# Coeur d'Alene Lake Management Program: Summary of Lake Status and Trends, 2008–2014

**State of Idaho**
**Department of Environmental Quality**
**and**
**Coeur d'Alene Tribe**

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# 1 Purpose, Background and Introduction

The Coeur d'Alene Lake Management Plan (LMP) is a collaborative effort among the Idaho Department of Environmental Quality, the Coeur d'Alene Tribe, and the region's many governmental and stakeholder groups to protect water quality within Coeur d'Alene Lake (IDEQ and Tribe, 2009). The United States Environmental Protection Agency (EPA) Manchester Lab has provided technical support, approved annual Quality Assurance Project Plans (QAPPs), and provided chemical analyses for water quality samples collected by IDEQ 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 is to 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 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 dissolved oxygen, trophic parameters such as phosphorus and chlorophyll *a*, 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 is intended to provide the lake's current status relative to long-term trends that have been discussed in prior reports. This report answers three fundamental questions regarding the water quality status of Coeur d'Alene Lake in relation to the LMP triggers. Those questions are;

1. How do the most recent trigger values from (2008-2014) compare with the values from (1991-1992) and (2003-2007) data sets?
2. How does the most recent 11-year data set (2003-2014) compare with the (1991-1992) data that was part of the basis for the LMP triggers?
3. Are the time-series trends from the (2003-2014) data set increasing, decreasing or not changing?

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. IDEQ and the Tribe are currently collaborating to produce a series of technical synthesis reports with the goals of identifying the dynamics and mechanisms that may explain the current lake conditions and trends described in this report.

## 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 dissolved oxygen data collected from 1996 – 2002 are also presented. Data from the 1991-1992 period was collected by the USGS and reported by Woods and Beckwith (1997). Data from the 2003-2006 period was collected by the USGS and reported by Wood and Beckwith (2008). Dissolved oxygen data from 1996-2002 for the northern lake were collected by IDEQ, with results generally summarized in draft addendums to the 1996 Coeur d’Alene Lake Management Plan (IDEQ, 1996; IDEQ, 2002; IDEQ; 2004). Data collected from 2007-2014 was collected by IDEQ and the Tribe and the early years of this data set were reported in annual reports;

1. *Lake Status (CY 2007-08)*— Tribe and IDEQ, 2010. Coeur d’Alene Lake Monitoring Program 2007-2008 Report. Coeur d’Alene Tribe, Plummer, Idaho and Idaho Department of Environmental Quality, Coeur d’Alene Idaho
2. *Lake Status (CY 2009)*— Tribe and IDEQ, 2012. Coeur d’Alene Lake Monitoring Program 2009 Report. Coeur d’Alene Tribe, Plummer, Idaho and Idaho Department of Environmental Quality, Coeur d’Alene Idaho.
3. *Lake Status (CY 2010)*— IDEQ, 2012. Coeur d’Alene Lake Monitoring Program 2010 Annual Report, Volume 1: State Waters. Idaho Dept. of Environmental Quality, Coeur d’Alene Idaho
4. *Lake Status (CY 2011)*— IDEQ, 2013. Coeur d’Alene Lake Monitoring Program 2011 Annual Report, Volume 1: State Waters. Idaho Dept. of Environmental Quality, Coeur d’Alene Idaho.

## 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 dissolved oxygen and trophic state indicators (total phosphorus and chlorophyll-a) are provided in Section 2 of this report. The dissolved oxygen trigger is generally based on the State and Tribe water quality standards for dissolved oxygen 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 dissolved oxygen 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. Note that, 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 while the State only incorporates water hardness into standards for cadmium. Consequently, 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 Quality Assurance Project Plans that accompany each of the Lake Monitoring Program reports enumerated previously, 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 1.0 m 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 Lake Management Program collects samples at the main-lake locations (Figure 1);

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

These sites were visited during the U.S. Geological Survey (USGS) studies conducted in CY 1991-92 and WY 2004-06. 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 Feb/March, April, May, June, July, August, Sept./Oct., and Nov./Dec. All lake stations are typically visited within the same week. The Feb/March sample is intended to capture lake conditions after a rain-on-snow event and the Nov/Dec sample is intended to capture lake conditions soon after lake turnover in late-fall/early winter. Additional details regarding the location and frequency of lake sampling are provided in the 2009 LMP as well as in the annual reports and quality assurance plans.

## 1.5 Analysis Methods and Report Format

The results for each LMP trigger variable are presented in table format that includes 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 Lake Management Plan (IDEQ and Tribe, 2009). 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 synthesis reports.

This report presents three types of tables for each of the measured LMP trigger variables. Each table presents one trigger variable at each Site and depth from SiteC1 (north) to C6 (south). The first table presents the geomean and range of values for LMP trigger variables for each of the three time periods described in section 1.1. The second table presents the results from a Mann-Whitney-Wilcoxon statistical test that determines if the concentrations of LMP trigger variables differ between the (1991-1992) and (2003-2014) time periods. This analysis was selected to assess if the concentrations of variables from the most recent continuous data set (2003-2014) differ from concentrations from the early data set from (1991-1992). Dissolved metals were not analyzed in the (1991-1992) time period so total metals concentrations were used for the Mann-Whitney-Wilcoxon tests. The third type of results table presents results from a Mann- Kendall statistical test that determines if a time-series trend (increasing, decreasing or none) exists for a variable. A Theil-Sen regression line was also fit to these trends to estimate the approximate magnitude of change. The Theil-Sen regression is a linear fit calculation that accounts for non-parametric data where statistical calculations are based on the median rather than the average. The Mann-Kendall trend test was run for LMP triggers criteria for the 2003 – 2014 dataset. This allowed for an assessment of the most recent continuous data set and provides the most up to date status of the trigger variables. For some criteria, additional trend analyses were run on a larger, more sensitive dataset.

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 "no 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, IDEQ 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 above. IDEQ 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.

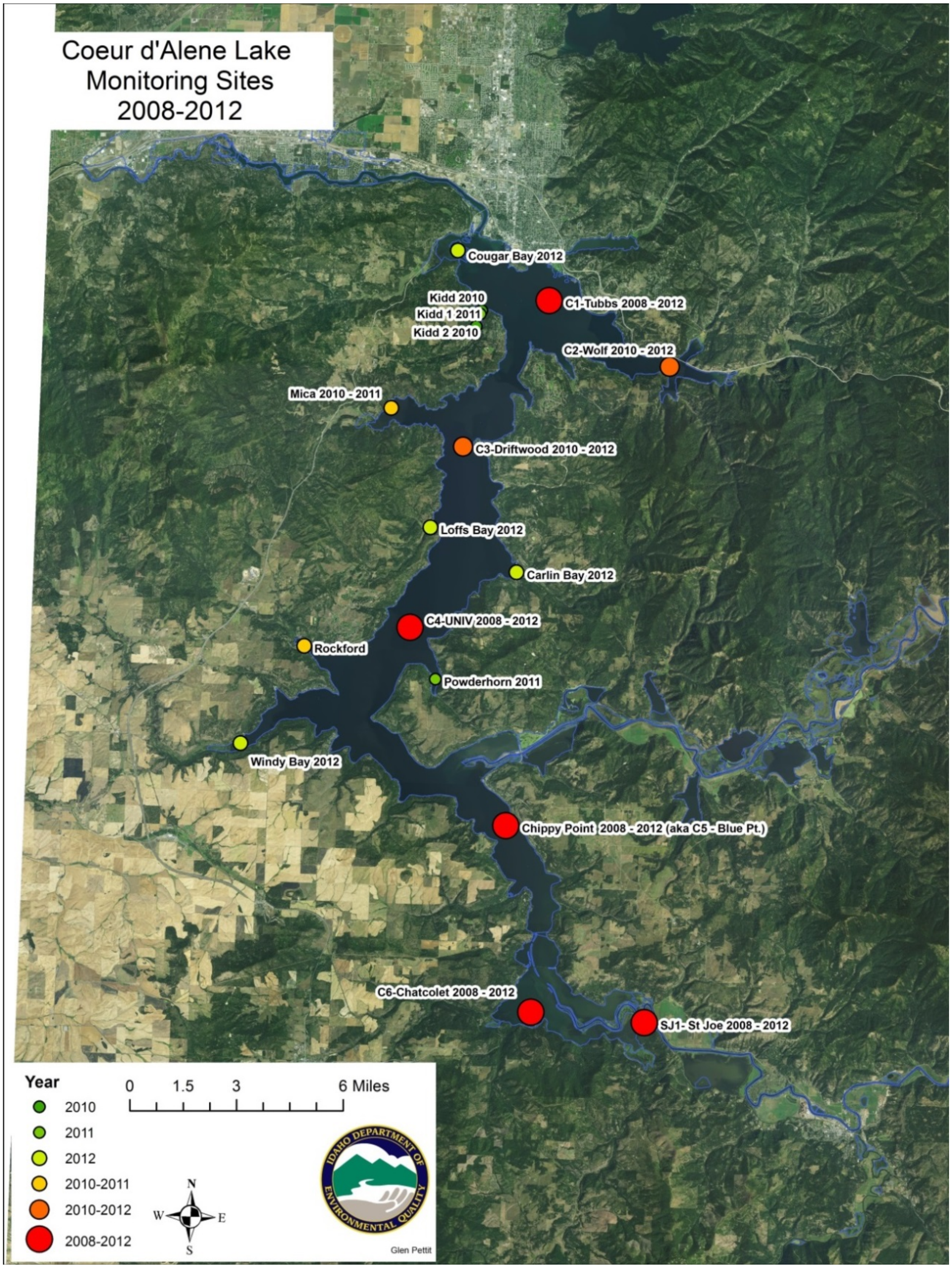


**Figure 1. Map of sampling locations on Coeur d'Alene Lake. Large red dots are core monitoring locations, small dots are bay sites, and medium orange dots are additional sampling locations occasionally visited to gather additional data to support trend analysis.**

# 2 Results

## 2.1 Total Phosphorus

Multi-year geometric mean (geomean) values for total phosphorus (TP) are presented in Table 1. Geomean TP values increased at all sites and depths from 1991-1992 to 2003-2007. The geomean also increased at C1 and C4 from 2003-2007 to 2008-2014, but decreased at sites C5 and C6 at all depths. The TP trigger condition has been exceeded at C5 and C6 since 2003. The TP trigger condition at C1 and C4 was not exceeded as a geomean across all years for 2008 – 2014, but it has been exceeded for some individual years at both sites.

Results from the two-population Mann-Whitney-Wilcoxon comparison for TP in the 1991-1992 dataset with the 2003 – 2014 dataset are presented in Table 2. Total phosphorus concentration at all sites and depths was significantly higher in 2003-2014 compared to the 1991-1992 period. The magnitude of increase in TP concentration was relatively consistent across all sites.

Results from the Mann-Kendall trend test for the 2003 – 2014 dataset are presented in Table 3. The Mann-Kendall test identified a trend of increasing TP concentration at all depths at site C1 (northern pool). The Mann-Kendall test also identified an increasing trend for TP at site C4 (central pool) in the mid hypolimnion (30m), but not at any other depths. The Mann-Kendall test identified a significantly decreasing trend for TP at site C5 at the near bottom. Site C6 did not exhibit any TP trend at either sample depths.

**Table 1. Status of the multi-year total phosphorus (TP) geometric mean trigger criteria at LMP core monitoring sites in relation to LMP trigger values.**

| Site | Depth | Variable | LMP Trigger (Annual geometric mean) | 1991-1992 geometric mean (µg/L) | 2003-2007 geometric mean (µg/L) | 2008-2014 geometric mean (µg/L) |
|---|---|---|---|---|---|---|
| C1 | 1-30m | TP | ≥8 µg/L | 2.7 | 4.7 | 6.2 |
| C4 | 1-30m | TP | ≥8 µg/L | 3.9 | 6.1 | 7.7 |
| C5 | Photic zone | TP | ≥8 µg/L | 5.8 | 11.6 | 11.4 |
| C5 | Near Bottom | TP | ≥8 µg/L | 5.5 | 15.3 | 12.9 |
| C6 | Photic zone | TP | ≥9 µg/L | 9.0 | 19.4 | 17.6 |
| C6 | Near Bottom | TP | ≥9 µg/L | 15.8 | 35.9 | 27.2 |

**Table 2. Mann-Whitney-Wilcoxon two sample test for total phosphorus (TP) concentration from 1991-1992 and 2003-2004 time periods (bold P-values are statistically significant at α=0.05).**

| Site | Depth | Variable | Median value (µg/L) and Sample size (n) | | P-Value | Conclusion |
|---|---|---|---|---|---|---|
| | | | 1991–1992 | 2003–2014 | | |
| C1 | 0-30m | TP | 3 (48) | 5.6 (219) | **<0.0001** | 91-92 < 03-14 |
| C1 | Near Bottom | TP | 4 (25) | 6 (76) | **<0.0001** | 91-92 < 03-14 |
| C4 | 0-30m | TP | 4.5 (52) | 6.95 (223) | **<0.0001** | 91-92 < 03-14 |
| C4 | Near Bottom | TP | 5.0 (26) | 7.6 (81) | **0.0001** | 91-92 < 03-14 |
| C5 | Photic Zone | TP | 7.5 (23) | 11 (85) | **<0.0001** | 91-92 < 03-14 |
| C5 | Near Bottom | TP | 7 (24) | 13 (85) | **<0.0001** | 91-92 < 03-14 |
| C6 | Photic Zone | TP | 8 (21) | 17 (81) | **<0.0001** | 91-92 < 03-14 |
| C6 | Near Bottom | TP | 13.5 (16) | 23 (82) | **0.006** | 91-92 < 03-14 |

**Table 3. Mann-Kendall trend analysis for total phosphorus (TP) from 2003–2014 at LMP core monitoring sites (bold P-values are statistically significant at α=0.05).**

| Time Period | Site | Depth | Variable | Mann-Kendall Trend Test (2003–2014) | | | |
|---|---|---|---|---|---|---|---|
| | | | | Sample Size (n) | P-Value | Theil-Sen slope [a] | Trend |
| 2003-2014 | C1 | Photic zone | TP | 79 | **0.025** | **0.13** | Increasing |
| | C1 | 20 m depth | TP | 72 | **0.002** | **0.18** | Increasing |
| | C1 | 30 m depth | TP | 61 | **0.001** | **0.27** | Increasing |
| | C1 | Near bottom | TP | 75 | **0.018** | **0.17** | Increasing |
| | C4 | Photic zone | TP | 81 | 0.30 | 0.02 | None |
| | C4 | 20 m depth | TP | 76 | 0.26 | 0.06 | None |
| | C4 | 30 m depth | TP | 61 | **0.013** | **0.37** | Increasing |
| | C4 | Near bottom | TP | 81 | 0.16 | 0.12 | None |
| | C5 | Photic zone | TP | 85 | 0.13 | | None |
| | C5 | Near bottom | TP | 85 | **0.016** | | Decreasing |
| | C6 | Photic zone | TP | 82 | 0.098 | | None |
| | C6 | Near bottom | TP | 82 | 0.092 | | None |

a. Slope is in units of mg/L per year. Positive slope is an increase. Charts shown in appendix.

## 2.2 Chlorophyll a

Multi-year geometric mean (geomean) values for chlorophyll *a* are presented in Table 4. The geomean for chlorophyll *a* steadily increased at all sites from 1991-1992 through 2003-2007 and 2008-2014. The annual geometric mean chlorophyll *a* trigger value was exceeded at site C6 in 2003-2007. Annual geomean chlorophyll *a* concentration at sites C1, C4 and C5 remained below the trigger value of 3 µg/l both as a multi-year average and for individual years.

Maximum observed values for chlorophyll *a*, over the representative time periods, are presented in Table 5. The maximum chlorophyll *a* concentration trigger value of 5 µg/L was exceeded at sites C5 and C6 during the 2003-2007 time period, but not at sites C1 or C4. The maximum chlorophyll *a* trigger was exceeded at all sites during the 2008-2014 period, with C6 exhibiting the highest maximum concentration (17.9 µg/l) of all sites. Note that this trigger was not exceeded each year, but rather for one or more years during the respective time period.

Results from the two-population Mann-Whitney-Wilcoxon comparison of the 1991-1992 dataset with the 2003 – 2014 dataset are presented in Table 6. Chlorophyll *a* concentration was significantly higher at all sites in 2003-2014 compared to the 1991-1992 period. The magnitude of increase in chlorophyll *a* concentration was similar at C1, C4 and C5 (2X higher than 1991-1992). However, chlorophyll *a* concentration at site C6 increased over 3X from 1991-1992 at site C6.

Results from the Mann-Kendall trend test for the 2003 – 2014 dataset are presented in Table 7. The Mann-Kendall test identified a trend of increasing chlorophyll *a* trend at site C5. Chlorophyll *a* also increased at sites C1, C4 and C6 through the 2003-2014 period. However, these trends are only significant at a lower confidence level (90% confidence, $\alpha = 0.10$). The P-values for the Mann-Kendall test are significant at the 90% confidence level, but not at the 95% confidence level.

**Table 4. Status of the multi-year geometric mean chlorophyll *a* (Fluorescence method) trigger criteria at LMP core monitoring sites in relation to LMP trigger values.**

| Site | Depth | Variable | LMP Trigger (Annual geometric mean), (µg/L) | 1991-1992 geometric mean (µg/L)[a] | 2003-2007 geometric mean (µg/L) | 2008-2014 geometric mean (µg/L) |
|---|---|---|---|---|---|---|
| C1 | Photic zone | Chlorophyll a | ≥3 | 0.9 | 1.5 | 2.1 |
| C4 | Photic zone | Chlorophyll a | ≥3 | 0.9 | 1.5 | 2.0 |
| C5 | Photic zone | Chlorophyll a | ≥3 | 1.1 | 1.7 | 2.0 |
| C6 | Photic zone | Chlorophyll a | ≥3 | 1.2 | 3.0 | 3.1 |

a. HPLC method values converted to fluorometric method results (Wood and Beckwith 2008).

**Table 5. Status of maximum chlorophyll *a* (Fluorescence method) at LMP core monitoring sites in relation to LMP trigger values.**

| Site | Depth | Variable | LMP Trigger (Annual Maximum), (µg/L) | 1991-1992 maximum (µg/L)[1] | 2003-2007 maximum (µg/L) | 2008-2014 maximum (µg/L) |
|---|---|---|---|---|---|---|
| C1 | Photic zone | Chlorophyll *a* | ≥5 | 1.7 | 3.3 | 8.4 |
| C4 | Photic zone | Chlorophyll *a* | ≥5 | 1.8 | 3.1 | 5.3 |
| C5 | Photic zone | Chlorophyll *a* | ≥5 | 2.2 | 5.3 | 6.7 |
| C6 | Photic zone | Chlorophyll *a* | ≥5 | 3.1 | 17.9 | 13.2 |

[1] HPLC method values converted to fluorometric method results (Wood and Beckwith 2008).

**Table 6. Mann-Whitney-Wilcoxon two sample test for chlorophyll a concentration from 1991-1992 and 2003-2004 time periods. (Bold P-values are statistically significant at α=0.05).**

| Site | Depth | Variable | Median value (µg/L) and Sample size (n) | | P-Value | Conclusion |
|---|---|---|---|---|---|---|
| | | | 1991-1992 | 2003-2014 | | |
| C1 | Photic zone | Chlorophyll *a* | 0.92 (24) | 1.9 (84) | **<0.0001** | 91-92 < 03-14 |
| C4 | Photic zone | Chlorophyll *a* | 0.92 (26) | 1.9 (84) | **<0.0001** | 91-92 < 03-14 |
| C5 | Photic zone | Chlorophyll *a* | 1.1 (24) | 2.2 (80) | **0.0002** | 91-92 < 03-14 |
| C6 | Photic zone | Chlorophyll *a* | 1.4 (22) | 4.8 (79) | **<0.0001** | 91-92 < 03-14 |

**Table 7. Mann-Kendall trend analysis for chlorophyll a (fluorescence method) from 2003-2014 at LMP core monitoring sites. (Bold P-values are statistically significant at α= 0.05).**

| Time Period | Site | Depth | Variable | Mann-Kendall Trend Test (2003 – 2014) | | | |
|---|---|---|---|---|---|---|---|
| | | | | Sample Size (n) | P-Value | Theil-Sen slope [a] | Trend |
| 2003-2014 | C1 | Photic zone | Chlorophyll a | 84 | 0.09 | 0.05 | None |
| | C4 | Photic zone | Chlorophyll a | 84 | 0.06 | 0.04 | None |
| | C5 | Photic zone | Chlorophyll a | 80 | **0.03** | | Increasing |
| | C6 | Photic zone | Chlorophyll a | 79 | 0.08 | | None |

a. Slope is in units of mg/L per year. Positive slope is an increase. Charts shown in Appendix.

## 2.3 Dissolved Oxygen

Minimum observed values for hypolimnetic dissolved oxygen (D.O.), over the representative time periods, are presented in Table 8. The trigger values for minimum dissolved oxygen (D.O.) concentration in the hypolimnion is >6 mg/L for IDEQ and >8 mg/L for the Tribe. Through all three time periods the southern sites C5 and C6 have never met the Tribe's trigger criteria of >8 mg/L. Site C6 exhibited hypolimnetic anoxia (devoid of oxygen) every year it was sampled through the three time periods. Site C5 has exhibited hypoxic (low oxygen) conditions every year it was sampled through the three time periods. In the 1991-1992 period D.O. was >6 mg/L at site C1 and C4. However, in the 2003-2007 period minimum D.O. dropped below 6 at site C4, and also dropped below 6 mg/L at sites C1 and C4 in the 2008-2014 period. Note that D.O. did not drop below 6 mg/L each year at sites C1 and C4, but rather for one or more years during this time period.

Results from the two-population Mann-Whitney-Wilcoxon comparison of the 1991-1992 dataset with the 2003 – 2014 dataset are presented in Table 9. Multi-year median near bottom hypolimnetic D.O. concentrations during the thermally-stratified summer period (July-September) appear to be lower during the 2003-2014 time period than in 1991-1992 at sites C1 and C4. However, this difference is not significant to within 95% confidence, and therefore no change can be detected at this level of confidence. No change in median values is apparent at sites C5 and C6.

Results from the Mann-Kendall trend test for the 2003 – 2014 dataset are presented in Table 10. The Mann-Kendall trend test for the period of 2003-2014 identified a decreasing trend in near bottom hypolimnetic D.O., measured during thermally-stratified summer period (July-

September) at sites C1 and C6. No trend was identified at sites C4 or C5 during this time period. However, if a larger dataset that evaluates DO trends over the period of 1991 – 2014 and includes data from stratified conditions in October is considered (Table 11), then there is a statistically significant trend of decreasing near bottom hypolimnetic D.O. at both sites C1 and C4 – over this longer time frame.

**Table 8. Status of minimum dissolved oxygen (DO) in the hypolimnion trigger criteria at LMP core monitoring sites in relation to LMP trigger values.**

| Site | Depth | Variable | LMP Trigger (minimum, mg/L) | 1991-1992 minimum (mg/L) | 2003-2007 minimum (mg/L) | 2008-2014 minimum (mg/L) |
|---|---|---|---|---|---|---|
| C1 | Hypolimnion | DO | >6 | 6.4 | 6.4 | 5.5 |
| C4 | Hypolimnion | DO | >6 | 6.4 | 5.9 | 5.8 |
| C5 | Hypolimnion | DO | >8 | 2.8 | 2.5 | 3.0 |
| C6 | Hypolimnion | DO | >8 | 0.0 | 0.2 | 0.0 |

**Table 9. Mann-Whitney-Wilcoxon two sample test for summer-season hypolimnetic dissolved oxygen (DO) concentration (July-September) from 1991-1992 and 2003-2014 time periods. (Bold P-values are statistically significant at $\alpha$ level 0.05).**

| Site | Depth | Variable | Median value (mg/L) and Sample size (n) | | P-Value | Conclusion |
|---|---|---|---|---|---|---|
| | | | 1991-1992 | 2003-2014 | | |
| C1 | Near bottom | DO | 8.3 (8) | 7.8 (25) | 0.16 | 91-92 = 03-14 |
| C4 | Near bottom | DO | 8.5 (8) | 8.0 (22) | 0.11 | 91-92 = 03-14 |
| C5 | Near bottom | DO | 5.4 (10) | 6.0 (53) | 0.48 | 91-92 = 03-14 |
| C6 | Near bottom | DO | 1.7 (8) | 1.4 (40) | 0.61 | 91-92 = 03-14 |

**Table 10. Mann-Kendall trend analysis beginning for hypolimnetic dissolved oxygen (DO) from 2003-2014 within 1.0 m of the bottom (June-September), at LMP core monitoring sites. (Bold P-values are statistically significant at $\alpha$ level 0.05).**

| Time Period | Site | Depth | Variable | Mann-Kendall Trend Test (2003–2014) | | | |
|---|---|---|---|---|---|---|---|
| | | | | Sample Size (n) | P-Value | Theil-Sen slope [a] | Trend |
| 2003-2014 | C1 | Near bottom | DO | 50 | **0.04** | **-0.08** | Decreasing |
| | C4 | Near bottom | DO | 44 | 0.19 | -0.04 | None |
| | C5 | Near bottom | DO | 53 | 0.29 | | None |
| | C6 | Near bottom | DO | 48 | **0.007** | | Decreasing |

a. Slope is in units of mg/L per year. Negative slope is a decrease. Charts shown in Appendix.

**Table 11. Mann-Kendall trend analysis beginning for hypolimnetic dissolved oxygen (DO) from 1991-2014 within 1.0 m of the bottom (July-October), at sites C1 and C4 in the northern and central pools. (Bold P-values are statistically significant at $\alpha$ level 0.05).**

| Time Period | Site | Depth | Variable | Mann-Kendall Trend Test (1991 – 2014) | | | |
|---|---|---|---|---|---|---|---|
| | | | | Sample Size (n) | P-Value | Theil-Sen slope [a] | Trend |
| 1991-2014 | C1 | Near bottom | DO | 79 | **0.017** | **-0.04** | Decreasing |
| | C4 | Near bottom | DO | 77 | **0.024** | **-0.03** | Decreasing |

a. Slope is in units of mg/L per year. Negative slope is a decrease. Charts shown in Appendix.

## 2.4 Zinc

Multi-year geometric mean (geomean) values for dissolved zinc are presented in Table 12. The trigger values for dissolved zinc are the values associated with Idaho State water quality standards (IDAPA 58.01.02) and Coeur d'Alene Tribe water quality standards (Coeur d'Alene Tribe 2010). Dissolved zinc was not analyzed in the 1991-1992 period (Woods and Beckwith 1997), and not data are available for that time period. During the 2003-2007 and 2008-2014 periods dissolved zinc consistently exceeded the trigger value at all sites and depths, except for site C6.

Results from the two-population Mann-Whitney-Wilcoxon comparison for total zinc in the 1991-1992 dataset with the 2003 – 2014 dataset are presented in Table 13. Total zinc is not an LMP trigger. However, assessing changes in total zinc concentrations from the 1991-1992 baseline data helps assess the status of water quality in the lake. Excluding site C6, total zinc concentration at all sites and depths is significantly lower in the 2003-2014 time period than it was in the 1991-1992 time period. The magnitude of decrease in total zinc was relatively consistent across all sites.

Results from the Mann-Kendall trend test for the 2003 – 2014 dataset are presented in Table 14. The Mann-Kendall trend test for identified a significant decreasing trend in dissolved zinc concentration at all depths at sites C1 and C4 . Site C5 exhibited no trend in dissolved zinc .

**Table 12. Status of dissolved zinc (Zn) at LMP core monitoring sites in relation to LMP trigger values for dissolved zinc (values are geometric mean and range for each time period).**

| Site | Depth | Variable | LMP Trigger (WQ standard), (µg/L) | 1991-1992 geometric mean (µg/L)[b] | 2003-2007 geometric mean (µg/L) | 2008-2014 geometric mean (µg/L) |
|---|---|---|---|---|---|---|
| C1 | All Depths[a] | Dissolved Zn | ≥36[c] | — | 61 (33-91) | 56 (34-81) |
| C4 | All Depths | Dissolved Zn | ≥36 | — | 68 (36-95) | 60 (34 -97) |
| C5 | Photic zone | Dissolved Zn | ≥23-38[d] | — | 19 (1.4-60 ) | 16 (<5-52.5) |
| C5 | Near Bottom | Dissolved Zn | ≥26-37 | — | 33 (1.2 -80) | 35 (<5-84.5) |
| C6 | Photic zone | Dissolved Zn | ≥23-38 | — | N/A[e] | N/A |
| C6 | Near Bottom | Dissolved Zn | ≥23-38 | — | N/A | N/A |

a All depths includes; photic zone, 20m, 30m and near bottom.
b Dissolved lead was not measured in 1991-1992.
c Idaho WQ Standard criterion continuous concentration (CCC) using a lower hardness cap of 25 mg/L.
d CDA Tribe WQ Standard criterion continuous concentration (CCC) using hardness adjusted equations.
e From 2003-2014, 73% and 80% of samples from the photic zone and near bottom had concentrations of zinc < MRL.

**Table 13. Mann-Whitney-Wilcoxon two sample test for total zinc (Zn) concentration from 1991-1992 and 2003-2004 time periods (bold P-values are statistically significant at α=0.05).**

| Site | Depth | Variable | Median value (µg/L) and Sample size (n) | | P-Value | Conclusion |
|---|---|---|---|---|---|---|
| | | | 1991-1992 | 2003-2014 | | |
| C1 | All depths[a] | Total Zn | 100 (26) | 61 (295) | **<0.0001** | 91-92 > 03-14 |
| C4 | All depths[a] | Total Zn | 120 (26) | 67 (316) | **<0.0001** | 91-92 > 03-14 |
| C5 | Photic zone | Total Zn | 60 (12) | 33.3 (62) | **0.05** | 91-92 > 03-14 |
| C5 | Near bottom | Total Zn | 90 (11) | 50 (62) | **0.05** | 91-92 > 03-14 |
| C6 | Photic zone | Total Zn | N/A2 | N/A2 | N/A | N/A |
| C6 | Near bottom | Total Zn | N/A | N/A | N/A | N/A |

a. All depths includes; photic zone, 20m, 30m and near bottom.
b From 1991-1992 and 2003-2014, 73% and 80% of samples from the photic zone and near bottom had concentrations of zinc <MRL.

**Table 14. Mann-Kendall trend analysis from 2003 through 2014 for dissolved zinc (Zn) at LMP core monitoring sites (bold P-values are statistically significant at α=0.05).**

| Time Period | Site | Depth | Variable | Mann-Kendall Trend Test (2003–2014) | | | |
|---|---|---|---|---|---|---|---|
| | | | | Sample Size (n) | P-Value | Theil-Sen slope [a] | Trend |
| 2003-2014 | C1 | Photic zone | Dissolved Zn | 82 | **0.013** | **-0.61** | Decreasing |
| | C1 | 20 m depth | Dissolved Zn | 62 | **<0.001** | **-1.4** | Decreasing |
| | C1 | 30 m depth | Dissolved Zn | 65 | **<0.001** | **-1.3** | Decreasing |
| | C1 | Near bottom | Dissolved Zn | 78 | **0.003** | **-0.96** | Decreasing |
| | C4 | Photic zone | Dissolved Zn | 81 | **0.025** | **-0.75** | Decreasing |
| | C4 | 20 m depth | Dissolved Zn | 78 | **<0.001** | **-1.4** | Decreasing |
| | C4 | 30 m depth | Dissolved Zn | 65 | **0.001** | **-1.4** | Decreasing |
| | C4 | Near bottom | Dissolved Zn | 81 | **<0.001** | **-1.6** | Decreasing |
| | C5 | Photic zone | Dissolved Zn | 83 | 0.40 | | None |
| | C5 | Near bottom | Dissolved Zn | 84 | 0.38 | | None |
| | C6 | Photic zone | Dissolved Zn | 88 | N/A[b] | | N/A |
| | C6 | Near bottom | Dissolved Zn | 88 | N/A | | N/A |

a. Slope is in units of µg/L per year. Negative slope is a decrease. Charts shown in Appendix.
b Dissolved zinc concentrations were less than the minimum reporting limit 73 % of the time.

## 2.5 Lead

Multi-year geometric mean (geomean) values for dissolved lead are presented in Table 15. The trigger values for dissolved lead are the values associated with Idaho State water quality standards (IDAPA 58.01.02) and Coeur d'Alene Tribe water quality standards (Coeur d'Alene Tribe 2010). Dissolved lead was not analyzed in the 1991-1992 period (Woods and Beckwith 1997). During the 2003-2007 and 2008-2014 periods the multi-year geomean concentration did not exceed the dissolved lead trigger. However, maximum observed values consistently exceeded the trigger value at all sites and depths, except for site C6.

Results from the two-population Mann-Whitney-Wilcoxon comparison for Total zinc in the 1991-1992 dataset with the 2003 – 2014 dataset are presented in Table 16. Total lead is not an

LMP trigger. However, assessing changes in total lead concentrations from the 1991-1992 baseline data helps assess the status water quality in the lake. Multi-year median values for total lead were higher in 1991-1992 time period than in the 2003 – 2014 period. However, this difference is only significant to within 95% confidence at sites C1, C5, and C6. The decrease is not significant to within 95% confidence at site C4.

Results from the Mann-Kendall trend test for the 2003 – 2014 dataset are presented in Table 17. The Mann-Kendall trend test identified a significant trend of increasing dissolved lead at 3 depths at site C1 in the northern pool (20m, 30m and near bottom). No significant trend was observed in the photic zone. At site C4 in the central pool, a significant trend of increasing dissolved lead was observed at the 30 m depth interval, but not at the other 3 depths (photic zone, 20 m, near bottom). Site C5 exhibited no trend in dissolved lead.

**Table 15. Status of dissolved lead (Pb) at LMP core monitoring sites in relation to LMP trigger values for dissolved lead (values are geometric mean and range for each time period).**

| Site | Depth | Variable | LMP Trigger (WQ standard), (µg/L) | 1991-1992 geometric mean (µg/L)[b] | 2003-2007 geometric mean (µg/L) | 2008-2014 geometric mean (µg/L) |
|---|---|---|---|---|---|---|
| C1 | All Depths[a] | Dissolved Pb | >0.54[c] | -- | 0.11 (0.04-0.90) | 0.18 (0.05-4.5) |
| C4 | All Depths | Dissolved Pb | >0.54 | -- | 0.24 (0.04 -2.8) | 0.36 (0.05-5.9) |
| C5 | Photic zone | Dissolved Pb | >0.30-0.57[d] | -- | 0.14 (0.04-0.65) | 0.15 (<0.1-0.87) |
| C5 | Near Bottom | Dissolved Pb | >0.34-0.58 | -- | 0.16 (0.04-0.95) | 0.20 (<0.1-1.1) |
| C6 | Photic zone | Dissolved Pb | >0.30-0.57 | -- | N/A[5] | N/A |
| C6 | Near Bottom | Dissolved Pb | >0.30-0.57 | -- | N/A | N/A |

a. All depths includes; photic zone, 20m, 30m and near bottom.
b. Dissolved lead was not measured in 1991-1992.
c. Idaho WQ Standard criterion continuous concentration (CCC) using a lower hardness cap of 25 mg/L.
d. CDA Tribe WQ Standard criterion continuous concentration (CCC) using hardness adjusted equations.
e. From 2003 through 2014, 92% and 95% of all samples from the photic zone and near bottom had concentrations of lead less than the minimum reporting limit.

**Table 16. Mann-Whitney-Wilcoxon two sample test for total lead (PB) concentration from 1991-1992 and 2003-2004 time periods (bold P-values are statistically significant at $\alpha$=0.05).**

| Site | Depth | Variable | Median value (µg/L) and Sample size (n) 1991-1992 | 2003-2014 | P-Value | Conclusion |
|---|---|---|---|---|---|---|
| C1 | All Depths[a] | Total Pb | 4.0 (26) | 0.7 (295) | **0.0001** | 91-92 > 03-14 |
| C4 | All Depths[a] | Total Pb | 3.5 (26) | 2.0 (316) | 0.12 | 91-92 = 03-14 |
| C5 | Photic Zone | Total Pb | 3.5 (12) | 0.95 (62) | **0.04** | 91-92 > 03-14 |
| C5 | Near Bottom | Total Pb | 5.0 (11) | 1.85 (62) | **0.05** | 91-92 > 03-14 |
| C6 | Photic Zone | Total Pb | N/A[b] | N/A[b] | N/A | N/A |
| C6 | Near Bottom | Total Pb | N/A[b] | N/A[b] | N/A | N/A |

a. All depths includes; photic zone, 20m, 30m and near bottom.
b. From 1991-1992 and 2003-2014, 73% and 80% of samples from the photic zone and near bottom had concentrations of lead <MRL.

**Table 17. Mann-Kendall trend analysis from 2003 through 2014 for dissolved lead at LMP core monitoring sites (bold P-values are statistically significant at $\alpha$=0.05).**

| Time Period | Site | Depth | Variable | Mann-Kendall Trend Test (2003–2014) | | | |
|---|---|---|---|---|---|---|---|
| | | | | Sample Size (n) | P-Value | Theil-Sen slope [b] | Trend |
| 2003–2014 | C1 | Photic zone | Dissolved Pb | 85 | 0.30 | 0.000 | None |
| | C1 | 20 m depth | Dissolved Pb | 62 | **0.001** | **0.017** | Increasing |
| | C1 | 30 m depth | Dissolved Pb | 66 | **0.014** | **0.015** | Increasing |
| | C1 | Near bottom | Dissolved Pb | 78 | **0.044** | **0.011** | Increasing |
| | C4 | Photic zone | Dissolved Pb | 81 | 0.26 | 0.0025 | None |
| | C4 | 20 m depth | Dissolved Pb | 79 | 0.33 | 0.000 | None |
| | C4 | 30 m depth | Dissolved Pb | 66 | **0.044** | **0.022** | Increasing |
| | C4 | Near bottom | Dissolved Pb | 81 | 0.50 | 0.000 | None |
| | C5 | Photic zone | Dissolved Pb | 83 | 0.26 | | None |
| | C5 | Near bottom | Dissolved Pb | 84 | 0.16 | | None |
| | C6 | Photic zone | Dissolved Pb | 88 | N/A[2] | | N/A |
| | C6 | Near bottom | Dissolved Pb | 88 | N/A | | N/A |

a. Slope is in units of µg/L per year. Positive slope is an increase. Charts shown in Appendix.
b. Dissolved lead concentrations were less than the minimum reporting limit 91% of the time.

## 2.6 Cadmium

Multi-year geometric mean (geomean) values for dissolved cadmium are presented in Table 18. The trigger values for dissolved cadmium are the values associated with Idaho State water quality standards (IDAPA 58.01.02) and Coeur d'Alene Tribe water quality standards (Coeur d'Alene Tribe 2010). Dissolved cadmium was not analyzed in the 1991-1992 period (Woods and Beckwith 1997). Dissolved cadmium levels vary with water hardness, and hardness varies seasonally and inter-annually. Analyses of dissolved cadmium trends need to account for this variability. During the 2003-2007 and 2008-2014 periods the multi-year geomean fell within the range of the trigger at sites C1 and C4, but not at site C5. However, maximum observed values for these time periods consistently exceeded the trigger value at all sites and depths, except for site C6.

In the 1991-1992 period the detection limit for total cadmium was above lake concentrations. Therefore, total cadmium concentrations from 1991 – 1992 cannot be directly compared with measurements from the 2003-2007 and 2008-2014 time periods.

Results from the Mann-Kendall trend test for the 2003 – 2014 dataset are presented in Table 19. The Mann-Kendall trend test identified a significant trend of decreasing dissolved cadmium at the near bottom depth at site C4, but not at the other depths. No trends for dissolved cadmium were found at site C1, for any depths. An increasing trend for dissolved cadmium was identified for the photic zone of site C5.

**Table 18. Status of dissolved cadmium (Cd) at LMP core monitoring sites in relation to LMP trigger values for dissolved cadmium (values are geometric mean and range for each time period).**

| Site | Depth | Variable | LMP Trigger (Annual geometric mean), (µg/L) | 1991-1992 geometric mean (µg/L)[b] | 2003-2007 geometric mean (µg/L) | 2008-2014 geometric mean (µg/L) |
|---|---|---|---|---|---|---|
| C1 | All Depths[a] | Dissolved Cd | >0.22-0.25[c] | — | 0.23 (0.15 -0.34) | 0.22 (0.16 -0.37) |
| C4 | All Depths | Dissolved Cd | >0.22-0.25 | — | 0.25 (0.16 -0.43) | 0.25 (0.11-0.41) |
| C5 | Photic zone | Dissolved Cd | >0.19-0.26[c] | — | 0.07 (0.02-0.16) | 0.09 (<0.1 -0.24) |
| C5 | Near Bottom | Dissolved Cd | >0.20-0.26 | — | 0.12 (0.02-0.29) | 0.13 (<0.1-0.38) |
| C6 | Photic zone | Dissolved Cd | >0.19-0.26 | — | N/A[d] | N/A |
| C6 | Near Bottom | Dissolved Cd | >0.19-0.26 | — | N/A | N/A |

a. All depths includes; photic zone, 20m, 30m and near bottom.
b. Dissolved cadmium was not measured in 1991-1992.
c. Idaho WQ Standard CDA Tribe WQ Standard criterion continuous concentration (CCC) using hardness adjusted equations.
d. From 2003 through 2014, 97% of all samples from the photic zone and near bottom had concentrations < MRL.

**Table 19. Mann-Kendall trend analysis from 2003 through 2014 for dissolved cadmium (Cd) at LMP core monitoring sites (bold P-values are statistically significant at $\alpha$=0.05).**

| Time Period | Site | Depth | Variable | Mann-Kendall Trend Test (2003–2014) | | | |
|---|---|---|---|---|---|---|---|
| | | | | Sample Size (n) | P-Value | Theil-Sen slope [a] | Trend |
| 2003-2014 | C1 | Photic zone | Dissolved Cd | 81 | 0.11 | 0.000 | None |
| | C1 | 20 m depth | Dissolved Cd | 62 | 0.22 | 0.000 | None |
| | C1 | 30 m depth | Dissolved Cd | 66 | 0.24 | 0.000 | None |
| | C1 | Near bottom | Dissolved Cd | 78 | 0.49 | 0.000 | None |
| | C4 | Photic zone | Dissolved Cd | 81 | 0.35 | 0.000 | None |
| | C4 | 20 m depth | Dissolved Cd | 79 | 0.18 | -0.0012 | None |
| | C4 | 30 m depth | Dissolved Cd | 66 | 0.11 | -0.0016 | None |
| | C4 | Near bottom | Dissolved Cd | 81 | **0.021** | -0.0025 | Decreasing |
| | C5 | Photic zone | Dissolved Cd | 83 | **0.006** | | Increasing |
| | C5 | Near bottom | Dissolved Cd | 84 | 0.17 | | None |
| | C6 | Photic zone | Dissolved Cd | 88 | N/A [2] | | N/A |
| | C6 | Near bottom | Dissolved Cd | 88 | N/A | | N/A |

a. Slope is in units of µg/L per year. Negative slope is a decrease. Charts shown in Appendix.
b. Dissolved cadmium concentrations were less than the minimum reporting limit 97% of the time.

# 3 Summary of Lake Status

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. Overall, the lake's water quality with respect to metals has begun to improve. Total zinc levels have declined since the 1990's and total lead levels have also declined at some locations. Dissolved zinc levels continue to decline. However, different trends are observed for the lake's trophic state indicators; chlorophyll *a*, oxygen, and phosphorus. Dissolved oxygen levels during the summer stratified season have slowly declined from their 1990's levels in the northern lake, while chlorophyll *a* and phosphorus levels have increased. The southern regions of the lake remain in a higher productivity state. The northern lake's trophic indicators appear to be trending away from the preferred oligotrophic state, though additional data and analysis is needed to more completely quantify these emerging trends and assess their potential impacts. Results from the different statistical analyses are summarized below.

## 3.1 Dissolved Metals

Dissolved metals (zinc, lead and cadmium) in the 2008-2014 period have regularly exceeded trigger criteria based on the Idaho and Tribe water quality standards. Dissolved zinc has consistently exceeded these water quality targets. The Mann-Whitney-Wilcoxon test indicates that total zinc is significantly lower in the 2003-2014 period than in the 1991 -1992 period at all sites and depths. Mann Kendall trend analysis of the most recent 2003-2014 continuous data set reveal a statistically significant trend of decreasing zinc at all sites and depths in the northern and central pools (sites C1, C4). No corresponding trend is seen in the southern lake (sites C5, C6).

For lead, the Mann-Whitney-Wilcoxon test indicates that total lead is significantly lower in the 2003-2014 period than in the 1991 -1992 period at sites C1 and C5. No statistically significant difference can be identified at site C4. Mann Kendall trend analysis of the most recent 2003-2014 continuous dataset reveal a statistically significant trend of increasing lead at some depths in the northern and central pools (20 m, 30, near bottom at C1; 30 m at C4). Other sampling depths do not show a trend. No corresponding trend is seen in the southern lake (sites C5, C6).

For cadmium, no meaningful comparison can be made between the 1991-1992 dataset and that for 2003-2014. Mann Kendall trend analysis of the most recent 2003-2014 continuous dataset reveal a trend of decreasing dissolved cadmium at the near bottom of site C4 (central pool) and increasing cadmium in the photic zone of site C5 (southern lake). Other locations and sampling depths do not show a trend that is statistically significant at the 95% confidence level.

## 3.2 Dissolved Oxygen

Dissolved oxygen has consistently dropped below trigger criteria in the southern lake, but has only intermittently dropped below trigger criteria in the northern lake. During the 2008-2014 period, near bottom minimum dissolved oxygen concentrations were substantially lower than LMP trigger values at sites C5 and C6. At the near bottom site C6 consistently became anoxic (zero dissolved oxygen) and site C5 was consistently hypoxic (3 mg/L). Near bottom minimum dissolved oxygen concentrations at sites C1 and C4 in the 2008-2014 period were at or slightly below the LMP trigger value of 6 mg/L. The Mann-Whitney-Wilcoxon test indicates that the multi-year median value for near bottom dissolved oxygen measured during thermally stratified periods in July through September is not significantly different between the 1991-1992 time period and the 2003-2014 time period for any sites, at the 95% confidence level.

In contrast, Mann Kendall trend analysis of the most recent 2003-2014 continuous dataset reveals a statistically significant trend of decreasing near bottom dissolved oxygen at sites C1 and C6. No trend can be discerned for sites C4 and C5 over this time period, at the 95% confidence level. However, analyses of a larger 1991 – 2014 dataset for near bottom dissolved oxygen measured during the July – October thermally stratified time period reveal a statistically significant trend of decreasing dissolved oxygen at sites C1 and C4.

## 3.3 Total Phosphorus and Chlorophyll a

Total phosphorus in the 2008-2014 time period has consistently exceeded trigger criteria (8 µg/L annual geomean) in the southern lake and intermittently exceeded criteria in the northern lake. Results from the Mann-Whitney-Wilcoxon test indicate that total phosphorus in the 2003-2014 period is significantly higher than in the 1991-1992 period, for all monitoring locations. Mann Kendall trend analysis of the most recent continuous dataset reveals a statistically significant trend of increasing total phosphorus at all depths at site C1 (northern pool). Site C4 (central pool) has experienced a statistically significant trend of increasing total phosphorus at the 30m (hypolimnion) depth, but no trends at other depths. Site C5 (southern lake) has experienced a statistically significant decreasing trend for total phosphorus at the near bottom depth.

Maximum chlorophyll *a* has exceeded the trigger criteria of 5 µg/L for one or more years at all sampling locations. Sites C1, C4, and C5 have not exceeded the annual geomean criteria of 3 µg/L. Results from the Mann-Whitney Wilcoxon test indicate that chlorophyll *a* in the 2003-2014 period is significantly higher than in the 1991-1992 period, for all monitoring locations. Mann Kendall trend analysis of the most recent continuous dataset reveals a statistically significant trend of increasing chlorophyll *a* at site C5. Similar trends are observed at sites C1, C4, and C6; but these trends are only statistically significant at a lower degree of confidence (90% confidence, $\alpha = 0.10$).

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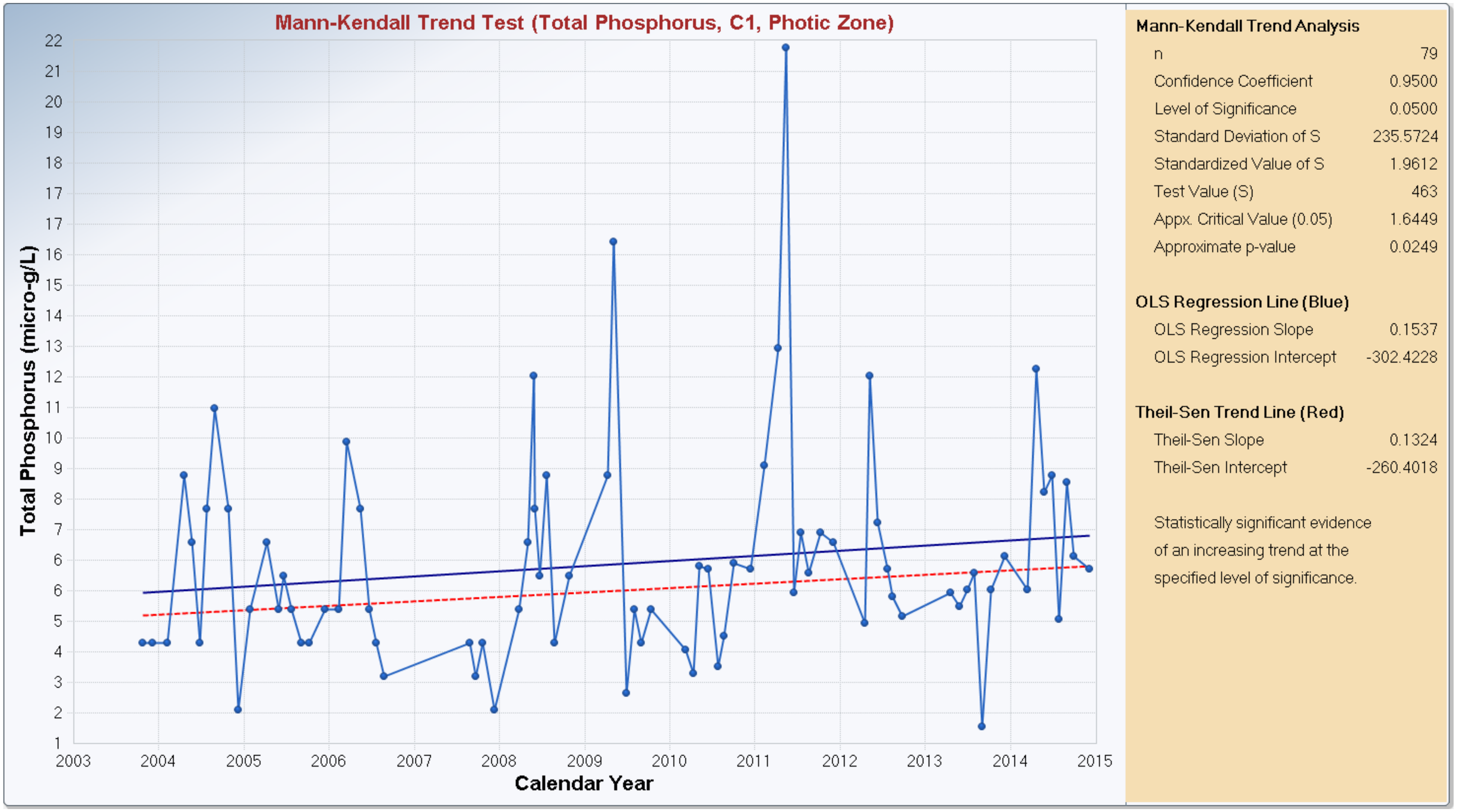
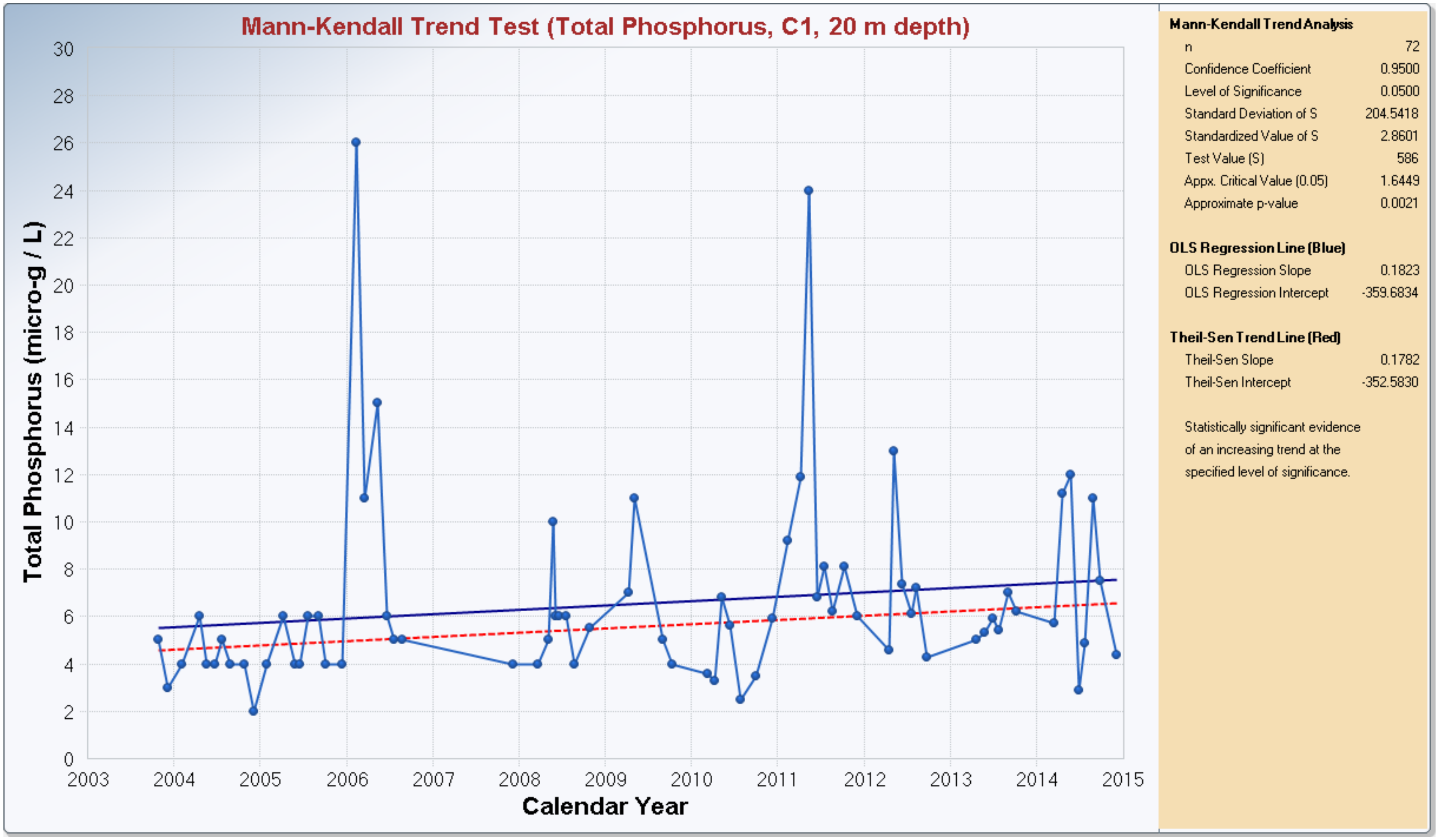
# Appendix A. Mann Kendall Trend Analyses for Total Phosphorus

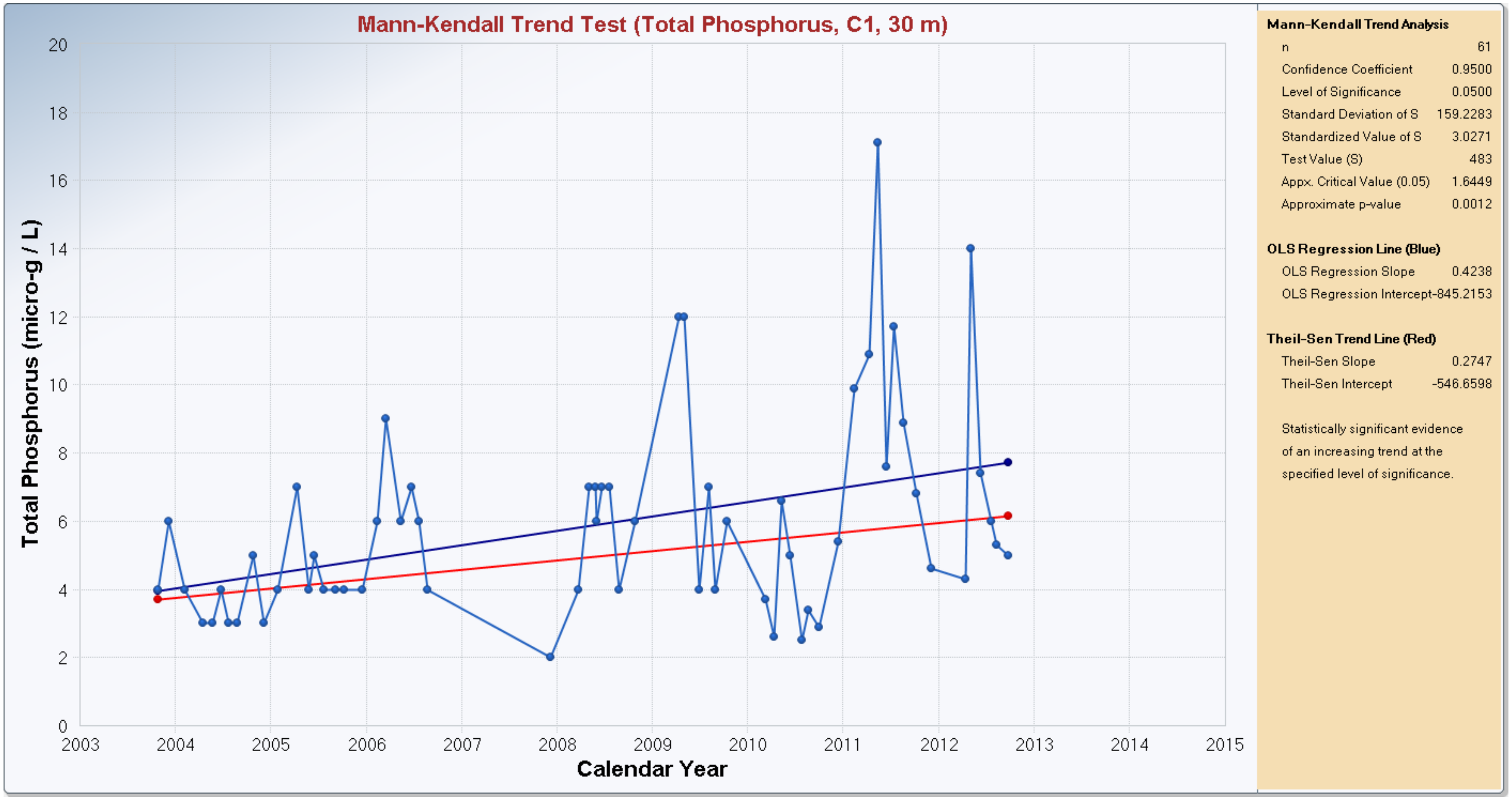
## Site C1, Tubbs Hill, Photic Zone



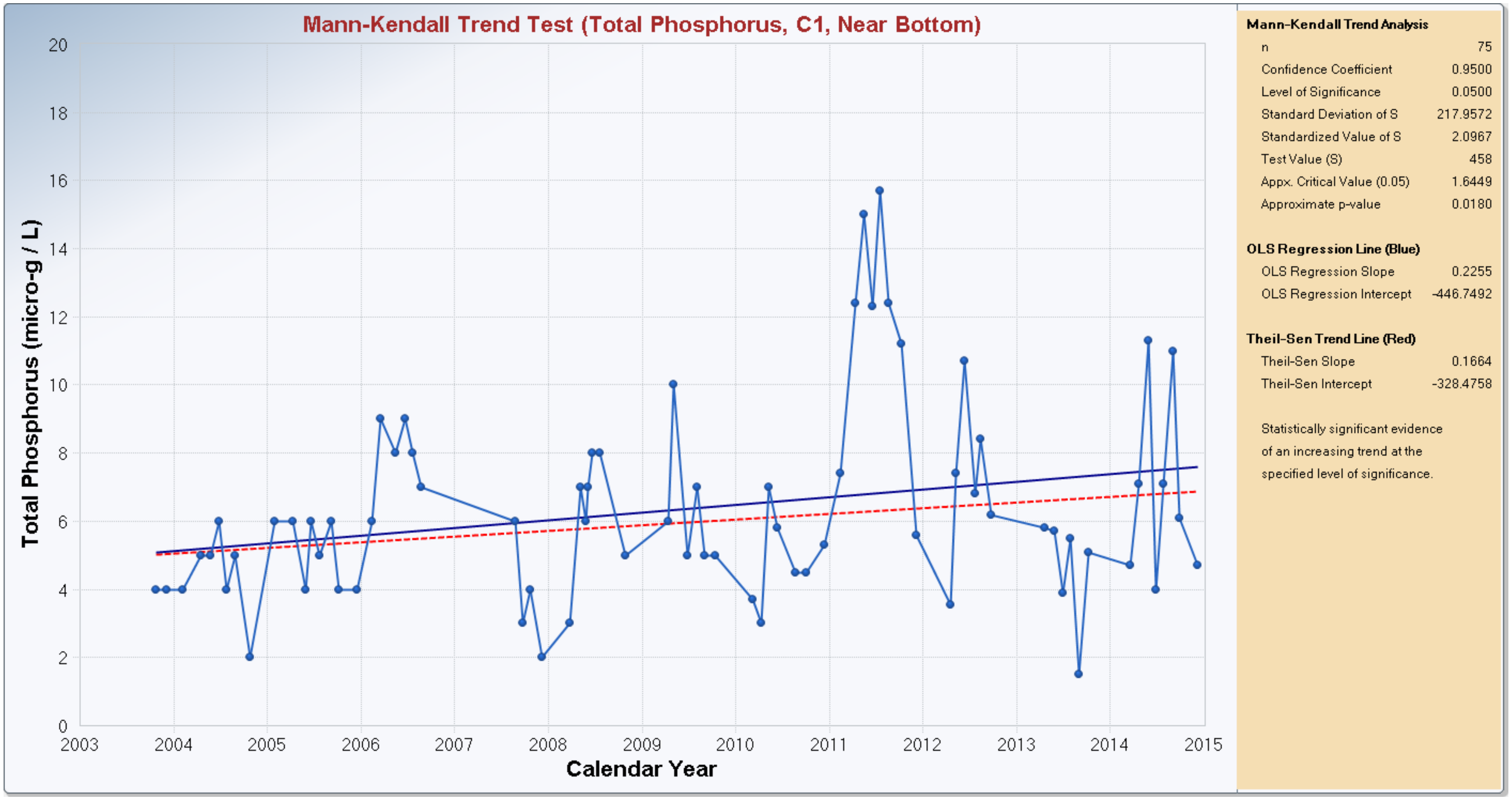
## Site C1, Tubbs Hill, 20 m depth



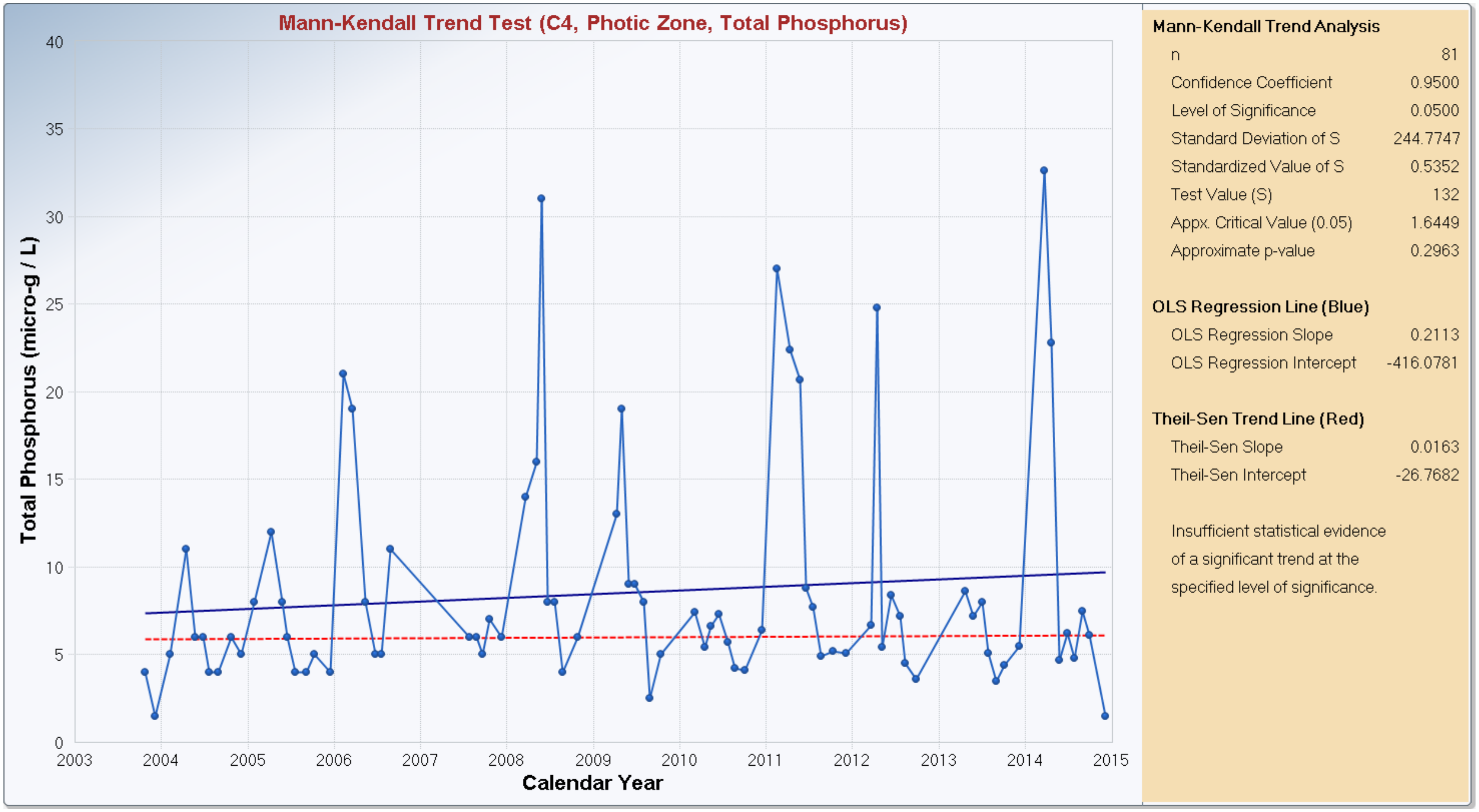
## Site C1, Tubbs Hill, 30 m depth



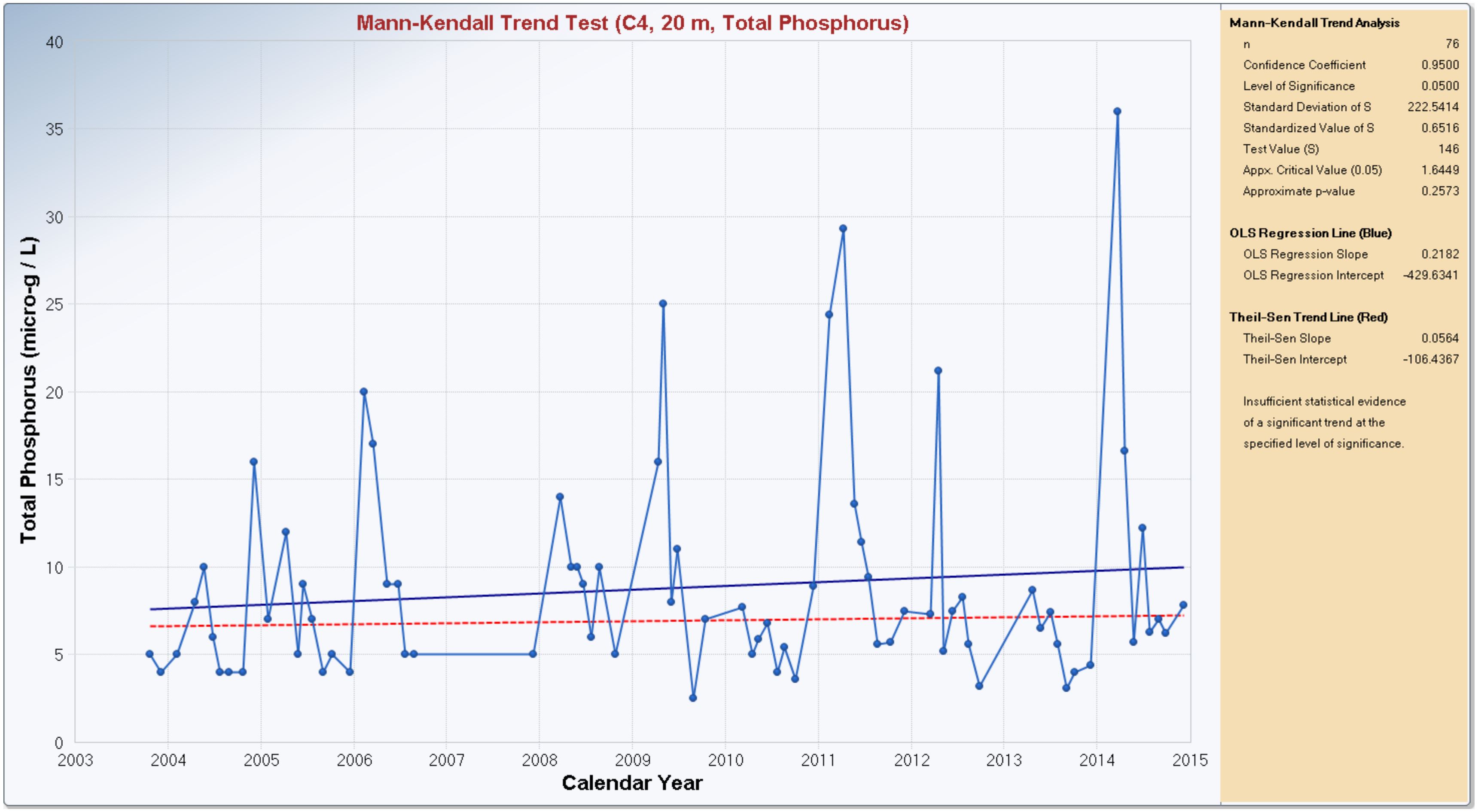
## Site C1, Tubbs Hill, Near Bottom



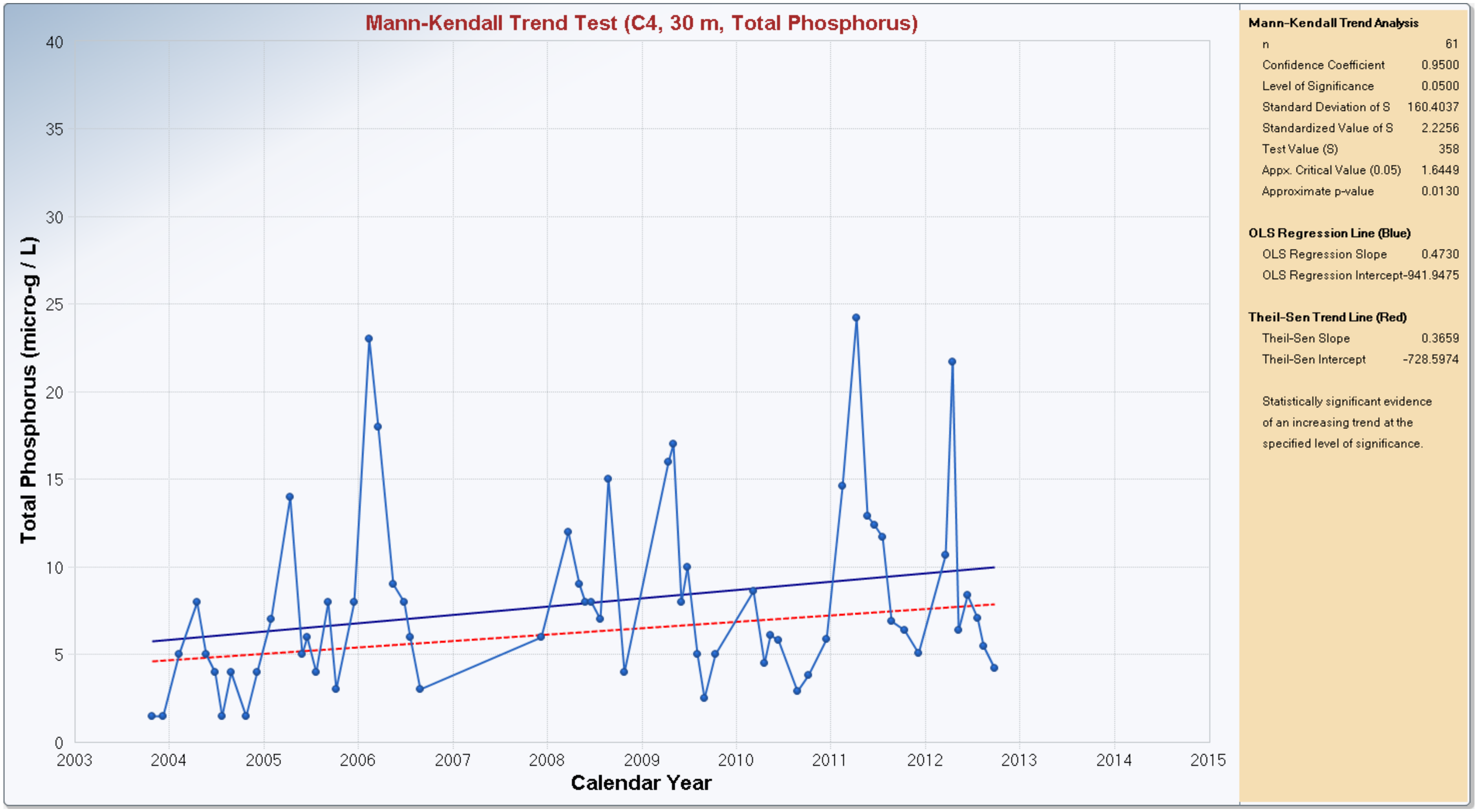
## Site C4, University Point, Photic Zone



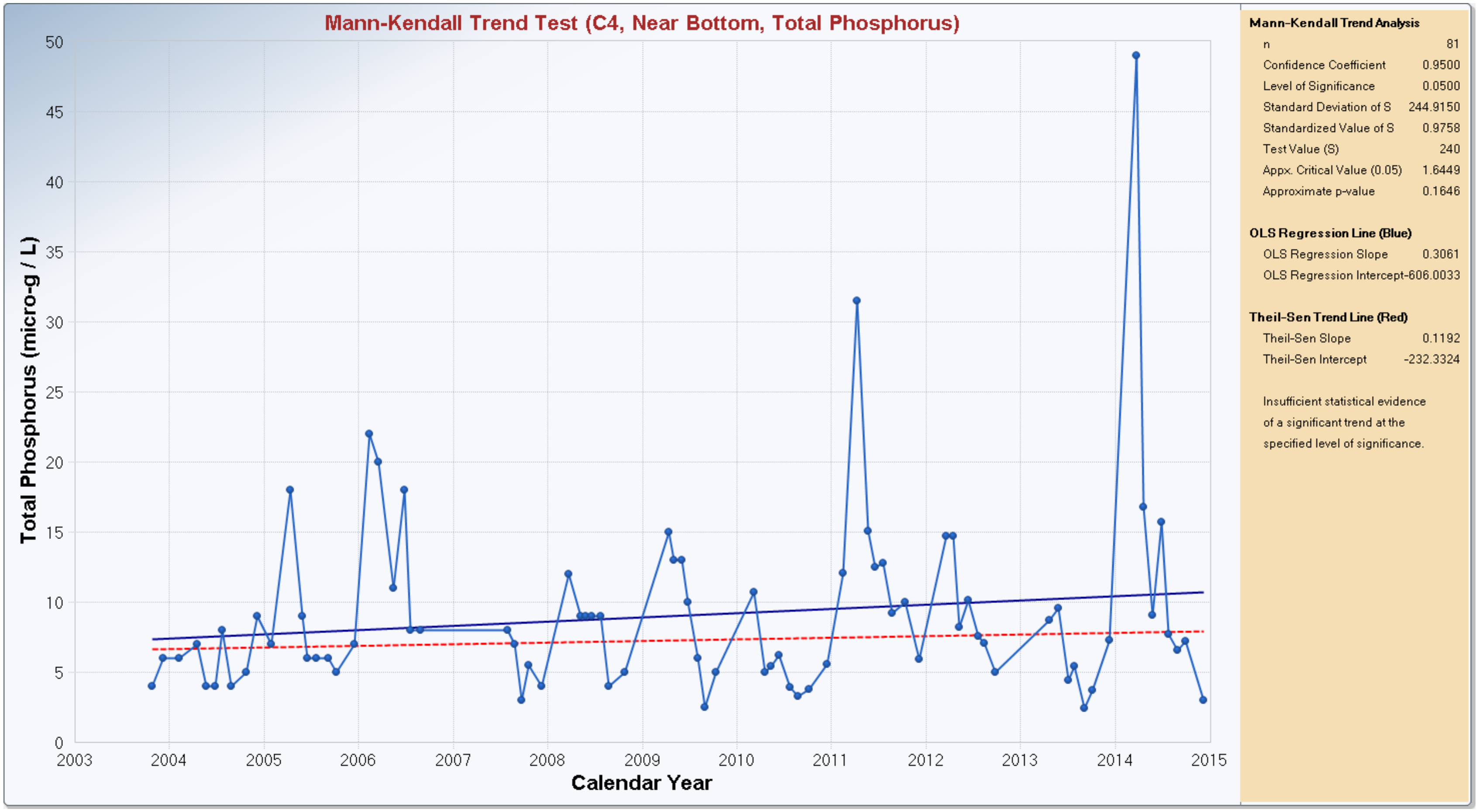
# Site C4, University Point, 20 m depth



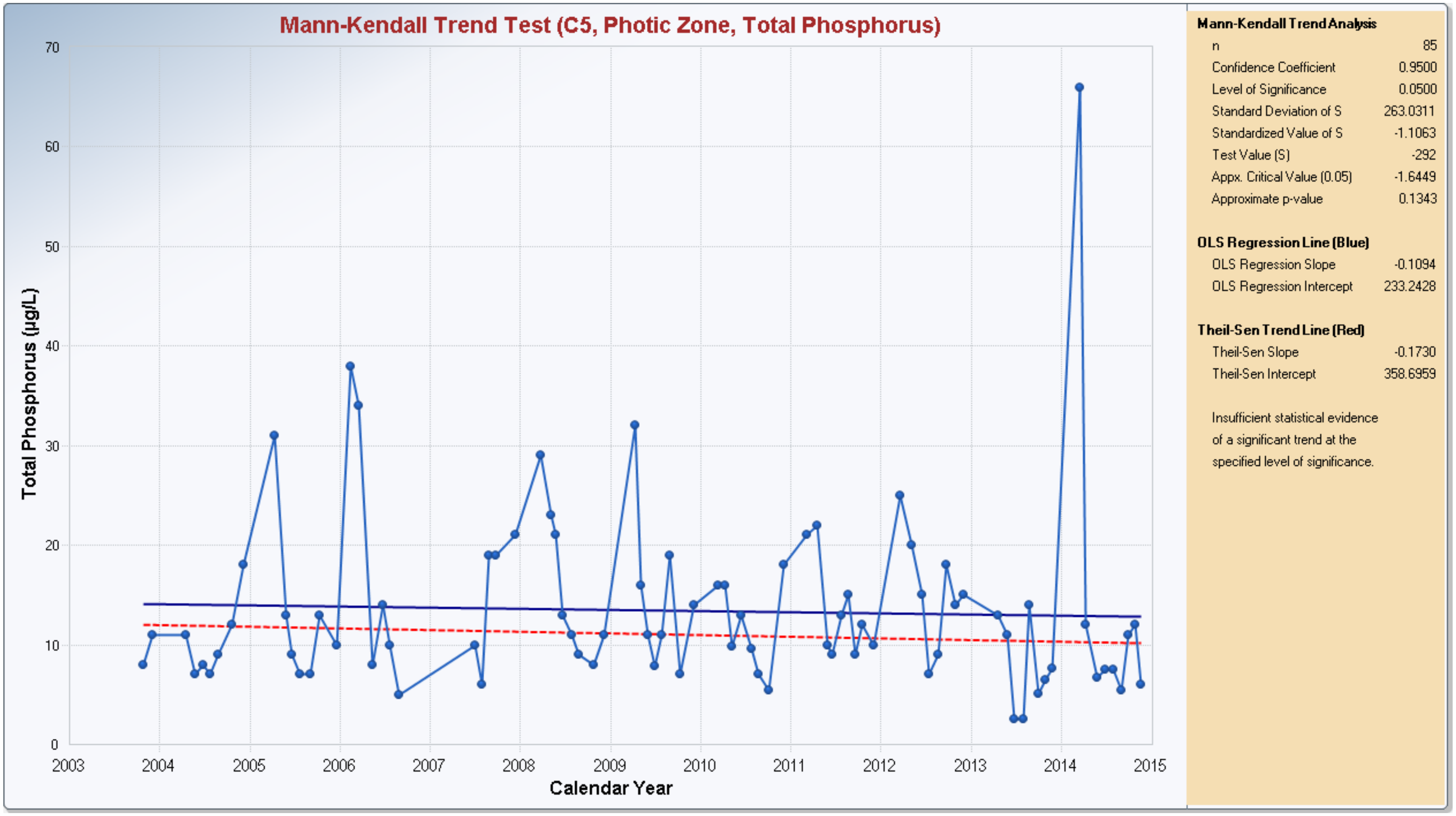
## Site C4, University Point, 30 m depth



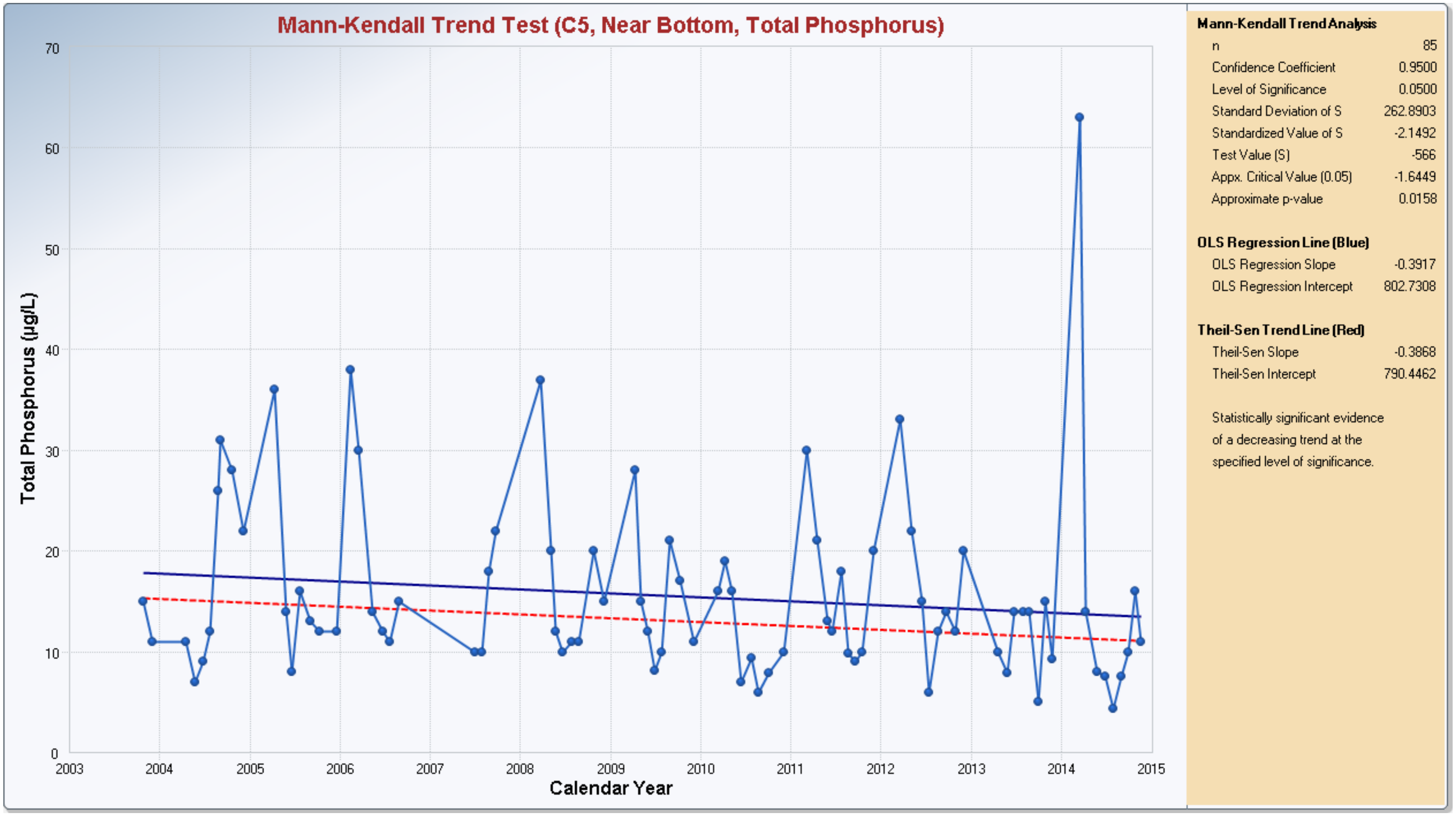
## Site C4, University Point, Near Bottom



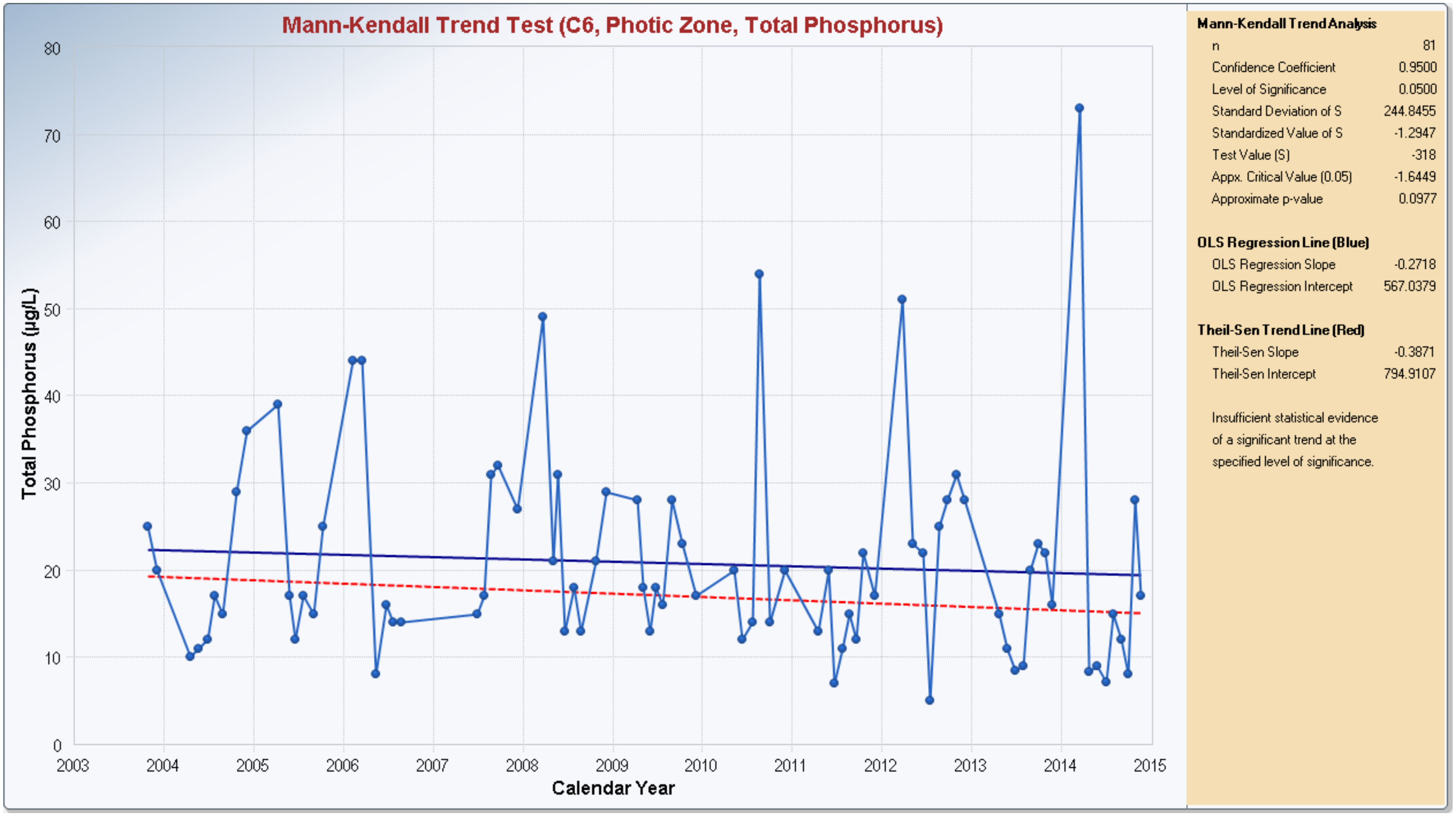
## Site C5, Chippy/Blue Point, Photic Zone



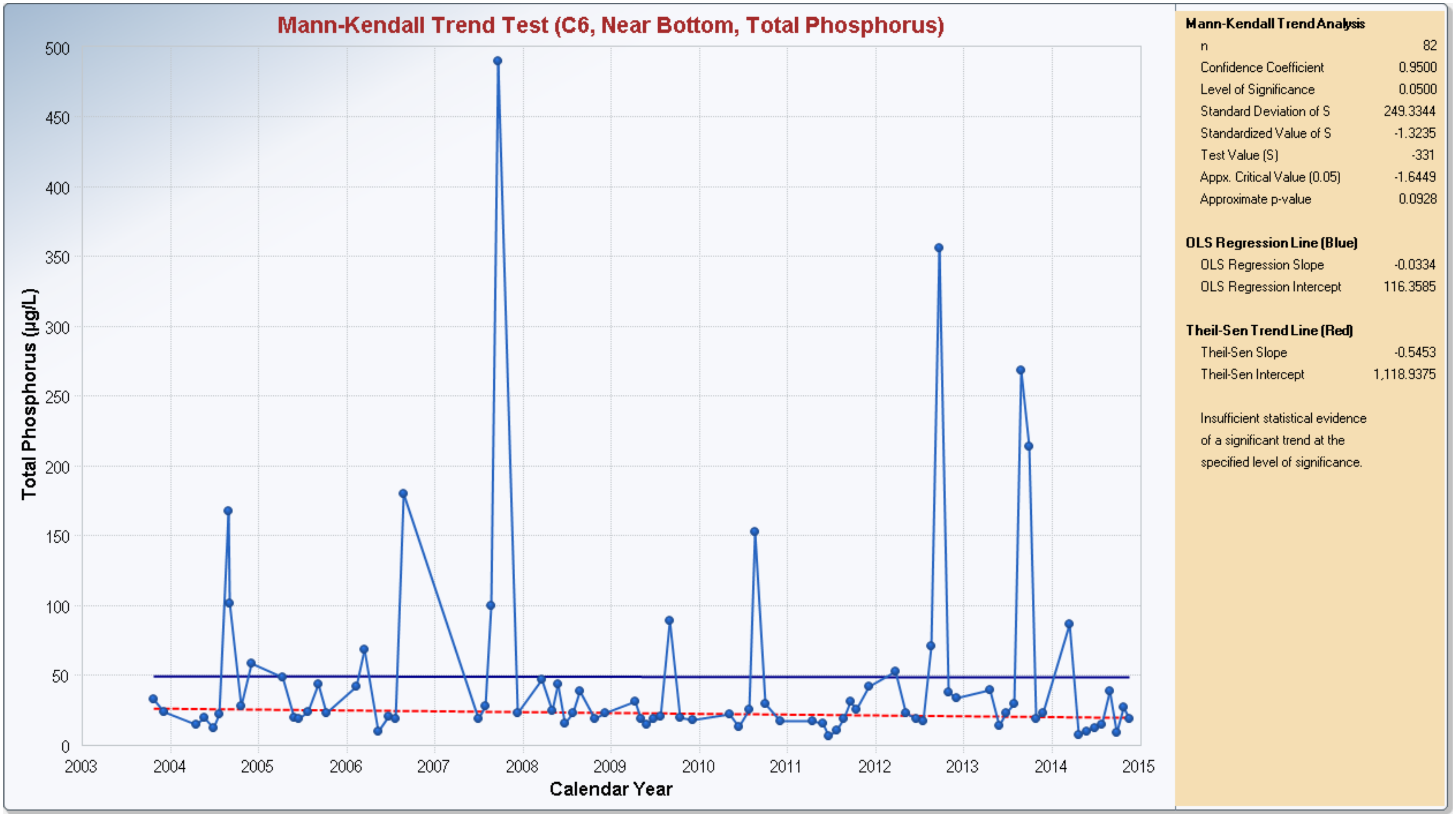
# Site C5, Chippy/Blue Point, Near Bottom



## Site C6, Chatcolet Lake, Photic Zone

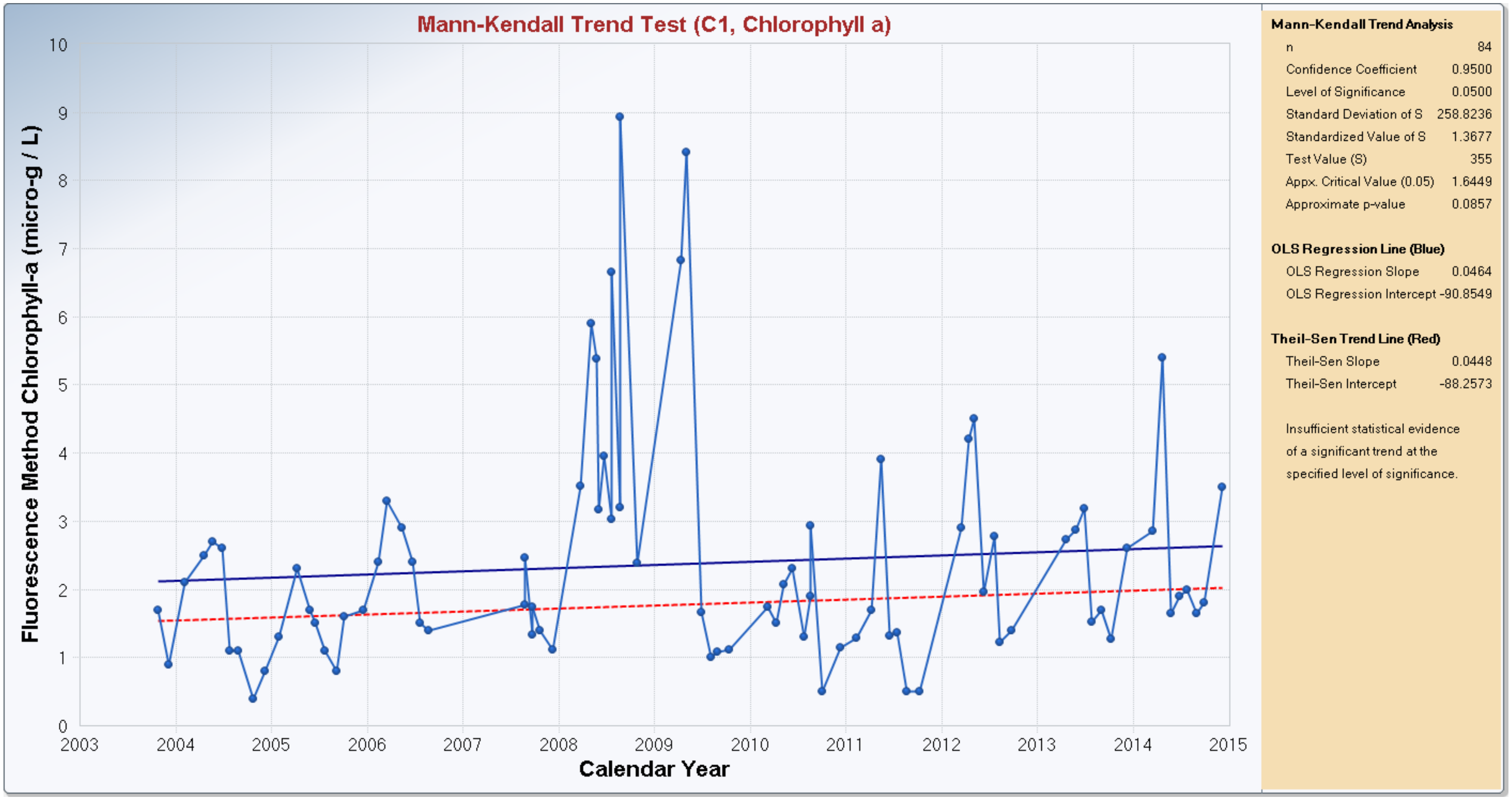


## Site C6, Chatcolet Lake, Near Bottom

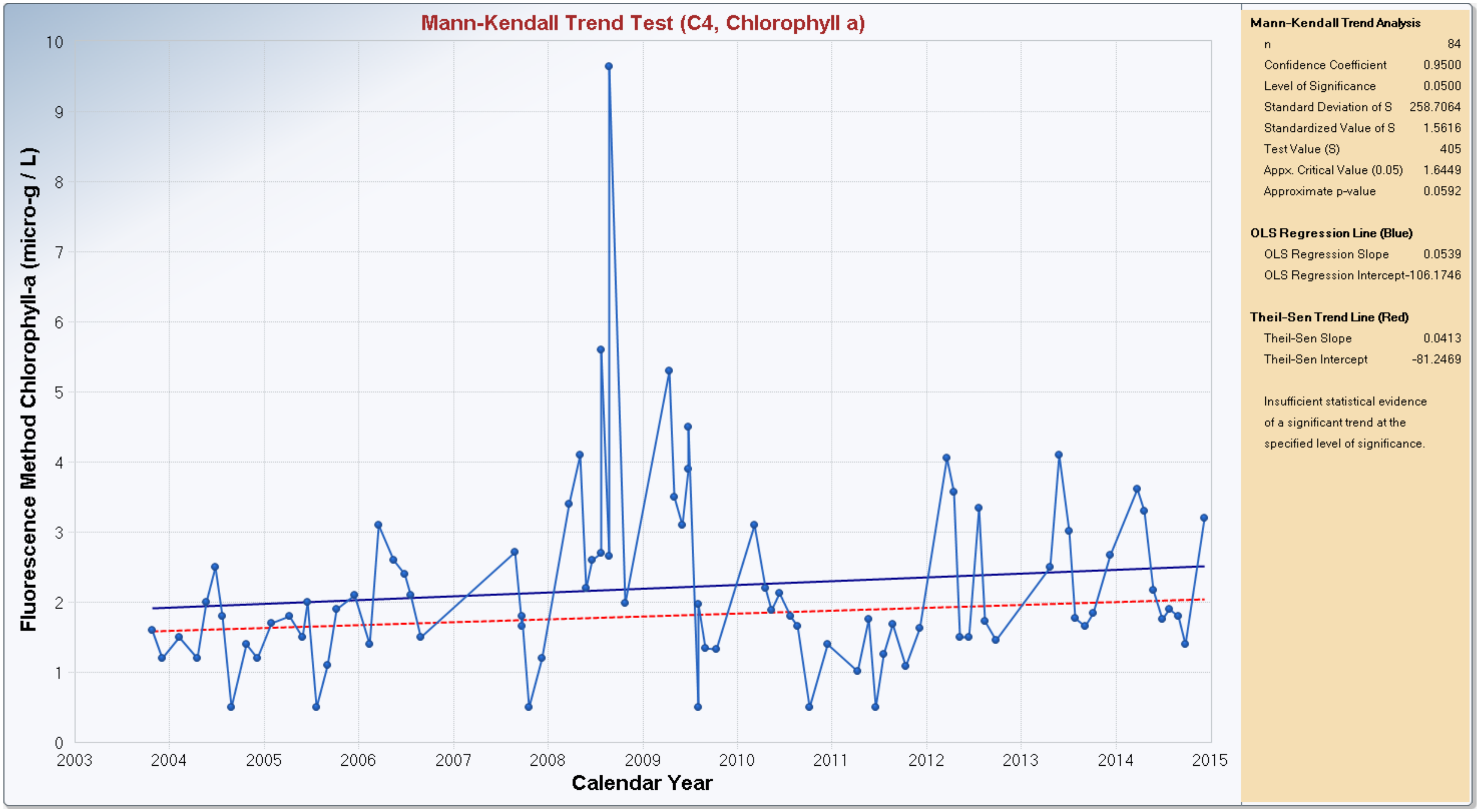


# Appendix B. Mann Kendall Trend Analyses for Chlorophyll a

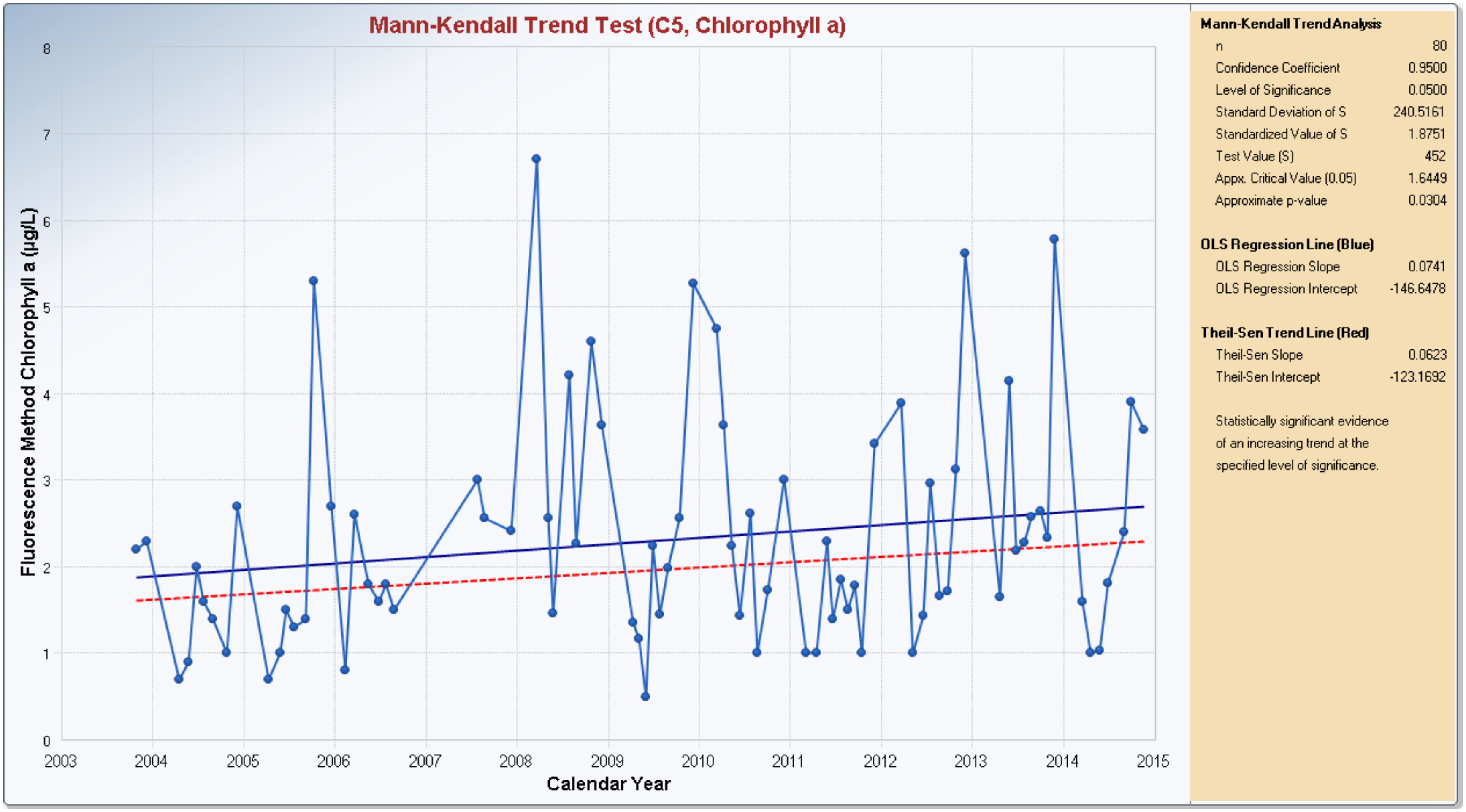
## Site C1, Tubbs Hill, Photic Zone



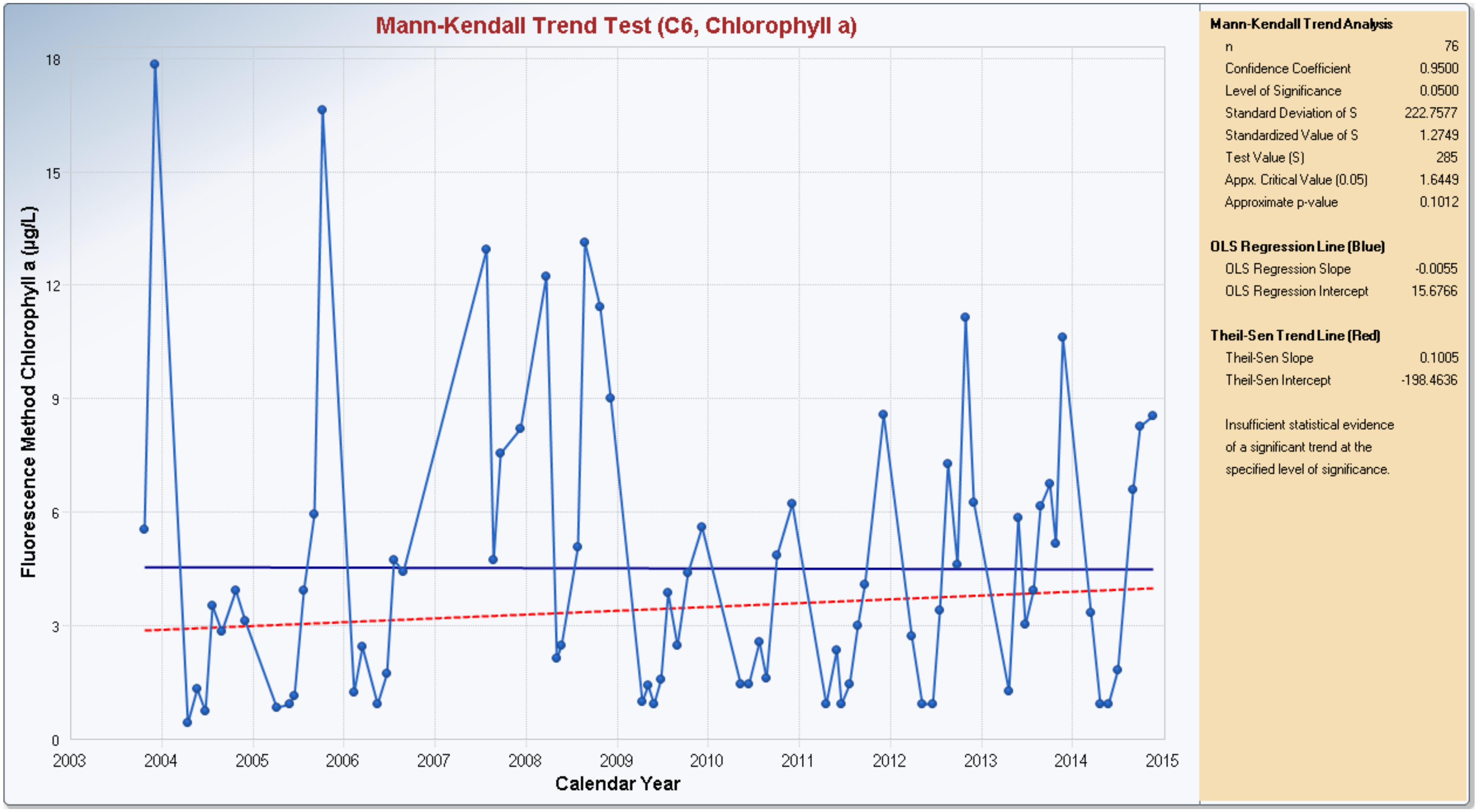
# Site C4, University Point, Photic Zone



## Site C5, Chippy/Blue Point, Photic Zone

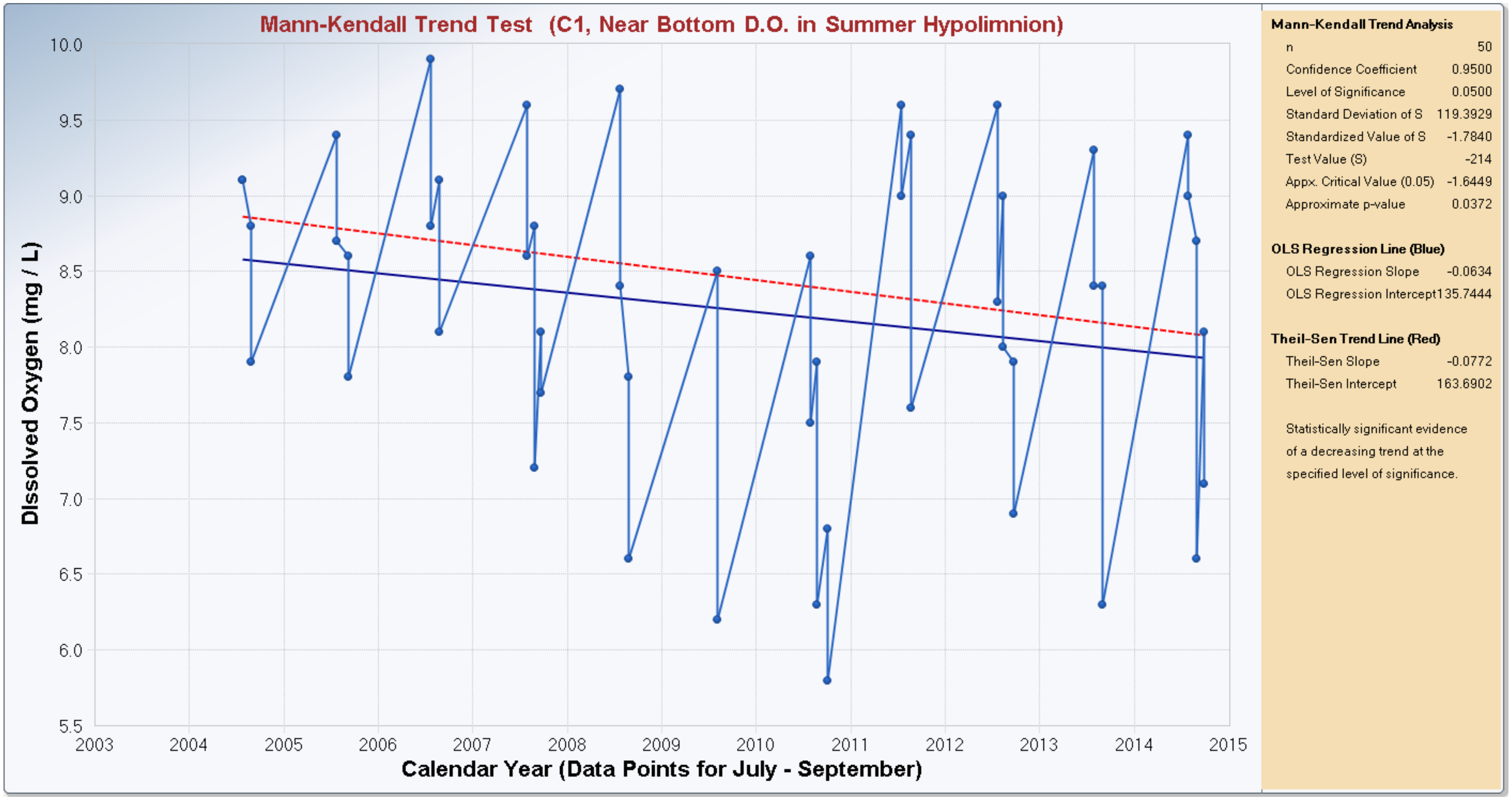


## Site C6, Chatcolet Lake, Photic Zone

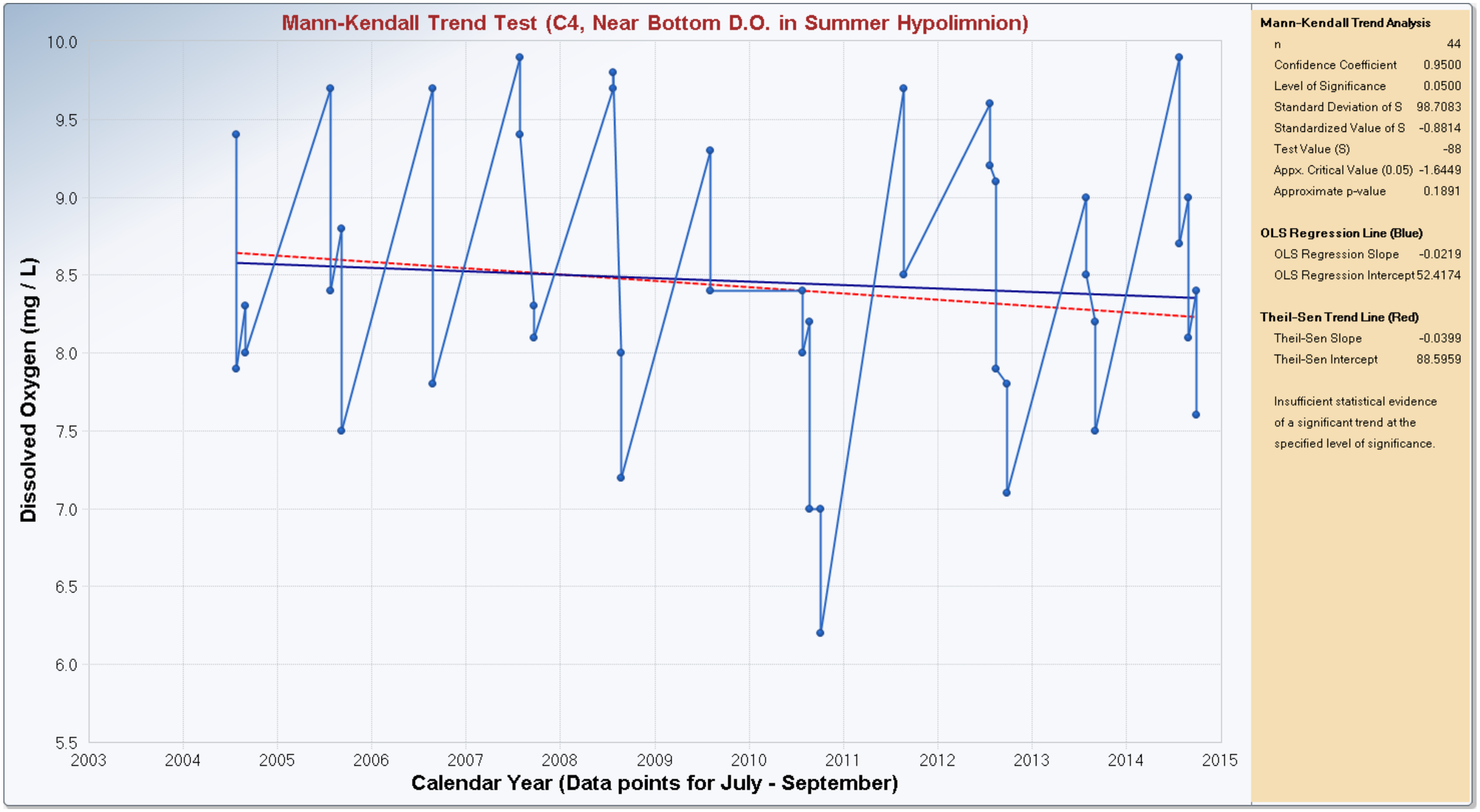


# Appendix C. Mann Kendall Trend Analyses for Dissolved Oxygen

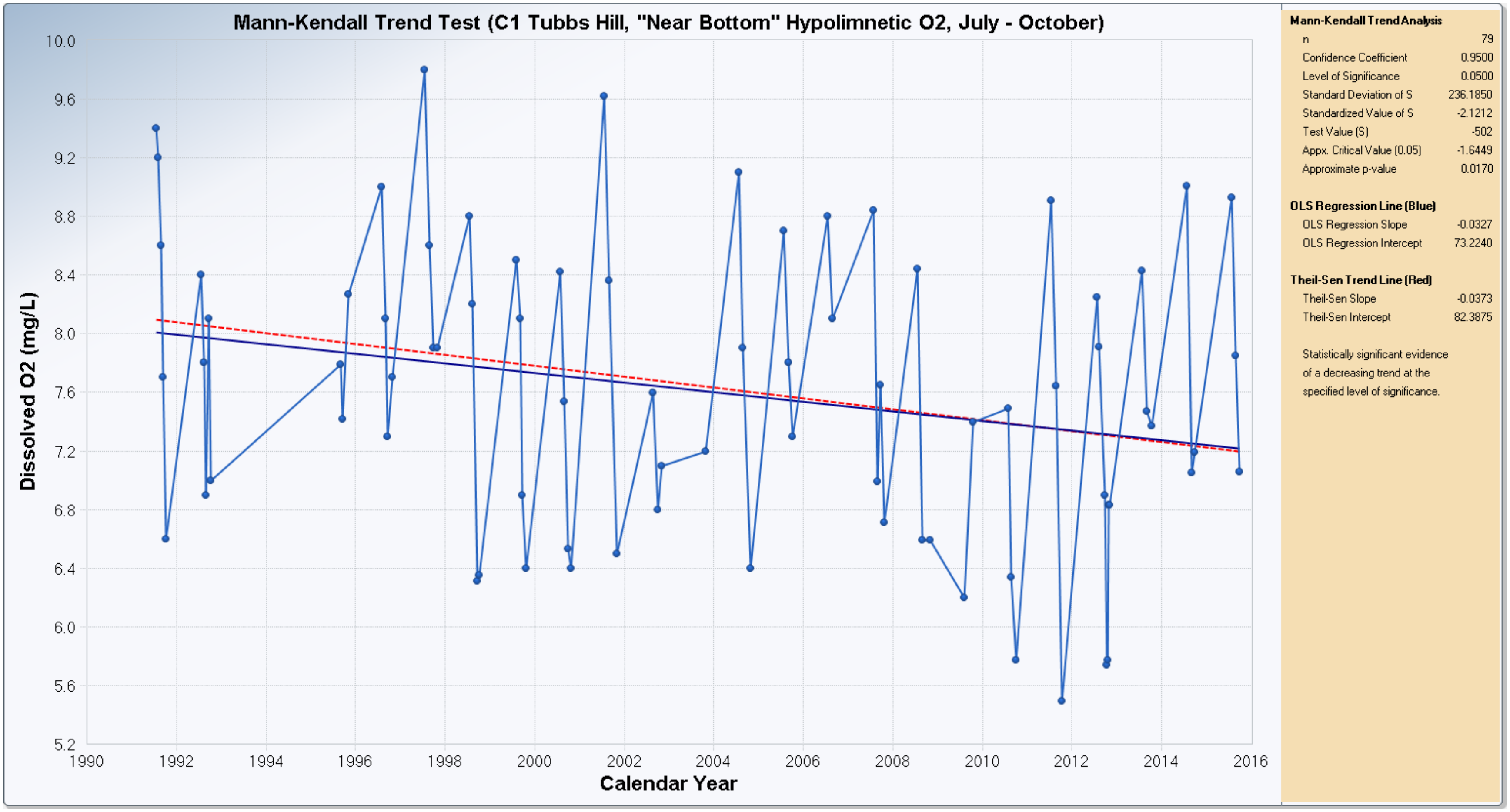
## Site C1, Tubbs Hill, time period of 2003 – 2014



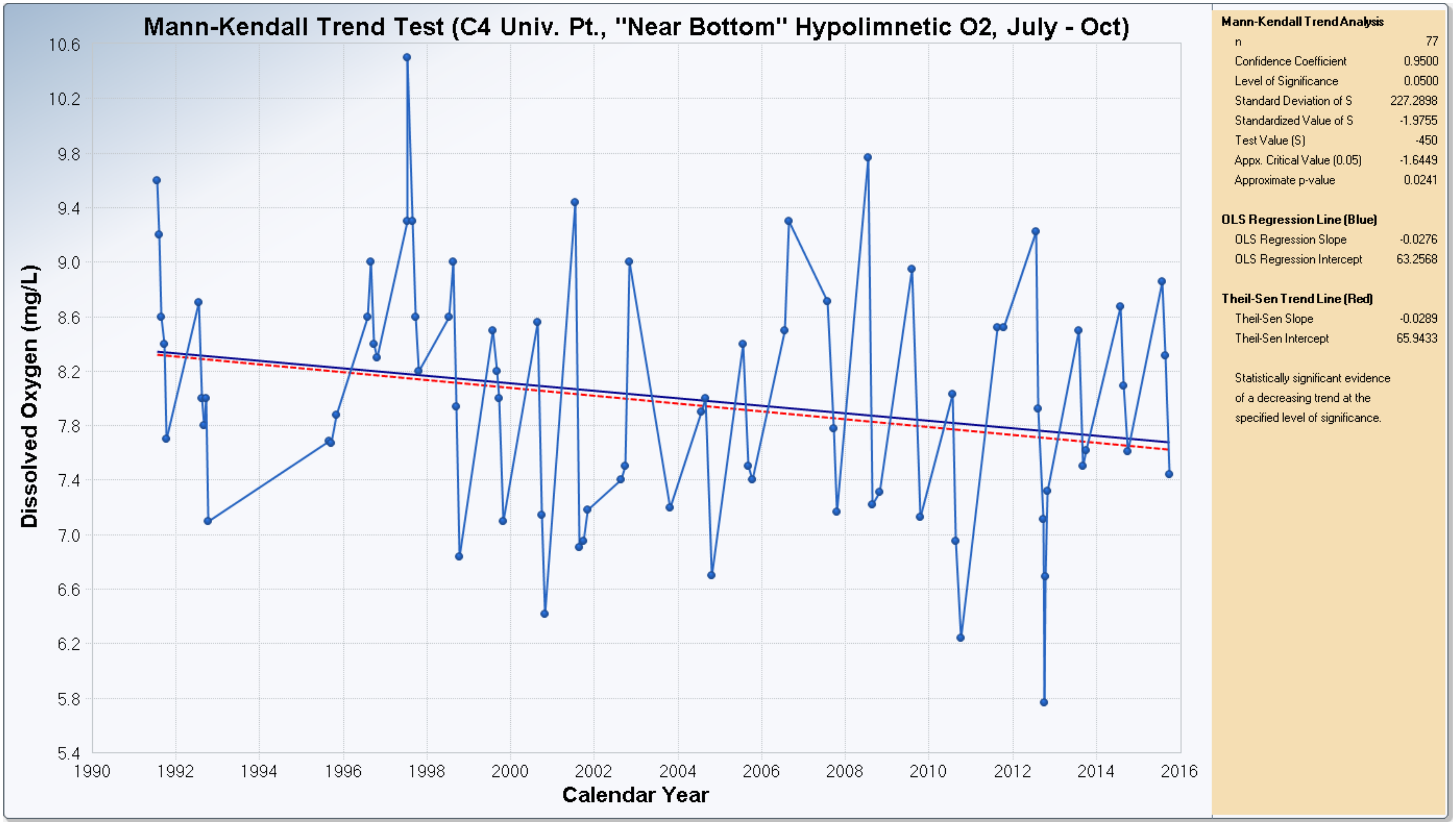
## Site C4, University Point, time period of 2003 – 2014



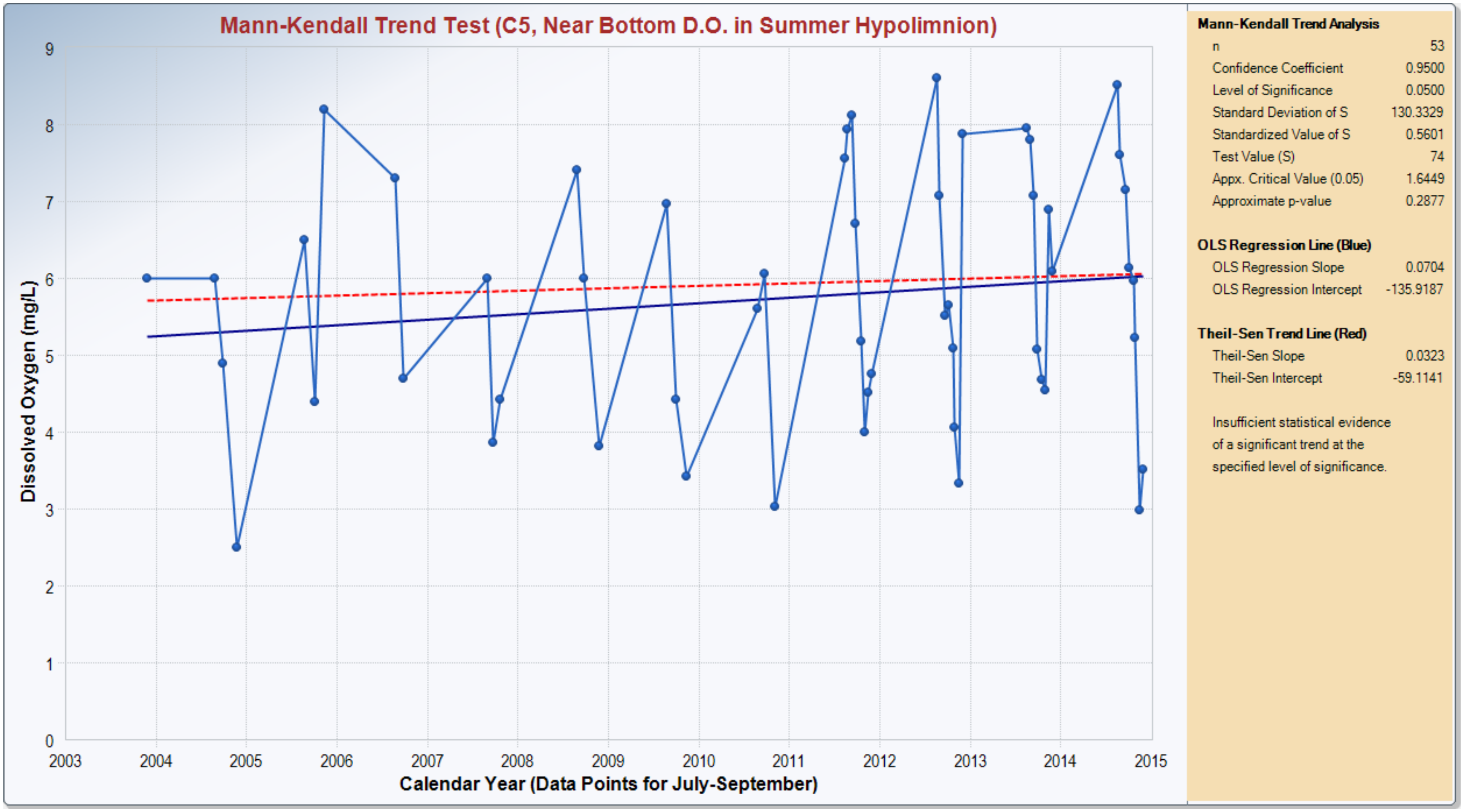
# Site C1, Tubbs Hill, time period of 1991 – 2014



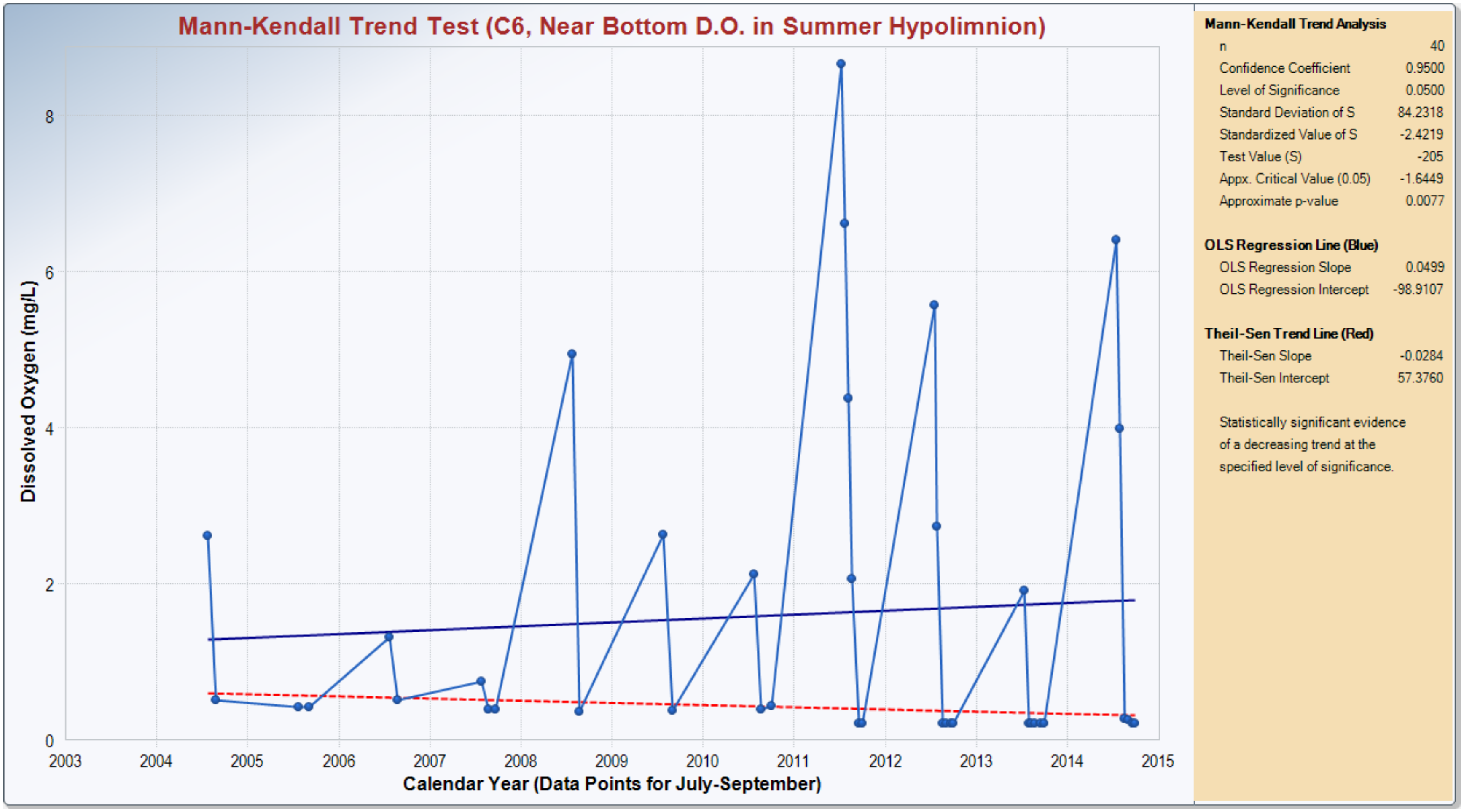
## Site C4, University Point, time period of 1991 – 2014



## Site C5, Chippy/Blue Point, time period of 2003-2014

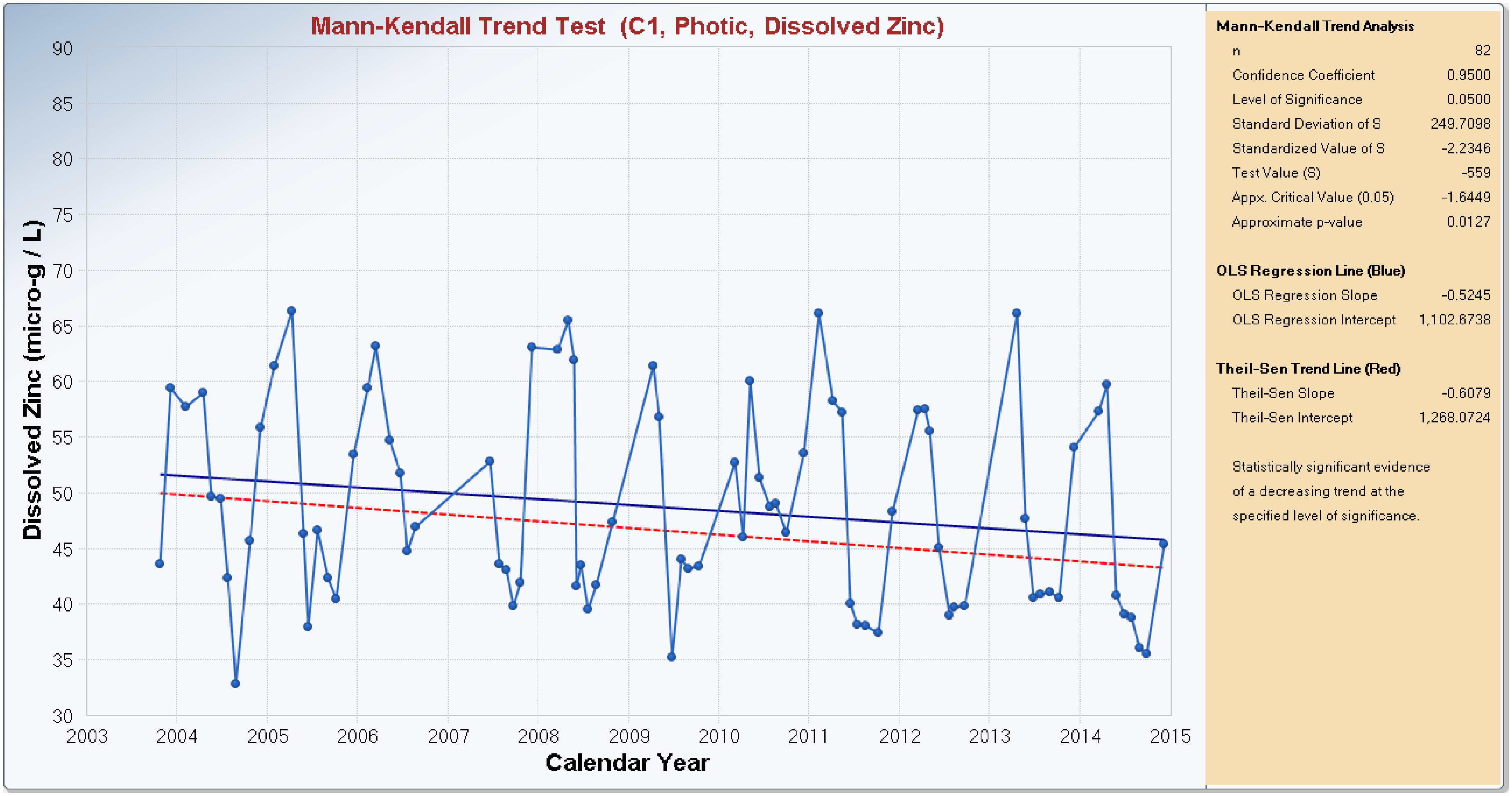


## Site C6, Chatcolet Lake, time period of 2003-2014

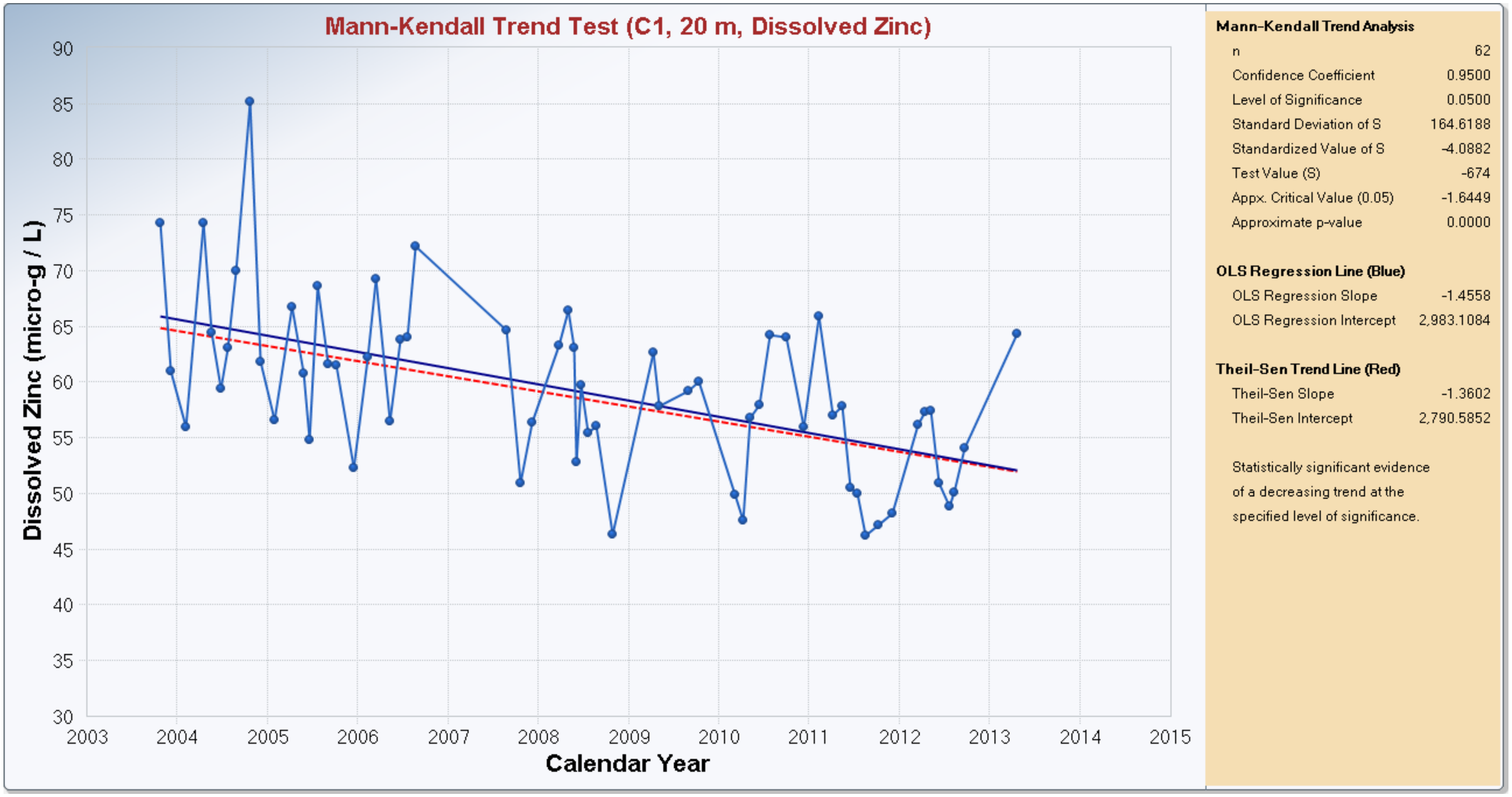


# Appendix D. Mann Kendall Trend Analyses for Dissolved Zinc

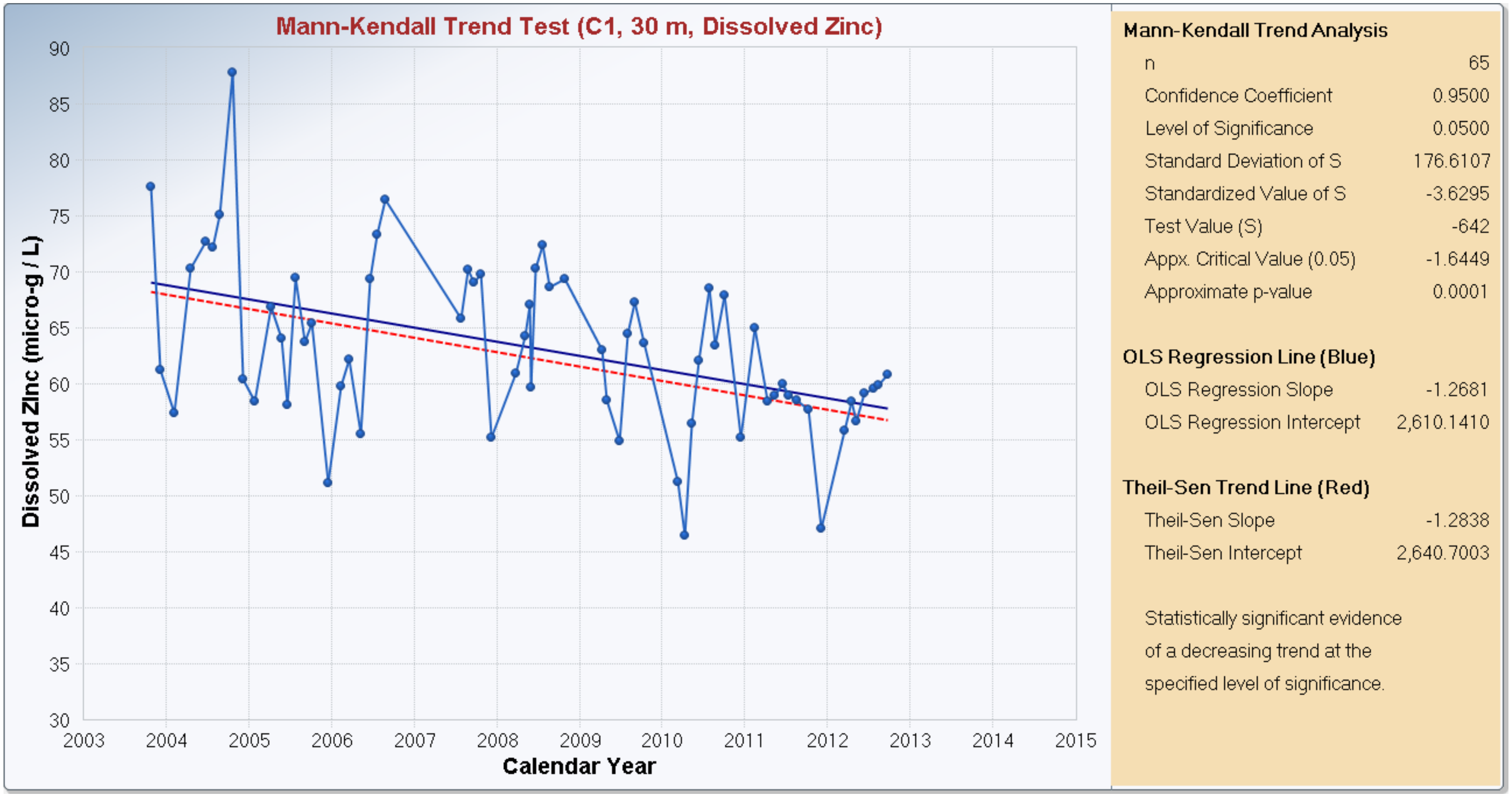
## Site C1, Tubbs Hill, Photic Zone



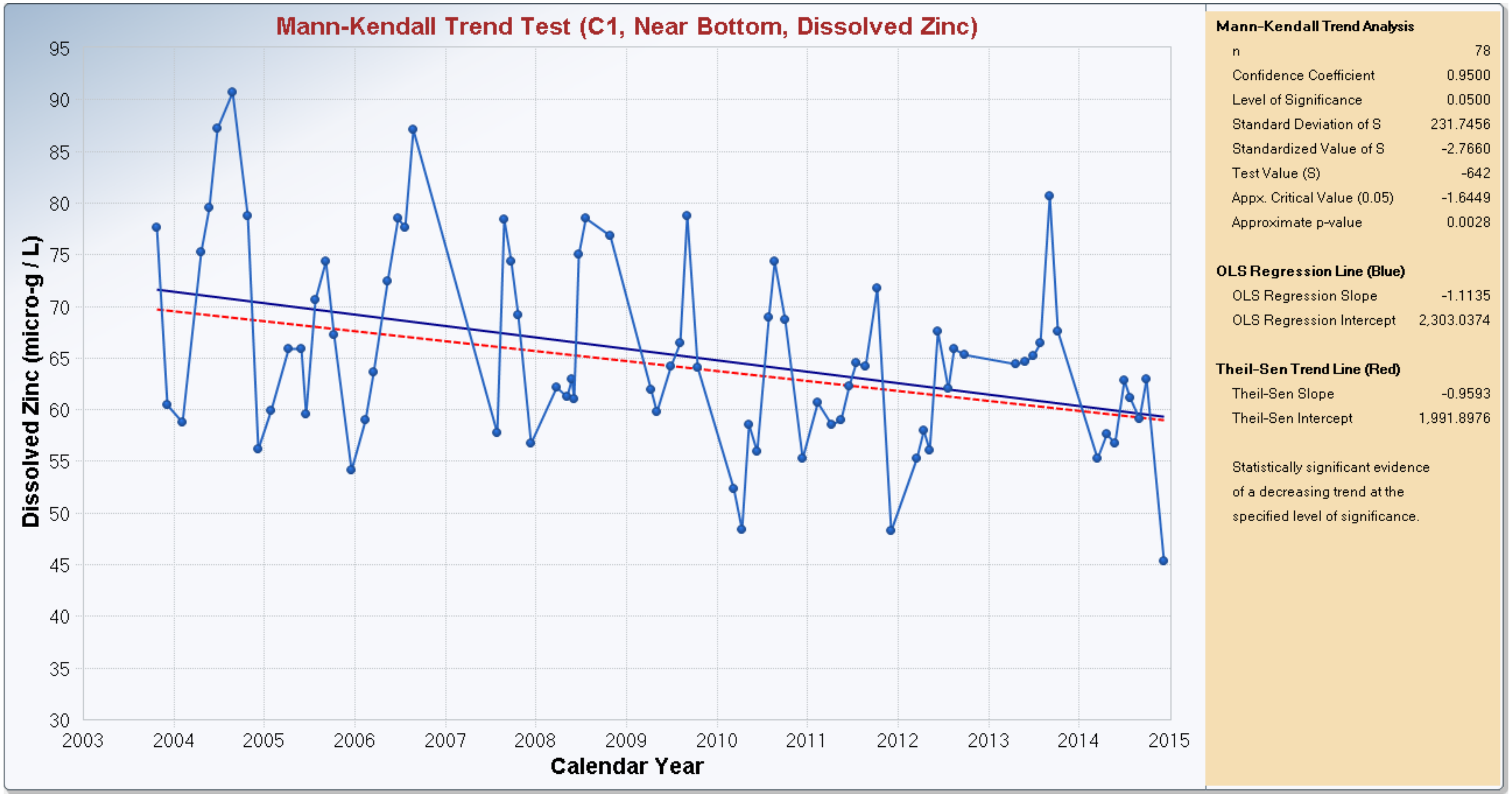
## Site C1, Tubbs Hill, 20 m depth



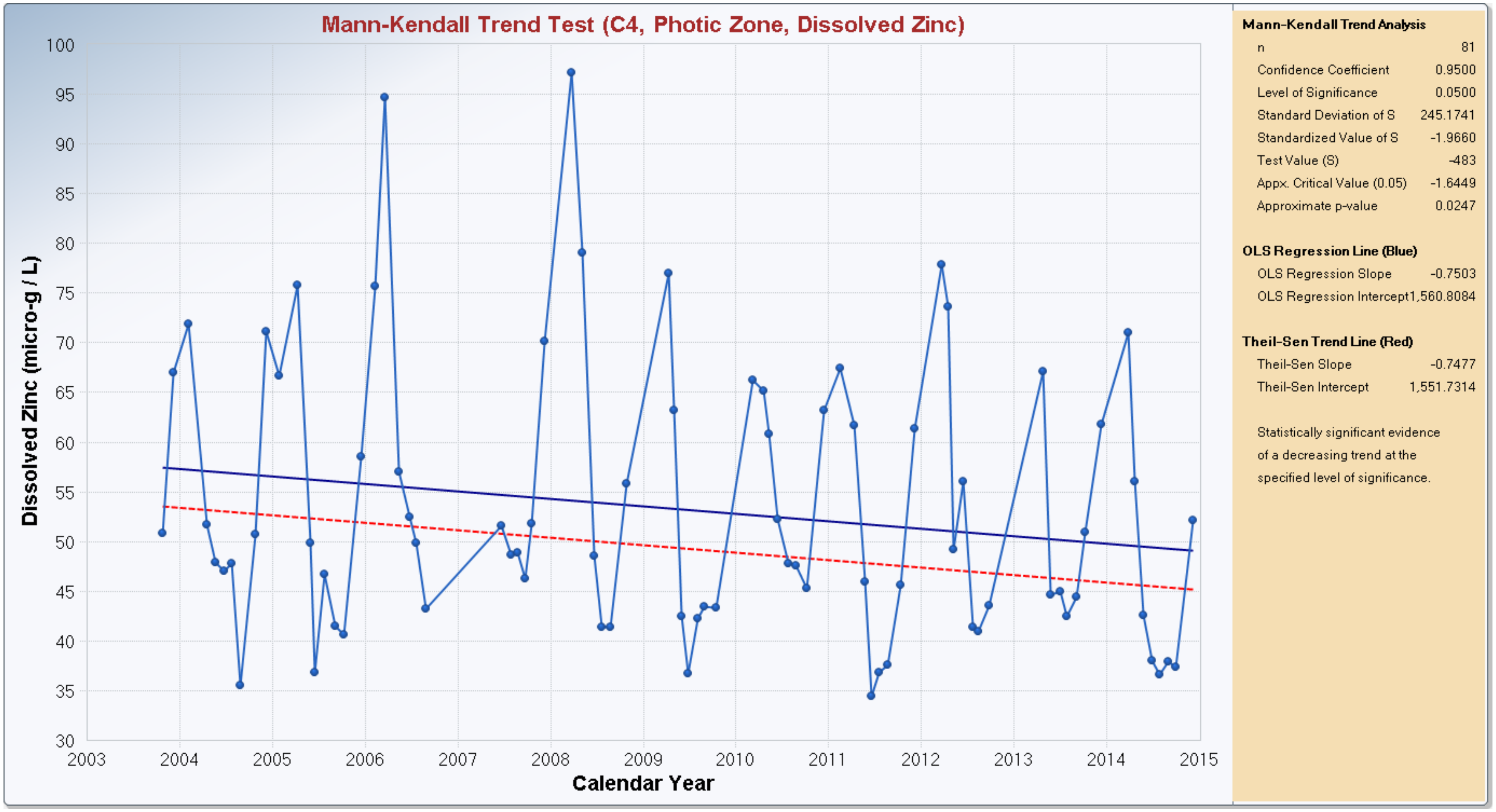
## Site C1, Tubbs Hill, 30 m depth



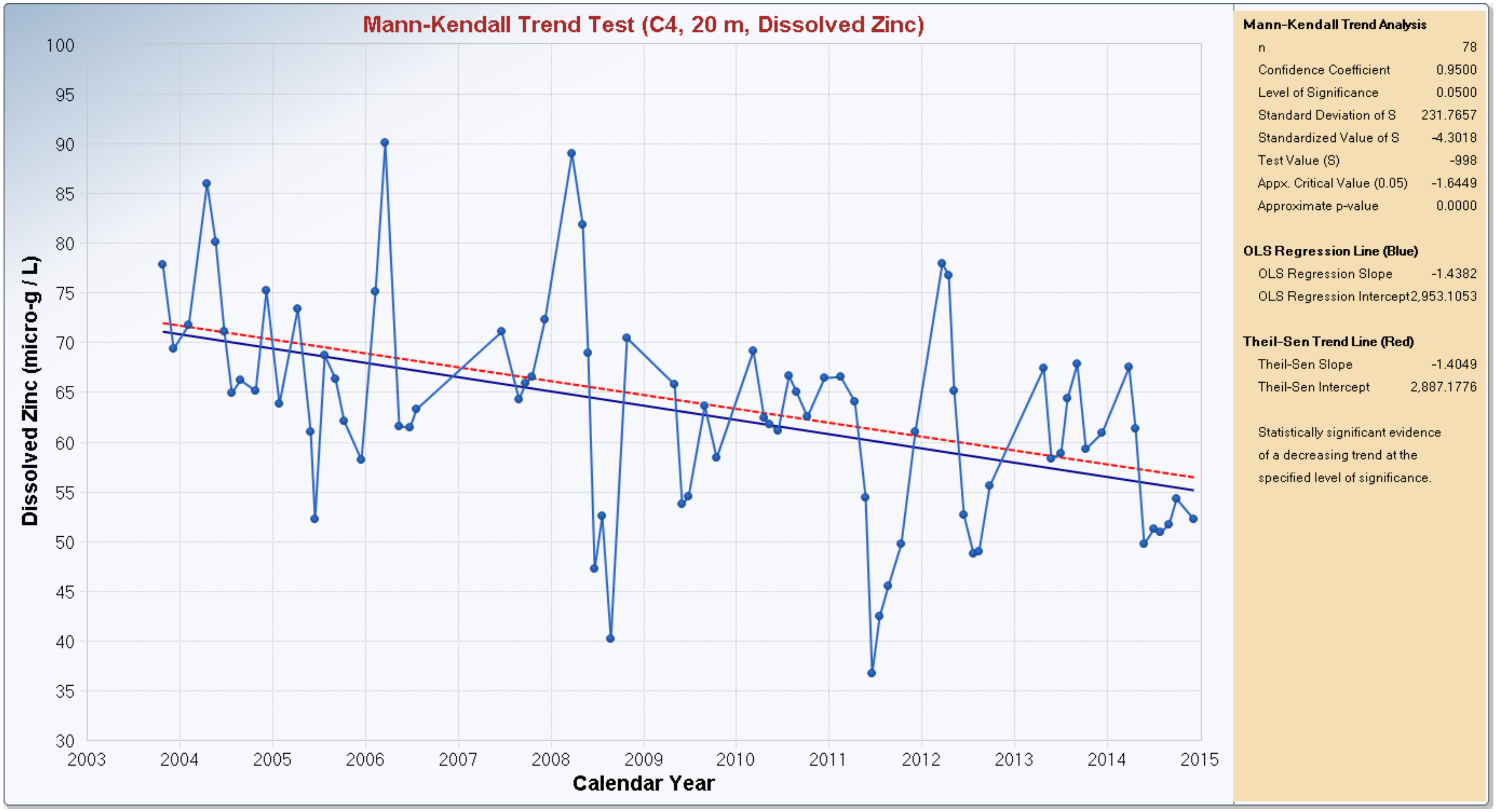
## Site C1, Tubbs Hill, Near Bottom



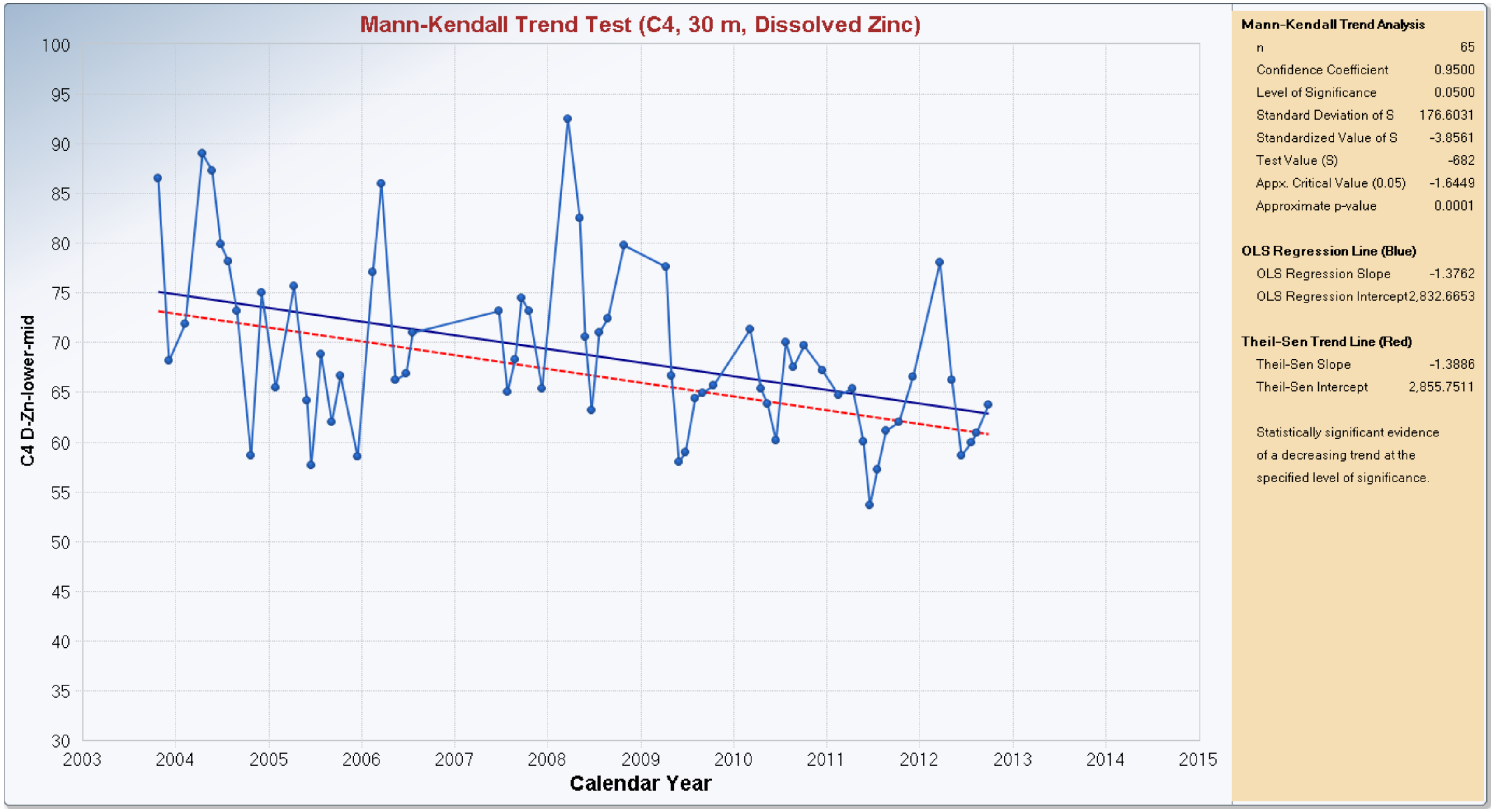
## Site C4, University Point, Photic Zone



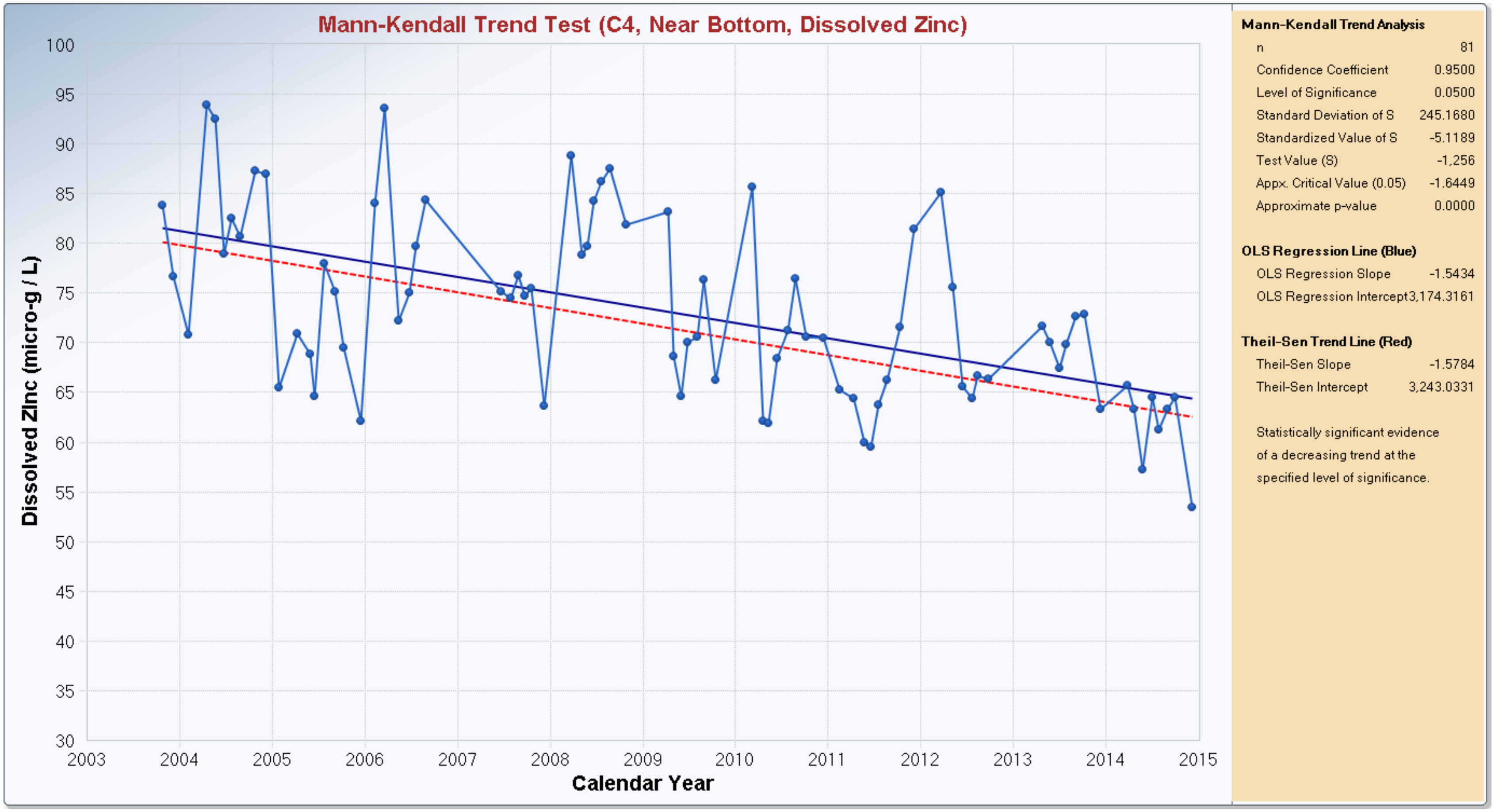
## Site C4, University Point, 20 m depth



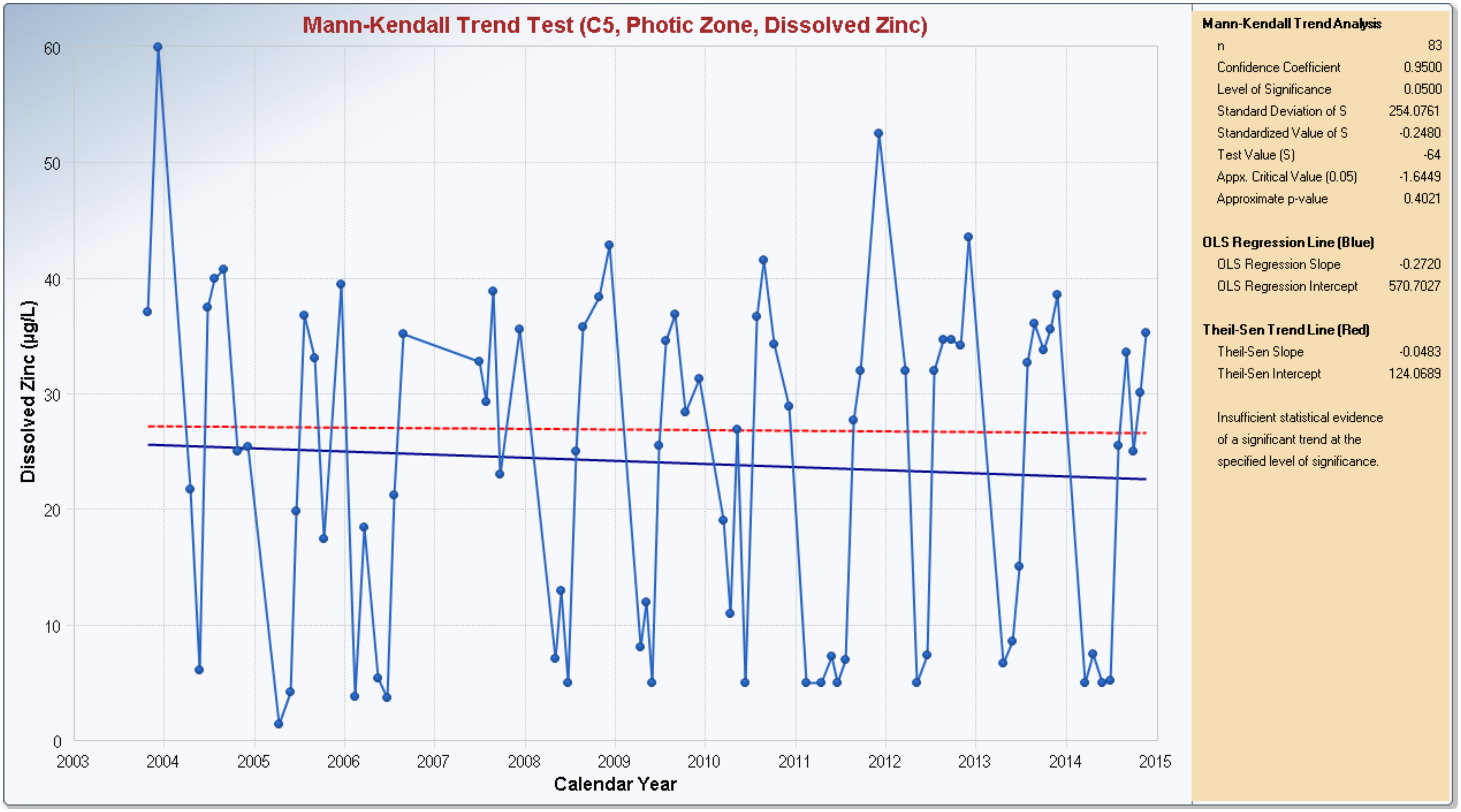
## Site C4, University Point, 30 m depth



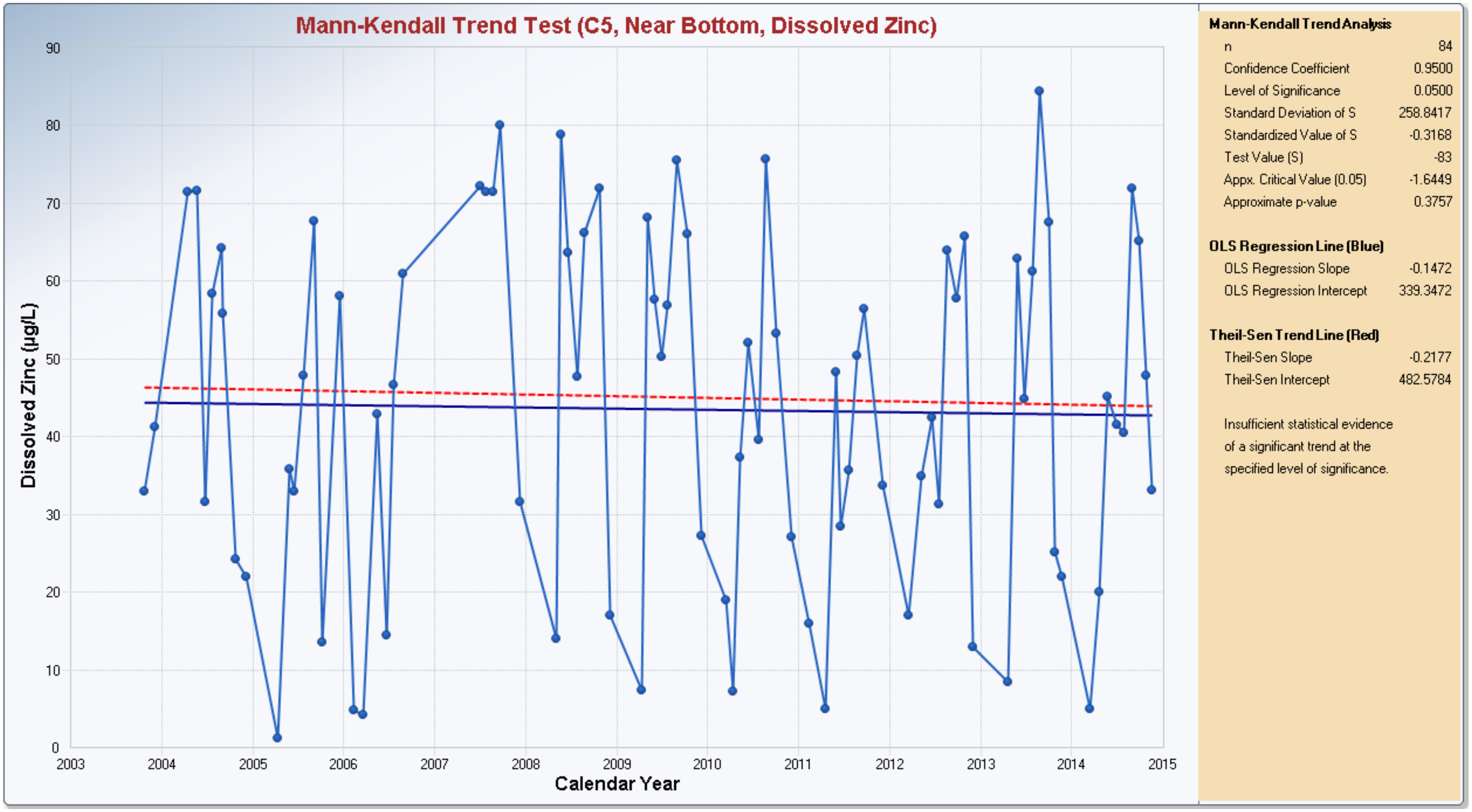
## Site C4, University Point, Near Bottom



## Site C5, Chippy/Blue Point, Photic Zone

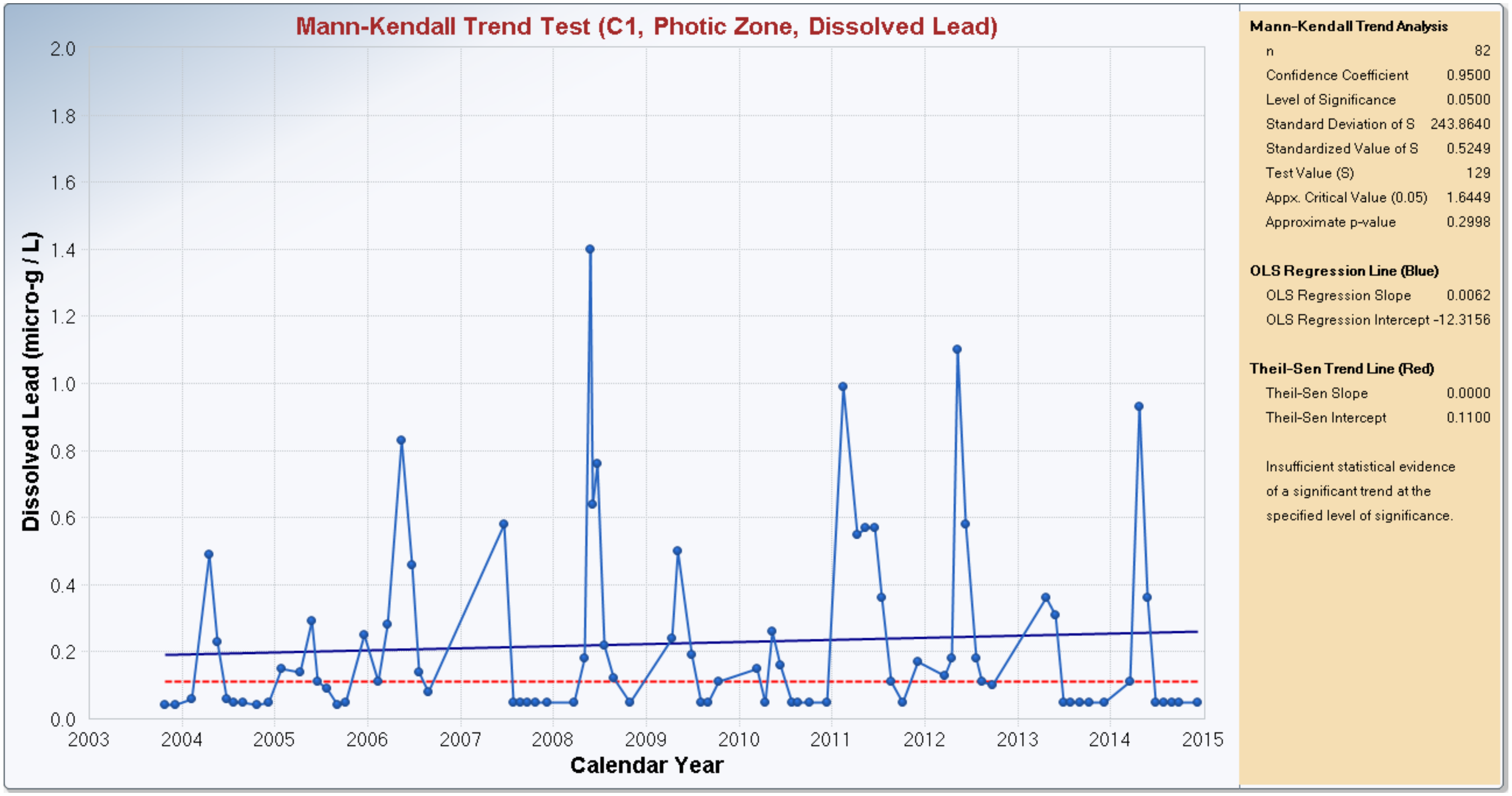


## Site C5, Chippy/Blue Point, Near Bottom

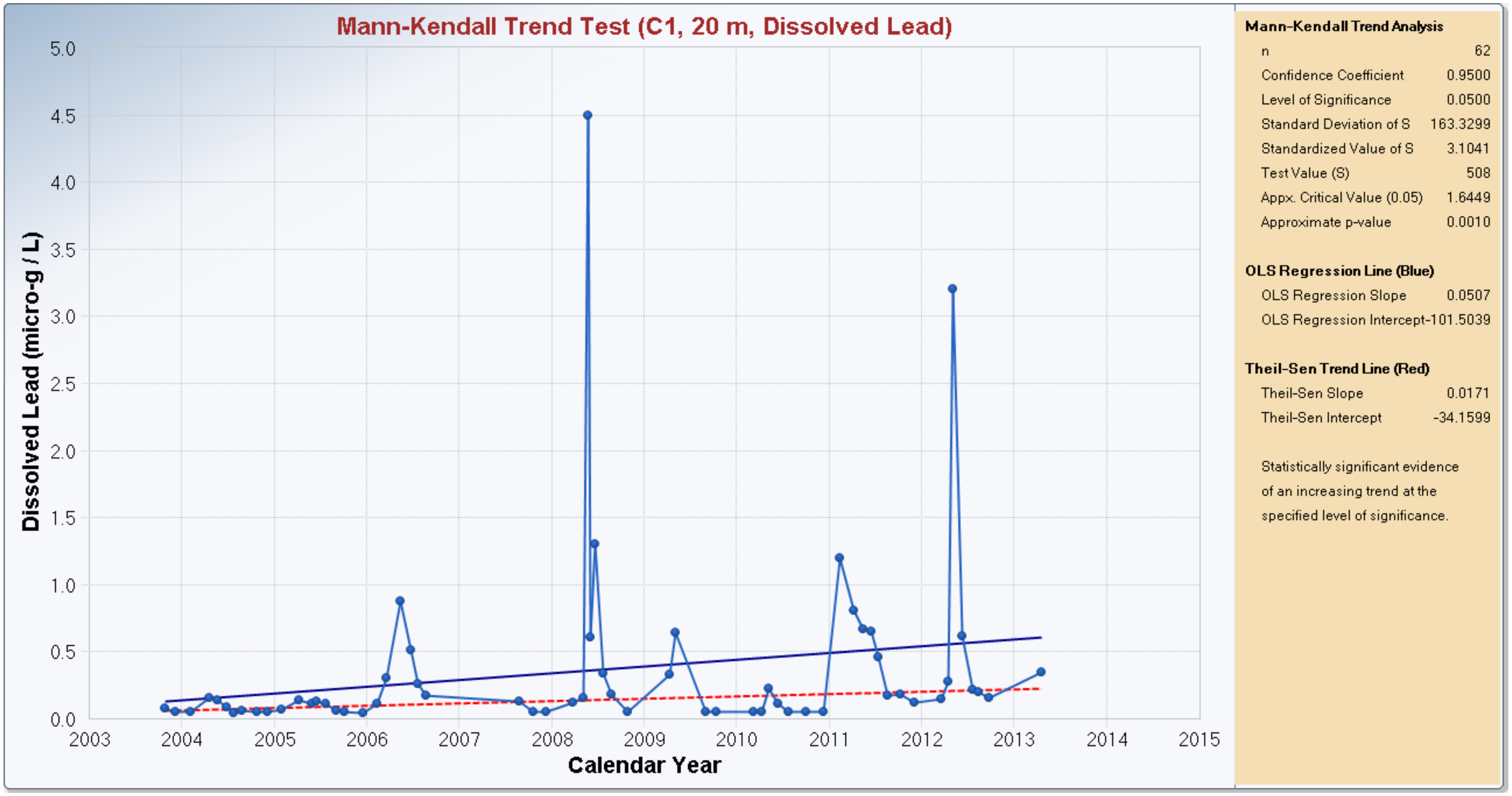


# Appendix E. Mann Kendall Trend Analyses for Dissolved Lead

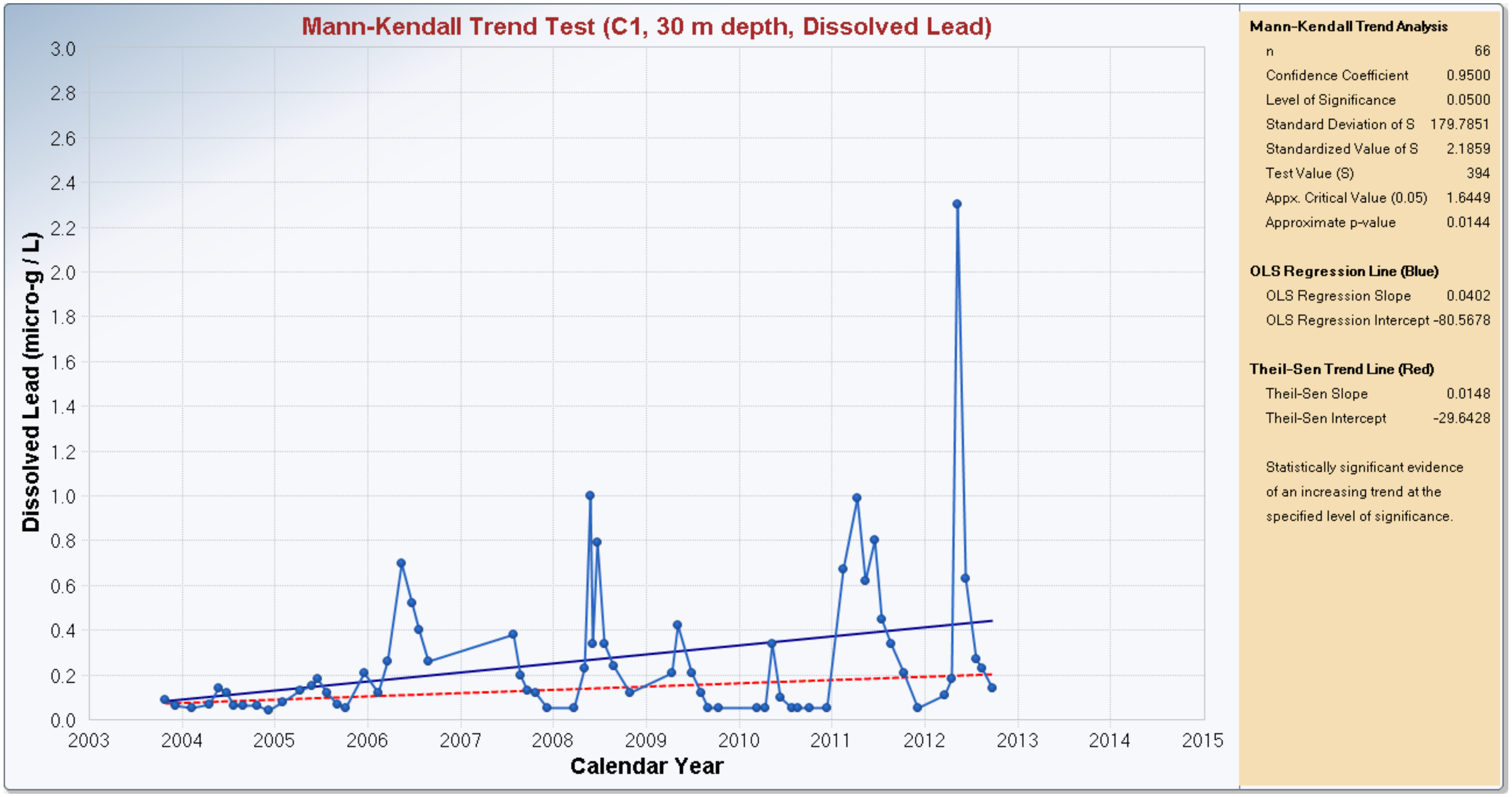
## Site C1, Tubbs Hill, Photic Zone



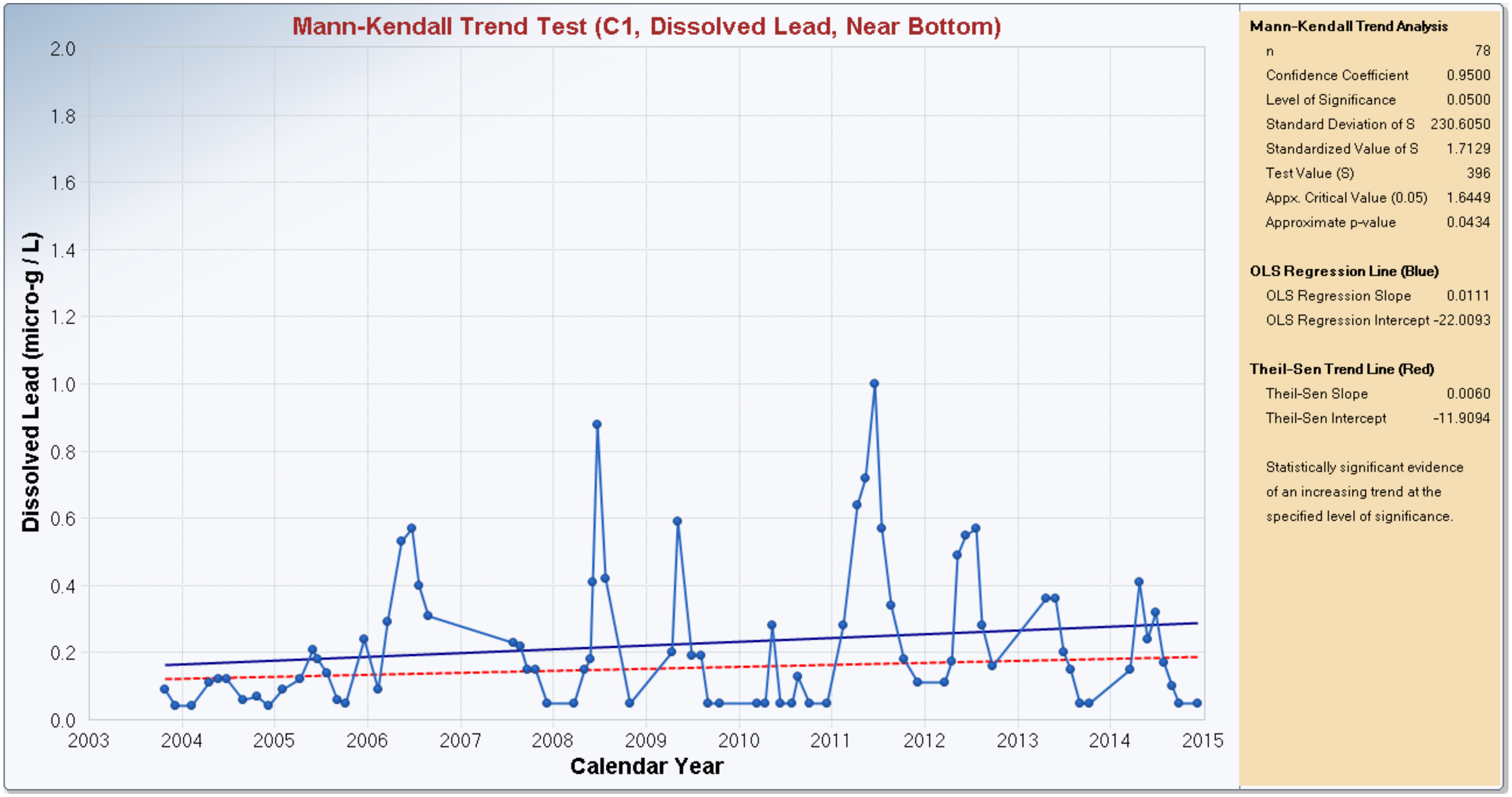
## Site C1, 20 m depth



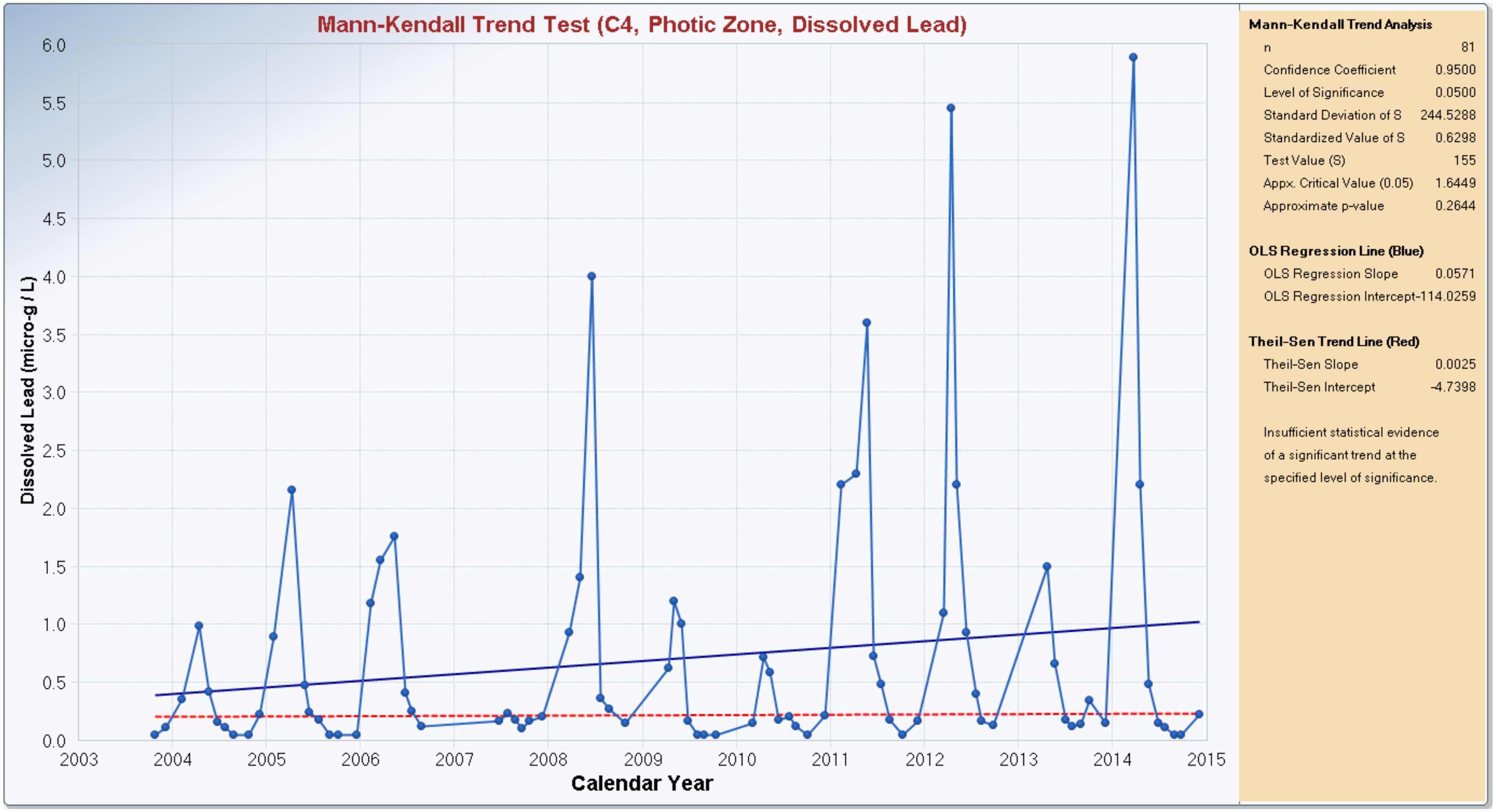
## Site C1, Tubbs Hill, 30 m depth



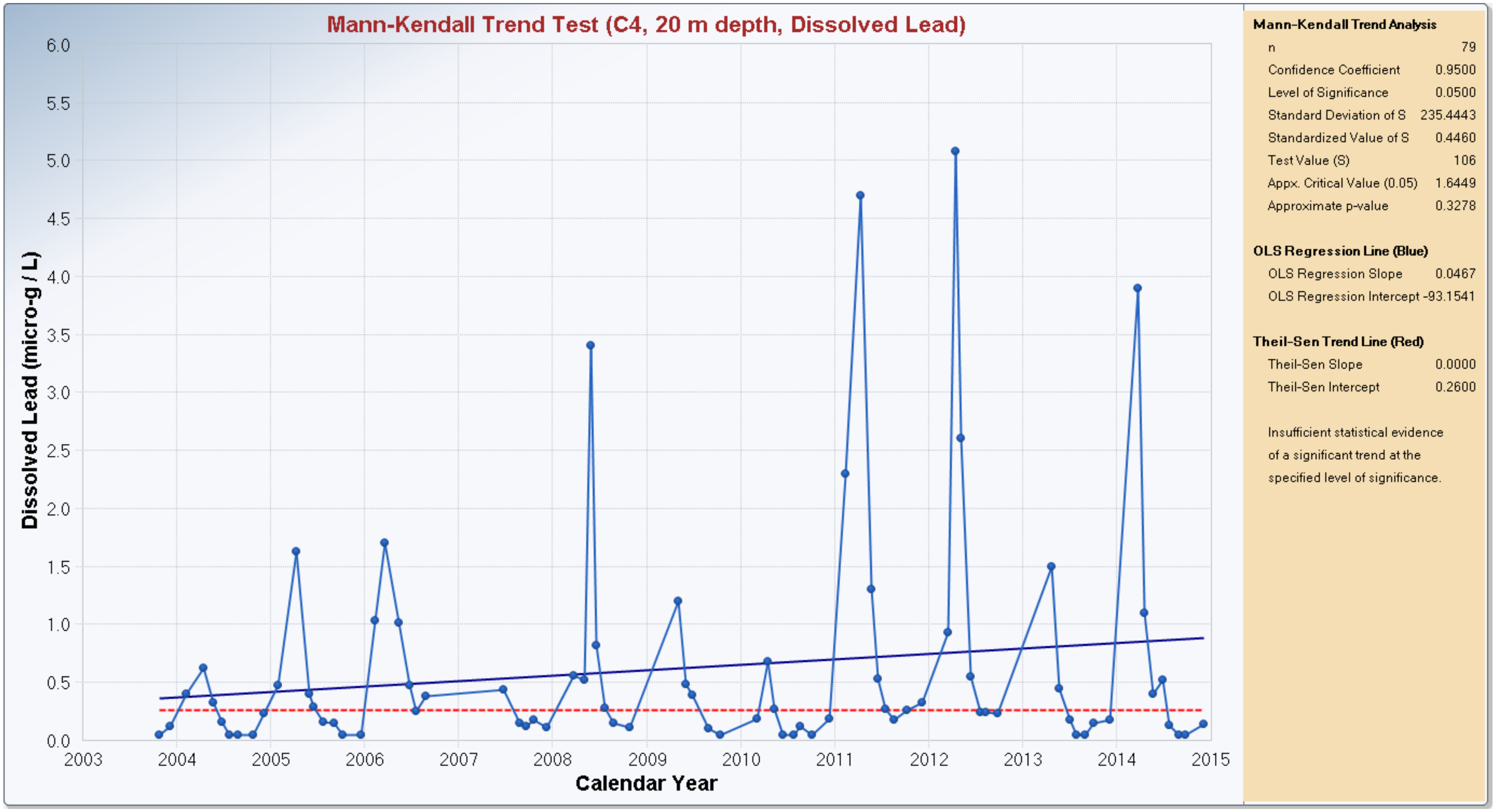
## Site C1, Tubbs Hill, Near Bottom



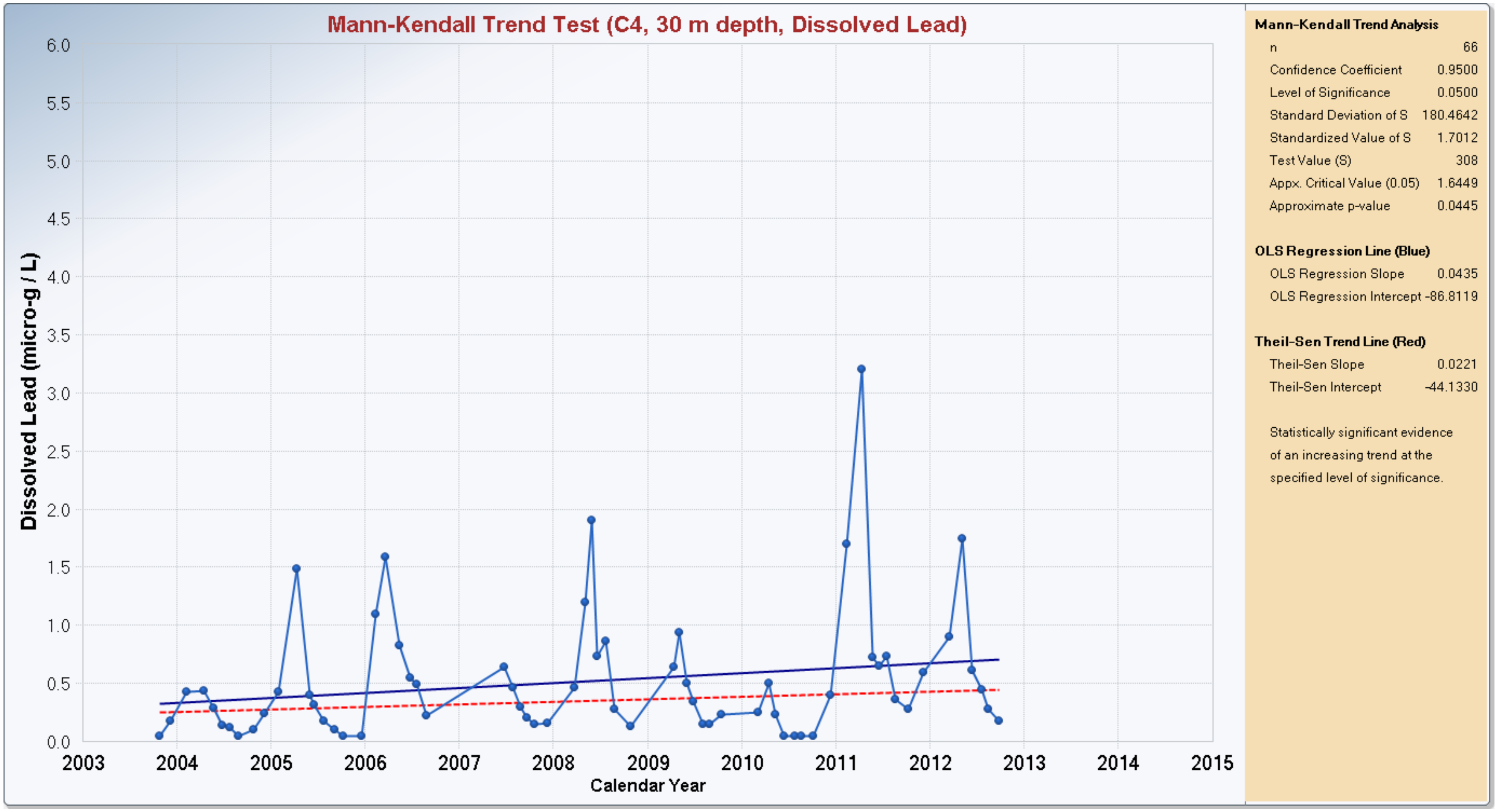
## Site C4, University Point, Photic Zone



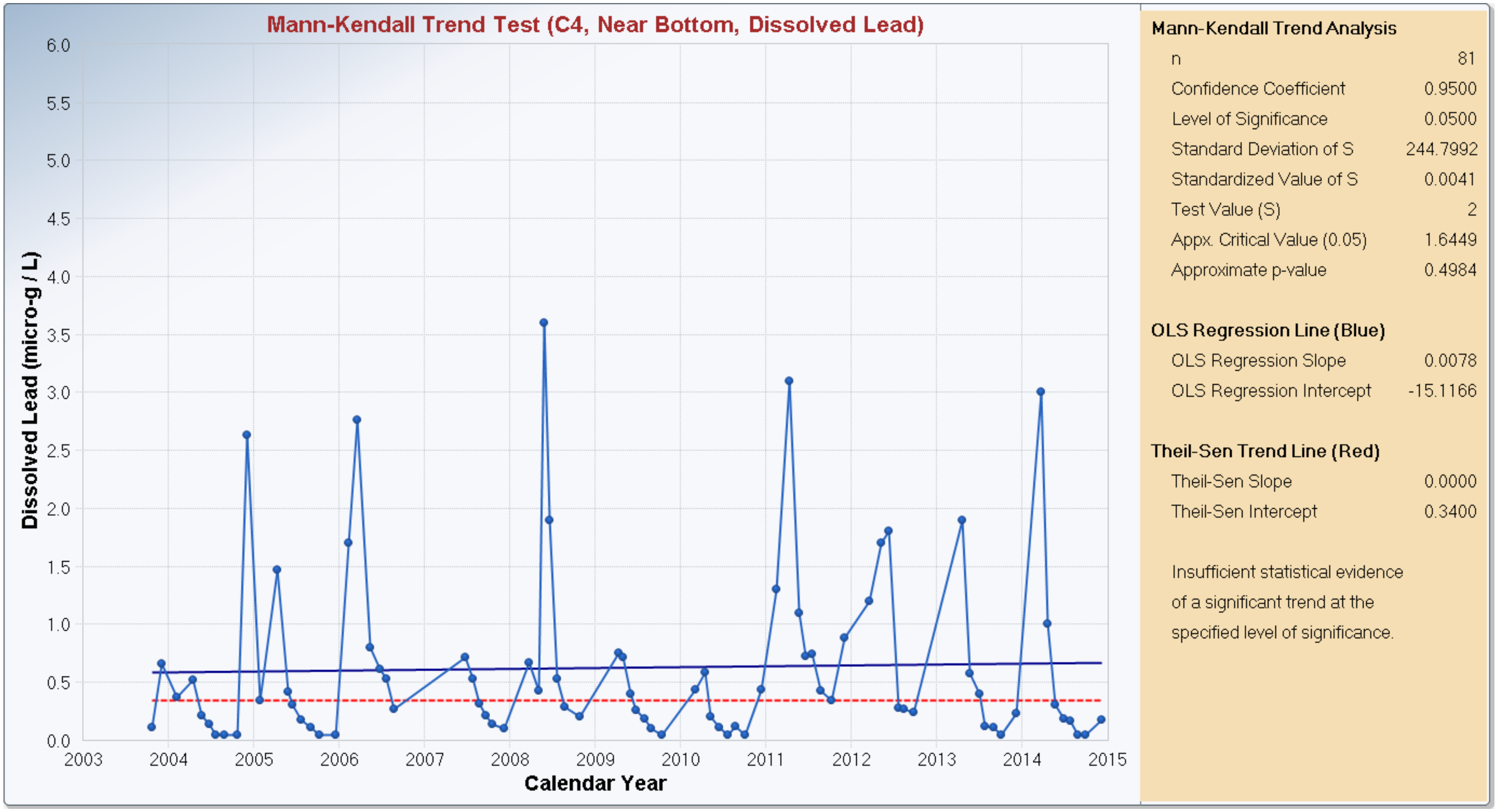
# Site C4, University Point, 20 m depth



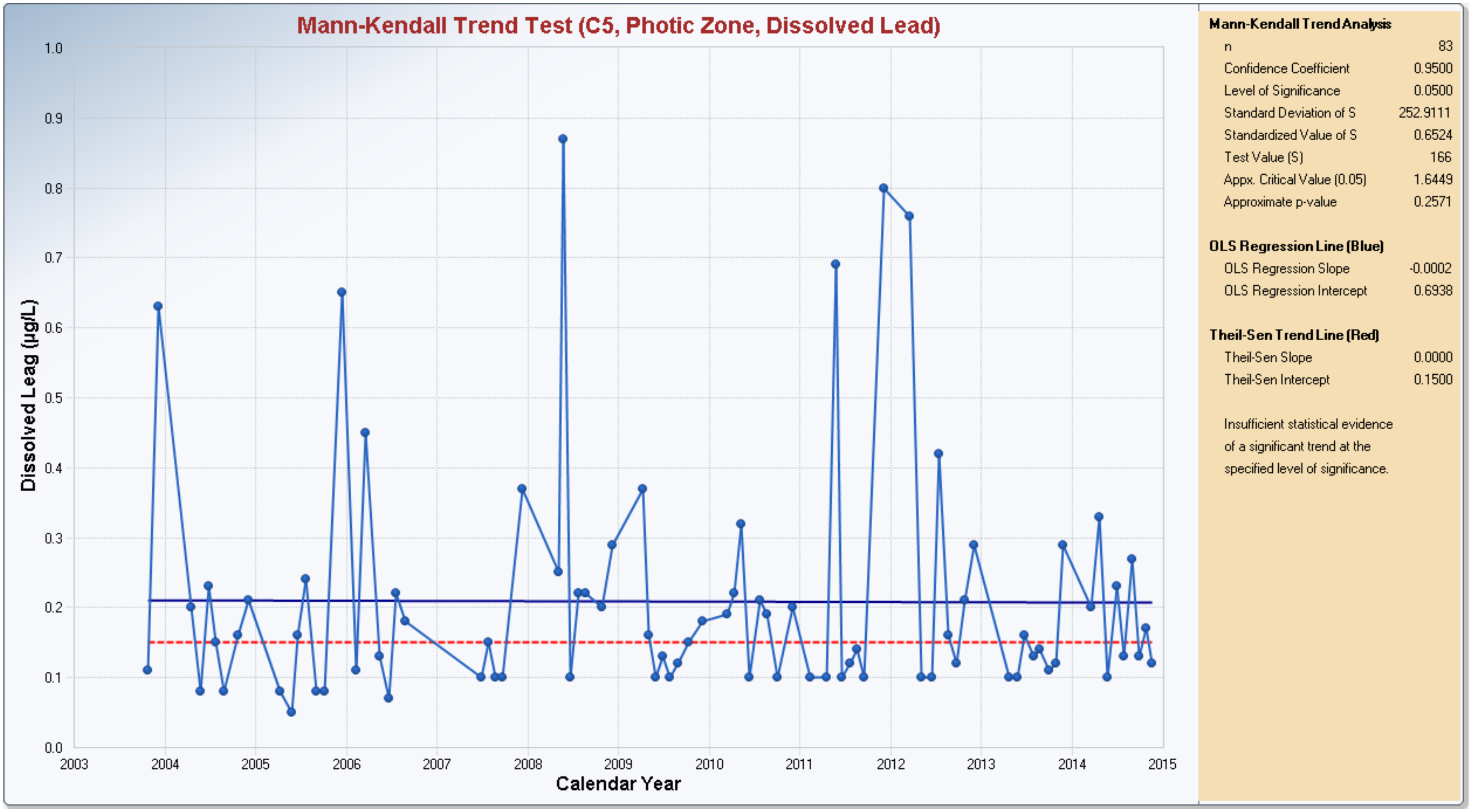
## Site C4, University Point, 30 m depth



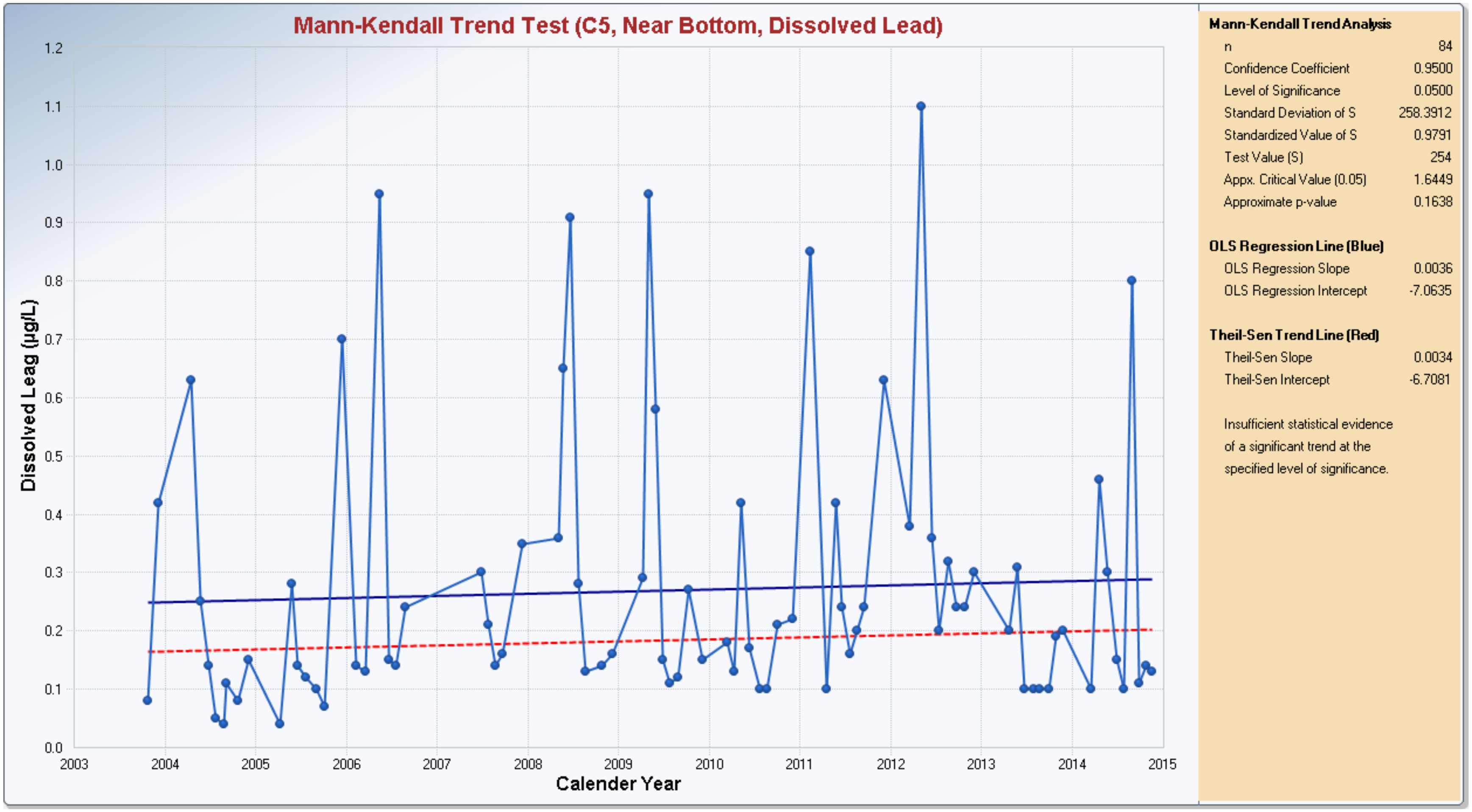
## Site C4, University Point, Near Bottom



## Site C5, Chippy/Blue Point, Photic Zone

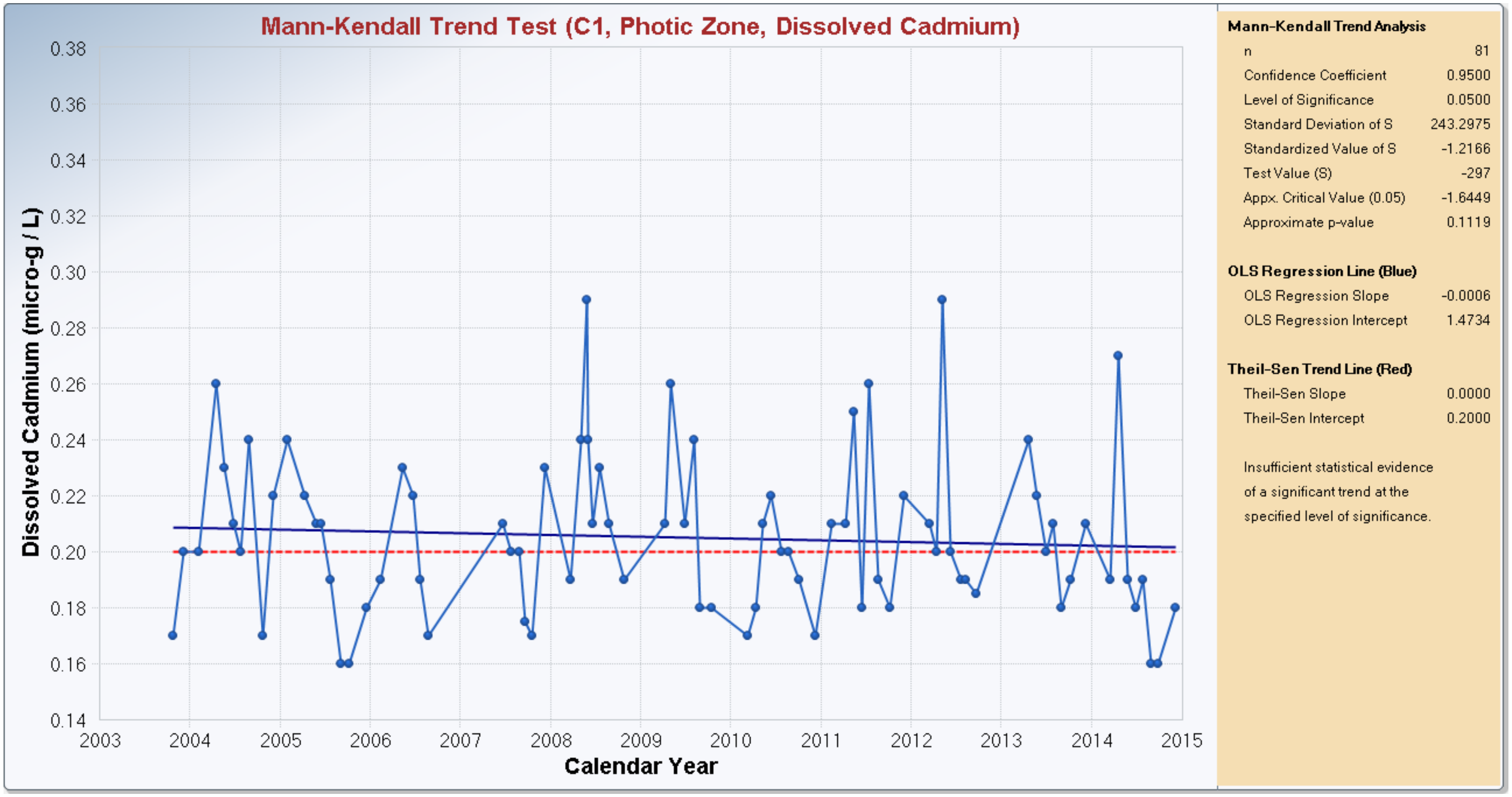


## Site C5, Chippy/Blue Point, Near Bottom

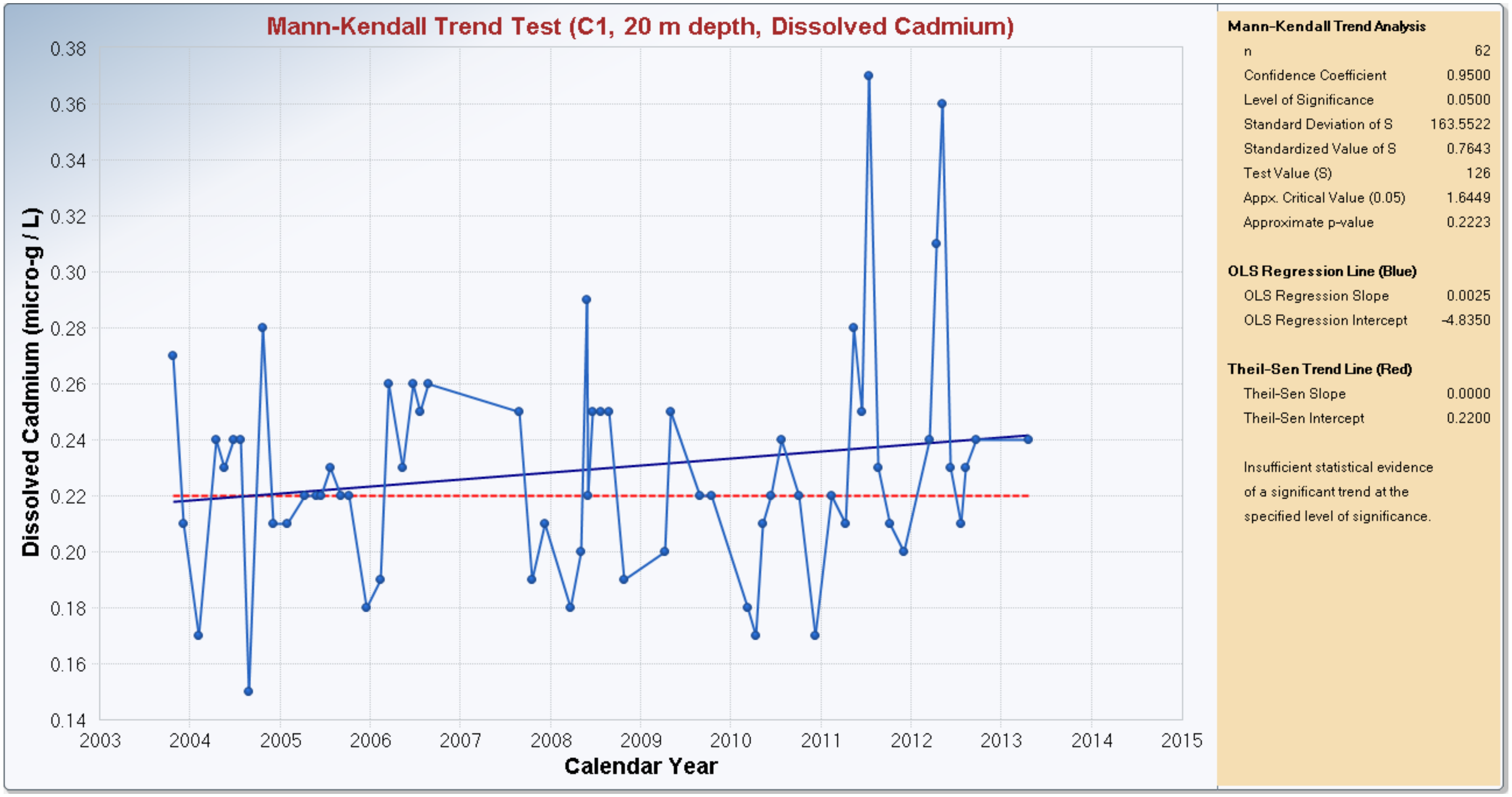


# Appendix F. Mann Kendall Trend Analyses for Dissolved Cadmium

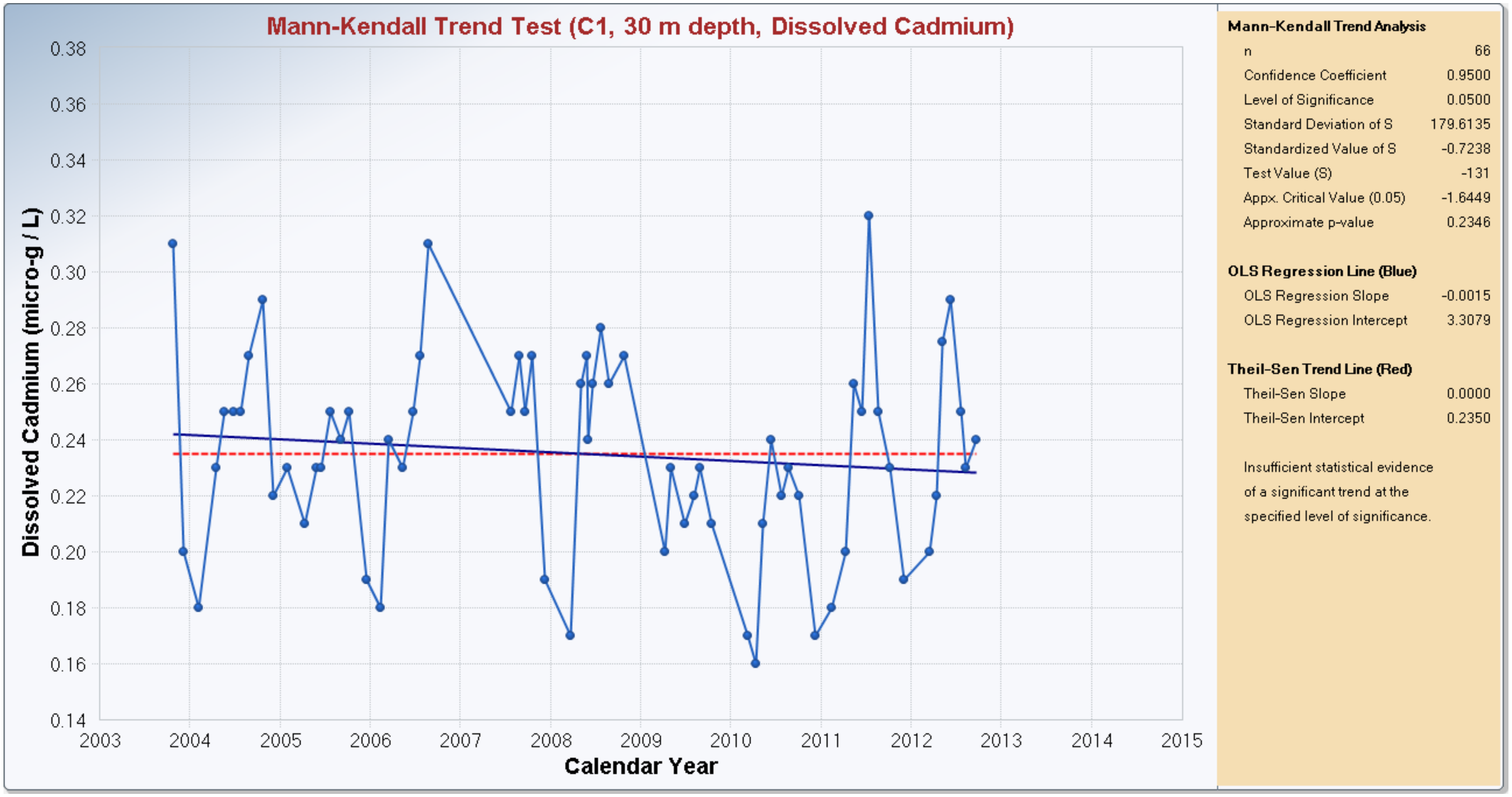
## Site C1, Tubbs Hill, Photic Zone



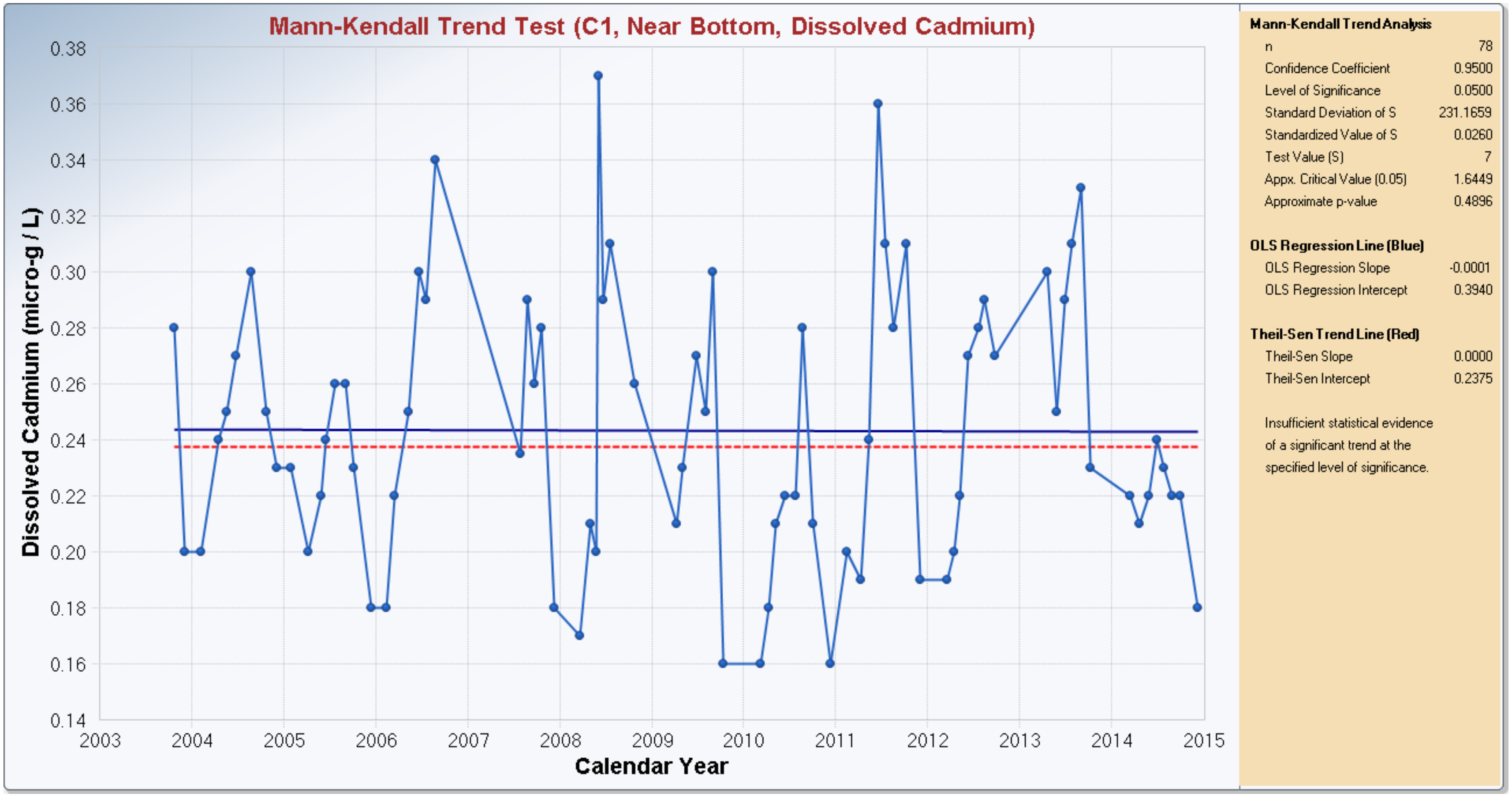
## Site C1, Tubbs Hill, 20 m



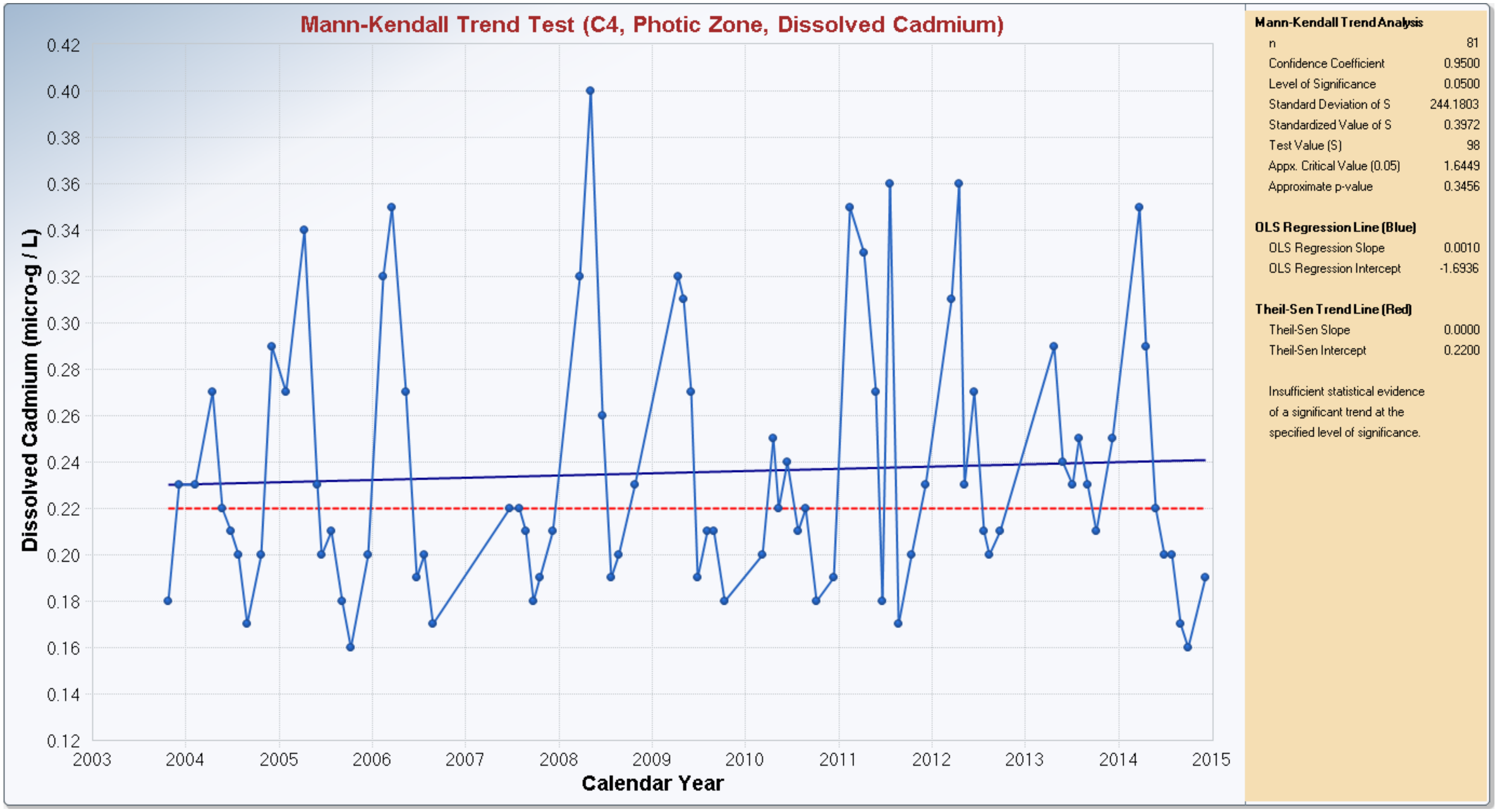
## Site C1, Tubbs Hill, 30 m



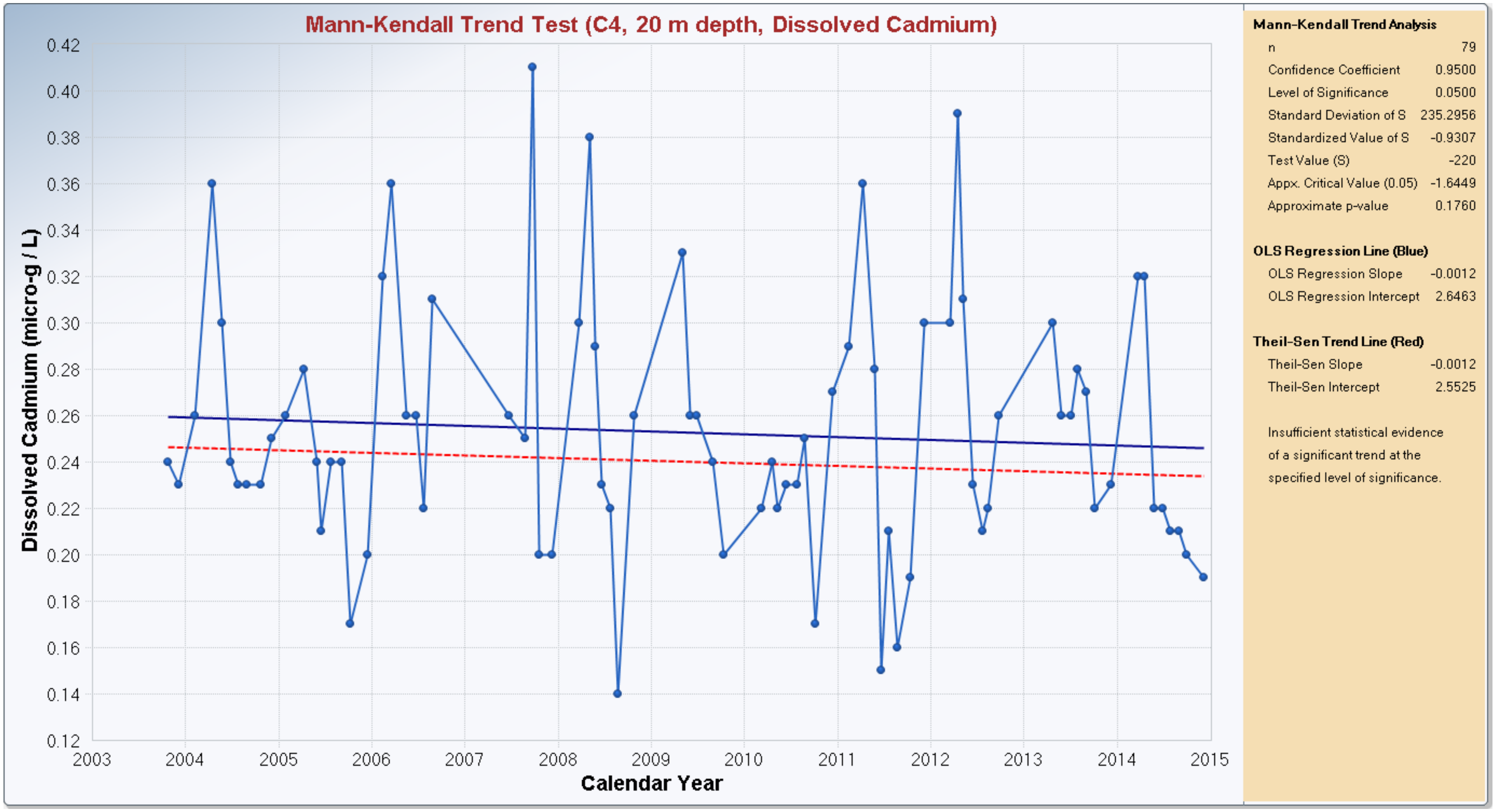
## Site C1, Tubbs Hill, Near Bottom



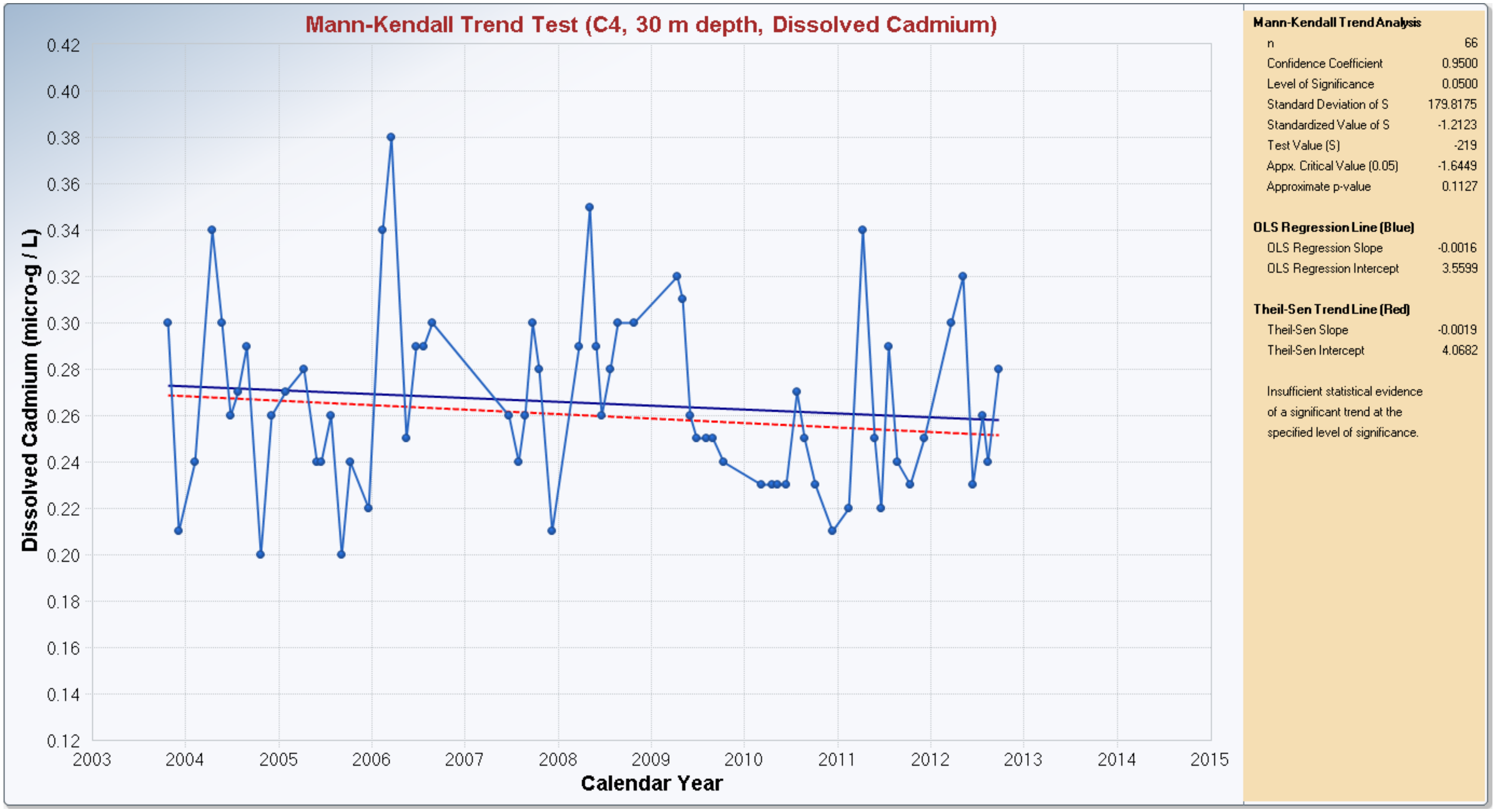
## Site C4, University Point, Photic Zone



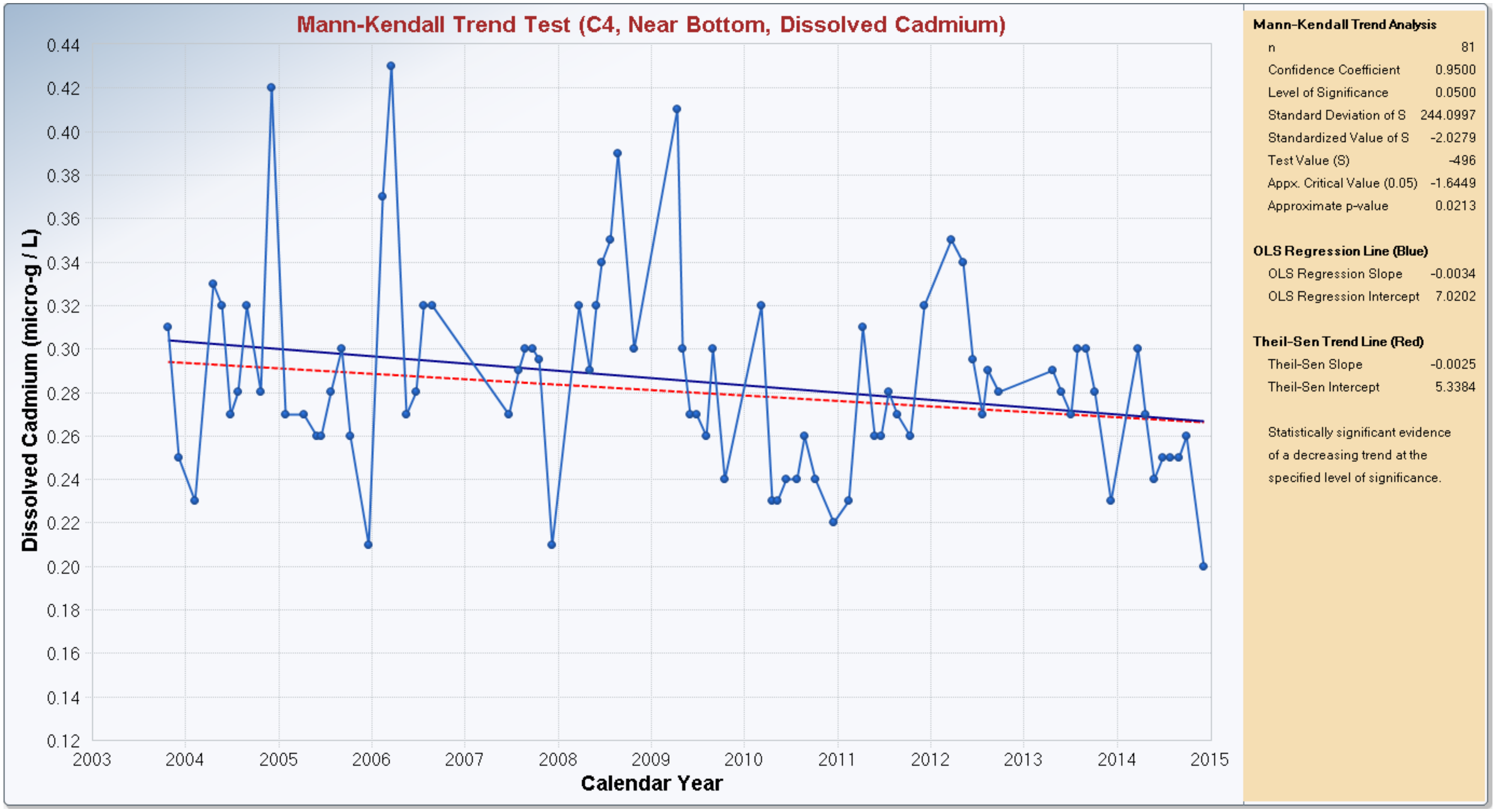
## Site C4, University Point, 20 m



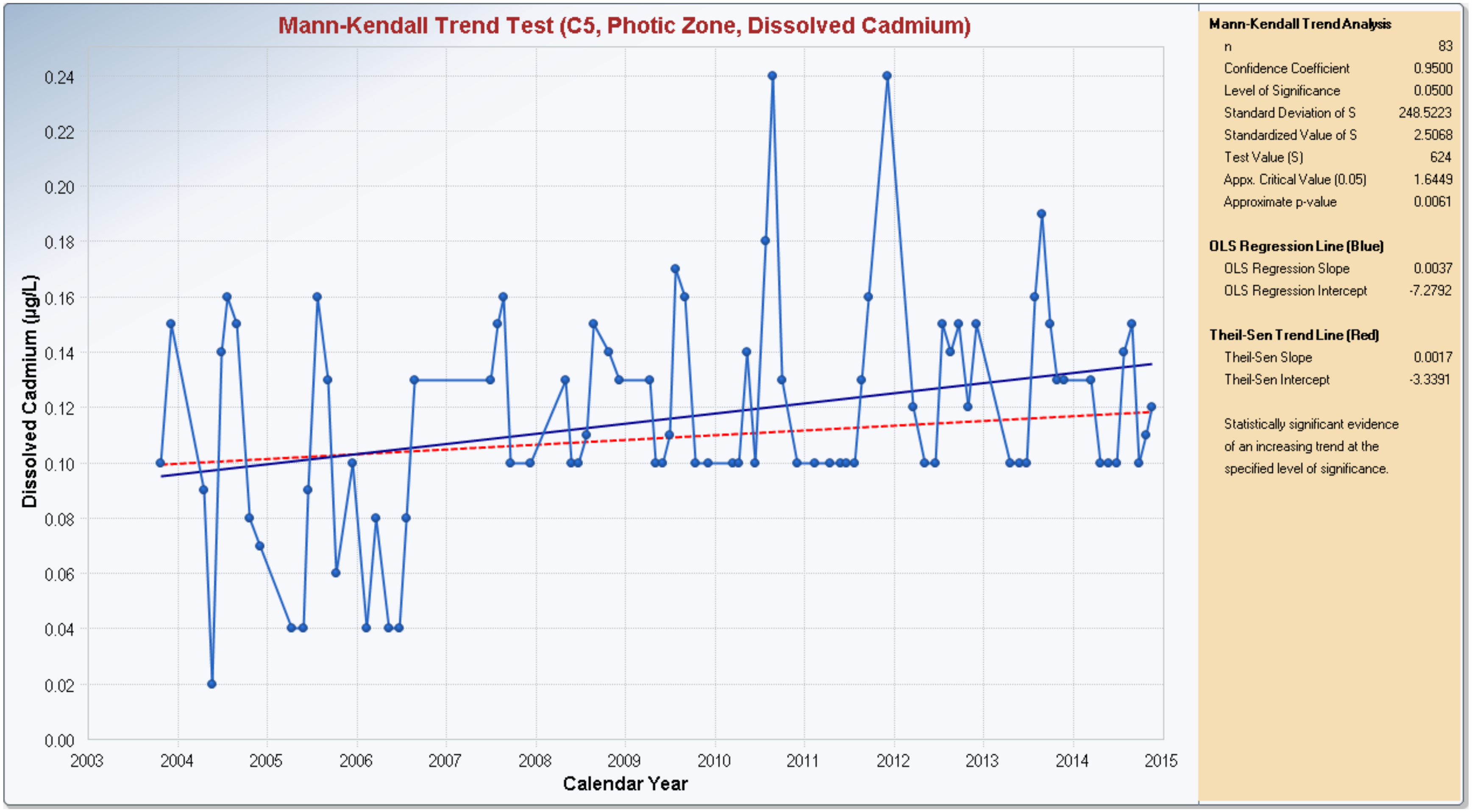
## Site C4, University Point, 30 m



## Site C4, University Point, Near Bottom



## Site C5, Chippy/Blue Point, Photic Zone



## Site C5, Chippy/Blue Point, Near Bottom