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# REVIEW OF THE DIAVIK DIAMOND MINE AQUATIC EFFECTS MONITORING PROGRAM (AEMP) 2008 ANNUAL REPORT

Technical Memorandum # 367-09-01

**Prepared for:**

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# 1.0 APPROACH TO THE 2008 AEMP REVIEW

A technical review was conducted of the core components of the DDMI 2008 AEMP, i.e., effluent and water chemistry, sediment chemistry, and plankton, benthic invertebrate, and fish communities. Additional components of the AEMP included in the review were dust deposition and the weight of evidence (WOE) analysis. Fisheries Authorization and Special Effects Studies (SES) commented on included dike monitoring studies, plankton SES, 2008 AEMP SES, and eutrophication indicators. Reviews were conducted by North/South Consultants Inc. (North/South) personnel with knowledge and experience in the related area.

The following review focused on a general overview of the results. Emphasis was placed on identifying results that may indicate any substantive environmental changes observed since the previous year of monitoring (DDMI 2008), and on identifying potential 2008 AEMP (DDMI 2009) implementation concerns considering the core aspects of the revised AEMP study design (DDMI 2007). In addition, recommendations for the 2008 AEMP Annual Report provided by the Wek'èezhìi Land and Water Board (WLWB) (WLWB 2008 Board Decision Package – DDMI AEMP Annual Report – July 4, 2008) and EMAB (EMAB 2009 EMAB letter to Diavik Diamond Mines dated January 8, 2009: Effects found in 2007 AEMP report – follow up) were taken into consideration. However, the review is not intended to be comprehensive.

Review criteria employed for the components included, but were not necessarily limited to:

- Assessment of completeness relative to the approved AEMP design and any follow up recommendations;
- Suitability of the study design (e.g., spatial area and site selection; seasonality; replication) and continuity between AEMP years;
- Effectiveness and relevance of the sampling methodologies used;
- Appropriate analytical parameters measured at detection limits below relevant guideline and/or benchmark levels, and transparency in reporting (e.g., agreement of information presented in non-technical summary with various attached technical appendices);
- Appropriate laboratory processing techniques and taxonomic identification, and transparency in reporting (e.g., inclusion of a detailed appendix);
- Adequate quality assurance/quality control procedures and transparency in the presentation of methodologies and results (e.g., inclusion of a detailed appendix);
- Appropriate data analysis techniques sufficient to address AEMP objectives and requirements;

- Appropriate interpretation and discussion of results sufficient to address AEMP objectives and meet all requirements, and recognition of certainty and uncertainty; and/or
- Relevance, accuracy and justification of conclusions drawn and importance of any recommendations made.

The combination of review criteria depended on applicability to the specific AEMP component under review.

The following review comments are based on the more detailed technical appendices, but generally reflect what was brought forward to the 2008 Annual Report. Section 2.1 provides an overall summary impression of the 2008 AEMP Annual Report and main concerns noted for each component reviewed; section 2.2 provides a more detailed technical review of each specific AEMP component. For ease of review, a summary of the detailed technical review and recommendations (section 2.2) were provided in a review matrix along with 2008 AEMP evaluation comments and key recommendations for EMAB to consider (Table 2-1).

# 2.0 EVALUATION OF THE 2008 AEMP

## 2.1 MAIN CONCERNS AND RECOMMENDATIONS

### Summary and General Comments

- Overall, the approach and presentation of results is clear and consideration of the majority of important information in the main body of the Annual Report as a non-technical summary greatly enhances the ability of the reader to evaluate the overall effects detected in the AEMP. In particular, the addition to most components of an effects summary table in the main body of the Annual Report that summarized the effect-level designations improved one's ability to evaluate the overall effects detected in the 2008 AEMP and was an excellent addition to AEMP reporting.

- It appears that the majority of effects observed to date were predicted during the Environmental Assessment (EA) process and, as such, there are no major concerns at this time. However, concerns raised regarding the potential effects of nutrient enrichment on mercury uptake in fish is a possible exception to this (not considered during the EA), and there are a number areas highlighted in Section 2.1 that would benefit from either further discussion and/or investigation.

- As suggested in the review of the 2007 AEMP and reiterated by EMAB, it would be beneficial if DDMI would carry forward any recommendations provided in technical appendices to the Annual Report and provide a rationale for accepting or rejecting (e.g., to be reconsidered in the Three Year Report with the benefit of multiple years of analysis and recommendations) each recommendation and a summary table of all recommendations for ease of future review(s) and consideration.

### Dust Deposition

- It would be useful to provide some discussion of the potential effects of additional phosphorus introduced via dustfall from the mine on surface water quality [as discussed in the review of the 2007 AEMP: this could include integrated discussion of total phosphorus (TP) concentrations in surface waters and sediment in the vicinity of the dustfall monitoring sites and/or discussion of total loading from dust relative to other sources and in-lake loads].

- The recommendation to discontinue temporary dust gauges monitoring may be somewhat premature and would benefit from additional discussion. DDMI states that the temporary dust collection gauges were deployed for comparative analysis to determine variances associated with frequency and duration of sample collection (Appendix I, Methodology, p. 5). In addition to comparing the variability of the estimates of annual dustfall deposition rate for these two approaches, it may be helpful for DDMI to provide some further explanation for the observed differences between co-located dust gauges (temporary vs. permanent).

## Effluent and Water Chemistry

- The reviewer noted some discrepancies in the reported number of water quality samples collected between the Annual Report (Section 3.2, p 15) and Appendix II (Section 2.1, p 6), which made the subsequent review more difficult and raised concern as the degree of completion of the 2008 AEMP water quality sampling may have been limited for the third open-water sample season (10 September – 12 October).

- The approach for handling non-detect data (water and sediment chemistry) is either unclear or inconsistent among technical appendices. A useful discussion on approaches for handling non-detect data may be found in Mitchell (2006).

- Appendix II, Section 3.3 reiterates a common problem in water quality monitoring programs in which the laboratory detection limits for parameters of interest are above a guideline for the protection of aquatic life or other criteria being considered. In some instances, this issue can be resolved with the analytical laboratory as they may be able to provide ultra low-level (i.e., trace) detection limits for certain parameters, especially metals. However, it may require additional cost per sample and a more rigorous SOP for the collection of samples to ensure they are of sufficient quality for trace analysis.

## Sediment Chemistry

- Bismuth and uranium in sediments were each assigned a high level effect classification as both NF and at least one MF area had mean concentrations greater than the reference area range. Although it was concluded that that the elevated concentrations of these elements are unlikely to pose a risk to aquatic life at this time, concentrations in sediments will potentially increase in the future as loadings from the mine continue (effluent quality criteria are for *total* metals). Although these two parameters are not included in the list of water quality parameters with effluent quality criteria as defined in the Water Licence, it may be useful to have some discussion concerning the inclusion of additional metals in the monitoring of monthly loads from the NIWTP (and subsequent determination of annual loads).

- The recommendation that the effect level classification guidelines for sediments should be reconsidered in the future may benefit from further discussion, particularly with respect to the procedure employed by the analytical laboratory to extract metals from the sediments. It is unclear whether total metals in sediments are being determined using a strong acid extraction, which may potentially overestimate effects. Of particular relevance with respect to the application of CCME sediment guidelines is the procedure used to extract metals from the sediments. In this respect CCME (2001 - Introduction) notes: *"Because the ISQG* [interim sediment quality guidelines] *are intended to be used for evaluating the potential for biological effects, "near total" trace metal extraction methods that remove the biologically available fraction of metals and not residual metals (i.e., those metals held within the lattice framework of the sediment) are recommended for determining sediment metal concentrations. A strong extraction method using hydrofluoric acid would remove both the bioavailable and residual fraction of metals in sediments. Therefore, (in the context of ISQG) the concentration of "total" metals refers* *to the concentration of metals recovered using a near-total (mild digestion; e.g., aqua regia, nitric acid or hydrochloric acid) method."*

## Benthic Invertebrates

- Total phosphorus and nitrogen were analysed in sediments (nutrient enrichment from mine effluent); however, these data were not included when considering the effects of habitat variation on the benthic invertebrate community metrics. As nutrients may provide more of a direct pathway (via influence on benthic algae in sediments if light penetration is sufficient) for any potential nutrient enrichment effect in the sediments linked to the mine it may be worthwhile to include them in the suite of habitat variables used to explain the benthic invertebrate community relationships.

- The discussion concerning the issue of usefulness of FFA and FFB areas as appropriate reference areas for use in comparisons with the NF and FF2 exposure areas is a valid one and it is recommended that DDMI considers confirming the potential differences (habitat, benthic invertebrate community characteristics) between the FF1 reference area, and the FFA and FFB references areas during future monitoring cycles, prior to the Three Year Report synthesis.

- The potentially confounding influence of Lac du Sauvage on invertebrate communities at FF2 is not discussed. Lac du Sauvage, which empties into Lac de Gras, is considered more productive than Lac de Gras and also has elevated barium concentrations in comparison to Lac de Gras reference areas, which could be contributing to the elevated open-water barium concentrations observed at FF2. The potentially confounding influence of Lac du Sauvage was raised in the AEMP Design Document (Section 4.4.3.2) and the influence of Lac du Sauvage should be understood to enable discrimination of its influence from mine effects, i.e., DDMI should be able to describe effects of their operation separate from other influences.

## Fish

- As its main conclusion the fish report states *"The fish tissues analyses from 1996, 2005, and 2008 indicate that there has been no increase in the concentration of metals, including mercury, over that period. Therefore, according to the study design document, there has not been an effect on the usability of lake trout."* However, the technical portions of the document provide considerable discussion about the limitations of some of the data, particularly the 1996 data. Therefore, although the conclusion is consistent with the analyses that they were able to do and there is no clear indication that mercury levels in lake trout have been going up, the reviewers felt there was still some uncertainty and that the conclusion was stated too strongly. Although this conclusion may yet prove to be valid, when stated unequivocally it seems premature.

- Given the limitations of the 1996 mercury data (i.e., the baseline condition) it is likely that it will always be difficult to make a strong statistical comparison between current and pre-project data. This presents a problem because according to the design document an Early Warning/Low Effect assessment is based on detecting a difference between pre-project and post-project levels. Consideration should be given to revising the Early Warning/Low Effect Description so that it includes detection of any increasing trend, rather than just a change relative to baseline.

- The report assesses lake trout usability based on the standard 0.5 ppm Health Canada guideline level for mercury in commercially marketed fish. This level is not necessarily appropriate when the fish are being used for domestic or subsistence purposes. For people who consume fish regularly, it has been recommended that a mean concentration of 0.2 ppm of mercury should not be exceeded in fish muscle (Wheately 1984). The reviewers suggest that more detailed calculations and recommendations could be made based on tolerable daily intake (TDI) recommendations for methyl mercury of 0.47 µg/kg body wt/day (0.20 µg/kg body wt/day for women and children up to age 12) by Health Canada (Health Canada 2007) to assess the health risk of local resource users.

- Appendix V reports that DFO has identified a research team that will conduct a specialized sediment core analysis study that may assist in understanding the source of mercury increases in slimy sculpin. DDMI has also agreed to conduct a SES on Possible Effects of Enrichment on Mercury Uptake. Both studies could be very useful in developing a better understanding of mercury uptake in Lac de Gras fish.

### Dike Monitoring Studies

- For consistency and following the same rationale applied for the main sediment quality monitoring program (i.e., the low rate of sedimentation in Lac de Gras), consideration should be granted to measurement of sediment chemistry in shallower sediment depths (i.e., 1 cm) for the dike monitoring program. This review comment also pertained to the 2007 AEMP and was being considered by DDMI in consultation with the DFO; an update with respect to the status of this item would be beneficial.

- Some sediment quality parameters had baseline concentrations above ISQGs; these included arsenic, chromium, copper, and cadmium. The PEL (probable effects level) for arsenic was also exceeded at the majority of stations where levels were above the ISQG. These exceedences were attributed to naturally occurring concentrations of metals, which reflect geological conditions in the region of Lac de Gras. Trace metal concentrations at AEMP sites were also screened against conservative sediment quality guidelines to assess the potential for ecological effects due to existing concentrations of these substances. Numerous trace metals measured at AEMP sites also exceeded various guideline levels (Appendix III, Section 3.2). However, neither Appendix VII nor Appendix III provided any further discussion of potential toxicological effects related to these parameters. It may be of benefit to consider integrating background concentrations of naturally elevated metals in the discussion of potential toxicological effects on benthic community metrics (Appendix IV), as sediment chemistry substances of interest identified in Appendix III do not demonstrate any relationship with benthic community metrics.

## Plankton Special Effects Study

- Similar to the 2007 AEMP Annual Report, no comparative statistics were provided for the 2008 zooplankton data (e.g. mean, min/max, standard deviation, standard errors). This was a requirement stipulated in the design document and was subsequently requested again by the WLWB after the 2007 AEMP report review.

## Eutrophication Indicators

- Prior to using the 2007 chlorophyll *a* results in any comparisons with past or future results, a literature review and method comparison SES was to be conducted in 2008 to address potential differences between sampling methods (the depth of light penetration was estimated from Secchi disk depths in 2007 only). This SES would be applicable to Appendices XI (Plankton SES) and XIII (Eutrophication Indicators); however it does not appear to have been conducted.

- The recommendation provided in Appendix XIII for allocating some existing stations to the MF3 mid-field area is excellent; more intensive investigations of these areas is warranted given that effects have been observed and the extent appears to be expanding. It is noted that DDMI prefers to consider changes to the study design following synthesis of information in the Three Year Report.

- In light of the shift in trophic status from ultra-oligotrophic to oligotrophic it may be prudent to revisit the discussion of the trophic status of the lake and EA predictions, and in particular make reference to the *CCME phosphorus Canadian guidance framework for the management of freshwater systems* (CCME 2004), in a more timely fashion than the Three Year Report.

## Weight of Evidence

- Refinements to the WOE approach substantially increase the strength of the causal linkage between the Exposure and Effect LOEs and represent a significant improvement over the approach presented in the 2007 Annual Report.

- Appendix XV concludes that the evidence for nutrient enrichment linked to mine activities was much stronger than the evidence for toxicological impairment, and that increases in primary productivity were extending beyond near-field areas. It was also concluded that the magnitude and type of response in Lac de Gras appears to be a mild enrichment to lake productivity and the benthic invertebrate community; the severity with respect to the ecological integrity of Lac de Gras associated with these changes to indicators of enrichment is considered to be low and consistent with the beginning of a shift from ultra-oligotrophic to oligotrophic status.

- Given that the overall severity of nutrient enrichment is considered mild by the WOE analysis, Appendix XV recommends that scientific investigative follow-up beyond the existing AEMP studies is not considered necessary at this time.

- The reviewers feel that this recommendation may be somewhat dismissive of the current degree of nutrient enrichment in Lac de Gras and the potential influence of this enrichment on mercury methylation processes (as commented on in the review of the 2007 AEMP Annual Report and to be investigated in the proposed SES on Possible Effects of Enrichment on Mercury Uptake). Observed effects are occurring after the mine has been fully operational for approximately 5 years (the first full year of mine production was 2004; NIWTP commissioned in 2002). It may be prudent at this time to review whether these effect levels were predicted in the EA to occur within this timeframe and project how severe they may become over the life of the mine (to approximately 2023) based on the rate of change seen to date. Essentially, if this review indicates that by the end of the mine's life the lake will no longer be in an acceptable condition (i.e., projected changes beyond EA predictions) options to manage nutrient loading should be investigated in a timely fashion.

## 2.2 SPECIFIC AEMP COMPONENT REVIEWS

### 2.2.1 Dust Deposition

*Relevant materials reviewed included:*

- 2008 Annual Report, Section 2.0
- Appendix I: Dust Deposition – 2008

The objective of the dust monitoring program is to measure the amount of dustfall at various locations around the mine and to determine the chemical characteristics of the dust deposited on the surface of Lac de Gras. The dust deposition monitoring program incorporates three methods of monitoring:

- Snow core surveys to collect snow samples for total suspended solids (TSS) analysis;
- Permanent dust collection gauges to gather samples of airborne particles;
- Temporary dust collection gauges for comparative analysis to determine variances associated with frequency and duration of sample collection.

In addition to the dust deposition program, chemical characteristics of snow water samples were determined at an analytical laboratory.

The following comments are based on the more detailed Appendix I, but reflect what was brought forward to Section 2.0 of the Annual Report.

- In general, there was poor qualification of the amount of change/degree of change observed in the snow water measured parameters. Generally, only the trend between 2007 and 2008 was provided without qualification of magnitude observed, e.g., zinc concentrations increased in snow water for all zones from 2007 to 2008. Is a more comprehensive evaluation expected in subsequent reports?

- A discussion of total phosphorous in the snow water was missing in Appendix I. Raw data indicated an increase in phosphorous in 2008 compared to 2007 that was not commented on;

- It would be useful to provide some discussion of the potential effects of this additional phosphorus introduced from the mine on surface water quality [as mentioned in the review of the 2007 AEMP: this could include integrated discussion of total phosphorus (TP) concentrations in surface waters and sediment in the vicinity of the monitoring sites and/or discussion of total loading from dust relative to other sources and in-lake loads]; and

- *"Permanent dustfall collectors measured 'minor' increases in dustfall deposition from 2007 to 2008, except at Dust 3 and 4"*. The reviewer disagrees with 'minor' as differences ranged from 7 to 143%, excluding Dust 3 and 4. A better qualification of these results would be helpful.

- DDMI's recommendation to continue remodelling of project-specific air quality emissions and dust deposition to develop more accurate model predictions than those generated during the EA is supported based on the 2008 observation that all dustfall deposition rates exceeded those predicted in the 1998 environmental effects model (often by an order of magnitude). What data would be used for remodelling (see next point)?

- The recommendation to discontinue temporary dust gauges monitoring may be somewhat premature and would benefit from additional discussion. DDMI states that the temporary dust collection gauges were deployed for comparative analysis to determine variances associated with frequency and duration of sample collection (Appendix I, Methodology, p. 5). In addition to comparing the variability of the estimates of annual dustfall deposition rate for these two approaches, it may be helpful for DDMI to provide some further explanation for the observed differences between co-located dust gauges (temporary vs. permanent). Would the overestimated dust deposition rates be used in their remodelling of project-specific deposition? If so, would their new predictions be overly insensitive to real observed increases/decreases in deposition? Presumably DDMI would rather have better estimates of dust deposition to develop more accurate model predictions, but not addressing the temporary dust gauge data suggests otherwise.

### 2.2.2 Effluent and Water Chemistry

*Relevant materials reviewed included:*

- 2008 Annual Report, Section 3.0

- Appendix II: Effluent and Water Chemistry Report in Support of the 2008 AEMP Annual Report for the Diavik Diamond Mine, NWT

The purpose of the water quality monitoring component of the revised AEMP was to describe the water chemistry of Lac de Gras spatially and temporally. The primary objective of this assessment was to determine if the Diavik Diamond Mine had an effect on the water chemistry of

Lac de Gras in 2008, and to classify any observed effect as low, moderate, or high. Guidelines for establishing the magnitude of effects are defined in Table 4.3-10 of the AEMP Design Document.

The following comments are based on the more detailed Appendix II, but reflect what was brought forward to Section 3.0 of the Annual Report.

- The reviewer noted some discrepancies in the reported number of samples collected between the Annual Report (Section 3.2, p 15) and Appendix II (Section 2.1, p 6), which made the subsequent review more difficult and raised concern as the degree of completion of the 2008 AEMP sampling could have been limited for the third open-water sample season (10 September – 12 October). For example, the Annual Report states "*In August a water sample was not collected at FF1-4 and in September at the FF1 and FF2 areas plus at stations FFB-2 and FFB-5 because weather prohibited sample collection"*, whereas Appendix II states *"Due to logistics and weather conditions, the FF2 stations were not sampled in the second open-water season and FF1 stations were not sampled in the third open-water sample season."*

- It is unclear how non-detect water chemistry data were handled. Subsequent appendices (e.g., Appendix III: Sediment Chemistry) with non-detect data refer to Appendix II for an explanation regarding handling of these data for the purposes of statistical analysis; however, this discussion does not appear in Appendix II.

- The reviewer noted some discrepancies in the 2007 and 2008 comparison of Substances of Interest (SOI) provided in the Annual Report (Section 3.3, p 18). For example, parameters identified as SOI in 2007 that were not identified as SOI in 2008 included nitrate.

- Graphical presentation of 2006, 2007, and 2008 water quality monitoring data collected at SNP 1645-18 is very helpful in discerning trends in concentrations (Appendix II, Section 3.2.1); however some figure captions provided in the Annual Report (Section 3.3.1) are incorrect.

- Appendix II, Section 3.3 reiterates a common problem in water quality monitoring programs in which the detection limits for parameters of interest are above a guideline for the protection of aquatic life or other criteria being considered. For example, the potential exceedence of benchmarks for cadmium and silver in water samples collected at the edge of the mixing zone could not be evaluated as the detection limit was above the benchmarks. In some instances, this issue can be resolved with the analytical laboratory as they may be able to provide low-level (i.e., trace) detection limits for certain parameters, especially metals. However, it may require additional cost per sample and a more rigorous SOP for the collection of samples to ensure they are of sufficient quality for trace analysis.

- Manganese was one of the seven water chemistry SOIs identified that have AEMP benchmarks and is discussed in Appendix II, Section 3.4.1; however, this discussion is not brought forward to the Annual Report (Section 3.3.3).

- The reviewer noted that Figure 3-11 (Annual Report, Section 3.3.3, p 26) is not the same figure presented as Figure 3-31 (Appendix II, Section 3.4.1, p 44) and that numerous supplemental figures in Appendix II (Appendix III, Supplemental Figures) have incorrect figure captions.

- As a more general comment, these types of discrepancies noted above result in some confusion on the part of the reviewer and call into question the accuracy of methods, results, and discussion points carried forward to the Annual Report from the numerous technical appendices.

- As suggested in the review of the 2007 AEMP and reiterated by EMAB, it would be beneficial if DDMI would carry forward any recommendations provided in technical appendices to the Annual Report and provide a rationale for accepting or rejecting (e.g., to be reconsidered in the Three Year Report with the benefit of multiple years of analysis and recommendations) each recommendation and a summary table of all recommendations for ease of future review(s) and consideration.

### 2.2.3 Sediment Chemistry

*Relevant materials reviewed included:*

- 2008 Annual Report, Section 4.0

- Appendix III: Sediment Report in Support of the 2008 AEMP Annual Report for the Diavik Diamond Mine, NWT

The objectives of the sediment monitoring component of the 2008 AEMP were to provide supporting environmental information for interpretation of the benthic invertebrate community survey, and to determine whether the mine has influenced the sediment chemistry of Lac de Gras and, if so, to classify any effect as low, moderate, or high.

The following comments are based on the more detailed Appendix III, but reflect what was brought forward to Section 4.0 of the Annual Report.

- Figure 2-1 in Appendix III provides a clear indication of the samples collected as part of the sediment monitoring component and is a welcome addition to AEMP reporting.

- The approach outlined for handling non-detect sediment chemistry data is unclear and would benefit from further explanation. A useful discussion on approaches for handling non-detect data may be found in Mitchell (2006).

- Total phosphorus and nitrogen were analysed in sediments (nutrient enrichment from mine effluent); however, these data were not included when considering the effects of habitat variation on the benthic invertebrate community metrics. As these sediment quality parameters provide more of a direct pathway (via influence on benthic algae in sediments if euphotic zone is sufficient) for any potential nutrient enrichment effect in the sediments linked to the mine it may be worthwhile to include them in the suite of important habitat variables used to explain the benthic invertebrate community relationships.

- Total phosphorus and nitrogen were analysed for in sediments (nutrient enrichment from mine effluent); however, there is minimal discussion of the results for these two parameters in Appendix III. TOC was used as a sediment quality indicator of potential nutrient enrichment that would become elevated in bottom sediments in areas of nutrient enrichment due to increased phytoplankton biomass settling to the lake bottom. This indirect pathway for effect does not appear to be a very sensitive indicator of change as 2008 chlorophyll *a* concentrations measured in the water at NF and FF exposure areas only approached 1.4 ug/L, but were still considered a moderate-level nutrient enrichment effect as maximum values of just under 1.0 ug/l were reported in the reference areas. It would be useful to have some discussion concerning the rationale of using TOC as a sediment quality indicator when sediment phosphorus and nitrogen data are both available and could potentially provide a more direct pathway (via influence on benthic algae in sediments if euphotic zone is sufficient) to describe any potential nutrient enrichment effect in the sediments linked to the mine.

- Although it has been discussed in the design and approval of the AEMP, the weak correlations of sediment parameters with physical variables, likely contributed to by the methodological inconsistencies, is again noted as less than ideal and may warrant revisiting this approach during the Three Year Report to see if there is a way to increase the utility of the physical data.

- Bismuth and uranium in sediments were each assigned a high level effect classification as both NF and at least one MF area had mean concentrations greater than the reference area range. Although it was concluded that that the elevated concentrations of these elements are unlikely to pose a risk to aquatic life at this time, concentrations in sediments will potentially increase in the future as loadings from the mine continue (effluent quality criteria are for *total* metals). Although these two parameters are not included in the list of water quality parameters with effluent quality criteria as defined in the Water Licence, it may be useful to have some discussion concerning the inclusion of additional metals in the monitoring of monthly loads from the NIWTP (and subsequent determination of annual loads).

- The recommendation that the effect level classification guidelines for sediments should be reconsidered in the future may benefit from further discussion, particularly with respect to the procedure employed by the analytical laboratory to extract metals from the sediments. It is unclear whether total metals in sediments are being determined using a strong acid extraction, which may potentially overestimate effects. CCME (2001) specifies that the occurrence of adverse biological effects cannot be predicted precisely from concentration data alone, particularly in the concentration ranges between the ISQGs and PELs. The chemical form in which metals are present will influence their biological availability and toxicity; furthermore, different aquatic species and life stages may exhibit varying levels of responses. Of particular relevance with respect to the application of CCME sediment guidelines is the procedure used to extract metals from the sediments. In this respect CCME (2001 - Introduction) notes: *"Because the ISQG are* *intended to be used for evaluating the potential for biological effects, "near total" trace metal extraction methods that remove the biologically available fraction of metals and not residual metals (i.e., those metals held within the lattice framework of the sediment) are recommended for determining sediment metal concentrations. A strong extraction method using hydrofluoric acid would remove both the bioavailable and residual fraction of metals in sediments. Therefore, (in the context of ISQG) the concentration of "total" metals refers to the concentration of metals recovered using a near-total (mild digestion; e.g., aqua regia, nitric acid or hydrochloric acid) method."*

### 2.2.4 Benthic Invertebrates

*Relevant materials reviewed included:*

- 2008 Annual Report, Section 5.0
- Appendix IV: Benthic Invertebrate Report in Support of the 2008 AEMP Annual Report for the Diavik Diamond Mine, NWT

The primary objective of this assessment was to determine if effects are occurring to the benthic invertebrate community of Lac de Gras due to the Diavik Diamond Mine and, if so, to classify these effects as early warning/low, moderate, or high in magnitude as per defined criteria.

The following comments are based on the more detailed Appendix IV, but reflect what was brought forward to Section 5.0 of the Annual Report.

- Figure 1-1 in Appendix IV provides a clear indication of the samples collected as part of the benthic invertebrate monitoring component and is a welcome addition to AEMP reporting.
- It is recommended that scientific names used follow the Integrated Taxonomic Information System (ITIS 2009). For example, Sphaeriidae is no longer valid and has been updated to Pisidiidae.
- As requested in the review of the 2007 AEMP Annual Report, benthic invertebrate biomass was determined as the total wet weight of the organisms in each sample and results were reported.
- The effect level criteria for gradient analysis (Appendix IV, Table 2-4, p 13) developed during the weight-of-evidence analysis of the 2007 AEMP results appear reasonable and the inclusion of gradient analysis will hopefully provide a more sensitive indicator of benthic invertebrate community response to mine effluent exposure.
- Total phosphorus and nitrogen were analysed in sediments (nutrient enrichment from mine effluent); however, these data were not included when considering the effects of habitat variation on the benthic invertebrate community metrics. As these sediment quality parameters provide more of a direct pathway (via influence on benthic algae in sediments if euphotic zone is sufficient) for any potential nutrient enrichment effect in the

sediments linked to the mine it may be worthwhile to include them in the suite of habitat variables used to explain the benthic invertebrate community relationships.

- Results of the power analysis done for ANOVA tests that did not detect a significant difference indicated that the desired power level of 0.90 was occasionally not achieved for metrics where a sample size of either five stations per sampling area or four [fewer than the intended five stations were sampled in two far-field areas (FF1 and FFA)] was achieved. However, even if statistical power is adequate to detect the chosen critical effect size of 2SD, sensitivity of among-area statistical comparisons tends to be low for the majority of metrics (other than Simpson's Diversity Index and % Chironomidae) due to the large background variability in benthic invertebrate community characteristics within Lac de Gras. It may be beneficial to have further discussion concerning this large background variability and how best to ensure the AEMP has a sufficient number of sampling sites to adequately characterize these areas and reduce variability within those areas (e.g., consider increasing sample size to improve sensitivity of among-area statistical comparisons).

- The inclusion of plots of benthic invertebrate community variables against distance from the diffuser (with reference area range of variability included) enhances the assessment of the approximate spatial extent of mine-related effects on the benthos and is a welcome addition to AEMP reporting.

- The magnitude and type of effects on the benthic invertebrate community detected during the 2008 AEMP were only partly consistent with effects detected in 2007. The 2008 effects were less pronounced and not entirely consistent with nutrient enrichment. Based on statistical comparisons, early warning/low level effects were found on total invertebrate density, richness, Bray-Curtis distance, *Heterotrissocladius* sp. density and percent Chironomidae. For these metrics, effect type varied between nutrient enrichment and a potential toxicological effect, with a stronger indication of an enrichment effect. A moderate level enrichment effect was found on *Procladius* sp. density and a high level enrichment effect was found on fingernail clam density, which extended into the MF1 and MF3 areas. Even though no relationships were found between sediment chemistry variables and benthic community metrics, the potential toxicological effects are concerning and may benefit from further consideration and discussion.

- The discussion concerning the issue of usefulness of FFA and FFB areas as appropriate reference areas for use in comparisons with the NF and FF2 exposure areas is a valid one and it is recommended that DDMI considers confirming the potential differences (habitat, benthic invertebrate community characteristics) between the FF1 reference area, and the FFA and FFB references areas during future monitoring cycles, prior to the Three Year Report synthesis.

- The potentially confounding influence of Lac du Sauvage on invertebrate communities at FF2 is not discussed. Lac du Sauvage, which empties into Lac de Gras, is considered more productive than Lac de Gras and has elevated barium concentrations in comparison to Lac de Gras reference areas, which could be contributing to the elevated open-water barium concentrations observed at FF2. The potentially confounding influence of Lac du

Sauvage was raised in the AEMP Design Document (Section 4.4.3.2) and the influence of Lac du Sauvage should be understood to enable discrimination of its influence from mine effects, i.e., DDMI should be able to describe effects of their operation separate from other influences. Traditional Knowledge could be a valuable source to evaluate Lac du Sauvage influence in Lac de Gras.

- Recommendations are sound given the rationales provided in Appendix IV. DDMI has already agreed to consider to the recommendation of adding a small number of stations to increase resolution along the MF1 and MF3 areas when re-evaluating the study design after the first three years of monitoring. Additionally, it is recommended that DDMI considers confirming the potential differences between the FF1 area, and the FFA and FFB areas during future monitoring cycles.

### 2.2.5 Fish

*Relevant materials reviewed included:*

- 2008 Annual Report, Section 6.0
- Appendix V: Metals in Lake Trout Report in Support of the 2008 AEMP Annual Report for the Diavik Diamond Mine, NWT

The primary objective of examining metals in fish tissue is to determine if DDMI is having an effect on fish usability. Given the findings of greater Hg concentrations in exposure-area slimy sculpin, a secondary objective of the 2008 lake trout survey was to determine if Hg levels, in particular, have increased in lake trout.

As a general comment, both Section 6.0 and Appendix V were at times difficult to read and confusing, primarily due to a lack of organization in the Results and Discussion sections. Furthermore, the different levels of statistical analyses and the conclusions drawn from each of these were somewhat confusing and lack a clear hierarchical structure. The following comments are based on the more detailed Appendix V, but reflect what was brought forward to Section 6.0 of the Annual Report.

- In the first paragraph of Section 2.0 (Methods) it is stated that the mercury data from the annual DDMI palatability studies were included in the temporal analysis of HG concentrations in lake trout, but they do not indicate how these data were incorporated or used.
- Despite the report statement in the first paragraph of Section 4.0 (Discussion), a valid comparison of length adjusted Hg concentrations between 1996 and 2008 data is impossible because in 1996 no individual fish can be associated with a specific Hg concentration. Thus the main conclusion of the report that Hg concentrations in fish tissues have not increased between 1996 and 2008 is not supported by a sound statistical analysis. Carrying this statement forward to the Conclusions, Section 6.0 in the body of the report and the Executive Summary, without an accompanying discussion of

limitations, leaves the unwarranted impression that the statement is made with some scientific certainty.

- In light of the inadequacies of the 1996 data set, it would have been particularly relevant to include the existing large data set for 2005 in an analysis of length adjusted Hg concentrations from Lac de Gras. From the scatter plot presented in Figure 3-2 the possibility exists that the 2008 Hg concentrations were higher than in 2005. Although it is correctly noted that it is not possible do determine a trend from two data points, an analysis of mean Hg concentrations between 2005 and 2008 would at least document if Hg concentrations have been stable or have changed in recent years. The report compares Hg levels between 1996 and 2008, but the authors also could have compared 1996 to 2005, particularly since the ANCOVA did not allow comparisons for muscle and kidney between 1996 and 2008. The argument for excluding the 2005 data from the statistical analysis, that the sampling was conducted by a different organization and at different locations, is not valid, unless there is evidence for site specific differences in Hg levels or that the sampling method had an effect on Hg concentrations.

- The inability to make a valid statistical comparison that includes length adjusted Hg concentrations between the 1996 data (i.e., the baseline condition) and the data from any later year poses a fundamental problem in assessing Effect Levels according to Table 1-1. Consideration should be given to revising the Early Warning/Low Effect Description so that it includes detection of any trend, rather than a change relative to baseline.

- Determining fish usability based on the 0.5 ppm Health Canada guideline level for commercially marketed fish is not appropriate where the use is for domestic purposes. For people who consume fish regularly, it has been recommended that a mean concentration of 0.2 ppm Hg should not be exceeded in fish muscle (Wheately 1984). Also, more detailed calculations and recommendations could be made based on tolerable daily intake (TDI) recommendations for methyl mercury of 0.47 µg/kg body wt/day (0.20 µg/kg body wt/day for women and children up to age 12) by Health Canada (Health Canada 2007) to assess the health risk of local resource users.

- The report also talks about adverse effects on fish health (last paragraph of the Discussion) and cites a 1998 reference supporting a lack of effects below tissue concentrations of 1 ppm. This reference is largely outdated and more recent evidence exists for fish (and wildlife) health effects of Hg at lower tissue levels (Scheuhammer et al. 2007).

- The report uses a statistical method (ANCOVA) for adjusting Hg concentrations for different sized fish that is sensitive to differences in the rate of increase of Hg levels with fish length and should not be applied if the rates differ. Such differences in slope often occur between years within fish populations or among different populations, and thus preclude (in the strict statistical sense) the use of the ANCOVA method of length standardization. However, other methods (such as calculating mean Hg concentrations for a fish of so-called “standard” length from log transformed data) exist to standardize Hg levels by fish size that don’t depend on such rigid assumptions as an ANCOVA, and can be applied under most conditions.

- In those cases where an ANCOVA comparison was not possible, the report draws unwarranted conclusions about inter-annual differences in Hg concentrations from a visual comparison of descriptive statistics (e.g. median concentrations). The statement (2nd paragraph of the Discussion) that the median flesh Hg concentration in 2008 was similar to 1996, but lower than in 2005 creates the wrong impression. While technically the 2008 median value may be lower than in 2005, all three Hg concentrations for 1996, 2005, and 2008 are very similar.

- In addition to the issues outlined above, the report contains other ambiguities and inconsistencies that make it difficult to ascertain exactly what was done and what data are actually reported:

    - For example, Hg concentrations are reported for "flesh", liver, and kidney. According to the 2008 method description (p 5) "flesh" seems to be boneless muscle tissue. However, according to Section 2.2.2 1996 Hg analysis was done on "flesh", kidney, and muscle (p 6), while "flesh", kidney, and liver were analyzed in 2008. The difference between flesh and muscle is not explained, and it can only be assumed that the inter-annual comparison of flesh Hg concentrations was actually done on muscle tissue.

    - Also, the measure of variance of mean Hg concentrations is inconsistent; standard error is used in Figure 3-3, whereas standard deviation is used in Table 3-3.

    - Much is said about outliers in Section 2.2.3, but the criteria used to classify an outlier are not provided.

    - According to its caption Table 4-1 shows fish lengths for 2005 (which would have been useful), but there are no such data in the table.

- Appendix V reports that DFO has identified a research team that will conduct a specialized sediment core analysis study that may assist in understanding the source of mercury increases in slimy sculpin. The objective will be to determine if mercury uptake is related to lake sediments rather than DDMI mine effluent. DDMI has also agreed to conduct a SES on Possible Effects of Enrichment on Mercury Uptake. Both studies could be very useful in developing a better understanding of mercury uptake in Lac de Gras fish.

### 2.2.6 Dike Monitoring Studies

*Relevant materials reviewed included:*

- 2008 Annual Report, Section 7.1.1

- Appendix VII: A21 Dike – Baseline Study

The objective of this study was to collect baseline data (benthic invertebrate community, sediment composition, and water chemistry) prior to dike construction that would be used during the dike monitoring program to verify predictions of dike-related effects in Lac de Gras made in the Environmental Assessment.

The following comments are based on the more detailed Appendix VII, but reflect what was brought forward to Section 7.1.1 of the Annual Report.

- For consistency and following the same rationale applied for the main sediment quality monitoring program (i.e., the low rate of sedimentation in Lac de Gras), consideration should be granted to measurement of sediment chemistry in shallower sediment depths (i.e., 1 cm) for the dike monitoring program. This review comment also pertained to the 2007 AEMP and was being considered by DDMI in consultation with the DFO; an update with respect to the status of this item would be beneficial.

- The handling of non-detect data differs from the approach taken in Appendices II and II and would benefit from further explanation. A useful discussion on approaches for handling non-detect data may be found in Mitchell (2006).

- Baseline water quality results for total phosphorus in the control area and at Lines 10 and 11 most likely reflect the influence of mine effluent.

- Some sediment quality parameters had baseline concentrations above ISQGs; these included arsenic, chromium, copper, and cadmium. The PEL for arsenic was also exceeded at the majority of stations where levels were above the ISQG. These exceedences were attributed to naturally occurring concentrations of metals, which reflect geological conditions in the region of Lac de Gras. Trace metal concentrations at AEMP sites were also screened against conservative SQGs to assess the potential for ecological effects due to existing concentrations of these substances. Numerous trace metals measured at AEMP sites also exceeded various guideline levels (Appendix III, Section 3.2). However, neither Appendix VII nor Appendix III provided any further discussion of potential toxicological effects related to these parameters. It may be of benefit to consider integrating background concentrations of naturally elevated metals in the discussion of potential toxicological effects on benthic community metrics (Appendix IV), as sediment chemistry SOIs identified in Appendix III do not demonstrate any relationship with benthic community metrics.

### 2.2.7 Plankton Special Effects Study

*Relevant materials reviewed included:*

- 2008 Annual Report, Section 7.2

- Appendix XI: Plankton Report in Support of the 2008 AEMP Annual Report for the Diavik Diamond Mine, NWT

The main objective of the Plankton Special Effects Study (SES) was to determine the feasibility and utility of using community composition and biomass (calculated) as sensitive metrics to detect DDMI-related effects on the Lac de Gras ecosystem (i.e., for phytoplankton = to verify the appropriateness of using chlorophyll *a* as a surrogate measure of the phytoplankton community; for zooplankton = to verify the use of biomass as an indicator). To meet this goal, three main objectives were addressed:

- Fill gaps in available baseline data on plankton community composition;
- Assess potentially mine-related changes in phytoplankton and zooplankton community composition over time; and
- Over the initial three years of the revised AEMP it will be determined if a single, open-water sample is adequate to describe community metrics and, if so, the best single period of the open-water season will be determined.

Additionally, archived phytoplankton samples were analyzed (collected between 1997 and 2006), combined with existing DDMI data (1997, 2002, and 2007), and were collectively evaluated to assess potential changes in phytoplankton community composition over time.

Finally, archived data for phytoplankton biomass were compared to corresponding chlorophyll *a* concentrations to qualitatively assess whether chlorophyll *a* provides an adequate measure of phytoplankton biomass.

The following comments are based on the more detailed Appendix XI, but reflect what was brought forward to Section 7.2 of the Annual Report.

- Detailed SOPs need to be followed carefully/rigorously to ensure sample collection methodology is consistent from site-to-site and year-to-year.
- The taxa groups indicated as having the highest relative biomass and therefore used for QA were Calanoida and Cladocera; however, Cyclopoida had higher relative biomass than Cladocera, but was not used to evaluate QA. Large discrepancies in the QA counts occurred by using Cladocera due to associated low biomass numbers; using Cyclpoida may have provided better confidence in the biomass results.
- Similar to the 2007 AEMP Annual Report, no comparative statistics were provided for the 2008 zooplankton data (e.g. mean, min/max, standard deviation, standard errors). This was a requirement stipulated in the design document and was subsequently requested again by the WLWB after the 2007 AEMP report review.
- Figure 3-11 was overloaded with information for the reviewer and did not complement the text well, e.g., the text refers to NF, MF, FF2, FFA, and FFB areas, but the figure only had ‘FF reference area’ and ‘FFB’ for far-field labels. Segregating some of the data into separate charts (e.g., by area) would have been useful due to the amount of information, as many generalities were determined from this graph, such as:
    - There appears to be a reasonable relationship between chlorophyll *a* and total phytoplankton biomass;

- ◦ A mild eutrophication effect is suggested within the NF, MF, and FF2 areas; and
- ◦ The usefulness of chlorophyll *a* as a surrogate for phytoplankton biomass when chlorophyll *a* concentrations are higher relative to other samples with similar phytoplankton biomass.

- Were there zooplankton biomass data from 2007? In the assessment, 2008 zooplankton results were referred to as being similar to 2007 in terms of species present, relative abundance, and relative biomass. This may have been a minor oversight as the reviewer understands there were no biomass data from 2007.

### 2.2.8 2008 AEMP Special Effects Studies

*Relevant materials reviewed included:*

- 2008 Annual Report, Section 7.3
- No technical appendix was associated with the 2008 AEMP SES

In conjunction with the 2008 AEMP a SES was conducted to evaluate ultra-low detection limits for mercury (total and methyl mercury in water; total mercury in sediments; total mercury in lake trout flesh) and to determine if the treated effluent from the NIWTP was a source of total or methyl mercury.

A SES was also conducted to obtain an estimate of the proportion of total chromium discharged as chromium VI at SNP 1645-18 to assist with comparisons to AEMP benchmarks.

The following comments are based on Section 7.3 of the Annual Report.

#### *2.2.8.1 Mercury Detection Limits*

- Results of the Mercury Detection Limits SES support DDMI's view that treated NIWTP effluent is likely not a source of mercury to Lac de Gras, and that there is little value in testing for mercury in water. DDMI will continue to conduct low level mercury analysis on a monthly basis at 1645-18 and if future results indicate a change, then consideration will be given to low level analysis at other SNP and/or AEMP sites. This approach is reasonable.
- Similarly, DDMI concludes that 0.4 ng/g limit (Flett Laboratories) is not justified and all future sampling at SNP and AEMP sites will use ALS Laboratories Simultaneous Extractable Metals (SEM) analytical procedure. This is also a reasonable approach. However, it is recommended that any changes in methodology be accompanied with a literature review of the various methods and possibly a method comparison SES.
- Finally, DDMI concludes that the ALS method and detection limit are adequate for future fish tissue analyses, and this also is a reasonable conclusion.

#### *2.2.8.2 Chromium VI*

- Given the low levels of chromium VI detected in the study and that the laboratory detection limit of CrVI is equivalent to the AEMP benchmark (0.001 mg/L), DDMI's intention to discontinue chromium IV sampling is appropriate; sampling could be reinitiated in the future if warranted (e.g., pertinent changes to the effluent treatment process).

### 2.2.9 Eutrophication Indicators

*Relevant materials reviewed included:*

- 2008 Annual Report, Section 7.4
- Appendix XIII: Eutrophication Indicators Report in Support of the 2008 AEMP Annual Report for the Diavik Diamond Mine, NWT

The overall objective of this assessment was to determine if effluent from the Diavik Diamond Mine is having an effect on concentrations of nutrients, chlorophyll *a* and zooplankton biomass in Lac de Gras.

The following comments are based on the more detailed Appendix XIII, but reflect what was brought forward to Section 7.4 of the Annual Report.

- Better integration between this appendix and Appendix XI (Plankton SES) would add value to the eutrophication assessment. For example, the issue regarding the usefulness of chlorophyll *a* as a surrogate for phytoplankton biomass when chlorophyll *a* concentrations are variable in samples with similar phytoplankton biomass was noted in the Plankton SES; how would this source of variability potentially influence the eutrophication assessment? Measurement of chlorophyll *a* in water is commonly used as an indicator of the amount (biomass) of phytoplankton growing in the water as it is feasible to obtain a large number of samples more efficiently/cost effectively in comparison to samples for phytoplankton enumeration. However, it should be recognized in the eutrophication assessment that this method is not very sensitive and does not provide any information on the type of phytoplankton present. Furthermore, because the chlorophyll *a* content varies between species of phytoplankton (0.3-3.0% of dry weight among algal species), the concentration of chlorophyll *a* may not accurately represent the absolute quantity of phytoplankton present (Lee 1980)
- The criteria used to classify an outlier are not provided (Appendix XIII, Section 2.2.1).
- A useful discussion on approaches for handling non-detect data may be found in Mitchell (2006).
- Prior to using the 2007 chlorophyll *a* results in any comparisons with past or future results, a literature review and method comparison SES was to be conducted in 2008 to address potential differences between sampling methods (in 2007 only, the euphotic zone

was estimated from Secchi disk depths). This SES would be applicable to Appendices XI (Plankton SES) and XIII (Eutrophication Indicators); however it does not appear to have been conducted.

- Total nitrogen levels exceeded the normal range during all sampling periods as discussed in the assessment, but only ice-cover concentrations were graphed. The extent of nitrogen effects is discussed, but it would have aided the interpretation if the open-water periods were graphed; similarly to the presentation of chlorophyll *a* and zooplankton data.

- In paragraph 1 on p 25, a comparison is made regarding the extent of chlorophyll effects in the open-water period 1 to the extent of effects on TP and total nitrogen during the ice-cover period. Since TP at exposure sites only exceeded the normal range under ice this comparison is understandable. However, total nitrogen levels exceeded the normal range during all sampling periods. Although total nitrogen concentrations were highest in the exposure area under ice, it is unclear whether the extent of effect was similar to or greater/less than in the open-water periods. Is the reviewer to assume that the boundary of effects for total nitrogen was greatest under ice? This reinforces the previous point.

- The affected area of the lake based on chlorophyll *a* represents 24% of the lake surface area. The area of the lake showing effects on total phosphorus throughout the water column is approximately 14% of the total lake area. The mine is having a moderate-level effect on chlorophyll *a* and TP, and a high-level effect on zooplankton. If the extent of effects on TP were to reach MF3-4 (extent had not conclusively reached this location in 2008), and that on chlorophyll *a* were to remain the same as presently observed, the level of effects on eutrophication would be considered high.

- The recommendation provided in Appendix XIII for allocating some existing stations to the MF3 mid-field area is excellent; more intensive investigations of these areas is warranted given that effects have been observed and the extent appears to be expanding. It is noted that DDMI prefers to consider changes to the study design following synthesis of information in the Three Year Report.

- In light of the shift in trophic status from ultra-oligotrophic to oligotrophic it may be prudent to revisit the discussion of the trophic status of the lake and EA predictions, and in particular make reference to the *CCME phosphorus Canadian guidance framework for the management of freshwater systems* (CCME 2004), in a more timely fashion than the Three Year Report.

### 2.2.10 Weight of Evidence

*Relevant materials reviewed included:*

- 2008 Annual Report, Section 9.0

- Appendix XV: Weight-of-Evidence (WOE) Assessment in Support of the 2008 AEMP Annual Report for the Diavik Diamond Mine, NWT

The objectives of the WOE assessment were two-fold:

- To apply a standardized process to evaluate strength of evidence for potential toxicological impairment and nutrient enrichment effects in the aquatic ecosystem of Lac de Gras; and

- To summarize the AEMP findings in a semi-quantitative manner that provided broad AEMP conclusions, which could inform decision-making for ongoing environmental stewardship of Lac de Gras.

The following comments are based on the more detailed Appendix XV, but reflect what is brought forward to Section 9.0 of the Annual Report.

- The WOE approach has been refined in 2008 to address weaknesses identified in the 2007 report. Specifically:

    - Separate WOE analyses to assess Nutrient Enrichment Impacts and Toxicological Impairment Impacts;

    - Revised effect ratings to include nutrient enrichment effects and separate ratings for chlorophyll a and TP;

    - Inclusion of Direction Weighting Factors for biological response variables to reflect the degree of support that an observed effect provides for the Nutrient Enrichment and Toxicological Impairment hypotheses; and Assessment of exposure and effect/response endpoints for LDG as a whole (i.e., no separation of NF and FF2 analysis.

- These refinements substantially increase the strength of the causal linkage between the Exposure and Effect LOEs and represent a significant improvement over the approach presented in the 2007 Annual Report.

- In 2007 a Moderate EOI (EOI Rank 2) was assigned to both productivity and benthic invertebrates at NF sites.

- With the 2008 revisions, evidence of toxicological impairment resulted in a Negligible EOI (EOI Rank 0) for Lake Productivity, and a Low EOI (EOI Rank 1) for Benthic Invertebrates. Evidence of nutrient enrichment resulted in a Strong (EOI Rank 3) for both Lake Productivity and Benthic Invertebrates.

- Appendix XV concludes that the evidence for nutrient enrichment linked to mine activities was much stronger than the evidence for toxicological impairment, and that increases in primary productivity were extending beyond near-field areas. It was also concluded that the magnitude and type of response in Lac de Gras appears to be a mild enrichment to lake productivity and the benthic invertebrate community; the severity with respect to the ecological integrity of Lac de Gras associated with these changes to indicators of enrichment is considered to be low and consistent with the beginning of a shift from ultra-oligotrophic to oligotrophic status.

- Given that the overall severity of nutrient enrichment is considered mild by the WOE analysis, Appendix XV recommends that scientific investigative follow-up beyond the existing AEMP studies is not considered necessary at this time. The reviewers feel that this recommendation may be somewhat dismissive of the current degree of nutrient enrichment in Lac de Gras and the potential influence of this enrichment on mercury methylation processes (as commented on in the review of the 2007 AEMP Annual Report and to be investigated in the proposed SES on Possible Effects of Enrichment on Mercury Uptake). Observed effects are occurring after the mine has been fully operational for approximately 5 years (the first full year of mine production was 2004; NIWTP commissioned in 2002). It may be prudent at this time to review whether these effect levels were predicted in the EA to occur within this timeframe and project how severe they may become over the life of the mine (to approximately 2023) based on the rate of change to date. Essentially, if this review indicates that by the end of the mine's life the lake will no longer be in an acceptable condition (i.e., projected changes beyond EA predictions) options to manage nutrient loading should be investigated in a timely fashion.

**Table 2-1. Technical review matrix of the 2008 Diavik Diamond Mine Incorporated (DDMI) Lac de Gras Aquatic Effects Monitoring Program (AEMP) Annual Report with evaluation comments and key recommendations for EMAB to consider.**

| 2008 AEMP Component | Detailed Technical Review and Recommendations | Evaluation Comments and Key Recommendations for EMAB |
|---|---|---|
| Dust Deposition | • In general, there was poor qualification of the amount of change/degree of change observed in the snow water measured parameters. Generally, only the trend between 2007 and 2008 was provided without qualification of magnitude observed, e.g., zinc concentrations increased in snow water for all zones from 2007 to 2008. Is a more comprehensive evaluation expected in subsequent reports?<br>• A discussion of total phosphorous in the snow water was missing in Appendix I. Raw data indicated an increase in phosphorous in 2008 compared to 2007 that was not commented on;<br>• It would be useful to provide some discussion of the potential effects of this additional phosphorus introduced from the mine on surface water quality [as mentioned in the review of the 2007 AEMP: this could include integrated discussion of total phosphorus (TP) concentrations in surface waters and sediment in the vicinity of the monitoring sites and/or discussion of total loading from dust relative to other sources and in-lake loads]; and<br>• "Permanent dustfall collectors measured 'minor' increases in dustfall deposition from 2007 to 2008, except at Dust 3 and 4". The reviewer disagrees with 'minor' as differences ranged from 7 to 143%, excluding Dust 3 and 4. A better qualification of these results would be helpful.<br>• DDMI's recommendation to continue remodelling of project-specific air quality emissions and dust deposition to develop more accurate model predictions than those generated during the EA is supported based on the 2008 observation that all dustfall deposition rates exceeded those predicted in the 1998 environmental effects model (often by an order of magnitude).<br>• The recommendation to discontinue temporary dust gauges monitoring may be somewhat premature and would benefit from additional discussion - it may be helpful for DDMI to provide some further explanation for the observed differences between co-located dust gauges (temporary vs. permanent).<br>• Would the overestimated dust deposition rates be used in their remodelling of project-specific deposition? If so, would their new predictions be overly insensitive to real observed increases/decreases in deposition? | • It would be useful to provide some discussion of the potential effects of additional phosphorus introduced from dust on surface water quality, i.e., provide a total loading estimate from dust and compare it to amounts from other sources.<br>• In the comparison of temporary/monthly dust collectors to permanent collectors, it appears DDMI is satisfied with the current way dust is collected, which potentially overestimates dust deposition rates (up to double the amount).<br>• How would the over-estimated dust deposition data affect remodelling of project-specific dust deposition? Would the new model predictions also be overestimates, thus making model predictions insensitive to real changes? |

| 2008 AEMP Component | Detailed Technical Review and Recommendations | Evaluation Comments and Key Recommendations for EMAB |
|---|---|---|
| Effluent and Water Chemistry | • The reviewer noted some discrepancies in the reported number of samples collected between the Annual Report (Section 3.2, p 15) and Appendix II (Section 2.1, p 6), which made the subsequent review more difficult and raised concern as the degree of completion of the 2008 AEMP sampling could have been limited for the third open-water sample season (10 September – 12 October). For example, the Annual Report states "In August a water sample was not collected at FF1-4 and in September at the FF1 and FF2 areas plus at stations FFB-2 and FFB-5 because weather prohibited sample collection", whereas Appendix II states "Due to logistics and weather conditions, the FF2 stations were not sampled in the second open-water season and FF1 stations were not sampled in the third open-water sample season."<br>• It is unclear how non-detect water chemistry data were handled. Subsequent appendices (e.g., Appendix III: Sediment Chemistry) with non-detect data refer to Appendix II for an explanation regarding handling of these data for the purposes of statistical analysis; however, this discussion does not appear in Appendix II.<br>• The reviewer noted some discrepancies in the 2007 and 2008 comparison of Substances of Interest (SOI) provided in the Annual Report (Section 3.3, p 18). For example, parameters identified as SOI in 2007 that were not identified as SOI in 2008 included nitrate.<br>• Graphical presentation of 2006, 2007, and 2008 water quality monitoring data collected at SNP 1645-18 is very helpful in discerning trends in concentrations (Appendix II, Section 3.2.1); however some figure captions provided in the Annual Report (Section 3.3.1) are incorrect.<br>• Appendix II, Section 3.3 reiterates a common problem in water quality monitoring programs in which the detection limits for parameters of interest are above a guideline for the protection of aquatic life or other criteria being considered. For example, the potential exceedence of benchmarks for cadmium and silver in water samples collected at the edge of the mixing zone could not be evaluated as the detection limit was above the benchmarks. In some instances, this issue can be resolved with the analytical laboratory as they may be able to provide low-level (i.e., trace) detection limits for certain parameters, especially metals. However, it may require additional cost per sample and a more rigorous SOP for the collection of samples to ensure they are of sufficient quality for trace analysis.<br>• Manganese was one of the seven water chemistry SOIs identified that have AEMP benchmarks and is discussed in Appendix II, Section 3.4.1; however, this discussion is not brought forward to the Annual Report (Section 3.3.3).<br>• The reviewer noted that Figure 3-11 (Annual Report, Section 3.3.3, p 26) is not the same figure presented as Figure 3-31 (Appendix II, Section 3.4.1, p 44) and that numerous supplemental figures in Appendix II (Appendix III, Supplemental Figures) have incorrect figure captions.<br>• As a more general comment, these types of discrepancies noted above result in some confusion on the part of the reviewer and call into question the accuracy of methods, results, and discussion points carried forward to the Annual Report from the numerous technical appendices.<br>• As suggested in the review of the 2007 AEMP and reiterated by EMAB, it would be beneficial if DDMI would carry forward any recommendations provided in technical appendices to the Annual Report and provide a rationale for accepting or rejecting (e.g., to be reconsidered in the Three Year Report with the benefit of multiple years of analysis and recommendations) each recommendation and a summary table of all recommendations for ease of future review(s) and consideration. | • A number of discrepancies were noted between the non-technical summary and appendix, which calls into question the accuracy of information presented.<br>• Technology exists to monitor water quality parameters at levels that allow comparisons to benchmark/guideline levels.<br>• Being able to detect trace metals allows evaluation of trends over time.<br>• Evaluate reducing detection limits to levels that allow comparison to benchmarks and evaluation of trends over time.<br>• Provide a summary table in the non-technical summary for all recommendations and a rationale for accepting/rejecting each for ease of review and consideration. |

| 2008 AEMP Component | Detailed Technical Review and Recommendations | Evaluation Comments and Key Recommendations for EMAB |
|---|---|---|
| Sediment Chemistry | • Figure 2-1 in Appendix III provides a clear indication of the samples collected as part of the sediment monitoring component and is a welcome addition to AEMP reporting.<br>• The approach outlined for handling non-detect sediment chemistry data is unclear and would benefit from further explanation. A useful discussion on approaches for handling non-detect data may be found in Mitchell (2006).<br>• Total phosphorus and nitrogen were analysed in sediments (nutrient enrichment from mine effluent); however, these data were not included when considering the effects of habitat variation on the benthic invertebrate community metrics. As these sediment quality parameters provide more of a direct pathway (via influence on benthic algae in sediments if euphotic zone is sufficient) for any potential nutrient enrichment effect in the sediments linked to the mine it may be worthwhile to include them in the suite of important habitat variables used to explain the benthic invertebrate community relationships.<br>• Total phosphorus and nitrogen were analysed for in sediments (nutrient enrichment from mine effluent); however, there is minimal discussion of the results for these two parameters in Appendix III. TOC was used as a sediment quality indicator of potential nutrient enrichment that would become elevated in bottom sediments in areas of nutrient enrichment due to increased phytoplankton biomass settling to the lake bottom. This indirect pathway for effect does not appear to be a very sensitive indicator of change as 2008 chlorophyll a concentrations measured in the water at NF and FF exposure areas only approached 1.4 ug/L, but were still considered a moderate-level nutrient enrichment effect as maximum values of just under 1.0 ug/l were reported in the reference areas. It would be useful to have some discussion concerning the rationale of using TOC as a sediment quality indicator when sediment phosphorus and nitrogen data are both available and could potentially provide a more direct pathway (via influence on benthic algae in sediments if euphotic zone is sufficient) to describe any potential nutrient enrichment effect in the sediments linked to the mine.<br>• Although it has been discussed in the design and approval of the AEMP, the weak correlations of sediment parameters with physical variables, likely contributed to by the methodological inconsistencies, is again noted as less than ideal and may warrant revisiting this approach during the Three Year Report to see if there is a way to increase the utility of the physical data.<br>• Bismuth and uranium in sediments were each assigned a high level effect classification as both NF and at least one MF area had mean concentrations greater than the reference area range. Although it was concluded that that the elevated concentrations of these elements are unlikely to pose a risk to aquatic life at this time, concentrations in sediments will potentially increase in the future as loadings from the mine continue (effluent quality criteria are for total metals). Although these two parameters are not included in the list of water quality parameters with effluent quality criteria as defined in the Water Licence, it may be useful to have some discussion concerning the inclusion of additional metals in the monitoring of monthly loads from the NIWTP (and subsequent determination of annual loads).<br>• The recommendation that the effect level classification guidelines for sediments should be reconsidered in the future may benefit from further discussion, particularly with respect to the procedure employed by the analytical laboratory to extract metals from the sediments. It is unclear whether total metals in sediments are being determined using a strong acid extraction, which may potentially overestimate effects. CCME (2001) specifies that the occurrence of adverse biological effects cannot be predicted precisely from concentration data alone, particularly in the concentration ranges between the ISQGs and PELs. The chemical form in which metals are present will influence their biological availability and toxicity; furthermore, different aquatic species and life stages may exhibit varying levels of responses. Of particular relevance with respect to the application of CCME sediment guidelines is the procedure used to extract metals from the sediments. In this respect CCME (2001 - Introduction) notes: “Because the ISQG are intended to be used for evaluating the potential for biological effects, “near total” trace metal extraction methods that remove the biologically available fraction of metals and not residual metals (i.e., those metals held within the lattice framework of the sediment) are recommended for determining sediment metal concentrations. A strong extraction method using hydrofluoric acid would remove both the bioavailable and residual fraction of metals in sediments. Therefore, (in the context of ISQG) the concentration of “total” metals refers to the concentration of metals recovered using a near-total (mild digestion; e.g., aqua regia, nitric acid or hydrochloric acid) method.” | • Evaluate the rationale of using total organic carbon as a sediment quality indicator when sediment phosphorus and nitrogen data are both available and could potentially provide a more direct pathway (via influence on benthic algae in sediments if light penetration is sufficient) to describe any potential nutrient enrichment effect in the sediments linked to the mine.<br>• Evaluate the inclusion of additional metals (e.g., bismuth, uranium) in the monitoring of loads from the NIWTP as high level effect classifications have been assigned for certain metals in sediments.<br>• Evaluate laboratory analytical methods for sediment metals extraction to determine if the fraction which is bioavailable is being measured and does not include residual metals. This may provide a better approximation of metal concentrations to evaluate against effect level classification guidelines (currently these effects may be overestimated). |

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| Benthic Invertebrates | • It is recommended that scientific names used follow the Integrated Taxonomic Information System (ITIS 2009). For example, Sphaeriidae is no longer valid and has been updated to Pisidiidae.<br>• As requested in the review of the 2007 AEMP Annual Report, benthic invertebrate biomass was determined as the total wet weight of the organisms in each sample and results were reported.<br>• The effect level criteria for gradient analysis (Appendix IV, Table 2-4, p 13) developed during the weight-of-evidence analysis of the 2007 AEMP results appear reasonable and the inclusion of gradient analysis will hopefully provide a more sensitive indicator of benthic invertebrate community response to mine effluent exposure.<br>• Total phosphorus and nitrogen were analysed in sediments (nutrient enrichment from mine effluent); however, these data were not included when considering the effects of habitat variation on the benthic invertebrate community metrics. As these sediment quality parameters provide more of a direct pathway (via influence on benthic algae in sediments if euphotic zone is sufficient) for any potential nutrient enrichment effect in the sediments linked to the mine it may be worthwhile to include them in the suite of habitat variables used to explain the benthic invertebrate community relationships.<br>• Results of the power analysis done for ANOVA tests that did not detect a significant difference indicated that the desired power level of 0.90 was occasionally not achieved for metrics where a sample size of either five stations per sampling area or four [fewer than the intended five stations were sampled in two far-field areas (FF1 and FFA)] was achieved. However, even if statistical power is adequate to detect the chosen critical effect size of 2SD, sensitivity of among-area statistical comparisons tends to be low for the majority of metrics (other than Simpson's Diversity Index and % Chironomidae) due to the large background variability in benthic invertebrate community characteristics within Lac de Gras. It may be beneficial to have further discussion concerning this large background variability and how best to ensure the AEMP has a sufficient number of sampling sites to adequately characterize these areas and reduce variability within those areas (e.g., consider increasing sample size to improve sensitivity of among-area statistical comparisons).<br>• The inclusion of plots of benthic invertebrate community variables against distance from the diffuser (with reference area range of variability included) enhances the assessment of the approximate spatial extent of mine-related effects on the benthos and is a welcome addition to AEMP reporting.<br>• The magnitude and type of effects on the benthic invertebrate community detected during the 2008 AEMP were only partly consistent with effects detected in 2007. The 2008 effects were less pronounced and not entirely consistent with nutrient enrichment. Based on statistical comparisons, early warning/low level effects were found on total invertebrate density, richness, Bray-Curtis distance, *Heterotrissocladius* sp. density and percent Chironomidae. For these metrics, effect type varied between nutrient enrichment and a potential toxicological effect, with a stronger indication of an enrichment effect. A moderate level enrichment effect was found on *Procladius* sp. density and a high level enrichment effect was found on fingernail clam density, which extended into the MF1 and MF3 areas. Even though no relationships were found between sediment chemistry variables and benthic community metrics, the potential toxicological effects are concerning and may benefit from further consideration and discussion.<br>• The discussion concerning the issue of usefulness of FFA and FFB areas as appropriate reference areas for use in comparisons with the NF and FF2 exposure areas is a valid one and it is recommended that DDMI considers confirming the potential differences (habitat, benthic invertebrate community characteristics) between the FF1 reference area, and the FFA and FFB references areas during future monitoring cycles, prior to the Three Year Report synthesis.<br>• The potentially confounding influence of Lac du Sauvage on invertebrate communities at FF2 is not discussed. Lac du Sauvage, which empties into Lac de Gras, is considered more productive than Lac de Gras and has elevated barium concentrations in comparison to Lac de Gras reference areas, which could be contributing to the elevated open-water barium concentrations observed at FF2. The potentially confounding influence of Lac du Sauvage was raised in the AEMP Design Document (Section 4.4.3.2) and the influence of Lac du Sauvage should be understood to enable discrimination of its influence from mine effects, i.e., DDMI should be able to describe effects of their operation separate from other influences.<br>• Recommendations are sound given the rationales provided in Appendix IV. DDMI has already agreed to consider to the recommendation of adding a small number of stations to increase resolution along the MF1 and MF3 areas when re-evaluating the study design after the first three years of monitoring. Additionally, it is recommended that DDMI considers confirming the potential differences between the FF1 area, and the FFA and FFB areas during future monitoring cycles. | • DDMI should consider confirming the potential differences (habitat, benthic invertebrate community characteristics) between the FF1 reference area, and the FFA and FFB references areas during future monitoring cycles, prior to the Three Year Report synthesis.<br>• The influence of Lac du Sauvage should be understood to enable discrimination of its influence from mine effects, i.e., DDMI should be able to describe effects of their operation separate from other influences.<br>• Traditional Knowledge could be a valuable source to evaluate Lac du Sauvage influence in Lac de Gras (e.g., potential influence on invertebrate community at FF2). |

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| Fish | • In the first paragraph of Section 2.0 (Methods) it is stated that the mercury data from the annual DDMI palatability studies were included in the temporal analysis of HG concentrations in lake trout, but they do not indicate how these data were incorporated or used.<br>• Despite the report statement in the first paragraph of Section 4.0 (Discussion), a valid comparison of length adjusted Hg concentrations between 1996 and 2008 data is impossible because in 1996 no individual fish can be associated with a specific Hg concentration. Thus the main conclusion of the report that Hg concentrations in fish tissues have not increased between 1996 and 2008 is not supported by a sound statistical analysis. Carrying this statement forward to the Conclusions, Section 6.0 in the body of the report and the Executive Summary, without an accompanying discussion of limitations, leaves the unwarranted impression that the statement is made with some scientific certainty.<br>• In light of the inadequacies of the 1996 data set, it would have been particularly relevant to include the existing large data set for 2005 in an analysis of length adjusted Hg concentrations from Lac de Gras. From the scatter plot presented in Figure 3-2 the possibility exists that the 2008 Hg concentrations were higher than in 2005. Although it is correctly noted that it is not possible do determine a trend from two data points, an analysis of mean Hg concentrations between 2005 and 2008 would at least document if Hg concentrations have been stable or have changed in recent years. The report compares Hg levels between 1996 and 2008, but the authors also could have compared 1996 to 2005, particularly since the ANCOVA did not allow comparisons for muscle and kidney between 1996 and 2008. The argument for excluding the 2005 data from the statistical analysis, that the sampling was conducted by a different organization and at different locations, is not valid, unless there is evidence for site specific differences in Hg levels or that the sampling method had an effect on Hg concentrations.<br>• The inability to make a valid statistical comparison that includes length adjusted Hg concentrations between the 1996 data (i.e., the baseline condition) and the data from any later year poses a fundamental problem in assessing Effect Levels according to Table 1-1. Consideration should be given to revising the Early Warning/Low Effect Description so that it includes detection of any trend, rather than a change relative to baseline.<br>• Determining fish usability based on the 0.5 ppm Health Canada guideline level for commercially marketed fish is not appropriate where the use is for domestic purposes. For people who consume fish regularly, it has been recommended that a mean concentration of 0.2 ppm Hg should not be exceeded in fish muscle (Wheately 1984). Also, more detailed calculations and recommendations could be made based on tolerable daily intake (TDI) recommendations for methyl mercury of 0.47 µg/kg body wt/day (0.20 µg/kg body wt/day for women and children up to age 12) by Health Canada (Health Canada 2007) to assess the health risk of local resource users.<br>• The report also talks about adverse effects on fish health (last paragraph of the Discussion) and cites a 1998 reference supporting a lack of effects below tissue concentrations of 1 ppm. This reference is largely outdated and more recent evidence exists for fish (and wildlife) health effects of Hg at lower tissue levels (Scheuhammer et al. 2007).<br>• The report uses a statistical method (ANCOVA) for adjusting Hg concentrations for different sized fish that is sensitive to differences in the rate of increase of Hg levels with fish length and should not be applied if the rates differ. Such differences in slope often occur between years within fish populations or among different populations, and thus preclude (in the strict statistical sense) the use of the ANCOVA method of length standardization. However, other methods (such as calculating mean Hg concentrations for a fish of so-called "standard" length from log transformed data) exist to standardize Hg levels by fish size that don't depend on such rigid assumptions as an ANCOVA, and can be applied under most conditions.<br>• In those cases where an ANCOVA comparison was not possible, the report draws unwarranted conclusions about inter-annual differences in Hg concentrations from a visual comparison of descriptive statistics (e.g. median concentrations). The statement (2nd paragraph of the Discussion) that the median flesh Hg concentration in 2008 was similar to 1996, but lower than in 2005 creates the wrong impression. While technically the 2008 median value may be lower than in 2005, all three Hg concentrations for 1996, 2005, and 2008 are very similar.<br>• In addition to the issues outlined above, the report contains other ambiguities and inconsistencies that make it difficult to ascertain exactly what was done and what data are actually reported:<br>  ◦ For example, Hg concentrations are reported for "flesh", liver, and kidney. According to the 2008 method description (p 5) "flesh" seems to be boneless muscle tissue. However, according to Section 2.2.2 1996 Hg analysis was done on "flesh", kidney, and muscle (p 6), while "flesh", kidney, and liver were analyzed in 2008. The difference between flesh and muscle is not explained, and it can only be assumed that the inter-annual comparison of flesh Hg concentrations was actually done on muscle tissue.<br>  ◦ Also, the measure of variance of mean Hg concentrations is inconsistent; standard error is used in Figure 3-3, whereas standard deviation is used in Table 3-3.<br>  ◦ Much is said about outliers in Section 2.2.3, but the criteria used to classify an outlier are not provided.<br>  ◦ According to its caption Table 4-1 shows fish lengths for 2005 (which would have been useful), but there are no such data in the table. | • Although Health Canada no longer officially endorses the domestic/subsistence consumption guideline value of 0.2 ppm, this level is still widely used in Canada and internationally. Health Canada's current tolerable daily intake (TDI) approach would provide a more accurate and reliable assessment of the health risk to local resource users.<br>• Given the complexity of the data and the analysis limitations discussed in the 2008 report, it is not possible at this time (without further analysis/re-analysis of existing data) to say whether or not DDMI's prediction in the Comprehensive Study Report (CSR) (0.182 µg/g level) has been exceeded for lake trout.<br>• Standardizing mean mercury concentrations allows comparisons to be made between samples of fish from the same location over time or between fish from other waterbodies, when sizes of fish sampled differ (Strange and Bodaly 1999). Therefore, re-analyse the mercury in lake trout data (particularly the 2005 and 2008 data) using standardized mercury concentration (i.e., based on a standard fish length).<br>• Assess recent trends in mercury concentrations (2005 to 2008), not just current versus baseline.<br>• The DFO has identified a research team that will conduct a specialized sediment core analysis study that may assist in understanding the source of mercury increases in slimy sculpin. The objective will be to determine if mercury uptake is related to lake sediments rather than DDMI mine effluent. DDMI has also agreed to conduct a SES on Possible Effects of Enrichment on Mercury Uptake. Both studies could be very useful in developing a better understanding of mercury uptake in Lac de Gras fish. |

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| Dike Monitoring Studies | • For consistency and following the same rationale applied for the main sediment quality monitoring program (i.e., the low rate of sedimentation in Lac de Gras), consideration should be granted to measurement of sediment chemistry in shallower sediment depths (i.e., 1 cm) for the dike monitoring program. This review comment also pertained to the 2007 AEMP and was being considered by DDMI in consultation with the DFO; an update with respect to the status of this item would be beneficial.<br>• The handling of non-detect data differs from the approach taken in Appendices II and II and would benefit from further explanation. A useful discussion on approaches for handling non-detect data may be found in Mitchell (2006).<br>• Baseline water quality results for total phosphorus in the control area and at Lines 10 and 11 most likely reflect the influence of mine effluent.<br>• Some sediment quality parameters had baseline concentrations above ISQGs; these included arsenic, chromium, copper, and cadmium. The PEL for arsenic was also exceeded at the majority of stations where levels were above the ISQG. These exceedences were attributed to naturally occurring concentrations of metals, which reflect geological conditions in the region of Lac de Gras. Trace metal concentrations at AEMP sites were also screened against conservative SQGs to assess the potential for ecological effects due to existing concentrations of these substances. Numerous trace metals measured at AEMP sites also exceeded various guideline levels (Appendix III, Section 3.2). However, neither Appendix VII nor Appendix III provided any further discussion of potential toxicological effects related to these parameters. It may be of benefit to consider integrating background concentrations of naturally elevated metals in the discussion of potential toxicological effects on benthic community metrics (Appendix IV), as sediment chemistry SOIs identified in Appendix III do not demonstrate any relationship with benthic community metrics. | • For consistency among AEMP components, sediment collected for chemical analyses should be collected from shallower sediment depths (i.e., 1 cm).<br>• Consider incorporating concentrations of naturally elevated sediment metals (e.g., arsenic) in the discussion of potential toxic effects on the benthic community (Appendix IV), as sediment chemistry substances of interest identified in Appendix III do not demonstrate any relationship with benthic community descriptors. |
| Plankton SES | • Detailed SOPs need to be followed carefully/rigorously to ensure sample collection methodology is consistent from site-to-site and year-to-year.<br>• The taxa groups indicated as having the highest relative biomass and therefore used for QA were Calanoida and Cladocera; however, Cyclopoida had higher relative biomass than Cladocera, but was not used to evaluate QA. Large discrepancies in the QA counts occurred by using Cladocera due to associated low biomass numbers; using Cyclpoida may have provided better confidence in the biomass results.<br>• Similar to the 2007 AEMP Annual Report, no comparative statistics were provided for the 2008 zooplankton data (e.g. mean, min/max, standard deviation, standard errors). This was a requirement stipulated in the design document and was subsequently requested again by the WLWB after the 2007 AEMP report review.<br>• Figure 3-11 was overloaded with information for the reviewer and did not complement the text well, e.g., the text refers to NF, MF, FF2, FFA, and FFB areas, but the figure only had 'FF reference area' and 'FFB' for far-field labels. Segregating some of the data into separate charts (e.g., by area) would have been useful due to the amount of information, as many generalities were determined from this graph, such as:<br>    • There appears to be a reasonable relationship between chlorophyll a and total phytoplankton biomass;<br>    • A mild eutrophication effect is suggested within the NF, MF, and FF2 areas; and<br>    • The usefulness of chlorophyll a as a surrogate for phytoplankton biomass when chlorophyll a concentrations are higher relative to other samples with similar phytoplankton biomass.<br>• Were there zooplankton biomass data from 2007? In the assessment, 2008 zooplankton results were referred to as being similar to 2007 in terms of species present, relative abundance, and relative biomass. This may have been a minor oversight as the reviewer understands there were no biomass data from 2007. | • Provide comparative statistics for the 2007 and 2008 zooplankton data (e.g., mean, min/max, standard deviation, standard error) and discuss comparisons. |

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| Special Effects Studies | **<u>Mercury Detection Limits</u>**<br>• Results of the Mercury Detection Limits SES support DDMI's view that treated NIWTP effluent is likely not a source of mercury to Lac de Gras, and that there is little value in testing for mercury in water. DDMI will continue to conduct low level mercury analysis on a monthly basis at 1645-18 and if future results indicate a change, then consideration will be given to low level analysis at other SNP and/or AEMP sites. This approach is reasonable.<br>• Similarly, DDMI concludes that 0.4 ng/g limit (Flett Laboratories) for total mercury in sediments is not justified and all future sampling at SNP and AEMP sites will use ALS Laboratories Simultaneous Extractable Metals (SEM) analytical procedure. This is also a reasonable approach. However, it is recommended that any changes in methodology be accompanied with a literature review of the various methods and possibly a method comparison SES.<br>• Finally, DDMI concludes that the ALS method and detection limit are adequate for future fish tissue analyses, and this also is a reasonable conclusion.<br><br>**<u>Chromium VI</u>**<br>• Given the low levels of chromium VI detected in the study and that the laboratory detection limit of CrVI is equivalent to the AEMP benchmark (0.001 mg/L), DDMI's intention to discontinue chromium IV sampling is appropriate; sampling could be reinitiated in the future if warranted (e.g., pertinent changes to the effluent treatment process). | • Any changes in laboratory analysis methods for mercury in sediments should be accompanied with a literature review of the various methods and possibly a method comparison SES. |

<table>
<tr><th>2008 AEMP Component</th><th>Detailed Technical Review and Recommendations</th><th>Evaluation Comments and Key Recommendations for EMAB</th></tr>
<tr><td>Eutrophication Indicators</td><td>
<ul>
<li>Better integration between this appendix and Appendix XI (Plankton SES) would add value to the eutrophication assessment. For example, the issue regarding the usefulness of chlorophyll a as a surrogate for phytoplankton biomass when chlorophyll a concentrations are variable in samples with similar phytoplankton biomass was noted in the Plankton SES; how would this source of variability potentially influence the eutrophication assessment? Measurement of chlorophyll a in water is commonly used as an indicator of the amount (biomass) of phytoplankton growing in the water as it is feasible to obtain a large number of samples more efficiently/cost effectively in comparison to samples for phytoplankton enumeration. However, it should be recognized in the eutrophication assessment that this method is not very sensitive and does not provide any information on the type of phytoplankton present. Furthermore, because the chlorophyll content varies between species of phytoplankton (0.3-3.0% of dry weight among algal species), the concentration of chlorophyll a may not accurately represent the absolute quantity of phytoplankton present (Lee 1980)</li>
<li>The criteria used to classify an outlier are not provided (Appendix XIII, Section 2.2.1).</li>
<li>A useful discussion on approaches for handling non-detect data may be found in Mitchell (2006).</li>
<li>Prior to using the 2007 chlorophyll a results in any comparisons with past or future results, a literature review and method comparison SES was to be conducted in 2008 to address potential differences between sampling methods (in 2007 only, the euphotic zone was estimated from Secchi disk depths). This SES would be applicable to Appendices XI (Plankton SES) and XIII (Eutrophication Indicators); however it does not appear to have been conducted.</li>
<li>Total nitrogen levels exceeded the normal range during all sampling periods as discussed in the assessment, but only ice-cover concentrations were graphed. The extent of nitrogen effects is discussed, but it would have aided the interpretation if the open-water periods were graphed; similarly to the presentation of chlorophyll a and zooplankton data.</li>
<li>In paragraph 1 on p 25, a comparison is made regarding the extent of chlorophyll effects in the open-water period 1 to the extent of effects on TP and total nitrogen during the ice-cover period. Since TP at exposure sites only exceeded the normal range under ice this comparison is understandable. However, total nitrogen levels exceeded the normal range during all sampling periods. Although total nitrogen concentrations were highest in the exposure area under ice, it is unclear whether the extent of effect was similar to or greater/less than in the open-water periods. Is the reviewer to assume that the boundary of effects for total nitrogen was greatest under ice? This reinforces the previous point.</li>
<li>The affected area of the lake based on chlorophyll a represents 24% of the lake surface area. The area of the lake showing effects on total phosphorus throughout the water column is approximately 14% of the total lake area. The mine is having a moderate-level effect on chlorophyll a and TP, and a high-level effect on zooplankton. If the extent of effects on TP were to reach MF3-4 (extent had not conclusively reached this location in 2008), and that on chlorophyll a were to remain the same as presently observed, the level of effects on eutrophication would be considered high.</li>
<li>The recommendation provided in Appendix XIII for allocating some existing stations to the MF3 mid-field area is excellent; more intensive investigations of these areas is warranted given that effects have been observed and the extent appears to be expanding. It is noted that DDMI prefers to consider changes to the study design following synthesis of information in the Three Year Report.</li>
<li>In light of the shift in trophic status from ultra-oligotrophic to oligotrophic it may be prudent to revisit the discussion of the trophic status of the lake and EA predictions, and in particular make reference to the CCME phosphorus Canadian guidance framework for the management of freshwater systems (CCME 2004), in a more timely fashion than the Three Year Report.</li>
</ul>
</td><td>
<ul>
<li>Better integration between this appendix and Appendix XI (Plankton SES) would add value to the eutrophication assessment. For example, the issue regarding the usefulness of chlorophyll a as a surrogate for phytoplankton biomass when chlorophyll a concentrations are variable in samples with similar phytoplankton biomass was noted in the Plankton SES; how would this source of variability potentially influence the eutrophication assessment?</li>
<li>Prior to using the 2007 chlorophyll a results in any comparisons with past or future results, a literature review and method comparison SES was to be conducted in 2008 to address potential differences between sampling methods. This SES would be applicable to Appendices XI (Plankton SES) and XIII (Eutrophication Indicators); however it does not appear to have been conducted.</li>
<li>In light of the shift in trophic status from ultra-oligotrophic to oligotrophic and the affected lake area increasing between 2007 and 2008, it may be wise to revisit the discussion of the trophic status of the lake and EA predictions in a more timely fashion than the Three Year Report.</li>
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| Weight of Evidence | • The WOE approach has been refined in 2008 to address weaknesses identified in the 2007 report. Specifically:<br>  • Separate WOE analyses to assess Nutrient Enrichment Impacts and Toxicological Impairment Impacts;<br>  • Revised effect ratings to include nutrient enrichment effects and separate ratings for chlorophyll a and TP;<br>  • Inclusion of Direction Weighting Factors for biological response variables to reflect the degree of support that an observed effect provides for the Nutrient Enrichment and Toxicological Impairment hypotheses; and Assessment of exposure and effect/response endpoints for LDG as a whole (i.e., no separation of NF and FF2 analysis.<br>• These refinements substantially increase the strength of the causal linkage between the Exposure and Effect LOEs and represent a significant improvement over the approach presented in the 2007 Annual Report.<br>• In 2007 a Moderate EOI (EOI Rank 2) was assigned to both productivity and benthic invertebrates at NF sites.<br>• With the 2008 revisions, evidence of toxicological impairment resulted in a Negligible EOI (EOI Rank 0) for Lake Productivity, and a Low EOI (EOI Rank 1) for Benthic Invertebrates. Evidence of nutrient enrichment resulted in a Strong (EOI Rank 3) for both Lake Productivity and Benthic Invertebrates.<br>• Appendix XV concludes that the evidence for nutrient enrichment linked to mine activities was much stronger than the evidence for toxicological impairment, and that increases in primary productivity were extending beyond near-field areas. It was also concluded that the magnitude and type of response in Lac de Gras appears to be a mild enrichment to lake productivity and the benthic invertebrate community; the severity with respect to the ecological integrity of Lac de Gras associated with these changes to indicators of enrichment is considered to be low and consistent with the beginning of a shift from ultra-oligotrophic to oligotrophic status.<br>• Given that the overall severity of nutrient enrichment is considered mild by the WOE analysis, Appendix XV recommends that scientific investigative follow-up beyond the existing AEMP studies is not considered necessary at this time. The reviewers feel that this recommendation may be somewhat dismissive of the current degree of nutrient enrichment in Lac de Gras and the potential influence of this enrichment on mercury methylation processes (as commented on in the review of the 2007 AEMP Annual Report and to be investigated in the proposed SES on Possible Effects of Enrichment on Mercury Uptake). Observed effects are occurring after the mine has been fully operational for approximately 5 years (the first full year of mine production was 2004; NIWTP commissioned in 2002). It may be prudent at this time to review whether these effect levels were predicted in the EA to occur within this timeframe and project how severe they may become over the life of the mine (to approximately 2023) based on the rate of change to date. Essentially, if this review indicates that by the end of the mine's life the lake will no longer be in an acceptable condition (i.e., projected changes beyond EA predictions) options to manage nutrient loading should be investigated in a timely fashion. | • The recommendation that scientific investigative follow-up beyond the existing AEMP studies is not considered necessary at this time may be somewhat dismissive of the current extent of nutrient enrichment in Lac de Gras in light of the potential influence of this enrichment on mercury methylation processes and subsequent effects on fish.<br>• Nutrient effects are occurring after the mine has been fully operational for only 5 years (the first full year of mine production was 2004). It may be wise at this time to review whether these effects were predicted in the EA to occur within this timeframe and forecast how severe they may become over the life of the mine based on the rate of change to date. If this review indicates that by the end of the mine's life the lake will no longer be in an acceptable condition (i.e., projected changes beyond EA predictions) options to manage nutrient loading should be investigated in a timely fashion. |

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