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Joseph Mackenzie, A/Chair
Wek'èezhìı Land and Water Board
PO Box 32
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14 March 2018

Dear Mr. Mackenzie:

Subject: ***2014 to 2016 Aquatic Effects Re-evaluation Report Version 1.0***

Enclosed please find Diavik Diamond Mines (2012) Inc. (DDMI) Aquatic Effects Monitoring Program (AEMP) 2014 to 2016 Aquatic Effects Re-evaluation Report Version 1.0, as required under W2015L2-0001 Part J Item 9.

In addition to the Water Licence requirements for re-evaluation reports, the 2014 to 2016 Aquatic Effects Re-evaluation Report Version 1.0 includes Wek'èezhìi Land and Water Board (WLWB or the Board) directives, as well as commitments and comments acknowledged by DDMI in response to reviews of the following documents:

- AEMP Design Version 4.0 and Version 4.1
- 2011 to 2013 Aquatic Effects Re-evaluation Report
- AEMP Reference Conditions Report
- 2014 AEMP Annual Report
- 2015 AEMP Annual Report
- 2016 AEMP Annual Report
- 2016 AEMP Response Plans and 2016 AEMP Fish Response Plan – Supplemental Report
- Water Licence Schedule 8 update

To assist the Board in their review of this document, Attachment #1 to this letter provides a Conformance Table outlining the sections of the report in which the applicable directives, commitments and comments have been addressed.

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

Yours sincerely,

Sean Sinclair, Superintendent
Environment

cc: Anneli Jokela, WLWB
Sarah Elsasser, WLWB

Attachments: Table #1- Conformance Table for the 2014 to 2016 Aquatic Effects Re-evaluation Report Version 1.0

Table 1 2014 to 2016 Aquatic Effects Re-evaluation Report Concordance Table

Location of Direction	Statement of Direction, Comment, or DDMI Commitment	Component or Location in Report	Location in Report # 1621
W2015L2-0001 Part J, Item 9 (OBJECTIVES)	a) To describe the Project-related effects on the Receiving Environment compared against Environmental Assessment (EA) predictions;	All	Dust - Section 3.4 WQ - Section 4.4 Eutro - Section 5.4 Sediment - Section 6.4 Plankton - Section 7.3.6 BIC - Section 8.3.5 Fish - Section 9.4 WOE - Section 10.5 TEK - 11.5
	b) To update predictions of Project-related effects on the Receiving Environment based on monitoring results obtained since Project inception; and,	All	Section 13
	c) To provide supporting evidence, if necessary, for proposed revisions to the AEMP Design Plan.	Study Design	Section 14
W2015L2-0001 Schedule 8, Item 5 (REQUIREMENTS)	a) a review and summary of AEMP data collected to date including a description of overall trends in the data and other key findings of the monitoring program;	All	Dust - Sections 3.2.1, 3.3, and 3.5 WQ - Sections 4.2.1, 4.3, and 4.5 Eutro - Sections 5.2.1, 5.3, and 5.5 Sediment - Sections 6.2.1, 6.3, and 6.5 Plankton - Sections 7.2.1, 7.3, and 7.4 BIC - Sections 8.2.1, 8.3, and 8.4 Fish - Sections 9.2.1.1, 9.2.2, 9.3.2, and 9.5 WOE - Sections 10.3, 10.4, and 10.6
	b) an analysis that integrates the results of individual monitoring components (e.g., water quality, fish health, etc.) to date and describes the overall ecological significance of the results;	WOE, Each component, Summary "Ecological Signicance" paragraph in overall report	Section 10
	c) a comparison of measured Project-related aquatic effects to predictions made during the Environmental Assessment and an evaluation of any differences and lessons learned;	All	Dust - Section 3.4 WQ - Section 4.4 Eutro - Section 5.4 Sediment - Section 6.4 Plankton - Section 7.3.6 BIC - Section 8.3.5 Fish - Section 9.4 WOE - Section 10.5
	d) updated predictions of Project-related aquatic effects or impacts from the time of writing to the end of mine life based on AEMP results to date and any other relevant operational monitoring data;	All	Section 13
	e) a plain language summary of the major results of the above analyses and a plain language interpretation of the significance of those results;	Plain Language Summary	Plain Language Summary
	f) recommendations, with rationale, for changes to Action Levels as set in the AEMP Design Plan;	All	Section 14.3
	g) recommendations, with rationale, for changes to any other aspect of the AEMP Design Plan; and,	Study Design	Section 14
	h) any other information required as requested by the Board.	All	Section 15 (Assessment of Response Framework Performance)

Table 1 2014 to 2016 Aquatic Effects Re-evaluation Report Concordance Table

Location of Direction	Statement of Direction, Comment, or DDMI Commitment	Component or Location in Report	Location in Report # 1621
Cover Letter for W2015L2-0001 Schedule 8 Update - Board Directive and Reasons for Decision (DIRECTION)	A. Address the influence of the continued quality control (QC) issues on the previously requested assessment of ammonia concentrations based on the revised dataset and as described in the Reasons for Decision for the 2015 AEMP Annual Report;	Effluent and Water Quality	WQ - 4.2.3.3 and Appendix 4B
	B. Note that the submission of the 2014 to 2016 Aquatic Effects Re-evaluation Report will not be delayed in the event that a Board decision on the additional reference conditions information is not issued prior to the submission deadline for the 2014 to 2016 Aquatic Effects Re-evaluation Report;	-	n/a
	C. Incorporate annual sampling for plankton variables at the mid-field (MF) stations as part of its updates to the AEMP Design that are to be submitted along with the 2014 to 2016 Aquatic Effects Re-evaluation Report;	Study Design, Plankton	Section 14
	D. Provide updated WOE analysis results for the Nutrient Enrichment Impact Hypothesis based on the corrected direction-weighting factor for tapeworm parasitism as part of the 2014 to 2016 Aquatic Effects Re-evaluation Report;	Weight of Evidence	Section 10.2 and 10.3
	E. Include the following, along with its assessment of classification of fish to ages using different methods:	-	n/a
	i. A consideration of the comparability to the normal ranges for fish health indicators;	Fish	Section 9.2.1.2.3, Appendix 9A
	ii. A proposed update, with detailed rationale, to the normal ranges for fish health indicators if it is determined that a modification to the approved normal ranges is necessary; and	Fish	Section 9.2.1.2.3, Appendix 9A
	iii. A re-evaluation of Action Level 3 for fish health, if comparability to the normal ranges is identified as being potentially problematic;	Fish	Section 9.2.2.7
	F. Propose methods to address seasonal differences in its analysis of phosphorus loadings from dust;	Eutrophication Indicators	Sections 3.2.3
	G. Provide updated WOE analysis results for the Nutrient Enrichment Impact Hypothesis based on the corrected a priori weighting factor for chlorophyll a; and	Weight of Evidence	Section 10.3
	H. Include the omitted rationales for the a priori weighting factors for fish endpoints. These rationales should be flagged for reviewers as having been omitted from the 2016 AEMP Annual Report;	Weight of Evidence	Section 10.2
Reviewer Comments - Board Directive and Reasons for Decision re. W2015L2-0001 Schedule 8 Update (SUMMARY OF COMMENTS)	The Re-evaluation Report will include a section specifically devoted to considering changes to the AEMP Design, along with a summary of the sampling design and schedule	Study Design	Sections 2.2 and 14
	a. EMAB comment 17 includes a recommendation to consider addition of dustfall sites.	Dust	Section 14.2.1
	b. EMAB comment 56 includes a recommendation regarding the sampling depth for phytoplankton.	Plankton	insufficient direction provided; not addressed
	c. EMAB comment 75 includes a recommendation regarding clarifying the method for calculating condition factor. The Board notes that the method is not currently described in the AEMP Design.	Fish	Section 9.2.1.2.2
	d. EMAB comment 81 includes a recommendation to review the variables included in the Action Level assessment for fish.	Fish	Section 14.3.2
	e. EMAB comment 85 includes a recommendation to add benthic macroinvertebrate density as an endpoint to the fish community component of the WOE analysis.	Weight of Evidence	Section 10.2
	f. EMAB comment 94 addresses the variation observed in the extent of chlorophyll a effects and recommends that DDMI consider additional data collection to help explain the fluctuations. The Board notes that DDMI has also recently been directed to consider a more explicit analysis of the role of nitrogen in explaining variation and the spatial extent of chlorophyll a effects as part of the 2014 to 2016 Aquatic Effects Re-evaluation Report	Eutrophication Indicators, Plankton	Eutro: Sections 5.3.3 and 5.3.5 Plankton: Section 7.3.5
	g. GNWT-ENR comments 6, 7, and 9 to 13 all appear to provide various recommendations about potential improvements that could be made to the statistical analyses.	All	Section 14
	h. GNWT-ENR comment 18 includes a recommendation for the inclusion of phytoplankton taxonomy to be done annually at all MF and FF-2 locations, as well as LDS-4. The Board notes that DDMI has already committed to including this annually at all MF stations (see Section 3.5 of these Reasons for Decision).	Plankton	Plankton - Section 14.2.6
DDMI Commitments - Board Directive and Reasons for Decision re. W2015L2-0001 Schedule 8 Update (SUMMARY OF DDMI COMMITMENTS)	a. DDMI stated that it will include an evaluation of the feasibility of including data from LDG-48 in future eutrophication analyses (EMAB comment 11).	Eutrophication Indicators	Sections 5.2.3 and 5.3.4
	b. DDMI has noted for consideration the recommendation to review location of duplicate and blank sample collection for dust program during the next revision of the AEMP Design (EMAB comment 29).	Study Design, Dust	Sections 3.2 and 14.2.1
	c. DDMI has stated that it will include an analysis to evaluate the relationships between nutrients, chlorophyll a and phytoplankton biomass (EMAB comment 47).	Eutrophication Indicators, plankton	Eutro - Section 5.3.5 Plankton - Section 7.6.4
	d. DDMI has indicated that it will include the results of the calculation of spatial extent of effects for phytoplankton biomass from 2007 to 2017 (EMAB comment 49).	Eutrophication Indicators	Section 5.3.1
	e. DDMI has stated that it will consider the incorporation of nutrient ratios (EMAB comment 61). The Board also notes that DDMI has been directed to more thoroughly consider the role of role of nitrogen in explaining variation and the spatial extent of chlorophyll a effects through a previous Board directive.	Eutrophication Indicators	Section 5.3.7
	f. DDMI has stated that it will consider inclusion of soluble reactive silica as a measured parameter and supporting water quality variable (EMAB comment 84).	Study Design	Section 14.2.5
	g. DDMI has stated that it will consider historical occurrences of parasites (GNWT-ENR comment 26).	Fish	Section 9.2.2.3
	h. DDMI has stated that alternative methods to examine reproductive success of Slimy Sculpin will be reviewed and considered (EMAB comment 80; GNWT-ENR comment 29).	Fish	Section 13.4

Table 1 2014 to 2016 Aquatic Effects Re-evaluation Report Concordance Table

Location of Direction	Statement of Direction, Comment, or DDMI Commitment	Component or Location in Report	Location in Report # 1621
2011 to 2013 Aquatic Effects Re-evaluation Report, Version 3.1 (DIRECTIVES)	With regards to the 2014 to 2016 Aquatic Effects Re-evaluation Report, the Board has decided that DDMI is to:	-	n/a
	A. Provide clear rationale and support for methods used in the estimation of background dust deposition rates.	Dust	Sections 3.2.2 and 2.3.2
	B. Consider restructuring the Dust Section to more clearly explain the methods.	Dust	Section 3.3.2
	C. Consider the inclusion of monitoring data from the Ekati Diamond Mine as an estimate of regional dust deposition rates.	Dust	Sections 3.2.2 and 3.2.3
	D. Include a full explanation of the treatment of outliers for the dust analyses.	Dust	Sections 3.2.2 and 3.2.3
	E. Use consistent methods for handling outliers throughout presented analyses, or provide rationale to justify the use of different methodologies.	All	Section 2.4
	F. Include an assessment of the performance of the WOE approach and the Response Framework.	Weight of Evidence	Section 10.6 and 15
	G. Include a more thorough explanation of how data are handled when there is a large proportion of values less than the detection.	All	Section 2.4 WQ - Sections 4.2.3.2 and 4.2.4.2.2 Sediment - Section 6.2.2.2 Fish - Section 9.3.1.2.3
	H. Include a more in-depth and integrative assessment of the plankton data.	Plankton	Plankton - 7.3.4
	I. Include a statistical evaluation of temporal trends in MF1 and MF3.	All	WQ - Section 4.3.2.1.2 Eutro - Section 5.3.3 Sediment - Section 6.3.3 Plankton - Section 7.3.2 BIC - Section 8.3.2
	J. Use both statistical and graphical interpretation, where appropriate, when considering temporal trends.	All	WQ - Section 4.3.2.1.2 Eutro - Section 5.3.3 Sediment - Section 6.3.3 Plankton - Section 7.3.2 BIC - Section 8.3.2 Fish - Sections 9.2.2.5 and 9.3.2.2
	K. Consider incorporating a statistical evaluation of trends for effluent chemistry.	Effluent and Water Quality	Section 4.3.1.1
	L. Include all available years of snow chemistry data in analyses.	Dust	Section 3.2.1
	M. Address the influence of methodological variation in nutrient sampling on the interpretation of effects for sediment quality.	Sediment	Sediment - Section 6.3.3.2
	N. Include an explanation of how variation through time in sediment sampling methodologies for all parameters has been considered when interpreting effects.	Sediment	Sediment - Section 6.2.1 and 6.3.3.1
	O. Provide more complete rationale when drawing conclusions related to effects hypotheses.	All	WQ - Section 4.5 Eutro - Section 5.5 Sediment - Section 6.5 Plankton - Section 7.4 BIC - Section 8.4 Fish - Section 9.5
	P. Include a summary of temporal trends in dissolved oxygen and temperature.	Effluent and Water Quality	Section 4.3.2.1.1
	Q. Include the type and level of information provided in their responses to reviewer comments listed in Section 3.13.1.	All	n/a
	R. Submit the 2014 to 2016 Aquatic Effects Re-evaluation Report within six months following the approval of the 2016 AEMP Annual Report.	-	n/a

Table 1 2014 to 2016 Aquatic Effects Re-evaluation Report Concordance Table

Location of Direction	Statement of Direction, Comment, or DDMI Commitment	Component or Location in Report	Location in Report # 1621
AEMP Design Plan, Version 4.0 (DIRECTIVES)	With regards to the 2014 to 2016 Aquatic Effects Re-evaluation Report, DDMI is directed to:	-	n/a
	A. Include a spatio-temporal assessment, which at minimum, includes figures and comments on the trends of all analyzed variables;	Effluent and Water Quality	Section 4.3.2.1 and Appendix 4C
	B. Include a statement explaining how it has incorporated key findings from the Plankton Report into the Eutrophication Report;	Eutrophication Indicators	Sections 5.3.6
	C. Include for consideration, if it wishes, a proposal to change the schedule for Slimy Sculpin sampling to include the condition that Slimy Sculpin would be sampled every six years, if two consecutive sampling events demonstrate that toxicological effects are not observed;	Fish	Section 14
	D. Include a consideration of the frequency of sampling at FF stations;	Fish	Section 13
	E. Include an evaluation of the potential use of nMDS results to identify environmental gradients influencing plankton community;	Plankton	Section 7.3.4
	F. Include a consideration of the recommendation regarding the taxonomic resolution issue for Bray-Curtis distance measures for benthic invertebrate data;	Benthic Invertebrates	Section 8.3.4.2
	G. Include a section specifically devoted to considering changes to the Design, along with a summary of the sampling design and schedule; and	All	Section 14
	H. Include the analysis proposed in Section 51 of the Design's Appendix A as part of the 2014 to 2016 Aquatic Effects Re-evaluation Report. RELEVANT BACKGROUND: Section 51 Text - A spatial gradient approach will be used to evaluate cumulative effects in Lac de Gras from the Ekati and Diavik mines. This will be done as part of the comprehensive reports, which will present a spatial analysis of results from the comprehensive sampling program where all stations will be sampled, including the FF areas. Effects will be assessed along the gradient of exposure at stations in the MF3, FFB and FFA areas and at Station LDG-48. The presence of a spatial trend with distance from the Diavik diffusers that is reversed as one moves west from the MF3 or FFB areas would suggest that effluent from both mines are a potential influence on the variable in question. Magnitude of effects will be evaluated by comparing the results to the normal range (as defined in the AEMP Reference Conditions Report Version 1.1). The AEMP results will be qualitatively compared to data collected at the Ekati Slipper Bay monitoring stations in Lac de Gras (e.g., S2, S3, S5 and S6) to further evaluate the potential contribution of Ekati to cumulative effects in Lac de Gras. <u>A temporal assessment of trends at relevant stations will be provided in the Aquatic Effects Re-evaluation Report and will follow the approach in Golder (2016b)</u>.	Effluent and Water Quality	Section 4.3.2.2.3
2014 AEMP Annual Report (DIRECTIVES)	With regards to the 2014 to 2016 Aquatic Effects Re-evaluation Report, the Board has decided that DDMI is to:	-	n/a
	A. Consider a more explicit analysis of the role of nitrogen in explaining variation and the spatial extent of chlorophyll a effects; and	Eutrophication Indicators	Section 5.3.5
	B. Evaluate the assumptions of the Action Level testing for Eutrophication Indicators.	Eutrophication Indicators	Section 5.3.8
	Clarification of "Effects Threshold" and "Significance Threshold" for indicators of Eutrophication	Eutrophication Indicators	Section 5.3.8
2015 AEMP Annual Report (DIRECTIVES)	With regards to the 2014 to 2016 Aquatic Effects Re-evaluation Report, the Board has decided that DDMI is to include the following:	-	n/a
	A. Include a thorough consideration of how the revised ammonia results compare to the historical ammonia data. The Board requires this consideration to include an assessment of the ability to detect changes over time in ammonia concentrations and to evaluate Action Levels for ammonia;	Effluent and Water Quality	Section 4.2.3.3 and Appendix 4B
	B. Consider the inclusion of phosphorus concentrations in the Response Framework. The Board requires this consideration to include a discussion of observed phosphorus concentrations and how they relate to the phosphorus management framework;	Eutrophication Indicators	Section 5.3.8
	C. Conduct an assessment of the reference area conditions used for the phytoplankton variables. The Board requires this assessment to include:	Plankton	Section 7.3.2.1
	i. a comparison of DDMI's AEMP results from 2014 to 2016 to reference conditions as defined using the currently approved 2007 to 2010 reference area data and to the 2013 reference area data as recommended by DDMI; and	Plankton	Section 7.3.2.1
	ii. a recommendation, with supporting rationale, for which reference conditions DDMI believes should be used moving forward;	Plankton	Section 7.3.2.1
	i. the analysis as described in the Design (i.e., comparison of tissue metal concentrations to baseline concentrations); and/or	TEK, Fish	Section 11.5 and Section 9.4
	ii. an explanation for if, and why, this should be considered differently in the future by providing a recommendation with supporting rationale, for a change to the AEMP Design;	TEK	Section 14.2.6
	E. Note that a comparison of fish tissue metal concentrations to CSR predictions is required; and	Fish	Section 9.4
	F. Consider the establishment of data quality objectives and potential changes to the sampling design for snow water chemistry.	Dust	Sections 3.2.2 and 3.2.3
Reference Conditions Report, Version 1.0 (COMMITMENT)	Commitment #27 Reference Conditions Report_Response to Reviewer Comments.docx. DDMI is currently working with Maxxam to identify a solution that will address the QA/QC issues identified with the ammonia data. Until an appropriate solution can be identified, the Maxxam ammonia data will be shown in the forthcoming AEMP annual reports but will not be compared with the NR. For the purpose of the three-year summary report, the NR for ammonia will be shown in the temporal plots for up to 2012, but will not be applied to the recent Maxxam data. This approach is consistent with that used for ammonia in the analyses conducted for the Effluent and Water Quality Report.	Effluent and Water Quality	Sections 4.2.3.3 and Appendix 4B

Table 1 2014 to 2016 Aquatic Effects Re-evaluation Report Concordance Table

Location of Direction	Statement of Direction, Comment, or DDMI Commitment	Component or Location in Report	Location in Report # 1621
AEMP Design Plan, Version 4.0 (COMMITMENT)	Commitment #29 (WLWB) AEMP Design Plan Ver4 Comment Responses_FINAL TO DDMI Oct.13.docx. Given that the stations used in this analysis have been historically sampled as part of the AEMP, can DDMI outline any limitations to including results of this analysis as part of the 2014 to 2016 Aquatic Effects Re-evaluation Report. Provided AEMP Design Version V4 has been approved we do not see a limitation to including this analysis as part of the 2014-2016 Aquatic Effects re-Evaluation Report. RELEVANT ADDITIONAL INFO: Section 6.1 Data Analysis Approach to Detect Cumulative Effects; Page 93-94 - Results to be provided in the Aquatic Effects Re-evaluation. This section proposes an analysis to assess cumulative effects in Lac de Gras with results being presented as part of the Aquatic Effects Re-evaluation Report.	Effluent and Water Quality	Section 4.3.2.2.3
	Commitment #47 (WLWB) AEMP Design Plan Ver4 Comment Responses_FINAL TO DDMI Oct.13.docx. DDMI proposes that as part of the next Aquatic Effects Re-evaluation Report, fish health endpoints be plotted both as mean values and as individual data points on graphs presented in support of the fish health component. This would allow for a visual evaluation of temporal trends. As discussed in Appendix A, Section 42, this visual presentation will not apply to the assessment of Action Level 1; for Action Level 1, comparisons to normal ranges are not required.	Fish	Sections 9.2.2.4 and 9.2.2.5
	Commitment #5 (EMAB) AEMP Design Plan Ver4 Comment Responses_FINAL TO DDMI Oct.13.docx. DDMI acknowledges the reviewers suggestion and will endeavor to incorporate key findings from the Plankton report in future comprehensive year Eutrophication reports and Re-evaluation reports. Phytoplankton biomass (biovolume) will be incorporated into future Eutrophication Reports in the following ways:	Eutrophication Indicators, Plankton	Section 5.3
	1)Comparison to the normal range;	Eutrophication Indicators, Plankton	Section 5.3.4
	2)Plot of total phytoplankton biomass against distance from the diffuser to visually evaluate spatial trends relative to the Mine discharge;	Eutrophication Indicators, Plankton	Section 5.3.1
	3)Boxplot of total phytoplankton biomass in Lac de Gras during the open-water season; and,	Eutrophication Indicators, Plankton	Section 5.3.4
	4) Calculation of spatial extent of effects on phytoplankton biomass.	Eutrophication Indicators, Plankton	Section 5.3.1
2014 AEMP Annual Report (COMMITMENT)	Commitment #7 (GNWT – ENR) in DDMI AEMP 2014 Golder Draft Responses.docx. The presence of toxicological impairment needs to be evaluated based on the full weight of evidence provided by the AEMP data set, including exposure indicators, toxicity test results, field-measured biological response variables, and potentially other lines of evidence. This is done by a formal weight-of-evidence analysis during comprehensive AEMP years, and is further evaluated during the Aquatic Effects Re-evaluation process.	Weight of Evidence	Section 10
	Commitment #11 (GNWT – ENR) in DDMI AEMP 2014 Golder Draft Responses.docx. The Significance Thresholds for the AEMP are "locked in" as approved in the AEMP Study Design Version 3.5. This recommendation would be best addressed at the time of the next AEMP re-evaluation and re-design cycle, following the 2016 AEMP Annual Report submission. DDMI suggests that the Significance Thresholds for this component should be based on biological response variables, rather than exposure variables. The recommendation from ENR was "ENR supports and recommends that the eutrophication significance threshold for each of the three eutrophication-related metrics should be as follows:	Eutrophication Indicators	Section 5.3.8
	a) The mean of the five Farfield A depth integrated chlorophyll a concentration does not exceed 4.5 µg/L; or,	Eutrophication Indicators	Section 5.3.8
	b) The mean of the five Farfield A total P concentrations does not exceed 10 µg/L; or,	Eutrophication Indicators	Section 5.3.8
	c) The mean of the five Farfield A total N concentrations does not exceed 700 µg/L."	Eutrophication Indicators	Section 5.3.8
2015 AEMP Annual Report (COMMITMENT)	Commitment # 9 (EMAB) in DDMI Submission – Response to Review Comments on the 2015 AEMP Annual Report.pdf. Continue to evaluate the relationship between chlorophyll a and phytoplankton biomass.	Eutrophication Indicators	Section 5.3.5
	Commitment # 21 (EMAB) in DDMI Submission – Response to Review Comments on the 2015 AEMP Annual Report.pdf. The reviewer correctly points out that concentrations of certain water quality variables were elevated in 2015 at stations along the MF3 area transect during the open-water season. The increase observed in these variables, however, is more likely related to sediment disturbance by construction of the A21 Dike, than to effects from dust released from the mine site. The A21 dike is situated in Lac de Gras at the southwest end of East Island. Construction of the dike began during early summer, 2015 and was ongoing during the open water AEMP sampling event in 2015. Given the timing and location of dike construction, effects on water quality variables would be expected to peak at stations along the MF3 area transect in the vicinity of the construction activities during open-water (e.g., stations MF3-2, MF3-3, MF3-4). This pattern of response is consistent with that observed in the open-water concentrations of aluminum and chromium.	Effluent and Water Quality	Section 4.3.2.2.2
	Effects of dike construction on water and sediment quality in Lac de Gras will be evaluated as part of the A21 Dike Monitoring Program, which DDMI has implemented as a condition of the Fisheries Authorization pertaining to construction of the A21 dike. Reports prepared based on results of the study will be submitted one year following completion of construction of the A21 dike (i.e., 2018).	Effluent and Water Quality	Section 4.3.2.2.2
	An analysis of spatial trends will be completed during the comprehensive AEMP in 2016, and temporal trends will be evaluated in the AEMP Re-evaluation report.	Effluent and Water Quality	Sections 4.3.1.1 and 4.3.2.1
	Commitment # 25 (EMAB) in DDMI Submission – Response to Review Comments on the 2015 AEMP Annual Report.pdf. Present nutrient ratios and evaluate trends over time.	Eutrophication Indicators	Section 5.3.7

Table 1 2014 to 2016 Aquatic Effects Re-evaluation Report Concordance Table

Location of Direction	Statement of Direction, Comment, or DDMI Commitment	Component or Location in Report	Location in Report # 1621
	Commitment # 29 in 2015 AEMP Comment Responses.docx. Potential reasons for comparatively less year-to-year variability in TN in comparison to other eutrophication indicators will be discussed. Additionally, will comment on the continued large spatial extent of effects on TN in 2015 in comparison to the reduction of extent for other parameters (i.e., TP, Chla, Zoop biomass). Additional inputs affecting TN concentration in Lac de Gras may be a contributing factor and should be considered in the discussion.	Eutrophication Indicators	Section 5.3.1
	Commitment #14 (GNWT – ENR) in 2015 AEMP Comment Responses.docx. Provide a temporal trend assessment for the list of analyses for SOIs.	Effluent and Water Quality	Sections 4.3.1.1 and 4.3.2.1
	Commitment #19 (EMAB) in 2015 AEMP Comment Responses.docx. Provide an assessment of the comparability of the 2015 data (new Maxxam method) with the historic ALS data (i.e., used to describe reference conditions), and describe any implications for ammonia data analysis going forward (e.g., for the 2014 to 2016 three year summary report).	Effluent and Water Quality	Sections 4.2.3.3 and Appendix 4B
2016 AEMP Annual Report (COMMITMENT)	Commitment #47 in Review Comment Table-2016 AMEP Report.pdf. Evaluate relationships between nutrients and chlorophyll a and phytoplankton biomass.	Eutrophication Indicators, Plankton	Plankton - Section 7.3.4 Eutro - Section 5.3.5
	Commitment #49 in Review Comment Table-2016 AMEP Report.pdf. DDMI will calculate the spatial extent of effects for phytoplankton biomass for previous years (i.e., 2007 to 2017). [comment on Eutrophication Indicators section].	Eutrophication Indicators	Section 5.3.1
	Commitment #61 in Review Comment Table-2016 AMEP Report.pdf. Review nutrient ratios to evaluate potential nutrient limitation and subsequent effects on N-fixing bacteria. [comment on plankton section].	Plankton	Section 7.3.4
	Commitment #66 and #68 and #93 in Review Comment Table-2016 AMEP Report.pdf. Comparison to past benthic invertebrate studies will be considered for the Re-evaluation report. Review statements throughout the document respecting decreases in Pisidiidae.	Benthic Invertebrates	Section 8.3.2.4
	Commitment #82 in Review Comment Table-2016 AMEP Report.pdf. The implications of livers being omitted from fish carcass samples submitted for tissue chemistry in 2016 will be reviewed.	Fish	Section 9.3.1.2.1
	Commitment #84 in Review Comment Table-2016 AMEP Report.pdf. Incorporation of other factors (committed to silica concentrations) that may affect plankton abundance and community composition within the analysis and discussion.	Plankton	Sections 7.3.4 and 7.4
	Commitment #90 in Review Comment Table-2016 AMEP Report.pdf. Historical parasitism levels will be considered. [Weight of Evidence section].	Fish	Fish: Section 9.2.1.3.3WOE: Section 10.2
	Commitment #92 in Review Comment Table-2016 AMEP Report.pdf. A list of previously recorded parasitism levels from 2013 to 2016 sculpin sampling in Lac de Gras will be considered in the Re-evaluation. [Weight of Evidence section].	Fish	Section 9.2.1.3.3
	Commitment #94 in Review Comment Table-2016 AMEP Report.pdf. Variation over time in eutrophication indicators will be evaluated and if applicable, recommendations will be made regarding other information that could be collected in future years to explain the variation in the extent of effects in Lac de Gras.	Eutrophication Indicators	Section 5.5
	Commitment #25 (under GNWT-ENR comments) in Review Comment Table-2016 AMEP Report.pdf. A summary of tapeworm historical occurrence during the AEMP fish surveys will be provided in the Re-evaluation report.	Fish	Section 9.2.2.3
	Commitment #26 (under GNWT-ENR comments) in Review Comment Table-2016 AMEP Report.pdf. Historical occurrence of parasites during the AEMP fish surveys will be considered in the Re-evaluation.	Fish	Section 9.2.2.3
	Commitment #27 (under GNWT-ENR comments) in Review Comment Table-2016 AMEP Report.pdf. Multi-year re-evaluation analysis to understand among-year changes in fish health and their magnitude.	Fish	Section 9.2.2
	Commitment #29 (under GNWT-ENR comments) in Review Comment Table-2016 AMEP Report.pdf. Alternative methods to examine reproductive success will be reviewed and considered in the re-evaluation report.	Fish	Sections 9.2.1.2.3 and 9.2.2.7
	Commitment #5 in WLWB Clarification Requests Responses_v2.docx. Fish health metrics will be reviewed in detail in the Response Plan. If the fish health effects are confirmed in the review process of the Response Plan, the Plan will evaluate the potential effects of the 2016 fish tissue concentrations on fish health. Fish tissue concentrations, temporal patterns of tissue concentrations, and sampling methods (including the issue of livers not being included in analyses in 2016) will be reviewed in the AEMP Re-evaluation Report.	Fish	Sections 9.3.1.2.1 and 9.3.2.2
	DDMI does not believe fish health sampling, scheduled for 2019, should be advanced to 2018, on the basis of the following:	Fish	n/a
	1) Despite the elevated metal concentrations in fish tissues in NF and MF, fish health effects are largely below the critical effect sizes identified in the MMER (2012), and those that are not (i.e., fish weight) are the subject of investigation as part of the Response Plan (which will include consideration of the influence of tissue chemistry as part of the investigation).	Fish	n/a
	2) The sampling itself is detrimental to the fish population, since large numbers of fish, specifically large, non-parasitized fish, are removed from the local sampling areas in Lac de Gras, and the overall sculpin population in the lake.	Fish	n/a
	In conclusion, given the choice of additional lethal sampling to increase precision of fish tissue metal concentrations (i.e., the effect of liver removal on metal burden results), or continuing desktop evaluation of sampling methods, temporal and spatial trends, and the effect of tissue chemistry on fish health, DDMI proposes to avoid additional lethal sampling. Rather, DDMI will implement the Response Plan investigation into fish health endpoints, and if valid (i.e., if effects are confirmed and further investigation is necessary), will consider the influence of tissue chemistry on fish health. A thorough review of sampling methods and temporal patterns of tissue metal concentrations will be included in the Re-evaluation Report.	Fish	Sections 9.3.1.2 and 9.3.2.2
	Commitment #6 in WLWB Clarification Requests Responses_v2.docx. In previous reports, there was a clear modality in length frequency distributions, and it was possible to assign age classes to these modes. Further, otolith age was used in previous reports (which is now known to be unreliable: Gray 2014). In the 2016 dataset, there was no clear modality in the length frequency distribution, therefore the length/GSI approach was used to assign age to fish.	Fish	n/a

Table 1 2014 to 2016 Aquatic Effects Re-evaluation Report Concordance Table

Location of Direction	Statement of Direction, Comment, or DDMI Commitment	Component or Location in Report	Location in Report # 1621
	The use of age-1+ abundance in the 2016 samples as an indicator of reproductive success was a biased approach, because:	Fish	n/a
	1) The approved field method is designed to target larger, non-parasitized Slimy Sculpin to best characterize adult fish health.	Fish	n/a
	2) Given this, an under-representation of smaller fish (i.e., those fish that would encompass the age-1+ size class) results.	Fish	n/a
	Therefore, the 2016 Slimy Sculpin dataset is biased against the inclusion of age-1+ fish, and an assessment of age-1+ abundance would be statistically invalid (given the assumption of random sampling is not met). This sample design limitation relative to assessing reproductive success using age-1+ fish will be examined in the AEMP Re-evaluation Report.	Fish	Sections 9.2.1.2.3, 9.2.1.3.4, and 9.2.2.7
	Commitment #7 in WLWB Clarification Requests Responses_v2.docx. There are no national fish tissue guidelines for most metals (with the exception of mercury, selenium, arsenic and lead). Therefore, the sentence referenced in comment 83 from EMAB was written with the intent to compare water quality and sediment results to their respective guidelines, rather than comparing fish tissue concentrations to fish tissue guidelines or benchmarks. Water and sediment guidelines were established to protect aquatic life, and given that the 2016 AEMP results were considerably below these guidelines, significant adverse effects on fish are not expected. A review of fish tissue metal concentrations as they relate to fish health will be included in the Response Plan. Tissue metal concentrations will also be considered thoroughly in the AEMP Re-evaluation Report.	Fish	Section 9.3
	Commitment #8 and #9 in WLWB Clarification Requests Responses_v2.docx. Parasitism could, indeed, be due to nutrient enrichment. The intention in the weight of evidence estimates was to be conservative and use a rating 1 for toxicological response. We agree with the reviewer, and the variable could also have a rating 1 for nutrient enrichment; however, the change in ratings would not influence the overall conclusion of the fish health analysis (i.e., triggering Action Level 2 due to possible toxicological effect). Furthermore, since the difference in parasitism incidence between NF and FF areas was 7.5%, it is not likely to be biologically significant, nor does it warrant additional investigation. In addition, the second highest parasitism incidence was recorded at FF1, while the lowest incidence was recorded at FF2, indicating that parasitism levels did not follow the expected gradient from NF to FF.	Fish	n/a
	No further examination of this scenario is deemed necessary in the 2016 AEMP annual report. The difference in parasitism over time will be examined in the Response Plan and the AEMP Re-evaluation Report. Historical parasitism levels will be considered in the Aquatic Effect Re-evaluation Report.	Fish	Section 9.2.2.3
	Given the provided response to comment #8, we do not believe a revision to the 2016 AEMP annual report is warranted. The statement regarding tapeworms and normal range in the 2016 AEMP annual report was made within the weight of evidence appendix (i.e., not in the fish health appendix), and it was made relative to Effects Ratings for fish health (where most endpoints do have a defined normal range). Wording in the weight of evidence assessment in the future will avoid including metrics that do not have normal ranges in such statements and/or summaries, without explicitly noting the absence of defined and approved normal ranges for those endpoints. The temporal patterns in parasitism levels will be examined in the Response Plan and in the AEMP Re-evaluation report.	Fish, Weight of Evidence	Section 9.2.2.3
	Commitment #12 in WLWB Clarification Requests Responses_v2.docx. All 2016 sediment quality data are provided in Appendix E of the Sediment Report (Appendix III), and were also provided as an Excel file with the first set of responses to the comments on the 2016 AEMP Annual Report.	Sediment	n/a
	DDMI wishes to seek approval of sediment reference values prior to completion and submission of the Re-evaluation report, in order to ensure agreement on the values used to determine SOI's and minimize the potential for revisions to the Re-evaluation Report. DDMI suggests that an addendum to the RCR, which provides sediment reference data for review, be submitted for approval by XXXX. Once approved, this information would be incorporated into the RCR and utilized in the Re-evaluation Report.	Sediment	Section 6.2.3.4
	Commitment #11 in PropRespReq_11170_response assignments_DW.xlsx. The feasibility of including LDG-48 data in future eutrophication analyses will be evaluated as part of the re-evaluation report.	Eutrophication Indicators	Section 5.2.3 and 5.3.4
2015 AEMP Annual Report V 1.1 Directive and Reasons for Decision (DIRECTIVE)	The Board has decided that Version 1.1 satisfies the Board's direction and has approved Version 1.1 of the 2015 AEMP Annual Report. The Board notes, however, that new information was provided regarding sampling location errors for Station SS3-6 as part of the Dust Monitoring component of the AEMP. This topic was recently addressed during the Board's consideration of the 2016 AEMP Annual Report and DDMI has been directed to address this as part of the 2014 to 2016 Aquatic Effects Re-evaluation Report.3	Dust	Section 3.1.2
Diavik AEMP Design V 4.1 Direcive and Reasons for Decisions (DIRECTIVES)	Board has thus decided that DDMI is to address the statistical comparisons for Action Levels 1 and 2 for biological components during comprehensive years as part of the 2014 to 2016 Aquatic Effects Re-evaluation. DDMI should clarify if comparisons are being made to the same year FF area means or to the reference conditions as defined in the approved Reference Conditions Report.	Fish, Plankton, Eutrotrophication, Benthic Invertebrates	Section 14.3.2
	The Board has thus decided that DDMI is to address the apparent misunderstanding in sediment sampling replication as part of the 2014 to 2016 Aquatic Effects Re-evaluation. The Board request that DDMI engage with ECCC on this topic and that proposed updates to the AEMP Design and the Quality Assurance Project Plan reflect the outcome of those discussions. The Board notes that this same directive was issued in the Board's decision for the QAPP Version 3.1.	Sediment	Section 14.2.4
	The Board would like to remind DDMI that it is to address updates to the AEMP Design as part the 2014 to 2016 Aquatic Effects Re-evaluation Report.	All	Section 14
WLWB 2016 AEMP Response Plans and 2016 AEMP Fish Response Plan - Supplemental Report - 24 January 2018	3. DDMI is to address the GNWT-ENR recommendations 10 and 11, with regards to changes to Action Levels for effluent and water chemistry, as part of the 2014 to 2016 Aquatic Effects Re-evaluation Report	Effluent and Water Quality	Section 14.2
	4. DDMI is to include relevant updates to Canadian Water Quality Guidelines as part of the proposed changes to the AEMP Design to be submitted with the 2015 to 2016 Aquatic Effects Re-evaluation Report.	Proposed Updates to AEMP Design Plan	Section 14.2

2014 to 2016 AQUATIC EFFECTS RE-EVALUATION REPORT FOR THE DIAVIK DIAMOND MINE, NORTHWEST TERRITORIES

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PLAIN LANGUAGE SUMMARY

This summary is intended for both technical and non-technical readers.

Section 1 – Introduction

The 2014 to 2016 Aquatic Effects Re-Evaluation Report provides a summary of all data collected under the Aquatic Effects Monitoring Program for the Diavik Diamond Mine. In this report the Aquatic Effects Monitoring Program is also called “the AEMP”, and the Diavik Diamond Mine is referred to as “the Mine”. The AEMP consists of monitoring the following components: dust, effluent, water quality, eutrophication indicators (for example, the nutrient phosphorus and the green algal pigment called chlorophyll *a*), plankton, sediment quality, benthic invertebrates, and fish. This report shows trends over time that may be occurring in these AEMP components, from 1995 to 2016. As well, this report compares the AEMP results for each of these components back to the predictions of Mine effects made in the original 1998 Environmental Assessment (EA), to see if they were accurate.

Section 2 – Study Design

The AEMP is the main program described in the Water Licence for monitoring the aquatic environment of Lac de Gras. Treated Mine water discharged into Lac de Gras is the main focus of the AEMP program, but it is designed to monitor all aquatic impacts from the Mine, including as dust deposition and runoff.

Most components of the AEMP have been monitored every year, during both ice-cover and open-water seasons. More recently, under the AEMP study design Version 3.5 (which was approved by the Wek’èezhìi Land and Water Board, also called “the WLWB” in this report), water, nutrients and plankton (i.e., algae and small crustaceans in lake water) are now sampled every year in only the areas where effluent is discharged to Lac de Gras – this area is called the near-field area. The nutrients and plankton are then sampled every three years throughout the rest of the lake – these areas are called the mid-field and far-field areas. Water quality is also measured monthly at the point where the effluent flows into the lake. Bottom sediments, benthic invertebrates (which are small animals that live in the sediments) and small-bodied fish (Slimy Sculpin) are monitored once every three years throughout the lake.

Section 3 – Dust

Dust deposition rate (also called dustfall) is measured quarterly along transects that extend away from the Diavik mine boundary. With the transition to underground mining in 2012, dust deposition has decreased. The amount of observed dustfall is greater than that predicted in the EA. Evaluation of dust deposition results identified a few exceedances of the British Columbia lower dust deposition objective, but only in a small area southeast of the Mine boundary. However, dust deposition rates drop quickly to levels similar to background rates, within approximately 4 kilometres (km) from the centre of the Mine footprint, or within approximately 1.5 km of the Mine boundary.

Section 4 – Effluent and Water Quality

Treated water from the open pits, underground workings and mine infrastructure is called effluent. Effluent was evaluated to see if the amount of chemicals discharged from the Mine is increasing over time. The amount of chemicals entering the lake is called the “loading rate”. Water was also collected near the point where effluent enters Lac de Gras (also called the mixing zone boundary) to see if the amount of effluent-related chemicals in the lake is increasing.

Treated effluent is sampled approximately every six days. In addition to chemical analysis of these samples, the effluent is tested for toxicity (which means the effluent is tested in the lab to see if it harms laboratory-grown fish and plankton). In these tests, freshwater test organisms are exposed to whole effluent and/or effluent dilutions for a pre-determined time period to evaluate the effluent’s effect on the organisms. Water quality sampling at the mixing zone boundary is conducted monthly at three stations, which are located along a semi-circle, 60 metres from the diffusers (pipes from which effluent is released into Lac de Gras).

The assessment of chemicals in the effluent was focused on the 31 chemicals that were identified as Substances of Interest (also called “SOIs” in this report). The annual loading rate of total dissolved solids (which is a measure of the amount of dissolved salts in effluent) and several associated salts (i.e.,calcium, chloride, fluoride, potassium, and sodium) increased from 2002 to approximately 2010, then remained at about the same level or declined slightly, until increasing again in 2015 and/or 2016, reflecting the increases in the amount of effluent discharged in recent years. Sulphate, fluoride and potassium also showed increases in loads due to increases of concentrations in the effluent. Effluent loads and/or concentrations of some metals have increased over time (strontium and vanadium); however, most have decreased (copper, manganese), fluctuated over time (barium, chromium, iron, lead, molybdenum, thallium, and uranium) or remained at relatively similar levels (aluminum, antimony, cobalt, and silicon). The concentrations of these SOIs at the mixing zone boundary generally followed the same patterns described in the annual loads for these variables.

Effluent tested between 2002 and 2016 was generally not toxic to aquatic test organisms as shown in over 700 toxicity tests conducted during this period. Mine effluent continues to meet the requirements for quality described in the Water Licence.

The goal of the AEMP water quality assessment was to provide a summary of changes and effects observed on the water quality of Lac de Gras over time. The importance of an effect was determined by comparing water chemistry concentrations in different areas in the lake to background values or to Effect Benchmarks and evaluating trends to see if concentrations were increasing or decreasing over time. Background values for Lac de Gras are those that fall within what is called the “normal range”. The normal range describes the natural variability within Lac de Gras. A concentration that is greater than the normal range is not considered normal for Lac de Gras, but it doesn’t mean that it is harmful. Effect Benchmarks (similar to water quality guidelines) are a better measure of when a chemical may be harmful to aquatic life.

Concentrations of total dissolved solids, chloride, fluoride, calcium, potassium, sodium, and sulphate in Lac de Gras were greater than the normal ranges in both the ice-cover and open-water seasons, and are generally increasing over time. Molybdenum and strontium were also found in Lac de Gras at concentrations above the normal range, particularly in the near-field and mid-field areas, which are closest to the Mine; concentrations of these two metals were generally increasing over time in all areas, although the concentration of molybdenum in the near-field area has begun to decrease in recent years. The increases in the concentrations of these various chemicals match trends in the loadings of these chemicals in the effluent.

Water quality results from 2015 and 2016 also showed the effects of the A21 dike construction on water quality in the mid-field areas. Concentrations of total suspended solids, turbidity, aluminum, bismuth, chromium, cobalt, copper, iron, lead, manganese, silicon, thallium, titanium, uranium, vanadium, and zirconium were greater at the mid-field stations closest to the A21 dike in 2016 than in past years. Several of these SOIs (aluminum, cobalt, iron, manganese, silicon, and titanium) had greater concentrations in 2015 at the same mid-field stations, which may also have been related to the A21 dike construction.

Greater concentrations of total dissolved solids, calcium, chloride, potassium, sodium, sulphate, molybdenum and strontium at Station LDG-48 (which is the lake outlet of Lac de Gras) and/or the far-field A area, compared to areas closer to the Mine (i.e., far-field B) indicate that cumulative effects may be occurring in this area because of the Diavik and Ekati mine discharges. While these results suggest cumulative effects may be occurring in the western region of Lac de Gras, concentrations of these chemicals in the affected area of Lac de Gras remained low, with additive effects being minor and not obvious in all years of monitoring.

The EA predicted that water quality at the mixing zone would be below ecological guidelines for the protection of aquatic life and drinking water guidelines. The Effects Benchmarks used for the AEMP are similar to the ecological thresholds established during the EA, but have been updated and revised over time for the Lac de Gras environment. The majority of chemicals with Effects Benchmarks had concentrations or levels that were consistently below Effects Benchmarks at the mixing zone boundary during the AEMP monitoring period from 2002 to 2016. Between 2014 and 2016, total copper and total manganese had concentrations above Effects Benchmarks at the mixing zone boundary; however, the concentrations of these chemicals in the effluent were below the Effects Benchmarks at the time. The pH of the water at the mixing zone boundary was below the lower Effects Benchmark of 6.5 on several occasions in 2015 and 2016, but pH values are frequently less than 6.5 throughout Lac de Gras, in both ice-cover and open-water seasons, at various depths, and over time.

Section 5 – Eutrophication Indicators

Eutrophication indicators consist of nutrients (phosphorus and nitrogen), phytoplankton, chlorophyll *a* and zooplankton. Nutrient monitoring is a key component of the AEMP because one of the predicted effects of the discharge of effluent was an increase in phytoplankton from more nutrients in Lac de Gras.

Nutrient concentrations remain low throughout Lac de Gras, but chlorophyll *a* and plankton show effects related to increased nutrients in the near-field and mid-field areas. The large increases in annual loadings of all forms of phosphorus from the Mine effluent did not result in increasing trends in phosphorus concentrations in lake water, even in the near-field area. The dike construction affected phosphorus concentrations in the mid-field 3 area in 2015 and 2016, but the effect was small and seen only in decreased zooplankton biomass in 2016.

Loadings of nitrogen from the Mine effluent have declined since the maximum loads observed between 2006 and 2008, and no trends, or only slight increasing trends were observed in the near-field and mid-field areas. Greater increases in TN were seen in the far-field areas and near the outlet of Lac de Gras, where concentrations are now slightly above the normal ranges.

Nitrogen concentrations have been above the normal range in over 20 percent (%) of the lake since 2008. The extent of lake area affected increased above 20% from 2007 to 2016, with 2016 having 84.7% of lake area considered affected. The area with greater chlorophyll *a* concentrations has also increased between 2007 and 2016, to over 40% of lake area. Phosphorus concentrations have been low and variable (either below or just above the normal range). Overall, phosphorus was above the normal range in less than 20%

of the lake area. The amount of phytoplankton and zooplankton (measured as “biomass”) has been more variable, but in 2016, biomass was above the normal range in less than 20% of the lake.

Relationships between chlorophyll *a*, nutrients and total dissolved solids were examined. The relationshp between phosphorus and chlorophyll *a* was weak, but a strong relationship between total dissolved solids and chlorophyll *a* was identified, suggesting that phytoplankton may be responding to a Mine-related increase in micronutrients associated with total dissolved solids, in addition to phosphorus. There was also a moderate to strong relationship between nitrogen and chlorophyll *a*, but that is likely the result of the strong relationship between nitrogen and total dissolved solids.

The EA predicted that phosphorus concentrations would not exceed 5 micrograms per litre in more than 20% of the area of Lac de Gras. So far, this prediction has been exceeded twice during the ice-cover season (2008 and 2013), but it has never been exceeded during the open-water season.

Section 6 – Sediment Quality

The sediment quality component of the AEMP measures chemicals in mud at the bottom of the lake. Seventeen chemicals measured in sediment from 2007 to 2016 had greater average concentrations in the near-field area compared to the far-field areas. However, none of these had concentrations above guideline values for protecting plants and animals that live in or near the sediments. The number of sediment substances of interest, or SOIs, showing effects have not increased over time. However, the concentrations of bismuth, lead and uranium increased in the near-field and mid-field areas from 2001 or 2002 until approximately 2006 to 2008. These three metals have remained at similar concentrations since then, and do not represent a concern to aquatic life in the lake.

Section 7 – Plankton

The plankton component of the AEMP evaluated whether there were any changes happening to phytoplankton and zooplankton in Lac de Gras. Changes in plankton can affect fish in the lake, because plankton are part of the food chain upon which fish rely. Changes in plankton can happen before fish are affected.

Differences in the plankton communities between near-field and far-field areas have been seen every year between 2007 to 2016. The amount of phytoplankton from 2009 to 2011 and 2016 was greater than the normal range but in 2015, biomass was below the normal range. Zooplankton biomass has been more variable than phytoplankton biomass, but in the near- and mid-field areas it has generally stayed within the normal range, with the exception of 2016 where it was below the normal range. Changes in the types of small plants and animals that make up the phytoplankton and zooplankton communities have also been occurring in the near-field area since 2007. In 2016, the biggest changes were seen in the zooplankton community in the mid-field 3 area, likely because of changes in water conditions caused by the dike contruction.

Conditions in Lac de Gras are suitable for growth of healthy plankton communities. Overall, the plankton communities in Lac de Gras continue to show a Mine-related nutrient enrichment effect in the near-field and mid-field areas.

Section 8 – Benthic Invertebrates

The benthic invertebrates component of the AEMP evaluated whether the discharge of effluent into Lac de Gras has caused changes over time in the numbers and types of small animals that live on the bottom of Lac de Gras. Benthic invertebrates include snails, clams, worms, clustaceans and insects. These organisms provide food for fish. Changes in the numbers and types of benthic invertebrates can eventually cause changes in the numbers and types of fish in the lake.

Effects of nutrient enrichment have also been observed on the benthic invertebrate community, but recent results suggest a weakening of this effect. Total invertebrate density and densities of most major invertebrate groups were greater in the near-field and mid-field areas compared to the far-field areas before 2013. In 2013 and 2016, returns to within the normal ranges were observed in the near-field and mid-field areas for total density, richness (which is the number of different types of invertebrates), and densities of most of the dominant invertebrates. Indices that measure community health have remained within their normal ranges throughout the monitoring period, although evenness in the near-field area and at some mid-field stations has declined in 2016. The types of benthic invertebrates observed over the years has also changed, but the change over time was seen in both the near-field and far-field areas, suggesting that the community undergoes natural changes over time.

Section 9 – Fish Health and Fish Tissue

The fish component of the AEMP provides a summary of changes to the health and tissue chemistry of Slimy Sculpin (a small fish), and mercury concentration in Lake Trout. Slimy Sculpin have been monitored every three years in Lac de Gras since 2007. Lake Trout are monitored through the fish tasting program every two years.

Slimy Sculpin closer to the mine (in the near-field area) are smaller than fish farther from the mine (in the far-field area). The fish in the near-field area are, however, staying the same size over time. This suggests other factors like fish habitat are responsible for the differences in size between fish near and far from the Mine. For example, water temperature is colder in the near-field than the far-field area and this might make some fish grow more slowly in the near-field area. In general, while there are some small differences in fish size, fish are healthy overall, and able to grow and reproduce.

Concentrations of molybdenum and uranium have consistently been elevated in Slimy Sculpin in the near-field area and are outside of the normal range. While this is likely a Mine-related effect, fish are still healthy and concentrations of these metals in water are consistently below guideline values. Mercury in Slimy Sculpin is not different closer to the Mine and is not increasing over time.

The original EA prediction was that mercury would remain below an average of 0.2 milligrams per kilogram wet weight. In many years of monitoring this prediction was met, but in six years it was exceeded. Older (longer) Lake Trout have mercury concentrations that occasionally exceed the Federal mercury guideline of 0.5 milligrams per kilogram wet weight. This is similar to what is seen in larger Lake Trout in other lakes in the north.

Section 10 – Weight-of-Evidence

The weight-of-evidence section of the AEMP combines the information and conclusions of the effluent and water quality, eutrophication indicators, sediment quality, plankton, benthic invertebrates, and fish (fish tissue chemistry and fish health) sections. A semi-quantitative process was used to estimate the strength (or weight) of evidence for nutrient enrichment or toxicological impairment occurring in Lac de Gras from 2007 to 2016. Overall, there is strong evidence for nutrient enrichment in Lac de Gras and weak evidence that toxicological impairment is occurring.

Section 11 – Traditional Ecological Knowledge

Traditional Knowledge (TK) is intended to be an integral component of the AEMP for the Mine. In response to feedback received from communities, DDMI proposed a new approach to working with each of the five Aboriginal Parties that are part of the Environmental Agreement to improve the fish palatability component of the AEMP, by incorporating more discussion and documentation of TK relating to fish health and water quality. Diavik proposed to fund the use of a third-party consultant, Thorpe Consulting Services, to engage with Aboriginal working groups. Participants for these working groups were to be selected by the Aboriginal organizations. This process was supported by the Tłı̨chǫ Government, Yellowknives Dene First Nation, Kitikmeot Inuit Association, Łutsel K'e Dene First Nation, and the North Slave Métis Alliance. Work to develop the program began in early 2011, with a goal of implementing the TK program at the community-based monitoring camp on Lac de Gras. The AEMP TK study design was successfully implemented in 2012 and 2015.

In both years, camp participants noted that the overall status of the fish and water in Lac de Gras near the Diavik mine is good. Those fish that were tasted as part of the palatability study resulted in scores of 1 (excellent for eating, looks better than fish usually caught) or 2 (good for eating, looks similar to fish usually caught) from all participants.

Camp participants described the environmental indicators that they use to assess water quality, such as condition of the shoreline and clarity of the water. Additionally, a tea test was used to assess water quality, and participants noted that when tea is made from water of poor quality, it results in film or scum on the surface of the cup. None of the water samples from Lac de Gras had this scum or film, and all the samples tasted acceptable to participants.

During the planning sessions, it was identified that TK is best captured and shared through video rather than written reports. A small camera crew was hired to conduct a training session for youth from the communities to film and record the camp activities while learning from their Elders. Written reports and documentary videos were produced and approved by all participants in both years. These videos captured the overall process and the results of the water quality and fish palatability studies. Recognizing the sensitivity of TK and acknowledging that some information cannot be shared publicly, each Aboriginal organization also received a copy of the raw, unedited video footage of their members sharing their traditional stories and knowledge, for use by the community organization. DDMI is currently planning to conduct the AEMP TK program again in 2018.

The EA predicted that there would be no change to the taste or texture of the fish in Lac de Gras as a result of metals in the fish flesh. Based on the fish tasting program, this prediction is true, as there have been no changes in taste noted so far.

Section 12 – AEMP Summary of Effects

As predicted by the EA, Lac de Gras is showing evidence of mild nutrient enrichment, as indicated by water quality and non-fish biological monitoring components. While the fish component results may be showing early warning changes consistent with toxicological impairment, the strength of evidence for nutrient enrichment from most components is moderate to strong, while the strength of evidence for toxicological impairment remains weak to moderate for biological communities.

Section 13 – Updates to Effect Predictions

After 15 years of monitoring under the AEMP, the primary effects predicted by the EA are often either being observed as predicted, or observed effects are less than predicted. No recommendations are provided for updates to predictions of Mine-related aquatic effects based on AEMP results to date.

Section 14 – Proposed Updates to AEMP Design Plan

This re-evaluation report has identified a few areas in the AEMP design that require updating. Recommended changes to individual monitoring components are provided in this document. The overall AEMP study design recommendation is that the AEMP should largely be converted to a gradient design, with sampling along three transects that extend across the lake in different directions, with corresponding changes to sampling locations and data analysis methods, where applicable. The AEMP design already had a gradient component, so this change only results in relocating a few stations in the lake, which will allow continued evaluation of long-term trends.

Section 15 – Assessment of Response Framework Performance

The Response Framework for the DDMI AEMP has been effective at identifying early Mine-related changes in water and biological variables during the period of 2014 to 2016. Five Response Plans were prepared in response to Action Level triggers during this time: one for each of water quality, eutrophication indicators, plankton, benthic invertebrates, and fish. Minor updates to the Action Levels are recommended to maintain or improve the effectiveness of the Response Framework to detect early Mine-related changes in Lac de Gras and allow timely response actions.

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Acronyms and Abbreviations

Term	Definition
AB	Alberta
AEMP	Aquatic Effects Monitoring Program
AFDM	ash-free dry mass
AIC	Akaike's Information Criterion
AICc	Akaike's Information Criterion corrected
AL	Action Level
ALS	ALS Canada Ltd.
ANCOVA	analysis of covariance
ANOSIM	analysis of similarities
ANOVA	analysis of variance
BC	British Columbia
BIC	benthic invertebrate community
BCI	Bray-Curtis index
CCME	Canadian Council of Ministers of the Environment
CFIA	Canadian Food Inspection Agency
CFU	colony forming units
CPUE	catch-per-unit-effort
CWQG	Canadian Water Quality Guidelines
DDMI	Diavik Diamond Mines (2012) Inc.
DFO	Freshwater Institute (Fisheries and Oceans Canada)
DL	detection limit
DO	dissolved oxygen
e.g.	for example
EA	Environmental Assessment
Eco-Logic	Eco-Logic Ltd.
EEM	environmental effects monitoring
EOI	Evidence of Impact
EQC	Effluent Quality Criteria
et al.	and more than one additional author
FF	far-field
GNWT-ENR	Government of the Northwest Territories, Environment and Natural Resources
Golder	Golder Associates Ltd.
GSI	gonadosomatic index
HydroQual	HydroQual Laboratories
i.e.	that is
IC	ice-cover (season)
ISQG	interim sediment quality guideline
k	number of standard deviations

Term	Definition
K	condition factor
LDG	Lac de Gras
LDS	Lac du Sauvage
LOE	line of evidence
LSI	liversomatic index
Maxxam	Maxxam Analytics Inc.
MF	mid-field
Mine	Diavik Diamond Mine
mMDS	metric multidimensional scaling
MDS	multidimensional scaling
N	nitrogen
N+N	nitrate + nitrite
N:P	ratio of nitrogen to phosphorus
n	sample size/count
NAD	North American Datum
NF	near-field
NIWTP	North Inlet Water Treatment Plant
nMDS	non-metric multidimensional scaling
No.	number
NR	normal range
OMOEE	Ontario Ministry of the Environment and Energy
OP	orthophosphate
OW	open water (season)
P	phosphorus
P	probability
PC	principal component
PCA	principal component analysis
PEL	probable effect level
PVC	polyvinylchloride
QA	quality assurance
QC	quality control
QAPP	Quality Assurance Project Plan
QQ	quantum-quartile
R	R-statistic
r	Pearson correlation co-efficient
*r*2	coefficient of determination
RCR	Reference Conditions Report
RPD	relative percent difference
SD	standard deviation
SDI	Simpson’s Diversity Index

Term	Definition
SEL	severe effect level
SES	special effects study
SIMPROF	similarity profile
SNP	Surveillance Network Program
SOI	substance of interest
sp.	species
SWE	snow water equivalence
SQG	sediment quality guideline
SRP	soluble reactive phosphorus
TDN	total dissolved nitrogen
TDP	total dissolved phosphorus
TDS	total dissolved solids
TK	Traditional Knowledge
TN	total nitrogen
TOC	total organic carbon
TP	total phosphorus
TSS	total suspended solids
TSI	Trophic State Index
UofA	University of Alberta Biogeochemical Analytical Laboratory
USEPA	United States Environmental Protection Agency
UTM	Universal Transverse Mercator
VEC	valued ecosystem component
vs	versus
WLWB	Wek'èezhìı Land and Water Board
WOE	Weight-of-Evidence
WQ	water quality
YOY	young-of-the-year
ZOI	zone of influence

Symbols and Units of Measure

Unit/Symbol	Definition
-	no data
%	percent
% dw	percent dry weight
+	plus
±	plus or minus
=	equals
<	less than
≤	less than or equal to
>	greater than
≥	greater than or equal to
°	degrees
°C	degrees Celsius
µg/g	micrograms per gram
µg/g wwt	micrograms per gram wet weight
µg/L	micrograms per litre
µm	micrometre
µg-N/L	micrograms nitrogen per litre
µg-P/L	micrograms phosphorus per litre
µm	micrometre
µS/cm	microsiemens per centimetre
cm	centimetre
g	gram
h	hour
ind/L	individuals per litre
kg	kilogram
kg/mo	kilograms per month
kg/yr	kilograms per year
km	kilometre
km^2	square kilometre
L	litre
m	metre
m/s	metres per second
m^2	square metre
mg	milligram
$mg/dm^2/yr$	milligrams per square decimetre per year

Unit/Symbol	Definition
mg/kg dw	milligrams per kilogram dry weight
mg/L	milligrams per litre
mg/m^3	milligrams per cubic metre
mL	millilitre
mm	millimetre
n/a	not applicable
no. of taxa	number of taxa
no./m^2	number per square metre
no.org/m^2	number of organisms per square metre
ns	not significant
NTU	nephelometric turbidity unit
P	probability

1 INTRODUCTION

1.1 Background

Diavik Diamond Mines (2012) Inc. (DDMI) operates under a Class A Water Licence issued by Wek'èezhìı Land and Water Board (WLWB). Until 1 November 2007, DDMI operated under the terms and conditions of the Water Licence issued in August 2000 (N7L2-1645). The licence was amended in May 2004 and was valid until August 2007. In August 2005, DDMI submitted an application to renew the water licence, and hearings were subsequently held in November 2006. Before and during the hearings, interveners expressed concerns relating to fulfilment of conditions in the first Water Licence, particularly in relation to the Ammonia Management Plan, the Abandonment and Restoration Plan, and the original Aquatic Effects Monitoring Program (AEMP) (DDMI 2001), herein referred to as Version 1.0. DDMI addressed these concerns and submitted a revised AEMP Design Document (herein referred to as Version 2.0) to the WLWB on 16 February 2007 (DDMI 2007). With approval of the AEMP Design Document, DDMI secured their Class A Water Licence (W2007L2-0003) renewal for a period of eight years, effective 1 November 2007 (WLWB 2007). The Water Licence was renewed again in 2015 (W2015L2-0001) and continues to be in effect until 2023.

DDMI has been monitoring the aquatic ecosystem of Lac de Gras under the AEMP since 2001. The AEMP Version 1.0 (DDMI 2001a) was in effect from 2001 to 2006. In 2007, the scale of monitoring was expanded as described in the AEMP Version 2.0, which was developed according to the final AEMP Terms of Reference (TOR) provided by the WLWB (WLWB and Gartner Lee 2007). The AEMP Version 2.0 was approved by the WLWB on 12 July 2007.The initial three years of AEMP monitoring under AEMP Version 2.0 was intended to include the years 2007, 2008 and 2009; however, for a number of reasons (e.g., delayed approval of the sampling program, difficult weather conditions) the open-water sampling in 2007 was divided into two seasons instead of having three distinct open-water sampling periods. Consequently, the WLWB ruled that 2007 would not fulfil the first year of the initial three years of monitoring under the AEMP Version 2.0. A review of the information collected during the initial four years of the AEMP Version 2.0 (i.e., 2007 to 2010, inclusively) was submitted to the WLWB in July 2011 (Golder 2011a).

Part K (9) of Water Licence W2007L2-0003 stated that DDMI was to submit a modified AEMP study design for approval in 2011, and every three years thereafter. The intent of periodically updating the study design is to provide opportunity to make modifications to the AEMP design, according to the findings of the previous three years of monitoring. The AEMP Study Design Version 3.0 was originally submitted to the WLWB in October 2011 (Golder 2011b), and underwent numerous revisions:

- Version 3.1: revisions made to the Response Framework component (Sections 5.3 and 5.4), approved by the WLWB 12 August 2013
- Version 3.2: revisions made as per 19 August 2013 WLWB directive (WLWB 2013a,b), approved 19 December 2013
- Version 3.3: revisions made as per 19 December 2013 directive (WLWB 2013c)
- Version 3.4: correction of an inconsistency in sampling schedule between the water quality and indicators of eutrophication components, approved by the WLWB 10 March 2014

- Version 3.5: incorporated an update to the plankton sampling schedule to align the water quality, indicators of eutrophication, and plankton sampling programs (Golder 2014a), and clarified benthic invertebrate sampling methods regarding sub-samples (i.e., individual grabs) would be composited, addressing a recommendation made in the *2013 AEMP Annual Report* (Golder 2014c), approved 29 May 2014

The AEMP Study Design Versions 3.0 to 3.5 covered the period of monitoring from 2012 to 2016. The 2014 to 2016 Aquatic Effects Re-evaluation Report has been prepared under Water Licence W2015L2-0001 and AEMP Study Design Version 3.5.

The AEMP Study Design Version 3.5 has since been updated, first to Version 4.0 in July 2016, and again to Version 4.1 in June 2017 in response to WLWB Directives (dated November 2015 and March 2017, respectively). Throughout this report, where deviations from the approved AEMP Study Design Version 3.5 were necessary, reference is made to the reason for the deviation and the source of the change (i.e., WLWB Directives, DDMI Commitments, reviewer comments, or updated best scientific practice since AEMP Study Design Version 3.5 as approved and reflected in Version 4.1).

As part of the review process of the *2011 to 2013 Aquatic Effects Re-evaluation Report* (Golder 2016a), the WLWB requested that DDMI submit an AEMP Reference Conditions Report (RCR) that detailed the calculation of normal ranges for all AEMP measurement variables (WLWB 2015a). DDMI submitted the *AEMP Reference Conditions Report Version 1.0* on 15 April 2015. Following comments from the WLWB, DDMI submitted a revised Version 1.1 of the report, which included re-calculated normal ranges according to the requirements listed in the WLWB 28 July 2015 Directive. The WLWB approved the *AEMP Reference Conditions Report Version 1.1* on 27 November 2015. A second revision of the RCR, updating the document to Version 1.2, was requested by the WLWB as part of the review process for the AEMP Design Plan Version 4.0 (WLWB 2017a), and was approved on 22 September 2017.

During the process of updating to *Reference Conditions Report Version 1.2*, DDMI developed normal ranges for missing variables in sediment quality (i.e., 19 variables) and water (i.e., bicarbonate) which were not previously incorporated in Version 1.1, and a Reference Conditions Report Supplement was submitted to the WLWB on 2 August 2017. Following review, the *Reference Conditions Report Version 1.2* and it's Supplement were not approved, and the WLWB directed DDMI to prepare Version 1.3 in a Directive dated 14 December 2017 (WLWB 2017b). The *AEMP Reference Conditions Report Version 1.3* remains in review at the time this 2014 to 2016 Aquatic Effects Re-evaluation Report is in preparation. Normal ranges used herein follow the *Reference Conditions Report Version 1.2*, with the exception of those additional variables that had normal ranges developed and approved in the 14 December 2017 WLWB directive (i.e., 18 new sediment quality variables and bicarbonate in water).

Part J, Item 4 of the Water Licence W2015L2-0001 specifies that DDMI must comply with the approved *AEMP Quality Assurance Project Plan* (QAPP). The main objective of the QAPP is to outline the quality assurance/quality control (QA/QC) procedures for the AEMP and to provide a mechanism by which QA/QC objectives can be measured, assessed, and controlled to allow for the collection of scientifically defensible and relevant data. The first QAPP was submitted with the AEMP Version 2.0 in July 2007. Every three years, or as directed by the WLWB, DDMI is required to review and revise the QAPP for WLWB approval. The QAPP was last updated in June 2017, as Version 3.1 (Golder 2017a).

1.2 Scope

Every three years, an integrated AEMP report is to be produced and submitted to the WLWB. The goal of this report, referred to as the Aquatic Effects Re-Evaluation Report (previously the Three Year Summary Report), is to meet the requirements of Water Licence W2015L2-0001 Part J Item 9, which has the following three objectives:

a) To describe the Project-related effects on the receiving environment compared against Environmental Assessment (EA) predictions;
b) To update predictions of Project-related effects on the Receiving Environment based on monitoring results obtained since project inception; and
c) To provide supporting evidence, if necessary, for proposed revisions to the AEMP Design Plan.

The report also must satisfy the requirements of Water Licence W2015L2-0001 Schedule 8 Item 5, which are:

a) a review and summary of AEMP data collected to date including a description of overall trends in the data and other key findings of the monitoring program
b) an analysis that integrates the results of individual monitoring components (e.g., water quality, fish health, etc.) to date and describes the overall ecological significance of the results
c) a comparison of measured Project-related aquatic effects to predictions made during the Environmental Assessment and an evaluation of any differences and lessons learned
d) updated predictions of Project-related aquatic effects or impacts from the time of writing to the end of mine life based on AEMP results to date and any other relevant operational monitoring data
e) a plain language summary of the major results of the above analyses and a plain language interpretation of the significance of those results
f) recommendations, with rationale, for changes to Action Levels as set in the AEMP Design Plan
g) recommendations, with rationale, for changes to any other aspect of the AEMP Design Plan; and,
h) any other information required as requested by the Board.

There are also a number of WLWB Directives and DDMI commitments that require the inclusion of additional information in the 2014 to 2016 AEMP Re-evaluation Report, as described in Section 1.2.1.

1.2.1 Reporting Requirements (Concordance Table)

The above noted Water Licence requirements, as well as WLWB Directives that relate to the 2014 to 2016 Aquatic Effects Re-evaluation Report are provided in Table 1-1. Numerous additional DDMI commitments and comments acknowledged by DDMI in response to reviews of the following documents are also included in Table 1-1 as concordance items:

- 2011 to 2013 Aquatic Effects Re-evaluation Report
- AEMP Design Plan, Version 4.0 and Version 4.1

- Reference Conditions Report, Version 1.0
- 2014 AEMP Annual Report
- 2015 AEMP Annual Report
- 2016 AEMP Annual Report
- Water Licence Schedule 8 update
- 2016 AEMP Response Plans and Fish Response Plan Supplement

References to sections of this report, where the details related to each Directive, comment, or DDMI commitment are addressed, are provided in the final column of Table 1-1.

Table 1-1 2014 to 2016 Aquatic Effects Re-evaluation Report Concordance Table

Location of Direction	Statement of Direction, Comment, or DDMI Commitment	Component or Location in Report	Location in Report # 1621
W2015L2-0001 Part J, Item 9 (OBJECTIVES)	a) To describe the Project-related effects on the Receiving Environment compared against Environmental Assessment (EA) predictions;	All	Dust - Section 3.4 WQ - Section 4.4 Eutro - Section 5.4 Sediment - Section 6.4 Plankton - Section 7.3.6 BIC - Section 8.3.5 Fish - Section 9.4 WOE - Section 10.5 TEK - 11.5
	b) To update predictions of Project-related effects on the Receiving Environment based on monitoring results obtained since Project inception; and,	All	Section 13
	c) To provide supporting evidence, if necessary, for proposed revisions to the AEMP Design Plan.	Study Design	Section 14
W2015L2-0001 Schedule 8, Item 5 (REQUIREMENTS)	a) a review and summary of AEMP data collected to date including a description of overall trends in the data and other key findings of the monitoring program;	All	Dust - Sections 3.2.1, 3.3, and 3.5 WQ - Sections 4.2.1, 4.3, and 4.5 Eutro - Sections 5.2.1, 5.3, and 5.5 Sediment - Sections 6.2.1, 6.3, and 6.5 Plankton - Sections 7.2.1, 7.3, and 7.4 BIC - Sections 8.2.1, 8.3, and 8.4 Fish - Sections 9.2.1.1, 9.2.2, 9.3.2, and 9.5 WOE - Sections 10.3, 10.4, and 10.6
	b) an analysis that integrates the results of individual monitoring components (e.g., water quality, fish health, etc.) to date and describes the overall ecological significance of the results;	WOE, Each component, Summary "Ecological Signicance" paragraph in overall report	Section 10
	c) a comparison of measured Project-related aquatic effects to predictions made during the Environmental Assessment and an evaluation of any differences and lessons learned;	All	Dust - Section 3.4 WQ - Section 4.4 Eutro - Section 5.4 Sediment - Section 6.4 Plankton - Section 7.3.6 BIC - Section 8.3.5 Fish - Section 9.4 WOE - Section 10.5
	d) updated predictions of Project-related aquatic effects or impacts from the time of writing to the end of mine life based on AEMP results to date and any other relevant operational monitoring data;	All	Section 13
	e) a plain language summary of the major results of the above analyses and a plain language interpretation of the significance of those results;	Plain Language Summary	Plain Language Summary
	f) recommendations, with rationale, for changes to Action Levels as set in the AEMP Design Plan;	All	Section 14.3
	g) recommendations, with rationale, for changes to any other aspect of the AEMP Design Plan; and,	Study Design	Section 14
	h) any other information required as requested by the Board.	All	Section 15 (Assessment of Response Framework Performance)

Table 1-1 2014 to 2016 Aquatic Effects Re-evaluation Report Concordance Table

Location of Direction	Statement of Direction, Comment, or DDMI Commitment	Component or Location in Report	Location in Report # 1621
Cover Letter for W2015L2-0001 Schedule 8 Update - Board Directive and Reasons for Decision (DIRECTION)	A. Address the influence of the continued quality control (QC) issues on the previously requested assessment of ammonia concentrations based on the revised dataset and as described in the Reasons for Decision for the 2015 AEMP Annual Report;	Effluent and Water Quality	WQ - 4.2.3.3 and Appendix 4B
	B. Note that the submission of the 2014 to 2016 Aquatic Effects Re-evaluation Report will not be delayed in the event that a Board decision on the additional reference conditions information is not issued prior to the submission deadline for the 2014 to 2016 Aquatic Effects Re-evaluation Report;	-	n/a
	C. Incorporate annual sampling for plankton variables at the mid-field (MF) stations as part of its updates to the AEMP Design that are to be submitted along with the 2014 to 2016 Aquatic Effects Re-evaluation Report;	Study Design, Plankton	Section 14
	D. Provide updated WOE analysis results for the Nutrient Enrichment Impact Hypothesis based on the corrected direction-weighting factor for tapeworm parasitism as part of the 2014 to 2016 Aquatic Effects Re-evaluation Report;	Weight of Evidence	Section 10.2 and 10.3
	E. Include the following, along with its assessment of classification of fish to ages using different methods:	-	n/a
	i. A consideration of the comparability to the normal ranges for fish health indicators;	Fish	Section 9.2.1.2.3, Appendix 9A
	ii. A proposed update, with detailed rationale, to the normal ranges for fish health indicators if it is determined that a modification to the approved normal ranges is necessary; and	Fish	Section 9.2.1.2.3, Appendix 9A
	iii. A re-evaluation of Action Level 3 for fish health, if comparability to the normal ranges is identified as being potentially problematic;	Fish	Section 9.2.2.7
	F. Propose methods to address seasonal differences in its analysis of phosphorus loadings from dust;	Eutrophication Indicators	Sections 3.2.3
	G. Provide updated WOE analysis results for the Nutrient Enrichment Impact Hypothesis based on the corrected a priori weighting factor for chlorophyll a; and	Weight of Evidence	Section 10.3
	H. Include the omitted rationales for the a priori weighting factors for fish endpoints. These rationales should be flagged for reviewers as having been omitted from the 2016 AEMP Annual Report;	Weight of Evidence	Section 10.2
Reviewer Comments - Board Directive and Reasons for Decision re. W2015L2-0001 Schedule 8 Update (SUMMARY OF COMMENTS)	The Re-evaluation Report will include a section specifically devoted to considering changes to the AEMP Design, along with a summary of the sampling design and schedule	Study Design	Sections 2.2 and 14
	a. EMAB comment 17 includes a recommendation to consider addition of dustfall sites.	Dust	Section 14.2.1
	b. EMAB comment 56 includes a recommendation regarding the sampling depth for phytoplankton.	Plankton	insufficient direction provided; not addressed
	c. EMAB comment 75 includes a recommendation regarding clarifying the method for calculating condition factor. The Board notes that the method is not currently described in the AEMP Design.	Fish	Section 9.2.1.2.2
	d. EMAB comment 81 includes a recommendation to review the variables included in the Action Level assessment for fish.	Fish	Section 14.3.2
	e. EMAB comment 85 includes a recommendation to add benthic macroinvertebrate density as an endpoint to the fish community component of the WOE analysis.	Weight of Evidence	Section 10.2
	f. EMAB comment 94 addresses the variation observed in the extent of chlorophyll a effects and recommends that DDMI consider additional data collection to help explain the fluctuations. The Board notes that DDMI has also recently been directed to consider a more explicit analysis of the role of nitrogen in explaining variation and the spatial extent of chlorophyll a effects as part of the 2014 to 2016 Aquatic Effects Re-evaluation Report	Eutrophication Indicators, Plankton	Eutro: Sections 5.3.3 and 5.3.5 Plankton: Section 7.3.5
	g. GNWT-ENR comments 6, 7, and 9 to 13 all appear to provide various recommendations about potential improvements that could be made to the statistical analyses.	All	Section 14
	h. GNWT-ENR comment 18 includes a recommendation for the inclusion of phytoplankton taxonomy to be done annually at all MF and FF-2 locations, as well as LDS-4. The Board notes that DDMI has already committed to including this annually at all MF stations (see Section 3.5 of these Reasons for Decision).	Plankton	Plankton - Section 14.2.6
DDMI Commitments - Board Directive and Reasons for Decision re. W2015L2-0001 Schedule 8 Update (SUMMARY OF DDMI COMMITMENTS)	a. DDMI stated that it will include an evaluation of the feasibility of including data from LDG-48 in future eutrophication analyses (EMAB comment 11).	Eutrophication Indicators	Sections 5.2.3 and 5.3.4
	b. DDMI has noted for consideration the recommendation to review location of duplicate and blank sample collection for dust program during the next revision of the AEMP Design (EMAB comment 29).	Study Design, Dust	Sections 3.2 and 14.2.1
	c. DDMI has stated that it will include an analysis to evaluate the relationships between nutrients, chlorophyll a and phytoplankton biomass (EMAB comment 47).	Eutrophication Indicators, plankton	Eutro - Section 5.3.5 Plankton - Section 7.6.4
	d. DDMI has indicated that it will include the results of the calculation of spatial extent of effects for phytoplankton biomass from 2007 to 2017 (EMAB comment 49).	Eutrophication Indicators	Section 5.3.1
	e. DDMI has stated that it will consider the incorporation of nutrient ratios (EMAB comment 61). The Board also notes that DDMI has been directed to more thoroughly consider the role of role of nitrogen in explaining variation and the spatial extent of chlorophyll a effects through a previous Board directive.	Eutrophication Indicators	Section 5.3.7
	f. DDMI has stated that it will consider inclusion of soluble reactive silica as a measured parameter and supporting water quality variable (EMAB comment 84).	Study Design	Section 14.2.5
	g. DDMI has stated that it will consider historical occurrences of parasites (GNWT-ENR comment 26).	Fish	Section 9.2.2.3
	h. DDMI has stated that alternative methods to examine reproductive success of Slimy Sculpin will be reviewed and considered (EMAB comment 80; GNWT-ENR comment 29).	Fish	Section 13.4

Table 1-1 2014 to 2016 Aquatic Effects Re-evaluation Report Concordance Table

Location of Direction	Statement of Direction, Comment, or DDMI Commitment	Component or Location in Report	Location in Report # 1621
2011 to 2013 Aquatic Effects Re-evaluation Report, Version 3.1 (DIRECTIVES)	With regards to the 2014 to 2016 Aquatic Effects Re-evaluation Report, the Board has decided that DDMI is to:	-	n/a
	A. Provide clear rationale and support for methods used in the estimation of background dust deposition rates.	Dust	Sections 3.2.2 and 2.3.2
	B. Consider restructuring the Dust Section to more clearly explain the methods.	Dust	Section 3.3.2
	C. Consider the inclusion of monitoring data from the Ekati Diamond Mine as an estimate of regional dust deposition rates.	Dust	Sections 3.2.2 and 3.2.3
	D. Include a full explanation of the treatment of outliers for the dust analyses.	Dust	Sections 3.2.2 and 3.2.3
	E. Use consistent methods for handling outliers throughout presented analyses, or provide rationale to justify the use of different methodologies.	All	Section 2.4
	F. Include an assessment of the performance of the WOE approach and the Response Framework.	Weight of Evidence	Section 10.6 and 15
	G. Include a more thorough explanation of how data are handled when there is a large proportion of values less than the detection.	All	Section 2.4 WQ - Sections 4.2.3.2 and 4.2.4.2.2 Sediment - Section 6.2.2.2 Fish - Section 9.3.1.2.3
	H. Include a more in-depth and integrative assessment of the plankton data.	Plankton	Plankton - 7.3.4
	I. Include a statistical evaluation of temporal trends in MF1 and MF3.	All	WQ - Section 4.3.2.1.2 Eutro - Section 5.3.3 Sediment - Section 6.3.3 Plankton - Section 7.3.2 BIC - Section 8.3.2
	J. Use both statistical and graphical interpretation, where appropriate, when considering temporal trends.	All	WQ - Section 4.3.2.1.2 Eutro - Section 5.3.3 Sediment - Section 6.3.3 Plankton - Section 7.3.2 BIC - Section 8.3.2 Fish - Sections 9.2.2.5 and 9.3.2.2
	K. Consider incorporating a statistical evaluation of trends for effluent chemistry.	Effluent and Water Quality	Section 4.3.1.1
	L. Include all available years of snow chemistry data in analyses.	Dust	Section 3.2.1
	M. Address the influence of methodological variation in nutrient sampling on the interpretation of effects for sediment quality.	Sediment	Sediment - Section 6.3.3.2
	N. Include an explanation of how variation through time in sediment sampling methodologies for all parameters has been considered when interpreting effects.	Sediment	Sediment - Section 6.2.1 and 6.3.3.1
	O. Provide more complete rationale when drawing conclusions related to effects hypotheses.	All	WQ - Section 4.5 Eutro - Section 5.5 Sediment - Section 6.5 Plankton - Section 7.4 BIC - Section 8.4 Fish - Section 9.5
	P. Include a summary of temporal trends in dissolved oxygen and temperature.	Effluent and Water Quality	Section 4.3.2.1.1
	Q. Include the type and level of information provided in their responses to reviewer comments listed in Section 3.13.1.	All	n/a
	R. Submit the 2014 to 2016 Aquatic Effects Re-evaluation Report within six months following the approval of the 2016 AEMP Annual Report.	-	n/a

Table 1-1 2014 to 2016 Aquatic Effects Re-evaluation Report Concordance Table

Location of Direction	Statement of Direction, Comment, or DDMI Commitment	Component or Location in Report	Location in Report # 1621
AEMP Design Plan, Version 4.0 (DIRECTIVES)	With regards to the 2014 to 2016 Aquatic Effects Re-evaluation Report, DDMI is directed to:	-	n/a
	A. Include a spatio-temporal assessment, which at minimum, includes figures and comments on the trends of all analyzed variables;	Effluent and Water Quality	Section 4.3.2.1 and Appendix 4C
	B. Include a statement explaining how it has incorporated key findings from the Plankton Report into the Eutrophication Report;	Eutrophication Indicators	Sections 5.3.6
	C. Include for consideration, if it wishes, a proposal to change the schedule for Slimy Sculpin sampling to include the condition that Slimy Sculpin would be sampled every six years, if two consecutive sampling events demonstrate that toxicological effects are not observed;	Fish	Section 14
	D. Include a consideration of the frequency of sampling at FF stations;	Fish	Section 13
	E. Include an evaluation of the potential use of nMDS results to identify environmental gradients influencing plankton community;	Plankton	Section 7.3.4
	F. Include a consideration of the recommendation regarding the taxonomic resolution issue for Bray-Curtis distance measures for benthic invertebrate data;	Benthic Invertebrates	Section 8.3.4.2
	G. Include a section specifically devoted to considering changes to the Design, along with a summary of the sampling design and schedule; and	All	Section 14
	H. Include the analysis proposed in Section 51 of the Design's Appendix A as part of the 2014 to 2016 Aquatic Effects Re-evaluation Report. RELEVANT BACKGROUND: Section 51 Text - A spatial gradient approach will be used to evaluate cumulative effects in Lac de Gras from the Ekati and Diavik mines. This will be done as part of the comprehensive reports, which will present a spatial analysis of results from the comprehensive sampling program where all stations will be sampled, including the FF areas. Effects will be assessed along the gradient of exposure at stations in the MF3, FFB and FFA areas and at Station LDG-48. The presence of a spatial trend with distance from the Diavik diffusers that is reversed as one moves west from the MF3 or FFB areas would suggest that effluent from both mines are a potential influence on the variable in question. Magnitude of effects will be evaluated by comparing the results to the normal range (as defined in the AEMP Reference Conditions Report Version 1.1). The AEMP results will be qualitatively compared to data collected at the Ekati Slipper Bay monitoring stations in Lac de Gras (e.g., S2, S3, S5 and S6) to further evaluate the potential contribution of Ekati to cumulative effects in Lac de Gras. <u>A temporal assessment of trends at relevant stations will be provided in the Aquatic Effects Re-evaluation Report and will follow the approach in Golder (2016b)</u>.	Effluent and Water Quality	Section 4.3.2.2.3
2014 AEMP Annual Report (DIRECTIVES)	With regards to the 2014 to 2016 Aquatic Effects Re-evaluation Report, the Board has decided that DDMI is to:	-	n/a
	A. Consider a more explicit analysis of the role of nitrogen in explaining variation and the spatial extent of chlorophyll a effects; and	Eutrophication Indicators	Section 5.3.5
	B. Evaluate the assumptions of the Action Level testing for Eutrophication Indicators.	Eutrophication Indicators	Section 5.3.8
	Clarification of "Effects Threshold" and "Significance Threshold" for indicators of Eutrophication	Eutrophication Indicators	Section 5.3.8
2015 AEMP Annual Report (DIRECTIVES)	With regards to the 2014 to 2016 Aquatic Effects Re-evaluation Report, the Board has decided that DDMI is to include the following:	-	n/a
	A. Include a thorough consideration of how the revised ammonia results compare to the historical ammonia data. The Board requires this consideration to include an assessment of the ability to detect changes over time in ammonia concentrations and to evaluate Action Levels for ammonia;	Effluent and Water Quality	Section 4.2.3.3 and Appendix 4B
	B. Consider the inclusion of phosphorus concentrations in the Response Framework. The Board requires this consideration to include a discussion of observed phosphorus concentrations and how they relate to the phosphorus management framework;	Eutrophication Indicators	Section 5.3.8
	C. Conduct an assessment of the reference area conditions used for the phytoplankton variables. The Board requires this assessment to include:	Plankton	Section 7.3.2.1
	i. a comparison of DDMI's AEMP results from 2014 to 2016 to reference conditions as defined using the currently approved 2007 to 2010 reference area data and to the 2013 reference area data as recommended by DDMI; and	Plankton	Section 7.3.2.1
	ii. a recommendation, with supporting rationale, for which reference conditions DDMI believes should be used moving forward;	Plankton	Section 7.3.2.1
	i. the analysis as described in the Design (i.e., comparison of tissue metal concentrations to baseline concentrations); and/or	TEK, Fish	Section 11.5 and Section 9.4
	ii. an explanation for if, and why, this should be considered differently in the future by providing a recommendation with supporting rationale, for a change to the AEMP Design;	TEK	Section 14.2.6
	E. Note that a comparison of fish tissue metal concentrations to CSR predictions is required; and	Fish	Section 9.4
	F. Consider the establishment of data quality objectives and potential changes to the sampling design for snow water chemistry.	Dust	Sections 3.2.2 and 3.2.3
Reference Conditions Report, Version 1.0 (COMMITMENT)	Commitment #27 Reference Conditions Report_Response to Reviewer Comments.docx. DDMI is currently working with Maxxam to identify a solution that will address the QA/QC issues identified with the ammonia data. Until an appropriate solution can be identified, the Maxxam ammonia data will be shown in the forthcoming AEMP annual reports but will not be compared with the NR. For the purpose of the three-year summary report, the NR for ammonia will be shown in the temporal plots for up to 2012, but will not be applied to the recent Maxxam data. This approach is consistent with that used for ammonia in the analyses conducted for the Effluent and Water Quality Report.	Effluent and Water Quality	Sections 4.2.3.3 and Appendix 4B

Table 1-1 2014 to 2016 Aquatic Effects Re-evaluation Report Concordance Table

Location of Direction	Statement of Direction, Comment, or DDMI Commitment	Component or Location in Report	Location in Report # 1621
AEMP Design Plan, Version 4.0 (COMMITMENT)	Commitment #29 (WLWB) AEMP Design Plan Ver4 Comment Responses_FINAL TO DDMI Oct.13.docx. Given that the stations used in this analysis have been historically sampled as part of the AEMP, can DDMI outline any limitations to including results of this analysis as part of the 2014 to 2016 Aquatic Effects Re-evaluation Report. Provided AEMP Design Version V4 has been approved we do not see a limitation to including this analysis as part of the 2014-2016 Aquatic Effects re-Evaluation Report. RELEVANT ADDITIONAL INFO: Section 6.1 Data Analysis Approach to Detect Cumulative Effects; Page 93-94 - Results to be provided in the Aquatic Effects Re-evaluation. This section proposes an analysis to assess cumulative effects in Lac de Gras with results being presented as part of the Aquatic Effects Re-evaluation Report.	Effluent and Water Quality	Section 4.3.2.2.3
	Commitment #47 (WLWB) AEMP Design Plan Ver4 Comment Responses_FINAL TO DDMI Oct.13.docx. DDMI proposes that as part of the next Aquatic Effects Re-evaluation Report, fish health endpoints be plotted both as mean values and as individual data points on graphs presented in support of the fish health component. This would allow for a visual evaluation of temporal trends. As discussed in Appendix A, Section 42, this visual presentation will not apply to the assessment of Action Level 1; for Action Level 1, comparisons to normal ranges are not required.	Fish	Sections 9.2.2.4 and 9.2.2.5
	Commitment #5 (EMAB) AEMP Design Plan Ver4 Comment Responses_FINAL TO DDMI Oct.13.docx. DDMI acknowledges the reviewers suggestion and will endeavor to incorporate key findings from the Plankton report in future comprehensive year Eutrophication reports and Re-evaluation reports. Phytoplankton biomass (biovolume) will be incorporated into future Eutrophication Reports in the following ways:	Eutrophication Indicators, Plankton	Section 5.3
	1)Comparison to the normal range;	Eutrophication Indicators, Plankton	Section 5.3.4
	2)Plot of total phytoplankton biomass against distance from the diffuser to visually evaluate spatial trends relative to the Mine discharge;	Eutrophication Indicators, Plankton	Section 5.3.1
	3)Boxplot of total phytoplankton biomass in Lac de Gras during the open-water season; and,	Eutrophication Indicators, Plankton	Section 5.3.4
	4) Calculation of spatial extent of effects on phytoplankton biomass.	Eutrophication Indicators, Plankton	Section 5.3.1
2014 AEMP Annual Report (COMMITMENT)	Commitment #7 (GNWT – ENR) in DDMI AEMP 2014 Golder Draft Responses.docx. The presence of toxicological impairment needs to be evaluated based on the full weight of evidence provided by the AEMP data set, including exposure indicators, toxicity test results, field-measured biological response variables, and potentially other lines of evidence. This is done by a formal weight-of-evidence analysis during comprehensive AEMP years, and is further evaluated during the Aquatic Effects Re-evaluation process.	Weight of Evidence	Section 10
	Commitment #11 (GNWT – ENR) in DDMI AEMP 2014 Golder Draft Responses.docx. The Significance Thresholds for the AEMP are "locked in" as approved in the AEMP Study Design Version 3.5. This recommendation would be best addressed at the time of the next AEMP re-evaluation and re-design cycle, following the 2016 AEMP Annual Report submission. DDMI suggests that the Significance Thresholds for this component should be based on biological response variables, rather than exposure variables. The recommendation from ENR was "ENR supports and recommends that the eutrophication significance threshold for each of the three eutrophication-related metrics should be as follows:	Eutrophication Indicators	Section 5.3.8
	a) The mean of the five Farfield A depth integrated chlorophyll a concentration does not exceed 4.5 µg/L; or,	Eutrophication Indicators	Section 5.3.8
	b) The mean of the five Farfield A total P concentrations does not exceed 10 µg/L; or,	Eutrophication Indicators	Section 5.3.8
	c) The mean of the five Farfield A total N concentrations does not exceed 700 µg/L."	Eutrophication Indicators	Section 5.3.8
2015 AEMP Annual Report (COMMITMENT)	Commitment # 9 (EMAB) in DDMI Submission – Response to Review Comments on the 2015 AEMP Annual Report.pdf. Continue to evaluate the relationship between chlorophyll a and phytoplankton biomass.	Eutrophication Indicators	Section 5.3.5
	Commitment # 21 (EMAB) in DDMI Submission – Response to Review Comments on the 2015 AEMP Annual Report.pdf. The reviewer correctly points out that concentrations of certain water quality variables were elevated in 2015 at stations along the MF3 area transect during the open-water season. The increase observed in these variables, however, is more likely related to sediment disturbance by construction of the A21 Dike, than to effects from dust released from the mine site. The A21 dike is situated in Lac de Gras at the southwest end of East Island. Construction of the dike began during early summer, 2015 and was ongoing during the open water AEMP sampling event in 2015. Given the timing and location of dike construction, effects on water quality variables would be expected to peak at stations along the MF3 area transect in the vicinity of the construction activities during open-water (e.g., stations MF3-2, MF3-3, MF3-4). This pattern of response is consistent with that observed in the open-water concentrations of aluminum and chromium.	Effluent and Water Quality	Section 4.3.2.2.2
	Effects of dike construction on water and sediment quality in Lac de Gras will be evaluated as part of the A21 Dike Monitoring Program, which DDMI has implemented as a condition of the Fisheries Authorization pertaining to construction of the A21 dike. Reports prepared based on results of the study will be submitted one year following completion of construction of the A21 dike (i.e., 2018).	Effluent and Water Quality	Section 4.3.2.2.2
	An analysis of spatial trends will be completed during the comprehensive AEMP in 2016, and temporal trends will be evaluated in the AEMP Re-evaluation report.	Effluent and Water Quality	Sections 4.3.1.1 and 4.3.2.1
	Commitment # 25 (EMAB) in DDMI Submission – Response to Review Comments on the 2015 AEMP Annual Report.pdf. Present nutrient ratios and evaluate trends over time.	Eutrophication Indicators	Section 5.3.7

Table 1-1 2014 to 2016 Aquatic Effects Re-evaluation Report Concordance Table

Location of Direction	Statement of Direction, Comment, or DDMI Commitment	Component or Location in Report	Location in Report # 1621
	Commitment # 29 in 2015 AEMP Comment Responses.docx. Potential reasons for comparatively less year-to-year variability in TN in comparison to other eutrophication indicators will be discussed. Additionally, will comment on the continued large spatial extent of effects on TN in 2015 in comparison to the reduction of extent for other parameters (i.e., TP, Chla, Zoop biomass). Additional inputs affecting TN concentration in Lac de Gras may be a contributing factor and should be considered in the discussion.	Eutrophication Indicators	Section 5.3.1
	Commitment #14 (GNWT – ENR) in 2015 AEMP Comment Responses.docx. Provide a temporal trend assessment for the list of analyses for SOIs.	Effluent and Water Quality	Sections 4.3.1.1 and 4.3.2.1
	Commitment #19 (EMAB) in 2015 AEMP Comment Responses.docx. Provide an assessment of the comparability of the 2015 data (new Maxxam method) with the historic ALS data (i.e., used to describe reference conditions), and describe any implications for ammonia data analysis going forward (e.g., for the 2014 to 2016 three year summary report).	Effluent and Water Quality	Sections 4.2.3.3 and Appendix 4B
2016 AEMP Annual Report (COMMITMENT)	Commitment #47 in Review Comment Table-2016 AMEP Report.pdf. Evaluate relationships between nutrients and chlorophyll a and phytoplankton biomass.	Eutrophication Indicators, Plankton	Plankton - Section 7.3.4 Eutro - Section 5.3.5
	Commitment #49 in Review Comment Table-2016 AMEP Report.pdf. DDMI will calculate the spatial extent of effects for phytoplankton biomass for previous years (i.e., 2007 to 2017). [comment on Eutrophication Indicators section].	Eutrophication Indicators	Section 5.3.1
	Commitment #61 in Review Comment Table-2016 AMEP Report.pdf. Review nutrient ratios to evaluate potential nutrient limitation and subsequent effects on N-fixing bacteria. [comment on plankton section].	Plankton	Section 7.3.4
	Commitment #66 and #68 and #93 in Review Comment Table-2016 AMEP Report.pdf. Comparison to past benthic invertebrate studies will be considered for the Re-evaluation report. Review statements throughout the document respecting decreases in Pisidiidae.	Benthic Invertebrates	Section 8.3.2.4
	Commitment #82 in Review Comment Table-2016 AMEP Report.pdf. The implications of livers being omitted from fish carcass samples submitted for tissue chemistry in 2016 will be reviewed.	Fish	Section 9.3.1.2.1
	Commitment #84 in Review Comment Table-2016 AMEP Report.pdf. Incorporation of other factors (committed to silica concentrations) that may affect plankton abundance and community composition within the analysis and discussion.	Plankton	Sections 7.3.4 and 7.4
	Commitment #90 in Review Comment Table-2016 AMEP Report.pdf. Historical parasitism levels will be considered. [Weight of Evidence section].	Fish	Fish: Section 9.2.1.3.3WOE: Section 10.2
	Commitment #92 in Review Comment Table-2016 AMEP Report.pdf. A list of previously recorded parasitism levels from 2013 to 2016 sculpin sampling in Lac de Gras will be considered in the Re-evaluation. [Weight of Evidence section].	Fish	Section 9.2.1.3.3
	Commitment #94 in Review Comment Table-2016 AMEP Report.pdf. Variation over time in eutrophication indicators will be evaluated and if applicable, recommendations will be made regarding other information that could be collected in future years to explain the variation in the extent of effects in Lac de Gras.	Eutrophication Indicators	Section 5.5
	Commitment #25 (under GNWT-ENR comments) in Review Comment Table-2016 AMEP Report.pdf. A summary of tapeworm historical occurrence during the AEMP fish surveys will be provided in the Re-evaluation report.	Fish	Section 9.2.2.3
	Commitment #26 (under GNWT-ENR comments) in Review Comment Table-2016 AMEP Report.pdf. Historical occurrence of parasites during the AEMP fish surveys will be considered in the Re-evaluation.	Fish	Section 9.2.2.3
	Commitment #27 (under GNWT-ENR comments) in Review Comment Table-2016 AMEP Report.pdf. Multi-year re-evaluation analysis to understand among-year changes in fish health and their magnitude.	Fish	Section 9.2.2
	Commitment #29 (under GNWT-ENR comments) in Review Comment Table-2016 AMEP Report.pdf. Alternative methods to examine reproductive success will be reviewed and considered in the re-evaluation report.	Fish	Sections 9.2.1.2.3 and 9.2.2.7
	Commitment #5 in WLWB Clarification Requests Responses_v2.docx. Fish health metrics will be reviewed in detail in the Response Plan. If the fish health effects are confirmed in the review process of the Response Plan, the Plan will evaluate the potential effects of the 2016 fish tissue concentrations on fish health. Fish tissue concentrations, temporal patterns of tissue concentrations, and sampling methods (including the issue of livers not being included in analyses in 2016) will be reviewed in the AEMP Re-evaluation Report.	Fish	Sections 9.3.1.2.1 and 9.3.2.2
	DDMI does not believe fish health sampling, scheduled for 2019, should be advanced to 2018, on the basis of the following:	Fish	n/a
	1) Despite the elevated metal concentrations in fish tissues in NF and MF, fish health effects are largely below the critical effect sizes identified in the MMER (2012), and those that are not (i.e., fish weight) are the subject of investigation as part of the Response Plan (which will include consideration of the influence of tissue chemistry as part of the investigation).	Fish	n/a
	2) The sampling itself is detrimental to the fish population, since large numbers of fish, specifically large, non-parasitized fish, are removed from the local sampling areas in Lac de Gras, and the overall sculpin population in the lake.	Fish	n/a
	In conclusion, given the choice of additional lethal sampling to increase precision of fish tissue metal concentrations (i.e., the effect of liver removal on metal burden results), or continuing desktop evaluation of sampling methods, temporal and spatial trends, and the effect of tissue chemistry on fish health, DDMI proposes to avoid additional lethal sampling. Rather, DDMI will implement the Response Plan investigation into fish health endpoints, and if valid (i.e., if effects are confirmed and further investigation is necessary), will consider the influence of tissue chemistry on fish health. A thorough review of sampling methods and temporal patterns of tissue metal concentrations will be included in the Re-evaluation Report.	Fish	Sections 9.3.1.2 and 9.3.2.2
	Commitment #6 in WLWB Clarification Requests Responses_v2.docx. In previous reports, there was a clear modality in length frequency distributions, and it was possible to assign age classes to these modes. Further, otolith age was used in previous reports (which is now known to be unreliable: Gray 2014). In the 2016 dataset, there was no clear modality in the length frequency distribution, therefore the length/GSI approach was used to assign age to fish.	Fish	n/a

Table 1-1 2014 to 2016 Aquatic Effects Re-evaluation Report Concordance Table

Location of Direction	Statement of Direction, Comment, or DDMI Commitment	Component or Location in Report	Location in Report # 1621
	The use of age-1+ abundance in the 2016 samples as an indicator of reproductive success was a biased approach, because:	Fish	n/a
	1) The approved field method is designed to target larger, non-parasitized Slimy Sculpin to best characterize adult fish health.	Fish	n/a
	2) Given this, an under-representation of smaller fish (i.e., those fish that would encompass the age-1+ size class) results.	Fish	n/a
	Therefore, the 2016 Slimy Sculpin dataset is biased against the inclusion of age-1+ fish, and an assessment of age-1+ abundance would be statistically invalid (given the assumption of random sampling is not met). This sample design limitation relative to assessing reproductive success using age-1+ fish will be examined in the AEMP Re-evaluation Report.	Fish	Sections 9.2.1.2.3, 9.2.1.3.4, and 9.2.2.7
	Commitment #7 in WLWB Clarification Requests Responses_v2.docx. There are no national fish tissue guidelines for most metals (with the exception of mercury, selenium, arsenic and lead). Therefore, the sentence referenced in comment 83 from EMAB was written with the intent to compare water quality and sediment results to their respective guidelines, rather than comparing fish tissue concentrations to fish tissue guidelines or benchmarks. Water and sediment guidelines were established to protect aquatic life, and given that the 2016 AEMP results were considerably below these guidelines, significant adverse effects on fish are not expected. A review of fish tissue metal concentrations as they relate to fish health will be included in the Response Plan. Tissue metal concentrations will also be considered thoroughly in the AEMP Re-evaluation Report.	Fish	Section 9.3
	Commitment #8 and #9 in WLWB Clarification Requests Responses_v2.docx. Parasitism could, indeed, be due to nutrient enrichment. The intention in the weight of evidence estimates was to be conservative and use a rating 1 for toxicological response. We agree with the reviewer, and the variable could also have a rating 1 for nutrient enrichment; however, the change in ratings would not influence the overall conclusion of the fish health analysis (i.e., triggering Action Level 2 due to possible toxicological effect). Furthermore, since the difference in parasitism incidence between NF and FF areas was 7.5%, it is not likely to be biologically significant, nor does it warrant additional investigation. In addition, the second highest parasitism incidence was recorded at FF1, while the lowest incidence was recorded at FF2, indicating that parasitism levels did not follow the expected gradient from NF to FF.	Fish	n/a
	No further examination of this scenario is deemed necessary in the 2016 AEMP annual report. The difference in parasitism over time will be examined in the Response Plan and the AEMP Re-evaluation Report. Historical parasitism levels will be considered in the Aquatic Effect Re-evaluation Report.	Fish	Section 9.2.2.3
	Given the provided response to comment #8, we do not believe a revision to the 2016 AEMP annual report is warranted. The statement regarding tapeworms and normal range in the 2016 AEMP annual report was made within the weight of evidence appendix (i.e., not in the fish health appendix), and it was made relative to Effects Ratings for fish health (where most endpoints do have a defined normal range). Wording in the weight of evidence assessment in the future will avoid including metrics that do not have normal ranges in such statements and/or summaries, without explicitly noting the absence of defined and approved normal ranges for those endpoints. The temporal patterns in parasitism levels will be examined in the Response Plan and in the AEMP Re-evaluation report.	Fish, Weight of Evidence	Section 9.2.2.3
	Commitment #12 in WLWB Clarification Requests Responses_v2.docx. All 2016 sediment quality data are provided in Appendix E of the Sediment Report (Appendix III), and were also provided as an Excel file with the first set of responses to the comments on the 2016 AEMP Annual Report.	Sediment	n/a
	DDMI wishes to seek approval of sediment reference values prior to completion and submission of the Re-evaluation report, in order to ensure agreement on the values used to determine SOI's and minimize the potential for revisions to the Re-evaluation Report. DDMI suggests that an addendum to the RCR, which provides sediment reference data for review, be submitted for approval by XXXX. Once approved, this information would be incorporated into the RCR and utilized in the Re-evaluation Report.	Sediment	Section 6.2.3.4
	Commitment #11 in PropRespReq_11170_response assignments_DW.xlsx. The feasibility of including LDG-48 data in future eutrophication analyses will be evaluated as part of the re-evaluation report.	Eutrophication Indicators	Section 5.2.3 and 5.3.4
2015 AEMP Annual Report V 1.1 Directive and Reasons for Decision (DIRECTIVE)	The Board has decided that Version 1.1 satisfies the Board's direction and has approved Version 1.1 of the 2015 AEMP Annual Report. The Board notes, however, that new information was provided regarding sampling location errors for Station SS3-6 as part of the Dust Monitoring component of the AEMP. This topic was recently addressed during the Board's consideration of the 2016 AEMP Annual Report and DDMI has been directed to address this as part of the 2014 to 2016 Aquatic Effects Re-evaluation Report.3	Dust	Section 3.1.2
Diavik AEMP Design V 4.1 Direcive and Reasons for Decisions (DIRECTIVES)	Board has thus decided that DDMI is to address the statistical comparisons for Action Levels 1 and 2 for biological components during comprehensive years as part of the 2014 to 2016 Aquatic Effects Re-evaluation. DDMI should clarify if comparisons are being made to the same year FF area means or to the reference conditions as defined in the approved Reference Conditions Report.	Fish, Plankton, Eutrotrophication, Benthic Invertebrates	Section 14.3.2
	The Board has thus decided that DDMI is to address the apparent misunderstanding in sediment sampling replication as part of the 2014 to 2016 Aquatic Effects Re-evaluation. The Board request that DDMI engage with ECCC on this topic and that proposed updates to the AEMP Design and the Quality Assurance Project Plan reflect the outcome of those discussions. The Board notes that this same directive was issued in the Board's decision for the QAPP Version 3.1.	Sediment	Section 14.2.4
	The Board would like to remind DDMI that it is to address updates to the AEMP Design as part the 2014 to 2016 Aquatic Effects Re-evaluation Report.	All	Section 14
WLWB 2016 AEMP Response Plans and 2016 AEMP Fish Response Plan - Supplemental Report - 24 January 2018	3. DDMI is to address the GNWT-ENR recommendations 10 and 11, with regards to changes to Action Levels for effluent and water chemistry, as part of the 2014 to 2016 Aquatic Effects Re-evaluation Report	Effluent and Water Quality	Section 14.2
	4. DDMI is to include relevant updates to Canadian Water Quality Guidelines as part of the proposed changes to the AEMP Design to be submitted with the 2015 to 2016 Aquatic Effects Re-evaluation Report.	Proposed Updates to AEMP Design Plan	Section 14.2

2 AEMP DESIGN SUMMARY AND RE-EVALUATION METHODS

2.1 AEMP Objectives

The AEMP is the primary program specified in Water Licence W2015L2-0001 for monitoring the effects of the Diavik Diamond Mine (the Mine) on the aquatic environment of Lac de Gras. The main objective of the AEMP is to assess Mine-related effects to the aquatic ecosystem of Lac de Gras in a scientifically defensible and cost-effective manner, over space and time. Mine water discharge represents the principal stressor of potential concern to Lac de Gras. Therefore, the Mine water discharge, and its potential impact on aquatic resources, is the focus of the AEMP. However, the AEMP monitors effects resulting from all Mine-related pathways leading to potential effects, including dust deposition.

The AEMP assesses ecological risks, so that appropriate actions can be taken in the Mine operations to mitigate potential adverse effects. The technical components of the AEMP include dust, effluent and water quality, lake productivity (i.e., eutrophication indicators), sediment quality, planktonic and benthic invertebrate communities, fish health and tissue chemistry, and the use of fisheries resources in Lac de Gras (i.e., Traditional Knowledge [TK]). During comprehensive years, all components of the AEMP are active. During interim years, only effluent and water quality, eutrophication indicators, and plankton components are active. An integration of data collected under these components (with the exception of TK) is compiled and interpreted by the Weight-of-Evidence (WOE) component during comprehensive years, and is also included herein as part of the AEMP re-evaluation process.

2.2 Summary of *AEMP Study Design Version 3.5*

2.2.1 Background

This section provides a brief summary of the *AEMP Study Design Version 3.5* to provide context for the data presented herein. It provides a description of the sampling schedule and locations, and a tabular summary of the AEMP study design (Table 2-1) for the period of monitoring from 2012 to 2016, under AEMP Study Design Versions 3.0 to 3.5.

An in-depth description of the rationale, background information and design of the AEMP is provided in the *AEMP Study Design Version 3.5* (Golder 2014a). Program changes from Version 2.0 to Version 3.5 are:

- development of an AEMP Response Framework, which includes Action Levels
- discontinuation of redundant sampling stations, and adding new of stations to better define the gradient along the longest transect sampled in Lac de Gras
- addition of three new stations in Lac du Sauvage
- modifications to the sampling schedule to sampling once during each of the ice-cover and open-water seasons

Refinements to the data analysis approach as a result of far-field study areas being exposed to effluent (and the creation of the *AEMP Reference Conditions Report Version 1.2* [Golder 2017b]) occurred subsequent to implementing the *AEMP Study Design Version 3.5* (Golder 2014a), and are considered herein where appropriate.

2.2.2 Sampling Areas and Stations

The locations and names of sampling areas and stations for the AEMP have changed since the baseline period, and over the various versions of the AEMP (Figures 2-1 to 2-5). A significant expansion of the sampling program occurred during the AEMP Version 2.0. Sampling areas were initially located according to effluent concentrations, which were estimated by plume delineation studies (DDMI 2007). Three types of sampling areas were defined, according to their level of exposure to effluent. The near-field (NF) area is located in the area near the discharge where plume delineation studies estimated effluent concentration to be approximately 1% or greater during the ice-cover season. Three mid-field (MF) areas are located outside of the 1% effluent zone, each representing a relatively wide range of effluent exposure. The MF areas extend in three different directions from the NF area, towards the far-field (FF) areas. Three FF areas are sampled to represent the general variability that could be expected in such a large lake. These areas were generally as far removed from effluent exposure as possible, and were originally intended to document background conditions.

The original sampling design allowed statistical comparisons of chemistry and biological variables between the NF and FF areas, according to a control-impact design. In addition, it also allowed gradient analysis of spatial trends along the three MF areas, which represent parts of transects along the Mine effluent exposure gradient between the NF area and corresponding FF areas. The three transects are the NF-MF1-FF1 transect, the NF-MF2-FF2 transect, and the NF-MF3-FFB-FFA transect.

The sampling locations for the AEMP Version 3.5 were generally the same as those sampled under AEMP Version 2.0, with minor modifications to better delineate the extent of the effects. Redundant stations were discontinued and some stations were re-allocated to better define the gradient along the longest exposure transect. A number of the stations along the NF-MF1-FF1 and NF-MF2-FF2 transects were discontinued, and sampling effort was re-allocated along the NF-MF3-FFB-FFA transect. In addition, three new stations were added in Lac du Sauvage to better characterize conditions at the inflow to Lac de Gras. Water from Lac du Sauvage enters the northeast portion of Lac de Gras (Figure 2-5). This “more productive” water (due to greater nutrient concentrations) has the potential to affect the FF2 area; therefore, it was important to evaluate whether changes occurring in the FF2 area were due to exposure to Mine effluent, or the quality of water entering Lac de Gras. Water quality, chlorophyll *a* and plankton were sampled at the three stations in Lac du Sauvage. Finally, water quality, nutrients and chlorophyll *a* were also sampled in the Coppermine River at the outlet from Lac de Gras (Station LDG-48, Figure 2-5) using the same methods since 2000.

Based on similar effects on water quality, plankton, and benthos observed in 2013 and before, the MF2 stations and the remaining two FF2 area stations were combined to an MF2-FF2 area which was considered to be a single MF area. The study design incorporates five replicate stations within each of the NF and FF1, FFA and FFB areas, and varying number of stations in each of the three MF areas, which do not serve as replicates.

During the period of 2014 to 2016, the areas sampled were those described above for the AEMP Version 3.5 (as listed below), and consist of 34 stations in Lac de Gras, three stations in Lac du Sauvage, and one station at the outlet of Lac de Gras (Figure 2-5):

- NF area (5 stations)
- MF1 area (3 stations)
- MF2-FF2 area (4 stations)
- MF3 area (7 stations)
- FF1 area (5 stations)
- FFA area (5 stations)
- FFB area (5 stations)
- Lac du Sauvage (3 stations)
- LDG-48 (1 station)

The AEMP sample stations in Lac de Gras are located where water depths are approximately 20 m, based on the necessity to sample benthic invertebrates at a consistent depth.

2.2.3 Sampling Schedule

During the four years of monitoring under the AEMP Version 2.0, water quality and plankton were sampled monthly during the open-water season, with an additional ice-cover sampling event for water quality. The ice-cover season was found to be the most sensitive time of year to assess effects on water quality. The variability among the three open-water seasons for all areas of the lake was, for most variables, very small relative to that seen between the ice-cover and open-water seasons, or between NF and FF areas. Moreover, effects were typically consistent across all three open-water sampling events. Given these results, only one open-water sampling event (in addition to the ice-cover season) was completed during the AEMP Version 3.0 (Table 2-1), with timing of sampling between August 15 and September 15.

The AEMP Version 2.0 demonstrated that the intensity of observed effects had reached a plateau and, for chlorophyll *a* and total nitrogen (TN) in particular, the extent of some effects was expanding. As a result, variables used as indicators of eutrophication, including plankton, continued to be sampled on an annual basis under AEMP Version 3.0 (Table 2-1). Water quality monitoring continued at a monthly frequency at the mixing zone boundary and at an annual frequency at all NF and MF stations to retain the ability to detect early warning effects or any unexpected changes in water quality. Sediment (with the exception of annual SNP sampling at the mixing zone boundary), benthic invertebrates and small-bodied fish were monitored at a frequency of once every three years at all stations. A large-bodied fish survey, if required, would be undertaken every six years.

Table 2-1 Overview of the 2014 to 2016 AEMP

Component	Frequency per Year and Timing	Sampling Depth	Sample Type	Number of Samples per Station	Number of Stations[(a)]	Frequency
Snow Monitoring (Dust Deposition)	once: 1 ice-cover	(not applicable)	composite of required number of cores for analysis	1	control (3) transects (19)	annual
Dust Gauge Monitoring (Dust Deposition)	3 per year: Mar, Aug, Dec	(not applicable)	discrete	1	control (2) xposure (8)	annual
Water Quality – Mixing Zone Boundary[(c)]	monthly	2-m intervals (5 depths)	discrete	5	SNP 19A, B2, C	annual
Water Quality – Field Measured Parameters	twice: 1 open-water 1 ice-cover	2-m intervals	profile	Profile	NF (5) MF (12) FF (17) LDS (3) LDG-48	annually at NF, MF and LDG-48 once every 3 years at all stations
Water Quality – Conventional, Metals, Nutrients[(f)]	twice: 1 open-water 1 ice-cover	NF and MF: 3 depths (2 m from surface, mid-depth, 2 m from bottom) FF/Ref: 1 depth (mid-depth)	discrete	NF and MF: 3 FF: 1	NF (5) MF (12) FF (17) LDS (3) LDG-48	annually at NF, MF and LDG-48 once every 3 years at all stations
Eutrophication Indicators – Total Nitrogen, Total Phosphorus and Chlorophyll *a*	twice: 1 open-water 1 ice-cover[(b)]	top 10 m	open-water: depth-integrated ice-cover: discrete	2 chlorophyll *a* 2 nutrients	NF (5) MF (12) FF (17) LDS (3) LDG-48	annually at NF, MF and LDG-48 once every 3 years at all stations
Sediment Quality – Mixing Zone Boundary[(c)]	once: 1 open-water	top 1 cm (core)	composite of (minimum) 3 cores	5	SNP 19A, B2, C	annual
Sediment Quality	once: 1 open-water	top 10-15 cm (full Ekman grab) for TOC and particle size top 1 cm (core) for chemistry	composite of (minimum) 3 grabs composite of (minimum) 3 cores	1 of each type	NF (5) MF (12) FF (17)	once every 3 years
Phytoplankton	once: 1 open-water	10 m	depth-integrated	1 taxonomy	NF (5) MF (12) FF (17) LDS (3)	annually at NF once every 3 years at all stations
Zooplankton	once: 1 open-water	full water column	depth-integrated composite of 3 tows	2 taxonomy 2 biomass	NF (5) MF (12) FF (17) LDS (3)	annually at NF once every 3 years at all stations
Benthic Invertebrates	once: 1 open-water	18 to 22 m	composite of 6 grabs	1	NF (5) MF (12) FF (17)	once every 3 years
Large-bodied Fish -Fish Palatability and -Fish Tissue Chemistry	once: 1 open-water	(not applicable)	individual fish, muscle and organs	10 fish	Lac de Gras	once every 3 years
Large-bodied Fish - Fish Tissue Mercury	once: 1 open-water	(not applicable)	non-lethal muscle plugs	30 fish per lake, 2 plugs per fish	Lac de Gras and Lac du Sauvage	once every 3 years
Small-bodied Fish - Fish Tissue Chemistry	once: 1 open-water	(not applicable)	composite by size; whole body, excluding stomach, otoliths, and gonad	Min of 8	NF (1) MF (2) FF (2)	once every 3 years
Small-bodied Fish - Fish Health	once: 1 open-water	(not applicable)	lethal survey	30 adult male 30 adult female 30 juvenile	NF (1) MF (2) FF (2)	once every 3 years
			non-lethal survey	additional 50 fish		

a) Refer to Figure 2-5 for sampling locations.
b) Sampling for chlorophyll *a* is not required during the ice-cover season
c) Water and sediment quality sampling at the mixing zone boundary are not part of the AEMP, but the data generated area analyzed along with AEMP data.
NF = near-field; MF = mid-field; FF = far-field; LDS = Lac de Sauvage; SNP = Surveillance Network Program; TOC = total organic carbon; min = minimum.

2.3 Determining Effects

An "effect" is a change that follows an event or cause. An effect is not inherently negative or positive. A linkage must be established between a measured change and a cause (e.g., mining activity) for the change to be deemed an effect. The DDMI AEMP is designed to detect changes in Lac de Gras. Changes are not considered "effects" until a link to the Mine has been established. Throughout the AEMP, Mine-related effects have been evaluated in AEMP annual reports using statistical tests, multivariate analysis, and qualitative, visual evaluation. Detailed data analysis methods are provided in annual reports.

Magnitudes of effects were evaluated by comparing variables at sampling areas to background values or benchmark values. Background values for Lac de Gras are those that fall within the range of natural variability, referred to as the normal range. The normal ranges used to assess effects of the Mine on individual components of the AEMP are described in the *AEMP Reference Conditions Report Version 1.2* (Golder 2017b). Values that exceed the normal range are above what would be considered natural levels for Lac de Gras, but do not necessarily represent levels that are harmful.

During the Project EA, the ecological tolerance of changes in Lac de Gras were evaluated based on benchmark concentrations (termed ecological thresholds in the EA) for chemistry variables. These benchmarks were defined as concentrations at which a specific use could begin to be affected, and were generally based on published guidelines, such as the Canadian Water Quality Guidelines (CWQGs) (CCME 1999a). The EA benchmarks have been carried through to the AEMP, and are referred to as Effects Benchmarks herein. Several of the CWQGs upon which EA benchmarks were based have changed over the years, and some of the guidelines (e.g., aluminum and cadmium) have been adapted to the specific conditions of Lac de Gras (Golder 2014b); accordingly, the Effects Benchmarks have been updated over time. The Effects Benchmarks represent values that are protective of aquatic life and are intended to be conservative. They represent a level which, if exceeded, could cause adverse effects, not a level which, if exceeded, would cause adverse effects.

The severity of effects was also categorized according to Action Levels, as part of the AEMP Response Framework. The Action Level classifications were developed to meet the goals of the draft *Guidelines for Adaptive Management – A Response Framework for Aquatic Effects Monitoring* (WLWB 2010; Racher et al. 2011), and are described for each component in the corresponding section in this report. The goal of the Response Framework is to ensure that significant adverse effects the environment never occur. This is accomplished by requiring proponents to take actions at defined Action Levels, which are triggered well before significant adverse effects could occur. A level of change that, if exceeded, would result in a significant adverse effect is termed a Significance Threshold.

The AEMP addresses two impact hypotheses for Lac de Gras under the WOE: a toxicological impairment hypothesis and a nutrient enrichment hypothesis. Toxicological impairment involves toxicity to aquatic organisms as the hypothetical response to substances released from the Mine (e.g., metals [1] in the effluent). Nutrient enrichment relates to increased primary productivity in response to inputs of nutrients as a result of mining activities (e.g., phosphorus and nitrogen). The WOE assessment is the process used to evaluate the strength of evidence for toxicological impairment and/or nutrient enrichment, and is also used to

[1] The term "metals" includes metalloids such as arsenic, and non-metals such as selenium.

establish a link between observed effects and the Mine. Both the evidence for the type of effect and for a link to the Mine must be strong for an effect to be deemed Mine-related.

2.4 Data Analysis for the Re-evaluation

2.4.1 Approach

The aquatic effects re-evaluation does not require additional analysis of Mine-related effects; rather, the effects documented by previous monitoring and data analysis are summarized and evaluated over time. Therefore, the main objective of data analysis during an aquatic effects re-evaluation is to summarize AEMP data collected to date in an accessible format and evaluate temporal trends. This is achieved through compiling datasets from baseline to the latest year included in the analysis, preparing data summary tables and figures, and analyzing the data for selected variables for temporal trends using statistical methods.

Data analysis methods unique to each AEMP component are provided in the respective sections in this document. Each component except dust and fish present results of statistical trend analysis of selected variables for each area or station with an available long-term data set. Trend analysis methods common to those components are provided in the next section.

2.4.2 Trend Analysis Methods

Linear mixed models were used to analyze spatial and temporal trends in the water quality, eutrophication, sediment quality, benthic invertebrate, and plankton component data. Data analysis methods for the dust component are presented in Section 3, and methods for the fish component are presented in Section 9.

Temporal trend analysis focused on areas and stations with available long-term data: NF, FFB, FFA, and FF1 areas, and FF2-2, MF1-3, MF3-4 stations. The model included both stations and areas, because in the case of NF and the three FF areas, the stations within the areas were subject to similar levels of exposure to the effluent. In contrast, stations within the MF areas were subject to varying levels of exposure to effluent, which necessitated the inclusion of individual stations (i.e., FF2-2, MF1-3, MF3-4) in the analysis. Mixed models were comprised of two constituents: fixed variables (i.e., time and area/station) and random variables (i.e., station within area [applicable for NF and FF areas]). The use of random variables allowed for the variability in different data components to be correctly assigned (i.e., to stations within areas, instead of to areas). Analyses were performed using the statistical environment R v. 3.4.2 (R Core Team 2017) and package nlme (Pinheiro et al. 2017).

The linear mixed model analysis proceeded as follows (additional details are provided in Sections 2.4.2.1 to 2.4.2.7):

1) Data transformations were applied, when necessary, to normalize residuals, as required by model assumptions.
2) The data were used to fit a set of candidate models and the best-supported model was selected.
3) Outliers were removed when necessary; if outliers were removed, steps 1 and 2 were repeated.

4) Heteroscedasticity (i.e., inequality of variance in errors or residuals) was examined, and if there was heteroscedasticity after data transformation and outlier removal, heteroscedasticity terms were added to the best-supported model.

5) Autocorrelation was examined, and if there were signs of autocorrelation between residuals, an autocorrelation term was added to the model.

6) The final model was examined for normality and heteroscedasticity of residuals (i.e., normality of the distribution of errors and equality of variance across fitted values, sampling stations/areas, and years).

7) The final models, which met assumptions of normality and homoscedasticity, and fit the observed data, were used to predict annual values at each station/area, and the results were used to interpret temporal and spatial trends.

2.4.2.1 Data Transformation

For each response variable, the data were transformed as follows:

- Relative data (0-1 or 0-100% data range) were logit transformed to create a continuous, unbounded dataset.
- All other data were transformed using Yeo-Johnson transformations (Yeo and Johnson 2000), which can be viewed as an extension of Box-Cox power transformations (Box and Cox 1964). The Box-Cox transformations are a family of transformations that include the commonly used log and square root transformations. The Box-Cox transformation process tests a series of power values, usually between -2 and +2, and records the log-likelihood of the relationship between the response and the predictor variables under each transformation. The transformation that maximizes the log-likelihood is the one that will best normalize the data. Therefore, the data are transformed using a power value identified by the transformation process. For a power value of zero, the data are natural log transformed. The Yeo-Johnson extension, which uses an offset for data with zero values, was better suited for use with environmental data than the original Box-Cox transformations, which cannot log-transform zero values. The full specification of the Yeo-Johnson transformations was as follows:

$$\text{Transformed value} = \frac{(\text{value} + 1)^{\lambda} - 1}{\lambda} \text{ if } \lambda \neq 0, \text{value} \geq 0$$

$$\text{Transformed value} = \ln(\text{value} + 1) \text{ if } \lambda = 0, \text{value} \geq 0$$

$$\text{Transformed value} = \frac{-[(-\text{value} + 1)^{2-\lambda} - 1]}{2 - \lambda} \text{ if } \lambda \neq 2, \text{value} < 0$$

$$\text{Transformed value} = -\ln(-\text{value} + 1) \text{ if } \lambda = 2, \text{value} < 0$$

2.4.2.2 Model Selection

For each response variable, two candidate models with different predictor variables were constructed:

1. a multiplicative model with an interaction between station/area and a parabola effect of year
2. a multiplicative model with an interaction between station/area and linear effect of year

The year effect in model 1 was modelled as a parabola (i.e., a second-order polynomial) to fit data where the trends reversed partway through the time series. Model 2 contained the same overall model structure as model 1, but it represented temporal effects as a linear effect, to best fit data that have a linear relationship with time. Once both models were fit, Akaike's information criterion (AIC) was used for model selection. The model with the lower AIC score was interpreted to have the strongest support, given the set of examined models and the collected data (Burnham and Anderson 2002), and thus was selected for interpretation. Models with AIC scores within 2 units of each other were considered to have similar levels of support; in those cases, the simpler model (model 2 – linear) was selected for interpretation (Arnold 2010). To allow AIC comparisons between models with different fixed effects, the models were fitted using maximum likelihood methods.

2.4.2.3 Identification of Outliers

Outliers were identified using quantile-quantile (QQ) plots, plots of model residuals vs. year, station/area, predicted values, and a standardized residual cut-off (i.e., more than 3.5 standard deviations [SD] from the mean were flagged as outliers). In a few cases, residuals that were not flagged as outliers were removed if inspection of plots identified points that had high leverage and could, therefore, strongly influence the overall fit of the model.

If outliers were identified, they were removed from subsequent analyses, but were retained for plots of model predictions, where they were shown using a different symbol from the rest of the data. The process of data transformation and model selection was repeated following outlier removal.

2.4.2.4 Residual Heteroscedasticity

Once outliers were removed and the final model was selected, the model was re-fitted using restricted maximum likelihood (REML) for an unbiased estimate of the random effects, and the residuals of the final model were examined for heteroscedasticity patterns. Three models were constructed to assess the effect of heteroscedasticity for each variable:

1) heteroscedasticity by area (i.e., data variability was allowed to differ among NF, MF, and FF)
2) heteroscedasticity by predicted value (accounting for the classic trumpet shape of heteroscedastic data)
3) heteroscedasticity by area and predicted value, combining the heteroscedasticity effects above, and allowing for heteroscedasticity within area type and among areas

Heteroscedasticity was modelled by area (i.e., NF, MF, FF) rather than by sampling station due to convergence difficulties with the latter. These three models were compared to the original model that did not account for heteroscedasticity, using AIC. The model with the lowest AIC score was chosen for subsequent analysis, unless a simpler model had an AIC score within 2 AIC units.

2.4.2.5 Autocorrelation

Autocorrelation effects are generally expected when performing trend analysis, since temporal data are frequently not independent. The failure to account for autocorrelation may influence the significance of results due to incorrect accounting for variability. To assess and reduce autocorrelation, partial autocorrelation plots were generated, and a simple first order autocorrelation term was added to the model, if the addition decreased the AIC score of the model by 2 units or more.

2.4.2.6 Final Model Examination

The final model was examined for residual normality and heteroscedasticity. Normality was assessed visually using normal QQ plots relative to a series of 29 QQ plots generated from a normal distribution with the same sample size and SD of the residuals. This approach was taken, because residuals need only be approximately normal for regression analysis, especially when sample sizes are large, and pre-testing for residual normality may increase the Type I error of the tests (e.g., Schucany and Ng 2006; Rasch et al. 2011; Rochon et al. 2012). Models that met assumptions of residual normality and homoscedasticity were used to interpret spatial and temporal trends in the study area.

2.4.2.7 Predictions

The models were used to output a summary of the significance of year, station/area, and their interaction. In addition, for linear temporal trends, the statistical significance of each station/area's slope being different from zero was assessed. For parabolic trends, multiple comparisons between stations/areas were performed for 2010, 2013, and 2016 data, to provide information on differences among stations/areas in years of comprehensive AEMP data collection. The *P*-values of multiple comparisons were adjusted using a Tukey adjustment (Tukey 1977). The models were also used to provide mean yearly predictions and 95% confidence intervals for each station/area. The confidence intervals, however, only accounted for uncertainty associated with the fixed effects (i.e., time and area), not random effects (i.e., stations within areas). The spatial and temporal trends were interpreted based on the (1) structure and significance of fixed effects, (2) plots of predicted means and 95% confidence intervals (shown as grey ribbons on the plots), and (3) station/area-specific information on slopes or year-specific information on differences among stations/areas.

3 DUST DEPOSITION

3.1 Introduction

3.1.1 Background

DDMI has been conducting studies and monitoring programs relating to the aquatic ecosystem of Lac de Gras since 1994, with AEMP data collected under AEMP study designs Version 1.0 (2001[2] to 2006), Version 2.0 (2007 to 2011), Version 3.0 (2012 to 2016), and most recently under Version 4.0 (2017). Since there is potential for Mine emissions to affect Lac de Gras, the dust deposition monitoring program has been included as a component of the AEMP since 2001, and is completed every year (i.e., in both comprehensive and interim years). The objective of the dust deposition monitoring program is to monitor the levels of dustfall in the area surrounding the Mine and verify the predictions set forth in the EA (DDMI 1998a). More specifically, the program has been designed and implemented to evaluate:

- total particulate deposition rates at various distances from the Mine and to compare the observed deposition rates to predictions outlined by DDMI (1998a); and
- the physical and chemical characteristics of particulate material that may be deposited into Lac de Gras from mining activities.

3.1.2 Component History

Dust deposition monitoring has been conducted since 2001. The design and sampling locations of the current program under the AEMP Version 3.5 (Figure 3-1) are essentially the same as the monitoring programs completed to date; however, some modifications to the program have been made over the years, and are summarized below.

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

2002 In response to recommendations made by the WLWB, DDMI amended the dust monitoring program to include two snow survey reference locations (referred to as "control"). In addition, five dust gauges (i.e., passive dust collectors) were deployed, one along each of the snow survey transects and one at a control location.

2003 In response to further recommendations from the WLWB, all four snow survey transects were extended in length to a distance of approximately 2,000 m from the Mine footprint. An additional five dust gauges, including a second control, were deployed.

[2] One year of baseline data was also collected in 2000 under Version 1.

2004 Increased construction activity necessitated further changes to the dust monitoring program. One dust gauge (Dust 02) was removed from its location to accommodate Mine footprint expansion, and was subsequently relocated and redeployed (Dust 2A).

2005 Dust deposition monitoring was carried out with no modifications to either the snow survey or the dust gauge portion of the program.

2006 An additional dustfall gauge was deployed, bringing the total to 11 (including two controls). Testing of Mini-Vol portable air samplers were conducted to determine feasibility of incorporation into the dust monitoring program. Preliminary findings proved the inclusion of the Mini-Vol samplers would be impractical.

2007 The snow survey portion of the program was amended with an additional snow survey transect being incorporated, bringing the total number of transects to five. As well, snow-water chemistry samples were collected adjacent to the pre-existing control locations as background references. Two additional dust gauges (temporary) were deployed adjacent to two pre-existing dust gauges. The intent of the temporary gauges was to compare results from the same location when sample collection frequency is altered.

2008 All of the dust gauges were modified to accommodate the replacement of the polyacrylic dust gauge inserts with brass Nipher gauge inserts in order to minimize loss associated with damage during the collection and handling of the dust gauges. An additional dust gauge was added to the program bringing the total to twelve permanently deployed (including two control) and two temporary dust gauges.

Three snow survey sample points (SS3-1, SS3-2 and SS3-3) were not sampled as they had become overtaken by construction activity and expansion of the Mine footprint; therefore, Transect 3 consisted of two stations and a control station, with Station SS3-4 being the NF station.

2009 The two temporary dust gauges deployed in 2007 were decommissioned. All twelve permanent gauges were collected quarterly. As a result of an error in collection/deployment, data were not collected at Station Dust 03 between 11 July and 9 September 2009. In addition, an error with the collection and analysis of the dust deposition sample at Station SS2-1 resulted in the sample being compromised; consequently, dust deposition data were not available for this location. The snow survey sampling was conducted in April for this year.

2010 All twelve permanent dust gauges were collected quarterly during 2010. Snow survey sampling was conducted throughout the month of April. An error in the collection or processing of samples resulted in missing data for two stations for the snow-water chemical analysis. The sample from Station SS2-1 was compromised during processing in the lab, and the data collection at Station SS5-2 was missed in the field.

2011 All twelve permanent dust gauges were collected quarterly during 2011. There were no data for station Dust 5 in September due to a compromised sample following repairs to the sampler. Snow survey sampling was conducted throughout the month of April; however, samples for stations SS1-4, SS1-5, SS2-1, SS2-2, SS2-3, SS2-4 and SSC-3 arrived at the Maxxam laboratory past the recommended holding time.

2012 All twelve permanent dust gauges were collected quarterly during 2012. A sample was not collected from Station Dust 9 in June as the sampler was found on its side. Snow survey sampling was conducted on 30 April and on 4 and 5 May 2012.

2013 All twelve permanent dust gauges were collected quarterly during 2013. Snow survey sampling was conducted from 26 to 29 April 2013.

2014 Three stations were added to snow sampling Transect 3 to replace those lost due to expansion of the Mine footprint in 2008. Two of the new stations (SS3-6 and SS3-7) are located between SS3-4 and the Mine footprint, and the third (SS3-8) is located between SS3-4 and SS-3-5.

2015 All twelve permanent dust gauges were collected quarterly during 2015. Snow survey sampling was conducted for 27 stations in 2015. There was an error for snow sampling station SS3-6; samples were taken 30 m closer to the mine site than planned. This does not affect the interpretation of these data.

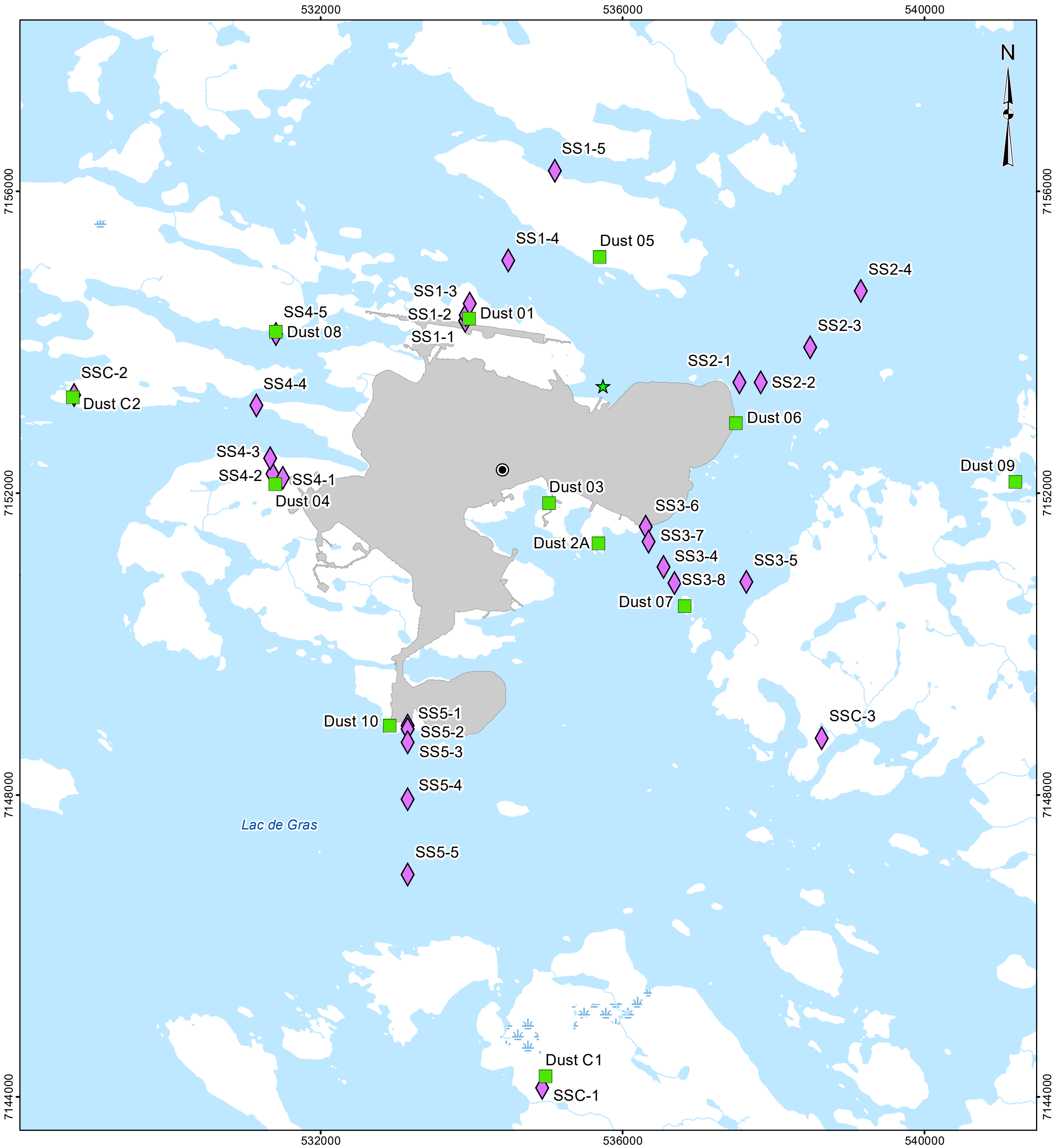
2016 There were no modifications to the dust gauges sampling program in 2016. There was an error for snow sampling station SS3-6; samples were taken 30 m closer to the mine site than planned. This does not affect the interpretation of these data.

3.1.3 Goals of the AEMP Re-Evaluation for Dust

The objectives of the 2014 to 2016 AEMP re-evaluation, with respect to dust, nutrient and metals deposition include the following:

- to estimate the background rate of dust and snow nutrients and metals deposition
- to investigate seasonal or annual temporal trends in the rates of dust deposition
- to determine the spatial trends in the rates of dust, nutrients, and metals deposition over time
- to estimate environmental (mass) loadings of dust, nutrients and metals to Lac de Gras and the Lac de Gras watershed

The following sections discuss the methods used to perform these analysis, the results of the analysis, a comparison to EA predictions and a summary of the 2014 to 2016 AEMP re-evaluation results for dust.



LEGEND

- DIFFUSERS
- DIAVIK FOOTPRINT CENTROID
- DUSTFALL GAUGE LOCATION
- SNOW SURVEY LOCATION
- WATERCOURSE
- DIAVIK FOOTPRINT (CURRENT TO 2016)
- WATERBODY

1.5 0 1.5

SCALE 1:75,000 KILOMETRES

PROJECT

DIAVIK DIAMOND MINES INC.

TITLE

DUSTFALL GAUGE AND SNOW SURVEY LOCATIONS

REFERENCE

PROJECTION: UTM ZONE 12 DATUM: NAD 83

GOLDER

PROJECT		1771843.4000	FILE No.	
DESIGN	TD	26 Apr. 2016	SCALE AS SHOWN	REV. 0
GIS	VV	14 Mar. 2018	FIGURE: 3-1	
CHECK	RS	14 Mar. 2018		
REVIEW	ZK	14 Mar. 2018		

I:\CLIENTS\DIAVIK\1771843\Mapping\MXD\Aquatics\2017AEMP_ReEvaluation_Report\Fig3-1_Dustfall and Snow Survey Locations_Rev0.mxd Date: 2018-03-14 9:50:27 AM

3.2 Methods

Analysis was undertaken to evaluate temporal or spatial trends in dust deposition rates, deposition of dust-borne nutrients (i.e., total phosphorus [TP], orthophosphate [OP], nitrate plus nitrite [N+N], and ammonia), and deposition of two dust-borne metals indicative of metal deposition in general (i.e., aluminum and lead). The natural and anthropogenic contributions of dustfall loadings and nutrient loadings to Lac de Gras and its watershed were also derived from the spatial and temporal analysis of dustfall and snow chemistry. The analysis was completed in Matlab, Version R2014a and ArcGIS, Version 10.4.1.

3.2.1 Data Sources

Three dust-related measurements related to the AEMP are collected at the Mine to assess potential impacts to the environment:

- seasonal (i.e., quarterly) dustfall gauge measurements of dust deposition rates (“dustfall gauge”) measured at 10 exposure stations and at two background stations (controls)
- annual snow survey measurements of dust deposition rates to the snowpack (“snowdust”) at 24 stations along five transects and at three control stations
- annual snow water chemistry analysis (“snow chemistry”) on samples collected at the 17 stations located on ice plus the three controls

Dustfall gauge, snowdust, and snow chemistry data for years 2002 through 2016 were obtained from DDMI. A summary of AEMP data collected up to 2016 is provided in Table 3-1.

Table 3-1 Summary of AEMP Data Collected (up to and including 2016)

Sample Type	Station Name	UTM Coordinates		Distance from, m		Years Samples															
		Easting, m	Northing, m	Mine Centre	Mine Boundary	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Dustfall	Dust 01	533964	7154321	2051	75		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Dust 2A	535678	7151339	1606	435		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Dust 03	535024	7151872	763	30		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Dust 04	531397	7152127	3014	200		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Dust 05	535696	7155138	3101	1195		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Dust 06	537502	7152934	3157	25			X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Dust 07	536819	7150510	3016	1155			X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Dust 08	531401	7154146	3517	1220			X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Dust 09	541204	7152154	6801	3810						X	X	X	X	X	X	X	X	X	X	X
	Dust 10	532908	7148924	3710	46								X	X	X	X	X	X	X	X	X
	Dust C1	534979	7144270	8068	4700			X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Dust C2	528714	7153276	5771	3075			X	X	X	X	X	X	X	X	X	X	X	X	X	X
Snow Sample	SS1-1	533911	7154288	2031	30	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
	SS1-2	533916	7154365	2105	115	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
	SS1-3	533969	7154518	2243	275	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
	SS1-4	534485	7155094	2777	920	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C
	SS1-5	535097	7156281	4023	2180	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C
	SS2-1	537548	7153471	3348	180	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C		D	D,C	D,C	D,C	D,C	D,C	D,C
	SS2-2	537826	7153473	3611	445	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C
	SS2-3	538484	7153939	4389	1220	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C
	SS2-4	539156	7154685	5308	2180	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C
	SS3-1	535867	7151922	1515	25	D	D	D	D	D	D										
	SS3-2	535994	7151844	1658	75	D	D	D	D	D	D										
	SS3-3	536276	7151684	1975	250	D	D	D	D	D	D										
	SS3-4	536541	7151024	2497	615	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C
	SS3-5	537641	7150828	3562	1325	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C
	SS3-6	536305	7151564	2044	60														D,C	D,C	D,C
	SS3-7	536344	7151366	2160	250														D,C	D,C	D,C
	SS3-8	536688	7150810	2736	830														D,C	D,C	D,C
	SS4-1	531491	7152211	2916	100	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C
	SS4-2	531358	7152259	3048	245	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C
	SS4-3	531329	7152466	3080	350	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C
	SS4-4	531141	7153167	3373	1065	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C
	SS4-5	531405	7154116	3498	1220	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C
	SS5-1	533150	7148925	3618	45							D	D	D	D	D	D	D	D	D	D
	SS5-2	533150	7148875	3665	95							D	D	D	D	D	D	D	D	D	D
	SS5-3	533150	7148700	3830	270							D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C
	SS5-4	533146	7147949	4547	1021							D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C
	SS5-5	533150	7146950	5513	2020							D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C
	SSC-1	534929	7144118	8217	4852	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C
	SSC-2	528722	7153308	5769	3075		D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C
	SSC-3	538639	7148758	5532	3570		D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C	D,C

a) Current AEMP station names are presented.

X: dustfall sample collected; D: dust deposition analyzed from snow sample; C: snow chemistry analyzed from snow sample; Blanks indicate no sampling.

3.2.2 Data Handling

The dustfall gauge, snowdust, and snow chemistry data were compiled into individual data tables that included data from all available years for all stations. A general assessment of QA/QC was conducted to check for errors and general inconsistencies.

Snow water concentrations of some nutrients and metals were below the analytical DL. These data were included in the analysis by substituting values of half of the detection limit (DL) during the re-evaluation. However, in the snow chemistry data, there were different DLs from different testing laboratories and for different years. For example, three DLs were reported for the TP data (0.001 mg/L, 0.005 mg/L and 0.002 mg/L). Data with variable DLs were excluded from the analysis as per Table 3-2. The percentage of below DL data ranged from 1.6% for aluminum to 27.0% for OP.

Table 3-2 Summary of Below Detection Limit Data

Variables	Number of samples	Number of below detection limit data	Percentage of below detection limit data,%
total phosphorus	156	23	14.7
orthophosphate	156	42	27.0
nitrate + nitrite	156	9	5.8
ammonia	156	5	3.7
aluminum	192	3	1.6
lead	192	10	5.2

Potential outliers in the dust deposition data and the snow chemistry data were screened by evaluating standardized Z-scores. An observation's Z-score is defined as the number of SDs the observed value is from the mean. The formula for Z-score is:

$$z = (x - \mu)/\sigma$$

in which: x is the value of the datum; μ is the mean of the population; and σ is the SD of the population. If the absolute value of the Z-score is greater than 3, the datum is considered an outlier to the population and is excluded from the analysis. The Z-score screening was conducted to identify the outliers for the following data:

- pooled annual dust deposition data for control stations
- annual dust deposition data for individual non-control stations
- pooled snow chemistry data for control stations
- snow chemistry data for individual non-control stations

A summary of outliers identified using the Z-score is presented in Table 3-3.

Table 3-3 Summary of Dustfall and Snowdust Deposition Outliers

Stations	Number of samples	Number of outliers	Percentage of outliers,%	Annual dust deposition (mg/dm^2/yr) and year
Dust 05	15	1	6.7	1433 (2004)
Control Dust gauge (Dust C1 and Dust C2)	28	1	3.6	549 (2007)
SS1-1	15	1	6.7	6643 (2005)
SS1-3	15	1	6.7	4851 (2012)
SS2-2	15	1	6.7	652 (2005)
SS4-1	15	1	6.7	1151 (2005)
Control snowdust (SSC-1, SSC-2, and SSC-3)	45	2	4.4	526 (2007) at SSC-1 461 (2004) at SSC-3

Snow chemistry sample duplicates for ammonia, N+N, TP, OP, total aluminum, and total lead are summarized in Table 3-4. There were 96 duplicates total, excluding those with data below DLs. Among the duplicates, there were 39 duplicates with relative percent differences larger than 20%. There were only two duplicates with relative percent differences greater than 80%. Following removal of data below DLs and outliers, duplicates were averaged to obtain a representative value.

Table 3-4 Summary of Snow Chemistry Sample Duplicates.

Year	Station	Ammonia		Nitrate plus Nitrite		Total Phosphorus		Orthophosphate		Total Aluminum		Total Lead	
		Deposition, mg/dm²/yr	RPD	Deposition, mg/dm²/yr	RPD	Deposition, mg/dm2/yr	RPD	Deposition, mg/dm²/yr	RPD	Deposition, mg/dm²/yr	RPD	Deposition, mg/dm2/yr	RPD
2011	SS1-4	0.079	29.71	0.118	37.66	n/a	n/a	n/a	n/a	0.373	12.42	0.001	0.58
2011	SS1-4	0.106		0.173		n/a		n/a		0.329		0.001	
2015	SS1-5	0.216	25.33	0.308	57.21	0.074	40.00	0.013	19.61	0.375	32.55	0.001	24.92
2015	SS1-5	0.167		0.554		0.050		0.011		0.521		0.001	
2013	SS2-2	0.054	8.20	0.120	5.43	0.046	40.37	0.007	34.82	0.316	27.40	0.000	18.86
2013	SS2-2	0.049		0.127		0.031		0.011		0.240		0.000	
2015	SS2-2	0.261	18.60	0.286	3.67	0.094	5.13	0.014	6.90	2.006	45.49	0.003	39.51
2015	SS2-2	0.315		0.297		0.089		0.015		1.262		0.002	
2012	SS2-4	0.114	39.68	0.262	27.48	0.035	30.79	0.004	33.33	0.271	57.86	0.001	27.18
2012	SS2-4	0.170		0.199		0.047		0.005		0.149		0.001	
2016	SS3-5	n/a	n/a	0.455	17.57	0.153	15.89	0.036	4.36	5.013	8.57	0.005	3.73
2016	SS3-5	n/a		0.543		0.179		0.034		5.462		0.005	
2014	SS3-7	0.291	108.36	0.268	9.91	0.118	31.03	0.014	0.44	1.341	22.21	0.002	13.35
2014	SS3-7	0.086		0.243		0.162		0.014		1.073		0.002	
2015	SS3-7	0.346	6.45	0.393	9.30	0.307	2.89	0.017	14.93	3.213	36.53	0.005	38.45
2015	SS3-7	0.369		0.431		0.299		0.014		2.220		0.003	
2014	SS4-4	0.110	52.48	0.175	4.09	0.078	1.29	0.021	1.52	0.772	3.19	0.001	1.52
2014	SS4-4	0.064		0.182		0.077		0.020		0.797		0.001	
2010	SS4-5	0.115	6.20	0.226	3.10	0.142	48.28	0.004	10.12	2.007	25.11	0.002	38.14
2010	SS4-5	0.122		0.219		0.232		0.003		2.583		0.003	
2015	SS4-5	0.223	39.86	0.182	15.29	0.065	20.88	0.017	19.93	2.025	4.81	0.002	0.16
2015	SS4-5	0.149		0.212		0.053		0.014		2.124		0.002	
2012	SS5-3	0.092	10.81	0.282	23.79	0.029	11.82	0.008	0.55	0.227	2.84	0.000	6.61
2012	SS5-3	0.083		0.358		0.033		0.008		0.233		0.000	
2010	SS5-5	0.098	12.00	0.364	1.52	0.013	55.86	n/a	n/a	0.244	38.89	0.000	9.03
2010	SS5-5	0.110		0.358		0.023		n/a		0.362		0.001	
2013	SS5-5	0.047	54.56	0.235	16.35	0.014	29.65	0.005	4.90	0.074	24.25	0.000	5.14
2013	SS5-5	0.027		0.199		0.011		0.006		0.095		0.000	
2014	SS5-5	0.121	4.67	0.250	9.00	0.034	10.91	0.017	24.26	0.333	1.75	0.001	11.90
2014	SS5-5	0.115		0.274		0.031		0.014		0.328		0.001	
2016	SS5-5	n/a	n/a	0.262	7.77	0.035	36.15	0.007	0.95	0.104	113.86	0.000	76.00
2016	SS5-5	n/a		0.242		0.024		0.007		0.377		0.00	
2011	SSC-3	0.224	11.27	0.368	0.00	0.097	7.14	n/a	n/a	1.812	7.29	0.00	8.37
2011	SSC-3	0.251		0.368		0.090		n/a		1.949		0.00	

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

n/a = not applicable; RPD = relative percent difference; mg/dm²/yr = milligram per square decimetres per year.

3.2.3 Data Analysis

3.2.3.1 Temporal Groupings

Dust deposition data and snow chemistry data were grouped into time periods to reflect changes in mining activities over time at the Mine. The time period groups were as follows:

- 2002 to 2005: open pit mine construction and open pit mining
- 2006 to 2009: underground mine construction and open pit mining
- 2010 to 2013: open pit transition to underground mining
- 2014 to 2016: underground mining with re-mining of the Waste Rock Storage Area – North Country Rock Pile

3.2.3.2 Loadings Calculations from Concentrations

Snow water chemistry data are reported as concentrations in the units of milligrams per litre of water (mg/L) or micrograms per litre of water (µg/L). Ancillary data collected with the snow cores (i.e., numbers of snow cores, volume of snow water, length of snow cores, and snow water equivalence [SWE]) enable the conVersion of concentrations in snow (mg/L) to an areal [3] deposition rate in milligrams per square decimetre per year (mg/dm^2/yr). The formula used to perform the conVersion is as follows:

$$D = \frac{C * V * 365}{N * A * T}$$

where D is areal deposition rate (mg/dm^2/yr), C is the concentration of a compound in snow water (mg/L), V is snow water volume in litres, N is the number of snow cores, A is the area of the snow core tube (0.2922 dm^2), and T is the number of exposure days.

Due to the gaps in the ancillary data prior to 2010, aerial deposition rates for nutrients and metals were only calculated for the last two temporal groups (i.e., 2010 to 2013 and 2014 to 2016).

3.2.3.3 Normal versus Log-Normally Distributed Data

Prior to analysis, dustfall gauge, snowdust and snow chemistry data were pre-screened using a Lilliefors test carried out at the 95% level of confidence (i.e., α = 0.05). The Lilliefors test is a two-sided goodness-of-fit test suitable for determining if data are normally distributed (an assumption of data used in parametric statistical testing). Data that were not normally distributed were log transformed and re-tested for normality.

Based on the screening results, the dust, nutrient, and metals deposition data were typically normally distributed when evaluating temporal trends associated with individual locations. For example, the dust

[3] Note, areal deposition is distinct from aerial deposition. Areal deposition is atmospheric deposition or deposition rate of a contaminant over a defined area. Aerial deposition is atmospheric deposition of contaminants to land, water and snow (i.e., not a defined area).

deposition rate measured quarterly at a single station were normally distributed. However, when comparing dust or nutrient deposition rates among stations during spatial analysis, the data were typically log-normally distributed, with values varying over 2 to 3 orders of magnitude between the NF and the FF (or control) stations. In these instances, geometric means and SDs are more appropriate for computing statistics and comparing results (e.g., using Student's t-tests).

3.2.3.4 Background Deposition Rates

Background rates of dust, nutrient and metals deposition are measured at two "control" dustfall gauges (Dust C1 and C2), and at three snow sampling locations (SSC-1, -2 and -3). Dust deposition rates at non-background sites were compared to deposition rates observed at the control locations using a two-tailed Student's *t*-test at the 95% confidence level.

This statistical method was used to determine which, if any, non-control dustfall gauge and snowdust locations had dust deposition rates that were significantly different from the rates observed at the control locations. Where dustfall or snowdust data were significantly different from the control values, they were presumed to have been impacted by Mine activity. Conversely, where deposition rates were not significantly different from rates observed at the control stations, dust deposition rates were presumed to be equivalent to background rates of dust deposition.

3.2.3.5 Seasonal Trends

Annual and seasonal trends in dust deposition recorded at the dustfall gauges were evaluated based on a visual inspection of the data. A time series of seasonal dustfall gauge data were plotted to visually inspect the annual trends. The seasonal dustfall gauge data were pooled for all years (2004 to 2016). The median of the seasonal data for each station was computed and plotted to examine the seasonal trends.

3.2.3.6 Spatial-Temporal Interpolation

A combined spatial-temporal analysis of the dustfall gauge and snowdust data was completed. Annual dust deposition rates for snow samples (in mg/dm^2/yr) were calculated as:

$$Annual\ dust\ deposition\ rate = \frac{winter\ time\ dust\ deposition\ rate}{exposure\ days} \times 365$$

where the exposure days refers to the number of days over which the snow accumulated each winter. Dustfall gauges are recovered seasonally (i.e., 4 times per year), but these seasonal deposition rates are expressed in mg/dm^2/yr. To form a consistent time basis, the arithmetic mean of the seasonal (N=4) dustfall gauge data was used calculate the annual dust deposition rate, at each station, in mg/dm^2/yr.

Dustfall and snowdust observations for each station were then grouped into the four temporal periods discussed previously (i.e., 2002 to 2005, 2006 to 2009, etc.). Using this approach, temporal trends in the spatial distribution of dust, nutrient and metals deposition were tabulated numerically, and illustrated graphically.

Dust deposition rates as a function of distance from the geographic centre of the Mine footprint (i.e., the centroid shown in Figure 3-1) were evaluated for each temporal period. Spatial trends in dust deposition as a function of distance from the centroid were fit using a first-order decay function, whose goodness-of-fit was evaluated using the coefficient of determination (r^2) from the least-squares regression. An r^2 larger than 0.5 indicated a robust fit of the dust deposition as a function of distance from the centroid. The 95% confidence intervals of the fit to a first order decay were also calculated and presented.

To calculate the annual mass loadings of dust (e.g., tonnes/yr), nutrients and metals for each temporal period required the application of spatial interpolation (i.e., Kriging) using a geographic information system (ArcGIS). This interpolation required an estimate of dust, nutrient and metals areal deposition rates at both the mine boundary, and at the boundary of the spatial domain over which the observations were being interpolated. Using the distance from the Mine centroid to the Mine boundary, and the first order decay function for dust deposition as a function of distance from the Mine centroid, the deposition rates at the Mine boundary were calculated at discrete points along the Mine perimeter, and used as input to the interpolation scheme. Dust deposition at the domain boundary were set equal to the background rates of dust deposition observed during each temporal period (see Table 3-1).

The size of the spatial domain over which the dust deposition data were interpolated is 17.5 km by 17.5 km. The grid resolution inside the domain was set to 20 m by 20 m, but excluded the area of the domain occupied by the mine footprint.

Prior to use during spatial interpolation, the observed areal deposition rates at the same location were arithmetically averaged then log transformed. Mass loadings (in tonnes/yr) were calculated by integrating the spatially interpolated areal loadings across the domain, and then back-transforming the log-normal results. This procedure is described by the following equation:

$$Mass\ Loading\ \left(\frac{t}{yr}\right) = sum\ of\ dust\ deposition\ data\ \left(\frac{mg}{dm^2 \cdot yr}\right) \times \frac{100\ dm^2}{m^2} \times 20\ m \times 20\ m\ \times\ \frac{t}{10^9\ mg}$$

where the “sum of dust deposition data” represents the sum of the areal loadings interpolated for each 20 m by 20 m grid cell. The “zonal statistics table” tool in ArcGIS was used to calculate mass loadings for four separate regions during each temporal period. These four regions correspond to: the mine footprint (excluded from analysis); the near-field region [4] (<1.5 km) outside the mine footprint; Lac de Gras; and the Lac de Gras watershed (excluding Lac de Gras). Total loadings to the Lac de Gras watershed can be obtained by summing deposition to Lac de Gras and the Lac de Gras watershed (see Section 3.3.4).

3.2.3.7 Relating Wintertime Nutrient and Metals Deposition to Annual Dust Deposition

To the extent possible, the analysis of the snow water chemistry data followed a similar approach to that employed when analyzing the dust data. However, snow chemistry data were only available for winter. To estimate mass loadings of nutrients and metals throughout the year, a relationship between TP, OP, N+N, and ammonia deposition to wintertime dust deposition must be established.

As a working hypothesis, it was assumed that TP, OP, N+N, and ammonia were particulate-bound. This assumption was likely valid for TP and OP, which are associated with the kimberlite ore; and, to a lesser

[4] This area is different from the “near-field area” of Lac de Gras referred to in other sections of this re-evaluation report.

extent unweathered overburden and gangue. N+N and ammonia may be associated with residues from explosives found in dust; however, N+N and ammonia emitted as gases from combustion sources will dry deposit from the gas-phase directly to the snowpack. In this instance, regression of wintertime N+N and ammonia deposition rates to wintertime dust deposition rates may result in poor correlations with dust.

Figures 3-2 and 3-3 illustrate the regressions of wintertime nutrient and metal (aluminum and lead) deposition versus wintertime dust deposition. As expected, wintertime TP, OP, aluminum and lead deposition are all well correlated to wintertime dust deposition. Wintertime deposition of N+N and ammonia are poorly correlated to wintertime dust deposition, indicating the majority of these compounds are associated with dry deposition of gases, not deposition of particulate-bound nitrogen species. By exploiting the relationship between wintertime TP, OP, aluminum, and lead and dust deposition, and combining it with the spatial-temporal trends in annual dust deposition, the spatial-temporal trends in annual TP, OP, aluminum, and lead mass loadings can be derived.

Figure 3-2 Correlations between Nutrients and Winter Dust Deposition

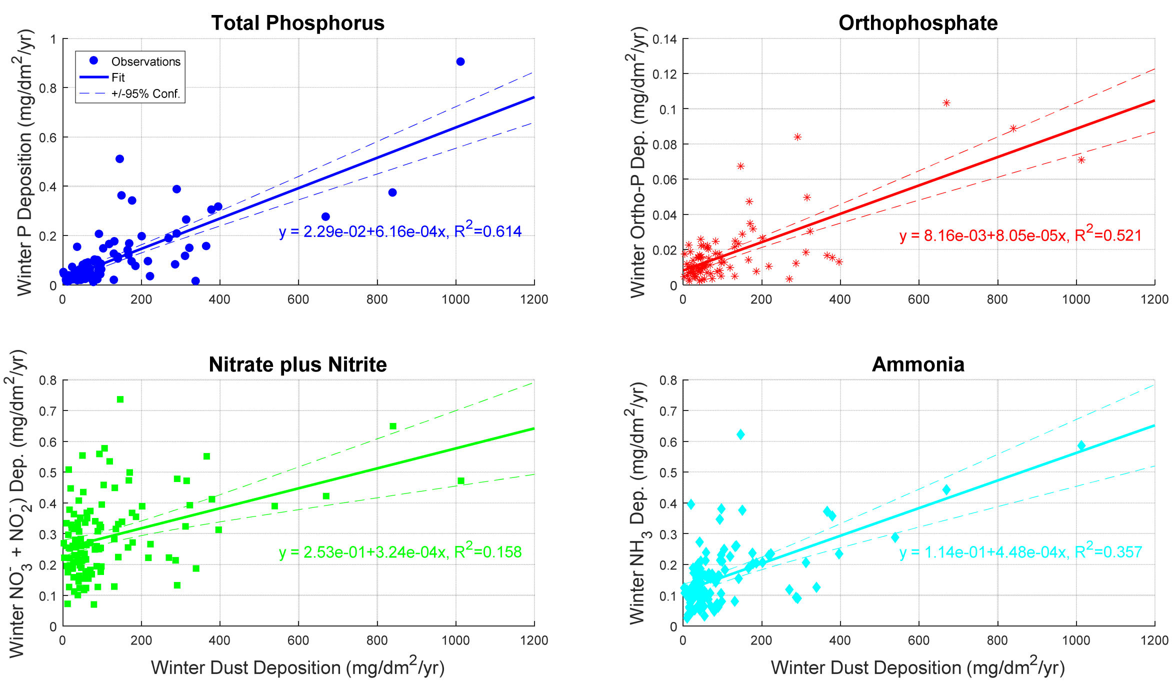
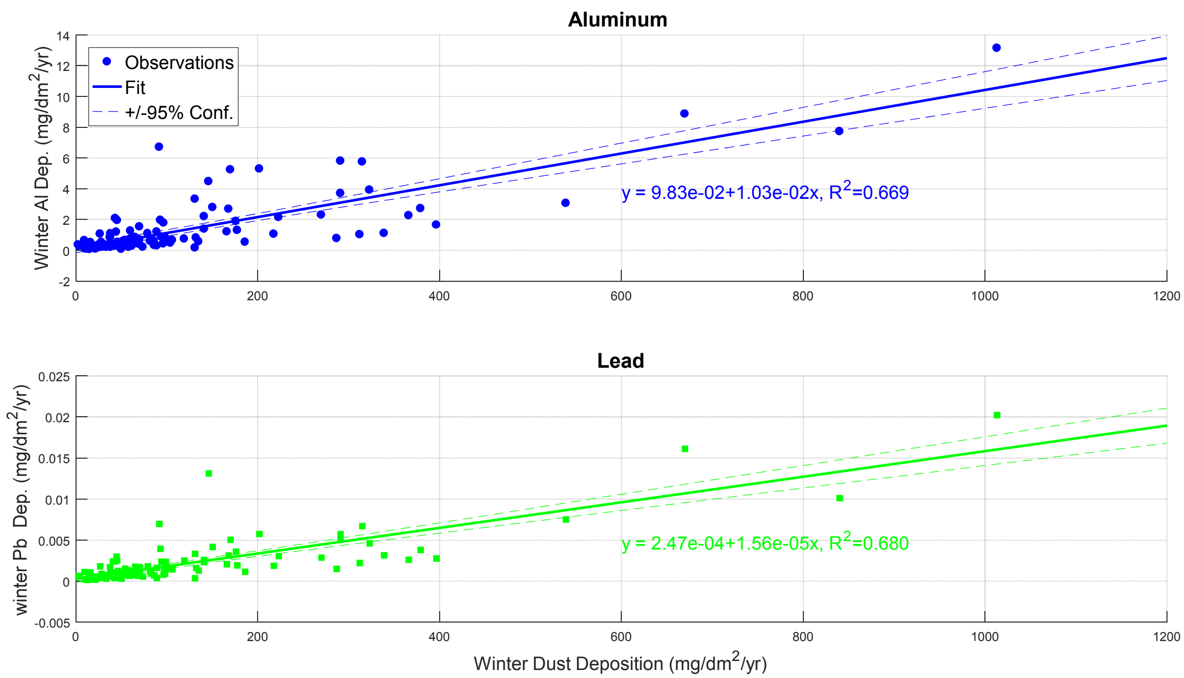


Figure 3-3 Correlations between Metals and Winter Dust Deposition



3.3 Results

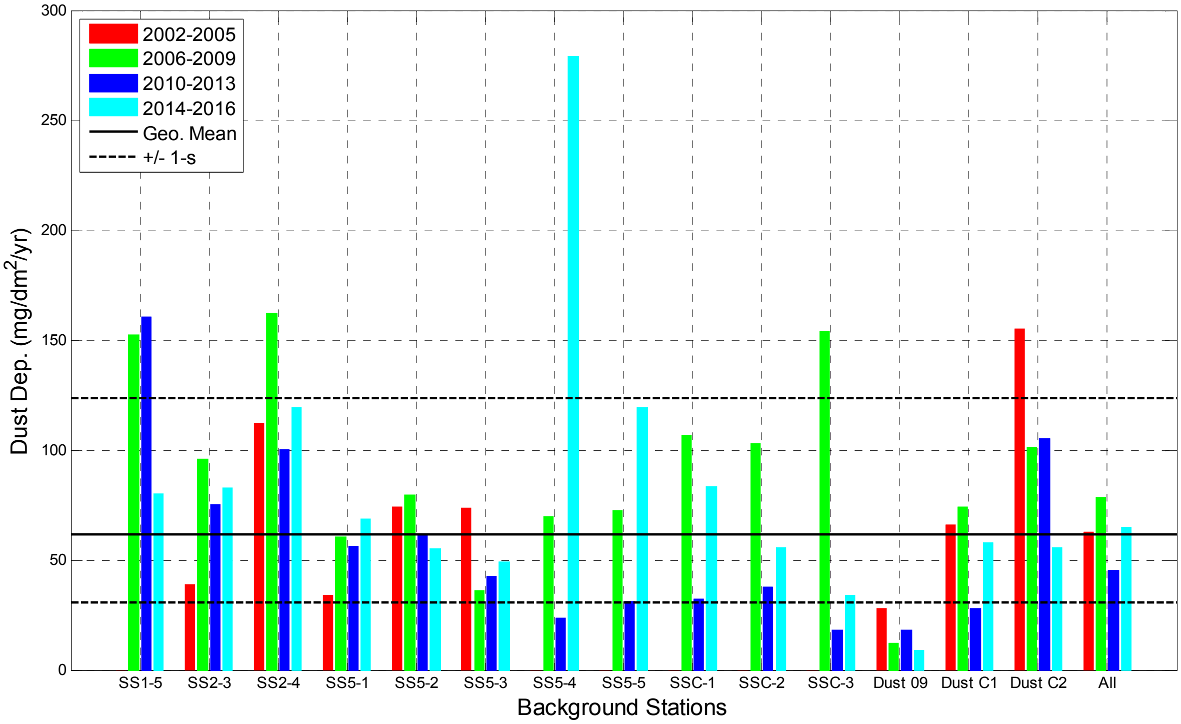
3.3.1 Background Deposition Rates

3.3.1.1 Dustfall

Two-tailed Student's *t*-test results show that the annual dust deposition rates at dust gauge station Dust 09 were not significantly different from the annual dust deposition rates at the control stations Dust C1 and Dust C2 ($P = 0.0006$). Similarly, the annual dust deposition rates observed at snowdust locations SS1-5, SS2-3, SS2-4, SS5-1, SS5-2, SS5-3, SS5-4, and SS5-5 were not statistically different from the control stations SSC-1, SSC-2, and SSC-3. For Dust 09, and the snowdust stations with deposition rates not significantly different from rates observed at the control stations, the data were pooled to form a composite estimate of background dust deposition.

Figure 3-4 and Table 3-5 summarize the dust deposition rates at the control stations and the stations that were identified as being not significantly different from the control stations. The overall background dust deposition rates were 62.5, 78.3, 45.4, and 64.7 mg/dm^2/yr for the four time periods being considered. The geometric mean deposition rate for all years and all background stations is 62 mg/dm^2/yr; the range of geometric mean ±1 SD of the background deposition rate is 31 to 125 mg/dm^2/yr. These background deposition rates were incorporated into the spatial-temporal analysis of dust deposition and the total dust loadings calculations.

Figure 3-4 Summary of Background Dust Deposition Rates



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

Table 3-5 Summary of Background Dust Deposition Rates (mg/dm^2/yr)

Background Stations	Time Periods				
	2002-2005	**2006-2009**	**2010-2013**	**2014-2016**	**All years (mean)**
SS1-5	N/D	152	161	80.2	**131**
SS2-3	38.7	96.0	75.2	82.8	**73.2**
SS2-4	112	162	100	119	**124**
SS5-1	34.2	60.6	56.0	68.7	**54.9**
SS5-2	74.1	79.5	61.8	54.9	**67.6**
SS5-3	73.6	36.1	42.6	49.3	**50.4**
SS5-4	N/D	69.9	23.8	279	**124**
SS5-5	N/D	72.5	31.2	119	**74.3**
SSC-1	N/D	106	32.2	83.6	**74.1**
SSC-2	N/D	103	37.7	55.7	**65.4**
SSC-3	N/D	154	18.1	33.8	**68.6**
Dust 09	28.2	12.3	18.4	9.1	**17.0**
Dust C1	65.9	74.3	28.1	57.7	**56.5**
Dust C2	155	101	105	55.8	**104**
All Stations (geomean)	**62.5**	**78.3**	**45.4**	**64.7**	**70.0**

N/D = no data; mean = temporal arithmetic mean; geomean = spatial geometric mean

3.3.1.2 Nutrients and Metals

Analysis of background deposition rates for nutrients and metals followed the same procedures as dust deposition, but was informed by the dust deposition analysis results. The dust gauge and snowdust stations with dust deposition not significantly different from the control stations were also treated as “background” stations for nutrients and metals deposition. Ancillary data required to transform nutrient and metals concentrations in snow water to their corresponding rates of areal deposition were only available for the last two time periods (i.e., 2010 to 2013 and 2014 to 2016). Data from these stations were grouped according to these time periods and data were pooled to estimate background deposition rates for nutrients and metals during these periods.

Tables 3-6 and 3-7 list the background deposition rates of ammonia, N+N, TP, and OP for 2010 to 2013 and 2014 to 2016. The overall background deposition rates were:

- 0.10 and 0.14 mg/dm^2/yr of ammonia in 2010 to 2013 and 2014 to 2016, respectively
- 0.27 mg/dm^2/yr of N+N for both time periods
- 0.038 and 0.046 mg/dm^2/yr of TP 2010 to 2013 and 2014 to 2016, respectively
- 0.008 and 0.010 mg/dm^2/yr of OP in 2010 to 2013 and 2014 to 2016 respectively

Generally, the time period of 2014 to 2016 had larger background deposition rates for TP, OP and ammonia than the time period of 2010 to 2013. Figure 3-5 illustrates background nutrient deposition rates for the two time periods among the stations identified as background.

Table 3-6 Summary of Background Ammonia and Nitrate plus Nitrite Deposition (mg/dm^2/yr)

Background Stations	Ammonia			Nitrate Plus Nitrite		
	2010-2013	2014-2016	All Years (mean)	2010-2013	2014-2016	All Years (mean)
SSC-1	0.06	0.11	**0.09**	0.29	0.28	**0.29**
SSC-2	0.06	0.16	**0.11**	0.20	0.29	**0.25**
SSC-3	0.15	0.18	**0.17**	0.35	0.28	**0.31**
SS1-5	0.12	0.12	**0.12**	0.29	0.36	**0.33**
SS2-3	0.22	0.20	**0.21**	0.36	0.25	**0.31**
SS2-4	0.13	0.14	**0.13**	0.27	0.19	**0.23**
SS5-3	0.09	0.11	**0.10**	0.19	0.21	**0.20**
SS5-4	0.11	0.14	**0.12**	0.24	0.31	**0.28**
SS5-5	0.07	0.10	**0.09**	0.26	0.27	**0.26**
All Stations (geomean)	**0.10**	**0.14**	**0.12**	**0.27**	**0.27**	**0.27**

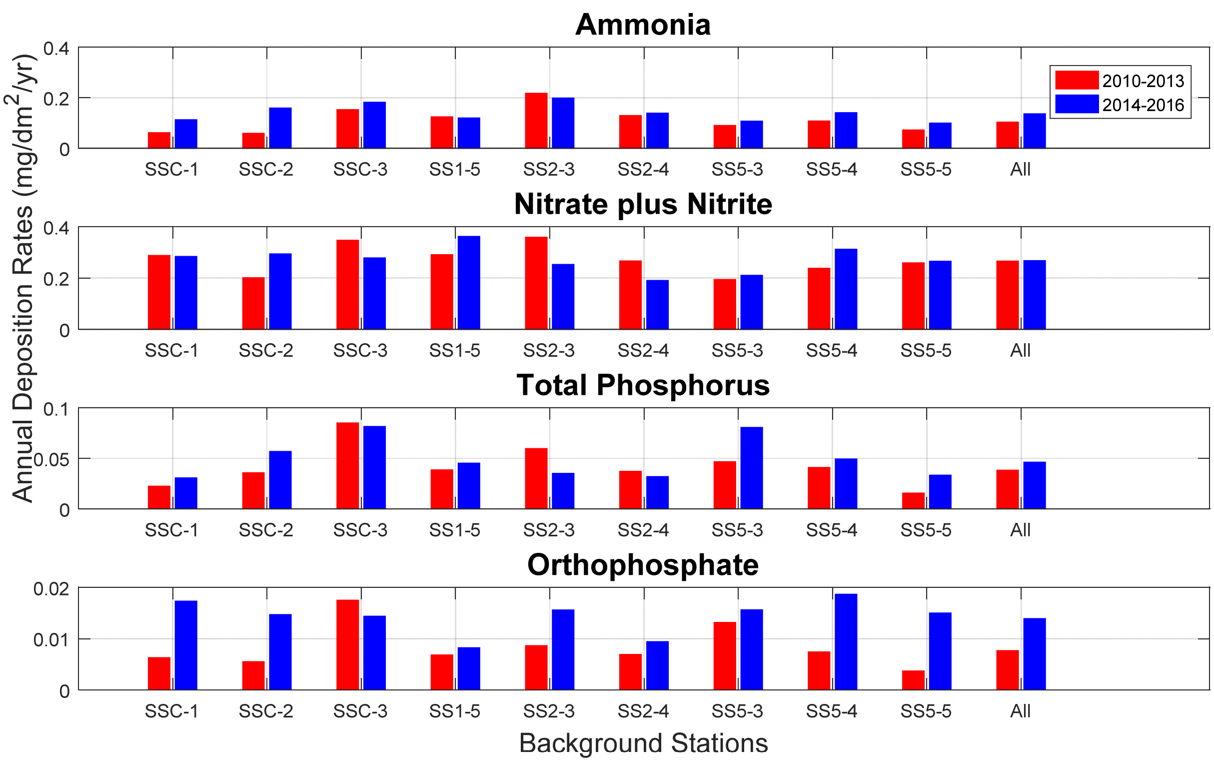
mean = temporal arithmetic mean; geomean = spatial geometric mean.

Table 3-7 Summary of Background Total Phosphorus and Orthophosphate Deposition ($mg/dm^2/yr$)

Background Stations	Total Phosphorus			Orthophosphate		
	2010-2013	2014-2016	All years (mean)	2010-2013	2014-2016	All years (mean)
SSC-1	0.023	0.031	**0.027**	0.006	0.017	**0.012**
SSC-2	0.036	0.057	**0.046**	0.006	0.015	**0.010**
SSC-3	0.085	0.082	**0.083**	0.018	0.014	**0.016**
SS1-5	0.039	0.045	**0.042**	0.007	0.008	**0.008**
SS2-3	0.060	0.035	**0.048**	0.009	0.016	**0.012**
SS2-4	0.037	0.032	**0.035**	0.007	0.009	**0.008**
SS5-3	0.047	0.081	**0.064**	0.013	0.016	**0.014**
SS5-4	0.041	0.050	**0.045**	0.007	0.019	**0.013**
SS5-5	0.016	0.034	**0.025**	0.004	0.015	**0.009**
All Stations (geomean)	**0.038**	**0.046**	**0.043**	**0.008**	**0.01**	**0.011**

mean = temporal arithmetic mean; geomean = spatial geometric mean

Figure 3-5 Summary of Background Deposition Rates of Nutrients



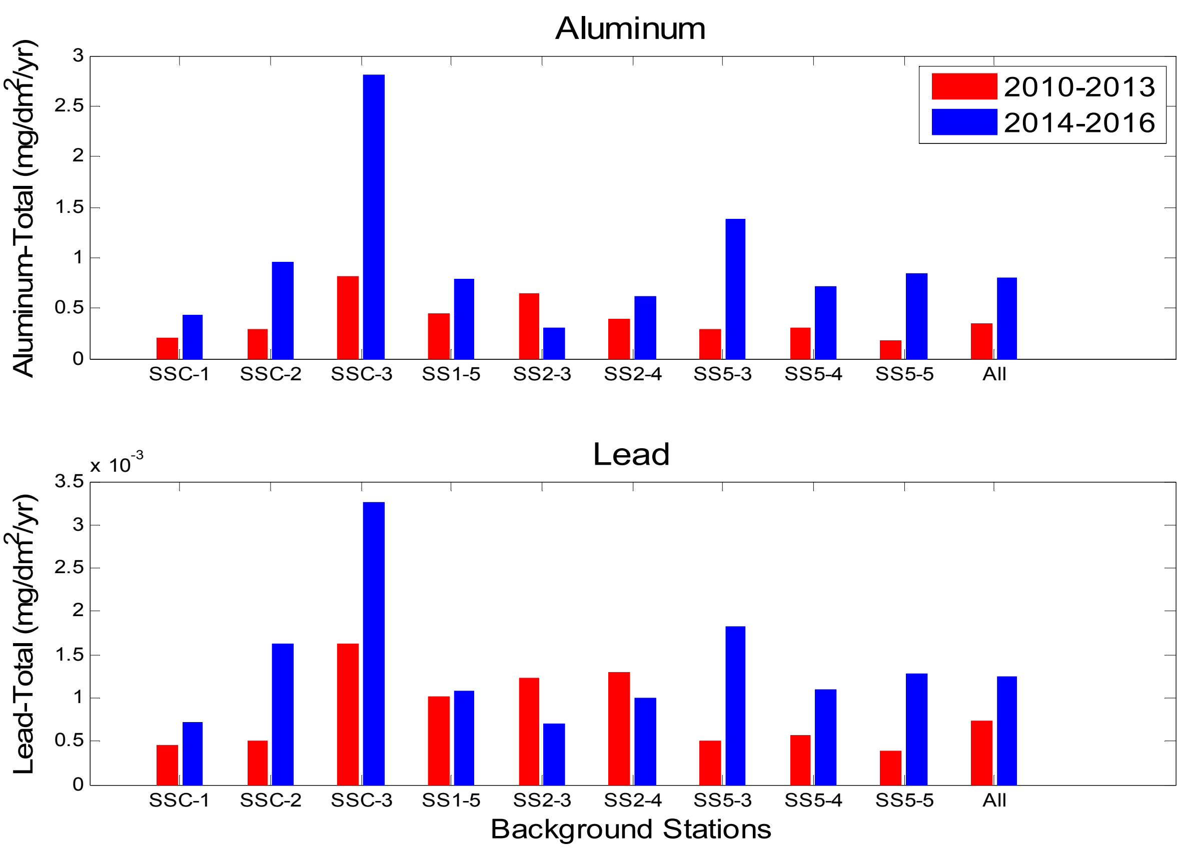
$mg/dm^2/yr$ = milligrams per square decimetre per year.

Table 3-8 and Figure 3-6 summarize the background deposition rates of aluminum and lead for the two most recent time periods. The background aluminum deposition rates were 0.35 and 0.80 $mg/dm^2/yr$ for the time periods of 2010 to 2013 and 2014 to 2016, respectively. The background deposition rates for lead were approximately 0.001 mg/dm²/yr for both time periods. The background deposition rates of metals were greater in 2014 to 2016 than 2010 to 2013. Comparisons of the background deposition rates at these stations are presented in Figure 3-6.

Table 3-8 Summary of Background Aluminum and Lead Deposition (mg/dm²/yr)

Background Stations	Aluminum			Lead		
	2010-2013	2014-2016	All years (mean)	2010-2013	2014-2016	All years (mean)
SSC-1	0.20	0.43	**0.31**	0.001	0.001	**0.001**
SSC-2	0.28	0.95	**0.62**	0.001	0.002	**0.001**
SSC-3	0.81	2.80	**1.81**	0.002	0.003	**0.002**
SS1-5	0.44	0.76	**0.60**	0.001	0.001	**0.001**
SS2-3	0.64	0.30	**0.47**	0.001	0.001	**0.001**
SS2-4	0.39	0.61	**0.50**	0.001	0.001	**0.001**
SS5-3	0.29	1.37	**0.83**	0.001	0.002	**0.001**
SS5-4	0.31	0.71	**0.51**	0.001	0.001	**0.001**
SS5-5	0.16	0.84	**0.50**	0.000	0.001	**0.001**
All Stations (geomean)	**0.35**	**0.80**	**0.60**	**0.001**	**0.001**	**0.001**

Figure 3-6 Summary of Background Deposition Rates of Aluminum and Lead



mg/dm²/yr = milligrams per square decimetre per year.

3.3.2 Annual and Seasonal Trends

Dust deposition is measured quarterly at 12 dust gauge stations surrounding the Mine. The stations were grouped into 4 zones based on their distance from the Mine boundary:

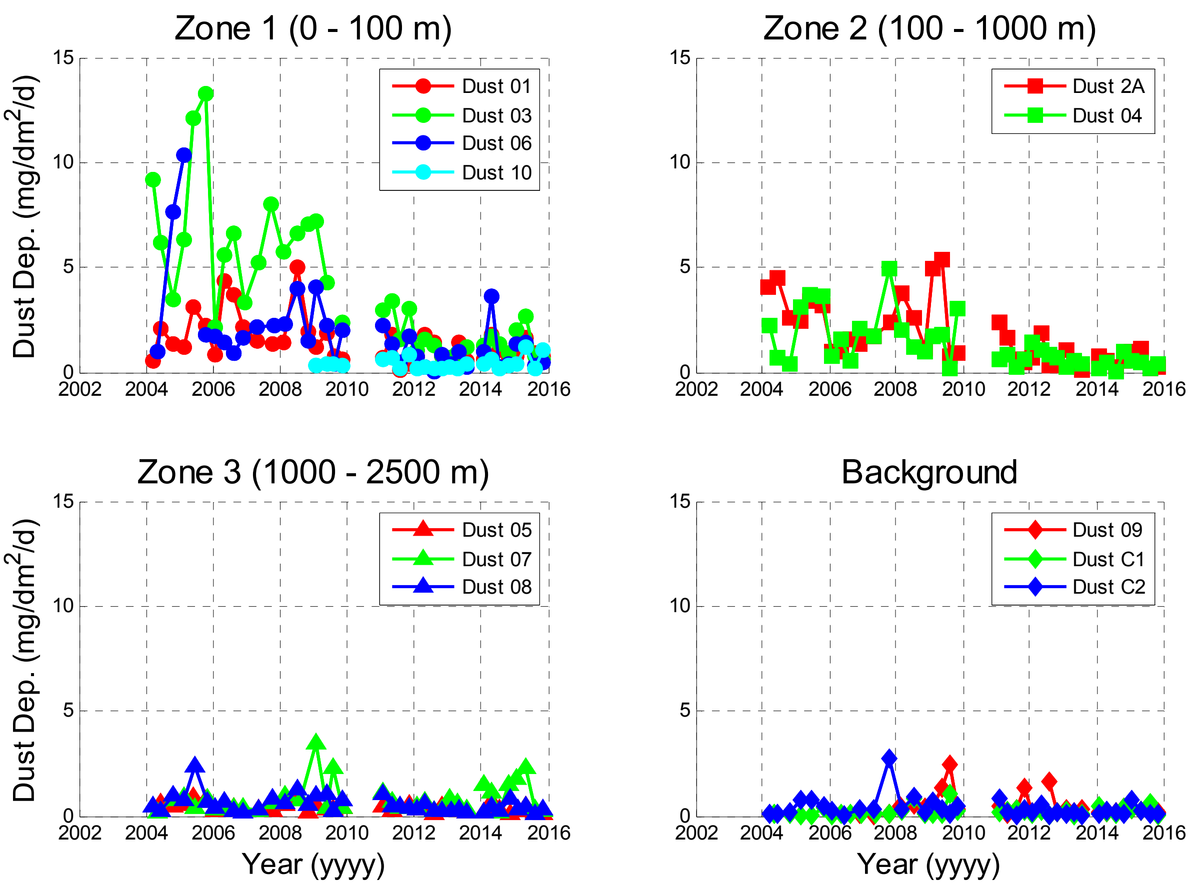
- Zone 1 (0 – 100 m) including Dust 01, Dust 03, Dust 06, and Dust 10
- Zone 2 (100 – 1000 m) including Dust 2A and Dust 04
- Zone 3 (1000 – 2500 m) including Dust 05, Dust 07, and Dust 08
- Background, including Dust 09, Dust C1, and Dust C2

Time series of quarterly dust deposition rates in the four zones are presented in Figure 3-7 to illustrate annual trends. In summary:

- For non-background stations, the first two time periods (2002 to 2005 and 2006 to 2009) had greater deposition rates than the other two time periods
- Zone 1 and Zone 2 dust deposition rates appeared to decrease from the time period of 2004 to 2009 to the time period of 2010 to 2016
- For Zone 3 and background stations, the second time period (2006 to 2009) had the highest deposition rates among the four time periods

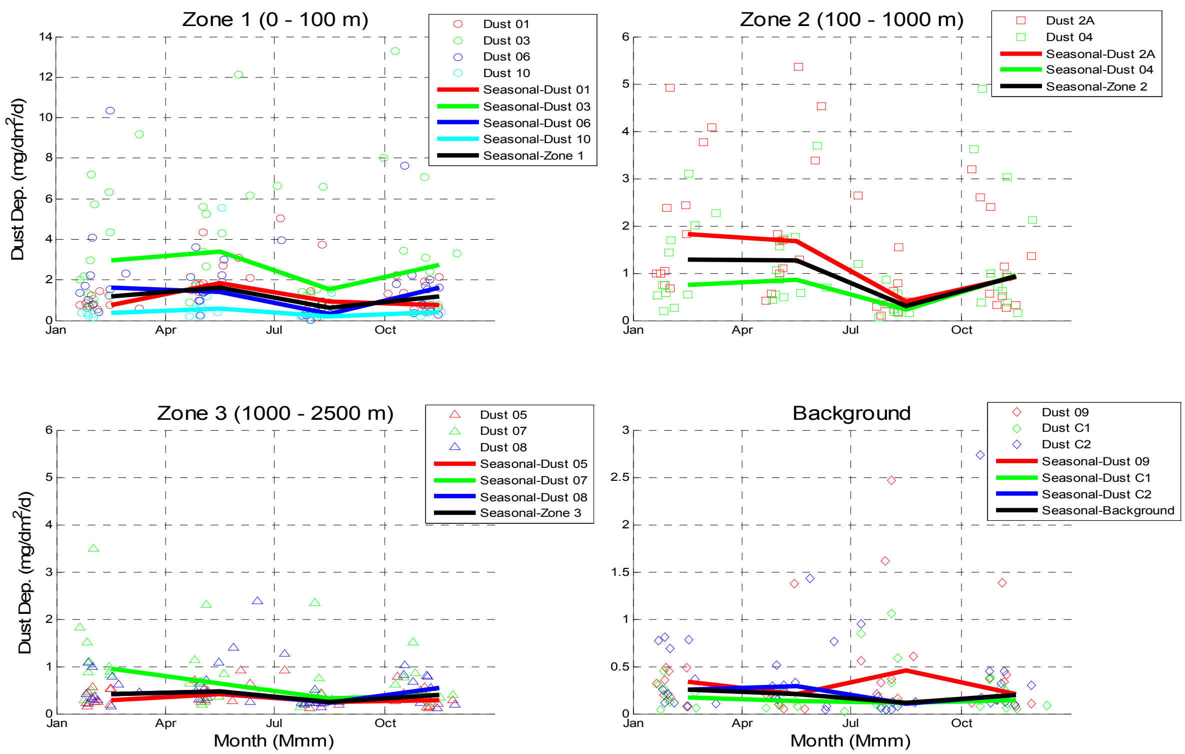
Seasonal trends of dust deposition for the dust gauge stations grouped into four zones (Note: x-axis differ) are presented in Figure 3-8. Seasonal trends for the four zones were similar, and while deposition rates were lowest in the fall, there were similar in magnitude in the other three seasons.

Figure 3-7 Time Series of Dust Deposition Rates for four Different Distances from the Mine



mg/dm²/yr = milligrams per square decimetre per year.

Figure 3-8 Seasonal Trends of Total Dust Deposition Rates by Distance from the Mine



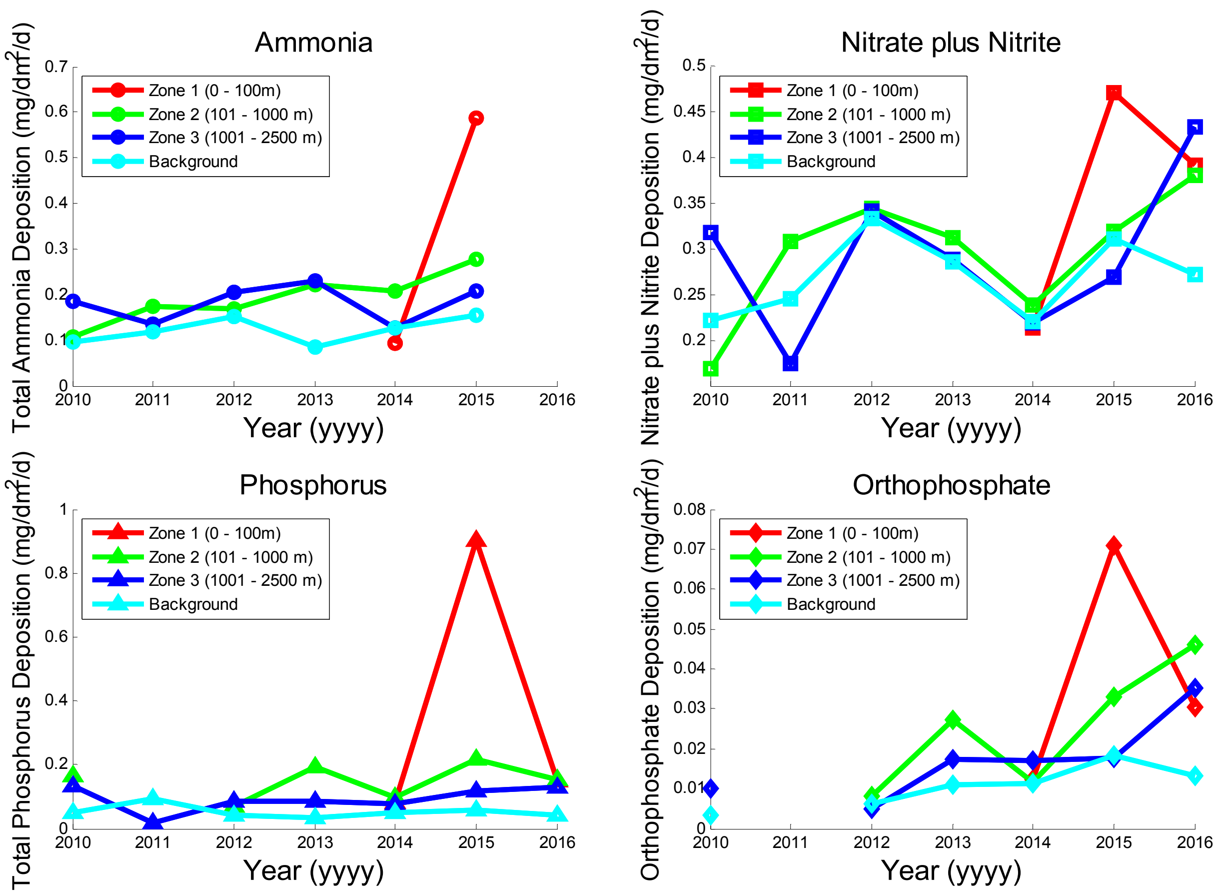
mg/dm^2/yr = milligrams per square decimetre per year.

The annual variation of the winter time nutrient deposition rates are presented in Figure 3-9, grouped by the distance to the Mine boundary:

- Zone 1 (0 – 100 m) including SS3-6 and SS5-2
- Zone 2 (100 – 1000m) including SS2-1, SS1-4, SS2-2, SS3-4, SS3-7, SS3-8, and SS5-3
- Zone 3 (1000 – 2500 m) including SS3-5, SS4-4, and SS4-5
- Background, including SSC-1, SSC-2, SSC-3, SS1-5, SS2-3, SS2-4, SS5-4, and SS5-5

The background nutrient deposition rates had relatively small variations during the time period of 2010 to 2016. The nutrient deposition rates in 2015 were the highest for zone 1 stations. For zone 2 and zone 3, the nutrient deposition rates presented an increasing trend from 2014 to 2016.

Figure 3-9 Time Series of Wintertime Ammonia (top-left), nitrate + nitriate (top-right), TP (bottom-left) and OP (bottom-right) Deposition Rates

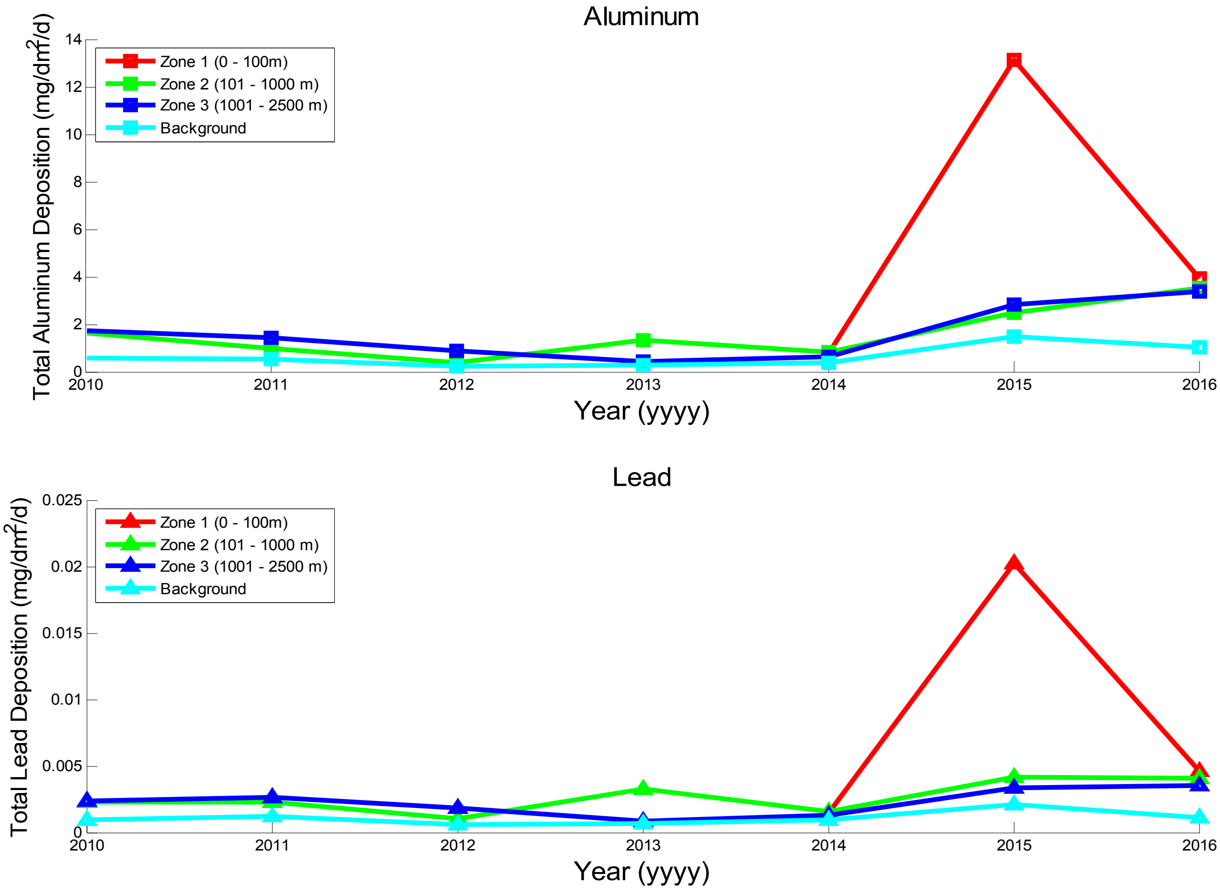


mg/dm^2/yr = milligrams per square decimetre per year.

The annual variation of the winter time metal deposition rates for the same station group as nutrient deposition is presented in Figure 3-10. Similar patterns were observed:

- The background metal deposition rates varied little during the time period of 2010 to 2016
- The metal deposition rates in 2015 were the highest for zone 1 stations
- For zone 2 and zone 3, the metal deposition rates presented an increasing trend from 2014 to 2016

Figure 3-10 Time Series of Wintertime Aluminum (top) and Lead (bottom) Deposition Rates



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

As discussed in Section 3.2.3.7, wintertime TP, OP, aluminum, and lead correlated well with winter dust depositions. The seasonal variations of nutrients and metals were expected to be similar to dust deposition rates.

3.3.3 Spatial and Temporal Trends

3.3.3.1 Dustfall

Seasonal dustfall gauge data were grouped into annual values so that their time-base was consistent with that of the snowdust data. Data from each station were then averaged into four temporal bins spanning the time periods 2002 to 2005, 2006 to 2009, 2010 to 2013, and 2014 to 2016 (as described in Section 3.2.3.1).

Figure 3-11 presents dust deposition rates as a function of distance from the centroid of the Mine (i.e., centre of the Mine footprint). The first order decay function resulted in a robust fit with respect to the distance from the centroid of the Mine (r^2 = 0.52 to 0.83)

The dust deposition data at the control stations were pooled, along with dustfall gauges (Dust 09) and snowdust stations (SS1-5, SS2-3, SS2-4, SS5-1, SS5-2, SS5-3, SS5-4, and SS5-5) that were not statistically different from background values (Section 3.3.1). This resulted in a composite 2002 to 2016 geometric mean dust deposition rate ± 1 SD of 62 mg/dm^2/yr ± 31 to 124 mg/dm^2/yr.

Using a dust deposition rate of 124 mg/dm^2/yr (i.e., the geometric mean plus one geometric SD) as the threshold above which dust deposition rates are likely to be significantly above the background rates of deposition, the regressions in Figure 3-11 were used to estimate the Mine's zone of influence (ZOI) with respect to dust deposition (Table 3-9).

Using the first order decay equations, estimates of the dust deposition at the Mine boundary (0.26 to 3.6 km from Mine centroid) were calculated for all locations along the Mine boundary, and for each of the four time periods. The maximum rate of dust deposition was defined as the rate of deposition observed at the location along the Mine boundary that is closest to the Mine centroid. Based on this spatial-temporal analysis of the data, the following conclusions may be drawn:

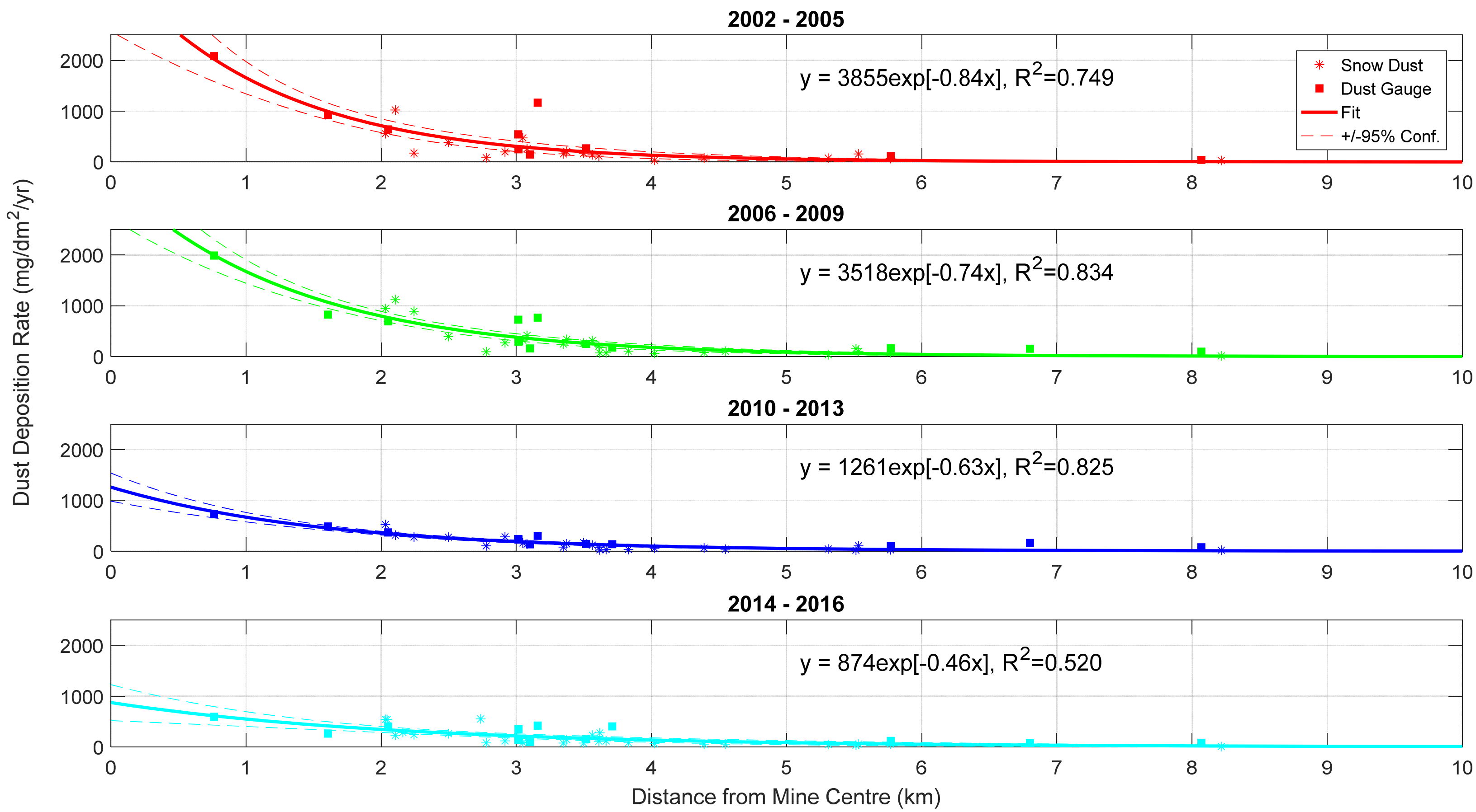
- The maximum dust deposition rate observed at the Mine boundary has declined over time:
  - 3,095 mg/dm^2/yr for the 2002 to 2005 period
  - 2,900 mg/dm^2/yr for the 2006 to 2009 period
  - 1,069 mg/dm^2/yr for the 2010 to 2013 period
  - 775 mg/dm^2/yr for the 2014 to 2016 period
- From 2002 and 2016, dust deposition rates beyond 4.2 ± 0.4 km from the Mine centroid were, on average, not significantly different from background values.
- From 2002 to 2016, dust deposition rates beyond 0.6 to 3.9 kilometres from the Mine boundary were, on average, not significantly different from background values.

Table 3-9 Length of the Zone of Influence of the Mine on Dust Deposition

Temporal Period	Zone of Influence[a] (from Centroid)
2002 to 2005	4.1 km
2006 to 2009	4.5 km
2010 to 2013	3.7 km
2014 to 2016	4.2 km

a) Zone of influence was defined as the intersection between one standard deviation greater than the geometric mean of background rates of dust deposition (123.5 mg/dm^2/yr) and the predicted decay rate of dust deposition with distance (Figures 3-11).

Figure 3-11 Dust Deposition as a Function of Distance from the Mine Centroid



Note: Results of the fit to a first-order decay function are plotted as solid lines, and 95% confidence intervals are plotted as dashed lines. Equations for the first-order decay function and the R^2 values are included as text within each sub-plot.

mg/dm²/yr = milligrams per square decimetre per year.

3.3.3.2 Nutrients and Metals

The deposition rates of TP, OP, and ammonia in snow from exposure stations were significantly greater than deposition observed in snow sampled at the background stations (Table 3-10). Deposition rates of N+N were not significantly different between exposure and background stations (*P*=0.252).

Table 3-10 Summary of Snow Water Nutrient Deposition Rates (mg/dm²/yr)

Nutrient	Location	n	Geometric Mean	Minimum	Maximum	t-test Result (*P*-value)
Ammonia	Background	54	0.10	0.03	0.40	Significant (*P*<0.0001)
	Exposure	47	0.18	0.05	0.62	
Nitrate plus Nitrite	Background	63	0.25	0.07	0.55	Not Significant (*P*=0.252)
	Exposure	57	0.28	0.07	0.74	
Total Phosphorus	Background	55	0.038	0.012	0.152	Significant (*P*<0.0001)
	Exposure	53	0.091	0.010	0.904	
Orthophosphate	Background	45	0.001	0.002	0.026	Significant (*P*=0.0055)
	Exposure	45	0.016	0.002	0.1036	

P = probability; n = sample size.

The deposition rates of aluminum and lead at exposure stations were significantly greater than deposition observed in snow sampled at the background stations (Table 3-11). The geometric mean deposition of aluminum at exposure stations was 1.10 mg/dm²/yr, which is almost three times the background deposition rate. The geometric mean lead deposition was 0.0019 mg/dm²/yr, which is approximately two times greater than the background rate of deposition.

Table 3-11 Summary of Snow Water Metals Deposition Rates (mg/dm²/yr)

Metal	Location	n	Geometric Mean	Minimum	Maximum	t-test Result (*P*-value)
Total Aluminum	Background	63	0.40	0.06	6.7	Significant (*P*<0.0001)
	Exposure	57	1.1	0.08	13	
Total Lead	Background	63	0.0008	0.0001	0.0070	Significant (*P*<0.0001)
	Exposure	57	0.0019	0.0003	0.0202	

P = probability; n = sample size.

Figures 3-12 to 3-17 present the deposition rates of TP, OP, N+N, ammonia, aluminum and lead as a function of distance from the Mine centre. Each figure contains two panels corresponding to the observed deposition in the two most recent time periods (i.e., 2010 to 2013 and 2014 to 2016).

Coefficients of determination (i.e., r^2) of the wintertime deposition rates for TP (Figure 3-12), aluminum (Figure 3-16) and lead (Figure 3-17) are robust as a function of distance from the mine. These observations are consistent with the high correlation between these variables and wintertime dust deposition, illustrated in Figures 3-2 and 3-3. These results tend to support the hypothesis that these compounds are likely particulate-bound and being emitted as fugitive dust from the mine.

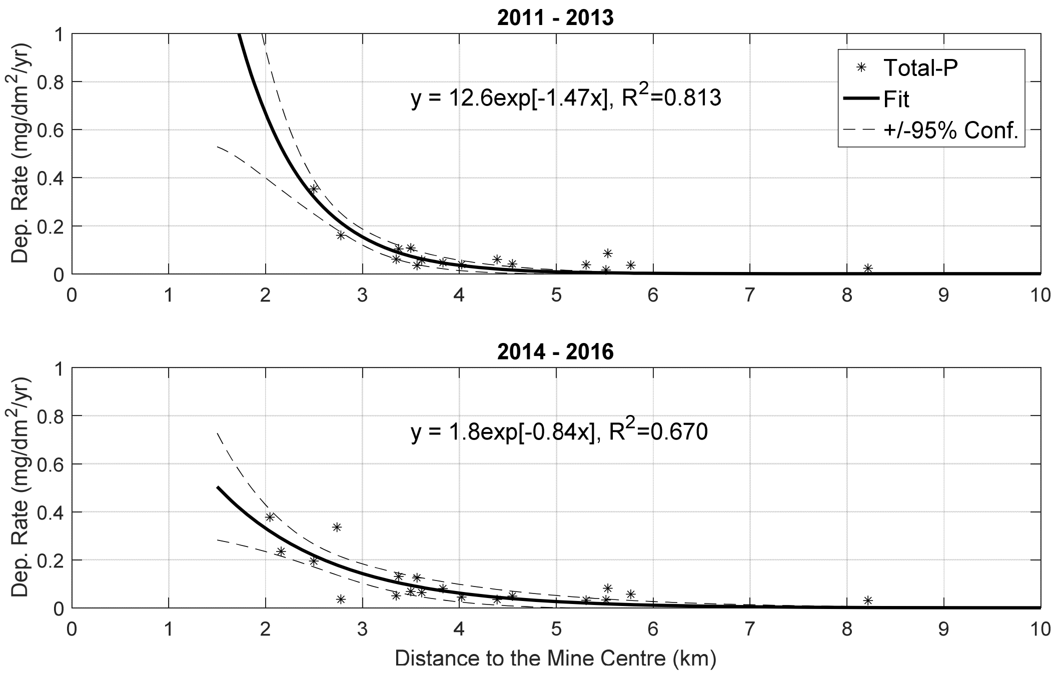
The fits for OP (Figure 3-13) and ammonia (Figure 3-14) as a function of distance from the Mine are less robust, but still indicate these compounds are emitted by the Mine. Wintertime OP deposition is correlated with wintertime dust deposition (r^2 = 0.521; Figure 3-2), whereas wintertime ammonia deposition is poorly correlated to wintertime dust deposition (r^2 = 0.357; Figure 3-2). These observations indicate that OP, like TP, is likely associated with Mine emissions of fugitive dust. Conversely, ammonia is likely emitted from multiple sources and dry deposited as a gas (e.g., from the wastewater treatment plant) or along with particulate matter (e.g., as a residue from ammonia nitrate and fuel oil explosives).

The regressions for N+N as a function of distance from the mine are poor (Figure 3-15), as are the regressions of wintertime N+N deposition to dust deposition (Figure 3-2). Oxides of nitrogen are emitted primarily from combustion and are not likely associated with mine emissions of fugitive dust.

Performing the same estimates of nutrient and metals deposition as completed for dust deposition, the following conclusions may be drawn regarding the spatial-temporal trends in nutrient and metals deposition:

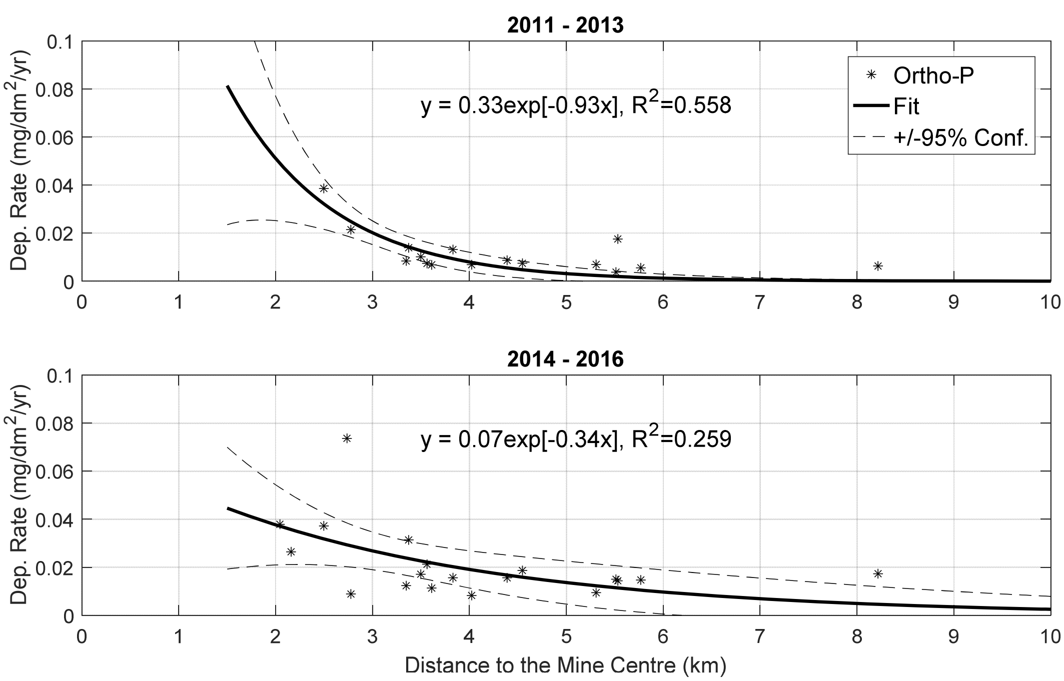
- The maximum wintertime TP deposition rate at the Mine boundary has declined over time, for example:
  - 8.6 mg/dm^2/yr for the 2010 to 2013 period
  - 1.7 mg/dm^2/yr for the 2014 to 2016 period
- The maximum wintertime OP deposition rate at the Mine boundary has declined over time, for example:
  - 0.26 mg/dm^2/yr for the 2010 to 2013 period
  - 0.07 mg/dm^2/yr for the 2014 to 2016 period
- The maximum wintertime aluminum deposition rate at the Mine boundary has declined over time, for example:
  - 26 mg/dm^2/yr for the 2010 to 2013 period
  - 15 mg/dm^2/yr for the 2014 to 2016 period
- The maximum wintertime lead deposition rate at the Mine boundary has declined over time, for example:
  - 0.17 mg/dm^2/yr for the 2010 to 2013 period
  - 0.02 mg/dm^2/yr for the 2014 to 2016 period

Figure 3-12 Total Phosphorus Deposition as a Function of Distance from the Mine Centroid



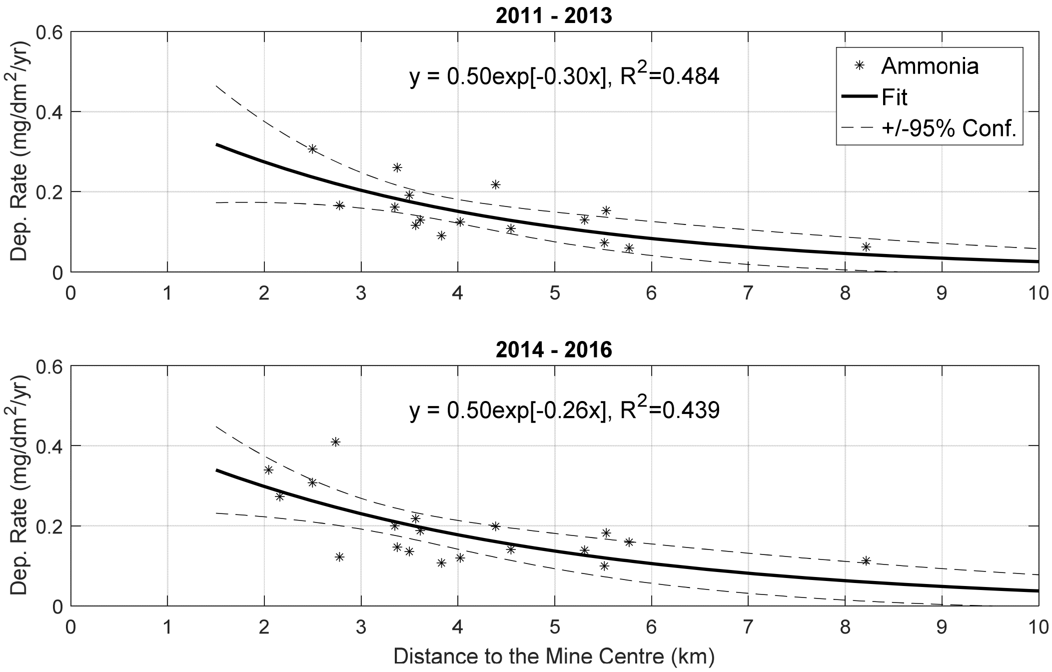
mg/dm²/yr = milligrams per square decimetre per year.

Figure 3-13 Orthophosphate Deposition as a Function of Distance from the Mine Centroid



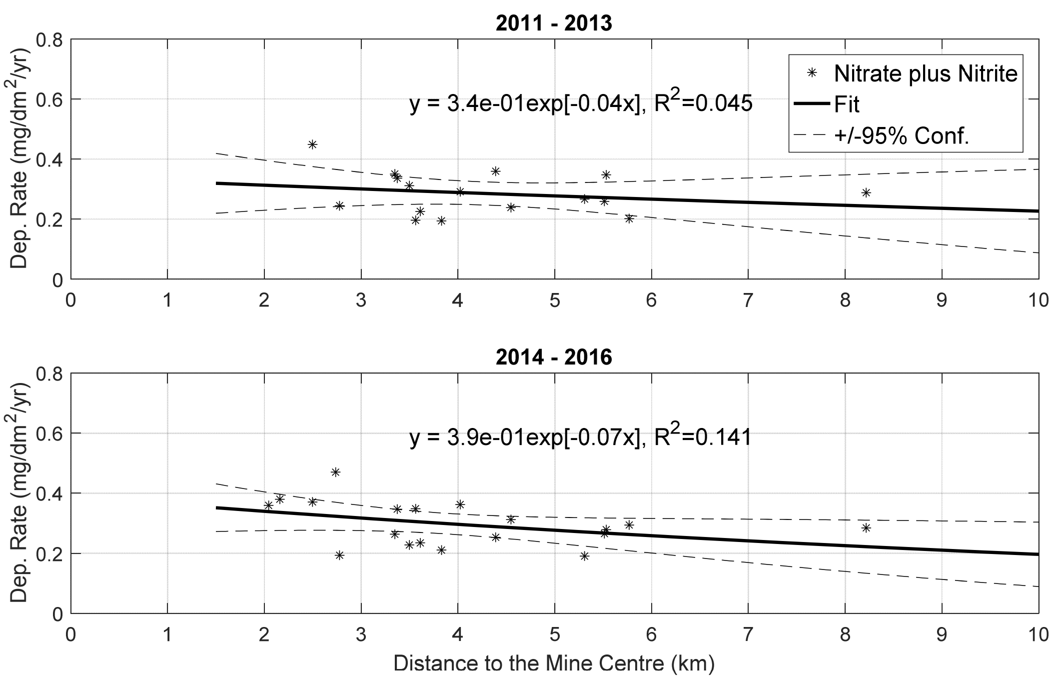
mg/dm²/yr = milligrams per square decimetre per year.

Figure 3-14 Ammonia Deposition as a Function of Distance from the Mine Centroid



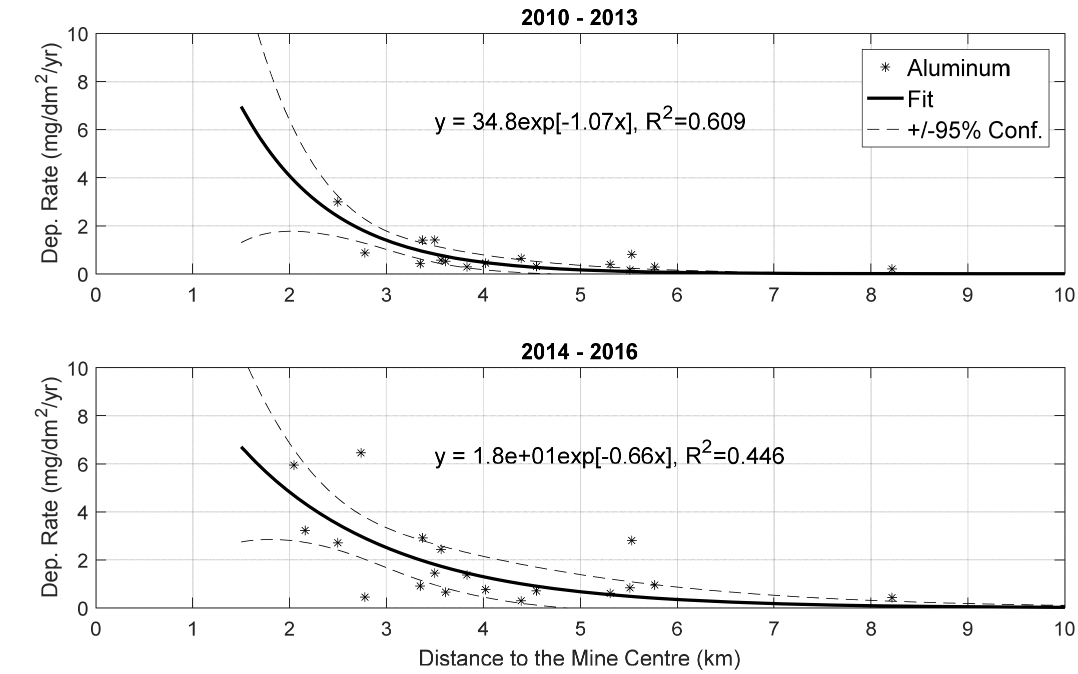
mg/dm²/yr = milligrams per square decimetre per year.

Figure 3-15 Nitrate + Nitrite Deposition as a Function of Distance from the Mine Centroid



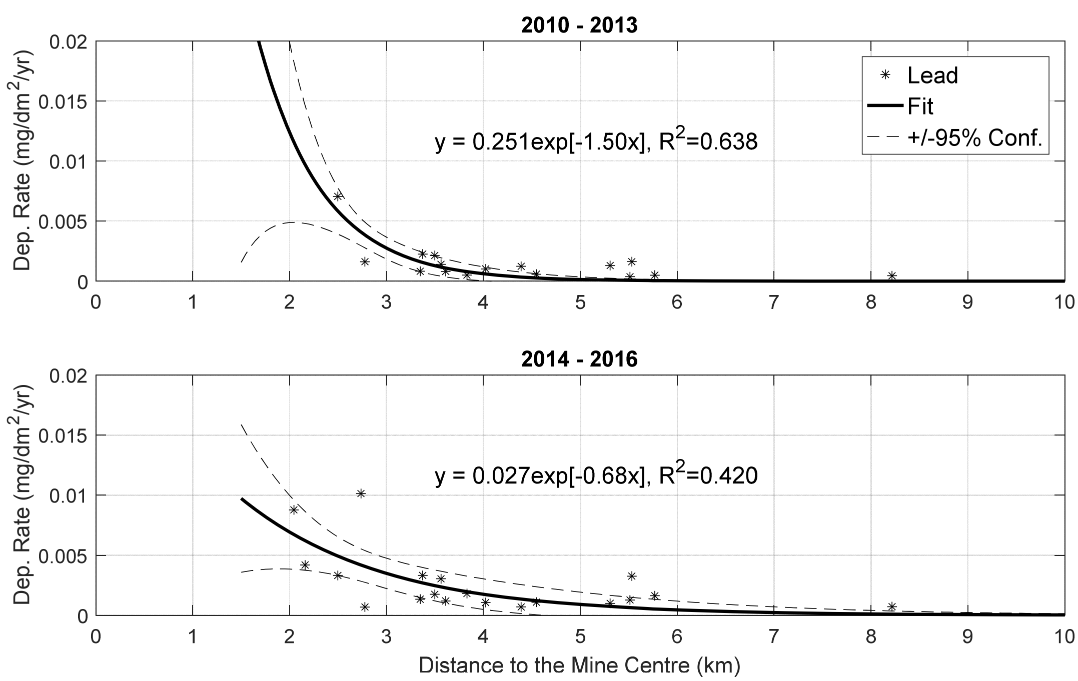
mg/dm²/yr = milligrams per square decimetre per year.

Figure 3-16 Aluminum Deposition as a Function of Distance from the Mine Centroid



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

Figure 3-17 Lead Deposition as a Function of Distance from the Mine Centroid



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

3.3.4 Spatial Distribution of Environmental Loadings

Environmental (or annual "mass") loadings (in t/yr) of dust, nutrients and metals were computed after spatially interpolating the areal loadings and integrating the resulting contour surface. Areal loadings within the Mine footprint are excluded from the analysis, because there are no observations in this region. Areal loadings in the near-field region (<1.5 km) outside the mine footprint as well as loadings deposited directly to Lac de Gras and to the Lac de Gras watershed, excluding Lac de Gras, were also computed. The spatial distribution of the loadings, and the magnitude of the background loadings versus loadings from the Mine are tabulated and discussed in the follow sections.

3.3.4.1 Dustfall

Figure 3-18 illustrates the spatial distribution of annual dust deposition rates around the Mine footprint for each of the four time periods. Table 3-12 summarizes the background and Mine-related loadings of dust for each period, for the near-field region, Lac de Gras , and the Lac de Gras watershed (excluding the lake).

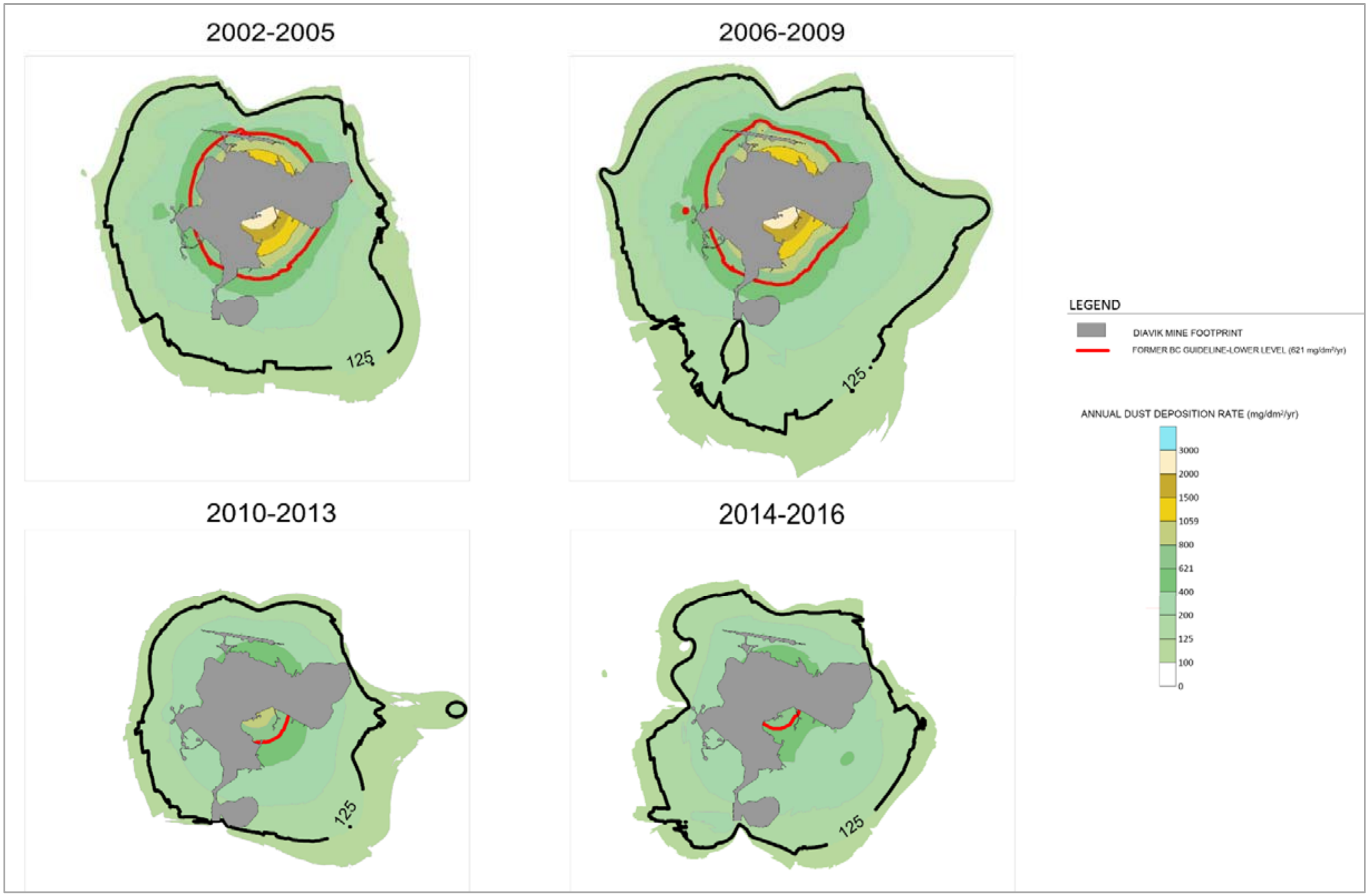
The red contour line on Figure 3-18 represents the former BC dustfall guideline of 621 mg/dm^2/yr. The area bound by the red contour peaked in the 2006 to 2009 time period and has declined since. The 125 mg/dm^2/yr contour represents the geometric mean, plus one geometric SD, of the background dust deposition rate. This area represents the contour beyond which dust deposition is effectively indistinguishable from the background rate of dust deposition.

Whereas loadings in the near-field region were as high as 4 times the background deposition rate in 2006 to 2009, the deposition rate in 2014 to 2016 is below 2 times the natural rate. Dust depositing to the aquatic environment in Lac de Gras from mining activities Lac de Gras increased local dust deposition by 15% to 30%, but deposition to the watershed as a whole is considered insignificant (i.e., <2.5% increase).

Table 3-12 Summary of Total Dust Deposition Loadings (t/yr)

Time Period	Near-Field (<1.5 km)		Lac de Gras		Watershed	
	Background	From Mine	Background	From Mine	Background	From Mine
2002-2005	335	1,259	3,580	1,023	22,146	517
2006-2009	419	1,422	4,485	1,153	27,742	599
2010-2013	243	654	2,600	576	16,085	285
2014-2016	346	594	3,704	504	22,912	232

Figure 3-18 Spatial Distribution of Dust Deposition around the Mine



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

3.3.4.2 Nutrients

Figure 3-19 illustrates the spatial distribution of TP and OP deposition around the Mine footprint for the most recent two time periods (i.e., 2010 to 2013 and 2014 to 2016).

The extent of nutrient deposition rates appear to increase from the 2010 to 2013 time period to the 2014 2016 time period. However, the deposition rates shown in the distribution map include the background rates of phosphorus deposition. The background deposition rates of TP and OP were greater in the 2014 to 2016 time period than in the 2010 to 2013 time period (Table 3-13). The greater background deposition rates have contributed to the apparently larger extent of phosphorus deposition in the later time period (2014 to 2016). The spatial extent of the high deposition rates (i.e. >0.4 mg/dm^2/yr of TP and >0.1 mg/dm^2/yr of OP) decreased from the 2010 to 2013 time period compared to the 2014 to 2016 time period.

The background and Mine-related loadings of TP and OP deposition in the near-field region (<1.5 km), Lac de Gras, and its watershed are summarized in Table 3-13 and Table 3-14. The TP loadings and the OP loadings from Mine activities that were deposited in the near-field, Lac de Gras, and Lac de Gras watershed all decreased from the 2010 to 2013, to the 2014 to 2016 time period. Whereas TP loadings were over 6 times background values in 2010 to 2013 in the near-field region, during the most recent period they were approximately 2.3 times the natural deposition rate.

Orthophosphate represents the most bioavailable form of phosphorus. In the 2010 to 2013 time period, Mine-related emissions resulted in OP deposition of approximately 2.3 times the natural rate in the near-field region. During the most recent observation period, the deposition rate was only 70% greater than the natural rate. It is important to note that observed variability in the natural background rate of OP deposition (~0.03 mg/dm^2/yr in the near-field region) is a significant fraction of the additional loadings due to mining activities (i.e., 0.09 and 0.05 mg/dm^2/yr in the near-field region for the two time periods).

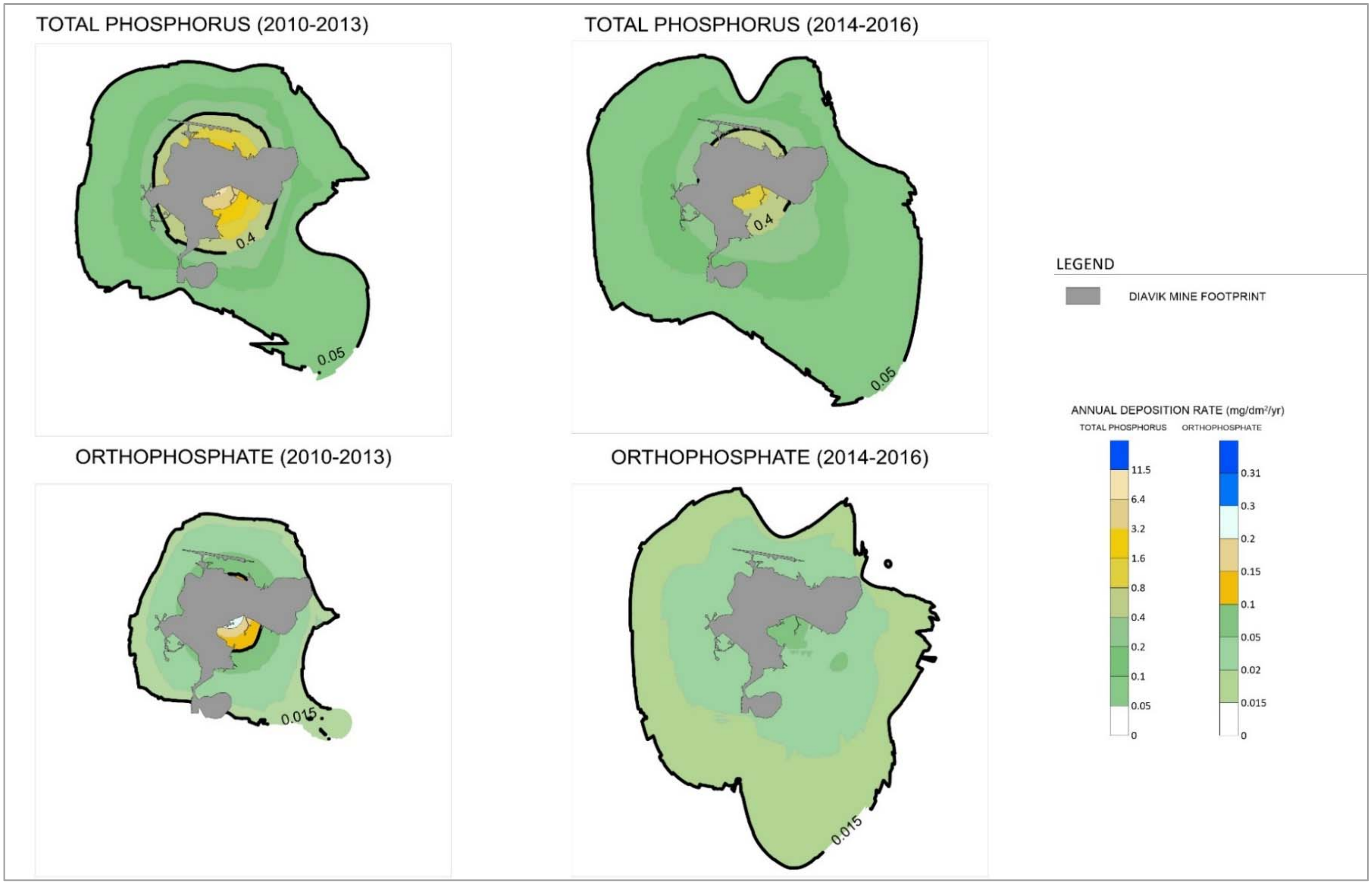
Table 3-13 Summary of Total Phosphorus Deposition Loadings (t/yr)

Time Periods	Near-Field (<1.5 km)		Lac de Gras		Watershed	
	Background	From Mine	Background	From Mine	Background	From Mine
2010-2013	0.20	1.35	2.2	0.87	14	0.56
2014-2016	0.25	0.56	2.7	0.44	16	0.24

Table 3-14 Summary of Orthophosphate Deposition Loadings (t/yr)

Time Intervals	Near-Field (<1.5 km)		Lac de Gras		Watershed	
	Background	From Mine	Background	From Mine	Background	From Mine
2010-2013	0.04	0.09	0.44	0.06	2.72	0.034
2014-2016	0.07	0.05	0.80	0.05	4.93	0.026

Figure 3-19 Spatial Distribution of Total Phosphorus and Orthophosphate Deposition around the Mine



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

3.3.4.3 Metals

Figure 3-20 presents the spatial distribution of aluminum and lead deposition around the Mine footprint for the two most recent time periods (i.e., 2010 to 2013 and 2014 to 2016). The metal deposition rates include the background deposition rates, which were greater during the period of 2014 to 2016 than 2010 to 2013 (Table 3-15 and 3-16).

The greater background deposition rates have contributed to the apparent larger spatial extent of metal deposition rates in 2014 to 2016. Similarly, the highest metal deposition rates were found closest to the Mine footprint. The extent of the high deposition rates (i.e. >10 mg/dm^2/yr of aluminum and >0.01 mg/dm^2/yr of lead) decreased between the 2010 to 2013 time period and the 2014 to 2016 time period.

The background and total loadings of aluminum and lead deposition in the near-field region (<1.5 km), Lac de Gras , and Lac de Gras watershed are summarized in Table 3-15 and Table 3-16. Aluminum deposition appears to have increased slightly from 2010 to 2013 time period versus the 2014 to 2016 time period. However, the difference in the aluminum loadings between these time periods (i.e., 0.7 mg/dm^2/yr) is smaller than the variability in the natural aluminum deposition in this period (i.e., 2.4 mg/dm^2/yr). Lead deposition may have decreased slightly between the two time periods.

Deposition of aluminum and lead are 2 to 4 times, and 1.4 to 7.5 times, respectively, greater than the background deposition rates in the near-field region. However, for deposition to Lac de Gras, these Mine-related inputs represent only a 17% to 28% increase in natural aluminum deposition, and 15% to 50% increase in natural lead deposition. Over the entire watershed, these additional inputs are insignificant to very low (i.e., <2.5% to <5%).

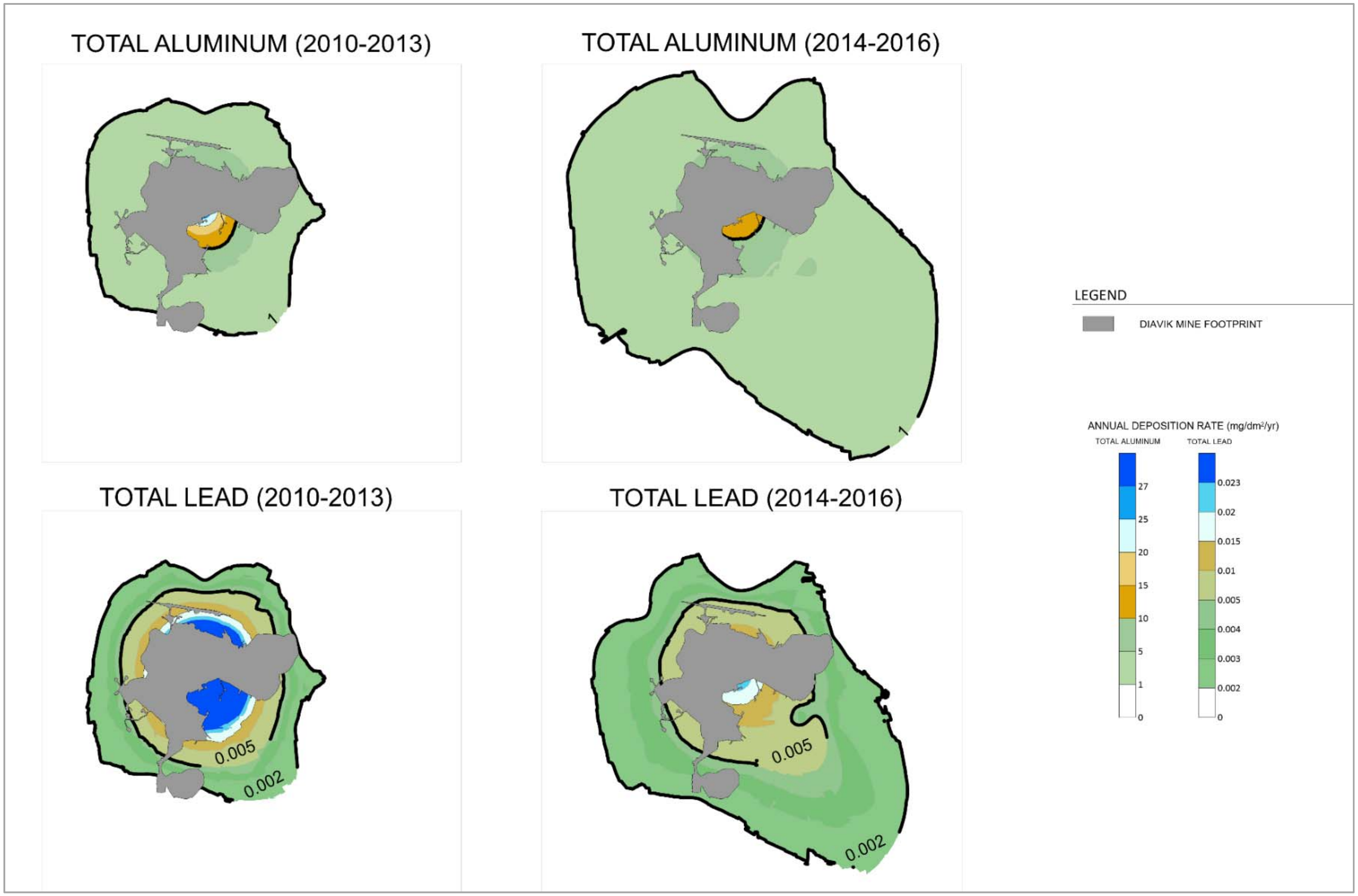
Table 3-15 Summary of Aluminum Deposition Loadings (t/yr)

Time Period	Near-Field (<1.5 km)		Lac de Gras		Watershed	
	Background	From Mine	Background	From Mine	Background	From Mine
2010-2013	1.9	7.6	20	5.5	123	3.0
2014-2016	4.3	8.3	46	7.7	283	3.9

Table 3-16 Summary of Lead Deposition Loadings (t/yr)

Time Period	Near-Field (<1.5 km)		Lac de Gras		Watershed	
	Background	From Mine	Background	From Mine	Background	From Mine
2010-2013	0.004	0.03	0.04	0.02	0.26	0.011
2014-2016	0.007	0.01	0.07	0.01	0.44	0.005

Figure 3-20 Spatial Distribution of Aluminum and Lead Deposition around the Mine



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

3.4 Comparison to EA Predictions

Overall, deposition rates of dust measured since 2001 have exceeded those predicted by the air quality modelling in the original EA (DDMI 1998b). A comparison of the EA predictions and the observations are found in Table 3-17.

During the EA, the air quality model predictions focussed on conservatively estimating effects to air quality during the operating phase of the mine. The model predictions assumed relatively small particulate matter sizes for dust, which tends to predict greater concentrations in air, and consequently lower rates of dust deposition (i.e., more dust remains suspended longer). The predictions also did not account for construction activities, which occurred in parallel with mining activities in 2005 through 2010. In general, these were the years with the highest observed dust deposition rates.

From a regulatory perspective, dust deposition rates are best compared to the former “lower” BC dustfall objective of 621 $mg/dm^2/yr$ for mining, smelting and related industries. As indicated in Table 3-17, only 3 stations exceeded this air quality objective in the 2010 to 2013 time period; one annual exceedance each at stations Dust 2A and Dust 03 in 2010, and one at Dust 03 in 2011. There have been two exceedances of this objective in the 2014 to 2016 time period, which occurred at the Dust 03 and Dust 10 stations in 2016.

An alternative metric is a comparison of the observed dustfall rates to the former “upper” BC dustfall objective of 1,059 $mg/dm^2/yr$ for mining, smelting and related industries. There was a single annual exceedance of this deposition rate in 2010 at Station Dust 03, and there have been no exceedances of this objective between 2011 and 2016 (Table 3-17).

Table 3-17 Predicted and Calculated Annual Dustfall Deposition Rates for Dust Gauges, 2002 to 2016

Dust Gauge	EA[(a)] ($mg/dm^2/yr$)	Observed Dustfall Deposition ($mg/dm^2/yr$)														
		2002	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
Dust 01	50	**905**	308	514	**834**	**1051**	521	**774**	420	501	281	430	262	353	391	462
Dust 2A	100	464	**797**	**1,299**	**1,118**	444	**748**	**953**	**1,162**	**1,023**	481	285	155	197	246	350
Dust 03	100	**810**	**1,415**	**2,062**	**4,046**	**1605**	**2,345**	**2,335**	**1,672**	**1,169**	**995**	430	315	480	582	**721**
Dust 04	20	369	179	338	**1,283**	519	**1,195**	500	**686**	257	210	371	122	140	148	134
Dust 05	40	113	47	***<u>1,433</u>***	279	136	103	245	155	148	151	110	121	110	103	81
Dust 06	125	—	**884**	**1,442**	**1,179**	526	**799**	**858**	**879**	561	309	166	175	430	346	486
Dust 07	40	—	131	166	442	134	153	326	563	433	135	157	192	385	458	213
Dust 08	25	—	43	237	524	142	211	338	303	221	127	128	95	157	121	199
Dust 09	15	—	—	—	—	40	31	187	352	93	206	242	102	89	88	63
Dust 10	25	—	—	—	—	—	—	215	137	237	152	31	122	133	282	**799**
Dust C1	6	—	26	38	52	31	40	199	114	101	95	55	49	105	98	45
Dust C2	12	—	46	46	245	90	*<u>549</u>*	239	158	130	122	83	67	61	112	185

Note: Values in **bold** indicate an exceedance of the "lower" BC dustfall objective for mines; values in *<u>italic and underline</u>* indicate outliers.

a) DDMI 1998a.

EA = Environmental Assessment

3.5 Summary and Conclusions

The following subsections summarize conclusions related to the deposition of dust, nutrients and the metals aluminum and lead.

Background Dust Deposition Rate

- The background dust deposition rates were 62, 78, 45, and 65 $mg/dm^2/yr$ for the time periods of 2002 to 2005, 2006 to 2009, 2010 to 2013, and 2014 to 2016, respectively. These values are based on the geometric mean of the pooled dustfall gauge and snowdust data collected at control stations, and the stations with dust deposition rates that were not significantly different from rates of deposition observed at the control stations.
- The composite 2002 to 2016 background dust deposition rate (and 1-σ range) was 62 $mg/dm^2/yr$ (31 to 124 $mg/dm^2/yr$).

Temporal Trends in Dust Deposition Rate

- Highest dust deposition rates were observed during the time period of 2004 to 2009 for most stations, but especially those nearest the mine. This was a period of active mining as well as mine construction.
- A weak seasonal trend was observed, with lowest deposition rates occurring in the fall. Deposition rates were similar in other seasons.
- The estimated maximum dust deposition rates at the Mine boundary have decreased over time. Values are summarized as follows:
  - 3,095 $mg/dm^2/yr$ for the 2002 to 2005 period
  - 2,900 $mg/dm^2/yr$ for the 2006 to 2009 period
  - 1,069 $mg/dm^2/yr$ for the 2010 to 2013 period
  - 775 $mg/dm^2/yr$ for the 2014 to 2016 period

Spatial Trends and Dust Loadings

- Based on data from 2002 to 2016, dust deposition rates at dustfall gauge Dust 09 were not significantly different from background values measured at control gauges Dust C1 and Dust C2.
- Snowdust stations generating data that could not be distinguished from background values (based on the mean of the pooled 2002 to 2016 dust deposition rates) were: SS1-5; SS2-3, SS2-4; and SS5-1 through SS5-5.
- Between 2002 and 2016, dust deposition rates beyond approximately 3.7 to 4.5 km (mean of 4.2 ± 0.4 km) from the Mine centroid were, on average, not significantly different from background deposition rates.

- Dust loadings in the near-field region (<1.5 km), excluding the Mine footprint, decreased from 1,422 t/yr in 2006 to 2009, to 594 t/yr in the 2014 to 2016 time period.
- Dust loadings from mining activities to Lac de Gras decreased from 1,153 t/yr in 2006 to 2009, to 504 t/yr in the 2014 to 2016 period.
- Dust loadings from mining activities to the Lac de Gras watershed also declining from 599 t/yr to 232 t/yr from the 2006 to 2006 period to the 2014 to 2016 time period.

Background Snow Water Nutrients Deposition Rates

- Background TP deposition rates were 0.038 mg/dm^2/yr and 0.46 mg/dm^2/yr in the 2010 to 2013, and 2014 to 2016 time periods, respectively. These data include stations identified as having dust deposition rates not significantly different from dust deposition rates at the background stations.
- Background OP deposition rates were 0.008 mg/dm^2/yr and 0.010 mg/dm^2/yr in the 2010 to 2013, and 2014 to 2016 time periods, respectively.

Temporal Trends in Nutrient Deposition Rates

- Robust linear regressions were found between winter TP and OP deposition and the winter dust depositions and enable temporal extrapolation of seasonal deposition rates to annual rates using annual rates of dust deposition.
- Estimates of TP deposition rates at the Mine boundary have decreased from 8.6 mg/dm^2/yr for the 2010 to 2013 period, to 1.7 mg/dm^2/yr for the 2014 to 2016 period.
- Estimates of OP deposition rates at the Mine boundary have decreased from 0.26 mg/dm^2/yr for the 2010 to 2013 period to 0.07 mg/dm^2/yr for 2014 to 2016 period.

Spatial Trends and Nutrient Loadings

- Linear regressions of wintertime TP and OP deposition to wintertime dust deposition were robust, indicating these compounds are likely particulate-bound and emitted as dust.
- Linear regressions of wintertime ammonia to wintertime dust deposition were poor, and regressions for N+N to wintertime dust deposition indicated no relationship. This indicates some ammonia may be emitted as a blasting residue associated with dust, but that the majority of the nitrogen species being deposited to the snowpack are not associated with fugitive emissions of mineral dust.
- Based on data from 2010 to 2016, the deposition rates of TP, OP, and ammonia in snow from exposure stations were significantly greater than rates observed in snow sampled at the background stations.
- Deposition rates of N+N were not significantly different between exposure and background stations.
- The TP loadings in the near-field region, over Lac de Gras, and in the watershed each decreased from the 2010 to 2013 time period to the 2014 to 2016 time period.

- The OP loadings in the near-field region, over Lac de Gras, and in the watershed each decreased from the 2010 to 2013 time period to the 2014 to 2016 time period.

Background Snow Water Metals Deposition Rates

- The background deposition rates of aluminum were 0.35 and 0.80 mg/dm^2/yr for the 2010 to 2013 period and 2014 to 2016 period, respectively.
- The background deposition rate for lead was 0.001 mg/dm^2/yr for both time periods.
- The background deposition rates of metals were greater in 2014 to 2016 period than during the 2010 to 2013 period.

Temporal Trends in Metals Deposition Rate

- Robust linear regressions were found between winter aluminum and lead deposition, and the winter dust deposition, indicating these compounds are emitted as dust.
- Estimates of aluminum deposition rates at the Mine boundary have decreased from 26 mg/dm^2/yr for the 2010 to 2013 period to 15 mg/dm^2/yr for 2014 to 2016 period.
- Estimates of lead deposition rates at the Mine boundary have decreased from 0.17 mg/dm^2/yr for the 2010 to 2013 period to 0.02 mg/dm^2/yr for 2014 to 2016 period.

Spatial Trends and Metal Loadings

- Based on data from 2010 to 2016, the deposition rates of aluminum and lead in snow calculated from exposure station data were significantly greater than deposition rates observed in snow sampled at the background stations.
- Aluminum loadings from mining activities to the near-field region in Lac de Gras, and watershed increased slightly from the 2010 to 2013 time period, versus the 2014 to 2016 time period. However, the increase in deposition was small compared to differences in the background rates of aluminum deposition in the two time periods.
- Total lead loadings from the Mine either decreased slightly or were unchanged between the 2010 to 2013 and the 2014 to 2016 time periods.

4 EFFLUENT AND WATER QUALITY

4.1 Introduction

This chapter provides a summary of changes observed in the Mine effluent from the North Inlet Water Treatment Plant (NIWTP) and water chemistry of Lac de Gras over time. The objectives of this chapter are to:

- summarize Mine-related effects on water quality in Lac de Gras, from 2014 to 2016, and compare these to effects observed previously (i.e., from 2007 to 2013)
- analyze temporal trends in the water quality of Lac de Gras for the period extending from baseline (i.e., 1996) to 2016

This chapter contains information on the background and history of the water quality component of the AEMP for the Mine, including details on data sources and changes in sampling locations over time. The methods for the analysis are discussed in terms of criteria for identifying substances of interest (SOIs), data handling (e.g., data screening and censoring; QA/QC), and data analysis for both the treated effluent (hereafter referred to as effluent) and water quality within Lac de Gras. Results for the effluent analysis include identification of temporal trends in effluent loads/concentrations and mixing zone concentrations of SOIs, comparisons of effluent quality to effluent quality criteria (EQC) in the Water Licence, and a summary effluent toxicity over time. Analysis of the AEMP water quality data includes:

- evaluation of temporal trends over time in both depth profiles of field measurements and discrete samples
- summary of Action Levels over time
- evaluation of the potential effects of dust deposition and dike construction
- evaluation of cumulative effects in Lac de Gras
- summary of WOE analysis results ratings associated with water quality
- comparison of water quality results to predictions from the EA

The results presented in this chapter assist in the interpretation of temporal patterns identified in other components of the AEMP.

4.1.1 Background

DDMI has been conducting baseline studies and monitoring programs related to the aquatic ecosystem of Lac de Gras since 1994, with AEMP data collected under AEMP study designs Version 1.0 (2001 [5] to 2006), Version 2.0 (2007 to 2011), Version 3.0 (2012 to 2016), and most recently under Version 4.0 (2017; to be reported in the *2017 AEMP Annual Report*). Since there is potential for Mine effluent to affect Lac de Gras,

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[5] One year of baseline data were also collected in 2000 under the AEMP Version 1.

water quality has been monitored annually since 2001 as part of the AEMP. The objective of the effluent and water quality component is to monitor Mine-related effects over space and time and to confirm the predictions set forth in the EA (DDMI 1998a). More specifically, the program has been designed and implemented to:

- monitor effluent quality/toxicity and water chemistry at the edge of the mixing zone and throughout Lac de Gras
- compare SOI concentrations in the NF area to MF and FF areas
- identify trends in SOI concentrations over time and along defined spatial gradients in Lac de Gras
- consider effects of Mine-generated dust on the water quality of Lac de Gras
- implement actions through the Response Framework when a variable triggers an Action Level
- investigate potential cumulative effects within Lac de Gras due to effluent discharges from both the Ekati and Diavik diamond mines
- provide evidence to support of the WOE evaluation process

4.1.2 Component History

Effluent and lake water quality data have been collected for the Mine's Surveillance Network Program (SNP) to track trends in the loading rates and concentrations of key variables in the Mine effluent over time, and to monitor water quality at the mixing zone boundary in Lac de Gras. The SNP monitoring period considered in this summary extends from 26 March 2002, when discharge of effluent from the Mine began, to 31 December 2016.

Water quality sampling for detailed chemistry analysis in Lac de Gras began in 1996 as part of the environmental baseline work completed to support the EA. Results obtained from these studies, up to and including results from 2000, represented the baseline or pre-development conditions in Lac de Gras. Water quality in Lac de Gras has been monitored as part of the Mine's AEMP since 2001; the original AEMP (Version 1.0) included one water quality sampling event in 2000 prior to the discharge of Mine effluent to Lac de Gras. The first AEMP water quality monitoring event during effluent discharge to Lac de Gras was in April 2002.

Water quality monitoring stations associated with the Mine's SNP and AEMP are described further in Section 4.2.1.

4.2 Methods

4.2.1 Data Sources

The effluent and water quality program for the Mine generates two types of data: 1) the SNP data for effluent and mixing zone chemistry, and 2) the AEMP data for water quality of Lac de Gras. For the effluent, mixing zone, and water quality in Lac de Gras, the same historical dataset as in the *2011 to 2013 Aquatic Effects Re-evaluation Report* (Golder 2016a) is used herein, and data from 2014, 2015, and 2016 were added. Therefore, the primary information sources for this monitoring component are as follows:

- *2011 to 2013 Aquatic Effects Re-evaluation Report* (Golder 2016a), including:
  - baseline data collected by DDMI from 1996 to 2000
  - data collected under AEMP Study Design Version 1.0 (2001 to 2006)
  - data collected under AEMP Study Design Version 2.0 (2007 to 2011)
  - data collected under AEMP Study Design Version 3.0 (2012 to 2013)
- *Effluent and Water Chemistry Report* (Appendix II) of the 2014 AEMP Annual Report (Golder 2016b)
- *Effluent and Water Chemistry Report* (Appendix II) of the 2015 AEMP Annual Report (Golder 2016c)
- *Effluent and Water Chemistry Report* (Appendix II) of the 2016 AEMP Annual Report (Golder 2017c)

Data used in figures, load calculations and the trend analysis were extracted from existing databases for the SNP effluent and mixing zone stations, and AEMP water quality stations. Sections 4.2.1.1 and 4.2.1.2 provide further details on the monitoring stations associated with these two data sources.

4.2.1.1 Effluent and Mixing Zone

Effluent from the NIWTP is sampled from two diffusers. Sampling station SNP 1645-18 is for the original diffuser, which discharged continuously to Lac de Gras over the 2002 to 2016 SNP monitoring period. Monitoring station SNP 1645-18B provides data for the second diffuser, which became operational on 13 September 2009. Samples are collected approximately every six days at these stations. In addition to the chemical analysis of these samples, acute and chronic toxicity of samples from both stations are tested on a quarterly basis. Lake water samples are collected monthly at the mixing zone boundary at each station, at the water surface and at 5 m depth intervals.

Water quality samples are collected at the mixing zone boundary at three stations (SNP 1645-19A, SNP 1645-19B/B2, and SNP 1645-19C), located along a semi-circle, approximately 60 m from the effluent diffusers. These stations represent the edge of the mixing zone, which covers an area of approximately 0.01 km^2. Station SNP 1645-19B2 was established in 2009 to replace Station SNP 1645-19B after the second diffuser became active in Lac de Gras.

Data from these SNP stations are incorporated into the water quality analysis for the AEMP, both annually and in re-evaluation reports, to evaluate the link between the Mine effluent and potential changes in water quality of Lac de Gras.

4.2.1.2 Water Quality

The AEMP for the Mine has sampled water quality at various locations throughout Lac de Gras over time (Table 4-1; Figures 2-1 to 2-5):

- the NF area located near the effluent diffusers
- the MF areas (i.e., MF1, MF2-FF2, and MF3)
- the FF areas (i.e., FF1, FFA, and FFB); data from these areas were used to develop normal ranges, as described in the *AEMP Reference Conditions Report Version 1.2* (Golder 2017b)

In addition to sampling in the aforementioned areas of Lac de Gras, water is also sampled in Lac du Sauvage, immediately upstream of the outflow to Lac de Gras (LDS-1, LDS-2, LDS-3), and at the outlet from Lac de Gras to the Coppermine River (LDG-48; Table 4-1).

The locations and the naming of sampling stations for the AEMP have changed since the baseline period, and over the various versions of the AEMP (Table 4-1). Changes in the AEMP design were implemented to support the overall goals of the AEMP to detect effects in the lake and the rationale for change is described in detail in the various design documents. For the water quality component, a significant expansion of the sampling program occurred during the *AEMP Study Design Version 2.0* (2007 to 2011). Sampling stations for Version 2.0 were located according to effluent concentrations, which were estimated by plume delineation studies (DDMI 2007). To better delineate the extent of effects and define gradients along each transect in *AEMP Study Design Version 3.0* (2012 to 2016; Golder 2011b), the number of stations within the NF-MF3-FFB-FFA transect was increased (i.e., MF3-7 was added) and the number of stations along the NF-MF1-FF1 transect decreased (i.e., MF1-2 and MF1-4 were removed). From 2012 onwards, the FF2 area has been considered to be part of the NF-MF2-FF2 transect and the number of stations along the transect was decreased (i.e., MF2-2, MF2-4, FF2-1, FF2-3 and FF2-4 were removed). The data collection in 2013 marked the first comprehensive year of sampling for the AEMP Version 3.0, which involved sampling every three years at all NF, MF, and FF stations, and LDG-48 and the three LDS stations; interim years do not include data collection at the FF areas or in Lac du Sauvage. Sampling at the three Lac du Sauvage stations began in 2013.

Samples included in this summary were analyzed by different analytical laboratories: Maxxam Analytics (Maxxam) in Calgary, Alberta (AB) (1996 to 1999 data); Enviro-Test Laboratories (ETL) in Edmonton, AB (2000 to 2006 data); ALS Environmental (ALS; now ALS Canada Ltd.), in Edmonton, AB (2007 to 2010 data), which purchased the ETL facility in 2007; and Maxxam in Burnaby, BC (2011 to 2016 data). Improvements in the analytical DLs over the 1996 to 2016 monitoring period confounded the temporal analysis for some variables. For these variables, data generated using the older, higher DLs could only be reported in the temporal figures as less than the DL (<DL). As well, the suite of variables analyzed since baseline has expanded. As a result, data for some analytes are not available during the baseline and earlier monitoring years.

Water quality data collected for 2014, 2015, and 2016 were collected under methods described in the *AEMP Study Design Version 3.5* (Golder 2014a). Although the *AEMP Study Design Version 3.5* is the approved Version of the AEMP design for the time period relevant to this re-evaluation report (i.e., 2014 to 2016), a number of updates outlined in the *AEMP Design Plan Version 4.0* (Golder 2016d) and in WLWB directives (28 July 2015, 26 May 2016, 14 November 2016 and 2 March 2017 Decision Packages) have been incorporated into the 2016 analysis and, therefore, this report. In general, these updates include an update to the procedure used to select water quality SOIs (i.e., addition of a third selection criterion), inclusion of a new method to evaluate effects from dust deposition, and revisions to the water quality Action Level 2 (Golder 2016d).

Table 4-1 Summary of Baseline and AEMP Water Quality Data, 1996 to 2016

Waterbody	Area	Station[a]	UTM Coordinates[b]		Distance from Diffusers[c] (km)	Years Sampled											
			Easting (m)	Northing (m)		1996-2000[d]	2001-2006[d]	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Lac de Gras[e]	Near-field	NF1	535740	7153854	0.4			X	X	X	X	X	X	X	X	X	X
		NF2 (WQ-06)	536095	7153784	0.5	X		X	X	X	X	X	X	X	X	X	X
		NF3	536369	7154092	0.9			X	X	X	X	X	X	X	X	X	X
		NF4	536512	7154240	1.1			X	X	X	X	X	X	X	X	X	X
		NF5 (LDG-42)	536600	7153864	1.0	X[g]	X	X	X	X	X	X	X	X	X	X	X
	Mid-field 1	MF1-1	535008	7154699	1.5		X	X	X	X	X	X	X	X	X	X	X
		MF1-2	533682	7155356	2.9			X	X	X	X	X					
		MF1-3 (WQ-02, LDG-40)	532236	7156276	4.7	X	X	X	X	X	X	X	X	X	X	X	X
		MF1-4	532494	7157657	7.2			X	X	X	X	X					
		MF1-5	528432	7157066	8.5			X[h]					X	X	X	X	X
	Mid-field 2	MF2-1	538033	7154371	2.4			X	X	X	X	X	X	X	X	X	X
		MF2-2	539198	7154643	3.7			X	X	X	X	X					
		MF2-3	540365	7156045	5.4			X	X	X	X	X	X	X	X	X	X
		MF2-4	540955	7157359	6.9			X	X	X	X	X					
	Far-field 2[f]	FF2-1	541500	7159522	9.3			X	X	X	X	X					
		FF2-2 (LDG-45)	541588	7158561	8.3	X[g]	X	X	X	X	X	X	X	X	X	X	X
		FF2-3	543478	7159267	10.1			X	X	X	X	X					
		FF2-4	543752	7158945	10.2			X	X	X	X	X					
		FF2-5	544724	7158879	11.4			X	X	X	X	X	X	X	X	X	X

Table 4-1 Summary of Baseline and AEMP Water Quality Data, 1996 to 2016

Waterbody	Area	Station(a)	UTM Coordinates(b)		Distance from Diffusers(c) (km)	Years Sampled											
			Easting (m)	Northing (m)		1996-2000(d)	2001-2006(d)	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Lac de Gras(e)	Mid-field 3	MF3-1	537645	7152432	2.7			X	X	X	X	X	X	X	X	X	X
		MF3-2 (WQ-07, LDG-43)	536816	7151126	4.2	X	X	X	X	X	X	X	X	X	X	X	X
		MF3-3	536094	7148215	7.2			X(h)					X	X	X	X	X
		MF3-4 (WQ-05, LDG-41)	532545	7147011	11.0	X	X	X	X	X	X	X	X	X	X	X	X
		MF3-5	528956	7146972	14.6			X(h)					X	X	X	X	X
		MF3-6 (LDG-44)	525427	7148765	18.5	X(g)	X	X	X	X	X	X	X	X	X	X	X
		MF3-7	521859	7150039	22.3								X	X	X	X	X
	Far-field 1	FF1-1	525430	7161043	13.6			X(h)	X	X	X	X		X			X
		FF1-2	524932	7159476	12.9			X(h)	X	X	X	X		X			X
		FF1-3	526407	7160492	12.8			X(h)	X	X	X	X		X			X
		FF1-4	526493	7159058	11.4			X(h)	X	X	X	X		X			X
		FF1-5	526683	7161824	12.8			X	X	X	X	X		X			X
	Far-field B	FFB-1	516831	7148207	26.4			X	X	X	X	X		X			X
		FFB-2	518473	7150712	25.0			X	X	X	X	X		X			X
		FFB-3	518048	7147557	25.2			X	X	X	X	X		X			X
		FFB-4	515687	7150036	27.6			X	X	X	X	X		X			X
		FFB-5 (LDG-50)	516533	7150032	26.8		X	X	X	X	X	X		X			X
	Far-field A	FFA-1	506453	7154021	36.8			X	X	X	X	X		X			X
		FFA-2	506315	7155271	38.3			X	X	X	X	X		X			X
		FFA-3	505207	7153887	38.7			X	X	X	X	X		X			X
		FFA-4	503703	7154081	40.2			X	X	X	X	X		X			X
		FFA-5 (LDG-46)	505216	7156657	40.0	X(g)	X	X	X	X	X	X		X			X
Outlet of Lac de Gras	n/a	LDG-48	490900	7161750	55.6			X	X	X	X	X	X	X	X	X	X
Lac du Sauvage	n/a	LDS-1	546398	7161179	-									X			X
		LDS-2	546807	7160027	-									X			X
		LDS-3	547191	7160256	-									X			X

Note: Shading identifies stations that were discontinued, as per the *AEMP Study Design Version 3.0* (Golder 2011b). These stations are not included in the current report.

a) Current AEMP station names are listed first, and historical sampling station names are provided in parentheses.

b) UTM coordinates are reported as Zone 12, North American Datum (NAD) 83.

c) Approximate distance from the Mine effluent diffusers along the most direct path of effluent flow.

d) For baseline (1996 to 2000) and the *AEMP Study Design Version 1* (2001 to 2006), information is provided only for stations located within current AEMP areas; one year of baseline data was collected in 2000 under *AEMP Study Design Version 1*.

e) SNP 1645-18 and SNP 1645-18B (effluent stations) and SNP 1645-19A, SNP 1645-19B/B2, and SNP 1645-19C (mixing zone stations) are not included in this AEMP data table, as they are specific to the Surveillance Network Program; however, they are used in the AEMP annually and in re-evaluation reports to evaluate the link between the Mine effluent and potential changes to the water quality of Lac de Gras. Data have been collected at these stations since 2002, which discharge from the Mine first began.

f) From 2012 onwards, the FF2 area is considered to be part of the NF-MF2-FF2 transect.

g) Baseline data were available for the year 2000 only.

h) Data were available for the ice-cover season only.

UTM = Universal Transverse Mercator coordinate system; - = not applicable.

4.2.2 Substances of Interest

The intent of selecting SOIs is to identify a meaningful set of variables that will undergo further analyses, while limiting analyses on variables that are less likely to show potential effects. The list of SOIs for this re-evaluation report was developed by including all the effluent and water quality SOIs identified in the 2014, 2015, and 2016 AEMP Annual Reports (Table 4-2).

The procedure used in the 2014, 2015, and 2016 AEMP Annual Reports for selecting SOIs involved criteria that considered concentrations of variables in both the final effluent and in the water of Lac de Gras. More specifically, the following criteria were used for SOI selection, with Criteria 1 and 2 being applied in 2014 and 2015, and all three criteria used in 2016:

- Criterion 1: effluent chemistry data collected at stations SNP 1645-18 and SNP 1645-18B were first compared to EQC defined in the Water Licence (Table 4-3). Variables that exceeded EQCs were considered SOIs. Variables in effluent with concentrations that exceeded AEMP Effects Benchmark values (Table 4-4) were also included in the SOI list, provided there was not a high percentage of values below the DL (greater than [>] 90%).
- Criterion 2: water quality variables were assessed according to the AEMP Response Framework (see Section 4.2.4.2.1). Variables that triggered Action Level 1 (Table 4-5) were added to the SOI list. Action Level 1 involves comparisons of the NF median to two times the median of the reference dataset as described in the *AEMP Reference Conditions Report Version 1.2* (Golder 2017b).
- Criterion 3: variables that trigger an effect equivalent to Action Level 1 at MF area stations that fall within the zone of influence (ZOI) from dust deposition in Lac de Gras (i.e., within approximately 1 km of the Mine boundary: stations MF1-1, MF2-1, MF3-1 and MF3-2) were added to the SOI list. Criterion 3 was first adopted in the *2016 AEMP Annual Report* (Golder 2017c), as directed by the WLWB (2016a), and retained herein to incorporate SOIs identified in association with dust deposition from the Mine.

The full suite of water quality variables analyzed in each year was initially evaluated against the applicable SOI criteria, with the exception of the following analytes or parameter groups:

- variables measured in the field, such as dissolved oxygen (DO), temperature, pH, and specific conductivity, are presented as depth profiles over time in Section 4.3.2.1.1
- carbonate and hydroxide, which are not detectable at the pH range encountered in Lac de Gras
- nutrients that are generally not toxic to aquatic organisms (e.g., phosphorus and some forms of nitrogen), which were evaluated in the Eutrophication Indicators Section (Section 5)
- combined N+N, which is evaluated separately as nitrate and nitrite
- dissolved metals; total metal concentrations were evaluated, which have defined reference conditions for Lac de Gras (as described in the *AEMP Reference Conditions Report Version 1.2* [Golder 2017b]) and AEMP Effects Benchmarks (Table 4-4)

Data for nitrogen parameters that may be toxic to aquatic organisms at elevated concentrations are included herein (i.e., ammonia, nitrate and nitrite) and the Eutrophication Indicators Section (Section 5), because they have the potential to result in both nutrient enrichment and toxicological effects.

In the *2011 to 2013 Aquatic Effects Re-evaluation Report (Golder 2016a)*, calcium, magnesium, potassium and sodium were evaluated as total concentrations. One of the reasons for using the total concentrations previously was because the DLs for the dissolved forms were relatively high and the reported values were often non-detectable (i.e., <DL). Given the recent advances in laboratory measurement of dissolved fractions of major ions and the lowering of associated DLs, the 2014 to 2016 AEMP Annual Reports presented results in terms of dissolved concentrations for these major ions. Because this report represents a transition between the previous and more recent method for handling total and dissolved fractions of these variables, figures and analyses have been presented for both forms and notes have been made if the analysis is specific to a given form.

Analysis of the open-water AEMP water quality data in 2016 demonstrated that construction of the A21 dike interfered with the evaluation of potential effects from Mine-related dust deposition (i.e., Criterion 3) at two of the stations that fall within the ZOI from dust deposition in Lac de Gras (i.e., stations MF3-1 and MF3-2). The influence of dike construction on the analysis of effects from dust and on SOI selection is discussed in Section 4.2.4.2.1 and Section 4.3.2.2.2.

Table 4-2 Effluent and Water Quality Substances of Interest

Substance of Interest	2014		2015		2016		
	Criterion 1 Effluent Screening	Criterion 2 Action Level 1	Criterion 1 Effluent Screening	Criterion 2 Action Level 1	Criterion 1 Effluent Screening	Criterion 2 Action Level 1	Criterion 3 Dust/Dike Effects
Conventional Parameters							
Total dissolved solids, calculated	-	X	-	X	-	X	X
Total suspended solids	-	-	-	-	-	-	X
Turbidity	-	-	-	X	-	X	X
Major Ions							
Calcium	-	X[(a)]	-	X[(a)]	-	X[(a)]	-
Chloride	-	X	-	X	-	X	X
Fluoride	X	-	X	-	X	-	-
Potassium	-	X[(a)]	-	X[(a)]	-	-	-
Sodium	-	X[(a)]	-	X[(a)]	-	X[(a)]	X
Sulphate	-	X	X	-	X	X	X
Nutrients							
Ammonia	-	[(b)]	-	X	-	[(b)]	[(b)]
Nitrate	-	X	-	X	-	X	X
Nitrite	-	-	X	-	X	-	-
Total Metals							
Aluminum	-	X	-	X	X	X	X
Antimony	-	X	-	X	-	-	-
Barium	-	X	-	-	-	-	-
Bismuth	-	-	-	-	-	-	X
Chromium	-	X	-	X	X	-	X
Cobalt	-	-	-	-	-	-	X
Copper	-	X	-	X	-	X	X
Iron	-	-	-	-	-	-	X
Lead	-	X	-	-	-	X	X
Manganese	-	-	-	-	X	X	X
Molybdenum	-	X	-	X	-	X	X
Silicon	-	X	-	X	X	X	X
Strontium	-	X	-	X	-	X	X
Thallium	-	-	-	-	-	-	X
Tin	-	X	-	-	-	-	-
Titanium	-	-	-	-	-	-	X
Uranium	-	X	-	X	-	X	X
Vanadium	-	-	-	X	-	-	X
Zirconium	-	-	-	-	-	-	X

a) Total concentrations in the NF area triggered Action Level 1.

b) Result for ammonia is uncertain due to laboratory quality control issues (Section 4.2.3)

Table 4-3 Effluent Quality Criteria for the North Inlet Water Treatment Plant Discharge to Lac de Gras

Variable[a]	Units	Maximum Average Concentration	Maximum Concentration of Any Grab Sample
Total ammonia	µg-N/L	6,000	12,000
Total aluminum	µg/L	1,500	3,000
Total arsenic	µg/L	50	100
Total copper	µg/L	20	40
Total cadmium	µg/L	1.5	3
Total chromium	µg/L	20	40
Total lead	µg/L	10	20
Total nickel	µg/L	50	100
Total zinc	µg/L	10	20
Nitrite	µg-N/L	1,000	2,000
Total suspended solids	mg/L	15	25
Turbidity	NTU	10	15
Biochemical oxygen demand	mg/L	15	25
Total petroleum hydrocarbons	mg/L	3	5
Fecal coliforms	CFU/100 mL	10	20

a) The water licence also specifies that the effluent pH must be between 6.0 and 8.4.

Source: WLWB 2015b; WLWB 2007 ("Total petroleum hydrocarbons" was previously listed as "Oil and Grease"); the values of the EQC remained the same in the renewed Water Licence of 2015 (W2015L2-0001; WLWB 2015b) compared to those listed in the previous Water Licence (W2007L2-0003; WLWB 2007).

NTU = nephelometric turbidity unit; CFU = colony forming unit; µg-N/L = micrograms nitrogen per litre.

Table 4-4 Effects Benchmarks for Water Quality Variables

Variable	Unit	Effects Benchmarks	
		Protection of Aquatic Life	Drinking Water
Conventional Parameters			
pH	pH units	6.5 to 9.0	6.5 to 8.5
Dissolved oxygen	mg/L	Cold water: early life stages = 9.5 other life stages = 6.5	-
Total dissolved solids	mg/L	500[a]	
Total alkalinity	mg/L	n/a[b]	-
Total suspended solids	mg/L	+5 (24 h to 30 days)[c] +25 (24 h period)[c]	-
Major Ions			
Chloride	mg/L	120	250
Sodium	mg/L	-	200
Fluoride	mg/L	0.12	1.5

Table 4-4 Effects Benchmarks for Water Quality Variables

Variable	Unit	Effects Benchmarks	
		Protection of Aquatic Life	Drinking Water
Sulphate	mg/L	100[(d)]	500
Nutrients			
Ammonia	µg-N/L	4,730[(e)]	-
Nitrate	µg-N/L	3,000	10,000
Nitrite	µg-N/L	60	1,000
Total Metals			
Aluminum (total)	µg/L	-	100/200[(f)]
Aluminum (dissolved)	µg/L	Variable with pH[(e)]	-
Antimony	µg/L	-	6
Arsenic	µg/L	5	10
Barium	µg/L	1,000[(d)]	1,000
Boron	µg/L	1,500	5,000
Cadmium	µg/L	0.1[(e)]	5
Chromium	µg/L	1 (Cr VI)[(g)]	50
Copper	µg/L	2	1,000
Iron	µg/L	300	300
Lead	µg/L	1	10
Manganese	µg/L	-	50
Mercury	µg/L	0.026 (inorganic); 0.004 (methyl)	1
Molybdenum	µg/L	73	-
Nickel	µg/L	25	-
Selenium	µg/L	1	10
Silver	µg/L	0.1	-
Strontium	µg/L	30,000[(h)]	-
Thallium	µg/L	0.8	-
Uranium	µg/L	15	20
Zinc	µg/L	30	5,000

a) Adopted from Alaska DEC (2012).
b) Alkalinity should be no less than 25% of natural background level. There is no maximum guideline (US EPA 1998).
c) Average increase of 5 mg/L (over a period of 24 hours to 30 days) or maximum increase of 25 mg/L in a 24 h-period.
d) British Columbia Ministry of Environment (BC MOE 2013).
e) See Appendix IV.1 in DDMI (2007b) and BC MOE (2001) for description.
f) 100 µg/L for conventional treatment and 200 µg/L for other treatment types.
g) Measurements of total chromium will be compared to the benchmark for chromium VI.
h) Based on results from HydroQual Laboratories(2009) and Pacholski (2009). See text for more information.
- = benchmark not available; IC = ice-cover; OW = open-water; NTU = nephelometric turbidity unit; µg-N/L = micrograms of nitrogen per litre.

Table 4-5 Action Level 1 for Water Quality, Excluding Indicators of Eutrophication

Action Level	Magnitude of Effect[a]	Extent of Effect	Action/Note
1	Median of NF greater than 2 times the median of reference dataset[b] (open-water or ice-cover) and strong evidence of link to Mine	Near-field (NF)	Early warning

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

b) In cases where the reference area median value reported in the reference conditions report was equal to the DL, half the DL was used to calculate the 2 x reference area median criterion to be consistent with data handling methods used for the AEMP.

4.2.3 Data Handling

4.2.3.1 Data Screening

Initial screening of the SNP effluent chemistry (SNP 1645 18 and SNP 1645 18B), mixing zone (SNP 1645 19A, SNP 1645 19B2, and SNP 1645 19C) and annual AEMP water quality datasets was completed before data analyses to identify unusually high or low values in the datasets and decide whether to exclude anomalous data from further analysis. Anomalous values for both the SNP and AEMP water quality datasets used herein are presented in tables and plots in Appendix 4A.

Initial data screening was conducted using a method based on Chebyshev's theorem (Mann 2010) combined with the visual examination of scatterplots. Thus, the data screening approach includes a numerical method to aid in the identification of outliers, removing the subjectivity of classifying values based on visual evaluation of data in scatterplots alone. Details on this data screening approach are provided in Section 2.5.1 of this report and the *Quality Assurance Project Plan Version 3.0* (Golder 2016e). This data screening approach has also been used in AEMP Annual Reports for the Mine (i.e., 2014, 2015, 2016; Golder 2016b,c, and 2017c, respectively).

In 2016, concentrations of a number of water quality variables were elevated at stations in the MF3 area near the A21 dike. When the screening procedure was applied, many of these values were flagged as anomalous (i.e., they were greater than 4.4.7 SD from the mean). Because these values likely represented true concentrations, a more conservative approach was taken. In cases where the screening identified a value in the MF3 area as anomalous, the value was conservatively retained in the dataset if the SD distance from the mean was less than two times the 4.47 SD criterion. This approach is the same as that applied at the mixing zone boundary and in the NF area, and results in the removal of only very extreme values from the dataset.

Initial screening for the SNP and AEMP datasets was completed separately for each calendar year, because concentrations of variables from the NIWTP often vary from one year to another. Data flagged as anomalous were not included in analyses in the effluent and water quality section of the report. While data screening for anomalous values was performed previously on the datasets (Golder 2016a,b,c and 2017c), the screening for the SNP and AEMP water quality datasets were performed again herein, because: 1) the SNP data for 2014 to 2016 was shifted to the calendar year, as opposed to the November to October period used in the annual reports, to calculate annual loadings, which affected the SD for those years and, therefore, the screening; and 2) additional variables were added to the analyses (e.g., variables flagged as SOIs in 2016 due to potential influences relating to dust deposition and dike construction), which required the determination of anomalous data for these variables in the AEMP dataset over time.

From 2002 to 2016, 130 anomalous values were identified within the effluent dataset and 58 anomalous values were identified within the mixing zone dataset, representing 0.2% and 0.08% of the total data points, respectively. In total, 103 anomalous values were identified in the baseline and AEMP water quality datasets, up to and including 2016, representing 0.07% of the total dataset.

4.2.3.2 Censored Data

For the purposes of the AEMP, censored data are concentrations reported below the analytical DL (referred to as non-detect values). Due to the location of Lac de Gras on the Canadian Shield, concentrations of many water quality and nutrient variables are low and at or below the DL. Prior to data analyses, non-detect values were multiplied by 0.5 to achieve a value of half the DL. Substitution with half the DL is a common approach used to deal with censored data (US EPA 2000) and is consistent with the approved methods applied in the calculation of the normal range in the *AEMP Reference Conditions Report Version 1.2* (Golder 2017b). The non-parametric (i.e., percentile based) methods used in this re-evaluation report to assess Action Levels for water quality (Section 4.2.4.2.1) minimized the influence of using a substitution method for censored data. The statistical analysis and handling of censored data for the trend analyses of the AEMP data is described generally in Section 2.4.2 and specifically for water quality in Section 4.2.4.2.2.

4.2.3.3 Quality Assurance/Quality Control

The *Quality Assurance Project Plan Version 3.0* (QAPP; Golder 2016e) outlines the QA/QC procedures employed to support the collection of scientifically defensible and relevant data to address the objectives of the AEMP. The QAPP represents an expansion of the SNP QA/QC plan. The QAPP is designed so that field sampling, laboratory analysis, data entry, data analysis, and report preparation activities produce technically sound and scientifically defensible results. The reader is directed to each of the AEMP Annual Reports and the *2011 to 2013 Aquatic Effects Re-evaluation Report* (Golder 2016a) for a detailed description of QA/QC practices applied to the water quality component of the AEMP and identification of specific quality control (QC) data issues in the years prior to 2014.

The main QC issues reported for the time period relevant to this *2014-2016 AEMP Re-evaluation Report* were as follows:

- In 2014, DDMI identified abnormal results in effluent and lake water samples analyzed for total and dissolved zinc (Golder 2016b). A follow-up investigation of laboratory and site-based procedures determined that the contamination likely originated from the sampling gloves used by the field crew during sample collection and handling (i.e., preservation, filtration). Samples collected during the open-water season were re-analyzed for total and dissolved zinc from a different sample container (routine chemistry). This sample was not filtered or preserved in the field. The open-water season re-analysis results for zinc were retained in all relevant analyses presented in the 2014 Annual Report and herein. Due to the timing of when the contamination was identified, the ice-cover samples could not be re-run from the routine chemistry bottle because the samples had been discarded. As a result, the ice-cover season zinc data were excluded from data analyses and summary tables presented herein and the *2014 AEMP Annual Report*.
- The sample collected at Station LDG-48 during the 2015 ice-cover season appeared to be contaminated. The concentrations of several total metals (aluminum, bismuth, cobalt, iron and tin) were elevated in the sample (Golder 2016c). However, the corresponding dissolved values for these metals

were within the range of concentrations expected for Lac de Gras and for the Coppermine River outflow based on results from previous years, indicating that the elevated values were likely the result of a field or laboratory quality control issue; affected values were removed from the dataset.

- In 2016, DDMI identified abnormal results in open-water AEMP samples analyzed for chloride and sulphate (Golder 2017c). Initial graphical evaluation of the data reported by Maxxam suggested a potential analytical bias within the data, whereby a subset of the samples had elevated chloride and sulphate concentrations. Given that chloride and sulphate are dominant ions in the calculation of total dissolved solids (TDS), the analytical bias also affected calculated TDS. Due to the QC issues identified for chloride, sulphate and TDS, affected values were removed from the open-water dataset.
- Data quality issues with analysis of low levels of ammonia in the AEMP occurred from 2011 to 2016, with the exception of 2015. In general, ammonia concentrations in blank samples analyzed by Maxxam were at or above levels found in Lac de Gras, while concentrations reported in lake-water samples were greater and more variable than values previously provided by another analytical laboratory (2007 to 2010). Efforts that have taken place over 2011 to 2017 to address these issues with ammonia are detailed in Appendix 4B. Due to the QC issues related to ammonia, the 2011 to 2014 and 2016 results were excluded from data analyses completed for the AEMP and herein. The data have been shown in figures to allow visual review of the results reported for ammonia; however, the data should be interpreted with caution given the contamination identified for this variable.

4.2.4 Data Analysis

4.2.4.1 Effluent

4.2.4.1.1 Temporal Trends

The Mine effluent has been assessed in terms of quantity and quality. Trends in effluent quantity were evaluated graphically by plotting total annual discharge volumes (m^3 per year) and loading rates (kilograms per year) of SOIs over time. Loading rates were calculated using the procedure described in the *AEMP Study Design Version 3.5* (Golder 2014a). The total annual load of an SOI was estimated as the sum of monthly loads calculated in each year from 2002 to 2016. Although selected as an SOI, turbidity was excluded from this assessment, because load is not a relevant measure for this variable.

In the *2011 to 2013 AEMP Re-evaluation Report* (Golder 2016a), annual loads were not calculated or plotted for variables with concentrations in effluent that were frequently below the DL (i.e., chloride, fluoride and antimony in 2002; soluble reactive phosphorus (SRP) and chromium from 2002 to 2010; copper from 2008 to 2010; and cadmium and tin from 2002 to 2013). Within this document, annual loads are estimated and plotted for all relevant variables (i.e., SOIs) and years, including those years where effluent concentrations were below the DL 50% or more of the time; half the DL value was used in the mass load calculation. Given the uncertainty of these estimations due to the relatively large number of concentrations below the DL, annual loads falling into this category have been identified specifically in the plots of loads over time.

Scatterplots showing the concentrations of SOIs in effluent were generated for 2002 to 2016. Results for individual grab samples were plotted separately for each sampling station (i.e., SNP 1645-18 and SNP 1645-18B [2009 and later]). Water sampling at the mixing zone is completed monthly at 5 m depth intervals at the three stations. Hence, up to 15 samples were collected each month from 2002 to 2016. Results are summarized by showing the median concentration and 5th and 95th percentile interval for each month. Gaps in the mixing zone concentration plots reflect times when samples could not be collected due to hazardous sampling conditions (e.g., ice-on and ice-off periods).

4.2.4.1.2 Comparison to Effluent Quality Criteria and Effects Benchmarks

The EQC for the Mine discharge are specified in the Water Licence for the Mine (WLWB 2007; WLWB 2015b). Variables that have EQC include total ammonia, aluminum, arsenic, copper, cadmium, chromium, lead, nickel, zinc, as well as nitrite, total suspended solids (TSS), turbidity, biochemical oxygen demand, total petroleum hydrocarbons, and fecal coliforms (Table 4-3). The Water Licence also specifies a range for the effluent pH.

The values of the EQC remained the same in the renewed Water Licence of 2015 (W2015L2-0001; WLWB 2015b) as those listed in the previous Water Licence (W2007L2-0003; WLWB 2007). “Oil and Grease” in the previous licence is now referred to as “Total Petroleum Hydrocarbons” in the renewed licence. In October 2016, the WLWB clarified that the definition of total petroleum hydrocarbons within the SNP would include the carbon range C_6-C_{50} (Petroleum Hydrocarbons F1-F4) (WLWB 2016b). Since November 2016, concentrations of the variable “C_6-C_{50} Hydrocarbons Calculated” have been compared to the EQC for total petroleum hydrocarbons; prior to this, the EQC was primarily compared to concentrations of the variable “Oil and Grease”.

In each annual report, the quality of the effluent has been assessed by comparing water chemistry results at Stations SNP 1645-18 and SNP 1645-18B with the EQC defined in the Water Licence (Table 4-3). A summary of the results is provided in Section 4.3.1.2.

Effluent data have been compared to Effects Benchmarks (Table 4-4) to identify SOIs (see Criterion 1 in Section 4.2.2). Mixing zone data have also been compared to Effects Benchmarks to evaluate EA predictions (see Section 4.3.2.3). The data were compared to benchmark values presented in the *AEMP Study Design Version 3.5* (Golder 2014a) and in Table 4-4.

Aquatic life benchmarks adopted for the AEMP (i.e., Effects Benchmarks) are based on CWQGs for the protection of aquatic life (CCME 1999b), the Canadian Drinking Water Quality Guidelines (Health Canada 1996, 2006), guidelines from other jurisdictions (e.g., provincial and state guidelines), adaptations of general guidelines to site-specific conditions in Lac de Gras (Appendix IV.1 in DDMI 2007), or when appropriate, values from the scientific literature. The Effects Benchmarks used for the AEMP are generally consistent with those established during the EA (referred to as ecological thresholds in the EA), but have incorporated a number of revisions to maintain their relevance over time for the Lac de Gras environment. The benchmarks represent concentrations intended to protect human health or aquatic life. For variables with both aquatic life and drinking water values, the Effects Benchmark is the lower of the two.

4.2.4.1.3 Effluent Toxicity

Part H, Item 30 of the current Water Licence (W2015L2-0001; WLWB 2015b) requires toxicity testing of effluent discharged to Lac de Gras; these same requirements were listed in Part H, Item 7 of the previous

Water Licence (WLWB 2007). The following toxicity tests, carried out on effluent samples from Stations SNP 1645-18 and SNP 1645-18B, have been completed on a quarterly basis:

- acute lethality to Rainbow Trout, *Oncorhynchus mykiss*, as per Environment Canada's Environmental Protection Series Biological Test Method EPS/1/RM/13
- acute lethality to the crustacean, *Daphnia magna*, as per Environment Canada's Environmental Protection Series Biological Test Method EPS/1/RM/14
- chronic toxicity to the amphipod, *Hyalella azteca*, as per a water-only protocol approved by the WLWB
- chronic toxicity to Rainbow Trout, *Oncorhynchus mykiss*, as per Environment Canada's Environmental Protection Series Biological Test Method EPS/1/RM/28
- chronic toxicity to the freshwater alga, *Pseudokirchneriella subcapitata*, as per Environment Canada's Environmental Protection Series Biological Test Method EPS/1/RM/25
- chronic toxicity to the crustacean *Ceriodaphnia dubia* as per Environment Canada's Environmental Protection Series Biological Test Method EPS/1/RM/21

Effluent toxicity has been tested since 2002. Toxicity tests on effluent samples from June 2002 to February 2008 were based on multiple effluent concentrations, whereas testing from March 2008 to December 2016 consisted of single concentration (100% effluent) tests. The multi-concentration tests are reported in terms of the percentage of effluent concentration causing mortality, or a reduction in growth or reproduction endpoints in aquatic test organisms. Toxicity in single concentration tests is considered to occur if there is more than a 50% decrease in the mean response of test organisms in the undiluted effluent sample. Results for single concentration tests are presented as a "pass" or "fail".

In 2014, acute lethality and sub-lethal toxicity tests were completed by HydroQual Laboratories Ltd. (HydroQual) in Calgary, AB; chronic survival and growth testing using the amphipod *Hyalella azteca* was completed by Maxxam, Yellowknife, NT. In 2015, acute lethality and chronic toxicity tests were completed by Nautilus Environmental (formerly HydroQual) in Calgary, AB and Burnaby BC and Maxxam, Burnaby, BC. In early 2015, a decision was made to transition from Nautilus to Maxxam for toxicity test services. During the transition in March 2015, acute and chronic toxicity testing was conducted at both laboratories to allow for a comparison of results between laboratories. In 2016, effluent samples were submitted to both Maxxam and Nautilus Environmental (Burnaby, BC) for toxicity testing. Analytical laboratories used years prior to 2014 are discussed in the annual reports for those years.

4.2.4.2 Water Quality

4.2.4.2.1 Summary of Effects

Action Levels

Water quality variables were assessed for a Mine-related effect as described in the Response Framework section of the AEMP Study Design Version 3.5 (Golder 2014a). The Action Levels for water quality were developed to meet the goals of the draft *Guidelines for Adaptive Management – A Response Framework for Aquatic Effects Monitoring* (WLWB 2010; Racher et al. 2011). The main goal of the Response

Framework is to ensure that significant adverse effects never occur. This is accomplished by requiring proponents to take actions at pre-defined Action Levels, which are triggered well before significant adverse effects could occur. A significant adverse effect, as it pertains to water quality, was defined in the EA as a concentration of a variable that exceeds an established guideline for the protection of aquatic life and drinking water quality by more than 20% (Government of Canada 1999). This effect must have a high probability of being permanent or long-term in nature and must occur throughout Lac de Gras.

The Response Framework for water chemistry was applied for the first time in the *2013 AEMP Annual Report* (Golder 2014c). Based on recommendations made in that report, Action Level 2 was revised, because it was being triggered prior to Action Level 1 (WLWB 2015c). The revisions to Action Level 2 were proposed as an update in the *AEMP Design Plan Version 4.0* (Golder 2016d), which was submitted for WLWB approval on July 15, 2016. The updated Action Levels for water chemistry are presented in Table 4-6. The revised Action Levels were applied successfully as part of the analyses completed for the *2011 to 2013 Aquatic Effects Re-evaluation Report* (Golder 2016a) and the 2014, 2015, and 2016 AEMP Annual Reports (Golder 2016b,c, 2017c). Formal review of the revised Action Level 2 occurred as part of the approval process for the *AEMP Design Plan Version 4.0* (Golder 2016d). The revisions to Action Level 2 were approved by the WLWB on December 22, 2015 (WLWB 2015c).

Water quality is assessed annually relative to the Action Levels for water chemistry. Magnitudes of effects on water chemistry variables were determined by comparing concentrations of variables between monitored areas of Lac de Gras affected by the Mine effluent (e.g., NF, mixing zone) and reference conditions or benchmark values. Reference conditions for Lac de Gras are those that fall within the range of natural variability, referred to as the normal range. The normal ranges used in the Action Level screening for water quality are summarized in Table 4-7 herein and described in the *AEMP Reference Conditions Report Version 1.2* (Golder 2017b). The Effects Benchmarks used in the Action Level assessment are presented in Table 4-4. The magnitude of effect was classified according to the appropriate Action Level (Table 4-6), with Action Level 9 representing a significant adverse effect. The results for all depths and stations sampled, both at the mixing zone boundary and at AEMP stations, were included in the calculation of the values considered at each Action Level. Water quality variables triggered Action Levels if concentrations in the monitored areas exceeded the relevant screening criteria in one or both sampling seasons (ice-cover or open-water).

Trends in Action Level exceedances for water quality SOIs over time are qualitatively evaluated in this report. While a summary of the results of the Action Level analysis over time for water quality is provided in Section 4.2.4.2.1, the reader is directed to the AEMP Annual Reports for detailed results for a given year.

Data quality issues with ammonia from 2011 to 2016, with the exception of 2015, did not allow an evaluation of Action Level exceedance for this variable. The reader is directed to Section 4.2.3 and Appendix 4B for further details.

For the *2011 to 2013 Aquatic Effects Re-evaluation Report* (Golder 2016a), calcium, magnesium, potassium and sodium were evaluated as total concentrations under the total metal category. For reasons specified in Section 4.2.2 (i.e., improvements in DLs for dissolved forms), there has been a shift to evaluating these variables as both dissolved and total fractions.

Table 4-6 Action Levels for Water Quality, Excluding Indicators of Eutrophication

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

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

b) Normal ranges and reference datasets are obtained from the *AEMP Reference Conditions Report Version 1.2* (Golder 2017b); the normal range for open-water are based on the August 15 to September 15 period. In cases where the reference area median value reported in the reference conditions report was equal to the DL, half the DL was used to calculate the 2 x reference area median criterion to be consistent with data handling methods used for the AEMP.

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

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

Table 4-7 Normal Ranges for Water Quality Variables

Variable	Unit	Normal Range			
		Ice-cover		Open-water	
		Lower Limit	Upper Limit	Lower Limit	Upper Limit
Conventional Parameters					
Total alkalinity	mg/L	3.2	6.0	3.1	4.7
Total hardness	mg/L	5.0	7.0	4.0	6.0
Total dissolved solids, calculated	mg/L	2.9	6.5	3.8	5.8
Total dissolved solids, measured	mg/L	0	24.0	0	20.0
Total suspended solids	mg/L	0	1.0	0	1.0
Total organic carbon	mg/L	2.0	3.1	1.9	3.0
Turbidity	NTU	0	0.18	0.13	0.29
Major Ions					
Calcium	mg/L	0.9	1.3	0.8	1.1
Chloride	mg/L	0	1.0	0	1.0
Fluoride	mg/L	0.02	0.03	0.019	0.03
Magnesium	mg/L	0.6	0.8	0.6	0.8
Potassium	mg/L	0.5	0.8	0.4	0.7
Sodium	mg/L	0	1.0	0	1.0
Sulphate	mg/L	1.9	2.5	1.7	2.1
Nutrients					
Ammonia	µg-N/L	14.3	23.0	0	5.0
Nitrate	µg-N/L	0	15.2	0	2.0
Nitrite	µg-N/L	0	2	0	2
Total Metals					
Aluminum	µg/L	2.3	3.9	3.4	6.2
Antimony	µg/L	0	0.02	0	0.02
Arsenic	µg/L	0.15	0.22	0.16	0.19
Barium	µg/L	1.74	2.18	1.61	1.94
Beryllium	µg/L	0	0.01	0	0.01
Bismuth	µg/L	0	0.005	0	0.005
Boron	µg/L	0	5	0	5
Cadmium	µg/L	0	0.005	0	0.005
Calcium	mg/L	0.94	1.15	0.87	1.00
Chromium	µg/L	0	0.06	0	0.06
Cobalt	µg/L	0.01	0.02	0.01	0.04
Copper	µg/L	0	0.8	0	0.6
Iron	µg/L	0	5.0	0	7.6
Lead	µg/L	0	0.007	0	0.006
Lithium	µg/L	1.2	1.5	1.2	1.3

Table 4-7 Normal Ranges for Water Quality Variables

Variable	Unit	Normal Range			
		Ice-cover		Open-water	
		Lower Limit	Upper Limit	Lower Limit	Upper Limit
Magnesium	mg/L	0.59	0.79	0.58	0.66
Manganese	µg/L	0.60	1.95	1.54	4.67
Mercury	µg/L	0	0.01	0	0.01
Molybdenum	µg/L	0.06	0.09	0.07	0.13
Nickel	µg/L	0.83	1.10	0.72	1.12
Potassium	mg/L	0.53	0.67	0.50	0.57
Selenium	µg/L	0	0.04	0	0.04
Silicon	µg/L	0	50	0	50
Silver	µg/L	0	0.005	0	0.005
Sodium	mg/L	0.56	0.75	0.55	0.68
Strontium	µg/L	6.70	8.78	6.51	8.01
Sulphur	mg/L	0.84	1.07	0.83	1.32
Thallium	µg/L	0	0.002	0	0.002
Tin	µg/L	0	0.01	0	0.01
Titanium	µg/L	0	0.5	0	0.5
Uranium	µg/L	0.027	0.030	0.024	0.029
Vanadium	µg/L	0	0.1	0	0.1
Zinc	µg/L	0.37	1.53	0.29	2.04
Zirconium	µg/L	0	0.05	0	0.05

Source: *AEMP Reference Conditions Report Version 1.2* (Golder 2017b)

NTU = nephelometric turbidity unit; µg-N/L micrograms nitrogen per litre.

Effects from Dust Deposition and Dike Construction

Concerns have been raised regarding the potential for dust emissions to affect water quality in Lac de Gras. To address these concerns, in 2016, an analysis of effects at stations potentially affected by dust deposition was conducted, as directed by the WLWB and as per the *AEMP Design Plan Version 4.0* (Golder 2016d). The ZOI from dust deposition in Lac de Gras is estimated to be approximately 4 km from the geographic centre of the Mine, or approximately 1 km from the Mine boundary, extending radially from the source (Golder 2016d). These distances were estimated based on gradient analysis of dust deposition relative to distance from the Mine site, and encompass the area of the lake where potential effects may be measureable (see Figures 3-5 and 3-6 and Table 3-1 in Golder 2016a). Beyond this estimated zone, dust deposition levels are similar to background levels. The AEMP sampling stations that fall within the expected ZOI from dust deposition include the five stations in the NF area and stations MF1-1, MF2-1, MF3-1 and MF3-2.

The combined effects from discharge of Mine effluent and potentially dust deposition on water quality in the NF area are assessed by way of water quality Action Level 1 (Table 4-6). A similar analysis was used to evaluate potential effects from dust emissions at stations in the MF area. Water quality variables at the aforementioned four MF area stations with median concentrations (i.e., of top, middle and bottom samples) that exceed two times the median of reference area data (i.e., the same criterion used in the assessment of Action Level 1 in the NF area) were considered potentially affected by dust deposition, in addition to potential effluent effects. This comparison was only done on the open-water season data, because dust deposition to lake-water under ice (where samples are collected) is prevented by ice cover during the winter. If a variable triggered an effect equivalent to Action Level 1 in the MF area, but not the NF area (i.e., where the concentration of effluent is greatest), it was considered that the effects at these stations may result from dust deposition, or a combination of dust deposition and effluent discharge.

Construction of the A21 dike was ongoing during the 2016 open-water AEMP survey and confounded the analysis of potential dust-related effects in the MF area. Water quality variables with elevated concentrations at AEMP stations near the A21 dike were considered potentially affected by dike construction. Plots were generated that illustrated the concentration of variables inside the silt curtain associated with the A21 dike construction together with concentrations reported at increasing distance from the effluent diffusers, to visually identify if the variables may have been elevated due to the dike construction.

Cumulative Effects in Lac de Gras

Analysis of the potential cumulative effects of the Diavik and Ekati mines on the water quality of Lac de Gras has been included in this re-evaluation report to meet a directive from the WLWB, using a method described in Appendix A – Section 51 in the *AEMP Study Design Version 4.1* (Golder 2017d). A similar analysis was completed for the *2011 to 2013 Aquatic Effects Re-evaluation Report* (Golder 2016a), with that approach adopted as a component of the *AEMP Study Design Version 4.1* and implemented herein.

According to the *2011 to 2013 Aquatic Effects Re-evaluation Report* (Golder 2016a), analysis of the Diavik AEMP water quality data prior to 2014 indicated that the concentrations of certain SOIs at the time (TDS, calcium, magnesium, sodium, sulphate, molybdenum, strontium, conductivity, and hardness) were increasing over time in the FF areas, and that concentrations had exceeded the normal range for Lac de Gras. The spatial trend in these SOIs with distance from the Diavik diffusers reversed as one moved west from the FFB area. These SOIs demonstrated an increase in concentration from the FFB area to the FFA area, and a further increase at station LDG-48. These data suggested that the Slipper Lake outlet, which conveys mine water from the Ekati Mine, was a likely influence on the SOI concentrations at LDG-48 and FFA. Concentrations of several of these SOIs were also elevated at the Ekati Slipper Bay monitoring stations (S2 and S3) in Lac de Gras. Although these results suggested that the Ekati discharge was an additional source of these constituents to Lac de Gras, SOI concentrations in the vicinity of the zone of confluence remained low, indicating that the combined effluent discharges from Ekati and Diavik resulted in a minor effect on Lac de Gras water quality.

As outlined in Appendix A - Section 51 of the *AEMP Study Design Version 4.1* (Golder 2017d), a spatio-temporal gradient approach has been used herein to further evaluate cumulative effects in Lac de Gras from the Diavik and Ekati mines. Given that the direction of water flow in Lac de Gras is from east to west, the concentration of a variable released in the Diavik Mine effluent would be expected to decrease with distance from the Mine effluent diffusers, with the lowest concentrations occurring at the far northwest end of Lac de Gras, at the mouth of the Coppermine River (Golder 2016a; Zajdlik & Associates Inc. 2016). However, an increase in the concentration of a variable in the vicinity of the convergence of the two effluent sources would suggest that the Ekati discharge is a likely influence on a given variable. This interaction would constitute a cumulative effect, since both mines are contributing to an increase in the concentration of a variable.

Cumulative effects were assessed using a temporal approach, by plotting mid-depth concentrations of current SOIs (Table 4-2) at FFB, FFA and LDG-48 over time, which is similar to the method employed in Zajdlik & Associates Inc. (2016) to identify potential cumulative effects on the west side of Lac de Gras. Magnitude of effects was assessed by comparison of SOI concentrations among stations and to the normal ranges for Lac de Gras (Golder 2017b). Data from the Ekati Slipper Bay stations in Lac de Gras (S2, S3, S5, S6) were considered qualitatively in the analysis, to further evaluate the potential influence of Ekati on trends in Lac de Gras.

Weight-of-Evidence Ratings

The results of the AEMP water quality surveys are integrated through the WOE evaluation process, which determines the strength of evidence supporting the two broad impact hypotheses for Lac de Gras (i.e., toxicological impariment and nutrient enrichment), as described in the *AEMP Study Design Version 3.5* (Golder 2014a). The WOE is not intended to determine the ecological significance or level of concern associated with a given change. The WOE effect ratings incorporate statistical comparisons of the NF and FF areas, and comparisons of the NF area to normal ranges defined by Golder (2017b). The AEMP water quality data were assessed according to the WOE effect level ratings described in Section 10 and summarized in Table 4-8. In 2014, the criterion for determining a moderate effect rating for water chemistry was refined to be consistent with the Action Level assessment for water chemistry.

The WOE effects ratings for water quality were applied to variables that were identified as SOIs. For the years 2014 to 2016, relevant to this re-evaluation report, the WOE assessment was completed in 2016 only, which was a comprehensive monitoring year.

Table 4-8 Effect Level Ratings Applied for Exposure Endpoints

LOE Group	Measurement Endpoint Analysis	No Response 0	Early Warning/Low ↑	Moderate ↑↑	High ↑↑↑
Water Quality (substances of potential toxicological concern)	Comparison to FF Areas, Normal Range, Benchmarks, and Effluent Toxicity[(a)]	Does not trigger criteria 1 and 2 of SOI selection procedure[(b)]	Statistically significant increase, NF vs FF areas **OR** Occurrence of effluent acute toxicity test failure	Low + 5th percentile of NF area >two times the FF area median **AND** 5th percentile of NF area >normal range **AND** 5th percentile of NF area greater than Effects Benchmark	Statistically significant increase, MF vs FF areas **AND** 75th percentile of MF area >normal range **AND** 75th percentile of MF area greater than Effects Benchmark

Notes: Normal ranges for each LOE group and measurement endpoint are defined and provided in the *AEMP Reference Conditions Report Version 1.2* (Golder 2017b).

a) Applied separately for each variable.

b) Only those water quality SOIs that met criteria 1 (effluent screening) and 2 (Action Level 1) of the SOI selection procedure were evaluated.

LOE = Line of Evidence; NF = near-field; MF = mid-field; FF = far-field; SOI = substance of interest; >= greater than.

4.2.4.2.2 Temporal Trends

Time Series Plots

Depth Profiles

Profile data for sampling stations used in the statistical analysis were plotted over time to evaluate if changes had occurred from baseline to present in terms of stratification of field-measured variables. Data are provided for DO, temperature, specific conductivity, and pH from 1996 to 2016, when available, at the following locations: NF; MF1-3; FF2-2; MF3-4; FF1; FFB; and FFA; these are the long-term monitoring stations that were selected for the detailed trend analysis. Data are presented for the ice-cover season in April/May and the open-water season, as represented by data recorded in August of each year. Replicate measurements in each of the NF, FF1, FFB, and FFA stations were averaged. It is acknowledged that the WLWB has directed DDMI to include vertical profile data collected at all stations as part of data appendices in future AEMP Annual Reports, beginning with the *2017 AEMP Annual Report* (WLWB 2017c). Data from replicate stations in a given area were averaged, because this report is intended to be a summary of relevant information over time. Data were sourced from the baseline and AEMP annual reports, as described in Section 4.2.1.

Discrete Samples

Discrete water quality sampling in the Mine’s AEMP involves collection of top, middle and bottom depth samples in the NF and MF areas, middle depth samples collected in the FF area, at LDG-48, and the three LDS stations (LDS-1, LDS-2, LDS-3). Near-surface water samples (top) were collected at a depth of 2 m below the water surface, and bottom samples were collected at 2 m above the lake bottom. Mid-depth samples were collected from the midpoint of the total water column depth.

Temporal trends in concentrations of variables in discrete samples from Lac de Gras were illustrated using time series plots; variables other than SOIs were included as directed by the WLWB (WLWB 2017d). These plots were organized based on the AEMP sampling areas in Lac de Gras (i.e., NF, MF, FF, LDG-48/LDS). Non-detect data were included in the time series plots as open symbols, plotted at half the value of the DL. Trends were visually evaluated in relation to the normal range for Lac de Gras and by statistical analysis, as described in the following section.

Mid-depth sample concentrations of SOIs for the ice-cover and open-water seasons have been presented and described in Section 4.3.2.1.2, while concentrations of SOIs in top and bottom samples for the NF and MF areas can be found in Appendix 4C. This appendix also includes the top, middle and bottom samples for the non-SOI variables, together with text describing trends in these variables over time.

Statistical Analysis

The general methods used for statistical analysis of AEMP data are described in Section 2.4.2. The information provided in the following text describes details specific to the statistical trend analysis of the AEMP water quality data.

Water quality data used in the statistical trend analysis were generally those collected after 1999. Observations below analytical DL were considered censored. Censored data can potentially bias summary statistics calculated using parametric statistics, because of violation of underlying assumptions. Based on USEPA guidance, a screening value of greater than 15% censoring was used to flag data sets that may require an alternative data analysis method. The decision of how to analyze the datasets, however, was determined on a variable-by-variable basis. The intent of this process was to select the appropriate method for each variable and season, based on the amount of censoring within each dataset.

In summary:

- The following 18 variables involved high percentages of detectable results and were assessed using the standard statistical method described in Section 2.4.2: turbidity, TDS (calculated), calcium (total), chloride, fluoride, potassium (total), sodium (total), sulphate, nitrate, aluminum, barium, cobalt, copper, iron, manganese, molybdenum, strontium, and uranium.
    - In seven cases, where earlier years of sampling confounded the analysis with many less than DL values, the data from more recent years were used in the analysis; if this was the case, the years of data used are specified for each variable in Section 4.3.2.1.2. Variables that required truncation of data due to high numbers of values less than DL in early years of monitoring included: chloride, fluoride, nitrate (early years and during the open-water season), cobalt, copper, iron, and uranium.
- For total antimony, lead, and tin, a logistic regression method was used, since less than DL values were recorded in multiple years and areas throughout the sampling program, but the overall trends were of interest. In these analyses, a logistic model predicted changes in the odds of observing data above the DL as a function of year and area. Simple, fixed-effects models, without random effects, weights, or autocorrelation terms, were used to allow model convergence. Data were expressed as presence/absence of detected data. Two additive models were constructed, with effects of area and year (as linear or parabolic effect). Model outputs included model selection (between linear and parabolic year effects), parameter significance, whether linear slopes were significantly different from zero, post-hoc multiple comparisons between areas within years, and plots of predicted probabilities overlaying the presence/absence of detected data.
- Trend analyses could not be completed for the following variables, because of the high percentage of data less than the DL: TSS, nitrite, bismuth, chromium, silicon, thallium, titanium, vanadium, and zirconium. The percentage of censored data for each variable is provided in Section 4.3.2.1.2.
- Trend analysis was not completed for ammonia due to QC issues, as described in Section 4.2.3.3 and Appendix 4B.

4.3 Results

4.3.1 Effluent and Mixing Zone

The following section provides information on temporal trends in concentrations in effluent and at the mixing zone boundary over the period of Mine discharge (2002 to 2016). A summary of the comparison of variable concentrations in the effluent to EQC is also provided, together with a summary of effluent toxicity results over time.

4.3.1.1 Temporal Trends in Effluent and at the Mixing Zone Boundary

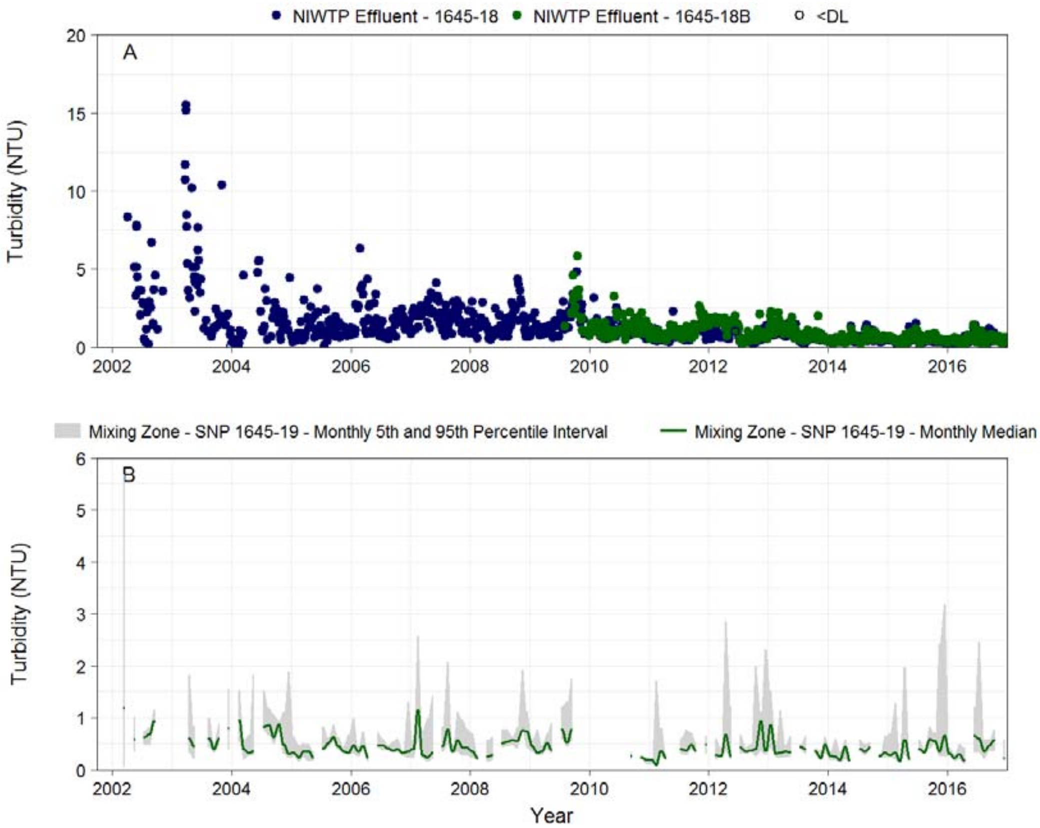
The following section provides details on the temporal trends of SOIs in effluent and the mixing zone from 2002 to the end of 2016. Trends have been assessed using plots of loadings to Lac de Gras from the effluent, rate of effluent discharge, concentrations in the effluent, and concentrations in the mixing zone over time. A statistical evaluation of trends for effluent chemistry was considered, but was determined to be inappropriate due to the non-linear (up and down) trends and seasonal/cyclical nature of concentrations in the effluent within a year and over time, as is illustrated in the figures presented in the following sub-sections of this report. The plots provided are considered to be sufficient to allow a visual evaluation of the variation in effluent variables over time.

4.3.1.1.1 Conventional Parameters

The turbidity of the effluent discharged from the NIWTP peaked during the first two years of effluent discharge (2002 to 2003), but declined gradually over the remainder of the monitoring period (Figure 4-1). Turbidity of the water at the mixing zone boundary was initially elevated, reflecting the increased values in effluent, but has remained within a similar seasonal range since that time.

The annual loads of TSS from the NIWTP generally increased over time from 2002 to 2009 (Figure 4-2), reflecting the increase in the annual volume of effluent discharged. The loading decreased from 2010 to 2012 and has remained within a similar range since that time. The concentration of TSS in the effluent showed a similar trend to the loads, increased from 2002 to approximately 2010, decreased to 2012, and have since remained in a similar range. The concentrations of TSS at the mixing zone was below the DL of 1 mg/L to 3 mg/L in approximately 80% of samples analyzed from 2002 to 2016; results have generally reflected patterns observed in the Mine effluent.

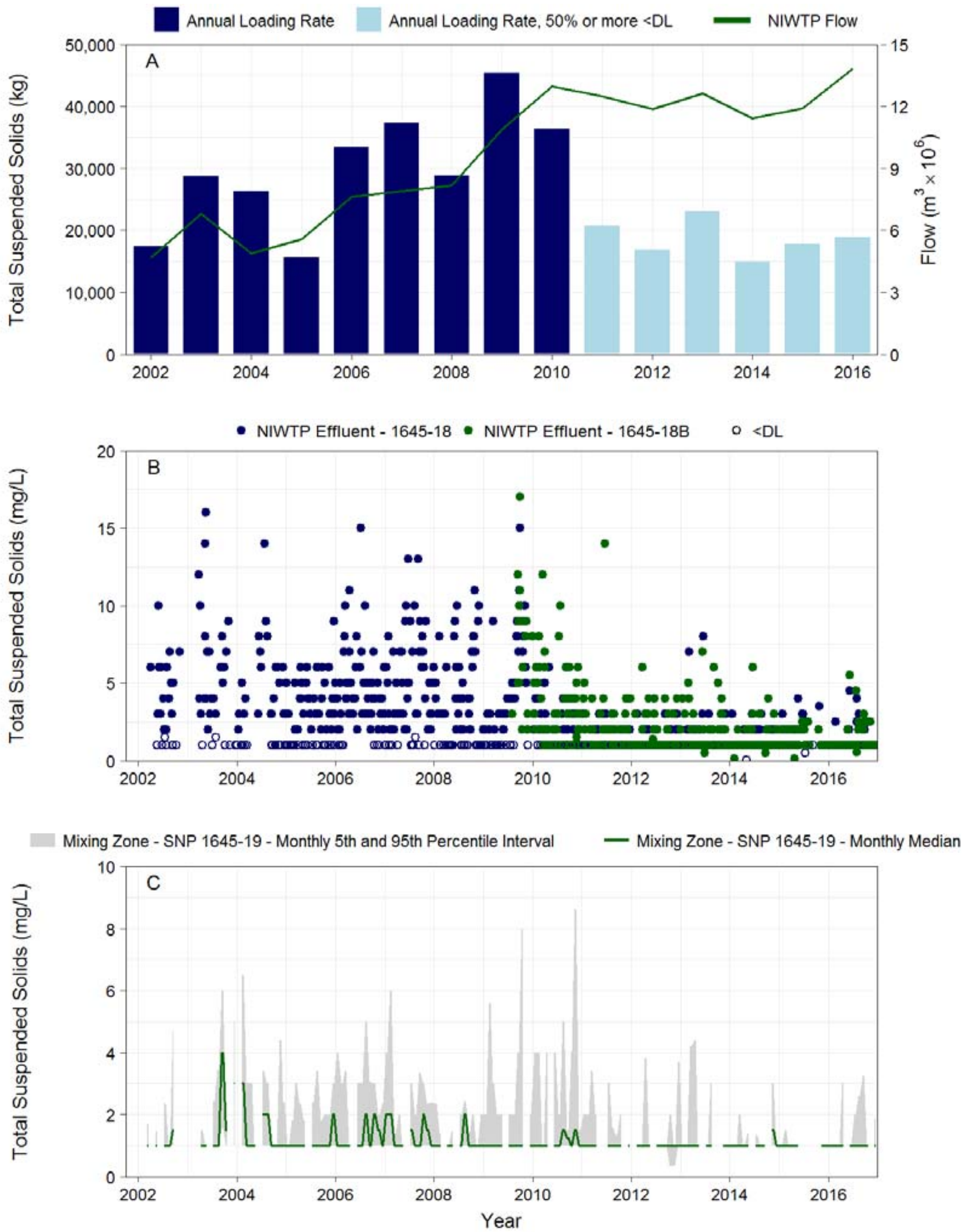
Figure 4-1 Turbidity in A) North Inlet Water Treatment Plant Effluent (SNP 1645-18 and SNP 1645-18B), and B) at the Mixing Zone Boundary (SNP 1645-19), 2002 to 2016



Note: Effluent values represent concentrations in individual samples. Mixing zone values represent the monthly median concentration and 5th and 95th percentile interval at three stations (i.e., SNP 1645-19A, SNP 1645-19B/B2, SNP 1645-19C) and five depths (i.e., 2 m, 5 m, 10 m, 15 m, and 20 m).

NIWTP = North Inlet Water Treatment Plant; SNP = Surveillance Network Program; NTU = Nephelometric Turbidity Units.

Figure 4-2 Total Suspended Solids: A) Annual Loading Rate from the North Inlet Water Treatment Plant and B) Concentration in Effluent (SNP 1645-18 and SNP 1645-18B) and C) at the Mixing Zone Boundary (SNP 1645-19), 2002 to 2016



Note: Annual Loading Rate, 50% or more <DL specifies the concentration was less than the detection limit in 50% or more of the samples, which indicates uncertainty in the load calculations. Effluent values represent concentrations in individual samples. Mixing zone values represent the monthly median concentration and the 5th percentile and 95th percentile interval at three stations (i.e., SNP 1645-19A, SNP 1645-19B/B2, SNP 1645-19C) and five depths (i.e., 2 m, 5 m, 10 m, 15 m, and 20 m).

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

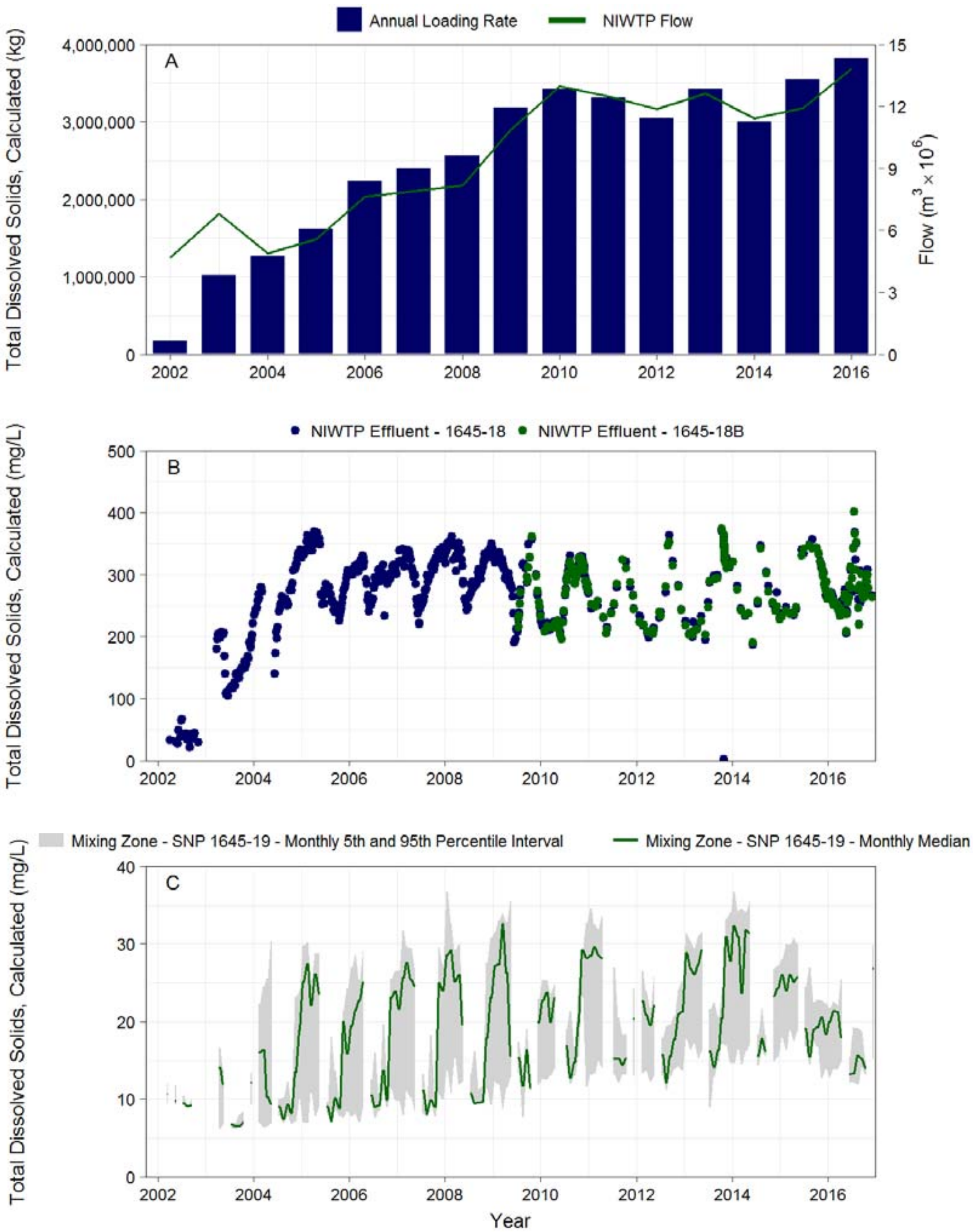
4.3.1.1.2 Total Dissolved Solids and Associated Ions

As discussed in Section 4.2.2, plots of both the total and dissolved forms of calcium, potassium, and sodium have been included. Similar trends were observed in both forms of these ions in the effluent and at the mixing zone and are, therefore, referred to collectively as calcium, potassium, and sodium in the following text, unless otherwise specified.

The annual loads of TDS (calculated) and several associated ions (calcium, chloride, fluoride, potassium, and sodium) from the NIWTP increased over time from 2002 to approximately 2010, then remained at approximately the same level or declined slightly, until increasing again in 2015 and/or 2016, primarily reflecting the increases in the annual volume of effluent discharged over time (Figures 4-3 to 4-11). Sulphate, fluoride and potassium also showed increases in loads due to increases of concentrations in the effluent. For example, the increase in the annual loads of sulphate to Lac de Gras was generally similar to that in TDS, but there was a more pronounced increase from 2008 that appears to reflect an increase in the concentration in the effluent (Figure 4-12). The 2011 effluent load of fluoride increased given an increase in effluent concentration; fluoride concentrations then remained within a similar range through to 2015, and then declined slightly in 2016, while the 2016 load increased, likely due to the increase in flow rate (Figure 4-7). The effluent load of potassium increased in 2013, reflecting an increase in the open-water season concentration; potassium loads have generally remained within a similar range since that time (Figures 4-8 and 4-9).

Mixing zone concentrations of TDS have increased gradually during 2004 to 2014, and then declined slightly in 2015 and 2016. The concentrations of calcium, chloride, potassium, and sodium at the mixing zone boundary have also slowly increased over time, whereas sulphate has seen a more pronounced increase in concentration. These concentration increases at the mixing zone reflect the increases in effluent loads. The concentration of fluoride at the mixing zone boundary was frequently below the DL (51% of samples analyzed) and no trends were evident during 2002 to 2016.

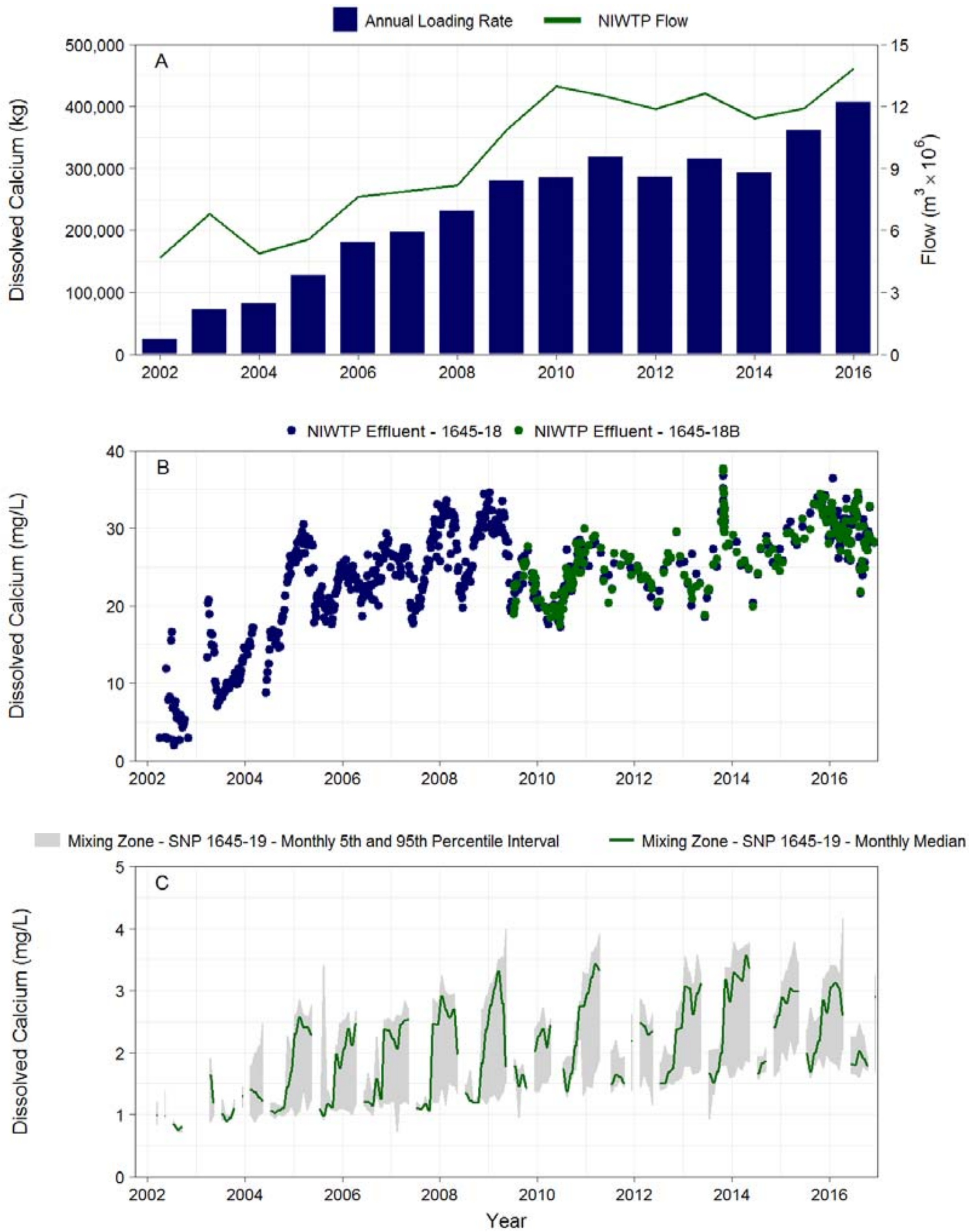
Figure 4-3 Total Dissolved Solids, Calculated: A) Annual Loading Rate from the North Inlet Water Treatment Plant and B) Concentration in Effluent (SNP 1645-18 and SNP 1645-18B) and C) at the Mixing Zone Boundary (SNP 1645-19), 2002 to 2016



Note: Effluent values represent concentrations in individual samples. Mixing zone values represent the monthly median concentration and 5th and 95th percentile interval at three stations (i.e., SNP 1645-19A, SNP 1645-19B/B2, SNP 1645-19C) and five depths (i.e., 2 m, 5 m, 10 m, 15 m, and 20 m). Gaps in the mixing zone dataset reflect times when samples could not be collected due to hazardous sampling conditions (e.g., ice-on and ice-off periods).

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

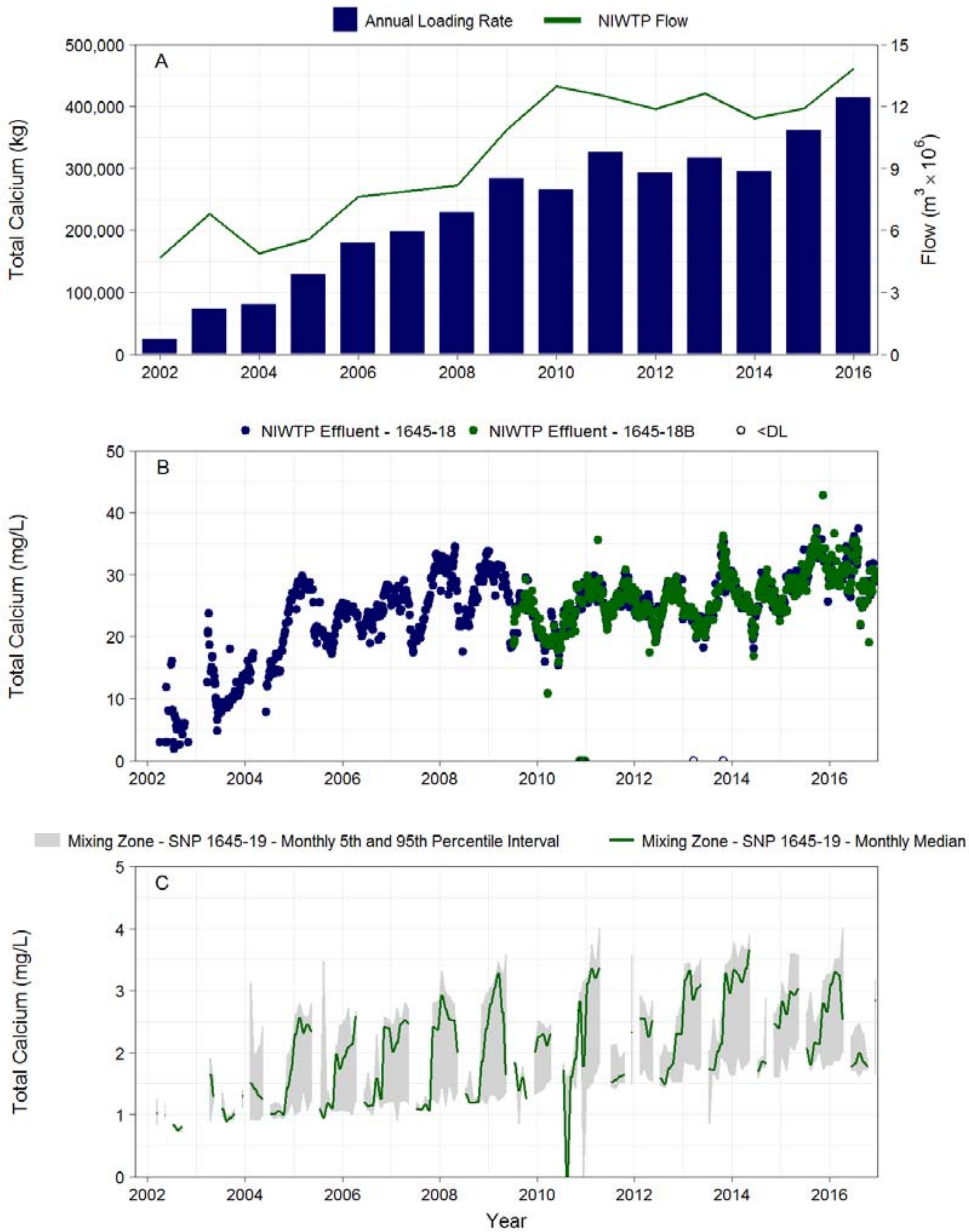
Figure 4-4 Dissolved Calcium: A) Annual Loading Rate from the North Inlet Water Treatment Plant and B) Concentration in Effluent (SNP 1645-18 and SNP 1645-18B), and C) at the Mixing Zone Boundary (SNP 1645-19), 2002 to 2016



Note: Effluent values represent concentrations in individual samples. Mixing zone values represent the monthly median concentration and 5th and 95th percentile interval at three stations (i.e., SNP 1645-19A, SNP 1645-19B/B2, SNP 1645-19C) and five depths (i.e., 2 m, 5 m, 10 m, 15 m, and 20 m). Gaps in the mixing zone dataset reflect times when samples could not be collected due to hazardous sampling conditions (e.g., ice-on and ice-off periods).

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

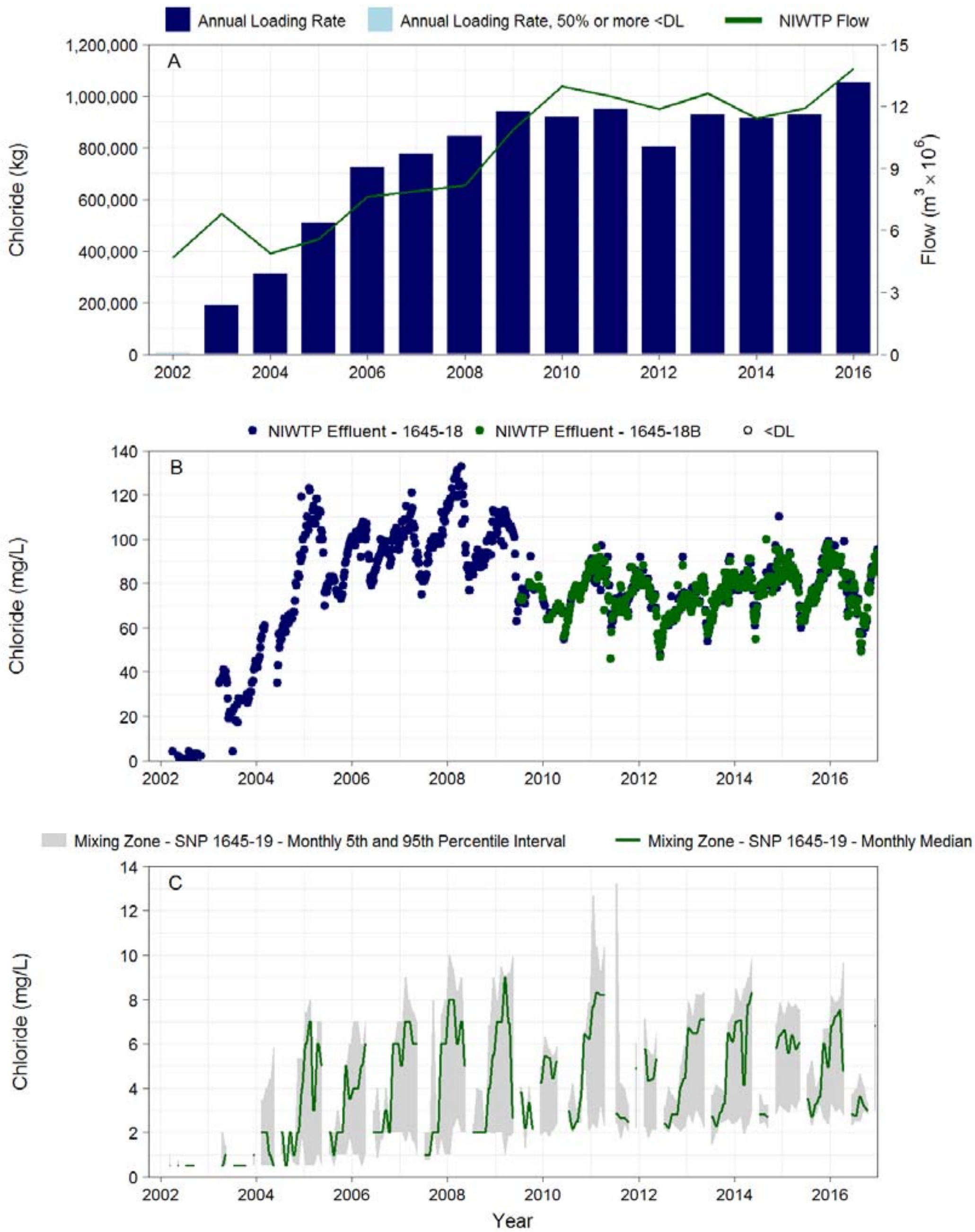
Figure 4-5 Total Calcium: A) Annual Loading Rate from the North Inlet Water Treatment Plant; and B) Concentration in Effluent (SNP 1645-18 and SNP 1645-18B) and C) at the Mixing Zone Boundary (SNP 1645-19), 2002 to 2016



Note: Effluent values represent concentrations in individual samples. Mixing zone values represent the monthly median concentration and 5th and 95th percentile interval at three stations (i.e., SNP 1645-19A, SNP 1645-19B/B2, SNP 1645-19C) and five depths (i.e., 2 m, 5 m, 10 m, 15 m, and 20 m). Gaps in the mixing zone dataset reflect times when samples could not be collected due to hazardous sampling conditions (e.g., ice-on and ice-off periods).

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

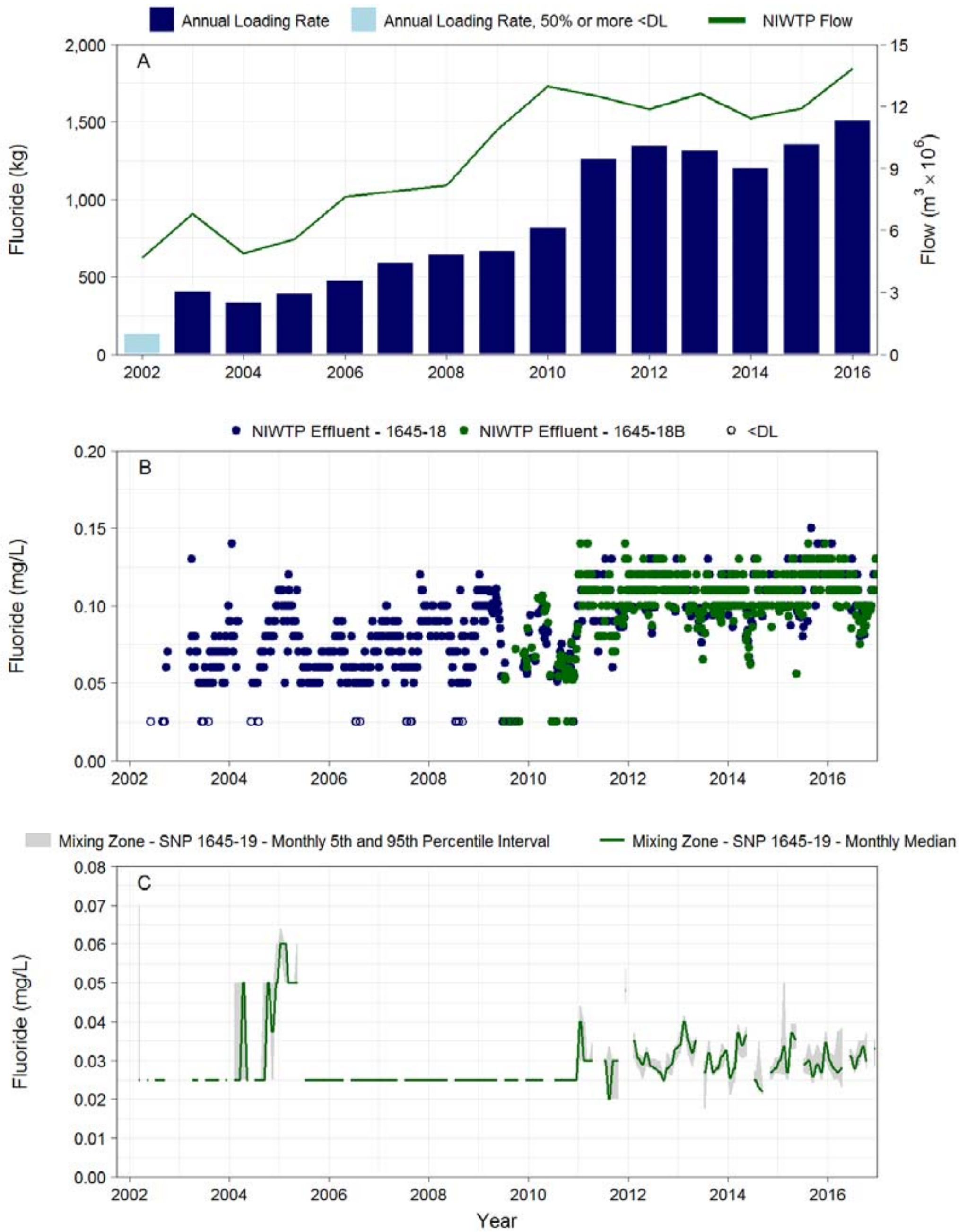
Figure 4-6 Chloride: A) Annual Loading Rate from the North Inlet Water Treatment Plant and B) Concentration in Effluent (SNP 1645-18 and SNP 1645-18B) and C) at the Mixing Zone Boundary (SNP 1645-19), 2002 to 2016



Note: Annual Loading Rate, 50% or more <DL specifies the concentration was less than the detection limit in 50% or more of the samples, which indicates uncertainty in the load calculations. Effluent values represent concentrations in individual samples. Mixing zone values represent the monthly median concentration and 5th and 95th percentile interval at three stations (i.e., SNP 1645-19A, SNP 1645-19B/B2, SNP 1645-19C) and five depths (i.e., 2 m, 5 m, 10 m, 15 m, and 20 m). Gaps in the mixing zone dataset reflect times when samples could not be collected due to hazardous sampling conditions (e.g., ice-on and ice-off periods).

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

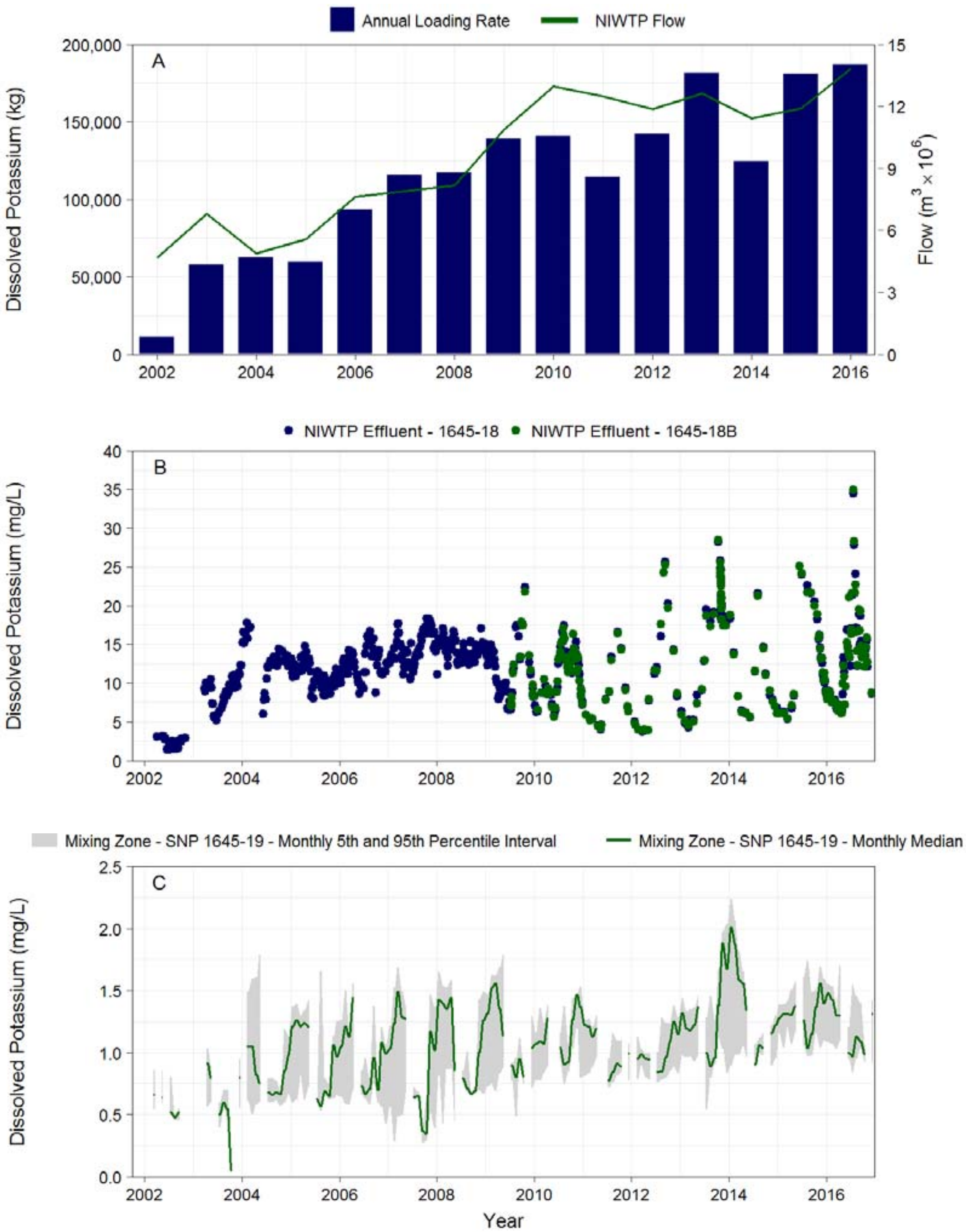
Figure 4-7 Fluoride: A) Annual Loading Rate from the North Inlet Water Treatment Plant and B) Concentration in Effluent (SNP 1645-18 and SNP 1645-18B) and C) at the Mixing Zone Boundary (SNP 1645-19), 2002 to 2016



Note: Annual Loading Rate, 50% or more <DL specifies the concentration was less than the detection limit in 50% or more of the samples, which indicates uncertainty in the load calculations. Effluent values represent concentrations in individual samples. Mixing zone values represent the monthly median concentration and 5th and 95th percentile interval at three stations (i.e., SNP 1645-19A, SNP 1645-19B/B2, SNP 1645-19C) and five depths (i.e., 2 m, 5 m, 10 m, 15 m, and 20 m). Gaps in the mixing zone dataset reflect times when samples could not be collected due to hazardous sampling conditions (e.g., ice-on and ice-off periods).

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

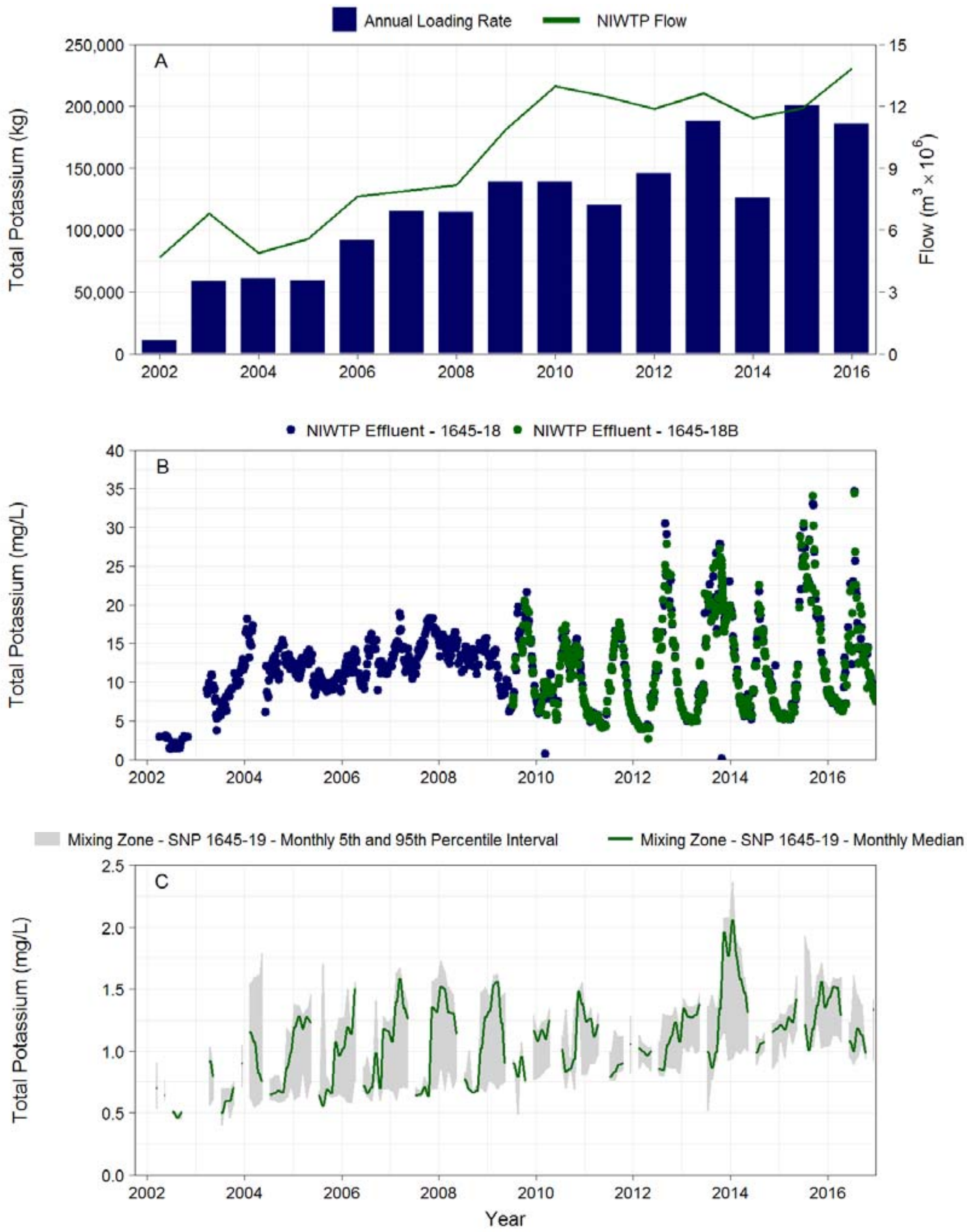
Figure 4-8 Dissolved Potassium: A) Annual Loading Rate from the North Inlet Water Treatment Plant and B) Concentration in Effluent (SNP 1645-18 and SNP 1645-18B) and C) at the Mixing Zone Boundary (SNP 1645-19), 2002 to 2016



Note: Effluent values represent concentrations in individual samples. Mixing zone values represent the monthly median concentration and 5th and 95th percentile intervals at three stations (i.e., SNP 1645-19A, SNP 1645-19B/B2, SNP 1645-19C) and five depths (i.e., 2 m, 5 m, 10 m, 15 m, and 20 m). Gaps in the mixing zone dataset reflect times when samples could not be collected due to hazardous sampling conditions (e.g., ice-on and ice-off periods).

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

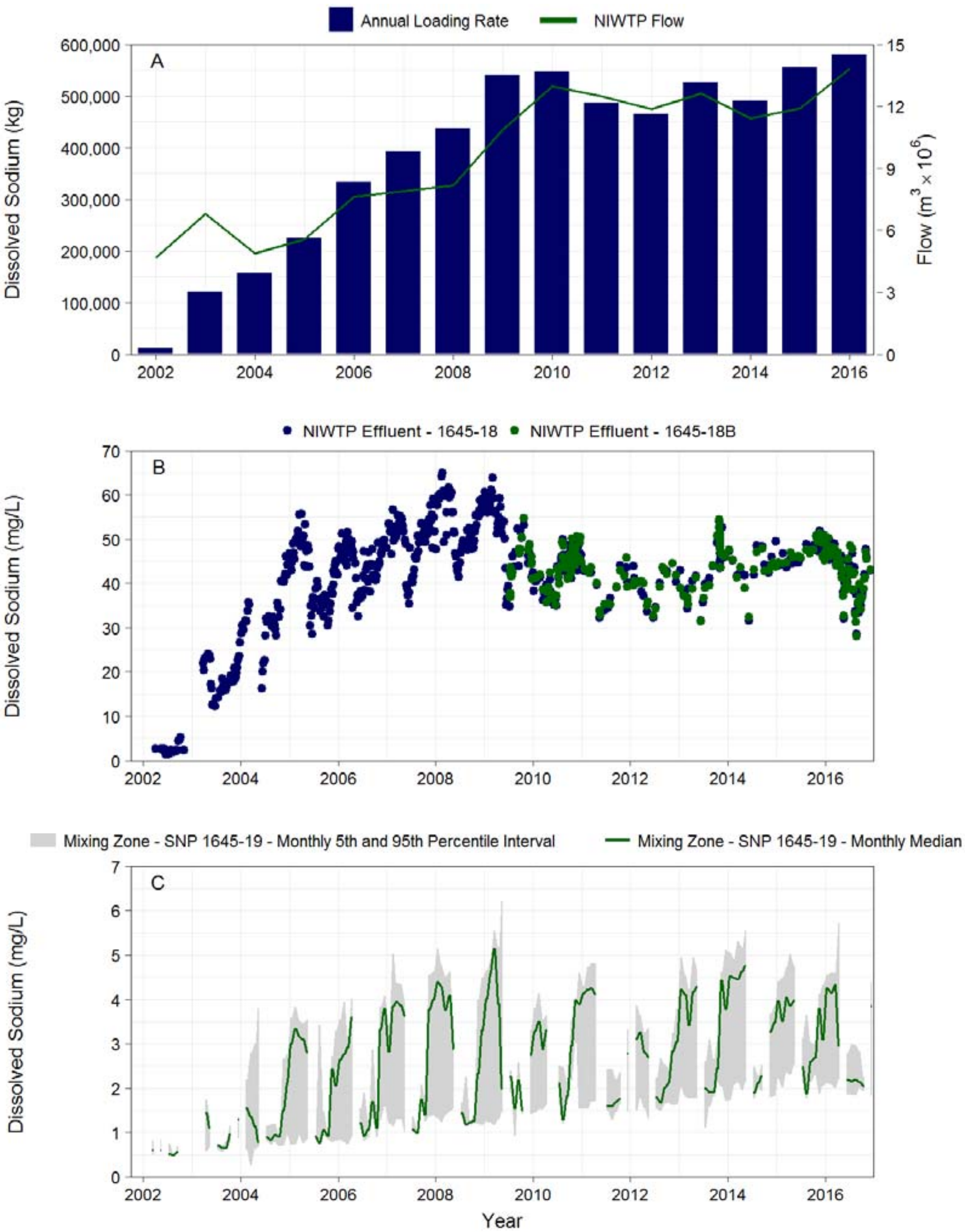
Figure 4-9 Total Potassium: A) Annual Loading Rate from the North Inlet Water Treatment Plant and B) Concentration in Effluent (SNP 1645-18 and SNP 1645-18B) and C) at the Mixing Zone Boundary (SNP 1645-19), 2002 to 2016



Note: Effluent values represent concentrations in individual samples. Mixing zone values represent the monthly median concentration and 5th and 95th percentile interval at three stations (i.e., SNP 1645-19A, SNP 1645-19B/B2, SNP 1645-19C) and five depths (i.e., 2 m, 5 m, 10 m, 15 m, and 20 m). Gaps in the mixing zone dataset reflect times when samples could not be collected due to hazardous sampling conditions (e.g., ice-on and ice-off periods).

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

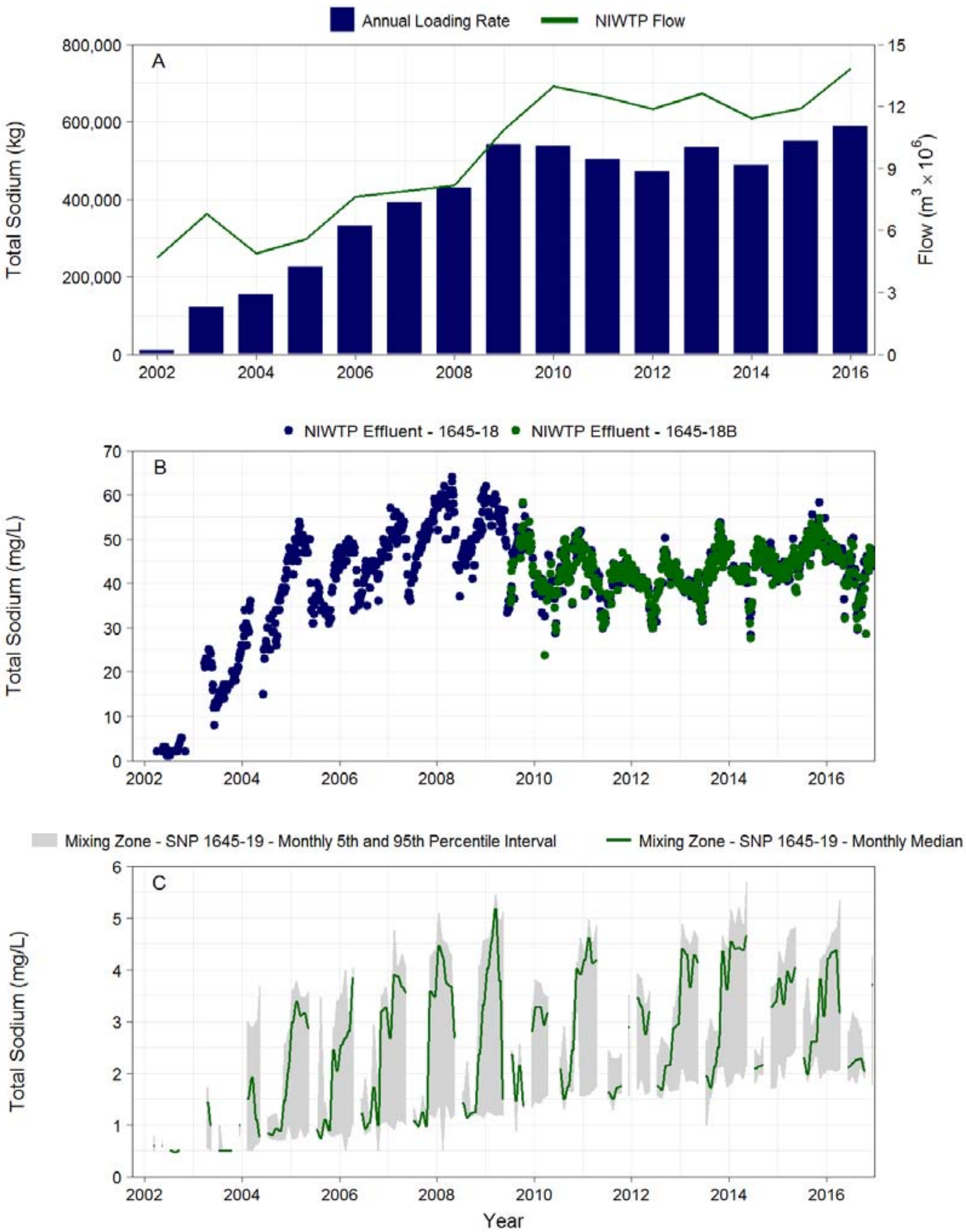
Figure 4-10 Dissolved Sodium: A) Annual Loading Rate from the North Inlet Water Treatment Plant and B) Concentration in Effluent (SNP 1645-18 and SNP 1645-18B), and C) at the Mixing Zone Boundary (SNP 1645-19), 2002 to 2016



Note: Effluent values represent concentrations in individual samples. Mixing zone values represent the monthly median concentration and 5th and 95th percentile interval at three stations (i.e., SNP 1645-19A, SNP 1645-19B/B2, SNP 1645-19C) and five depths (i.e., 2 m, 5 m, 10 m, 15 m, and 20 m). Gaps in the mixing zone dataset reflect times when samples could not be collected due to hazardous sampling conditions (e.g., ice-on and ice-off periods).

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

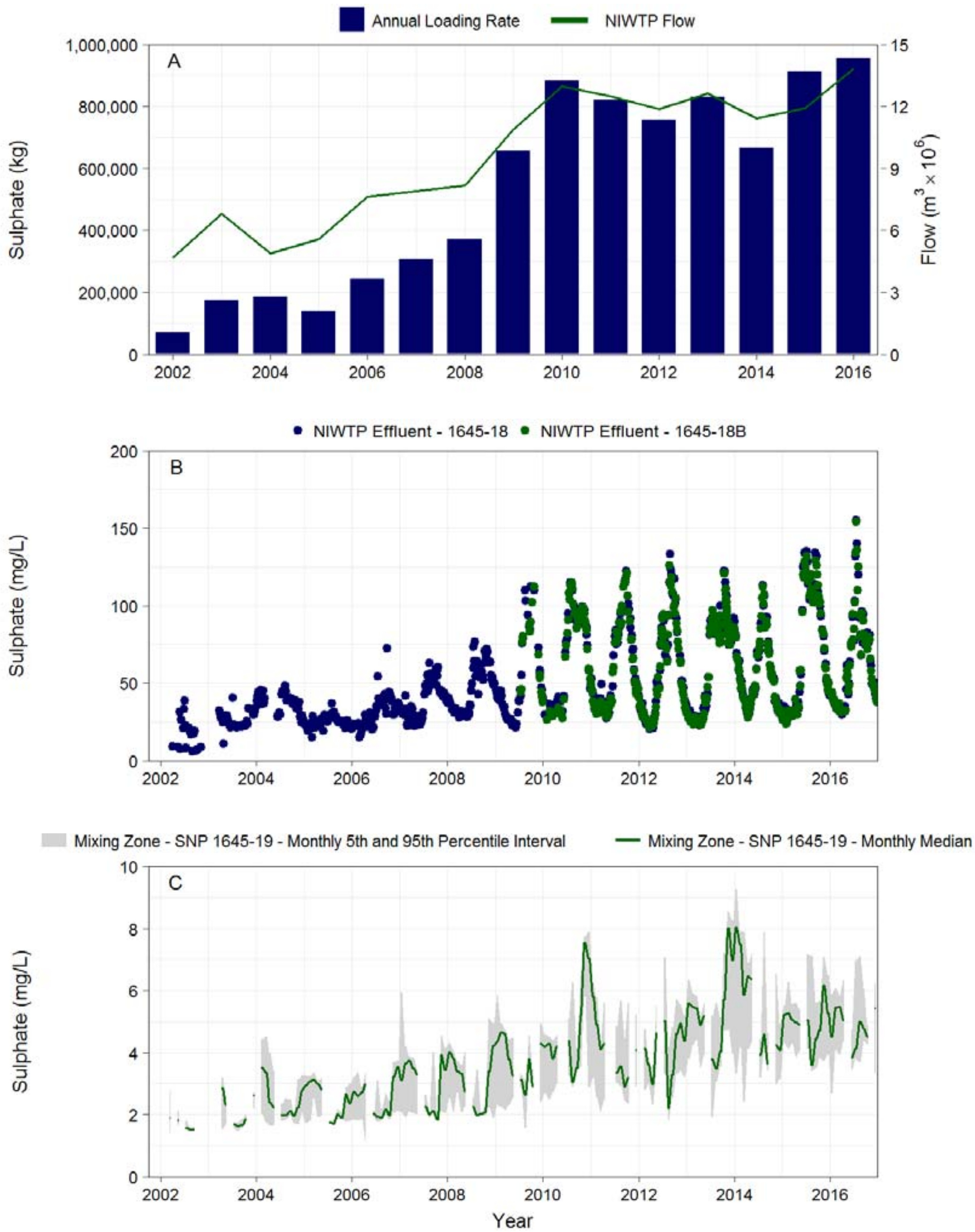
Figure 4-11 Total Sodium: A) Annual Loading Rate from the North Inlet Water Treatment Plant and B) Concentration in Effluent (SNP 1645-18 and SNP 1645-18B) and C) at the Mixing Zone Boundary (SNP 1645-19), 2002 to 2016



Note: Effluent values represent concentrations in individual samples. Mixing zone values represent the monthly median concentration and 5th and 95th percentile interval at three stations (i.e., SNP 1645-19A, SNP 1645-19B/B2, SNP 1645-19C) and five depths (i.e., 2 m, 5 m, 10 m, 15 m, and 20 m). Gaps in the mixing zone dataset reflect times when samples could not be collected due to hazardous sampling conditions (e.g., ice-on and ice-off periods).

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

Figure 4-12 Sulphate: A) Annual Loading Rate from the North Inlet Water Treatment Plant and B) Concentration in Effluent (SNP 1645-18 and SNP 1645-18B) and C) at the Mixing Zone Boundary (SNP 1645-19), 2002 to 2016



Note: Effluent values represent concentrations in individual samples. Mixing zone values represent the monthly median concentration and 5th percentile and 95th percentile interval at three stations (i.e., SNP 1645-19A, SNP 1645-19B/B2, SNP 1645-19C) and five depths (i.e., 2 m, 5 m, 10 m, 15 m, and 20 m). Gaps in the mixing zone dataset reflect times when samples could not be collected due to hazardous sampling conditions (e.g., ice-on and ice-off periods).

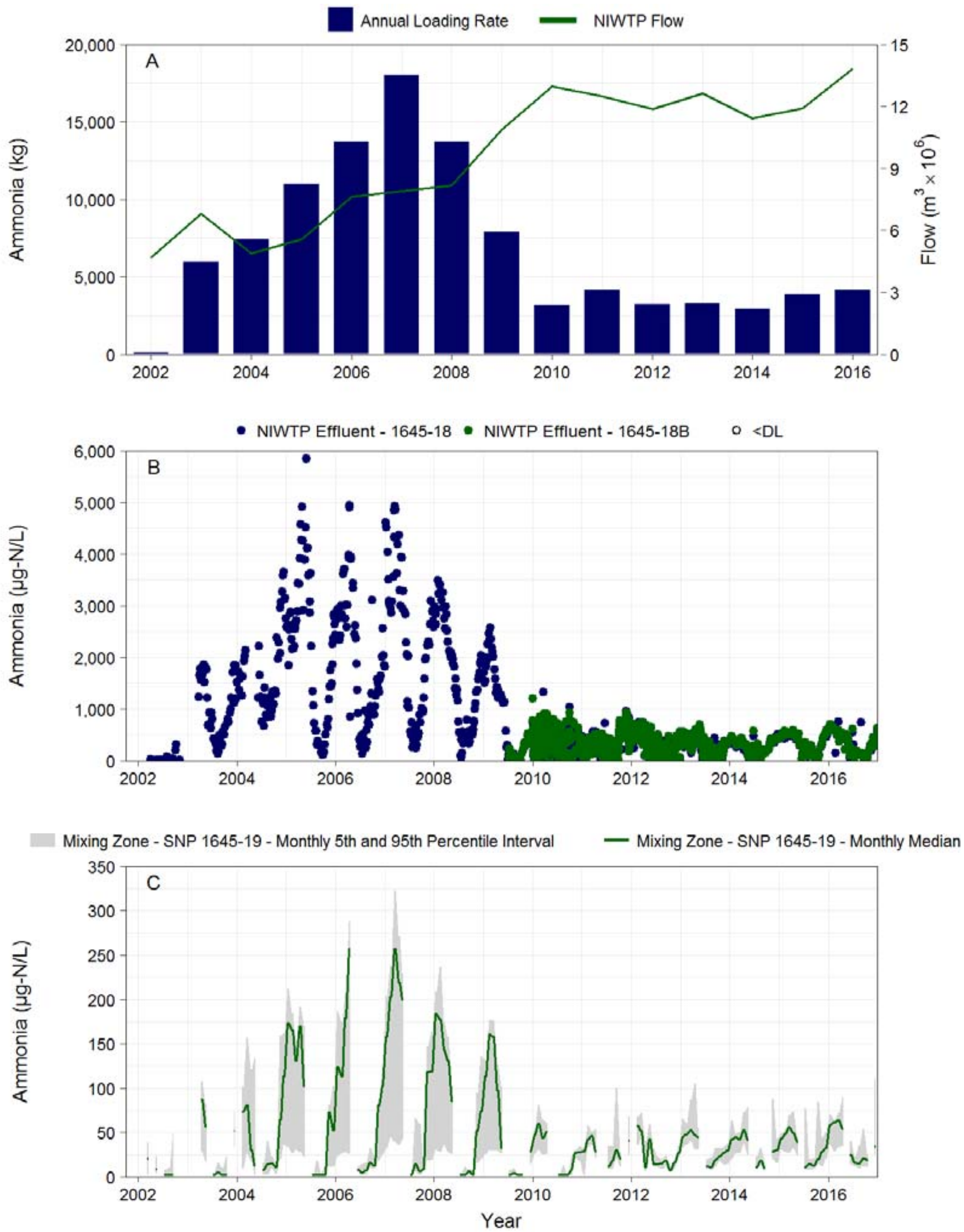
NIWTP = North Inlet Water Treatment Plant; SNP = Surveillance Network Program.

4.3.1.1.3 Nutrients

The annual loading rates of ammonia, nitrate, and nitrite to Lac de Gras increased over time from 2002 to approximately 2007, as the concentration of nitrogen in Mine effluent increased (Figures 4-13 to 4-15). The loads and concentrations of these compounds subsequently declined to 2010. Loads of these SOIs have remained at similar levels since 2010, increasing slightly in 2015 and 2016, as concentrations in the effluent and flow rates increased.

Temporal patterns in the concentration of ammonia, nitrate, and nitrite at the mixing zone boundary generally reflected patterns observed in the Mine effluent. The variability of the mixing zone concentrations of ammonia, nitrate, and nitrite declined after 2010, reflecting the lower and less variable concentrations in the effluent.

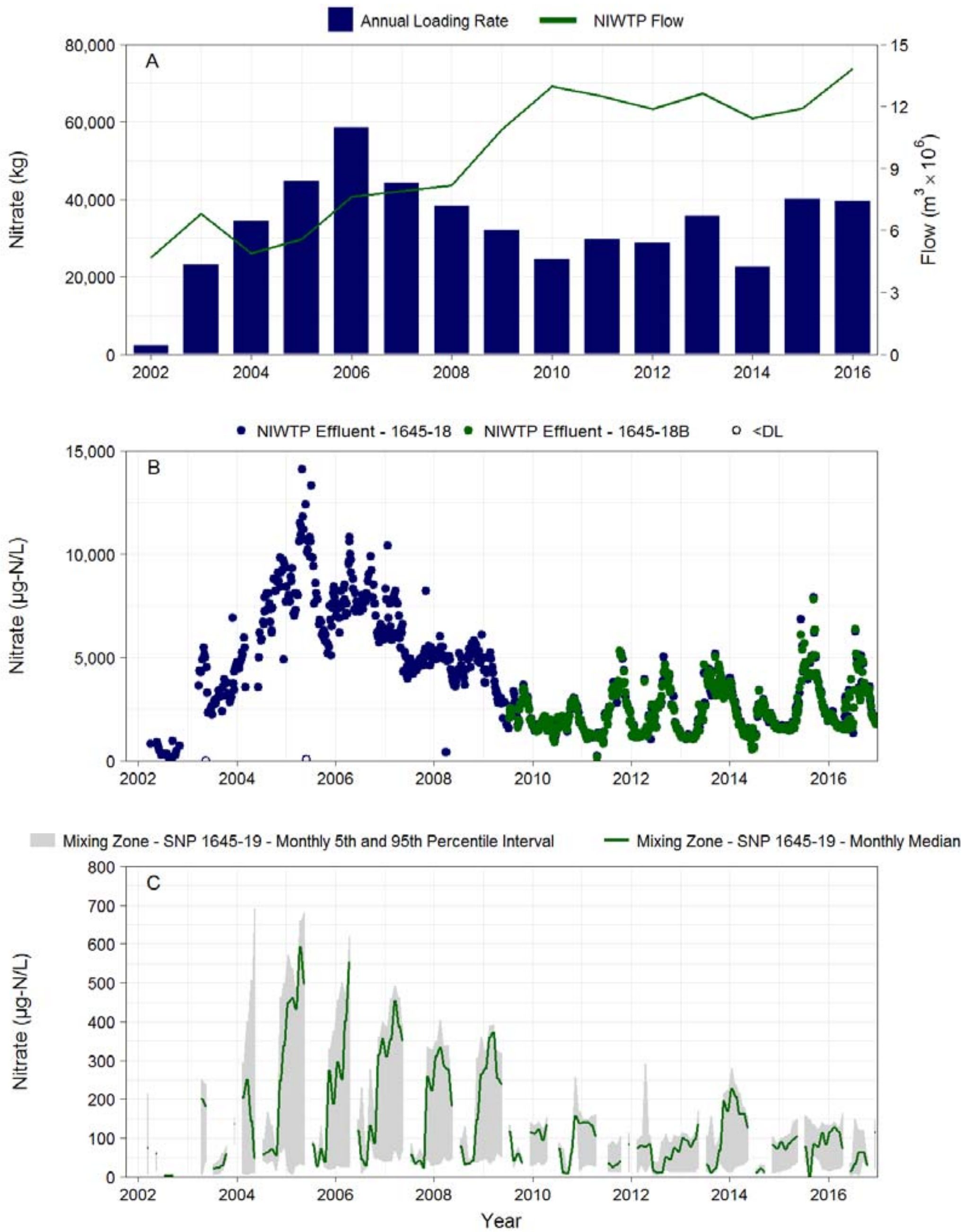
Figure 4-13 Ammonia: A) Annual Loading Rate from the North Inlet Water Treatment Plant and B) Concentration in Effluent (SNP 1645-18 and SNP 1645-18B) and C) at the Mixing Zone Boundary (SNP 1645-19), 2002 to 2016



Note: Effluent values represent concentrations in individual samples. Mixing zone values represent the monthly median concentration and 5th and 95th percentile interval at three stations (i.e., SNP 1645-19A, SNP 1645-19B/B2, SNP 1645-19C) and five depths (i.e., 2 m, 5 m, 10 m, 15 m, and 20 m). Gaps in the mixing zone dataset reflect times when samples could not be collected due to hazardous sampling conditions (e.g., ice-on and ice-off periods).

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

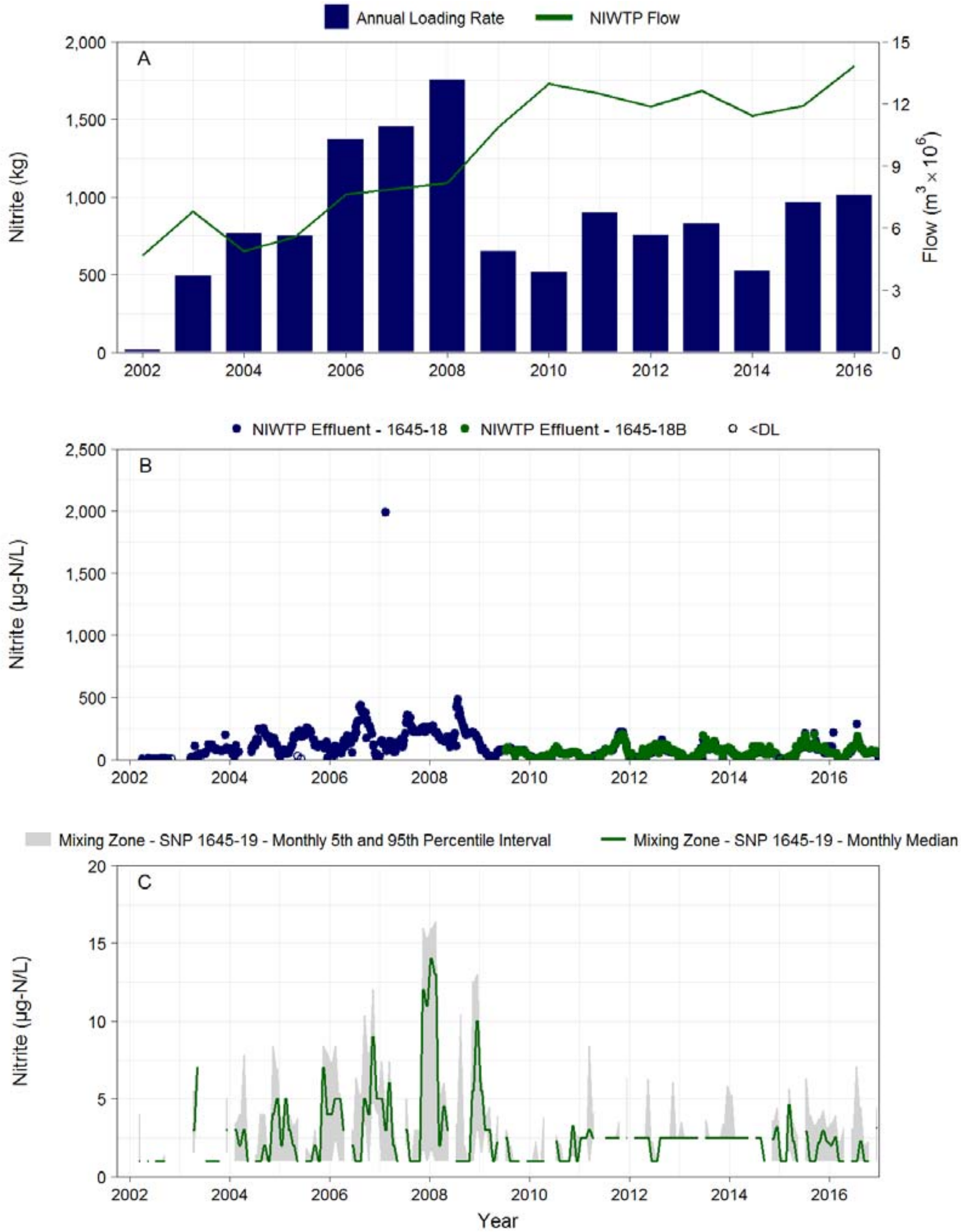
Figure 4-14 Nitrate: A) Annual Loading Rate from the North Inlet Water Treatment Plant and B) Concentration in Effluent (SNP 1645-18 and SNP 1645-18B) and C) at the Mixing Zone Boundary (SNP 1645-19), 2002 to 2016



Note: Effluent values represent concentrations in individual samples. Mixing zone values represent the monthly median concentration and 5th and 95th percentile interval at three stations (i.e., SNP 1645-19A, SNP 1645-19B/B2, SNP 1645-19C) and five depths (i.e., 2 m, 5 m, 10 m, 15 m, and 20 m). Gaps in the mixing zone dataset reflect times when samples could not be collected due to hazardous sampling conditions (e.g., ice-on and ice-off periods).

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

Figure 4-15 Nitrite: A) Annual Loading Rate from the North Inlet Water Treatment Plant and B) Concentration in Effluent (SNP 1645-18 and SNP 1645-18B) and C) at the Mixing Zone Boundary (SNP 1645-19), 2002 to 2016



Note: Effluent values represent concentrations in individual samples. Mixing zone values represent the monthly median concentration and 5th and 95th percentile interval at three stations (i.e., SNP 1645-19A, SNP 1645-19B/B2, SNP 1645-19C) and five depths (i.e., 2 m, 5 m, 10 m, 15 m, and 20 m). Gaps in the mixing zone dataset reflect times when samples could not be collected due to hazardous sampling conditions (e.g., ice-on and ice-off periods).

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

4.3.1.1.4 Total Metals

Effluent loads and concentrations over time, together with mixing zone concentrations, for SOI total metals are presented in Figures 4-16 to 4-34, in alphabetical order. Although effluent loads and/or concentrations of some metals have been increasing over time (strontium and vanadium; Figures 4-28, and 4-33), most have decreased (copper, manganese; Figures 4-22 and 4-25), fluctuated over time (barium, chromium, iron, lead, molybdenum, thallium, and uranium; Figures 4-18, 4-20, 4-23, 4-24, 4-26, 4-29, and 4-32), or have remained at relatively similar levels (aluminum, antimony, cobalt, and silicon; Figures 4-16, 4-17, 4-21, and 4-27).

Concentrations of four metals (bismuth, tin, titanium, and zirconium; Figures 4-19, 4-30, 4-31 and 4-34) in the effluent were below DLs in the SNP dataset (bismuth = 0.005 to 0.2 µg/L, tin = 0.01 to 0.4 µg/L, titanium = 0.5 to 5.0 µg/L, and zirconium = 0.05 to 0.1 µg/L) in a large proportion of samples analyzed from 2002 to 2016 (95%, 94%, 87%, and 99% of samples, respectively), which restricted interpretation of trends for these SOIs. Bismuth, cobalt, iron, thallium, titanium and zirconium were included as SOIs in this re-evaluation report because they met Criterion 3 relating to potential dust and dike construction effects (Table 4-2), rather than due to effluent-related criteria, so it is not surprising that the concentrations of some of these SOIs would be largely below DL in the effluent.

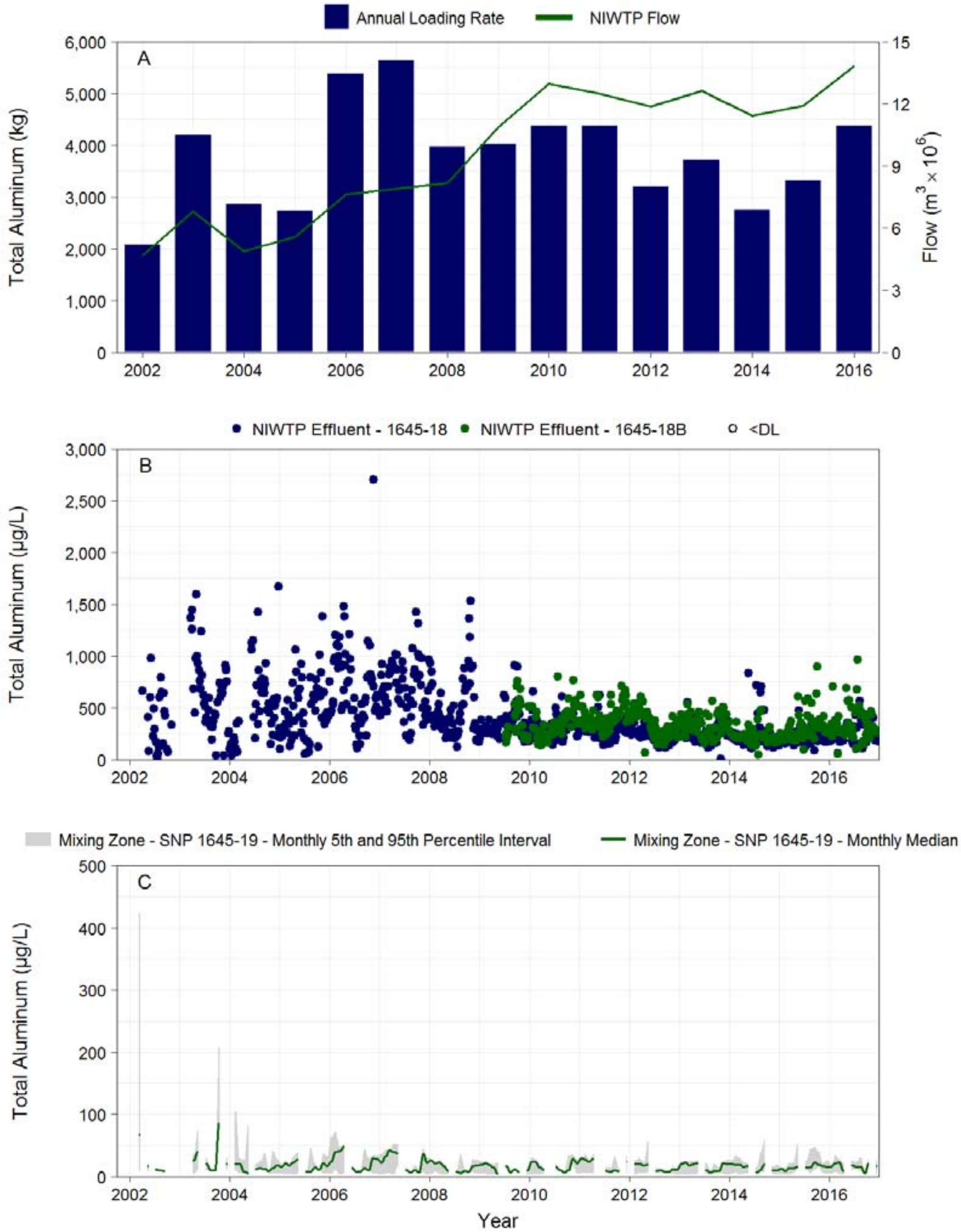
The annual loading rates of strontium and vanadium followed the same general pattern described for TDS, reflecting the increase in the annual volume of effluent discharged from the NIWTP (Figures 4-28 and 4-33). The concentration of strontium in effluent has remained in a similar range, involving a repetitive seasonal fluctuation, since 2005. The concentration of vanadium in effluent has remained in a similar range, with seasonal fluctuations, since 2009. At the mixing zone boundary, concentrations of strontium have been increasing since 2002. No temporal trends were observed in the concentrations of vanadium at the mixing zone from 2002 to 2016.

Other trends of note for the effluent loads/concentrations and mixing zone concentrations of the SOI total metals are as follows:

- Data quality issues identified with antimony prior to 2007 interfered with the interpretation of trends at the mixing zone boundary. Antimony concentrations reported from 2002 to 2006 were an order of magnitude greater than values reported from 2007 to 2016; however, concentrations have remained at similar levels since 2007 (Figure 4-17).
- The annual loading rate and the concentration of barium from the NIWTP increased from 2002 to 2006, and both have subsequently declined since 2006. Loads and concentrations have stabilized since 2011 (Figure 4-18). Trends for barium at the mixing zone reflected those in effluent.
- Annual loads for chromium increased in 2006 and 2007, reflecting an increase in concentration in the effluent. The annual loading rate of chromium to Lac de Gras was within a similar range from 2008 to 2015 (Figure 4-20), but increased in 2016, reflecting an increase in the effluent flow rate.
- The annual load of lead from the NIWTP generally decreased from 2002 to 2005. The load increased in 2006 and again in 2008, reflecting an increase in the concentration of the effluent and has generally declined since that time (Figure 4-24).
- Annual loads of manganese decreased over time from 2002 to 2015, but increased in 2016 due to increases in the concentrations of this variable in the effluent (Figure 4-25).

- The load of molybdenum in the effluent increased from 2002 to a peak in 2010, and has since slowly declined (Figure 4-26). The concentration of molybdenum in effluent was relatively stable during initial monitoring and then increased during 2009 to a fluctuating seasonal range; peak values of molybdenum concentrations in the effluent have decreased in recent years. Concentrations of molybdenum at the mixing zone increased until approximately 2013 and have declined slightly since.
- The annual loads of silicon to Lac de Gras were not available from 2002 to 2010, because silicon was not analyzed during that period. The annual loading rates increased slightly from 2011 to 2013; however, this increase was not reflected in the concentration of silicon in effluent (Figure 4-27). The annual loading decreased in 2014 and has remained at a similar level since that time. Concentrations of silicon at the mixing zone generally decreased from 2011 to 2016.
- The DL for thallium in effluent decreased from 0.1 to 0.002 µg/L in 2011. Prior to 2011, detected concentrations in the effluent were highly variable; after 2011, concentrations were much lower and the effluent loads have remained fairly constant since that time (Figure 4-29).
- The concentration of uranium at the mixing zone was elevated in 2002, but declined markedly after the first year of monitoring (Figure 4-32). Uranium concentrations continued to gradually decline through 2016. Given the absence of trends for uranium in effluent, these data appear to confirm that the elevated uranium concentrations encountered at the mixing zone in 2002 originated from the A154 dike (DDMI 2011a).

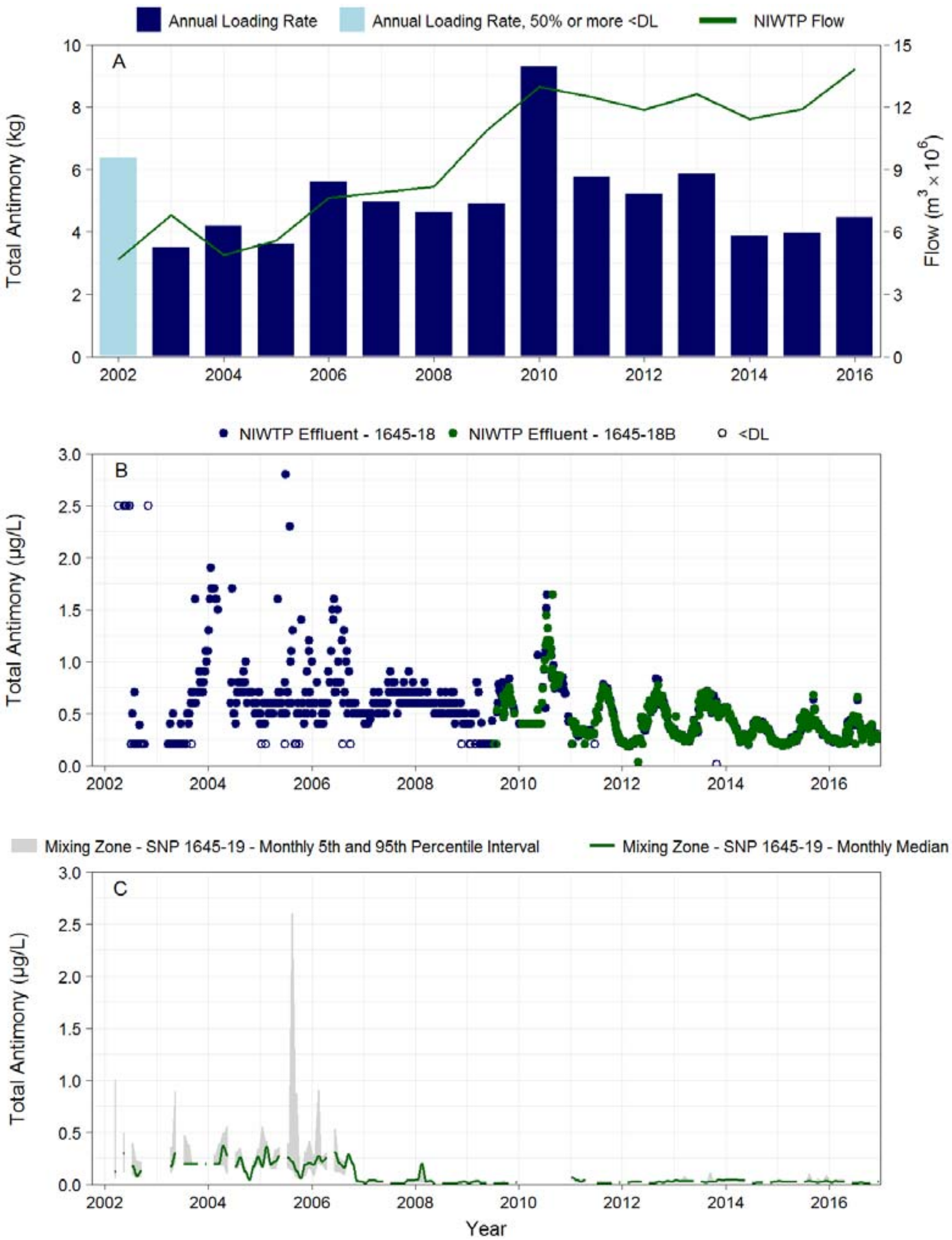
Figure 4-16 Total Aluminum: A) Annual Loading Rate from the North Inlet Water Treatment Plant and B) Concentration in Effluent (SNP 1645-18 and SNP 1645-18B) and C) at the Mixing Zone Boundary (SNP 1645-19), 2002 to 2016



Note: Effluent values represent concentrations in individual samples. Mixing zone values represent the monthly median concentration and 5th percentile and 95th percentile interval at three stations (i.e., SNP 1645-19A, SNP 1645-19B/B2, SNP 1645-19C) and five depths (i.e., 2 m, 5 m, 10 m, 15 m, and 20 m). Gaps in the mixing zone dataset reflect times when samples could not be collected due to hazardous sampling conditions (e.g., ice-on and ice-off periods).

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

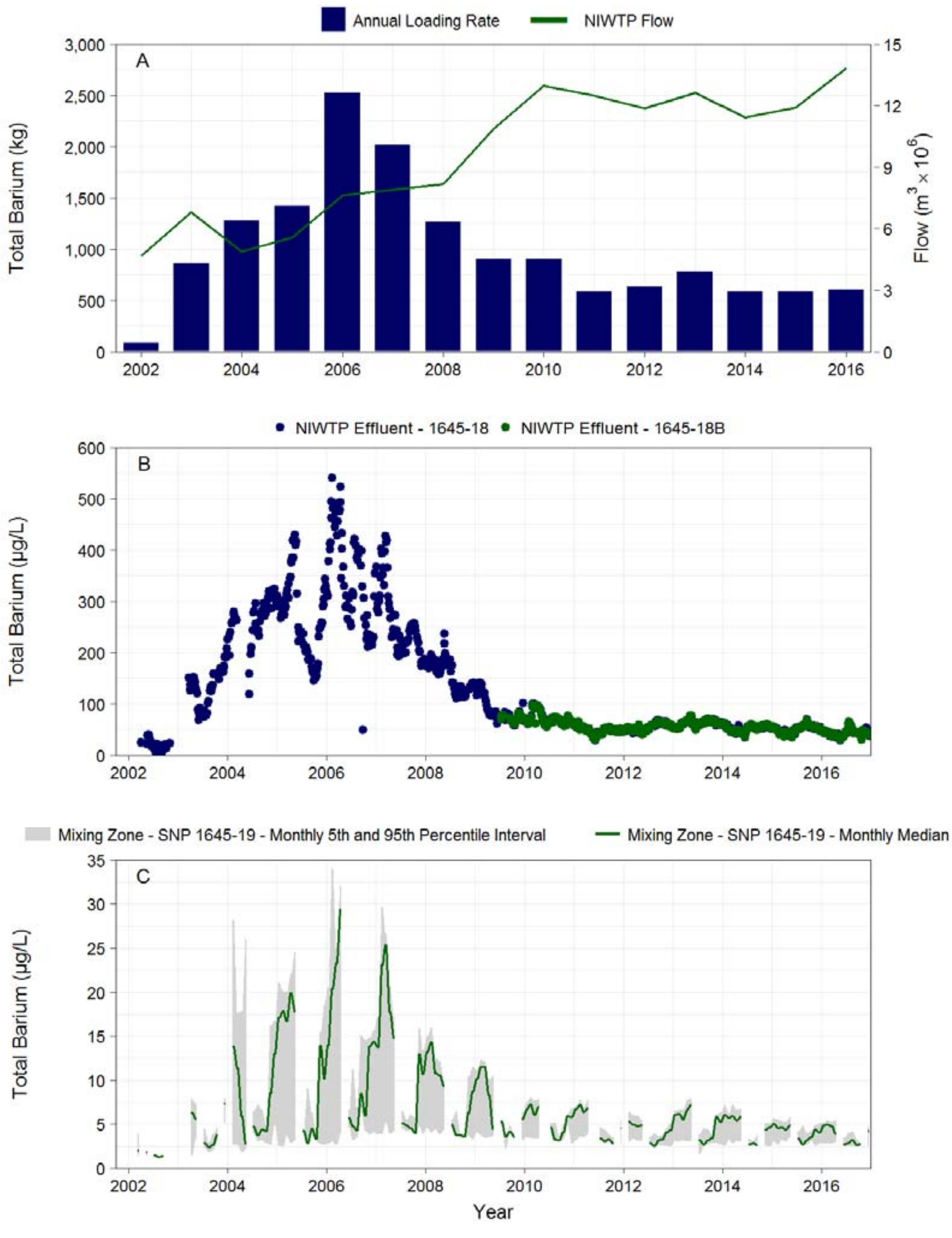
Figure 4-17 Total Antimony: A) Annual Loading Rate from the North Inlet Water Treatment Plant and B) Concentration in Effluent (SNP 1645-18 and SNP 1645-18B) and C) at the Mixing Zone Boundary (SNP 1645-19), 2002 to 2016



Note: Annual Loading Rate, 50% or more <DL specifies the concentration was less than the detection limit in 50% or more of the samples, which indicates uncertainty in the load calculations. Effluent values represent concentrations in individual samples. Mixing zone values represent the monthly median concentration and 5th and 95th percentile interval at three stations (i.e., SNP 1645-19A, SNP 1645-19B/B2, SNP 1645-19C) and five depths (i.e., 2 m, 5 m, 10 m, 15 m, and 20 m). Gaps in the mixing zone dataset reflect times when samples could not be collected due to hazardous sampling conditions (e.g., ice-on and ice-off periods).

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

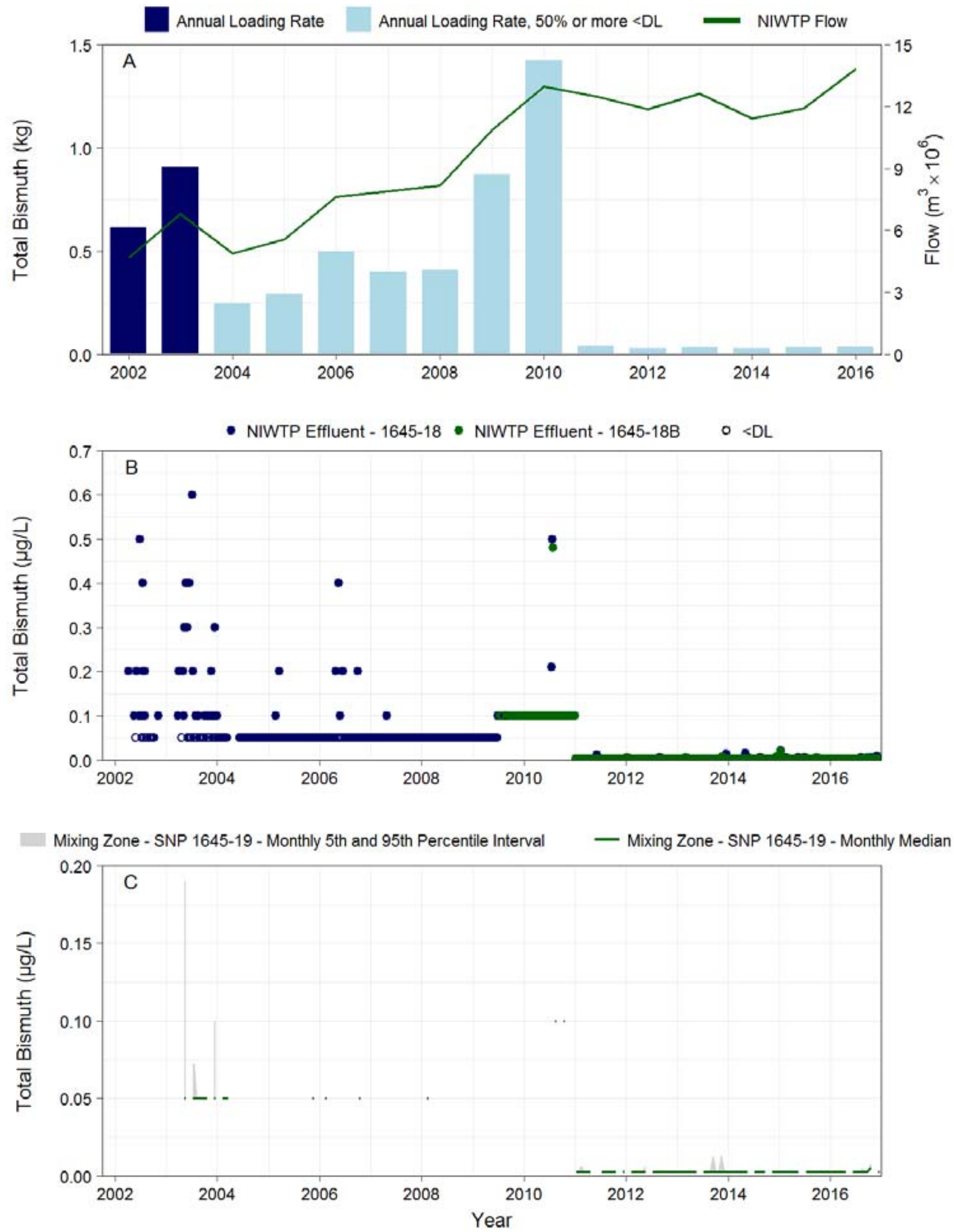
Figure 4-18 Total Barium: A) Annual Loading Rate from the North Inlet Water Treatment Plant and B) Concentration in Effluent (SNP 1645-18 and SNP 1645-18B) and C) at the Mixing Zone Boundary (SNP 1645-19), 2002 to 2016



Note: Effluent values represent concentrations in individual samples. Mixing zone values represent the monthly median concentration and 5th percentile and 95th percentile interval at three stations (i.e., SNP 1645-19A, SNP 1645-19B/B2, SNP 1645-19C) and five depths (i.e., 2 m, 5 m, 10 m, 15 m, and 20 m). Gaps in the mixing zone dataset reflect times when samples could not be collected due to hazardous sampling conditions (e.g., ice-on and ice-off periods).

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

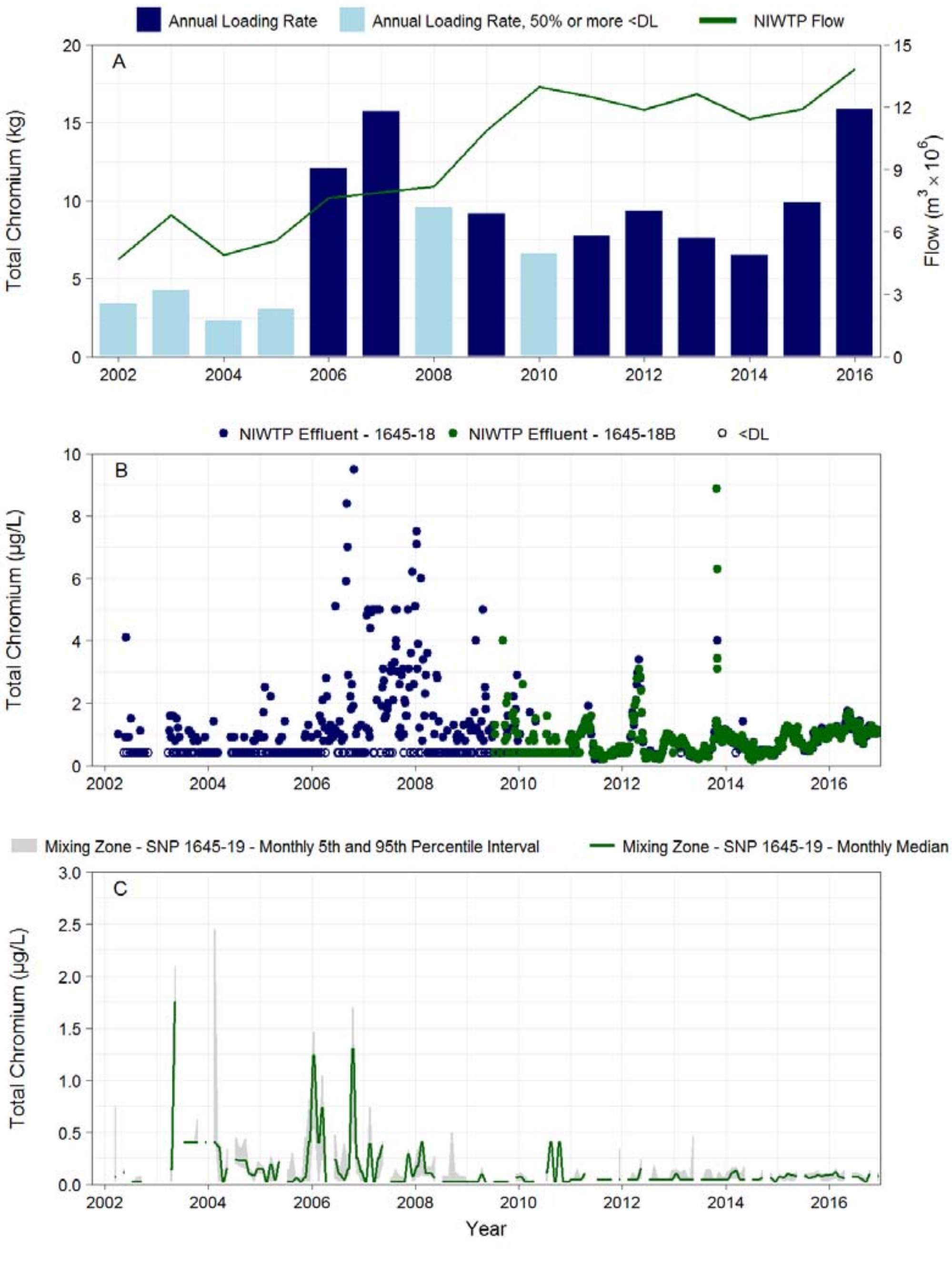
Figure 4-19 Total Bismuth: A) Annual Loading Rate from the North Inlet Water Treatment Plant and B) Concentration in Effluent (SNP 1645-18 and SNP 1645-18B) and C) at the Mixing Zone Boundary (SNP 1645-19), 2002 to 2016



Note: Annual Loading Rate, 50% or more <DL specifies the concentration was less than the detection limit in 50% or more of the samples, which indicates uncertainty in the load calculations. Effluent values represent concentrations in individual samples. Mixing zone values represent the monthly median concentration and 5th and 95th percentile interval at three stations (i.e., SNP 1645-19A, SNP 1645-19B/B2, SNP 1645-19C) and five depths (i.e., 2 m, 5 m, 10 m, 15 m, and 20 m). This variable was not part of the standard laboratory analysis prior to 2011; gaps in the mixing zone dataset after 2011 reflect times when samples could not be collected due to hazardous sampling conditions (e.g., ice-on and ice-off periods). A value of 2.6 µg/L from March 26, 2002 was not illustrated in Panel C; it was not flagged as an anomalous data point in the data screening because it is the only datum for that year.

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

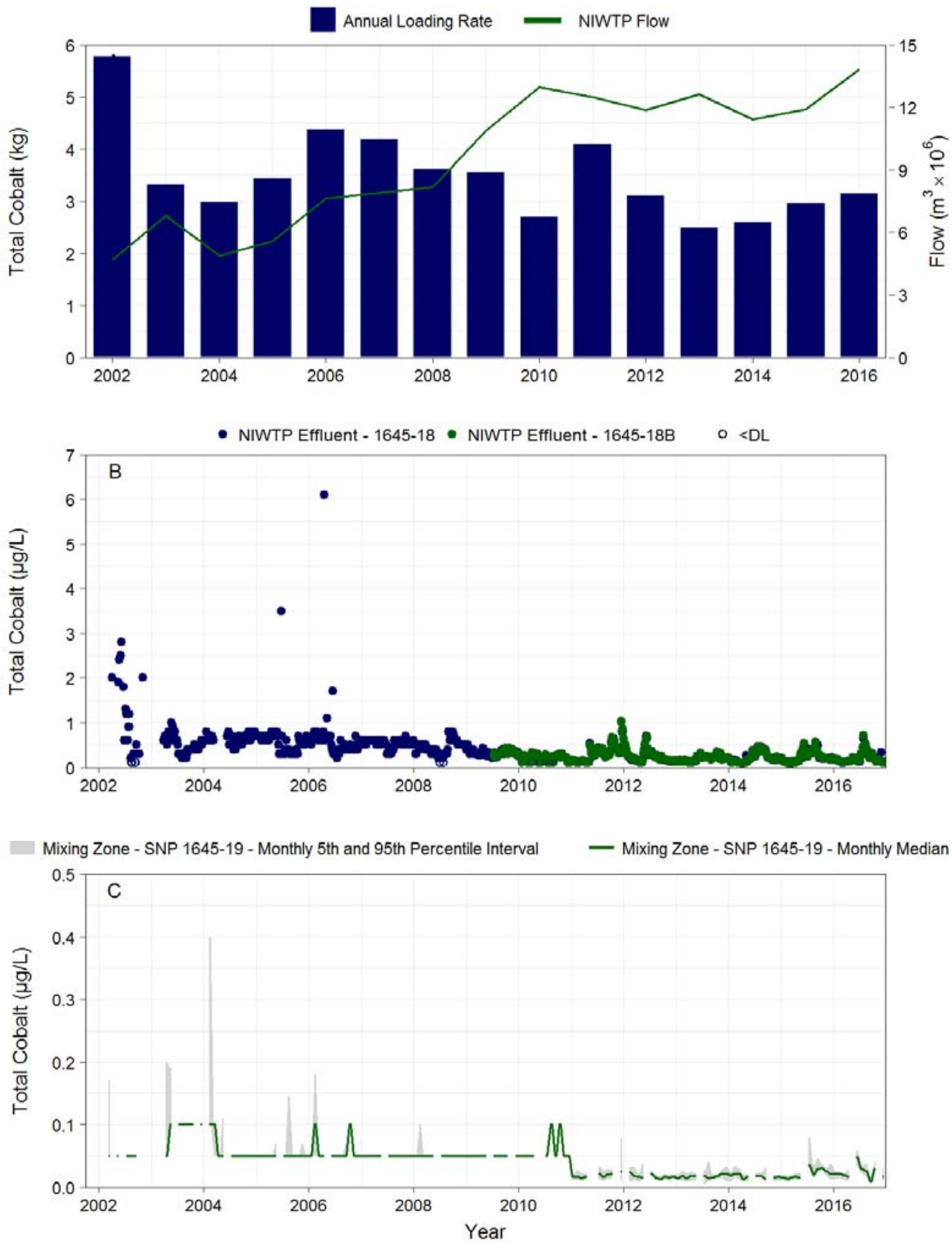
Figure 4-20 Total Chromium: A) Annual Loading Rate from the North Inlet Water Treatment Plant and B) Concentration in Effluent (SNP 1645-18 and SNP 1645-18B) and C) at the Mixing Zone Boundary (SNP 1645-19), 2002 to 2016



Note: Annual Loading Rate, 50% or more <DL specifies the concentration was less than the detection limit in 50% or more of the samples, which indicates uncertainty in the load calculations. Effluent values represent concentrations in individual samples. Mixing zone values represent the monthly median concentration and 5th and 95th percentile interval at three stations (i.e., SNP 1645-19A, SNP 1645-19B/B2, SNP 1645-19C) and five depths (i.e., 2 m, 5 m, 10 m, 15 m, and 20 m). Gaps in the mixing zone dataset reflect times when samples could not be collected due to hazardous sampling conditions (e.g., ice-on and ice-off periods).

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

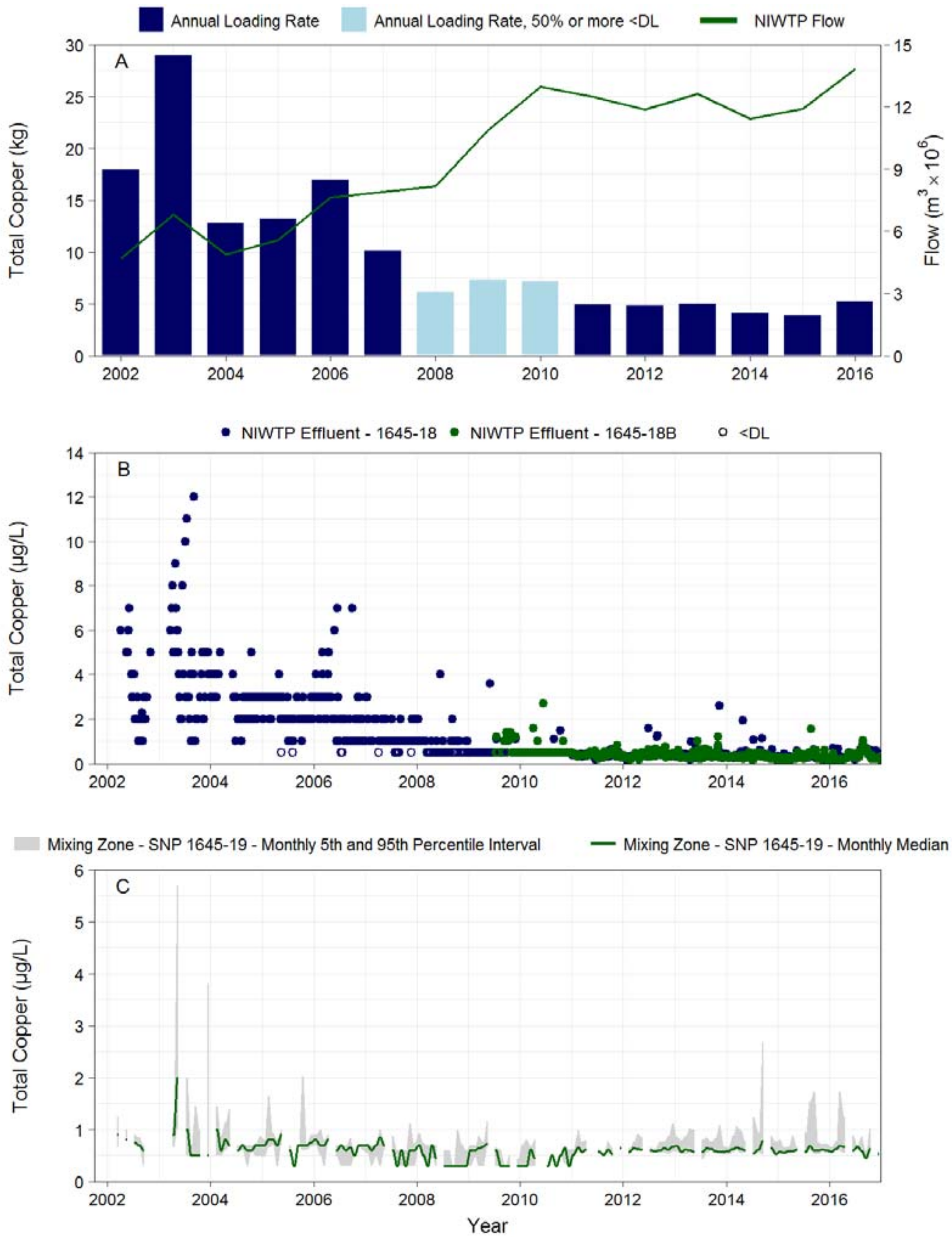
Figure 4-21 Total Cobalt: A) Annual Loading Rate from the North Inlet Water Treatment Plant and B) Concentration in Effluent (SNP 1645-18 and SNP 1645-18B) and C) at the Mixing Zone Boundary (SNP 1645-19), 2002 to 2016



Note: Effluent values represent concentrations in individual samples. Mixing zone values represent the monthly median concentration and 5th percentile and 95th percentile interval at three stations (i.e., SNP 1645-19A, SNP 1645-19B/B2, SNP 1645-19C) and five depths (i.e., 2 m, 5 m, 10 m, 15 m, and 20 m). Gaps in the mixing zone dataset reflect times when samples could not be collected due to hazardous sampling conditions (e.g., ice-on and ice-off periods).

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

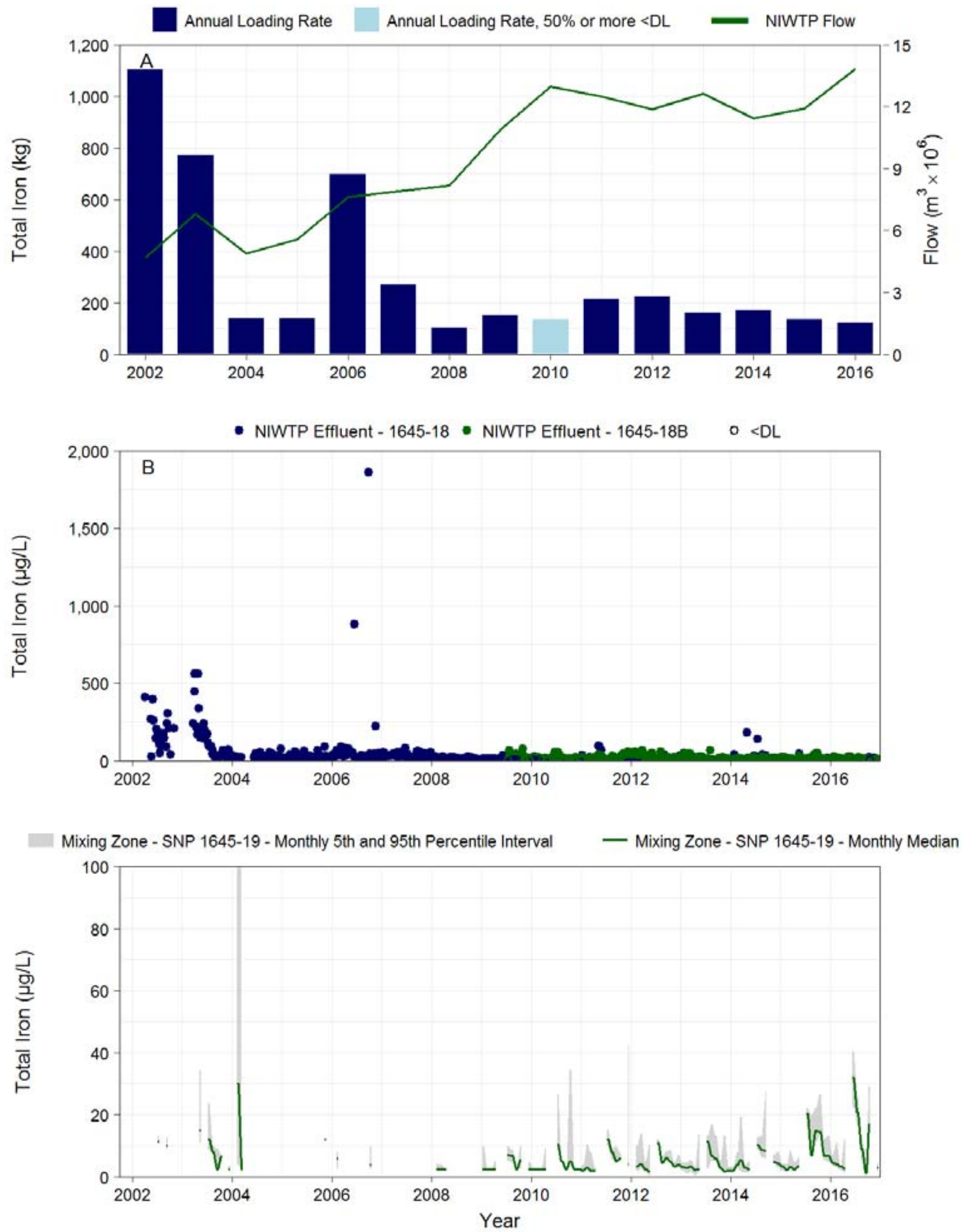
Figure 4-22 Total Copper: A) Annual Loading Rate from the North Inlet Water Treatment Plant and B) Concentration in Effluent (SNP 1645-18 and SNP 1645-18B) and C) at the Mixing Zone Boundary (SNP 1645-19), 2002 to 2016



Note: Annual Loading Rate, 50% or more <DL specifies the concentration was less than the detection limit in 50% or more of the samples, which indicates uncertainty in the load calculations. Effluent values represent concentrations in individual samples. Mixing zone values represent the monthly median concentration and 5th and 95th percentile interval at three stations (i.e., SNP 1645-19A, SNP 1645-19B/B2, SNP 1645-19C) and five depths (i.e., 2 m, 5 m, 10 m, 15 m, and 20 m). Gaps in the mixing zone dataset reflect times when samples could not be collected due to hazardous sampling conditions (e.g., ice-on and ice-off periods).

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

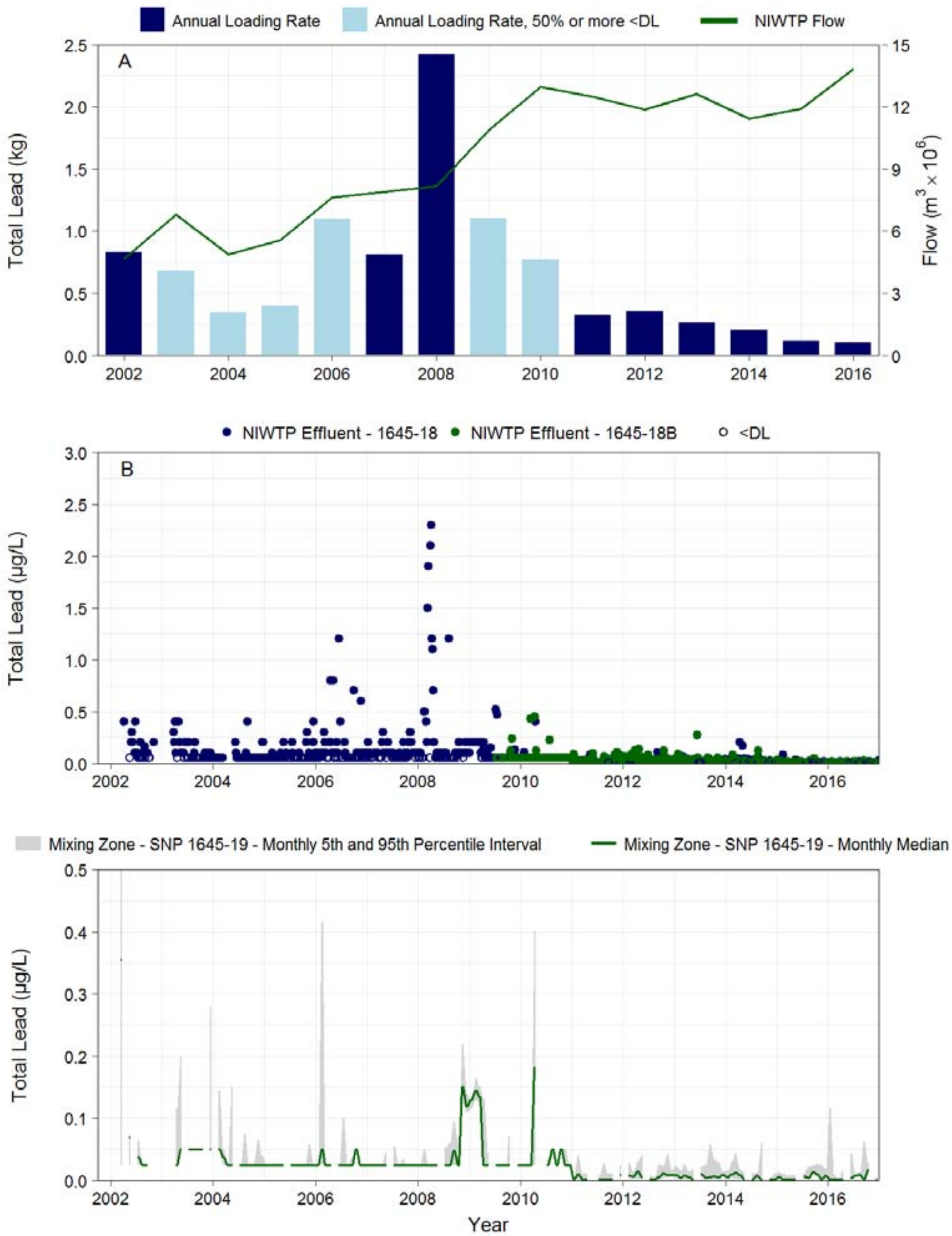
Figure 4-23 Total Iron: A) Annual Loading Rate from the North Inlet Water Treatment Plant and B) Concentration in Effluent (SNP 1645-18 and SNP 1645-18B) and C) at the Mixing Zone Boundary (SNP 1645-19), 2002 to 2016



Note: Annual Loading Rate, 50% or more <DL specifies the concentration was less than the detection limit in 50% or more of the samples, which indicates uncertainty in the load calculations. Effluent values represent concentrations in individual samples. Mixing zone values represent the monthly median concentration and 5th and 95th percentile interval at three stations (i.e., SNP 1645-19A, SNP 1645-19B/B2, SNP 1645-19C) and five depths (i.e., 2 m, 5 m, 10 m, 15 m, and 20 m). This variable was not part of the standard laboratory analysis prior to 2011; gaps in the mixing zone dataset after 2011 reflect times when samples could not be collected due to hazardous sampling conditions (e.g., ice-on and ice-off periods). Total iron values of 1,380 µg/L and 429 µg/L were recorded at the mixing zone on February 5, 2004 and are creating the spike in the 5th and 95th percentile interval for that year, which extends beyond the maximum value of the y-axis.

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

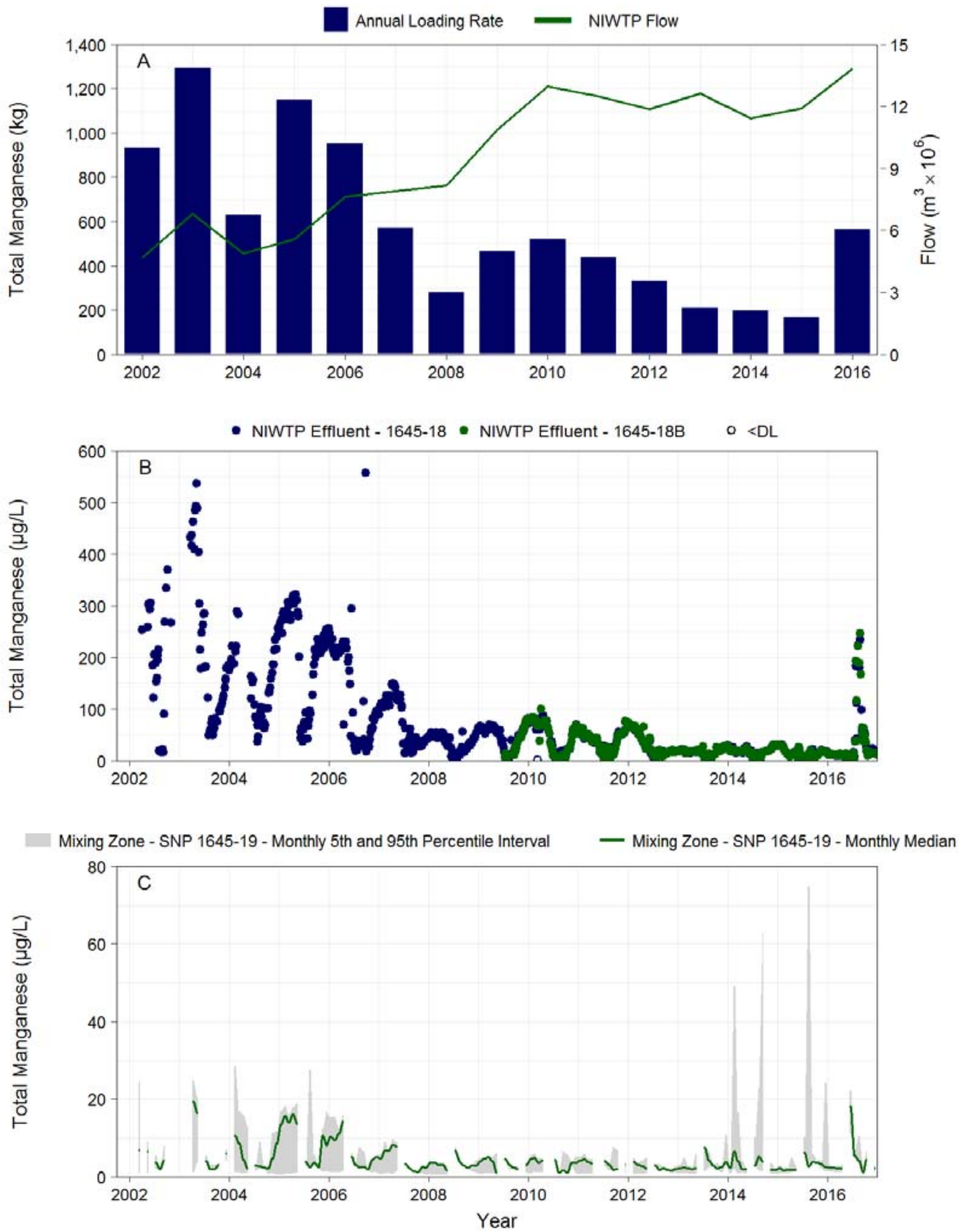
Figure 4-24 Total Lead: A) Annual Loading Rate from the North Inlet Water Treatment Plant and B) Concentration in Effluent (SNP 1645-18 and SNP 1645-18B) and C) at the Mixing Zone Boundary (SNP 1645-19), 2002 to 2016



Note: Annual Loading Rate, 50% or more <DL specifies the concentration was less than the detection limit in 50% or more of the samples, which indicates uncertainty in the load calculations. Effluent values represent concentrations in individual samples. Mixing zone values represent the monthly median concentration and 5th and 95th percentile interval at three stations (i.e., SNP 1645-19A, SNP 1645-19B/B2, SNP 1645-19C) and five depths (i.e., 2 m, 5 m, 10 m, 15 m, and 20 m). Gaps in the mixing zone dataset reflect times when samples could not be collected due to hazardous sampling conditions (e.g., ice-on and ice-off periods). Three total lead values (1.14 µg/L; 1.41 µg/L; 3.6 µg/L) were recorded at the mixing zone in March 2002 and are creating the spike in the 5th and 95th percentile interval for that year, which extends beyond the maximum value of the y-axis.

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

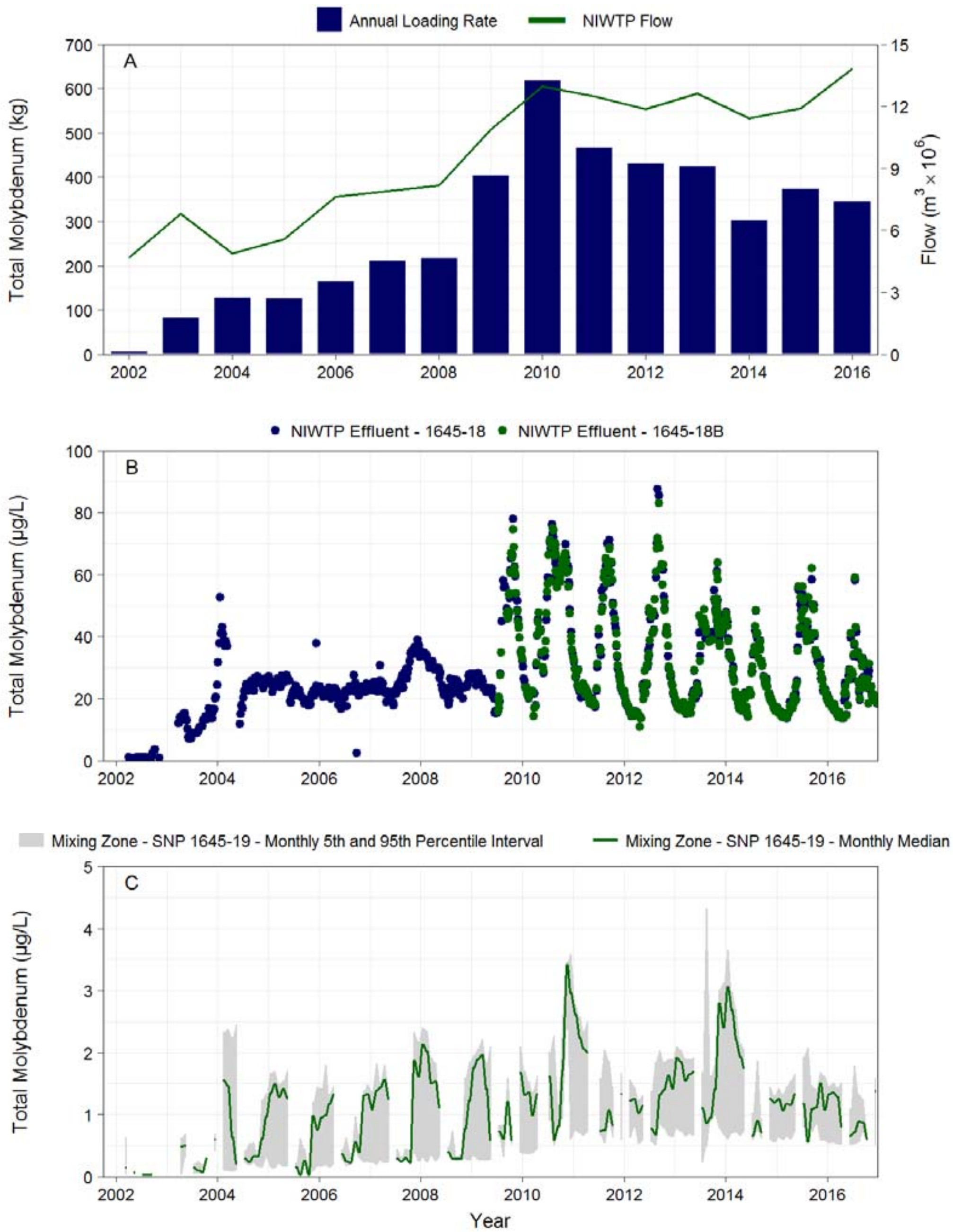
Figure 4-25 Total Manganese: A) Annual Loading Rate from the North Inlet Water Treatment Plant and B) Concentration in Effluent (SNP 1645-18 and SNP 1645-18B) and C) at the Mixing Zone Boundary (SNP 1645-19), 2002 to 2016



Note: Effluent values represent concentrations in individual samples. Mixing zone values represent the monthly median concentration and 5th percentile and 95th percentile interval at three stations (i.e., SNP 1645-19A, SNP 1645-19B/B2, SNP 1645-19C) and five depths (i.e., 2 m, 5 m, 10 m, 15 m, and 20 m). Gaps in the mixing zone dataset reflect times when samples could not be collected due to hazardous sampling conditions (e.g., ice-on and ice-off periods).

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

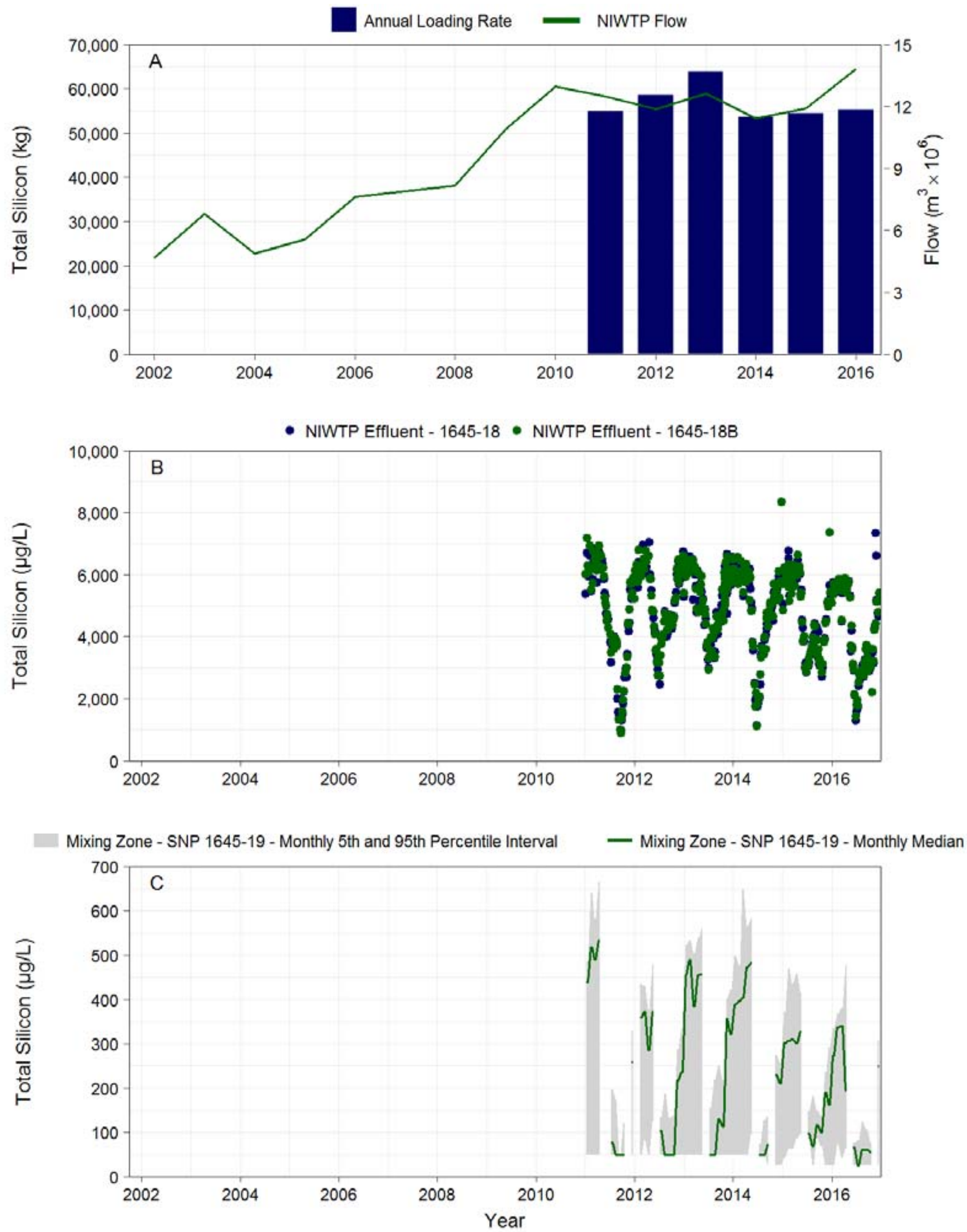
Figure 4-26 Total Molybdenum: A) Annual Loading Rate from the North Inlet Water Treatment Plant and B) Concentration in Effluent (SNP 1645-18 and SNP 1645-18B) and C) at the Mixing Zone Boundary (SNP 1645-19), 2002 to 2016



Note: Effluent values represent concentrations in individual samples. Mixing zone values represent the monthly median concentration and 5th percentile and 95th percentile interval at three stations (i.e., SNP 1645-19A, SNP 1645-19B/B2, SNP 1645-19C) and five depths (i.e., 2 m, 5 m, 10 m, 15 m, and 20 m). Gaps in the mixing zone dataset reflect times when samples could not be collected due to hazardous sampling conditions (e.g., ice-on and ice-off periods).

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

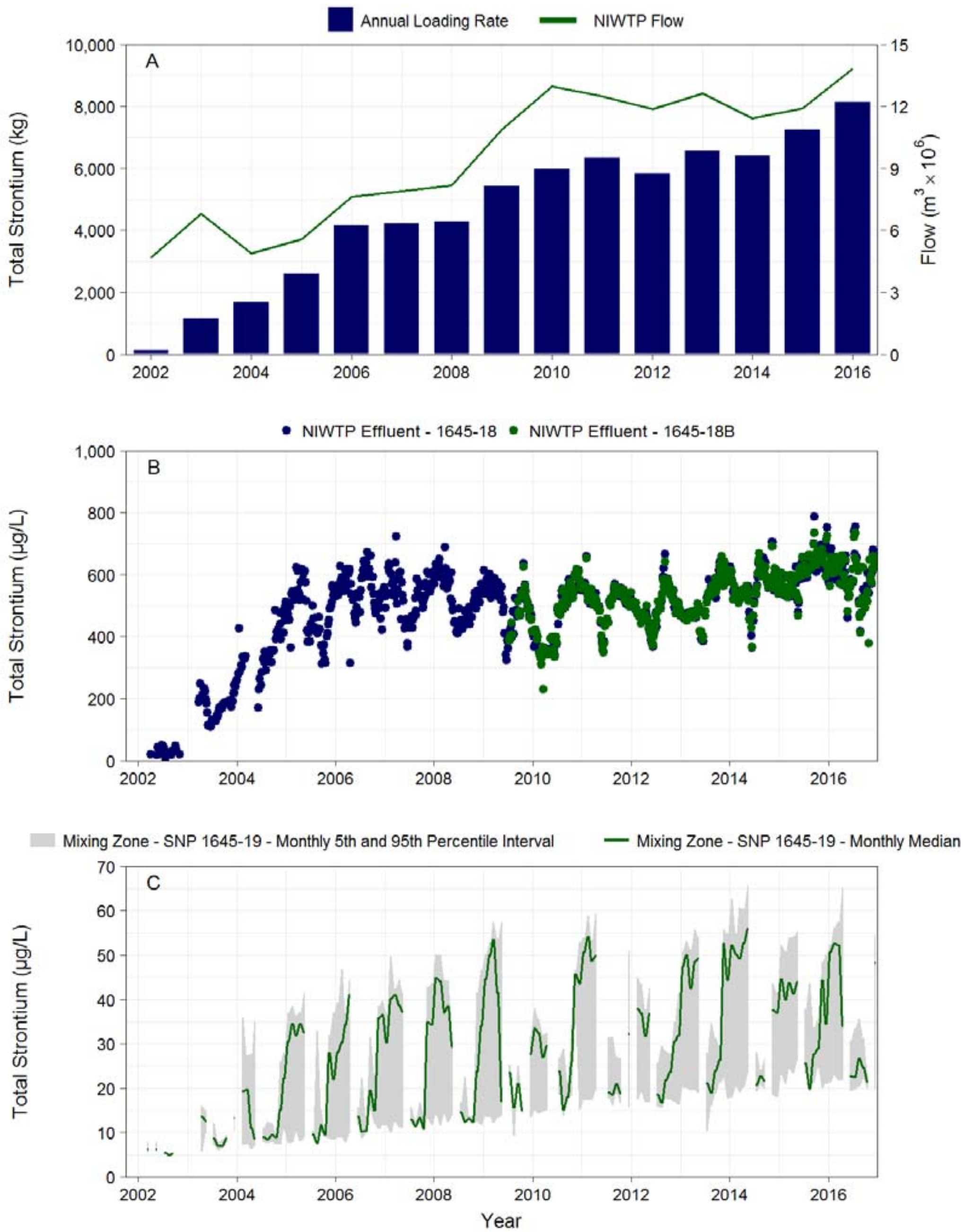
Figure 4-27 Total Silicon: A) Annual Loading Rate from the North Inlet Water Treatment Plant and B) Concentration in Effluent (SNP 1645-18 and SNP 1645-18B) and C) at the Mixing Zone Boundary (SNP 1645-19), 2002 to 2016



Note: Annual Loading Rate, 50% or more <DL specifies the concentration was less than the detection limit in 50% or more of the samples, which indicates uncertainty in the load calculations. Effluent values represent concentrations in individual samples. Mixing zone values represent the monthly median concentration and 5th and 95th percentile interval at three stations (i.e., SNP 1645-19A, SNP 1645-19B/B2, SNP 1645-19C) and five depths (i.e., 2 m, 5 m, 10 m, 15 m, and 20 m). This variable was not part of the standard laboratory analysis prior to 2011; gaps in the mixing zone dataset after 2011 reflect times when samples could not be collected due to hazardous sampling conditions (e.g., ice-on and ice-off periods).

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

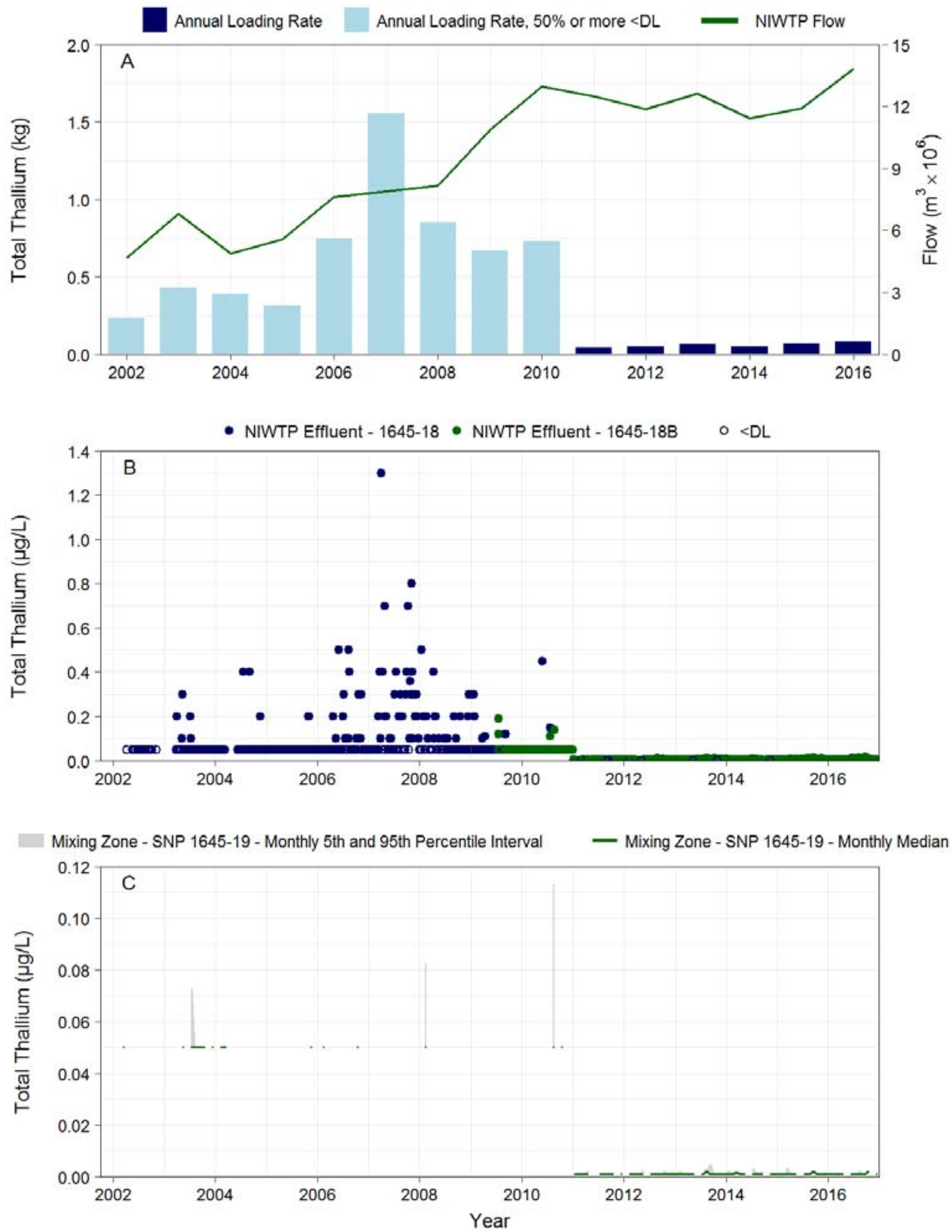
Figure 4-28 Total Strontium: A) Annual Loading Rate from the North Inlet Water Treatment Plant and B) Concentration in Effluent (SNP 1645-18 and SNP 1645-18B) and C) at the Mixing Zone Boundary (SNP 1645-19), 2002 to 2016



Note: Effluent values represent concentrations in individual samples. Mixing zone values represent the monthly median concentration and 5th percentile and 95th percentile interval at three stations (i.e., SNP 1645-19A, SNP 1645-19B/B2, SNP 1645-19C) and five depths (i.e., 2 m, 5 m, 10 m, 15 m, and 20 m). Gaps in the mixing zone dataset reflect times when samples could not be collected due to hazardous sampling conditions (e.g., ice-on and ice-off periods).

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

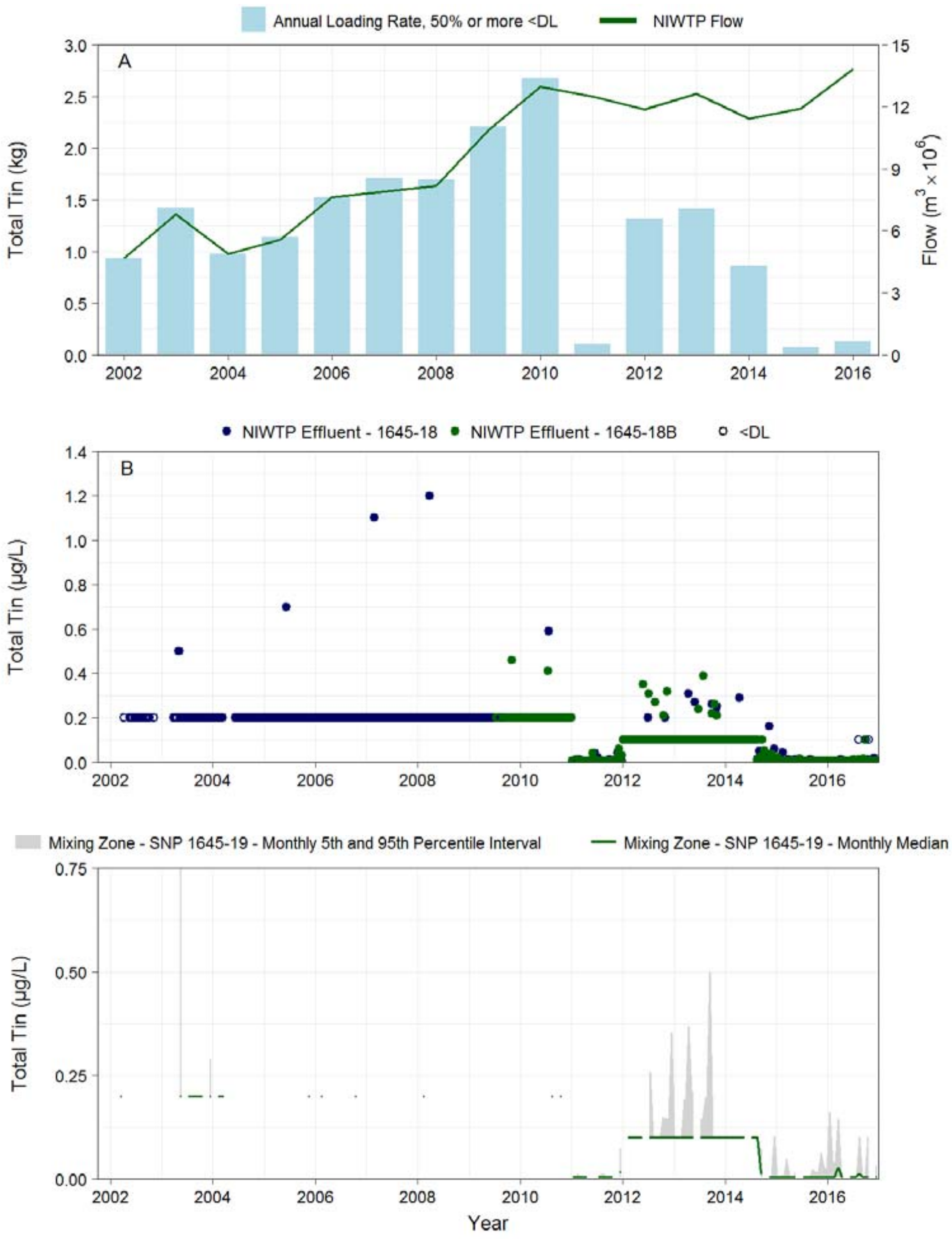
Figure 4-29 Total Thallium: A) Annual Loading Rate from the North Inlet Water Treatment Plant and B) Concentration in Effluent (SNP 1645-18 and SNP 1645-18B) and C) at the Mixing Zone Boundary (SNP 1645-19), 2002 to 2016



Note: Annual Loading Rate, 50% or more <DL specifies the concentration was less than the detection limit in 50% or more of the samples, which indicates uncertainty in the load calculations. Effluent values represent concentrations in individual samples. Mixing zone values represent the monthly median concentration and 5th and 95th percentile interval at three stations (i.e., SNP 1645-19A, SNP 1645-19B/B2, SNP 1645-19C) and five depths (i.e., 2 m, 5 m, 10 m, 15 m, and 20 m). This variable was not part of the standard laboratory analysis prior to 2011; gaps in the mixing zone dataset after 2011 reflect times when samples could not be collected due to hazardous sampling conditions (e.g., ice-on and ice-off periods).

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

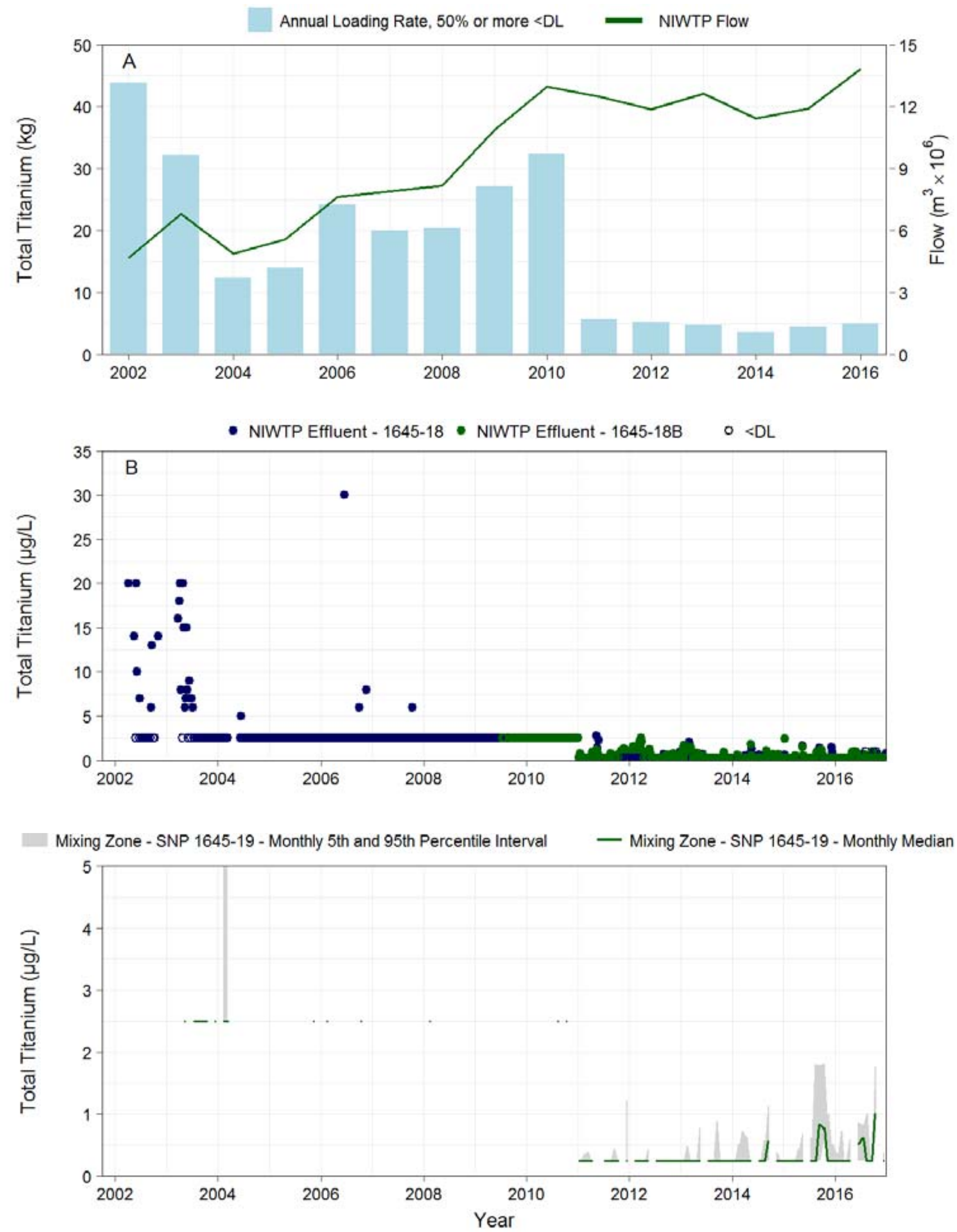
Figure 4-30 Total Tin: A) Annual Loading Rate from the North Inlet Water Treatment Plant and B) Concentration in Effluent (SNP 1645-18 and SNP 1645-18B) and C) at the Mixing Zone Boundary (SNP 1645-19), 2002 to 2016



Note: Annual Loading Rate, 50% or more <DL specifies the concentration was less than the detection limit in 50% or more of the samples, which indicates uncertainty in the load calculations. Effluent values represent concentrations in individual samples. Mixing zone values represent the monthly median concentration and 5th and 95th percentile interval at three stations (i.e., SNP 1645-19A, SNP 1645-19B/B2, SNP 1645-19C) and five depths (i.e., 2 m, 5 m, 10 m, 15 m, and 20 m). This variable was not part of the standard laboratory analysis prior to 2011; gaps in the mixing zone dataset after 2011 reflect times when samples could not be collected due to hazardous sampling conditions (e.g., ice-on and ice-off periods). Three total tin values (2.7 µg/L; 5.8 µg/L; 7.6 µg/L) were recorded at the mixing zone in May 2003 and are creating the spike in the 5th and 95th percentile interval for that year, which extends beyond the maximum value of the y-axis.

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

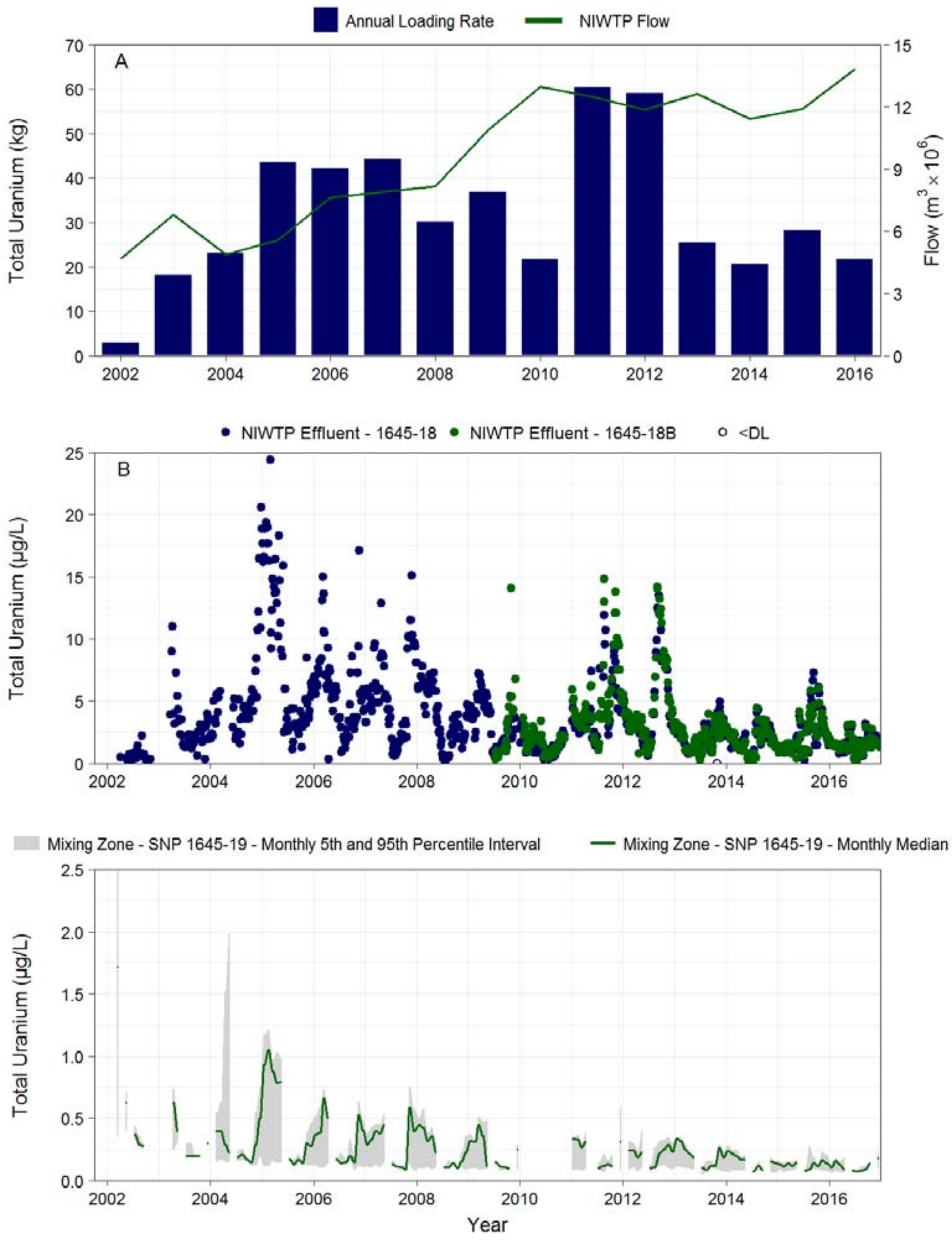
Figure 4-31 Total Titanium: A) Annual Loading Rate from the North Inlet Water Treatment Plant and B) Concentration in Effluent (SNP 1645-18 and SNP 1645-18B) and C) at the Mixing Zone Boundary (SNP 1645-19), 2002 to 2016



Note: Annual Loading Rate, 50% or more <DL specifies the concentration was less than the detection limit in 50% or more of the samples, which indicates uncertainty in the load calculations. Effluent values represent concentrations in individual samples. Mixing zone values represent the monthly median concentration and 5th and 95th percentile interval at three stations (i.e., SNP 1645-19A, SNP 1645-19B/B2, SNP 1645-19C) and five depths (i.e., 2 m, 5 m, 10 m, 15 m, and 20 m). This variable was not part of the standard laboratory analysis prior to 2011; gaps in the mixing zone dataset after 2011 reflect times when samples could not be collected due to hazardous sampling conditions (e.g., ice-on and ice-off periods). Two total titanium values (21 µg/L; 68 µg/L) were recorded at the mixing zone in February 2004 and are creating the spike in the 5th and 95th percentile interval for that year, which extends beyond the maximum value of the y-axis.

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

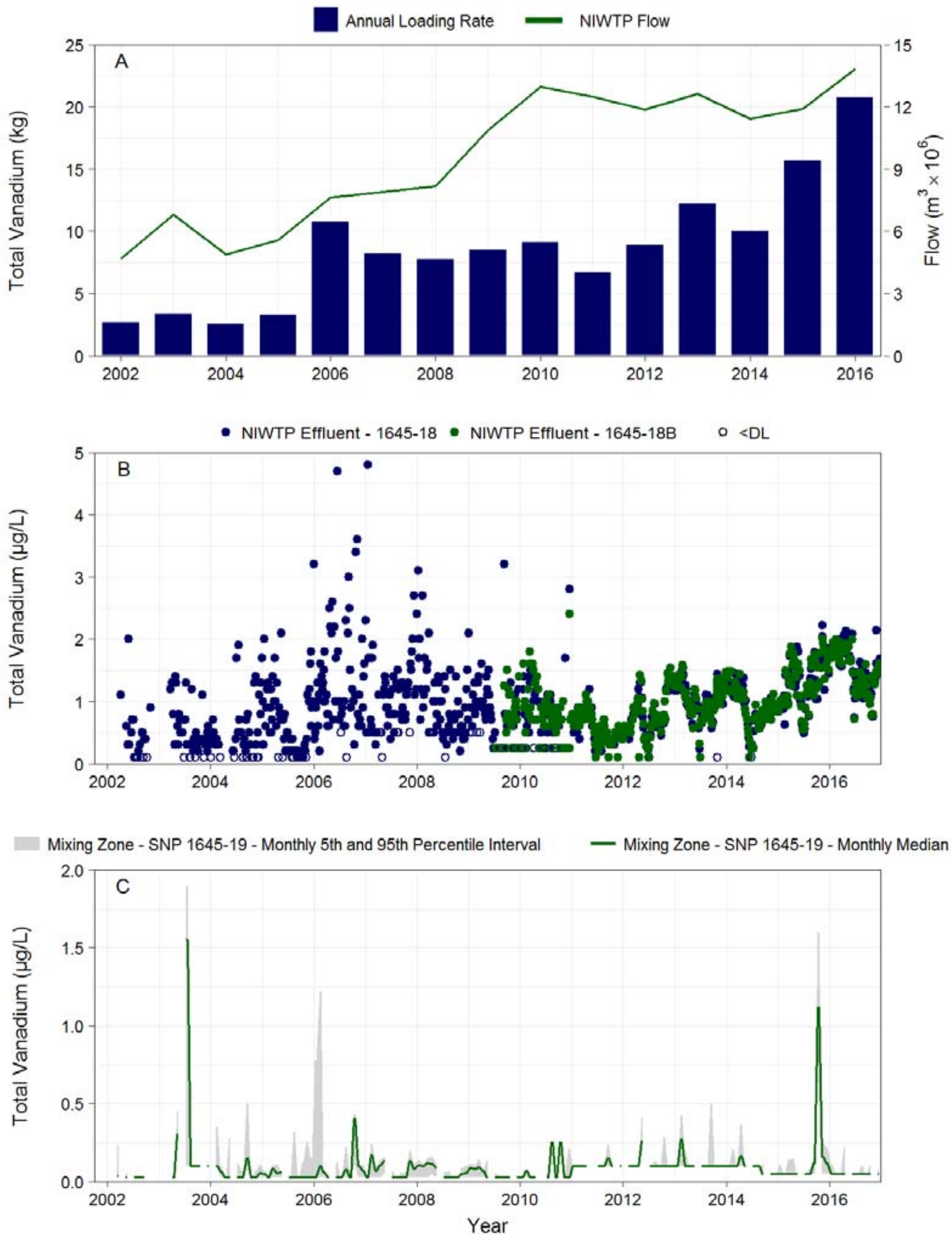
Figure 4-32 Total Uranium: A) Annual Loading Rate from the North Inlet Water Treatment Plant and B) Concentration in Effluent (SNP 1645-18 and SNP 1645-18B) and C) at the Mixing Zone Boundary (SNP 1645-19), 2002 to 2016



Note: Effluent values represent concentrations in individual samples. Mixing zone values represent the monthly median concentration and 5th percentile and 95th percentile interval at three stations (i.e., SNP 1645-19A, SNP 1645-19B/B2, SNP 1645-19C) and five depths (i.e., 2 m, 5 m, 10 m, 15 m, and 20 m). With the exception of 2010, gaps in the mixing zone dataset reflect times when samples could not be collected due to hazardous sampling conditions (e.g., ice-on and ice-off periods). Five total uranium values (3.16 µg/L; 3.39 µg/L; 4.27 µg/L; 4.64 µg/L; 12.6 µg/L) were recorded at the mixing zone in March 2002 and are creating the spike in the 5th and 95th percentile interval for that year, which extends beyond the maximum value of the y-axis.

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

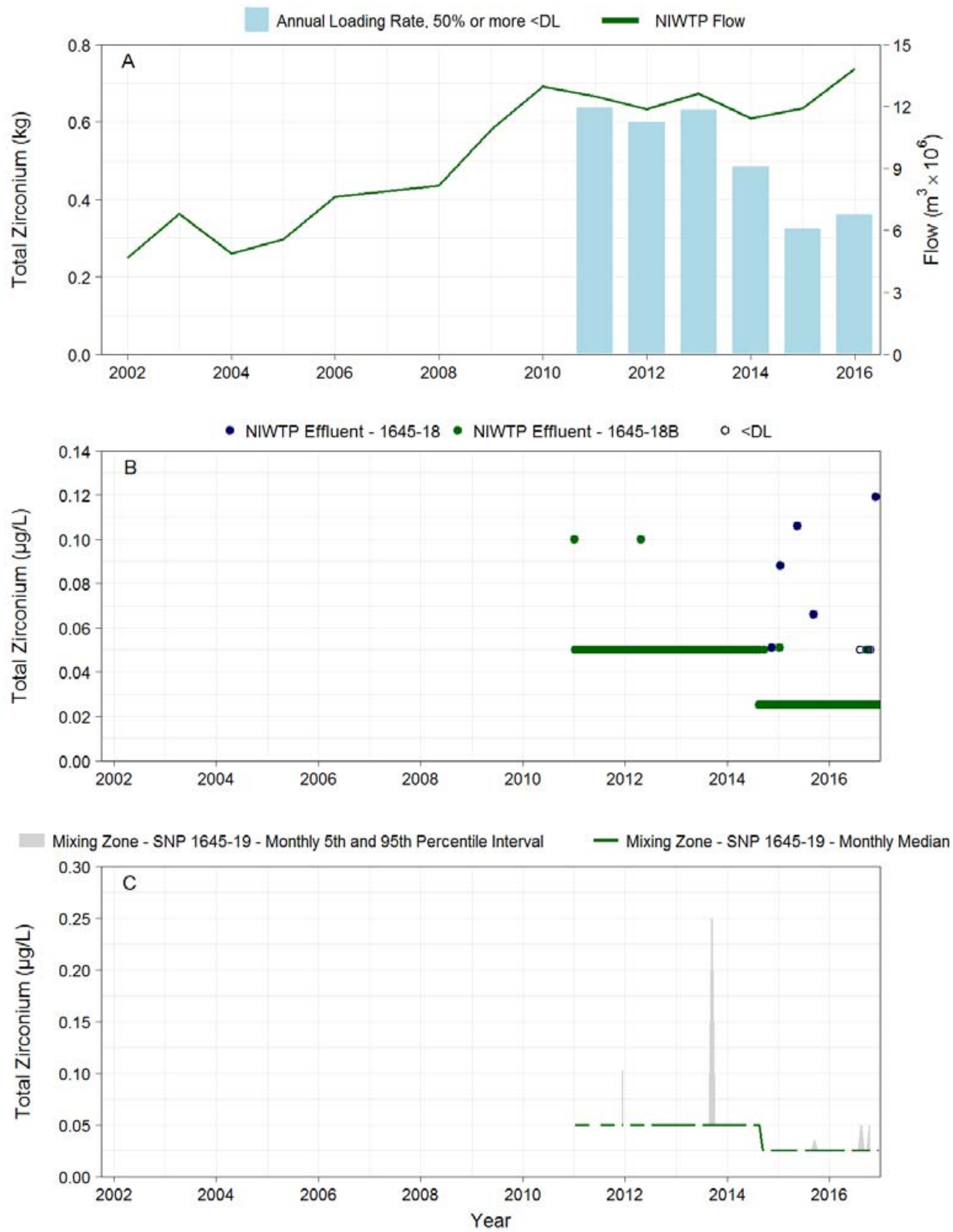
Figure 4-33 Total Vanadium: A) Annual Loading Rate from the North Inlet Water Treatment Plant and B) Concentration in Effluent (SNP 1645-18 and SNP 1645-18B) and C) at the Mixing Zone Boundary (SNP 1645-19), 2002 to 2016



Note: Effluent values represent concentrations in individual samples. Mixing zone values represent the monthly median concentration and 5th percentile and 95th percentile interval at three stations (i.e., SNP 1645-19A, SNP 1645-19B/B2, SNP 1645-19C) and five depths (i.e., 2 m, 5 m, 10 m, 15 m, and 20 m). Gaps in the mixing zone dataset reflect times when samples could not be collected due to hazardous sampling conditions (e.g., ice-on and ice-off periods).

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

Figure 4-34 Total Zirconium: A) Annual Loading Rate from the North Inlet Water Treatment Plant and B) Concentration in Effluent (SNP 1645-18 and SNP 1645-18B) and C) at the Mixing Zone Boundary (SNP 1645-19), 2002 to 2016



Note: Annual Loading Rate, 50% or more <DL specifies the concentration was less than the detection limit in 50% or more of the samples, which indicates uncertainty in the load calculations. Effluent values represent concentrations in individual samples. Mixing zone values represent the monthly median concentration and 5th and 95th percentile interval at three stations (i.e., SNP 1645-19A, SNP 1645-19B/B2, SNP 1645-19C) and five depths (i.e., 2 m, 5 m, 10 m, 15 m, and 20 m). This variable was not part of the standard laboratory analysis prior to 2011; gaps in the mixing zone dataset after 2011 reflect times when samples could not be collected due to hazardous sampling conditions (e.g., ice-on and ice-off periods).

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

4.3.1.2 Comparison to Effluent Quality Criteria

During 2014 to 2016, all variables that have EQC (i.e., those in Table 4-3) were below both the maximum allowable concentration criterion in any grab sample and the maximum average concentration criterion (Table 4-3; Golder 2016b,c and 2017c), with one exception. A single elevated oil and grease value of 6.5 mg/L collected at Station SNP 1645-18 on 22 September 2014 exceeded the maximum allowable concentration of 5 mg/L. However, this result was due to a quality control issue, which was communicated to the WLWB, and is not generally representative of oil and grease concentrations in effluent. All other oil and grease samples in 2014 were well below the maximum allowable concentration, with the majority (89%) being lower than the DL.

Exceedances of EQC that have occurred throughout the operation of the NIWTP (i.e., from 2002 to 2013) are discussed in the AEMP annual reports for each year of monitoring. As well, the SNP reports submitted to the WLWB on a monthly basis provide graphs demonstrating conformity of effluent chemistry to EQC. These reports are accessible on the WLWB public registry.

4.3.1.3 Effluent Toxicity

The results of lethal and sub-lethal toxicity testing from 2002 to 2016 indicated that the Mine effluent was generally non-toxic to aquatic test organisms (Tables 4-9 and 4-10; Golder 2016a,b,c and 2017c). From June 2002 to February 2008, a total of 160 effluent samples were submitted for acute and chronic lethality testing, and a total of 100 samples were submitted for sub-lethal testing. Toxicity test results demonstrated no toxic effects to aquatic test organisms in all but one of the samples submitted for lethal testing. Sub-lethal toxicity was observed in 12 samples during this period (see Golder 2016a, Appendix 4B, Tables 4B-1 and 4B-2).

More recent results from March 2008 to December 2016 indicate that the effluent continues to be not acutely toxic, with only one of the 271 samples submitted for testing demonstrating acute toxicity (Table 4-9). One *D. magna* test in September 2010 at SNP 1645-18B had a result of greater than 50% mortality, indicating acute toxicity. To follow up on and confirm the September 2010 result, acute toxicity testing on *D. magna* was completed monthly in November and December 2010 and throughout 2011, and indicated no acute toxicity.

Of the 191 effluent samples collected from March 2008 to December 2016 for sub-lethal toxicity testing, only six demonstrated sub-lethal toxicity (Table 4-10). Reductions in *C. dubia* reproduction were detected in tests of effluent conducted in June 2009, September 2010, March 2014, December 2014 and December 2015. A reduction in embryo vitality for Rainbow Trout was detected at Station SNP 1645-18B for a sample collected on 30 August 2016. Mean Rainbow Trout embryo viability was 79.6% in the control and 69.2% in the sample exposed to 100% effluent. However, a follow-up sample collected at this location on 13 September 2016 had a relative difference of 0.8% from the control. The repeat sample was considered a pass, and results for all other test species demonstrated no toxic response.

Table 4-9 Acute and Chronic Lethality Toxicity Testing Results, North Inlet Water Treatment Plant Effluent, 2008 to 2016

Species	Month	2008[b]	2009		2010		2011		2012		2013		2014		2015		2016	
		1645-18	1645-18	1645-18B	1645-18	1645-18B	1645-18	1645-18B	1645-18	1645-18B	1645-18	1645-18B	1645-18	1645-18B	1645-18	1645-18B	1645-18	1645-18B
Rainbow Trout[a]	January	[c]	-	-	-	-	Pass	Pass	-	-	Pass	Pass	-	-	-	-	-	-
	February	[c]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	March	Pass	Pass	-	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass
	April	Pass	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	May	Pass	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Pass	Pass
	June	Pass	Pass	-	Pass	Pass	-	-	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	-	-
	July	Pass	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	August	Pass	-	-	-	-	Pass	Pass	-	-	-	-	-	-	-	-	Pass	Pass
	September	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	-	Pass	Pass	-	-
	October	[d]	-	-	-	-	-	-	-	-	-	-	-	Pass	-	-	-	-
	November	[d]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	December	Pass	Pass	Pass	Pass	Pass	Pass	-	Pass	Pass	-	-	Pass	Pass	Pass	Pass	Pass	Pass
Ceriodaphnia dubia[a]	January	[e]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	February	[e]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	March	[e]	[e]	[e]	[e]	[e]	[e]	[e]	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass
	April	[e]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	May	[e]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Pass	Pass
	June	[e]	[e]	[e]	[e]	[e]	[e]	[e]	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	-	-
	July	[e]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	August	[e]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Pass	Pass
	September	[e]	[e]	[e]	[e]	[e]	[e]	[e]	Pass	Pass	Pass	Pass	Pass	-	Pass	Pass	-	-
	October	[e]	-	-	-	-	-	-	-	-	-	-	-	Pass	-	-	-	-
	November	[e]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	December	[e]	[e]	[e]	[e]	[e]	[e]	[e]	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass

Table 4-9 Acute and Chronic Lethality Toxicity Testing Results, North Inlet Water Treatment Plant Effluent, 2008 to 2016

Species	Month	2008[b]	2009		2010		2011		2012		2013		2014		2015		2016	
		1645-18	1645-18	1645-18B	1645-18	1645-18B	1645-18	1645-18B	1645-18	1645-18B	1645-18	1645-18B	1645-18	1645-18B	1645-18	1645-18B	1645-18	1645-18B
Daphnia magna[a]	January	[c]	-	-	-	-	Pass	Pass	-	-	-	-	-	-	-	-	-	-
	February	[c]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	March	Pass	Pass	-	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass
	April	Pass	-	-	-	-	Pass	Pass	-	-	-	-	-	-	-	-	-	-
	May	Pass	-	-	-	-	Pass	Pass	-	-	-	-	-	-	-	-	Pass	Pass
	June	Pass	Pass	-	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	-	-
	July	Pass	-	-	-	-	Pass	Pass	-	-	-	-	-	-	-	-	-	-
	August	Pass	-	-	-	-	Pass	Pass	-	-	-	-	-	-	-	-	Pass	Pass
	September	Pass	Pass	Pass	Pass	Fail[g]	Pass	Pass	Pass	Pass	Pass	Pass	Pass	-	Pass	Pass	-	-
	October	[d]	-	-	-	-	Pass	Pass	-	-	-	-	-	Pass	-	-	-	-
	November	[d]	-	-	Pass	Pass	-	-	Pass	Pass	-	-	-	-	-	-	-	-
	December	Pass	Pass	Pass	Pass	Pass	-	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass
Hyalella azteca[a]	January	[f]	Pass	-	-	-	-	-	-	-	-	-	-	-	Pass	Pass	-	-
	February	[f]	Pass	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	March	[f]	Pass	-	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass
	April	[f]	Pass	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	May	Pass	Pass	-	-	-	-	-	-	-	-	-	-	-	-	-	Pass	Pass
	June	Pass	Pass	-	Pass	Pass	-	-	-	-	Pass	Pass	Pass	Pass	Pass	Pass	-	-
	July	Pass	[d]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	August	Pass	[d]	-	-	-	Pass	Pass	-	-	-	-	-	-	-	-	Pass	Pass
	September	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	[h]	[h]	Pass	-	Pass	Pass	-	-
	October	Pass	-	-	-	-	-	-	-	-	-	-	-	Pass	-	-	-	-
	November	Pass	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	December	Pass	Pass	Pass	Pass	Pass	Pass	Pass	-	-	Pass	Pass	Pass	Pass	-	-	Pass	Pass

a) Test is considered a "fail" if mortality is ≥50%.
b) Results for SNP 1645-18B are reported from 2009 and later.
c) Acute toxicity testing results in January and February of 2008 are presented in Appendix 4A, Table 4A 1 of Golder 2016a.
d) Monthly testing was no longer required.
e) The *Ceriodaphnia dubia* test was not performed prior to March 2012.
f) The *Hyalella azteca* test was not performed prior to May 2008.
g) 100% mortality of test organisms reported.
h) The effluent sample collected in September for *Hyalella azteca* testing was misplaced in transit from the Mine to the analytical laboratory.
- = data not available.

Table 4-10 Sub-lethal Lethality Toxicity Testing Results, North Inlet Water Treatment Plant Effluent, 2008 to 2016

Species	Month	2008	2009		2010		2011		2012		2013		2014		2015		2016	
		1645-18	1645-18	1645-18B	1645-18	1645-18B	1645-18	1645-18B	1645-18	1645-18B	1645-18	1645-18B	1645-18	1645-18B	1645-18	1645-18B	1645-18	1645-18B
Rainbow Trout[a]	January	-	-	-	-	-	-	-	-	-	Pass	Pass	-	-	Pass	Pass	-	-
	March	Pass	Pass	-	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	-	-	Pass	Pass
	April	-	-	-	-	-	-	-	-	-	-	-	-	-	Pass	Pass	-	-
	May	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Pass	Pass
	June	Pass	Pass	-	Pass	Pass	-	-	Pass	Pass	-	-	Pass	Pass	Pass	Pass	-	-
	July	-	-	-	-	-	-	-	-	-	Pass	Pass	-	-	-	-	-	-
	August	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Fail[j]
	September	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass[g]	Pass	Pass	Pass	Pass	-	Pass	Pass	-	Pass
	October	-	-	-	-	-	-	-	-	-	-	-	-	Pass	-	-	-	-
	December	Pass	Pass	Pass	Pass	Pass	Pass	-	Pass	Pass	-	-	Pass	Pass	-	-	Pass	Pass
Ceriodaphnia dubia[b]	March	Pass	Pass	-	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Fail[h]	Pass	Pass	Pass	Pass	Pass
	May	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Pass	Pass
	June	Pass	Pass[d]	-	Pass	Pass	-	-	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	-	-
	August	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Pass	Pass
	September	Pass	Pass	Pass	Fail[e]	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	-	Pass	Pass	-	-
	October	-	-	-	-	-	-	-	-	-	-	-	-	Pass	-	-	-	-
	December	Pass	Pass	Pass	Pass	Pass	-	Pass	Pass	Pass	Pass	Pass	Fail[i]	Pass	Fail[i]	Pass	Pass	Pass
Pseudokirchn-eriella subcapitata[c]	January	-	-	-	-	-	-	-	-	-	-	-	-	-	Pass[f]	Pass[f]	-	-
	March	Pass	Pass	-	Pass	Pass	Pass[f]	Pass[f]	Pass	Pass	Pass	Pass	Pass[f]	Pass[f]	Pass[f]	Pass[f]	Pass[f]	Pass[f]
	May	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Pass[f]	Pass[f]
	June	Pass	Pass	-	Pass	Pass	-	-	Pass	Pass	Pass	Pass	Pass[f]	Pass[f]	Pass[f]	Pass[f]	-	-
	August	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Pass	Pass[f]
	September	Pass	Pass	Pass	Pass	Pass	-	Pass[f]	Pass	Pass	Pass	Pass	Pass[f]	-	Pass[f]	Pass[f]	-	-
	October	-	-	-	-	-	-	-	-	-	-	-	-	Pass[f]	-	-	-	-
	December	Pass	Pass	Pass	Pass	Pass	-	-	Pass	Pass	Pass	Pass	Pass[f]	Pass[f]	-	-	Pass[f]	Pass[f]

a) Trout embryo (early life stage) survival test is considered a “fail”, if reduction in viable embryos is ≥50% compared to control.
b) Test is considered a “fail” if inhibitory effect on reproduction compared to control in ≥50%.
c) Test is considered a “fail” if reduction in growth compared to control is ≥50%.
d) Initial test results indicated that% mortality was 60%. When the sample was reanalyzed to verify the results, mortality was 0%.
e) The% mortality in this sub-lethal test on effects to reproduction was 70%.
f) Lab results indicate enhanced algal growth compared to the control.
g) The result for this test was a marginal pass (reduction in viable embryos compared to the control was 48%).
h) The result for the test was a marginal fail (inhibitory effect on reproduction compared to the control was 53%).
i) The result for this test was a marginal fail (inhibitory effect on reproduction compared to the control was 50%).
j) The result for this test was a fail (embryo vitality was 69.2%; a relative difference compared to the control of 10.4%).

4.3.2 Water Quality

The following section provides information on temporal trends in variables measured as depth profiles and as discrete samples within the AEMP for the Mine. A summary of effects is presented in terms of Action Level exceedances; potential effects from dust deposition and A21 dike construction; potential cumulative effects to Lac de Gras from Diavik and Ekati mines; and WOE effects rankings.

4.3.2.1 Temporal Trends

4.3.2.1.1 Depth Profiles

This section describes the *in situ* (i.e., field-measured) water quality measurements for DO, water temperature, pH and specific conductivity recorded at AEMP stations from 1996 to 2016 (Figures 4-35 to 4-38).

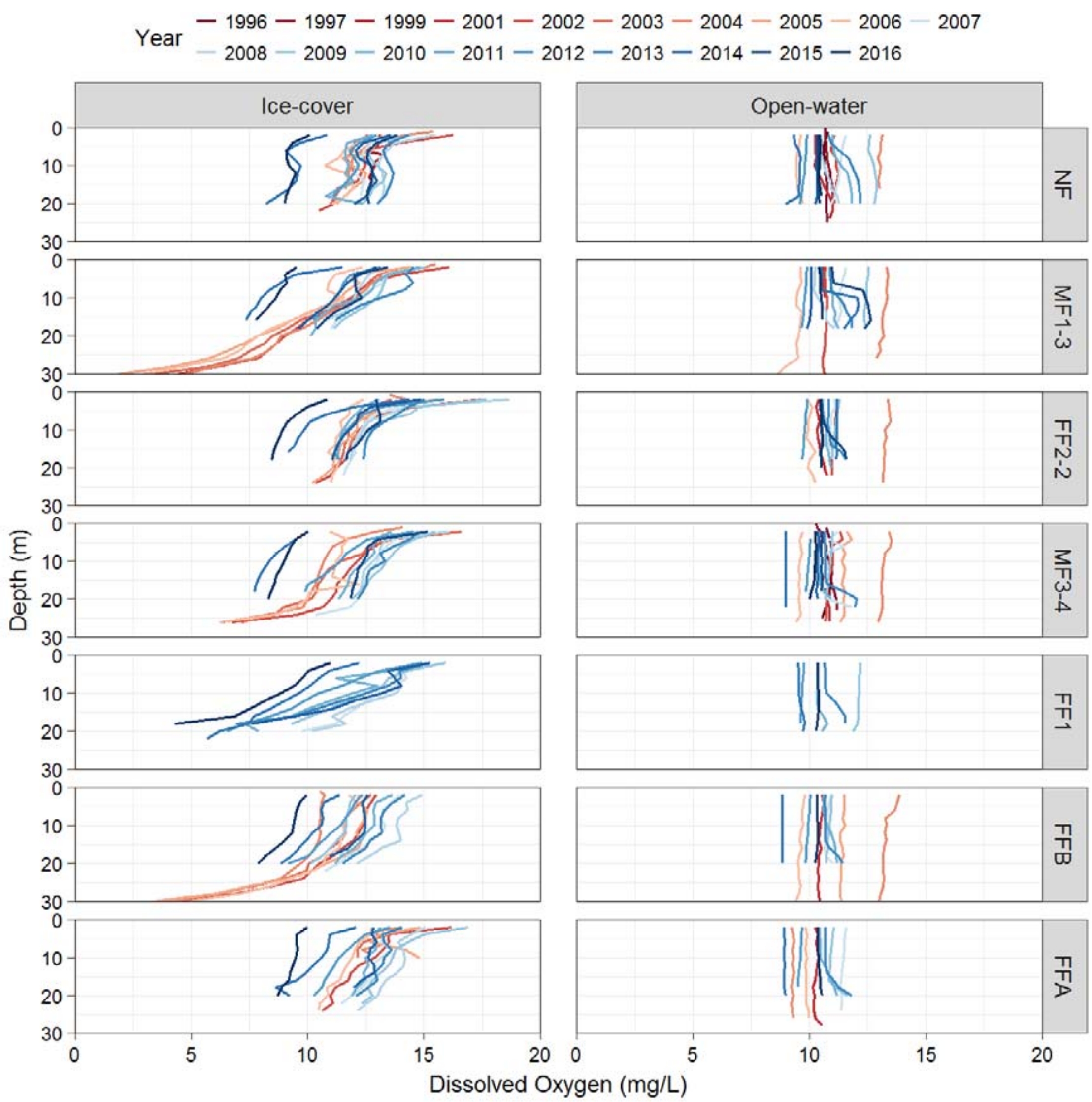
No trends occurred in DO concentration over time, as indicated by profile measurements from different years occurring at similar levels of DO (Figure 4-35). During the open-water season, DO concentrations were typically uniform throughout the water column; values recorded at or above 13 mg/L in the open-water season of 2004 are unusally high, for unknown reasons. During the ice-cover season, DO concentrations were usually highest just below the ice and declined with increasing depth; DO concentrations recorded for the ice-cover seasons in 2013 and 2016 had lower values than other years at all stations/areas. At Station MF1-3 and the FF1 and FFB areas, near-bottom DO concentrations during ice-cover were at or below the Effects Benchmark of 6.5 mg/L for the protection of aquatic life for “other” life stages (i.e., non-early life stages). The lower DO values at these stations are not likely mine-related, as the reduction in DO near the lake bottom is not present in the NF area where the effect would be expected to be greatest if it was caused by the Mine discharge.

As with DO, no trends were observed in water temperature over time, both at a given location and among stations (Figures 4-36). Temperature profiles in Lac de Gras were vertically homogeneous at most stations during the ice-cover season, with a slight increase in temperature from 0ºC to 3ºC with depth, as would be expected. During the open-water season, water temperature at most stations was vertically homogeneous or decreased gradually with depth. Weak stratification was present at several stations (e.g., MF1-3, FF2-2, MF3-4, FF1, FFB, FFA) in some years.

Depth profile data for pH indicate a tendency for pH to be slightly elevated in more recent years, particularly in the ice-cover season at NF, MF and FF locations (Figure 4-37). This is not surprising because the pH of the effluent is slightly alkaline, with the median pH of the effluent dataset at approximately 7.5. In both seasons, pH typically decreased gradually with depth. The slightly greater pH values closer to the water surface in a given year likely reflected the removal of dissolved carbon dioxide through photosynthesis. The pH Effects Benchmark for protection of aquatic life is a range from 6.5 to 9.0, while the drinking water Effects Benchmark is 6.5 to 8.5 (Table 4-4). As illustrated in Figure 4-37, the pH range of Lac de Gras in all areas is generally between 6.0 and 7.0 in the ice-cover season, and 6.0 to 7.5 in the open-water season; values are, therefore, below the lower benchmark value of 6.5 throughout Lac de Gras in both seasons, at various depths, and over time. Given the general range of a majority of the pH depth profiles, the profiles during the ice-cover season with pH values below 5.0 or greater than 8.0 are anomalous.

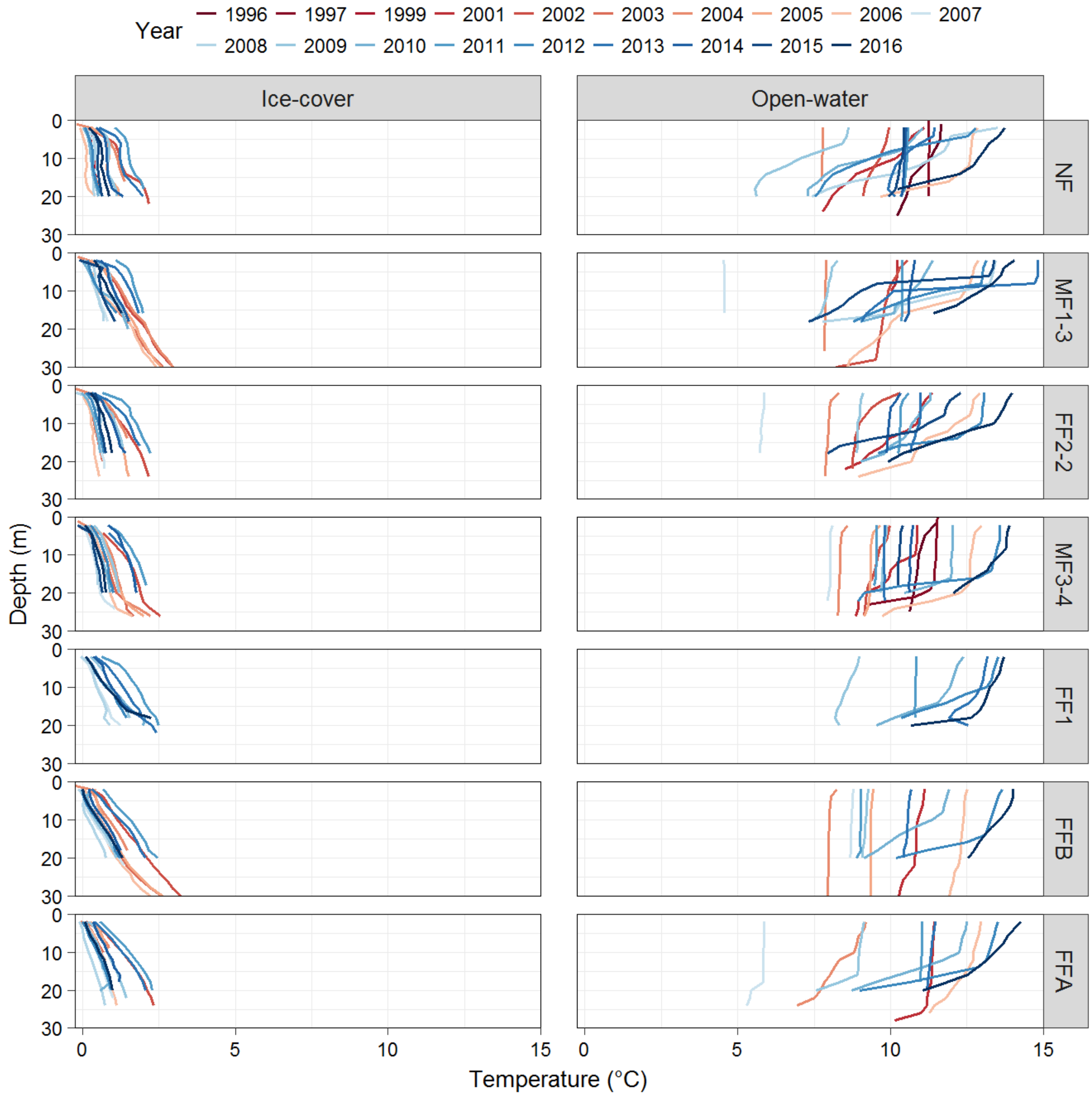
In general, specific conductivity has increased by about 20 µS/cm throughout Lac de Gras over the period of record, with greater increases in the NF area, which has had a maximum of nearly 60 µS/cm in recent years (Figure 4-38). During the ice-cover season in most years, specific conductivity increased with depth in the NF area to approximately 12 m depth and then declined slightly with increasing water depth (Figure 4-38). The greater specific gravity of the effluent, combined with the absence of wind and wave-driven mixing during the ice-cover season, resulted in elevated conductivity in the bottom two-thirds of the water column in the NF area. The greater conductivity at this depth indicates the depth range where the effluent plume was located. Complete vertical mixing of the effluent was generally observed at stations beyond the NF during the ice-cover season and the open-water season. The slight increases in conductivity at the top of the profiles during the ice-cover season is the result of solute exclusion from ice.

Figure 4-35 Dissolved Oxygen Depth Profiles in Lac de Gras, 1996 to 2016



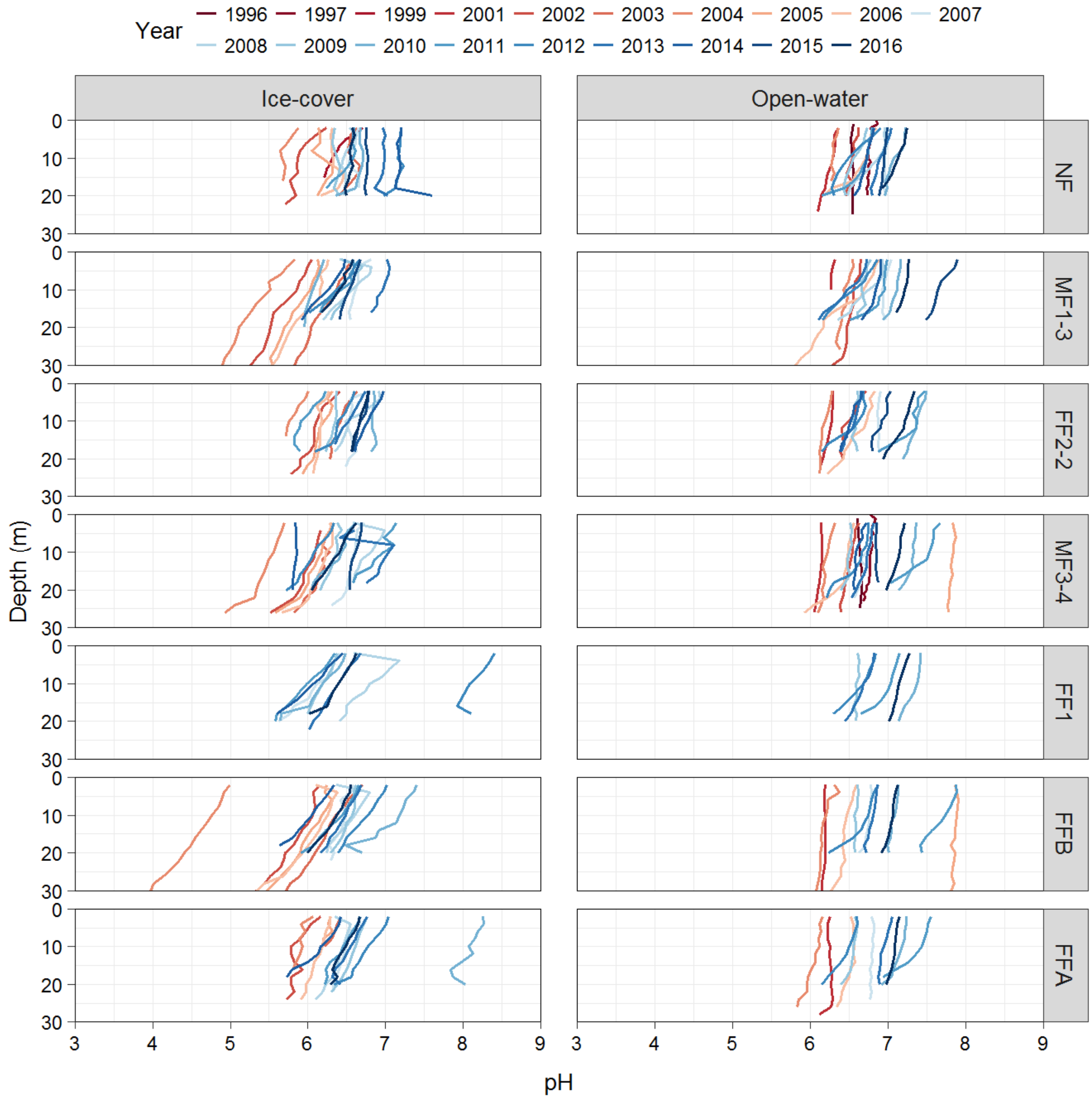
Note: Depth profiles prior to 2007 were measured at historical locations that were deeper than station locations after 2007 (see Table 4-1 for the pairing of historical and contemporary AEMP stations).

Figure 4-36 Temperature Depth Profiles in Lac de Gras, 1996 to 2016



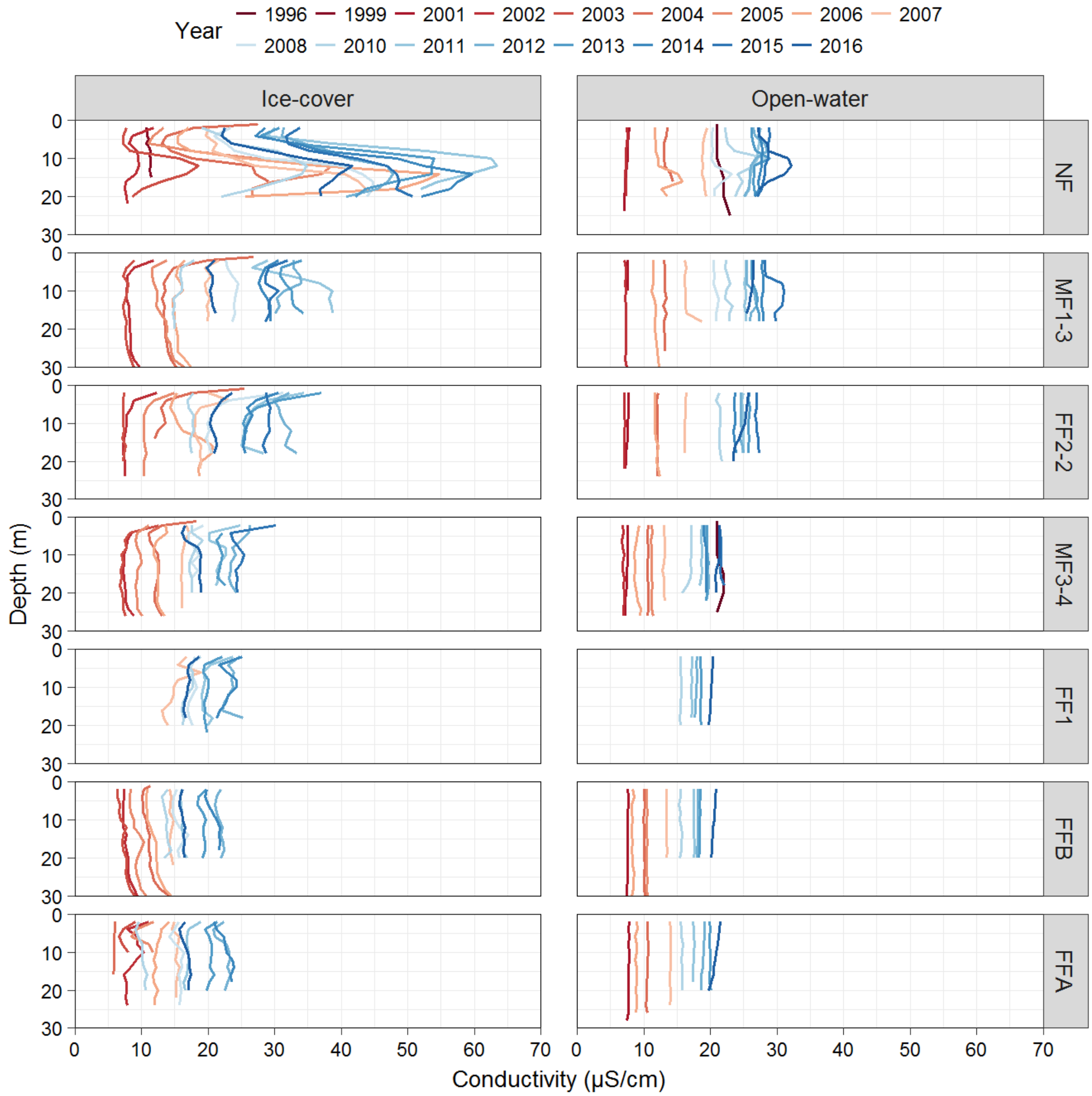
Note: Depth profiles prior to 2007 were measured at historical locations that were deeper than station locations after 2007 (see Table 4-1 for the pairing of historical and contemporary AEMP stations).

Figure 4-37 pH Depth Profiles in Lac de Gras, 1996 to 2016



Note: Depth profiles prior to 2007 were measured at historical locations that were deeper than station locations after 2007 (see Table 4-1 for the pairing of historical and contemporary AEMP stations).

Figure 4-38 Specific Conductivity Depth Profiles in Lac de Gras, 1996 to 2016



Note: Depth profiles prior to 2007 were measured at historical locations that were deeper than station locations after 2007 (see Table 4-1 for the pairing of historic and contemporary AEMP stations).

4.3.2.1.2 Discrete Samples

Time series plots showing mid-depth concentrations of SOIs at AEMP stations in Lac de Gras and Lac du Sauvage, near the outlet to Lac de Gras, are presented in Figures 4-39 to 4-93. Mid-depth concentrations are presented herein, because that is the depth where the effluent plume is most likely to be present in a typical year considering the full period of record (see Section 4.3.2.1.1, Figure 4-38; Appendix 4C). Presenting the mid-depth data in this section also allows for the inclusion of more data, because the FF areas are currently sampled at the mid-depth only, as were historical stations (i.e., stations sampled prior to 2007).

Plots of concentrations of SOIs in top and bottom samples for the NF and MF can be found in Appendix 4C. This appendix also includes the top, middle and bottom samples for the non-SOI variables, together with text describing any trends in these variables over time.

In general, temporal trends that were identified in the previous AEMP Re-evaluation Reports (Golder 2011a, 2016a) persisted following the inclusion of the 2014 to 2016 data in the time series plots. The following general observations were made based on the updated time series plots:

- Pre-2007 data were typically more variable than 2007 to 2016 data, reflecting improvements in analytical techniques (e.g., DLs) and refinements to the AEMP design.
- Concentrations of SOIs were generally greater and more variable during the ice-cover season than during the open-water season, particularly at stations closest to the effluent diffusers. Reduced mixing from wind and wave action during the ice-cover season likely resulted in the limited vertical mixing of the effluent plume in the ice-cover season, as illustrated in Figure 4-38.
- Concentrations in the top and bottom samples were generally less than the mid-depth samples (see Appendix 4C). The top depth samples generally exhibited lower concentrations, while the bottom and mid-depth samples were more similar in concentration.
- Increasing temporal trends in the concentrations of TDS (calculated), associated major ions and some total metals (e.g., strontium) at AEMP stations generally reflected trends identified in effluent and at the edge of the mixing zone boundary (Section 4.3.1.1).
- Results from the 2016 open-water season indicated the effects of the A21 dike construction, and potentially dust deposition, on water quality in the MF area as illustrated by elevated concentrations/levels for TSS, turbidity, aluminum, bismuth, chromium, cobalt, copper, iron, lead, manganese, silicon, thallium, titanium, uranium, vanadium, and zirconium. The potential effects of dust deposition and dike construction are described further in Section 4.3.2.2.2 and Section 4.3.2.3.3.
- Greater ice-cover concentrations of TDS, calcium, chloride, potassium, sodium, sulphate, molybdenum and strontium at LDG-48 and/or FFA than at FFB are likely indicative of cumulative effects of the Diavik discharge and the Ekati mine discharge at the Slipper Bay area. See Section 4.3.2.2.3 for further details.

Detailed results of the time series plots and trend analysis for SOIs are provided in the following sections. Trend analyses could not be completed for the following SOI variables because of the high proportion of data being less than the DL: TSS, nitrite, total bismuth, chromium, silicon, thallium, titanium, vanadium, and zirconium; the percentage of censored data for each variable is provided in the following sections.

Conventional Parameters

In general, data collected since 2011 indicate that turbidity and TSS are similar to the normal ranges for these variables in the NF, MF and FF areas, especially during the ice-cover season (Figures 4-39 and 4-41). Exceptions include turbidity in the NF area, which was occasionally above the normal range in the open-water season. As well, turbidity and TSS were elevated in the MF3 area during 2015 and/or 2016, potentially due to the A21 dike construction. In addition, turbidity and TSS were elevated throughout the lake in 2006, which corresponded to the construction of the A418 dike.

In the trend analysis for turbidity, a linear model was selected for interpretation of both the ice-cover and open-water season data (Appendix 4D). The results indicated that temporal trends were not significantly different among areas for the ice-cover or open-water season, as shown by non-significant interaction terms in Table 4-11. However, for the different areas evaluated (Figure 4-40), the slopes for the NF and FFA areas during ice-cover were significantly different from zero, indicating a decreasing trend, while the slope for MF3-4 during the open-water season was significantly different from zero, indicating an increasing trend (Table 4-12). This result most likely reflects elevated turbidity in the MF3 area caused by dike construction in 2015 and 2016. The trend analysis for turbidity was performed with more than 15% of the values less than the DL in certain cases (28% in ice-cover for the MF; 27% in ice-cover for the FF), and the assumptions of normality were not met for the dataset; therefore, results should be interpreted with caution.

Temporal trend analysis could not be performed for TSS because of the number of data below the DL (ice-cover: 91% to 95% for all three areas; 90% to 98% for all three areas).

Table 4-11 Turbidity: Significance of Water Quality Fixed Effects Models, 2004 to 2016

Variable	Season	Coefficient	Numerator DF	Denominator DF	F-value	*P*-value
Turbidity	Ice-cover	Area	6	18	0.326	0.915
		Year	1	136	11.2	0.001
		Area × Year	6	136	0.326	0.922
	Open-water	Area	6	18	1.58	0.208
		Year	1	140	0.282	0.596
		Area × Year	6	140	1.59	0.154

Note: Significance of the interaction term was evaluated at a *P*-value <0.05.

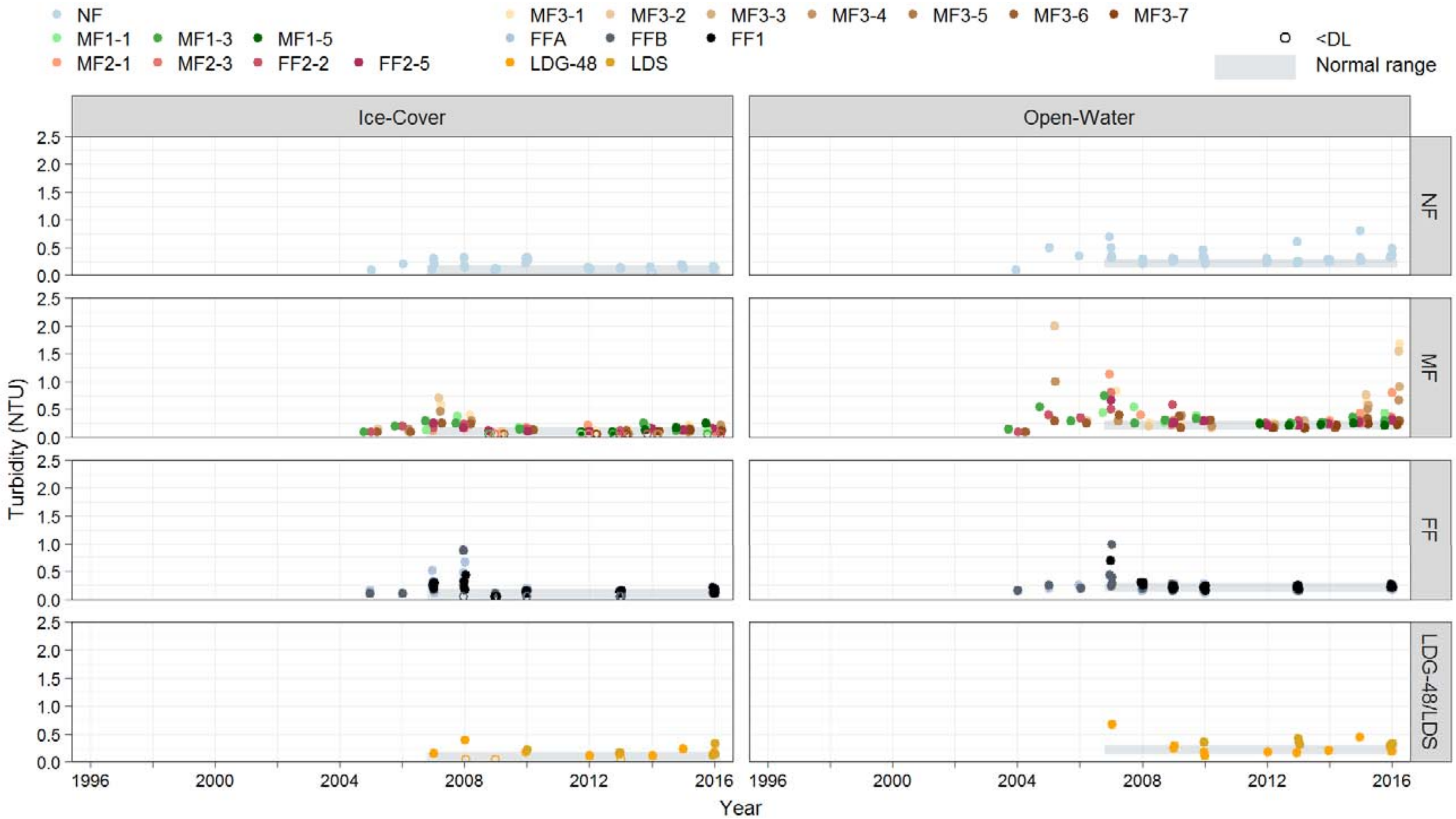
DF = degrees of freedom.

Table 4-12 Turbidity: Estimated Significance of Difference of Linear Slopes from Zero

Variable	Season	NF	MF1-3	FF2-2	MF3-4	FF1	FFB	FFA
Turbidity	Ice-cover	**0.007** ↓	0.197	0.094	0.533	0.516	0.233	**0.024** ↓
	Open-water	0.614	0.546	0.842	**0.011** ↑	0.986	0.364	0.166

Note: **Bold text** = *P*-value significant at <0.05. Arrows after significant *P*-values indicate direction of trend.

Figure 4-39 Turbidity at AEMP Stations, 2004 to 2016



Note: Values represent concentrations in individual samples taken at mid-depth.
LDG = Lac de Gras; LDS = Lac du Sauvage; NTU = nephelometric turbidity unit.

Figure 4-40 Trend Analysis Plots for Turbidity, 2004 to 2016

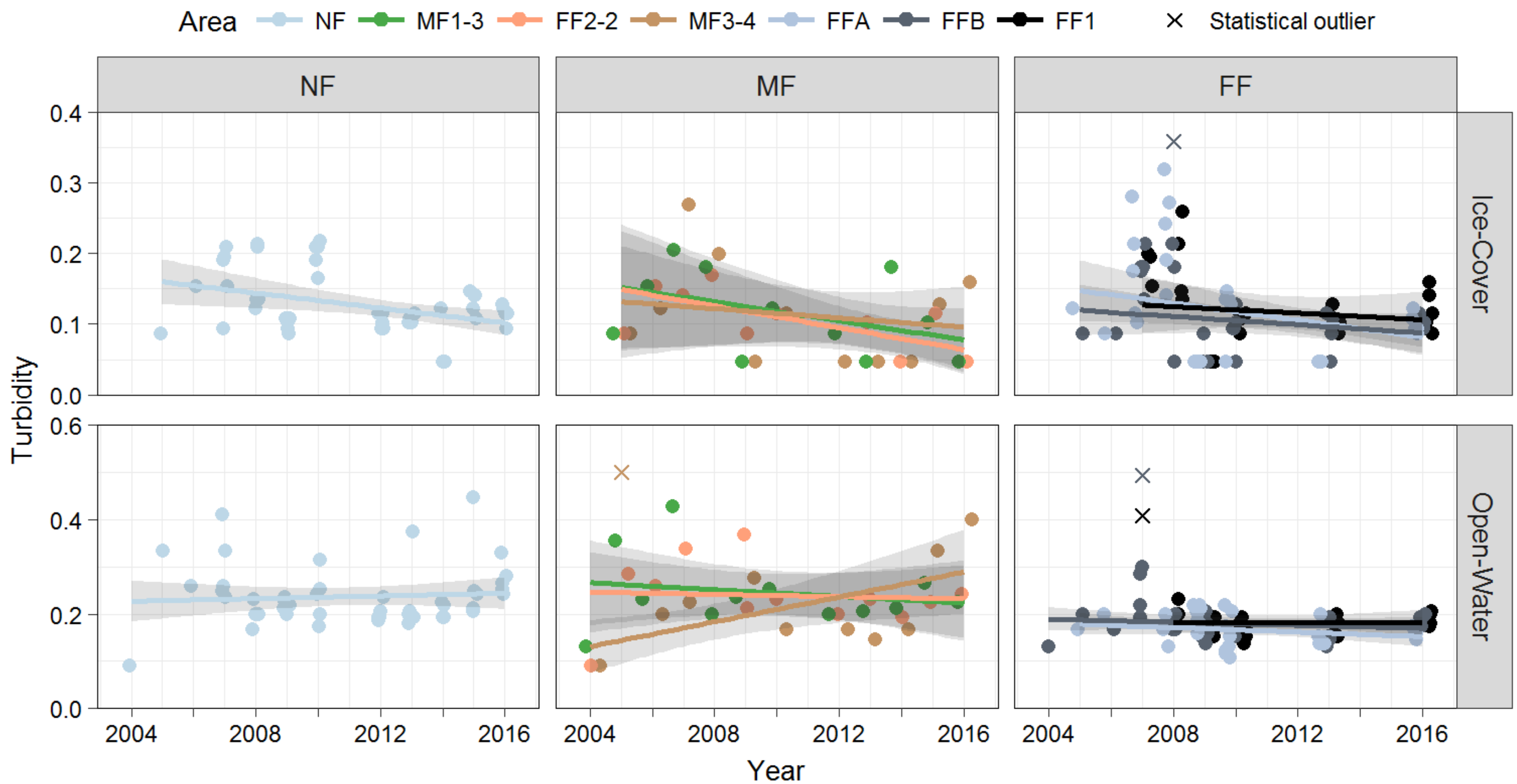
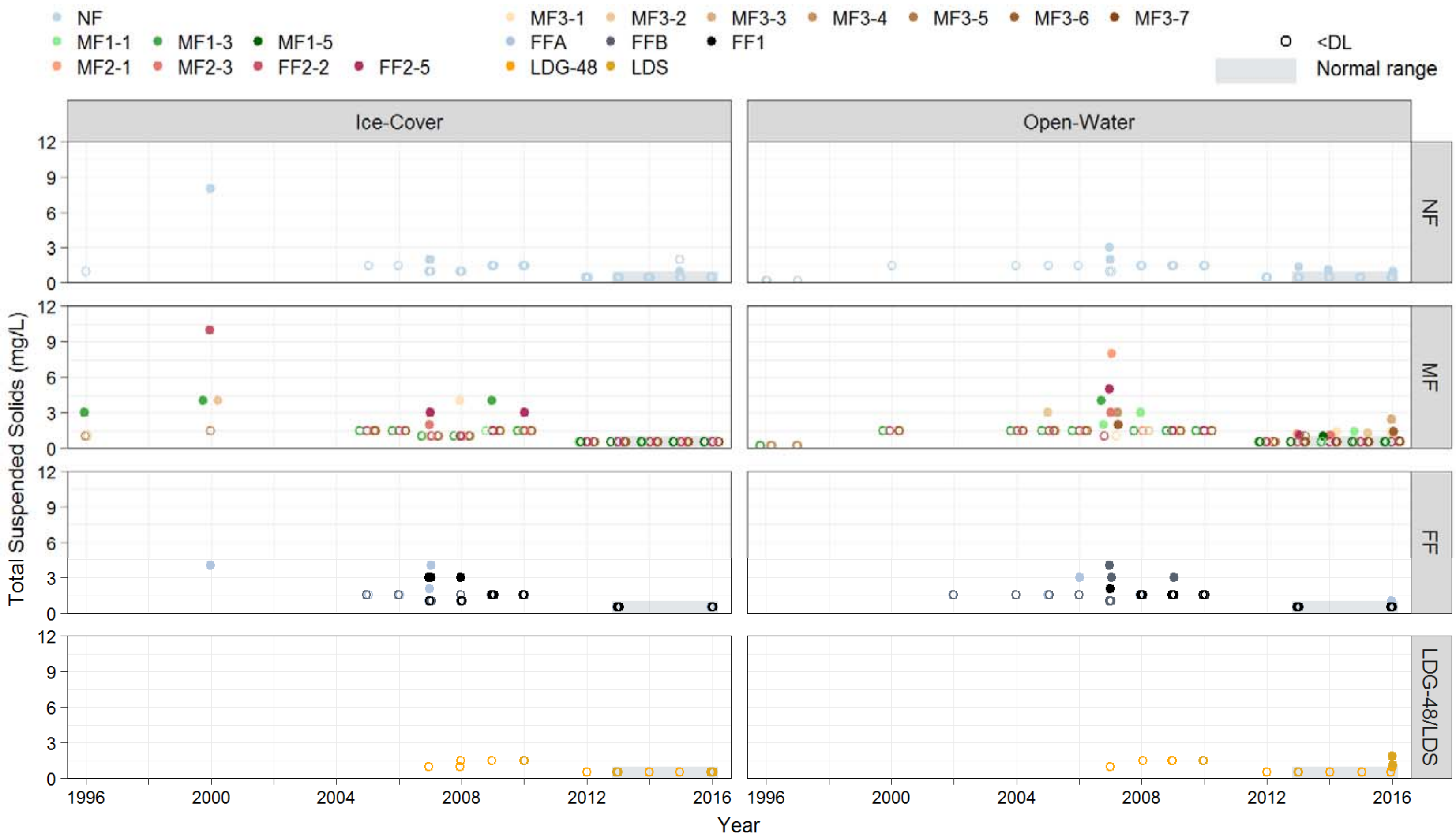


Figure 4-41 Total Suspended Solids Concentrations at AEMP Stations, 1996 to 2016



Note: Values represent concentrations in individual samples taken at mid-depth.
LDG = Lac de Gras; LDS = Lac du Sauvage

Total Dissolved Solids and Associated Ions

As shown by the time series plots, concentrations of TDS (calculated), chloride, calcium, potassium, sodium, and sulphate were greater than normal ranges in both the ice-cover and open-water seasons (Figures 4-42, 4-47, 4-44, 4-45, 4-51, 4-52, 4-54, 4-55, 4-57, respectively). In general, concentrations of TDS and major ions were greater and more variable during the ice-cover season compared to the open-water season. Concentrations of dissolved calcium, potassium, and sodium tended to be somewhat less than total concentrations and closer to the normal range, particularly in the FF areas and LDG-48. Concentrations of chloride, potassium, and sulphate at the FFA and LDG-48 stations may be influenced slightly by the contribution of the Ekati mine discharge, as described in Section 4.3.2.2.3.

Fluoride concentrations in Lac de Gras were primarily below the DL used by ETL and ALS from 2002 to 2010 (0.05 mg/L; Figure 4-49). Starting in 2011, a lower DL was used and detectable results were obtained for most samples. Exceedances of the normal range for fluoride were noted from 2014 to 2016 during both the ice-cover and open-water seasons, particularly in the NF and MF areas.

For the statistical analysis of TDS (calculated), a parabolic model was selected (Appendix 4D). In the NF area, for both ice-cover and open-water seasons, the model predicted a shallow parabolic increase since 2001 (Figure 4-43). These increases generally reflect trends in the effluent loading of TDS (calculated) over time (Section 4.3.1.1.2; Figure 4-3). Increases in TDS concentrations also occurred in the MF and FF, although these trends were closer to linear in nature (Figure 4-43). The model had a significant interaction between area and year, indicating that temporal trends were significantly different among areas/stations (Table 4-13). For the ice-cover season, multiple comparisons among areas/stations for 2010 and 2013 identified significant differences among the NF and MF1-3 and MF3-4/FF1/FFB/FFA areas/stations; in 2016, significant differences were noted only between the NF and the three FF areas (Table 4-14). For the open-water season, the NF, MF1-3, and FF2-2 area/stations were significantly different from the MF3-4 station and the FF areas in 2010 and 2013, while in 2016 only the NF and FF1 were significantly different (Table 4-14). These results support findings in past annual reports (e.g., Golder 2017c) that suggest the effluent has been distributed throughout Lac de Gras over time, since increases in concentrations have occurred throughout the lake, and there were fewer differences among areas/stations in 2016 (Table 4-14).

Trend analyses for total calcium, potassium and sodium have been included herein; trend analyses for dissolved fractions were not included, as they would be redundant. Visual assessment of the time series plots for both dissolved and total concentrations of these variables indicated that total and dissolved concentrations had similar trends over time, although total concentrations were generally greater, particularly in the FF areas (Figures 4-44, 4-45, 4-51,4-52, 4-54, 4-55).

A parabolic model was selected for both total calcium and total sodium (Appendix 4D). The shapes of the curves in the NF, MF and FF areas were similar to those for TDS (Figures 4-43, 4-46 and 4-56) and again reflected the general trend in the effluent loads of these variables (Figures 4-5 and 4-11). The model had a significant interaction between area and year, indicating that temporal trends for sodium were significantly different among areas/stations in both the ice-cover and open-water seasons. This was true only during the ice-cover season for calcium (Table 4-13).

For the statistical analysis of total potassium, a parabolic trend was selected for the ice-cover season and a linear trend was selected for the open-water season (Appendix 4D). For ice-cover, the parabolic trends for the NF, MF and FF were similar to TDS (calculated) as well as calcium and sodium, increasing over time and following the general trend in effluent loads (Figures 4-53 and 4-9); the parabolic model had a significant interaction between area and year, indicating that temporal trends were significantly different among areas/stations (Table 4-13). For the open-water season, the linear trends in the NF, MF, and FF were also increasing and significantly different from a slope of zero for all areas/stations analyzed (Table 4-14); a significant interaction between area/station and year occurred, indicating that the temporal trends were significantly different among areas/stations (Table 4-13).

Multiple comparisons among areas/stations for total calcium, potassium (ice-cover season), and sodium indicated that, for 2010 and 2013 during the ice-cover season, the NF area was different from the MF stations, which were also different from the FF areas (Table 4-14). In the open-water season, the NF and MF areas were more similar to each other and different from the FF areas. These differences among areas/stations became less pronounced in 2016 for both the ice-covered and open-water seasons.

Because of the number of values less than the DL for the earlier years of chloride monitoring, the trend analysis included data from 2008 to 2016, when measurable concentrations were detected. A parabolic trend was selected for both the ice-cover and open-water seasons (Appendix 4D). The parabolic trends for the NF area and MF stations were shallow to nearly flat for the period of analysis for both seasons, likely reflecting that the loads of chloride in the effluent were no longer increasing, but had stabilized shortly after 2008 until approximately 2016, when they increased slightly (Figures 4-48 and 4-6). For the ice-cover season, the parabolic model had a significant interaction between area and year, indicating that temporal trends were significantly different among areas/stations (Table 4-13). For the open-water season, there was no significant difference in trend among areas/stations (Table 4-13). For the ice-cover season, chloride concentrations at multiple areas/stations were significantly different from each other in 2010, but became more similar over time, as indicated by fewer significant differences between the FF and other areas (Table 4-14). For the open-water season, the NF, MF1-3, and FF2-2 were significantly different from the MF3-4 station and the FF areas in 2010 and 2013, while in 2016 only the NF and FFB were significantly different (Table 4-14).

Fluoride, similar to chloride, had a high percentage of values below the DL in the initial years of monitoring; therefore, the trend analysis only included data from 2011 to 2016. A linear trend was selected for both the ice-cover and open-water seasons (Appendix 4D). For both seasons, there were no significant Area × Year interactions, indicating that trends were similar in all areas (Table 4-13). For the ice-cover season, MF1-3, FF1, FFB, and FFA had increasing slopes that were significantly different from zero (Table 4-15). For the open-water season, the NF, FF2-2 and all three FF areas also had increasing slopes that were significantly different from zero (Table 4-15). These increasing trends generally followed the trend in the load of fluoride from the effluent (Figures 4-50 and 4-7).

For sulphate, like total potassium, a parabolic trend was selected for the ice-cover season, while a linear trend was selected for the open-water season (Appendix 4D). The parabolic trends for the ice-cover season were increasing and nearly linear (Figure 4-58). The parabolic model had a significant interaction between area and year, indicating that temporal trends were significantly different among areas/stations (Table 4-13). For the ice-cover season, sulphate concentrations at multiple areas/stations were significantly different from each other in 2010, but became statistically more similar over time (Table 4-14). The increasing linear trends in the open-water season were similar to the parabolic trends for the ice-cover season, with the exception of FF1 (Figure 4-58). For the open-water season, all areas/stations, except FF1, had increasing slopes that were significantly different from zero (Table 4-15). These increasing trends generally followed the trend in the sulphate load from the effluent (Figure 4-12).

Table 4-13 Major Ions: Significance of Water Quality Fixed Effects Models

Variable	Season	Coefficient	Numerator DF	Denominator DF	F-value	*P*-value
Total Dissolved Solids, calculated	Ice-cover	Area	6	18	5.23	0.003
		Year	1	151	22.9	<0.001
		$Year^2$	1	151	23.1	<0.001
		Area × Year	6	151	5.23	**<0.001**
		Area × $Year^2$	6	151	5.23	**<0.001**
	Open-water	Area	6	18	7.94	<0.001
		Year	1	130	0.044	0.833
		$Year^2$	1	130	0.034	0.854
		Area × Year	6	130	7.93	**<0.001**
		Area × $Year^2$	6	130	7.93	**<0.001**
Calcium (total)	Ice-cover	Area	6	18	5.68	0.002
		Year	1	179	2.13	0.146
		$Year^2$	1	179	2.05	0.154
		Area × Year	6	179	5.67	**<0.001**
		Area × $Year^2$	6	179	5.65	**<0.001**
	Open-water	Area	6	18	1.72	0.175
		Year	1	188	0.224	0.636
		$Year^2$	1	188	0.188	0.665
		Area × Year	6	188	1.71	0.120
		Area × $Year^2$	6	188	1.71	0.121
Chloride	Ice-cover	Area	6	16	12.4	<0.001
		Year	1	123	2.42	0.122
		$Year^2$	1	123	2.40	0.124
		Area × Year	6	123	12.4	**<0.001**
		Area × $Year^2$	6	123	12.4	**<0.001**
	Open-water	Area	6	16	2.06	0.116
		Year	1	129	23.4	<0.001
		$Year^2$	1	129	23.3	<0.001
		Area × Year	6	129	2.06	0.062
		Area × $Year^2$	6	129	2.06	0.062
Fluoride	Ice-cover	Area	6	16	1.95	0.134
		Year	1	63	39.4	<0.001
		Area × Year	6	63	1.95	0.087
	Open-water	Area	6	16	1.83	0.156
		Year	1	74	51.8	<0.001
		Area × Year	6	74	1.83	0.105

Table 4-13 Major Ions: Significance of Water Quality Fixed Effects Models

Variable	Season	Coefficient	Numerator DF	Denominator DF	F-value	*P*-value
Potassium (total)	Ice-cover	Area	6	18	7.44	<0.001
		Year	1	178	12.0	0.001
		Year^2	1	178	12.2	0.001
		Area × Year	6	178	7.44	**<0.001**
		Area × Year ^{2}	6	178	7.44	**<0.001**
	Open-water	Area	6	18	3.37	0.021
		Year	1	196	873	<0.001
		Area × Year	6	196	3.41	**0.003**
Sodium (total)	Ice-cover	Area	6	18	22.2	<0.001
		Year	1	176	1.75	0.188
		Year^2	1	176	1.63	0.204
		Area × Year	6	176	22.2	**<0.001**
		Area × Year ^{2}	6	176	22.2	**<0.001**
	Open-water	Area	6	18	8.66	<0.001
		Year	1	189	0.160	0.690
		Year^2	1	189	0.202	0.654
		Area × Year	6	189	8.66	**<0.001**
		Area × Year ^{2}	6	189	8.66	**<0.001**
Sulphate	Ice-cover	Area	6	18	10.8	<0.001
		Year	1	165	15.5	<0.001
		Year^2	1	165	15.7	<0.001
		Area × Year	6	165	10.8	**<0.001**
		Area × Year ^{2}	6	165	10.8	**<0.001**
	Open-water	Area	6	18	7.21	<0.001
		Year	1	178	190	<0.001
		Area × Year	6	178	7.23	**<0.001**

Note: Significance of the interaction term was evaluated at a *P*-value <0.05.

DF = degrees of freedom.

Table 4-14 Major Ions: Multiple Comparisons of Parabolic Trends in 2010, 2013, and 2016

Variable	Season	Year	NF	MF1-3	FF2-2	MF3-4	FF1	FFB	FFA
Total Dissolved Solids, calculated	Ice-cover	2010	d	c	bc	ab	a	a	ab
		2013	d	c	bc	ab	a	a	ab
		2016	b	ab	ab	ab	a	a	a
	Open-water	2010	b	b	b	a	a	a	a
		2013	b	b	b	a	a	a	a
		2016	b	ab	ab	ab	a	ab	ab
Total Calcium	Ice-cover	2010	c	b	b	ab	a	a	a
		2013	c	b	b	ab	a	a	a
		2016	b	ab	ab	a	a	a	a
	Open-water	2010	b	b	b	a	a	a	a
		2013	b	b	b	a	a	a	a
		2016	c	bc	bc	ab	a	a	a
Chloride	Ice-cover	2010	e	d	c	bc	ab	a	ab
		2013	e	d	cd	bc	a	a	b
		2016	c	abc	bc	abc	a	b	ab
	Open-water	2010	b	b	b	a	a	a	a
		2013	b	b	b	a	a	a	a
		2016	c	bc	bc	abc	ab	a	abc
Total Potassium	Ice-cover	2010	d	c	bc	ab	a	a	a
		2013	d	c	bc	ab	a	a	a
		2016	c	bc	bc	ab	b	a	a
Total Sodium	Ice-cover	2010	d	c	c	b	a	a	a
		2013	d	c	c	b	a	a	a
		2016	b	ab	ab	ab	a	a	a
	Open-water	2010	b	b	b	a	a	a	a
		2013	b	b	b	a	a	a	a
		2016	d	cd	cd	abc	a	ab	b
Sulphate	Ice-cover	2010	d	c	bc	bc	a	b	c
		2013	e	d	cd	bc	a	b	c
		2016	b	ab	ab	ab	a	a	a

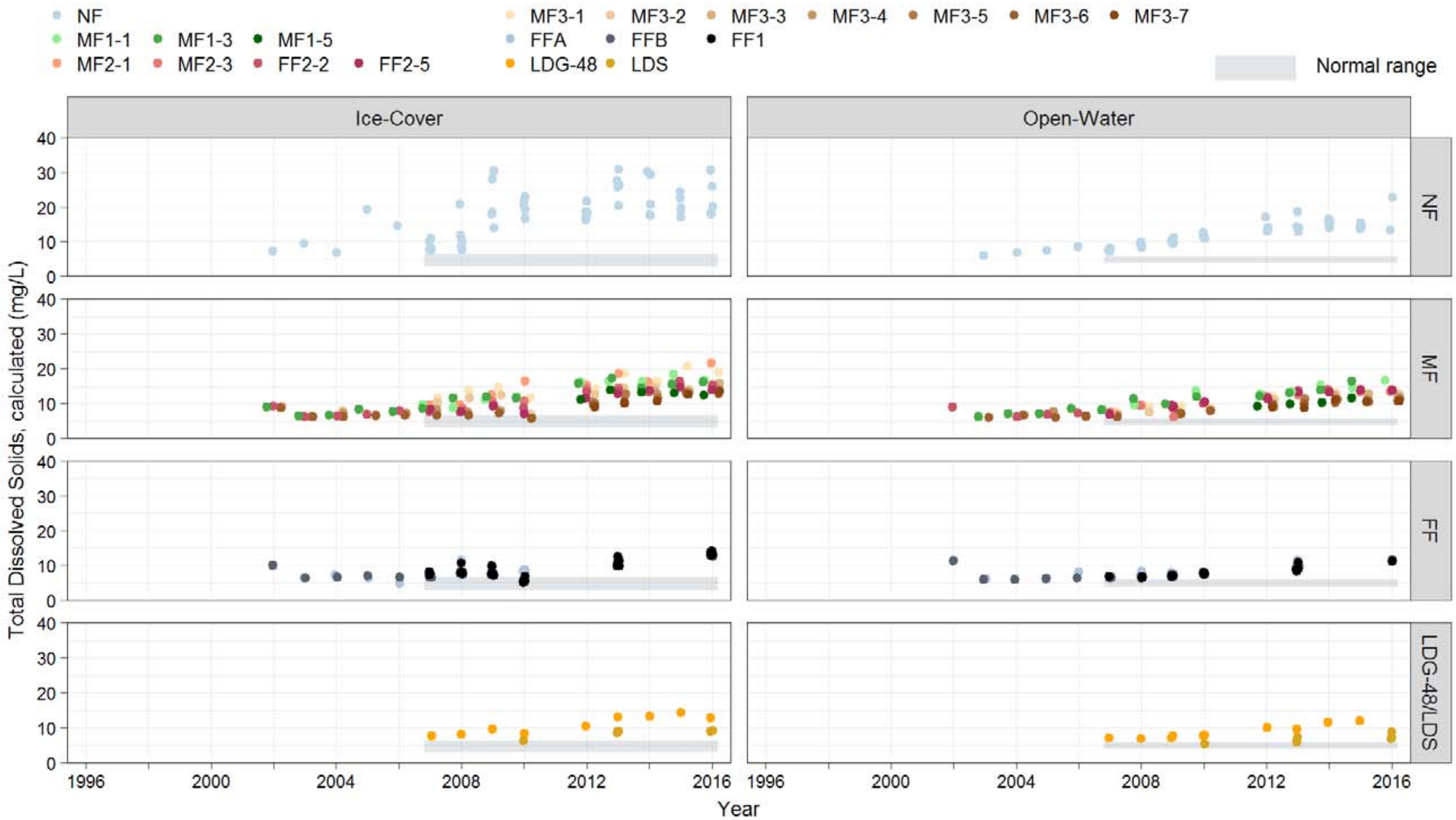
Note: Different letters designate areas/stations that are significantly different at the $P<0.05$ level.

Table 4-15 Major Ions: Estimated Significance of Difference of Linear Slopes from Zero

Variable	Season	NF	MF1-3	FF2-2	MF3-4	FF1	FFB	FFA
Fluoride	Ice-cover	0.125	**0.003** ↑	0.202	0.455	**0.002** ↑	**<0.001** ↑	**<0.001** ↑
	Open-water	**<0.001** ↑	0.174	**<0.001** ↑	0.070	**<0.001** ↑	**0.047** ↑	**<0.001** ↑
Potassium	Open-water	**<0.001** ↑	**<0.001** ↑	**<0.001** ↑	**<0.001** ↑	**<0.001** ↑	**<0.001** ↑	**<0.001** ↑
Sulphate	Open-water	**<0.001** ↑	**<0.001** ↑	**<0.001** ↑	**<0.001** ↑	0.509	**0.001** ↑	**<0.001** ↑

Note: **Bold text** = *P*-value significant at <0.05. Arrows after significant *P*-values indicate direction of trend.

Figure 4-42 Total Dissolved Solids, Calculated Concentrations at AEMP Stations, 2002 to 2016



Note: Values represent concentrations in individual samples taken at mid-depth. Major ions were not analysed in 2011.
LDG = Lac de Gras; LDS = Lac du Sauvage

Figure 4-43 Trend Analysis Plots for Total Dissolved Solids, Calculated, 2002 to 2016

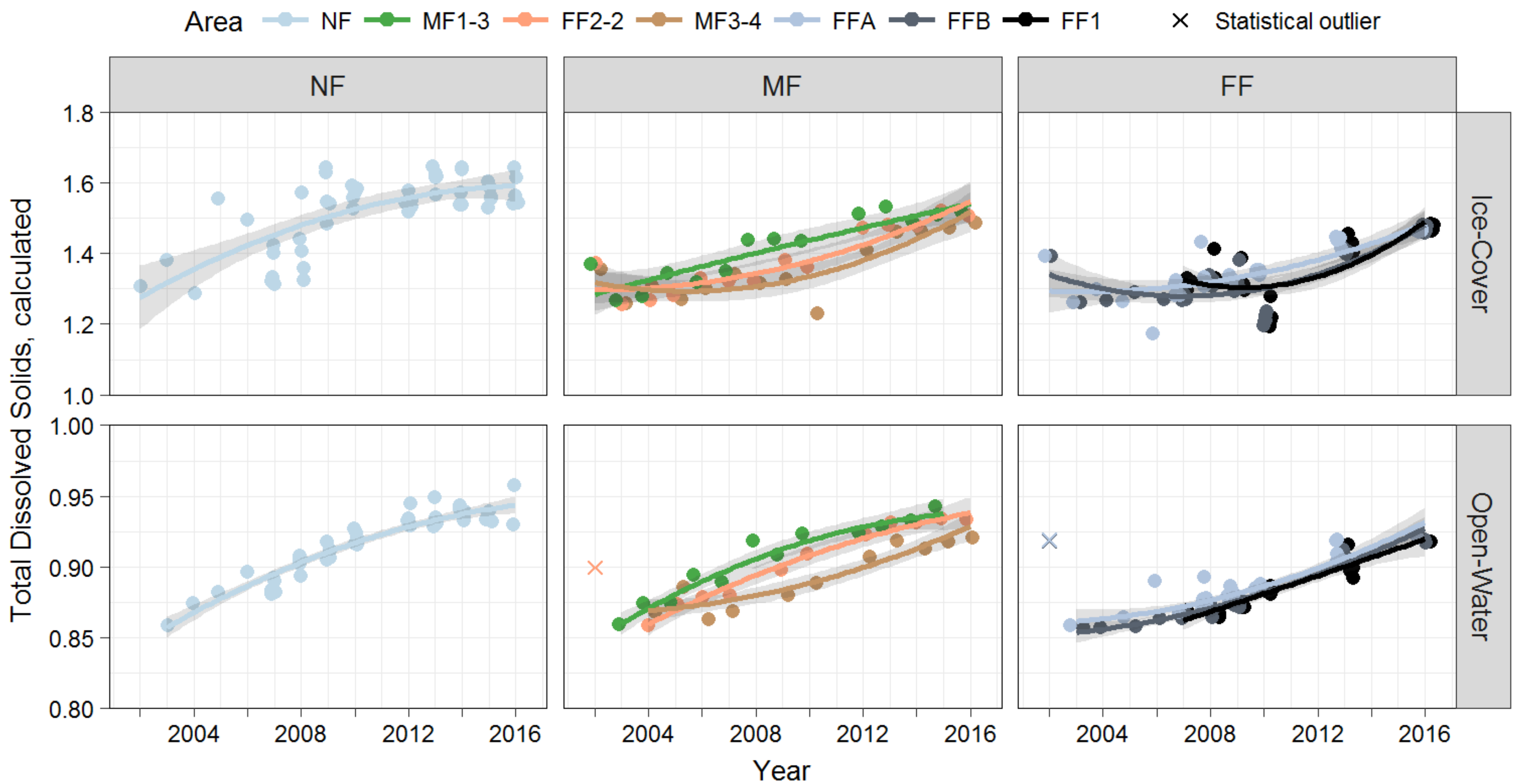
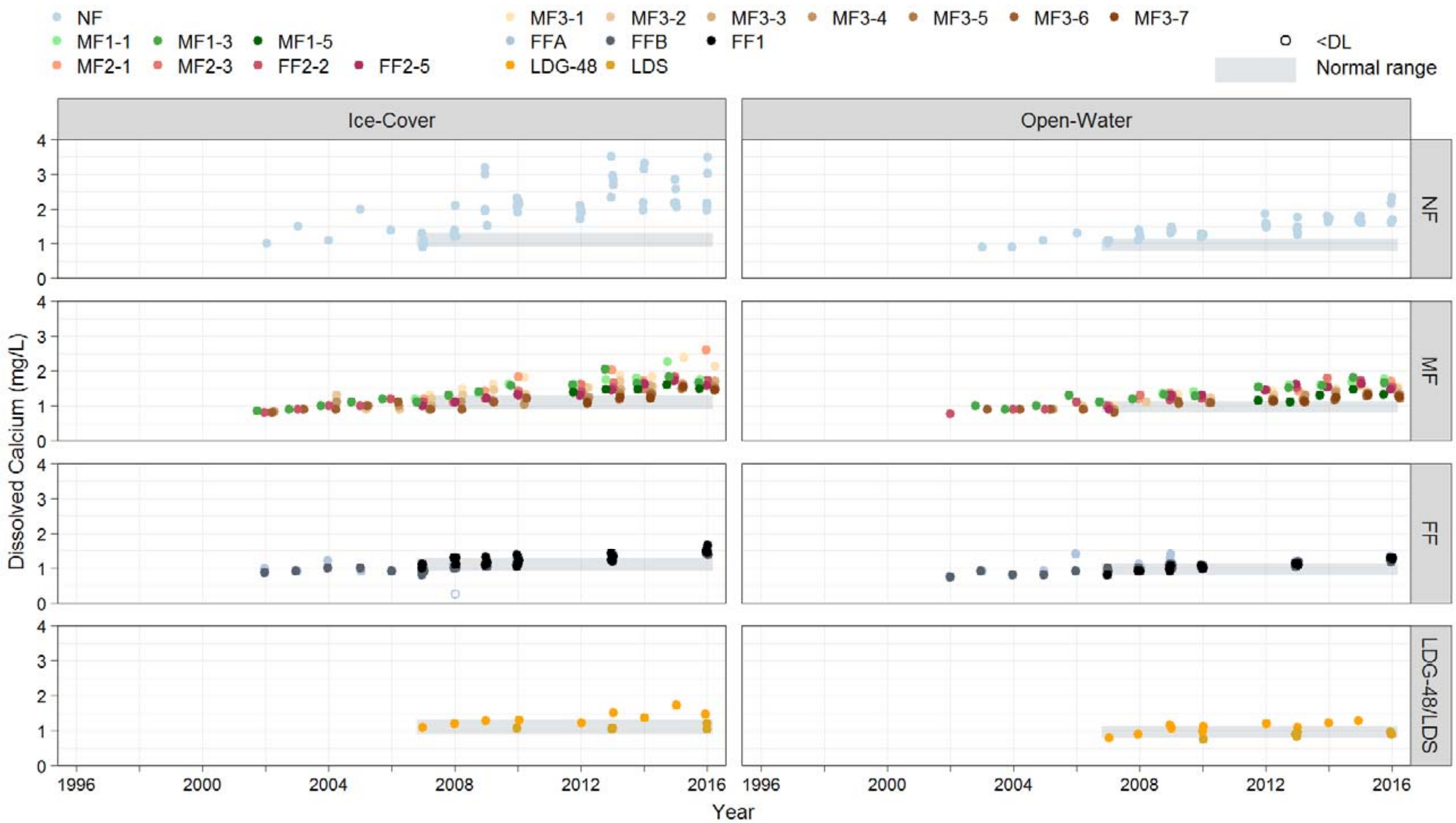
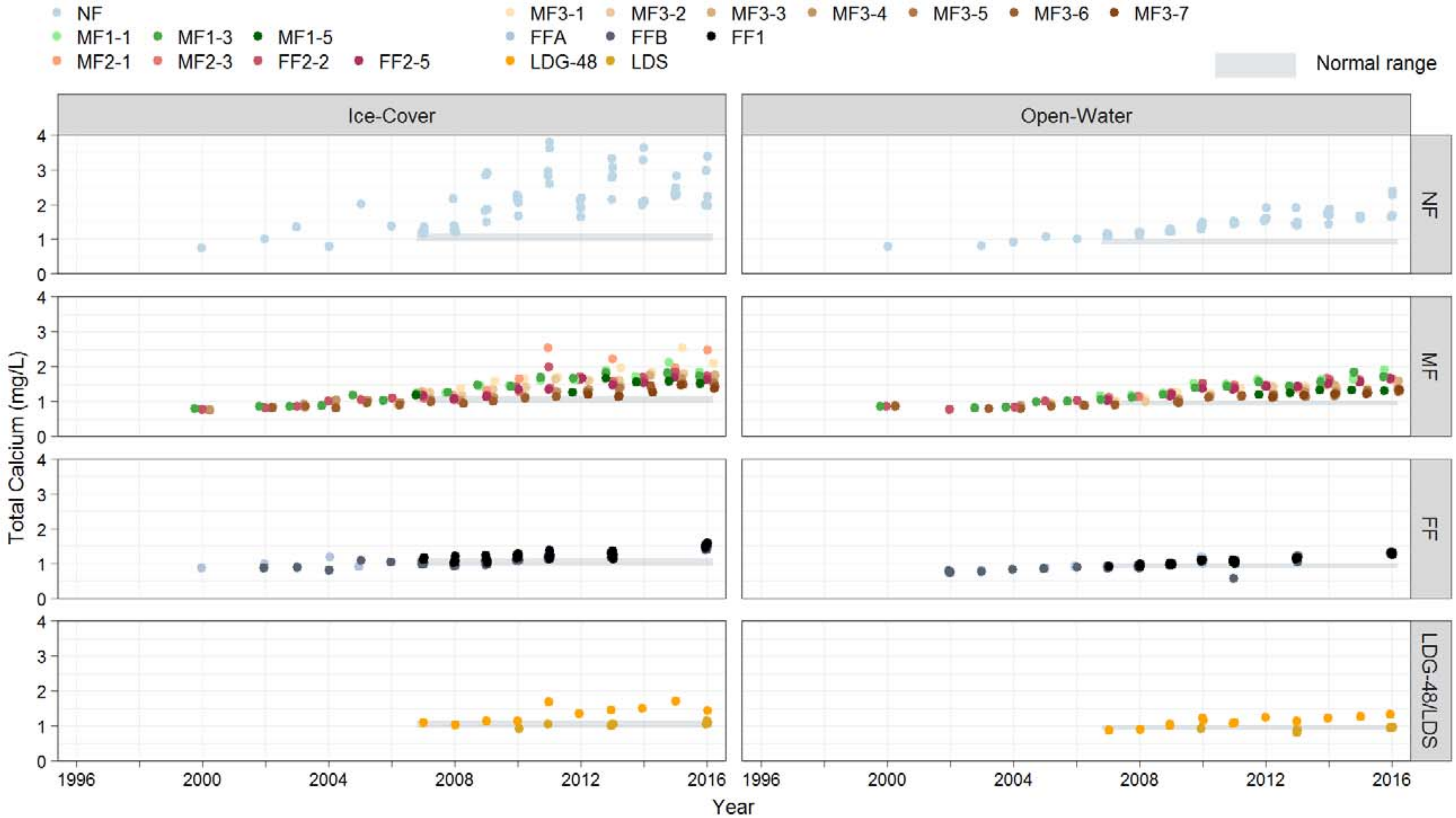


Figure 4-44 Dissolved Calcium Concentrations at AEMP Stations, 2002 to 2016



Note: Values represent concentrations in individual samples taken at mid-depth. Dissolve calcium was not analysed in 2011.
LDG = Lac de Gras; LDS = Lac du Sauvage

Figure 4-45 Total Calcium Concentrations at AEMP Stations, 2000 to 2016



Note: Values represent concentrations in individual samples taken at mid-depth.
LDG = Lac de Gras; LDS = Lac du Sauvage

Figure 4-46 Trend Analysis Plots for Total Calcium, 2000 to 2016

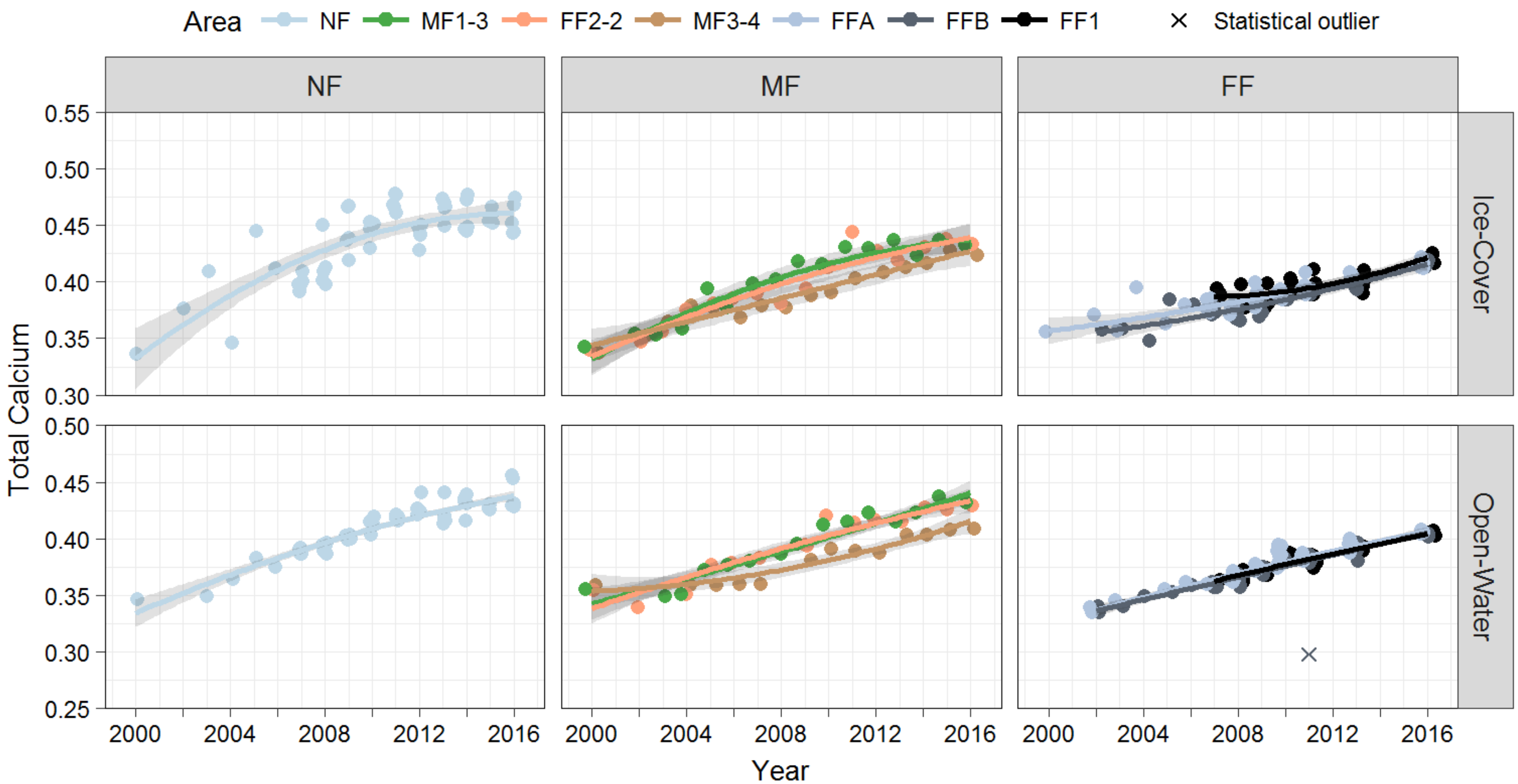
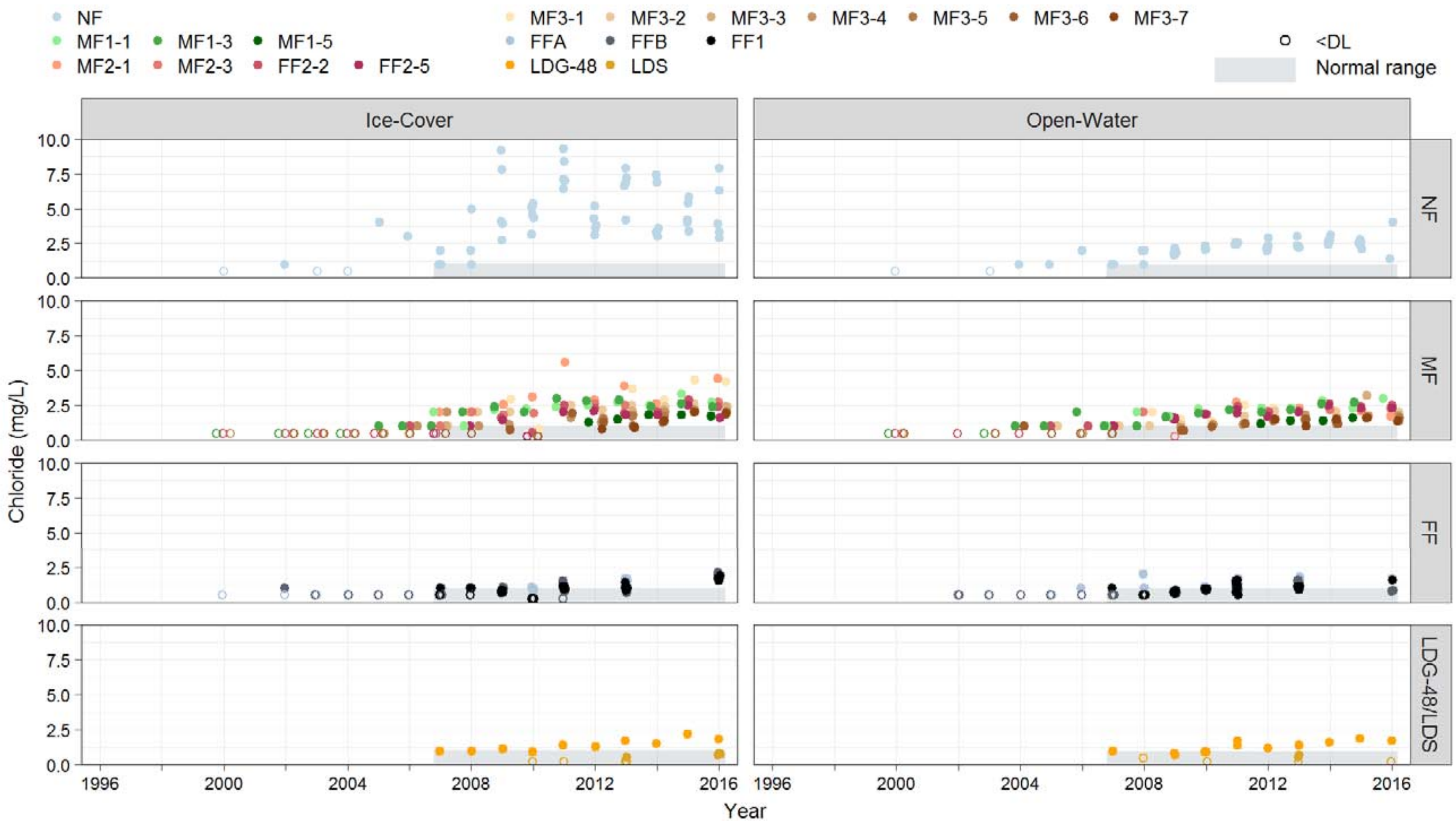


Figure 4-47 Chloride Concentrations at AEMP Stations, 2000 to 2016



Note: Values represent concentrations in individual samples taken at mid-depth.
LDG = Lac de Gras; LDS = Lac du Sauvage

Figure 4-48 Trend Analysis Plots for Chloride, 2008 to 2016

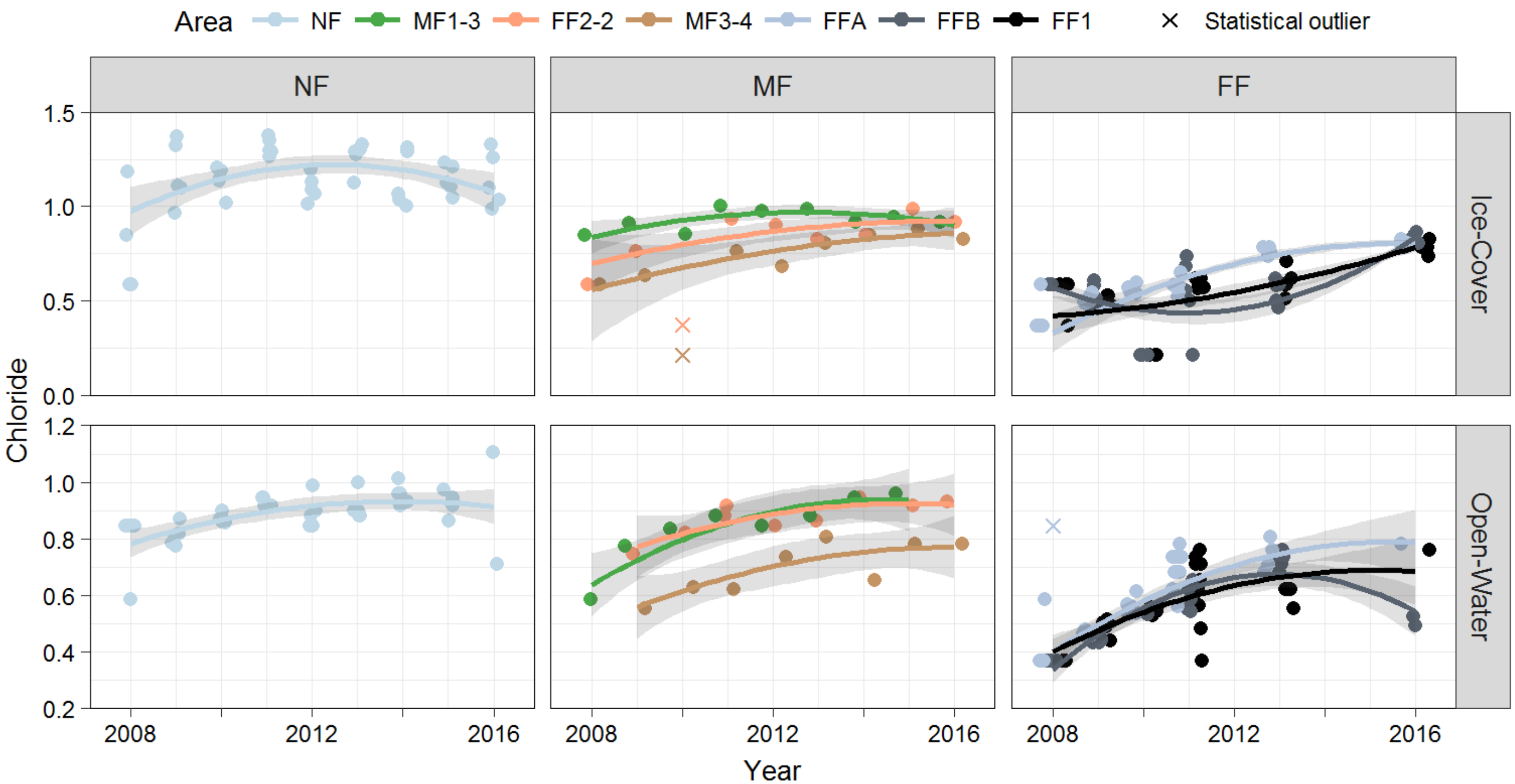
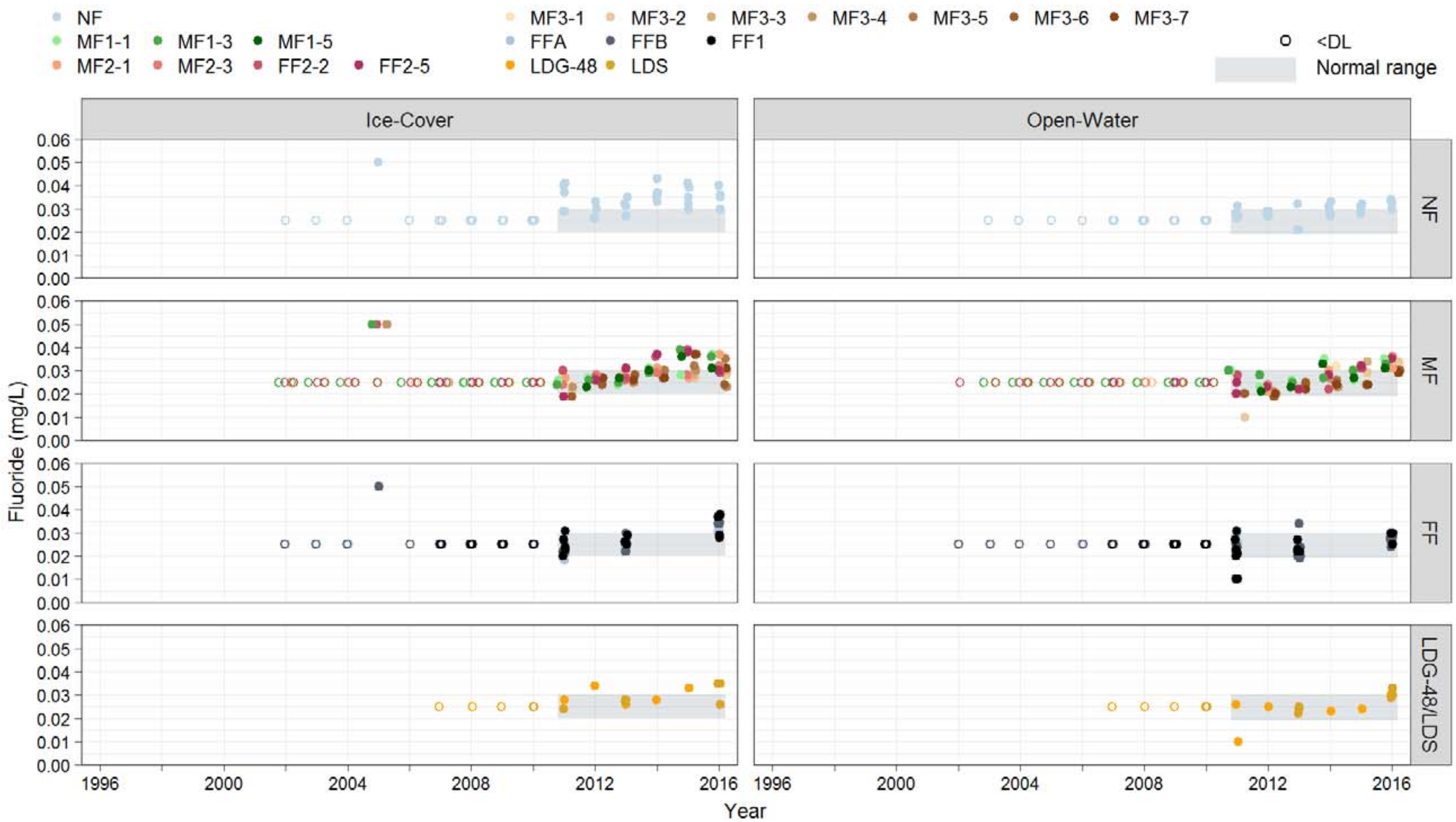


Figure 4-49 Fluoride Concentrations at AEMP Stations, 2002 to 2016



Note: Values represent concentrations in individual samples taken at mid-depth
LDG = Lac de Gras; LDS = Lac du Sauvage.

Figure 4-50 Trend Analysis Plots for Fluoride, 2011 to 2016

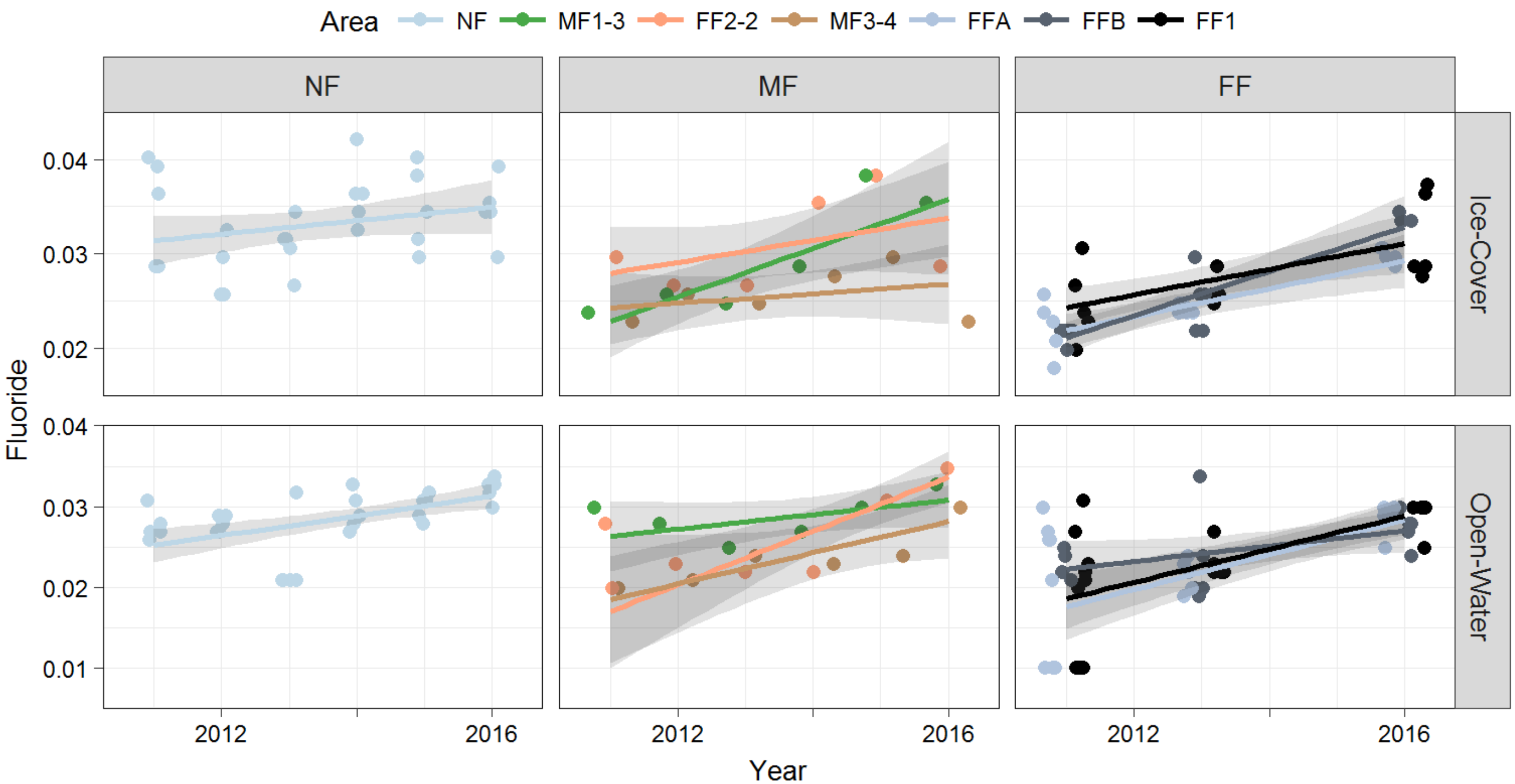
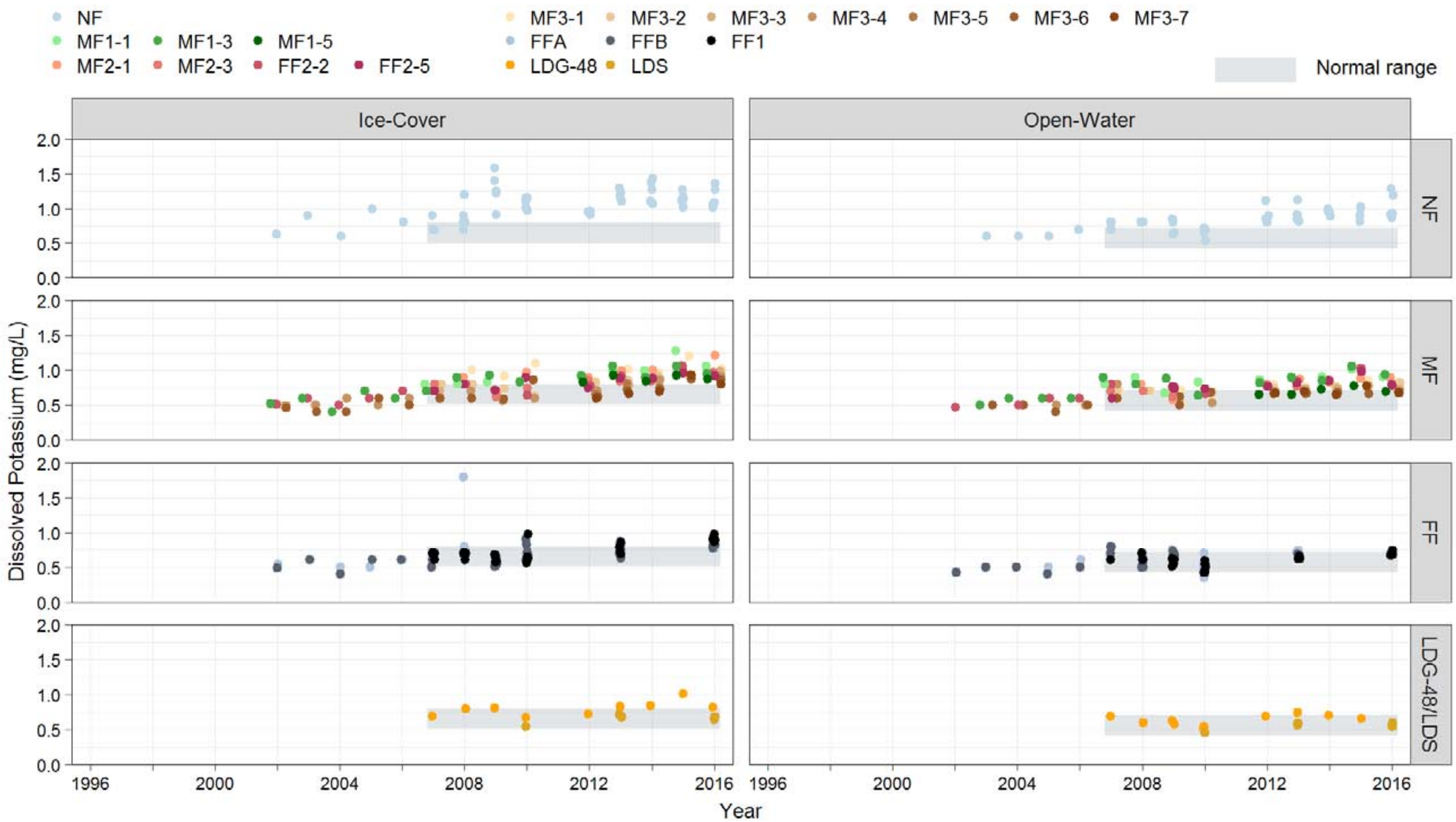
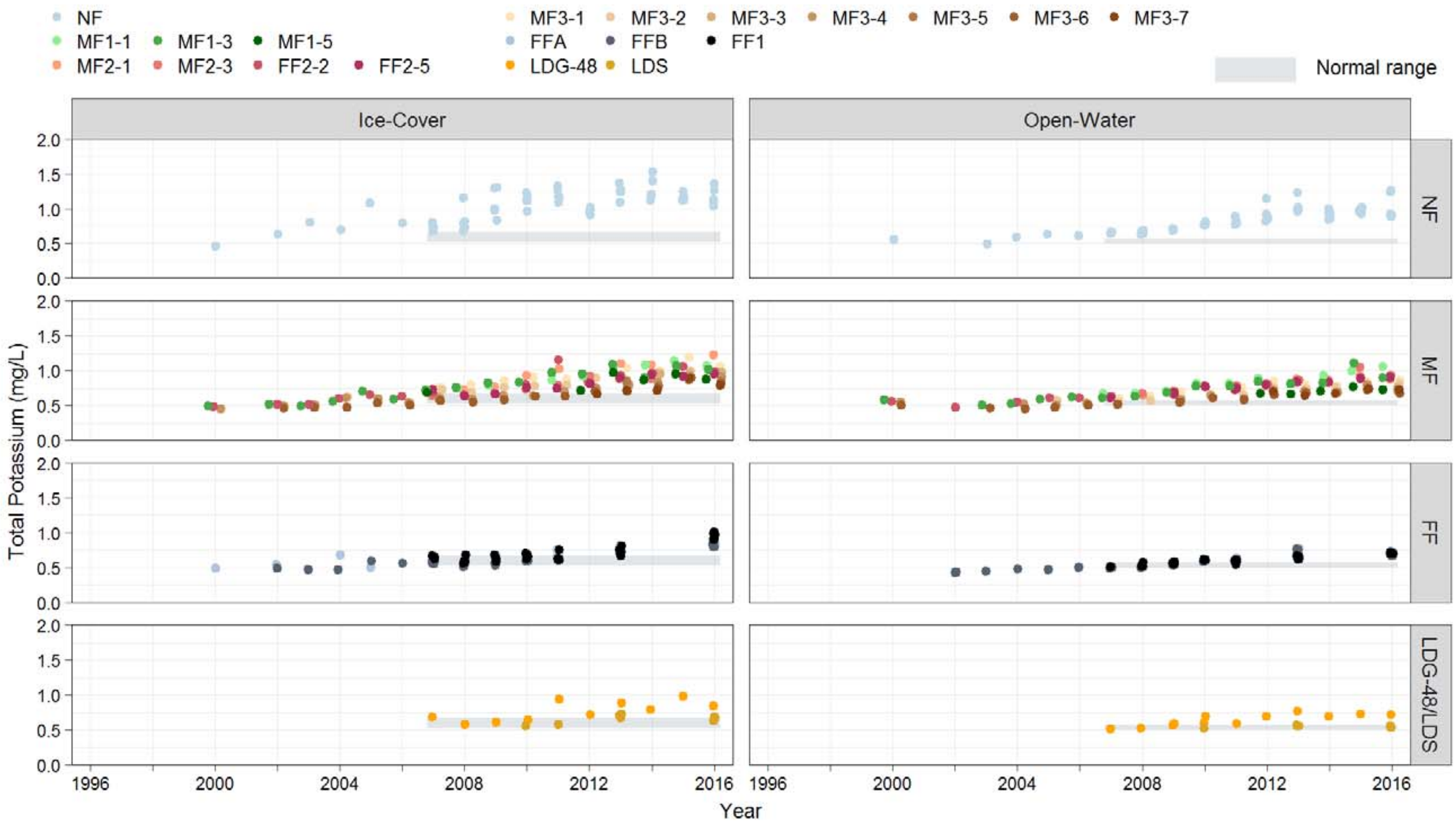


Figure 4-51 Dissolved Potassium Concentrations at AEMP Stations, 2002 to 2016



Note: Values represent concentrations in individual samples taken at mid-depth. Dissolved potassium was not analysed in 2011.
LDG = Lac de Gras; LDS = Lac du Sauvage

Figure 4-52 Total Potassium Concentrations at AEMP Stations, 2000 to 2016



Note: Values represent concentrations in individual samples taken at mid-depth.
LDG = Lac de Gras; LDS = Lac du Sauvage

Figure 4-53 Trend Analysis Plots for Total Potassium, 2000 to 2016

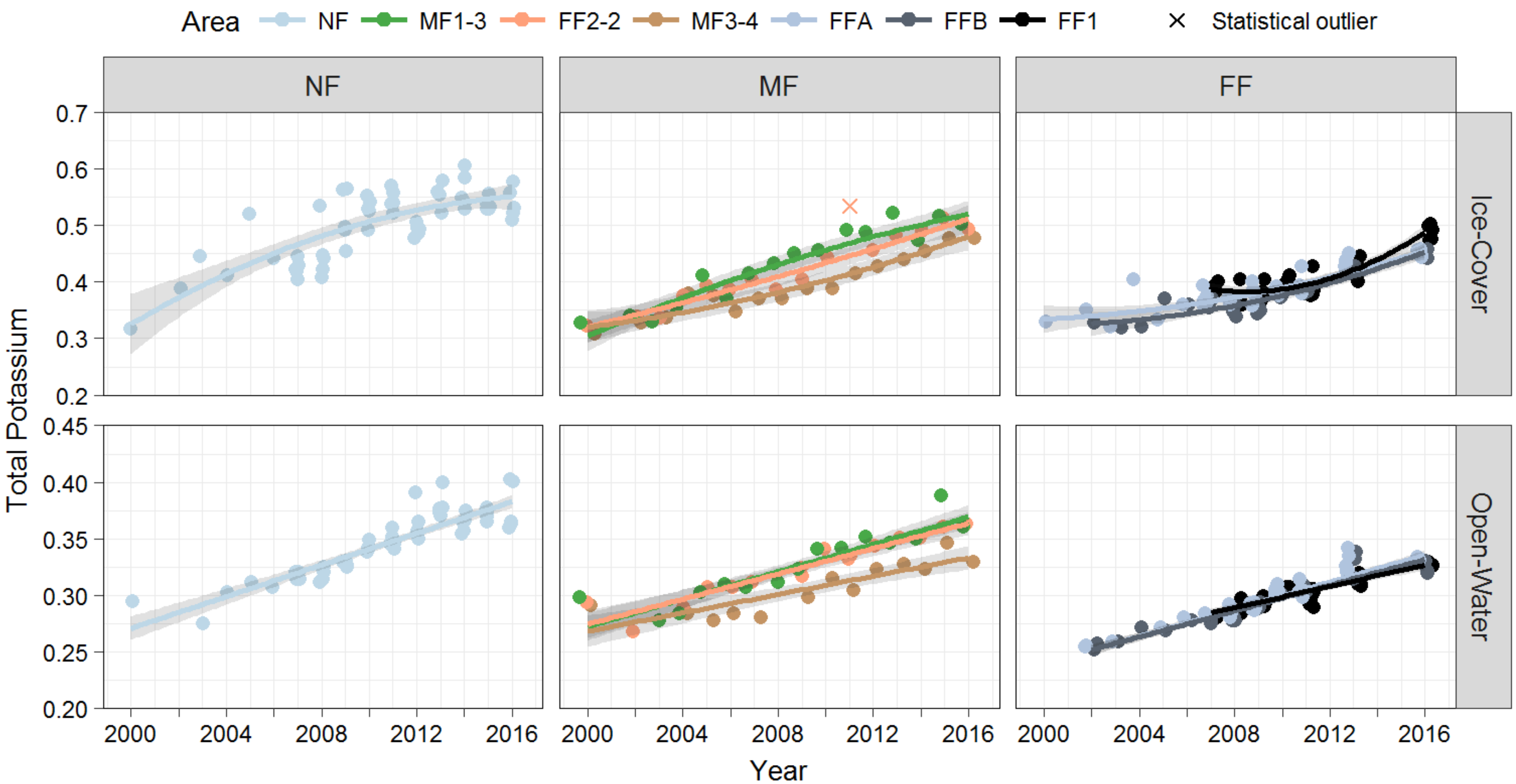
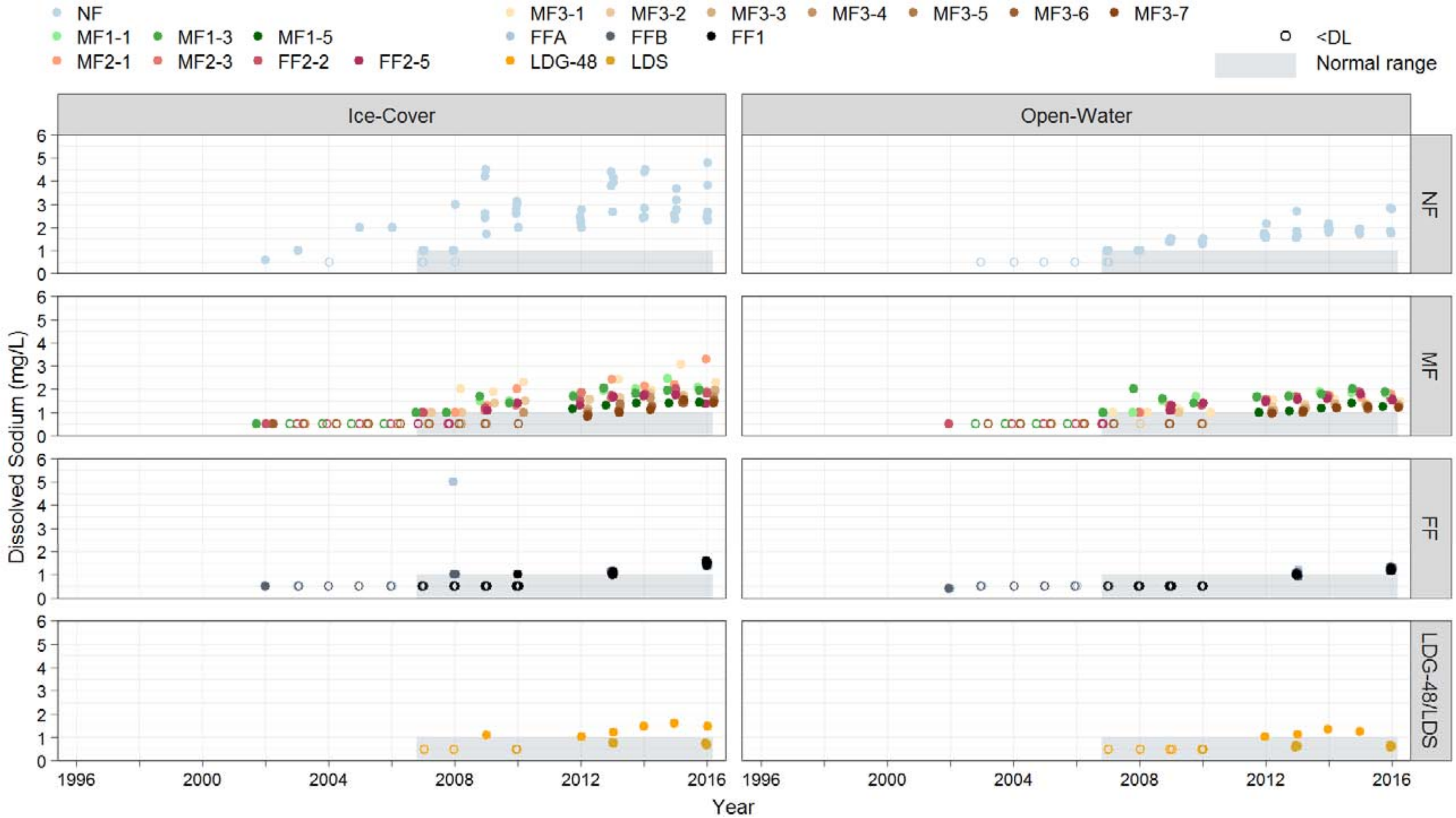
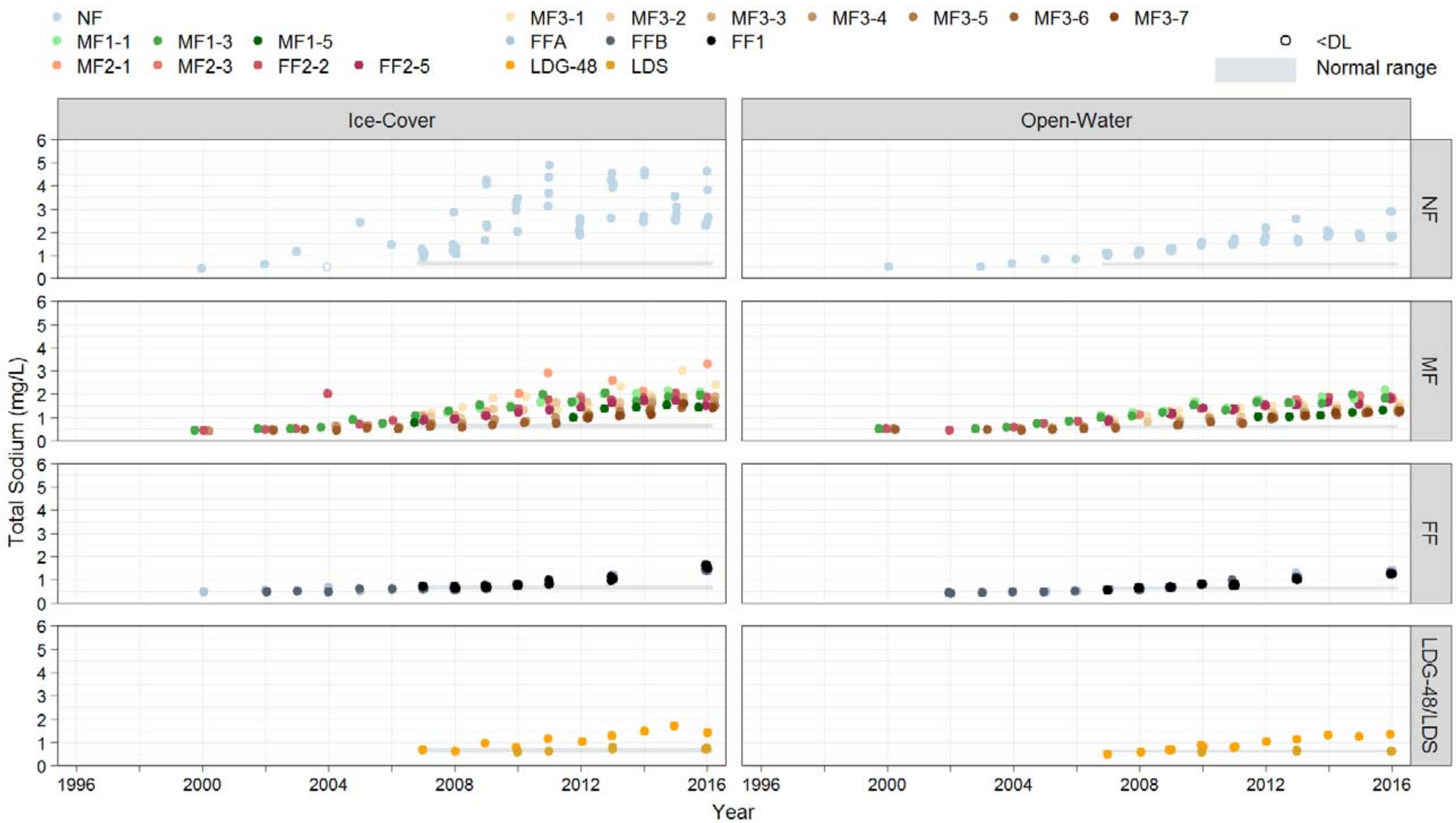


Figure 4-54 Dissolved Sodium Concentrations at AEMP Stations, 2002 to 2016



Note: Values represent concentrations in individual samples taken at mid-depth. Dissolved sodium was not analysed in 2011.
LDG = Lac de Gras; LDS = Lac du Sauvage

Figure 4-55 Total Sodium Concentrations at AEMP Stations, 2000 to 2016



Note: Values represent concentrations in individual samples taken at mid-depth.
LDG = Lac de Gras; LDS = Lac du Sauvage

Figure 4-56 Trend Analysis Plots for Total Sodium, 2000 to 2016

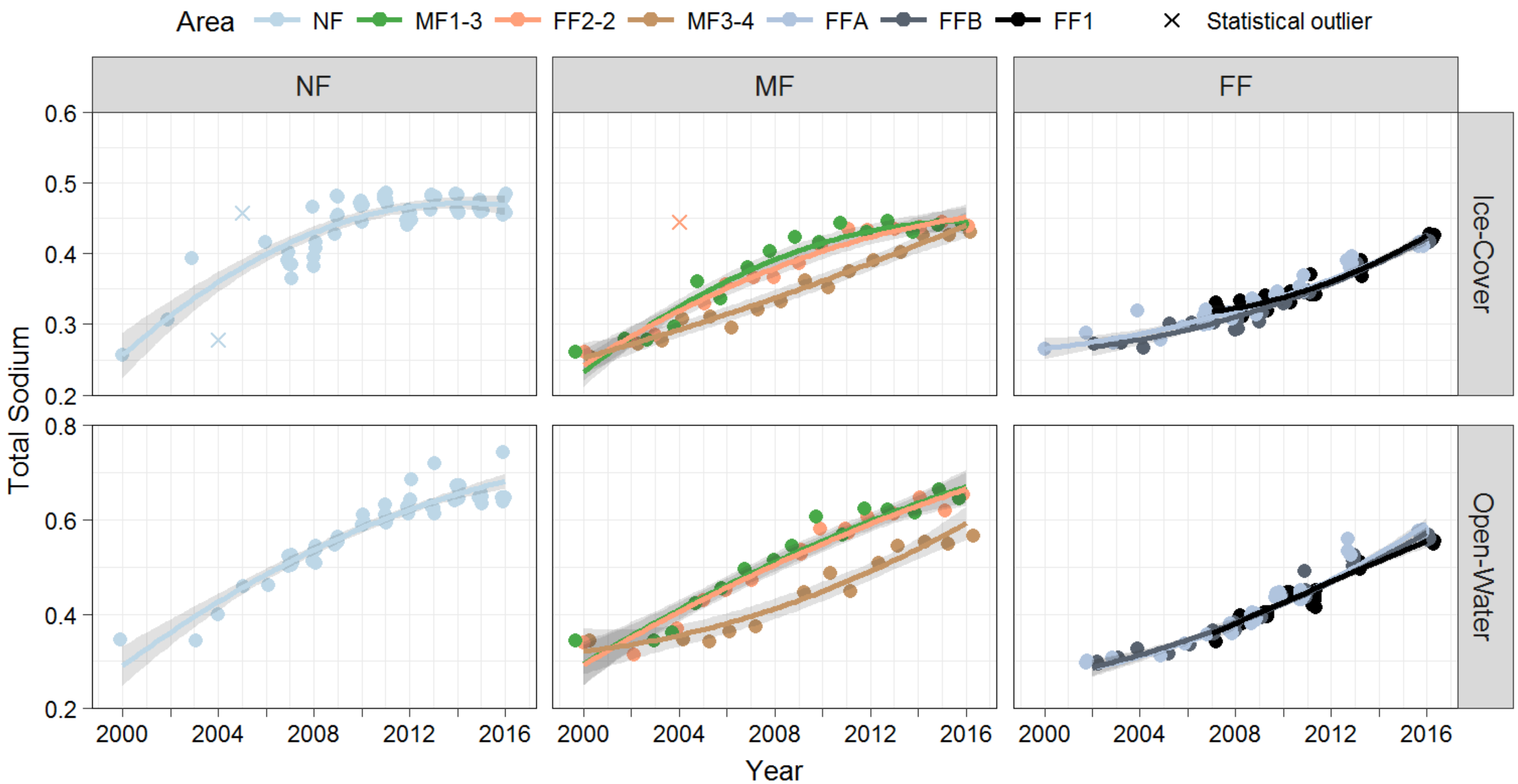
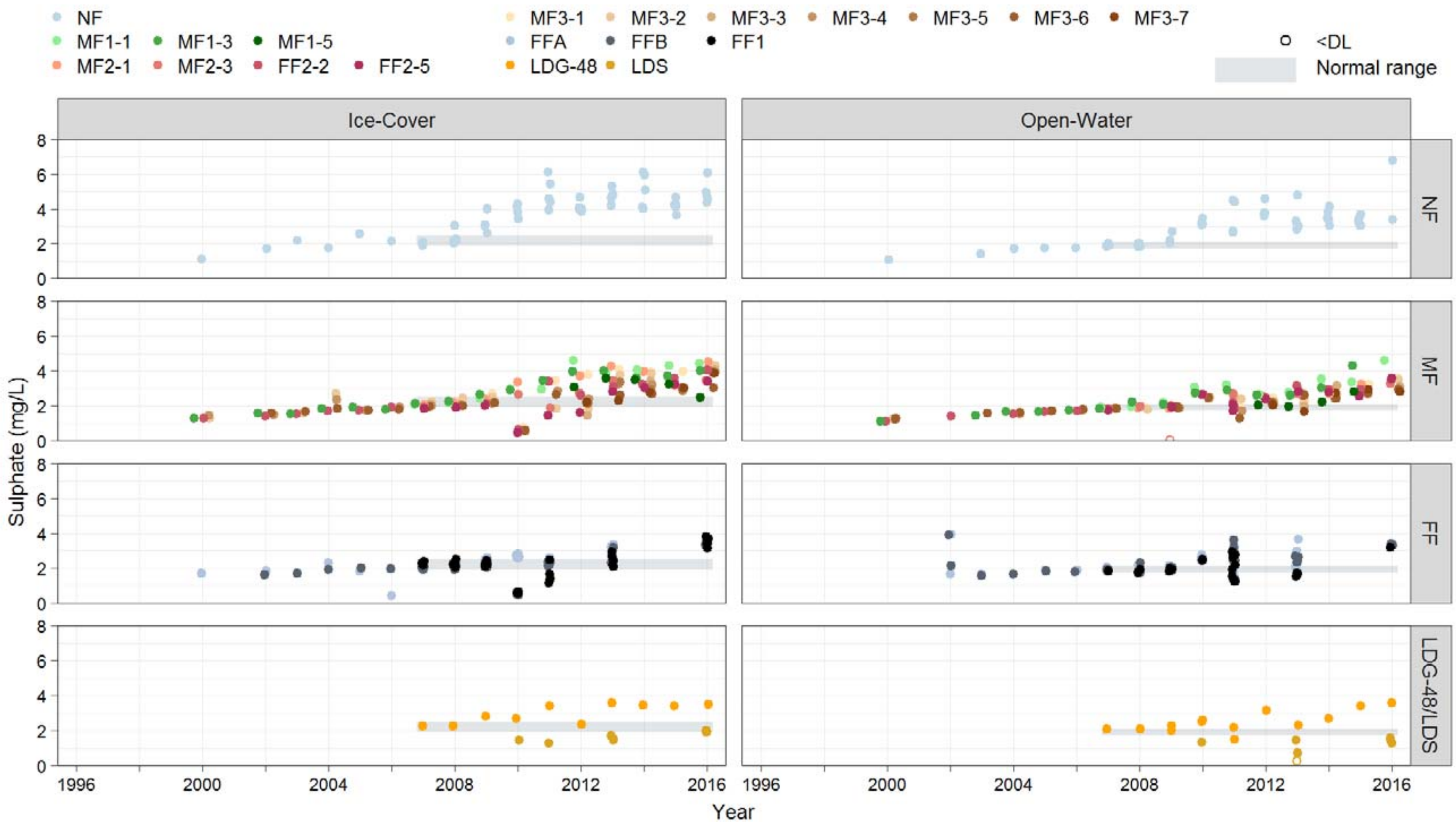
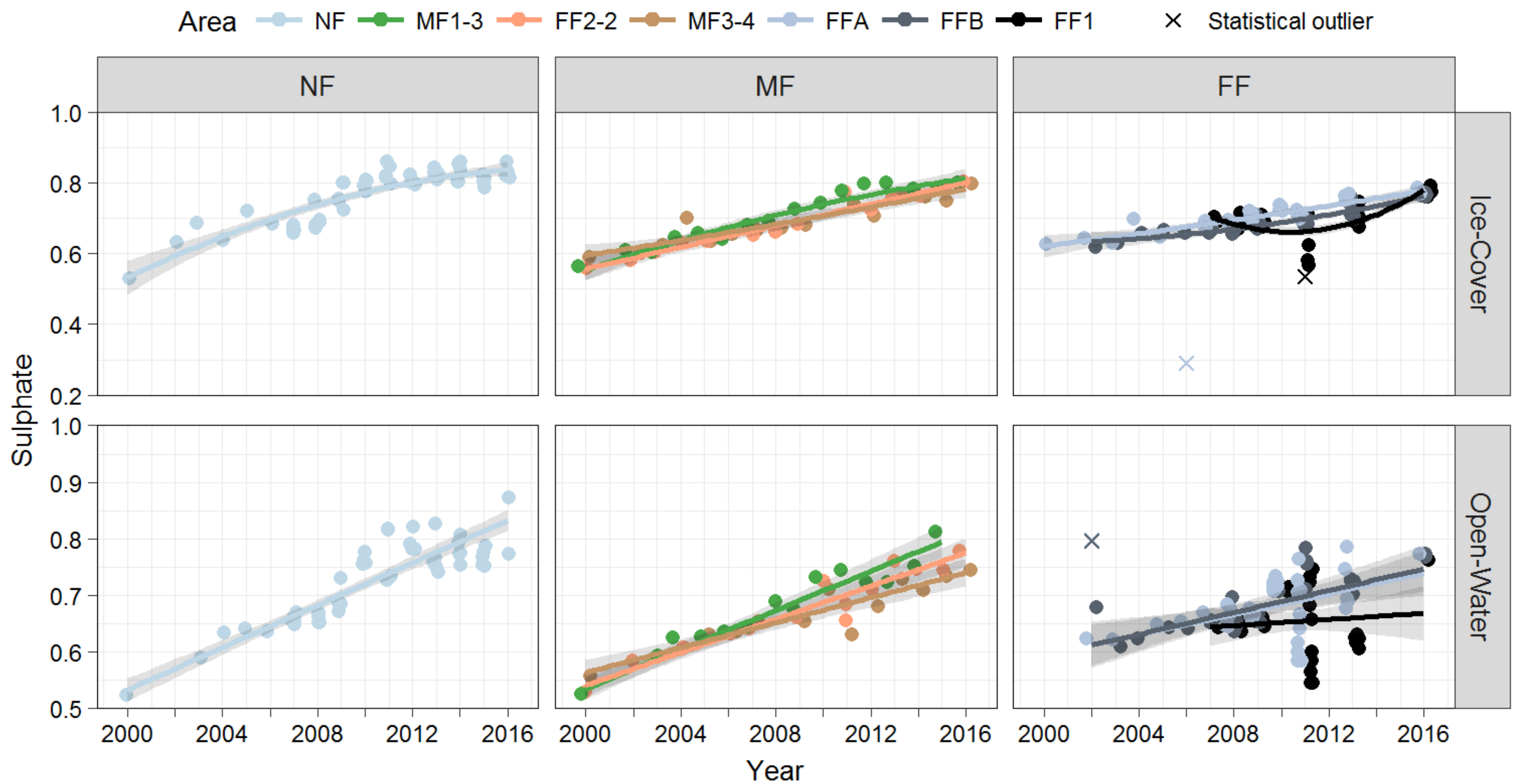


Figure 4-57 Sulphate Concentrations at AEMP Stations, 2000 to 2016



Note: Values represent concentrations in individual samples taken at mid-depth.
LDG = Lac de Gras; LDS = Lac du Sauvage

Figure 4-58 Trend Analysis Plots for Sulphate, 2000 to 2016



Nutrients

Data quality issues with analysis of low levels of ammonia in the AEMP occurred from 2011 to 2016, with the exception of 2015. In general, ammonia concentrations in blank samples analyzed by Maxxam were at or above levels found in Lac de Gras, while concentrations reported in Lac de Gras samples were greater and more variable than values previously provided by ALS (2007 to 2010; Figure 4-59). As a result, the ammonia data were not compared to the normal range, which is based on ALS data, and a trend analysis was not completed for ammonia. Efforts that have taken place between 2011 and 2017 to address the QC issues for ammonia are detailed in Appendix 4B.

The ammonia data are presented in Figure 4-59 to allow visual review of the results reported for ammonia. In general, slight increasing trends are apparent upon visual examination of the plots. However, potential trends should be interpreted with caution given the quality control issues identified for this variable. For example, greater concentrations and variability in ammonia since 2011 may be related to the laboratory data quality issues, rather than true increasing trends in time, particularly since ammonia concentrations in the effluent stabilized at relatively low levels (i.e., less than 1 mg/L) beginning in 2010 (Figure 4-13; Appendix 4B).

While many nitrate values have been reported as less than the DL over time, nitrate concentrations have been above the normal range in the NF area in both the ice-cover and open-water seasons (Figure 4-60). Concentrations have also been above the normal range in the MF area and LDS, primarily during the ice-cover season.

Statistical trend analysis could only be completed for nitrate in the ice-cover season, not including FFB and FFA, because of the high percentage of data below the DL (ice-cover: FF = 51%; open-water: NF = 22%, MF = 71%, FF = 96%). A parabolic model was selected for nitrate (Appendix 4D; Figure 4-61). Of the areas/stations included in the analysis, temporal trends among areas were significantly different (Table 4-16), and indicate declines in concentrations in recent years in the NF and MF areas, with the exception of Station MF3-4, and increasing concentration in the FF1 area (Figure 4-61). Multiple comparisons between areas/stations indicated that for the 2010 and 2013 ice-cover season, the NF and MF1-3 were significantly different from the FF1 area (Table 4-17). In 2016, the NF was significantly different from FF2-2 and FF1 (Table 4-17).

Nitrite concentrations were generally below the DL (ice-cover: range of 71% to 99% for NF/MF/FF; open-water: 98% to 100% for the three areas). As a result, statistical trend analysis was not conducted for this variable. However, exceedances of the normal range were noted in the ice-cover season in the NF and MF areas (Figure 4-62).

Table 4-16 Nitrate: Significance of Water Quality Fixed Effects Models, 2002 to 2016

Variable	Season	Coefficient	Numerator DF	Denominator DF	F-value	*P*-value
Nitrate	Ice-cover	Area	4	8	5.28	0.022
		Year	1	109	4.22	0.042
		$Year^2$	1	109	4.24	0.042
		Area × Year	4	109	5.29	**0.001**
		Area × $Year^2$	4	109	5.29	**0.001**

Note: Significance of the interaction term was evaluated at a *P*-value <0.05.

DF = degrees of freedom

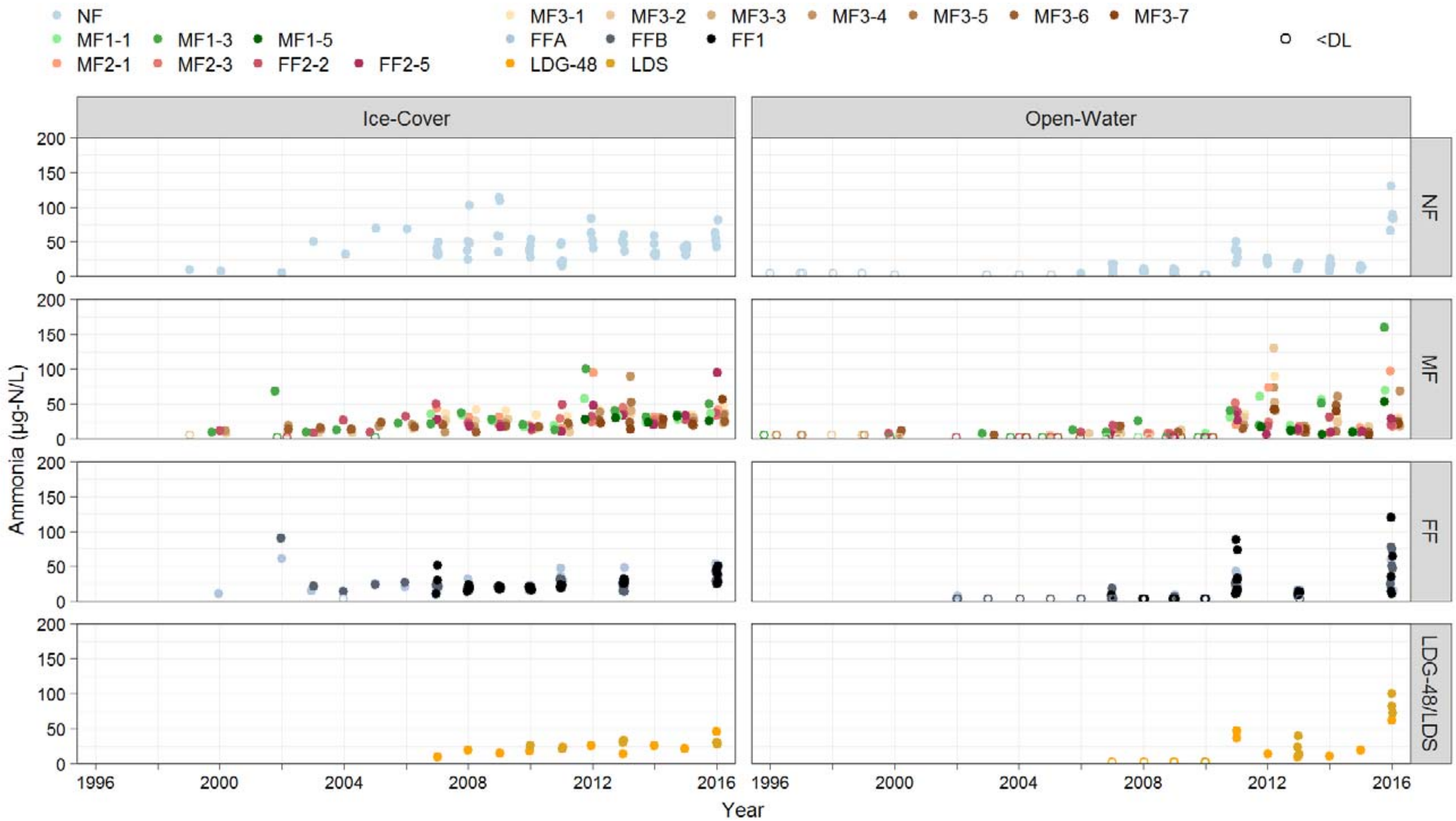
Table 4-17 Nitrate: Multiple Comparisons of Parabolic Trends in 2010, 2013, and 2016

Variable	Season	Year	NF	MF1-3	FF2-2	MF3-4	FF1	FFB	FFA
Nitrate	Ice-cover	2010	c	c	bc	ab	a	-	-
		2013	c	b	b	ab	a	-	-
		2016	b	ab	a	ab	a	-	-

Note: different letters designate areas/stations that are significantly different at the *P*<0.05 level.

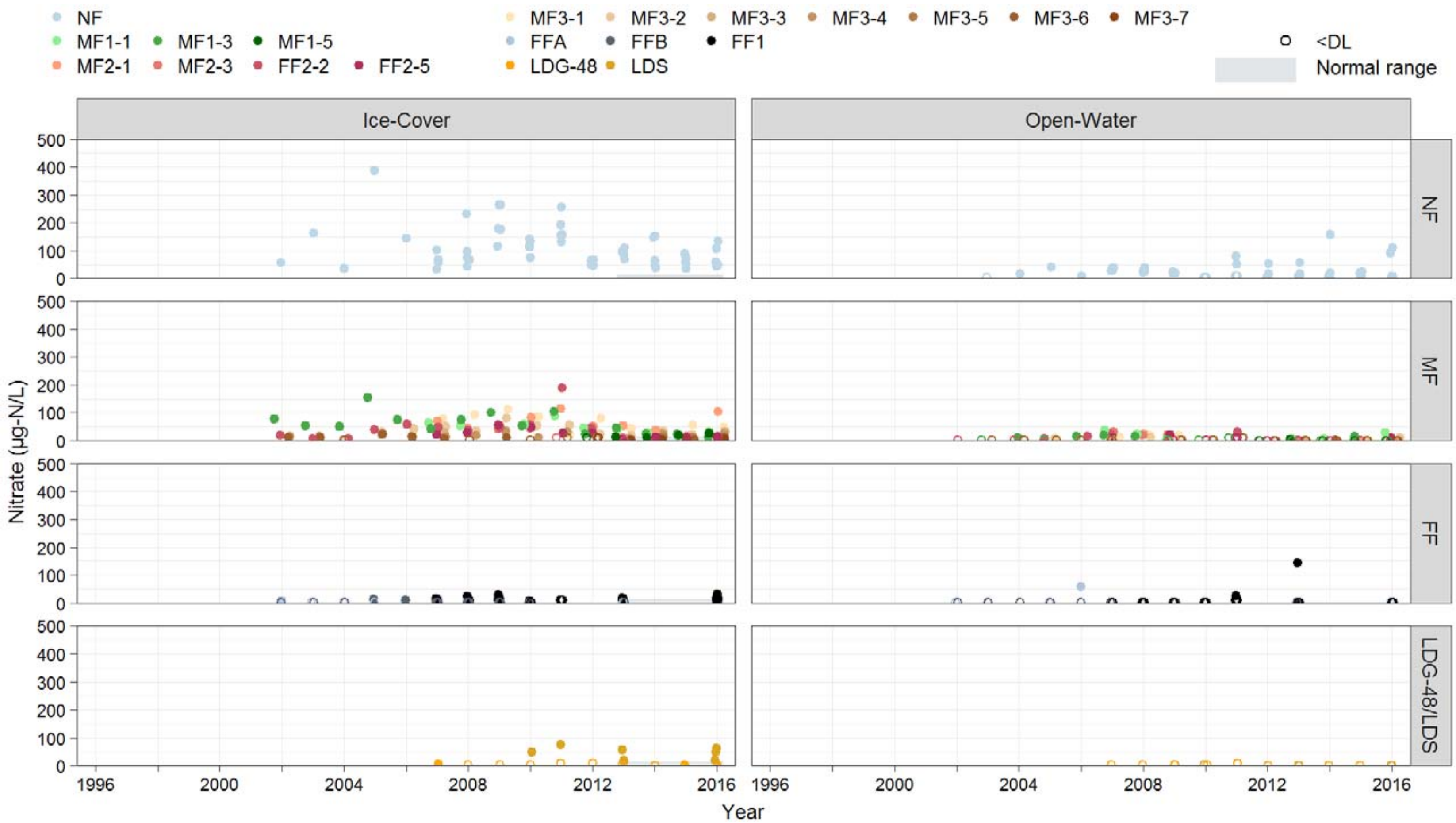
- = data not available

Figure 4-59 Ammonia Concentrations at AEMP Stations, 1996 to 2016



Note: Values represent concentrations in individual samples taken at mid-depth. Because of data quality issues with the ammonia concentrations since 2011, data could not be compared to a normal range, which is typically based on data from 2007 to 2010; see Appendix 4B for further details on the ammonia QC issue.
LDG = Lac de Gras; LDS = Lac du Sauvage

Figure 4-60 Nitrate Concentrations at AEMP Stations, 2002 to 2016



Note: Values represent concentrations in individual samples taken at mid-depth.
LDG = Lac de Gras; LDS = Lac du Sauvage

Figure 4-61 Trend Analysis Plots for Nitrate, 2002 to 2016

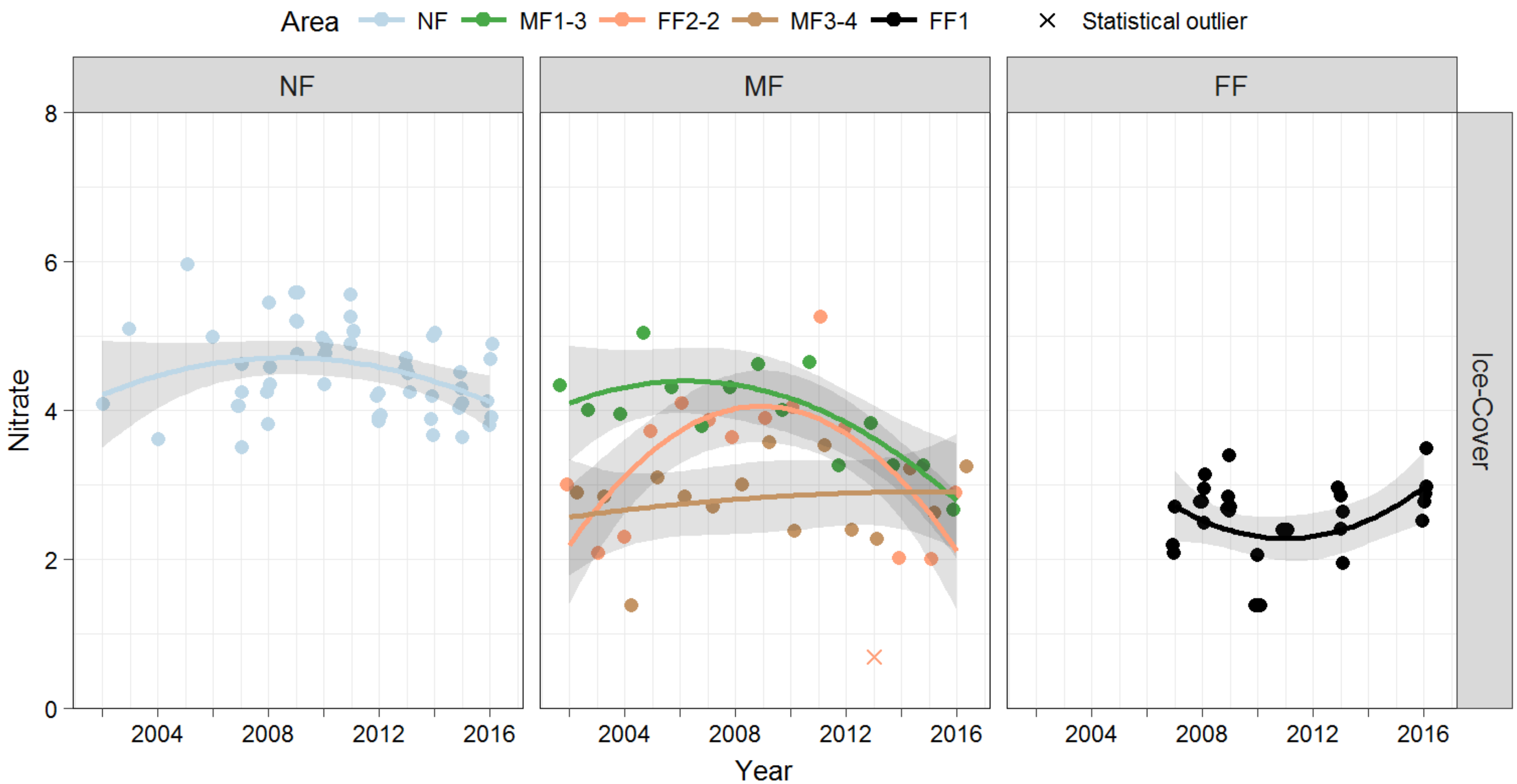
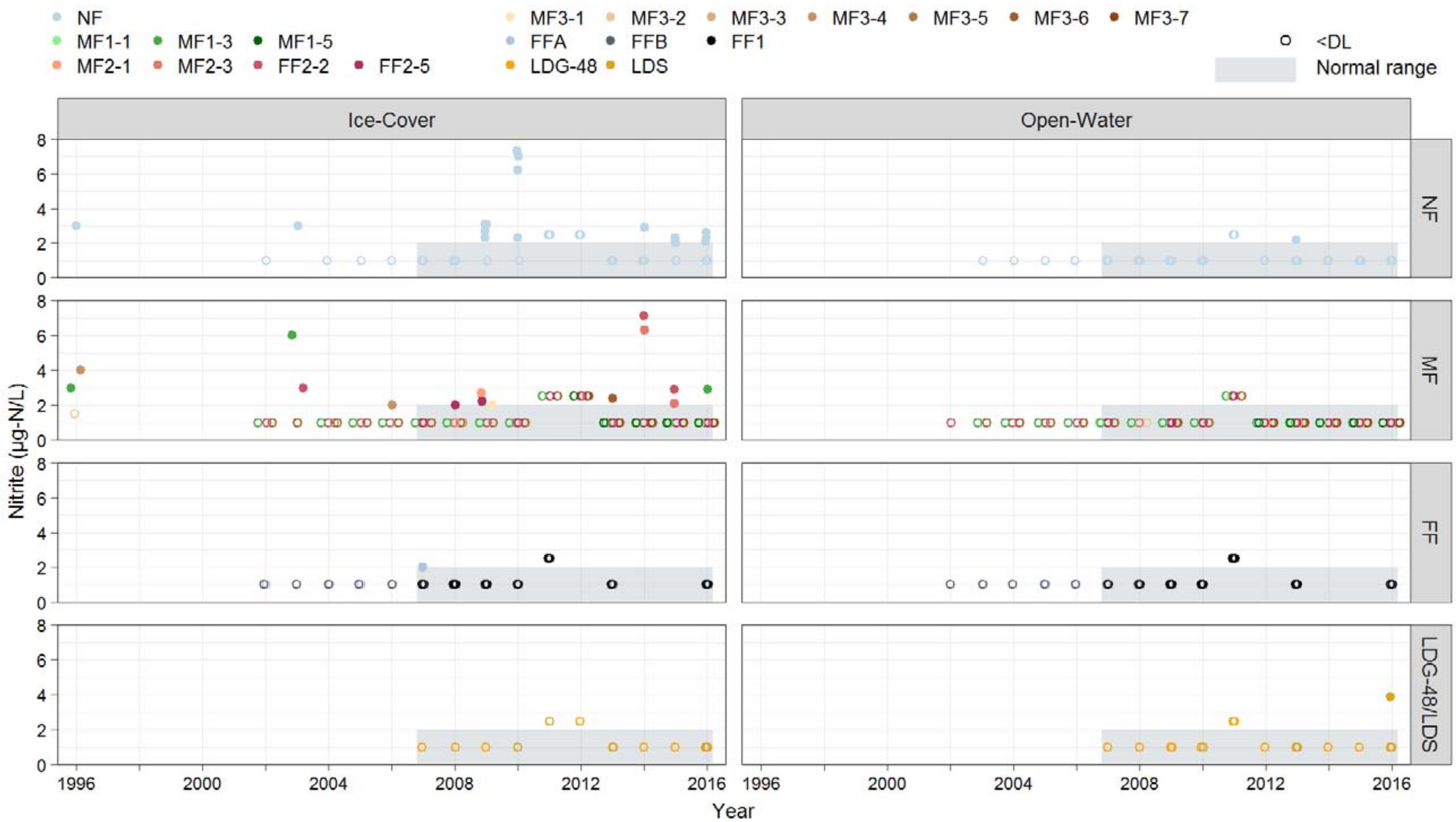


Figure 4-62 Nitrite Concentrations at AEMP Stations, 1996 to 2016



Note: Values represent concentrations in individual samples taken at mid-depth.
LDG = Lac de Gras; LDS = Lac du Sauvage

Total Metals

Time series and trend analysis plots for total metal SOIs are provided in Figures 4-63 to 4-93, in alphabetical order. The following text describes differences, if any, between measured concentrations and the normal range for each variable. Statistical trend analyses are also provided; details are provided if trend analysis could not be completed for a given variable, or has been modified due to data limitations. A summary of major findings relating to total metal SOIs is provided at the end of this section.

For aluminum, concentrations in the NF and MF have been above the normal range over time, while concentrations at the FF areas and LDG-48 have been within or occasionally above the normal range (Figure 4-63). A linear trend was selected for aluminum in the ice-cover season, while a parabolic trend was selected for the open-water season (Figure 4-64; Appendix 4D). No significant differences were identified in linear trends among areas for the ice-cover season (Table 4-18) and slopes of trend lines at all areas/stations analyzed were not significantly different than zero (Table 4-19), indicating that no statistically significant increasing or decreasing trends were identified in any area for aluminum for the ice-cover season. For the open-water season, there was no significant Area × Year interaction (Table 4-18). As indicated in Figures 4-63 and 4-64, aluminum concentrations were slightly elevated in the MF3-1 to MF3-4 stations in 2015 and 2016, potentially due to the A21 dike construction (see Section 4.3.2.2.2 for further details). Multiple comparisons for 2010, 2013, and 2016 indicated that significant differences in total aluminum occurred between the NF and FFA and/or FFB areas during the open-water season (Table 4-20).

Concentrations of antimony have been frequently below the DL, particularly since 2007 (Figures 4-65 and 4-66). As a result, the standard statistical trend analysis method could not be employed, and was replaced with a logistic regression (as described in Section 4.2.4.2.2). Significant differences were identified among areas and over time (Table 4-21), and results indicated declining trends in all areas/stations analyzed (i.e., greater frequency of non-detect values in recent years; Figure 4-66).

Concentrations of barium were consistently above the normal range in the NF and MF stations closer to the Mine since 2007, and were occasionally elevated above the normal range at FFA and LDG-48 (Figure 4-67). Barium concentrations in the NF and MF areas increased from 2000 to 2007, as the loading rate of barium from the Mine effluent increased (Figure 4-18). However, concentrations in these areas decreased slightly in recent years (Figures 4-67 and 4-68), reflecting the lower concentrations and loads of barium in effluent since 2007. A parabolic trend was selected for barium in both seasons (Appendix 4D). The model had a significant interaction between area and year in both seasons, indicating that temporal trends were significantly different among areas/stations (Table 4-18). For barium, multiple comparisons indicated a high variability in the areas/stations that were significantly different from each other among years (2010, 2013, 2016) and within seasons (Table 4-20). In general, the NF area was consistently significantly different from one or all three of the FF areas.

Bismuth concentrations were generally below DLs (ice-cover: range of 98% to 100% for NF/MF/FF; open-water: 95% to 100% for the three areas), as were chromium concentrations (ice-cover: 48% to 78% for the three areas; open-water: 63% to 96% for the three areas; Figures 4-69 and 4-70). As a result, statistical trend analyses were not conducted for these variables. As discussed in Section 4.3.2.2.2, these two metals had elevated concentrations in MF3 area in 2016, which may have been related to the A21 dike construction.

Concentrations of cobalt were generally below the DL prior to 2011 and subsequently within the normal range, with the exception of elevated concentrations in the MF3 area in 2015 and 2016 (Figure 4-71). A linear model was selected for cobalt in both seasons (Appendix 4D). In the ice-cover season, the model had a significant interaction between area and year, indicating that temporal trends were significantly different among areas/stations (Table 4-18). Increasing trends for MF3-4, FF1, FFB, and FFA were indicated by slopes that were significantly different from zero during the ice-cover season, while during the open-water season, the NF, MF3-4 and FFA areas/stations had increasing trends with slopes that were significantly different from zero (Table 19; Figure 4-72).

Copper concentrations were frequently below detection prior to 2011, but since then have consistently been in the upper region of the normal range; copper concentrations were occasionally recorded above the normal range in the NF and MF areas from 1996 to 2016 (Figure 4-73). Copper concentrations at MF3-1 and MF3-2 were two times the median of the reference dataset in 2016, and copper was one of the variables that demonstrated a dike-related effect in the MF area (see Section 4.3.2.2.2). A linear model was selected for copper for each season, based on data from 2011 to 2016 (Appendix 4D; Figure 4-74). While the model identified a significant interaction between area and year for the open-water season, no statistical differences were identified between trends for the ice-cover season (Table 4-18). During the ice-cover season, only Station MF3-4 had a positive increasing trend with a slope that was significantly different from zero (Table 4-19; Figure 4-74). During the open-water season, increasing trends were also identified for Station MF3-4, and for the FF1 and FFA areas (Table 4-19; Figure 4-74). The increasing trend at Station MF3-4 had a notably greater slope compared to other areas, which indicates a likely effect of the A21 dike construction.

Iron concentrations were reported infrequently prior to 2009, but reporting has increased since then, and concentrations have been at or above the upper level of the normal range, particularly in the NF and MF areas. Iron concentrations were elevated at the MF3 stations in 2015 and 2016 (Figure 4-75), likely reflecting dike construction-related effects. A linear model was selected for interpretation of iron, using data from 2011 to 2016 (Appendix 4D). In both seasons, the trend lines for MF3-4, FF1, FFB and FFA had slopes that were significantly greater than zero, indicating increasing trends in concentrations (Table 19; Figure 4-76). The NF area also had an increasing trend in the open-water season.

Lead concentrations, similar to antimony, was frequently reported at less than the DL and, as a result, a logistic regression method was used to analyze trends for this variable (Figure 4-77). The logistic model for ice-cover indicated the absence of detected values early in the monitoring period, with a shift to the presence of detected values starting in approximately 2008, and then a subsequent shift back to non-detect values in the last several years (Figures 4-77 and 4-78). The trend in the open-water season was somewhat different, as the model identified the absence of detected values in the early years of monitoring, which shifted to the presence of detected values in approximately 2008 (similar to ice-cover), but values remained detectable after 2008 (Figures 4-77 and 4-78). A significant difference was identified for area and year in the ice-cover season for lead, while only a significant difference for year was identified for the open-water season (Table 4-21).

Manganese frequently occurred at concentrations greater than the normal range during the ice-cover season in all areas over time, but only occasionally exceeded the normal range during the open-water season (Figure 4-79). Manganese was elevated in the MF area in 2015, and was one of the variables that demonstrated a dike-related effect in the MF3 area in 2016 (see Section 4.3.2.2.2). A parabolic model was selected for manganese in the ice-cover season, while a linear model was selected for the open-water season (Appendix 4D; Figure 4-80). A significant Area × Year interaction was identified for the open-water season (Table 4-18). Multiple comparisons for the ice-cover season identified significant differences between the NF and FF2-2/MF3-4/FFB in both 2010 and 2013, but no differences among areas/stations in 2016 (Table 4-20). For the open-water season, trend lines in the NF and FF1 had slopes that were significantly greater than zero (Table 4-19), indicating increasing trends. The assumptions of normality were not met for the open-water manganese dataset; therefore, results should be interpreted with caution.

Molybdenum concentrations have been above the normal ranges in Lac de Gras over time, and have been increasing until recent years, when concentrations levelled off in areas other than the FF areas (Figures 4-81). A parabolic model was selected for molybdenum in both seasons (Appendix 4D; Figure 4-82). Concentrations in the NF area generally reflect the trend in the load of molybdenum in the effluent (Figures 4-82 and 4-26). The model had a significant interaction between area and year, indicating that temporal trends were significantly different among areas/stations (Table 4-18). For molybdenum, multiple comparisons showed a high variability in the areas/stations that were significantly different from each other among years (2010, 2013, 2016) and within a season (Table 4-20). In general, for the ice-cover season, areas/stations were more similar in 2016 than in previous years.

Strontium concentrations, similar to molybdenum, have been above the normal range in Lac de Gras and increasing over time (Figure 4-84). Increasing concentrations of strontium over time reflect the increasing load of strontium in the Mine effluent (Figure 4-28). A parabolic model was selected for both seasons (Appendix 4D; Figure 4-85), and results show that concentration increases have been slower in recent years in the NF and MF areas, but not in the FF areas, where increasing trends are closer to linear. As also observed for molybdenum, the model for strontium had a significant interaction between area and year, indicating that temporal trends were significantly different among areas/stations (Table 4-18). Multiple comparison analysis indicated multiple areas/stations that were significantly different in both seasons, generally involving four groupings, i.e., NF; MF1-3/FF2-2; MF3-4 and the three FF areas (Table 4-20).

Silicon was not analyzed during baseline sampling (1996 to 1999) and for several years of monitoring (2005 to 2010; Figure 4-83). Concentrations in the NF area frequently exceeded the normal range during the ice-cover season. These exceedances were generally not present during the open-water season, since silicon is taken up by algae (e.g., diatoms) during that season. In areas other than the NF, silicon concentrations were frequently below the DL (ice-cover: 61% in MF and 76% in FF; open-water: 84% in NF, 77% in MF and 98% in FF). As a result, statistical trend analysis was not completed for this variable. Detectable concentrations were often above the normal range in all areas/stations (Figure 4-83). Silicon was elevated at the MF3 area in 2015 and 2016, potentially as a result of dike construction.

Tin was first analyzed in water samples in 2011. Due to a high number of values being recorded as less than the DL, logistic regression was chosen as the method for statistical analysis. Detectable values in all areas and both seasons were generally above the normal range (Figure 4-87). The logistic models for both seasons indicated the absence of detected values early in the monitoring period, with a shift to the presence of detected values starting in approximately 2012, and then a subsequent shift back to non-detect values in 2015 and 2016 (Figures 4-77 and 4-78). The shifting to detectable concentrations between 2012 and 2014 corresponds to the period when detectable concentrations of tin were recorded in the effluent (Figure 4-30). Multiple comparisons indicated no statistical differences among areas/stations in any of the three years evaluated (Table 4-20).

Uranium concentrations in the NF and MF areas have been above the normal range for the period of record; they peaked in 2002 and then declined to 2007 (Figure 4-90). Concentrations in the NF and MF generally stabilized since that time, with the exception of an increase in the MF3 area in 2016. A similar pattern was identified for uranium at the mixing zone boundary, excluding the increase in 2016 identified for the MF3 area (Figure 4-32). Effluent loads and concentrations have varied considerably over time without demonstrating any consistent trends (Figure 4-32). The elevated results in the MF3 area in 2016 may be due to construction of the A21 dike (see Section 4.3.2.2.2). A linear model was selected for uranium concentrations in the ice-cover season, while a parabolic model was selected for the open-water season (Appendix 4D). Due to high percentages of data below the DL prior to 2011, the trend analysis included data from 2011 to 2016 (Figure 4-91). Both the linear and parabolic models had a significant interaction term between area and year, indicating that temporal trends were significantly different among areas/stations (Table 4-18). For the ice-cover season, the NF, MF1-3, and FF2-2 and FFA had slopes that were significantly different from zero and indicated slightly declining trends over time (Table 19; Figure 4-91). Multiple comparison analysis for the open-water season identified significant differences between NF/MF stations and FF stations in the three years evaluated (Table 4-20).

Thallium, titanium, vanadium, and zirconium occasionally had concentrations above the normal range, particularly in 2015 (titanium and vanadium only) and 2016 (Figures 4-86, 4-89, 4-92, 4-93), which may have been associated with the construction of the A21 dike (see Section 4.3.2.2.2). Trend analyses were not conducted for these four variables because of the high percentages of non-detect values reported in the NF, MF, and FF areas:

- thallium: ice-cover = 78% to 95%; open-water = 84% to 98%
- titanium: ice-cover = 89% to 100%; open-water = 79% to 100%
- vanadium: ice-cover = 72% to 99%; open-water = 89% to 100%
- zirconium: ice-cover = 97% to 100%; open-water = 100%

Review of the time series plots and trend analyses for the total metals SOIs resulted in the following main findings:

- Molybdenum and strontium were consistently detected at concentrations above the normal range, particularly in the NF and MF areas, and were increasing over time in all areas, although the concentration of molybdenum has begun to decrease in recent years (Figures 4-81, 4-82, 4-84 and 4-85). These trends match the loads of these variables in the Mine effluent (Section 4.3.1.1).
- Aluminum, cobalt, copper, iron, manganese, silicon and vanadium were generally within the ranges of concentrations observed historically, although exceedances of the normal range were noted in the NF and MF areas for each of these SOIs, particularly in 2015 and/or 2016. Concentrations of aluminum in the NF area were frequently above the normal range. Annual loading rates of these SOIs from the NIWTP demonstrated no consistent trends over time (aluminum, chromium, cobalt, iron, lead), no change over time (silicon) or generally decreasing trends over time (copper, manganese; Section 4.3.1.1).
- Results from the 2016 sampling event indicated potential effects of the A21 dike construction, and potentially dust deposition, on water quality in the MF3 area at stations near the dike, as illustrated by elevated SOI concentrations/levels for aluminum, bismuth, chromium, cobalt, copper, iron, lead,

manganese, silicon, thallium, titanium, uranium, vanadium, and zirconium. The potential effects of dust deposition and dike construction are described further in Section 4.3.2.2.2 and Section 4.3.2.3.3. Several of these SOIs (aluminum, cobalt, iron, manganese, silicon, and titanium) exhibited an increase in 2015 at MF3 stations as well, which may also have been related to the A21 dike construction.

- Bismuth, thallium, titanium, and zirconium concentrations at AEMP stations have mostly remained below the DLs from 1996 to 2016. Bismuth, cobalt, iron, thallium, titanium and zirconium were included as SOIs in this re-evaluation report because they met Criterion 3 (Table 4-2) relating to potential dust and dike construction effects, not due to effluent-related criteria; therefore, it is not surprising that the concentrations of some of these SOIs (e.g., bismuth, titanium, and zirconium) would be largely below DLs in both the effluent and Lac de Gras.

Table 4-18 Total Metals: Significance of Water Quality Fixed Effects Models

Variable	Season	Coefficient	Numerator DF	Denominator DF	F-value	*P*-value
Aluminum	Ice-cover	Area	6	18	0.715	0.642
		Year	1	185	0.356	0.552
		Area × Year	6	185	0.723	0.632
	Open-water	Area	6	18	1.03	0.439
		Year	1	186	8.19	0.005
		$Year^2$	1	186	8.23	0.005
		Area × Year	6	186	1.03	0.406
		Area × $Year^2$	6	186	1.03	0.405
Barium	Ice-cover	Area	6	18	10.2	<0.001
		Year	1	177	34.3	<0.001
		$Year^2$	1	177	34.2	<0.001
		Area × Year	6	177	10.2	**<0.001**
		Area × $Year^2$	6	177	10.3	**<0.001**
	Open-water	Area	6	18	5.69	0.002
		Year	1	187	34.9	<0.001
		$Year^2$	1	187	34.8	<0.001
		Area × Year	6	187	5.68	**<0.001**
		Area × $Year^2$	6	187	5.68	**<0.001**
Cobalt	Ice-cover	Area	6	16	3.89	0.014
		Year	1	63	21.6	<0.001
		Area × Year	6	63	3.90	**0.002**
	Open-water	Area	6	16	1.86	0.151
		Year	1	55	14.4	<0.001
		Area × Year	6	55	1.86	0.105

Table 4-18 Total Metals: Significance of Water Quality Fixed Effects Models

Variable	Season	Coefficient	Numerator DF	Denominator DF	F-value	*P*-value
Copper	Ice-cover	Area	6	16	1.61	0.208
		Year	1	62	0.051	0.822
		Area × Year	6	62	1.61	0.159
	Open-water	Area	6	16	3.85	0.014
		Year	1	71	20.8	<0.001
		Area × Year	6	71	3.85	**0.002**
Iron	Ice-cover	Area	6	16	1.79	0.164
		Year	1	63	18.0	<0.001
		Area × Year	6	63	1.79	0.115
	Open-water	Area	6	16	1.68	0.189
		Year	1	56	7.91	0.007
		Area × Year	6	56	1.69	0.142
Manganese	Ice-cover	Area	6	18	0.700	0.653
		Year	1	177	19.4	<0.001
		$Year^2$	1	177	19.5	<0.001
		Area × Year	6	177	0.699	0.651
		Area × $Year^2$	6	177	0.699	0.651
	Open-water	Area	6	18	2.53	0.059
		Year	1	175	2.95	0.087
		Area × Year	6	175	2.52	**0.023**
Molybdenum	Ice-cover	Area	6	18	11.1	<0.001
		Year	1	161	38.1	<0.001
		$Year^2$	1	161	37.9	<0.001
		Area × Year	6	161	11.1	**<0.001**
		Area × $Year^2$	6	161	11.1	**<0.001**
	Open-water	Area	6	18	8.38	<0.001
		Year	1	158	23.8	<0.001
		$Year^2$	1	158	23.6	<0.001
		Area × Year	6	158	8.36	**<0.001**
		Area × $Year^2$	6	158	8.35	**<0.001**

Table 4-18 Total Metals: Significance of Water Quality Fixed Effects Models

Variable	Season	Coefficient	Numerator DF	Denominator DF	F-value	*P*-value
Strontium	Ice-cover	Area	6	18	25.1	<0.001
		Year	1	178	55.0	<0.001
		$Year^2$	1	178	54.4	<0.001
		Area × Year	6	178	25.1	**<0.001**
		Area × $Year^2$	6	178	25.1	**<0.001**
	Open-water	Area	6	18	8.60	<0.001
		Year	1	189	59.9	<0.001
		$Year^2$	1	189	59.1	<0.001
		Area × Year	6	189	8.59	**<0.001**
		Area × $Year^2$	6	189	8.59	**<0.001**
Uranium	Ice-cover	Area	6	16	8.19	<0.001
		Year	1	63	29.9	<0.001
		Area × Year	6	63	8.17	**<0.001**
	Open-water	Area	6	16	4.12	0.011
		Year	1	67	11.8	0.001
		$Year^2$	1	67	11.8	0.001
		Area × Year	6	67	4.12	**0.001**
		Area × $Year^2$	6	67	4.12	**0.001**

Note: Significance of the interaction terms was evaluated at a *P*-value of <0.05.
DF = degrees of freedom.

Table 4-19 Total Metals: Estimated Significance of Difference of Linear Slopes from Zero

Variable	Season	NF	MF1-3	FF2-2	MF3-4	FF1	FFB	FFA
Aluminum	Ice-cover	0.365	0.907	0.296	0.198	0.481	0.577	0.529
Cobalt	Ice-cover	0.988	0.824	0.732	**0.003** ↑	**0.007** ↑	**<0.001** ↑	**<0.001** ↑
	Open-water	**<0.001** ↑	0.504	0.992	**0.007** ↑	0.313	0.911	**0.008** ↑
Copper	Ice-cover	0.841	0.907	0.140	**0.049** ↑	0.176	0.323	0.459
	Open-water	0.275	0.521	0.955	**<0.001** ↑	**<0.001** ↑	0.542	**0.001** ↑
Iron	Ice-cover	0.319	0.704	0.948	**0.001** ↑	**0.004** ↑	**0.018** ↑	**0.006** ↑
	Open-water	**<0.001** ↑	0.992	0.843	**0.007** ↑	**0.032** ↑	**0.010** ↑	**0.030** ↑
Manganese	Open-water	**0.025** ↑	0.198	0.285	0.488	**0.031** ↑	0.065	0.819
Uranium	Ice-cover	**<0.001** ↓	**0.009** ↓	**0.032** ↓	0.203	0.610	0.664	**<0.001** ↓

Note: **Bold text** = *P*-value significant at <0.05. Arrows after significant *P*-values indicate direction of trend.

Table 4-20 Total Metals: Multiple Comparisons of Parabolic Trends in 2010, 2013, and 2016

Variable	Season	Year	NF	MF1-3	FF2-2	MF3-4	FF1	FFB	FFA
Aluminum	Open-water	2010	c	abc	abc	abc	bc	ab	a
		2013	c	abc	ab	bc	bc	a	a
		2016	b	ab	ab	b	ab	a	a
Barium	Ice-cover	2010	e	de	cd	bc	ab	a	ab
		2013	d	cd	c	bc	a	ab	ab
		2016	b	ab	a	ab	a	a	a
	Open-water	2010	c	c	c	b	a	b	b
		2013	d	cd	cd	bc	a	b	b
		2016	b	ab	ab	ab	a	a	a
Lead	Ice-cover	2010	ab	ab	ab	ab	b	ab	a
		2013	ab	ab	ab	ab	b	ab	a
		2016	ab	ab	ab	ab	b	ab	a
Manganese	Ice-cover	2010	c	ab	a	a	bc	a	ab
		2013	b	ab	a	a	b	a	a
		2016	a	a	a	a	a	a	a
Molybdenum	Ice-cover	2010	e	d	d	c	a	b	c
		2013	e	d	d	c	a	b	b
		2016	b	b	b	b	a	a	a
	Open-water	2010	c	c	c	ab	a	ab	b
		2013	b	b	b	a	a	a	a
		2016	c	bc	bc	ab	a	a	a
Strontium	Ice-cover	2010	d	c	c	b	a	a	a
		2013	d	c	c	b	a	a	a
		2016	c	b	bc	b	a	a	a
	Open-water	2010	d	cd	c	b	a	a	b
		2013	d	cd	c	b	a	a	a
		2016	b	b	b	a	a	a	a
Tin	Ice-cover	2010	a	a	a	a	a	a	a
		2013	a	a	a	a	a	a	a
		2016	a	a	a	a	a	a	a
	Open-water	2010	a	a	a	a	a	a	a
		2013	a	a	a	a	a	a	a
		2016	a	a	a	a	a	a	a
Uranium	Open-water	2010	c	abc	c	bc	ab	a	ab
		2013	b	b	b	a	a	a	a
		2016	bc	ab	bc	c	a	a	a

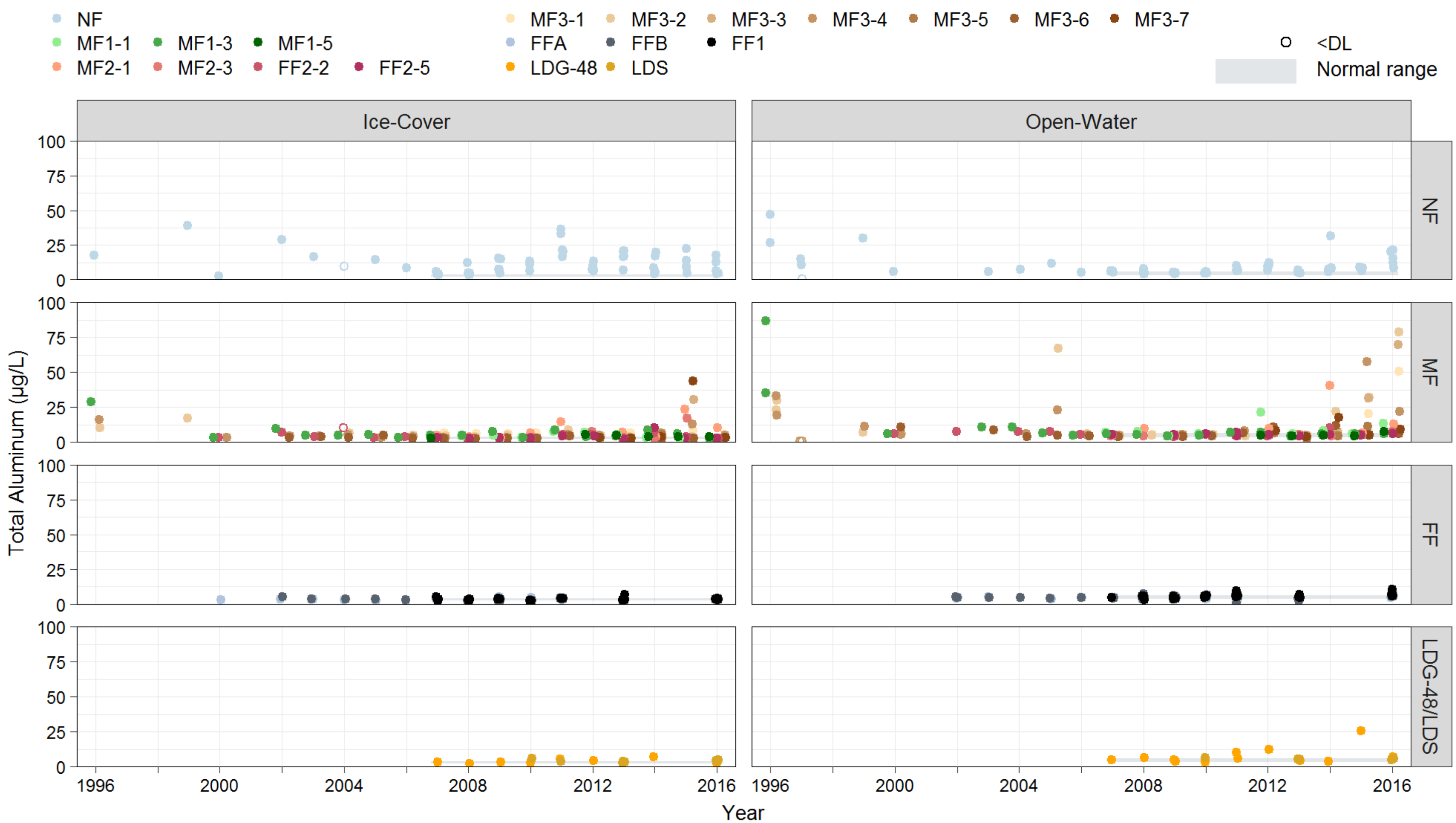
Note: Different letters designate areas/stations that are significantly different at the *P*<0.05 level.

Table 4-21 Total Metals (Logistic Regression): Significance of Water Quality Fixed Effects Models

Variable	Season	Coefficient	Degrees of Freedom	Chi Squared	*P*-value
Antimony	Ice-cover	Area	5	51.8	**<0.001**
		Year	1	27.6	**<0.001**
	Open-water	Area	5	17.2	**0.004**
		Year	1	40.3	**<0.001**
Lead	Ice-cover	Area	6	20.1	**0.003**
		Year	1	30.2	**<0.001**
		$Year^2$	1	18.4	**<0.001**
	Open-water	Area	6	5.64	0.464
		Year	1	33.6	**<0.001**
Tin	Ice-cover	Area	6	8.65	0.194
		Year	1	55.7	**<0.001**
		$Year^2$	1	60.0	**<0.001**
	Open-water	Area	6	11.7	0.070
		Year	1	25.6	**<0.001**
		$Year^2$	1	26.8	**<0.001**

Note: **Bold text** = *P*-value significant at <0.05.

Figure 4-63 Total Aluminum Concentrations at AEMP Stations, 1996 to 2016



Note: Values represent concentrations in individual samples taken at mid-depth.
LDG = Lac de Gras; LDS = Lac du Sauvage

Figure 4-64 Trend Analysis Plots for Total Aluminum, 2000 to 2016

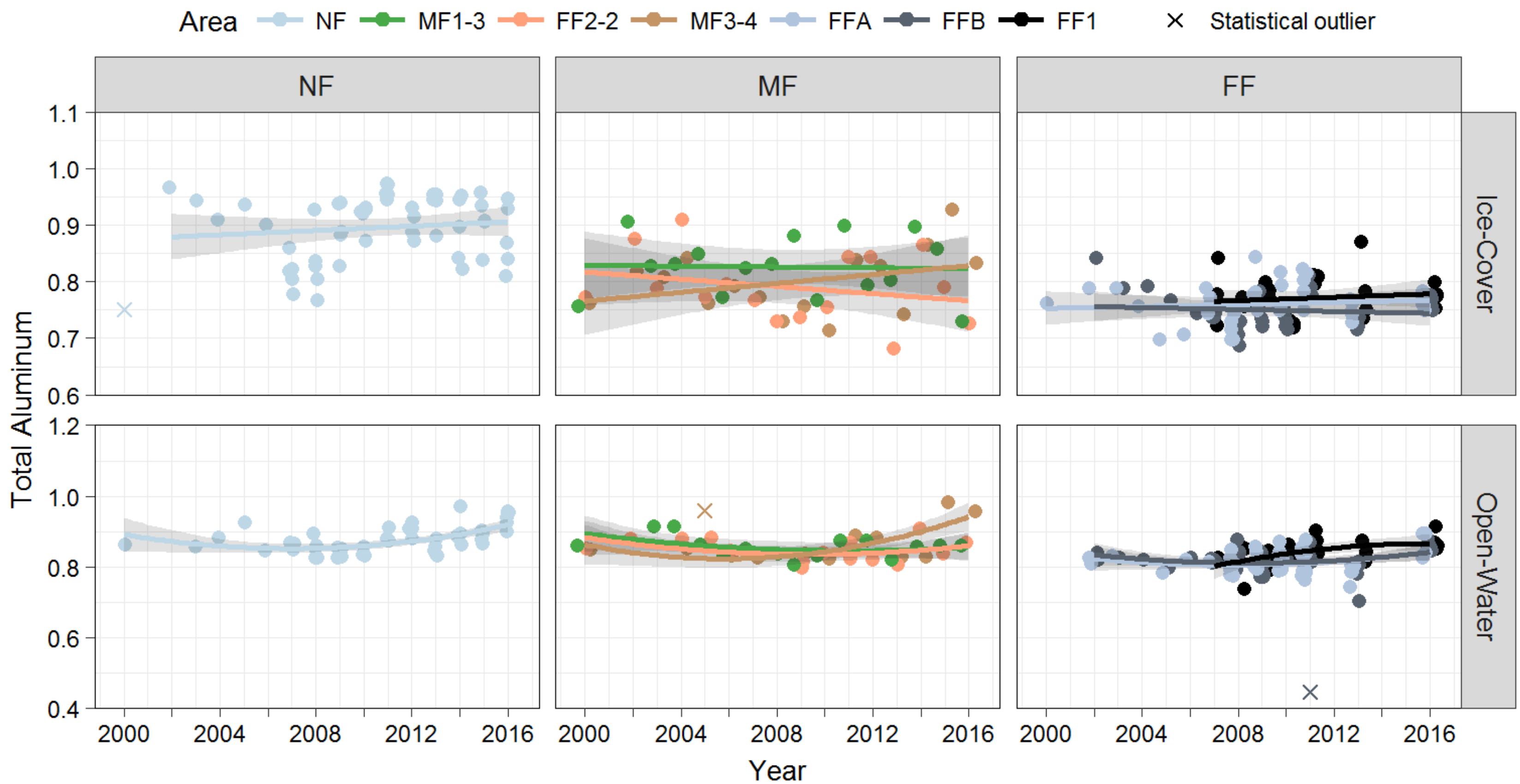
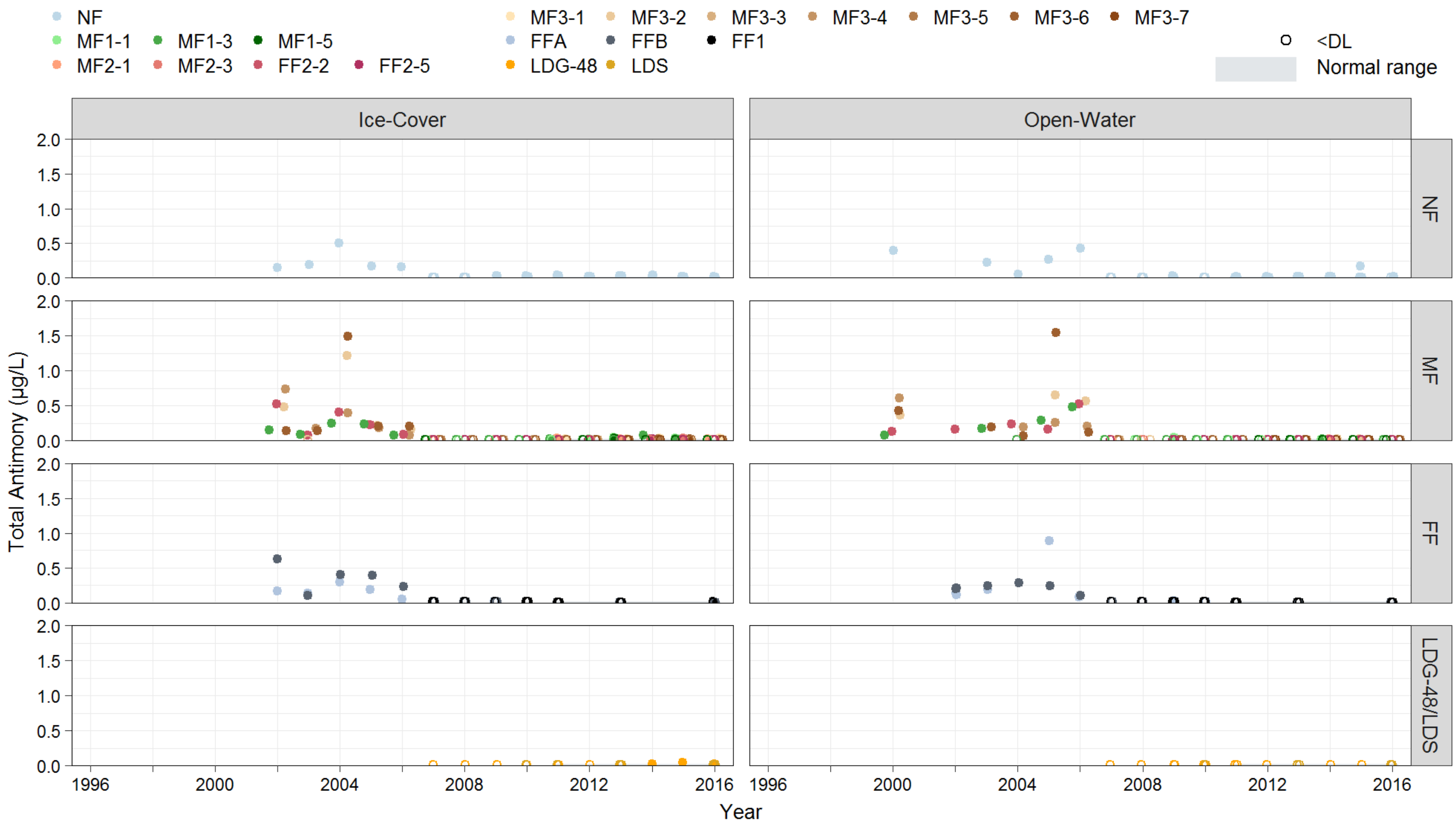


Figure 4-65 Total Antimony Concentrations at AEMP Stations, 2000 to 2016



Note: Values represent concentrations in individual samples taken at mid-depth. Six total antimony values from May 2000 were omitted from this figure because their elevated values resulted in a graphic scale that obscured details: NF = 13.1 µg/L; MF1-3 = 11.6 µg/L; FF2-2 = 8.19 µg/L; MF3-2 = 7.43 µg/L; MF3-4 = 8.91 µg/L; FFA = 8.19 µg/L.
LDG = Lac de Gras; LDS = Lac du Sauvage

Figure 4-66 Trend Analysis (Logistic Regression) Plots for Total Antimony, 2000 to 2016

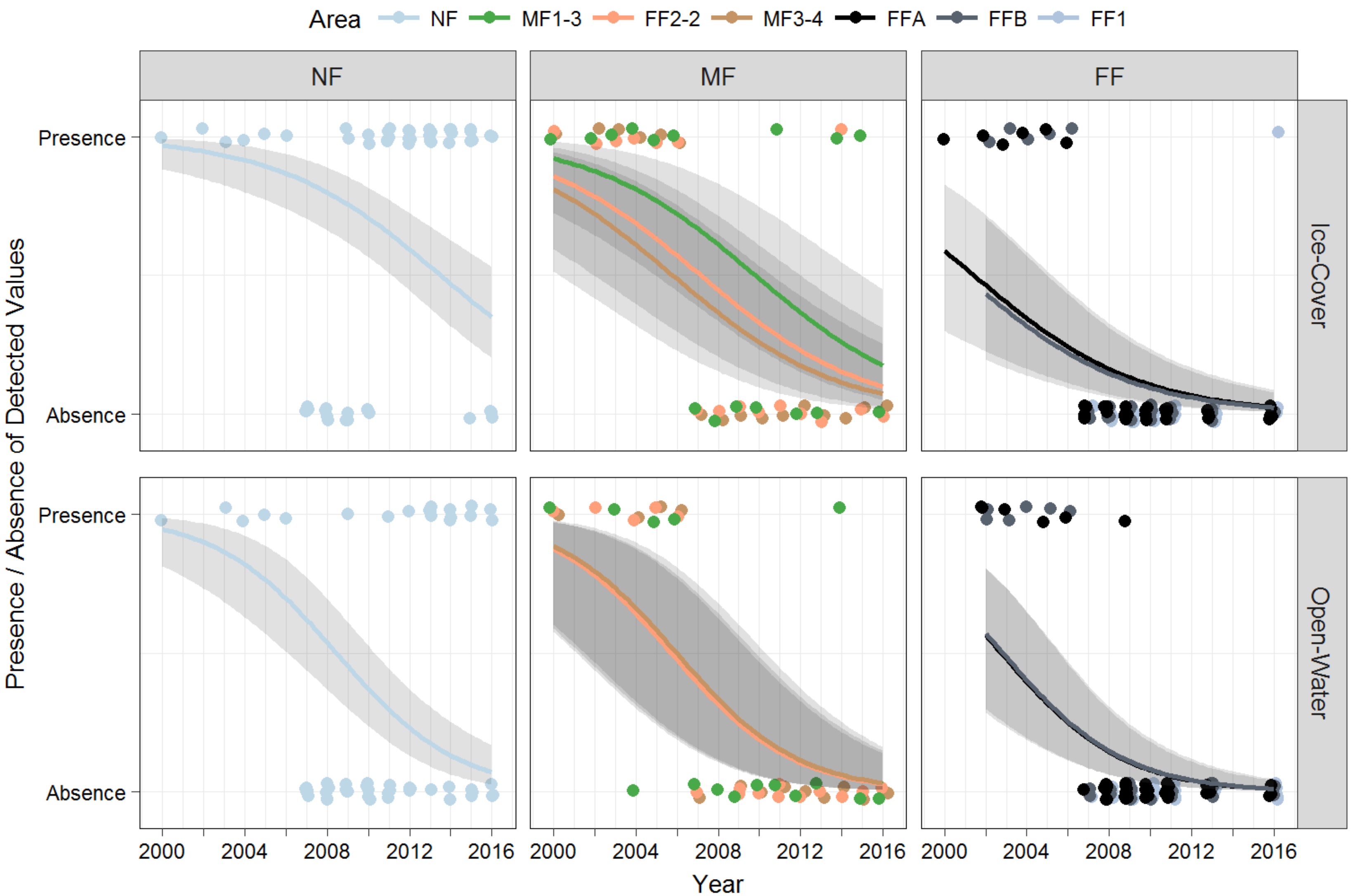
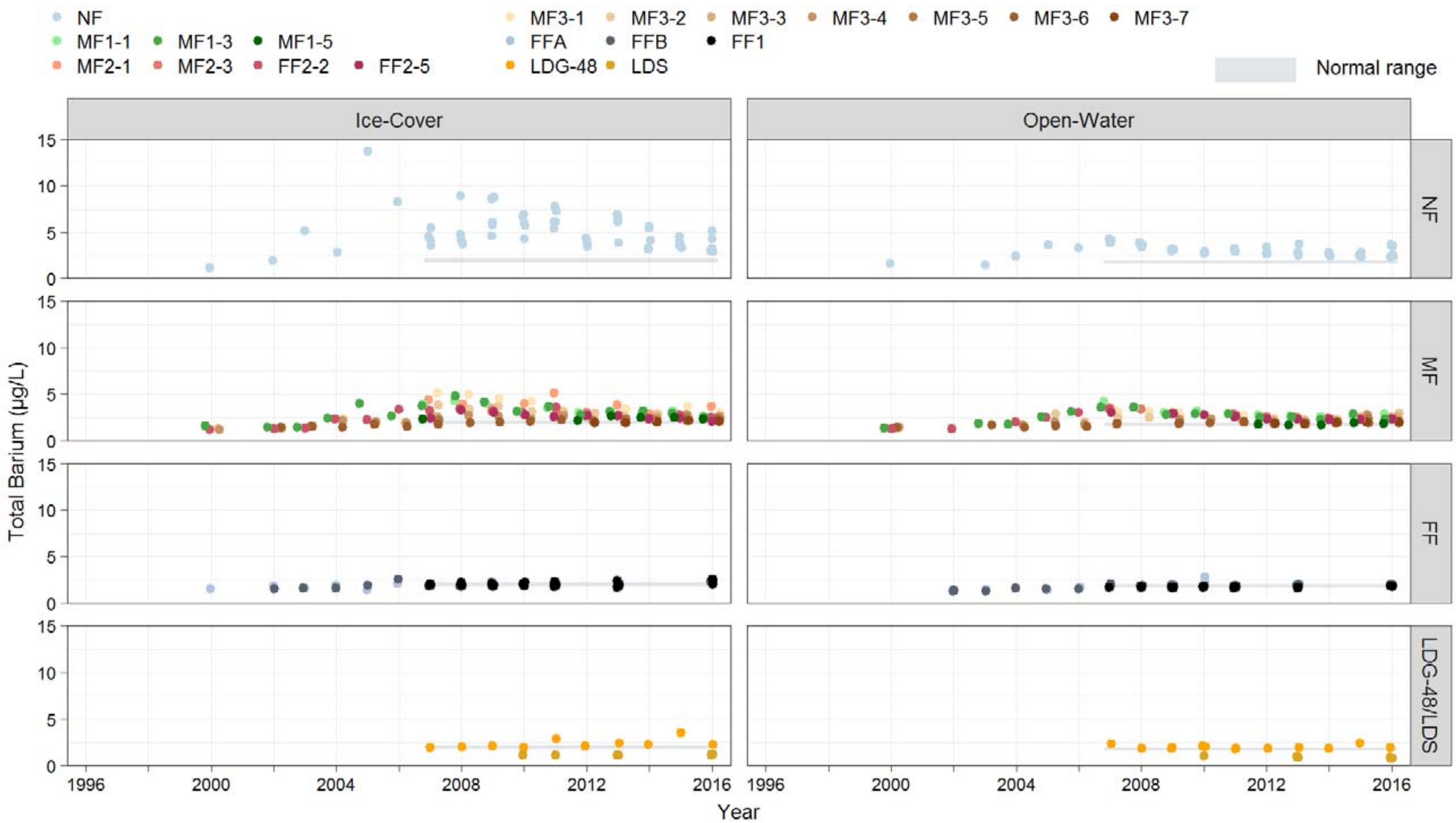


Figure 4-67 Total Barium Concentrations at AEMP Stations, 2000 to 2016



Note: Values represent concentrations in individual samples taken at mid-depth.
LDG = Lac de Gras; LDS = Lac du Sauvage

Figure 4-68 Trend Analysis Plots for Total Barium, 2000 to 2016

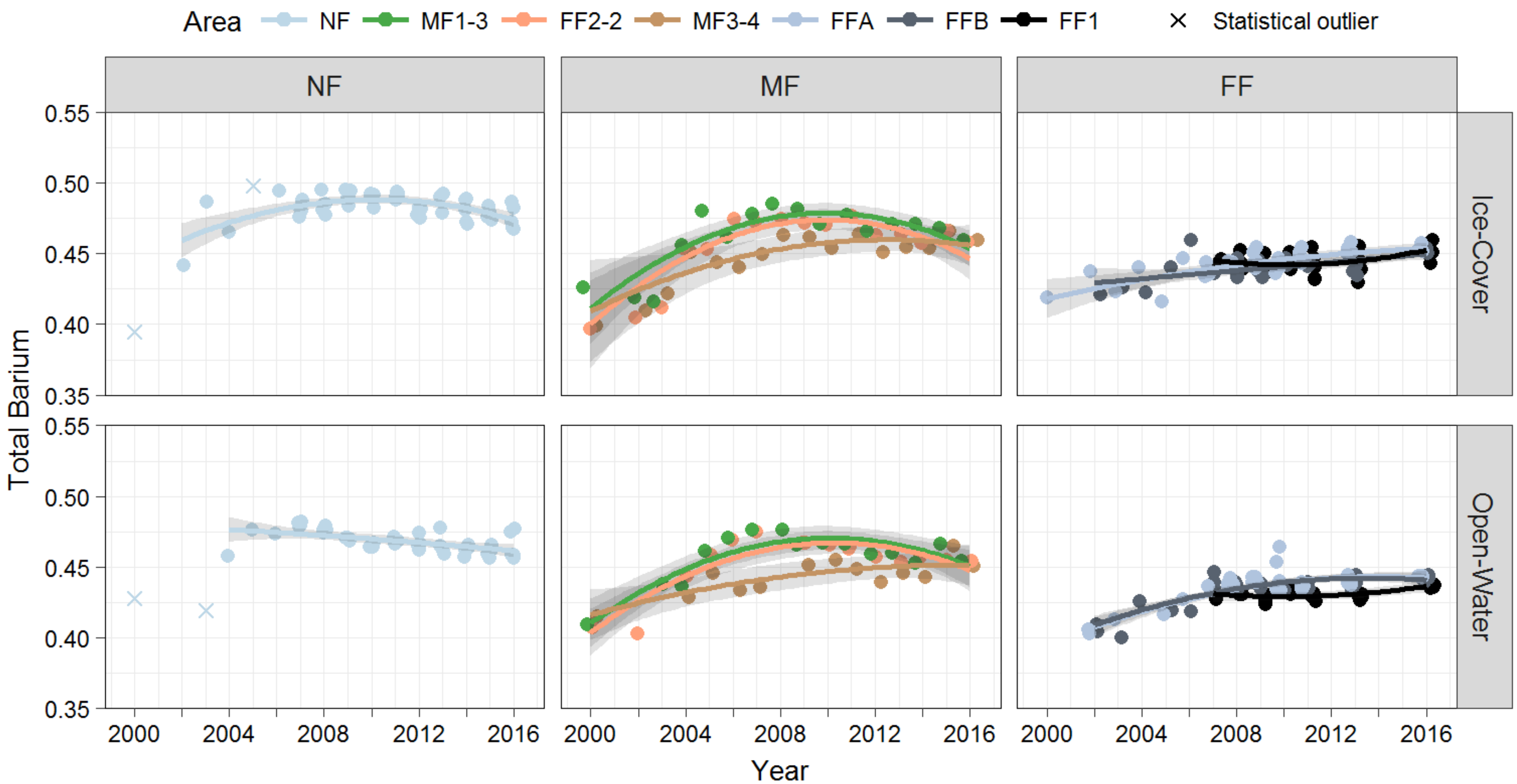
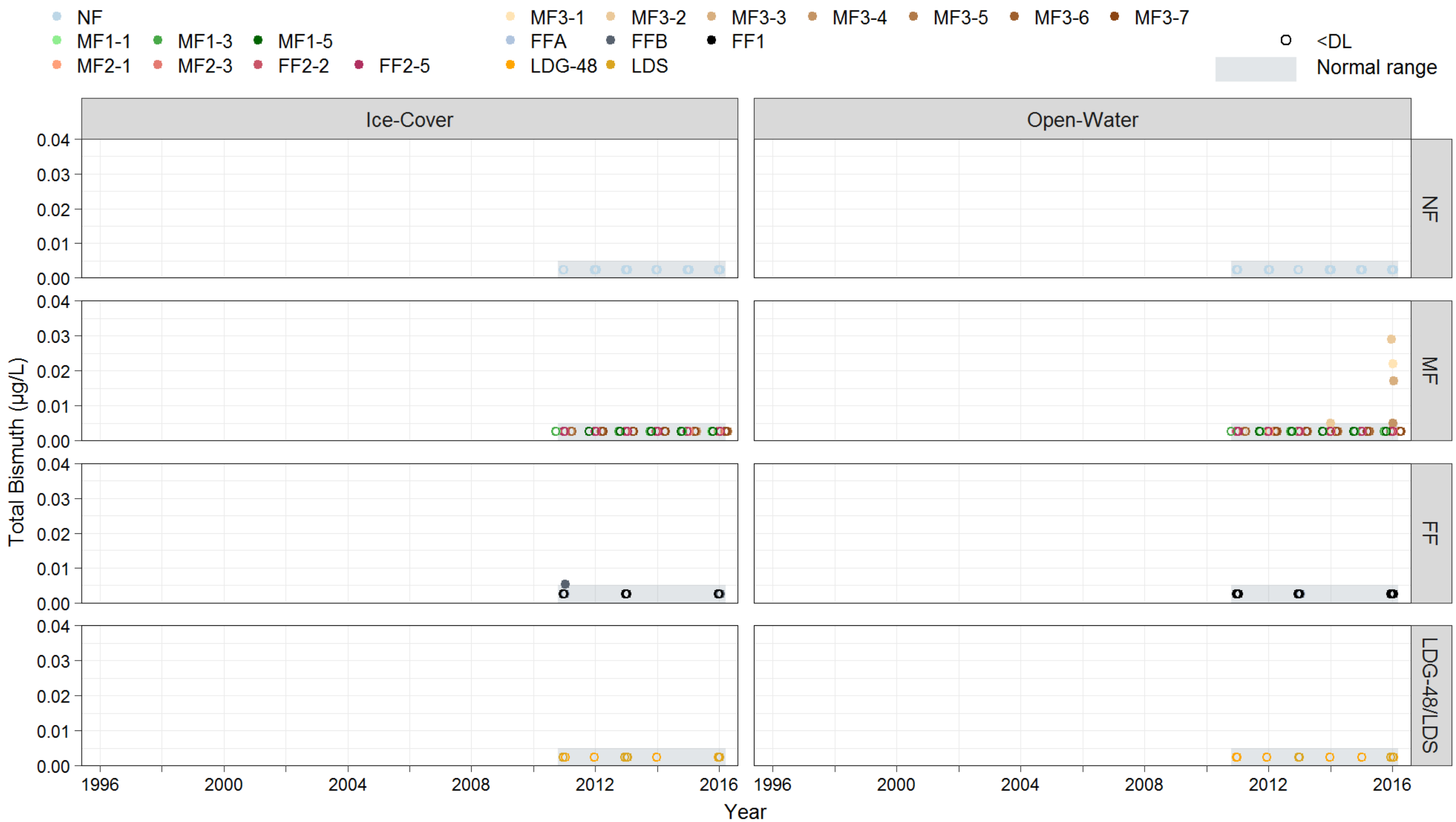


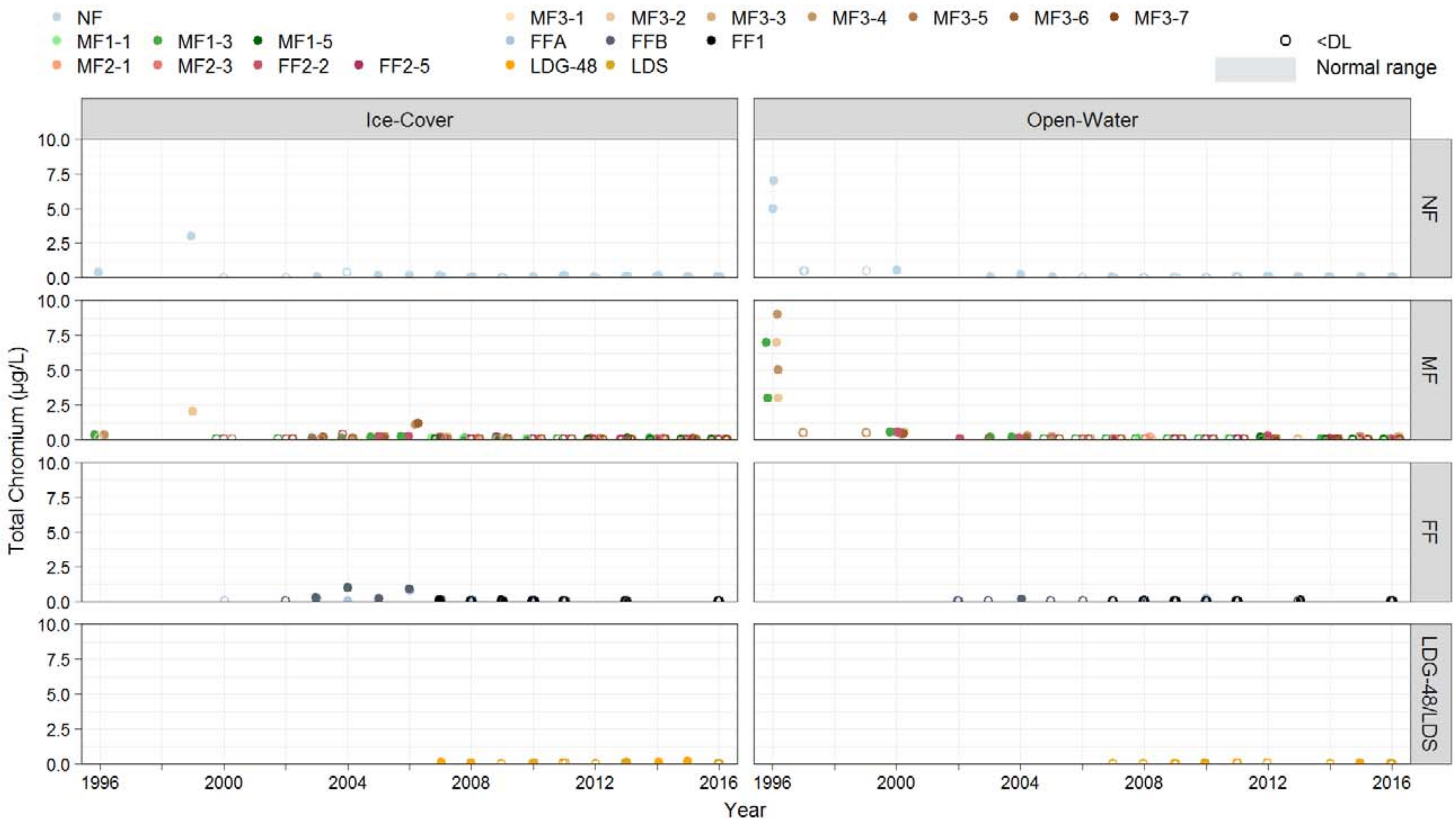
Figure 4-69 Total Bismuth Concentrations at AEMP Stations, 2011 to 2016



Note: Values represent concentrations in individual samples taken at mid-depth. An elevated value of less than the detection limit of 0.2 µg/Lfor August 2010 in the FF was removed from the plot because its elevated value resulted in a graphic scale that obscured details.

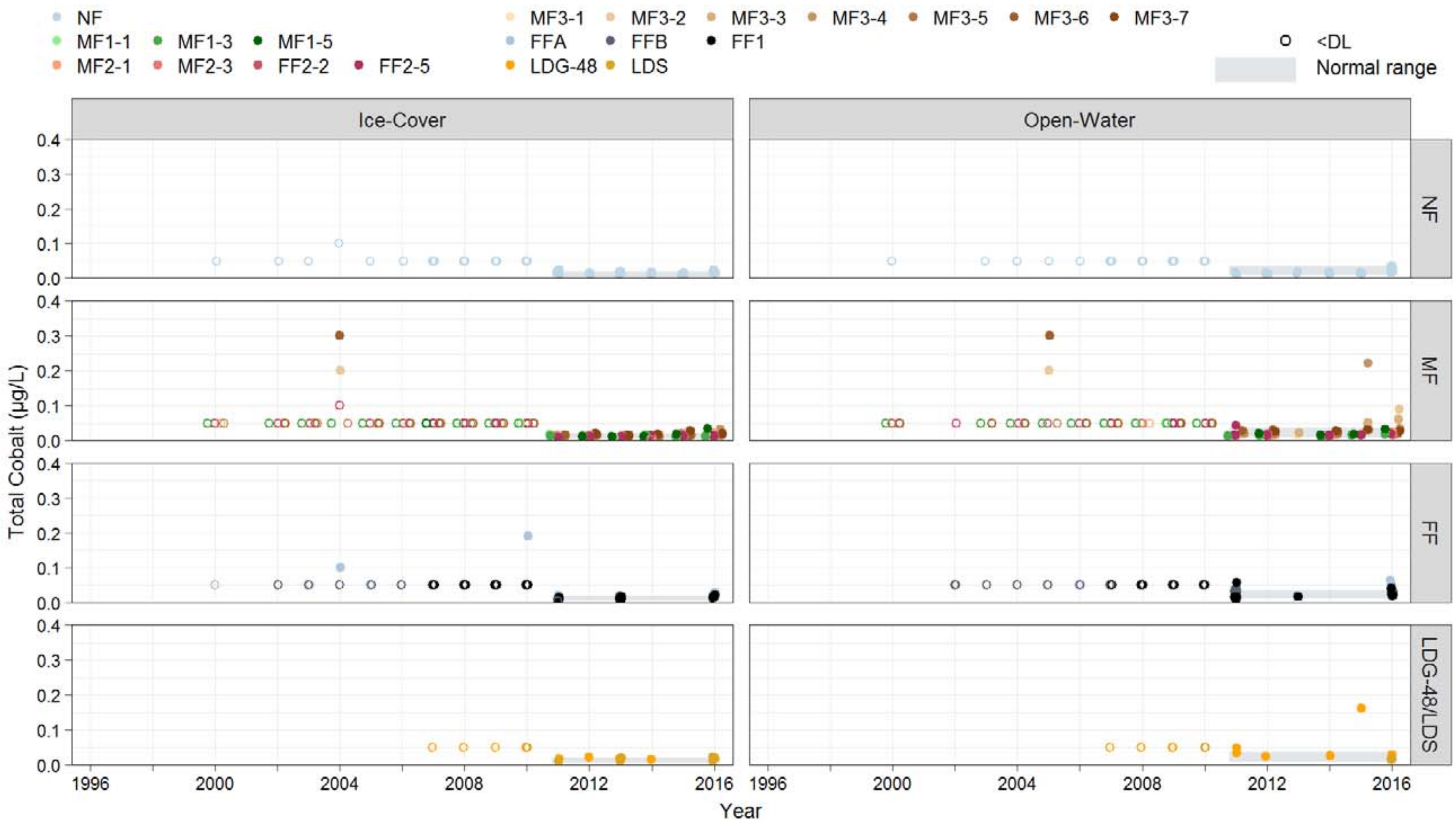
LDG = Lac de Gras; LDS = Lac du Sauvage

Figure 4-70 Total Chromium Concentrations at AEMP Stations, 1996 to 2016



Note: Values represent concentrations in individual samples taken at mid-depth.
LDG = Lac de Gras; LDS = Lac du Sauvage

Figure 4-71 Total Cobalt Concentrations at AEMP Stations, 2000 to 2016



Note: Values represent concentrations in individual samples taken at mid-depth.
LDG = Lac de Gras; LDS = Lac du Sauvage

Figure 4-72 Trend Analysis Plots for Total Cobalt, 2011 to 2016

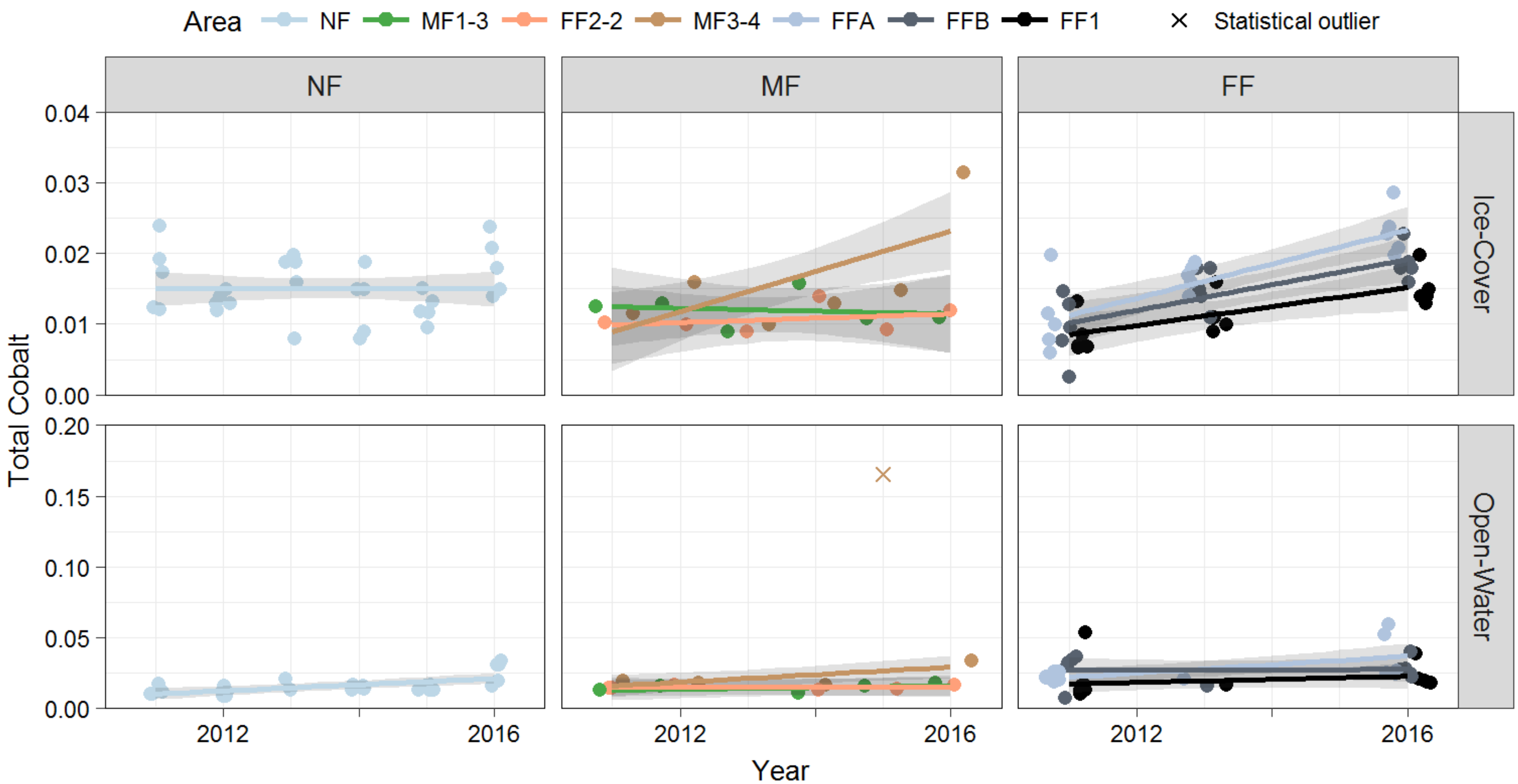
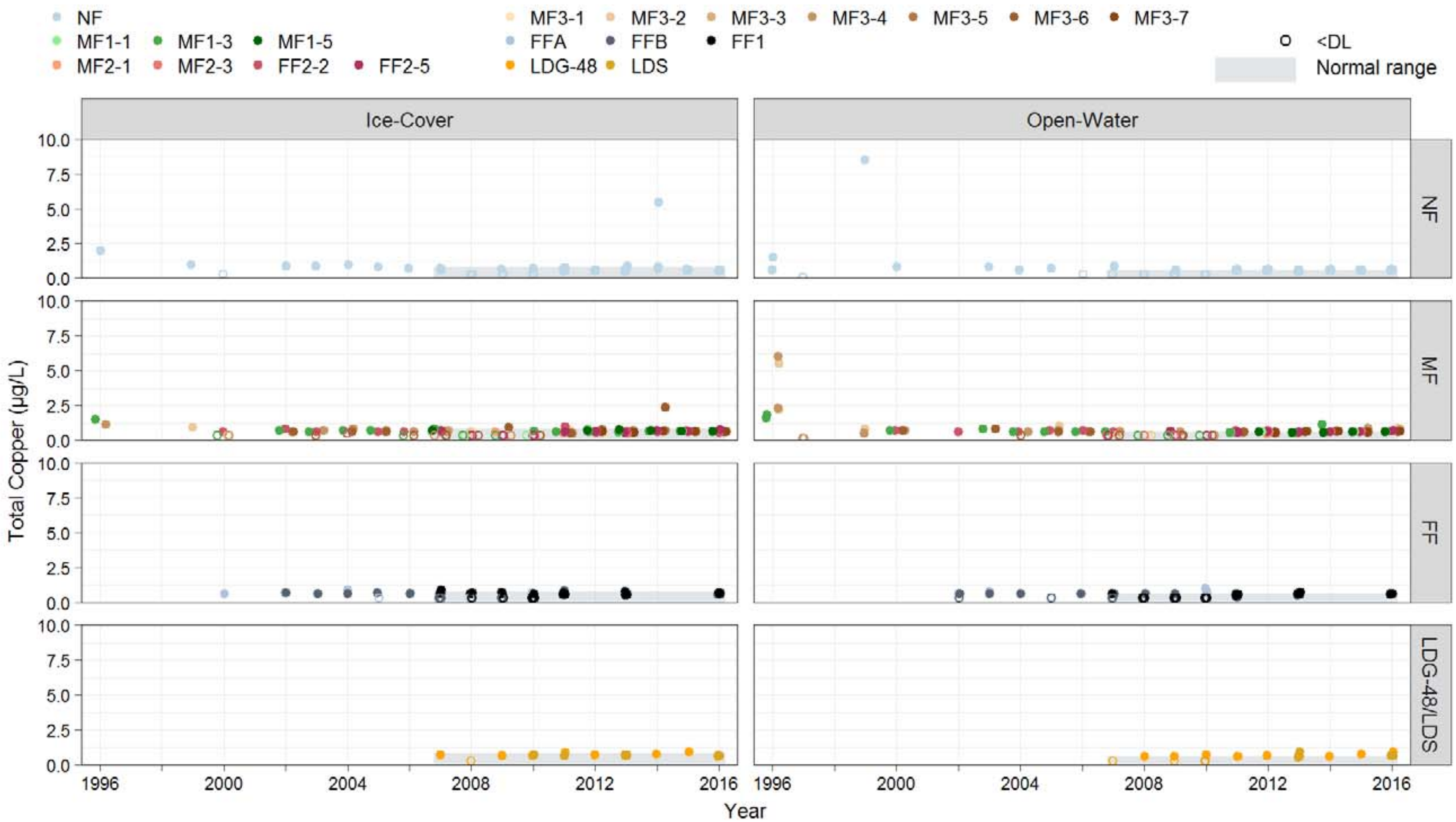


Figure 4-73 Total Copper Concentrations at AEMP Stations, 1996 to 2016



Note: Values represent concentrations in individual samples taken at mid-depth.
LDG = Lac de Gras; LDS = Lac du Sauvage

Figure 4-74 Trend Analysis Plots for Total Copper, 2011 to 2016

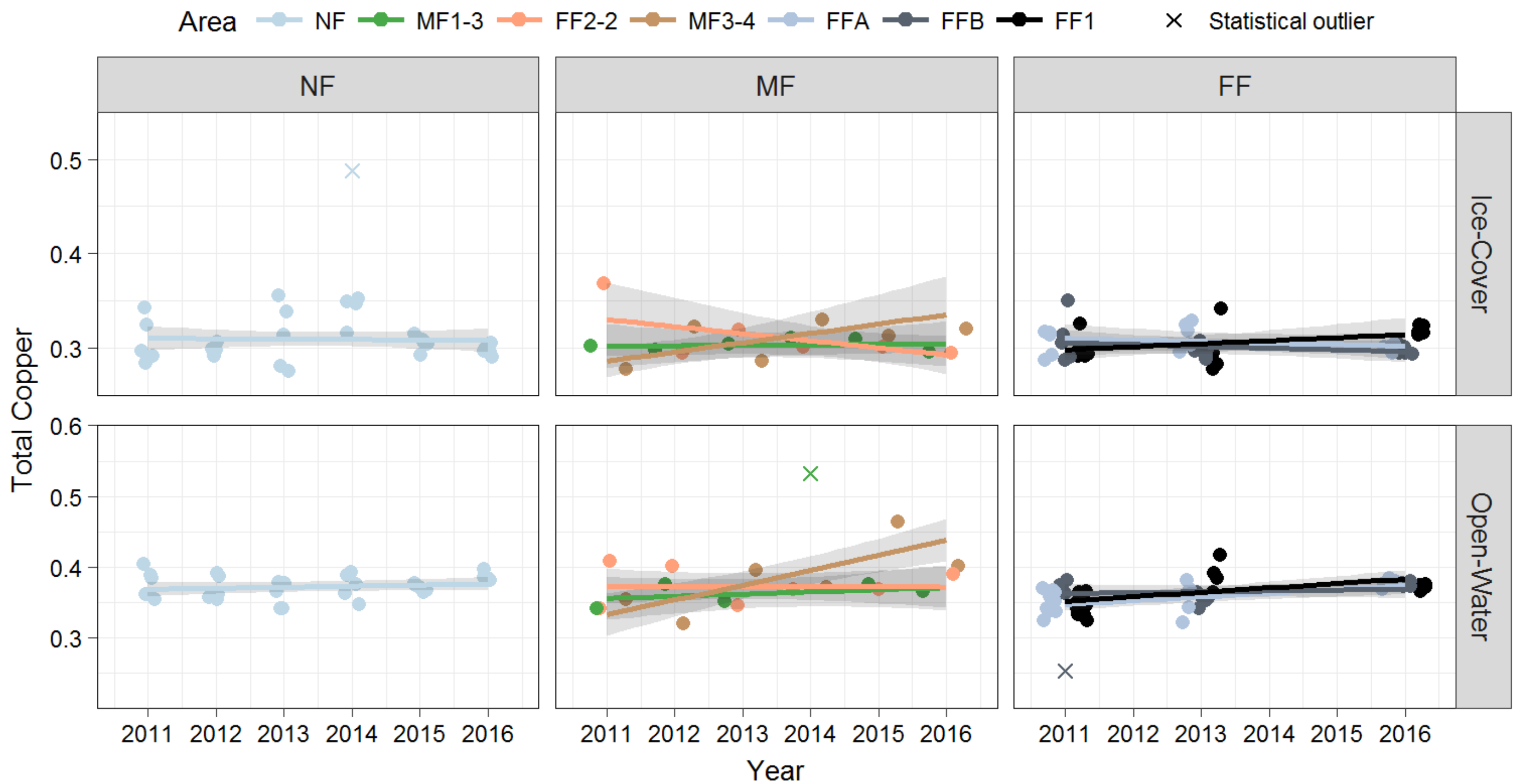
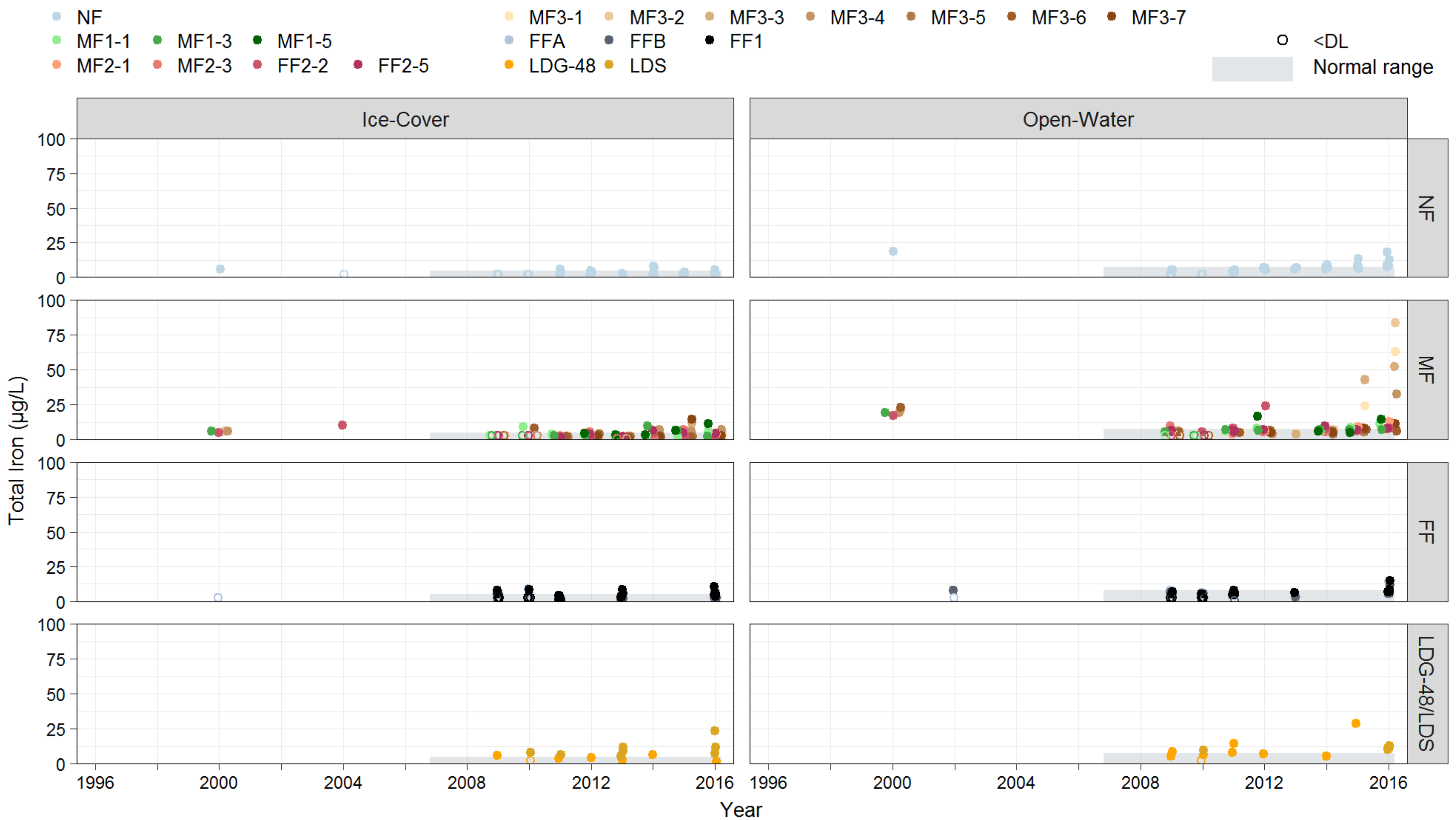


Figure 4-75 Total Iron Concentrations at AEMP Stations, 2000 to 2016



Note: Values represent concentrations in individual samples taken at mid-depth. An elevated value of 176 µg/L for MF3-4 in August 2015 was removed from the plot because its elevated value resulted in a graphic scale that obscured details.
LDG = Lac de Gras; LDS = Lac du Sauvage

Figure 4-76 Trend Analysis Plots for Total Iron, 2011 to 2016

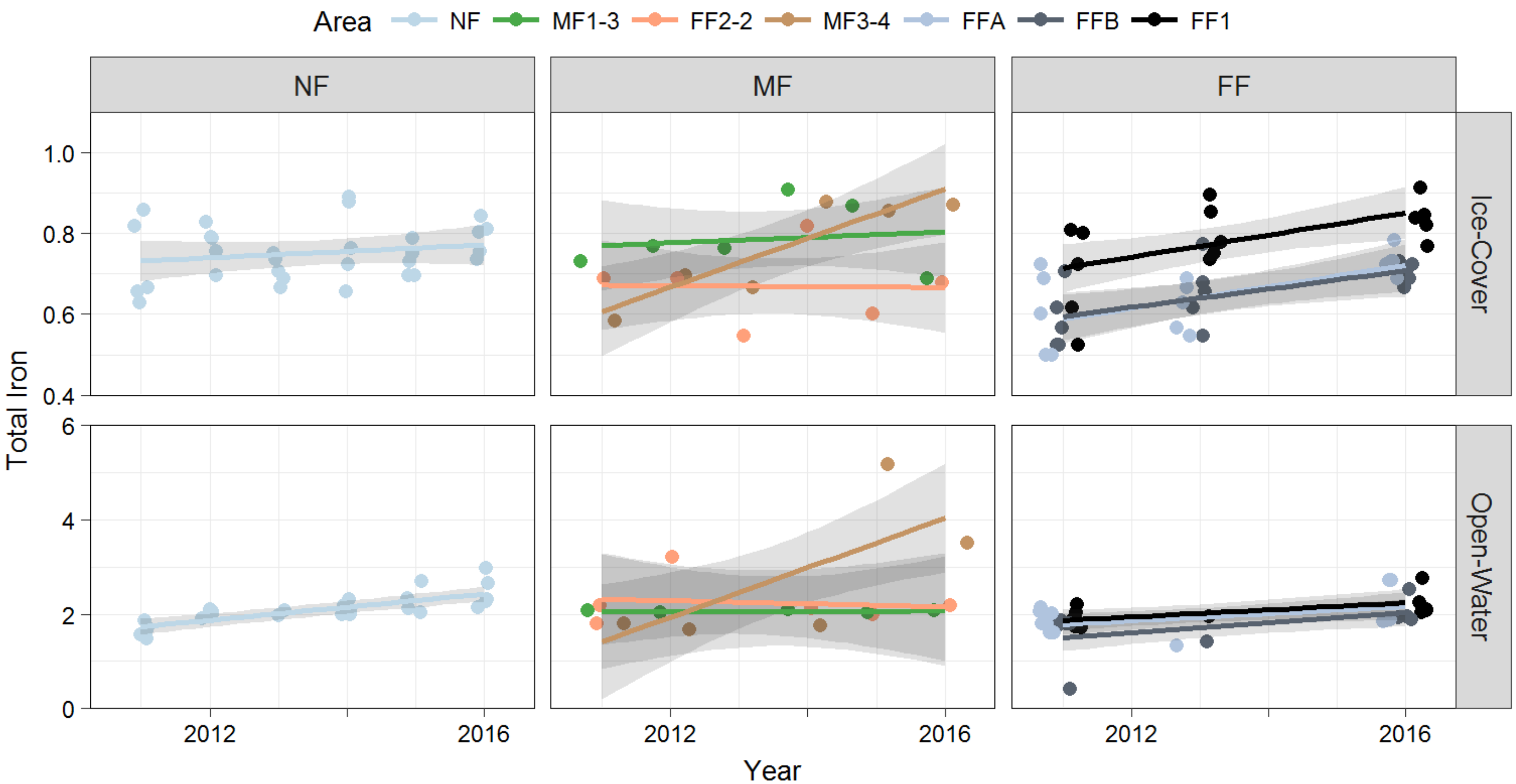
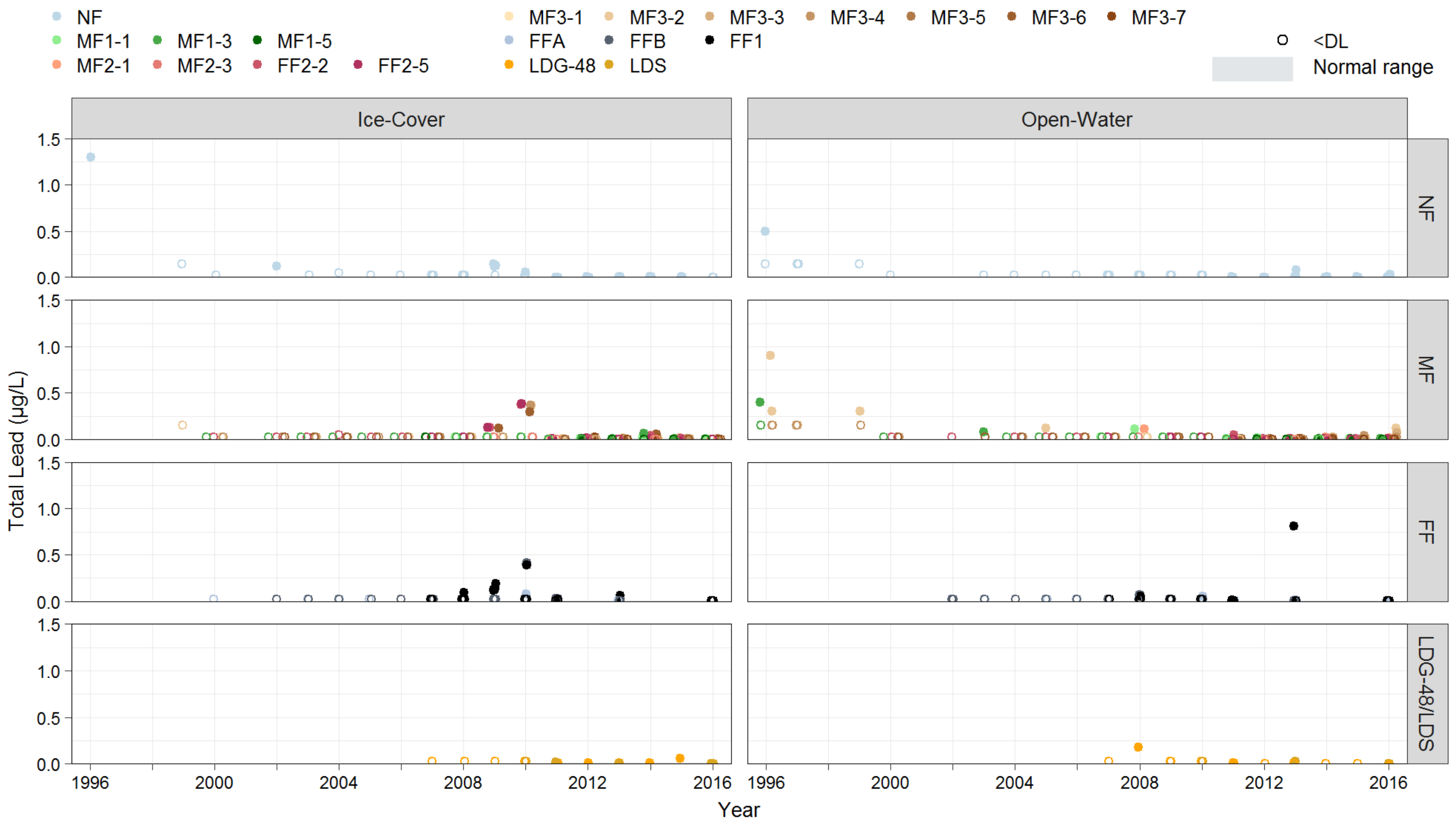


Figure 4-77 Total Lead Concentrations at AEMP Stations, 1996 to 2016



Note: Values represent concentrations in individual samples taken at mid-depth. Three total lead values from April/May 1996 were omitted from this figure because their elevated values resulted in a graphic scale that obscured details: MF1-3 = 3 µg/L; MF3-2 = 2 µg/L; MF3-4 = 2.4 µg/L.

LDG = Lac de Gras; LDS = Lac du Sauvage

Figure 4-78 Trend Analysis (Logistic Regression) Plots for Total Lead, 1996 to 2016

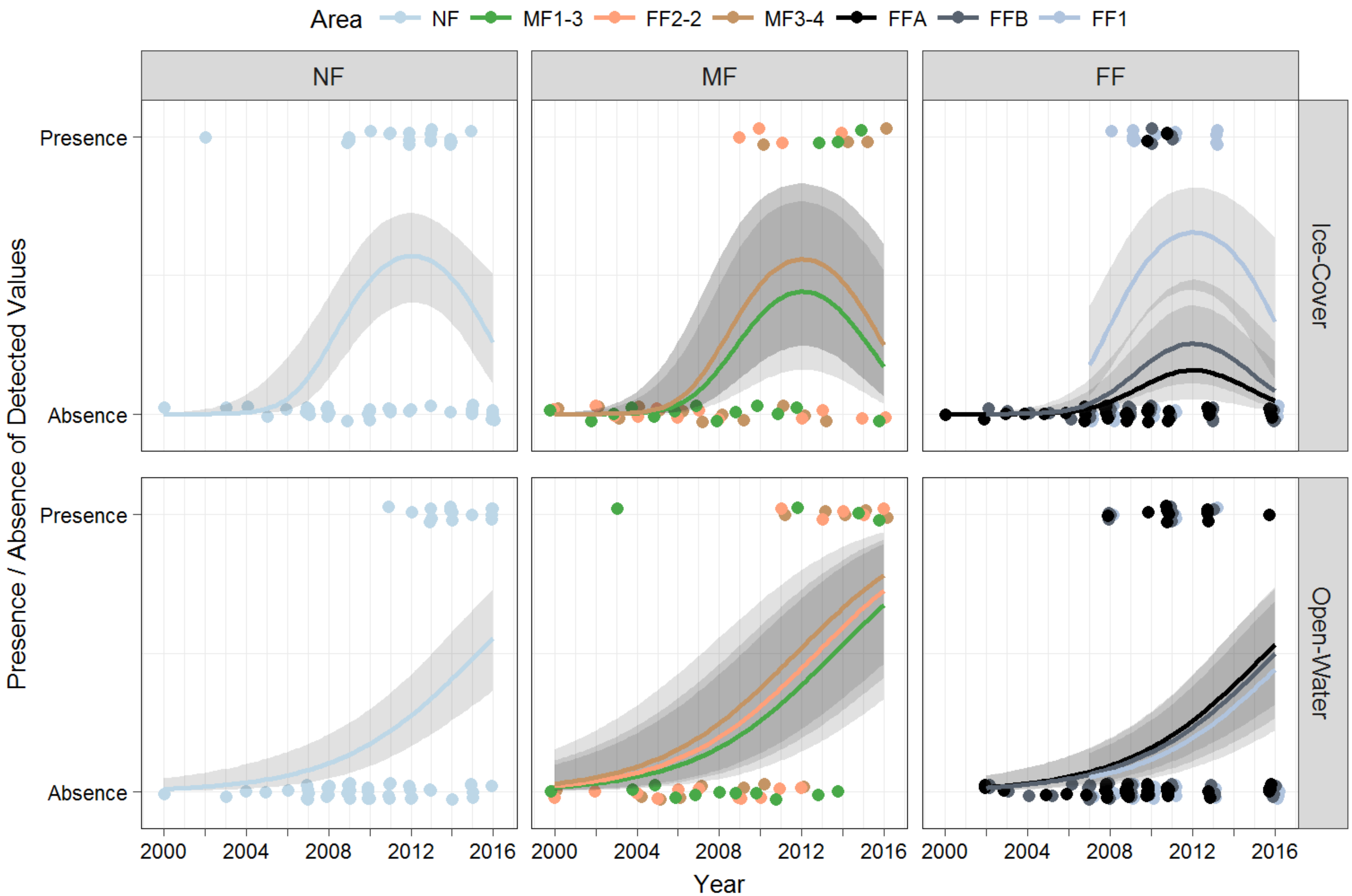
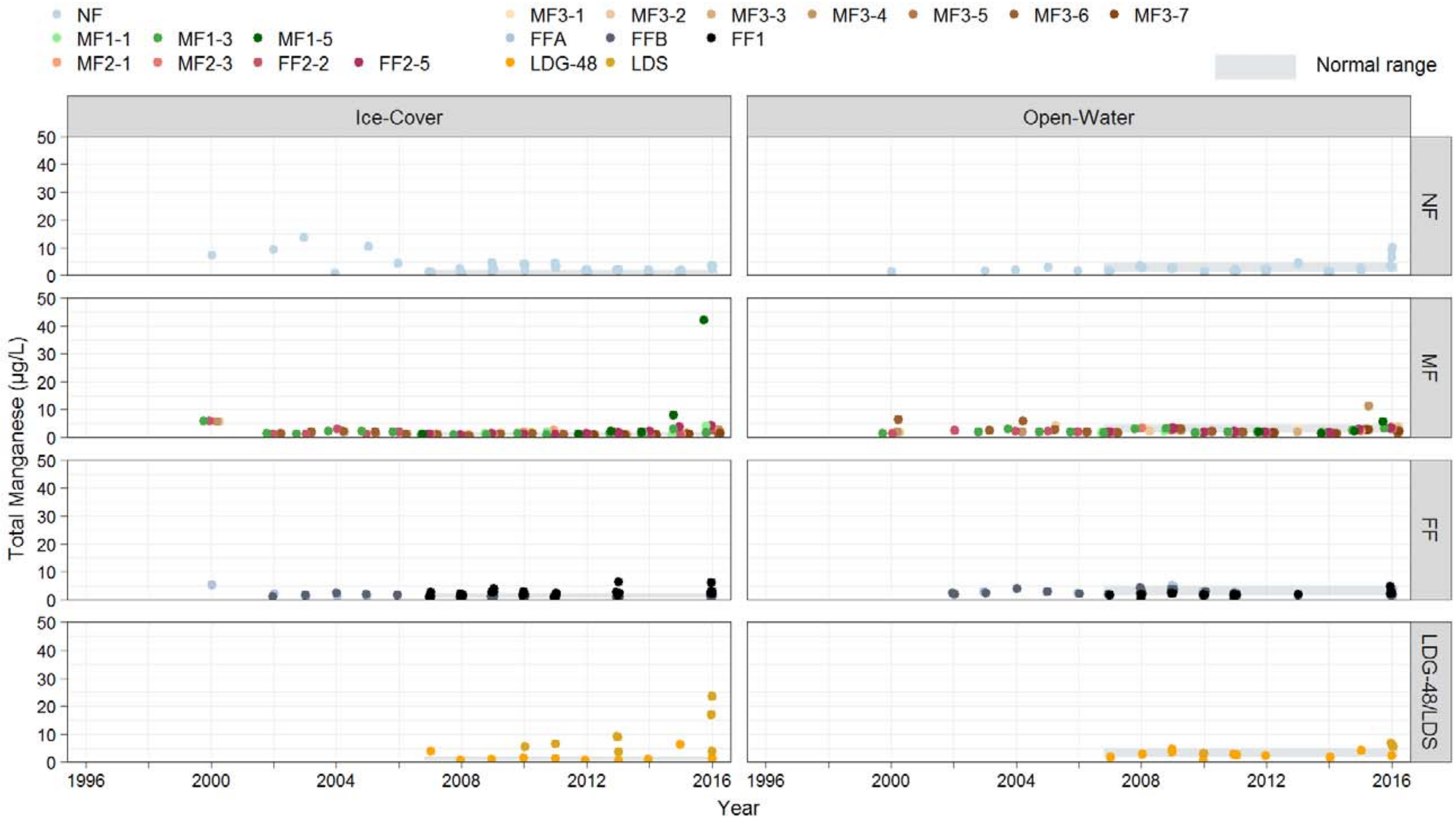


Figure 4-79 Total Manganese Concentrations at AEMP Stations, 2000 to 2016



Note: Values represent concentrations in individual samples taken at mid-depth.
LDG = Lac de Gras; LDS = Lac du Sauvage

Figure 4-80 Trend Analysis Plots for Total Manganese, 2000 to 2016

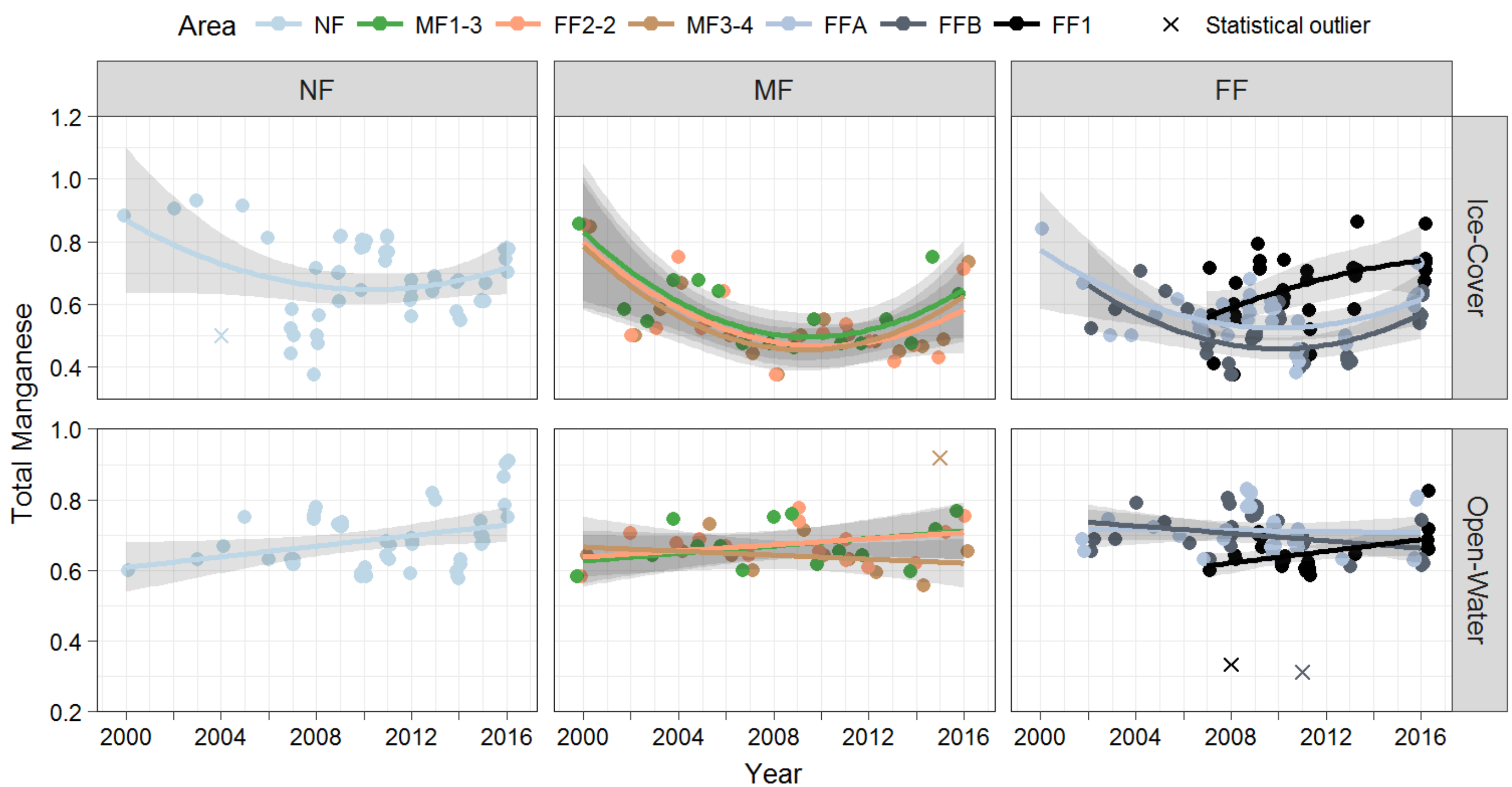
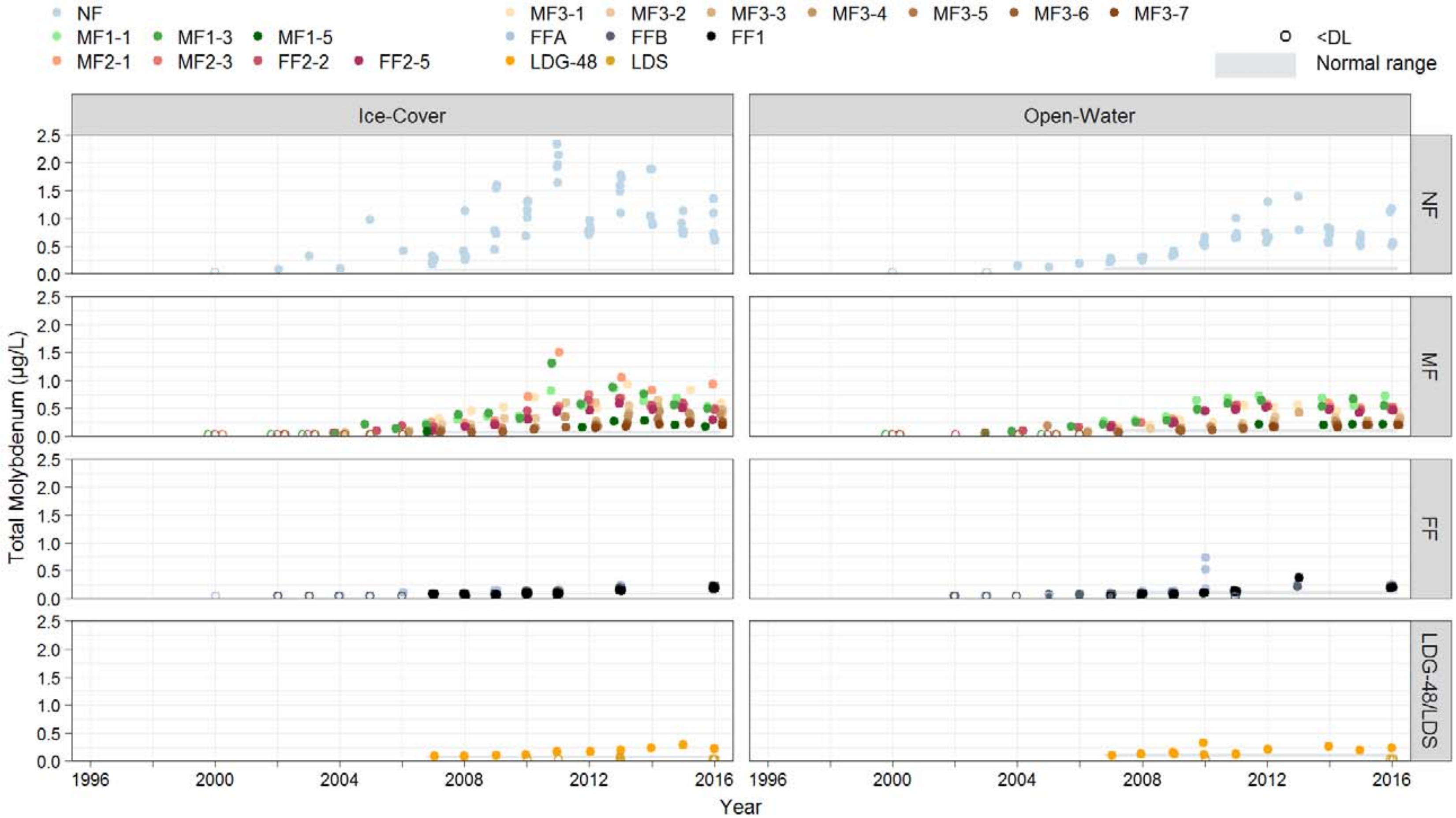


Figure 4-81 Total Molybdenum Concentrations at AEMP Stations, 2000 to 2016



Note: Values represent concentrations in individual samples taken at mid-depth.
LDG = Lac de Gras; LDS = Lac du Sauvage

Figure 4-82 Trend Analysis Plots for Total Molybdenum, 2000 to 2016

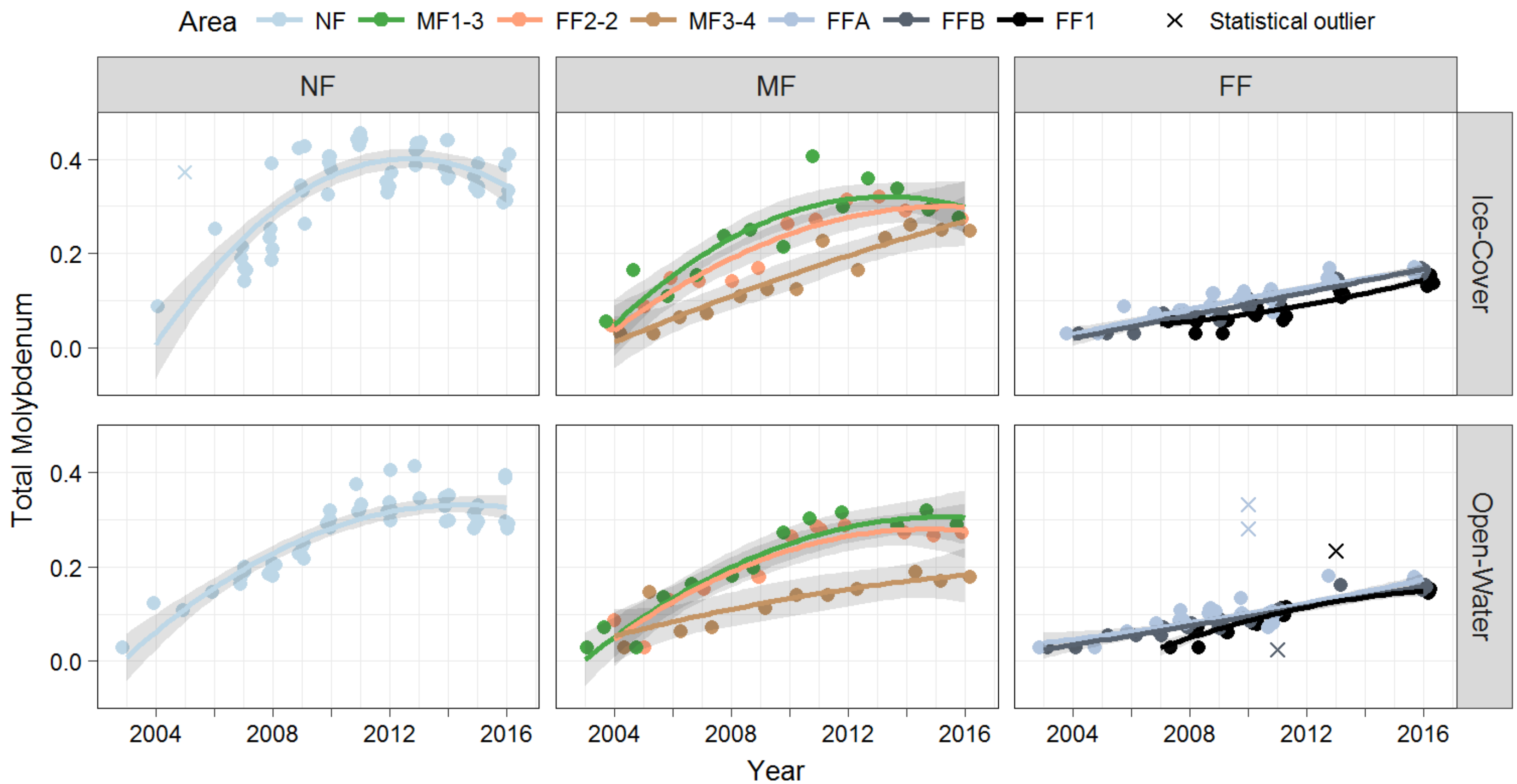
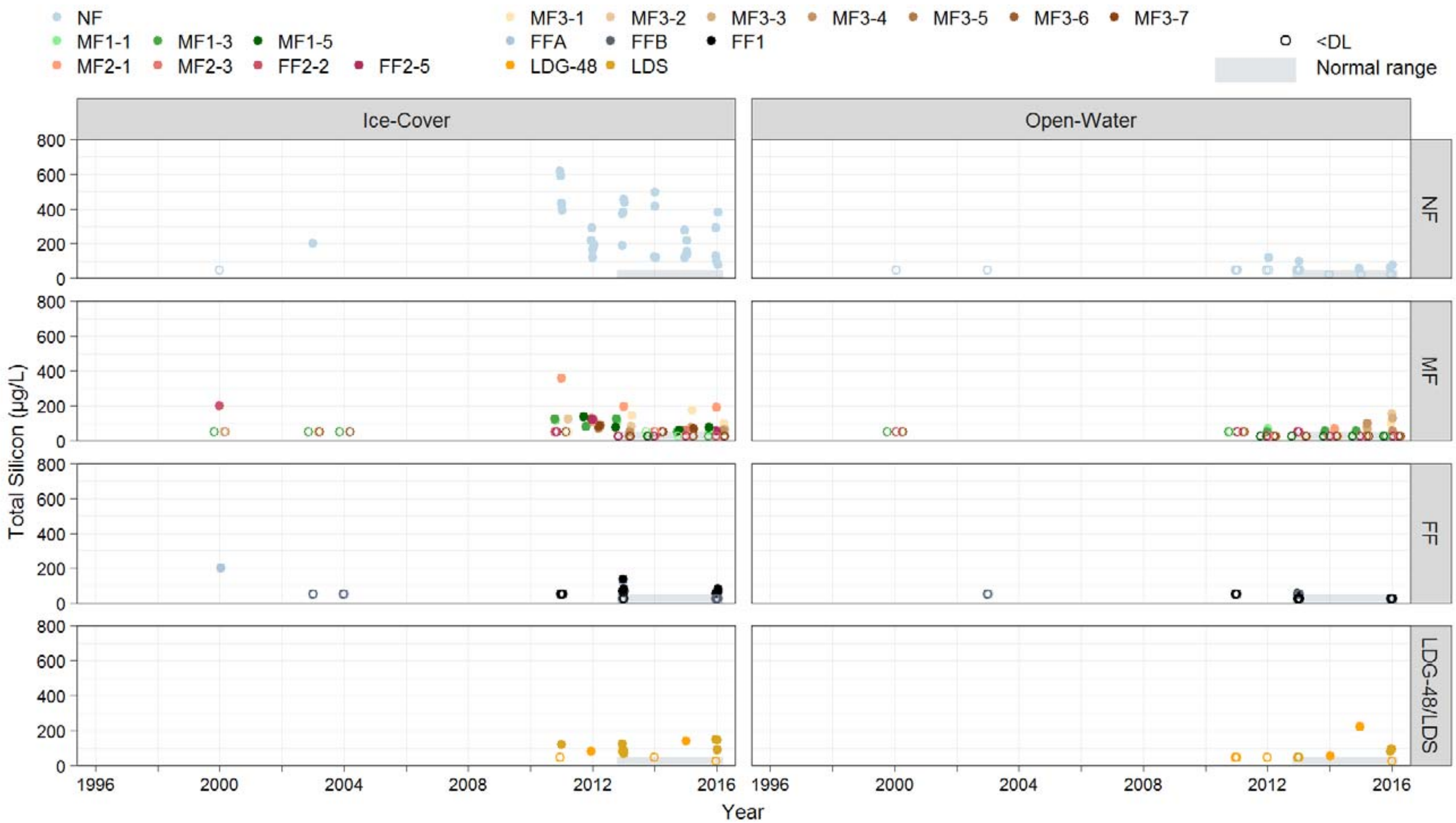
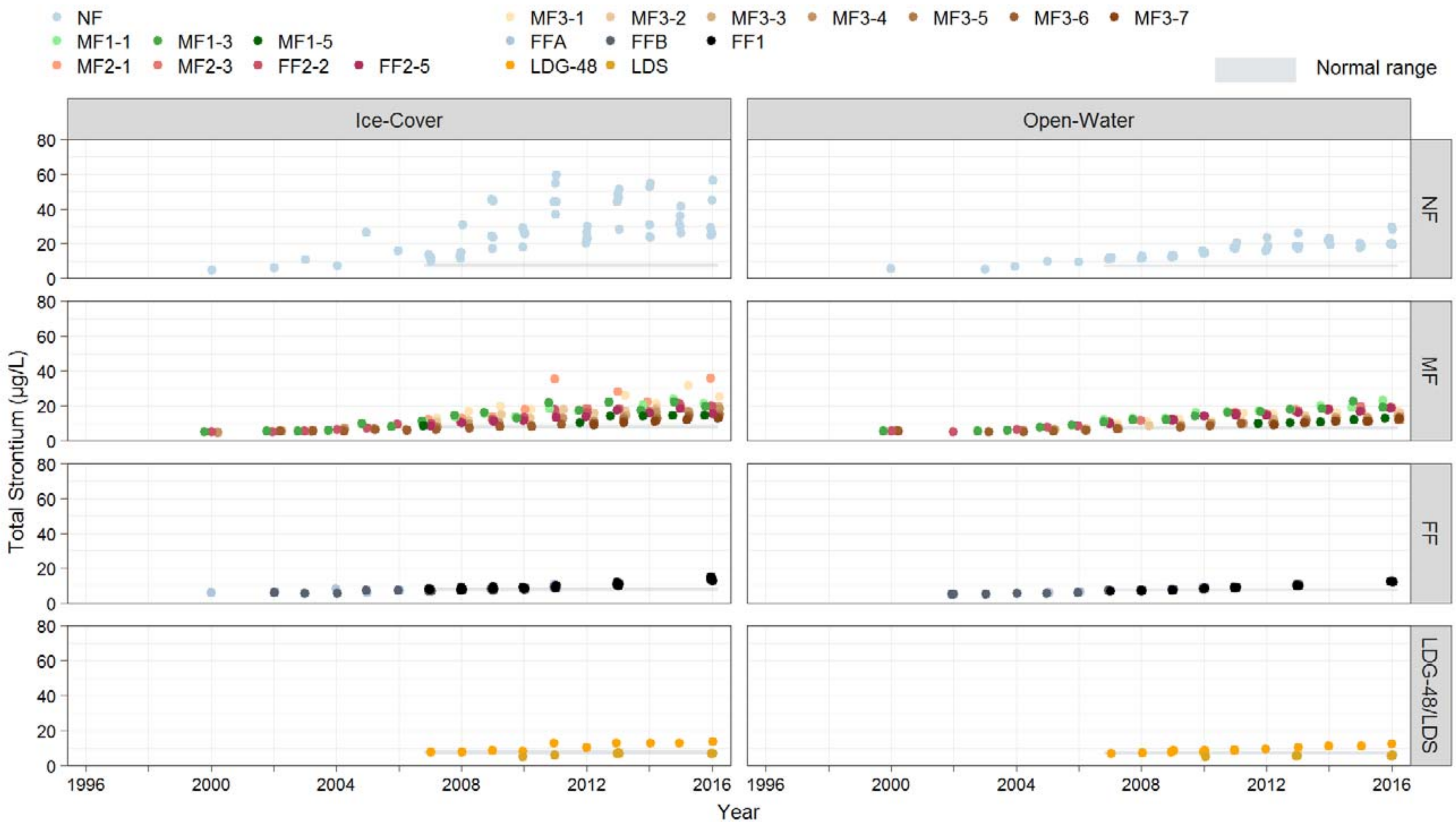


Figure 4-83 Total Silicon Concentrations at AEMP Stations, 2000 to 2016



Note: Values represent concentrations in individual samples taken at mid-depth.
LDG = Lac de Gras; LDS = Lac du Sauvage

Figure 4-84 Total Strontium Concentrations at AEMP Stations, 2000 to 2016



Note: Values represent concentrations in individual samples taken at mid-depth.
LDG = Lac de Gras; LDS = Lac du Sauvage

Figure 4-85 Trend Analysis Plots for Total Strontium, 2000 to 2016

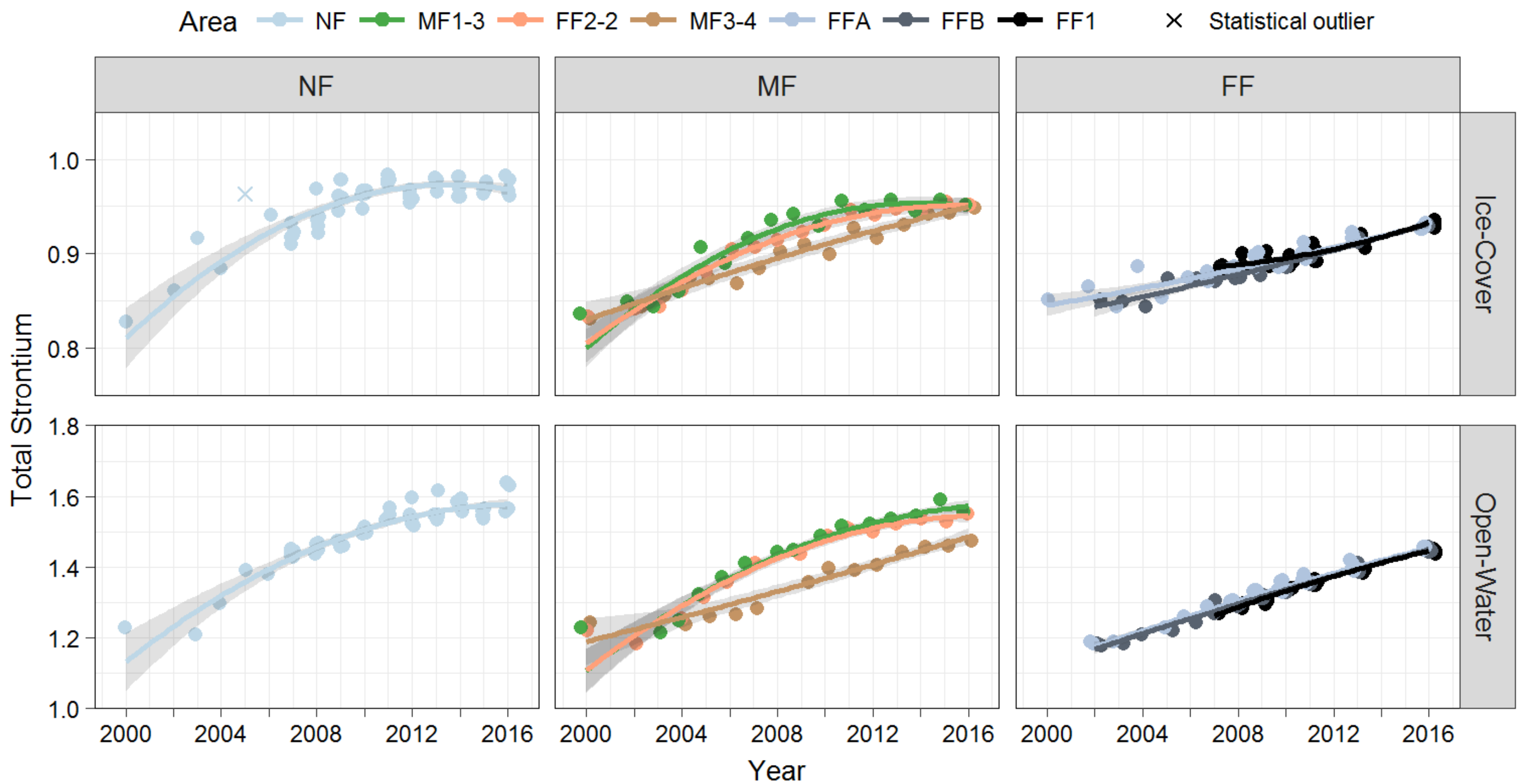
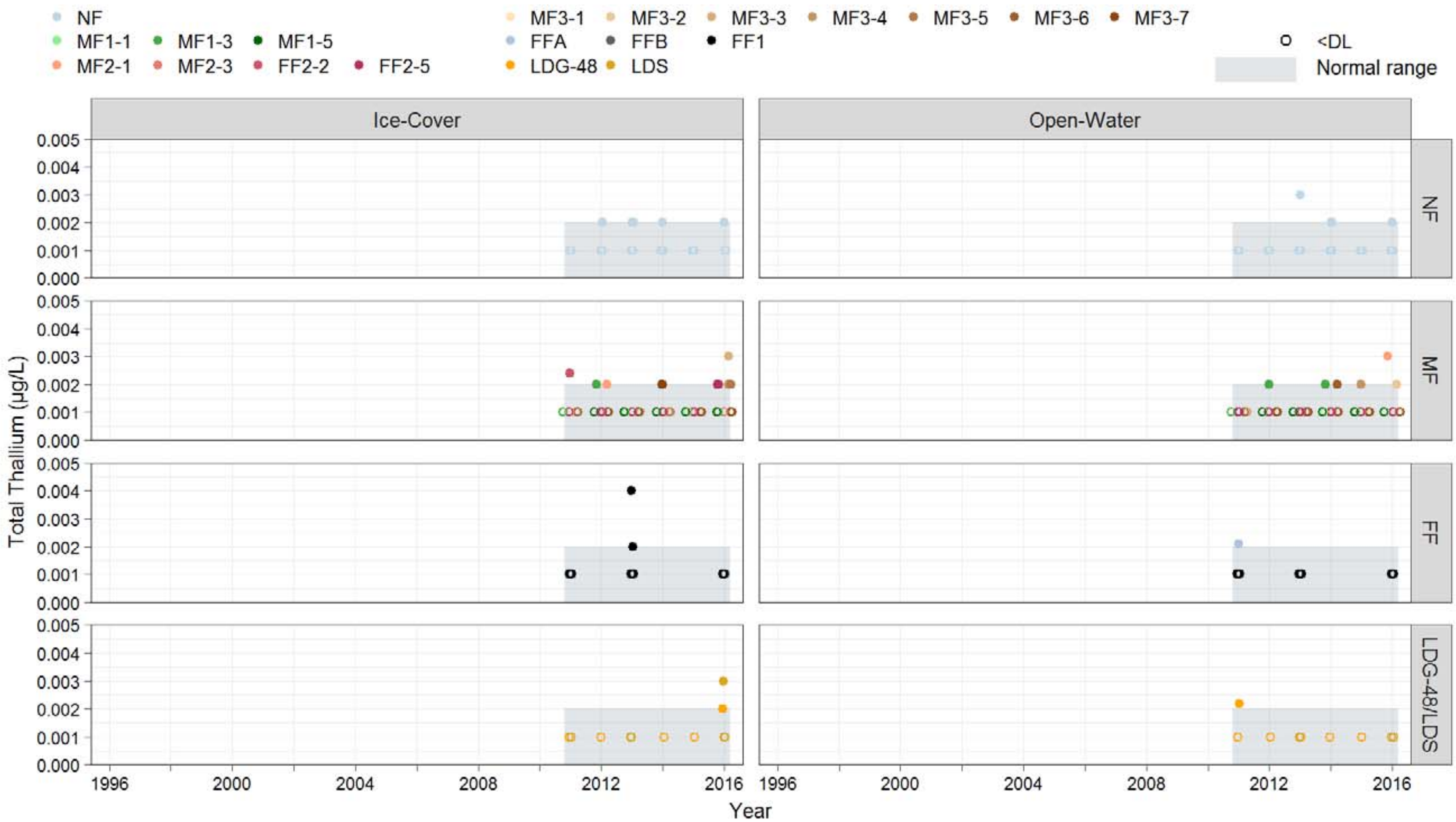
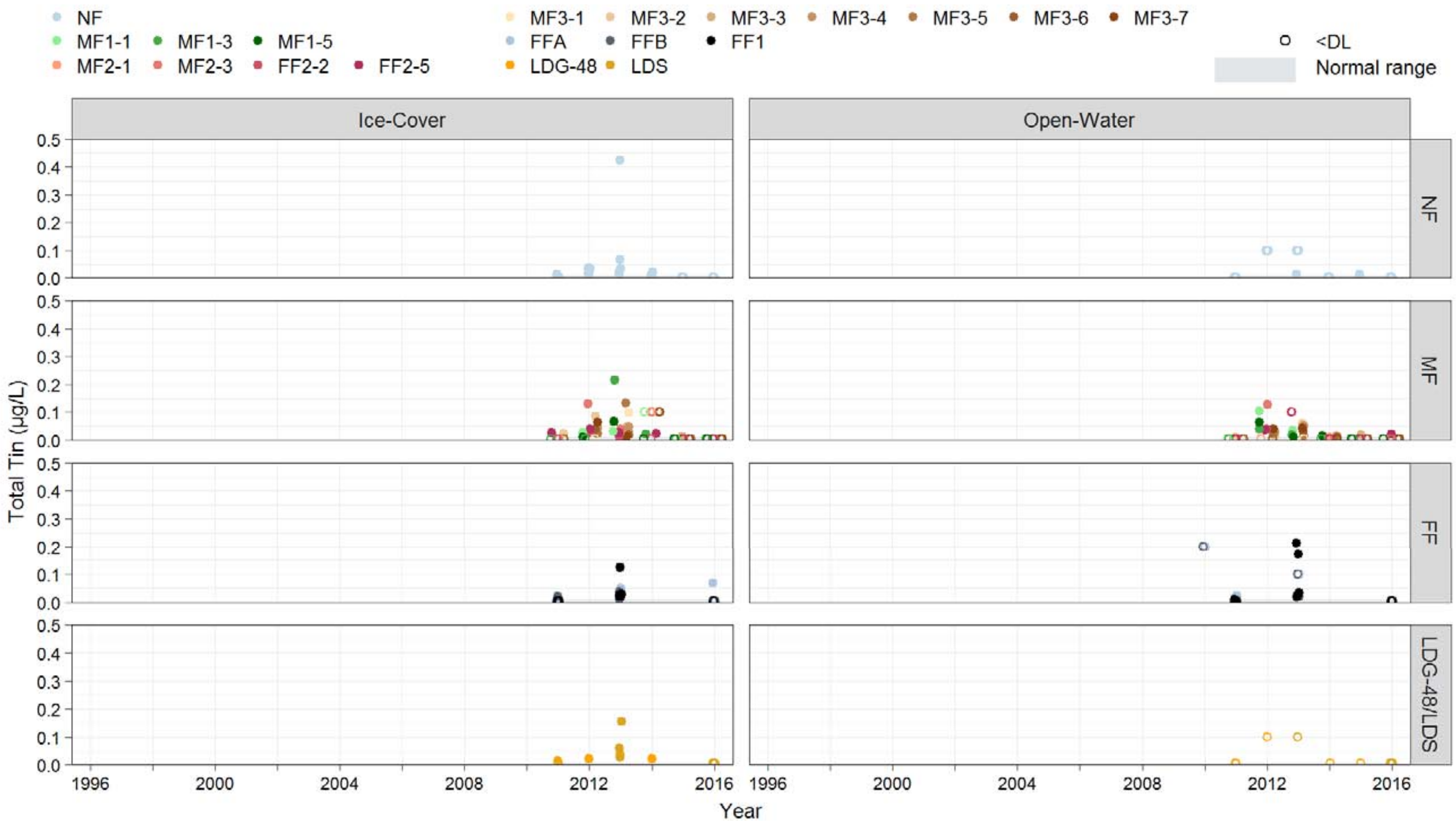


Figure 4-86 Total Thallium Concentrations at AEMP Stations, 2011 to 2016



Note: Values represent concentrations in individual samples taken at mid-depth. An elevated value of less than the detection limit of 0.1 µg/Lfor August 2010 was removed from the plot because its elevated value resulted in a graphic scale that obscured details.
LDG = Lac de Gras; LDS = Lac du Sauvage

Figure 4-87 Total Tin Concentrations at AEMP Stations, 2011 to 2016



Note: Values represent concentrations in individual samples taken at mid-depth.
LDG = Lac de Gras; LDS = Lac du Sauvage

Figure 4-88 Trend Analysis (Logistic Regression) Plots for Total Tin, 2011 to 2016

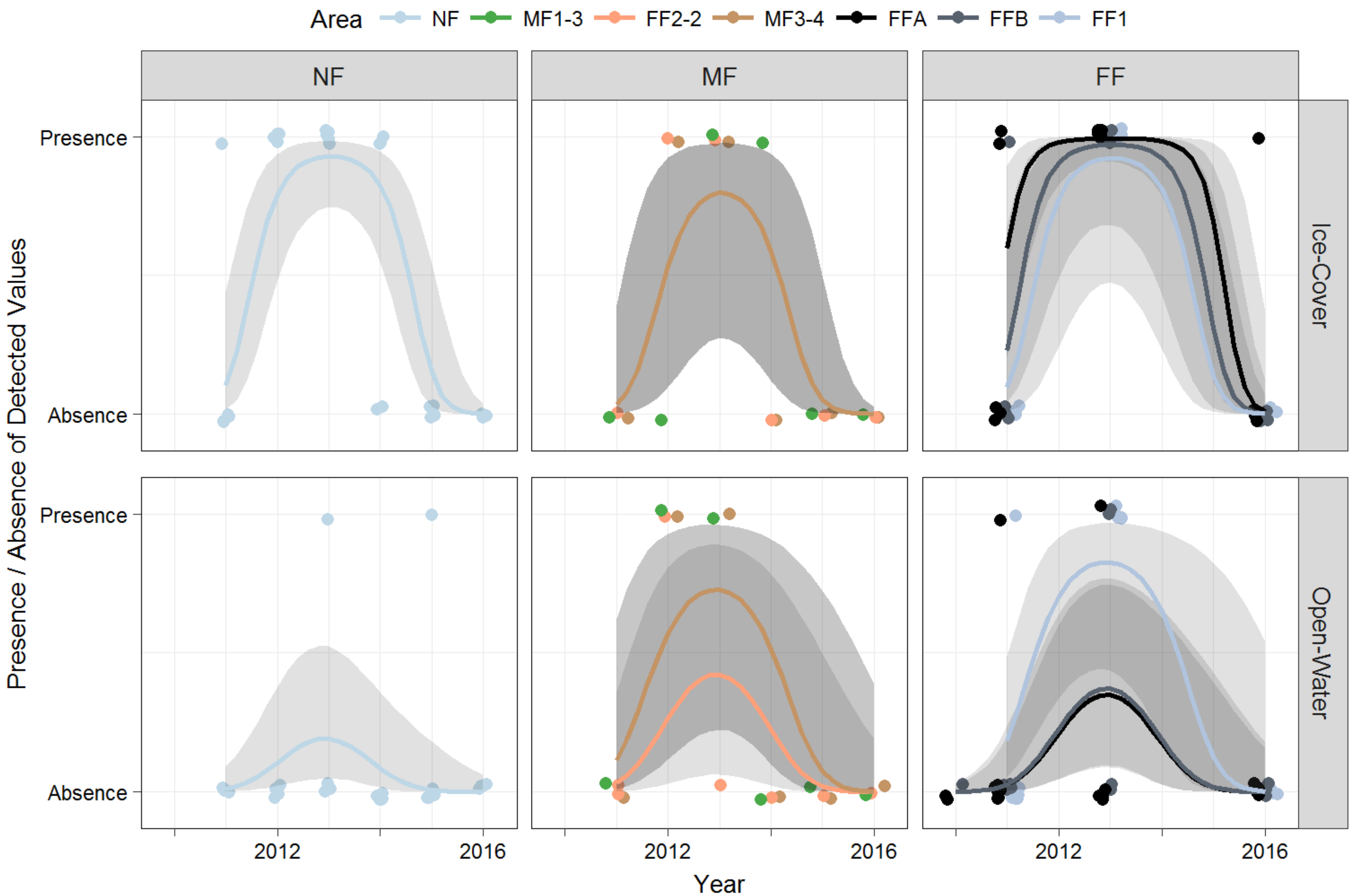
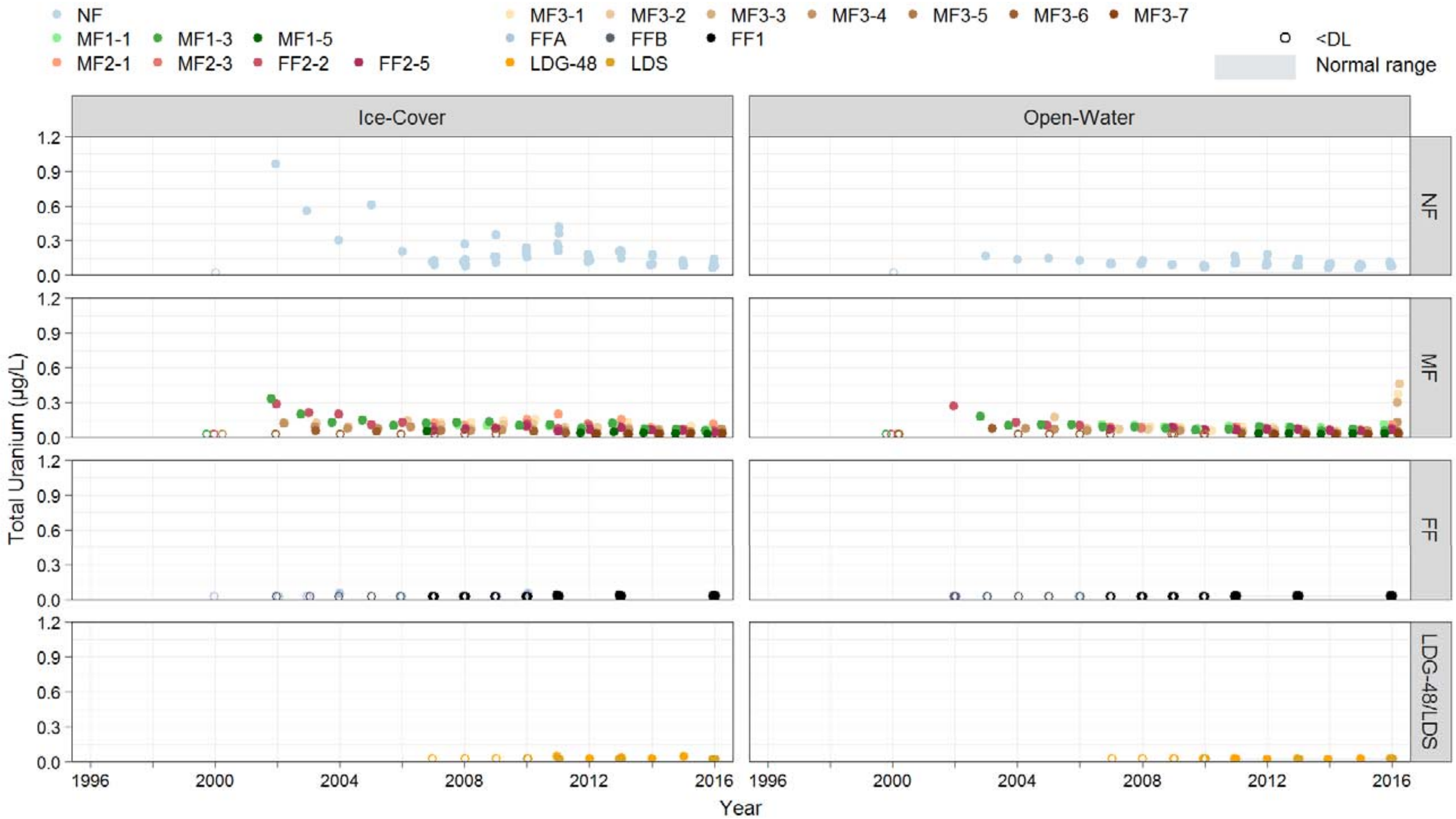


Figure 4-89 Total Titanium Concentrations at AEMP Stations, 2011 to 2016

Note: Values represent concentrations in individual samples taken at mid-depth.
LDG = Lac de Gras; LDS = Lac du Sauvage

Figure 4-90 Total Uranium Concentrations at AEMP Stations, 2000 to 2016



Note: Values represent concentrations in individual samples taken at mid-depth.
LDG = Lac de Gras; LDS = Lac du Sauvage

Figure 4-91 Trend Analysis Plots for Total Uranium, 2011 to 2016

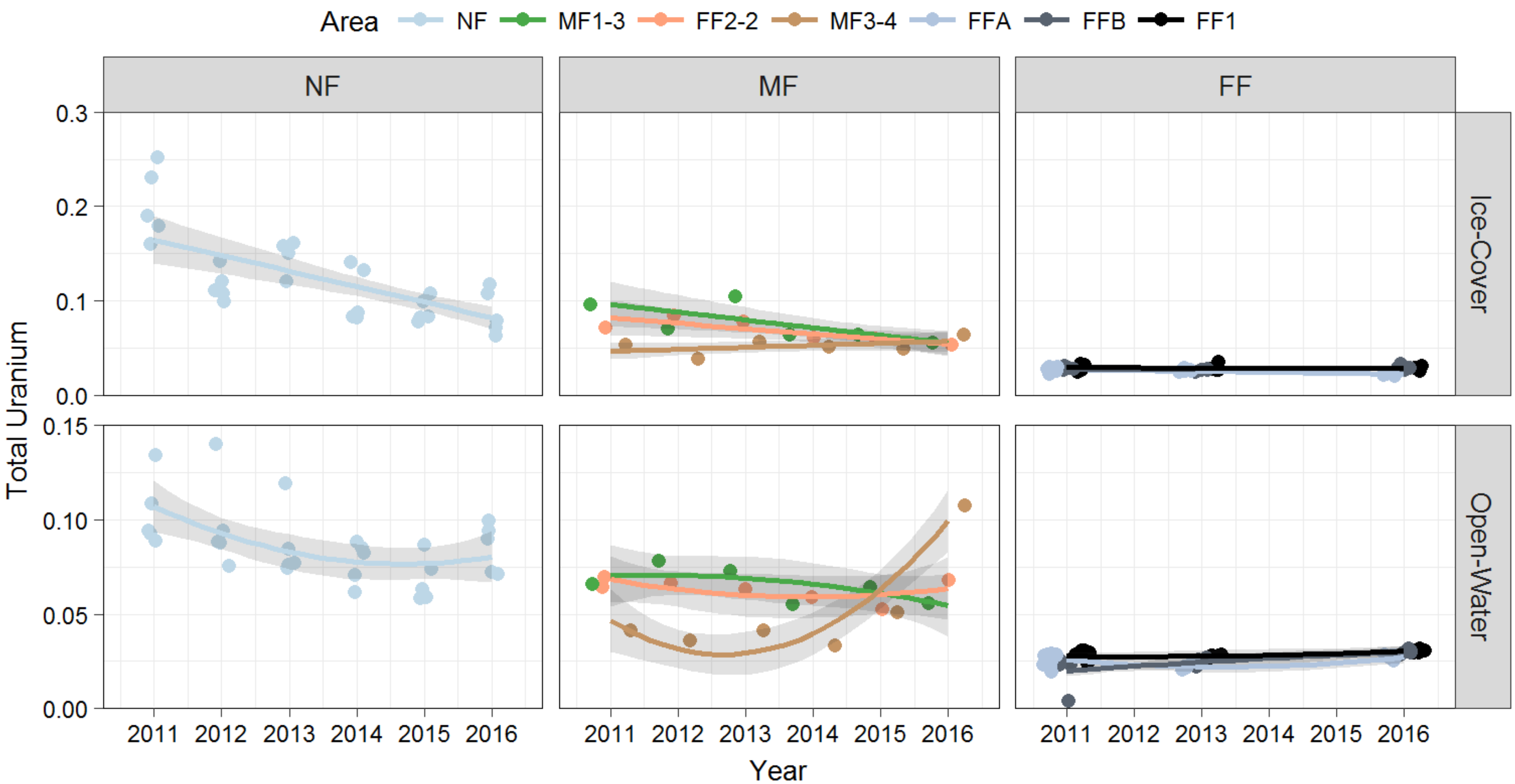
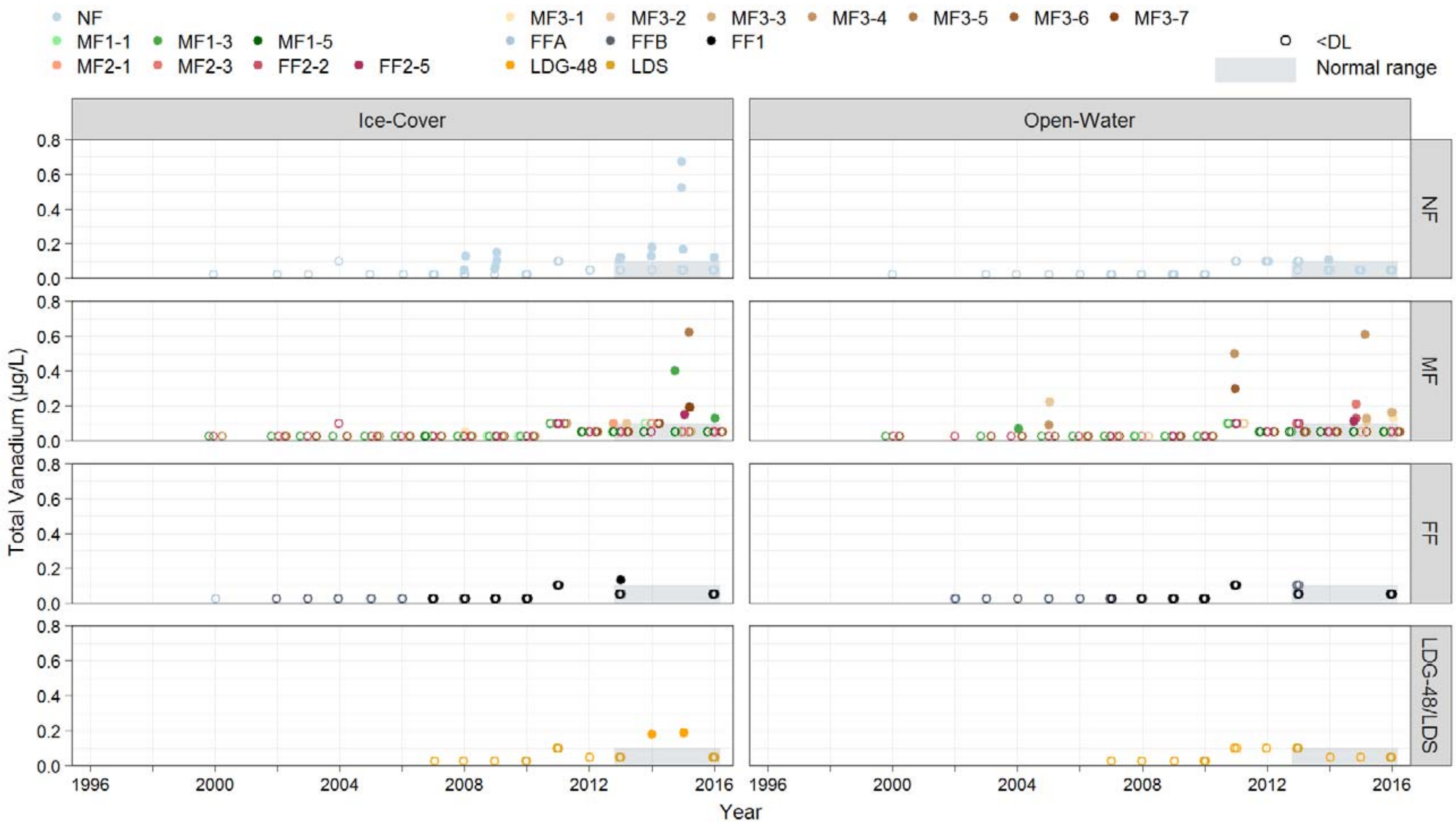
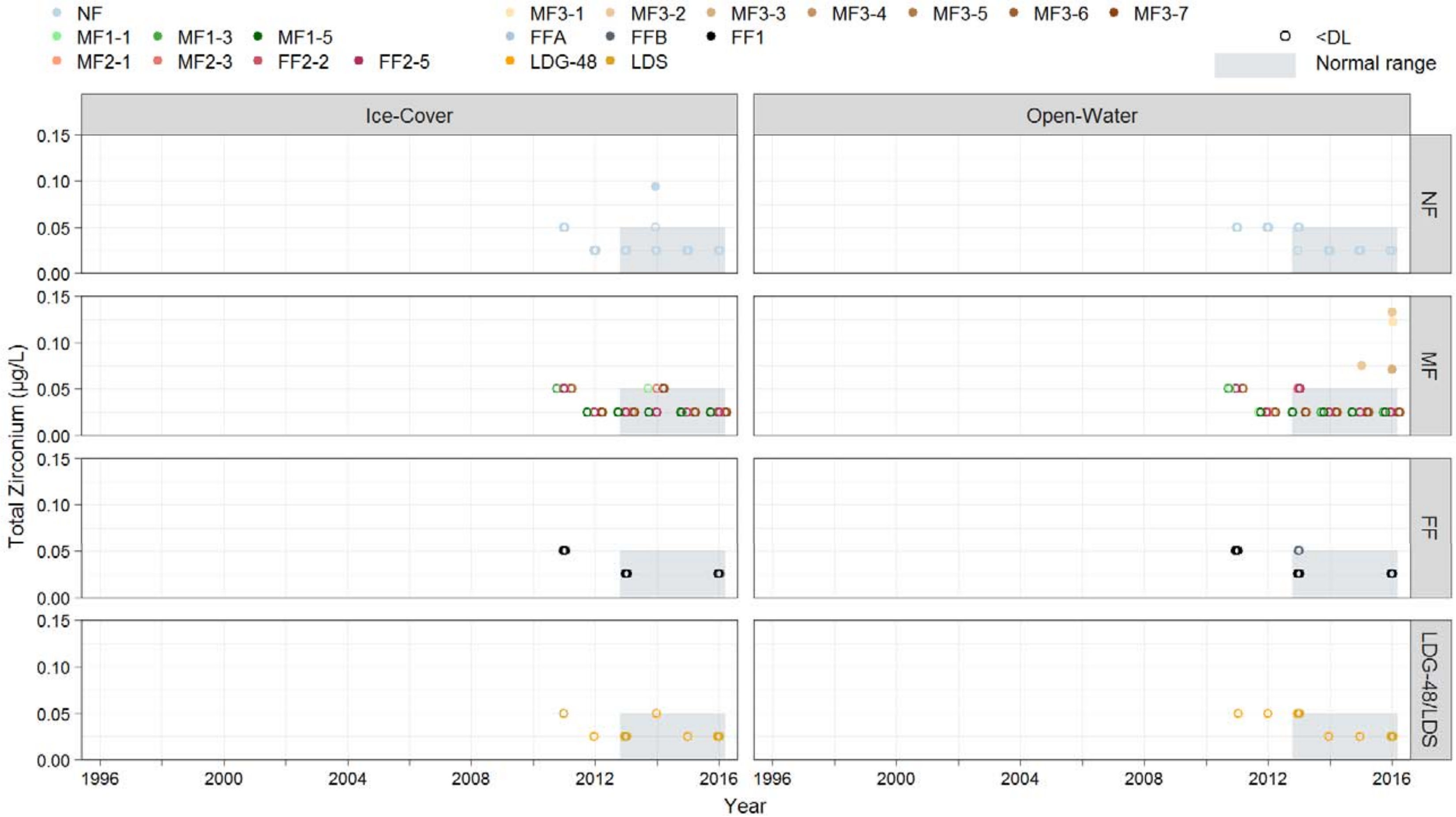


Figure 4-92 Total Vanadium Concentrations at AEMP Stations, 2000 to 2016



Note: Values represent concentrations in individual samples taken at mid-depth.
LDG = Lac de Gras; LDS = Lac du Sauvage

Figure 4-93 Total Zirconium Concentrations at AEMP Stations, 2011 to 2016



Note: Values represent concentrations in individual samples taken at mid-depth.
LDG = Lac de Gras; LDS = Lac du Sauvage

4.3.2.2 Summary of Effects

4.3.2.2.1 Action Levels

Mine-related effects on water quality were categorized according to Action Levels (Table 4-6). While a summary of the results of the Action Level analysis over time is provided herein, the following relevant sections of the AEMP Annual Reports and the *2011 to 2013 AEMP Re-evaluation Report* (Golder 2016a) contain further information, including detailed calculations and tables:

- *2011 to 2013 AEMP Re-evaluation Report* (Golder 2016a): Section 5.3.1.1, Table 5-6; Appendix 5B, Tables 5B-1 and 5B-2
- *Effluent and Water Chemistry Report* (Appendix II) of the *2014 AEMP Annual Report* (Golder 2016b): Section 3.4, Tables 3-4 to 3-6 and Figures 3-25 to 3-45
- *Effluent and Water Chemistry Report* (Appendix II) of the *2015 AEMP Annual Report* (Golder 2016c): Section 3.4, Tables 3-3 to 3-5 and Figures 3-24 to 3-43
- *Effluent and Water Chemistry Report* (Appendix II) of the *2016 AEMP Annual Report* (Golder 2017c): Section 3.4, Tables 3-5 to 3-7 and Figures 3-26 to 3-43

In the AEMP annual reports, Action Levels were assessed separately for the ice-cover and open-water seasons; the ice-cover season was defined as November to June, and the open-water season was defined as July to October. For this re-evaluation report, a variable was reported as having triggered an Action Level if the trigger occurred in one or both seasons, as identified in the annual report. Additional details on seasonality of Action Level triggers are provided in the aforementioned sections and tables of the 2014, 2015, and 2016 Annual Reports (Golder 2016b,c, 2017c). In general, Action Levels were triggered more frequently during the ice-cover season.

Action Level 1 was triggered for variables that had a two-fold difference between the NF area median concentration and the reference dataset median concentration (as defined in the *AEMP Reference Conditions Report Version 1.2* [Golder 2017b]). In addition, the increase in concentration in the NF area had to be linked to the Mine (i.e., present in the Mine effluent or in another Mine source such as dust) to trigger Action Level 1. No management action is required under the Response Framework when a water quality variable triggers Action Level 1 (Table 4-6). All SOIs that triggered Action Level 1 were evaluated against Action Level 2.

Action Level 2 was triggered if the 5th percentile concentration in the NF area was greater than two times the median concentration in reference datasets and was greater than the normal range for Lac de Gras (Table 4-6). Variables that triggered Action Level 2 were evaluated for an effect at Action Level 3. Action Level 3 was triggered if the 75th percentile concentration at the mixing zone boundary was greater than the normal range plus 25% of the distance between the top of the normal range and the AEMP Effects Benchmark (Table 4-6). Over the period of evaluation (2007 to 2016), no variable triggered an Action Level higher than Action Level 3 (Table 4-22).

Several variables consistently triggered Action Level 1 and fall into one of two categories (Table 4-22). They either:

- triggered Action Level 1 periodically over time with some years not triggering an Action Level: turbidity (after 2011), calcium, sulphate, barium (after 2009), chromium, copper, lead, manganese, tin and vanadium, or
- fluctuated from Action Level 1 to Action Level 2 in certain years (as indicated by the year after the variable name) and then returned to Action Level 1: turbidity (2010), ammonia (2008, 2015), aluminum (2011), antimony (2014), barium (2009), silicon (2012, 2015), and tin (2013)

Variables that consistently triggered Action Level 2, particularly since 2011, included TDS (calculated), chloride, sodium, nitrate, molybdenum, strontium and uranium. Under the Response Framework, when a water quality variable triggers Action Level 2, the required management action is to establish an AEMP Effects Benchmark for that variable, if one does not already exist (Table 4-6). As a result, DDMI has developed Effects Benchmarks for turbidity, dissolved sodium, total aluminum, total antimony, total silicon, and total tin. These Effects Benchmarks are described in the *AEMP Design Plan Version 4.1* (Section 5.3 in Golder 2017d).

None of the water quality variables triggered Action Level 3 between 2014 and 2016 (Table 4-22; Golder 2016b,c, 2017c). The only Action Level 3 trigger occurred for chromium in 2007 (Golder 2016a); the 75th percentile value for chromium at the mixing zone boundary (0.31 µg/L) was just above the screening value used at Action Level 3 (0.30 µg/L) during a single sampling event from the ice-cover season of 2007. As reported in the *2011 to 2013 Aquatic Effects Re-evaluation Report* (Golder 2016a), in light of the lack of an Action Level 3 exceedance for chromium after 2007 and the conservative nature of the benchmark, a management action related to the trigger of Action Level 3 by total chromium in 2007 was not warranted (Golder 2016a).

A discussion of variables that have triggered the equivalent of Action Level 1 in the MF areas at stations located within the estimated ZOI for dust deposition, and the potential effects to water quality in Lac de Gras from dust deposition and dike construction, is presented in Section 4.3.2.2.2.

Table 4-22 Results of the Action Level Evaluation for Water Quality, 2007 to 2016

Substance of Interest	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Conventional Parameters										
Total dissolved solids, calculated	-	AL1	AL2	AL2	n/a	AL2	AL2	AL2	AL2	AL2[(e)]
Total suspended solids	-	-	-	-	-	-	-	-	-	[(f,g)]
Turbidity	AL1	-	AL1	AL2	n/a	AL1	AL1	-	AL1	AL1[(e, g)]
Major Ions										
Calcium	-	-	-	-	AL1	-	AL1	AL1[(d)]	AL1[(d)]	AL1[(d)]
Chloride	AL1	AL1	AL2	AL2	AL2	AL2	AL2	AL2	AL2	AL2[(e)]
Fluoride[(a)]	n/c	n/c	n/c	n/c	-	-	-	-	-	-
Potassium	-	-	-	-	-	-	-	AL1[(d)]	AL1[(d)]	-
Sodium	-	AL1	AL1	AL2	AL2	AL2	AL2	AL2[(d)]	AL2[(d)]	AL2[(d,e)]
Sulphate	-	-	-	-	-	-	AL1	AL1	-	AL1[(e)]
Nutrients[(b)]										
Ammonia	AL1	AL2	AL1	-	[(c)]	[(c)]	[(c)]	[(c)]	AL2	[(c)]
Nitrate	AL2	AL2	AL2	AL2	AL2	AL2	AL2	AL2	AL2	AL2[(e)]
Nitrite[(a)]	-	-	-	-	-	-	-	-	-	-
Total Metals										
Aluminum	-	-	-	AL1	AL2	AL1	AL1	AL1	AL1	AL1[(e, g)]
Antimony	n/c	n/c	n/c	n/c	AL1	AL1	AL1	AL2	AL1	-
Barium	AL1	AL1	AL2	AL1	AL1	-	AL1	AL1	-	-
Bismuth	-	-	-	-	-	-	-	-	-	[(f, g)]
Chromium	AL3	-	-	-	n/c	n/c	AL1	AL1	AL1	[(f, g)]
Cobalt	-	-	-	-	-	-	-	-	-	[(f, g)]
Copper	AL1	-	-	AL1	AL1	-	AL1	AL1	AL1	AL1[(e, g)]
Iron	-	-	-	-	-	-	-	-	-	[(f, g)]
Lead	n/c	n/c	AL1	n/c	-	-	-	AL1	-	AL1[(e, g)]
Manganese	-	-	-	AL1	AL1	-	-	-	-	AL1[(e, g)]

Table 4-22 Results of the Action Level Evaluation for Water Quality, 2007 to 2016

Substance of Interest	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Molybdenum	AL2	AL2	AL2	AL2	AL2	AL2	AL2	AL2	AL2	AL2[e]
Silicon	n/a	n/a	n/a	n/a	AL1	AL2	AL1	AL1	AL2	AL1[e, g]
Strontium	-	-	AL1	AL1	AL2	AL2	AL2	AL2	AL2	AL2[e]
Thallium	-	-	-	-	-	-	-	-	-	[f, g]
Tin	n/a	n/a	n/a	n/a	-	AL1	AL2	AL1	-	-
Titanium	-	-	-	-	-	-	-	-	-	[f, g]
Uranium	AL2	AL2	AL2	AL2	AL2	AL2	AL2	AL2	AL2	AL2 [e, g]
Vanadium	-	-	-	-	-	-	-	-	AL1	[f, g]
Zirconium	-	-	-	-	-	-	-	-	-	[f,g]

Notes: - = did not trigger an Action Level; n/c = Action Level comparison could not be completed for one or both sampling seasons (i.e., ice-cover, open-water) due to an elevated detection limit; n/a = not analyzed in one or both sampling seasons; AL1 = Action Level 1 triggered; AL2 = Action Level 2 triggered; AL3 = Action Level 3 triggered.

a) Fluoride and nitrite did not trigger an Action Level from 2007 to 2016; however, they are presented in this table for context because they were added to the list of SOIs based on the results of the effluent screening associated with SOI Criterion 1 (Section 4.2.2).

b) Nutrients that are generally not toxic to aquatic organisms are evaluated in the Eutrophication Indicators section of this report (Section 5).

c) Action Level results for ammonia from 2011 to 2016, excluding 2015, are uncertain due to laboratory quality control issues (Section 4.2.3 and Appendix 4B).

d) Total concentration in the NF area triggered Action Level 1 in 2014, 2015 and/or 2016, however, Action Level 1 was applied to the dissolved form even though the NF area concentration in 2014, 2015 and/or 2016 was just below the threshold value used at Action Level 1. This approach was taken to be consistent with the annual reports from 2014 to 2016. Action Level evaluation for these variables prior to 2014 involved the total concentration, not the dissolved fraction.

e) Variable triggered Action Levels in the NF area during one or both seasons, and the median value at one or more MF area stations located within the estimated ZOI from dust deposition was greater than two times the median of the reference dataset. For more detail, refer to Section 4.3.2.2.2, and Section 3.7 of Golder (2017c).

f) Variable median value at one or more MF area stations located within the estimated ZOI from dust deposition was greater than two times the median of the reference dataset, but did not trigger Action Level 1 in the NF area. For more detail, refer to Section 4.3.2.2.2 and Section 3.7 of Golder (2017c).

g) Variable demonstrated a dike construction-related effect in the MF area. For more detail, refer to Section 4.3.2.2.2 and Section 3.7 of Golder (2017c).

4.3.2.2.2 Effects from Dust Deposition and Dike Construction

The following is a detailed summary of the analysis of potential effects from dust deposition and dike construction as originally presented in the 2016 AEMP Annual Report (Golder 2017c). This information has been included in detail, not only to provide context, but also because of the links between this analysis and the results of both the trend analysis in Section 4.3.2.1.2 and the comparison to EA predictions in Section 4.3.2.3.3.

In 2016, median concentrations of 23 SOIs exceeded two times the median of the reference dataset (the metric used in the evaluation of Action Level 1; Tables 4-22 and 4-23) at one or more of the four MF area stations located within the estimated ZOI from dust deposition (i.e., Stations MF1-1, MF2-1, MF3-1 and MF3-2; Golder 2017c). Of these, 14 SOIs also triggered Action Levels 1 or 2 in the NF area (which are identified by footnote (e) in Table 4-22), indicating that the exceedances in the MF areas were at least partly caused by dispersion of Mine effluent in the lake. The remaining nine SOIs (i.e., TSS, bismuth, chromium, cobalt, iron, thallium, titanium, vanadium, and zirconium, which are identified by footnote (f) in Table 4-22) exceeded two times the median of the reference dataset value in the MF area only. These nine SOIs did not trigger Action Level 1 in the NF area in either season, indicating that the increases in the MF area were not likely solely effluent-related. Evaluation of the AEMP water quality data indicated that each of these nine SOIs were affected by sediment releases from construction of the A21 dike. In addition, seven of the SOIs that also triggered Action Level 1 (i.e., turbidity, aluminum, copper, lead, manganese, silicon, uranium, which are identified by footnote (g) in Table 4-22) demonstrated spatial trends consistent with a dike-related effect, based on visual assessment. This interpretation is based on the following:

- Concentrations of most particulate-related variables, including TSS (Figure 4-94), turbidity (Figure 4-95) and several total metals were elevated in the MF3 area at stations near the A21 dike (i.e., Stations MF3-1, MF3-2 MF3-3 and MF3-4). The elevated metals included aluminum (Figure 4-96), cadmium (Figure 4-97), copper (Figure 4-98), manganese (Figure 4-99) together with barium, bismuth, chromium, cobalt, iron, lead, lithium, nickel, silicon, thallium, tin, titanium, uranium, vanadium, zinc, and zirconium (Table 4-23; the reader is directed to Appendix D of Golder 2017c for additional supporting figures).
- Each of the water quality variables that demonstrated a dike-related effect in the MF3 area was detected at greater concentrations inside the turbidity curtain (i.e., at Stations T1, T2 and T3; Figures 4-94 to 4-99 and Appendix D of Golder 2017c), which was in place to isolate the in-water work area within Lac de Gras. An exception was cadmium, which had MF3 area concentrations that were greater than those reported at stations inside the turbidity curtain and in the NF area of Lac de Gras, indicating that the elevated values in the MF3 area do not appear to be entirely related to the dike or to dispersion of effluent in the lake (Figure 4-97). There was no clear explanation for the increase in cadmium concentrations in the MF3 area. Although not identified as anomalous in the initial data screening, these concentrations were unusually high compared to other values reported for cadmium in Lac de Gras, and may have been caused by a QC issue, or potentially stochastic variability.
- Of the four stations that appeared to be affected by dike construction, stations MF3-1 and MF3-2 fall within the ZOI from dust deposition. These stations are located to the northeast of the A21 dike in the general direction that the wind was blowing within approximately 36 hours before sampling for the AEMP.

- Nearly all of the SOIs that exceeded the two times the median of the reference dataset value in the MF area did so at stations near the A21 dike (i.e., Stations MF3-1 and MF3-2; Table 4-23).

For many SOIs, the increases observed at dike-affected stations were less than or similar to those observed in the NF area, where the concentration of Mine effluent is greatest. In addition, SOI concentrations at dike-affected stations were below the AEMP Effects Benchmarks for the protection of aquatic life and drinking water in all samples (including the elevated cadmium values discussed above), with the exception of three total aluminum samples collected at stations MF3-1 and MF3-2, which exceeded the AEMP drinking water Effects Benchmark of 100 µg/L. Given that sediment-related impacts resulting from in-water construction are typically limited to the duration of construction or shortly after the period of construction, the increases in SOI concentrations observed in the MF3 area were likely of short duration.

Of the nine SOIs that exceeded two times the median of the reference dataset value only in the MF area, four (i.e., chromium, iron, thallium and titanium) also did so at stations MF1-1 and/or MF2-1, which are located outside the area of Lac de Gras shown to be affected by dike construction (Golder 2016a). In most cases, the concentration increases were small or just above the DL (Table 4-23) and were less than those observed in the NF area and/or at dike-affected stations. These small increases in SOI concentrations may have resulted from dust deposition, a combination of dust deposition and effluent discharge, or stochastic variability.

Table 4-23 Evaluation of Effects from Dust Deposition and Dike Construction in Lac de Gras, 2016

Variable	Unit	2016 Detection Limit	Screening Value 2 x Median of Reference Dataset[(a)]	2016 AEMP Result Median of MF Station[(b)] MF1-1	MF2-1	MF3-1	MF3-2	Median of MF Station >2 x Median of Reference Dataset[(a)] (Yes/No)	Dike Effect Present Based on Visual Assessment (Yes/No)
Conventional Parameters									
Total alkalinity	mg/L	0.5	8	5.3	5.7	4.5	4.3	No	No
Total dissolved solids, calculated	mg/L	-	10.6	**15.6**	**14.1**	**13.3**	**12.7**	**Yes[(c)]**	No
Total dissolved solids, measured	mg/L	1	20	18	15	18	18	No	No
Total suspended solids	mg/L	1	1	<1	<1	**1.7**	**1.7**	**Yes**	**Yes**
Total organic carbon	mg/L	0.2	4.4	2.5	2.3	2.3	2.1	No	No
Turbidity – lab	NTU	0.1	0.42	**0.47**	**0.57**	**1.29**	**1.56**	**Yes[(c)]**	**Yes**
Major Ions									
Calcium	mg/L	0.05	2.00	1.73	1.68	1.52	1.45	No	No
Chloride	mg/L	0.5	2	**2.7**	1.7	**2.1**	2	**Yes[(c)]**	No
Fluoride	mg/L	0.01	0.044	0.035	0.025	0.030	0.033	No	No
Magnesium	mg/L	0.05	1.4	0.9	1.0	0.9	0.9	No	No
Potassium	mg/L	0.05	1.2	0.9	0.9	0.8	0.8	No	No
Sodium	mg/L	0.05	1.0	**1.8**	**1.8**	**1.5**	**1.4**	**Yes[(c)]**	No
Sulphate	mg/L	0.5	3.8	**4.3**	3.6	3.6	3.5	**Yes[(c)]**	No
Nutrients									
Ammonia	µg-N/L	5	5	**68**	**74**	**30**	**27**	[(d)]	No
Nitrate	µg-N/L	2	2	**28.6**	**2.8**	**10.5**	**12.1**	**Yes[(c)]**	No
Nitrite	µg-N/L	2	2	<2	<2	<2	<2	No	No

Table 4-23 Evaluation of Effects from Dust Deposition and Dike Construction in Lac de Gras, 2016

Variable	Unit	2016 Detection Limit	Screening Value	2016 AEMP Result				Median of MF Station >2 x Median of Reference Dataset[(a)] (Yes/No)	Dike Effect Present Based on Visual Assessment (Yes/No)
				Median of MF Station[(b)]					
			2 x Median of Reference Dataset[(a)]	MF1-1	MF2-1	MF3-1	MF3-2		
Total Metals									
Aluminum	µg/L	0.2	8.8	**13.3**	**14**	**94.5**	**111**	**Yes[(c)]**	**Yes**
Antimony	µg/L	0.02	0.02	<0.02	<0.02	<0.02	<0.02	No	No
Arsenic	µg/L	0.02	0.34	0.28	0.29	0.27	0.28	No	No
Barium	µg/L	0.02	3.62	2.84	2.46	2.97	3.12	No	**Yes**
Beryllium	µg/L	0.01	0.01	<0.01	<0.01	<0.01	<0.01	No	No
Bismuth	µg/L	0.005	0.005	<0.005	<0.005	**0.029**	**0.034**	**Yes**	**Yes**
Boron	µg/L	5	5	<5	<5	<5	<5	No	No
Cadmium	µg/L	0.005	0.005	<0.005	<0.005	<0.005	<0.005	No	**Yes**
Calcium	mg/L	0.05	1.92	1.81	1.65	1.61	1.47	No	No
Chromium	µg/L	0.05	0.06	**0.07**	0.06	**0.21**	**0.28**	**Yes**	**Yes**
Cobalt	µg/L	0.005	0.04	0.02	0.03	**0.08**	**0.10**	**Yes**	**Yes**
Copper	µg/L	0.05	0.6	**0.67**	**0.64**	**0.95**	**1.05**	**Yes[(c)]**	**Yes**
Iron	µg/L	1	10	**11.2**	**14**	**79.2**	**105**	**Yes**	**Yes**
Lead	µg/L	0.005	0.005	**0.015**	**0.016**	**0.108**	**0.148**	**Yes[(c)]**	**Yes**
Lithium	µg/L	0.5	2.4	1.8	1.7	1.5	1.7	No	**Yes**
Magnesium	mg/L	0.05	1.26	1.06	0.98	1.01	0.944	No	No
Manganese	µg/L	0.05	4.88	**5.59**	3.68	4.01	3.95	**Yes[(c)]**	**Yes**
Mercury	µg/L	0.002	0.01	<0.002	<0.002	<0.002	<0.002	No	No
Molybdenum	µg/L	0.05	0.18	**0.69**	**0.52**	**0.43**	**0.33**	**Yes[(c)]**	No
Nickel	µg/L	0.02	1.90	0.71	0.65	1.02	1.19	No	**Yes**

Table 4-23 Evaluation of Effects from Dust Deposition and Dike Construction in Lac de Gras, 2016

Variable	Unit	2016 Detection Limit	Screening Value	2016 AEMP Result				Median of MF Station >2 x Median of Reference Dataset[(a)] (Yes/No)	Dike Effect Present Based on Visual Assessment (Yes/No)
				Median of MF Station[(b)]					
			2 x Median of Reference Dataset[(a)]	MF1-1	MF2-1	MF3-1	MF3-2		
Potassium	mg/L	0.05	1.08	1.02	0.88	0.87	0.82	No	No
Selenium	µg/L	0.04	0.04	<0.04	<0.04	<0.04	<0.04	No	No
Silicon	µg/L	50	50	<50	<50	**147**	**177**	**Yes[(c)]**	**Yes**
Silver	µg/L	0.005	0.005	<0.005	<0.005	<0.005	<0.005	No	No
Sodium	mg/L	0.05	1.26	**2.17**	**1.83**	**1.59**	**1.44**	(e)	No
Strontium	µg/L	0.05	14.6	**23**	**19**	**17.1**	**15.7**	**Yes[(c)]**	No
Sulphur	mg/L	0.5	1.82	1.6	1.21	0.92	0.84	No	No
Thallium	µg/L	0.002	0.002	<0.002	**0.003**	<0.002	<0.002	**Yes**	**Yes**
Tin	µg/L	0.01	0.01	<0.01	<0.01	<0.01	<0.01	No	**Yes**
Titanium	µg/L	0.5	0.5	<0.5	**0.58**	**3.42**	**4.66**	**Yes**	**Yes**
Uranium	µg/L	0.002	0.056	**0.11**	**0.122**	**0.413**	**0.482**	**Yes[(c)]**	**Yes**
Vanadium	µg/L	0.1	0.1	<0.1	<0.1	**0.19**	**0.23**	**Yes**	**Yes**
Zinc	µg/L	0.1	1.5	0.4	0.4	0.9	1	No	**Yes**
Zirconium	µg/L	0.05	0.05	<0.05	<0.05	**0.22**	**0.14**	**Yes**	**Yes**

Note: Shading indicates a dike-affected station. Bolding indicates that a value exceeds two times the reference dataset median.

a) The two times the median value was based on the reference area median concentrations presented in the *AEMP Reference Conditions Report Version 1.2* (Golder 2017b). In cases where the median concentration was less than the DL, the reference area median value was considered to be equal to half of the DL.

b) The median of MF area values was calculated from data pooled across all sample depths (i.e., top, middle and bottom).

c) Concentration in the NF area triggered both Action Level 1 (during one or both seasons) and an effect equivalent to Action Level 1 at one or more MF area stations located within the estimated zone of influence from dust deposition.

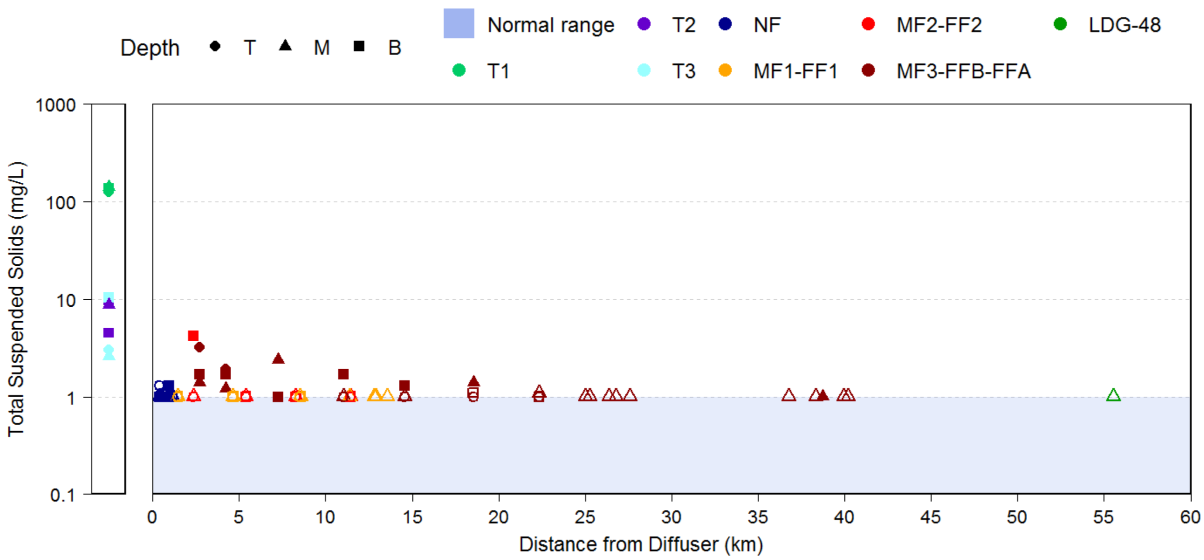
d) Result uncertain due to laboratory quality control issues identified in 2016 (Section 4.3.2 and Appendix 4B).

e) “Yes” applied to dissolved value.

Source: Golder 2017c.

NTU = nephelometric turbidity unit; µg-N/L = micrograms nitrogen per litre.

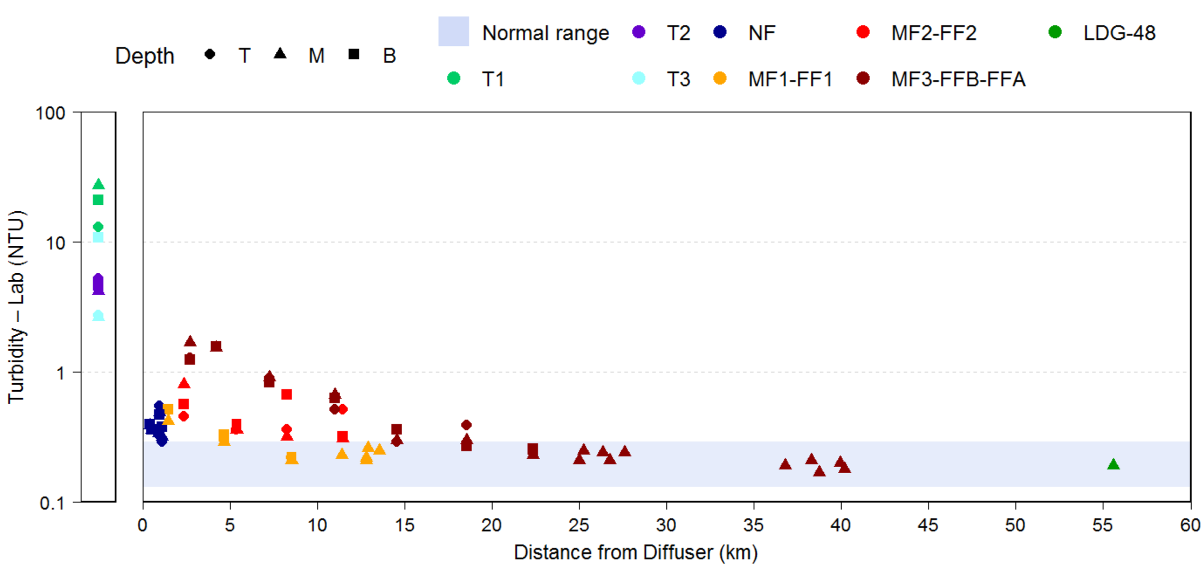
Figure 4-94 Spatial Variation in Total Suspended Solids Concentration with Distance from the Mine-effluent Diffusers, Open-water Season, 2016



Notes: Values represent concentrations in individual samples collected at top, middle and bottom depths. Open symbols represent non-detect data. Stations T1, T2 and T3 were located inside the A21 dike turbidity curtain.

LDG = Lac de Gras;T = top; M = middle; B = bottom

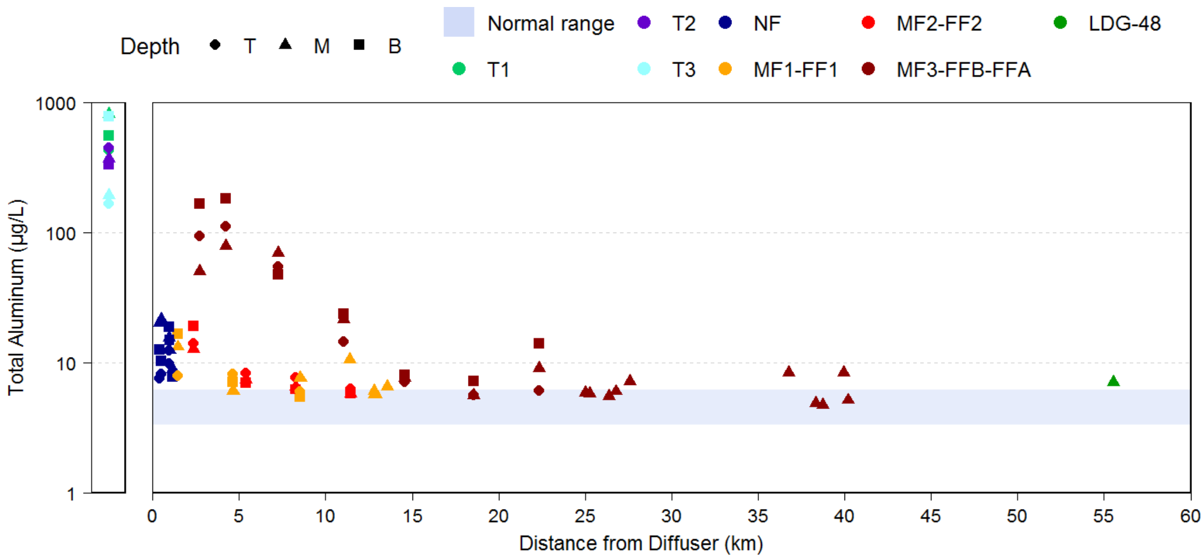
Figure 4-95 Spatial Variation in Turbidity with Distance from the Mine-effluent Diffusers, Open-water Season, 2016



Notes: Values represent concentrations in individual samples collected at top, middle and bottom depths. Open symbols represent non-detect data. Stations T1, T2 and T3 were located inside the A21 dike turbidity curtain.

LDG = Lac de Gras; T = top; M = middle; B = bottom; NTU = nephelometric turbidity unit.

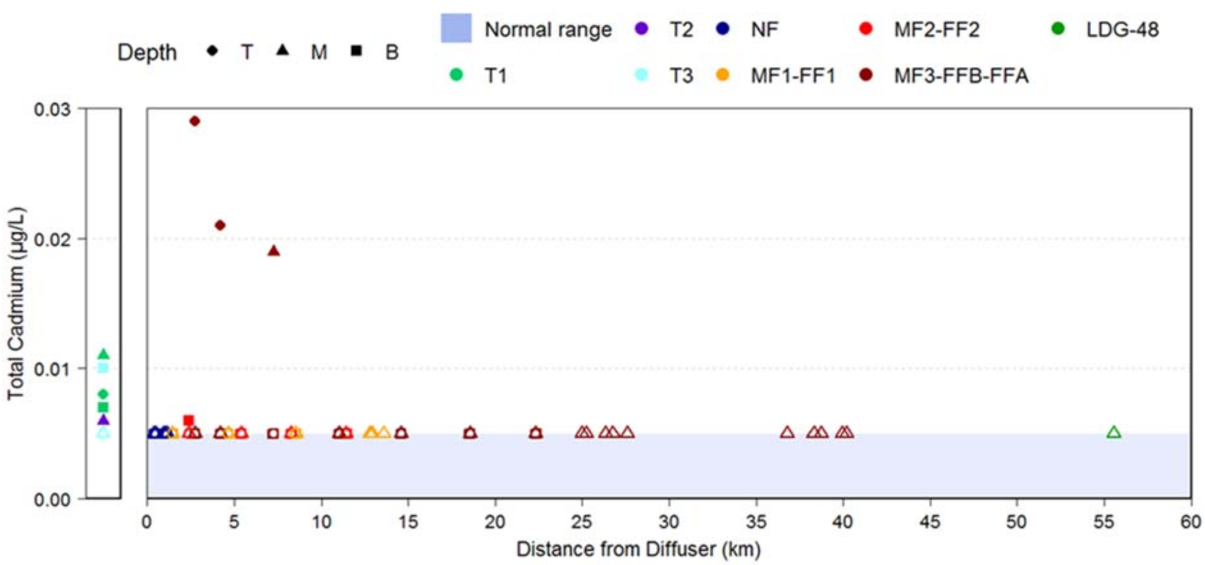
Figure 4-96 Spatial Variation in Aluminum Concentration with Distance from the Mine-effluent Diffusers, Open-water Season, 2016



Notes: Values represent concentrations in individual samples collected at top, middle and bottom depths. Open symbols represent non-detect data. Stations T1, T2 and T3 were located inside the A21 dike turbidity curtain.

LDG = Lac de Gras;T = top; M = middle; B = bottom.

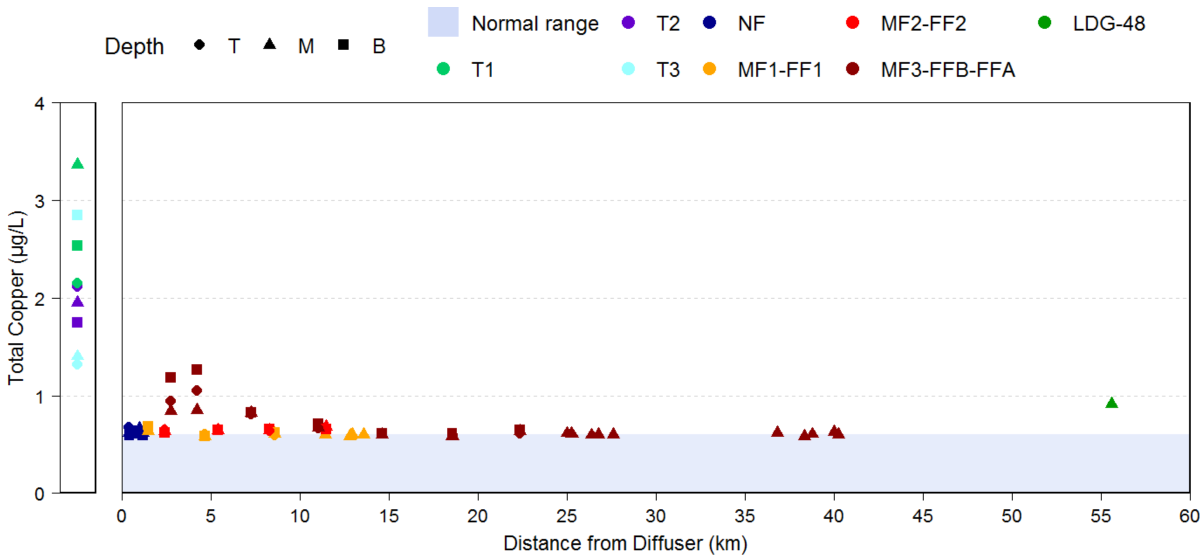
Figure 4-97 Spatial Variation in Cadmium Concentration with Distance from the Mine-effluent Diffusers, Open-water Season, 2016



Notes: Values represent concentrations in individual samples collected at top, middle and bottom depths. Open symbols represent non-detect data. Stations T1, T2 and T3 were located inside the A21 dike turbidity curtain.

LDG = Lac de Gras;T = top; M = middle; B = bottom.

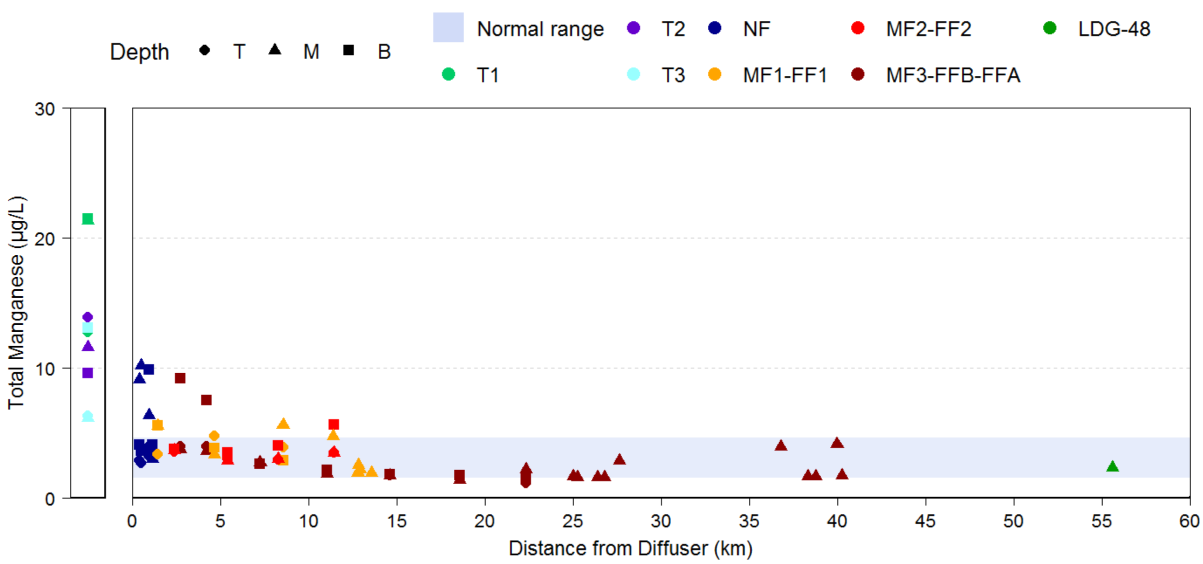
Figure 4-98 Spatial Variation in Copper Concentration with Distance from the Mine-effluent Diffusers, Open-water Season, 2016



Notes: Values represent concentrations in individual samples collected at top, middle and bottom depths. Open symbols represent non-detect data. Stations T1, T2 and T3 were located inside the A21 dike turbidity curtain.

LDG = Lac de Gras;T = top; M = middle; B = bottom.

Figure 4-99 Spatial Variation in Manganese Concentration with Distance from the Mine-effluent Diffusers, Open-water Season, 2016



Notes: Values represent concentrations in individual samples collected at top, middle and bottom depths. Open symbols represent non-detect data. Stations T1, T2 and T3 were located inside the A21 dike turbidity curtain.

LDG = Lac de Gras;T = top; M = middle; B = bottom.

4.3.2.2.3 Cumulative Effects in Lac de Gras

To investigate the potential cumulative effects of the Diavik and Ekati mines on the water quality of Lac de Gras, plots of concentration over time were generated for the current SOIs (Figures 4-100 to 4-108). From east to west in Lac de Gras, areas and stations included in the plots were FFB (mid-lake), FFA (closest to the Ekati mine discharge via Slipper Lake) and LDG-48 (outlet to the Coppermine River; Figure 4-109). Given that the general direction of water flow in Lac de Gras is from east to west, the concentration of a variable released in the Diavik Mine effluent would be expected to decrease with distance from the Mine effluent diffusers, with the lowest concentrations occurring at the far northwest end of Lac de Gras (i.e., LDG-48; Golder 2016a; Zajdlik & Associates Inc. 2016). Cumulative effects of the two discharges are unlikely in the FFB area, which is expected to be influenced primarily by the Diavik effluent, as indicated by observed gradients in concentrations of water quality variables since the Diavik Mine began operations.

The plots in Figures 4-100 to 4-108 generally support the conclusion from the *2011 to 2013 Aquatic Effects Re-evaluation Report* (Golder 2016a) that certain SOIs are found in greater concentrations at the lake outlet (LDG-48) than at FFB, which is closer to the Diavik Mine. More specifically, of the current SOIs, TDS (calculated), calcium, chloride, potassium, sodium, sulphate, molybdenum, and strontium generally had concentrations that were: 1) greater than the normal range, 2) increasing over time, and 3) greater at LDG-48 and/or FFA than at FFB during recent years, predominantly during the ice-cover season, but also in the open-water season (e.g., chloride). These observations suggest that cumulative effects may be occurring for these variables on the west side of Lac de Gras. Concentrations of barium and copper, while not consistently above the normal range, have also been greater at LDG-48 and/or FFA than at FFB, particularly in the ice-cover season since 2011 for barium and the open-water season of 2016 for copper. Total aluminum, iron, titanium and vanadium have concentrations at FFB, FFA, and LDG-48 mostly within the normal range, with the exception of several elevated concentrations at LDG-48; however, it is not possible to determine if these elevated concentrations were due to cumulative effects.

These results indicating cumulative effects for some water quality variables are largely consistent with another recent evaluation of potential cumulative effects. Using data collected prior to 2015 and similar plotting methods to those employed herein, Zajdlik & Associates Inc. (2016) concluded that cumulative effects from the Diavik and Ekati mine effluents were detected at the western end of Lac de Gras for conductivity and chloride. They also stated that there was evidence, although somewhat limited, for augmentation of the Diavik plume by the Ekati discharge for strontium and copper as well.

As indicated in the 2016 AEMP Annual Report for the Ekati mine (ERM 2017a), concentrations of chloride, potassium, sulphate, molybdenum, and strontium have increased in monitored lakes and streams downstream of the Long Lake Containment Facility as far as Station S3, while the concentration of barium has increased as far as Station S2, as a result of the Ekati mine operations (ERM 2017a; Figure 4-109). In 2016, concentrations of the nine SOIs identified in this assessment were elevated at S2 (although with poor agreement between duplicate samples), but declined from S3 to S5, and then to S6. Concentrations at S6 were similar to those reported by the Diavik AEMP for the FFB area (which is only affected by Diavik) in the same year (Table 4-24). Therefore, it is not possible to predict which of the SOIs would be affected by both developments based on the 2016 data. This is not surprising, since concentrations of the eight SOIs in 2016 with potential cumulative effects (i.e., TDS, calcium, chloride, potassium, sodium, sulphate, molybdenum, and strontium) were more similar among FFB, FFA, and LDG-48 than in previous years, and do not indicate as clear of a cumulative effect as data from previous years.

Overall, based on the pattern in the time series plots for the variables evaluated, the concentrations of the eight SOIs at stations to the northwest of FFB, in the vicinity of the convergence of the two effluent sources (i.e., around FFA and downstream at LDG-48) suggests that the Ekati discharge is a likely influence on their concentrations (Figures 4-100 to 4-108). However, as indicated by the general similarity of concentrations in sampled areas in the western part of Lac de Gras and by the 2016 results (Table 4-24), the interaction between the effects of the two mines on water quality variables is at most slight, and cannot be detected in all years.

Table 4-24 Concentrations at Ekati Slipper Bay Monitoring Stations S2 and S6, and Diavik FFB Area, 2016

Variable	Units	April			August		
		S2	S6	FFB (mean)	S2	S6	FFB (mean)
		Dup1/Dup2	Dup1/Dup2		Dup1/Dup2	Dup1/Dup2	
Total dissolved solids	mg/L	116 / 17.2	14.7 / 14.6	13.2	32.7 / 36.5	14.3 / 14.1	11.2
Calcium (total)	mg/L	7.03 / 1.56	1.30 / 1.30	1.44	2.15 / 2.28	1.30 / 1.29	1.28
Chloride	mg/L	25.6 / 2.03	1.74 / 1.73	1.94	6.40 / 7.62	1.7 / 1.7	0.8
Potassium (total)	mg/L	6.65 / 0.89	0.75 / 0.75	0.82	1.84 / 1.94	0.73 / 0.72	0.69
Sodium (total)	mg/L	21.4 / 1.61	1.34 / 1.32	1.45	5.45 / 6.07	1.33 / 1.32	1.28
Sulphate	mg/L	29.0 / 4.03	3.44 / 3.42	3.28	8.28 / 9.56	3.25 / 3.25	3.35
Barium (total)	µg/L	19.20 / 2.58	2.14 / 2.05	2.24	3.93 / 4.12	1.94 / 1.94	1.93
Molybdenum (total)	µg/L	5.25 / 0.26	0.21 / 0.21	0.22	2.19 / 2.53	0.24 / 0.24	0.21
Strontium (total)	µg/L	120.0 / 14.5	11.9 / 12.0	13.3	29.9 / 32.8	12.1 / 12.1	12.1

Source: ERM (2017b) Tables 3.4-2 and 3.4-3 (Mid-depth samples); Golder (2017c).
Dup = duplicate sample.

Figure 4-100 Total Dissolved Solids (Calculated), Total Suspended Solids and Turbidity at FFB, FFA, and Station LDG-48

LDG = Lac de Gras;TDS = total dissolved solids; TSS = total suspended solids; NTU = Nephelometric Turbidity Units

Figure 4-101 Chloride, Fluoride, and Total Calcium at FFB, FFA, and Station LDG-48

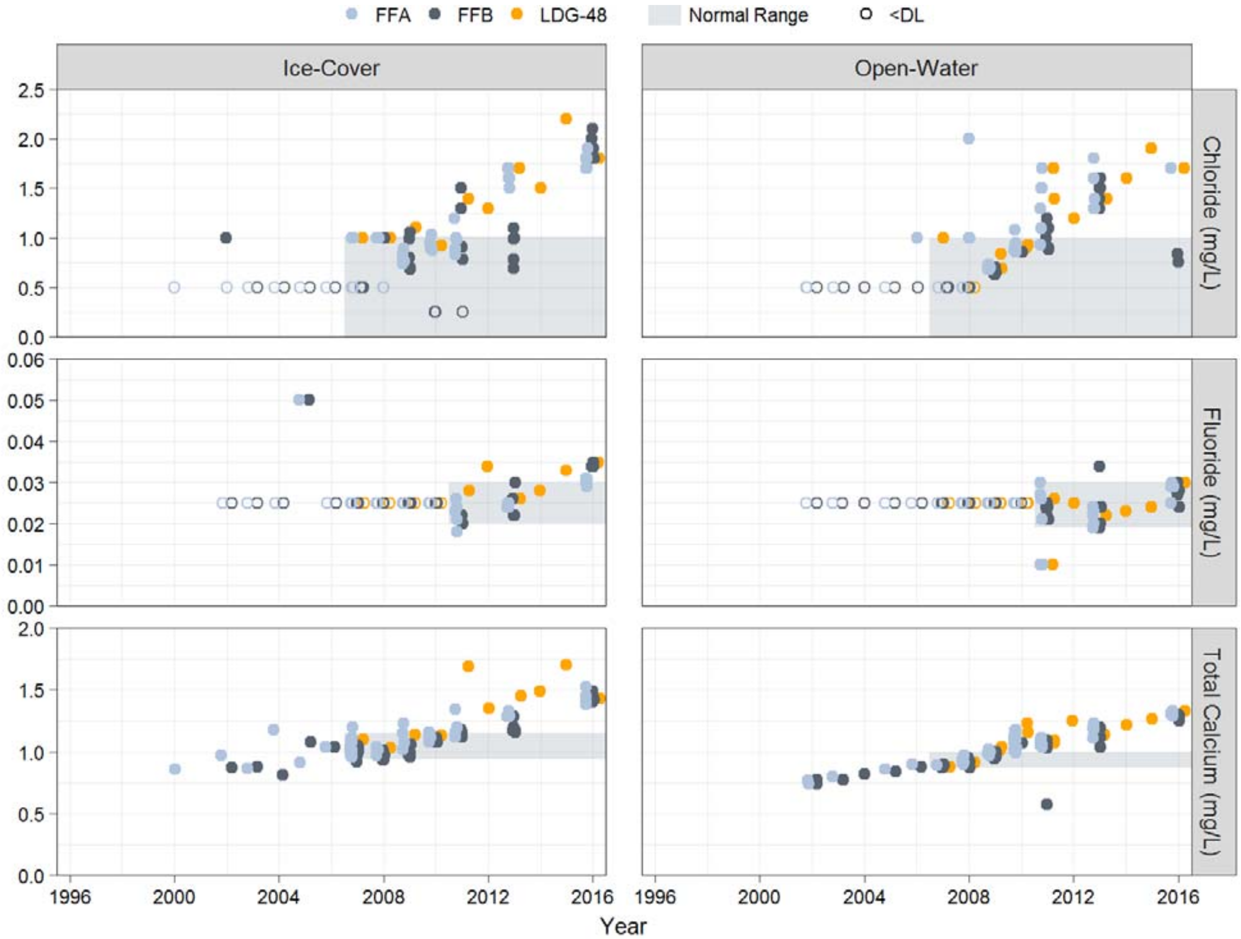


Figure 4-102 Sulphate, Total Potassium, Total Sodium at FFB, FFA, and Station LDG-48

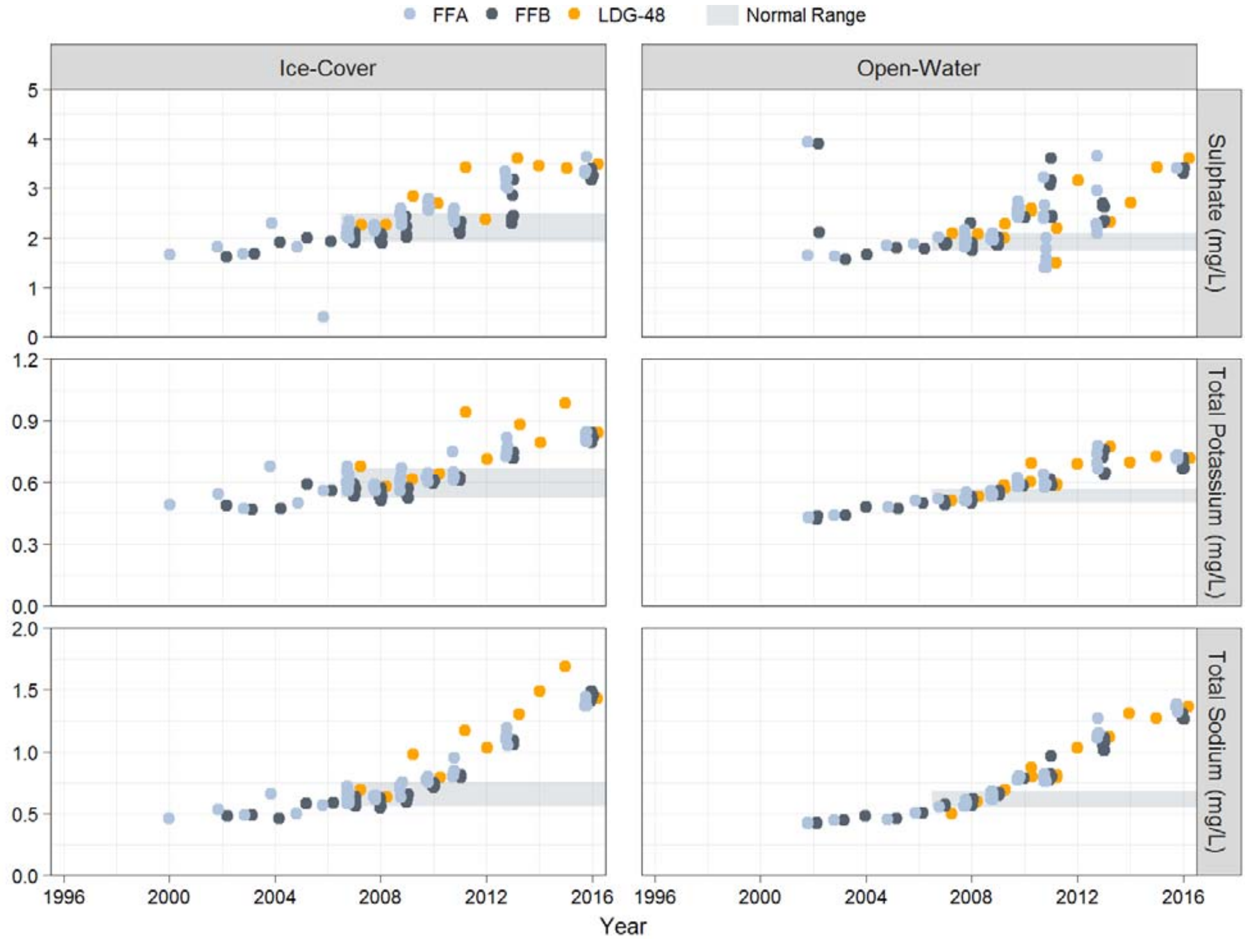
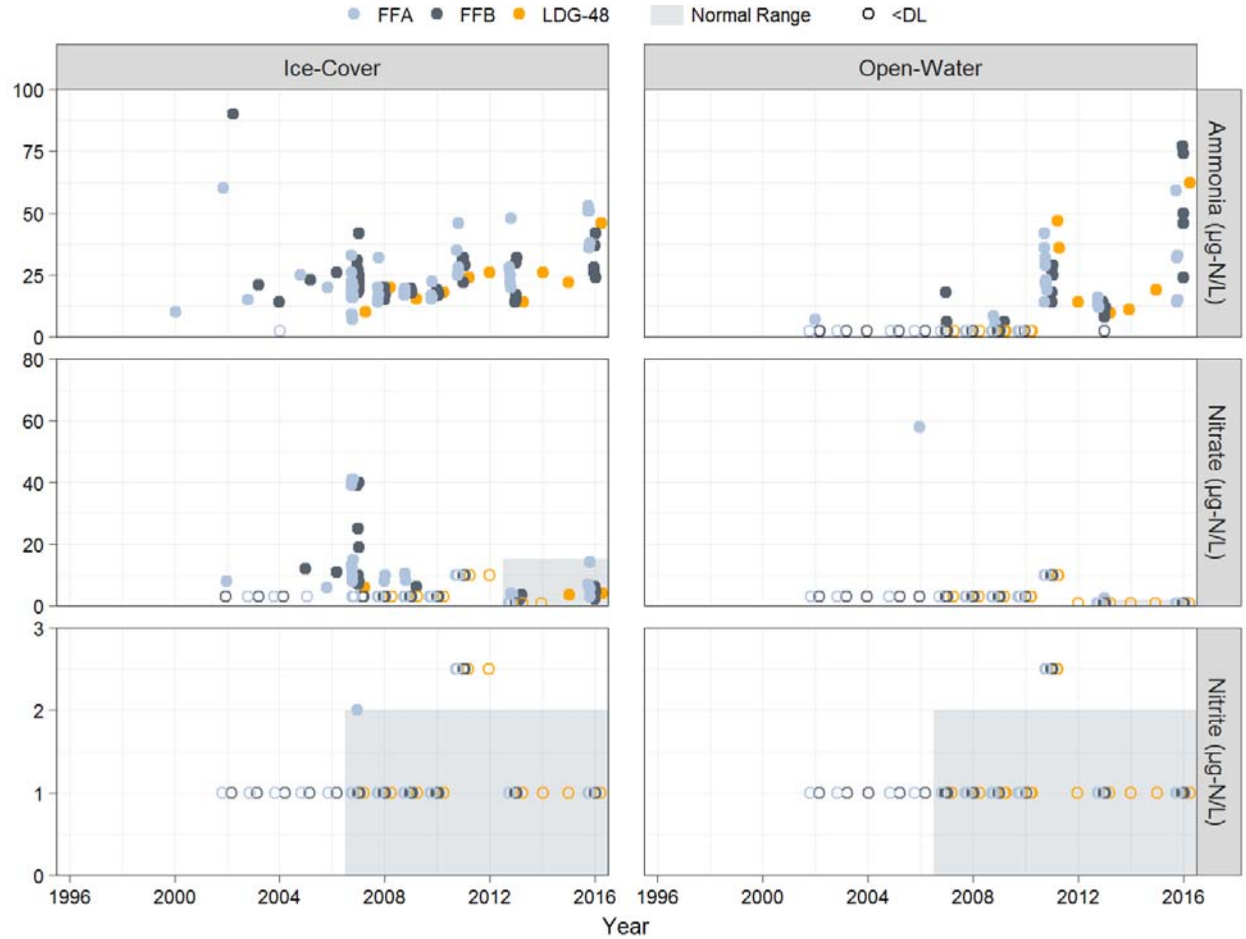


Figure 4-103 Ammonia, Nitrate and Nitrite at FFB, FFA, and Station LDG-48



µg-N/L = micrograms of nitrogen per litre

Figure 4-104 Total Aluminum, Antimony, Barium and Bismuth at FFB, FFA, and Station LDG-48

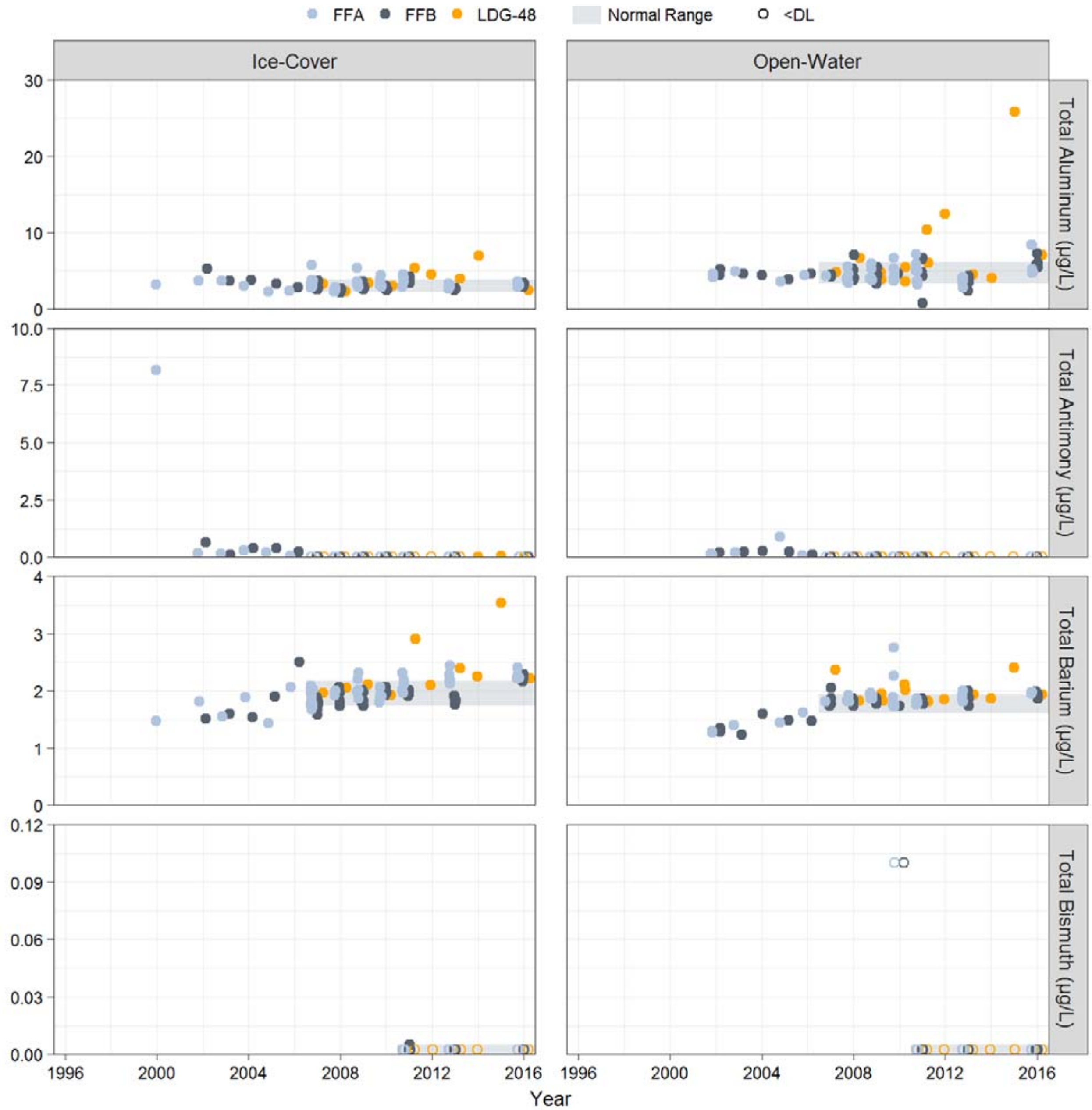


Figure 4-105 Total Chromium, Cobalt, Copper and Iron at FFB, FFA, and Station LDG-48

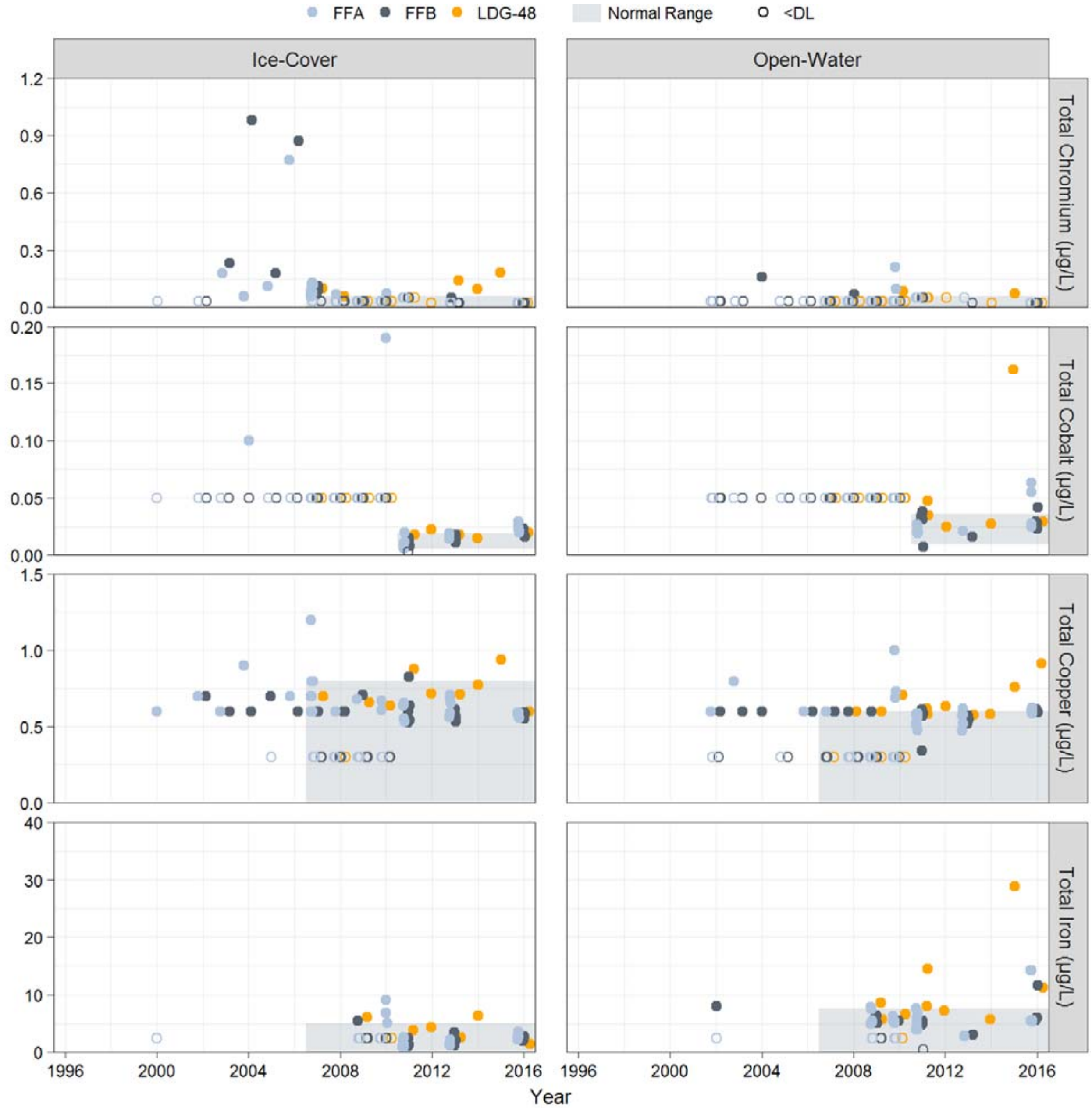


Figure 4-106 Total Lead, Manganese, Molybdenum and Silicon at FFB, FFA, and Station LDG-48

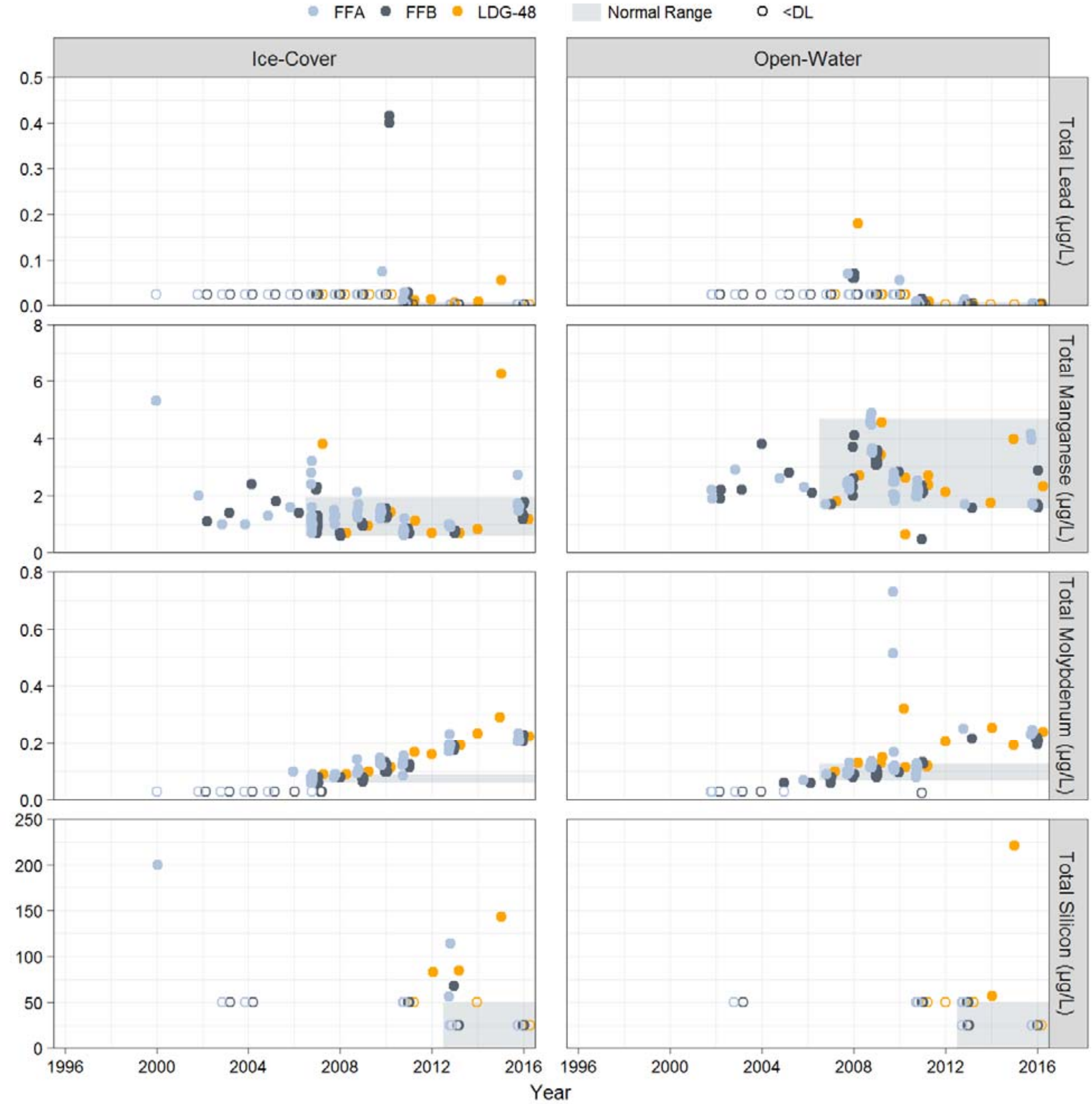


Figure 4-107 Total Strontium, Thallium, Tin and Titanium at FFB, FFA, and Station LDG-48

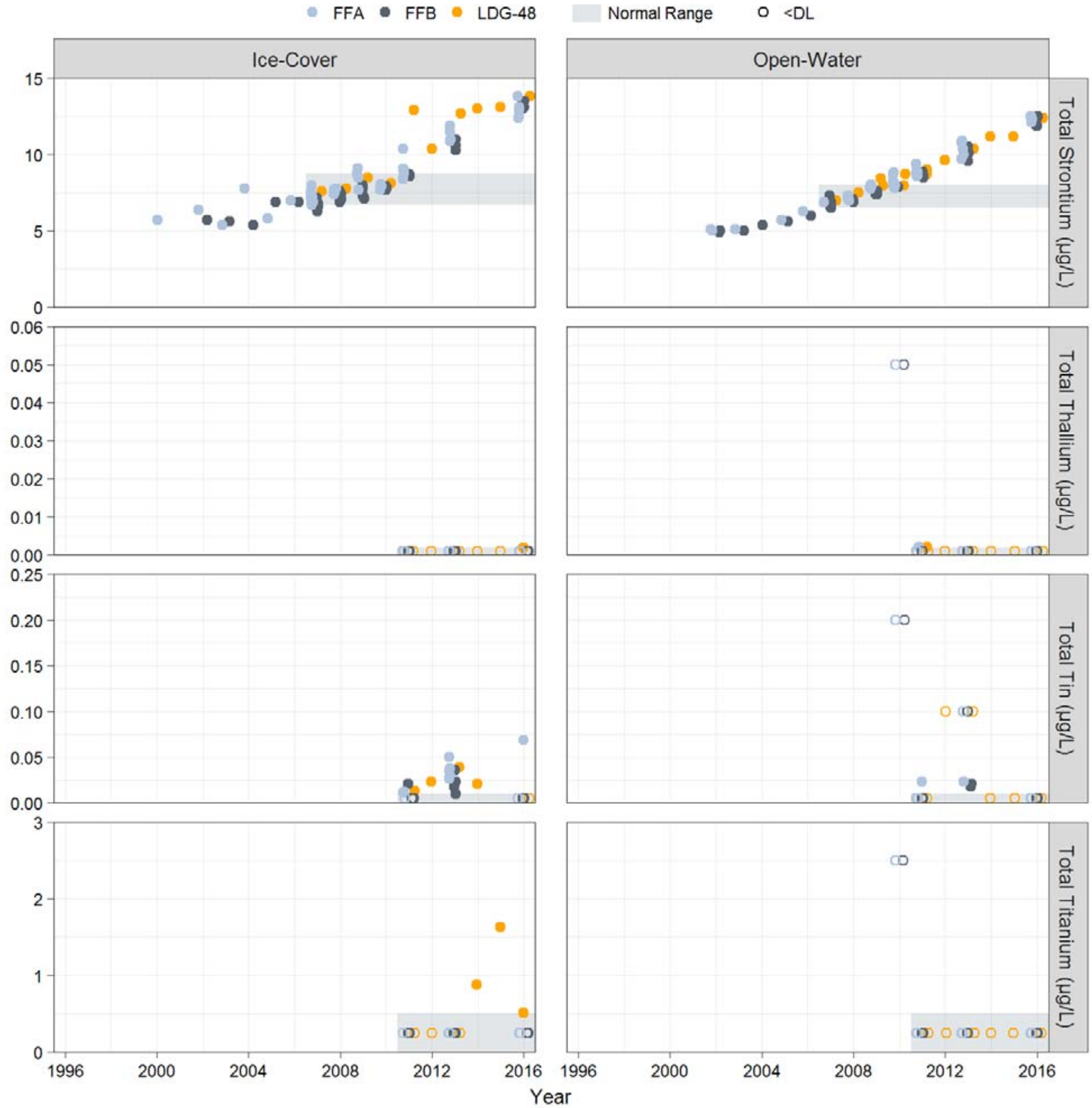
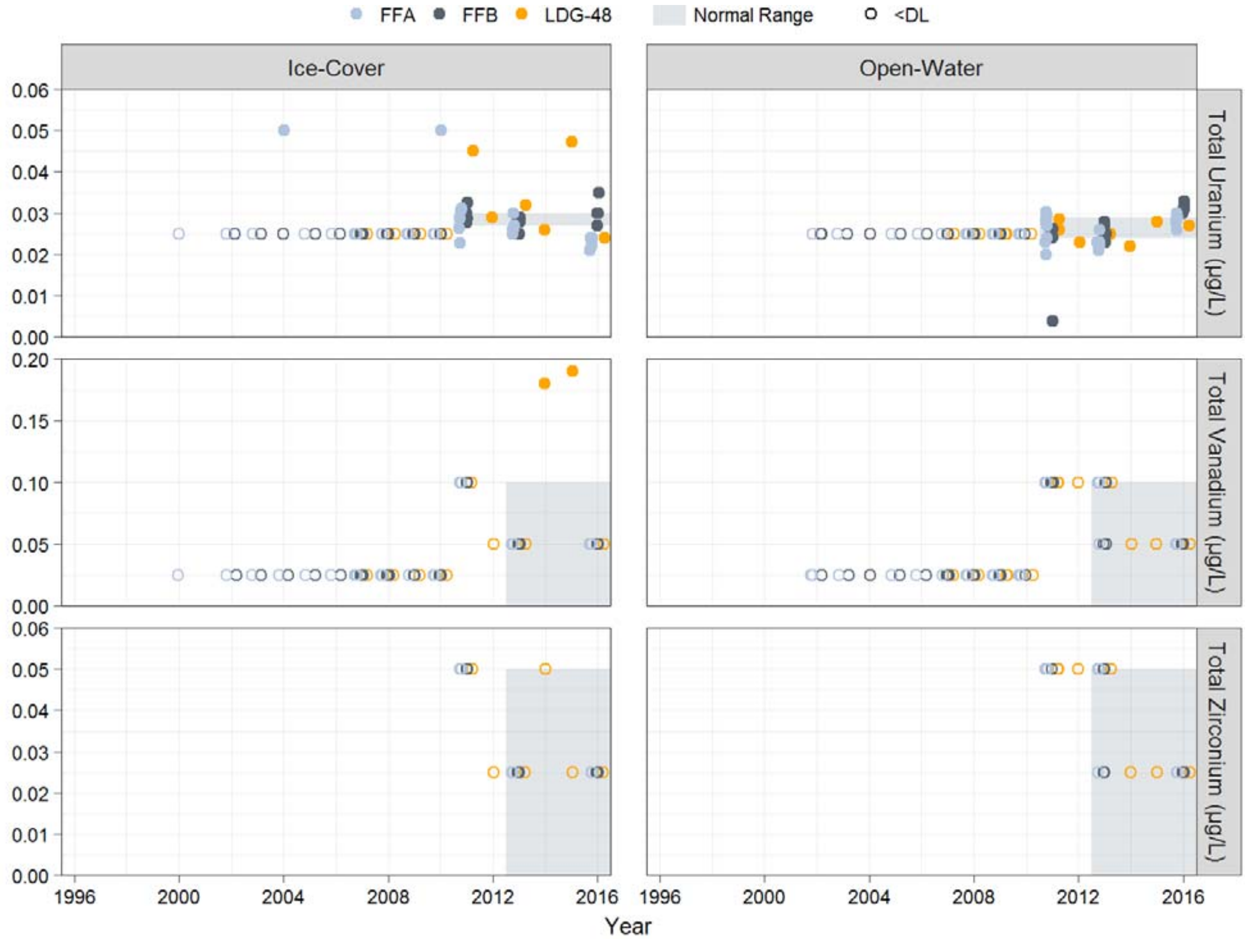
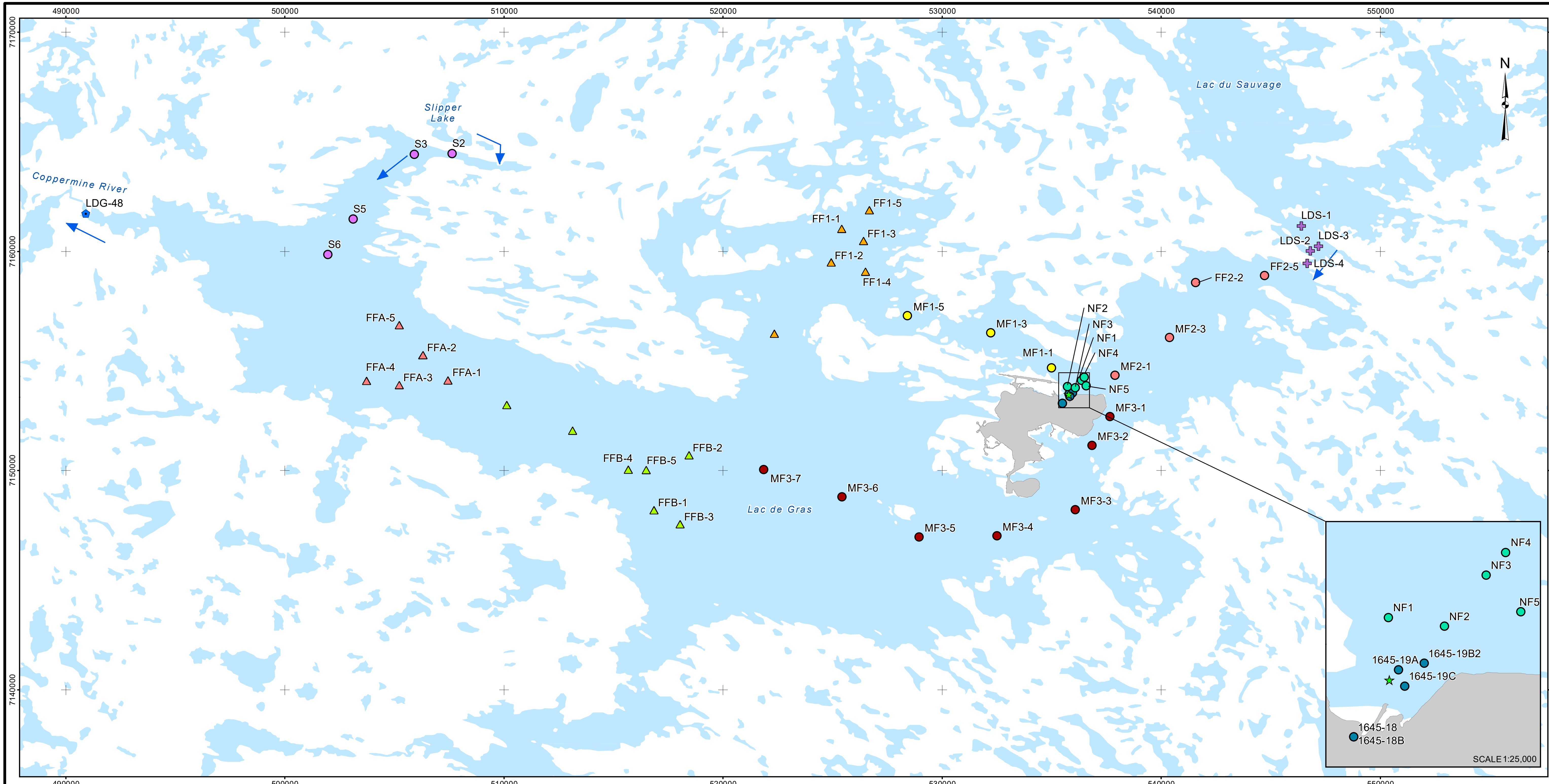


Figure 4-108 Total Uranium, Vanadium, and Zirconium at FFB, FFA, and Station LDG-48





LEGEND

★	DIFFUSERS
STATION LOCATION	
●	NEAR-FIELD
●	MID-FIELD 3
●	MID-FIELD 1
●	FAR-FIELD 2; MID-FIELD 2
▲	FAR-FIELD 1
▲	FAR-FIELD A
▲	FAR-FIELD B
●	EKATI SLIPPER BAY MONITORING STATION
●	SURVEILLANCE NETWORK PROGRAM
✚	LAC DU SAUVAGE
⬟	LDG 48
→	FLOW DIRECTION
■	DIAVIK FOOTPRINT
■	WATERBODY

5 0 5

SCALE 1:175,000 KILOMETRES

REFERENCE

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

PROJECT

[redacted]

TITLE

LOCATIONS OF AEMP WATER QUALITY SAMPLING STATIONS, 2017

[redacted]

PROJECT	1771843.4000		FILE No.	
DESIGN	TL	18 Jan. 2017	SCALE AS SHOWN	REV. 0
GIS	VV	14 Mar. 2018	**FIGURE: 4-109**	
CHECK	RS	14 Mar. 2018		
REVIEW	ZK	14 Mar. 2018		

I:\CLIENTS\DIAVIK\1771843\Mapping\MXD\Aquatics\2017AEMP_ReEvaluation_Report\Fig4-109_2016_Diavik_andEkati_LacDeGras_Stations_Rev0.mxd

4.3.2.2.4 Weight-of-Evidence Effect Ratings

In general, most water quality SOIs selected based on effluent discharge effects in a given year satisfied the requirement for an early warning/low WOE effect rating (Table 4-8; Table 4-25). A moderate rating was not applied to any of the SOIs in the years evaluated. Results of the WOE effects ranking for the water quality component over the years evaluated feed into the analysis conducted in Section 10.

Chloride, sodium, nitrate, molybdenum, and uranium consistently satisfied the requirement for an early warning/low-level rating in each of the 7 years evaluated (Table 4-25). Calculated TDS, turbidity, ammonia, barium, and strontium satisfied the requirement for an early warning/low-level rating most of the years evaluated (i.e., 5 or 6 years). Aluminum (since 2010); calcium, fluoride, and silicon (since 2011); and sulphate (since 2013) consistently satisfied the requirement for an early warning/low-level rating in recent years. Variables that once or sporadically satisfied the requirement for an early warning/low-level rating included antimony, chromium, copper, lead, tin, nitrite, and manganese. TSS, potassium, bismuth, cobalt, iron, thallium, titanium, vanadium, and zirconium did not satisfy the requirements for an early warning/low-level rating in the years when these variables were identified as SOIs by the Action Level screening. With the exception of potassium, these variables were identified as SOIs based on dike-related effects.

Table 4-25 Weight-of-Evidence Effect Ratings for Water Quality, 2007 to 2011, 2013 and 2016

Substance of Interest	2007	2008	2009	2010	2011	2013	2016
Conventional Parameters							
Total dissolved solids, calculated	0	↑	↑	↑	n/a	↑	↑
Total suspended solids	0	0	0	0	0	0	0[(c)]
Turbidity	↑	0	↑	↑	n/a	↑	↑
Major Ions							
Calcium	0	0	0	0	↑	↑	↑[(d)]
Chloride	↑	↑	↑	↑	↑	↑	↑
Fluoride	0	0	0	0	↑	↑	↑
Potassium	0	0	0	0	0	0	0
Sodium	0	↑	↑	↑	↑	↑	↑[(d)]
Sulphate	0	0	0	0	0	↑	↑
Nutrients							
Ammonia	↑	↑	↑	0	↑[(b)]	↑[(b)]	↑[(b)]
Nitrate	↑	↑	↑	↑	↑	↑	↑
Nitrite	0	0	0	0	0	0	↑
Total Metals							
Aluminum	0	0	0	↑	↑	↑	↑
Antimony	0	0	0	0	↑	↑	0
Barium	↑	↑	↑	↑	↑	↑	0
Bismuth	0	0	0	0	0	0	0[(c)]
Chromium	↑	0	0	0	0	↑	↑
Cobalt	0	0	0	0	0	0	0[(c)]
Copper	0[(a)]	0	0	↑	↑	0[(a)]	↑
Iron	0	0	0	0	0	0	0[(c)]
Lead	0	0	↑	0	0	0	↑
Manganese	0	0	0	0[(a)]	↑	0	0
Molybdenum	↑	↑	↑	↑	↑	↑	↑
Silicon	n/a	n/a	n/a	n/a	↑	↑	↑
Strontium	0	0	↑	↑	↑	↑	↑
Thallium	0	0	0	0	0	0	0[(c)]
Tin	n/a	n/a	n/a	n/a	0	↑	0
Titanium	0	0	0	0	0	0	0[(c)]
Uranium	↑	↑	↑	↑	↑	↑	↑
Vanadium	0	0	0	0	0	0	0
Zirconium	0	0	0	0	0	0	0[(c)]

Notes: 0 = no effect or not an SOI in that year; ↑ = early warning/low effect rating; n/a = not analyzed in one or both sampling seasons; WOE = weight-of-evidence.

WOE results are not shown for 2012, 2014, and 2015 because sampling of FF areas was not required in those years.

a) Variable identified as an SOI based on Action Level Results, but did not trigger a low effect rating.

b) WOE results for ammonia for 2011, 2013 and 2016 are uncertain due to laboratory quality control issues (Section 4.2.3.3 and Appendix 4B).

c) This variable was selected as an SOI based on Criterion 3, which relates to potential dust deposition or dike construction effects. In 2016, only those water quality SOIs that met criteria 1 (effluent screening) and 2 (Action Level 1) of the SOI selection procedure were evaluated in the WOE assessment.

d) In 2016, the WOE analysis involved consideration of dissolved and total concentrations; previously, analysis involved total concentrations.

4.4 Comparison to EA Predictions

The EA included predictions on the influence of effluent discharge on water quality at the mixing zone boundary, and dust deposition and dike construction on the water quality of Lac de Gras (DDMI 1998a). Predictions were also made during the EA regarding the dispersion of TDS, which would serve as an effluent tracer in Lac de Gras over time. This section provides a comparison of relevant AEMP data to these EA predictions. As outlined in the following sections, AEMP results are generally consistent with the EA predictions for water quality.

4.4.1.1.1 Water Quality at the Mixing Zone Boundary

The EA predicted that concentrations of water quality variables at the mixing zone boundary would be below guidelines for the protection of aquatic life. With the exception of chromium in 2004 and 2006, the monthly median concentration at the mixing zone boundary of the 13 SOIs with Effects Benchmarks were below benchmark values between 2002 and 2013 (Golder 2016a). The median concentration of chromium exceeded the AEMP Effects Benchmark during two sampling events (January 2006: median = 1.24 µg/L, and October 2006: median = 1.30 µg/L).

For the 2014 to 2016 re-evaluation period, the full suite of water chemistry data at the mixing zone boundary was compared to AEMP water quality Effects Benchmarks (Table 4-4). Mixing zone values that exceeded Effects Benchmarks are summarized in Table 4-26. Exceedances were typically associated with total copper and total manganese, which had corresponding dissolved concentrations that were below the benchmarks and well below the total concentrations. One of the copper exceedances and two of the manganese exceedances were associated with concentrations that were classified as anomalous values in the initial screening, as was the one zinc exceedance, which was reported in 2016. As well, the copper and manganese exceedances at the mixing zone that were not considered anomalous based on the data screening, occurred during periods of time when effluent concentrations of these variables were below the benchmark values (Figures 4-22 and 4-26). The total copper and manganese concentrations above benchmarks represent only 1.8% and 1.0%, respectively, of total concentrations of each variable measured during the 2014 to 2016 period.

The three dissolved aluminum concentrations that exceeded the benchmark on 4 July 2015 are likely erroneous, due to potential contamination associated with the filtering of the dissolved samples. The dissolved concentrations of aluminum were approximately five times the total concentrations; dissolved lead and zinc were also elevated in those samples compared to the total concentrations, although not to the same extent as the aluminum.

In addition to the parameters listed in Table 4-26, pH was below the lower Effects Benchmark in 2015 and 2016 on several occasions. More specifically, 43 and 47 pH measurements at the mixing zone boundary in 2015 and 2016, respectively, were below the Effects Benchmark value of 6.5. However, as illustrated in Figure 4-37 in Section 4.3.2.1.1, pH values are frequently less than 6.5 throughout Lac de Gras, in both ice-cover and open-water seasons, at various depths, and over time.

Overall, the SNP data are generally consistent with the EA prediction that concentrations at the mixing zone boundary would be below guidelines for the protection of aquatic life. The majority of variables with benchmarks were consistently below benchmarks at the mixing zone boundary during the AEMP monitoring period from 2002 to 2016. Between 2014 and 2016, only copper and manganese had verified (non-QC-issue related) exceedances of the benchmarks at the mixing zone boundary. However, these exceedences did not appear to be corroborated by concurrent effluent chemistry data and had corresponding dissolved concentrations that were below the benchmarks and well below the total concentrations.

Table 4-26 Mixing Zone Values that Exceeded Effects Benchmarks, 2014 to 2016

Variable	Units	Effects Benchmark	Concentration		SNP Station[a]	Date
			Total	Dissolved		
Aluminum (dissolved)	µg/L	50[b]	11.9	63.2[c]	1645-19B2-2	4 Jul 2015
			14.8	64.0[c]	1645-19B2-5	4 Jul 2015
			13.9	54.7[c]	1645-19B2-10	4 Jul 2015
Copper (total)	µg/L	2	2.11	0.51	1645-19B2-2	13 Jul 2014
			3.07	0.47	1645-19B2-10	18 Sep 2014
			2.41	0.47	1645-19C-10	18 Sep 2014
			9.41[d]	0.50	1645-19A-15	4 Dec 2014
			2.49	0.53	1645-19A-10	14 Aug 2015
			2.10	0.51	1645-19A-5	6 Sep 2015
			2.23	0.50	1645-19C-15	6 Sep 2015
			2.43	0.50	1645-19C-10	13 Mar 2016
Manganese (total)	µg/L	50	254[d]	0.21	1645-19A-2	10 Dec 2013[e]
			73.3	1.84	1645-19A-2	18 Sep 2014
			77.6	37.3	1645-19C-2	18 Sep 2014
			56.1	2.5	1645-19C-10	18 Sep 2014
			173	0.17	1645-19B2-20	14 Aug 2015
			266[d]	0.95	1645-19B2-15	13 Dec 2016
Zinc (total)	µg/L	30	40.5[d]	5.97	1645-19A-2	10 Sep 2016

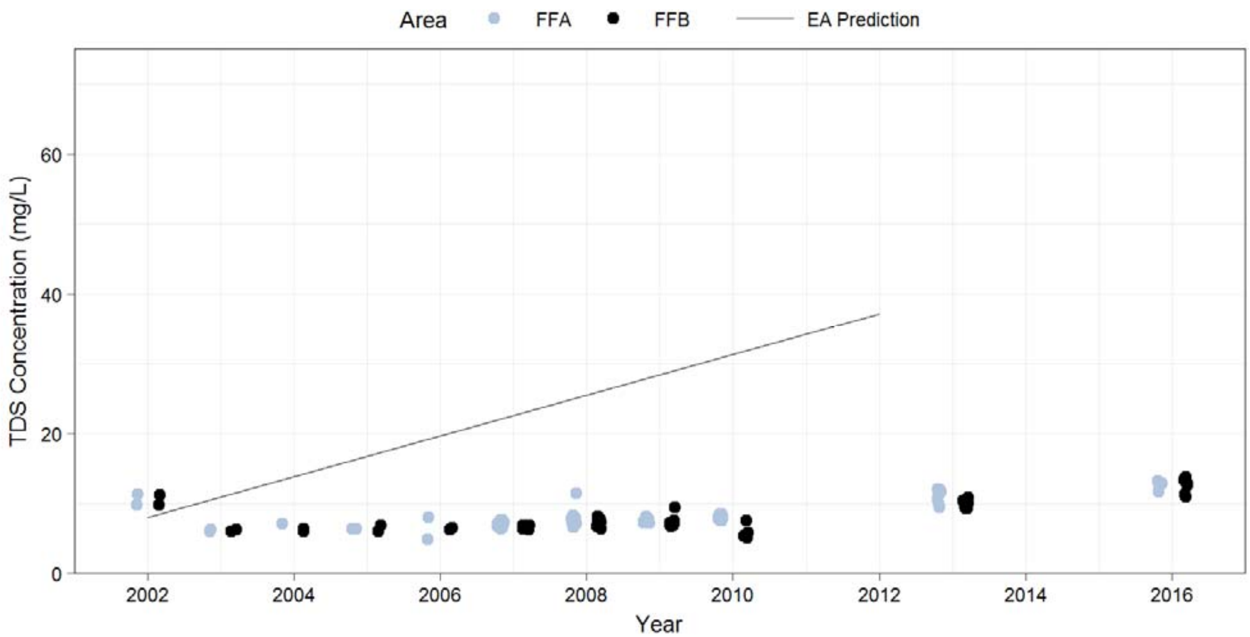
Note: Shaded cells identify values affected by quality control issues; these resuts are unlikely to represent Mine effects.
a) The last one or two digits of the station identifier indicate the sampling depth in metres.
b) The guideline value relevant to the pH of the three samples (>6.5) is shown.
c) These dissolved aluminum concentrations are considered most likely erroneous, due to potential contamination associated with the filtering of the dissolved samples; note the lower total aluminum concentrations for these samples.
d) These values were flagged as anomalous values in the initial data screening.
e) This 2013 exceedance was associated with the dataset for the *2014 AEMP Annual Report* (Golder 2016b).
SNP = Surveillance Network Program.

4.4.1.1.2 Total Dissolved Solids

Dispersion modelling during the EA was conducted for TDS (DDMI 1998a). For the modelling, TDS was simulated as a conservative variable that would act as an effluent tracer. Simulated TDS concentrations would reflect the effects of dispersion and dilution of the minewater discharge in Lac de Gras. Continuous dispersion modelling was conducted for a 10-year period simulating worst-case conditions on the west side of Lac de Gras.

The AEMP monitoring results are consistent with EA predictions for TDS. Although TDS from the effluent has reached the FF areas (Figure 4-41), the vast majority of TDS (calculated) concentrations are less than those predicted by the modelling, and the slope of the increasing trend in the FF areas is notably shallower than predicted in the EA (Figure 4-110).

Figure 4-110 Concentration of Total Dissolved Solids (Calculated) at Sampling Stations FFB and FFA Relative to the Predicted Concentration in the EA



Notes: TDS values are provided for both the ice-cover and open-water seasons. FFA concentrations are presented on the left side of the year tick mark on the X-axis, while FFB are presented on the right side of the tick mark.

4.4.1.1.3 Dust Deposition and Dike Construction

In the EA, the worst-case increase in TSS concentrations in Lac de Gras due to deposition of airborne dust was predicted to be 3 mg/L, which would translate into a negligible magnitude effect of mid-term duration (i.e., 3 to 30 years) in the local area (i.e., approximately 1 km around the dikes; DDMI 1998a). As described in Section 4.3.2.2.2, four MF area stations (i.e., MF1-1, MF2-1, MF3-1 and MF3-2) are located within the estimated ZOI for dust deposition, which has been defined as the area within approximately 1 km of the Mine boundary. In 2016, TSS exceeded two times the median of the reference dataset value in the MF3 area, but not the NF area; as such, the exceedance may be due to dike construction, or potentially (but less likely) dust deposition, rather than effluent discharge (Table 4-23). The MF3-1 and MF3-2 stations both had median TSS concentrations of 1.7 mg/L in August 2016, which is below the EA prediction of a 3 mg/L increase (Table 4-23). Since these concentrations are more likely to be attributable to the ongoing A21 dike construction at the time of sampling than dust deposition, the likely effect of dust deposition on TSS concentration in Lac de Gras is even less (or non-detectable) than suggested by the 2016 monitoring results.

The EA also predicted that construction of the dikes would cause some variables (e.g., aluminum, cadmium, copper, manganese) to exceed effects thresholds (i.e., Effects Benchmarks used in the EA) at the smallest assessment boundary (i.e., 0.01 km^2 or 60 m from the dike; DDMI 1998a), which would translate into a high magnitude effect of short-term duration (i.e., less than three years). The EA further predicted that at the next assessment boundary (i.e., 1 km^2 or 1 km distance from the dike), only aluminum would exceed the effects threshold, resulting in a low magnitude effect of short-term duration (DDMI 1998a). In 2016, aluminum, cadmium, copper, and manganese were elevated in the MF3 area at stations near the A21 dike (i.e., stations MF3-1, MF3-2, MF3-3, and MF3-4), together with TSS, turbidity, barium, bismuth, chromium, cobalt, iron, lead, lithium, nickel, silicon, thallium, tin, titanium, uranium, vanadium, zinc, and zirconium (Table 4-23, Figures 4-94 to 4-99 and supporting figures in Appendix D in Golder 2017c). However, concentrations of these variables at the dike-affected stations in 2016 were below the AEMP Effects Benchmarks for the protection of aquatic life and drinking water. The exception was three total aluminum samples collected at stations MF3-1 and MF3-2, which exceeded the AEMP Effects Benchmark of 100 µg/L.

4.5 Summary and Conclusions

The following conclusions can be drawn from the analysis of effluent and water quality data for the Mine SNP and AEMP over time:

- Mine effluent continues to meet EQC specified in the Water Licence.
- Effluent tested between 2002 and 2016 was generally non-toxic to aquatic test organisms, as shown in over 430 acute toxicity tests and over 290 sub-lethal toxicity tests.
- The annual loads of TDS and several associated ions (calcium, chloride, fluoride, potassium, and sodium) from the NIWTP increased over time from 2002 to approximately 2010, then remained at about the same level or declined slightly, until increasing again in 2015 and/or 2016, primarily reflecting the increases in the annual volume of effluent discharged over time. Effluent loads and/or concentrations of strontium and vanadium have also increased over time, consistent with increased effluent volume. The load of molybdenum in the effluent increased from 2002 to a peak in 2010, and has since slowly declined.
- Trends in the concentrations of SOIs at the mixing zone boundary generally reflected the temporal patterns described in the annual loading rates for these variables from effluent. The magnitude of the variation observed at the mixing zone, however, was often less pronounced than that in the effluent.
- The type of trends for SOIs at the AEMP stations/areas varied according to variable, season, and station/area, as illustrated in Table 4-27. The following general observations for trends in AEMP water quality data were made:
  - Concentrations of TDS (calculated), chloride, fluoride, calcium, potassium, sodium, and sulphate in Lac de Gras were greater than normal ranges in both the ice-cover and open-water seasons, and are generally increasing over time. These increases reflect trends in the loadings of these variables via the effluent discharge.
  - Molybdenum and strontium were consistently detected in Lac de Gras at concentrations above the normal range, particularly in the NF and MF areas, and were generally increasing over time in all areas, although the concentration of molybdenum in the NF has begun to decrease in recent years. These trends match those in the loads of these variables from the Mine effluent.

- Nitrate and uranium generally had decreasing or flat trends (i.e., slopes not statistically different from zero) in Lac de Gras over time, with the exception of increasing trends in nitrate at FF1 in the ice-cover season and uranium at MF3-4 in the open-water season.
- Logistic regression was used to analyze trends for antimony, lead and tin, the results of which indicated generally non-detect data in recent years, with the exception of lead in the open-water season.

- The majority of SOIs, except for those added to assess dike/dust effects, triggered either Action Level 1 or Action Level 2 during the period of evaluation (2007 to 2016). As a result of the Action Level 2 triggers, DDMI has developed Effects Benchmarks for turbidity, dissolved sodium, total aluminum, total antimony, total silicon, and total tin. These Effects Benchmarks are described in the *AEMP Design Plan Version 4.1* (Section 5.3 in Golder 2017d) and will be used in the water quality analysis in subsequent years.
- Results from the 2016 sampling event indicated the potential effects of the A21 dike construction on water quality in the MF areas, as illustrated by elevated concentrations/levels for TSS, turbidity, aluminum, bismuth, chromium, cobalt, copper, iron, lead, manganese, silicon, thallium, titanium, uranium, vanadium, and zirconium.
- Greater ice-cover season concentrations of TDS, calcium, chloride, potassium, sodium, sulphate, molybdenum and strontium at Station LDG-48 at the lake outlet and/or the FFA area, compared to areas closer to the Mine (i.e., FFB), are potentially indicative of cumulative effects of the Diavik and Ekati mine discharges. While these results suggest cumulative effects may be occurring in the western region of Lac de Gras, concentrations of the affected variables in the zone of confluence in Lac de Gras remained low, and additive effects were minor and not apparent in all years of monitoring.
- In general, results of the AEMP are consistent with EA predictions related to water quality at the mixing zone boundary, potential effects of dust deposition and dike construction on the water quality of Lac de Gras, and TDS concentration in the FF areas of Lac de Gras.

Table 4-27 Trend Summary for Water Quality Substances of Interest

Substances of Interest	Ice-cover Season[(c)]							Open-water Season[(c)]						
	NF	MF1-3	FF2-2	MF3-4	FF1	FFB	FFA	NF	MF1-3	FF2-2	MF3-4	FF1	FFB	FFA
Conventional Parameters														
Total dissolved solids, calculated	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑
Total suspended solids[(a)]	na	na	na	na	na	na	na	na	na	na	na	na	na	na
Turbidity	↓	ns	ns	ns	ns	ns	↓	ns	ns	ns	↑	ns	ns	ns
Major Ions														
Calcium (total)	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑
Chloride	—	—	↑	↑	↑	↑	↑	↑ —	↑	↑	↑	↑	↓	↑
Fluoride	ns	↑	ns	ns	↑	↑	↑	↑	ns	↑	ns	↑	↑	
Potassium (total)	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑
Sodium (total)	↑ —	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑
Sulphate	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	ns	↑	↑
Nutrients														
Ammonia[(a)]	na	na	na	na	na	na	na	na	na	na	na	na	na	na
Nitrate	↓	↓	↓	—	↑	na	na	na	na	na	na	na	na	na
Nitrite[(a)]	na	na	na	na	na	na	na	na	na	na	na	na	na	na
Total Metals														
Aluminum	ns	ns	ns	ns	ns	ns	ns	—	—	—	—	—	—	—
Antimony[(b)]	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓
Barium	↓	↓	↓	↑	↑ —	↑ —	↑ —	↓	↓	↓	↑	↑ —	↑ —	↑ —
Bismuth[(a)]	na	na	na	na	na	na	na	na	na	na	na	na	na	na
Chromium[(a)]	na	na	na	na	na	na	na	na	na	na	na	na	na	na
Cobalt	ns	ns	ns	↑	↑	↑	↑	↑	ns	ns	↑	ns	ns	↑
Copper	ns	ns	ns	↑	ns	ns	ns	ns	ns	ns	↑	↑	ns	↑
Iron	ns	ns	ns	↑	↑	↑	↑	↑	ns	ns	↑	↑	↑	↑

Table 4-27 Trend Summary for Water Quality Substances of Interest

Substances of Interest	Ice-cover Season(c)							Open-water Season(c)						
	NF	MF1-3	FF2-2	MF3-4	FF1	FFB	FFA	NF	MF1-3	FF2-2	MF3-4	FF1	FFB	FFA
Lead(b)	↓	↓	↓	↓	↓	↓	↓	↑	↑	↑	↑	↑	↑	↑
Manganese	↑	↑	↑	↑	↑	↑	↑	↑	ns	ns	ns	↑	ns	ns
Molybdenum	↓	—	↑	↑	↑	↑	↑	↑ —	↑	↑	↑	↑	↑	↑
Silicon(a)	na	na	na	na	na	na	na	na	na	na	na	na	na	na
Strontium	↑ —	↑ —	↑ —	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑
Thallium(a)	na	na	na	na	na	na	na	na	na	na	na	na	na	na
Tin(b)	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓
Titanium(a)	na	na	na	na	na	na	na	na	na	na	na	na	na	na
Uranium	↓	↓	↓	ns	ns	ns	↓	↓ —	↓	—	↑	—	—	—
Vanadium(a)	na	na	na	na	na	na	na	na	na	na	na	na	na	na
Zirconium(a)	na	na	na	na	na	na	na	na	na	na	na	na	na	na

a) Variable could not be assessed because of the high percentage of values less than the detection limit, or in the case of ammonia, due to quality control issues with the data.

b) Variable was assessed using logistic regression because of elevated numbers of values less than the detection limit.

c) Linear trends with slopes that are significantly different from a slope of zero have been reported. Parabolic trends have been summarized based on visual inspections of the trend plots for recent years, particularly those past the vertex of the parabola when applicable.

↑ = increasing trend; ↓ = decreasing trend; — = no trend or no consistent trend; ↑ — or ↓ — = potential slightly increasing or slightly decreasing trend; na = not available; ns = linear slope is not significantly different from a slope of zero.