Total Maximum Daily Load (TMDL) for Phosphorus in Conesus Lake

Livingston County, New York

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TABLE OF CONTENTS

1.0 INTRODUCTION 4
1.1. Background 4
1.2. Problem Statement 4
1.3. Applicable Water Quality Standards 6
2.0 WATERSHED AND LAKE CHARACTERIZATION 7
2.1. Watershed Characterization 7
2.2. Lake Morphometry 12
2.3. Water Quality Assessment History 13
3.0 NUMERIC WATER QUALITY TARGET 15
4.0 ASSESSMENT of PHOSPHORUS SOURCES 16
4.1. Point Sources 16
4.2. Nonpoint Sources 16
5.0 Phosphorus Loading Capacity Analysis 19
6.0 TMDL POLLUTANT LOAD ALLOCATIONS 21
6.1. TMDL Margin of Safety and Allocation Calculations 21
6.2. Critical conditions 23
6.3. Seasonal Variation 24
6.4. Reasonable Assurance 24
7.0 IMPLEMENTATION PLAN 25
7.1. Nonpoint Source Reductions are Both in Watershed and Internally 25
7.2. Follow-up Monitoring 33
8.0 PUBLIC PARTICIPATION 33
9.0 REFERENCES 35

List of Tables:

Table 1 - 303(d) listing information for Conesus Lake ……..... 6

Table 2 - Land Use Acres and Percent in Conesus Lake Watershed ……..…..……10

Table 3 - Conesus Lake Characteristics …….……12

Table 4 - Growing season mean chlorophyll-a concentrations in Conesus Lake from 2007 through 2014 predicted by TMDL scenario CE-QUAL W2 model ……...……20

Table 5 - Total phosphorus total maximum daily load (TMDL) for Conesus Lake, expressed as annual and daily phosphorus loads ……22

List of Figures:

Figure 1 - Conesus Lake Direct Drainage Basin ……..…….…….8

Figure 2 - Aerial Image of Conesus Lake ……..9

Figure 3 - Percent Land Use in Conesus Lake Watershed …….……..10

Figure 4 - Land Use in Conesus Lake Drainage Basin ……11

Figure 5 - Bathymetric Map of Conesus ……..12

Figure 6 - Chl-a Data Table from the 2003 Conesus Lake Report …..…….…14

Figure 7 - Annual Nonpoint Source Phosphorus Loads from Conesus Lake Watershed …….…17

Figure 8 - Annual Phosphorus Loading From Conesus Lake Bottom Sediments ……18

Figure 9 - Conesus Lake Watershed Steep Slopes that might benefit from stabilization ……..... 30

APPENDIX A. CE-QUAL-W2 Model Setup and Calibration for Conesus Lake.....37

APPENDIX B. Conesus Lake CE-QUAL-W2 Model Temperature and Water Quality Profile Plots 64

APPENDIX C. Numeric Endpoint Development for Potable Water Use…….…112

APPENDIX D Total Equivalent Daily Phosphorus Load Allocations……...…123

1.0 INTRODUCTION

1.1. Background

Section 303(d) of the Federal Clean Water Act (CWA) requires US states and territories to identify waters within their boundaries that are not meeting state or territorial water quality standards. Section 303(d) also requires EPA, states, and territories to develop a Total Maximum Daily Load (TMDL) for any pollutant violating or causing violation of an applicable water quality standard for each impaired waterbody. A TMDL defines the maximum amount of a pollutant that a waterbody can receive while continuing to meet water quality standards. A TMDL also allocates the maximum allowable pollutant load between point and nonpoint sources of the pollutant. TMDLs provide the framework that allows states to establish and implement pollution control and management plans with the ultimate goal indicated in Section 101(a)(2) of the CWA: "water quality which provides for the protection and propagation of fish, shellfish, and wildlife, and recreation in and on the water, wherever attainable" (USEPA, 1991a).

This report presents a TMDL for total phosphorus for Conesus Lake in Livingston County, New York.

1.2. Problem Statement – Waterbody and Pollutants of Concern

Conesus Lake (WI/PWL ID 0402-0004) is situated in the Towns of Livonia, Geneseo, Groveland, and Conesus within Livingston County, New York. Over the past couple of decades, the lake has experienced degraded water quality that has reduced the lake's recreational and aesthetic value. Eurasian Watermilfoil (*Myriophyllum spicatum*) has become increasingly abundant in the littoral zone of Conesus Lake in recent years. This nuisance aquatic plant growth is due to excess nutrient loading from the lake's watershed and its many tributaries (J. Makarewicz, personal communication, January 16, 2008).

Although a variety of sources of phosphorus are contributing to the poor water quality in Conesus Lake, it is primarily influenced by runoff events from the drainage basin. In response to precipitation, nutrients, such as phosphorus – naturally found in New York soils – drain into the lake from the surrounding drainage basin by way of streams, overland flow, and subsurface flow. Nutrients are then deposited and stored in the lake bottom sediments.

Phosphorus is often the limiting nutrient in temperate lakes and ponds and can be thought of as a fertilizer; a primary food for plants, including algae. In Conesus Lake, modeling and monitoring data indicate that at certain times nitrogen is intermittently the limiting pollutant. EPA studies in the 1970s, however, indicate during the summer the limiting pollutant is phosphorus. The definition for this stoichiometric ratio, called the Redfield Ratio, for N:P varies from 16:1 to 14:1. At ratios less than 14:1, the lake could've been viewed as nitrogen limited, however during the summer algal season data had indicated the limiting nutrient is predominantly phosphorus in Conesus Lake. This difference is important because in the summer, when then lake receives excess phosphorus, it "fertilizes" the lake by feeding the algae.

The 2016 New York State Section 303(d) List of Impaired/TMDL Waters identifies phosphorus and oxygen demand as the causes of nonattainment of water quality standards in Conesus Lake. The focus of this TMDL is phosphorus as the key nutrient that limits algae growth in the lake during the summer growing season. Inputs of excess phosphorus to a lake can have several negative effects on water quality and ecosystem health. For example, high phosphorus levels often spur algae blooms and can contribute to the overgrowth of rooted aquatic plants. As these algae and aquatic plants are decomposed by microorganisms, dissolved oxygen levels become depressed, creating conditions that are unsuitable for fish and other wildlife. Excess algae and aquatic plant growth also reduces the recreational and aesthetic value of a lake, and some forms of harmful algal blooms can produce toxins(cyanobacteria for example).

The low dissolved oxygen levels further contribute to water quality degradation when oxygen levels are completely dissipated at the sediment interface. Under those conditions, phosphorus in the sediments is released to the water column as soluble reactive phosphorus (SRP) where it is available to grow additional algae. In this vicious cycle, low dissolved oxygen foster release of SRP, increased algae growth and decomposition, continued oxygen depletion and so on. In this document, the release of SRP from bottom sediments is referred to as internal loading.

Table 1. 303(d) listing information for Conesus Lake. Information is derived from the 2016 New York 303(d) list of impaired waters.

Water Index Number	Waterbody Name (WI/PWL ID)	Class	Cause/ Pollutant	Source	Year
Ont 117-40-P67	Conesus Lake (0402-0004)	AA	Phosphorus Low DO	Agriculture, non-point and Internal Loading	2016

1.3. Applicable Water Quality Standards

Under New York surface water quality standards, all waters in New York State are assigned a letter classification that denotes their best uses. Conesus Lake is designated as a Class AA waterbody.

Best uses of Class AA waters are defined as (6 CRR-NY 701.5):

a) A source of water supply for drinking, culinary or food processing purposes; primary and secondary contact recreation; and fishing. The waters shall be suitable for fish, shellfish and wildlife propagation and survival.

b) This classification may be given to those waters that, if subjected to approved disinfection treatment, with additional treatment if necessary to remove naturally present impurities, meet or will meet New York State Department of Health drinking water standards and are or will be considered safe and satisfactory for drinking water purposes.

New York water quality standards establish criteria for water quality that correspond to attainment of best uses. The criterion for phosphorus is narrative and states that phosphorus shall not be present

within the waterbody "in amounts that will result in growths of algae, weeds and slimes that will impair the waters for their best usages" (6 CRR-NY 703.2).

2.0 WATERSHED AND LAKE CHARACTERIZATION

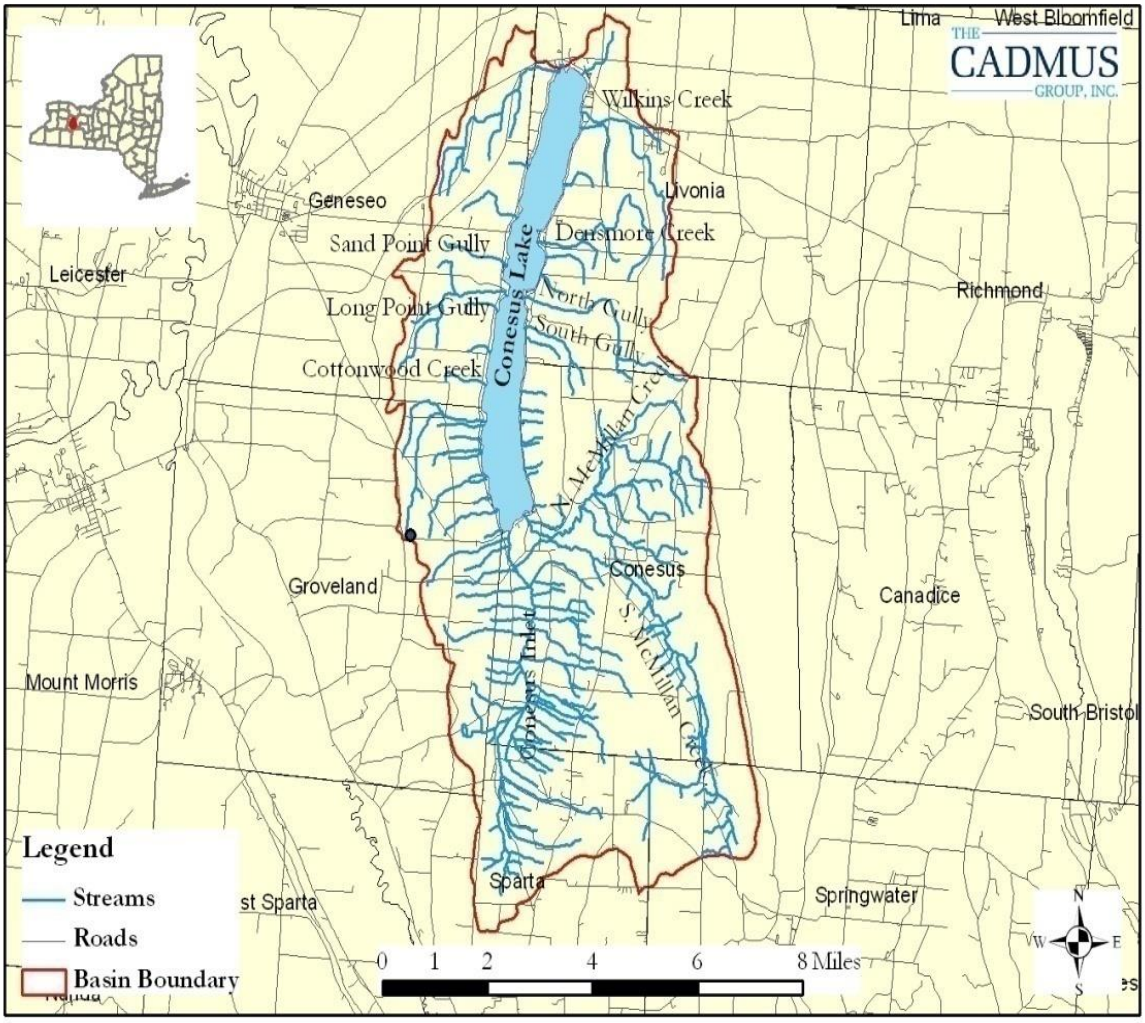
2.1. Watershed Characterization

Conesus Lake, in Livingston County, is the westernmost Finger Lake. It is also one of the five small Finger Lakes and is a multi-purpose lake located in the Genesee River Basin. The Conesus Lake watershed encompasses approximately 70 square miles and includes all or part of seven municipalities within Livingston County. The Towns of Conesus, Geneseo, Groveland Livonia, Springwater, and Sparta and the Village of Livonia are all or partially located within the watershed. Municipal water supply is withdrawn by the villages of Geneseo and Avon and is supplied to approximately 20,000 Livingston County residents. In addition to being a potable water source and the primary water supply to local municipalities, the lake is heavily used for recreation including summer and winter fishing, boating, and swimming. Heavy and prolonged harmful algal blooms have negatively impacted recreational uses in recent years.

Four towns (Geneseo, Livonia, Conesus, and Groveland) share the shoreline. The Village of Livonia, 3 km east of the lake, is the largest urban concentration in the watershed, but the hamlet of Lakeville surrounds the outlet of the lake, and virtually the entire shoreline is developed as residential area. In the watershed as a whole, about half the area is in active agriculture and a third is forested. Land use in the watershed has remained relatively constant over the past 100 years.

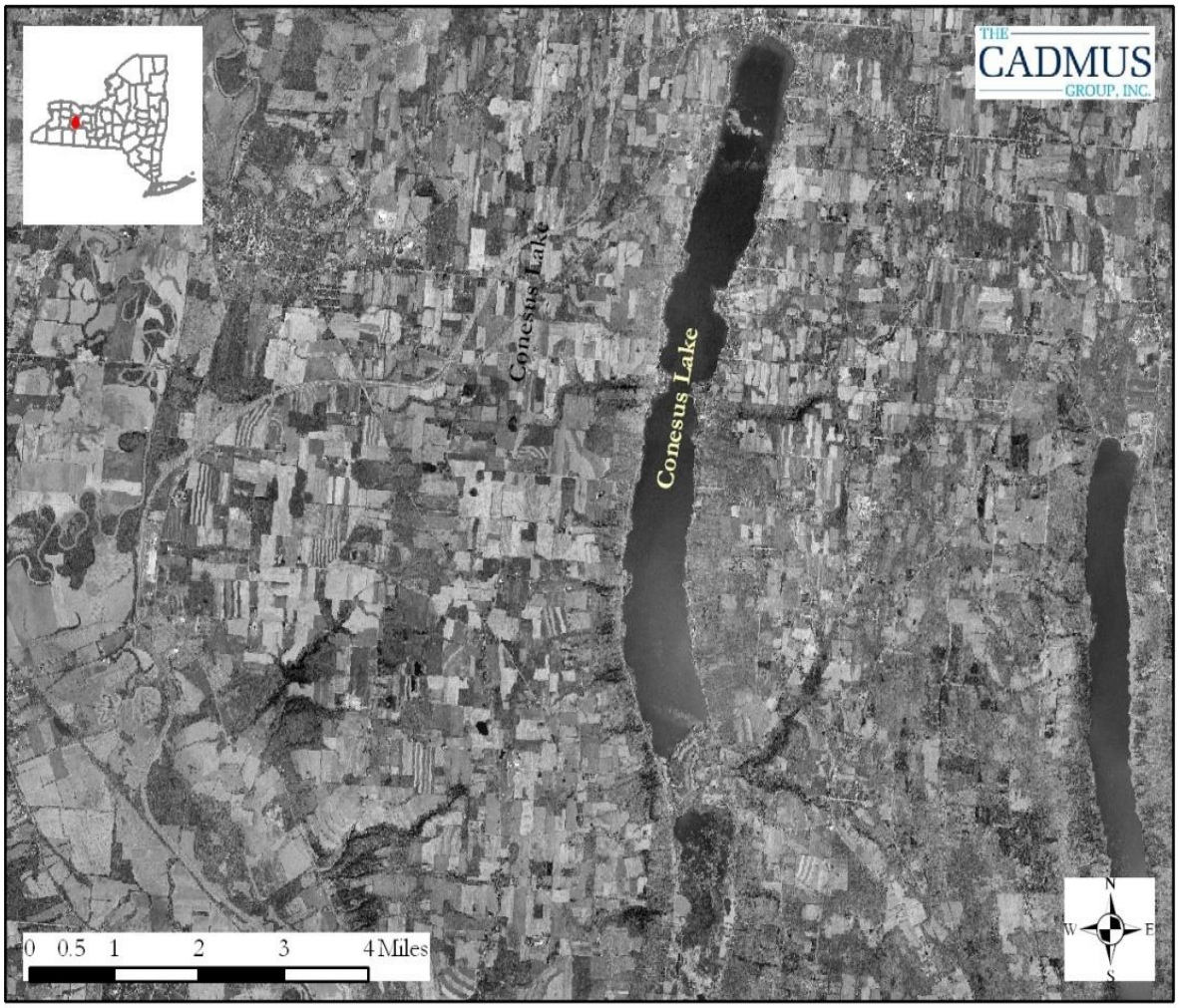
Conesus Lake has a direct drainage basin area of 41,429 acres excluding the surface area of the lake (Figure 1). Elevations in the lake's basin range from approximately 2,047 feet above mean sea level (AMSL) to as low as 817 feet AMSL at the surface of the lake. There are more than 18 tributaries draining into Conesus Lake, with the North and South McMillan Creeks contributing up to 70% of the flow into the lake (Livingston County Planning Department, 2002).

Figure 1. Conesus Lake Direct Drainage Basin



Existing land use and land cover in the Conesus Lake drainage basin was determined from digital aerial photography and geographic information system (GIS) datasets. Digital land use/land cover data were obtained from the 2011 National Land Cover Dataset (NLCD). The NLCD is a consistent representation of land cover for the conterminous United States generated from classified 30-meter resolution Landsat thematic mapper satellite imagery data. High-resolution color orthophotos were used to manually update and refine land use categories for portions of the drainage basin to reflect current conditions in the drainage basin (Figure 2). Appendix A provides additional detail about the refinement of land use for the drainage basin.

Figure 2. Aerial Image of Conesus Lake



Land use categories (including individual category acres and percent of total) in Conesus Lake's drainage basin are listed in Table 2 and presented in Figures 3 and 4.

Figure 3. Percent Land Use in Conesus Lake Drainage Basin

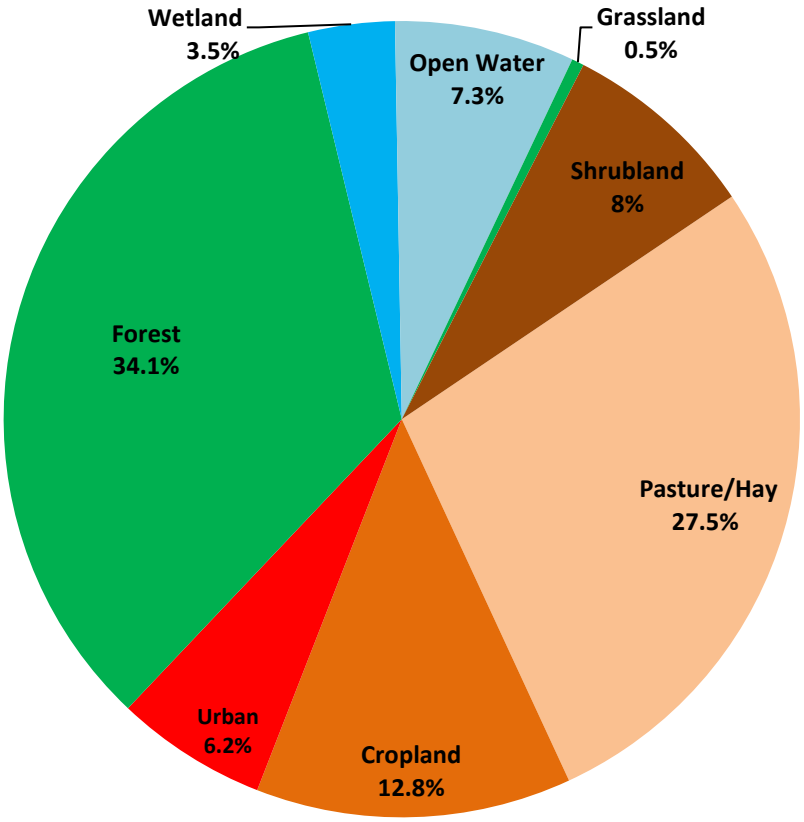
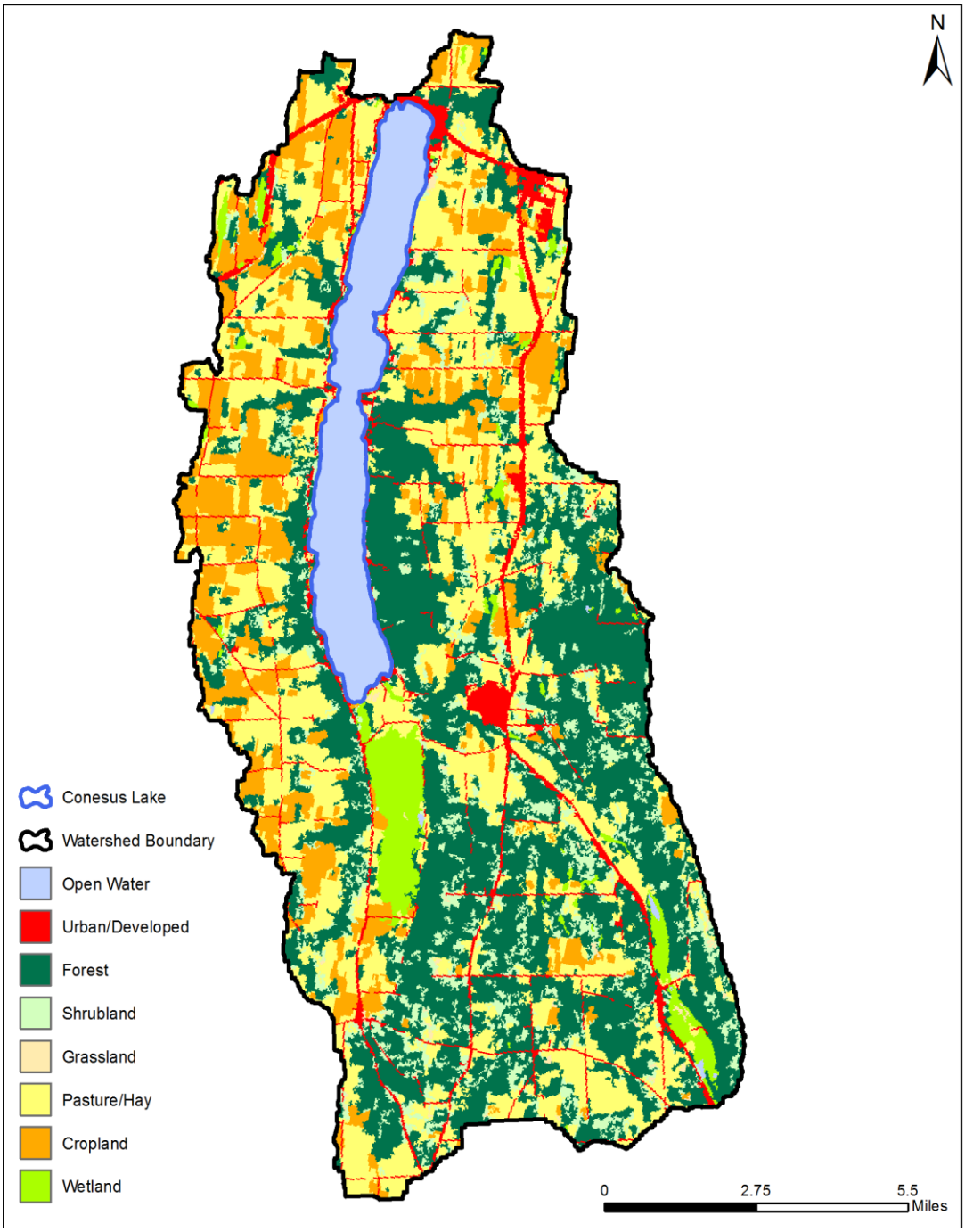


Table 2. Land use in the Conesus Lake watershed. Based on the National Land Cover Database 2011 land cover dataset.

Land Use	Acres	Percent of Watershed
Forest	15,486	34%
Pasture/Hay	12,493	27%
Cropland	5,813	13%
Shrubland	3,635	8%
Open Water	3,319	7%
Urban	2,791	6%
Wetland	1,593	4%
Grassland	225	1%
Total	45,355	100%

Figure 4. Land Use in Conesus Lake Drainage Basin



2.2. Lake Morphometry

Conesus Lake is a 3,206 acre waterbody at an elevation of about 817 feet AMSL. Figure 5 shows a bathymetric map for Conesus Lake based on lake contour maps developed by NYS DEC. Table 3 summarizes key morphometric characteristics for Conesus Lake.

The Finger Lakes originated as deeply scoured glacial valleys with thick unconsolidated sediments overlying the bedrock. Conesus Lake is 12.6 km long, and slightly over 1 km wide in most places. The shape is almost cylindrical, with the long axis tilting slightly toward the northeast. The waist is constricted by stream deltas at Long Point and McPherson's Point, separating north and south basins. The deeper portion, at about 20 meters deep, is in the southern basin.

Figure 5. Bathymetric Map of Conesus

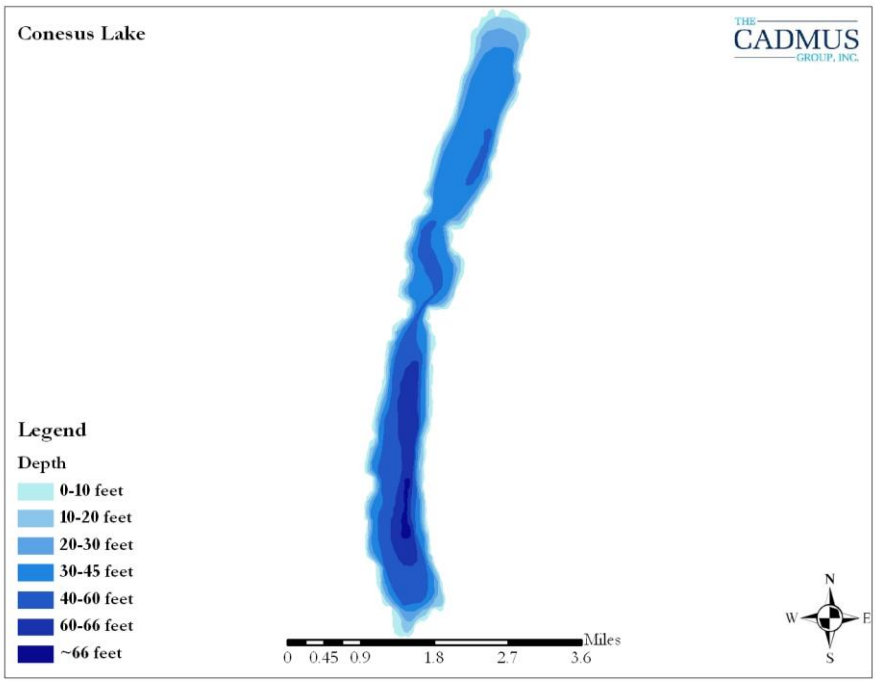


Table 3. Conesus Lake Characteristics

Surface Area (acres)	3,206
Elevation (ft AMSL)	817
Maximum Depth (ft)	66
Mean Depth (ft)	35
Length (ft)	36,580
Width at widest point (ft)	4,088
Shoreline perimeter (ft)	97,007
Direct Drainage Area (acres)	41,429
Watershed: Lake Ratio	13:1
Mass Residence Time (years)	1.4
Hydraulic Residence Time (years)	2.7

2.3. Water Quality Assessment History

Conesus Lake water quality has been assessed by multiple parties over a period of several decades:

1974 EPA Working Paper # 156

In the early 1970s, DEC and EPA' led a joint effort leading to *Working Paper No. 156: Report on Conesus Lake*. The paper sited various survey and loading rate sources as attributing eutrophic and mesotropic attributes to Conesus Lake and its' watershed. Since then, trophic conditions within Conesus Lake have increased somewhat and the mean annual total phosphorus level of the lake increased to slightly above the 20 μg/l NYS guidance value for recreational waters. (The more restrictive chl-a target for drinking water is discussed later in this document). Water clarity was found to be declining moderately.

In addition to the general tropic observations, more specifically lake sampling found phosphorus to be the limiting nutrient during the anoxic portion of the summer (and nitrogen at that time during the early spring and late fall). Working Paper No. 156 states, on page 1, that:

"…the lake data indicate that nitrogen was limiting during the May and October sampling (N/P ratios were less than 8:1), and phosphorus was limiting during the July sampling when the N/P ratio was 19:1."

This further validates the finding that Phosphorus was the limiting nutrient for the primary algal growth portion simulation period, June to September, modeled in this TMDL. It was also estimated that the lake was accumulating both nutrients at a significant rate, net accumulation of 6,210 lbs/yr phosphorus and 132,220 lbs/yr nitrogen, based on a mass balance considering lake outlet outflow and watershed inflow. These nutrient estimates were based on one year of sampling in 1972.

DEC CSLAP Monitoring and Water Quality Reports

DEC's Citizens Statewide Lake Assessment Program (CSLAP) is a cooperative volunteer monitoring effort between DEC and the New York Federation of Lake Associations (NYS FOLA). The goal of the program is to establish a volunteer lake monitoring program that provides data for a variety of purposes, including establishment of a long-term database for NYS lakes, identification of water quality problems on individual lakes, geographic and ecological groupings of lakes, and education for data collectors and users. The data collected in CSLAP are fully integrated into the state database for lakes, have been used to assist in local lake management and evaluation of trophic status, spread of invasive species, and other problems seen in the state's lakes.

Volunteers undergo on-site initial training and follow-up quality assurance and quality control sessions are conducted by DEC and trained NYS FOLA staff. After training, equipment, supplies, and preserved bottles are provided for bi-weekly sampling for a 15 week period between May and October. Water samples are analyzed for standard lake water quality indicators, with a focus on evaluating eutrophication status-total phosphorus, nitrogen (nitrate, ammonia, and total), chlorophyll *a,* pH, conductivity, color, and calcium. Field measurements include water depth, water temperature, and Secchi disk transparency. Volunteers also evaluate use impairments through the use of field observation forms, utilizing a methodology developed in Minnesota and Vermont. Aquatic vegetation samples, deepwater samples, and occasional tributary samples are also collected by sampling volunteers at some lakes. Data are sent from the laboratory to DEC and annual interpretive summary reports are developed and provided to the participating lake associations and other interested parties.

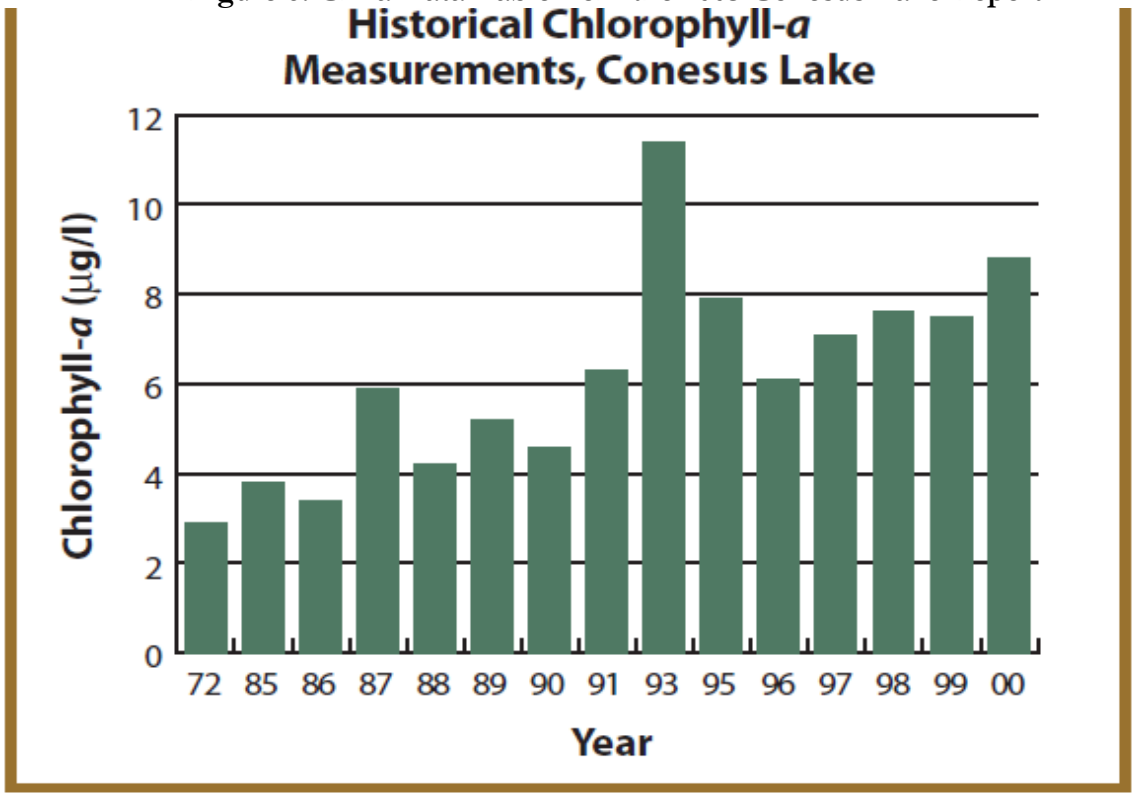
Monitoring efforts on Conesus Lake have been conducted as part of CSLAP from 1986 to 1990 and then again in 2017. Water quality parameters monitored as part of CSLAP generally include:

- Water temperature
- Total phosphorus (TP)
- Chlorophyll a (chl-a)
- Specific conductivity
- Water clarity (Secchi depth)
- Total nitrogen (TN)
- pH
- Color

Monitoring efforts under CSLAP were conducted at one location near the center of the Southern basin of Conesus Lake during the 1986-1990 sampling period. In 2017, sampling was conducted at two locations, in the Northern and the Southern basins of the lake.

Other monitoring efforts conducted in Conesus Lake include the NYSDEC Disinfection by-products (DBPs) Study (Callinan et al. 2013) in 2004, NYSDEC Lake Classification and Inventory (LCI) Monitoring Program in 2002 and 2005, and the Finger Lakes Synoptic Water Quality Investigation (FL/SWQI) from 1996 to 2000. In addition to these monitoring efforts, individual researchers have studied Conesus Lake's water quality since the early 20th century. Earlier studies related to nutrient loadings, water clarity, sedimentation, and biological surveys are detailed in the Conesus Lake Watershed Characterization Report Update (LCPD and EcoLogic 2013).

Figure 6. Chl-a Data Table from the 2003 Conesus Lake Report



Sources: 1972 (Mills, 1975); 1985, 1988-1 and 1991–1993 (Crego, 1994); 1986–1988-2, 1989 &1990 and 1995–1999 (NYSDEC); 2000 Makarewicz et al.

Conesus Lake Watershed Management Plan (CLWMP)
In 2003, the local watershed stakeholders developed a Conesus Lake Watershed Management Plan (CLWMP) that is the foundation for an ongoing annual planning effort, assessment of progress, and prioritization of further corrective actions. Since 2002, the CLWMP has assisted in directing many millions of dollars from federal, state and local sources toward efforts to restore and protect Conesus Lake and its watershed, monitor the effectiveness of these efforts, and communicate the findings to the public. In addition to the financial investment, there have been ongoing efforts from many of the volunteers, municipal employees, agency representatives and community leaders. The CLWMP and associated efforts will be discussed in greater detail in the Implementation Section.

TP concentrations in the lake during 2009 and 2012, two mid-range years included in the modeling scenarios, for example, were 22.4 and 22.7 ug/l respectively. The Chlorophyll-a measured during these years were 6.5 and 5.1 ug/l respectively. Both of these years representing the mid-range of those modeling were in excess of chl-a target of 4 ug/l.

3.0 NUMERIC WATER QUALITY TARGET

The TMDL target is a numeric endpoint specified to represent the level of acceptable water quality that is to be achieved by implementing the TMDL. The water quality classification for Conesus Lake is AA, which means that the best usages of the lake are a source of water supply for drinking, culinary or food processing purposes; primary and secondary contact recreation; and fishing. The lake must also be suitable for fish propagation and survival. New York State has a narrative standard for nutrients: "none in amounts that will result in growths of algae, weeds and slimes that will impair the waters for their best usages" (6 NYSCRR Part 703.2).

In order to determine the pollutant loading capacity of a waterbody one or more numeric water quality targets must be selected that describe in-lake conditions which correspond to attainment of water quality standards. As noted in Section 1.3, New York water quality standards establish a narrative criterion for phosphorus. DEC has identified an in-lake growing season average chlorophyll-a concentration of less than or equal to 4 micrograms per liter (μg/l) as corresponding to attainment of the phosphorus narrative criterion. Chlorophyll-a is an indicator of algal growth within a lake and is therefore a measure of ecosystem response to phosphorus loading.

Since phosphorus has been identified as the limiting pollutant during the summer season when the algal blooms occur and often are in excess of the chlorophyll-a narrative criterion**,** it was necessary to also develop a correlation between the phosphorus loading and the chlorophyll-a numeric representation concentrations. This then enabled the development of a target reduction in phosphorus loading that is expected to lower the chlorophyll-a concentrations to the acceptable level; defined as an epilimnetic summer mean value of 4 μg/l for Class AA Conesus Lake. The TP value that corresponded to 4 ug/l for the years for which the data was available in a DEC database ranged from 8 to 24 ug/l with an average of 13 ug/l TP. Please see Appendix C for a discussion of how the 4 ug/l correlates to a possible range of TP values based on collected TP vs Chl-a data, and why a Chl-a Target is selected over a Phosphorus concentration target for this lake.

The 4.0 μg/l chlorophyll-a target for a Class AA Lake is used because Conesus Lake is a designated drinking water source.

Accordingly, the TMDL has been developed to achieve this 4 μg/l chlorophyll-a target. The phosphorus sources are assessed in Section 4 of this document and the watershed and lake modeling efforts are detailed in Appendices A and B respectively.

4.0 ASSESSMENT OF PHOSPHORUS SOURCES

4.1 Point Sources

Point sources of pollution, as defined by the federal Clean Water Act, include any discrete conveyance that discharges pollutants to a waterbody, such as pipes or ditches discharging wastewater from a sewage treatment plant or industrial facility. Point sources of pollution are regulated by the NYSDEC State Pollutant Discharge Elimination System (SPDES) permit program.

There is one single family residential system permitted as a surface discharge with a permitted flow of 500 gpd, discharging to an inflowing tributary. It is considered to be de minimis and is part of the expected 'Developed Land' loading contribution. The City of Rochester MS4 is nearest to the Conesus Lake Watershed, and its southernmost boundary is approximately 10 miles to the north of the watershed and is accordingly not considered to contribute to this watershed loading.

4.2 Nonpoint Sources

4.2.1 *Watershed Runoff*

Nonpoint sources of pollution include any sources that do not meet the definition of a point source. A key nonpoint source of phosphorus to a waterbody is runoff of precipitation from the watershed. Watershed runoff carries phosphorus deposited on the land surface and subsurface into a waterbody. Watershed runoff can originate from naturally vegetated areas (forest, grassland, etc.) or from developed lands (residential lots, agricultural fields, etc.) and the quantity and chemical quality of runoff is highly dependent on watershed characteristics such as land use, soils, and slopes.

Land use in the Conesus Lake watershed is summarized in Table 2 and in Figures 3 and 4. The watershed is predominantly under agricultural cover (41% of the watershed area). Rural residences are distributed throughout the watershed and higher density residential areas occur along the Conesus Lake shoreline and in the northwest portion of the watershed in the Town of Livonia. Undeveloped areas are predominantly forested.

Phosphorus loads from Conesus Lake watershed runoff for the period 2007 through 2014 were estimated using the Soil and Water Assessment Tool (SWAT). SWAT is a watershed model that uses information on watershed characteristics, weather records, and mathematical equations describing runoff generation and water quality processes to generate daily predictions of watershed runoff and pollutant loads (Neitsch et al. 2011). The SWAT model utilized to estimate phosphorus loads from the Conesus Lake watershed was originally developed by researchers at SUNY Brockport as part of a larger effort to model the Genesee River watershed. Details of the Genesee River watershed SWAT modeling study and model configuration are provided in Makarewicz et al. (2013). The SWAT model developed by SUNY-Brockport researchers was modified for this TMDL study to extend the simulation period to include the years 2013 and 2014. No modifications were made to model parameters that affect nonpoint source phosphorus outputs.

SWAT represents a watershed as a collection of Hydrologic Response Units (HRUs). Each HRU is a land area with a unique land use-soil-slope combination. SWAT-estimated loads of total phosphorus from HRUs in the Conesus Lake watershed are displayed in Figure 7. SWAT predicts that the average total phosphorus loading over 2007 through 2014 is 4,279 kilograms per year (kg/year).

The SWAT model of the Conesus Lake watershed includes HRUs for three different land use types: forest, agriculture, and urban.

SWAT model results indicate that a substantial portion of the nonpoint source phosphorus load from the Conesus Lake watershed originates from agricultural and urban sources. Agricultural sources of phosphorus can include crop fertilizers, livestock manure, and erosion of phosphorus-laden sediment from fields with exposed soils following crop harvest or tillage. Urban sources of phosphorus in watershed runoff can include lawn fertilizer, pet waste, septic system effluent, sewage from leaky sanitary sewers, and washoff of phosphorus deposited on impervious surfaces.

Figure 7. Annual nonpoint source phosphorus loads from the Conesus Lake watershed. Estimates are average annual loads for the period 2007 through 2014 from the SWAT watershed model of the Conesus Lake watershed.

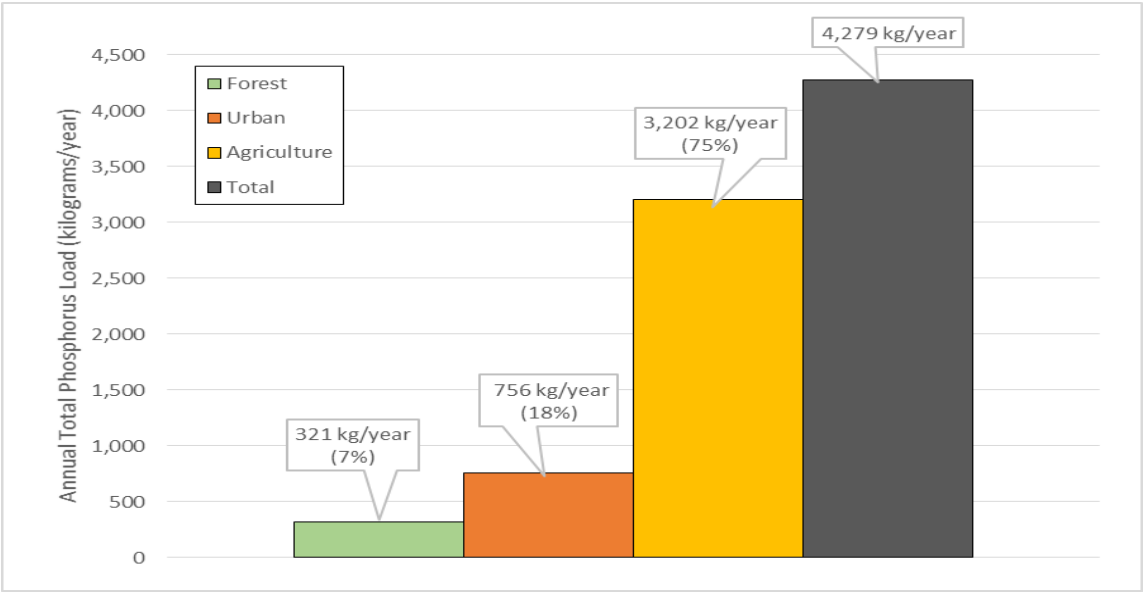


Figure 7 displays SWAT-estimated total phosphorus loads from forest, agriculture, and urban HRUs in the Conesus Lake watershed. The average total phosphorus load over 2007 through 2014 is 321 kg/year for forest HRUs (7% of the total load), 3,202 kg/year for agriculture HRUs (75% of the total load), and 756 kg/year from urban HRUs (18% of the total load).

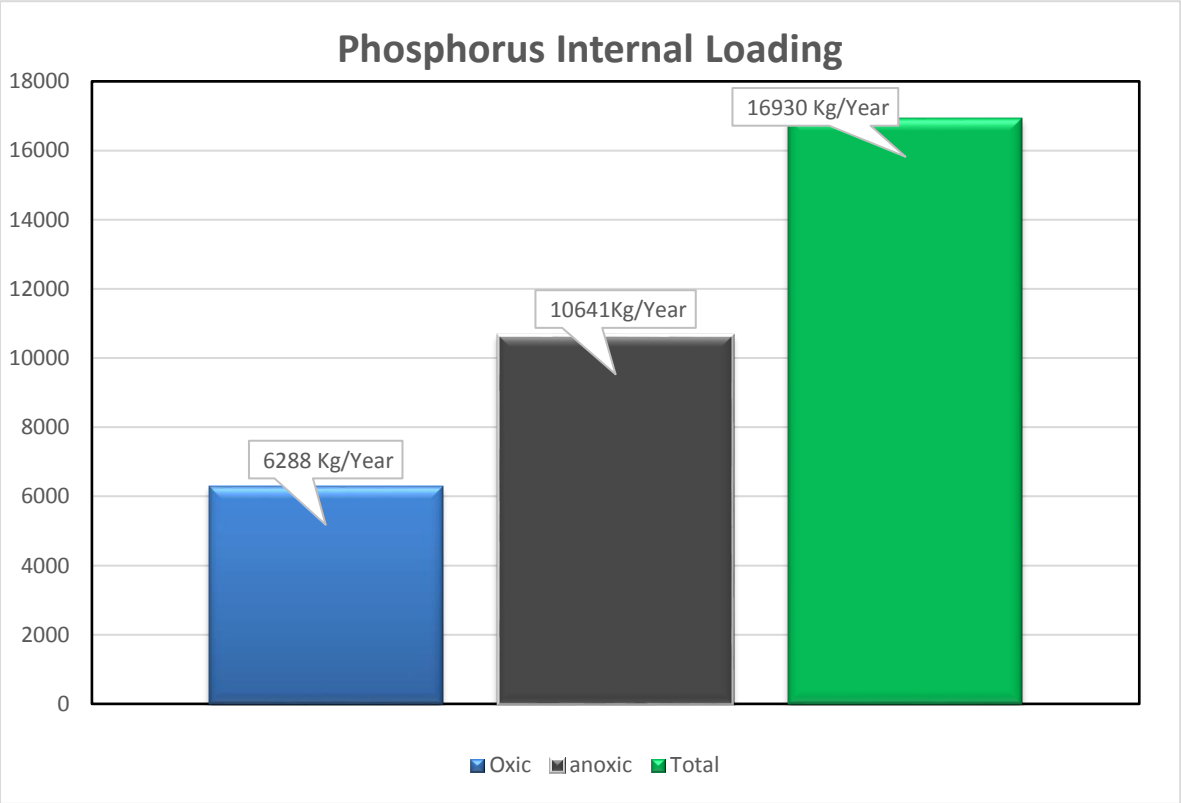
4.2.2 Internal Loading

After phosphorus enters a lake, it cycles between forms (inorganic and organic) and between the water column and bottom sediment. Over an annual time step, the net release of phosphorus from bottom sediments into the water column can be significant in lakes where several years of high phosphorus loading have left a legacy of stored phosphorus. Release of phosphorus from bottom sediments can occur through a variety of processes, including aerobic and anaerobic decomposition of organic sediments or release of iron-bound phosphorus under anoxic conditions.

Estimates of phosphorus release in Conesus Lake from bottom sediments were derived from the CE-QUAL-W2 lake model. CE-QUAL-W2 is a two-dimensional (longitudinal and vertical) hydrodynamic and water quality model developed by the US Army Corps of Engineers and the Water Quality Research Group at Portland State University (Cole and Wells, 2014). Details of the CE-QUAL-W2 lake modeling effort are provided in Appendix A.

CE-QUAL-W2 offers two methods to simulate the effects of bottom sediment on water column nutrient concentrations. Both methods were implemented in the Conesus Lake model. The first method uses a constant zero-order release and demand approach to simulate organic sediment decay under anaerobic conditions. Nutrient release from bottom sediment does not occur from the zero-order function when dissolved oxygen concentrations in the overlying water column are above a specified minimum value. When anoxic conditions develop, nutrient release from the zero-order process are a function of user-supplied sediment oxygen demand (grams of oxygen per square meter per day), anoxic release rates for nutrients, and water temperature.

Figure 8. Annual phosphorus loading from Conesus Lake bottom sediments. Estimates are the average of 2007 through 2014 annual loads from the CE-QUAL-W2 lake model of Conesus Lake.



The second method uses a sediment compartment to track accumulation of organic bottom sediments and allow their decay under oxic conditions. The first-order sediment compartment is not a true sediment diagenesis compartment as it does not keep track of organic nutrient delivery to the sediments, their decay, and subsequent release back into the water column during hypoxic/anoxic conditions. However, it does keep track of organic matter delivery to the sediments via particulate organic matter and dead algal cells, and the subsequent water column oxygen demand that is exerted.

Nutrient releases and oxygen demand are dependent on sediment accumulation, a first-order process. There is no release of nutrients when the overlying water column is anoxic since the first-order sediment compartment represents labile, oxic decay of organic sediment.

Estimates of oxic and anoxic sediment phosphorus release are displayed in Figure 8. Average oxic phosphorus release over 2007 to 2014 is in 6,288 kg/year and average anoxic phosphorus release is 10,641 kg/year. Based on the large magnitude of anoxic and oxic phosphorus releases, loading of legacy phosphorus from bottom sediments appears to be a significant net source of phosphorus to the Conesus Lake water column over annual time scales.

It is important to note that bottom sediments should not be considered an independent source of phosphorus to a lake. A fundamental coupling exists between loading of phosphorus from external sources (watershed runoff, point sources, etc.) and loading from bottom sediments. The magnitude of phosphorus loading from bottom sediments is largely determined by the amount of phosphorus entering a lake in any given year and by historical phosphorus loading.

5.0 PHOSPHORUS LOADING CAPACITY ANALYSIS

The phosphorus loading capacity of Conesus Lake is the maximum phosphorus load to the lake that results in attainment of the chlorophyll-a target listed in Section 3. The phosphorus loading capacity of Conesus Lake was analyzed using the CE-QUAL-W2 lake model described in Appendix A. The Conesus Lake CE-QUAL-W2 model simulates in-lake physical, chemical, and biological processes based on user-supplied inputs related to lake bathymetry, tributary inflows, lake outflows, and meteorological conditions. The CE-QUAL-W2 model is a continuous model and can output predictions of lake conditions at hourly or finer time steps.

Analysis of the phosphorus loading capacity of Conesus Lake was completed by developing a "TMDL scenario" model from the calibrated Conesus Lake CE-QUAL-W2 model to predict the lake response to reduced phosphorus loading.

The calibrated Conesus Lake CE-QUAL-W2 model was modified for the TMDL scenario by:

1. Reducing the concentrations of dissolved and organic phosphorus in inflows from the Conesus Lake watershed.

2. Reducing the sediment release rate of phosphorus (PO4R). This parameter affects the release rate of phosphorus from the zero-order sediment compartment under anaerobic conditions.

   Reducing the modeled sediment release rate of phosphorus as part of loading capacity analysis reflects the assumption that reduced phosphorus loads from the Conesus Lake watershed will result in a reduction in anaerobic phosphorus release from bottom sediments.

The development of the TMDL scenario model was an iterative process. The model inputs listed above (watershed phosphorus concentrations and the sediment release rate of phosphorus) were incrementally decreased until the growing season mean chlorophyll-a concentrations predicted by the model were at or below the 4 μ/L target in 7 of the 8 years of the simulation period. Changes to model inputs were made so that the reduction in watershed phosphorus loading was approximately

proportional to the reduction in phosphorus loading from anaerobic sediment release. For example, if the watershed phosphorus load was reduced by 30% then phosphorus loading from anaerobic sediment release was also reduced by approximately 30%.

The CE-QUAL-W2 model provides continuous predictions of chlorophyll-a concentrations throughout Conesus Lake. Evaluation of the chlorophyll-a target focused on model predictions at the deepest point of the lake, where water quality monitoring occurs.

Evaluation of the chlorophyll-a target was completed by:

1. Extracting hourly model predictions of chlorophyll-a concentrations for the model segment containing the deepest point in Conesus Lake.

2. Calculating the growing season (June to September) mean chlorophyll-a concentration in the surface model layer for each year in the simulation period (2007 through 2014).

3. Comparing to the predicted growing season mean chlorophyll-a concentrations to the 4µg/L chlorophyll-a target.

The TMDL scenario CE-QUAL-W2 model shows that the chlorophyll-a target of 4 µg/L is achieved in 7 of 8 years (Table 4) with an average total phosphorus loading capacity of 1,628 kilograms per year from the Conesus Lake watershed, 2,480 kilograms per year from aerobic sediment release, and 8,046 kilograms per year from anaerobic sediment release. The phosphorus loading capacity of Conesus Lake is therefore an average total phosphorus load of 12,154 kilograms per year.

Table 4. Growing season mean chlorophyll-a concentrations in Conesus Lake from 2007 through 2014 predicted by TMDL scenario CE-QUAL-W2 model.

Year	Growing Season Chlorophyll-a (µg/L)
2007	1.2
2008	1.8
2009	3.1
2010	4.0
2011	3.9
2012	3.8
2013	3.7
2014	4.6

6.0 TMDL POLLUTANT LOAD ALLOCATIONS

6.1 TMDL Margin of Safety and Allocation Calculations

The objective of a TMDL is to define the pollutant loading capacity of a waterbody and to allocate loads among pollutant sources. Wasteload allocations (WLAs) are assigned to point source discharges regulated by SPDES permits. Nonpoint source loads are assigned load allocations (LAs). A TMDL is expressed as the sum of all individual WLAs for point source loads, LAs for nonpoint source loads, and an appropriate margin of safety (MOS) that factors in a specific level of uncertainty (Equation 1).

Equation 1. Calculation of the TMDL.

$$TMDL = \sum WLA + \sum LA + MOS$$

As presented in Section 3, the phosphorus loading capacity of Conesus Lake is 12,154 kilograms per year. This total was distributed as LAs, WLAs, and a MOS using the following approach:

- The WLA is set to zero since there are no SPDES permitted point sources in the watershed;
- The MOS is calculated as 10% of the Conesus Lake TMDL loading capacity (i.e., 10% of 12,154 kilograms per year).
- The LA for forested lands is set to the existing load (i.e., zero percent reduction).
- The LA for anaerobic and aerobic sediment release is set to the average annual load predicted in the TMDL scenario CE-QUAL-W2 model described in Section 3.
- The LA for agricultural and urban lands is set to the remaining allocable load after accounting for the MOS.

The Conesus Lake phosphorus TMDL is presented in Table 5 as annual and daily loads. Daily loads were calculated as annual loads divided by 365.25 (the average number of days in a year).

Table 5. Total phosphorus total maximum daily load (TMDL) for Conesus Lake, expressed as annual and daily phosphorus loads. Also displayed are estimated existing total phosphorus loads by source.

Source	Existing Load (kilograms/year)	TMDL (kilograms/year)	Existing Load (kilograms/day)	TMDL (kilograms/day)	% Reduction
Load Allocation (LA)	**21,208**	**10,939**	**58.1**	**29.9**	**48%**
Forest	321	321	0.9	0.9	0%
Agriculture	3,202	2,700	8.8	7.4	16%
Urban	756	700	2.1	1.9	7%
Internal Loading - Aerobic Sediment Release	6,288	2,680	17.2	7.3	57%
Internal Loading - Anaerobic Sediment Release	10,641	4,538	29.1	12.4	57%
Wasteload Allocation (WLA)	**0**	**0**	**0**	**0**	**-**
Margin of Safety (MOS)	**-**	**1,215**	**-**	**3.3**	**-**
Total	**21,208**	**12,154**	**58.1**	**33.3**	**43%**

* ***Values reported in Table 5 are annually integrated. Daily equivalent values are provided in Appendix-D.***

The percent reduction across the individual sectors may be changed so long as the total reduction remains the same.

The margin of safety (MOS) can be implicit (incorporated into the TMDL analysis through conservative assumptions) or explicit (expressed in the TMDL as a portion of the loadings) or a combination of both. For the Conesus Lake TMDL, the MOS is explicitly accounted for during the allocation of loadings. An implicit MOS could have been provided by making conservative assumptions at various steps in the TMDL development process (e.g., by selecting conservative model input parameters or a conservative TMDL target). However, making conservative assumptions in the modeling analysis can lead to errors in projecting the benefits of BMPs and in projecting lake responses. Therefore, the recommended method is to formulate the mass balance using the best scientific estimates of the model input values and keep the margin of safety in the "MOS" term. The TMDL contains an explicit margin of safety corresponding to 10% of the loading capacity, or MOS=1,215 kg/yr. The MOS can be reviewed in the future as new data becomes available. This 10% MOS applies to the Lake and shown in Table 4 as well as Appendix D, is considered appropriate to address the uncertainty in the TMDL.

The initial watershed phosphorus loading used as input to the CEQUAL was calculated based on the Genesee River Project Soil Water Assessment Tool (SWAT) Model run to develop data for a Report to the United States Department of Agriculture. The Genesee River Project, conducted from August 2010 to August 2013, provides a detailed picture of sediment and phosphorus concentrations (e.g., weekly water chemistry sampling), nutrient loading, allocation and identification of phosphorus sources, and the effectiveness of management practices on the four major Genesee River tributaries (Canaseraga, Honeoye, Black, and Oatka Creeks), the Upper Genesee River, and the Lower Genesee River. During this project, the TSS and TP loads were highly correlated for the main stem sites. In fact, if all main stem sites are combined, the R-squared value of 0.82 was observed – showing good agreement between modeled values and the monitored concentrations.

Watershed Water Quality Loadings for most constituents were derived initially using the SWAT model developed for modeling of the Genesee River Basin. Then, in an effort to minimize errors in loading calculations and assumptions, the nitrogen loading calculations were then calibrated based on the lake-specific data collected by the State University of New York at Brockport (SUNY Brockport) using the concentrations actually measured for tributary inflows to define the correct basis for these loadings.

6.2 Critical Conditions

TMDLs must consider critical environmental conditions to ensure that water quality is protected during times when it is most vulnerable. Critical conditions for chlorophyll-a concentrations in Conesus Lake are during the growing season months when temperatures are conducive to aquatic plant growth. The chlorophyll-a water quality target was evaluated during growing season months and critical conditions were therefore considered in the development of this TMDL.

6.3 Seasonal Variation

TMDLs must consider seasonal variation in environmental conditions. Chlorophyll-a concentrations in Conesus Lake vary seasonally, with higher concentrations occurring during growing season months. The chlorophyll-a water quality target was evaluated during growing season months and seasonal variation was therefore considered in the development of this TMDL.

6.4 Reasonable Assurance

EPA's 1991 TMDL Guidance states that TMDLs developed for waters impaired by both point and nonpoint sources should provide Reasonable Assurances that nonpoint source control measures will achieve expected load reductions if those expected reductions serve as a basis for determining WLAs.

This TMDL intends to provide 'Reasonable Assurance' that phosphorous loadings will be reduced adequately to result in the attainment of organic matter concentration targets. These targets, and the nutrient loadings modeled necessary to attain them, are designed to insure Conesus Lake to be useable for potable water and recreation and to include a 10% Phosphorous loading Margin of Safety. Follow up monitoring will occur that will trigger additional TP reduction responses if needed. In addition to the nonpoint source incentives and BMP options the 'Diet for a Small Lake', found on the DEC website, provides multiple corrective options that may be attempted to correct the lakes' internal loading. These monitoring and implementation correcting assessments are already a part of the CLWMP ongoing procedures.

As presented in Section 2, Conesus Lake is impaired by nonpoint sources of phosphorus only. Meeting the loading limits specified in this TMDL will require reductions from watershed nonpoint sources and the reduction of internal loading. Implementation will rely upon a blend of existing programs which have proven successful in reducing loads from the targeted source sectors and innovative solutions based on proven science to address internal loading.

The watershed Implementation Plan discussed in Chapter 7 is intended to be a dynamic plan (rather than a static plan) with effectiveness to be assessed on a regular basis, and flexible enough to modify phosphorous control methods if monitoring results warrant it. The Implementation Plan will predominantly be a continuation of the Conesus Lake Watershed Management Plan (CLWMP) with additional credits now being possible for projects that impact impaired waters.

An example of this dynamic plan flexibility is the monitoring of the BMP impact on the export of watershed nutrients and sediments from individual tributaries by sampling at the base of the subwatershed streams near the confluence with Conesus Lake. This provides data on the effectiveness of implemented BMPs and helps to better guide the use of future resources.

Since 2002, the CLWMP has provided a foundation for a continuing annual planning effort, assessment of progress, and prioritization of further corrective actions. The CLWMP has assisted in directing many millions of dollars from federal, state and local sources toward efforts to restore and protect Conesus Lake and its watershed as well as monitor the effectiveness of these efforts. The TMDL should enhance this effort and help assure the annual selection of the most needed watershed corrective measures continue to work towards the lake's nutrient targets.

7.0 IMPLEMENTATION PLAN

One of the critical factors in the successful development and implementation of TMDLs is the identification of potential management alternatives, such as BMPs, in collaboration with the involved stakeholders. For Conesus Lake the implementation of BMPs, and other nutrient control techniques intended to result in achieving water quality targets, are expected to result primarily from the continued work of the Conesus Lake Watershed Management Plan (CLWMP). The CLWMP is implemented by the Conesus Lake Watershed Council (CLWC) in conjunction with the Livingston County Planning Department. The CLWC has a technical committee to help design and implement BMPs and to monitor nutrient loadings on an annual basis. In addition, the CLWC performs progress reviews and publishes an annual 'Lake Report Card' for public review.

The elimination of the phosphorus based impairment, and corresponding removal of Conesus Lake from the EPA 303 (d) Priority Waterbodies List, is aligned with the already existing CLWMP Mission Statement of: "To Design a Management Plan That Preserves, Restores, and Enhances the Health, Natural Beauty, and Rural Character of Conesus Lake and Its Watershed." DEC will support where possible the efforts of these local watershed interests to address the sources of impairment, using regulatory and non-regulatory tools in the watershed to effect implementation of this plan.

There are several watershed nutrient control efforts expected to be assisted by the development of this TMDL. The watershed nutrient reduction methods discussed in the sections below are expected to continually reduce phosphorus loadings until the clean water best usage target is achieved. The follow-up monitoring and review process will aid in assessing and 'fine tuning' the implementation measures until nutrient objectives are met.

7.1 Nonpoint Sources Reductions (Watershed and Internal Sources)

Meeting the loading limits specified in this TMDL will require reductions from nonpoint sources as well as reduction of internal loadings. Implementation will rely upon existing programs which have proven successful in reducing loads from the targeted source sector and possibly innovative solutions based on proven science to address internal loading.

Loading reductions may result from:

- Watershed land and conservation practices and BMPs reducing runoff to the lake,
- Internal Loading Treatment practices that stabilize sediment phosphorus and prevent it from returning to the lake water column, and
- A natural attenuation or reduction in the stored residual lake phosphorus may occur as the agricultural and other basin loading contributions decrease to levels below the outflow phosphorus. In this way the different loading sectors may actually interact with land reductions reducing the potential for future internal loading contributions.

The following Implementation Sub-Sections discuss a number of the general loading reduction options available in various watershed nonpoint sectors. These include established Agricultural Best

Management Practices (BMPs), erosion control options, and a number of the lake treatment options discussed in the DEC Web Publication "Diet for a Small Lake." This last group includes methods for phosphorus removal and/or other algal growth control techniques that include a variety of physical removal, chemical treatment and biomanipulation options.

*7.1.1 Recommended Phosphorus Management Strategie*s for Agricultural Lands

Agricultural source sector implementation strategies rely upon voluntary installation of BMPs to augment the existing regulations in this area. Financial assistance and resource conservation provides participation incentives in some instances when regulations do not require BMPs. In the Conesus Lake Watershed, the following strategies are among those regularly assessed and evaluated for additional nutrient management opportunities on an annual basis.

Terraces with underground outlets
Terraces control soil erosion by intercepting and slowing the flow of surface runoff during heavy rains. These systems are designed so that runoff is captured in the terrace basin and removed through the underground pipe outlet.

Grass lined water and sediment control basins
A water and sediment control basin is a short earthen embankment or a combination ridge and channel constructed across the slope of minor watercourses to form a sediment trap and water detention basin with a stable outlet. It traps water and sediment running off cropland upslope from the structure, and reduces gully erosion by controlling flow within the drainage area. The basin releases water slowly, usually through infiltration or a pipe outlet and tile line. Basins can be effective in reducing sedimentation of nearby waters, especially in areas where residue management or other practices are impractical.

Forest and Grass Buffers
Forest buffers are linear wooded areas, usually accompanied by shrubs and other vegetation, that are adjacent to rivers, streams and shorelines. Forest buffers help filter nutrients, sediments and other pollutants from runoff as well as remove nutrients from groundwater. Grass buffers consist of linear strips of grass or other non-woody vegetation maintained between the edge of fields and streams or rivers that help filter nutrients and sediment and improve habitat.

Cover Crops
Cereal cover crops reduce erosion and nutrients leaching to groundwater or volatilizing by maintaining a vegetative cover on cropland and holding nutrients within the root zone. This practice involves planting and growing, but not harvesting, cereal crops with minimal soil disturbance. The crop is seeded directly into vegetative cover or crop residue and captures nutrients in its tissue as it grows. When the cover crop is incorporated in the spring, trapped nutrients are released and used by the following crop.

Nutrient Management Planning
Nutrient management plans optimize nutrient use to minimize nutrient loss while maintaining crop yield. These plans attempt to maximize use of on-farm nutrients such as manure and cover crops and minimize nutrient imports such as purchased fertilizer. Nutrient management BMPs are developed by certified planners in New York. Certified planners come from both the public and private sector. In

order to sustain nutrient reductions, technical support for plan development, continued plan implementation and regular updates are necessary.

Conservation Planning
Farm conservation plans are a combination of agronomic, management and engineered practices that protect and improve soil productivity and water quality, and prevent natural resource deterioration on a farm. Soil conservation plans are comprehensive plans that meet USDA NRCS Field Office Technical Guide criteria. They help control erosion by modifying operational or structural practices. Operational practices include crop rotations, tillage practices, or cover crops and may change from year to year. Structural practices are longer-term and include, but are not limited to, grass waterways in areas with concentrated flow, terraces, diversions, sediment basins and drop structures.

7.1.2 Recommended Phosphorus Management Strategies for Developed Lands

Developed lands represent a minor part of the total load delivered to the lake compared to internal loading and agriculture, but it is a sector that may become more significant if the watershed is not properly managed. In addition, some reductions may still presently be achieved through Nonpoint Source Management Programs such as the methods presently in use and stated below. The de minimis contribution from the singular residential system is such that no further action is necessary.

Training Resources for Stormwater Management and Erosion Control
Training workshops and materials can provide guidance to municipal Town and Village Boards, Planning Boards, Zoning Boards of Appeals and Code Enforcement Officer on development regulations impacting water quality and best practices for stormwater management and erosion control during the development process.

Land Use Regulations
An analysis of existing land use regulations and local laws can identify areas of improvement for water quality protection.

Water quality protection measures may include the following:

- Designation of environmentally sensitive areas such as steep slopes, streambanks, and forested areas;
- Construction phase and post-construction runoff and stormwater management;
- Sediment and erosion control;
- Reduction in impervious surfaces; and
- Green infrastructure and low impact development.

Land Acquisition and Preservation
Partner with local land trusts or others to prioritize and acquire land through the purchase of private property or use of conservation easements. A conservation easement limits or restricts development, management, or use of property, protects important natural features of property, and provides the landowner with certain retained rights. Purchased land could be used for passive recreation space, parkland, or as an education preserve.

Natural Shoreline Restoration
Naturally restored shoreline projects utilize a variety of structural and organic materials, such as wetland plants, submerged aquatic vegetation, logs, sand fill, and stone to create a naturally stabilized buffer area in the nearshore and shoreline area.

The benefits of natural shoreline restoration include:

- Stabilization of the shoreline;
- Protection of surrounding riparian and intertidal environment;
- Improvement of water quality via filtration of upland run-off; and
- Creation of habitat for aquatic and terrestrial species.

Stormwater Retrofits and Green infrastructure
Changes in land cover and the increased imperviousness of the urban environment have resulted in larger volumes of runoff traveling at faster velocities. This has caused extensive streambank erosion and has compromised aquatic habitat. Many areas were developed without adequate stormwater controls and must be addressed to restore water quality and decrease erosion. Using green infrastructure for urban stormwater retrofits can reduce stormwater pollution while simultaneously reducing the burden and demand on existing infrastructure. The distributed green infrastructure network is designed to limit the conversion of precipitation to runoff by capturing rainwater where it falls, managing stormwater at the surface, and maximizing soil and vegetation contact during treatment. This combination allows green infrastructure to reduce stormwater volumes, peak flow rates, and pollutant concentrations. Practices include, but are not limited to, green roofs, tree planting, riparian buffers, downspout and impervious cover disconnection, permeable pavement, and bioretention.

Septic System Repair and Replacement
Funding may be available to implement a septic system repair and replacement program for qualifying low income households.

Public Education
Continuous promotion of stewardship and best management practices through Watershed Education Center, Conesus Stewardship Initiative, and additional programming. Topics may include, but are not limited to, promotion of zero phosphorus fertilizer, landscaping best management practices, invasive species spread prevention, green infrastructure practices, shoreline restoration, and erosion control best management practices.

Illicit Sewer Connection Inspections
An inspection program can identify and eliminate illicit storm sewer connections and reduce the frequency of combined sewer overflow events. When stormwater is illicitly connected into the sanitary sewer system, the increased volume of water during a heavy rain event can overwhelm the system capacity and result in a discharge of untreated sewage. Visual inspection, dye, and smoke testing are used to identify these illicit connections for removal.

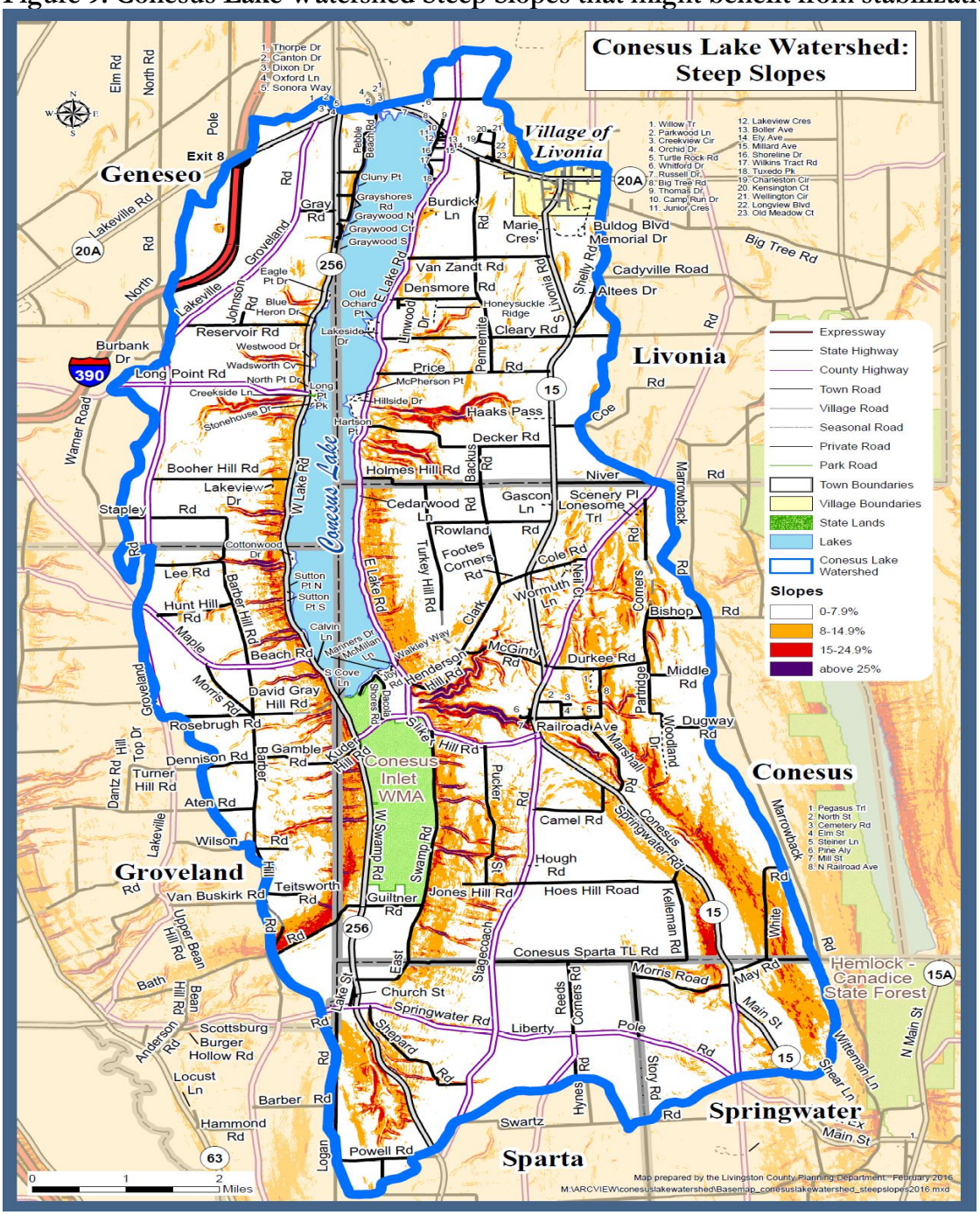
It should be noted that though it is stated above that the developed lands load to the lake is comparatively minor compared to some other sectors, the residential acreage for the decade ending in 2010 has increased by 3.7 %, whereas the agricultural acreage decreased by 8.9% during that same

time. This implies that the developed lands loading is becoming a more significant component of the watershed loading and merits due attention.

7.1.3 Streambank and Slope Erosion Control Measures

Minimization of erosion thorough the stabilization and remediation of vulnerable steep slopes of stream banks and road ditches could reduce phosphorus loading to the lake. Eroded sediment particles carry phosphorus, though this contribution may be difficult to quantify since it varies with land use and soil. Measures that limit the erosion based phosphorus loadings will focus on streambank and road ditch remediation.

Figure 9. Conesus Lake Watershed Steep Slopes that might benefit from stabilization.



As seen in Figure 9 above, there are steep slope areas with varying amounts of vegetative cover that may be susceptible to erosion and might benefit from slope stabilization efforts. Although some erosion is natural and expected, unstable slopes result in higher amounts of eroded sediment material being transported to downstream waterbodies. Any excess of this sediment material that could have been prevented by stabilization techniques will result in a similar excess of phosphorus being transported to the lake. Selection of the stabilization vegetation method or bank protective structure will be based on specifics of the size and characteristics of the stream types and area land uses.

Streambank Remediation
Increased surface runoff, removal of deep rooted riparian vegetation, and forecasted frequency of heavy rain events can cause erosion and widened or incised stream channels. Buffer strips, bank stabilization, and natural channel restoration can remediate erosion issues.

Stream stability is an active process, and while streambank erosion is a natural part of this process, human development activities often exacerbates erosion rates. Any land use changes in a watershed, such as clearing land or development, can increase stream bank erosion. The damage or removal of streamside vegetation reduces bank stability and can cause an increase in stream bank erosion. A degraded streambed results in higher and often unstable, eroding banks.

Road Ditch Remediation
The large network of rural roads makes roadside ditches an important pathway and innovative opportunity to abate stormwater runoff for both quality and quantity issues. Appropriate hydrologic, sediment and nutrient control practices including the use of ditches as bio-retention structures, could be implemented. Increases in Hydro-seeding and mulching capacity are encouraged.

7.1.4 Recommended Phosphorus Management Strategies for Internal Loading

Internal Loading is considered to be a significant source of the seasonally released phosphorus promoting the growth of an excess of algal material. This phenomenon is most pronounced in thermally stratified lakes that have accumulated an internal loading of this limiting nutrient.

Most lakes greater than 20-30 feet become thermally stratified during the summer. When a lake is thermally stratified, colder, heavier water sinks to the bottom and lighter, warmer water rises to the top. This creates distinct layers that do not mix easily. In these lakes, the discrete thermal layers become less distinct during the spring and fall months and mix together in the process known as destratification or turnover. During summer stratification, the bottom water, or hypolimnion, receives little or no exposure to the atmosphere, which can lead to oxygen depletion as organic material (such as algae) falls out of the upper waters and are broken down by bacteria. This is usually much more severe in the summer stratification, during the four warmest months of the year. Several chemical changes can occur in response to this anoxia, or oxygen depletion, including release of nutrients from deep and shallow sediments. This combination of oxygen depletion and chemical reactions can lead to deoxygenated, high-nutrient conditions.

These hypolimnetic reactions are the source of most of the seasonal phosphorus in Conesus Lake.

7.1.4.a Physical Removal of Internal Phosphorus

Hypolimnetic aeration or Destratification
When the hypolimnion has sufficient oxygen, the release of phosphorus (and other pollutants) from oxygen depleted bottom sediments will be minimized. Hypolimnetic aeration is used to increase oxygen circulation within a lake and increase oxygen concentration in the deep waters without causing enough disturbance to disrupt stratification. Aeration of the lake bottom waters uses an air-lift device to pump or lift the deep, stagnant water layer for exposure to the atmosphere. This results in aeration

and the loss of some gases such as carbon dioxide and methane. Then the water sinks back to the hypolimnion.

Hypolimnetic aeration may also be accomplished by injecting pure oxygen or air into the bottom waters or by using an air-lift device along with the injection. With more vigorous aeration and water movement, the hypolimnion can be broken down (destratified), mixing the entire water column and increasing oxygen levels from both the aeration and increased exposure to the atmosphere.

Hypolimnetic withdrawal
Hypolimnetic withdrawal can be accomplished through the installation of a pipe or siphon along the bottom of the lake, usually at the outlet. Water flows out of the hypolimnion by gravity, past the outlet to the receiving waters. If there is insufficient elevation for gravity flow, an auxiliary pump can be installed. Summertime hypolimnetic withdrawal serves to remove the high nutrient waters, thus reducing the potential for algal blooms during fall turnover. Oxygen deficits and elevated phosphorus concentrations are decreased.

7.1.4.b Internal Phosphorus control with chemicals.

Algal growth can be controlled with algaecides or by decreasing the availability of the nutrients in the lake. Two of the most common methods are mentioned here, but some chemical additions can elicit or trigger toxicity, or necessitate other environmental implications.

1. **Algaecide**s are generally copper-based chemicals used to kill algae cells (although other products are registered for use in New York), and to reduce the use impairments associated with excessive algal growth. Copper sulfate is the most common algaecide and one of the most popular algae control techniques. There are, however, a variety of copper based algaecides that may be chosen for various algal problems, Algaecides may be beneficial in treating the symptoms of eutrophication, and can provide some short-term relief from the impacts associated with excessive algae growth, including reduced swimming opportunities, fish kills from die-off of large unmanaged blooms, additional water treatment costs, and poor aesthetic conditions. These benefits are more likely if the water is treated immediately before blooms occur. Some algaecides, such as hydrogen peroxide-based products, break down into benign compounds and may break down toxins produced in some blue green algae (cyanobacteria) blooms.

   Copper -based algaecides may impact the benthic organisms in lakes where these have been applied. The use of algaecides while a bloom peaks can also create oxygen deficits and may release algal toxins that are otherwise bound within algae cells which are more likely to be controlled through conventional or expanded water treatment techniques. In addition, toxins in the absence of algae cells can leave swimmers vulnerable to toxin exposure in water recently cleared of these cells. Therefore, the timing and use of algaecides in Conesus Lake would need to be very closely evaluated and approval by DEC. Perhaps most importantly, the use of algaecides will not result in the attainment of the required phosphorous targets (and therefore are unlikely to result in long-term reductions in algae growth).

2. **Nutrient Inactivation**. Nutrient precipitation and inactivation is a common lake management technique in other states in which a chemical agent, such as alum (aluminum sulfate), is used to remove phosphorus from the water column and prevent sediment release

of additional phosphorus. Nutrient inactivation works by sealing the bottom sediments to prevent the release of phosphorous to the over lying water with low oxygen concentrations. Alum may be less toxic than algaecides in many instances, less expensive than dredging, and aluminum toxicity is unlikely given the high alkalinity of Conesus Lake (and can be further prevented with the use of buffered alum). If successful, alum may reduce migration of nutrients from bottom sediments into the lake, providing a long-term reduction in algae growth.

To employ this option, it is advisable to check with DEC for any necessary approval.

DEC and DOH should be consulted prior to consideration of any chemical treatment, issued by DEC Region 8 staff and reviewed by both DEC and DOH

7.2 Follow-up Monitoring:

Annual assessment of BMP efforts is accomplished in the Conesus Lake Watershed by use of targeted monitoring to determine the effectiveness of the nutrient reduction efforts associated with this TMDL. Sampling is regularly coordinated by the County and Watershed Council.

Conesus Lake has been added to the New York Citizens Statewide Lake Assessment Program (CSLAP) in 2017, and DEC is working toward a long-term CSLAP partnership between DEC, the New York State Federation of Lake Associations, and the Conesus Lake Association to facilitate biweekly monitoring on the lake each year. It is anticipated that this will help to support long-term evaluation of lake conditions and TMDL-related management actions. In addition, the DEC LCI monitoring may serve to document the lake improvement at it progresses to achieve targets intended to indicate it is no longer "impaired". LCI and CSLAP Samples will be analyzed for standard lake water quality indicators, with a focus on evaluating eutrophication status: total phosphorus, nitrogen (nitrate, ammonia, and total), chl-a, pH, conductivity, color, and calcium. Field measurements include water depth, water temperature, and Secchi disk transparency. The TMDL progress towards achieving algal growth targets may allow Conesus Lake to be deemed 'unimpaired'. This improvement would be validated through CSLAP, the LCI, and other monitoring programs.

8. PUBLIC PARTICIPATION:

Public participation helped inform the development of the Conesus Lake TMDL and has involved many steps with the DEC, Livingston County, and the Conesus Lake Watershed Council.

The public outreach efforts prior to the public notice of the draft Conesus Lake TMDL included:

- DEC Presentation of the TMDL concept and development at a public town meeting in December of 2014; and
- Public meeting in August of 2015 providing the initial modeling information and responding to input received from the public and other watershed stakeholders.

Both meetings were very well attended and provided valuable input into the drafting of the Conesus Lake TMDL.

Notice of availability of the Draft TMDL was made to local government representatives, interested parties and the public at large on January 16, 2019 via the Environmental Notice Bulletin. Comments were accepted until the close of business on February 19, 2019

During this public comment period there was a public meeting held in the Livonia Middle School auditorium on February 4, 2019 to discuss the TMDL and answer any questions from the public. The meeting was well attended, with 35 people attending and posing 20 questions to the DEC staff after a slide presentation. Only one commenter submitted written comments to waterlog@dec.ny.gov.

PUBLIC COMMENTS

Q1: The draft TMDL was developed using cherry picked data that are 12 -15 years old from the Brockport study. Conesus Lake is in worse shape now in 2019.

A1: The Conesus Lake TMDL analysis began in 2014. The TMDL was developed using a number of different data sets that are within 7 years of the initial TMDL work. DEC used all available data without cherry picking which data set to use. DEC used the Brockport study commissioned in 2013 to estimate the pollution load to Conesus Lake. The data used in the Brockport study are relatively recent to the study and not 15 years old. DEC then used additional water quality monitoring data in the Conesus Lake watershed between 2007 and 2011 to calibrate the pollution load model for a more accurate estimate. It has taken DEC a few years to finalize the TMDL. However, DEC is confident that the pollution load estimate and the recommended load reduction are still applicable such that actions recommended by the TMDL should restore the water quality of the Lake.

Q2: Internal loading vs watershed loading - the commenter felt that Internal Phosphorus Loading was overstated as a nutrient source and that Watershed Nutrient Loading was not adequately considered.

A2: We agree that the watershed currently contributes a significant amount of nutrients to the lake. However, over a period of many years this watershed loading has resulted in a large amount of phosphorus in the sediment which is now "internal loading". This material originally came from the watershed, accumulated in the lake, and is now the largest source of phosphorus loading. The Conesus Lake TMDL does recommend implementation measures to address both internal and watershed phosphorus loadings.

Q3: Health problem underestimated: The commenter cited an example of a person in the hospital they believed to have been from HABs exposure, and of dogs either becoming ill or dying as a result of HABS exposure.

A3: DEC checked with the local health department. The Livingston County Department of Health could not confirm HAB exposure causing human illness, pet death, or pet illness in the Conesus Lake watershed in 2018.

9. REFERENCES:

40 CFR Part 130 Water Quality Planning and Management

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APPENDIX A. CE-QUAL-W2 Model Setup and Calibration for Conesus Lake

Prepared by The Cadmus Group, Inc. for U.S. Environmental Protection Agency Region 2

April 2016

Introduction: This Appendix describes the setup and calibration of a CE-QUAL-W2 hydrodynamic and water quality model for Conesus Lake in Livingston County, New York. The CE-QUAL-W2 lake model was developed by The Cadmus Group, Inc., and Dr. Scott Wells and Dr. Chris Berger of Wells and Associates. The model was used to support analysis of a phosphorus Total Maximum Daily Load (TMDL) for Conesus Lake.

Description of CE-QUAL-W2

CE-QUAL-W2 is a public domain two-dimensional (longitudinal and vertical), time-variable hydrodynamic and water quality model (Cole and Wells 2015). The model assumes lateral homogeneity within a waterbody and is therefore ideally suited for long and narrow waterbodies such as rivers or narrow lakes. CE-QUAL-W2 is capable of predicting water surface elevations, velocities, temperature, and several water quality constituents. The model represents a waterbody using multiple longitudinal segments and multiple vertical layers within each segment. Typical model longitudinal resolution is between 100 to 1000 meters and vertical resolution is typically between 0.5 and 2 meters. The model was originally developed by the US Army Corps of Engineers and has been maintained by Dr. Scott Wells of Portland State University in recent years. The user manual and documentation can be found at http://www.cee.pdx.edu/w2.

Model Setup

Overview of Model Setup and Data Requirements

Steps for setting up a CE-QUAL-W2 model include horizontal and vertical segmentation of the lake, defining segment morphology, preparing weather time series inputs, preparing inflow and outflow time series data, selecting water quality constituents to model, and selecting initial parameter values. Data required to setup a CE-QUAL-W2 model are summarized in **Table 3**.

Table 3: Data needs for CE-QUAL-W2 lake modeling.

Data Type	Purpose
Bathymetric map of lake	Define dimensions of model segments and layers
Hourly or daily inflow flow rates, water temperatures, and concentrations of water quality constituents for all inflows (tributaries, direct drainage, point sources, etc.)	Define upstream boundary conditions
Hourly or daily outflow flow rates and locations of all outflows (outlets, withdrawals, etc.)	Define downstream boundary conditions.
Outlet structure details for spillways, including rating curves for the spillways	The centerline elevation of outlets and weir crest elevations are of importance in predicting vertical stratification in a lake and outflow during spill events
Hourly meteorological records (air temperature, dew point temperature, wind speed, wind direction, solar radiation, and cloud cover)	Define meteorological forcings
Water surface elevation records	Model calibration
In-lake water temperature and water quality records	Model calibration
Measured kinetic or estimated model coefficients from field data (if available)	Defining initial parameter values

Model Bathymetry

CE-QUAL-W2 represents a lake as a two-dimensional grid consisting of multiple longitudinal segments and multiple vertical layers within each segment. The model grid for Conesus Lake was developed using geospatial bathymetric data for the lake (based on a 2009 bathymetric survey; acquired from the Livingston County Planning Department) and Watershed Modeling System (WMS) software. The model grid was configured with segment lengths of approximately 200 meters and 20 active vertical layers (**Figure 1**). Characteristics of the model grid for Conesus Lake are listed **Table 4**.

Table 4. CE-QUAL-W2 model grid characteristics for Conesus Lake.

Lake	No. of Longitudinal Segments	Longitudinal Segment Length (meters)	Total Length (meters)	No. of Vertical Layers	Vertical Layer Depth (meters)
Conesus	52 (50 active)	151-270	12,230	22 (20 active)	1.07

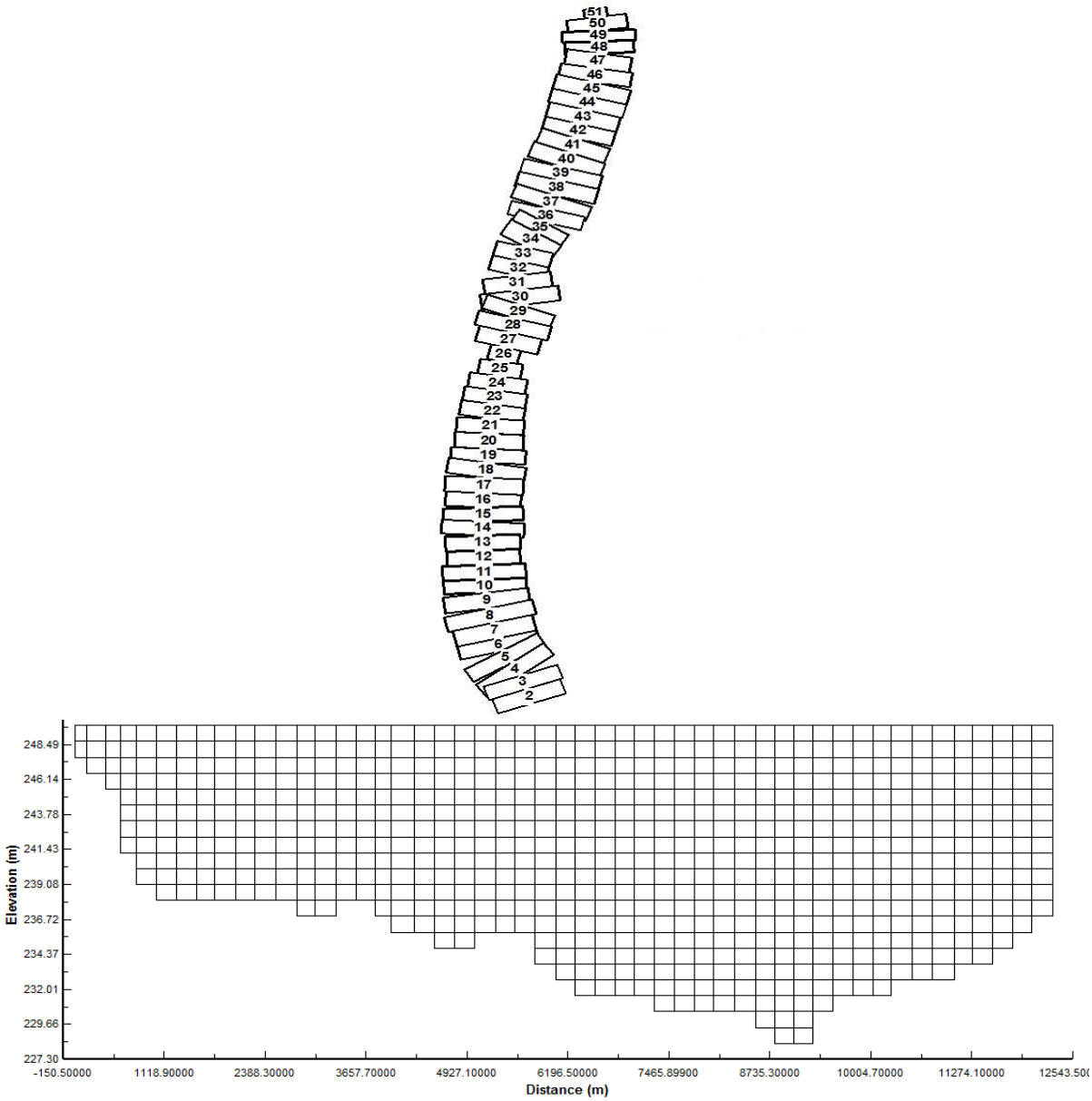


Figure 1. Top and side view of the Conesus Lake CE-QUAL-W2 model grid.

Meteorological Data

CE-QUAL-W2 requires hourly records of the following meteorological variables: air temperature, dew point temperature, wind speed and direction, and cloud cover. Records of these variables were obtained from the National Climate Data Center (NCDC) website for Dansville Municipal Airport weather station (**Table 5**). The Dansville Municipal Airport station is located approximately 10.5 miles from Conesus Lake (**Table 5**). Gaps in the meteorological time series were filled as the average of the preceding and next available record with data.

Cloud cover ratings in the NCDC dataset were reported on a scale of zero (no clouds) to four (overcast), while CE-QUAL-W2 requires cloud cover on a scale of zero (no clouds) to ten (overcast). NCDC cloud cover ratings were translated to a zero to ten scale for input to CE-QUAL-W2 using values listed in **Table 6**. The NCDC dataset also includes a cloud cover rating of five for surface-based obscurations, such as fog, that were assumed to correspond to full cloud cover for input to CE-QUAL-W2.

CE-QUAL-W2 also allows users to input precipitation records. Daily precipitation records from the Hemlock Lake weather station (**Table 5**) were acquired from the NCDC website and input to the Conesus Lake model.

Table 5. Meteorological station summary.

Station Name	Latitude	Longitude	Elevation (meters)
Dansville Municipal Airport	42.57083°	-77.71333°	208.8
Hemlock Lake	42.7743°	-77.6083°	274.9

Table 6. Conversion table used to translate NCDC cloud cover to CE-QUAL-W2 cloud cover.

NCDC Cloud Cover	NCDC Cloud Cover Description	CE-QUAL-W2 Cloud Cover
0	Clear	0
1	Few Clouds	1.9
2	Scattered Clouds	4.4
3	Broken Clouds	7.5
4	Overcast	10
5	Obscured	10

Water Quality Constituents

Water quality constituents selected for simulation in the CE-QUAL-W2 Conesus Lake model are:

- Inorganic Suspended Solids (1 group)
- Algae (2 groups)
- Epiphyton (1 group)
- Macrophytes (1 group)
- Zooplankton (1 group)

- Phosphate Phosphorus
- Ammonium Nitrogen
- Nitrate + Nitrite Nitrogen
- Labile Dissolved Organic Matter (LDOM)
- Refractory Dissolved Organic Matter (RDOM)
- Labile Particulate Organic Matter (LPOM)
- Refractory Particulate Organic Matter (RPOM)
- Labile Dissolved Organic Matter – Phosphorus (LDOM-P)
- Refractory Dissolved Organic Matter – Phosphorus (RDOM-P)
- Labile Particulate Organic Matter – Phosphorus (LPOM-P)
- Refractory Particulate Organic Matter – Phosphorus (RPOM-P)
- Labile Dissolved Organic Matter – Nitrogen (LDOM-N)
- Refractory Dissolved Organic Matter – Nitrogen (RDOM-N)
- Labile Particulate Organic Matter – Nitrogen (LPOM-N)
- Refractory Particulate Organic Matter – Nitrogen (RPOM-N)
- Dissolved Organic Carbon (DOC)
- Total Organic Carbon (TOC)
- Total Nitrogen (TN)
- Total Phosphorus (TP)
- Chlorophyll-a

Bottom Sediments

CE-QUAL-W2 offers two methods to simulate the effects of bottom sediment on water column nutrient and dissolved oxygen concentrations. The first method uses a constant zero-order release and demand approach to simulate organic sediment decay under anaerobic conditions. Nutrient release from bottom sediment does not occur from the zero-order function when dissolved oxygen concentrations in the overlying water column are above a specified minimum value. When anoxic conditions develop, nutrient release from the zero-order process are a function of user-supplied sediment oxygen demand (grams of oxygen per square meter per day), anoxic release rates for nutrients, and water temperature.

The second method uses a sediment compartment to track accumulation of organic bottom sediments and allow their decay under oxic conditions. The first-order sediment compartment is not a true sediment diagenesis compartment as it does not keep track of organic nutrient delivery to the sediments, their decay, and subsequent release back into the water column during hypoxic/anoxic conditions. However, it does keep track of organic matter delivery to the sediments via particulate organic matter and dead algal cells, and the subsequent water column oxygen demand that is exerted. Nutrient releases and oxygen demand are dependent on sediment accumulation, a first-order process. There is no release of nutrients when the overlying water column is anoxic since the first-order sediment compartment represents labile, oxic decay of organic sediment.

A description of zero-order and first-order sediment decay parameters is provided in Table 8. Both methods were implemented in the Conesus Lake model.

Table 7. Description of bottom sediment parameters in the CE-QUAL-W2 model.

Parameter	Applies To	Description
Sediment oxygen demand, grams per square meter per day (SOD)	Zero-Order Decay	Sediment oxygen demand for the zero-order sediment compartment.
Sediment release rate of phosphorus, as a fraction of SOD (PO4R)	Zero-Order Decay	Release rate of phosphorus from the zero-order sediment compartment under anaerobic conditions, specified as a fraction of sediment oxygen demand.
Lower temperature for sediment decay, degrees Celsius (SODT1)	Zero-Order & First-Order Decay	Lower temperature for decay rate multiplier curve.
Upper temperature for sediment decay, degrees Celsius (SODT2)	Zero-Order & First-Order Decay	Upper temperature for decay rate multiplier curve.
Fraction of SOD or sediment decay rate at lower temperature (SODK1)	Zero-Order & First-Order Decay	Decay rate multiplier at lower temperature.
Fraction of SOD or sediment decay rate at upper temperature (SODK2)	Zero-Order & First-Order Decay	Decay rate multiplier at upper temperature.
Initial sediment concentration, grams per square meter	First-Order Decay	Initial concentration of organic sediment in 1st-order bottom compartment. Determines initial concentrations of N, P, and C in the 1st-order sediment compartment using stoichiometric coefficients.
Sediment settling rate, per day (SEDS)	First-Order Decay	Settling rate of organic sediment from the water column to the 1st-order sediment compartment.
Sediment decay rate, per day (SEDK)	First-Order Decay	Maximum decay rate of organic sediment in the 1st-order sediment compartment.
Sediment burial rate, per day (SEDBR)	First-Order Decay	Burial rate of organic sediment in the 1st-order sediment compartment. Organic sediment is not available for decay after burial.

Lake Inflows

CE-QUAL-W2 allows three types of lake inflows to be defined:

1. Branch inflow – Inflow to the most upstream model segment, such as inflow from an inlet stream or river;

2. Tributary inflow – Inflow to any model segment, such as inflow from a tributary stream to the middle/lower portion of a lake;

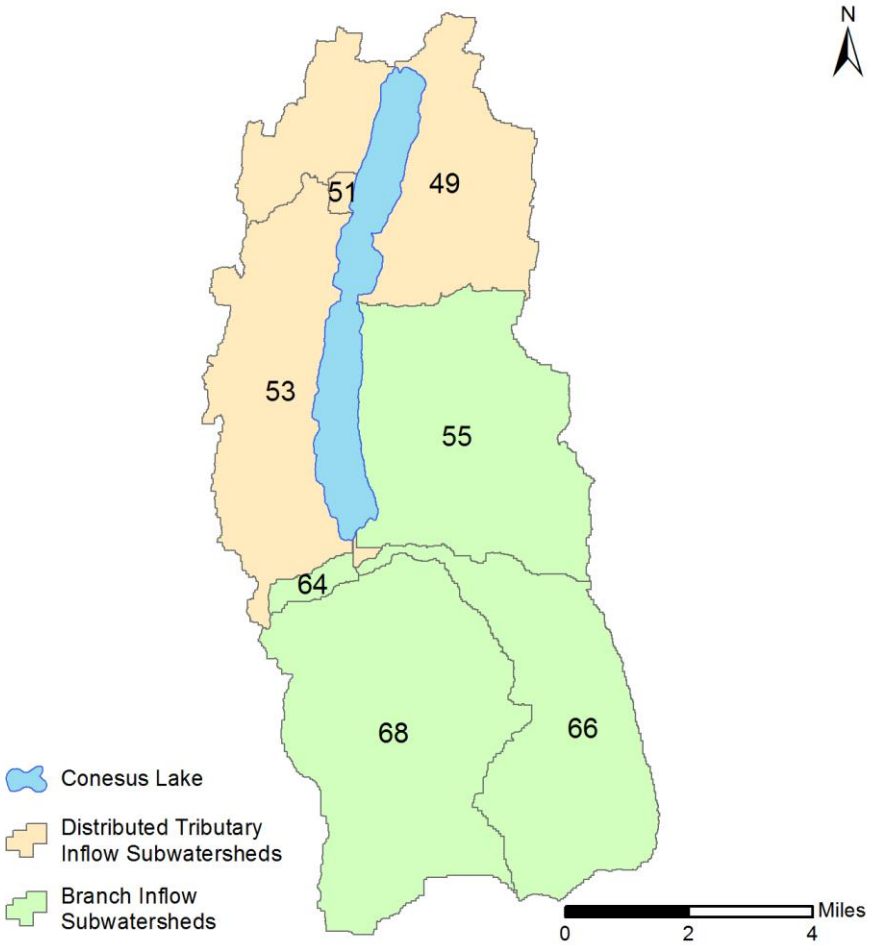
3. Distributed tributary inflow – Inflow that is distributed between all model segments, such as direct drainage from nearshore areas.

Rates of watershed inflow to Conesus Lake were estimated using the Soil and Water Assessment Tool (SWAT). SWAT is a continuous, process-based watershed model that simulates runoff using information on watershed characteristics (land use, soils, slope, etc.) and weather records (Neitsch et al. 2011). SWAT models for the entire Genesee River watershed (including the Conesus Lake watershed) were developed as part of a separate effort by researchers at the State University of New York at Brockport (SUNY Brockport) for the US Department of Agriculture. A summary of the Genesee River watershed SWAT modeling effort is provided in Makarewicz et al. (2013a, b). The project created multiple SWAT models that together cover the Genesee River watershed. The Conesus Lake watershed is within the area covered by the "Mainstem Genesee River" SWAT model, which includes the lower Genesee River and its smaller tributaries.

SWAT model files for the Mainstem Genesee River model were acquired from SUNY Brockport for use in the Conesus Lake modeling effort. Minor revisions were applied to the model after acquisition and review of model files. The simulation period was extended to cover January 1, 2006 through December 31, 2014. This required extending daily precipitation and air temperature records for weather stations in each model to include the years 2013 and 2014 using weather data from the NCDC website. The first year of the SWAT simulation period (2006) was considered a "warm-up" period for initial conditions to stabilize and was input to the CE-QUAL-W2 lake model.

Output from the Mainstem Genesee SWAT model was used to derive daily branch inflow and distributed tributary inflow rates to Conesus Lake over the period January 1, 2007 through December 31, 2014. Inflow rates were extracted from daily flow predictions in the SWAT Reach Output file. Branch inflow consisted of predictions for SWAT model reach 64 (which drains model subwatersheds 64, 68, and 66) and for SWAT model subwatershed 55 (**Figure 2**). Distributed inflow consisted of predictions of incremental flow (i.e., excluding flow entering from upstream reaches) from SWAT subwatersheds 49, 51, 53, and 62 (**Figure 2**).

Figure 2. Mainstem Genesee SWAT model subwatersheds used to define branch and tributary inflows for the Conesus Lake CE-QUAL-W2 model.



Lake Outflows

Daily outflow rates from Conesus Lake were derived from US Geological Survey (USGS) daily mean streamflow records in Conesus Creek measured 1.5 miles downstream of the Conesus Lake outlet (USGS ID 04227995; Conesus Creek near Lakeville, NY). Because Conesus Creek receives watershed runoff and effluent flow from the Honeoye Creek Wastewater Treatment Plant (WWTP) between the Conesus Lake outlet and the USGS stream gage, streamflow records were adjusted for input to CE-QUAL-W2. Daily streamflow records were adjusted by subtracting SWAT model estimates of flow contributed by subwatershed 47 in the Mainstem Genesee SWAT model. Subwatershed 47 lies between the Conesus Lake outlet and the Conesus Creek USGS stream gage.

Conesus Creek daily streamflow records were also adjusted to subtract effluent flow from the Honeoye WWTP. The Honeoye WWTP effluent flow rate was assumed to equal 0.02 cubic meters per second, based on effluent flow monitoring reported in Makarewicz et al. (2013b). A final adjustment was made to maintain a minimum flow of 10 cubic feet per second, the minimum Conesus Lake outflow specified in reservoir release rules (US Army Corps of Engineers, 2010).

An outlet weir was included in the Conesus Lake CE-QUAL-W2 model with the following stage-discharge equation:

$$Q = \alpha H^{\beta}$$

where α is an empirical parameter that was adjusted during model calibration, β is an empirical parameter assumed equal to 1.5, H is head in meters (difference between the water surface elevation and invert elevation downstream of the outlet), and Q is flow rate in cubic meters per second. The invert of Conesus Creek at the lake outlet was estimated to be 248.57 meters (US Army Corps of Engineers, 2010).

Withdrawals

Conesus Lake serves as a municipal water supply source. Municipal water withdrawals by the Village of Geneseo and the Village of Avon are simulated in the Conesus Lake CE-QUAL-W2 model. Monthly withdrawal rates for the Village of Geneseo withdrawal were set to values provided by the New York State Department of Environmental Conservation (NYSDEC) for the period January 2000 through December 2014. Geneseo withdrawal rates varied between 0.9259 million gallons per day and 1.5491 million gallons per day. A constant withdrawal rate for the Village of Avon was estimated at 0.8 million gallons per day by NYSDEC. Spatial specifications of Conesus Lake withdrawals (model segment and depth) were based on information provided by NYSDEC.

Watershed Water Quality Loadings

Daily time series' of water quality constituent concentrations are needed for branch, tributary, and distributed tributary inflows in CE-QUAL-W2 models. Concentrations of most constituents were derived using the Mainstem Genesee SWAT model described in Section A8. SWAT-predicted daily loads reported in reach output files were divided by mean daily flows to estimate daily concentrations in Conesus Lake branch and distributed tributary inflows. Below is a summary of methods applied to derive inflow concentrations for CE-QUAL-W2 state variables.

- Phosphate Phosphorus (PO4-P) – Set to SWAT mineral phosphorus (MINP);
- Nitrate + Nitrite Nitrogen (NOxN) – Calculated as SWAT nitrate (NO3) plus nitrite (NO2);
- Labile Dissolved Organic Phosphorus (LDOM-P), Refractory Dissolved Organic Phosphorus (RDOM-P), Labile Particulate Organic Phosphorus (LPOM-P), and Refractory Particulate Organic Phosphorus (RDOM-P) – Each calculated as SWAT organic phosphorus (ORGP) divided by 4;
- Labile Dissolved Organic Nitrogen (LDOM-N), Refractory Dissolved Organic Phosphorus (RDOM-N), Labile Particulate Organic Phosphorus (LPOM-N), Refractory Particulate Organic Nitrogen (RDOM-N) – Each calculated as SWAT organic nitrogen (ORGN) divided by 4;
- Labile Dissolved Organic Matter (LDOM), Refractory Dissolved Organic Matter (RDOM), Labile Particulate Organic Matter (LPOM), and Refractory Particulate Organic Matter (RPOM) – Each calculated as total organic matter divided by 4. Total organic matter was estimated using SWAT organic phosphorus (ORGN), organic nitrogen (ORGP), and methods described in Debele et al. (2007).
- Inorganic Suspended Solids (ISS) – Calculated as SWAT sediment (SED) minus labile and refractory particulate organic matter (LPOM + RPOM);
- Ammonium Nitrogen (NH4N) – Set to 0.1 milligrams per liter;
- Algae – Set to 0.02 milligrams per liter;

- Dissolved Oxygen (DO) – Calculated from average daily air temperature at the Hemlock weather station and equation 1:1.3.13 in SWAT Theoretical Documentation (Neitsch et al. 2011);
- Water Temperature – Calculated from daily water temperature estimates and equation 3 in Debele et al. (2007).

During water quality calibration of the Conesus Lake CE-QUAL-W2 model, it became apparent that the branch inflow nitrate concentration derived from SWAT were over-estimated and that an adjustment was needed to reduce their magnitude. The decision to adjust branch inflow nitrate concentrations was based on:

(1) Calibration methods used for the Mainstem Genesee SWAT model. The Mainstem Genesee SWAT model was calibrated using observations of streamflow, phosphorus, and sediment from several sampling sites in the Genesee River watershed (see Makerewicz et al. 2013). None of these sites are located in the Conesus Lake watershed; they are all downstream of Conesus Lake or on other Genesee River tributaries. Furthermore, nitrogen loading and routing parameters in the Mainstem Genesee SWAT model were left at default values. Since the SWAT model was not calibrated to observed stream nitrogen data from the Conesus Lake watershed, the CE-QUAL-W2 inputs derived from SWAT predictions were considered initial estimates that could be adjusted if necessary.

(2) Comparison of observed stream nitrate concentrations in the Conesus Lake watershed to SWAT predictions. Nitrate concentrations for streams in the Conesus Lake watershed are reported in Makarewicz and Lewis (2010), Makarewicz et al. (2011; 2012b) for the years 2003 through 2011. The dataset includes samples collected from three streams that drain to Conesus Lake at the southern (upstream) end of the lake: North McMillan Creek, South McMillan Creek, and the Conesus Lake Inlet. Nitrate sample data from these streams are consistently lower than the SWAT-derived concentrations for branch inflow. The mean branch inflow nitrate concentration derived from SWAT from 2006 through 2014 is 18 milligrams N per liter; while the observed mean nitrate concentration in North McMillan Creek over 2003 through 2010 is 0.168 milligrams N per liter, a difference of two orders of magnitude. This discrepancy indicated that SWAT-derived nitrate estimates should be reduced for input to CE-QUAL-W2.

(3) Comparison of observed Conesus Lake nitrogen concentrations to CE-QUAL-W2 predictions. Initial runs of the Conesus Lake CE-QUAL-W2 model used un-adjusted branch inflow nitrate concentrations. These model runs consistently predicted total nitrogen concentrations in Conesus Lake that were much greater than observed concentrations.

Based on the above findings, the branch inflow nitrate concentration time series was reduced by a factor of 0.0094 for input to the Conesus Lake CE-QUAL-W2 model. This adjustment factor is equal to the ratio of the mean 2006 through 2014 SWAT-derived nitrate concentration (18 milligrams N per liter) to the 2003 through 2010 mean nitrate concentration observed in North McMillan Creek (0.168 mg N per liter).

Atmospheric Water Quality Loadings

Atmospheric loading of water quality constituents to the surface of a lake are input in CE-QUAL-W2 as constituent concentrations in precipitation. The Conesus Lake CE-QUAL-W2 was setup to simulate atmospheric loading of ammonium nitrogen, nitrate plus nitrate nitrogen, and phosphate phosphorus.

Concentrations of ammonium nitrogen and nitrate plus nitrate nitrogen in precipitation were set to mean annual values for 2007 through 2014 reported for a precipitation chemistry monitoring site in the town of Alfred in Allegheny County, New York (**Table 8**). The Alfred monitoring site is part of the National Atmospheric Deposition Program (NADP) Network National Trends Network (station ID NY01; latitude 42.2276 longitude -77.8016). Mean annual ammonium nitrogen and nitrate nitrogen concentrations for the Alfred site were acquired from the NADP website.

Table 8. Mean annual concentrations of ammonium nitrogen (NH4-N) and nitrate nitrogen (NO3-N) measured in precipitation at the Alfred monitoring site.

Year	NH4-N (mg/L)	NO3-N (mg/L)
2007	0.204	0.885
2008	0.224	0.878
2009	0.186	0.748
2010	0.201	0.732
2011	0.244	0.881
2012	0.234	0.857
2013	0.255	0.874
2014	0.253	0.814

The concentration of phosphate phosphorus in precipitation was estimated from an aerial loading rate reported in USGS (2005), based on precipitation chemistry samples collected at Mendon Ponds County Park in Monroe County, New York during the years 2000 through 2002. The average atmospheric aerial loading rate of phosphate phosphorus over this period is 233 pounds per square mile. This values was converted to a phosphate phosphorus concentration of 0.079 milligrams per liter using the Conesus Lake surface area and precipitation totals.

Sediment Temperature

Bottom sediment temperature was set to the mean annual air temperature from the Dansville Municipal Airport weather station (9.08 degrees Celsius) in the Conesus Lake CE-QUAL-W2 model. This is the approach recommended in the CE-QUAL-W2 user manual (Cole and Wells 2015).

Initial Model Parameter Values

Initial values of remaining hydrodynamic and water quality parameters were set to default values specified in the CE-QUAL-W2 user manual (Cole and Wells 2015).

Simulation Period

The simulation period for the Conesus Lake CE-QUAL-W2 is January 1, 2007 through December 31, 2014.

Model Calibration

Model calibration consisted of evaluating model hydrodynamics (water level and flow), water temperatures, and water quality constituent concentrations using in-lake observations and adjusting model parameter values and inputs so that simulated data better matched observed data.

Water Surface Level

Daily observations of water surface elevations were available for a mid-lake monitoring site in Conesus Lake (USGS gage 04227980; Conesus Lake near Lakeville, NY). Calibration of water surface levels consisted of comparing predictions from the CE-QUAL-W2 model to observed water levels and adjusting distributed tributary inflows to balance inflows and outflows. This was an iterative process, where water balance flows were manually adjusted until predicted water levels matched observations.

The mean water balance flow for the Conesus Lake model averaged -0.001 cubic meters per second. Error statistics for water level were a mean error of 0.009 meters and a mean absolute error of 0.031 meters. **Figure 3** illustrates calibrated water surface levels in the Conesus Lake model.

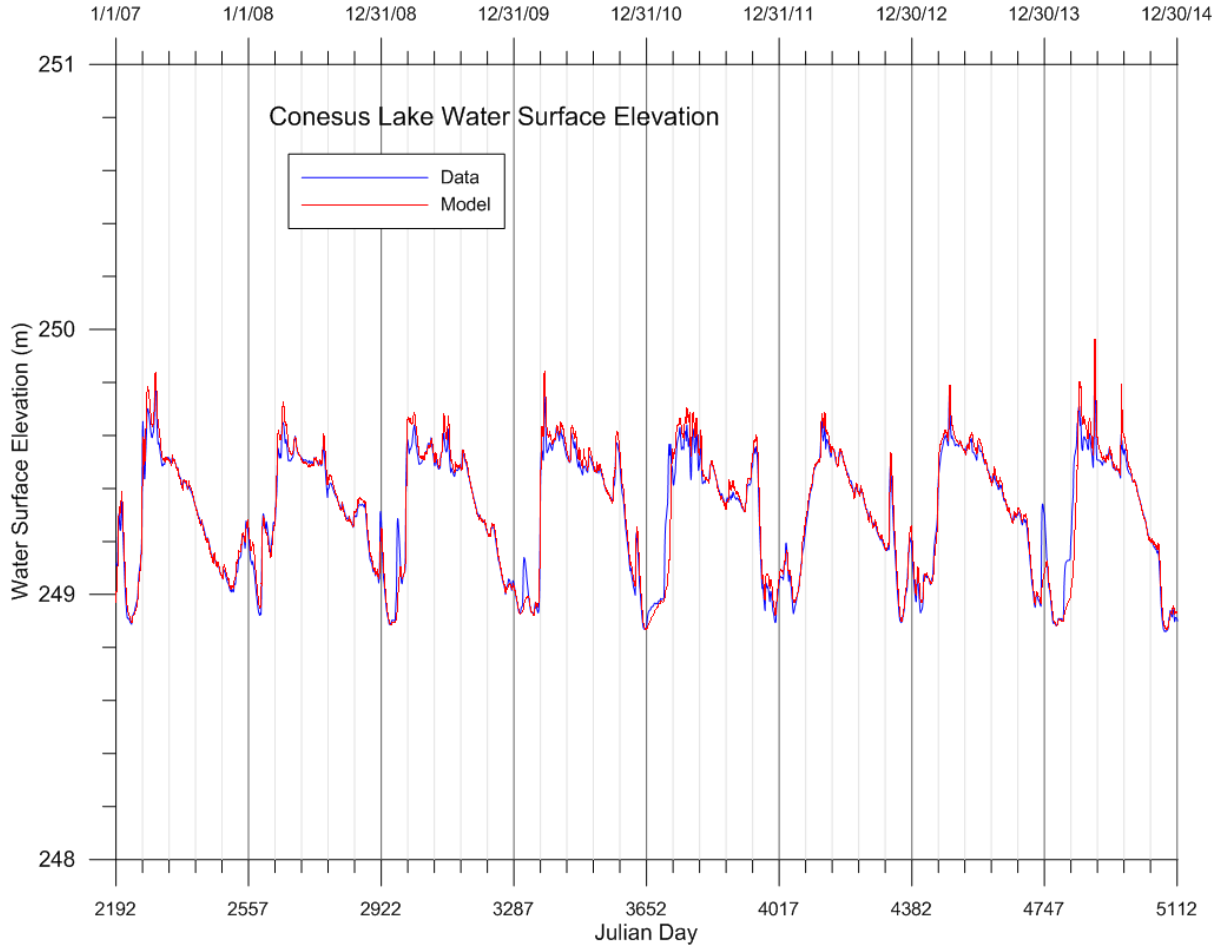


Figure 3. Predicted (red) and observed (blue) Conesus Lake water surface level.

Temperature and Water Quality Calibration

Sources of observed data for temperature and water quality calibration included in-lake monitoring data for the years 2009, 2012, and 2014 reported in Makarewicz and Lewis (2009), Makarewicz et al. (2012a), and Makarewicz and Lewis (2014). These documents report water quality sample data from the deepest point in the lake's south basin (latitude 42.75473 longitude -77.71535; model segment 15) and the deepest point in the north basin (latitude 42.77973 longitude -77.7178; model segment 26). Samples of temperature, dissolved oxygen, soluble reactive phosphorus, total phosphorus, nitrate-nitrite nitrogen, total nitrogen, and chlorophyll-a were available for calibration.

Calibration of water quality in the Conesus Lake CE-QUAL-W2 model focused on adjusting parameters related to zero-order and first-order sediment decay, algal growth, and algal nutrient stoichiometry. Calibration was challenging because of uncertainty regarding the accuracy of input data on meteorological conditions and inflow water quantity/quality. Meteorological inputs were based on conditions at a weather station located 10.5 miles from Conesus Lake (see Section A5) rather than on-site meteorological records. The inflow water volumes and constituent concentrations were derived from a SWAT watershed model (see Section A11) rather than from field monitoring. We strived to match predicted water quality dynamics over the long-term to trends in field monitoring data. We did not undertake a major effort to adjust wind sheltering, meteorological records, or other inputs to further reduce differences between model predictions and monitoring data (other than nitrate concentrations in branch inflow; see Section A3.9). This provides a model that is not over-fit to observed data and is better-suited for simulating water quality management strategies.

Zero-order sediment oxygen demand (SOD) was calibrated to a value of 2.0 grams O_2 per square meter per day. Zero-order SOD represents the oxygen demand exerted by legacy organic matter deposited to the lake bottom prior to the simulation period. Typical values for SOD for eutrophic systems range from 1.0 to 5.0 grams O_2 per square meter per day (Cole and Wells 2015). Hypolimnetic phosphorus concentrations were sensitive to the zero-order sediment release rate of phosphorus, calibrated to a value of 0.001. Since the zero-order sediment release rate of phosphorus is specified as a fraction of SOD, the calibrated value of 0.001 equates to an anaerobic phosphorus release rate of 2 milligrams P per square meter per day. This is on the order of the anaerobic release rate of 4 milligrams P per square meter per day derived from laboratory analysis of Conesus Lake sediment cores (Ecologic 2004). Anoxic phosphorus release in Conesus Lake has also been estimated as 8.7 milligrams P per square meter per day (Makarewicz and Lewis 2009). This estimate was derived from monitoring of phosphorus concentrations in the hypolimnion of Conesus Lake during May and August of 2009 and is not directly comparable to the modeled release rate because of two key assumptions:

1. The difference between May and August hypolimnion phosphorus concentrations is entirely due to phosphorus release from sediment. Differences in external loading from the watershed between the two time periods are not considered;

2. Phosphorus samples collected from the monitoring site at the deepest point of the lake are representative of the entire horizontal area of the lake.

The first-order sediment compartment was used to model oxic decay of organic matter deposited to the lake bottom during the simulation period. The first-order sediment compartment is not a true sediment diagenesis compartment as it does not keep track of organic nutrient delivery to the sediments, their decay, and subsequent release back into the water column during hypoxic/anoxic conditions. However, it does keep track of organic matter delivery to the sediments via particulate organic matter and dead algal cells, and the subsequent demand on water column oxygen that is exerted. Calibration of first-order sediment compartment parameters focused on the first-order sediment decay rate (calibrated to 0.06 per day) and the sediment burial rate (calibrated to 0.01 per day).

The growth of algae in Conesus Lake was sensitive to values of algal growth rates, temperature coefficients, and stoichiometric fractions for nitrogen (the ratio between nitrogen in algal biomass and

total algal biomass) and phosphorus (the ratio between phosphorus in algal biomass and total algal biomass). The stoichiometric fraction for phosphorus was calibrated to 0.001 for both algae groups and the stoichiometric fraction for nitrogen fractions was calibrated to 0.1 for both algae groups. Calibrated values indicated that Conesus Lake is a system in which algae growth is phosphorus limited (discussed further the Discussion of Model Results below).

Table 9 lists performance statistics for the calibrated Conesus Lake CE-QUAL-W2 model. Plots of observed versus predicted concentrations of phosphorus, nitrogen, and chlorophyll-a are provided in **Figure 4** through **Figure 6**. General guidelines for acceptable performance of CE-QUAL-W2 models include mean absolute errors (MAE) of less than 1 degree Celsius for temperature and less than 1.0 mg/l for dissolved oxygen. For the Conesus Lake model, the temperature MAE (0.882) is below the guideline and the dissolved oxygen MAE (1.032) is slightly above the guideline. A calibration guideline for chlorophyll-a is MAE less than 0.2 times the range of observed concentrations. For Conesus Lake, the chlorophyll-a MAE is approximately 0.17 times the range of observations.

Table 9. Conesus Lake water quality error statistics.

Constituent	# of Profiles	# of Samples	Mean Error	Mean Absolute Error	Root Mean Square Error
Temperature, degrees Celsius	31	600	0.285	0.882	1.092
Dissolved Oxygen, mg/l	31	598	-0.069	1.032	1.472
Soluble Reactive Phosphorus, mg/l	31	121	0.024	0.062	0.078
Total Phosphorus, mg/l	31	121	0.015	0.069	0.086
Nitrite-Nitrate Nitrogen, mg/l	31	121	0.252	0.255	0.274
Total Kjeldahl Nitrogen, ,mg/l	14	42	0.042	0.346	0.425
Total Nitrogen, mg/l	17	79	0.363	0.385	0.445
Chlorophyll a, μg/l	45	614	-1.302	3.924	4.543
Zooplankton, mg/l	24	24	0.046	0.094	0.094

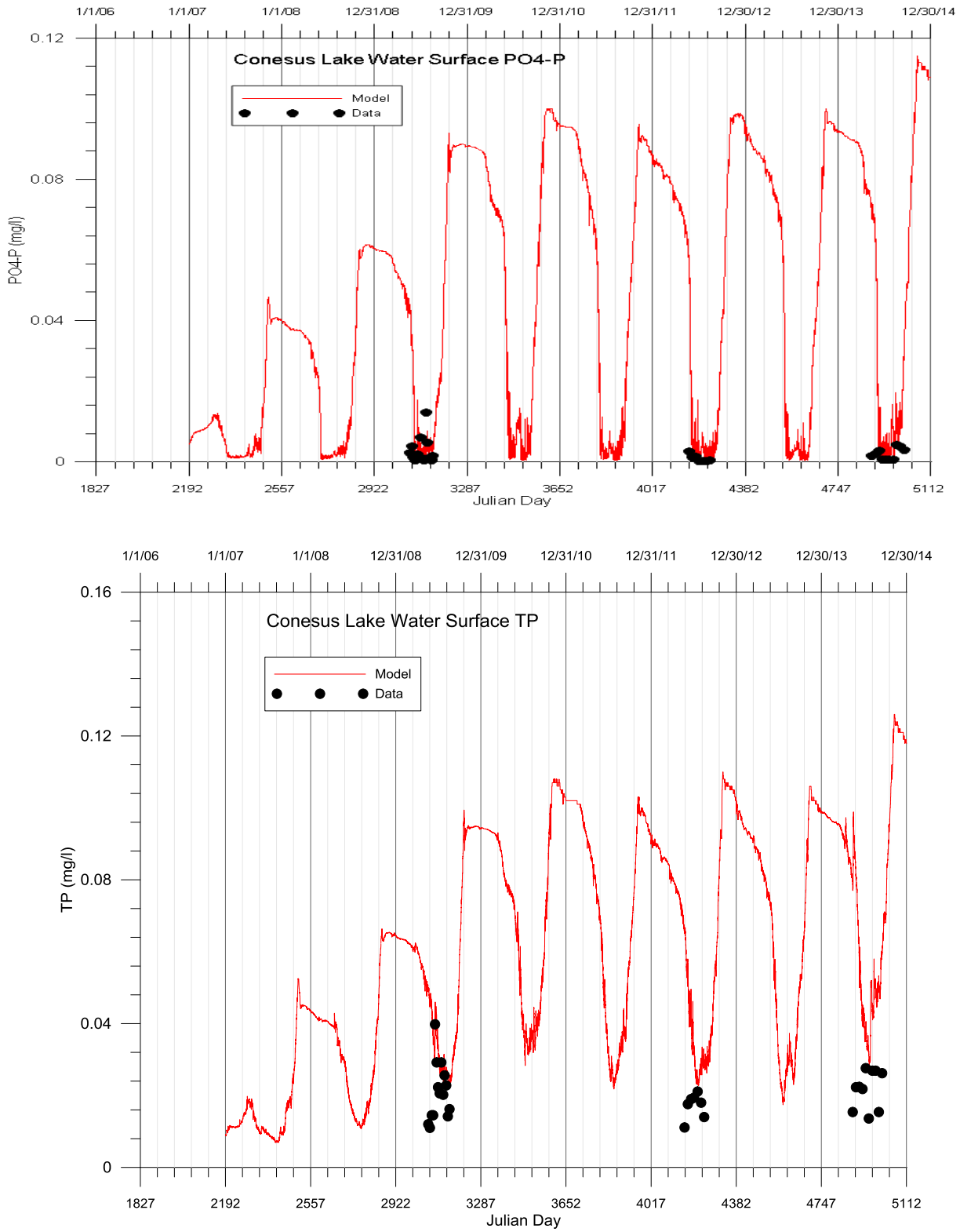


Figure 4. Predicted (red line) and observed (black points) concentrations of phosphate phosphorus (PO4-P; top) and total phosphorus (TP; bottom) at the surface of Conesus Lake at the south basin deepest point.

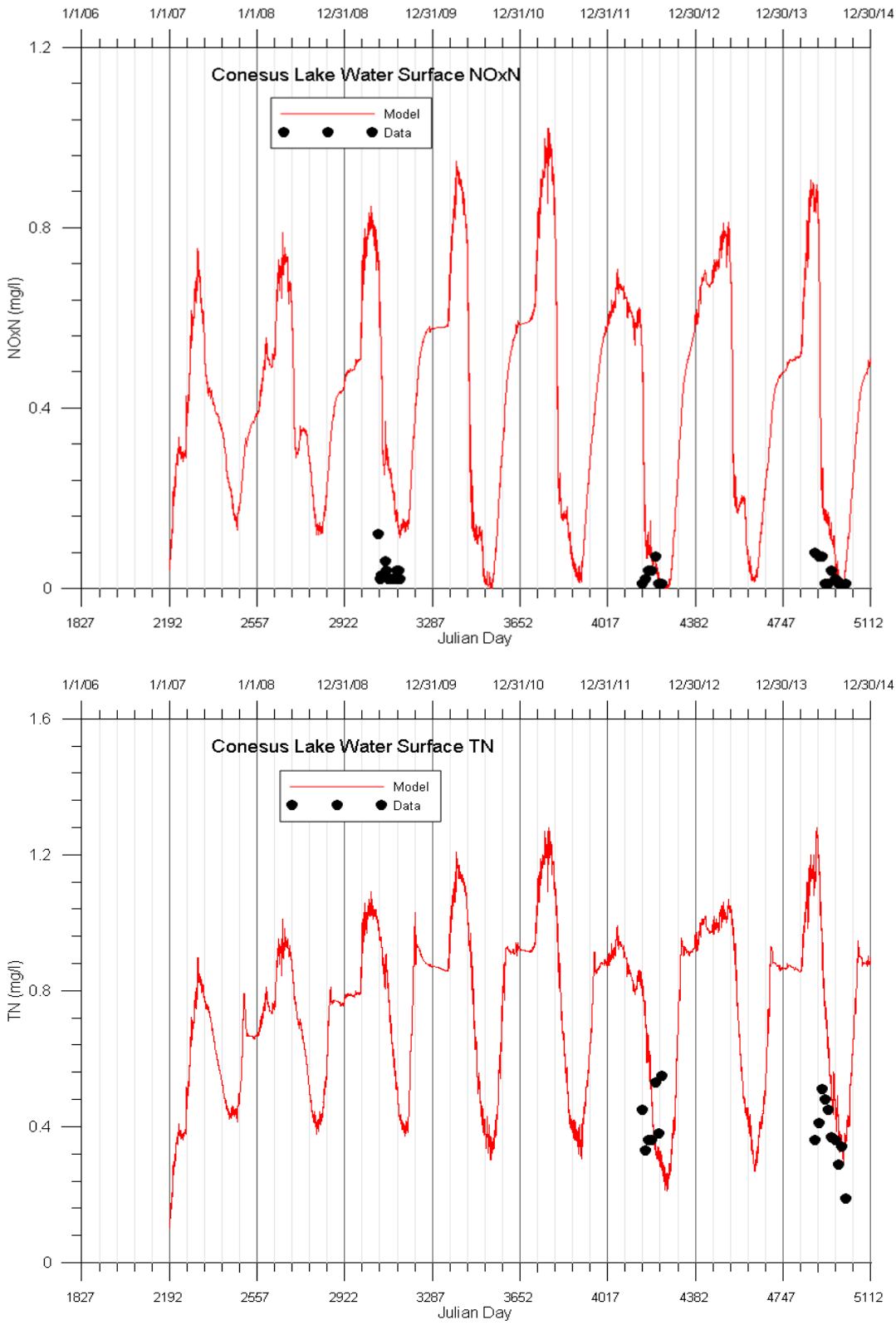


Figure 5. Predicted (red line) and observed (black points) concentrations of nitrate-nitrite nitrogen (NOxN; top) and total phosphorus (TN; bottom) at the surface of Conesus Lake at the south basin deepest point.

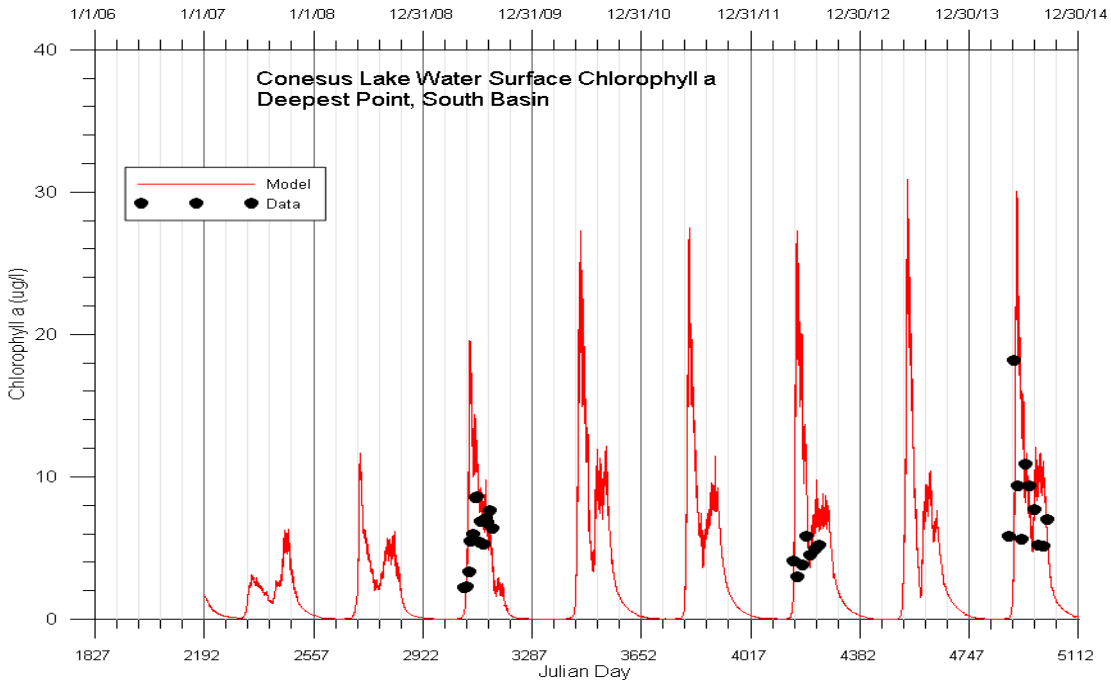


Figure 6. Predicted (red line**) and observed (**black points**) concentrations of chlorophyll-a at the surface of Conesus Lake at the north basin deepest point (**top**) and south basin deepest point (**bottom**).**

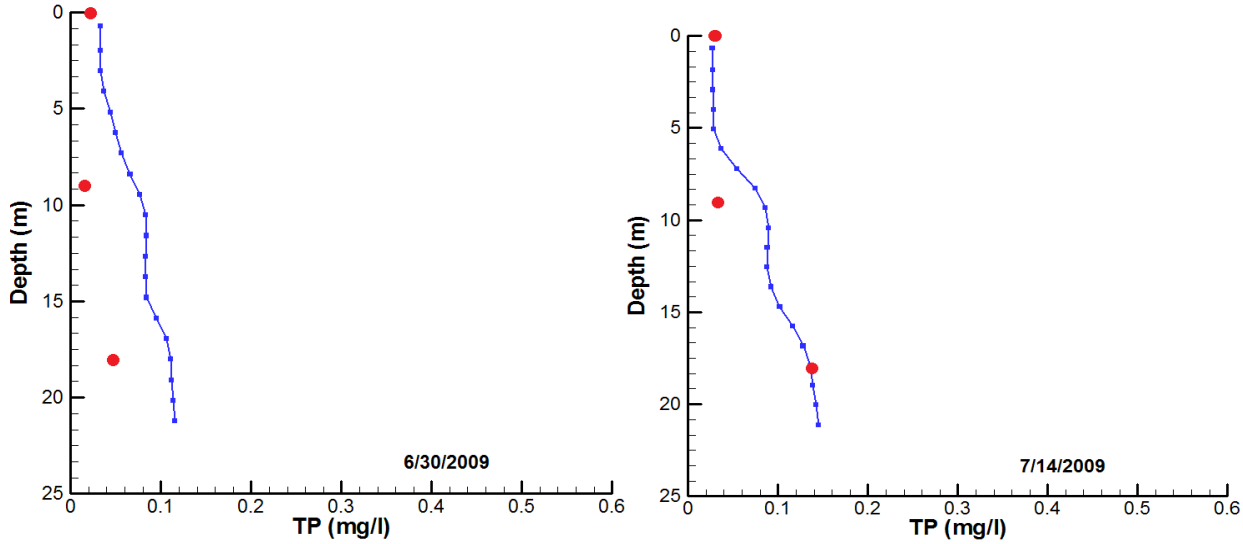


Figure 7. Predicted (blue line) and observed (red point) total phosphorus concentrations at the Conesus Lake south basin deepest point on 6/30/2009 (left) and 7/14/2009 (right).

Figure 7 illustrates predicted and observed total phosphorus concentrations at the south basin deepest point at two different times during the simulation period. These plots demonstrate our calibration approach and implications on model performance statistics. The 6/30/2009 plot shows that the model predicts a vertical phosphorus gradient (bottom concentrations greater than surface concentrations) that is stronger than the gradient in observed concentrations. Observations from 7/14/2009 show that the strong vertical gradient predicted by the model has developed in the lake. We attribute the error in 6/30/2009 prediction to meteorological and inflow input data. Further

adjustment of model parameters to achieve a better fit to 6/30/2009 observations would result in greater errors during other sample dates.

Table 10 lists sampled and modeled mean growing season (June through September) surface chlorophyll-a concentrations in Conesus Lake for 2009, 2012, and 2014 (years with monitoring data). One of the intended applications of the Conesus Lake CE-QUAL-W2 model is to assess mean epilimnion growing season chlorophyll-a concentrations under alternative nutrient loading scenarios. The ability of the model to recreate observed patterns in mean epilimnion growing season chlorophyll-a concentrations is therefore of interest for evaluating model performance. Modeled growing season chlorophyll-a concentrations average 7.3 micrograms per liter while sampled concentrations average 6.1 micrograms per liter, a difference of 1.2 micrograms per liter or 20% of the sampled mean. The frequency of sampling should be considered when evaluating modeled versus sampled concentrations. Chlorophyll-a was sampled 6 to 12 times per year in 2009, 2012 , and 2014, which may not be adequate for characterizing the growing season mean in years with high chlorophyll-a variability.

Table 10. Sampled and modeled mean growing season (June through September) chlorophyll-a concentrations in Conesus Lake. Samples are from the surface of Conesus Lake at the deepest point in the south basin. Modeled concentrations are for the upper two model layers at the deepest point in the south basin.

Year	Sampled Chlorophyll-a (μg/L)	Modeled Chlorophyll-a (μg/L)	Sample Notes
2009	6.5	5.7	Sample size = 12; no September samples.
2012	5.1	7.9	Sample size = 6; no September samples.
2014	6.8	8.2	Sample size = 8
Average	6.1	7.3	-

Calibrated Parameter Values

Calibrated parameter values in the Conesus Lake CE-QUAL-W2 model are displayed in **Table 11**. Also displayed are typical parameter ranges from the CE-QUAL-W2 user manual (Cole and Wells 2015).

Table 11. Calibrated parameter values in the Conesus Lake CE-QUAL-W2 model. Typical values ranges reported in Cole and Wells (2015).

Parameter	Description	Units	Typical Values	Calibrated Value
WSC	Wind sheltering coefficient		0.8-1.2	0.85-1.02
BETA	Fraction of incident solar radiation absorbed at the water surface		0.45	0.45
EXH20	Extinction for water	/m	0.25	0.25
EXA	Extinction due to algae	$m^3/m/g$	0.1-0.2	0.2
AG, group 1	Maximum growth rate	/day	1 – 2.5	1.5
AS, group 1	Settling rate	/day	0-1	0.3
ASAT, group 1	Saturation intensity at maximum photosynthetic rate	W/m^2	10-150	90
AT1, group 1	Lower temperature for algal growth	^oC	4-10	8
AT2, group 1	Lower temperature for maximum algal growth	^oC	6-20	12
AT3, group 1	Upper temperature for maximum algal growth	^oC	15-25	20
AT4, group 1	Upper temperature for algal growth	^oC	20-30	30
ALGP, group 1	Stoichiometric equivalent between organic matter and phosphorus		0.003-0.014	0.01

Parameter	Description	Units	Typical Values	Calibrated Value
ALGN, group 1	Stoichiometric equivalent between organic matter and nitrogen		0.04-0.11	0.10
AHSP, group 1	Half-saturation constant for phosphorous	g/m	0.002 to 0.1	0.003
AHSN, group 1	Half-saturation constant for nitrogen	g/m^3	0.005-0.2	0.007
ACHLA, group 1	Ratio between algal biomass and chlorophyll a in terms of mg algae/µg chl a	mg algae/µg chl a	0.01 to 0.4	0.12
AG, group 2	Maximum growth rate	/day	1 – 2.5	2.3
AS, group 2	Settling rate	/day	0-1	0.3
ASAT, group 2	Saturation intensity at maximum photosynthetic rate	W/m^2	10-100	90
AT1, group 2	Lower temperature for algal growth	^oC	4-10	20
AT2, group 2	Lower temperature for maximum algal growth	^oC	6-20	25
AT3, group 2	Upper temperature for maximum algal growth	^oC	15-25	28
AT4, group 2	Upper temperature for algal growth	^oC	20-30	35
ALGP, group 2	Stoichiometric equivalent between organic matter and phosphorus		0.003-0.014	0.01
ALGN, group 2	Stoichiometric equivalent between organic matter and nitrogen		0.04-0.11	0.10
AHSP, group 2	Half-saturation constant for phosphorous	g/m	0.002 to 0.1	0.003
AHSN, group 2	Half-saturation constant for ammonia	g/m^3	0.005-0.2	0.007
ACHLA, group 2	Ratio between algal biomass and chlorophyll a in terms of mg algae/µg chl a	mg algae/µg chl a	0.01 to 0.4	0.18
EG	Epiphyton growth rate	/day	1 – 2.5	1.5
EHS	Biomass limitation factor	$g\text{-}m^{-2}$		40.0
ESAT	Saturation intensity at maximum photosynthetic rate	W/m^2	10-100	150
EP	Epiphyton stoichiometric equivalent between organic matter and phosphorus		0.003-0.014	0.008
EN	Epiphyton stoichiometric equivalent between organic matter and nitrogen		0.04-0.11	0.1
ZG	Maximum zooplankton growth rate	/day		
LDOMDK	Labile DOM decay rate	/day	0.04-0.12	0.1
RDOMDK	Maximum refractory DOM decay rate	/day	0.001	0.001
LPOMDK	Labile Detritus decay rate	/day	0.001 to 0.1	0.08
POMS	Detritus settling rate	m/day	0.35-1.5	1.0
SEDK	Sediment decay rate	/day	0.06	0.06
SEDBR	Sediment burial rate	/day	0.01	0.01
PO4R	Sediment release rate of phosphorus, fraction of SOD		0.0005 to 0.02	0.003
NH4DK	Ammonia decay rate (nitrification rate)	/day	0.001 to 0.12	0.05
NH4R	Sediment release rate of ammonium, fraction of SOD		0.001 to 0.015	0.05
NO3DK	Nitrate decay rate (denitrification rate)	/day	0.05-0.15	0.15
O2AG	Oxygen stoichiometric equivalent for algal growth		1.4	1.6, group 1 1.4, group 2
SOD	Zero-order sediment oxygen demand for each segment	$g\ O2\ m^{-2}\ day^{-1}$	0.1 to 3	2.0

Discussion of Model Results

Water Residence Time

Water residence time can be tracked in CE-QUAL-W2 as a "dummy" generic water quality constituent. **Figure 8** displays the predicted water residence time in Conesus Lake throughout the simulation period. Water residence time reaches a maximum of approximately 700 days (1.9 years) during the simulation period. This shows that lake conditions in any given year are in part influenced by conditions during the preceding 1 to 2 years. Furthermore, model predictions during the first two years of the simulation period (2007 & 2008) are highly dependent on assumptions related to initial conditions.

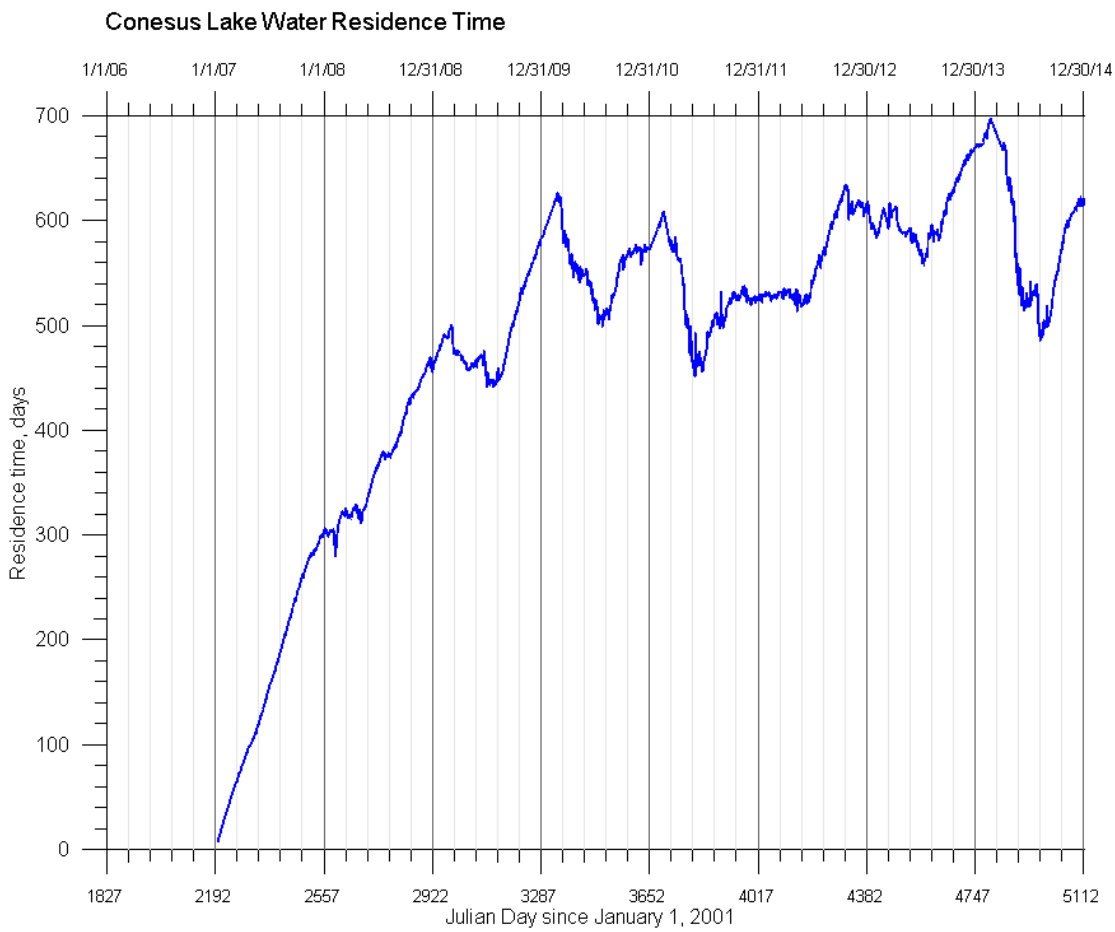


Figure 8. Water residence time in Conesus Lake.

Thermal Stratification and Turnover

The degree of thermal stratification in a lake is dependent on surface heat transfer processes such as incoming short-wave solar radiation, long-wave atmospheric radiation, back radiation, evaporation, and conduction. Wind energy primarily determines the depth of the thermocline. The thermal structure of Conesus Lake directly impacts water quality. Strong thermal stratification results in a large anoxic volume at depth over an extended time period. Such conditions support anoxic release of

nutrients from bottom sediments into the water column. Large algal blooms can occur if nutrient rich bottom waters mix with upper layers during the growing season.

Model predicted surface and bottom temperatures at the deepest point of Conesus Lake are shown in **Figure 9**. Results show a strongly stratified dimictic lake. Stratification develops in the spring (approximately May 15th) and turnover occurs in the fall (generally by November 1st) when the lake becomes well mixed vertically. Hypolimnetic water is separated from surface water during this period of stratification, and dissolved oxygen levels decline significantly over this time. Bottom temperatures are typically 10-12°C during the summer, while surface temperatures are at least 10°C warmer.

Winter stratification also occurs in the Conesus Lake model, with surface temperatures less than bottom temperatures as a result of the density-temperature relationship for water. Ice cover was predicted by the model; ranging from no ice cover to at most 0.35 meters of ice in the winter of 2006/2007 and 2010/2011. The 2011/2012 winter was the only year predicted to have no ice cover during the simulation period, a finding that agrees with field observations.

Model predicted temperature profiles in **Figure 10** show the typical progression and decrease of stratification, as well as inverse winter stratification, for 2008.

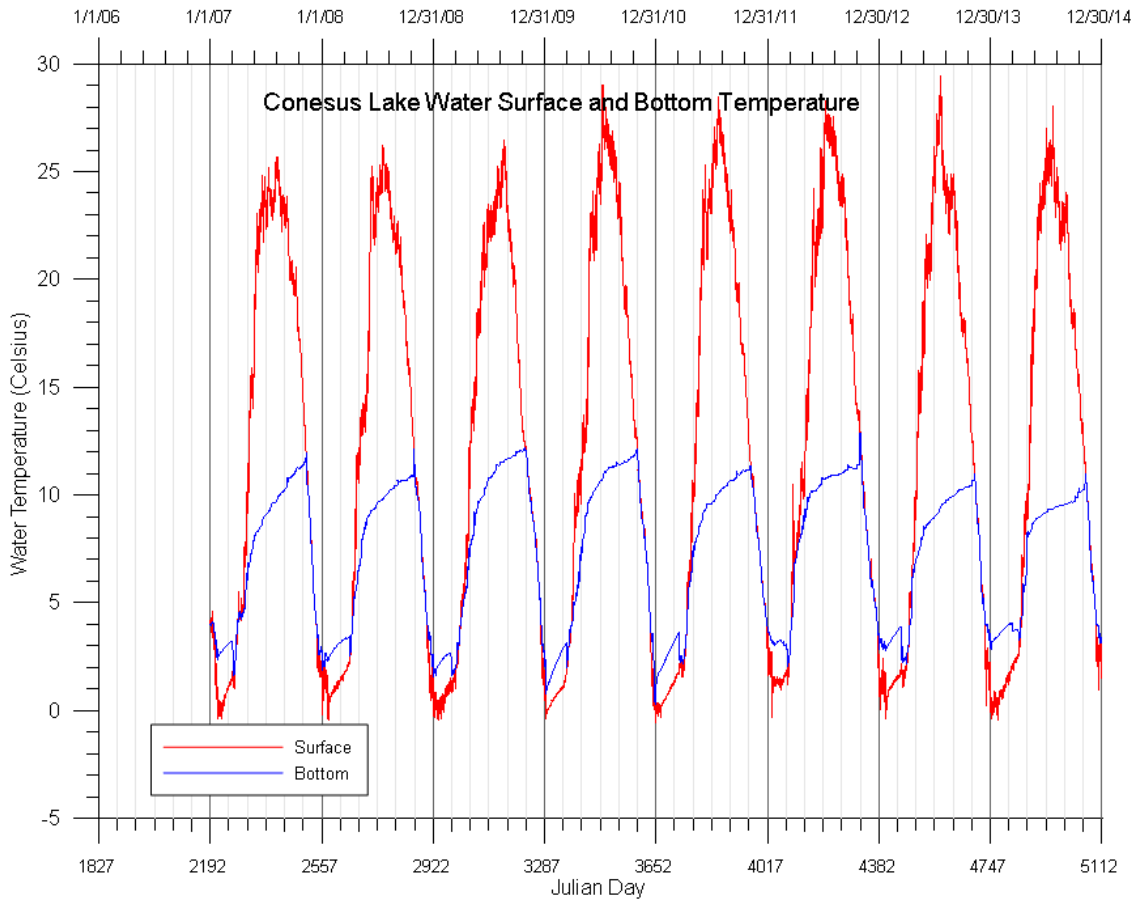


Figure 9. Predicted surface and bottom water temperature in Conesus Lake.

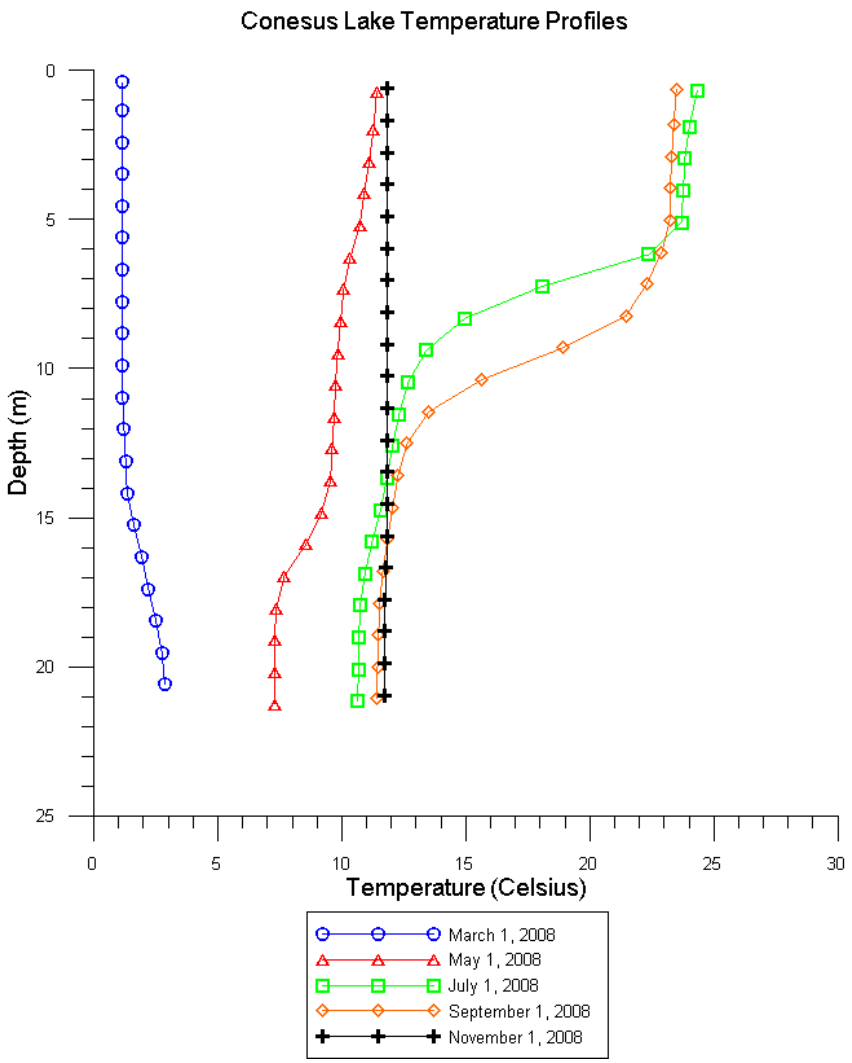


Figure 10. Water temperature profiles for 2008 at the deepest point in Conesus Lake.

Nutrient Limitation for Algal Growth

Algal growth in the Conesus Lake CE-QUAL-W2 is in part a function of growth rate multipliers for nutrients. Rate multipliers vary over time between 0 (complete growth limitation) and 1 (no growth limitation) based on water column nutrient concentrations. Separate rate multipliers are computed in the model for nitrogen and phosphorus. The nutrient with the lowest magnitude multiplier at any point is the limiting nutrient for algal growth at that time.

Growth rate multipliers can be used to explore nutrient limitation for algal growth in Conesus Lake. Algal growth rate multipliers for phosphorus and nitrogen are displayed in **Figure 11**. Throughout most of the simulation period, the rate multiplier for phosphorus is much lower than the rate multiplier for nitrogen, indicating that phosphorus is predominantly the limiting nutrient for algal growth in Conesus Lake. The exception is during portions of 2010, 2012, and 2014, when high phosphorus loading resulted in a temporary shift to nitrogen limitation.

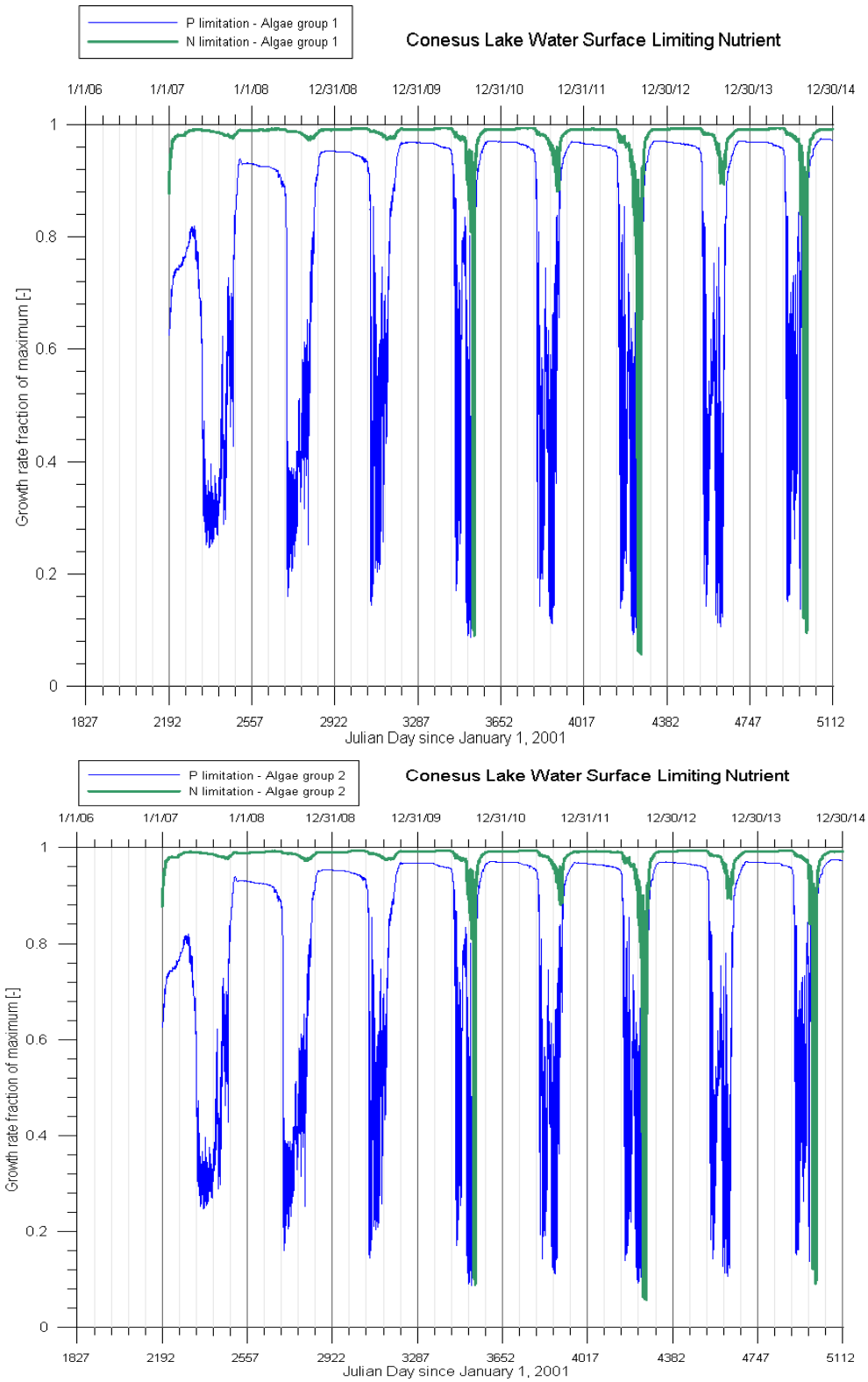


Figure 11. Growth rate multiplier for nitrogen (green) and phosphorus (blue) for algae group 1 (top) and algae group 2 (bottom) in the Conesus Lake CE-QUAL-W2 model.

Nutrient Mass Balance & Fluxes

An understanding of the relative magnitude nutrient inputs, outputs, and internal transformations within a waterbody is useful for evaluating water quality improvement strategies. This section uses CE-QUAL-W2 model output to present the cumulative mass of nitrogen and phosphorus that enters, exits, and is stored in Conesus Lake throughout the simulation period.

Phosphorus and nitrogen mass balance plots for Conesus Lake are displayed in **Figure 12** and **Figure 13**, respectively. These plots include the following curves:

- Branch Inflow – The cumulative mass of nitrogen/phosphorus entering Conesus Lake from the watershed in branch inflow;
- Distributed Tributary – The cumulative mass of nitrogen/phosphorus entering Conesus Lake from the watershed in distributed tributary inflow;
- Precipitation – The cumulative mass of nitrogen/phosphorus entering Conesus Lake from direct precipitation onto the lake surface;
- Sediment Release – The cumulative mass of nitrogen/phosphorus released into the water column of Conesus Lake from zero-order anoxic sediment decay and first-order oxic sediment decay;
- Outflow – The cumulative mass of nitrogen/phosphorus output from Conesus Lake from the lake outlet;
- Withdrawal – The cumulative mass of nitrogen/phosphorus output from Conesus Lake in water withdrawals by the Village of Geneseo and the Village of Avon;
- Sediment Settling – The cumulative mass of nitrogen/phosphorus that settles out of the water column of Conesus Lake into the first-order sediment compartment;
- Water Column – The instantaneous mass of nitrogen/phosphorus that is stored in the water column of Conesus Lake;
- Aquatic Plants – The instantaneous mass of nitrogen/phosphorus that is stored in the aquatic plant community of Conesus Lake.

The largest input of phosphorus to Conesus Lake is bottom sediment release followed by branch inflow, distributed tributary inflow, and precipitation. The largest output of phosphorus is settling to bottom sediment followed by lake outflow and water withdrawals. Note that although the bottom sediment represents a large phosphorus input term the ultimate source of this phosphorus is the Conesus Lake watershed. Bottom sediment is also a large sink for water column phosphorus, and phosphorus is continually cycled between the water column and sediment. At the end of the simulation, the cumulative mass of phosphorus released from bottom sediment is slightly greater than the mass that settles out of the water column, indicating that there is a net release of phosphorus from bottom sediments during the simulation period. However, external inputs of phosphorus from the Conesus Lake watershed far outweigh net sediment release. The nitrogen mass balance plot demonstrates similar patterns.

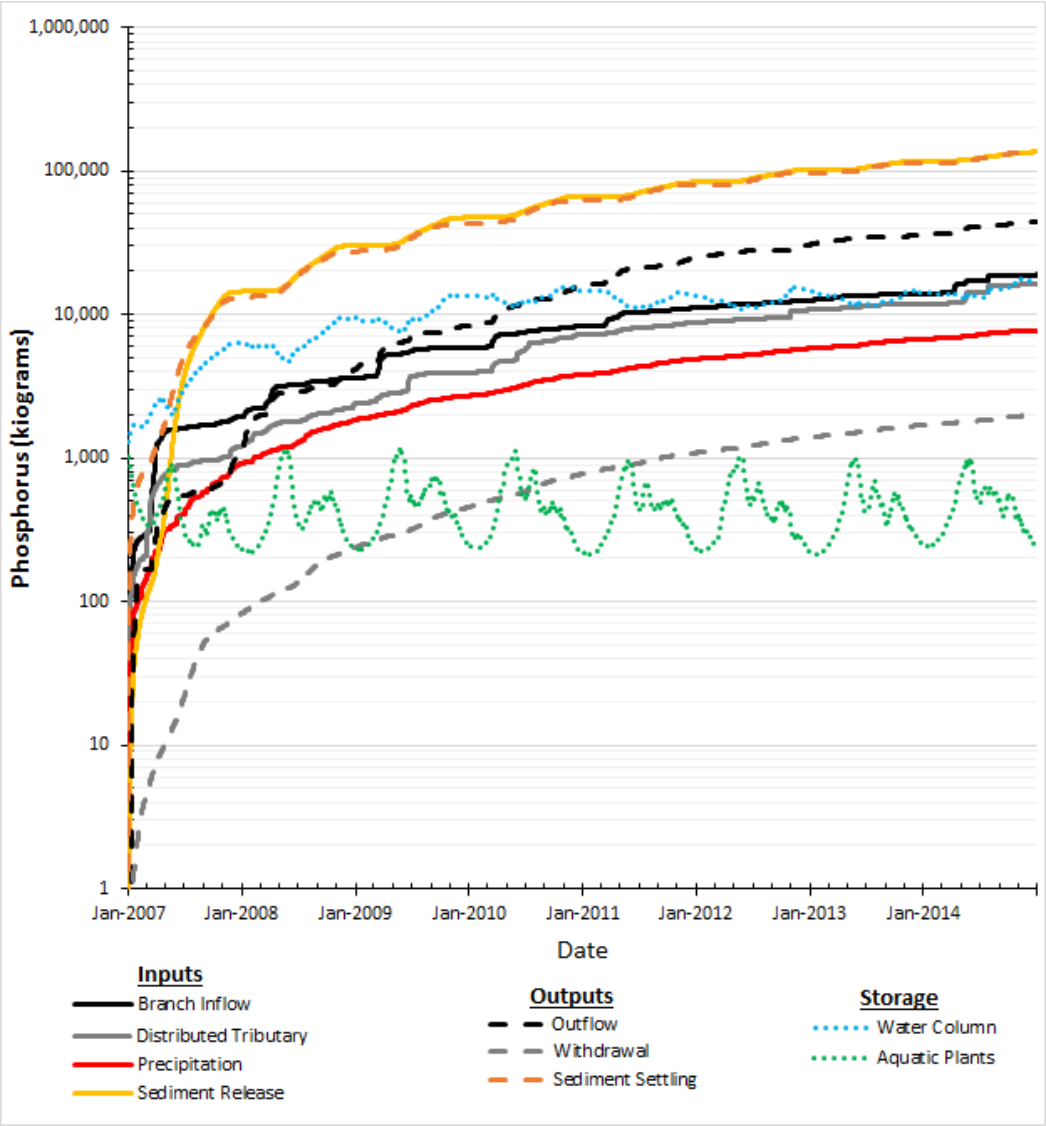


Figure 12. Phosphorus mass balance plot for Conesus Lake. Masses are cumulative for inputs and outputs and instantaneous for storage terms.

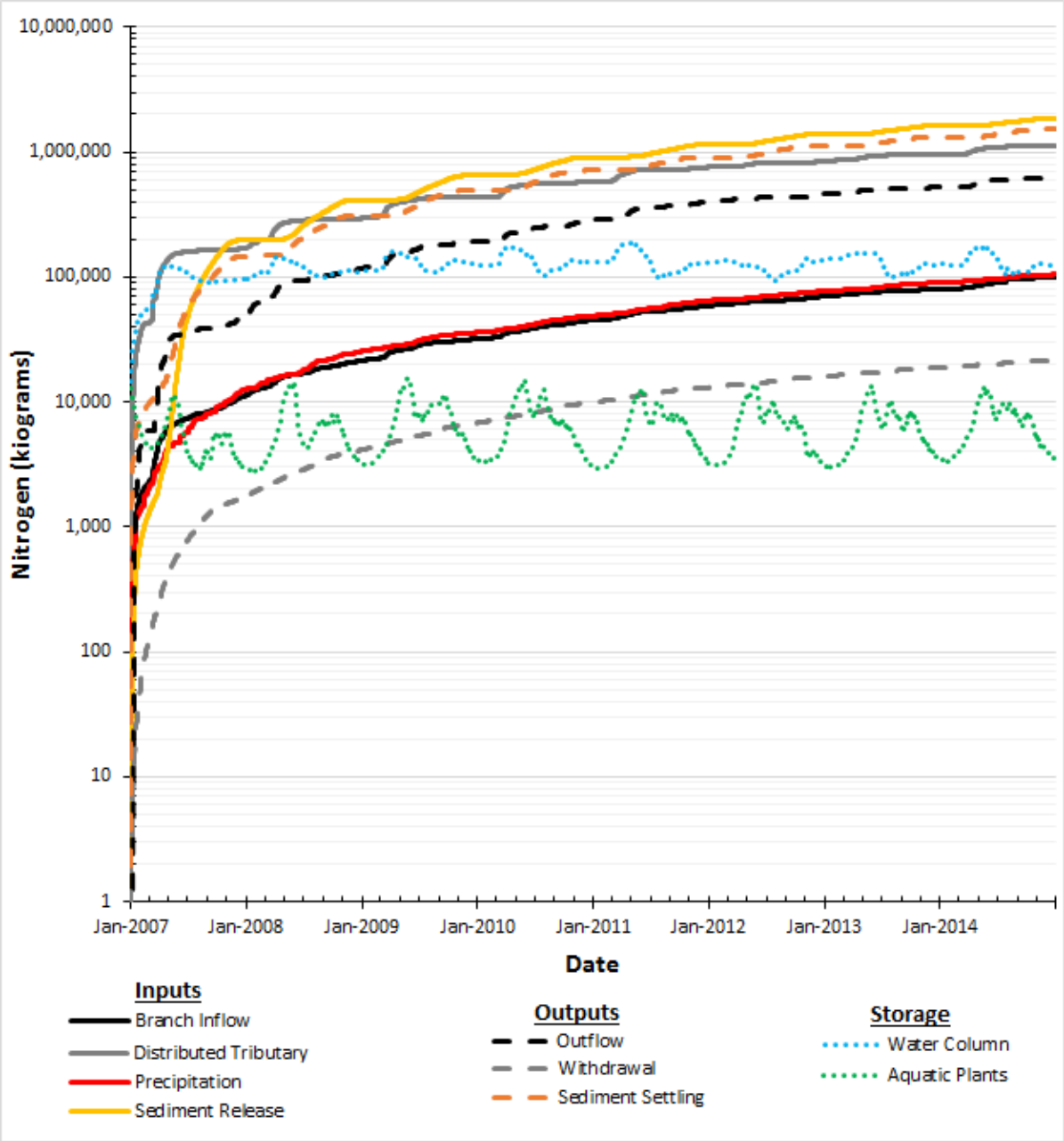


Figure 13. Nitrogen mass balance plot for Conesus Lake. Masses are cumulative for inputs and outputs and instantaneous for storage terms.

Conclusions

A CE-QUAL-W2 model of Conesus Lake was developed to support development of a phosphorus TMDL for the lake. While the model is adequate for use in water quality planning, several areas for improvement were noted during model setup and calibration that could be addressed in a later modeling study. These include:

- Meteorological forcing data are from the Dansville Municipal Airport station, located 10.5 miles from Conesus Lake. On-site meteorological data from each lake would provide more representative model inputs. Spot measurements of wind speed and air temperature on each lake, for example, could be collected and used to adjust records from the Dansville Municipal Airport station.
- Measured wind speed at the Dansville Municipal Airport station included a large number of zero values. This may reflect an error in weather station records.
- SWAT model estimates of inflow rates and water quality constituent concentrations could be refined using measurements of flow and water quality from each lake watershed. Inflows could also be refined spatially to represent multiple tributary inputs from different subwatersheds.
- The model computational grids were developed without any layers above the average water surface elevation of the lake. A refined model grid could incorporate Digital Elevation Models (DEMs) of the surrounding landscape to include areas above the average water surface elevation.
- Mussels were not explicitly represented in the Conesus Lake CE-QUAL-W2 model. Their effect on water quality could be important as they facilitate recycling of nutrients between bottom sediments and the water column.
- Observations of macrophyte biomass were not available for comparison to model predictions. Field data on macrophyte biomass are needed to verify the model predicted macrophyte dynamics.
- The Conesus Lake CE-QUAL-W2 model does not use the detailed sediment diagenesis submodel available in the latest release of CE-QUAL-W2. The sediment diagenesis submodel is useful for evaluating alternative nutrient loading reduction strategies since the model predicts sediment responses to reduced nutrient loads. In the zero-order sediment decay function used in the current Conesus Lake model, nutrient releases occur independently of external nutrient loading and load reduction scenarios must assume a fixed reduction rate from zero-order sediment decay.

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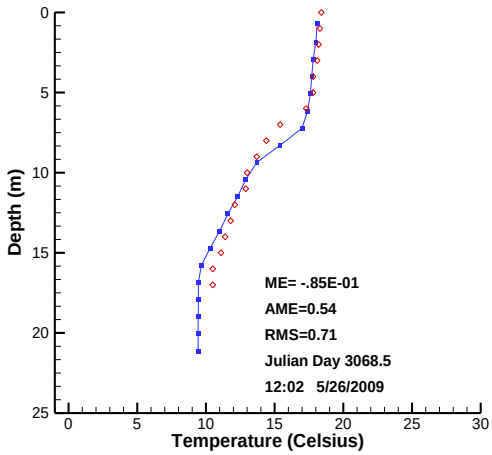
APPENDIX B:
Conesus Lake CE-QUAL-W2 Model Temperature and Water Quality Profile Plots

B1 Water Temperature Profile Plots:

Red dots = Actual data points.

Blue dots and lines = modeled simulations



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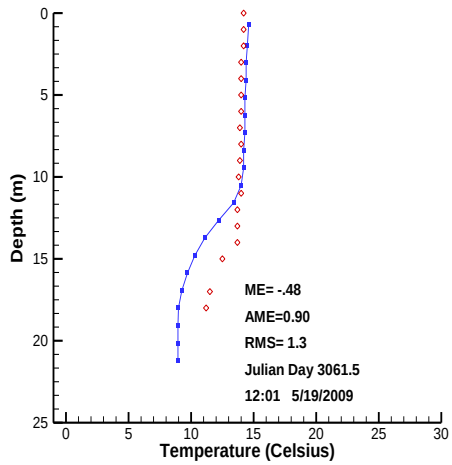

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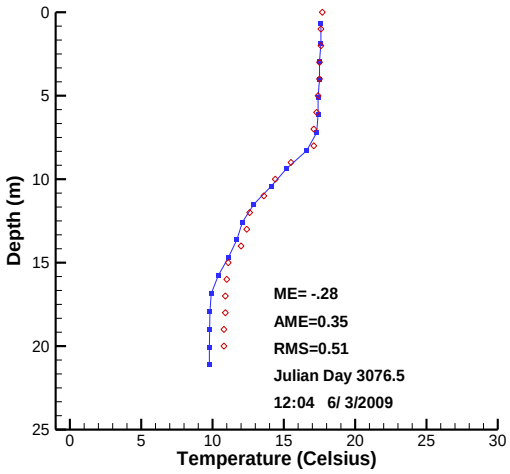

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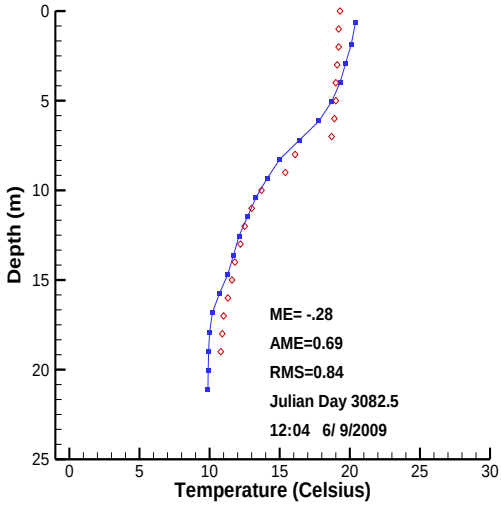

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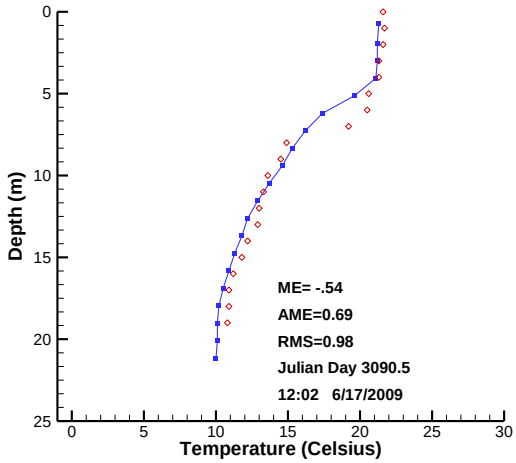
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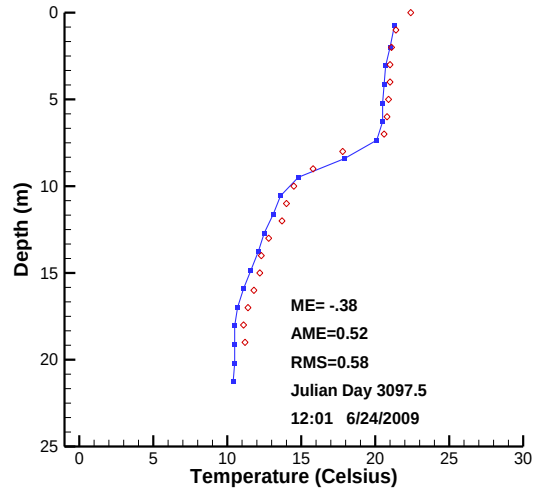
Temperature (Celsius)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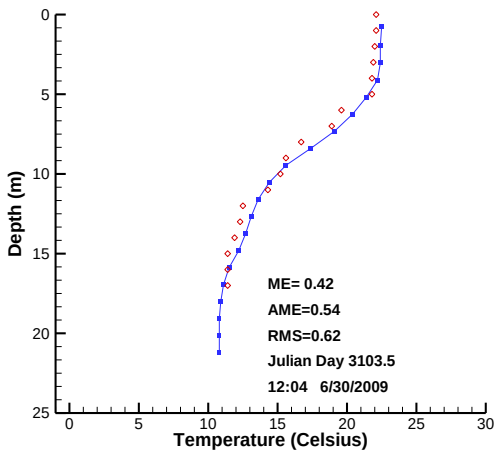
18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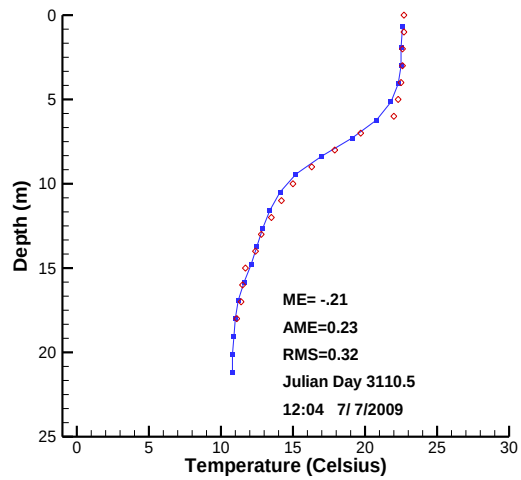
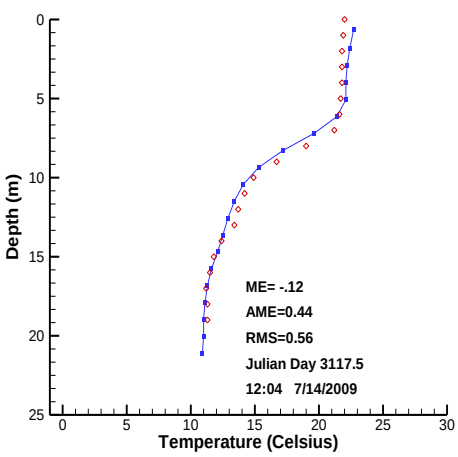
Temperature (Celsius)

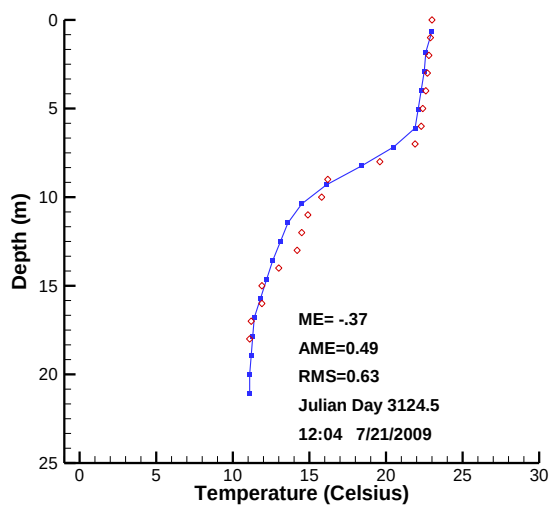
19


ME= -.21
AME=0.23
RMS=0.32
Julian Day 3110.5
12:04 7/ 7/2009
Depth (m)
Temperature (Celsius)

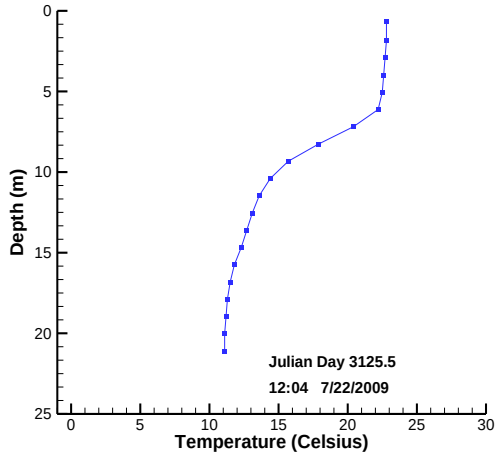
20


ME= -.12
AME=0.44
RMS=0.56
Julian Day 3117.5
12:04 7/14/2009
Depth (m)
Temperature (Celsius)

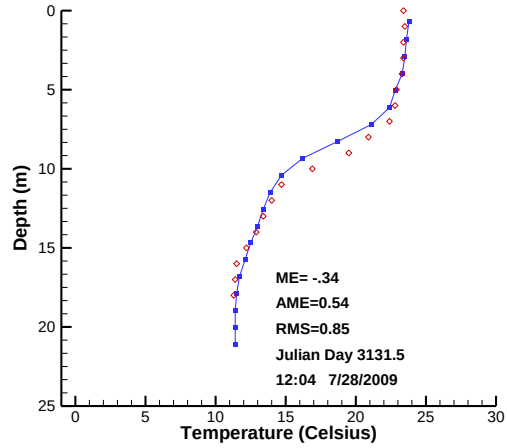
21


ME= -.37
AME=0.49
RMS=0.63
Julian Day 3124.5
12:04 7/21/2009
Depth (m)
Temperature (Celsius)

22

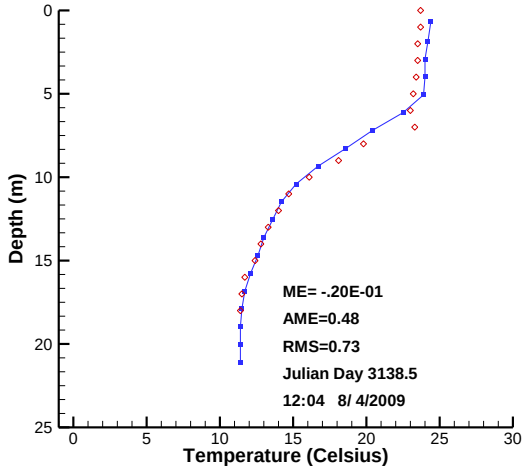


23

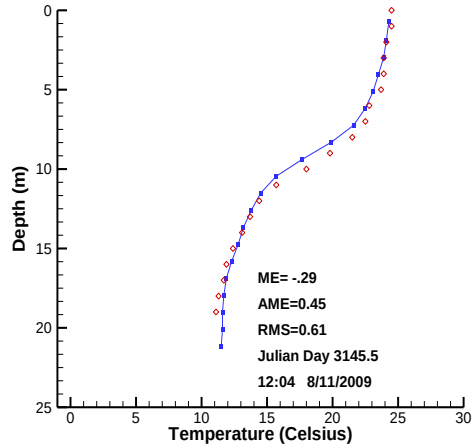


24

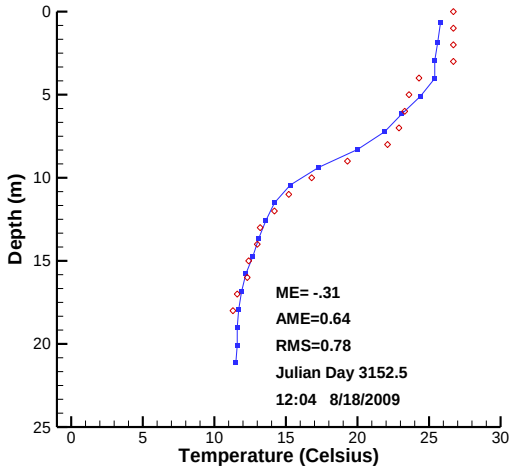
25



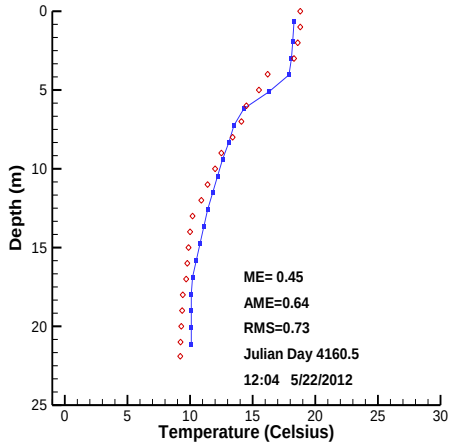
26



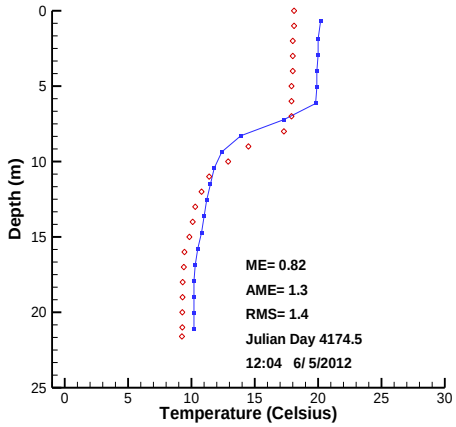
27



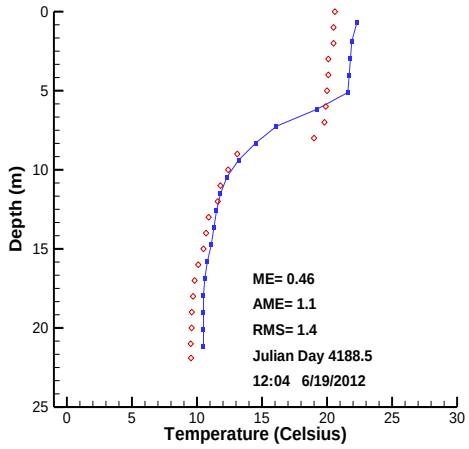
28



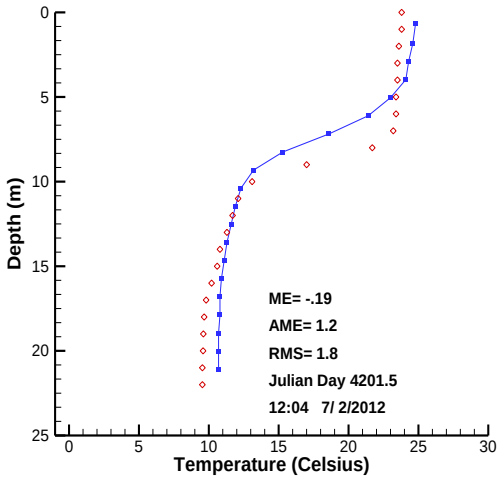
29


ME= 0.82
AME= 1.3
RMS= 1.4
Julian Day 4174.5
12:04 6/ 5/2012
Depth (m)
Temperature (Celsius)

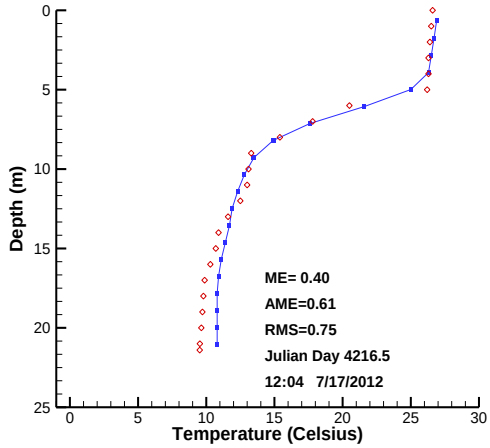
30


ME= 0.46
AME= 1.1
RMS= 1.4
Julian Day 4188.5
12:04 6/19/2012
Depth (m)
Temperature (Celsius)

31


ME= -.19
AME= 1.2
RMS= 1.8
Julian Day 4201.5
12:04 7/ 2/2012
Depth (m)
Temperature (Celsius)

32


ME= 0.40
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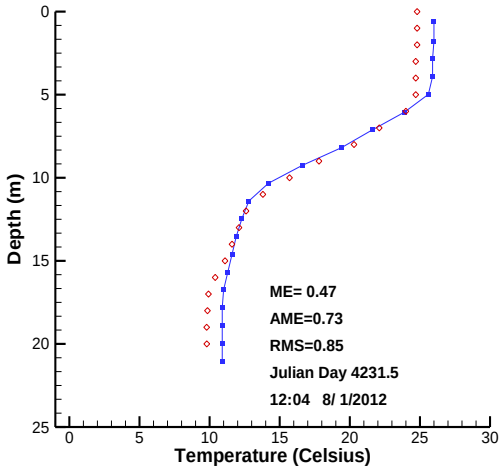
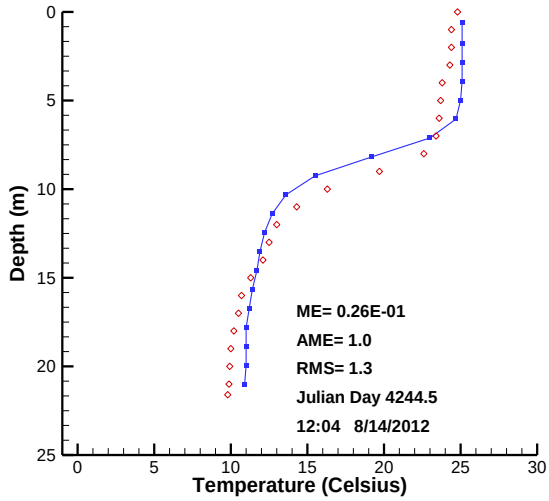
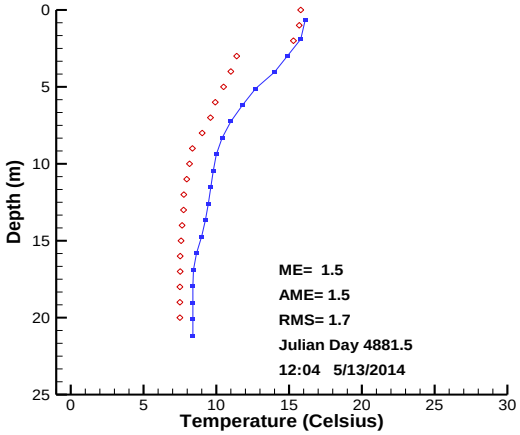
RMS=0.75
Julian Day 4216.5
12:04 7/17/2012
Depth (m)
Temperature (Celsius)

33

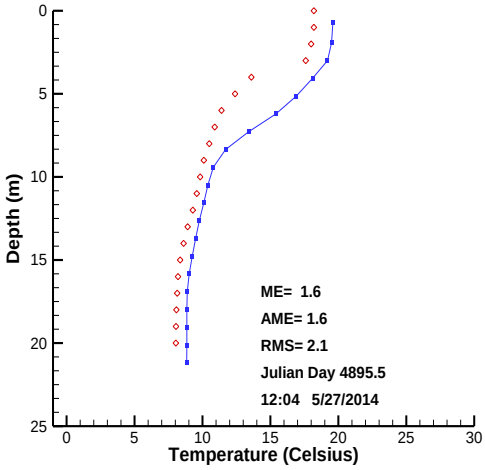

ME= 0.47
AME=0.73
RMS=0.85
Julian Day 4231.5
12:04 8/ 1/2012
Depth (m)
Temperature (Celsius)


ME= 0.26E-01
AME= 1.0
RMS= 1.3
Julian Day 4244.5
12:04 8/14/2012
Depth (m)
Temperature (Celsius)

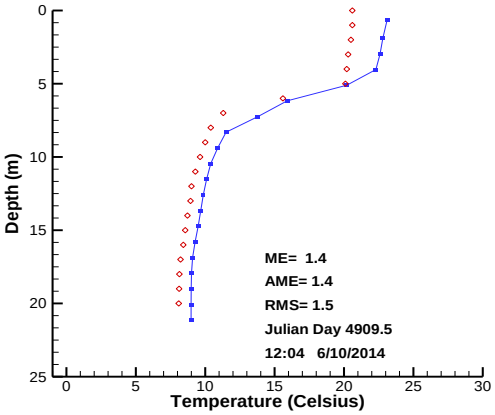
34



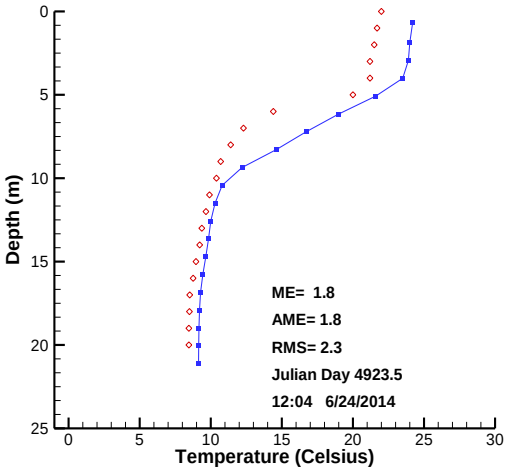
35



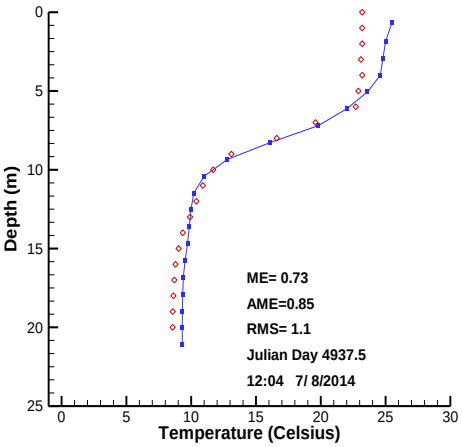
36



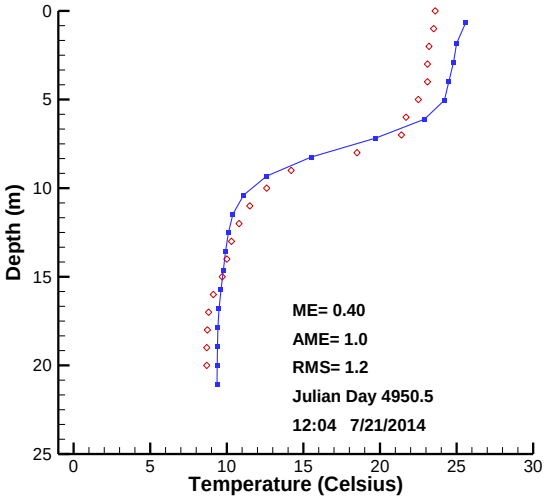
37



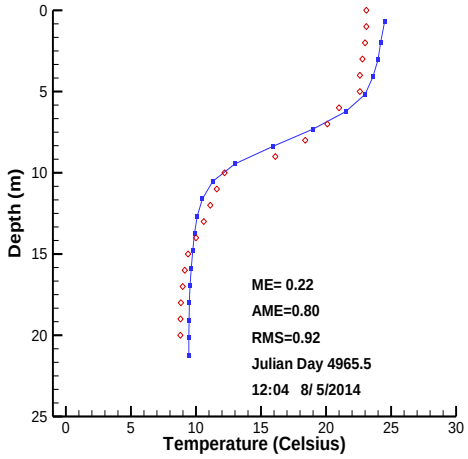
38



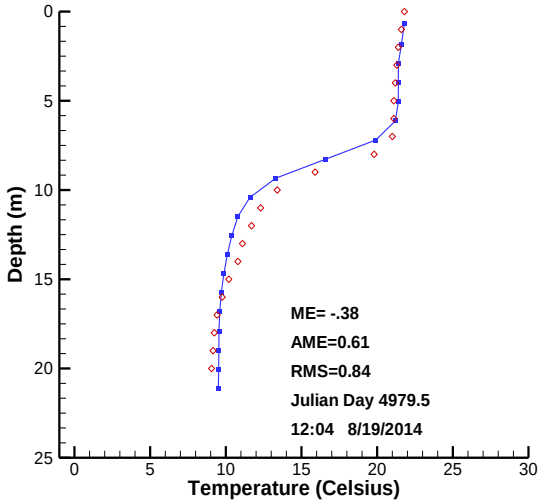
39



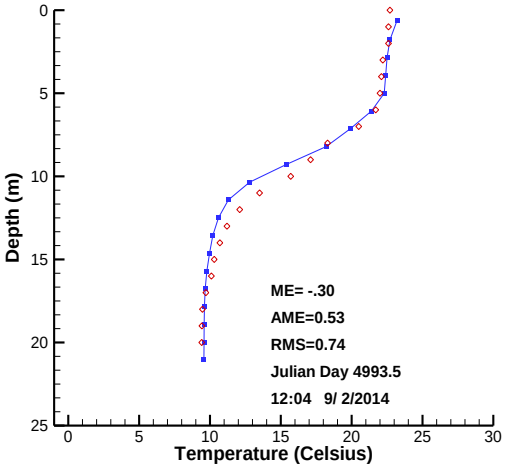
40


Depth (m)
Temperature (Celsius)
ME= 0.22
AME=0.80
RMS=0.92
Julian Day 4965.5
12:04 8/ 5/2014

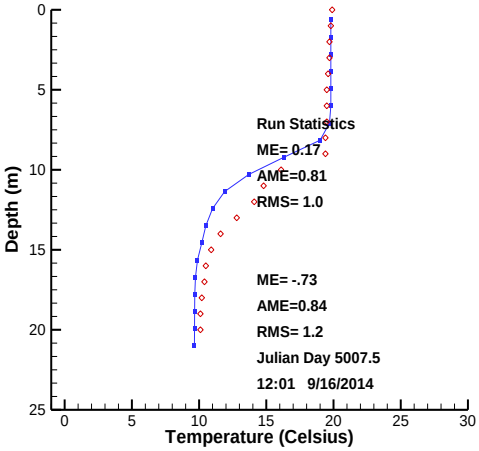
41


Depth (m)
Temperature (Celsius)
ME= -.38
AME=0.61
RMS=0.84
Julian Day 4979.5
12:04 8/19/2014

42


Depth (m)
Temperature (Celsius)
ME= -.30
AME=0.53
RMS=0.74
Julian Day 4993.5
12:04 9/ 2/2014

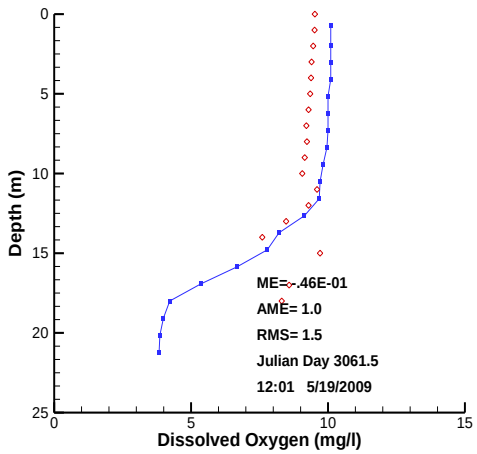
43


Depth (m)
Temperature (Celsius)
Run Statistics
ME= 0.17
AME=0.81
RMS= 1.0
ME= -.73
AME=0.84
RMS= 1.2
Julian Day 5007.5
12:01 9/16/2014

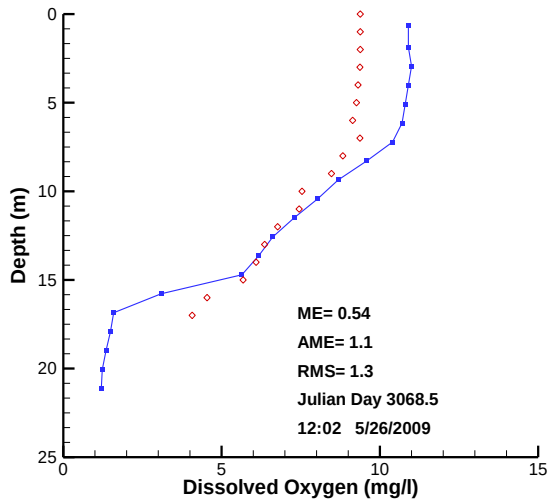
44

45

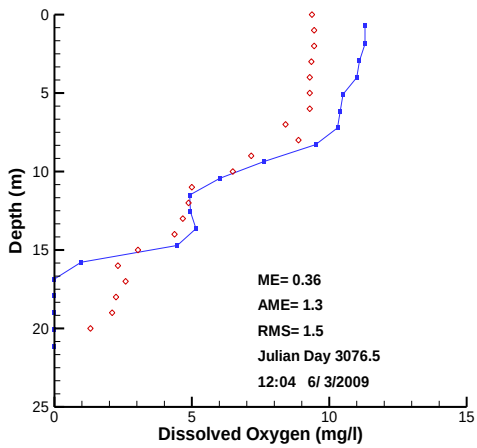
Dissolved Oxygen Profile Plots



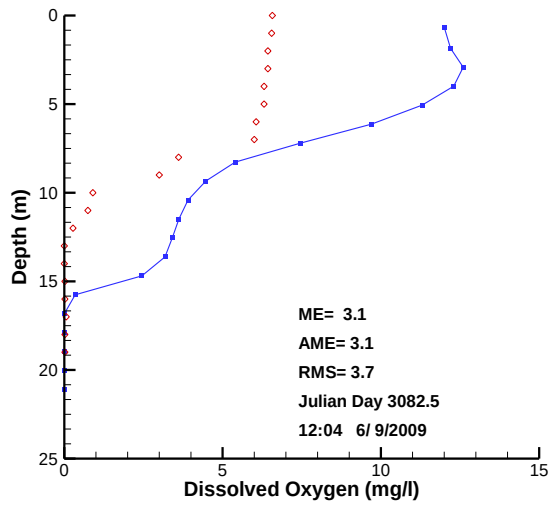
46



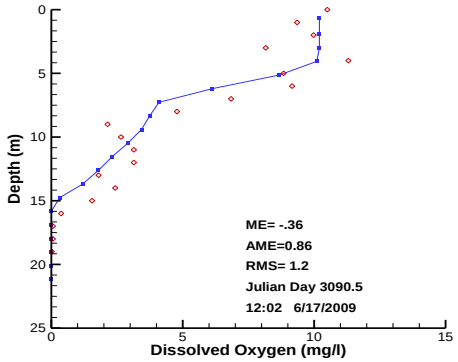
47



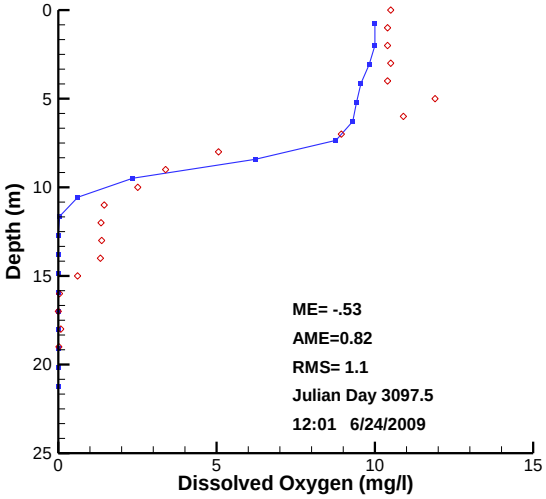
48



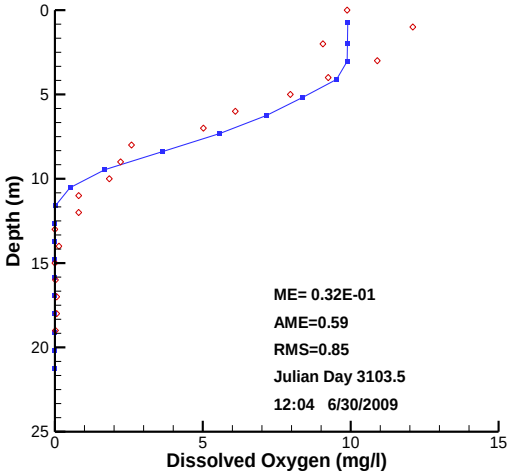
49



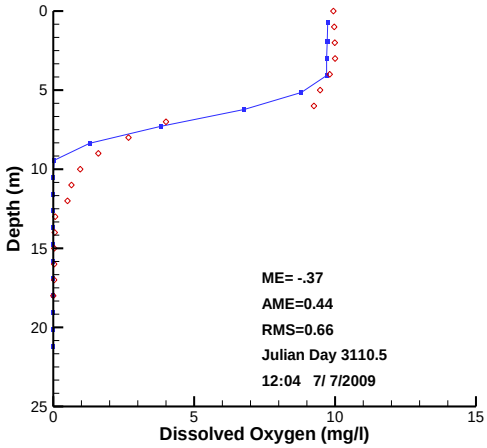
50



51

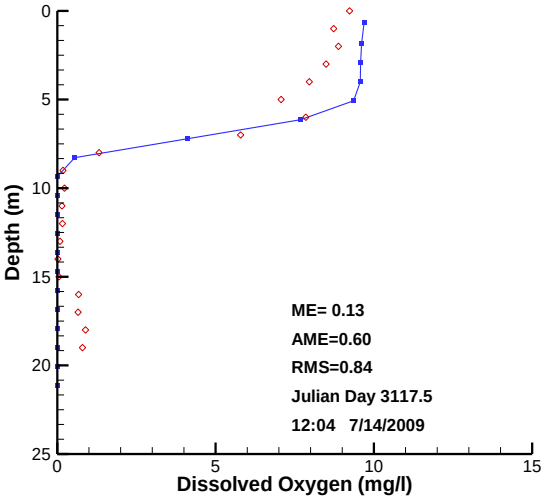


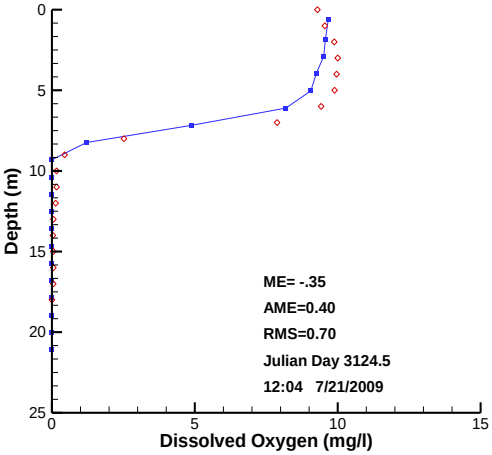
52



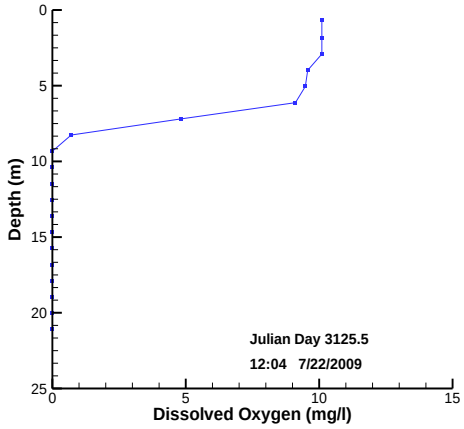
53

54

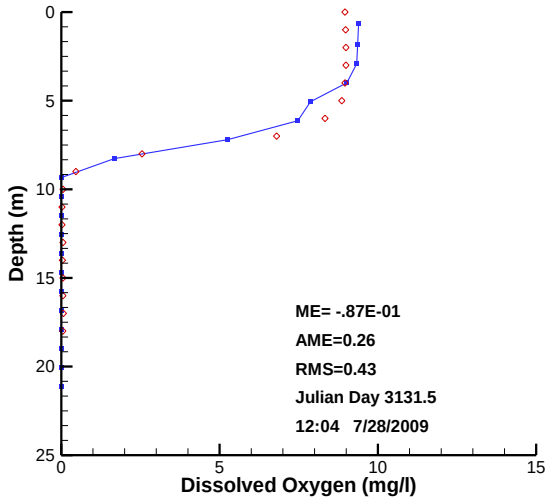




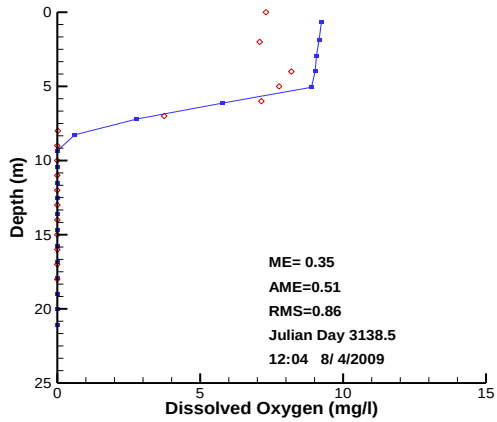
55



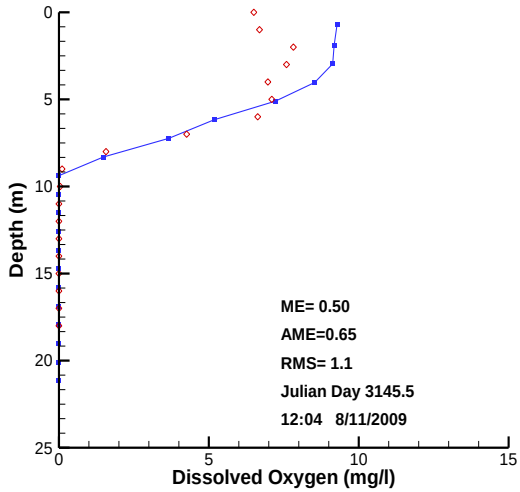
56



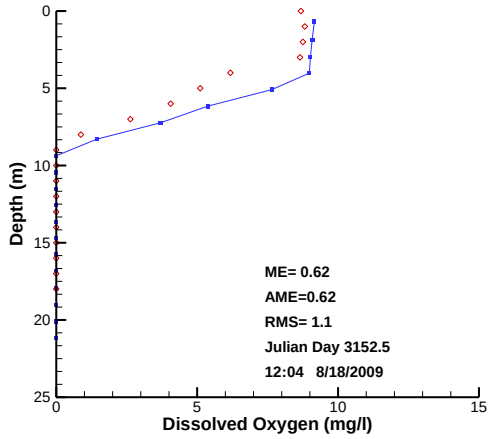
57



58



59



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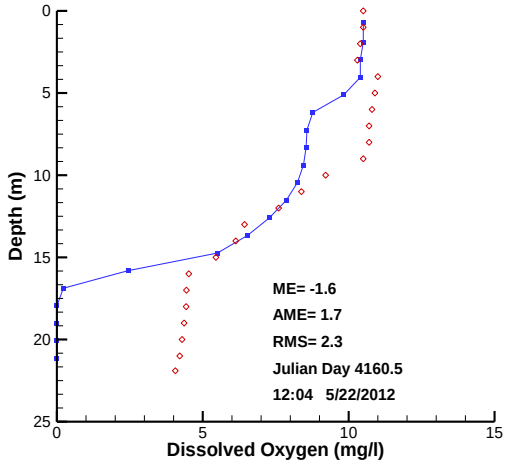
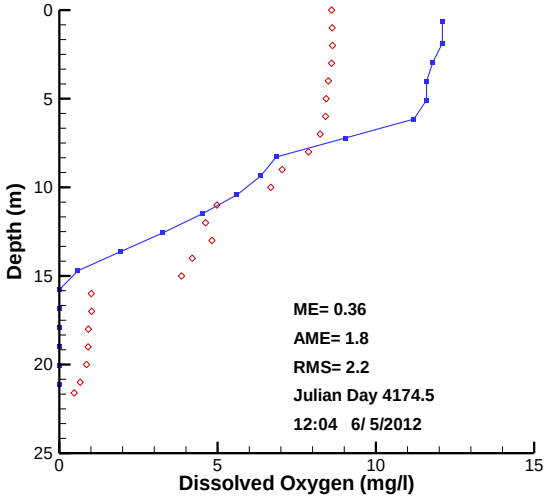
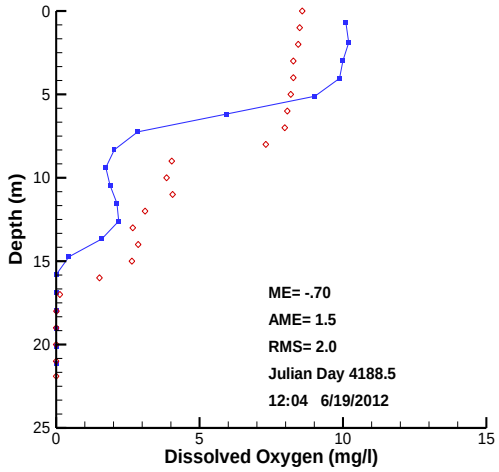


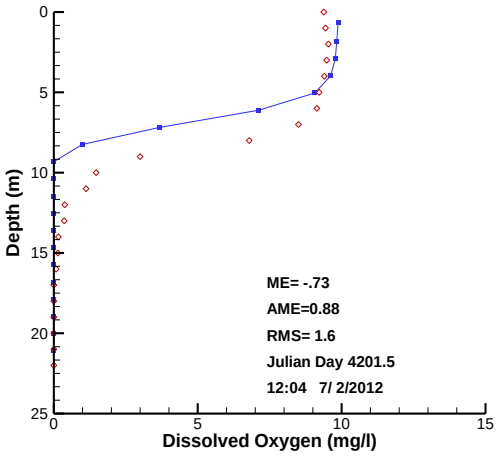
61

62

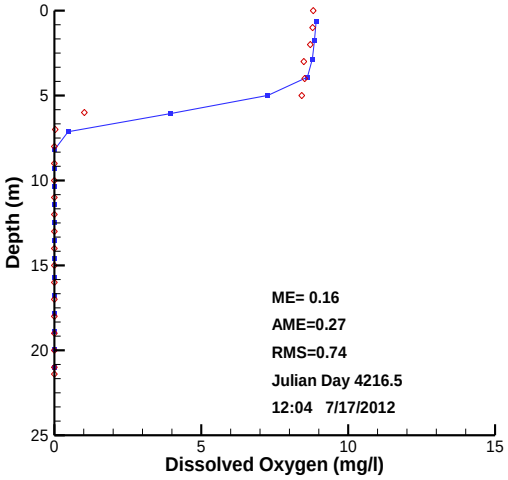




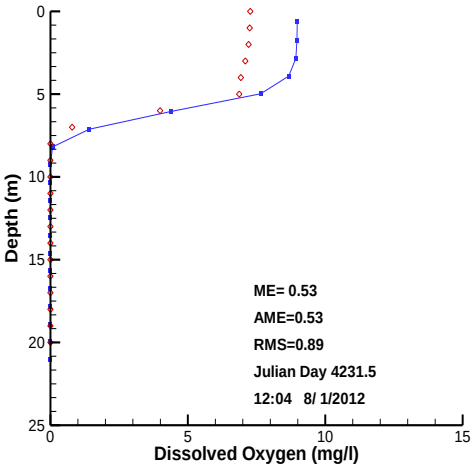
63



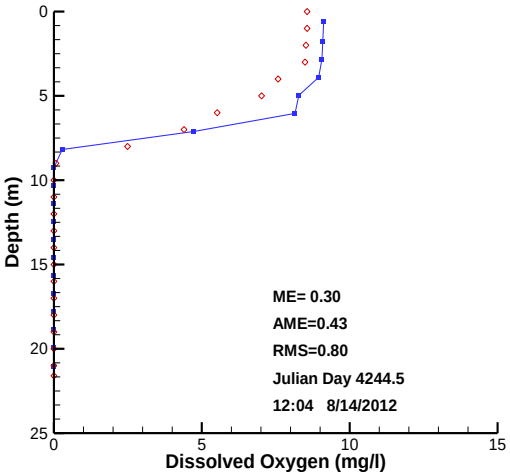
64



65

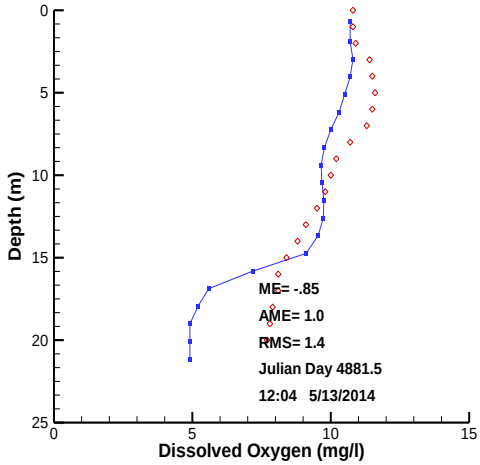


66

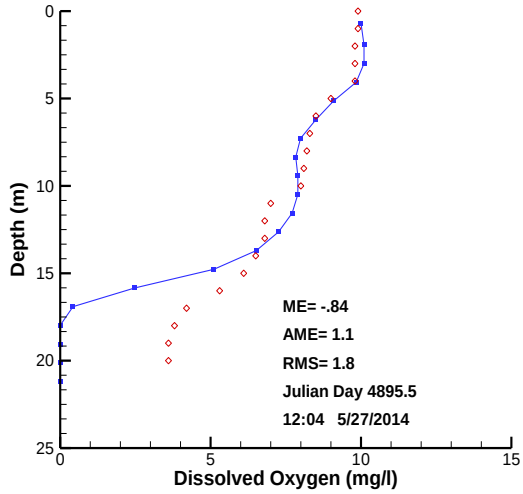


67

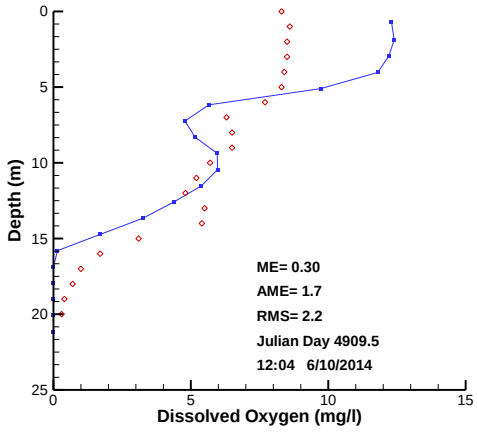
68



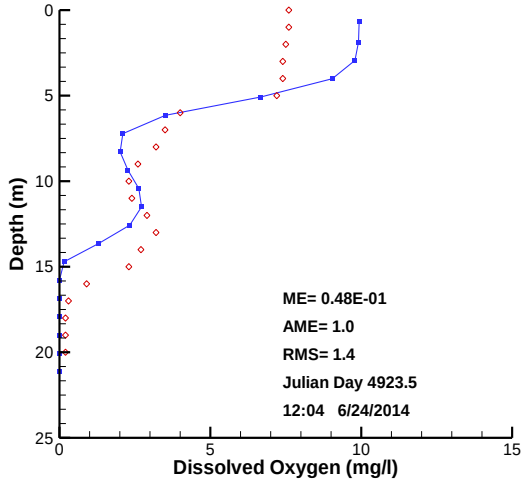
69



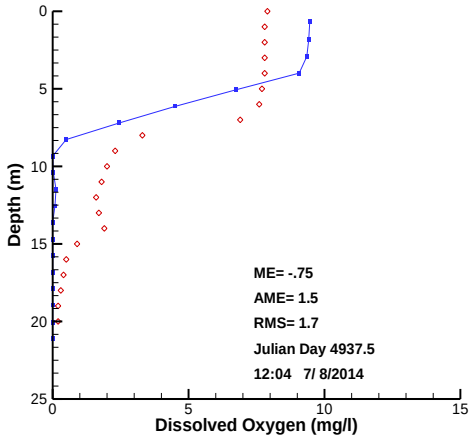
70



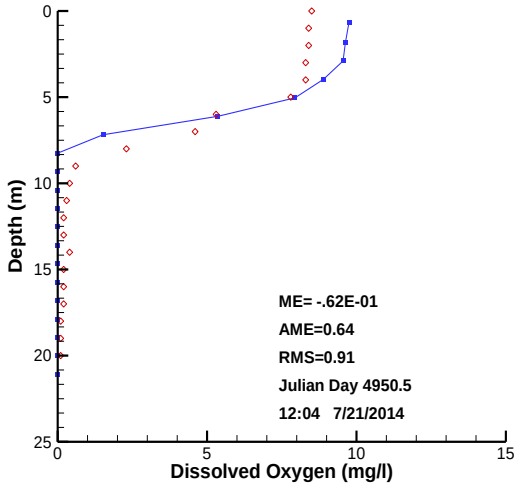
71



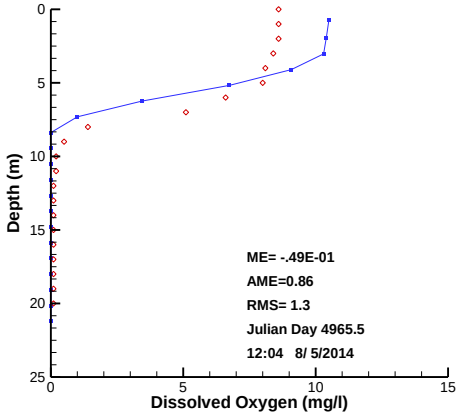
72



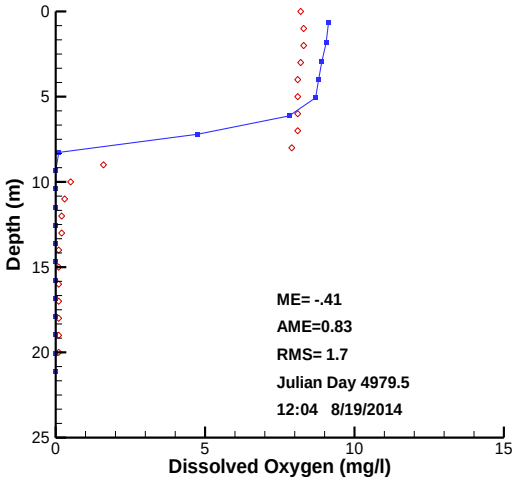
73



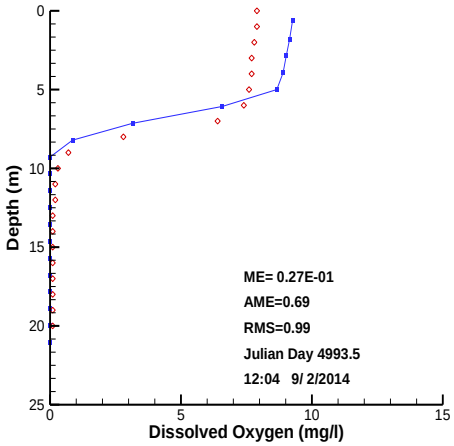
74


Depth (m)
Dissolved Oxygen (mg/l)
ME= -.49E-01
AME=0.86
RMS= 1.3
Julian Day 4965.5
12:04 8/ 5/2014

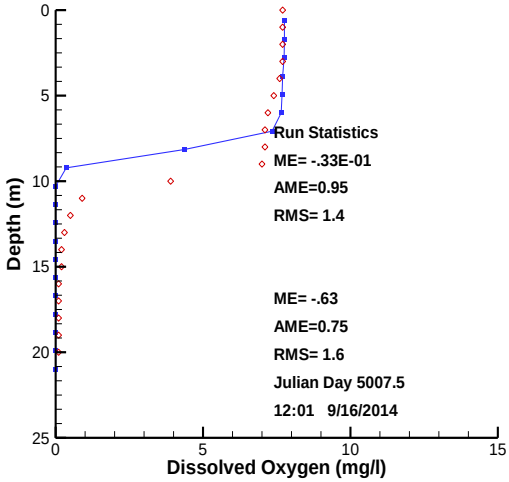
75


Depth (m)
Dissolved Oxygen (mg/l)
ME= -.41
AME=0.83
RMS= 1.7
Julian Day 4979.5
12:04 8/19/2014

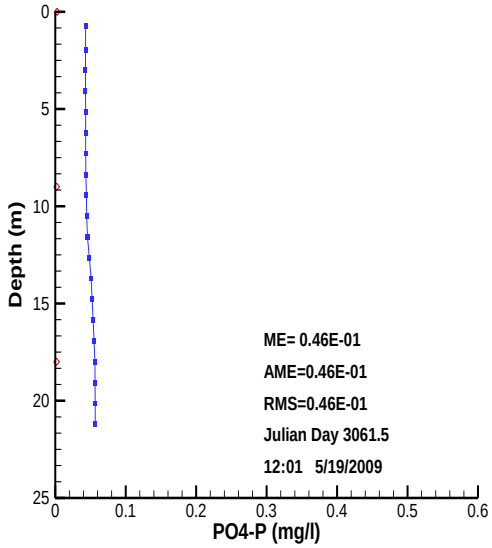
76


Depth (m)
Dissolved Oxygen (mg/l)
ME= 0.27E-01
AME=0.69
RMS=0.99
Julian Day 4993.5
12:04 9/ 2/2014

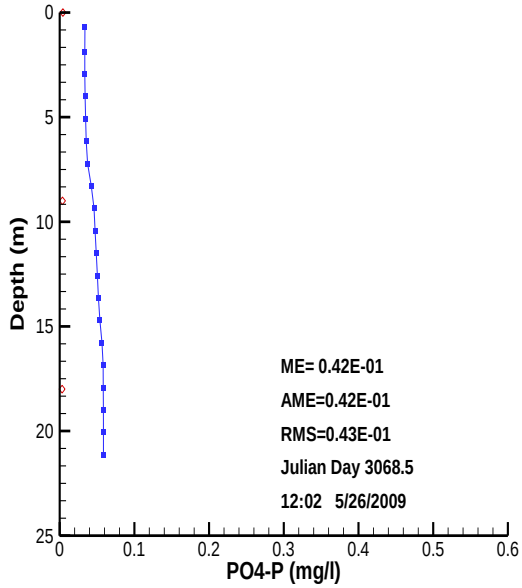
77


Depth (m)
Dissolved Oxygen (mg/l)
Run Statistics
ME= -.33E-01
AME=0.95
RMS= 1.4
ME= -.63
AME=0.75
RMS= 1.6
Julian Day 5007.5
12:01 9/16/2014

Phosphate Phosphorus Profile Plots



78



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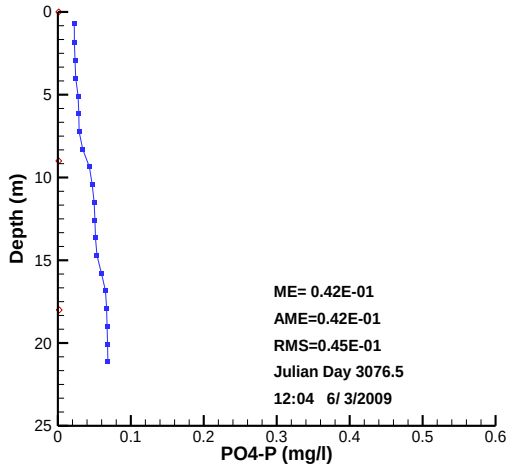
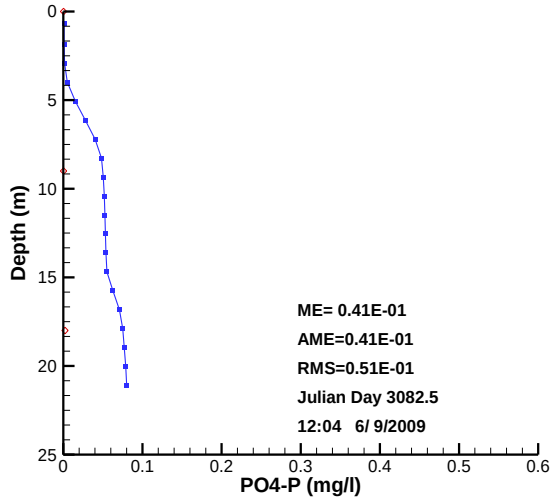
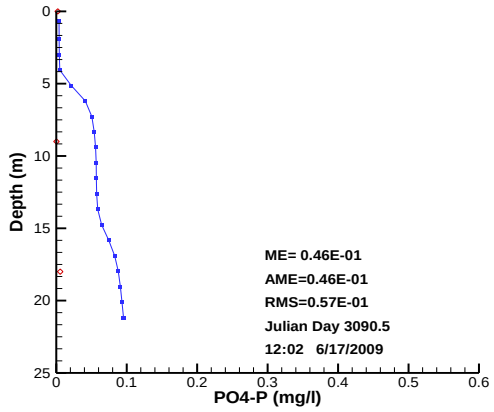
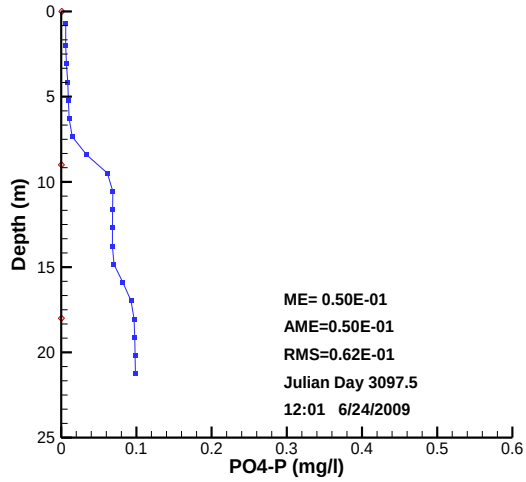




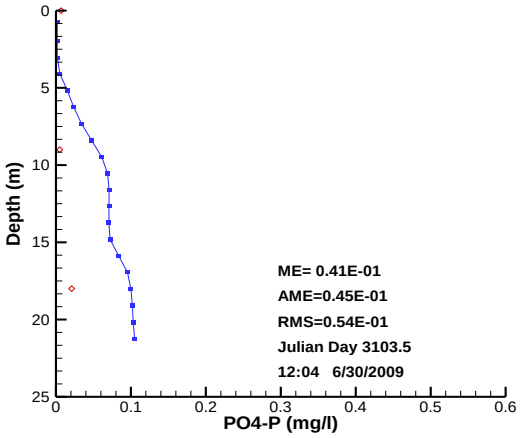
80



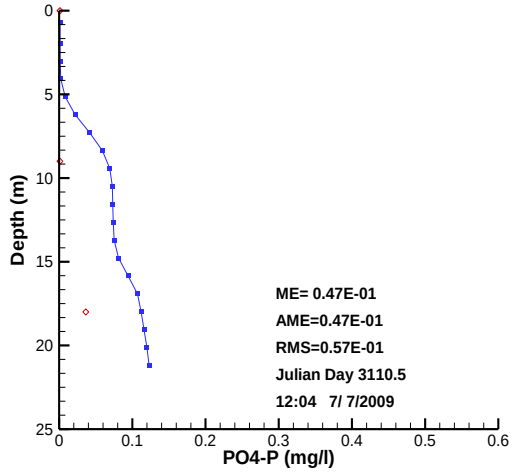
81



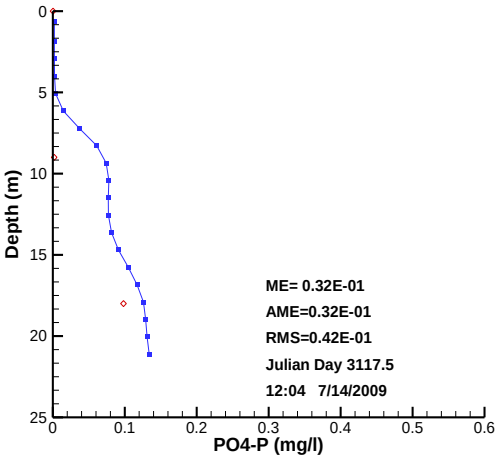
82



83



84



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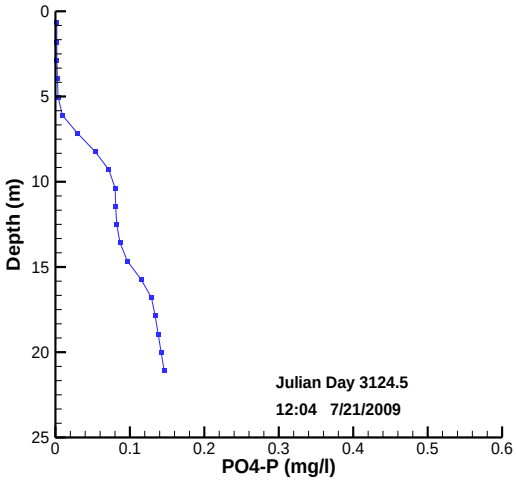
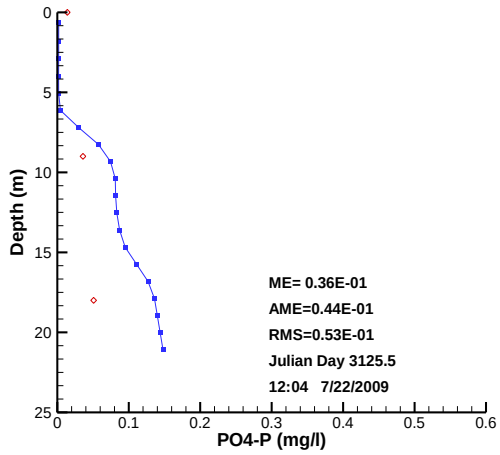
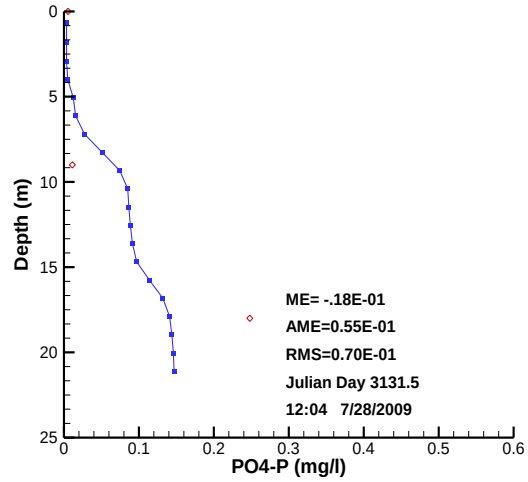


86



87



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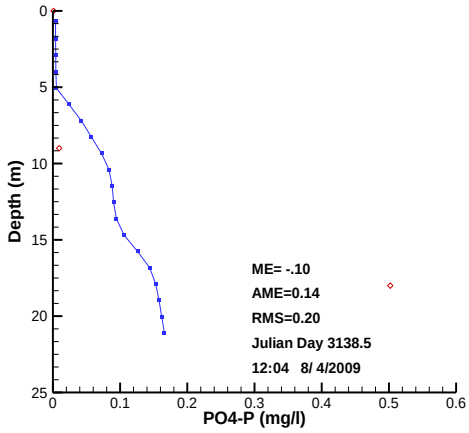
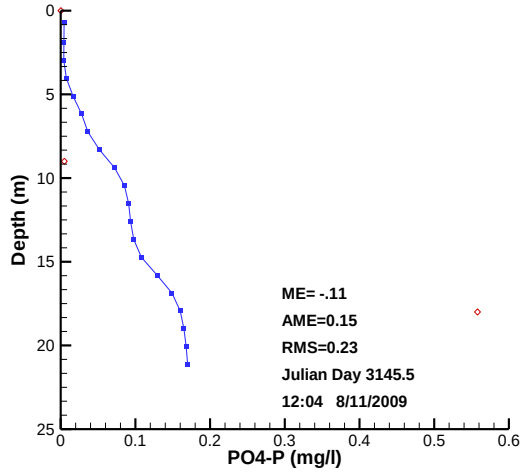
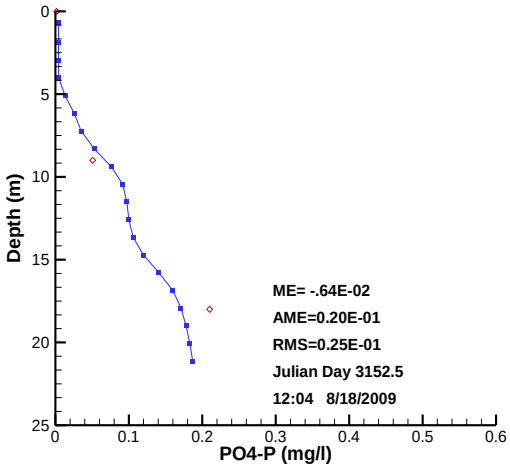


89

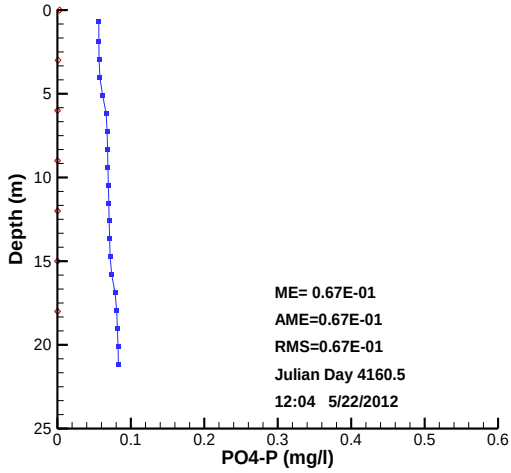


90

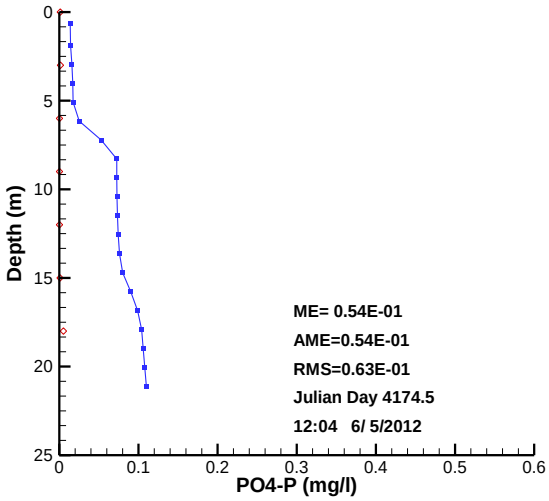
91

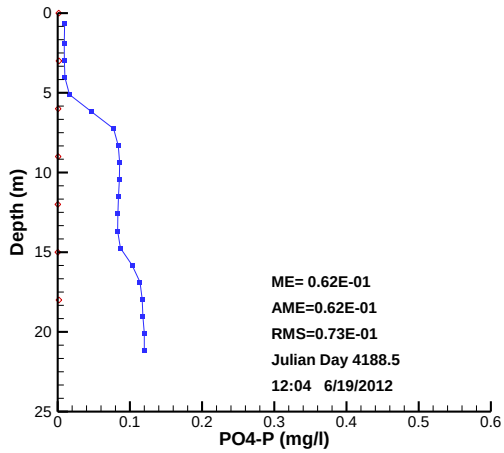


92

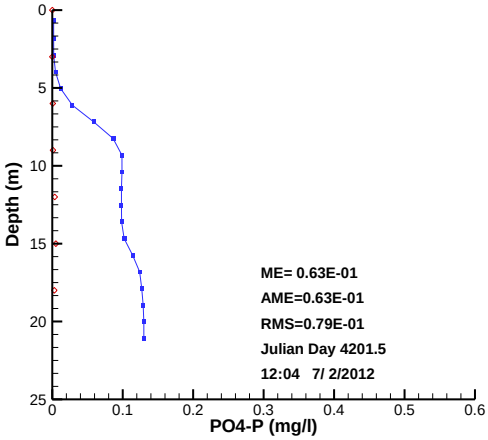


93





94



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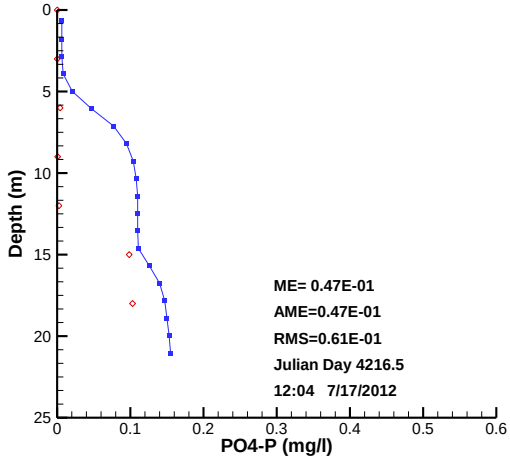
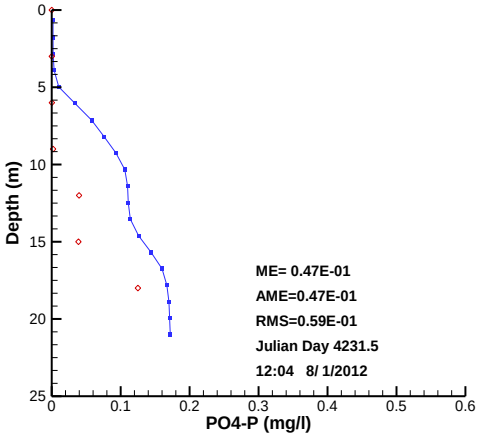


96

97



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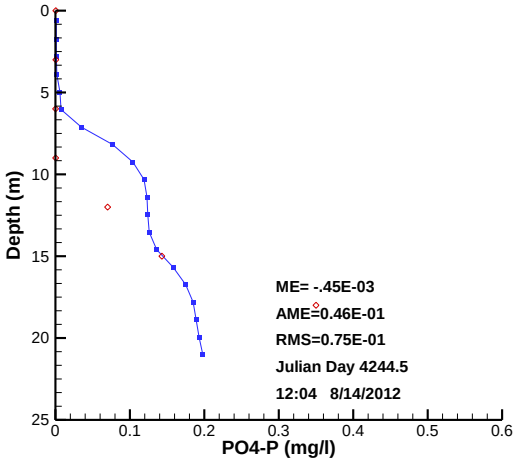

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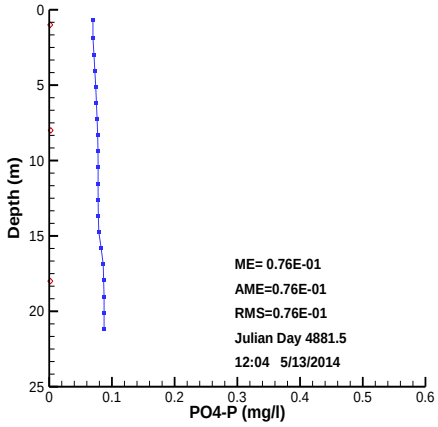

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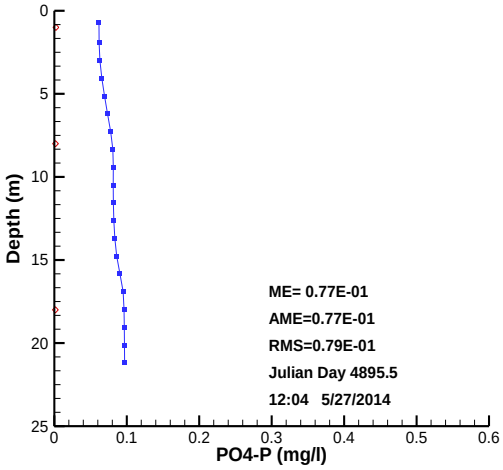

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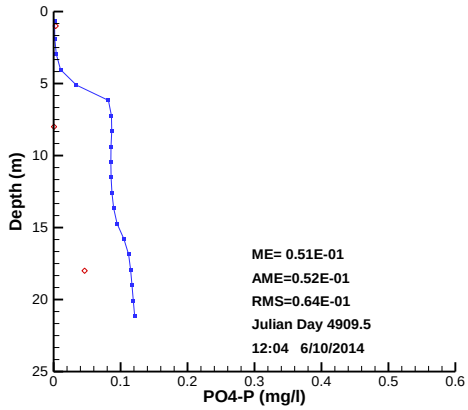
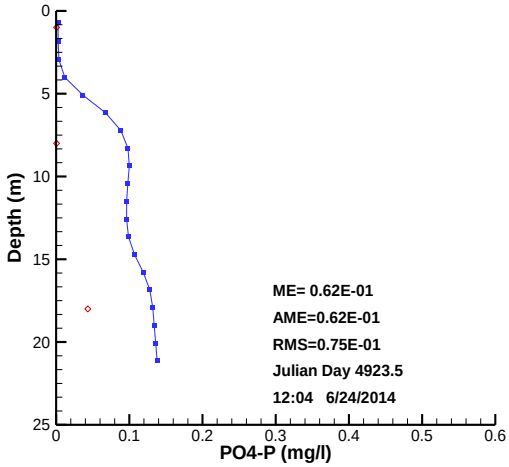
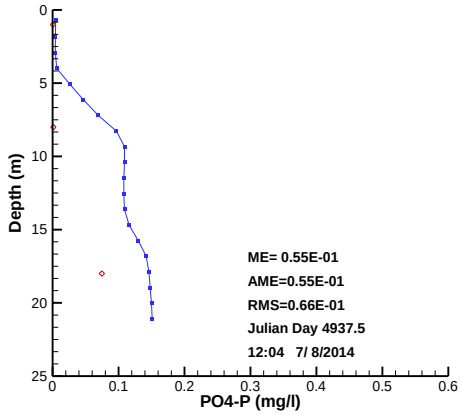


102



103



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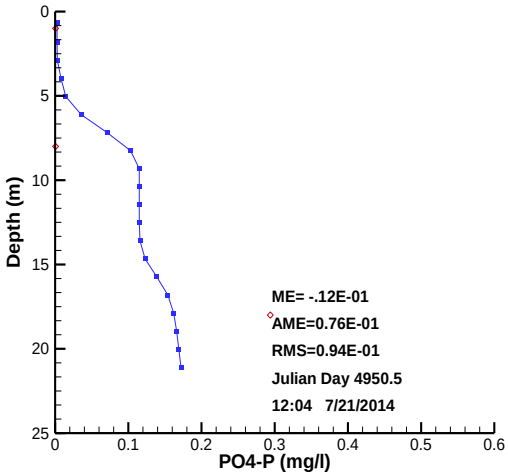
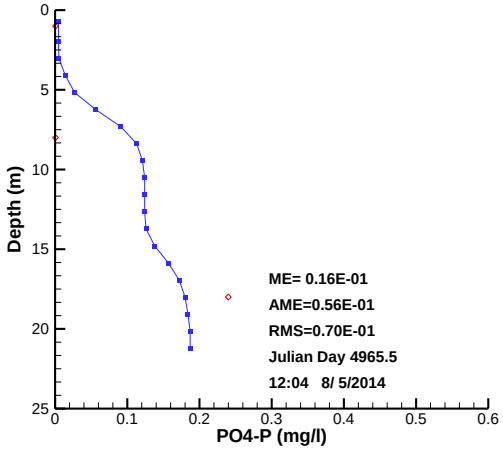
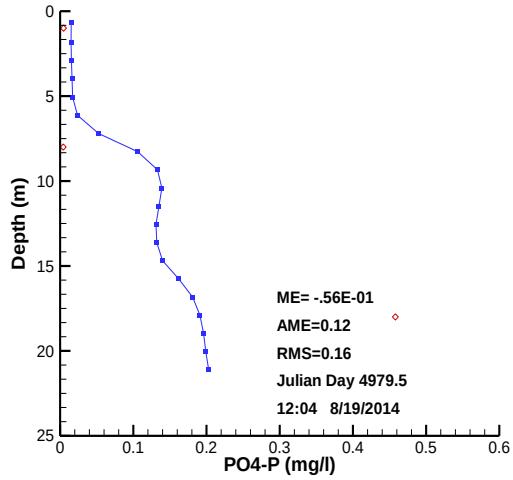
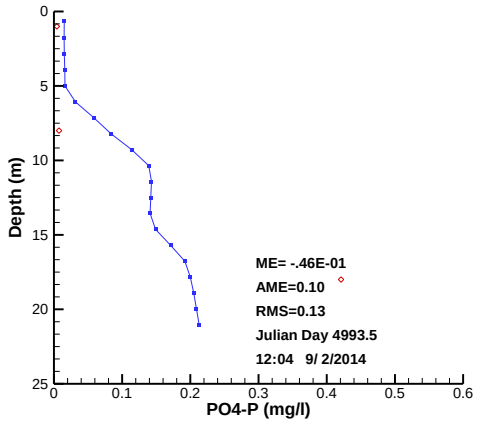


105

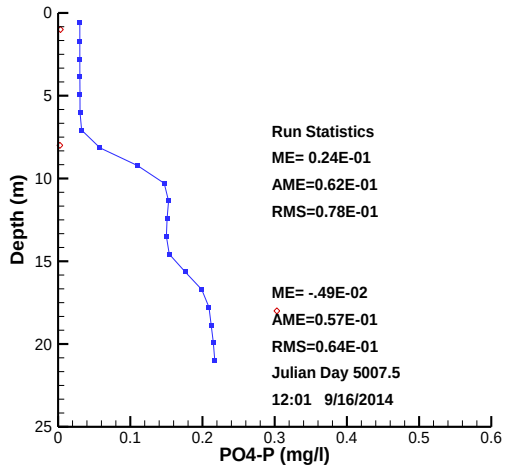

Depth (m)
PO4-P (mg/l)
ME= 0.16E-01
AME=0.56E-01
RMS=0.70E-01
Julian Day 4965.5
12:04 8/ 5/2014


Depth (m)
PO4-P (mg/l)
ME= -.56E-01
AME=0.12
RMS=0.16
Julian Day 4979.5
12:04 8/19/2014

106


Depth (m)
PO4-P (mg/l)
ME= -.46E-01
AME=0.10
RMS=0.13
Julian Day 4993.5
12:04 9/ 2/2014

107


Depth (m)
PO4-P (mg/l)
Run Statistics
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AME=0.62E-01
RMS=0.78E-01
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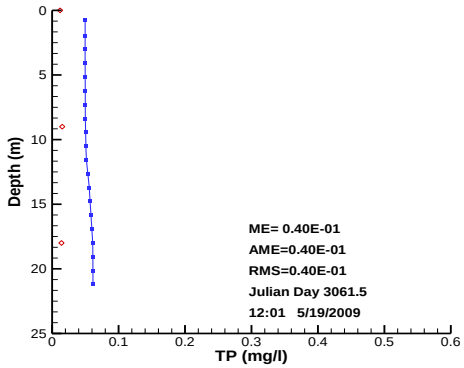
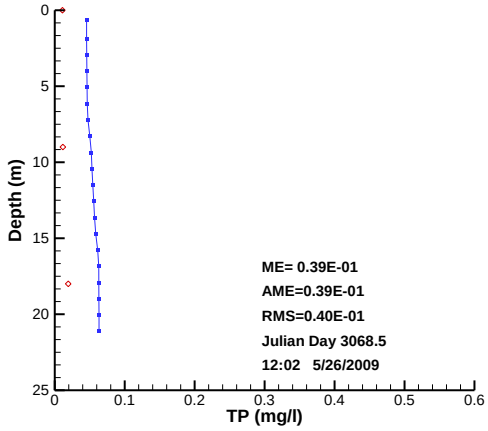
AME=0.57E-01
RMS=0.64E-01
Julian Day 5007.5
12:01 9/16/2014

108

Total Phosphorus Profile Plots

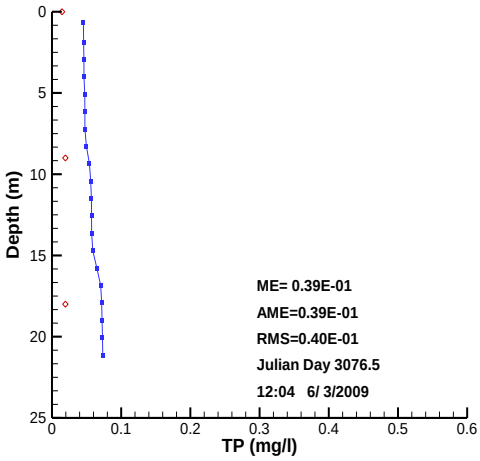


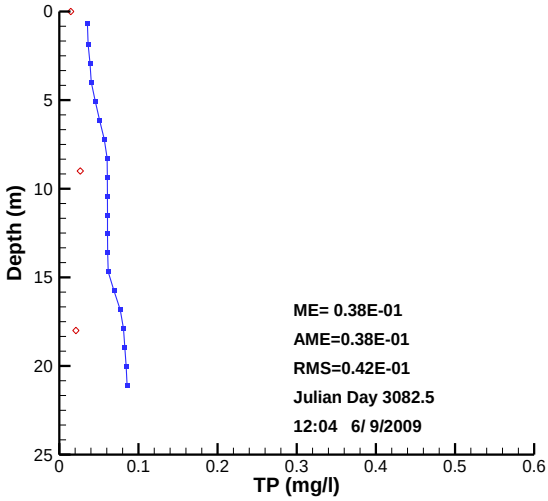
109



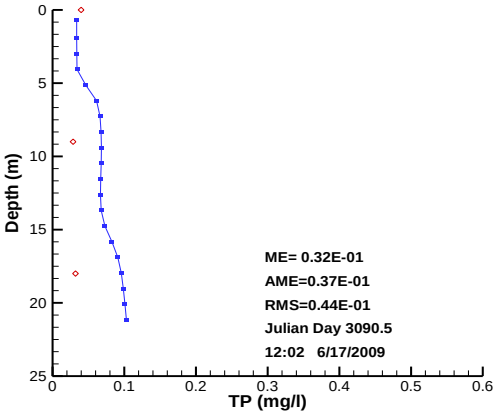
110

111

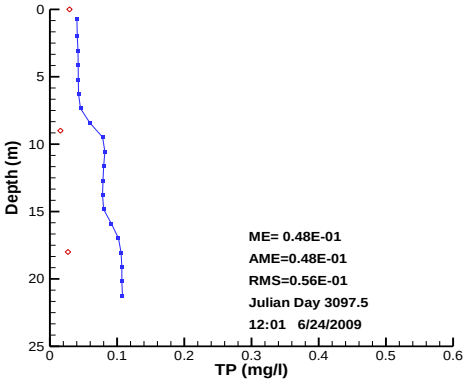




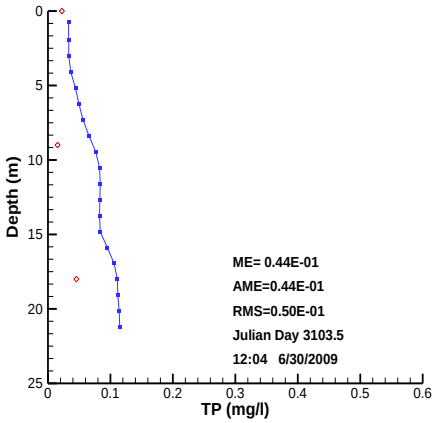
112



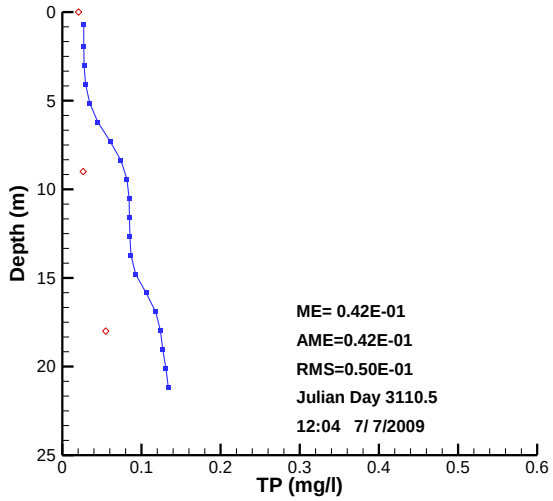
113



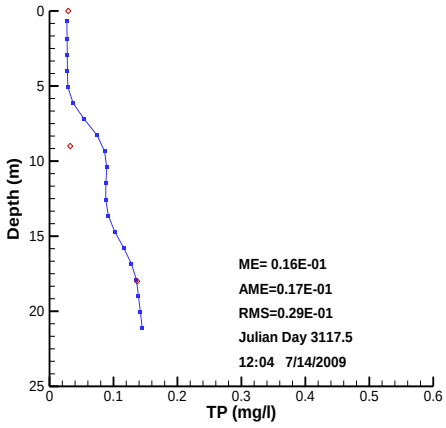
114



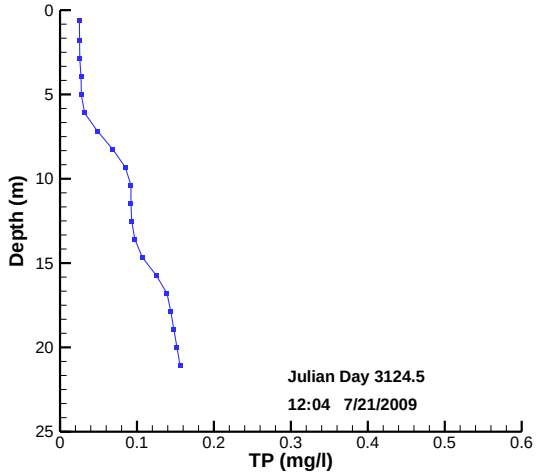
115



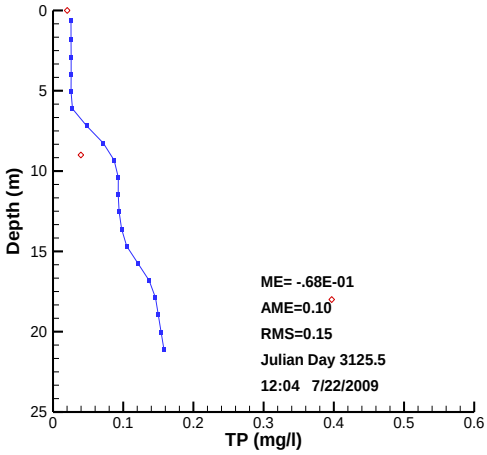
116



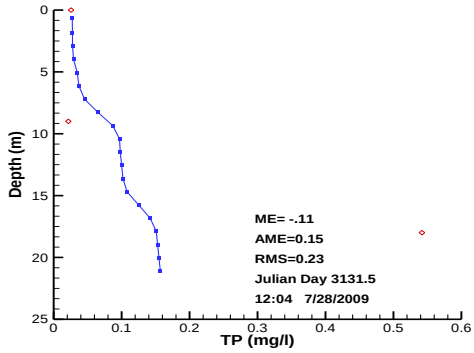
117



118

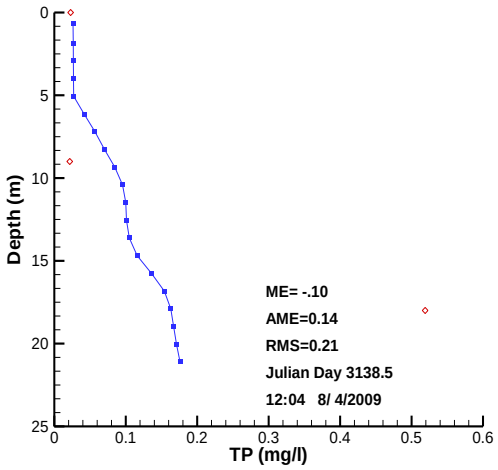


119



120

121



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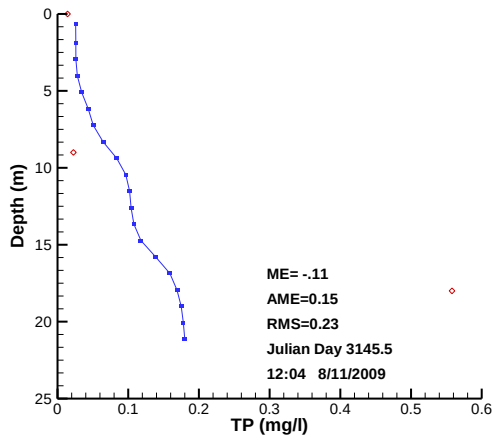

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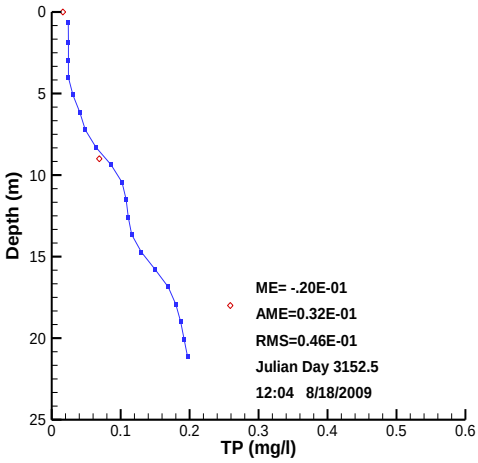
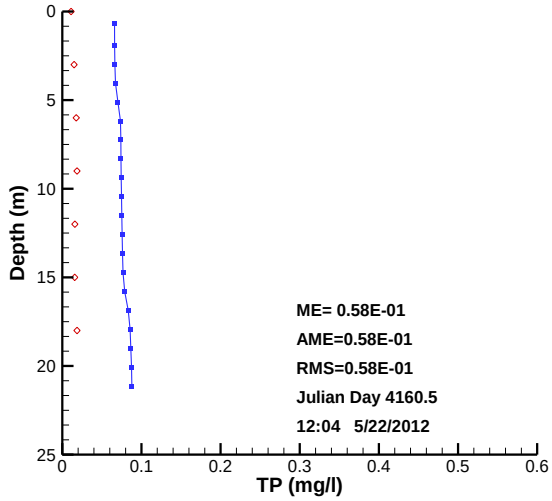
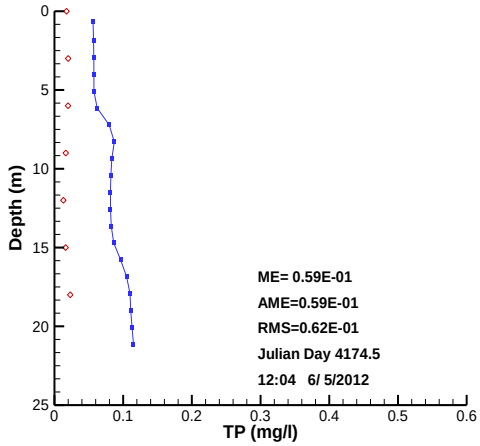
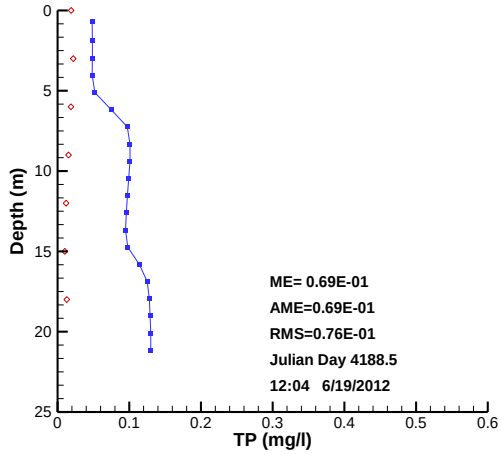




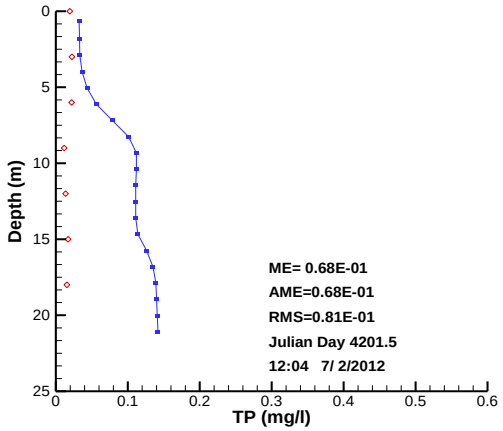
124



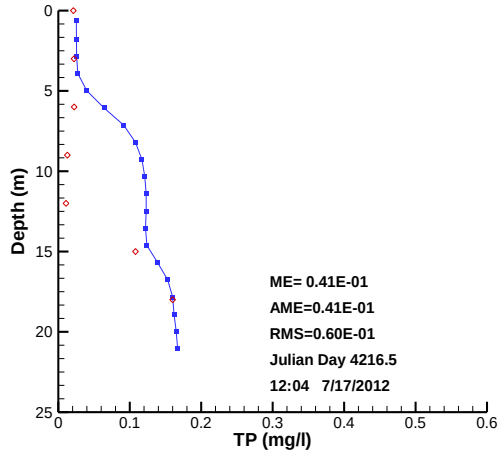
125



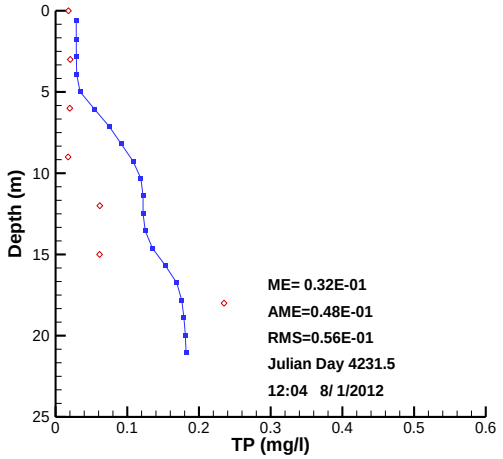
126



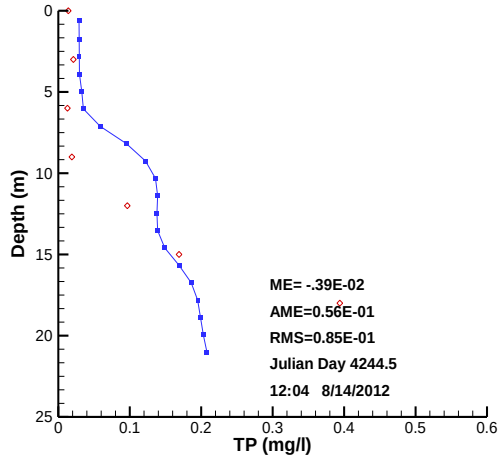
127



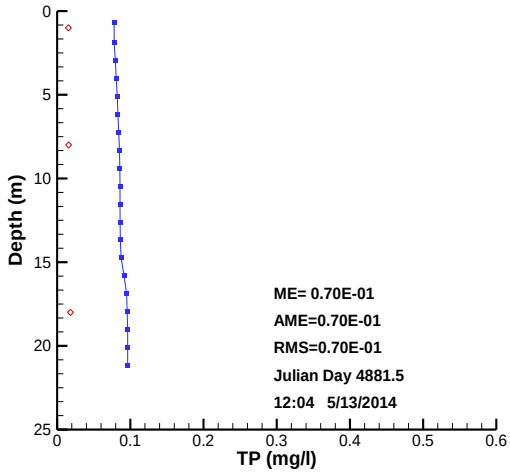
128



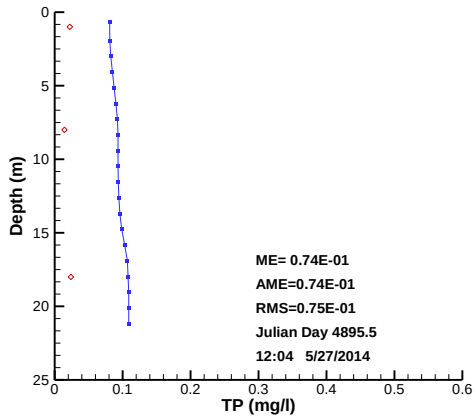
129



130



131



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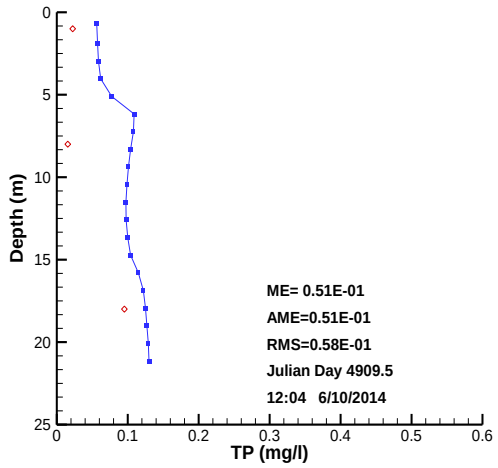

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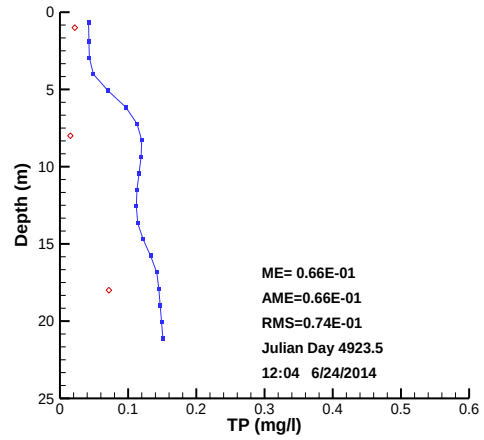

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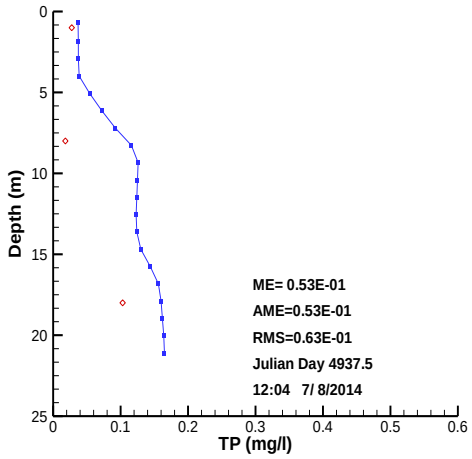

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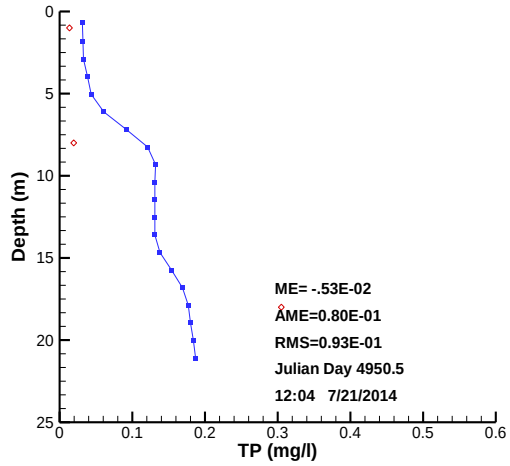

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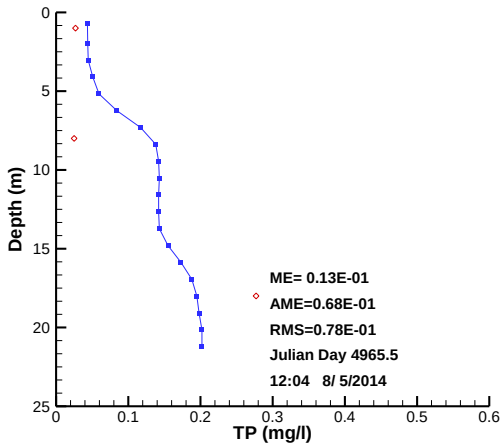

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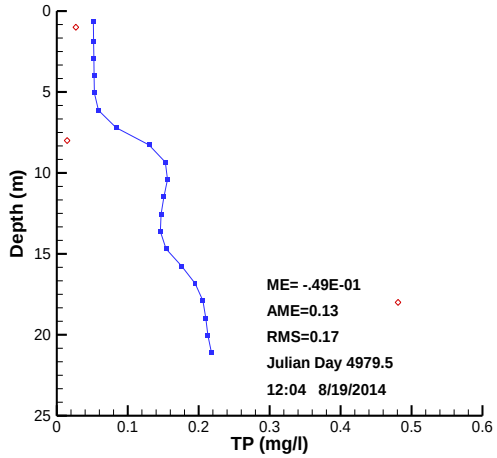

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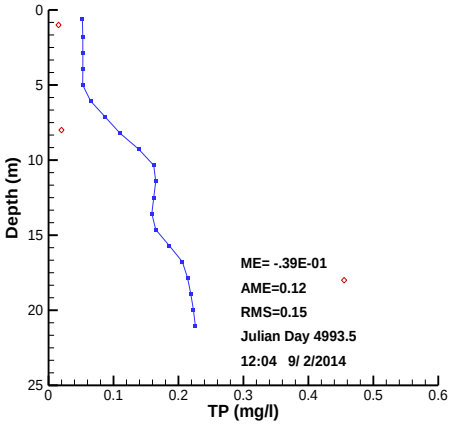

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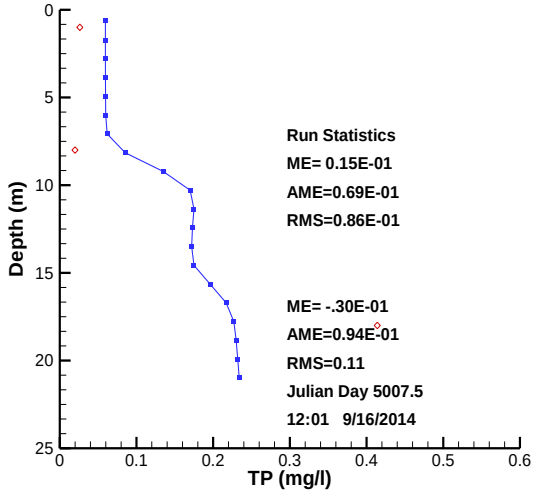

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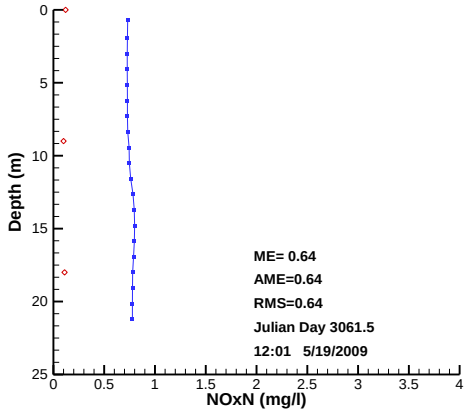
Nitrate Plus Nitrite Nitrogen Profile Plots



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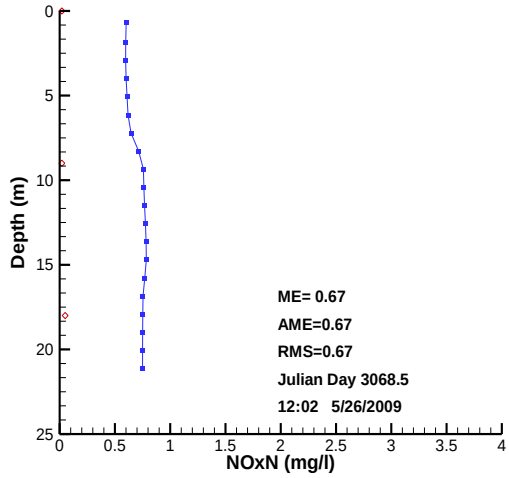

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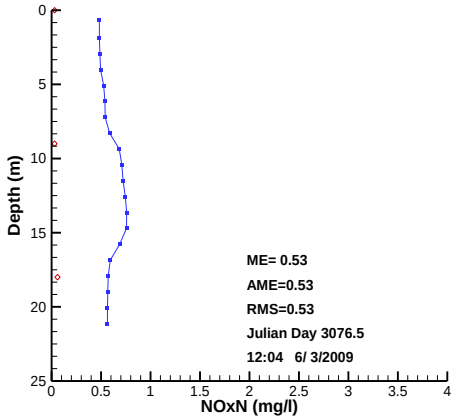

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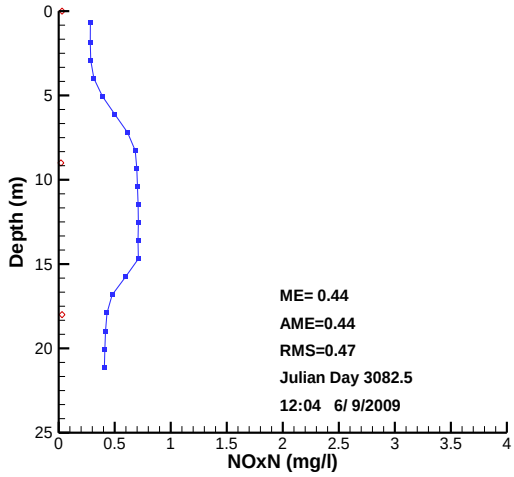

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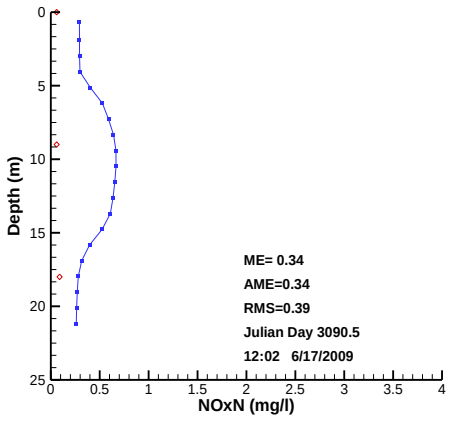

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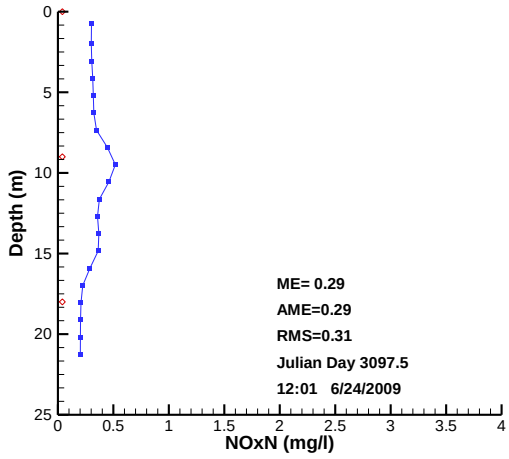

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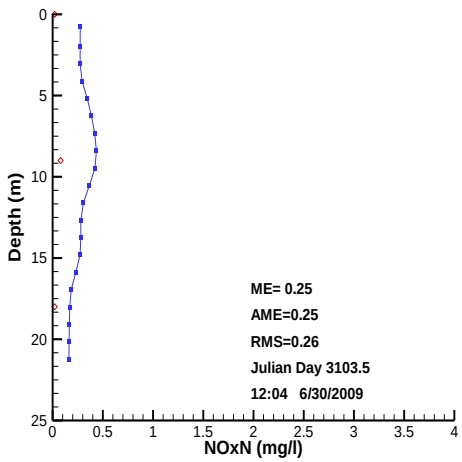

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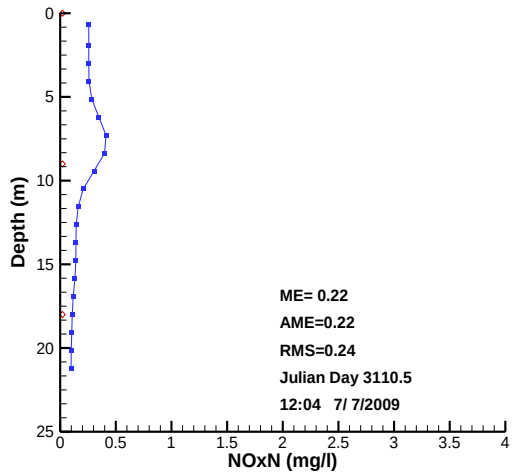

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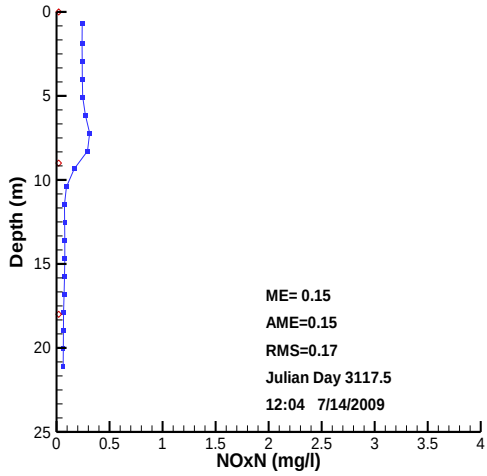

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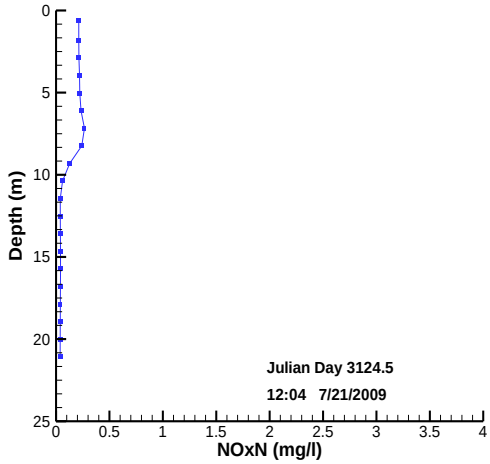

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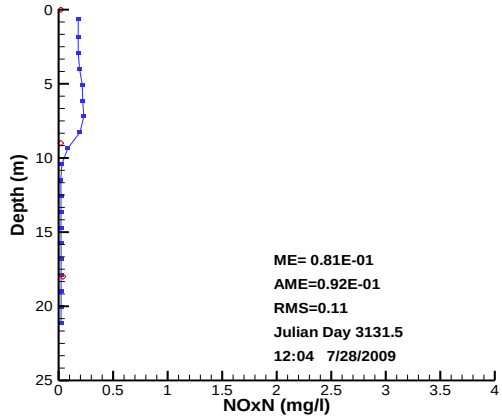

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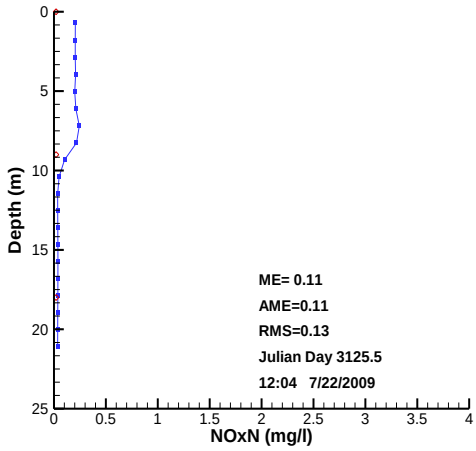

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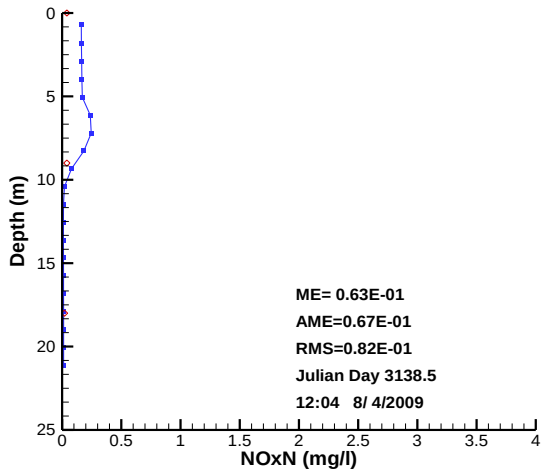

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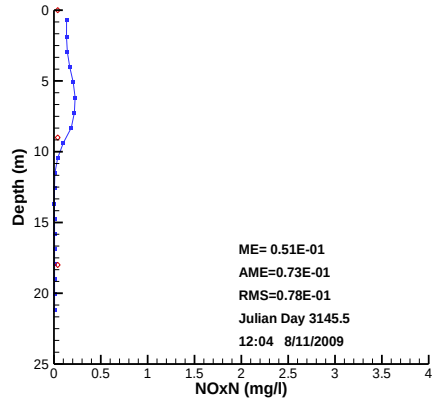

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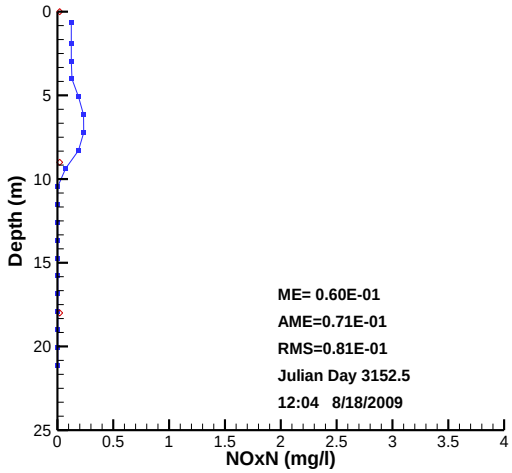

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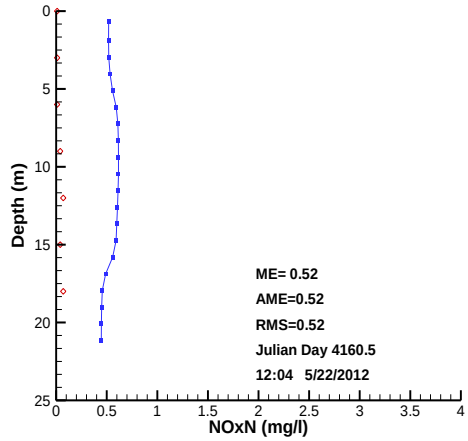

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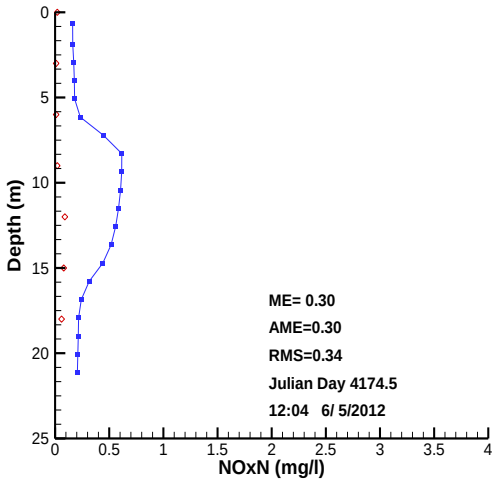

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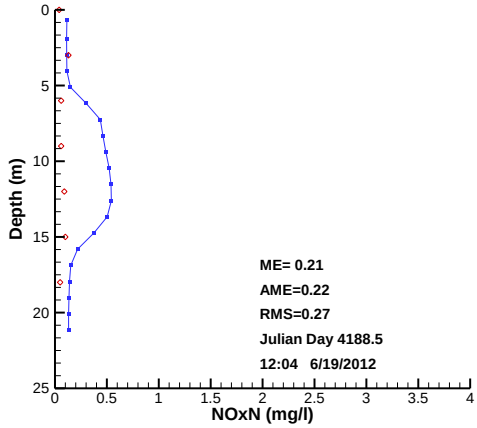

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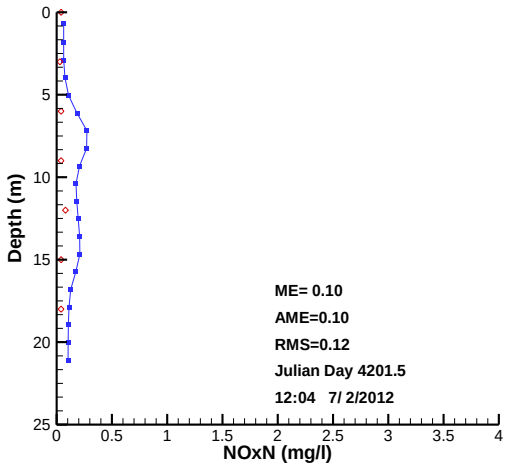

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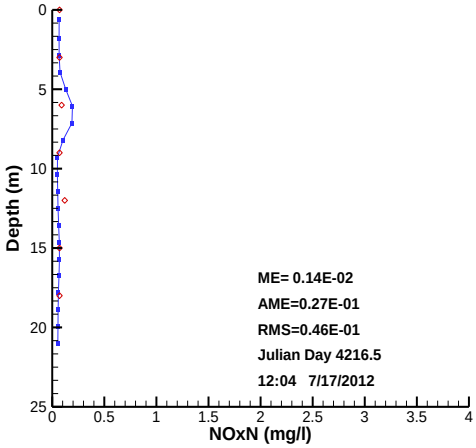

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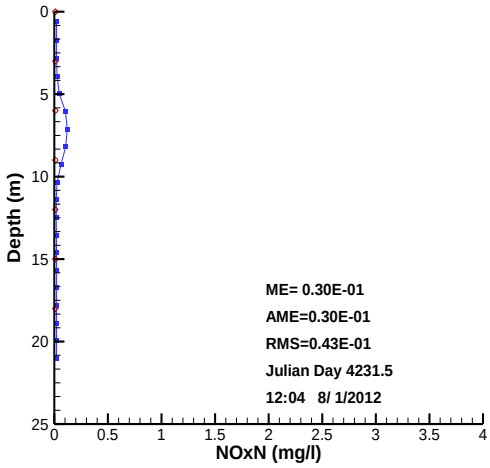

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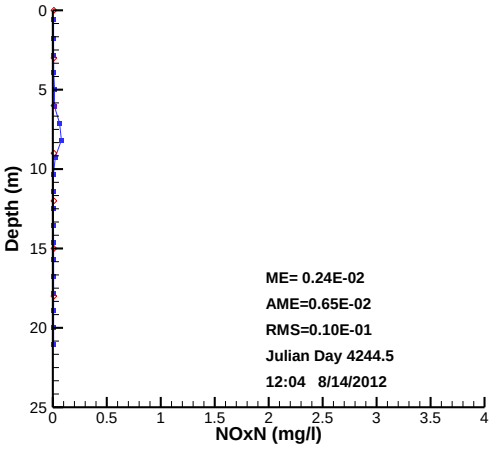

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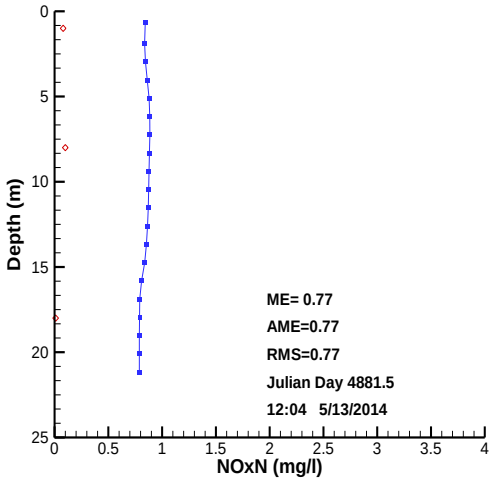

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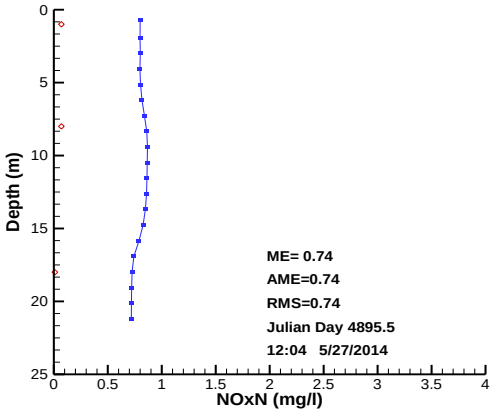

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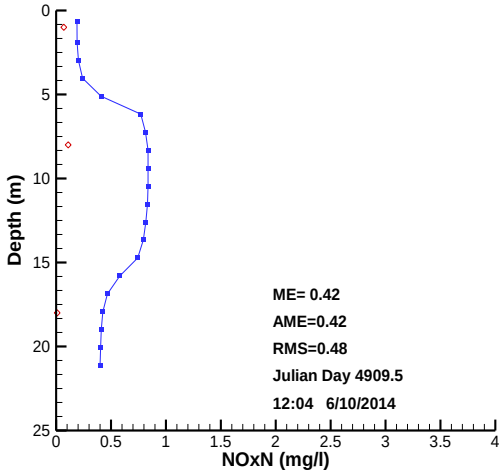

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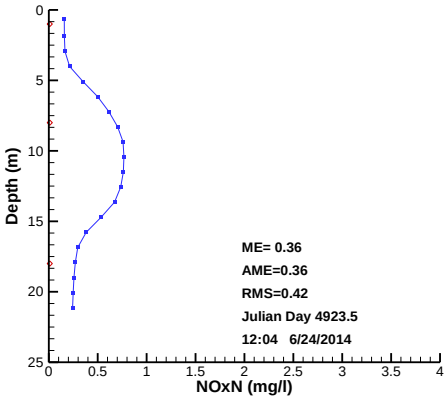

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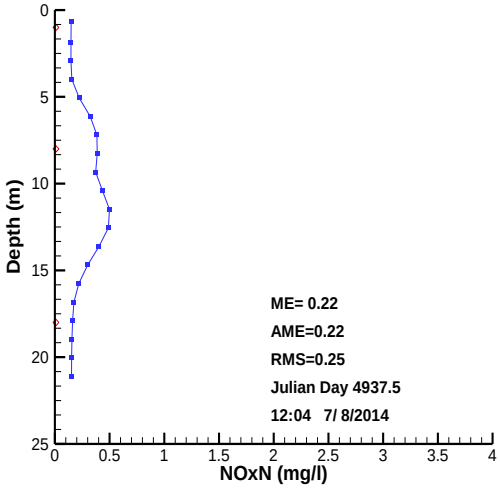

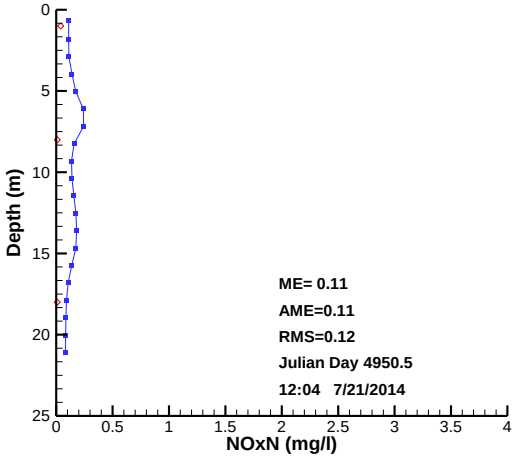

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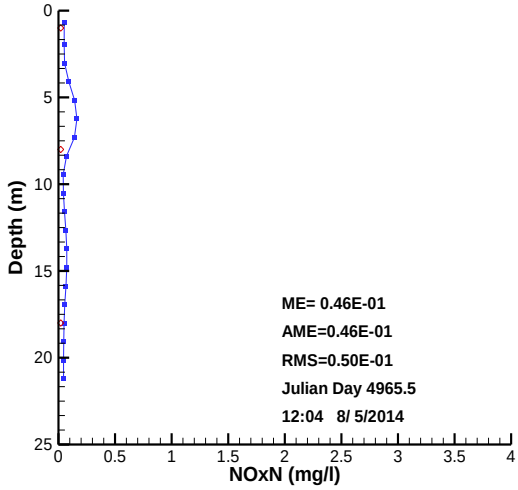

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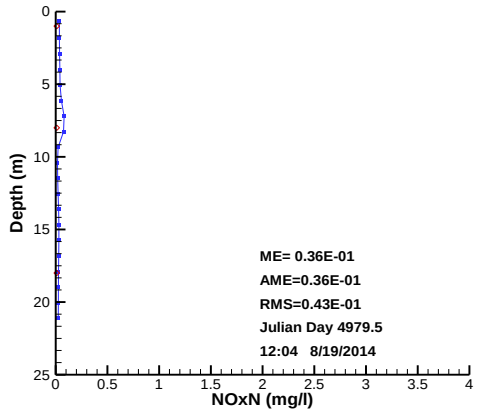

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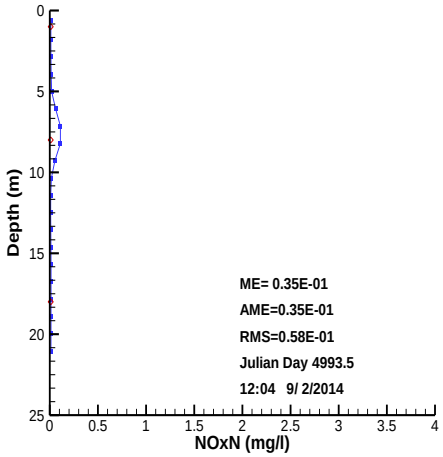

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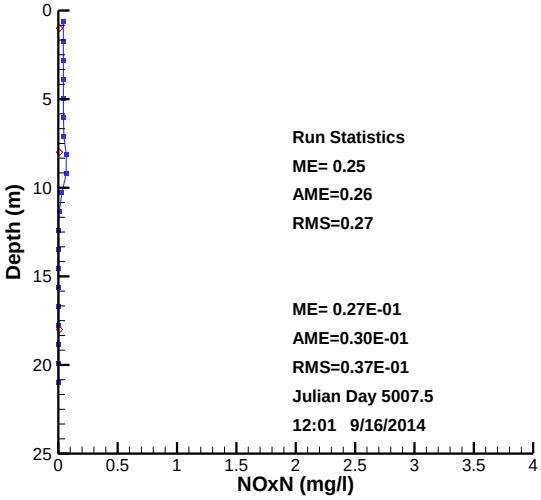

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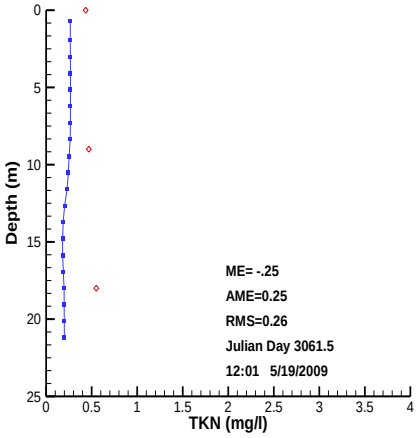
Total Kjeldahl Nitrogen Profile Plots



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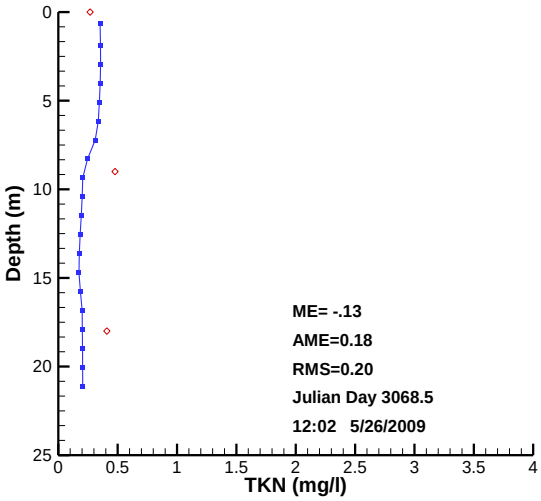

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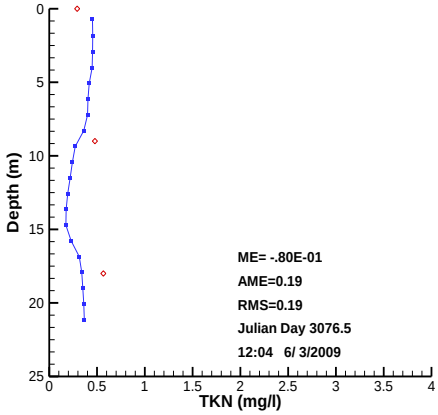

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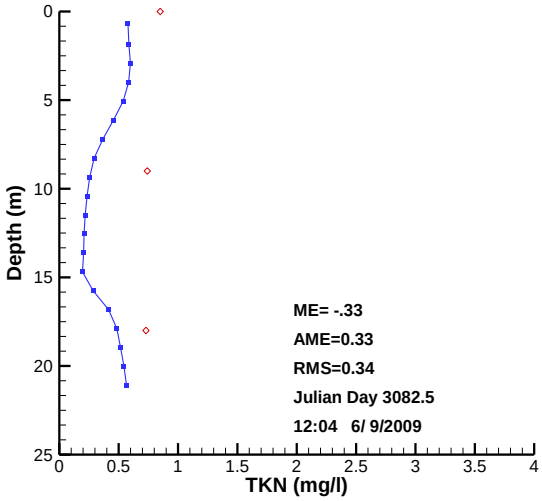

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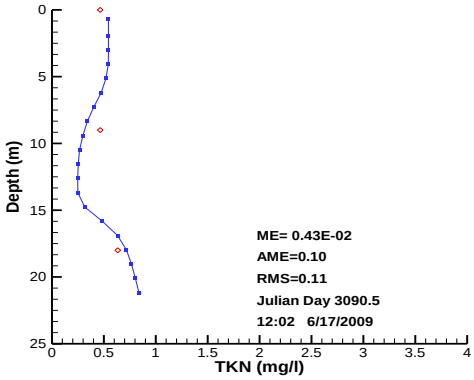

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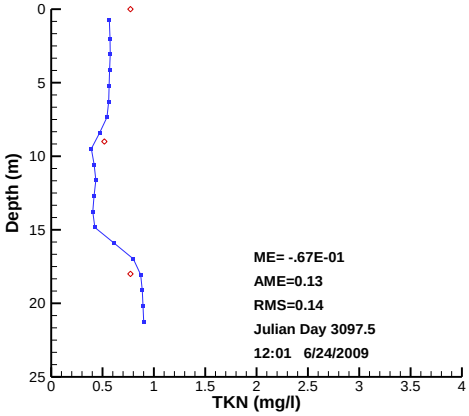

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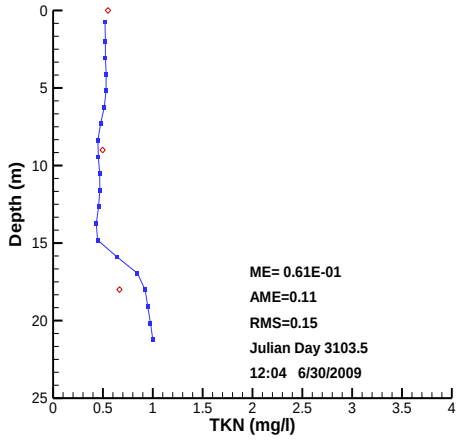

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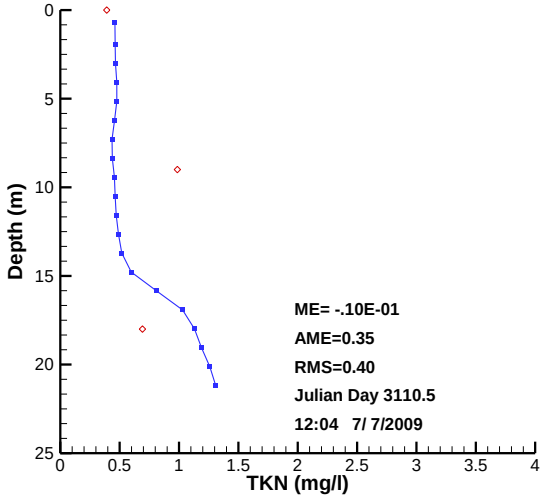

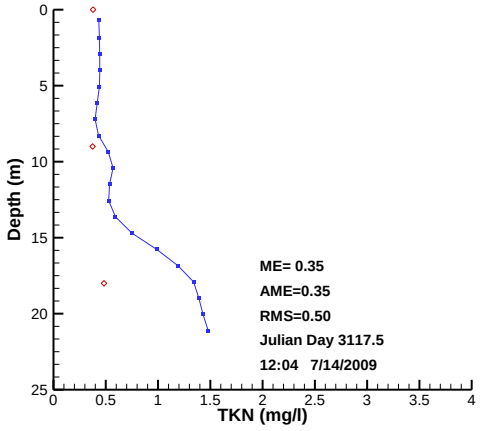

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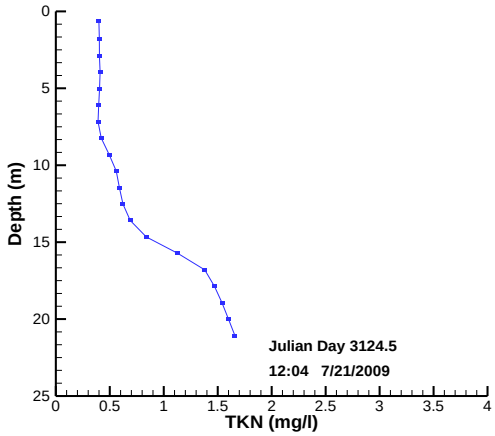

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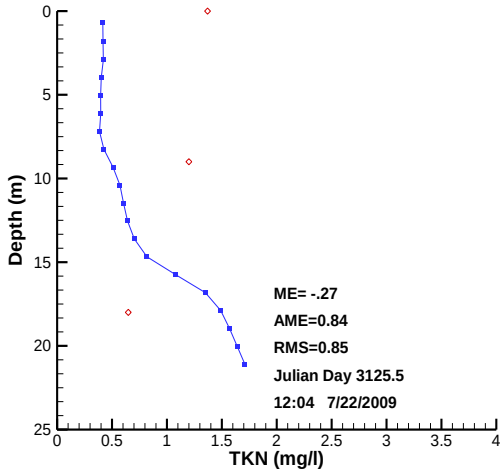

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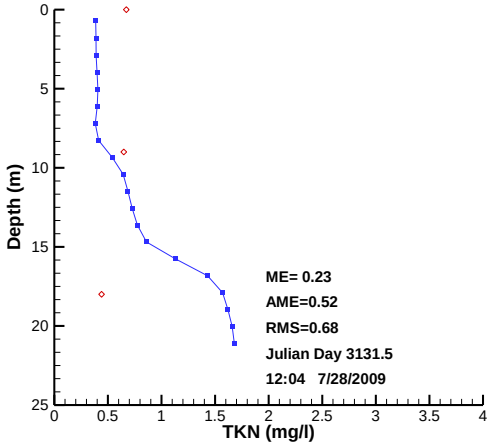

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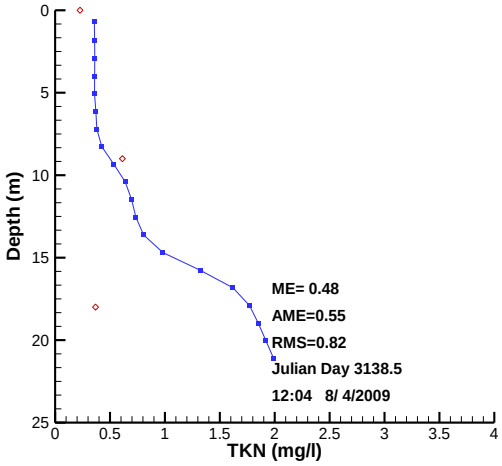

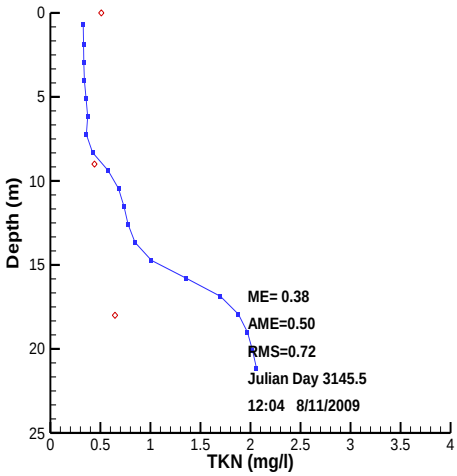

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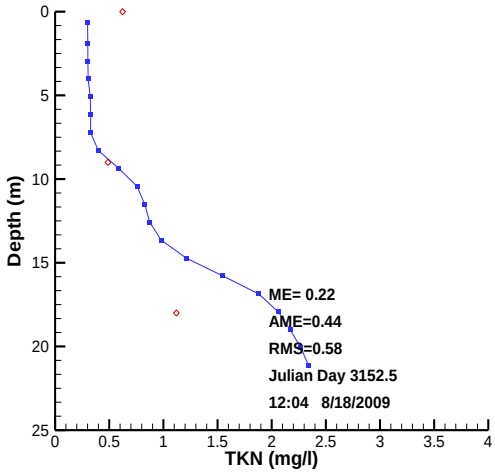

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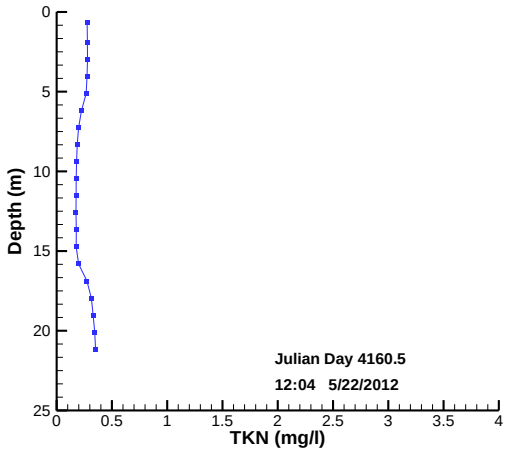

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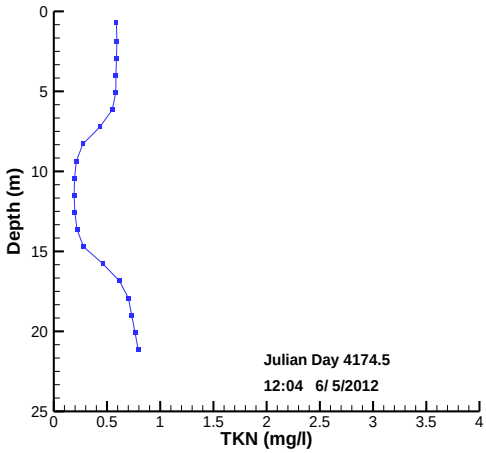

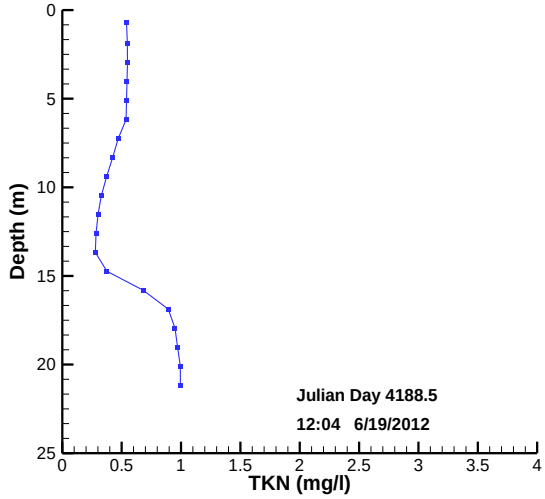

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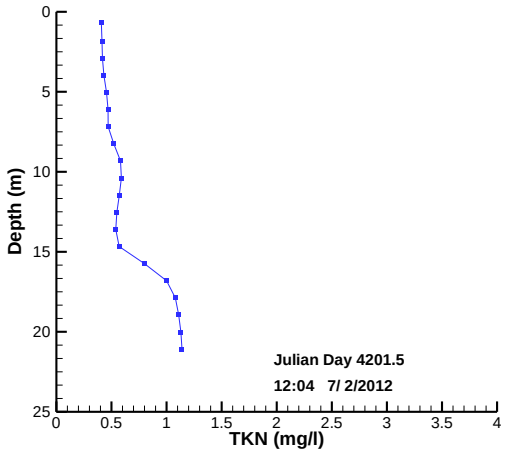

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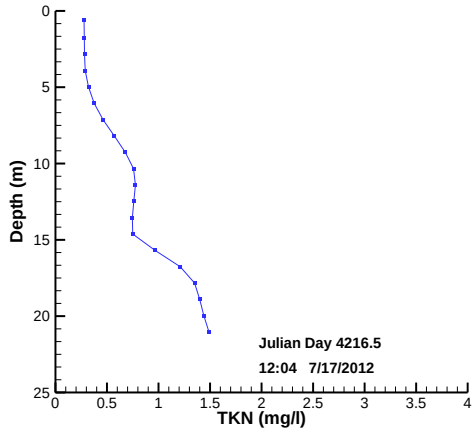

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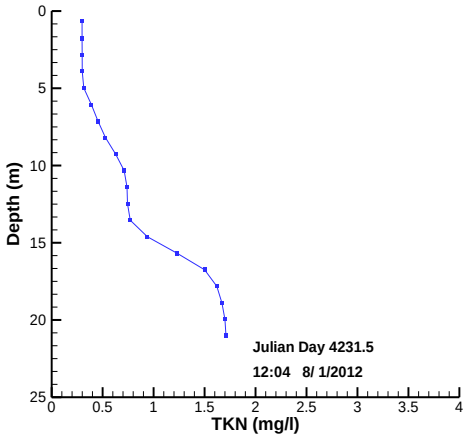

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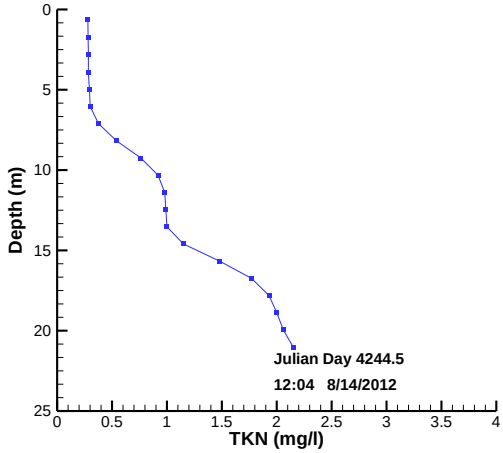

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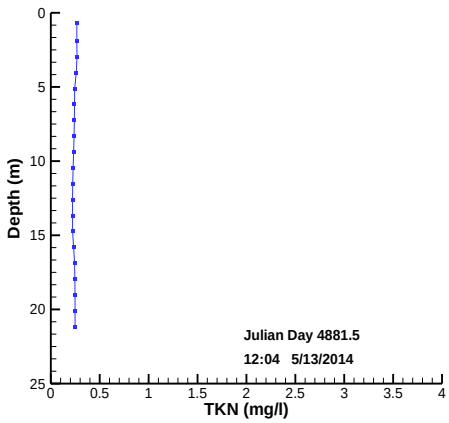

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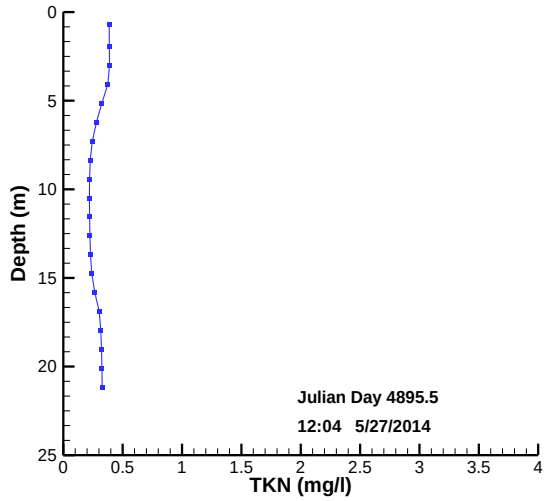

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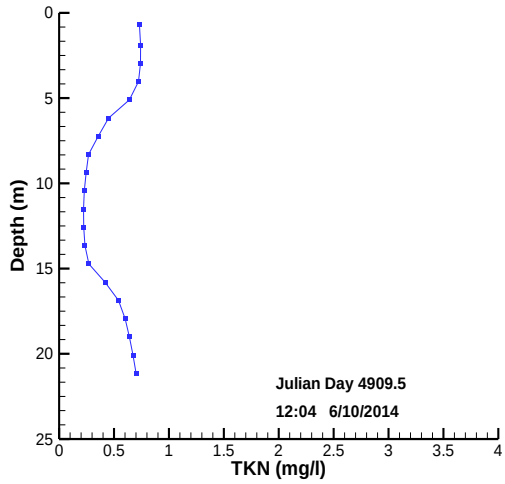

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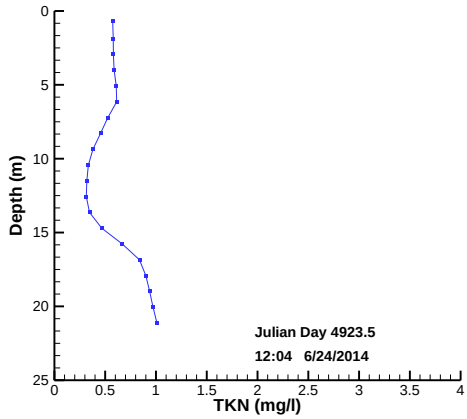

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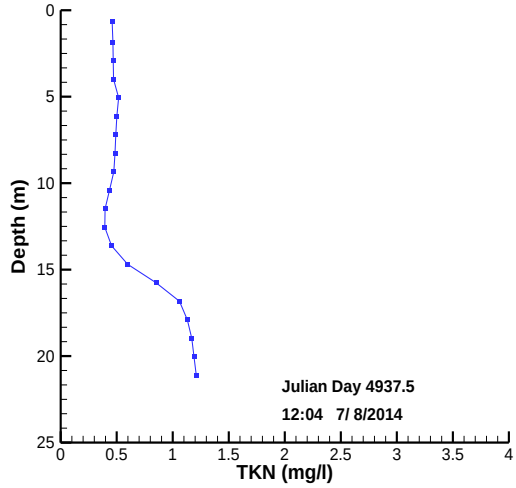

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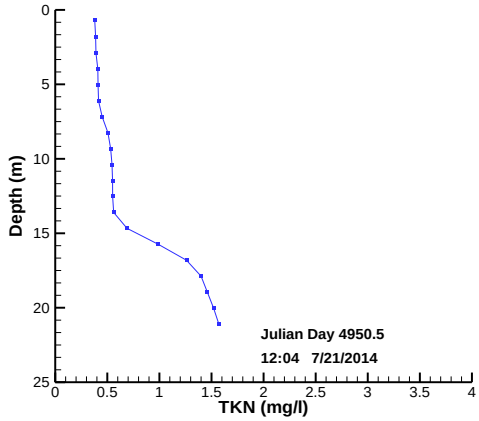

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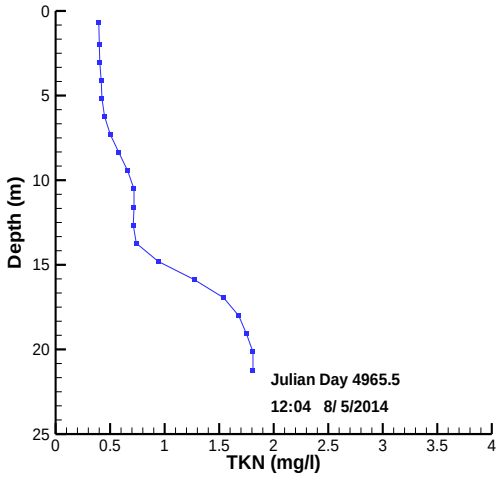

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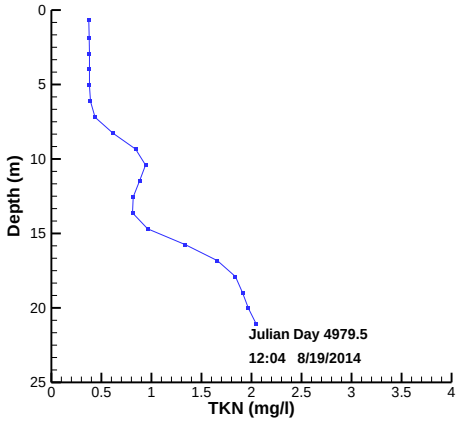

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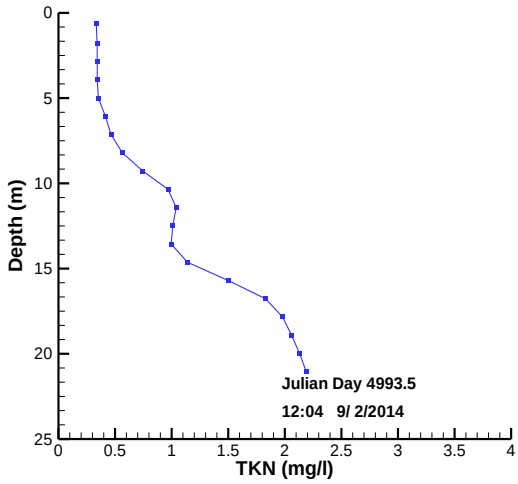

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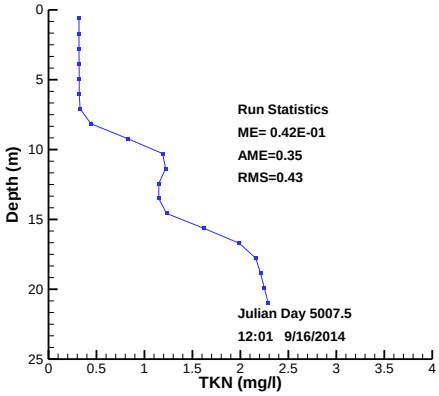

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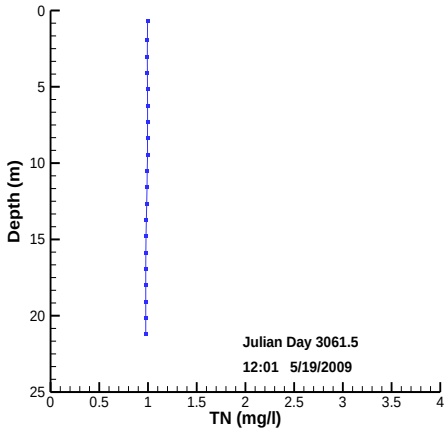
Total Nitrogen Profile Plots



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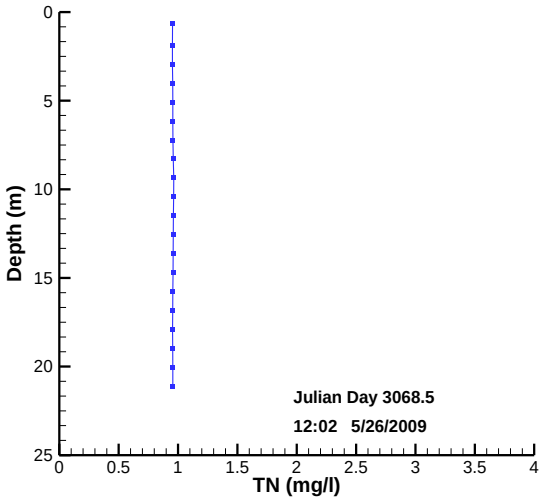

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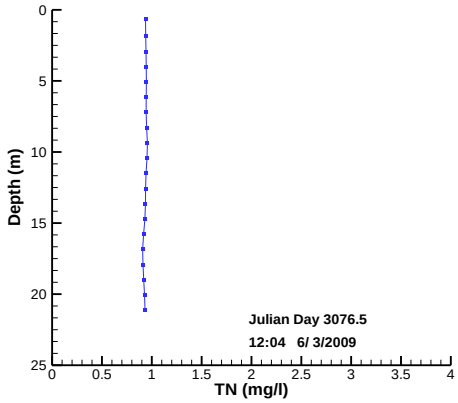

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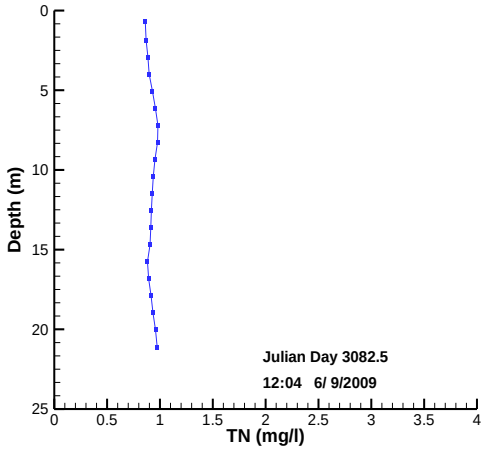

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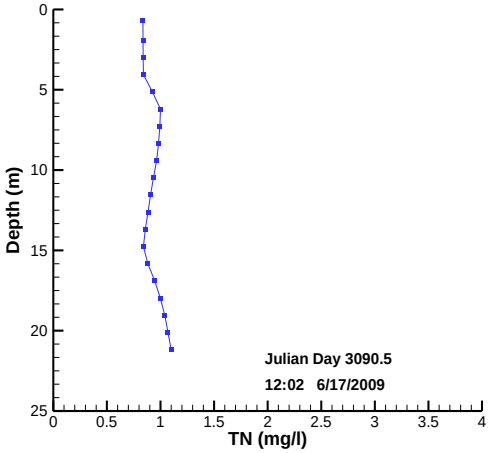

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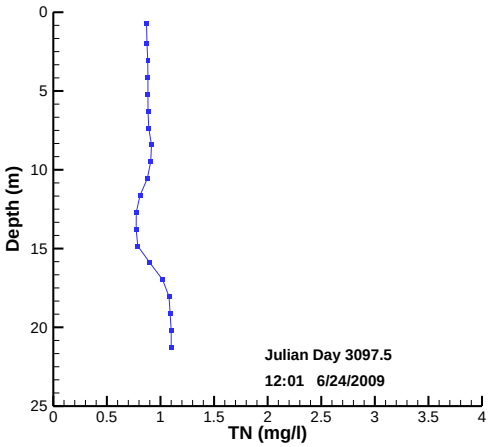

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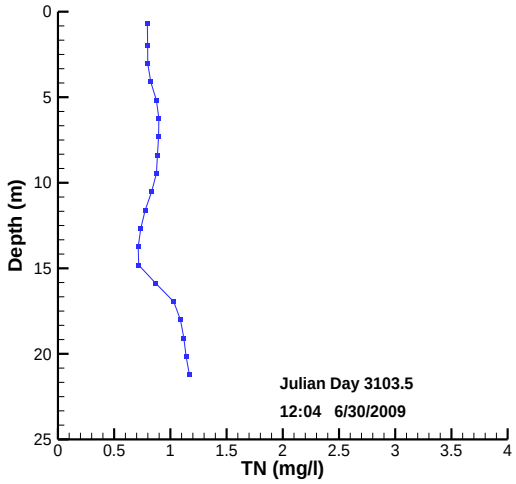

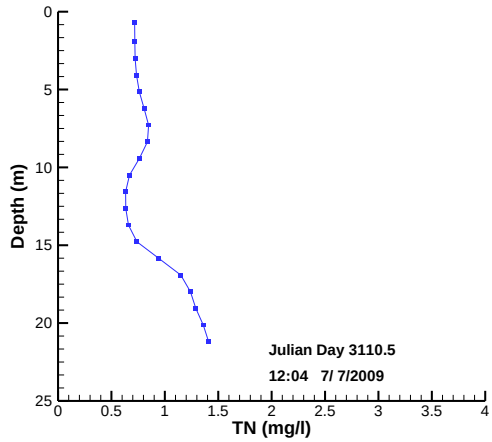

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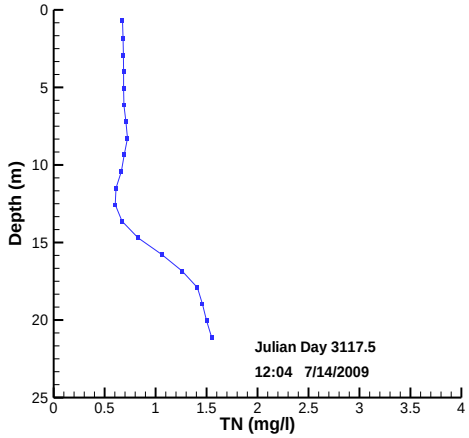

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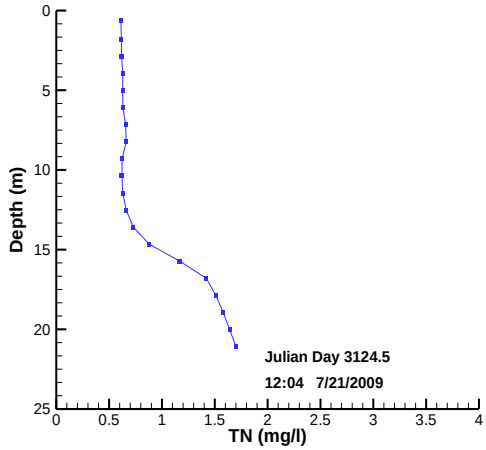

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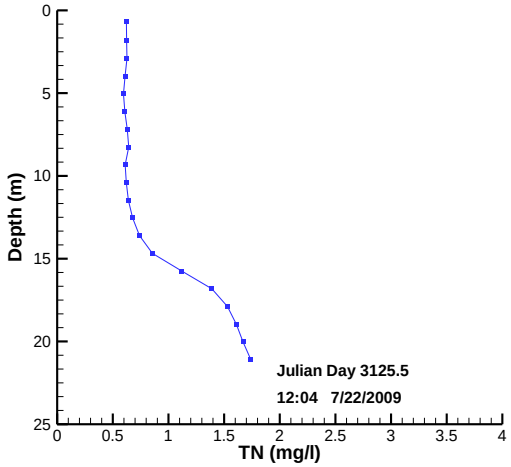

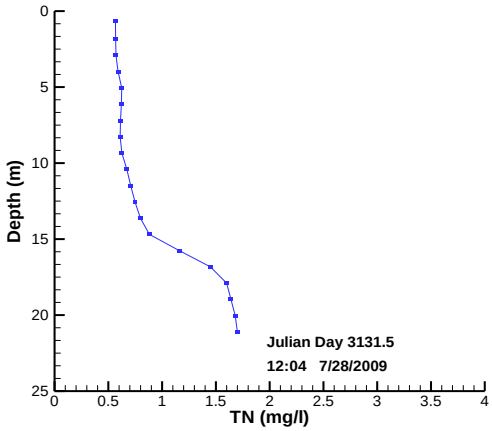

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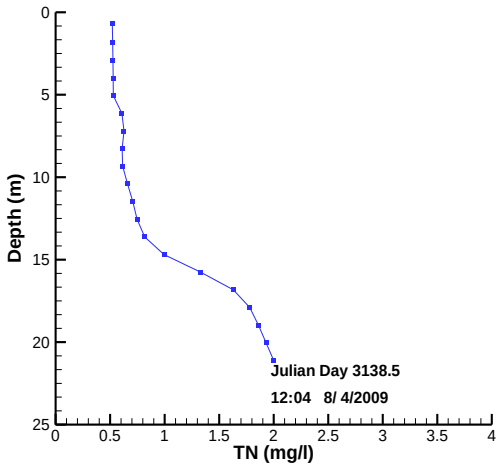

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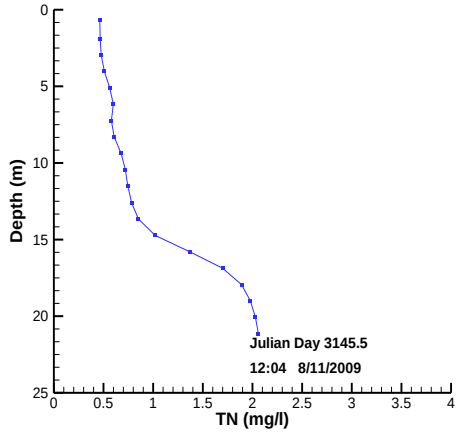

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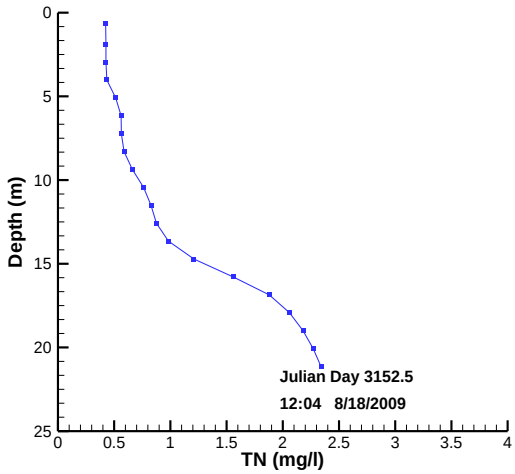

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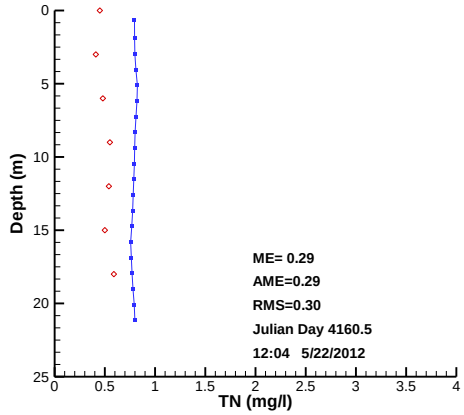

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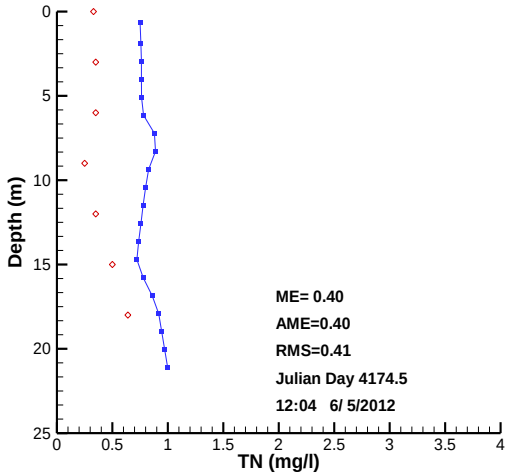

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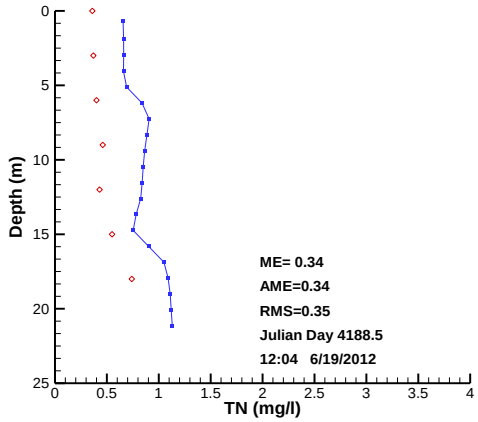

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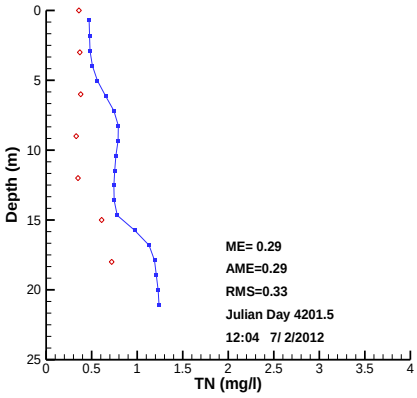

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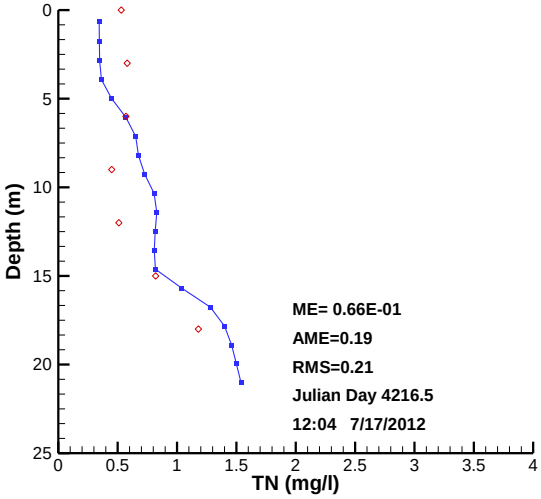

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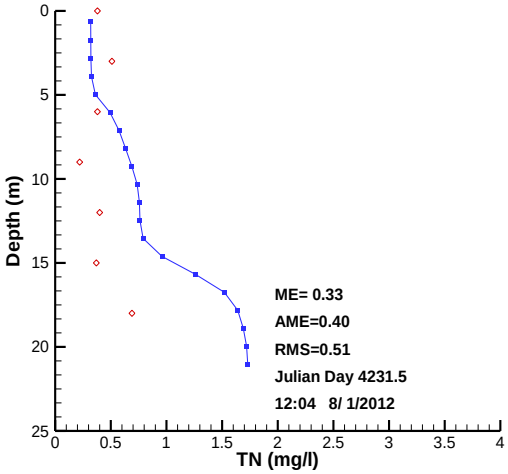

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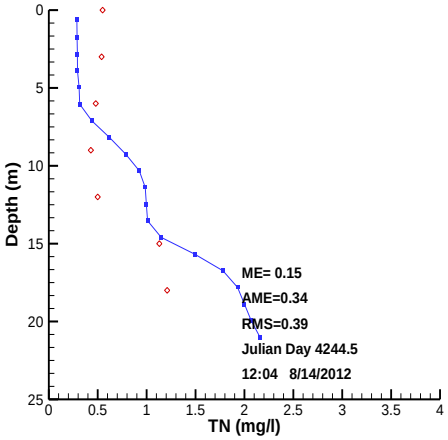

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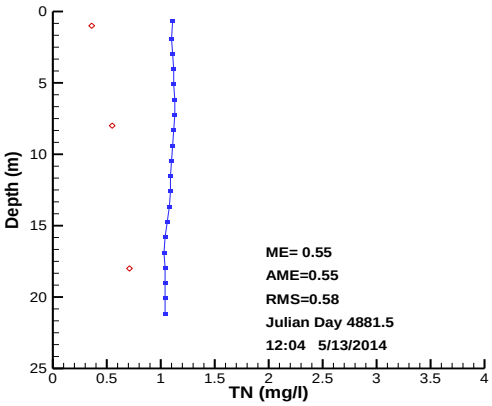

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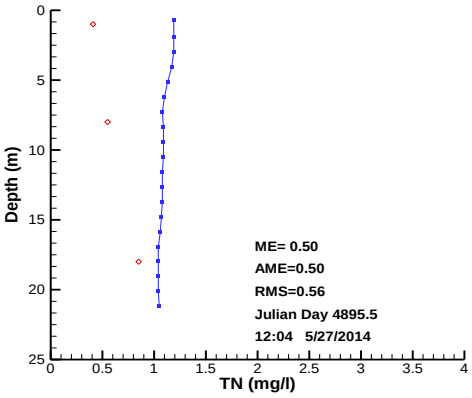

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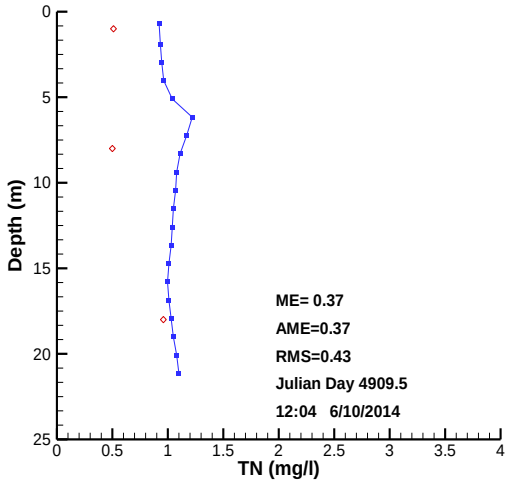

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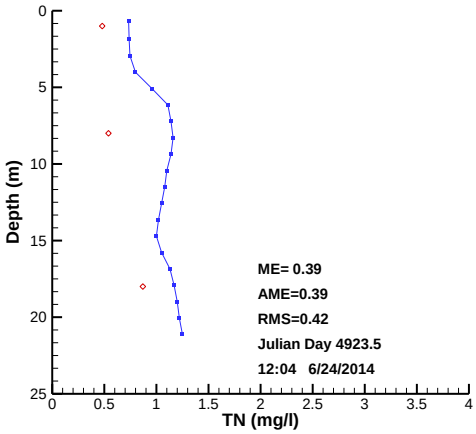

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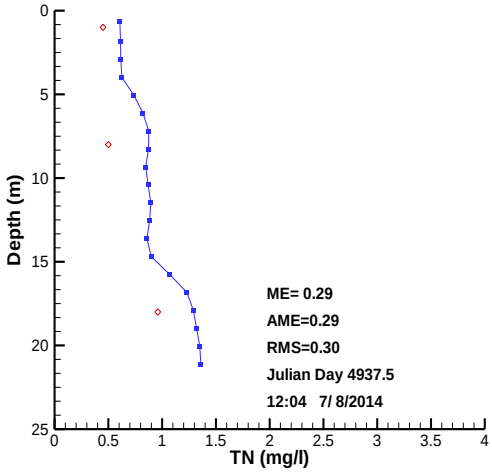

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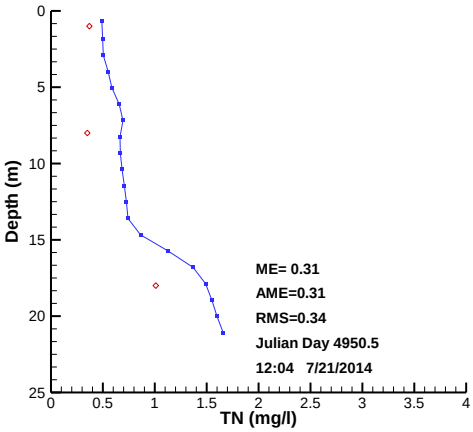

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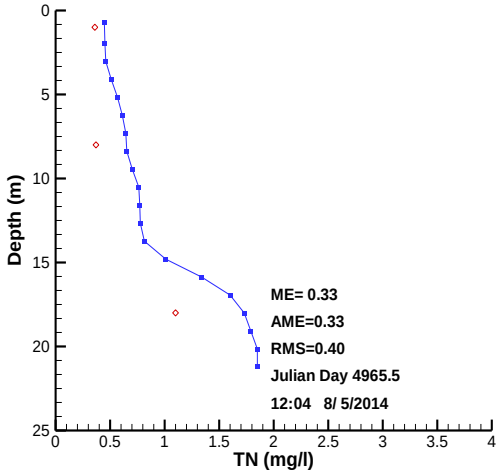

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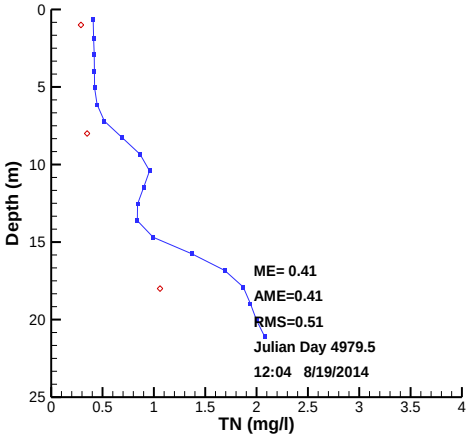

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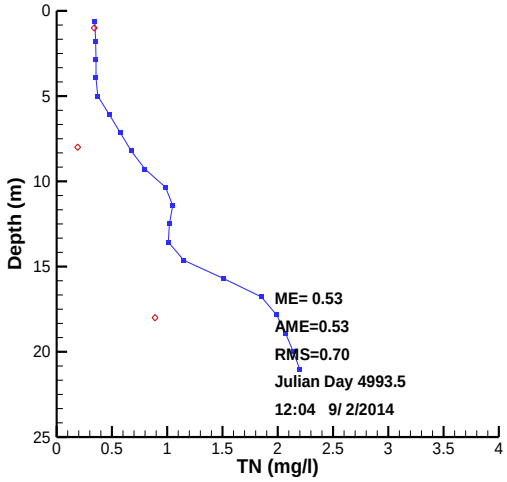

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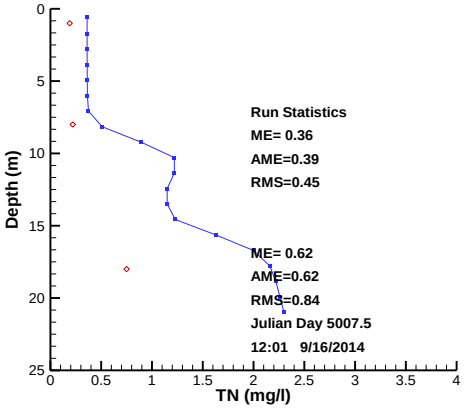

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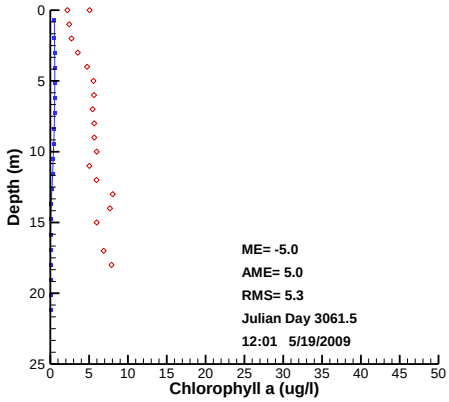
Chlorophyll-a Profile Plots



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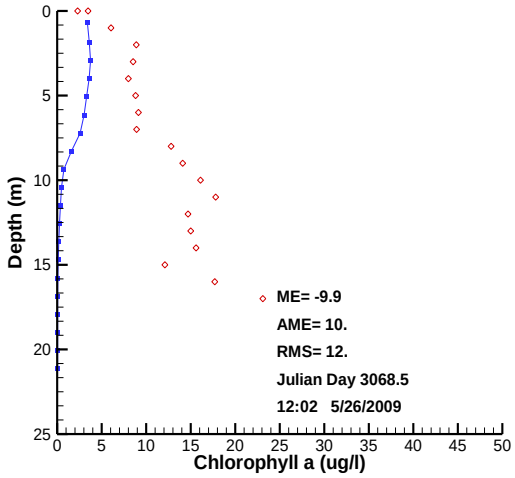

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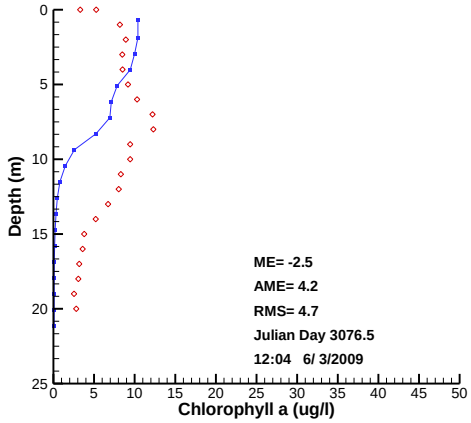

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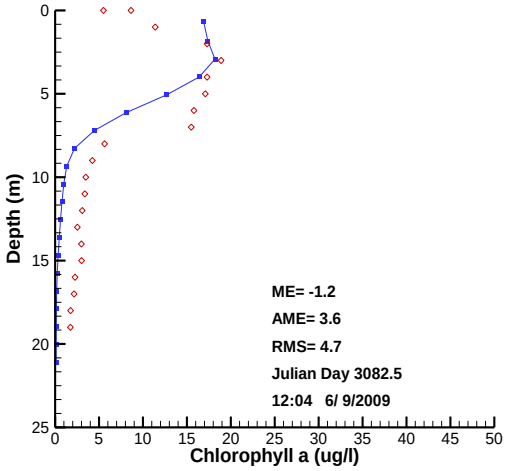

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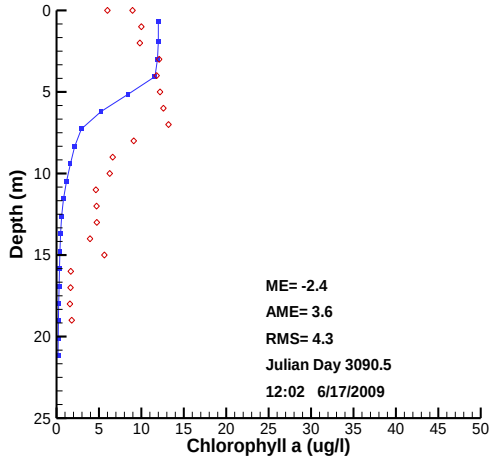

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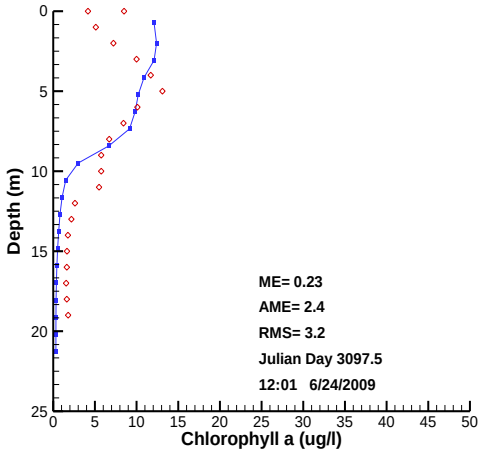

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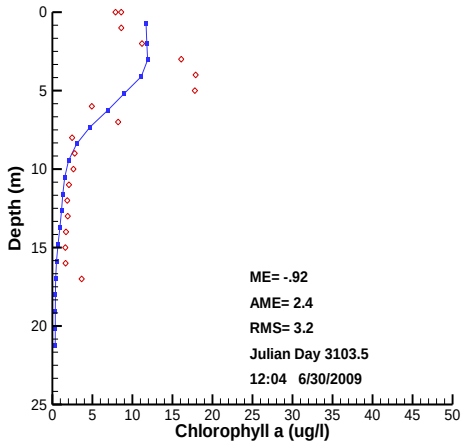

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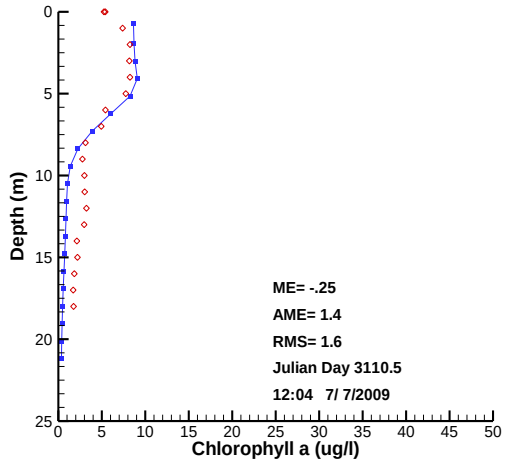

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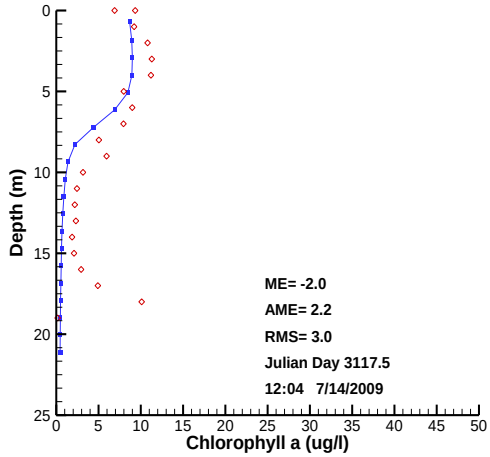

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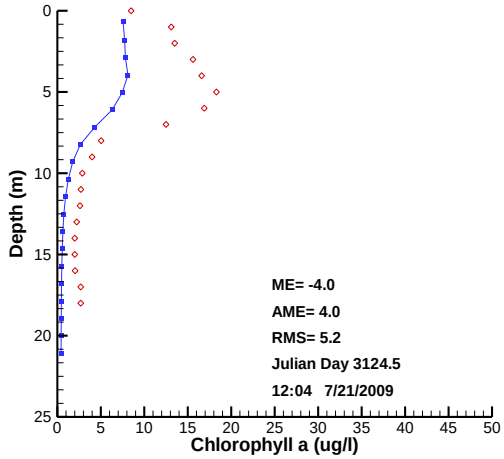

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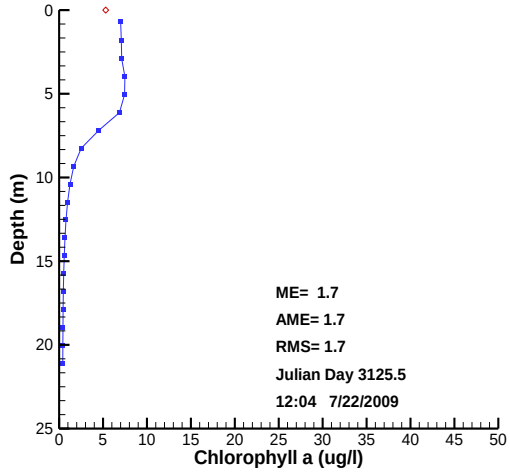

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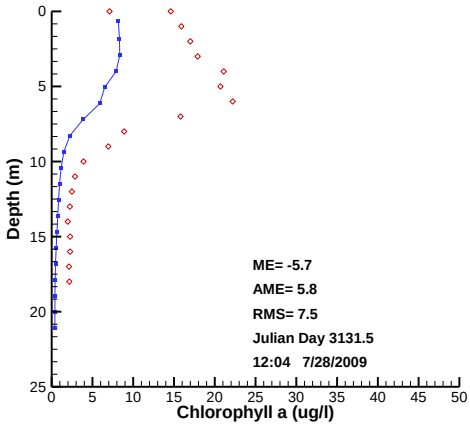

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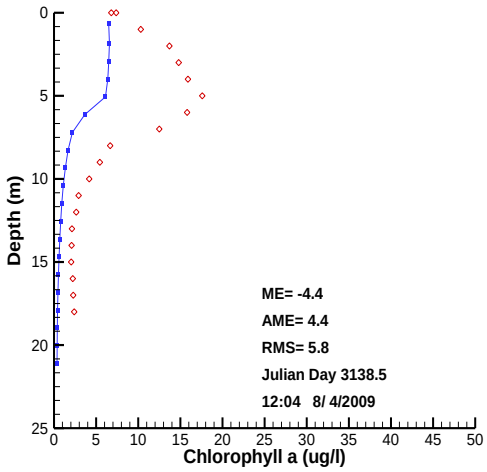

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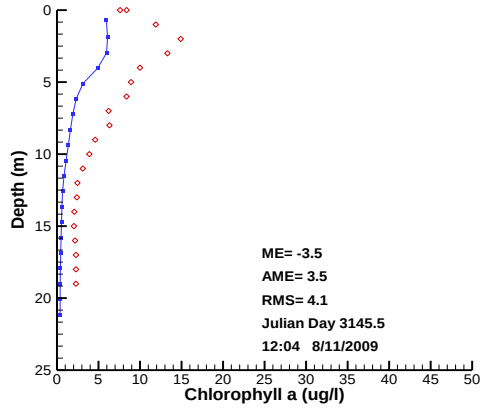

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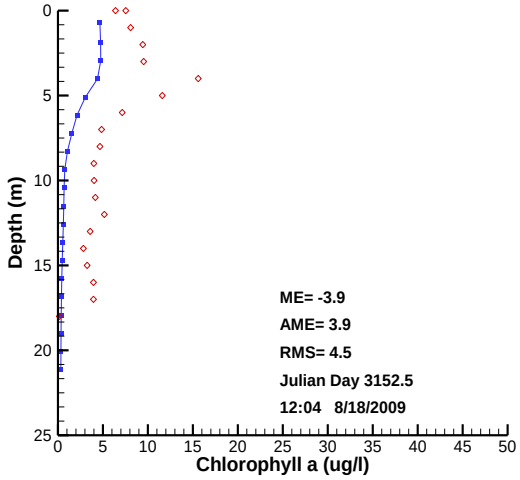

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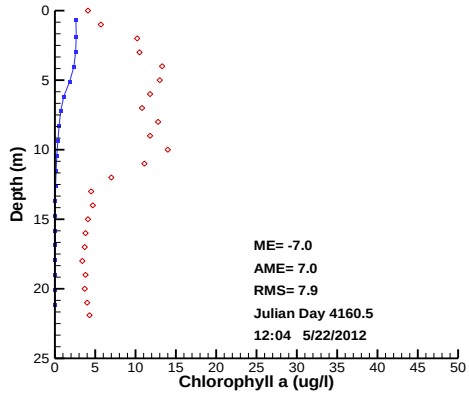

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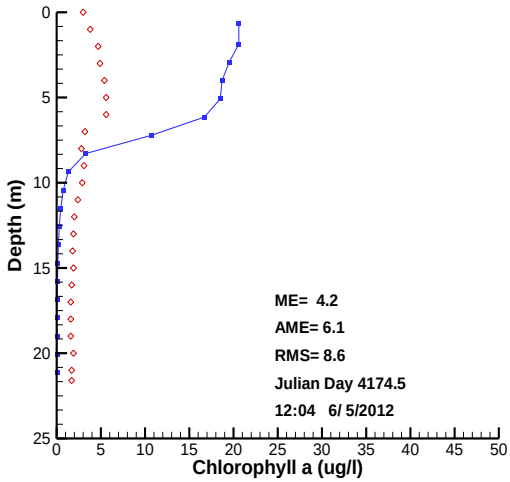

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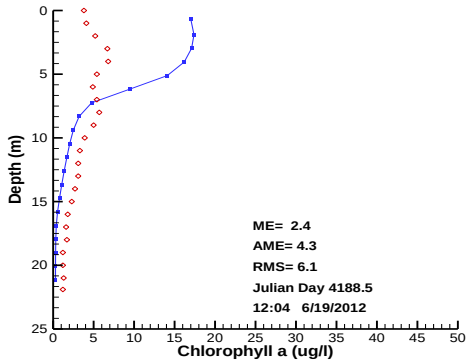

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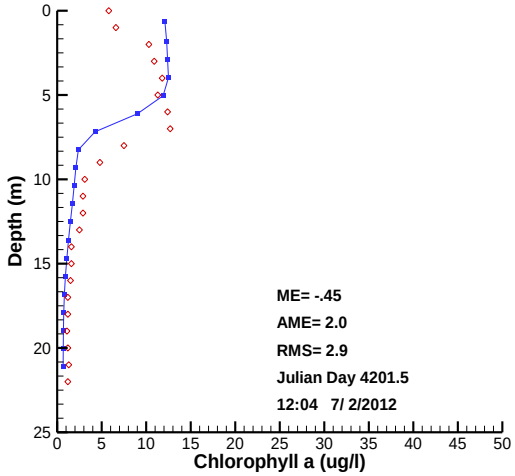

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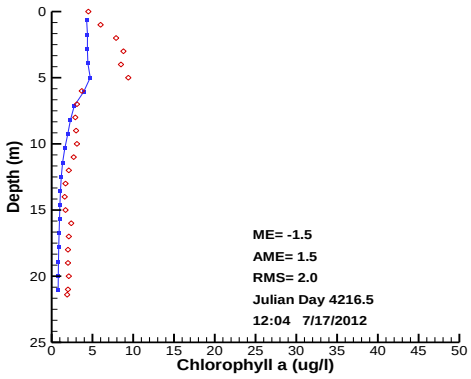

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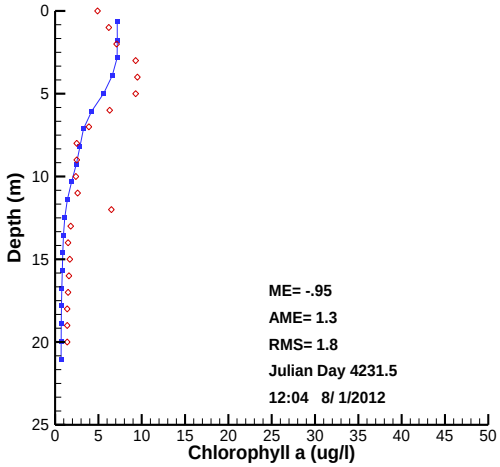

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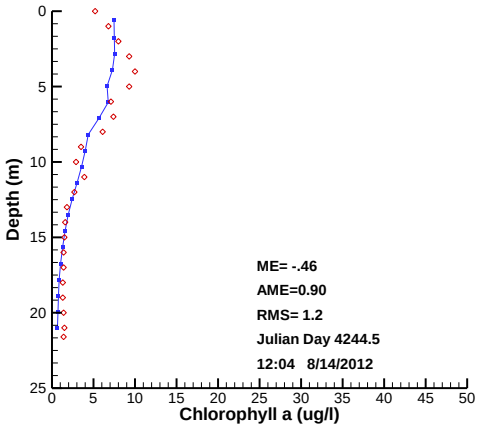

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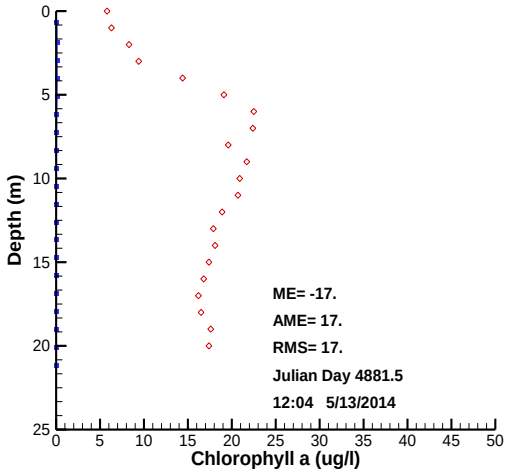

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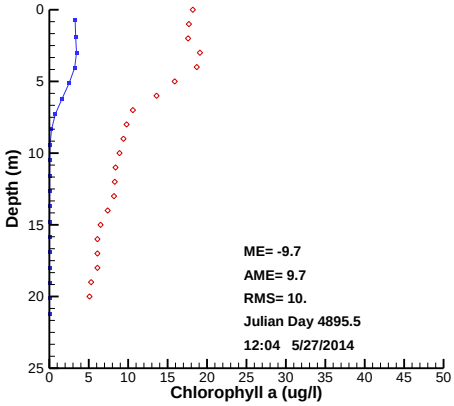

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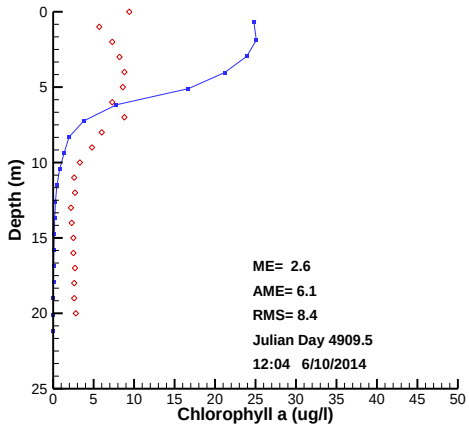

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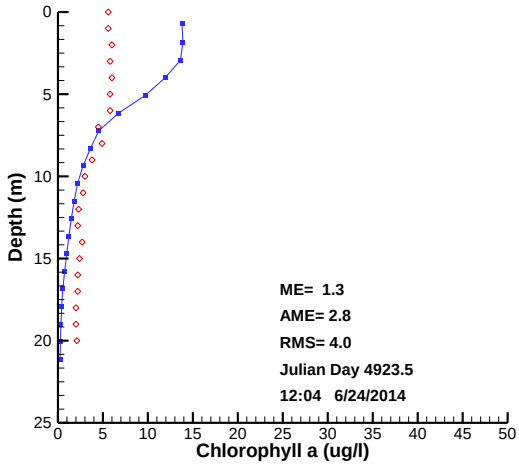

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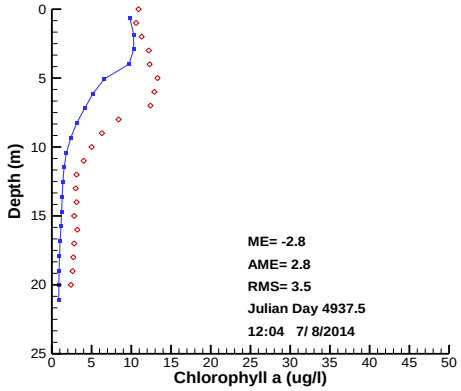

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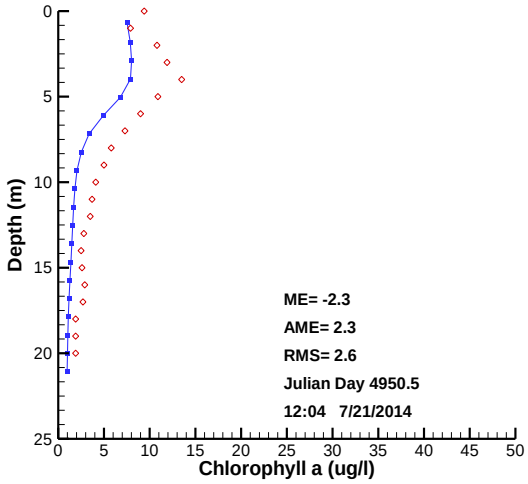

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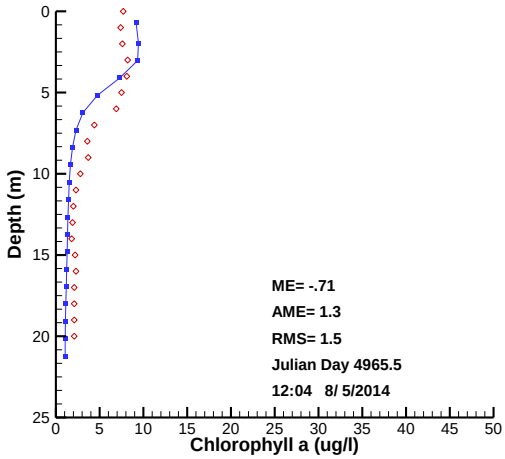

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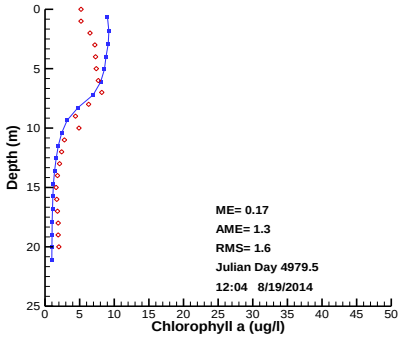

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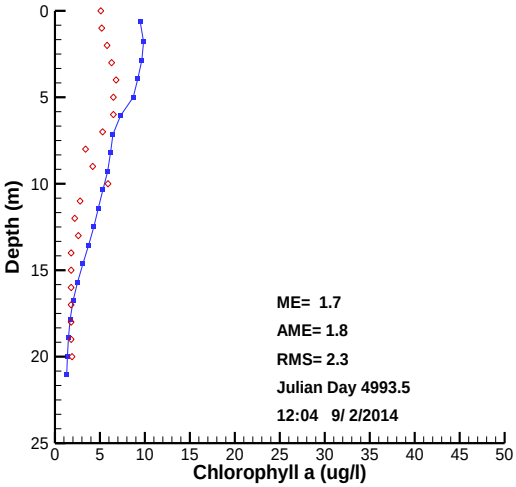

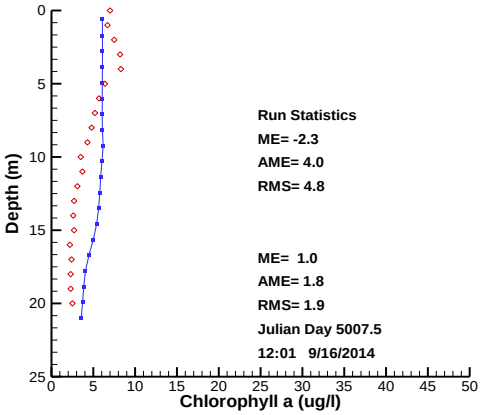

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Appendix C: Numeric Endpoint Development for Potable Water Use.

The development of a TMDL requires a scientifically defensible numeric endpoint which will ensure that the best uses of the water body are met. For the purpose of TMDL development in this watershed, a link between phosphorus concentrations and protection of the best use of the water body as a source of drinking water must be established. New York State's current guidance value for phosphorus is 20 μg/l (DEC 1993) but was derived to protect primary and secondary contact recreational uses from impairment due to aesthetic effects. The current guidance value was not specifically derived to protect the drinking water use of water bodies, such as Conesus Lake. The link is best made through a site-specific interpretation of New York State's existing narrative ambient water quality standard for phosphorus (6NYCRR 703.2): "none in amounts that will result in growths of algae, weeds and slimes that will impair the waters for their best usages"(DEC 2008), because an appropriate numeric translator for drinking water use has not been adopted.

In 2000, DEC incorporated such a site-specific interpretation of the narrative criterion protective of drinking water use into TMDLs for the New York City Reservoirs (DEC 2000). The USEPA, DEC and the New York City Department of Environmental Protection (NYCDEP) worked toward the development of water supply-based phosphorus criteria for the New York City Reservoir Watershed, as part of the Phase II TMDL process. A weight-of-evidence approach utilized all available NYC reservoir-specific data to develop a relationship between phosphorus and chl-a levels, and a selected set of water quality variables which have been demonstrated to negatively affect the water quality of the drinking water supplied by the reservoirs in the Watershed. Five water quality variables that are important concerns to water supply and are associated with excessive nutrient loading and reservoir water quality were selected, including THM precursor concentrations for certain reservoirs (Stepczyk 1998) (NYCDEP 1999). Using the weight-of-evidence approach, the EPA-approved TMDL used a site-specific phosphorus guidance value of 15 μg/l as the ambient phosphorus level to protect NYC source water reservoirs used directly for public water supply.

Eutrophication-related water quality impairments adversely affect a broad spectrum of water uses, including water supply and recreation, and also adversely affect aquatic life. Concerns about cultural eutrophication (human induced enhancement of primary productivity) are not unique to New York, and the issue is widely recognized as a significant water quality concern at the national and international levels. These concerns lead the USEPA (USEPA, 1998) to initiate a National Nutrient Strategy in 1998 with the goal of assisting all states in the development of numeric nutrient criteria.

To further the process of developing numeric nutrient criteria protective of potable water use, the DEC, in collaboration with investigators from the New York State Department of Health (NYSDOH), Upstate Freshwater Institute (UFI), State University of New York College of Environmental Science and Forestry (SUNY-ESF), and Morgan State University, conducted a study to investigate the relationship between nutrient-related indices and certain human health related indices. The study was funded by the USEPA as part of that agency's National Nutrient Criteria Strategy (USEPA, 1998). The study involved the monthly collection of paired water column samples from 21 lakes and reservoirs during the growing season (May to October, 2004 and/or 2007). The study systems were distributed throughout New York State, and spanned a relatively broad range of trophic conditions ranging from oligotrophic systems (low primary productivity) to eutrophic systems (high primary productivity).

From that study, DEC has developed a process for determining Ambient Water Quality Values for ponded sources of potable waters in New York State, (DEC, 2010) which has undergone EPA and peer-review. That research for that process, as described in a peer-review journal (Callinan 2013), is used as the basis to evaluate the degree to which the TMDL target is adequately protective for the Conesus Lake TMDL, and to provide a correlation between chlorophyll-a (chl-a) and Total Phosphorus (TP) suggests the optimal protective value for drinking water given the site-specific data available. This methodology, using the data available in the NYSDEC monitoring, suggests using the ug/l chl-a as the metric is preferable to using a TP concentration to determine the acceptable Watershed Phosphorous Loadings.

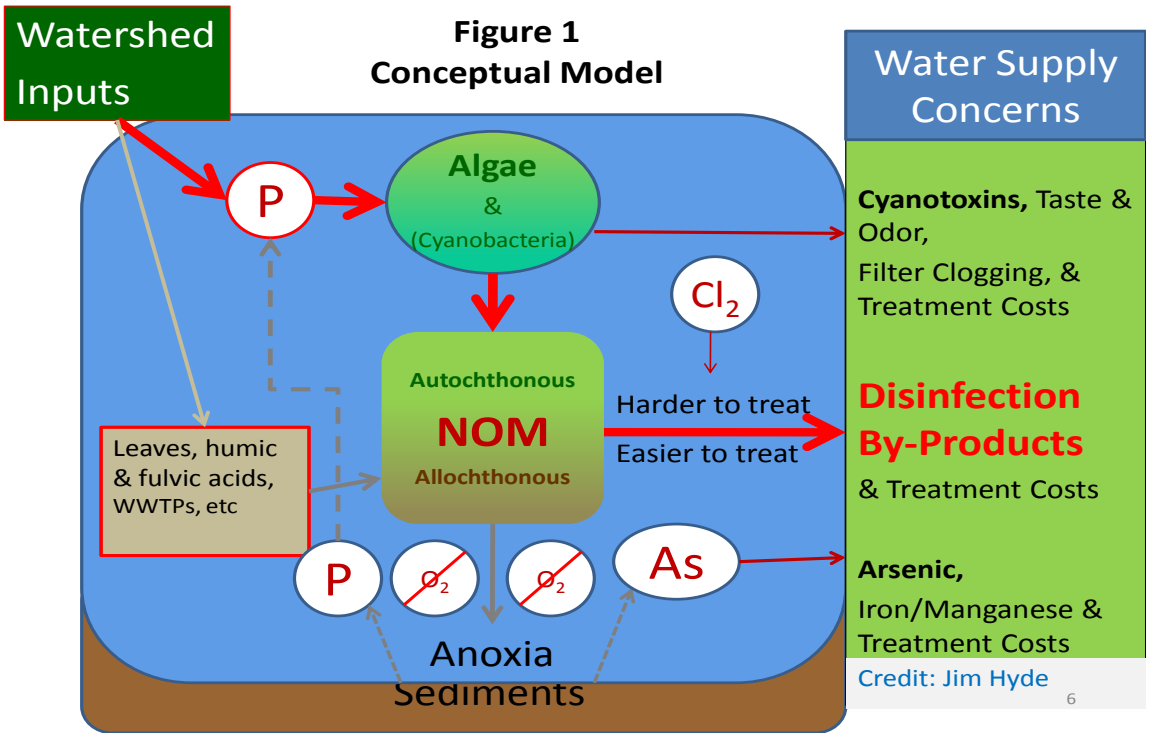
Given the years of available data it was decided to use only the DEC data is assessing this target concentrations options for consistency since it was DEC based Quality Assurance Project Plan (QAPP) criteria and calculation methods used to determine the graphical correlation shown later in this Appendix would also have been used in calculation of the DEC monitoring data. Using this DEC monitoring data collected, the 4 ug/l correlated to TP concentrations ranging from 11 ug/l to 21 ug/l in varying years (with an average value near 15 ug/l). This wide range, in combination with the fact the chl-a value more closely aligns to the NYS regulatory narrative for potable water best use, suggests that the 4 ug/l chl-a is the appropriate target upon which to base the modeling that determined the desirable watershed loading of Total Phosphorus (TP) for Conesus Lake.

USEPA recently issued guiding principles "to offer clarity to states about an optional approach for developing a numeric nutrient criterion {Editor's Note: Herein referred to as target concentration} that integrates causal (nitrogen and phosphorus) and response parameters into one water quality standard (WQS). …These guiding principles apply when states wish to rely on response parameters to indicate that a designated use is protected. …A criterion must protect the designated use of the water, and states should clearly identify the use(s) they are seeking to protect. Where a criterion is intended to protect multiple designated uses, states must ensure that it protects the most sensitive one (40 CFR 131.11(a))…. Documentation supporting the criterion should identify all applicable nutrient pathways, addressing all potential direct and indirect effects (e.g., as identified in a conceptual model that outlines the effects of nutrient pollution)" (USEPA 2013).

C.1 Conceptual Model

Nutrient enrichment of lakes and reservoirs used for potable water supply (PWS) can cause adverse effects, ranging from operational problems to increases in health related risks such as disinfection by-products (DBPs), cyanotoxins, and arsenic.

The linkages between eutrophication and PWS concerns are shown in Figure 1. As illustrated by the red arrows in the figure, the primary route of concern is: (1) nutrient (P) enrichment leads to (2) increases in algae (measured as chl-a), which results in (3) increases in natural organic matter (NOM), which (4) combines with chlorination (Cl_2) to form disinfection by-products.



Additional phosphorus inputs may further accelerate eutrophication, which may lead to oxygen depletion, which may cause reductive release of sediment-bound arsenic and phosphorus, which can provide a positive feedback to further nutrient enrichment, and production of cyanotoxins. Although an increase in arsenic levels and production of cyanotoxins are health concerns for PWS, the DEC study found that formation of DBPs was likely to be the most sensitive endpoint for developing a phosphorus criterion for PWS, and it is the relationship to formation of DBPs that is the focus of the site-specific phosphorus target in this TMDL.

Disinfection By-Products

Disinfection by-products (DBPs) are a group of compounds formed as a result of chemical reactions between natural organic matter (NOM) and certain disinfection agents (e.g., chlorine). The two major classes of DBPs are trihalomethanes (THMs) and haloacetic acids (HAAs). Several of these compounds (e.g., bromodichloromethane, trichloroacetic acid) are considered to be carcinogenic (ATSDR 1997, USEPA 2006). There is also some evidence linking DBPs to adverse reproductive effects (USEPA, 2006).

The link between nutrient enrichment and increased production of DBPs occurs because in many temperate freshwater systems, phosphorus acts as the limiting growth factor for primary production. This increase in primary production leads to: (a) an increase in the level of NOM, and (b) a change in the nature of NOM within the system, which heightens the risk for DBP production when the water is subjected to disinfection. The DEC study discussed below was limited to total THMs (TTHMs).The USEPA (2006) defines TTHMS as the sum of four chlorinated compounds: chloroform, bromodichloromethane, dibromochloromethane, and bromoform.

Research on DBPs initially focused on the allochthonous (watershed; e.g., leaves and wastewater) precursor pool; however, subsequent studies also identified the autochthonous (in-lake; e.g., algae) precursor pool as important (Figure 1). There are important distinctions between allochthonous and autochthonous precursors that are relevant to PWS management. For example, autochthonous precursors are both more amenable to mitigation through nutrient management and more difficult to remove through water treatment. Furthermore, autochthonous precursors may produce greater quantities of unregulated DBPs.

C.2 Derivation of Site-specific Ambient Water Quality Values (Criteria)

The approach taken in the DEC study to derive appropriate site-specific ambient water quality values (AWQVs) is based upon findings from DEC's Disinfection By-Product/Algal Toxins Project (DBP-AT Project), as well as pertinent material from other independent investigations (both peer reviewed literature and technical reports).

The toxicological basis for the criteria in the DBP-AT Project was based upon previous drinking-water related toxicological findings for disinfection by-products (specifically total trihalomethanes) derived to meet the current maximum contaminant levels (MCLs) as summarized and presented in the Code of Federal Regulations (40 CFR January 4, 2006).

Several assumptions were made in the derivation of nutrient thresholds THMs.

1. The target nutrient thresholds are designed to attain the current maximum contaminant level (MCL) for TTHMs, presently set at 80 μg/l per the USEPA Stage 2 Disinfectants and Disinfection Byproducts Rule (USEPA 2006).

2. The applicable toxicological evidence as presented in the USEPA Stage 2 Rule in support of the current MCL is adequate for the protection of human health. The current MCL for TTHMs is deemed the appropriate target value given that the criteria are directed toward protection of public water supply use which, in all instances for ponded surface waters, involves disinfection.

3. The nutrient thresholds defined for THMs are sufficient to protect for HAAs. Some studies suggest that algae are equally important in the generation of HAAs and TTHMs (Nguyen, et al., 2005), thus, it is assumed that limiting algae production will have comparable effects of both major classes of DBPs.

The DEC's DBP-AT Study involved the collection of paired ambient water samples that were analyzed for Trihalomethane Formation Potential (THMFP) and nutrient-related indices. THMFP is commonly used in research investigations to normalize results for the purpose of system comparisons.

The study developed relationships for each step in the conceptual model. For the first step, the regression relationship between mean chl-a and TP indicates that approximately 78% of the variability in phytoplankton biomass (based on chl-a) is accounted for by changes in TP, which supports the idea that phytoplankton biomass is controlled by phosphorus during the growing season. Study findings also offer several lines of evidence in support of the hypothesis that increased primary productivity (or cultural eutrophication) leads to an increase in the generation of THMFP:

- The relationship between mean Dissolved Organic Carbon (DOC) (a measure of NOM) and chl-a indicates a trend of increasing DOC concentrations with increasing chl-a.
- THMFP levels are substantially influenced by algal biomass. (The importance of the autochthonous precursor pool is supported by observed increases in THMFP concentrations with increases in trophic state, observed correlations between mean concentrations of THMFP and trophic indexes, and observed increases in THMFP concentrations during the growing season in most study systems).
- The relationship between mean THMFP and DOC, shows that approximately 80% of the variation in mean THMFP is attributable to mean DOC.

The observed relationships between THMFP and trophic indexes in the DEC's DBP-AT Project provide a sound basis for the derivation of nutrient-related thresholds protective of PWS. These findings are also consistent with a significant body of literature demonstrating a qualitative relationship between nutrient enrichment and the risk of increased THMFP production (Palmstrom, et al 1988, Wardlaw, et al. 1991, Cooke and Kennedy 2001) and showed similar quantitative relationships to research by Arruda and Fromm (1989) and the Colorado Department of Public Health and Environment (2011).

Building upon the relationships discussed above, the next step in the criteria development process is to identify potential AWQVs for the nutrient indices that are protective of potable waters with respect to DBPs. This required associating the measured THMFP to the TTHM drinking water standard. THMFP represents something of a "worst case" scenario in that the analytical protocol is designed to fully exploit the reaction between the available natural organic matter (NOM) and the disinfectant agent. In contrast, water treatment plant (WTP) operators attempt to minimize the generation of TTHMs, and other DBPs, while providing adequate disinfection.

This THMFP to TTHM translation, involved fitting observed THMFP data to a TTHM simulation model, and running the model using representative treatment/distribution system conditions coupled with the TTHM maximum contaminant level (MCL) of 80 µg/l. Using the relationships among chl-a, DOC and THMs established in the DEC's DBP-AT Project, a threshold of chl-a = 4.0 µg/l was derived, where values apply as growing season (May-October) means within the photic zone of the lake or reservoir.

Target Concentrations (Endpoint)

DEC's DBP-AT Project derived threshold for chl-a is 4.0 µg/l as an AWQV to protect Class AA waters, given that these systems are required to meet applicable drinking water standards following only disinfection[1] (without coagulation, sedimentation and/or filtration treatments).

For ponded waters it is appropriate to derive distinct target concentrations for different water use classes of ponded surface waters carrying best usage of source of potable water supply, because of the differing level of expected treatment inherent in the specific use classes. Classes AA will be subject to

[1] *Class AA: "This classification may be given to those waters that, if subjected to approved disinfection treatment, with additional treatment if necessary to remove naturally present impurities, meet or will meet New York State Department of Health drinking water standards and are or will be considered safe and satisfactory for drinking water purposes".* (6 NYCRR Part 701).

the more stringent target concentrations given that these waters are expected to meet applicable drinking water standards after only disinfection, whereas, ponded water supply source waters carrying water use Classes A will be subject to a somewhat less stringent target concentrations given that they are expected to meet applicable drinking water standards following "conventional" water treatment.[2]

Conventional water treatment processes (*coagulation, sedimentation and, filtration)* can reduce levels of DOC in raw source water, however, removal efficiency diminishes as trophic level increases. Thus, the draft fact sheet assumed a somewhat conservative DOC removal efficiency of 10% - note, this is a reduction in DOC, not in phosphorus or chl-a. Thus, using the relationships among chl-a, DOC and THMs established in the DEC DBP-AT Project, the draft fact sheet proposed a chl-a concentration of 6.0 µg/l for Class A waters.

Although water use classes listed above include a caveat relating to "naturally present impurities", this was not deemed applicable for situations of cultural eutrophication, which, by definition are driven by anthropogenic-driven processes.

The DEC findings compare well with other independent investigations. Arruda and Fromm (1989) investigated the relationship between trophic indexes and THMs in 180 Kansas lakes and arrived at a recommended chl-a threshold of 5 µg/l to attain a TTHM limit of 100 µg/l (MCL in place at that time). Colorado (Colorado DPHE, 2011) conducted a study patterned on New York's study, although with enhancements including use of the Uniform Formation Conditions method (Summers 1996) that also targeted HAA formation and alternative methods of interpretation, and determined that a mean chl-a concentration of 5 µg/l would be an appropriate threshold for direct use public water supply reservoirs.

An endpoint for phosphorus is premised on an extensive body of literature indicating that phosphorus is the limiting nutrient (or causal variable) for primary productivity in most temperate, freshwater, ponded waters. The rationale behind setting criteria for chl-a is that it provides the most widely accepted measure of primary productivity (response variable) within freshwater ponded systems.

DEC has focused on the response variable, chl-a as the more appropriate ambient target because of its closer relationship to NOM and DBPs which directly affect the drinking water use. Thus, demonstration of the achievement of the water quality standard for Total Phosphorus, including for the purpose of a TMDL, would be informed by site-specific biomass response. This approach is consistent with the EPA guiding principles about an optional approach for developing a numeric nutrient criterion that apply when states wish to rely on response parameters to indicate that a designated use is protected (USEPA 2013). The EPA recognized that developing numeric values for phosphorus may present challenges associated with the temporal and spatial variability, as well as the

[2] *Class A:* "*This classification may be given to those waters that, if subjected to approved treatment equal to coagulation, sedimentation, filtration and disinfection, with additional treatment if necessary to reduce naturally present impurities, meet or will meet New York State Department of Health drinking water standards and are or will be considered safe and satisfactory for drinking water purposes.*" (6 NYCRR Part 701)

ability to tie them directly to environmental outcome. Therefore, the USEPA guiding principles allow a State approach that integrates causal (nitrogen and phosphorus) and response parameters into one water quality standard.

DEC's subsequent study, *River Disinfection By-Product/Algal Toxin Study*, prepared for the USEPA recommended that the primary metric for the establishment of numerical nutrient criteria be chl-a (response variable) because it is the parameter most closely linked to autochthonous DBP precursors (DEC 2010). While consideration was given to establishing a single numerical stressor (total phosphorus) criteria for flowing potable waters, the study concluded that the available dataset could not support the establishment of a single criteria value due to the variability in the relationships between both total phosphorus and chl-a as well as between total phosphorus and THMFP. Such variability is to be expected in natural systems including ponded water as the relationship between stressor and response variables has inherent variability.

Given findings from the DEC ponded and flowing water studies, as well as findings from other comparable studies, the more appropriate approach for establishing the stressor target (total phosphorus) is to establish a criteria "band" delineated by the prediction bands for the regression relationships. USEPA has proposed such an approach for the derivation of nutrient criteria in the state of Florida (USEPA, 2010). Ideally such an approach would use site-specific information regarding the response variable to fine-tune the stressor target, but would also be informed by general relationships demonstrated in robust datasets of multiple water bodies. Site-specific information, even where collected over several years with a variety of hydrological conditions is limited to the empirical range of the measurements. In the case of impaired waters, observations generally would not include chl-a levels that meet the target threshold, so the relationship would need to be extrapolated. Therefore a broader database of lakes, covering a broad band of trophic conditions including those which meet the target threshold chl-a level, provides additional context to a stressor-response model.

C.3 Model Development

The general approach for establishing the stressor target for Conesus Lake was to:

- Select a criterion for the response variable (chl-a = 4 μg/l) appropriate for protection of a drinking water use in a Class AA water based on the DEC's DBP-AT Project;
- Use the (slope of the regression) relationship between mean chl-a and mean total phosphorus in combination with the 50% prediction interval to establish possible stressor criteria based on best-fit; and,
- Define the upper and lower prediction bands in which the criteria relationship would be used.
- Determine the practicality and usefulness between the options of using chl-a or TP as the target based on purpose, modeling to be used, and the specific goals of the waterbody.

The process to establish a best fit and prediction bands for the total phosphorus to chl-a relationship considered available DEC and other quality assured data for lakes in New York State. Figure 2 shows the total phosphorus to chl-a relationship for lakes in NYS (PWS or otherwise denoted) with at least three year of extensive seasonal data. The prediction bands are denoted by the dashed lines around the regression line of best fit. This broader database was chosen over the DEC's DBP-AT Study results because the latter only covered 21 lakes/reservoirs with a single year of data, but had a similar TP to chl-a relationship. *(Figure will use μg/l units, note symbols for ponds and prediction lines (dashed)).*

C.4 Model Application

Application of the stressor-response model developed in the previous section requires specification of how and when the model will be applied. The rationale used to make decisions on how to account for assessed conditions within the model framework and how the target values will be expressed are described in the following sections.

C.4.1 Accounting for Site-specific Information

To incorporate site-specific context into the stressor-response relationship, the actual measured mean chl-a concentration is used as a starting point for the analysis. Next, the slope of the general stressor-response relationship is used to determine an appropriate mean Total Phosphorus concentration target, by solving for the response threshold of 4 μg/l chl-a. The relative improvement in the chl-a at each site is accomplished through changes in the Total Phosphorus concentration, weighted by the pre-factor from the regression equation.

For Conesus Lake there were only actually 8 years of DEC database monitoring information since 1986, with the other years otherwise collected. Although these other sources may have ELAP labs and adequate collection methods, to assure a consistency with the statistical metric determined by using a database comprised of statewide drinking water lakes, it was desirable to use the data that was derived using the same Quality Assurance Project Plan (QAPP) criteria as that statistical database that was the basis for the chl-a vs TP correlation shown in the graph in Figure 2.

C.4.2 Site Specific NYSDEC Sampling Data as Target Basis for Conesus Lake:

The table below provides the Conesus Lake DEC monitoring data available from 1986 to 2017 (except for dates omitted due to data outliers). Values are the summer mean concentration per year for TP and chl-a, and are only the values for those years when both values were in the DEC database.

Table 1: DEC Monitoring Data for Conesus Lake

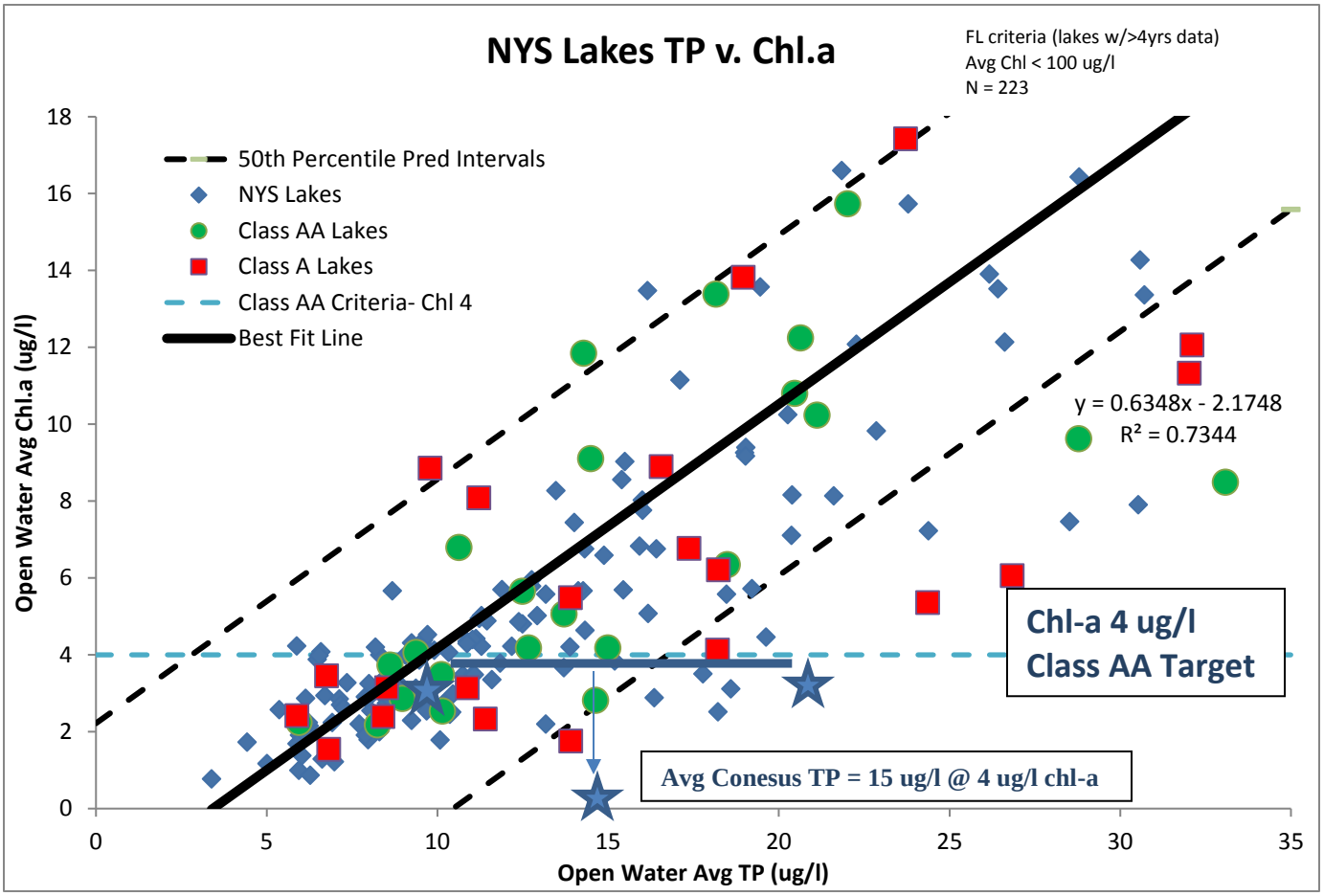
Year	TP meas (ug/l)	Chl-a (ug/l)	TP if chl-a=4ug/l
1986	20.2	3.4	24.1
1987	13.7	5.9	9.3
1988	15.7	3.8	16.3
1989	20.8	5.3	15.8
1990	11.9	4.2	11.3
1996	18.4	9.5	7.8
1997	22.8	9.0	10.2
1999	20.1	7.5	10.7
2004	22.6	7.6	12.0
Average	**18.0**	**6.1**	**13.0**

Data in this table are from CSLAP for the years of 1986-1990, and from the Finger Lakes Assessment Report for the year 1996 to 1999.

The final column is calculated using the equation:

[(TPmeas x Chla(target) / Chla(meas)] = TP predicted (at 4 ug/l chl-a)

Where 0.634 is the slope of the graphical correlation of TP vs Chla



The target range for the data is largely, but not entirely within the best fit prediction bands at the higher TP concentrations. The Chl-a selected as the target rather than TP concentration because:

1. The TP range correlating to the 4 ug/l criteria is too wide (from 9.725 to 21.256). It is not assured to be within the predictability bands that provide a high degree of statistical confidence.

2. Chl-a is the more direct metric since it is more closely aligned with the narrative standard for the Class AA waterbody.

3. The CEQUAL-W2 lake model used for this TMDL, provides a predicted correlation between Phosphorous loading and resulting chl-a concentration.

C.4.3 Application of the target concentrations

The response model was developed using average phosphorus concentrations from May through October (growing season). This was done because this was the identified critical period when phosphorus concentrations were measured and sunlight and temperature are favorable, creating the best condition for the production of algae. The associated NOM from production of algae is available for formation of DBPs. The applicability of the response model is therefore the same: an average TP concentration calculated over the May through October growing season.

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[3] The target of 21 was chosen by using the prediction band intercept of the chl-a target, rather than calculating from the measured trophic values which yields a target 39.

APPENDIX D. TOTAL EQUIVALENT DAILY PHOSPHORUS LOAD ALLOCATIONS

Total phosphorus total maximum daily load (TMDL) for Conesus Lake, expressed as annual and daily phosphorus loads. Also displayed are estimated existing total phosphorus loads by source.

Source	Existing Load (kilograms/year)	TMDL (kilograms/year)	Existing Load (kilograms/day)	TMDL (kilograms/day)	% Reduction	TMDL (Pounds /day)
Load Allocation (LA)	**21,208**	**10,939**	**58.1**	**29.9**	**48%**	**65.9**
Forest	321	321	0.9	0.9	0%	2.0
Agriculture	3,202	2,700	8.8	7.4	16%	16.3
Urban	756	700	2.1	1.9	7%	4.2
Internal Loading - Aerobic Sediment Release	6,288	2,680	17.2	7.3	57%	16.2
Internal Loading - Anaerobic Sediment Release	10,641	4,538	29.1	12.4	57%	27.4
Wasteload Allocation (WLA)	**0**	**0**	**0**	**0**	**-**	**0**
Margin of Safety (MOS)	**-**	**1,215**	**-**	**3.3**	**-**	**7.3**
Total	**21,208**	**12,154**	**58.1**	**33.3**	**43%**	**73.3**

The percent reduction across the individual sectors may be changed so long as the total reduction remains the same.