RioTinto

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Joseph Mackenzie, A/Chair
Wek'èezhìı Land and Water Board
PO Box 32
Wekweètì, NT X1A 3S3
Canada

29 March 2019

Dear Mr. Mackenzie:

Subject: ***2018 AEMP Annual Report V1.0***

The 2018 Aquatic Effects Monitoring Plan (AEMP) Annual Report is attached as required under the Wek'èezhìı Land and Water Board (WLWB) Water Licence W2015L2-0001 Part J Item 8. Sampling for the 2018 AEMP was carried out according to the requirements specified in the *AEMP Study Design Version 4.1* for an interim monitoring year, which included sampling in the NF and MF areas of the lake.

In addition to the Water Licence requirements for annual reports, the 2018 AEMP Annual Report Version 1.0 includes WLWB directives, as well as commitments and comments acknowledged by DDMI in response to reviews of the following documents:

- 2014 AEMP Annual Report
- 2015 AEMP Annual Report
- 2016 AEMP Annual Report
- 2017 AEMP Annual Report

Under Water Licence W2015L2-0001, Action Level exceedance reporting (Part J Item 6) is required as part of the 2018 AEMP Annual Report. Action Level exceedances documented by the AEMP in 2018 are summarized in Table 1 attached to this letter and detailed within the 2018 AEMP Annual Report V1.0.

The results of the Action Level evaluation completed for the 2018 AEMP identified 19 water quality variables that triggered Action Levels (Table 1). Nineteen triggered Action Level 1 and ten subsequently also triggered Action Level 2. None of the water quality variables triggered an Action Level 3 in 2018. An additional four variables were included in the Action Level assessment because they triggered an effect equivalent to Action Level 1 at one or more mid-field stations located within the estimated zone of influence from dust deposition (but not in the near-field area). When a variable triggers an Action Level 2, the required management action is to develop an AEMP Effects Benchmark for that variable if one does not already exist. One of the variables that triggered Action Level 2 (i.e., calcium) does not have an existing Effects Benchmark, therefore DDMI will develop an AEMP Effects Benchmark for calcium as part of an AEMP Response Plan. No further action is required based on the results of the Action Level evaluation for water quality in 2018.

The 2018 AEMP results also indicated that chlorophyll *a* triggered Action Level 1 in the Response Framework for Indicators of Eutrophication (Table 1). Because an Action Level 2 has been triggered in previous years, an Effects Benchmark for chlorophyll *a* has previously been established (i.e., 4.5 ug/L) and was presented in *AEMP Study Design Version 3.5.* No further action is required in response to the Action Level 1 trigger in 2018.

The 2018 plankton data do not suggest that a toxicological effect is occurring in Lac de Gras. Action Levels for toxicological impairment were not triggered and results are consistent with nutrient enrichment, as demonstrated by increased total phytoplankton and zooplankton biomass in the NF area.

To assist the Board in their review of this document, Table 2 attached to this letter provides a Conformance Table outlining the sections of the report in which the applicable WLWB directives, commitments and comments have been addressed.

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

Yours sincerely,

Sean Sinclair, Superintendent
Environment

cc: Anita Ogaa, WLWB
Anneli Jokela, WLWB

Attachments: Table #1 - Summary of Action Level Exceedances and Required Management Actions, 2018 AEMP
Table #2- Conformance Table for the 2018 AEMP Annual Report Version 1.0

Table 1. Summary of Action Level Exceedances and Required Management Actions, 2018 AEMP

Component	Variable	Action Level	How the Action Level Exceedance was Determined	Detailed Results of Action Level Evaluation	Relation to Significance Threshold	Action Required[a]
Water Quality	Total dissolved solids, calculated	2	See Appendix II, Section 2.3.6.1	See Appendix II, Section 3.4	Below Significance Threshold	None
	Turbidity – lab	1				None
	Calcium (dissolved)	2				DDMI to develop Effects Benchmark
	Chloride	2				None
	Magnesium (dissolved)	1				None
	Potassium (dissolved)	1				None
	Sodium (dissolved)	2				None
	Sulphate	2				None
	Ammonia	(b)				None
	Nitrate	2				None
	Aluminum	1				None
	Antimony	2				None
	Barium	1				None
	Chromium	1				None
	Copper	1				None
	Iron	(b)				None
	Lead	(b)				None
	Manganese	1				None
	Molybdenum	2				None
	Silicon	1				None
	Strontium	2				None
	Titanium	(b)				None
	Uranium	2				None
Eutrophication Indicators	Chlorophyl *a*	1	See Appendix XIII, Section 2.3.10	See Appendix XIII, Section 3.9		None

(a) Management action required under the AEMP Response Framework

(b) Variable added to the list of substances of interest because it triggered an effect equivalent to Action Level 1 at one or more mid-field stations located within the estimated zone of influence from dust deposition (see Section 3.6), but not in the near-field area

Table 2: 2018 AEMP Annual Report Conformance Table

Location of Direction	Statement of Direction, Comment, or DDMI Commitment	Component or Location in Report	Location in Report #1713 and associated Technical Appendices (#1732 #1733 and #1734)
W2015L2-0001 Part J, Item 8 (OBJECTIVES)	This Report shall satisfy the requirements of Schedule 8, Item 4, and include information relating to data collected in the preceding calendar year	All	-
W2015L2-0001 Schedule 8, Item 4 (REQUIREMENTS)	a) a summary of activities conducted under the Aquatic Effects Monitoring Program;	All	Main Report, Section 2.2, 3.2, 4.2, 6.2, and 10.2 Appendix I, Section 2 Appendix II, Section 2 Appendix XI, Section 2 Appendix XIII, Section 2
	b) tabular summaries of all data and information generated under the AEMP in an electronic and printed format acceptable to the Board	All	Appendix I, Appendices B to D Appendix II, Appendix D* Appendix XI, Appendix B* and C* Appendix XIII, Appendix E* (*also provided as electronic files)
	c) An interpretation of the results, including an evaluation of any identified environmental changes that occurred as a result of the Project	All	Main Report, Section 13.1 Appendix I, Section 3 and 4 Appendix II, Sections 3.0 and 4.0 Appendix XI, Sections 3.0 and 4.0 Appendix XIII, Sections 3.0 and 4.0
	d) an evaluation of any adaptive management response actions implemented during the year	All	Main Report, Section 12 Appendix II, Section 5.0 Appendix XI, Section 5.0 Appendix XIII, Section 5.0
	e) recommendations for refining the Aquatic Effects Monitoring Program to improve its effectiveness as required; and,	All	Main Report, Section 13.2
	f) an evaluation of the overall effectiveness of the Aquatic Effects Monitoring Program to date; and, any other information specified in the approved Aquatic Effects Monitoring Program or that may be requested by the Board.	All	Main Report, Section 13.3
2014 AEMP Annual Report Reasons for Decision	3. DDMI is to include the required subsection (on nutrient loading from dust) starting with the 2016 AEMP Annual Report.	WQ, Eutro	Appendix II, Section 3.7 Appendix XIII, Section 3.2 and Appendix D
	2A. Consider role of N in the Eutrophication Indicators section	Eutro	Appendix XIII, Section 3.4
2014 AEMP Annual Report DDMI Commitment	3.8 Concentrations listed under "major ions" will be clearly indicated as dissolved in future reports	WQ	Appendix II (Figures 3-3, 3-5, 3-6, 3-7, 3-26, 3-27, 3-34, 3-36, 3-37, 3-38 and 3-54; Tables 2-2, 2-5, 2-7 and 3-1)

Table 2: 2018 AEMP Annual Report Conformance Table

Location of Direction	Statement of Direction, Comment, or DDMI Commitment	Component or Location in Report	Location in Report #1713 and associated Technical Appendices (#1732 #1733 and #1734)
2015 AEMP Annual Report Reasons for Decision	2A. Include the vertical profile data and Secchi depth data collected at all AEMP stations in the data appendices;	WQ, Eutro	Vertical profile: Appendix II, Section 3.3, Appendix D Secchi depth: Appendix XIII, Section 3.5, Appendix E
	2B. Include all relevant information, such as changes in detection limits, necessary to interpret monitoring results;	WQ	Appendix II, Section 2.2 (Table 2-2 and associated footnotes), Appendix B
	2C. Clarify the meaning of 'slight increase in trophic status';	Eutro, Plankton	This statement does not appear in the 2018 AEMP Annual Report.
	2D. Include a footnote to Figures 3.1-1 to 3.3-1 explaining the absence of any medians from the 0 to 100m zone; and	Dust (ERM)	Appendix I, Section 3.3
	2E. Include an explanation of the lower and upper range of the BC dustfall objective for the mining industry.	Main Report, Dust (ERM)	Main Report Section 2.2.1, 13.1 Appendix I, Section 2.2
2015 AEMP Annual Report DDMI Commitments	The GNWT-ENR recommended that DDMI provide the raw toxicity test data as part of the AEMP reports (GNWT-ENR comment 9). In its response, DDMI stated that they would consider including these results as an appendix to the annual AEMP reports.	WQ	Appendix II, Section 3.2.6, Appendix E
	Board staff recommended that DDMI consider including definitions of "T", "M", and "B" in footnote for Figure 4-3 (Board staff comment 1). In its response, DDMI stated that this will be added in future reports.	WQ, Eutro	Appendix II, Section 3.5 Appendix XIII, Section 3.6
	With regards to the 2017 AEMP Annual Report, the Board has decided that DDMI is to include the results of its investigation and proposed recommendations regarding ammonia contamination issues;	WQ	Appendix II Section 2.4.1, Appendix B
	EMAB comment 37 recommended that depth profile figures for each NF station be provided. As part of the 2015 AEMP Annual Report, the Board has directed to DDMI to include vertical profile data collected at all stations as part of data appendices in future AEMP Annual Reports. This inclusion will begin with the 2017 AEMP Annual Report.	WQ (duplication)	Appendix II, Section 3.3, Appendix D
	The results of the investigation and proposed recommendations regarding ammonia contamination issues will be included.	WQ (duplication)	Appendix II Section 2.4.1, Appendix B
2016 AEMP Annual Report Reasons for Decision	2. With regards to the 2017 AEMP Annual Report, the Board has decided that DDMI is to include the results of its investigation and proposed recommendations regarding ammonia contamination issues;	WQ (duplication)	Appendix II Section 2.4.1, Appendix B
	3.12, 1, b EMAB comment 37 recommended that depth profile figures for each NF station be provided. As part of the 2015 AEMP Annual Report, the Board has directed to DDMI to include vertical profile data collected at all stations as part of data appendices in future AEMP Annual Reports. This inclusion will begin with the 2017 AEMP Annual Report	WQ (duplication)	Appendix II, Section 3.3, Appendix D

Table 2: 2018 AEMP Annual Report Conformance Table

Location of Direction	Statement of Direction, Comment, or DDMI Commitment	Component or Location in Report	Location in Report #1713 and associated Technical Appendices (#1732 #1733 and #1734)
2016 AEMP Annual Report DDMI Commitments	1. For future AEMP Annual Reports: a. DDMI stated that it will include maps that illustrate the A21 dike (EMAB comments 5 and 32).	Main report	Main Report Figure 1-1, 1-2
	b. DDMI stated that it will include labelling of project infrastructure on figures showing the DDMI mine site (EMAB comment 8).	Main report	Main Report Figure 1-2
	c. Because Secchi depth data will be included in future AEMP Annual Reports following a previous Board directive, DDMI has stated that it will use this information, as appropriate, in the interpretation of results for phytoplankton biomass, taxonomy, and chlorophyll a (EMAB comments 13 and 45).	Eutro	Appendix XIII, Section 3.5 and 3.8.1
	d. DDMI will consider including seasonal dust deposition data (EMAB comment 21).	Eutro	Appendix XIII, Section 3.2
	e. DDMI will remove reference to an 80% threshold in the RPD calculations for snow water chemistry (EMAB comment 25).	Dust (ERM)	This reference does not appear in the 2018 AEMP Annual Report.
	i. DDMI has stated that it will consider using a non-parametric alternative to the one-sample t-test in cases where non-detect values occur in the NF area in future AEMP Annual Reports (GNWT-ENR comment 14)	All	Appendix II, Section 2.3.3
	j. DDMI has noted that it will use a screening value of greater than 15% censoring to flag data sets that may require alternative analysis methods in future AEMP Annual Reports (Board staff comment 13).	All	Appendix II, Section 2.3.3 Appendix XIII, Section 2.3.2 (a)
	3 A. Include data for SS3-6 (i.e., the 0-100m) zone on Figures 3.3-1 to 3.3-4. If anomalies in trends through time are visible because of the sampling location error in 2015 and 2016, this can be explained in the supporting text or in footnotes; and	Dust (ERM)	Appendix I, Section 3.1
	B. Provide all raw data for all variables monitored as part of the AEMP in excel spreadsheet format;	All (duplication)	Appendix I, Appendices B to D Appendix II, Appendix D Appendix XI, Appendix B and C Appendix XIII, Appendix E
2017 AEMP Annual Report and DDMI Commitments	DDMI agreed to add results for LDS-4 to Figures in future AEMP reports (EMAB comments 17 and 18)	Eutro	Main Report, Figure 1-1, Sections 4.3.4 and 4.3.5 Appendix XIII, Sections 3.4, 3.6, 3.7, 3.8.2, and 3.8.3
	DDMI committed to evaluating TDN concentrations at LDG-48 in 2018 to determine if the 2017 value is typical (WLWB comment 22).	Eutro	Appendix XIII, Section 3.6
	DDMI will consider including the raw toxicity results as an appendix to the annual AEMP reports (GNWT comment 5)	WQ/Tox (duplication)	Appendix II, Section 3.2.6, Appendix E
	DDMI stated that it will add dissolved oxygen and pH benchmark values to the depth profile plots in future AEMP annual reports and will examine and evaluate evidence related to any potential mine-effects (EMAB comment 6)		Appendix II, Section 3.3, Appendix D
	DDMI will consider adding QAQC standards for dustfall (WLWB comment 8)	Dust (ERM)	Appendix I, Section 3.4, Appendix G
	Future AEMP Design Plans will include a footnote explaining that plankton are not collected at LDG-48, but that nutrient and chlorophyll a are collected at LDG-48 and are included in the Eutrophication Indicators assessment. (WLWB comment 17)	Eutro	Appendix XIII, Section 2.1.2

Table 2: 2018 AEMP Annual Report Conformance Table

Location of Direction	Statement of Direction, Comment, or DDMI Commitment	Component or Location in Report	Location in Report #1713 and associated Technical Appendices (#1732 #1733 and #1734)
2017 AEMP Annual Report Reasons for Decision	DDMI to include the results of its investigation and proposed recommendations regarding ammonia contamination issues with the 2018 AEMP Annual Report.	WQ (duplication)	Appendix II Section 2.4.1, Appendix B
	DDMI to present spatial extent of the effects of eutrophication indicators for both the ice-covered and open-water seasons in future AEMP Annual Reports.	Eutro	Not included in 2018 AEMP Annual Report due to insufficient time between receipt of Directive (25 March 2019) and due date for the 2018 AEMP Annual Report (31 March 2019). DDMI commits to complete this in future AEMP Annual Reports.
	DDMI to provide a tabular summary of results for eutrophication indicators with percent change from baseline and the previous year in future AEMP Annual Reports.	Eutro	Not included in 2018 AEMP Annual Report due to insufficient time between receipt of Directive (25 March 2019) and due date for the 2018 AEMP Annual Report (31 March 2019). DDMI commits to complete this in future AEMP Annual Reports.

Notes:
(a) The 15% censoring was used to flag data sets in 2018 as per DDMIs response to WLWB 13, and the alternate method to Kruskal-Wallis is stated in the noted sections as percentile based as per GNWT-ENR 15.

DIAVIK DIAMOND MINES (2012) INC.

AQUATIC EFFECTS MONITORING PROGRAM
2018 ANNUAL REPORT

Submitted to:

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DISTRIBUTION

1 Copy – Diavik Diamond Mines (2012) Inc., Yellowknife, NT
1 Copy – Golder Associates Ltd., Calgary, AB
1 Copy – Wek'èezhìı Land and Water Board

March 2019
1893542

Doc No. RPT-1713 Ver. 0
PO No. D04160

Executive Summary

Diavik Diamond Mines (2012) Inc. (DDMI) conducts environmental monitoring programs under the terms and conditions of Water Licence W2015L2-0001 issued for the Diavik Diamond Mine (Mine). The Aquatic Effects Monitoring Program (AEMP) is the main monitoring program described in the Water Licence for monitoring the aquatic environment of Lac de Gras.

The AEMP is a monitoring program "designed to determine the short and long-term effects in the aquatic environment resulting from the Project, to evaluate the accuracy of impact predictions, to assess the effectiveness of impact mitigation measures, and to identify additional impact mitigation measures to reduce or eliminate environmental effects of the licensed undertaking" (WLWB 2015). The goal of the AEMP is to protect the valued ecosystem components of Lac de Gras, which consist of water chemistry, sediment chemistry, lake productivity, plankton 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, and a lake-based monitoring program, as represented by the AEMP. The lake monitoring program includes the following components:

- water chemistry monitoring in Lac de Gras
- aquatic biota monitoring in Lac de Gras (including fish surveys, plankton and benthic invertebrate community studies, and supporting sediment and water chemistry data collection)
- monitoring of water chemistry at the inflow and outflow to Lac de Gras
- dust deposition monitoring on east island, the mainland and on ice in Lac de Gras during winter
- special effects studies, as required

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

- the near-field (NF) area, located near the effluent diffusers
- three mid-field (MF) areas, MF1, MF2-FF2, and MF3, generally surrounding the east island, and extending away from the NF area
- three far-field (FF) areas, FF1, FFA, and FFB, located further from the Mine

All AEMP sampling areas are exposed to Mine effluent to varying degrees, with greatest exposure in the NF area, lowest exposure in the FF1, FFA and FFB areas, and intermediate levels of exposure in the MF1, MF2-FF2 and MF3 areas. The 2018 AEMP was carried out according to the requirements specified in the *AEMP Design Plan Version 4.1* (Golder 2017a) for an interim monitoring year, which requires sampling in the NF and MF areas of the lake (Golder 2017a). All FF areas in Lac de Gras are sampled every third year during the comprehensive monitoring program, to allow a detailed assessment of Mine-related effects. The next comprehensive monitoring program is scheduled for 2019.

The focus of the assessment for an interim year Annual Report is on the analyses of effects on water quality, nutrients, and plankton, to determine whether actions are required to manage effects. This is done by evaluating the presence and magnitude of each effect (e.g., is the concentration of a water quality variable greater than the background range and is it reaching a guideline?) and spatial extent of effects (e.g., how much of the lake is affected?). Dust deposition is also monitored during interim years. The importance of effects is evaluated by comparisons to Action Levels, which are part of a Response Framework. The goal of the Response Framework is to ensure that significant adverse effects never occur in Lac de Gras. A detailed spatial analysis and an assessment of trends over time will be provided in the next Aquatic Effects Re-evaluation Report, which will be submitted in 2020 (Golder 2017a), or as directed by the Wek'èezhìı Land and Water Board.

To better communicate AEMP results to the range of interested technical and non-technical parties, information has been provided in two ways. First, the main body of the Annual Report provides a non-technical summary of the most important results from the 2018 studies. Second, technical appendices provide a full description of the analyses conducted and results obtained. These appendices are intended for parties with more technical interests.

Key findings from the 2018 AEMP include the following:

- Dust deposition rates in 2018 were higher than in 2017. Deposition rates were highest close to the Mine and decreased with distance from the Mine. Concentrations of snow chemistry variables were below the effluent concentration limits in the Water Licence for all samples.
- Nineteen water quality variables triggered Action Level 1 (out of a total of 9 Action Levels for water quality) in the Response Framework for water quality, which is considered an early-warning indicator of effects in Lac de Gras. These variables included turbidity, calculated total dissolved solids, calcium, chloride, magnesium, potassium, sodium, sulphate, nitrate, aluminum, antimony, barium, chromium, copper, manganese, molybdenum, silicon, strontium, and uranium. Four additional variables (i.e., ammonia, iron, lead and titanium) were added to the list of substances of interest in 2018, because concentrations at stations potentially affected by dust in the MF area were greater than reference conditions for Lac de Gras. Of the 19 substances of interest that triggered Action Level 1, 10 also triggered Action Level 2. These variables included calculated total dissolved solids, calcium, chloride, sodium, sulphate, nitrate, antimony, molybdenum, strontium, and uranium. Since an AEMP Effects Benchmark has not been developed for calcium, DDMI will submit an AEMP Response Plan for this task. Regulated effluent parameters were below applicable effluent quality criteria.
- Elevated concentrations of nutrients extending to various distances from the Mine (depending on variable and season), along with concentrations of chlorophyll *a* that exceeded the upper limits of the normal range in the NF and MF areas, suggest the Mine is having a nutrient enrichment effect in Lac de Gras. In 2018, total phosphorus concentration was elevated above the normal range in 0.5% of the area of Lac de Gras. The extent of effects on total nitrogen was greater than or equal to 40.8% of the lake area, and on phytoplankton and zooplankton biomass (as ash-free-dry-mass) the extent of effects was 16.8% and greater than or equal to 12.8%, respectively, of Lac de Gras. The extent of effects on chlorophyll *a* was estimated as greater than or equal to 12.8% of the lake area. The magnitude of the effect in chlorophyll *a* triggered Action Level 1.
- The 2018 plankton data do not suggest that a toxicological effect is occurring in Lac de Gras. Action Levels for toxicological impairment were not triggered and results are consistent with nutrient enrichment, as demonstrated by increased total phytoplankton and zooplankton biomass in the NF area.

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Acronyms and Abbreviations

AEMP	Aquatic Effects Monitoring Program
AFDM	ash-free dry mass
ALS	ALS Laboratories
BC	British Columbia
DDMI	Diavik Diamond Mines (2012) Inc.
DL	detection limit
DO	dissolved oxygen
EQC	effluent quality criteria
ERM	ERM Consultants Canada Ltd.
FF	far-field
Golder	Golder Associates Ltd.
Khione	Khione Resources Limited
LDG	Lac de Gras
LDS	Lac du Sauvage
Maxxam	Maxxam Analytics Inc.
MF	mid-field
NF	near-field
NIWTP	North Inlet Water Treatment Plant
SNP	Surveillance Network Program
SOI	substance of interest
SRP	soluble reactive phosphorus
Mine	Diavik Diamond Mine
NT	Northwest Territories
TDN	total dissolved nitrogen
TDP	total dissolved phosphorus
TDS	total dissolved solids
TN	total nitrogen
TP	total phosphorus
WLWB	Wek'èezhìı Land and Water Board
ZOI	zone of influence

Symbols and Units of Measure

+	plus
%	percent
µg/L	micrograms per litre
µg-N/L	micrograms nitrogen per litre
µg-P/L	micrograms phosphorus per litre
cm	centimetre
km	kilometre
m	metre
mg/L	milligrams per litre
kg	kilogram
kg/yr	kilograms per year
$mg/dm^2/d$	milligrams per square decimetre per day
$mg/dm^2/y$	milligrams per square decimetre per year

1 INTRODUCTION

1.1 Background Information

Diavik Diamond Mines (2012) Inc. (DDMI) conducts environmental monitoring programs under the terms and conditions of Water Licence W2015L2-0001 (hereafter, referred to as the Water Licence) issued for the Diavik Diamond Mine (Mine). The Mine is an open-pit diamond mining operation which discharges effluent to Lac de Gras following treatment at an on-site water treatment plant, the North Inlet Water Treatment Plan (NIWTP) (Figure 1-1). The Aquatic Effects Monitoring Program (AEMP) is the primary program described in the Water Licence for monitoring the aquatic environment of Lac de Gras.

The Water Licence for the Mine requires that DDMI review and update the AEMP design plan every three years, or as directed by the Wek'èezhìı Land and Water Board (WLWB). The current AEMP design is described in the document titled *Diavik Diamond Mines Inc. (2012) – Aquatic Effects Monitoring Program – Design Plan Version 4.1*, (also called the *AEMP Design Plan Version 4.1* [Golder 2017a]). The *AEMP Design Plan Version 4.1* describes the updated AEMP design, and provides a summary of how water, sediment, and biological monitoring studies are to be conducted under the AEMP. The reader is encouraged to review the document for specifics regarding the current AEMP design.

A summary report of all AEMP data collected since before mining began, up to and including 2016, was described in the *2014 to 2016 Aquatic Effects Re-evaluation Report* (Golder 2018a). The report evaluated trends over time in AEMP components, and as such, the *2014 to 2016 Aquatic Effects Re-evaluation Report* (Golder 2018a) is an important reference when considering ongoing monitoring results.

As summarized in the *AEMP Design Plan Version 4.1* (Golder 2017a), Mine effluent discharge (i.e., effluent) represents the main concern for Lac de Gras. The effluent, combined with other Mine-related stressors (e.g., dust) and their 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 on the lake, specifically, the results of Traditional Knowledge studies.

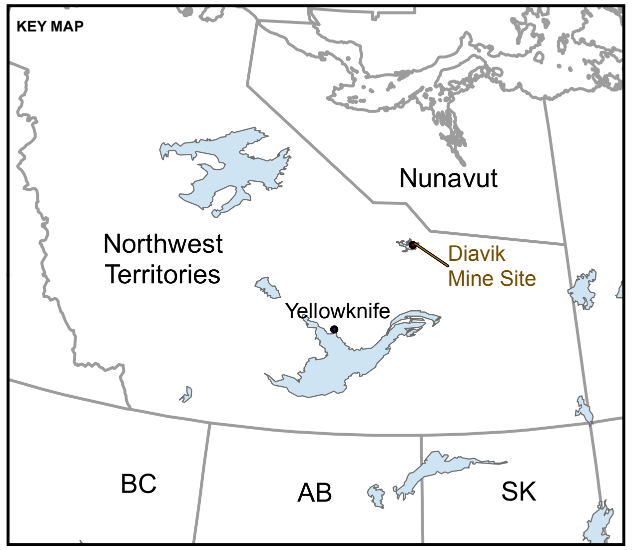
Sampling for the AEMP is required once during late ice-cover conditions (i.e., April and/or May) and once during open-water conditions (i.e., between 15 August and 15 September). The magnitude of effects are evaluated by comparing water chemistry and biological results for the near-field (NF) and mid-field (MF) areas to "reference conditions". Reference conditions for Lac de Gras are those that fall within the range of natural variability, referred to as the "normal range". The normal ranges used to assess effects of the Mine on individual components of the AEMP are described in the *AEMP Reference Conditions Report Version 1.3* (Golder 2018b). Values that exceed the normal range are considered different from what would be considered natural levels for Lac de Gras, but do not necessarily represent levels that are harmful. To evaluate whether water quality variables are reaching potentially harmful concentrations, results are compared to AEMP Effects Benchmarks (as defined in the *AEMP Design Plan Version 4.1* [Golder 2017a]). Similar to water quality guidelines, AEMP Effects Benchmarks are intended to protect fish and other aquatic life in Lac de Gras. Comparison of water quality results to Effects Benchmarks provides an indication of how close the concentrations of water quality variables (e.g., metals[1]) are to concentrations that could be harmful to aquatic life in the lake.

[1] The term metal is used throughout this report and includes non-metals (e.g., selenium) and metalloids (e.g. arsenic).

LEGEND

Display

INFRASTRUCTURE



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REFERENCE(S)

1. 2018 WORLDVIEW IMAGE OBTAINED FROM CLIENT

PROJECTION: UTM ZONE 12 DATUM: NAD 83

CLIENT

RioTinto

PROJECT

DIAVIK DIAMOND MINES INC.

TITLE

SITE PLAN

CONSULTANT

GOLDER

YYYY-MM-DD	2019-03-04
DESIGNED	LJ
PREPARED	ANK
REVIEWED	RLS
APPROVED	ZK

PROJECT NO.	PHASE	REV.	FIGURE
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1.2 Purpose and Objectives

As defined in the Water Licence, the AEMP is a monitoring program designed to “determine the short and long-term effects in the aquatic environment resulting from the Project, to evaluate the accuracy of impact predictions, to assess the effectiveness of impact mitigation measures, and to identify additional impact mitigation measures to reduce or eliminate environmental effects of the licensed undertaking” (WLWB 2015). The AEMP is focused on the valued ecosystem components of Lac de Gras, which have been evaluated in previous site investigations, including the Environmental Assessment, and consist of fish, fish habitat, water quality, sediment quality, lake productivity, plankton and benthic invertebrate communities, and the use of fisheries resources in Lac de Gras (DDMI 1998).

In 2015, DDMI’s Water Licence was renewed for a period of eight years, effective 19 October 2015. The 2018 AEMP Annual Report was conducted under the 2015 Water Licence W2015L2-0001 (WLWB 2015). The 2018 AEMP Annual Report addresses the requirements specified in Part J Item 8 of the Water Licence (Table 1-1).

Table 1-1 Aquatic Effects Monitoring Program Annual Reporting Requirements Specified in Part J, Item 8 of the Water Licence

Item	Location in Report
a) a summary of activities conducted under the AEMP;	Main Report, Section 2.2, 3.2, 4.2, 6.2, and 10.2 Appendix I, Section 2 Appendix II, Section 2 Appendix XI, Section 2 Appendix XIII, Section 2
b) tabular summaries of all data and information generated under the AEMP in an electronic and printable format acceptable to the Board;	Appendix I, Appendices B to D Appendix II, Appendix D* Appendix XI, Appendix B* and C* Appendix XIII, Appendix E* (*also provided in attached electronic files)
c) an interpretation of the results, including an evaluation of any identified environmental changes that occurred as a result of the Project;	Main Report, Section 13.1 Appendix I, Section 3 and 4 Appendix II, Sections 3.0 and 4.0 Appendix XI, Sections 3.0 and 4.0 Appendix XIII, Sections 3.0 and 4.0
d) an evaluation of any adaptive management response actions implemented during the year;	Main Report, Section 12 Appendix II, Section 5.0 Appendix XI, Section 5.0 Appendix XIII, Section 5.0
e) recommendations for refining the AEMP to improve its effectiveness as required; and	Section 13.2
f) an evaluation of the overall effectiveness of the AEMP to date; and, any other information specified in the approved AEMP or that may be requested by the Board.	Section 13.3

An objective of the AEMP is to monitor the Mine effluent discharge and assess potential ecological risks, so that appropriate actions can be taken in the Mine operations to prevent adverse effects from occurring in the environment. The AEMP is subject to adaptive management, meaning the AEMP will be updated as necessary, as new information and findings become available. The AEMP compares effluent quality to effluent quality criteria (EQC), as defined in the Water Licence, and evaluates compliance monitoring and the effectiveness of operational management (e.g., mitigation) measures.

The AEMP consists 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 surveys
- a dust deposition monitoring program
- special effects studies as required as part of the Water Licence and the Fisheries Authorization for the Mine

Three general areas of Lac de Gras are monitored under the AEMP:

- the NF exposure area, located near the effluent diffusers (Figure 1-2)
- the MF exposure areas (i.e., MF1, MF2-FF2, and MF3), generally surrounding the east island and extending away from the NF area (Figure 1-2)
- the far-field (FF) exposure areas (i.e., FF1, FFA, and FFB), located further from the Mine[2]

The FF1, FFA and FFB areas were formerly reference areas, and data from these areas were used to develop normal ranges. In addition to sampling the above areas of Lac de Gras, water chemistry is also sampled at the Lac du Sauvage outflow to Lac de Gras (Station LDS-4, located at the Narrows; Stations LDS-1, LDS-2 and LDS-3 located near the outflow to Lac de Gras) and at the Lac de Gras outflow to the Coppermine River (LDG-48).

Sampling for the AEMP in 2018 was carried out according to the requirements specified in the *AEMP Design Plan Version 4.1* (Golder 2017a) for an interim monitoring year. Dust deposition monitoring, and sampling of water quality, plankton and eutrophication indicators in the NF and MF areas of Lac de Gras are included in interim years, as well as water quality sampling at the Narrows (i.e., LDS-4) and the mouth of the Coppermine River (Golder 2017a). The three FF areas (i.e., FF1, FFA, FFB) in Lac de Gras and the additional stations located in Lac du Sauvage at the outflow of Lac de Gras (i.e., LDS-1, LDS-2 and LDS-3) are sampled every third year during the comprehensive monitoring program to allow detailed spatial assessment of Mine-related effects. The comprehensive program also includes sediment sampling, more detailed biological sampling (i.e., benthic invertebrates and fish sampling) and an overall weight-of-evidence analysis. The next comprehensive monitoring program is scheduled for 2019.

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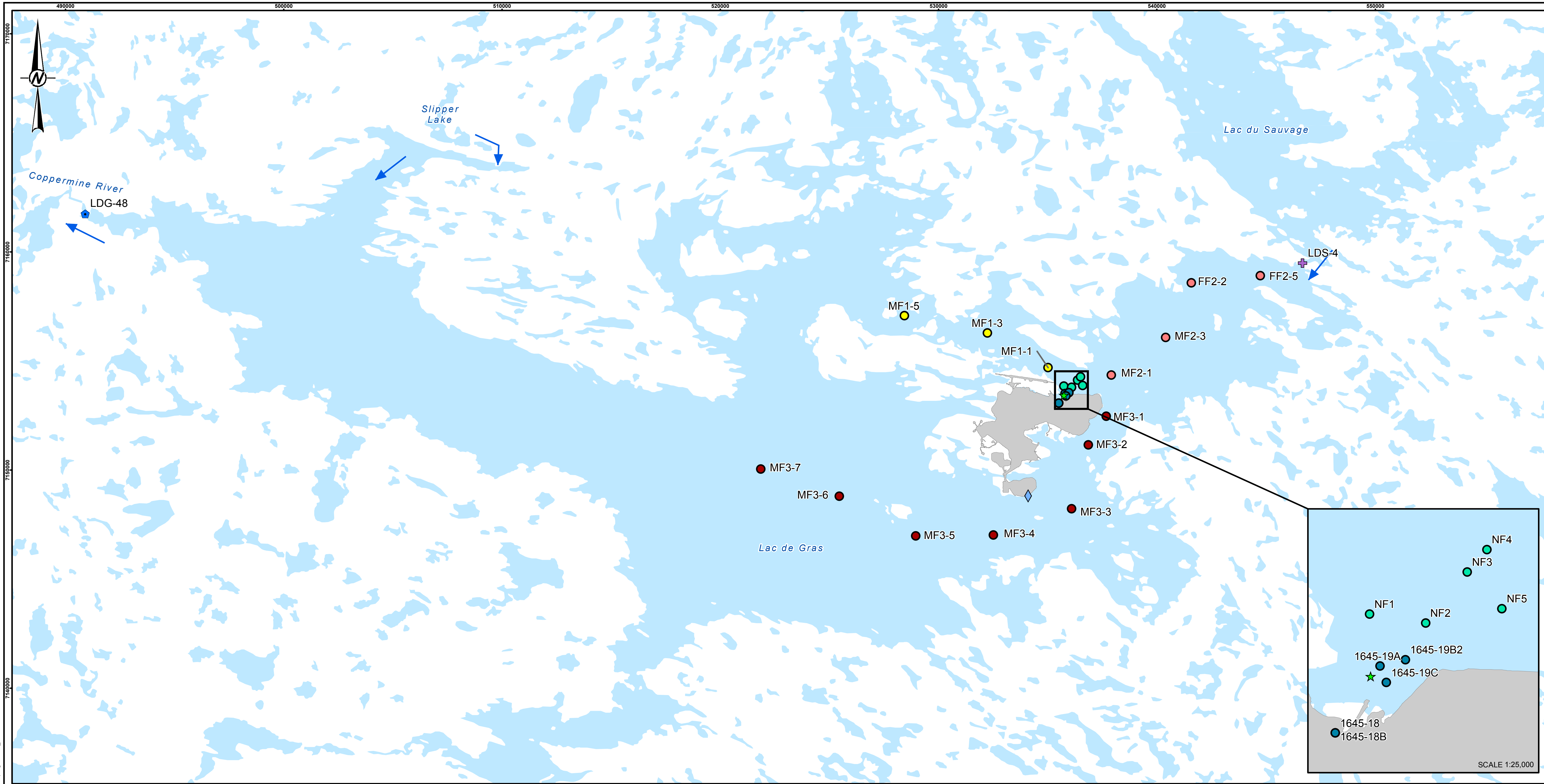
[2] Far-field sampling areas are only sampled in comprehensive years and 2018 was not a comprehensive year. The far-field sampling areas are shown on Figure 1-2 in the *Aquatic Effects Monitoring Program 2016 Annual Report* (Golder 2017b).

The objective of this Annual Report is to present the results of the 2018 interim monitoring program conducted as part of the AEMP. Similar Annual reports containing results from 2007 through to the 2017 AEMP were reported by DDMI (2008, 2009, 2010, 2011, 2012, 2013) and Golder (2014, 2016a,b, 2017b, 2018c). Every third year, AEMP results from the previous three years are integrated in an Aquatic Effects Re-evaluation Report, which includes detailed spatial analysis of effects, analyses of trends over time, and a comparison of results to predicted impacts (Government of Canada 1999). The last re-evaluation report was submitted in March 2018, covering the period of 2014 to 2016 (Golder 2018a). The next re-evaluation report will be submitted December 31, 2020.



LEGEND

- A21 DEWATERING DIFFUSER
- DIFFUSER
- LAC DU SAUVAGE
- LDG-48

EXPOSURE

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

- FLOW DIRECTION
- DIAVIK FOOTPRINT
- WATERBODY

0 5 10
1:175,000 KILOMETRES

REFERENCE(S)
HYDROGRAPHY DATA OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 12 DATUM: NAD 83

CLIENT
RioTinto

PROJECT
DIAVIK DIAMOND MINES INC.

CONSULTANT
GOLDER

YYYY-MM-DD	2019-03-07
DESIGNED	LJ
PREPARED	ANK
REVIEWED	RLS
APPROVED	ZK

TITLE
SAMPLING STATIONS, 2018 AEMP

PROJECT NO.	PHASE	REV.	FIGURE
1893542	5000	0	1-1

1.3 AEMP Annual Report Content and Organization

The organization of this report follows the outline provided in Section 7.3 of the *AEMP Design Plan Version 4.1* (Golder 2017a). To better communicate the results of the AEMP to the range of technical and non-technical parties who are interested, we have provided information in two ways. First, this main body of the report provides a summary of the most important results from the 2018 studies, presented in a non-technical way. Second, the appendices provide a full technical description of the analyses conducted and results obtained. These appendices are intended for parties with more technical interests. The technical appendices prepared for the 2018 Annual Report include:

- Appendix I – Dust Deposition Report
- Appendix II – Effluent and Water Chemistry Report
- Appendix XI – Plankton Report
- Appendix XIII – Eutrophication Indicators Report
- Appendix XIV – Traditional Knowledge

Appendix I was prepared by ERM Consultants Canada Ltd. Appendices II, XI and XIII were prepared by Golder Associates Ltd. (Golder), and Appendix XIV was prepared by Thorpe Consulting Services.

The order in which the appendices appear in the Annual Report and the appendix number for a given component are the same from year to year, even though there may not be a technical report for a given component each year. This was done to meet reporting commitments stated in the *AEMP Design Plan Version 4.1* (Golder 2017a) and as a means of tracking available information. The technical report "placeholder" appendices (i.e. those which do not contain a technical report) for 2018 include:

- Appendix III – Sediment Report
- Appendix IV – Benthic Invertebrate Report
- Appendix V – Fish Report[3]
- 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[4], Fish Health, and Fish Tissue Chemistry Survey
- Appendix XII – Special Effects Study Reports
- Appendix XV – Weight-of-Evidence Report

There are no technical reports for these components in 2018, therefore, a note has been inserted in the appropriate appendix placeholder stating that the component was not monitored in 2018.

[3] The Appendix V Fish Report relates to mercury sampling in large-bodied fish (i.e., Lake Trout [*Salvelinus namaycush*]).

[4] The Fish Palatability portion of Appendix X is included in 2018 and presented herein. The small-bodied Fish Health and Fish Tissue Chemistry Survey was not completed in 2018.

2 DUST DEPOSITION

2.1 Introduction and Objectives

Many of the activities at the Mine 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 settles on the ground or the water surface. In accordance with the Environmental Assessment and requirements associated with the AEMP, a dust monitoring program was initiated in 2001.The objective of the dust monitoring program is to measure the amount of dustfall at various distances from the Mine footprint and to describe the chemical characteristics of the dustfall deposited into Lac de Gras and the surrounding area.

The detailed technical report on the findings from the 2018 dust deposition monitoring program is provided in Appendix I. An overview of the dust deposition monitoring program and a summary of the 2018 results are provided herein.

2.2 Methods

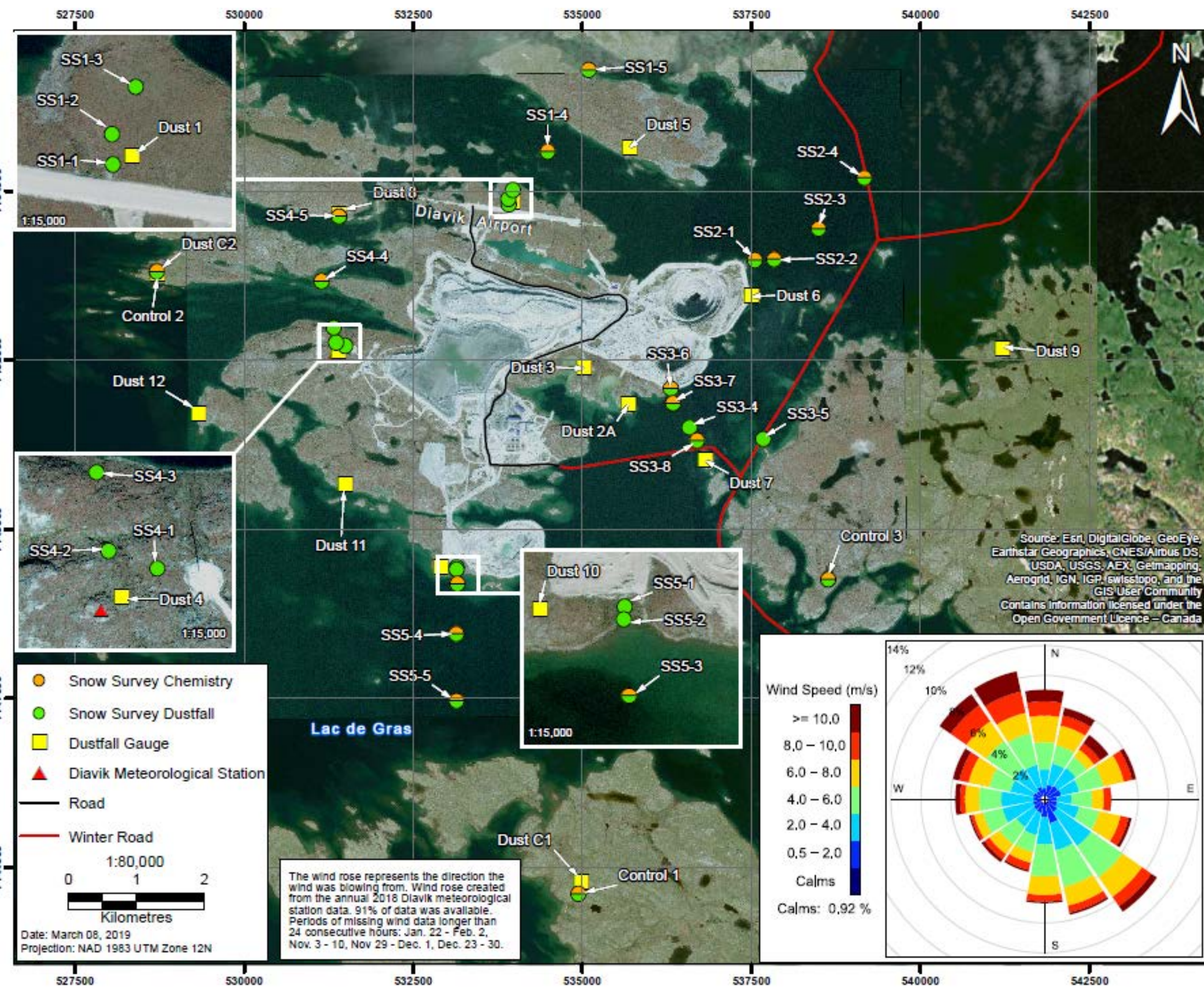
The 2018 dustfall monitoring program used three sampling methods: dustfall gauges, snow surveys, and snow water chemistry. Sampling was completed at varying distances around the Mine along five transects, including three control locations.

2.2.1 Dustfall Gauges

Passive sampling of airborne particles was done with dustfall collection gauges. A dustfall gauge is a hollow brass cylinder, 52 cm in length and 12.5 cm in diameter, surrounded by a fibreglass shield with the shape of an inverted bell (e.g., Nipher snow gauge, Photo 2-1). The dust gauges used in 2018 were located around the Mine site and at reference stations (referred to as “control” stations) located away from the Mine site, as presented in Figure 2-1.

Photo 2-1 Dustfall gauge

Figure 2-1 Dustfall Gauge and Snow Survey Locations, 2018



In 2018, dust was collected from 14 gauges, including two control stations. All fourteen stations collected dustfall year-round, with samples collected every three months from 24 December 2017 to 4 January 2019, for an average total sampling period of 360 days. The dry weight of the material collected in the gauges was recorded, and the mean daily dustfall rate over the collection period was estimated.

Estimated dustfall rates were compared to the former British Columbia Ministry of Environment (BC MOE) dustfall objectives for the mining, smelting, and related industries (BC MOE 2016). The dustfall objective ranges from 1.7 to 2.9 milligrams per square decimetre per day (mg/dm^2/d), or 621 to 1,059 milligrams per square decimetre per year (mg/dm^2/y). While this dustfall objective is no longer used in British Columbia, it was used for the purposes of this report to be consistent with prior dust deposition reports, and is consistent with reporting for other mines in the region. There are no dustfall standards or objectives for the Northwest Territories.

2.2.2 Snow Core Surveys

In the snow core surveys, a cylindrical section of snow was collected by drilling into the snowpack with a hollow tube (Photo 2-2). The collected snow was then brought back to the laboratory, thawed, filtered, and the residue was dried, and weighed. Mean daily dustfall was calculated over the collection period, and dustfall rates were compared to the British Columbia dustfall objectives (BC MOE 2016).

Snow core samples were collected along five transects at 27 stations, including three control stations along five transects around the Mine (Figure 2-1). The average total sampling season in 2018 was 168 days. The start dates correspond to the first snowfall for land stations on 2 October 2017, and shortly after freeze-up for ice stations on 2 November 2017.

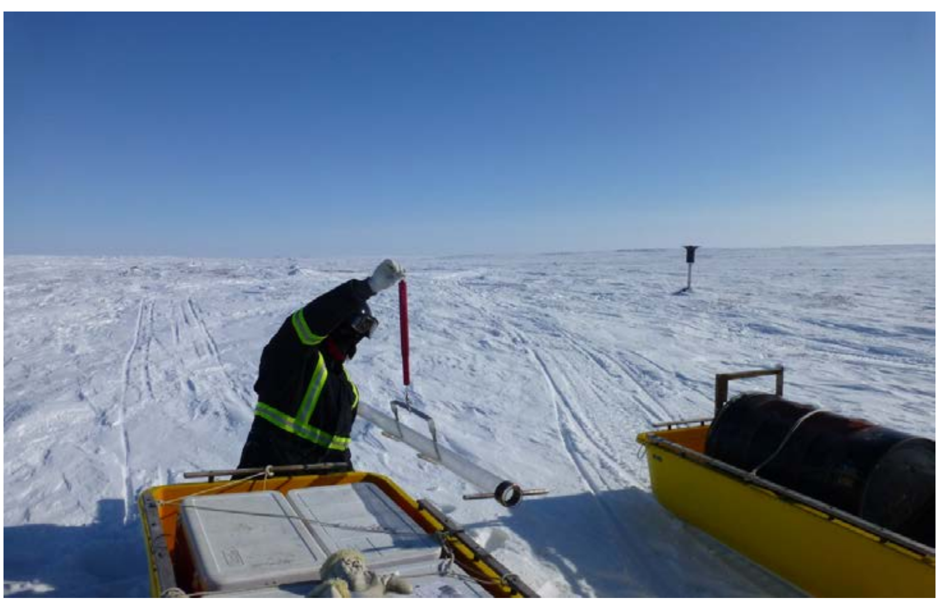


Photo 2-2 Snow core sampling

2.2.3 Snow Water Chemistry

Samples for snow water chemistry analysis were collected using a snow corer at 17 locations, including three control stations (Figure 2-1). On average, for the 17 sampling locations, the total sampling season was 164 days in 2018. Snow cores were processed and shipped to Maxxam Analytics for water chemistry analyses. Snow water chemistry results were compared to the EQCs outlined in DDMI's Water Licence. Snow chemistry variables of interest included variables with EQCs (i.e., aluminum, ammonia, arsenic, cadmium, chromium, copper, lead, nickel, nitrite, and zinc).

2.3 Results and Discussion

2.3.1 Dustfall Gauges

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. The greatest estimated dustfall rate measured using gauges occurred at Dust 3, 25 m from the Mine. Dust 3 measured dustfall in 2018 as 796 mg/dm^2/y. The second highest estimated dustfall rates measured using gauges occurred at Dust 7 (667 mg/dm^2/y) and Dust 10 (645 mg/dm^2/y), both of which are located south of the Mine. Dust 7 is located 1,147 m from the Mine, but very close to the winter road (Figure 2-1), and Dust 10 is located 46 m from the Mine adjacent to the A21 open pit. Similar to 2017, the lowest dustfall rates were measured at control stations Dust C2 (3,036 m west; 78 mg/dm^2/y) and Dust C1 (4,646 m south; 85 mg/dm^2/y).

Comparisons of mean and maximum dustfall values suggest that dustfall rates in 2018 were the highest since 2008. The higher dustfall rates were likely influenced by the surface activity at the Mine, particularly the A21 open pit, which began active mining (i.e. stripping till and rock) in December 2017. Dustfall values remained lower than the British Columbia dustfall objective for the mining industry (BC MOE 2016) except at the four sites that recorded the highest dustfall rates in 2018 (i.e., Dust 3, 7, 10, and 1).

Table 2-1 2018 Dustfall Deposition Results

Zone	Station	Approximate Distance from Mine Footprint (m)	Dustfall (mg/dm^2/y)
0 to 100 m	Dust 1	70	642
	Dust 3	25	796
	Dust 6	13	163
	Dust 10	46	645
	SS1-1	30	4,603
	SS3-6	35	138
	SS4-1	61	95
	SS5-1	31	752
	SS5-2	65	1,007
Mean			982
Median			645
Standard Deviation			1,396
95% Confidence Interval (Mean +/-)			1,073
Lower to Upper Limit of 95% Confidence Interval			(0 – 2,056)
101 to 250 m	Dust 4	173	152
	SS1-2	115	389
	SS2-1	145	46
	SS3-7	244	80
	SS4-2	203	47
Mean			143
Median			80
Standard Deviation			144
95% Confidence Interval (Mean +/-)			179
Lower to Upper Limit of 95% Confidence Interval			(0 – 322)
251 to 1,000 m	Dust 2A	425	267
	Dust 11	747	391
	SS1-3	263	192
	SS1-4	899	112
	SS2-2	427	35
	SS3-4	613	61
	SS3-8	826	422
	SS4-3	346	43
	SS5-3	270	1,349
	SS5-4	941	231
Mean			319
Median			192
Standard Deviation			412
95% Confidence Interval (Mean +/-)			317
Lower to Upper Limit of 95% Confidence Interval			(2 – 636)

Table 2-1 2018 Dustfall Deposition Results

Zone	Station	Approximate Distance from Mine Footprint (m)	Dustfall ($mg/dm^2/y$)
1,001 to 2,500 m	Dust 5	1,183	156
	Dust 7	1,147	667
	Dust 8	1,213	127
	Dust 12	2,326	105
	SS1-5	2,177	175
	SS2-3	1,194	22
	SS2-4	2,164	19
	SS3-5	1,325	81
	SS4-4	1,030	61
	SS4-5	1,214	40
	SS5-5	1,894	57
+2,500 m	Dust 9	3,796	149
Mean			138
Median			93
Standard Deviation			175
95% Confidence Interval (Mean +/-)			111
Lower to Upper Limit of 95% Confidence Interval			(27 – 249)
Control	Dust C1	4,646	85
	Dust C2	3,036	78
	Control 1	4,802	32
	Control 2	3,047	26
	Control 3	3,550	69
Mean			58
Median			69
Standard Deviation			27
95% Confidence Interval (Mean +/-)			34
Lower to Upper Limit of 95% Confidence Interval			(24 – 92)
Reference Levels			621–1,059

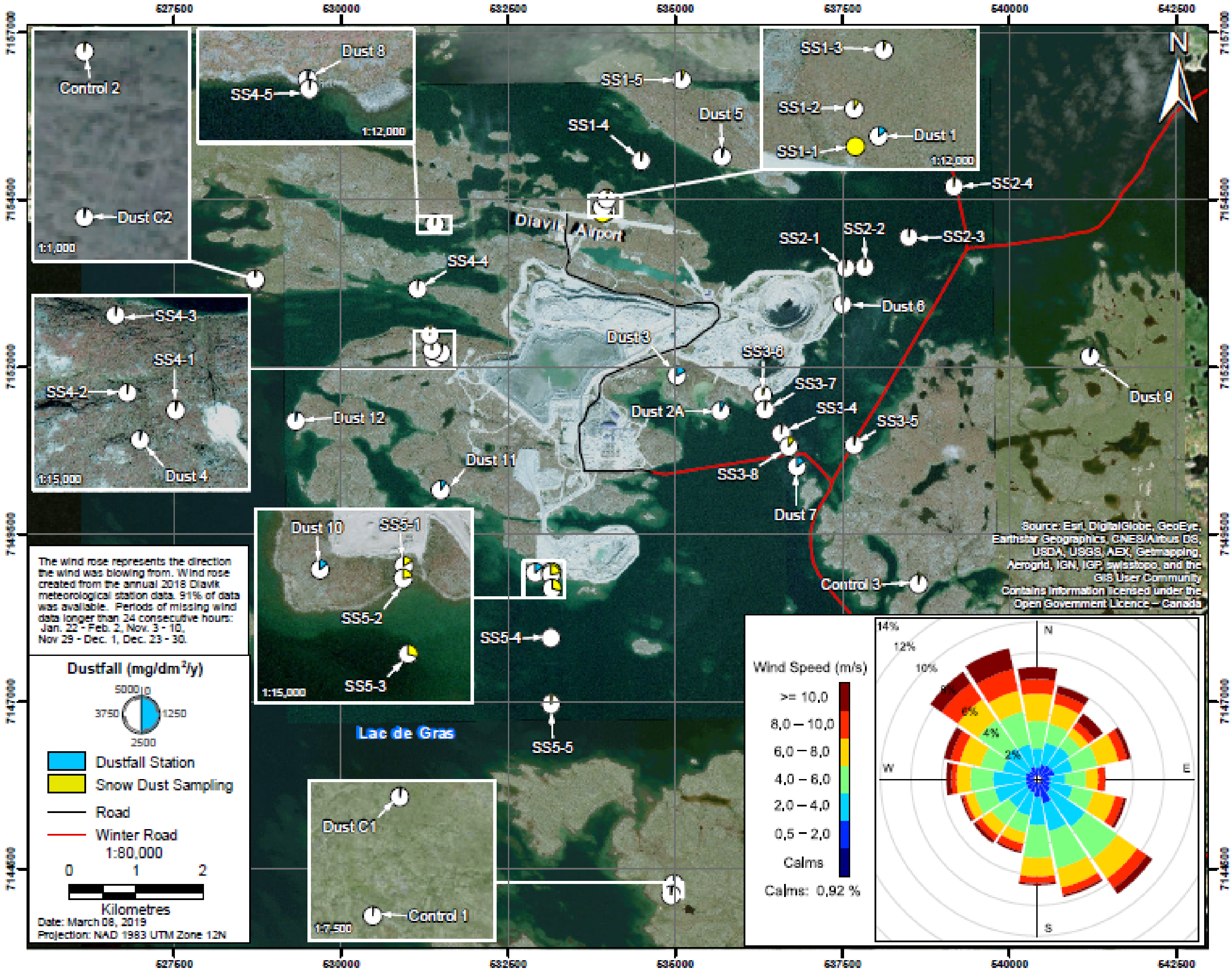
$mg/dm^2/y$ = milligrams per square decimetre per year.

2.3.1 Snow Core Surveys

Annual dustfall rates estimated from 2018 snow survey data ranged from 19 to 4,603 $mg/dm^2/y$ (Table 2-1). In general, dustfall rates decreased with increasing distance from the Mine site. The highest dustfall rate was recorded at SS1-1, likely influenced by the proximity to the airstrip (Figure 2-2). The lowest dustfall rate was recorded at SS2-4 (19 $mg/dm^2/y$) followed by SS2-3 (22 $mg/dm^2/y$); both are lower than the control stations (Table 2-1).

Annual dustfall estimated from each snow survey station in 2018 was generally higher than historical dustfall estimates. Comparisons of mean and maximum values suggest that dustfall rates were generally higher in 2018 than in 2017 and 2016. Annual dustfall rates measured at 4 out of 27 stations during the 2018 snow survey were higher than the former British Columbia dustfall objective for the mining industry (621 – 1,059 $mg/dm^2/y$).

Figure 2-2 Dustfall Results, Diavik Diamond Mine, 2018



2.3.2 Snow Water Chemistry

In general, concentrations of variables in snow meltwater decreased with distance from the Mine site, and measured concentrations in 2018 were lower than in 2017. Concentrations of aluminum, arsenic, chromium, and nickel have generally increased in recent years, while concentrations of copper, lead, phosphorus and zinc have generally decreased. High concentrations of certain variables of interest (i.e., aluminum: 2,080 µg/L and chromium: 13.5 µg/L) were recorded at Station SS3-8, located in the 251 to 1,000 m zone. All 2018 samples had concentrations less than their corresponding EQC.

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 be exposed to the material released, and potentially be affected. Water quality is a valuable early-warning indicator of potential effects on aquatic life in Lac de Gras. The objective of the water quality monitoring component of the AEMP is to assess the effects of Mine effluent and other Mine-related inputs on water quality in Lac de Gras.

A detailed technical report on the findings of the 2018 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 2018 results.

3.2 Methods

Water quality sampling at AEMP stations in 2018 was carried out according to the requirements of the interim year monitoring program (Golder 2017a). Water quality samples were collected from the NF area, the three MF areas (i.e., MF1, MF2-FF2, and MF3), at the outlet of Lac de Gras to the Coppermine River (LDG-48), and the Lac du Sauvage outflow to Lac de Gras (LDS-4, located at the Narrows; Figure 1-2). The AEMP water quality sampling was carried out over two monitoring seasons: ice-cover and open-water. The ice-cover season sampling was completed from 23 April to 7 May 2018. Open-water sampling was completed from 21 to 30 August 2018. Station LDS-4 was sampled during the open-water season only.

Stations in the NF and MF areas were sampled at three depths (i.e., top, middle, and bottom) during each season, as these stations were likely to have differences in water quality at the different depths due to the Mine discharge. Near-surface water samples (i.e., 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. Stations LDG-48 and LDS-4 are in shallow water and were sampled at middle depth only.

Data from the Surveillance Network Program (SNP) were incorporated into the 2018 AEMP report. Effluent samples were collected approximately once every six days from the NIWTP from both diffusers (i.e., SNP 1645-18 and SNP 1645-18B), and monthly at the mixing zone boundary (i.e., SNP 1645-19A SNP 1645-19B2, and SNP 1645-19C). The SNP sampling period summarized in this report extended from 1 November 2017 to 31 October 2018.

Dewatering of the lake area isolated by the A21 dike occurred during the 2018 sampling period, from 3 November 2017 to 24 April 2018 (DDMI 2018). Approximately 50% of the water was directly discharged to Lac de Gras at SNP 1645-41 from 3 to 24 November 2017, because it met Water Licence limits. When water quality variables began to approach Water Licence limits, the remaining water was directed to the NIWTP at SNP 1645-41N for treatment prior to discharge. A detailed description of water management and associated sampling activities for the A21 Dike Dewatering Program is provided in DDMI 2018. The potential effect of dewatering the A21 Dike on the water quality of Lac de Gras was considered herein.

Water samples were sent to Maxxam Analytics Inc. (Maxxam) in Burnaby, British Columbia (BC), Canada, for chemical analysis. Effluent toxicity samples were sent to Maxxam and Nautilus Environmental Company, Inc. in Burnaby, BC. Analyses of water samples for concentrations of ammonia were conducted by Maxxam and ALS Laboratories (ALS) BC, Canada in 2018. Field measurements of water quality were also completed at AEMP stations by lowering a specialized electronic device (i.e., YSI water quality meter) slowly down to the bottom of the lake, which recorded the measurements of temperature, dissolved oxygen (DO) concentration, conductivity, turbidity, and pH at regular depth intervals.

Initial data analyses 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 would undergo further analyses, while limiting analyses of variables that were less likely to be affected. The process of developing the list of SOIs was based on concentrations in the final effluent, at the mixing zone boundary, and the NF and MF areas according to four criteria:

- *Criterion 1*: effluent chemistry data collected at SNP 1645-18 and SNP 1645-18B were compared to EQC defined in the Water Licence (WLWB 2015). Variables with concentrations in individual grab samples greater than EQC for the Maximum Average Concentration were included as SOIs.
- *Criterion 2*: variables with concentrations that exceeded AEMP Effects Benchmark values at the mixing zone boundary (i.e., SNP 1645-19A, SNP 1645-19B2, SNP 1645-19C, located along a semi-circle, 60 m from the effluent diffusers) were also included in the SOI list.
- *Criterion 3*: water quality variables were assessed according to the AEMP Response Framework. Variables that triggered Action Level 1 in the NF area were added to the SOI list. Action Level 1 is when the median concentration in the NF area is greater than two times the median concentration in the reference dataset, together with evidence of a link to the Mine.
- *Criterion 4*: variables that triggered an effect equivalent to Action Level 1 at MF area stations that fall within the zone of influence (ZOI) from dust deposition in Lac de Gras (i.e., within approximately 1 km of the Mine boundary as defined in *AEMP Design Plan Version 4.1*: MF1-1, MF2-1, MF3-1 and MF3-2) were added to the SOI list.

All water quality variables analyzed in 2018 were initially evaluated against the above four criteria, with the exception of the following: DO, temperature, pH, specific conductivity, carbonate and hydroxide, bicarbonate, hardness, nutrients, nitrate + nitrite (examined separately), and dissolved metals, because these variables were assessed using different methods, or were not detectable in all samples, or were redundant with other variables.

If any one of the above criteria were met for a variable, it was added as an SOI. The following analyses were completed on SOIs that satisfied Criteria 1 to 4:

- an examination of loads in Mine effluent and effluent chemistry (from SNP 1645-18 and SNP 1645-18B) and effluent toxicity
- an examination of water chemistry at the edge of the mixing zone (from SNP 1645-19A, SNP 1645-19B2, SNP 1645-19C)
- an assessment of the magnitude and extent of effects, as defined by the Action Levels in the Response Framework for water quality

- an evaluation of spatial trends in concentrations with distance from the diffuser
- an examination of potential effects from the A21 dewatering and dust deposition

As stated in the *AEMP Study Design Version 4.1* (Golder 2017a), water quality at the mixing zone boundary and in the NF and MF areas of Lac de Gras were compared to AEMP Effects Benchmarks. The Effects Benchmarks used for the AEMP are generally the same as those used in the Project Environmental Assessment (Government of Canada 1999) but include a number of revisions to maintain their relevance over time for the Lac de Gras environment. The Effects Benchmarks are based on the current Canadian Water Quality Guidelines for the protection of aquatic life (CCME 1999 + updates), the Canadian Drinking Water Quality Guidelines (Health Canada 1996, 2006), adaptations of general guidelines to site-specific conditions in Lac de Gras, or when appropriate, values from the primary literature (Golder 2017a).

Water quality variables were assessed for a Mine-related effect according to the Response Framework for water chemistry (Table 3-1). Magnitudes of effects on water chemistry variables were determined by comparing concentrations between NF, MF, and FF sampling areas and reference conditions or Effects Benchmarks. Reference conditions for Lac de Gras are those that fall within the range of natural variability, referred to as the normal range. The normal ranges used in the Action Level screening for water quality were obtained from the *AEMP Reference Conditions Report Version 1.3* (Golder 2018b), as approved by the WLWB.

The full suite of water chemistry variables analyzed in 2018 was initially evaluated in the Action Level assessment, with the exception of pH (which was assessed qualitatively) and nutrients such as phosphorus and nitrogen (which are evaluated in the Eutrophication Indicators Report [Section 4; Appendix XIII]). Variables measured in the field (i.e., conductivity, DO, temperature and pH) were discussed qualitatively and were not considered for inclusion as SOIs. Effects were assessed separately for the ice-cover and open-water seasons.

An analysis of effects from other sources, such as the A21 dewatering and dust was also conducted. Spatial trends were analyzed at the stations nearest to the A21 Dike (i.e., MF3-3 and MF3-4) and stations within the ZOI from dust deposition (NF stations, and MF1-1, MF2-1, MF3-1, and MF3-2).

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

Action Level	Magnitude of Effect[a]	Extent of Effect	Action/Note
1	Median of NF greater than 2 times the median of reference dataset[b] (open-water or ice-cover) and strong evidence of link to Mine	Near-field (NF)	Early warning.
2	5th percentile of NF values greater than 2 times the median of reference areas AND normal range[b]	NF	Establish Effects Benchmark if one does not exist.
3	75th percentile of MZ values greater than normal range plus 25% of Effects Benchmark[c]	Mixing zone (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 EQC if one does not exist
4	75th percentile of MZ values greater than normal range plus 50% of Effects Threshold[c]	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%	Mid-field (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%	Far-field B (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%	Far-field A (FFA)	Significance Threshold.[d]

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

b) Normal ranges and reference datasets are obtained from the *AEMP Reference Conditions Report Version 1.3* (Golder 2018b); the normal range for open-water will be based on the 15 August to 15 September period. In cases where the reference area median value reported in the reference conditions report was equal to the detection limit (DL), half the DL was used to calculate the 2 × reference area median criterion to be consistent with data handling methods used for the AEMP.

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

d) Although the Significance Threshold is not an Action Level, it is presented as the highest Action Level to show escalation of effects towards the Significance Threshold.

NF = near-field; MF = mid-field; FFB = far-field B; FFA = far-field A; MZ = mixing zone; WLWB = Wek'èezhìı Land and Water Board; EQC = Effluent Quality Criteria

3.3 Results and Discussion

In total, 23 variables met the criteria to be included as SOIs in 2018 (Table 3-2). Nineteen variables triggered Action Level 1 in the NF area (Criterion 3), which is considered an early-warning indicator of effects in that area. Seventeen variables were included as SOIs, because they triggered an effect similar to Action Level 1 at one or more of the MF area stations located within the estimated ZOI from dust deposition from the Mine site (Criterion 4). Of these, thirteen variables met both Criteria 3 and 4, while four variables only met Criterion 4 at the MF stations. No variables were added to the list of SOIs based on comparison of mixing zone data with the Effects Benchmark (Criterion 2). No variables were added to the SOI list based on the comparison of EQC to concentrations of variables in the effluent (Criterion 1).

Table 3-2 Water Quality Substances of Interest, 2018

Substance of Interest	Substances of Interest Criteria			
	1 Effluent Screening	2 Mixing Zone Screening	3 Action Level 1	4 Potential Dust Effects
Conventional Parameters				
Total dissolved solids, calculated	-	-	X	X(c)
Turbidity – lab	-	-	X	-
Major Ions				
Calcium	-	-	X(a)	X(b,c)
Chloride	-	-	X	X(c)
Magnesium	-	-	X(a)	-
Potassium	-	-	X(a)	-
Sodium	-	-	X(a)	X(b,c)
Sulphate	-	-	X	-
Nutrients				
Ammonia	-	-	-	X
Nitrate	-	-	X	X(c)
Total Metals				
Aluminum	-	-	X	X(c)
Antimony	-	-	X	X(c)
Barium	-	-	X	-
Chromium	-	-	X	X(c)
Copper	-	-	X	X(c)
Iron	-	-	-	X
Lead	-	-	-	X
Manganese	-	-	X	X(c)
Molybdenum	-	-	X	X(c)
Silicon	-	-	X	-
Strontium	-	-	X	X(c)
Titanium	-	-	-	X
Uranium	-	-	X	X(c)

a) Both the total and dissolved fractions of calcium, potassium, and sodium triggered Action Level 1. Only the total fraction of magnesium triggered Action Level 1. To avoid redundancy and match methods from previous annual reports, the analysis was conducted on the dissolved fractions only.

b) Total and dissolved sodium and total calcium triggered an effect equivalent to Action Level 1 at one or more of the four mid-field (MF) area stations located within the estimated zone of influence (ZOI) from dust deposition from the Mine site. To avoid redundancy and match methods from previous annual reports, the analysis was conducted on the dissolved fractions only.

c) Variable triggered both Action Level 1 (during one or both seasons) and an effect equivalent to Action Level 1 in the MF area at stations located within the estimated ZOI from dust deposition, indicating that the exceedances at the MF stations were likely caused by dispersion of Mine effluent into the lake.

X = criterion met; - = criterion not met

3.3.1 Effluent and Mixing Zone Water Quality

The monthly loads of total dissolved solids (TDS) and several associated ions (i.e., calcium, chloride, magnesium, potassium, sodium and sulphate) from the NIWTP decreased from November 2017 to approximately April 2018, reflecting the difference in the monthly volume of effluent discharged (Figure 3-1). The loads of these SOIs increased during the late ice-cover to early open-water season as flow rates from the NIWTP and effluent concentrations increased. The concentrations of TDS, calcium, chloride, magnesium, and sodium in Mine effluent decreased from November to December or January and either increased gradually over the remainder of the reporting season, or remained within a similar range until April or May before subsequently increasing through the late ice-cover and open-water season. The concentrations of potassium and sulphate decreased during the ice-cover season, increased rapidly from May to August and then gradually declined again during the open-water season.

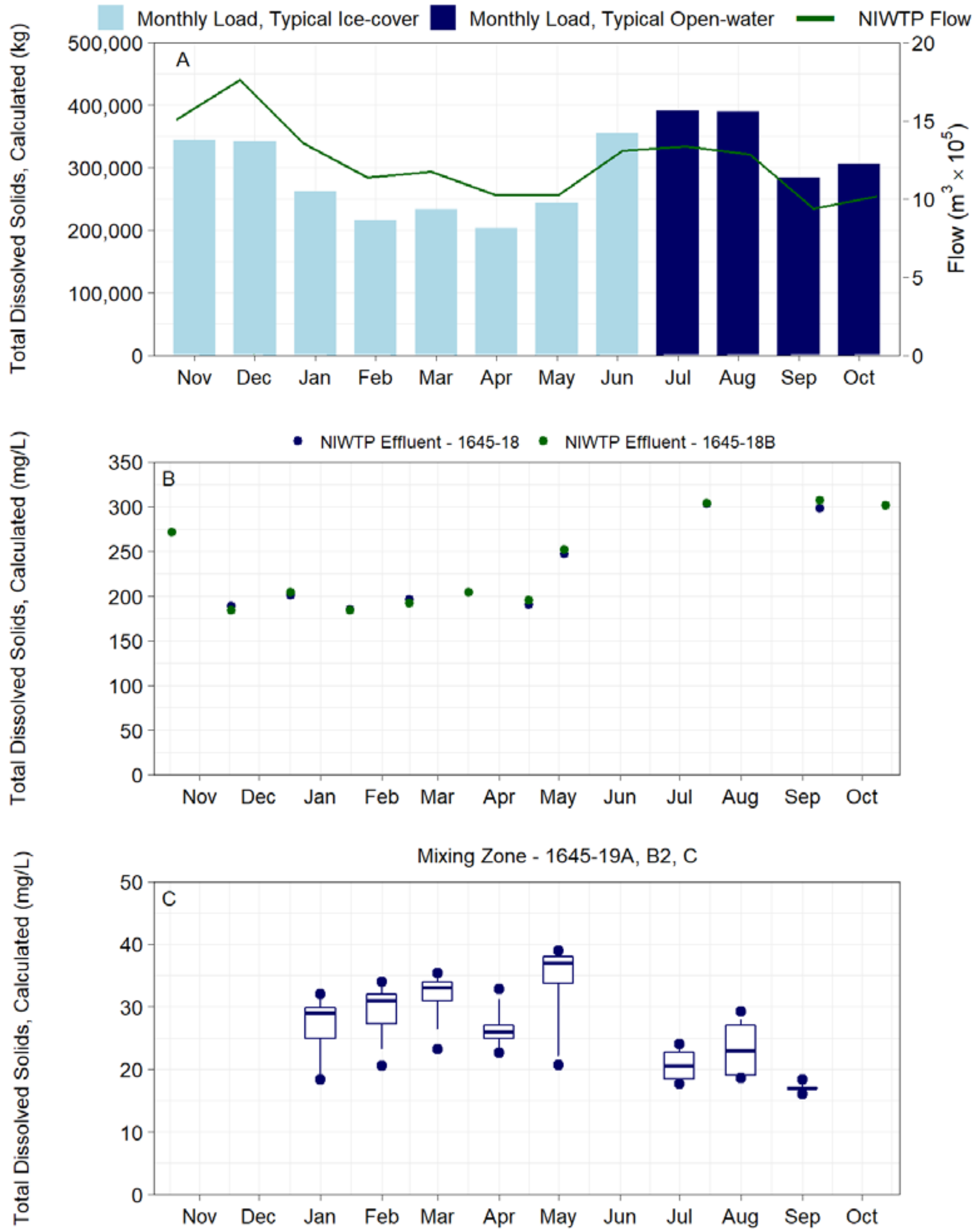
The monthly loads of ammonia increased from November to December and declined in January and February. From February to May, monthly loads of ammonia remained within a similar range and increased through July before declining again in the open-water season. The seasonal trend in the loading rate of ammonia generally reflected that in the effluent concentration. The load and concentration of nitrate declined during the ice-cover season from November 2017 to April 2018, and increased throughout the late ice-cover season to early open-water season, peaking in August, before decreasing in September and October.

In general, the monthly loading rates of total metal SOIs either reflected trends in the effluent flow rate or chemistry, or were influenced by a combination of the two. The types of changes in the concentrations of total metal SOIs in the effluent over the reporting period were variable-specific. The concentrations of most total metal SOIs at the mixing zone boundary were greater and/or more variable during the ice-cover season than during the open-water season. Concentrations in the effluent were greater than the concentrations measured at the mixing zone boundary in most total metal SOIs in 2018 (except occasionally copper), indicating that the Mine effluent is a source of these variables to Lac de Gras.

During the 2018 sampling period, effluent chemistry demonstrated compliance with EQCs. Concentrations of variables in effluent with EQC were below both the maximum allowable concentration in any grab sample and the maximum average concentration. All discharges from the NIWTP in 2018 had a pH between 6.0 and 8.4, as per the Water Licence requirements (WLWB 2015).

Water chemistry at the mixing zone boundary was compared to the relevant AEMP water quality Effects Benchmarks for the protection of aquatic life and drinking water. No pH values at the mixing zone boundary in 2018 exceeded the upper bounds of the Effects Benchmarks, however, field pH values were measured below the Effects Benchmark value. Because the pH of the Mine effluent was slightly alkaline (i.e., pH more than 7) and the pH throughout Lac de Gras was often below the Effects Benchmark in both seasons at various depths and over time, pH was not considered a SOI.

Figure 3-1 Total Dissolved Solids, Calculated: A) Monthly Loading Rate from the North Inlet Water Treatment Plant and Concentration in B) Effluent (SNP 1645-18 and SNP 1645-18B) and at C) the Mixing Zone Boundary (SNP 1645-19), 1 November 2017 to 31 October 2018



Notes: Effluent values represent concentrations in individual samples. Mixing zone boxplots represent the 10th, 25th, 50th (median), 75th, and 90th percentile concentrations at three stations (i.e., 1645-19A, 1645-19B2, 1645-19C) and five depths (i.e., 2 m, 5 m, 10 m, 15 m, and 20 m); circles represent the 5th and 95th percentile concentrations. The mixing zone samples could not be collected in November and December 2017 as well as June and October 2018 due to hazardous sampling conditions.

NIWTP = North Inlet Water Treatment Plant; SNP = Surveillance Network Program.

3.3.2 Effluent Toxicity

Toxicity testing results for the 2018 sampling season showed that effluent samples were not toxic to aquatic test organisms. These results are consistent with results in previous years, which have indicated that the Mine effluent is generally non-toxic to aquatic test organisms.

3.3.3 Depth Profiles

Depth profiles were prepared for conductivity, DO, water temperature, pH, and turbidity at the AEMP stations sampled in 2018. Specific conductivity increased with depth in the NF area during the ice-cover season to approximately 10 m and then declined slightly with increasing water depth, but was uniform throughout the water column during the open-water season. 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 approximately two thirds of the water column in the NF area. The greater conductivity at this depth indicated the presence of the effluent plume. Complete vertical mixing of the effluent was observed at most stations along the three MF transects.

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 and declined slightly with depth. The greatest declines in DO near the lake bottom were measured at MF1-1, MF1-5, FF2-5, and MF3-5, where near-bottom DO concentrations were at or below the Effects Benchmark of 9.5 mg/L for the protection of aquatic life for early life stages. Some concentrations measured at stations MF1-1, MF1-5, and MF3-5 were also below the Effects Benchmark of 6.5 mg/L for the protection of aquatic life for “other” life stages (i.e., non-early life stages). The lower DO values at these stations are not likely Mine-related, as the reduction in DO near the lake bottom is not present in the NF area where the effect would be expected to be greatest, and because the measured values are within the range of concentrations observed during the Winter Dissolved Oxygen Baseline Survey undertaken in 2000 prior to commencement of Mine discharge (DDMI 2000).

The pH values measured in Lac de Gras in 2018 were greater during the open-water season compared to the ice-cover season, and typically decreased gradually with depth during both seasons. Field pH values were often below the Effects Benchmark. These are likely natural and unrelated to the mine discharge since the effluent is alkaline and there is no spatial pattern in pH in relation to the diffuser. A single pH value measured near the lake bottom was just beyond the upper bound of the Effects Benchmark. This appeared to be caused by a natural increase in pH near the lake bottom.

During the open-water season, water temperature profiles were similar at all depths, while temperature increased gradually with depth at most stations during ice-cover. Turbidity concentrations were generally uniform throughout the water column during both seasons, and field turbidity values were within the respective Effects Benchmarks for all measurements.

3.3.4 Action Levels

Water quality variables measured in Lac de Gras during the 2018 AEMP were assessed for a Mine-related effect according to Action Levels. Nineteen variables triggered Action Level 1, which is considered an early-warning indicator of effects in Lac de Gras (Table 3-3). These variables had NF area median concentrations that were greater than two times the median concentrations in reference datasets. Each of the SOIs that triggered Action Level 1 had elevated concentrations in the NIWTP effluent (except copper), indicating that the increase observed could be linked to the Mine.

Of the 19 variables that triggered Action Level 1, ten also triggered Action Level 2, because the 5th percentile concentration in the NF area was greater than two times the median concentration in reference datasets and was greater than the normal range for Lac de Gras (Table 3-3). None of the SOIs triggered Action Level 3 in 2018.

Table 3-3 Action Level Summary for Water Quality Substances of Interest, 2018

2018 SOIs	Action Level Classification
Conventional Parameters	
Total dissolved solids, calculated	2
Turbidity – lab	1
Major Ions	
Calcium	2
Chloride	2
Magnesium	1
Potassium	1
Sodium	2
Sulphate	2
Nutrients	
Nitrate	2
Total Metals	
Aluminum	1
Antimony	2
Barium	1
Chromium	1
Copper	1
Manganese	1
Molybdenum	2
Silicon	1
Strontium	2
Uranium	2

1 = Action Level 1 triggered; 2 = Action Level 2 triggered

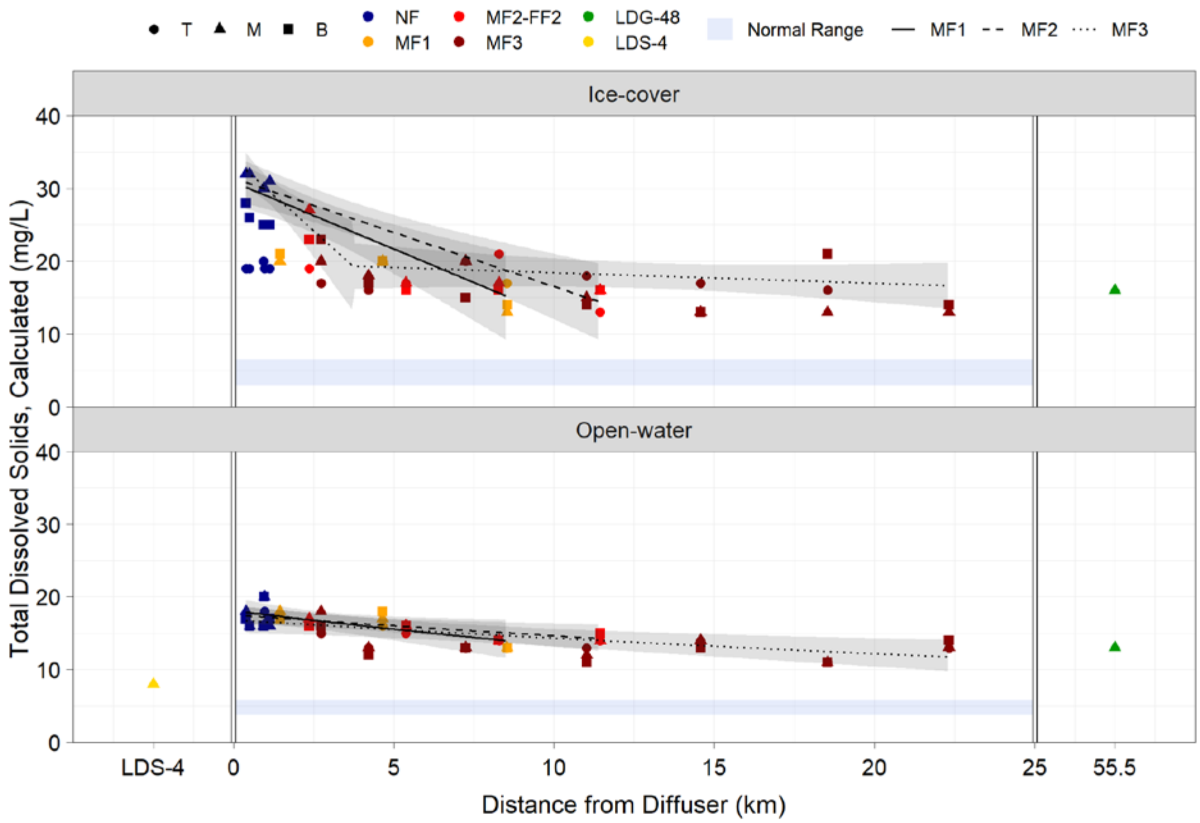
3.3.5 Spatial Trends with Distance from the Diffusers

The spatial gradients in concentrations of water quality SOIs were assessed along the MF transects to see if spatial trends of decreasing concentrations with distance from the Mine effluent discharge were evident. This was considered confirmation that the increases observed in the NF area were related to the Mine effluent discharge. In general, clear spatial trends of decreasing concentrations with distance from the Mine effluent diffusers were observed for most variables that triggered Action Level 1 or greater (Figure 3-2). Open-water concentrations of TDS, calcium, chloride, magnesium, potassium, sodium, and sulphate were generally less at LDS-4 compared to stations located in the body of Lac de Gras, while turbidity was slightly greater at LDS-4. Concentrations of most SOIs at LDG-48 were similar to those measured at the far end of the MF3 transect (i.e., MF3-7) during both seasons.

Statistical analysis of ammonia and nitrate concentrations was only done for the ice-cover season, because many of the samples had concentrations below the detection limit during open-water conditions. A clear spatial trend of decreasing concentrations with distance from the Mine effluent was observed in ammonia concentrations for the MF1 transect; however, there was no trend along the MF2 and MF3 transects. Nitrate concentrations decreased with distance from the Mine effluent diffuser along the MF2 and MF3 transects, but showed no trend along the MF1 transect. Ammonia and nitrate concentrations at LDS-4 were generally similar to the concentrations measured in the main body of Lac de Gras, while concentrations at LDG-48 were similar to concentrations at MF3-7 during both seasons.

During the ice-cover season, most total metals decreased in concentrations with increasing distance from the Mine diffuser along the MF transects, except for antimony (two of the three MF transects only) and copper (one of the three MF transects only). During the open-water season, concentrations of total metals decreased in relation to the diffuser stations along at least two of the three MF transects, except for manganese, which showed no trends along MF transects. Station LDS-4 had lower concentrations of barium, molybdenum, strontium, and uranium, and increased concentrations of silicon during the open-water season compared to the main body of Lac de Gras. Concentrations of other SOIs at LDS-4 were generally similar to those measured in Lac de Gras. Concentrations of most total metal SOIs at LDG-48 were similar to concentrations at MF3-7 during both seasons; aluminum and antimony were exceptions during open-water, and had slightly greater concentrations at LDG-48.

Figure 3-2 Concentrations of Total Dissolved Solids (Calculated) According to Distance from the Effluent Discharge, 2018



Note: Values represent concentrations in individual samples collected at top, middle and bottom depths. Open symbols represent non-detect data. Shaded bands around fitted prediction lines are 95% confidence intervals (back-transformed to original scale of the variable).

T= top depth; M = mid-depth; B = bottom depth; NF = near-field; MF = mid-field; FF = far-field; LDG = Lac de Gras; LDS = Lac du Sauvage.

3.3.6 Effects from the A21 Dike

During the open-water season in 2018, seven total metals (i.e., aluminium, antimony, boron, chromium, copper, lead, and tin) showed spatial trends consistent with a dike-related effect, based on a graphical assessment of the data. The concentrations of these metals were unusually large at the stations nearest to the A21 Dike (i.e., MF3-3 and MF3-4) and were well above values observed in the NF area, indicating that the increases near the dike were not related to the NIWTP discharge. The concentrations of a number of additional variables, including turbidity and the total fractions of iron, manganese, titanium and vanadium, were also slightly elevated in one or more samples (e.g., top, mid or bottom) collected at MF3-3 and MF3-4; however, the increases observed in these variables were not as pronounced as for the above-mentioned seven metals.

The water quality variables that demonstrated spatial patterns in relation to the dike are parameters that typically show a response as a result of sediment releases. In general, these variables also demonstrated a similar response pattern (i.e., an increase in concentration at MF3 stations near the dike) during in-water construction of the A21 Dike in 2016 (Golder 2017c); however, concentrations of aluminum, antimony, boron, and tin were greater in 2018 than in 2016. There was no clear indication of a spatial trend consistent with a dike effect in the dissolved fraction of total metals, major ions, and nitrogen parameters.

Most of the parameters that demonstrated concentration increases at the two MF3 stations near the dike were well below Effects Benchmarks for the protection of aquatic life and drinking water. The exception was total aluminum, which exceeded the AEMP aquatic life and drinking water Effects Benchmarks of 87 µg/L and 100 µg/L, respectively, in three samples collected at stations MF3-3 and MF3-4. There was no evidence of toxicological impairment at these stations to biological indicators.

The exact cause of the increases in the above-mentioned parameters near the A21 Dike is uncertain; however, it appears that the responses were likely related to the A21 dewatering event. A possible explanation for the observed increases during the open-water season is that fine particulates that settled out from the water discharged during the early ice-cover season were re-suspended by wave action and mixing during open-water, resulting in a pulse in the concentration of sediment-associated parameters at AEMP stations close to the dike. The direct discharge of A21 Pit water to Lac de Gras was a one-time event required to complete dewatering of the A21 Pit before mining and, therefore, is not anticipated to be an ongoing source of effects on the water quality of Lac de Gras. Future water management for the A21 Pit will involve collection and diversion of flows for treatment and discharge via the North Inlet.

3.3.7 Effects from Dust Deposition

During the open-water season of 2018, 17 variables exceeded two times the median of the reference dataset at one or more of the four MF area stations located within the estimated ZOI from dust deposition (i.e., MF1-1, MF2-1, MF3-1 and MF3-2; Table 3-3). Of these 17 SOIs, 13 also triggered Action Level 1 in the NF area, indicating that the exceedances at the MF stations were at least partly caused by dispersion of Mine effluent into the lake; however, as the NF area is located within the ZOI, there is some potential that dust deposition may also be contributing to the increases observed in these variables in the NF area. In most cases, concentrations at the MF stations were well below those reported in the NF area; exceptions were chloride, aluminum, copper and manganese, which demonstrated an increase in concentration at the MF stations compared to the NF area. These results indicate that the elevated values within the ZOI may not be solely related to dispersion of effluent in the lake and may possibly be related to dust deposition from the Mine site. There is no clear indication that these increases were related to the A21 Dike. There was no dike effect evident for chloride and concentrations of aluminum, copper and manganese at MF3-2 were less than those observed at MF2-1 and MF3-1, and in the NF area. This pattern is not consistent with a spatial trend related to the dike, as MF3-2 is closer to the dike than MF2-1 and MF3-1.

The remaining four SOIs (i.e., ammonia, iron, lead, and titanium) exceeded two times the median of the reference dataset value at one or more of the four MF stations within the dust ZOI only (i.e., not in the NF area), indicating that these increases at the MF stations may have resulted from dust deposition, a combination of dust deposition and effluent discharge, or potentially stochastic (i.e., random) variation. In the case of ammonia, the concentration increases may have been due to QC issues.

Overall, analysis of the 2018 AEMP water quality data provided only limited evidence to suggest an effect of dust deposition from the Mine site on the water quality of Lac de Gras. In total, eight variables (i.e., chloride, aluminum, copper, manganese, ammonia, iron, lead and titanium) demonstrated an increase in concentration at the MF area stations within the ZOI from dust deposition, indicating that Mine-related dust, in addition to Mine effluent, may be a factor affecting the concentrations of these variables at these MF area stations. There was no indication of an increase in concentration for most water quality variables at stations within the ZOI, indicating that dust deposition is unlikely to be an important source of effects on the water quality of Lac de Gras.

3.3.8 Comparison to Effects Benchmarks

Concentrations of water quality variables at AEMP stations were compared to available Effects Benchmarks. Copper concentration in one sample (7.2 µg/L) collected during the open-water season exceeded the Aquatic Life Effects Benchmark (2 µg/L). This exceedance is suspected to be an error given all other samples collected in Lac de Gras were well below benchmarks. Three total aluminum concentrations (189 µg/L, 149 µg/L, and 102 µg/L) in samples collected during the open-water season in the MF3 area exceeded both the Aquatic Life and Drinking Water Effects Benchmarks of 87 µg/L and 100 µg/L, respectively. These are likely true exceedances, as concentrations were consistently elevated at two stations in this area, and potentially reflect the influence of direct discharge of dewatering flows from the A21 Dike. One field pH value at LDG-48 exceeded the upper bound of the Effects Benchmark; however, this was likely an error as all other field pH measurements were within the expected range for Lac de Gras. Concentrations in all other samples collected during the 2018 AEMP were below the relevant Effects Benchmarks for the protection of aquatic life and drinking water.

4 EUTROPHICATION INDICATORS

4.1 Introduction and Objectives

The Environmental Assessment predicted that operation of the Mine would release nutrients (i.e., nitrogen and phosphorus) into Lac de Gras. Phosphorus naturally occurs in the groundwater that seeps into the Mine workings. Nitrogen enters Mine effluent 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 are found in greater concentrations in the NIWTP effluent compared to baseline concentrations in Lac de Gras.

Lac de Gras is a nutrient-poor (i.e., oligotrophic) lake. Aquatic organisms in the lake, including algae, invertebrates, and fish, live with limited nutrient availability, but have low abundances compared to more productive lakes. 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 nutrient enrichment on Lac de Gras was expected to be an increase in primary productivity (i.e., greater abundance of microscopic plants called algae or phytoplankton), sometimes referred to as eutrophication.

The objective of the eutrophication indicators assessment is to describe the AEMP results for nutrients, chlorophyll *a*, phytoplankton biomass and zooplankton biomass, which are monitored as indicators of eutrophication. Chlorophyll *a* is what gives plants their green colour and can be used to measure the amount of algae in the water. Algae or phytoplankton are small aquatic plants, which are the first aquatic organisms to respond to a change in nutrient levels. Zooplankton biomass is a measure of the total mass of these tiny animals that live in the water and feed on algae, and is measured as ash-free dry mass (AFDM).

The following is a summary of the 2018 eutrophication indicators program. Appendix XIII provides a more complete analysis and presents detailed results.

4.2 Methods

The AEMP eutrophication indicators program was completed over two sampling seasons. Ice-cover season samples were collected from 23 April to 7 May 2018, and the open-water samples were collected from 21 to 30 August 2018. Nutrient samples were collected during both ice-cover and open-water conditions from the NF area and the three MF areas (i.e., MF1, MF2-FF2 and MF3) in Lac de Gras, at the outlet of Lac de Gras to the Coppermine River (i.e., LDG-48), and during the open-water season only at the Narrows (i.e., between Lac de Gras and Lac du Sauvage, LDS-4) (Figure 1-2). Chlorophyll *a*, phytoplankton biomass and zooplankton biomass samples were collected during the open-water season, when biological activity was greatest; however, plankton samples were not collected from LDG-48 and LDS-4 due to the shallow depth (i.e., less than 1 m) at these AEMP stations.

During the ice-cover season, nutrient samples were collected from three depths (i.e., top, middle, and bottom) in Lac de Gras, and from mid-depth at LDG-48. No sample was collected at LDS-4 during the ice-cover season. Water column profile measurements were also recorded, according to the methods described in the Effluent and Water Chemistry Report (Section 3; Appendix II).

During the open-water season, nutrients, chlorophyll *a* and phytoplankton biomass were collected using a depth-integrated sampler (Photo 4-1). This device collects lake water over a range of sample depths. The top 10 m of the water column was sampled for chlorophyll *a*, phytoplankton biomass and nutrients during the open-water season, since this is the depth where most algae are found. Zooplankton samples were collected using a fine mesh plankton net, which was pulled up through the water, from 1 m above the bottom to the surface.

In 2018, nutrient data from the SNP were incorporated into the Eutrophication Indicators report. Treated effluent samples were collected approximately once every six days from the NIWTP from both diffusers (i.e., SNP 1645-18 and SNP 1645-18B), and monthly at the mixing zone boundary (i.e., SNP 1645-19A, SNP 1645-19B2, and SNP 1645-19C).

The 2018 nutrient and zooplankton biomass samples were analyzed by Maxxam, Burnaby, BC. Analysis of samples for ammonia were completed by both Maxxam and ALS, Burnaby, BC. Chlorophyll *a* samples were analyzed by the Biogeochemical Analytical Service Laboratory at the University of Alberta, Edmonton, Alberta. Phytoplankton biomass samples were analyzed by Advanced Eco-Solutions Inc. (Advanced Eco-Solutions), Newman Lake, Washington, United States of America.

The quality of the effluent was assessed in Section 3; Appendix II; however, results for the key nutrient variables (e.g., total phosphorus) are presented herein. To assess potential effects from dust emissions on nutrient enrichment in Lac de Gras, open-water phosphorus and chlorophyll *a* concentrations within the estimated ZOI from dust deposition were evaluated visually and compared to results at other nearby stations and the normal range (Golder 2017a). If phosphorus or chlorophyll *a* concentrations at the dust-affected stations (i.e., all NF stations and MF1-1, MF2-1, MF3-1 and MF3-2) were above the normal range, a potential dust effect was assumed. Possible effects from the direct discharge of A21 dewatering flows on the nutrient enrichment in Lac de Gras were evaluated visually, with more weight on stations that are closest to the A21 Dike. The 2018 AEMP results were analyzed to identify and understand spatial patterns in relation to the Mine effluent discharge. Data were compared to the background values (i.e., normal range) to determine if they fall within the natural range of variability. The magnitude of effects for chlorophyll *a* was evaluated according to Action Levels (Table 4-1).

Photo 4-1 Depth integrated sampler

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)]	MF station	Early warning.
2	NF and MF values greater than normal range[(a)]	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[(c)]	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%	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%	FFA	Significance Threshold[(d)].

a) The normal range for chlorophyll *a* was obtained from the *AEMP Reference Conditions Report Version 1.3* (Golder 2018b).

b) Indicates 25% of the difference between the Effects Benchmark and the top of the normal range.

c) Indicates 50% of the difference between the Effects Threshold and the top of the normal range.

d) Although the Significance Threshold is not an Action Level, it is presented as the greatest Action Level to demonstrate escalation of effects towards the Significance Threshold.

NF = near-field; MF = mid-field; FFB = far-field B; FFA = far-field A; WLWB = Wek'èezhìı Land and Water Board; EQC = Effluent Quality Criteria.

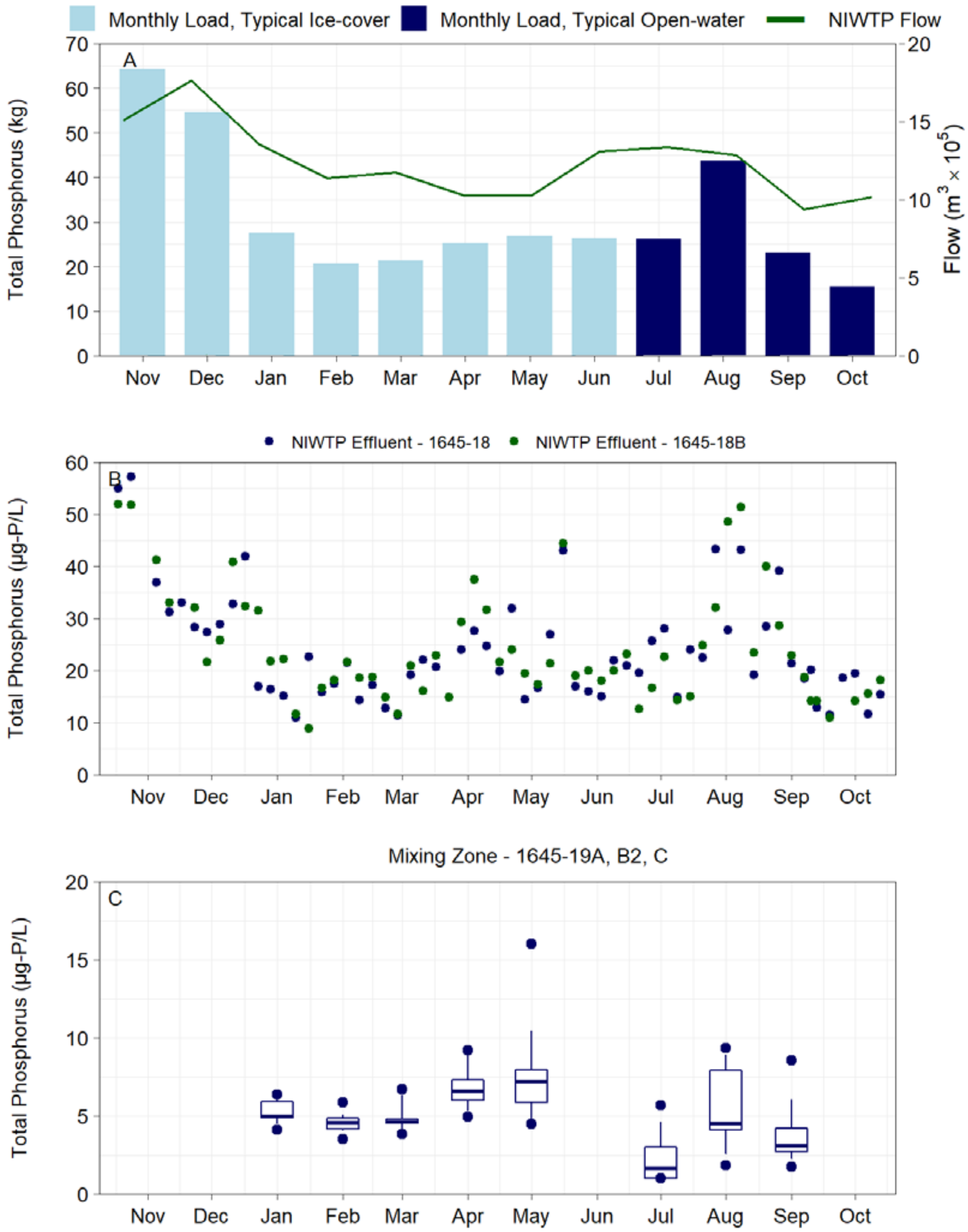
4.3 Results and Discussion

4.3.1 Nutrients in Effluent and at the Mixing Zone

Trends in monthly nutrient loads generally reflected concentrations in the Mine effluent, rather than the effluent volume (Figure 4-1). In 2018, total phosphorus (TP), total dissolved phosphorus (TDP) and soluble reactive phosphorus (SRP) concentrations and loads were more variable during the ice-cover season. Concentrations and loads of TP, TDP and SRP were greatest in November 2017 due to the A21 dewatering flows to the NIWTP. During the open-water season, concentrations and loads were the greatest in August 2018. The monthly loads of TP in 2018 did not exceed the Water Licence TP load limit of 300 kilograms per month (kg/month), with the greatest monthly load of TP (64 kg) occurring in November 2017. This monthly TP load was approximately twice what was observed in the previous year and is due to the A21 dewatering flows. The annual TP load in 2018 was 375 kg, which was below the the Water Licence TP load limit of 1,000 kg/yr (WLWB 2015).

Nitrogen concentrations and loads in effluent tracked closely together and most of the total nitrogen (TN) was present as nitrate in the effluent (Figure 4-2). Concentrations and loadings of TN and nitrate were smallest during the ice-cover season and greatest during the open-water season. Total ammonia loads and concentrations in effluent did not follow the same patterns as other nitrogen species. The greatest concentrations of total ammonia were observed in the ice-cover season and in July 2018 of the open-water season. The decreases in concentrations of TN, total ammonia, and nitrate at the mixing zone boundary between May and July 2018 reflects quick assimilation (i.e., uptake and use) by algae and bacterial nitrification (Wetzel 2001).

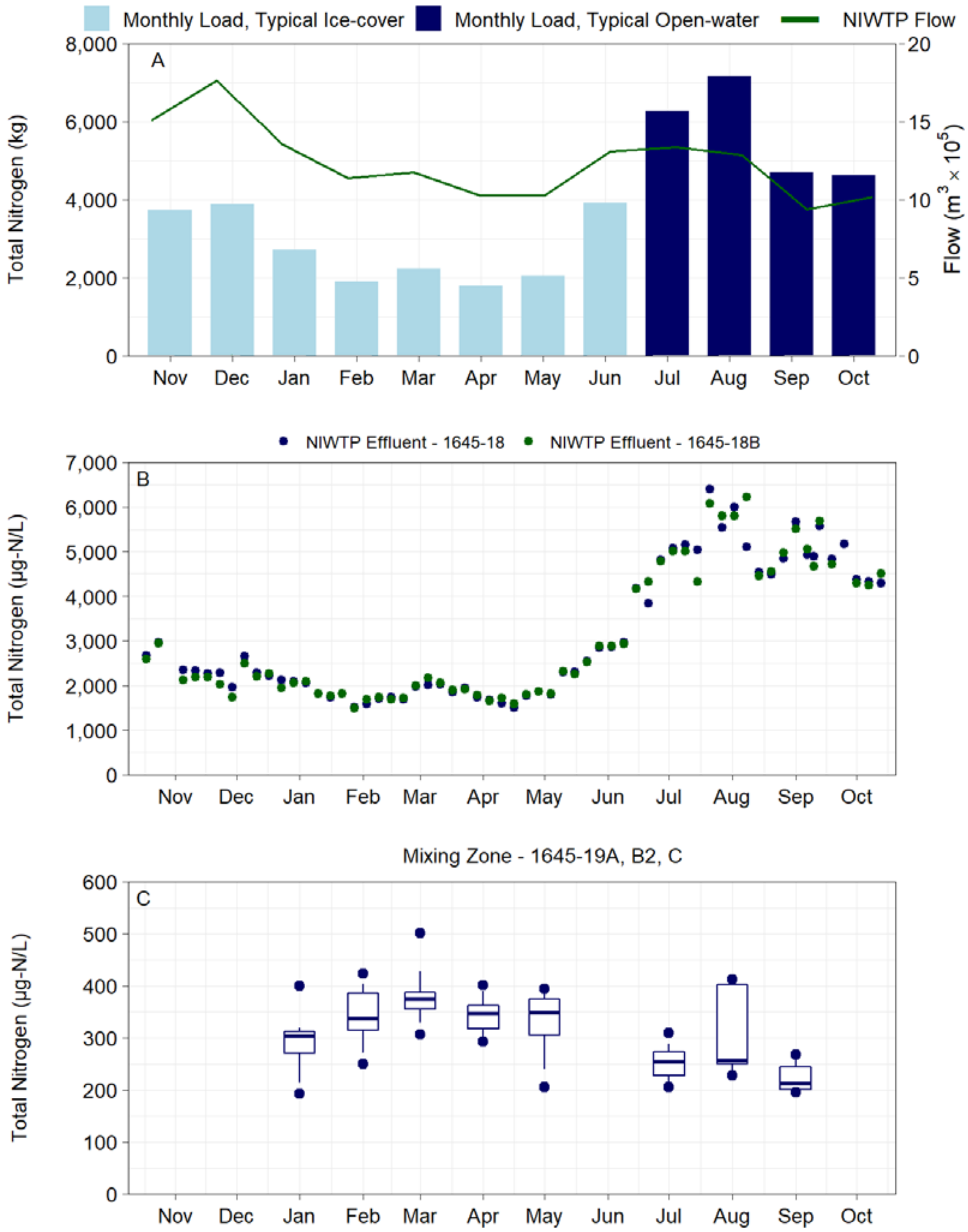
Figure 4-1 Total Phosphorus: A) Total Monthly Loads in Effluent, B) Concentrations in Effluent, C) at the Mixing Zone Boundary, November 2017 to October 2018



Notes: Concentrations in effluent are for individual samples. Mixing zone values represent the monthly 5th percentile, median, and 95th percentile concentrations at three stations (1645-19A, 1645-19B2, 1645-19C) and five depths (2 m, 5 m, 10 m, 15 m and 20 m). The mixing zone samples could not be collected in November and December 2017, and June and October 2018 due to hazardous sampling conditions (ice-on period).

µg-P/L = micrograms phosphorus per litre; NIWTP = North Inlet Water Treatment Plant; SNP = surveillance network program.

Figure 4-2 Total Nitrogen: A) Total Monthly Loads in Effluent, B) Concentrations in Effluent, C) at the Mixing Zone Boundary, November 2017 to October 2018



Notes: Concentrations in effluent are for individual samples. Mixing zone values represent the monthly 5th percentile, median, and 95th percentile concentrations at three stations (1645-19A, 1645-19B2, 1645-19C) and five depths (2 m, 5 m, 10 m, 15 m and 20 m). The mixing zone samples could not be collected in November and December 2017, and June and October 2018 due to hazardous sampling conditions (ice-on period).

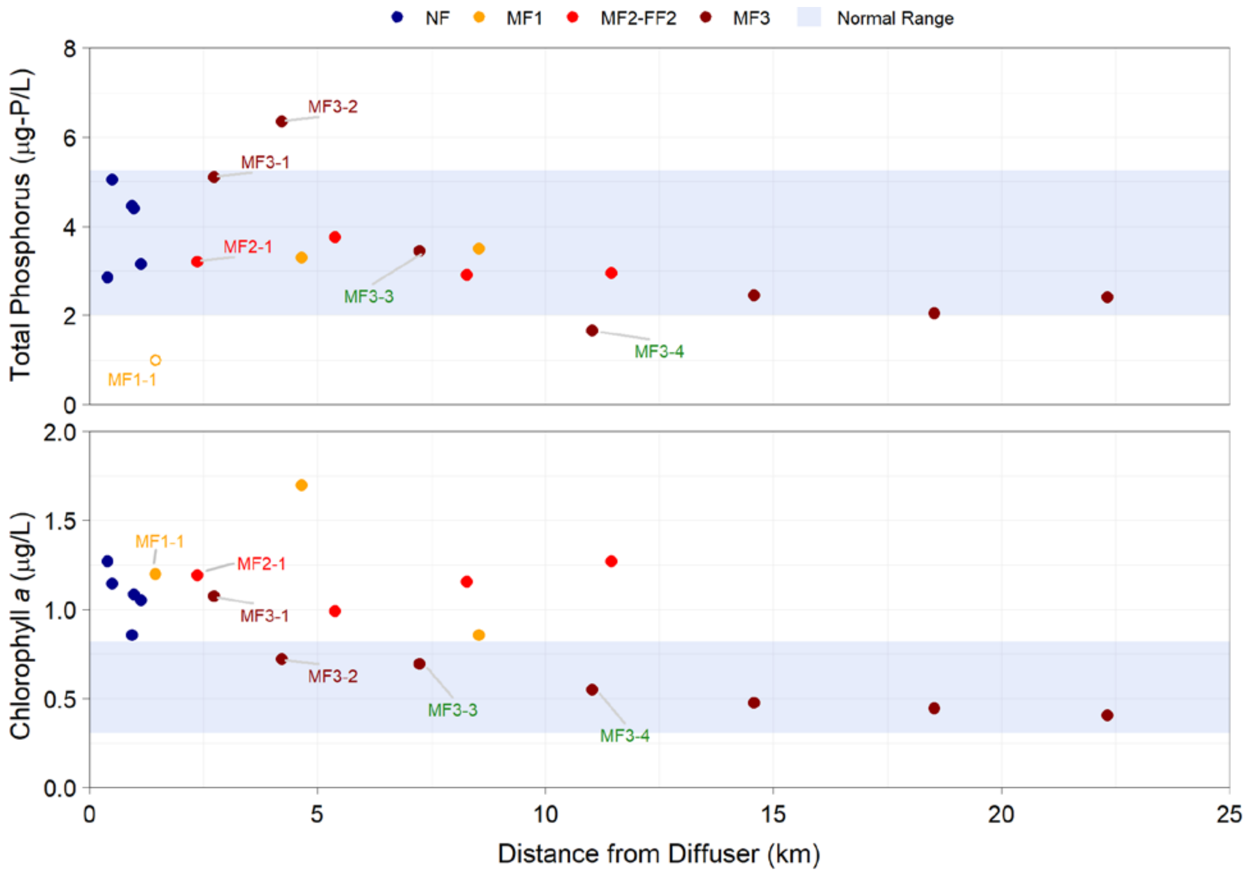
µg-N/L = micrograms nitrogen per litre; NIWTP = North Inlet Water Treatment Plant; SNP = surveillance network program.

4.3.2 Effects from Dust Deposition

The amount of dust deposition, based on data collected using dust gauges during the open-water season and snow cores during the ice-cover season, was similar between the two seasons. The rate of dust deposition was greatest within the Mine footprint and declined with distance from the Mine. In the 2014 to 2016 Aquatic Effects Re-evaluation Report, it was determined that the ZOI from dust deposition extends to approximately 4.2 km from the Mine centroid, or approximately 1.5 km from the boundary of the Mine footprint (Golder 2018a).

Concentrations of TP during the open-water season in 2018 were within the normal range at most stations within the ZOI from dust deposition (i.e., stations NF1 to NF5, MF1-1, MF2-1, and MF3-1) with the exception of MF3-2 (Figure 4-3). Chlorophyll *a* concentrations were greater than the normal range in the NF area and at three of the four MF stations located within the ZOI from dust deposition. Chlorophyll *a* concentrations at these four stations were within the range observed for other MF stations, and the overall declining trend in concentrations with distance from the diffuser was consistent with an effluent-related, rather than a dust-related, effect. The 2018 AEMP results provided no clear evidence that dust deposition had an additional measurable effect on concentrations of TP or chlorophyll *a* in Lac de Gras, on top of the effect apparent from the Mine effluent discharge.

Figure 4-3 Concentrations of Total Phosphorus and Chlorophyll *a* in Lac de Gras in Relation to Dust Deposition during the Open-water Season, 2018

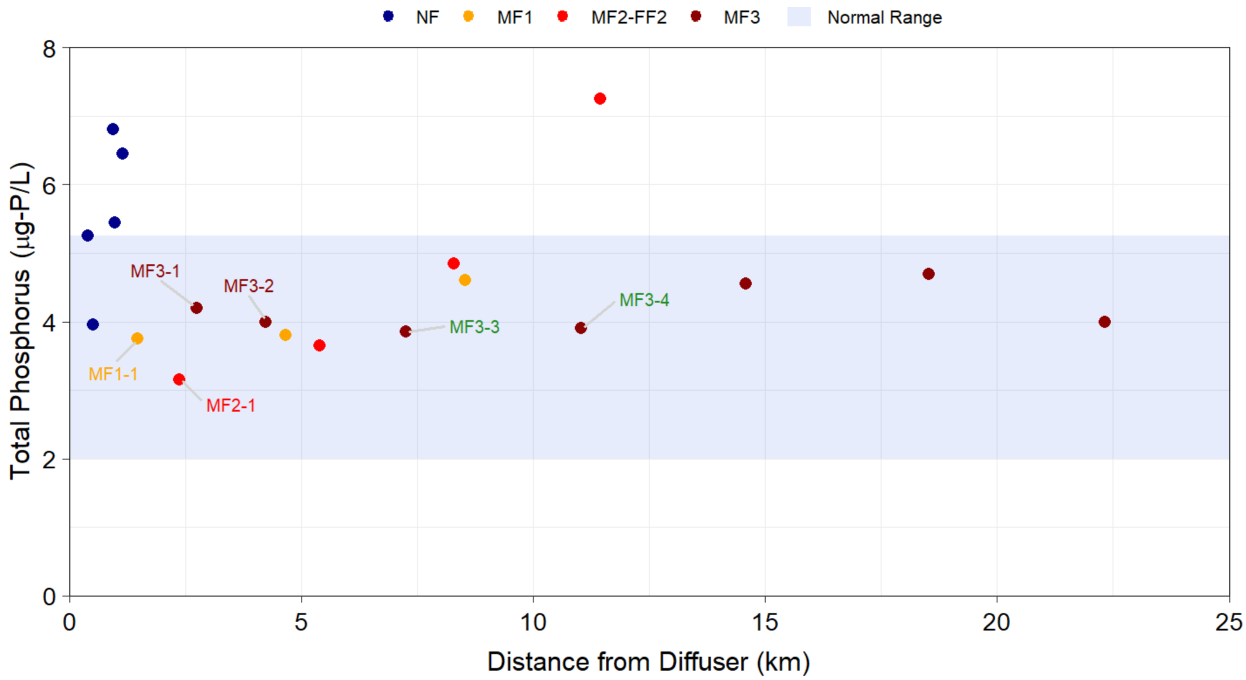


Note: Mid-field (MF) stations in the zone of influence from dust deposition are labelled (i.e., MF1-1, MF2-1, MF3-1, MF3-2); all NF stations are also within the zone of influence. MF stations that may be potentially influenced by the dike are labelled in green (i.e., MF3-3 and MF3-4). NF = near-field; MF = mid-field; FF = far-field.

4.3.3 Direct Discharge of A21 Dewatering Flows

Total loading of TP in the A21 dewatering discharge was 25.1 kg, and occurred in November 2017. The ice-cover season water sampling began in April 2018, which was five months after direct discharge ended. There is no evidence of increased TP concentrations during both the ice-cover and open-water seasons at the stations closest to the A21 Dike (i.e., MF3-3 and MF3-4; Figure 4-4). The maximum concentrations were within the normal range. Chlorophyll *a* concentrations were not elevated at these stations and were within the normal range. It does not appear that the A21 dewatering discharge contributed to nutrient enrichment in Lac de Gras.

Figure 4-4 Concentrations of Total Phosphorus in Lac de Gras in Relation to A21 Dike during the Ice-Cover Season, 2018



Note: Near-field (NF) stations are labelled in red. Mid-field (MF) stations that may be potentially influenced by the dike are labelled (in green). Maximum concentration of the top, middle, and bottom depths for each station are plotted.

NF = near-field; MF = mid-field; FF = far-field.

4.3.4 Nutrients and Water Chemistry in Lac de Gras

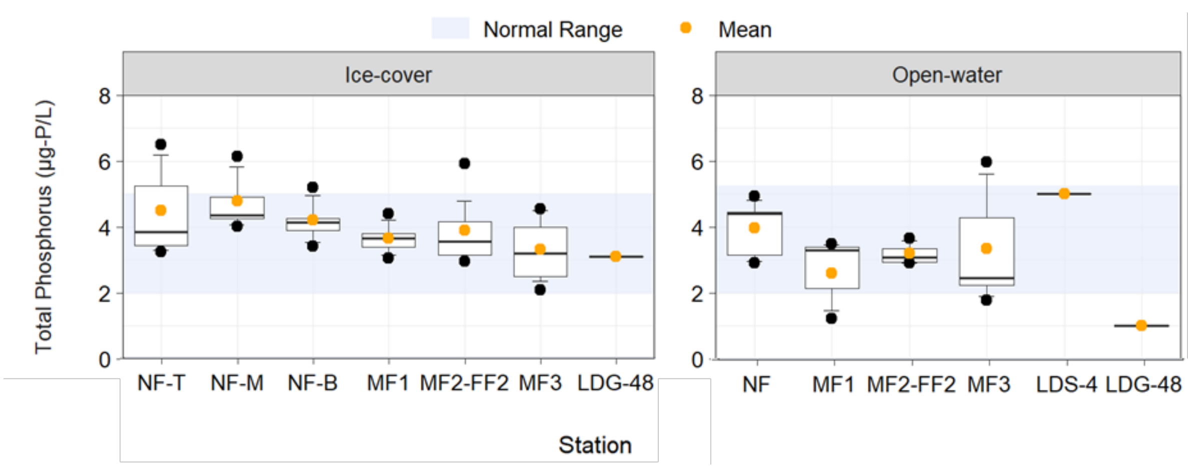
In 2018, concentrations of TP were generally greatest in the NF area during the ice-cover season and least in the MF areas and at LDS-48 (Figure 4-5). Mean TP concentrations were within the normal range. TDP concentrations were variable during the ice-cover season and within or below the normal range with the exception of MF1-5T, MF2-1B, and MF2-1T. During the open-water season, concentrations of TDP were the greatest in the NF area, with three stations having values greater than normal range (i.e., NF1, NF2, and NF5). All other concentrations at other stations were within the normal range. Concentrations of TDP at LDS-4 and LDG-48 were greater than mean concentrations in the MF2-FF2 and MF3 areas. Concentrations of SRP were mostly below detection during the ice-cover season, and detected concentrations were within the normal range. During the open-water season, SRP concentrations were greatest in the MF1 area, with two of the three stations above the normal range. Concentrations of SRP at LDS-4 and LDG-48 were less than the DL.

During the ice-cover season, concentrations of TN and total dissolved nitrogen (TDN) were greatest in the NF area at the middle and bottom depths compared to the top, reflecting the discharge of effluent (Figure 4-6). Concentrations were generally above normal range, with the exception of some MF3 stations. Concentrations of TN and TDN at LDG-48 were similar to those measured in MF3. During the open-water season, concentrations of TN and TDN were less than in the ice-cover season, and more stations had concentrations within normal range. At LDG-48 during the open-water season, TN concentrations were greater than at all other stations in Lac de Gras, and TDN concentrations were similar to those in NF and MF1 areas. At LDS-4 during the open-water season, TN concentration was similar to mean concentrations in the NF area, but TDN was one of the smaller concentrations measured. Nitrate and nitrate + nitrite concentrations followed the same pattern as TN. Most concentrations were greater than normal range and concentrations at LDG-48 were among the lowest observed.

Total ammonia concentrations during the ice-cover season were greater in the NF area at the middle depth. Ammonia results from ALS and Maxxam were different. Results from Maxxam followed the same pattern as TN and TDN, with greater concentrations at the middle depth than the top. Results from ALS showed mean total ammonia concentrations that were similar between these two depths. In both sets of data, most concentrations were greater than the normal range. Total ammonia concentrations at LDG-48 during the ice-cover season were among the smallest values. Smaller total ammonia concentrations were measured during the open-water season. Total ammonia concentrations were greater than normal range in stations of the MF2-FF2 and MF3 areas (Maxxam dataset) and in the MF1 and MF2-FF2 areas (ALS dataset).

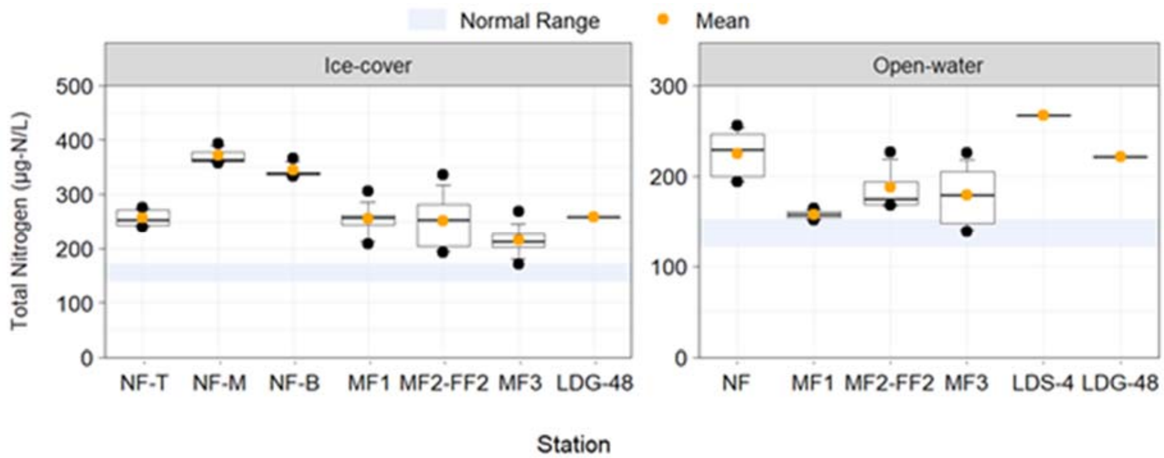
In 2018, a Mine-related nutrient enrichment effect was reported for the primary producers of Lac de Gras. Chlorophyll *a* concentrations were greatest at the stations closest to the effluent diffusers, consistent with a point source of nutrients to Lac de Gras (Figure 4-7). All stations in the NF, MF1 and MF2-FF2 areas had concentrations above the normal range. The smallest chlorophyll *a* concentration was measured at LDG-48. Mean phytoplankton biomass in the NF area and MF2-FF2 area was greater than the normal range (Figure 4-8). Mean zooplankton biomass (as AFDM) in the NF, MF1 and MF2-FF2 areas was greater than the normal range (Figure 4-9).

Figure 4-5 Concentrations of Total Phosphorus in Lac de Gras during the Ice-Cover and Open-Water Seasons, 2018



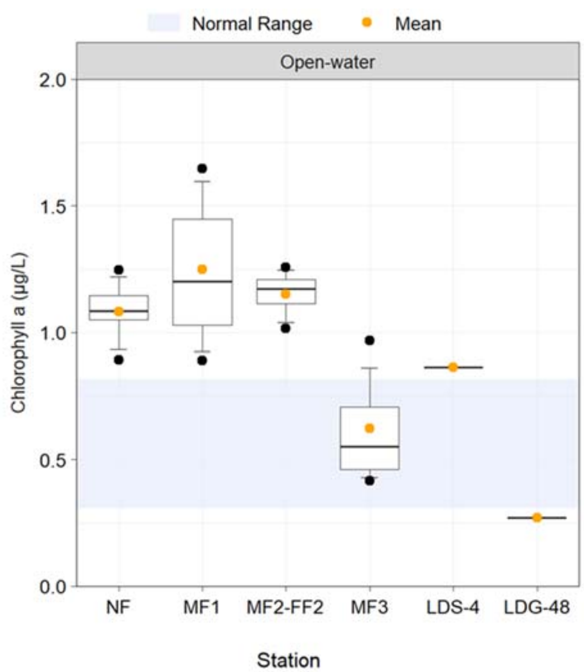
µg-P/L = micrograms phosphorus per litre; NF = near-field; MF = mid-field; FF = far-field; LDG-48 = Lac de Gras outlet; T = top depth; M = middle depth; B = bottom depth.

Figure 4-6 Concentrations of Total Nitrogen in Lac de Gras during the Ice-Cover and Open-Water Seasons, 2018



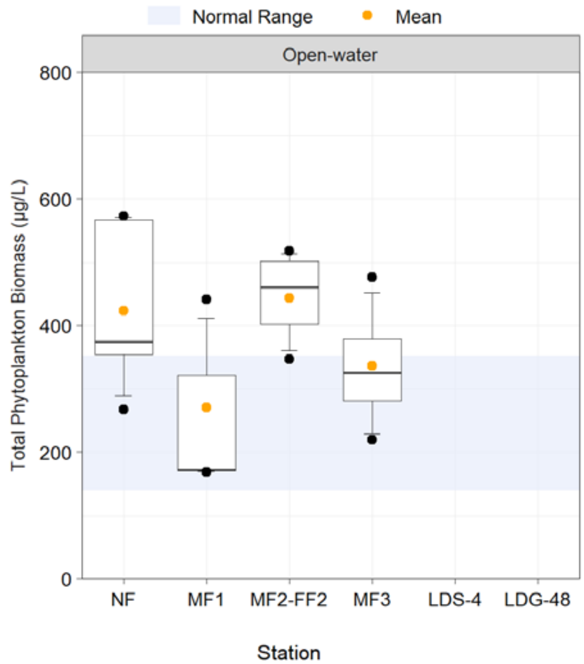
µg-N/L = micrograms nitrogen per litre; NF = near-field; MF = mid-field; FF = far-field; LDG-48 = Lac de Gras outlet; T = top depth; M = middle depth; B = bottom depth.

Figure 4-7 Concentration of Chlorophyll *a* in Lac de Gras during the Open-Water Season, 2018



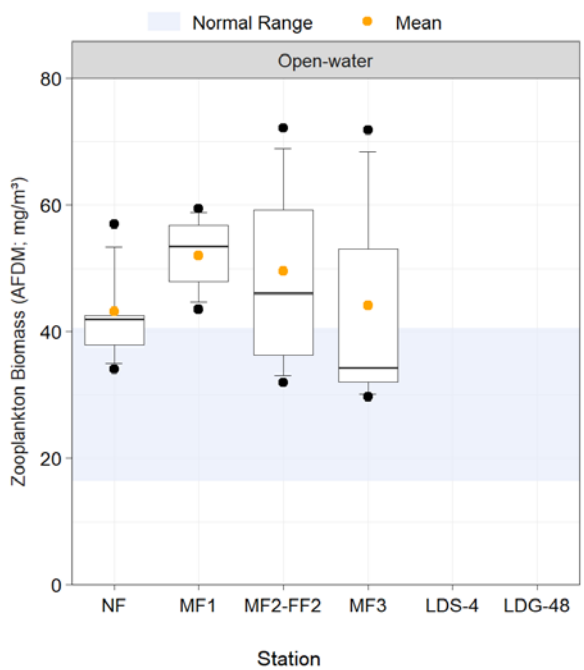
NF = near-field; MF = mid-field; FF = far-field; LDS-4 = Lac du Sauvage narrows; LDG-48 = Lac de Gras outlet.

Figure 4-8 Total Phytoplankton Biomass in Lac de Gras during the Open-Water Season, 2018



NF = near-field; MF = mid-field; FF = far-field; LDS-4 = Lac du Sauvage narrows; LDG-48 = Lac de Gras outlet.

Figure 4-9 Total Zooplankton Biomass (as AFDM) in Lac de Gras during the Open-Water Season, 2018



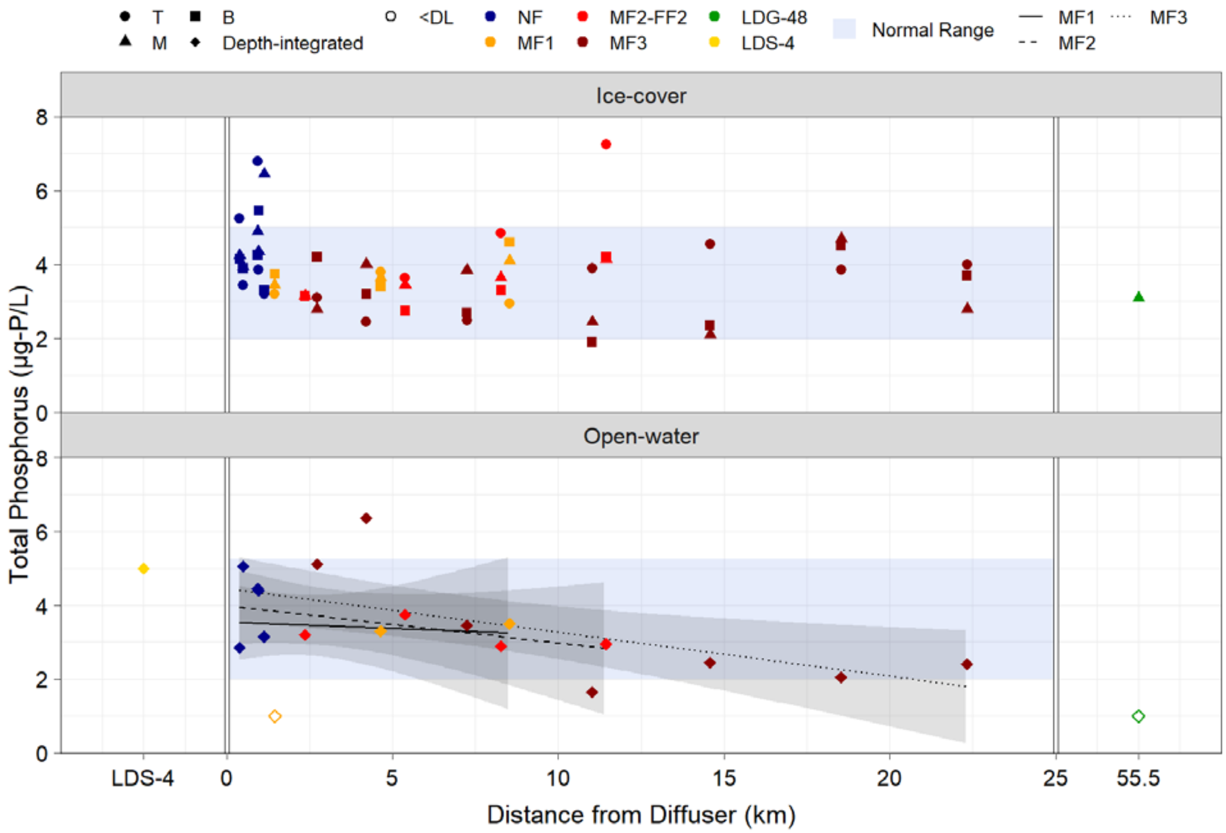
AFDM = ash-free dry mass; NF = near-field; MF = mid-field; FF = far-field; LDS-4 = Lac du Sauvage narrows; LDG-48 = Lac de Gras outlet.

4.3.5 Spatial Analysis

During the ice-cover season, there were no significant trends with distance from the diffuser along any transect for TDP concentrations. Concentrations of TP were within the normal range at the majority of stations during the ice-cover season, with the exceptions of four NF stations, and one station along MF2-FF2 transect (Figure 4-10). TDP concentrations during the ice-cover season were within the normal range at the majority of stations. Concentrations of SRP were within the normal range at all stations during the ice-cover season. During the open-water season, there were no significant trends in TP concentrations with distance from the diffuser along any transect and all TP concentrations in Lac de Gras were within the normal range, except at MF3-2. Concentrations of TDP during the open-water season were all within normal range except for three stations in the NF area. Concentrations of SRP during the open-water season were greater than the normal range at almost all stations where concentrations were greater than the DL. Spatial analysis was not done on TDP from the open-water season or SRP from the ice-cover and open-water seasons because these parameters had a large number of values that were less than DLs. In addition, regression analysis was not performed for any variables that did not meet the linear regression assumption of a linear relationship between x and y (where x = the distance from diffuser and y = the variable of interest). The assumption of linearity was not met for TP in the ice-cover season..

Strong decreasing trends in TN concentrations were observed along most transects during both seasons, except the MF2-FF2 transect during open-water season. Concentrations of TN were above the normal range during both seasons with few exceptions (Figure 4-11). Significant decreasing trends in concentrations of TDN were observed along all transects during the ice-cover season, and along the MF1 and MF3 transects during the open-water season. Concentrations of TDN were above the normal range during both seasons with some exceptions at stations along the MF3 transect. A weak decreasing trend of total ammonia was observed with distance from the diffuser along the MF3 transect when the Maxxam dataset was used, and no trends were observed using the ALS dataset. Total ammonia concentrations reported by both laboratories (i.e., Maxxam and ALS) were generally greater than the normal range during the ice-cover season. Total ammonia was not detected frequently enough during the open-water season for spatial analysis (i.e., there were 31% <DL in the Maxxam dataset and 48% <DL in the ALS dataset). Strong decreasing trends in nitrate and nitrate + nitrite were observed at the MF2-FF2 and MF3 transects during the ice-cover season. These nutrients were not detected frequently enough during the open-water season to allow spatial analysis. Concentrations of nitrate were greater than the normal range during the ice-cover season. Detected nitrate concentrations during the open-water season were also generally greater than the normal range.

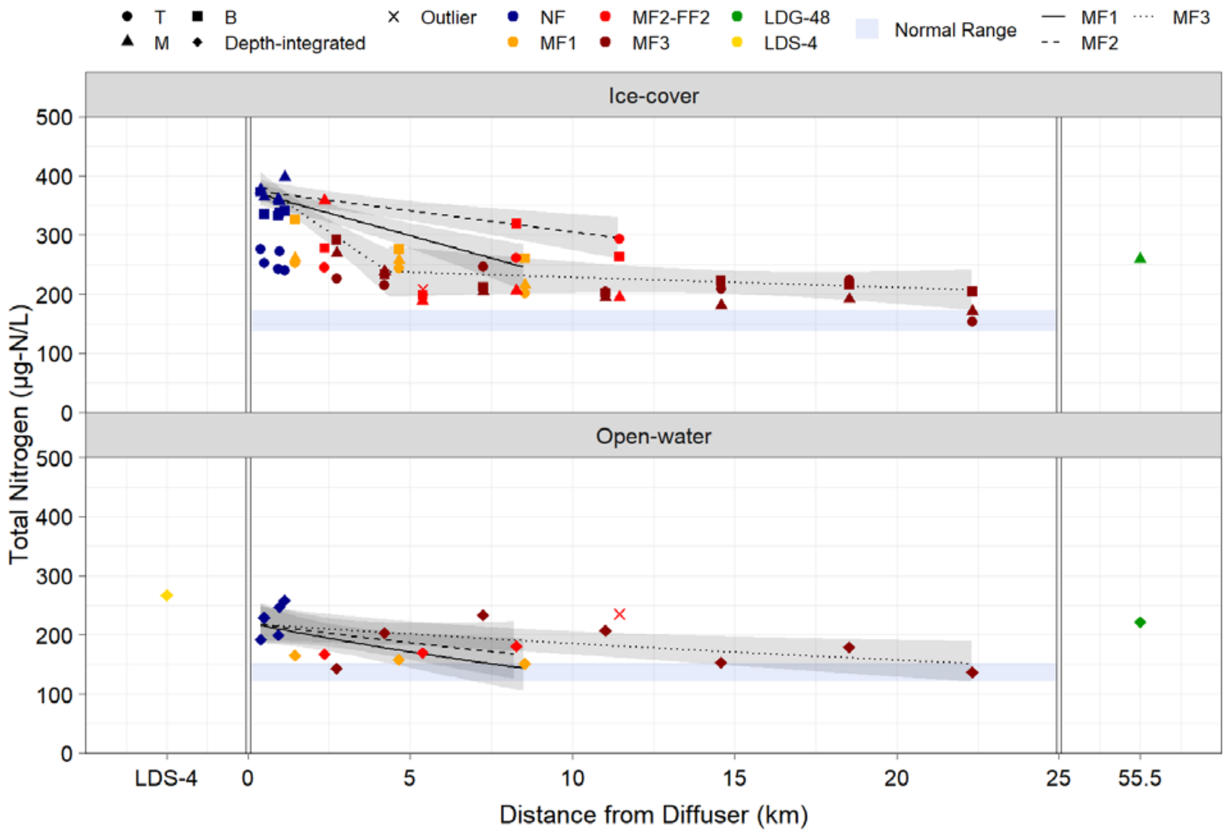
Figure 4-10 Concentrations of Total Phosphorus According to Distance from the Effluent Discharge, 2018



Note: Samples collected from Lac du Sauvage are presented to the left of the y-axis in a separate panel and LDG-48 in presented to the right of the y-axis. Shaded bands around fitted prediction lines are 95% confidence intervals (back-transformed to original scale of the variable).

µg-P/L = micrograms phosphorus per litre; NF = near-field; MF = mid-field; FF = far-field; LDG-48 = Lac de Gras outlet; LDS = Lac du Sauvage.

Figure 4-11 Concentrations of Total Nitrogen According to Distance from the Effluent Discharge, 2018

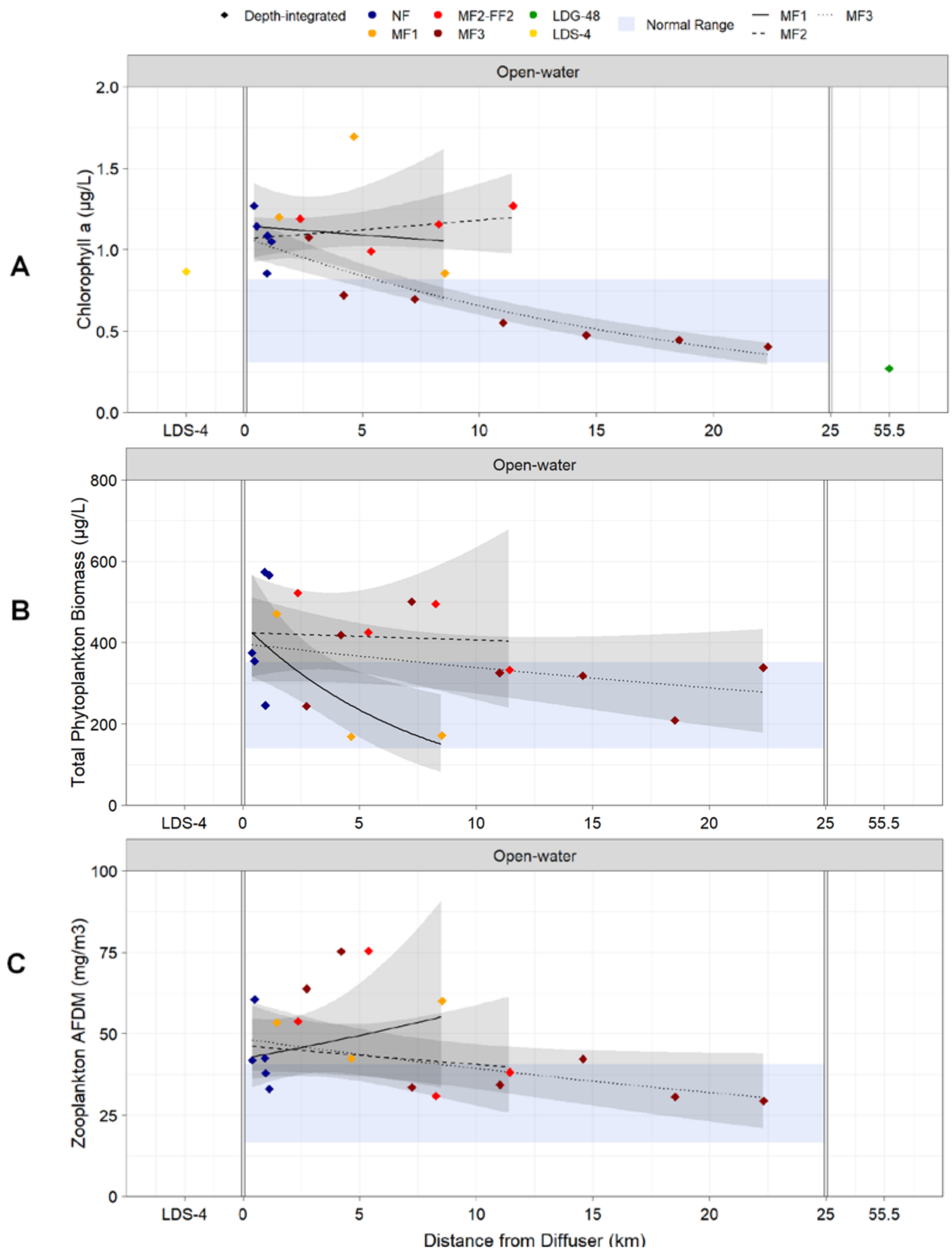


Note: Samples collected from Lac du Sauvage are presented to the left of the y-axis in a separate panel and LDG-48 in presented to the right of the y-axis. Shaded bands around fitted prediction lines are 95% confidence intervals (back-transformed to original scale of the variable).

µg-N/L = micrograms nitrogen per litre; NF = near-field; MF = mid-field; FF = far-field; LDG-48 = Lac de Gras outlet; LDS = Lac du Sauvage.

Open-water chlorophyll *a* concentrations were greater than the normal range at all stations in the NF area, along the MF1 and MF2-FF2 transects, and at one station along the MF3 transect. There was a significant decreasing trend in chlorophyll *a* concentration with distance from the diffuser along the MF3 transect (Figure 4-12). Phytoplankton biomass was greater than the normal range at the majority of NF and MF2-FF2 stations, and one or more of the MF1 and MF3 stations. Phytoplankton biomass had a weak decreasing trend with distance from the diffuser along the MF1 transect. Zooplankton biomass was greater than the normal range at three of the five NF stations, all MF1 stations, and several stations along the MF2-FF2 and MF3 transects. Zooplankton showed no significant trends with distance from the diffuser at any of the three transects in 2018.

Figure 4-12 A) Concentrations of Chlorophyll *a*, B) Phytoplankton Biomass, and C) Zooplankton Biomass (as AFDM) in Lac de Gras Relative to Distance from the Effluent Discharge during the Open-Water Season, 2018

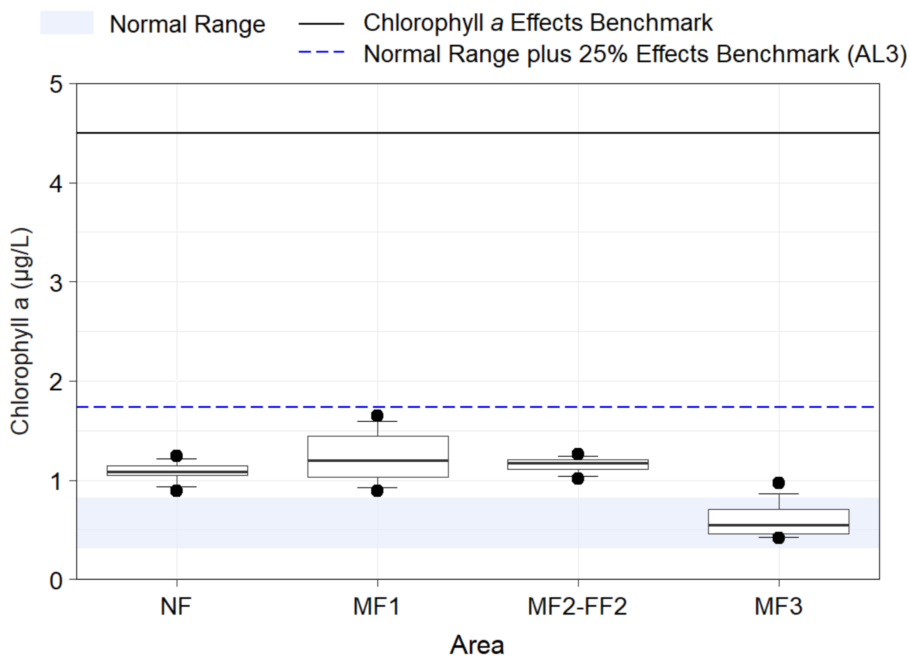


Note: Samples collected from Lac du Sauvage are presented to the left of the y-axis in a separate panel and LDG-48 in presented to the right of the y-axis. Shaded bands around fitted prediction lines are 95% confidence intervals.
AFDM = ash-free dry mass; NF = near-field; MF = mid-field; FF = far-field; LDG-48 = Lac de Gras outlet; LDS = Lac du Sauvage.

4.3.6 Action Level Evaluation

The 2018 AEMP results indicate that Action Level 1 has been triggered for nutrient enrichment, because the 95th percentile of the MF values for chlorophyll *a* was greater than normal range (Figure 4-13). In 2018, 12.2% of the lake area had chlorophyll *a* concentrations above the upper limit of the normal range. Therefore, Action Level 2, which is defined as an area of more than 20% of the lake surface above the normal range, was not triggered. According to the Response Framework, there are no corresponding actions to Action Level 1.

Figure 4-13 Concentrations of Chlorophyll *a* by Area in Lac de Gras, 2018



AL = Action Level; NF = near-field; MF = mid-field; FF = far-field

5 SEDIMENT CHEMISTRY

Sediment chemistry sampling was not completed in 2018. Consequently, Appendix III is a place-holder in this AEMP Annual Report.

6 PLANKTON

6.1 Introduction and Objectives

Plankton are small, usually microscopic plants and animals that live suspended in open water. For the purpose of the AEMP, phytoplankton refers to algae and zooplankton refers to microscopic animals, such as crustaceans (i.e., animals with hard shells similar to, but much smaller than, crabs or shrimp) that live suspended in lake water.

The overall objective of the plankton component of the AEMP is to monitor the potential ecological effects of the Mine on the phytoplankton and zooplankton communities in Lac de Gras, and to assess whether toxicological changes are occurring in the plankton community. The plankton component monitors phytoplankton and zooplankton community endpoints (i.e., abundance, biomass, and taxonomic composition) as indicators of potential effects. Changes in plankton can affect fish in the lake, because plankton are part of the food chain. Such changes to plankton can occur before fish are affected, which makes plankton a good early warning indicator.

The following is a summary of the 2018 plankton program. Appendix XI provides a more complete analysis and presents detailed results.

6.2 Methods

Phytoplankton and zooplankton samples were collected in the NF area and in three MF areas (i.e., MF1, MF2-FF2 and MF3 areas) of Lac de Gras (Figure 1-2). Samples were collected during the open-water season, from 21 to 29 August 2018. A depth-integrated sampler (Photo 4-1), which collected water from the surface to a depth of 10 m, was used to collect phytoplankton samples. Duplicate zooplankton samples were collected at each station using a plankton net (Photo 6-1). Each sample consisted of a composite of three vertical hauls through the entire water column, beginning at a depth of 1 m from the bottom. Phytoplankton samples were sent to Advanced Eco-Solutions Inc., Washington, USA, and zooplankton samples were sent to Salki Consultants Inc. in Winnipeg, Manitoba, Canada, for analysis of taxonomic composition, abundance, and biomass.

The importance of effects on phytoplankton or zooplankton biomass and taxonomic richness (i.e., the number of different types of organisms) was categorized according to Action Levels (Table 6-1). The magnitude of effect was evaluated by comparing community endpoints in the NF area to normal ranges defined based on the 2007 to 2010 reference condition (Golder 2018b).

Photo 6-1 Zooplankton sampling net

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[a]	Near-field	Examine ecological significance Set Action Level 4 Identify mitigation options
4	TBD[b]	TBD[b]	Define conditions required for the Significance Threshold
5[c]	Decline in biomass or richness likely to cause a greater than 20% change in fish population(s)	Far-field A (FFA)	Significance Threshold

a) Normal ranges were obtained from the AEMP Reference Conditions Report Version 1.3 (Golder 2018b).

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

c) Although the Significance Threshold is not an Action Level, it is shown as the highest Action Level to demonstrate escalation of effects towards the Significance Threshold.

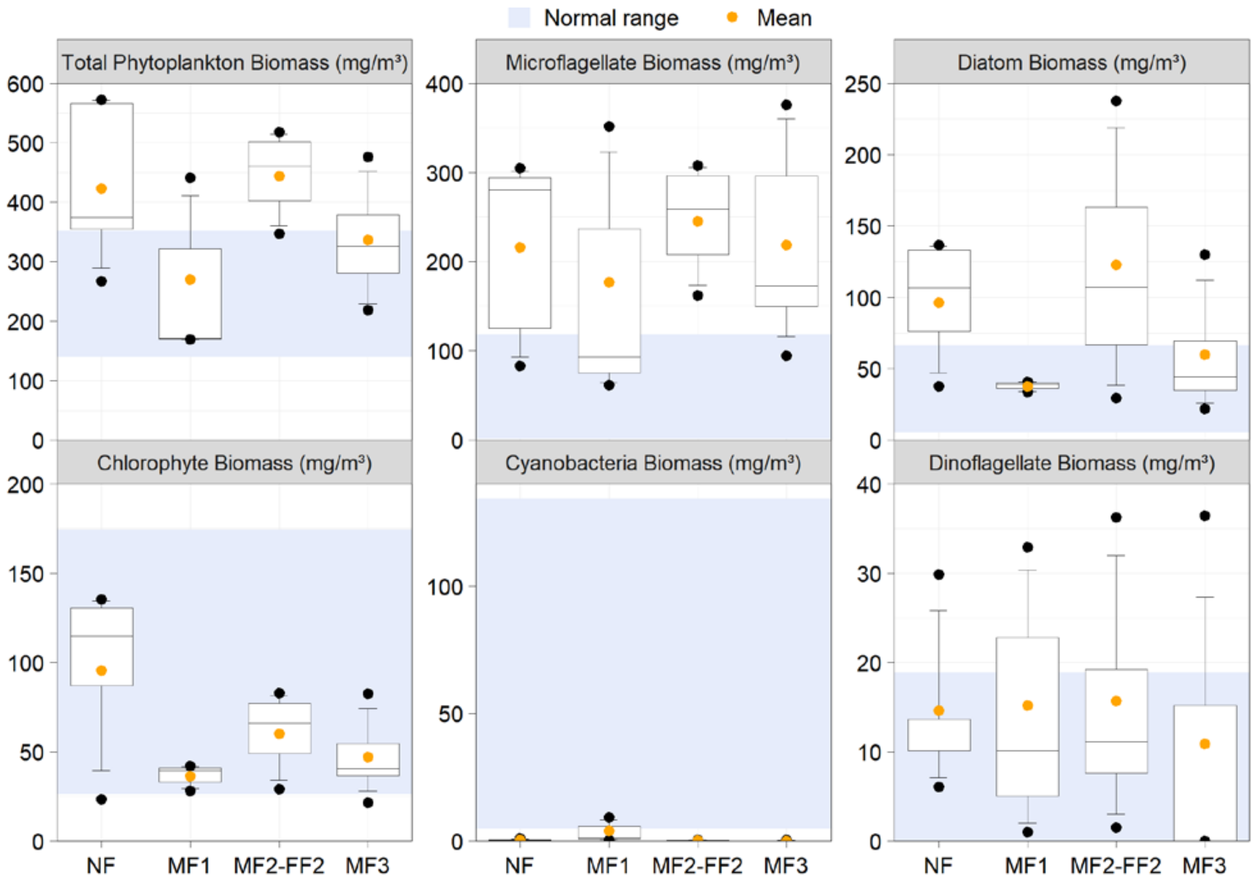
6.3 Results and Discussion

6.3.1 Phytoplankton

In 2018, the number of phytoplankton taxa at stations in the NF and MF areas were within the normal range. Mean total phytoplankton biomass, microflagellate, and diatom biomass in the NF area of Lac de Gras were above the normal range, while cyanobacteria biomass was below the normal range (Figure 6-1). Other phytoplankton groups were within their respective normal ranges in the NF area. Mean total phytoplankton biomass and diatom biomass in the MF2-FF2 area, and microflagellate biomass in all three MF areas were above the normal range. No clear spatial patterns in relation to distance from the effluent discharge were observed in phytoplankton taxonomic richness, biomass, or the biomass of the major groups in 2018.

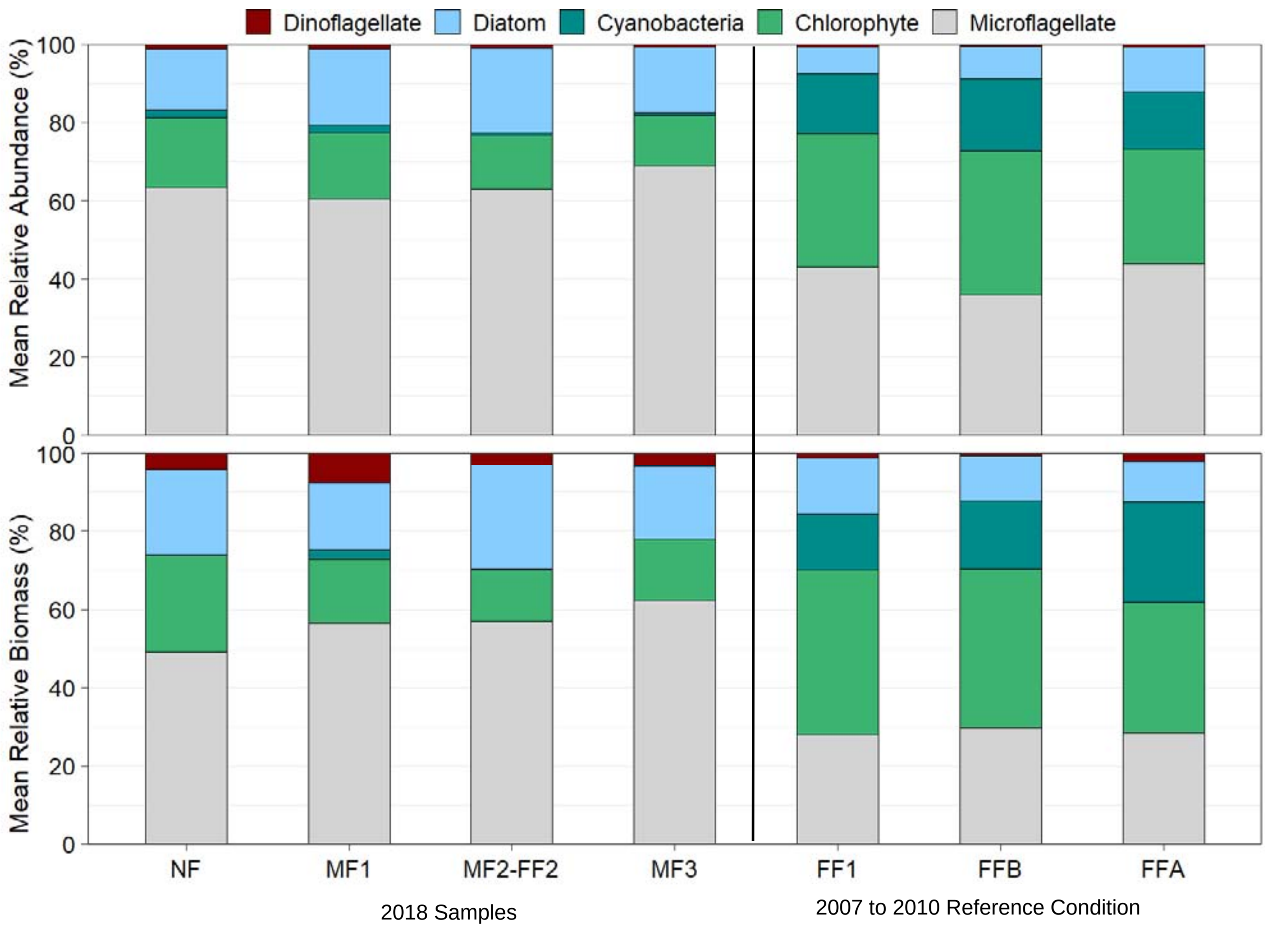
Phytoplankton community composition in the 2018 NF and MF areas of Lac de Gras had greater relative abundance and biomass of microflagellates and diatoms and a lower relative abundance and biomass of chlorophytes and cyanobacteria compared to the 2007 to 2010 reference area communities (Figure 6-2). While community differences were observed, these results should be interpreted with caution, as the change in taxonomist in 2013 places uncertainties in the results of comparisons of previous years results to the reference conditions. Overall, the 2018 phytoplankton results provided no evidence of toxicological impairment, and no Action Level was triggered.

Figure 6-1 Biomass of Major Phytoplankton Groups in Lac de Gras, 2018



NF = near-field; MF = mid-field; FF = far-field.

Figure 6-2 Mean Relative Phytoplankton Abundance and Biomass in Lac de Gras, 2018



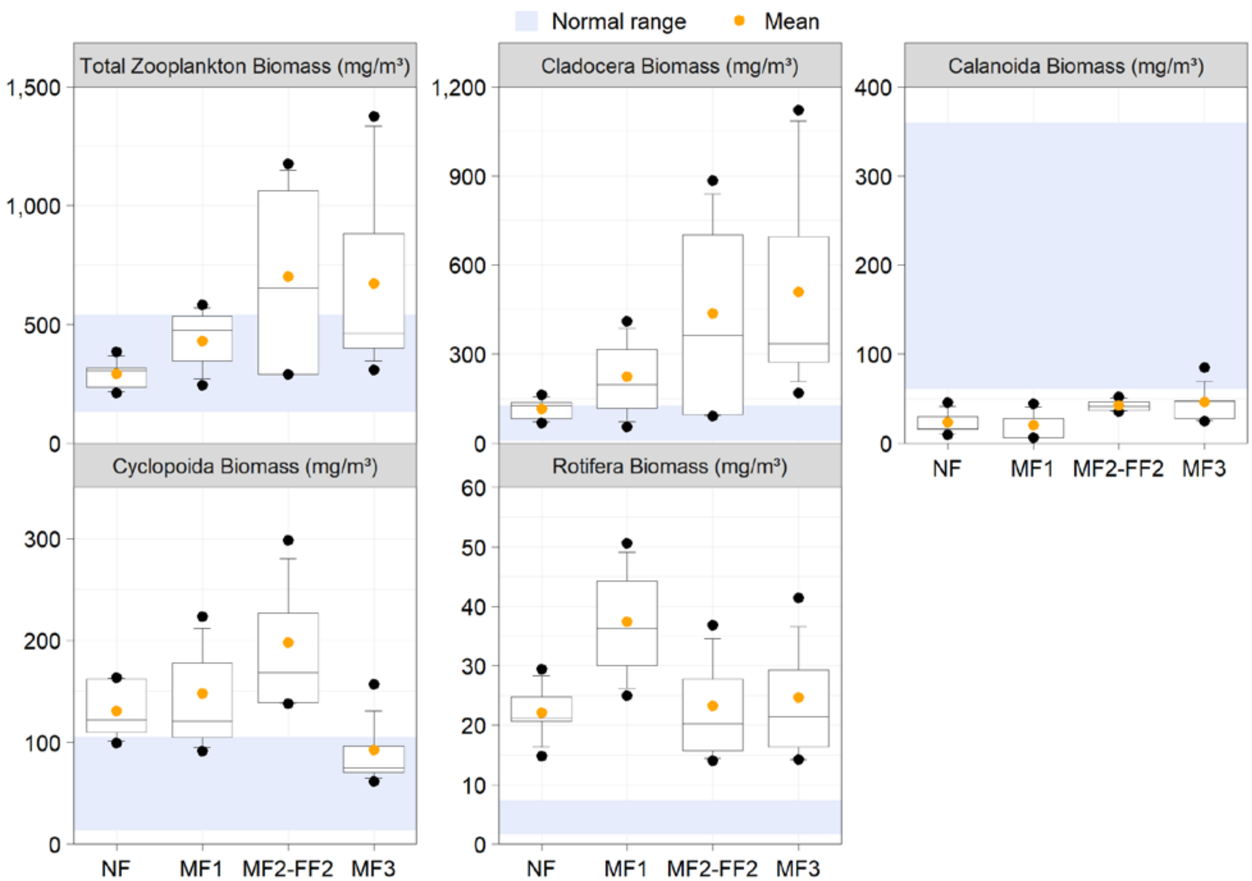
NF = near-field; MF = mid-field; FF = far-field.

6.3.2 Zooplankton

In 2018, the number of zooplankton taxa at stations in the NF and MF areas were within or slightly above the normal range and the NF area mean in 2018 was greater than the reference areas. Total zooplankton biomass and cladoceran biomass were greater in the MF areas compared to the NF area, with mean total zooplankton biomass above the normal range at MF2-1, MF2-3, MF3-1 and MF3-2 and mean cladoceran biomass above the normal range in all MF areas (Figure 6-3). Mean cyclopoid copepod biomass was above the normal range in the NF, MF1 and MF2-FF2 areas. Rotifer biomass was above the normal range at all stations in the NF and MF areas of Lac de Gras, while calanoid copepod biomass was below the normal range at the majority of stations. No clear spatial patterns were observed in cyclopoid, rotifer, or calanoid biomass in 2018.

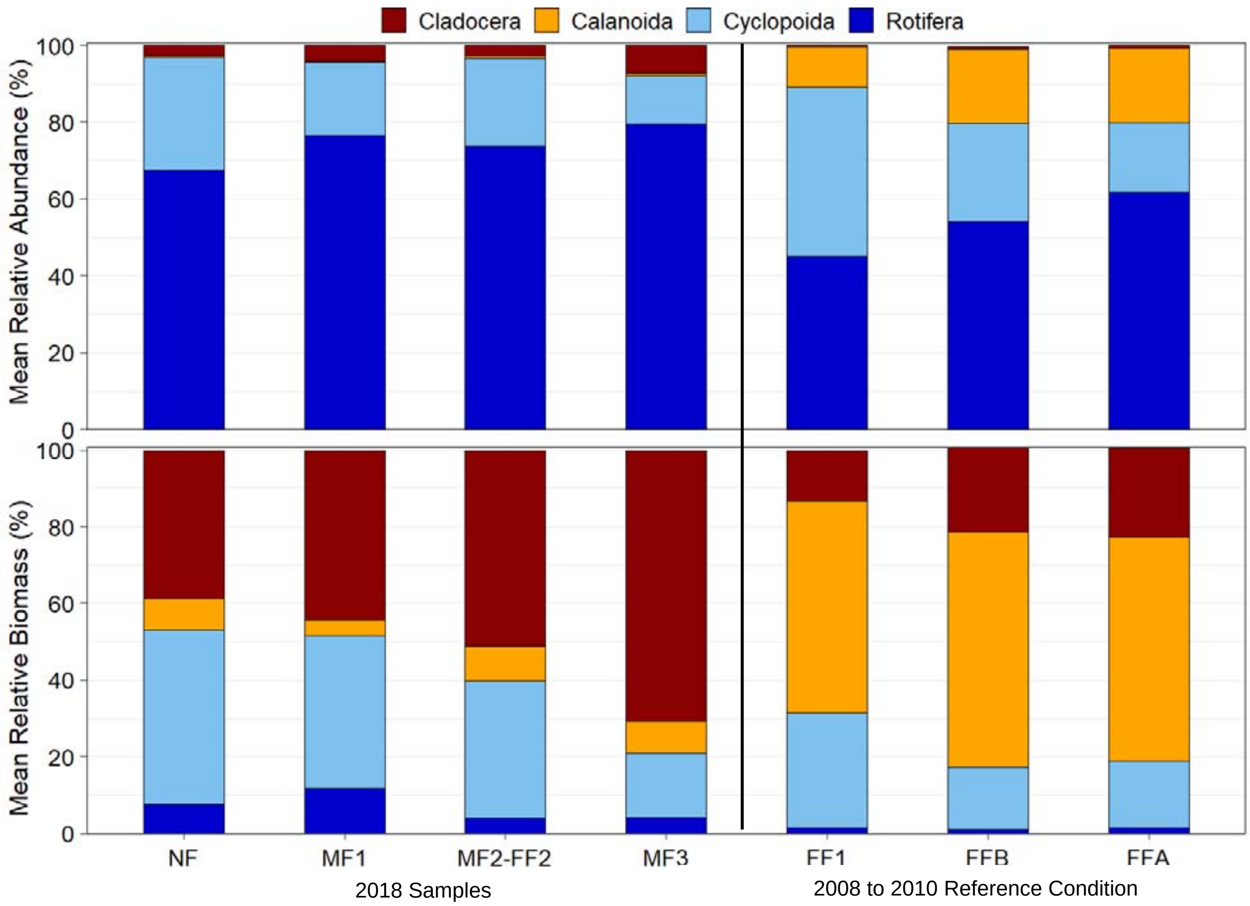
Zooplankton community composition in the NF and MF areas of Lac de Gras in 2018 was different from the reference condition (Figure 6-4). Mean relative abundance of zooplankton communities in the NF and MF areas were dominated by a greater number of rotifers, compared to the reference community. Relative abundances of copepods (i.e., cyclopoids and calanoids) in the NF and MF areas in 2018 were less than those in the reference community. Cladocerans were a minor component of the zooplankton community by abundance, but were more abundant in the MF2-FF2 and MF3 areas in 2018. Mean zooplankton biomass in the NF and MF areas was dominated by cladocerans, followed by cyclopoid copepods, while the reference communities were dominated by calanoid copepods followed by cyclopoid copepods or cladocerans. Overall, 2018 zooplankton results showed a community shift to more cladocerans and fewer copepods in the NF and MF areas compared to the reference condition. The 2018 zooplankton results provided no evidence of toxicological impairment, and no Action Level was triggered.

Figure 6-3 Biomass of Major Zooplankton Groups in Lac de Gras, 2018



NF = near-field; MF = mid-field; FF = far-field.

Figure 6-4 Mean Relative Zooplankton Abundance and Biomass in Lac de Gras, 2018



NF = near-field; MF = mid-field; FF = far-field.

7 BENTHIC INVERTEBRATES

Benthic invertebrate sampling was not completed in 2018. Consequently, Appendix IV is a placeholder in this AEMP Annual Report.

8 FISH

Large-bodied fish tissue sampling was not completed in 2018. Consequently, Appendix V is a placeholder in this AEMP Annual Report.

9 FISHERIES AUTHORIZATION AND SPECIAL EFFECTS STUDIES

9.1 Plume Delineation Survey

Plume delineation surveys did not take place in 2018. Consequently, Appendix VI is a place-holder in this AEMP Annual Report.

9.2 Fisheries Authorization Studies

9.2.1 Dike Monitoring Study

Dike monitoring did not take place in 2018. Consequently, Appendix VII is a place-holder in this AEMP Annual Report.

9.2.2 Fish Salvage Program

A fish salvage program was not conducted in 2018. Consequently, Appendix VIII is a place-holder in this AEMP Annual Report.

9.2.3 Fish Habitat Compensation Monitoring

A fish habitat offsetting monitoring program was not conducted in 2018. Consequently, Appendix IX is a place-holder in this AEMP Annual Report.

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

As per the AEMP Study Design Version 4.1, the fish tasting and texture studies have been incorporated into the Traditional Knowledge program. Further, the fish health and fish tissue chemistry programs were not conducted in 2018. Consequently, Appendix X is a place-holder in this annual report, and information relating to the fish tasting and texture studies conducted in 2018 have been incorporated into the Traditional Knowledge Studies (i.e., Section 10; Appendix XIV).

9.3 Special Effects Study Reports

There were no special effects studies in 2018. Consequently, Appendix XII is a place-holder in this AEMP Annual Report.

10 TRADITIONAL KNOWLEDGE STUDIES

10.1 Introduction and Objectives

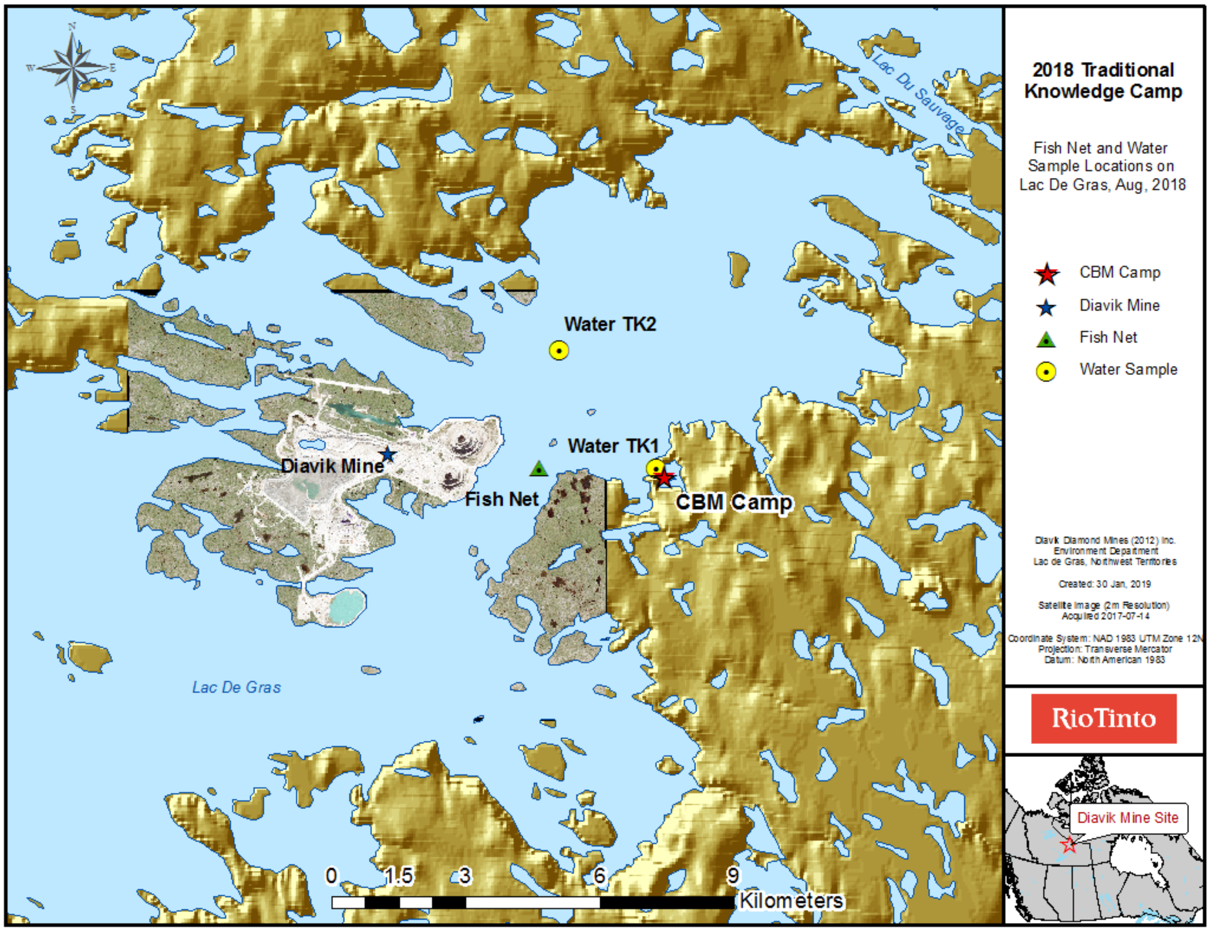
Traditional Knowledge is an integral component of the AEMP. The following is a summary of the 2018 Traditional Knowledge studies; Appendix XIV provides a more complete analysis and presents detailed results for Traditional Knowledge.

The objective of the Traditional Knowledge Study is to facilitate a two-way flow of information, resources, and understanding between the Traditional Knowledge holders and scientists regarding the health of fish and water in Lac de Gras during a camp held near the Diavik Diamond Mine at Lac de Gras during the summer of 2018. These efforts were part of the AEMP, established by DDMI with five Aboriginal parties to their Environmental Agreement: Kitikmeot Inuit Association (KIA), Łutsel K'e Dene First Nation (LKDFN), North Slave Métis Alliance (NSMA), Tłı̨chǫ Government (TG or Tłı̨chǫ), and Yellowknives Dene First Nation (YKDFN). The companion deliverable to this report is a video-documentary entitled *Our Youth, Our Future: Monitoring our Land, Water, Fish and Air* which was filmed and produced through a partnership of participating youth and a production crew (aRTLeSS Collective 2018, https://vimeo.com/322890065). The authors advise that it is important to consider the Traditional Knowledge report in conjunction with the video.

10.2 Methods

A two-day Planning Session was held in Yellowknife from 15 to 16 May 2018 where previous results were reviewed, and thoughts were shared about the future camp agenda, activities, logistics and lessons to teach. The 2018 Traditional Knowledge Camp with Elders, youth and scientists occurred from 2 August to 6 August 2018 on the southeast side of Lac de Gras (approximately 3.5 km from the Mine; Figure 10-1). The Traditional Knowledge Camp consisted of the fish health and palatability test, water quality and taste test, excursions on-the-land and to the Narrows, recording a video-documentary, various interviews, honouring cultural practices and ceremonies, and health and safety preparations. A verification workshop was held on 6 December and 7 December 2018 in Yellowknife to present preliminary results and to allow for meaningful community review of both the video-documentary and report.

Figure 10-1 Traditional Knowledge Study Fishnet Set Location and Water Sample Locations



All metals analyzed as part of the standard tissue metals scan are provided in the Traditional Knowledge report (Appendix XIV). Summary statistics, including sample size, percentage of metal concentrations greater than the DL, minimum, median, maximum, and SD values are included in the TK report. However, as previously indicated through AEMP Reviews, the TK fish palatability results are not suitable as an early warning trigger for conducting a larger mercury in Lake Trout program as the sampling protocols, sample size, fishing locations, and size of fish are not consistent between years because these are not items that participants identified as concerning. As such, detailed temporal or special statistical analyses of the fish tissue chemistry collected as part of the TK program is not appropriate.

10.3 Results and Discussion

A total of 36 fish (i.e., 35 Lake Trout and 1 Lake Whitefish) were captured from two locations. During the fish processing, fish were generally described as healthy with typical gills, tissue, skin, scales, hearts, livers, pipes (i.e., esophagus and stomach), and eggs. Size, shape and tissue rebound were also mostly rated typical. Four Lake Trout were baked, boiled, fried, and grilled and the taste description of each fish was positive (i.e., good, very good, healthy and typical). Participants suggested that the number of fish with cysts and worms (parasites) appeared to have increased compared to previous years. While some people recognized that parasites occur naturally and are present in fish within all communities, there was still an interest in trying to understand why fish in 2018 appeared to have more cysts than previous years. During the Verification Session in December, results of documented cysts from previous years were compared to 2018 and did not show and increase.

Camp participants determined that water quality was good by virtue of observing water clarity, movement, temperature, vegetation, fish activity, and taste. A water tasting test was conducted at two sampling locations (i.e., near the lakeshore and in deeper water) where samples were tested as tea, boiled then cooled and tested cold direct from Lac de Gras. Water “taken too close to the land” was described as “fishy” or “swampy” whereas water collected at depth in open water was much preferred. Water collected at the surface wasn’t as tasty as deep water. Overall, it was determined that the water remains “good” in Lac de Gras. Participants did not have any concerns or worries about water in Lac de Gras during the 2018 study.

Boat travel was limited due to the weather; however, participants made short trips to the Narrows between Lac de Gras and Lac du Sauvage. Returning to this important caribou crossing and cultural site was a powerful experience that inspired much storytelling. Throughout the camp, Elders shared important teachings, reflected on the past and spoke to the challenges facing youth and communities today. The camp was successful in bridging gaps between Nations, generations and disciplines. The importance of sharing and maintaining traditional laws as well as strength of youth stood out as key threads throughout the camp.

11 WEIGHT-OF-EVIDENCE

The weight-of-evidence evaluation was not required in 2018. Consequently, Appendix XV is a placeholder in this AEMP Annual Report.

12 ADAPTIVE MANAGEMENT RESPONSE ACTIONS

Part J, Schedule 8, Item 4d of Water Licence W2015L2-0001 requires that the Annual AEMP include an evaluation of any adaptive management response actions implemented during the year. In 2018 there were no specific response actions to evaluate.

A summary of the results of the AEMP Action Level assessment results is provided below.

Dust Deposition

There are no Action Levels for Dust Deposition in the Response Framework.

Effluent and Water Chemistry

Regulated effluent parameters were below applicable EQC values in 2018, and toxicity test results indicated that the effluent discharged to Lac de Gras in 2018 was non-toxic. Nineteen water quality variables measured in Lac de Gras triggered Action Level 1. No management action is required under the Response Framework when a variable triggers Action Level 1. Of the 19 variables that triggered Action Level 1, ten also triggered Action Level 2. The required management action when a water quality variable triggers Action Level 2 is to establish an AEMP Effects Benchmark for that variable if one does not already exist. One out of the ten variables (i.e., calcium) that triggered Action Level 2, does not have an existing Effects Benchmark. Therefore, DDMI will develop an AEMP Effects Benchmark for this variable as part of an AEMP Response Plan. None of the water quality variables triggered an effect equivalent to Action Level 3.

Eutrophication Indicators

Chlorophyll *a* concentrations were assessed for a Mine-related effect according to Action Levels in the Response Framework. Chlorophyll *a* concentrations in 2018 indicated that Action Level 1 had been triggered for eutrophication indicators. According to the Response Framework, Action Level 1 serves as an early warning, and no further action is required based on the 2018 monitoring results.

Plankton

There were no Action Level triggers for Plankton in 2018.

13 CONCLUSIONS AND RECOMMENDATIONS

13.1 Conclusions

Conclusions for each section of the 2018 AEMP report are summarized below.

Dust Deposition

- Dustfall levels were greater in 2018 than in recent years. Dustfall rates decreased with distance from the Mine, as observed in previous years.
- Although there are no dustfall standards for the Northwest Territories, 2018 dustfall rates were generally below the former BC MOE (2016) dustfall objective for mining, smelting, and related industries.
- Snow water chemistry variables of interest included aluminum, ammonia, arsenic, cadmium, chromium, copper, lead, nickel, nitrite, phosphorus, and zinc. Concentrations of these variables were below the effluent concentration limits in the Water Licence for all samples.

Effluent and Water Chemistry

- Regulated effluent parameters were below applicable EQC values in 2018, and toxicity test results indicated that the effluent discharged to Lac de Gras in 2018 was non-toxic.
- Of the water quality variables assessed, 19 triggered Action Level 1 (i.e., TDS [calculated], turbidity, calcium, chloride, magnesium, potassium, sodium, sulphate, nitrate, aluminum, antimony, barium, chromium, copper, manganese, molybdenum, silicon, strontium, and uranium). These variables were included in the list of SOIs in 2018.
- Of the 19 SOIs that triggered Action Level 1, ten also triggered Action Level 2 (i.e., TDS [calculated], calcium, chloride, sodium, sulphate, nitrate, antimony, molybdenum, strontium and uranium). The required management action when a water quality variable triggers Action Level 2 is to establish an AEMP Effects Benchmark for that variable if one does not already exist. One of the ten SOIs that triggered Action Level 2 in 2018 does not have an existing Effects Benchmark (i.e., calcium); therefore, DDMI will develop an AEMP Effects Benchmark for this variable. This will be done in an AEMP Response Plan.
- Four additional variables (i.e., ammonia, iron, lead and titanium) were added to the list of SOIs in 2018 because concentrations at potentially dust-affected stations in the MF area were greater than reference conditions for Lac de Gras.
- Seven metals (i.e., aluminium, antimony, boron, chromium, copper, lead, and tin) showed spatial trends consistent with a dike-related effect (specifically, related to the dewatering discharge) during the open-water season. These metals showed similar response during the in-water construction of the dike in 2016; however, concentrations of antimony, boron and tin were greater in 2018 than those measured in 2016.

Eutrophication Indicators

- The Mine had a nutrient enrichment effect in Lac de Gras, as evidenced by greater concentrations of nutrients in the NF and MF areas, and concentrations of chlorophyll *a* greater than the upper limit of the normal range. The introduction of nutrients by the Mine effluent, particularly phosphorus, was predicted to result in an increase in primary productivity (Government of Canada 1999).
- In 2018, 0.5% of Lac de Gras was considered affected by increased TP concentrations, based on concentrations elevated above the normal range. The extent of effects on TN concentrations was greater than or equal to 40.8% of the lake area.
- In 2018, the extent of effects on phytoplankton and zooplankton biomass (as AFDM) were 16.8% and greater than or equal to 12.8% of Lac de Gras, respectively.
- The extent of effects on chlorophyll *a* was greater than or equal to 12.8% of the lake area. The magnitude of the effect on chlorophyll *a* is equivalent to Action Level 1 in the Response Framework.

Plankton

- In 2018, mean total phytoplankton biomass and mean biomass of the major phytoplankton groups were either greater than, or within the normal range in the NF and MF areas, with the exception of cyanobacteria biomass. There were no clear spatial patterns in relation to the distance from the effluent discharge in phytoplankton biomass, richness, or the biomass of the major phytoplankton groups. The phytoplankton communities in the NF and MF areas of Lac de Gras were dominated by microflagellates, which differed from the reference condition.
- The phytoplankton results for 2018 continue to support the nutrient enrichment hypothesis and did not trigger an Action Level for toxicological impairment.
- In 2018, mean zooplankton biomass was within the normal range in the NF and MF-1 areas, and above the normal range in the MF2-FF2 and MF3 areas. In the MF2-FF2 and MF3 areas, stations with large zooplankton biomass above the normal range also had large cladoceran biomass. Mean cladoceran biomass was within the normal range in the NF area and above the normal range in the MF areas. Cyclopoid copepod biomass was above the normal range in the NF, MF1 and MF2-FF2 areas and close to the upper limit in the MF3 area, while calanoid copepod biomass was below the normal range for all but one station (MF3-2). Rotifer biomass was above the normal range at all stations in the NF and MF areas.
- Total zooplankton biomass and cladoceran biomass were greater in the MF areas compared to the NF area, with mean total zooplankton biomass above the normal range at MF2-1, MF2-3, MF3-1 and MF3-2 and mean cladoceran biomass above the normal range in all MF areas. Zooplankton taxonomic richness at all stations in the NF and MF areas was within or slightly above the normal range. Zooplankton community composition in the 2018 NF and MF areas of Lac de Gras differed from the reference communities.
- The zooplankton results for 2018 are consistent with nutrient enrichment, and did not trigger an Action Level for toxicological impairment.

13.2 Recommendations

Recommendations are typically provided for refining the AEMP to improve its effectiveness in each Annual Report, as necessary. There are no recommendations based on the 2018 AEMP results for the dust deposition, effluent and water chemistry, eutrophication indicators, and plankton components of the AEMP.

13.3 Summary

The AEMP is effective at monitoring the Mine effluent discharge and assessing potential ecological risks so that appropriate actions can be taken in the Mine operations to prevent adverse effects from occurring in the environment. Under the Response Framework, the AEMP is subject to response actions, if triggered, to confirm, further investigate, or mitigate effects documented by the AEMP. The AEMP design will be updated as new information and findings indicate it necessary.

14 CONTRIBUTORS

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APPENDIX I

DUST DEPOSITION REPORT

APPENDIX II

EFFLUENT AND WATER CHEMISTRY REPORT

APPENDIX III

SEDIMENT REPORT

No information was available for this appendix in 2018.

APPENDIX IV

BENTHIC INVERTEBRATE REPORT

No information was available for this appendix in 2018.

APPENDIX V

FISH REPORT

No information was available for this appendix in 2018.

APPENDIX VI

PLUME DELINEATION SURVEY

No information was available for this appendix in 2018.

APPENDIX VII

DIKE MONITORING STUDY

No information was available for this appendix in 2018.

APPENDIX VIII

FISH SALVAGE PROGRAM

No information was available for this appendix in 2018.

APPENDIX IX

FISH HABITAT COMPENSATION MONITORING

No information was available for this appendix in 2018.

APPENDIX X

FISH PALATABILITY, FISH HEALTH, AND FISH TISSUE CHEMISTRY SURVEY

Information relating to the fish tasting and texture studies conducted in 2018 have been incorporated into the Traditional Knowledge Studies (i.e., Section 10; Appendix XIV).

No Fish Health or Fish Tissue Chemistry information was available for this appendix in 2018.

APPENDIX XI

PLANKTON REPORT

APPENDIX XII

SPECIAL EFFECTS STUDY REPORT

No information was available for this appendix in 2018.

APPENDIX XIII

EUTROPHICATION INDICATORS REPORT

APPENDIX XIV

TRADITIONAL KNOWLEDGE STUDIES

APPENDIX XV

WEIGHT-OF-EVIDENCE REPORT

No information was available for this appendix in 2018.