISH TISSUE CHEMISTRY (RAW DATA)

These data are provided as an Excel file in a "Raw Data Folder" on the compact disc, rather than in hard copy form.

APPENDIX VI

PLUME DELINEATION SURVEY

No information was available for this appendix in 2013.

APPENDIX VII

DIKE MONITORING STUDY

No information was available for this appendix in 2013.

APPENDIX VIII

FISH SALVAGE PROGRAM

No information was available for this appendix in 2013.

APPENDIX IX

FISH HABITAT COMPENSATION MONITORING

No information was available for this appendix in 2013.

APPENDIX X

FISH PALATABILITY, FISH HEALTH, AND FISH TISSUE CHEMISTRY SURVEY

No information was available for this appendix in 2013.

APPENDIX XI

PLANKTON REPORT

PLANKTON REPORT
IN SUPPORT OF THE 2013 AEMP ANNUAL REPORT FOR THE DIAVIK DIAMOND MINE, NORTHWEST TERRITORIES

Submitted to:

Diavik Diamond Mines (2012) Inc.
P.O. Box 2498
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Yellowknife, NT
X1A 2P8

DISTRIBUTION

1 Copy – Diavik Diamond Mines (2012) Inc., Yellowknife, NT
1 Copy – Golder Associates Ltd., Calgary, AB
3 Copies – Wek’èezhìi Land and Water Board

March 2014
13-1328-0001

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EXECUTIVE SUMMARY

In 2011, Diavik Diamond Mines (2012) Inc. (DDMI) revised its Aquatic Effects Monitoring Program (AEMP), as required by Water Licence W2007L2-0003. As part of the AEMP Study Design Version 3.0 and Version 3.3, plankton sampling was included as a monitoring component. The main goal of the plankton component is to monitor phytoplankton and zooplankton communities (i.e., abundance, biomass, and taxonomic composition) as indicators of the effects of the Diavik Diamond Mine (Mine) on the Lac de Gras ecosystem. This report presents results of the 2013 phytoplankton and zooplankton community surveys.

The 2013 monitoring results suggest that plankton communities in Lac de Gras are exhibiting a Mine-related nutrient enrichment effect and not a toxicological effect. This conclusion is based on the following findings:

- phytoplankton richness and biomass were statistically greater in the near-field exposure area relative to the reference areas;
- separation was observed between the near-field exposure area and the reference areas in the phytoplankton NMDS ordination plots;
- zooplankton richness was statistically greater in the near-field exposure area compared to the reference areas;
- separation was observed between the Near-field exposure area and the reference areas in the zooplankton NMDS ordination plots; and,
- there were differences in zooplankton community composition between the near-field exposure area and the reference areas, with greater proportions of rotifers and cladocerans, and fewer calanoids in the near-field area compared to the reference areas.

Sufficient differences in phytoplankton biomass and community structure, and zooplankton community structure were observed between the exposure and reference areas to indicate that the Mine is having an effect on the plankton community. These observations are consistent with the findings of the Eutrophication Indicators component of the AEMP. The 2013 results provided no evidence for toxicological impairment. Overall, the plankton biomass and taxonomic richness data indicate that an Action Level 1 for plankton has not been reached.

LIST OF ACRONYMS AND ABBREVIATIONS

AEMP	Aquatic Effects Monitoring Program
ANOVA	analysis of variance
DDMI	Diavik Diamond Mines (2012) Inc.
e.g.	for example
FF	far-field
HSD	Honestly significant difference
i.e.	that is
MF	mid-field
Mine	Diavik Diamond Mine
NF	near-field
NMDS	non-metric multidimensional scaling
P	probability
QA/QC	quality assurance/quality control
QAPP	Quality Assurance Project Plan
RPD	relative percent difference
SD	standard deviation
SE	standard error
SOP	standard operating procedure
sp.	species
spp.	more than one species
UTM	Universal Transverse Mercator
WLWB	Wek’èezhìi Land and Water Board
WOE	Weight-of-evidence

LIST OF UNITS

%	percent
±	plus or minus
µm	micrometre
cm	centimetre
cells/L	cells per litre
ind/L	individuals per litre
m	metre
mg/m^3	milligrams per cubic metre
mL	millilitre
km^2	square kilometers

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1 INTRODUCTION

1.1 BACKGROUND

The term “plankton” is a general term referring to small, usually microscopic, organisms that live suspended in non-flowing waterbodies, such as lakes. For the purpose of this study, the term “phytoplankton” refers to the algal component of plankton and includes the following five major ecological groupings:

- cyanobacteria;
- chlorophytes (Chlorophyceae, Prasinophyceae, Euglenophyceae, Trebouxiophyceae, Pedinophyceae, Nephroselmidophyceae, Conjugatophyceae, and Klebsormidiophyceae);
- microflagellates (Chrysophyceae, Cryptophyceae, Coccolithophyceae, Xanthophyceae, and Haptophyceae);
- dinoflagellates (Dinophyceae); and
- diatoms (Bacillariophyceae).

The term “zooplankton” refers to small animals, ranging from microscopic to visible with the naked eye, and includes crustaceans (i.e., Cladocera [cladocerans], Cyclopoida [cyclopoids], Calanoida [calanoids]), and Rotifera (rotifers).

Plankton communities were examined over the course of the previous Aquatic Effects Monitoring Program (AEMP) Version 2.0 as part of a special effects study (SES) (DDMI 2007). The main objective of the SES was to determine the feasibility and utility of using plankton community composition and biomass as sensitive indicators to evaluate potential biological effects of the Diavik Diamond Mine (Mine). A secondary objective was to determine if a single, open-water sampling event can collect data that are adequate to describe community metrics and, if so, identify the best single period for the open-water sampling.

A review of four years of data in the Three-Year Summary Report demonstrated that plankton could indeed be useful and sensitive monitoring endpoints (Golder 2011a). It also indicated that, based on the seasonal variation observed during the SES, any open-water period would be equally appropriate for plankton monitoring.

In 2013, Diavik Diamond Mines (2012) Inc. (DDMI) revised its AEMP, as required by Water Licence W2007L2-0003 (WLWB 2007). Among the revisions in the AEMP Study Design Version 3.0 was the addition of plankton as a monitoring component.

It was also decided that plankton monitoring would occur during a single open-water monitoring season consistent with the other AEMP components (Golder 2011b).

This report presents the assessment of plankton data collected during the 2013 AEMP field program, which was carried out by DDMI according to the AEMP Study Design Version 3.0 (Golder 2011b). The assessment of effects was based on the updated Version 3.3 Study Design (Golder 2014a), which was approved by the Wek’èezhìi Land and Water Board (WLWB) on February 19, 2014 (WLWB 2014). Details on methods used are provided in Section 2. Section 3 provides results of the assessment, while Section 4 provides a discussion of the results. Conclusions, together with recommendations for program changes or enhancements, are provided in Section 5.

1.2 OBJECTIVES

The principal goal of the AEMP is to monitor the Mine water discharge and other stressors from the Mine, and to assess potential ecological effects. Within the plankton component, phytoplankton and zooplankton community endpoints (i.e., abundance, biomass and taxonomic composition) are monitored and assessed as indicators of potential effects.

1.3 SCOPE AND APPROACH

The plankton component is designed to monitor both spatial and temporal changes in phytoplankton and zooplankton community composition. As described in Study Design Version 3.3 (Golder 2014a), the objective of the annual report and the comprehensive sampling report (current document) is to assess the spatial extent of Mine-related effects.

Effects were assessed by comparing areas of the lake exposed to effluent to areas of the lake that are not exposed to effluent (i.e., reference areas). Plankton community endpoints were statistically tested to establish whether the differences seen among areas were related to the Mine (i.e., demonstrated a statistically-significant difference) or whether they may have occurred by chance.

The magnitude of effect was assessed by comparing community endpoints in exposure areas to background values. Background values for Lac de Gras are those that fall within the *normal range*, which is defined as the historical reference area mean ± 2 standard deviations (± 2 SD). Values that are beyond the normal range are exceeding what would be considered natural levels for Lac de Gras. The importance of effects observed on community endpoints was determined according to the Action Level classification defined in Golder (2014a).

2 METHODS

2.1 FIELD PROGRAM

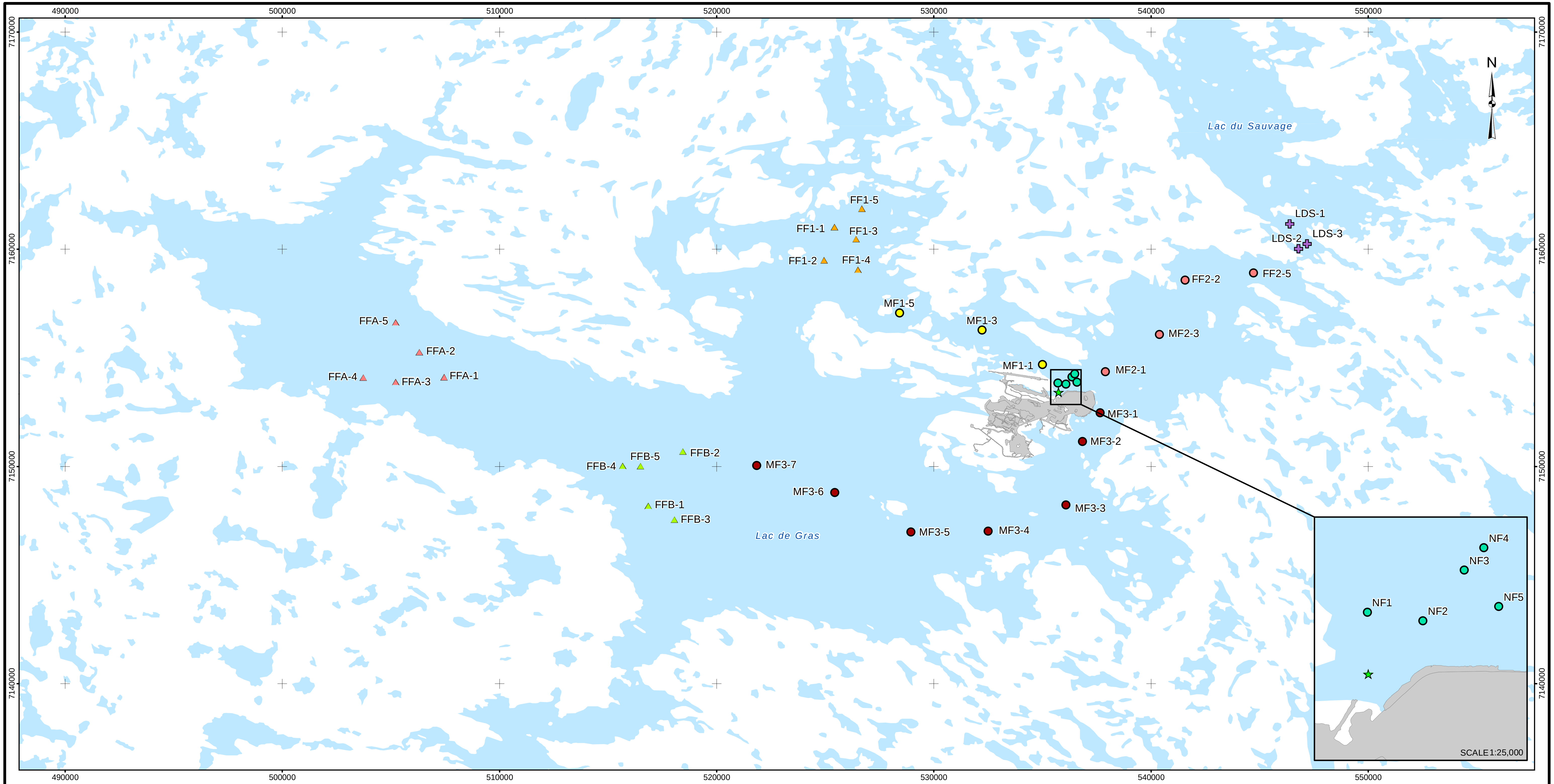
Thirty-four stations located within five general areas of Lac de Gras, and three stations located in one general area in Lac du Sauvage were sampled by DDMI during the 2013 plankton program. Sampling areas were selected based on exposure to the Mine effluent (Golder 2011b), and consisted of the near-field (NF) exposure area and three far-field reference areas (FF1, FFA, and FFB) (Figure 2-1). In addition, three transect lines (referred to as mid-field [MF] areas) between the NF and FF areas were sampled. The MF1-FF1 transect was sampled towards the FF1 reference area, northwest of the exposure area. The MF2-FF2 transect was sampled to the northeast, towards the FF2 area near the Lac du Sauvage inlet. The MF3-FFB-FFA transect was sampled south of the exposure area towards FFB and FFA reference areas.

Within each sampling area, clusters of replicate stations were sampled. Five stations were sampled in the NF exposure area and in each of the three FF reference areas. To better delineate the extent of effects and define gradients along each transect, the number of stations within the other areas differed (Golder 2011b). A total of four stations were sampled along the MF2-FF2 transect, three stations were sampled in the MF1 area, and seven stations were sampled in the MF3 area (Figure 2-1).

In addition to stations in Lac de Gras, three stations were sampled in Lac du Sauvage, close to the narrows separating the two lakes. Lac du Sauvage is more productive than Lac de Gras and has the potential to affect the FF2 area; therefore, monitoring stations were added in Lac du Sauvage to assess changes to the quality of water entering Lac de Gras from the Lac du Sauvage inlet (Golder 2011b). Universal Transverse Mercator (UTM) coordinates for all stations are provided in Table B-2 of Appendix B.

Sampling occurred between August 18 and September 7, 2013, in accordance with Study Design Version 3.0 (Golder 2011b) and DDMI Standard Operating Procedure (SOP): ENVR-003-0702 R13. That SOP is not reproduced within this report, but it has been previously provided to the WLWB. Water column profile measurements and samples for water chemistry were collected concurrently as part of the water quality component and are presented in Golder (2014b) and Golder (2014c).

A depth-integrated sampler, which collected water from the surface to a depth of 10 metres (m), was used to collect phytoplankton samples. Twelve depth-integrated samples from each station were composited, and the composite sample was used to fill a sample bottle for phytoplankton taxonomy. Field sampling was conducted by DDMI staff, who reported that a phytoplankton sample could not be collected at station MF3-4 because of inclement weather during sample collection.



LEGEND

★ DIFFUSER

EXPOSURE

● NEAR-FIELD

● MID-FIELD 3

● MID-FIELD 1

● FAR-FIELD 2; MID-FIELD 2

REFERENCE

▲ FAR-FIELD 1

▲ FAR-FIELD A

▲ FAR-FIELD B

✚ LAC DU SAUVAGE

▨ DIAVIK FOOTPRINT

▨ WATERBODY

5 0 5

SCALE 1:175,000 KILOMETRES

REFERENCE

HYDROGRAPHY DATA OBTAINED FROM CANVEC © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 12 DATUM: NAD 83

PROJECT

DIAVIK
DIAMOND MINES INC.

TITLE

PLANKTON SAMPLING STATIONS, 2013 AEMP

Golder Associates

PROJECT	13-1328-0001		FILE No.
DESIGN	LJ	28 Jan. 2014	SCALE AS SHOWN REV. 0
GIS	JC	20 Mar. 2014	FIGURE: 2-1
CHECK	TD	20 Mar. 2014	
REVIEW	CF	20 Mar. 2014	

I:\2011\11-1328\11-1328-0038\Mapping\MXD\2013AEMP\FINAL\Fig2-1_2013_AEMP_Phytoplankton_Sampling_Locations_20140221_Final.mxd

A Wisconsin plankton net with a 75-micrometre (µm) mesh and a 30.5-centimetre (cm) mouth diameter was used to collect duplicate zooplankton samples at each station. Each sample consisted of a composite of three vertical hauls from the entire water column, beginning at a depth of 1 m above the bottom. Field sampling was conducted by DDMI staff, who did not report deviations from the SOP during sample collection.

2.2 SAMPLE SORTING AND TAXONOMIC IDENTIFICATION

2.2.1 Phytoplankton Community

A total of 39 phytoplankton samples (including three split samples) were collected in 2013 and submitted to Eco-Logic Ltd., Vancouver, British Columbia, for analysis of taxonomic composition as both abundance and biomass. Samples were analyzed according to methods provided by Eco-Logic, which are summarized below.

Phytoplankton samples were gently shaken for 60 seconds to homogenize the sample. Aliquots of 25 millilitres (mL) were then removed and poured into settling chambers and allowed to settle for a minimum of 4 hours. Quantitative counts were done on a Carl Zeiss Inverted phase-contrast plankton microscope at a high power of 1,560x magnification followed by a low power scan at 625x magnification. The lower power scans were performed to confirm both a uniform settlement of the sample on the bottom of the plate and to determine the occurrence of rare species (Utermohl 1958). A minimum of 250 and a maximum of 300 cells or counting units were enumerated in each sample for statistical accuracy (Lund et al. 1958). Taxonomic identifications were based primarily on Prescott (1978), Canter-Lund and Lund (1995), and Wehr and Sheath (2003). Phytoplankton taxa were identified to genus level, and abundance was reported as cells per litre (cells/L).

Fresh weight biomass was calculated from recorded abundance and specific biovolume estimates based on geometric solids (Rott 1981). Biovolumes were estimated from the average dimensions of 10 to 15 individuals; the biovolumes of colonial taxa were based on the number of individuals within each colony. Assuming a specific gravity of 1, the biovolume of each species was converted to biomass, reported in milligrams per cubic metre (mg/m^3).

2.2.2 Zooplankton Community

A total of 81 zooplankton samples (including seven split samples) were submitted to Salki Consultants Inc., Winnipeg, Manitoba, for analysis of taxonomic composition. Samples were analyzed for abundance and biomass of crustaceans and rotifers according to the methods provided by Salki Consultants Inc., which are summarized below. Each sample underwent three levels of analysis, as follows:

- 1/40 or 1/80 of each sample was examined under a compound microscope at 63x to 160x magnification, and all specimens of crustaceans and rotifers were identified to the lowest taxonomic level (typically species) and assigned to size categories as indicated in the species list;
- a second sub-sample, representing 11 percent (%) of the sample volume, was examined under a stereoscope at 12x magnification for the large species (i.e., *Heterocope septentrionales, Holopedium gibberum, Daphnia middendorffiana*, and *D. longiremis*) and rare species (e.g., *Eubosmina longispina, Diaptomus ashlandi, Epischura nevadensis, Chydorus sphaericus,* and *Cyclops capillatus*), which were enumerated and assigned to size classes; and,
- the entire sample was examined under the stereoscope to improve abundance estimates for the largest species (i.e., adult male and female *Heterocope septentrionales*, *Holopedium gibberum, Daphnia middendorffiana,* and *D. longiremis*).

Cyclopoida and Calanoida specimens (mature and immature) were identified to species, with the exception of nauplii, which were classified as either Calanoida or Cyclopoida, as appropriate. Cladocera were identified to species. Rotifers were identified to genus. Zooplankton abundance was reported as individuals per litre (ind/L). Taxonomic identifications were based primarily on Brooks (1957), Wilson (1959) and Yeatman (1959).

Biomass estimates for each taxon were obtained using mean adult sizes determined during the analysis of the 2007 zooplankton samples (Golder 2008) and from length-weight regression equations developed by Malley et al. (1989). Additional measurements were made on all newly encountered species. Zooplankton biomass was reported in milligrams per cubic metre.

2.3 DATA ANALYSES

2.3.1 Phytoplankton Community Analysis

The following methods were used to summarize the 2013 phytoplankton data:

- Abundance and biomass data were divided into the five major ecological groups present in the 2013 samples (cyanobacteria, chlorophytes, microflagellates, dinoflagellates, and diatoms). The relative abundance and biomass (expressed as a percentage) accounted for by each major group were calculated separately for each sampling area (i.e., for NF, MF1, MF2, MF3, FF1, FF2, FFA, FFB, and Lac du Sauvage) to assess spatial variability in community structure.

- Richness was calculated at the genus level. This variable provides an indication of the diversity of phytoplankton in an area; a greater richness value typically indicates a more healthy and balanced community.
- A summary of the dominant taxa found in the NF exposure area compared to the FF reference areas was presented; dominant taxa were identified as taxa present in proportions greater than 5% of total biomass.
- Summary statistics were calculated for total phytoplankton abundance and biomass.

To visually evaluate spatial trends relative to the Mine discharge, total phytoplankton biomass and taxonomic richness were plotted against distance from the diffuser. Potential effects were evaluated by comparing biomass and taxonomic richness in the exposure area to the normal range in the reference areas (FF1, FFB, and FFA). The normal range was calculated by pooling the August 15 to September 15 data from 2007 to 2010 to form a reference area mean, plus or minus two standard deviations (±2 SD).

Total phytoplankton biomass was also compared visually among sampling areas by plotting biomass in each area along the distance gradient of ice-cover barium concentrations. The greatest extent of barium effects was observed under ice-cover (Golder 2014b); therefore, ice-cover barium concentrations were plotted. Barium is a conservative element in the environment and can be used as a tracer of treated Mine effluent. Greater total biomass in areas with greater barium concentrations would suggest a Mine-related eutrophication effect.

Multivariate and univariate statistical analyses were used to statistically evaluate potential Mine-related effects on the phytoplankton community in Lac de Gras. Variables included in the statistical analysis included phytoplankton biomass and taxonomic richness.

2.3.2 Zooplankton Community Analysis

The following methods were used to summarize the 2013 zooplankton data:

- Abundance and biomass data were divided into the four major ecological groups (Calanoida, Cyclopoida, Cladocera, and Rotifera).
- Mean abundance and biomass were calculated for duplicate samples collected at each station.
- Relative abundance and biomass accounted for by each major taxonomic group were calculated separately for each sampling area (i.e., NF, MF1, MF2, MF3, FF1, FF2, FFA, FFB, and Lac du Sauvage) to assess spatial variability in community structure.
- Richness was calculated at the lowest taxonomic level: species level for Cladocera, Cyclopoda, and Calanoida; and genus level for Rotifera.

- A summary of the dominant taxa found in the NF exposure area compared to the FF reference areas was presented; dominant taxa were identified as taxa present in proportions greater than 5% of total biomass.
- Summary statistics were calculated for total zooplankton abundance and biomass.

To visually evaluate spatial trends relative to the Mine discharge, total zooplankton biomass and taxonomic richness were plotted against distance from the diffuser, as described above for phytoplankton. The normal range for the zooplankton data was calculated from the August 15 to September 15 data collected from 2008 to 2010. Normal range calculations do not include 2007 data due to sampling errors in that year (Golder 2011a).

A qualitative comparison of total zooplankton biomass plotted against ice-cover barium concentrations was completed, as described for phytoplankton. Although, greater total biomass in areas with greater barium concentrations would suggest a Mine-related eutrophication effect, lower total biomass in areas with greater barium concentrations would also suggest a Mine-related toxicity effect on the zooplankton community.

Multivariate and univariate statistical analyses were used to determine whether visual differences were significant. Variables included in the statistical analysis included zooplankton biomass and taxonomic richness.

2.3.3 Statistical Analysis

2.3.3.1 Approach

The objective of the statistical comparisons was to compare the NF exposure area to the three reference areas (FFA, FFB, and FF1). Statistical testing was conducted with the Kruskal-Wallis test. To visualize the level of similarity of communities at individual stations, a multivariate statistical technique called non-metric multidimensional scaling (NMDS) was used.

Prior to undertaking statistical analyses, the data were screened for outliers or inaccurate entries. Calculations and statistical summaries were conducted in Excel 2010 for Windows (Microsoft Corporation, Cambridge, MA). Multivariate statistics were performed using Systat 13 for Windows (Systat Software, San Jose, California). Univariate statistics were performed using the R Program (R Core Team, Vienna, Austria). Summary plots were created in SigmaPlot, version 11.0 for Windows (SPSS Inc., Chicago, IL).

2.3.3.2 Testing Assumptions for Statistical Analysis

Comparisons among areas were to be conducted by analysis of variance (ANOVA). Parametric tests such as ANOVA assume that the data fit the normal distribution (since the residuals [or error terms of the variates] are assumed to fit the normal distribution). If a measurement variable is not normally distributed, there is an increased chance of a false positive result (Type I error). Goodness-of-fit of plankton data to the normal distribution was tested with the Kolmogorov-Smirnov test. Since many data sets that are significantly non-normal can still be appropriate for ANOVA, issues with non-normality were only addressed with a *P* value less than 0.01. . If a measurement variable was not normally distributed, the data were subjected to data transformations (e.g., log transformation) and then re-assessed for normality.

Another important assumption in ANOVA is that group variances are equal. When variances differ markedly, various data transformations will typically remedy the problem. As with normality, the consequences of moderate deviations from the assumption of equal variances do not compromise the overall test of significance. Bartlett’s and Levene’s tests were performed to test the homogeneity of variances of the plankton data.

Following the testing of assumptions for ANOVA, it was determined that the plankton data were clearly non-normally distributed and had large differences in group variances. Therefore, the plankton data were analyzed using the non-parametric Kruskal-Wallis test.

2.3.3.3 Statistical Comparisons

The Kruskal-Wallis test was used to test for differences among sampling areas, within a sampling year. First, the means of the four areas were compared to one another. Upon finding a significant overall difference, planned contrasts were conducted to test differences between the NF exposure area and the pooled reference areas (Gibbons 1976). To assess natural variability, the three reference areas were compared to one another (FF1 vs. FFA vs. FFB). The multiple-comparison procedure employed followed Dunn (1964) and is the nonparametric analogue to unplanned tests using the *Tukey’s honestly significant difference (HSD)* method for normally-distributed data.

Kruskal-Wallis tests were considered significant at $P<0.1$. The multiple-comparison procedure controls the experiment-wise error rates for the Type I error and, therefore, holds the probability of correctly finding no difference at $1 - \alpha$. However, under this scenario, the task of correctly detecting differences that are significant (*i.e.*, $1 - \beta$) is more difficult (Daniel 1990). To maintain a sufficiently small Type II error (β) with the multiple comparisons, a larger α (or *P* value) was used. The contrasts were tested at $\alpha = 0.1$, and the multiple comparisons were conducted with $\alpha = 0.15$.

2.3.3.4 Multivariate Analysis

Phytoplankton and zooplankton community structure were summarized using the non-parametric ordination method NMDS (Clarke 1993). Duplicate samples were plotted for zooplankton data. Both the zooplankton and phytoplankton data were log (x+1) transformed to improve the separation of the data among stations on the NMDS plots and to reduce weighting of the analysis by the most abundant taxa. A Bray-Curtis distance matrix was generated, and the NMDS procedure was applied to this matrix. Using rank order information, NMDS determined the relative positions of stations in two dimensions based on community composition. Goodness-of-fit was determined by examining the Shepard diagrams as well as the stress values, which were calculated from the deviations in the Shepard diagrams. Lower stress values (i.e., less than 0.10) indicate less deviation and a greater goodness-of-fit. Points that fall close together on the NMDS ordination plot represent samples with similar community composition; points that are far apart from each other represent samples with dissimilar community composition.

2.4 ACTION LEVELS FOR PLANKTON

The importance of effects to a phytoplankton or zooplankton assessment endpoint (i.e., biomass or taxonomic richness) has been categorized according to Action Levels described in Golder (2014a). The Action Level classifications were developed to meet the goals of the Response Framework for Aquatic Effects Monitoring that was drafted by the WLWB (WLWB 2010; Racher et al. 2011). The goal of the Response Framework is to ensure that significant adverse effects never occur. A significant adverse effect, as it pertains to aquatic biota, was defined in the Environmental Assessment as a change in fish population(s) that is greater than 20% (Government of Canada 1999). This effect must have a high probability of being permanent or long-term in nature and must occur throughout Lac de Gras. The Significance Thresholds for all aquatic biota, including plankton, are therefore related to impacts that could result in a change in fish population(s) that is greater than 20%.

Although the AEMP addresses two broad impact hypotheses for Lac de Gras, the toxicological impairment hypothesis and the nutrient enrichment hypothesis (Golder 2014d), the Action Levels for plankton address the toxicological impairment hypothesis. The nutrient enrichment hypothesis is assessed in the Eutrophication Indicators component (Golder 2014c).

Phytoplankton and zooplankton biomass and taxonomic richness are assessed annually to evaluate effects as described in the Action Levels for Biological Effects (Golder 2014a). This involves testing biomass and richness in the NF exposure area against those in the three FF reference areas (FFI, FFB, and FFA). The occurrence of an Action Level 1 will be determined by finding significantly lower biomass or richness in the exposure area compared to those in the reference areas. Conditions required for Action Levels 1 to 3 are defined in Table 2-1. Action Level 4 will be defined if Action Level 3 is reached.

Defining higher Action Levels after initial effects are encountered is consistent with the draft guidelines for preparing a response framework in AEMPs (WLWB 2010; Racher et al. 2011).

Table 2-1 Action Levels for Plankton Effects

Action Level	Plankton	Extent	Action
1	Mean biomass or richness significantly less than reference area means	Near-field	Confirm effect
2	Mean biomass or richness significantly less than reference area means	Nearest Mid-field station	Investigate cause
3	Mean richness less than normal range	Near-field	Examine ecological significance Set Action Level 4 Identify mitigation options
4	TBD[a]		Define conditions required for the Significance Threshold
5[b]	Decline in biomass or richness likely to cause a >20% change in fish population(s)	Far-field A (FFA)	Significance Threshold

Notes: >= greater than; % = percent.

a) To be determined if Action Level 3 is reached.

b) Significance Threshold.

2.5 QUALITY CONTROL

The Quality Assurance Project Plan Version 2.0 (QAPP) outlines the quality assurance/quality control (QA/QC) procedures employed to support the collection of scientifically-defensible and relevant data required to meet the objectives of the AEMP (Golder 2013). The QAPP is designed so that field sampling, laboratory analysis, data entry, data analysis, and report preparation activities produce technically-sound and scientifically-defensible results. A description of the QA/QC program is provided in Appendix A.

2.6 WEIGHT OF EVIDENCE INPUT

Results of the plankton survey feed into the Weight of Evidence (WOE) assessment, which is described in the Weight of Evidence Report (Golder 2014d). The WOE integrates results from the AEMP components to help understand the underlying cause(s) of biological responses. Whereas the annual report for each AEMP component assesses the effects separately to determine if changes in individual components are meaningful, the WOE approach integrates measures of exposure (e.g., water quality, sediment quality) with measures of biological response (e.g., plankton, benthos, fish) to assess the underlying causes of biological changes. These biological changes can reflect either nutrient enrichment or toxicological impairment effects. Thus, the WOE will provide the strength of evidence for toxicological impairment or nutrient enrichment associated with observed changes. It is not intended to reflect the ecological significance or level of concern associated with a given change.

The WOE assessment is undertaken by applying a rating scheme to determine the degree of change in individual AEMP components. It then proceeds to integrate the individual component ratings into an overall score. The methods, as applied to plankton, are described in Sections 2 of the Weight of Evidence Report.

3 RESULTS

The list of 2013 phytoplankton taxa, abundance and biomass data, and the QC results pertaining to taxonomic analysis are provided in Appendix C. The list of 2013 zooplankton taxa, abundance and biomass data, and associated QC results are provided in Appendix D. Abundance and biomass summary statistics for phytoplankton and zooplankton data are provided in Appendix E.

3.1 PHYTOPLANKTON COMMUNITY

3.1.1 Phytoplankton Biomass and Taxonomic Richness

Overall, phytoplankton biomass was greater at stations exposed to effluent than at more distant stations. Stations along the MF2-FF2 transect (MF2-1, FF2-2, and FF2-5) were above the normal range, and station MF3-1 to the southeast of the Mine was at the upper limit of the normal range. Phytoplankton biomass was statistically greater in the NF exposure area compared to the reference areas in 2013 (Table 3-1), but the NF exposure area was still within the normal range, which was calculated on the August 15 to September 15 pooled reference area data collected from 2007 to 2010 (Figure 3-1; Table 3-1). There was no clear relationship between water column barium concentration and total phytoplankton biomass (Figure 3-2). However, the smallest biomass values were encountered at stations with low Barium concentrations.

Phytoplankton biomass at the Lac du Sauvage stations was greater than that observed in the three reference areas in Lac de Gras (Figure 3-1). Of the three Lac du Sauvage stations, two were within the Lac de Gras normal range, and the third was above the normal range, with values similar to those observed at stations along the MF2-FF2 transect.

Table 3-1 Kruskal-Wallis Test on Phytoplankton Biomass and Taxonomic Richness in Lac de Gras, 2013

		Summary Statistics								**Exposure vs. Reference Area Comparisons$^{(a)}$**	**Reference vs. Reference Area Comparison$^{(b)}$**	**Exposure Area vs. Normal Range$^{(c)}$**	
		Near-Field (NF)		**Far-Field 1 (FF1)**		**Far-Field B (FFB)**		**Far-Field A (FFA)**		**NF vs. FFA+FFB+FF1**	**FFA vs. FFB vs. FF1**		
Variable	**Units**	**n**	**Mean ± SD**	**n**	**Mean ± SD**	**n**	**Mean ± SD**	**n**	**Mean ± SD**	***P***	***P***	**>NR**	**<NR**
Total Phytoplankton Biomass	mg/m^3	5	341 ± 97	5	217 ± 99	5	235 ± 130	5	148 ± 61	**	ns	No	No
Total Phytoplankton Taxonomic Richness	Taxa$^{(d)}$	5	32 ± 4.0	5	30 ± 4.3	5	26 ± 1.4	5	26 ± 1.6	**	ns	Yes	No

Notes: mg/m^3 = milligrams per cubic metre; SD = standard deviation; n = number of samples; ± = plus or minus; *P* = probability; ns = not significant; NR = normal range;> = greater than; < = less than.

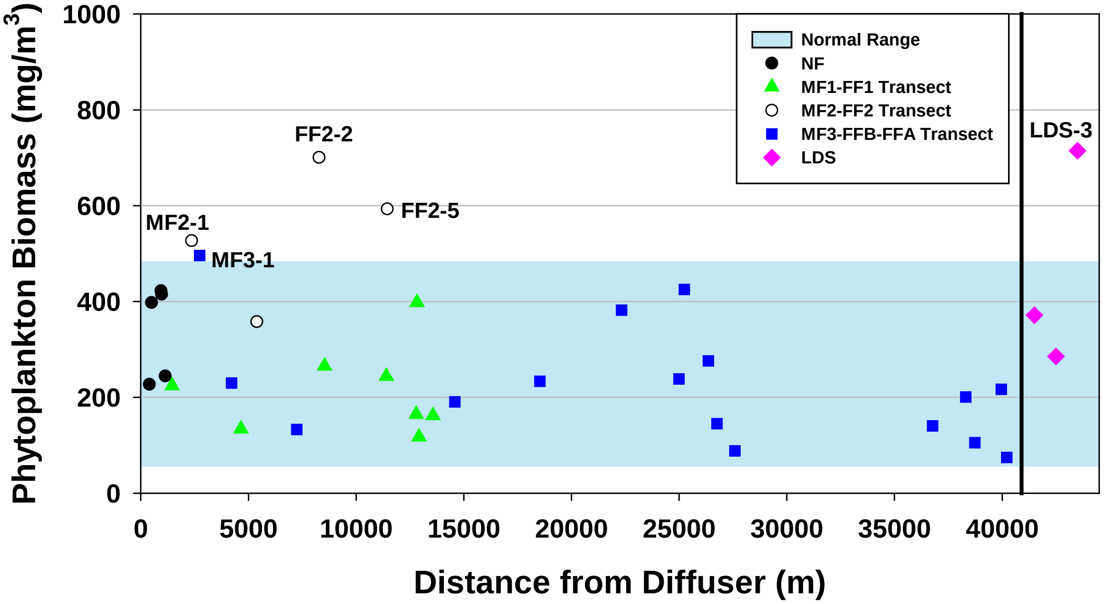
a) Probability of Type 1 Error for Planned Comparisons (NF vs. Reference): * = <0.1, ** = <0.01, *** = <0.001, **** = <0.0001.

b) Probability of Type 1 Error for Unplanned Comparisons (reference vs reference comparisons) * = <0.15, ** = <0.01, *** = <0.001.

c) The normal range was calculated using the pooled reference area mean from 2007 to 2010 plus or minus two standard deviations.

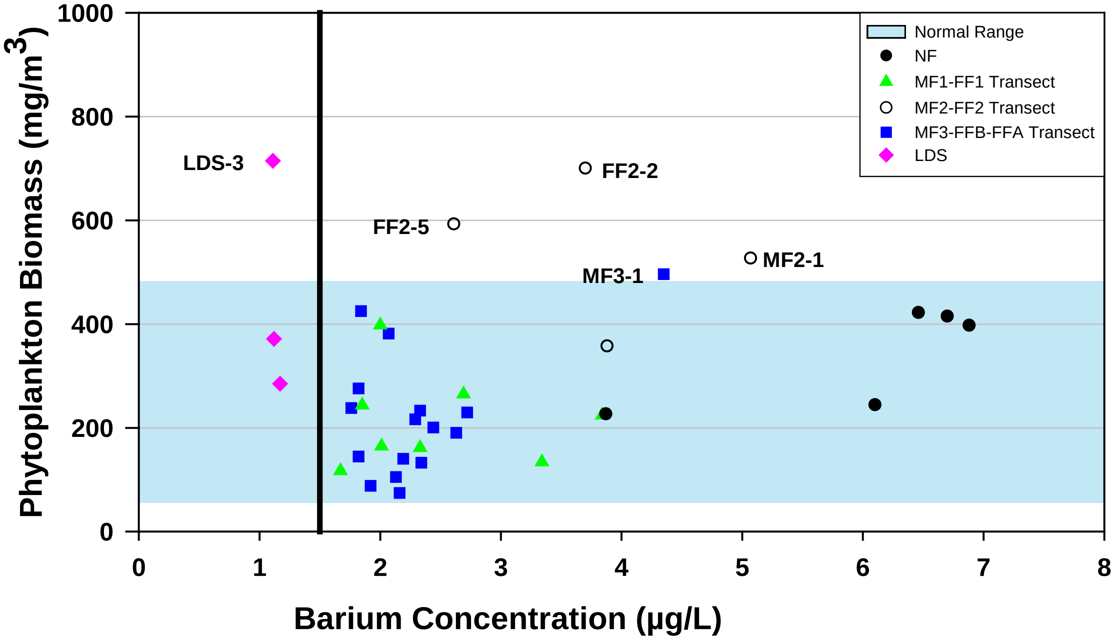
d) Genus-level assessment.

Figure 3-1 Phytoplankton Biomass in Lac de Gras and Lac du Sauvage According to Distance from the Diffuser, 2013



Notes: mg/m^3 = milligrams per cubic metre; m = metres; NF = near-field; MF = mid-field; FF = far-field; LDS = Lac du Sauvage; SD = standard deviation. The normal range was calculated using the pooled reference area mean plus or minus two standard deviations, using 2007 to 2010 data.

Figure 3-2 Phytoplankton Biomass in Lac de Gras and Lac du Sauvage According to Barium Concentrations, 2013

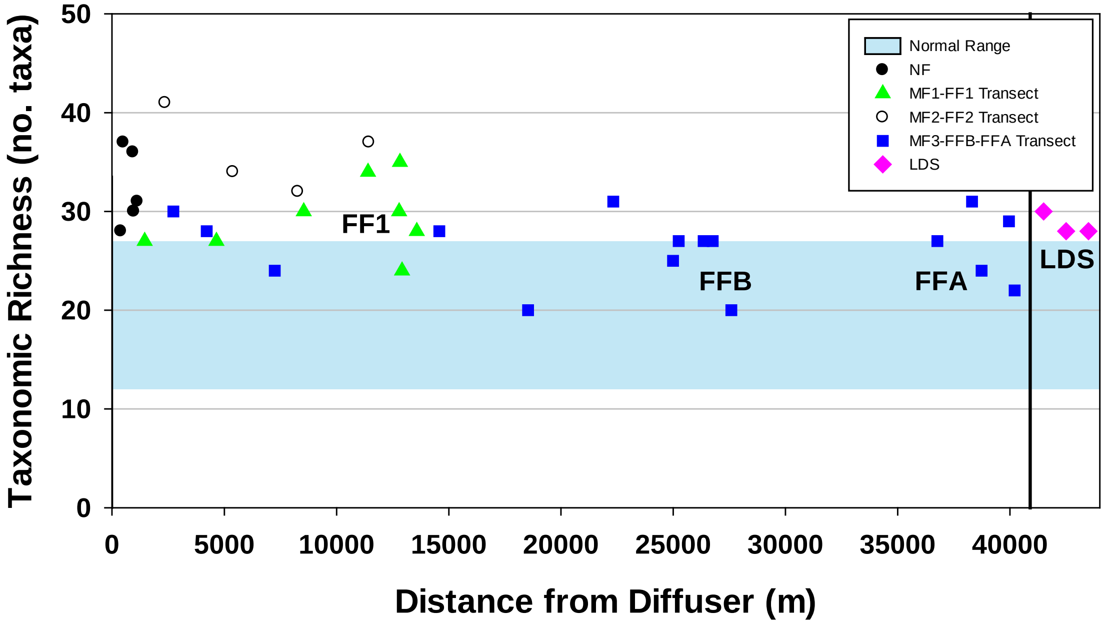


Notes: mg/m3 = milligrams per cubic metre; m = metre; NF = near-field; MF = mid-field; FF = far-field; LDS = Lac du Sauvage; SD = standard deviation. The normal range was calculated using the pooled reference area mean plus or minus two standard deviations from 2007 to 2010.

In total, 73 taxa were identified in the 2013 phytoplankton samples (Appendix C). In general, the NF and FF2 exposure areas had greater taxonomic richness compared to the reference areas (Figure 3-3). Overall, phytoplankton taxonomic richness was statistically greater in the NF exposure area compared to the 2013 reference areas, and it was greater than the normal range, based on the 2007 to 2010 pooled reference area mean (Table 3-1).

Mean taxonomic richness was lowest in the FFB area (25.5 taxa) and greatest in the MF2 area (37.5 taxa; Appendix C). Nearly all exposure stations to the north of the Mine(NF, MF2-FF2, MF1) and most of the FF1 reference area stations had richness values greater than the normal range (Figure 3-3). In addition the FFB and FFA stations were either at or above the upper limit of the normal range in 2013. This pattern of overall greater taxonomic richness in 2013 compared to the normal range (2007 to 2010 data) likely reflects the switch in phytoplankton taxonomists in 2013.

Figure 3-3 Phytoplankton Taxonomic Richness (at Genus level) in Lac de Gras and Lac du Sauvage According to Distance from the Diffuser, 2013



Notes: NF = near-field; MF = mid-field; FF = far-field; LDS = Lac du Sauvage; m = metre; no. = number. The normal range was calculated using the pooled reference area mean plus or minus two standard deviations from 2007 to 2010.

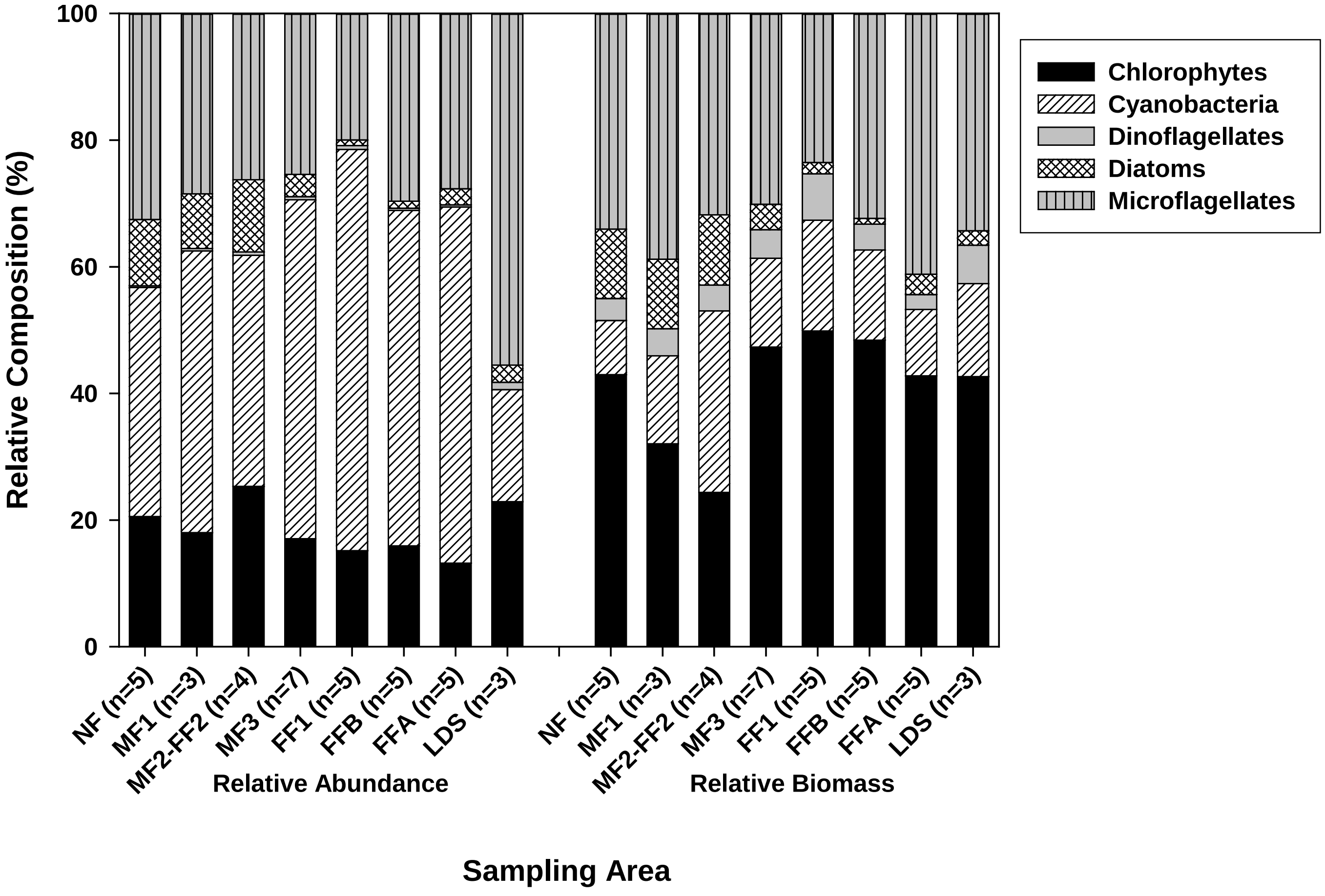
3.1.2 Phytoplankton Community Structure

In 2013, phytoplankton community structure in Lac de Gras was characterized by a dominance of cyanobacteria by abundance (ranging from 33% to 63% by abundance, and 9% to 38%, by biomass), and a dominance of chlorophytes by biomass (ranging from 23% to 50% by biomass, and 13% to 30% by abundance; Figure 3-4). The contribution of cyanobacteria to total phytoplankton community biomass was less than abundance because of the relatively small size of most cyanobacteria cells, whereas the relative biomass of chlorophytes was greater than abundance because of their large cell size. Microflagellates were the second most dominant group by both abundance and biomass (ranging from 20% to 56% by abundance and 23% to 41% by biomass). Diatoms and dinoflagellates contributed a relatively small proportion by both abundance and biomass in Lac de Gras, with diatoms ranging from 1% to 12% by abundance and 1% to 14% by biomass, and dinoflagellates ranging from 0% to 1% by abundance and 3% to 7% by biomass. Phytoplankton community structure did not differ substantially, in terms of either relative abundance or biomass, between the NF exposure area and the reference areas in 2013.

Phytoplankton community structure in Lac du Sauvage differed from that in Lac de Gras in terms of relative abundance; however, relative biomass was similar among the Lac du Sauvage stations and the FF reference area stations (Figure 3-4). The Lac du Sauvage stations were dominated by microflagellates by abundance (49% to 61%), with lower abundances of cyanobacteria compared to stations in Lac de Gras. By biomass, the Lac du Sauvage stations were dominated by chlorophytes (14% to 65%) and microflagellates (ranging from 30% to 39%). Community structure at the Lac du Sauvage stations differed from that at the MF2-FF2 stations. The MF2-FF2 stations had greater proportions of cyanobacteria by both abundance and biomass (ranging from 27% to 53% by abundance, and 11% to 62% by biomass), compared to the Lac du Sauvage stations (ranging from 12% to 25% by abundance, and 1% to 42% by biomass).

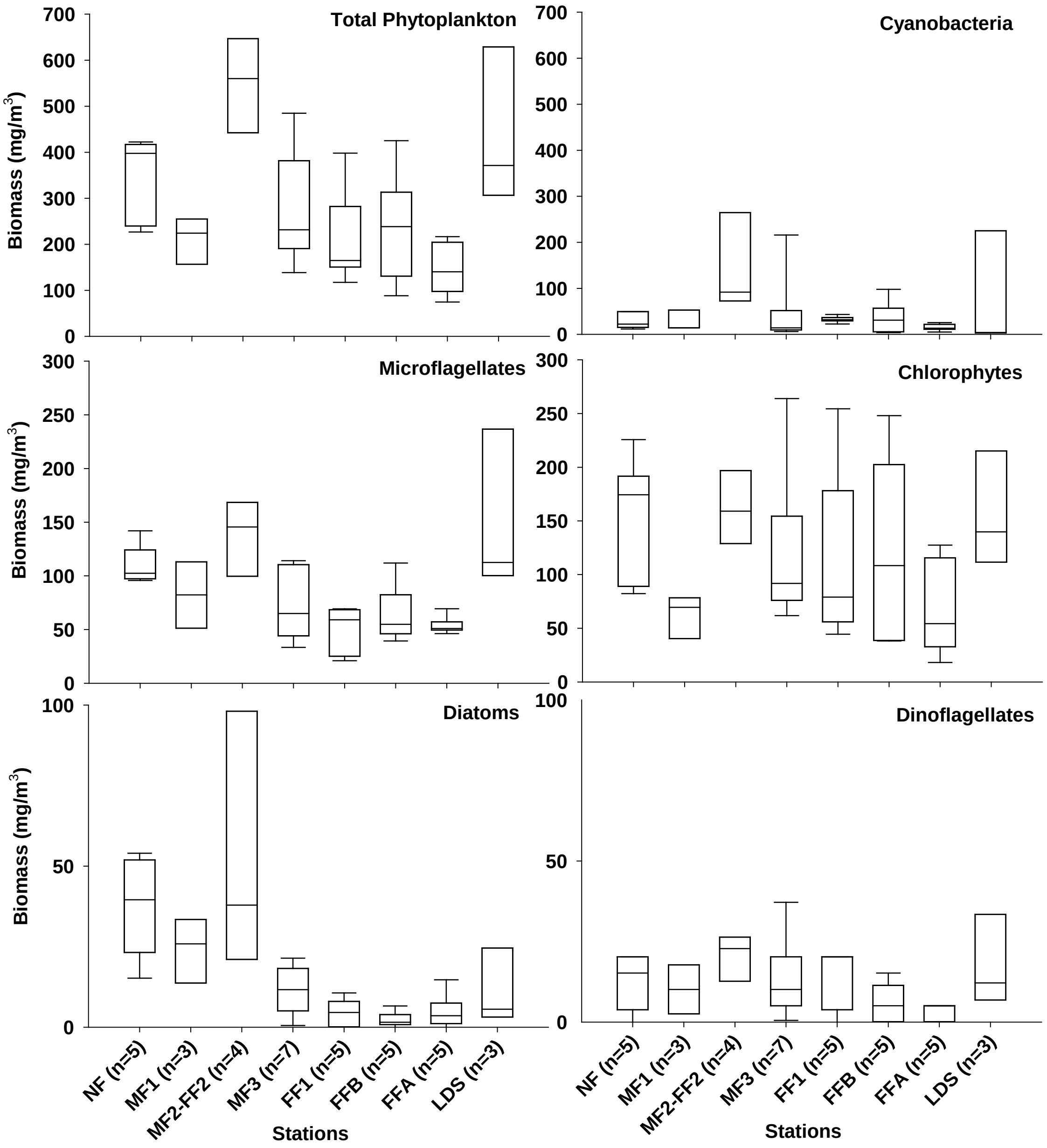
Phytoplankton biomass was greatest at the MF2-FF2 and Lac du Sauvage stations (Figure 3-5). A declining trend with distance in phytoplankton biomass, and biomasses of most major groups except chlorophytes was observed from the NF exposure area south of the Mine, along the MF3 transect (MF3, FFB, and FFA stations). Greater cyanobacteria biomass was observed at the stations along the MF2-FF2 transect (mean biomass of 169 mg/m^3) compared to the other stations in Lac de Gras (area means ranging from 16 to 55 mg/m^3). Cyanobacteria biomass varied greatly among the Lac du Sauvage stations, ranging from 3 to 299 mg/m^3. The Lac du Sauvage stations had greater microflagellate biomass (162 mg/m^3), and the MF2-FF2 and NF stations had greater diatom biomass (area means ranging from 60 mg/m^3 to 37 mg/m^3 in the MF2-FF2 area and NF area, respectively) compared to the other stations in Lac de Gras (means ranging from 2 to 24 mg/m^3). Chlorophyte biomass was similar among areas, with the exception of area MF1 (mean of 61 mg/m^3) which had substantially lower chlorophyte biomass compared to the other areas (area means ranging from 70 to 163 mg/m^3). Dinoflagellate biomass was similar among areas.

Figure 3-4 **Mean Relative Phytoplankton Abundance and Biomass by Sampling Area in Lac de Gras and Lac du Sauvage, 2013**



Notes: % = percent; NF = near-field; MF = mid-field; FF = far-field; LDS = Lac du Sauvage; n = number of samples.

Figure 3-5 Phytoplankton Biomass of Major Ecological Groups by Sampling Area in Lac de Gras and Lac du Sauvage, 2013

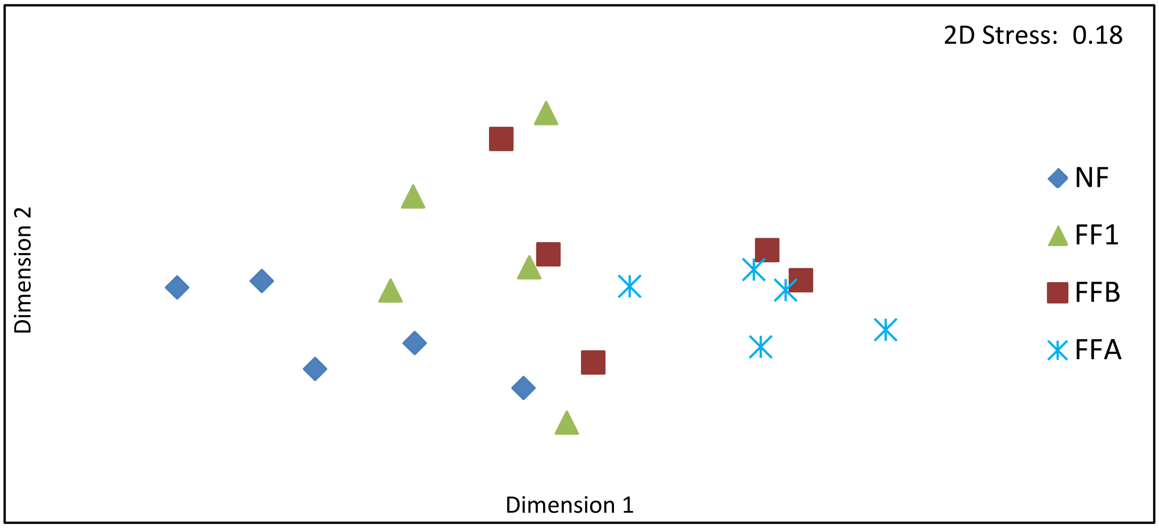


Notes: mg/m^3 = milligrams per cubic metre; NF = near-field; MF = mid-field; FF = far-field; LDS = Lac du Sauvage; n = number of samples. The box plots show the distribution of the data. The bottom and top of the box are the first and third quartiles, respectively, and the band inside the box is the median; the whiskers represent the 10th and 90th percentile of the data.

The two dimensional NMDS configuration for phytoplankton biomass had a stress value of 0.18, indicating a reasonable level of fit to the original data (Figure 3-6). The ordination plot indicates separation between the NF exposure area stations and reference area stations in terms of phytoplankton community composition. Slight overlap was observed in two of the five NF stations with the FF1 reference area stations; however, there was a clear distinction between NF exposure area stations and the FFA and FFB reference area stations, indicating that community composition in the NF exposure area is diverging from that in the reference areas.

Out of the 73 taxa identified in the 2013 phytoplankton samples, the same four taxa dominated in both the NF exposure area and the reference areas (Table 3-2). Within the NF exposure area, the microflagellate *Ochromonas sp.* was the dominant taxon followed by three chlorophytes, *Planctonema sp.*, *Planktosphaeria* sp., and *Ankistrodesmus* sp. *Planktosphaeria* sp. and *Ochromonas sp.* were also dominant in the FF reference areas in 2013. In the FF1 area, *Planctonema sp.* and the cyanobacterium *Lyngbya* sp. were among the dominant taxa. In the FFB area, *Planctonema sp.* was among the dominant taxa, and in the FFA area, two additional microflagellates, *Cryptomonas sp.* and *Komma* sp. were among the dominant taxa. Although, community composition in the NF exposure area appears to be diverging from that in the reference areas (Figure 3-6), overall taxonomic dominance was similar between the NF exposure area and the reference areas (Table 3-2).

Figure 3-6 Non-metric Multidimensional Scaling of Phytoplankton Biomass in Lac de Gras, 2013



Notes: NF = near-field; MF = mid-field; FF = far-field; 2D = two dimensional plot.

Table 3-2 Dominance of Phytoplankton Taxa in the Near-Field and Reference Areas in Lac de Gras, 2013

Area	Ecological Grouping	Dominant Taxa[(a)]	Dominance Ranking	Biomass (mg/m^3)	Proportion of total sample (%)
Near-Field (NF)	Microflagellate	*Ochromonas* sp.	1	43.59	13
	Chlorophyte	*Planctonema* sp.	2	37.51	11
	Chlorophyte	*Planktosphaeria* sp.	3	24.33	7
	Chlorophyte	*Ankistrodesmus* sp.	4	20.44	6
Far-Field 1 (FF1)	Chlorophyte	*Planktosphaeria* sp.	1	38.52	18
	Chlorophyte	*Planctonema* sp.	2	28.38	13
	Microflagellate	*Ochromonas* sp.	3	22.81	11
	Cyanobacteria	*Lyngbya* sp.	4	13.18	6
Far-Field B (FFB)	Chlorophyte	*Planktosphaeria* sp.	1	62.85	27
	Chlorophyte	*Planctonema* sp.	2	30.41	13
	Microflagellate	*Ochromonas* sp.	3	27.88	12
Far-Field A (FFA)	Chlorophyte	*Planktosphaeria* sp.	1	20.27	14
	Microflagellate	*Ochromonas sp.*	2	18.75	13
	Microflagellate	*Cryptomonas* sp.	3	8.11	6
	Microflagellate	*Komma* sp.	4	7.70	5

Notes: mg/m^3 = milligrams per cubic metre; % = percent; sp. = species.

a) Dominant taxa were identified as taxa present in proportions greater than 5% of total biomass.

3.2 ZOOPLANKTON COMMUNITY

3.2.1 Zooplankton Biomass (calculated) and Taxonomic Richness

Zooplankton biomass in the NF exposure area was not statistically different from that in the reference areas in 2013 (Table 3-3). All stations were within the normal range based on the 2008 to 2010 pooled reference area data, with the exception of MF1-3 (Figure 3-7). The high zooplankton biomass observed at station MF1-3 was also observed in the ash-free-dry-mass estimate of zooplankton biomass presented in the Eutrophication Indicators report (Golder 2014c). This unusual result likely reflects a natural clustering of zooplankton that was encountered at that station during sampling since there was no indication of increased zooplankton biomass in relation to the diffuser in 2013 (Figure 3-7).

There was no clear relationship between water column barium concentration and total zooplankton biomass (Figure 3-8). Greater barium concentrations were observed at the majority of the NF exposure stations; however, biomass values in the NF area did not differ from those in the reference areas, where barium concentrations were lower. Overall, no obvious spatial trends in zooplankton biomass were observed in the 2013 data.

Table 3-3 Kruskal-Wallis Test on Zooplankton Biomass (calculated) and Taxonomic Richness in Lac de Gras, 2013

		Summary Statistics								**Exposure Area vs. Reference Comparisons(a)**	**Reference Area vs. Reference Comparison (b)**	**Exposure Area vs. Normal Range(c)**	
		Near-Field (NF)		**Far-Field 1 (FF1)**		**Far-Field B (FFB)**		**Far-Field A (FFA)**		**NF vs. FFA+FFB+FF1**	**FFA vs. FFB vs. FF1**	**>NR**	**<NR**
Variable	**Units**	**n**	**Mean ± SD**	**n**	**Mean ± SD**	**n**	**Mean ± SD**	**n**	**Mean ± SD**	***P***	***P***		
Total Zooplankton Biomass	mg/m^3	5	399 ± 69	5	304 ± 103	5	401 ± 83	5	357 ± 52	ns	ns	No	No
Total Zooplankton Taxonomic Richness	Taxa	5	16 ± 0.8	5	14 ± 1.4	5	13 ± 1.2	5	13 ± 1.3	**	ns	No	No

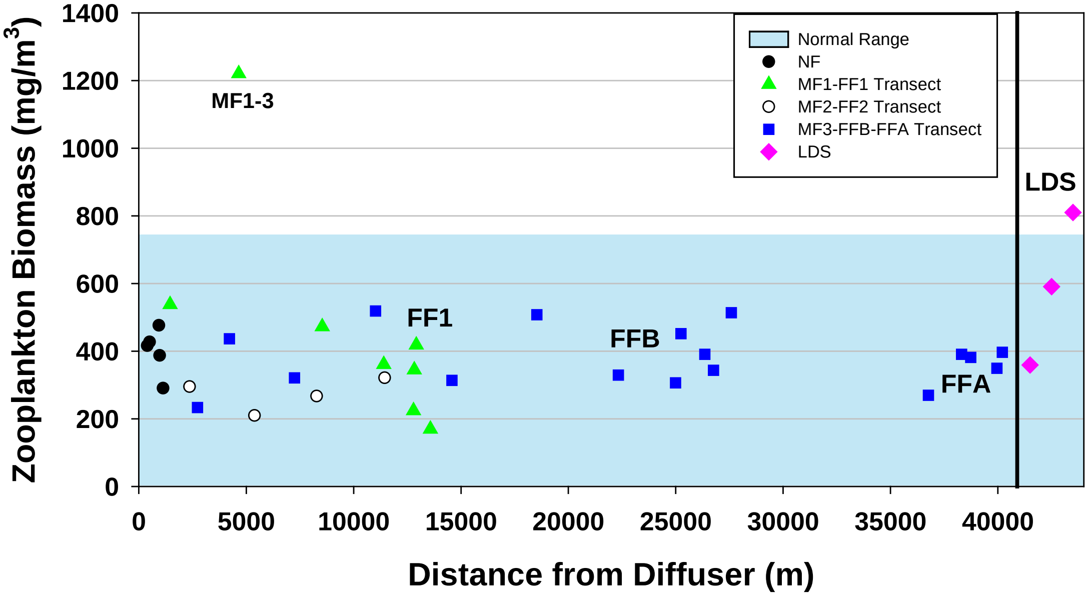
Notes: mg/m^3 = milligrams per cubic metre; SD = standard deviation; n = number of samples; ± = plus or minus; *P* = probability; ns = not significant; NR = normal range; > = greater than; < = less than.

a) Probability of Type 1 Error for Planned Comparisons (NF vs. Reference): * = <0.1, ** = <0.01, *** = <0.001, **** = <0.0001.

b) Probability of Type 1 Error for Unplanned Comparisons (reference vs reference comparisons) * = <0.15, ** = <0.01, *** = <0.001.

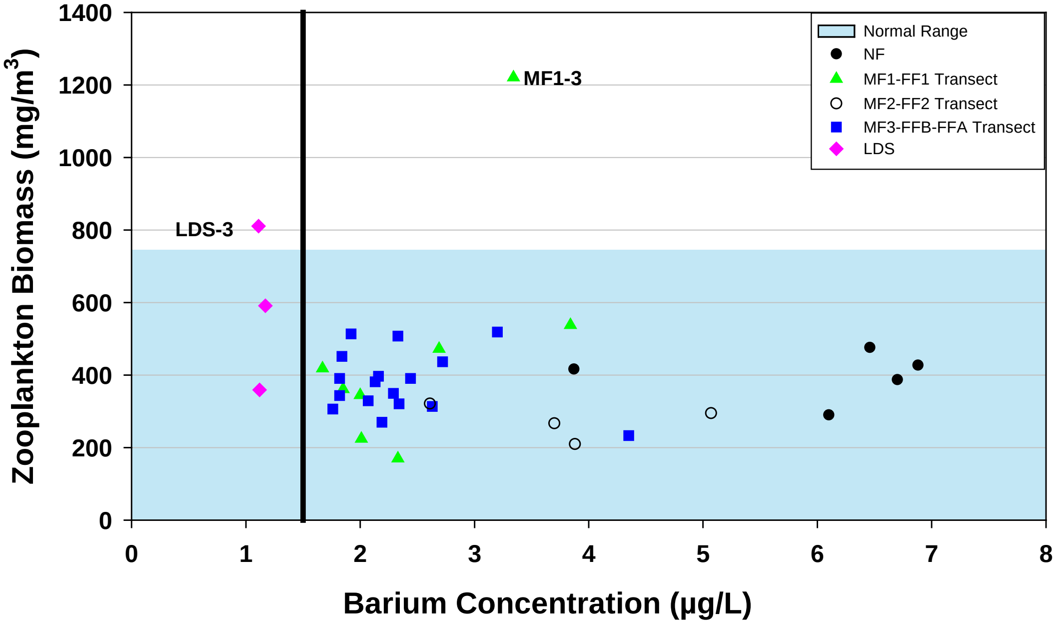
c) The normal range was calculated using the pooled reference area mean plus or minus two standard deviations, using 2007 to 2010 data.

Figure 3-7 Zooplankton Biomass (calculated) in Lac de Gras and Lac du Sauvage According to Distance from the Diffuser, 2013



Notes: mg/m^3 = milligrams per cubic metre; m = metre; NF = near-field; MF = mid-field; FF = far-field; LDS = Lac du Sauvage; SD = standard deviation. The normal range was calculated using the pooled reference area mean plus or minus two standard deviations from 2008 to 2010.

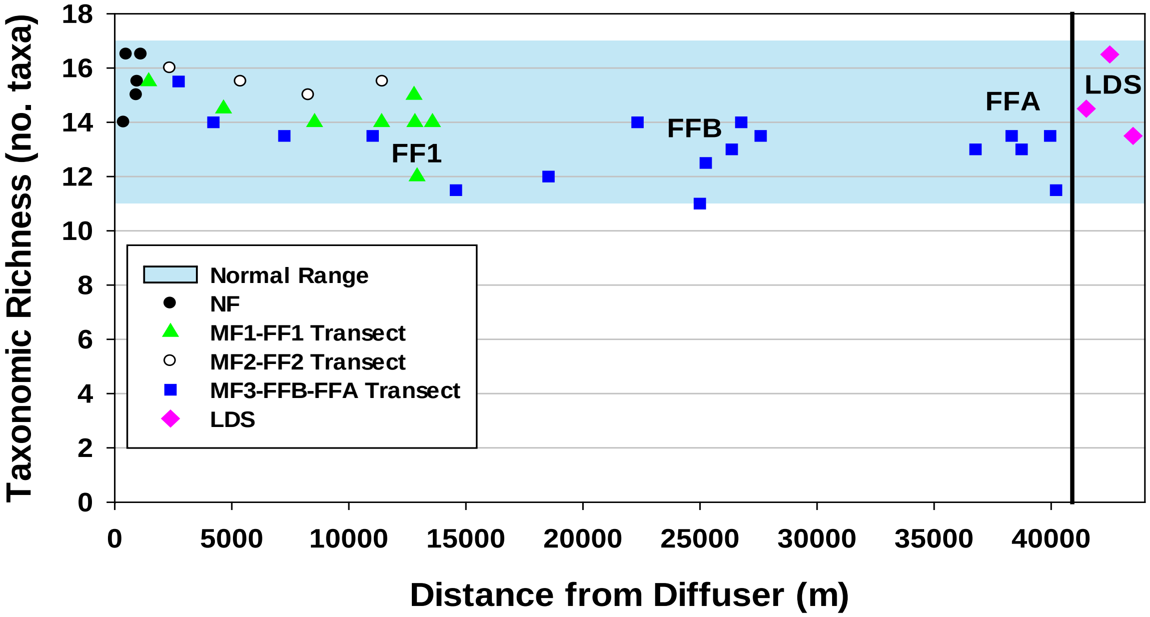
Figure 3-8 Zooplankton Biomass (calculated) in Lac de Gras and Lac du Sauvage According to Barium Concentrations, 2013



Notes: mg/m^3 = milligrams per cubic metre; m = metre; NF = near-field; MF = mid-field; FF = far-field; LDS = Lac du Sauvage; SD = standard deviation. The normal range was calculated using the pooled reference area mean plus or minus two standard deviations from 2008 to 2010.

In total, 25 zooplankton taxa were identified in the 2013 samples (Appendix D). Taxonomic richness was similar among stations, although NF stations and those located along the MF2-FF2 transect and in the Lac du Sauvage sampling area had slightly greater taxonomic richness than those located along the MF3-FFB-FFA transect (Figure 3-9). All stations were within the normal range, based on the 2008 to 2010 pooled reference area mean (Figure 3-9; Table 3-3). Zooplankton taxonomic richness was statistically greater in the NF exposure area compared to the reference areas in 2013 (Table 3-3).

Figure 3-9 Zooplankton Taxonomic Richness in Lac de Gras and Lac du Sauvage According to Distance from the Diffuser, 2013



Notes: NF = near-field; MF = mid-field; FF = far-field; LDS = Lac du Sauvage; no.= number of taxa; m = metre. The normal range was calculated using the pooled reference area mean plus or minus two standard deviations from 2007 to 2010.

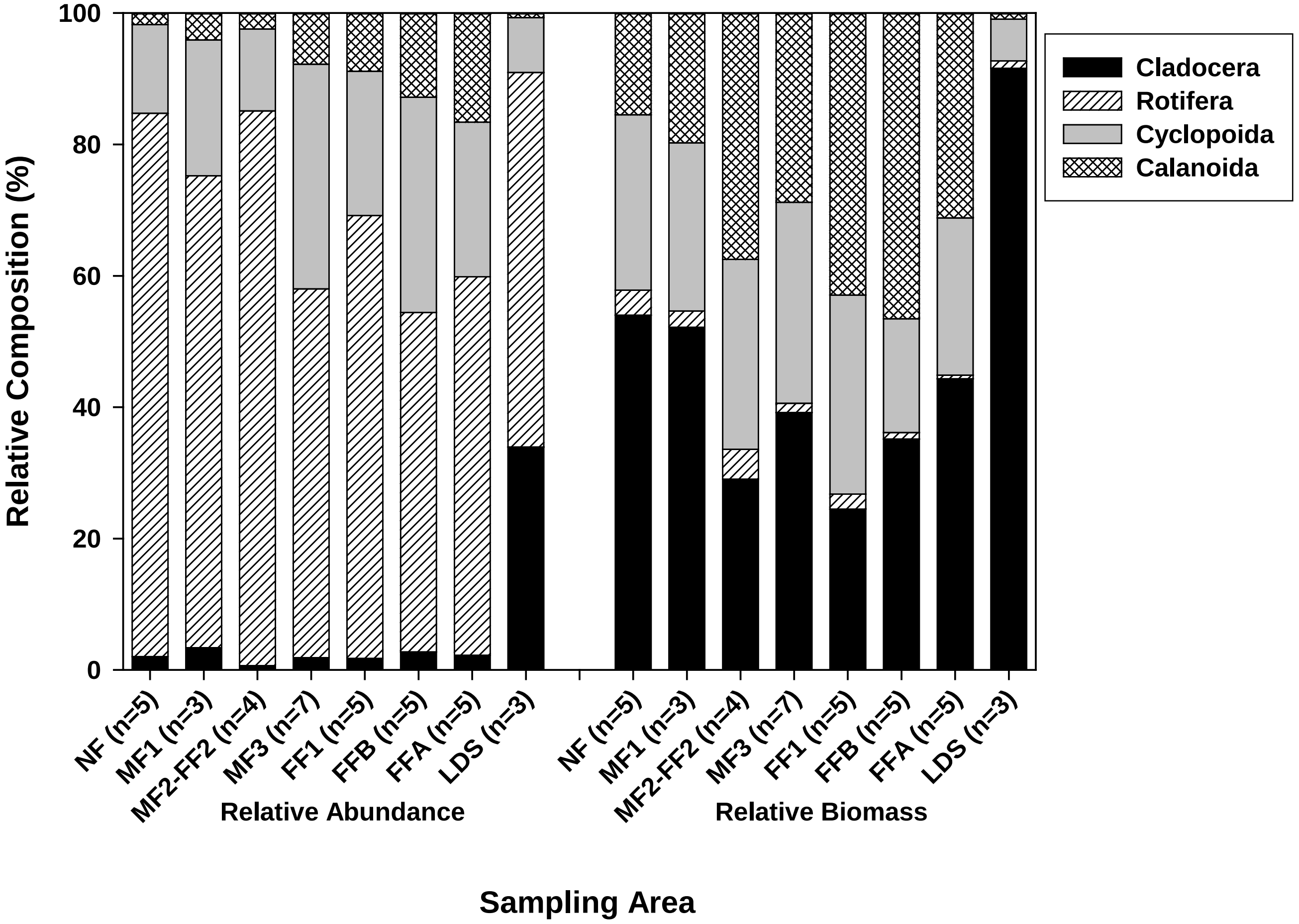
3.2.2 Zooplankton Community Structure

Zooplankton community structure in Lac de Gras was characterized by a dominance of rotifers by abundance, ranging from 52% to 84% (Figure 3-10). Despite accounting for a large proportion of the relative abundance, rotifers accounted for a small proportion (1% to 5%) of the zooplankton biomass, reflective of their small size. While cladocerans were trivial in abundance (1% to 3%), they contributed a large proportion to the overall biomass (25% to 92%), reflective of their large size. Zooplankton biomass in Lac de Gras was not dominated by any particular group; rather it was co-dominated by cladocerans, calanoid copepods, and cyclopoid copepods (Figure 3-10). Calanoid copepods accounted for approximately 1% to 17% of the zooplankton community abundance and 16% to 47% of zooplankton biomass, across all sampling areas. Cyclopoid copepods accounted for approximately 8% to 34% of the zooplankton community abundance and 6% to 31% of zooplankton biomass, across all sampling areas. Zooplankton community structure did not differ substantially in terms of relative abundance between the NF exposure area and the reference areas; however, differences were observed in terms of relative biomass. Greater cladoceran biomass, and less calanoid biomass was observed in the NF exposure area compared to the reference areas.

Zooplankton community structure in Lac du Sauvage differed from that in Lac de Gras in terms of relative abundance and biomass (Figure 3-10). The Lac du Sauvage stations were still dominated by rotifers by abundance (53% to 63%), but their proportion was lower in Lac du Sauvage compared to Lac de Gras. Greater abundances of cladocerans were observed at the Lac du Sauvage stations (26% to 39%) compared to stations in Lac de Gras (1% to 3%). By biomass, the Lac du Sauvage stations were dominated by cladocerans (88% to 94%), with minimal biomasses accounted for by the other groups (calanoids, cyclopoids, and rotifers).

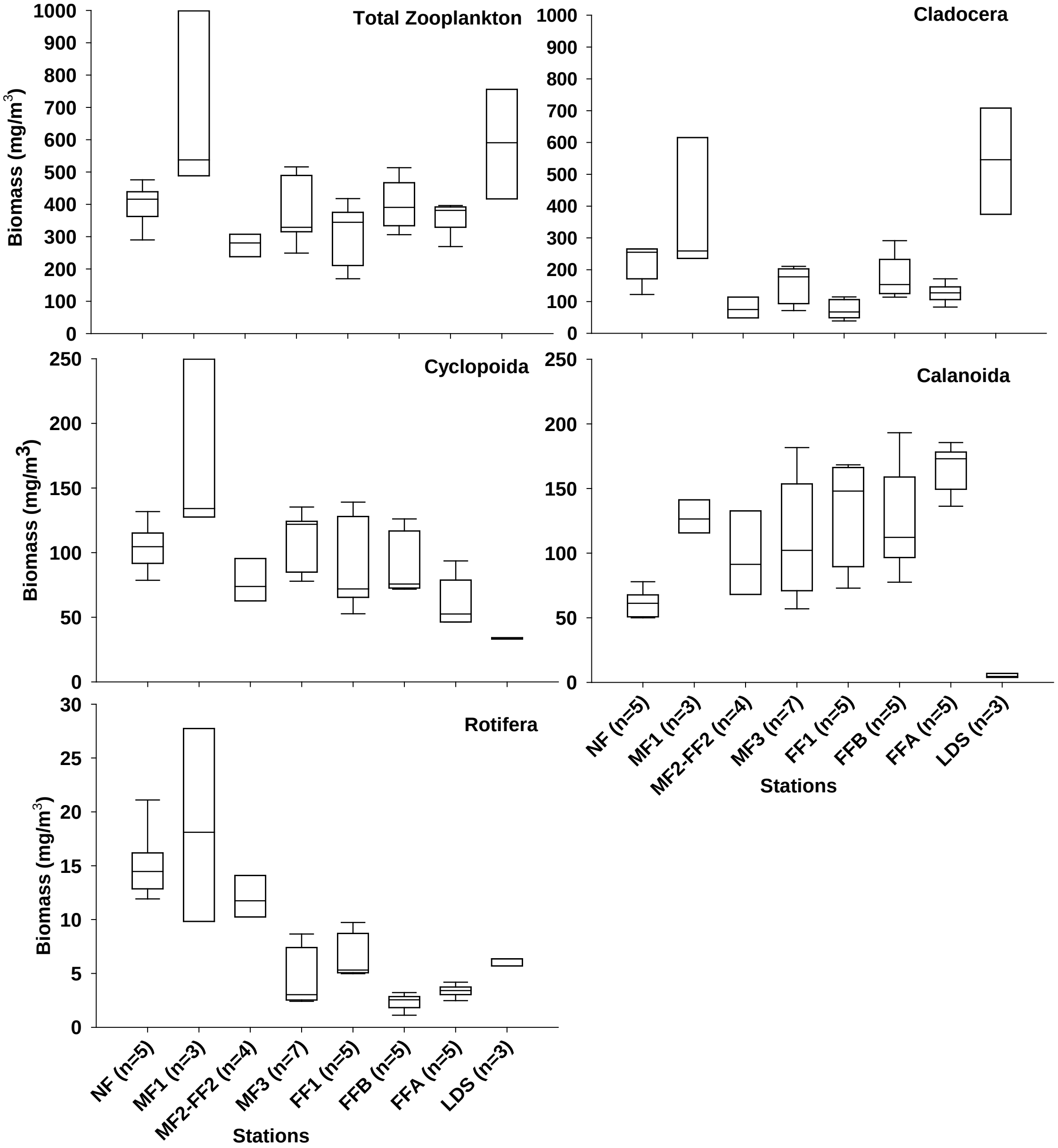
Mean zooplankton biomass was greatest at the MF1 and Lac du Sauvage stations (744 and 587 mg/m^3, respectively), but did not differ substantially among the remaining stations (area means ranging from 252 to 399 mg/m^3; Figure 3-11). Spatial patterns in cladoceran biomass followed the patterns observed in total zooplankton biomass, with MF1 and Lac du Sauvage stations having the greatest biomass with no substantial differences among the remaining stations. A declining trend with distance was observed in cyclopoid copepod and rotifer biomass from the exposure areas to the reference areas. The reverse pattern was observed in calanoid copepod biomass. Calanoid biomass in the NF exposure area (61 mg/m^3) was lower than in the other areas in Lac de Gras (area means ranging from 91 to 161 mg/m^3). Biomasses of cyclopoid and calanoid copepods were substantially lower in Lac du Sauvage (34 and 5 mg/m^3, respectively) compared to those observed in Lac de Gras (calanoid area means ranging from 61 to 161 mg/m^3, and cyclopoid area means ranging from 63 to 190 mg/m^3).

Figure 3-10 Mean Relative Zooplankton Abundance and Biomass (calculated) by Sampling Area in Lac de Gras and Lac du Sauvage, 2013



Notes: % = percent; NF = near-field; MF = mid-field; FF = far-field; LDS = Lac du Sauvage; n = number of samples.

Figure 3-11 Zooplankton Biomass (calculated) of Each Major Ecological Grouping by Sampling Area in Lac de Gras and Lac du Sauvage, 2013



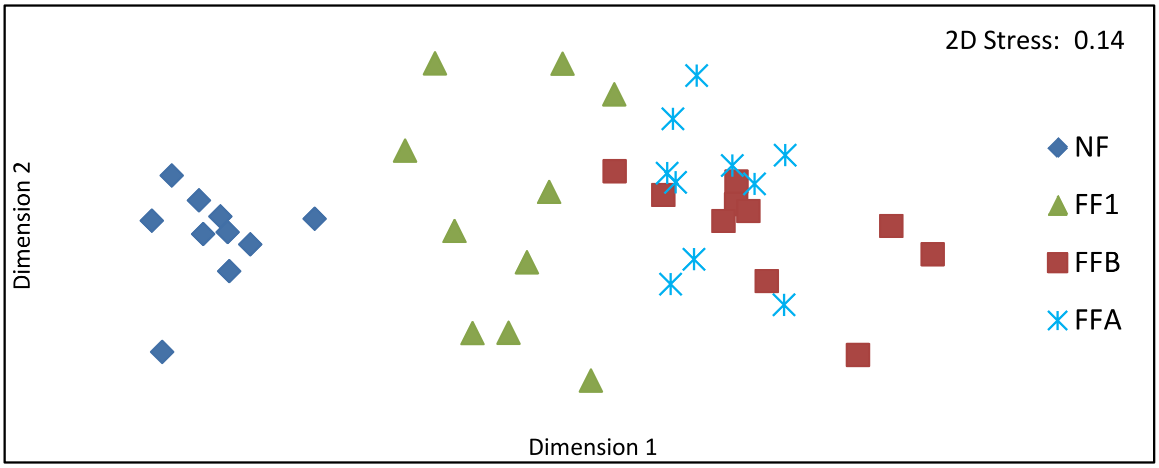
Notes: mg/m^3 = milligrams per cubic metre; NF = near-field; MF = mid-field; FF = far-field; LDS = Lac du Sauvage; n = number of samples. The box plots show the distribution of the data. The bottom and top of the box are the first and third quartiles, respectively and the band inside the box is the median; the whiskers represent the 10th and 90th percentile of the data.

The two dimensional NMDS configuration for zooplankton biomass data had a stress value of 0.14, indicating a reasonable level of fit to the original data (Figure 3-12). The ordination plot indicates separation between the NF exposure area stations and reference area stations in terms of zooplankton community composition, indicating that the zooplankton community in the NF exposure area is diverging from that in the reference areas.

Six species of cladocera were identified in the 2013 samples, with *Daphnia middendorffiana*, *D. longiremis*, *Holopedium gibberum*, and *Eubosmina longispina* observed in most samples (Appendix D). *Chydorus sphaericus* was present in a few samples at low abundances. *H. gibberum* dominated the cladoceran assemblage in the NF, FF2, FF1, and MF2 areas, while *D. middendorffiana* dominated the FFA and FFB reference area cladoceran assemblage. Six species of calanoid copepods were identified in the 2013 samples. *Heterocope septentrionales*, *Diaptomus sicilis*, *D. pribilofensis*, and *D. minutus* were the dominant species at the FF1 and all of the MF areas, while *D. pribilofensis* and *D. sicilis* were the dominant species in the NF, FF2, FFA, and FFB areas. Three species of cyclopoid copepods were identified. *Cyclops scutifer* dominated the assemblage in 2013, while *C. vernalis*, *C. bicuspidatus* and *C. thomasi* were only present in low numbers.

Within the NF exposure area, the cladoceran *Holopedium gibberum* was the most dominant species, accounting for over 43% of total abundance, followed by the cyclopoid *Cyclops scutifer*, the cladoceran *Daphnia longiremis*, and two calanoids, *Diaptomus sicilis* and *Diaptomus pribilofensis* (Table 3-4). Similar species dominated in all four areas (NF, FF1, FFB, and FFA); however, the proportions of each differed. The proportion of *H. gibberum* in the samples decreased with increasing distance from the diffuser; in the NF exposure area *H. gibberum* accounted for over 43% of the sample, while in the FF1 area it accounted for 27%, and in the FFB and FFA areas it accounted for 12% and 13%, respectively. *Daphnia middendorffiana*, a larger cladoceran, was the dominant species at stations in the FFB and FFA areas.

Figure 3-12 Non-metric Multidimensional Scaling of Zooplankton Biomass (calculated) in Lac de Gras, 2013



Notes: NF = near-field; MF = mid-field; FF = far-field; 2D = two dimensional plot.

Table 3-4 Dominance of Zooplankton Taxa in the Near-Field and Reference Areas in Lac de Gras, 2013

Area	Ecological Grouping	Dominant Taxa[(a)]	Dominance Ranking	Biomass (mg/m^3)	Proportion of Total Sample (%)
Near-Field (NF)	Cladocera	*Holopedium gibberum*	1	172.33	43.17
	Cyclopoida	*Cyclops scutifer*	2	85.83	21.50
	Cladocera	*Daphnia longiremis*	3	41.92	10.50
	Calanoida	*Diaptomus sicilis*	4	24.02	6.02
	Calanoida	*Diaptomus pribilofensis*	5	20.41	5.11
Far-Field 1 (FF1)	Cyclopoida	*Cyclops scutifer*	1	80.73	26.60
	Cladocera	*Holopedium gibberum*	2	63.98	21.08
	Calanoida	*Diaptomus sicilis*	3	54.35	17.91
	Calanoida	*Diaptomus minutus*	4	31.22	10.29
	Calanoida	*Diaptomus pribilofensis*	5	28.65	9.44
Far-Field B (FFB)	Cladocera	*Daphnia middendorffiana*	1	131.75	32.85
	Cyclopoida	*Cyclops scutifer*	2	82.71	20.62
	Calanoida	*Diaptomus sicilis*	3	63.53	15.84
	Cladocera	*Holopedium gibberum*	4	46.38	11.56
	Calanoida	*Diaptomus pribilofensis*	5	44.54	11.11
Far-Field A (FFA)	Cladocera	*Daphnia middendorffiana*	1	76.38	21.37
	Calanoida	*Diaptomus pribilofensis*	2	67.34	18.84
	Calanoida	*Diaptomus sicilis*	3	63.31	17.71
	Cyclopoida	*Cyclops scutifer*	4	55.30	15.47
	Cladocera	*Holopedium gibberum*	5	46.77	13.08
	Calanoida	*Diaptomus minutus*	6	18.28	5.11

Notes: mg/m^3 = milligrams per cubic metre; % = percent.

a) Dominant taxa were identified as taxa present in proportions greater than 5% of total biomass.

3.3 ACTIONS LEVELS FOR PLANKTON

The Action Levels for plankton effects address the toxicological impairment hypothesis. Both phytoplankton and zooplankton biomass and taxonomic richness indicate that an Action Level 1 for plankton has not been reached. An Action Level 1 would be reached when significantly lower biomass or richness is observed in the exposure area compared to those in the reference areas (Table 2-2).

3.4 WEIGHT OF EVIDENCE INPUT

As described in Section 2.6, the results described in the preceding sections feed into the WOE approach described in the Weight of Evidence Report (Golder 2014d). The results of the WOE approach relevant to plankton components are described in Section 3.1.5 of the Weight of Evidence Report.

4 DISCUSSION

4.1 PHYTOPLANKTON COMMUNITY

The 2013 AEMP plankton report assessed phytoplankton community composition (taxa richness, abundance, and biomass) in Lac de Gras and Lac du Sauvage during the summer 2013 sampling season. The phytoplankton communities in Lac de Gras were typically characterized by dominance of cyanobacteria and microflagellates by abundance, and chlorophytes and microflagellates by biomass in all sampling areas and did not differ between the NF exposure area and the reference areas. The phytoplankton communities in Lac du Sauvage were similar in composition; however, Lac du Sauvage had lower abundances of cyanobacteria compared to Lac de Gras.

Phytoplankton biomass was statistically greater in the NF area compared to the reference areas in 2013, but was still within the normal range. Generally, phytoplankton biomass was greater at stations closer to the diffuser compared to more distant stations. Phytoplankton biomass in Lac du Sauvage was generally greater than in Lac de Gras. The extent of effects on phytoplankton biomass (based on comparisons to the normal range) were limited to the MF2-FF2 area to the northeast of the Mine and to station MF3-1 to the south of the Mine in Lac de Gras (Figure 4-1). The NF stations were within the normal range and a clear trend with distance from the Mine was not observed. It is possible that the relatively elevated phytoplankton biomass in the MF2-FF2 area was the result of influx of higher productivity waters from Lac du Sauvage, as demonstrated by similar biomass values at the Lac du Sauvage stations.

Phytoplankton taxonomic richness was statistically greater in the NF area compared to the reference areas, and was greater than the normal range. The NMDS ordination plot demonstrated separation between the NF exposure area stations and reference area stations, indicating that community composition in the NF area is diverging from that in the reference areas. However, overall taxonomic dominance was similar between the NF area and the reference areas.

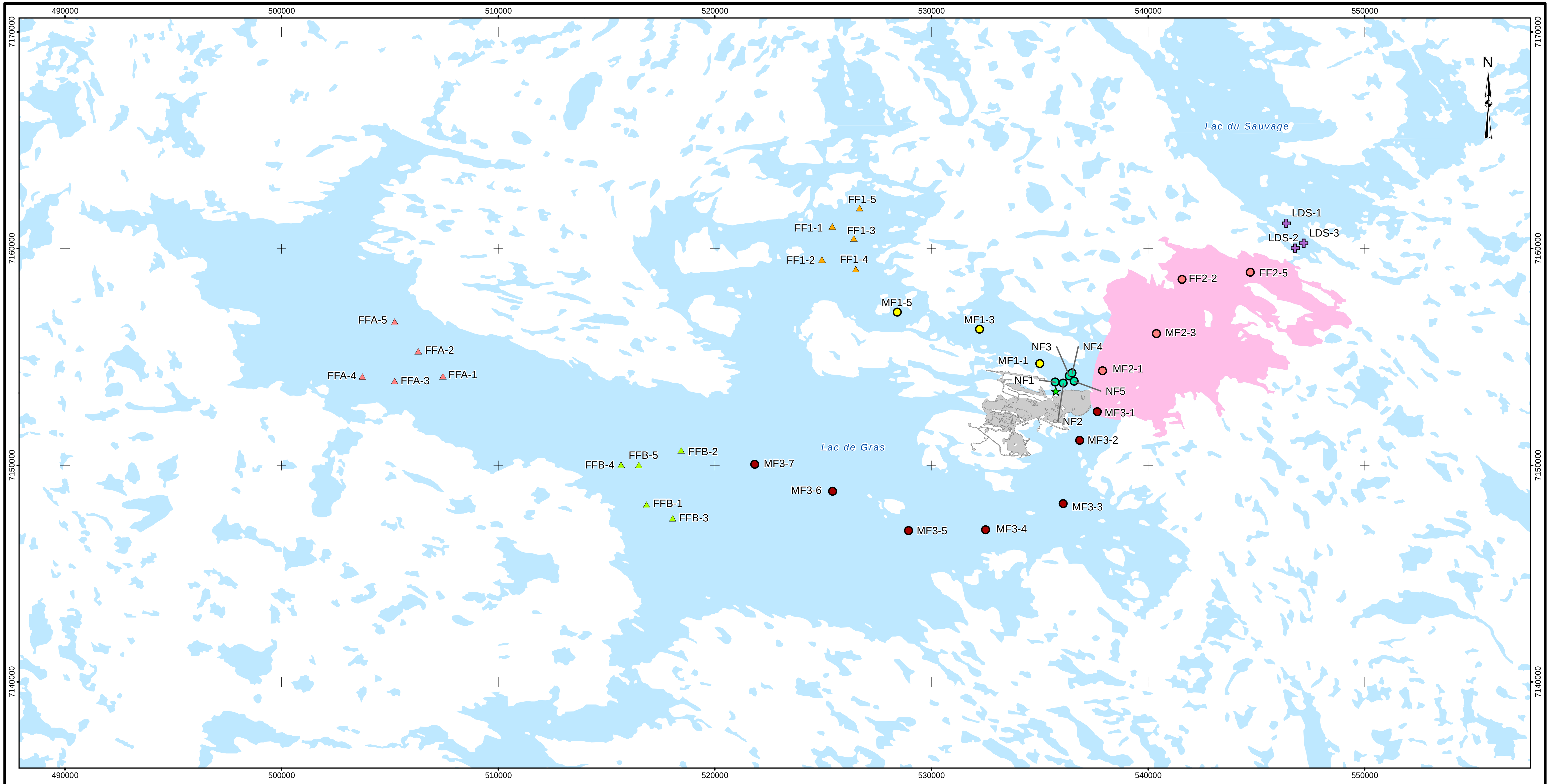
Sufficient differences in biomass and community structure were observed in the phytoplankton community between the exposure and reference areas in 2013 to indicate that the Mine is having an enrichment effect on the phytoplankton community. These observations are consistent with the findings of the Eutrophication Indicators component of the AEMP (Golder 2014c). The 2013 data did not indicate any toxicological impairment. Overall, the phytoplankton biomass and taxonomic richness data indicate that effects have not reached Action Level 1.

4.2 ZOOPLANKTON COMMUNITY

The 2013 AEMP plankton report assessed zooplankton community composition (taxa richness, abundance, and biomass) in Lac de Gras during the 2013 open-water season. Zooplankton communities in Lac de Gras were characterized by a dominance of rotifers by abundance, and co-dominated by cladocerans, calanoid copepods, and cyclopoid copepods by biomass in all sampling areas. Community structure in the NF exposure area was similar to the reference areas, in terms of relative abundance; however, differences were observed in terms of relative biomass. Greater cladoceran biomass, and less calanoid biomass was observed in the NF exposure area compared to the reference areas. In addition, greater abundances of cladocerans were observed at the Lac du Sauvage stations compared to stations in Lac de Gras, and biomass was dominated by cladocerans, with minimal biomass accounted for by the other groups.

Zooplankton biomass in the NF exposure area was not statistically different from that in the reference areas and there was no obvious spatial trends in zooplankton biomass were observed. Zooplankton taxonomic richness was statistically greater in the NF area compared to the reference areas in 2013, but was within the normal range. A clear separation was observed between the NF area and the reference areas in the NMDS plots, and relative biomass of major groups differed between the NF area and reference areas. Greater proportions of rotifers and cladocerans, and fewer calanoids, were observed in the NF area compared to the reference areas. Overall, similar species dominated in all four areas; however, the proportions of each differed.

Sufficient differences in community structure were observed in the zooplankton community between the exposure and reference areas in 2013 to indicate that the Mine is having an enrichment effect. These observations are consistent with the findings of the Eutrophication Indicators component of the AEMP (Golder 2014b). The 2013 data did not indicate toxicological impairment. Overall, the zooplankton biomass and taxonomic richness data indicate that effects have not reached Action Level 1.



LEGEND

★	DIFFUSER	✚	LAC DU SAUVAGE
EXPOSURE		🟪	AFFECTED AREA
●	NEAR-FIELD	▨	DIAVIK FOOTPRINT
●	MID-FIELD 3	🟦	WATERBODY
●	MID-FIELD 1		
●	FAR-FIELD 2; MID-FIELD 2		
REFERENCE			
▲	FAR-FIELD 1		
▲	FAR-FIELD A		
▲	FAR-FIELD B		

REFERENCE

HYDROGRAPHY DATA OBTAINED FROM CANVEC © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 12 DATUM: NAD 83

5 0 5
SCALE 1:175,000 KILOMETRES

PROJECT
DIAVIK DIAMOND MINES INC.

TITLE

PHYTOPLANKTON BIOMASS AFFECTED AREA, 2013 AEMP

Golder Associates

PROJECT		05-1328-008	FILE No.	
DESIGN	TD	13 Feb. 2014	SCALE AS SHOWN	REV. 0
GIS	JC	20 Mar. 2014	FIGURE: 4-1	
CHECK	TD	20 Mar. 2014		
REVIEW	CF	20 Mar. 2014		

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5 CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

This report presents an analysis of phytoplankton and zooplankton data collected during the 2013 AEMP field program. It addresses the main objective of the plankton component by assessing Mine-related changes in the plankton community of Lac de Gras (i.e., spatial changes).

The results suggest that the plankton communities in Lac de Gras are exhibiting a Mine-related nutrient enrichment effect and not a toxicological effect. This conclusion is based on the following findings:

- phytoplankton richness and biomass were statistically greater in the Near-field exposure area relative to the reference areas;
- separation was observed between the Near-field exposure area and the reference areas in the phytoplankton NMDS ordination plots;
- zooplankton richness was statistically greater in the Near-field exposure area compared to the reference areas;
- separation was observed between the Near-field exposure area and the reference areas in the zooplankton NMDS ordination plots; and,
- there were differences in zooplankton community composition between the Near-field exposure area and the reference areas, with greater proportions of rotifers and cladocerans, and fewer calanoids, in the Near-field area compared to the reference areas.

The response framework for Plankton addresses the toxicological impairment hypothesis. Phytoplankton and zooplankton biomass and taxonomic richness do not suggest that a toxicological effect is occurring in Lac de Gras. Therefore, an Action Level 1 for plankton was not reached in 2013.

5.2 RECOMMENDATIONS

The following recommendation is made for future AEMPs at Lac de Gras:

- To be consistent with eutrophication indicator endpoints, plankton should only be sampled every three years at reference areas (FF1, FFA, FFB). Action levels would be based on the most recent reference area data. This recommendation should be implemented for the 2014 open-water sampling period.

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7 CLOSURE

We trust that the information in this report meets your requirements at this time. If you have any questions relating to the information contained in this document please do not hesitate to contact us.

GOLDER ASSOCIATES LTD.

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APPENDIX A

QUALITY ASSURANCE/QUALITY CONTROL

The quality assurance/quality control (QA/QC) program followed during the 2013 AEMP sampling program is detailed in the Quality Assurance Project Plan (QAPP Version 2.0 (Golder 2013). The QAPP outlines the QA/QC procedures employed t)o support the collection of scientifically defensible and relevant data. The QAPP is designed so that field sampling, laboratory analysis, data entry, data analysis, and report preparation activities produce technically sound and scientifically defensible results. Detailed results of the 2013 plankton QA/QC program are presented below.

Quality Assurance

Field Operations

Field work was completed by Diavik staff according to specified instructions and the following Standard Operating Procedures (SOPs):

- Plankton Sampling ENVR-003-0702 R13;
- Quality Assurance/ Quality Control ENVR-303-0112 R0; and,
- Chain of Custody ENVR-206-0112 R0.

These SOPs include guidelines for field record keeping and sample tracking, relevant technical procedures, and sample labelling, shipping, and tracking protocols.

Office Operations

A data management system provided an organized system of data control, analysis, and filing. Relevant operations included the following:

- reviewing taxonomy data as they were received from the subconsultants;
- creating backup files prior to beginning data analysis; and,
- completing appropriate data reviews to verify the accuracy of calculations.

Quality Control

Methods

Quality control is a specific aspect of QA. The field QC program included duplicate zooplankton samples. The laboratory QC program included three phytoplankton split samples and seven zooplankton split samples that were re-counted by the same taxonomist to verify counting efficiency[1]. The duplicate samples are used to check within-station variation, while split samples are used to check the taxonomist's counting efficiency. The data were entered into electronic format by the taxonomist and were double-checked by the same taxonomist upon entry; errors were corrected as necessary before transferring the electronic files to DDMI.

Duplicate zooplankton samples consisted of two samples collected from the same station at the same time, using the same sampling and sample handling procedures. They were labelled and preserved individually, and were submitted separately to the taxonomist for identical analyses.

The inherent variability associated with the plankton samples makes the establishment of a QC threshold value difficult. For the purposes of the plankton QC, samples were flagged and assessed further if there was a greater than 50% difference calculated as the relative percent difference (RPD) in total abundance between the original and duplicate samples. Similarly, samples were flagged and assessed further if there was a greater than 50% difference in total abundance between the taxonomist's split samples.

In addition, the Bray-Curtis index, which is a measure of ecological distance between two communities, was used to assess the overall similarity between the taxonomist's split samples; all index values greater than 0.5 were flagged and follow-up discussions with the taxonomist were initiated. Due to the high variability in species present in the original compared to the recounted samples, the Bray-Curtis comparisons were performed on species grouped at the Major Ecological Grouping level for the phytoplankton community (i.e., Chlorophyceae, microflagellates, dinoflagellates, cyanobacteria, and Bacillariophyceae), and the major ecological grouping level for the zooplankton community (i.e., Cladocera, Cyclopoida, Calanoida, and Rotifera). The value of the Bray-Curtis index ranges from 0 (identical communities) to 1 (very dissimilar communities) and is calculated using the following formula:

$$b = \frac{\sum_{k=1}^{n} \left| x_{ik} - x_{jk} \right|}{\sum_{k=1}^{n} \left(x_{ik} + x_{jk} \right)}$$

where x_{ik} and x_{jk} are abundance or biomass from the original and re-counted samples respectively.

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[1] Counting efficiency is a measure of the reproducibility, skill, and competency of the taxonomist.

Duplicate zooplankton data were not automatically rejected because of some exceedance of the acceptance criterion; rather, they were evaluated on a case by case basis, as some level of within-station variability is expected for duplicate samples. If there were departures from the acceptance criterion, the samples were flagged, and a variety of follow-up assessments were performed. These assessments included plotting the data for visual identification of outliers. If there were visual outliers, the data were plotted with the corresponding 2008 to 2012 data for a range comparison. If the data were outside the corresponding 2008 to 2012 range, laboratory re-analysis occurred. If laboratory re-analysis confirmed the results, the outlier points were retained in the final data set, unless there was a technically defensible reason to exclude them.

Results

The results of the QC check of the 2013 phytoplankton data indicated that the abundance of dominant species and ecological group totals were consistent among the 3 sets of split samples. None of the differences between phytoplankton samples exceeded an RPD of 50% for total abundance (Table A-1). All phytoplankton split samples had Bray-Curtis Index values below 0.5, indicating a reasonable overall similarity between the split samples. Therefore, further follow-up assessments were not performed.

The results of the QC check of the 2012 zooplankton data indicated that the occurrence of dominant species was consistent among the seven sets of split samples. In addition, none of the split samples exceeded an RPD of 50% (Table A-1), and all of the Bray-Curtis Index values were below 0.5 (Appendix D, Table D-3).

The taxonomist identified a number of issues with zooplankton sample integrity, which were recorded in Appendix D. They included poor preservation of samples at stations NF2, MF2-3, MF3-7, FF2-5, and both replicates from station FF1-5; some specimens were dried within the sample from MF3-3, and *Polyarthra* sp. specimens from stations FFA-5 and FFB-2 were decomposed.

Table A-1 Summary of Counting Efficiency from QC Samples for Plankton, 2013

Sample Type	Station	Result 1	Result 2	Relative Percent Difference (%)	Bray-Curtis Index	QC Flag
Phytoplankton Abundance (cells/L)	FF2-5	6,254,450	6,021,302	4	0.10	No
	FFA-2	2,595,039	2,807,914	8	0.04	No
	FFB-3	3,456,673	3,568,179	3	0.03	No
Zooplankton Abundance (ind/L)	NF5	50.41	55.44	10	0.05	No
	MF3-5	19.23	19.66	2	0.03	No
	FFA-5	20.04	24.58	20	0.10	No
	LDS3	34.33	39.99	15	0.08	No
	MF3-2	33.03	28.61	14	0.15	No
	FF1-1	21.42	22.25	4	0.02	No
	FFA-5	19.35	19.54	<1	0.02	No

Notes: NF = near-field; MF = mid-field; FF = far-field; LDS = Lac du Sauvage; % = percent; >= greater than; cells/L = cells per litre; ind/L = individuals per Litre.

Table A-2 Summary of Duplicate Sample Results for Zooplankton Abundance (ind/L), 2013

Station	Result 1	Result 2	Relative Percent Difference (%)	QC Flag
NF1	59.76	73.71	21	No
NF2	52.66	62.56	17	No
NF3	50.93	56.69	11	No
NF4	45.07	63.21	34	No
NF5	50.41	56.79	12	No
MF1-1	67.35	74.00	9	No
MF1-3	113.65	120.51	6	No
MF1-5	32.21	32.65	2	No
MF2-1	58.17	46.66	22	No
MF2-3	41.45	52.10	23	No
MF3-1	40.56	37.09	9	No
MF3-2	25.47	33.03	26	No
MF3-3	20.27	28.04	32	No
MF3-4	24.31	23.85	2	No
MF3-5	19.23	17.20	11	No
MF3-6	22.40	24.94	11	No
MF3-7	16.27	13.81	16	No
FF2-2	54.26	62.25	14	No
FF2-5	49.02	39.89	21	No
FF1-1	18.74	21.42	13	No
FF1-2	28.81	35.30	20	No
FF1-3	20.45	23.75	15	No
FF1-4	31.43	29.74	6	No
FF1-5	27.08	27.08	<1	No
FFA-1	18.23	18.25	<1	No
FFA-2	18.24	17.61	4	No
FFA-3	17.17	16.35	5	No
FFA-4	14.77	16.95	14	No
FFA-5	20.04	19.35	4	No
FFB-1	12.90	19.83	42	No
FFB-2	10.30	11.89	14	No
FFB-3	24.41	22.44	12	No
FFB-4	17.22	18.59	7	No
FFB-5	14.21	14.80	4	No
LDS-1	36.92	35.78	3	No
LDS-2	35.13	39.61	12	No
LDS-3	36.63	38.94	13	No

Notes: NF = near-field; MF = mid-field; FF = far-field; LDS = Lac du Sauvage; % = percent; ind/L = individuals per Litre.

APPENDIX B

2013 AEMP SAMPLING SCHEDULE AND STATION COORDINATES

Table B-1 2013 AEMP Sampling Schedule

Sampling Station	August										September			
	18	**21**	**22**	**24**	**25**	**26**	**27**	**29**	**30**	**31**	**1**	**3**	**5**	**7**
NF1	**p**													
NF2							**p**							
NF3							**p**							
NF4							**p**							
NF5							**p**							
FF2-2						**p**								
FF2-5						**p**								
MF1-1		**p**												
MF1-3		**p**												
MF1-5					**p**									
MF2-1							**p**							
MF2-3						**p**								
MF3-1					**p**									
MF3-2					**p**									
MF3-3					**p**									
MF3-4													**p**	
MF3-5														**p**
MF3-6														**p**
MF3-7					**p**									
FF1-1				**p**										
FF1-2			**p**											
FF1-3				**p**										
FF1-4				**p**										
FF1-5			**p**											
FFA-1								**p**						
FFA-2								**p**						
FFA-3								**p**						
FFA-4									**p**					
FFA-5												**p**		
FFB-1													**p**	
FFB-2											**p**			
FFB-3													**p**	
FFB-4											**p**			
FFB-5											**p**			
LDS-1						**p**								
LDS-2						**p**								
LDS-3						**p**								

Notes: p = plankton sample collected; NF = near-field; MF = mid-field; FF = far-field; LDS = Lac du Sauvage.

Table B-2 Station Depth, Location, and Distance from Diffuser Along Approximate Flow Path

Area	Station	Depth (m)	Easting	Northing	Distance from Diffuser along Approximate Flow Path (m)
Near-field (exposure)	NF1	18.7	535725	7153839	394
	NF2	21.0	536095	7153784	501
	NF3	19.1	536385	7154101	936
	NF4	22.0	536513	7154250	1,131
	NF5	19.8	536625	7153873	968
Mid-field 1 (exposure)	MF1-1	20.5	535014	7154690	1,452
	MF1-3	19.7	532225	7156295	4,650
	MF1-5	17.5	528214	7157050	8,535
Mid-field 2 (exposure)	MF2-1	20.0	538000	7154296	2,363
	MF2-3	20.0	540379	7156096	5,386
Mid-field 3 (exposure)	MF3-1	20.5	537664	7152454	2,730
	MF3-2	18.5	536833	7151142	4,215
	MF3-3	20.7	536090	7148108	7,245
	MF3-4	22.1	532516	7147026	11,023
	MF3-5	19.5	528946	7146978	14,578
	MF3-6	18.0	525445	7148819	18,532
	MF3-7	21.5	521921	7150017	22,330
Far-field 1 (reference)	FF1-1	21.0	525404	7161022	13,571
	FF1-2	18.8	524896	7159441	12,915
	FF1-3	19.8	526407	7160492	12,788
	FF1-4	22.2	526334	7159076	11,399
	FF1-5	18.3	526553	7161775	12,823
Far-field 2 (exposure)	FF2-2	19.0	541599	7158552	8,276
	FF2-5	22.0	544724	7158879	11,444
Far-field A (reference)	FFA-1	18.8	506453	7153999	36,769
	FFA-2	18.0	506315	7155278	38,312
	FFA-3	21.9	505207	7153924	38,734
	FFA-4	21.0	503703	7154088	40,211
	FFA-5	18.5	505216	7156639	39,956
Far-field B (reference)	FFB-1	18.7	516846	7148237	26,355
	FFB-2	17.1	518496	7150693	24,991
	FFB-3	22.1	518058	7147573	25,245
	FFB-4	18.5	515687	7150045	27,591
	FFB-5	21.8	516543	7150025	26,761

Area	Station	Depth (m)	Easting	Northing	Distance from Diffuser along Approximate Flow Path (m)
Lac du Sauvage	LDS-1	19.0	546397	7161160	n/a
	LDS-2	17.1	546811	7160026	n/a
	LDS-3	10.7	547186	7160273	n/a

Notes: NF = near-field; MF = mid-field; FF = far-field; LDS = Lac du Sauvage; n/a = not available; m = metre.

APPENDIX C

PHYTOPLANKTON COMMUNITY DATA (RAW DATA AND QUALITY CONTROL DATA)

These data are provided as an Excel file in a "Raw Data Folder" on the compact disc, rather than in hard copy form.

APPENDIX D

ZOOPLANKTON COMMUNITY DATA (RAW DATA AND QUALITY CONTROL DATA)

These data are provided as an Excel file in a "Raw Data Folder" on the compact disc, rather than in hard copy form.

APPENDIX E

PLANKTON SUMMARY STATISTICS

Table E-1 Summary Statistics for Phytoplankton Abundance (cells per litre) in Lac de Gras, 2013

Area (Sample Size)	Summary Statistic	Microflagellates	Cyanobacteria	Dinoflagellates	Diatoms	Chlorophytes	Total
NF (n=5)	Mean	1,344,149	1,968,581	12,164	464,269	831,224	4,620,386
	Median	1,267,109	1,865,185	10,137	486,570	790,676	4,206,802
	SD	346,927	1,761,038	8,481	205,556	213,477	1,943,154
	SE	155,151	787,560	3,793	91,928	95,470	869,005
	Minimum	952,866	243,285	0	202,737	638,623	2,078,059
	Maximum	1,784,090	4,612,277	20,274	689,307	1,175,877	7,399,917
MF1 (n=3)	Mean	817,706	2,429,470	13,516	216,253	516,981	3,993,927
	Median	729,855	810,950	20,274	152,053	446,022	2,311,207
	SD	352,953	3,206,527	11,705	176,257	285,457	2,949,742
	SE	203,778	1,851,289	6,758	101,762	164,809	1,703,035
	Minimum	516,981	354,791	0	81,095	273,696	2,270,659
	Maximum	1,206,288	6,122,670	20,274	415,612	831,224	7,399,916
MF2 (n=2)	Mean	1,383,683	1,799,295	25,342	516,980	1,403,957	5,129,257
	Median	1,383,683	1,799,295	25,342	516,980	1,403,957	5,129,257
	SD	910,317	1,154,024	7,168	100,350	150,525	2,006,998
	SE	643,691	816,018	5,068	70,958	106,437	1,419,162
	Minimum	739,992	983,277	20,274	446,022	1,297,520	3,710,095
	Maximum	2,027,374	2,615,313	30,411	587,939	1,510,394	6,548,420
FF2 (n=2)	Mean	585,911	1,990,882	25,342	755,197	1,302,588	5,788,154
	Median	587,939	2,351,754	25,342	755,197	1,302,588	5,788,154
	SD	226,599	907,536	24,504	838,639	365,560	659,442
	SE	92,509	370,500	15,205	593,007	258,490	466,296
	Minimum	375,064	71,971,739	10,137	162,190	1,044,098	5,321,858
	Maximum	942,729	2,980,240	40,548	1,348,204	1,561,078	6,254,450
MF3[a] (n=6)	Mean	716,339	2,324,723	15,205	119,953	488,260	3,664,479
	Median	603,144	2,078,059	13,137	86,163	496,705	3,106,953
	SD	303,000	2,157,584	13,973	101,250	95,829	2,406,083
	SE	123,699	880,830	5,704	41,335	39,122	982,279
	Minimum	358,201	324,380	0	0	364,927	1,246,835
	Maximum	1,104,919	6,163,218	40,548	253,422	598,075	8,089,225
FF1 (n=5)	Mean	1,464,778	2,240,249	14,192	30,411	443,995	3,065,390
	Median	1,464,778	2,240,249	20,274	30,411	395,338	3,294,483
	SD	250,875	817,135	9,067	33,620	207,175	1,227,997
	SE	177,395	577,802	3,702	13,725	84,579	501,328
	Minimum	1,287,383	1,662,447	0	0	263,559	1,378,615
	Maximum	1,642,173	2,818,050	20,274	81,095	800,813	4,328,444
FFB (n=5)	Mean	772,430	1,563,106	22,808	36,493	441,968	2,822,105
	Median	679,170	1,338,067	20,274	30,411	486,579	3,112,020
	SD	251,734	916,796	15,205	29,204	166,812	1,116,221
	SE	112,579	410,004	7,603	13,060	74,601	499,189
	Minimum	496,707	679,170	10,137	0	152,053	1,338,067
	Maximum	1,145,467	2,939,693	40,548	70,958	577,802	4,165,844
FFA (n=5)	Mean	650,787	1,666,502	6,082	77,040	312,216	2,712,627
	Median	608,212	1,875,321	10,137	70,958	354,791	3,081,609
	SD	142,350	929,823	5,552	81,600	70,011	1,050,197
	SE	63,661	415,829	2,483	36,493	31,310	469,662
	Minimum	466,296	293,969	0	0	212,874	983,277
	Maximum	831,224	2,848,461	20,274	212,874	364,927	3,750,643
LDS (n=3)	Mean	1,662,447	574,423	27,032	74,337	577,802	2,916,040
	Median	1,287,383	304,106	30,411	91,232	567,665	2,270,659
	SD	916,084	485,865	15,484	29,263	66,472	1,343,292
	SE	528,901	280,515	8,940	16,895	38,378	775,550
	Minimum	993,413	283,832	10,137	40,547	516,980	2,017,238
	Maximum	2,706,545	1,135,330	40,547	91,232	648,760	4,460,224

Notes: NF = near-field; MF = mid-field; FF = far-field; LDS = Lac du Sauvage; n = sample size; SD = standard deviation; SE = standard error. a- The number of stations sampled in the MF3 area was 6, rather than 7 because station MF3-4 could not be sampled due to inclement weather.

Table E-2 Summary Statistics for Phytoplankton Biomass (milligrams per cubic metre) in Lac de Gras, 2013

Area (Sample Size)	Summary Statistic	Microflagellates	Cyanobacteria	Dinoflagellates	Diatoms	Chlorophytes	Total
NF (n=5)	Mean	111.25	29.85	12.16	37.15	150.82	341.23
	Median	102.43	22.40	15.21	39.53	174.43	397.61
	SD	19.31	18.21	9.21	16.55	61.83	97.08
	SE	8.64	8.14	4.12	7.40	27.65	43.42
	Minimum	95.69	11.66	0.00	15.21	82.21	226.81
	Maximum	141.97	49.42	20.27	53.98	225.75	422.33
MF1 (n=3)	Mean	82.14	31.35	10.14	23.82	60.54	208.00
	Median	82.21	14.24	10.14	25.85	69.51	224.38
	SD	41.16	29.82	10.14	13.29	26.41	66.99
	SE	23.76	17.21	5.85	7.68	15.25	38.68
	Minimum	40.95	14.04	0.00	9.63	30.82	134.33
	Maximum	123.26	65.78	20.27	35.99	81.30	265.28
MF2 (n=2)	Mean	122.58	79.24	22.81	37.89	179.84	442.36
	Median	155.58	79.24	22.81	37.89	179.84	442.36
	SD	87.77	26.99	3.58	9.14	53.36	119.70
	SE	62.06	19.08	2.53	3.46	37.73	84.64
	Minimum	60.52	60.16	20.27	31.42	142.11	357.72
	Maximum	184.64	98.33	25.34	44.35	217.57	527.00
FF2 (n=2)	Mean	145.51	257.96	16.22	81.22	145.93	646.84
	Median	145.51	257.96	16.22	81.22	145.93	646.84
	SD	9.68	244.17	15.77	99.81	42.92	75.99
	SE	6.84	172.66	11.15	70.58	30.35	53.74
	Minimum	138.67	85.30	5.07	10.64	115.58	593.11
	Maximum	152.36	430.61	27.37	151.80	176.28	700.58
MF3[(a)] (n=6)	Mean	71.89	54.97	14.11	11.40	125.07	277.44
	Median	64.98	14.24	10.14	11.66	91.74	231.52
	SD	34.19	89.41	14.30	8.68	80.68	135.22
	SE	13.96	36.50	5.84	3.54	32.94	55.21
	Minimum	32.24	5.68	0.00	0.00	60.18	132.86
	Maximum	114.55	234.31	39.03	21.79	276.20	496.23
FF1 (n=5)	Mean	48.79	32.73	13.18	4.46	118.09	217.25
	Median	59.10	31.88	20.27	4.56	78.97	164.77
	SD	23.28	7.45	9.88	4.61	86.83	110.91
	SE	9.50	3.04	4.03	1.88	35.45	45.28
	Minimum	20.93	22.50	0.00	0.00	44.45	117.38
	Maximum	69.29	43.41	20.27	10.64	254.49	398.10
FFB (n=5)	Mean	65.39	36.45	6.08	2.43	124.17	234.53
	Median	54.84	30.86	5.07	1.52	108.36	238.32
	SD	28.70	38.14	6.67	2.57	92.56	129.92
	SE	12.84	17.06	2.96	1.15	41.39	58.10
	Minimum	39.38	3.90	0.00	0.00	38.22	88.20
	Maximum	111.91	97.92	15.21	6.59	248.10	425.14
FFA (n=5)	Mean	54.05	15.60	3.04	4.97	69.85	147.51
	Median	50.99	13.58	5.07	3.55	54.28	140.40
	SD	8.91	7.83	2.78	5.77	47.50	60.78
	SE	3.99	3.50	1.24	2.58	21.24	27.18
	Minimum	46.17	5.22	0.00	0.00	18.09	74.56
	Maximum	69.34	25.54	5.07	14.70	127.47	216.73
LDS (n=3)	Mean	162.24	101.96	19.26	12.94	160.71	457.12
	Median	112.47	4.16	12.16	5.58	139.77	371.47
	SD	100.72	170.32	18.77	15.65	71.50	227.30
	SE	58.15	98.34	10.84	9.04	41.28	131.23
	Minimum	96.10	3.09	5.07	2.33	102.03	285.08
	Maximum	278.16	298.63	40.55	30.92	240.35	714.80

Notes: NF = near-field; MF = mid-field; FF = far-field; LDS = Lac du Sauvage; n= sample size; SD = standard deviation; SE = standard error.

a) The number of stations sampled in the MF3 area was 6, rather than 7 because station MF3-4 could not be sampled due to inclement weather.

Table E-3 Summary Statistics for Zooplankton Abundance and Biomass in Lac de Gras, 2013

Area	Summary Statistic	Biomass (mg/m^3)					
		n	Calanoida	Cyclopoida	Cladocera	Rotifera	Total Zooplankton
NF	Mean	5	60.83	104.11	219.18	15.04	399.16
	Median		61.12	104.53	255.21	14.47	416.05
	SD		11.33	19.45	63.10	3.56	68.93
	SE		5.07	8.70	28.22	1.59	30.82
	Minimum		49.93	78.56	122.36	11.92	289.99
	Maximum		77.80	131.78	265.37	21.10	475.84
MF1	Mean	3	128.24	189.57	407.04	18.71	743.56
	Median		126.47	134.17	259.00	18.10	537.74
	SD		17.11	103.70	283.94	11.94	414.54
	SE		9.88	59.87	163.93	6.90	239.33
	Minimum		112.08	125.33	227.72	7.08	472.20
	Maximum		146.17	309.21	734.41	30.94	1220.73
MF2	Mean	2	91.32	73.81	75.17	11.74	252.04
	Median		91.32	73.81	75.17	11.74	252.04
	SD		26.93	8.17	23.56	1.60	60.26
	SE		19.05	5.77	16.66	1.13	42.61
	Minimum		72.27	68.03	58.51	10.61	209.43
	Maximum		110.36	79.58	91.83	12.87	294.65
FF2	Mean	2	109.39	84.13	87.59	12.60	293.72
	Median		109.39	84.13	87.59	12.60	293.72
	SD		64.55	38.13	68.72	3.87	38.43
	SE		45.64	26.96	48.59	2.74	27.17
	Minimum		63.75	57.17	39.00	9.86	266.54
	Maximum		155.03	111.10	136.18	15.33	320.89
MF3	Mean	7	113.55	109.44	152.18	4.63	379.81
	Median		102.14	121.88	177.58	3.03	328.99
	SD		51.60	23.70	60.14	2.77	108.56
	SE		19.50	8.96	22.73	1.05	41.03
	Minimum		53.66	77.56	68.65	2.41	233.10
	Maximum		188.69	138.01	212.47	8.74	518.42
FF1	Mean	5	129.99	91.51	75.34	6.70	303.54
	Median		148.07	71.84	67.11	5.31	344.76
	SD		43.46	37.79	32.55	2.20	102.83
	SE		19.43	16.90	14.56	0.99	45.98
	Minimum		72.86	52.64	39.12	4.98	169.71
	Maximum		168.37	139.11	114.53	9.73	418.00
FFB	Mean	5	126.65	92.02	180.07	2.33	401.07
	Median		112.17	75.70	153.52	2.55	390.79
	SD		44.87	25.84	72.72	0.79	83.06
	SE		20.07	11.56	32.52	0.36	37.15
	Minimum		77.51	71.68	113.84	1.12	306.16
	Maximum		193.22	126.04	291.52	3.22	513.37
FFA	Mean	5	164.89	62.49	126.71	3.38	357.47
	Median		173.04	52.47	127.40	3.40	381.24
	SD		19.69	20.69	32.48	0.62	52.38
	SE		8.81	9.25	14.53	0.28	23.43
	Minimum		136.30	46.32	82.77	2.48	269.62
	Maximum		185.60	93.51	171.55	4.19	396.44
LDS	Mean	3	541.80	6.06	33.65	5.31	586.82
	Median		545.82	6.35	34.09	4.56	590.81
	SD		222.58	0.51	0.77	2.15	225.74
	SE		128.50	0.29	0.45	1.24	130.33
	Minimum		317.25	5.47	32.75	3.64	359.11
	Maximum		762.35	6.36	34.10	7.73	810.54

Area	Summary Statistic	Abundance (Ind/L)					
		n	Calanoida	Cyclopoida	Cladocera	Rotifera	Total Zooplankton
NF	Mean	5	0.97	7.55	1.15	47.50	57.18
	Median		0.86	7.62	1.13	43.77	54.14
	SD		0.18	2.02	0.18	7.36	5.59
	SE		0.08	0.91	0.08	3.29	2.50
	Minimum		0.81	4.43	0.97	42.18	53.60
	Maximum		1.17	10.09	1.41	60.07	66.73
MF1	Mean	3	2.23	14.46	2.82	53.72	73.23
	Median		2.32	16.86	1.79	50.03	70.67
	SD		0.21	6.75	2.67	33.82	42.63
	SE		0.12	3.90	1.54	19.53	24.61
	Minimum		1.99	6.84	0.82	21.90	31.93
	Maximum		2.38	19.67	5.85	89.24	117.08
MF2	Mean	2	1.25	6.50	0.37	41.47	49.59
	Median		1.25	6.50	0.37	41.47	49.59
	SD		0.27	1.92	0.21	1.59	3.99
	SE		0.19	1.36	0.15	1.12	2.82
	Minimum		1.06	5.14	0.22	40.34	46.77
	Maximum		1.44	7.86	0.52	42.59	52.41
FF2	Mean	2	1.18	5.77	0.26	44.14	51.35
	Median		1.18	5.77	0.26	44.14	51.35
	SD		0.32	2.80	0.26	12.51	9.76
	SE		0.22	1.98	0.19	8.84	6.90
	Minimum		0.96	3.79	0.07	35.30	44.45
	Maximum		1.41	7.75	0.44	52.99	58.25
MF3	Mean	7	1.78	8.19	0.44	14.34	24.75
	Median		1.70	8.95	0.43	11.42	24.08
	SD		0.81	1.83	0.15	6.93	7.72
	SE		0.31	0.69	0.06	2.62	2.92
	Minimum		0.93	4.71	0.17	8.60	15.04
	Maximum		3.01	9.85	0.67	27.68	38.83
FF1	Mean	5	2.42	5.72	0.47	17.78	26.38
	Median		2.14	5.22	0.43	15.91	27.08
	SD		1.03	1.67	0.25	3.75	5.21
	SE		0.46	0.74	0.11	1.68	2.33
	Minimum		1.24	4.27	0.23	14.34	20.08
	Maximum		3.51	8.58	0.88	22.58	32.06
FFB	Mean	5	2.16	5.48	0.44	8.68	16.76
	Median		2.03	5.09	0.37	8.88	16.37
	SD		0.71	1.81	0.15	2.41	4.74
	SE		0.32	0.81	0.07	1.08	2.12
	Minimum		1.32	4.23	0.29	5.25	11.09
	Maximum		3.14	8.61	0.66	11.82	23.92
FFA	Mean	5	2.92	4.15	0.39	10.23	17.70
	Median		3.01	4.44	0.38	10.12	17.93
	SD		0.32	0.65	0.09	1.47	1.47
	SE		0.14	0.29	0.04	0.66	0.66
	Minimum		2.37	3.08	0.30	7.93	15.86
	Maximum		3.22	4.69	0.54	11.56	19.70
LDS	Mean	3	12.49	20.97	3.07	0.25	36.79
	Median		13.38	20.01	2.76	0.27	36.63
	SD		2.56	1.79	0.57	0.05	0.53
	SE		1.48	1.03	0.33	0.03	0.30
	Minimum		9.60	19.86	2.73	0.19	36.35
	Maximum		14.49	23.03	3.73	0.29	37.37

Notes: NF = near-field; MF = mid-field; FF = far-field; LDS = Lac du Sauvage; n = sample size; SD = standard deviation; SE = standard error; Ind/L = individuals per litre; mg/m^3 = milligrams per cubic metre.

PHYTOPLANKTON ADDENDUM REPORT IN SUPPORT OF THE 2012 AEMP ANNUAL REPORT FOR THE DIAVIK DIAMOND MINE, NORTHWEST TERRITORIES

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EXECUTIVE SUMMARY

In 2011, Diavik Diamond Mines (2012) Inc. (DDMI) revised its Aquatic Effects Monitoring Program (AEMP), as required by Water Licence W2007L2-0003. As part of the AEMP Study Design Version 3.0, plankton sampling was included as a monitoring component. The main goal of the plankton component is to monitor phytoplankton and zooplankton communities (i.e., abundance, biomass, and taxonomic composition) as indicators of the effects of the Diavik Diamond Mine (Mine) on the Lac de Gras ecosystem. This addendum report presents results of the 2012 phytoplankton survey in support of the 2012 AEMP Annual Report for DDMI.

Overall, the 2012 phytoplankton community exhibited a small amount of variation in taxonomic richness among sampling areas, with greater richness observed in exposure areas compared to reference areas. The phytoplankton community in Lac de Gras was characterized by the dominance of Chrysophyceae, by abundance, in the reference areas and Cyanobacteria, by biomass, in the exposure areas. Spatially, total phytoplankton biomass was greatest at exposure stations nearest the effluent discharge. Sufficient differences in biomass, taxonomic richness, and composition were observed between the exposure and reference areas to demonstrate that the Mine is having an influence on the phytoplankton community in Lac de Gras. Moreover, temporal trends in phytoplankton biomass suggest that an enrichment effect in the near-field and mid-field areas is occurring.

The results of the 2012 phytoplankton investigation suggest that the phytoplankton community in Lac de Gras is exhibiting a Mine-related nutrient enrichment effect, consistent with that seen in previous years.

LIST OF ACRONYMS AND ABBREVIATIONS

AEMP	Aquatic Effects Monitoring Program
Bio-Limno	Bio-Limno Research and Consulting, Inc.
DDMI	Diavik Diamond Mines Inc.
e.g.	for example
FF	far-field
i.e.	that is
MF	mid-field
Mine	Diavik Diamond Mine
NF	near-field
QA/QC	quality assurance/quality control
QAPP	Quality Assurance Project Plan
RPD	relative percent difference
SD	standard deviation
SE	standard error
SES	special effects study
SOP	standard operating procedure
sp.	species
spp.	more than one species
UTM	Universal Transverse Mercator
WLWB	Wek’èezhìi Land and Water Board

LIST OF UNITS

%	percent
±	plus or minus
µm	micrometre
m	metre
mg/m^3	milligrams per cubic metre
mL	millilitre
mm^3/m^3	cubic millimetres per cubic metre

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1 INTRODUCTION AND OBJECTIVES

1.1 BACKGROUND

The term “plankton” is a general term referring to small, usually microscopic, organisms that live suspended in non-flowing waterbodies such as lakes. For the purpose of this study, the term “phytoplankton” refers to the algal component of plankton and includes the following nine major taxonomic groups:

- Cyanobacteria (blue-green algae);
- Chlorophyceae (chlorophytes);
- Chrysophyceae (chrysophytes);
- Cryptophyceae (cryptophytes);
- Bacillariophyceae (diatoms);
- Pyrrhophyceae (dinoflagellates);
- Euglenophyceae (euglenophytes);
- Xanthophyceae (xanthophytes); and,
- Haptophyceae (haptophytes).

In 2011, Diavik Diamond Mines Inc. (DDMI) revised its Aquatic Effects Monitoring Program (AEMP), as required by Water Licence W2007L2-0003 (WLWB 2007). One of the revisions to the AEMP was the addition of the plankton component (Golder 2011a). Plankton was examined over the course of the previous AEMP Version 2.0 as part of a special effects study (SES; DDMI 2007a). The main objective of the SES was to determine the feasibility and utility of using plankton community composition and biomass as sensitive metrics to assess effects caused by the Diavik Diamond Mine (Mine). A review of four years of data demonstrated that plankton could indeed be a useful and sensitive monitoring endpoint (Golder 2011b); therefore, plankton was added as a monitoring component in Version 3.0 of the AEMP (Golder 2011a).

The main goal of the plankton component is to monitor phytoplankton and zooplankton community composition (i.e., abundance, biomass, and taxonomic composition) as indicators of the effects of the Mine on the Lac de Gras ecosystem. This report presents phytoplankton data collected during the 2012 AEMP field program. The 2012 phytoplankton data were not available in time to include in the 2012 AEMP report (Golder 2013a). Zooplankton samples were also collected in Lac de Gras during the 2012 AEMP, and results for that program were presented in the 2012 AEMP report.

1.2 OBJECTIVES

The primary goal of the plankton component of the Mine’s AEMP is to monitor phytoplankton and zooplankton communities during the open-water sampling period and to assess the effects of the Mine on these communities. The plankton component is designed to monitor both spatial and temporal changes in phytoplankton and zooplankton community composition. As described in Golder (2011a), the objective of the 2012 annual report was to provide updates to trends in the data observed in previous years of monitoring. A detailed spatial analysis will be conducted following the comprehensive sampling program in 2013.

2 METHODS

2.1 2012 PHYTOPLANKTON PROGRAM

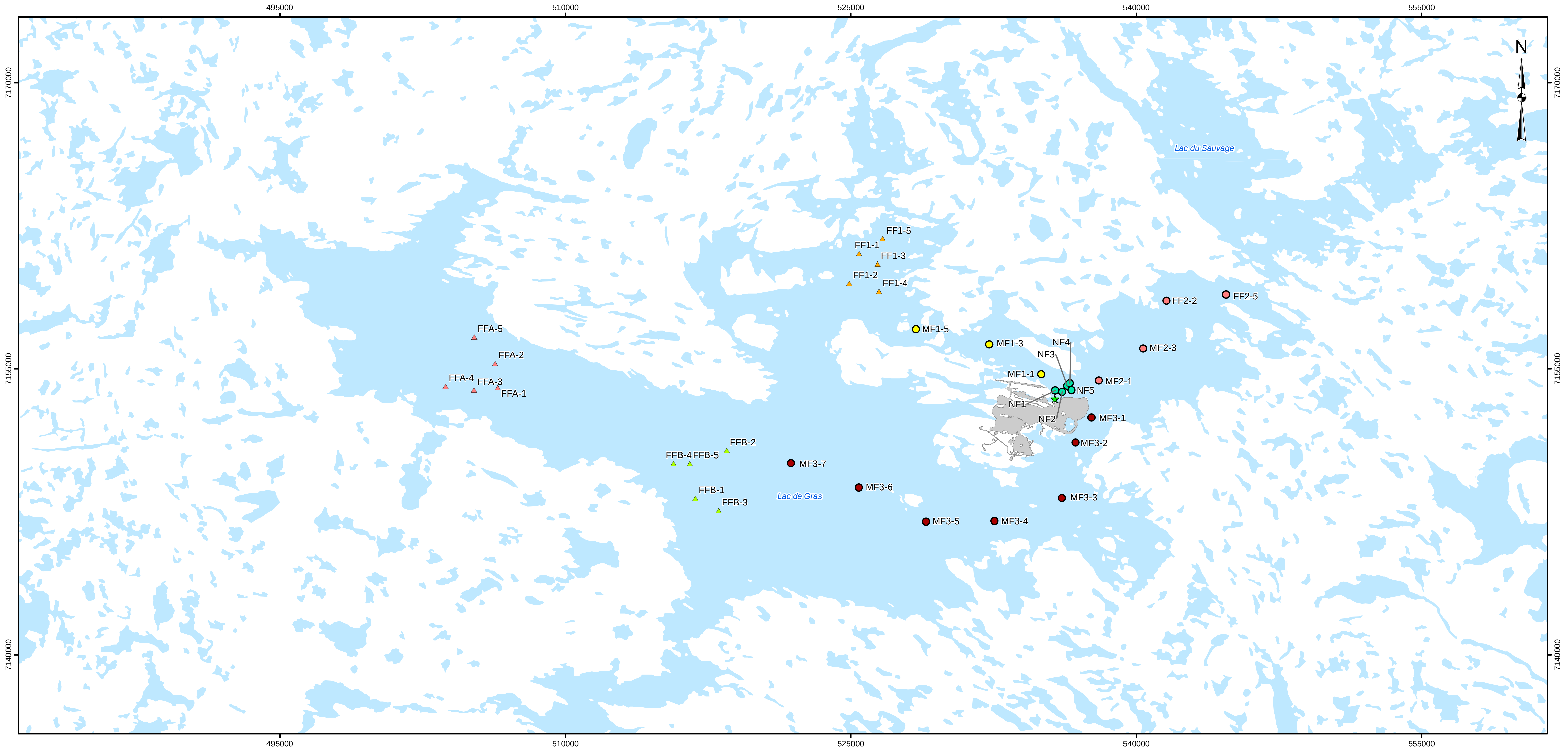
Thirty-four stations located within five general areas of Lac de Gras were sampled for the 2012 phytoplankton program. Sampling areas were selected based on exposure to the Mine effluent (Golder 2011a), and consisted of the near-field (NF) exposure area, the far-field (FF) exposure area (FF2), and three far-field reference areas (FF1, FFA, and FFB) (Figure 2-1). In addition, three mid-field (MF) areas (MF1, MF2, and MF3) were located along three transects between the NF and FF areas.

The study design incorporated clusters of replicate stations in each of the areas of the lake. Five stations were sampled in the NF exposure area and two stations in the FF2 exposure area. Five stations were sampled in each of the three FF reference areas. The number of stations in the MF areas were related to the length of the each transect, with three stations in the MF-1 area, two stations in the MF-2 area, and seven stations in the MF-3 area (Figure 2-1). Universal Transverse Mercator (UTM) coordinates of the stations, as well as their distance from the effluent discharge point, are provided in Table B-2 of Appendix B. The water depth at all sampling stations was approximately 20 m.

Sampling occurred from August 16 to August 23, 2012, in accordance with the relevant standard operating procedure (SOP: ENVR-003-0211 R9). That document is not reproduced within this report but has been previously provided to the Wek’èezhìi Land and Water Board (WLWB). Water column profile measurements and samples for water chemistry were collected concurrently as part of the water quality component of the AEMP (Golder 2013b).

A depth-integrated sampler, which collected water from the surface to a depth of 10 m, was used to collect the phytoplankton samples. Twelve depth-integrated samples from each station were composited, and the composite sample was used to fill a sample bottle for phytoplankton taxonomy. Field sampling was conducted by DDMI staff, who did not report any deviations from the SOP during sample collection.

I:\2011\11-1328\11-1328-0038\Mapping\MXD\2012AEMP\Figure 2-1 Plankton Sampling Stations in Lac de Gras and Lac du Sauvage, 2012 AEMP_20130319.mxd



LEGEND

★	DIFFUSER	▨	DIAVIK FOOTPRINT
		▨	WATERBODY

EXPOSURE

●	FAR-FIELD 2; MID-FIELD 2
●	MID-FIELD 1
●	MID-FIELD 3
●	NEAR-FIELD

REFERENCE

▲	FAR-FIELD 1
▲	FAR-FIELD A
▲	FAR-FIELD B

REFERENCE

HYDROGRAPHY DATA OBTAINED FROM CANVEC © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 12 DATUM: NAD 83

5 0 5
SCALE 1:200,000 KILOMETRES

PROJECT

DIAVIK DIAMOND MINES INC.

TITLE

PLANKTON SAMPLING STATIONS IN
LAC DE GRAS AND LAC DU SAUVAGE,
2012 AEMP

Golder Associates

PROJECT No. 12-1328-0018			SCALE AS SHOWN / REV. 0
DESIGN	TD	28 Feb. 2013	FIGURE: 2-1
GIS	CW	19 Mar. 2013	
CHECK	TD	19 Mar. 2013	
REVIEW	CF	19 Mar. 2013	

2.2 SAMPLE SORTING AND TAXONOMIC IDENTIFICATION

A total of 37 phytoplankton samples (including three split samples) were collected in 2012 and submitted to Bio-Limno Research and Consulting, Inc. (Bio-Limno), Halifax, Nova Scotia, for analysis of taxonomic composition as both abundance and biomass. Samples were analyzed according to methods provided by Bio-Limno which are summarized below.

Aliquots of 7 mL of the preserved phytoplankton samples were allowed to settle overnight in sedimentation chambers following the procedure of Lund et al. (1958). Algal units were counted from randomly selected transects on a Zeiss Axiovert 40 CFL inverted microscope. Counting units were individual cells, filaments, or colonies depending on the organization of the algae. A minimum of 400 units were counted for each sample. The majority of the samples were analyzed at 500 times magnification (x), with initial scanning for large and rare organisms (e.g., *Ceratium* sp.) completed at 250x. Taxonomic identifications were based on Geitler (1932); Skuja (1949); Findlay and Kling (1976); Huber-Pestalozzi (1961, 1972, 1982, 1983); Anton and Duthie (1981); Prescott (1982); Whitford and Schumacher (1984); Starmach (1985); Tikkanen (1986); Krammer and Lange-Bertalot (1986, 1988, 1991a,b); Komárek and Anagnostidis (1998, 2005), and Wehr and Sheath (2003).

Fresh weight biomass was calculated from recorded abundance and specific biovolume estimates based on geometric solids (Rott 1981), assuming a specific gravity of 1. The biovolume (cubic millimetres per cubic metre [mm^3/m^3]) of each species was estimated from the average dimensions of 10 to 15 individuals. The biovolumes of colonial taxa were based on the number of individuals within each colony. All calculations for cell densities and biomass were performed with Hamilton’s (1990) computer program.

2.3 DATA ANALYSES

The following methods were used to summarize the 2012 phytoplankton data:

- Abundance and biomass data were divided into the six major taxonomic groups present in the 2012 samples (Cyanobacteria, Chlorophyceae, Chrysophyceae [including Haptophyceae], Cryptophyceae, Bacillariophyceae, and Pyrrhophyceae). Euglenophyceae and Xanthophyceae were not present in the samples in 2012. The relative abundance and biomass accounted for by each major taxonomic group were calculated separately for each sampling area (i.e., for NF, MF1, MF2, MF3, FF1, FF2, FFA, and FFB) to assess temporal and spatial variability in community structure.

- Richness was calculated at the lowest taxonomic level. This measurement provides an indication of the diversity of phytoplankton in an area; a higher richness value typically indicates a more healthy and balanced community.
- Summary statistics were calculated for total phytoplankton abundance and biomass.

To visually evaluate spatial trends relative to the Mine discharge, total phytoplankton biomass was plotted against distance from the diffuser. Potential effects were evaluated by comparing biomass in each exposure area to the normal range in the reference areas (FF1, FFB, and FFA), estimated as the pooled reference area mean plus or minus two standard deviations (±2 SD).

Time series plots were also generated for the Open-water 2 (August 5 to Sept 10) sampling period, using available data from 1996 to 2012. Annual means of total biomass, taxonomic richness, and relative biomass of Cyanobacteria, Chlorophyceae, Chrysophyceae, Bacillariophyceae, and “Others” (Cryptophyceae, Pyrrhophyceae, Euglenophyceae, and Xanthophyceae) in the NF, FF2 and MF areas were qualitatively compared to the normal range. Normal ranges for the time series plots, estimated as the pooled reference area (FF1, FFA, and FFB) mean ±2 SD, were based on data collected from 2007 to 2010. Means of the NF and FF2 area stations were plotted together, while data for individual MF stations were plotted as a separate series because each MF station is subject to a different level of effluent exposure. In addition, the individual reference area annual means from 1996 to 2012 were plotted to document annual variation.

Calculations and statistical summaries were conducted with Excel 2007 for Windows (Microsoft Corporation, Cambridge, MA). Graphs were created in SigmaPlot, version 11.0 for Windows (SPSS Inc., Chicago, IL).

2.4 QUALITY CONTROL

The Quality Assurance Project Plan (QAPP) outlined the quality assurance/quality control (QA/QC) procedures employed to support the collection of scientifically-defensible and relevant data required to meet the objectives of the AEMP (DDMI 2007a; Golder 2011a). The QAPP served to ensure that field sampling, laboratory analysis, data entry, data analysis, and report preparation activities produced technically-sound and scientifically-defensible results. A description of the QA/QC program is provided in Appendix A.

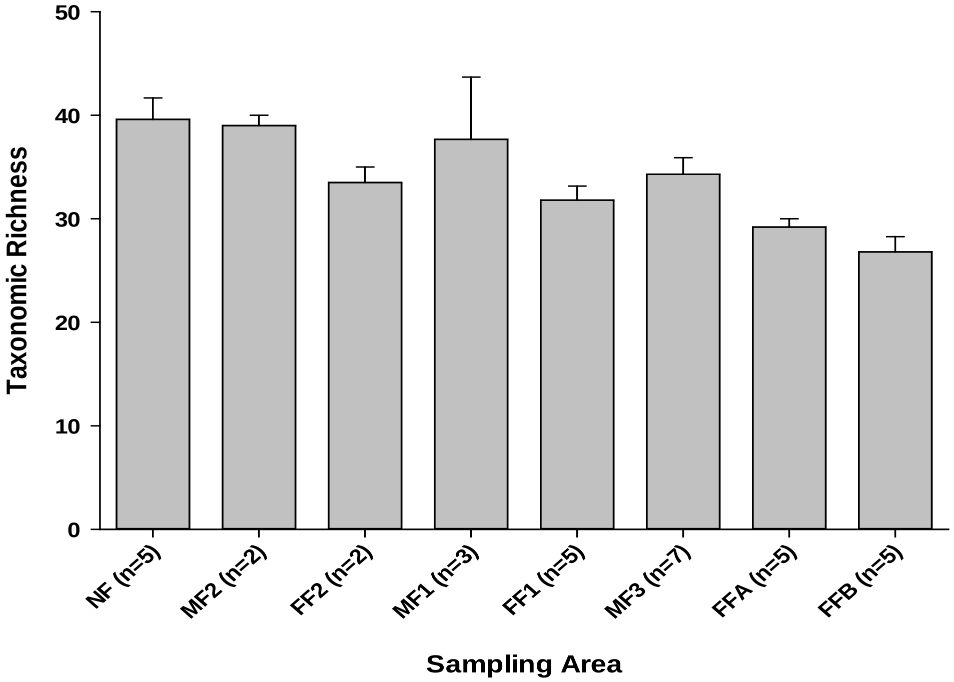
3 RESULTS

The 2012 phytoplankton taxa, abundance and biomass data, as well as the QC results pertaining to taxonomic analysis, are provided in Appendix C. Abundance and biomass summary statistics for phytoplankton are provided in Appendix D, and time series plots for phytoplankton at the mid field and far field stations are provided in Appendix E.

3.1 COMMUNITY STRUCTURE

In total, 123 taxa were identified in the 2012 phytoplankton samples (Appendix C). In general, the NF and MF exposure areas had slightly greater taxonomic richness compared to the reference areas. Mean (± Standard error [SE]) taxonomic richness was lowest in the FFB area (26.8 ± 1.46) and greatest in the NF area (39.6 ± 2.06) (Figure 3-1).

Figure 3-1 Mean Phytoplankton Taxonomic Richness, 2012



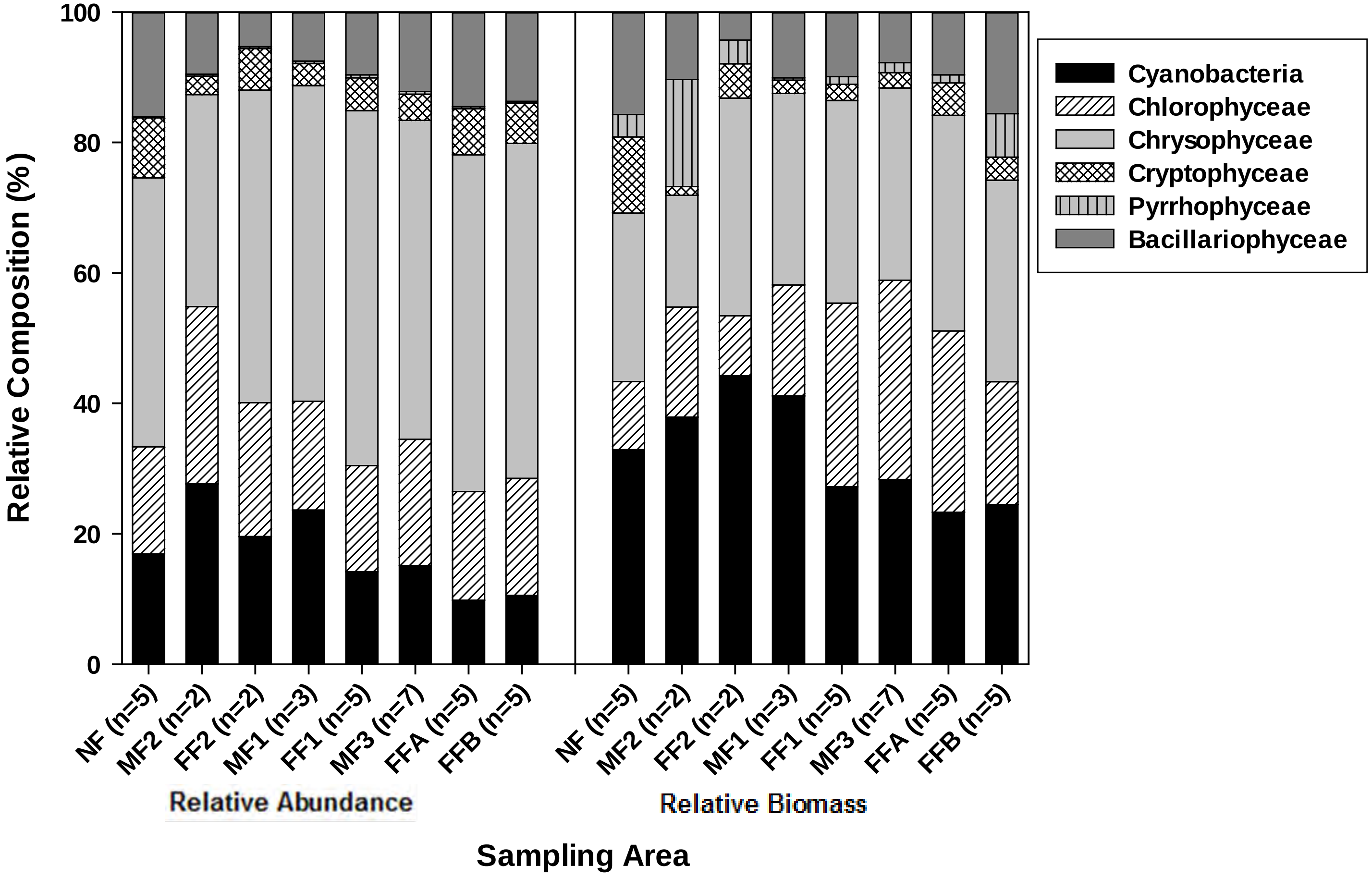
Notes: Error bars represent one standard error; NF = near-field; MF = mid-field; FF = far-field.

In general, the phytoplankton community in Lac de Gras was characterized by the dominance of Chrysophyceae for abundance (33% to 54%) and Cyanobacteria for biomass (22% to 44%) (Figure 3-2). Dominance by Chrysophyceae was less apparent when based on biomass due to the relatively small size of most Chrysophyte cells. Species composition of the Chrysophyceae group was variable among areas, but unidentified naked Chrysophytes were the dominant taxa in the majority of sampling areas (Appendix C). The dominant Cyanobacteria taxa included colonial forms such as *Aphanocapsa delicatissima*, *Aphanothece clathrata* and a filamentous form, *Limnothrix* spp. Bacillariophyceae (diatoms) were found in all of the samples (Figure 3-2), with the greatest relative biomass represented by *Cyclotella bodanica* and a large centric diatom species (i.e., 7 to 14 micrometre (µm) diameter; Appendix C).

Abundance and biomass of Pyrrhophyceae (dinoflagellates) and Cryptophyceae were relatively low in all sampling areas compared to the Chrysophyceae and Cyanobacteria (Figure 3-2; Appendix C). Although the relative abundance of Chlorophyceae was similar across all areas, its relative biomass was greater in reference areas. This was likely because of a greater abundance of large filamentous chlorophytes present in the reference samples.

Haptophyte presence in Lac de Gras is uncertain as the taxonomist identified the possible haptophyte as either *Erkenia* sp. or *Chrysochromulina* sp. and placed it under the chrysophyte group. *Erkenia* sp. is a chrysophyte, while *Chrysochromulina* sp. is a haptophyte. The unidentified haptophyte/chrysophyte complex has been left under the chrysophyte group for the purposes of this and further reports. The unidentified haptophyte/chrysophyte complex was present in all samples in 2012, with the greatest relative abundance and biomass observed at the MF3 (0.5%) and FF1 (15%) stations, respectively (Appendix C). Euglenophyceae and Xanthophyceae were not observed in 2012.

Figure 3-2 Mean Relative Phytoplankton Abundance and Biomass by Sampling Area in Lac de Gras, 2012

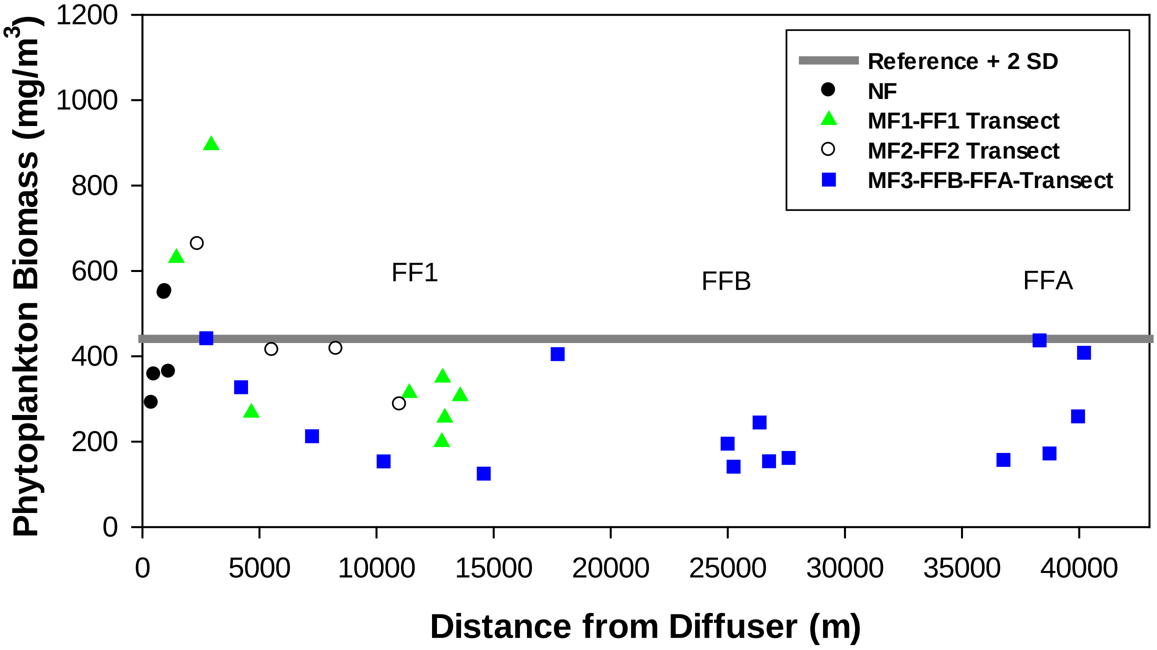


Notes:%= percent; NF = near-field; MF = mid-field; FF = far-field.

3.2 SPATIAL TRENDS

Generally, phytoplankton biomass was greater at the NF exposure stations than at the reference stations, although many of the exposure stations were within the normal range based on the pooled reference station data (Figure 3-3). Sampling stations with biomass values greater than the normal range, were those closest to the effluent discharge location; they consisted of two NF stations, two MF1 stations, and one MF2 station. As a result, a weakly declining trend in total biomass was observed with increasing distance from the diffuser.

Figure 3-3 Phytoplankton Biomass in Lac de Gras According to Distance from the Diffuser, 2012



Note: mg/m^3 = milligrams per cubic metre; m = metres; NF = near-field; MF = mid-field; FF = far-field; SD = standard deviation. The reference line is based on the mean of the pooled reference area data collected in 2012 plus two standard deviations.

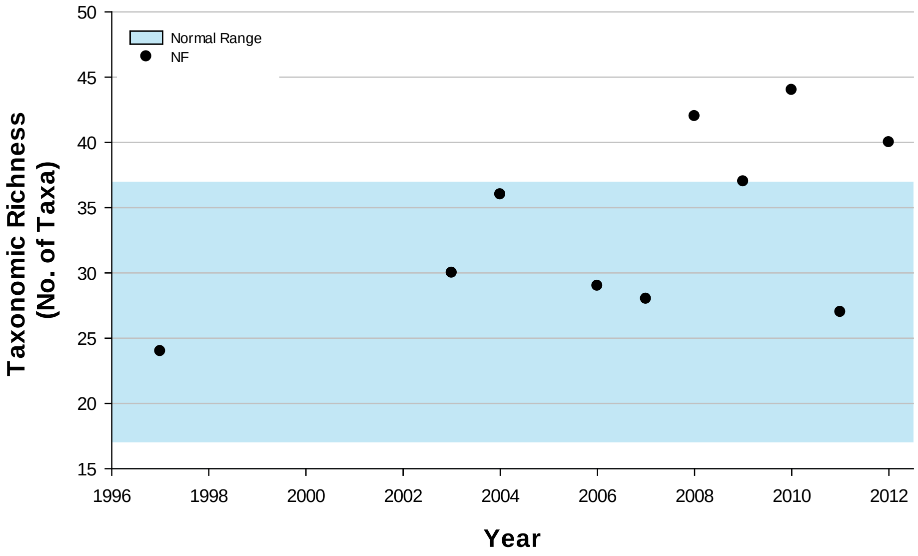
3.3 TEMPORAL TRENDS

Taxonomic richness in the NF area has shown an overall increasing trend from baseline to 2012, with most richness values since 2007 outside the normal range; however, the lowest abundance since baseline was encountered during this time period (i.e., in 2011) (Figure 3-4). A similar pattern has been observed in the MF areas, with the greatest taxonomic richness occurring from 2008 to 2010 (Appendix E, Figure E-1). Richness in the FF reference areas has been relatively consistent since baseline.

Total biomass in the NF area has varied from 236 milligrams per cubic metre (mg/m^3) (2011) to 648 mg/m^3 (2008) over the years of monitoring, with no apparent trend (Figure 3-5). Biomass measured in 2012 was just outside the normal range. Total biomass in the MF areas has been generally similar to that in the NF area, with biomass values frequently exceeding the normal range since 2007 (Appendix E, Figure E-2). Biomass in the FF reference areas has consistently been less than 400 mg/m^3.

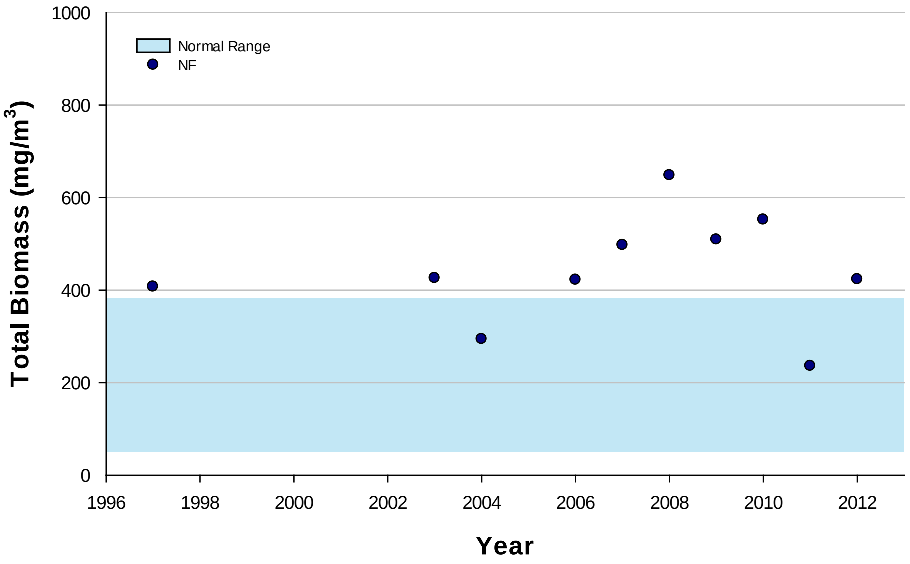
Relative biomass of all the major groups of phytoplankton in the NF area remained within the normal range in 2012, and there does not appear to be any temporal trend in the data (Figure 3-6). The relative biomass of chlorophytes has remained at baseline levels since 2008. Similar patterns were observed among these taxa in the FF reference areas and MF areas (Appendix E, Figures E-3 to E-6). Although most relative biomass values were within the normal range in 2012, exceptions occurred at MF2-1 where “Others” were outside the normal range and at MF3-6 where Chlorophyceae was outside the normal range.

Figure 3-4 Mean Phytoplankton Taxonomic Richness in the Near Field Area, Open-water 2, 1996 to 2012



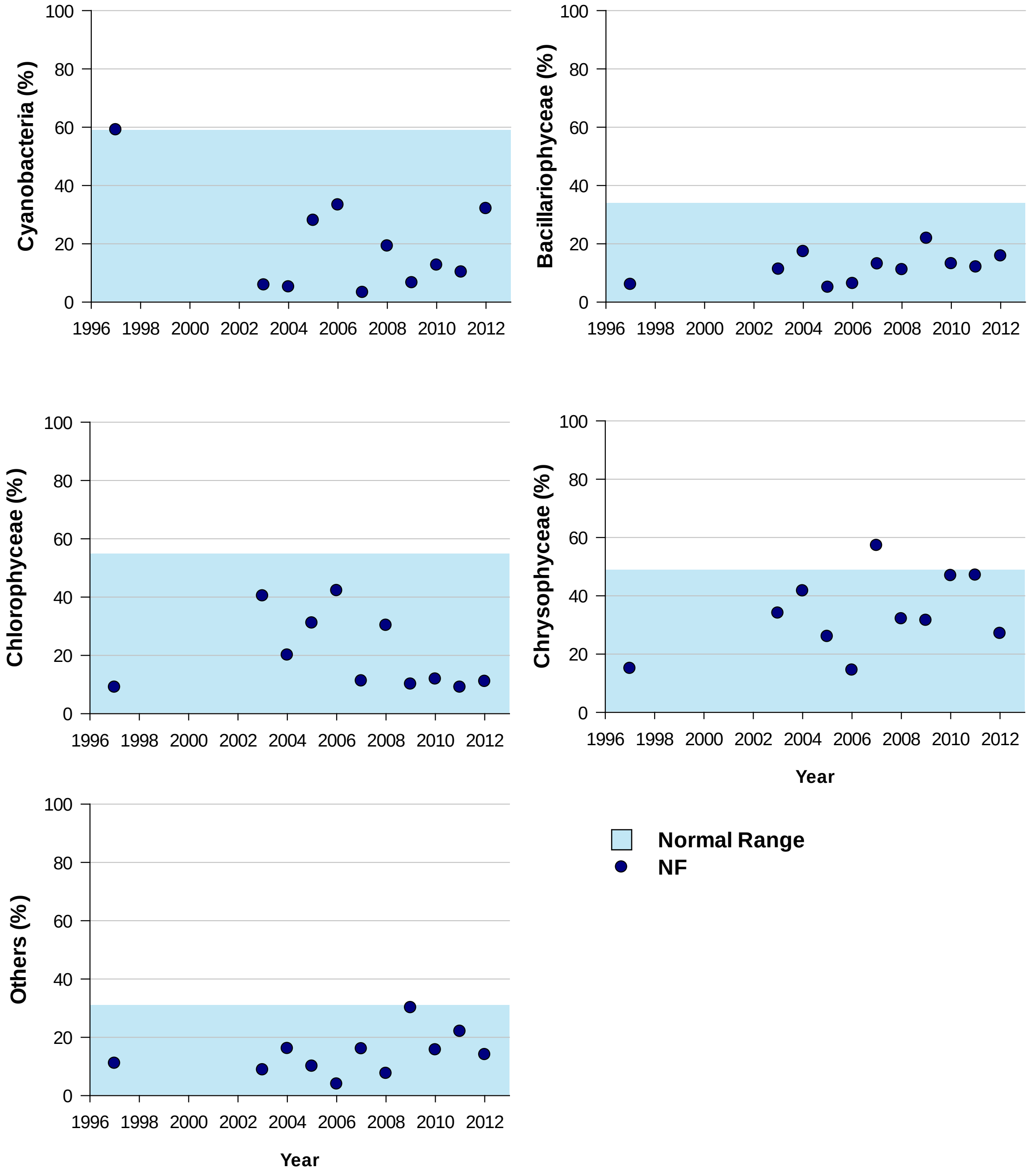
Notes: NF = near-field; No. = number. The shaded area indicates the normal range based on mean annual concentration plus/minus two standard deviation units of the reference area (FF1, FFA and FFB) from the open-water 2 period from 2007 to 2010. The 1997 data point is baseline data collected under open-water 1 (July).

Figure 3-5 Mean Phytoplankton Total Biomass in the Near Field Area, Open-water 2, 1996 to 2012



Notes: NF = near-field; mg/m^3 = milligrams per cubic metre. The shaded area indicates the normal range based on mean annual concentration plus/minus two standard deviation units of the reference area (FF1, FFA and FFB) from the open-water 2 period from 2007 to 2010. The 1997 data point is baseline data collected under open-water 1 (July).

Figure 3-6 Mean Phytoplankton Relative Biomass in the Near Field Area, Open-water 2, 1996 to 2012



Notes: NF = near-field;% = percent. The shaded area indicates the normal range based on mean annual concentration plus/minus two standard deviation units of the reference area (FF1, FFA and FFB) from the open-water 2 period from 2007 to 2010. The 1997 data point is baseline data collected under open-water 1 (July).

4 DISCUSSION

The phytoplankton community in Lac de Gras was characterized by the dominance of Chrysophyceae. Although dominant in relative abundance, chrysophytes were less abundant in terms of relative biomass and only in the reference areas. Cyanobacteria relative biomass was dominant in the exposure areas. Taxonomic richness was generally greater at exposure stations compared to reference area stations, and has remained at similar levels since 2007. Total phytoplankton biomass was greatest at exposure stations nearest the effluent discharge in 2012; however, biomass values in the exposure areas have been at similar levels since 2007. Although the effects from the Mine on algal abundance and biomass are apparent, the magnitude of the effect does not appear to be changing over time.

There are sufficient differences in the biomass, taxonomic richness, and composition of the phytoplankton communities among areas to indicate that the Mine is having a nutrient enrichment effect on the phytoplankton community in Lac de Gras. Spatial trends in phytoplankton biomass and richness in 2012 suggest that the enrichment effect is occurring in the NF and parts of the MF areas. These observations are consistent with the findings of the Eutrophication Indicators component of the AEMP (Golder 2013c).

5 CONCLUSIONS

This report presents a summary of phytoplankton data collected during the 2012 field program. It addresses the main objective of the phytoplankton component, by assessing changes in the phytoplankton community both spatially and over time.

The results suggest that the phytoplankton community in Lac de Gras is exhibiting a Mine-related nutrient enrichment effect, consistent with that seen in previous years. This conclusion is based on the following findings:

- phytoplankton richness and biomass were generally greater in the exposure areas relative to the reference areas;
- differences in phytoplankton community dominance between the exposure and reference areas; and
- temporal trends showed values of taxonomic richness and biomass in exposure areas that have been consistent since 2007.

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7 CLOSURE

We trust that the information in this report meets your requirements at this time. If you have any questions relating to the information contained in this document please do not hesitate to contact us.

GOLDER ASSOCIATES LTD.

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APPENDIX A

QUALITY ASSURANCE/QUALITY CONTROL

The QA/QC program followed during the 2012 sampling program is described in the QAPP (DDMI 2007b). The QAPP outlines the QA/QC procedures employed to support the collection of scientifically-defensible and relevant data. The QAPP is designed so that field sampling, laboratory analysis, data entry, data analysis, and report preparation activities produce technically-sound and scientifically-defensible results. Results of the 2012 phytoplankton QA/QC program are presented below.

Quality Assurance

Field Operations

So that field data were of known and defensible quality, field work was completed by Diavik staff according to specified instructions and the following SOPs:

- Aquatic Effects (Open water) ENVR-003-0211 R9;
- Quality Assurance/ Quality Control ENVR-303-0112 R0; and,
- Chain of Custody ENVR-206-0112 R0.

These SOPs include guidelines for field record keeping and sample tracking, relevant technical procedures, and sample labelling, shipping and tracking protocols.

Office Operations

A data management system provided an organized system of data control, analysis, and filing. Relevant operations included the following:

- reviewing taxonomy data as they were received from the subconsultants;
- creating backup files prior to beginning data analysis; and,
- completing appropriate logic checks to ensure the accuracy of all calculations.

Quality Control

Methods

Quality control is a specific aspect of QA. The laboratory QC program included three phytoplankton split samples, which were used to check the taxonomist's counting efficiency[1]. The data were entered into electronic format by the taxonomist and were double-checked by the same taxonomist upon entry. Errors were corrected as necessary before transferring the electronic files to DDMI.

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[1] Counting efficiency is a measure of the reproducibility, skill, and competency of the taxonomist.

The inherent variability associated with the plankton samples makes the establishment of a QC threshold value difficult. For the purposes of the plankton QC, samples were flagged and assessed further if there was a greater than 50% difference in total abundance between the split samples.

In addition, the Bray-Curtis index, which is a measure of ecological distance between two communities, was used to assess the overall similarity between the taxonomist's split samples. All values greater than 0.5 were flagged and follow-up discussions with the taxonomist were initiated. Due to the high variability in species present between the split samples, Bray-Curtis comparison tests were performed on the data grouped at the major taxa level (i.e., cyanobacteria, chrysophytes, chlorophytes, cryptophytes, dinoflagellates, and diatoms). The value of the Bray-Curtis index ranges from 0 (identical communities) to 1 (very dissimilar communities) and is calculated using the formula:

$$b = \frac{\sum_{k=1}^{n} \left| x_{ik} - x_{jk} \right|}{\sum_{k=1}^{n} \left(x_{ik} + x_{jk} \right)}$$

where x_{ik} and x_{jk} are abundance or biomass from the first and second split samples, respectively.

Results

Although one of the three sets of split samples slightly exceeded a relative percent difference (RPD) of 50% for total abundance, all three sets of split samples had Bray-Curtis Index values below 0.5, indicating a reasonable overall similarity between the split samples (Table A-1). Consequently, the counting efficiency was deemed to be acceptable and further follow-up assessments were not performed.

Table A-1 Summary of Taxonomic Counting Efficiency from QA/QC Samples for Phytoplankton (cells/L), 2012

Station	Result 1	Result 2	Relative Percent Difference (%)	Bray-Curtis Index	QC Flag
NF1	1,268,941	1,298,106	2	0.06	No
MF3-4	**632,030**	**1,072,035**	**52**	**0.26**	**Yes**
LDS-3	1,220,334	1,064,752	14	0.07	No

Note: A QC flag is added when the relative percent difference between duplicate sample results is >50%. NF = near-field; MF = mid-field; FF = far-field;% = percent; >= greater than; cells/L = cells per litre.

APPENDIX B

2012 SAMPLING SCHEDULE AND STATION COORDINATES

Table B-1 2012 Sampling Schedule

Sites	August														
	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
NF1	p														
NF2		p													
NF3		p													
NF4		p													
NF5		p													
FF2-2						p									
FF2-5						p									
MF1-1								p							
MF1-3						p									
MF1-5						p									
MF2-1								p							
MF2-3								p							
MF3-1								p							
MF3-2								p							
MF3-3								p							
MF3-4								p							
MF3-5								p							
MF3-6								p							
MF3-7								p							
FF1-1	p														
FF1-2				p											
FF1-3	p														
FF1-4				p											
FF1-5	p														
FFA-1							p								
FFA-2							p								
FFA-3							p								
FFA-4							p								
FFA-5							p								
FFB-1							p								
FFB-2							p								
FFB-3							p								
FFB-4							p								
FFB-5							p								

Note: P = plankton sample collected on that date.

Table B-2 Station Depth, Location and Distance From Diffuser Along Approximate Flow Path

Area	Station	Depth (m)	Easting	Northing	Distance from Diffuser along Approximate Flow Path (m)
Near-field (exposure)	NF1	19.5	535740	7153854	394
	NF2	18.7	536095	7153784	501
	NF3	18.6	536369	7154092	936
	NF4	21.8	536512	7154240	1,131
	NF5	21.1	536600	7153864	968
Mid-field 1 (exposure)	MF1-1	20.5	535008	7154699	1,452
	MF1-3	18.7	532280	7156268	4,650
	MF1-5	16.5	528432	7157066	8,535
Mid-field 2 (exposure)	MF2-1	19.0	538033	7154371	2,363
	MF2-3	21.0	540365	7156045	5,386
Mid-field 3 (exposure)	MF3-1	21.0	537645	7152432	2,730
	MF3-2	20.0	536816	7151126	4,215
	MF3-3	20.6	536094	7148215	7,245
	MF3-4	25.0	532545	7147011	11,023
	MF3-5	20.0	528956	7146972	14,578
	MF3-6	17.6	525427	7148765	18,532
	MF3-7	22.0	521859	7150039	22,330
Far-field 1 (reference)	FF1-1	21.8	525430	7161043	13,571
	FF1-2	19.8	524932	7159476	12,915
	FF1-3	19.2	526407	7160492	12,788
	FF1-4	17	526493	7159058	11,399
	FF1-5	18.5	526683	7161824	12,823
Far-field 2 (exposure)	FF2-2	18.5	541588	7158561	8,276
	FF2-5	19.3	544724	7158879	11,444
Far-field A (reference)	FFA-1	20.0	506453	7154021	36,769
	FFA-2	18.5	506315	7155271	38,312
	FFA-3	22.0	505207	7153887	38,734
	FFA-4	19.0	503703	7154081	40,211
	FFA-5	18.0	505216	7156657	39,956
Far-field B (reference)	FFB-1	19.7	516831	7148207	26,355
	FFB-2	18.0	518473	7150712	24,991
	FFB-3	22.0	518048	7147557	25,245
	FFB-4	19.0	515687	7150036	27,591
	FFB-5	20.6	516533	7150032	26,761

Note: m = metre.

APPENDIX C

2012 PHYTOPLANKTON COMMUNITY DATA (RAW DATA AND QUALITY CONTROL DATA)

These data are provided as an Excel file in a "Raw Data Folder" on the compact disc, rather than in hard copy form.

APPENDIX D

PHYTOPLANKTON SUMMARY STATISTICS

Table D-1 Summary Statistics for Phytoplankton Abundance (individuals per litre) in Lac de Gras, Open-water 2, 2012

Area (Sample Size)	Summary Statistic	Bacillariophyceae	Chlorophyceae	Chrysophyceae	Cryptophyceae	Cyanobacteria	Pyrrhophyceae	Total Phytoplankton
NF (n=5)	Mean	273,239	268,368	669,972	157,040	278,100	2,917	1,649,635
	Median	306,301	247,951	670,946	153,149	311,161	0	1,713,817
	SD	119,411	57,745	68,189	73,022	105,665	6,523	286,028
	SE	53,402	25,824	30,495	32,657	47,255	2,917	127,916
	Minimum	68,063	211,487	593,153	48,618	145,855	0	1,268,941
	Maximum	379,230	364,631	773,046	240,665	408,401	14,585	1,983,650
MF1 (n=3)	Mean	136,131	269,827	770,614	58,342	444,867	7,292	1,687,074
	Median	138,563	291,701	743,872	72,927	561,555	0	1,947,183
	SD	83,896	57,881	151,288	25,263	308,726	12,631	588,167
	SE	48,438	33,417	87,346	14,586	178,243	7,292	339,578
	Minimum	51,045	204,197	634,480	29,171	94,805	0	1,013,698
	Maximum	218,785	313,583	933,490	72,928	678,242	21,877	2,100,340
MF2 (n=2)	Mean	123,977	353,694	422,984	36,464	360,996	3,646	1,301,760
	Median	123,977	353,694	422,984	36,464	360,996	3,646	1,301,760
	SD	1.4	5,156	0.7	51,568	87,668	5,156	36,101
	SE	1.0	3,646	0.5	36,464	61,991	3,646	25,527
	Minimum	123,976	350,048	422,983	0	299,005	0	1,276,233
	Maximum	123,978	357,340	422,984	72,928	422,986	7,292	1,327,287
MF3 (n=7)	Mean	117,378	189,954	486,188	42,020	161,135	5,556	1,002,230
	Median	116,683	165,298	369,501	34,032	111,820	4,861	768,160
	SD	43,093	72,282	199,306	28,857	116,778	7,778	428,151
	SE	16,288	27,320	75,331	10,907	44,138	2,940	161,826
	Minimum	58,341	87,507	281,986	14,584	68,063	0	617,443
	Maximum	182,319	298,997	736,581	102,100	386,522	21,877	1,662,763
FF1 (n=5)	Mean	91,400	156,546	516,334	47,646	133,700	3,889	949,515
	Median	109,388	153,141	481,327	43,757	121,544	0	875,128
	SD	32,002	52,381	110,050	11,219	28,764	6,338	194,288
	SE	14,312	23,426	49,216	5,017	12,864	2,835	86,888
	Minimum	48,615	94,803	422,984	38,894	102,097	0	809,492
	Maximum	116,683	233,365	707,412	65,635	167,735	14,584	1,290,830
FF2 (n=2)	Mean	83,866	306,294	721,997	94,806	280,775	3,646	1,491,383
	Median	83,866	306,294	721,997	94,806	280,775	3,646	1,491,383
	SD	67,039	51,569	206,276	10,314	87,667	5,156	242,374
	SE	47,404	36,465	145,859	7,293	61,990	3,646	171,384
	Minimum	36,462	269,829	576,138	87,513	218,785	0	1,319,999
	Maximum	131,269	342,758	867,856	102,099	342,765	7,292	1,662,767
FFA (n=5)	Mean	108,903	160,439	453,127	56,883	92,373	2,917	874,642
	Median	102,097	138,559	503,204	58,341	87,511	0	926,181
	SD	30,818	65,524	144,809	31,018	37,464	6,522	244,899
	SE	13,782	29,303	64,760	13,872	16,754	2,917	109,522
	Minimum	80,217	97,234	296,570	19,446	53,477	0	607,718
	Maximum	160,441	240,661	619,892	102,100	153,148	14,584	1,159,551
FFB (n=5)	Mean	113,766	131,753	400,618	54,452	76,329	2,431	779,350
	Median	138,563	123,977	430,274	58,341	77,787	0	751,153
	SD	52,686	37,989	50,976	16,180	31,112	3,437	112,058
	SE	23,562	16,989	22,797	7,236	13,914	1,537	50,114
	Minimum	36,460	77,785	340,328	36,463	34,032	0	666,064
	Maximum	160,440	175,024	444,862	72,927	109,391	7,292	904,299

Notes: NF = near-field; MF = mid-field; FF = far-field; n= sample size; SD = standard deviation; SE = standard error.

Table D-2 Summary Statistics for Phytoplankton Biomass (milligrams per cubic metre) in Lac de Gras, Open-water 2, 2012

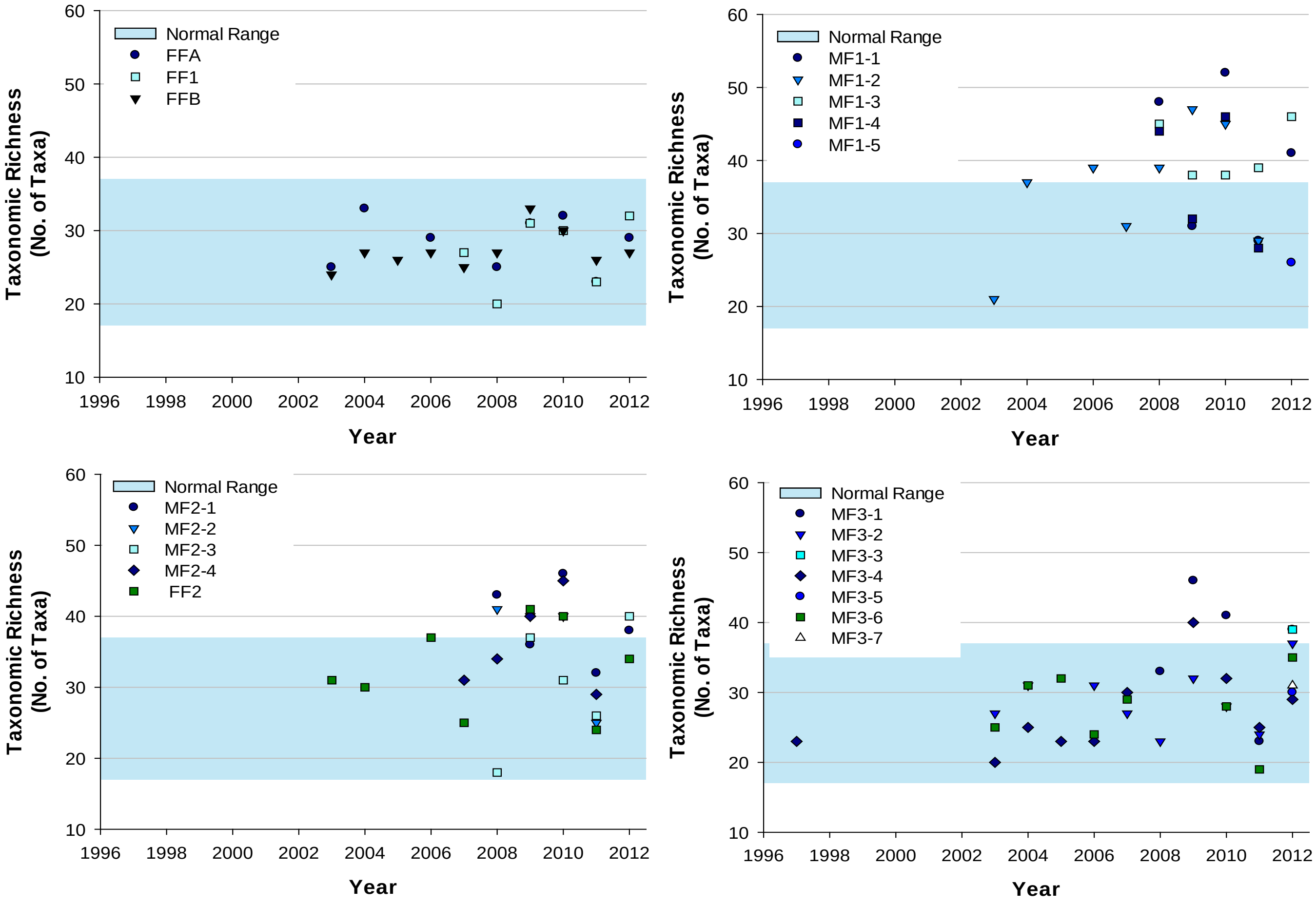
Area (Sample Size)	Summary Statistic	Bacillariophyceae	Chlorophyceae	Chrysophyceae	Cryptophyceae	Cyanobacteria	Pyrrhophyceae	Total Phytoplankton
NF (n=5)	Mean	69	45	113	48	136	12	423
	Median	84	34	82	65	159	0	364
	SD	34	25	55	32	52	27	120
	SE	15	11	25	14	23	12	54
	Minimum	13	24	64	7	60	0	291
	Maximum	98	87	177	77	182	61	553
MF1 (n=3)	Mean	69	73	148	13	292	3	598
	Median	79	79	156	14	302	0	631
	SD	52	19	26	8	244	5	315
	SE	30	11	15	4	141	3	182
	Minimum	13	51	119	5	43	0	268
	Maximum	115	88	169	20	531	9	895
MF2 (n=2)	Mean	47	85	85	6	208	109	539
	Median	47	85	85	6	208	109	539
	SD	38	7	14	8	88	154	175
	SE	27	5	10	6	62	109	124
	Minimum	20	80	76	0	146	0	415
	Maximum	74	90	95	11	270	218	663
MF3 (n=7)	Mean	20	85	73	6	75	5	262
	Median	19	58	57	5	67	3	213
	SD	12	84	36	4	59	8	128
	SE	5	32	14	2	22	3	48
	Minimum	8	11	28	2	22	0	125
	Maximum	42	267	130	15	195	21	442
FF1 (n=5)	Mean	29	82	89	7	75	4	285
	Median	13	78	88	8	78	0	307
	SD	26	36	20	2	16	6	59
	SE	12	16	9	1	7	3	26
	Minimum	10	48	67	4	54	0	199
	Maximum	71	134	117	10	90	15	350
FF2 (n=2)	Mean	13	30	114	18	163	15	353
	Median	13	30	114	18	163	15	353
	SD	15	7	0	1	94	22	92
	SE	11	5	0	0	66	15	65
	Minimum	2	25	114	17	97	0	288
	Maximum	24	36	114	18	229	31	418
FFA (n=5)	Mean	36	58	84	10	72	27	287
	Median	41	37	97	9	57	0	259
	SD	12	48	30	6	46	61	130
	SE	5	21	13	3	20	27	58
	Minimum	21	25	52	3	27	0	157
	Maximum	49	142	116	18	148	136	437
FFB (n=5)	Mean	17	51	60	9	41	2	179
	Median	17	46	58	8	42	0	162
	SD	9	24	22	4	14	3	42
	SE	4	11	10	2	6	1	19
	Minimum	9	24	33	5	20	0	141
	Maximum	29	82	91	14	54	5	245

Notes: NF = near-field; MF = mid-field; FF = far-field; n= sample size; SD = standard deviation; SE = standard error.

APPENDIX E

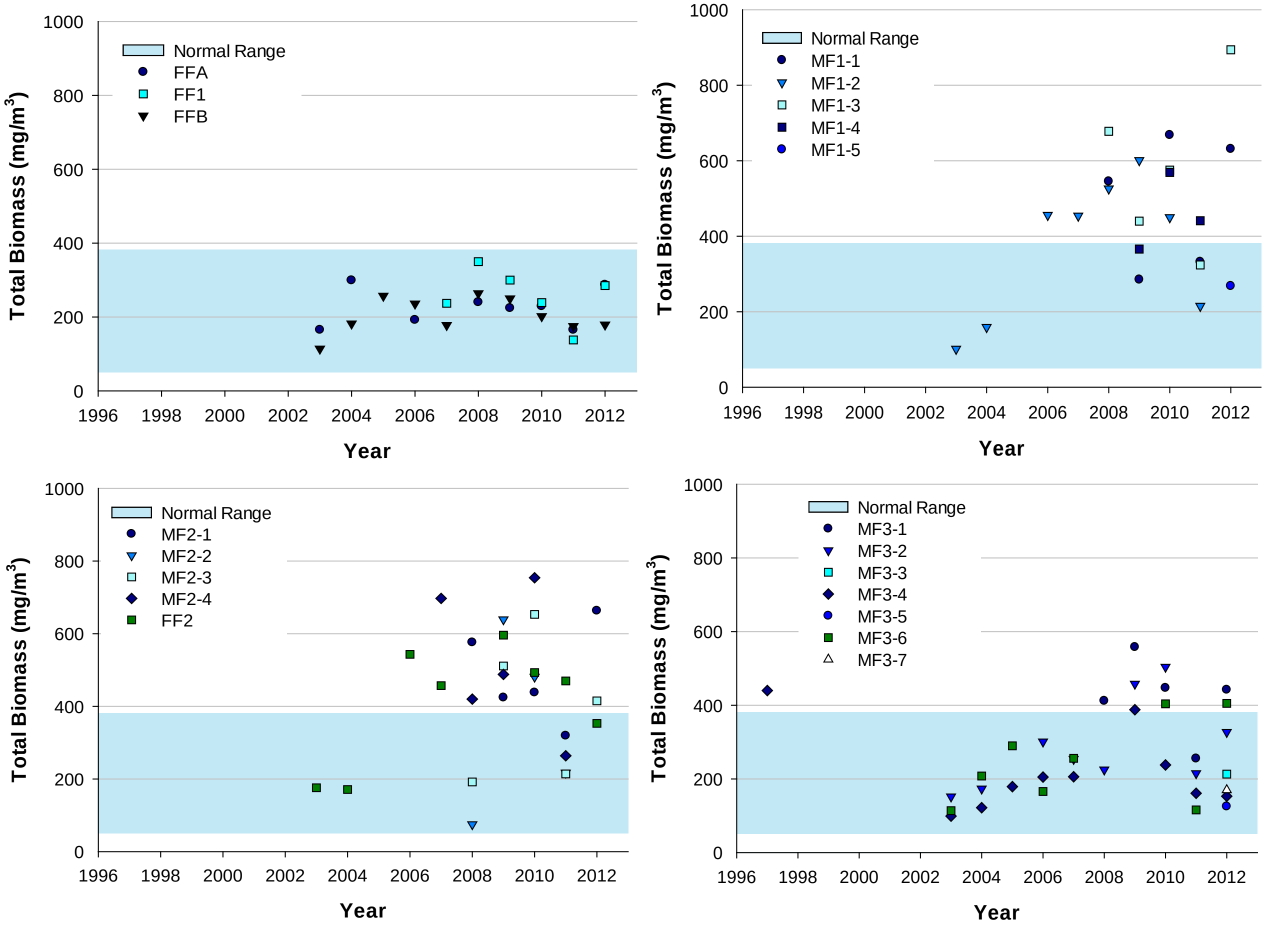
TEMPORAL TRENDS IN FAR-FIELD AND MID-FIELD AREAS

Figure E-1 Mean Annual Phytoplankton Taxonomic Richness in the Reference, Midfield and Farfield-2 Areas of Lac de Gras, Open-water 2, 1996 to 2012



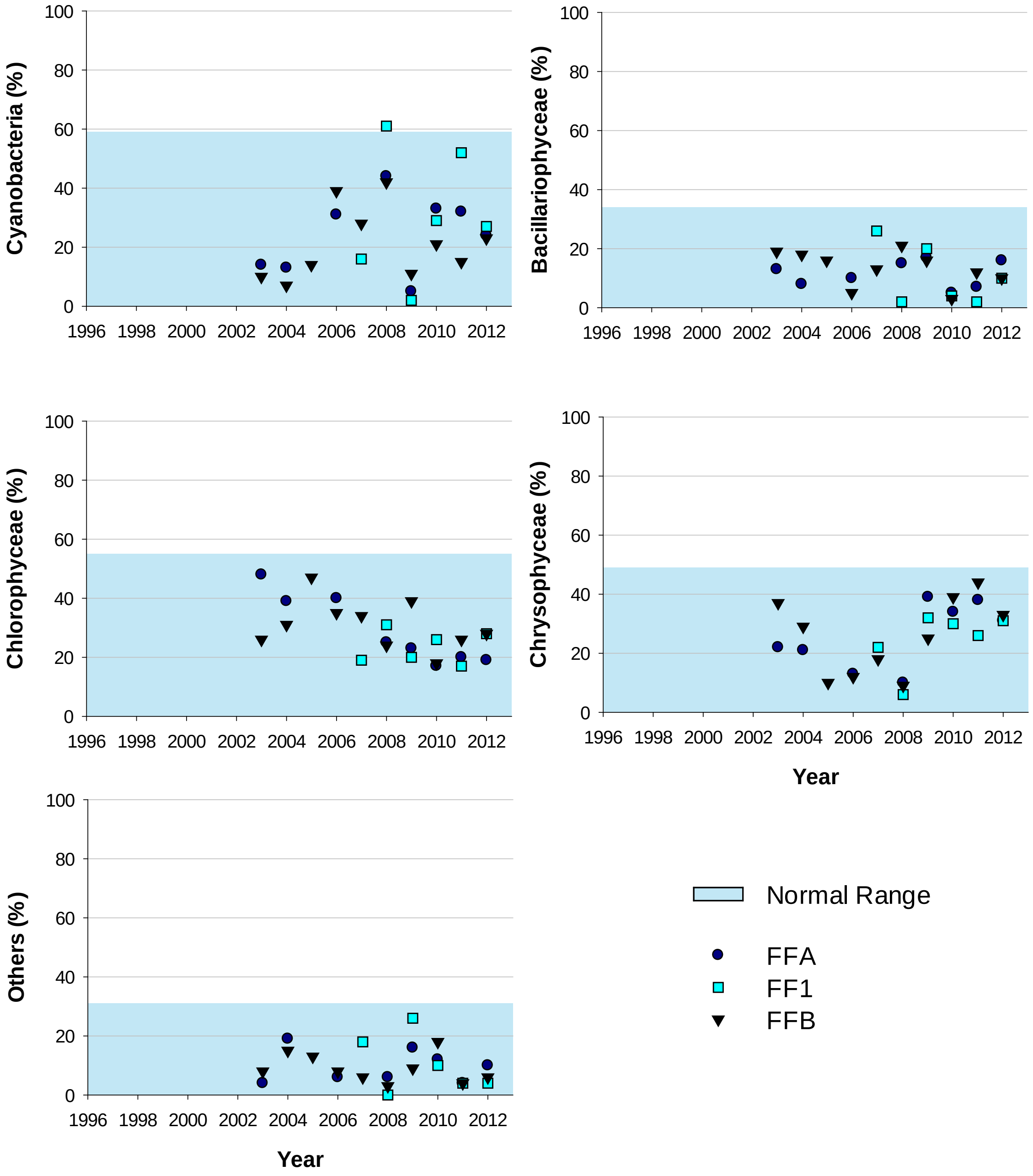
Notes: MF = mid-field; FF = far-field; number or letter (1, A) represents specific area; the shaded area indicates the normal range based on mean annual concentration plus/minus two standard deviation units of the reference area (FF1, FFA and FFB) from the open-water 2 period from 2007 to 2010. The 1997 data point is baseline data collected under open-water 1 (July).

Figure E-2 Mean Annual Phytoplankton Biomass in the Reference, Midfield and Farfield-2 Areas of Lac de Gras, Open-water 2, 1996 to 2012



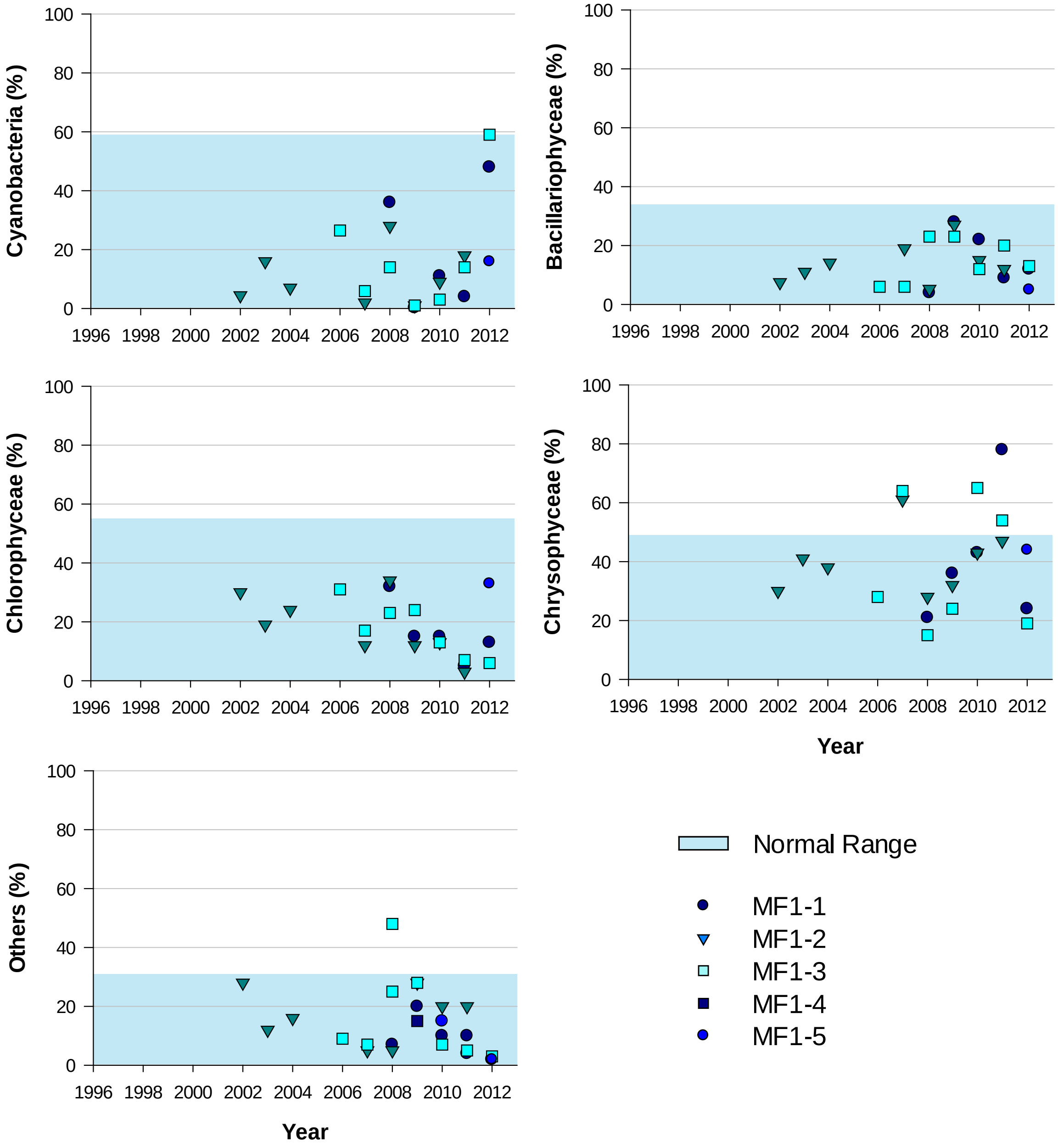
Notes: MF = mid-field; FF = far-field; number or letter (1, A) represents specific area; mg/m^3 = milligrams per cubic metre; from the open-water 2 period from 2007 to 2010. The 1997 data point is baseline data collected under open-water 1 (July).

Figure E-3 Mean Annual Phytoplankton Relative Biomass in the Reference Areas of Lac de Gras, Open-water 2, 1996 to 2012



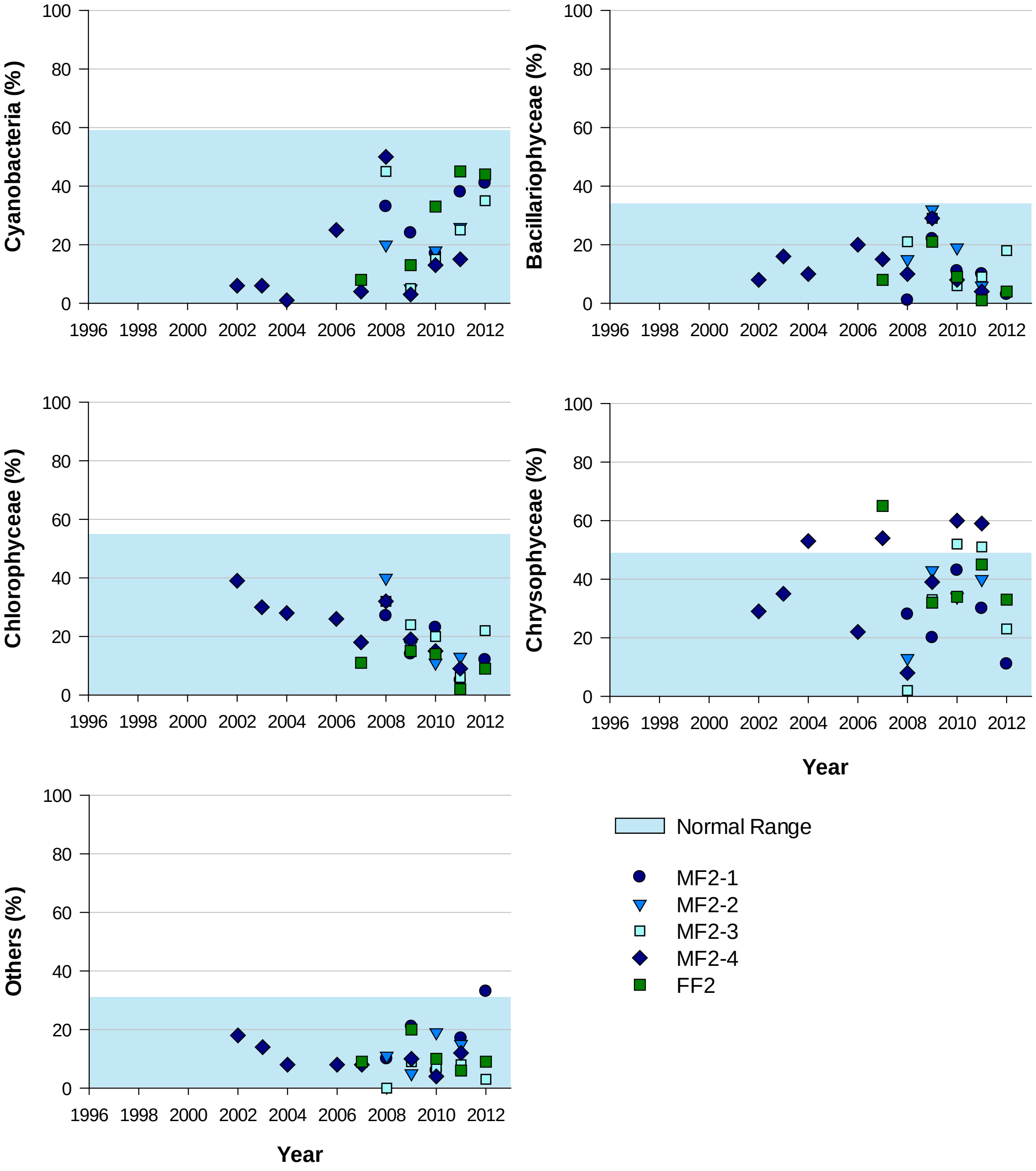
Notes: FF = far-field; number or letter (1, A) represents specific area;% = percent; from the open-water 2 period from 2007 to 2010. The 1997 data point is baseline data collected under open-water 1 (July).

Figure E-4 Mean Annual Phytoplankton Relative Biomass in the Midfield-1 Area of Lac de Gras, Open-water 2, 1996 to 2012



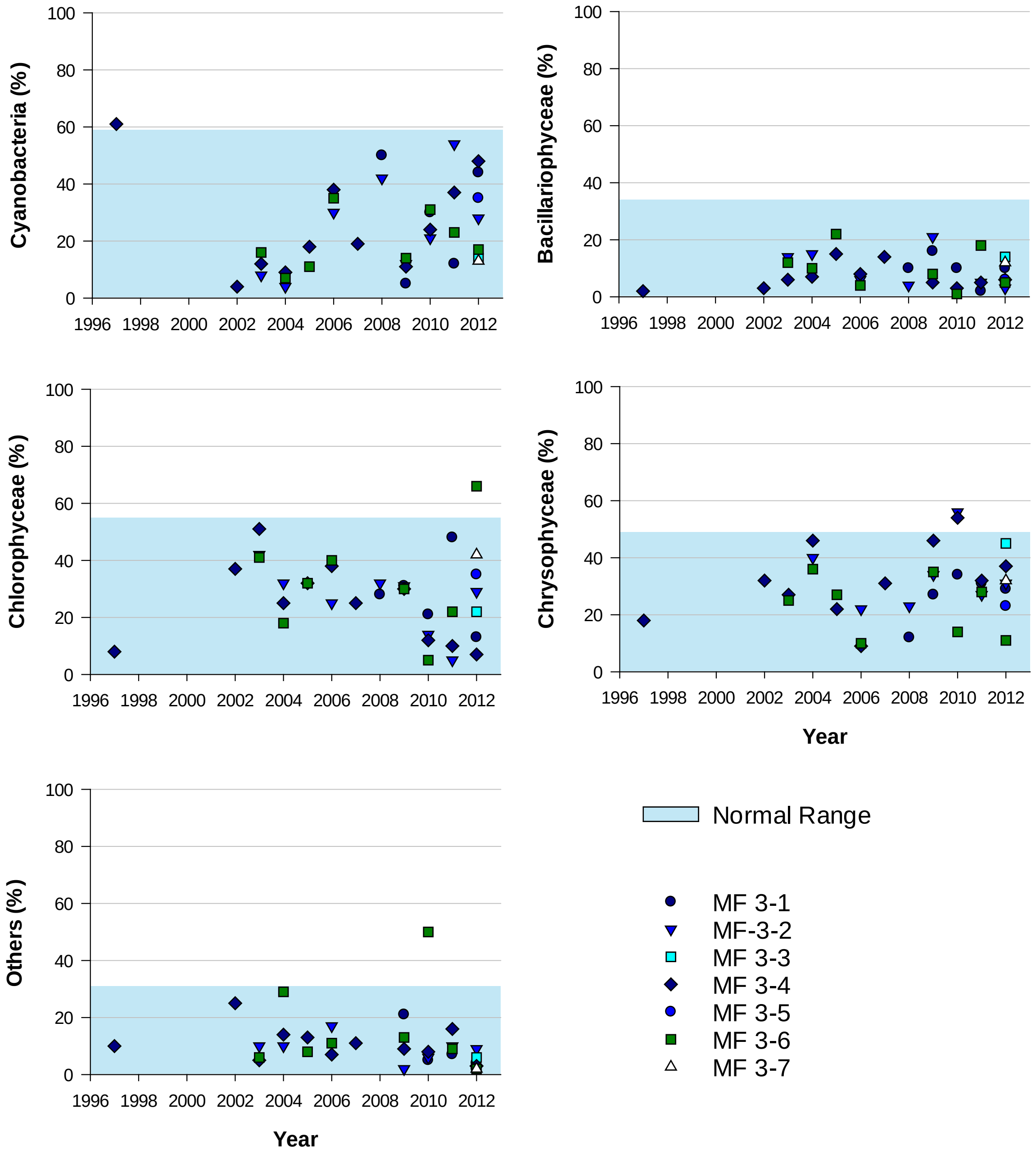
Notes: MF = mid-field; number (1, 2, 3) represents specific area;% = percent; from the open-water 2 period from 2007 to 2010. The 1997 data point is baseline data collected under open-water 1 (July).

Figure E-5 Mean Annual Phytoplankton Relative Biomass in the Midfield and Farfield-2 Areas of Lac de Gras, Open-water 2, 1996 to 2012



Notes: MF = mid-field; FF = far-field; number (1, 2, 3) represents specific area;% = percent; from the open-water 2 period from 2007 to 2010. The 1997 data point is baseline data collected under open-water 1 (July).

Figure E-6 Mean Annual Phytoplankton Relative Biomass in the Midfield-3 Area of Lac de Gras, Open-water 2, 1996 to 2012



Notes: MF = mid-field; number (1, 2, 3) represents specific area;% = percent; from the open-water 2 period from 2007 to 2010. The 1997 data point is baseline data collected under open-water 1 (July).

APPENDIX XII

SPECIAL EFFECTS STUDY REPORT

No information was available for this appendix in 2013.

APPENDIX XIII

EUTROPHICATION INDICATORS REPORT

EUTROPHICATION INDICATORS REPORT IN SUPPORT OF THE 2013 AEMP ANNUAL REPORT FOR THE DIAVIK DIAMOND MINE, NORTHWEST TERRITORIES

Submitted to:

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DISTRIBUTION

1 Copy – Diavik Diamond Mines Inc., Yellowknife, NT
1 Copy – Golder Associates Ltd., Calgary, AB
3 Copies – Wek'èezhìi Land and Water Board

March 2014
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EXECUTIVE SUMMARY

In 2013, Diavik Diamond Mines (2012) Inc. completed the field component of an Aquatic Effects Monitoring Program (AEMP) in Lac de Gras, Northwest Territories, as required by Water License W2007L2-0003 and according to the Aquatic Effects Monitoring Program Study Design Version 3.0. This report presents the assessment of eutrophication indicators data collected during the 2013 AEMP.

To determine whether effluent from the Diavik Diamond Mine is causing eutrophication in Lac de Gras, indicators of eutrophication, consisting of chlorophyll *a*, total phosphorus, total nitrogen and zooplankton biomass, were measured in areas exposed to effluent (near-field [NF] and mid-field [MF] exposure areas) and in areas of the lake not exposed to effluent (reference areas FFA, FFB, and FF1).

The analysis indicated that the Mine is causing a nutrient enrichment effect. Statistically greater concentrations of chlorophyll *a*, total phosphorus and total nitrogen, as well as zooplankton biomass, in the near-field exposure area relative to reference areas (FFA, FFB, and FF1) indicated that the Mine was the cause of these increases. During both ice-cover and open-water, the increased concentrations of total phosphorus and total nitrogen covered less than 20% of the lake. The area of the lake showing effects on chlorophyll *a* concentrations and zooplankton biomass was substantially larger. Although zooplankton biomass in the Near-field exposure area did not exceeded the upper limit of the normal range, biomass in mid-field stations did exceed the normal range. This resulted in an extent of effects on zooplankton biomass representing 37.1% of the lake. Concentrations of chlorophyll *a* exceeded the upper boundary of the normal range of the reference areas over an area representing 24.9% of the lake. Consequently, the magnitude of the eutrophication effect is equivalent to Action Level 2 of the Response Framework.

LIST OF ACRONYMS

AEMP	Aquatic Effects Monitoring Program
AFDM	Ash-free dry mass
ANOVA	analysis of variance
DDMI	Diavik Diamond Mines (2012) Inc.
DL	detection limit
EA	environmental assessment
FF	far-field
HSD	honestly significant difference
MF	mid-field
NF	near-field
P	probability
QA/QC	quality assurance/quality control
QAPP	Quality Assurance Project Plan
RPD	relative percent difference
SD	standard deviation
SOP	standard operating procedure
Mine	Diavik Diamond Mine
TP	total phosphorus
TN	total nitrogen
UofA	University of Alberta
US EPA	United States Environmental Protection Agency
UTM	Universal Transverse Mercator
WLWB	Wek’èezhìi Land and Water Board
WOE	weight of evidence

LIST OF UNITS

%	Percent
+	plus or minus
kg/month	kilograms per month
kg/yr	kilograms per year
km^2	square kilometre
m	Metre
mg/L	milligrams per litre
mg/m^3	milligrams per cubic metre
µg/L	micrograms per litre

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1 INTRODUCTION

1.1 BACKGROUND

As required by Water Licence W2007L2-0003 (WLWB 2007), Diavik Diamond Mines (2012) Inc. (DDMI) has been monitoring indicators of eutrophication in Lac de Gras as a component of the Aquatic Effects Monitoring Program (AEMP) since 2007. This has been a key component of the AEMP because the Environmental Assessment (EA) predicted that the discharge of effluent from the Diavik Diamond Mine (Mine) would cause a slight increase in the trophic status (a classification of productivity) in up to 20 percent (%) of Lac de Gras as a result of nutrient enrichment (Government of Canada 1999).

This report presents the assessment of eutrophication indicators data collected during the 2013 AEMP field program, which was carried out by DDMI according to the AEMP Study Design Version 3.0 (Golder 2011a). The assessment of effects was based on the updated Version 3.3 Study Design (Golder 2014a), which was approved by the Wek’èezhìi Land and Water Board (WLWB) on February 19, 2014 (WLWB 2014). Details on methodology are provided in Section 2. Section 3 provides results of the assessment, while Section 4 provides a discussion of the results. Conclusions, together with recommendations for program changes or enhancements, are provided in Section 5.

1.2 OBJECTIVES

The overall objective of this work was to determine if effluent from the Mine is having an effect on concentrations of nutrients and chlorophyll *a*, and on zooplankton biomass in Lac de Gras.

1.3 SCOPE AND APPROACH

The Eutrophication Indicators component is designed to monitor both spatial and temporal changes in nutrients, chlorophyll *a*, and zooplankton biomass. As described in Version 3.3 Study Design (Golder 2014a), the objective of the annual reports and the comprehensive sampling reports (current document) is to assess the spatial extent of effluent effects.

Effects were assessed by comparing areas of the lake exposed to effluent, to areas of the lake that are not exposed to effluent (i.e., reference areas). Eutrophication indicator endpoints were statistically tested to establish whether the differences seen among areas were related to the Mine (i.e., demonstrated a statistically-significant difference) or whether they may have occurred by chance.

The magnitude of effects was assessed by comparing eutrophication indicator endpoints in exposure areas to background values. Background values for Lac de Gras are those that fall within the *normal range*, which is defined as the historical reference area mean plus or minus two standard deviations (± 2 SD). Values that are beyond the normal range are exceeding what would be considered natural levels for Lac de Gras. The extent of effects was established by determining the surface area of the lake demonstrating effects that exceed the top of the normal range. The importance of effects observed on eutrophication endpoints was determined according to the Action Level classification defined in Golder (2014a).

2 METHODS

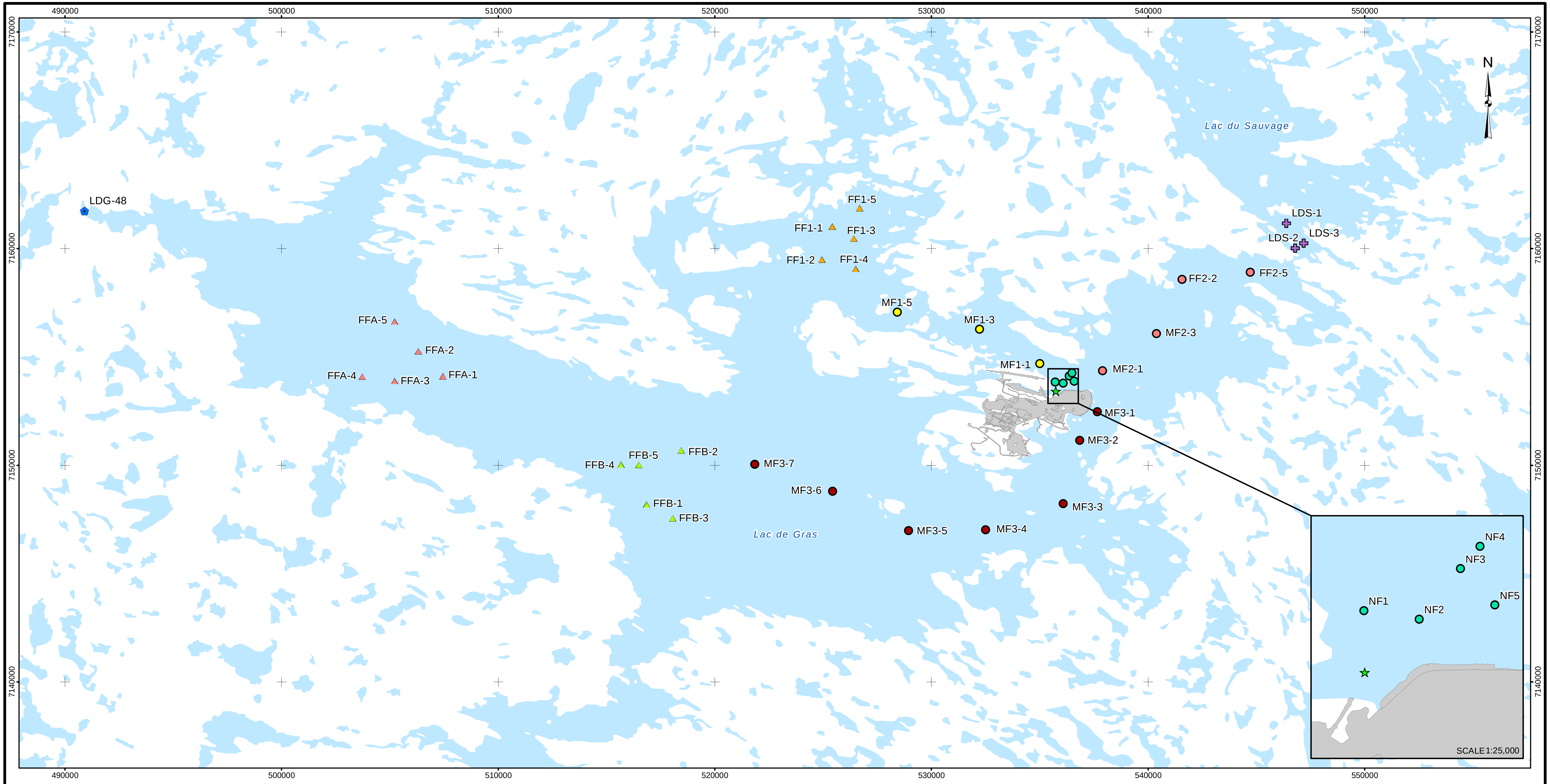
2.1 FIELD SAMPLING

Thirty-four stations located within five general areas of Lac de Gras were sampled by DDMI during the 2013 AEMP program. Sampling areas were selected based on exposure to the Mine effluent (Golder 2011a), and consisted of the near-field (NF) exposure area and three far-field reference areas (FF1, FFA, and FFB) (Figure 2-1). In addition, three transect lines (referred to as mid-field [MF] areas) between the NF and FF areas were sampled. The MF1-FF1 transect was sampled towards the FF1 reference area, northwest of the exposure area. The MF2-FF2 transect was sampled to the northeast, towards the FF2 area near the Lac du Sauvage inlet. The MF3-FFB-FFA transect was sampled south of the exposure area towards FFB and FFA reference areas.

Within each sampling area, clusters of replicate stations were sampled. Five stations were sampled in the NF exposure area and in each of the three FF reference areas. To better delineate the extent of effects and define gradients along each transect, the number of stations within the other areas differed (Golder 2011a). A total of four stations were sampled along the MF2-FF2 transect, three stations were sampled in the MF1 area, and seven stations were sampled in the MF3 area (Figure 2-1).

In addition to stations in Lac de Gras, three stations were sampled in Lac du Sauvage. Lac du Sauvage water is more productive than Lac du Gras and has the potential to affect the FF2 area; therefore, monitoring stations were added in Lac de Sauvage to assess changes to the quality of water entering Lac de Gras from the Lac du Sauvage inlet (Golder 2014a). Nutrients and chlorophyll *a* were also sampled at the outlet from Lac de Gras to the Coppermine River (Station LDG 48). Universal Transverse Mercator (UTM) coordinates for all stations are provided in Table 2-1.

The field sampling program, undertaken by Diavik staff, included the collection of *in situ* nutrients, chlorophyll *a*, zooplankton biomass and water quality measurements. Water column profile measurements were collected with a multi-variable Datasonde logger (Hydrolab and YSI) following the methods described in DDMI’s Standard Operating Procedure (SOP), ENVR 608-0112 RO “Biophysical Measuring”.



5 0 5

SCALE 1:175,000 KILOMETRES

LEGEND

★ DIFFUSER

EXPOSURE

● NEAR-FIELD

● MID-FIELD 3

● MID-FIELD 1

● FAR-FIELD 2; MID-FIELD 2

REFERENCE

▲ FAR-FIELD 1

▲ FAR-FIELD A

▲ FAR-FIELD B

⬟ LDG 48

✚ LAC DU SAUVAGE

▨ DIAVIK FOOTPRINT

▨ WATERBODY

REFERENCE

HYDROGRAPHY DATA OBTAINED FROM CANVEC © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 12 DATUM: NAD 83

PROJECT

DIAVIK DIAMOND MINES INC.

TITLE

EUTROPHICATION INDICATORS
SAMPLING STATIONS, 2013 AEMP

Golder Associates

PROJECT		13-1328-0001	FILE No.	
DESIGN	LJ	28 Jan. 2014	SCALE AS SHOWN	REV. 0
GIS	JC	20 Mar. 2014	FIGURE: 2-1	
CHECK	TD	20 Mar. 2014		
REVIEW	CF	20 Mar. 2014		

I:\2011\11-1328\11-1328-0038\Mapping\MXD\2013AEMP\FINAL\Fig2-1_2013_AEMP_Eutrophication_Indicators_Sampling_Station_20140318_Final.mxd

Table 2-1 UTM Coordinates (NAD83 Zone 12) of the 2013 AEMP Sampling Stations

Area	Station[(a)]	Easting	Northing	Area	Station	Easting	Northing
Near-field (exposure)	NF1	535740	7153854	Far-field 2 (exposure)	FF2-1	541588	7158561
	NF2	536095	7153784		FF2-2	544724	7158879
	NF3	536369	7154092	Far-field 1 (reference)	FF1-1	525430	7161043
	NF4	536512	7154240		FF1-2	524932	7159476
	NF5	536600	7153864		FF1-3	526407	7160492
Mid-field 1 (exposure)	MF1-1	535008	7154699		FF1-4	526493	7159058
	MF1-3	532236	7156276		FF1-5	526683	7161824
	MF1-5	528432	7157066	Far-field A (reference)	FFA-1	506453	7154021
Mid-field 2 (exposure)	MF2-1	538033	7154371		FFA-2	506315	7155271
	MF2-3	540365	7156045		FFA-3	505207	7153887
Mid-field 3 (exposure)	MF3-1	537645	7152432		FFA-4	503703	7154081
	MF3-2	536816	7151126		FFA-5	505216	7156657
	MF3-3	536094	7148215	Far-field B (reference)	FFB-1	516831	7148207
	MF3-4	532545	7147011		FFB-2	518473	7150712
	MF3-5	528956	7146972		FFB-3	518048	7147557
	MF3-6	525427	7148765		FFB-4	515687	7150036
	MF3-7	521859	7150039		FFB-5	516533	7150032
Lac de Sauvage	LDS-1	546398	7161179	Outlet of Lac de Gras	LDG48	490900	7161750
	LDS-2	546807	7160027				
	LDS-3	547191	7160256				

Notes: UTM = Universal Transverse Mercator; AEMP = Aquatic Effects Monitoring Program.

a) Stations are shown in Figure 2-1.

The sampling protocol for nutrients differed between the ice-cover and open-water sampling events. During the ice-cover season, samples were collected at three discrete depths (top, middle, and bottom) at each of the NF and MF exposure stations, since these were the stations most likely to have vertical gradients in water quality as a result of the Mine discharge. Water samples for nutrients were collected according to protocols described in DDMI's SOP, ENVR-014-0311 R3 "AEMP Sampling-Ice Cover". Surface samples were collected at a depth of 2 metres (m) from water surface, and bottom samples were collected at 2 m from the lake bottom. Mid-depth samples were collected at the middle of the total water column depth. In reference areas, water samples were collected from the middle of the water column.

During the open-water season, depth-integrated samples for both nutrients and chlorophyll *a* were collected from all sampling areas. Depth-integrated samples were collected for nutrients during the open-water season to provide a better estimate of the levels of nutrients to which phytoplankton are exposed. Depth-integrated samples were collected from the top 10 m of the water column. Samples for other water chemistry variables were collected from the same three discrete depths as the ice-cover samples in exposure areas and from the middle depth in reference areas (Golder 2014b). Procedures followed during the open-water period are outlined in DDMI's SOP, ENVR-003-0702 R9 "Aquatic Monitoring Program (Open Water)". Water samples were handled according to DDMI SOPs, ENVR-303-0112 R0 "Laboratory Quality Assurance/Quality Control" and ENVR-206-0112 R0 "Processing Maxxam Samples and Tracking Documentation".

Plankton samples (for the determination of chlorophyll *a* concentrations and zooplankton biomass) were collected during the open-water season only. Samples for chlorophyll *a* were collected as depth-integrated samples from the top 10 m of the water column. Twelve sub-samples (or depth-integrated grabs) were collected and combined into a collection bucket to form a composite sample. Aliquots from this collection bucket were then placed into chlorophyll *a*, nutrient, and phytoplankton taxonomy jars provided by the laboratories. Two chlorophyll *a* jars and one nutrient jar were filled with the sample; hence, split samples for chlorophyll *a* were provided for analysis. Zooplankton samples were collected with a zooplankton sampling net, and each sample consisted of a composite of three vertical tows of the entire water column. Duplicate samples (each consisting of three tows) were collected at each station. An analysis of all duplicate and split samples is provided in Appendix A.

Sampling was conducted once under ice-cover conditions and once in the open-water season:

- Ice-cover: April 10 to April 19, 2013; and
- Open-water: August 18 to September 7, 2013.

Samples collected during the ice-cover season were sent to the Biogeochemical Analytical Laboratory at the University of Alberta (UofA), Edmonton, for the following analyses: chlorophyll *a*; total, dissolved and particulate nitrogen; total, dissolved and particulate phosphorus; particulate carbon; ammonia; nitrite; nitrate+nitrite; and, soluble reactive phosphorus. Depth-integrated samples collected in the open-water season were sent to Maxxam Analytics (Maxxam), Burnaby, British Columbia, for the following analyses: total nitrogen (TN); dissolved phosphorous; ammonia; nitrite; nitrate+nitrite; and, soluble reactive phosphorus. Particulate nitrogen, particulate phosphorus and particulate carbon were not measured by Maxxam for the open-water samples. In addition, total dissolved nitrogen was not measured directly during the open-water season, instead it was calculated from total ammonia and nitrate+nitrite. Zooplankton biomass was estimated with the ash-free dry mass (AFDM) method by Hydroqual Laboratories Ltd. (Calgary). Water samples for analysis of bicarbonate and pH were sent to Maxxam as described in the Effluent and Water Chemistry Report (Golder 2014b).

In total, nutrient samples were collected from 38 stations; 35 stations in Lac de Gras (including LDG 48), and 3 stations in Lac du Sauvage. All stations were sampled once during ice-cover and once during the open-water sampling season. A summary of sample events is provided in Appendix B, Table B-1.

2.2 DATA ANALYSIS

2.2.1 Data Handling

Raw effluent and water quality data were screened for inaccurate entries, missing information and potential outliers. Outlier values were identified based on a visual assessment of plots prepared for each variable. Outliers deemed to be errors were removed from the data set. All chlorophyll *a* and zooplankton samples consisted of splits or duplicates, respectively, which were averaged prior to analyses.

Values below the detection limit (DL) were assumed to follow the distribution of the data that were above the limit of detection. A reasonable assumption regarding the location of the non-detect data along the distribution curve would be at the location demarcating 50% of the area of the curve to the left of the DL; this value was estimated by multiplying the limit of detection by 0.71 (Roger Green, University of Western Ontario, personal communication). Guidance provided by the United States Environmental Protection Agency (US EPA; 2000) for replacing non-detectable data were considered; however, most of their recommended approaches, such as trimmed mean, Cohen's adjustment or Winsorized mean, were not suitable for this data set. Therefore, the 0.71 × DL approach was applied to all non-detect values.

2.2.2 Statistical Analysis

2.2.2.1 Approach

The objective of the statistical comparisons was to compare the NF exposure area to the three reference areas (FF1, FFA, and FFB). Statistical testing was conducted by analysis of variance (ANOVA) or the Kruskal-Wallis test. During the ice-cover season, water samples were collected at three depths in the NF exposure area (top, middle, and bottom) and at a single depth in the FF reference areas (middle). Water column profile data collected in the near field demonstrated that the plume from the effluent discharge was concentrated in the lower half of the water column during this season. Although data from all three sampling depths were analyzed, the bottom-depth data provided the greatest difference between NF and FF areas for TN, and the top-depth data provided the greatest difference between NF and FF areas for total phosphorus (TP). To provide the most conservative view of effects, results of the analyses with the NF bottom layer data for TN and the top layer data for TP are presented. For the open-water season, comparisons were based on the depth-integrated data obtained at all of the sampling areas. Statistical analyses were performed with the R Program (R Core Team, Vienna, Austria).

2.2.2.2 Testing Assumptions for Analysis of Variance

Parametric tests such as ANOVA assume that the data fit the normal distribution (since the residuals [or error terms of the variates] are assumed to fit the normal distribution). If a measurement variable is not normally distributed, there is an increased chance of a false positive result (Type I error). Fortunately, an ANOVA is not sensitive to moderate deviations from normality, because when a large number of random samples are taken from a population, the means of those samples are approximately normally distributed even when the population is not normal (Sokal and Rohlf 1995).

The goodness-of-fit of the data to the normal distribution were tested with the Kolmogorov-Smirnov test. Many data sets that are significantly non-normal will still be appropriate for an ANOVA; therefore, issues with non-normality were only addressed with a *P* value less than 0.01. Another important assumption in ANOVA is that group variances are equal. When variances differ markedly, various data transformations will typically remedy the problem. As with normality, the consequences of moderate deviations from the assumption of equal variances do not compromise the overall test of significance. The results of tests to assess the goodness-of-fit of the data to the normal distribution (the Kolmogorov-Smirnov test) and to test the homogeneity of variance of the data (Bartlett’s and Levene’s test) are provided in Appendix C, Table C-1.

If the data were clearly non-normal and/or had large differences in group variances, and if transformations did not remedy the problem, the data were then analyzed using a non-parametric test (e.g., Kruskal-Wallis test). In addition, if a variable consisted of a high percentage of non-detect values, the non-parametric Kruskal-Wallis test was automatically used because it is a more appropriate approach than using ANOVA for these types of data (Helsel 2005).

2.2.2.3 Analysis of Variance

The means of the four areas were compared to one another in an overall ANOVA. Within the overall ANOVA, an *a priori* comparison (planned contrast) was then conducted to test the differences of means among specific areas (e.g., NF exposure area versus the FF reference areas). Multiple comparison techniques (*a posteriori*) are frequently used with environmental assessment data; however, these techniques are not always appropriate for testing hypotheses (Hoke et al. 1990). The preferred approach is to analyze the data using planned, linear orthogonal contrasts by formulating meaningful comparisons among treatments (sampling areas) prior to conducting the study and outlining these in a study design. This preferred approach was used to help answer the question of whether effluent is having an effect in the exposure area of Lac de Gras.

In some cases, there were unforeseen differences observed among reference areas. To assess this natural variability, comparisons were also made among reference areas, thereby quantifying "natural" differences among different areas of Lac de Gras. Such comparisons are considered unplanned (*a posteriori*) comparisons. The procedure used for these comparisons was *Tukey's honestly significant difference (HSD) method*, also known as the *T-method*. This test adopts a conservative approach by employing experiment-wise error rates for the Type I error (Day and Quinn 1989). Therefore, the P value used for these tests was 0.1, the same P value used for the planned contrasts.

2.2.2.4 Kruskal-Wallis Test

For variables that did not meet parametric test assumptions, the Kruskal-Wallis test was used to test for differences among sampling areas. The same approach was taken as described for ANOVA. Upon finding a significant overall difference, planned contrasts were conducted to test differences between the NF exposure area and the pooled reference areas (Gibbons 1976). To assess natural variability, the three reference areas were compared to one another (FF1 vs. FFA vs. FFB). The multiple-comparison procedure employed followed Dunn (1964) and is the nonparametric analogue to the unplanned tests using Tukey's HSD method described under ANOVA. Kruskal-Wallis tests were considered significant at P <0.1. The multiple-comparison procedure controls the experiment wise error rates for the Type I error and, therefore, holds the probability of correctly finding no difference at $1 - \alpha$. However, under this scenario, the task of correctly detecting differences that are significant (i.e., $1 - \beta$) is more difficult (Daniel 1990). To maintain a sufficiently small Type II error (β) with the multiple comparisons, a larger α (or P value) was used. The contrasts were tested at $P = 0.1$, and the multiple comparisons were conducted with $P = 0.15$.

2.2.3 Normal Ranges

Throughout the AEMP, potential effects were evaluated by comparing the NF exposure area to the normal range of the reference areas (FF1, FFB, and FFA). The normal range is defined as the historical pooled reference area mean ± 2 SD (Golder 2014a). Owing to the potential for effluent to reach the reference areas of Lac de Gras, normal ranges were calculated using reference area data collected from 2007 to 2010, during the AEMP Version 2.0 (DDMI 2007). The normal range for ice-cover was calculated with all ice-cover data from 2007 to 2010. The open-water normal range was calculated with data collected during the sample dates that correspond with the Open-water period for the AEMP Version 3.3 (i.e., August 15 to September 15). The upper boundary of the normal range was the value used for the evaluation of eutrophication effects.

The normal range calculation for zooplankton biomass was based on a reduced dataset. Biomass data were unavailable for 2007 because of field sub-sampling errors in that year. In 2008, the zooplankton biomass samples consisted of composite hauls collected from the top 10 m of the water column, while in 2009 and 2010 zooplankton biomass samples consisted of composite tows of the entire water column. As such, the 2008 data were also excluded from the normal range calculation. The normal range calculation for zooplankton biomass, therefore, used the August 15 to September 15 data collected in 2009 and 2010.

2.2.4 Spatial Analysis in Lac de Gras

To visually evaluate spatial trends relative to the Mine discharge, concentrations of nutrients and chlorophyll *a*, as well as zooplankton biomass, were plotted against distance from the diffuser. Values in the NF exposure area and MF areas were plotted against the current years reference area data and upper boundary of the normal range. The area of the lake with values greater than the normal range was estimated, and this measure was used to determine the extent of effects.The extent of effects calculated for 2013 was compared with those established over the AEMP Version 2.0 (Golder 2011b) to assess if effects are spreading further into the lake with time. To provide the most conservative view of effluent effects, the season and depth with the greatest extent of effects was selected for this evaluation.

2.2.5 Magnitude of Effect and Action Levels

The severity of possible effects to an assessment endpoint has been categorized according to the Action Level Framework described for indicators of eutrophication in the AEMP Study Design Version 3.3 (Golder 2014a). The Action Level classifications were developed to meet the goals of the Response Framework for Aquatic Effects Monitoring which was drafted by the WLWB (WLWB 2010; Racher et al. 2011). The main goal of the Response Framework is to ensure that significant adverse effects never occur. This is accomplished by requiring proponents to take actions at predefined Action Levels, which are triggered well before significant adverse effects could occur.

Termed a Significance Threshold in the Action Levels, a significant adverse effect for total phosphorous was defined in the EA (Government of Canada 1999). The magnitude of effect for total phosphorous at the Significance Threshold level was defined as a concentration that exceeds the EA benchmark by more than 20%. Therefore, in keeping with the intent of this definition, the Significance Threshold for the indicators of eutrophication is a concentration of chlorophyll *a* that exceeds the Effects Threshold by more than 20% in the FFA area of Lac de Gras (Table 2-2). In contrast to toxicological impairment responses to water chemistry (e.g., concentrations of metals), eutrophication responses are difficult to link to nutrient concentrations. As demonstrated by years of monitoring in Lac de Gras, concentrations of phosphorus do not predict the actual biological response to nutrient enrichment. Rather, the increase in the biomass of algae as measured by chlorophyll *a* has been a very good measure of the effects of nutrient enrichment.

Elevated concentrations of nutrients were expected in approximately 20% of Lac de Gras (Government of Canada 1999). Specifically, up to 20% (116 square kilometres [km^2]) of the surface area of Lac de Gras was expected to exceed the EA Benchmark for phosphorus during peak operations during the open-water season (and up to 11% [64 km^2] of the lake during the ice-cover season). The "extent of effect" for the chlorophyll *a* Action Levels reflects this prediction (Table 2-2).

Table 2-2 Action Levels Classification for Chlorophyll *a*

Action Level	Magnitude of Effect	Extent of Effect	Action/Notes
1	95th percentile of MF values greater than normal range(a)	Mid-field (MF) station	Early warning.
2	Near-field (NF) and MF values greater than normal range	20% of lake area or more	Establish *Effects Benchmark*.
3	NF and MF values greater than normal range plus 25% of Effects Benchmark(b)	20% of lake area or more	Confirm site-specific relevance of existing benchmark. Establish *Effects Threshold*.
4	NF and MF values greater than normal range plus 50% of Effects Threshold(b)	20% of lake area or more	Investigate mitigation options.
5	NF and MF values greater than Effects Threshold	20% of lake area or more	The WLWB to re-assess EQC for phosphorus. Implement mitigation required to meet new EQC if applicable.

Table 2-2 Action Levels Classification for Chlorophyll *a* (continued)

Action Level	Magnitude of Effect	Extent of Effect	Action/Notes
6	NF and MF values greater than Effects Threshold +20%	20% of lake area or more	The WLWB to re-assess EQC for phosphorus. Implement mitigation required to meet new EQC if applicable.
7	95th percentile of MF values greater than Effects Threshold +20%	All MF stations	The WLWB to re-assess EQC for phosphorus. Implement mitigation required to meet new EQC if applicable.
8	95th percentile of FFB values greater than Effects Threshold +20%	Far-field B (FFB)	The WLWB to re-assess EQC for phosphorus. Implement mitigation required to meet new EQC if applicable.
9	95th percentile of FFA values greater than Effects Threshold+20%	Far-field A (FFA)	Significance Threshold.

Notes: % = percent; WLWB = Wek'èezhìi Land and Water Board; EQC = Effluent Quality Criteria; AEMP = Aquatic Effects Monitoring Program.

a) The normal range is based on AEMP Version 2.0 data, from the August 15 to September 15 sampling period only.

b) Indicates 25% or 50% of the difference between the benchmark and the top of the normal range.

2.2.5.1 Benchmarks for Indicators of Eutrophication

The EA threshold for TP of 5 micrograms per litre (µg/L) in the whole lake was selected to maintain the trophic status of the lake (DDMI 1998). Based on 205 reference area samples collected over four years (from 2007 to 2010, inclusively) the average background concentration of TP for Lac de Gras is 3.5 µg/L (Golder 2011b). The same value was obtained for ice-cover and open-water periods. The normal range (calculated as the reference area mean ± 2 SD) of TP concentrations for Lac de Gras is 1.4 to 5.6 µg/L during open-water periods and 1.9 to 5.1 µg/L during the ice-cover period. This suggests that the EA benchmark of 5 µg/L is within the natural background range and is, therefore, not appropriate as a benchmark.

Total phosphorus concentration alone is not sufficient to evaluate changes to lake productivity. In fact, the measure of TP can only evaluate the potential for an increase in lake productivity. Ideally, some direct measure of biological response to nutrient enrichment can be made. Several years of monitoring in Lac de Gras have shown that the concentration of chlorophyll *a* (an indicator of phytoplankton biomass and/or standing crop) has been a sensitive and robust measure of biological response to nutrient inputs from the Mine (Golder 2014a).

In consideration of the foregoing discussion, Action Levels for the eutrophication response were based on chlorophyll *a* concentrations. Therefore, an Effects Benchmark for chlorophyll *a* was developed for the DDMI AEMP. The chlorophyll *a* Effects Benchmark concentration of 4.5 µg/L that was established is appropriate in terms of both the aesthetic quality and food web functionality in Lac de Gras. Aesthetic qualities are likely to be preserved at chlorophyll *a* concentrations up to 10 µg/L, while a benchmark of 4.5 µg/L maintains the trophic classification of the lake as oligotrophic (Golder 2014a). Further, it is anticipated that even if chlorophyll *a* concentrations surpassed 4.5 µg/L in Lac de Gras, the lake would recover to baseline conditions shortly after the end of mining operations.

2.3 NUTRIENTS IN EFFLUENT AND THE MIXING ZONE

The effluent discharge from the North Inlet Water Treatment Plant to Lac de Gras was evaluated in terms of nutrient concentration and load. Ammonia and nitrite concentrations were compared with the discharge criteria defined in the Water Licence (W2007L2-0003). Total phosphorus has a discharge criterion specified in terms of load, rather than concentration, in the Water Licence. The Licence specifies that the load of TP should not exceed a maximum of 300 kilograms per month (kg/month), an average annual loading of 1,000 kilograms per year (kg/yr) during the life of the Mine, and a maximum loading of 2,000 kg/yr.

Nutrient quantity was evaluated graphically by plotting total monthly loads as bar charts and calculating total annual loads. The daily load was calculated by multiplying the discharge rate by the concentration for each effluent diffuser station (SNP 1645-18 and SNP 1645-18B) separately. Linear interpolation was used to estimate the concentrations between sampling events. The total load was calculated as the sum of loads from the two diffusers. Mean daily loads for each month and year were estimated from the daily results. The period of effluent discharge summarized in this report included information collected from November 1, 2012, to October 31, 2013, at stations SNP 1645-18 and SNP 1645-18B.

Water quality samples were collected monthly at the edge of the mixing zone, as per the conditions of the Water Licence, using the methods described in Section 2.1. The mixing zone sampling program included three stations that were monitored as part of the Surveillance Network Program (SNP); SNP1645-19a, SNP1645-19b2 and SNP1645-19c. The Water Licence requires that samples be c45ollected at the surface and at 5 m intervals to depth (i.e., greatest depth rounded to 5 m intervals) at each station. Plots showing concentrations of nutrients at the mixing zone boundary are provided in Appendix E, Figures E-11 to E-26 in the Water Quality Report (Golder 2014b).

2.4 QUALITY ASSURANCE/QUALITY CONTROL

The Quality Assurance Project Plan (QAPP) Version 2.0 (Golder 2013a) outlined the quality assurance/quality control (QA/QC) procedures employed to support the collection of scientifically-defensible and relevant data required to meet the objectives of the AEMP Study Design Version 3.0 (Golder 2011a). The QAPP is designed so that field sampling, laboratory analysis, data entry, data analysis, and report preparation activities produce technically sound and scientifically defensible results. A description of the QA/QC program is provided in Appendix A.

2.5 WEIGHT OF EVIDENCE INPUT

Results of the indicators of eutrophication survey feed into the Weight of Evidence (WOE) assessment, which is described in the Weight of Evidence Report (Golder 2014c). The WOE integrates results from the AEMP components to help understand the underlying cause(s) of biological responses. Whereas the annual report for each AEMP component assesses the effects separately to determine if changes in individual components are meaningful, the WOE approach integrates measures of exposure (e.g., water quality, sediment quality) with measures of biological response (e.g., plankton, benthos, fish) to assess the underlying causes of biological changes. These biological changes can reflect either nutrient enrichment or toxicological impairment effects. Thus, the WOE will provide the strength of evidence for toxicological impairment or nutrient enrichment associated with observed changes. It is not intended to reflect the ecological significance or level of concern associated with a given change.

The WOE assessment is undertaken by applying a rating scheme to determine the degree of change in individual AEMP components. It then proceeds to integrate the individual component ratings into an overall score. The methods as applied to indicators of eutrophication are described in Section 2 of the Weight of Evidence Report.

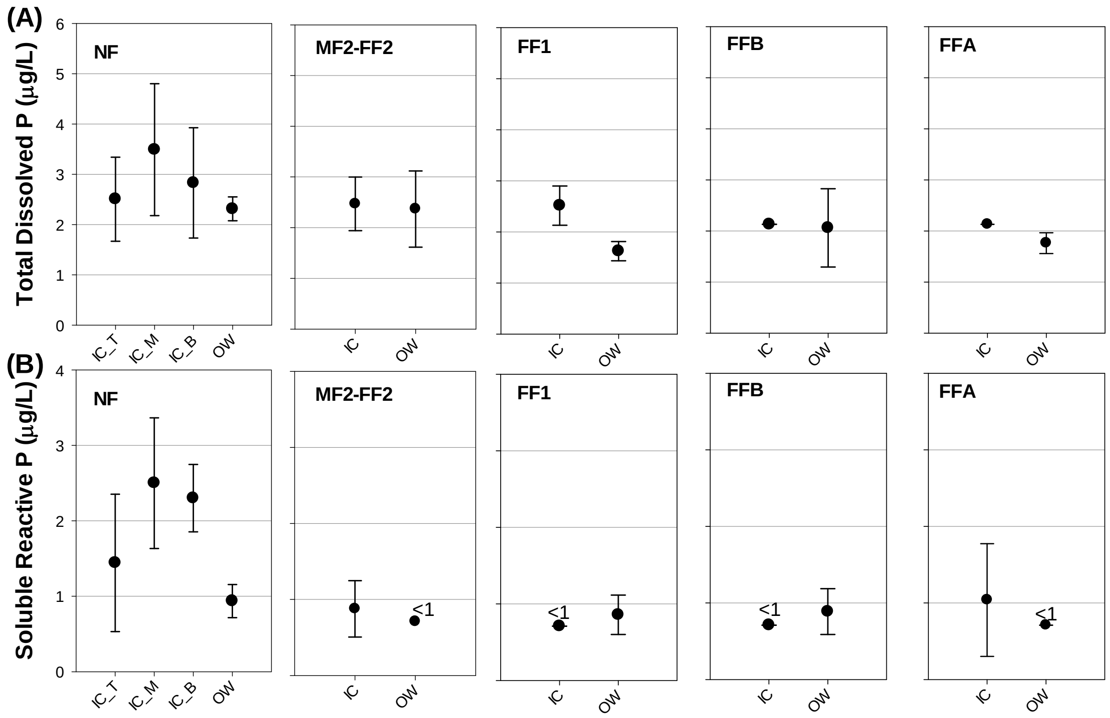
3 RESULTS

3.1 WATER CHEMISTRY

Phosphorus and nitrogen enter Lac de Gras with Mine effluent throughout the year, although seasonal cycles of effluent concentrations are apparent (Golder 2011b). This may be seen by the higher concentrations of total dissolved phosphorus (Figure 3-1A, Appendix D) and total dissolved nitrogen (Figure 3-2A, Appendix D) in the NF area, particularly during the ice-cover period. Total dissolved phosphorus concentrations in the reference areas under ice-cover ranged from 2.1 µg/L at FFA and FFB to 2.5 µg/L at FF1, whereas concentrations in the NF exposure area ranged from 2.5 µg/L (at the top depth) to a maximum value of 3.5 µg/L (at the middle depth). Since a major proportion of the dissolved phosphorous is molybdate-reactive (soluble reactive phosphorus), much of this dissolved phosphorus is likely in a suitable form for stimulating algal growth (Figure 3-1B). The observed decrease in total dissolved phosphorus and soluble reactive phosphorus in exposure areas during the open-water season suggests that much of the dissolved phosphorus being discharged is being assimilated by algae. Concentrations of TP followed a similar spatial pattern as seen in previous years (Golder 2011b), with significantly greater concentrations in the NF exposure area compared to the reference areas (Figure 3-3A, Tables 3-1 and 3-2).

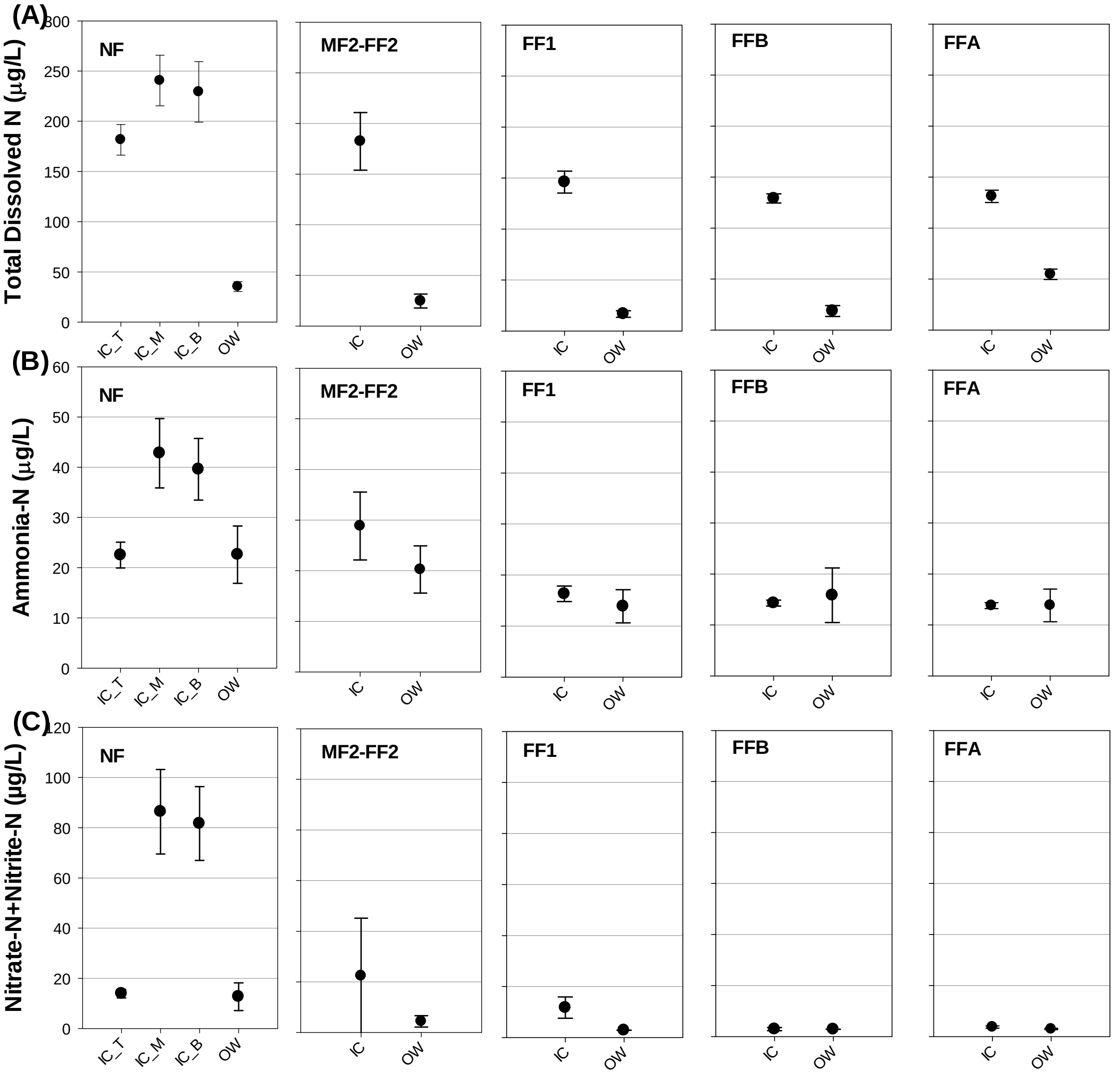
Dissolved nitrogen entering the lake from the Mine effluent includes ammonia and nitrate-nitrite (as reflected in the NF area during ice-cover, Figure 3-2B,C). As with phosphorus, dissolved nitrogen concentrations decreased from the ice-cover to the open-water season, and ammonia and nitrate-nitrite were essentially depleted in most areas by the time sampling took place in August. Most of the nitrate-nitrite available for algal uptake in the exposure areas appears to be originating from the effluent. The contribution of ammonia to the lake from the effluent was less pronounced (based on concentration differences among areas), although the effluent as a source of ammonia in the NF area was still apparent. Total nitrogen concentrations were significantly greater in the NF exposure area compared to reference areas during both the ice-cover and open-water seasons (Figure 3-3B, Tables 3-1 and 3-2).

Figure 3-1 Concentrations (Mean ± SD) of Total Dissolved Phosphorus (A), and Soluble Reactive Phosphorus (B) in Lac de Gras, 2013



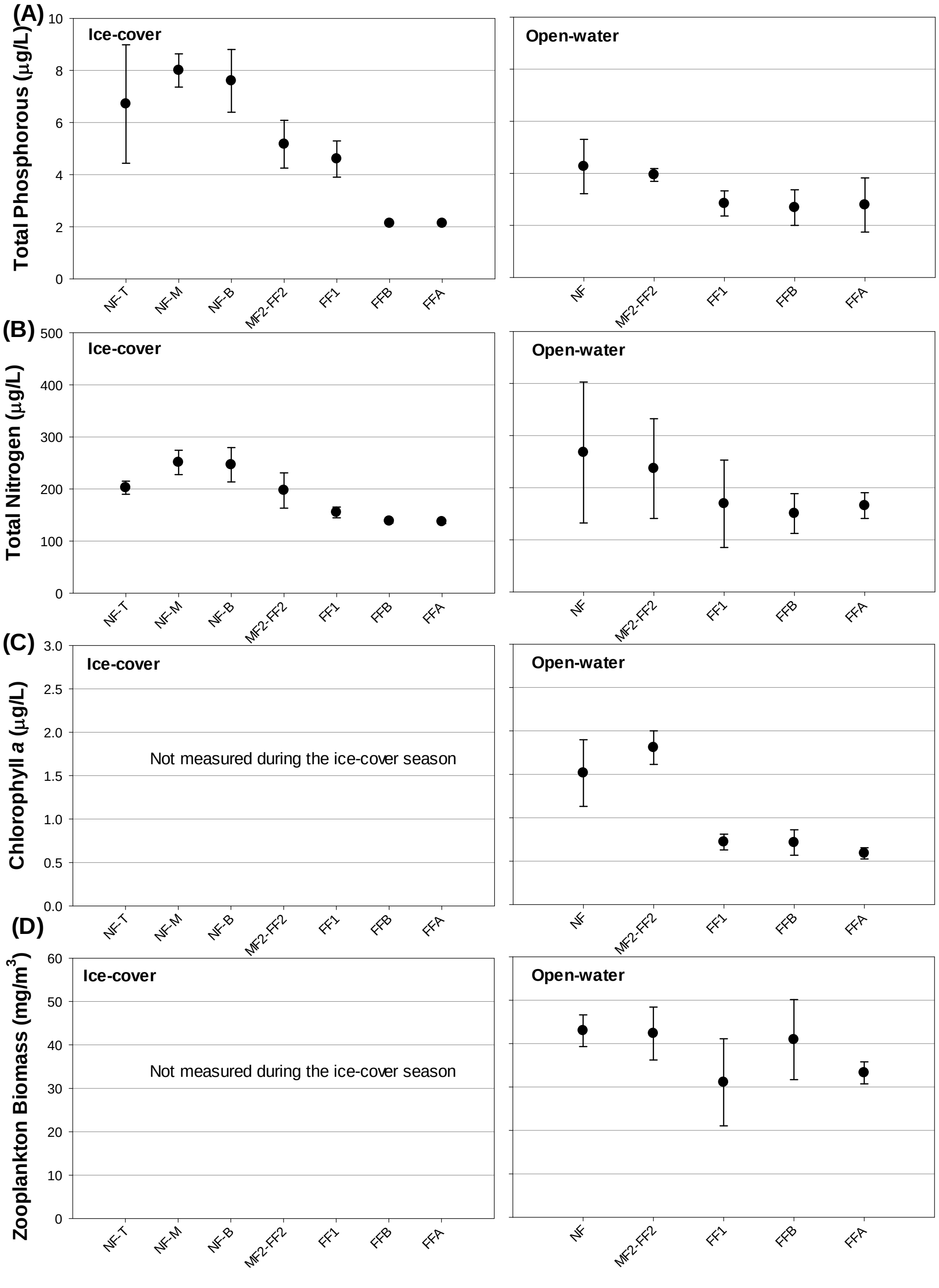
Notes: NF = near-field; MF = mid-field; FF = far-field; µg/L = micrograms per litre; IC = ice-cover sampling from top (T), middle (M) or bottom (B) depths, samples analyzed by the UofA. OW= open-water season, depth- integrated samples collected and analyzed by Maxxam. Soluble reactive P was analyzed by Maxxam as ortho-phosphorus during the OW (see text for details). Standard deviation at MF2-FF2 calculated from four samples, all other stations standard deviation based on five samples.

Figure 3-2 Concentrations (Mean ± SD) of Total Dissolved Nitrogen (A), Ammonia (B), and Nitrate-Nitrite (C) in Lac de Gras, 2013



Notes: NF = near-field; MF = mid-field; FF = far-field; µg/L = micrograms per litre; IC = ice-cover sampling from top (T), middle (M) or bottom (B) depths, samples analyzed by the UofA. OW= open-water season, depth- integrated samples collected and analyzed by Maxxam. Soluble reactive P was analyzed by Maxxam as ortho-phosphorus during the OW (see text for details). Standard deviation at MF2-FF2 calculated from four samples, all other stations standard deviation based on five samples.

Figure 3-3 Mean (± SD) Concentrations of Total Phosphorus (A), Total Nitrogen (B) and Chlorophyll *a* (C), and Zooplankton Biomass (Ash-Free Dry Mass) (D) in Lac de Gras, 2013



Notes: NF = near-field; MF = mid-field; FF = far-field; µg/L = micrograms per litre; Ice-cover = ice-cover sampling from top (T), middle (M) or bottom (B) depths; samples analyzed by the UofA. OW= open-water season, depth-integrated samples collected and analyzed by Maxxam. Soluble reactive P was analyzed by Maxxam as ortho-phosphorus during the OW (see text for details). Standard deviation at MF2-FF2 calculated from four samples, at all other stations, standard deviation based on five samples. The detection limits for total phosphorous differed between the open-water and under-ice seasons, due to differences between labs. For samples collected during the ice-cover season the detection limit was 3.0 µg/L, in the open-water season the detection limit was 2.0 µg/L.

Table 3-1 Concentrations of Total Phosphorus, Total Nitrogen and Chlorophyll *a*, and Zooplankton Biomass (Ash-Free Dry Mass) in Lac de Gras, 2013

Variable	Unit	Near-Field (NF)		Mid-field 2-Far-Field 2 (MF2-FF2)		Far-Field 1 (FF1)		Far-Field A (FFA)		Far-Field B (FFB)	
		n	Mean ± SD	n	Mean ± SD	n	Mean ± SD	n	Mean ± SD	n	Mean ± SD
Total phosphorus, Ice-cover (a)	µg/L	5	8.0 ± 0.64	4	5.2 ± 0.92	5	4.6 ± 0.70	5	2.13 ± 0.0	5	2.13 ± 0.0
Total phosphorus, Open-water	µg/L	5	4.26 ± 1.0	4	3.94 ± 0.25	5	2.8 ± 0.48	5	2.8 ± 1.0	5	2.7 ± 0.68
Total nitrogen, Ice-cover (b)	µg/L	5	251 ± 23	4	197 ± 34	5	155 ± 10	5	137 ± 3	5	138 ± 4
Total nitrogen, Open-water	µg/L	5	268 ± 135	4	197 ± 31	5	155 ± 10	5	166 ± 25	5	150 ± 38
Chlorophyll *a*, Ice-cover (c)	µg/L	0	n/a	0	n/a	0	n/a	0	n/a	0	n/a
Chlorophyll *a*, Open-water	µg/L	5	1.52 ± 0.38	4	1.81 ± 0.19	5	0.72 ± 0.09	5	0.59 ± 0.06	5	0.71 ± 0.15
Zooplankton, Ice-cover(c)	mg/m^3	0	n/a	0	n/a	0	n/a	0	n/a	0	n/a
Zooplankton, Open-water	mg/m^3	5	43 ± 4	4	42 ± 6	5	31± 10	5	33 ± 3	5	41 ± 9

Notes: SD = standard deviation; n/d = not determined; n/a = not available; µg/L = micrograms per liter; mg/m^3 = milligrams per cubic metre.

a) Values for the NF area of the TP samples are for the top-depth sample, which had the highest concentrations among the three sampling depths. Only mid-depth samples were collected at the other four areas. The open-water samples were depth integrated.

b) Values for the NF area of the TN samples are for the bottom-depth sample, which had the highest concentrations among the three sampling depths. Only mid-depth samples were collected at the other four areas. The open-water samples were depth integrated.

c) Samples for zooplankton and chlorophyll *a* were not collected under ice-cover conditions.

Table 3-2 Statistical Comparisons of Concentrations of Total Phosphorus, Total Nitrogen, Chlorophyll *a* and Zooplankton Biomass (Ash-Free Dry Mass) in Lac de Gras, 2013

Variable	Statistical Test[(a)]	Exposure Area vs. Reference Area Comparisons[(b)]	Reference Area vs. Reference Area Comparison	Exposure Area greater than Upper boundary of the Normal Range[(c)]
		NF vs. FFA+FFB+FF1	FFA vs. FFB vs. FF1	
		***P*[(d)]**	***P*[(d)]**	
Total phosphorus, Ice-cover	KW	**	*[(FFA = FFB) ≠ FF1]	Yes
Total phosphorus, Open-water	ANOVA^{log}	*	ns	No
Total nitrogen, Ice-cover	KW	**	ns	Yes
Total nitrogen, Open-water	KW	*	ns	Yes
Chlorophyll *a*, Ice-cover (e)	n/d	n/d	n/d	n/d
Chlorophyll *a*, Open-water	ANOVA^{log}	***	ns	Yes
Zooplankton, Ice-cover (e)	n/d	n/d	n/d	n/d
Zooplankton, Open-water	KW	*	ns	No

Notes: SD = standard deviation; NF = near-field; MF = mid-field; FF = far-field; Y = yes; N = no; n/d = not determined.

a = ANOVA = Analysis of Variance (log-transformed data indicated by superscript); KW = Kruskal-Wallis test.

b = For the NF area the top-depth values for TP and the bottom-depth values for TN were used because they had the highest concentrations among the three sampling depths.

c = The normal range was calculated using the pooled reference area mean plus two standard deviations from August 15 to September 15, 2007 to 2010.

d = Probability of Type 1 Error for Planned Comparisons (ANOVA and KW Test; NF vs. Reference): * = <0.1, ** = <0.01, *** = <0.001, **** = <0.0001. Probability of Type 1 Error for unplanned comparisons (ANOVA [Tukey's HSD Method]; reference vs. reference comparison): * = <0.1, ** = <0.01, *** = <0.001, **** = <0.0001. Probability of Type 1 Error for unplanned Comparisons (KW Test; reference vs reference comparisons) * = <0.15, ** = <0.01, *** = <0.001.

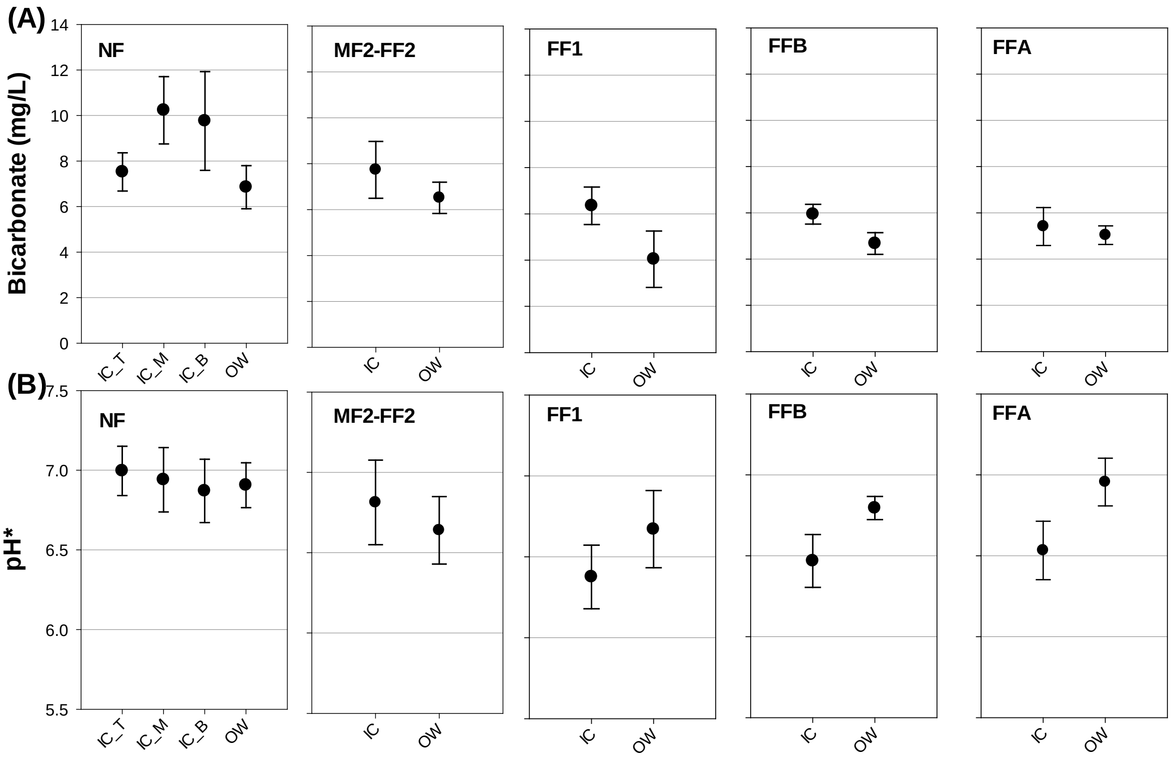
e = Samples for zooplankton and chlorophyll *a* were not collected under ice-cover conditions.

Bicarbonate concentrations were low throughout the lake although, as with inorganic nitrogen and phosphorus, they were greater in the exposure areas (Figure 3-4A). Figure 3-4A). A seasonal pattern was evident, with greater concentrations during the ice-cover season. When phytoplankton begin to grow during the open-water season, uptake of dissolved inorganic carbon by the phytoplankton would have caused a decrease in carbon dioxide, resulting in an increase in pH; however, this change in pH was only observed in the reference areas (Figure 3-4B). It may be that bicarbonate concentrations were sustained throughout the open-water season in the exposure areas due to effluent. As a consequence, the increase in pH typically associated with a decrease in carbon dioxide was not observed in the NF exposure area.

Concentrations of major ions (e.g., calcium, magnesium, sodium, potassium, and chloride) were generally greater during ice-cover compared to the open-water season (Golder 2014b). Chloride concentrations were less than 10% of the benchmark for the protection of aquatic life (120 milligrams per litre [mg/L]; Golder 2014b). The pattern of greater ion concentrations under ice-cover is reflected in the conductivity profiles taken in each sampling area (Figure 3-5B). The input of these elements from the effluent is also apparent in the NF profile, in which conductivity is elevated at the mid to bottom depths (Figure 3-5B).

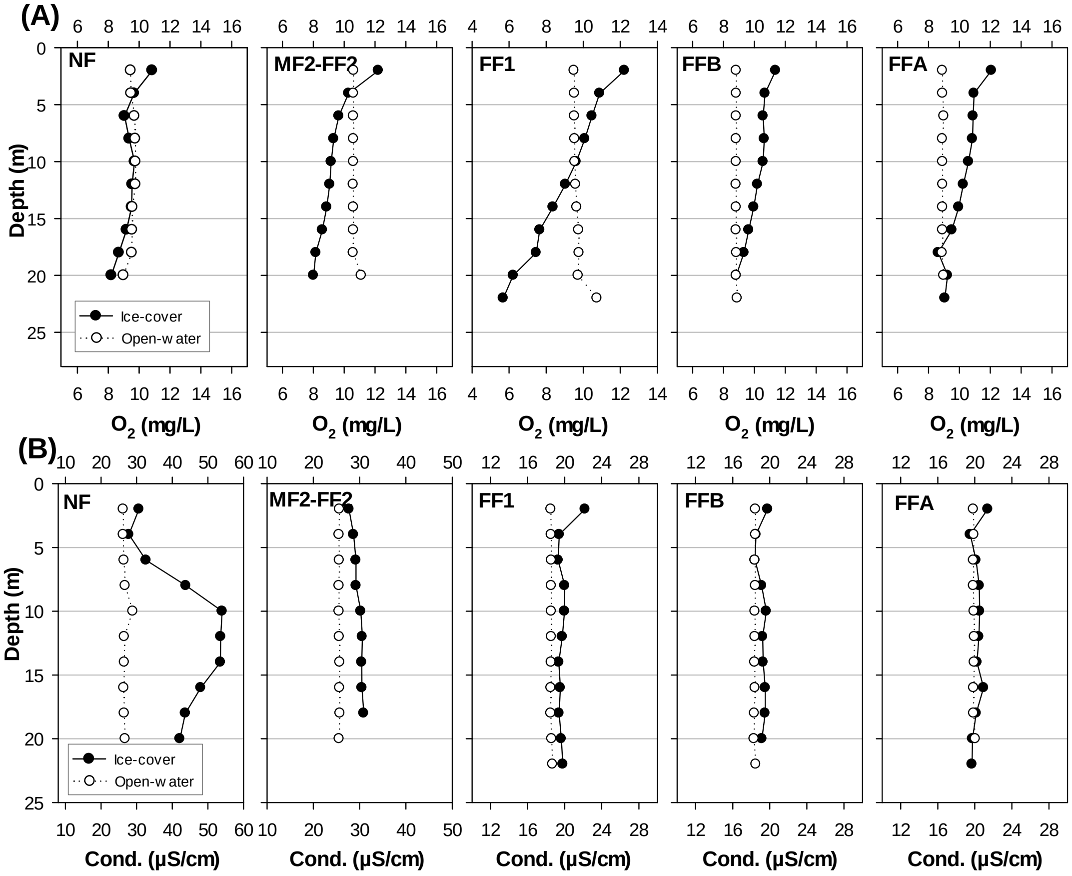
The water column appeared to remain generally well oxygenated throughout the year (Figure 3-5A); however, there was a sharp decline in oxygen concentrations towards the bottom in the FF1 area under ice-cover. A similar decline was also observed in 2011 and 2012 in the FF1 area. The ice-cover gradient, seen in all areas of the lake, likely reflects a combination of the input of oxygen at the surface as water freezes and the uptake of oxygen at the bottom as organic matter decomposes. The oxygen profile gradient was less pronounced at the NF area likely because of the well-oxygenated effluent that concentrates at lower depths under ice-cover in the NF area (Figure 3-5B; Golder 2014b).

Figure 3-4 Mean Concentrations of Bicarbonate (± SD; A), and Mean pH (± Data Range; B) in Lac de Gras, 2013



Notes: IC = ice-cover sampling from top (T), middle (M) or bottom (B) depths; samples analyzed by the UofA. OW= open-water season from depth-integrated samples; samples analyzed by Maxxam. pH based on field profile data: Top depth = 2 to 6 m, Middle depth = 8 to 12 m, bottom depth = 14 to 20 m. Bicarbonate samples for the Open-water period consist of top and middle depth samples. NF = near-field; MF = mid-field; FF = far-field; LDS = Lac du Sauvage.

Figure 3-5 Dissolved Oxygen (O_2) Concentration (A) and Conductivity (B) in Lac de Gras during the Ice-cover and the Open-Water Seasons, 2013



Notes: µS/cm = microSiemens per centimetre; m = metre. NF = near-field; MF = mid-field; FF = far-field; Cond. = conductivity; O_2 = dissolved oxygen.

3.2 CHLOROPHYLL *a* AND ZOOPLANKTON BIOMASS

Phytoplankton standing crops in Lac de Gras, as measured by chlorophyll *a* concentrations, were not measured during the ice-cover season, since ice and snow reduce the amount of light entering the lake to a fraction of surface solar radiation; consequently, algal growth under ice-cover is limited by light, and chlorophyll *a* concentrations have been found to be very low throughout Lac de Gras during this season (Golder 2008). There were significantly greater Chlorophyll *a* concentrations in the NF exposure area compared to concentrations in the reference areas (Figure 3-3C, Tables 3-1 and 3-2). This increased algal growth reflects the increased levels of dissolved nutrients in these areas. Chlorophyll *a* concentrations in the NF exposure area were greater than 1.5 µg/L compared to a maximum mean value of 0.72 µg/L in the reference areas (Figure 3-3C, Tables 3-1 and 3-2, Appendix D).

Zooplankton biomass in the NF exposure area was also significantly greater than in the reference areas of Lac de Gras (Figure 3-3D, Tables 3-1 and 3-2). Substantially greater zooplankton biomass was observed at station MF1-3 compared to other stations in Lac de Gras. This was also observed in the calculated zooplankton biomass data presented in the Plankton report (Golder 2014d). The increased biomass at MF1-3 is likely the result of a natural clustering of zooplankton encountered at that station during sampling.

3.3 SPATIAL ANALYSIS IN LAC DE GRAS

During the open-water season, concentrations of chlorophyll *a* in the NF exposure-area exceeded the upper boundary of the normal range (Table 3-2; Figure 3-6A). Concentrations of chlorophyll *a* were elevated along a line running from NF to FF2, suggesting that the effluent effects are reaching the entire northeast portion of Lac de Gras (MF2-FF2 Transect in Figure 3-6A). Elevated chlorophyll *a* concentrations were also observed to the northwest portion along the MF1-FF1 transect, reaching a portion of Lac de Gras between MF1-1 and MF1-3. Chlorophyll *a* concentrations were also elevated running in the southwest direction, reaching a portion of Lac de Gras between MF3-4 and MF3-5 along the MF3-FFB-FFA transect.

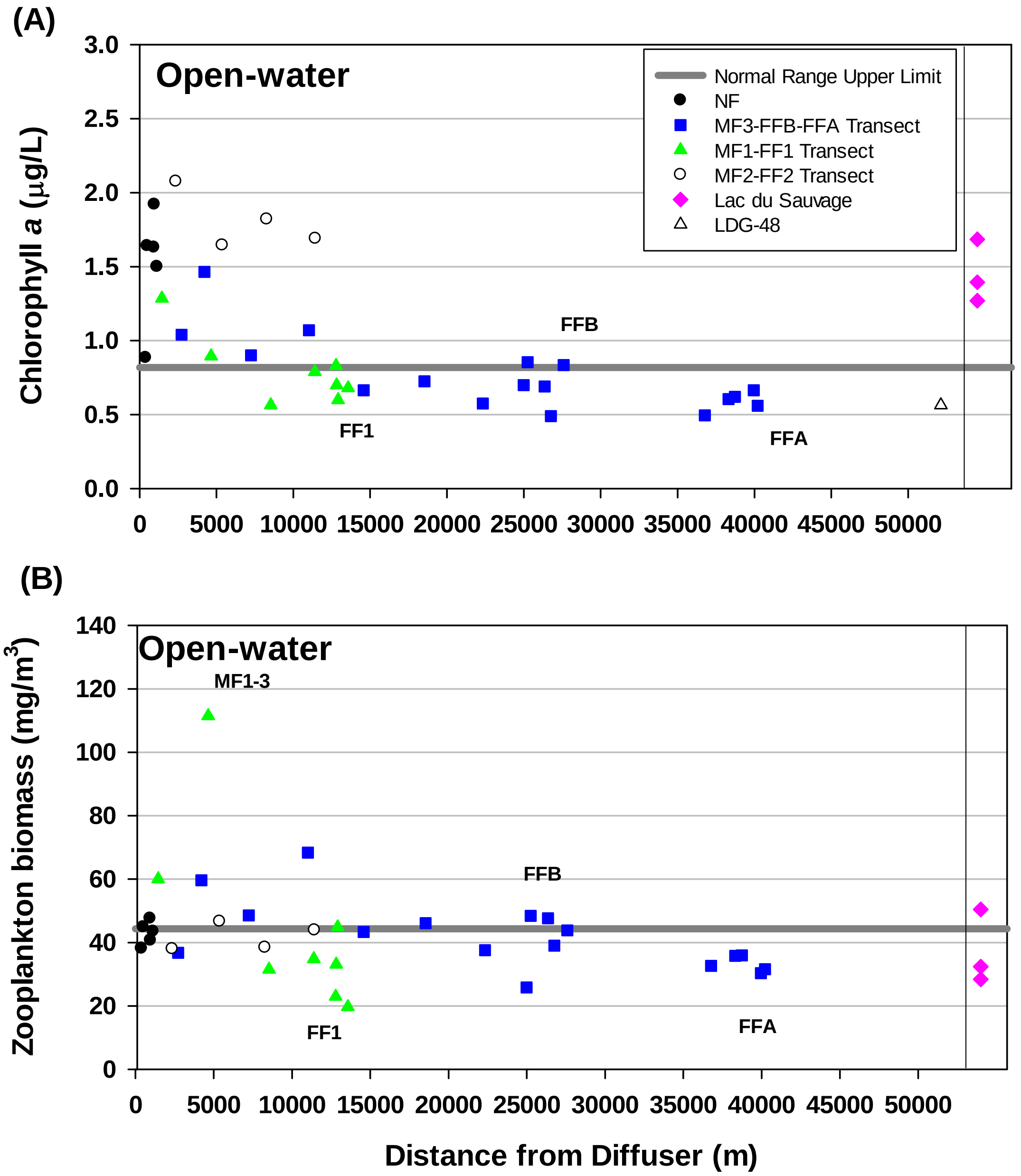
Although a significant difference was observed in zooplankton biomass between the NF and 2013 reference areas, biomass in the NF area was below the upper bound of the normal range (based on 2009 and 2010 data). Zooplankton biomass along the MF2-FF2 transect was similar to that in the NF area, suggesting that the effluent effects on zooplankton are reaching the entire northeast portion of Lac de Gras (Figure 3-6B). Zooplankton biomass was also above the normal range at MF1-1 and MF1-3 stations, along the MF1-FF1 transect. Zooplankton biomass was elevated at many of the MF stations in the southwest direction, along the MF3-FFB-FFA transect, but returned to background between the MF3-6 and MF3-7 stations.

During the ice-cover season TP concentrations in the NF exposure area exceeded the upper bound of the normal range at all depths (Figure 3-7). The greatest extent of effects were observed at the top depth, where concentrations of TP decreased along the MF3-FFB-FFA transect and returned to background levels at MF3-2 station. Total phosphorus concentrations were below the upper limit of the normal range along the MF2-FF2 and MF1-FF1 transects.

Concentrations of TN decreased with distance from the diffuser at all depths under ice-cover (Figure 3-8). Concentrations of TN exceeded the upper bound of the normal range at the bottom and mid depths in the NF exposure area, but remained within the normal range at the top depth. The greatest extent of effects under ice-cover were observed at the bottom depth, where concentrations of TN were above the normal range at MF1-1, MF3-1 and MF2-1 stations.

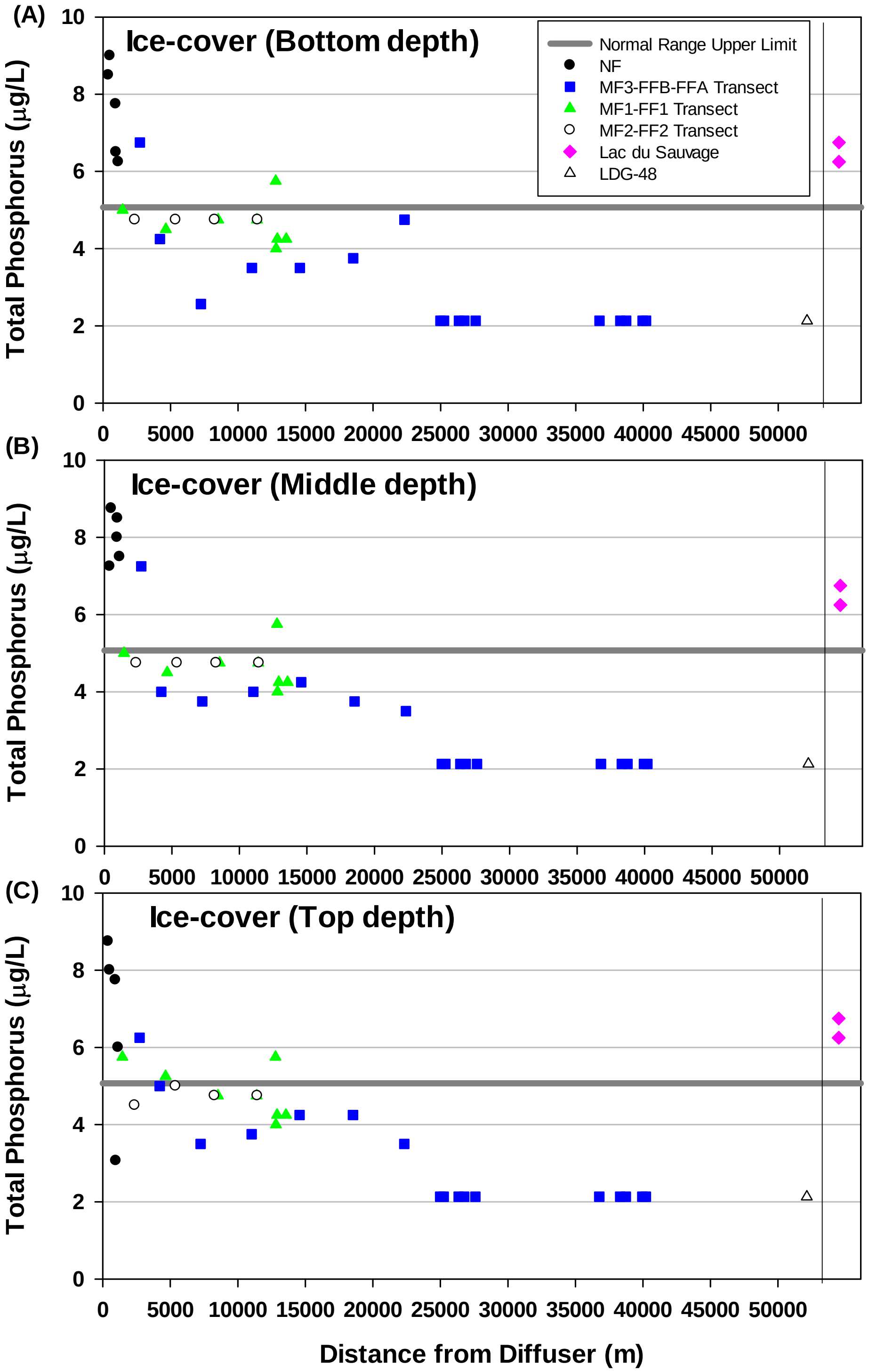
During the open-water season concentrations of TP were all below the upper bound of the normal range (Figure 3-9B). Concentrations of TN were more variable during the open-water period compared to the ice-cover period. As described in Golder (2014b), this is a result of the different laboratory used for the open-water samples. In three years of ammonia analyses by Maxxam (2011, 2012 and 2013), concentrations in blank samples were at or above levels found in Lac de Gras, and the concentrations reported for lake water samples were elevated compared to historic values. This is seen by the two stations at FFB and the majority of stations in the FFA reference area with concentrations above the normal range. Consequently, the extent of effects were based on the ice-cover data.

Figure 3-6 Chlorophyll *a* Concentrations (A) and Zooplankton Biomass (Ash-Free Dry Mass) (B) in Lac de Gras and Lac du Sauvage According to Distance from the Effluent Discharge during the Open-Water Season, 2013



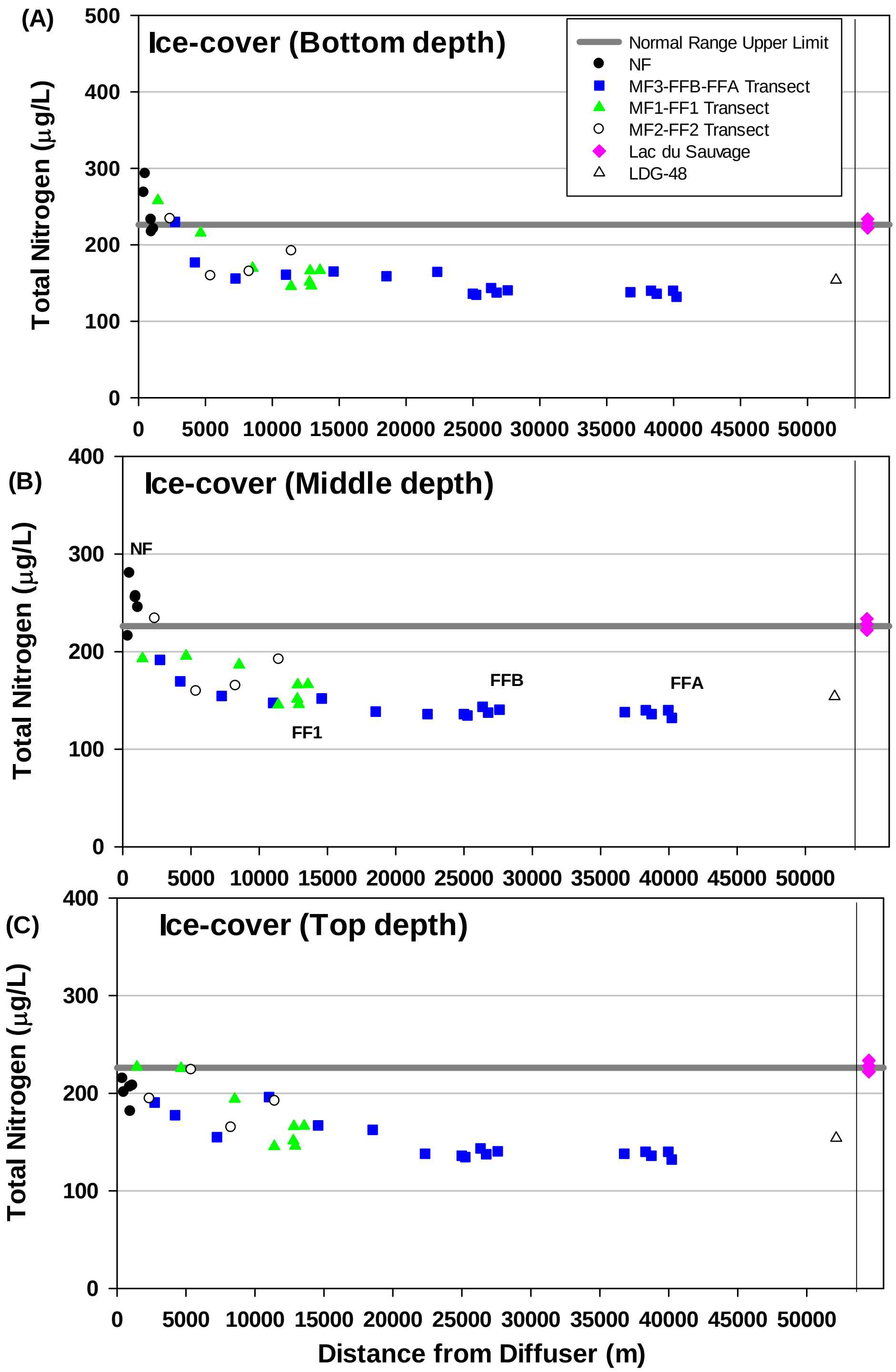
Notes: µg/L = micrograms per litre; mg/m^3 = milligrams per cubic metre; m = metre. No zooplankton samples collected at station LDG48.

Figure 3-7 Total Phosphorus Concentrations in Lac de Gras and Lac du Sauvage According to Distance from the Effluent Discharge during the Ice-cover Season, 2013



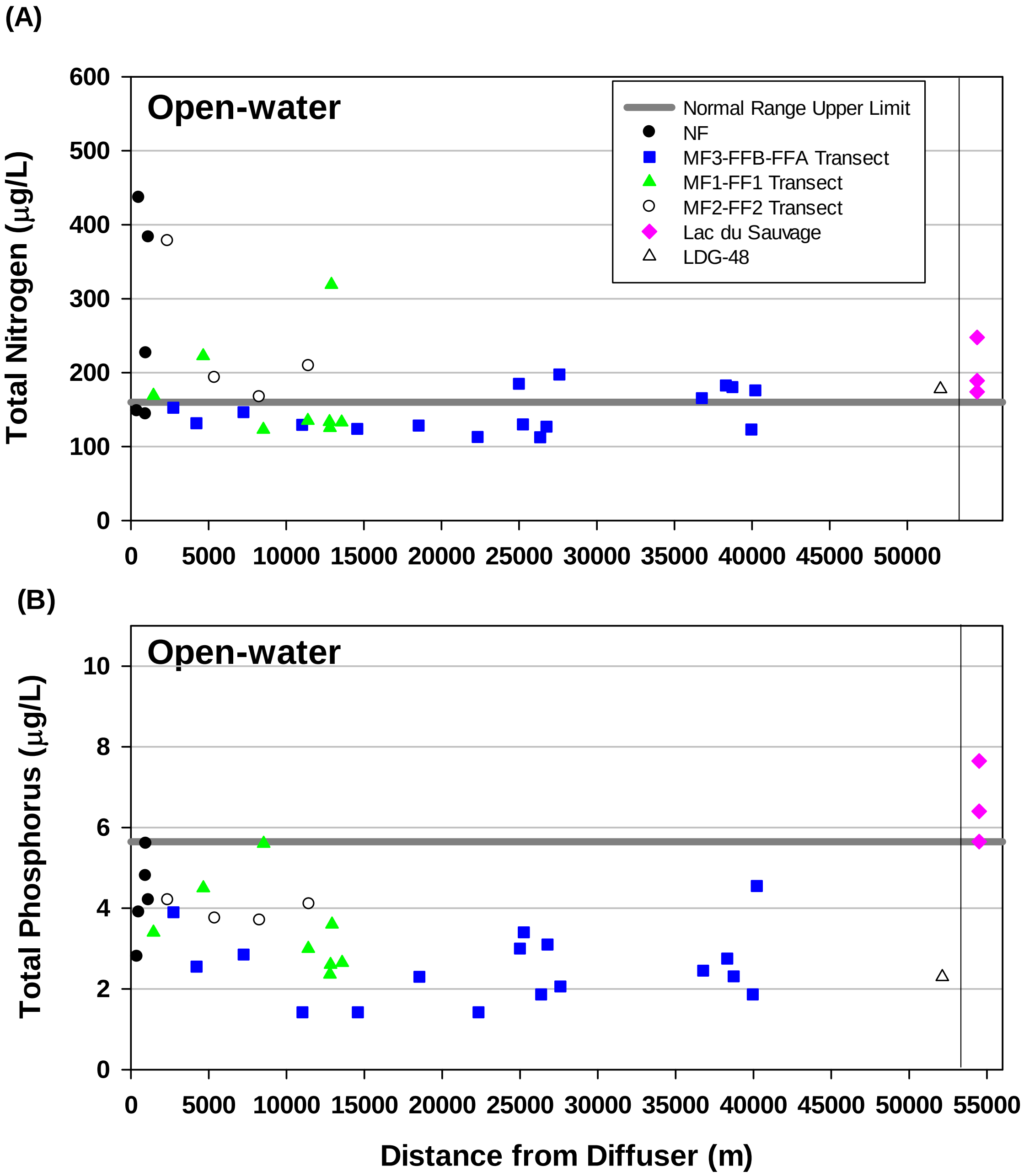
Notes: µg/L = micrograms per litre; m = metre.

Figure 3-8 Total Nitrogen Concentrations in Lac de Gras and Lac du Sauvage According to Distance from the Effluent Discharge during the Ice-cover Season, 2013



Notes: µg/L = micrograms per litre; m = metre.

Figure 3-9 Total Nitrogen (A) and Total Phosphorous (B) in Lac de Gras and Lac du Sauvage According to Distance from the Effluent Discharge during the Open-Water Season, 2013

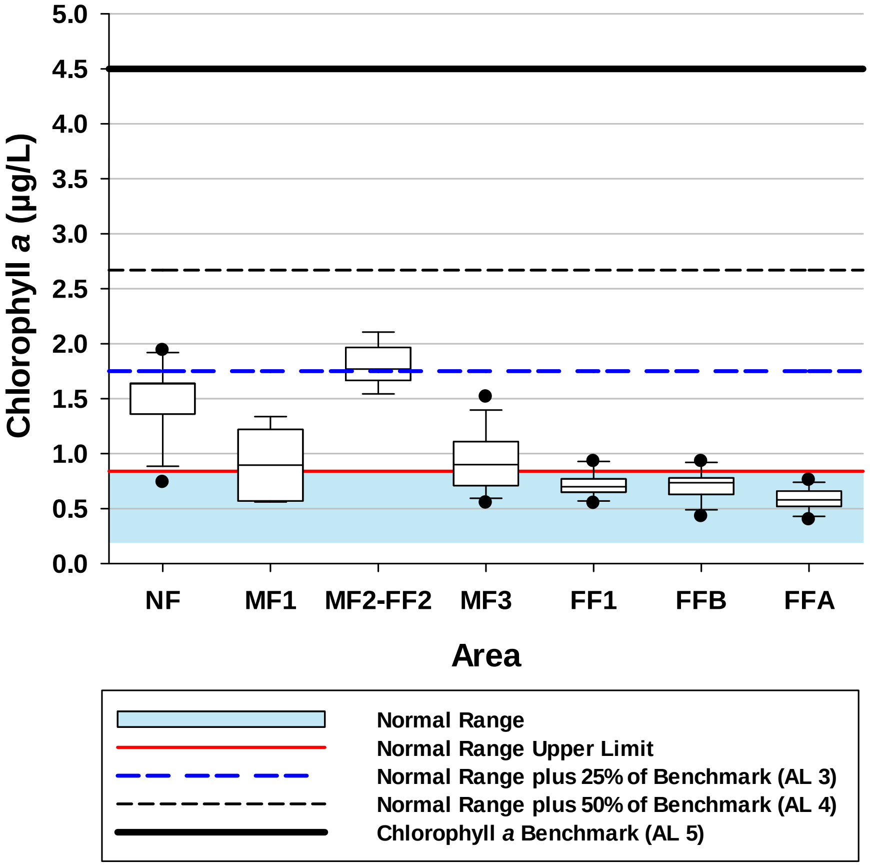


Notes: µg/L = micrograms per litre; m = metre.

3.4 ACTIONS LEVELS FOR EUTROPHICATION

Current conditions indicate that an Action Level 2 has been reached. An Action Level 2 is identified when chlorophyll *a* concentrations in the NF and MF exposure areas representing more than 20% of the lake area are greater than the normal range. In 2013, 24.9% of the lake area had, chlorophyll *a* concentrations uniformly greater than 0.82 µg/L (Figures 3-6A and 3-10; Table 3-3).

Figure 3-10 Chlorophyll *a* Concentrations by Area in Lac de Gras, 2013



Notes: µg/L = micrograms per Litre; normal range is calculated as the 2007 to 2010 pooled reference area mean +2 SDs.

Table 3-3 Action Levels Classification for Chlorophyll *a*, 2013

Action Level	Action Level Classification				2013 Assessment	
	Magnitude of Effect	Extent of Effects	Description	Value (µg/L)	Value (µg/L)	Extent of Effects
1	Top of normal range[a]	MF station	95th percentile of MF values greater than normal range	0.82	1.06	MF area
2	Top of normal range[a]	20% of lake area or more	NF and MF values greater than normal range	0.82	>0.82	24.9% of lake
3	Normal range plus 25% of benchmark[b]	20% of lake area or more	NF and MF values greater than normal range plus 25% of Effects Benchmark[b]	1.8	<1.8	0% of lake
4	Normal range plus 50% of benchmark[b]	20% of lake area or more	NF and MF values greater than normal range plus 50% of Effects Threshold[b]	2.7	<2.7	0% of lake
5	Benchmark	20% of lake area or more	NF and MF values greater than Effects Threshold	4.5	<4.5	0% of lake
6	Benchmark + 20%	20% of lake area or more	NF and MF values greater than Effects Threshold +20%	5.4	<5.4	0% of lake
7	Benchmark + 20%	All MF stations	95th percentile of MF values greater than Effects Threshold +20%	5.4	<5.4	MF area
8	Benchmark + 20%	Far-field B (FFB)	95th percentile of FFB values greater than Effects Threshold +20%	5.4	<5.4	FFB area
9	Benchmark + 20%	Far-field A (FFA)	95th percentile of FFA values greater than Effects Threshold+20%	5.4	<5.4	FFA area

Notes: <= less than; MF = mid-field; NF = near-field; FF = far-field;% = percent.

a) The normal range is calculated as the 2007 to 2010 pooled reference area mean +2 SD.

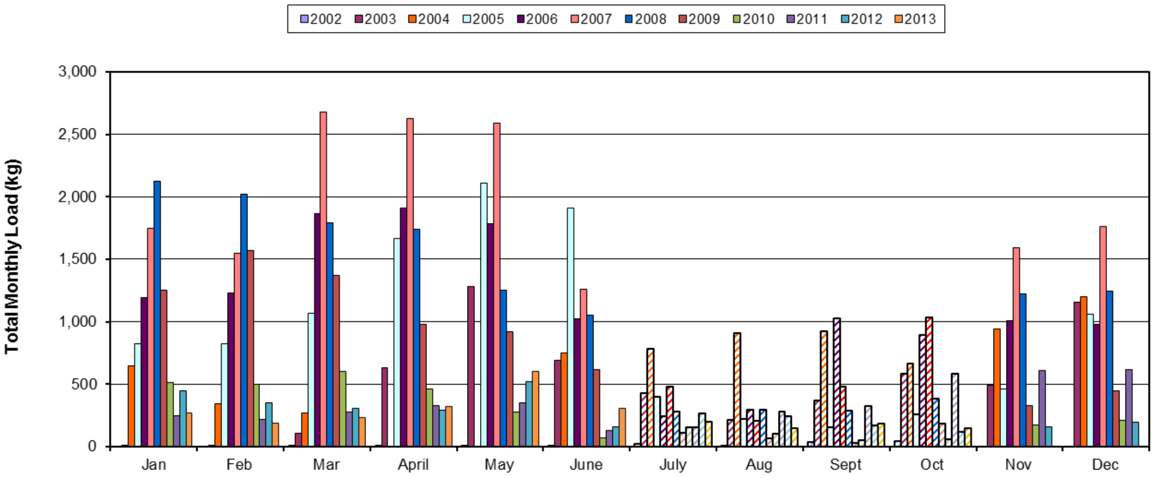
b) Indicates 25% or 50% of the difference between the benchmark and the top of the normal range.

3.5 NUTRIENT LOADING FROM EFFLUENT

Annual loads of ammonia (as nitrogen) to Lac de Gras increased from 2002 to 2007, but have since been decreasing in the effluent. In general, monthly loads of ammonia were greater during the ice-cover season compared to the open-water season (Figure 3-11). The monthly load of phosphorous has not exceeded the monthly criterion (300 kg/month) in any month from 2002 to 2013 (Figures 3-12 and 3-13). The highest monthly load (140 kg/month) occurred in May 2013. Total annual loads have increased from 41 to 710 kg/yr between 2002 and 2013. The TP load in 2013 (710 kg/yr) was the highest annual loading since 2002, but below the average annual loading criterion of 1,000 kg/yr.

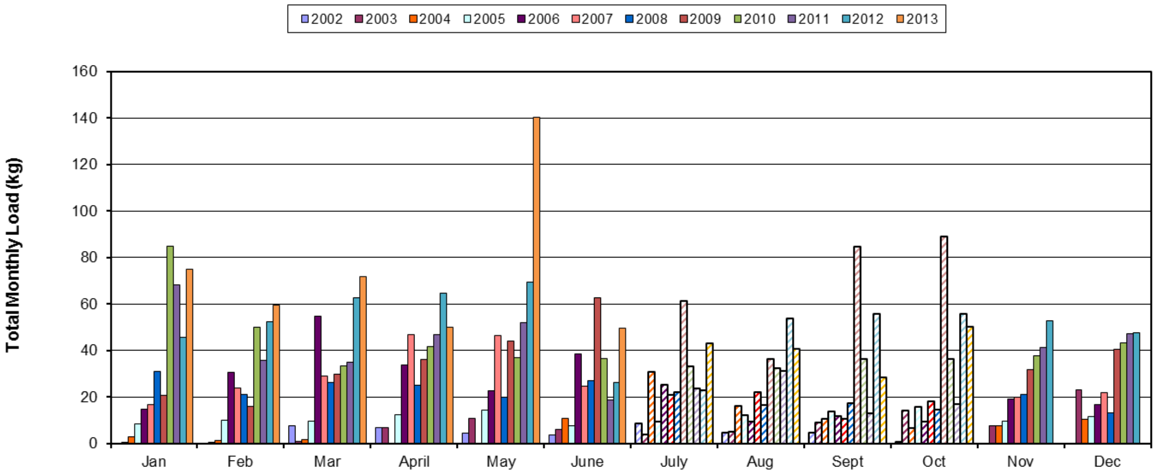
Monthly nitrate and nitrite loads to Lac de Gras followed a similar pattern, with greater loads observed during the open-water season (Figures 3-14 and 3-15) compared to the ice-cover season. Both nitrate and nitrite loads increased from March to July. Nitrogen-based ions can be variable in the discharge and can be influenced by the Mine discharge as well as by biological uptake.

Figure 3-11 Total Monthly Loads of Ammonia (Nitrogen) from the North Inlet Water Treatment Plant, 2002 to 2013



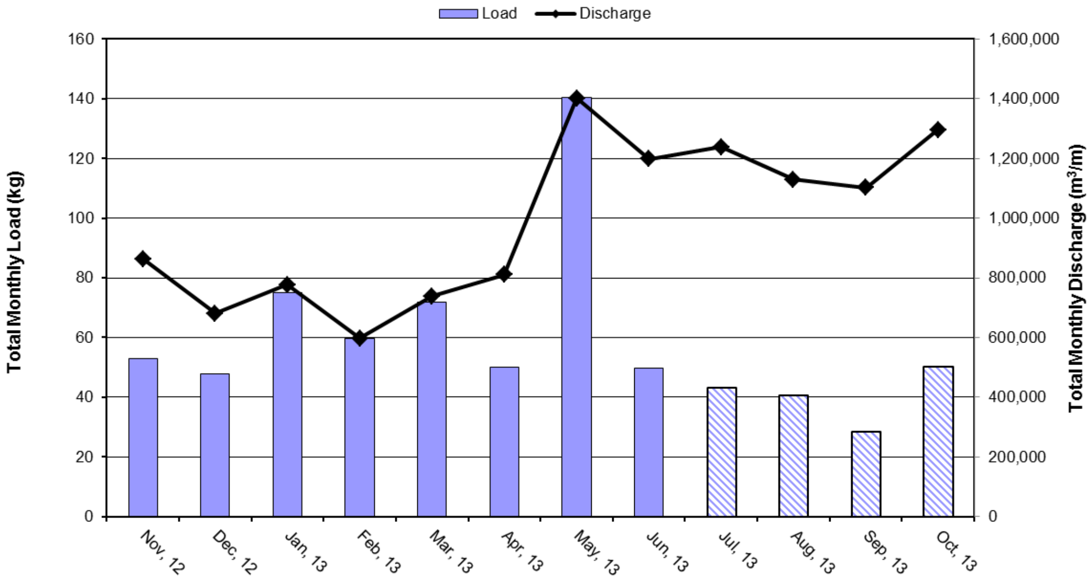
Notes: Solid bars = typical ice-cover season; striped bars = typical open-water season.

Figure 3-12 Total Monthly Loads of Phosphorus from the North Inlet Water Treatment Plant, 2002 to 2013



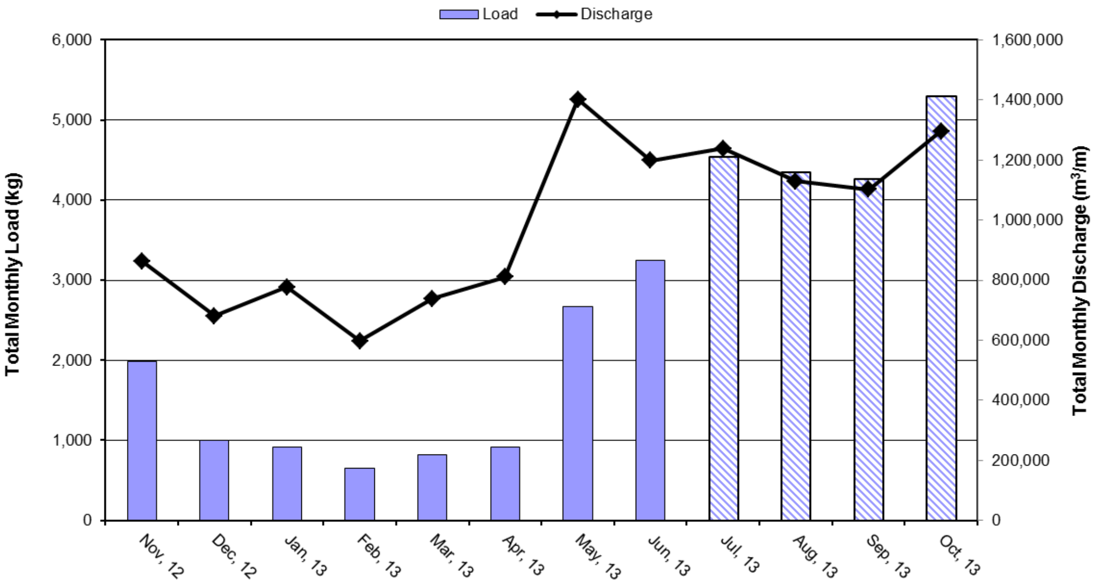
Notes: Solid bars = typical ice-cover season; striped bars = typical open-water season.

Figure 3-13 Total Monthly Loads of Phosphorus from the North Inlet Water Treatment Plant, 2013



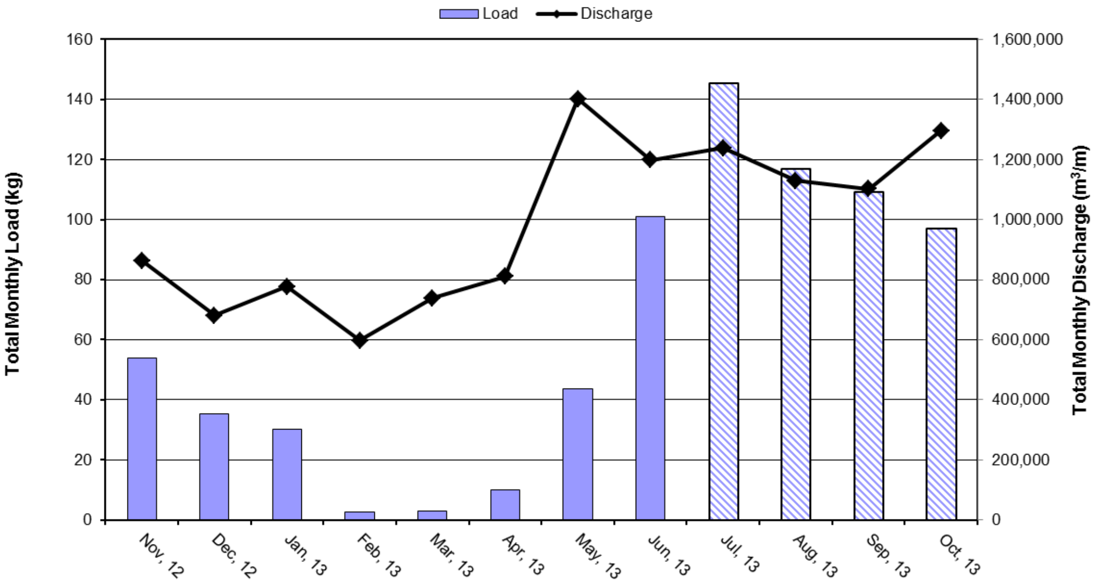
Notes: Solid bars = typical ice-cover season; striped bars = typical open-water season.

Figure 3-14 Total Monthly Loads of Nitrate (as Nitrogen) from the North Inlet Water Treatment Plant, 2013



Notes: kg = kilograms; m^3/m = cubic metres per month; solid bars = typical ice-cover season; striped bars = typical open-water season.

Figure 3-15 Total Monthly Loads of Nitrite (as Nitrogen) from the North Inlet Water Treatment Plant, 2013



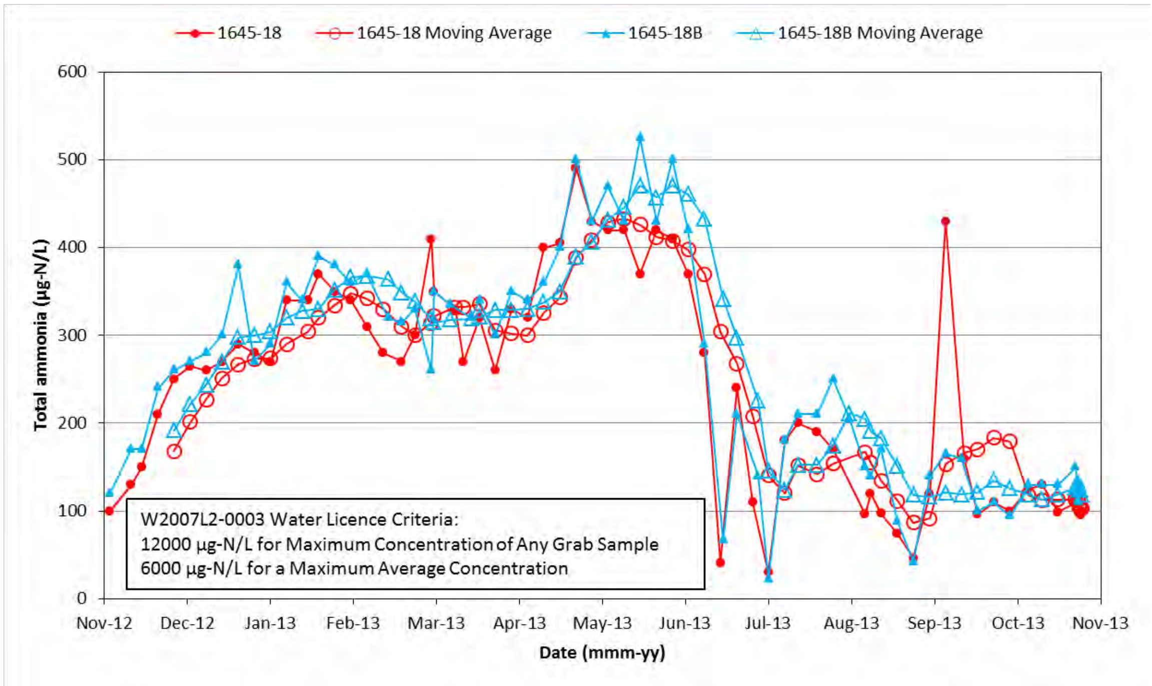
Notes: kg = kilograms; m^3/m = cubic metres per month; solid bars = typical ice-cover season; striped bars = typical open-water season.

3.6 NUTRIENT CONCENTRATIONS IN EFFLUENT

Effluent concentrations for nitrate (Figure 3-17) are presented to complement total ammonia (Figure 3-16) and nitrite concentrations (Figure 3-18), even though there are no discharge criteria for nitrate. Total phosphorus data (Figure 3-19) are presented because phosphorus is a regulated variable, although it does not have discharge criteria for maximum or maximum 5-day average concentrations. None of the effluent chemistry results from November 2012 to October 2013 at SNP 1645-18 and SNP 1645-18B were greater than applicable discharge criteria.

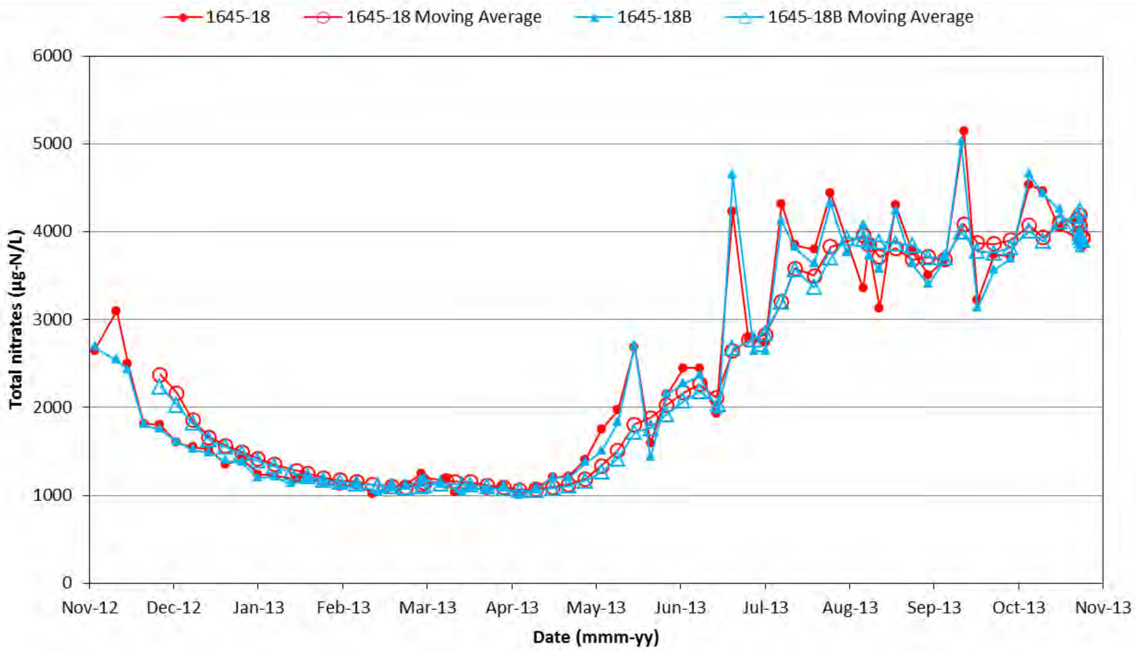
The concentrations of ammonia and TP at stations SNP 1645-18 and SNP 1645-18B were lower during the open-water season compared to ice-cover (Figures 3-16 and 3-19). The opposite pattern was apparent for nitrate and nitrite which increased from May to August (Figure 3-17 and 3-18).

Figure 3-16 Ammonia (as Nitrogen) Concentration Measured at SNP 1645-18 and 1645-18B, November 2012 to October 2013



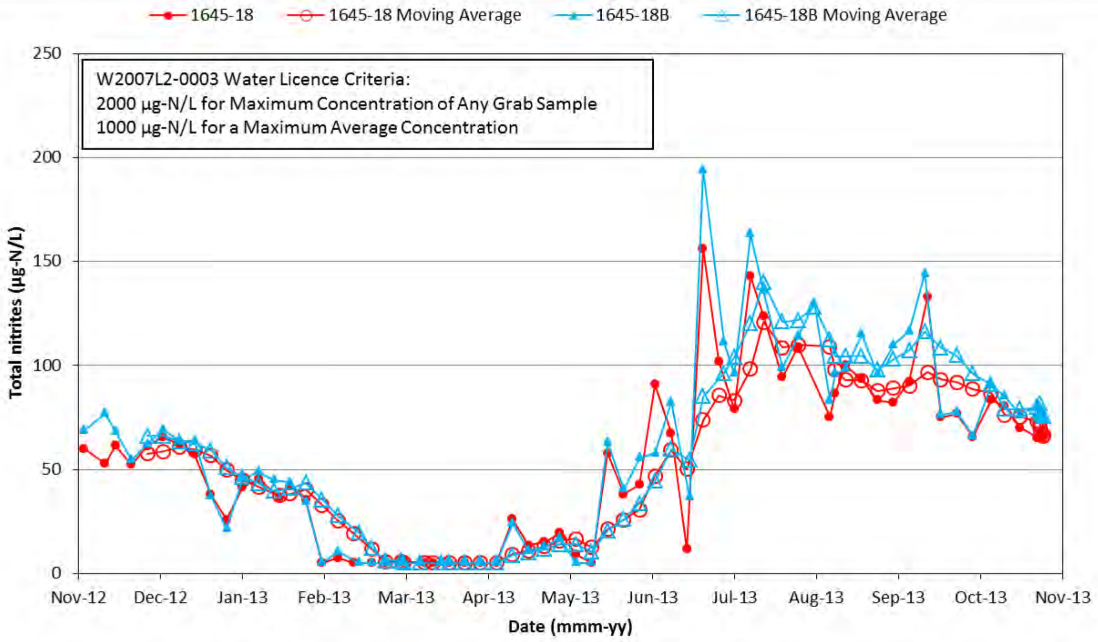
Notes: µg/L = micrograms per litre; Water Licence discharge criteria are shown in text box.

Figure 3-17 Nitrate Concentration Measured at SNP 1645-18 and 1645-18B, November 2012 to October 2013



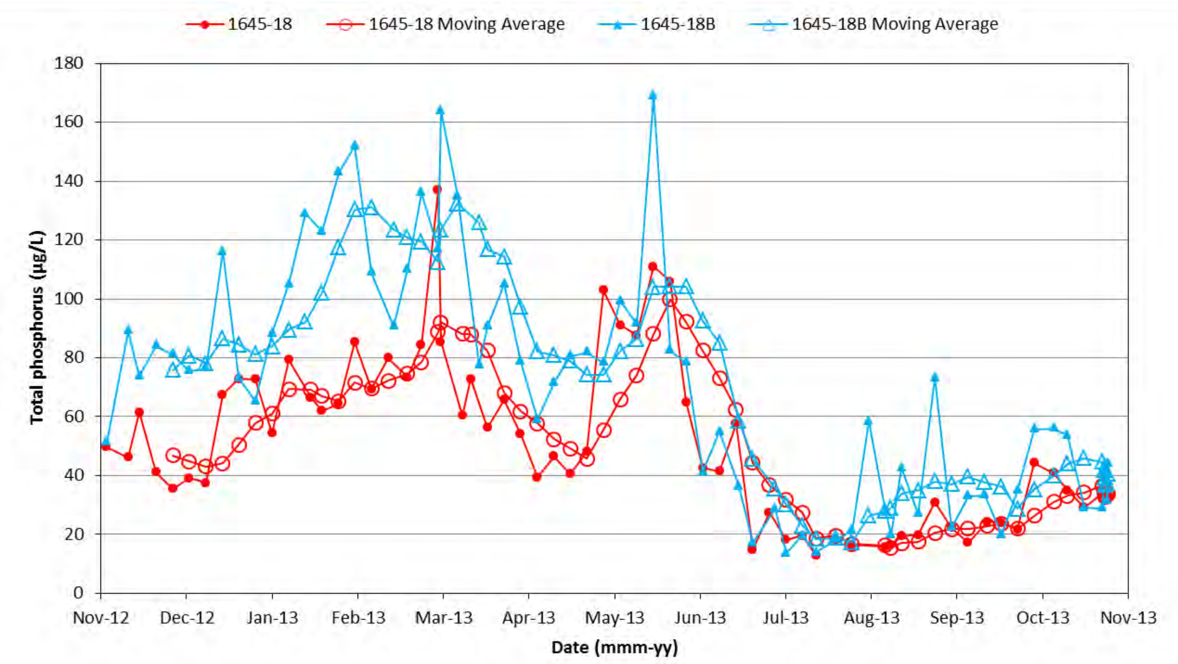
Note: µg/L = micrograms per litre.

Figure 3-18 Nitrite Concentration Measured at SNP 1645-18 and 1645-18B, November 2012 to October 2013



Notes: µg/L = micrograms per litre; Water Licence discharge criteria are shown in text box.

Figure 3-19 Total Phosphorus Concentration at SNP 1645-18 and 1645-18B, November 2012 to October 2013



Note: µg/L = micrograms per litre.

3.7 WEIGHT OF EVIDENCE INPUT

The results described in the preceding sections also feed into the WOE approach described in the Weight of Evidence Report (Golder 2014c). The results of the Weight of Evidence approach relevant to nutrients, chlorophyll *a*, and zooplankton biomass (AFDM) are described in Section 3.1.4 of the Weight of Evidence Report.

4 DISCUSSION

The effect of nutrient enrichment on the primary producers of Lac de Gras was evident in the NF exposure areas. The spatial extent of effluent effects was determined by comparing the concentrations of nutrients and chlorophyll *a* and the zooplankton biomass in each of the exposure and MF areas to the normal range (i.e., the 2007 to 2010 pooled reference area mean +2 SDs). To provide the most conservative view of effluent effects, the season and depth for each variable with the greatest extent of effects was selected. Since only open-water samples were collected for chlorophyll *a* and zooplankton biomass, the open-water data was used for determining the extent of spatial effects. For TP and TN, the ice-cover season was selected, choosing the top and bottom depth, respectively.

For chlorophyll *a*, the extent of effects during the open-water season encompassed all stations to the northeast (MF2-FF2 transect) of the Mine. The boundary of effects on chlorophyll *a* to the northwest extended to a location between station MF1-1 and MF1-3 (MF1-FF1 transect). The boundary of effects on chlorophyll *a* south of the Mine extended to a location between stations MF3-4 and MF3-5. The extent of effects on chlorophyll *a*, based on the affected stations, was calculated to be 143 km^2. Compared to the total surface area of the lake (573 km^2), the affected area based on chlorophyll *a* represents 24.9% of the lake (Figure 4-1). The affected chlorophyll *a* area in 2013 was similar to that observed in 2012 (Table 4-1).

Table 4-1 Extent of Effects on Chlorophyll *a*, Total Nitrogen and Total Phosphorus Concentrations, and on Zooplankton Biomass (Ash-Free Dry Mass) from 2007 to 2013

Year	Chlorophyll *a*		Total Phosphorus		Total Nitrogen		Zooplankton Biomass (ash-free dry mass)	
	Area (km^2)	Proportion of Lake (%)	Area (km^2)	Proportion of Lake (%)	Area (km^2)	Proportion of Lake (%)	Area (km^2)	Proportion of Lake (%)
2007	93.4	16.3	77.7	13.6	49.8	8.7	-	-
2008	120	21.0	91.6	16.0	121	21.1	57.7	5.7
2009	177	31.0	63.7	11.1	143	24.9	77.7	13.7
2010	180	31.4	85.8	15.50	138	24.0	32.6	10.1
2011	88.8	15.5	197	34.4	204	35.6	195	34.0
2012	140	27.3	1.78	0.31	211	36.9	0.92	0.16
2013	143	24.9	8.4	1.5	15	2.6	212	37.1

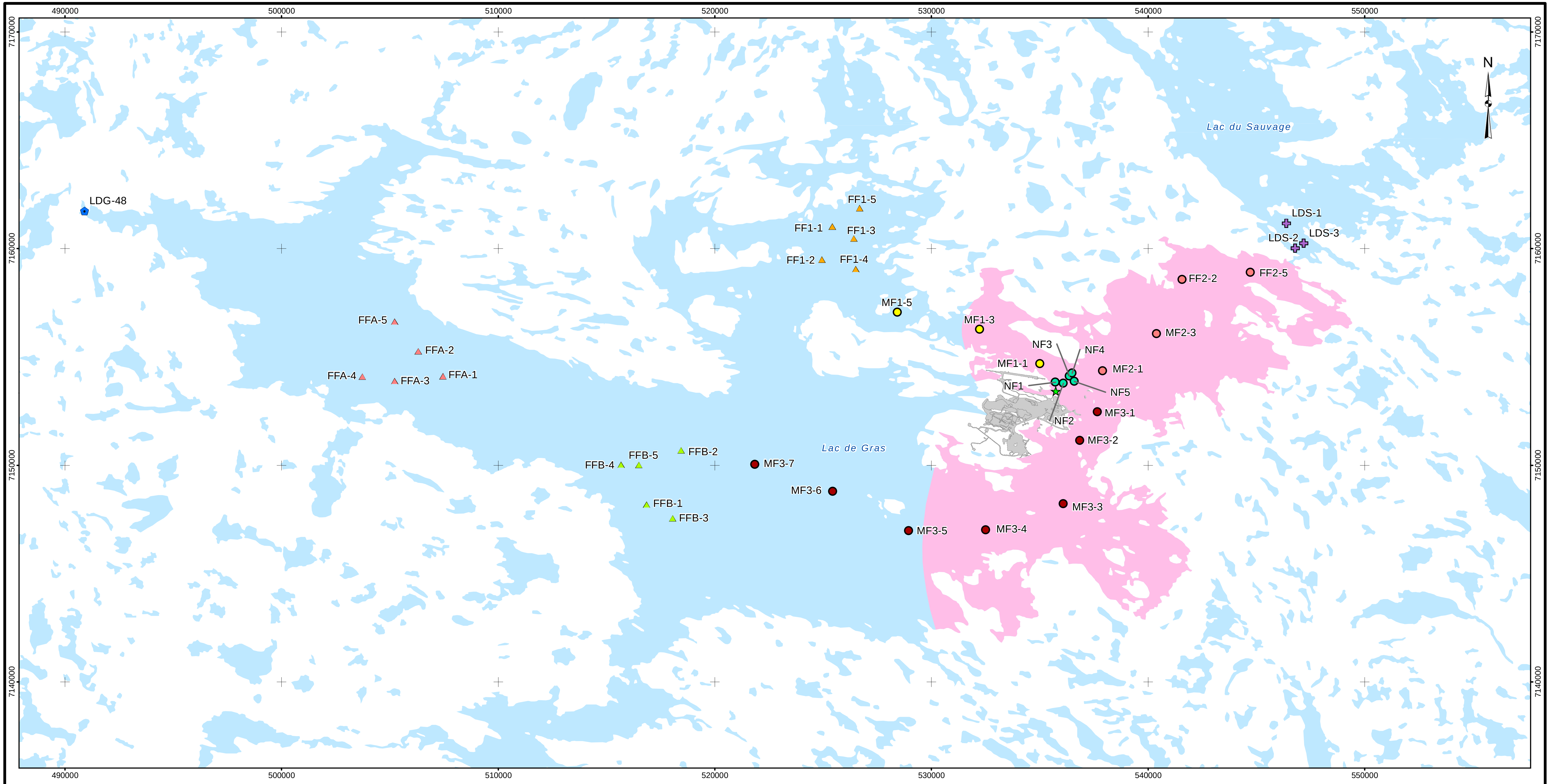
Notes: "-" = no sample; km^2 = square kilometres;% = percent; the proportion of the lake affected calculation is based on the area affected divided by the total surface area of the lake (573 km^2) .

The extent of effects on TP was limited to the NF area of Lac de Gras and to the northeast (MF2-FF2 transect). The boundary of effects on TP to the northwest extended to station MF1-1 (MF1-FF1 transect) and the boundary of effects south of the Mine extended to station MF3-2 (MF3-FFB-FFA transect). The resulting TP affected area of the lake was calculated as 8 km^2, or 1.5% of the lake (Figure 4-2), which is slightly greater than the affected area calculated for 2012 (Table 4-1), but less than affected area calculations from previous years (Table 4-1).

The extent of effects on TN during the ice-cover season to the northeast of the Mine extended to a location between stations MF2-1 and MF2-3 (MF2-FF2 transect). The boundary of effects south of the Mine extended to between station MF3-1 and station MF3-2 (MF3-FFB-FFA transect). The resulting TN affected area of the lake was calculated to be 15 km^2, or 2.6% of the lake (Figure 4-3), which is less than the affected area calculated in previous years. The main reason for this apparent decrease is that the historical normal range, upon which the extent of effect is calculated, is greater than the normal ranges used in previous reports. Previous AEMPs used a normal range calculated from that year’s data. There were slight laboratory changes to nitrogen analysis in 2008 which resulted in very low values. These data will be re-evaluated for their suitability in the calculation of the historical normal range. Moreover, the next three-year summary report will include determinations of extent of effects for previous years based on the historical normal range.

The extent of effects on zooplankton biomass during the open-water season encompassed all stations northeast (MF2-FF2 transect) of the Mine. The boundary of effects on zooplankton biomass to the northwest extended to a location between station MF1-3 and MF1-5 (MF1-FF1 transect). The boundary of effects south of the Mine extended to between stations MF3-6 and MF3-7 (MF3-FFB-FFA transect). The resulting zooplankton biomass affected area of the lake was calculated to be 212 km^2, or 37.1% of the lake (Figure 4-4), which is greater than the affected area calculated for 2012 (Table 4-1), but is similar to the affected area calculated in 2011.

The December 19, 2013 decision document for the Study Design Version 3.2 (Golder 2013b), recommended that: “Annual reports (and the Three Year Summary Report) review phosphorus loadings against EC framework”. However the EC framework (Environment Canada 2004) deals with non-toxic endpoints and management strategies for phosphorous, and does not specifically address loadings. Loadings for phosphorus were addressed, however, in Section 3.5.



LEGEND

★	DIFFUSER	✚	LAC DU SAUVAGE
EXPOSURE		⬟	LDG 48
●	NEAR-FIELD	🟪	AFFECTED AREA
●	MID-FIELD 3	⬜	DIAVIK FOOTPRINT
●	MID-FIELD 1	🟦	WATERBODY
●	FAR-FIELD 2; MID-FIELD 2		
REFERENCE			
▲	FAR-FIELD 1		
▲	FAR-FIELD A		
▲	FAR-FIELD B		

5 0 5

SCALE 1:175,000 KILOMETRES

REFERENCE

HYDROGRAPHY DATA OBTAINED FROM CANVEC © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 12 DATUM: NAD 83

PROJECT

DIAVIK DIAMOND MINES INC.

TITLE

CHLOROPHYLL A AFFECTED AREA, 2013 AEMP

Golder Associates

PROJECT		05-1328-008	FILE No.	
DESIGN	TD	13 Feb. 2014	SCALE AS SHOWN	REV. 0
GIS	JC	20 Mar. 2014	FIGURE: 4-1	
CHECK	TD	20 Mar. 2014		
REVIEW	CF	20 Mar. 2014		

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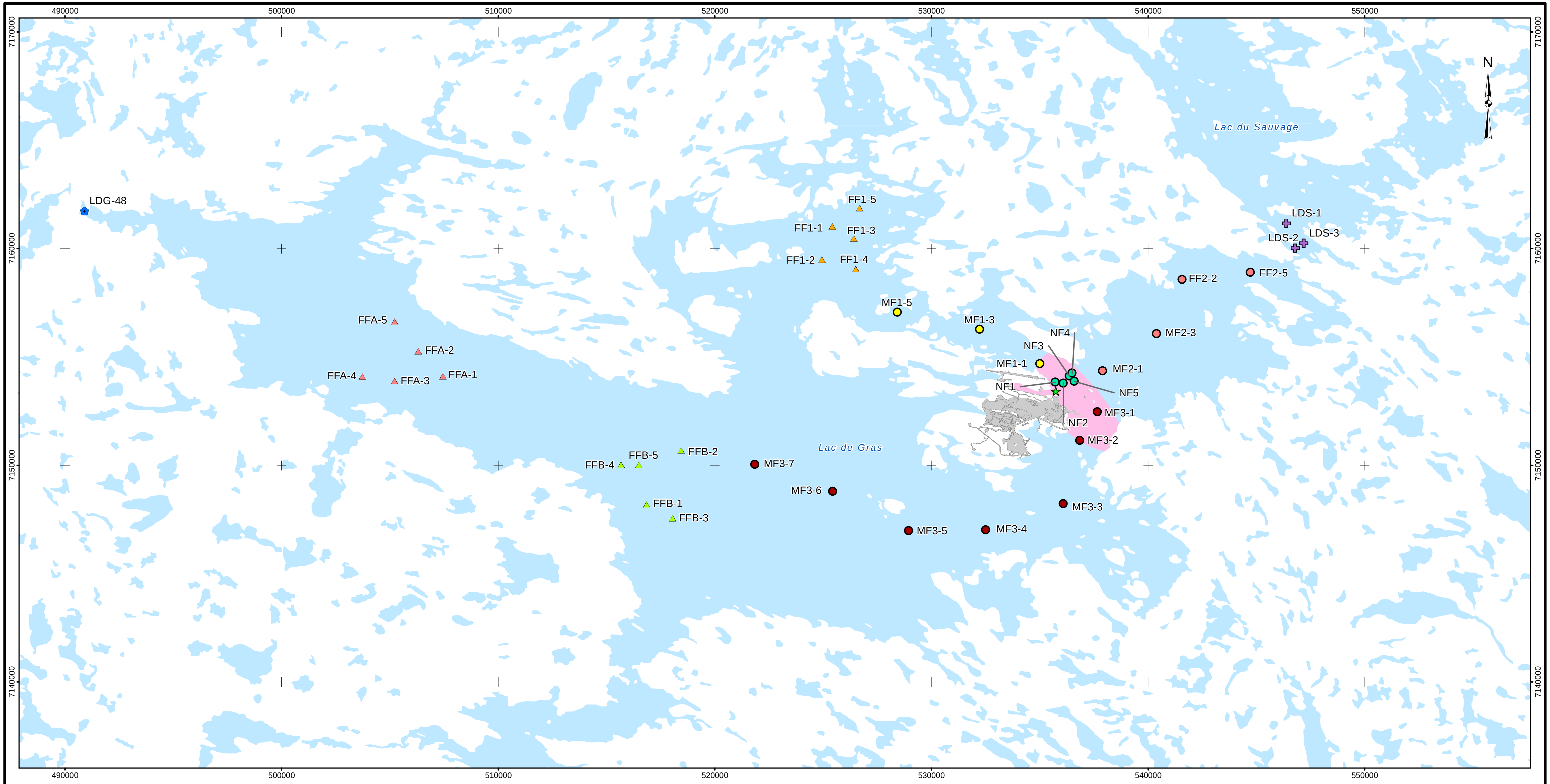

5 0 5

SCALE 1:175,000 KILOMETRES

LEGEND

★ DIFFUSER

EXPOSURE

● NEAR-FIELD

● MID-FIELD 3

● MID-FIELD 1

● FAR-FIELD 2; MID-FIELD 2

REFERENCE

▲ FAR-FIELD 1

▲ FAR-FIELD A

▲ FAR-FIELD B

✚ LAC DU SAUVAGE

⬟ LDG 48

▨ AFFECTED AREA

▨ DIAVIK FOOTPRINT

▨ WATERBODY

REFERENCE

HYDROGRAPHY DATA OBTAINED FROM CANVEC © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 12 DATUM: NAD 83

PROJECT

DIAVIK DIAMOND MINES INC.

TITLE

TOTAL PHOSPHORUS AFFECTED AREA, 2013 AEMP

Golder Associates

PROJECT		05-1328-008	FILE No.
DESIGN	TD	13 Feb. 2014	SCALE AS SHOWN REV. 0
GIS	JC	20 Mar. 2014	FIGURE: 4-2
CHECK	TD	20 Mar. 2014	
REVIEW	CF	20 Mar. 2014	

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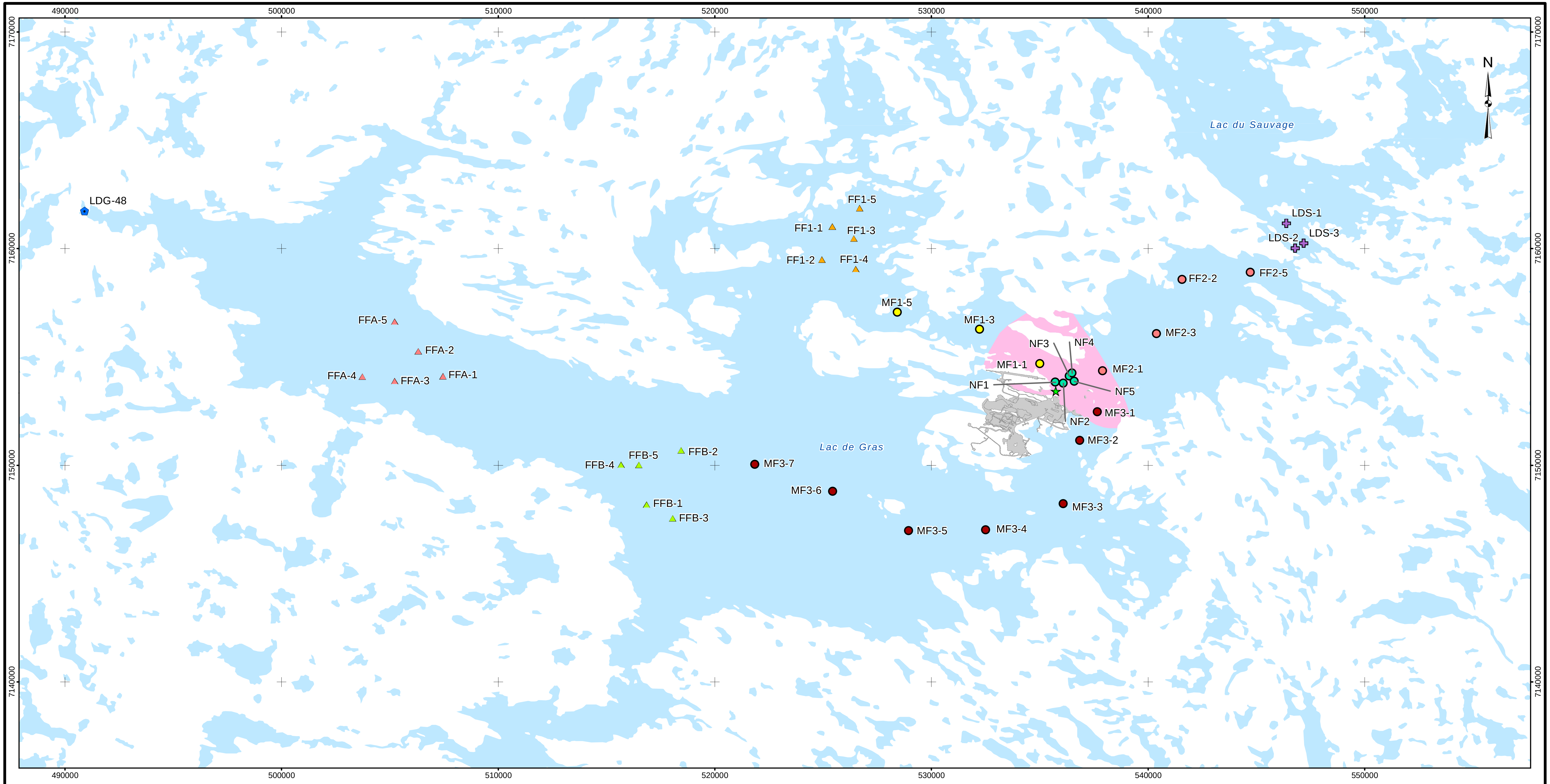

LEGEND

★ DIFFUSER

EXPOSURE

● NEAR-FIELD

● MID-FIELD 3

● MID-FIELD 1

● FAR-FIELD 2; MID-FIELD 2

REFERENCE

▲ FAR-FIELD 1

▲ FAR-FIELD A

▲ FAR-FIELD B

✚ LAC DU SAUVAGE

⬟ LDG 48

▨ AFFECTED AREA

▨ DIAVIK FOOTPRINT

▨ WATERBODY

REFERENCE

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PROJECTION: UTM ZONE 12 DATUM: NAD 83

5 0 5
SCALE 1:175,000 KILOMETRES

PROJECT

DIAVIK DIAMOND MINES INC.

TITLE

TOTAL NITROGEN AFFECTED AREA, 2013 AEMP

Golder Associates

PROJECT		05-1328-008	FILE No.	
DESIGN	TD	13 Feb. 2014	SCALE AS SHOWN	REV. 0
GIS	JC	20 Mar. 2014	FIGURE: 4-3	
CHECK	TD	20 Mar. 2014		
REVIEW	CF	20 Mar. 2014		

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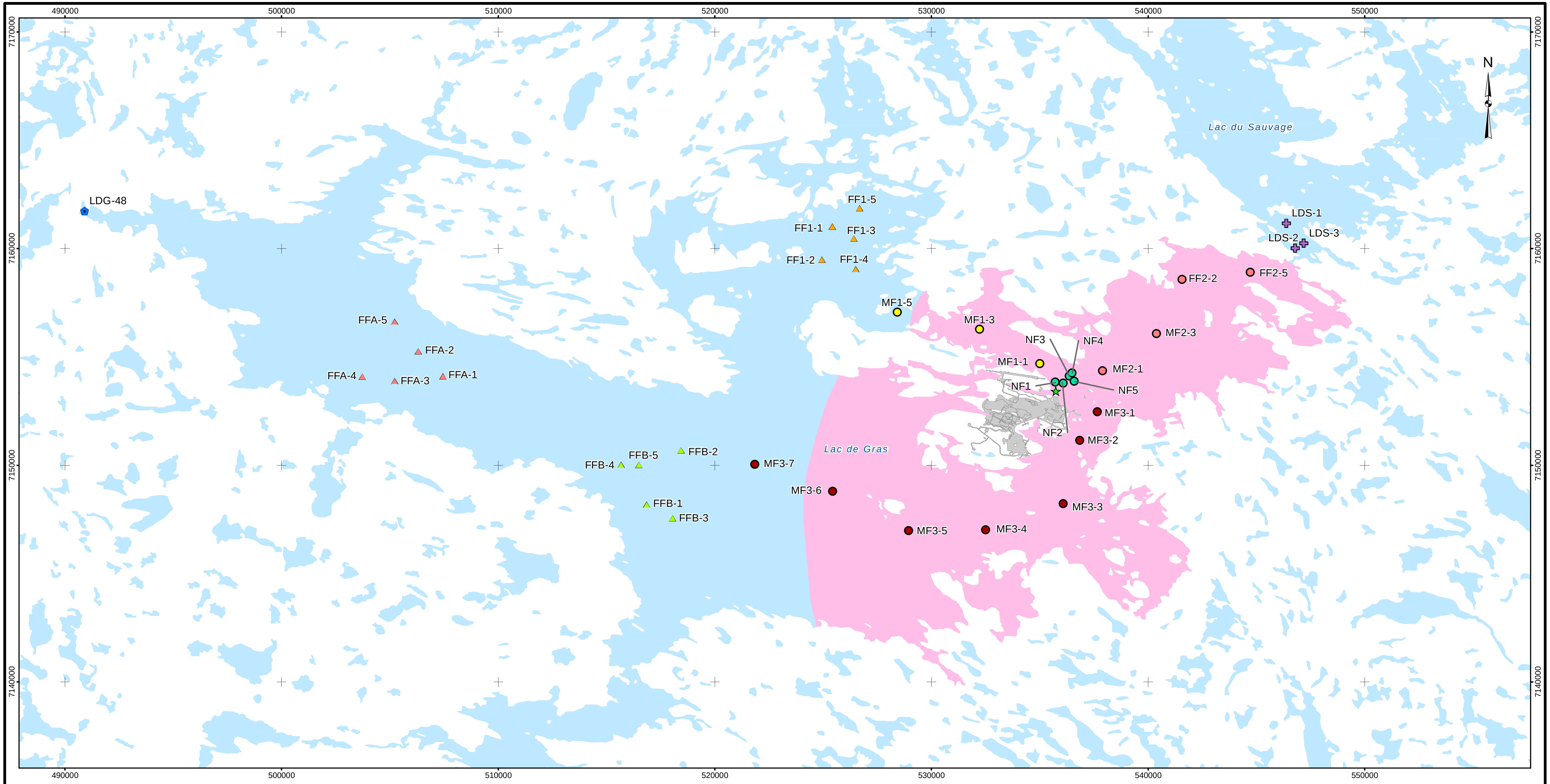

LEGEND

★ DIFFUSER

EXPOSURE

● NEAR-FIELD

● MID-FIELD 3

● MID-FIELD 1

● FAR-FIELD 2; MID-FIELD 2

REFERENCE

▲ FAR-FIELD 1

▲ FAR-FIELD A

▲ FAR-FIELD B

✚ LAC DU SAUVAGE

⬟ LDG 48

🟪 AFFECTED AREA

⬜ DIAVIK FOOTPRINT

🟦 WATERBODY

REFERENCE

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PROJECTION: UTM ZONE 12 DATUM: NAD 83

5 0 5

SCALE 1:175,000 KILOMETRES

PROJECT

DIAVIK DIAMOND MINES INC.

TITLE

ZOOPLANKTON BIOMASS (AFDM) AFFECTED AREA, 2013 AEMP

Golder Associates

PROJECT		05-1328-008	FILE No.	
DESIGN	TD	13 Feb. 2014	SCALE AS SHOWN	REV. 0
GIS	JC	20 Mar. 2014	FIGURE: 4-4	
CHECK	TD	20 Mar. 2014		
REVIEW	CF	20 Mar. 2014		

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5 CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

This report presents the assessment of data collected by DDMI for the indicators of eutrophication component of the 2013 AEMP. The conclusions from this assessment were the following:

- The Mine is having a nutrient enrichment effect on Lac de Gras. This was evidenced by the statistically greater concentrations of chlorophyll *a*, TP and TN, as well as zooplankton biomass, in the near-field exposure area.
- The extent of the effect on TP and TN covered less than 20% of the lake.
- Although biomass in the near-field exposure area did not exceeded the upper limit of the normal range, biomass in mid-field stations did exceed the normal range. This resulted in an extent of effects on zooplankton biomass representing 37.1% of the lake.
- The magnitude of the eutrophication effect is equivalent to Action Level 2 of the Response Framework. This conclusion is based on the fact that concentrations of chlorophyll *a* exceeded the upper boundary of the normal range of the reference areas over a lake area representing 24.9% of the lake.

5.2 RECOMMENDATIONS

There are no recommendations for changes to the eutrophication indicators component of the AEMP at this time.

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7 CLOSURE

We trust that the information in this report meets your requirements at this time. If you have any questions relating to the information contained in this document please do not hesitate to contact the undersigned.

GOLDER ASSOCIATES LTD.

Report prepared by:	**Report reviewed by:**
Original Signed Stephanie Mogensen, M.Sc. Aquatic Biologist	
Original Signed Kelly Hille, M.Sc. Aquatic Biologist	***Original Signed*** Chris Fraikin, M.Sc. Associate, Senior Aquatic Scientist

APPENDIX A

QUALITY ASSURANCE/QUALITY CONTROL

The QA/QC program followed during the 2013 AEMP sampling program is detailed in the QAPP (Golder 2013a). The QAPP outlines the QA/QC procedures employed to support the collection of scientifically defensible and relevant data. The QAPP is designed to ensure that field sampling, laboratory analysis, data entry, data analysis, and report preparation activities produce technically sound and scientifically defensible results. Detailed results of the 2013 eutrophication indicators QA/QC program are presented below.

Quality Assurance

Field Operations

To ensure that field data were of known and defensible quality, field work was completed by Diavik staff according to specified instructions outlined in the following SOPs:

- ENVR-014-0311 R3 AEMP Sampling (Ice-Cover);
- ENVR-003-0702 R9 AEMP Monitoring Program (Open-Water);
- ENVR-608-0112 R0 Hydrolab;
- ENVR-303-0112 R0 Laboratory Quality Assurance/Quality Control; and
- ENVR-206-0112 R0 Processing Maxxam Samples and Tracking Documentation.

These SOPs include guidelines for field record keeping and sample tracking, guidance for use of sampling equipment, relevant technical procedures, and sample labelling, shipping and tracking protocols.

Office Operations

A data management system was in place to ensure an organized system of data control, analysis, and filing. Relevant operations included the following:

- reviewing laboratory data as they were received from the analytical laboratory;
- creating backup files prior to beginning data analysis; and
- completing appropriate logic checks to ensure the accuracy of all calculations.

Quality Control

Methods

Quality control is a specific aspect of QA, and it includes the techniques used to assess data quality. The field QC program consisted of the collection of field blanks, equipment blanks, and duplicate and split samples. The blanks are used to assess potential sample contamination in the field, the duplicates are used to assess within-station variation and sampling precision, and the split samples are used to assess analytical precision. QC samples were submitted to the UofA for the analysis of nutrients during the ice-cover season and open-water chlorophyll *a* samples. QC samples were submitted to Maxxam for the analysis of nutrients during the open-water period, and to Hydroqual Laboratories for the analysis of zooplankton biomass. Field and equipment blank samples were submitted for nutrient analysis, split samples were analyzed for the analysis of nutrients and chlorophyll *a* and duplicate samples were analyzed for zooplankton.

Field and Equipment Blanks

Field blanks consisted of samples prepared in the field using laboratory-provided de-ionized water to fill a set of sample bottles, which were then submitted blind to the appropriate laboratory for the same analyses as the field samples. Equipment blanks consisted of de-ionized water exposed to all aspects of sample collection and analysis, including the same procedures used in the field and contact with all sampling devices and other equipment. Equipment blank water was then submitted blind to the appropriate laboratory for the same analyses as the field samples. Equipment blanks provide information regarding potential cross-over contamination from the equipment to the samples.

The field and equipment blanks were also used to detect potential contamination during collection, shipping and analysis. Analytes should not have been detected in the field blanks. If they were detected, their concentrations were considered notable if they were greater than five times the corresponding detection limit (DL). This threshold is based on the Practical Quantitation Limit defined by US EPA (1985), which takes into account the potential for data accuracy error when variable concentrations approach or are below the detection limit.

Notable results observed in the field blanks were evaluated relative to analyte concentrations observed in the field samples to determine whether sample contamination was limited to the QC sample or was apparent in other samples as well. Where, based on this comparison, sample contamination was not an isolated occurrence, the field data were flagged and interpreted with this limitation in mind.

Duplicate and Split Samples

Duplicate samples consisted of two separate samples collected from the same location at the same time, using the same sampling and sample handling procedures. They were labelled and preserved individually, and submitted separately to the analytical laboratories for identical analyses. Split samples consisted of splitting a single sample into two and submitting them as two separate samples. Split samples were only collected during the open water season. Duplicate samples are used to check within-station variation and the precision of field sampling methods, while split samples are used to check the precision of the laboratory analysis.

For the AEMP QC analysis, differences in variable concentrations between the duplicate nutrient samples and between the nutrient split samples were considered notable if they were greater than 20% and concentrations in both duplicate or both split samples were greater than five times the detection limit.

The inherent variability associated with the chlorophyll *a* and zooplankton samples makes the establishment of a QC threshold value difficult. For the purposes of the Eutrophication Indicators QC, samples were flagged and assessed further if there was a greater than 50% difference in chlorophyll *a* and zooplankton biomass between the original and duplicate samples.

To calculate the relative percent difference (RPD) between the duplicate or split samples, with concentrations below the limit of detection, non-detect concentrations were estimated to be 0.71 times the detection limit (see Section 2.2.1; Roger Green, University of Western Ontario, personal communication).

The QC duplicate criterion utilized for the AEMP program was developed and approved to be consistent with the QC criterion set by the laboratories for assessing precision (*i.e.*, the degree of similarity between replicate measurements) between split samples, as well as maintaining consistency with other regulatory agencies (BC MOE 2006). Each laboratory establishes its own acceptance criteria for assessing precision through analysis of laboratory split samples. The acceptance criterion is often expressed as the RPD when the comparison between two replicates (*i.e.*, duplicates) is analyzed. This acceptance criterion will often vary among analytes or groups of analytes. For example, a laboratory may specify an acceptance criterion of ≤20% RPD for one group of analytes, and ≤50% RPD for another analyte group. Because precision decreases as analyte concentrations approach detection limits, laboratories typically qualify their acceptance criteria so that they are only applied when the analyte is detected in both the original and the duplicate sample, at concentrations at least five times the detection limit.

For the AEMP duplicate and split QC analysis, QC data that met the acceptance criteria were considered acceptable with respect to accuracy. Duplicate data were not automatically rejected because of some exceedance of the acceptance criterion; rather, they were evaluated on a case by case basis, as some level of within-site variability is expected for duplicate samples. If there were departures from the acceptance criterion, the samples were flagged, and a variety of follow-up assessments were performed. These assessments included plotting the data for visual identification of outliers. If there were visual outliers, the data were plotted with the corresponding 2007 to 2012 data for a range comparison. If the data were outside the corresponding 2007 to 2012 range, laboratory re-analysis occurred. If laboratory re-analysis confirmed the results, the outlier points were retained in the final data set unless there was a technically defensible reason to exclude them.

Results

Six field blanks and six equipment blanks were collected during the 2013 AEMP; four samples were collect under ice-cover and two samples were collected during the open-water season. Each blank was analyzed for six nutrient analytes (Tables A-1). Thirty eight split samples were analyzed for chlorophyll *a* during the open-water season, and thirty seven duplicate samples were analyzed for zooplankton biomass.

Field Blanks

None of the 35 field blank results, had concentrations greater than five times the detection limit. There were detectable concentrations of ammonia in both of the open water field blanks; however, concentrations were less than five times the limit of detection (Table A-1).

Equipment Blanks

None of the 35 equipment blank results, had concentrations greater than five times the detection limit. There were detectable concentrations of ammonia in both of the open water field blanks; however, concentrations were less than five times the limit of detection (Table A-1).

Nutrient Split Samples

Four results (17% of total) showed a relative difference of more than 20% between splits, while having concentrations greater than five times the detection limit (Table A-2). Three of the flagged split samples were for ammonia for stations NF1, NF4, and MF3-7, while the remaining flagged result was for nitrate + nitrite for station NF4. Further analysis of these data was conducted by generating scatter plots and box-and-whisker plots to determine if these data were visual outliers, and a comparison to previous year's results were also conducted. The magnitude of the differences in these flagged splits was considered normal based on typical variability in the nutrient data, and none of the flagged data were considered outliers or unusual based on visual examination of the data. In addition, the maximum concentrations in each of these flagged samples was within the expected range based on a comparison to the historical data range.

Table A-1 Field and Equipment Blank Results, Total Dissolved Nitrogen, Ammonia, Nitrite, Nitrate+Nitrite, Total Dissolved Phosphorus, and Soluble Reactive Phosphorus, 2013 AEMP

Sample Type	Season	Station	Total Dissolved Nitrogen (µg/L)			Ammonia (µg/L)			Nitrite (µg/L)			Nitrate-N+Nitrite-N (µg/L)			Total Dissolved Phosphorus (µg/L)			Soluble Reactive Phosphorus (µg/L)		
			DL	Result	>5*DL	DL	Result	>5*DL	DL	Result	>5*DL	DL	Result	>5*DL	DL	Result	>5*DL	DL	Result	>5*DL
Field Blank	Ice-cover	FFB-4M Dup 1	5.0	<5.0	N	2.0	<2.0	N	1.0	<1.0	N	1.0	<1.0	N	3.0	<3.0	N	1.0	<1.0	N
	Ice-cover	FFB-4M Dup 2	5.0	<5.0	N	2.0	<2.0	N	1.0	<1.0	N	1.0	<1.0	N	3.0	<3.0	N	1.0	<1.0	N
	Ice-cover	MF2-1M Dup 1	5.0	<5.0	N	2.0	<2.0	N	1.0	<1.0	N	1.0	<1.0	N	3.0	<3.0	N	1.0	<1.0	N
	Ice-cover	MF2-1M Dup 2	5.0	<5.0	N	2.0	<2.0	N	1.0	<1.0	N	1.0	<1.0	N	3.0	<3.0	N	1.0	<1.0	N
	Open-water	FF1-2	-	-	-	5.0	22.0	N	2.0	<2.0	N	2.0	2.8	N	2.0	<2.0	N	1.0	<1.0	N
	Open-water	NF4	-	-	-	5.0	9.2	N	2.0	<2.0	N	2.0	12.0	Y	2.0	<2.0	N	1.0	<1.0	N
Equipment Blank	Ice-cover	NF1T Dup 1	5.0	<5.0	N	2.0	<2.0	N	1.0	<1.0	N	1.0	<1.0	N	3.0	<3.0	N	1.0	<1.0	N
	Ice-cover	NF1T Dup 2	5.0	<5.0	N	2.0	<2.0	N	1.0	<1.0	N	1.0	<1.0	N	3.0	<3.0	N	1.0	<1.0	N
	Ice-cover	FFM-5M Dup 1	5.0	<5.0	N	2.0	2.0	N	1.0	<1.0	N	1.0	<1.0	N	3.0	<3.0	N	1.0	<1.0	N
	Ice-cover	FFM-5M Dup 2	5.0	<5.0	N	2.0	<2.0	N	1.0	<1.0	N	1.0	<1.0	N	3.0	<3.0	N	1.0	<1.0	N
	Open-water	FFB-3	-	-	-	5.0	7.3	N	2.0	<2.0	N	2.0	<2.0	N	2.0	<2.0	N	1.0	<1.0	N
	Open-water	MF2	-	-	-	5.0	14.0	N	2.0	<2.0	N	2.0	<2.0	N	2.0	<2.0	N	1.0	<1.0	N

Notes: DL = detection limit; < = less than; >= greater than; µg/L = micrograms per litre; Y = Yes; N = No; **bolded values** = QC flag, - data not measured.

Table A-2 Summary of Split Sample Results for Nutrient Analytes, 2013 AEMP

Analyte	Season	Station	DL (µg/L)	Result 1 (µg/L)	Result 2 (µg/L)	Max Result (µg/L)	RPD (%)	>5×DL	QC Flag
Ammonia	**Open-water**	**NF1**	**2.0**	**27.0**	**13.0**	**27.0**	**107.7**	**Y**	**Y**
	Open-water	**NF4**	**2.0**	**17.0**	**14.0**	**17.0**	**21.4**	**Y**	**Y**
	Open-water	MF3-4	2.0	14.0	16.0	16.0	14.3	Y	N
	Open-water	**MF3-7**	**2.0**	**24.0**	**13.0**	**24.0**	**84.6**	**Y**	**Y**
Nitrite	Open-water	NF1	2.0	<2.0	<2.0	<2.0	0.0	N	N
	Open-water	NF4	2.0	<2.0	<2.0	<2.0	0.0	N	N
	Open-water	MF3-4	2.0	<2.0	<2.0	<2.0	0.0	N	N
	Open-water	MF3-7	2.0	<2.0	<2.0	<2.0	0.0	N	N
Nitrate-N + Nitrite-N	Open-water	NF1	2.0	8.1	4.1	8.1	97.1	N	N
	Open-water	**NF4**	**2.0**	**12.8**	**9.4**	**12.8**	**36.1**	**Y**	**Y**
	Open-water	MF3-4	2.0	2.8	2.8	2.8	1.4	N	N
	Open-water	MF3-7	2.0	2.8	2.8	2.8	0.0	N	N
Total Dissolved Phosphorus	Open-water	NF1	3.0	2.0	2.6	4.5	4.5	N	N
	Open-water	NF4	3.0	2.0	2.3	3.0	3.0	N	N
	Open-water	MF3-4	3.0	2.0	<2.0	<2.0	0.0	N	N
	Open-water	MF3-7	3.0	2.0	<2.0	<2.0	0.0	N	N
Soluble Reactive Phosphorus	Open-water	NF1	1.0	<1	<1	0.0	0.0	N	N
	Open-water	NF4	1.0	<1	<1	0.0	0.0	N	N
	Open-water	MF3-4	1.0	<1.0	1.0	1.0	40.8	N	N
	Open-water	MF3-7	1.0	1.7	<1.0	1.7	139.4	N	N
Total Phosphorus	Open-water	NF1	2.0	3.0	2.6	3.0	15.4	N	N
	Open-water	NF4	2.0	3.5	4.3	4.3	22.9	N	N
	Open-water	MF3-4	2.0	4.3	2.0	4.3	115.0	N	N
	Open-water	MF3-7	2.0	4.3	2.6	4.3	65.4	N	N

Notes: DL = detection limit; max = maximum; RPD = relative percent difference; < = less than ;>= greater than; µg/L = microgram per litre; Y = Yes; N = No; **bolded values** = QC flag.

Chlorophyll *a* split samples

None of the 38 chlorophyll *a* split samples exceeded the 50% QC threshold criterion (Table A-3).

Zooplankton Biomass (ash-free dry mass) Duplicate Samples

A total of two out of 34 samples exceeded the 50% QC threshold criterion, at stations MF2-3 and FFB-4, triggering QC flags (Table A-4). A graphical examination of these data was performed to detect unusually large within-station variability, the flagged duplicates both fell within the expected within-station variability.

Table A-3 Summary of Duplicate Sample Results for Chlorophyll *a*, 2013 AEMP

Station	DL (μg/L)	Result 1 (μg/L)	Result 2 (μg/L)	Maximum Result (μg/L)	Relative Percent Difference (%)	>5×DL	QC Flag
NF1	0.05	1.03	0.74	1.03	39.19	Y	N
NF2	0.05	1.64	1.64	1.64	0.00	Y	N
NF3	0.05	1.63	1.63	1.63	0.00	Y	N
NF4	0.05	1.64	1.36	1.64	20.59	Y	N
NF5	0.05	1.94	1.90	1.94	2.11	Y	N
MF1-1	0.05	1.35	1.22	1.35	10.66	Y	N
MF1-3	0.05	0.84	0.95	0.95	13.10	Y	N
MF1-5	0.05	0.57	0.56	0.57	1.79	Y	N
MF2-1	0.05	2.00	2.15	2.15	7.50	Y	N
MF2-3	0.05	1.78	1.51	1.78	17.88	Y	N
MF3-2	0.05	1.38	1.55	1.55	12.32	Y	N
MF3-1	0.05	1.38	1.11	1.38	14.43	Y	N
MF3-3	0.05	0.84	0.96	0.96	14.29	Y	N
MF3-4	0.05	1.11	1.03	1.11	7.77	Y	N
MF3-5	0.05	0.60	0.73	0.73	21.67	Y	N
MF3-6	0.05	0.74	0.71	0.74	4.23	Y	N
MF3-7	0.05	0.54	0.61	0.61	12.96	Y	N
FF1-1	0.05	0.59	0.77	0.77	30.51	Y	N
FF1-2	0.05	0.65	0.55	0.65	18.18	Y	N
FF1-3	0.05	0.73	0.93	0.93	27.40	Y	N
FF1-4	0.05	0.93	0.65	0.93	43.08	Y	N
FF1-5	0.05	0.69	0.71	0.71	2.90	Y	N
FF2-2	0.05	1.71	1.93	1.93	12.87	Y	N
FF2-5	0.05	1.76	1.62	1.76	8.64	Y	N
FFA-1	0.05	0.40	0.59	0.59	47.50	Y	N
FFA-2	0.05	0.64	0.57	0.64	12.28	Y	N
FFA-3	0.05	0.72	0.52	0.72	32.46	Y	N

Table A-3 Summary of Duplicate Sample Results for Chlorophyll *a*, 2013 AEMP (continued)

Station	DL (µg/L)	Result 1 (µg/L)	Result 2 (µg/L)	Maximum Result (µg/L)	Relative Percent Difference (%)	>5×DL	QC Flag
FFA-4	0.05	0.66	0.46	0.66	43.48	Y	N
FFA-5	0.05	0.57	0.76	0.76	33.33	Y	N
FFB-1	0.05	0.75	0.63	0.75	19.05	Y	N
FFB-2	0.05	0.68	0.72	0.72	5.88	Y	N
FFB-3	0.05	0.93	0.78	0.93	19.23	Y	N
FFB-4	0.05	0.91	0.76	0.91	19.74	Y	N
FFB-5	0.05	0.43	0.55	0.55	27.91	Y	N
LDS-1	0.05	1.35	1.44	1.44	6.67	Y	N
LDS-2	0.05	1.77	1.60	1.77	10.63	Y	N
LDS-3	0.05	1.20	1.34	1.34	11.67	Y	N
LDG48 A	0.05	0.56	0.57	0.57	1.79	Y	N

Notes: DL = detection limit; >= greater than; µg/L = microgram per litre; Y = Yes; N = No; **bolded values** = QC flag;

Table A-4 Summary of Duplicate Sample Results for Zooplankton Biomass, 2013 AEMP

Station	**Result 1 (µg/L)**	**Result 2 (µg/L)**	**Maximum Result (µg/L)**	**Relative Percent Difference (%)**	**QC Flag**
NF1	43.0	33.4	43.0	28.8	N
NF2	45.6	44.1	45.6	3.6	N
NF3	48.8	46.4	48.8	5.2	N
NF4	43.2	43.9	43.9	1.7	N
NF5	38.1	43.3	43.3	13.7	N
MF1-1	59.2	60.8	60.8	2.6	N
MF1-3	97.9	125.0	125.0	27.7	N
MF1-5	32.5	30.5	32.5	6.5	N
MF2-1	39.7	36.3	39.7	9.3	N
MF2-3	**81.7**	**11.5**	**81.7**	**612.1**	**Y**
MF3-1	38.5	35.0	38.5	10.2	N
MF3-2	66.0	53.2	66.0	24.1	N
MF3-3	47.4	49.7	49.7	4.9	N
MF3-4	69.3	67.4	69.3	2.8	N
MF3-5	42.7	43.9	43.9	2.7	N
MF3-6	46.9	45.3	46.9	3.6	N
MF3-7	39.2	36.0	39.2	9.0	N
FF2-2	42.1	34.7	42.1	21.1	N
FF2-5	48.7	39.1	48.7	24.3	N
FF1-1	20.5	18.9	20.5	8.3	N
FF1-2	42.2	47.5	47.5	12.4	N
FF1-3	22.7	23.3	23.3	2.8	N
FF1-4	31.8	37.9	37.9	19.1	N
FF1-5	33.9	32.3	33.9	5.1	N
FFA-1	34.9	30.3	34.9	15.1	N
FFA-2	34.6	37.0	37.0	7.1	N
FFA-3	36.2	35.7	36.2	1.2	N
FFA-4	30.2	33.0	33.0	9.4	N
FFA-5	30.8	29.9	30.8	3.1	N
FFB-1	56.6	38.6	56.6	46.5	N
FFB-2	25.4	26.2	26.2	3.1	N
FFB-3	55.6	41.1	55.6	35.1	N
FFB-4	**27.4**	**60.2**	**60.2**	**119.5**	**Y**
FFB-5	34.0	44.0	44.0	29.6	N
LDS1	25.4	31.4	31.4	23.7	N
LDS2	51.0	49.9	51.0	2.3	N
LDS3	29.5	35.2	35.2	19.5	N

Notes: Y = Yes; N = No; bolded values = QC flag;

APPENDIX B

2013 AEMP SAMPLING SCHEDULE

Table B-1 2013 Eutrophication Indicators AEMP Sampling Schedule

Sites	Ice-Cover										Open-water																				
	April										August														September						
	10	11	12	13	14	15	16	17	18	19	18	19	20	21	22	23	24	25	26	27	28	29	30	31	01	02	03	04	05	06	07
NF1										An	An																				
NF2										An										An											
NF3	An																			An											
NF4	An																			An											
NF5	An																			An											
MF1-1		An												An																	
MF1-3		An												An																	
MF1-5		An																An													
MF2-1			An																	An											
MF2-3			An																An												
FF2-2								An											An												
FF2-5								An											An												
MF3-1										An								An													
MF3-2			An															An													
MF3-3				An		An												An													
MF3-4				An																									An		
MF3-5				An																											An
MF3-6							An																								An
MF3-7							An											An													
FF1-1							Mn										Mn														
FF1-2							Mn								Mn																
FF1-3							Mn										Mn														
FF1-4							Mn										Mn														
FF1-5							Mn								Mn																
FFA-1					Mn																	Mn									
FFA-2					Mn																	Mn									
FFA-3					Mn																	Mn									
FFA-4					Mn																		Mn								
FFA-5					Mn																						Mn				
FFB-1						Mn																							Mn		
FFB-2						Mn																			Mn						
FFB-3						Mn																							MMn		
FFB-4						Mn																			Mn						
FFB-5						Mn																			Mn						
LDS-1								Mn											Mn												
LDS-2								Mn											Mn												
LDS-3								Mn											Mn												
LDG-48					Mn																			Mn							

Notes: M = Water Quality mid-depth sample only; A = Water Quality surface, mid-depth and bottom samples collected; n = Nutrients.
QAQC Samples color coded = GW, EBW, FBW, TBW, DUP1/DUP2, DUPSP1/DUPSP2

APPENDIX C

TESTS FOR NORMALITY AND HOMOGENEITY OF VARIANCE

Table C-1 Results of the Kolmogorov-Smirnov Test for Normality and Bartlett’s and Levene’s Tests for Homogeneity of Variance

Analyte	Season	Kolmogorov-Smirnov Test				Bartlett’s Test	Levene’s Test	
		NF	FFA	FFB	FF1		Means	Medians
Total Phosphorus	Ice-cover	****	****	****	****	**	*	ns
	Open-water	****	****	****	****	ns	ns	ns
LOG Total Phosphorus	Ice-cover	**	**	**	*	***	**	ns
	Open-water	**	**	**	*	***	ns	ns
Total Nitrogen	Ice-cover	****	****	****	****	***	**	ns
	Open-water	****	****	****	****	ns	*	ns
LOG Total Nitrogen	Ice-cover	****	****	****	****	**	ns	ns
	Open-water	****	****	****	****	**	**	**
Chlorophyll *a*	Ice-cover	-	-	-	-	-	-	-
	Open-water	****	**	**	**	**	ns	ns
LOG Chlorophyll *a*	Ice-cover	-	-	-	-	-	-	-
	Open-water	ns	ns	ns	ns	ns	ns	ns
Zooplankton	Ice-cover	-	-	-	-	-	-	-
	Open-water	****	****	****	****	*	ns	ns
LOG Zooplankton	Ice-cover	-	-	-	-	-	-	-
	Open-water	****	****	****	****	ns	ns	ns

Notes = Probability of Type 1 Error: * = <0.1, ** = <0.01, *** <0.001, **** = <0.0001, ns = not significant; n/d = not determined due to lack of variance within areas; LOG = logarithmic data transformation.

APPENDIX D

EUTROPHICATION INDICATORS RAW DATA

These data are provided as an Excel file in a "Raw Data Folder" on the compact disc, rather than in hard copy form.

APPENDIX XIV

TRADITIONAL KNOWLEDGE STUDIES

No information was available for this appendix in 2013.

APPENDIX XV

WEIGHT-OF-EVIDENCE REPORT

WEIGHT-OF-EVIDENCE ANALYSIS IN SUPPORT OF THE 2013 AEMP ANNUAL REPORT FOR THE DIAVIK DIAMOND MINE, NORTHWEST TERRITORIES

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1 Copy – Diavik Diamond Mines (2012) Inc., Yellowknife, NT
1 Copy – Golder Associates Ltd., Calgary, AB
3 Copies – Wek'èezhìi Land and Water Board

March 2014
13-1328-0001

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EXECUTIVE SUMMARY

In 2013, Diavik Diamond Mines (2012) Inc. (DDMI) completed the field component of its Aquatic Effects Monitoring Program (AEMP), as required by Water Licence W2007L2-0003. This report presents the Weight of Evidence (WOE) integration of the AEMP findings, which was carried out by Golder Associates Ltd. according to the AEMP Study Design Version 3.3. It is based on data collected during the 2013 AEMP field program.

Weight-of-evidence analyses were conducted separately to address two broad impact[1] hypotheses for Lac de Gras:

- **Toxicological Impairment Hypothesis:** Toxicity to aquatic organisms could occur due to chemical contaminants (primarily metals) released to Lac de Gras.
- **Nutrient Enrichment Hypothesis:** Eutrophication could occur due to the release of nutrients (phosphorus and nitrogen) to Lac de Gras.

For each hypothesis, the WOE analysis integrated the results of endpoints for exposure and biological response (measured in the field) with *a priori*[2] weighting factors, direction-weighting factors[3] and *a posteriori*[4] weighting factors to derive Evidence of Impact (EOI) rankings for lake productivity, the benthic invertebrate community, and fish population health. A higher rank represents a higher strength of support for a particular hypothesis. The EOI ranking results for each hypothesis were then interpreted to draw conclusions with respect to types of effects that are most likely occurring in Lac de Gras.

The EOI rankings and key supporting findings of the 2013 Aquatic Effects Monitoring Program, which formed the basis for the rankings, are described below.

Evidence of Toxicological Impairment

- **Lake Productivity –** EOI Rank 0 (Negligible):
  - There was a statistically significant increase in the water column concentrations of multiple Substances of Interest (SOIs) in the near-field (NF) area relative to reference areas. These findings were linked to effluent release from the Mine.

---

[1] The term “Impact” is used to indicate a change (positive or negative) in Lac de Gras related to the Diavik Diamond Mine (Mine) or Mine activities; however, it is not intended to reflect the ecological significance or level of concern associated with a given change.

[2] Four *a priori* factors were applied: representativeness; methodological robustness; clarity of interpretation; and, permanence of effects.

[3] Direction-weighting factors reflected the degree of support that an observed biological response contributed to each of the impact hypotheses.

[4] *A posteriori* factors were applied for coherence of response and evidence of causality.

  - The observed responses in all plankton biomass endpoints (chlorophyll *a*, phytoplankton biomass and zooplankton biomass (increases in exposed areas relative to reference areas) were not consistent with toxicological impairment, resulting in negligible support for this hypothesis. Although a shift in community structure of both phytoplankton and zooplankton was apparent, the most likely cause was enrichment, not toxicity.

- **Benthic Invertebrate Community –** EOI Rank 0 (Negligible):

  - Multiple sediment quality parameters were significantly higher in the NF area relative to reference area. Of these, bismuth, lead and uranium also exceeded the normal range in the NF. However, none of the parameters that had statistical differences exceeded available sediment quality guidelines indicating generally that the differences were of low toxicological concern.

  - Based on the pattern of response in benthic invertebrates, none of the responses were indicative of toxicological impairment.

- **Fish Population Health –** EOI Rank 1 (Low):

  - Bismuth, and uranium concentrations in fish from the NF area were greater than the reference normal range with the differences being statistically significant. However, there was uncertainty as to whether these elevated metals in fish tissues were related to effluent release from the Mine.

  - The pattern of response in fish health endpoints was mostly consistent among all age/sex classes and included statistically-significant decreases in the NF area relative reference areas for body size, energy reserves and reproductive investment. Although these changes were in the direction of a toxicological impairment response, the lack of similar responses in previous years in which similar concentrations of metals in fish were found, and the lack of toxic impairment responses in the plankton and benthic communities suggests that the fish health responses for 2013 may represent a random fluctuation within normal variability and/or could have been caused by other ecological/abiotic factors.

Evidence of Nutrient Enrichment

- **Lake Productivity –** EOI Rank 3 (Strong):

  - The average total phosphorus and total nitrogen concentrations in the NF area exceeded the reference normal range with the elevated concentrations covering less than 20% of the lake area.

  - There was a statistically significant increase exceeding the reference normal range in chlorophyll *a* in NF areas compared to reference areas, which extended beyond 20% of the lake area. There were also indications of increased phytoplankton and zooplankton abundance as well nutrient-related shifts in plankton community structure in the NF areas relative to reference areas.

  - The strong linkage of elevated nutrient concentrations to the Mine combined with a clear indication of responses in primary and secondary productivity provided strong evidence for an enrichment effect on Lake Productivity.

- **Benthic Invertebrate Community –** EOI Rank 3 (Strong):
  - There was a statistically significant increase exceeding the reference normal range in chlorophyll *a* in NF areas compared to reference areas (representing increased food supply for benthic invertebrates), which extended beyond 20% of the lake area. This increased food supply has a clear linkage to the Mine as a result of corresponding increases in nutrients (nitrogen and phosphorous) in NF areas.
  - There was a statistically significant increase in total invertebrate density, in NF areas compared to reference areas. Increases in dominant taxa and a shift in community composition were also evident as a result of nutrient enrichment.
  - The strong linkage to elevated food supply to nutrient releases from the Mine combined with a clear indication of increased biomass of the benthic community provide strong evidence for an enrichment effect on Benthic Invertebrates.
- **Fish Population Health –** EOI Rank 1 (Low):
  - There was a statistically significant increase exceeding the normal range in chlorophyll *a* in NF compared to reference areas, which extended beyond 20% of the lake area. This increased primary productivity is indicative of a potential corresponding increase in zooplankton and/or benthic invertebrate food supply for slimy sculpin.
  - Based on the pattern of response in fish health, none of the responses were indicative of nutrient enrichment. The overall low EOI Rank was entirely due to the high rating for chlorophyll *a* (which indicates nutrient exposure only) rather than actual biological responses in fish health. There was no evidence that this exposure was causing an enrichment response in the fish health endpoints in 2013.

The evidence for nutrient enrichment in Lac de Gras is much stronger than the evidence for toxicological impairment. For 2013, there continued to be a relatively clear link between nutrient releases to Lac de Gras, increases in nutrient concentrations in exposed areas, and increases in lake productivity in exposed areas. There was also a consistent response of increases in invertebrate density and a mild community shift in the benthic invertebrate community that can be linked to the observed enrichment.

The magnitude and type of response in Lac de Gras appears to be increased lake productivity as a result of nutrient enrichment. Although there are statistically significant changes to indicators of enrichment in the near-field area (and in some cases mid-field areas), the severity with respect to the ecological integrity of Lac de Gras associated with these changes is considered to be low.

Responses for fish health were in the direction of a toxicological impairment response. However, such responses have not been observed in previous years and there was a lack of toxic impairment responses in the plankton and benthic communities. Moreover, the body burdens of metals in fish and the concentrations of metals in water are well below levels known to cause toxicity in fish. Therefore, it remains inconclusive if a true toxicological effect has occurred. The response may simply reflect random fluctuations within a normal range of variability and/or it could have been caused by other ecological or abiotic factors such as the colder water encountered in exposure areas.

LIST OF ACRONYMS

AEMP	aquatic effects monitoring program
AFDM	ash-free dry mass
CCME	Canadian Council of Ministers of the Environment
DDMI	Diavik Diamond Mines (2012) Inc.
EOI	evidence of impact
ERA	ecological risk assessment
FF	far-field
GSI	gonadosomatic index
ISQG	interim sediment quality guideline
K	condition factor
LEL	lowest effect level
LOE	line(s) of evidence
LSI	liver-somatic index
MF	mid-field
Mine	Diavik Diamond Mine
NF	near-field
NMDS	non-metric multidimensional scaling
NWT	Northwest Territories
OMOEE	Ontario Ministry of Environment and Energy
PEL	probable effects level
QA/QC	quality assurance/quality control
ROPCs	receptors of potential concern
SD	standard deviation
SEL	severe effect level
SOI	substance of interest
SQG	sediment quality guideline
TN	total nitrogen
TP	total phosphorus
US EPA	United States Environmental Protection Agency
VECs	valued ecosystem components
WLWB	Wek’èezhìi Land and Water Board
WOE	weight-of-evidence

LIST OF UNITS AND OPERATORS

%	percent
>	greater than
≥	greater than or equal to
<	less than
cm	centimetre

GLOSSARY OF TERMS

Alpha	In statistics, the probability of a Type I error.
Action level	A categorization indicating the severity of possible effects to an assessment endpoint in the AEMP
A *posteriori*	After the fact; without prior knowledge. A *posteriori* weighting criteria are derived after data have been collected.
A *priori*	Derived by reasoning in advance. A *priori* weighting criteria are established before data have been collected.
Assessment endpoint	Valued characteristics of an ecosystem or ecosystem component that may be affected by exposure to a stressor.
Benthic	An adjective used to describe organisms, samples, or material related to, living in, or associated with the bottom of a waterbody.
Benthic invertebrate community	Refers to the community of invertebrate organisms that live in or on the bottom sediments of rivers, streams, and lakes.
Best professional judgment	The ability of a person or team to draw conclusions, give opinions, and make interpretations based on experiments, measurements, observations, knowledge, experience, literature, and/or other sources of information.
Bioavailability	The availability of a substance to be taken up by organisms.
Contamination	The presence of potentially toxic substances (contaminants) in an environmental matrix. The presence of contamination does not necessarily imply that adverse effects are occurring.
Ecological risk assessment	The determination of the probability of an adverse effect occurring to an ecological system as a result of exposure to stressors, such as contaminants or nutrients.
Ecosystem	An interacting system of all living organisms in a circumscribed region of similar characteristics, together with the non-living substrate, nutrients, energy, and other environmental components; the biotic community and its abiotic environment. Lac de Gras is an example of a lake ecosystem.
Environmental quality guidelines	Specific levels of contaminants in water, sediment or biological tissues that, if exceeded, may render the matrix unsuitable for its designated use (e.g., water quality guidelines for the protection of aquatic life).
Eutrophication	Enrichment of a waterbody with nutrients, usually nitrogen or phosphorus, which stimulate the growth of phytoplankton, algae and plants.
Homogeneous	Of the same or a similar kind or nature. In natural systems, lacking in variability.
Impact	A change (positive or negative), for instance related to the Mine or Mine activities.
Invertebrates	Animals lacking a spine, such as zooplankton and benthic invertebrates.
Measurement endpoint	A measurable environmental characteristic that is related to the valued characteristic chosen as the assessment endpoint.
Periphyton	Small, unicellular or multicellular plants that grow on the surface of rocks or macrophytes within the littoral (i.e., nearshore) area
Phytoplankton	Plant life, mostly microscopic, found floating or drifting in the oceans or large freshwater waterbodies; forms the basis of these waterbodies' aquatic food chains as the main primary producer.
Pollution	Contamination that results in adverse biological effects to populations or communities of organisms.

Problem formulation	The stage in an ecological risk assessment that specifies the scope and approach of the assessment and includes: specification of assessment endpoints (i.e., what are we trying to protect?); preparation of the conceptual model (i.e., what are the pathways by which human activities may result in harm?); specification of measurement endpoints (i.e., what are the tools that can be used to evaluate the probability and magnitude of harm?); and, development of an analysis plan.
Reference area	An area that is not exposed to a potential source of contamination but exhibits similar natural characteristics to exposed monitoring sites.
Standard deviation	A statistical measure of variability in a population of individuals or in a set of data; the square root of the variance.
Stochasticity	The quality of lacking any predictable order or plan: haphazardness, randomness, noise. In natural systems, often synonymous with natural variability.
Stressors	Physical, chemical, or biological perturbations to a system that are either (a) foreign to that system or (b) natural to the system but applied at an excessive [or deficient] level. Stressors cause significant changes in the ecological components, patterns and processes in natural systems. Examples include water withdrawal, pesticide use, timber harvesting, traffic emissions, stream acidification, trampling, poaching, land-use change and water pollution.
Toxicity	The inherent potential or capacity of a substance or material to cause adverse effect(s) to organisms. The effect(s) could be lethal or sublethal.
Trophic level	Position in the food chain determined by the number of energy-transfer (i.e., predator-prey) steps to reach that level.
Type I error	In statistics, the case where the statistical findings indicate a difference when in truth there is none (i.e., a false positive; or rejecting a null hypothesis when it is actually true). The probability of a Type I error is indicated by alpha.
Type II error	In statistics, the case where the statistical findings do not indicate a difference when in truth there is one (i.e., a false negative; or failing to reject a null hypothesis which should have been rejected).
Ultra-oligotrophic	In freshwater lakes refers to the condition of having very low nutrient (phosphorus) concentrations, low primary productivity, and very high water clarity.
Valued ecosystem components	Physical and/or biological components of an ecosystem that are considered important based on ecological, social, cultural or economic values, and may be influenced by environmental changes resulting from a development
Weight-of-evidence	A process used in ecological risk assessments and environmental monitoring by which multiple measurement endpoints (often referred to in this context as “lines of evidence”) are related to an assessment endpoint for a particular receptor.
Zooplankton	The animal component of plankton; animals suspended or drifting in the water column.

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Appendix A Weight-Of-Evidence Analysis – Quantitative Integration of Endpoints, Weighting Factors, Combined Scores and Evidence of Impact Rankings

1 INTRODUCTION AND OBJECTIVES

1.1 BACKGROUND

In 2013, Diavik Diamond Mines (2012) Inc. (DDMI) completed the field component of its Aquatic Effects Monitoring Program (AEMP), which was carried out by DDMI according to the AEMP Study Design Version 3.0 (Golder 2011), and as required by Water Licence W2007L2-0003 (WLWB 2007a). This report presents the Weight of Evidence (WOE) integration of the AEMP findings, which was carried out by Golder Associates Ltd. (Golder) according to the AEMP Study Design Version 3.3 (Golder 2014a). The Study Design Version 3.3 was approved by the Wek'èezhìi Land and Water Board (WLWB) on February 19, 2014 (WLWB 2014).

The goal of the DDMI AEMP is to determine if effluent released from the Diavik Diamond Mine (Mine) is having an effect on the aquatic ecosystem of Lac de Gras. It focuses on Mine-related stressors (primarily metals[1] and nutrients) that are released to Lac de Gras. Related to these stressors, the AEMP has identified two broad impact hypotheses for Lac de Gras:

- **Toxicological Impairment Hypothesis:** Toxicity to aquatic organisms could occur due to chemical contaminants (primarily metals) released to Lac de Gras.
- **Nutrient Enrichment Hypothesis:** Eutrophication could occur due to the release of nutrients (phosphorus and nitrogen) to Lac de Gras.

The WOE analysis is structured to distinguish between these two hypotheses. The products of the WOE analysis are estimates of the Evidence of Impact (EOI) in support of each hypothesis. Note that the term "Impact" is used in this report in a generic sense to indicate a change (positive or negative) in Lac de Gras related to the Mine or Mine activities. It is not intended to reflect the ecological significance or level of concern associated with a given change, nor is it intended to indicate that "pollution[2]" of Lac de Gras has occurred.

As described in the updated Version 3.3 Study Design (Golder 2014a), ecological significance and the severity of possible effects to an assessment endpoint are categorized in the AEMP according to Action Levels. These classifications were developed to meet the goals of the Response Framework for Aquatic Effects Monitoring that was recently drafted by the WLWB (Racher et al. 2011). The goal of the Response Framework is to ensure that significant adverse effects never occur. When Action Levels are met for a

---

[1] The term "metals" as used herein also includes metalloids (e.g., arsenic) and non-metals (e.g., selenium).

[2] The term "pollution" is used to indicate contamination that results in adverse biological effects to populations or communities of organisms.

particular component of the AEMP, then the findings of the WOE analysis serve to inform response planning and environmental stewardship.

This report presents the WOE analysis on the findings of the 2013 AEMP. For 2013, the AEMP integrated the following field components: water quality; sediment quality; fish tissue chemistry; lake productivity (nutrients, chlorophyll *a* and zooplankton biomass); plankton communities; benthic invertebrates; and, fish population health. Details on methodology are provided in Section 2. Section 3 provides results and discussion of the WOE analysis, while Section 4 provides conclusions, together with recommendations, for program changes or enhancements.

1.2 OBJECTIVES

An ecological risk assessment (ERA) process is designed to provide a systematic means for prioritizing environmental response pathways, for collecting appropriate data to evaluate those pathways, and for acknowledging uncertainties identified in each component of the assessment process. In particular, it combines measures of exposure (e.g., water quality or sediment chemistry) with either laboratory- or field-based biological responses (e.g., benthic invertebrate density or fish growth). The WOE analysis applies an ERA-like framework for integrating the AEMP findings for various ecosystem components. The objectives of the WOE analysis are two-fold:

- to apply a standardized process to evaluate strength of evidence for potential toxicological impairment and nutrient enrichment effects in the aquatic ecosystem of Lac de Gras; and,
- to summarize the AEMP findings in a semi-quantitative manner that provides broad AEMP conclusions, to inform decision-making with respect to Action Levels and environmental stewardship of Lac de Gras.

2 METHODS

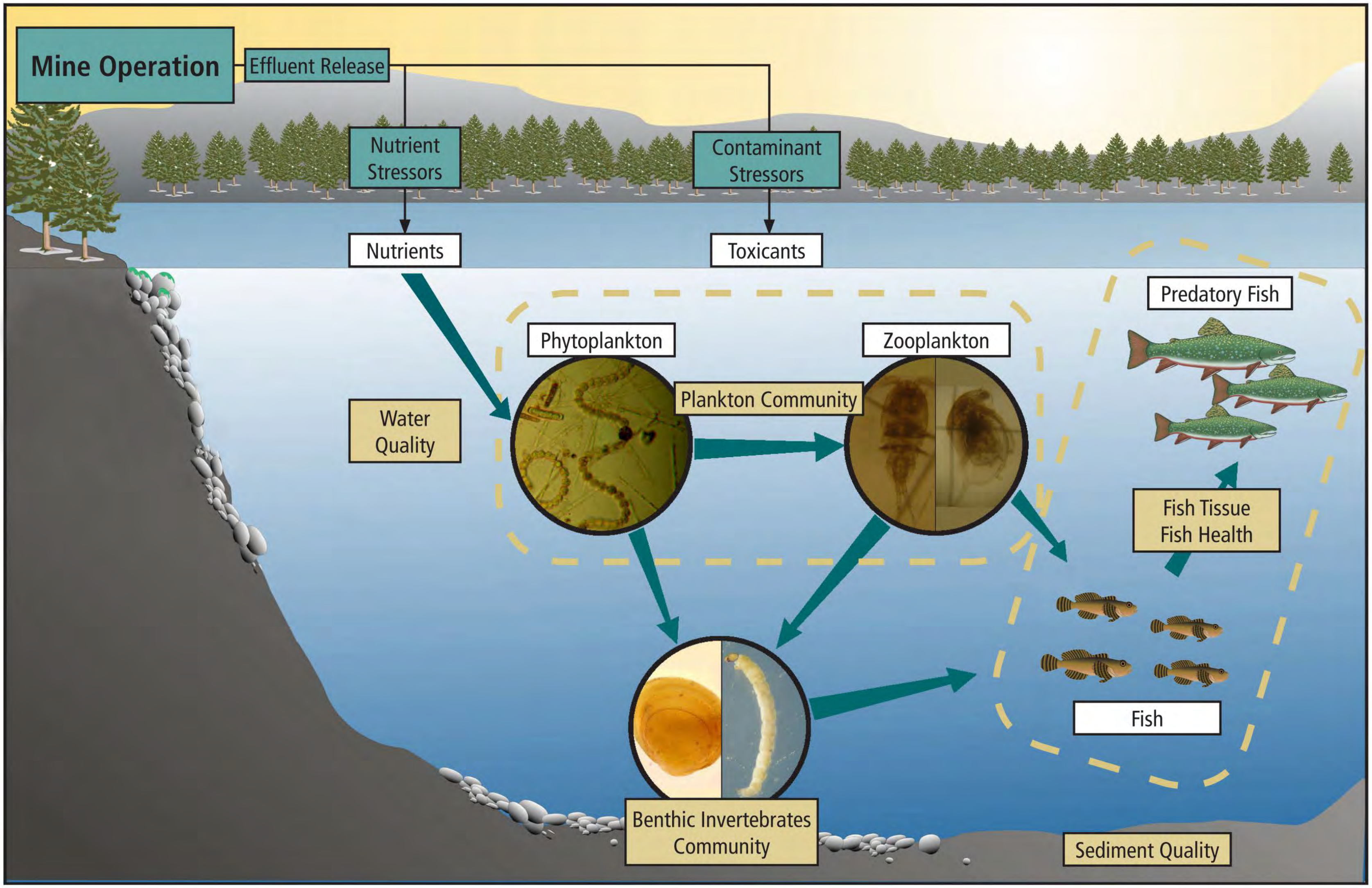
This section describes the conceptual model and endpoints that are included in the AEMP and then develops the Weight of Evidence Framework that is applied for integrating the AEMP findings.

2.1 CONCEPTUAL MODEL

The general conceptual model for the Mine and Lac de Gras is presented in Figure 2-1. The primary exposure route for receptors of potential concern (ROPCs) is via Mine effluent, which could lead to increases in Mine-related toxicological stressors (e.g., metals concentrations) or Mine-related enrichment stressors (e.g., nutrients) in Lac de Gras. Receptors of potential concern can consist of individual species, functional groups (e.g., trophic levels) or communities. For Lac de Gras, the broad ecosystem components that have common routes of exposure to Mine-related stressors include:

- phytoplankton (microscopic floating plants, mainly algae, that live suspended in the water column;
- zooplankton (animal component of plankton, including microscopic animals suspended or drifting in the water column);
- soft-bottom benthic invertebrate community (macroinvertebrates found within or on the surface of the sediment bed);
- demersal fish (e.g., Slimy Sculpin, *Cottus cognatus*); and,
- pelagic fish (e.g., Lake Trout, *Salvelinus namaycush*).

The distinction between pelagic (i.e., inhabiting upper layers of lake water) and demersal (i.e., living in close proximity to bottom sediments) fish accounts for potential different exposure to stressors from exposure to sediments (and associated sediment porewater) versus surface waters. In years that the fish community is monitored, slimy sculpin are used as surrogates (or sentinel species) for other members of the fish community found in Lac de Gras.



PROJECT

DIAVIK DIAMOND MINES INC.

TITLE

AEMP CONCEPTUAL MODEL

Golder Associates

PROJECT No.	13.1328.0001.10000	FILE No.	131328000110000A001
DESIGN	TD	13 Mar. 2014	SCALE AS SHOWN | REV. 0
CADD	BTM	19 Mar. 2014	
CHECK	TD	20 Mar. 2014	FIGURE: 2-1
REVIEW	CF	20 Mar. 2014	

2.2 ASSESSMENT AND MEASUREMENT ENDPOINTS

The problem formulation for the AEMP identified multiple assessment and measurement endpoints that form the basis for evaluating potential changes, responses, or effects in Lac de Gras related to the Mine. Assessment endpoints are characteristics of the aquatic ecosystem that may be affected by the Mine, expressed explicitly as statements of the actual environmental values that are to be protected (Suter 1990; US EPA 1992; Warren-Hicks et al. 1989). Considerations in the selection of assessment endpoints include ecological relevance, policy goals, future land use, societal values, susceptibility to substances of interest (SOIs), and the ability to define the endpoint in operational terms.

The assessment endpoints were used to select appropriate measurement endpoints, which are measurable responses to the stressor that are related to the valued characteristics chosen as the assessment endpoint (Suter 1990). Measurement endpoints may include measures of exposure (e.g., chemical concentrations in water and sediments) and measures of effects (e.g., plankton biomass and benthic invertebrate community structure). Measurement endpoints are operationally defined and can be assessed using appropriate field and laboratory studies.

Valued ecosystem components (VECs) for Lac de Gras and their corresponding assessment and measurement endpoints are described in Table 5.2-1 of the AEMP Version 3.3 Study Design (Golder 2014a). The VECs applicable to the WOE Framework as well as additional component relative to the AEMP, include:

- water quality;
- sediment quality;
- fish tissue chemistry
- lake productivity;
- benthic invertebrate community structure; and,
- fish health.

These components are integrated to assess the evidence of nutrient enrichment and toxicological impairment. Separate WOE analyses and conclusions are made for each impact hypothesis because, in most cases, nutrient enrichment may act in opposition to toxicological impairment. For example, nutrient enrichment is likely to increase biological productivity, whereas toxicological impairment is likely to decrease biological productivity.

The WOE analysis for each impact hypothesis focused on the following three ecosystem components of Lac de Gras: lake productivity, benthic invertebrate community health, and fish population health. The assessment of these components was supported by the measures of water chemistry, sediment chemistry, and tissue chemistry, all of which had also been identified as VECs.

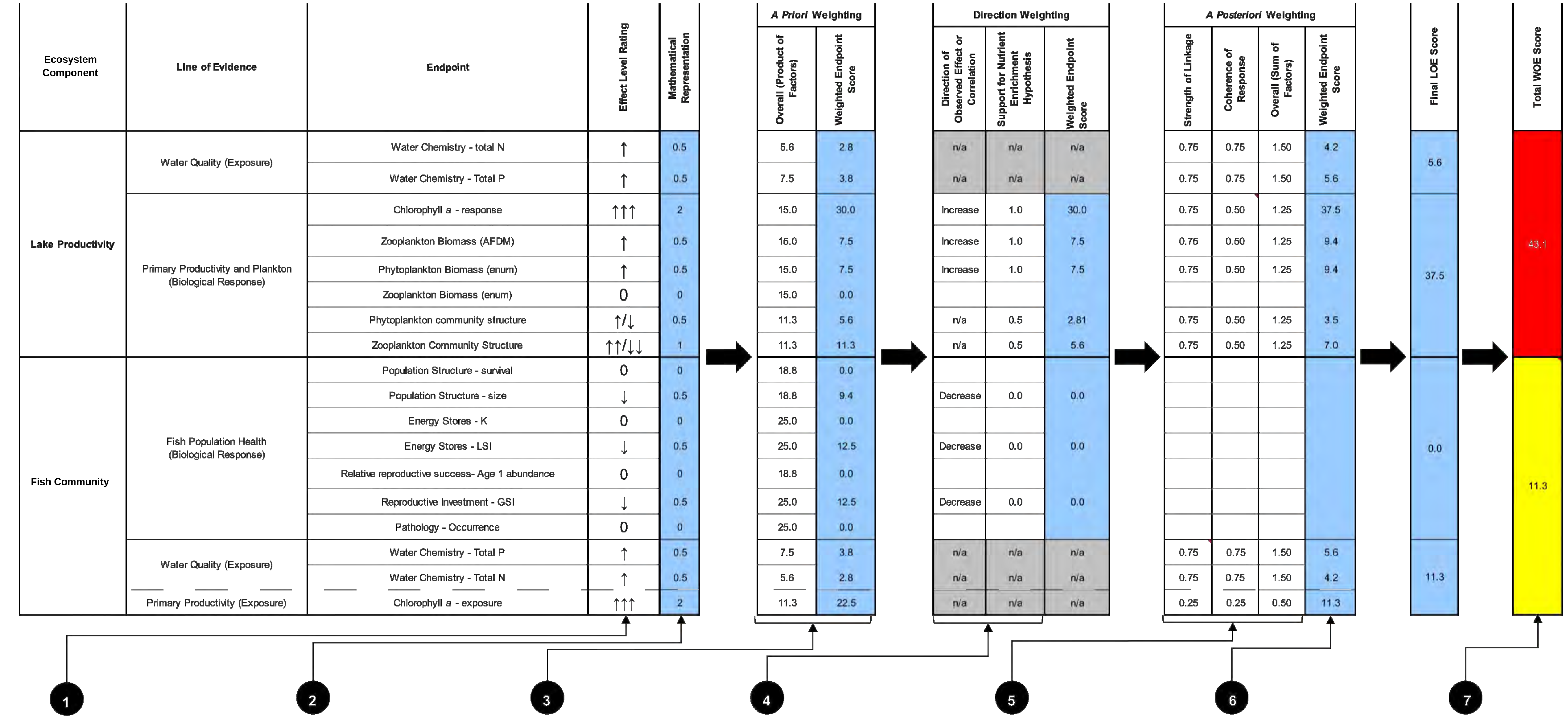
The strength of evidence for toxicological impairment or nutrient enrichment associated with observed changes was evaluated using an array of measurement endpoints specific to the WOE analysis. Endpoints were selected to be relevant to each of these stressor types and, wherever possible, to be directly linked to the Mine. For example, measures of water quality, compared between near-field and reference areas, provides an indication of exposure to toxicants or nutrients, and can be linked to effluent release. Similarly, increases or decreases in plankton biomass provide an indication of a biological response to increases in nutrients or toxicants. The various endpoints were integrated in the WOE Framework to yield overall assessments for each ecosystem component under each impact hypothesis (toxicological impairment versus nutrient enrichment).

2.3 WEIGHT-OF-EVIDENCE FRAMEWORK

WOE analysis provides a systematic and transparent method for integrating the complexity of data generated in environmental assessment programs. The basis for decision-making within a WOE analysis is a combination of statistical analyses and scoring systems incorporated into a logic system. Best professional judgment is also a key component of any WOE analysis (Chapman et al. 2002), and it was incorporated as appropriate. Key components that make up the design of the WOE Framework for the DDMI AEMP are summarized in the following sections:

- Section 2.3.1: Line of Evidence (LOE) groups and measurement endpoints included in the WOE Framework;
- Section 2.3.2: Description of the process for evaluating the effect levels observed for the endpoints in each LOE group; and,
- Section 2.3.3: Description of the process for determining the appropriate weighting of each endpoint towards the overall WOE conclusions.

An example of the WOE process and framework applied in the AEMP is presented in Figure 2-2. The following sections provide a more detailed explanation of the components of the framework.



					A Priori Weighting		Direction Weighting			*A Posteriori* Weighting					
Ecosystem Component	Line of Evidence	Endpoint	Effect Level Rating	Mathematical Representation	Overall (Product of Factors)	Weighted Endpoint Score	Direction of Observed Effect or Correlation	Support for Nutrient Enrichment Hypothesis	Weighted Endpoint Score	Strength of Linkage	Coherence of Response	Overall (Sum of Factors)	Weighted Endpoint Score	Final LOE Score	Total WOE Score
Lake Productivity	Water Quality (Exposure)	Water Chemistry - total N	↑	0.5	5.6	2.8	n/a	n/a	n/a	0.75	0.75	1.50	4.2	5.6	43.1
		Water Chemistry - Total P	↑	0.5	7.5	3.8	n/a	n/a	n/a	0.75	0.75	1.50	5.6		
	Primary Productivity and Plankton (Biological Response)	Chlorophyll *a* - response	↑↑↑	2	15.0	30.0	Increase	1.0	30.0	0.75	0.50	1.25	37.5	37.5	
		Zooplankton Biomass (AFDM)	↑	0.5	15.0	7.5	Increase	1.0	7.5	0.75	0.50	1.25	9.4		
		Phytoplankton Biomass (enum)	↑	0.5	15.0	7.5	Increase	1.0	7.5	0.75	0.50	1.25	9.4		
		Zooplankton Biomass (enum)	0	0	15.0	0.0									
		Phytoplankton community structure	↑/↓	0.5	11.3	5.6	n/a	0.5	2.81	0.75	0.50	1.25	3.5		
		Zooplankton Community Structure	↑↑/↓↓	1	11.3	11.3	n/a	0.5	5.6	0.75	0.50	1.25	7.0		
Fish Community	Fish Population Health (Biological Response)	Population Structure - survival	0	0	18.8	0.0								0.0	11.3
		Population Structure - size	↓	0.5	18.8	9.4	Decrease	0.0	0.0						
		Energy Stores - K	0	0	25.0	0.0									
		Energy Stores - LSI	↓	0.5	25.0	12.5	Decrease	0.0	0.0						
		Relative reproductive success- Age 1 abundance	0	0	18.8	0.0									
		Reproductive Investment - GSI	↓	0.5	25.0	12.5	Decrease	0.0	0.0						
		Pathology - Occurrence	0	0	25.0	0.0									
	Water Quality (Exposure)	Water Chemistry - Total P	↑	0.5	7.5	3.8	n/a	n/a	n/a	0.75	0.75	1.50	5.6	11.3	
		Water Chemistry - Total N	↑	0.5	5.6	2.8	n/a	n/a	n/a	0.75	0.75	1.50	4.2		
	Primary Productivity (Exposure)	Chlorophyll *a* - exposure	↑↑↑	2	11.3	22.5	n/a	n/a	n/a	0.25	0.25	0.50	11.3		

① Individual endpoints for each LOE Group were assigned a qualitative rating corresponding to the observed level of effect. Decision criteria are summarized in Tables 2-3 and 2-4 and discussed in Section 3.1.

② Each qualitative rating was converted to a numerical equivalent to allow mathematical calculation. Numerical equivalents were:

- Negligible (0) = 0
- Early Warning/Low (↑/↓) = 0.5
- Moderate (↑↑/↓↓) = 1
- High (↑↑↑/↓↓↓) = 2

(note that an upward arrow indicates increases while a downward arrow indicates decreases. Both arrows are used for community structure endpoints because changes to community structure are not directional)

③ *A priori* weighting factors for representativeness, methodological robustness, clarity of interpretation and permanence of effect were applied (Table 2-5). These four individual factors were multiplied to generate an overall *a priori* weighting factor. Qualitative equivalents of the numerical *a priori* factors were:

- Poor = 1
- Satisfactory = 2
- High = 3

The numerical equivalents from Step (2) were multiplied by the overall *a priori* weighting score.

④ Direction weighting factors were applied (Table 2-6) to represent the degree of support for a particular hypothesis (*i.e.,* nutrient enrichment vs. toxicological impairment) indicated by the direction of observed changes in biological response endpoints. Qualitative equivalents of the numerical direction factors were:

- High = 1
- Moderate = 0.75
- Neutral = 0.5
- Low = 0.25
- None = 0

The numerical equivalents for biological/response endpoints from Step (3) were multiplied by the direction weighting factors.

⑤ *A posteriori* weighting factors for coherence and strength of linkage were developed and applied. Scores of low, medium and high were assigned based the results for exposure and biological response endpoints. Qualitative equivalents of the numerical causality and coherence weighting factors were:

- Low = 0.25
- Medium/Neutral = 0.5
- High = 0.75

The numerical equivalents from Step (2) or (3) were multiplied by the direction weighting factors.

⑥ The final scores for each endpoint were the values from Step (5). The numerical process results in more weight bing assigned to those endpoints with high *a priori* and *a posteriori* weighting scores and a direction of change that supported the hypothesis being examined.

The final score for each Line of Evidence is the maximum endpoint score within the Line of Evidence.

⑦ The final score for each Ecosystem Component is the sum of the Line of Evidence Scores within an Ecosystem Component (i.e., Exposure + Biological Response). This numerical value was converted to an "Evidence of Impact" (EOI) Rank representing the strength of evidence for a particular impact hypothesis.

EOI Ranking Scale:

EOI Rank 3	🟥 >40.0
EOI Rank 2	🟧 >20.0
EOI Rank 1	🟨 >10.0
EOI Rank 0	🟩 <10

NOTES

LOE = LINE(S) OF EVIDENCE
WOE = WEIGHT-OF-EVIDENCE
N = NITROGEN
P = PHOSPHORUS
AFDM = ASH-FREE DRY MATTER
ENUM = ENUMERATION
K = CONDITION FACTOR
LSI = LIVER-SOMATIC INDEX
GSI = GONADO-SOMATIC INDEX
EOI = EVIDENCE OF IMPACT

REFERENCE

THE ECOSYSTEM COMPONENTS, LOE GROUPS, ENDPOINTS, RATINGS AND RESULTS ARE PRESENTED FOR ILLUSTRATIVE PURPOSES ONLY (BENTHIC INVERTEBRATES NOT SHOWN). THE WOE ANALYSIS SPREADSHEETS FOR THE 2013 AEMP ARE PROVIDED IN APPENDIX I.

PROJECT
DIAVIK DIAMOND MINES INC.

TITLE

EXAMPLE OF WEIGHT-OF-EVIDENCE
FRAMEWORK FOR THE AEMP

Golder Associates

PROJECT No.	13.1328.0001.10000		FILE No.	131328000110000A002
DESIGN	TD	13 Mar. 2014	SCALE AS SHOWN	REV. 0
CADD	BTM	19 Mar. 2014	FIGURE: 2-2	
CHECK	TD	20 Mar. 2014		
REVIEW	CF	20 Mar. 2014		

2.3.1 Lines of Evidence and Measurement Endpoints

The endpoints and ecosystem components included in the WOE Framework for each impact hypothesis are summarized in Tables 2-1 and 2-2. Within each ecosystem component, two distinct LOE groups were assessed to integrate exposure and effects in the WOE:

- **Exposure group**: measures of the potential exposure of receptors to Mine-related SOIs, including surface water, sediment and tissue chemistry; and,
- **Biological Response group:** observationally-based measures of potential ecological changes, including measures of primary productivity, zooplankton biomass, benthic invertebrate community structure and fish population health.

These two LOE groups bring distinct types of information to the WOE Framework. For example, sediment chemistry analyses (exposure endpoints for benthic invertebrates) provide information on contamination but not on biological effects. Measuring the diversity of the benthic invertebrate community present in Lac de Gras (a biological response endpoint) provides evidence of substance-related effects in the environment; however, any observed alterations may also be due to biological (e.g., predation, seasonal abundance, competition) and/or physical effects (e.g., habitat alteration) unrelated to contaminants or nutrient enrichment. Results that demonstrate a high degree of linkage between the two LOE groups provide stronger evidence regarding potential Mine-related ecological effects than reliance on one type of LOE in isolation. *A posteriori* weighting factors are applied in the WOE analysis to account for the degree of linkage between endpoints in the exposure and biological response LOE groups.

Within each LOE group there are one or more lines of evidence that encompass different stressor types, media, levels of biological organization, and data analysis methods:

- Exposure LOE: nutrient exposure, contaminant exposure and primary productivity[1]; and,
- Biological Response LOE: biological productivity, benthic invertebrates-statistical differences, benthic invertebrates-gradients and fish population health.

---

[1] Primary productivity is used as an indicator of both exposure (for higher levels of biological organization) and response (included as an endpoint under the "biological productivity" line of evidence). Further discussion is provided in Section 3.1.2.

Table 2-1 Endpoints and Lines of Evidence for Each Ecosystem Component Evaluated in the 2013 AEMP – Nutrient Enrichment

Endpoints	Line of Evidence	Ecosystem Component
Water Quality - Total N	Nutrient Exposure	Lake Productivity
Water Quality - Total P		
Chlorophyll *a*	Biological Productivity (Biological Response)	
Zooplankton Biomass (AFDM)		
Phytoplankton Biomass (enumeration)		
Zooplankton Biomass (enumeration)		
Phytoplankton Community Structure/Richness		
Zooplankton Community Structure/Richness		
Water Quality - Total N	Nutrient Exposure	Benthic Invertebrates
Water Quality - Total P		
Sediment Quality - TOC		
Chlorophyll *a*	Primary Productivity (Biological Response	
Total Invertebrate Density	Benthic Invertebrate Community (Biological Response)	
Dominant Taxa Density		
Richness		
Simpson's Diversity Index		
Evenness		
Dominance		
Bray-Curtis Distance		
Relative Abundance of Dominant Taxa		
Water Quality - Total N	Nutrient Exposure	Fish Community
Water Quality - Total P		
Chlorophyll *a*	Primary Productivity (Biological Response)	
Population Structure - Survival	Fish Population Health (Biological Response)	
Population Structure - Size		
Energy Stores - K		
Energy Stores - LSI		
Relative Reproductive Success - Age 1 Abundance		
Reproductive Investment - GSI		
Pathology - Occurrence		

Notes: AFDM = ash-free dry mass; GSI - gonadosomatic index; K = condition factor; LSI = liver-somatic index; TOC = total organic carbon; total N = total nitrogen; total P = total phosphorus.

Table 2-2 Endpoints and Lines of Evidence for Each Ecosystem Component Evaluated in the 2013 AEMP – Toxicological Impairment

Endpoints	Line of Evidence	Ecosystem Component
Water Quality (substances of toxicological concern)	Contaminant Exposure	Lake Productivity
Chlorophyll *a*	Biological Productivity (Biological Response)	
Zooplankton Biomass (AFDM)		
Phytoplankton Biomass (enumeration)		
Zooplankton Biomass (enumeration)		
Phytoplankton Community Structure/Richness		
Zooplankton Community Structure/Richness		
Water Quality (substances of toxicological concern)	Contaminant Exposure	Benthic Invertebrates
Water Quality (substances of toxicological concern)		
Total Invertebrate Density	Benthic Invertebrate Community (Biological Response)	
Dominant Taxa Density		
Richness		
Simpson's Diversity Index		
Evenness		
Dominance		
Bray-Curtis Distance		
Relative Abundance of Dominant Taxa		
Water Quality (substances of toxicological concern)	Contaminant Exposure	Fish Community
Sculpin Tissue Chemistry		
Population Structure - Survival	Fish Population Health (Biological Response)	
Population Structure - Size		
Energy Stores - K		
Energy Stores - LSI		
Relative Reproductive Success - Age 1 Abundance		
Reproductive Investment - GSI		
Pathology - Occurrence		

Note: AFDM = ash-free dry mass; GSI - gonadosomatic index; K = condition factor; LSI = liver-somatic index.

For many of the LOE groups, multiple endpoints have been measured in Lac de Gras providing a “battery” approach for assessing the degree of effect associated with each LOE. The evaluation of multiple endpoints for each LOE means that a wide variety of possible changes are considered in the overall analysis. The endpoint findings are discussed in further detail in separate reports for:

- Effluent and Water Chemistry (Golder 2014b);
- Sediment Chemistry (Golder 2014c);
- Eutrophication Indicators (Golder 2014d);
- Plankton (Golder 2014e);
- Benthic Invertebrates (Golder 2014f); and,
- Fish Health (Golder 2014g).

The WOE Framework includes weighting factors that account for how well a particular endpoint detects or indicates changes in Lac de Gras (i.e., *a priori* weighting factors). The weighting factors also consider the relevance of the endpoint with regards to the impact hypothesis (Nutrient Enrichment vs. Toxicological Impairment). With separate WOE analyses for each impact hypothesis, these direction-weighting factors indicate the degree of support that a given endpoint response provides to each hypothesis.

In general terms, the endpoint results are *rated* according to a series of decision criteria, *weighted* to reflect the strength and relevance of the evidence they brought to the analysis, and then *integrated* to provide an overall assessment. This integration is accomplished using a WOE assessment framework based on McDonald et al. (2007), including guidance from Chapman and co-authors (Chapman 1990, 1996; Chapman et al. 1997, 2002; Chapman and McDonald 2005; Chapman and Anderson 2005; Chapman and Hollert 2006).

2.3.2 Rating the Magnitude of Observed Effects

2.3.2.1 Overview

The results for each of the endpoints within a LOE group were assessed relative to an appropriate reference condition or benchmark (typically near-field vs. reference comparisons or gradients in response), resulting in a rating for the endpoint depending on established effects criteria. Rating schemes in WOE frameworks can vary from assessment to assessment. WOE frameworks by Chapman and coauthors (e.g., Chapman et al. 2002; Chapman and McDonald 2005) use non-numerical rating systems in which endpoint results are assigned to one of a ranked series of categories (e.g., “↑”, “↑↑”, “↑↑↑”). Conversely, Menzie et al. (1996) proposed numerical ratings based on a set of attributes scored between 1 and 5 according to a series of causal criteria.

The WOE Framework applied in DDMI’s AEMP uses a hybrid of the numerical and non-numerical systems to exploit the strengths of each:

- Each endpoint is initially rated according to a non-numerical scheme (Chapman et al. 2002; Chapman and Anderson 2005). This approach emphasizes the semi-quantitative nature of rating each endpoint.
- These semi-quantitative ratings are then temporarily transformed into an arbitrary scale of numerical values to facilitate weighting and integration using simple mathematical functions (i.e., addition, multiplication). This approach is highly systematic as all cases use the same formulae. This approach is also highly transparent (especially with respect to the application of professional judgement) as stakeholders and reviewers can see the effect of each assumption and decision on the outcome of the WOE analysis.

- After weighting and integration, the numerical output of the WOE analysis is transformed back into a non-numerical set of categories termed EOI Rankings (Figure 2-2).

2.3.2.2 Effect Level Rating Criteria

During the original design of the AEMP, the effect ratings were agreed upon through a regulatory process with direct input from the WLWB and other reviewers (DDMI 2007; WLWB 2007b). Since 2008, revised effects ratings have been applied to improve consistency in treatment of endpoints in the WOE analysis and address refinements that were recommended based on the experience with the WOE analysis in the 2007 AEMP. In addition, new effect ratings have been developed for new endpoints that are included in the revised AEMP.

Observed changes or differences in exposure and biological response endpoints are classified using a scale ranging from “negligible” to “high” to represent the degree of response in the particular endpoint. Typically, a finding of no difference between exposed and reference areas indicated a rating of “negligible” effect (represented by “0” in the WOE table), whereas increasingly large and/or statistically significant differences received ratings of “early warning/low” (represented by “↑” or “↓”), “moderate” (represented by “↑↑” or “↓↓”) or “high” (represented by “↑↑↑” or “↓↓↓”). The following general categories have been adopted for distinguishing the strength of evidence provided by observed changes:

- **Early Warning/Low –** This level indicates that a change has occurred in the NF area but the potential for ecologically significant effects or harm is low. Some measurement endpoints are appropriate as early warnings on a project basis whereas others are not. For example, water and sediment chemistry alterations in the NF area would be expected to manifest prior to effects on benthos variables. An early warning/low level effect identified for benthos would serve as an early warning of potential responses in the Lac de Gras ecosystem. For nutrients, this rating occurs only once concentrations are beyond the normal range to account for the complex nature of eutrophication responses.
- **Moderate –** An observed effect is classified as moderate when a measured indicator is in excess of an early warning/low effect (e.g., for biota, both a statistical difference in the NF area relative to the reference areas, and NF area data beyond the normal range of the reference area data). The spatial extent of observed effects is also considered to determine whether or not the change extends beyond the NF area. For nutrients, a moderate rating is applied once a change extends beyond NF.
- **High –** A high level effect represents situations where moderate-level effects are extending beyond the NF area, meaning that the detected effect is being observed over a significant portion of Lac de Gras. The larger spatial area of changes is considered to pose a possibly larger overall impact on the ecosystem components of Lac de Gras.

These ratings for negligible, early warning/low, moderate and high level effects were converted to numerical equivalents (0, 0.5, 1 and 2, respectively) for the purposes of the integration process. This conversion was necessary so that integration could proceed using simple mathematical equations (i.e., weighted sums) rather than attempting to establish decision rules for each possible combination of semi-quantitative ratings.

Exposure Endpoints

The effect ratings applied in the WOE analysis for exposure endpoints are presented in Table 2-3. The exposure endpoints are similar to those used in previous AEMPs and effects ratings for each endpoint are rated by comparing near-field to reference and benchmarks.

For exposure endpoints, the studies of water and sediment chemistry generally employed an SOI approach. For sediment this approach focused the analysis only on those substances that were elevated, statistically different, or displaying a gradient in Lac de Gras that appeared to be a result of the Mine activities.

For water, SOIs were determined as those parameters that triggered an Action Level of 1 or greater. The SOIs were then analyzed statistically to confirm whether observed increases were mine-related. Therefore WOE ratings for water quality were applied to SOIs only. Because multiple SOIs were selected for each endpoint, the rating result for a particular endpoint was conservatively based on the worst-case result for all SOIs (i.e., chemistry results were aggregated and classified overall using the criteria in Table 2-1). The criteria for determining a moderate rating for water quality were refined to be consistent with the data analysis in support of Action Levels and the benchmarks for water quality are defined in Section 2.4.7.2 of the water quality report (Golder 2014b).

Comparison to guidelines for sediment quality results includes the use of Canadian Council of Ministers of the Environment (CCME) interim sediment quality guidelines (ISQGs) and probable effects level (PELs; CCME 2002) or Ontario Ministry of Environment and Enegy (OMOEE) low effect levels (LELs) and severe effect levels (SELs; OMOEE 1993). The method for deriving the ISQGs and PELs is such that concentrations below the ISQG indicate that effects on benthic invertebrates are unlikely while, once the PEL is exceeded, effects on benthic invertebrates become likely – but not certain. Between the ISQG and the PEL, the likelihood of effects on benthic invertebrates is less certain. Thus, exceeding the ISQG is deemed to be an indicator of a potential low-level rather than moderate-level effect, but exceeding the PEL is retained as an indicator of a potential high-level effect. The average of the ISQG and the PEL was used to represent the threshold for a potential moderate-level effect. For substances without ISQGs or PELs but having LELS and SELs, a similar logic has also been applied for guideline interpretation.

Table 2-3 Effect Level Ratings Applied for Exposure Endpoints

LOE Group	Measurement Endpoint	No Response 0	Early Warning/Low ↑	Moderate ↑↑	High ↑↑↑
Water Quality (substances of toxicological concern)	**Comparison to Benchmarks and Reference[(a)]**	No difference	Statistically significant increase, NF vs reference	Low + 75th percentile of NF area > reference normal range (2007-2010) **AND** Exceeding benchmark in NF area	Statistically significant increase, MF vs reference **AND** 75th percentile of MF area > reference normal range (2007-2010) **AND** Exceeding benchmark in MF area
Water Quality (nutrients)	**Comparison to Reference[(a)]**	No difference	NF area greater than normal range (2007-2010)	Less than or equal to 20% of the lake area greater than the normal range	More than 20% of the lake area greater than the normal range
Sediment Quality (substances of toxicological concern)	**Comparison to Guidelines And Reference[(a)]**	< ISQG	Statistically significant increase, NF vs reference	Low + NF > (ISQG+PEL)/2 (or other appropriate guideline)[(b)] **AND** NF area mean > reference normal range (2007-2010)	MF > (ISQG+PEL)/2 (or other appropriate guideline) **AND** MF area mean > reference normal range (2007-2010) **OR** NF > PEL **AND** NF area mean > reference normal range (2007-2010)
Sculpin Tissue Chemistry (substances of toxicological concern)	**Comparison to Reference[(a)]**	No difference	Statistically significant increase, NF vs reference	Low + NF area mean > reference normal range (2007-2013)	Moderate + MF area mean > reference normal range (2007-2013)

Notes: NF = near-field; MF = mid-field; FF = far-field; LEL = Lowest effect level; PEL = Probable effect level, SEL = severe effect level; ISQG = Interim sediment quality guideline; > = greater than; < = less than.

a) Applied separately for each SOI.

b) For example, the OMOEE [LEL+SEL]/2.

Biological Response Endpoints

The effect ratings applied in the WOE analysis for biological response endpoints are presented in Table 2-4.

Effect rating criteria have been developed for new biological response endpoints:

- Plankton and Productivity – zooplankton biomass as ash-free dry mass (AFDM) was added as a biological indicator of nutrient enrichment;
- Plankton and Productivity – phytoplankton and zooplankton community structure/richness were added as biological indicators of either nutrient enrichment or toxicological impairment; and,
- Benthic Invertebrates – benthic invertebrate community structure (i.e., relative abundance of dominant taxa) was added as a biological indicator of either nutrient enrichment or toxicological impairment.

Biological response endpoints generally used a similar rating system to exposure indicator endpoints with comparison of near-field to reference and baseline. The exceptions were the rating system for the newly added community structure endpoints.

For plankton community composition a low level effect corresponds to a divergent community structure, at the species or genus-level, between the NF exposure area and reference areas and a statistically significant change in taxonomic richness between the NF exposure area and the reference areas (Table 2-2). This level of response is assessed using the multivariate non-metric multidimensional scaling (NMDS) plots with the direction of response (i.e., in support of Nutrient Enrichment or Toxicological Impairment) assessed based on whether an increase or decrease in taxonomic richness is observed. A moderate level effect corresponds to a shift in community structure, at the ecological grouping level, between the NF and reference area. Ecological groupings for phytoplankton include cyanobacteria, chlorophytes, microflagellates, dinoflagellates, and diatoms. For zooplankton these groupings include: cladocerans, cyclopoids, calanoids, and rotifers. A high level effect would occur with a combined moderate rating for community structure and a statistically significant change in taxonomic richness in the NF exposure area compared to the current years reference area mean plus or minus (±) 2 standard deviations (SDs).

For benthos, the community structure assessment is based on visual examination of relative density plots (stacked bar graphs) for major taxa, and NMDS results. A Low rating is applied when there is a visual difference between NF and reference in major taxa, with progressive Moderate or High ratings applied as the differences extend further into the MF areas.

A final consideration is that for Nutrient Enrichment, chlorophyll *a* acts as both an indicator of biological response (for Lake Productivity) and as an indicator of exposure (for secondary consumers such as benthos). For both cases, the effect ratings for chlorophyll *a* remain the same.

Table 2-4 Effect Level Ratings Applied for Biological Response Endpoints

LOE Group	Measurement Endpoint	No Response 0	Early Warning/Low ↑/↓	Moderate ↑↑/↓↓	High ↑↑↑/↓↓↓
Biological Productivity	**Comparison to Reference(a)** Chlorophyll *a*(b) Zooplankton Biomass (AFDM) Phytoplankton Biomass (enumeration) Zooplankton Biomass (enumeration)	No difference	Statistically significant change, NF vs reference	Low + NF area mean outside reference normal range (2007-2010)	Moderate over > 20% of lake
	Community Structure(a) Phytoplankton Community Composition Zooplankton Community Composition	No difference	Divergent community structure, at the species or genus-level, NF vs reference **and,** Statistically significant change in taxonomic richness, NF vs reference	A shift in community structure, at the ecological grouping(b) level, between the NF and reference areas[4]	Moderate + a statistically significant change in taxonomic richness > two standard deviations
Benthic Community	**Comparison to Reference(a)** Total Invertebrate Density Density of Dominant Invertebrates (multiple endpoints) Richness Simpson's Diversity Index Dominance Evenness Bray-Curtis Distance	No difference	Statistically-significant change, NF vs reference	Low + NF area mean outside reference normal range (2007-2010)	Moderate rating extending beyond NF
	Community Structure(a) Relative Abundance of Major Invertebrate Taxa	No difference	Difference in relative abundances of major taxa in NF compared to reference areas	Difference in relative abundances of major taxa in NF and first MF station	Difference in relative abundances of major taxa extending further into MF or loss of major taxon from community in NF
Fish Population Health	**Comparison to Reference(a)** Population structure-survival Population Structure - Size Energy Stores - K Energy Stores - LSI Reproductive Investment – Age 1 Abundance Reproductive Investment – GSI Pathology - Occurrence	No difference	Statistically-significant change, NF vs reference	Low + NF area mean outside reference normal range (2007-2010)	Moderate rating extending beyond NF

Notes: AFDM = ash-free dry mass; GSI = gonadosomatic index; K = condition factor; LSI = liver-somatic index; SD = standard deviation; NF = near-field; MF = mid-field; FF = far-field; >= greater than; <= less than.

a) Applied separately for each SOI.

b) Chlorophyll *a* is interpreted both as an exposure and as a biological response endpoint.

2.3.3 Weighting of Endpoints Prior to Integration

In the WOE Framework, greater weight is given to endpoints that accommodate natural variability, produce reliable and robust data, and have strong association with ecological effects (Menzie et al. 1996; Chapman et al. 2002; Chapman and Anderson 2005). Conversely, lower weight is given to endpoints subject to high natural variability, that relied on new or inherently variable techniques, or that had unclear relevance to ecological effects. In addition, in the WOE evaluation for each impact hypothesis, higher weighting was given to endpoint results that supported the particular hypothesis being examined. Three sets of weighting criteria were applied to the endpoint results:

- *a priori* weighting factors;
- direction-weighting factors; and,
- *a posteriori* weighting factors.

A Priori Weighting Factors

This first set of weights was established *a priori* based on professional judgement regarding the strength and relevance of the evidence contributed by each endpoint. Each endpoint was assigned an overall *a priori* weighting based on the product of scores assigned to four *a priori* factors. Each factor was assigned a score ranging from 1 to 3 (i.e., 1=poor; 2=satisfactory; 3=good). The a *priori* weighting factors for each endpoint were:

- **Representativeness:** This factor reflects the replicability of an endpoint, and its ability to capture natural variability or stochasticity. Techniques that integrate spatial or temporal variation, or that measure relatively homogeneous variables, were up-weighted. Highly temporally- or spatially-variable endpoints were down-weighted.
- **Methodological Robustness:** This factor reflects the degree of confidence in the quality of data (e.g., accuracy, statistical power) produced by the sampling and analysis techniques employed. Precise and well-established methods with accepted quality assurance (QA) and quality control (QC) measures were up-weighted. Experimental (new) or inherently variable techniques were down-weighted.
- **Clarity of Interpretation:** This factor reflects the strength of association between a measurement endpoint and effects to VECs (assessment endpoints). Endpoints with unclear ecological relevance, many confounding factors, or that require uncertain laboratory-to-field extrapolation were down-weighted.
- **Permanence of Effects:** This factor reflects the relevance of the endpoint to long-term ecological effects. Transient effects or effects on a highly resilient ecosystem component (one that is able to rapidly recolonize or recover following a disturbance or upon removal of a chronic stressor) were down-weighted.

The scores assigned for each factor were originally established through internal discussions and review among senior professionals within Golder specializing in risk assessment and environmental monitoring, and considering criteria established in previous Golder projects that applied a WOE process to similar monitoring data (e.g., McDonald et al. 2007). Reviewer comments on specific *a priori* weightings that were considered during the 2007-2010 AEMP Summary Report (DDMI 2011) have also contributed to the weighting of specific factors. The factors are:

Similar *a priori* weightings for endpoints have been applied since 2008, the first year that the combined toxicological impairment and nutrient enrichment WOE process was applied. However, for 2013, some new endpoints have also been included and *a priori* weightings for these endpoints were estimated considering similar endpoints in the AEMP.

The *a priori* weighting process is summarized in Table 2-5. The following generalizations are possible regarding the combined *a priori* weighting factors:

- Biological response variables (*a priori* weightings of 15 to 25) are weighted higher than chemical and nutrient exposure indicators (*a priori* weightings of 3.8 to 11.3). Overall, actual biological responses in Lac de Gras are deemed to provide a more direct indicator of potential effects in the aquatic ecosystem than indicators of exposure to nutrients or chemicals because the exposure indicators do not consider the dose-response relationship between exposure and response. Higher weighting for biological response measures is consistent with guidance from the literature that field-based effect studies should be weighted higher than laboratory and chemistry-based analyses (Chapman and Anderson 2005; Wenning et al. 2005).
- For indicators of chemical exposure, sediment chemistry endpoints (*a priori* weighting of 7.5) are weighted higher than water chemistry endpoints (*a priori* weighting 3.8), primarily because sediment chemistry integrates chemical emissions/exposures in Lac de Gras over time compared to water chemistry, which only provides a “snapshot” of water conditions, which may have considerable temporal variability.
- Indicators of nutrient exposure have higher *a priori* weighting than indicators of chemical exposure because, for an ultra-oligotrophic lake such as Lac de Gras, a response would be expected at any level of enrichment (i.e., the threshold for a biological response is low). Therefore, the potential link to biological responses is clearer for nutrient exposure relative to chemical exposure.
- Differences in the *a priori* weighting of biological response variables are primarily related to the degree of influence that confounding factors have on each endpoint.

Table 2-5 *A Priori* Weighting Factors Applied to Individual Line of Evidence Endpoints Used in the Weight-of-Evidence Analysis

Lines of Evidence - Endpoints	Representativeness		Methodological Robustness		Clarity of Interpretation		Permanence of Effects		Overall Product of Factors
	Weight	Rationale	Weight	Rationale	Weight	Rationale	Weight	Rationale	
Exposure									
Water Quality – Toxicological Parameters	1.0	Samples of water collected at a set of representative stations may be an imperfect representation of spatial and temporal variability.	2.5	Methodologies are well established, with accepted QA/QC measures, and data analysis techniques.	1.5	Linkage of external chemical concentrations to ecological effects is generally considered weak and prone to multiple confounding factors.	1.0	Water quality would vary seasonally depending on the source strength of contaminants from the Mine and the water balance of Lac de Gras.	3.8
Sediment Quality – Toxicological Parameters	2.0	Composite samples of sediment integrate chemical concentrations over time but are an imperfect representation of spatial variability.	2.5	Methodologies are well established, with accepted QA/QC measures, and data analysis techniques.	1.0	Linkage of sediment concentrations to ecological effects is generally considered weak and prone to multiple confounding factors such as chemical bioavailability and organism sensitivity.	1.5	Mine-related contaminants, in particular metals, could persist in the biologically active zone of sediments for a long period of time. However, the bioavailability of sediment contaminants is likely to be limited.	7.5
Water Quality - Total Nitrogen	1.0	Grab samples of water are an imperfect representation of spatial and temporal variability.	2.5	Methodologies are well established, with accepted QA/QC measures, and data analysis techniques.	1.5	The linkage between water nitrogen concentrations and primary productivity is relatively well-established. However, for Lac de Gras, phosphorus, rather than nitrogen is expected to be the limiting nutrient and therefore, the influence of nitrogen on primary productivity is less clear.	1.5	Water quality would vary seasonally depending on the source strength of contaminants from the Mine and the water balance of Lac de Gras. However, this variable is an indicator or eutrophication which has a high degree of permanence.	5.6
Water Quality - Total Phosphorus	1.0	Grab samples of water are an imperfect representation of spatial and temporal variability.	2.5	Methodologies are well established, with accepted QA/QC measures, and data analysis techniques.	2.0	The linkage between water phosphorus concentrations and primary productivity is relatively well-established. However, the bioavailability of phosphorus in the water column may change seasonally in response to a variety of factors.	1.5	Water quality would vary seasonally depending on the source strength of contaminants from the Mine and the water balance of Lac de Gras. However, this variable is an indicator or eutrophication which has a high degree of permanence.	7.5
Sediment Total Organic Carbon	2.0	Composite samples of sediment integrate changes in organic carbon over time but are an imperfect representation of spatial variability.	2.5	Methodologies are well established, with accepted QA/QC measures, and data analysis techniques.	1.0	Sediment organic carbon is an indicator of potential nutrient supply for deposit-feeding benthos. However, it provides a poor representation of nutrient supply for filter-feeding benthos. Many factors that are not related to enrichment (such as grain size and circulation patterns) may also influence organic carbon concentrations in a particular area.	1.5	An enrichment in sediment organic carbon could persist in the biologically active zone of sediments for a relatively long period of time. However, as the sediment organic carbon undergoes diagenesis, it may become a less energy dense or bioavailable supply of nutrients.	7.5
Chlorophyll *a* - exposure	1.5	High natural variability in phytoplankton communities. Depending on composition of phytoplankton community, chlorophyll *a* may or may not be representative of total biomass However, biomass was monitored at multiple times and locations during the open-water season reducing the influence of temporal and spatial variability.	2.5	Methodologies are well established, with accepted QA/QC measures and data analysis methods.	1.5	Chlorophyll *a* is an indicator of potential nutrient supply for filter-feeding benthos. However, it provides a poor representation of nutrient supply for deposit-feeding benthos and is only an indirect indicator of potential enrichment of the fish community	2.0	Although primary productivity is variable and ephemeral it is an indicator or eutrophication which has a high degree of permanence.	11.3

Table 2-5 *A Priori* Weighting Factors Applied to Individual Line of Evidence Endpoints Used in the Weight-of-Evidence Analysis (continued)

Lines of Evidence - Endpoints	Representativeness		Methodological Robustness		Clarity of Interpretation		Permanence of Effects		Overall Product of Factors
	Weight	Rationale	Weight	Rationale	Weight	Rationale	Weight	Rationale	
Biological Responses									
Chlorophyll *a* - response	1.5	High natural variability in plankton communities. Although, the plankton communities were monitored at multiple times and locations during the open water season, migration, aggregation, predation can lead to patchy distributions that are difficult to characterize in field studies.	2.5	Methodologies are well established, with accepted QA/QC measures and data analysis methods.	2.0	Changes in community-level measures such as biomass provide a reasonable indicator of ecological effects but they can also be related to natural processes, habitat differences and other confounding factors. Community structure indices are subject to additional uncertainty because there is no one "ideal" community structure and differences in these endpoints are likely to occur naturally.	2.0	Although primary productivity and plankton biomass can be variable and ephemeral they provide an indicator or eutrophication which has a high degree of permanence.	15.0
Phytoplankton Biomass (enumeration)	1.5		2.5		2.0		2.0		15.0
Zooplankton Biomass (AFDM and Enumeration)	1.5		2.5		2.0		2.0		15.0
Phytoplankton Community Structure/Richness	1.5		2.5		1.5		2.0		11.3
Zooplankton Community Structure/Richness	1.5		2.5		1.5		2.0		11.3
Total Invertebrate Density	2.0	Moderate natural spatial variability and patchiness in zoobenthos communities means that accurate characterization in field studies is challenging.	2.5	Methodologies are well established, with accepted QA/QC measures and data analysis techniques.	2.0	Total invertebrate density and richness provide a reasonable indicator of ecological effects but they can also be related to natural processes, habitat differences and other confounding factors. Benthic community indices, densities of dominant taxa, and relative abundance are subject to additional uncertainty because there is no one "ideal" community structure and differences in these endpoints are likely to occur naturally.	2.0	Larval and resident invertebrates have low mobility and recolonization and regrowth of affected populations, or recovery to pre-enrichment conditions will take time. Recovery would be faster in areas dominated by aquatic insect larvae because of relatively high dispersal by adult life stages and therefore the permanence of effect weighting is lower for insects than for other taxa such as Pisidiidae.	20.0
Density of Pisidiidae	2.0		2.5		1.5		2.5		18.8
Density of Other Dominant Taxa	2.0		2.5		1.5		2.0		15.0
Benthic Richness	2.0		2.5		2.0		2.5		25.0
Simpson's Diversity Index	2.0		2.5		1.5		2.5		18.8
Other Benthic Community Indices[(a)]	2.0		2.5		1.5		2.0		15.0
Fish Population Structure - survival	2.5	Some natural variability in forage fish communities - energy expenditure/stores and reproductive investment can vary seasonally and inter-annually. However, fish populations represent a higher-level of organization in aquatic communities meaning that effects to fish health are indicative of wider ecosystem impacts.	2.5	Methodologies are well established, with accepted QA/QC measures and data analysis methods. Visual inspection for pathology may be subjective	1.5	Energy stores and reproductive investment measures in the field have clear relevance to ecological effects and increased incidence of pathology can be linked to a source of stress on fish health. The fish population structure and Age 1 abundance measurements may be somewhat uncertain due to uncertainty in the ageing of slimy sculpin and therefore apparent effects could be an artifact of the aging process rather than actual health effects.	2.0	Likely low resilience of fish populations to a high incidence of deformities. Impacts to population structure would take generations to recover. Energy expenditure/stores and reproductive investment affect long-term productivity and stability of populations.	18.8
Fish Population Structure - size	2.5		2.5		1.5		2.0		18.8
Energy Stores - K	2.5		2.5		2.0		2.0		25.0
Fish Energy Stores - LSI	2.5		2.5		2.0		2.0		25.0
Relative Reproductive Success - Age 1 abundance	2.5		2.5		1.5		2.0		18.8
Fish Reproductive Investment - GSI	2.5		2.5		2.0		2.0		25.0
Fish Pathology - Occurrence	2.5		2.5		2.0		2.0		25.0

Note: QA/QC = Quality Assurance/Quality Control; LSI = liver-somatic index; K = condition factor; GSI – gonadosomatic index.

a = Evenness, dominance, Bray-Curtis distance, relative abundance of dominant taxa.

Direction Weighting Factors

Direction weighting factors for endpoints in biological response LOE groups were established to reflect the degree of support that an observed biological response contributes to each of the impact hypotheses. Weighting factors for various contingencies were established *a priori*, and then specific weighting factors were selected *a posteriori* based on the endpoint results. Direction-weighting factors were scaled from 0 to 1. The considerations for establishing the direction weighting factors were established based on the following criteria:

- the factor applied for a given endpoint was contingent on the observed direction of change or relationship;
- the factors represented proportional support for each impact hypothesis indicated by the direction of change in an endpoint or the direction of the relationship of an endpoint with effluent exposure; and,
- the factors for all contingencies (increase/positive and decrease/inverse) were established *a priori* and then applied *a posteriori*, contingent on the endpoint results.

As with the a priori factors, the direction-weighting factors were based on the professional judgement of Golder scientists experienced in ecological risk assessment and environmental effects monitoring (McDonald et al. 2007), combined with consideration of reviewer comments on direction weightings that were considered during the 2007-2010 AEMP Summary Report (DDMI 2011). The following levels of support and numerical ratings were applied:

- **High (1.0) –** The direction of change or relationship only supports one of the hypotheses. There are no situations where the direction of change or relationship would be expected under the alternative hypothesis.
- **Moderate (0.75) –** The direction of change or relationship supports one of the hypotheses under most situations. However, it is possible that under certain conditions, the direction of change or relationship would be expected under the alternative hypothesis.
- **Neutral (0.5) –** The direction of change or relationship could support either hypothesis.
- **Low (0.25) -** The direction of change or relationship supports the alternative hypothesis under most situations.
- **None (0) –** The direction of change or relationship only supports the alternative hypothesis.

The support levels presume that nutrient enrichment or toxicological impairment are the only factors acting on endpoints in Lac de Gras (i.e., they answer the question: "If nutrient enrichment or toxicological impairment are the only factors acting on endpoints, what is the degree of support for each hypothesis under a given direction of endpoint change or relationship?”). The potential influences of confounding factors, natural variability and uncertainty are represented in the *a priori* and *a posteriori* weighting factors. For a given change or relationship in an endpoint, the direction-weighting factors summed to 1 (e.g., if a given endpoint response provided 0.75 proportional support to the nutrient enrichment hypothesis, then the corresponding support for the Toxicological Impairment Hypothesis was 0.25). Direction weighting factors were not applied for endpoints in exposure LOE groups because the direction of effect is implicit in the effect ratings for these endpoints. The direction-weighting factors that were applied to endpoint results where an effect was observed, depending on the direction of change or relationship are presented in Table 2-6.

Table 2-6 Direction-weighting Factors Applied to Endpoint Results

Line of Evidence	Endpoint	Direction of Change in Endpoint or Relationship of Endpoint with Effluent Exposure			
		Increase or Positive Relationship		Decrease or Inverse Relationship	
		Support for Nutrient Enrichment Hypothesis	Support for Toxicological Impairment Hypothesis	Support for Nutrient Enrichment Hypothesis	Support for Toxicological Impairment Hypothesis
Biological Productivity	Chlorophyll *a*	1	0	0	1
	Phytoplankton Biomass (enumeration)	1	0	0	1
	Zooplankton Biomass (AFDM and Enumeration)	1	0	0	1
	Phytoplankton Community Structure and Richness	1	0	0.5	0.5
	Zooplankton Community Structure and Richness	1	0	0.5	0.5
Benthic Invertebrates	Total Invertebrate Density	1	0	0	1
	Density of Pisidiidae and Other Dominant Taxa	0.75	0.25	0.25	0.75
	Richness	1	0	0.5	0.5
	Benthic Community Indices[(a)]	0.5	0.5	0.5	0.5
Fish Population Health	Population Structure – survival	0.5	0.5	0.5	0.5
	Population Structure - size	0.75	0.25	0	1
	Energy Stores - K	1	0	0	1
	Energy Stores - LSI	0.75	0.25	0	1
	Relative Reproductive Success - Age 1 abundance	1	0	0.25	0.75
	Reproductive Investment - GSI	1	0	0	1
	Pathology - Occurrence	0.5	0.5	1	0

Notes: LSI = liver-somatic index; K = condition factor; GSI – gonadosomatic index.

a) Simpson’s diversity index, evenness, dominance, Bray-Curtis distance, relative abundance of dominant taxa.

Rationales for the various direction-weighting factors were as follows:

- An increase in biomass, total density indicators for plankton and benthos provides a high level of support (1.0 or 100% support) for the Nutrient Enrichment Hypothesis. In the absence of other factors, this response would only be expected if nutrient enrichment were occurring. The converse is also true for biomass and density endpoints, where decreases provide a high level of support for the Toxicological Impairment Hypothesis.
- An increase in benthic richness benthos provides a high level of support (1.0 or 100% support) for the Nutrient Enrichment Hypothesis. For decreases in benthic richness, the cause can be equivocal (0.5 support for either hypothesis), indicating that either selective toxicity is occurring to certain species, or that certain species are benefiting from enrichment disproportionately relative to other species, lowering richness as fewer species dominate the system.
- For shifts in phytoplankton or zooplankton community structure, the support for each hypothesis is dependent on the direction of change in richness. The rationale for interpreting the direction of change in richness is similar to that for benthos – community structure shifts combined with increases in richness provide a high level of support (1.0 or 100% support) for the Nutrient Enrichment Hypothesis whereas community structure shifts combined with decreases in richness are equivocal (0.5 support for either hypothesis).
- Family-specific or genus-specific indicators of biomass (density of Pisidiidae and other dominant taxa) follow a similar pattern to community-level biomass endpoints except that the degree of support for each hypothesis is only moderate. For these endpoints, an increase or positive relationship normally supports the Nutrient Enrichment Hypothesis while the converse normally supports the Toxicological Impairment Hypothesis (i.e., direction-weighting of 0.75). However, there are situations where these endpoints could potentially respond differently than expected when an ecosystem is influenced by enrichment or toxicity. For example, if toxicity acted selectively on a particular genus or family, then this could give a competitive advantage to a tolerant genus or family that occupied a similar niche and, in this case, the density of this tolerant genus or family might be expected to increase.
- Multiple indicators of community structure for benthos (diversity, evenness, dominance, Bray-Curtis distance, relative abundance are typically equivocal with respect to supporting each impact hypothesis. These endpoints can indicate a change relative to a reference area; however, the cause of change in the biological community is less clear because there is no one "ideal" community structure and differences in these endpoints are likely to occur naturally. A positive or negative change in these endpoints could support either impact hypothesis and their direction-weighting is neutral (0.5).
- Responses in the number of older/larger fish in a population (i.e., survival) are often equivocal. An increase could be due to lower survival of juveniles (toxic effect), which changes population proportions and competition for larger fish, or increased nutrient supply which is better-utilized by higher age/larger fish. The converse is also

true with decreases in the number of older/larger fish being related to lower overall survival (toxic effect), to enrichment which is disproportionally beneficial to smaller fish, or to neither.

- Increased body size is indicative of increased resource availability. This can be due to an increase in the absolute amount of resources available as a result of nutrient enrichment or, in certain situations, could be due to an increase in the relative amount of resources available as a result of increased mortality (toxic effect) and reduced competition. Decreased size is most likely related to inhibited growth (i.e., toxicity).
- Increased growth, energy stores and reproductive investment in fish are likely a reflection of greater abundance of resources (i.e., enrichment), while decreases in these endpoints may reflect toxicity and would not be expected to result from nutrient enrichment. This warrants clear-cut direction weighting factors with an increase indicating nutrient enrichment (1.0 or 100% support) and a decrease indicating toxicological impairment (1.0 or 100% support).
- Age-1 abundance is a less certain indicator of reproductive investment because decreased Age-1 abundance could be due to lower survival of juveniles (toxic effect, weighted at 0.75), or (less likely) an increased nutrient supply (enrichment effect, weighted at 0.25) which is better-utilized by higher age/larger fish, which in turn puts predatory pressure on smaller fish.
- Increased liver size typically indicates an increase in glycogen stores related to nutrient enrichment (weighting of 0.75), but in certain situations might indicate toxicological stress (i.e., abnormality; weighting of 0.25). Decreased liver size would result from toxicological stress (1.0 or 100% support), but is unlikely to be caused by nutrient enrichment alone.
- Potential causes of pathology are not always clear-cut and can depend on the type of pathology observed (for example, many apparent pathologies could be caused by toxicity-related stress, while others, such as fatty liver, might be due to nutrient enrichment). On the other hand if pathology decreases, this might be due to increased resources which increase the immunity resistance of fish, but is unlikely to be the result of a toxic response.

A Posteriori Weighting Factors

A final set of weights was established *a posteriori* to reflect additional insight gained during collection and analyses of the data. Two *a posteriori* criteria were developed and applied to integrate information about the pattern of findings and inter-relationships among endpoints and LOE groups:

- **Coherence of Response:** This factor reflects consistency in response among the individual endpoints within an LOE group, i.e., similarity of findings from multiple exposure endpoints or effects endpoints. Coherence of response was scaled from 0.25 to 0.75 for all LOE. The endpoint results within an LOE group are down-weighted if the constituent endpoints in the LOE group respond inconsistently.

- **Strength of Linkage:** This factor reflects correspondence between endpoint results and their causative agents. For exposure endpoints, this includes evidence that changes in chemical concentrations are related to Mine activities (e.g., spatial gradients). For effect endpoints this includes exposure-effect relationships in endpoints that showed effects, and especially in the endpoint with the highest weighted score. An endpoint is down-weighted if there is no evidence for a linkage between observed responses and causative agents. Strength of linkage was scaled from 0.25 to 0.75 for all LOE.

The values for strength of linkage and coherence of response were added to generate a combined *a posteriori* weighting factor. Combinations of medium-medium or high-low therefore result in a combined *a posteriori* weighting factor of 1.0 (i.e., no change in the weight of the endpoint). Combinations of “low-low” result in a combined *a posteriori* weighting factor of 0.5 (i.e., halving the weight of the endpoint), whereas combinations of “high-high” result in a combined *a posteriori* weighting factor of 1.5 (i.e., increasing the weight of the endpoint).

The *a posteriori* weighting factors were applied once the AEMP results for 2013 we known, further discussion is provided in Section 3.2.

2.3.4 Integrating of Observed Effects and Weighting Factors

2.3.4.1 Overview

Separate WOE ratings were estimated for each impact hypothesis. Within each WOE analysis, integrated WOE numerical scores for each of the ecosystem components were calculated as the sum of the highest scores (after weighting) for individual endpoints in each type of LOE group (exposure and biological response). The final WOE score was based on the addition of the final scores for the two groups. The numerical scores for each ecosystem component were converted back to the EOI Ranking.

The numerical scores for each ecosystem component were converted back to a final, semi-quantitative rating, termed “Evidence of Impact” (EOI). The EOI consists of four rankings:

- EOI Rank 0 – Negligible Evidence of Impact;
- EOI Rank 1 – Low Evidence of Impact;
- EOI Rank 2 – Moderate Evidence of Impact; and,
- EOI Rank 3 – Strong Evidence of Impact.

The EOI rankings primarily provide an indication of strength of evidence with respect to the impact hypotheses associated with apparent effects on a particular ecosystem component. This strength of evidence serves to inform, along with other considerations such as ecological significance and feasibility of solutions/actions, response plans when Action Levels are met under the AEMP Response Framework.

A stronger EOI ranking is not necessarily intended to indicate that a higher or more intensive level of follow-up is needed. For example, strong EOI for a given ecosystem component might support the conclusion that there is a high confidence in the monitoring program for this component, meaning that an equal or lower level of effort could be considered for future monitoring. Conversely, a lower EOI due to uncertainty or less sensitive endpoints might provide an indication that this aspect of the monitoring program needs to be improved or expanded.

2.3.4.2 Calibration of EOI Rankings

Calibration of final numerical scores to the EOI Ranking scale was necessary to formulate EOI Rankings that were consistent with the level of effect ratings, and *a priori* weightings for endpoints. This calibration was achieved by "solving" for the numerical score for all hypothetical outcomes of the WOE Framework using the average *a priori* weighting factors, while assuming that the direction of effect completely supported a particular hypothesis (i.e., direction-weighting of 1.0) and the *a posteriori* weighting factors were neutral (i.e., values of 0.5 for both coherence of response and evidence of causality). A summary of the calibration process is provided in Table 2-5.

Solving for each possible combination of the two LOE categories generated a series of hypothetical numerical scores (Table 2-7). Note that for some effect combinations, two hypothetical scores were possible because the contaminant exposure endpoints had different average *a priori* weighting than the nutrient exposure endpoints. The same calibration was applied for both impact hypotheses.

Table 2-7 Calibration of Final Weight-of-Evidence Ratings and Numerical Scores for Toxicological Impairment Weight-of-Evidence and Nutrient Enrichment Weight-of-Evidence

	Semi-Quantitative Effect Rating		**Numerical WOE "Score"(a)**	**WOE Score Threshold**	**EOI Ranking**	**Description**
	Biological Response LOE Groups	**Exposure LOE Groups**				
Possible Effect Rating Combinations	0	0	0	<10	**0**	**Negligible Evidence of Impact** This category includes scenarios where biological response endpoints indicate negligible effects and exposure endpoints are negligible to moderate, or where an early warning/low effect is apparent for biological response endpoints which is not attributable to exposure.
	↑/↓	0	9.6			
	0	↑	2.7-4.5			
	0	↑↑	5.3-9.0			
	↑/↓	↑	12.3-14.1	≥10	**1**	**Low Evidence of Impact** This category includes scenarios where: (a) a moderate level effect is seen in biological response that is not explained by exposure endpoints; (b) early warning/low effect ratings in biological response are attributable to early warning/low or moderate effects for exposure endpoints; or, (c) where a high effect rating is apparent for exposure endpoints but the effect levels biological response endpoints are negligible.
	↑/↓	↑↑	14.9-18.6			
	↑↑/↓↓	0	19.2			
	0	↑↑↑	10.6-17.9			
	↑/↓	↑↑↑	17.6-20.2	≥20	**2**	**Moderate Evidence of Impact** This category includes scenarios where: (a) high effect ratings for exposure endpoints coincide with early warning/low or moderate effect ratings for biological response; (b) moderate effect ratings for biological response endpoints are attributable to early warning/low or moderate effect ratings for exposure endpoints; or, (c) a high effect rating is apparent for biological response endpoints, even though exposure endpoint responses are rated as negligible.
	↑↑/↓↓	↑	21.9-23.7			
	↑↑/↓↓	↑↑	24.5-28.2			
	↑↑/↓↓	↑↑↑	29.8-37.1			
	↑↑↑/↓↓↓	0	38.4			
	↑↑↑/↓↓↓	↑	41.1-42.9	>40	**3**	**Strong Evidence of Impact** This category includes all scenarios where a high effect rating is apparent for biological response endpoints and any effect rating greater than negligible is observed for exposure endpoints.
	↑↑↑/↓↓↓	↑↑	43.7-47.4			
	↑↑↑/↓↓↓	↑↑↑	49.0-56.3			

Note: LOE = Line of Evidence; WOE = Weight-of-Evidence; > = greater than; ≥ = greater than or equal to; < = less than.

a) The average *a priori* weighting factor for the Contaminant Exposure LOE was 5.3, for Nutrient Exposure LOE was 9.0, and for all Biological Response LOE was 19.2. The direction-weighting factors and *a posteriori* weighting factors were set to 1.0 for the purpose of this calibration process.

A range of these scores was identified for each semi-quantitative EOI rating, as follows:

- **EOI Rank 0 – Negligible Evidence of Impact:** Numerical scores <10 were considered to represent an overall ranking of negligible for that particular ecosystem component. This rank is consistent with the "no change" result described in the AEMP design document (DDMI 2007).
- **EOI Rank 1 – Low Evidence of Impact:** Numerical scores between 10 and 20 were considered to represent an overall ranking of low for that particular ecosystem component. This low level evidence of impact indicates that there are corresponding changes in exposure and resulting biological responses in the NF area but that the potential for a wide-spread change in Lac de Gras is low.
- **EOI Rank 2 – Moderate Evidence of Impact:** Numerical scores between 20 and 40 were considered to represent an overall WOE rating of moderate for the particular ecosystem component. This moderate evidence of impact indicates that a changes in exposure and biological response have occurred in Lac de Gras that exceeds the early warning/low classification either in magnitude or spatial scale. The actual ecological significance of effects or changes depends on their magnitude. If changes are expected to be ecologically significant, then this EOI rank would warrant increased concern and this would be a consideration for Action Level response planning.
- **EOI Rank 3 – Strong Evidence of Impact:** Numerical scores exceeding 40 were considered to represent an overall WOE rating of strong for the particular ecosystem component. This strong evidence of impact indicates that a change has occurred in Lac de Gras that is: (i) equal to the magnitude of the moderate classification but great in spatial scale; or, (ii) exceeds the moderate classification. For this EOI Rank, it can be concluded there is a potential for a spatially wide-spread change in Lac de Gras. The actual ecological significance of effects or changes depends on their magnitude. If changes are expected to be ecologically significant, then this EOI rank would warrant a high level of concern and this would be a consideration for Action Level response planning.

3 RESULTS AND DISCUSSION

This section applies the effect rating scheme from Section 2.3.2 to classify the AEMP component findings, sets the *a posteriori* weighting for the WOE analysis, and then applies the WOE Framework to characterize the degree of support for each impact hypothesis.

3.1 EFFECT RATING RESULTS FOR COMPONENT FINDINGS

The resulting effect level ratings for all endpoints were based on the analysis and findings of the component reports (Golder 2014b,c,d,e,f,g). Summaries of the effect level results for water quality, sediment quality, fish tissue quality, eutrophication indicators, plankton, benthic invertebrates, and fish health are provided in the following subsections.

3.1.1 Water Quality

Table 3-1 lists the water quality parameters that were identified as SOIs (i.e., triggering an Action Level) and the effects rating for each. Fifteen substances of interest (SOIs; conductivity, total dissolved solids [calculated], dissolved calcium, chloride, dissolved sodium, sulphate, ammonia, nitrate, aluminum, barium, chromium, molybdenum, silicon, strontium, and uranium) satisfied the requirement for an early warning/low-level rating, because concentrations in the NF area were significantly higher than in reference areas in one or both sampling seasons (ice-cover or open-water).

Substances of interest were evaluated against the criteria used to designate a moderate level effect. Each of the 15 SOIs that reached a low level effect also had 75th percentile concentrations in the NF exposure area that were greater than the normal range for Lac de Gras. However, concentrations in all samples collected in 2013 were within the AEMP aquatic life or drinking water Effects Benchmarks (whichever was applicable or more conservative). Therefore, a moderate level rating was not applied to any of the SOIs.

Table 3-1 Effect Ratings for Water Quality Results, 2013 AEMP

Endpoint Analysis	Parameter	Rating
Comparison of NF to Benchmarks and Reference	Specific Conductivity	↑
	Total dissolved solids[(a)]	↑
	Calcium	↑
	Chloride	↑
	Sodium	↑
	Sulphate	↑
	Ammonia (as nitrogen)	↑
	Nitrate (as nitrogen)	↑
	Aluminum	↑
	Barium	↑
	Chromium	↑
	Molybdenum	↑
	Silicon	↑
	Strontium	↑
	Uranium	↑
	Remaining parameters	No response

Notes: ↑ = early warning/low rating; ↑↑ = moderate level rating ↑↑↑ = high level rating.

3.1.2 Sediment Quality

Table 3-2 lists the sediment quality parameters that were rated as Early Warning/Low or higher. Thirteen metals in 2013 (aluminum, bismuth, boron, calcium, chromium, lead, lithium, magnesium, potassium, sodium, tin, titanium, and uranium) satisfied the requirement for the low rating, because mean concentrations in the NF area were significantly higher than in the reference areas. Three of these 13 metals (bismuth, lead, and uranium) also had mean NF concentrations that were greater than their respective normal ranges, which is one of the requirements for classification as a moderate effect level. Considerations regarding sediment quality guidelines included:

- SQGs for bismuth do not currently exist and no information is available regarding bismuth toxicity in aquatic sediments. Results of the 2006 dike monitoring study (Golder 2007), and current and past AEMP benthic invertebrate surveys have detected no toxicity-related effect on the benthic community in areas of Lac de Gras with bismuth concentrations above the background range, suggesting no sediment toxicity due to bismuth.
- Lead concentrations in all samples from 2013 were well below the CCME ISQG and OMOEE LEL.
- CCME or OMOEE guidelines do not exist for uranium but Sheppard et al. (2005) report a predicted no-effect level for freshwater benthos of 100 mg/kg dw. Uranium, at an average concentration of 14.8 mg/kg dw (maximum of 26.7 mg/kg dw) in the NF area in 2013 is therefore considered unlikely to pose a toxicological risk in the NF area.

Table 3-2 Effect Ratings for Sediment Quality Results, 2013 AEMP

Endpoint Analysis	Parameter	Rating
Comparison of NF to Guidelines and Reference	Aluminum	↑
	Bismuth	↑
	Boron	↑
	Calcium	↑
	Chromium	↑
	Lead	↑
	Lithium	↑
	Magnesium	↑
	Potassium	↑
	Sodium	↑
	Tin	↑
	Titanium	↑
	Uranium	↑
	Remaining parameters	No response

Notes: ↑ = early warning/low rating; ↑↑ = moderate level rating ↑↑↑ = high level rating.

Based on these considerations, bismuth, lead and uranium did not meet the requirements for classification as a moderate effect level.

3.1.3 Fish Tissue Chemistry

Table 3-3 lists the fish tissue chemical parameters that were analyzed statistically to determine if any were elevated, significantly different, or displaying a gradient in Lac de Gras that appeared to be a result of the Mine activities. Five metals (bismuth, lead, strontium, thallium, and uranium), had near-field (NF) area mean concentrations that were statistically greater than 2013 reference area mean concentrations. Of these, bismuth and uranium had NF area concentrations that were greater than the normal range (2007 to 2013).

Table 3-3 Effect Ratings for Fish Tissue Chemistry Results, 2013 AEMP

Endpoint Analysis	Parameter	Rating
Comparison of NF to Reference	Bismuth	↑↑
	Lead	↑
	Strontium	↑
	Thallium	↑
	Uranium	↑↑
	Remaining parameters	No response

Notes: ↑ = early warning/low rating; ↑↑ = moderate level rating ↑↑↑ = high level rating.

Based on effect levels defined in Table 2-1, lead, strontium and thallium were assigned a low level effect; and bismuth and uranium) were assigned a moderate level effect.

3.1.4 Eutrophication Indicators

The effects ratings for eutrophication indicators are provided in Table 3-4. For total phosphorous and total nitrogen, the NF exposure area concentrations exceeded the upper bound of the normal range relative to reference areas but the affected area for both covered less than 20% of the lake resulting in an effect rating of low for each of these parameters. Chlorophyll *a* concentrations in the NF area were significantly higher than reference areas, and exceeded the upper bound of the reference normal range (i.e., the 2007 to 2010 pooled reference area mean +2 SDs). The extent of this difference extended over 24.9% of the lake area resulting in an effect rating of high for chlorophyll *a*. For zooplankton AFDM, there was a statistical difference in zooplankton biomass between the NF and reference areas, but the NF area biomass did not exceed the upper limit of the normal range, resulting in a low effect rating. However, an additional consideration is that AFDM at mid-field stations did exceed the normal range suggesting an extent of effects on zooplankton biomass representing 37.1% of the lake; this finding was considered in the *a posteriori* weighting of the zooplankton AFDM results.

Table 3-4 Effect Ratings for Eutrophication Indicators, 2013 AEMP

Measurement Endpoint Analysis	Sub-endpoint	Rating	Type of Effect[(a)]
Comparison of NF to Reference	Chlorophyll *a*	↑↑↑	Nutrient Enrichment-
	Zooplankton biomass (AFDM)	↑	Nutrient Enrichment
	Total phosphorus	↑	n/a[(a)]
	Total nitrogen	↑	n/a[(a)]

Notes: ↑/↓ = early warning/low level effect; ↑↑/↓↓ = moderate level effect ↑↑↑/↓↓↓= high level effect for biological metrics, the direction of the sign (↑ or ↓) indicates the direction of difference relative to the reference areas (AFDM = ash-free dry mass.

a) Type of effect was only inferred for biological response endpoints (chlorophyll *a* and zooplankton biomass).

3.1.5 Plankton Community

The effects ratings for the plankton community are provided in Table 3-5. A low level rating was determined for phytoplankton biomass because a statistical difference was observed between the NF exposure area and the reference areas mean. The increase in phytoplankton biomass would only be expected in response to nutrient enrichment. A low level rating was also determined for phytoplankton community structure based on the genus-level NMDS plots. There was a clear distinction between NF exposure area stations and the FFA and FFB reference area stations. Slight overlap was observed in two of the five NF stations with the FF1 reference area; however, overall the NMDS plots indicate exposure area community composition diverging from that of the reference area. The taxonomic richness data indicate that the difference in community structure was most likely due to enrichment.

There was no apparent response for the NF to reference comparison for zooplankton biomass (based on enumeration), in 2013. However, a moderate rating was applied to zooplankton community structure based on the NMDS and relative zooplankton biomass plots. A clear separation was observed between the NF exposure area and the reference area mean in the NMDS plots and relative composition was different between the NF exposure area and reference areas, with greater proportions of rotifers and cladocerans and fewer calanoids in the NF compared to the reference areas. A statistically significant difference was observed in taxonomic richness between the NF exposure area and the reference areas; however, the difference was not greater than the normal range. The taxonomic richness data indicates that the difference in community structure was most likely due to enrichment.

Table 3-5 Effect Ratings for Plankton Results, 2013 AEMP

Measurement Endpoint Analysis	Sub-endpoint	Rating	Type of Effect
Comparison of NF to Reference	Phytoplankton Biomass (based on enumeration)	↑	Nutrient Enrichment
	Phytoplankton Community Structure	↑/↓	Nutrient enrichment (most likely)
	Zooplankton biomass (based on enumeration)	No response	-
	Zooplankton Community Structure	↑↑/↓↓	Nutrient enrichment (most likely)

Notes: ↑/↓ = early warning/low level effect; ↑↑/↓↓ = moderate level effect ↑↑↑/↓↓↓= high level effect for biological metrics, the direction of the sign (↑ or ↓) indicates the direction of difference relative to the reference areas. AFDM = ash-free dry mass.

3.1.6 Benthic Invertebrates

The effects ratings for the benthic invertebrate community are provided in Table 3-6. A low level rating was determined for total invertebrate density and densities of some dominant taxa (*Procladius* sp. and *Heterotrissocladius* sp.) because a statistical difference was observed between the NF exposure area and the reference areas mean. There were fewer significant differences detected for benthic invertebrate endpoints compared to previous years, which lead to fewer differences between NF and reference areas. This is likely a result of exclusion of FF2 from statistical analyses. The statistically significant difference for *Heterotrissocladius* appeared to be related to an outlier and the change was not significant once the outlier was removed. However, the change in *Heterotrissocladius* was still considered to provide support for nutrient enrichment, and therefore the low rating was retained for this endpoint.

A low level rating was also determined for benthic invertebrate community composition (i.e., relative abundance of dominant taxa) based on NMDS. The community composition displayed higher relative densities of Chironomidae and lower relative densities of Pisidiidae in the NF, MF1 and MF2 areas. The NMDS showed some separation of NF and MF stations from the reference stations, but this separation was less that observed in other years.

Table 3-6 Effect Ratings for Benthic Invertebrate Results, 2013 AEMP

Measurement Endpoint Analysis	Sub-endpoint	Rating	Type of Effect
Comparison of NF to Reference	Total density	↑	Nutrient enrichment
	Pisidiidae density	No response	-
	Procladius sp. density	↑	Nutrient enrichment
	Heterotrissocladius sp. density	↑	Nutrient enrichment
	Microtendipes sp. density	No response	-
	Richness	No response	-
	Dominance	No response	-
	Simpson's diversity index	No response	-
	Evenness	No response	-
	Bray-Curtis distance	No response	-
	Relative Abundance of Dominant Taxa	↑/↓	Nutrient enrichment or toxicological impairment

Notes: ↑/↓ = early warning/low level effect; ↑↑/↓↓ = moderate level effect ↑↑↑/↓↓↓= high level effect for biological metrics, the direction of the sign (↑ or ↓) indicates the direction of difference relative to the reference areas.

3.1.7 Fish Health

The effects ratings for the fish health are provided in Table 3-7. Endpoint results for fish health were determined separately for adult (male and female) and juvenile (age-1) slimy sculpin with an overall rating for each endpoint based on integration of the findings for these age and sex-classes. The rationale for the effects ratings included:

- **Population structure-survival**: there was no indication NF vs reference differences in survival based on the size structure of the 5 populations (no response).
- **Population structure-size:** Adult males and Age-1 fish were significantly smaller at NF stations compared to reference (low effect ratings for each class) resulting in an overall rating of low for this endpoint. There were fewer larger fish at NF compared to FF1, no difference compared to FFA
- **Energy Stores - K:** For Age-1 fish, condition factor (K) was significantly lower in the NF area relative to reference. However, the magnitude of the difference for Age-1 fish was low (<10%) and differences for adult fish (NF versus reference) were not statistically significant resulting in an overall rating of no response.
- **Energy Stores – LSI:** For Age-1 fish, liver-somatic index (LSI) was significantly lower in the NF area relative to reference resulting in a low rating for this age class. Although no response was observed for adult males and females there were negative trends overall and statistical power may not have been high enough to detect a difference in adults. Therefore an overall rating of low was applied for this endpoint.

- **Reproductive Investment - Age-1 abundance:** Age-1 fish were less abundant in the NF area relative to reference and the difference was statistically significant (effect rating of low). However, there did not appear to be a gradient with distance from the mine (i.e., MF and FF2 which are exposed to Mine impact had higher Age-1 abundance than reference areas) suggesting that the NF versus reference difference was not Mine-related. Based on this consideration the overall rating for Age-1 abundance was set as no response.
- **Reproductive Investment - GSI:** adult female relative gonad size (gonadosomatic index [GSI]) was smaller in the NF exposure area relative to the reference areas and the difference was statistically significant resulting in a rating of low for both females and overall.
- **Pathology – Occurrence:** There was no difference (NF versus reference) in the incidence of pathology in slimy sculpin adults and juveniles resulting in a rating of no response for this endpoint.

Table 3-7 Effect Ratings for Fish Health Results, 2013 AEMP

Endpoint Analysis	Sub-endpoint	Rating				Type of Effect
		Female	Male	Age 1+	Overall	
Comparison of NF to Reference	Population Structure – Survival	No response	No response	No response	No response	-
	Population Structure – Size	↓	↓	↓	↓	Toxicological Effect
	Growth – Size at age	n/a	n/a	↓	↓	Toxicological Effect
	Energy Stores – K	No response	No response	↓	No response	-
	Energy Stores – LSI	No response	No response	↓	↓	Toxicological Effect
	Relative Reproductive Success – Age 1 Abundance	n/a	n/a	↓	No response	-
	Relative Reproductive Success – GSI	↓	No response	n/a	↓	Toxicological Effect
	Pathology - Occurrence	No response	No response	No response	No response	-

Notes: ↑/↓ = early warning/low level effect; ↑↑/↓↓ = moderate level effect ↑↑↑/↓↓↓= high level effect for biological metrics, the direction of the sign (↑ or ↓) indicates the direction of difference relative to the reference areas; n/a = analysis not conducted sex/age-class.

In all cases where a low overall rating was applied, the nature of change (NF versus reference) was a decrease in size, energy reserves or reproductive investment. These decreases would only generally be anticipated as a result of toxicological impairment.

3.2 *A POSTERIORI* WEIGHTING

As described in Section 2.2.3, *a posteriori* weighting factors for strength of linkage and coherence of response were applied for each endpoint by examining the relationships among endpoints within and between LOE groups.

A summary of the *a posteriori* weighting factors applied for the WOE analyses are provided in Tables 3-8 and 3-9. Up-weighting or down-weighting was only relevant for endpoints where non-negligible effects were observed since a negligible effect was given a numerical score of 0, which would override the weighting factors. It was also only relevant for endpoints with a non-zero score following direction-weighting, since a zero score carried through the analysis regardless of the *a posteriori* weighting.

For the Toxicological Impairment WOE analysis, the considerations that contributed to up-weighting or down-weighting of endpoint results were:

- ***Water chemistry endpoints* –** The analysis of effluent chemistry, mixing zone chemistry and NF, MF, and reference area chemistry suggested a relatively strong link between SOI concentrations and effluent release from the Mine. In addition, a similar magnitude and extent of statistical differences was observed for most of the SOIs (further detail is provided in Golder 2014b). Based on these findings, both coherence of response and strength of linkage were increased to 0.75 for water chemistry endpoints resulting in an overall up-weighting in the Toxicological Impairment WOE analysis.
- ***Sediment chemistry endpoints* –** Comparison of water quality findings with sediment quality findings indicates correspondence of the low ratings for aluminum, calcium, chromium and uranium. Although the other metals that reached a low rating for sediments did not directly correspond to water quality, changes in the rating criteria for 2013 led to more accurate correspondence in rating levels between water quality and sediment quality (i.e., sediment metals concentrations must now exceed a sediment quality guideline to reach a moderate or high rating). The multiple sediment metals at the low rating indicated a high coherence of response (weighting increased to 0.75) and the low rating for sediments was considered to be linked to Mine operation (weighting increased to 0.75).

- ***Fish tissue chemistry*** – For bismuth and uranium, the statistical differences that result in the moderate effect for tissue chemistry appear to be correlated with sediment metals concentrations, the cause of which is unclear. Discussions in previous AEMP reports (e.g., Golder 2012) described how elevated bismuth and uranium in sediments of the NF area might be related to dike construction as opposed to an ongoing and progressive effluent-related effect in Lac de Gras. Therefore, the strength of linkage for tissue chemistry was reduced to 0.25 (i.e., down-weighting in the Toxicological Impairment WOE analysis) to reflect this uncertainty. No change in weighting was applied for coherence of response because multiple metals achieved a low or moderate rating in fish tissue, although the ratings varied between the metals (lead, strontium and thallium were low whereas bismuth and uranium were moderate).
- ***Plankton community endpoints* –** Based on consideration of plankton richness, the phytoplankton and zooplankton community structure responses did not appear related to toxicological impairment. Therefore, strength of linkage for these responses was down-weighted to 0.25 in the WOE analysis.

- ***Benthic invertebrate endpoints* –** For endpoints demonstrating statistical differences the differences, the response was opposite to that expected if toxicity was occurring (i.e., increases in density rather than decreases). Also, the change in community structure and density of dominant taxa was unlikely to be related to toxicological effects from Mine-related contaminants because no water quality or sediment quality benchmarks were exceeded for SOIs. Based on these considerations, both strength of linkage and coherence for all benthic invertebrate endpoints were reduced to 0.25 (i.e., down-weighting in the Toxicological Impairment WOE analysis) to reflect the lack of a causality with respect to contaminant releases from the Mine and lack of coherence with the type of responses that would be expected to result from toxicological impairment. Further information is provided in Golder (2014f).

- ***Fish health endpoints* –** Fish tissue metals concentrations, the key indicator of contaminant exposure, did not exceed levels that would be of toxicological concern, suggesting that any apparent responses in the fish populations (NF vs reference) may not to be related to metals exposure. Therefore strength of linkage was kept down-weighted to 0.25 in the Toxicological Impairment WOE analysis. For energy stores-K reproductive investment-GSI, and population structure – size, the decreasing responses were somewhat variable between age/sex-classes but in a consistent direction, and coherence of response was maintained at 0.5. The decreased weighting, in general for these apparent fish health responses was also warranted based on:
  - The difference in response relative to previous AEMP years. In previous years where slimy sculpin was sampled, the pattern of response has generally been consistent with enrichment, even though the degree of exposure to metals in water and fish tissue was not markedly different than in 2013.
  - The lack of any toxicological impairment responses in plankton or benthos. If effluent release were increasing the toxic exposure in Lac de Gras, then some impairment responses in these organism classes also would be expected.

Table 3-8 *A Posteriori* Weighting Factors Applied to Endpoints in the Toxicological Impairment Weight-of-Evidence Analysis

Line of Evidence	Endpoint	Strength of Linkage	Coherence of Response	Combined Factor
Water Quality	Comparison to Benchmarks and Reference	0.75	0.75	1.5
Sediment Quality	Comparison to Guidelines And Reference	0.75	0.75	1.5
Sculpin Tissue Chemistry	Comparison to Reference	0.25	0.5	0.75
Biological Productivity	Phytoplankton Community Structure/Richness	0.25	0.5	0.75
	Zooplankton Community Structure/Richness	0.25	0.5	0.75
Benthic Invertebrates	Density of *Procladius* and *Heterotrissocladius*	0.25	0.25	0.5
	Relative Abundance of Dominant Taxa	0.25	0.25	0.5
Fish Population Health	Population Structure - size	0.25	0.5	0.75
	Energy Stores - LSI	0.25	0.5	0.75
	Reproductive Investment - GSI	0.25	0.5	0.75

Notes: *A posteriori* weighting factors were not applied for the remaining endpoints because no effect was observed or they had a direction-weighting score of zero. The rationale for up-weighting or down-weighting is described in the text.

Table 3-9 *A Posteriori* Weighting Factors Applied to Endpoints in the Nutrient Enrichment Weight-of-Evidence Analysis

Line of Evidence	Endpoint	Strength of Linkage	Coherence of Response	Combined Factor
Water Quality	Comparison to Benchmarks and Reference	0.75	0.75	1.5
Biological Productivity	Chlorophyll *a*	0.75	0.5	1.25
	Phytoplankton Biomass (enumeration)	0.75	0.5	1.25
	Zooplankton Biomass (AFDM)	0.75	0.5	1.25
	Phytoplankton Community Structure/Richness	0.75	0.5	1.25
	Zooplankton Community Structure/Richness	0.75	0.5	1.25
Benthic Invertebrates	Total Invertebrate Density	0.75	0.5	1.25
	Density of *Procladius* and *Heterotrissocladius*	0.75	0.5	1.25
	Relative Abundance of Dominant Taxa	0.75	0.5	1.25

Notes: *A posteriori* weighting factors were not applied for the remaining endpoints because no effect was observed or they had a direction-weighting score of zero: The rationale for up-weighting or down-weighting is described in the text.

These considerations suggest that the fish health responses for 2013, although consistent with a pattern of toxic response, could also be due to random fluctuations or other ecological/abiotic factors.

For the Nutrient Enrichment WOE analysis, the considerations that contributed to up-weighting or down-weighting of endpoint results were:

- ***Nutrient exposure endpoints* –** The analyses of effluent chemistry, mixing zone chemistry and NF, MF and reference area chemistry suggested a relatively strong link between nutrient concentrations and effluent release from the Mine. In addition, a similar magnitude and extent of statistical differences was observed for TN and TP (further detail is provided in Golder 2014d). Based on these findings, both coherence of response and strength of linkage were increased to 0.75 for these water chemistry endpoints resulting in an overall up-weighting in the Nutrient Enrichment WOE analysis. Chlorophyll *a* was also used as an exposure endpoint for benthic invertebrates and fish. Benthic invertebrates showed a response consistent with enrichment and therefore the up-weighting described below was applied for chlorophyll *a* as an exposure endpoint. However, for fish health, none of the responses were consistent with enrichment, and applying the up-weighting for chlorophyll *a* would result an unrepresentative EOI Ranking. Therefore, chlorophyll *a* was down-weighted *a posteriori* when considered as a nutrient exposure endpoint for fish health.
- ***Chlorophyll a, phytoplankton biomass and community structure, zooplankton biomass and community structure* –** The increase in chlorophyll *a* in the NF area coincided with significantly higher total phosphorus (TP) and total nitrogen (TN) concentrations in the NF area. Similarly, the increase in zooplankton biomass in the NF area coincided with significantly higher chlorophyll *a* concentrations in the NF area. These findings indicated a relatively strong link between nutrient release in Mine effluent and responses in primary and secondary productivity. Therefore, strength of linkage for these endpoints was increased to 0.75 (i.e., up-weighting in the

Nutrient Enrichment WOE analysis. Chlorophyll *a*, phytoplankton biomass and zooplankton biomass (AFDM) each had positive responses to the nutrient enrichment, but the degree of effect different between the endpoints (i.e., high rating for chlorophyll *a* but low ratings for the other endpoints) and therefore coherence of response was not adjusted for these endpoints. Similarly, phytoplankton community structure and zooplankton community structure are both showing a nutrient related shift (strength of linkage increased to 0.75) but the effect rating varied and coherence of response was not adjusted.

- ***Benthic invertebrate endpoints –*** The type of effect observed for all of the benthic invertebrate endpoints where a response was observed was consistent with mild nutrient enrichment contributed by the Mine effluent, with a shift in community structure proportional to effluent exposure. This included the increased total density, increased *Procladius* and *Hetertrissocladius* densities and the altered community structure. As a result, both strength of linkage and coherence of response were increased to 0.75 (i.e., up-weighting in the Nutrient Enrichment WOE analysis) for these benthic endpoints except, the apparent link to nutrient releases from the Mine and coherence in endpoint responses.
- ***Fish population endpoints –*** *A posteriori* weighting was not applied to fish health endpoints because direction weighting of the responsive endpoints reduced the scores to zero (none of the responses supported the Nutrient Enrichment hypothesis).

3.3 WEIGHT OF EVIDENCE RESULTS

The results of the WOE analyses are summarized in Table 3-10. The full analysis, including all endpoints, *a priori,* direction, and *a posteriori* weighting factors, combined scores and EOI Rankings, is provided in Appendix II.

Sources of uncertainty in the assessment of each ecosystem component are discussed in Section 3.4. Detailed discussion regarding the WOE outcome for each of the two impact hypotheses is provided in the subsections, below.

3.3.1 Toxicological Impairment

3.3.1.1 Lake Productivity

The endpoint responses for biological productivity did not indicate any toxicity-related decrease in chlorophyll *a,* phytoplankton biomass or zooplankton biomass or toxicity-related changes in community structure. Rather, these endpoints exhibited changes that were only consistent with enrichment. Therefore, based on the direction-weighting factors, none of the endpoint responses for biological productivity provided support for the Toxicological Impairment hypothesis (i.e., direction-weighting was 0 for both chlorophyll *a* and zooplankton biomass).

For consistency in application of the WOE Framework, the water quality endpoints for substances of toxicological concern were carried through the WOE process, despite the lack of impairment responses in biological productivity endpoints. Based on statistically-significant increases in the NF area relative to reference areas, early warning/low effects were concluded for multiple SOIs including conductivity, total dissolved solids [calculated], dissolved calcium, chloride, dissolved sodium, sulphate, ammonia, nitrate, and multiple metals.

Combining the weighted scores for biological productivity and water chemistry resulted in an EOI Rank of 0, which represents negligible evidence of toxicological impairment, overall, to lake productivity from Mine activities and effluent discharge. The lack toxicity related changes in any of the lake productivity ratings, supports this negligible EOI ranking.

Table 3-10 Weight-of-Evidence Results, 2013 AEMP

Ecosystem Component	Exposure Lines of Evidence			Biological Response Lines of Evidence			Total Score	EOI Ranking
	Key Endpoint(s)[a]	Effect Rating	Weighted Score	Key Endpoint(s)[a]	Effect Rating	Weighted Score		
Toxicological Impairment								
Lake Productivity	Water Quality – several parameters	↑	2.8	None[b]	0	0	2.8	**0**
Benthic Invertebrates	Sediment Quality – several parameters	↑	5.6	Relative Abundance of Dominant Taxa	↑/↓	1.9	7.5	**0**
Fish Health	Sculpin Tissue Chemistry – bismuth, uranium	↑↑	10.5	Energy Stores – LSI Reproductive Investment – GSI	↓	9.4	19.9	**1**
Nutrient Enrichment								
Lake Productivity	Water Quality - total P	↑	5.6	Chlorophyll *a* (biological response)	↑↑↑	37.5	43.1	**3**
Benthic invertebrates	Chlorophyll *a* (enrichment exposure)	↑↑↑	28.1	Total Invertebrate Density	↑	12.5	40.6	**3**
Fish Health	Chlorophyll *a* (enrichment exposure)	↑↑↑	11.3	None(c)	0	0	11.3	**1**

Notes**:** EOI = Evidence of impact; 0 = Negligible; ↑/↓ = Early warning/low; ↑↑/↓↓ = Moderate; ↑↑↑/↓↓↓ = High; n/a = not applicable.

a) These endpoints resulted in the highest weighted score for the ecosystem component. Where multiple endpoints are listed, the weighted scores were the same for each endpoint.

b) None of the plankton community responses were in the direction that would be expected in response to toxicity = None of the fish health responses were in the direction that would be expected in response to enrichment.

3.3.1.2 Benthic Invertebrates

Multiple sediment quality parameters were significantly higher in the NF area relative to reference area. Of these, bismuth, lead and uranium also exceeded the normal range in the NF. However, none of the parameters that had statistical differences exceeded available sediment quality guidelines indicating that the NF versus reference differences were generally of low toxicological concern. This resulted in an overall rating of early warning/low for multiple sediment parameters including: aluminum, bismuth, boron, calcium, chromium, lead, lithium, magnesium, potassium, sodium, tin, titanium and uranium.

Based on the direction-weighting factors, three endpoint responses (*Procladius* density, *Heterotrissocladius* density and relative abundance of dominant taxa) could potentially support the Toxicological Impairment hypothesis in certain situations. Relative abundance of dominant taxa was the only endpoint that provided 0.5 or greater support for the Toxicological Impairment hypothesis. The change in relative abundance of dominant taxa could indicate a potential shift in community structure as a result of proximity to the Mine and, based on the effect level designations for toxicological impairment, was rated as early warning/low effects. However, this endpoint is non-specific with respect to effect type and considering the overall pattern in response the observed change was most likely related to enrichment rather than toxicological impairment. Based on these considerations, both strength of linkage and coherence for this endpoint were each reduced to 0.25 (i.e., down-weighting in the Toxicological Impairment WOE analysis) to reflect the lack of a causality with respect to contaminant releases from the Mine and lack of coherence with the type of responses that would be expected to result from toxicological impairment.

Combining the weighted scores for sediment quality and benthic invertebrates resulted in an EOI Rank of 0, which represents negligible evidence of toxicological impairment, overall, to the benthic invertebrate community from Mine activities and effluent discharge. The overall pattern of biological response which was not consistent with toxicological impairment, supports this negligible EOI ranking.

3.3.1.3 Fish Health

The exposure indicator with the highest weighting for fish health was sculpin tissue chemistry. Five metals (bismuth, lead, strontium, thallium, and uranium), had NF area mean concentrations that had statistically significant increases relative to reference area mean concentrations. Of these, bismuth and uranium had NF area concentrations that were greater than the normal range, resulting in an effect rating of Moderate for these metals. As discussed in Section 3.2 there was uncertainty as to whether these elevated metals in fish tissues were related to effluent release from the Mine, and therefore, strength of linkage was down-weighted to 0.25 in the WOE analysis.

The pattern of response in fish health endpoints measured for slimy sculpin included statistically significant decreases in the NF area relative to reference for population structure-size, energy stores-LSI and reproductive investment-GSI. These decreases would only generally be anticipated as a result of toxicological impairment and were rated as early warning/low. Strength of linkage was reduced to 0.25 for these endpoints because tissue metals concentrations had uncertain linkage to the Mine and did not indicate levels of toxicological concern Reduced weighting of these fish health responses was also warranted based on the lack of similar responses in previous years where elevated fish metals concentrations were also found, and by the lack of toxic impairment responses in the plankton and benthic communities. As a result of the *a posteriori* down-weighting of some endpoints, the responses for fish health resulted in the same WOE scores for energy stores-LSI and reproductive investment-GSI.

Combining the weighted scores for sculpin tissue chemistry and fish health resulted in an EOI Rank of 1, which represents Low evidence of toxicological impairment, overall, to the fish community from Mine activities and effluent discharge.

It should be noted that the final EOI Rank was sensitive to the *a posteriori* weighing applied to some endpoints and that without the down-weighting, the EOI Rank would have been 2 (Moderate). However, the lack of similar responses in previous years where elevated fish metals concentrations were also found, and the lack of toxic impairment responses in the plankton and benthic communities suggests that the fish health responses for 2013, although consistent with a pattern of toxic response, could also be due to random fluctuations or other ecological/abiotic factors. Based on these considerations, the EOI Rank of 1 (Low) was considered appropriate.

3.3.2 Nutrient Enrichment

3.3.2.1 Lake Productivity

The AEMP findings indicated a consistent pattern of response between nutrient enrichment in the water column and enrichment responses in the plankton community of NF areas of Lac de Gras.

Concentrations of both total nitrogen and total phosphorus were beyond the reference normal range in NF and some MF areas but these elevated concentrations did not extend over greater than 20% of the lake area, resulting in an overall rating of Moderate for these endpoints. The *a posteriori* weighting factors for both strength of linkage and coherence of response for these endpoints were each up-weighted from 0.5 to 0.75 to reflect linkage to Mine activities (primarily the release of wastewater effluent) and the similarity in findings.

The endpoint responses for biological productivity indicated significant increases in chlorophyll *a*, phytoplankton biomass and zooplankton biomass that each provided a high degree of support (direction-weighting of 1.0) for the Nutrient Enrichment hypothesis. There were also indications nutrient-related shifts in plankton community structure combined with increased richness, in the NF areas relative to reference areas, which also indicated nutrient enrichment. The highest level of response (and resulting weighted score) was obtained for chlorophyll *a* which exhibited a statistically significant increase beyond the normal range over great than 20% of the lake area, resulting in a rating of High. The observed increases in chlorophyll *a* in NF and MF areas of Lac de Gras and enrichment responses in other biological productivity endpoints areas were expected given the increases in TN and TP in the NF area. Therefore, strength of linkage was up-weighted to 0.75 for all biological productivity responses.

Combining the weighted scores for nutrient enrichment exposure and biological productivity responses resulted in an EOI Rank of 3, which represents strong evidence that the response in lake productivity is due to nutrient enrichment related to Mine activities and effluent discharge. The exposure and biological response endpoint results with the highest weighted scores included total-P and chlorophyll *a*.

3.3.2.2 Benthic Invertebrates

The AEMP findings also indicated a consistent pattern of response between nutrient enrichment in the water column and enrichment responses in the benthic invertebrate community of NF areas of Lac de Gras.

There was a statistically significant increase exceeding the normal range in chlorophyll *a* in NF compared to reference areas (representing increased food supply for benthic invertebrates). The increase extended beyond 20% of the lake area, resulting in a rating of High. This increased food supply had a clear linkage to the Mine as a result of corresponding increases in nutrients (nitrogen and phosphorous) in NF areas and therefore, strength of linkage was up-weighted to 0.75 for all chlorophyll *a*.

There was a statistically significant increase in total invertebrate density, and the densities of P*rocladius* sp. and *Heterotrissocladiu*s sp, in NF areas compared to reference areas. A low-level community shift in benthic invertebrate community composition (i.e., relative abundance of dominant taxa) was also evident based on NMDS. Both strength of linkage and coherence of response were increased to 0.75 (i.e., up-weighting in the Nutrient Enrichment WOE analysis) to reflect the similar responses suggesting enrichment which appear linked to increased chlorophyll *a* and phytoplankton abundance. Following weighting, total invertebrate density had the highest overall score.

Combining the weighted scores for nutrient enrichment exposure and benthic invertebrate responses resulted in an EOI Rank of 3 (High), which represents strong evidence that the response in the benthic invertebrate community is resulting from nutrient enrichment related to Mine activities and effluent discharge.

3.3.2.3 Fish Health

The increased chlorophyll *a* in NF and MF areas is indicative of enrichment-related increases in zooplankton and/or benthic invertebrate food supply for slimy sculpin, and as with the benthic invertebrate analysis, this change was rated as high for chlorophyll *a*. However, for fish health, none of the responses were consistent with enrichment, and applying the up-weighting for chlorophyll *a* that was applied for plankton and benthic invertebrates would result an unrepresentative EOI Ranking. Therefore, chlorophyll *a* was down-weighted *a posteriori* (both strength of linkage and coherence of response set at 0.25) when considered as a nutrient exposure endpoint for fish health.

Based on the direction of responses for fish health, none of the responses were indicative of nutrient enrichment and following direction-weighting had scores of zero in the analysis.

For consistency in application of the WOE Framework, the weighted score for chlorophyll *a* was carried through the WOE process, despite the lack of enrichment responses in fish health endpoints. This resulted in an EOI Rank of 1 (Low). This ranking was entirely due to the high rating for chlorophyll *a* which indicates nutrient exposure rather than actual biological responses in fish health, and therefore was somewhat of an artifact of the WOE analysis framework. There was no evidence of an enrichment response in the fish health endpoints in 2013.

3.4 UNCERTAINTY

The strength of evidence supporting the WOE analyses for each ecosystem component varies with the amount and quality of information available. Potential sources of uncertainty in the WOE analyses fall into four general classes:

- Difficulty in characterizing potential changes, responses and effects (e.g., natural variability, potential confounding factors, presence of multiple stressors, uncertain persistence of any observed changes) can be described and estimated but cannot be eliminated. This type of uncertainty was characterized for each endpoint and LOE group in the WOE Framework in the *a priori* weighting factors for representativeness and persistence of effects. The *a posteriori* assessments of coherence and causality of endpoints also served to focus the WOE analyses on those endpoints that were most likely to reflect real and robust effects of the Mine, reducing the influence of this type of uncertainty on the WOE analyses.
- Uncertainty arising from simplification of the real world (e.g., the extrapolation of effects measured for certain benthic indicator species to the benthic community of Lac de Gras in general) can be reduced by increased realism in endpoints, but cannot

be eliminated. This type of uncertainty was characterized for each endpoint in the WOE Framework in the *a priori* weighting factor for clarity of interpretation. The use of multiple effects endpoints for each LOE (e.g., for benthic invertebrate field effects measures addressing community structure, richness, diversity, total abundance, and species abundance), as well as the selection of study species that are robust indicators of response in a particular area (i.e., most benthic invertebrate species are relatively sedentary), reduced the influence of this type of uncertainty on the WOE analyses.

- Imperfect knowledge or error can be reduced or in some cases eliminated (e.g., through proper QA/QC procedures). This type of uncertainty was characterized for each endpoint in the WOE Framework in the *a priori* weighting factor for methodological robustness. Appropriate QA/QC procedures were included for every endpoint to reduce the influence of this type of uncertainty on the WOE analyses. QA/QC issues for specific endpoints are discussed in their respective reports (Golder 2014b,c,d,e,f,g).
- The ecological significance of observed effects and changes is uncertain because most of the effect levels do not identify what type of change would represent a significant degradation to Lac de Gras (this is the purpose of the Action Levels). The current effect levels focus on statistical significance, which does not always coincide with ecological significance, especially for an ultra-oligotrophic system such as Lac de Gras where even a small magnitude change is likely to be detected for certain endpoints. This is especially important for nutrient enrichment effects, for which standardized approaches to estimating ecological significance are not in widespread use. Overall, the WOE analysis is intended to err on the side of conservatism, identifying evidence of impact regardless of whether the apparent changes, responses or effects are expected to have ecological significance.

Sources of uncertainty for the endpoints associated with individual ecosystem components are described in the individual reports for each component (Golder 2014b,c,d,e,f,g). For all endpoints, a significant source of uncertainty is natural spatial and temporal variability in Lac de Gras. Given the inherent variability of natural systems, it is never possible to eliminate the possibility of false negative results, primarily for relatively subtle effects (i.e., failing to detect the effect of the Mine on a particular endpoint, when one actually exists) or false positive results (i.e., concluding that the Mine has had an effect on a particular endpoint, when the apparent change is due to natural variability or a confounding factor with natural causes).

As with previous years, this report describes a “point-in-time” analysis with inherent uncertainty. While the WOE findings may change from year to year, overall knowledge of the system and potential impacts to Lac de Gras will improve over time as patterns emerge that transcend year-to-year variability. The longer-term trend and pattern in AEMP findings will ideally guide further studies, refinements to the AEMP, and management actions as appropriate and necessary.

4 CONCLUSIONS

This report presents the WOE analysis for data collected during the 2013 AEMP field program. Specific endpoints for exposure and biological response were integrated to examine the evidence of impact associated with two distinct types of stressors: toxicological impairment and nutrient enrichment.

4.1 TOXICOLOGICAL IMPAIRMENT FINDINGS

The AEMP findings for water quality, sediment quality and sculpin tissue chemistry indicate that effluent releases from the Mine have resulted in increases in the concentrations of metals and other toxic substances in effluent-exposure areas. In some cases the observed concentrations exceed the normal range for reference areas, but none of the observed exposure concentrations exceeded effects benchmarks, guidelines or levels considered to have toxic effects.

For 2013, no toxicological impairment effects to lake productivity (primary productivity and the plankton community) or benthic invertebrates were apparent. The pattern of response in fish health endpoints measured for slimy sculpin in the NF area included decreases in body size, energy reserves and reproductive investment for most age/sex classes. Although these changes were in the direction of a toxicological impairment response, the lack of similar responses in previous years, in which fish had similar body burdens of metals, and the lack of toxic impairment responses in the plankton and benthic communities, suggest that these findings in fish need to be confirmed in a subsequent survey before we can conclude that a toxicological effect has occurred. The fish health responses for 2013 could also be due to random fluctuations or other ecological/abiotic factors such as the colder waters encountered in the exposure areas.

Based on the results of the Toxicological Impairment WOE analysis, EOI Rankings have been derived for lake productivity, benthic invertebrates and fish population health in Lac de Gras. The EOI Rankings, and key supporting endpoint results are summarized below:

- **Lake Productivity –** EOI Rank 0 (Negligible):
  - Exposure - Statistically significant increase in the water column concentrations of multiple SOIs in the NF area relative to reference areas.
  - Biological Response- No toxicological impairment responses in lake productivity.
- **Benthic Invertebrates –** EOI Rank 0 (Negligible):
  - Exposure - Statistically significant increase in the sediment concentrations of multiple SOIs in the NF area relative to reference areas.

  - Biological Response – Relative abundance of dominant taxa was different in the NF area relative to reference areas, but this response is unlikely to have been related to a toxicological impairment response in benthic invertebrates.
- **Fish Population Health** – EOI Rank 1 (Low):
  - Exposure - Statistically significant increase beyond the normal range in the sculpin tissue concentrations of bismuth and uranium in the NF area relative to reference areas.
  - Biological Response – Decreases in the NF area relative to reference areas in body size, energy reserves and reproductive investment for some age/sex classes, which could occur as a result of toxicological impairment.

4.2 NUTRIENT ENRICHMENT FINDINGS

The endpoint results relevant to nutrient enrichment support the interpretation that Mine discharges are resulting in changes to lake productivity and the benthic invertebrate community that are consistent with nutrient enrichment. For exposure areas, there appears to be a consistent response between release of nutrients from the Mine, increases in primary productivity and secondary productivity in the water column, combined with a plankton community shift. This response is also consistent for increases in density of the benthic invertebrate community and a shift in community structure. The area of effect for increases in primary productivity also extends into MF areas.

In contrast to this consistent response for the plankton community and benthic invertebrate community, none of the fish health responses were consistent with enrichment. Thus, although the increased primary productivity in NF and MF areas suggested the potential for increased food supply to fish, the results for 2013 did not indicate a response to this increased food supply.

Based on the results of the Nutrient Enrichment WOE analysis, EOI Rankings have been derived for lake productivity and benthic invertebrates and fish population health in Lac de Gras. The EOI Rankings, and key supporting endpoint results and weighting considerations that formed the basis for the rankings are summarized below:

- **Lake Productivity –** EOI Rank 3 (Strong):
  - Exposure - Water column concentration of total phosphorous in the NF area exceeded the normal range for reference areas. The area of effect was beyond NF but less than 20% of the lake area.
  - Biological Response- Statistically significant increase exceeding the reference normal range in chlorophyll *a* in NF areas compared to reference areas, which extended beyond 20% of the lake area.

- **Benthic Invertebrates –** EOI Rank 3 (Strong):
  - Exposure- Statistically significant increase exceeding the reference normal range in chlorophyll *a* in NF areas compared to reference areas, which extended beyond 20% of the lake area.
  - Biological Response – Statisically significant increase in total invertebrate density, in NF areas compared to reference areas.
- **Fish Population Health –** EOI Rank 1 (Low):
  - Exposure- Statistically significant increase exceeding the reference normal range in chlorophyll *a* in NF areas compared to reference areas, which extended beyond 20% of the lake area.
  - Biological Response – No nutrient enrichment responses in fish health.

4.3 OVERALL CONCLUSION

Comparison of the EOI Rankings indicates that the evidence for a response to nutrient enrichment in Lac de Gras is much stronger than the evidence for toxicological impairment. There appears to be a clear link between nutrient releases to Lac de Gras as a result of Mine effluent, increases in nutrient concentrations in exposed areas, and increases in lake productivity in exposed areas. There is also a consistent response of increases in invertebrate density and a mild community shift in the benthic invertebrate community that can be linked to the observed enrichment.

The magnitude and type of response in Lac de Gras appears to be an increase in lake productivity due to nutrient enrichment. Although there are statistically significant changes to indicators of enrichment in the NF area (and in some cases MF areas), the severity with respect to the ecological integrity of Lac de Gras associated with these changes appears be low.

In contrast, there is negligible evidence of impairment to lake productivity or the benthic invertebrate community. Responses in fish health were in the direction of a toxicological impairment response. However, the lack of similar responses in previous years, in which similar levels of fish metals concentrations were found, and the lack of toxic impairment responses in the plankton and benthic communities suggests that the fish health responses for 2013 could represent a random fluctuation within normal variability, or they could be caused by other ecological/abiotic factors.

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6 CLOSURE

We trust the information in this report meets your requirements at this time. If you have any questions relating to the information contained in this document please do not hesitate to contact us.

GOLDER ASSOCIATES LTD.

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APPENDIX A

WEIGHT-OF-EVIDENCE ANALYSIS – QUANTITATIVE INTEGRATION OF ENDPOINTS, WEIGHTING FACTORS, COMBINED SCORES AND EVIDENCE OF IMPACT RANKINGS

Table A-1 WOE Analysis for Toxicological Impairment Impacts – 2013 AEMP

Ecosystem Component	Line of Evidence Group	LOE/Endpoints	Effect Level Rating	Mathematical Representation	*A Priori* Weighting		Direction Weighting			*A Posteriori* Weighting				Final LOE Score	Total WOE Score
					A Priori Weighting Factor	Weighted LOE Score	Direction of Observed Effect or Correlation	Support for Toxicity Hypothesis	Weighted LOE Score	Strength of Linkage	Coherence of Response	Overall (Sum of Factors)	Weighted LOE Score		
Lake Productivity	Contaminant Exposure	Water Quality - Comparison to Benchmarks and Reference	↑	0.5	3.8	1.9	n/a	n/a	n/a	0.75	0.75	1.50	2.8	2.8	2.8
	Biological Productivity - NF vs Reference (Biological Response)	Chlorophyll a (biological response)	↑↑↑	2	15.0	30.0	Increase	0.00	0.0					0.0	
		Zooplankton Biomass (AFDM)	↑	0.5	15.0	7.5	Increase	0.00	0.0						
		Phytoplankton Biomass (enum)	↑	0.5	15.0	7.5	Increase	0.00	0.0						
		Zooplankton Biomass (enum)	0	0	15.0	0.0									
		Phytoplankton Community Structure/Richness	↑/↓	0.5	11.3	5.6	Increase	0.00	0.0	0.25	0.50	0.75	0.0		
		Zooplankton Community Structure/Richness	↑↑/↓↓	1	11.3	11.3	Increase	0.00	0.0	0.25	0.50	0.75	0.0		
Fish Community	Fish Population Health - NF vs Reference (Biological Response)	Population Structure - survival	0	0	18.8	0.0								9.4	19.9
		Population Structure - size	↓	0.5	18.8	9.4	Decrease	1.00	9.4	0.25	0.50	0.75	7.0		
		Energy Stores - K	0	0	25.0	0.0									
		Energy Stores - LSI	↓	0.5	25.0	12.5	Decrease	1.00	12.5	0.25	0.50	0.75	9.4		
		Relative reproductive success- Age 1 abundance	0	0	18.8	0.0									
		Reproductive Investment - GSI		0.5	25.0	12.5	Decrease	1.00	12.5	0.25	0.50	0.75	9.4		
		Pathology - Occurrence	0	0	25.0	0.0									
	Contaminant Exposure	Water Quality - Comparison to Benchmarks and Reference	↑	0.5	3.8	1.9	n/a	n/a	n/a	0.75	0.75	1.50	2.8	10.5	
		Sculpin Tissue Chemistry - Comparison to Reference	↑↑	1	14.1	14.1	n/a	n/a	n/a	0.25	0.50	0.75	10.5		
Benthic Invertebrates	Contaminant Exposure	Sediment Quality - Comparison to Guidelines and Reference	↑	0.5	7.5	3.8	n/a	n/a	n/a	0.75	0.75	1.50	5.6	5.6	7.5
		Water Quality - Comparison to Benchmarks and Reference	↑	0.5	3.8	1.9	n/a	n/a	n/a	0.75	0.75	1.50	2.8		
	Benthic Invertebrates - NF vs Reference (Biological Response)	Total Invertebrate Density	↑	0.5	20.0	10.0	Increase	0.00	0.0					1.88	
		Pisidiidae Density	0	0	18.8	0.0									
		Procladius Density	↑	0.5	15.0	7.5	Increase	0.25	1.9	0.25	0.25	0.50	0.9		
		Heterotrissocladius Density	↑	0.5	15.0	7.5	Increase	0.25	1.9	0.25	0.25	0.50	0.9		
		Microtendipes Density	0	0	15.0	0.0									
		Richness	0	0	25.0	0.0									
		Simpson's Diversity Index	0	0	18.8	0.0									
		Evenness	0	0	15.0	0.0									
		Dominance	0	0	15.0	0.0									
		Bray-Curtis	0	0	15.0	0.0									
		Relative Abundance of Dominant Taxa	↑/↓	0.5	15.0	7.5	Increase	0.50	3.8	0.25	0.25	0.50	1.9		

Notes:
LOE = line of evidence
AFDM = ash-free dry mass
Enum = enumeration
K = condition factor
LSI = liver-somatic index
GSI = gonado-somatic index

↑/↓ = early warning/low level effect; ↑↑/↓↓ = moderate level effect ↑↑↑/↓↓↓= high level effect for biological metrics, the direction of the sign (↑ or ↓) indicates the direction of difference relative to the reference areas

WOE Score Color Coding

EOI Rank 3	🟥 >40.0
EOI Rank 2	🟧 >20.0
EOI Rank 1	🟨 >10.0
EOI Rank 0	🟩 <10

Table A-2 WOE Analysis for Nutrient Enrichment Impacts – 2013 AEMP

Ecosystem Component	Line of Evidence Group	LOE/Endpoints	Effect Level Rating	Mathematical Representation	*A Priori* Weighting		Direction Weighting			*A Posteriori* Weighting				Final LOE Score	Total WOE Score
					Overall (Product of Factors)	Weighted Endpoint Score	Direction of Observed Effect or Correlation	Support for Nutrient Enrichment Hypothesis	Weighted Endpoint Score	Strength of Linkage	Coherence of Response	Overall (Sum of Factors)	Weighted Endpoint Score		
Lake Productivity	Nutrient Exposure	Total N - Comparison to Reference	↑	0.5	5.6	2.8	n/a	n/a	n/a	0.75	0.75	1.50	4.2	5.6	43.1
		Total P - Comparison to Reference	↑	0.5	7.5	3.8	n/a	n/a	n/a	0.75	0.75	1.50	5.6		
	Biological Productivity - NF vs Reference (Biological Response)	Chlorophyll *a* (biological response)	↑↑↑	2	15.0	30.0	Increase	1.0	30.0	0.75	0.50	1.25	37.5	37.5	
		Zooplankton Biomass (AFDM)	↑	0.5	15.0	7.5	Increase	1.0	7.5	0.75	0.50	1.25	9.4		
		Phytoplankton Biomass (enum)	↑	0.5	15.0	7.5	Increase	1.0	7.5	0.75	0.50	1.25	9.4		
		Zooplankton Biomass (enum)	0	0	15.0	0.0									
		Phytoplankton Community Structure/Richness	↑/↓	0.5	11.3	5.6	Increase	1.0	5.63	0.75	0.50	1.25	7.0		
		Zooplankton Community Structure/Richness	↑↑/↓↓	1	11.3	11.3	Increase	1.0	11.3	0.75	0.50	1.25	14.1		
Fish Community	Fish Population Health - NF vs Reference (Biological Response)	Population Structure - survival	0	0	18.8	0.0								0.0	11.3
		Population Structure - size	↓	0.5	18.8	9.4	Decrease	0.0	0.0						
		Energy Stores - K	0	0	25.0	0.0									
		Energy Stores - LSI	↓	0.5	25.0	12.5	Decrease	0.0	0.0						
		Relative reproductive success- Age 1 abundance	0	0	18.8	0.0									
		Reproductive Investment - GSI	↓	0.5	25.0	12.5	Decrease	0.0	0.0						
		Pathology - Occurrence	0	0	25.0	0.0									
	Nutrient Exposure	Total N - Comparison to Reference	↑	0.5	5.6	2.8	n/a	n/a	n/a	0.75	0.75	1.50	4.2	11.3	
		Total P - Comparison to Reference	↑	0.5	7.5	3.8	n/a	n/a	n/a	0.75	0.75	1.50	5.6		
	Primary Productivity (Exposure)	Chlorophyll *a* (enrichment exposure)	↑↑↑	2	11.3	22.5	n/a	n/a	n/a	0.25	0.25	0.50	11.3		
Benthic Invertebrates	Nutrient Exposure	Total Organic Carbon	0	0	7.5	0.0	n/a	n/a	n/a					28.1	40.6
		Total N - Comparison to Reference	↑	0.5	5.6	2.8	n/a	n/a	n/a	0.75	0.75	1.50	4.2		
		Total P - Comparison to Reference	↑	0.5	7.5	3.8	n/a	n/a	n/a	0.75	0.75	1.50	5.6		
	Primary Productivity (Exposure)	Chlorophyll *a* (enrichment exposure)	↑↑↑	2	11.3	22.5	n/a	n/a	n/a	0.75	0.50	1.25	28.1		
	Benthic Invertebrates - NF vs Reference (Biological Response)	Total Invertebrate Density	↑	0.5	20.0	10.0	Increase	1.00	10.0	0.75	0.50	1.25	12.5	12.5	
		Pisidiidae Density	0	0	18.8	0.0									
		Procladius Density	↑	0.5	15.0	7.5	Increase	0.75	5.6	0.75	0.50	1.25	7.0		
		Heterotrissocladius Density	↑	0.5	15.0	7.5	Increase	0.75	5.6	0.75	0.50	1.25	7.0		
		Microtendipes Density	0	0	15.0	0.0									
		Richness	0	0	25.0	0.0									
		Simpson's Diversity Index	0	0	18.8	0.0									
		Evenness	0	0	15.0	0.0									
		Dominance	0	0	15.0	0.0									
		Bray-Curtis	0	0	15.0	0.0									
		Relative Abundance of Dominant Taxa	↑/↓	0.5	15.0	7.5	n/a	0.50	3.75	0.75	0.50	1.25	4.7		

Notes:
LOE = line of evidence
Total N = total nitrogen
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AFDM = ash-free dry mass
Enum = enumeration
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