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September 17, 2018

Angela Love, EP
Regulatory Specialist
Mackenzie Valley Land and Water Board
P.O. Box 2130
Yellowknife, Northwest Territories
X1A 2P6

Dear Ms. Love:

RE: AEMP Response Plan – Water Quality, Plankton and Benthic Invertebrates at Gahcho Kué Mine (MV2005L2-0015), Version 2

De Beers is pleased to submit the Version 2 of the AEMP Response Plan for Water Quality, Plankton and Benthic Invertebrates at Gahcho Kué Mine, for the conformity confirmation by the Board staff.

This Plan is submitted in accordance with the additional requirements in the approval of the Version 1 of the Response Plan. These requirements include:

Review Comment ID	Recommendation	Required Update
ECCC-2	ECCC recommends that De Beers Canada Inc. (the Proponent) provide comparison to the AEMP benchmark for the action level for nutrient enrichment	De Beers to provide a comparison to the AEMP benchmark of nitrate in Table 3.1-2 as suggested by ECCC-2.
ECCC-3 & ECCC-4	ECCC recommends that the Proponent provide data or graphical representation to support the rationale provided and aid reviewers in the analysis of whether the low action level exceedance is a mine related effect, a result of annual variability, or due to the limited baseline data	De Beers to include the figures or figure references in section 3.2.3 and 3.3.3 and any other sections that require data or graphical support.
ENR-2	In any cases where De Beers concludes that increases in parameters are of low consequence given that increases were predicted in the EIS, ENR recommends that summary tables be updated to include an additional column which outlines EIS prediction values (or ranges) for that parameter.	De Beers to update the necessary summary tables to include an additional column which outlines EIS prediction values (or ranges) for that parameter.

Should you have any questions or comments, please contact me directly at (867) 445-1485 or at william.liu@debeersgroup.com.

Sincerely,

William Liu
Regulatory Specialist

Cc: Sarah McLean, DBCI
Joe Heron, GNWT, Lands

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Gahcho Kué Mine

2017 Aquatic Effects Monitoring Program Response Plan for Water Quality, Plankton, and Benthic Invertebrates – Version 2

October 2018

ABBREVIATIONS AND ACRONYMS

Abbreviation / Acronym	Definition
AEMP	Aquatic Effects Monitoring Program
ANOSIM	analysis of similarities
BACI	before-after control-impact
CCME	Canadian Council of Ministers for the Environment
CWQG-PAL	Canadian water quality guideline for the protection of aquatic life
De Beers	De Beers Canada Inc.
DO	dissolved oxygen
EIS	Environmental Impact Statement
e.g.	for example
Golder	Golder Associates Ltd.
i.e.	that is
MDS	multidimensional scaling
Mine	Gahcho Kué Mine
MVLWB	Mackenzie Valley Land and Water Board
nMDS	non-metric multidimensional scaling
NWT	Northwest Territories
SNP	Surveillance Network Program
TDS	total dissolved solids
WMP	water management pond

UNITS OF MEASURE AND SYMBOLS

Unit / Symbol	Definition
%	percent
↑	increase
↓	decrease
mg/L	milligrams per litre
mg-N/L	milligrams of nitrogen per litre
org/m^2	organisms per square metre
µg/L	micrograms per litre

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1 INTRODUCTION

De Beers Canada Inc. (De Beers) monitors hydrology, water and sediment quality, plankton, benthic invertebrates, and fish and fish habitat in lakes and streams near the Gahcho Kué Mine (Mine) as components of the Aquatic Effects Monitoring Program (AEMP). The purpose of the AEMP is to identify potential effects of the Mine on the surrounding aquatic environment and evaluate whether aquatic ecosystems and their uses are adequately protected in areas affected by the Mine. Monitoring under the AEMP is a requirement of Water Licence MV2005L2-0015, issued by the Mackenzie Valley Land and Water Board (MVLWB or the Board; MVLWB 2014).

The 2017 AEMP was conducted by Golder Associates Ltd. (Golder) according to the approved AEMP Design Plan Version 5, which was submitted to MVLWB in January 2016 (De Beers 2016a). The AEMP endpoints are assessed for a Mine-related effect according to Action Levels in the AEMP Response Framework described in Section 8 of the AEMP Design Plan. Action Levels address the three impact hypotheses evaluated by the AEMP:

- the toxicological impairment hypothesis;
- the nutrient enrichment hypothesis; and
- the physical habitat alteration hypothesis.

Action Levels for physical habitat alteration were not assessed in 2017 due to the considerations discussed in Section 8.6.2 of the 2017 AEMP Annual Report (De Beers 2018a), and are not discussed further herein.

Based on results of the 2017 AEMP, Action Level triggers were identified for:

- toxicological impairment:
  - one water quality parameter in Area 8 (under-ice: uranium) and five water quality parameters in Lake N11 (under-ice: calculated total dissolved solids [TDS], nitrate, nickel, and strontium; open-water: barium and strontium); and
  - one benthic invertebrate community variable (Pisidiidae density) in Lake N11.
- nutrient enrichment:
  - one water quality parameter in Lake N11 (under-ice: nitrate);
  - one plankton variable (phytoplankton community composition) in Lake N11; and
  - five benthic invertebrate community variables (total density, richness and the densities of Nematoda, Pisidiidae, and *Micropsectra/Tanytarsus*) in Area 8.

De Beers notified the MVLWB of these Action Level exceedances on April 12, 2018, in accordance with Part 1 Condition 7 of the Water Licence MV2005L2-0015 (De Beers 2018b). The submission of this Response Plan satisfies the requirements of Schedule 6, Item 4 of the Water Licence, which states that De Beers is required to submit an AEMP Response Plan within ninety days of when the exceedances were detected.

In accordance with Schedule 6, Item 4 of Water Licence MV2005L2-0015, the Response Plan should contain the following information where appropriate:

a) *a description of the parameter, its relation to Significance Thresholds and the ecological implication of the Action Level exceedances;*

b) *a summary of how the Action Level exceedance was determined and confirmed;*

c) *recommended values for subsequent Action Levels;*

d) *a description of likely causes of the Action Level exceedances and potential mitigation options if appropriate;*

e) *a description of actions to be taken by the Licensee in response to the Action Level exceedances including:*

   i) *a justification of the selected action, which may include a cost/benefit analysis;*

   ii) *a description of timelines to implement the proposed actions;*

   iii) *a projection of the environmental response to the planned actions, if appropriate;*

   iv) *a monitoring plan for tracking the response to the actions, if appropriate; and*

   v) *a schedule to report on the effectiveness of actions and to update the AEMP Response Plan as required; and*

f) *Any other information necessary to assess the response to an Action Level exceedance or that has been requested by the Board.*

Components of the aquatic environment that triggered Action Levels for toxicological impairment and nutrient enrichment are presented in the sections that follow, along with a discussion of the likely causes, ecological implications, and response actions. Full details relating to the annual monitoring results for these components are provided in the corresponding sections of the 2017 AEMP Annual Report (De Beers 2018a).

2 TOXICOLOGICAL IMPAIRMENT

2.1 Water Quality

2.1.1 Parameter Description

The 2017 water quality data were evaluated in relation to Action Levels for toxicological impairment responses under the Response Framework in the AEMP Design Plan (De Beers 2016a). Based on the toxicological impairment hypothesis, concentrations of five water quality parameters in Lake N11 (TDS, nitrate, barium, nickel, strontium) and one in Area 8 (uranium) triggered a Low Action Level.

The Significance Thresholds for Lake N11, Area 8, and all waters downstream of Kennady Lake are defined in Section 8.3 of the AEMP Design Plan (De Beers 2016a). Significance Thresholds are the levels of change that, if exceeded, would result in significant adverse effects to valued components of the environment. The selection of Significance Thresholds was based on the commitment by De Beers that traditional water uses should not be affected by mining activities throughout construction, operations, and closure and reclamation. Traditional water uses include drinking the water and harvesting and consuming fish. The Significance Thresholds for the water quality component are defined as:

- Water is not drinkable (i.e., risk to human health and/or wildlife).
- Ecological function is not maintained (i.e., inadequate food for fish; fish unable to survive, grow and reproduce; and/or sustained absence of a fish species).

An effect equivalent to the Significance Threshold for a water quality parameter would occur if:

- a risk assessment determined that water is not safe for humans and or wildlife, or
- if water quality conditions result in an adverse effect on ecological function to the extent that it is no longer maintained.

The Low Action Levels triggered in 2017 pertain to ecological function. No Action Levels were triggered for drinking water; therefore, Action Levels and the Significant Threshold related to drinking water are not discussed further in this document.

2.1.2 Action Level Determination

Action Levels for toxicological impairment for the water quality component, as it relates ecological function, are defined in the AEMP Design Plan (Section 8.4; De Beers 2016a) and are reproduced in Table 2.1-1. The Action Level classifications incorporate the results of the before-after control-impact (BACI) analysis and comparisons of AEMP data to the normal range, as described in Sections 5.2.3.2.3 and 5.2.3.2.2, respectively of the 2017 AEMP Annual Report (De Beers 2018a).

To assess whether, on average, water quality parameter concentrations or values measured in the core lakes in 2017 fell outside the range of natural variability, whole-lake mean/median concentrations were compared to their representative normal ranges. In general, the normal ranges were developed in consideration of baseline data (i.e., 1996 to 2013, or a subset of those years). The method to calculate the normal ranges for whole-lake mean concentrations is described in the 2015 AEMP Annual Report (De Beers 2016b).

Table 2.1-1 Action Levels for Toxicological Impairment for the Water Quality Component

Action Level	Toxicological Impairment
Low[a]	Lake-wide average value/concentration greater than normal range or EIS prediction, supported by a visual temporal trend **AND** Lake-wide average concentration exceeds 75% of AEMP benchmark[b] **OR** Relative difference between core lake and reference lakes statistically significant compared to baseline (i.e., significant BACI effect detected)
Moderate	*TBD*[c]
High	*TBD*[c]

a) Changes below the Low Action Level are within the estimated magnitude of background variation and are considered to represent negligible levels of environment change.

b) Benchmarks currently used in the AEMP to which substance concentrations are compared (i.e., EIS benchmarks and CCME guidelines for the protection of aquatic life). This criterion does not apply if no benchmark exists.

c) TBD if Low Action Level is reached.

TBD = to be determined; BACI = before-after control-impact; AEMP = Aquatic Effects Monitoring Program; EIS = Environmental Impact Statement.

To evaluate potential Low Action Level triggers, concentrations in core lakes were compared to AEMP benchmarks, which were developed based on Canadian Council of Ministers for the Environment Canadian water quality guidelines for the protection of aquatic life (CCME CWQG-PAL; CCME 1999); some of the AEMP benchmarks are lake specific, as defined in Table 9.2-5 of the AEMP Design Plan (De Beers 2016a).

For the purpose of the Action Level evaluation, it was assumed that the criterion related to the BACI analysis was met if:

1) significant BACI effects are detected relative to both reference lakes, with the changes representing increases relative to the reference lakes;

2) the measurement endpoint (i.e., concentration or value) in the *impact* (i.e., core) lake showed a clear increase between the *before* and the *after* period, with the exception of pH and dissolved oxygen (DO), which could cause toxicological impairment if they decrease, and the direction of this change differed from the trends observed in the *control* (i.e., reference) lakes; and

3) the effects can be linked to the Mine through corresponding changes of sufficient magnitude in other ecosystem components (e.g., hydrology, Surveillance Network Program [SNP] results, and potentially other supporting environmental data).

During the ice-cover season, significant BACI effects were detected in Lake N11 for TDS, nitrate, nickel, and strontium (Table 2.1-2). Lake-wide mean/median ice-cover concentrations of these four parameters also exceeded the normal range in Lake N11. As a result, a Low Action Level was triggered for TDS, nitrate, nickel, and strontium during ice-cover conditions based on the toxicological impairment hypothesis.

During the open-water season, significant BACI effects with a positive effect size were detected for concentrations of barium and strontium in Lake N11 (Table 2.1-2). Lake-wide mean/median concentrations of these two parameters were also above the upper bound of the normal range in Lake N11. Open-water concentrations of barium and strontium in Lake N11 therefore triggered a Low Action Level based on the toxicological impairment hypothesis.

During the open-water season, significant BACI effects relative to both reference lakes were measured for uranium in Area 8 (Table 2.1-2). Uranium concentrations did not exceed water quality guidelines or 75% of the AEMP benchmarks; however, lake-wide mean/median uranium concentrations were above the upper bound of the normal range in Area 8. As a result, a Low Action Level for uranium in Area 8 was triggered based on the toxicological impairment hypothesis.

In reference to the 2012 Supplemental EIS (De Beers 2012), lake-wide mean/median concentrations of TDS, nitrate, total nickel, barium, and strontium in Lake N11 were less than the maximum predicted concentrations during operations, with the exception of strontium during the ice-cover season (Table 2.1-2). For Area 8, water quality predictions were not tabulated for the operations phase in the EIS; however, they were graphically represented for each parameter. The rationale was that during operations, parameter concentrations were predicted to primarily increase only as a result of evaporation; that is, the increase in residence time and evaporation rates due to the short-circuiting of Area 8 would result in all parameter concentrations being above background concentrations during operations. The magnitude of the increase above background is illustrated in the time-series plots presented in the 2012 Supplemental EIS (Appendix 8.IV, pages 8.IV-20 to 8.IV-38; De Beers 2012).

Table 2.1-2 Summary of Comparisons for Water Quality Action Levels for Toxicological Impairment

Lake	Parameter	Unit	Normal Range		2017 AEMP Lake-wide Mean/ Median	Normal Range Exceeded?	AEMP Benchmark	Exceeds 75% of AEMP Benchmark?	EIS Predictions (Maximum Operations Conditions)[b]	Exceeds EIS Predictions?	BACI Analysis	
			Lower Bound	Upper Bound							Type of Effect[a]	Direction Relative to Reference Lakes
Ice-cover												
Lake N11	TDS, calculated	mg/L	5	8.2	19	yes	500	no (4%)	57	no	Press and Pulse	↑
	Nitrate	mg-N/L	0.00496	0.0403	0.62	yes	2.93	no (21%)	1.5	no	Press and Pulse	↑
	Nickel	µg/L	0.216	0.344	0.536	yes	25	no (2%)	1.2	no	Press	↑
	Strontium	µg/L	9.23	13	18	yes	14,000	no (0.1%)	15	yes	Press and Pulse	↑
Open-water												
Lake N11	Barium	µg/L	1.96	2.49	2.73	yes	1,000	no (0.3%)	17	no	Pulse	↑
	Strontium	µg/L	6.01	6.54	8.51	yes	14,000	no (0.1%)	15	no	Pulse	↑
Area 8	Uranium	µg/L	0.00502	0.00854	0.0107	yes	15	no (0.1%)	nd[c]	no	Press	↑

a) Press (long-term) and pulse (short-term) effects.

b) Source: De Beers (2012). Note that the 2012 Supplemental EIS predictions were not separated by ice-cover and open-water seasons. Therefore, the maximum predictions for operations would have been equivalent to under-ice conditions.

c) The 2012 Supplemental EIS (De Beers 2012) does not specifically present tabulated water quality parameter concentrations for Area 8 during operations. However, time-series plots for all water quality parameters, which include the Mine operations phase, are included in Appendix 8.IV (pages 8.IV-20 to 8.IV-38).

BACI = before-after control-impact; EIS = Environmental Impact Statement; TDS = total dissolved solids; ↑ = increase; - = not applicable or data not available; mg/L = milligrams per litre; mg-N/L = milligrams of nitrogen per litre; µg/L = micrograms per litre.

2.1.3 Likely Causes and Lines of Evidence

Although water quality in Lake N11 and Area 8 satisfied the Low Action Level conditions for toxicological impairment, analysis of other lines of evidence provided no consistent indication of a toxicological impairment effect in Lake N11 and Area 8. This interpretation is based on the following lines of evidence:

- Significant BACI effects indicating increasing concentrations relative to both reference lakes and concentrations above the normal ranges in Lake N11 were identified for TDS, nitrate, total nickel, and strontium during ice-cover conditions, and specific conductivity, pH, barium, and strontium during open-water conditions (Figures 5.4-27 to 5.4-30 and Figures 5.4-32, 5.4-34, 5.4-35, and 5.4-38, respectively in the 2017 AEMP Annual Report; see also Appendix 5D; Golder 2018a). These changes are attributed to the operational discharges from the water management pond (WMP) to Lake N11. However, lake-wide mean/median concentrations for all water quality parameters in Lake N11 during ice-cover and open-water conditions were within expectations, and remained below 75% of the AEMP benchmarks (De Beers 2010, 2011, 2012). A change in water quality was expected during operations; the EIS projected that concentrations of nutrients, TDS, major ions, and some metals in Lake N11 would increase as a result of operational discharge from the WMP to Lake N11, but were anticipated to remain within AEMP benchmarks (De Beers 2011, 2012; see also modelled water quality parameter time series plots for Lake N11 in Appendix 9.II of the 2012 EIS Supplement, pp. 9.II-1 through 9.II-19).
- Significant BACI effects indicating increasing concentrations relative to both reference lakes and concentrations above the normal ranges were identified for uranium in Area 8 during open-water conditions (Figures 5.4-24 and 5D-62a in the 2017 AEMP Annual Report; Golder 2018a). These increasing concentrations may be related to hydrological changes to Area 8 through its isolation from Kennady Lake and its upper watershed, resulting in a modified watershed area and reduced flows (i.e., longer retention time and greater potential for evaporation). Further compounding the hydrological changes was the consecutive dry climate conditions and the short duration of downstream flow mitigation pumping from Lake N11. A combination of these factors has likely influenced water quality in Area 8, and therefore contributed to the increasing concentrations of these parameters, especially during ice-cover conditions. A change in water quality was expected during operations; the EIS projected that concentrations of nutrients, TDS, major ions, and some metals in Area 8 would increase as a result of isolation of Area 8 from Kennady Lake, but were anticipated to remain within AEMP benchmarks (De Beers 2011, 2012; see also modelled water quality parameter time series plots for Area 8 in Appendix 8.IV of the 2012 EIS Supplement, pp. 8.IV-20 through 8.IV-38).
- Concentrations of the parameters listed above exceeded the upper bound of their respective normal ranges. However, there is uncertainty associated with the accuracy of the normal ranges, as a result of limited data used to calculate them. The core lake normal ranges may be re-defined at the Aquatic Effects Re-evaluation stage, based on an evaluation of data collected from each core lake during the construction and early operational phases of the Mine.
- The Low Action Level triggers in 2017 are attributed in part to the application of highly conservative Action Level criteria. Under the current AEMP Response Framework, a Low Action Level is triggered for water quality if the lake-wide average of a parameter exceeds the normal range and <u>either</u> there is a significant BACI effect <u>or</u> lake-wide average concentration exceeds 75% of the AEMP benchmark. The Action Level criteria used for assigning a Low Action Level for toxicological impairment should be revised so that the sensitivity of the AEMP Response Framework is appropriate for responding to Mine-related effects or appropriate magnitude. This recommended revision involves changing the Low Action Level definitions to replace the "or" logical operator with "and", thereby requiring all three criteria be met

before a Low Action Level is triggered. Under the current Action Level definition, the Low Action Level was triggered when the lake-wide average concentration was less than 5% (all but one parameter) to 21% (nitrate) of the AEMP benchmark (Table 2.1-2), indicating negligible concern related to toxicological impairment.

2.1.4 Ecological Implications

The Low Action Level triggers identified for water quality during the 2017 monitoring period are considered to represent a low-level effect on water quality in Lake N11 and Area 8, well below levels that would be of concern to aquatic life. Concentrations of each parameter that triggered Low Action Levels based on the toxicological impairment hypothesis remain below AEMP benchmarks for the protection of aquatic life. The ecological implications of the observed change in water quality on the aquatic ecosystems of Lake N11 and Area 8 are therefore considered to be negligible to minor.

2.1.5 Response Actions

Annual and seasonal water quality monitoring will continue in the core and reference lakes, according to the schedule defined in the AEMP Design Plan (De Beers 2016a). The 2018 AEMP monitoring data will be examined to confirm whether the observed changes in water quality in Lake N11 and Area 8 have persisted or reverted back to conditions similar to baseline. The results will be reported in the 2018 AEMP Annual Report, to be submitted in May 2019. Weight-of-evidence assessment will continue as part of the 2018 AEMP to determine the strength of linkage between exposure, toxicity, and field biological responses.

The water quality parameters that triggered Low Action Levels in 2018 did so based on the results of the BACI analysis and/or normal range comparisons. Lake-wide average concentrations of all parameters were well below 75% of AEMP benchmark criterion. Therefore, concentrations of water quality parameters with Low Action Level exceedances do not represent concentrations expected to adversely affect aquatic life.

The results of the water quality data analysis provide some indication that the Low Action Levels triggered represent Mine-related effects in Lake N11 and Area 8. However, the magnitudes of the observed effects are low and not reflective of the changes typically associated with an Action Level trigger. Therefore, the main response action is intended to address oversensitivity of the currently approved Action Levels in response to Mine-related effects. Data analysis methods used for the AEMP that may have contributed to the unrealistically high sensitivity of the Action Levels will also be examined as part of the Aquatic Effects Re-evaluation and changes to the Action Levels will be proposed as appropriate. The Aquatic Effects Re-evaluation Report is scheduled to be submitted to the MVLWB in December 2019.

Data handling and analysis methods used for the AEMP that may have contributed to oversensitivity of the Action Levels will also be examined in the Aquatic Effects Re-evaluation Report. Consideration will be given to specific recommendations for changes to Action Levels and data analysis methods provided in Section 4 of this technical memorandum.

2.2 Benthic Invertebrate Community

2.2.1 Parameter Description

The 2017 benthic invertebrate community data were evaluated in relation to Action Levels for toxicological impairment and nutrient enrichment under the Response Framework in the AEMP Design Plan (De Beers 2016a). Results of the Action Level determination indicate that the density of Pisidiidae (fingernail clams) triggered a Low Action Level for toxicological impairment in Lake N11. None of the variables evaluated in Area 8 triggered Action Levels based on the toxicological impairment hypothesis.

The Significance Threshold for benthic invertebrates is defined in terms of a corresponding effect on fish communities, as:

- *Ecological function is not maintained (i.e., inadequate food for fish; fish unable to survive, grow and reproduce; and/or sustained absence of a fish species).*

Therefore, an effect equivalent to the Significance Threshold for benthic invertebrates would occur if changes in benthic invertebrate abundance or community structure resulted in a change in food availability that adversely affects fish communities.

2.2.2 Action Level Determination

Action Levels for toxicological impairment for the benthic invertebrate component are defined in the AEMP Design Plan (Section 8.4; De Beers 2016a) and are reproduced in Table 2.2-1. The Action Level classifications incorporate the results of the BACI analysis and comparisons of AEMP data to the normal range, as described in Sections 8.2.3.5.2 and 8.2.3.4, respectively, of the 2017 AEMP Annual Report (De Beers 2018a).

Table 2.2-1 Action Levels for Toxicological Impairment for the Benthic Invertebrate Component

Action Level	Toxicological Impairment
Low[(a)]	Lake-wide average value for total density, richness, Simpson’s diversity index, or densities of dominant taxa less than normal range **OR** Relative difference in total density, richness, Simpson’s diversity index, or densities of dominant taxa, between core lake and reference lakes statistically significant compared to baseline (i.e., significant BACI effect detected)
Moderate	*TBD*[(b)]
High	*TBD*[(b)]

a) Changes below the Low Action Level are within the estimated magnitude of background variation and are considered to represent negligible levels of environmental change.

b) TBD if Low Action Level is reached.

BACI = before-after control-impact; TBD = to be determined.

For the purpose of the Action Level evaluation, it was assumed that the criterion related to the BACI analysis was met only if:

1) the BACI interaction term was significant relative to both reference lakes, with the changes occurring in the same direction relative to both reference lakes; and

2) the direction of the effect was consistent with the impact hypothesis (i.e., an increase in a variable in the exposure area would indicate a nutrient enrichment effect, whereas a decrease would indicate a toxicological effect).

One variable (Pisidiidae density) in Lake N11 had a significant BACI effect with a response pattern showing an overall decrease in density relative to each of the reference lakes (Table 2.2-2). This resulted in a Low Action Level trigger based on the toxicological impairment hypothesis. Average values for all variables in Lake N11 were within the normal range. None of the variables evaluated in Area 8 triggered a Low Action Level based on the toxicological impairment hypothesis.

Table 2.2-2 Summary of Comparisons for Benthic Invertebrate Action Levels for Toxicological Impairment

Area	Variable	Normal Range		2017 AEMP Lake-wide Mean	Outside Normal Range?	BACI Analysis	
		Lower Bound	Upper Bound			Type of Effect	Direction Relative to Reference Lakes
Lake N11	Pisidiidae Density (org/m^2)	247	2,455	582	No	Press	↓

BACI = before-after control-impact; org/m^2 = organisms per square metre; ↓ = decrease.

2.2.3 Likely Causes and Lines of Evidence

Although density of Pisidiidae satisfied the Low Action Level conditions for toxicological impairment, analysis of the benthic invertebrate community data in Lake N11 provided no consistent indication of a toxicological effect in Lake N11. The observed responses, rather, appear to be related to habitat characteristics and year-to-year variability in the benthic invertebrate community. This conclusion is based on the following lines of evidence:

- The results of the habitat evaluation in 2017 indicate that the density of Pisidiidae was positively correlated with the percentage of fine sediments at AEMP stations (Table 8.4.2 in the 2017 AEMP Annual Report; Golder 2018a). Qualitative comparison of the variation in Pisidiidae density among years and lakes with that observed in percent fine sediment indicates that these variables follow a similar pattern. This suggests that the percentage of fines found at a station likely accounts for a portion of the variation observed in the density of Pisidiidae among years and lakes. This interpretation is supported by studies in the primary literature that have reported that pisidiid clams, particularly *Pisidium* sp., the dominant genus in these lakes, show a preference for habitats with a high proportion of fine sediments (Hamill et al. 1979; Dillon 2004).
- The results of the data analysis in 2017 showed that although the density of Pisidiidae decreased in Lake N11 from the *before* to the *after* period relative to each of the reference lakes, the trend from 2015 to 2017 (i.e., during AEMP monitoring years) has been an increase in the density of this taxon (Figures 8.4-22 and 8A-21 in the 2017 AEMP Annual Report; Golder 2018a). In addition, as discussed in the 2017 AEMP Annual Report and in previous annual reports, inclusion of a single year of *before* data in the BACI analysis may interfere with the ability of the analysis to detect true changes from baseline, as the small sample size included in the *before* group may not provide an adequate estimate of natural variability.

- The water quality component identified increases in the concentrations of several variables that have the potential to cause toxicity to aquatic organisms (TDS, nitrate, barium, nickel, and strontium in water); however, none of the concentrations of these parameters exceeded guidelines in the core lakes, indicating that they are not found at concentrations that would result in a toxicological effect on the benthic invertebrate community in Lake N11. Additionally, none of the sediment variables had increasing BACI effects and none of the plankton variables demonstrated a response consistent with a toxicity-related effect Lake N11.

In addition to the above factors that relate to the 2017 results, there is uncertainty associated with the accuracy of the normal ranges used for the benthic invertebrate component, as they are based on a single year of baseline monitoring data and, therefore, may not accurately represent baseline conditions in the core lakes. This may have interfered with the ability of the Action Level evaluation to differentiate between Mine-related effects and year-to-year variability in the benthic invertebrate community.

2.2.4 Ecological Implications

Overall, there was no consistent evidence to suggest that the Low Action Level exceedance identified for Pisidiidae density in Lake N11 was caused by mining activities, or that the changes observed in 2017 were related to toxicological impairment of the benthic invertebrate community. The observed changes likely reflect habitat differences and/or among-year variability in the benthic invertebrate community. Oversensitivity of the Low Action Level criterion, related to meeting a single condition for a trigger, also contributed to the Low Action Level trigger reported in 2017. As such, the response observed in Pisidiidae density does not reflect an adverse effect on the aquatic ecosystem of Lake N11.

2.2.5 Response Actions

Benthic invertebrate communities in the core and reference lakes will continue to be monitored on an annual basis according to the schedule defined in the AEMP Design Plan (De Beers 2016a). The 2018 AEMP monitoring data will be examined to confirm whether the observed changes in Pisidiidae density in Area 8 have persisted and the results will be reported in the 2018 AEMP Annual Report to be submitted in May 2019.

The results of the benthic invertebrate community data analysis do not provide an indication that the Low Action Level trigger identified for Pisidiidae density in 2017 represents a Mine-related effect in Lake N11, or that the change that triggered the Action Level was outside of natural variability. Therefore, the main response action is to address the unrealistically high sensitivity of the currently approved Action Levels. As described in Section 2.1.5, data analysis methods used for the AEMP that may contribute to sensitivity of the Action Levels will be examined as part of the Aquatic Effects Re-evaluation Report, which is scheduled to be submitted in December 2019. This will include evaluating potential changes to the Action Levels as part of updates to the AEMP Response Framework. Specific recommendations for changes to Action Levels and data analysis methods are discussed in Section 4.

2.3 Summary – Toxicological Impairment

Based on the toxicological impairment hypothesis, water quality Low Action Levels were triggered in Lake N11 for TDS, nitrate, nickel, and strontium during ice-cover conditions, and for barium and strontium during open-water conditions. A Low Action Level based on the toxicological impairment hypothesis was also triggered for open-water concentrations of uranium in Area 8. Changes in Lake N11 are attributed to the operational discharges from the WMP to Lake N11. However, lake-wide mean/median concentrations for all water quality parameters in Lake N11 were within expectations (i.e., EIS predictions), and remained below 75% of the AEMP benchmarks. Increasing parameter concentrations in Area 8 may be related to hydrological changes to Area 8 through its isolation from Kennady Lake, but exacerbated by consecutive dry climate conditions, and/or the short duration of downstream flow mitigation pumping from Lake N11. However, increases in water quality parameter concentrations in Area 8 were predicted in the EIS, and remained below 75% of the AEMP benchmarks.

The results of the Action Level determination for the benthic invertebrate component indicate that Pisidiidae density triggered a Low Action Level based on the toxicological impairment hypothesis. Even though the Action Level conditions were met for Pisidiidae density, the overall conclusions of the analysis provided no indication of toxicity-related effects on benthic invertebrate communities in Lake N11.

The response actions identified to address the Low Action Level exceedances for toxicological impairment for the water quality and benthic invertebrate components will be:

1) to continue monitoring these components on an annual (and seasonal, where applicable) basis according to the schedule defined in the AEMP Design Plan (De Beers 2016a); and

2) to re-evaluate the AEMP Response Framework and data analysis methods that may contribute to higher than reasonable sensitivity of the Action Levels, as part of the Aquatic Effects Re-evaluation Report.

At this time, criteria for subsequent Action Levels (i.e., Moderate and High Action Levels) are not developed. The current Low Action Levels are believed to be inappropriately scaled and appear to result in false positive triggers. Therefore, Low Action Level criteria need to be re-evaluated during the Aquatic Effects Re-evaluation before establishing Moderate and High Action Levels for the toxicological impairment hypothesis.

3 NUTRIENT ENRICHMENT

3.1 Water Quality

3.1.1 Parameter Description

The 2017 water quality data were evaluated in relation to Action Levels for nutrient enrichment responses, and Low Action Levels for nutrient enrichment were triggered in Lake N11 under the Response Framework of the approved AEMP Design Plan (De Beers 2016a). The Significance Thresholds for water quality are defined in Section 2.1.1. and the threshold pertinent to nutrient enrichment is:

- *Ecological function is not maintained (i.e., inadequate food for fish; fish unable to survive, grow and reproduce; and/or sustained absence of a fish species).*

3.1.2 Action Level Determination

Action Levels for nutrient enrichment for the water quality component are defined in the AEMP Design Plan (Section 8.4; De Beers 2016a) and are reproduced in Table 3.1-1. Data analysis methods used to assess Action Levels based on nutrient enrichment responses are the same as those described for toxicological impairment in Section 2.1.2, and apply to nitrogen and phosphorus parameters.

Table 3.1-1 Action Levels for Nutrient Enrichment for the Water Quality Component

Action Level	Nutrient Enrichment
Low[a]	Lake-wide average nitrogen and phosphorus nutrient concentrations greater than normal range or EIS prediction, supported by a visual temporal trend **AND** Lake-wide average nitrogen and phosphorus nutrient concentrations exceed 75% of AEMP benchmark[b] **OR** Relative difference of nitrogen and phosphorus nutrient concentrations between core lake and reference lakes statistically significant compared to baseline (i.e., significant BACI effect detected)
Moderate	*TBD*[c]
High	*TBD*[c]

a) Changes below the Low Action Level are within the estimated magnitude of background variation and are considered to represent negligible levels of environment change.

b) Benchmarks currently used in the AEMP to which substance concentrations are compared (i.e., EIS benchmarks and CCME guidelines). This criterion does not apply if no benchmark exists.

c) TBD if Low Action Level is reached.

TBD = to be determined; BACI = before-after control-impact; AEMP = Aquatic Effects Monitoring Program; EIS = Environmental Impact Statement.

During the ice-cover season, significant BACI effects were detected in Lake N11 for concentrations of nitrate (Table 3.1-2). The lake-wide mean/median ice-cover concentration of nitrate also exceeded the upper bound of the normal range in Lake N11, but remained well below 75% of the AEMP Benchmark (Table 3.1-2). As a result, ice-cover concentrations of nitrate in Lake N11 triggered a Low Action Level based on the nutrient enrichment hypothesis.

Table 3.1-2 Summary of Comparisons for Water Quality Action Levels for Nutrient Enrichment in Lake N11

Lake	Parameter	Unit	Normal Range		2017 AEMP Lake-wide Mean/ Median	Upper Bound Exceeded ?	AEMP Benchmark	Exceeds 75% of AEMP Benchmark ?	EIS Predictions (Maximum Operations Conditions)[(b)]	Exceeds EIS Predictions ?	BACI Analysis	
			Lower Bound	Upper Bound							Type of Effect	Direction Relative to Reference Lakes
Under-ice												
Lake N11	Nitrate	mg-N/L	0.00496	0.0403	0.62	yes	2.93	no (21%)	1.5	no	Press and Pulse	↑

EIS = Environmental Impact Statement; BACI = before-after control-impact; ↑ = increase; mg-N/L = milligrams of nitrogen per litre.

3.1.3 Likely Causes and Lines of Evidence

Although water quality in Lake N11 satisfied the Low Action Level conditions for nutrient enrichment, analysis of other lines of evidence provided no consistent indication of a nutrient enrichment effect in Lake N11. This interpretation is based on the following lines of evidence:

- A significant BACI effect indicating increasing concentrations relative to both reference lakes and concentrations above the normal range in Lake N11 was identified for nitrate during ice-cover conditions (Figures 5.4-28 and 5D-8b in the 2017 AEMP Annual Report; Golder 2018a). These changes are attributed to the operational discharges from the WMP to Lake N11. In the EIS, concentrations of nutrients, including nitrate in Lake N11 were projected to increase as a result of operational discharge from the WMP to Lake N11 (De Beers 2011, 2012; see also nutrient time series plots for Lake N11 in Appendix 9.II of the 2012 EIS Supplement, pp. 9.II-4 to 9.II-6). However, phosphorus (i.e., the limiting nutrient) is a more relevant parameter to determine the potential for nutrient enrichment in Lake N11, and in 2017 no significant effects were detected on phosphorus concentrations (Tables 5.4-31 and 5.4-33 in the 2017 AEMP Annual Report; Golder 2018).
- The Low Action Level triggers in 2017 in part resulted from applying highly conservative Action Level criteria. Under the current AEMP Response Framework, a Low Action Level is triggered for water quality if the lake-wide average of a parameter exceeds the normal range, and either there is a significant BACI effect or the lake-wide average concentration exceeds 75% of the AEMP benchmark. The recommended revision involves changing the Low Action Level definitions to replace the “or” logical operator with “and”, thereby requiring all three criteria be met before a Low Action Level is triggered. In addition, because the current AEMP benchmark for nitrate is only appropriate for evaluating effects related to toxicity, either development of an additional benchmark specific to nutrient enrichment is recommended for this parameter, or the parameters to be evaluated need to be specified in light of the limiting nutrient in the core lakes (i.e., potentially limiting the Action Level evaluation to phosphorus).

3.1.4 Ecological Implications

The Low Action Level exceedance identified for water quality during the 2017 monitoring period is considered to represent a low-level effect on water quality in Lake N11, below levels that would be of concern to aquatic life. Even though nitrate concentrations triggered a Low Action Level based on the nutrient enrichment hypothesis, no corresponding significant effects were detected for the limiting nutrient (i.e., phosphorus) in Lake N11. In addition, ecological implications of the observed changes in phytoplankton community composition on the aquatic ecosystem of Lake N11 are considered to be minor (Section 3.2), and none of the individual plankton variables evaluated in Lake N11 triggered Action Levels based on the nutrient enrichment hypothesis (Section 3.3). The ecological implications of the increases observed in nitrate on the aquatic ecosystem of Lake N11 are considered to be negligible to minor.

3.1.5 Response Actions

Annual and seasonal water quality monitoring will continue in the core and reference lakes, according to the schedule defined in the AEMP Design Plan (De Beers 2016a). The 2018 AEMP monitoring data will be examined to confirm whether the observed changes in nitrate concentration in Lake N11 have persisted or reverted back to baseline conditions, and the results will be reported in the 2018 AEMP Annual Report submitted in May 2019.

In addition, data handling and analysis methods used for the AEMP that may contribute to oversensitivity of the Action Levels will be examined as part of the Aquatic Effects Re-evaluation Report, which is scheduled to be submitted in December 2019. This will include investigating potential changes to statistical analysis methods and Action Level criteria. Specific recommendations for changes to Action Levels and data analysis methods that will be evaluated as part of the Aquatic Effects Re-evaluation are discussed in Section 4.

3.2 Plankton

3.2.1 Parameter Description

The 2017 plankton community data were evaluated in relation to Action Levels for nutrient enrichment responses under the Response Framework in the AEMP Design Plan (De Beers 2016a). Results of the Action Level evaluation indicate that one of the plankton endpoints (phytoplankton community composition) triggered an Action Level for nutrient enrichment in Lake N11. None of the variables evaluated in Area 8 triggered Action Levels based on the nutrient enrichment hypothesis.

The Significance Threshold for plankton is defined in terms of a corresponding effect on fish communities, as:

- *Ecological function is not maintained (i.e., inadequate food for fish; fish unable to survive, grow and reproduce; and/or sustained absence of a fish species).*

Therefore, an effect equivalent to the Significance Threshold for plankton would occur if changes in phytoplankton or zooplankton biomass or community structure resulted in a change in food availability that adversely affects fish communities.

3.2.2 Action Level Determination

Action Levels for nutrient enrichment for the plankton component are defined in the AEMP Design Plan (Section 8.4; De Beers 2016a) and are reproduced in Table 3.2-1. The Action Level classifications incorporate comparisons of AEMP data to the normal range, changes in plankton community composition, and the results of the BACI analysis, as described in Sections 7.2.3.8.1 and 7.2.3.7, respectively of the 2017 AEMP Annual Report (De Beers 2018a).

Only the Action Level criterion related to changes in community composition is described in detail below, as the others are not relevant to the Low Action Level exceedance for phytoplankton community composition in Lake N11.

For the nutrient enrichment hypothesis, an ecologically relevant change in the plankton community composition was defined as a change in community composition (by biomass) that persisted for at least two sampling events. Results from the following approaches were examined, in combination, to make these comparisons:

1) monthly multidimensional scaling (MDS) ordination plots based on biomass data;

2) analysis of similarities (ANOSIM) results for biomass; and

3) monthly stacked bar time series plots of lake-wide means for community composition by major taxonomic group.

Table 3.2-1 Action Levels for Nutrient Enrichment for the Plankton Component

Action Level	Nutrient Enrichment
Low[b]	Lake-wide average value for total phytoplankton biomass, zooplankton abundance, or zooplankton biomass persistently (three consecutive years) above normal range[c] **OR** An ecologically relevant change in phytoplankton or zooplankton community composition[d] **OR** A statistically significant relative difference in total phytoplankton biomass, zooplankton abundance, or zooplankton biomass, between core lake and reference lakes compared to baseline (i.e., significant BACI effect detected)
Moderate	*TBD*[a]
High	*TBD*[a]

a) TBD if Low Action Level is reached.

b) Changes below the Low Action Level are within the estimated magnitude of background variation and are considered to represent negligible levels of environmental change.

c) Some level of nutrient enrichment is expected and, at a low level, the nutrient enrichment may be beneficial to the plankton community. Thus, a more persistent (i.e., three consecutive years) effect on the plankton community is required to reach the Low Action Level for nutrient enrichment.

d) An ecologically relevant change in plankton community composition was assessed by examining ANOSIM results from monthly MDS ordination plots and monthly stacked bar time series plots of lake-wide means for community composition by major taxonomic group.

TBD = to be determined; BACI = before-after control-impact; ANOSIM = analysis of similarities; MDS = multidimensional scaling.

When interpreting the ANOSIM results and community composition time series plots, a change was considered noteworthy if the 2017 community composition in the core lakes differed from baseline and also from the composition observed in the reference lakes in 2017. Plots and analyses were done separately for each sampling event (i.e., June/July, August, and September) and examined to determine whether the change in plankton community composition persisted for at least two sampling events. Significant ANOSIM results and distinct changes in the community composition, based on the time series plots, during at least two sampling events were considered indicative of an ecologically relevant change, thus triggering a Low Action Level for nutrient enrichment.

According to non-metric multidimensional scaling (nMDS) results, the phytoplankton community (by biomass) in Lake N11 during June/July, August, and September, 2017 was unique from baseline and the other AEMP sampling periods. Analysis of similarity (ANOSIM) results and examination of community composition time series plots confirmed that the 2017 community differed from baseline and reference lakes during June/July and September. The differences from baseline and reference lakes were observed during two sampling events; therefore, this was considered to be an ecologically relevant change in community composition, triggering a Low Action Level for nutrient enrichment in Lake N11 based on phytoplankton.

3.2.3 Likely Causes and Lines of Evidence

Although phytoplankton community composition in Lake N11 satisfied the Low Action Level conditions for nutrient enrichment, analysis of other key parameters in Lake N11 provided minimal evidence for a nutrient enrichment effect in Lake N11. The observed response, rather, appears to be related to year-to-year variability and potentially, oversensitivity of the Action Levels. This interpretation is based on the following lines of evidence:

- During the open-water season, some changes in water quality, which can be attributed to operational discharges from the WMP to Lake N11, were observed in Lake N11 including increased nitrate concentrations. However, no consistent significant effects were detected on the concentration of the limiting nutrient (i.e., phosphorus) relative to reference lakes (Section 5.4.2.5.4 in the 2017 AEMP Annual Report; Golder 2018a).
- Other plankton variables sensitive to nutrient enrichment (i.e., chlorophyll *a*[1], and total phytoplankton and zooplankton biomass) did not consistently indicate effects consistent with nutrient enrichment. Mean annual phytoplankton biomass showed only a minor increase in 2017 (comparable to 2015 concentrations), while zooplankton biomass decreased (Figures 7.4-10 and 7.4-21, respectively, in the 2017 AEMP Annual Report; Golder 2018a). When examined seasonally, significant BACI effects were detected for chlorophyll *a*, while on an annual basis, mean chlorophyll *a* concentrations remained similar between 2016 and 2017.

Overall, there was inconsistent evidence to support a nutrient enrichment effect in Lake N11. The observed changes in phytoplankton community composition more likely reflect among-year variability in the phytoplankton community.

3.2.4 Ecological Implications

The Low Action Level exceedance identified for plankton during the 2017 monitoring period is considered to represent a potential negligible to low-level effect on plankton in Lake N11. Although a shift was observed in phytoplankton community composition in Lake N11, concentration of the limiting nutrient and other plankton variables sensitive to nutrient enrichment did not indicate effects consistent with nutrient enrichment. Based on other measures of the plankton community (biomass, chlorophyll *a*), the shift in phytoplankton community structure was highly unlikely to result in a change in food availability that would adversely affect the fish communities. As such, the response of phytoplankton community composition remains well below the Significance Threshold defined for plankton in the AEMP Design Plan (De Beers 2016a) and in Section 3.2.1. The ecological implications of the observed changes in phytoplankton community composition on the aquatic ecosystem of Lake N11 are considered to be minor.

3.2.5 Response Actions

The proposed response actions for the Action Level trigger identified for phytoplankton community composition based on nutrient enrichment are the same as those identified in Section 3.1.5 for the water

[1] Chlorophyll *a* is currently not evaluated in the Action Levels assessment. A recommendation was made in the 2017 AEMP Annual Report (De Beers 2018a) to add chlorophyll *a* to the Action Levels assessment for plankton, as it is a proven useful and complementary indicator of phytoplankton biomass, and is subject to lower spatial and temporal variation than phytoplankton biomass. A specific recommendation for this change to the Action Level assessment will be provided as part of the Aquatic Effects Re-evaluation.

quality component, and consist of continued monitoring and evaluating statistical analysis methods and Action Level criteria as part of the Aquatic Effects Re-evaluation.

3.3 Benthic Invertebrate Community

3.3.1 Parameter Description

The 2017 benthic invertebrate community data were evaluated in relation to Action Levels for nutrient enrichment responses under the Response Framework in the AEMP Design Plan (De Beers 2016a). Results of the Action Level determination indicate that total density, richness, and the density of three common taxa (Nematoda, Pisidiidae, and *Micropsectra/Tanytarsus*) triggered an Action Level in Area 8 based on the nutrient enrichment hypothesis in Area 8. None of the variables evaluated in Lake N11 triggered Action Levels based on the nutrient enrichment hypothesis. The Significance Threshold for benthic invertebrates is defined in Section 2.2.1.

3.3.2 Action Level Determination

Action Levels for nutrient enrichment for the benthic invertebrate component are defined in the AEMP Design Plan (Section 8.4; De Beers 2016a) and are reproduced in Table 3.3-1. Data analysis methods used to assess Action Levels for the nutrient enrichment hypothesis are the same as those described for toxicological impairment in Section 2.2.2.

Table 3.3-1 Action Levels for Nutrient Enrichment for the Benthic Invertebrate Component

Action Level	Nutrient Enrichment
Low[(a)]	Lake-wide average value for total density, richness, Simpson's diversity index, or densities of dominant taxa greater than normal range **OR** Relative difference in total density, richness, Simpson's diversity index, or densities of dominant taxa, between core lake and reference lakes statistically significant compared to baseline (i.e., significant BACI effect detected)
Moderate	*TBD*[(b)]
High	*TBD*[(b)]

a) Changes below the Low Action Level are within the estimated magnitude of background variation and are considered to represent negligible levels of environmental change.

b) TBD if Low Action Level is reached.

TBD = to be determined; BACI = before-after control-impact.

Lake-wide means for total density, richness, and the density of three common taxa (Nematoda, Pisidiidae, and *Micropsectra/Tanytarsus*) were above the upper bound of the normal range in Area 8, each triggering a Low Action Level based on the nutrient enrichment hypothesis (Table 3.3-2). Density of Pisidiidae in Area 8 also had a significant BACI effect with a response pattern showing an overall increase in density relative to both East Lake and Lake 3. None of the variables assessed in Lake N11 met the criteria for a Low Action Level based on nutrient enrichment.

Table 3.3-2 Summary of Comparisons for Benthic Invertebrate Action Levels for Nutrient Enrichment in Area 8

Area	Variable	Normal Range		2017 AEMP Lake-wide Mean	Upper Bound Exceeded	BACI Analysis	
		Lower Bound	Upper Bound			Type of Effect	Direction Relative to Reference Lakes
Area 8	Total Density (org/m^2)	1,044	6,408	12,843	Yes	-	-
	Richness (taxa/station)	14.4	23.3	24	Yes	-	-
	Nematoda Density (org/m^2)	128	883	4,363	Yes	-	-
	Pisidiidae Density (org/m^2)	0	10	716	Yes	Press	↑
	Micropsectra/Tanytarsus Density (org/m^2)	6	565	709	Yes	-	-

BACI = before-after control-impact; org/m^2 = organisms per square metre; - = not applicable; ↑ = increase.

3.3.3 Likely Causes and Lines of Evidence

The 2017 AEMP benthic invertebrate data provided only very limited evidence to suggest a nutrient enrichment effect in Area 8. Habitat variation, year-to-year variability in the benthic invertebrate community and oversensitivity of the Action Level criteria may also have accounted for the Action Level exceedances noted for the benthic invertebrate community in 2017. This interpretation is based on the following lines of evidence:

- The BACI analysis in Area 8 detected a significant increase in Pisidiidae density from the *before* to the *after* period, indicating an overall increase in density since the baseline period. However, in recent years, the overall trend has been a reduction in density from 2015 to 2017 (based on visual evaluation; Figures 8.4-14 and 8A-13 in the 2017 AEMP Annual Report; Golder 2018a), indicating that density of Pisidiidae is moving toward baseline values, not away from them. As discussed in Section 2.2.3, inclusion of only a single year of *before* data in the BACI may be insufficient to detect true changes from baseline.
- As discussed in Section 2.2.3, density of Pisidiidae was positively correlated with the percentage of fine sediments at AEMP stations. In addition, plots of spatial and temporal variation in percent fines (Figure 8.4-5 in the 2017 AEMP Annual Report; Golder 2018a) and density of Pisidiidae (Figures 8.4-14 and 8A-13 in the 2017 AEMP Annual Report; Golder 2018a) show that the variation in Pisidiidae density among years and lakes included in the BACI analysis reflected that in percent fines. These results indicate that habitat variability likely contributed to the response observed in the density of Pisidiidae in Area 8.
- The results of the 2017 AEMP water and sediment quality and plankton community component data analyses provided limited evidence to link the observed increase in the density of Pisidiidae in Area 8 to trends in other ecosystem components. The plankton component identified an increase in the concentration of chlorophyll *a* in both core lakes relative to the reference lakes between the *before* and *after* periods, indicating that the increase in Pisidiidae density in Area 8 may have been influenced by an increase in primary production. However, on an annual basis, mean chlorophyll *a* concentrations remained similar between 2016 and 2017 (Figure 7.4-1 in the 2017 AEMP Annual Report; Golder 2018a). In Lake N11, the density of Pisidiidae decreased from the *before* to the *after* period. None of

the other variables assessed by the plankton component (i.e., depth-integrated nutrients, phytoplankton biomass, and zooplankton biomass) displayed trends that were consistent with a nutrient enrichment-related effect. The AEMP water quality component detected an increase in the concentration of nitrate in Area 8; however, no significant effects were detected on the concentration of the limiting nutrient (i.e., phosphorus).

- Lake-wide means in Area 8 for total density, richness, and the densities of three common taxa (Nematoda, Pisidiidae and *Micropsectra/Tanytarsus*) were above the upper bound of the normal range estimated based on the 2011 baseline data (Table 8.4-3 in the 2017 AEMP Annual Report; Golder 2018a). However, due to the considerations discussed in Section 2.2.3, there is uncertainty associated with the normal ranges used in these comparisons, which may have interfered with the determination of Action Levels for these variables.

3.3.4 Ecological Implications

Although several benthic invertebrate variables satisfied the criteria for a Low Action Level trigger in 2017, the results of the 2017 AEMP data analysis do not clearly suggest that these triggers were caused by nutrient enrichment of Area 8. Rather, the changes may reflect habitat differences, among-year variation in the benthic invertebrate community and, potentially, oversensitivity of the Action Levels. Responses for other AEMP endpoints were also inconsistent and do not clearly indicate a Mine-related nutrient enrichment effect in Area 8. Additional monitoring is needed to confirm whether the changes observed in the benthic invertebrate community in Area 8 are indeed Mine-related and represent nutrient enrichment. As such, the 2017 results do not clearly suggest that an adverse effect on the benthic invertebrate community and aquatic ecosystem of Area 8 has occurred.

3.3.5 Response Actions

The proposed response actions for Action Level triggers identified for benthic invertebrate community variables based on nutrient enrichment are the same as those identified in Section 3.1.5 for the water quality component, and consist of continued monitoring and evaluating statistical analysis methods and Action Level criteria as part of the Aquatic Effects Re-evaluation.

3.4 Summary – Nutrient Enrichment

Based on the nutrient enrichment hypothesis for water quality, concentrations of nitrate in Lake N11 triggered a Low Action Level during the ice-cover season. These changes are attributed to the operational discharges from the WMP to Lake N11. Even though nitrate concentrations triggered a Low Action Level based on the nutrient enrichment hypothesis, no significant effects were detected on the limiting nutrient (i.e., phosphorus) in Lake N11. Therefore, the nitrate increases represent a low-level, likely transient effect on water quality, with negligible ecological implications.

Phytoplankton community composition in Lake N11 during June/July and September, 2017 was unique from baseline, reference lakes, and the other AEMP sampling periods. Because the differences were observed during two sampling events, this was considered to be an ecologically relevant change in community composition, triggering a Low Action Level for nutrient enrichment in Lake N11 based on phytoplankton. The observed changes occurred independently of any significant changes in the key limiting nutrient, and other plankton variables sensitive to nutrient enrichment did not indicate effects consistent with nutrient enrichment. Therefore, uncertainty exists regarding the cause of the shift in phytoplankton community composition in Lake N11.

Density of Pisidiidae increased from the *before* to the *after* period relative to trends in each of the reference lakes. However over the last three years, Pisidiidae density has been declining, which is inconsistent with a progressive nutrient enrichment effect. The plankton component identified an increase in the concentration of chlorophyll *a* in both of the core lakes relative to the reference lakes, indicating that the increase in Pisidiidae density in Area 8 may have been influenced by an increase in primary production. However, none of the other variables used to evaluate nutrient enrichment demonstrated trends that were consistent with nutrient enrichment. Results of the habitat evaluation for benthic invertebrates indicated the trend observed in Pisidiidae density is at least partly explained by habitat variation.

The response actions identified to address the Low Action Level exceedances for nutrient enrichment for the water quality, plankton, and benthic invertebrate components will be:

1) to continue monitoring these components on an annual (and seasonal, where applicable) basis according to the schedule defined in the AEMP Design Plan (De Beers 2016a);
2) to re-evaluate the data analysis methods; and
3) to re-evaluate Low Action Level criteria, as part of the Aquatic Effects Re-evaluation Report.

At this time, proposal of criteria for subsequent Action Levels (i.e., Moderate and High Action Levels) is not warranted. The current Low Action Levels are believed to be inappropriately scaled and appear to result in false positive triggers. The Low Action Levels need to be re-evaluated during the Aquatic Effects Re-evaluation prior to establishing Moderate and High Action Levels for the nutrient enrichment hypothesis.

4 RECOMMENDATIONS

The following recommendations are made to address oversensitivity of the AEMP Response Framework. Additional rationale for these recommendations is provided in Section 15.7 of the 2017 AEMP Annual Report (De Beers 2018a):

- The Action Level criteria used for assigning a Low Action Level for toxicological impairment and nutrient enrichment hypotheses should be re-evaluated so that the sensitivity of the AEMP Response Framework is appropriate for managing Mine-related effects. Under the current AEMP Response Framework, a Low Action Level is triggered for:
  - water quality: if the lake-wide average of a parameter is greater than the normal range or EIS prediction AND it exceeds 75% of the AEMP benchmark OR there is a significant BACI effect;
  - plankton: if the lake-wide average of a variable is persistently (three consecutive years) outside the normal range, OR there is an ecologically relevant change in community composition, OR there is a signficiant BACI effect; and
  - benthic invertebrates: if the lake-wide average of a variable is outside the normal range, OR there is a significant BACI effect.

  A recommended revision consists of changing the Low Action Level definitions to replace the “OR” logical operators between the Action Level criteria with “AND”. This would require all of the criteria to be met before a Low Action Level is triggered. A single criterion by itself (e.g., normal range exceedance, or significant BACI effect) should not be sufficient to trigger a Low Action Level, because the evaluation needs to consider both a change in direction relative to the reference lakes and the magnitude of the resulting value. In the case of water chemistry-related components, the magnitude of the measured concentration needs to be considered to avoid triggers that result from normal range exceedances combined with significant BACI results, but at concentrations far below those of toxicological concern.

- Comparisons of AEMP data to normal ranges is a key factor in the evaluation of Action Level exceedances for the water quality, sediment quality, plankton, and benthic invertebrate components. A recommended revision may be to include 2015 (and potentially 2016) data in the normal ranges for the core lakes, or to otherwise adjust normal ranges to appropriately account for year-to-year variability. Inclusion of these data in datasets used to calculate normal ranges would provide a more robust estimate of natural variability in the core lakes and would address issues with the sensitivity of the normal range used to evaluate Mine-related changes.

Revisions to Action Levels and to data analyses that factor into the Action Levels will be evaluated and reported as part of the Aquatic Effects Re-evaluation Report and AEMP Design Plan update. The Aquatic Effects Re-evaluation Report is scheduled to be submitted to the MVLWB in December 2019; submission of the AEMP Design Plan is expected to follow shortly after. The deadline for submission of the updated AEMP Design Plan will be established in consultation with the MVLWB.

5 SUMMARY AND CONCLUSIONS

Given the 2017 AEMP data and the methods established in the AEMP Design Plan, Low Action Levels were triggered for:

- Toxicological impairment: open-water concentrations of uranium in Area 8, ice-cover concentrations of four water quality parameters (i.e., calculated TDS, nitrate, nickel, and strontium) and open-water concentrations of two water quality parameters (i.e., strontium and barium) in Lake N11, and one benthic invertebrate variable (i.e., Pisidiidae density) in Lake N11.
- Nutrient enrichment: ice-cover concentrations of nitrate and phytoplankton community composition (by biomass) in Lake N11, and five benthic invertebrate variables (i.e., total density, richness and the density of Nematoda, Pisidiidae, and *Micropsectra/Tanytarsus*) in Area 8.

The 2017 AEMP results for water and sediment quality identified changes, which have been determined to be negligible (for water quality, this is defined as a measurable increase in a parameter within the range of baseline values and/or below the water quality guideline [i.e., AEMP Benchmark] for that parameter; De Beers 2010).

The response actions consist of continued monitoring in 2018 according to the existing AEMP schedule, which will further inform the interpretation of Action Level triggers observed in 2017, and re-evaluation of Action Level criteria, normal ranges, and data analysis methods.

The Low Action Level triggers for plankton and benthic invertebrate communities may have resulted from narrow normal ranges, combined with Action Level criteria that are too sensitive, because a single criterion by itself (i.e., normal range exceedance, significant BACI effect, or change in community composition) can trigger an Action Level. The factors that may account for Action Level exceedances representing false positive triggers are discussed in more detail in the 2017 AEMP Annual Report, and recommendations are provided for refining Action Levels to achieve an appropriate level of sensitivity to environmental change (De Beers 2018a).

Recommendations include updating normal ranges using the 2015 (and potentially 2016) water and sediment quality, plankton, and benthic invertebrate data, re-evaluating the data analysis methods, and adjusting the Action Level criteria to reduce false positive triggers by requiring multiple criteria to be true before a Low Action Level is triggered. The 2015 to 2018 Aquatic Effects Re-evaluation Report and AEMP Design Plan update will provide an opportunity to re-evaluate the Action Levels for the AEMP.

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