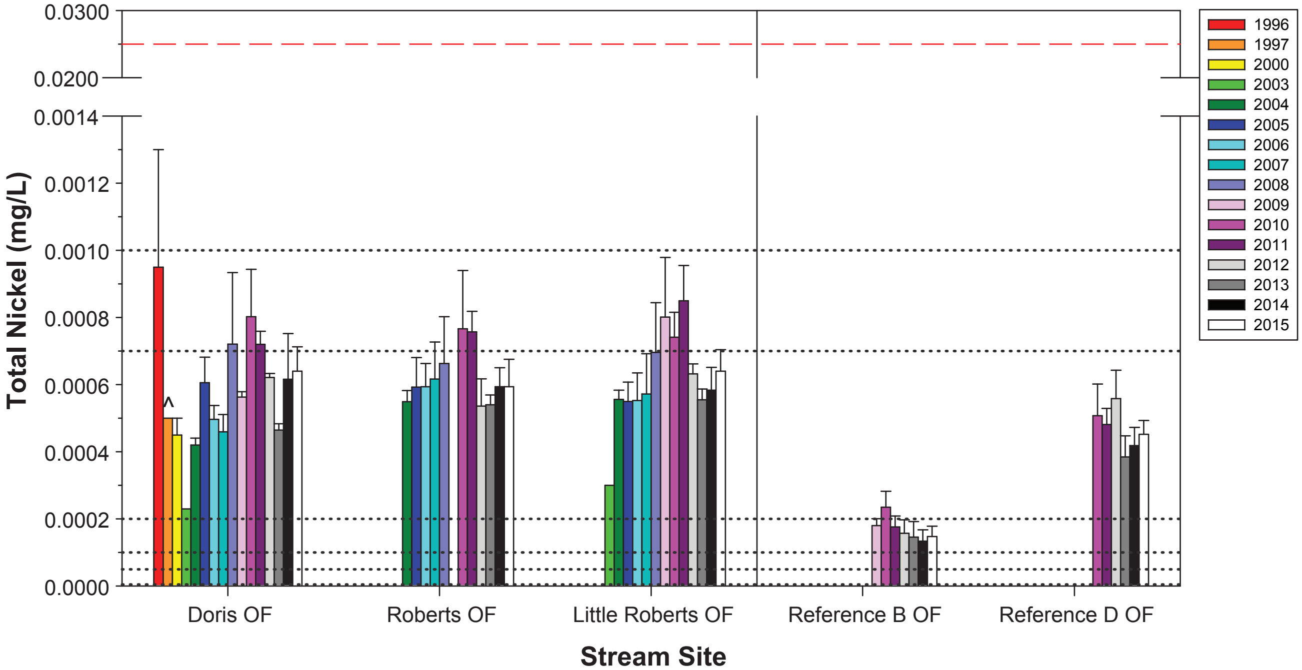
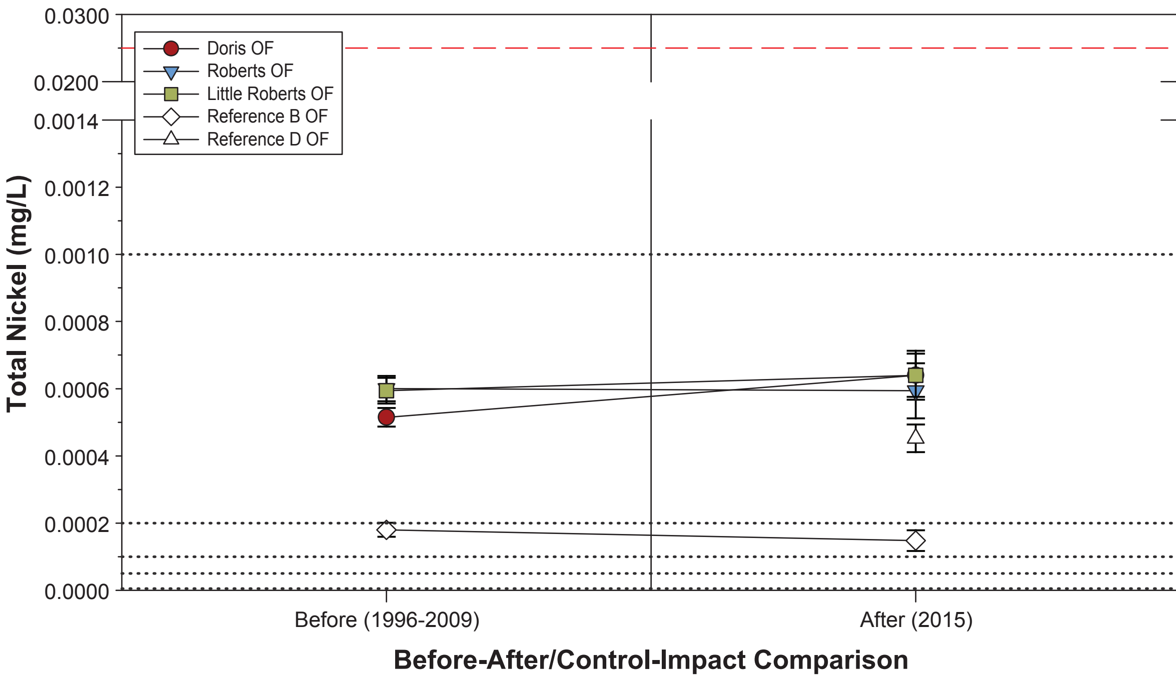
Figure 3.3-17

Total Nickel Concentration in AEMP Stream Sites, Doris North Project, 1996 to 2015





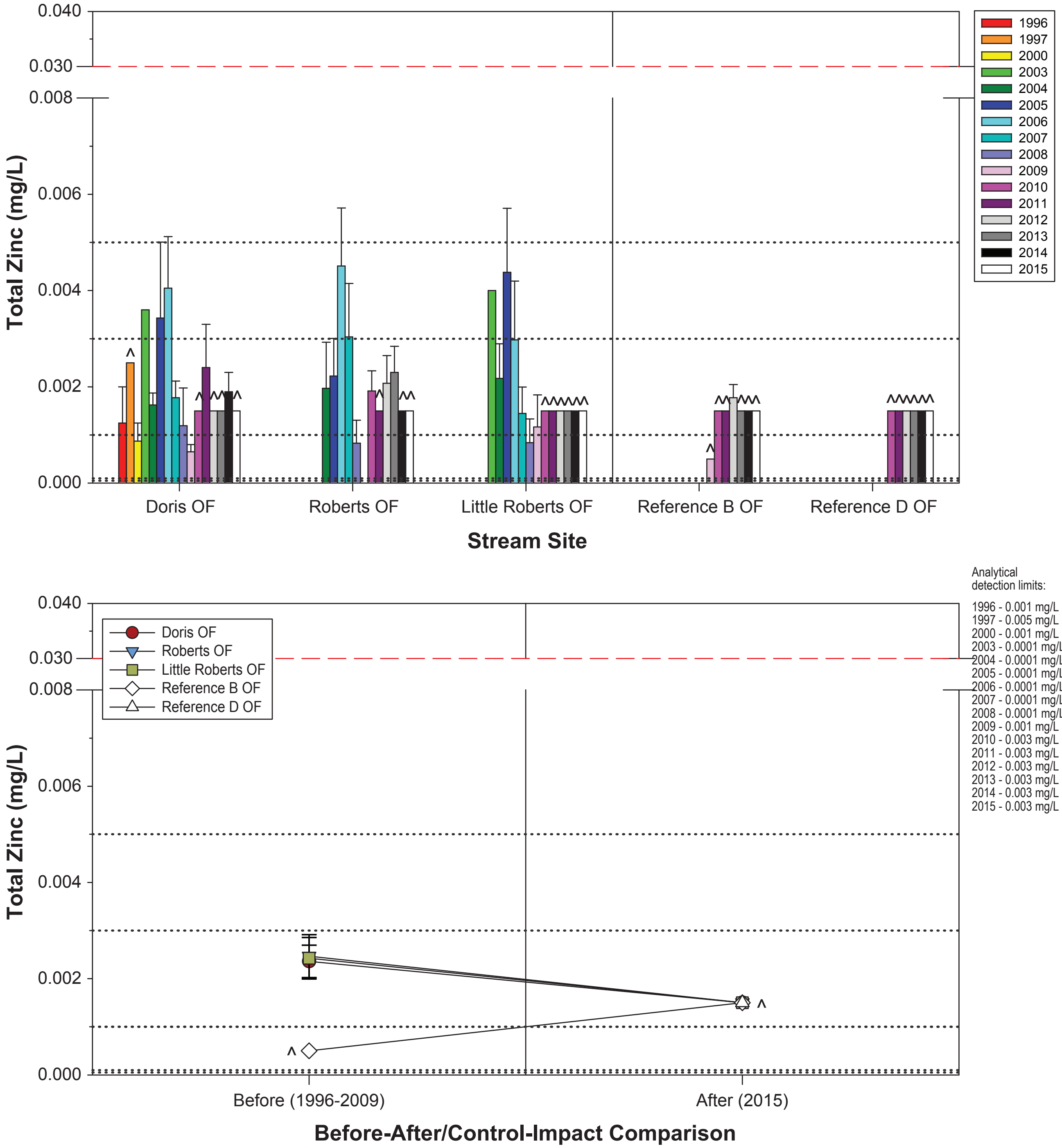
Analytical detection limits:

1996 - 0.0001 mg/L
1997 - 0.001 mg/L
2000 - 0.0001 mg/L
2003 - 0.00005 mg/L
2004 - 0.000005 mg/L
2005 - 0.000005 mg/L
2006 - 0.000005 mg/L
2007 - 0.000005 mg/L
2008 - 0.000005 mg/L
2009 - 0.0001 mg/L
2010 - 0.0002 mg/L
2011 - 0.0002 mg/L
2012 - 0.0002 or 0.0007 mg/L
2013 - 0.0002 mg/L
2014 - 0.0002 mg/L
2015 - 0.0002 mg/L

Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
The CCME freshwater guideline for nickel is hardness dependent.
Red dashed lines represent the minimum CCME freshwater guideline for nickel regardless of water hardness (0.025 mg/L).
Total nickel is regulated as a deleterious substance in effluents as per Schedule 4 of the MMER.

Figure 3.3-18

Total Zinc Concentration in AEMP Stream Sites, Doris North Project, 1996 to 2015



Analytical detection limits:

1996 - 0.001 mg/L
1997 - 0.005 mg/L
2000 - 0.001 mg/L
2003 - 0.0001 mg/L
2004 - 0.0001 mg/L
2005 - 0.0001 mg/L
2006 - 0.0001 mg/L
2007 - 0.0001 mg/L
2008 - 0.0001 mg/L
2009 - 0.001 mg/L
2010 - 0.003 mg/L
2011 - 0.003 mg/L
2012 - 0.003 mg/L
2013 - 0.003 mg/L
2014 - 0.003 mg/L
2015 - 0.003 mg/L

Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
Red dashed lines represent the CCME freshwater guideline for zinc (0.03 mg/L).
Total zinc is regulated as a deleterious substance in effluents as per Schedule 4 of the MMER.

Because of comparability in lake sizes, Reference Lake B was used as a reference site for the Doris Lake sites (these larger lakes are both > 3 km^2 in surface area) and Reference Lake D was used as a reference site for Little Roberts Lake (these smaller lakes are both < 1 km^2 in surface area). There was little evidence of vertical physico-chemical stratification in any lake, so all samples were included in graphical and statistical analyses regardless of depth of sampling, and no depth effect was introduced into statistical models. Because no baseline data were available for Reference Lake D, no statistical analyses were possible for this lake, and no BACI analysis was possible for Little Roberts Lake. Graphs showing water quality trends in lakes over time are shown in Figures 3.3-19 to 3.3-36. All statistical results are presented in Appendix B.

3.3.2.1 pH

pH is a required variable for water quality monitoring as per Schedule 5, s. 7(1)(c) of the MMER. pH levels measured in 2015 in exposure lakes were within the recommended CCME guideline range of 6.5 to 9.0, and were similar to baseline pH levels (Figure 3.3-19). The before-after analysis showed that the mean baseline pH levels were not statistically distinguishable from the mean 2015 pH for Doris Lake South ($p = 0.16$) and Doris Lake North ($p = 0.19$). However, in Little Roberts Lake, there was a significant increase in pH from baseline years (mean pH of 7.22) to 2015 (mean pH of 7.68; $p = 0.0015$). The mean 2015 pH in Little Roberts Lake of 7.68 remained within the optimal pH range for freshwater aquatic life (CCME 2015b). A BACI analysis was not possible to determine if a parallel change occurred in Reference Lake D since there were no baseline data available for this reference lake. However, pH did increase significantly at Reference Lake B in 2015 compared to 2009 ($p = 0.043$), suggesting that slight annual variation in pH levels can occur naturally and is not necessarily related to the Project. Given that there were no pH changes in waterbodies upstream of Little Roberts Lake and that a similar change occurred in one of the reference lakes, it is unlikely that Project activities had an effect on pH in Little Roberts Lake.

3.3.2.2 Total Alkalinity

Total alkalinity is a required variable for effluent characterization and water quality monitoring as per Schedule 5, s. 4(1) and s. 7(1)(c) of the MMER. Total alkalinity (as $CaCO_3$) levels measured in 2015 were slightly higher than baseline alkalinity levels (Figure 3.3-20); however, the before-after analysis confirmed that the slight increase was not statistically significant for the exposure lakes ($p = 0.089$ for Doris Lake South, $p = 0.088$ for Doris Lake North, and $p = 0.91$ for Little Roberts Lake). Thus, there was no evidence that 2015 Project activities affected total alkalinity in exposure lakes.

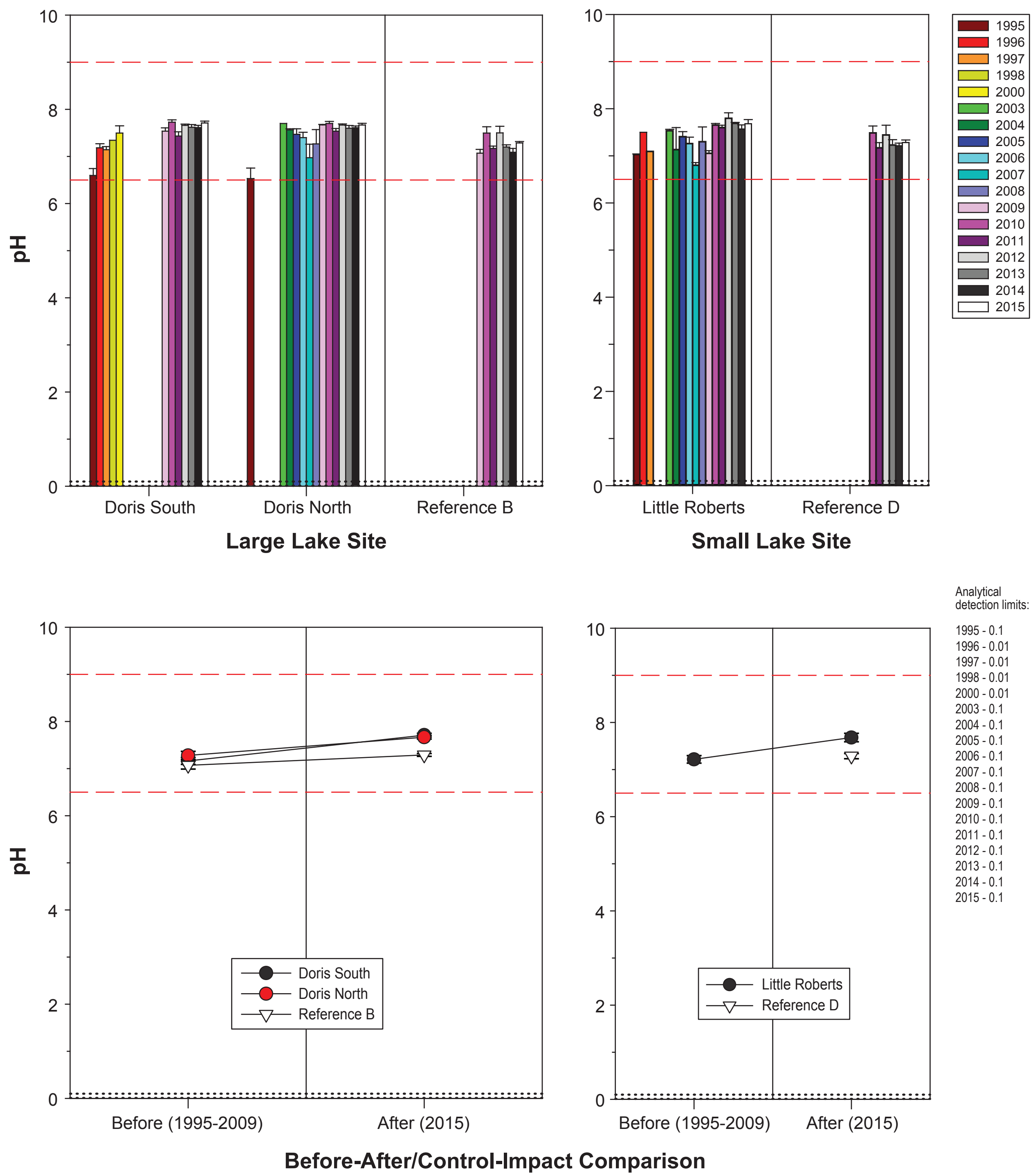
3.3.2.3 Hardness

Hardness is a required variable for effluent characterization and water quality monitoring as per Schedule 5, s. 4(1) and s. 7(1)(c) of the MMER. At the exposure lakes, 2015 mean hardness levels were slightly higher than baseline means (Figure 3.3-21). The before-after analysis indicated that this increase was statistically significant for Doris Lake South ($p = 0.027$) but not for Doris Lake North ($p = 0.083$) or Little Roberts Lake ($p = 0.84$). The BACI analysis further revealed that the change in hardness at Doris Lake South was paralleled at Reference Lake B ($p = 0.69$); therefore, the difference in hardness levels in Doris Lake South between baseline years and 2015 was likely attributable to a natural process, and there was no evidence that 2015 Project activities had an effect on lake water hardness.

Figure 3.3-19

pH in AEMP Lake Sites, Doris North Project, 1995 to 2015

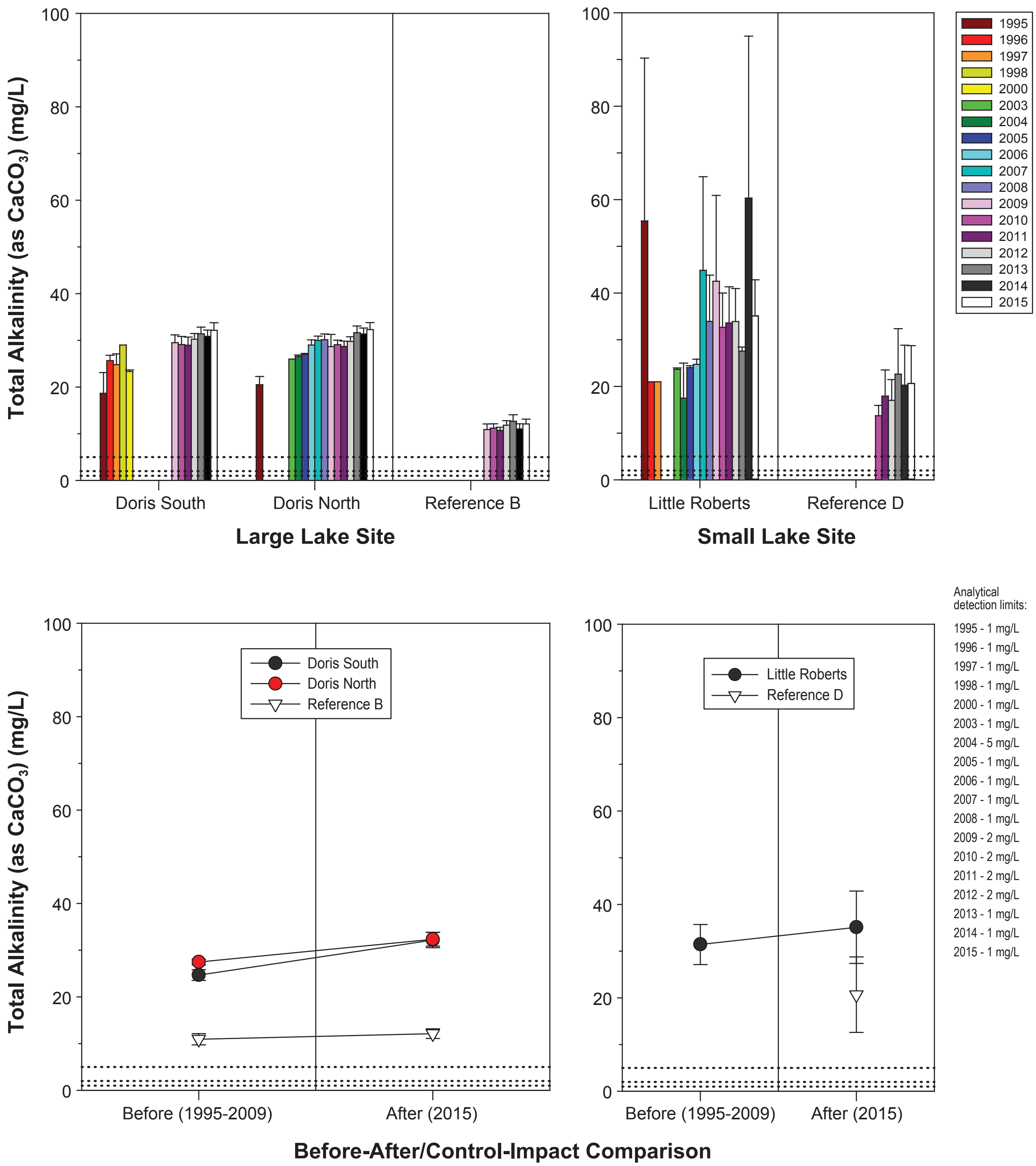
ERM



Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits.
Red dashed lines represent the CCME freshwater guideline pH range (6.5–9.0).
pH is a required parameter for water quality monitoring as per Schedule 5, s. 7(1)(c) of the MMER.

Figure 3.3-20

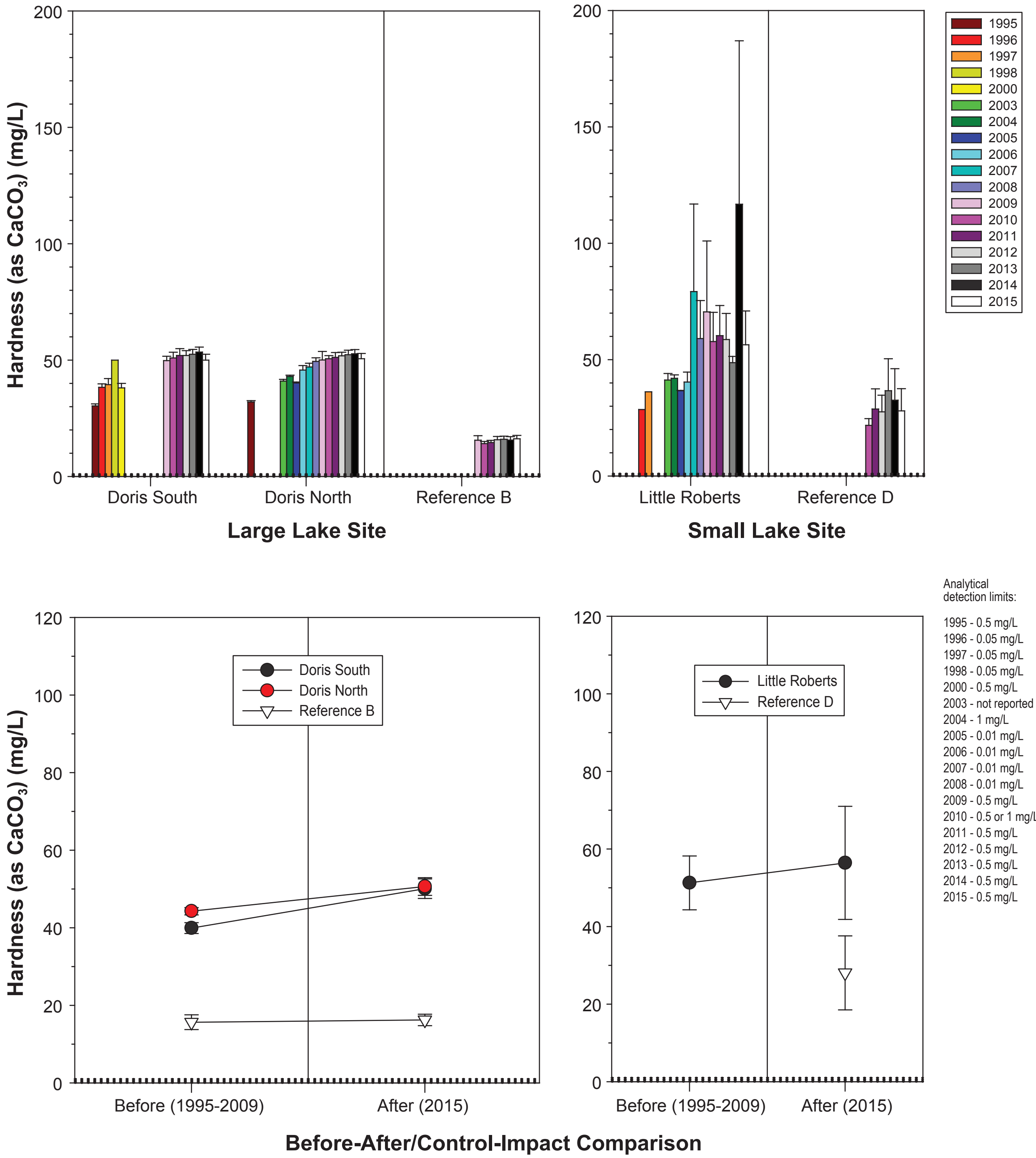
Total Alkalinity in AEMP Lake Sites, Doris North Project, 1995 to 2015



Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
Total alkalinity is a required parameter for effluent characterization and water quality monitoring as per Schedule 5, s. 4(1) and s. 7(1)(c) of the MMER.

Figure 3.3-21

Hardness in AEMP Lake Sites, Doris North Project, 1995 to 2015



Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits.
Hardness is a required parameter for effluent characterization and water quality monitoring as per Schedule 5, s. 4(1) and s. 7(1)(c) of the MMER.

3.3.2.4 Total Suspended Solids

TSS are regulated as deleterious substances in effluents as per Schedule 4 of the MMER. Mean TSS concentrations were inter-annually variable, particularly in Little Roberts Lake (Figure 3.3-22). Mean 2015 TSS concentrations measured in the exposure lakes were within the range of baseline concentrations, and the before-after analysis showed that 2015 means were not statistically different from baseline means in any of the exposure lake sites (p = 0.91 for Doris Lake South, p = 0.76 for Doris Lake North, and p = 0.24 for Little Roberts Lake). Therefore, there was no apparent effect of 2015 activities on TSS levels in these lakes.

The CCME guideline for TSS is dependent upon background levels (for clear-flow waters with background TSS levels below 25 mg/L, a maximum increase of 25 mg/L is allowable for any short-term exposure or 5 mg/L for longer term exposure; CCME 2015b). Because there was no increase in TSS concentrations from background levels, 2015 TSS concentrations in exposure lakes were below the CCME guideline.

3.3.2.5 Total Ammonia

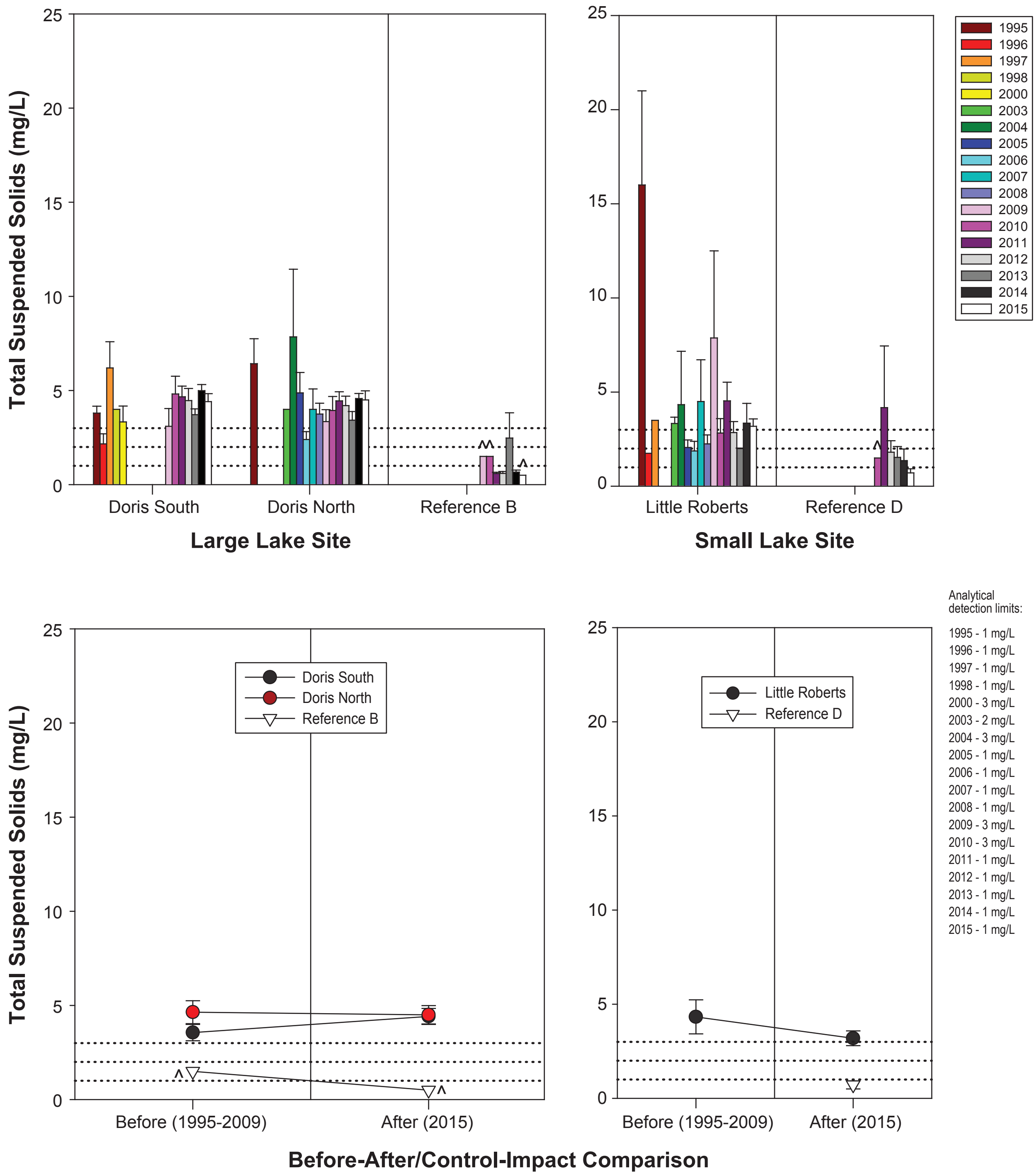
Total ammonia is a required variable for effluent characterization as per Schedule 5, s. 4(1) of the MMER. Baseline and 2015 concentrations of total ammonia in exposure and reference lakes were well below the pH- and temperature-dependent CCME guideline (Figure 3.3-23). Mean 2015 total ammonia concentrations at the exposure lakes were lower than baseline means; however, the before-after analysis determined that there was no significant difference between baseline and 2015 means for any exposure lake site (p = 0.12 for Doris Lake South, p = 0.11 for Doris Lake North, and p = 0.14 for Little Roberts Lake). Therefore, there was no evidence of an adverse effect of 2015 Project activities on ammonia concentrations at these sites.

3.3.2.6 Nitrate

Nitrate is a required variable for effluent characterization as per Schedule 5, s. 4(1) of the MMER. Both within-year and inter-annual variability in nitrate concentrations were relatively high in the exposure and reference lakes (Figure 3.3-24). Nitrate concentrations measured in exposure lakes in 2015 were well below the long-term CCME guideline of 3.0 mg nitrate-N/L (Figure 3.3-24). All 2015 nitrate concentrations measured in Doris Lake South and North were below the analytical detection limit of 0.005 mg/L, so there was no evidence of an adverse effect of Project activities on nitrate concentrations in this lake. In Little Roberts Lake, 88% of nitrate concentrations were below the detection limit in the 2015 dataset, and 68% of concentrations were below the detection limit in the combined baseline and 2015 dataset. The before-after comparison showed that the baseline and 2015 mean nitrate concentrations were not significantly different (p = 0.28). These results indicate that Project activities did not adversely affect nitrate concentrations in exposure lakes in 2015.

Figure 3.3-22

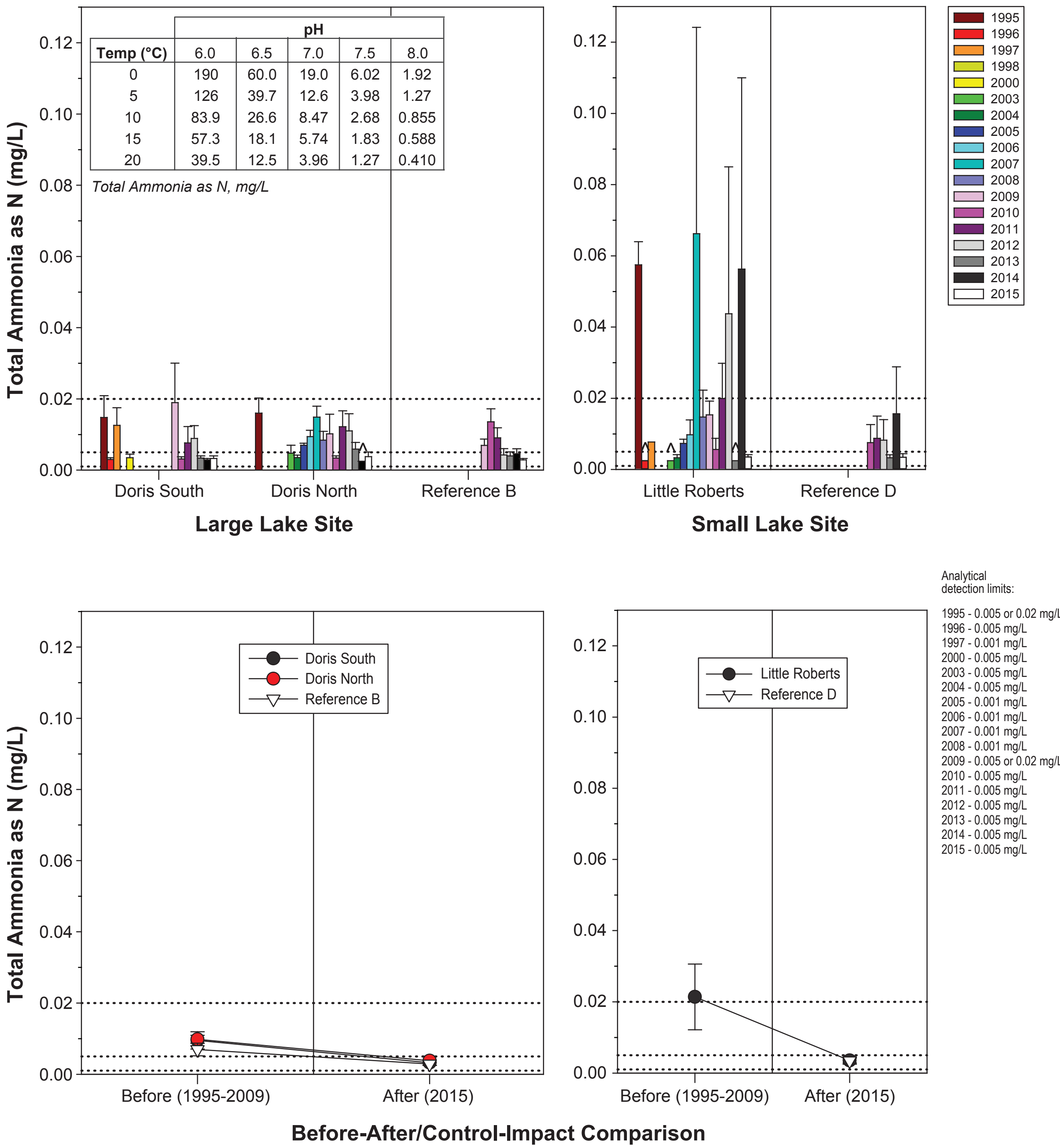
Total Suspended Solids in AEMP Lake Sites, Doris North Project, 1995 to 2015



Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
^ Indicates that concentrations were below the detection limit in all samples.
The CCME freshwater guideline for total suspended solids is dependent upon background levels.
Total suspended solids are regulated as deleterious substances in effluents as per Schedule 4 of the MMER.

Figure 3.3-23

**Total Ammonia in AEMP Lake Sites,
Doris North Project, 1995 to 2015**



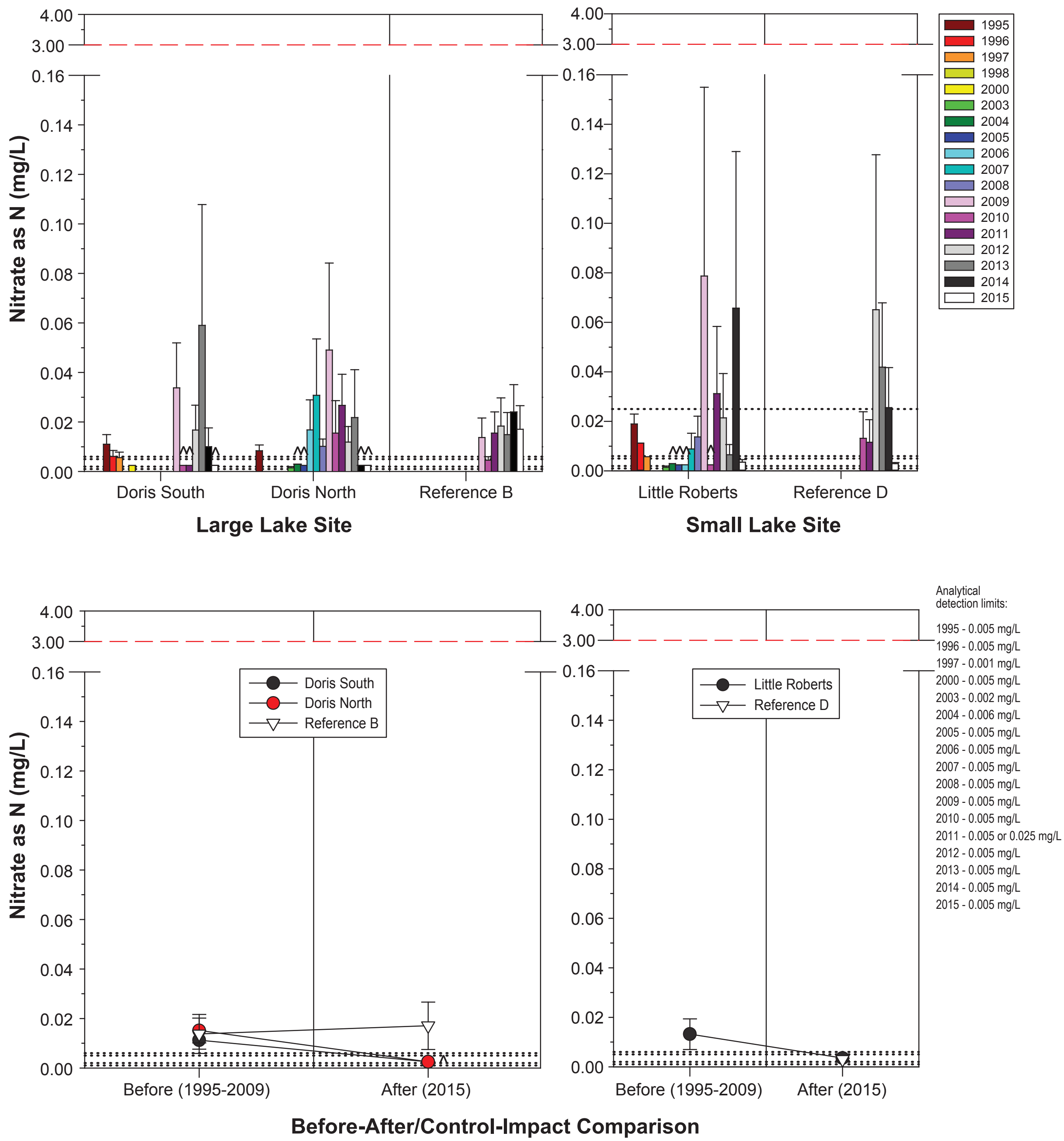
	pH				
Temp (°C)	6.0	6.5	7.0	7.5	8.0
0	190	60.0	19.0	6.02	1.92
5	126	39.7	12.6	3.98	1.27
10	83.9	26.6	8.47	2.68	0.855
15	57.3	18.1	5.74	1.83	0.588
20	39.5	12.5	3.96	1.27	0.410

Total Ammonia as N, mg/L

Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
^ Indicates that concentrations were below the detection limit in all samples.
Inset table shows the pH- and temperature-dependent CCME freshwater guideline for total ammonia.
Total ammonia is a required parameter for effluent characterization as per Schedule 5, s. 4(1) of the MMER.

Figure 3.3-24

Nitrate in AEMP Lake Sites, Doris North Project, 1995 to 2015



Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
^ Indicates that concentrations were below the detection limit in all samples.
Red dashed line represents the CCME freshwater guideline for nitrate as N (3.0 mg/L; long-term concentration).
The anomalously high nitrate concentrations of 4.51 mg/L reported for Doris South in August 1996 and 5.3 mg/L reported for Little Roberts Lake in September 2004 were considered outliers and was excluded from plots.
Nitrate is a required parameter for effluent characterization as per Schedule 5, s. 4(1) of the MMER.

3.3.2.7 Total Cyanide

Total cyanide is regulated as a deleterious substance in effluents as per Schedule 4 of the MMER. All total cyanide concentrations measured in exposure and reference lakes in 2015 were below the analytical detection limit of 0.001 mg/L (Figure 3.3-25). Therefore, there was no evidence of an increase in total cyanide concentrations due to 2015 Project activities.

Free cyanide concentrations (cyanide existing in the form of HCN and CN^-) in lake samples were measured in 2015 to allow for direct comparisons with the CCME guideline for cyanide (0.005 mg/L as free cyanide). Concentrations of free cyanide in lakes samples were always below the detection limit of 0.001 mg/L, with the exception of a single sample collected from Little Roberts Lake in September 2015 which had a free cyanide concentration of 0.0011 mg/L (just over the detection limit; Appendix A). Therefore, all free cyanide concentrations measured in lakes in 2015 were well below the CCME guideline and would not be expected to pose a threat to freshwater aquatic life.

3.3.2.8 Radium-226

Radium-226 is regulated as a deleterious substance in effluents as per Schedule 4 of the MMER. Because of the high proportion of non-detectable radium-226 concentrations (> 75%) in the combined baseline and 2015 datasets for the exposure lake sites, statistical results are not discussed. Radium-226 concentrations at the exposure sites were near or below the analytical detection limit, and were similar to baseline concentrations (Figure 3.3-26). Therefore, there was no evidence of an increase in radium-226 concentrations due to 2015 Project activities.

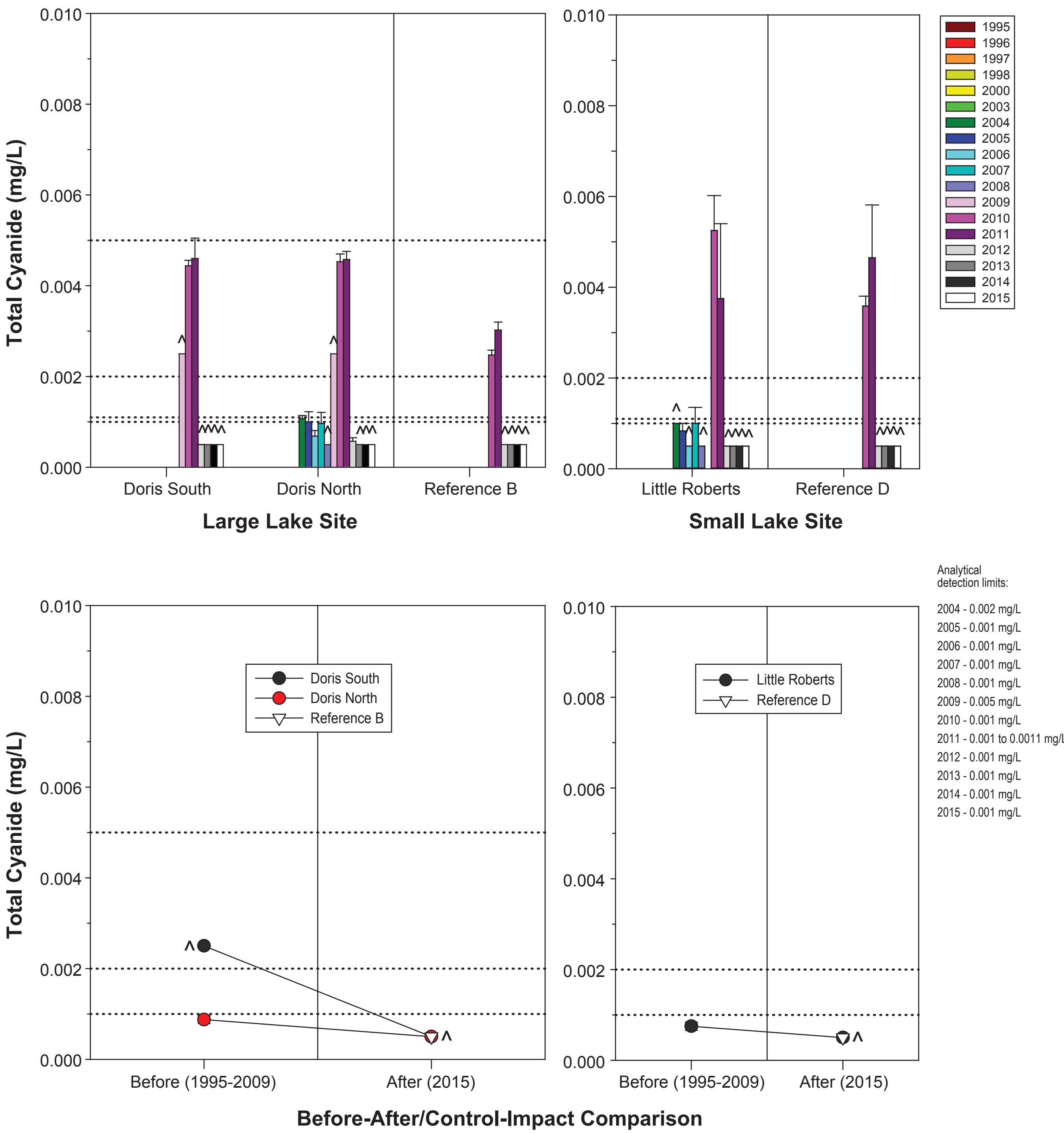
3.3.2.9 Total Aluminum

Total aluminum is a required variable for effluent characterization as per Schedule 5, s. 4(1) of the MMER. In the exposure lake sites, mean 2015 total aluminum concentrations were within the range of baseline means, and below the pH-dependent CCME guideline of 0.1 mg/L (Figure 3.3-27). The before-after analysis confirmed that the mean 2015 total aluminum concentration was not distinguishable from the baseline mean for any exposure lake site ($p = 0.70$ for Doris Lake South, $p = 0.91$ for Doris Lake North, and $p = 0.46$ for Little Roberts Lake). Therefore, there was no apparent effect of 2015 Project activities on total aluminum concentrations in the exposure lakes.

3.3.2.10 Total Arsenic

Total arsenic is regulated as a deleterious substance in effluents as per Schedule 4 of the MMER. Mean 2015 total arsenic concentrations in exposure lakes were well below the CCME guideline of 0.005 mg/L, and were similar to or less than baseline means (Figure 3.3-28). The before-after comparison indicated that there was no difference between the 2015 mean total arsenic concentration and the baseline mean at Doris Lake South ($p = 0.42$) and Little Roberts Lake ($p = 0.48$). The mean 2015 total arsenic concentration at Doris Lake North was significantly lower than the baseline mean ($p = 0.0019$); however, this was an artifact of the substitution of values that were below detection with half the analytical detection limit instead of the full detection limit, which would have resulted in the means being indistinguishable from each other ($p = 0.13$). Regardless, since the change was a decrease, there was no adverse effect of 2015 Project activities on total arsenic concentrations in the exposure lakes.

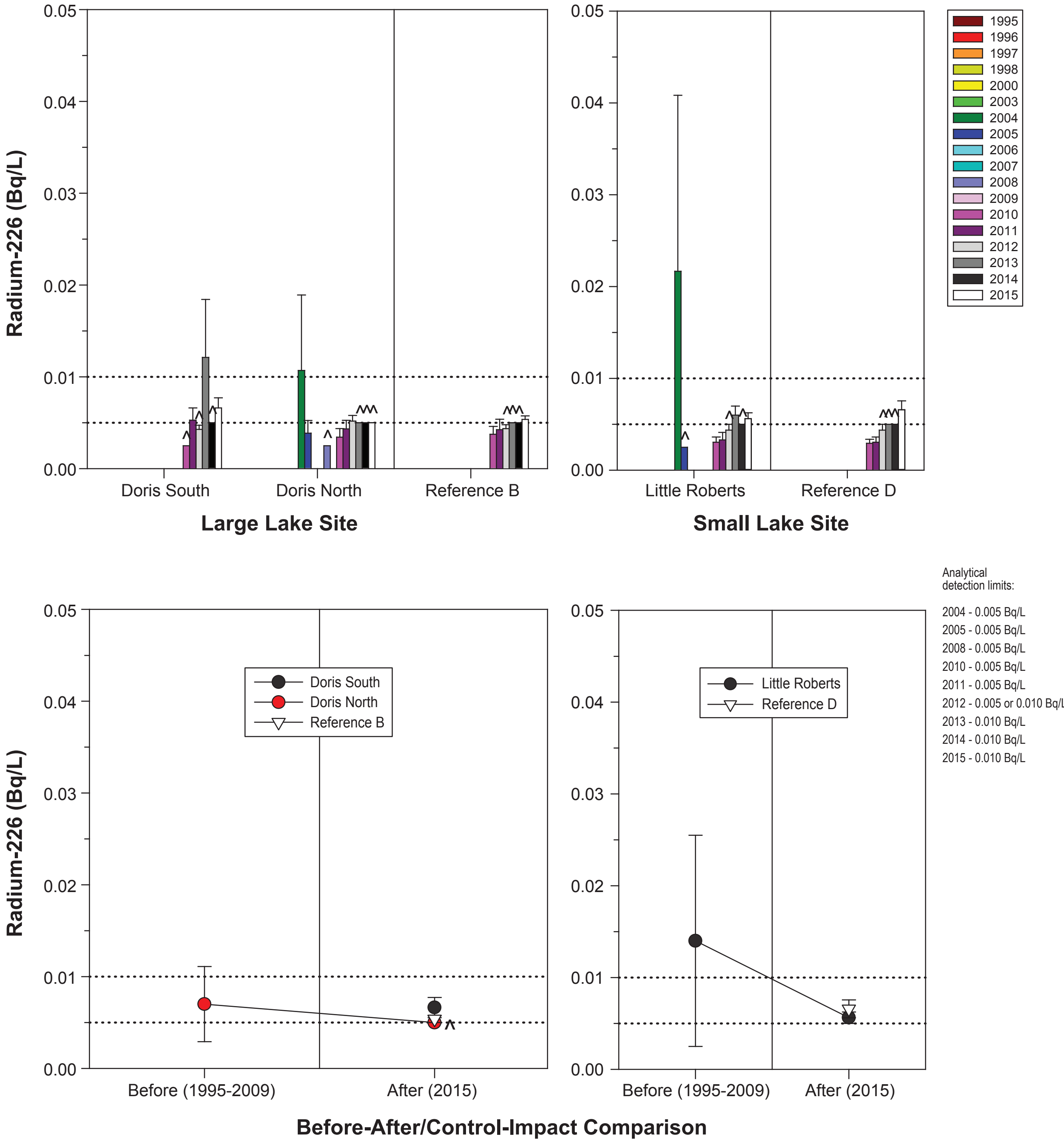
Figure 3.3-25
Total Cyanide in AEMP Lake Sites, Doris North Project, 1995 to 2015



Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
^ Indicates that concentrations were below the detection limit in all samples.
Total cyanide is regulated as a deleterious substance in effluents as per Schedule 4 of the MMER.

Figure 3.3-26

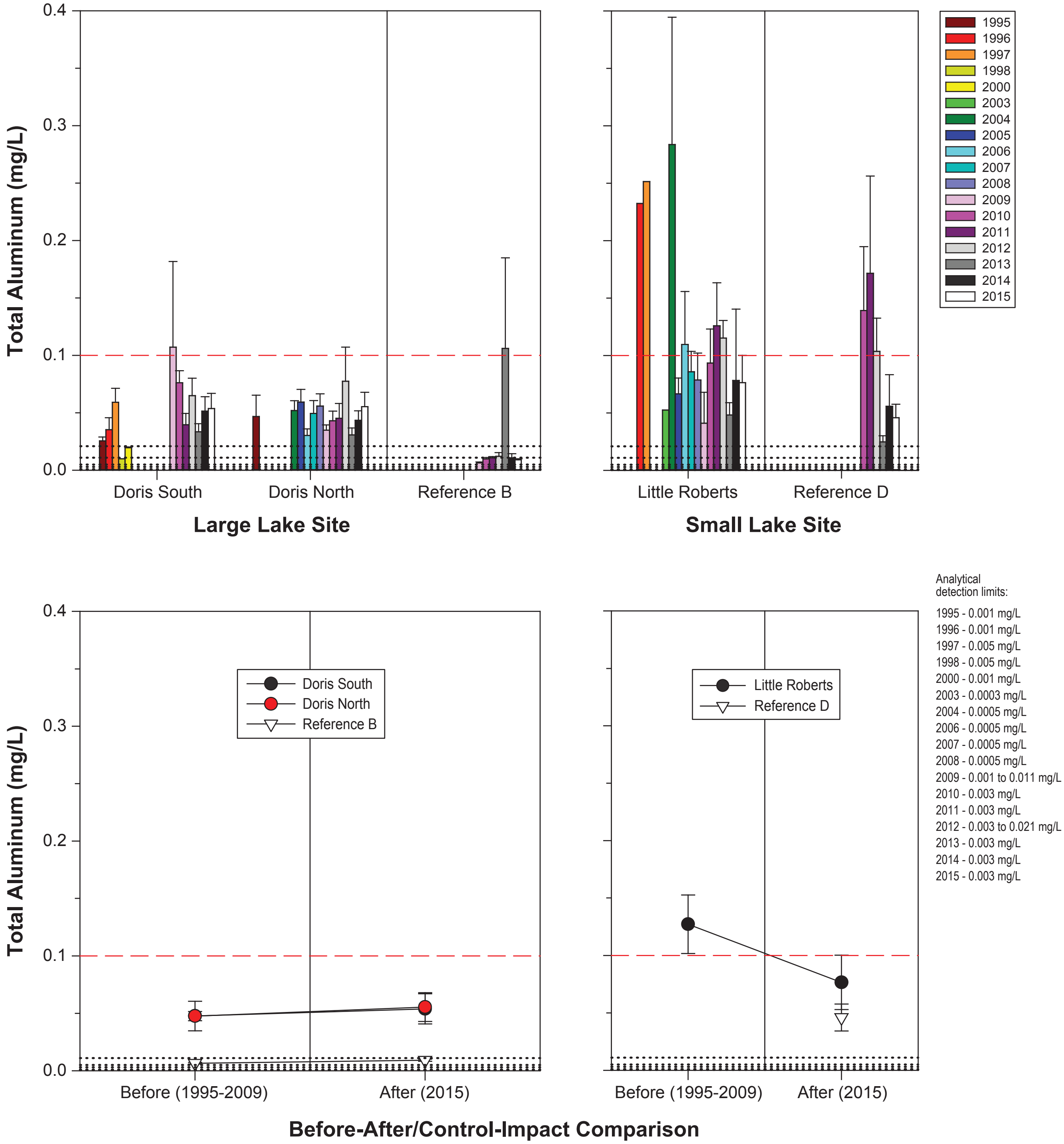
Radium-226 in AEMP Lake Sites, Doris North Project, 1995 to 2015



Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
^ Indicates that concentrations were below the detection limit in all samples.
Radium-226 is regulated as a deleterious substance in effluents as per Schedule 4 of the MMER.

Figure 3.3-27

Total Aluminum Concentration in AEMP Lake Sites, Doris North Project, 1995 to 2015

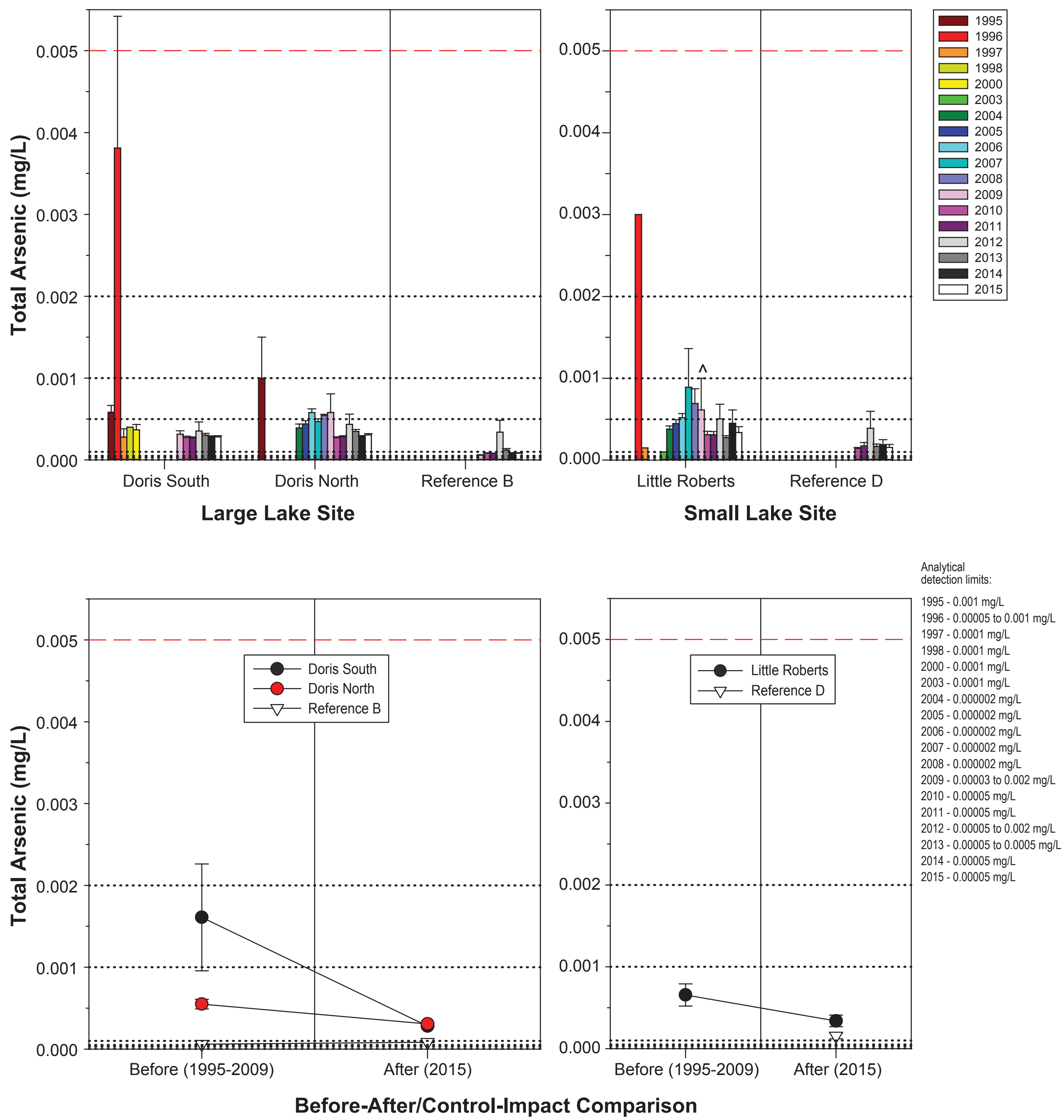


Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
Red dashed lines represent the pH-dependent CCME freshwater guideline for aluminum (0.005 mg/L at pH < 6.5; 0.1 mg/L at pH ≥ 6.5).
Mean annual pH levels were greater than 6.5 in all exposure and reference lakes.
Total aluminum is a required parameter for effluent characterization as per Schedule 5, s. 4(1) of the MMER.

Figure 3.3-28

Total Arsenic Concentration in AEMP Lake Sites, Doris North Project, 1995 to 2015

ERM



Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
^ Indicates that concentrations were below the detection limit in all samples.
Red dashed lines represent the CCME freshwater guideline for arsenic (0.005 mg/L).
Total arsenic is regulated as a deleterious substance in effluents as per Schedule 4 of the MMER.

3.3.2.11 Total Cadmium

Total cadmium is a required variable for effluent characterization as per Schedule 5, s. 4(1) of the MMER. In 2015, total cadmium concentrations at the Doris Lake sites were below the analytical detection limit of 0.000005 mg/L (Figure 3.3-29). Thus, there was no evidence of an effect of 2015 Project activities on the Doris Lake South and North exposure sites. For Little Roberts Lake, most (75%) of the 2015 cadmium concentrations were below the analytical detection limit, and a comparison to baseline data was problematic because of the high proportion of data in the combined baseline and 2015 dataset that were below detection limits (76%). Results of the before-after comparison were considered unreliable and are not discussed. However, since most total cadmium concentrations in Little Roberts Lake were below the analytical detection limit in 2015 and the detectable concentrations from 2015 were similar to baseline concentrations, there was no apparent effect of 2015 Project activities on total cadmium in Little Roberts Lake. Total cadmium concentrations measured in lakes in 2015 were well below the CCME hardness-dependent cadmium guideline (Figure 3.3-29).

3.3.2.12 Total Copper

Total copper is regulated as a deleterious substance in effluents as per Schedule 4 of the MMER. In all three exposure lake sites, mean 2015 total copper concentrations were within the range of baseline means (Figure 3.3-30). The before-after analysis found that 2015 mean total copper concentrations were not distinguishable from baseline means at the exposure lake sites ($p = 0.20$ for Doris Lake South, $p = 0.27$ for Doris Lake North, and $p = 0.62$ for Little Roberts Lake). The mean 2015 total copper concentrations at Doris Lake South and North were slightly below the minimum CCME guideline of 0.002 mg/L, while the mean 2015 total copper concentration at Little Roberts Lake was slightly above the guideline (Figure 3.3-30; Appendix A). However, the baseline mean total copper concentration at Little Roberts Lake was also above the CCME guideline, suggesting that total copper concentrations are naturally elevated in this lake. Therefore, there was no apparent effect of 2015 Project activities on total copper concentrations in any exposure lake.

3.3.2.13 Total Iron

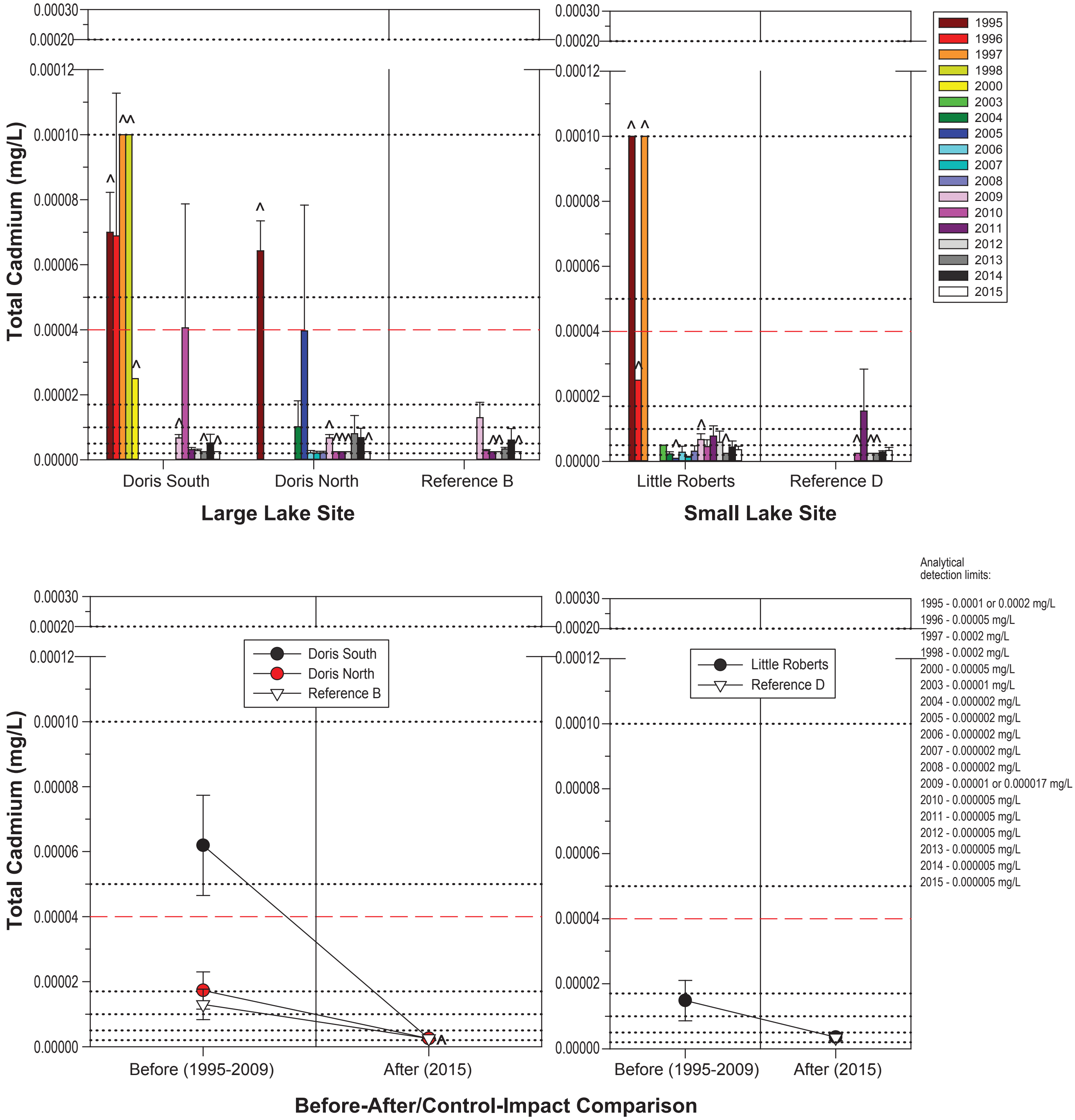
Total iron is a required variable for effluent characterization as per Schedule 5, s. 4(1) of the MMER. Mean total iron concentrations at the exposure lake sites in 2015 were within the range of mean baseline concentrations and below the CCME guideline of 0.3 mg/L (Figure 3.3-31). For all exposure sites, the before-after analysis showed that mean 2015 total iron concentrations were not distinguishable from mean baseline concentrations ($p = 0.68$ for Doris Lake South, $p = 0.49$ for Doris Lake North, and $p = 0.27$ for Little Roberts Lake), suggesting that 2015 Project activities did not have an effect on total iron concentrations in exposure lakes (Figure 3.3-31).

3.3.2.14 Total Lead

Total lead is regulated as a deleterious substance in effluents as per Schedule 4 of the MMER. Mean 2015 total lead concentrations for all the exposure lakes were within the range or lower than baseline means and below the hardness-dependent CCME guideline (Figure 3.3-32), suggesting that there was no adverse effect of Project activities on total lead concentrations in lakes. The before-after analysis confirmed that there was no significant difference between the 2015 and baseline mean concentrations for any exposure lake ($p = 0.32$ for Doris Lake South, $p = 0.71$ for Doris Lake North, and $p = 0.49$ for Little Roberts Lake).

Figure 3.3-29

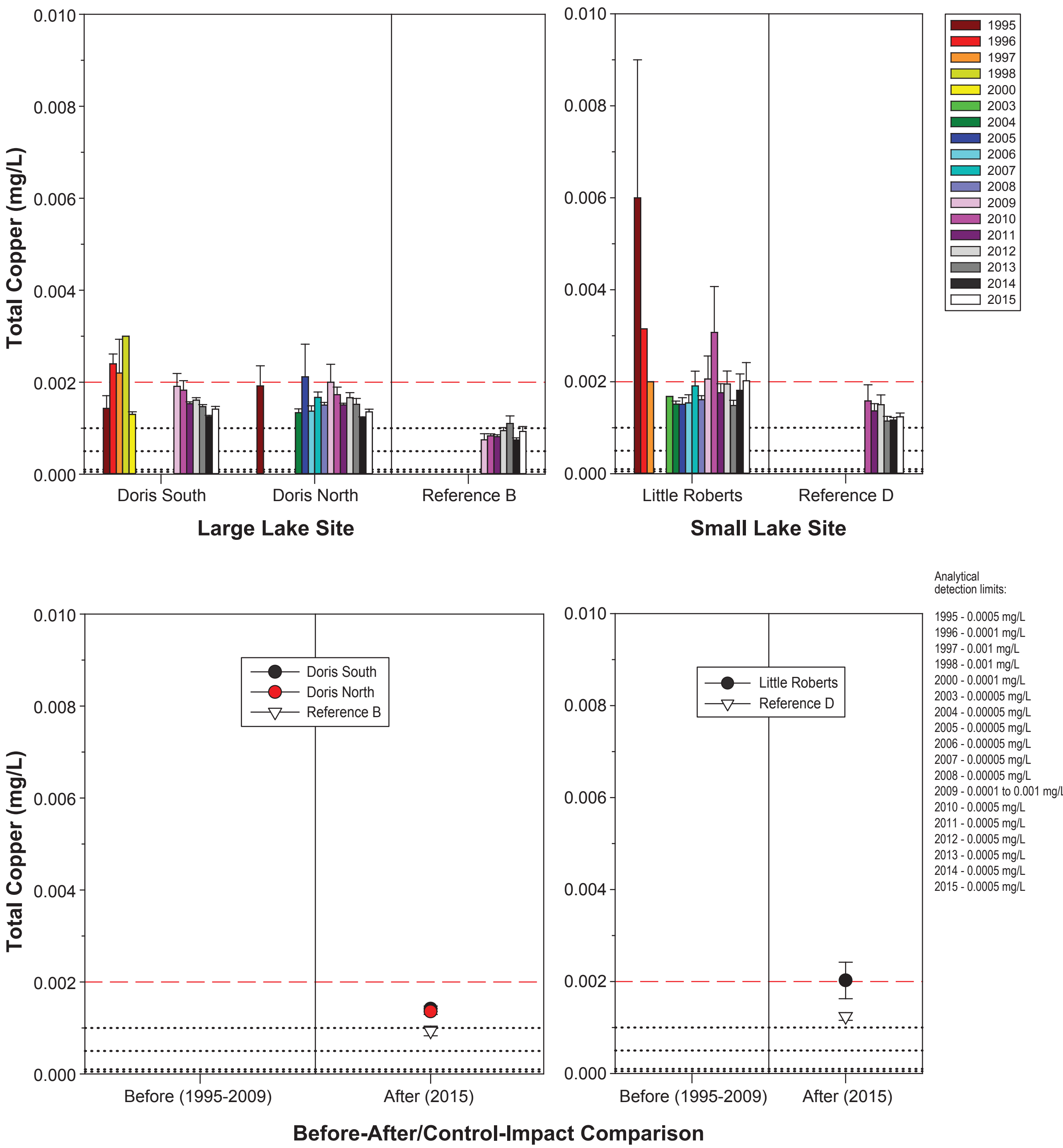
Total Cadmium Concentration in AEMP Lake Sites, Doris North Project, 1995 to 2015



Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
^ Indicates that concentrations were below the detection limit in all samples.
The CCME freshwater guideline for cadmium is hardness dependent.
Red dashed lines represent the minimum CCME freshwater guideline for cadmium based on the minimum hardness measured in exposure lakes between 1996 and 2015 (hardness: 14.3 mg/L; CCME guideline: 0.00004 mg/L).
Total cadmium is a required parameter for effluent characterization as per Schedule 5, s. 4(1) of the MMER.

Figure 3.3-30

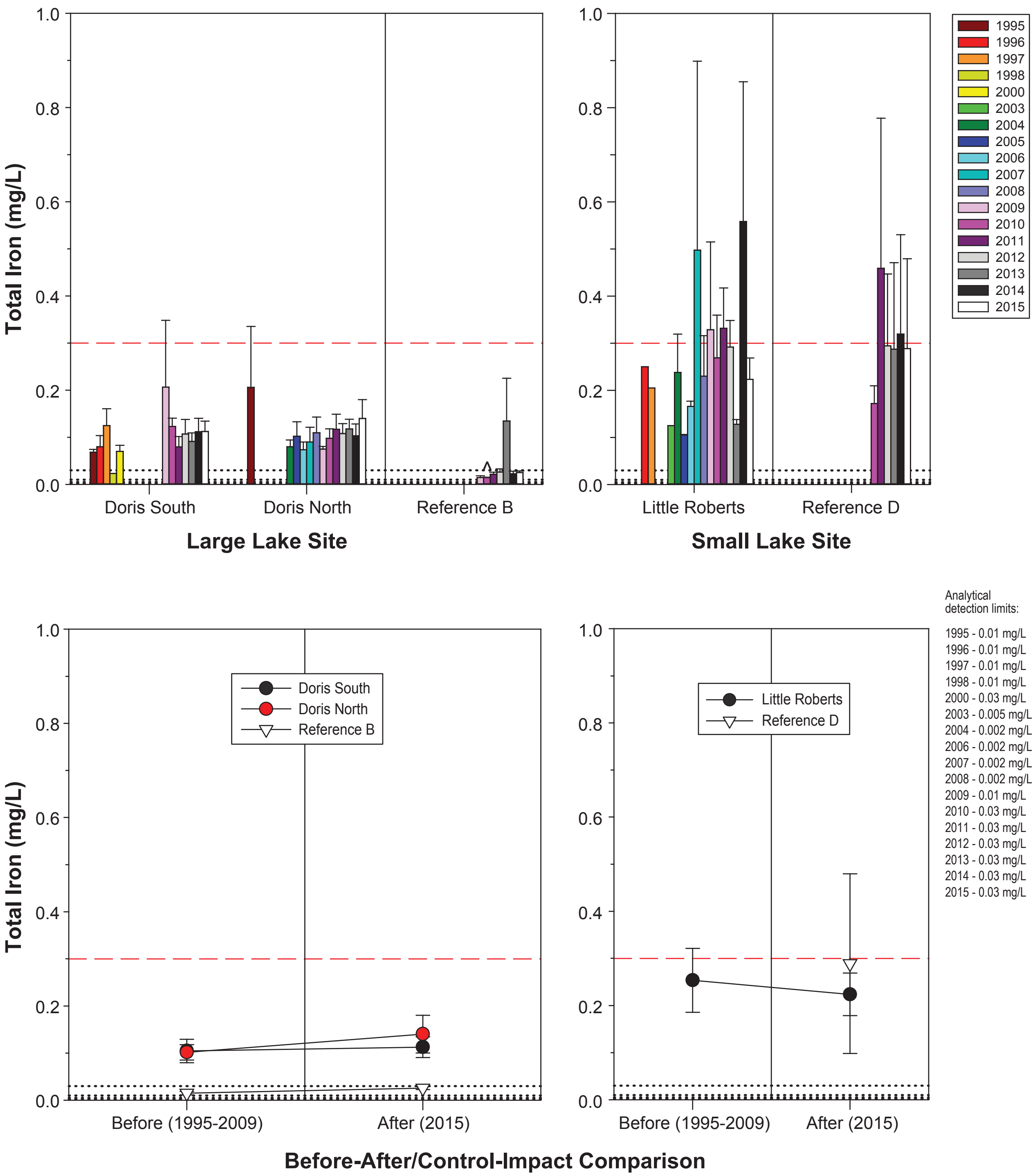
Total Copper Concentration in AEMP Lake Sites, Doris North Project, 1995 to 2015



Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
^ Indicates that concentrations were below the detection limit in all samples.
The CCME freshwater guideline for copper is hardness dependent.
Red dashed lines represent the minimum CCME freshwater guideline for copper regardless of water hardness (0.002 mg/L).
Total copper is regulated as a deleterious substance in effluents as per Schedule 4 of the MMER.

Figure 3.3-31

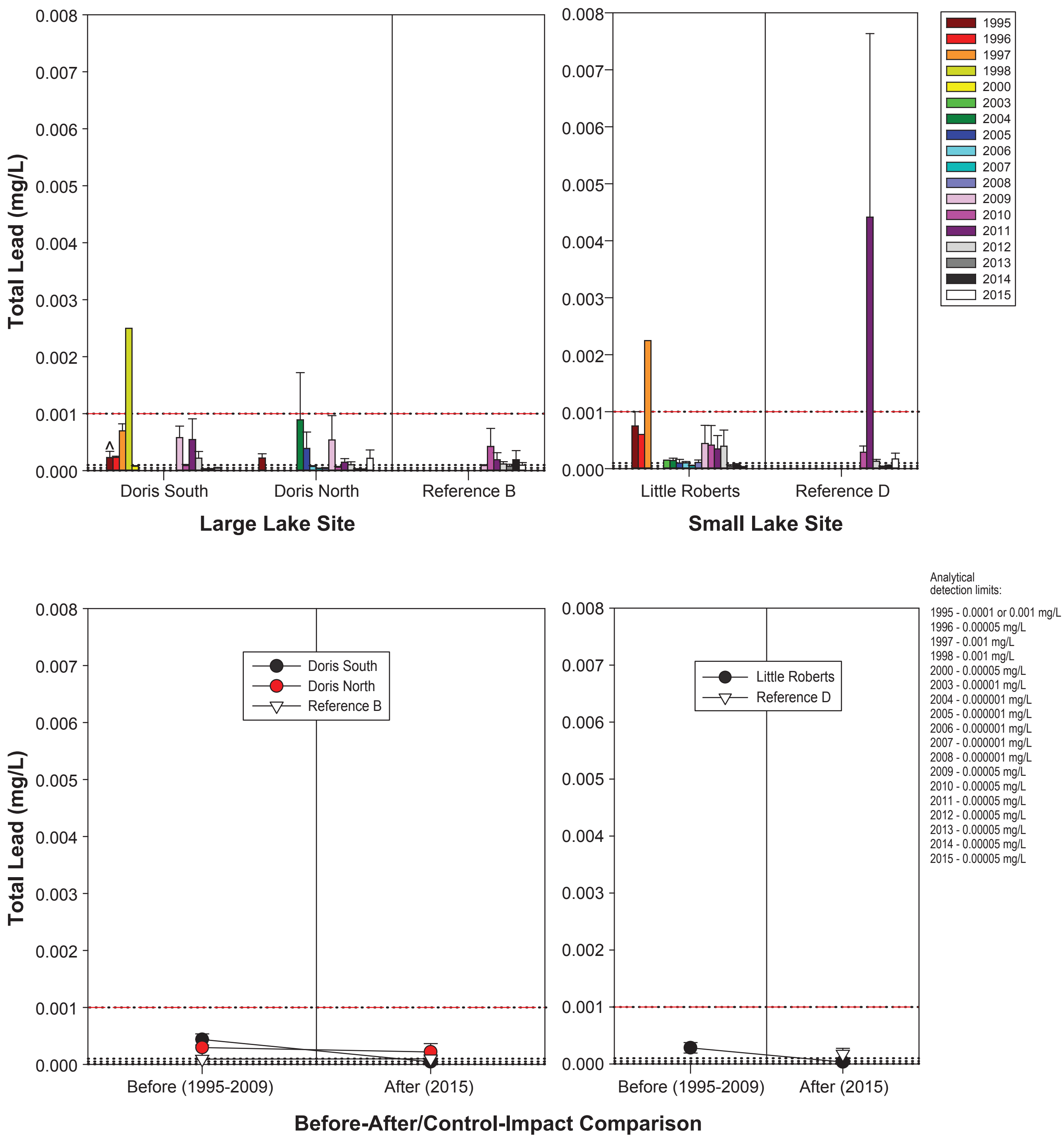
Total Iron Concentration in AEMP Lake Sites, Doris North Project, 1995 to 2015



Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
^ Indicates that concentrations were below the detection limit in all samples.
Red dashed lines represent the CCME freshwater guideline for iron (0.3 mg/L).
Total iron is a required parameter for effluent characterization as per Schedule 5, s. 4(1) of the MMER.

Figure 3.3-32

Total Lead Concentration in AEMP Lake Sites, Doris North Project, 1995 to 2015



Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
^ Indicates that concentrations were below the detection limit in all samples.
The CCME freshwater guideline for lead is hardness dependent.
Red dashed lines represent the minimum CCME freshwater guideline for lead regardless of water hardness (0.001 mg/L).
Total lead is regulated as a deleterious substance in effluents as per Schedule 4 of the MMER.

3.3.2.15 Total Mercury

Total mercury is a required variable for effluent characterization as per Schedule 5, s. 4(1) of the MMER. Total mercury concentrations in exposure lakes in 2015 were similar to concentrations in reference lakes and well below the CCME guideline for inorganic mercury of 0.000026 mg/L (Figure 3.3-33; Appendix A). Mean total mercury concentrations measured in exposure lakes in 2015 were within or lower than the range of baseline concentrations. The before-after analysis indicated that there was no difference between the baseline and 2015 mean for either Doris Lake North ($p = 0.28$) or Little Roberts Lake ($p = 0.30$). At Doris Lake South, all baseline data were below widely variable detection limits, making comparison to these data difficult. In the combined baseline and 2015 total mercury dataset for Doris Lake South, 77% of concentrations were below analytical detection; therefore, the before-after results for Doris Lake South were considered unreliable and are not discussed. However, total mercury concentrations in Doris Lake South in 2015 were low and similar to concentrations observed in Reference Lake B. Thus, there was no evidence of Project-related effects on total mercury at Doris Lake South or any other exposure lake site in 2015.

3.3.2.16 Total Molybdenum

Total molybdenum is a required variable for effluent characterization as per Schedule 5, s. 4(1) of the MMER. Mean 2015 total molybdenum concentrations were similar among exposure lakes and well below the interim CCME guideline of 0.073 mg/L (Figure 3.3-34). In Doris Lake South and North, mean 2015 total molybdenum concentrations were similar to baseline means (Figure 3.3-34). The before-after analysis confirmed that mean 2015 total molybdenum concentrations at these sites were not distinguishable from baseline means ($p = 0.56$ for Doris Lake South and $p = 0.96$ for Doris Lake North), suggesting that there was no effect of 2015 Project activities on total molybdenum levels in these exposure sites.

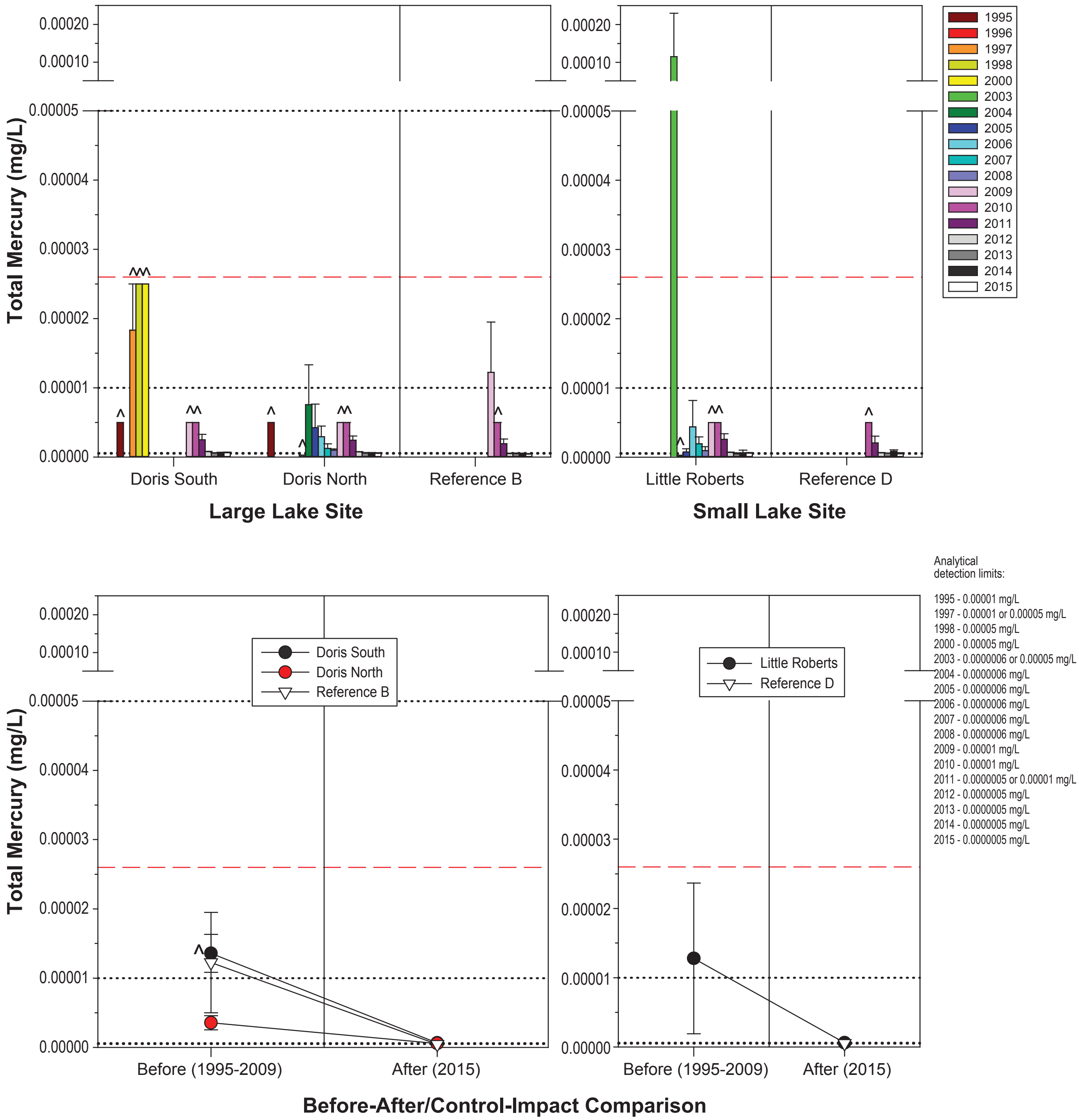
At Little Roberts Lake, the mean molybdenum concentration was slightly higher in 2015 than in the baseline period. Although the change was slight (mean baseline concentration (after removal of censored outliers) of 0.000190 mg/L compared to mean 2015 concentration of 0.000203 mg/L), it was statistically significantly (before-after comparison: $p = 0.027$). A BACI analysis was not possible given the absence of baseline data for Reference Lake D. Even though the before-after change was statistically significant, it is not considered environmentally or biologically important as the actual difference in concentrations was slight (7% increase), and 2015 concentrations remained well below the CCME guideline of 0.073 mg/L. Therefore, there was no adverse effect of 2015 Project activities on total molybdenum concentrations in Little Roberts Lake.

3.3.2.17 Total Nickel

Total nickel is regulated as a deleterious substance in effluents as per Schedule 4 of the MMER. Total nickel concentrations measured in exposure lakes in 2015 were well below the hardness-dependent CCME guideline for total nickel and within the range of baseline concentrations (Figure 3.3-35). This suggests that 2015 Project activities did not cause an increase in total nickel concentrations in exposure lakes. The before-after comparison confirmed that mean nickel concentrations did not change significantly in any exposure lake in 2015 compared to baseline years ($p = 0.62$ for Doris Lake South, $p = 0.88$ for Doris Lake North, and $p = 0.70$ for Little Roberts Lake).

Figure 3.3-33

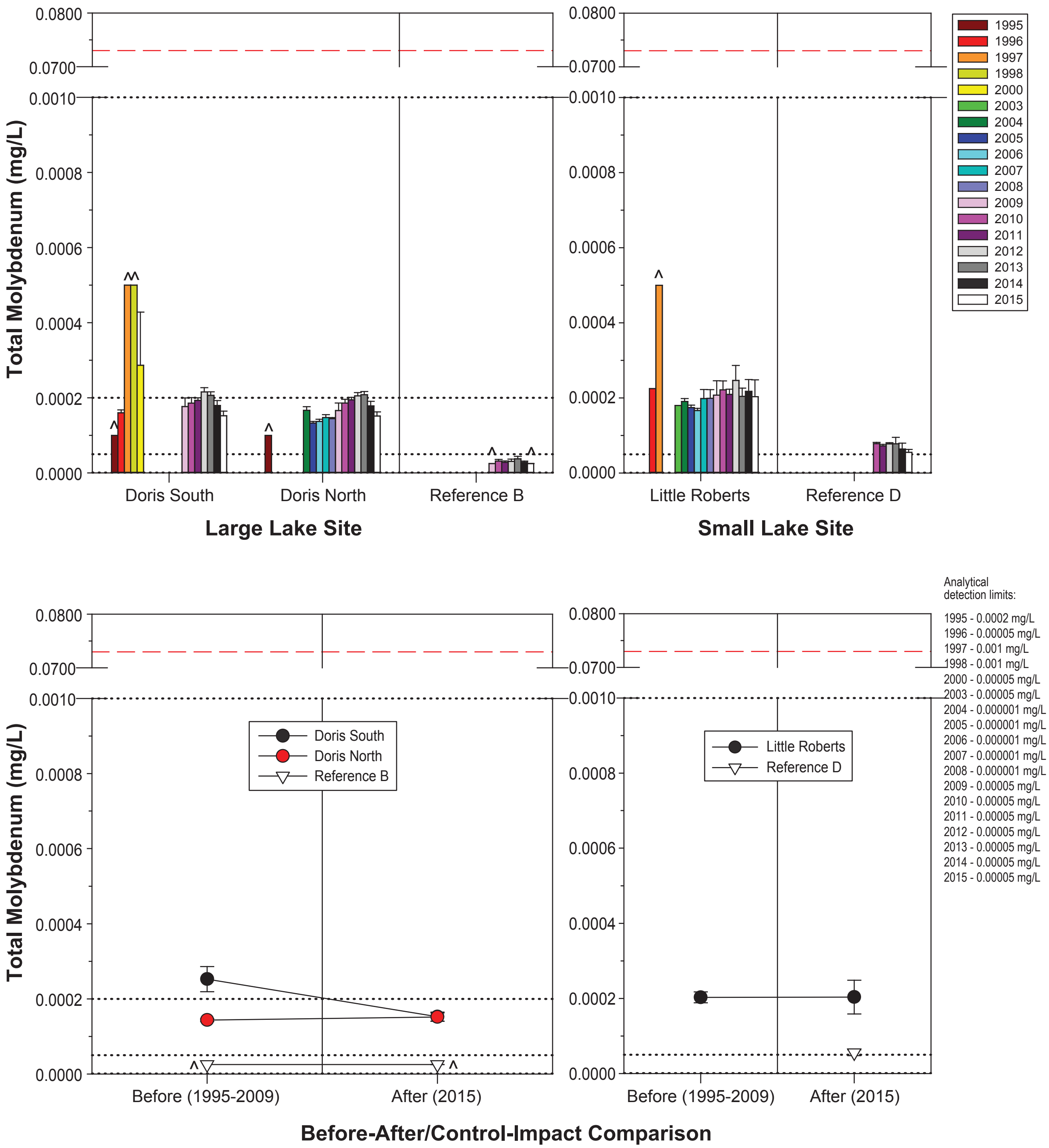
Total Mercury Concentration in AEMP Lake Sites, Doris North Project, 1995 to 2015



Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
^ Indicates that concentrations were below the detection limit in all samples.
Red dashed lines represent the CCME freshwater guideline for inorganic mercury (0.000026 mg/L).
Total mercury is a required parameter for effluent characterization as per Schedule 5, s. 4(1) of the MMER.

Figure 3.3-34

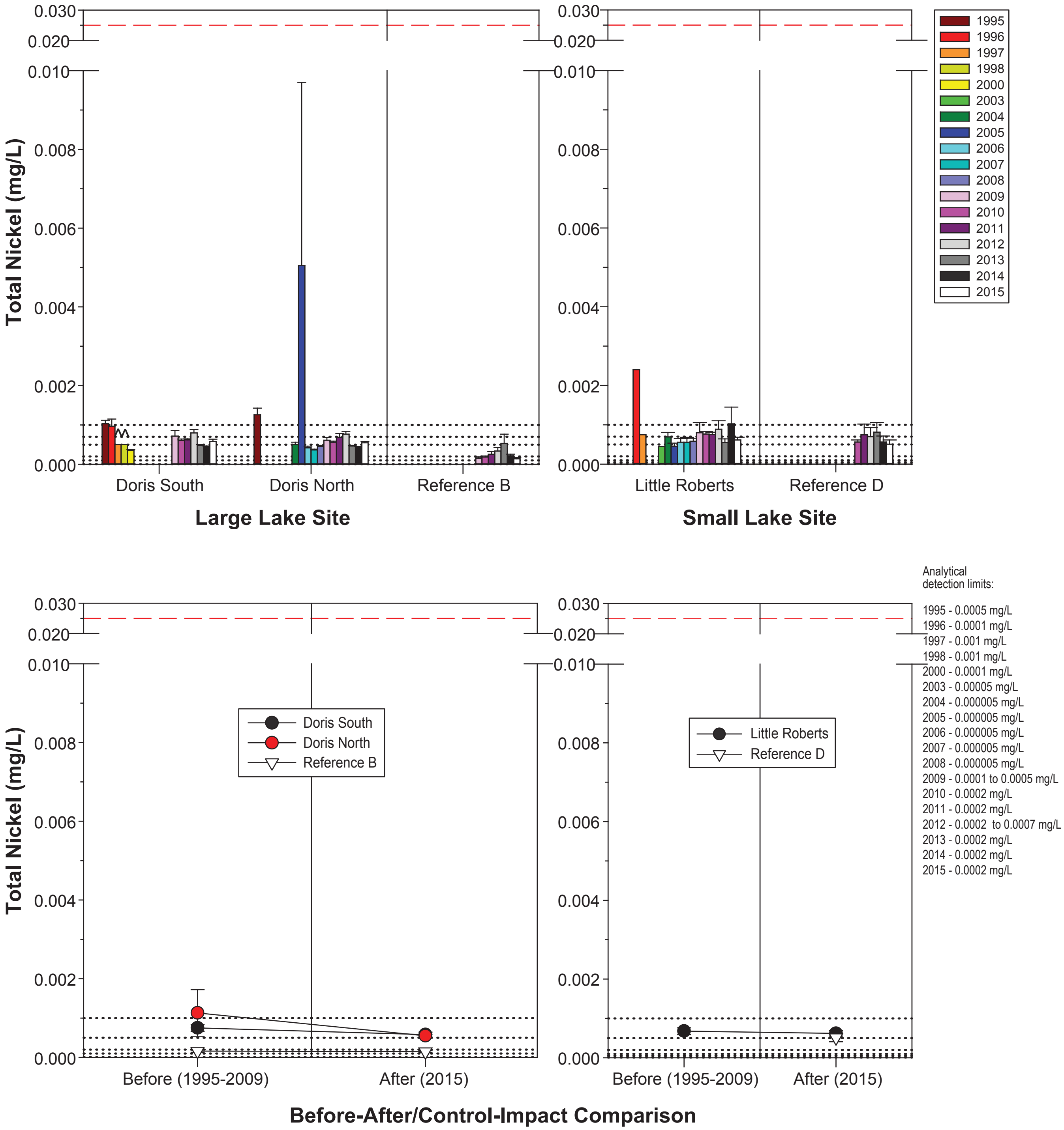
Total Molybdenum Concentration in AEMP Lake Sites, Doris North Project, 1995 to 2015



Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
^ Indicates that concentrations were below the detection limit in all samples.
Red dashed lines represent the interim CCME freshwater guideline for molybdenum (0.073 mg/L).
Total molybdenum is a required parameter for effluent characterization as per Schedule 5, s. 4(1) of the MMER.

Figure 3.3-35

Total Nickel Concentration in AEMP Lake Sites, Doris North Project, 1995 to 2015



Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
^ Indicates that concentrations were below the detection limit in all samples.
The CCME freshwater guideline for nickel is hardness dependent.
Red dashed lines represent the minimum CCME freshwater guideline for nickel regardless of water hardness (0.025 mg/L).
Total nickel is regulated as a deleterious substance in effluents as per Schedule 4 of the MMER.

3.3.2.18 Total Zinc

Total zinc is regulated as a deleterious substance in effluents as per Schedule 4 of the MMER. In 2015, all total zinc concentrations measured in exposure lakes were below the analytical detection limit of 0.003 mg/L and well below the CCME guideline of 0.03 mg/L (Appendix A; Figure 3.3-36). Therefore, there was no evidence of an increase in total zinc in exposure lakes as a result of 2015 Project activities.

3.3.3 Marine

Water quality samples from marine areas were collected from two exposure sites in Roberts Bay (RBW and RBE) and one reference site in Ida Bay (REF-Marine 1) in 2015. Baseline data from 2009 are available for all sites, and additional baseline data from 1996 and 2004 to 2008 are available for site RBE. All 2015 samples were collected at the surface (0 to 1 m depth), therefore any baseline data collected from near the water-sediment interface were excluded from the baseline dataset used for the effects analyses.

3.3.3.1 pH

pH is a required variable for water quality monitoring as per Schedule 5, s. 7(1)(c) of the MMER. Mean 2015 pH levels in marine exposure and reference sites were within the recommended marine CCME guideline range of 7.0 to 8.7 (Figure 3.3-37). pH levels measured at RBW and RBE in 2015 were similar to levels measured at REF-Marine 1 and to baseline pH levels (Figure 3.3-37). Marine environments have a high buffering capacity compared to freshwater systems, so pH is relatively insensitive to change. The before-after comparison showed that there was no change in marine pH in 2015 compared to baseline years for site RBE ($p = 0.86$), but there was a significant difference between baseline (2009) and 2015 pH levels at RBW ($p = 0.037$). However, the BACI analysis showed that a parallel change occurred at the reference site from 2009 to 2015 ($p = 0.83$), so the slight change in pH at site RBW was not related to the Project.

3.3.3.2 Total Alkalinity

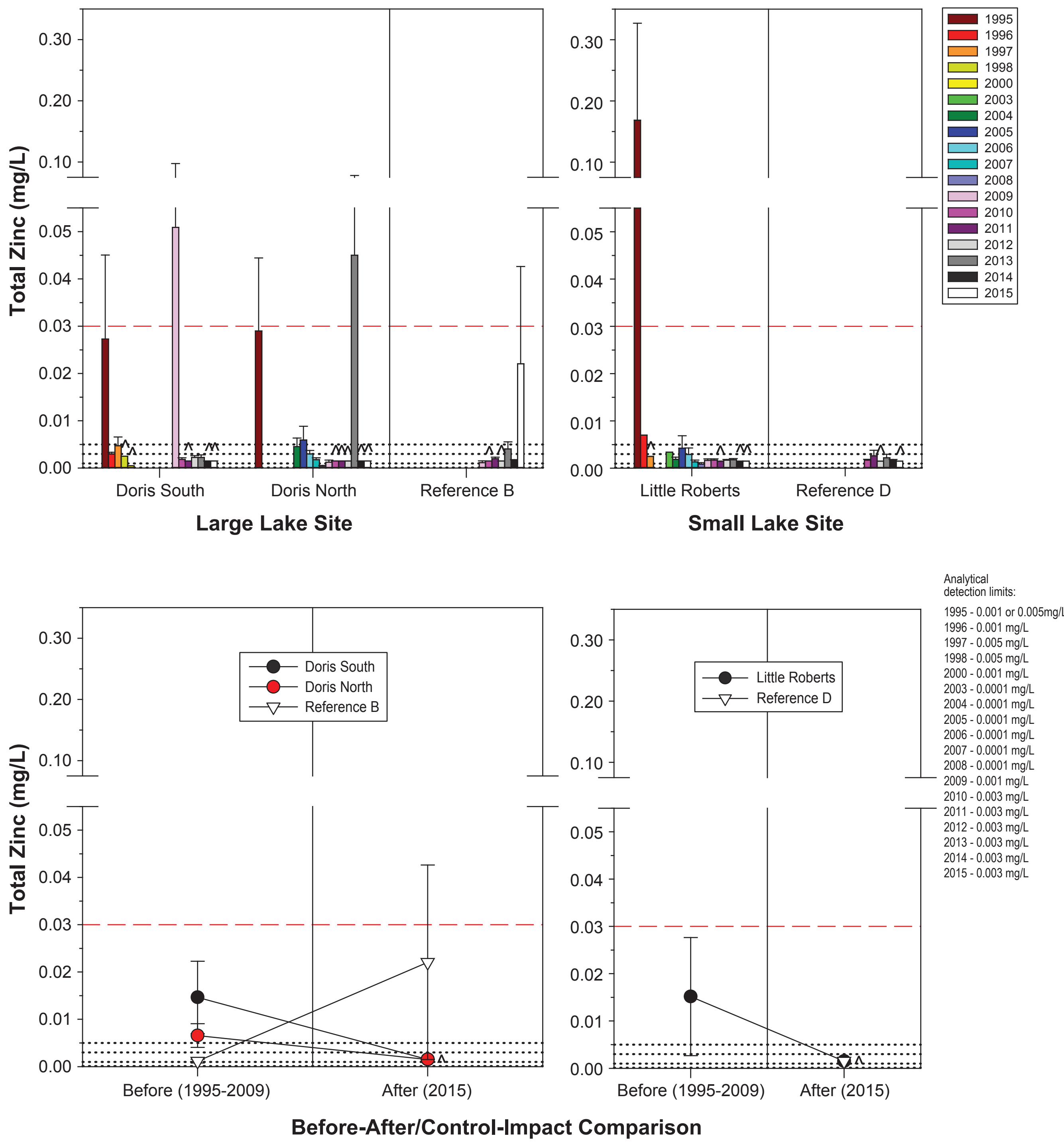
Total alkalinity is a required variable for effluent characterization and water quality monitoring as per Schedule 5, s. 4(1) and s. 7(1)(c) of the MMER. RBE is the only site for which baseline total alkalinity data are available. At this site, the mean 2015 alkalinity was within the range of baseline means (Figure 3.3-38), and the before-after comparison indicated that there was no statistically significant change in alkalinity in 2015 at RBE compared to baseline levels ($p = 0.20$). Although no statistical analysis was possible for site RBW, mean 2015 alkalinity was within the range of alkalinity levels measured at this site between 2010 and 2014 as well as reference site alkalinity levels (Figure 3.3-38). Thus, there was no evidence that 2015 Project activities affected total alkalinity at the exposure sites.

3.3.3.3 Hardness

Hardness is a required variable for effluent characterization and water quality monitoring as per Schedule 5, s. 4(1) and s. 7(1)(c) of the MMER. Mean hardness (as $CaCO_3$) levels measured in 2015 in Roberts Bay sites were within or lower than the range of baseline hardness levels, and were also similar to the hardness levels measured in Ida Bay (REF-Marine-1; Figure 3.3-39). The before-after comparison confirmed that 2015 hardness levels at RBW and RBE were not distinguishable from baseline levels ($p = 0.93$ for RBW and $p = 0.82$ for RBE), suggesting that there was no effect of 2015 Project activities on the hardness of marine waters at exposure sites.

Figure 3.3-36

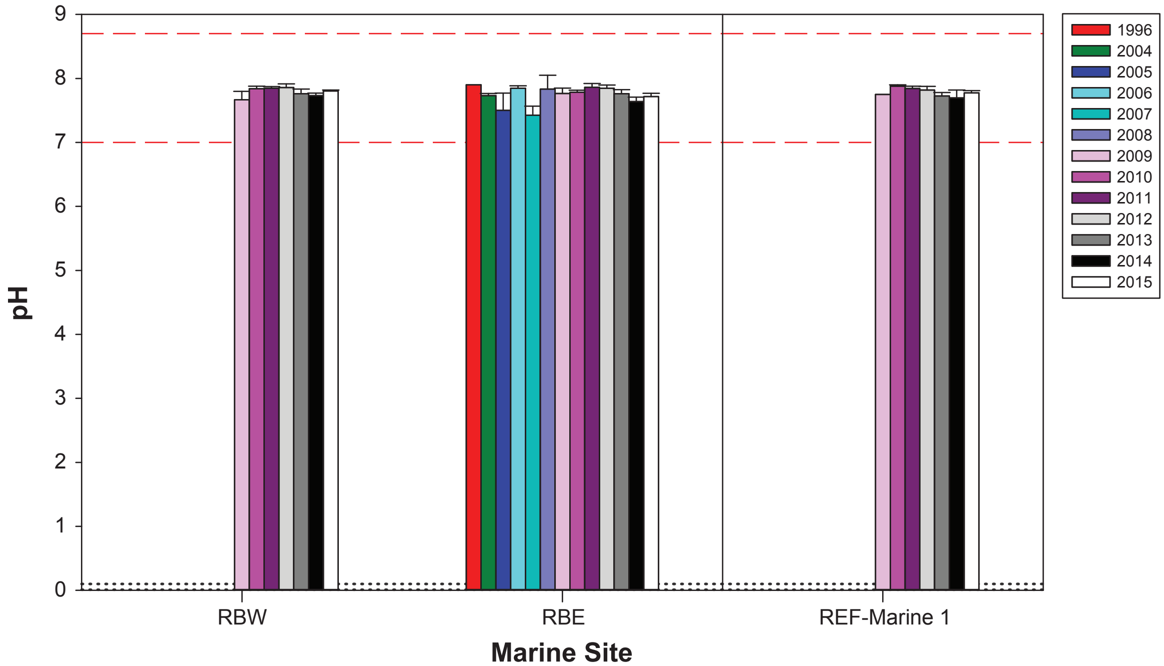
Total Zinc Concentration in AEMP Lake Sites, Doris North Project, 1995 to 2015

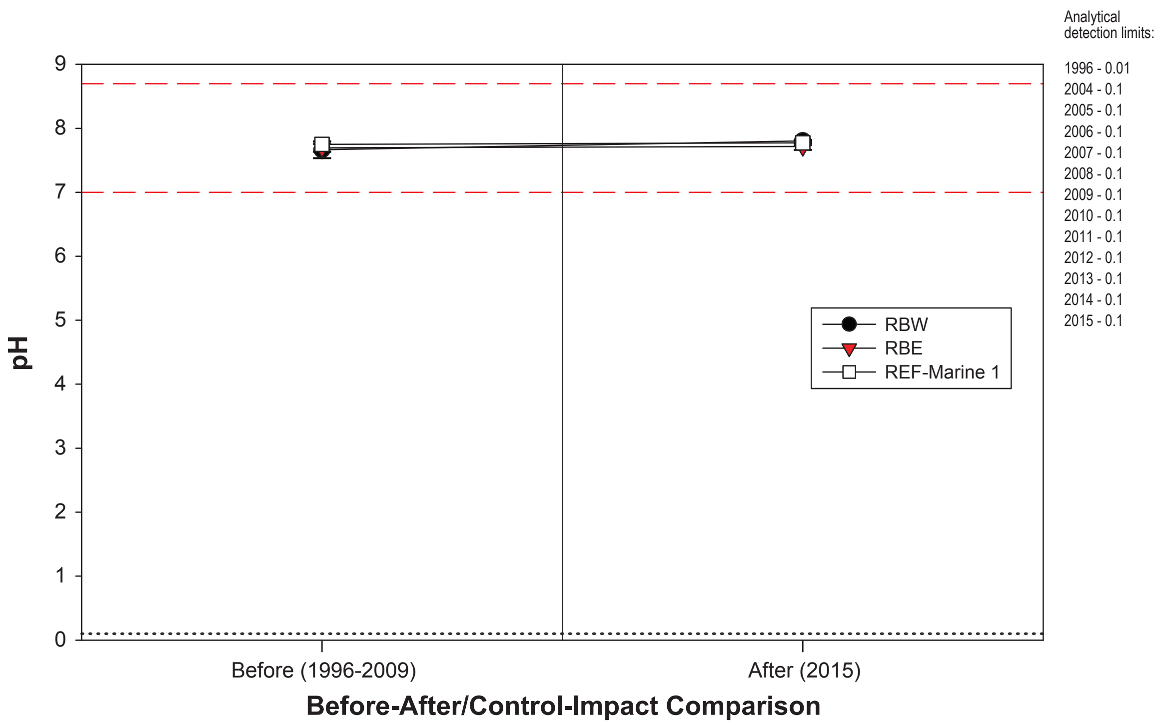


Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
^ Indicates that concentrations were below the detection limit in all samples.
Red dashed lines represent the CCME freshwater guideline for zinc (0.03 mg/L).
Total zinc is regulated as a deleterious substance in effluents as per Schedule 4 of the MMER.

Figure 3.3-37

pH in AEMP Marine Sites, Doris North Project, 1996 to 2015

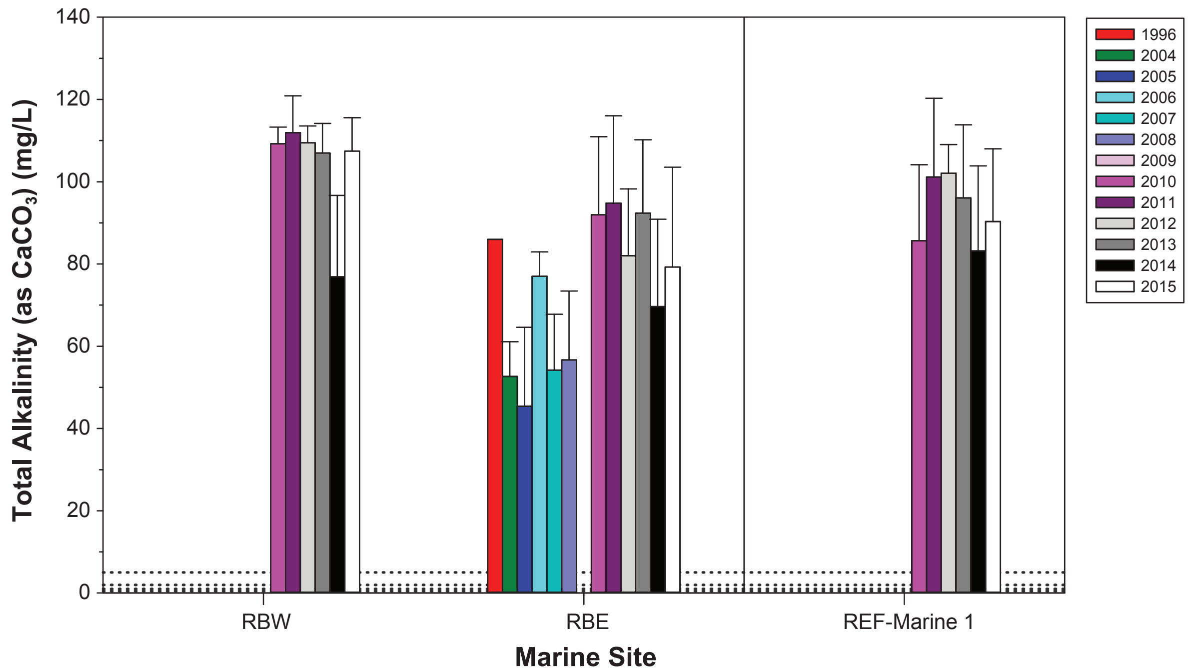


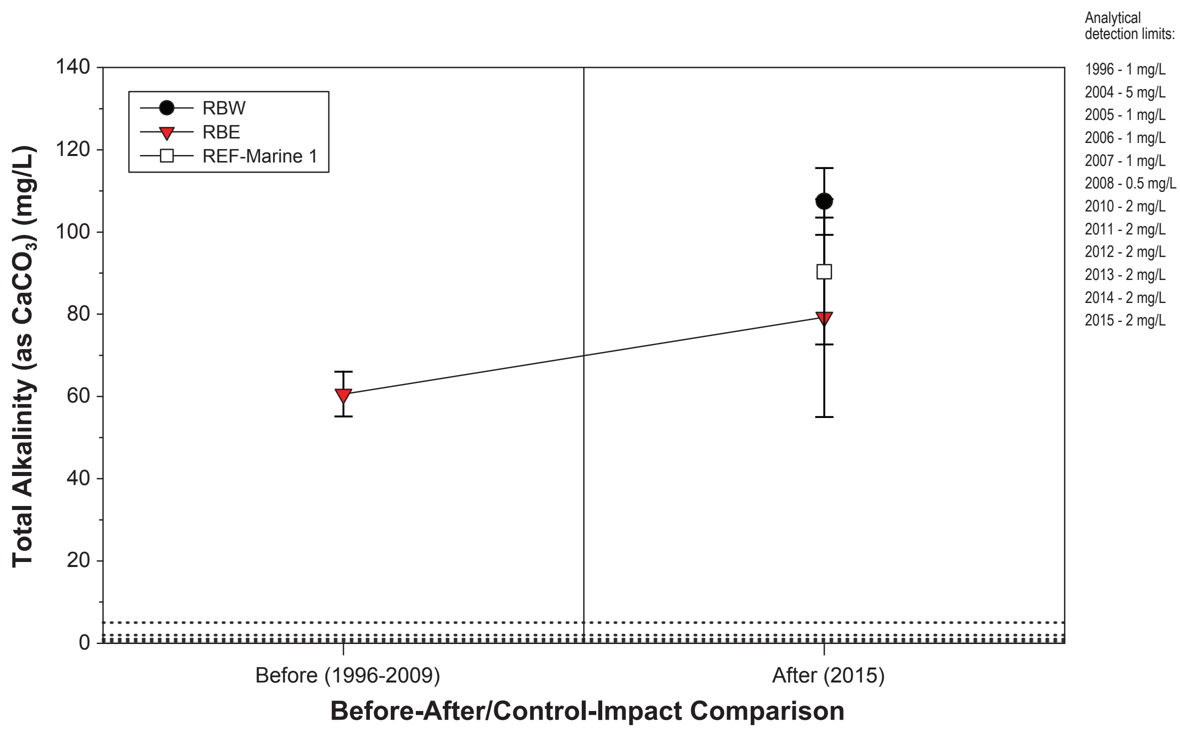


Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits.
Red dashed lines represent the CCME marine and estuarine guideline pH range (7.0–8.7).
pH is a required parameter for water quality monitoring as per Schedule 5, s. 7(1)(c) of the MMER.

Figure 3.3-38

Total Alkalinity in AEMP Marine Sites, Doris North Project, 1996 to 2015

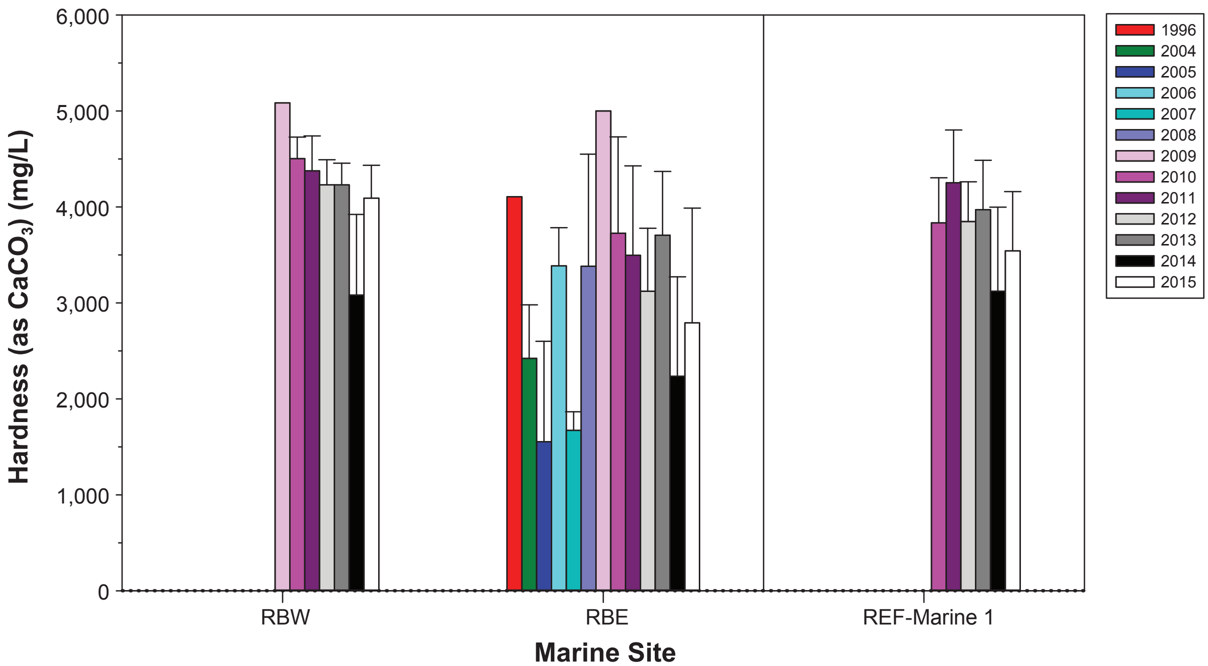


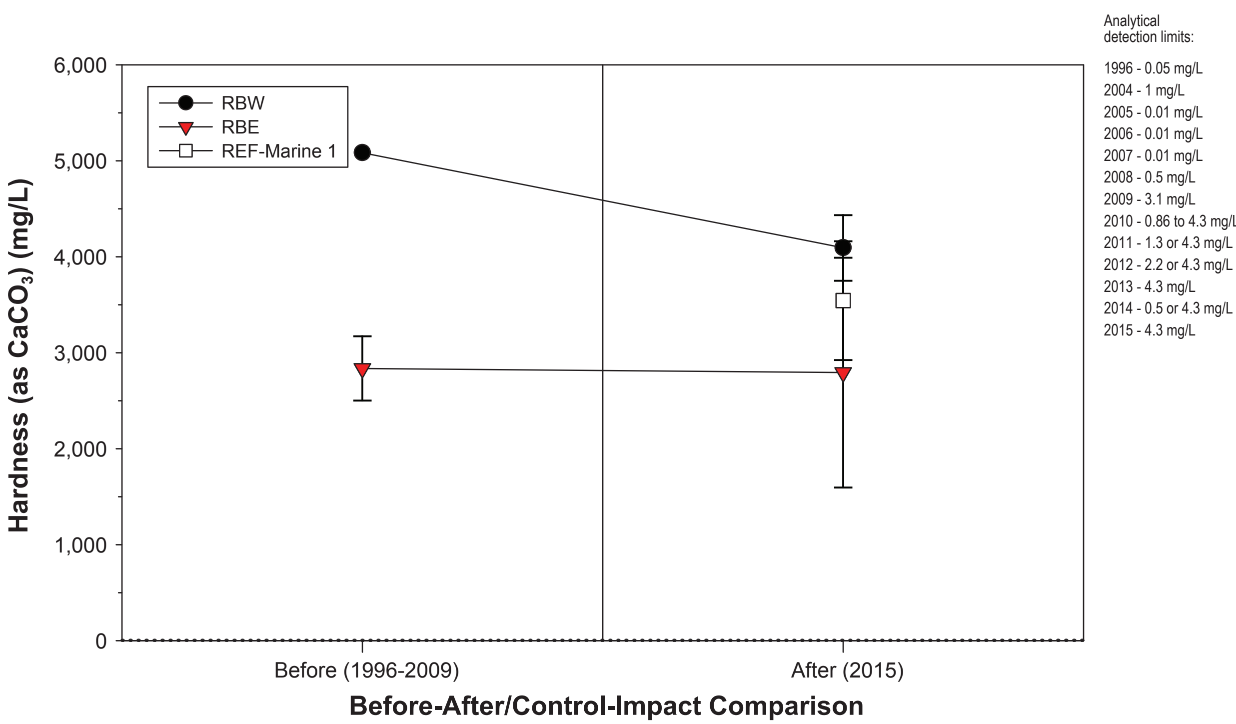


Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
Total alkalinity is a required parameter for effluent characterization and water quality monitoring as per Schedule 5, s. 4(1) and s. 7(1)(c) of the MMER.

Figure 3.3-39

Hardness in AEMP Marine Sites, Doris North Project, 1996 to 2015





Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits.
Hardness is a required parameter for effluent characterization and water quality monitoring as per Schedule 5, s. 4(1) and s. 7(1)(c) of the MMER.

3.3.3.4 Total Suspended Solids

TSS are regulated as deleterious substances in effluents as per Schedule 4 of the MMER. TSS concentrations in the marine environment were highly variable seasonally and inter-annually (Figure 3.3-40 and Appendix A). Mean 2015 TSS concentrations at RBW and RBE were within or lower than the range of baseline means (Figure 3.3-40). The before-after comparison confirmed that the 2015 means were not statistically distinguishable from the baseline means ($p = 0.33$ at RBW and $p = 0.31$ at RBE). Therefore, there was no apparent adverse effect of 2015 Project activities on marine TSS concentrations at exposure sites.

The marine CCME guideline for TSS is dependent upon background (for clear-flow waters with background TSS levels below 25 mg/L, a maximum increase of 25 mg/L is allowable for any short-term exposure or 5 mg/L for longer term exposure; CCME 2015b). Because there was no increase in TSS concentrations from background levels at either RBW or RBE, 2015 TSS concentrations in marine exposure sites continued to remain below the CCME guideline.

3.3.3.5 Total Ammonia

Total ammonia is a required variable for effluent characterization as per Schedule 5, s. 4(1) of the MMER. Total ammonia concentrations in all 2015 samples collected from site RBW were below the analytical detection limit of 0.005 mg ammonia-N/L. Thus there was no evidence of an effect of Project activities on total ammonia concentrations at this site. At site RBE, all 2015 concentrations were below the detection limit except for the duplicate samples collected from RBE in September, which had a mean concentration of 0.0063 mg ammonia-N/L (slightly over the detection limit; Figure 3.3-41). At site RBE, baseline total ammonia concentrations were widely variable and were most often higher than 2015 concentrations (Figure 3.3-41). The before-after comparison confirmed that the 2015 mean total ammonia concentration at RBE was not significantly different from the baseline mean ($p = 0.28$). Therefore, there was no evidence of an effect of 2015 Project activities on total ammonia concentrations at the marine exposure sites.

3.3.3.6 Nitrate

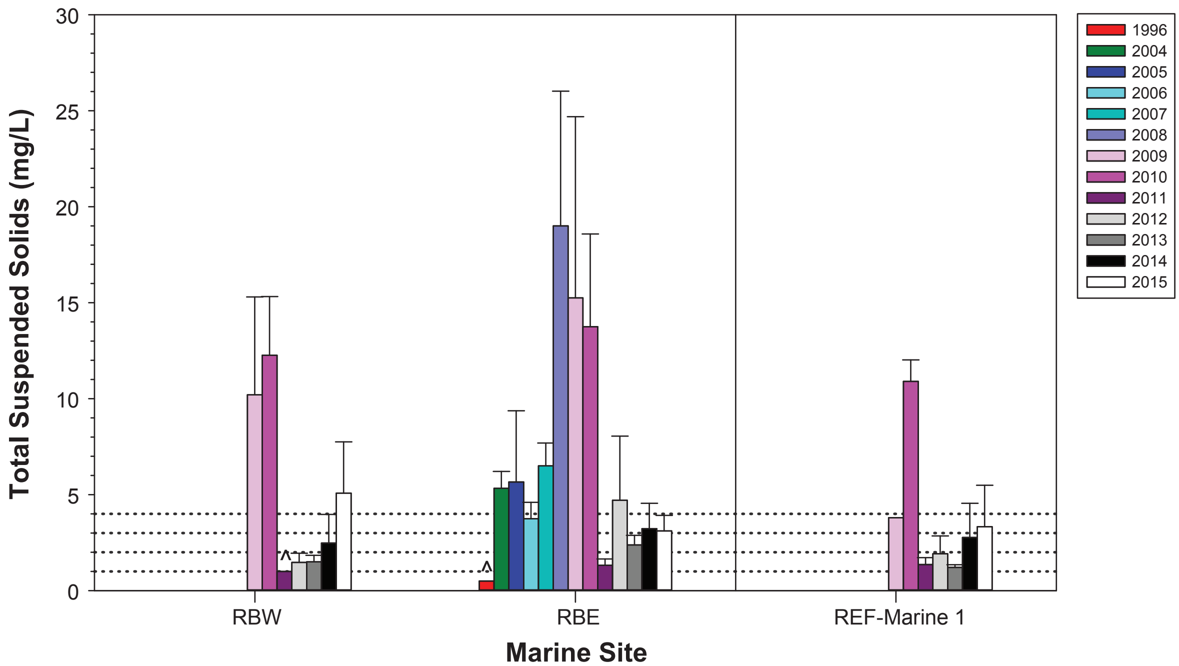
Nitrate is a required variable for effluent characterization as per Schedule 5, s. 4(1) of the MMER. All 2015 nitrate concentrations measured in marine exposure sites were within the range of baseline concentrations, and well below the marine CCME guideline of 45 mg nitrate-N/L (Figure 3.3-42). The before-after analysis confirmed that the 2015 and baseline means were not significantly different for both RBW ($p = 0.37$) and RBE ($p = 0.94$). Thus, there was no apparent effect of 2015 Project activities on nitrate concentrations in the marine exposure sites.

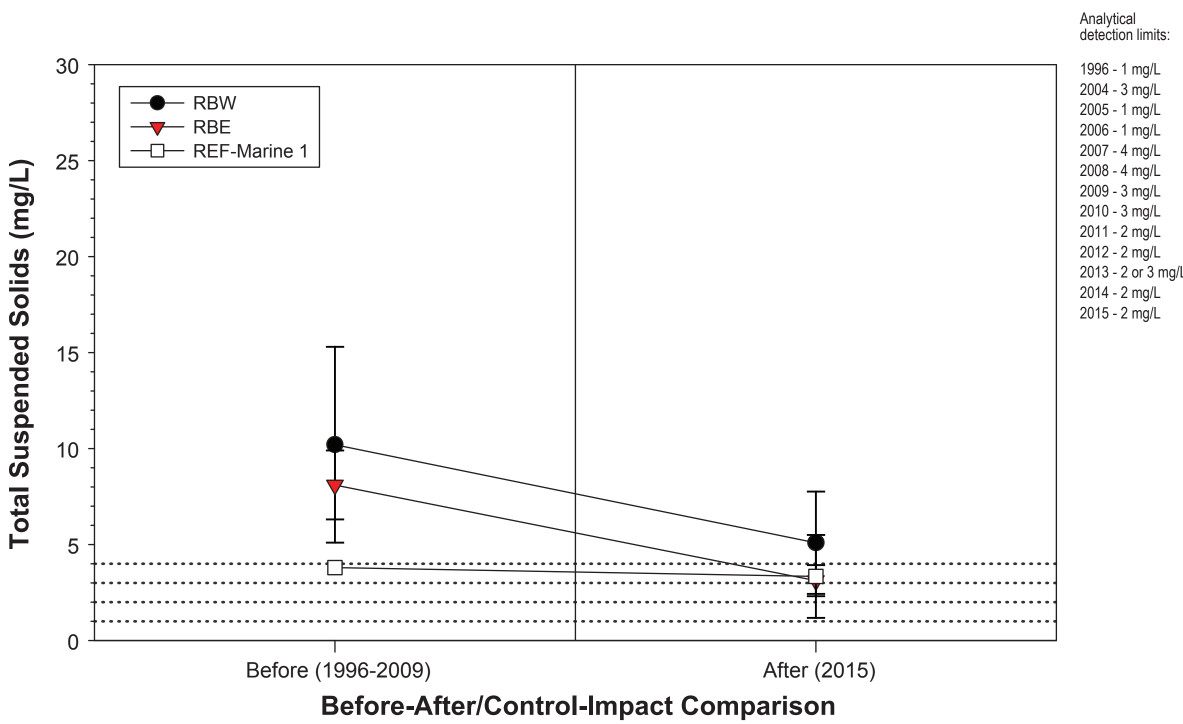
3.3.3.7 Total Cyanide

Total cyanide is regulated as a deleterious substance in effluents as per Schedule 4 of the MMER. All 2015 total cyanide concentrations were below the detection limit of 0.001 mg/L at all marine exposure and reference sites (Figure 3.3-43). Free cyanide concentrations were also measured at marine sites in 2015, and all concentrations were below the detection limit of 0.001 mg/L (Appendix A). Therefore, there was no evidence that 2015 Project activities adversely affected cyanide concentrations at marine exposure sites.

Figure 3.3-40

Total Suspended Solids Concentration in AEMP Marine Sites, Doris North Project, 1996 to 2015

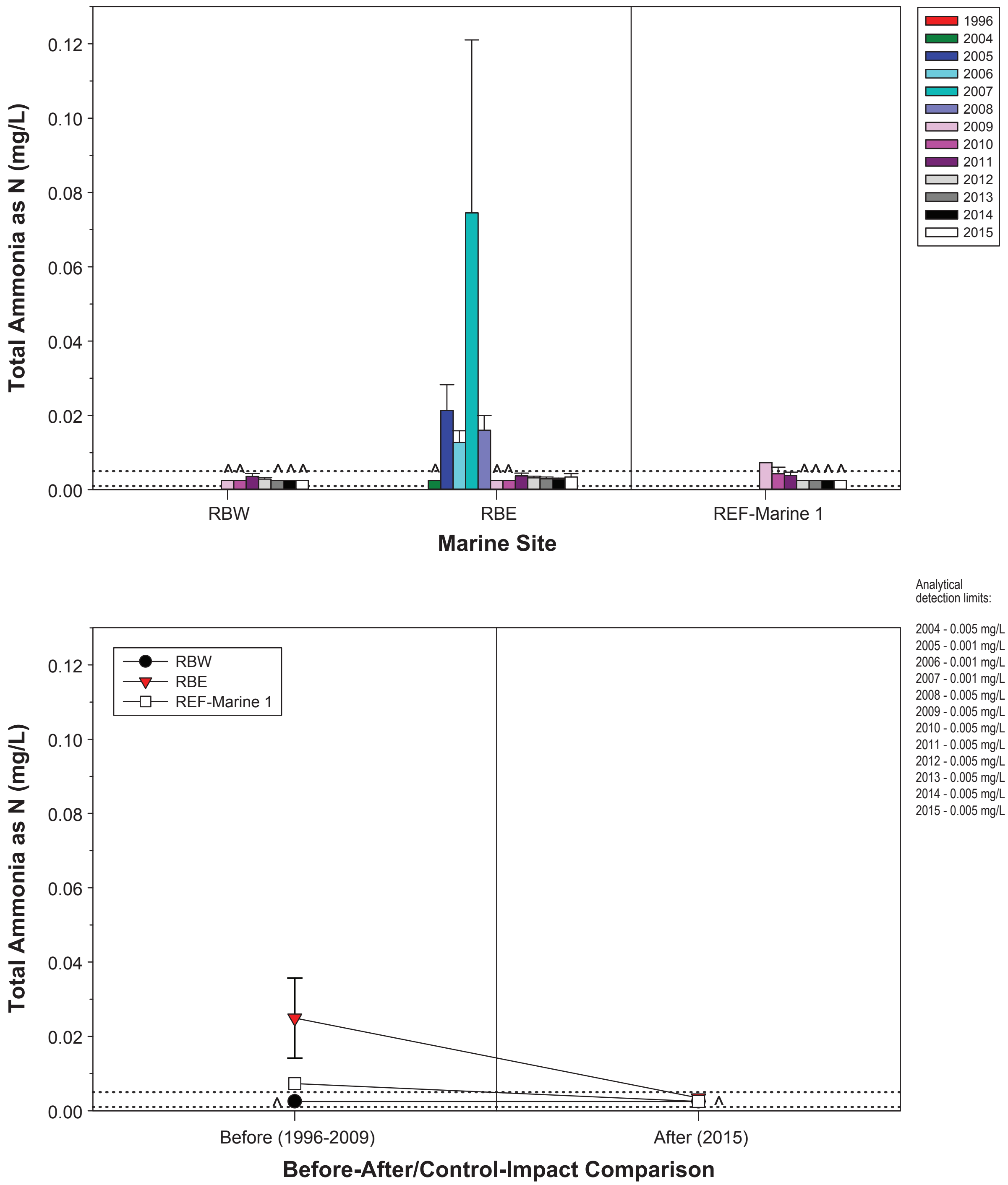




Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
^ Indicates that concentrations were below the detection limit in all samples.
The CCME marine guideline for total suspended solids is dependent upon background levels.
Total suspended solids are regulated as deleterious substances in effluents as per Schedule 4 of the MMER.

Figure 3.3-41

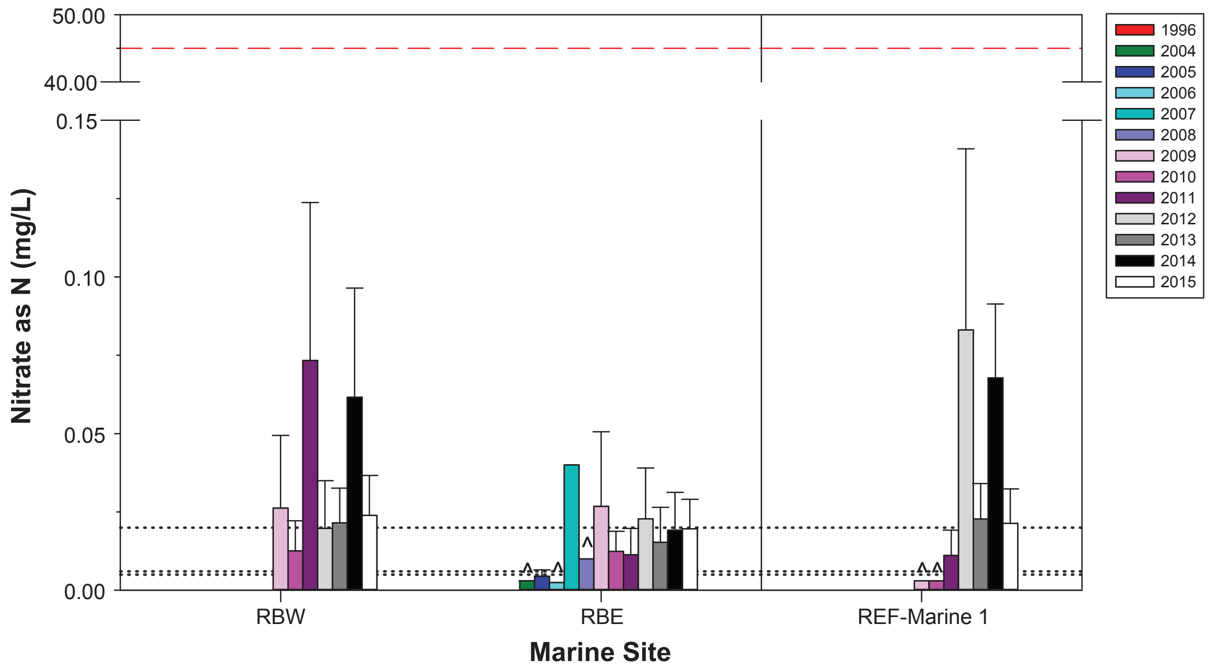
Total Ammonia Concentration in AEMP Marine Sites, Doris North Project, 1996 to 2015

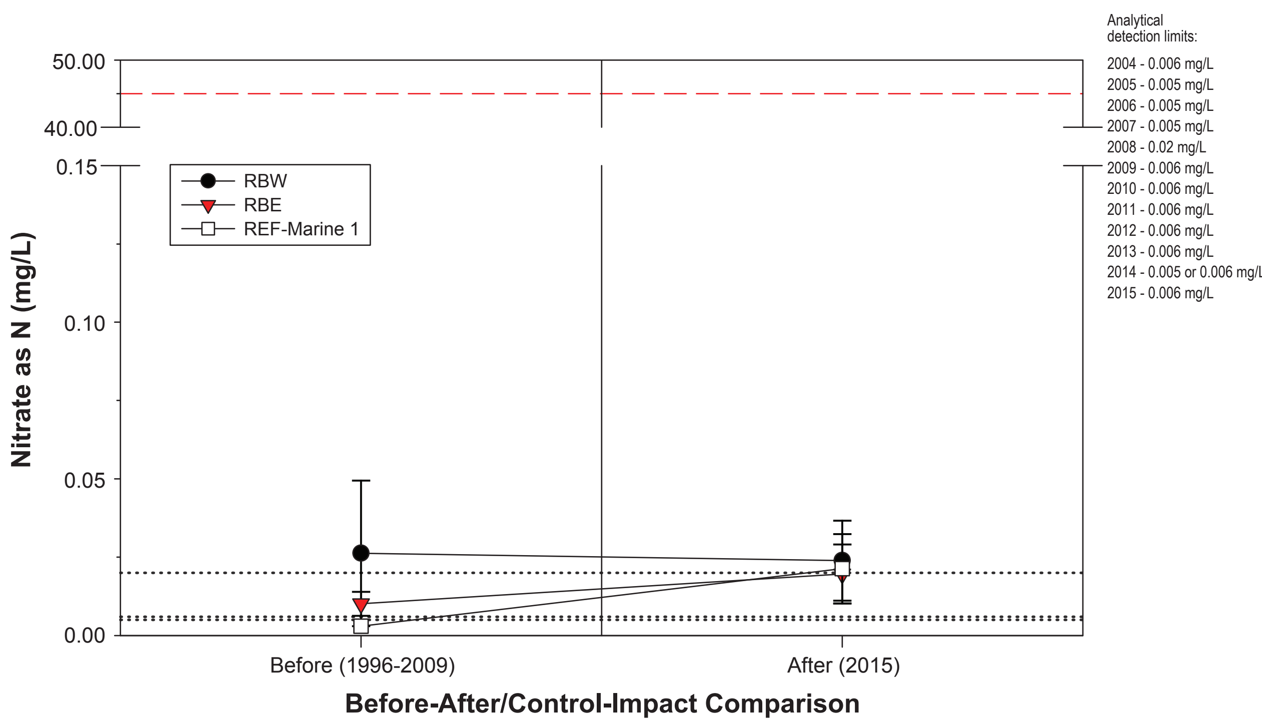


Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
Sample concentrations that were below the very high detection limit of 5 mg/L were excluded from plots.
^ Indicates that concentrations were below the detection limit in all samples.
Total ammonia is a required parameter for effluent characterization as per Schedule 5, s. 4(1) of the MMER.

Nitrate Concentration in AEMP Marine Sites, Doris North Project, 1996 to 2015

ERM

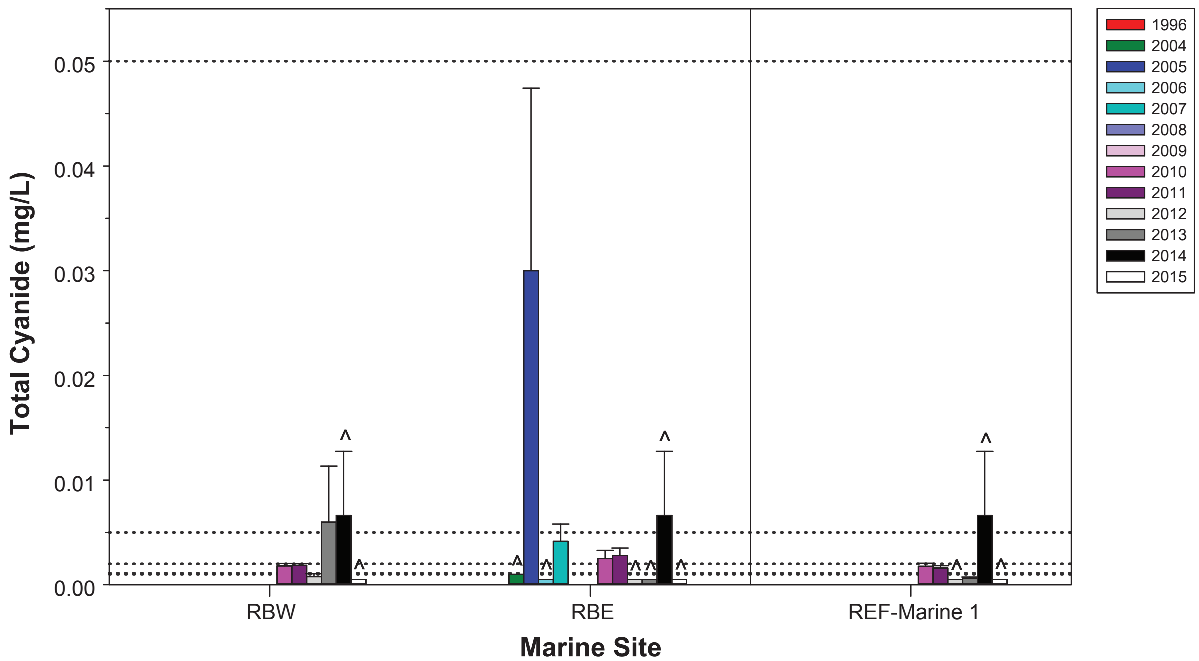


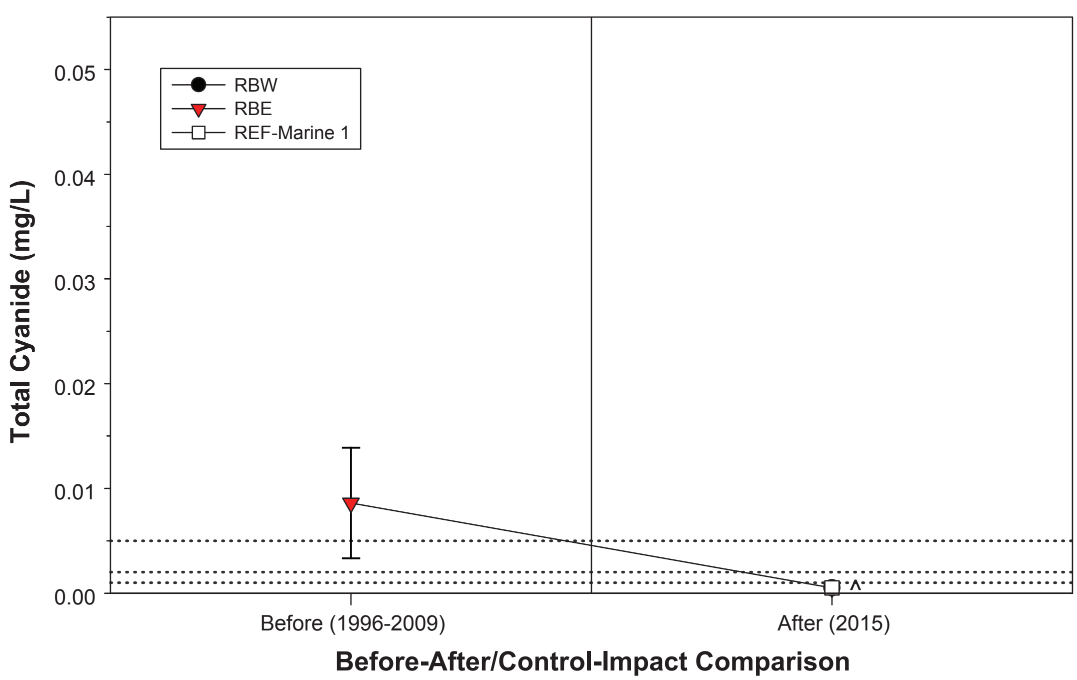


Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
Sample concentrations that were below the very high detection limits of 0.1, 0.25, 0.5, or 2.5 mg/L were excluded from plots.
^ Indicates that concentrations were below the detection limit in all samples.
Red dashed line represents the CCME marine guideline for nitrate as N (45 mg/L; long-term concentration).
Nitrate is a required parameter for effluent characterization as per Schedule 5, s. 4(1) of the MMER.

Figure 3.3-43

Total Cyanide Concentration in AEMP Marine Sites, Doris North Project, 1996 to 2015





Analytical detection limits:

2004 - 0.002 mg/L
2005 - 0.001 mg/L
2006 - 0.001 mg/L
2007 - 0.005 mg/L
2010 - 0.001 or 0.005 mg/L
2011 - 0.001 or 0.0011 mg/L
2012 - 0.001 mg/L
2013 - 0.001 mg/L
2014 - 0.001 or 0.05 mg/L
2015 - 0.001 mg/L

Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
Sample concentrations that were below the very high detection limits of 0.5 or 5 mg/L were excluded from plots.
^ Indicates that concentrations were below the detection limit in all samples.
Total cyanide is regulated as a deleterious substance in effluents as per Schedule 4 of the MMER.

3.3.3.8 Radium-226

Radium-226 is regulated as a deleterious substance in effluents as per Schedule 4 of the MMER. All radium-226 concentrations measured at the marine exposure sites in 2015 were below the analytical detection limit of 0.01 Bq/L, except a single sample collected at RBW in April that had a concentration of 0.01 Bq/L (same as the detection limit; Figure 3.3-44). Statistical results are not presented because > 85% of concentrations in the combined baseline and 2015 dataset were below detection limits. Mean 2015 radium-226 concentrations at the exposure sites were less than the 2015 mean at the reference site in Ida Bay. Therefore, there was no evidence of an effect of 2015 Project activities on radium-226 concentrations at the marine exposure sites.

3.3.3.9 Total Aluminum

Total aluminum is a required variable for effluent characterization as per Schedule 5, s. 4(1) of the MMER. At site RBE, the mean 2015 total aluminum concentration was within the range of baseline means (Figure 3.3-45). At site RBW, the 2015 mean was higher than the 2009 mean (Figure 3.3-45). However, the before-after comparison for both marine exposure sites indicated that the 2015 means were not statistically different from the baseline means ($p = 0.62$ for RBW and $p = 0.73$ for RBE). This suggests that there was no effect of 2015 Project activities on total aluminum concentrations at the marine exposure sites.

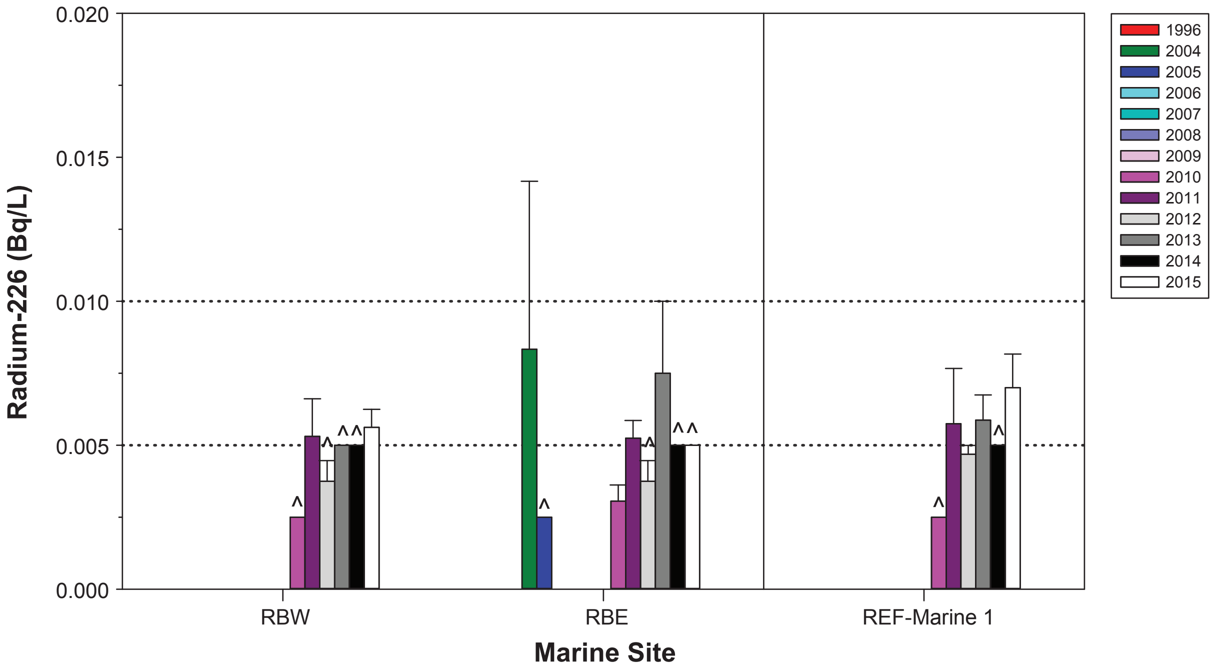
3.3.3.10 Total Arsenic

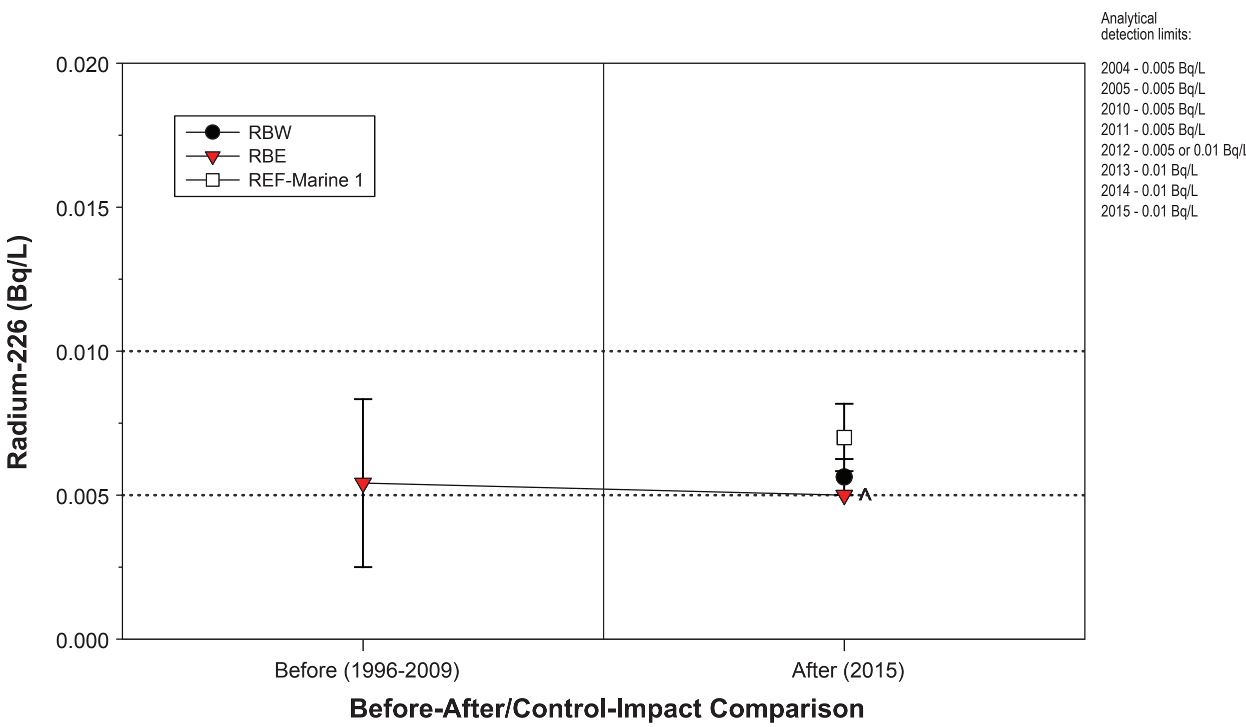
Total arsenic is regulated as a deleterious substance in effluents as per Schedule 4 of the MMER. All total arsenic concentrations measured at marine exposure and reference sites in 2015 were well below the marine CCME guideline of 0.0125 mg/L (Figure 3.3-46). The mean 2015 total arsenic concentration at RBW was similar to the mean baseline concentration from 2009. At RBE, the mean 2015 total arsenic concentration was within the range of baseline concentrations measured between 2007 and 2009, but much lower than the anomalously high arsenic concentrations measured between 2004 and 2006 (Figure 3.3-46). The 2004 to 2006 data were treated as outliers and removed from the dataset for the statistical analyses to increase the ability of statistical tests to detect differences. The before-after comparisons revealed that the 2015 mean total arsenic concentrations at RBW and RBE were not distinguishable from the baseline means ($p = 0.31$ for RBW and $p = 0.75$ for RBE). Therefore, there was no apparent effect of 2015 Project activities on total arsenic concentrations at the marine exposure sites.

3.3.3.11 Total Cadmium

Total cadmium is a required variable for effluent characterization as per Schedule 5, s. 4(1) of the MMER. In 2015, total cadmium concentrations in samples collected from RBW, RBE, and REF-Marine 1 were below the marine CCME guideline of 0.00012 mg/L (Figure 3.3-47). At the exposure sites, 2015 total cadmium concentrations were within the range of baseline concentrations (Figure 3.3-47), and before-after statistical comparisons confirmed that the 2015 and baseline means were not statistically distinguishable for either marine exposure site ($p = 0.21$ for RBW and $p = 0.80$ for RBE). Therefore, there was no apparent effect of 2015 Project activities on total cadmium concentrations at the marine exposure sites.

Radium-226 Concentration in AEMP Marine Sites, Doris North Project, 1996 to 2015

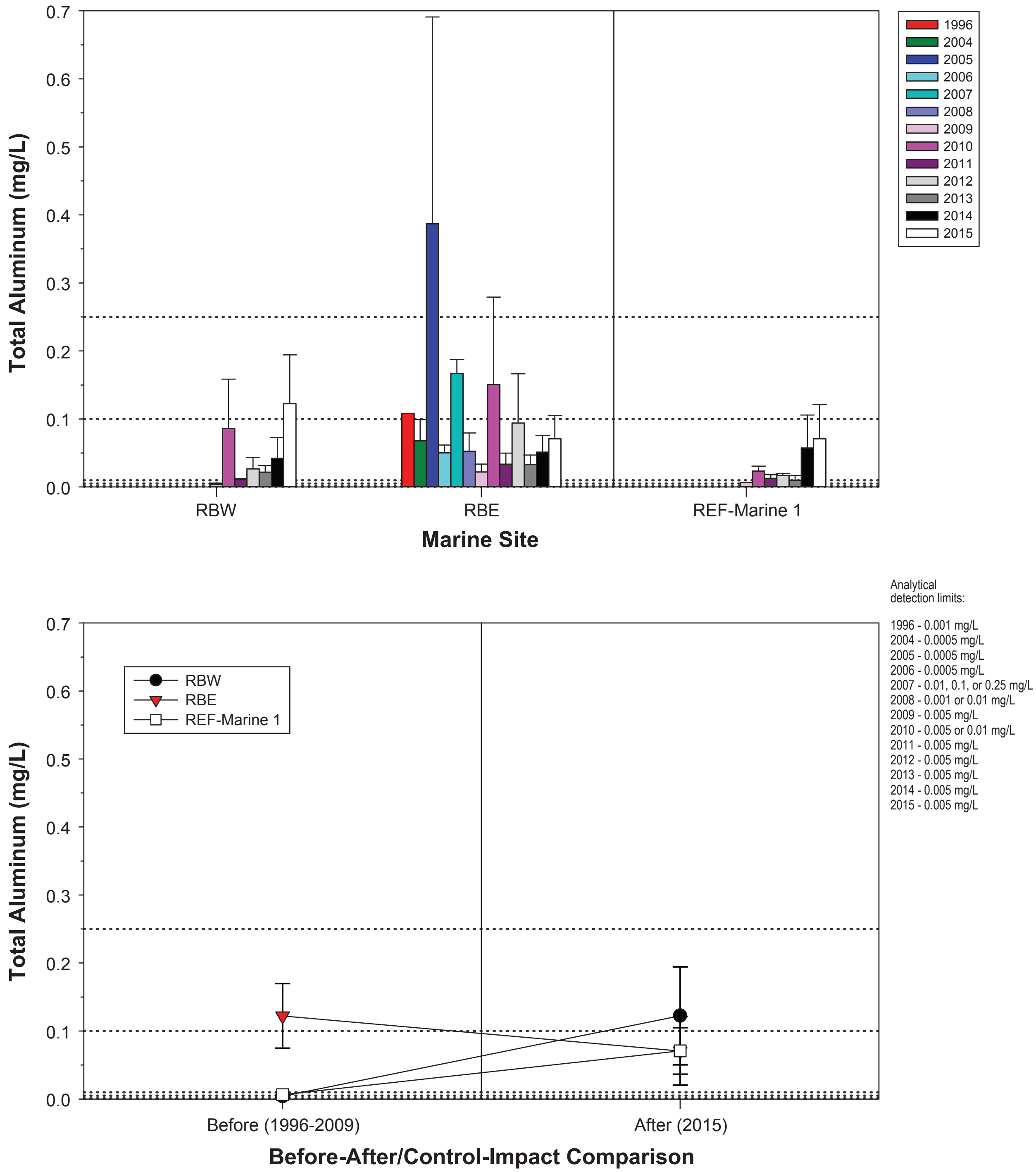




Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
^ Indicates that concentrations were below the detection limit in all samples.
Radium-226 is regulated as a deleterious substance in effluents as per Schedule 4 of the MMER.

Figure 3.3-45

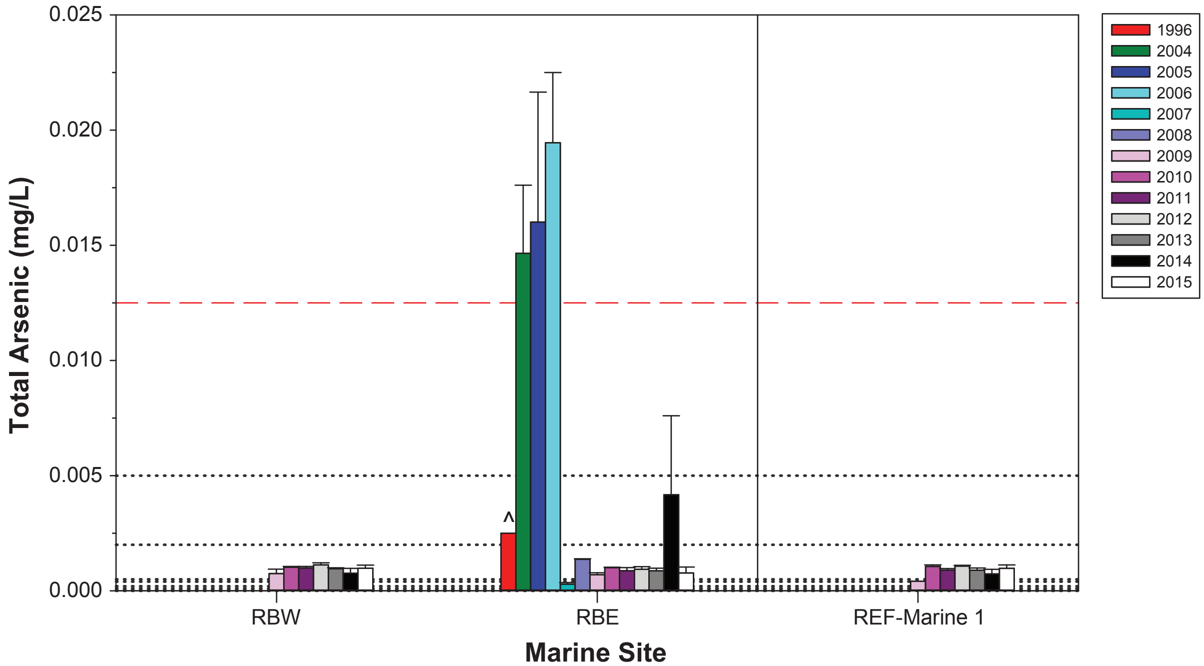
Total Aluminum Concentration in AEMP Marine Sites, Doris North Project, 1996 to 2015

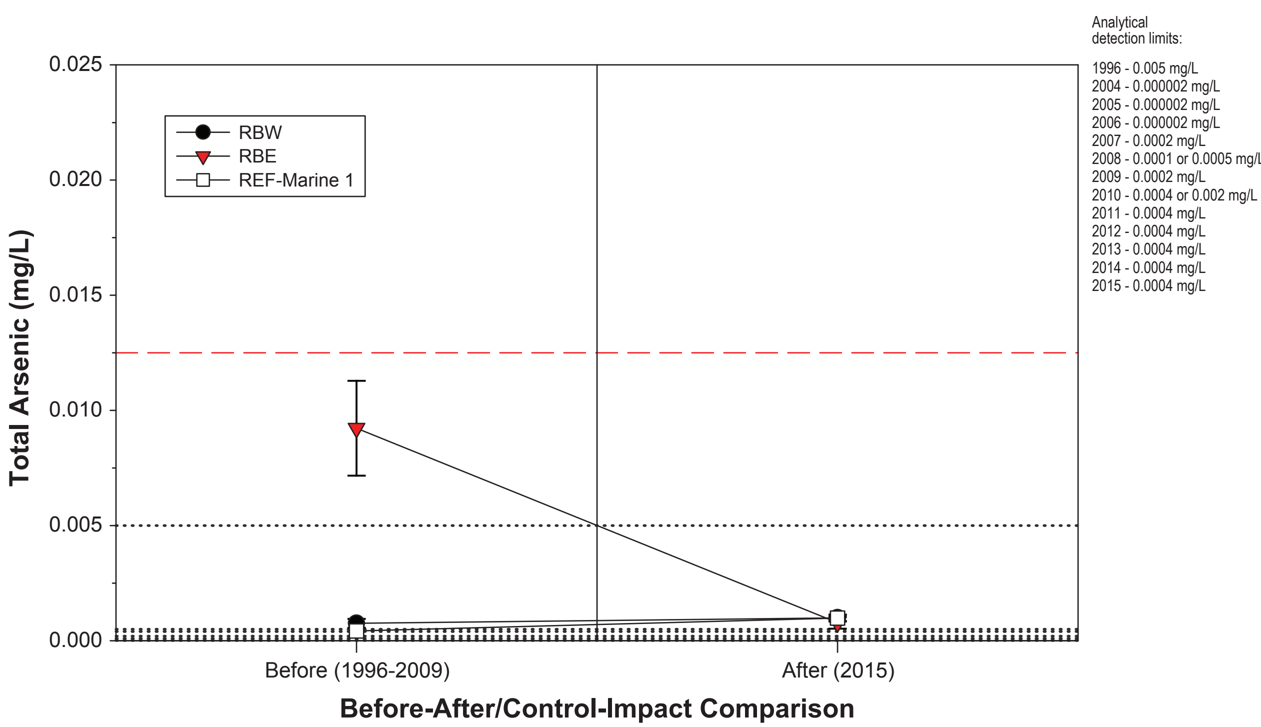


Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
Total aluminum is a required parameter for effluent characterization as per Schedule 5, s. 4(1) of the MMER.

Figure 3.3-46

Total Arsenic Concentration in AEMP Marine Sites, Doris North Project, 1996 to 2015

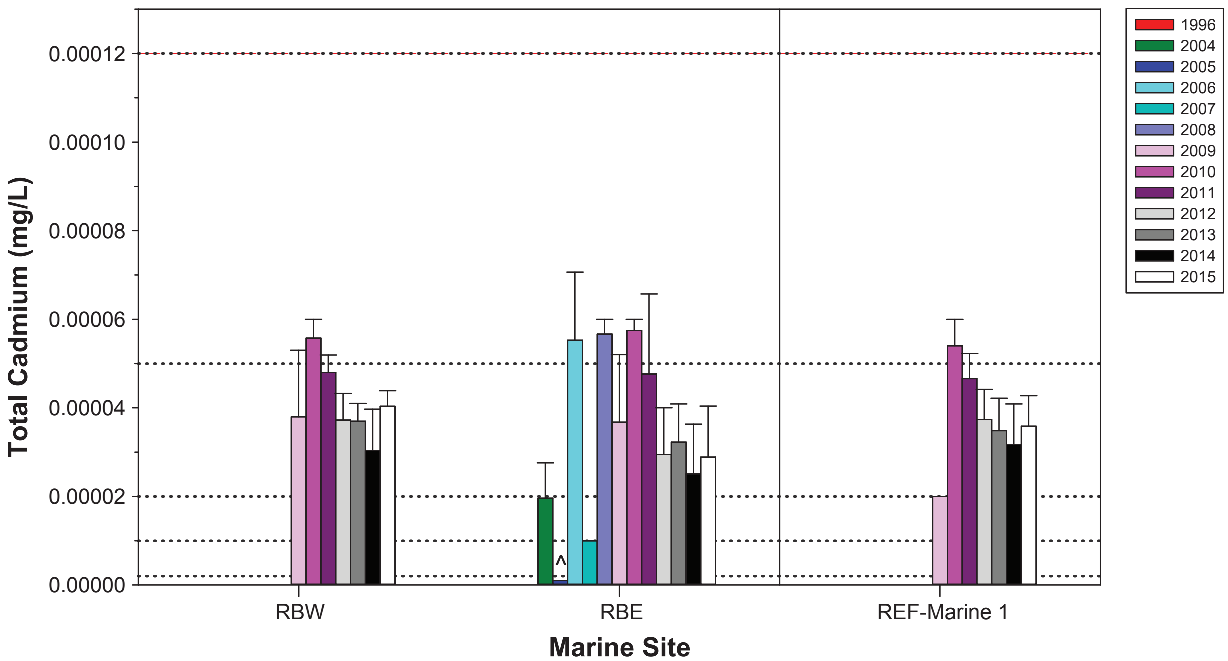


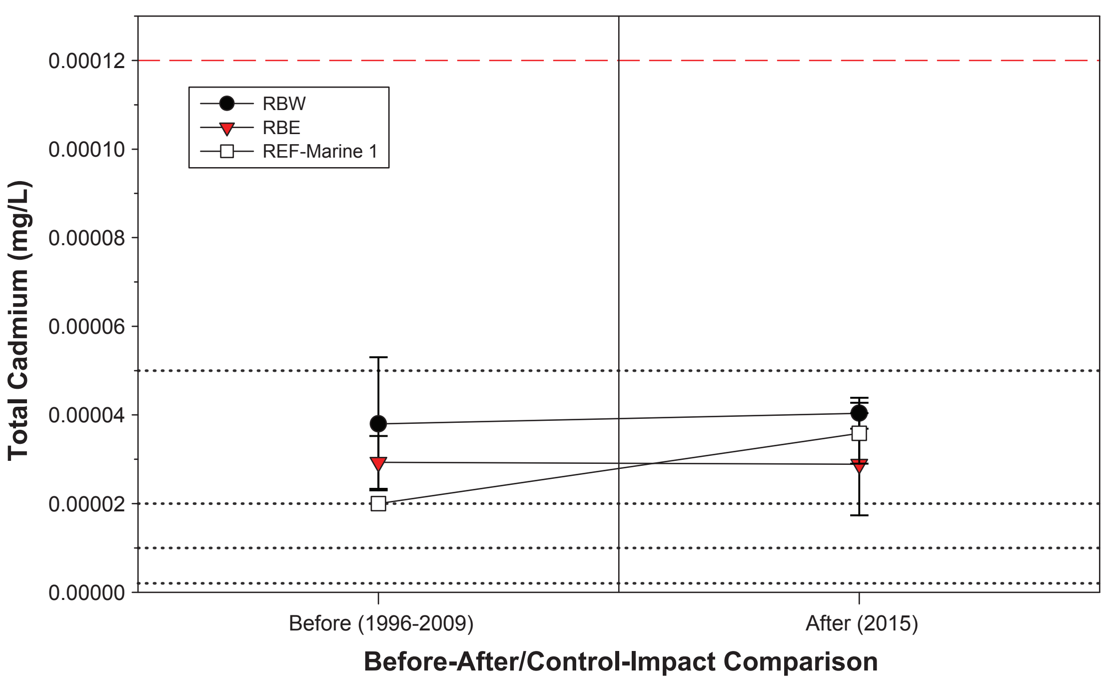


Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
^ Indicates that concentrations were below the detection limit in all samples.
Red dashed lines represent the interim CCME marine guideline for arsenic (0.0125 mg/L).
Total arsenic is regulated as a deleterious substance in effluents as per Schedule 4 of the MMER.

Figure 3.3-47

Total Cadmium Concentration in AEMP Marine Sites, Doris North Project, 1996 to 2015





Analytical detection limits:

2004 - 0.000002 mg/L
2005 - 0.000002 mg/L
2006 - 0.000002 mg/L
2007 - 0.000002 or 0.00002 mg/L
2008 - 0.00001 or 0.00005 mg/L
2009 - 0.00002 mg/L
2010 - 0.00002 or 0.00012 mg/L
2011 - 0.00002 mg/L
2012 - 0.00002 mg/L
2013 - 0.00002 mg/L
2014 - 0.00002 mg/L
2015 - 0.00001 or 0.00002 mg/L

Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
^ Indicates that concentrations were below the detection limit in all samples.
Red dashed lines represent the CCME marine guideline for cadmium (0.00012 mg/L).
The anomalously high total cadmium concentration of 0.00348 mg/L reported for RBE in August 1996 was considered an outlier and was excluded from plots.
Total cadmium is a required parameter for effluent characterization as per Schedule 5, s. 4(1) of the MMER.

3.3.3.12 Total Copper

Total copper is regulated as a deleterious substance in effluents as per Schedule 4 of the MMER. From 1996 to 2009, total copper concentrations at RBE were inter-annually variable. The 2015 mean concentration at RBE was within the range of baseline concentrations (Figure 3.3-48). At RBW and REF-Marine 1, 2015 total copper concentrations were slightly higher than 2009 concentrations (Figure 3.3-48). The before-after comparison showed that for both RBW and RBE, there was no significant difference between baseline and 2015 mean total copper concentrations ($p = 0.63$ for RBW and $p = 0.69$ for RBE). Therefore, there was no apparent effect of 2015 Project activities on total copper concentrations at the marine exposure sites.

3.3.3.13 Total Iron

Total iron is a required variable for effluent characterization as per Schedule 5, s. 4(1) of the MMER. At site RBE, the mean 2015 total iron concentration was within the range of the widely varying baseline concentrations (Figure 3.3-49). At sites RBW and REF-Marine 1, mean 2015 total iron concentrations were higher than baseline (2009) concentrations (Figure 3.3-49). The before-after analysis showed that 2015 means were not distinguishable from baseline means at the exposure sites ($p = 0.59$ for RBW and $p = 0.65$ for RBE), indicating that there was no effect of 2015 Project activities on total iron concentrations at the marine exposure sites.

3.3.3.14 Total Lead

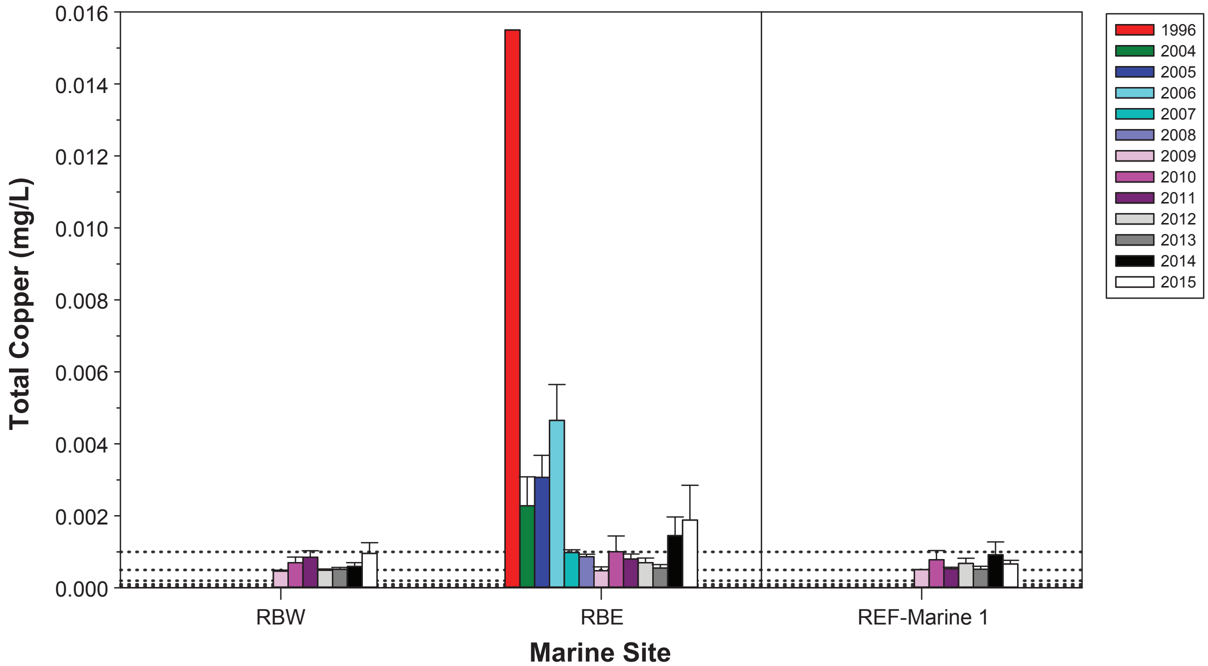
Total lead is regulated as a deleterious substance in effluents as per Schedule 4 of the MMER. In 2015, mean total lead concentrations at RBW and RBE were similar to or lower than baseline means, and similar to concentrations measured at the reference site (Figure 3.3-50). The before-after analysis confirmed that the 2015 means were not distinguishable from the baseline means ($p = 0.83$ at RBW and $p = 0.67$ at RBE). Thus, there was no apparent effect of 2015 Project activities on total lead concentrations at marine exposure sites.

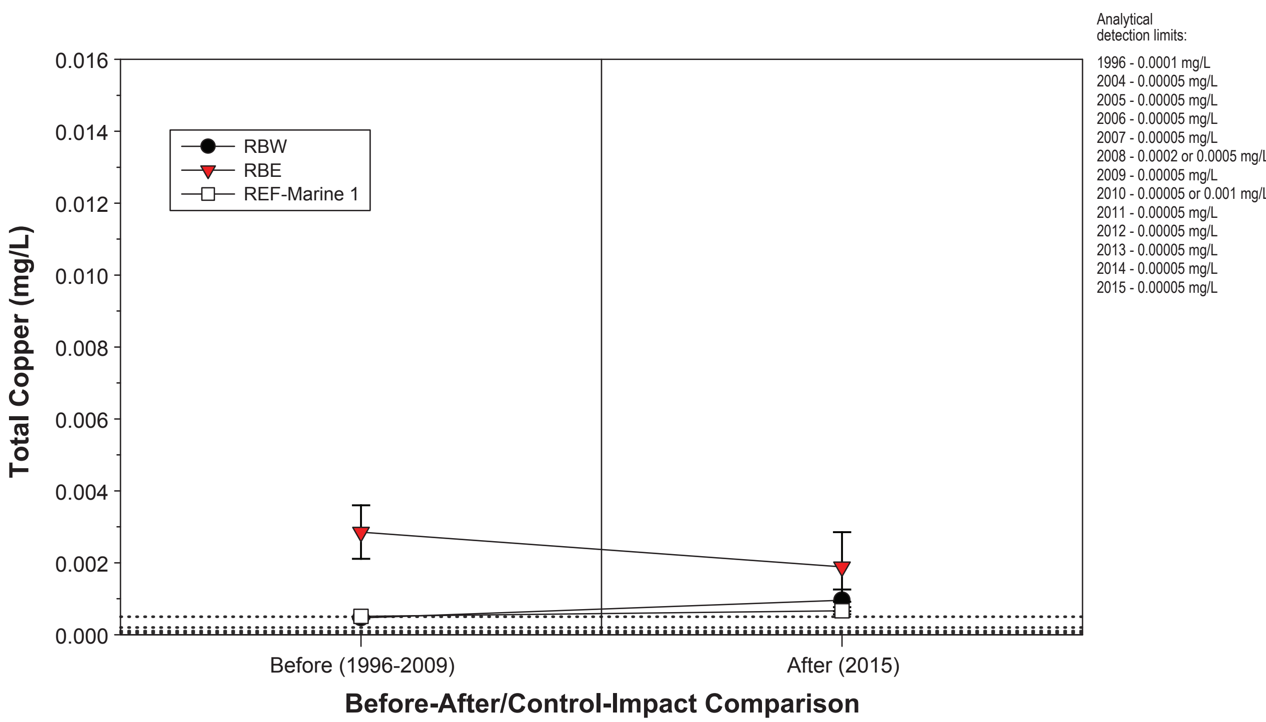
3.3.3.15 Total Mercury

Total mercury is a required variable for effluent characterization as per Schedule 5, s. 4(1) of the MMER. In 2015, all total mercury concentrations measured at marine exposure and reference sites were near or below the ultra-low detection limit of 0.0000005 mg/L (Figure 3.3-51) and well below the interim CCME guideline for inorganic mercury of 0.000016 mg/L (Appendix A). At site RBW, all total mercury concentrations measured in 2015 were below the analytical detection limit. At site RBE, 2015 concentrations were at the lower end of the range of baseline concentrations, and the before-after analysis showed that the baseline and 2015 means were not significantly different ($p = 0.31$). Thus, there was no apparent effect of 2015 Project activities on total mercury concentrations at the marine exposure sites.

Figure 3.3-48

Total Copper Concentration in AEMP Marine Sites, Doris North Project, 1996 to 2015

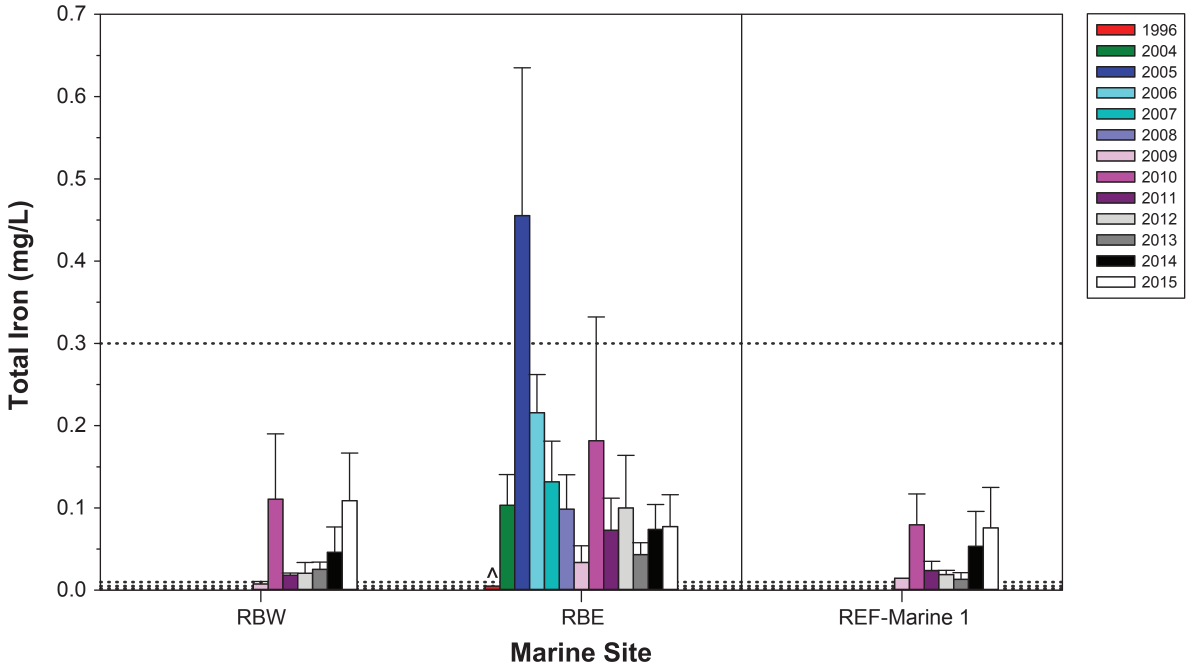


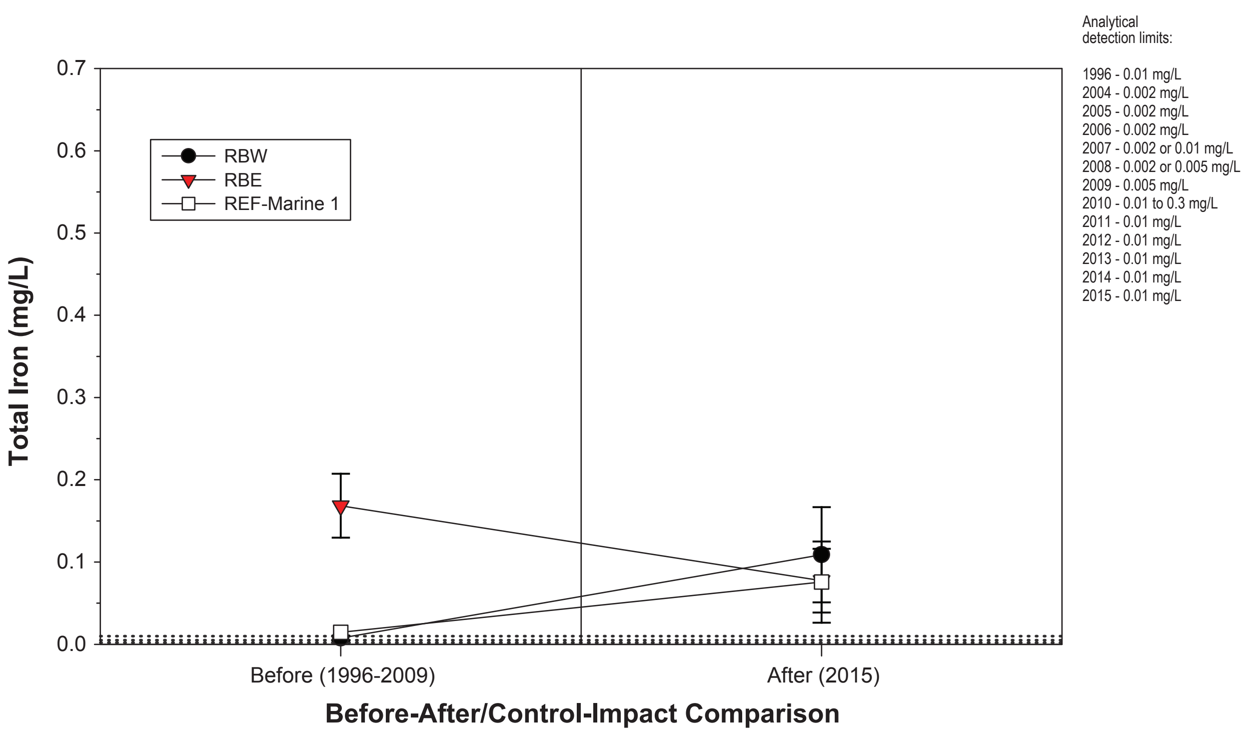


Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
^ Indicates that concentrations were below the detection limit in all samples.
Total copper is regulated as a deleterious substance in effluents as per Schedule 4 of the MMER.

Figure 3.3-49

Total Iron Concentration in AEMP Marine Sites, Doris North Project, 1996 to 2015

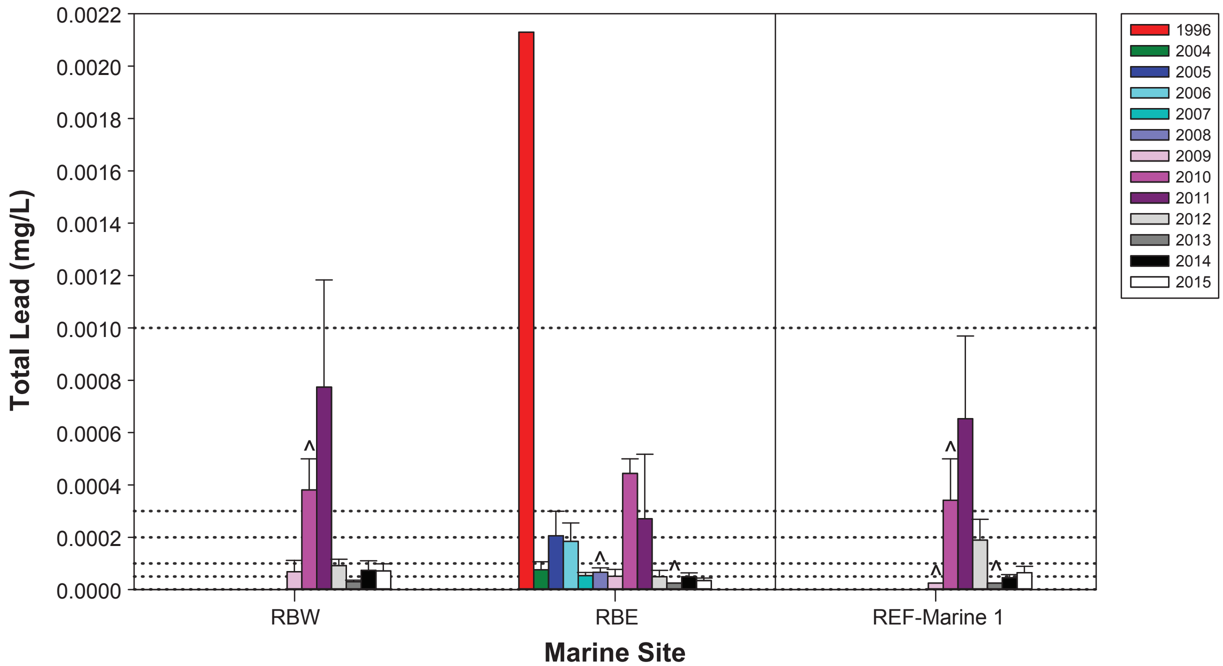


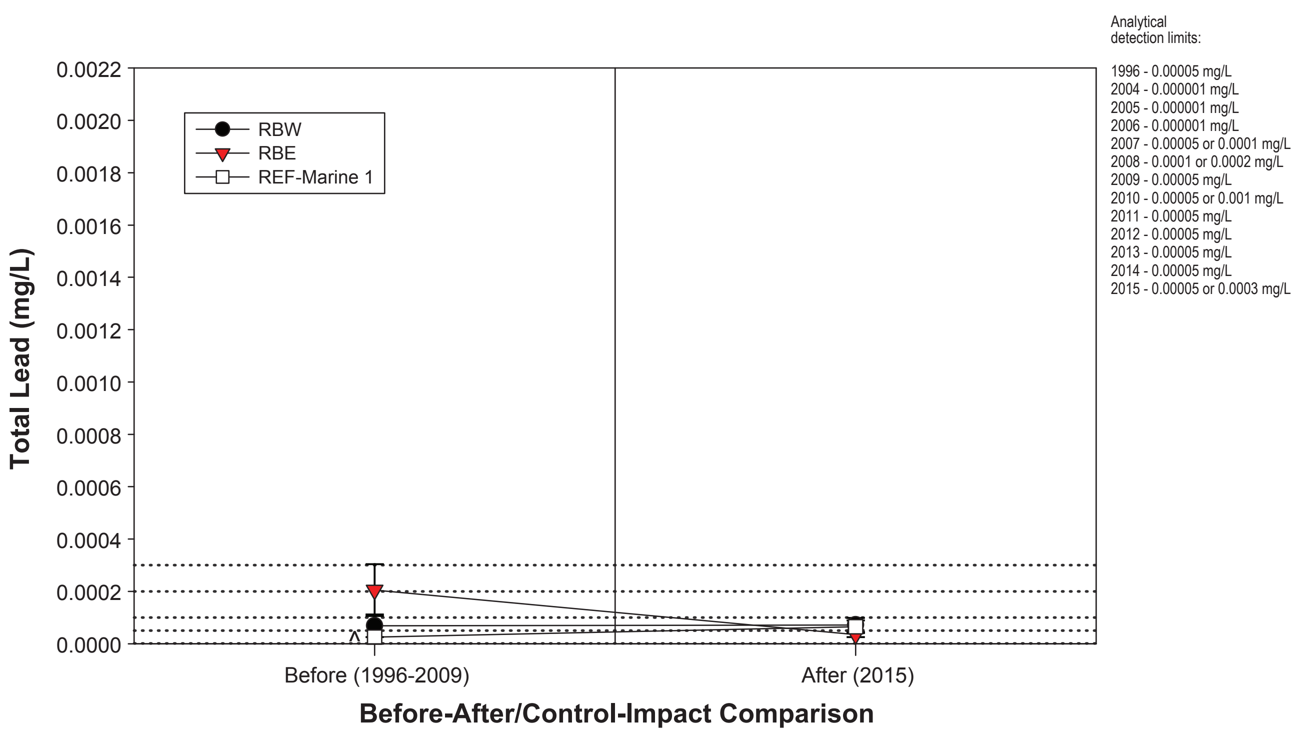


Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
^ Indicates that concentrations were below the detection limit in all samples.
Total iron is a required parameter for effluent characterization as per Schedule 5, s. 4(1) of the MMER.

Figure 3.3-50

Total Lead Concentration in AEMP Marine Sites, Doris North Project, 1996 to 2015

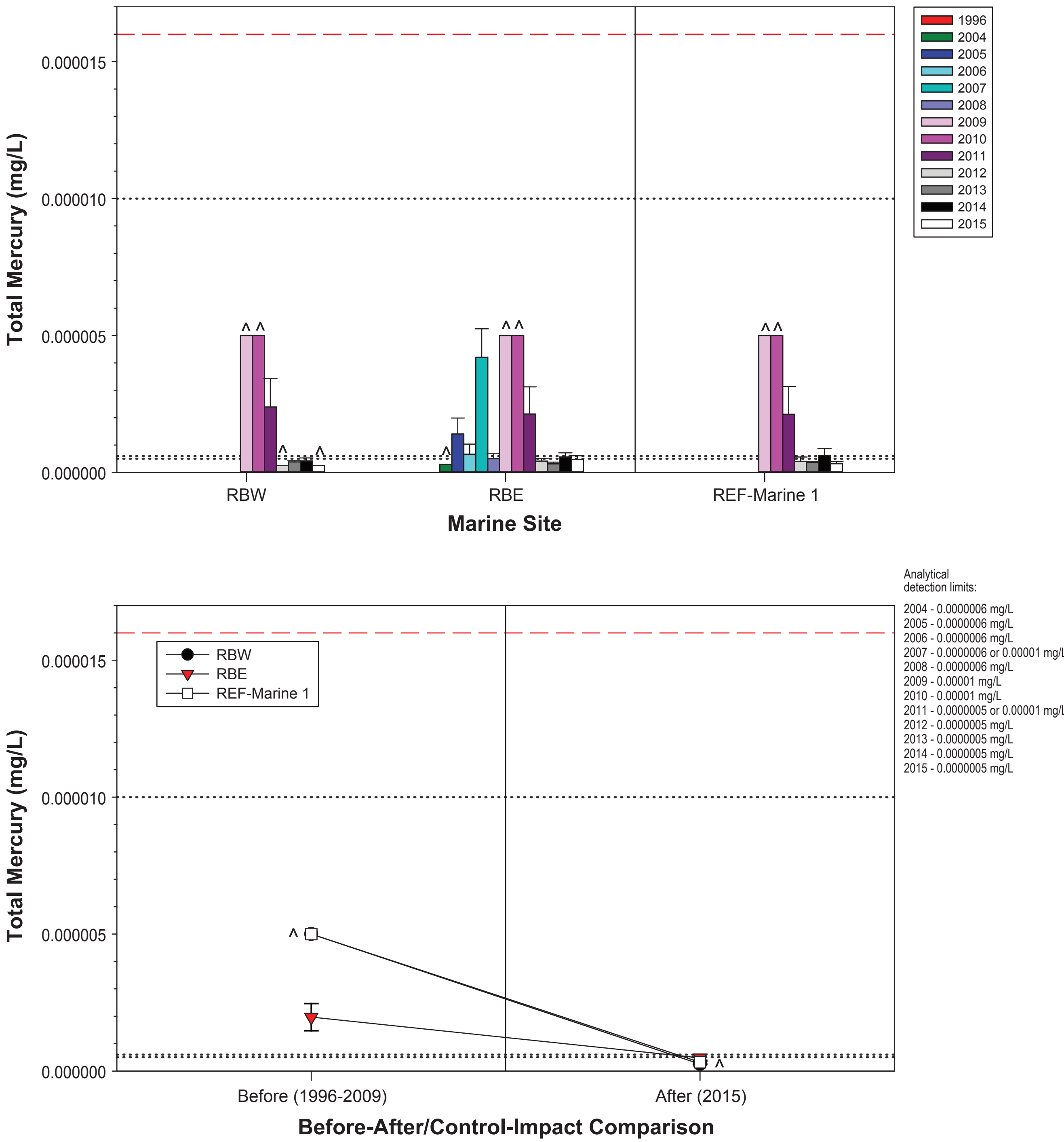




Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
^ Indicates that concentrations were below the detection limit in all samples.
Total lead is regulated as a deleterious substance in effluents as per Schedule 4 of the MMER.

Figure 3.3-51

Total Mercury Concentration in AEMP Marine Sites, Doris North Project, 1996 to 2015



Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
^ Indicates that concentrations were below the detection limit in all samples.
Red dashed lines represent the interim CCME marine guideline for inorganic mercury (0.000016 mg/L).
Total mercury is a required parameter for effluent characterization as per Schedule 5, s. 4(1) of the MMER.

3.3.3.16 Total Molybdenum

Total molybdenum is a required variable for effluent characterization as per Schedule 5, s. 4(1) of the MMER. 2015 total molybdenum concentrations at the two marine exposure sites were within the range of baseline concentrations (Figure 3.3-52). The before-after comparison confirmed that there was no difference between 2015 mean concentrations and baseline means for the Roberts Bay sites ($p = 0.40$ for RBW and $p = 0.85$ for RBE). Therefore, 2015 Project activities had no apparent effect on total molybdenum concentrations at the marine exposure sites.

3.3.3.17 Total Nickel

Total nickel is regulated as a deleterious substance in effluents as per Schedule 4 of the MMER. The mean 2015 total nickel concentration at site RBW was slightly higher than the mean 2009 concentration, while the mean 2015 total nickel concentration at RBE was lower than the baseline mean (Figure 3.3-53). The before-after analysis showed that the baseline and 2015 means were not statistically distinguishable for either marine exposure site ($p = 0.60$ for RBW and $p = 0.78$ for RBE). Therefore, there was no indication that 2015 Project activities had an effect on total nickel concentrations at the marine exposure sites.

3.3.3.18 Total Zinc

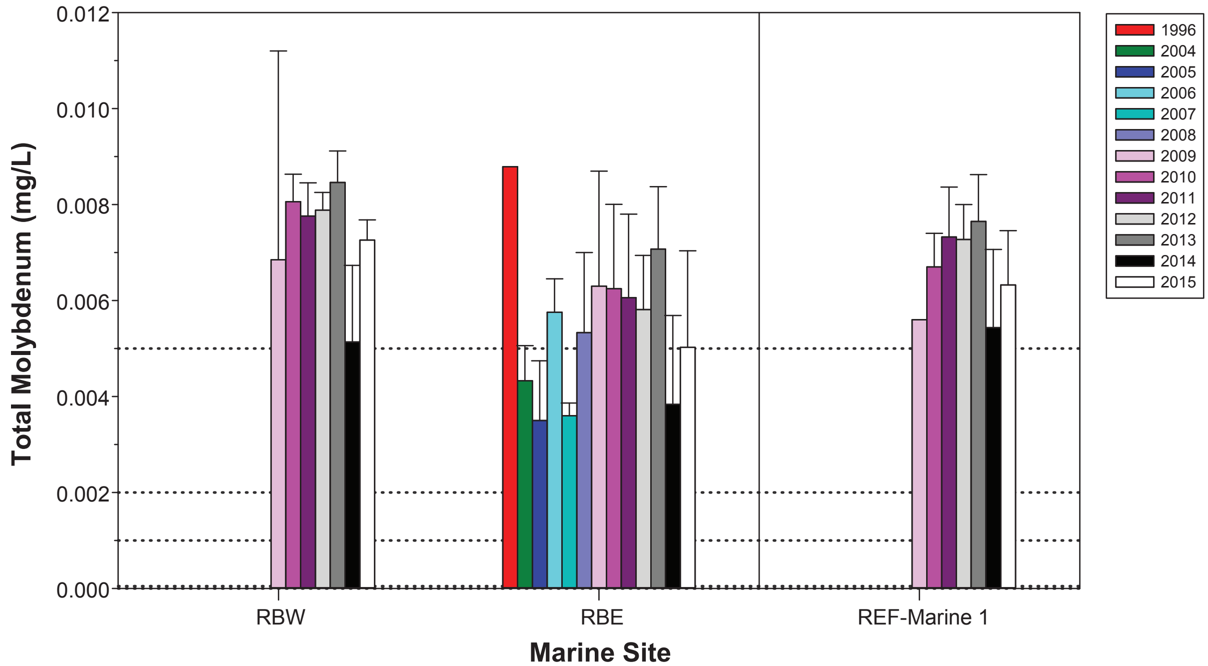
Total zinc is regulated as a deleterious substance in effluents as per Schedule 4 of the MMER. At site RBW, the mean total zinc concentration was higher in 2015 than in 2009; while at RBE, the 2015 mean was within the range of means for the baseline years (Figure 3.3-54). The before-after comparison showed that there was no significant difference between baseline and 2015 mean zinc concentrations for either of the Roberts Bay sites ($p = 0.63$ for RBW and $p = 0.40$ for RBE), indicating that 2015 Project activities did not affect total zinc concentrations at the marine exposure sites.

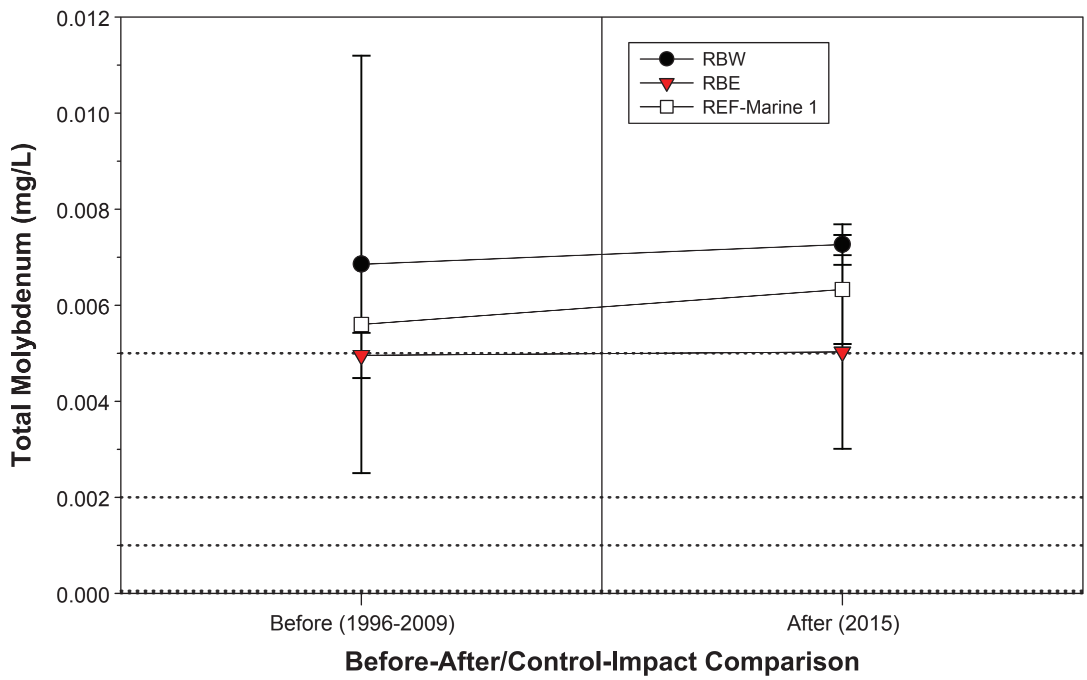
3.4 SEDIMENT QUALITY

As per the MMER, Schedule 5, s. 16(a) (iii), sediment samples were collected and analyzed for particle size and TOC content to complement the benthic invertebrate community surveys. In this section, the sediment quality data collected from stream, lake, and marine sites in 2015 are compared against available baseline information as well as reference sites to evaluate whether 2015 Project activities caused changes to these sediment quality variables. Sediment quality variables for which there are CCME sediment quality guidelines for the protection of aquatic life (CCME 2015a) were also evaluated. CCME guidelines for sediments include interim sediment quality guidelines (ISQGs) and probable effects levels (PELs). The more conservative ISQGs are levels below which adverse biological effects are rarely observed. The higher PELs correspond to concentrations above which negative effects would be expected (CCME 2015a). Sediment quality variables were compared to applicable CCME guidelines to determine whether concentrations posed a concern for freshwater and marine aquatic life. Site-specific baseline conditions were considered in addition to CCME guidelines to determine whether any detected changes would result in a potential adverse effect to freshwater and marine life.

Figure 3.3-52

Total Molybdenum Concentration in AEMP Marine Sites, Doris North Project, 1996 to 2015





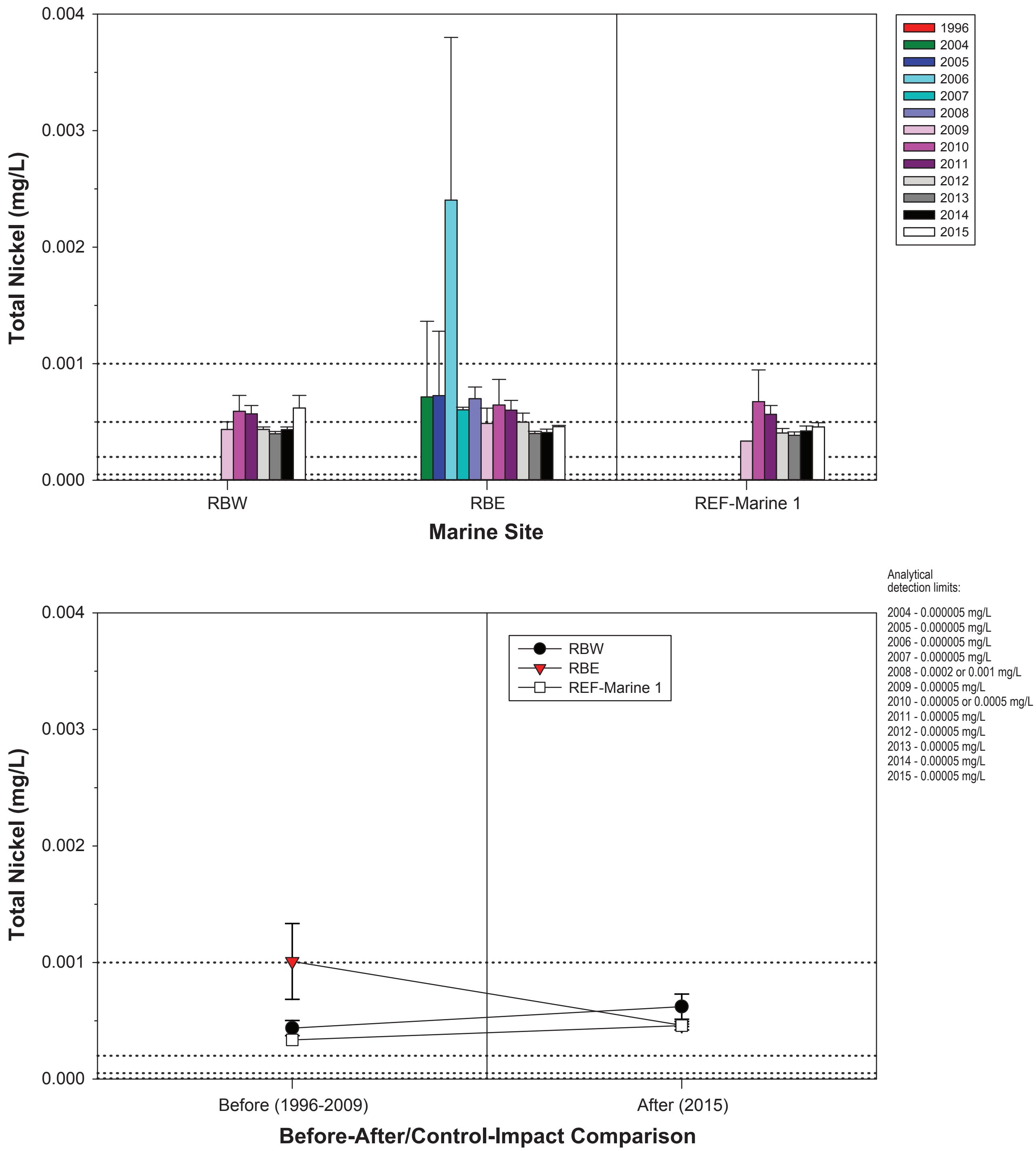
Analytical detection limits:

1996 - 0.00005 mg/L
2004 - 0.000001 mg/L
2005 - 0.000001 mg/L
2006 - 0.000001 mg/L
2007 - 0.000001 mg/L
2008 - 0.001 mg/L
2009 - 0.005 mg/L
2010 - 0.002 mg/L
2011 - 0.002 mg/L
2012 - 0.002 mg/L
2013 - 0.002 mg/L
2014 - 0.002 mg/L
2015 - 0.002 mg/L

Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
^ Indicates that concentrations were below the detection limit in all samples.
Total molybdenum is a required parameter for effluent characterization as per Schedule 5, s. 4(1) of the MMER.

Figure 3.3-53

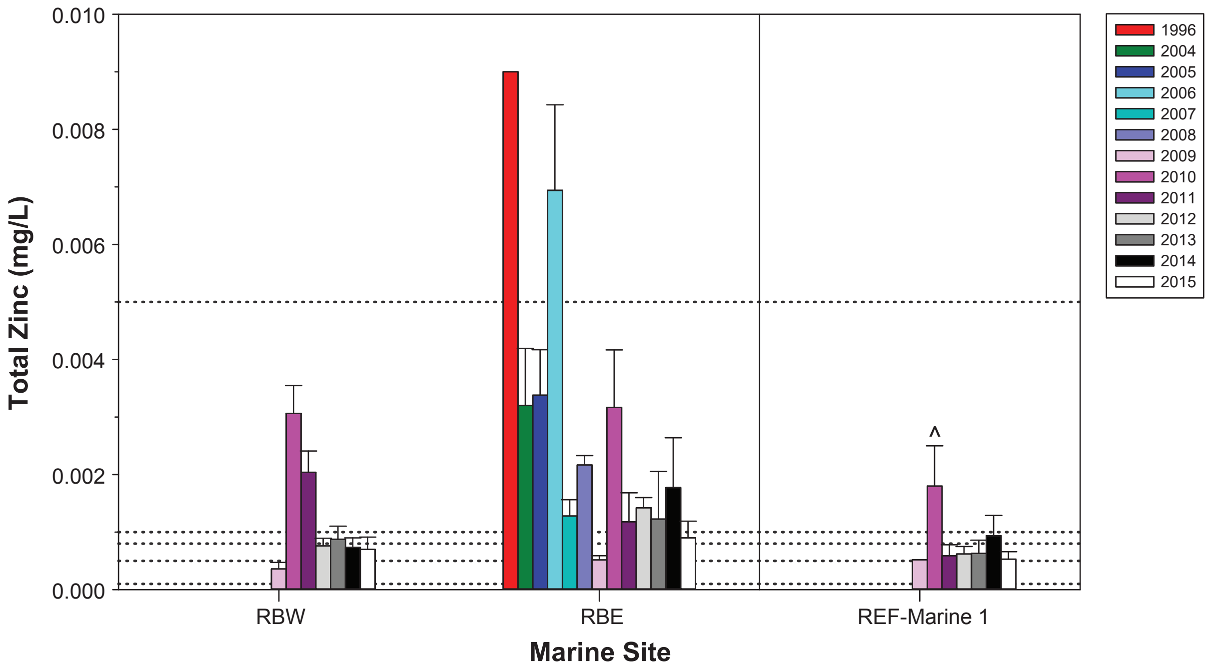
Total Nickel Concentration in AEMP Marine Sites, Doris North Project, 1996 to 2015

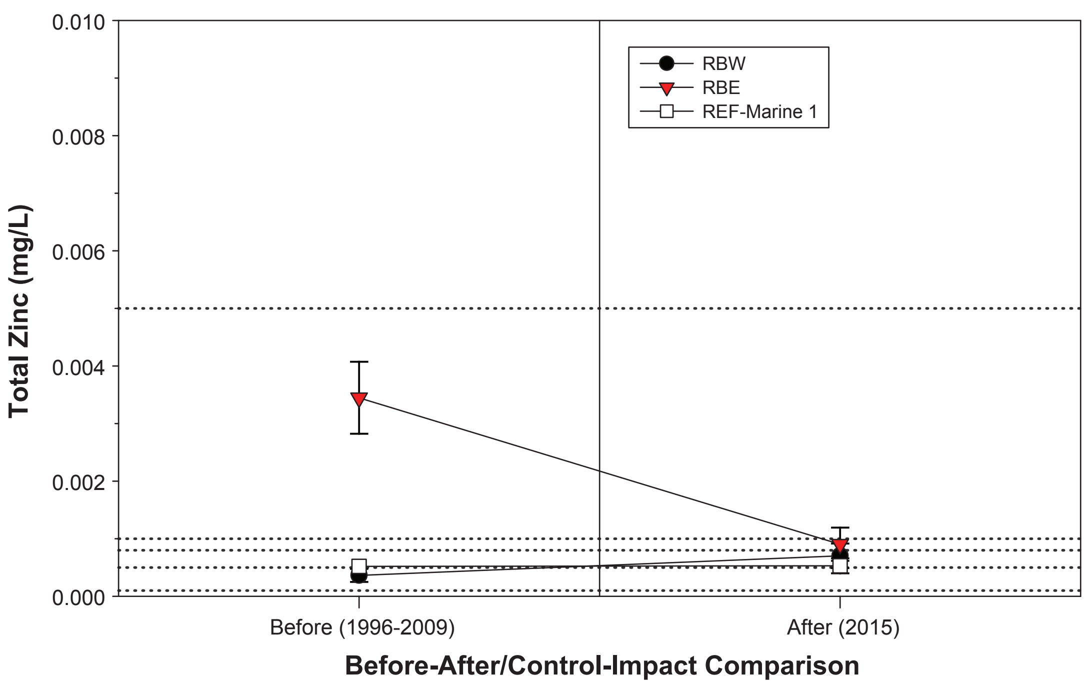


Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
^ Indicates that concentrations were below the detection limit in all samples.
The anomalously high total nickel concentration of 0.0215 mg/L reported for RBE in August 1996 was considered an outlier and was excluded from plots.
Total nickel is regulated as a deleterious substance in effluents as per Schedule 4 of the MMER.

Figure 3.3-54

Total Zinc Concentration in AEMP Marine Sites, Doris North Project, 1996 to 2015





Analytical detection limits:
1996 - 0.001 mg/L
2004 - 0.0001 mg/L
2005 - 0.0001 mg/L
2006 - 0.0001 mg/L
2007 - 0.0005 mg/L
2008 - 0.001 or 0.005 mg/L
2009 - 0.0005 mg/L
2010 - 0.0008 to 0.005 mg/L
2011 - 0.0008 mg/L
2012 - 0.0008 mg/L
2013 - 0.0008 mg/L
2014 - 0.0008 mg/L
2015 - 0.0008 mg/L

Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
^ Indicates that concentrations were below the detection limit in all samples.
Total zinc is regulated as a deleterious substance in effluents as per Schedule 4 of the MMER.

For both graphical and statistical analyses, a value equal to half the detection limit was substituted for sediment quality concentrations that were below analytical detection limits. All statistical results are presented in Appendix B.

3.4.1 Streams

Sediment quality samples from streams were collected from three exposure streams (Doris Outflow, Roberts Outflow, and Little Roberts Outflow) and two reference streams (Reference B Outflow and Reference D Outflow). Baseline data for stream sediments are available only from 2009 and only for Doris, Little Roberts, and Reference B outflows. Data from 2015 were compared to 2009 data to identify potential changes to sediment variables. Stream sediment sampling was conducted in August during both years at the sampled sites. For the calculations of annual means for each variable, all analytical results for stream sediment samples collected in a given year were averaged. Note that sediment quality data and statistical analysis results for Roberts Outflow are shown in the following figures and in Appendices A and B, but this stream is not discussed in the following sections. Roberts Outflow is not expected to be affected by the Project but rather serves to characterize any influence of a closed silver mine and past neighbouring exploration activity (North Arrow Minerals Inc.) on Roberts Outflow and potentially downstream, and to be able to differentiate this from potential effects of TIA discharge upstream.

3.4.1.1 Particle Size

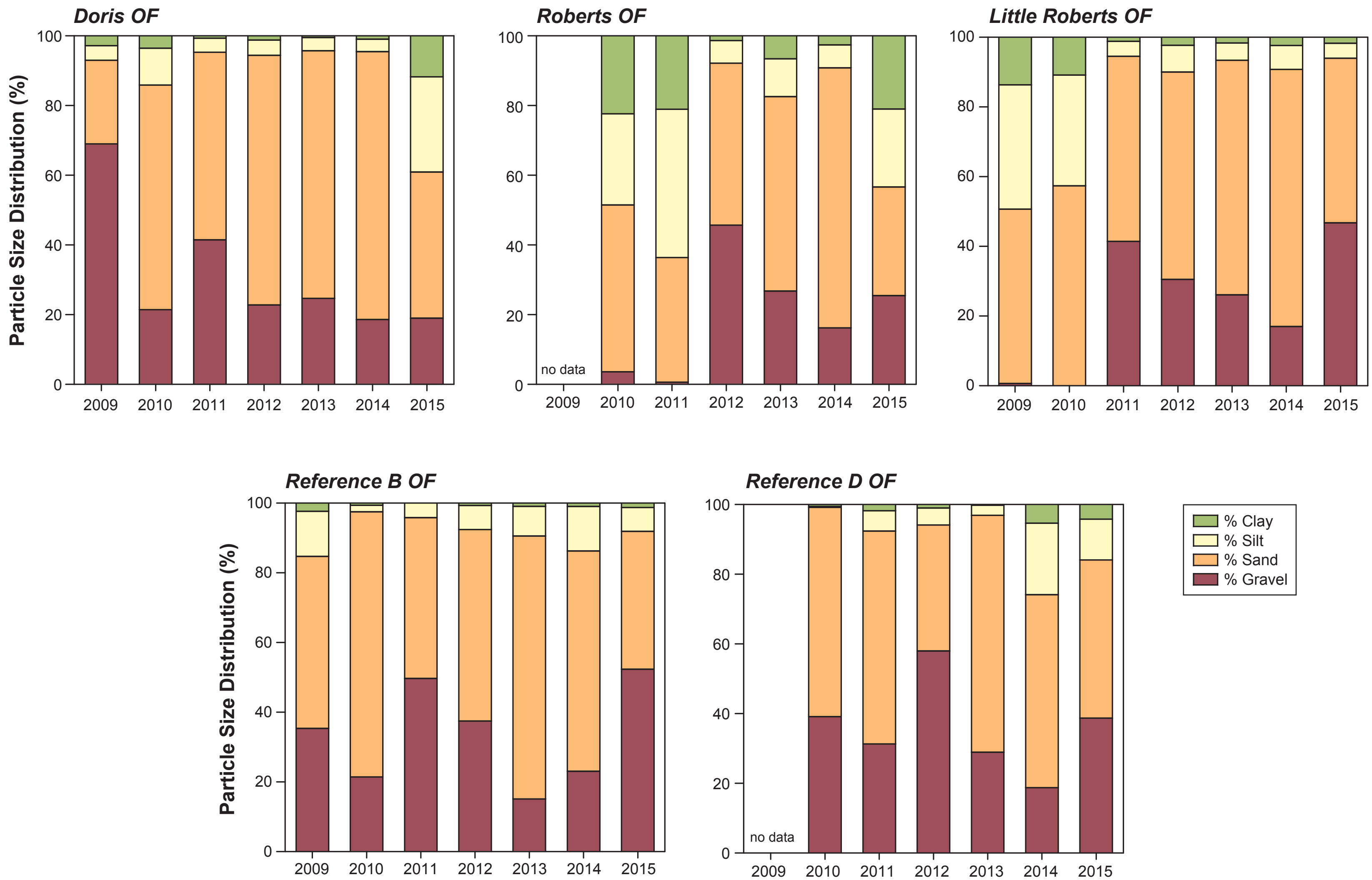
Particle size is a required sediment variable to complement the benthic invertebrate surveys as per Schedule 5, s. 16(a) (iii) of the MMER. There were some important differences in the particle size composition of stream sediments in 2015 compared to 2009 (Figure 3.4-1). This most likely resulted from natural spatial heterogeneity in sediment particle size composition.

In Doris Outflow, 2015 sediments contained higher proportions of sand, silt, and clay, and a lower proportion of gravel compared to 2009. The before-after analysis showed that the observed changes in particle size in Doris Outflow sediments were statistically significant for gravel ($p = 0.010$), but not for the other size classes ($p = 0.25$ for sand, $p = 0.22$ for silt, and $p = 0.26$ for clay). The BACI analysis showed that there was evidence of significant non-parallelism for gravel content in Doris Outflow compared to the reference streams ($p = 0.0067$). Figure 3.4-1 shows that Doris Outflow sediments sampled in 2009 contained approximately twice as much gravel as sediment samples collected annually from 2010 to 2015, and that the Doris Outflow sediment particle size composition was generally similar between 2010 and 2015.

In Little Roberts Outflow, contrary to the differences observed in Doris Outflow, the gravel content was higher and the clay and silt content was lower in 2015 than 2009 (Figure 3.4-1). The before-after analysis for Little Roberts Outflow showed that the changes in particle size were statistically significant for gravel ($p = 0.0004$), silt ($p = 0.0003$), and clay ($p = 0.0002$), but that sand content was not significantly different between 2009 and 2015 ($p = 0.53$). The BACI analysis showed that there was evidence of non-parallelism for the decreases in both clay ($p = 0.0005$) and silt ($p = 0.024$) compared to the reference streams, but that the increase in gravel was parallel to the trend seen in the reference streams ($p = 0.095$).

Figure 3.4-1

Particle Size Distribution in AEMP Stream Sediments, Doris North Project, 2009 to 2015



Notes: Stacked bars represent the mean of replicate samples.
Particle size distribution of sediments is a required parameter as part of benthic invertebrate surveys as per Schedule 5, s.16a (iii) of the MMER.

Variation in sediment particle size composition is unlikely to be related to 2015 Project activities, and probably reflects natural spatial heterogeneity in stream sediments since corresponding Project-related changes in water quality have not been observed (e.g., increases in TSS). This observed variability in sediment particle size between 2009 and 2015 in Doris and Little Roberts outflows confounds the comparison of sediment chemistry variables between 2009 and 2015, since metal and TOC concentrations are closely related to sediment particle size and tend to be greater in finer sediments (e.g., Lakhan, Cabana, and LaValle 2003; Secrieri and Oaie 2009). Relative to 2009 samples, Doris Outflow sediments were finer in 2015, while Little Roberts sediments were coarser in 2015. Based on particle size alone, the expectation based on well-established trends would be that metal and TOC concentrations in Doris Outflow sediments would be higher in 2015 than 2009, and conversely, that metal and TOC concentrations in Little Roberts Outflow sediments would be lower in 2015 than 2009, though this would be unrelated to Project activities. As discussed below, this expectation was met as concentrations of nearly all the variables subjected to evaluation increased in Doris Outflow and decreased in Little Roberts Outflow between 2009 and 2015; however, in the case of Doris Outflow, none of the increases were statistically significant changes.

3.4.1.2 Total Organic Carbon

TOC content is a required sediment variable that is meant to support the benthic invertebrate surveys as per Schedule 5, s. 16(a) (iii) of the MMER. In both exposure and reference stream sediments, the TOC content was highly variable both inter-annually and among replicates collected from each stream within a year (Figure 3.4-2). Although the mean TOC content of Doris Outflow sediments was higher in 2015 than in 2009, the before-after comparison showed that the 2015 mean was not distinguishable from the 2009 mean ($p = 0.35$).

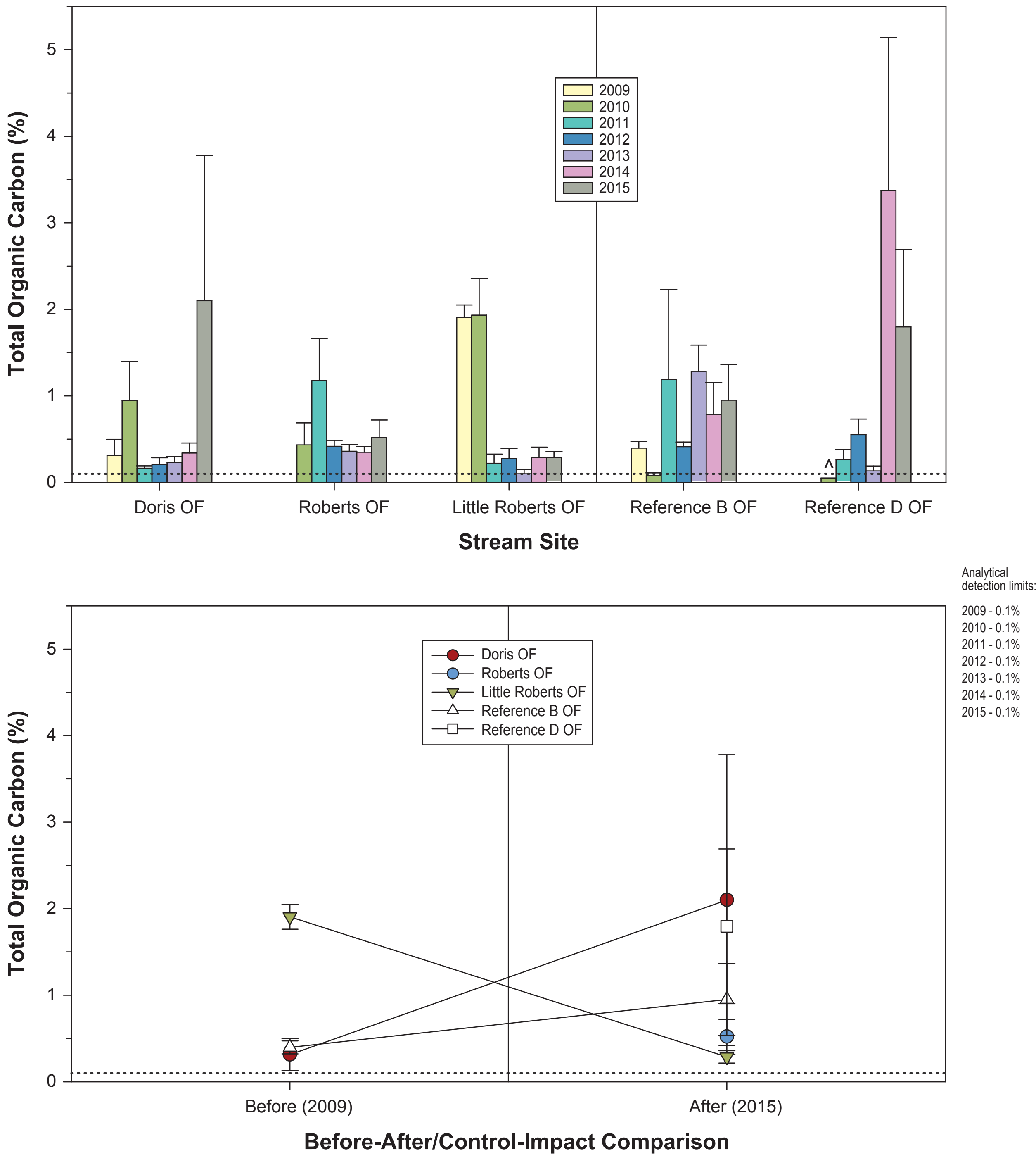
For Little Roberts Outflow, the before-after comparison showed that the TOC content of sediments decreased significantly in 2015 compared to 2009 ($p = 0.0005$), and the BACI analysis indicated that there was no parallel decrease observed at the reference streams ($p = 0.0013$). This differential decrease in TOC at Little Roberts Outflow was likely related to the lower proportion of fine sediments in 2015 samples compared to 2009, since TOC concentrations tend to be higher in finer sediments (e.g., Secrieri and Oaie 2009). Indeed, the highest TOC levels in Little Roberts Outflow sediments were measured in 2009 and 2010 (Figure 3.4-2), corresponding to the years that sediments in this stream were markedly finer than other years (Figure 3.4-1). There is no reason to suspect that 2015 Project activities caused a decrease in the sediment TOC content of Little Roberts Outflow.

3.4.1.3 Total Arsenic

Mean arsenic concentrations in exposure stream sediments in 2015 were below the CCME ISQG of 5.9 mg/kg and the PEL of 17 mg/kg (Figure 3.4-3). The before-after comparison showed that there were no significant differences between 2009 and 2015 mean arsenic concentrations at Doris Outflow ($p = 0.31$) or Little Roberts Outflow ($p = 0.74$). Therefore, there was no indication that 2015 Project activities adversely affected arsenic concentrations in exposure stream sediments.

Figure 3.4-2

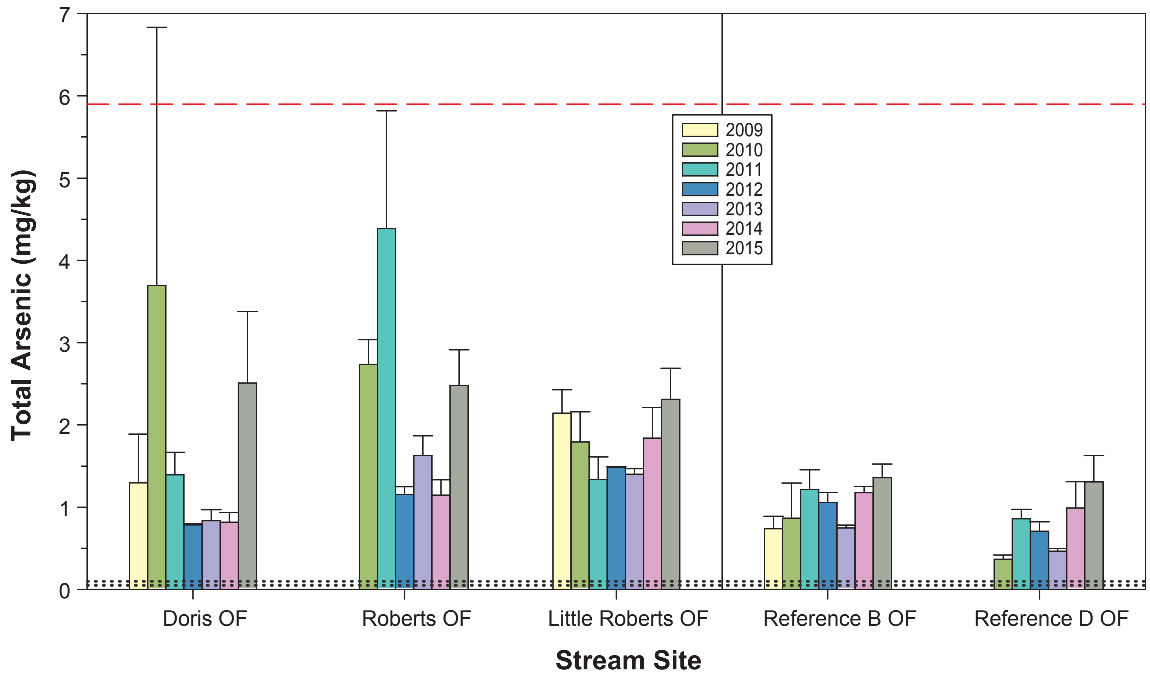
Total Organic Carbon Concentrations in AEMP Stream Sediments, Doris North Project, 2009 to 2015

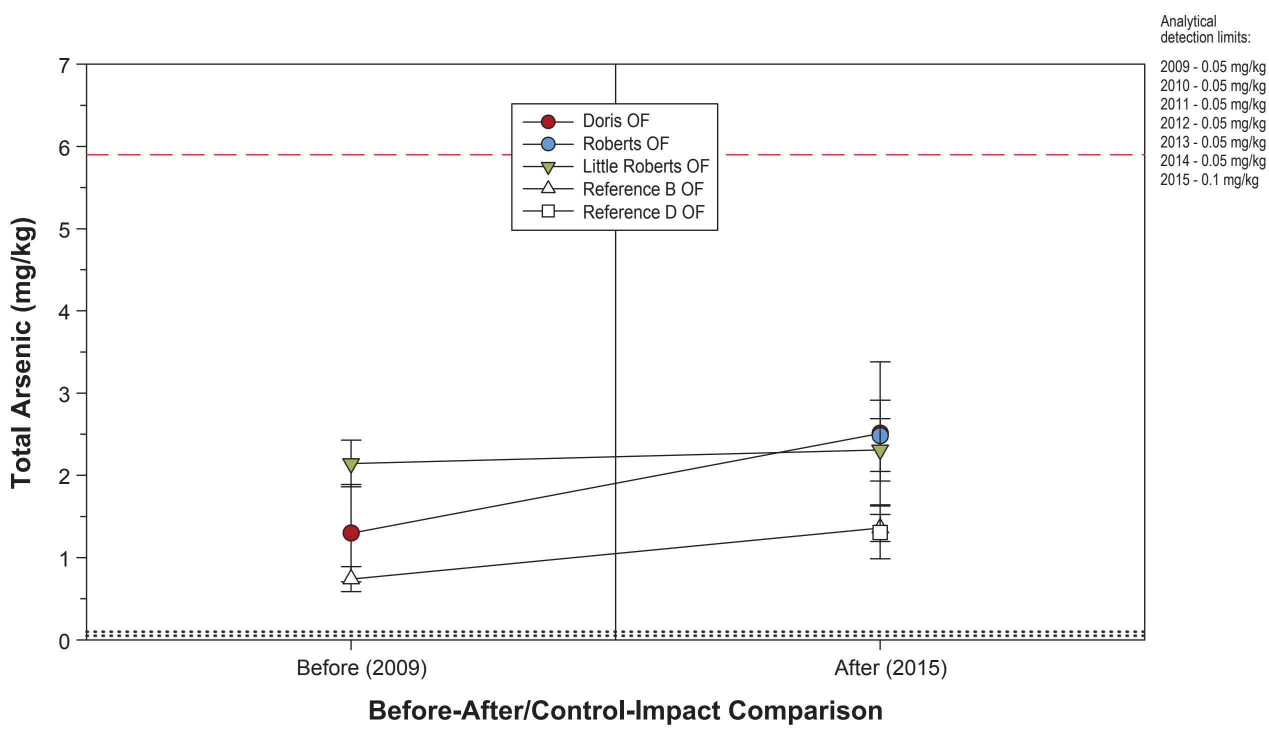


Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
^ Indicates that concentrations were below the detection limit in all samples.
Total organic carbon content of sediments is a required parameter as part of benthic invertebrate surveys as per Schedule 5, s.16a (iii) of the MMER.

Figure 3.4-3

Total Arsenic Concentrations in AEMP Stream Sediments, Doris North Project, 2009 to 2015





Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
Red dashed lines represent the CCME freshwater interim sediment quality guideline (ISQG) for arsenic (5.9 mg/kg); the probable effects level (PEL) for arsenic (17 mg/kg) is not shown.

3.4.1.4 Total Cadmium

In the exposure streams, concentrations of cadmium in the sediments were near or below the detection limit of 0.05 mg/kg in 2015, and well below the CCME ISQG of 0.6 mg/kg and the PEL of 3.5 mg/kg (Figure 3.4-4). The before-after analysis for Little Roberts Outflow was not considered reliable for cadmium in stream sediments because of the large proportion of data that were below analytical detection limits in the combined baseline and 2015 dataset (83%). For Doris Outflow, the before-after analysis indicated that the mean 2015 cadmium concentration was not statistically distinguishable from the 2009 mean ($p = 0.61$). Therefore, there was no apparent effect of 2015 Project activities on sediment cadmium concentrations in the exposure streams.

3.4.1.5 Total Chromium

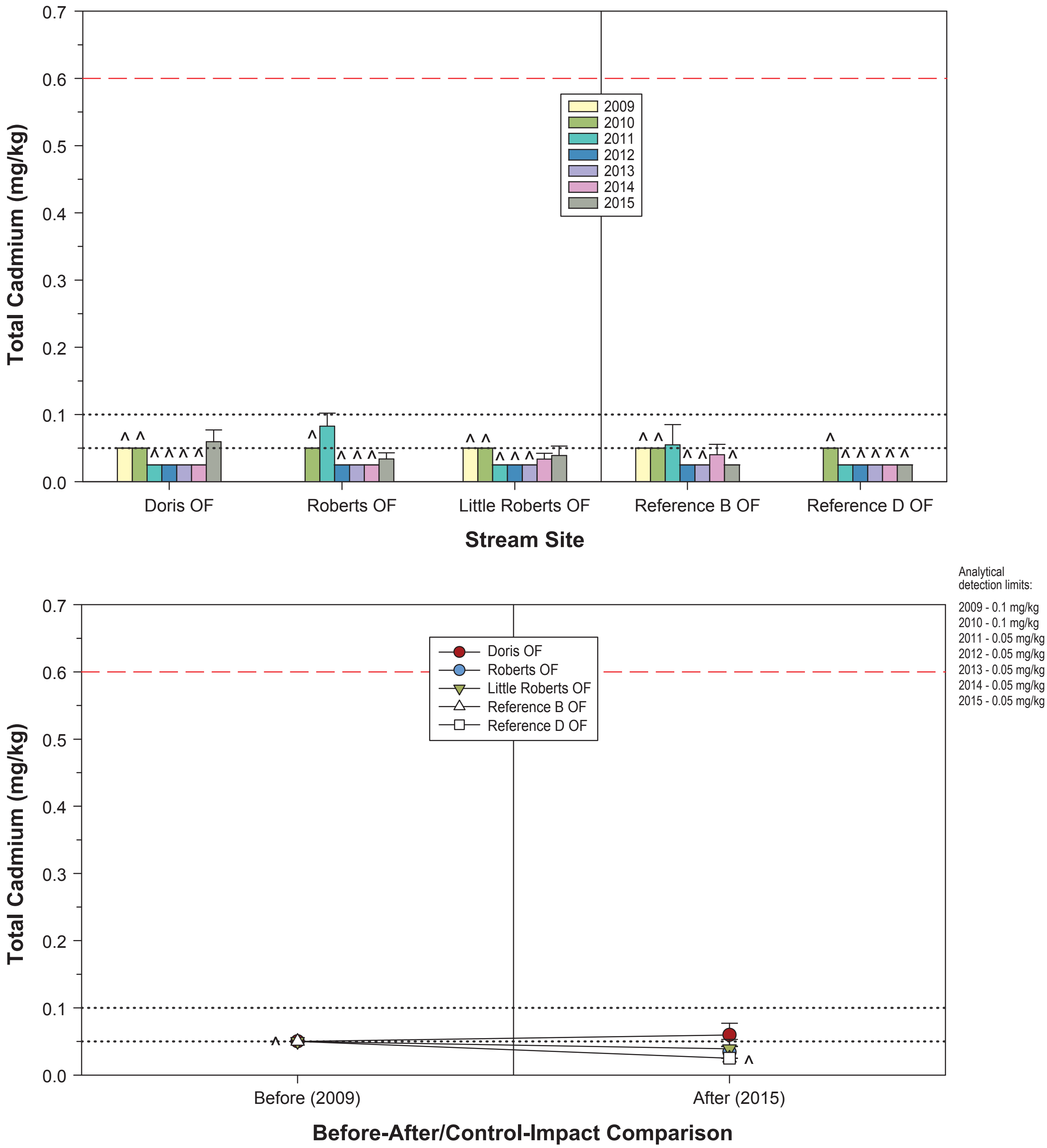
Mean 2015 chromium concentrations in Little Roberts Outflow sediments were below the CCME ISQG of 37.3 mg/kg and the CCME PEL of 90 mg/kg, but mean 2015 concentrations at Doris Outflow was slightly greater than the ISQG (Figure 3.4-5). Between 2009 and 2015, sediment chromium concentrations frequently approached or were greater than the ISQG of 37.3 mg/kg, and occasionally approached or exceeded the PEL of 90 mg/kg, suggesting that exposure streams sediments are naturally high in chromium. The before-after analysis showed that mean 2009 and 2015 chromium concentrations were not significantly different for either Doris Outflow ($p = 0.51$) or Little Roberts Outflow ($p = 0.070$). Thus, there was no apparent effect of 2015 Project activities on sediment chromium concentrations in exposure streams.

3.4.1.6 Total Copper

Mean 2015 sediment copper concentrations were below the CCME ISQG of 35.7 mg/kg and the PEL of 197 mg/kg (Figure 3.4-6). In Doris Outflow sediments, the 2015 mean copper concentration was greater than the 2009 mean, but the before-after analysis showed that the 2009 and 2015 means were not distinguishable ($p = 0.29$). In Little Roberts Outflow, the before-after analysis showed that there was a statistically significant decrease in the mean copper concentration in 2015 compared to 2009 ($p = 0.016$), and BACI analysis indicated that there was evidence of a non-parallel change in copper over the before-after period for Little Roberts Outflow relative to the reference streams ($p = 0.018$). This differential decrease in copper concentration is not of environmental concern, and is likely related to the coarser nature of the sediments collected in 2015 compared to the finer sediments collected in 2009. Therefore, 2015 Project activities had no apparent adverse effect on sediment copper concentrations in the exposure streams.

Figure 3.4-4

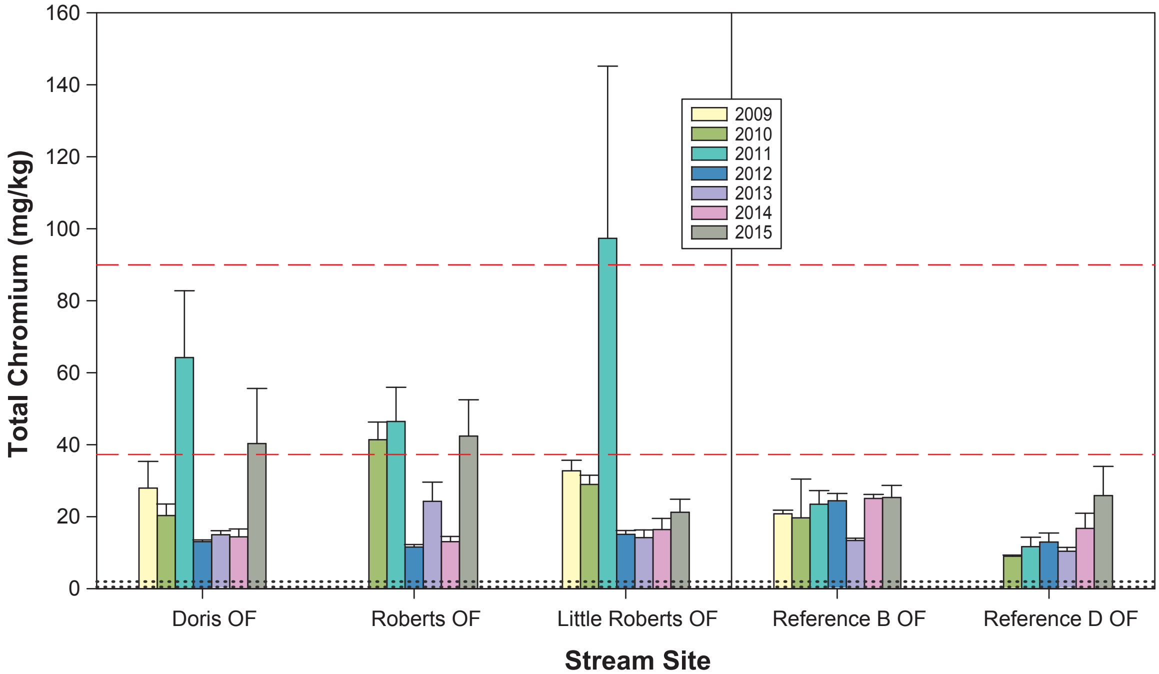
Total Cadmium Concentrations in AEMP Stream Sediments, Doris North Project, 2009 to 2015

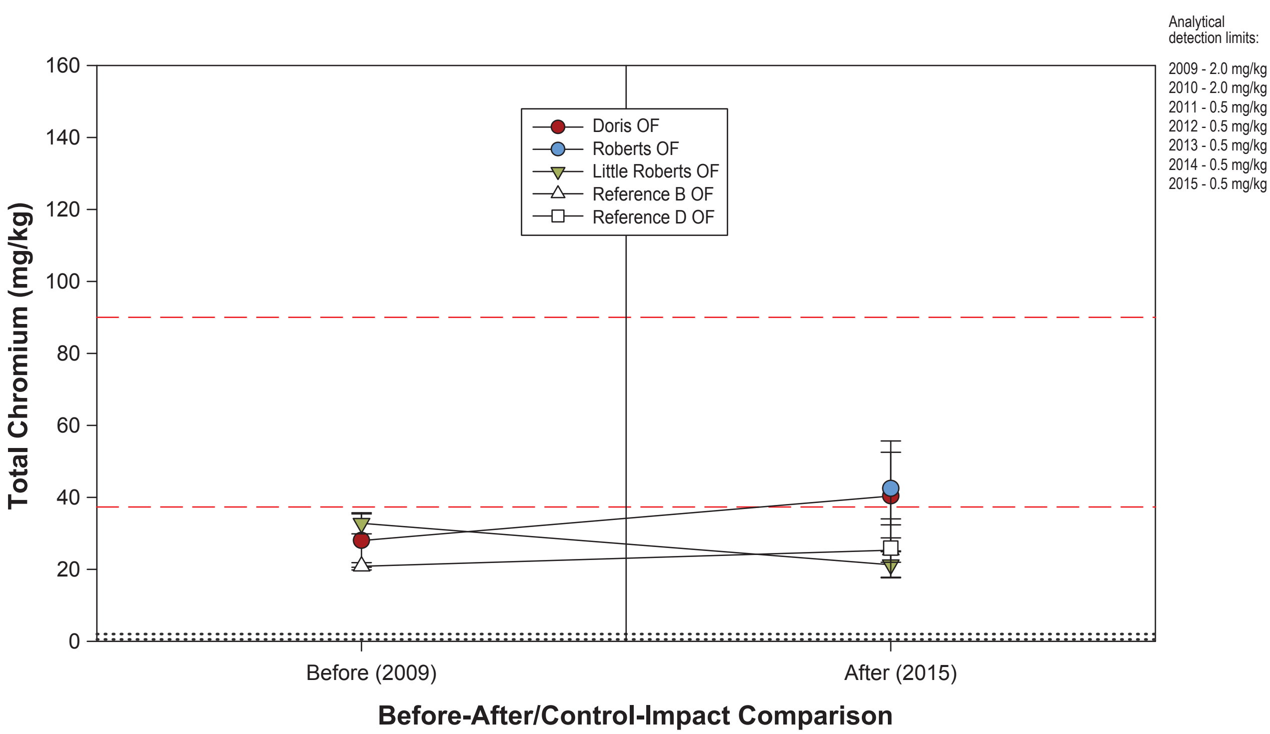


Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
^ Indicates that concentrations were below the detection limit in all samples.
Red dashed lines represent the CCME freshwater interim sediment quality guideline (ISQG) for cadmium (0.6 mg/kg); the probable effects level (PEL) for cadmium (3.5 mg/kg) is not shown.

Figure 3.4-5

Total Chromium Concentrations in AEMP Stream Sediments, Doris North Project, 2009 to 2015

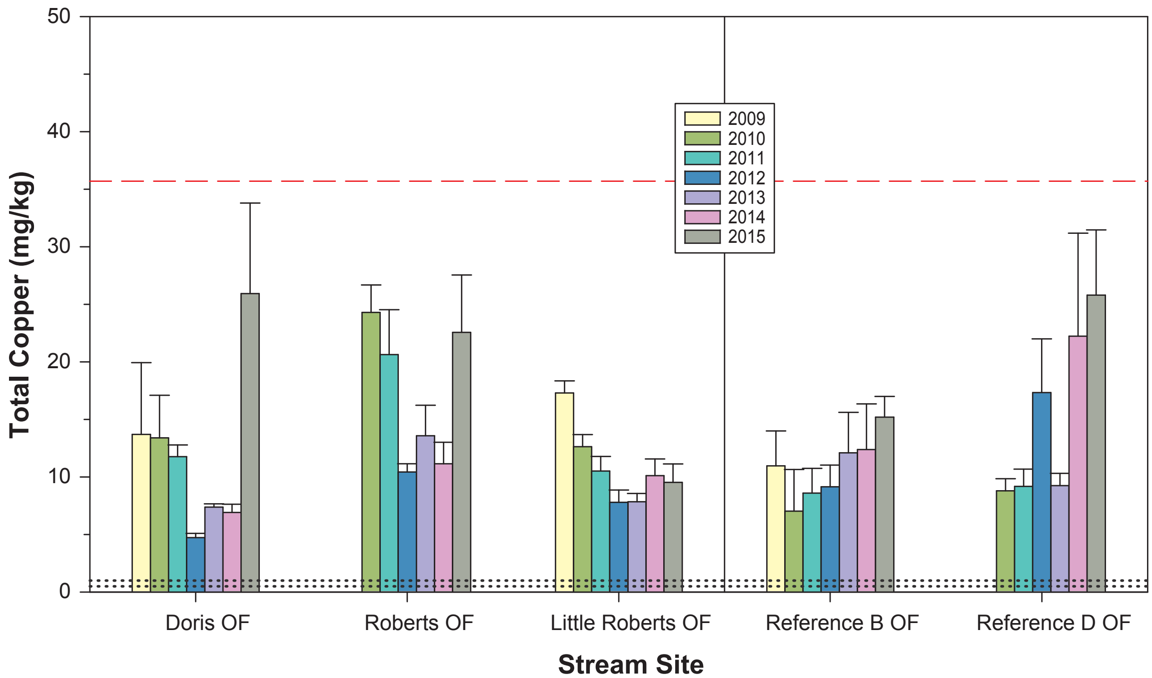


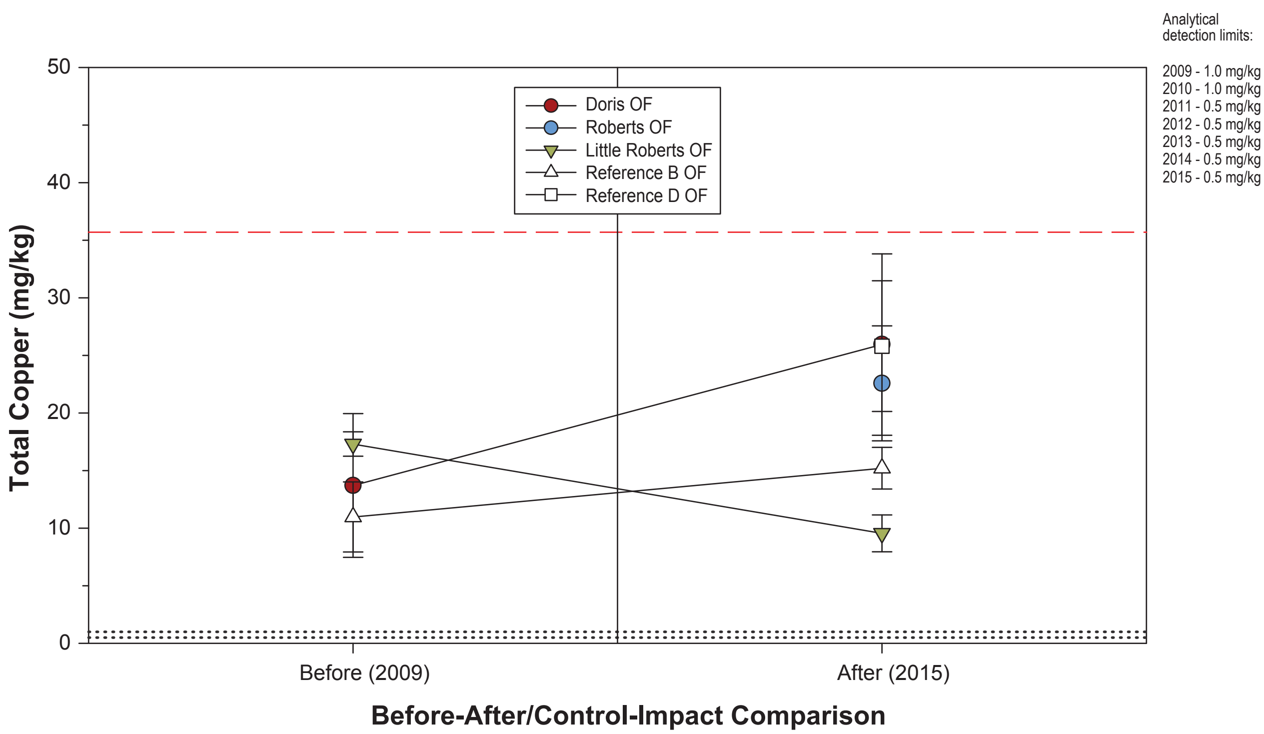


Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
Red dashed lines represent the CCME freshwater interim sediment quality guideline (ISQG)
for chromium (37.3 mg/kg) and the probable effects level (PEL) for chromium (90 mg/kg).

Figure 3.4-6

Total Copper Concentrations in AEMP Stream Sediments, Doris North Project, 2009 to 2015





Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
Red dashed lines represent the CCME freshwater interim sediment quality guideline (ISQG) for copper (35.7 mg/kg); the probable effects level (PEL) for copper (197 mg/kg) is not shown.

3.4.1.7 Total Lead

2015 lead concentrations in exposure stream sediments were well below the CCME ISQG of 35 mg/kg and the PEL of 91.3 mg/kg (Figure 3.4-7). In Little Roberts Outflow, the mean lead concentration in sediments was lower in 2015 than in 2009 (Figure 3.4-7), and the before-after analysis showed that this decrease was statistically significant ($p = 0.027$). The BACI analysis indicated that the decrease in lead concentration in Little Roberts Outflow sediments was not paralleled at the reference streams ($p = 0.0085$). This differential decrease in lead concentration is not of environmental concern, and is likely related to the coarser nature of the sediments collected in 2015 compared to the finer sediments collected in 2009. For Doris Outflow, although the mean 2015 total concentration in the sediments was higher than the 2009 mean (Figure 3.4-7), the before-after analysis showed that 2009 and 2015 means were not distinguishable ($p = 0.44$). Thus, there was no apparent adverse effect of 2015 Project activities on lead in exposure stream sediments.

3.4.1.8 Total Mercury

At the exposure sites, mercury concentrations in sediments were well below the CCME ISQG of 0.17 mg/kg and the PEL of 0.486 mg/kg (Figure 3.4-8). Mercury concentrations measured in Little Roberts Outflow sediments in 2015 were below the analytical detection limit of 0.005 mg/kg. In Doris Outflow sediments, the mean 2015 mercury concentration was not statistically distinguishable from the 2009 mean ($p = 0.36$). Consequently, there was no apparent effect of 2015 Project activities on mercury concentrations in the sediments of exposure streams.

3.4.1.9 Total Zinc

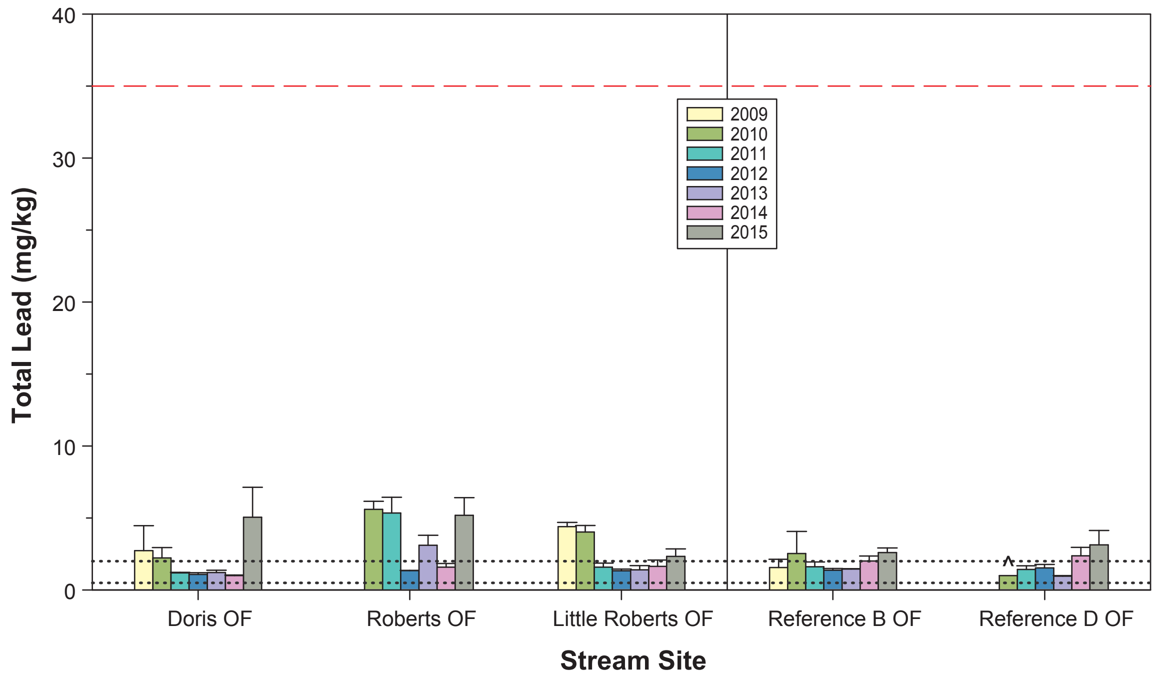
In the exposure streams, 2015 zinc concentrations in sediments were well below the CCME ISQG of 123 mg/kg and the PEL of 315 mg/kg (Figure 3.4-9). The before-after comparison indicated that the mean 2015 zinc concentration was not distinguishable from the 2009 mean for either Doris Outflow ($p = 0.38$) or Little Roberts Outflow ($p = 0.053$). Thus, there was no evidence that 2015 Project activities adversely affected zinc concentrations in exposure stream sediments.

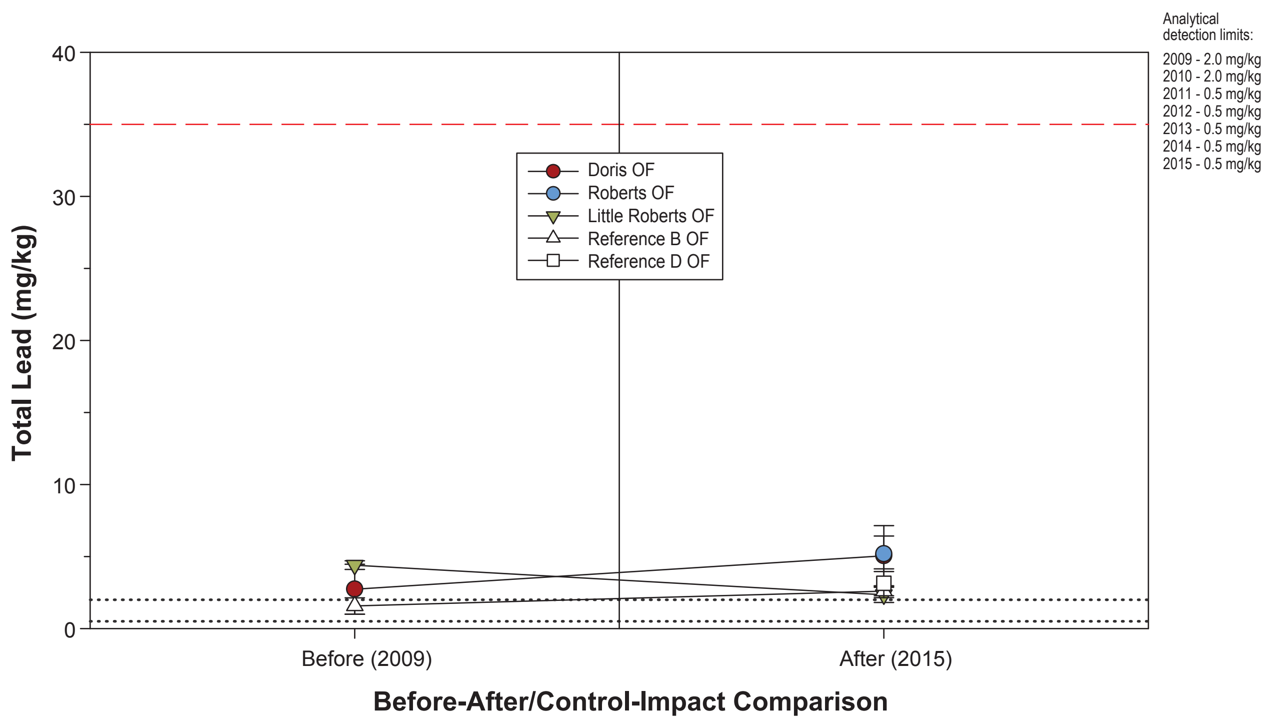
3.4.2 Lakes

Sediment quality samples were collected from three exposure sites (Doris Lake North, Doris Lake South, and Little Roberts Lake) and two reference sites (Reference Lake B and Reference Lake D) in 2015. Sediment samples have been collected in the Doris North area since 1996. However, most of the historical data were not directly comparable to 2015 data because of differences in sampling locations, depth strata, and sampling methodology (Appendix B).

Sediment quality data from 1997 and 2009 were used for before-after comparisons for Doris Lake South and Little Roberts Lake, and data from 2009 were used for before-after comparisons for Doris Lake North. 1997 sediment sampling was conducted in July, while 2009 and 2014 sediment sampling was conducted in August. No baseline sediment quality data are available for the reference lakes; therefore, no before-after or BACI analyses were possible for the lake exposure sites. For the calculations of annual means for each variable, all analytical results for lake sediment samples collected in a given year were averaged.

Total Lead Concentrations in AEMP Stream Sediments, Doris North Project, 2009 to 2015

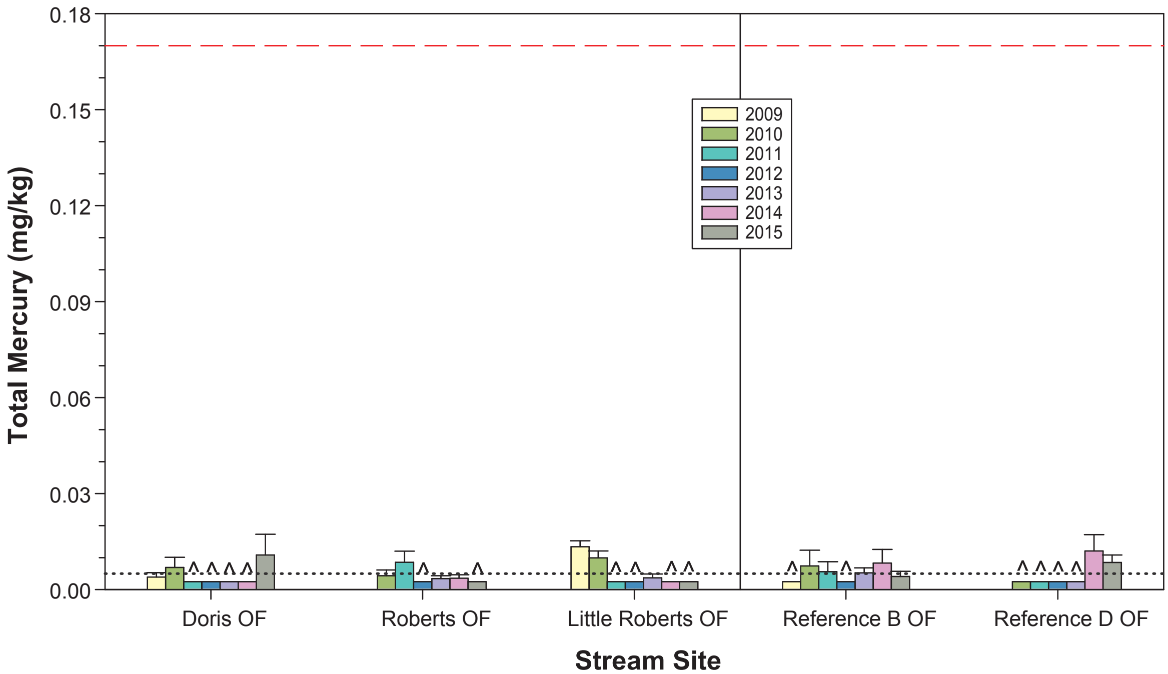


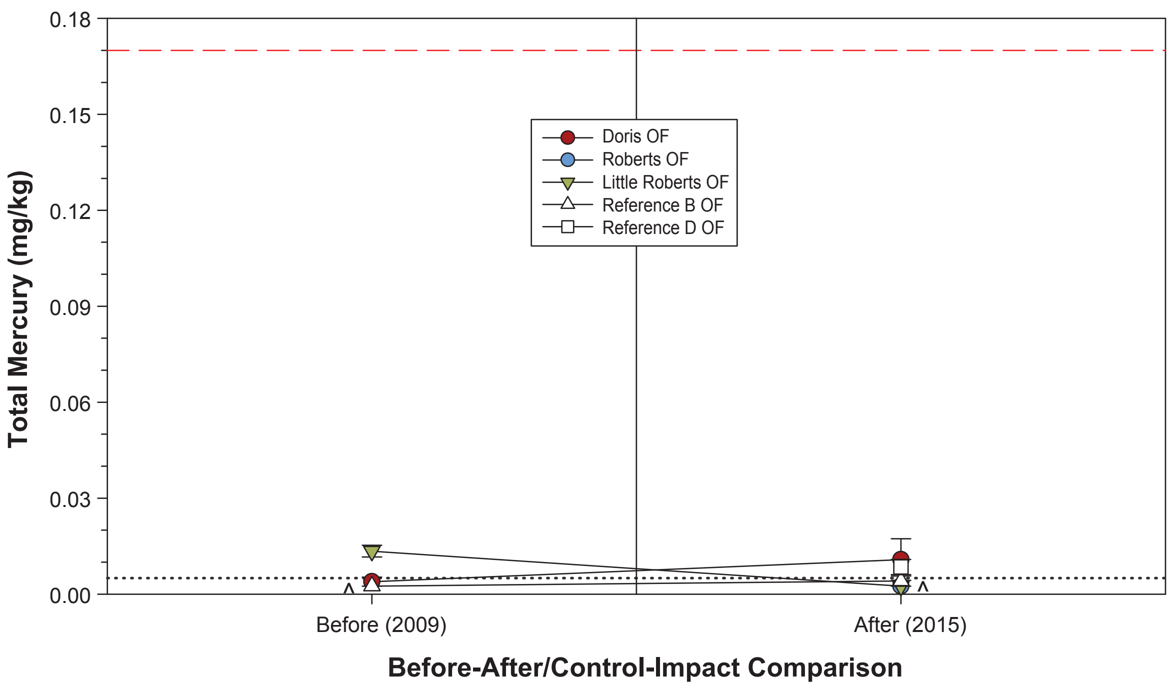


Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
^ Indicates that concentrations were below the detection limit in all samples.
Red dashed lines represent the CCME freshwater interim sediment quality guideline (ISQG) for lead (35 mg/kg); the probable effects level (PEL) for lead (91.3 mg/kg) is not shown.

Figure 3.4-8

Total Mercury Concentrations in AEMP Stream Sediments, Doris North Project, 2009 to 2015





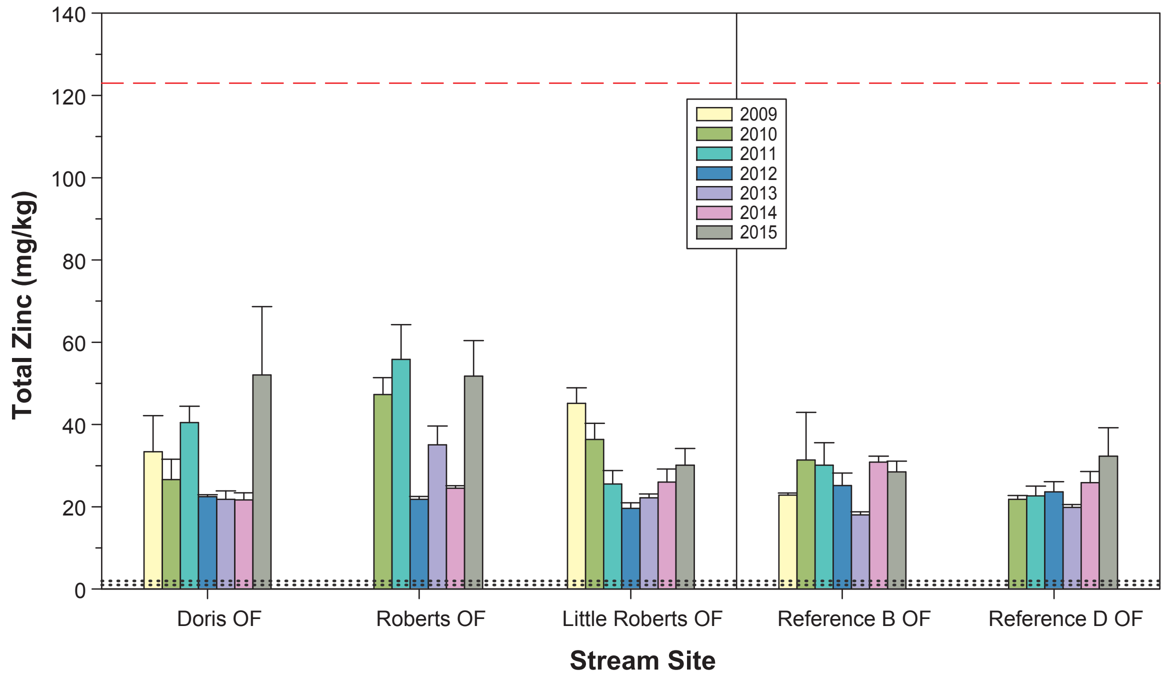
Analytical detection limits:

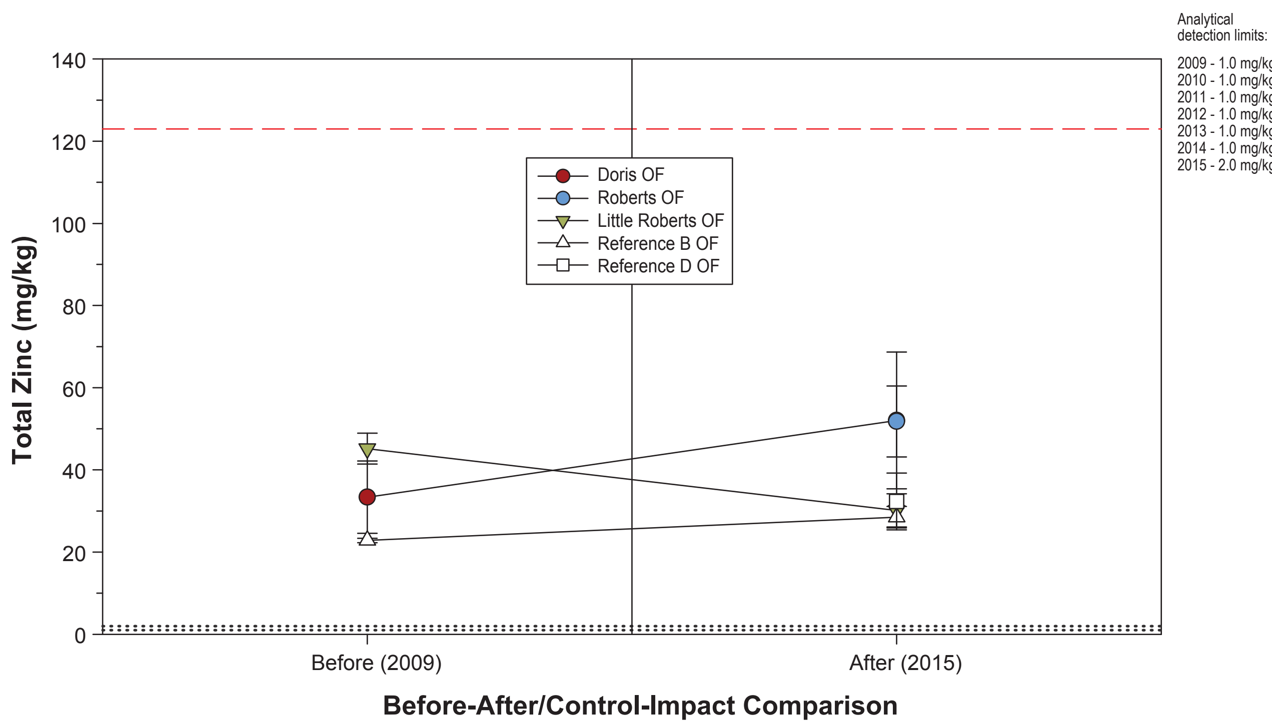
2009 - 0.005 mg/kg
2010 - 0.005 mg/kg
2011 - 0.005 mg/kg
2012 - 0.005 mg/kg
2013 - 0.005 mg/kg
2014 - 0.005 mg/kg
2015 - 0.005 mg/kg

Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
^ Indicates that concentrations were below the detection limit in all samples.
Red dashed lines represent the CCME freshwater interim sediment quality guideline (ISQG) for mercury (0.17 mg/kg); the probable effects level (PEL) for mercury (0.486 mg/kg) is not shown.

Figure 3.4-9

Total Zinc Concentrations in AEMP Stream Sediments, Doris North Project, 2009 to 2015





Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
Red dashed lines represent the CCME freshwater interim sediment quality guideline (ISQG) for zinc (123 mg/kg); the probable effects level (PEL) for zinc (315 mg/kg) is not shown.

3.4.2.1 Particle Size

Consistent with previous years, exposure and reference lakes were dominated by fine sediments (silt and clay) in 2015 (Figure 3.4-10). In the three exposure lakes, the particle size composition was generally similar between 2009 and 2015 (Figure 3.4-10). However, the before-after analysis indicated that the sand content increased significantly in all three exposure lakes in 2015 compared to 2009 ($p = 0.028$ in Doris Lake South, $p = 0.019$ for Doris Lake North, and $p = 0.025$ Little Roberts Lake). Overall, sand made up less than 3% of the sediment composition in the two Doris Lake exposure sites in 2015, so this increase in sand is likely not important. In Little Roberts Lake, sand content increased more substantially from 9% in 2009 to 19% in 2015. In addition, the clay content of sediments in Little Roberts Lake decreased from 28% in 2009 to 19% in 2015, and the before-after analysis indicated that this change was also statistically significant ($p = 0.0031$). BACI analyses could not be performed due to a lack of baseline data for reference lakes. Overall, the sediment particle size composition was largely similar between 2009 and 2015 in all the exposure lake sites, and the minor changes observed were likely the result of natural spatial heterogeneity in lake sediments rather than being Project-related.

3.4.2.2 Total Organic Carbon

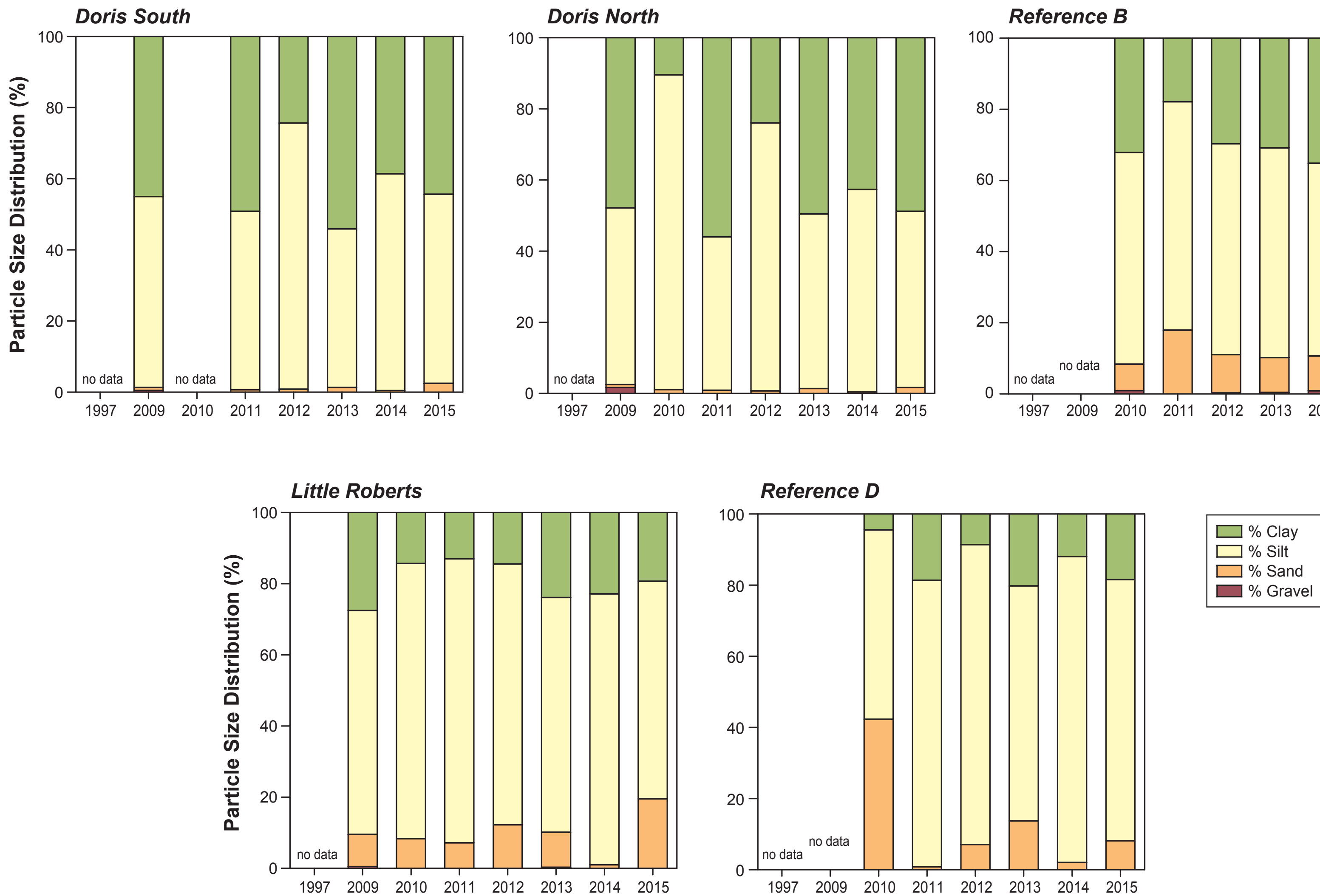
Mean 2015 TOC levels in Doris Lake North sediments were slightly higher than baseline TOC levels, and the before after analysis concluded that there was a significant difference between the means ($p = 0.0049$). No BACI analysis could be performed because no baseline data exists for the reference lakes. The difference between 2009 and 2015 mean TOC levels for Doris North is quite small (8.2%) and is likely related to natural variability rather than Project effects. In Doris Lake South and Little Roberts Lake, mean 2015 TOC levels in sediments were similar to baseline means (Figure 3.4-11), and the before-after comparison confirmed that the baseline and 2015 means were not distinguishable for either Doris Lake South ($p = 0.97$) or Little Roberts Lake ($p = 0.35$). Therefore, there was likely no effect of 2015 Project activities on the sediment TOC content of exposure lakes.

3.4.2.3 Total Arsenic

As observed in baseline years, mean 2015 arsenic concentrations in Doris Lake South and Doris Lake North sediments were higher than the CCME ISQG of 5.9 mg/kg. Doris Lake South sediment arsenic concentrations were also slightly above the PEL of 17 mg/kg (Figure 3.4-12). Arsenic concentrations were generally lower in Little Roberts Lake, where the mean 2015 arsenic concentration was lower than both the CCME ISQG and PEL guidelines (Figure 3.4-12). The before-after analysis showed that 2015 mean arsenic concentrations in sediments were indistinguishable from baseline means for all the exposure lake sites ($p = 0.33$ for Doris Lake South, $p = 0.50$ for Doris Lake North, and $p = 0.25$ for Little Roberts Lake). Therefore, there was no evidence of an adverse effect of Project activities on arsenic levels in exposure lake sediments in 2015.

Figure 3.4-10

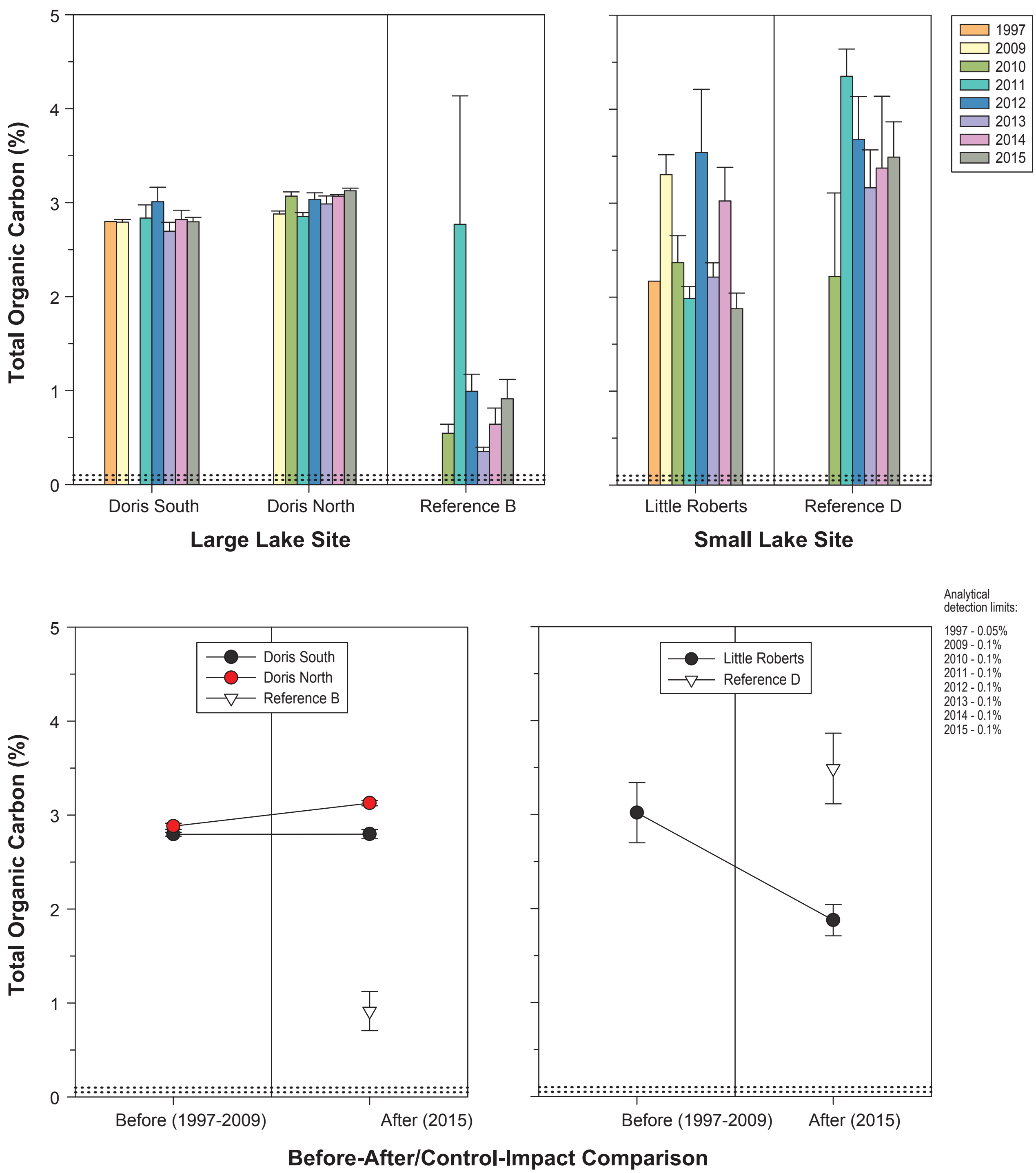
Particle Size Distribution in AEMP Lake Sediments, Doris North Project, 1997 to 2015



Notes: Stacked bars represent the mean of replicate samples.
Particle size distribution of sediments is a required parameter as part of benthic invertebrate surveys as per Schedule 5, s.16a (iii) of the MMER.

Figure 3.4-11

Total Organic Carbon Concentrations in AEMP Lake Sediments, Doris North Project, 1997 to 2015

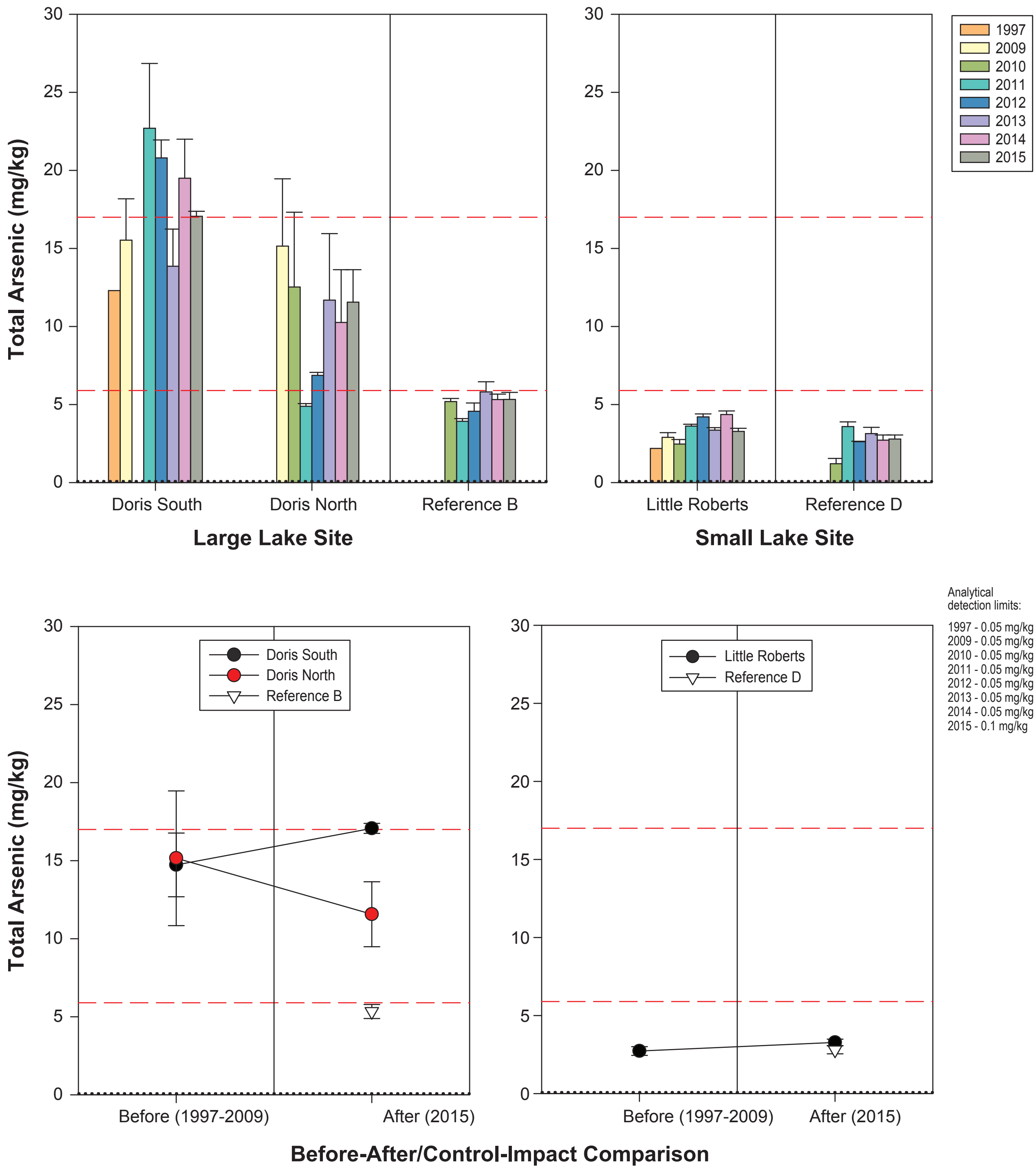


Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
Total organic carbon content of sediments is a required parameter as part of benthic invertebrate surveys as per Schedule 5, s.16a (iii) of the MMER.

Figure 3.4-12

Total Arsenic Concentrations in AEMP Lake Sediments, Doris North Project, 1997 to 2015

ERM



Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
Red dashed lines represent the CCME freshwater interim sediment quality guideline (ISQG) for arsenic (5.9 mg/kg) and the probable effects level (PEL) for arsenic (17 mg/kg).

3.4.2.4 *Total Cadmium*

Mean 2015 cadmium concentrations in Doris Lake South and Little Roberts Lake sediments were within the range of baseline means, while the mean 2015 cadmium concentration in Doris Lake North sediments was lower than the 2009 mean (Figure 3.4-13). The 2015 mean cadmium concentrations in exposure and reference lake sediments were below the CCME ISQG of 0.6 mg/kg and the PEL of 3.5 mg/kg (Figure 3.4-13). Based on the before-after analysis, there were no significant changes in mean sediment cadmium concentrations between baseline years and 2015 for Doris Lake South ($p = 0.88$) and Little Roberts Lake ($p = 0.77$). There was a significant decrease in the mean sediment cadmium concentration between 2009 and 2015 in Doris Lake North ($p = 0.021$); however, a decline in cadmium levels is not of concern. Thus, 2015 Project activities had no apparent adverse effect on cadmium concentrations in the exposure lake sediments.

3.4.2.5 *Total Chromium*

Sediment chromium concentrations were naturally high in the exposure and reference lake sediments, as all baseline and 2015 concentrations were above the CCME ISQG of 37.3 mg/kg, but below the CCME PEL of 90 mg/kg, except the Doris Lake South sediments in 1997 which were also above the CCME PEL (Figure 3.4-14). Mean 2015 sediment chromium concentrations were slightly lower than mean baseline concentrations in all the exposure lakes, but the before-after analysis showed that these decreases were not statistically significant ($p = 0.47$ for Doris Lake South, $p = 0.17$ for Doris Lake North, and $p = 0.080$ for Little Roberts Lake). Therefore, there was no evidence of an effect of 2015 Project activities on total chromium concentrations in exposure lake sediments.

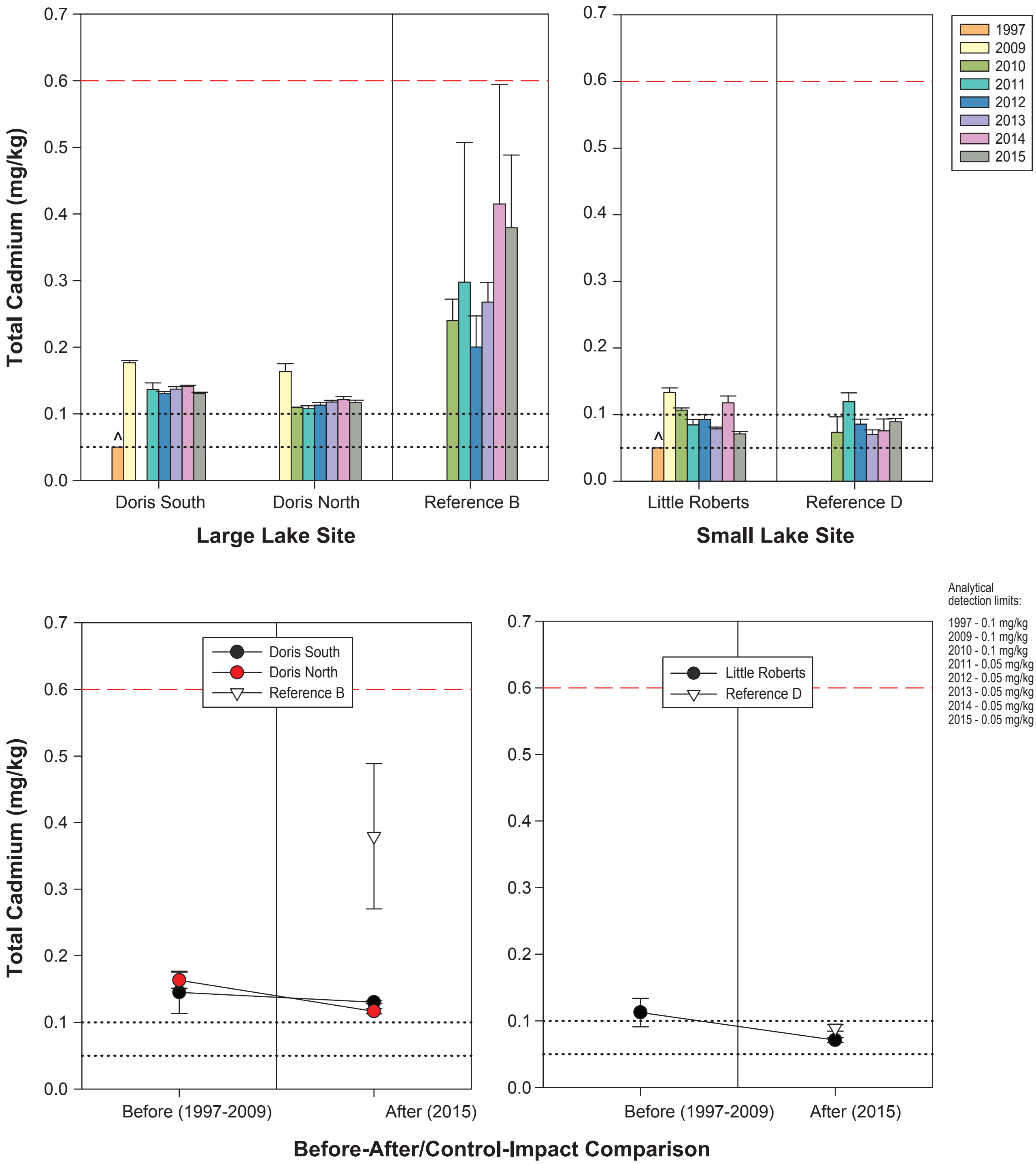
3.4.2.6 *Total Copper*

In all three exposure lakes, copper concentrations in the sediments decreased between baseline years and 2015 (Figure 3.4-15). Sediments in both exposure sites within Doris Lake were naturally high in copper, as all historical mean annual concentrations were higher than the CCME ISQG of 35.7 mg/kg, but were well below the PEL of 197 mg/kg (Figure 3.4-15). In 2015, the mean copper concentration dropped slightly below the CCME ISQG in Doris Lake South (Figure 3.4-15). In Little Roberts Lake, mean baseline and 2015 concentrations remained below both the ISQG and PEL guidelines (Figure 3.4-15).

The before-after analysis indicated that the decrease in copper concentrations between baseline years and 2015 was statistically significant for Doris Lake South ($p < 0.0001$) and Doris Lake North sediments ($p < 0.0001$), but that there was no significant difference between the baseline and the 2015 mean for Little Roberts Lake sediments ($p = 0.27$). A decrease in copper concentrations in Doris Lake South and North sediments is not of concern; therefore, 2015 Project activities did not adversely affect copper concentrations in the sediments of exposure lakes.

Figure 3.4-13

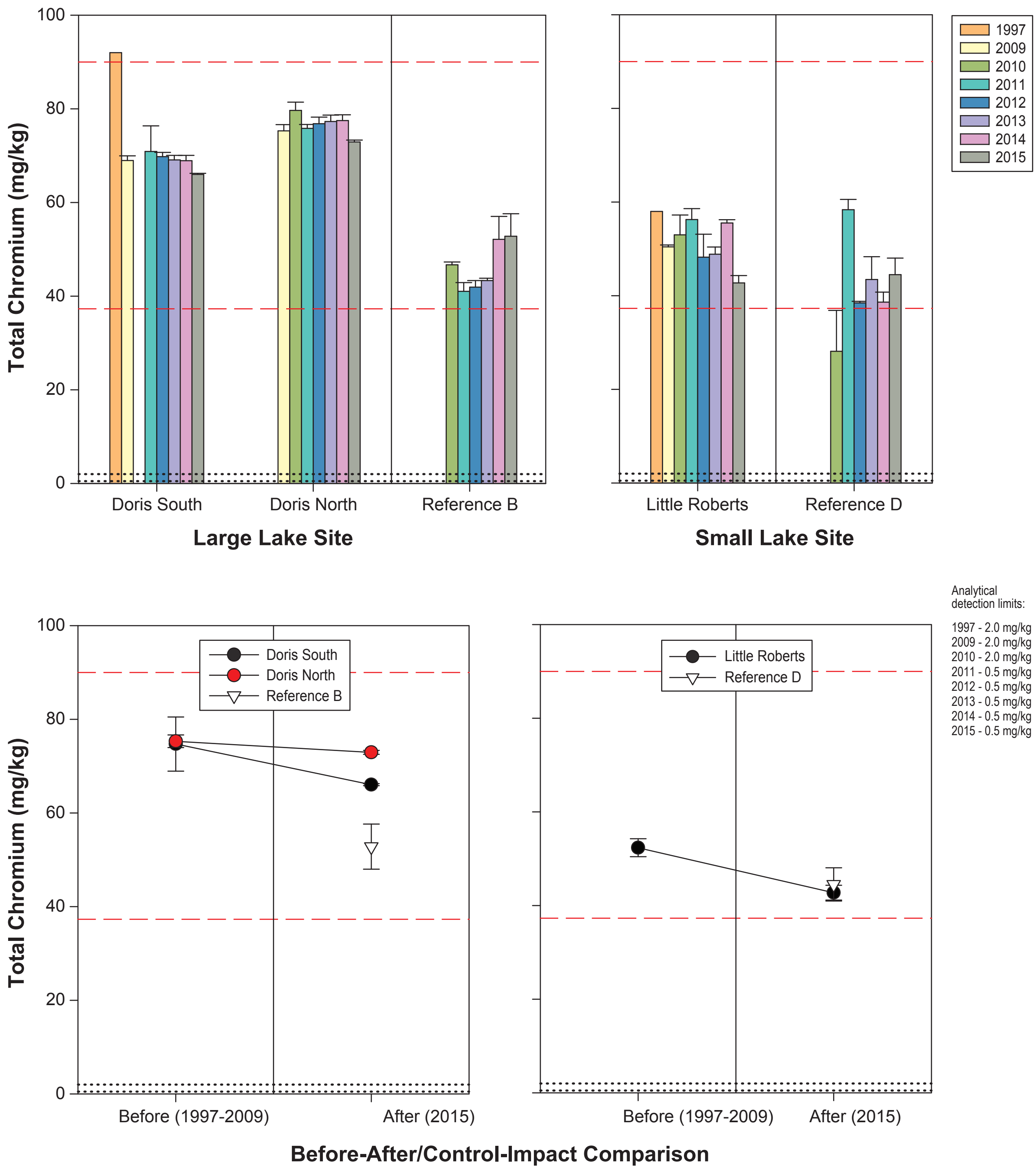
Total Cadmium Concentrations in AEMP Lake Sediments, Doris North Project, 1997 to 2015



Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
^ Indicates that concentrations were below the detection limit in all samples.
Red dashed lines represent the CCME freshwater interim sediment quality guideline (ISQG) for cadmium (0.6 mg/kg); the probable effects level (PEL) for cadmium (3.5 mg/kg) is not shown.

Figure 3.4-14

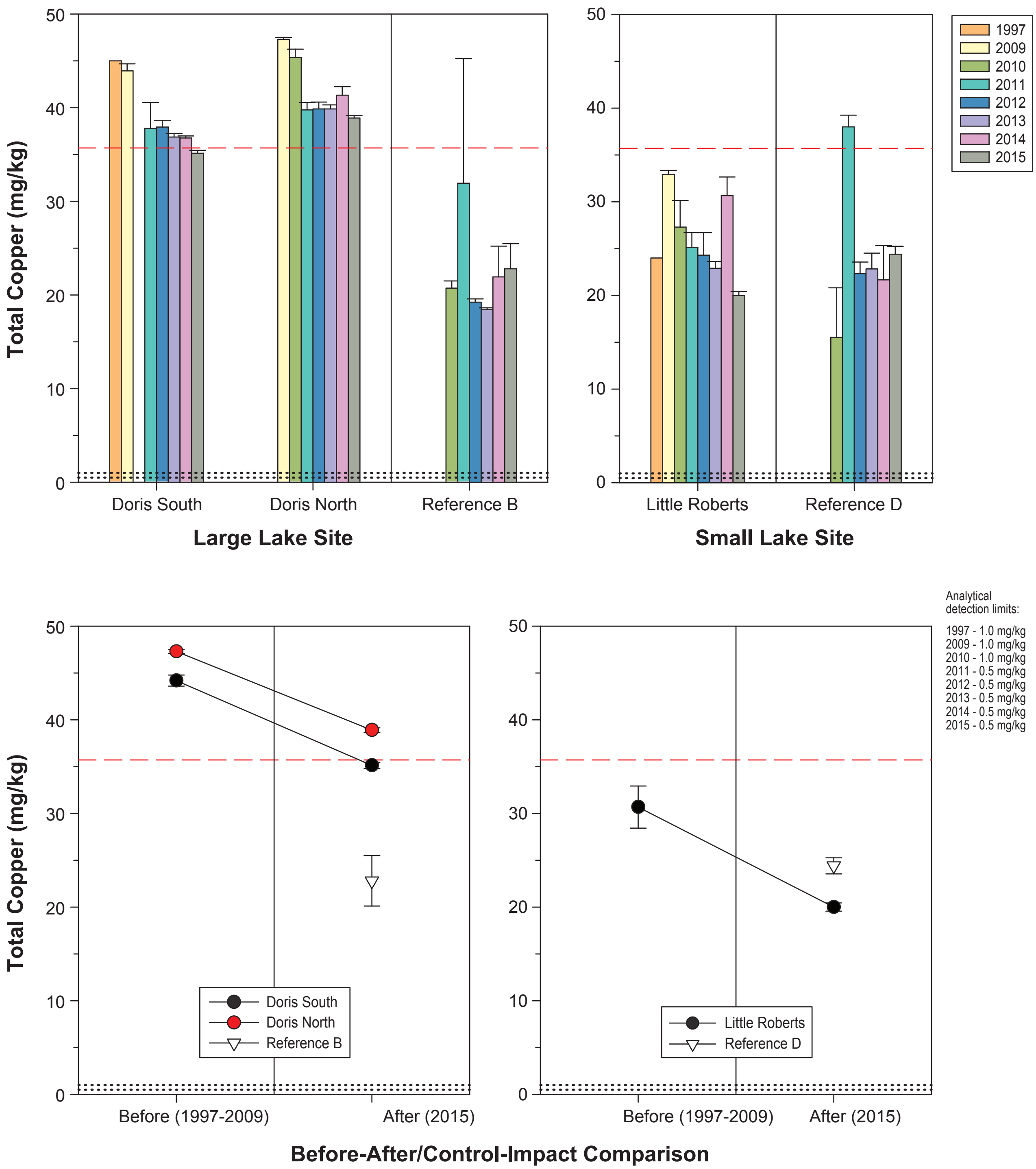
Total Chromium Concentrations in AEMP Lake Sediments, Doris North Project, 1997 to 2015



Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
Red dashed lines represent the CCME freshwater interim sediment quality guideline (ISQG) for chromium (37.3 mg/kg) and the probable effects level (PEL) for chromium (90 mg/kg).

Figure 3.4-15

Total Copper Concentrations in AEMP Lake Sediments, Doris North Project, 1997 to 2015



Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
Red dashed lines represent the CCME freshwater interim sediment quality guideline (ISQG) for copper (35.7 mg/kg); the probable effects level (PEL) for copper (197 mg/kg) is not shown.

3.4.2.7 Total Lead

Mean sediment lead concentrations in 2015 were lower than the baseline range for all exposure lakes and well below the CCME ISQG of 35 mg/kg and the PEL of 91.3 mg/kg (Figure 3.4-16). The before-after comparison showed that the mean 2015 sediment lead concentrations were significantly lower than the baseline means for all the exposure lakes ($p = 0.043$ for Doris Lake South, $p = 0.011$ for Doris Lake North, and $p < 0.0001$ for Little Roberts Lake). A decrease in sediment lead levels over time is of no concern; therefore, there was no apparent adverse effect of 2015 Project activities on lead concentrations in the sediments of exposure lakes.

3.4.2.8 Total Mercury

Baseline and 2015 concentrations of mercury in exposure and reference lake sediments were well below the CCME ISQG of 0.17 mg/kg and the PEL of 0.486 mg/kg (Figure 3.4-17). In the Doris Lake exposure sites, 2015 mean concentrations of mercury in sediments were similar to baseline levels, and the before-after analysis confirmed that there was no significant difference between baseline and 2015 means for total mercury in either Doris Lake South ($p = 0.77$) or Doris Lake North ($p = 0.83$). In Little Roberts Lake, mean mercury concentrations in sediments were slightly higher in 2015 compared to baseline years, but the before-after analysis showed that the means were statistically indistinguishable ($p = 0.18$). Thus, there was no indication that 2015 Project activities affected sediment mercury concentrations in exposure lakes.

3.4.2.9 Total Zinc

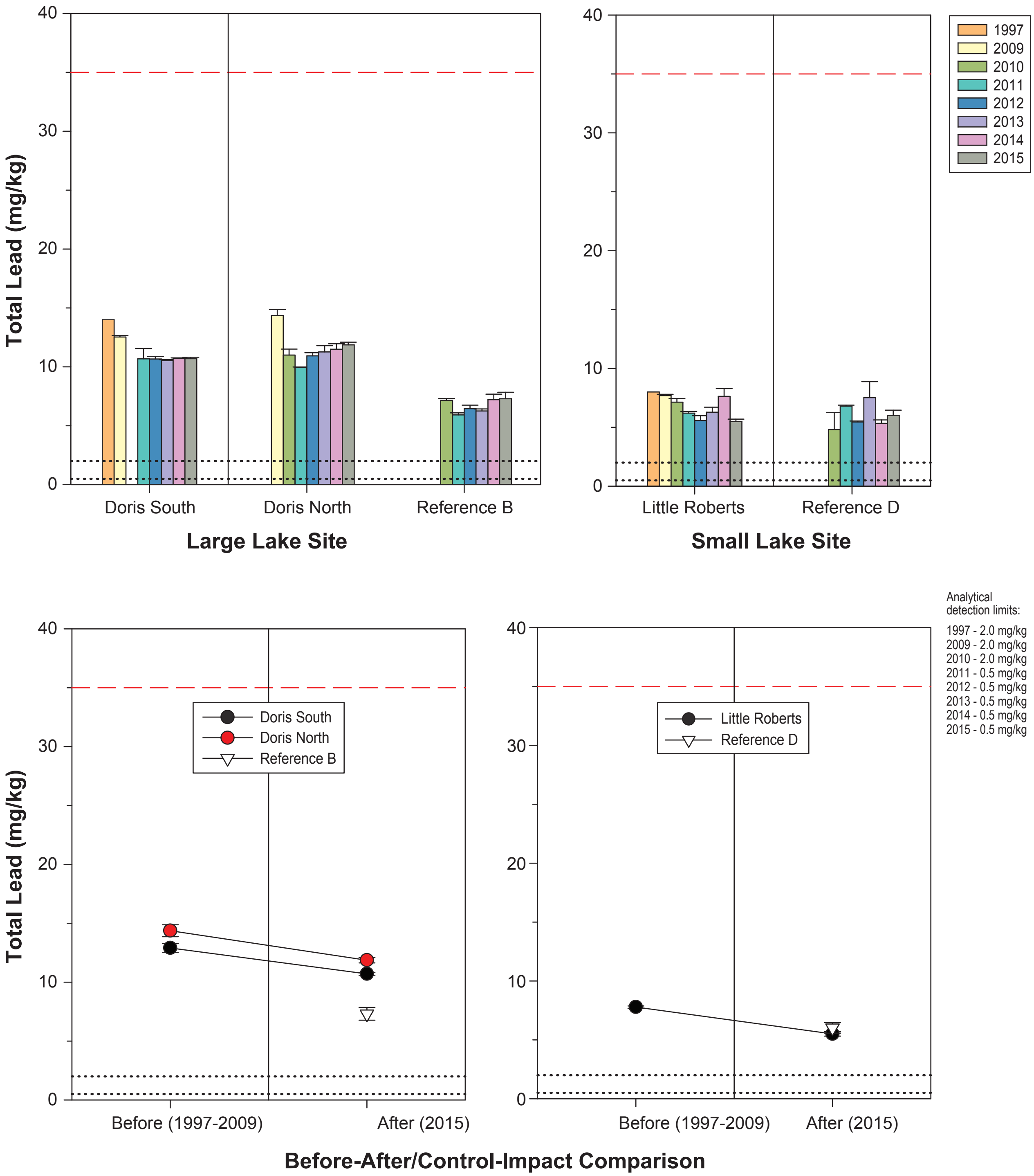
2015 zinc concentrations in the exposure and reference lake sediments were below the CCME ISQG of 123 mg/kg and the PEL of 315 mg/kg (Figure 3.4-18). Compared to baseline years, concentrations of zinc in sediments decreased in 2015 in all the exposure lake sites. The before-after analysis showed that this decrease was statistically significant for Doris Lake North ($p = 0.0007$) and Little Roberts Lake ($p < 0.0001$), but not for Doris Lake South ($p = 0.33$). A decrease in sediment zinc concentrations is not a concern, thus there were no apparent adverse effects of Project activities on sediment zinc concentrations in lake exposure sites.

3.4.3 Marine

Sediment quality samples from the marine environment were collected from two exposure sites in Roberts Bay (RBW and RBE) and one reference site in Ida Bay (REF-Marine 1). Baseline sediment quality data were collected in Roberts Bay in 1997, 2002, and 2009. However, not all of the baseline data were directly comparable to the 2015 samples, either because they were not collected in the immediate vicinity of the AEMP sampling sites or because they were collected from different depth strata than 2015 samples (Appendix B). There were no suitable baseline data available for RBE, but there was one year of baseline data available for RBW (2002) and REF-Marine 1 (2009).

Figure 3.4-16

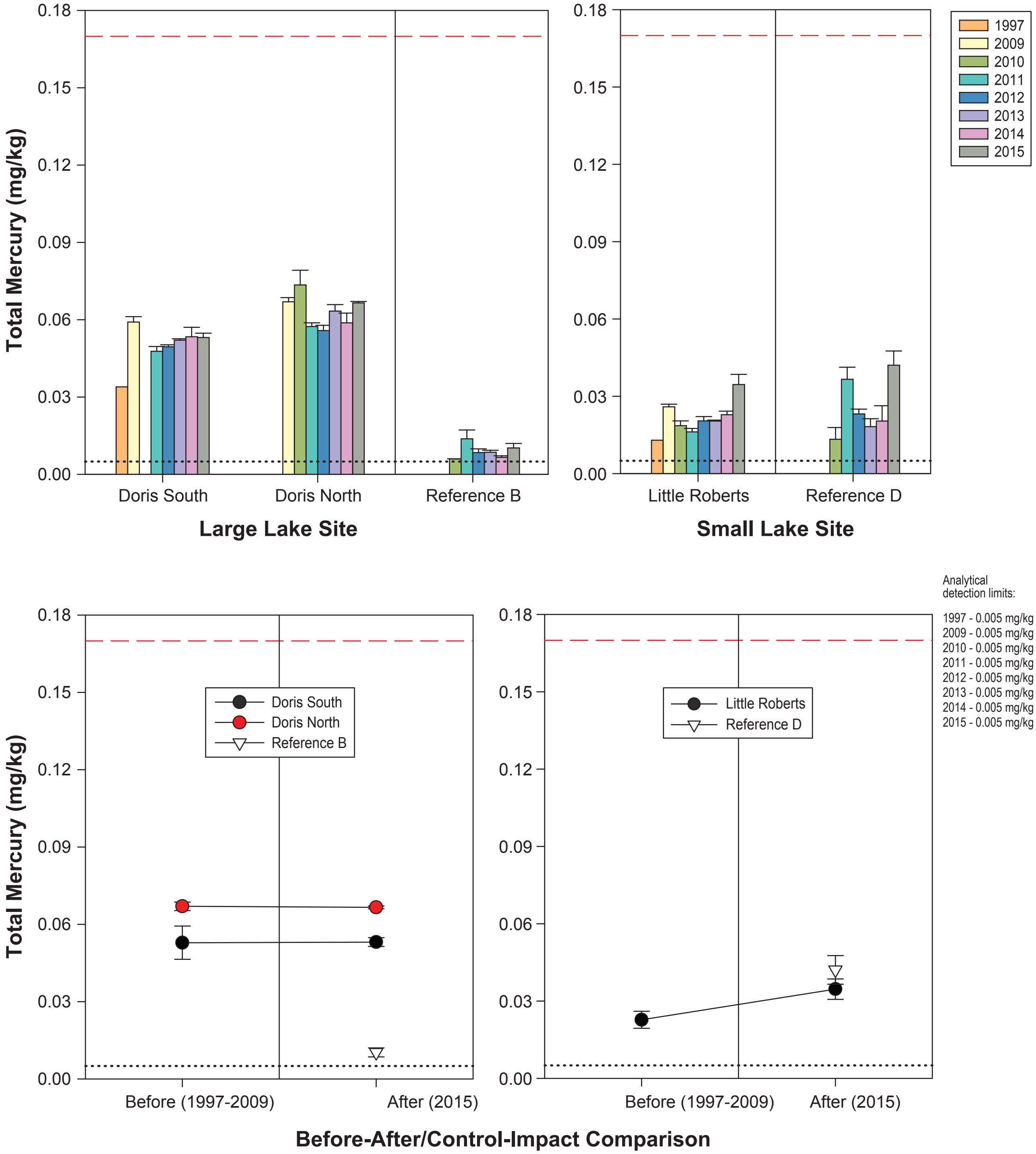
Total Lead Concentrations in AEMP Lake Sediments, Doris North Project, 1997 to 2015



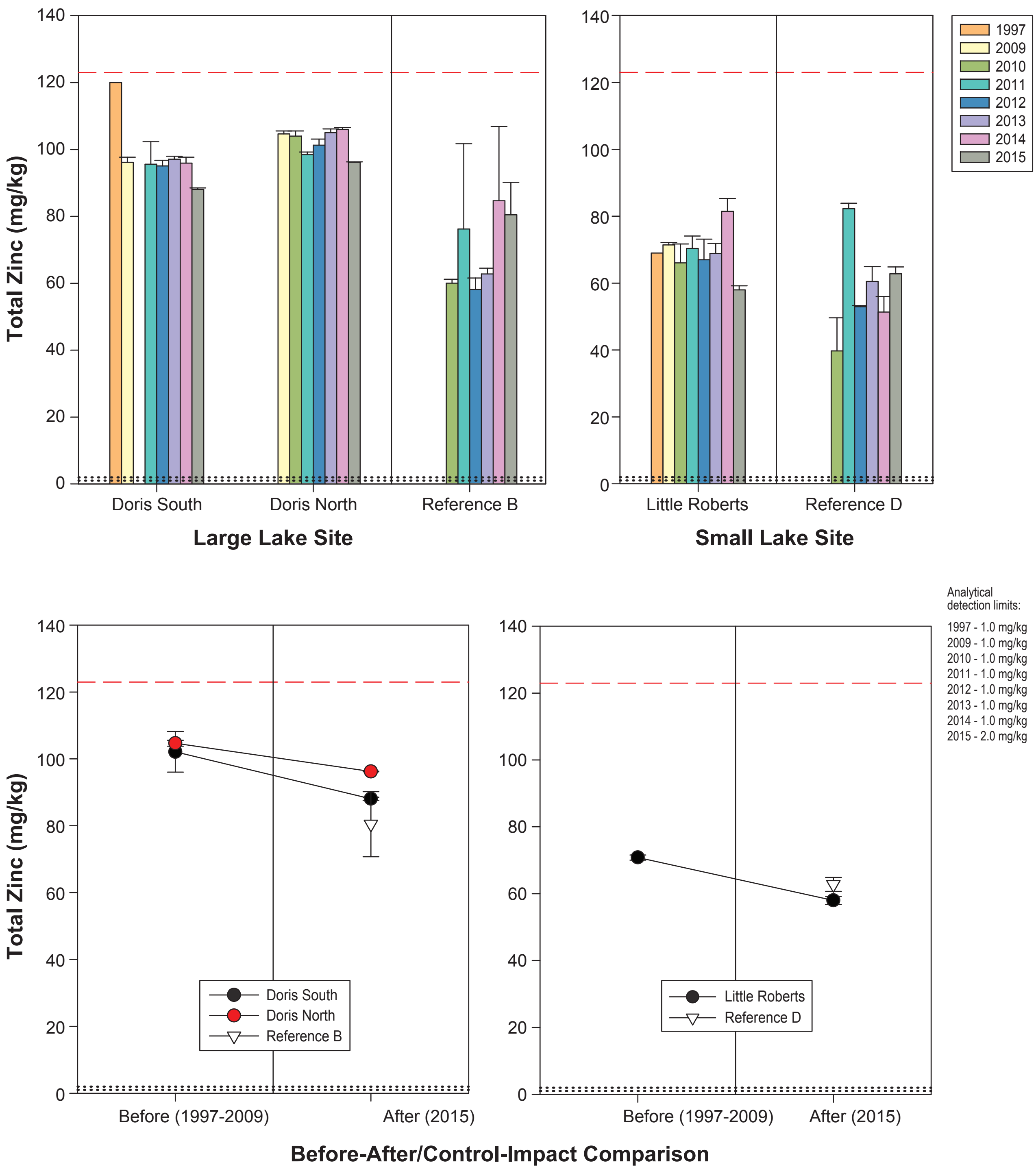
Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
Red dashed lines represent the CCME freshwater interim sediment quality guideline (ISQG) for lead (35 mg/kg); the probable effects level (PEL) for lead (91.3 mg/kg) is not shown.

Total Mercury Concentrations in AEMP Lake Sediments, Doris North Project, 1997 to 2015

ERM



Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
Red dashed lines represent the CCME freshwater interim sediment quality guideline (ISQG) for mercury (0.17 mg/kg); the probable effects level (PEL) for mercury (0.486 mg/kg) is not shown.



Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
Red dashed lines represent the CCME freshwater interim sediment quality guideline (ISQG) for zinc (123 mg/kg); the probable effects level (PEL) for zinc (315 mg/kg) is not shown.

Because the available baseline data were from two different years, a change in any variable at the exposure site, RBW, from 2002 to 2015 could not be directly compared to the change at the reference station, REF-Marine 1, between 2009 and 2015. Any change at REF-Marine 1 could only be used to show the inherent inter-annual variability that occurs in sediment variables. Also, caution must be exercised when interpreting changes at RBW because there was a 13 year gap between the collection of before and after data. No BACI analysis could be performed for RBE because there was no suitable baseline sediment data collected near this exposure site.

3.4.3.1 Particle Size

At site RBW in 2015, sediments consisted of a nearly even mix of sand (44%) and silt (40%), with some clay (16%) and negligible amounts of gravel. The baseline samples collected in 2002 at RBW consisted of a higher proportion of sand (52%) and clay (20%), and a lower proportion of silt (27%). The before-after analysis showed that these difference in grain size composition were statistically significant for all three of these particle size classes ($p = 0.0012$ for sand, $p < 0.0001$ for silt, and $p = 0.0059$ for clay). The gravel content of sediments did not change significantly between years ($p = 0.65$). These slight differences between years are likely due to spatial heterogeneity in sediments rather than any Project-related effects. Overall, the proportion of fine particles (silt and clay) was slightly higher in 2015 (56%) than in 2002 (47%), and this may complicate the interpretation of sediment quality variables as finer sediments tend to contain higher levels of TOC and metals (e.g., Lakhan, Cabana, and LaValle 2003; Secrieri and Oaie 2009). As described in the following sections, mean concentrations of TOC and most evaluated metals increased significantly at RBW in 2015 compared to baseline years, and these increases may be at least partially attributable to the higher proportion of fine sediments in the 2015 sediment samples (Figure 3.4-19).

In 2015, sediments collected from marine exposure site RBE consisted mainly of sand (81%), with some silt (14%), and small amounts of clay and gravel. This is similar to the sediment composition observed annually at this site from 2010 to 2014, and there is no evidence of an effect of 2015 Project activities on the sediment particle size at this site (Figure 3.4-19).

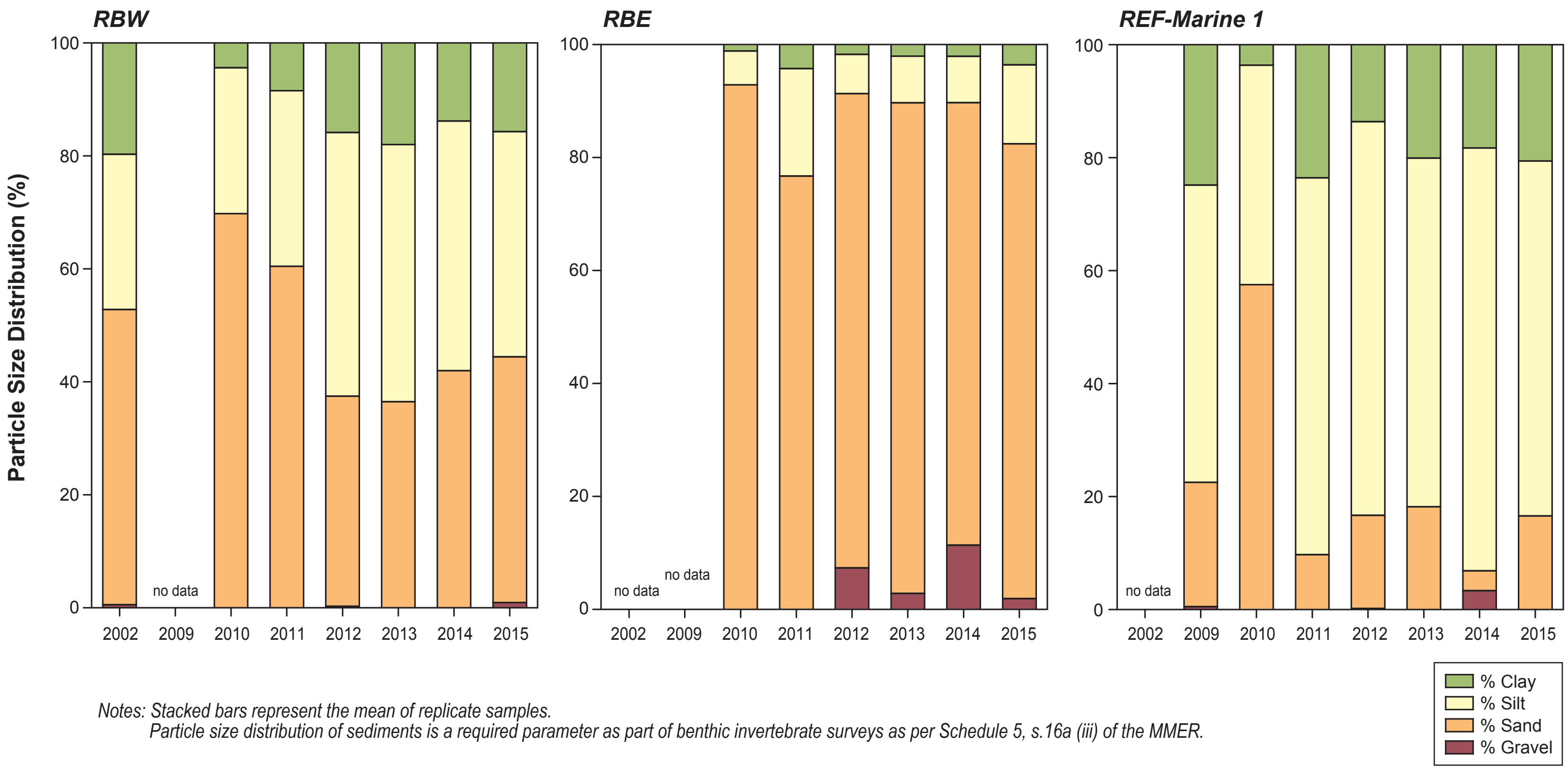
At site REF-Marine 1, sediments were finer than in the marine exposure sites. In both 2009 and in 2015, REF-Marine 1 sediments consisted mainly of silt (53% in 2009 and 63% in 2015), with approximately equal proportions of sand and clay (ranging from 17 to 26%) and negligible amounts of gravel. The before-after analysis showed that the proportion of silt was significantly higher in 2015 than in 2009 ($p = 0.019$), while the mean proportions of sand and clay were indistinguishable between years ($p = 0.068$ for sand, $p = 0.076$ for clay). The BACI analysis showed that the changes in particle size between baseline years and 2015 were similar between RBW and REF-Marine 1 ($p = 0.66$ for clay, $p = 0.38$ for silt, $p = 0.24$ for sand, and $p = 0.37$ for gravel) (Figure 3.4-19).

3.4.3.2 Total Organic Carbon

Overall, the TOC levels measured in marine site sediments appear to be mainly related to the particle size of the sediments, as the sand-dominated site RBE contained very little TOC, while RBW sediments consisting mainly of sand and silt (with some clay) had an intermediate level of TOC, and the silt-dominated REF-Marine 1 contained the highest proportion of TOC (Figures 3.4-19 and 3.4-20). This is the expected pattern as TOC levels are typically higher in finer sediments (e.g., Secrieri and Oaie 2009).

Figure 3.4-19

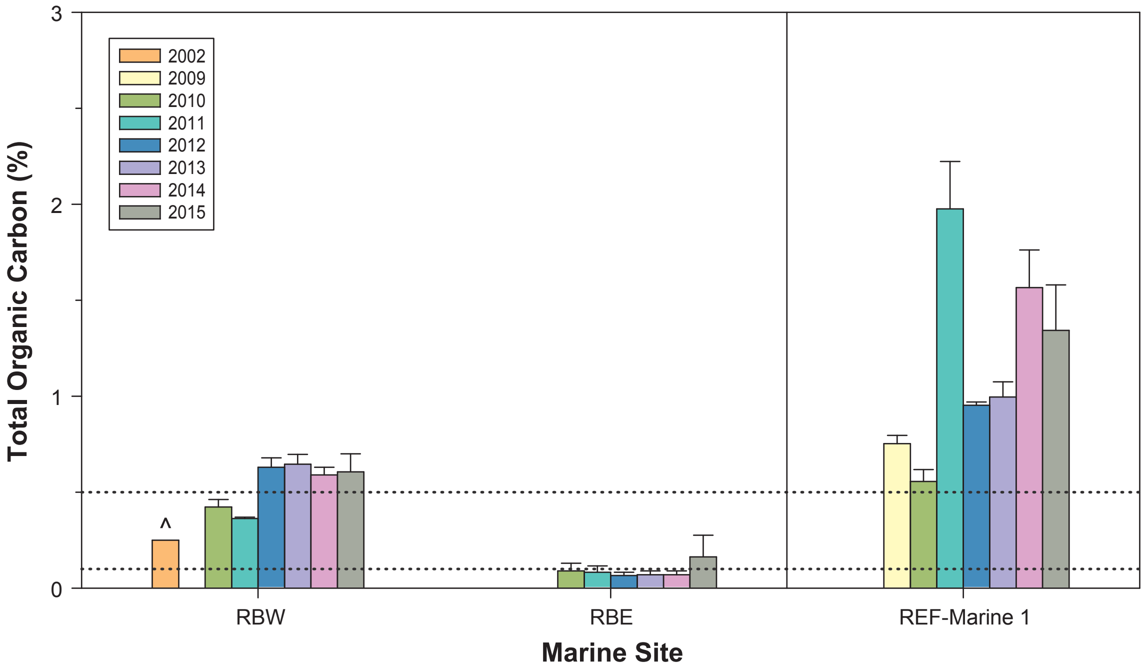
Particle Size Distribution in AEMP Marine Sediments, Doris North Project, 2002 to 2015



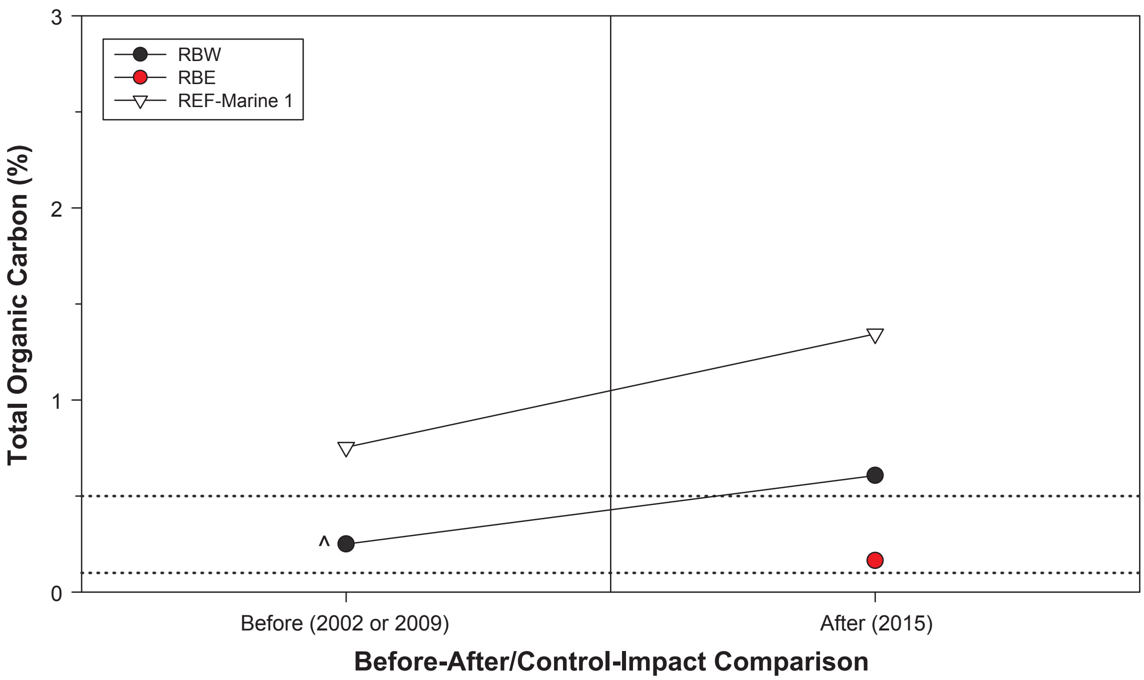
Notes: Stacked bars represent the mean of replicate samples.
Particle size distribution of sediments is a required parameter as part of benthic invertebrate surveys as per Schedule 5, s.16a (iii) of the MMER.

Figure 3.4-20

Total Organic Carbon Concentrations in AEMP Marine Sediments, Doris North Project, 2002 to 2015



Analytical detection limits:
2002 - 0.5%
2009 - 0.1%
2010 - 0.1%
2011 - 0.1%
2012 - 0.1%
2013 - 0.1%
2014 - 0.1%
2015 - 0.1%



Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
Total organic carbon content of sediments is a required parameter as part of benthic invertebrate surveys as per Schedule 5, s.16a (iii) of the MMER.

The mean TOC content in sediments from RBW increased slightly from below the detection limit of 0.5% in 2002 to 0.61% 2015 (Figure 3.4-20), and the before-after comparison indicated that this increase was statistically significant ($p = 0.0020$). However, this result was an artifact of the substitution of values that were below detection with half the analytical detection limit instead of the full detection limit, which would have resulted in the means being indistinguishable from each other ($p = 0.17$). Nevertheless, the BACI analysis showed that the increase in TOC from baseline years to 2015 at RBW was indistinguishable from the increase at the reference site ($p = 0.31$); therefore, any change in TOC was unrelated to Project activities.

As in previous years, the mean TOC content in sediments from RBE was very low (0.16%) in 2015 and was close to the detection limit of 0.1%.

3.4.3.3 Total Arsenic

The arsenic concentrations measured in exposure and reference site sediments in 2015 were below the CCME ISQG of 7.24 mg/kg and the PEL of 41.6 mg/kg. Mean arsenic concentrations in sediments from RBW increased significantly from 1.9 mg/kg in 2002 to 3.3 mg/kg in 2015 (before-after: $p < 0.0001$; Figure 3.4-21). The increase in sediment arsenic concentrations may have been related to the increase in the total proportion of fine sediments in the 2015 samples. Mean arsenic concentrations also increased from 3.1 mg/kg in 2009 to 4.1 mg/kg in 2015 at REF-Marine 1, but the before-after analysis indicated that this increase was not statistically significant ($p = 0.063$). However, the BACI analysis showed that there was no evidence of a differential increase in arsenic concentration in RBW sediments compared to the reference site ($p = 0.28$). Thus, any increase in arsenic levels in the sediments at site RBW was unrelated to 2015 Project activities.

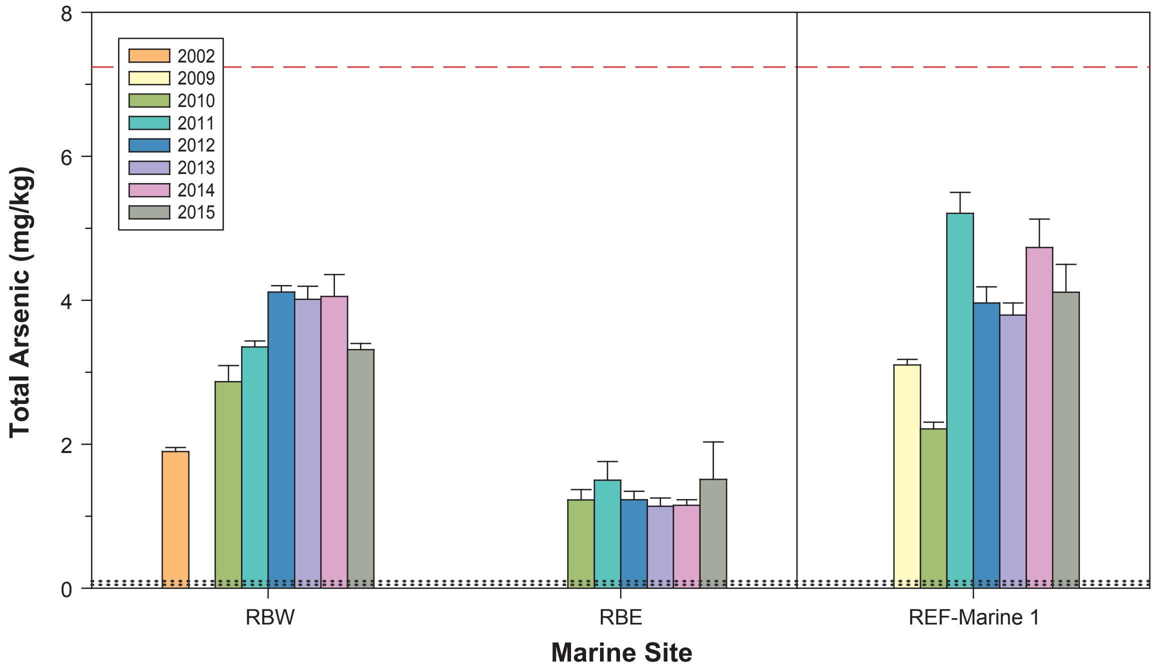
In sediments from site RBE, the mean 2015 arsenic concentration of 1.5 mg/kg was similar to the arsenic concentrations measured in sediments at that site between 2010 and 2014, and lower than mean concentrations at RBW and REF-Marine 1. Therefore, there was no evidence of an effect of Project activities on 2015 sediment arsenic concentrations at site RBE.

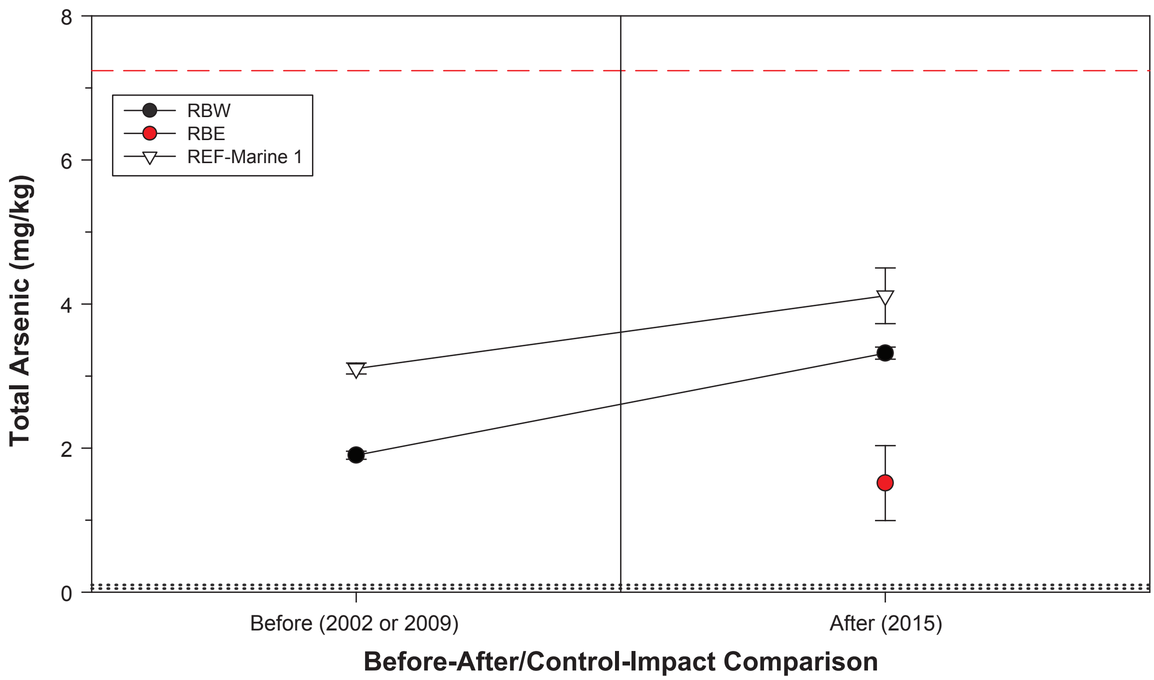
3.4.3.4 Total Cadmium

Cadmium concentrations were below the analytical detection limit (< 0.05 mg/kg) in all sediment samples collected from RBW and RBE in 2015 (Figure 3.4-22). All 2015 concentrations were also well below the CCME ISQG of 0.7 mg/kg and the PEL of 4.2 mg/kg. Therefore, there was no indication that 2015 Project activities had an effect on cadmium concentrations in sediments at the marine exposure sites.

Figure 3.4-21

Total Arsenic Concentrations in AEMP Marine Sediments, Doris North Project, 2002 to 2015





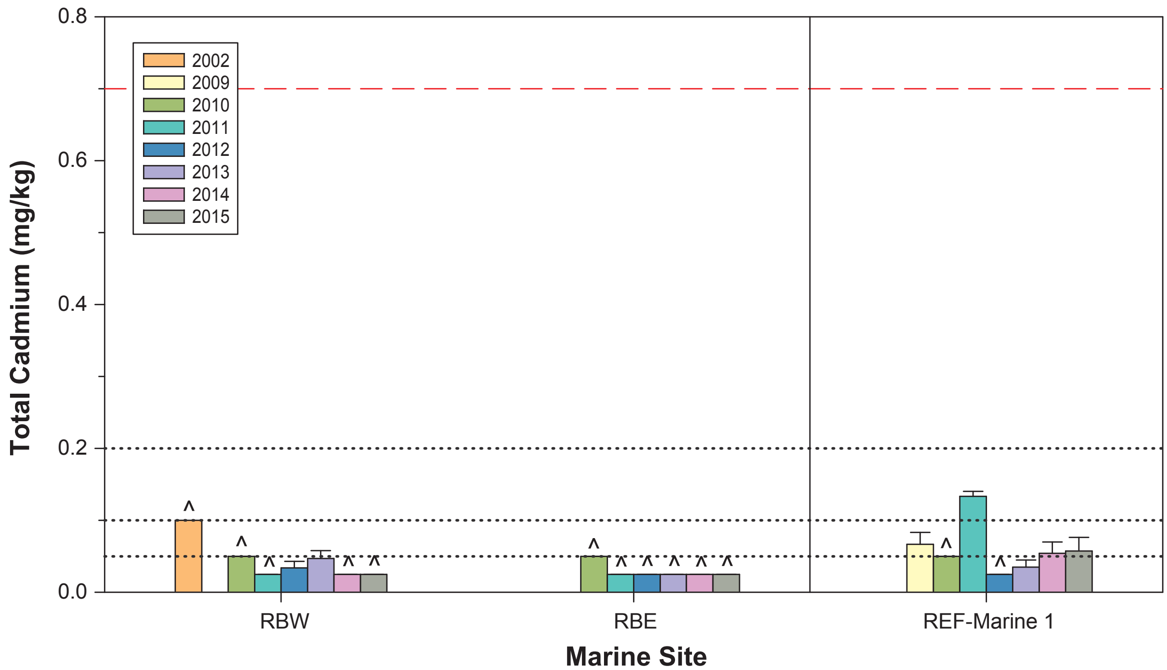
Analytical detection limits:

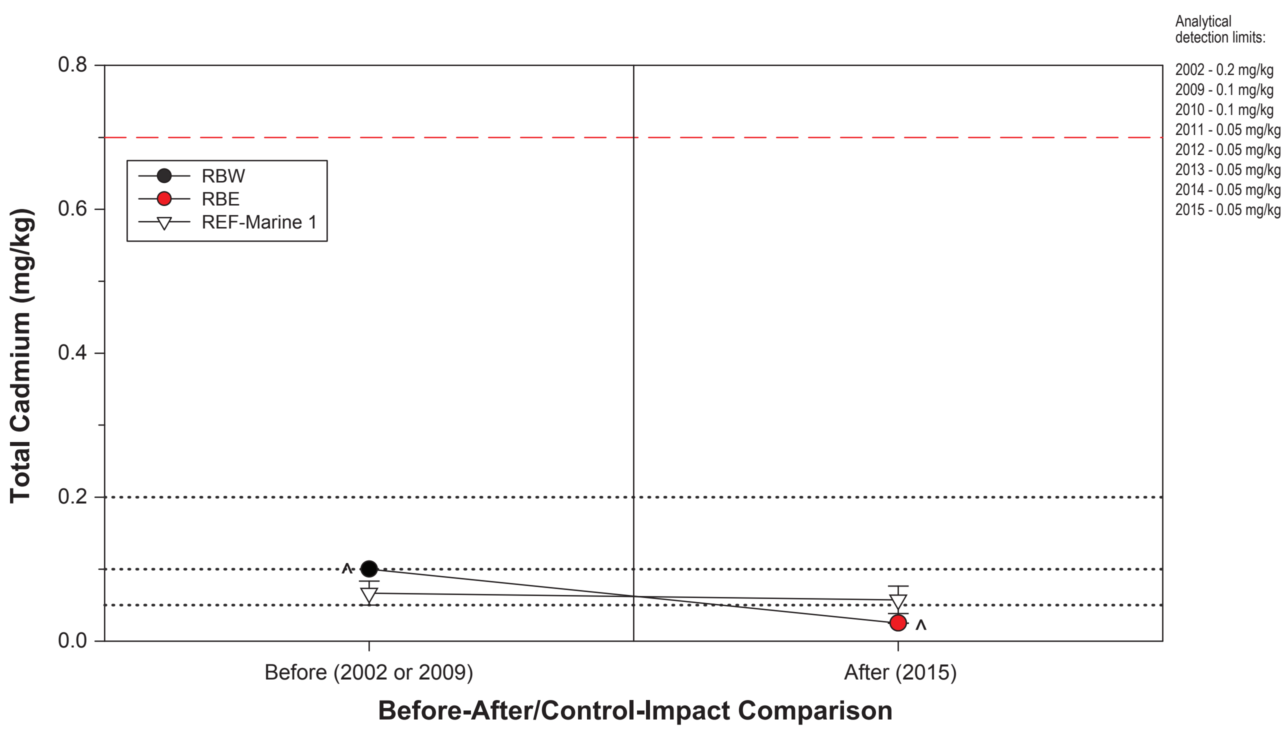
2002 - 0.1 mg/kg
2009 - 0.05 mg/kg
2010 - 0.05 mg/kg
2011 - 0.05 mg/kg
2012 - 0.05 mg/kg
2013 - 0.05 mg/kg
2014 - 0.05 mg/kg
2015 - 0.1 mg/kg

Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
Red dashed lines represent the CCME marine and estuarine interim sediment quality guideline (ISQG) for arsenic (7.24 mg/kg); the probable effects level (PEL) for arsenic (41.6 mg/kg) is not shown.

Total Cadmium Concentrations in AEMP Marine Sediments, Doris North Project, 2002 to 2015

ERM





Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
^ Indicates that concentrations were below the detection limit in all samples.
Red dashed lines represent the CCME marine and estuarine interim sediment quality guideline (ISQG) for cadmium (0.7 mg/kg); the probable effects level (PEL) for cadmium (4.2 mg/kg) is not shown.

3.4.3.5 Total Chromium

Mean chromium concentrations in RBW sediments increased significantly from 18.2 mg/kg in 2002 to 30.2 mg/kg in 2015 (before-after: $p < 0.0001$; Figure 3.4-23). The BACI analysis showed that there were different trends in sediment chromium concentrations over time at RBW compared to the reference site ($p < 0.0001$), where there was a significant decrease from 38.9 mg/kg in 2009 to 34.0 mg/kg in 2015 (before-after: $p = 0.048$; Figure 3.4-23). Overall, the mean chromium concentration in the sediments of RBW in 2015 (30.2 mg/kg) remained below the CCME ISQG of 52.3 mg/kg and the PEL of 160 mg/kg, and was lower than the mean reference site concentration (34.0 mg/kg), so it is unlikely that Project activities adversely affected sediment chromium concentrations at this exposure site.

No baseline data were available for comparison at RBE, but the mean 2015 chromium concentration in sediments (15.4 mg/kg) was lower than the mean 2015 concentrations in sediments from RBW and REF-Marine 1, and 2015 concentrations at RBE appeared to be similar to 2010 to 2014 concentrations (Figure 3.4-23). All 2015 concentrations were below the CCME ISQG of 52.3 mg/kg and the PEL of 160 mg/kg. Thus, there was no evidence of an effect of 2015 Project activities on sediment chromium concentrations at site RBE in Roberts Bay.

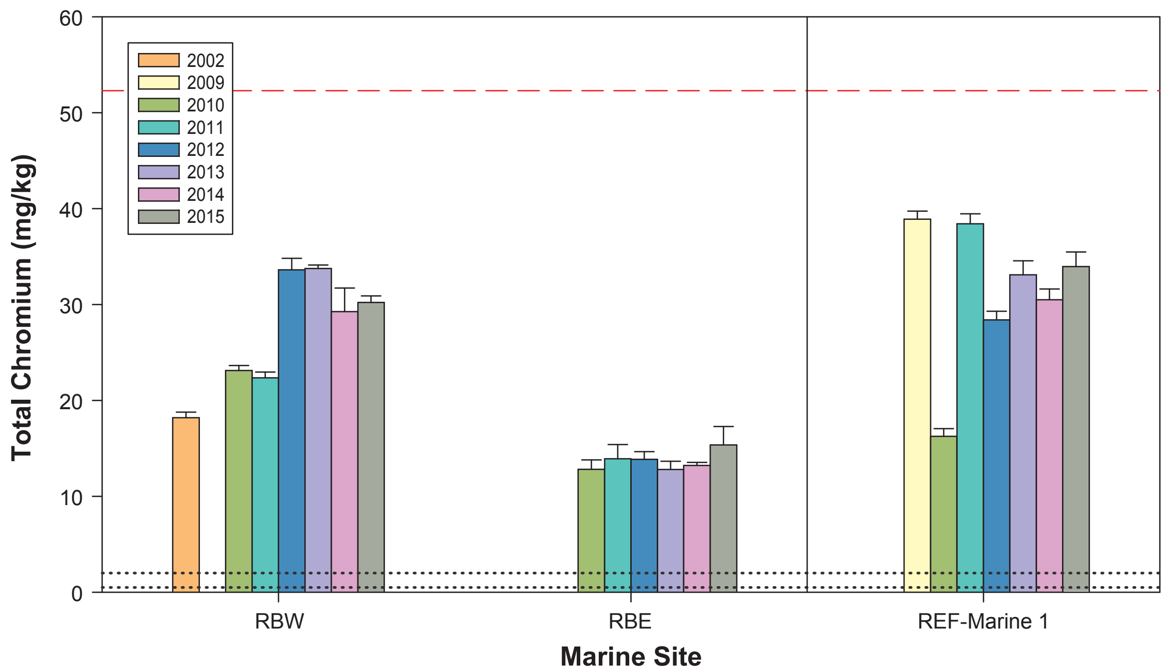
3.4.3.6 Total Copper

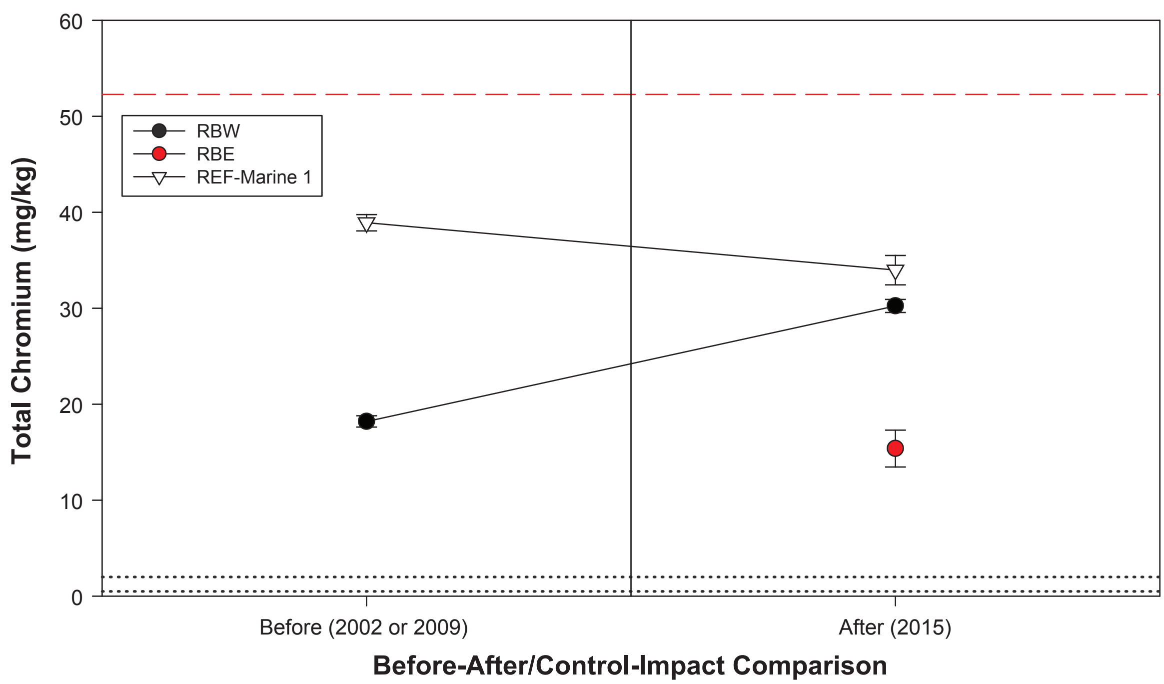
Mean copper concentrations in sediments from RBW increased from 8.4 mg/kg in 2002 to 19.6 mg/kg in 2015, which was slightly above the CCME ISQG of 18.7 mg/kg, but well below the PEL of 108 mg/kg (Figure 3.4-24). This increase was statistically significant ($p < 0.0001$) based on the before-after analysis. A similar increase from baseline levels did not occur at the reference site (before-after: $p = 0.12$, BACI: <0.0001). However, data from the reference site does demonstrate that copper concentrations can be highly variable inter-annually as there is more than a 2-fold difference between the lowest and highest annual mean concentration in REF-Marine 1 sediments. Inter-annual variability in sediment copper concentrations was also high at RBW, with annual means ranging from 8.4 mg/kg in 2002 to 26.9 mg/kg in 2012. Mean copper concentrations in sediments often approached the CCME ISQG of 18.7 mg/kg at both RBW and REF-Marine 1, and mean copper concentrations in RBW sediments exceeded this guideline every year from 2012 to 2015. Sediments at RBW were also finer between 2012 and 2015 compared to previous years, which may have contributed to the higher copper concentrations measured from 2012 to 2015. 2015 sediment copper concentrations at RBW were within the range of concentrations measured in previous years, and are likely naturally elevated at this site. In addition, the mean 2015 sediment copper concentration of 19.6 mg/kg at RBW was similar to the mean concentration of 18.1 mg/kg measured at the reference site in 2011. Thus, it is unlikely that 2015 Project activities are responsible for the concentrations of copper measured in the sediments of RBW.

There are no baseline data for RBE, but the mean 2015 copper concentration in sediments (10.5 mg/kg) was lower than mean concentration in sediments from RBW and REF-Marine 1, which is consistent with the coarser nature of the sediment at RBE (Figure 3.4-24). Copper concentrations at RBE were also relatively consistent over time between 2010 and 2015. Therefore, there was no indication that 2015 Project activities affected sediment copper concentrations at this marine exposure site.

Figure 3.4-23

Total Chromium Concentrations in AEMP Marine Sediments, Doris North Project, 2002 to 2015





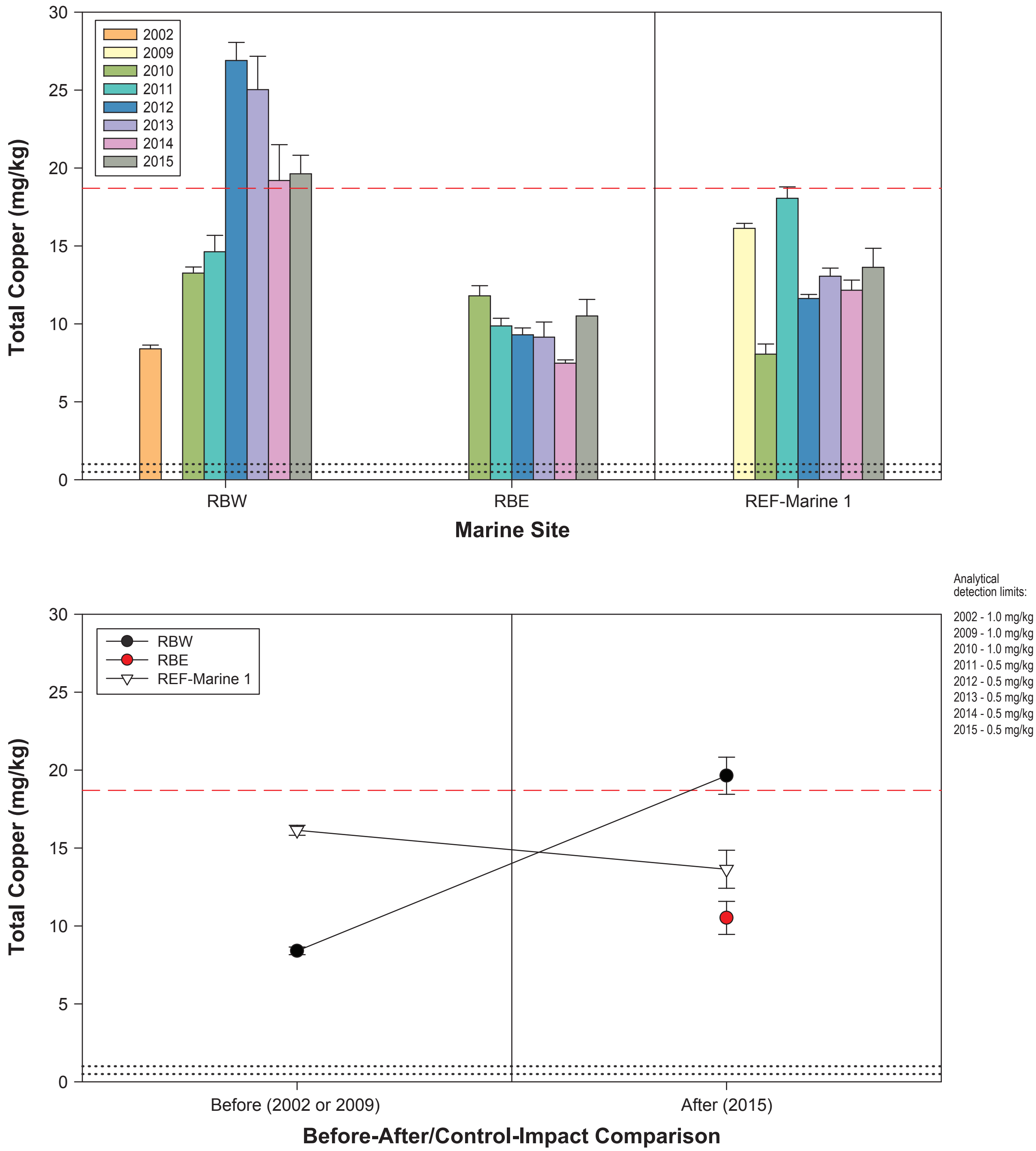
Analytical detection limits:

2002 - 2.0 mg/kg
2009 - 2.0 mg/kg
2010 - 2.0 mg/kg
2011 - 0.5 mg/kg
2012 - 0.5 mg/kg
2013 - 0.5 mg/kg
2014 - 0.5 mg/kg
2015 - 0.5 mg/kg

Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
Red dashed lines represent the CCME marine and estuarine interim sediment quality guideline (ISQG) for chromium (52.3 mg/kg); the probable effects level (PEL) for chromium (160 mg/kg) is not shown.

Figure 3.4-24

Total Copper Concentrations in AEMP Marine Sediments, Doris North Project, 2002 to 2015



Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
Red dashed lines represent the CCME marine and estuarine interim sediment quality guideline (ISQG) for copper (18.7 mg/kg); the probable effects level (PEL) for copper (108 mg/kg) is not shown.

3.4.3.7 Total Lead

All 2015 sediment lead concentrations at the marine sites were well below the CCME ISQG of 30.2 mg/kg and the PEL of 112 mg/kg (Figure 3.4-25). The mean 2015 lead concentration in RBW sediments of 4.0 mg/kg was significantly higher than the 2002 mean of 2.6 mg/kg ($p = 0.0074$; Figure 3.4-25). The BACI analysis showed that there were differential changes in sediment lead concentrations over time at RBW compared to the reference site ($p = 0.0001$), where there was a significant decrease from 6.0 mg/kg in 2009 to 4.7 mg/kg in 2015 (before-after: $p = 0.0014$; Figure 3.4-25). Overall, the mean lead concentration in RBW sediments in 2015 (4.0 mg/kg) remained well below CCME guidelines and was lower than the mean reference site concentration (4.7 mg/kg), so it is unlikely that Project activities adversely affected sediment lead concentrations at this exposure site.

Although no before data exist for RBE, sediments from RBE had the lowest mean 2015 concentration of lead (1.6 mg/kg) compared to the other marine sites, and concentrations were generally consistent over time from 2010 to 2015 (Figure 3.4-25). Thus, there was no apparent effect of 2015 activities on sediment lead concentrations at the marine exposure sites.

3.4.3.8 Total Mercury

Mercury concentrations in all exposure and reference site sediments collected in 2015 were well below the CCME ISQG of 0.13 mg/kg and the PEL of 0.7 mg/kg (Figure 3.4-26). Statistical results are not reported for RBW because 75% of the combined baseline and 2015 dataset for mercury concentrations are below analytical detection limits; however, Figure 3.4-26 shows that sediment mercury concentrations at RBW were lower in 2015 than in the baseline year 2002. Thus, there is no evidence of an adverse effect of Project activities on sediment mercury concentrations at this site.

Concentrations of mercury from RBE sediments in 2015 were below the analytical detection limit of 0.005 mg/kg. There was no evidence that 2015 Project activities adversely affected mercury concentrations in the sediments at this site.

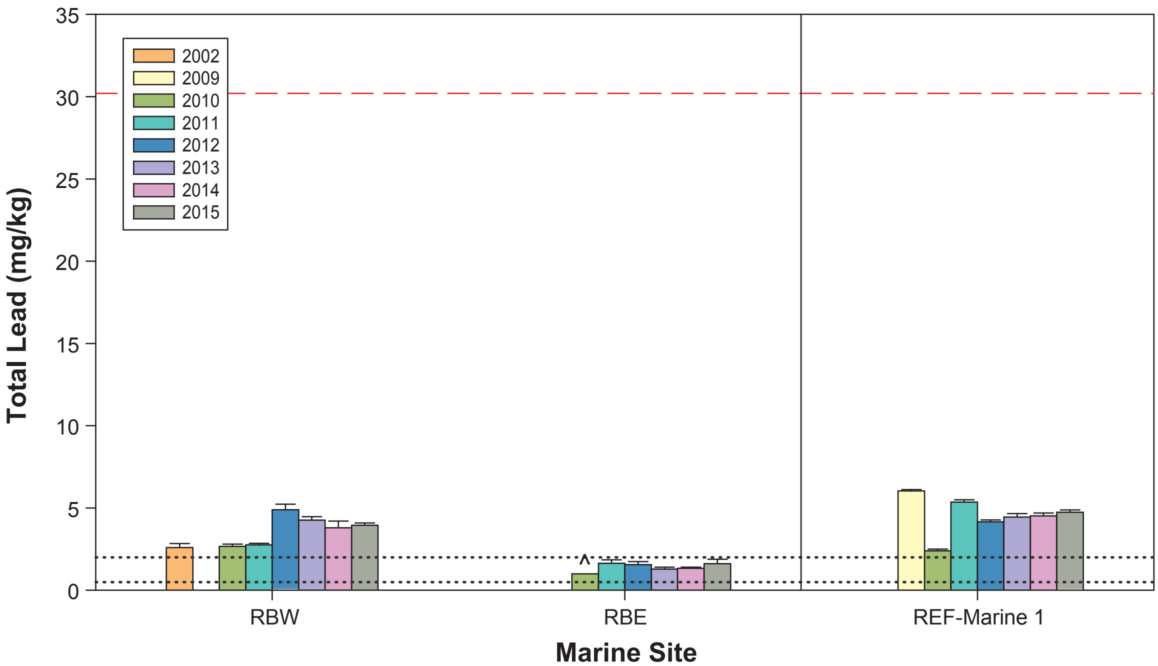
3.4.3.9 Total Zinc

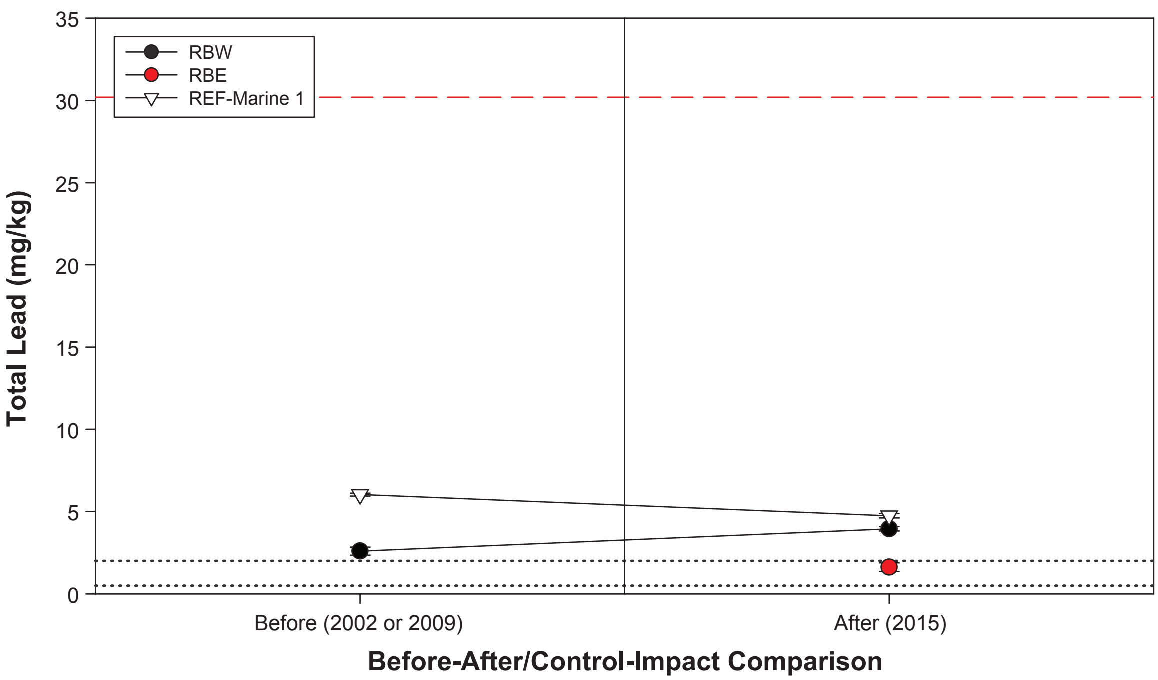
The mean 2015 zinc concentration of 34.3 mg/kg in sediments from RBW was significantly higher than the 2002 mean of 20.6 mg/kg ($p < 0.0001$; Figure 3.4-27). The before-after and BACI analyses showed that a similar increase was not observed at the reference site (before-after: $p = 0.19$, BACI: $p < 0.0001$). However, the mean zinc concentration in RBW sediments in 2015 (34.3 mg/kg) remained well below the CCME ISQG of 124 mg/kg and the PEL of 271 mg/kg, and was lower than the mean reference site concentration (40.9 mg/kg). Thus, it is unlikely that Project activities adversely affected sediment zinc concentrations at this exposure site.

Although no before data are available for RBE, sediments from RBE had the lowest mean 2015 concentration of zinc (15.6 mg/kg) compared to the other marine sites and zinc concentrations at RBE also appeared to be consistent through time (Figure 3.4-27). The relatively low zinc concentrations observed at RBE is consistent with the coarser nature of the sediments at this site. All 2015 sediment zinc concentrations measured in RBE samples were also well below the CCME ISQG of 124 mg/kg and the PEL of 271 mg/kg (Figure 3.4-27). Thus, there was no apparent effect of 2015 Project activities on sediment zinc concentrations at exposure site RBE.

Figure 3.4-25

Total Lead Concentrations in AEMP Marine Sediments, Doris North Project, 2002 to 2015



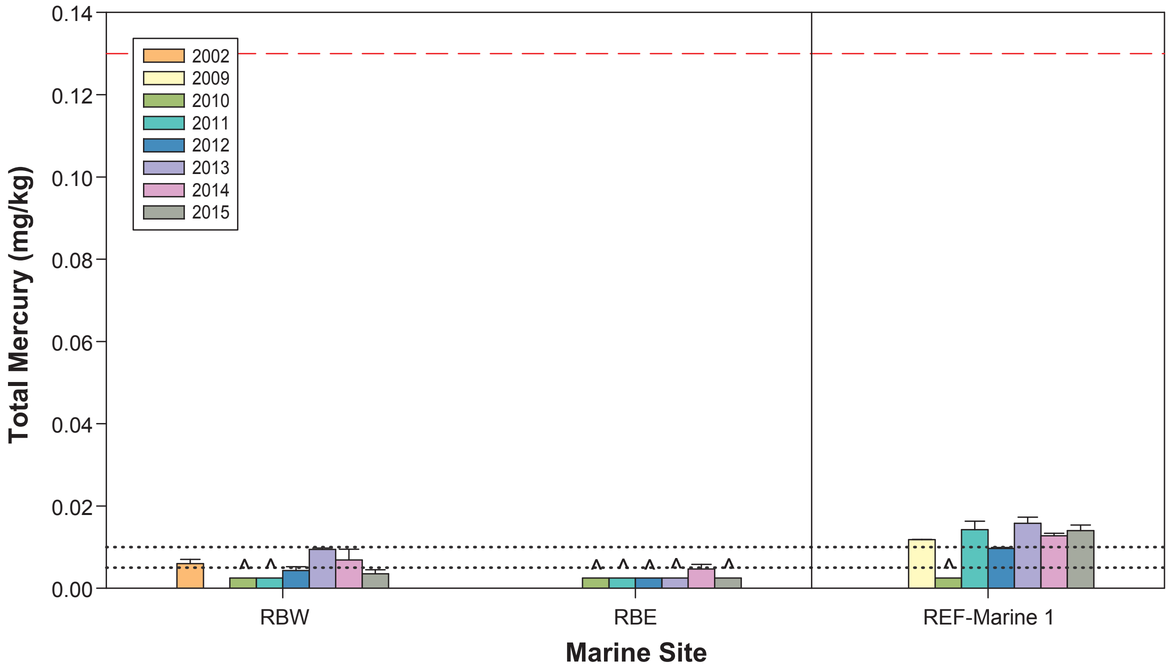


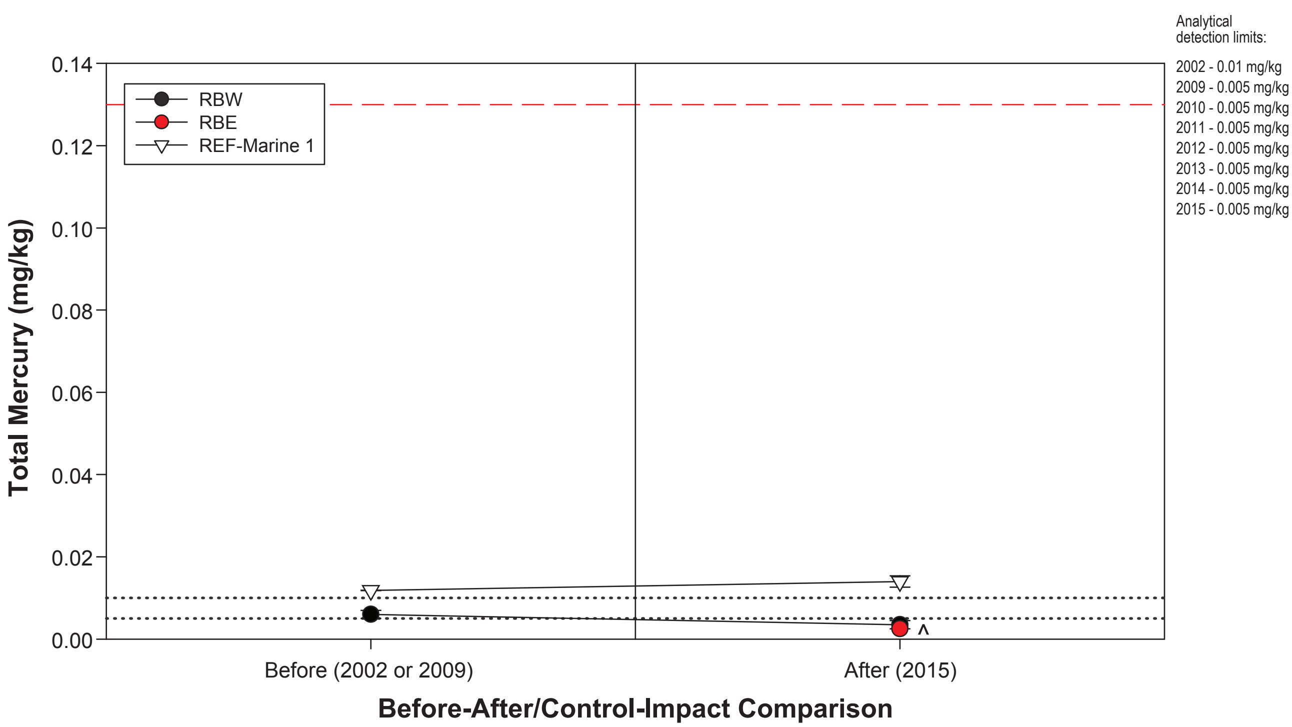
Analytical detection limits:
2002 - 2.0 mg/kg
2009 - 2.0 mg/kg
2010 - 2.0 mg/kg
2011 - 0.5 mg/kg
2012 - 0.5 mg/kg
2013 - 0.5 mg/kg
2014 - 0.5 mg/kg
2015 - 0.5 mg/kg

Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
^ Indicates that concentrations were below the detection limit in all samples.
Red dashed lines represent the CCME marine and estuarine interim sediment quality guideline (ISQG) for lead (30.2 mg/kg); the probable effects level (PEL) for lead (112 mg/kg) is not shown.

Figure 3.4-26

Total Mercury Concentrations in AEMP Marine Sediments, Doris North Project, 2002 to 2015

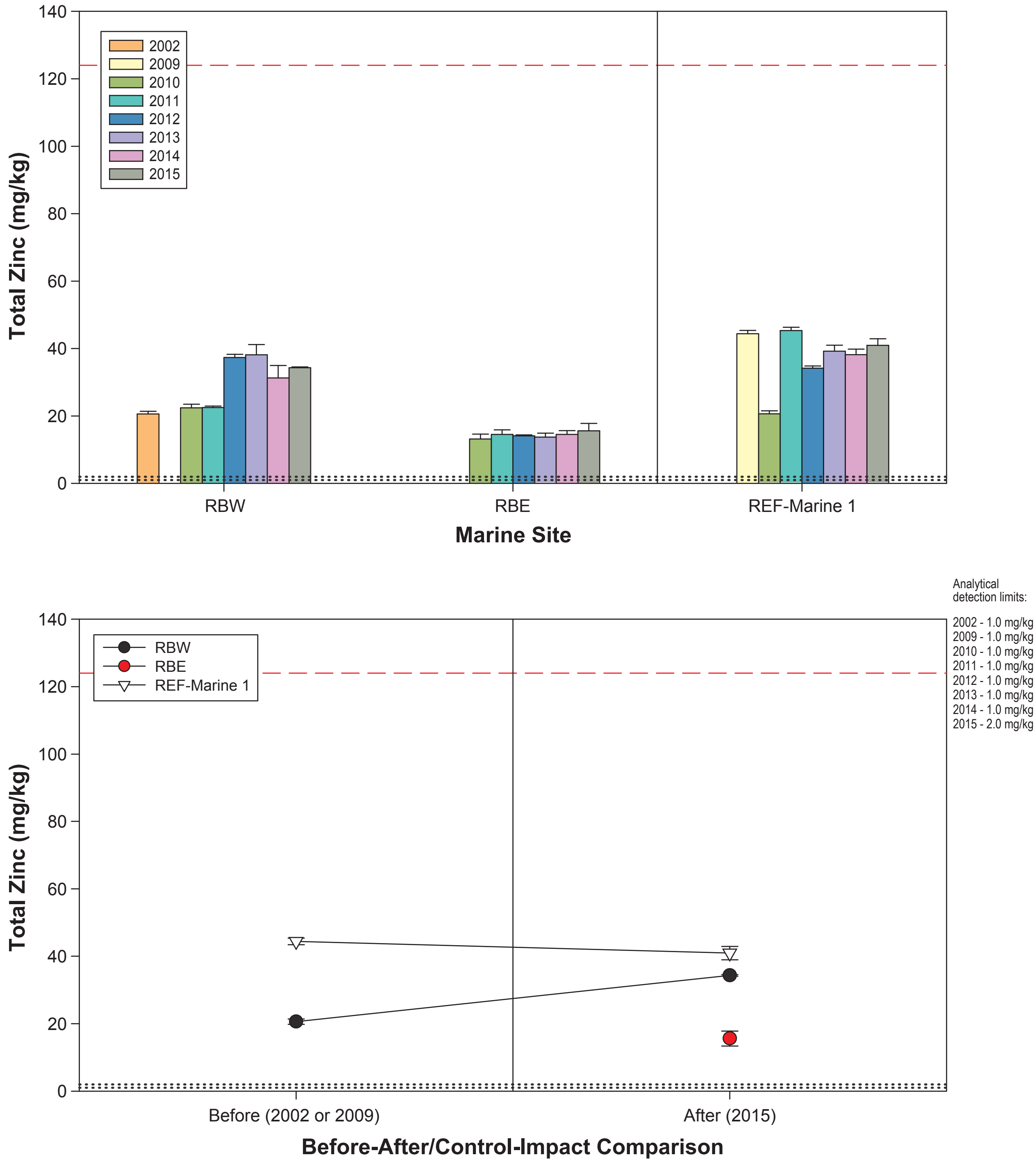




Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
^ Indicates that concentrations were below the detection limit in all samples.
Red dashed lines represent the CCME marine and estuarine interim sediment quality guideline (ISQG) for mercury (0.13 mg/kg); the probable effects level (PEL) for mercury (0.7 mg/kg) is not shown.

Figure 3.4-27

Total Zinc Concentrations in AEMP Marine Sediments, Doris North Project, 2002 to 2015



Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
Red dashed lines represent the CCME marine and estuarine interim sediment quality guideline (ISQG) for zinc (124 mg/kg); the probable effects level (PEL) for zinc (271 mg/kg) is not shown.

3.5 PRIMARY PRODUCERS

Primary producer biomass (as chlorophyll *a*) samples were collected in streams, lakes, and the marine environment to assess potential changes due to eutrophication or toxicity.

Historical primary producer (phytoplankton and periphyton) biomass sampling has been conducted in the Project area since 1996. The main criteria for the selection of relevant baseline periphyton and phytoplankton biomass data for inclusion in the effects analysis were the proximity of baseline sampling sites to 2015 sampling sites and the use of comparable sampling methodologies.

Graphical analyses, before-after comparisons, and BACI analyses (where possible) were used to determine whether there were changes in primary producer biomass in the Project area. For all graphical and statistical analyses, replicate samples collected on the same date were averaged prior to analysis. The complete results of all statistical methods and analyses are provided in Appendix B.

3.5.1 Stream Periphyton Biomass

Stream periphyton biomass samples were collected from three exposure streams (Doris, Roberts, and Little Roberts outflows) and two reference streams (Reference B and Reference D outflows). Baseline data for stream periphyton biomass that were comparable to 2015 data in terms of sampling locations and methodologies are available from 1997, 2000, and 2009 for Doris Outflow, and from 2009 for Little Roberts and Reference B Outflows (Appendix B). There were too few degrees of freedom in the before period for Little Roberts and Reference B outflows, so before-after analyses could not be performed for periphyton data from these streams; however, there were sufficient degrees of freedom to conduct a BACI analysis. Note that periphyton biomass data and statistical analysis results for Roberts Outflow are shown in the following figures and in Appendices A and B, but this stream is not discussed in the following sections. Roberts Outflow is not expected to be affected by the Project but rather serves to characterize any influence of a closed silver mine and past neighbouring exploration activity (North Arrow Minerals Inc.) on Roberts Outflow and potentially downstream, and to be able to differentiate this from potential effects of TIA discharge upstream.

Periphyton biomass was highly variable over time, particularly at Doris Outflow, where several years of baseline data are available (Figure 3.5-1). Periphyton biomass at this stream site decreased by an order of magnitude between 1997 and 2009, before the commencement of any Project activities. This degree of natural variability makes it difficult to isolate trends from natural background variability. Mean 2015 periphyton biomass at Doris Outflow was intermediate to 2000 and 2009 mean biomass levels, and the before-after analysis confirmed that there was no significant difference between the baseline mean biomass and the 2015 mean biomass at this site ($p = 0.37$).

At Little Roberts Outflow, mean periphyton biomass was higher in 2015 than 2009 (Figure 3.5-1). Although a before-after analysis could not be performed, the BACI analysis indicated that a parallel increase from 2009 to 2015 was apparent for the reference streams ($p = 0.051$), so there was no evidence of a Project-related effect on periphyton biomass in Little Roberts Outflow. Graphical analysis also indicated that trends were similar between Little Roberts Outflow and reference streams. Additionally, there were no Project-related changes in water quality in Little Roberts Outflow that would have resulted in a change in periphyton biomass. Thus, the difference in biomass levels at Little Roberts Outflow between 2009 and 2015 was likely unrelated to Project activities.

There was no indication that Project activities had any effect on periphyton biomass in exposure streams.

3.5.2 Lake Phytoplankton Biomass

Phytoplankton biomass samples were collected from three exposure lake sites (Doris Lake South, Doris Lake North, and Little Roberts Lake) and two reference lake sites (Reference Lake B and Reference Lake D) in 2015. Baseline data for lake phytoplankton biomass that were comparable to 2015 data in terms of sampling locations and methodologies are available from 1997, 2000, and 2009 for Doris Lake South, 1997 and 2009 for Little Roberts Lake, and 2009 for Doris Lake North and Reference Lake B (Appendix B). No baseline data are available for Reference Lake D, so a BACI analysis could not be performed for Little Roberts Lake.

At the exposure lake sites Doris South and Little Robert Lake, mean 2015 phytoplankton biomass levels were within the range of baseline means, while at Doris North, mean biomass was slightly higher in 2015 than 2009 (Figure 3.5-2). However, the before-after analysis confirmed that the mean 2015 phytoplankton biomass was not significantly different from the mean baseline biomass at any exposure lake site ($p = 0.54$ for Doris Lake South, $p = 0.87$ for Doris Lake North, and $p = 0.92$ for Little Roberts Lake). Thus, there was no apparent effect of 2015 Project activities on phytoplankton biomass in exposure lakes.

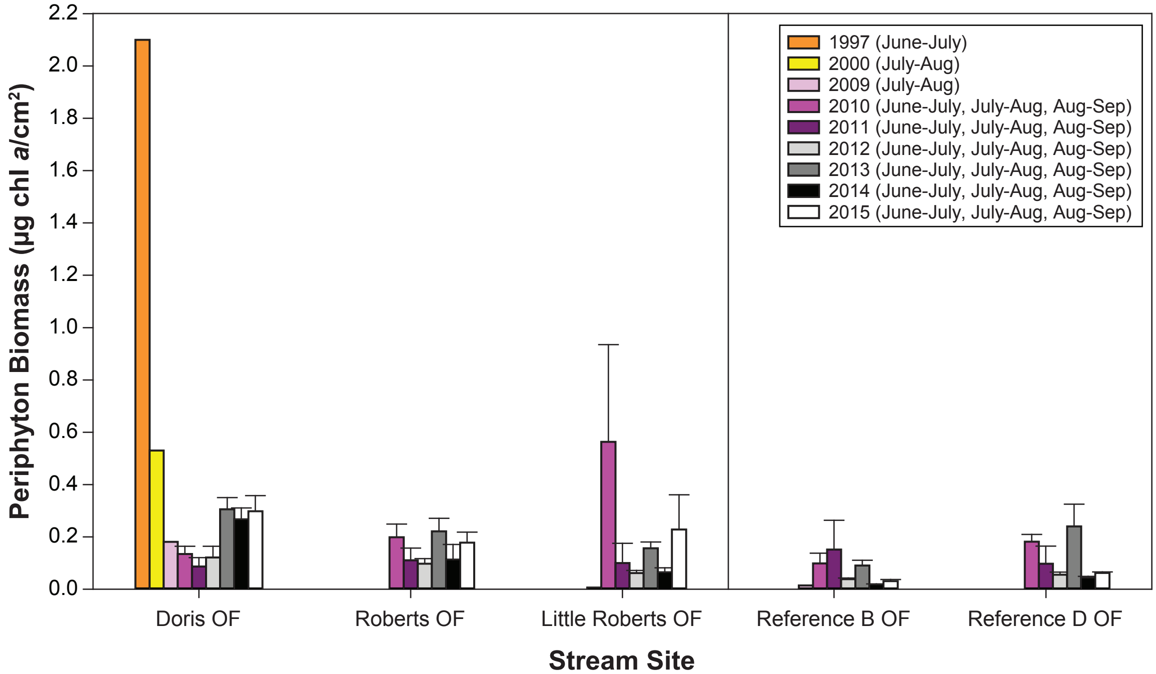
3.5.3 Marine Phytoplankton Biomass

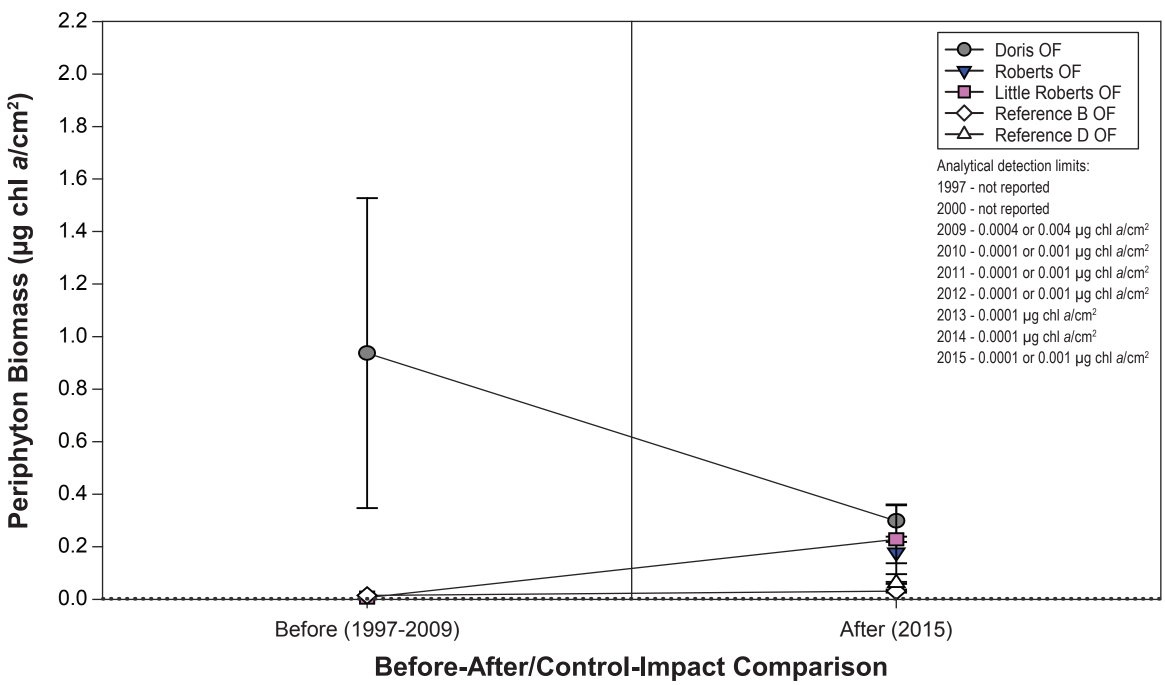
Phytoplankton biomass samples from marine areas were collected from two exposure sites in Roberts Bay (RBW and RBE) and one reference site in Ida Bay (REF-Marine 1) in 2015. Historical phytoplankton biomass data have been collected in Roberts Bay since 2006. However, only baseline data from 2009 were considered comparable to 2015 data. Historical data collected between 2006 and 2008 were excluded because of differences in sampling methodology (Appendix B). Baseline data from 2009 are available for all marine exposure and reference sites.

Marine phytoplankton biomass concentrations were lower at all sites in 2009 than in 2015 (Figure 3.5-3). Mean phytoplankton biomass concentrations measured in 2009 were below the detection limit (< 0.04 µg chl *a*/L) at both RBE and RBW and slightly above the detection limit at REF-Marine 1 (0.045 µg chl *a*/L). In 2015, mean biomass concentrations at the marine sites were: 0.31 µg chl *a*/L at RBW, 2.01 µg chl *a*/L at RBE, and 0.35 µg chl *a*/L at REF-Marine 1 (Figure 3.5-3). The apparent increase in biomass levels between 2009 and 2015 may be related to natural seasonal differences, as samples collected in 2009 were collected only during one month (August) compared to four months in 2015 (April, July, August, and September). Although, it was not possible to perform before-after analyses on marine phytoplankton data (there were too few degrees of freedom to fit the model; Appendix B), the BACI analysis indicated that the 2009 to 2015 changes observed at the exposure sites were parallel to the 2009 to 2015 change observed at the reference site ($p = 0.14$ for RBW and $p = 0.80$ for RBE). Therefore, the apparent increases in phytoplankton biomass at RBW and RBE were unrelated to 2015 Project activities.

Figure 3.5-1

Periphyton Biomass (as Chlorophyll *a*) in AEMP Stream Sites, Doris North Project, 1997 to 2015

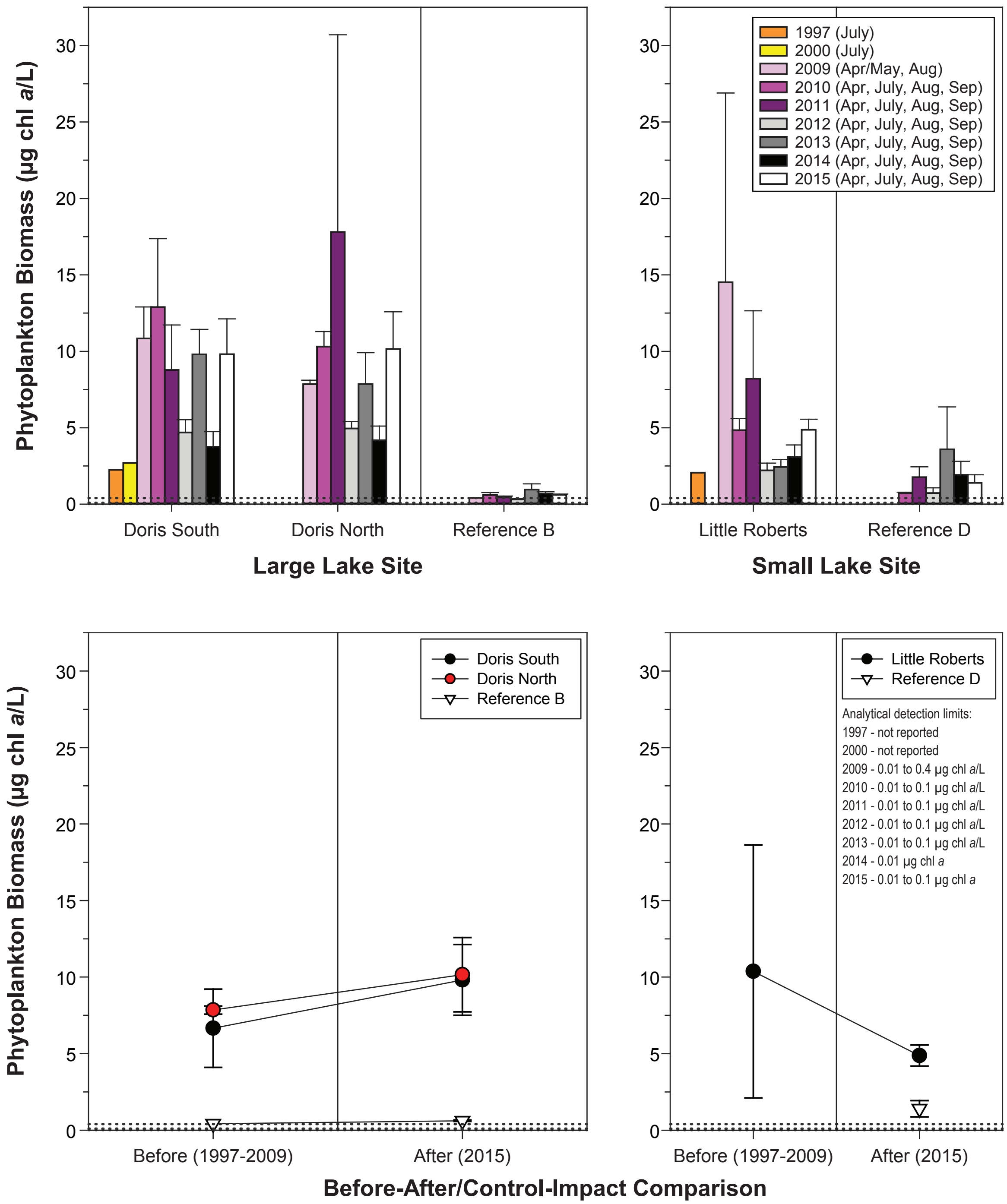




Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits.
The anomalously high periphyton biomass of 194.4 mg chl a/cm² reported for Doris Outflow in July-August 1997 was considered an outlier and was excluded from plots and statistical analyses.

Figure 3.5-2

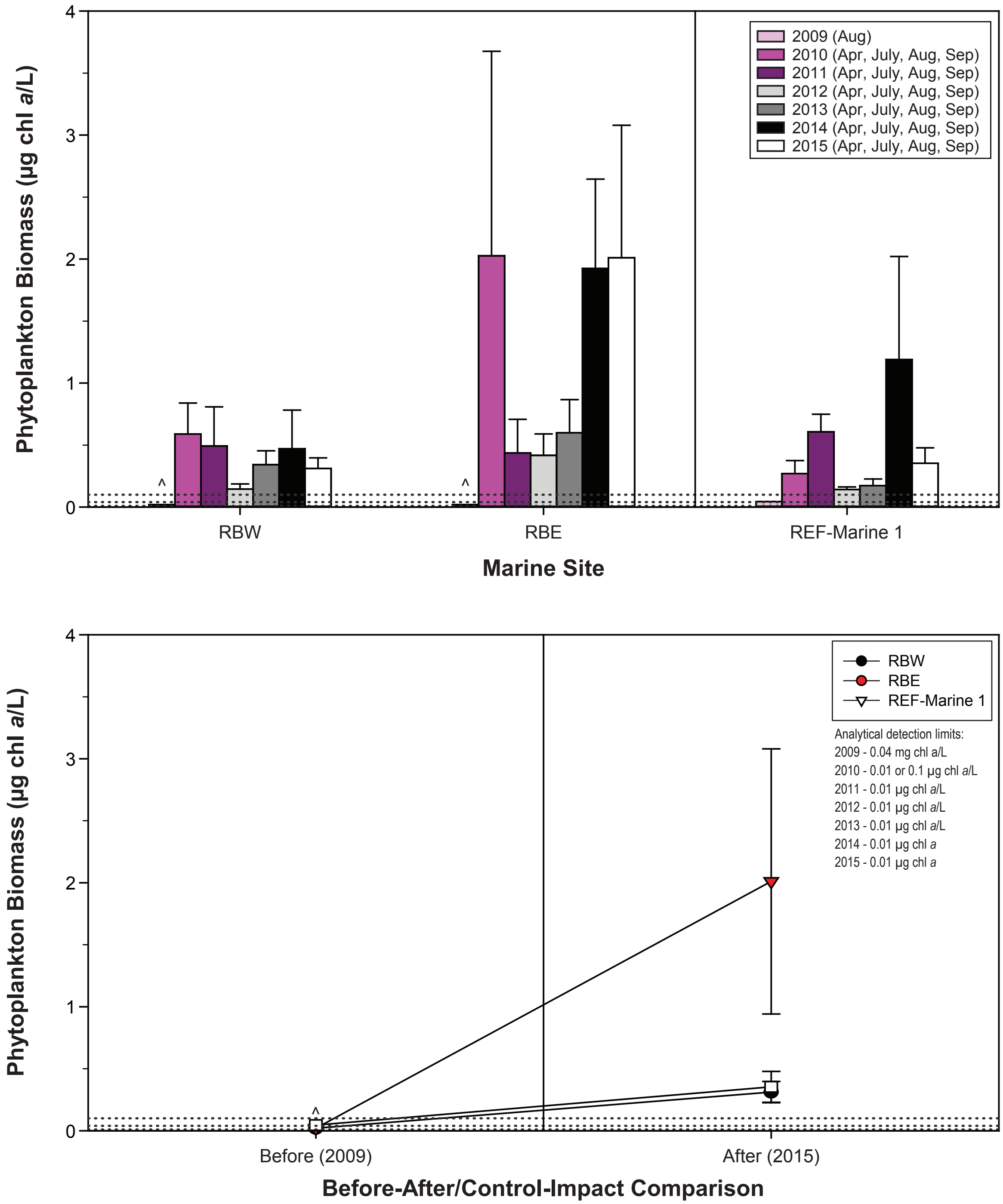
Phytoplankton Biomass (as Chlorophyll *a*) in AEMP Lake Sites, Doris North Project, 1997 to 2015



Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits.

Figure 3.5-3

Phytoplankton Biomass (as Chlorophyll *a*) in AEMP Marine Sites, Doris North Project, 2009 to 2015



Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
^ Indicates that concentrations were below the detection limit in all samples.

3.6 BENTHOS

As required in Schedule 5 of the MMER, benthic invertebrate community surveys were conducted in 2015 at stream, lake, and marine sites, and the data gathered were used to calculate benthos density, evenness (Simpson's Evenness Index), taxa richness, and a similarity index (Bray-Curtis Index). Simpson's Diversity Index, which incorporates taxa richness and evenness, was also calculated. The level of taxonomic resolution used to calculate community descriptors was family-level, as recommended in the EEM guidance document (Environment Canada 2011). All summary statistics for these community descriptors are provided in Appendix A.

The effects analysis for benthos requires a different approach than that used for the other evaluated variables because of the lack of comparable baseline data for benthos. The method used to collect benthos samples from 2010 to 2015 involved the pooling of three subsamples for each of five replicate samples; therefore, data collected since 2010 were not considered comparable to baseline data (as replicates collected during baseline studies were not composite samples). Instead of employing before-after or BACI comparisons for benthos data, an impact level-by-time analysis was used, whereby the change in benthos at exposure sites between 2010 and 2015 was compared to the change in benthos at reference sites to test for non-parallelism over time. The results of the analysis of effects for benthos are discussed below, and complete statistical methodology and results are presented in Appendix B.

3.6.1 Stream Benthos

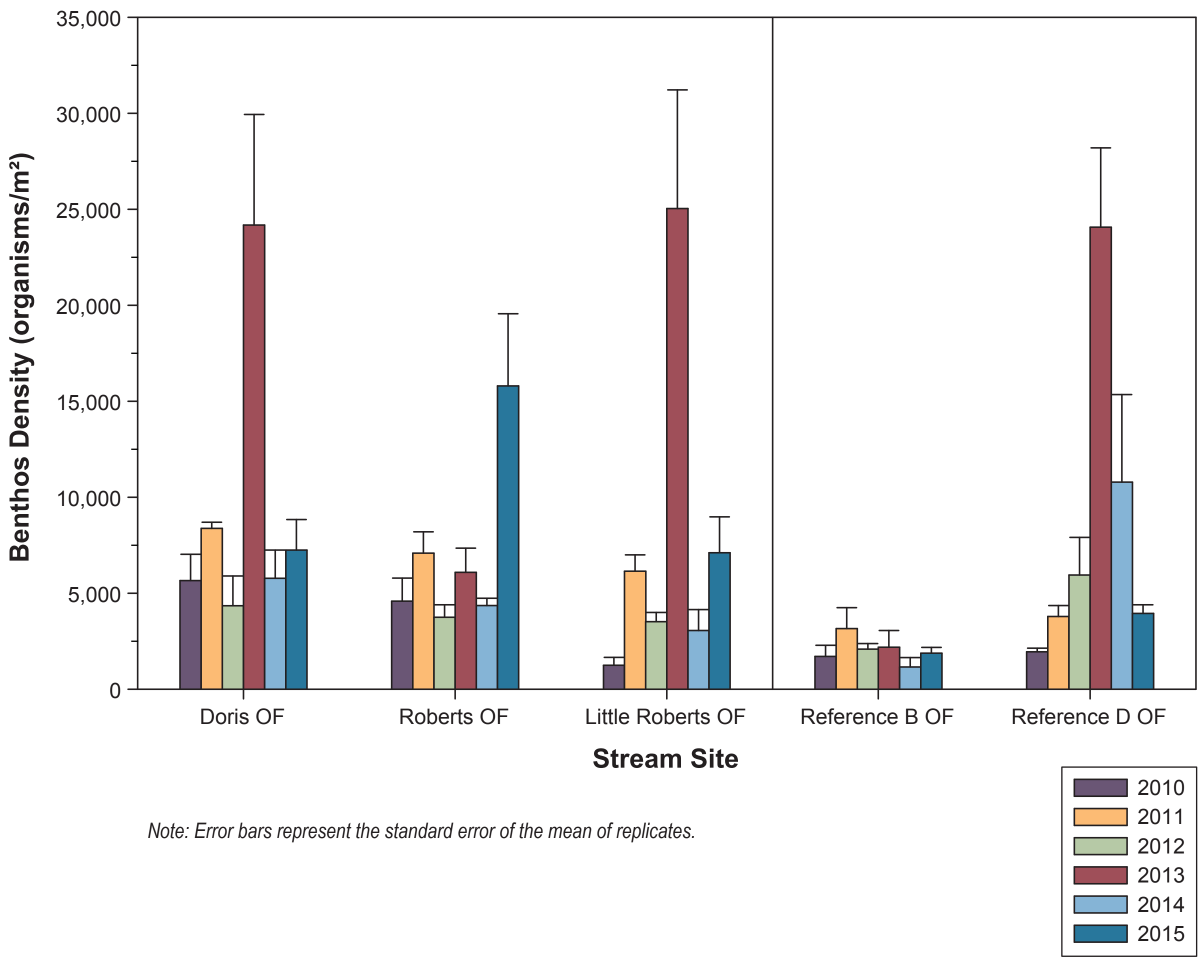
Note that benthos data and statistical analysis results for Roberts Outflow are shown in the following figures and in Appendices A and B, but this stream is not discussed in the following sections. Roberts Outflow is not expected to be affected by the Project but rather serves to characterize any influence of a closed silver mine and past neighbouring exploration activity (North Arrow Minerals Inc.) on Roberts Outflow and potentially downstream, and to be able to differentiate this from potential effects of TIA discharge upstream.

3.6.1.1 Density

Stream benthos density is naturally a highly variable parameter, ranging over an order of magnitude from year to year at some exposure and reference sites. This high variability makes it difficult to determine whether Project activities may be affecting stream benthos density. At all sites, mean 2015 benthic invertebrate density was within the range of mean densities recorded from 2010 to 2014 (Figure 3.6-1). There was no evidence of significant non-parallelism between the reference streams and Doris Outflow ($p = 0.17$), but there was evidence of non-parallelism between the reference streams and Little Roberts Outflow ($p = 0.026$). Despite the significant non-parallelism found for Little Roberts Outflow, graphical analysis indicated that the non-parallelism in density was likely a natural phenomenon unrelated to Project activities. In Reference D Outflow, the wide range of mean benthos densities (1,945 to 24,070 organisms/m^2) recorded between 2010 and 2015 was similar to the range and inter-annual variability seen in the exposure streams (Figure 3.6-1). There was no clear trend in benthos density data between 2010 and 2015 at any site, and no reason to expect that any differences are attributable to the Project rather than to natural variability.

Figure 3.6-1

Benthos Density in AEMP Stream Sites, Doris North Project, 2010 to 2015



Note: Error bars represent the standard error of the mean of replicates.

3.6.1.2 *Community Richness, Evenness, and Diversity*

2015 benthos family richness was generally similar to previous years in all exposure streams (Figure 3.6-2), while family richness in the reference streams was slightly higher in 2015 than in previous years. There was no evidence of significant non-parallelism in benthos richness between either exposure stream and the reference streams, though the evidence was marginal for Doris Outflow ($p = 0.050$ for Doris Outflow and $p = 0.23$ for Little Roberts Outflow).

Benthos family evenness was slightly lower in 2015 than in previous years at Doris, Little Roberts, and Reference B outflows, while the 2015 evenness at Reference D Outflow was within the range of previous years. There was evidence of non-parallelism in evenness for Doris Outflow compared to the reference streams ($p = 0.0011$), but not for Little Roberts Outflow ($p = 0.23$). Given that the slight decrease in evenness at Doris Outflow in 2015 was also observed at one of the reference streams, there is no reason to believe that any decrease in evenness in the exposure streams was due to the Project.

In Doris Outflow, benthos family diversity in 2015 was slightly lower than diversity levels from 2010 to 2014. In Little Roberts Outflow as well as the reference streams, 2015 diversity levels were within the range of previous years (Figure 3.6-2). There was no evidence of non-parallelism in 2010 to 2015 trends when comparing exposure streams to reference streams ($p = 0.38$ for Doris Outflow and $p = 0.84$ for Little Roberts Outflow). This suggests that there were no Project effects on benthic family diversity in the exposure streams in 2015.

3.6.1.3 *Bray-Curtis Index*

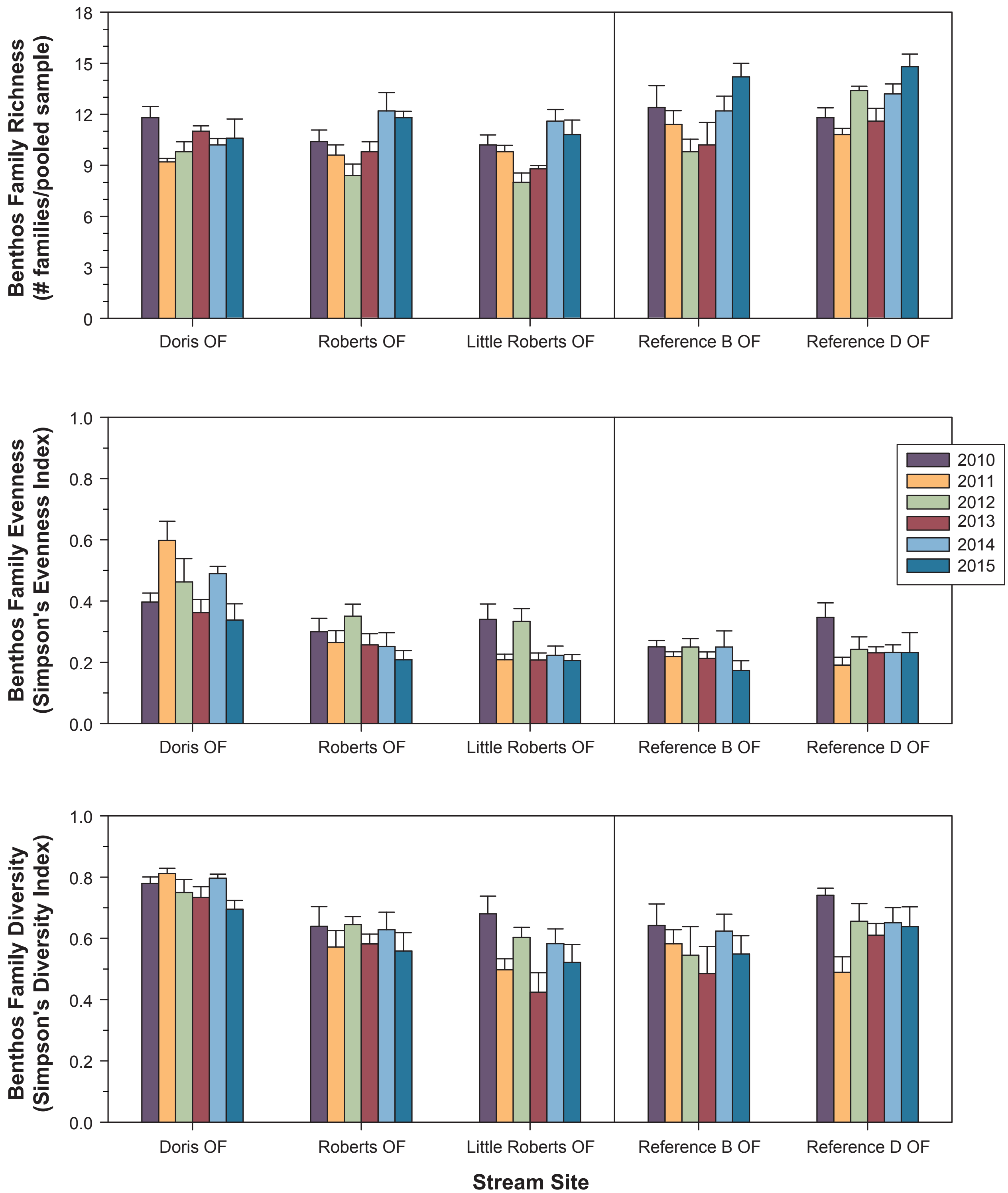
The Bray-Curtis Index is a measure of the percentage of difference between an exposure site benthos community composition and the median reference benthos community composition. The Bray-Curtis Index for Little Roberts Outflow in 2015 was within the range of previous years, and there was no evidence of non-parallelism in trends between this exposure stream and the reference streams (Figure 3.6-3; $p = 0.25$). In Doris Outflow, there appears to be a decreasing trend in the Bray-Curtis Index from 2010 to 2015, with the lowest values occurring in 2015 (Figure 3.6-3), suggesting that the benthic assemblage in Doris Outflow is becoming increasingly similar to the reference communities. There is evidence of non-parallelism in the Bray-Curtis Index between Doris Outflow and the reference streams ($p = 0.032$); however, increasing similarity to the reference communities is not a concern.

3.6.2 Lake Benthos

At Doris Lake South, 2010 data were collected from a shallow site, whereas 2011 to 2015 data were collected from a deep site in the southern section of Doris Lake. Therefore, 2010 data are excluded from the analyses.

Figure 3.6-2

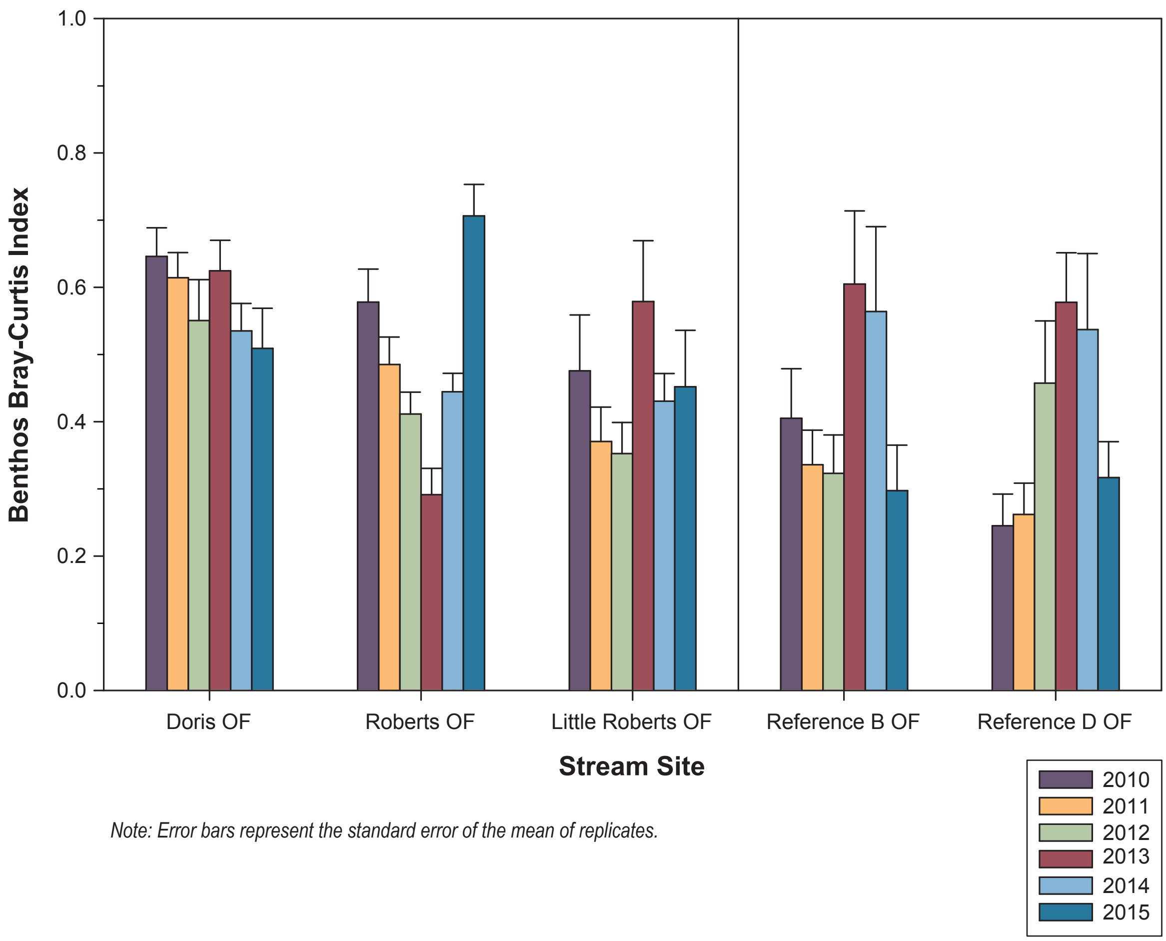
Benthos Richness, Eveness, and Diversity in AEMP Stream Sites, Doris North Project, 2010 to 2015



Note: Error bars represent the standard error of the mean of replicates.

Figure 3.6-3

Benthos Bray-Curtis Index for AEMP Stream Sites, Doris North Project, 2010 to 2015



Note: Error bars represent the standard error of the mean of replicates.

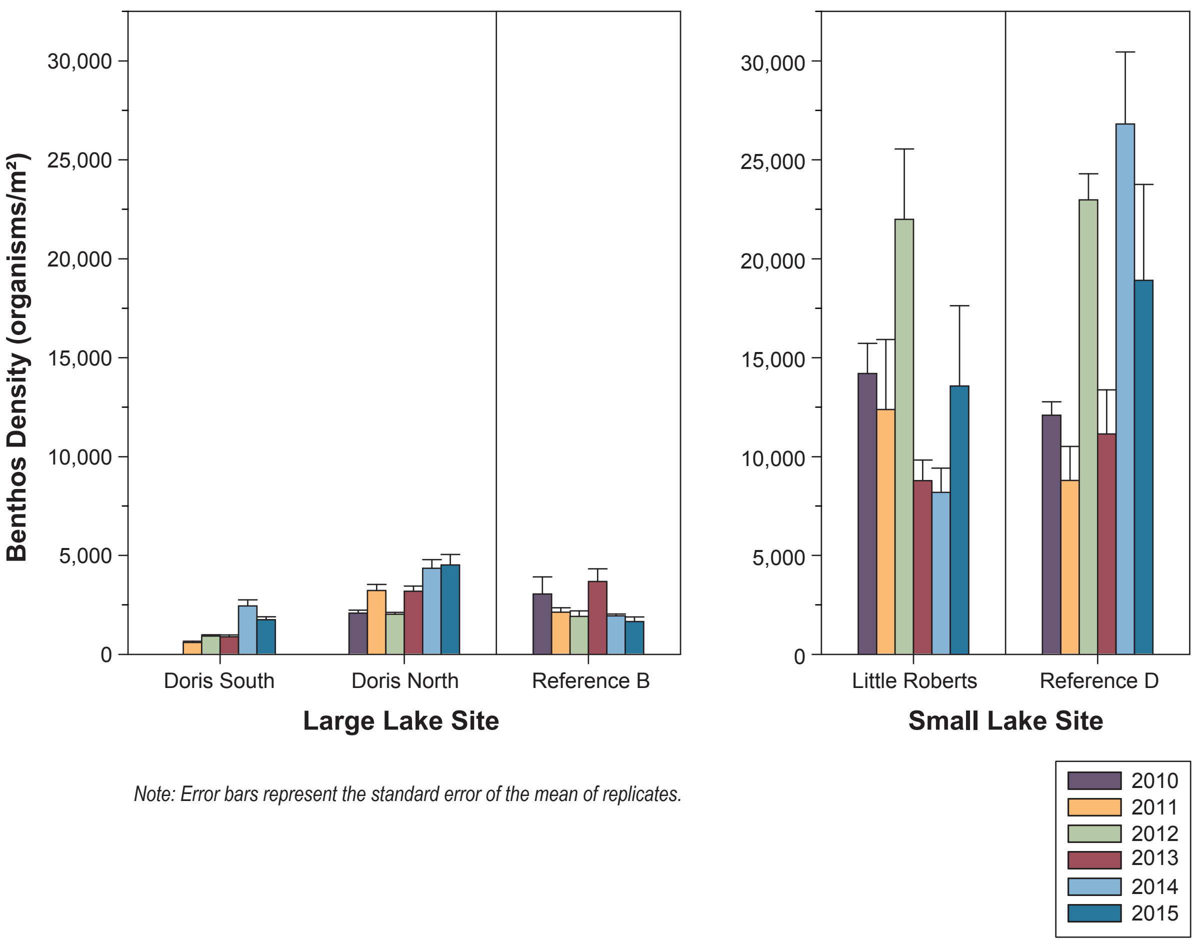
3.6.2.1 Density

Benthic invertebrate density was consistently higher at the small lake sites (Little Roberts Lake and Reference Lake D) than at the large lake sites (Doris Lake South, Doris Lake North, and Reference Lake B) between 2010 and 2015 (Figure 3.6-4). There was evidence of non-parallelism in density trends over time between all exposure and reference lakes ($p < 0.0001$ for both Doris Lake South and Doris Lake North, $p = 0.0034$ for Little Roberts Lake). 2015 densities at Doris Lake South and Doris Lake North were among the highest from 2010 to 2015, whereas 2015 densities in Reference B Lake were the lowest over the six years of benthos monitoring (Figure 3.6-4). There was no evidence of an adverse effect (i.e., a decrease in density) of 2015 Project activities on benthos density in the Doris Lake sites. Benthos density was highly inter-annually variable in both Little Roberts Lake and Reference Lake D, but benthos densities in both of these small lakes varied over a similar range between 2010 and 2015 (Figure 3.6-4). In 2015, benthos density in Little Roberts Lake was near the middle of the range of densities observed since 2010. Although the density trend over time in this exposure lake was different from the trend in Reference Lake D ($p = 0.0034$), this was likely due to natural inter-annual variability and there is no reason to suspect any Project-related effect on benthos density in Little Roberts Lake.

3.6.2.2 Community Richness, Evenness, and Diversity

Benthos family richness tended to be higher at the small lakes sites than the large lake sites between 2010 and 2015 (Figure 3.6-5). Family richness was relatively similar over time at each site, although there was some evidence of non-parallelism in trends for Doris Lake South and Little Roberts Lake relative to reference lakes ($p = 0.0028$ for Doris Lake South and $p = 0.0015$ for Little Roberts Lake), but not for Doris Lake North ($p = 0.099$). In Doris Lake South, 2015 family richness was slightly lower than the range of mean family richness between 2011 and 2014, whereas in Little Roberts Lake, family richness in 2015 was slightly higher than in previous years. These trends in family richness were likely due to natural variability rather than Project-related effects.

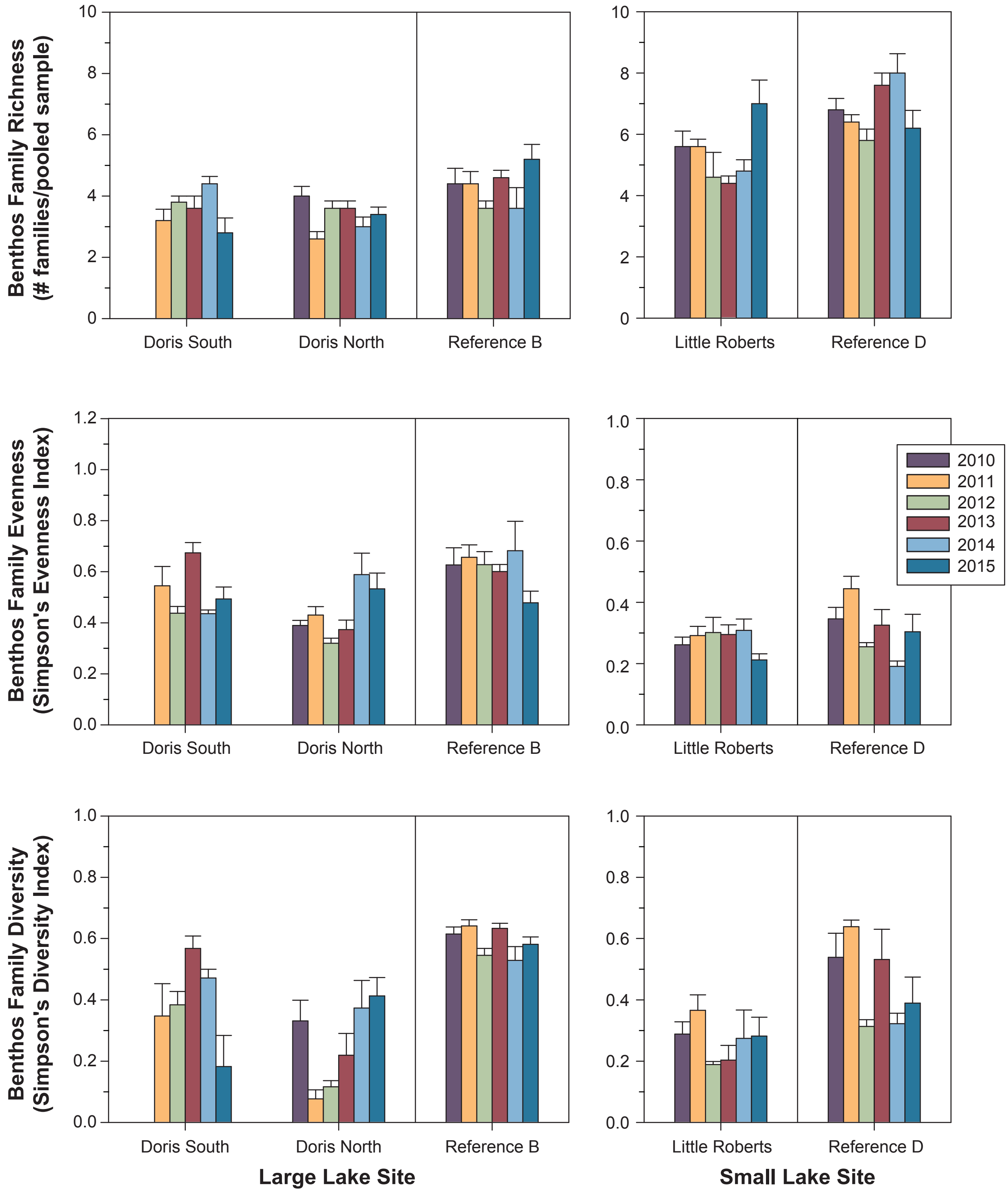
For each exposure and reference lake, the mean 2015 Simpson's Evenness Index calculated for the benthos community was generally similar to the evenness calculated in previous years (Figure 3.6-2). There was evidence of non-parallelism in benthos evenness trends for all three exposure lake sites compared to reference lakes ($p = 0.035$ for Doris Lake South, $p = 0.038$ for Doris Lake North, and $p = 0.0065$ for Little Roberts Lake). However, the graphical analysis indicated that the evenness levels in 2015 were within the range expected for each exposure site given the naturally high inter-annual variability in the data that was evident at the reference sites. There was no apparent adverse effect of Project activities on benthos community evenness in the exposure lake sites in 2015.



Note: Error bars represent the standard error of the mean of replicates.

Figure 3.6-5

Benthos Richness, Eveness, and Diversity in AEMP Lake Sites, Doris North Project, 2010 to 2015



Note: Error bars represent the standard error of the mean of replicates.

In Doris Lake South, the mean Simpson's Diversity Index calculated for 2015 was lower than in previous years, whereas in Doris Lake North, the mean Simpson's Diversity Index for 2015 was higher than in previous years (Figure 3.6-5). For both these lakes sites, there was evidence of non-parallelism with Reference Lake B ($p = 0.011$ for Doris Lake South and $p = 0.0003$ for Doris Lake North). Diversity levels in these Doris Lake sites have been highly variable over time, but a similarly high level of inter-annual variability is evident in Reference Lake D. Therefore, it is likely that this high variability occurs naturally, and can explain the levels of diversity calculated for 2015. In Little Roberts Lake, the mean 2015 diversity index is within the range of previous years, and there was no evidence of non-parallelism compared to Reference Lake D ($p = 0.16$). Thus, there were no apparent effects of 2015 Project activities on benthos diversity in the exposure lakes.

3.6.2.3 Bray-Curtis Index

The Bray-Curtis Index was highly inter-annually variable at all sites (Figure 3.6-6). For the exposure lakes, 2015 Bray-Curtis Index values were within the range of previous years, suggesting that there was no effect of 2015 Project activities on the benthos community composition at these sites. Given the high inter-annual variability, there were no clear trends over time at any exposure or reference site, and no reason to expect that trends would be similar across sites. Indeed, there was evidence of non-parallelism in the Bray-Curtis Index trends for all exposure lakes compared to the reference lakes ($p < 0.0001$ for both Doris Lake South and Doris Lake North, and $p = 0.044$ for Little Roberts Lake), but this is likely attributable to high inter-annual variability rather than to Project effects.

3.6.3 Marine Benthos

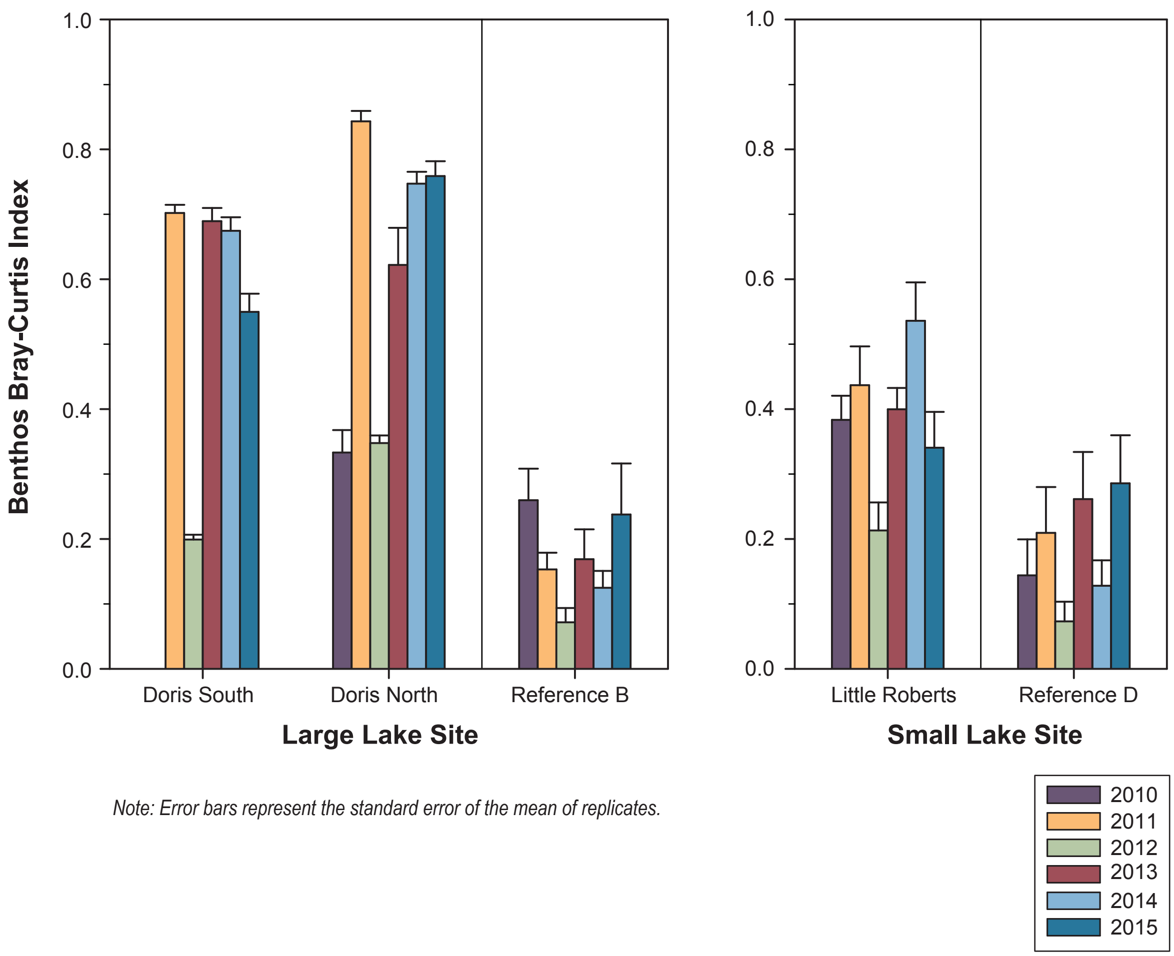
As recommended in the EEM guidance document (Environment Canada 2011), the marine benthos community was analyzed for the whole community (adults and juveniles) as well as for the adult community subset because juvenile benthos can respond differently to environmental disturbances than adult benthos.

3.6.3.1 Density

Between 2011 and 2015, mean whole community as well as mean adult benthos densities were similar between marine sites RBW and REF-Marine 1, but comparatively low at site RBE (Figure 3.6-7). In both the whole community and the adult subset, there was evidence of non-parallelism in the 2010 to 2015 benthos density trends between RBW and REF-Marine 1 (both $p < 0.0001$). For RBW, the observed non-parallelism in trends was largely driven by the relatively high densities observed in 2010 compared to later years at RBW and the correspondingly low 2010 density at the reference site compared to later years, coupled with an increasing trend at the reference site which was not observed at RBW. Benthos density (whole community and adult subset) remained relatively constant between 2011 and 2015 at RBW, and there was no apparent Project-related effect on benthos density at this site.

Figure 3.6-6

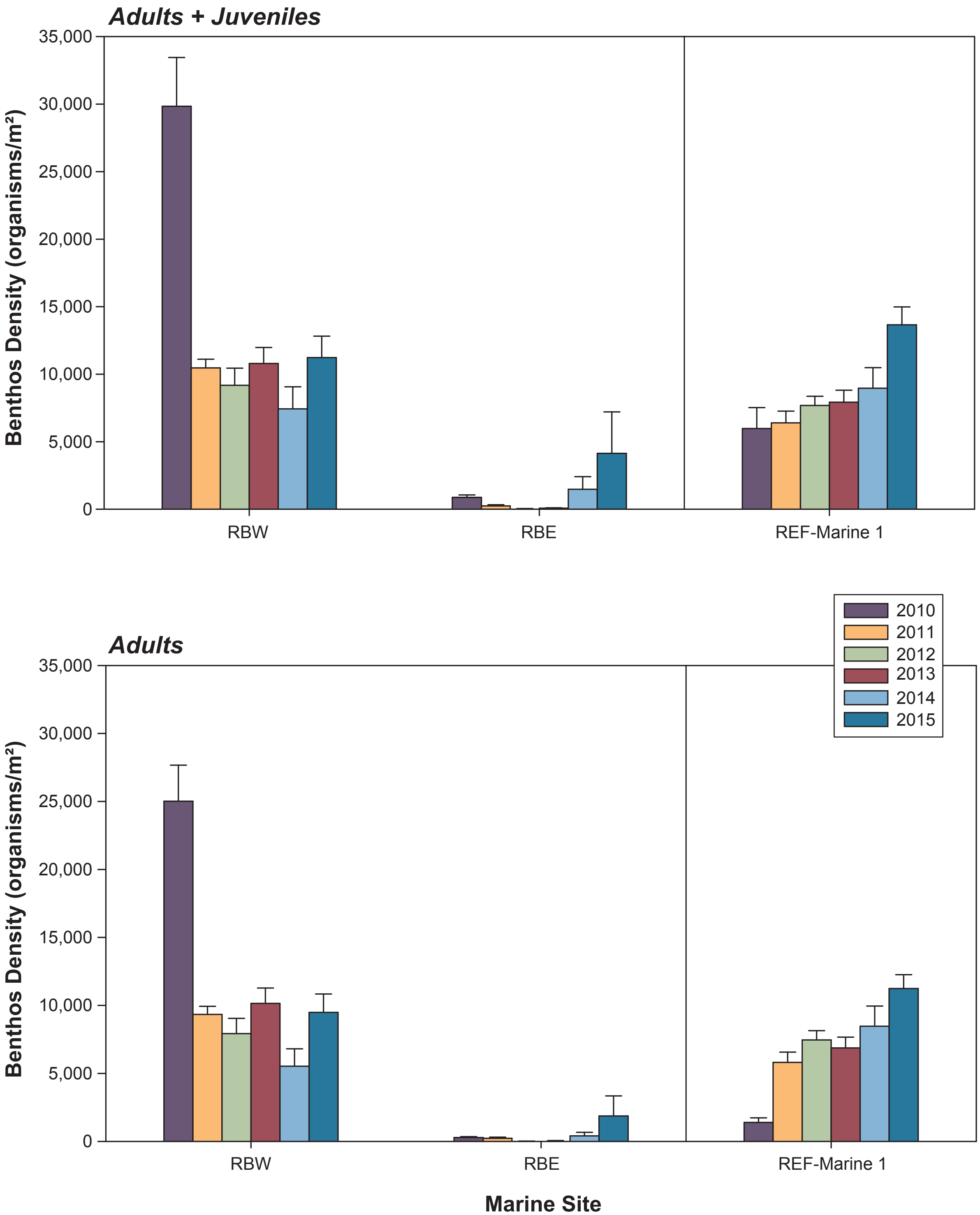
Benthos Bray-Curtis Index for AEMP Lake Sites, Doris North Project, 2010 to 2015



Note: Error bars represent the standard error of the mean of replicates.

Figure 3.6-7

Benthos Density in AEMP Marine Sites, Doris North Project, 2010 to 2015



Note: Error bars represent the standard error of the mean of replicates.

For RBE, adult and whole community benthos densities were higher in 2015 than previous years, and a similar increasing trend was apparent at the marine reference site (Figure 3.6-7). Whole community 2010 to 2015 density trends were parallel between RBE and REF-Marine 1 ($p = 0.60$); however, adult densities showed evidence of non-parallelism over time at RBE compared to REF-Marine 1 ($p < 0.0001$). Despite this statistically significant difference, trends were generally similar between RBE and REF-Marine 1, and it is unlikely that non-parallelism in density compared to the reference site was related to Project activities.

3.6.3.2 Community Richness, Evenness, and Diversity

At site RBW, mean 2015 family richness was within the range observed in previous years for both the whole benthos community and the adult subset (Figures 3.6-8a and 3.6-8b). However, there has been an apparent increasing trend in family richness at the reference site for both the whole community and the adult only subset, which contributed to the finding of non-parallelism between RBW and REF-Marine 1 ($p < 0.0001$ for both the whole community and the adult community). At site RBE, 2015 adult richness was the same as in 2011 and higher than other years, while whole community richness was higher than previous years. Although the 2015 family richness at REF-Marine 1 was also higher than previous years, there was evidence of non-parallelism between RBE and REF-Marine 1 ($p < 0.0001$ for both the whole community and the adult community). Despite the significant difference in trends between the exposure sites and the reference site, there is no indication that 2015 Project activities adversely affected benthos community family richness in the marine exposure sites.

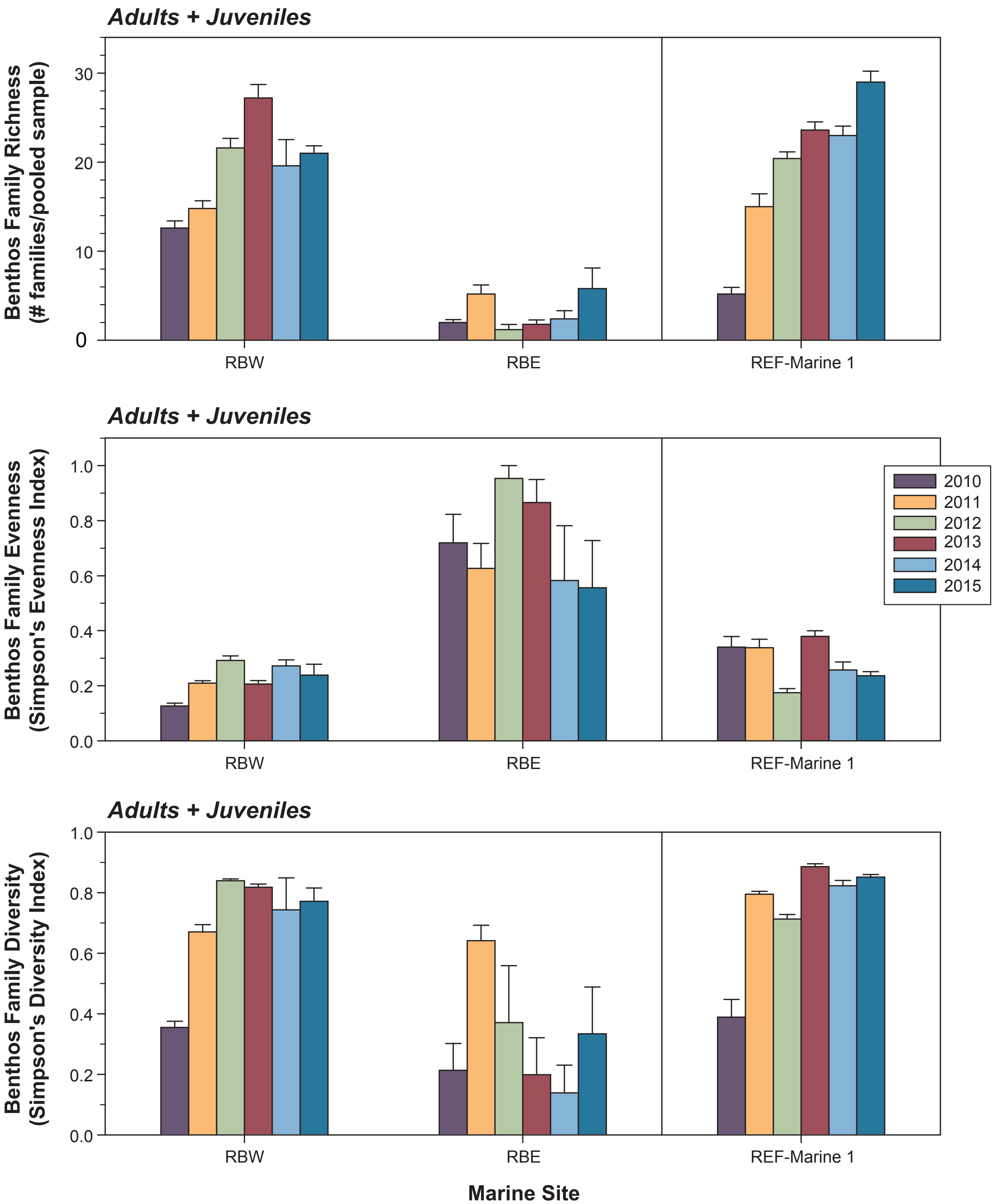
In both the whole community and adult datasets, family evenness and diversity were inter-annually variable at all marine sites (Figures 3.6-8a and 3.6-8b). At site RBE, 2015 family evenness for the whole community dataset was slightly lower than previous years, but there was no evidence of non-parallelism compared to the reference site ($p = 0.12$). 2015 adult evenness as well as whole community and adult diversity at RBE were within the range of previous years, but there was evidence of non-parallelism for these variables compared to the trends for REF-Marine 1 (evenness: $p = 0.036$ for adults; diversity: $p = 0.0020$ for the whole community and $p = 0.0013$ for adults). Similarly, at site RBW, the impact level-by-time analysis showed that there was significant non-parallelism in the 2010 to 2015 evenness and diversity trends between the exposure sites and the reference site for both the whole community and the adult subset (evenness: $p < 0.0001$ for both whole community and for adults; diversity: $p = 0.043$ for the whole community and $p = 0.0002$ for adults). However, the graphical analysis showed that the 2015 evenness and diversity indices for RBW and RBE were well within the range of previous years (except RBE whole community evenness for which there was no evidence of non-parallelism), and there is no evidence that these benthos community indicators were adversely affected by 2015 Project activities.

3.6.3.3 Bray-Curtis Index

The benthos Bray-Curtis Index measured for each marine site in 2015 fell within the range of previous years for both the whole community dataset and the adult subset (Figure 3.6-9). However, there was evidence of significant non-parallelism in the Bray-Curtis Index over time for both the whole community ($p = 0.0006$ for RBW and $p < 0.0001$ for RBE) and the adult datasets ($p = 0.0025$ for RBW and $p < 0.0001$ for RBE). Despite these differences compared to the reference site, the relative consistency in the Bray-Curtis Index over time within each marine exposure site suggests that there were no Project-related effects on the benthos Bray-Curtis Index in the marine exposure sites.

Figure 3.6-8a

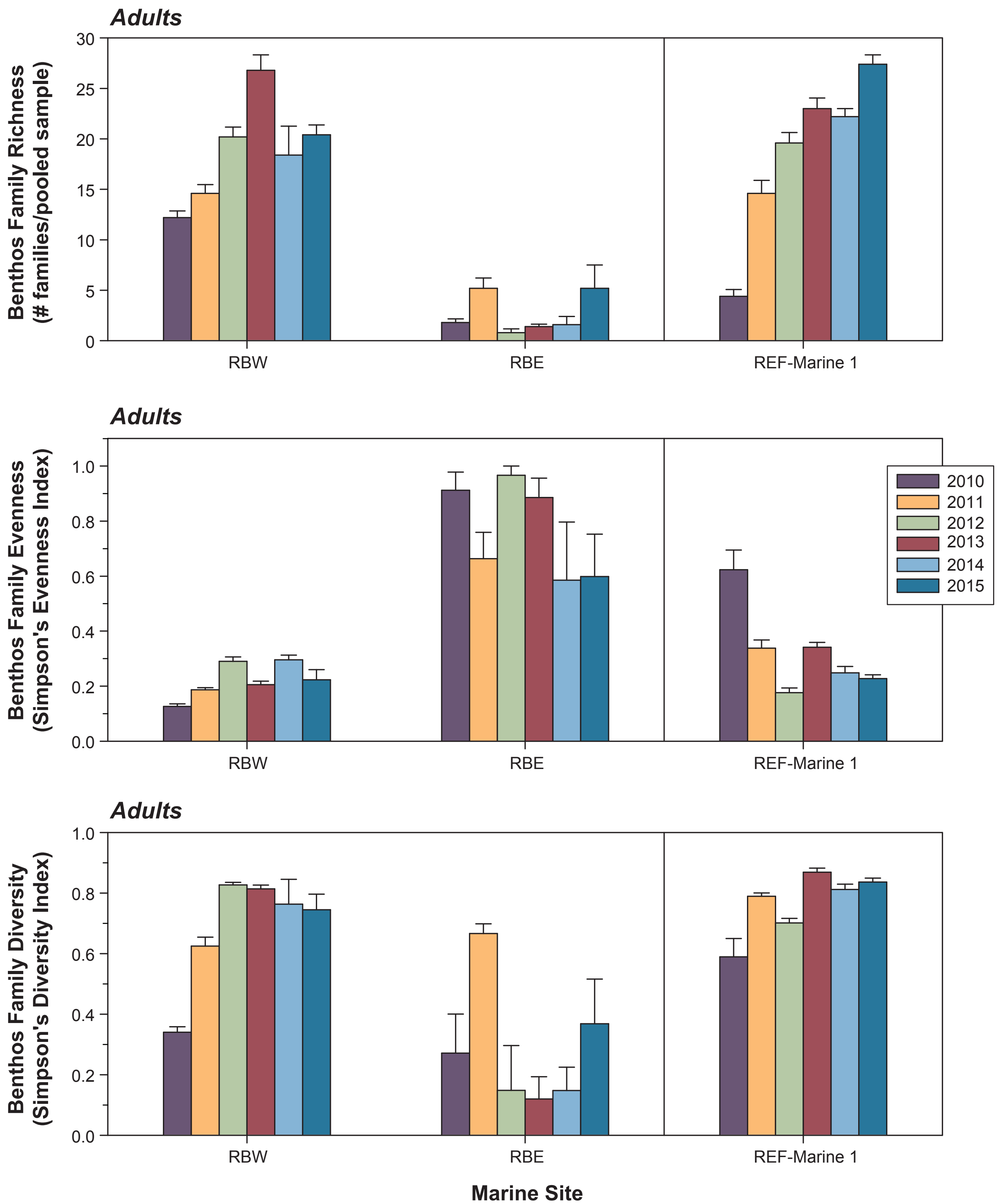
Benthos Richness, Eveness, and Diversity in AEMP Marine Sites, Doris North Project, 2010 to 2015



Note: Error bars represent the standard error of the mean of replicates.

Figure 3.6-8b

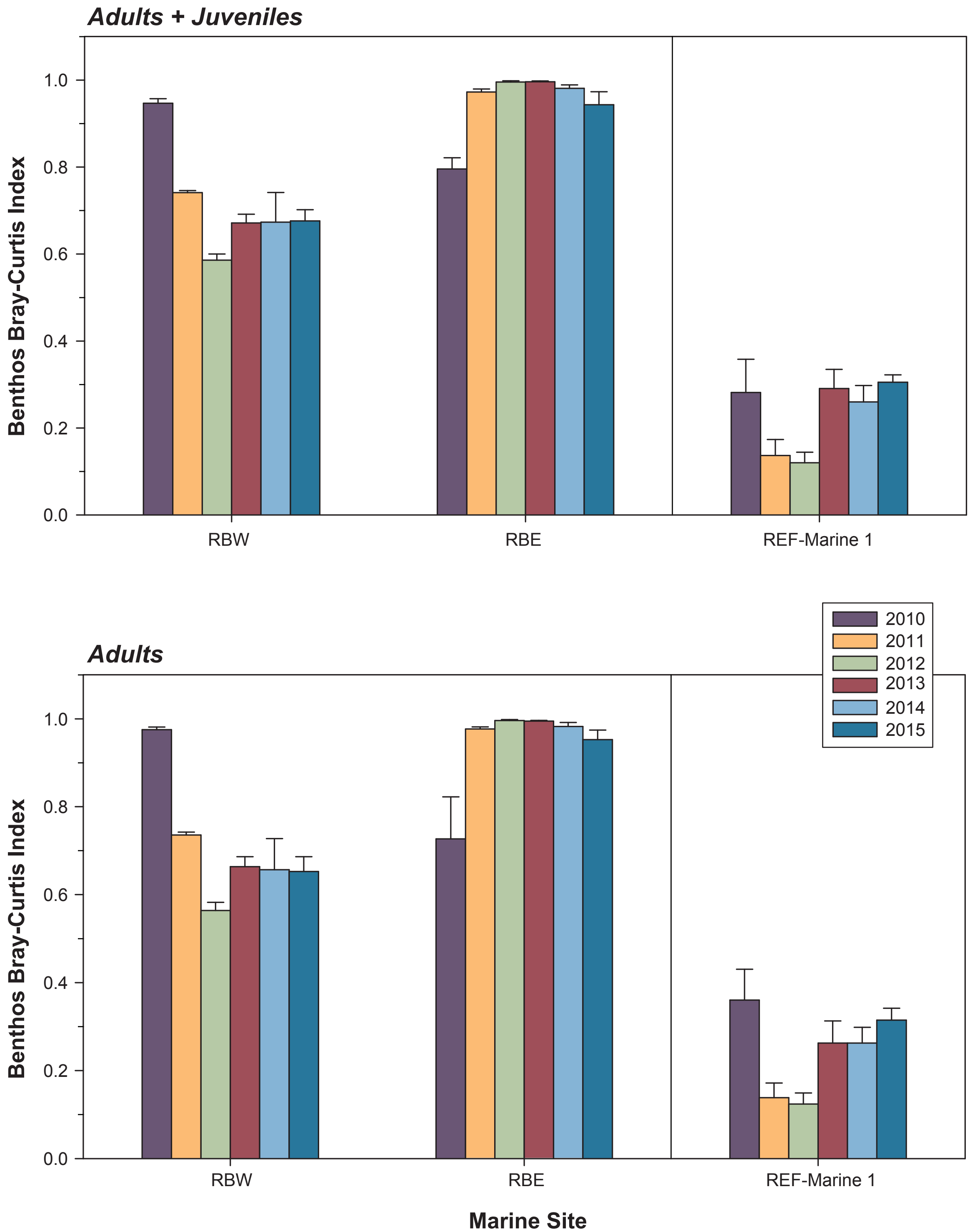
Benthos Richness, Eveness, and Diversity in AEMP Marine Sites, Doris North Project, 2010 to 2015



Note: Error bars represent the standard error of the mean of replicates.

Figure 3.6-9

Benthos Bray-Curtis Index for AEMP Marine Sites, Doris North Project, 2010 to 2015



Note: Error bars represent the standard error of the mean of replicates.

4. SUMMARY OF EFFECTS ANALYSIS

The effects analysis employed graphical and statistical methods to identify potential effects to the aquatic environment that may have resulted from Project activities in 2015. When historical information was available, before (baseline, 1995-2009 or 2010) and after (evaluation year, 2015) data for specific variables were first compared at each of the exposure sites to determine whether there was a discernible change in evaluated variables in 2015 compared to baseline years. If there was a change, before-after trends in the exposure sites were compared to those at the reference sites (BACI design) to determine if parallel changes occurred (no effect) or if there was a differential change between the exposure and reference waterbodies (potential effect). Graphical analysis was used to supplement statistical results and to aid in the interpretation of temporal trends. Professional judgment was always used for the evaluation of effects to determine whether effects resulted from natural processes or Project activities.

4.1 STREAMS

A summary of the 2015 effects analysis for the AEMP exposure streams is presented in Table 4.1-1. There was sufficient historical information to evaluate potential Project-related effects on water and sediment quality, periphyton biomass, and the benthic invertebrate community. Overall, there were no apparent Project-related effects on any of the evaluated variables in exposure streams. Data for Roberts Outflow are shown in the report figures and in Appendices A and B, but this stream is not discussed here. Roberts Outflow is not expected to be affected by the Project but rather serves to characterize any influence of a closed silver mine and past neighbouring exploration activity (North Arrow Minerals Inc.) on Roberts Outflow and potentially downstream, and to be able to differentiate this from potential effects of TIA discharge upstream.

The water quality effects analysis found that mean 2015 pH levels and concentrations of evaluated nutrients and metals in exposure streams were all below CCME guidelines, except total aluminum. However, the total aluminum guideline was frequently exceeded in all exposure streams during baseline years, suggesting that the exposure streams contain naturally high concentrations of aluminum. Based on the 18 water quality variables that were evaluated, there were no apparent adverse changes to the water quality of exposure streams as a result of 2015 Project activities.

Mean 2015 sediment quality concentrations in AEMP exposure streams were below CCME ISQGs and PELs, except chromium in the sediments of Doris Outflow, which was slightly higher than the ISQG. At Doris and Little Roberts outflows, there were some differences in the particle size composition of sediment samples collected in 2015 compared to the particle size composition of baseline samples. Variation in sediment particle size composition was likely unrelated to 2015 Project activities, and probably reflected natural spatial heterogeneity in stream sediments. At Little Roberts Outflow, sediments in 2015 contained significantly lower concentrations of TOC, copper, lead, and mercury than did baseline sediments. These decreases were likely attributable to the significant decrease in the proportion of fine sediments in 2015 samples compared to baseline samples, since fine sediments tend to be associated with higher concentrations of TOC and metals than coarse sediments. Decreases in sediment metal concentrations are not of concern. Therefore, there were no apparent adverse effects of 2015 Project activities on the sediment quality of exposure streams.

There was no indication that 2015 Project activities affected periphyton biomass in the exposure streams.

There was no evidence of Project-related effects on benthos density, richness, evenness or diversity in exposure streams despite significant evidence of non-parallelism in trends in benthos family evenness and the Bray-Curtis Index between Doris Outflow and the reference streams, and total density between Little Roberts Outflow and the reference streams. Benthos community descriptors tended to be highly variable over time in both the exposure and reference streams, and the 2015 results were generally similar to previous years or within the range expected given these high levels of natural variability. The non-parallelism in trends between the exposure and reference sites was likely a result of the naturally high variability in the data, and no adverse effects of Project activities on stream benthos were found.

4.2 LAKES

Table 4.2-1 presents the summary of the 2015 effects analysis for the AEMP exposure lakes. There was sufficient historical information to evaluate potential Project-related effects on under-ice dissolved oxygen concentrations, Secchi depth, water and sediment quality, phytoplankton biomass, and the benthic invertebrate community. Overall, there were no apparent Project-related effects on any of the evaluated variables in the AEMP exposure lakes.

There was no evidence of an effect of 2015 Project activities on either under-ice dissolved oxygen concentrations or Secchi depths in the exposure lakes.

The water quality effects analysis found that mean 2015 pH levels and concentrations of evaluated nutrients and metals in exposure lakes were all below CCME guidelines, except total copper which was slightly above the CCME guideline in Little Roberts Lake. However, the baseline mean total copper concentration at Little Roberts Lake was also above this CCME guideline, suggesting that copper concentrations are naturally elevated in this lake. Based on the 18 water quality variables that were evaluated, there were no apparent adverse changes to the water quality of exposure streams as a result of 2015 Project activities. Although pH increased significantly at Little Roberts Lake and hardness increased significantly at Doris Lake South in 2015, similar increases in pH and hardness occurred at Reference Lake B in 2015. This suggests that slight changes in pH and hardness can occur naturally and are not necessarily related to Project activities. There was also a slight (7%) increase in the total molybdenum concentration in Little Roberts Lake between baseline years and 2015. Although this increase in molybdenum was statistically significant, it is not considered environmentally or biologically important, as the increase was slight and 2015 concentrations remained well below the CCME guideline concentration. Therefore, there was no evidence of adverse effects of Project activities on stream water quality.

Table 4.1-1. Summary of Evaluation of Effects, AEMP Streams, Doris North Project, 2015

Variable	Method of Evaluation	Within Waterbody Before-After Difference (BA analysis)[a]				Before-After Trend Relative to Reference Sites (BACI analysis)[a]		Conclusion of Effect[b, c]	
		Doris OF	Little Roberts OF	Reference B OF	Reference D OF	Doris OF	Little Roberts OF	Doris OF	Little Roberts OF
Water Quality									
pH	GA, BA	No difference	No difference	No difference	-	☐	☐	No effect	No effect
Alkalinity, Total	GA, BA	No difference	No difference	No difference	-	☐	☐	No effect	No effect
Hardness	GA, BA	No difference	No difference	No difference	-	☐	☐	No effect	No effect
Total Suspended Solids	GA, BA	No difference	No difference	-	-	☐	☐	No effect	No effect
Ammonia (as N)	GA, BA	No difference	No difference	-	-	☐	☐	No effect	No effect
Nitrate (as N)	GA, BA	-	-	No difference	-	-	-	No effect	No effect
Cyanide, Total	GA	-	-	-		-	-	No effect	No effect
Radium-226	GA	-	-	-	-	-	-	No effect	No effect
Aluminum, Total	GA, BA	No difference	No difference	No difference	-	☐	☐	No effect	No effect
Arsenic , Total	GA, BA	No difference	No difference	No difference	-	☐	☐	No effect	No effect
Cadmium, Total	GA, BA	-	No difference	**-**	-	-	☐	No effect	No effect
Copper, Total	GA, BA	No difference	**Decrease**	No difference	-	☐	Parallel	No effect	No effect
Iron , Total	GA, BA	No difference	No difference	No difference	-	☐	☐	No effect	No effect
Lead, Total	GA, BA	No difference	No difference	-	-	☐	☐	No effect	No effect
Mercury, Total	GA, BA	-	No difference	**Decrease**	-	-	☐	No effect	No effect
Molybdenum, Total	GA, BA	No difference	No difference	-	-	☐	☐	No effect	No effect
Nickel, Total	GA, BA	No difference	No difference	No difference	-	☐	☐	No effect	No effect
Zinc, Total	GA, BA	No difference	No difference	-	-	☐	☐	No effect	No effect
Sediment Quality									
% Gravel (>2 mm)	GA, BA, BACI	**Decrease**	**Increase**	No difference	-	**Non-parallel**	Parallel	No effect[d]	No effect
% Sand (2.0 mm - 0.063 mm)	GA, BA	No difference	No difference	No difference	-	☐	☐	No effect	No effect
% Silt (0.063 mm - 4 µm)	GA, BA, BACI	No difference	**Decrease**	No difference	-	☐	**Non-parallel**	No effect	No effect[d]
% Clay (<4 µm)	GA, BA, BACI	No difference	**Decrease**	No difference	-	☐	**Non-parallel**	No effect	No effect[d]
Total Organic Carbon	GA, BA, BACI	No difference	**Decrease**	No difference	-	☐	**Non-parallel**	No effect	No effect[d]
Arsenic	GA, BA	No difference	No difference	**Increase**	-	☐	☐	No effect	No effect
Cadmium	GA, BA	No difference	-	-	-	-	-	No effect	No effect
Chromium	GA, BA	No difference	No difference	No difference	-	☐	☐	No effect	No effect
Copper	GA, BA, BACI	No difference	**Decrease**	No difference	-	☐	**Non-parallel**	No effect	No effect
Lead	GA, BA, BACI	No difference	**Decrease**	No difference	-	☐	**Non-parallel**	No effect	No effect
Mercury	GA, BA, BACI	No difference	**Decrease**	-	-	-	**Non-parallel**	No effect	No effect
Zinc	GA, BA	No difference	No difference	No difference	-	☐	☐	No effect	No effect
Periphyton									
Biomass	GA, BA, BACI	No difference		-	-	☐	Parallel	No effect	No effect
						2010 to 2015 Trend Relative to Reference Sites (Impact Level-by-Time analysis)[a]			
Benthic Invertebrates									
Total Density	GA, ILBT	-	**-**	-	-	Parallel	**Non-parallel**	No effect	No effect[d]
Family Richness	GA, ILBT	-	**-**	-	-	**Marginal**	Parallel	No effect[d]	No effect
Simpson's Evenness Index	GA, ILBT	-	**-**	-	-	**Non-parallel**	Parallel	No effect[d]	No effect
Simpson's Diversity Index	GA, ILBT	-	**-**	-	-	Parallel	Parallel	No effect	No effect
Bray-Curtis Index	GA, ILBT	-	**-**	-	-	**Non-parallel**	Parallel	No effect[d]	No effect

Notes:

GA - Graphical analysis; BA - Before-After analysis; BACI - Before-After-Control-Impact analysis; ILBT - Impact Level-by-Time analysis

[a] *Statistically significant difference at p<0.05, marginal difference at p = 0.05.*

[b] *Conclusion of effect is based on graphical analysis, statistical analyses, and professional judgment.*

[c] *For water pH, water alkalinity, water hardness, sediment total organic carbon, sediment particle size, periphyton biomass, and benthos community descriptors, a change in any direction is considered to be an effect. For winter dissolved oxygen concentrations, only a decrease is considered to be an effect. For all remaining variables, only an increase is considered to be an effect.*

[d] *Although there was a significant difference, this change was not attributed to Project activities.*

For both the BACI and the ILBT analyses, a differential increase or decrease in exposure site variables over time relative to the reference sites (i.e., a non-parallel effect) may indicate a Project-related effect.

Dash (-) indicates that statistical analysis was not possible because of missing data (i.e., no historical data available), the high proportion of nondetectable concentrations, too few degrees of freedom for the analysis, or the lack of variation in a variable over time (having no measure of variation causes F-statistic to be infinite).

Square (☐) indicates that BACI results are not reported because the within waterbody before-after comparison shows that there was no significant difference between baseline and 2015 means.

Table 4.2-1. Summary of Evaluation of Effects, AEMP Lakes, Doris North Project, 2015

Variable	Method of Evaluation	Within Waterbody Before-After Difference (BA analysis)[a]					Before-After Trend Relative to Reference Site (BACI analysis)[a]			Conclusion of Effect[b, c]		
		Doris South	Doris North	Reference B	Little Roberts	Reference D	Doris South	Doris North	Little Roberts	Doris South	Doris North	Little Roberts
Physical Limnology												
Winter Dissolved Oxygen	GA	-	-	-	-	-	-	-	-	No effect	No effect	No effect
Secchi Depth	GA, BA	No difference	No difference	-	No difference	-	□	□	-	No effect	No effect	No effect
Water Quality												
pH	GA, BA	No difference	No difference	**Increase**	**Increase**	-	□	□	-	No effect	No effect	No effect[d]
Alkalinity, Total	GA, BA	No difference	No difference	**Increase**	No difference	-	□	□	-	No effect	No effect	No effect
Hardness	GA, BA, BACI	**Increase**	No difference	No difference	No difference	-	Parallel	□	-	No effect	No effect	No effect
Total Suspended Solids	GA, BA	No difference	No difference	-	No difference	-	□	□	-	No effect	No effect	No effect
Ammonia (as N)	GA, BA	No difference	No difference	**Decrease**	No difference	-	□	□	-	No effect	No effect	No effect
Nitrate (as N)	GA, BA	No difference	No difference	-	No difference	-	□	□	-	No effect	No effect	No effect
Cyanide, Total	GA	-	-	-	-	-	-	-	-	No effect	No effect	No effect
Radium-226	GA	-	-	-	-	-	-	-	-	No effect	No effect	No effect
Aluminum, Total	GA, BA	No difference	No difference	No difference	No difference	-	□	□	-	No effect	No effect	No effect
Arsenic , Total	GA, BA, BACI	No difference	**Decrease**	No difference	No difference	-	□	**Non-parallel**	-	No effect	No effect	No effect
Cadmium, Total	GA	-	-	-	-	-	□	□	-	No effect	No effect	No effect
Copper, Total	GA, BA	No difference	No difference	No difference	No difference	-	□	□	-	No effect	No effect	No effect
Iron , Total	GA, BA	No difference	No difference	No difference	No difference	-	□	□	-	No effect	No effect	No effect
Lead, Total	GA, BA	No difference	No difference	No difference	No difference	-	□	□	-	No effect	No effect	No effect
Mercury, Total	GA, BA	-	No difference	**Decrease**	No difference	-	□	□	-	No effect	No effect	No effect
Molybdenum, Total	GA, BA, BACI	No difference	No difference	-	**Increase**	-	□	□	-	No effect	No effect	No effect[d]
Nickel, Total	GA, BA	No difference	No difference	No difference	No difference	-	□	□	-	No effect	No effect	No effect
Zinc, Total	GA	No difference	No difference	-	No difference	-	□	□	-	No effect	No effect	No effect
Sediment Quality												
% Gravel (>2 mm)	GA	-	-	-	-	-	-	-	-	No effect	No effect	No effect
% Sand (2.0 mm - 0.063 mm)	GA, BA	**Increase**	**Increase**	-	**Increase**	-	-	-	-	No effect[d]	No effect[d]	No effect[d]
% Silt (0.063 mm - 4 µm)	GA, BA	No difference	No difference	-	No difference	-	-	-	-	No effect	No effect	No effect
% Clay (<4 µm)	GA, BA	No difference	No difference	-	**Decrease**	-	-	-	-	No effect	No effect	No effect[d]
Total Organic Carbon	GA, BA	No difference	**Increase**	-	No difference	-	-	-	-	No effect	No effect[d]	No effect
Arsenic	GA, BA	No difference	No difference	-	No difference	-	-	-	-	No effect	No effect	No effect
Cadmium	GA, BA	No difference	**Decrease**	-	No difference	-	-	-	-	No effect	No effect	No effect
Chromium	GA, BA	No difference	No difference	-	No difference	-	-	-	-	No effect	No effect	No effect
Copper	GA, BA	**Decrease**	**Decrease**	-	No difference	-	-	-	-	No effect	No effect	No effect
Lead	GA, BA	**Decrease**	**Decrease**	-	**Decrease**	-	-	-	-	No effect	No effect	No effect
Mercury	GA, BA	No difference	No difference	-	No difference	-	-	-	-	No effect	No effect	No effect
Zinc	GA, BA	No difference	**Decrease**	-	**Decrease**	-	-	-	-	No effect	No effect	No effect
Phytoplankton												
Biomass	GA, BA	No difference	No difference	-	No difference	-	□	□	-	No effect	No effect	No effect
							2010 to 2015 Trend Relative to Reference Sites (Impact Level-by-Time analysis)[a]					
Benthic Invertebrates												
Total Density	GA, ILBT	-	-	-	-	-	**Non-parallel**	**Non-parallel**	**Non-parallel**	No effect[d]	No effect[d]	No effect[d]
Family Richness	GA, ILBT	-	-	-	-	-	**Non-parallel**	Parallel	**Non-parallel**	No effect[d]	No effect	No effect[d]
Simpson's Evenness Index	GA, ILBT	-	-	-	-	-	**Non-parallel**	**Non-parallel**	**Non-parallel**	No effect[d]	No effect[d]	No effect[d]
Simpson's Diversity Index	GA, ILBT	-	-	-	-	-	**Non-parallel**	**Non-parallel**	Parallel	No effect[d]	No effect[d]	No effect
Bray-Curtis Index	GA, ILBT	-	-	-	-	-	**Non-parallel**	**Non-parallel**	**Non-parallel**	No effect[d]	No effect[d]	No effect[d]

Notes:

GA - Graphical analysis; BA - Before-After analysis; BACI - Before-After-Control-Impact analysis; ILBT - Impact Level-by-Time analysis

[a] *Statistically significant difference at $p<0.05$.*

[b] *Conclusion of effect is based on graphical analysis, statistical analyses, and professional judgment.*

[c] *For water pH, water alkalinity, water hardness, sediment total organic carbon, sediment particle size, periphyton biomass, and benthos community descriptors, a change in any direction is considered to be an effect. For winter dissolved oxygen concentrations, only a decrease is considered to be an effect. For all remaining variables, only an increase is considered to be an effect.*

[d] *Although there is a significant difference, this change is not attributed to Project activities or is not considered to be environmentally important.*

For both the BACI and the ILBT analyses, a differential increase or decrease in exposure site variables over time relative to the reference sites (i.e., a non-parallel effect) may indicate a Project-related effect.

Dash (-) indicates that statistical analysis was not possible because of missing data (i.e., no historical data available), the high proportion of nondetectable concentrations, too few degrees of freedom for the analysis, or the lack of variation in a variable over time (having no measure of variation causes F-statistic to be infinite).

Square (□) indicates that BACI results are not reported because the within waterbody before-after comparison shows that there was no significant difference between baseline and 2015 means.

Mean 2015 concentrations of sediment quality variables were generally below CCME ISQGs, except arsenic in Doris Lake South and Doris Lake North, chromium at all exposure and reference sites, and copper at Doris Lake North. The arsenic PEL was also slightly exceeded at Doris Lake South. At all three lake exposure sites, there were some differences in the particle size composition in the sediment samples collected in 2015 compared to the particle size composition of baseline samples. Variation in sediment particle size composition was likely unrelated to 2015 Project activities, and probably reflected natural spatial heterogeneity in lake sediments. There was evidence of a slight increase in the TOC content in Doris Lake North sediments in 2015; however, the increase was quite small (8.2%) and was likely related to natural variability rather than Project effects. Concentrations of several metals decreased in the sediments of exposure lakes in 2015 including cadmium in Doris Lake North, copper in Doris Lake South and North, lead in all three exposure sites, and zinc in Doris Lake North and Little Roberts Lake. Decreases in the concentrations of metals in sediments are not a cause for concern, so there were no apparent adverse effects of 2015 Project activities on sediment quality in exposure lake sites.

There was no indication of a Project-related effect on 2015 phytoplankton biomass in the exposure lakes.

In lake exposure sites, there was non-parallelism in 2010 to 2015 trends for nearly all benthos community descriptors when compared to the reference sites. There was evidence of significant non-parallelism for benthos density, the Simpson's Evenness Index, and the Bray Curtis Index for all exposure lakes relative to reference lakes. Benthos family richness trends were also non-parallel for Doris Lake South and Little Roberts Lake relative to the reference lakes, and Simpson's Diversity Index trends were non-parallel for Doris Lake North and South compared to the reference lakes. Benthos community descriptors tended to be highly variable over time in both the exposure and reference lakes, and the 2015 results were generally similar to previous years or within the range expected given these high levels of natural variability. The non-parallelism in trends between the exposure and reference sites was likely a result of the naturally high variability in the data, and no adverse effects of Project activities on lake benthos were found.

4.3 MARINE

Table 4.3-1 presents the summary of the 2015 effects analysis for the AEMP marine exposure sites. There was sufficient historical information to evaluate potential Project-related effects on under-ice dissolved oxygen concentrations, water and sediment quality, phytoplankton biomass, and the benthic invertebrate community. Overall, there were no apparent Project-related effects on any of the evaluated variables in the marine exposure sites.

There was no evidence of an effect of 2015 Project activities on under-ice dissolved oxygen concentrations at the marine exposure sites in Roberts Bay, and 2015 concentrations remained above the CCME interim guideline for the minimum concentration of dissolved oxygen in marine and estuarine waters (8.0 mg/L).

The water quality effects analysis found that mean 2015 pH levels and concentrations of evaluated nutrients and metals in marine exposure sites were all below CCME guidelines. Based on the 18 water quality variables that were evaluated, there were no apparent adverse changes to the water quality of marine exposure sites that can be attributed to the Project.

Mean 2015 concentrations of sediment quality variables were generally below CCME ISQGs, except for copper at site RBW near the jetty. All sediment metal concentrations remained well below CCME PEL guidelines. Although there was no suitable baseline data to compare against 2015 sediment quality data from site RBE, concentrations of sediment quality variables were consistently lowest at this site, likely due to the greater levels of sand compared to the finer sediments at sites RBW and REF-Marine 1. At site RBW, there were significant increases in TOC and arsenic concentrations in sediments, but these increases were found to be parallel to the changes at the reference site, suggesting that the observed changes were unrelated to the Project. There were also increases in several metals in RBW sediments in 2015 that were not parallel to reference site changes, including chromium, copper, lead, and zinc. Concentrations of all these metals except for copper were higher in REF-Marine 1 sediments than RBW sediments in 2015, suggesting that concentrations of these metals in RBW sediments remained within levels expected for the region, and that Project activities did not adversely affect the sediment quality at RBW. 2015 sediment copper concentrations at RBW were within range of concentrations measured at that site since 2012, and were just slightly higher than the upper limit of the range of copper concentrations measured in reference site sediments between 2009 and 2015. Thus, it is unlikely that 2015 Project activities are responsible for the increased concentrations of copper measured in the sediments of RBW, and the difference between baseline (2002) and 2015 copper levels at RBW is probably due to natural variability.

There was no indication of a Project-related effect on 2015 phytoplankton biomass at the marine exposure sites.

In the whole benthos community (adults and juveniles) and the adult subset of the community, significant non-parallelisms were detected for all evaluated benthos community descriptors at RBW and RBE relative to the REF-Marine 1, except for whole community benthos density and Simpson's Evenness Index at RBE. Most 2015 benthos community descriptors were within range of previous years, and there was no indication that benthos communities in 2015 at RBW or RBE were adversely affected by Project activities. Non-parallelisms in trends in the benthos communities were likely attributable to high inter-annual variability of all community descriptors at the exposure and reference sites.

Table 4.3-1. Summary of Evaluation of Effects, AEMP Marine Sites, Doris North Project, 2015

		Within Waterbody Before-After Difference (BA analysis)[a]			Before-After Trend Relative to Reference Site (BACI analysis)[a]		Conclusion of Effect[b, c]	
Variable	Method of Evaluation	Roberts Bay West (RBW)	Roberts Bay East (RBE)	Ida Bay (REF-Marine 1)	Roberts Bay West (RBW)	Roberts Bay East (RBE)	Roberts Bay West (RBW)	Roberts Bay East (RBE)
Physical Oceanography								
Winter Dissolved Oxygen	GA	-	-	-	-	-	No effect	No effect
Water Quality								
pH	GA, BA, BACI	**Increase**	No difference	No difference	Parallel	☐	No effect	No effect
Alkalinity, Total	GA, BA	-	No difference	-	-	-	No effect	No effect
Hardness	GA, BA	No difference	No difference	-	-	-	No effect	No effect
Total Suspended Solids	GA, BA	No difference	No difference	No difference	☐	☐	No effect	No effect
Ammonia (as N)	GA, BA	-	No difference	-	-	☐	No effect	No effect
Nitrate (as N)	GA, BA	No difference	No difference	No difference	☐	☐	No effect	No effect
Cyanide, Total	GA	-	-	-	-	-	No effect	No effect
Radium-226	GA	-	-	-	-	-	No effect	No effect
Aluminum, Total	GA, BA	No difference	No difference	No difference	☐	☐	No effect	No effect
Arsenic , Total	GA, BA	No difference	No difference	No difference	☐	☐	No effect	No effect
Cadmium, Total	GA, BA	No difference	No difference	No difference	☐	☐	No effect	No effect
Copper, Total	GA, BA	No difference	No difference	No difference	☐	☐	No effect	No effect
Iron , Total	GA, BA	No difference	No difference	No difference	☐	☐	No effect	No effect
Lead, Total	GA, BA	No difference	No difference	-	☐	☐	No effect	No effect
Mercury, Total	GA, BA	-	No difference	-	-	☐	No effect	No effect
Molybdenum, Total	GA, BA	No difference	No difference	No difference	☐	☐	No effect	No effect
Nickel, Total	GA, BA	No difference	No difference	No difference	☐	☐	No effect	No effect
Zinc, Total	GA, BA	No difference	No difference	No difference	☐	☐	No effect	No effect
Sediment Quality								
% Gravel (>2 mm)	GA, BA	No difference	-	**-**	☐	-	No effect	No effect
% Sand (2.0 mm - 0.063 mm)	GA, BA	**Decrease**	-	No difference	Parallel	-	No effect	No effect
% Silt (0.063 mm - 4 µm)	GA, BA	**Increase**	-	**Increase**	Parallel	-	No effect	No effect
% Clay (<4 µm)	GA, BA	**Decrease**	-	No difference	Parallel	-	No effect	No effect
Total Organic Carbon	GA, BA	**Increase**	-	No difference	Parallel	-	No effect	No effect
Arsenic	GA, BA	**Increase**	-	No difference	Parallel	-	No effect	No effect
Cadmium	GA, BA	-	-	No difference	-	-	No effect	No effect
Chromium	GA, BA	**Increase**	-	**Decrease**	**Non-parallel**	-	No effect[d]	No effect
Copper	GA, BA	**Increase**	-	No difference	**Non-parallel**	-	No effect[d]	No effect
Lead	GA, BA	**Increase**	-	**Decrease**	**Non-parallel**	-	No effect[d]	No effect
Mercury	GA, BA	-	-	No difference	-	-	No effect	No effect
Zinc	GA, BA	**Increase**	-	No difference	**Non-parallel**	-	No effect[d]	No effect

(continued)

Table 4.3-1. Summary of Evaluation of Effects, AEMP Marine Sites, Doris North Project, 2015 (completed)

Variable	Method of Evaluation	Within Waterbody Before-After Difference (BA analysis)[a]			Before-After Trend Relative to Reference Site (BACI analysis)[a]		Conclusion of Effect[b, c]	
		Roberts Bay West (RBW)	Roberts Bay East (RBE)	Ida Bay (REF-Marine 1)	Roberts Bay West (RBW)	Roberts Bay East (RBE)	Roberts Bay West (RBW)	Roberts Bay East (RBE)
Phytoplankton								
Biomass	GA, BACI	-	-	-	Parallel	Parallel	No effect	No effect
					2010 to 2015 Trend Relative to Reference Sites (Impact Level-by-Time analysis)[a]			
Benthic Invertebrates (Adults + Juveniles)								
Total Density	GA, ILBT	-	-	-	**Non-parallel**	Parallel	No effect[d]	No effect
Family Richness	GA, ILBT	-	-	-	**Non-parallel**	**Non-parallel**	No effect[d]	No effect[d]
Simpson's Evenness Index	GA, ILBT	-	-	-	**Non-parallel**	Parallel	No effect[d]	No effect
Simpson's Diversity Index	GA, ILBT	-	-	-	**Non-parallel**	**Non-parallel**	No effect[d]	No effect[d]
Bray-Curtis Index	GA, ILBT	-	-	-	**Non-parallel**	**Non-parallel**	No effect[d]	No effect[d]
Benthic Invertebrates (Adults)								
Total Density	GA, ILBT	-	-	-	**Non-parallel**	**Non-parallel**	No effect[d]	No effect[d]
Family Richness	GA, ILBT	-	-	-	**Non-parallel**	**Non-parallel**	No effect[d]	No effect[d]
Simpson's Evenness Index	GA, ILBT	-	-	-	**Non-parallel**	**Non-parallel**	No effect[d]	No effect[d]
Simpson's Diversity Index	GA, ILBT	-	-	-	**Non-parallel**	**Non-parallel**	No effect[d]	No effect[d]
Bray-Curtis Index	GA, ILBT	-	-	-	**Non-parallel**	**Non-parallel**	No effect[d]	No effect[d]

Notes:

GA - Graphical analysis; BA - Before-After analysis; BACI - Before-After-Control-Impact analysis; ILBT - Impact Level-by-Time analysis

[a] *Statistically significant difference at $p<0.05$.*

[b] *Conclusion of effect is based on graphical analysis, statistical analyses, and professional judgment.*

[c] *For water pH, water alkalinity, water hardness, sediment total organic carbon, sediment particle size, phytoplankton biomass, and benthos community descriptors, a change in any direction is considered to be an For winter dissolved oxygen concentrations, only a decrease is considered to be an effect. For all remaining variables, only an increase is considered to be an effect.*

[d] *Although there was a significant or marginal difference, this change was not attributed to Project activities.*

For both the BACI and the ILBT analyses, a differential increase or decrease in exposure site variables over time relative to the reference sites (i.e., a non-parallel effect) may indicate a Project-related effect.

Dash (-) indicates that statistical analysis was not possible because of missing data (i.e., no historical data available), the high proportion of nondetectable concentrations, too few degrees of freedom for the analysis, or the lack of variation in a variable over time (having no measure of variation causes F-statistic to be infinite).

Square (☐) indicates that BACI results are not reported because the within waterbody before-after comparison shows that there was no significant difference between baseline and 2015 means.

REFERENCES

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

2002. Metal Mining Effluent Regulations, SOR 2002-222

CCME. 2015a. *Canadian sediment quality guidelines for the protection of aquatic life: summary table*. Accessed December 2015. In: Canadian environmental quality guidelines, 1999. Canadian Council of Ministers of the Environment: Winnipeg, MB.

CCME. 2015b. C*anadian water quality guidelines for the protection of aquatic life: summary table.* Accessed December 2015. In: Canadian environmental quality guidelines, 1999. Canadian Council of Ministers of the Environment: Winnipeg, MB.

Cole, G. A. 1983. *Textbook of Limnology. Third ed. Prospect Heights, Illinois: Waveland Press, Inc.*

Eisenhauer, J. G. 2011. *Degrees of Freedom in Statistical Inference. In International Encyclopedia of Statistical Science*. Ed. M. Lovric. 365-67. Berlin, Heidelberg: Springer Berlin Heidelberg.

Environment Canada. 2011. *2011 Metal Mining Environmental Effects Monitoring (EEM) Technical Guidance Document*. Environment Canada: Ottawa, ON.

ERM. 2015. *Doris North Project: 2014 Aquatic Effects Monitoring Program*. Prepared for TMAC Resources Inc. by ERM Consultants Canada Ltd. : Yellowknife, NT.

ERM. 2016. *Memorandum: Doris North Project 2015 Hydrology Compliance Monitoring Program.* Prepared for TMAC Resources Inc. but ERM Consultants Canada Ltd.: Yellowknife, NT.

ERM Rescan. 2014. *Doris North Project: 2013 Aquatic Effects Monitoring Program Report*. Prepared for TMAC Resources Inc. by ERM Rescan: Yellowknife, NT.

Golder Associates Ltd. 2005. *Doris North Project Aquatic Studies 2004*. Prepared for Miramar Hope Bay Ltd. by Golder Associates Ltd. Report No. 04-1373-009:

Golder Associates Ltd. 2006. *Doris North Project Aquatic Studies 2005.* Prepared for Miramar Hope Bay Ltd. by Golder Associates Ltd. Report No. 05-1373-014-F:

Golder Associates Ltd. 2007. *Doris North Project Aquatic Studies 2006*. Prepared for Miramar Hope Bay Ltd. by Golder Associates Ltd. Report No. 06-1373-026:

Golder Associates Ltd. 2008. *Doris North Project Aquatic Studies 2007*. Prepared for Miramar Hope Bay Ltd. by Golder Associates Ltd. Report No. 07-1373-0018D:

Golder Associates Ltd. 2009. *Hope Bay Gold Project 2008 Annual Aquatic Studies Report*. Prepared for Hope Bay Mining Ltd. by Golder Associates Ltd. Report No. 08-1373-0026-1000:

Klohn-Crippen Consultants Ltd. 1995. *Doris Lake Project, Northwest Territories: 1995 Environmental Study*. Prepared for BHP Minerals Canada Ltd. by Klohn-Crippen Consultants Ltd.:

Lakhan, V. C., K. Cabana, and P. D. LaValle. 2003. Relationship between grain size and heavy metals in sediments from beaches along the coast of Guyana. *Journal of Coastal Research*, 19 (3): 600–08.

Parsons, T. R., M. Takahashi, and B. Hargrave. 1984. *Biological Oceanographic Processes.* Oxford, UK: Pergamon Press.

Rescan. 1997. *Environmental Baseline Studies Report 1996*. Prepared for BHP World Minerals by Rescan Environmental Services Ltd.:

Rescan. 1998. *1997 Environmental Data Report*. Prepared for BHP World Minerals by Rescan Environmental Services Ltd.:

Rescan. 1999. *1998 Environmental Data Report*. Prepared for BHP Diamonds Inc. by Rescan Environmental Services Ltd.:

Rescan. 2001. *2000 Supplemental Environmental Baseline Data Report, Hope Bay Belt Project.* Prepared for Hope Bay Joint Venture by Rescan Environmental Services Ltd.: Yellowknife, NT.

Rescan. 2010a. 2009 F*reshwater Baseline Report, Hope Bay Belt Project.* Prepared for Hope Bay Mining Ltd. by Rescan Environmental Services Ltd.:

Rescan. 2010b. 2009 *Marine Baseline Report, Hope Bay Belt Project*. Prepared for Hope Bay Mining Ltd. by Rescan Environmental Services Ltd.:

Rescan. 2010c. *Doris North Gold Mine Project: Aquatic Effects Monitoring Plan*. Prepared for Hope Bay Mining Ltd. by Rescan Environmental Services Ltd. Feburary 2010:

Rescan. 2011. *Doris North Gold Mine Project: 2010 Aquatic Effects Monitoring Program Report.* Prepared for Hope Bay Mining Limited by Rescan Environmental Services Ltd.: Vancouver, BC.

Rescan. 2012. *Doris North Gold Mine Project: 2011 Aquatic Effects Monitoring Program Report.* Prepared for Hope Bay Mining Limited by Rescan Environmental Services Ltd.: Vancouver, BC.

Rescan. 2013. *Doris North Gold Mine Project: 2012 Aquatic Effects Monitoring Program Report*. Prepared for Hope Bay Mining Limited by Rescan Environmental Services Ltd.: Vancouver, BC.

RL&L Environmental Services Ltd. / Golder Associates Ltd. 2003a. *Doris North Project Aquatic Studies 2002*. Prepared for Miramar Hope Bay Ltd. by RL&L Environmental Services Ltd. and Golder Associates Ltd. Report No. 022-7010:

RL&L Environmental Services Ltd. / Golder Associates Ltd. 2003b. *Doris North Project Aquatic Studies 2003*. Prepared for Miramar Hope Bay Ltd. by RL&L Environmental Services Ltd. and Golder Associates Ltd. Report No. 03-1370-007:

Rysgaard, S., T. G. Nielsen, and B. W. Hansen. 1999. Seasonal variation in nutrients, pelagic primary production, and grazing in a high-Arctic coastal marine ecosystem, Young Sound, Northeast Greenland. *Mar Ecol Prog Ser*, 179: 13–25.

Secrieri, D. and G. Oaie. 2009. The Relation between the Grain Size Composition of the Sediments from the NW Black Sea and their Total Organic Carbon (TOC) Content. *Geo-Eco-Marina,* 15: 5-11.

SRK. 2012. *Doris North Project: Interim Water Management Plan (Revision 5)*. . Prepared for Hope Bay Mining Ltd. by SRK Consulting (Canada) Inc.: Vancouver, BC.

Wiens, J. A. and K. R. Parker. 1995. Analyzing the effects of accidental environmental impacts: approaches and assumptions. *Ecological Applications*, 5 (4): 1069-83.

Appendix A

2015 Data Report

APPENDIX A. 2015 DATA REPORT

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ANNEXES

APPENDIX A. 2015 DATA REPORT

A.1 Overview of Report

This report presents the complete dataset as well as summary graphs and tables of the results of the 2015 Aquatic Effects Monitoring Program (AEMP) for the Doris North Gold Mine Project. The 2015 AEMP included the following: physical profiles of temperature, dissolved oxygen, and salinity (marine sites only); Secchi depths; water quality; sediment quality; primary producer biomass; and benthic invertebrate (benthos) taxonomy and density. Details of the sampling methodology and data analysis are provided in the main body of the report. Figure A.1-1 provides an overview of sampling sites included in the 2015 AEMP and Figures A.1-2 to A.1-7 show detailed maps of each lake and marine sampling site, including sampling details and bathymetric contours (if available).