Coeur d’Alene Lake Management Plan: Coeur d’Alene Lake Status Update, 2015

State of Idaho
Department of Environmental Quality
and
Coeur d’Alene Tribe

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Executive Summary

This document provides an update on the status of water quality in Coeur d'Alene Lake in calendar year 2015, relative to long-term trends in key water quality parameters previously identified in the 2008-2014 Lake Trends Analysis (DEQ and Tribe, 2016). These key parameters, or trigger criteria, are dissolved metals (cadmium, lead, zinc), total phosphorus, chlorophyll-a, and dissolved oxygen in the lake's bottom waters. The Lake Management Plan (LMP) also monitors water clarity, phytoplankton community structure, and invasive species. Trends in these parameters are not reported here, as consensus quantitative metrics for trend analyses for these criteria have not yet been developed. These parameters will be assessed in future reports.

The prior 2008 – 2014 Lake Trends Analysis (DEQ and Tribe, 2016) assessed long-term trends in the lake's status relative to the 1991 – 1992 baseline established by the U.S. Geological Survey (Woods and Beckwith, 1997). The 2016 report concluded that the lake is changing in different ways, with different trends observed in different locations. The report stated that metals levels in the Lake had declined, relative to the 1990's condition, but that the trophic state indicators that measure the lake's productivity were trending toward a higher trophic state. This report updates those trends with data from calendar year 2015, and concludes the following.

1. *Dissolved metals data is only available back to 2003. Different metals show different trends*.
    a. Zinc levels are declining or stable.
    b. Cadmium levels are increasing in southern waters, but may be beginning to decline at some locations in the northern Lake.
    c. Lead levels are slowly increasing at some locations and stable at others.
2. *Chlorophyll-a levels in the lake are higher than in the 1990's, and are increasing at all monitoring locations*. This is true for both annual median levels and maximum observed values.
3. *Total phosphorus levels in the lake are higher than in the 1990's, and are increasing in the northern lake*. No trend is seen in the southern lake since 2003.
4. *Bottom water oxygen levels are lower than in the 1990's at some locations, and may be slowly declining at those locations*. No trend is seen in the southern lake since 2003.

> Coeur d'Alene Lake status in 2015 reflects a continuance of previously reported trends. Zinc levels continue to decline, cadmium and lead show variability in trends, and the Lake is trending toward a higher trophic state status.

The prior 2008 – 2014 Lake Trends Analysis concluded that metals levels in the Lake had begun to decline, but that new challenges were emerging. The lake's trophic status is changing in ways that are not consistent with the management objectives of (i) managing nutrients to maintain the Lake in a lower productivity state and (ii) trapping contaminant metals in the sediments by maintaining elevated oxygen levels in the Lake's bottom waters.

This update report concludes that the Lake has continued along the previously established trends. Some potential divergences were observed for total phosphorus, chlorophyll-a, and dissolved cadmium at some locations, but there is insufficient data to make a conclusive determination. A generalized "report card" for the lake status is presented on the following pages.

Dissolved Metals location and trigger value (µg/L) *all values are the geometric mean over the given depth and period*	**1970's 1 year, for closest site**	**1991 - 1992 over the 2 yr record**	**2003 - 2007 over the 5 yr record**	**2008 - 2012 over the 5 yr record**	**2013 single year**	**2014 single year**	**2015 single year**	**Current Trend (2003 - 2015)**
Dissolved Cadmium— *trigger exceeded if annual geometric mean ≥ Idaho/Tribe WQS (C1, C4 is the mean over all depths; C5 is separate for photic zone, near bottom)*								
C1 Tubbs Hill, northern pool (0.22-0.25)	*no data*	*totals only*	**0.23**	**0.22**	**0.24**	**0.20**	**0.19**	**none ☒**
C4 University Pt, central pool (0.22-0.25)	*no data*	*totals only*	**0.25**	**0.26**	**0.26**	**0.23**	**0.24**	**none ☒**
C5 Chippy Pt., southern pool (0.21-0.24)	*no data*	*totals only*	**0.07, 0.12**	**0.09, 0.13**	**0.10, 0.13**	**0.08, 0.13**	**0.08, 0.17**	***increasing* ☒**
C6 Chatcolet Lake, southern lake	*no data*	*totals only*	*Most values below measurement reporting limits.*					
Dissolved Lead— *trigger exceeded if annual geometric mean ≥ Idaho/Tribe WQS (C1, C4 is the mean over all depths; C5 is separate for photic zone, near bottom)*								
C1 Tubbs Hill, northern pool (0.54)	*no data*	*totals only*	**0.11**	**0.20**	**0.28**	**0.24**	**0.11**	***increasing* ☒**
C4 University Pt, central pool (0.54)	*no data*	*totals only*	**0.24**	**0.39**	**0.31**	**0.48**	**0.38**	***increasing* ☒**
C5 Chippy Pt., southern pool (0.38-0.49)	*no data*	*totals only*	**0.14, 0.18**	**0.15, 0.25**	**0.11, 0.10**	**0.16, 0.16**	**0.12, 0.17**	**none ✓**
C6 Chatcolet Lake, southern lake	*no data*	*totals only*	*Most values below measurement reporting limits.*					
Dissolved Zinc— *trigger exceeded if aannual geometric mean ≥ Idaho/Tribe WQS (C1, C4 is the mean over all depths; C5 is separate for photic zone, near bottom)*								
C1 Tubbs Hill, northern pool (36)	*no data*	*totals only*	**61**	**57**	**56**	**50**	**50**	***decreasing* ✓**
C4 University Pt, central pool (36)	*no data*	*totals only*	**66**	**62**	**60**	**53**	**58**	***decreasing* ✓**
C5 Chippy Pt., southern pool (28-34)	*no data*	*totals only*	**19, 33**	**16, 35**	**22, 38**	**12, 31**	**18, 30**	**none ☒**
C6 Chatcolet Lake, southern lake	*no data*	*totals only*	*Most values below measurement reporting limits.*					

- *Grey* = incomplete data or no data available
- ***Green*** = meets criteria (no trigger exceedance)
- ***Yellow*** = value is close to criteria (within 10%) may meet or exceed
- ***Orange*** = does not meet criteria (exceeds trigger)
- ☒ denotes an undesired trend (away from target), and ✓ denotes a desired trend (towards target)

Trophic State location and trigger value (µg/L unless otherwise stated)	EPA, 1975 1 year, for closest site	1991 - 1992 over the 2 yr record	2003 - 2007 over the 5 yr record	2008 - 2012 over the 5 yr record	2013 single year	2014 single year	2015 single year	Current Trend (2003 - 2015)
Hypolimnetic Dissolved O2— *trigger exceeded if minimum observed value at the 1.0 m off the bottom depth interval is < 6.0 mg/L (C1, C4) or < 8 mg/L (C5, C6)*								
C1 Tubbs Hill, northern pool (>6)	*no data*	> 6.0	6.4	5.5	7.4	7.1	6.8	*slight decline* ☒
C4 University Pt, central pool (>6)	*no data*	> 6.0	5.9	5.8	7.5	7.6	8.0	*slight decline* ☒
C5 Chippy Pt., southern pool (>8)	*no data*	2.9	3.8	3.5	4.6	3.0	2.3	none ☒
C6 Chatcolet Lake, southern lake (>8)	*no data*	0.0	0.0	0.0	0.0	0.0	0.0	*decreasing* ☒
Chlorophyll-a— *trigger exceeded if annual geometric mean ≥ 3 µg/L OR maximum observed value is ≥ 5 µg/L (given values are geometric mean, maximum in photic zone)*								
C1 Tubbs Hill, northern pool (< 5, 3)	7, 17	1.0, 1.7	1.5, 3.3	2.3, 8.4	2.2, 3.1	2.1, 5.1	2.3, 3.3	*increasing* ☒
C4 University Pt, central pool (< 5, 3)	12, 26	1.0, 1.9	1.5, 3.1	2.1, 5.3	2.4, 4.1	2.3, 4.0	1.8, 5.2	*increasing* ☒
C5 Chippy Pt., southern pool (< 5, 3)	3, 5	1.1, 2.2	1.7, 5.3	2.0, 6.7	2.7, 5.8	1.9, 3.9	2.5, 3.9	*increasing* ☒
C6 Chatcolet Lake, southern lake (< 5, 3)	*no data*	1.2, 3.1	3.0, 18	2.9, 13	4.7, 10.7	2.9, 8.6	3.9, 9.6	*increasing* ☒
Total Phosphorus— *trigger exceeded if annual geometric mean is ≥ 8 µg/L in specified depth intervals (≥ 9 µg/L for Chatcolet Lake)*								
C1 Tubbs Hill, northern pool (< 8, mean over the upper 30 m)	13	< 3	4.7	6.0	5.1	7.4	8.8	*increasing* ☒
C4 University Pt, central pool (< 8, mean over the upper 30 m)	16	3.8	5.9	8.1	5.1	10.3	8.2	*increasing* ☒
C5 Chippy Pt., southern pool (< 8 for photic zone, near bottom)	23	5.8, 5.5	12, 15	13, 14	6.5, 10.3	10.3, 11.3	8.0, 9.7	*decreasing* ✓
C6 Chatcolet Lk., southern lake (< 9 for photic zone, near bottom)	*no data*	9.0, 16	19, 36	19, 27	14.6, 42	14.4, 18.1	17.2, 44.9	none ☒

- *Grey* = incomplete data or no data available
- *Green* = meets criteria (no trigger exceedance)
- *Yellow* = value is close to criteria (within 10%) may meet or exceed
- *Orange* = does not meet criteria (exceeds trigger)
- ☒ denotes an undesired trend (away from target), and ✓ denotes a desired trend (towards target)

1 Purpose, Background, and Introduction

The Coeur d'Alene Lake Management Plan (LMP) is a collaborative effort among the Idaho Department of Environmental Quality (DEQ), the Coeur d'Alene Tribe (Tribe), and the region's many governmental and stakeholder groups to protect water quality within Coeur d'Alene Lake (DEQ and Tribe 2009). The US Environmental Protection Agency (EPA) Manchester Laboratory has provided technical support, approved annual quality assurance project plans (QAPPs), and provided chemical analyses for water quality samples collected by DEQ and the Tribe.

> *The Lake Management Plan goal is to "protect and improve lake water quality by limiting basin-wide nutrient inputs that impair lake water quality conditions, which in turn influence the solubility of mining-related metals contamination contained in lake sediments".*

This overall goal will be achieved by attempting to maintain the lake in a low nutrient status, which will lead to high levels of hypolimnetic (deep water) dissolved oxygen (DO) and low solubility of lake-bed metals. The LMP established *trigger criteria* to compare the lake's status relative to water quality standards, historic data, and the goal stated above. These trigger criteria include metals levels, hypolimnetic DO, trophic parameters such as chlorophyll-*a*, phosphorus, and a suite of bioindicators that reflect changes in trophic status and may provide more sensitive indicators. This report provides a summary update of the lake's current status relative to the quantitative triggers criteria established in the LMP.

This report provides the lake's status in calendar year 2015 relative to long-term trends that have been discussed in prior reports. This report answers two questions regarding the water quality status of Coeur d'Alene Lake in relation to the LMP triggers:

1. What is the status of Coeur d'Alene Lake relative to the water quality trigger criteria?
2. How do the most recent trigger values from CY 2015 compare with trends derived from the prior datasets (1991 – 1992, 2003 – 2007, 2008 – 2014)?

This report summarizes results from statistical analyses of the quantitative LMP trigger variables and is *not* a synthesis or conclusion of what these data may imply for future lake management decisions. DEQ and the Tribe are currently collaborating to produce a series of technical synthesis reports to identifying the dynamics and mechanisms that may explain the current lake conditions and trends described in this report and prior summaries.

1.1 Data Sources

This report is primarily based on analyses of LMP trigger variables from three time periods (1991–1992, 2003–2006, and 2007–2014). Additional analyses that incorporate DO data collected from 1996–2002 are also presented. Data from the 1991–1992 period was collected by the US Geological Survey (USGS) and reported by Woods and Beckwith (1997). Data from the 2003–2006 period was collected by USGS and reported by Wood and Beckwith (2008). DO data from 1996–2002 for the northern lake were collected by DEQ, with results generally summarized in draft addendums to the 1996 Coeur d'Alene LMP (DEQ 1996; DEQ 2002; DEQ 2004). Data collected from 2007–2015 was collected by DEQ and the Tribe. These datasets were reported in the following annual reports:

1. Lake Status (CY 2007–2008)— Tribe and DEQ. 2010. *Coeur d'Alene Lake Monitoring Program 2007–2008 Report*. Plummer, ID: Coeur d'Alene Tribe and Coeur d'Alene ID: Idaho Department of Environmental Quality
2. Lake Status (CY 2009)— Tribe and DEQ. 2012. *Coeur d'Alene Lake Monitoring Program 2009 Report*. Plummer, ID: Coeur d'Alene Tribe and Coeur d'Alene ID: Idaho Department of Environmental Quality
3. Lake Status (CY 2010)— DEQ. 2012. *Coeur d'Alene Lake Monitoring Program 2010 Annual Report, Volume 1: State Waters*. Coeur d'Alene ID: Idaho Department of Environmental Quality
4. Lake Status (CY 2011)— DEQ. 2013. *Coeur d'Alene Lake Monitoring Program 2011 Annual Report, Volume 1: State Waters*. Coeur d'Alene ID: Idaho Department of Environmental Quality
5. Lake Status (CY 2008-2014)— Tribe and DEQ. 2016. *Coeur d'Alene Lake Management Program: Summary of Lake Status and Trends, 2008–2014*. Coeur d'Alene ID: Idaho Department of Environmental Quality

1.2 Water Quality Trigger Criteria

Section 3.1 of the LMP states:

> There are several key water quality variables that need to be tracked in order to measure the long term health of the lake. These include, but are not limited to: levels of zinc, lead, cadmium, phosphorus, phytoplankton, and dissolved oxygen. The 2009 LMP establishes triggers for each of these variables and others, to gauge lake health. An annual comprehensive monitoring program produces trend data that provides an "early warning system" for deteriorating conditions. Ideally, this will allow corrective steps to be taken before conditions deteriorate to the point they would be very difficult and expensive to reverse, i.e., exceeding a trigger.

Trigger criteria values for DO and trophic state indicators (total phosphorus and chlorophyll-*a*) are provided in section 2 of this report. The DO trigger is generally based on the state and Tribe water quality standards for DO levels in the hypolimnion (summer bottom waters). The oxygen criteria support beneficial use by providing suitable habitat for cold water salmonids. However, since Coeur d'Alene Lake also has metals contamination issues that can be alleviated by maintaining high oxygen levels, the DO trigger extends these values down to the sediment-water interface. This trigger condition is specific to Coeur d'Alene Lake management and is distinct from Idaho water quality criteria.

Trigger criteria values for dissolved metals are based on water quality standards for surface waters, as defined by the State of Idaho and the Coeur d'Alene Tribe. From a policy and regulatory standpoint, the triggers criteria are treated differently than state and Tribe water quality standards. State water quality criteria are used in the northern waters, generally north of the City of Harrison. Tribe water quality criteria apply to reservation waters, generally south of the City of Harrison. The Tribe incorporates water hardness into water quality standards for cadmium, lead, and zinc. The State also incorporates water hardness into standards for cadmium, lead, and zinc. However, Tribal water quality standards can be more stringent and vary with water depth to a greater extent.

1.3 Sampling Methods

Details of lake monitoring methods are provided in the QAPPs that accompany each of the LMP reports listed in section 1.1, with key information provided in the reports themselves. In general, a profile of the lake's conditions is gathered first using automated methods. These data include temperature, pH, chlorophyll-*a* fluorescence, specific conductance, turbidity, and light transmittance as a function of depth. These data are then used to establish the depth of the photic zone and the depth to bottom (lake depth varies over time). Next, samples for chemical and biological analyses are collected for a photic-zone composite (photic zone mean) and discrete samples at mid-depths and 1 meter off the bottom. These samples are preserved in the field and sent to EPA-certified laboratories for analysis. All sample collection and analysis is conducted using rigorous data-quality procedures.

1.4 Monitoring Locations and Sampling Schedule

The LMP collects samples at the main lake locations (Figure 1):

1. Site C1, southeast of Tubbs Hill— northern pool (pelagic zone, 40 meters deep)
2. Site C4, northeast of University Point—central pool (pelagic zone, 40 meters deep)
3. Site C5, southeast of Chippy Point—southern pool (pelagic zone, 18 meters deep)
4. Site C6, Chatcolet Lake—southern (shallow zone, 11 meters deep)

These sites were visited during the US Geological Survey (USGS) studies conducted in calendar year (CY) 1991–1992 and water year (WY) 2004–2006. Water samples are collected 8 times per year at the main lake stations. Samples are collected to coincide with major hydrologic and limnologic events, generally in February/March, April, May, June, July, August, September/October, and November/December. All lake stations are typically visited within the same week. The February/March sample is intended to capture lake conditions after a rain-on-snow event and the November/December sample is intended to capture lake conditions soon after lake turnover in late fall/early winter. Additional details about the location and frequency of lake sampling are provided in the 2009 LMP as well as in the annual reports and QAPPs.

1.5 Analysis Methods and Report Format

This report presents lake status relative to trigger criteria established in the 2009 Lake Management Plan (DEQ and Tribe, 2009), as well as long-term trends reported in the 2008-2014 Lake Trends Analysis (DEQ and Tribe, 2016). One table and two sets of figures are presented for each of the measured LMP variables.

1. The first set of figures provides bar charts that summarize the current lake status relative to long-term geometric means for different historic time periods, for each of the trigger parameters. This provides a status relative to the trigger criteria established in the 2009 Lake Management Plan (DEQ and Tribe, 2009).

2. The table provides summary results from a Mann-Kendall analysis for both the original 2003-20014 time period as reported in the 2008 – 2014 Lake Trends Analysis (DEQ and Tribe, 2016) and the most recent 2003 – 2015 time period. This evaluates whether the current trend has changed relative to the previously reported trend.

3. The second set of figures provides an updated visualization of long-term trends for trigger parameters, for each combination of depth range and location for the core monitoring locations in the main lake. These charts show all data collected at that site and depth, the annual median for each parameter, and the Theil-Sen trend lines reported in the 2008 – 2014 Lake Trends Analysis (DEQ and Tribe, 2016). This provides a visual representation of current lake status relative to previously identified trends.

The results for each LMP trigger variable are presented for each of the core LMP monitoring sites in the main lake (C1, C4, C5, and C6) and depths associated with the LMP triggers as reported in the Coeur d'Alene LMP (DEQ and Tribe 2009). Different depth ranges are used for the geometric means (bar charts) and trend analyses (tables, line charts) because the trend analyses were conducted at specific depths while the original trigger criteria combined data over multiple depths. The Mann-Kendall statistical test used to derive the long-term trends in the 2008 – 2014 trend analysis (DEQ and Tribe, 2016) can only be conducted for a single depth. Similarly, the Theil Sen trend line that is derived from the difference between measured data and the annual median value is also specific to a single combination of depth and monitoring site. These depth-specific trends are more meaningful and diagnostic than the original trigger criteria established in 2009 (DEQ and Tribe, 2009). Consequently, analysis of whether the current year's data falls along this trend is also more meaningful.

Analyses of data for the bays adjacent to the northern lake are not presented in this report. The dataset for these monitoring locations is not as comprehensive and continuous as for the main lake and is consequently less informative. These data will be presented in future reports.

All statistical tests were run using the EPA water quality statistics software ProUCL 5.0 (Singh and Maichle 2013; Singh and Singh 2013). All statistical tests were run at an alpha level of 0.05, with the presence or absence of trends assessed at a 95% confidence level. Note that weaker trends that may occur at lower confidence levels (e.g., 90% confidence, $\alpha = 0.10$) are reported as a *potential trend* here. The absence of a trend at the tighter standard of 95% confidence ($\alpha = 0.05$) does not mean that a trend does not exist. This absence simply means that a trend cannot be clearly identified to a high degree of confidence, with the data that are currently available.

To reduce the size of this report, DEQ and the Tribe will assess data quality in stand-alone data quality reports that cover data collected from 2011–2014 that were not part of the reports listed in section 1.1. DEQ and the Tribe may also produce additional "stand alone" technical reports to assess other aspects of lake water quality. This report is a summary of findings for key water quality indicators whose trigger criteria are quantitative and can be statistically assessed.

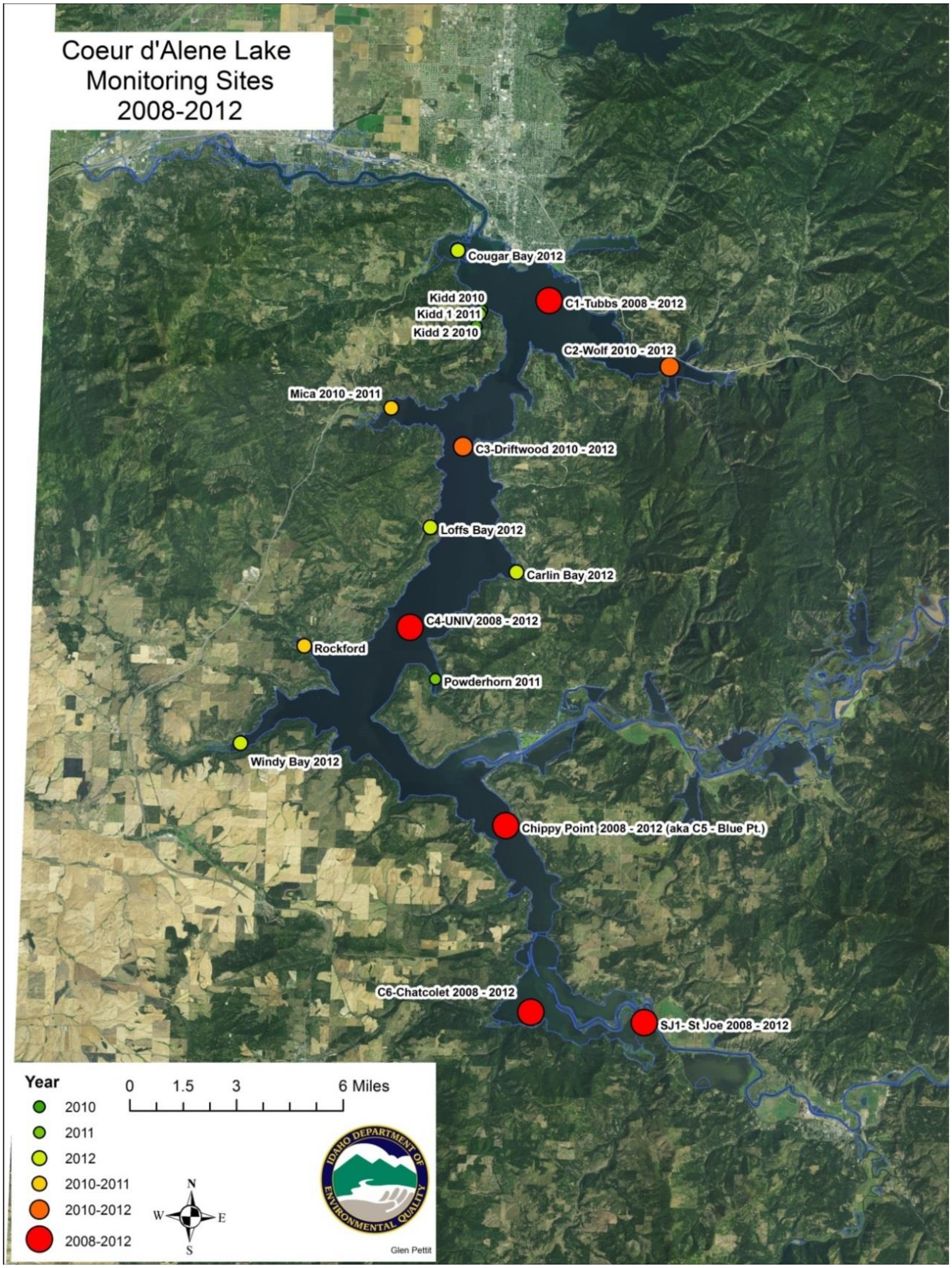


Figure 1. Map of sampling locations on Coeur d'Alene Lake. Large red dots are core monitoring locations, small dots are bay sites sample prior to 2013, and medium orange dots are additional sampling locations occasionally visited to gather additional data to support trend analysis.

2 Results

2.1 Total Phosphorus

Current (2015) and multiyear geometric mean values for total phosphorus (TP) are presented in Figure 2 for the upper 30 m at Tubbs Hill (C1) and University Point (C4), and in Figure 3 for the photic zone and near bottom samples at Chippy Point (C5) and Chatcolet Lake (C6). These data show the following.

- *Tubbs Hill (upper 30 m)*— geometric mean total phosphorus for 2015 exceeded the trigger value of 8 µg/L and continues the trend of increasing concentrations.

- *University Point (upper 30 m)*— geometric mean total phosphorus for 2015 exceeded the trigger value of 8 µg/L and continues the trend of increasing concentrations.

- *Chippy Point (photic zone, near bottom)*— geometric mean total phosphorus for 2015 exceeds the trigger value of 8 µg/L and is consistent with prior trends where current levels are higher than in 1991 – 1992.

- *Chatcolet Lake (photic zone, near bottom)*— geometric mean total phosphorus for 2015 exceeds the trigger value of 9 µg/L and is consistent with prior trends where current levels are higher than in 1991 – 1992.

Results from a Mann-Kendall statistical analysis of long-term trends in total phosphorus are provided in Table 1. Trend charts are presented in Figure 4 for Tubbs Hill (C1), Figure 5 for University Point (C4), and in Figure 6 for Chippy Point (C5) and Chatcolet Lake (C6).

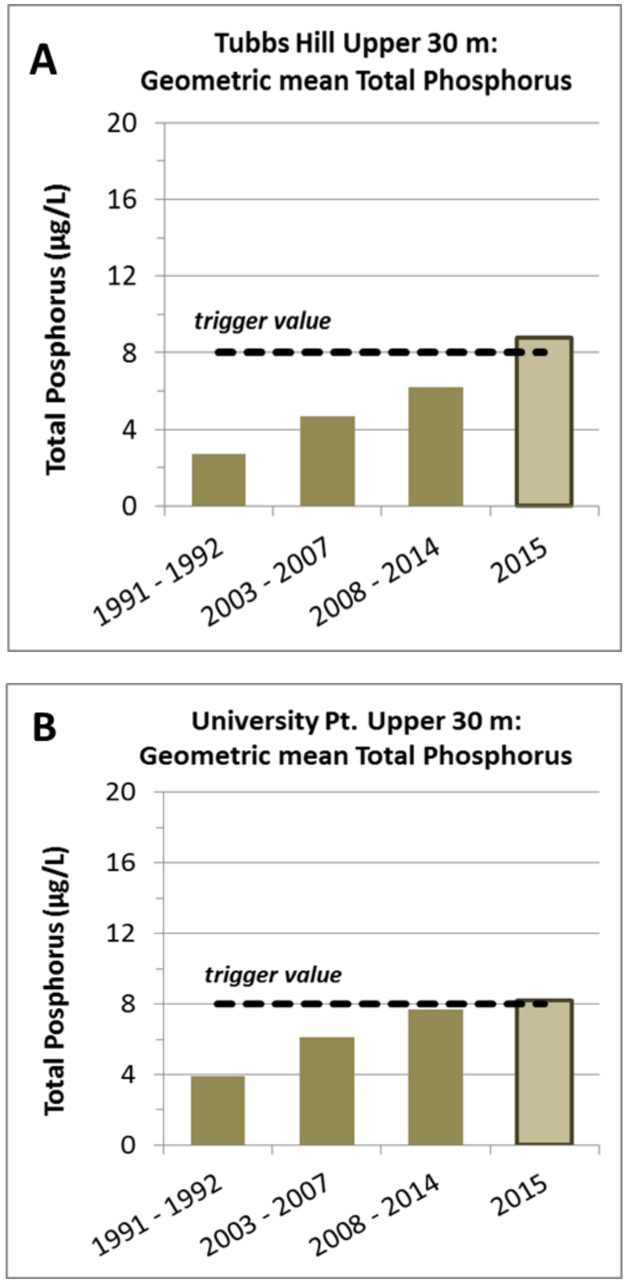


Figure 2. Total phosphorus geometric mean values over the reported time period for site C1 Tubbs Hill upper 30 m (A), and site C4 University Point upper 30 m (B).

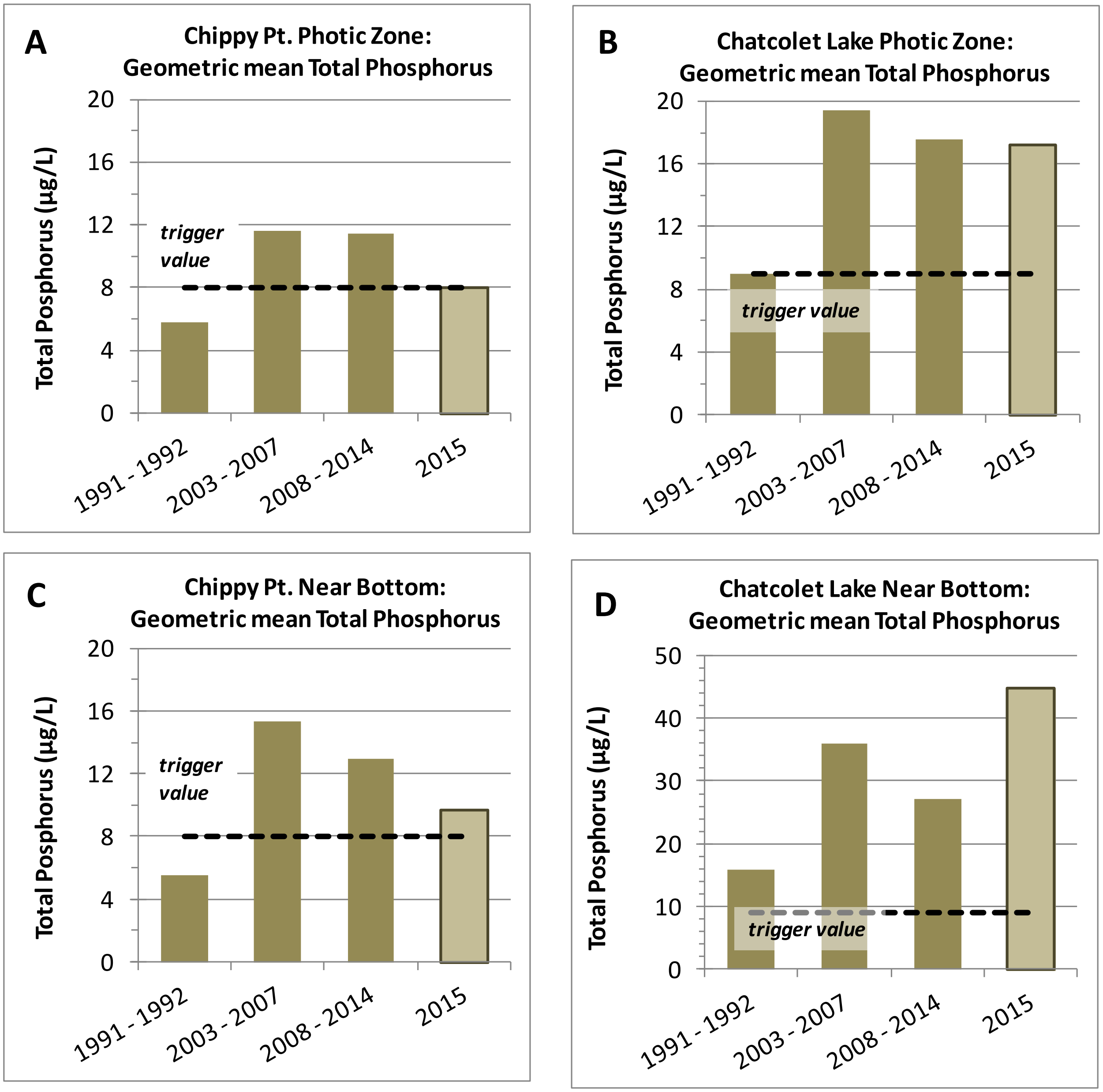


Figure 3. Total phosphorus geometric mean values over the reported time period for site C5 Chippy Point photic zone (A), site C6 Chatcolet Lake photic zone (B), site C5 Chippy Point near bottom(C), and site C6 Chatcolet Lake near bottom (D).

The phosphorus trend analyses summarized in Table 1 demonstrate that different total phosphorus trends are observed in different regions of the lake. In the northern pool (C1, Tubbs Hill), total phosphorus increased over the 2003 – 2014 time period for all depths. These trends are also observed for the updated 2003 – 2015 time period. The P-value for the photic zone and near bottom trends at C1 and C5 are notably lower in the updated 2003 – 2015 trend than in the prior 2003 – 2014 trend. This suggests that these trends may be becoming more distinct. However, additional data is needed. For the central pool (C4, University Point), total phosphorus only increased at the 30 m depth interval during the 2003 – 2014 time period. Except for the near bottom sample, these trends are also observed for the 2003 – 2015 time period. For the near bottom sample, a potential new trend of increasing total phosphorus is observed for the 2003 – 2015 time period. This new trend is only significant to within 90% confidence.   Overall, the 2003 – 2015 total phosphorus trends for the northern lake are consistent with the 2003 – 2014 trends. The updated data from 2015 suggests that the trends of increasing total phosphorus may be becoming more distinct. Note that phosphorus data was not collected at 30 m depth in the northern lake in 2015, and thus the trend for 30 m depth cannot be updated at this time.

Table 1. Mann-Kendall trend analysis for total phosphorus (TP) from 2003-2014 and 2003-2015 (current) at LMP core monitoring sites. Bold P-values are statistically significant at α=0.05 Italic P-values are statistically significant at α=0.10 but not α=0.05.

Time Period	Site	Depth	Variable	Mann-Kendall Trend Test (2003–2014, 2003-2015)			
				Sample Size (n)	P-Value	Theil-Sen Slope [a]	Trend
2003–2014	C1	Photic zone	TP	79	**0.025**	**0.13**	**Increasing**
	C1	20-meter depth	TP	72	**0.002**	**0.18**	**Increasing**
	C1	30-meter depth	TP	61	**0.001**	**0.27**	**Increasing**
	C1	Near bottom	TP	75	**0.018**	**0.17**	**Increasing**
2003-2015 (current)	C1	Photic zone	TP	87	**0.003**	**0.19**	**Same**
	C1	20-meter depth	TP	80	**0.001**	**0.20**	**Same**
	C1	30-meter depth	TP	61	**0.001**	**0.27**	**Same**
	C1	Near bottom	TP	83	**0.004**	**0.19**	**Same**
2003-2014	C4	Photic zone	TP	81	0.30	0.02	None
	C4	20-meter depth	TP	76	0.25	0.06	None
	C4	30-meter depth	TP	60	**0.017**	**0.34**	**Increasing**
	C4	Near bottom	TP	81	0.17	0.12	None
2003-2015 (current)	C4	Photic zone	TP	88	0.30	0.02	Same
	C4	20-meter depth	TP	83	0.15	0.09	Same
	C4	30-meter depth	TP	60	**0.017**	**0.34**	**Same**
	C4	Near bottom	TP	88	*0.060*	*0.18*	*Increasing*
2003-2014	C5	Photic zone	TP	85	0.13	-0.17	None
	C5	Near bottom	TP	85	**0.016**	**-0.39**	**Decreasing**
2003-2015 (current)	C5	Photic zone	TP	94	**0.016**	**-0.30**	**Decreasing**
	C5	Near bottom	TP	94	**0.002**	**-0.47**	**Same**
2003-2014	C6	Photic zone	TP	82	*0.098*	*-0.39*	*Decreasing*
	C6	Near bottom	TP	82	*0.093*	*-0.55*	*Decreasing*
2003-2015 (current)	C6	Photic zone	TP	90	0.13	0.28	None
	C6	Near bottom	TP	91	0.28	-0.20	None

Slope is in units of micrograms per liter (ug/L) per year. Positive slope is an increase.

For the Chippy Point monitoring site in the southern pool (C5), total phosphorus decreased at the near bottom depth during the 2003 – 2014 time period, but had no trend in the photic zone. A decreasing trend is now seen in both the photic zone and the near bottom strengthened for the updated 2003 – 2015 time period. For the Chatcolet Lake monitoring site in the southern pool (C6), total phosphorus decreased at all depths over the 2003 – 2014 time period. This apparent trend is only significant at a 90% confidence interval and is not significant at a more rigorous 95% confidence interval. Total phosphorus in the photic zone and near bottom at Chatcolet Lake showed no trends for the updated 2003 – 2015 time period.

Overall, the 2003 – 2015 total phosphorus trends for the southern lake are consistent with the previously reported 2003 – 2014 trends. Total phosphorus continues to decrease slightly at the Chippy Point site (C5) in the southern pool, and no trend is observed at Chatcolet Lake (C6).

Annual monitoring data for total phosphorus are plotted relative to the 2003 – 2014 trends in Figure 4 (Tubbs Hill), Figure 5 (University Point), and Figure 6 (Chippy Point and Chatcolet Lake). These plots show different patterns of lake status relative to long-term trends at different combinations of depth and monitoring location.

1. *Tubbs Hill (C1, northern pool)*— Monitoring data for 2015 are consistent with the 2003-2014 trend line for all depths where monitoring data is available. 2015 median values are ~20 –40% higher than trend line predictions. The annual median value is above both the trigger criteria (8 µg/L) and the value predicted by the trend line for all depths where data is available for 2015. *This represents a continuance of the long-term trend of increasing total phosphorus at C1 Tubbs Hill.*
2. *University Point (C4, central pool)*— Monitoring data for 2015 are consistent with the 2003-2014 trend line for all depths where monitoring data is available. 2015 median values are ~20 –50% higher than trend line predictions. The annual median value is above both the trigger criteria (8 µg/L) and the value predicted by the trend line for all depths where data is available for 2015. *This is consistent with the prior observation that total phosphorus at C4 University Point is increasing at some depths. Data is not available for the 30 m depth interval in 2015.*
3. *Chippy Point (C5, southern pool)*— Except for the early-season sampling dates, monitoring data for 2015 from the photic zone are lower relative to the 2003-2014 trend line. In the photic zone the annual median value of 7.0 ug/L is lower relative to the trigger and trend. In the near bottom the annual median value of 8.0 ug/L is at the trigger value and is lower than the 2003-2014 trend. *This represents a continuance of a decreasing trend in total phosphorus in the near bottom at C5 Chippy Point.*
4. *Chatcolet Lake (C6, southern pool)*— Monitoring data for 2015 from the photic zone are consistent with the 2003-2014 trend line. In the photic zone the annual median value of 21.0 µg/L is higher relative to the trigger of 9.0 ug/L and trend. In the near bottom the annual median value of 26.0 ug/L is higher than the trigger value of 9.0 ug/L and is higher than the 2003-2014 trend. Total phosphorus in the near bottom at C6 is highly variable due to the seasonal anoxia the site experiences. *This represents a neutral trend in total phosphorus in the photic zone and near bottom at C6 Chatcolet Lake.*

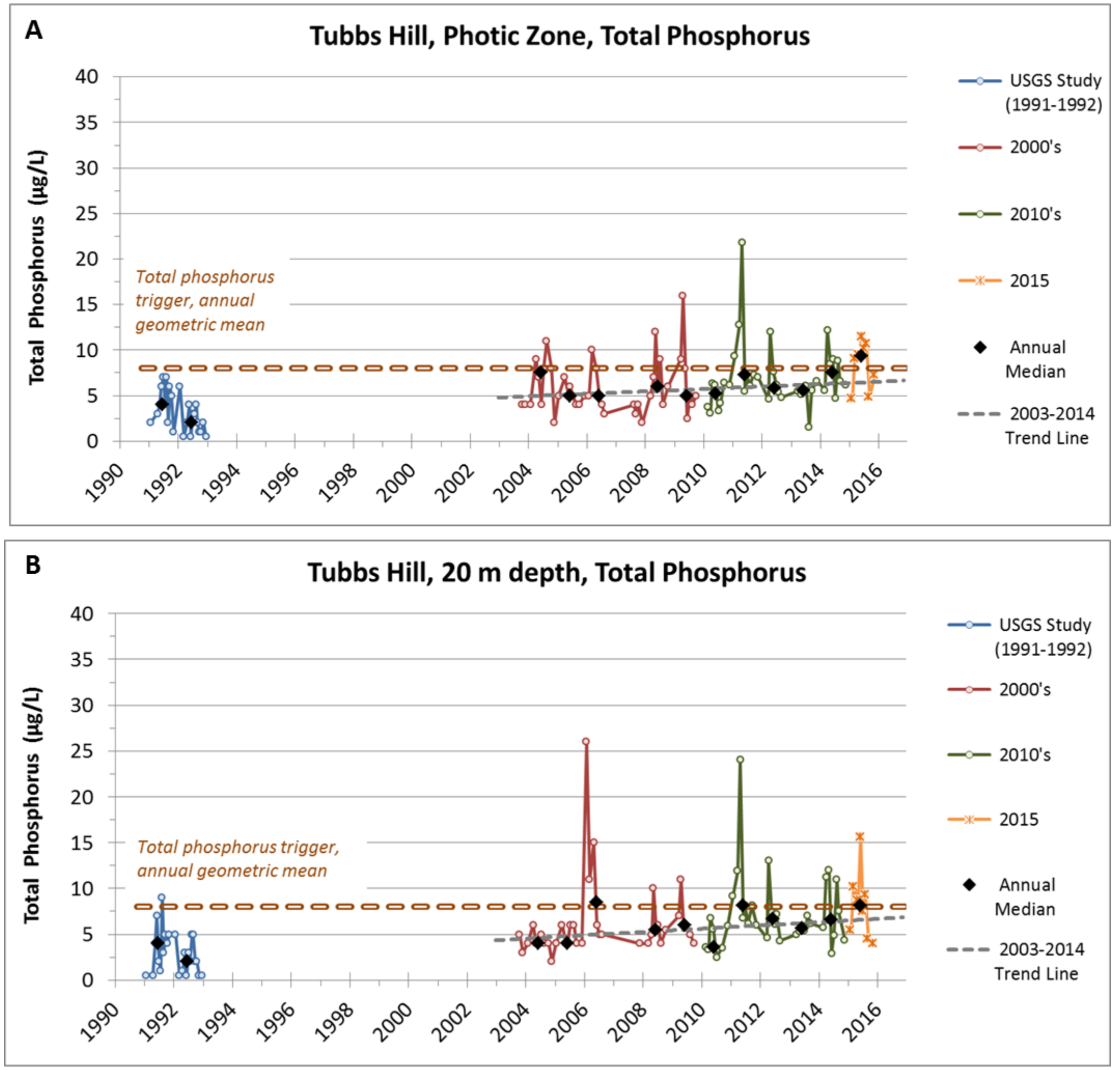
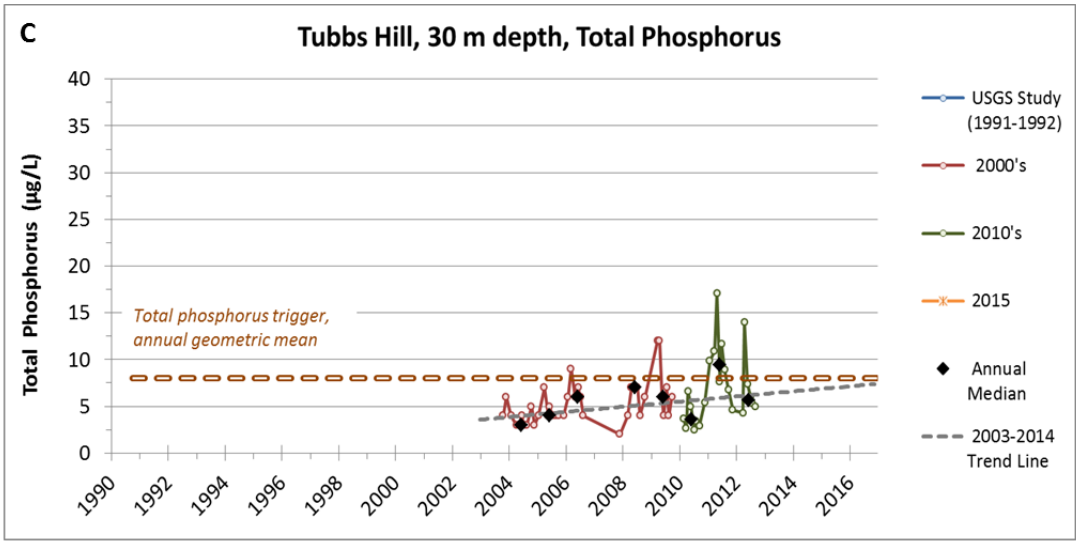


Figure 4. Total phosphorus trend data for site C1 Tubbs Hill photic zone (A), 20 m depth (B), 30 m depth (C), and near bottom (D). Colored points and lines represent data for different historic periods, black points are annual median values, grey dashed line is the trend calculated from data for CY 2003-2014, and the brown dashed line is the trigger criteria.



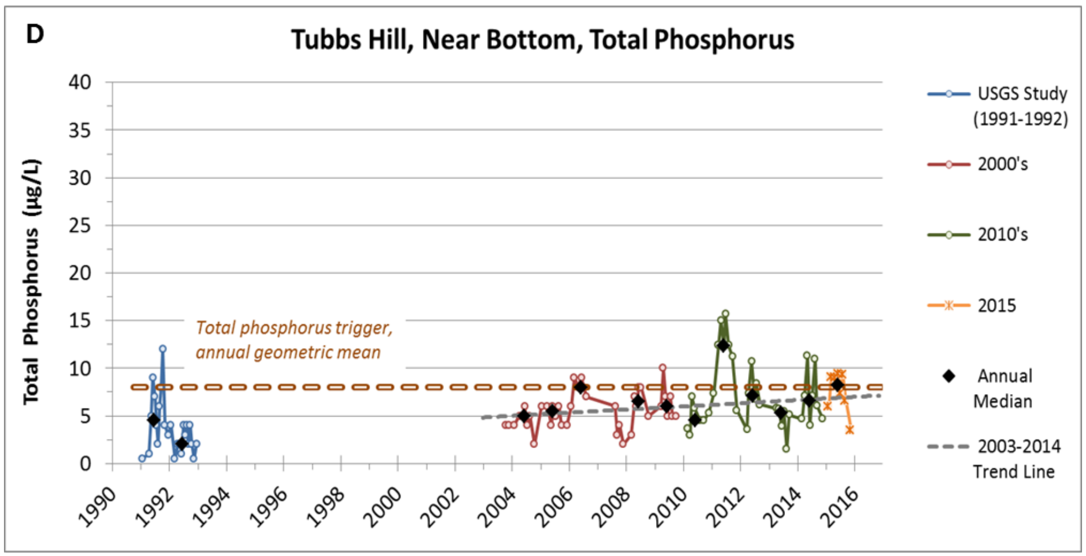


Figure 4 (continued). Total phosphorus trend data for site C1 Tubbs Hill photic zone (A), 20 m depth (B), 30 m depth (C), and near bottom (D). Colored points and lines represent data for different historic periods, black points are annual median values, grey dashed line is the trend calculated from data for CY 2003-2014, and the brown dashed line is the trigger criteria.

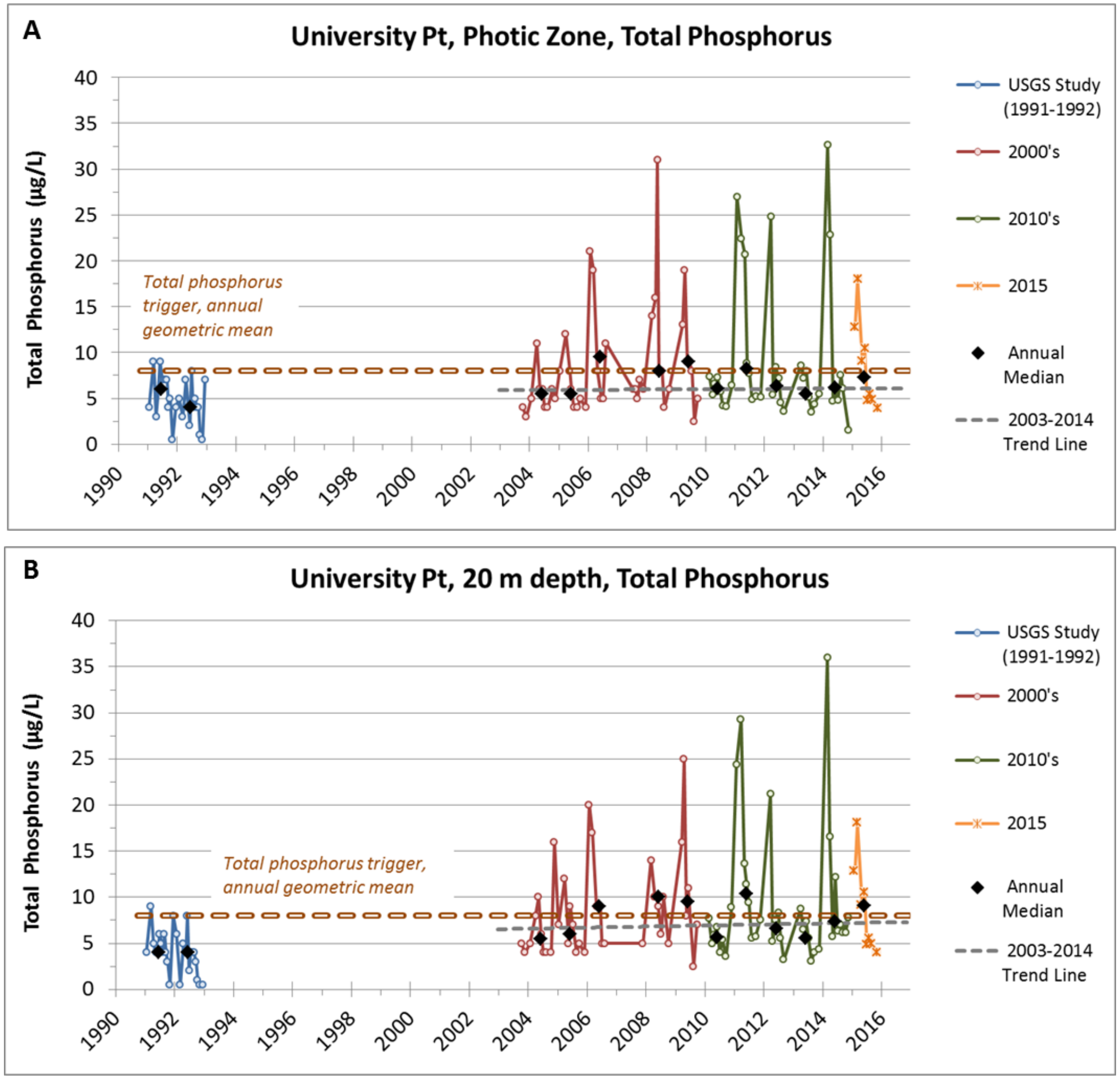
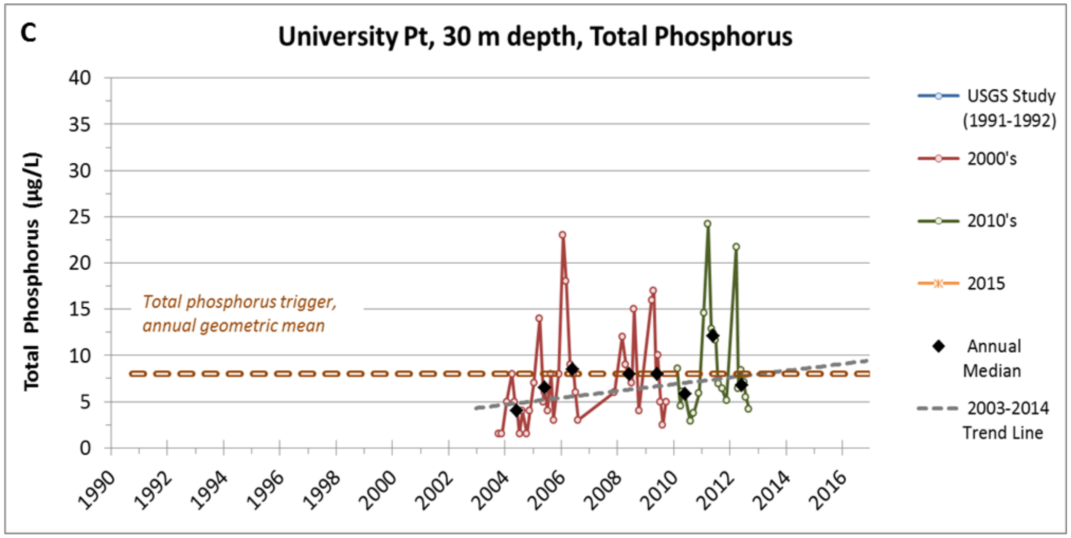


Figure 5. Total phosphorus trend data for site C4 University Point photic zone (A), 20 m depth (B), 30 m depth (C), and near bottom (D). Colored points and lines represent data for different historic periods, black points are annual median values, grey dashed line is the trend calculated from data for CY 2003-2014, and the brown dashed line is the trigger criteria.



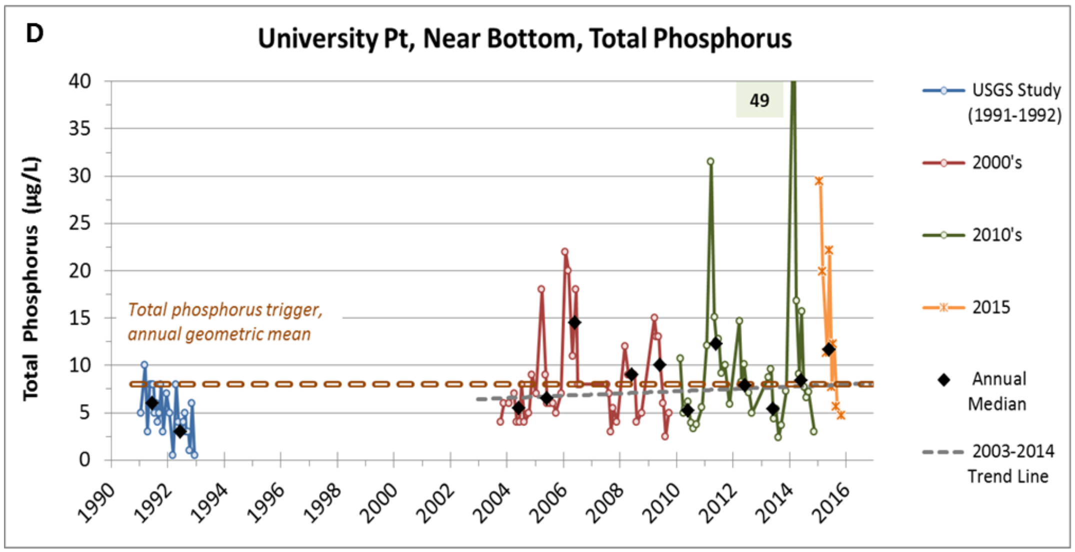
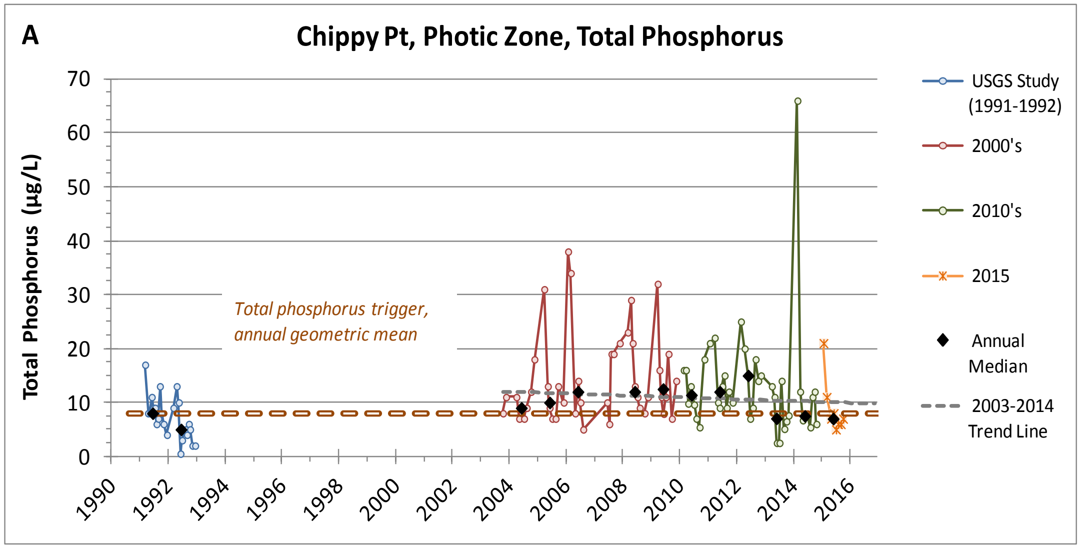


Figure 5 (continued). Total phosphorus trend data for site C4 University Point photic zone (A), 20 m depth (B), 30 m depth (C), and near bottom (D). Colored points and lines represent data for different historic periods, black points are annual median values, grey dashed line is the trend calculated from data for CY 2003-2014, and the brown dashed line is the trigger criteria.



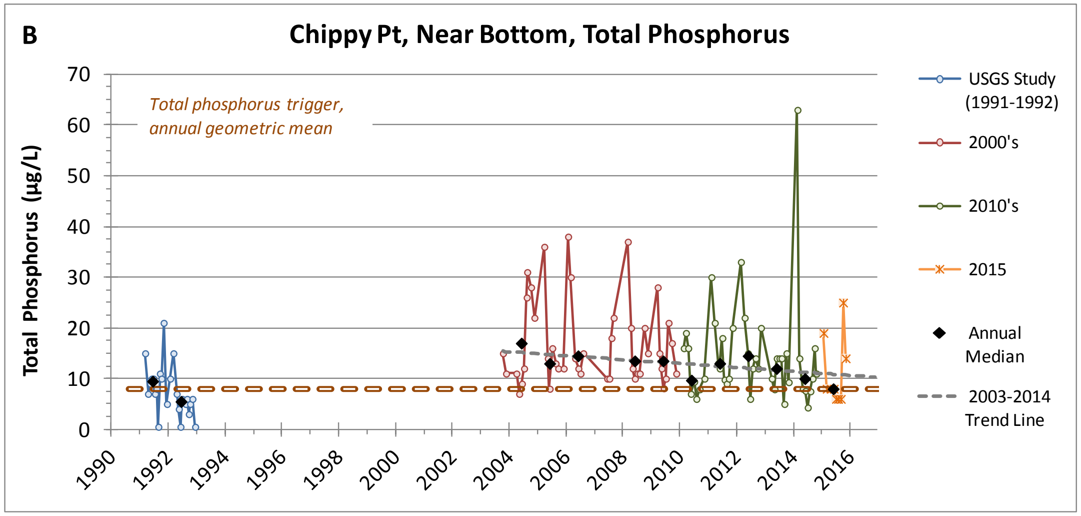
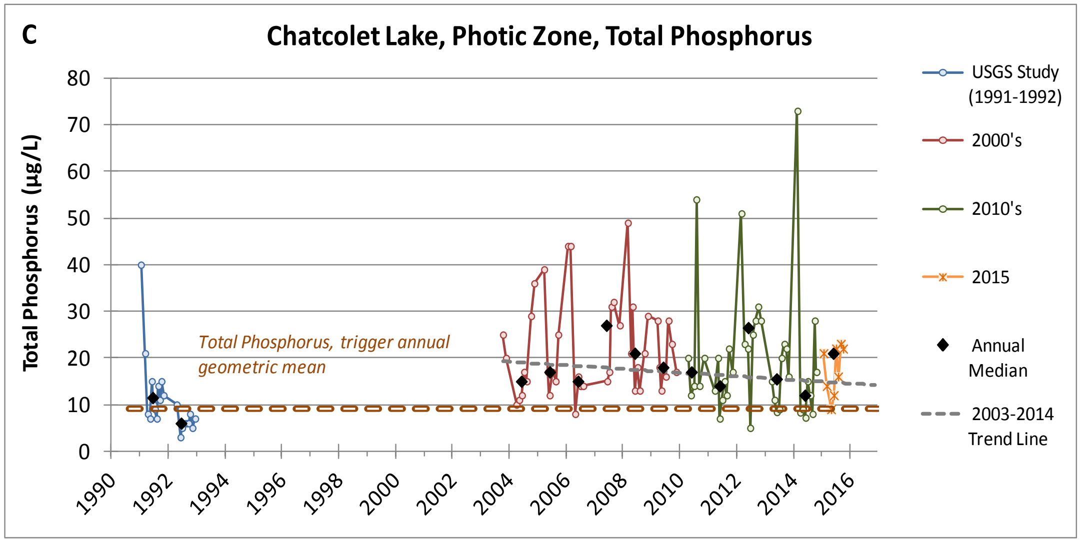


Figure 6. Total phosphorus trend data for site C5 Chippy Point photic zone (A), C5 Chippy Point near bottom (B), C6 Chatcolet Lake photic zone (C), and C6 Chatcolet Lake near bottom (D). Colored points and lines represent data for different historic periods, black points are annual median values, grey dashed line is the CY 2003-2014 trend, and the brown dashed line is the trigger criteria.



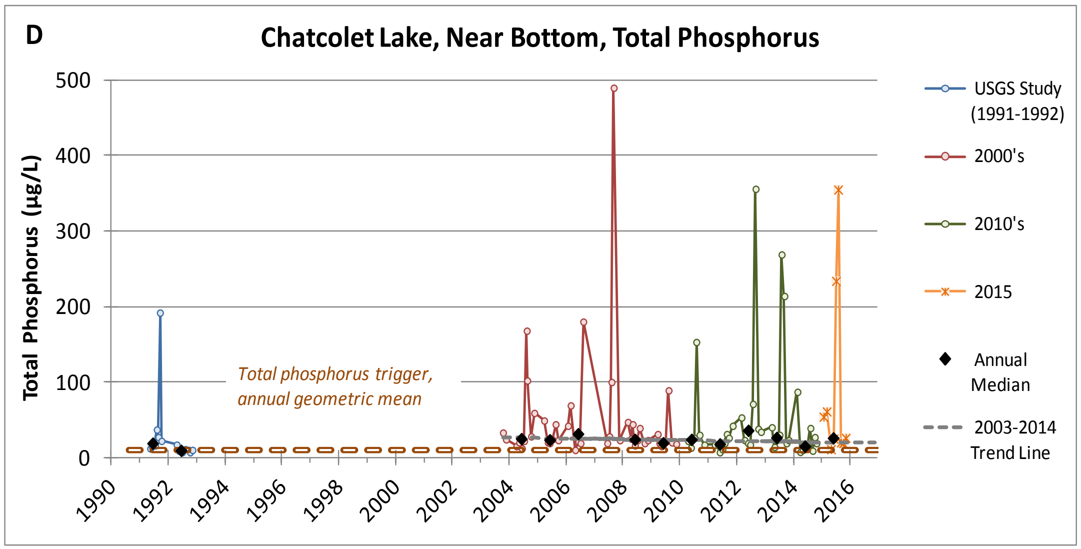


Figure 6 (continued). Total phosphorus trend data for site C5 Chippy Point photic zone (A), C5 Chippy Point near bottom (B), C6 Chatcolet Lake photic zone (C), and C6 Chatcolet Lake near bottom (D). Colored points and lines represent different historic periods, black points are annual median values, grey dashed line is the CY 2003-2014 trend, and the brown dashed line is the trigger criteria.

2.2 Chlorophyll *a*

Current (2015) and multiyear geometric mean and maximum-observed values for chlorophyll-a (Chla) are presented in Figure 7 for the photic zone at Tubbs Hill (C1) and University Point (C4). These data are shown in Figure 8 for the photic zone at Chippy Point (C5) and Chatcolet Lake (C6). These data show the following.

- *Tubbs Hill (photic zone)*— geometric mean chlorophyll-a for 2015 remained below the trigger level of 3 µg/L but did continue the long-term trend of increasing chlorophyll-a concentrations at this site. The geometric mean level in 2015 was higher than for all prior time periods. The maximum observed chlorophyll-a in 2015 did not exceed the trigger level of 5 µg/L. The maximum observed level in 2015 was less than the highest observed during the 2008 – 2014 time period, equivalent to that observed during the 2003 – 2007 time period, and higher than was observed in the 1991 – 1992 period.

- *University Point (photic zone)*— geometric mean chlorophyll-a for 2015 remained below the trigger level of 3 µg/L but did continue the long-term trend of increasing chlorophyll-a concentrations at this site. The geometric mean level in 2015 was slightly lower than the geometric mean for the 2008 – 2014 time period but higher than those observed for 2003 – 2007 and 1991 – 1992. The maximum observed chlorophyll-a in 2015 did not exceed the trigger level of 5 µg/L. The maximum observed level in 2015 was less than the highest observed during the 2008 – 2014 time period, equivalent to that observed during the 2003 – 2007 time period, and higher than was observed in the 1991 – 1992 period.

- *Chippy Point (photic zone)*— geometric mean chlorophyll-a for 2015 values of 2.5 µg/L remained below the trigger level of 3 µg/L but did continue the long-term trend of increasing chlorophyll-a concentrations at C5. Maximum observed chlorophyll-a of 3.9 µg/L for 2015 did not exceed the trigger level of 5 µg/L The maximum observed level in 2015 was lower than the 2003 – 2007 and 2008 – 2014 time periods and higher than observed during 1991 – 1992 time periods.

- *Chatcolet Lake (photic zone)*— geometric mean chlorophyll-a for 2015 of 3.9 µg/L was above the trigger level of 3 µg/L and did continue the long-term trend of increasing chlorophyll-a concentrations at C6. Maximum observed chlorophyll-a of 9.6 µg/L for 2015 exceeded the trigger level of 5 µg/L. The maximum observed chlorophyll-a level in 2015 was lower than the 2003 – 2007 and 2008 – 2014 time periods and higher than observed during 1991 – 1992 time periods.

Results from a Mann-Kendall *s*tatistical analysis of long-term trends in chlorophyll-a are provided in Table 2. Trend charts are presented in Figure 9 for Tubbs Hill (C1) and University Point (C4), and in Figure 10 for Chippy Point (C5) and Chatcolet Lake (C6). These data are discussed on the following pages.

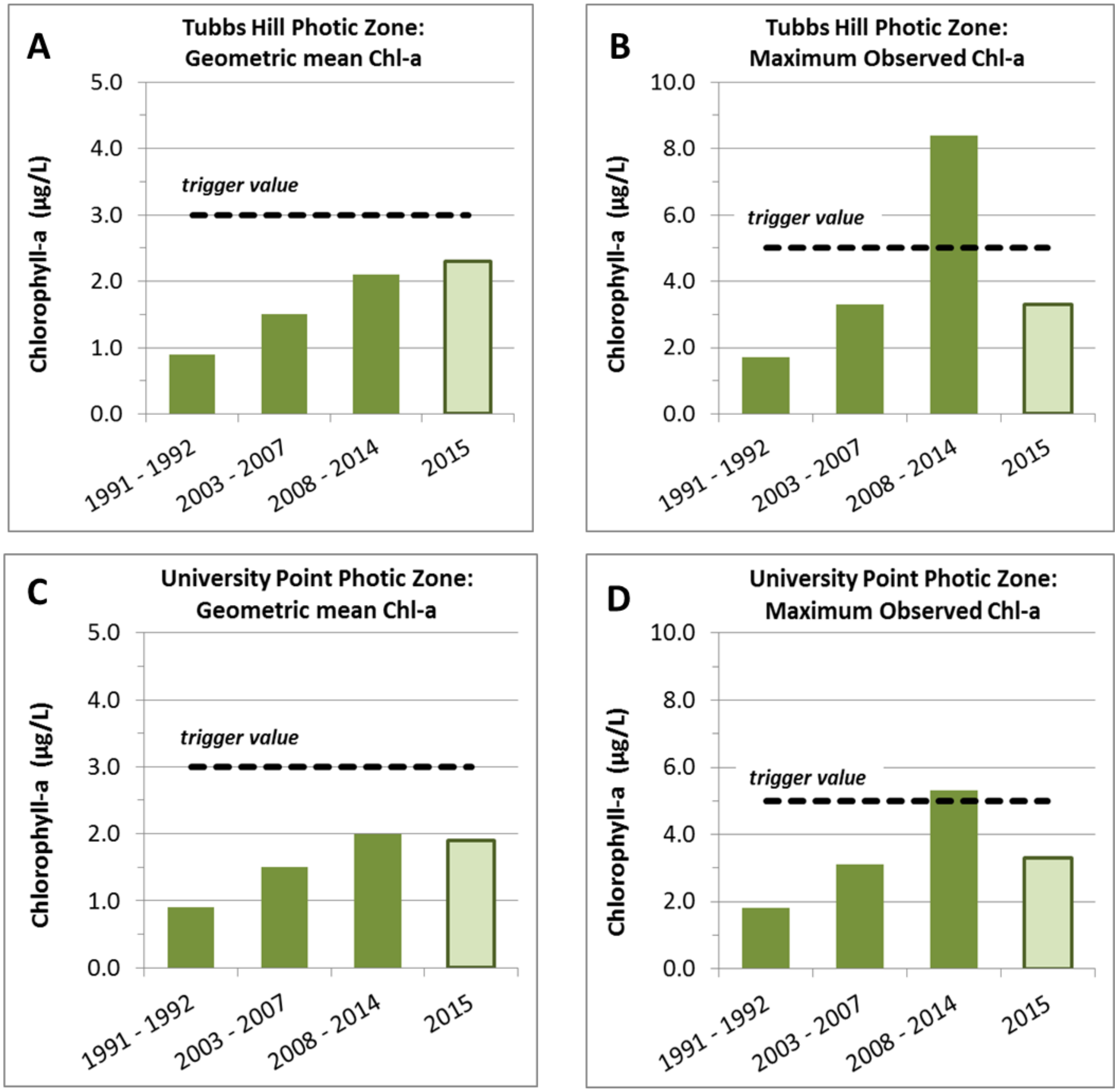


Figure 7. Maximum observed and geometric mean chlorophyll-a values over the reported time *period fo*r *site C1 Tubbs Hil*l photic zone geometric mean (A), C1 Tubbs Hill photic zone maximum observed (B), C4 University Point photic zone geometric mean (C), and C4 University Point photic zone maximum observed (D).

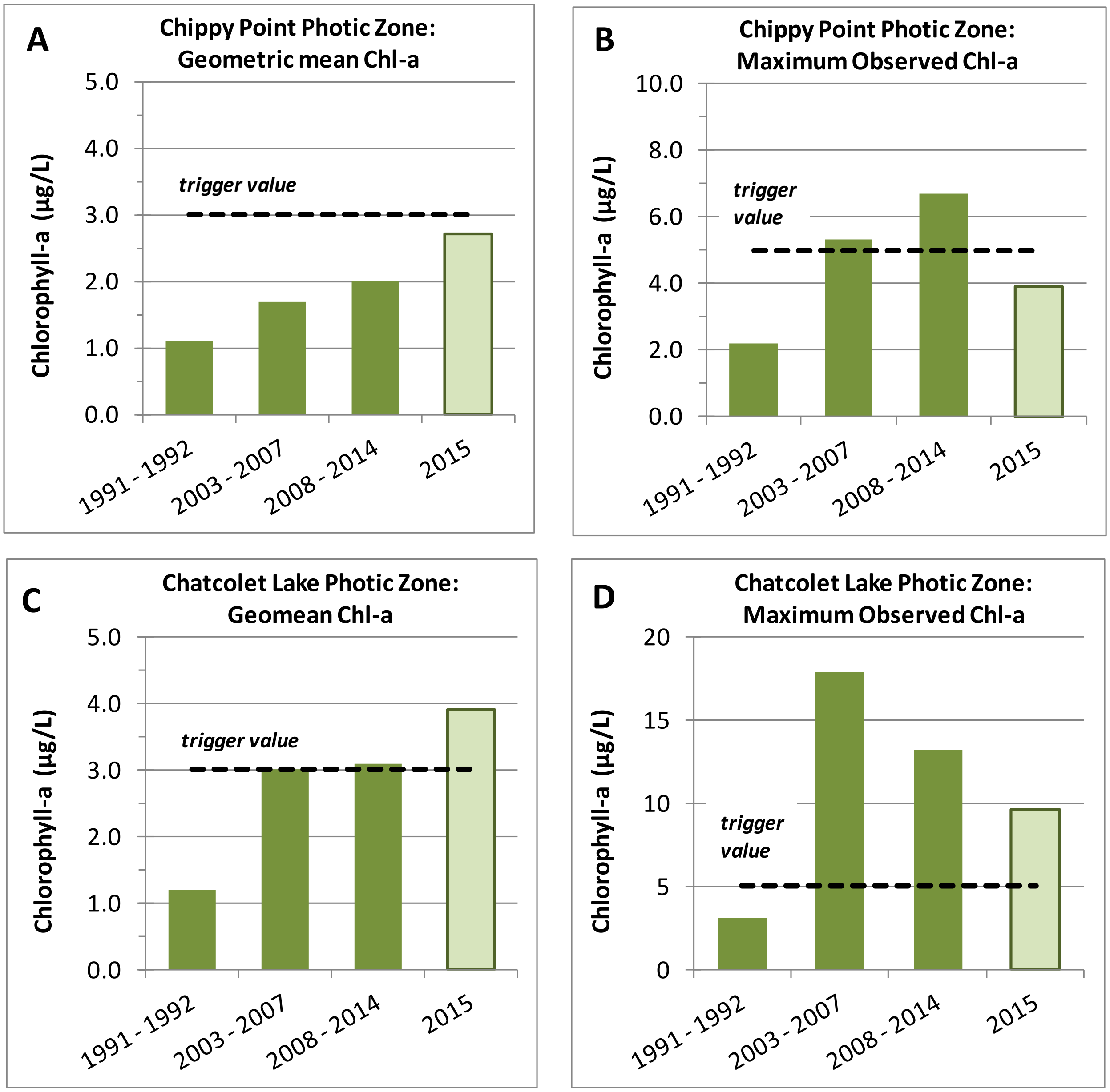


Figure 8. Maximum observed and geometric mean chlorophyll-a values over the reported time period for site C5 Chippy Point photic zone geometric mean (A), C5 Chippy Point photic zone maximum observed (B), C6 Chatcolet Lake photic zone geometric mean (C), and C6 Chatcolet Lake photic zone maximum observed (D).

The chlorophyll-a trend analyses summarized in Table 2 demonstrate that chlorophyll-a levels are generally increasing across the lake. The trend analyses for the 2003 – 2014 time period showed an apparent increase at all monitoring locations, though that increase was significant to within 95% confidence only at the Chippy Point monitoring location in the southern lake (C5). The increase was only significant to within 90% confidence at all other monitoring locations. These trends are also observed for the updated 2003 – 2015 time period. Additionally, the P-value for the trend at C1 Tubbs Hill is now < 0.05 (significant to > 95% confidence). The updated data from 2015 suggests that the trends of increasing chlorophyll-a may be becoming more distinct at C1 Tubbs Hill. Additional data is needed to evaluate this potential change for chlorophyll-a. The trend at C4 University Point remains unchanged. Overall, the 2003 – 2015 chlorophyll-a trends for the northern lake are consistent with the 2003 – 2014 trends. The updated data from 2015 suggests that the trends of increasing chlorophyll-a may be becoming more distinct at the C1 Tubbs Hill monitoring site in the northern lake.

Table 2. Mann-Kendall trend analysis for chlorophyll a (fluorescence method) from 2003-2014 and 2003-2015 (current) at LMP core monitoring sites. Bold P-values are statistically significant at α= 0.05. Italic P-values are statistically significant at α=0.10 but not α=0.05.

Time Period	**Site**	**Depth**	**Variable**	**Mann-Kendall Trend Test (2003–2014, 2003-2015)**			
				Sample Size (n)	**P-Value**	**Theil-Sen Slope [a]**	**Trend**
2003–2014	C1	Photic zone	Chlorophyll-*a*	84	*0.086*	*0.05*	*Increasing*
	C4	Photic zone	Chlorophyll-*a*	84	*0.059*	*0.04*	*Increasing*
	C5	Photic zone	Chlorophyll-*a*	80	**0.030**	**0.06**	**Increasing**
	C6	Photic zone	Chlorophyll-*a*	79	*0.10*	*0.10*	*Increasing*
2003-2015 (current)	C1	Photic zone	Chlorophyll-*a*	92	**0.043**	**0.05**	**Same**
	C4	Photic zone	Chlorophyll-*a*	93	*0.076*	*0.04*	*Same*
	C5	Photic zone	Chlorophyll-*a*	89	**0.005**	**0.08**	**Same**
	C6	Photic zone	Chlorophyll-*a*	88	*0.053*	*0.03*	*Same*

a. Slope is in units of micrograms per liter (µg/L) per year. Positive slope is an increase.

Adding the 2015 chlorophyll-a data to the trend for the Chippy Point monitoring location in the southern pool (C5), lowered the P-value for the increasing trend relative to the 2003 – 2014 trend. For the Chatcolet monitoring site in the southern pool (C6), the P-value for the increasing trend from the 2003-2014 period is lower (more significant) when the 2015 data was added. Overall, the 2010 – 2015 chlorophyll-a trends for Tubbs Hill and Chippy Point are more significant (lower P-value) than for the previously reported 2003 – 2014 trends.

Annual monitoring data for chlorophyll-a are plotted relative to the trends previously reported for the 2003 – 2014 time period in Figure 9 (Tubbs Hill, University Point), and Figure 10 (Chippy Point, Chatcolet Lake). These plots show chlorophyll-a is increasing across the spatial extent of the lake.

1. *Tubbs Hill (C1, northern pool)*— Monitoring data for 2015 are consistent with the 2003-2014 trend line. The median value for 2015 is ~25% higher than trend-line predictions. The annual median value for 2015 is not above the trigger criteria (3 µg/L). The maximum observed value did not exceed the 5 µg/L trigger in 2015. *This represents a continuance of the long-term trend of increasing chlorophyll-a at C1 Tubbs Hill*.

2. *University Point (C4, central pool)*— Monitoring data for 2015 are consistent with the 2003-2014 trend line. The median value for 2015 is within 5% of the trend line prediction. The annual median value for 2015 is below the trigger criteria (3 µg/L). The maximum observed value did not exceed the 5 µg/L trigger. *This represents a continuance of the long-term trend of increasing chlorophyll-a at C4 University Point*.

3. *Chippy Point (C5, southern pool)*— Except for the earliest sampling, monitoring data for 2015 are higher relative to the 2003-2014 trend line. The annual median value of 3.0 µg/L is equal to the trigger and above the trend. *This represents a continuance of the long-term trend of increasing chlorophyll-a at C5 Chippy Point.*

4. *Chatcolet Lake (C6, southern pool)*— Monitoring data for 2015 are consistent relative to the 2003-2014 trend line. The annual median value of 4.4 µg/L is above the 3.0 µg/L trigger and slightly above the trend. *This represents a continuance of the long-term trend of increasing chlorophyll-a trend at C6 Chatcolet Lake.*

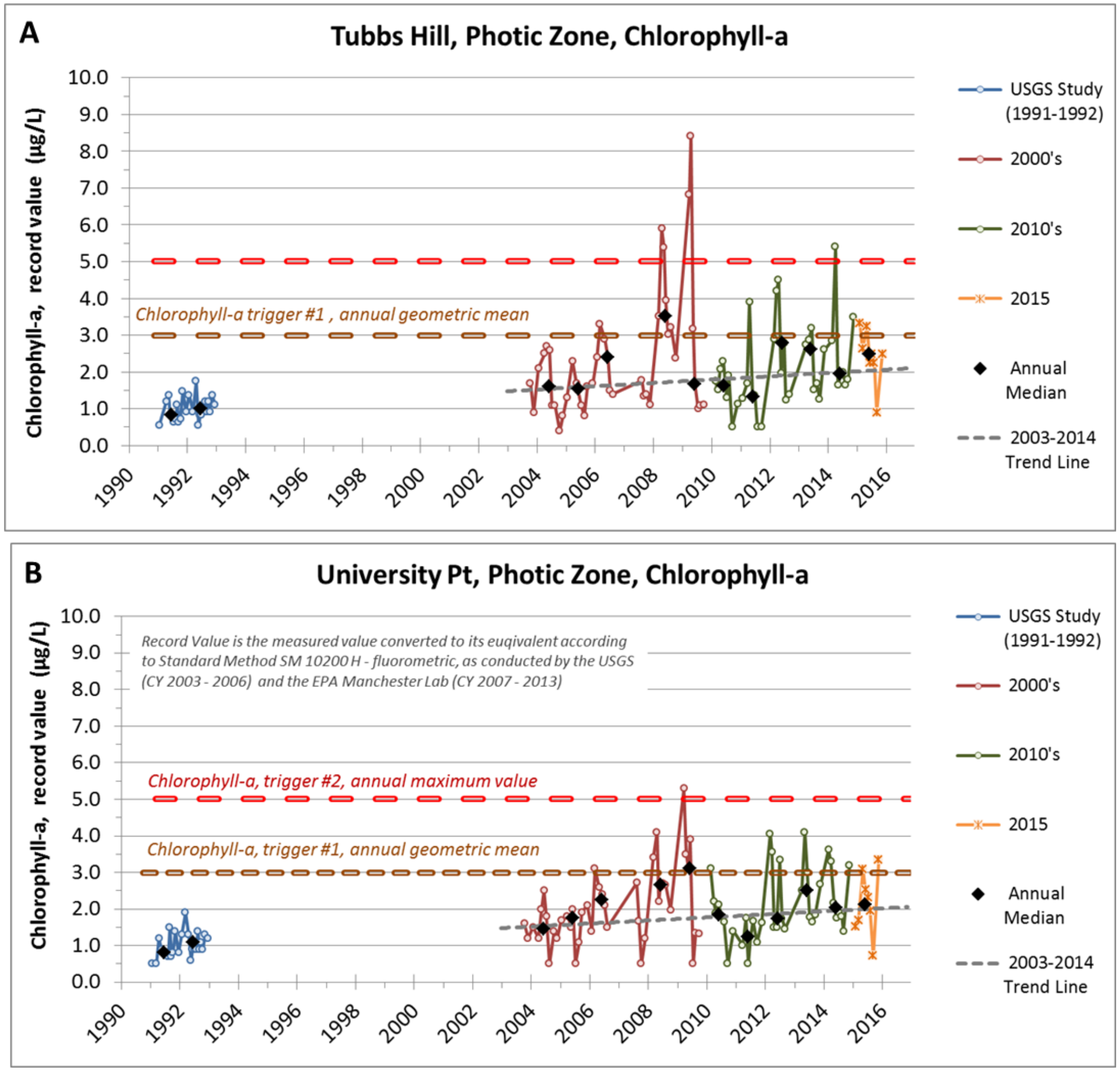


Figure 9. Chlorophyll-a trend data for site C1 Tubbs Hill photic zone (A) and site C4 University Point photic zone (B). Colored points and lines represent *data for different historic periods, black points are annual median values, grey dashed line is the trend calculated from data* for CY 2003-2014, and the brown and red dashed lines are the annual trigger criteria.

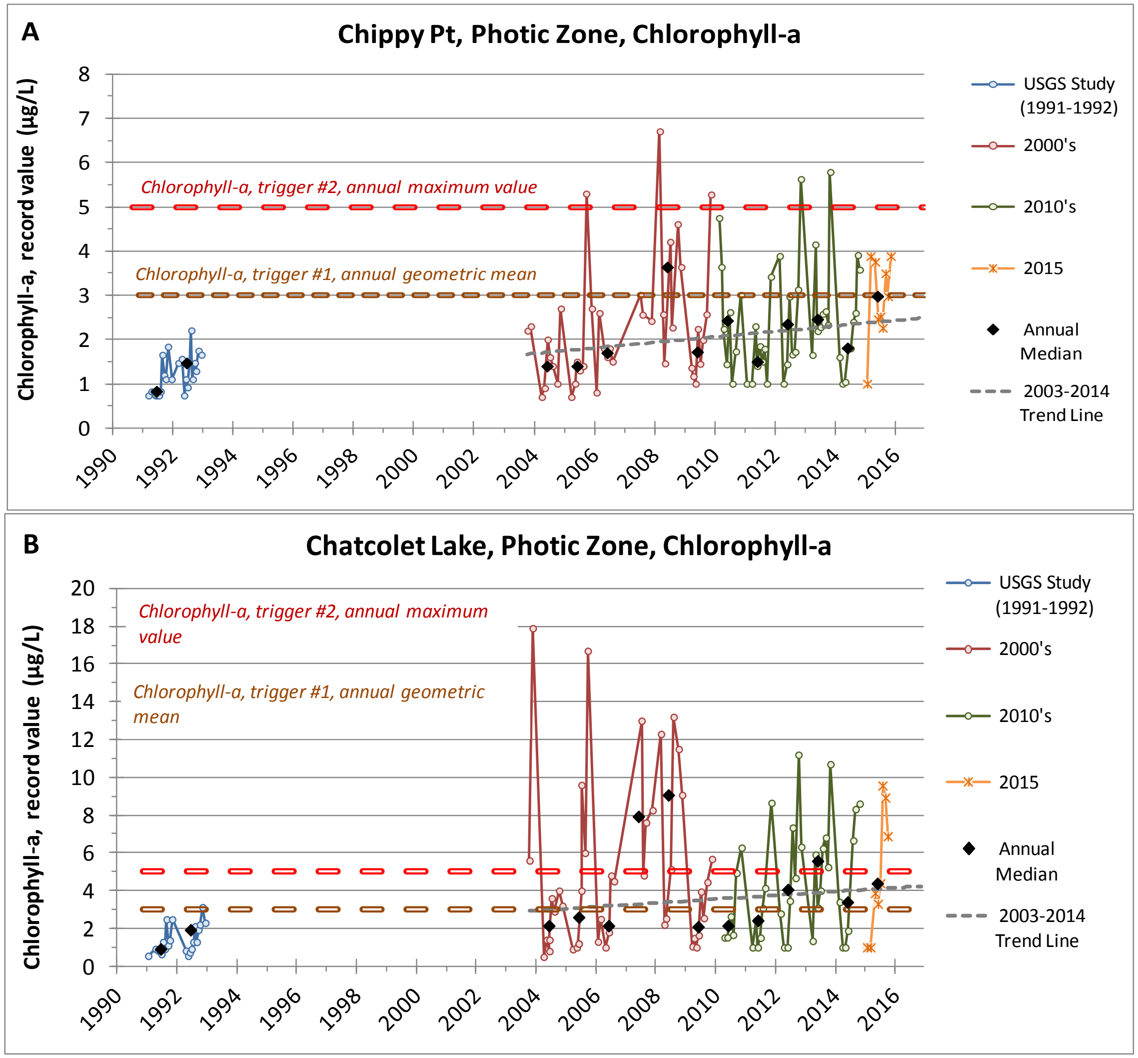


Figure 10. Chlorophyll-a trend data for site C5 Chippy Point photic zone (A) and site C6 Chatcolet Lake photic zone (B). Colored points and lines represent data for different historic periods, black points are annual median values, grey dashed line is the trend calculated from data for CY 2003-2014, and the brown and red dashed lines are the annual trigger criteria.

2.3 Dissolved Oxygen

Current (2015) and multiyear minimum observed and annual median values for near bottom dissolved oxygen in the July – October hypolimnion are presented in Figure 11 for Tubbs Hill (C1) and University Point (C4). Data for the July – October/November hypolimnion are shown in Figure 12 for Chippy Point (C5) and July-September Chatcolet Lake (C6). These data show the following.

- *Tubbs Hill (Jul-Oct near bottom)*— the minimum observed dissolved oxygen for 2015 was above the trigger level of 6 mg/L (meets objectives). This single-year value is higher than the minimum observed for prior multi-year observation periods. The 2015 median value for near bottom dissolved oxygen in the Jul-Oct hypolimnion is consistent with the long-term trend of declining oxygen values at the Tubbs Hill monitoring site.

- *University Point (Jul-Oct near bottom)*— the minimum observed dissolved oxygen for 2015 was above the trigger level of 6 mg/L (meets objectives). This single-year value is higher than the minimum observed for prior multi-year observation periods. The 2015 median value for near bottom dissolved oxygen in the Jul-Oct hypolimnion falls within the range of values previously observed at the University Point monitoring site.

- *Chippy Point (Jul-Oct near bottom)*— the minimum observed dissolved oxygen concentration of 2.3 mg/L for 2015 was below the trigger level of 8 mg/L and was the lowest measured dissolved oxygen concentration for the period of record from 1991 to the present. The median value of 5.5 mg/L is lower than the long term-trend.

- *Chatcolet Lake (Jul-Oct near bottom)*— the minimum observed dissolved oxygen value of 0.0 mg/L for 2015 was below the trigger level of 8 mg/L and the median value of 0.1 mg/L is consistent with seasonal anoxia and the long term-trend.

Results from a Mann-Kendall statistical analysis of long-term trends in hypolimnetic dissolved oxygen is provided in Table 3. Trend charts are presented in Figure 13 for Tubbs Hill (C1) and University Point (C4), and in Figure 14 for Chippy Point (C5) and Chatcolet Lake (C6). These data are discussed on the following pages.

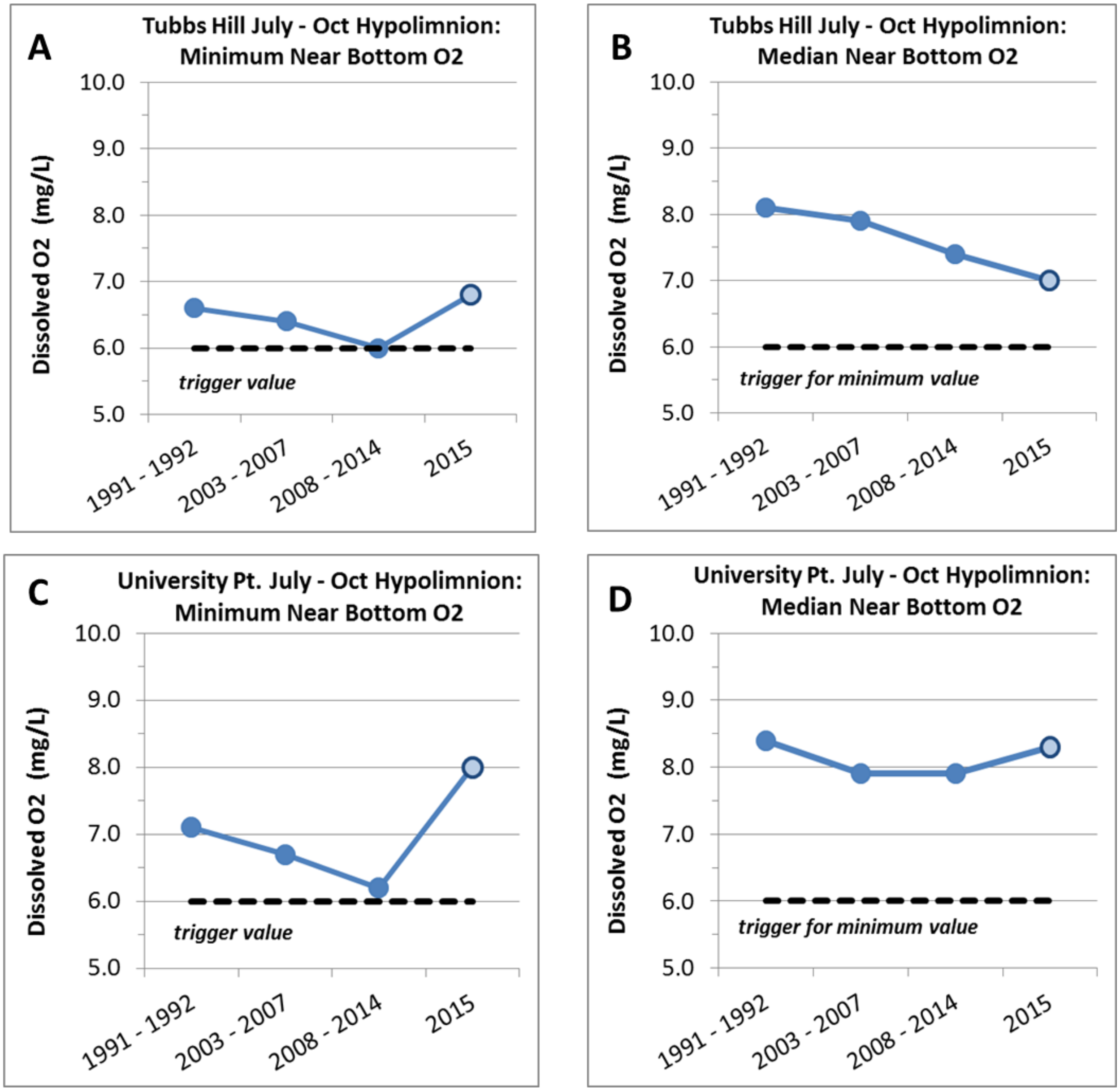


Figure 11. Near bottom dissolved oxygen values for the July – October hypolimnion over the reported time period at site C1 Tubbs Hill minimum observed (A), C1 Tubbs Hill Jul-Oct median (B), C4 University Point minimum observed (C), and C4 University Point median (D).

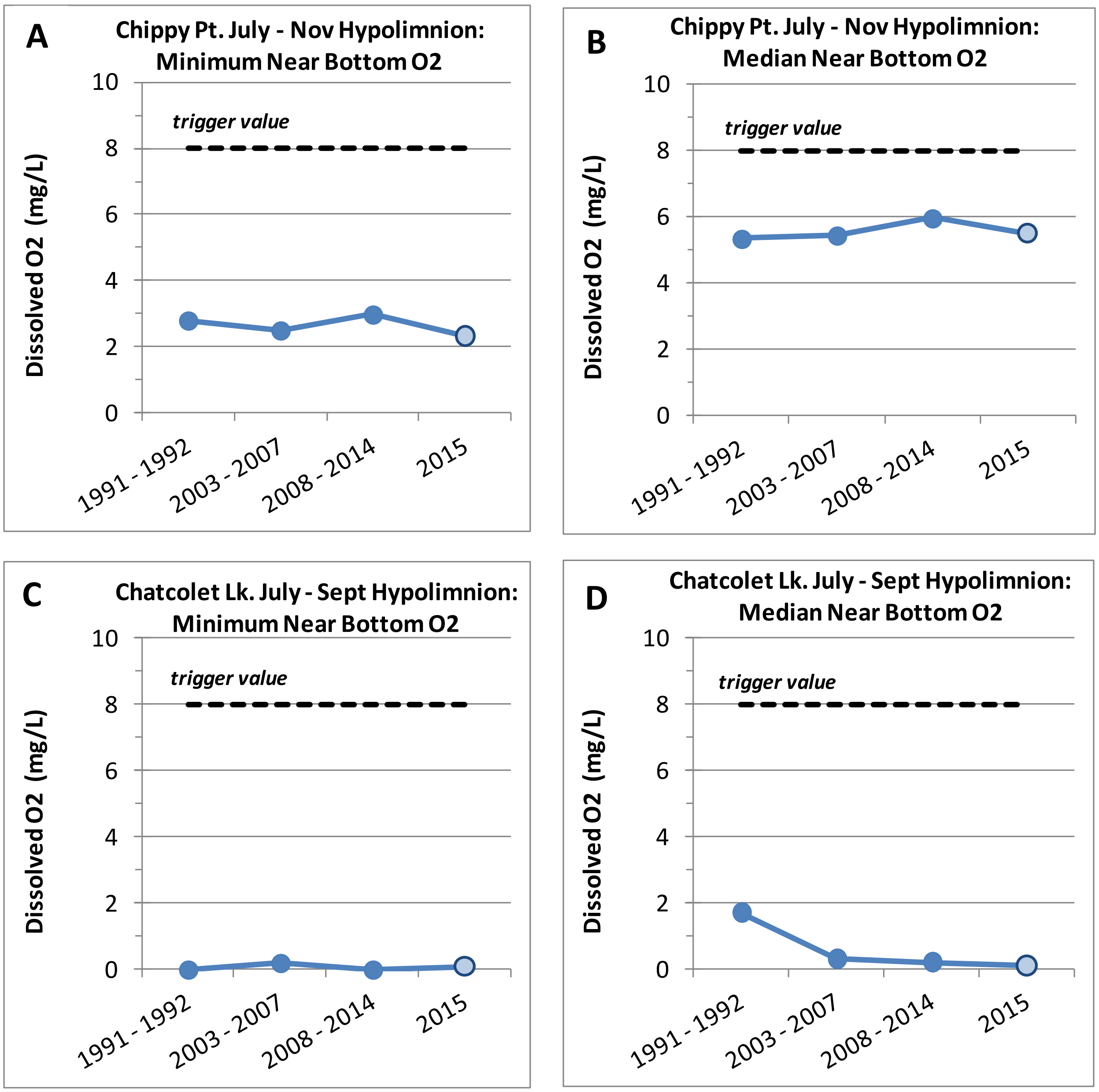


Figure 12. Near bottom dissolved oxygen values for the July – October hypolimnion over the reported time period at site C5 Chippy Point minimum observed (A), C5 Chippy Point Jul-Oct median (B), C6 Chatcolet Lake minimum observed (C), and C6 Chatcolet Lake median (D).

The oxygen trend analyses summarized in Table 3 demonstrate that hypolimnetic dissolved oxygen levels have been slowly decreasing in the northern lake (C1 Tubbs Hill, C4 University Point), but that this decrease is only significant to a high level of confidence (95% confidence) when analyzed over the entire 25 year data record (1991 – 2015). A potential trend is also apparent at the Tubbs Hill location in the northern pool, to a lower degree of confidence for the record for the past 12 years (2003 – 2015). This shorter trend is significant to within 85% confidence for the July – October hypolimnion ($P \leq 0.15$) and to within 90% confidence for the June – September hypolimnion ($P \leq 0.10$). No trend in hypolimnetic dissolved oxygen is observed at C4 University Point for the shorter 12-year record (2003 – 2015). Overall, the updated 2003 – 2015 trends for hypolimnetic dissolved oxygen in the northern lake are consistent with the previously reported trends. A decreasing trend in bottom water oxygen is observed in the 25-year record for both locations in the northern lake (1991 – 2015), but comparable trends are not seen in the more recent record from 2003 – 2015. The more recent record does show a potential trend of decreasing hypolimnetic dissolved oxygen at the C1 Tubbs Hill monitoring site, but this trend is not significant to within 95% confidence.

Note that, for the northern lake (C1, C4), trend analyses for two different summer hypolimnion periods are reported in Table 3. Trends for 1991 – 2015 and for 2003 – 2015 time periods are all for the July-October hypolimnion. Trends for the 2003 – 2014 time period are for the June – September hypolimnion. This discrepancy arose from trying to identify a consistent summer hypolimnion period that applies to both the northern and southern lake, which accommodates the different times at which the hypolimnion can form and dissipate in these disparate regions. Analyses conducted subsequent to the 2008 – 2014 trends report (DEQ and Tribe, 2016) established a consistent seasonal basis for assessing oxygen trends in the summer hypolimnion. This basis is used for the 2003 – 2015 trend analysis in Table 3.

A full 25-year record of monitoring data from 1991 – 2015 is only available for sites in the central and northern lake (C1 Tubbs Hill, C4 University Point). A similar record is not available for the southern lake (C5 Chippy Point, C6 Chatcolet Lake). Data are only available for the 1991 – 1992 time periods and the years since 2003 for these sites in the southern lake. Consequently, trend analyses can only be conducted for data collected since 2003 for the C5 Chippy Point and C6 Chatcolet Lake sites.

The 10-year 2003 – 2014 record for the July – September hypolimnion at C6 and July – November at C5 in the southern lake indicates that bottom water oxygen levels are decreasing at C6 Chatcolet Lake, while there is no trend at C5 Chippy Point. These trends were unchanged for the updated 2003 – 2015 time period. Overall, the 2003 – 2015 dissolved oxygen trends for the southern lake are consistent with the previously reported 2003 – 2014 trends.

Table 3. Mann-Kendall trend analysis beginning for hypolimnetic dissolved oxygen (DO) from 1991-2015, 2003–2014, and 2003-2015 (current) within 1.0 meter of the bottom during the summer stratified period at LMP core monitoring sites. Bold P-values are statistically significant at α level 0.05. Italic P-values are statistically significant at α=0.10 but not α=0.05.

Time Period	Site	Depth	Variable	Mann-Kendall Trend Test (1991–2015, 2003–2014, 2003—2015)			
				Sample Size (n)	P-Value	Theil-Sen Slope [a]	Trend
1991–2015 (Jul-Oct)	C1	Near bottom	DO	77	**0.026**	**-0.03**	**Decreasing**
	C4	Near bottom	DO	73	**0.039**	**-0.02**	**Decreasing**
2003–2015 (C1, C4; Jun-Sept)	C1	Near bottom (Jun-Sept)	DO	39	*0.077*	*-0.06*	*Decreasing*
	C4	Near bottom (Jun – Sept)	DO	35	0.49	0.00	None
2003-2014 (C5)	C5	Near bottom (July-Nov)	DO	48	0.10	0.02	None
(C6)	C6	Near bottom (Jul-Sept)	DO	48	**0.007**	**-0.03**	**Decreasing**
2003-2015 (all sites) Different summer periods	C1	Near bottom (Jul-Oct)	DO	40	*0.15*	*-0.05*	*Same*
	C4	Near bottom (Jul-Oct)	DO	36	0.41	0.01	None
	C5	Near bottom (Jul-Nov)	DO	56	0.34	0.005	None
	C6	Near bottom (Jul-Sept)	DO	**56**	**0.02**	**-0.02**	**Same**

Slope is in units of milligrams per liter (mg/L) per year. Negative slope is a decrease

.

Annual monitoring data for near bottom dissolved oxygen in the July – October hypolimnion are plotted relative to the trends previously reported for the northern lake (C1 Tubbs Hill, C4 University Point) for the 1991 – 2015 and the 2003 – 2015 time periods in Figure 9 (Tubbs Hill, University Point). Data for the southern lake are plotted in Figure 10. Southern lake trends are for the July – November hypolimnion at Chippy Point (C5) and July – September at Chatcolet Lake (C6). These plots show the following, across the spatial extent of the lake.

1. *Tubbs Hill (C1, northern pool)*— Monitoring data for 2015 are consistent with both the 1991 – 2014 and 2003 – 2014 trend lines. The median for 2015 is within 5% of the trend line prediction. The minimum observed value for 2015 is above the trigger criteria (6 mg/L). *This represents a continuance of the long-term trend of decreasing hypolimnetic dissolved O_2 at C1 Tubbs Hill*.

2. *University Point (C4, central pool)*— Monitoring data for 2015 are consistent with both the 1991 – 2014 and 2003 – 2014 trend lines. The median value for 2015 is ~8% higher than trend-line predictions. The minimum observed value for 2015 is above the trigger criteria (6 mg/L). *This represents a continuance of the long-term trend of decreasing hypolimnetic dissolved O_2 at C4 University Point*. *However, this trend is weaker than that at Tubbs Hill and the last 3 years data are higher than those predicted by the both the 1991 – 2014 and 2003 – 2014 trend lines*.

3. *Chippy Point (C5, southern pool)*— Monitoring data for 2015 are consistent with the 2003-2014 trend line. The annual median value of 5.5 mg/L is lower than the trigger and trend. *This represents the continuance of a neutral long term trend characterized by seasonal hypoxia in the hypolimnion.*

4. *Chatcolet Lake (C6, southern pool)*— Monitoring data for 2015 are consistent with the 2003-2014 trend line, but variability is high at this site depending on when anoxia develops in the hypolimnion. The annual median value of 0.1 mg/L is lower than the trigger and trend. *This represents a continuance of a decreasing long-term trend with seasonal anoxia in the hypolimnion.*

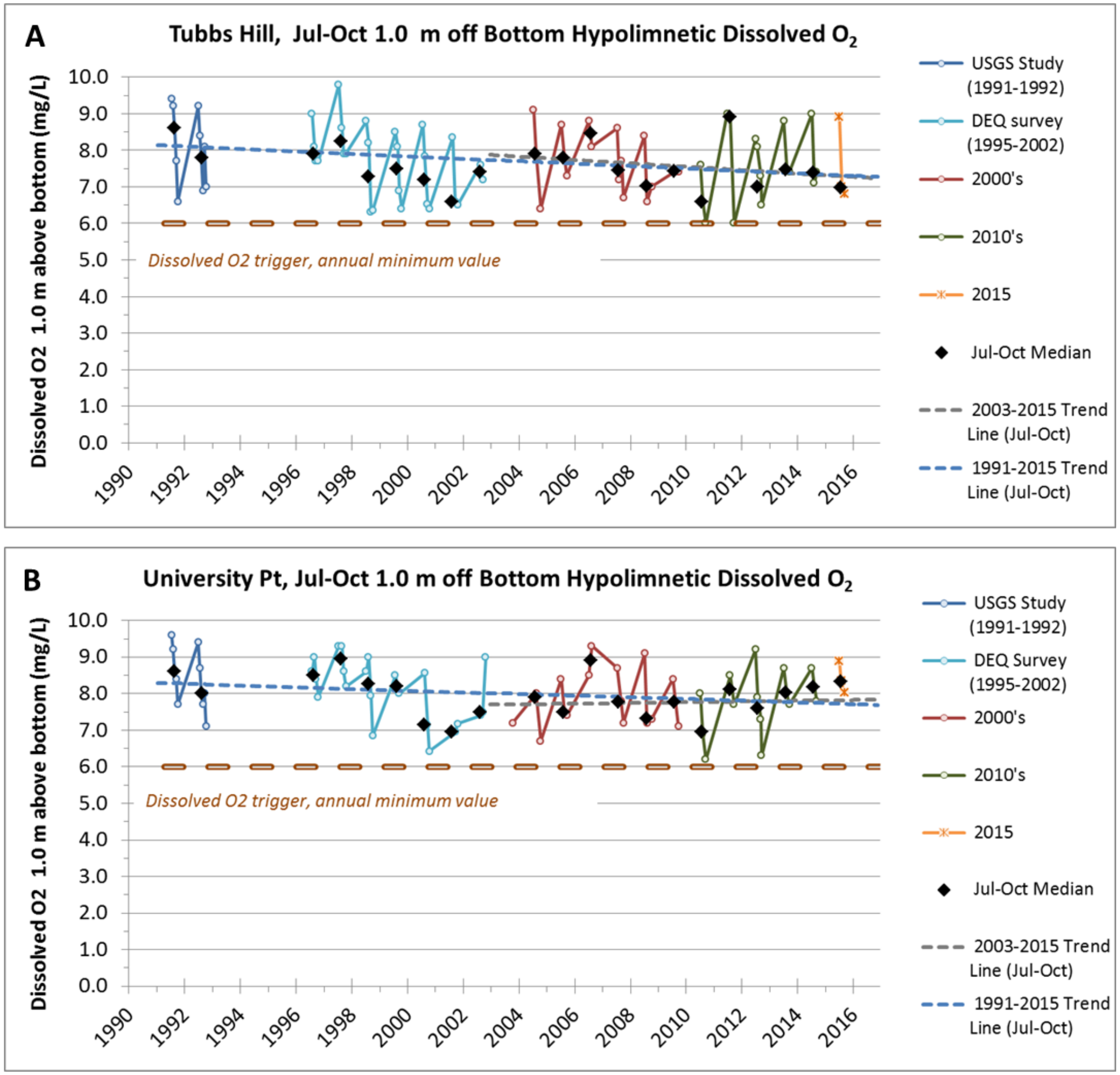


Figure 13. Near bottom dissolved oxygen trend data for the July – October hypolimnion at C1 Tubbs Hill (A) and C4 University Point (B). Colored points and lines represent data for different historic periods, black points are annu*al median values, dashed lines are the trend calculated from data for CY 2003-2015 and CY 1991 – 2015*, and the brown dashed line is the trigger criteria.

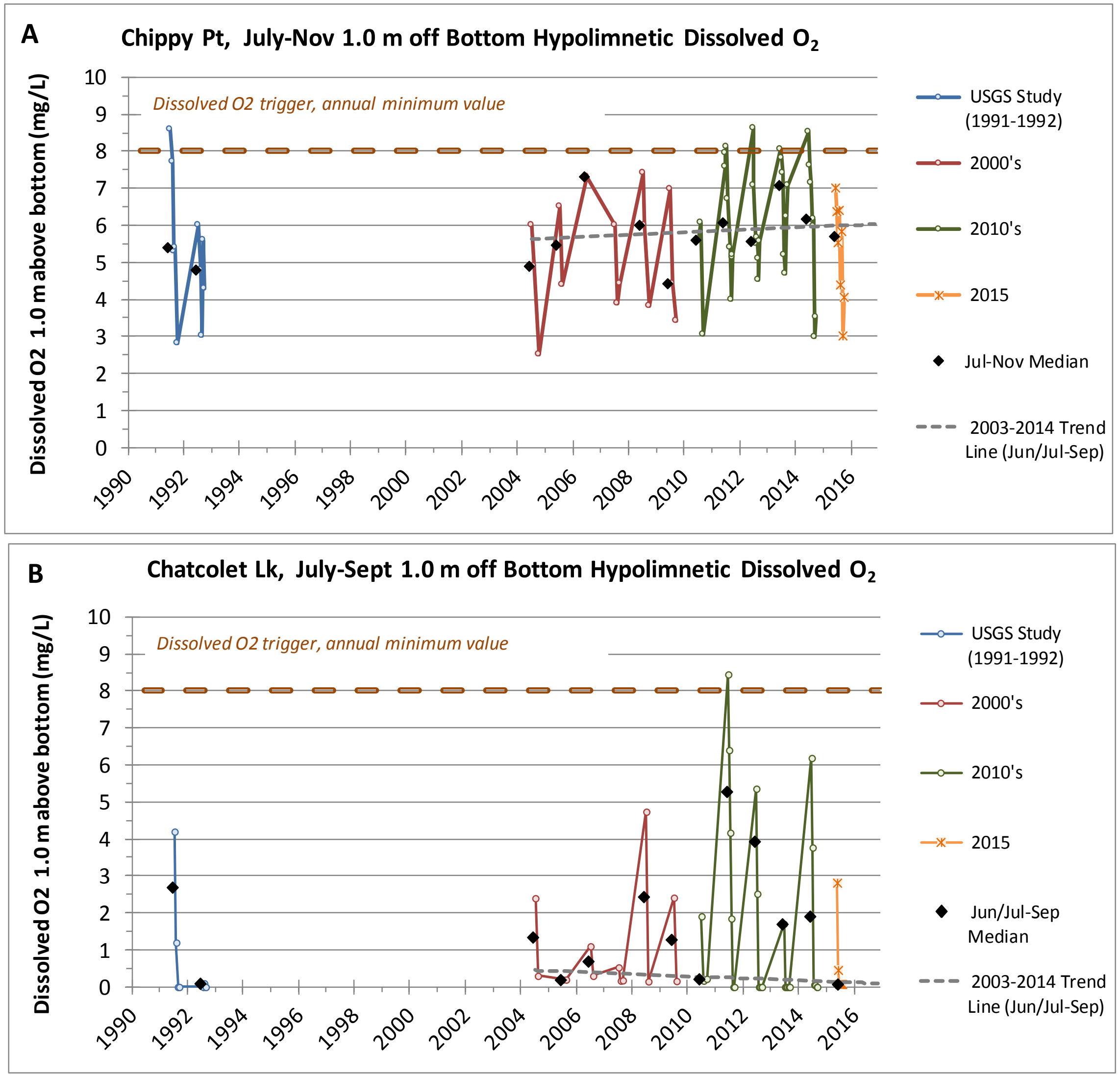


Figure 14. Near bottom dissolved oxygen trend data for the July – November Hypolimnion at site C5 Chippy Point (A) and July-September at site C6 Chatcolet Lake (B). Colored points and lines represent data for different historic periods, black points are annual median values, grey dashed line is the trend calculated from data for CY 2003-2014, and the brown dashed line is the trigger criteria.

2.4 Dissolved Zinc

Current (2015) and multiyear geometric mean values for dissolved zinc (Zn) are presented in Figure 15 for all depths at site C1 Tubbs Hill and site C4 University point in the northern lake. For the southern lake, data for specific depths (i.e. photic zone, near bottom) at Chippy Point are also presented in Figure 15. Metals data are not provided for site C6 Chatcolet Lake, as there are too few data points to enable meaningful analysis. Dissolved metals levels at this site are below detection levels for over 70% of samples. These data show the following.

- *Tubbs Hill (overall water column)*— geometric mean dissolved zinc for 2015 exceeded the trigger value of 36 µg/L. Values are consistent with the trend of decreasing concentrations observed for the 2003 – 2014 time period.
- *University Point (overall water column)*— geometric mean dissolved zinc for 2015 exceeded the trigger value of 36 µg/L. Values are consistent with the trend of decreasing concentrations observed for the 2003 – 2014 time period.
- *Chippy Point (photic zone)*— geometric mean dissolved zinc for 2015 does not exceed the hardness-based trigger value range of 27 µg/L – 33 µg/L. Values are consistent with the neutral trend observed for the 2003 – 2014 time period.
- *Chippy Point (near bottom)*— geometric mean dissolved zinc for 2015 exceeds the hardness-based trigger value range of 27 µg/L – 33 µg/L. Values are consistent with the neutral trend observed for the 2003 – 2014 time period.

Results from a Mann-Kendall statistical analysis of long-term trends in dissolved zinc is provided in Table 4. Trend charts are presented in Figure 16 for Tubbs Hill (C1), Figure 17 for University Point (C4), and in Figure 18 for Chippy Point (C5). No metals trend data are presented for site C6 Chatcolet Lake.

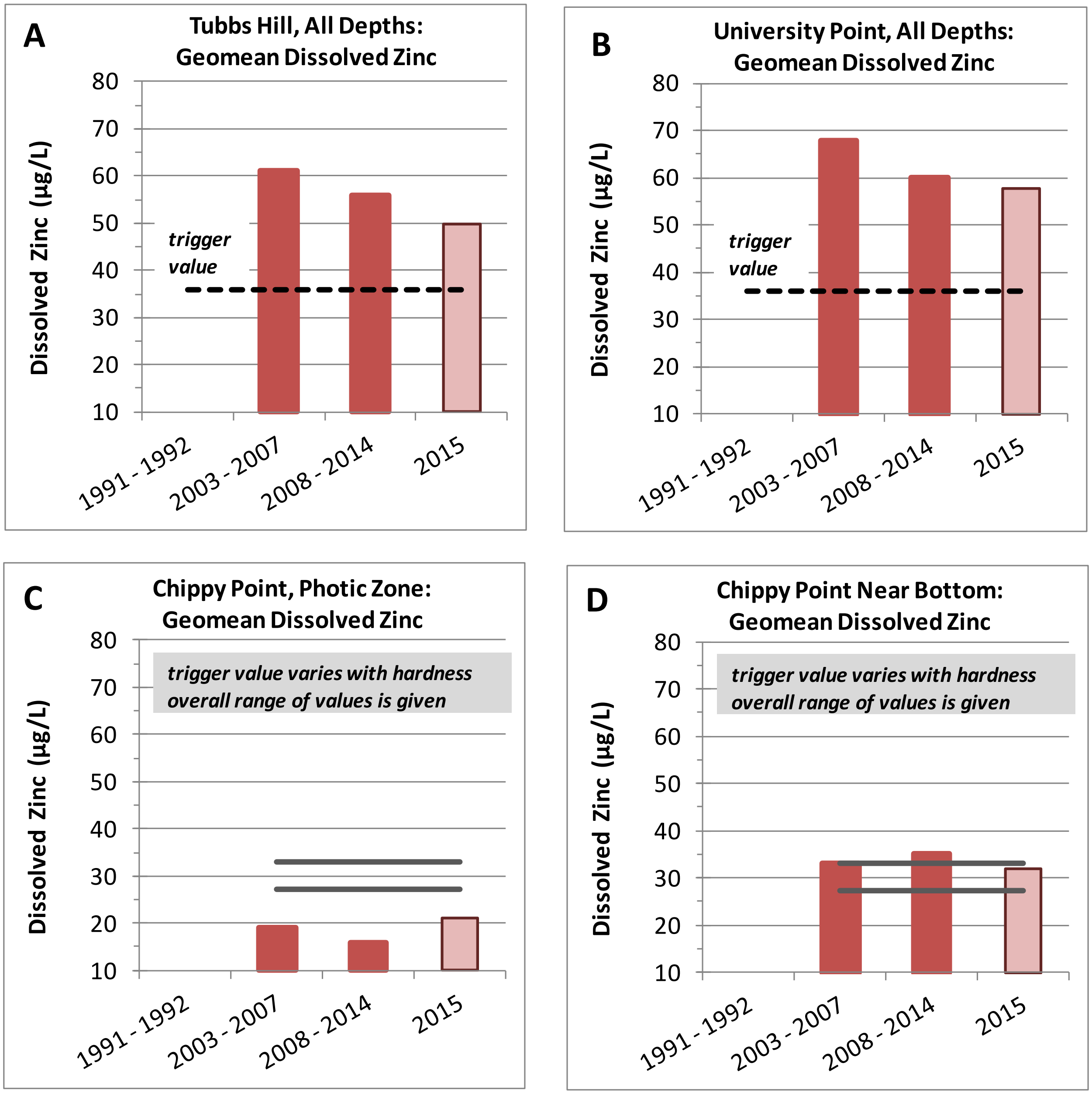


Figure 15. Dissolved zinc geometric mean values over the reported time period for all depths at site C1 Tubbs Hill (A), all depths at site C4 University Point (B) the photic zone at site C5 Chippy Point (C), and the near bottom at site C5 Chippy Point (D).

The zinc trend analyses summarized in Table 4 demonstrate that dissolved zinc levels are generally decreasing in the lake, though some differences are observed in different regions of the lake. In the northern pool (C1, Tubbs Hill), dissolved zinc decreased over the 2003 – 2014 time period for all depths. These trends are also observed for the updated 2003 – 2015 time period.

For the central pool (C4, University Point), dissolved zinc trends for the updated 2003 – 2015 time period are the same as in the prior 2003 – 2014 time period for all depths. Overall, the 2003 – 2015 dissolved zinc trends for the northern lake are consistent with the previously reported 2003 – 2014 trends. Note that zinc data was not collected at 30 m depth in the northern lake in 2015, and thus the trend for 30 m depth cannot be updated at this time.

Table 4. Mann-Kendall trend analysis from 2003-2014 and 2003-2015 (current) for dissolved zinc (Zn) at LMP core monitoring sites. Bold P-values are statistically significant at α=0.05. Italic P-values are statistically significant at α=0.10 but not at α=0.05

Time Period	Site	Depth	Variable	Mann-Kendall Trend Test (2003–2014, 2003-2015)			
				Sample Size (n)	P-Value	Theil-Sen Slope [a]	Trend
2003–2014	C1	Photic zone	Diss. Zn	82	**0.013**	**-0.61**	**Decreasing**
	C1	20-meter depth	Diss. Zn	62	**<0.001**	**-1.4**	**Decreasing**
	C1	30-meter depth	Diss. Zn	65	**<0.001**	**-1.3**	**Decreasing**
	C1	Near bottom	Diss. Zn	78	**0.003**	**-0.96**	**Decreasing**
2003-2015	C1	Photic zone	Diss. Zn	90	**0.006**	**-0.59**	**Same**
	C1	20-meter depth	Diss. Zn	62	**<0.001**	**-1.4**	**Same**
	C1	30-meter depth	Diss. Zn	65	**<0.001**	**-1.3**	**Same**
	C1	Near bottom	Diss. Zn	86	**0.0001**	**-1.1**	**Same**
2003-2014	C4	Photic zone	Diss. Zn	81	**0.025**	**-0.75**	**Decreasing**
	C4	20-meter depth	Diss. Zn	78	**<0.001**	**-1.4**	**Decreasing**
	C4	30-meter depth	Diss. Zn	65	**0.001**	**-1.4**	**Decreasing**
	C4	Near bottom	Diss. Zn	81	**<0.001**	**-1.6**	**Decreasing**
2003-2015	C4	Photic zone	Diss. Zn	89	**0.027**	**-0.62**	**Same**
	C4	20-meter depth	Diss. Zn	85	**< 0.001**	**-1.2**	**Same**
	C4	30-meter depth	Diss. Zn	65	**0.001**	**-1.4**	**Same**
	C4	Near bottom	Diss. Zn	89	**< 0.001**	**-1.5**	**Same**
2003-2014	C5	Photic zone	Diss. Zn	83	0.40	-0.05	None
	C5	Near bottom	Diss. Zn	84	0.38	-0.22	None
2003-2015	C5	Photic zone	Diss. Zn	92	0.47	0.00	Same
	C5	Near bottom	Diss. Zn	92	0.45	0.05	Same
2003-2014	C6	Photic zone	Diss. Zn	80	N/A[b]		N/A
	C6	Near bottom	Diss. Zn	80	N/A[b]		N/A
2003-2015	C6	Photic zone	Diss. Zn	88	N/A[c]		N/A
	C6	Near bottom	Diss. Zn	88	N/A[c]		N/A

a. Slope is in units of micrograms per liter (µg/L) per year. Negative slope is a decrease.
b. Dissolved zinc concentrations were less than the minimum reporting limit 73 % of the time.
c. Dissolved zinc concentrations were less than the minimum reporting limit 80 % of the time.

For the Chippy Point monitoring site in the southern pool (C5), dissolved zinc displayed no trends at any depth during the 2003 – 2014 time period. No zinc trend was observed for the updated 2003 – 2015 time period. Most metal samples were below detection limits at the Chatcolet Lake monitoring location, and therefore trends cannot be assessed at that location. Overall, the 2003 – 2015 dissolved zinc trends for the southern lake are consistent compared to the previously reported 2003 – 2014 trends.

Annual monitoring data for dissolved zinc are plotted relative to the 2003 – 2014 trends in Figure 16 (Tubbs Hill), Figure 17 (University Point), and Figure 18 (Chippy Point). These plots show different patterns of lake status relative to long-term trends at different combinations of depth and monitoring location.

1. *Tubbs Hill (C1, northern pool)*— Monitoring data for 2015 are consistent with the 2003-2014 trend line for all depths where monitoring data is available. The annual median value is within 5% of the trend line prediction at both depths. The annual median value is above both the trigger criteria (36 µg/L) for all depths where data is available. Monitoring data is not available for 20m or 30 m depth. *This data represents a continuance of the long-term trend of decreasing dissolved zinc at C1 Tubbs Hill.*

2. *University Point (C4, central pool)*— Monitoring data for 2015 are consistent with the 2003-2014 trend line for all depths where monitoring data is available. The annual median value is within 5% of the trend line prediction in the photic zone, 12% above predictions at 20m depth, and 8% above predicted values at the near bottom depth interval. The annual median value is above both the trigger criteria (36 µg/L) for all depths where data is available. Monitoring data is not available for 30 m depth. *This data represents a continuance of the long-term trend of decreasing dissolved zinc at C4 University Point.*

3. *Chippy Point (C5, southern pool)*— Monitoring data for 2015 from the photic zone are consistent with the 2003-2014 trend line. The annual median value of 25.0 µg/L in the photic zone is lower than the trigger and trend. Monitoring data for 2015 from the near bottom is consistent with the 2003-2014 trend line. The annual median value of 56.9 µg/L in the near bottom is higher than the trigger and trend. *This data represents a continuance of the long-term neutral trend of dissolved zinc at C5 Chippy Point.*

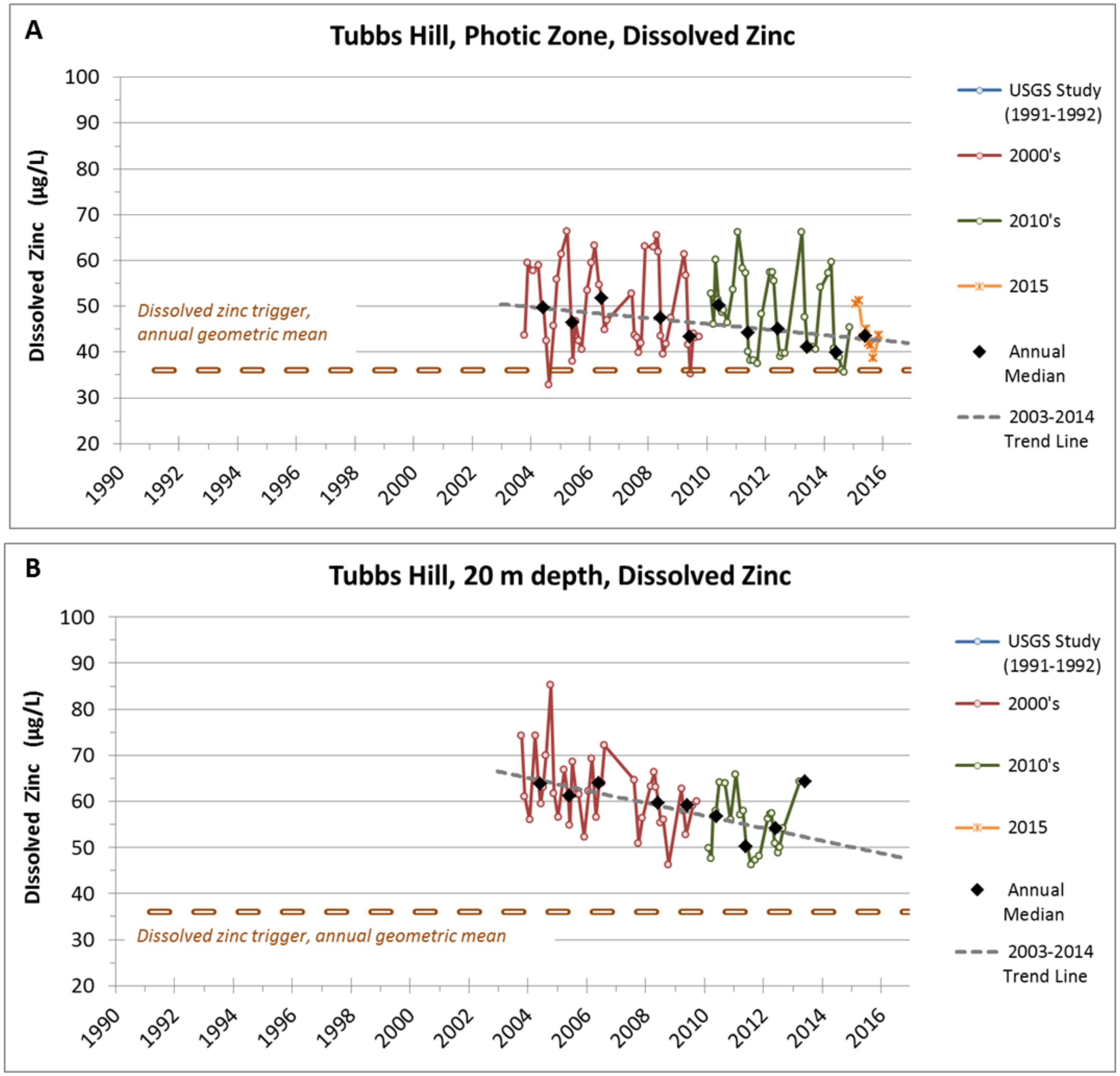
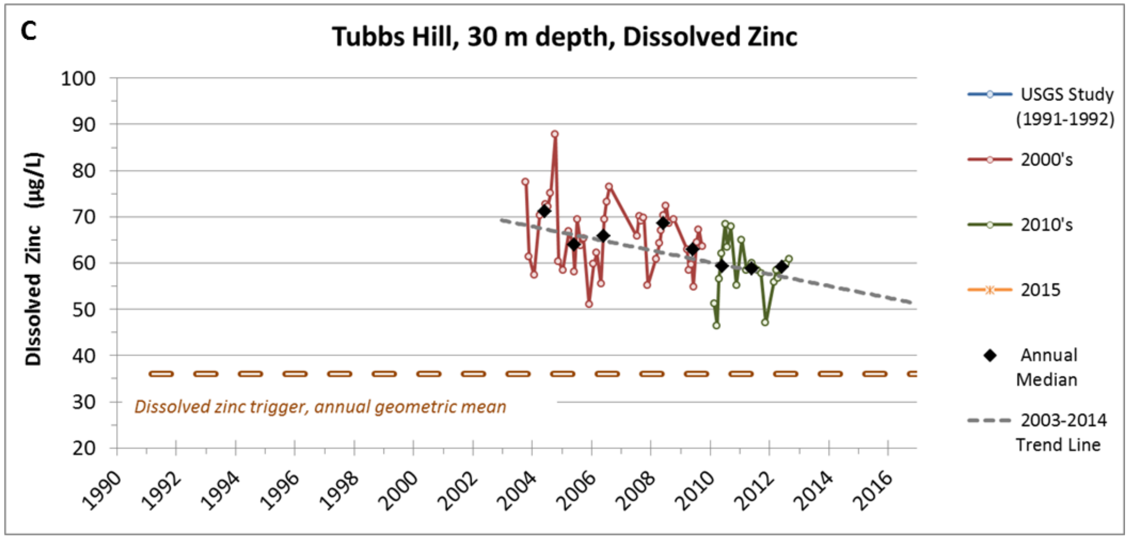


Figure 16. Dissolved zinc trend data for site C1 Tubbs Hill photic zone (A), 20 m depth (B), 30 m depth (C), and near bottom (D). Colored points and lines represent data for different historic periods, black points are annual median values, grey dashed line is the trend calculated from data for CY 2003-2014, and the brown dashed line is the trigger criteria.



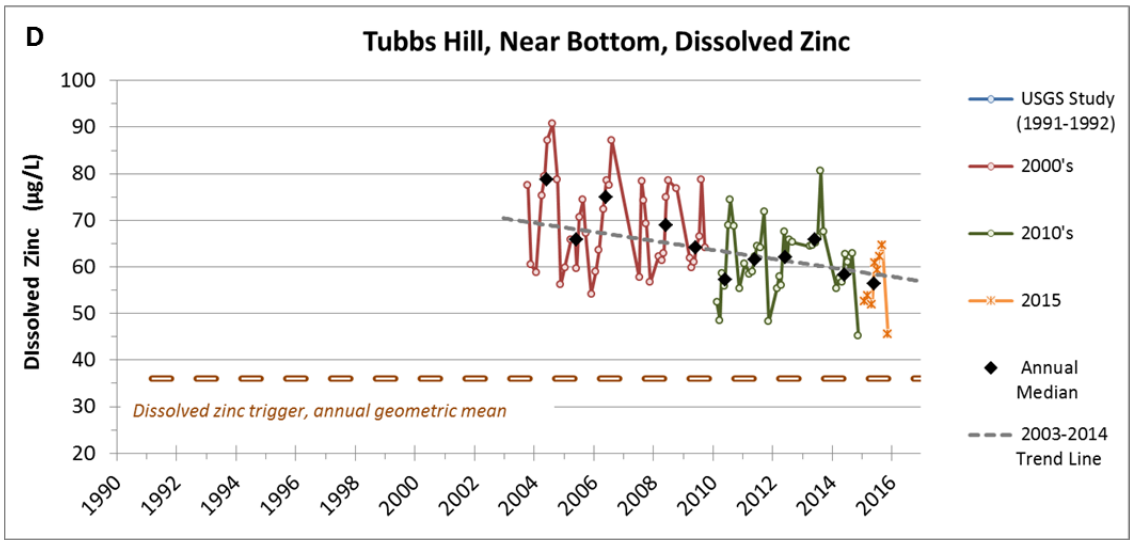


Figure16 (continued). Dissolved zinc trend data for site C1 Tubbs Hill photic zone (A), 20 m depth (B), 30 m depth (C), and near bottom (D). Colored points and lines represent data for different historic periods, black points are annual median values, grey dashed line is the trend calculated from data for CY 2003-2014, and the brown dashed line is the trigger criteria.

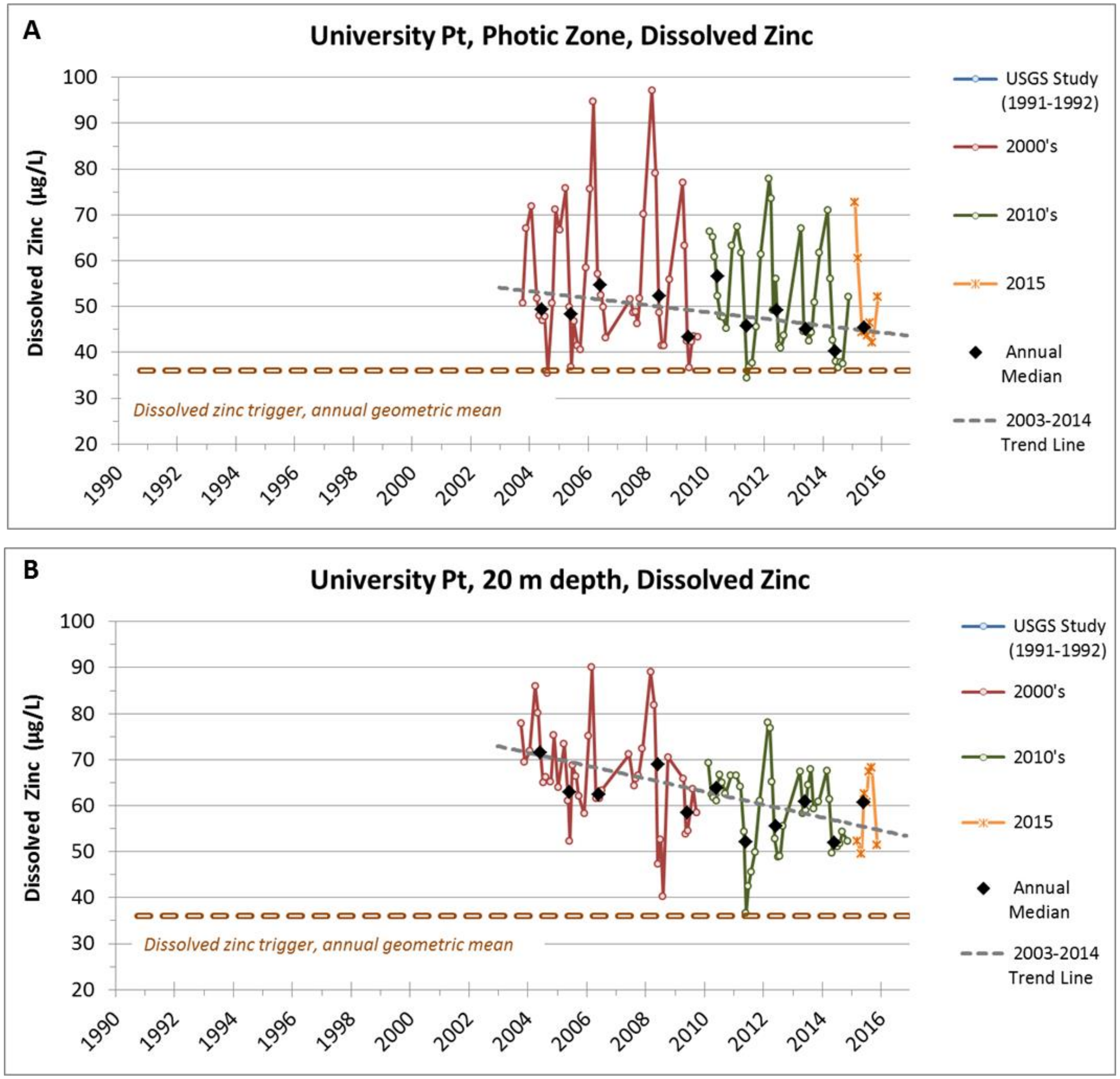
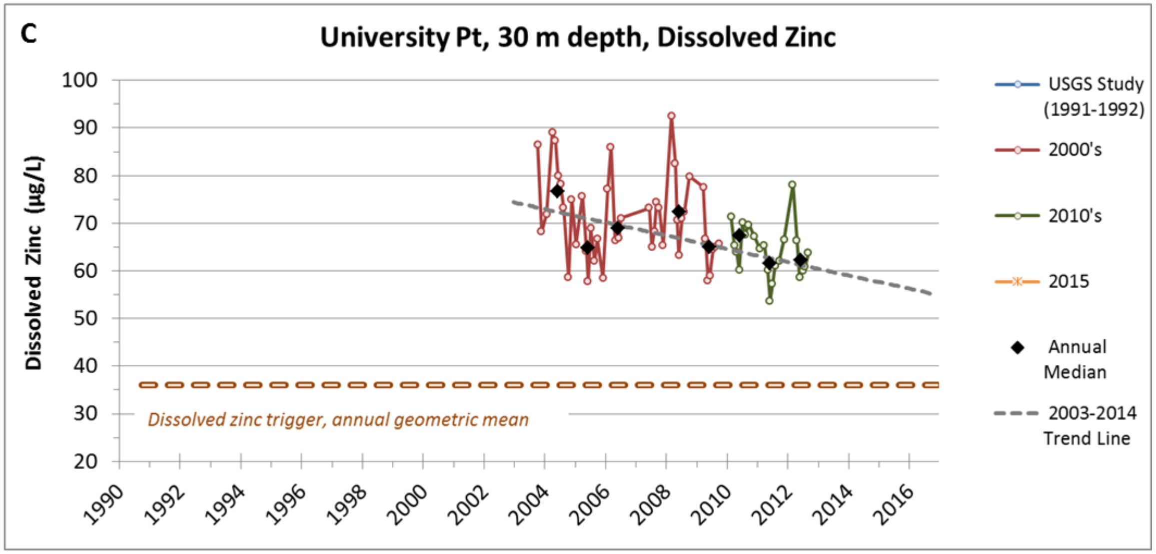


Figure 17. Dissolved zinc trend data for site C4 University Point photic zone (A), 20 m depth (B), 30 m depth (C), and near bottom (D). Colored points and lines represent data for different historic periods, black points are annual median values, grey dashed line is the trend calculated from data for CY 2003-2014, and the brown dashed line is the trigger criteria.



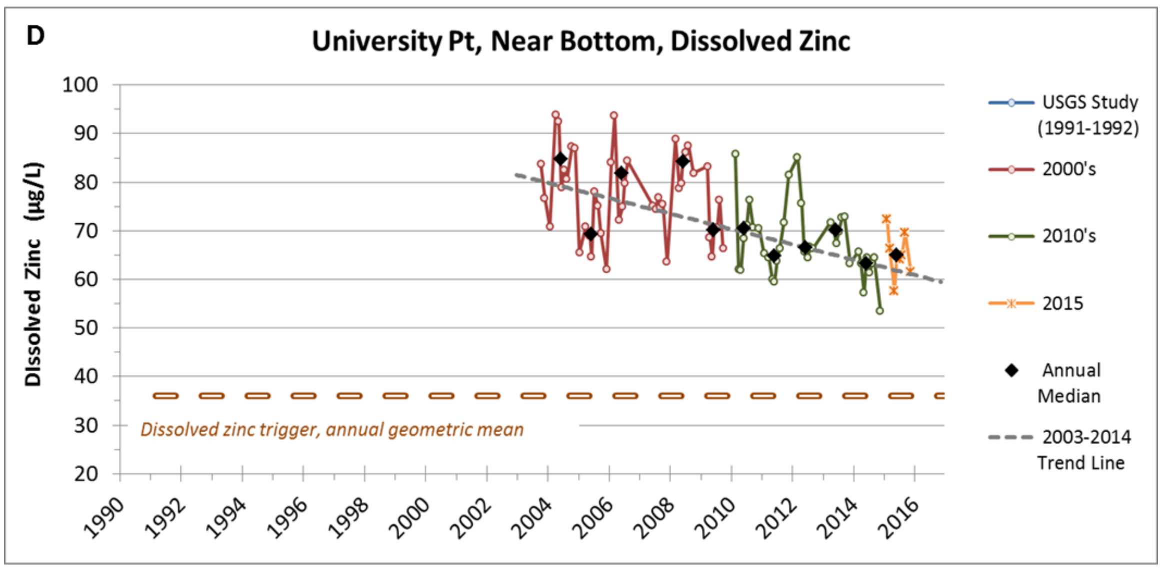


Figure 17 (continued). Dissolved zinc trend data for site C4 University Point photic zone (A), 20 m depth (B), 30 m depth (C), and near bottom (D). Colored points and lines represent data for different historic periods, black points are annual median values, grey dashed line is the trend calculated from data for CY 2003-2014, and the brown dashed line is the trigger criteria.

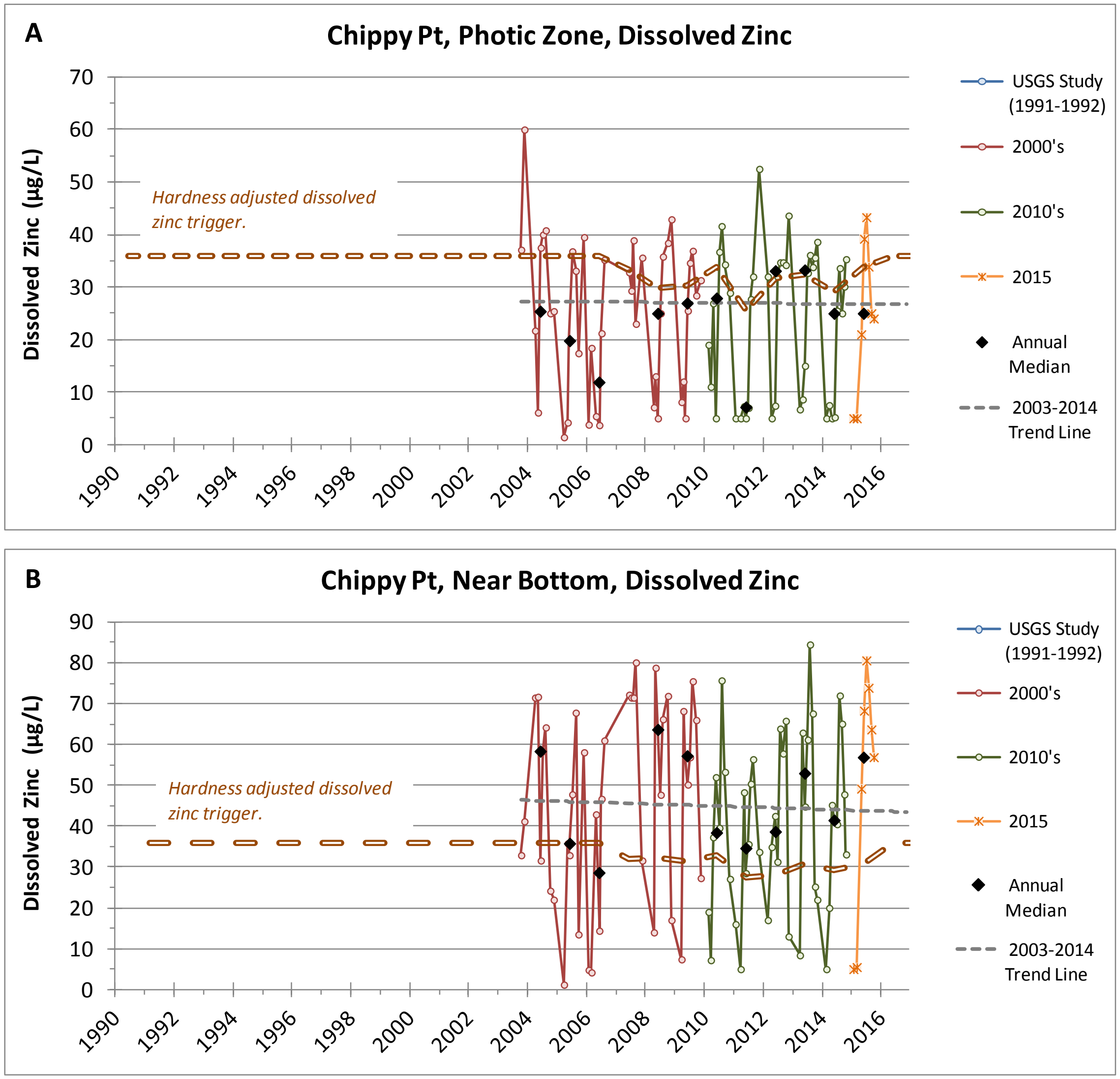


Figure 18. Dissolved zinc trend data for site C5 Chippy Point photic zone (A) and C5 Chippy Point near bottom (B). Colored points and lines represent data for different historic periods, black points are annual median values, grey dashed line is the trend calculated from data for CY 2003-2014, and the brown dashed line is the trigger criteria.

2.5 Dissolved Lead

Current (2015) and multiyear geometric mean values for dissolved lead (Pb) are presented in Figure 19 for all depths at site C1 Tubbs Hill and site C4 University point in the northern lake. For the southern lake, data for specific depths (i.e. photic zone, near bottom) at Chippy Point are also presented in Figure 19. Metals data are not provided for site C6 Chatcolet Lake, as there are too few data points to enable meaningful analysis. Dissolved metals levels at this site are below detection levels for over 90% of samples. These data show the following.

- *Tubbs Hill (overall water column)*— geometric mean dissolved lead for 2015 did not exceed the trigger value of 0.54 µg/L. Observed values for 2015 are lower than the trend of increasing concentrations observed for the 2003 – 2014 time period.
- *University Point (overall water column)*— geometric mean dissolved lead for 2015 did not exceed the trigger value of 0.54 µg/L. Observed values for 2015 are consistent with the trend of increasing concentrations observed for the 2003 – 2014 time period.
- *Chippy Point (photic zone)*— geometric mean dissolved lead for 2015 does not exceed the hardness-based trigger value range of 0.37 µg/L – 0.47 µg/L. Values are consistent with the neutral trend observed for the 2003 – 2014 time period.
- *Chippy Point (near bottom)*— geometric mean dissolved lead for 2015 does not exceed the hardness-based trigger value range of 0.37 µg/L – 0.47 µg/L. Values are consistent with the neutral trend observed for the 2003 – 2014 time period.

Results from a Mann-Kendall statistical analysis of long-term trends in dissolved lead is provided in Table 5. Trend charts are presented in Figure 20 for Tubbs Hill (C1), Figure 21 for University Point (C4), and in Figure 22 for Chippy Point (C5). No metals trend data are presented for site C6 Chatcolet Lake.

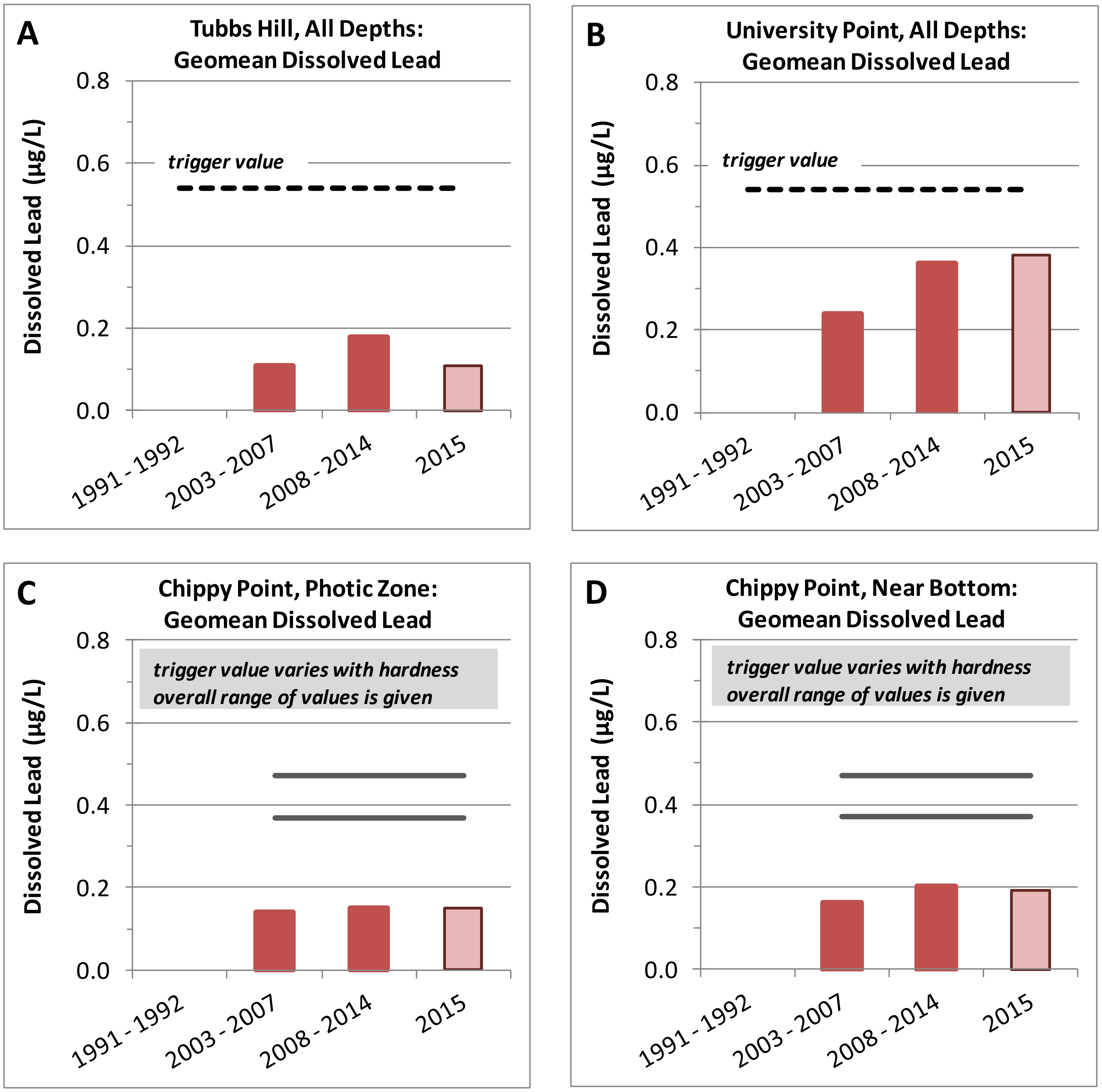


Figure 19. Dissolved lead geometric mean values over the reported time period for all depths at site C1 Tubbs Hill (A), all depths at site C4 University Point (B) the photic zone at site C5 Chippy Point (C), and the near bottom at site C5 Chippy Point (D).

The lead trend analyses summarized in Table 5 demonstrate that notably different lead trends are observed in different regions of the lake. For some locations, lead trends also vary with depth interval. In the northern pool (C1, Tubbs Hill), dissolved lead increased over the 2003 – 2014 time period for the 20m, 30m, and near bottom depth intervals. No trend was observed in the photic zone. These trends are also observed for the updated 2003 – 2015 time period. However, the P-value for the near bottom sample is ~50% higher for the updated 2003 – 2015 trend relative to that for the prior 2003 – 2014 trend and represents a shift from a trend that is significant at 95% confidence to one that is only significant to within 90% confidence. This shift may arise from the unique hydrologic conditions in 2015, and additional data are needed. For the central pool (C4, University Point), dissolved lead trends for the updated 2003 – 2015 time period are the same as in the prior 2003 – 2014 time period for all depths. Overall, the 2003 – 2015 dissolved lead trends for the northern lake are consistent with the previously reported 2003 – 2014 trends. Note that lead data was not collected at 30 m depth in the northern lake in 2015, and thus the trend for 30 m depth cannot be updated at this time.

Table 5. Mann-Kendall trend analysis from 2003-2014 and 2003-2015 (current) for dissolved lead (Pb) at LMP core monitoring sites. Bold P-values are statistically significant at α=0.05. Italic P-values are statistically significant at α=0.10 but not at α=0.05

Time Period	Site	Depth	Variable	Mann-Kendall Trend Test (2003–2014, 2003-2015)			
				Sample Size (n)	P-Value	Theil-Sen Slope [a]	Trend
2003–2014	C1	Photic zone	Diss. Pb	85	0.30	0.000	None
	C1	20-meter depth	Diss. Pb	62	**0.001**	**0.017**	**Increasing**
	C1	30-meter depth	Diss. Pb	66	**0.014**	**0.015**	**Increasing**
	C1	Near bottom	Diss. Pb	78	**0.044**	**0.011**	**Increasing**
2003-2015	C1	Photic zone	Diss. Pb	90	0.49	0.000	Same
	C1	20-meter depth	Diss. Pb	62	**0.001**	**0.017**	**Same**
	C1	30-meter depth	Diss. Pb	66	**0.014**	**0.015**	**Same**
	C1	Near bottom	Diss. Pb	86	*0.088*	*0.003*	*Same*
2003-2014	C4	Photic zone	Diss. Pb	81	0.26	0.0025	None
	C4	20-meter depth	Diss. Pb	79	0.33	0.000	None
	C4	30-meter depth	Diss. Pb	66	**0.044**	**0.022**	**Increasing**
	C4	Near bottom	Diss. Pb	81	0.50	0.000	None
2003-2015	C4	Photic zone	Diss. Pb	89	0.42	0.000	Same
	C4	20-meter depth	Diss. Pb	86	0.34	0.000	Same
	C4	30-meter depth	Diss. Pb	66	**0.044**	**0.022**	**Same**
	C4	Near bottom	Diss. Pb	89	0.35	0.002	Same
2003-2014	C5	Photic zone	Diss. Pb	83	0.26	0.000	None
	C5	Near bottom	Diss. Pb	84	0.16	0.004	None
2003-2015	C5	Photic zone	Diss. Pb	92	0.34	0.000	Same
	C5	Near bottom	Diss. Pb	92	0.29	0.001	Same
2003-2014	C6	Photic zone	Diss. Pb	80	N/A[b]		N/A
	C6	Near bottom	Diss. Pb	80	N/A[b]		N/A
2003-2015	C6	Photic zone	Diss. Pb	88	N/A[c]		N/A
	C6	Near bottom	Diss. Pb	88	N/A[c]		N/A

a. Slope is in units of micrograms per liter (µg/L) per year. Negative slope is a decrease.
b. Dissolved lead concentrations were less than the minimum reporting limit 91 % of the time.
c. Dissolved lead concentrations were less than the minimum reporting limit 92 % of the time.

For the Chippy Point monitoring site in the southern pool (C5), dissolved lead displayed no trends at any depth during the 2003 – 2014 time period. No lead trend was observed for the updated 2003 – 2015 time period. Most metal samples were below detection limits at the Chatcolet Lake monitoring location, and therefore trends cannot be assessed at that location. Overall, the 2003 – 2015 dissolved lead trends for the southern lake are neutral, and are consistent compared to the previously reported 2003 – 2014 trends.

Annual monitoring data for dissolved lead are plotted relative to the 2003 – 2014 trends in Figure 20 (Tubbs Hill), Figure 21 (University Point), and Figure 22 (Chippy Point). These plots show different patterns of lake status relative to long-term trends at different combinations of depth and monitoring location.

1. *Tubbs Hill (C1, northern pool)*— Monitoring data for 2015 are consistent with the 2003-2014 trend line for all depths where monitoring data is available. The annual median value is 20 – 30% below trend line predictions. The annual median value is above below the trigger criteria (0.54 µg/L) for all depths where data is available. Monitoring data is not available for 20m or 30 m depth in 2015. *This data represents a continuance of the long-term trend of increasing dissolved lead at C1 Tubbs Hill*.

2. *University Point (C4, central pool)*— Monitoring data for 2015 are consistent with the 2003-2014 trend line for all depths where monitoring data is available. The annual median value is 57% below trend line predictions in the photic zone and ~10% below predictions at the 20 m and near bottom depth intervals. The annual median value is above below the trigger criteria (0.54 µg/L) for all depths where data is available. Monitoring data is not available for 30 m depth in 2015. *This data is consistent with the long-term trend of increasing lead at only one depth at C4 University Point (30 m).*

3. *Chippy Point (C5, southern pool)*— Monitoring data for 2015 from the photic zone are consistent with the 2003-2014 trend line. The annual median value of 0.15 µg/L in the photic zone is lower than the trigger and equal to the trend. Monitoring data for 2015 from the near bottom is consistent with the 2003-2014 trend line. The annual median value of 0.19 µg/L in the near bottom is lower than the trigger and equal to the trend. *This data represents a continuance of the long-term neutral trend of dissolved lead at C5 Chippy Point.*

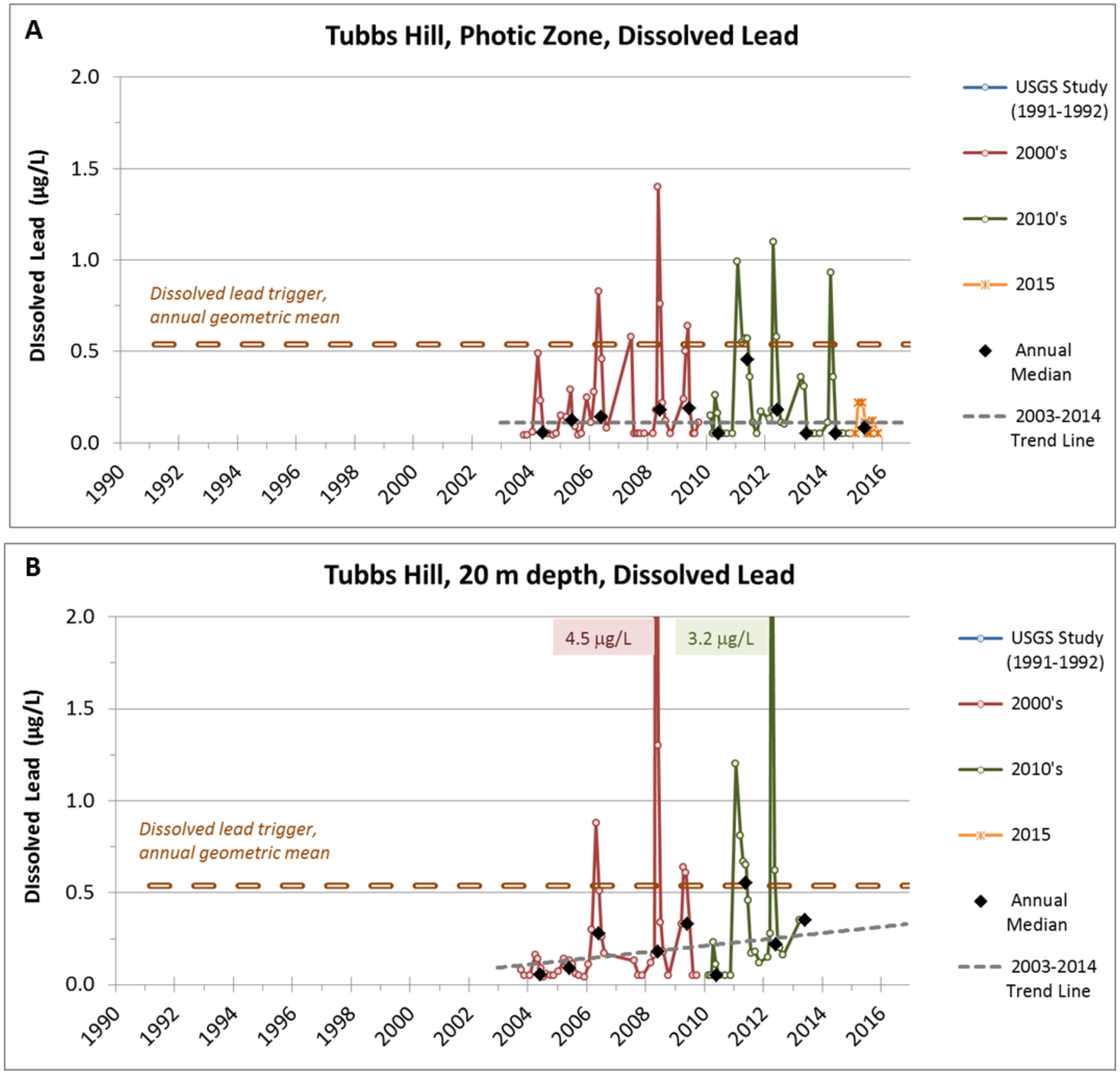
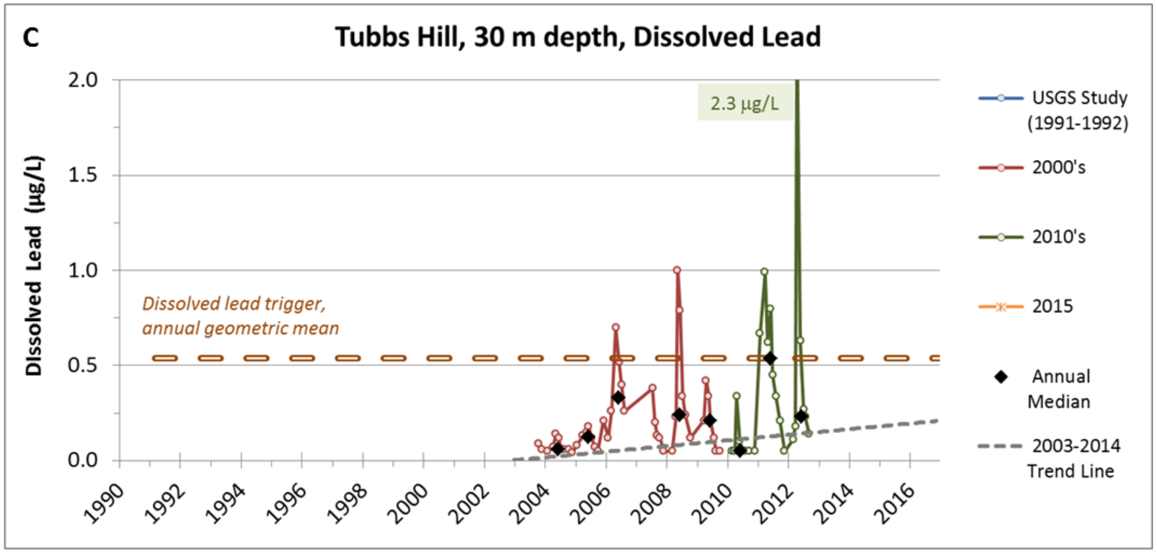


Figure 20. Dissolved lead trend data for site C1 Tubbs Hill photic zone (A), 20 m depth (B), 30 m depth (C), and near bottom (D). Colored points and lines represent data for different historic periods, black points are annual median values, grey dashed line is the trend calculated from data for CY 2003-2014, and the brown dashed line is the trigger criteria.



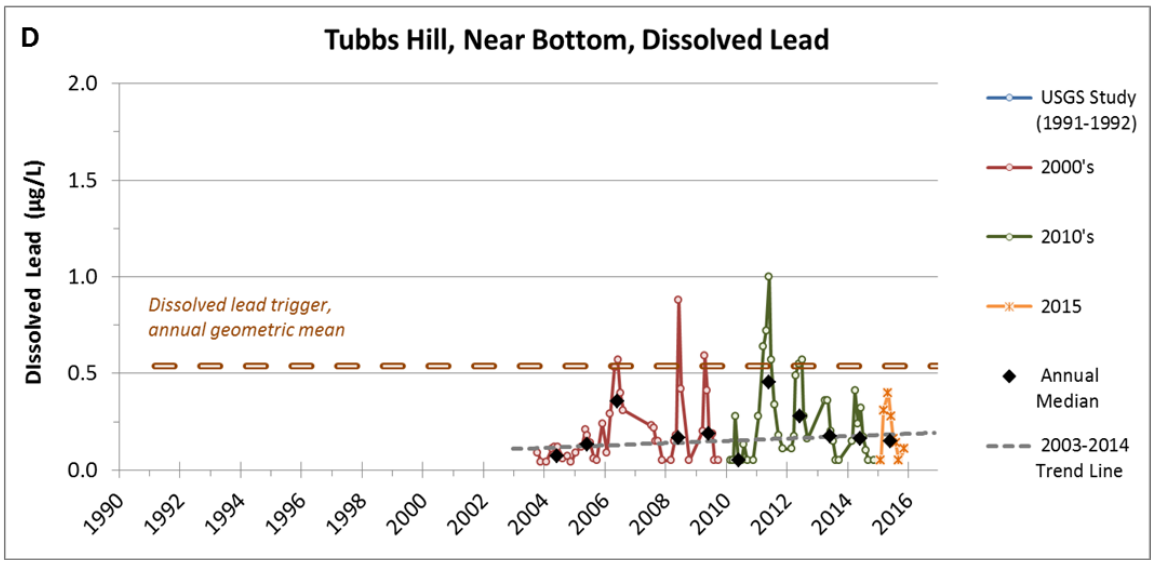
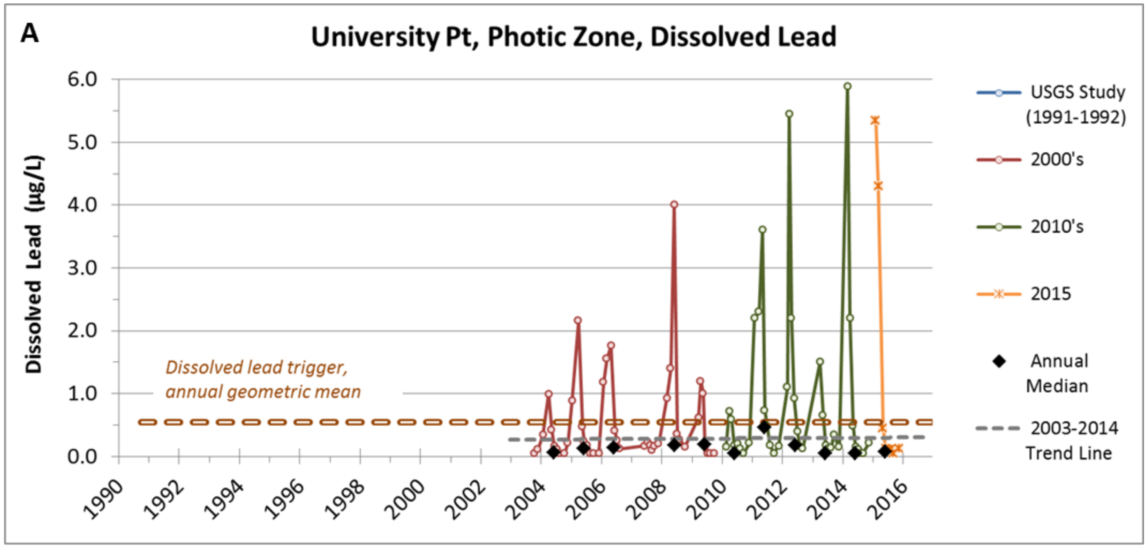


Figure 20 (continued). Dissolved lead trend data for site C1 Tubbs Hill photic zone (A), 20 m depth (B), 30 m depth (C), and near bottom (D). Colored points and lines represent data for different historic periods, black points are annual median values, grey dashed line is the trend calculated from data for CY 2003-2014, and the brown dashed line is the trigger criteria.



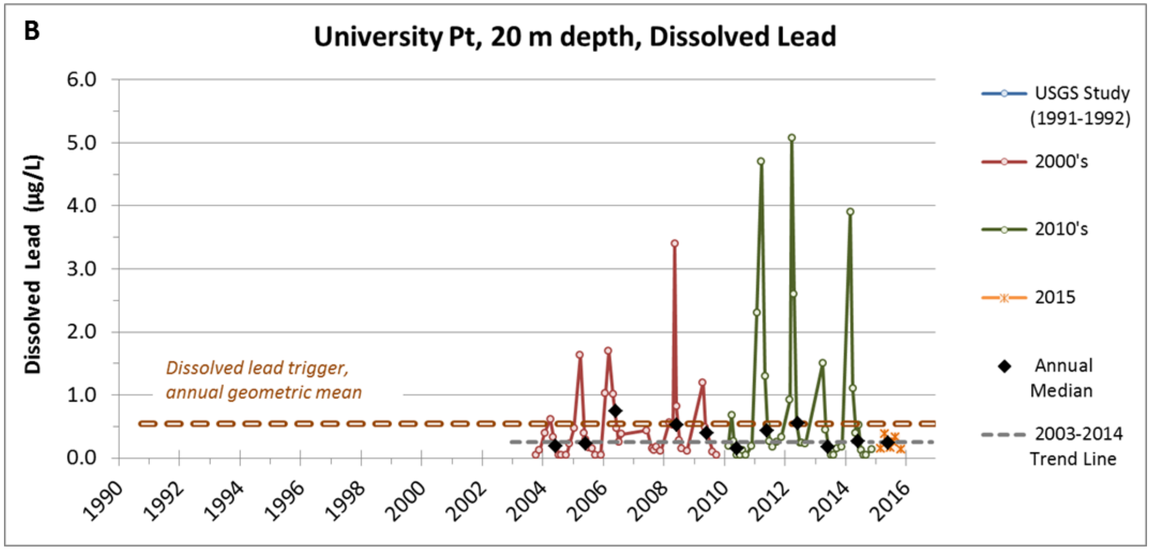
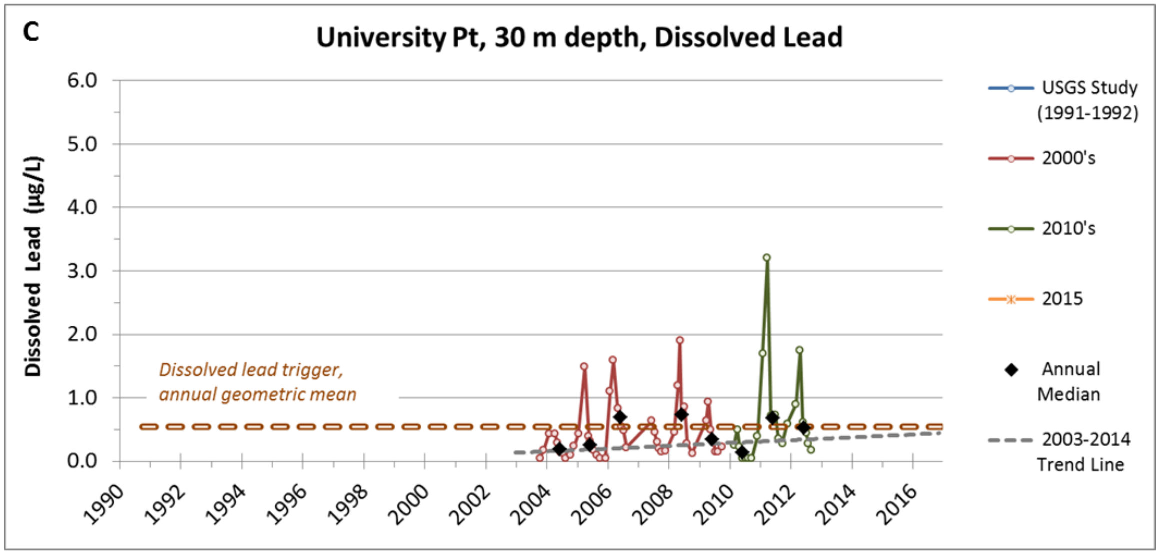


Figure 21. Dissolved lead trend data for site C4 University Point photic zone (A), 20 m depth (B), 30 m depth (C), and near bottom (D). Colored points and lines represent data for different historic periods, black points are annual median values, grey dashed line is the trend calculated from data for CY 2003-2014, and the brown dashed line is the trigger criteria.



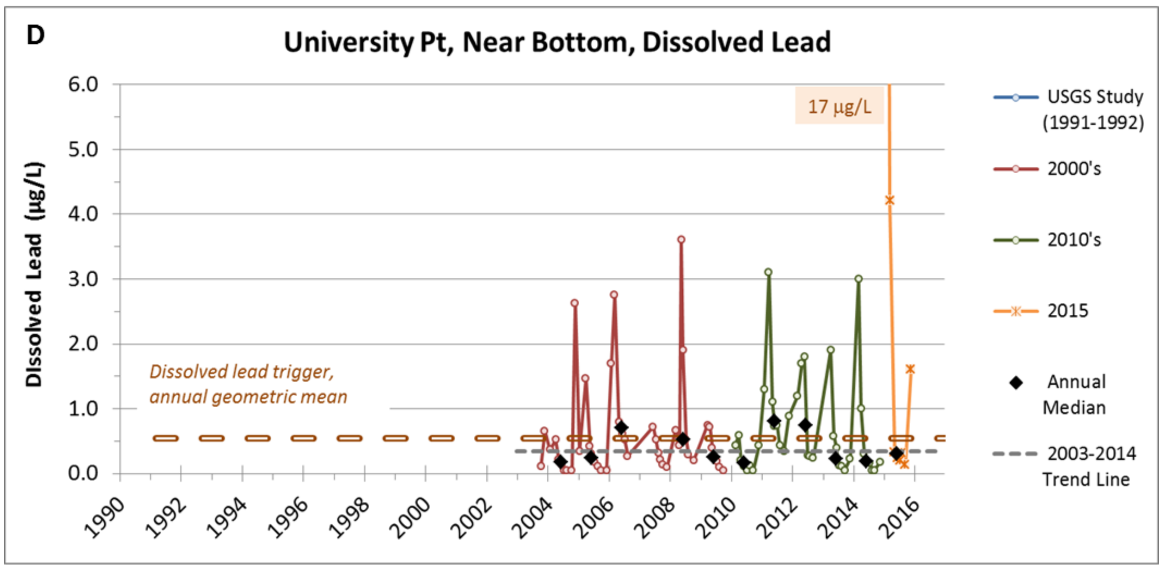


Figure 21 (continued). Dissolved lead trend data for site C4 University Point photic zone (A), 20 m depth (B), 30 m depth (C), and near bottom (D). Colored points and lines represent data for different historic periods, black points are annual median values, grey dashed line is the trend calculated from data for CY 2003-2014, and the brown dashed line is the trigger criteria.

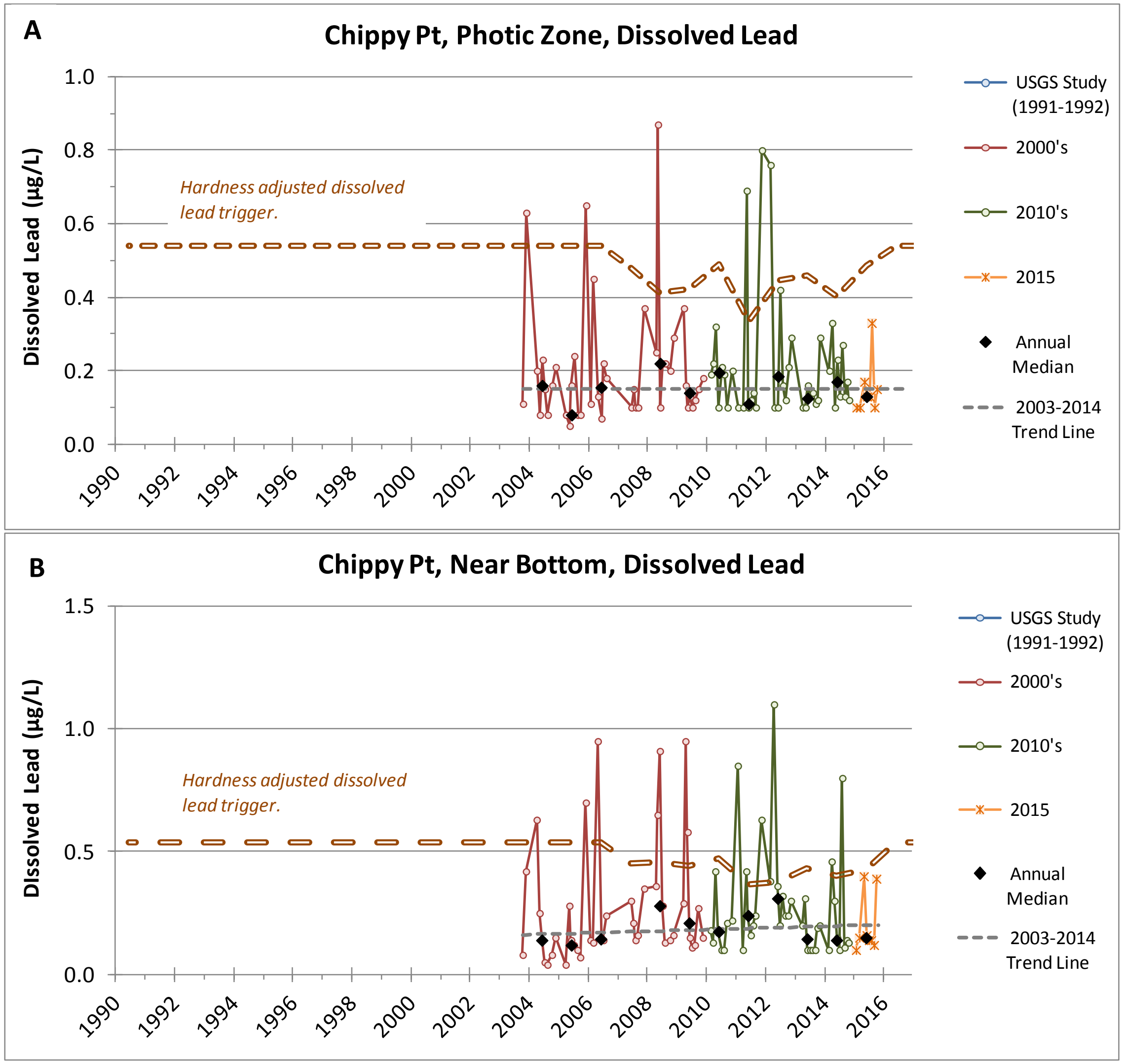


Figure 22. Dissolved lead trend data for site C5 Chippy Point photic zone (A) and C5 Chippy Point near bottom (B). Colored points and lines represent data for different historic periods, black points are annual median values, grey dashed line is the trend calculated from data for CY 2003-2014, and the brown dashed line is the trigger criteria.

2.6 Dissolved Cadmium

Current (2015) and multiyear geometric mean values for dissolved cadmium (Cd) are presented in Figure 23 for all depths at site C1 Tubbs Hill and site C4 University point in the northern lake. For the southern lake, data for specific depths (i.e. photic zone, near bottom) at Chippy Point are also presented in Figure 23. Metals data are not provided for site C6 Chatcolet Lake, as there are too few data points to enable meaningful analysis. Dissolved metals levels at this site are below detection levels for over 90% of samples. These data show the following.

- *Tubbs Hill (overall water column)*— geometric mean dissolved cadmium for 2015 did not exceed the hardness-based trigger value that ranged from 0.22 – 0.24 µg/L. Observed values for 2015 display a potential shift toward a trend of decreasing cadmium concentrations.

- *University Point (overall water column)*— geometric mean dissolved cadmium for 2015 exceeded the hardness-based trigger value that ranged from 0.22 – 0.25 µg/L. Observed values for 2015 are consistent with the prior observation of no long-term change over the 2003 – 2014 time period.

- *Chippy Point (photic zone)*— geometric mean dissolved cadmium for 2015 does not exceed the hardness-based trigger value range of 0.21 µg/L – 0.24 µg/L. Values are consistent with the trend of increasing cadmium observed for the 2003 – 2014 time period.

- *Chippy Point (near bottom)*— geometric mean dissolved cadmium for 2015 does not exceed the hardness-based trigger value range of 0.21 µg/L – 0.24 µg/L. Values are consistent with the trend of increasing cadmium observed for the 2003 – 2014 time period.

*Results from a Mann-Kendal*l statistical analysis of long-term trends in dissolved cadmium is provided in Table 6. Trend charts are presented in Figure 24 for Tubbs Hill (C1), Figure 25 for University Point (C4), and in Figure 26 for Chippy Point (C5). No metals trend data are presented for site C6 Chatcolet Lake.

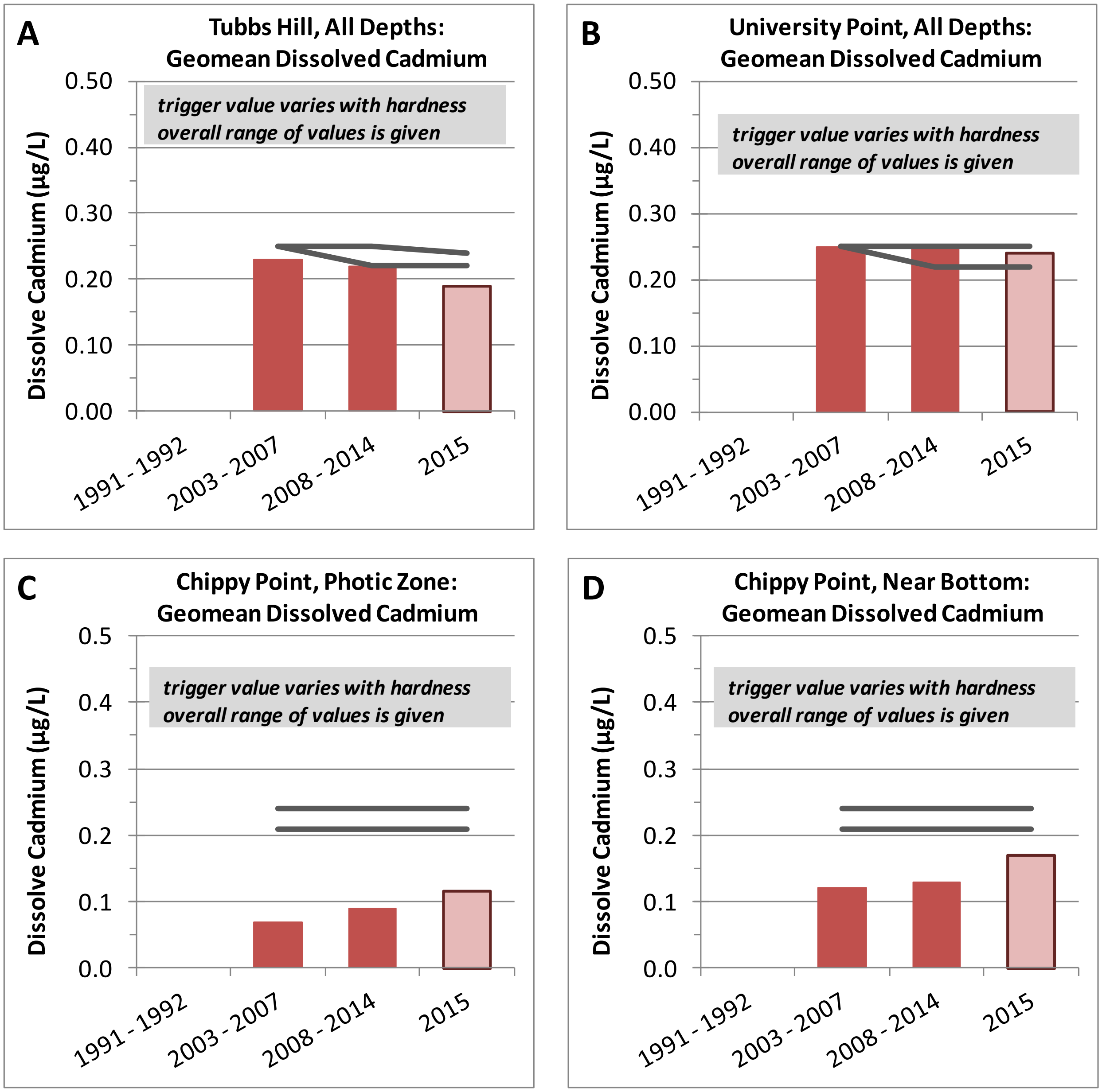


Figure 23. Dissolved cadmium geometric mean values over the reported time period for all depths at site C1 Tubbs Hill (A), all depths at site C4 University Point (B) the photic zone at site C5 Chippy Point (C), and the near bottom at site C5 Chippy Point (D).

The cadmium trend analyses summarized in Table 6 demonstrate that different cadmium trends are observed in different regions of the lake. For some locations, cadmium trends also vary with depth interval. In the northern pool (C1, Tubbs Hill), dissolved cadmium displayed no significant trend over the 2003 – 2014 time period for any depth interval. Except for the photic zone, these trends are also observed for the updated 2003 – 2015 time period. For the photic zone, a trend of decreasing dissolved cadmium is observed for the 2003 – 2015 time period. The slope of this trend is extremely small. For the central pool (C4, University Point), dissolved cadmium trends for the updated 2003 – 2015 time period are the same as in the prior 2003 – 2014 time period for all depths. Overall, the 2003 – 2015 dissolved cadmium trends for the northern lake are consistent with the previously reported 2003 – 2014 trends, though cadmium may be beginning to decrease at Tubbs Hill. Additional data is needed to evaluate this potential change. Note that cadmium data was not collected at 30 m depth in the northern lake in 2015, and the trend for 30 m depth cannot be updated at this time.

Table 6. Mann-Kendall trend analysis from 2003-2014 and 2003-2015 (current) for dissolved cadmium (Cd) at LMP core monitoring sites. Bold P-values are statistically significant at α=0.05. Italic P-values are statistically significant at α=0.10 but not at α=0.05

Time Period	Site	Depth	Variable	Mann-Kendall Trend Test (2003–2014, 2003-2015)			
				Sample Size (n)	P-Value	Theil-Sen Slope [a]	Trend
2003–2014	C1	Photic zone	Diss. Cd	81	0.11	0.000	None
	C1	20-meter depth	Diss. Cd	62	0.22	0.000	None
	C1	30-meter depth	Diss. Cd	66	0.24	0.000	None
	C1	Near bottom	Diss. Cd	78	0.49	0.000	None
2003-2015	C1	Photic zone	Diss. Cd	89	**0.019**	**-0.002**	**Decreasing**
	C1	20-meter depth	Diss. Cd	62	0.22	0.000	Same
	C1	30-meter depth	Diss. Cd	66	0.24	0.000	Same
	C1	Near bottom	Diss. Cd	86	0.23	0.000	Same
2003-2014	C4	Photic zone	Diss. Cd	81	0.35	0.000	None
	C4	20-meter depth	Diss. Cd	79	0.18	-0.0012	None
	C4	30-meter depth	Diss. Cd	66	0.11	-0.0016	None
	C4	Near bottom	Diss. Cd	81	**0.021**	**-0.0025**	**Decreasing**
2003-2015	C4	Photic zone	Diss. Cd	89	0.39	0.000	Same
	C4	20-meter depth	Diss. Cd	86	0.11	-0.0015	Same
	C4	30-meter depth	Diss. Cd	66	0.11	-0.0016	Same
	C4	Near bottom	Diss. Cd	89	**0.011**	**-0.0025**	**Same**
2003-2014	C5	Photic zone	Diss. Cd	83	**0.006**	**0.002**	**Increasing**
	C5	Near bottom	Diss. Cd	84	0.17	0.002	None
2003-2015	C5	Photic zone	Diss. Cd	92	**0.017**	**0.001**	**Same**
	C5	Near bottom	Diss. Cd	92	*0.09*	*0.003*	*Increasing*
2003-2014	C6	Photic zone	Diss. Cd	80	N/A[b]		N/A
	C6	Near bottom	Diss. Cd	80	N/A[b]		N/A
2003-2015	C6	Photic zone	Diss. Cd	88	N/A[c]		N/A
	C6	Near bottom	Diss. Cd	88	N/A[c]		N/A

a. Slope is in units of micrograms per liter (µg/L) per year. Negative slope is a decrease.
b. Dissolved cadmium concentrations were less than the minimum reporting limit 97 % of the time.
c. Dissolved cadmium concentrations were less than the minimum reporting limit 98 % of the time.

For the Chippy Point monitoring site in the southern pool (C5), dissolved cadmium displayed a slightly increasing trend in the photic zone and no trend at the near bottom during the 2003 – 2014 time period. With inclusion of the 2015 data a potential increasing trend now exists at the near bottom. The updated 2003 – 2015 trend shows increasing cadmium in both the photic zone and near bottom. Most metal samples were below detection limits at the Chatcolet Lake monitoring location, and therefore trends cannot be assessed at that location. Overall, the 2003 – 2015 dissolved cadmium trends for the southern lake consistent with the previously reported 2003 – 2014 trends.

Annual monitoring data for dissolved cadmium are plotted relative to the 2003 – 2014 trends in Figure 24 for Tubbs Hill (C1), Figure 25 for University Point (C4), and in Figure 26 for Chippy Point (C5). These plots show different patterns of lake status relative to long-term trends at different combinations of depth and monitoring location.

1. *Tubbs Hill (C1, northern pool)*— Monitoring data for 2015 are consistent with the 2003-2014 trend line for all depths where monitoring data is available. Observed concentrations are within 5% of trend line predictions. The annual median value is below the trigger criteria (0.22 – 0.24 µg/L) in the photic zone and roughly equivalent to this criteria in the near bottom depth interval. Monitoring data is not available for 20m or 30 m depth in 2015. *This data is consistent with the 2003 – 2014 trend of "no significant change" at C1 Tubbs Hill, but also supports a potential divergence toward a decreasing trend in the photic zone when calendar year 2015 data is included.*

2. *University Point (C4, central pool)*— Monitoring data for 2015 are consistent with the 2003-2014 trend line for all depths where monitoring data is available. The annual median value is ~10% below trend line predictions in the photic zone and within 5% at all other depth intervals. The annual median value is below the trigger criteria (0.22 – 0.24 µg/L) in the photic zone, equivalent to the criteria at 20 m depth, and exceeds this criteria in the near bottom depth interval. Monitoring data is not available for 30 m depth in 2015. *This data is consistent with the long-term trend of "no significant change in the upper 30 m" at C4 University Point, and a decreasing trend for the near bottom depth interval.*

3. *Chippy Point (C5, southern pool)*— Monitoring data for 2015 from the photic zone is consistent with the 2003-2014 trend line. The annual median value of 0.12 µg/L in the photic zone is lower than the trigger and slightly higher than the trend. Monitoring data for 2015 from the near bottom is consistent with the 2003-2014 trend, but also supports a potential shift to an increasing trend at the near bottom depth interval. The annual median value of 0.17 µg/L in the near bottom is lower than the trigger. *This data represents a continuance of the long-term trend of potentially increasing dissolved cadmium at C5 Chippy Point. The inclusion of the 2015 data decreased the P-value for the trend and the trend is significant at α=0.10.*

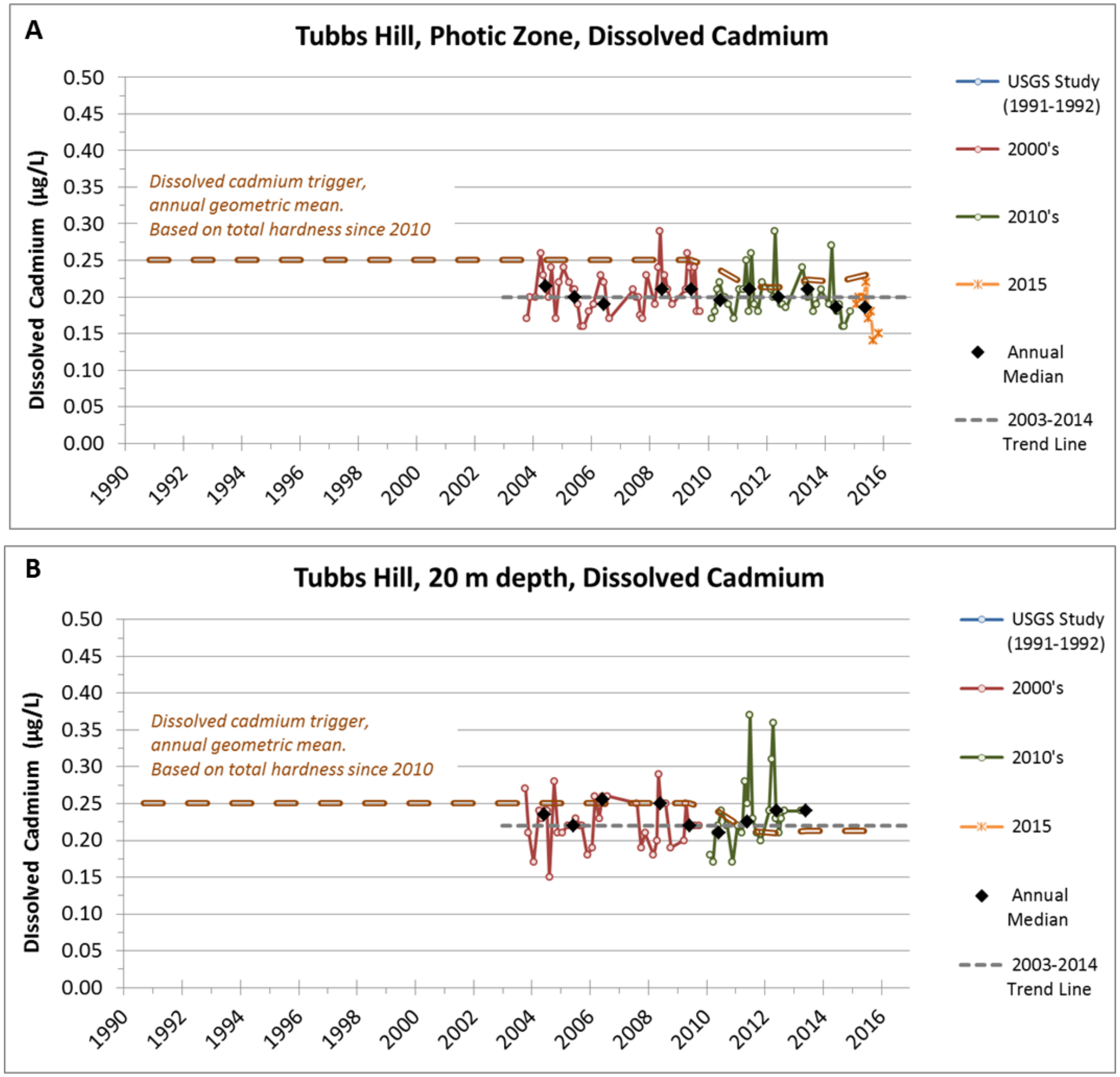
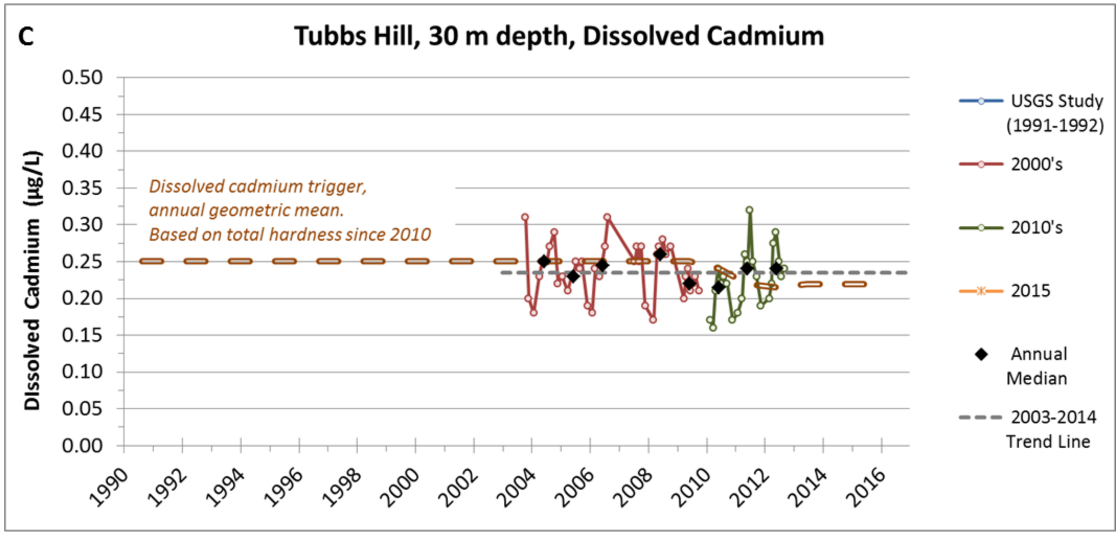


Figure 24. Dissolved cadmium trend data for site C1 Tubbs Hill photic zone (A), 20 m depth (B), 30 m depth (C), and near bottom (D). Colored points and lines represent data for different historic periods, black points are annual median values, grey dashed line is the trend calculated from data for CY 2003-2014, and the brown dashed line is the trigger criteria.



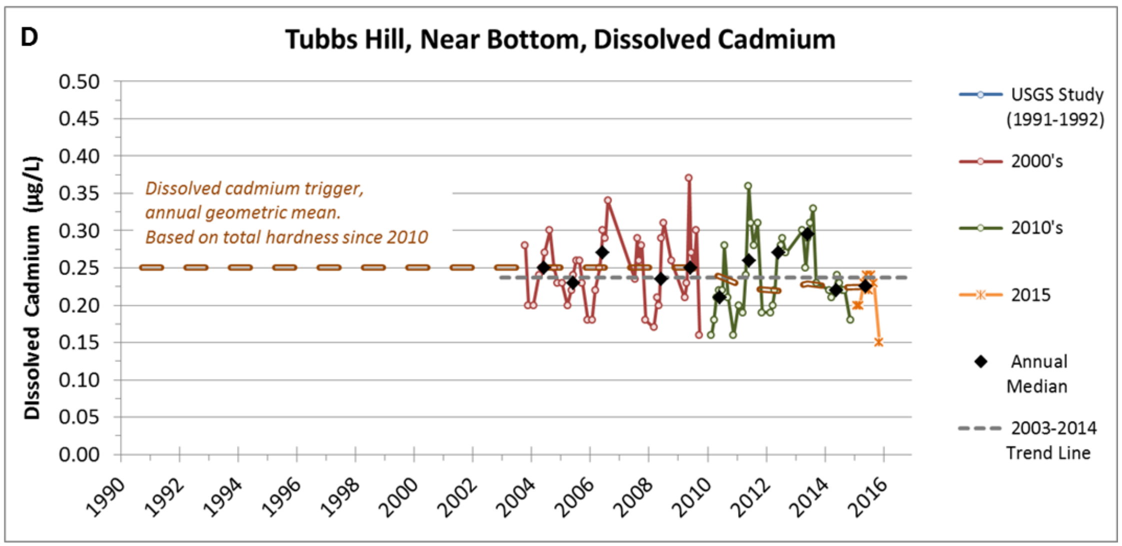


Figure 24 (continued). Dissolved cadmium trend data for site C1 Tubbs Hill photic zone (A), 20 m depth (B), 30 m depth (C), and near bottom (D). Colored points and lines represent data for different historic periods, black points are annual median values, grey dashed line is the trend calculated from data for CY 2003-2014, and the brown dashed line is the trigger criteria.

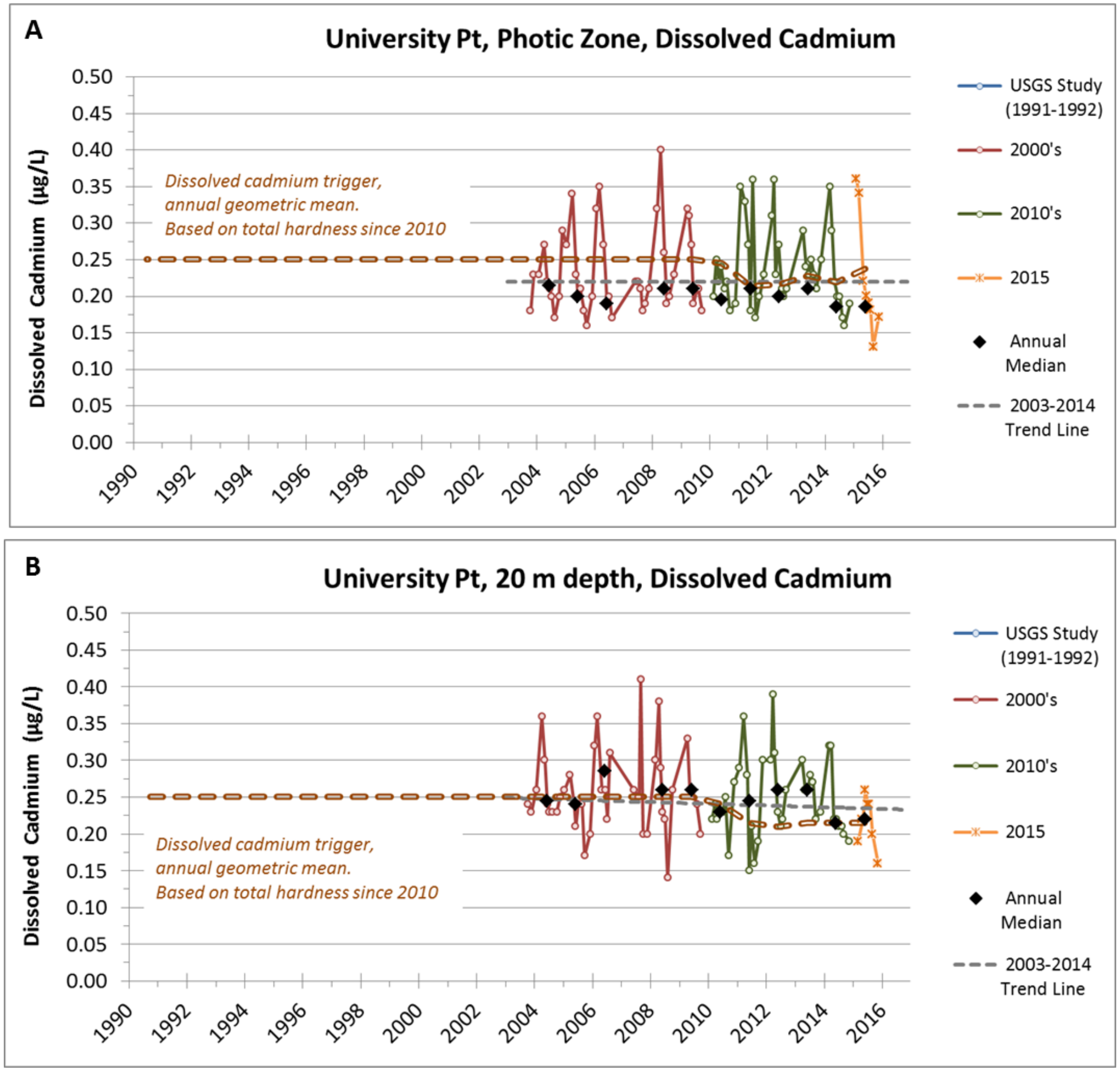
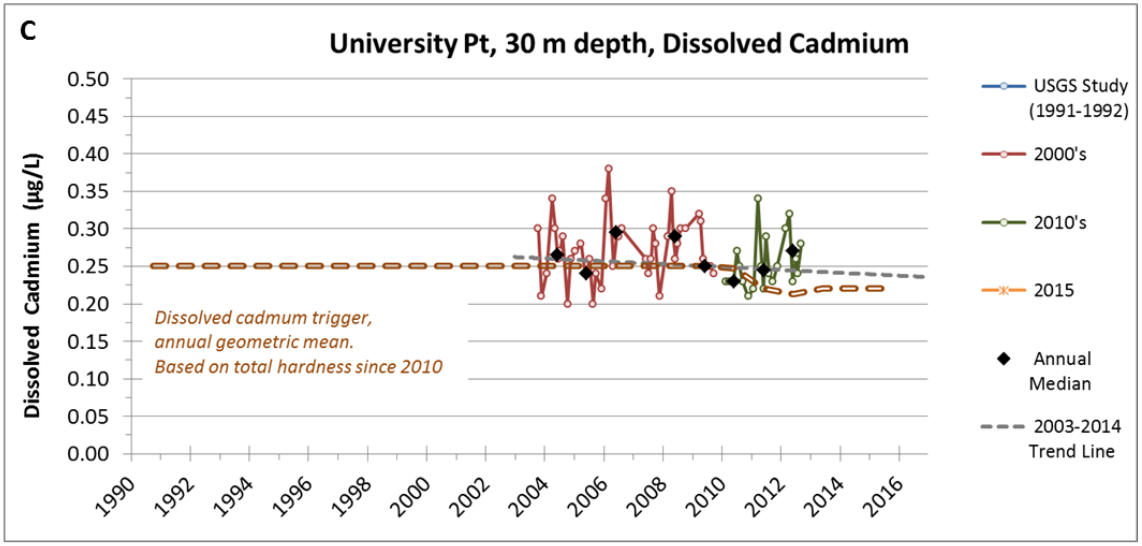


Figure 25. Dissolved cadmium trend data for site C4 University Point photic zone (A), 20 m depth (B), 30 m depth (C), and near bottom (D). Colored points and lines represent data for different historic periods, black points are annual median values, grey dashed line is the trend calculated from data for CY 2003-2014, and the brown dashed line is the trigger criteria.



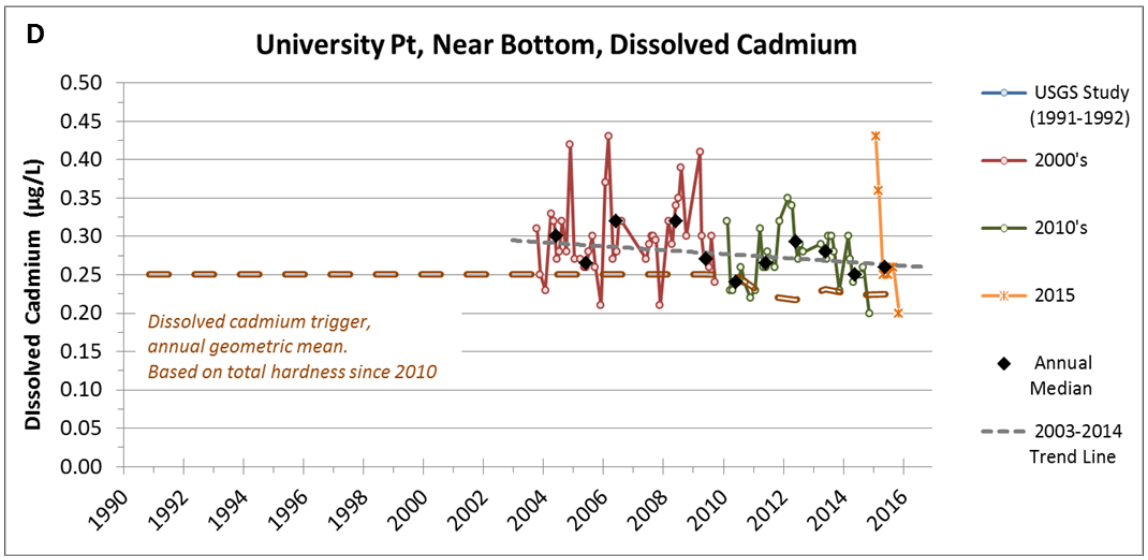
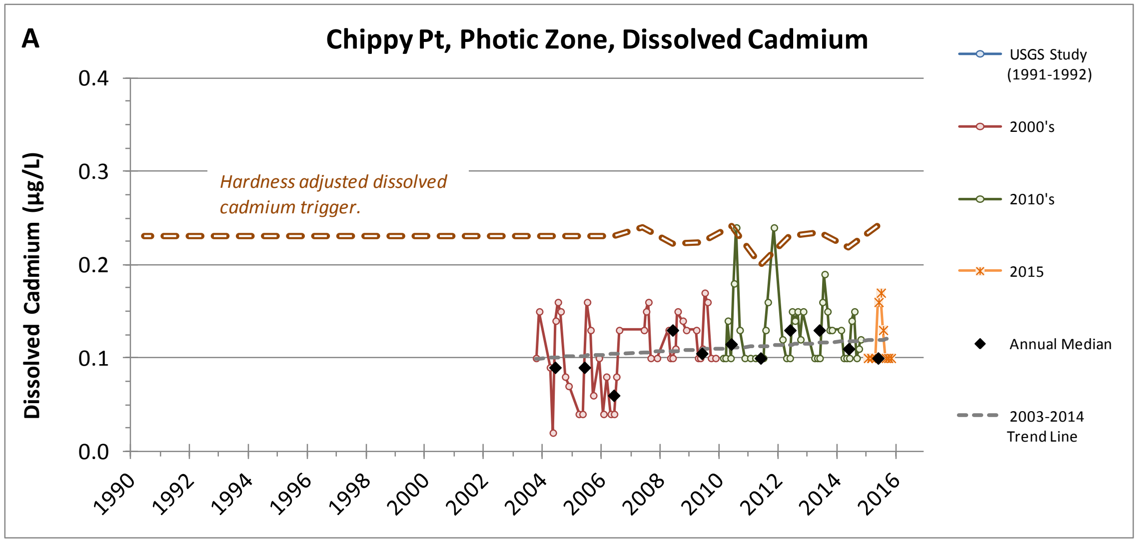


Figure 25 (continued). Dissolved cadmium trend data for site C4 University Point photic zone (A), 20 m depth (B), 30 m depth (C), and near bottom (D). Colored points and lines represent data for different historic periods, black points are annual median values, grey dashed line is the trend calculated from data for CY 2003-2014, and the brown dashed line is the trigger criteria.



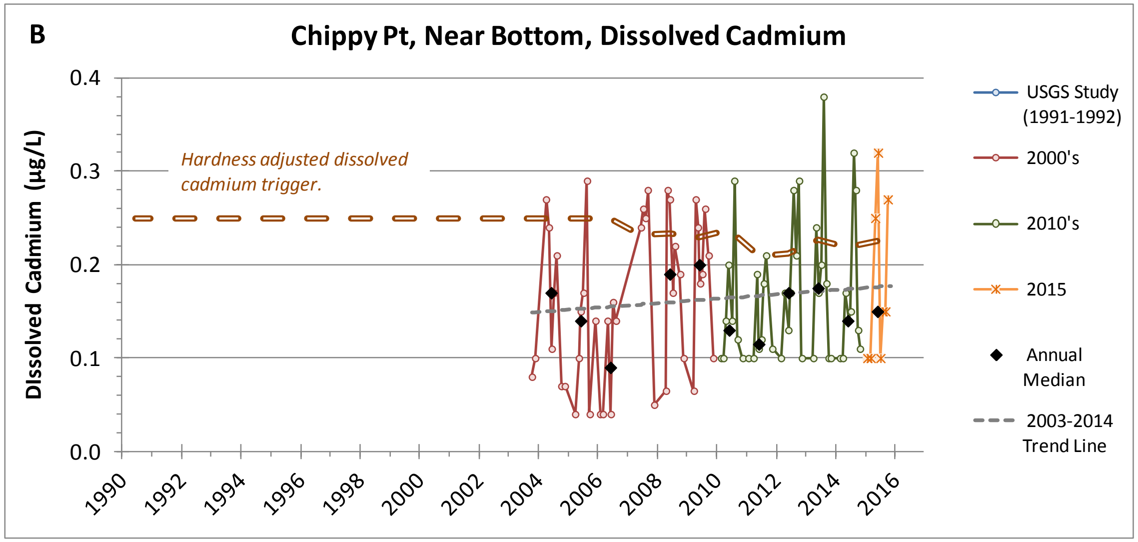


Figure 26. Dissolved lead trend data for site C5 Chippy Point photic zone (A) and C5 Chippy Point near bottom (B). Colored points and lines represent data for different historic periods, black points are annual median values, grey dashed line is the trend calculated from data for CY 2003-2014, and the brown dashed line is the trigger criteria.

3 Summary of Lake Status

The 2008 – 2014 Lake Trends Analysis (DEQ and Tribe, 2016) reported that Coeur d’Alene Lake has changed since the 1991–1992 time period. Some of those changes reflect improvements in water quality. Others reflect the emergence of new management challenges. This report assesses lake status for calendar year 2015, relative to these previously identified trends. In conducting annual assessments, it is important to consider lake status in light of the hydrologic conditions for that year. Coeur d’Alene Lake received low flows of influent water from the Coeur d’Alene Basin in water year 2015. For 2015, annual average Coeur d’Alene River flows at Cataldo were in the 20th percentile relative to the record maintained since 1921. The lake also experienced abnormally high surface temperatures in the early summer. These abnormal conditions could influence the lake conditions in 2015 relative to long-term, “typical” conditions.

Prior analyses (DEQ and Tribe, 2016) concluded that total zinc levels have declined since the 1990s and total lead levels had also declined at most locations. There was insufficient data for total cadmium to make a definitive conclusion. Dissolved zinc levels have steadily declined in the northern lake since 2003, when monitoring data became available. Dissolved lead and cadmium levels showed mixed results during the 2003 – 2014 time period, with levels declining at some locations and increasing or showing “no change” at others. These trends generally continued in 2015, but there is some indication that cadmium levels may be beginning to decline more distinctly at some locations (C1 Tubbs, photic) while increasing more distinctly at others (C5 Chippy Pt, near bottom). The largest shift in dissolved cadmium occurred at site C5 in the near bottom zone, where dissolved cadmium appears to be increasing at the 90% confidence level. The declines in dissolved metals levels are consistent with lake management objectives.

A distinctly different set of trends are observed for the lake’s trophic state indicators; chlorophyll-*a*, oxygen, and phosphorus. Previously reported trends indicate that DO levels during the summer stratified season have slowly declined from the 1990’s levels in the northern lake, while chlorophyll-*a* and phosphorus levels have increased. Trophic indicators in the northern lake appear to be trending away from the preferred low productivity oligotrophic state, while the southern regions of the lake remain in a higher productivity mesotrophic state. These trends also continued in 2015. These changes in trophic state indicators are not consistent with lake management objectives, and continue to progress in an undesired direction. The drivers of these changes are not well understood. Data collection and analysis is continuing. Results from the different statistical analyses are summarized below.

3.1 Dissolved Metals

Prior analyses (DEQ and Tribe, 2016) conclude that dissolved metals (zinc, lead, and cadmium) in the 2003 – 2014 time period regularly exceeded trigger criteria based on the Idaho and Tribe water quality standards. Dissolved zinc consistently exceeded these water quality targets. Lead and cadmium sporadically exceeded their targets. The following trends in dissolved metals were observed for the 2003 – 2014 time period.

- Trend analyses indicated that dissolved zinc levels were steadily decreasing at all sites and depths in the northern lake (sites C1, C4), but corresponding trends were not seen in the southern lake (sites C5, C6).
- Trend analyses indicated that dissolved lead levels were increasing at some combinations of depth and location in the northern lake (sites C1, C4), but showing no trend at other depths. No corresponding trend was observed in the southern lake (sites C5, C6).
- Trend analyses indicated that dissolved cadmium levels were decreasing at the near bottom depth interval at site C4 in the northern lake, but had no trend at other combinations of depth and location in the northern lake. Cadmium was increasing in the photic zone at site C5 in the southern lake, but had no trend at other locations in the southern lake.

Dissolved metals data collected in 2015 are generally consistent with these historic trends. Annual geometric mean dissolved metal concentrations in 2015 are consistent with historic patterns for both the northern and southern lake. Annual geometric mean zinc level exceeded the trigger criteria in the northern lake, and in the near bottom depth interval for site C5 Chippy Point in the southern lake. Annual geometric mean cadmium only exceeded trigger criteria at site C4 University Point in the central pool. Annual geometric mean dissolved lead concentrations did not exceed trigger criteria for any location in 2015.

Mann-Kendall trend analyses for dissolved metals for the updated 2003 – 2015 time period yield results that are also generally consistent with these prior results. However, there are some differences for some combinations of metal and monitoring location that could mark a potential divergence. The potential divergences for the 2003 – 2015 trend analyses relative to the 2003 – 2014 trend analyses are as follows.

- Dissolved cadmium now shows a trend of decreasing concentrations in the photic zone at site C1 Tubbs Hill for the updated 2003 – 2015 time period at 95% confidence ($\alpha < 0.05$).
- Dissolved cadmium continues to show an increasing trend in the photic zone at site C5 Chippy Point. With the inclusion of the 2015 data, dissolved cadmium in the near bottom zone at site C5 now also shows a new increasing trend at 90% confidence ($\alpha < 0.1$).

All other results from the Mann-Kendall trend analyses are consistent for both the 2003 – 2015 and 2003 – 2014 time periods, to within the ability for this technique to detect changes in lake trends with the available data. More comprehensive monitoring at the 20 m and 30 m depth intervals at northern lake monitoring sites is needed to fully assess trends.

With respect to Theil-Sen trend line forecasts, dissolved zinc levels in 2015 were all within ~10% of trend line predictions in the northern lake. The same holds true for dissolved cadmium in the northern lake. Dissolved lead levels in the northern lake in 2015 were 20 – 30% lower than trend line predictions at all depths at site C1 in the northern pool, and 60% lower in the photic zone at site C4 in the central pool. Lead levels were within 10% of trend line predictions at the 20 m and near bottom depth intervals at site C4. All dissolved metals data collected in 2015 is consistent with the range of data previously observed and the associated long-term trends. The low lead levels are notable, but are consistent with low flow conditions and fall within the extent of variability recorded in the historic data record.

When all dissolved metal data and analyses are considered as a group, in the context of hydrologic conditions for 2015, we conclude that lake status for 2015 is consistent with previously documented trends for dissolved metals. *Zinc is generally decreasing, lead is generally stable or slightly increasing, and cadmium is generally stable and may be slightly increasing or decreasing at different locations within the lake*.

3.2 Dissolved Oxygen

Prior analyses (DEQ and Tribe, 2016) conclude that hypolimnetic dissolved oxygen for the near bottom depth interval (1.0 meter off the lake bottom during stratified months) has consistently dropped below trigger criteria in the southern lake but has only intermittently dropped below trigger criteria in the northern lake. The following trends were observed.

- Dissolved oxygen levels in the northern lake have intermittently dropped below trigger levels, but predominantly remain above the 6 mg/L target. Trend analyses conducted over the 25 year dataset (1991 – 2015) that hypolimnetic oxygen levels during the stratified summer and fall months were slowly decreasing at both C1 Tubbs Hill and C4 University Point. Trend analyses conducted over the shorter 12-year dataset (2003 – 2015) show a weak trend of declining hypolimnetic DO is observed at C1 Tubbs Hill but not at C4 University Point for this shorter time period.
- Dissolved oxygen levels in the southern lake have consistently dropped below trigger levels. Site C5 Chippy Point drops below 3 –5 mg/L each year (hypoxic) and site C6 Chatcolet Lake becomes anoxic each year (zero oxygen). Trend analyses indicated that hypolimnetic oxygen levels during the stratified summer and fall months were slowly decreasing at Chatcolet Lake but holding steady at Chippy Point.

Dissolved oxygen data collected in 2015 are consistent with these historic trends. Minimum observed oxygen levels in the northern lake did not drop below the 6 mg/L trigger in 2015. Median dissolved oxygen for the July – October hypolimnion in 2015 continued the declining pattern at C1 Tubbs Hill (northern pool), but did not appear to continue this trend at site C4 University Point (central pool). Minimum observed oxygen levels in 2015 in the southern lake dropped below that region's trigger of 8 mg/L. Bottom water oxygen was hypoxic at site C5 Chippy Point (< 3.0 mg/L) and anoxic at site C6 Chatcolet Lake. Median dissolved oxygen for the July – November hypolimnion at C5 was consistent with past years. Median dissolved oxygen at site C6 (July-September) was consistent with past years as the site was anoxic for an extended period.

Updated Mann-Kendall trend analyses conducted for the northern lake for July – October hypolimnetic dissolved oxygen at the near bottom depth interval for both the 1991 – 2015 and the 2003 – 2015 time periods are consistent with previously described trends. Declines observed at C1 Tubbs Hill have been larger and more consistent than those observed at C4 University Point. Updated Mann-Kendall trend analyses conducted for the southern lake for July – November at C5 and July-September at C6 for hypolimnetic dissolved oxygen at the near bottom depth interval are consistent with previously identified trends.

With respect to Theil-Sen trend line forecasts for the northern lake, median July – October hypolimnetic dissolved oxygen at the near bottom depth interval in 2015 was within ~10% of trend line predictions for both northern lake sites. All dissolved oxygen data collected in 2015 is consistent with the range of data previously observed and the associated long-term trends. When all dissolved oxygen data and analyses are considered as a group, we conclude that lake status for 2015 is consistent with previously documented trends. *Dissolved oxygen levels continue to decline at C1 Tubbs Hill and C6 Chatcolet Lake. Weaker and less consistent declines have been observed at C4 University Point. Bottom water oxygen levels are generally stable at C5 Chippy. The decline is most apparent over long time intervals with continuous datasets.*

3.3 Chlorophyll-*a*

Prior analyses (DEQ and Tribe, 2016) conclude that maximum chlorophyll-a has regularly exceeded the associated trigger criteria of 5 µg/L at site C6 Chatcolet Lake, and intermittently exceeded this criteria at other locations within the northern and southern lake. Annual geometric mean chlorophyll-a has intermittently exceeded the associated trigger criteria of 3 µg/L at site C6 Chatcolet Lake, and has not exceeded this criteria at other locations within the northern and southern lake. The following trends were observed.

- Chlorophyll-a levels in the northern lake were increasing at both site C1 Tubbs Hill and C4 University Point. The trend was only significant to within 90% confidence for both sites.
- Chlorophyll-a levels in the southern lake were increasing at both site C5 Chippy Point and C6 Chatcolet Lake. The trend was significant to within 95% confidence at C5 Chippy Point and only 90% confidence at C6 Chatcolet Lake.

Chlorophyll-a data collected in 2015 are consistent with these historic trends. Geometric mean chlorophyll-a in 2015 did not exceed the trigger of 3 µg/L in the northern lake. Maximum chlorophyll-a in 2015 did not exceed the trigger of 5 µg/L at either site C4 University Point or site C1 Tubbs Hill. Geometric mean chlorophyll-a in 2015 at site C5 did not exceed the 3.0 µg/L trigger but exceeded the trigger at C6. Maximum observed chlorophyll-a in 2015 in the southern lake. Maximum chlorophyll-a did not exceed the 5 µg/L trigger at C5 but did at C6.

Mann-Kendall trend analyses for chlorophyll-a for the updated 2003 – 2015 time period yield results that are consistent with these prior results. However, there are some differences for some monitoring locations that could mark a potential divergence. The potential divergences for the 2003 – 2015 trend analyses relative to the 2003 – 2014 trend analyses are as follows.

- The trend of increasing chlorophyll-a concentrations in the photic zone at site C1 Tubbs Hill is more distinct for the updated 2003 – 2015 time period (lower P-value).

With respect to Theil-Sen trend line forecasts, median chlorophyll-a levels for 2015 were within 5% of trend line predictions at site C4 University point in the central pool but 25% higher than trend line predictions at site C1 Tubbs Hill in the northern pool. All chlorophyll-a data collected in 2015 is consistent with the range of data previously observed and the associated long-term trends. When all chlorophyll-a data and analyses are considered as a group, we conclude that lake status for 2015 is consistent with previously documented trends. *Chlorophyll-a levels are steadily increasing at all core monitoring locations in both the northern and southern lake*.

3.4 Total Phosphorus

Prior analyses (DEQ and Tribe, 2016) conclude that total phosphorus has consistently exceeded trigger criteria (8 µg/L annual geometric mean) in the southern lake and intermittently exceeded criteria in the northern lake. The following trends were observed.

- Total phosphorus levels in the northern lake were increasing at all depths at site C1 Tubbs Hill (northern pool). An increasing trend was observed at the 30 m depth interval at site C4 University Point (central pool), but no trend was observed at other depth intervals. All trends were significant to 95% confidence.
- Total phosphorus levels in the southern lake were decreasing at site C6 Chatcolet Lake. A decreasing trend was observed in the near bottom depth interval at site C5 Chippy Point, but no trend was observed in the photic zone. The decreasing trends were significant to within 95% confidence at C5 Chippy Point and only 90% confidence at C6 Chatcolet Lake.

Total phosphorus data collected in 2015 are consistent with these historic trends. Geometric mean total phosphorus exceeded the trigger criteria of 8 µg/L at sites C1 Tubbs Hill and C4 University Point in the northern lake, as well as at site C5 Chippy Point in the southern lake. The trigger criteria of 9 µg/L was exceeded at site C6 Chatcolet Lake.

Mann-Kendall trend analyses for total phosphorus in the updated 2003 – 2015 time period yield results that are consistent with these prior results. However, there are some differences for some combinations of depth and monitoring location. These potential divergences are as follows.

- There is a more distinct trend of increasing total phosphorus in the photic zone and near bottom at site C1 Tubbs Hill for the 2003 – 2015 time period (lower P-value).
- There is a more distinct trend of increasing total phosphorus at the 30 m depth interval and a new trend of increasing total phosphorus at the near bottom depth interval at site C4 University Point for the 2003 – 2015 time period (lower P-value).
- There is a more distinct trend of decreasing total phosphorus at the near bottom depth interval at site C5 and a potential new trend of decreasing total phosphorus in the photic zone (lower P-value).

With respect to Theil-Sen trend line forecasts, median total phosphorus levels for 2015 were higher than trend line predictions for all locations and depth intervals in the northern lake. Observed phosphorus levels were 20 – 50% higher than trend line predictions at site C1 Tubbs Hill in the northern pool and 20 – 40% higher than trend line predictions at site C4 University Point in the central pool. The historic data record incorporates a high degree of variability, and all total phosphorus data collected in 2015 is consistent with the range of data previously observed and the associated long-term trends. When all total phosphorus data and analyses are considered as a group, we conclude that lake status for 2015 is consistent with previously documented trends for total phosphorus. *Total phosphorus levels are steadily increasing at all core monitoring locations in the northern lake, but steady or decreasing in the southern lake*.

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