EVALUATION OF THE EFFECTIVENESS OF THE ALUM SEDIMENT INACTIVATION TREATMENT TO LAKE JESSAMINE

Final Report
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SECTION 1

INTRODUCTION

This report provides a summary of work efforts performed by Environmental Research & Design, Inc. (ERD) for the Orange County Environmental Protection Division (OCEPD) to conduct sediment nutrient inactivation in Lake Jessamine and to evaluate the resulting impacts to water quality and sediment chemistry.

1.1 Overview

Lake Jessamine is a 289-acre urban lake located approximately 3 miles southeast of downtown Orlando. A location map for Lake Jessamine is given in Figure 1-1. The watershed areas surrounding the lake are highly developed, with a mixture of residential and commercial land use activities. Many of these areas were constructed prior to implementation of regulations requiring stormwater treatment and discharge untreated runoff directly into the lake. Historical water quality in Lake Jessamine has been highly variable, ranging from oligotrophic to eutrophic conditions over the available period of record.

1.2 Impaired Waters Designation

Section 303(d) of the Clean Water Act (CWA) requires states to submit lists of surface waterbodies that do not meet applicable water quality standards. These waterbodies are defined as "impaired waters" and Total Maximum Daily Loads (TMDLs) must be established for these waters on a prioritized schedule. The Florida Department of Environmental Protection (FDEP) has established a series of guidelines to identify impaired waters which may require the establishment of TMDLs. Waterbodies within the State of Florida have been divided into five separate groups for planning purposes, with Lake Jessamine located in the Kissimmee River Basin in Group 4.

During 2005, the draft verified list of impaired waterbodies for the Kissimmee River Basin was released by FDEP and included Lake Jessamine as an impaired waterbody due to elevated trophic state index (TSI) values during the verified period from 1998-2003. Based upon available historical water quality data for Lake Jessamine, the lake is characterized as a low color, phosphorus-limited system. Therefore, control of phosphorus loadings to the lake is essential for improvement of water quality.

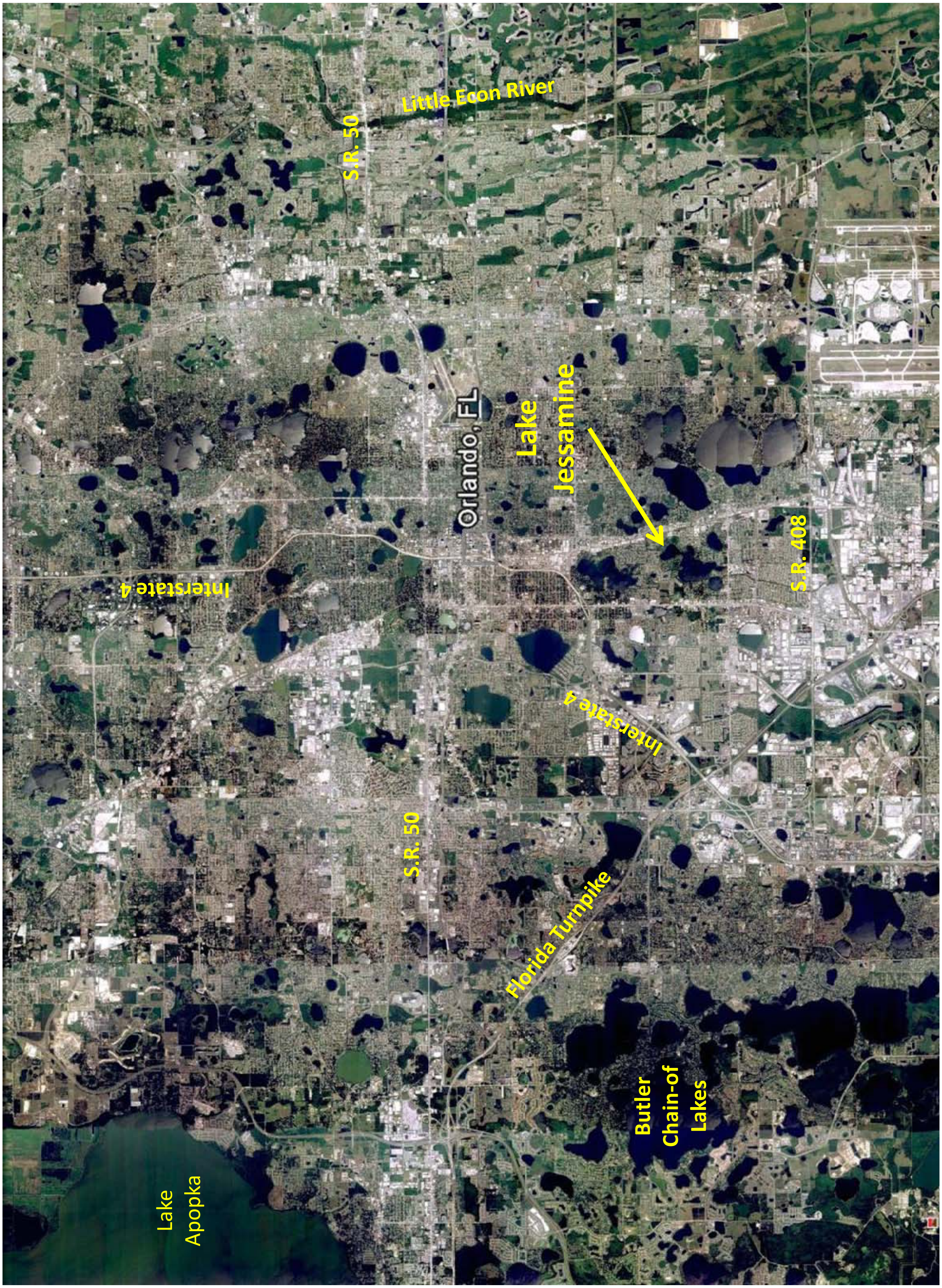


Figure 1-1. Location Map for Lake Jessamine.

1.3 Physical Characteristics of Lake Jessamine

A general overview of Lake Jessamine is given on Figure 1-2. Lake Jessamine is highly irregular in shape and consists of a central area which is connected to northeastern, eastern, southern, and southwestern lobes. The general nomenclature illustrated on Figure 1-2 is used throughout this report to describe areas within the lake.

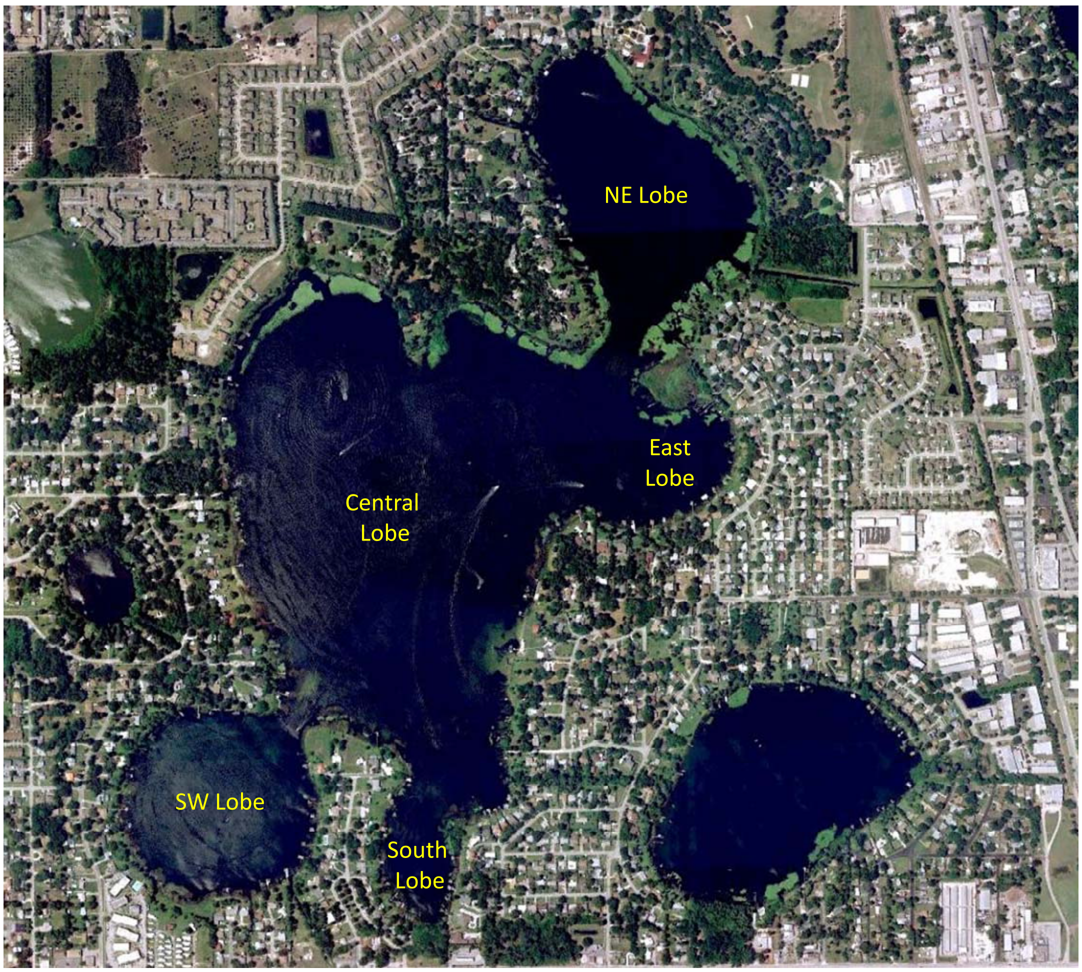


Figure 1-2. General Overview of Lake Jessamine.

A bathymetric survey of Lake Jessamine was conducted by ERD on March 29, 2011 to evaluate water column depth as well as thickness of unconsolidated sediments within the lake. Measurements of water depth and sediment thickness were conducted at 249 individual sites within the lake. Probing locations used for the bathymetric study are indicated on Figure 1-3. Each of the data collection sites was identified in the field by longitude and latitude coordinates using a portable GPS device. The water level elevation in Lake Jessamine on March 29, 2011 was approximately 92.06 ft.

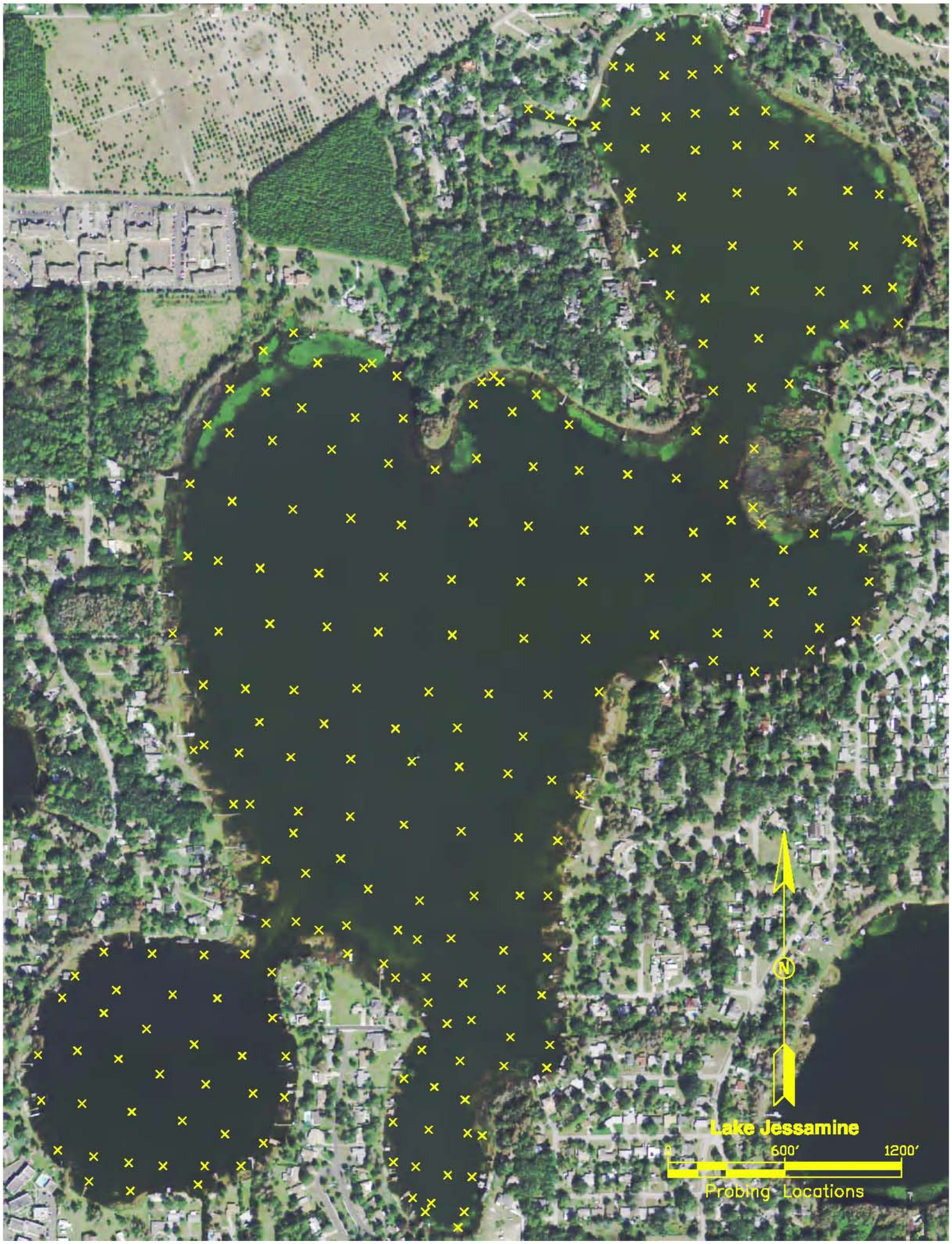


Figure 1-3. Probing Locations for Water and Muck Depths in Lake Jessamine (March 29, 2011).

A water depth contour map for Lake Jessamine, based on the field monitoring program conducted by ERD, is given on Figure 1-4. The bottom bathymetry in Lake Jessamine is highly irregular, with areas ranging from relatively shallow to relatively deep. The deepest areas within the lake are located within the central lobe with a water depth that extends to approximately 29 ft, and in the eastern lobe with a water depth that also extends to approximately 29 ft. Maximum water depths in the northeastern, southern, and southwestern lobes range from approximately 15-17 ft. In the central lobe, side slopes appear to be relatively modest along the east side, with a gradual increase in water depth with increasing distance into the lake. However, the western portion of the central lobe appears to have relatively steep side slopes which extend rapidly to a water depth of approximately 20 ft. The bathymetric signature of Lake Jessamine indicated on Figure 1-4 suggests that the lake originated as a result of multiple independent sinkhole features which became hydraulically interconnected.

Stage-area-volume relationships for Lake Jessamine are summarized on Table 1-1 based upon the bathymetric survey performed by ERD. At the water surface elevation of 89.84 ft present on March 29, 2011, the lake surface area is approximately 288.5 acres. The lake volume at this surface area is 3,175 ac-ft which corresponds to a mean water depth of approximately 11.0 ft which is approximately normal for a Central Florida lake. A summary of bathymetric characteristics of Lake Jessamine is given in Table 1-2.

1.4 Organic Sediment Accumulations

A bathymetric contour map of the depth of unconsolidated organic sediments in Lake Jessamine is given in Figure 1-5. Significant accumulations of organic muck are present in multiple areas of the lake, with muck depths extending to approximately 11 ft or more. The areas containing the accumulated organic muck are likely deeper areas resulting from the original sinkhole activity that formed the lake that have subsequently become filled with muck deposits. The accumulated organic muck within the lake is comprised primarily of dead algal cells and other partially decomposed vegetation as well as solids which have entered the lake from the adjacent watershed areas. However, many areas of the lake appear to have relatively little muck accumulation, with muck depths ranging from 0-1 ft.

Estimates of area-volume relationships for organic muck accumulations in Lake Jessamine are given in Table 1-3. Approximately 107 acres (37%) of the lake area have existing muck accumulations ranging from 0-1 ft in depth, with 26% of the lake bottom covered by muck accumulations ranging from 1-2 ft in depth, and 19% with accumulations ranging from 2-3 ft in depth. Overall, Lake Jessamine contains approximately 495.2 ac-ft (21,570,912 ft^3) of unconsolidated organic sediments. The volume of unconsolidated sediment in Lake Jessamine is sufficient to cover the entire lake bottom to a depth of approximately 1.72 ft. This mean muck depth in Lake Jessamine is approximately 15% greater than the mean muck depth of 1.5 ft measured by ERD in Lake Holden during 2004 and approximately 13% less than the mean muck depth of 1.97 ft measured in Lake Pineloch during 2006.

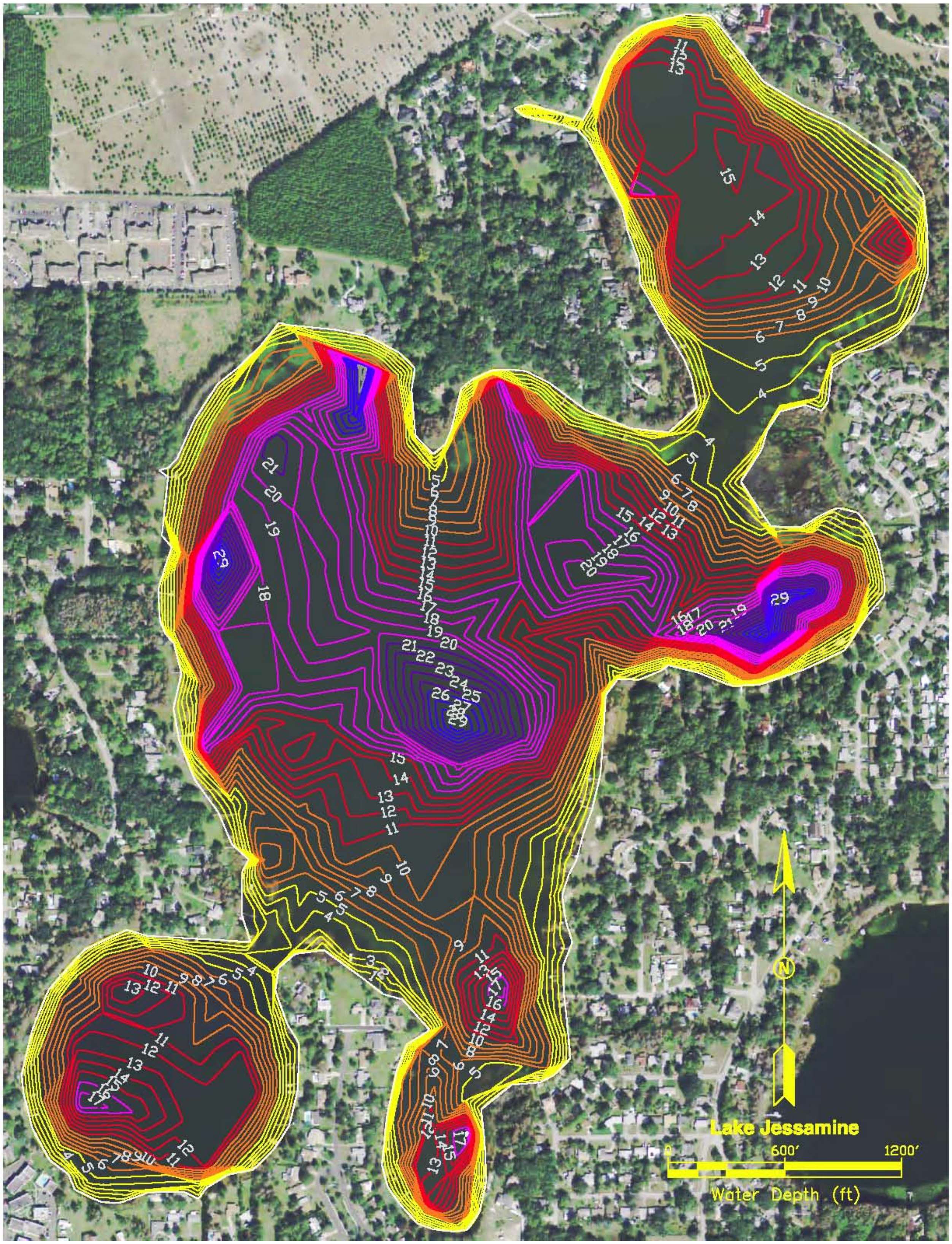


Figure 1-4. Water Depth Contours (ft) for Lake Jessamine on March 29, 2011.
(Water Elevation = 89.84 ft).

TABLE 1-1

DEPTH-AREA-VOLUME RELATIONSHIPS FOR LAKE JESSAMINE (Elev. 89.84 ft)

WATER DEPTH (ft)	AREA (acres)	CUMULATIVE VOLUME (ac-ft)	ELEVATION (ft)	AREA (acres)	CUMULATIVE VOLUME (ac-ft)
0	288.5	3,173	16	63.7	217
1	279.6	2,889	17	54.1	158
2	270.9	2,613	18	43.4	109
3	261.7	2,347	19	28.3	73.3
4	246.9	2,093	20	18.1	50.2
5	231.5	1,853	21	12.0	35.1
6	217.3	1,629	22	9.1	24.6
7	203.5	1,419	23	6.9	16.5
8	189.2	1,222	24	5.1	10.5
9	174.8	1,040	25	3.5	6.23
10	159.2	873	26	2.3	3.32
11	143.1	722	27	1.3	1.50
12	127.3	587	28	0.6	0.52
13	109.0	469	29	0.2	0.10
14	91.0	369	30	0.0	0.00
15	74.5	286			

TABLE 1-2

BATHYMETRIC CHARACTERISTICS OF LAKE JESSAMINE

BATHYMETRIC PARAMETER[1]	VALUE
Surface Area	288.5 acres
Total Volume	3,173 ac-ft
Mean Depth	11.0 ft
Maximum Depth	~ 30 ft
Shoreline Length	26,072 ft 4.94 miles

1. Based upon a water surface elevation of 89.84 ft (NGVD) on March 29, 2011

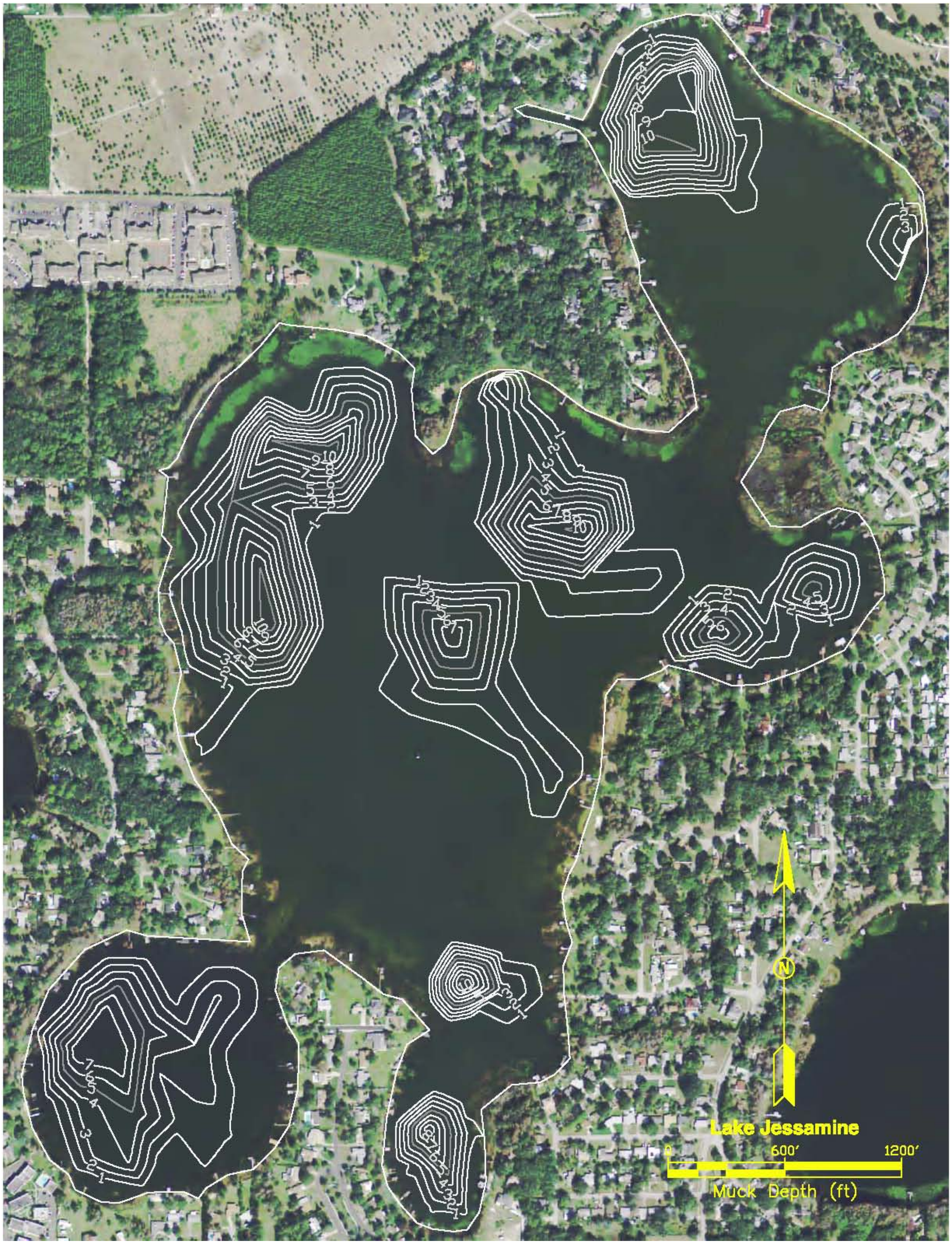


Figure 1-5. Muck Depth Contours (ft) in Lake Jessamine on March 29, 2011.

TABLE 1-3

DEPTH-AREA-VOLUME RELATIONSHIPS FOR ORGANIC MUCK IN LAKE JESSAMINE

MUCK DEPTH (ft)	AREA (acres)	CUMULATIVE VOLUME (ac-ft)	MUCK DEPTH (ft)	AREA (acres)	CUMULATIVE VOLUME (ac-ft)
0	288.5	495.2	6	20.0	36.0
1	107.2	297.3	7	13.3	19.4
2	75.6	205.9	8	7.9	8.75
3	54.1	141.1	9	3.9	2.85
4	39.6	94.3	10	0.9	0.44
5	28.5	60.3	11	0.0	0.00

1.5 Project History

During 2010-2011, ERD conducted a detailed study for OCEPD to quantify pollutant loadings to the lake and identify areas or opportunities where nutrient load reductions could be achieved to improve water quality within the lake. A field monitoring program was conducted from April 2010-April 2011 to collect hydrologic and water quality data for use in developing hydrologic and nutrient budgets for the lake. The hydrologic budget included estimated inputs from precipitation, stormwater runoff, inflow from interconnected lakes, and groundwater seepage. The nutrient budget included inputs from bulk precipitation, stormwater runoff, inflow from interconnected lakes, groundwater seepage, and internal recycling. An evaluation of sediment characteristics in Lake Jessamine was also conducted which included physical and chemical characterization of surficial sediments and evaluation of internal phosphorus recycling. Specific nutrient load reduction projects were evaluated and recommended to maximize load reductions to the lake and improve water quality. These work efforts were funded by the Lake Jessamine Property Owners Association and managed by OCEPD.

The Final Report for the ERD study was issued in January 2012 in a document titled "Lake Jessamine Hydrologic/Nutrient Budget and Water Quality Management Plan". This report provided a discussion of the physical characteristics of Lake Jessamine, including lake bathymetry, sediment accumulation and characteristics, and water quality. Detailed hydrologic and nutrient budgets are provided which include inputs of total nitrogen, total phosphorus, and TSS. Based on the mean annual total phosphorus budget, approximately 43% of the annual phosphorus inputs to Lake Jessamine occur as a result of internal recycling, with 23% contributed by bulk precipitation, 13% by stormwater runoff, and 9% by groundwater seepage. Inputs from overland flow and inflows from interconnected waterbodies each contribute 1-5% of the annual phosphorus loadings. The ERD report recommended that a sediment inactivation project be conducted, with approximately 189,000 gallons of alum and 48,000 gallons of sodium aluminate added to Lake Jessamine during three separate applications.

1.6 Work Efforts Conducted by ERD

During June 2012, ERD was contracted by OCEPD to conduct the recommended sediment inactivation project to Lake Jessamine. The contracted work efforts included three separate chemical applications to Lake Jessamine, with pre- and post-water quality monitoring conducted for each of the three events. The services also included collection and analysis of post-treatment sediment samples to document the effectiveness of the sediment inactivation for reducing the availability of phosphorus within Lake Jessamine sediments. The three chemical applications to Lake Jessamine were conducted during July 2012, October-November 2012, and June 2013. Post-treatment sediment samples were collected during September 2013 and compared with the pre-treatment samples to evaluate the effectiveness of the treatments.

This report is divided into four separate sections for presentation of the work efforts conducted by ERD. Section 1 contains an introduction to the report, a discussion of physical characteristics of Lake Jessamine, a historical summary of water quality issues, and a brief summary of work efforts conducted by ERD. Details concerning the alum treatment process, determination of alum dose, and application activities conducted by ERD are provided in Section 2. A summary of the results of the sediment and water quality monitoring efforts are provided in Section 3, along with an evaluation of the success of the inactivation project. A summary of the conclusions from the study is given in Section 4. Appendices are attached which contain historical water quality data for Lake Jessamine and visual sediment data collected by ERD during this project.

SECTION 2

ALUM DOSE CALCULATIONS AND APPLICATION DETAILS

This section provides a discussion of the methodology used by ERD to evaluate sediment inactivation requirements in Lake Jessamine and application methods used during the inactivation process. Since the application dose is based upon the mass of available phosphorus within the sediments of Lake Jessamine, a discussion is provided for sediment characterization techniques, methods of analysis, and sediment speciation, along with general pre-treatment sediment characteristics.

2.1 Sediment Characterization Techniques

Sediment core samples were initially collected in Lake Jessamine during December 2010 to evaluate the characteristics of existing sediments and potential impacts on water quality within the lake. Sediment core samples were collected at 42 separate locations within the lake by ERD personnel. Locations of sediment sampling sites in Lake Jessamine are illustrated on Figure 2-1. The results of the initial sediment monitoring event were used to identify general sediment characteristics as well as to estimate bonding mechanisms for phosphorus within the lake sediments. Isopleth contour plots were developed for each of the evaluated sediment characteristics, including phosphorus speciation.

A detailed discussion of the results of this initial sediment monitoring event is provided in the January 2012 ERD report titled "Lake Jessamine Hydrologic/Nutrient Budget and Water Quality Management Plan". This document also provides calculations of the mass of total available phosphorus within the top 0-10 cm layer of the sediments in Lake Jessamine and provides calculations for the quantity of alum required for sediment inactivation. The information contained in the January 2012 report is used as the basis for the subsequent sediment inactivation project.

Additional sediment monitoring was conducted by ERD in Lake Jessamine during September 2013 to evaluate post-treatment sediment characteristics resulting from the recommended alum applications to the lake and document the changes in available phosphorus in the lake sediments. During this supplemental sediment monitoring event, sediment core samples were collected at each of the 42 locations used for the initial pre-treatment sediment monitoring event, as illustrated on Figure 2-1. The results of the pre- and post-treatment sediment monitoring events are discussed in Section 3.

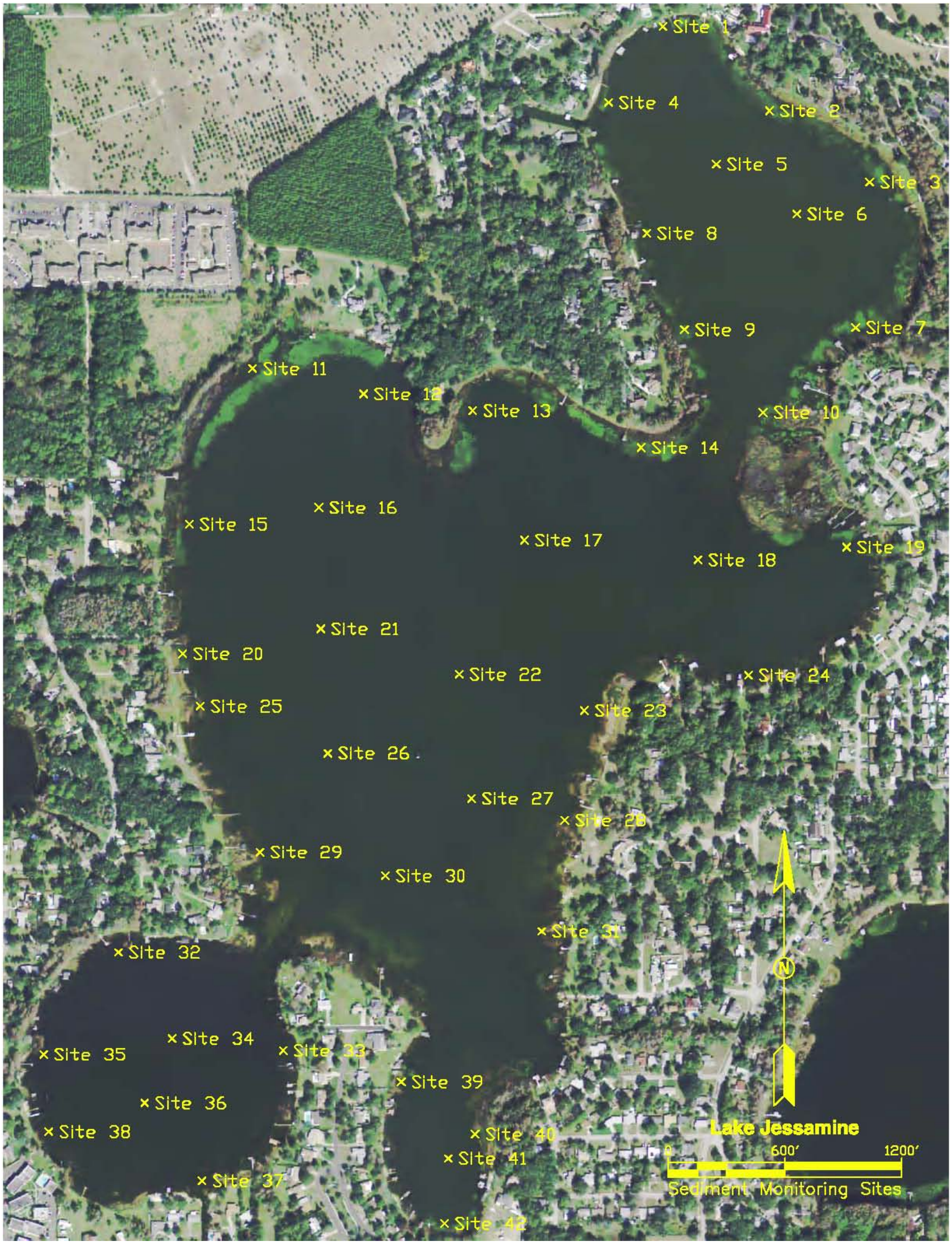


Figure 2-1. Location of Sediment Monitoring Sites in Lake Jessamine.

2.1.1 Sampling Techniques

Sediment samples were collected at each of the 42 monitoring sites using a stainless steel split-spoon core device, which was penetrated into the sediments at each location to a minimum distance of approximately 0.5 m. After retrieval of the sediment sample, any overlying water was carefully decanted before the split-spoon device was opened to expose the collected sample. Visual characteristics of each sediment core sample were recorded, and the 0-10 cm layer was carefully sectioned off and placed into a polyethylene container for transport to the ERD laboratory. Duplicate core samples were collected at each site, and the 0-10 cm layers were combined together to form a single composite sample for each of the 42 monitoring sites. The polyethylene containers used for storage of the collected samples were filled completely to minimize air space in the storage container above the composite sediment sample. Each of the collected samples was stored on ice and returned to the ERD laboratory for physical and chemical characterization.

2.1.2 Sediment Analysis and Speciation Techniques

Each of the 42 collected pre- and post-treatment sediment core samples was analyzed for a variety of general parameters, including moisture content, organic content, pH, sediment density, total nitrogen, and total phosphorus. Methodologies utilized for preparation and analysis of the sediment samples for these parameters are outlined in Table 2-1.

TABLE 2-1

ANALYTICAL METHODS FOR SEDIMENT ANALYSES

MEASUREMENT PARAMETER	SAMPLE PREPARATION	ANALYSIS REFERENCE	REFERENCE PREP./ANAL.*	METHOD DETECTION LIMITS (MDLs)
pH	EPA 9045	EPA 9045	3 / 3	0.01 pH units
Moisture Content	p. 3-54	p. 3-58	1 / 1	0.1%
Organic Content (Volatile Solids)	p. 3-52	pp. 3-52 to 3-53	1 / 1	0.1%
Total Phosphorus	pp. 3-227 to 3-228 (Method C)	EPA 365.4	1 / 2	0.005 mg/kg
Total Nitrogen	p. 3-201	pp. 3-201 to 3-204	1 / 1	0.010 mg/kg
Specific Gravity Density)	p. 3-61	pp. 3-61 to 3-62	1 / 1	NA

*REFERENCES:

1. Procedures for Handling and Chemical Analysis of Sediments and Water Samples, EPA/Corps of Engineers, EPA/CE-81-1, 1981.
2. Methods for Chemical Analysis of Water and Wastes, EPA 600/4-79-020, Revised March 1983.
3. Test Methods for Evaluating Solid Wastes, Physical-Chemical Methods, Third Edition, EPA-SW-846, Updated November 1990.

In addition to general sediment characterization, a fractionation procedure for inorganic soil phosphorus was conducted on each of the 42 collected sediment samples. The modified Chang and Jackson Procedure, as proposed by Peterson and Corey (1966), originally developed for agricultural soils, was used as the basis for the phosphorus fractionation. The Chang and Jackson Procedure allows the speciation of phosphorus in soils into saloid-bound phosphorus (defined as the sum of soluble plus easily exchangeable sediment phosphorus), iron-bound phosphorus, and aluminum-bound phosphorus. Although not used in this project, subsequent extractions of the Chang and Jackson procedure also provide calcium-bound and residual fractions.

The Chang and Jackson procedure was originally developed at the University of Wisconsin to evaluate phosphorus bonding in dried agricultural soils. However, drying of wet sediments will significantly impact the phosphorus speciation, particularly the soluble and iron-bound associations. Therefore, the basic Chang and Jackson method was adapted and modified by ERD during 1992 for wet sediments by adjusting solution concentrations and extraction timing to account for the liquid volume in the wet sediments and the reduced solids mass. This modified method has been used as the basis for all sediment inactivation projects which have been conducted in the State of Florida.

Saloid-bound phosphorus is considered to be available under all conditions at all times. Iron-bound phosphorus is relatively stable under aerobic environments, generally characterized by redox potentials greater than 200 mv (E_h), while unstable under anoxic conditions, characterized by redox potential less than 200 mv. Aluminum-bound phosphorus is considered to be stable under all conditions of redox potential and natural pH conditions. A schematic of the Chang and Jackson Speciation Procedure for evaluating sediment phosphorus bounding is given in Figure 2-2.

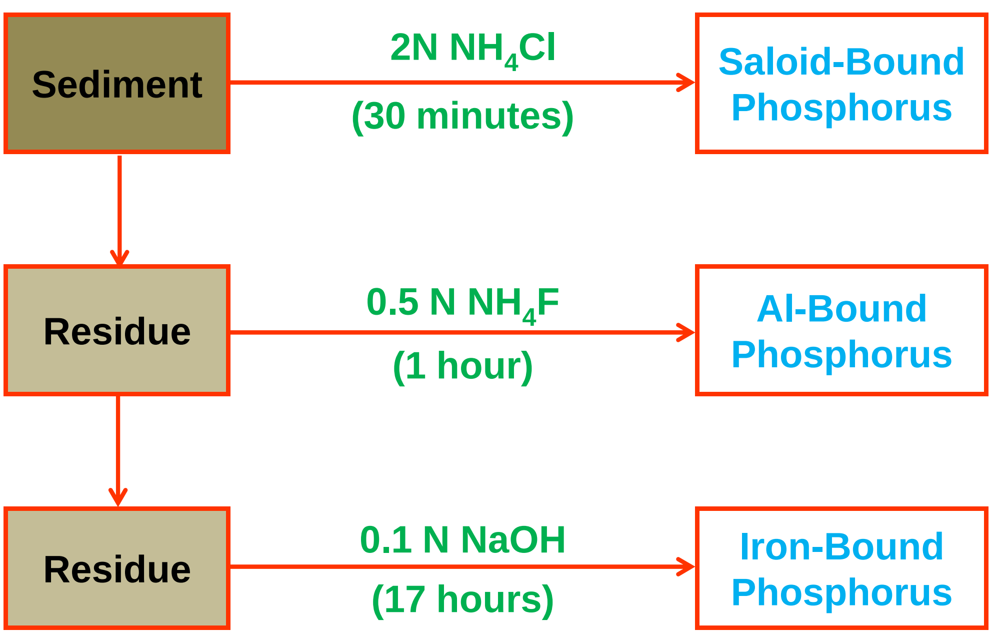


Figure 2-2. Schematic of Chang and Jackson Speciation Procedure for Evaluating Soil Phosphorus Bonding.

For purposes of evaluating release potential, ERD typically assumes that potentially available inorganic phosphorus in soils/sediments, particularly those which exhibit a significant potential to develop reduced conditions below the sediment-water interface, is represented by the sum of the soluble inorganic phosphorus and easily exchangeable phosphorus fractions (collectively termed saloid-bound phosphorus), plus iron-bound phosphorus which can become solubilized under reduced conditions. Aluminum-bound phosphorus is generally considered to be unavailable in the pH range of approximately 5.5-7.5 under a wide range of redox conditions.

2.2 Inactivation Dose Determination

2.2.1 Introduction

Sediment phosphorus inactivation is a lake restoration technique which is designed to substantially reduce sediment phosphorus release by combining available phosphorus in the sediments with a metal salt to form an insoluble inert precipitate, rendering the sediment phosphorus unavailable for release into the overlying water column. Although salts of aluminum, calcium, and iron have been used for sediment inactivation in previous projects, aluminum salts are the clear compounds of choice for most applications. Inactivation of sediment phosphorus using aluminum is a substantially less expensive option for reducing sediment phosphorus release compared with sediment removal by dredging.

Sediment phosphorus inactivation is most often performed using aluminum sulfate, commonly called alum, which is applied at the surface in a liquid form using a boat or barge. Upon entering the water column, the alum forms an insoluble precipitate of aluminum hydroxide which attracts phosphorus, bacteria, algae, and suspended solids within the water column, settling these constituents into the bottom sediments. Upon reaching the bottom sediments, the residual aluminum binds tightly with phosphorus within the sediments, forming an inert precipitate which will not be re-released under any conceivable condition of pH or redox potential which could occur in a natural lake system.

It is generally recognized that the top 10 cm layer of the sediments is the most active in terms of release of phosphorus under anoxic conditions. Therefore, the objective of a sediment inactivation project is to provide sufficient alum to bind the saloid- and iron-bound phosphorus associations in the top 10 cm of the sediments. These sediment treatments have been shown to be effective from 5-20 years in other Florida lakes, depending upon the sediment accumulation rate within the lake from the remaining phosphorus sources.

2.2.2 Calculation of Sediment Inactivation Requirements

Calculation of sediment inactivation requirements are based upon the mass of total available phosphorus which can potentially mobilize from the sediments to the overlying water column. Estimates of the mass of total available phosphorus within the top 0-10 cm layer of the sediments in Lake Jessamine were generated by graphically integrating the total available phosphorus isopleths presented on Figure 2-16 of the January 2012 ERD report. A copy of this map is given on Figure 2-3. The top 0-10 cm layer of the sediments is considered to be the most active layer with respect to exchange of phosphorus between the sediments and the overlying water column. Inactivation of phosphorus within the 0-10 cm layer is typically sufficient to substantially inactivate sediment release of phosphorus within a lake.

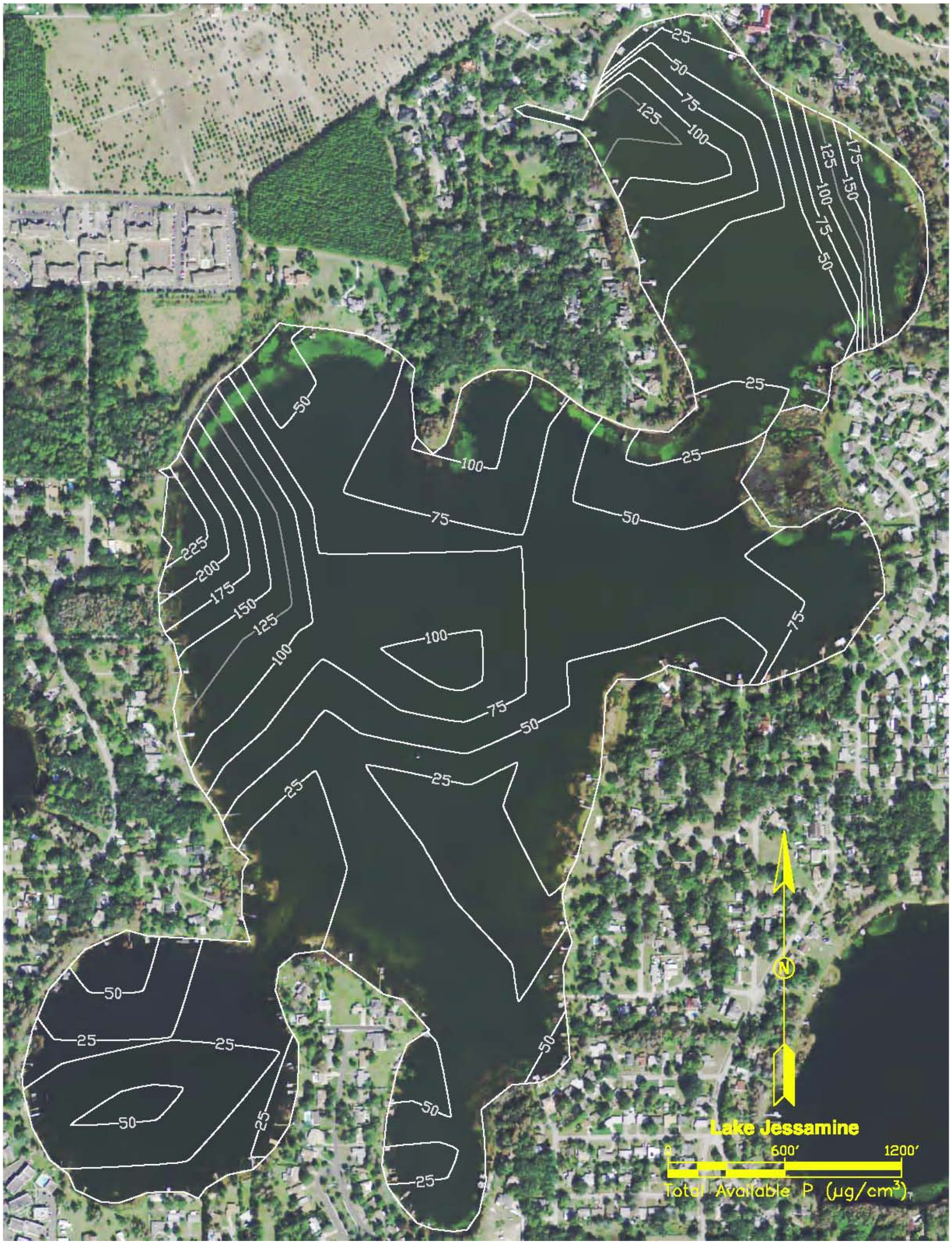


Figure 2-3. Isopleths of Total Available Phosphorus in the Top 10 cm of Sediments in Lake Jessamine.

Prior research involving sediment inactivation has indicated that an excess of aluminum is required within the sediments to cause phosphorus to preferentially bind with aluminum rather than other available competing ions. Previous sediment inactivation projects performed by ERD have been conducted at molar Al:P ratios of 2, 3, 5, and 10, with most recent sediment inactivation projects performed using a 10:1 ratio. An Al:P ratio of 10:1 was used in Lake Jessamine.

A summary of estimated total available phosphorus in the sediments of Lake Jessamine is given in Table 2-2. The measured available phosphorus contour intervals are divided into separate ranges for each of the isopleth lines indicated on the figure. The lake surface area contained within each contour interval is then determined using GIS. The available phosphorus is calculated by multiplying the contour area times the interval mid-point for each contour interval, over a depth of 10 cm. This results in an estimate of the mass of available phosphorus contained in each contour interval within the lake which are then summed to estimate the total available phosphorus mass in the top 10 cm of the lake. The available phosphorus mass is converted into an equivalent number of moles of phosphorus based on the molecular weight of 31 g/mole. Moles of aluminum required for sediment inactivation are then calculated based upon a molar Al:P ratio of 10:1. The moles of aluminum are then converted into an equivalent volume of liquid alum.

TABLE 2-2

ESTIMATES OF AVAILABLE SEDIMENT PHOSPHORUS AND INACTIVATION REQUIREMENTS FOR LAKE JESSAMINE

AVAILABLE P CONTOUR INTERVAL ($\mu g/cm^3$)	CONTOUR INTERVAL MID-POINT ($\mu g/cm^3$)	CONTOUR AREA (acres)	AVAILABLE PHOSPHORUS		ALUM REQUIREMENTS (Al:P Ratio = 10:1)	
			kg	moles	moles Al	gallons alum
< 25	12.5	40.35	204	6,588	65,879	8,022
25-50	37.5	96.79	1,470	47,405	474,048	57,724
50-75	62.5	61.70	1,561	50,364	503,639	61,327
75-100	87.5	47.10	1,669	53,825	538,249	65,541
100-125	112.5	17.37	791	25,516	255,157	31,070
125-150	137.5	8.85	493	15,893	158,928	19,352
150-175	162.5	4.71	310	10,002	100,016	12,179
175-200	187.5	8.77	666	21,483	214,827	26,159
200-225	212.5	2.11	181	5,848	58,479	7,121
> 225	237.5	1.47	141	4,562	45,623	5,555
Overall Totals:		**289.2**	**7,486**	**241,484**	**2,414,845**	**294,050**

On a mass basis, the sediments of Lake Jessamine contain approximately 7,486 kg of available phosphorus in the top 10 cm, equivalent to approximately 241,484 moles of available phosphorus to be inactivated as part of the sediment inactivation process. Estimated inactivation requirements were calculated for Lake Jessamine based upon a molar Al:P ratio of 10:1. Prior research involving sediment inactivation has indicated that an excess of aluminum is required within the sediments to cause phosphorus to preferentially bind with aluminum rather than other available complexing agents. Based upon this ratio, inactivation of phosphorus release from sediments in Lake Jessamine will require approximately 2,414,845 moles of aluminum which equates to approximately 294,050 gallons of alum, equivalent to 65.3 tankers of alum containing 4,500 gallons each. The equivalent amount of aluminum required for sediment inactivation is 75,201 kg.

An average water column dose of alum required for sediment inactivation was calculated by dividing the required alum volume of 294,050 gallons by the overall volume of the lake (3,173 ac-ft). Since the alum application would occur at the surface, the overall whole-lake alum dose must be evaluated in addition to sediment requirements. Application of approximately 294,050 gallons of alum to Lake Jessamine into a water column volume of approximately 3,173 ac-ft would result in an applied alum dose of 16.8 mg Al/liter, which is within the range of concentrations typically calculated for sediment inactivation projects in the Central Florida area. However, a dose in this range would substantially exceed the available buffering capacity of the lake and would need to be divided into multiple individual applications and incorporate a supplemental buffering compound to minimize the impact on pH in the lake.

2.2.3 <u>Chemical Additions</u>

A summary of chemical additions to Lake Jessamine during the three applications is given in Table 2-3. In order to maintain a minimum pH value of approximately 6.0-6.5 during the application process, a supplemental buffering agent (sodium aluminate) was required in addition to alum. Sodium aluminate is an alkaline form of alum which can be applied in conjunction with alum to control pH at any desired level. Alum contains approximately 4.4% aluminum by weight, while sodium aluminate contains approximately 10.6% aluminum by weight. In addition to providing buffering capacity, sodium aluminate also provides a substantial amount of additional aluminum for generation of floc which reduces the quantity of alum required. The total desired aluminum mass of 75,201 kg to be applied to Lake Jessamine was achieved through a combination of alum and sodium aluminate so that the combined aluminum mass contributed by the two chemicals is equivalent to the desired aluminum mass of 75,201 kg. The specific ratios of alum and sodium aluminate used during each of the three applications were determined through a series of laboratory jar tests conducted approximately one week prior to each application.

Applied water column aluminum doses during the three applications ranged from 5.9-7.0 mg Al/liter. Sodium aluminate contributed approximately 37% of the total aluminum applied during the initial application, 31% of the second application, and 34% of the final application. Alum/sodium aluminate (SA) ratios are provided near the bottom of Table 2-3 for each of the three applications. An alum:SA ratio of 4.5 indicates that 4.5 gallons of alum are applied for every 1 gallon of sodium aluminate. This ratio increases to 6.0 during the second application, decreasing slightly to 5.1 during the final application. These ratios were used by the application crew to pace the chemical additions of alum and sodium aluminate to match the calculated ratios for each treatment.

TABLE 2-3

SUMMARY OF CHEMICAL ADDITIONS TO LAKE JESSAMINE DURING THE THREE APPLICATIONS

PARAMETER	UNITS	APPLICATION		
		1 (July 17-30, 2012)	**2 (Oct. 19-Nov. 5, 2012)**	**3 June 3-14, 2013**
Lake Area	acres	288.5	288.5	288.5
Lake Volume	ac-ft	3,173	3,173	3,173
Volume of Alum Added	tankers gallons	16 72,000	16 72,000	18 81,000
Alum Characteristics	wt/lb % Al	11.1 0.044	11.1 0.044	11.1 0.044
Volume of Sodium Aluminate Added	tankers gallons	4 16,000	3 12,000	4 16,000
Sodium Aluminate Characteristics	wt/lb % Al	12.3 0.106	12.3 0.106	12.3 0.106
Alum Water Column Dose	mg Al/liter	4.1	4.1	4.6
Sodium Aluminate Water Column Dose	mg Al/liter	2.4	1.8	2.4
Total Water Column Dose	mg Al/liter	6.5	5.9	7.0
Alum:SA Ratio	**--**	**4.5**	**6.0**	**5.1**
Aluminum Added	kg	25,398	23,035	27,391

Applied Areal Dose = 64.9 g Al/m^2

Calculations of the total mass of aluminum added to Lake Jessamine during each of the three applications is given in the final row of Table 2-3. A total of 25,398 kg of aluminum was added during the initial application, with 23,035 kg added during the second application, and 27,391 kg added during the third application. Overall, a total of 75,824 kg of aluminum was added to Lake Jessamine during the three applications, compared with the calculated aluminum requirement of 75,201 kg. The applied areal dose was 64.9 g Al/m^2.

As indicated on Figure 2-3, concentrations of available phosphorus within the sediments of Lake Jessamine are highly variable, and some areas of Lake Jessamine require a larger volume of alum for sediment inactivation than other areas where the available phosphorus concentrations are less. An application map was developed by ERD which divides Lake Jessamine into five separate zones which include each of the lobes and divides the larger central lobe into two smaller areas. An overview of the designated zones is given on Figure 2-4. The total available phosphorus contained within each of the four zones was calculated and expressed as a percentage of the overall total available sediment phosphorus within the entire lake.

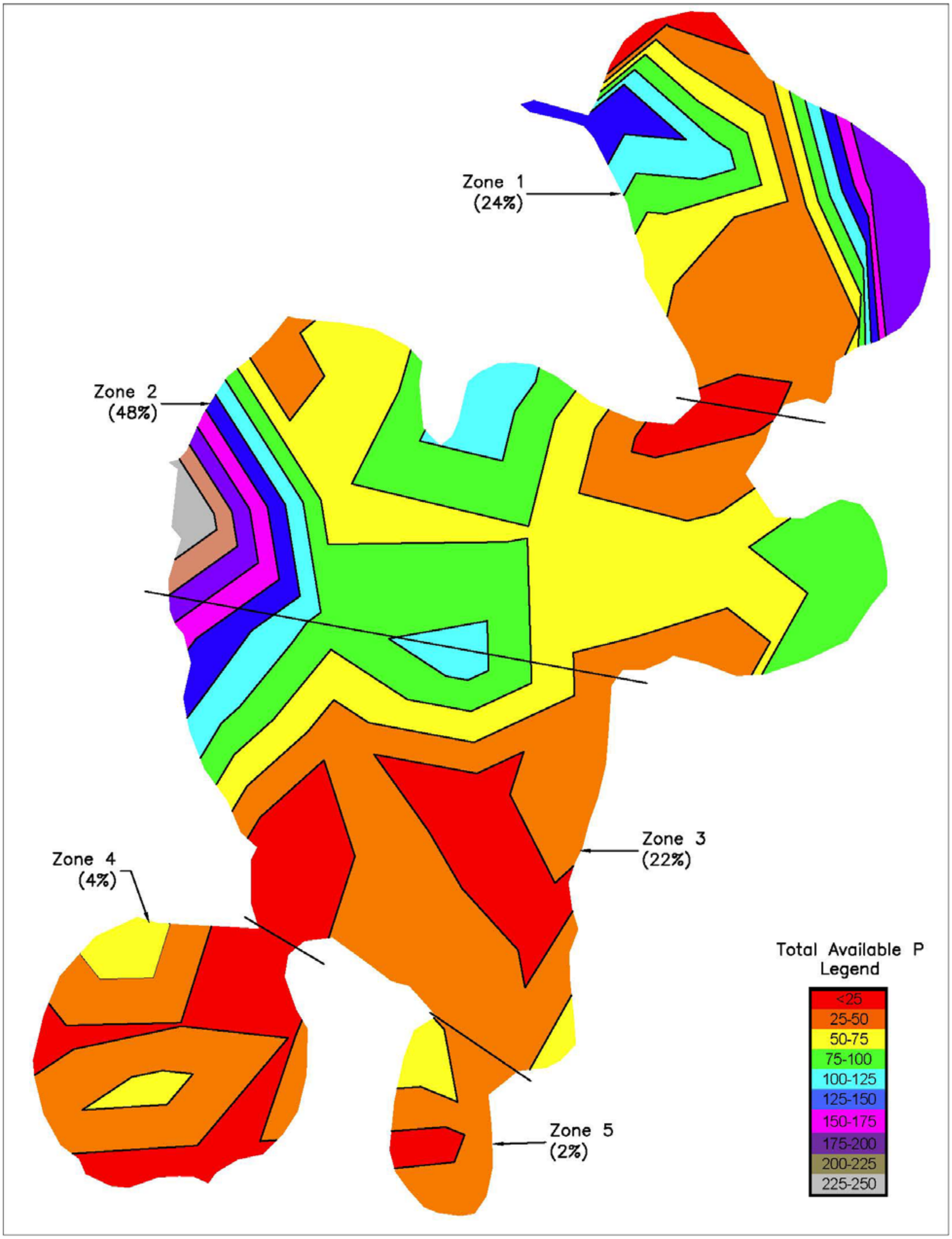


Figure 2-4. Application Map Indicating the Fraction of Total Alum to be Applied to the Identified Zones.

A summary of calculations used to estimate available sediment phosphorus and sediment inactivation requirements for each of the five zones in Lake Jessamine is given in Table 2-4. Estimates of available phosphorus are calculated for each of the five zones by integrating the available phosphorus contours within each of the five areas and converting the available phosphorus into an equivalent mass of aluminum based upon an Al:P ratio of 10:1. The equivalent amount of alum required to contribute the required aluminum mass is approximately 298,417 gallons.

As discussed previously, the sediment inactivation was conducted using a combination of alum and sodium aluminate. A summary of the total quantity of alum and sodium aluminate added to each of the five zones during the three applications is given in Table 2-5. Overall, sediment inactivation in Lake Jessamine required a total of 189,000 gallons of alum and 48,000 gallons of sodium aluminate, with an average of 63,000 gallons of alum and 16,000 gallons of sodium aluminate applied during each of the three treatments.

Based upon the application map, Zone 1 would receive approximately 24% of the total aluminum applied during each of the three individual applications, with Zone 2 receiving 48%, Zone 3 receiving 22%, Zone 4 receiving approximately 4%, and Zone 5 receiving 2% of the total applied aluminum. As a result, approximately 70% of the total aluminum applied to Lake Jessamine during the three applications was applied within Zones 2 and 3 in central portions of the lake. The smallest amount of aluminum (2%) was applied in Zone 5 which is referred to as the southeast lobe.

2.2.4 Application Methods

Each of the alum applications to Lake Jessamine was conducted using the application boat and tanker barge combination illustrated on Figure 2-5. The smaller tank in the application boat holds approximately 500 gallons and was used to hold sodium aluminate. The tanker barge holds approximately 1,000 gallons and was used to hold alum. The application boat and tanker barge would pull up to the shoreline area and alum and sodium aluminate were pumped from the tanker delivery trucks into the boat and barge tanks. The application boat and barge would then travel to the zone of the lake where the chemicals were to be applied, and the application process would begin.

During the application, the alum is sprayed through a spreader bar located on the front of the application boat. The pumping system contains an intake for lake water, and lake water and alum were pre-mixed before being sprayed onto the lake surface which helps mix the alum with the water prior to application onto the lake surface. If the alum is not initially pre-mixed with water, there is a risk that the alum (which is approximately 40% denser than water) would simply settle through the water column without adequately mixing with the lake water. The sodium aluminate buffer was sprayed from a spreader bar attached to the rear of the barge.

During the application process, ERD conducted field measurements of pH on an hourly basis within each zone where alum is being applied. In addition, water samples were collected on a daily basis from each of the application zones and returned to the ERD Laboratory for analysis of alkalinity to ensure that the alum addition did not reduce alkalinity levels within the water column to an undesirable range.

TABLE 2-4

CALCULATED SEDIMENT INACTIVATION REQUIREMENTS FOR THE FIVE ZONES IN LAKE JESSAMINE

Zone 1

AVAILABLE PHOSPHORUS CONTOUR (μg/cm^3)	CONTOUR MID-POINT (μg/cm^3)	CONTOUR AREA (acres)	AVAILABLE PHOSPHORUS		Al:P RATIO = 10:1	
			kg	moles	moles Al	gallons of Alum
< 25	12.5	3.15	16	514	5,144	626
25-50	37.5	20.87	317	10,224	102,236	12,449
50-75	62.5	9.35	237	7,633	76,333	9,295
75-100	87.5	6.67	236	7,626	76,259	9,286
100-125	112.5	5.83	266	8,565	85,647	10,429
125-150	137.5	4.06	226	7,295	72,952	8,883
150-175	162.5	1.28	84	2,723	27,226	3,315
175-200	187.5	5.64	428	13,806	138,060	16,811
Overall Totals:		**56.9**	**1,810**	**58,386**	**583,858**	**71,095**

Zone 2

AVAILABLE PHOSPHORUS CONTOUR (μg/cm^3)	CONTOUR MID-POINT (μg/cm^3)	CONTOUR AREA (acres)	AVAILABLE PHOSPHORUS		Al:P RATIO = 10:1	
			kg	moles	moles Al	gallons of Alum
< 25	12.5	2.78	14	454	4,538	553
25-50	37.5	15.02	228	7,358	73,577	8,959
50-75	62.5	39.23	993	32,021	320,211	38,991
75-100	87.5	33.86	1,200	38,695	386,954	47,119
100-125	112.5	7.48	341	10,995	109,952	13,389
125-150	137.5	2.94	164	5,274	52,744	6,423
150-175	162.5	2.84	187	6,018	60,184	7,329
175-200	187.5	2.71	206	6,641	66,412	8,087
200-225	212.5	2.21	190	6,121	61,213	7,454
>225	237.5	1.54	148	4,782	47,820	5,823
Overall Totals:		110.6	3,669	118,361	1,183,606	144,125

TABLE 2-4 -- CONTINUED

CALCULATED SEDIMENT INACTIVATION REQUIREMENTS FOR THE FIVE ZONES IN LAKE JESSAMINE

Zone 3

AVAILABLE PHOSPHORUS CONTOUR (μg/cm³)	CONTOUR MID-POINT (μg/cm³)	CONTOUR AREA (acres)	AVAILABLE PHOSPHORUS		Al:P RATIO = 10:1	
			kg	moles	moles Al	gallons of Alum
< 25	12.5	20.59	104	3,362	33,619	4,094
25-50	37.5	38.11	579	18,667	186,671	22,730
50-75	62.5	10.08	255	8,230	82,303	10,022
75-100	87.5	8.73	309	9,979	99,793	12,152
100-125	112.5	4.85	221	7,126	71,262	8,677
125-150	137.5	2.25	125	4,042	40,417	4,921
150-175	162.5	0.81	53	1,720	17,196	2,094
175-200	187.5	0.30	23	744	7,440	906
Overall Totals:		85.7	1,670	53,870	538,701	65,596

Zone 4

AVAILABLE PHOSPHORUS CONTOUR (μg/cm³)	CONTOUR MID-POINT (μg/cm³)	CONTOUR AREA (acres)	AVAILABLE PHOSPHORUS		Al:P RATIO = 10:1	
			kg	moles	moles Al	gallons of Alum
< 25	12.5	14.10	71	2,302	23,019	2,803
25-50	37.5	7.25	110	3,549	35,493	4,322
50-75	62.5	3.94	100	3,215	32,150	3,915
Overall Totals:		25.3	281	9,066	90,662	11,040

Zone 5

AVAILABLE PHOSPHORUS CONTOUR (μg/cm³)	CONTOUR MID-POINT (μg/cm³)	CONTOUR AREA (acres)	AVAILABLE PHOSPHORUS		Al:P RATIO = 10:1	
			kg	moles	moles Al	gallons of Alum
< 25	12.5	1.59	8	259	2,590	315
25-50	37.5	7.25	110	3,549	35,493	4,322
50-75	62.5	1.94	49	1,580	15,799	1,924
Overall Totals:		10.8	167	5,388	53,883	6,561

TABLE 2-5

APPLIED CHEMICAL QUANTITIES FOR LAKE JESSAMINE SEDIMENT INACTIVATION

ZONE	FRACTION OF TOTAL	ALUM (gallons)	SODIUM ALUMINATE (gallons)	GALLONS / APPLICATION	
				Alum	Sodium Aluminate
1	0.24	45,027	11,436	15,009	3,812
2	0.48	91,280	23,182	30,427	7,727
3	0.22	41,545	10,551	13,848	3,517
4	0.04	6,993	1,776	2,331	592
5	0.02	4,155	1,055	1,385	352
	TOTAL:	189,000	48,000	63,000	16,000

Figure 2-5. Application Boat and Tanker Barge Used for Alum Application in Lake Jessamine.

SECTION 3

RESULTS

This section provides a summary and analysis of changes in water quality and sediment characteristics in Lake Jessamine resulting from the sediment inactivation project. Changes in water quality characteristics are evaluated based upon historical water quality data collected in Lake Jessamine by OCEPD, LAKEWATCH, and ERD. Changes in sediment characteristics and phosphorus speciation are based upon sediment monitoring events conducted by ERD.

3.1 Impacts to Water Quality Characteristics

Changes in water quality characteristics in Lake Jessamine resulting from the alum additions are evaluated based upon a comparison of historical water quality for Lake Jessamine and pre- and post-treatment monitoring conducted by ERD during each of the three alum applications. A discussion of historical water quality characteristics in Lake Jessamine is given in the following sections, followed by an analysis of pre- and post-treatment data collected by ERD.

3.1.1 Historical Water Quality

3.1.1.1 Historical Water Quality Data Availability

Relatively extensive historical water quality monitoring has been conducted in Lake Jessamine by the Orange County Environmental Protection Division (OCEPD) and the LAKEWATCH Program through the University of Florida. A summary of available historical water quality data for Lake Jessamine is given on Table 3-1. Historical water quality data were collected by LAKEWATCH from May 1993 to May 2000, with samples collected near the center of the lake. The LAKEWATCH monitoring was conducted on a monthly to quarterly basis, with a total of 48 samples collected over the available period of record. Measurements are conducted on the collected samples for nutrients and chlorophyll-a, and a measurement of Secchi disk depth is performed at the time of each sample collection.

Water quality monitoring in Lake Jessamine was initiated by OCEPD during June 1989 at a single monitoring site near the center of the lake (BM17M). Monitoring at this site was conducted on approximately a quarterly basis, with a total of 97 separate samples collected to date (January 2013). Beginning in June 1994, quarterly monitoring was also conducted in the northeast lobe (BC17NE) and the southwest lobe (BC17SW), with a total of 76 separate samples collected in the northeast lobe and 63 samples collected in the southwest lobe to date (January 2013). Each of the collected samples was evaluated for general parameters, nutrients, demand parameters, microbiological parameters, and metals. A listing of available historical water quality data for Lake Jessamine is given in Appendix A. The historical data does not include any data collected after the alum applications to the lake.

TABLE 3-1

SUMMARY OF AVAILABLE HISTORICAL WATER QUALITY DATA FOR LAKE JESSAMINE

DATA SOURCE	PERIOD OF RECORD	LOCATION	NUMBER OF SAMPLES	MONITORING FREQUENCY	PARAMETERS MEASURED
LAKEWATCH	5/93 - 5/00	Middle	48	Monthly to quarterly	Nutrients, Secchi Depth, Chlorophyll-a
OCEPD	6/89 – 1/13	Middle (BC17M)	97	Quarterly	General Parameters, Nutrients, Demand Parameters, Microbiological Parameters, Metals
	6/94 – 1/13	NE Lobe (BC17NE)	76	Quarterly	
	6/94 – 1/13	SW Lobe (BC17SW)	63	Quarterly	

3.1.1.2 Historical Water Quality Characteristics and Trends

Historical water quality characteristics in Lake Jessamine were evaluated by ERD based upon an examination of the results of individual monitoring events as well as mean annual concentrations for total phosphorus, total nitrogen, chlorophyll-a, Secchi disk depth, TN/TP ratio, and TSI. This analysis is an update to the evaluation provided in the January 2012 ERD report which includes data through 2009.

A summary of historical trends in total nitrogen in Lake Jessamine from 1989-2013 is given in Figure 3-1. Four separate plots of total nitrogen concentrations are provided on Figure 3-1. The top plot includes data collected at each of the three historical surface water monitoring sites which allows a comparison of water quality characteristics between different areas within the lake. Below that, total nitrogen concentrations are plotted individually for each of the three monitoring sites (middle, northeast lobe and southwest lobe) to evaluate potential water quality trends within various areas of the lake.

3.1.1.2.1 Total Nitrogen

A trend line obtained using linear regression techniques is also provided to assist in identifying significant water quality trends. The trend line is calculated based on annual average concentrations so that each year of data is given equal weight in the calculations. The calculated probability value (p value) is also provided which indicates the level of significance associated with each regression model. A model which is significant at a 95% confidence level would be associated with a p value of 0.05. However, lakes exhibit normal seasonal cyclic variations in water quality which can reduce the statistical significance of the regression model. For evaluating water quality trends in lakes, a p value of <0.1 is generally considered to indicate a significant statistical trend, with p values from 0.1-0.2 indicating weakly significant trends, and p values greater than 0.2 suggesting insignificant trends.

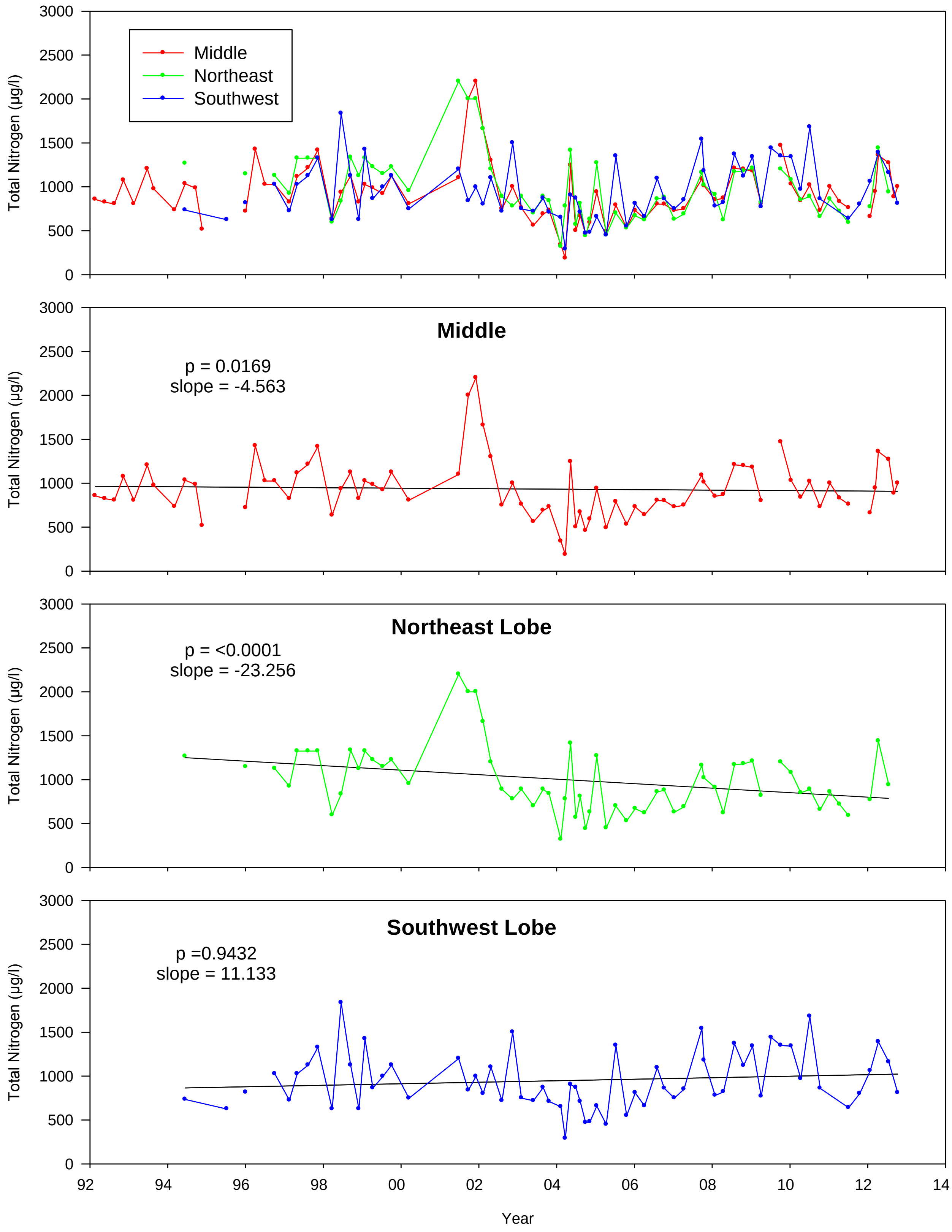


Figure 3-1. Trends in Total Nitrogen Concentrations in Lake Jessamine from 1989-2013.

In general, the majority of total nitrogen concentrations within the lake have ranged primarily from 500-1500 μg/l, with a small number of values both below and above this range. Measured total nitrogen concentrations in the northeast and middle lobes appear to be relatively similar during a majority of the monitoring dates, with slightly higher total nitrogen concentrations measured in the southwest lobe. Total nitrogen concentrations within the lake appear to peak from 2000-2002, with concentrations approaching 2000-2500 μg/l .

A trend of decreasing total nitrogen concentrations is apparent in the middle portion of the lake, based upon the calculated trend line. Based upon the calculated p value of 0.0169, this decreasing trend in total nitrogen concentrations is statistically significant. A trend of decreasing total nitrogen concentrations is also apparent in the northeast lobe of the lake, with the calculated p value of <0.0001 indicating that the trend is highly significant. A trend of increasing nitrogen concentrations appears to be occurring in the southwest lobe, although the calculated p value of 0.9432 indicates that the trend is not statistically significant.

3.1.1.2.2 <u>Total Phosphorus</u>

A graphical summary of historical trends in total phosphorus concentrations in Lake Jessamine from 1989-2013 is given on Figure 3-2. The vast majority of measured total phosphorus concentrations within the lake have ranged from approximately 10-30 μg/l, with isolated values both above and below this range. Phosphorus concentrations in the middle and northeast lobe appear to be relatively similar throughout much of the available period of record, with somewhat higher concentrations in the southwest lobe during many of the monitoring events. Peaks in phosphorus concentrations in the lake were observed in 1996 and in late-2005. A trend of slightly decreasing total phosphorus concentrations is apparent in middle portions of the lake over time. Based on the calculated p value of 0.0371, the trend of decreasing phosphorus concentrations appears to be statistically significant. A trend of decreasing total phosphorus concentrations is also apparent in the northeast lobe of the lake, and the calculated p value of 0.0235 suggests that the trend is also significant. An apparent trend of increasing total phosphorus concentrations is observed in the southwest lobe, but the p value of 0.5117 indicates that the trend is not statistically significant.

3.1.1.2.3 <u>Chlorophyll-a</u>

A graphical summary of historical trends in chlorophyll-a concentrations in Lake Jessamine from 1989-2013 is given on Figure 3-3. In general, measured chlorophyll-a concentrations in Lake Jessamine have ranged from approximately 1-30 mg/m^3, with a few isolated values both above and below this range. Chlorophyll-a concentrations appear to be more variable in the southwest lobe compared with measurements conducted in the middle and northeast lobes. Chlorophyll-a concentrations in the middle and northeast lobes have been relatively similar over the available period of record, with slightly higher values observed in the northeast lobe during the early-2000s and more elevated values in the middle lobe observed during the late-2000s. A trend of increasing chlorophyll-a concentrations has been observed in the middle lobe based upon the historical data, and the calculated p value of <0.0001 indicates that the increasing trend in chlorophyll-a is highly significant. A trend of increasing chlorophyll-a is apparent in the northeast lobe, although the calculated p value of 0.5683 suggests that the relationship is not statistically significant. A trend of increasing chlorophyll-a over time is also apparent in the southwest lobe, and the p value of 0.0071 indicates that the trend is highly significant.

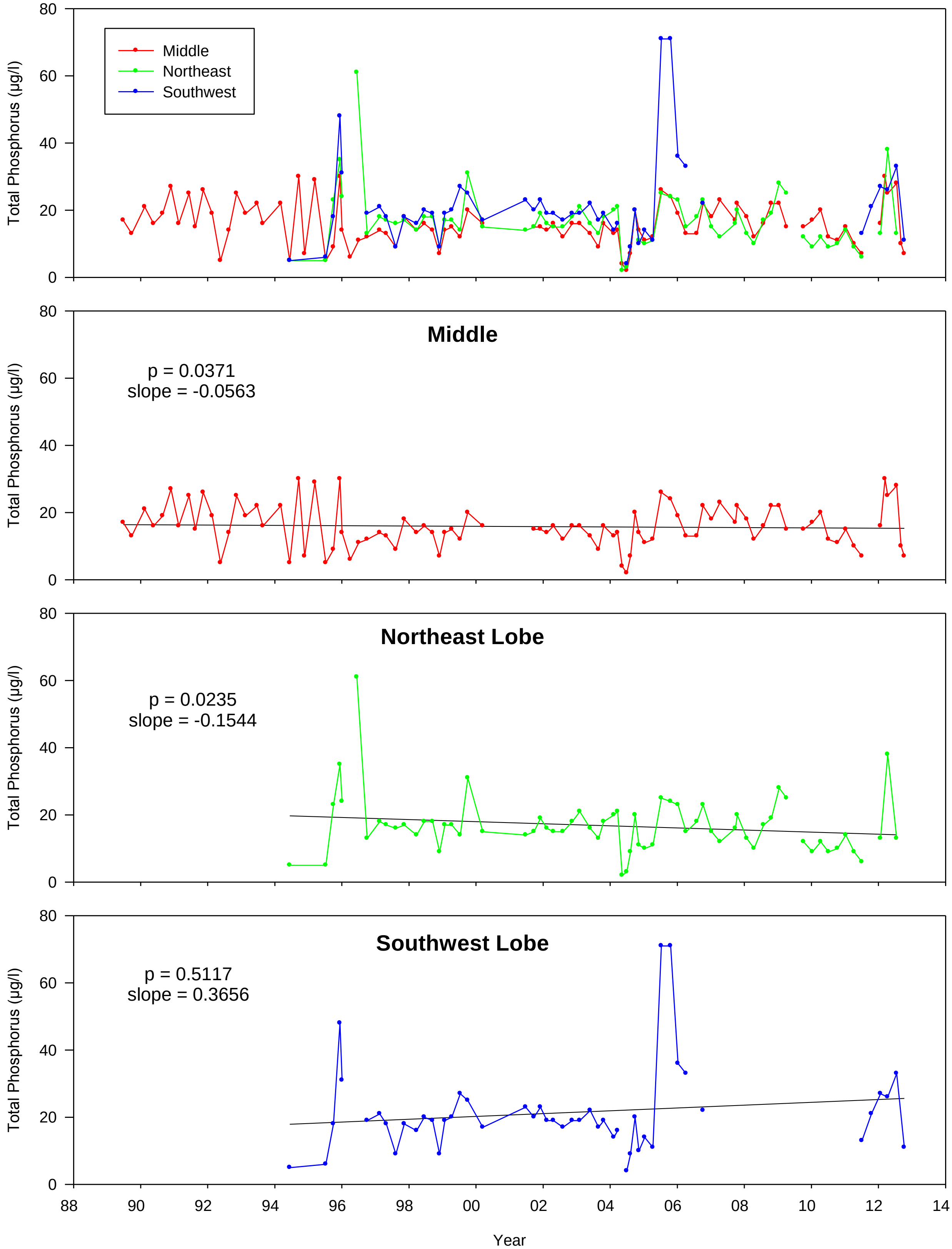


Figure 3-2. Trends in Total Phosphorus Concentrations in Lake Jessamine from 1989-2013.

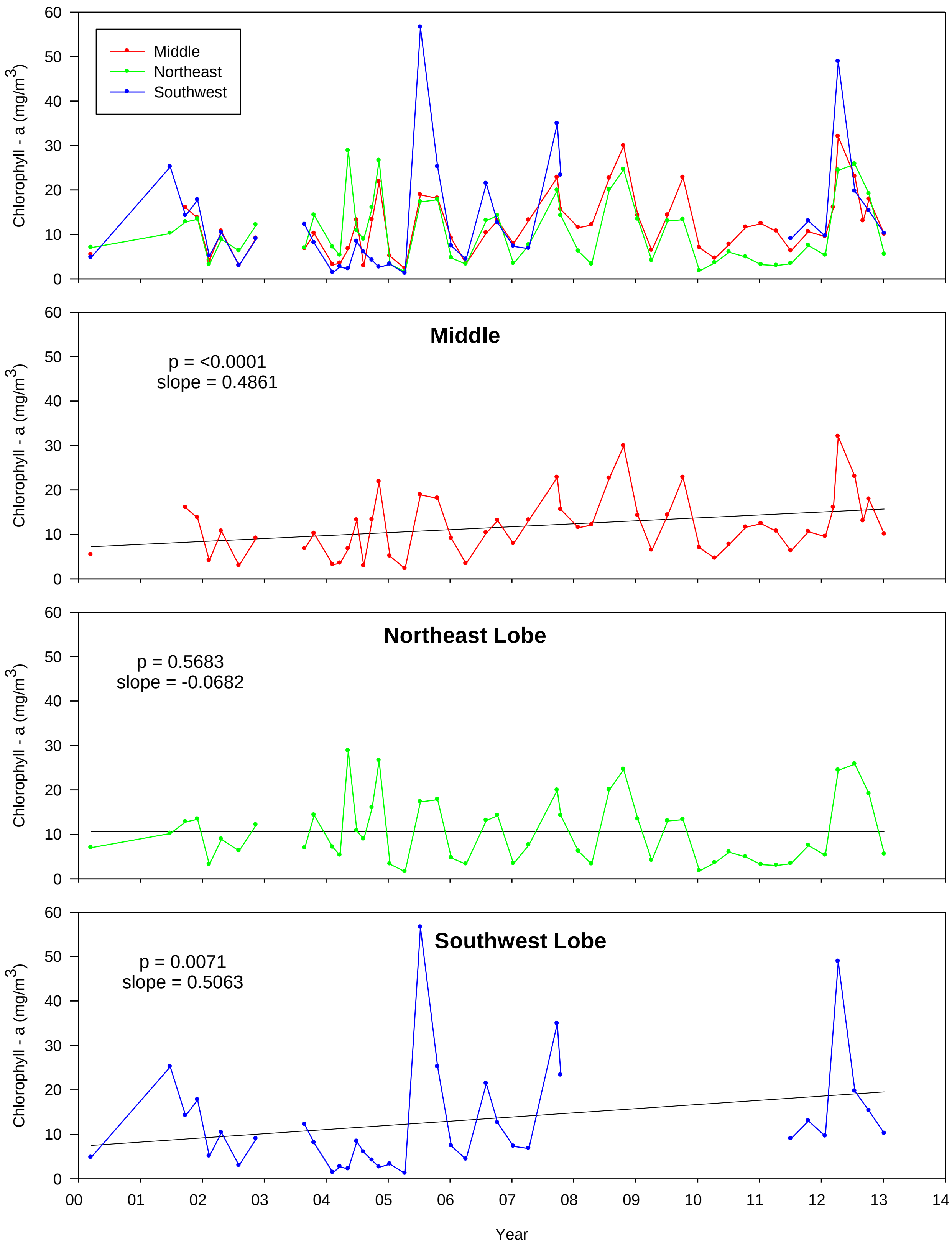


Figure 3-3. Trends in Chlorophyll-a Concentrations in Lake Jessamine from 2000-2013.

3.1.1.2.4 Secchi Disk Depth

A graphical summary of measured Secchi disk depths in Lake Jessamine from 1989-2013 is given on Figure 3-4. Measured Secchi disk depths within the lake have ranged from 0.5-3 m during a majority of the monitoring events, although isolated values occur which are both above and below this range. A general trend of decreasing Secchi disk depth has occurred in the middle lobe of the lake, and the calculated p value of 0.0191 suggests that the relationship is highly significant. A trend of increasing Secchi disk depth has been observed in the northeast lobe, and the calculated p value of 0.0068 indicates that the trend is statistically significant, although the trend of increasing water clarity is likely related to the explosive growth of aquatic macrophytes in the lake rather than reductions in nutrients. A similar trend of increasing Secchi disk depth has been observed in the southwest lobe, although the calculated p value of 0.9471 indicates that the trend is not significant.

3.1.1.2.5 Nutrient Limitation

Nutrient limitation in a waterbody is often evaluated using the total nitrogen/total phosphorus (TN/TP) ratio. The calculated TN/TP ratio is a numerical ratio of the measured water column concentrations of total nitrogen and total phosphorus. This ratio is useful in evaluating the relative significance of nitrogen and phosphorus in regulating primary productivity (algal growth) in a waterbody. Measured TN/TP ratios less than 10 are considered to indicate nitrogen-limited conditions, suggesting that phosphorus is relatively abundant and nitrogen is the element which regulates primary productivity and the growth of algae within the lake system. Calculated TN/TP ratios between 10-30 indicate nutrient-balanced conditions, with both nitrogen and phosphorus considered important for limiting aquatic growth. Calculated TN/TP ratios in excess of 30 indicate phosphorus-limited conditions, which suggests that nitrogen is abundant within the system and algal growth is limited by the availability of phosphorus. This is the typical situation observed in many lakes in the Central Florida area. This condition indicates that inputs of phosphorus into the lake system should be controlled to regulate the growth of algal biomass within the lake.

A summary of total nitrogen/total phosphorus (TN/TP) ratios in Lake Jessamine from 1992-2013 is given in Figure 3-5. It appears Lake Jessamine is predominantly a phosphorus-limited lake, with relatively similar TN/TP ratios throughout the lake. This ratio indicates that control of phosphorus loadings is necessary to improve and restore water quality in the lake.

3.1.1.2.6 Trophic State Index

Florida Trophic State Index (TSI) values were also calculated for each monitoring event in the four lakes over the period of historical data from 1993-2013. TSI is a summary statistic which incorporates measured concentrations of significant parameters in lake systems and is often considered the best overall indicator of the health of a lake system. Calculated TSI values less than 50 indicate oligotrophic conditions, representing lakes with low nutrient loadings and good to excellent water quality characteristics. Calculated TSI values from 50-60 indicate mesotrophic or fair water quality characteristics. Calculated TSI values between 60-70 indicate eutrophic or poor water quality characteristics, with hypereutrophic conditions, reflecting very poor water quality, indicated by TSI values in excess of 70.

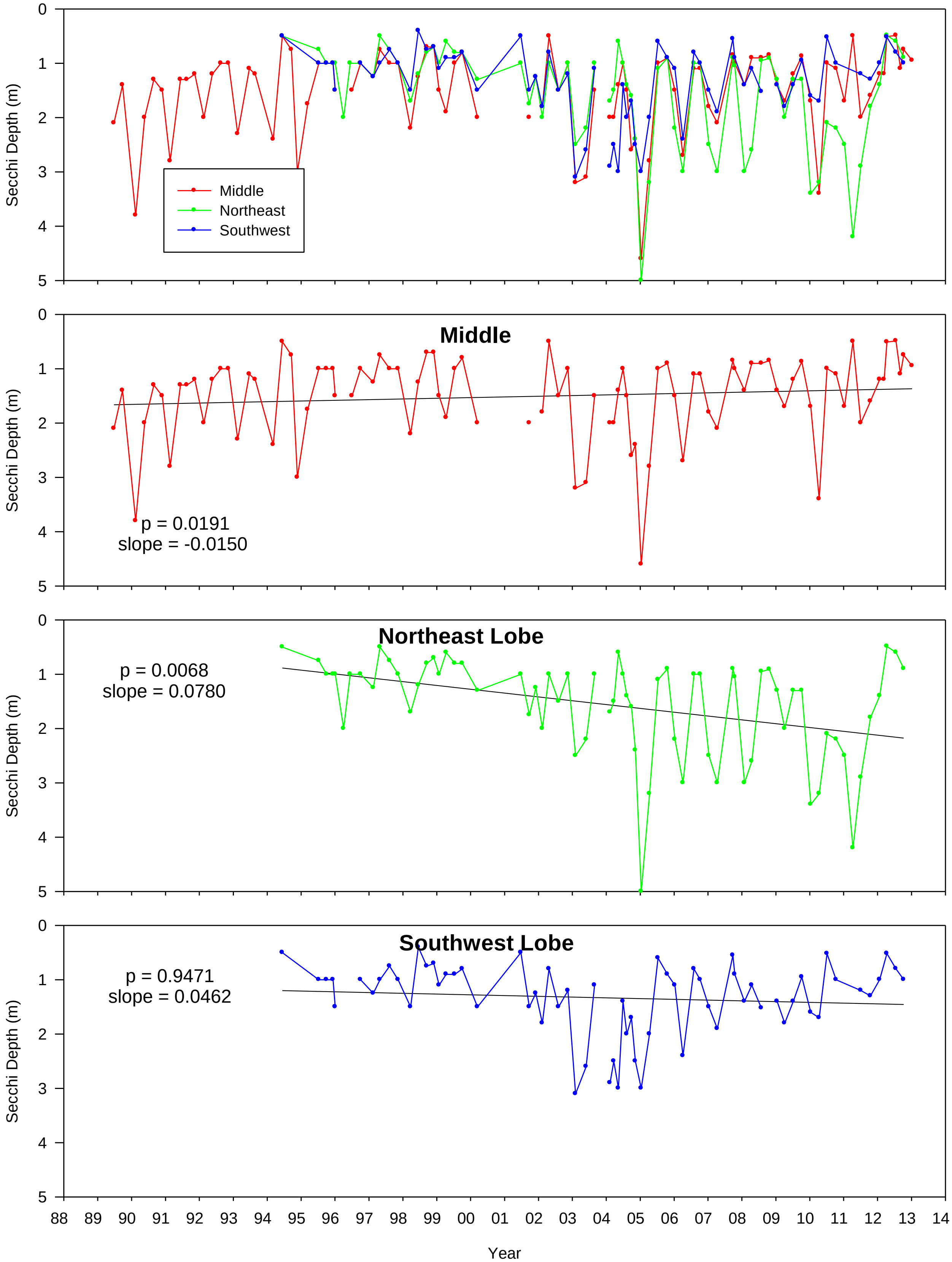


Figure 3-4. Trends in Secchi Disk Depth in Lake Jessamine from 1989-2013.

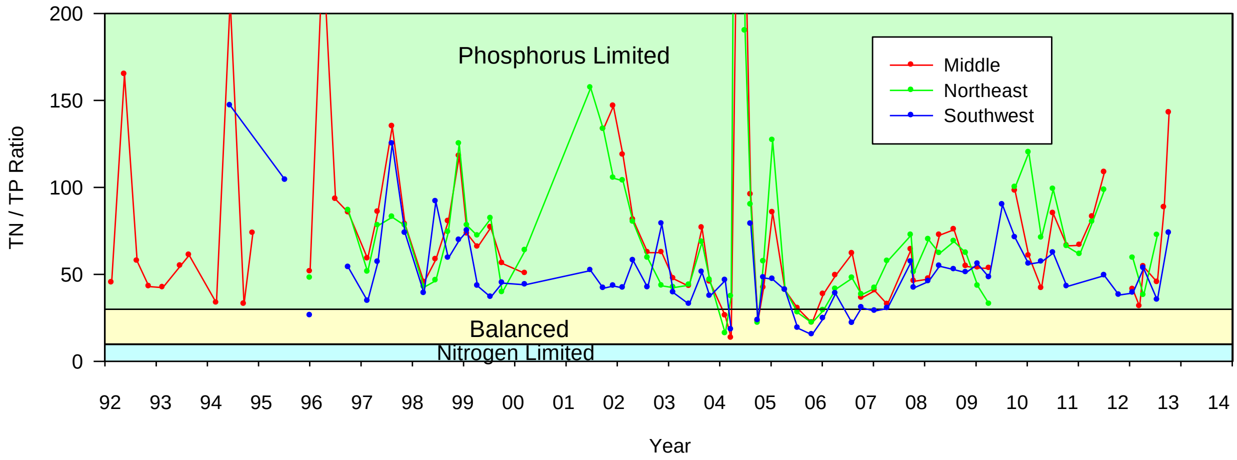


Figure 3-5. Calculated TN/TP Ratios in Lake Jessamine from 1992-2013.

The trophic state index was developed by Carlson (1977) as a relative measure of the degree of biological productivity in lakes. The TSI biological productivity concept incorporates forcing functions such as nutrient supplies, light availability, seasonality, and other factors. Since the TSI value is intended to reflect the level of biological productivity, the best estimator for productivity is chlorophyll-a. Some calculations also incorrectly include concentrations of nutrients and Secchi disk depth in addition to chlorophyll-a. However, nutrients and Secchi disk depth should only be included as surrogates for biological productivity when chlorophyll data are not available. Therefore, TSI calculations were conducted for Lake Jessamine using measured concentrations of chlorophyll-a only according to the following relationship:

$$\text{TSI (chl-a)} \quad = \quad 16.8 + 14.4 \ln \text{chl-a (mg/m}^3\text{)}$$

Calculated TSI values in Lake Jessamine from 2000-2009 are summarized on Figure 3-6. Mean annual TSI conditions in Lake Jessamine have ranged from oligotrophic to eutrophic conditions. It appears that water quality within the lake has been highly variable from 2000 to the present, with borderline mesotrophic-oligotrophic conditions generally observed within the lake. Statistically significant increases in TSI values over time are apparent in middle ($p < 0.0001$) and southwest ($p = 0.0043$) portions of the lake, although a statistically significant decrease in TSI values ($p = 0.0048$) is apparent in the northeast lobe.

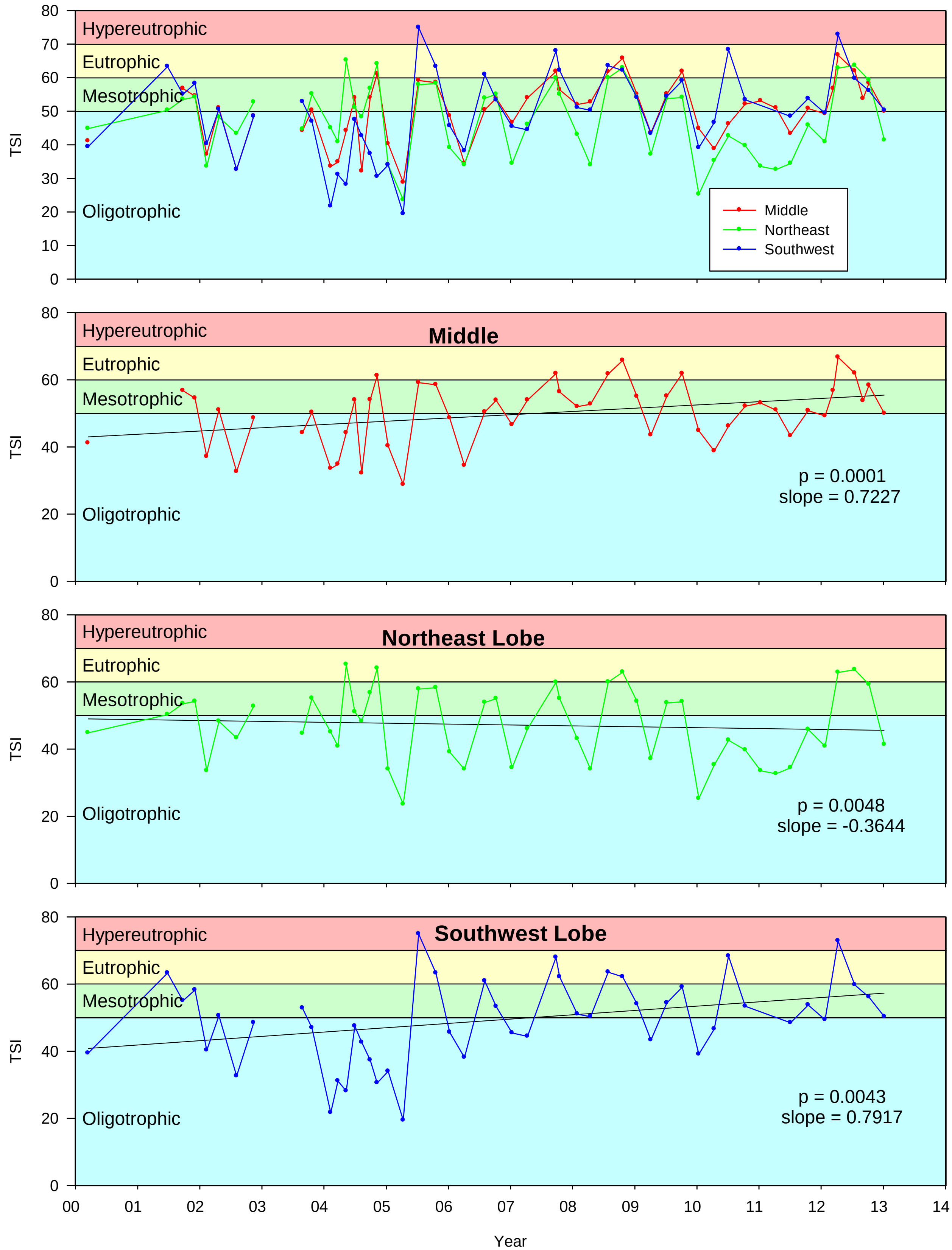


Figure 3-6. Trends in TSI Values in Lake Jessamine from 2000-2013.

3.1.1.2.7 Seasonal Trends

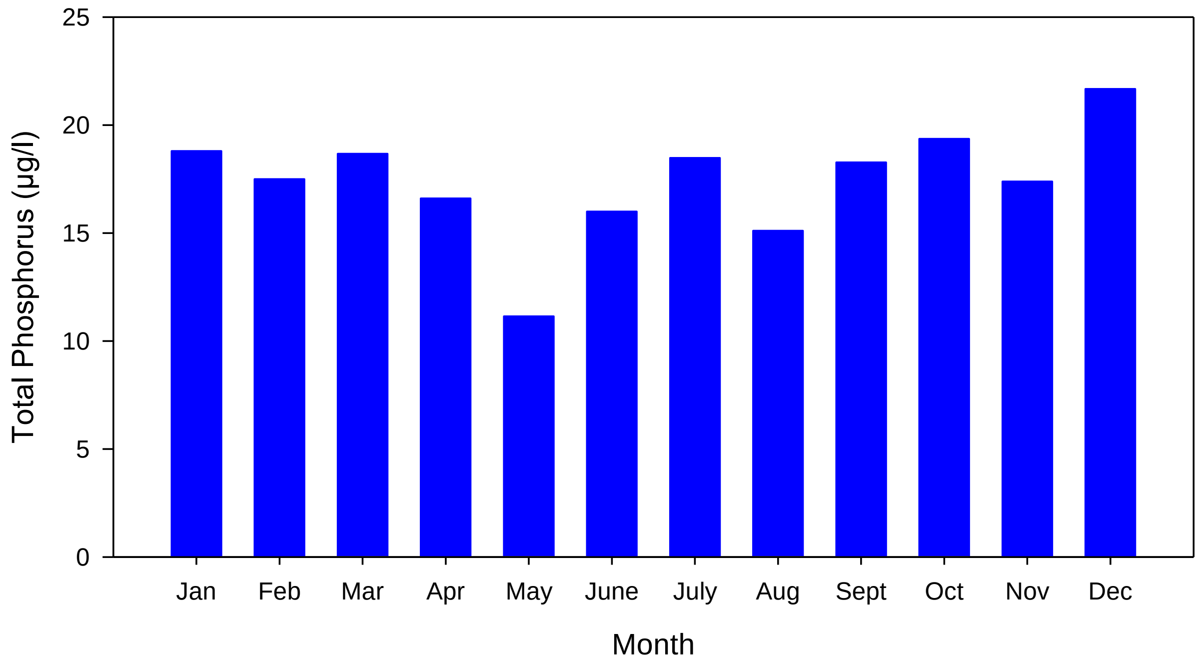
An additional analysis was performed by ERD to examine seasonal variations in nutrient concentrations in Lake Jessamine. For this evaluation, mean monthly concentrations were calculated for total phosphorus and total nitrogen over the period of record from 1989-2013 using the OCEPD data. A comparison of mean monthly concentrations of total phosphorus in Lake Jessamine from 1989-2013 is given in Figure 3-7. In general, it appears that mean monthly phosphorus concentrations in Lake Jessamine during “dry” season conditions are equal to or greater than phosphorus concentrations measured during “wet” season conditions. Since the “dry” season months are characterized by low rainfall and reduced runoff inputs, the increases in phosphorus concentrations observed during portions of this period suggest that phosphorus sources in addition to stormwater runoff are impacting water quality in Lake Jessamine.

The general pattern of monthly phosphorus concentrations exhibited in Figure 3-7 suggests that significant internal recycling may be occurring in Lake Jessamine. During late-spring through early-fall, lakes in Central Florida typically become stratified, with anoxic conditions developing in lower portions of the lake. These anoxic conditions accelerate the release of phosphorus from the bottom sediments which begin to accumulate in the lower isolated portions of the waterbody. When water temperatures cool during late-fall and winter, the water column begins to circulate, and accumulated phosphorus concentrations in lower layers of the lake are distributed throughout the entire water column, resulting in increases in phosphorus levels within the lake. The trend exhibited by total phosphorus for Lake Jessamine suggests that significant internal recycling, fueled by upwelling of high phosphorus water during circulating events, may be occurring within the lake. The sediment inactivation project summarized in this report is designed to reduce the phosphorus peaks during non-rainy periods to reduce the observed elevated fall, winter, and spring total phosphorus concentrations.

Average monthly concentrations of total nitrogen in Lake Jessamine from 1989-2013 are also included on Figure 3-7. Total nitrogen concentrations in Lake Jessamine appear to be greatest during the winter, summer, and fall months, with lowest concentrations during the spring months. Nitrogen can also be released from anoxic bottom sediments, primarily in the form of ammonia, which may be partially responsible for the patterns of total nitrogen indicated on Figure 3-7.

3.1.1.2.8 Water Quality Summary

A summary of historical water quality characteristics of Lake Jessamine from 1989-2013 is given in Table 3-2 for significant water quality parameters based upon the OCEPD data set. Geometric mean values are provided for each of the listed parameters measured by OCEPD at the middle, northeast, and southwest monitoring sites. The geometric mean is used since the data sets are not normally distributed, and the geometric mean provides a better indication of central tendency than an arithmetic mean value. In general, measured values for pH, alkalinity, conductivity, and TSS are similar to values commonly observed in urban lakes. Measured values of total nitrogen, total phosphorus, chlorophyll-a, and Secchi disk depth appear to be better than average for urban lakes.



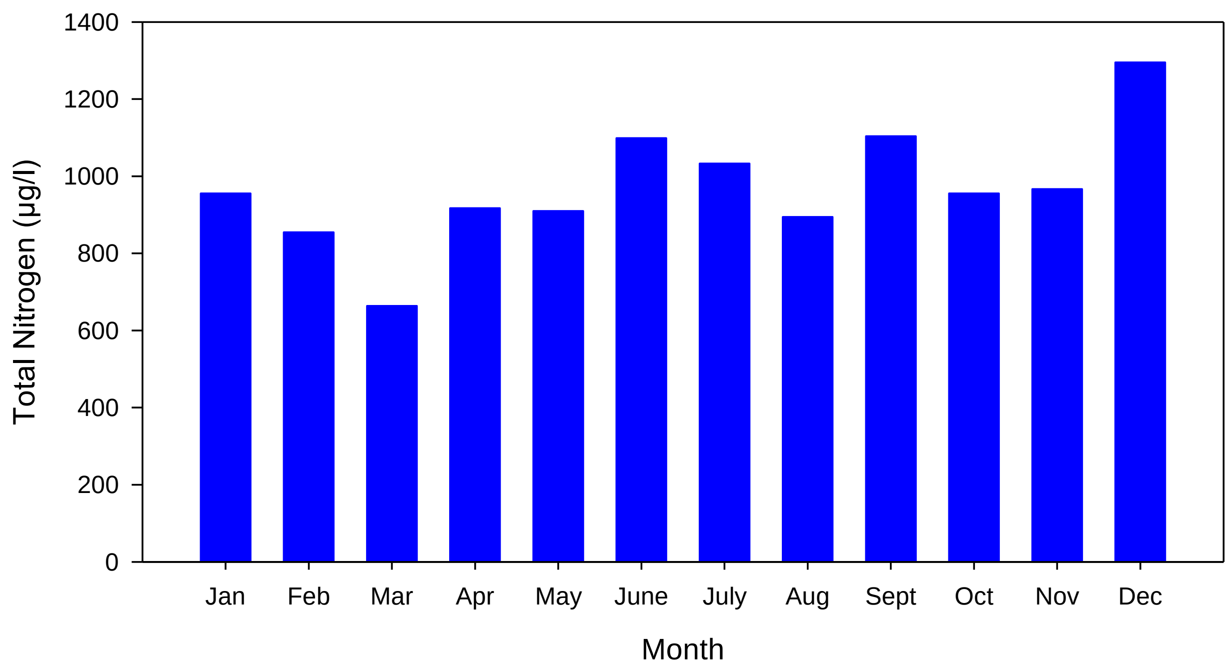


Figure 3-7. Mean Monthly Concentrations of Total Phosphorus and Total Nitrogen in Lake Jessamine from 1989-2013.

TABLE 3-2

SUMMARY OF HISTORICAL WATER QUALITY CHARACTERISTICS OF LAKE JESSAMINE FROM 2000-2013[1]

PARAMETER	UNITS	GEOMETRIC MEAN VALUE		
		Middle	Northeast	Southwest
pH	s.u.	7.63	7.30	7.51
Alkalinity	mg/l	56.9	54.9	58.0
Conductivity	μmho/cm	214	207	212
Total N	μg/l	812	775	876
Total P	μg/l	14	14	19
TSS	mg/l	3.5	3.3	4.2
Chlorophyll-a	mg/m^3	9.4	8.0	8.6
Secchi Disk	m	1.4	1.5	1.4
TSI	--	49.1	46.7	47.8

1. OCEPD data

3.1.2 Pre-/Post-Treatment Water Quality Characteristics

3.1.2.1 Monitoring Activities

Pre- and post-treatment surface water quality monitoring was conducted in Lake Jessamine by ERD at three fixed monitoring locations within the lake for each of the three chemical applications. Approximate locations of the surface water monitoring sites in Lake Jessamine are indicated on Figure 3-8. The water quality monitoring sites were selected to allow evaluation of horizontal variability in water quality characteristics, vertical variability in deep areas of the lake, as well as provide general information on changes in water quality characteristics resulting from the alum applications. Water quality monitoring was conducted immediately prior to each of the three applications (pre) and 1-3 days following each application (post).

Sample collection procedures followed methods outlined in DEP-SOP-001/01 titled "Department of Environmental Protection Standard Operating Procedures for Field Activities" dated February 1, 2004. Surface water samples were collected using a battery-powered peristaltic pump constructed of plastic and stainless steel. Two separate samples were collected at each site during each monitoring event. The first sample was collected at a depth equal to 50% of the Secchi disk depth at the time of sample collection, with the second sample collected at a depth of 0.5 m above the sediment/water interface. Each of the collected samples was preserved as appropriate for the parameter to be analyzed, stored in ice, and returned to the ERD Laboratory for chemical analyses. A listing of laboratory measurements performed on the collected samples is given in Table 3-3, along with a summary of analytical methods and laboratory detection limits.

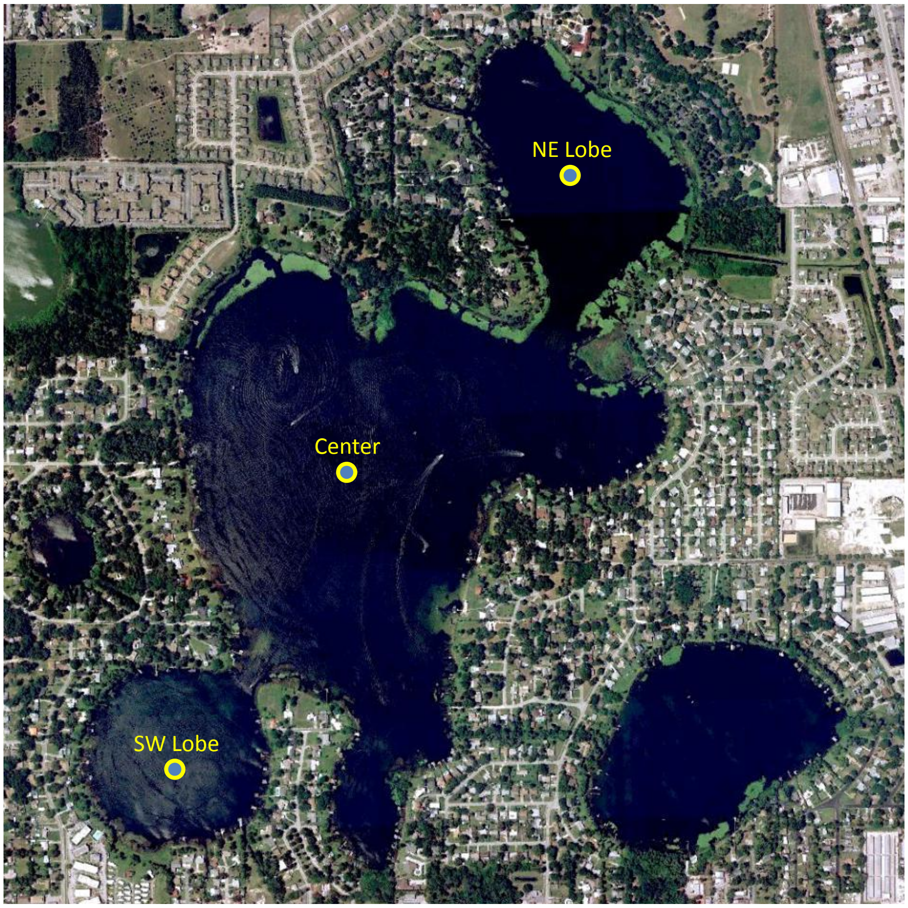


Figure 3-8.

Locations of the Surface Water Monitoring Sites in Lake Jessamine.

TABLE 3-3

ANALYTICAL METHODS AND DETECTION LIMITS FOR LABORATORY ANALYSES CONDUCTED BY ENVIRONMENTAL RESEARCH AND DESIGN, INC.

MEASUREMENT PARAMETER		METHOD[1]	METHOD DETECTION LIMITS (MDLs)[2]
General Parameters	Hydrogen Ion (pH)	SM-21, Sec. 4500-H^+ B	N/A
	Alkalinity	SM-21, Sec. 2320 B	0.5 mg/l
	TSS	SM-21, Sec. 2540 D	0.7 mg/l
	Color	SM-21, Sec. 2120 C	1 Pt-Co Unit
	Specific Conductivity	SM-21, Sec. 2510 B	0.2 μmho/cm
	Turbidity	SM-21, Sec. 2130 B	0.3 NTU
Nutrients	Ammonia-N (NH_3-N)	SM-21, Sec. 4500-NH3 G	0.005 mg/l
	Nitrate + Nitrite (NO_x-N)	SM-21, Sec. 4500-NO3 F	0.005 mg/l
	Total Nitrogen	SM-21, Sec. 4500-N C	0.025 mg/l
	Orthophosphorus	SM-21, Sec. 4500-P F	0.001 mg/l
	Total Phosphorus	SM-21, Sec. 4500-P B.5	0.001 mg/l
Biological Parameters	Chlorophyll-a	SM-19, Sec. 10200 H.1.3	0.08 mg/m^3

1. Standard Methods for the Examination of Water and Wastewater, 21st Ed., 2005.
2. MDLs are calculated based on the EPA method of determining detection limits.

During each monitoring event, vertical profiles of pH, temperature, conductivity, dissolved oxygen, ORP, and turbidity were conducted at each site. Field measurements were collected at water depths of 0.25 m and at 0.5 m, and at 0.5 m intervals to the bottom at each site. All field measurements were performed using Hydrolab Data Sonde H2O and Data Sonde 4a units. A measurement of Secchi disk depth was also performed at each site.

In addition to the pre- and post-treatment vertical field profiles, field measurements were also collected at 1-2 hour intervals during the daily applications in areas of the lake where chemicals were being applied. These measurements were intended primarily to evaluate pH within the water column to ensure that the chemical additions were not depressing the pH levels within the lake to an undesirable level. The field measurements were typically conducted at a single water depth of 0.5-1 m since this is the portion of the lake where the maximum pH impacts would be expected. Field measurements collected during each of these daily monitoring events are also provided in Appendix B.1.

3.1.2.2 Field Profiles

A complete listing of vertical field profiles collected in Lake Jessamine during the three pre- and post-treatment monitoring events is given in Appendix B.1. Pre- and post-treatment vertical profiles were collected during both the first and second alum treatment. Vertical profiles for the third (final) event are available only for the post-treatment monitoring due to an equipment malfunction during the pre-treatment monitoring.

3.1.2.2.1 Northeast Lobe

A graphical summary of vertical field profiles collected at the northeast monitoring site during the three alum applications is given in Figure 3-9. Water depths at this site during the monitoring events ranged from approximately 4-4.8 m. Pre- and post-treatment vertical field profiles for temperature, pH, conductivity, and dissolved oxygen are provided for the first and second applications, with only post-treatment data available for the third application event. Relatively isograde temperature profiles were observed during both pre- and post-treatment monitoring events in the northeast lobe. A substantial decrease in water column temperature occurred between the pre- and post-treatment monitoring events for the October-November 2012 application, but this difference is due to seasonal temperature changes in water column temperature. Similarly, a slight increase in water column temperature occurred between the pre- and post-treatment monitoring events for the January 2012 monitoring event which is also likely related to seasonal increases in water temperature.

Measured pre-treatment surface pH values ranged from approximately 7.6-7.8 for each of the first two applications. A relatively stratified pH profile was observed during each of the pre-treatment events, with rapid decreases in pH occurring below a water depth of approximately 2.5 m. Under post-treatment conditions, a much more uniform water column pH was observed during the October-November 2012 monitoring event as well as the June 2013 post-treatment event, with pH values approximately 0.3-0.4 units lower than observed under pre-treatment conditions. Slightly lower surface pH values were observed in the post-treatment event during July 2012, with a surface pH of approximately 7.1, increasing to approximately 7.4 in mid-portions of the water column, before decreasing to approximately 6.7 at water depths below approximately 4 m.

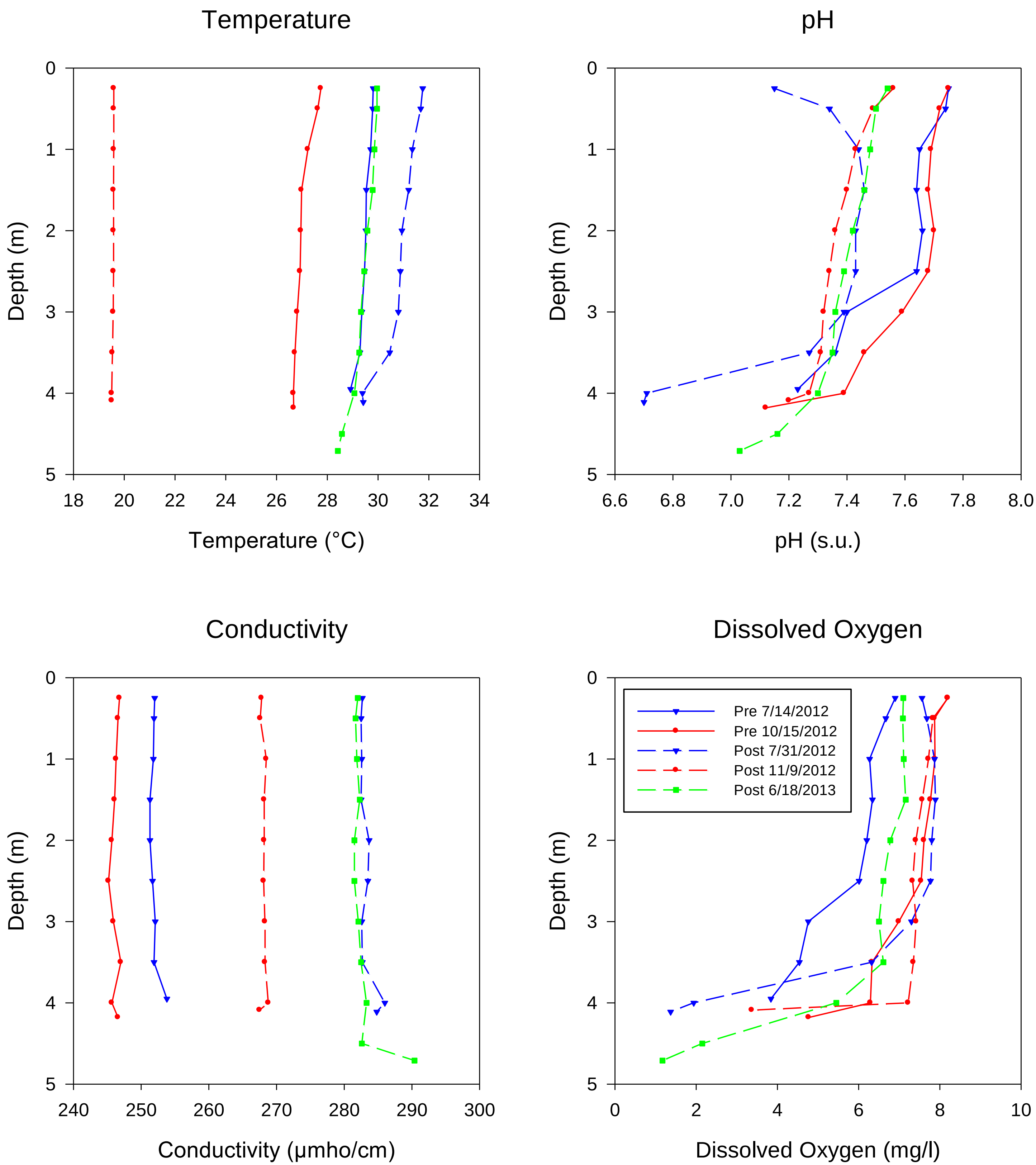


Figure 3-9. Pre- and Post-Treatment Vertical Field Profiles Collected in the Northeast Lobe.

Measured conductivity profiles were relatively uniform throughout the water column under both pre- and post-treatment conditions for each of the monitored events. However, an increase in conductivity of approximately 30 μmho/cm occurred during the July 2012 event, with a water column increase of approximately 25 μmho/cm during the October-November 2012 event. This increase in conductivity is commonly observed following alum treatments as a result of introduction of sulfate ions into the water column from the alum.

Relatively uniform dissolved oxygen profiles were observed in upper portions of the water column at the northeast site during each of the pre- and post-treatment monitoring events, extending to a water depth of approximately 3.5 m. Within this zone, dissolved oxygen concentrations typically ranged from 5-8 mg/l. Substantial reductions in dissolved oxygen concentrations were observed near the water-sediment interface during most of the monitoring events. A water column increase of approximately 2 mg/l was observed under post-treatment conditions for the July 2012 event, with no significant increase or decrease in dissolved oxygen observed as a result of the October-November 2012 event.

3.1.2.2.2 Middle Lobe

A graphical summary of pre- and post-treatment vertical field profiles collected at the middle lobe monitoring site is given on Figure 3-10. Monitored water depths at this site ranged from approximately 5.5-7.5 m. Relatively isograde temperature conditions were observed during both pre- and post-treatment conditions for the October-November 2012 monitoring event, with a substantial decrease in post-treatment temperature resulting from seasonal temperature changes. A weak thermal stratification was present during the July 2012 and June 2013 monitoring events which was observed in both the pre- and post-treatment samples. A temperature increase of approximately 2°C occurred between the pre- and post-treatment monitoring events for the July 2012 date, although it is likely that the difference is due to seasonal temperature changes rather than impacts from the alum addition.

Highly stratified pH conditions were observed during both the July 2012 and October-November 2012 applications at the middle site, with relatively elevated surface pH values ranging from approximately 7.8-8.3, decreasing to bottom pH measurements ranging from approximately 6.6-6.9. In contrast, the post-treatment pH profiles for the October-November 2012 and June 2013 events exhibit relatively isograde conditions throughout the entire water column, indicating that the water column is well mixed. The equilibrium post-treatment pH for the October-November 2012 event is approximately 0.6-0.8 units less than the pre-treatment profile. A general pH reduction of approximately 0.6 units was observed between pre- and post-treatment monitoring events for the July 2012 event, although stratification in pH was still observed under post-treatment conditions at depths below approximately 4 m.

Measured conductivity profiles were relatively uniform in upper portions of the water column during each of the monitoring events to a water depth of 4 m. Below this depth, increases in conductivity were observed which are common occurrences in a eutrophic urban lake. The post-treatment profiles exhibited higher conductivity levels than the pre-treatment profiles, with an increase of approximately 25 μmho/cm during the October-November 2012 event and an increase of approximately 30-40 μmho/cm during the July 2012 event.

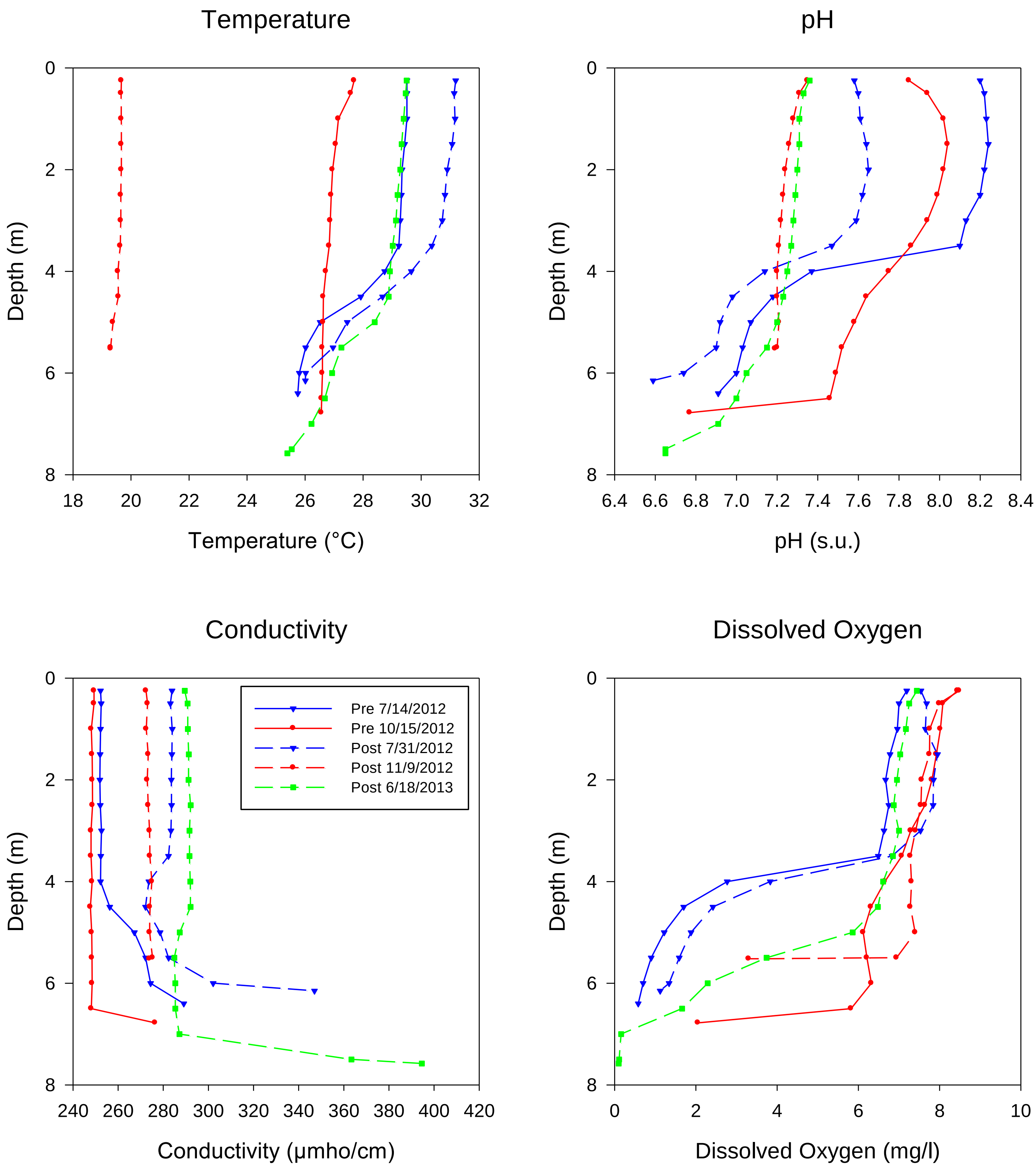


Figure 3-10. Pre- and Post-Treatment Vertical Field Profiles Collected in the Middle Lobe.

Measured dissolved oxygen profiles were relatively similar between the pre- and post-treatment values in upper portions of the water column at depths of approximately 3.5 m or less. Below this depth, dissolved oxygen concentrations decreased relatively rapidly, approaching concentrations less than 1 mg/l at depths below approximately 6-7 m. Pre- and post-treatment vertical profiles for dissolved oxygen appear to be relatively similar in both value and shape.

3.1.2.2.3 Southwest Lobe

A graphical summary of pre- and post-treatment vertical field profiles collected at the southwest lobe monitoring site is given in Figure 3-11. Monitored water depths at this site ranged from 3.5-4 m. Measured temperature profiles in the southwest lobe appear to be very similar to the temperature profiles observed in the north lobe, with relatively isograde temperature measurements under both pre- and posts-treatment conditions. A significant decrease in temperature also occurred in the southwest lobe under post-treatment conditions, likely due to seasonal changes in temperature. A slight increase in temperature is also apparent for the July 2012 application, resulting from seasonal increases in temperature.

Relatively isograde temperature profiles were observed under both pre- and post-treatment conditions to water depths of approximately 3 m, below which measured pH values decreased relatively rapidly. The pre-treatment events are characterized by pH values ranging from approximately 7.3-7.4 compared with the pre-treatment pH values ranging from approximately 7.8-8.1.

Measured conductivity profiles in the southwest lobe are also very similar to ones measured in the north lobe, with relatively isograde conductivity measurements throughout the entire water column with the exception of a substantial increase observed near the sediment-water interface. An overall increase in conductivity of approximately 20 μmho/cm was observed as a result of the October-November 2012 application, with a lobe-wide increase of approximately 25 μmho/cm during the July 2012 event.

Measured dissolved oxygen profiles appear to be very similar between the pre- and post-treatment profiles. Water column concentrations of dissolved oxygen are relatively uniform, ranging from approximately 6-8 mg/l, to a water depth of approximately 3 m. Below this depth, concentrations decrease rapidly, reaching 1-2 mg/l near the water-sediment interface. No significant difference appears to exist between dissolved oxygen profiles under pre- or post-treatment conditions.

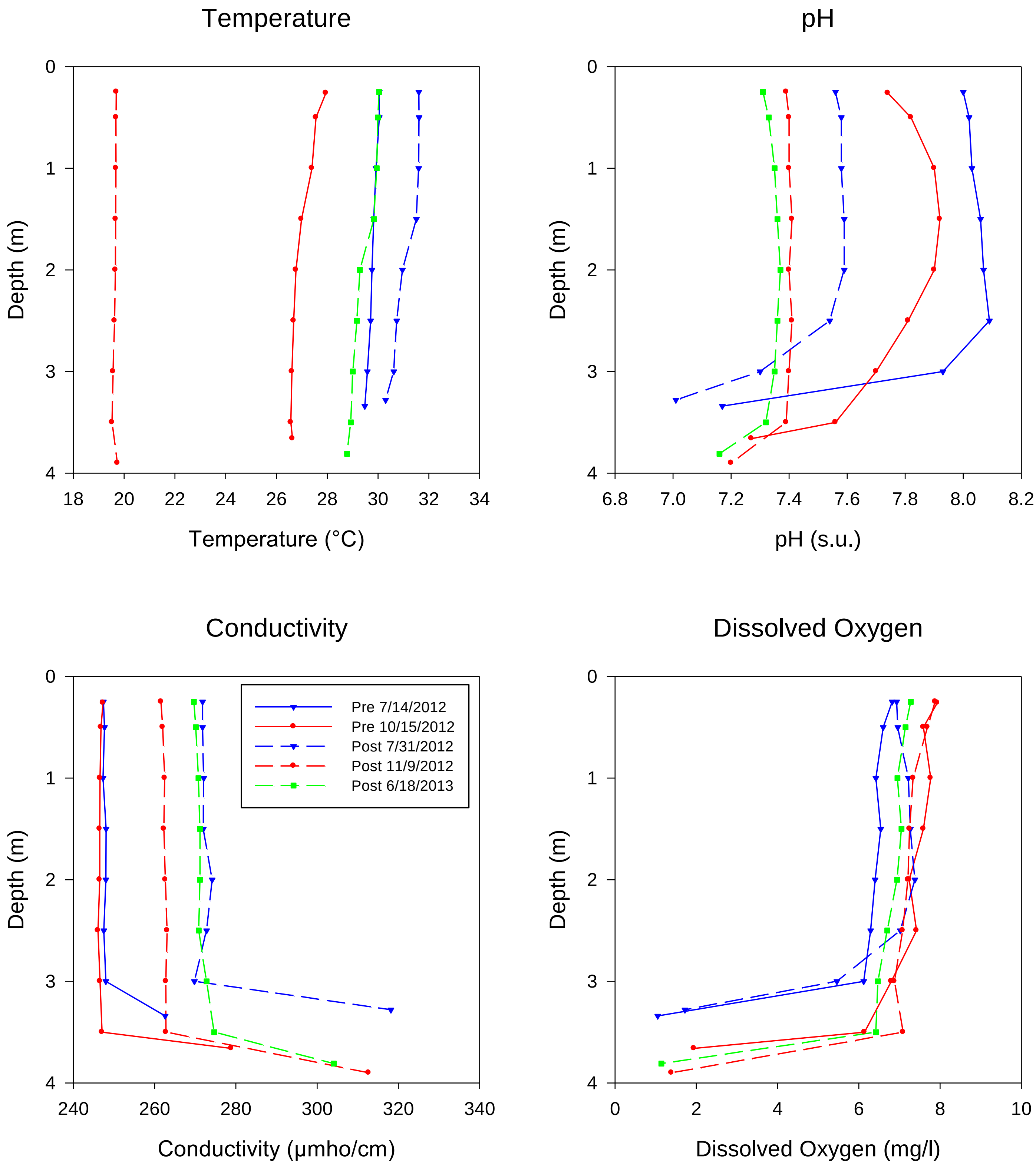


Figure 3-11. Pre- and Post-Treatment Vertical Field Profiles Collected in the Southwest Lobe.

3.1.2.3 Pre-/Post-Treatment Water Quality Characteristics

A complete listing of water quality characteristics measured on each of the pre- and post-treatment samples collected in Lake Jessamine during the three alum applications is given in Appendix B.2. Pre- and post-treatment surface water monitoring was conducted at each of the three locations indicated on Figure 3-8, with separate samples collected in surface and bottom portions of the water column.

A graphical comparison of pre- and post-treatment concentrations of total nitrogen in Lake Jessamine at each of the three monitoring sites is given on Figure 3-12. Historical concentrations of total nitrogen measured at each of the three sites over the previous 5-year period are also provided for comparison purposes. Two separate data points are provided for each of the three alum treatments, with the first point in chronological order reflecting the pre-treatment sample and the second point reflecting the post-treatment sample for each of the three treatments.

The addition of alum to the middle and southwest lobes resulted in substantial reductions in total nitrogen concentrations, particularly in the middle and southwest lobes. Since alum has no particular affinity for ammonia or nitrate, the observed reductions in total nitrogen are likely due to removal of particulate nitrogen associated with algal cells, and to a lesser extent, removal of dissolved organic nitrogen. Slight increases in total nitrogen concentrations were observed in the middle and southwest lobes between the applications followed by an additional substantial reduction in concentration with the next subsequent alum treatment. Equilibrium total nitrogen concentrations at the completion of the three alum treatments appear to be approximately half of the long-term average total nitrogen concentrations in each of the three lobes.

A comparison of pre- and post-treatment concentrations of total phosphorus in Lake Jessamine are illustrated on Figure 3-13. Alum addition to each of the three lobes resulted in substantial reductions in measured concentrations of total phosphorus, with concentrations decreasing from approximately 20-30 μg/l as the historical average to approximately 5-10 μg/l following the alum treatments. Total phosphorus concentrations did not appear to exhibit a significant rebound between the individual alum applications. Each of the individual treatments appear to result in sequentially lower total phosphorus concentrations within each lobe.

A comparison of pre- and post-treatment Secchi disk depths in each of the three lobes of Lake Jessamine is given on Figure 3-14. The initial alum treatment resulted in relatively minimal improvements in water column clarity in each of the three lobes. However, a substantial improvement in water column clarity was observed in the northeast and southwest lobes following the second application, although no significant improvement was observed in the middle lobe. During the third (and final) alum treatment, a substantial improvement in water clarity was observed in the middle lobe, with only slight additional improvements in water clarity in the northeast and southwest lobes. In general, water clarity in each of the three lobes ranged from approximately 0.5-1 m prior to the alum applications, with Secchi disk depths ranging from approximately 2-3 m following the final application.

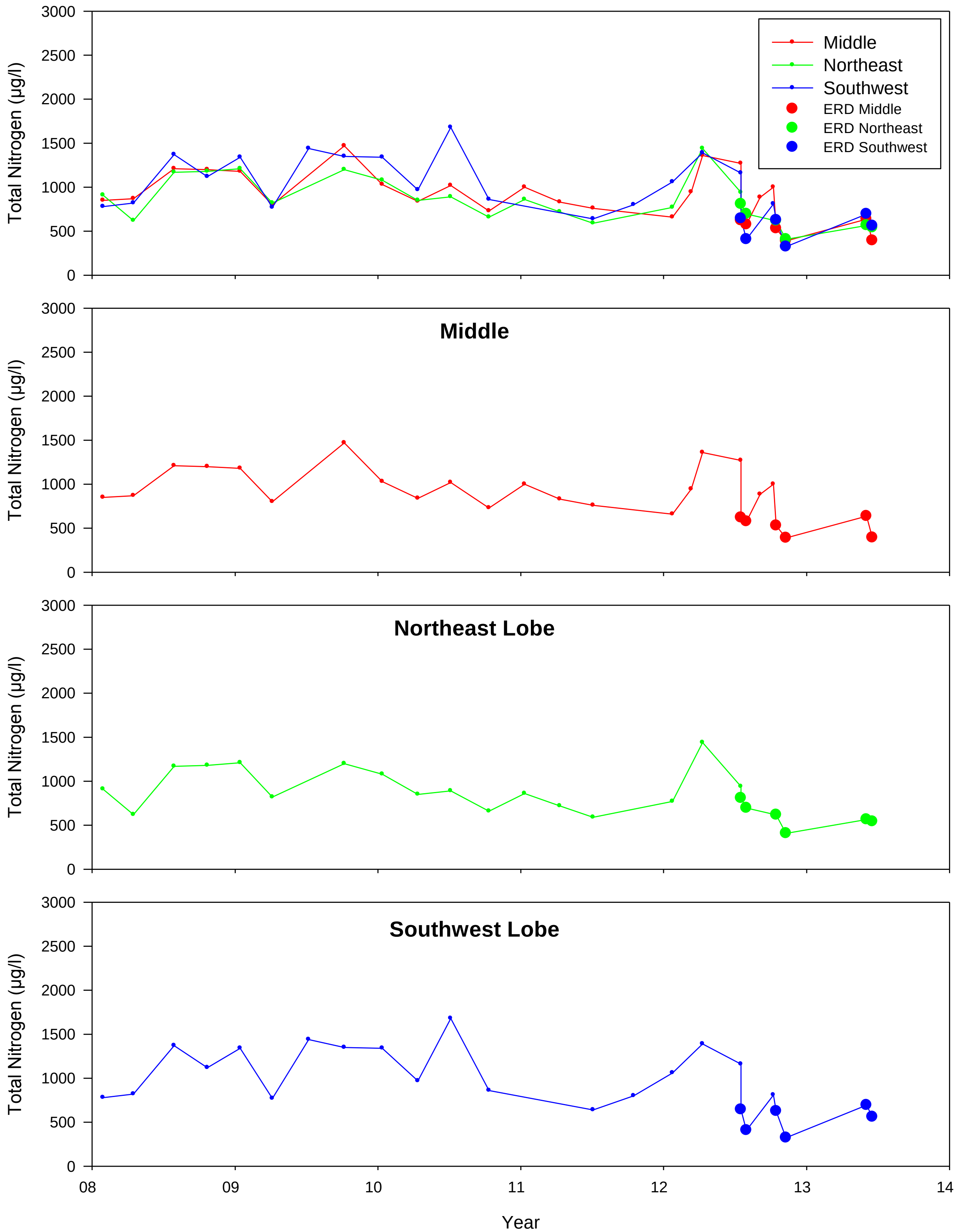


Figure 3-12. Comparison of Pre- and Post-Treatment Concentrations of Total Nitrogen in Lake Jessamine.

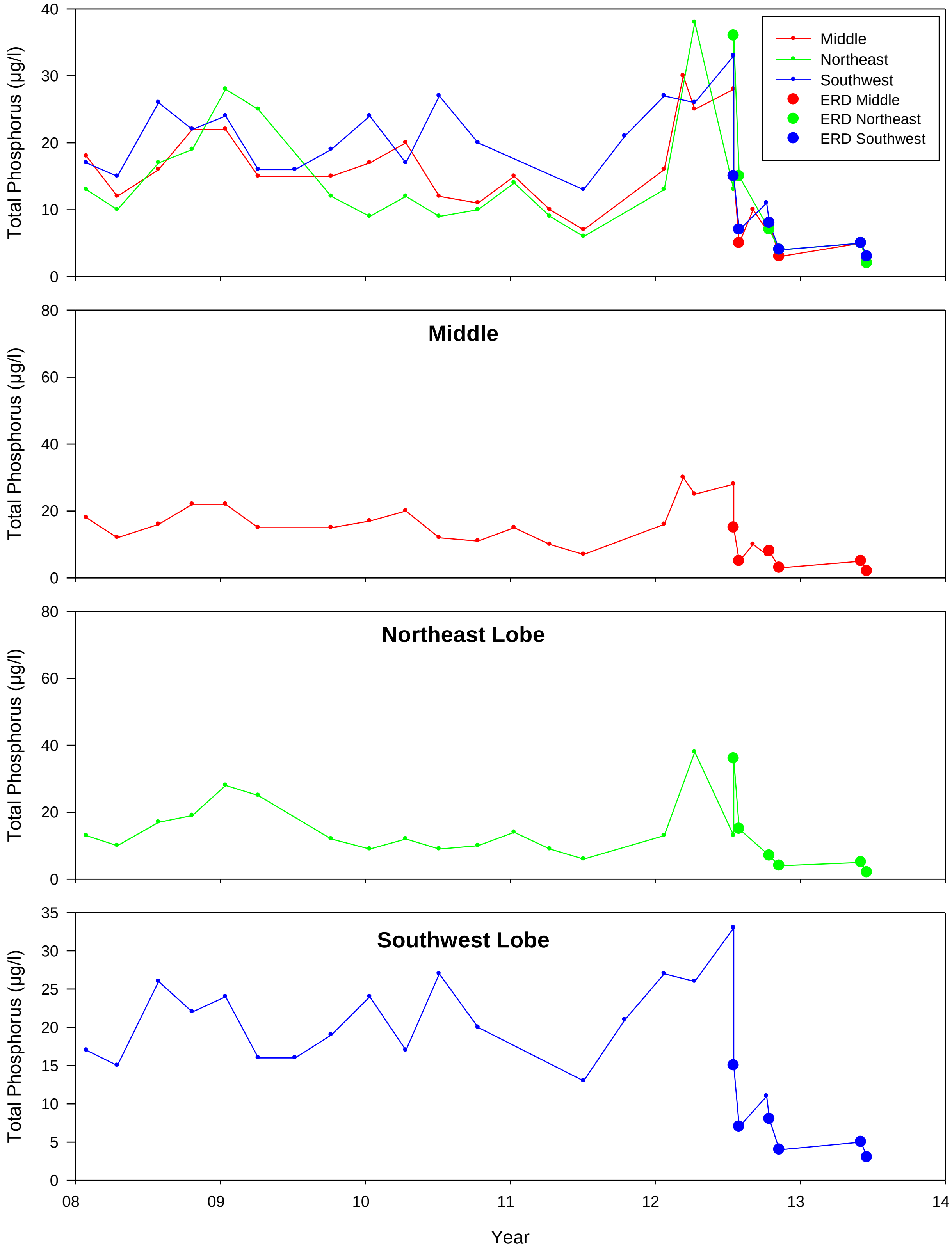


Figure 3-13. Comparison of Pre- and Post-Treatment Concentrations of Total Phosphorus in Lake Jessamine.

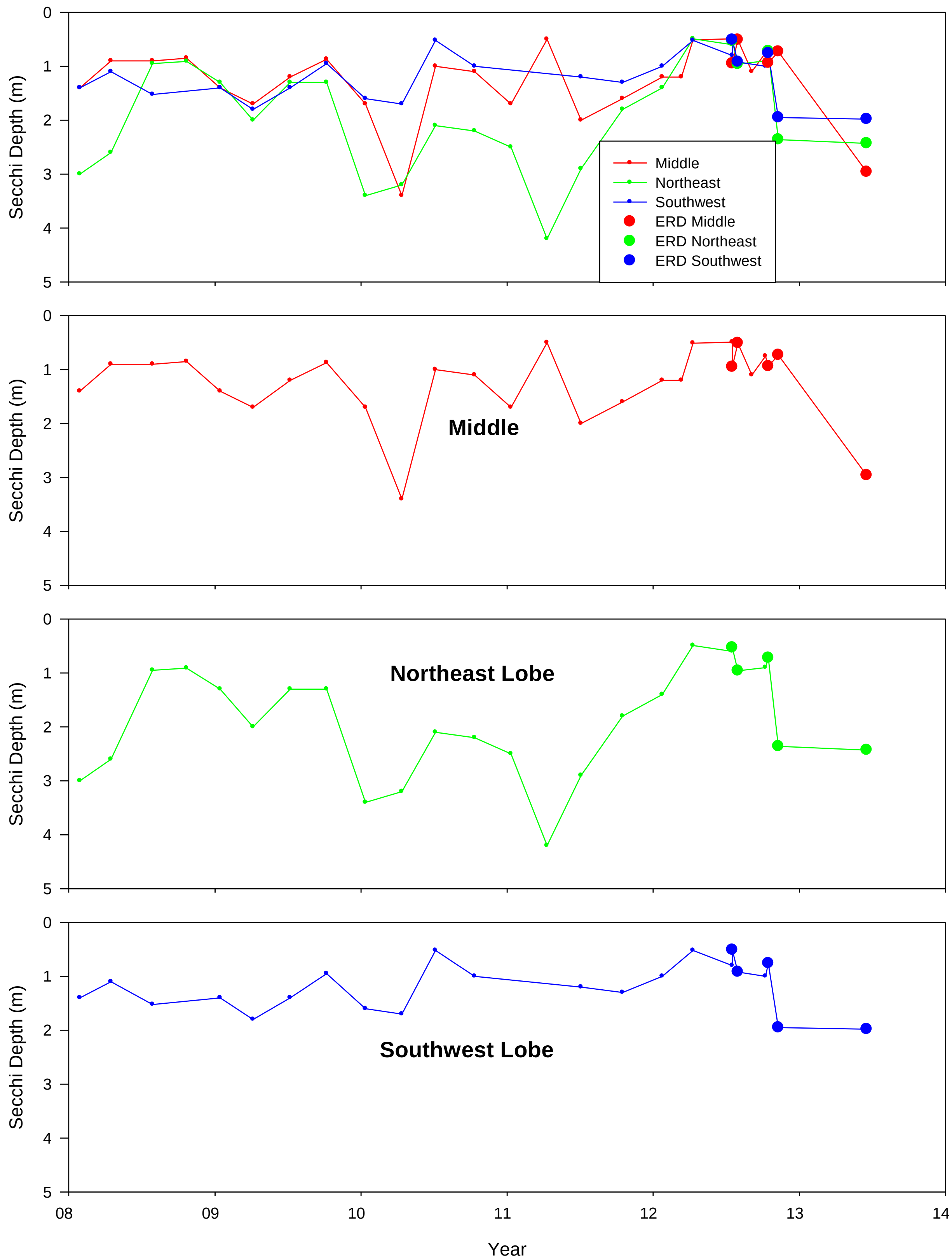


Figure 3-14. Comparison of Pre- and Post-Treatment Secchi Disk Depths in Lake Jessamine.

A comparison of pre- and post-treatment concentrations of chlorophyll-a in the three lobes of Lake Jessamine is given on Figure 3-15. Pre-treatment concentrations of chlorophyll-a ranged from approximately 5-30 mg/m^3 in the middle and northeast lobes, with concentrations ranging from 5-50 mg/m^3 in the southwest lobe. The alum additions resulted in substantial reductions in measured concentrations of chlorophyll-a in each of the three lobes. A slight rebound in chlorophyll-a concentrations was observed in each of the three lobes between alum treatments, followed by substantial concentration reductions following each application. Equilibrium chlorophyll-a concentrations in each of the three lobes were equal to approximately 10 mg/m^3 or less at the completion of the applications.

A comparison of pre- and post-treatment trophic state index (TSI) values in each of the three lobes in Lake Jessamine is given on Figure 3-16. Prior to the alum additions, each of the three lobes exhibited TSI values ranging from oligotrophic to eutrophic which is typical of lakes experiencing elevated nutrient loadings. The alum treatments resulted in reductions in measured TSI values during each of the three applications. Calculated TSI values rebounded slightly between the individual applications, with final TSI values at the completion of the alum application indicating oligotrophic conditions in the middle lobe, and borderline oligotrophic-mesotrophic characteristics in the northeast and southwest lobes.

A tabular comparison of pre- and post-treatment water quality characteristics of surface samples collected in Lake Jessamine is given on Table 3-4. The data in Table 3-4 reflect the samples collected at 50% of the Secchi disk depth during each event. The alum additions to Lake Jessamine had no substantial impact on pH within the water column of the lake since the alum addition was buffered with sodium aluminate. Slight reductions in alkalinity occurred in the surface samples with each alum addition since alum consumes alkalinity from the water column as part of the precipitation reaction.

The alum additions had no significant impact on concentrations of either ammonia or NO_x during any of the three applications. Slight reductions in concentrations of dissolved organic nitrogen were observed during the second and third applications. However, the most significant reductions for nitrogen species occurred with particulate nitrogen which was substantially reduced in concentration during each application. Overall, a concentration reduction of approximately 19% was observed for total nitrogen during the initial application, with a reduction of 37% during the second application and 21% during the final application.

The alum additions to Lake Jessamine resulted in substantial reductions in measured concentrations of SRP and particulate phosphorus, and to a lesser degree, dissolved organic phosphorus. Total phosphorus concentrations were reduced by approximately 59% during the initial application, 50% during the second application, and 60% during the final application. Overall, total phosphorus was reduced by approximately 91% between the beginning of the initial application and completion of the final application. The alum additions also resulted in moderate to substantial reductions in turbidity and color.

The alum additions reduced concentrations of chlorophyll-a during each of the three treatments. A reduction of approximately 53% in chlorophyll-a was observed during the initial application, with a 36% reduction in the second application and a 52% reduction with the final application. Overall, chlorophyll-a concentrations were reduced by approximately 60% between the initial and final applications.

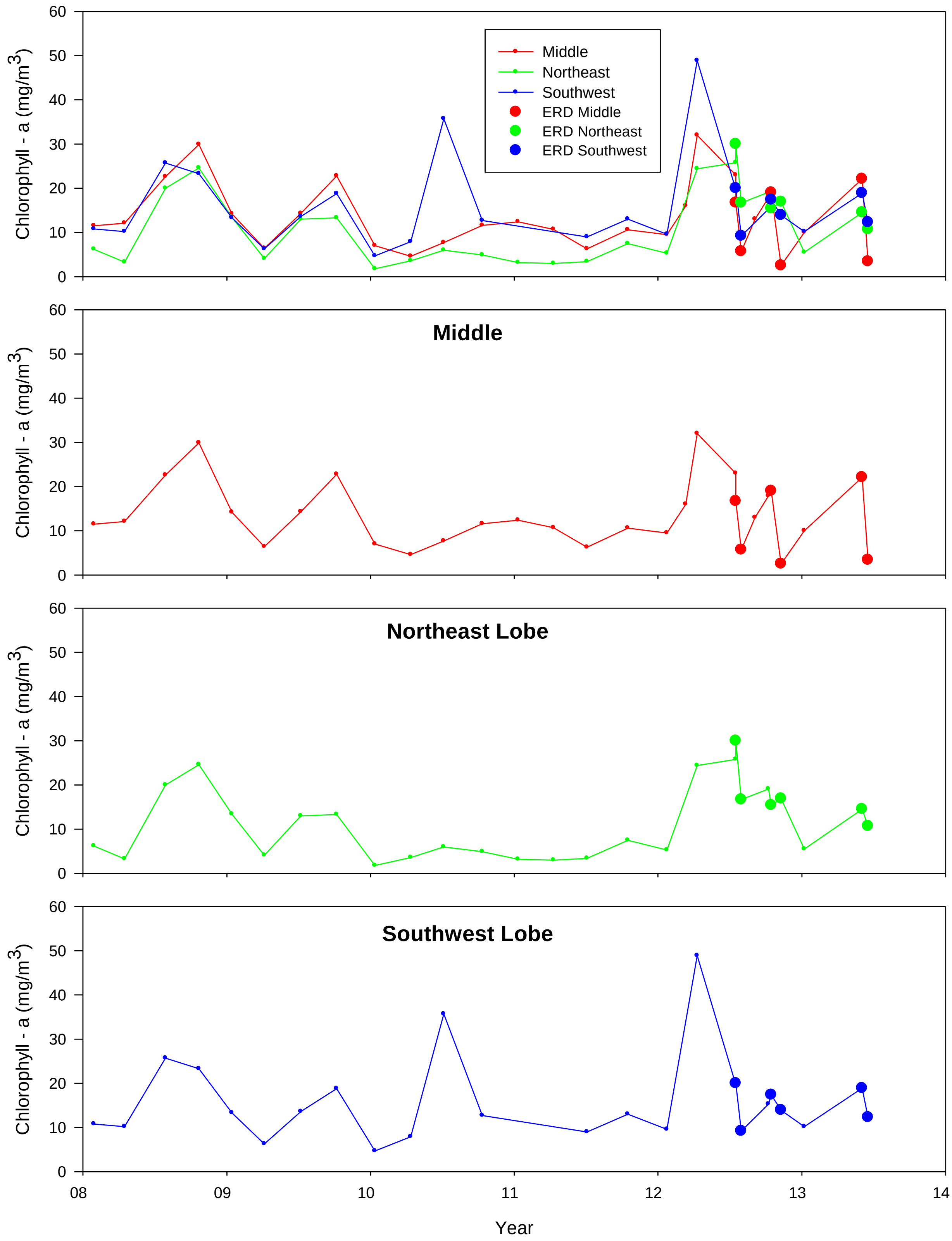


Figure 3-15. Comparison of Pre- and Post-Treatment Chlorophyll-a Concentrations in Lake Jessamine.

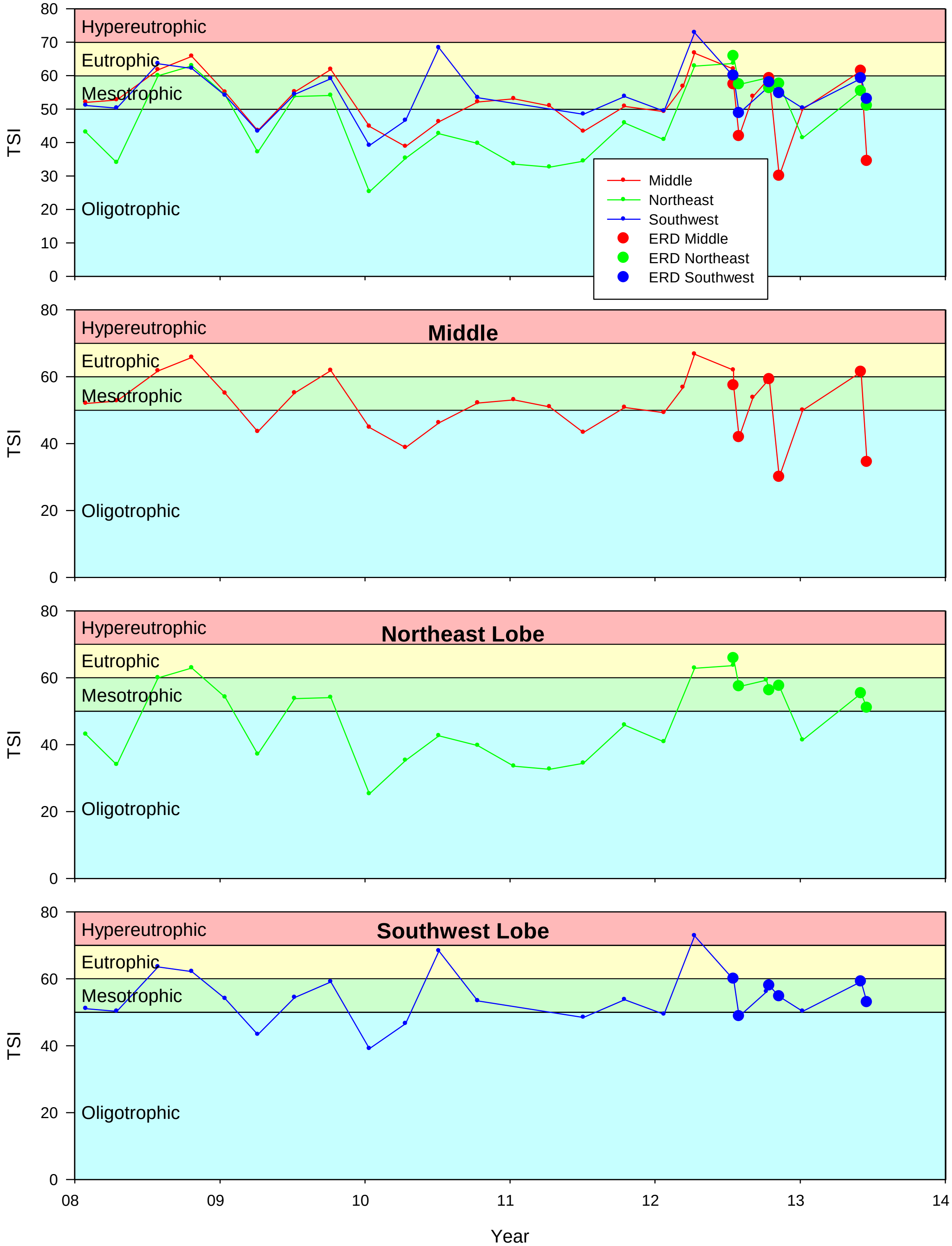


Figure 3-16. Comparison of Pre- and Post-Treatment TSI Values in Lake Jessamine.

TABLE 3-4

COMPARISON OF PRE- AND POST-TREATMENT WATER QUALITY CHARACTERISTICS OF SURFACE SAMPLES COLLECTED IN LAKE JESSAMINE

PARAMETER	UNITS	APPLICATION #1 (July 2012)		APPLICATION #2 (Oct.-Nov. 2012)		APPLICATION #3 (June 2013)	
		Pre	Post	Pre	Post	Pre	Post
pH	s.u.	7.31	7.36	7.12	7.25	7.20	6.93
Alkalinity	mg/l	64.1	51.8	50.2	42.0	37.9	30.7
Ammonia	μg/l	< 5	< 5	< 5	< 5	< 5	< 5
NO_x	μg/l	8	< 5	< 5	< 5	< 5	< 5
Diss. Organic N	μg/l	274	292	344	205	453	349
Particulate N	μg/l	408	263	231	162	173	142
Total N	μg/l	691	560	590	373	632	498
SRP	μg/l	5	1	2	1	1	< 1
Diss. Organic P	μg/l	4	3	2	1	< 1	< 1
Particulate P	μg/l	13	6	4	2	4	2
Total P	μg/l	22	9	8	4	5	2
Turbidity	NTU	4.0	2.4	3.0	2.7	3.6	2.1
Color	Pt-Co	20	9	14	6	15	7
Chlorophyll-a	mg/m^3	22.2	10.5	17.3	11.1	18.5	8.8
Diss. Aluminum	μg/l	55	249	134	99	137	106

Measured concentrations of dissolved aluminum increased from 55 μg/l to 249 μg/l during the initial application. However, dissolved aluminum concentrations decreased from 134 μg/l to 99 μg/l during the second application, with an additional decrease from 137 μg/l to 106 μg/l during the final application. The final equilibrium dissolved aluminum concentration of 106 μg/l at the completion of the final application is typical of final equilibrium concentrations commonly observed during alum treatments.

A comparison of pre- and post-treatment water quality characteristics of bottom samples collected in Lake Jessamine is given in Table 3-5. In general, measured concentrations of pH and alkalinity during the three applications in the bottom samples are relatively similar to values measured in the surface samples. A similar pattern is also apparent for concentrations of nitrogen species, although the overall total nitrogen concentrations are slightly higher in the bottom samples than observed in the top samples.

Measured concentrations of phosphorus species in the bottom samples were similar to values measured in the surface samples during each of the three treatments, with equilibrium bottom total phosphorus concentrations virtually identical to values measured in the surface samples. The addition of alum resulted in reductions in turbidity and color in the bottom portions of the lake. Measured concentrations of chlorophyll-a were also relatively similar between surface and bottom samples, with removal efficiencies similar to those observed in the surface samples.

TABLE 3-5

COMPARISON OF PRE- AND POST-TREATMENT WATER QUALITY CHARACTERISTICS OF BOTTOM SAMPLES COLLECTED IN LAKE JESSAMINE

PARAMETER	UNITS	APPLICATION #1 (July 2012)		APPLICATION #2 (Oct.-Nov. 2012)		APPLICATION #3 (June 2013)	
		Pre	Post	Pre	Post	Pre	Post
pH	s.u.	7.16	7.25	7.19	7.20	7.09	6.79
Alkalinity	mg/l	66.67	56.13	51.00	39.60	39.08	32.87
Ammonia	µg/l	< 5	< 5	< 5	< 5	< 5	20
NO_x	µg/l	< 5	< 5	< 5	< 5	< 5	< 5
Diss. Organic N	µg/l	320	379	331	252	419	353
Particulate N	µg/l	449	277	248	200	211	162
Total N	µg/l	774	663	596	458	636	539
SRP	µg/l	6	1	2	1	1	1
Diss. Organic P	µg/l	5	2	1	1	< 1	< 1
Particulate P	µg/l	8	6	5	2	3	2
Total P	µg/l	19	9	8	4	4	2
Turbidity	NTU	4.8	3.2	3.5	2.5	3.4	2.6
Color	Pt-Co	20	9	12	6	15	6
Chlorophyll-a	mg/m^3	22.7	12.6	20.5	11.4	22.2	16.0
Diss. Aluminum	µg/l	43	129	105	98	120	82

3.2 Sediment Characteristics

3.2.1 Visual Characteristics

Visual characteristics of sediment core samples were recorded for each of the 42 pre- and post-treatment sediment samples collected in Lake Jessamine. A summary of visual characteristics of sediment core samples during the December 2010 (pre-treatment) and September 2013 (post-treatment) events is given in Appendix C. In general, visual characteristics of sediment core samples collected in Lake Jessamine are relatively similar for a given monitoring site during each of the sediment collection events. Shoreline areas of Lake Jessamine are typically characterized by sandy sediments with little or no visual accumulations of organic muck. The base material which forms the bottom of the lake consists primarily of light brown and dark brown fine sand, along with white sandy clay.

As water depths increase within the lake, the accumulations of unconsolidated organic muck become visible. Areas where deep deposits of organic muck have accumulated are characterized by a surface layer of unconsolidated organic muck, approximately 1-12 inches in thickness. This unconsolidated surficial muck layer is comprised primarily of fresh organic material (such as dead algal cells and detritus) which has recently accumulated onto the bottom of the lake and is easily disturbed by strong wind action or boating activities. In deeper portions of the lake, characterized by thick muck deposits, the organic muck becomes more consolidated beneath the surficial layer (with a consistency similar to pudding), reflecting organic deposits which are resistant to further degradation. These layers typically do not resuspend into the water column except during vigorous and sustained wind activity on the lake.

Photographs of typical sandy sediment characteristics in Lake Jessamine are given on Figure 3-17, with photographs of muck-type sediments given in Figure 3-18, based upon photographs collected during the December 2010 sediment collection event. The photographs provided in Figures 3-17 and 3-18 are typical of sediments throughout Lake Jessamine.

3.2.2 General Sediment Characteristics

After return to the ERD Laboratory, the collected pre- and post-treatment sediment core samples were evaluated for general sediment characteristics, including pH, moisture content, organic content, sediment density, total nitrogen, and total phosphorus. A tabular summary of general characteristics of sediment core samples collected in Lake Jessamine during December 2010 (prior to alum addition) is given in Table 3-6, with general characteristics of sediment core samples collected during the September 2013 (post-treatment) event provided in Table 3-7. Geometric mean values are provided at the bottom of each table as a measure of central tendency for each of the evaluated parameters during each monitoring event.

In general, both the pre- and post-treatment sediments in Lake Jessamine were found to be slightly acidic to approximately neutral in pH, with overall mean pH values of 6.41 for the pre-treatment sediments and 6.24 for the post-treatment sediments. Measurements of sediment moisture content and organic content in Lake Jessamine sediments were found to be highly variable throughout the lake. Many of the collected sediment samples are characterized by a relatively low moisture content and low organic content, suggesting that these sediments are comprised primarily of fine sand. In contrast, other sediment core samples are characterized by elevated values for moisture content and organic content, suggesting areas of accumulated organic muck. Sediment moisture contents in excess of 50% are often indicative of highly organic sediments, while moisture contents less than 50% reflect either sand or mixtures of sand and muck. Sediment organic content values in excess of 20-30% are often indicative of organic muck type sediments, with values less than 20-30% representing either sand or mixtures of sand and muck.

Thick light brown sand over brown sand

Dark brown sand

Brown sand with detritus layer

Thick light brown sand

Figure 3-17. Photographs of Typical Sandy Sediments Collected in Lake Jessamine During December 2010.

Thick unconsolidated organic muck

Unconsolidated organic muck over brown sand

Thin layer of unconsolidated organic muck over sand

Thin layer of unconsolidated organic muck over sand

Figure 3-18. Photographs of Typical Sandy and Organic Muck Sediments Collected in Lake Jessamine During December 2010.

TABLE 3-6

GENERAL CHARACTERISTICS OF PRE-TREATMENT SEDIMENT CORE SAMPLES COLLECTED IN LAKE JESSAMINE DURING DECEMBER 2010

SITE	pH (s.u.)	MOISTURE CONTENT (%)	ORGANIC CONTENT[1] (%)	WET DENSITY (g/cm^3)	TOTAL NITROGEN (µg/cm^3)	TOTAL PHOSPHORUS (µg/cm^3)
1	6.42	26.4	0.4	2.10	3,200	107
2	6.00	58.2	5.6	1.59	989	44
3	5.93	76.7	11.5	1.31	2,779	261
4	6.01	43.9	4.6	1.80	4,109	209
5	6.06	89.6	52.5	1.07	519	237
6	6.50	39.1	2.4	1.89	930	240
7	6.06	91.9	39.6	1.07	521	89
8	6.90	58.6	5.8	1.59	3,903	234
9	6.35	43.4	2.6	1.83	566	62
10	6.38	84.6	21.5	1.18	3,333	117
11	6.08	51.8	3.3	1.70	718	124
12	6.80	37.1	3.3	1.91	4,186	299
13	6.20	90.9	41.0	1.08	2,278	211
14	6.09	41.7	2.7	1.85	1,091	153
15	6.87	24.1	0.8	2.13	3,105	1,927
16	6.22	89.6	60.6	1.06	3,900	160
17	5.92	90.9	55.9	1.06	954	138
18	6.59	42.0	2.6	1.85	890	133
19	6.47	52.1	4.5	1.69	593	123
20	6.43	54.3	4.8	1.65	2,422	222
21	6.57	42.5	2.6	1.84	3,970	275
22	6.20	89.5	52.7	1.07	4,566	160
23	7.00	30.7	1.0	2.03	2,190	68
24	6.34	35.2	1.3	1.96	944	133
25	6.74	30.9	1.1	2.03	3,452	329
26	6.65	23.4	0.8	2.14	3,011	144
27	6.61	25.8	0.6	2.11	3,234	41
28	7.08	28.8	0.9	2.06	578	138
29	6.95	32.4	0.9	2.00	565	34
30	6.61	30.8	1.5	2.02	2,161	94
31	7.29	28.5	1.0	2.06	765	28
32	6.60	48.5	3.9	1.74	3,317	218
33	6.48	69.1	8.6	1.42	2,894	155
34	6.45	87.4	50.8	1.09	4,155	50
35	6.40	66.4	6.9	1.47	931	46
36	6.31	89.2	36.6	1.10	2,527	87
37	6.59	50.7	3.0	1.72	430	42
38	6.46	43.3	3.1	1.82	2,281	121
39	6.41	94.9	52.3	1.04	1,612	90
40	5.81	56.9	4.7	1.62	776	124
41	6.24	85.2	42.6	1.13	1,304	41
42	5.44	90.7	29.5	1.10	1,952	213
Minimum	**5.44**	**23.4**	**0.4**	**1.04**	**430**	**28**
Maximum	**7.29**	**94.9**	**60.6**	**2.14**	**4,566**	**1,927**
Geometric Mean	**6.41**	**51.2**	**5.4**	**1.57**	**1,653**	**119**

1. Dry wt. basis

TABLE 3-7

GENERAL CHARACTERISTICS OF POST-TREATMENT SEDIMENT CORE SAMPLES COLLECTED IN LAKE JESSAMINE DURING SEPTEMBER 2013

SITE	pH (s.u.)	MOISTURE CONTENT (%)	ORGANIC CONTENT[1] (%)	WET DENSITY (g/cm^3)	TOTAL NITROGEN ($\mu g/cm^3$)	TOTAL PHOSPHORUS ($\mu g/cm^3$)
1	6.07	36.8	2.3	1.93	3,754	102
2	5.47	46.5	4.0	1.77	828	140
3	5.89	37.8	2.1	1.91	2,850	128
4	6.14	61.9	9.0	1.52	3,106	141
5	6.13	91.0	52.6	1.06	845	198
6	6.30	42.4	2.9	1.84	991	193
7	5.90	92.7	42.6	1.06	791	48
8	6.47	31.8	1.5	2.01	3,773	266
9	5.99	75.8	13.3	1.31	963	57
10	6.29	63.8	6.8	1.51	2,480	49
11	5.78	49.8	3.7	1.73	871	73
12	6.27	89.3	41.6	1.09	3,759	206
13	6.44	48.1	4.1	1.75	1,950	113
14	6.25	85.1	26.1	1.17	942	161
15	6.41	25.0	1.1	2.11	3,276	183
16	6.38	87.7	45.5	1.10	2,891	101
17	6.20	89.4	58.6	1.07	770	128
18	6.46	45.9	2.9	1.79	807	106
19	6.39	33.7	2.0	1.97	782	142
20	6.51	28.7	0.7	2.06	2,304	249
21	6.21	85.8	37.7	1.13	4,890	150
22	6.14	89.3	43.3	1.09	3,839	129
23	6.42	44.2	2.3	1.82	2,808	107
24	6.12	89.9	55.1	1.07	720	91
25	6.43	35.2	1.5	1.96	2,631	152
26	6.49	25.4	1.0	2.11	2,433	197
27	6.54	26.2	0.5	2.10	3,354	50
28	5.98	32.1	1.0	2.01	530	184
29	5.79	33.5	1.1	1.99	386	29
30	6.30	26.5	1.0	2.09	2,472	69
31	6.75	30.2	0.9	2.04	692	41
32	6.29	38.5	2.4	1.90	3,778	262
33	6.53	52.5	6.6	1.67	1,895	75
34	6.43	90.1	32.5	1.10	2,854	67
35	6.17	40.6	2.3	1.87	932	60
36	6.23	35.6	2.0	1.95	2,412	217
37	6.39	85.5	36.4	1.14	384	26
38	6.38	59.1	6.6	1.57	1,018	184
39	6.26	61.8	6.5	1.54	1,174	105
40	6.36	41.9	2.6	1.85	960	96
41	6.26	87.3	53.8	1.09	808	116
42	6.13	67.9	7.9	1.44	931	187
Minimum	**4.98**	**25.0**	**0.5**	**1.06**	**384**	**26**
Maximum	**6.75**	**92.7**	**58.6**	**2.11**	**4,890**	**266**
Geometric Mean	**6.21**	**50.8**	**5.6**	**1.58**	**1,522**	**111**

1. Dry wt. basis

Mean sediment moisture contents were relatively similar between the pre- and post-treatment monitoring events, with a mean pre-treatment moisture content of 51.2% and a mean post-treatment value of 50.8%. Measured sediment organic contents were also relatively similar, with mean values ranging from 5.4% in the pre-treatment sediments to 5.6% in the post-treatment sediments. The collected pre- and post-treatment samples suggest that the multiple applications to Lake Jessamine had no significant impact on either the moisture content or organic content of the sediments within the lake.

Measured sediment density values are also useful in evaluating the general characteristics of sediments within a lake. Sediments with calculated densities between 1.0-1.5 are indicative of highly organic muck type sediments, while sediment densities of approximately 2.0 or greater are indicative of sandy sediment conditions. Sediments collected from Lake Jessamine exhibited a wide range of wet density values, ranging from near 1.0 to greater than 2.0 throughout the lake. Measured pre- and post-treatment sediment densities were virtually identical, with a mean pre-treatment sediment density of 1.57 g/cm^3 and a post-treatment sediment density of 1.58 g/cm^3. The sediment data indicates that the multiple additions of alum to Lake Jessamine have little impact on sediment density within the lake.

Measured concentrations of total phosphorus in Lake Jessamine sediments were found to be highly variable throughout the lake, with values ranging from near 30 $\mu g/cm^3$ to more than 1000 $\mu g/cm^3$. In general, sandy sediments are often characterized by low concentrations of total phosphorus, while highly organic muck type sediments are characterized by elevated total phosphorus concentrations. The multiple additions of alum to Lake Jessamine had little impact on measured phosphorus concentrations within the lake sediments, with a mean total phosphorus sediment concentration of 119 $\mu g/cm^3$ in the pre-treatment core samples, compared with a mean of 111 $\mu g/cm^3$ in the post-treatment samples.

Sediment nitrogen concentrations are also highly variable throughout Lake Jessamine, with measured values ranging from several hundred to several thousand. Alum additions to Lake Jessamine also appear to have little impact on measured sediment nitrogen concentrations, with a geometric mean nitrogen concentration of 1,653 $\mu g/cm^3$ in the pre-treatment sediments compared with 1,522 $\mu g/cm^3$ in the post-treatment samples.

A tabular summary of mean general characteristics of pre- and post-treatment sediment core samples collected in Lake Jessamine is given in Table 3-8. In general, sediment characteristics within Lake Jessamine appear to be relatively similar in the pre- and post-treatment samples. The summary data provided in Table 3-8 suggests that the multiple additions of alum to Lake Jessamine have had little impact on general sediment characteristics within the lake.

TABLE 3-8

SUMMARY OF MEAN GENERAL CHARACTERISTICS OF PRE-TREATMENT AND POST-TREATMENT SEDIMENT CORE SAMPLES COLLECTED IN LAKE JESSAMINE DURING DECEMBER 2010 AND SEPTEMBER 2013

PARAMETER	UNITS	MEAN VALUE BY SEDIMENT COLLECTION DATE[1]	
		December 2010	September 2013
pH	s.u.	6.41	6.21
Moisture Content	%	51.2	50.8
Organic Content	%	5.4	5.6
Density (wet)	g/cm^3	1.57	1.58
Total Nitrogen	µg/cm^3	1,653	1,522
Total Phosphorus	µg/cm^3	119	111

1. Reflects geometric mean values

A statistical summary of pre- and post-treatment values of pH, wet sediment density, total nitrogen, and total phosphorus in Lake Jessamine is given on Figure 3-19 in the form of Tukey box plots, also often called “box and whisker plots”. The bottom of the box portion of each plot represents the lower quartile, with 25% of the data points falling below this value. The upper line of the box represents the 75% upper quartile, with 25% of the data falling above this value. The **blue horizontal line** within the box represents the median value, with 50% of the data falling both above and below this value, while the **red horizontal line** represents the mean value. The vertical lines, also known as "whiskers", represent the 10 and 90 percentiles for the data sets. Individual values which lie outside of the 10-90 percentile range are indicated as **red dots**.

A relatively high degree of variability was observed in measured pH values in the pre-treatment sediments collected from Lake Jessamine, with measured sediment pH values ranging from approximately 5.44-7.29 and a geometric mean value of 6.41. As indicated on Figure 3-19, a somewhat lower degree of variability in sediment pH values was measured during the post-treatment monitoring event, with measured pH values ranging from 5.47-6.75 and a geometric mean value of 6.22. An overall decrease in mean sediment pH of approximately 0.2 units occurred following the alum treatments to Lake Jessamine.

Measured sediment moisture contents were virtually unchanged as a result of the alum applications in Lake Jessamine, with pre-treatment sediment moisture contents ranging from 23.4-94.9%, with an overall geometric mean of 51.2%. Post-treatment sediment moisture contents ranged from 25.0-92.7%, with an overall geometric mean of 50.8%.

The addition of alum to Lake Jessamine had no significant impact on sediment organic content within the lake sediments. Pre-treatment sediment organic contents ranged from 0.4-60.6% (dry weight basis), with an overall geometric mean of 5.4%. Post-treatment sediment organic content ranged from 0.5-58.6%, with an overall geometric mean of 5.6%.

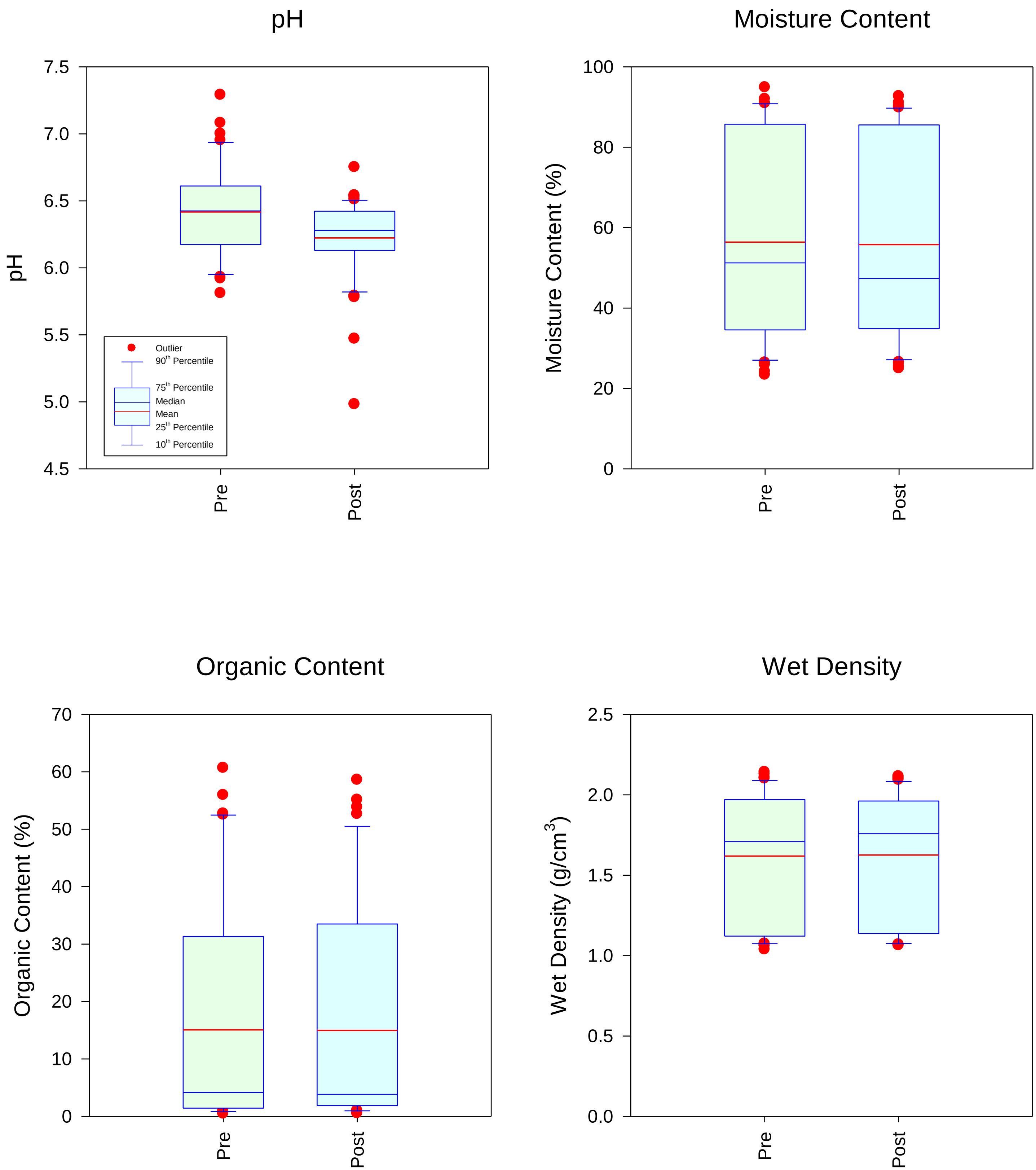


Figure 3-19. Statistical Summary of Pre- and Post-Treatment Values of pH, Moisture Content, Organic Content, and Wet Density in the Top 10 cm of Lake Jessamine Sediments.

Similar to the trends observed for moisture content and organic content, alum additions to Lake Jessamine had virtually no impact on wet sediment density within the lake. Pre-treatment wet densities ranged from 1.04-2.14 g/cm^3, with an overall geometric mean of 1.57 g/cm^3. Post-treatment wet sediment densities ranged from 1.06-2.11 g/cm^3, with an overall geometric mean of 1.58 g/cm^3.

A statistical summary of pre- and post-treatment sediment concentrations of total nitrogen and total phosphorus in the top 10 cm of Lake Jessamine sediments is given on Figure 3-20. In general, measured sediment concentrations of total nitrogen were relatively similar between the pre- and post-treatment monitoring events. The observed differences in geometric mean values for the monitoring events do not exhibit a significant trend of either increasing or decreasing concentration over time and appear to reflect normal variability in sediment nitrogen concentrations. Pre-treatment sediment nitrogen concentrations ranged from 430-4,566 μg/cm^3, with an overall geometric mean of 1,653 μg/cm^3. Post-treatment sediment nitrogen concentrations ranged from 384-4,890 μg/cm^3, with an overall geometric mean of 1,522 μg/cm^3.

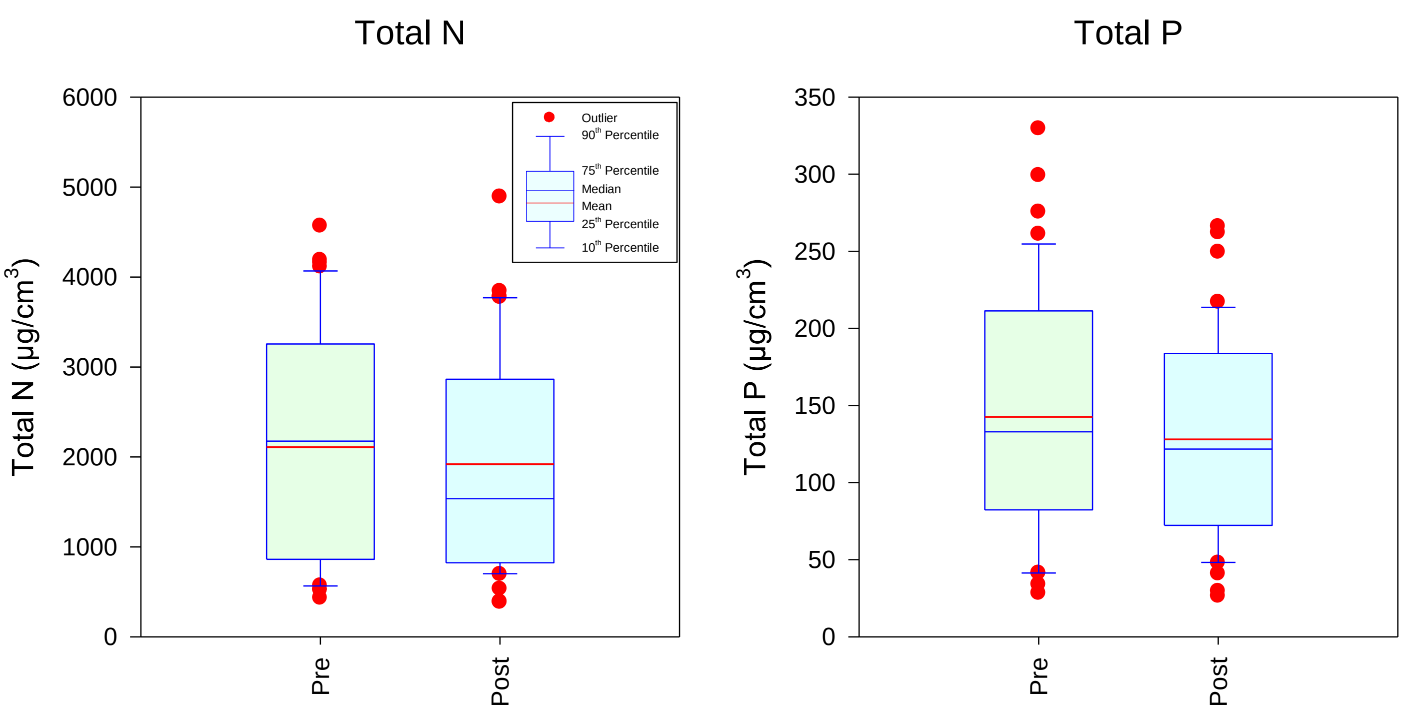


Figure 3-20. Statistical Summary of Pre- and Post-Treatment Concentrations of Total Nitrogen and Total Phosphorus in the Top 10 cm of Lake Jessamine Sediments.

Similar to the trends observed for total nitrogen, no significant changes are apparent in measured sediment concentrations of total phosphorus between the pre- and post-treatment sediment monitoring period. Geometric mean concentrations of total phosphorus for each of the sediment monitoring events are virtually identical, with an overall geometric mean of 119 $\mu g/cm^3$ in the pre-treatment sediments compared with 111 $\mu g/cm^3$ in the post-treatment sediments.

3.2.3 Sediment Speciation

As discussed in Section 2.1.2, sediment core samples collected at each of the 42 monitoring sites were carried through a phosphorus fractionation procedure which allows the speciation of phosphorus into saloid-bound phosphorus (defined as the sum of soluble plus easily exchangeable phosphorus), iron-bound phosphorus, and aluminum-bound phosphorus. A tabular summary of pre-treatment phosphorus speciation in sediment core samples collected in Lake Jessamine during December 2010 (prior to alum addition) is given in Table 3-9, with phosphorus speciation in sediment core samples collected in post-treatment samples provided in Table 3-10. Geometric mean values are provided at the bottom of each table as a measure of central tendency for each of the evaluated parameters during each monitoring event.

A statistical summary of pre- and post-treatment sediment phosphorus speciation in Lake Jessamine sediments is given on Figure 3-21. Sediment concentrations of saloid-bound phosphorus in the pre-treatment sediment samples ranged from approximately 0.07-5.9 $\mu g/cm^3$, with a geometric mean of 0.41 $\mu g/cm^3$. Significant reductions in saloid-bound phosphorus concentrations in Lake Jessamine sediments were measured during the post-treatment sediment monitoring event. Saloid-bound phosphorus concentrations in the post-treatment samples ranged from 0.01-0.44 $\mu g/cm^3$, with an overall geometric mean value of 0.05 $\mu g/cm^3$.

The pre-treatment sediment samples exhibited relatively high concentrations of iron-bound phosphorus, with measured values ranging from approximately 6-188 $\mu g/cm^3$, and a geometric mean value of 49 $\mu g/cm^3$. Substantial reductions in iron-bound phosphorus concentrations were observed in the post-treatment sediments, with concentrations ranging from 2-38 $\mu g/cm^3$ and a geometric mean of 7 $\mu g/cm^3$. Iron-bound phosphorus concentrations in the post-treatment sediments exhibited a substantially lower range of values as well as substantially lower median concentrations compared with pre-treatment sediments.

Measured sediment concentrations of available phosphorus, which reflects the sum of the saloid-bound and iron-bound phosphorus fractions, follow a trend similar to the trend exhibited by iron-bound phosphorus since the iron-bound phosphorus comprises a vast majority of the calculated available phosphorus concentration. A wide range of available sediment phosphorus concentrations were observed within the pre-treatment sediment samples, ranging from 7-188 $\mu g/cm^3$, with a mean of 50 $\mu g/cm^3$. Substantial reductions in both the degree of variability in measured concentrations, as well as median values, are apparent in the post-treatment samples, with concentrations ranging from 2-38 $\mu g/cm^3$ and a geometric mean of 7 $\mu g/cm^3$.

TABLE 3-9

PHOSPHORUS SPECIATION IN PRE-TREATMENT SEDIMENT CORE SAMPLES COLLECTED IN LAKE JESSAMINE DURING DECEMBER 2010

SITE	SALOID-P ($\mu g/cm^3$)	Fe-BOUND P ($\mu g/cm^3$)	TOTAL AVAILABLE P ($\mu g/cm^3$)	Al-BOUND P ($\mu g/cm^3$)	% OF TP AVAILABLE (%)
1	0.36	23	23	25	22
2	0.21	37	37	19	83
3	0.14	188	188	43	72
4	0.10	148	148	51	71
5	1.02	113	114	60	48
6	5.86	32	38	24	16
7	2.46	47	49	88	55
8	0.77	64	65	42	28
9	0.30	40	40	16	65
10	0.67	45	46	16	39
11	0.08	38	38	15	30
12	0.75	59	59	42	20
13	0.29	121	122	40	58
14	1.38	116	117	33	77
15	0.35	146	146	149	76
16	2.81	63	66	68	41
17	1.44	72	73	86	53
18	0.19	61	62	36	46
19	0.10	103	103	33	84
20	0.44	165	165	61	75
21	0.53	89	90	40	33
22	0.86	112	113	97	70
23	0.12	40	41	21	60
24	0.20	38	38	14	29
25	0.32	122	122	54	37
26	0.14	29	29	30	20
27	0.28	13	14	6	33
28	0.23	45	46	19	33
29	0.44	6	7	5	20
30	0.23	33	33	11	35
31	0.22	15	15	8	53
32	1.24	70	71	70	33
33	1.53	42	44	35	28
34	0.51	24	24	28	48
35	0.18	17	17	28	38
36	0.47	60	60	70	69
37	0.34	12	13	22	30
38	0.07	47	47	29	39
39	2.39	60	62	43	69
40	0.26	44	44	12	36
41	0.29	15	15	63	37
42	0.39	49	49	13	23
Minimum	**0.7**	**6**	**7**	**5**	**16**
Maximum	**5.86**	**188**	**188**	**149**	**84**
Geometric Mean	**0.41**	**49**	**50**	**31**	**42**

TABLE 3-10

PHOSPHORUS SPECIATION IN POST-TREATMENT SEDIMENT CORE SAMPLES COLLECTED IN LAKE JESSAMINE DURING SEPTEMBER 2013

SITE	SALOID-P (μg/cm^3)	Fe-BOUND P (μg/cm^3)	TOTAL AVAILABLE P (μg/cm^3)	Al-BOUND P (μg/cm^3)	% OF TP AVAILABLE (%)
1	0.05	4	4	38	4
2	0.04	4	4	45	3
3	0.02	18	18	60	14
4	0.01	15	15	82	11
5	0.08	14	14	97	7
6	0.44	5	5	65	3
7	0.10	4	5	139	10
8	0.15	6	6	67	2
9	0.04	6	6	33	11
10	0.01	5	5	22	10
11	0.01	4	4	25	5
12	0.13	12	12	59	6
13	0.03	13	13	73	12
14	0.22	12	12	56	8
15	0.04	38	38	173	21
16	0.13	14	14	91	14
17	0.20	14	14	129	11
18	0.01	8	8	47	8
19	0.01	9	9	47	6
20	0.04	12	12	86	5
21	0.08	8	8	67	5
22	0.14	22	22	133	17
23	0.02	4	4	41	4
24	0.02	4	4	25	4
25	0.04	16	16	97	11
26	0.02	5	5	54	3
27	0.04	2	2	13	4
28	0.04	7	7	28	4
29	0.04	2	2	9	8
30	0.04	5	5	16	7
31	0.04	3	3	12	7
32	0.09	6	6	115	2
33	0.26	4	4	74	6
34	0.06	6	6	64	10
35	0.02	4	4	72	6
36	0.05	13	13	122	6
37	0.05	2	2	57	7
38	0.01	6	6	50	3
39	0.21	11	11	88	11
40	0.02	4	4	31	4
41	0.04	4	4	91	3
42	0.05	6	6	34	3
Minimum	**0.01**	**2**	**2**	**9**	**2**
Maximum	**0.44**	**38**	**38**	**173**	**21**
Geometric Mean	**0.05**	**7**	**7**	**53**	**6**

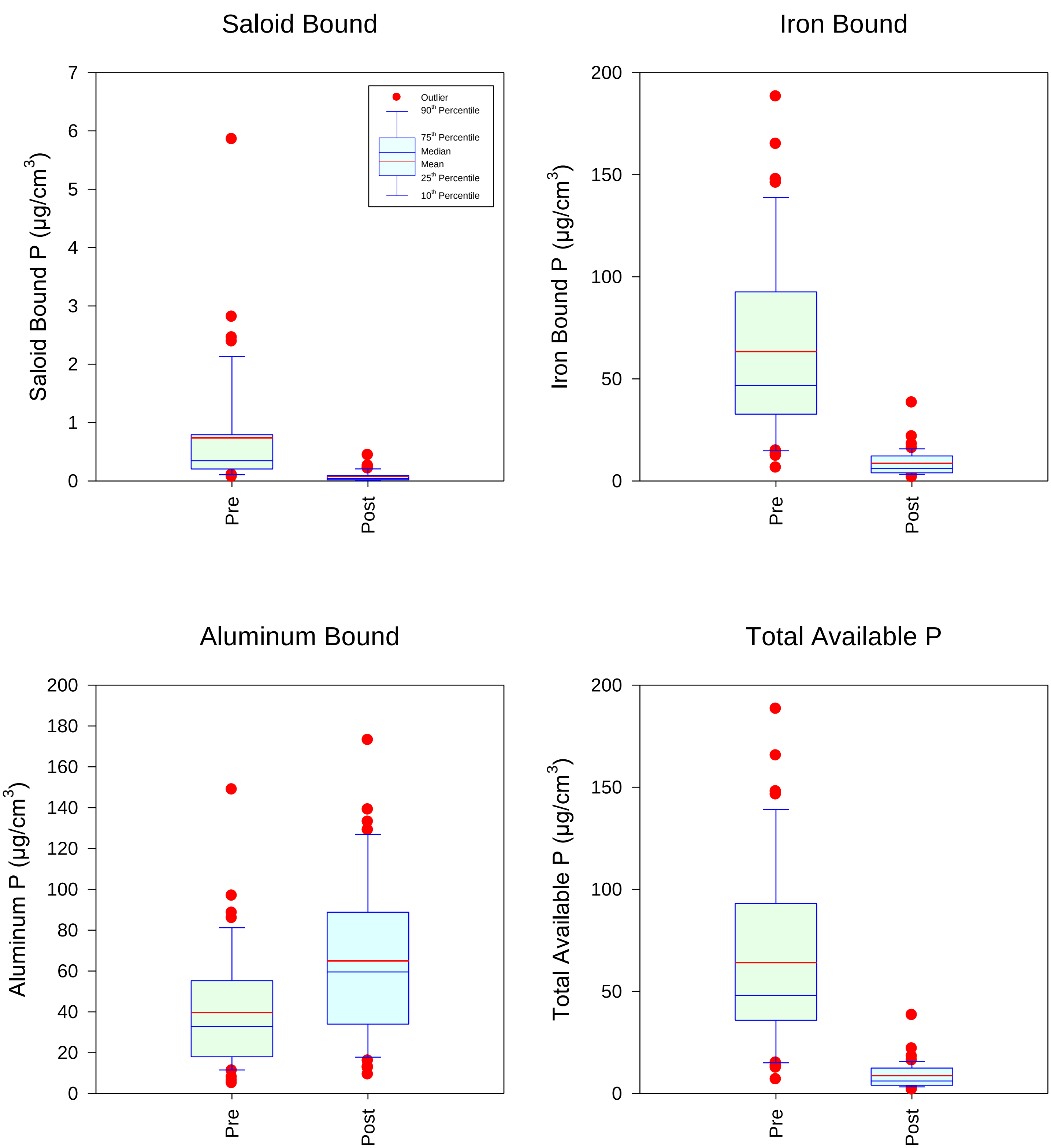


Figure 3-21. Statistical Summary of Pre- and Post-Treatment Values of Sediment Phosphorus Speciation in Lake Jessamine Sediments.

The primary objective of an alum sediment inactivation project is to provide an abundance of aluminum within the sediments so that phosphorus which is released from a bonding mechanism with iron will preferentially attach to aluminum in an inert, stable state. If this process occurs within the sediments, then the measured concentrations of aluminum-bound phosphorus should increase as the iron-bound phosphorus associations decrease. As indicated on Figure 3-21, the concentrations of aluminum-bound phosphorus increased substantially between the pre- and post-treatment samples, with a mean pre-treatment concentration of 31µg/cm^3 compared with a post-treatment concentration of 53 µg/cm^3. The increasing concentrations of aluminum-bound phosphorus provides physical evidence that the sediment inactivation program has been successful in increasing the stability of phosphorus within the sediments of Lake Jessamine.

A summary of mean phosphorus speciation in sediment core samples collected in Lake Jessamine during pre- and post-treatment conditions is given on Table 3-11. The mean values provided in this table reflect geometric mean values. The pre-treatment sediments were characterized by a mean saloid-phosphorus concentration of 0.41 µg/cm^3 compared with a mean concentration of 0.05 µg/cm^3 in the post-treatment monitoring event. This corresponds to a reduction of approximately 89% in saloid-phosphorus concentrations within the sediments as a result of the inactivation project.

TABLE 3-11

SUMMARY OF MEAN PRE-TREATMENT AND POST-TREATMENT PHOSPHORUS SPECIATION IN SEDIMENT CORE SAMPLES COLLECTED IN LAKE JESSAMINE

PARAMETER	UNITS	MEAN VALUE BY SEDIMENT COLLECTION DATE[1]		CHANGE IN CONCENTRATION (%)
		Pre- (12/10)	Post- (9/13)	
Saloid-Bound P	µg/cm^3	0.41	0.05	-89
Fe-Bound P	µg/cm^3	49	7	-86
Total Available P	µg/cm^3	50	7	-86
% of Total Sediment P	%	42	6	-85
Al-Bound P	µg/cm^3	31	53	74

1. Reflects geometric mean values

Pre-treatment sediment samples in Lake Jessamine exhibited a mean iron-bound phosphorus concentration of 49 $\mu g/cm^3$. Sediments collected at the completion of the inactivation project had a mean iron-bound phosphorus concentration of 7 $\mu g/cm^3$, reflecting a reduction of approximately 86%. Total available phosphorus decreased from a mean of 50 $\mu g/cm^3$ in the pre-treatment samples to a mean of 7 $\mu g/cm^3$ under post-treatment conditions, a reduction of 86%. In addition, the percentage of the total sediment phosphorus available for release into the overlying water column decreased from 50% in the pre-treatment samples to only 7% under post-treatment conditions. As indicated on Table 3-11, mean concentrations of aluminum-bound phosphorus increased following the alum applications, increasing from a mean of 31 $\mu g/cm^3$ in the pre-treatment samples to 53 $\mu g/cm^3$ in the post-treatment samples, an increase of approximately 74%.

A summary of post-/pre-treatment ratios for sediment phosphorus speciation in Lake Jessamine is given in Table 3-12. The values summarized in this table reflect the ratio of the post-treatment sediment characteristics for each phosphorus speciation parameter divided by the pre-treatment characteristics. Saloid-bound phosphorus in the post-treatment sediment samples ranged from 2-18.5% of the pre-treatment saloid-bound concentrations. Iron-bound phosphorus associations in the post-treatment samples range from 7.3-35.7% of the pre-treatment concentrations, with available phosphorus in the post-treatment sediments ranging from 7.3-34% of the pre-treatment values. In contrast, post-treatment aluminum-bound phosphorus range from 141-275% of the pre-treatment values.

A statistical summary of post-/pre-treatment ratios of sediment phosphorus speciation in Lake Jessamine is given in Figure 3-22 based upon the information summarized in Table 3-12. The post-/pre-treatment ratios for saloid-bound, iron-bound, and available phosphorus are all low in value, with a relatively low degree of variability which is an indication that the alum application reached all areas of the lake and achieved the objective of reducing concentrations for each of these parameters. A substantial increase in aluminum-bound phosphorus was observed under post-treatment conditions, indicating that phosphorus had been successfully bound to aluminum in an unavailable inert form.

The sediment data indicate that the alum sediment inactivation project was successful in reducing approximately 86% of the available phosphorus within the sediments of Lake Jessamine. As a result, release of phosphorus from internal recycling should also be reduced by a similar value. However, the observed reduction in available sediment phosphorus will likely exceed 86% due to the improved water quality characteristics within the lake which reduces the opportunity for anoxic conditions to occur that stimulate sediment phosphorus release. Not only has the amount of available phosphorus been reduced, but conditions within the lake have improved substantially which makes release of the remaining available phosphorus less likely.

TABLE 3-12

SUMMARY OF POST-TREATMENT / PRE-TREATMENT RATIOS FOR SEDIMENT PHOSPHORUS SPECIATION IN LAKE JESSAMINE

SITE	SALOID-P	Fe-BOUND P	TOTAL AVAILABLE P	Al-BOUND P
1	0.141	0.174	0.173	1.531
2	0.172	0.109	0.110	2.417
3	0.143	0.096	0.096	1.407
4	0.099	0.102	0.102	1.596
5	0.078	0.124	0.124	1.630
6	0.075	0.155	0.143	2.750
7	0.043	0.096	0.093	1.573
8	0.195	0.094	0.095	1.581
9	0.133	0.150	0.150	2.063
10	0.021	0.106	0.105	1.402
11	0.123	0.107	0.107	1.717
12	0.172	0.205	0.205	1.421
13	0.101	0.107	0.107	1.807
14	0.159	0.103	0.104	1.716
15	0.120	0.262	0.262	1.163
16	0.047	0.223	0.215	1.332
17	0.137	0.197	0.195	1.502
18	0.053	0.130	0.130	1.295
19	0.101	0.087	0.087	1.425
20	0.095	0.073	0.073	1.416
21	0.151	0.090	0.090	1.680
22	0.163	0.194	0.194	1.374
23	0.174	0.099	0.099	1.913
24	0.100	0.106	0.106	1.787
25	0.121	0.131	0.131	1.804
26	0.143	0.171	0.171	1.759
27	0.152	0.149	0.150	2.083
28	0.171	0.154	0.154	1.479
29	0.091	0.357	0.340	1.888
30	0.185	0.152	0.153	1.437
31	0.185	0.203	0.203	1.574
32	0.072	0.086	0.086	1.640
33	0.168	0.094	0.096	2.109
34	0.123	0.273	0.270	2.288
35	0.109	0.215	0.214	2.581
36	0.106	0.217	0.216	1.738
37	0.155	0.146	0.147	2.645
38	0.145	0.130	0.130	1.745
39	0.088	0.185	0.181	2.054
40	0.058	0.091	0.091	2.498
41	0.136	0.270	0.267	1.437
42	0.129	0.123	0.123	2.666
Minimum	**0.021**	**0.073**	**0.073**	**1.407**
Maximum	**0.185**	**0.357**	**0.340**	**2.750**
Geometric Mean	**0.112**	**0.140**	**0.139**	**1.741**

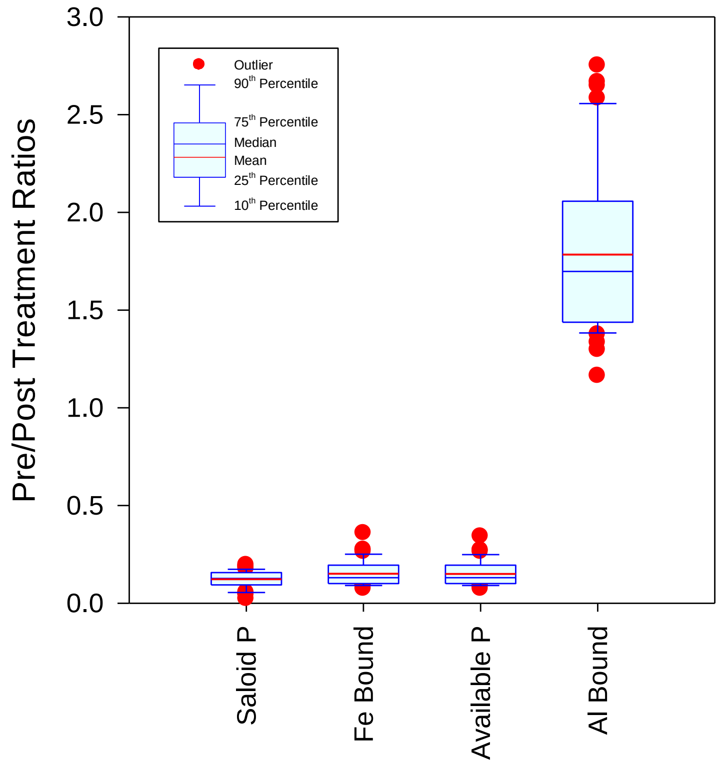


Figure 3-22. Statistical Summary of Post-/Pre-Treatment Ratios of Sediment Phosphorus Speciation in Lake Jessamine.

SECTION 4

SUMMARY

A sediment inactivation project was initiated in Lake Jessamine during July 2012. The objective of the sediment inactivation treatment was to inactivate available phosphorus contained within the top 10 cm of sediments in Lake Jessamine based upon a sediment characterization study conducted during 2010. Due to the relatively large amount of available phosphorus within the sediments, and the corresponding large volume of alum required for sediment inactivation in Lake Jessamine, the recommended total alum volume was divided into three smaller applications, and a supplemental buffering compound (sodium aluminate) was also used to reduce chemical and biological impacts to the lake. Three separate applications were conducted by ERD during July 2012, October-November 2012, and June 2013, with a total of 225,000 gallons of alum and 44,000 gallons of sodium aluminate applied to Lake Jessamine during the three treatments. The final alum application was completed during June 2013.

The alum applications resulted in substantial improvements in water quality characteristics within Lake Jessamine, with large reductions in water column concentrations of total phosphorus and improvements in Secchi disk depths within the lake. Calculated TSI values in Lake Jessamine improved from eutrophic conditions prior to the application to primarily oligotrophic and oligotrophic-mesotrophic conditions following the application. Water clarity improved from pre-treatment Secchi disk depths ranging from 0.5-1.0 m to post-treatment depths ranging from 2-3 m. Visual characteristics of Lake Jessamine improved substantially following the sediment inactivation treatments, with improved water column appearance and visibility.

Prior to implementation of the sediment inactivation project, phosphorus concentrations within the lake exhibited a distinct seasonal variability, with higher concentrations during dry season conditions and lower concentrations during wet season conditions. If the alum treatment is successful, the distinct seasonal pattern of phosphorus concentrations should be substantially absent, indicating that the sediment inactivation has been successful in reducing the release of phosphorus from the sediments and recirculating this phosphorus into upper portions of the water column during circulation events. Continued water quality monitoring is recommended in Lake Jessamine to document changes in seasonal water quality characteristics.

Sediment monitoring was conducted at 42 locations in Lake Jessamine by ERD on two separate occasions: during 2010 (prior to initiation of the alum inactivation project) and in 2013 (following the final alum addition). Each of the sediment samples was analyzed for general parameters, nutrient, and sediment phosphorus speciation. The alum sediment inactivation project had no significant impact on sediment concentrations for pH, moisture content, organic content, density, total nitrogen, or total phosphorus.

However, the alum sediment inactivation project resulted in significant changes in phosphorus speciation in sediment core samples, with large reductions in concentrations of saloid-bound phosphorus and iron-bound phosphorus, and increases in phosphorus bonding with aluminum. The alum sediment inactivation project was successful in inactivating approximately 86% of the available phosphorus within the sediments of Lake Jessamine while increasing the phosphorus-aluminum bonding by 74%.

APPENDICES

APPENDIX A

AVAILABLE HISTORICAL WATER QUALITY DATA FOR LAKE JESSAMINE

Historical Water Quality Data for Lake Jessamine

Lake	Date	pH (s.u.)	Alkalinity (mg/l)	Conductivity (µmho/cm)	Ammonia (mg/l)	NOx (mg/l)	Organic N (mg/l)	Total N (mg/l)	SRP (mg/l)	Total P (mg/l)	Chlorophyll-a (mg/m^3)	Color (PCU)	Secchi (m)	Diss.O_2 (mg/l)	Temp. (^oC)	TSS (mg/l)	Turbidity (NTU)
Jessamine M	6/26/89	8.00	43.0	285	0.021		0.657		0.003	0.017			2.1	7.4	29.26	2.0	1.6
Jessamine M	9/26/89	7.50	52.0	272	0.035		0.555		0.001	0.013			1.4	6.8	27.81	2.0	1.7
Jessamine M	2/14/90	6.90	52.0	257	0.069		0.634		0.001	0.021			3.8	7.8	20.30	0.4	1.5
Jessamine M	5/21/90	8.10	54.5	268	0.037		0.716		0.001	0.016		15	2.0	7.9	28.00	1.0	1.4
Jessamine M	8/29/90	8.00	46.0	241					0.001	0.019		20	1.3	8.4	29.90	9.0	3.3
Jessamine M	11/27/90	7.60	55.0	263	0.030		0.510		0.001	0.027		17	1.5	9.1	22.50	3.0	2.2
Jessamine M	2/20/91	7.90	60.0		0.020		0.700		0.001	0.016		20	2.8	8.9	18.00	12.0	1.5
Jessamine M	6/11/91	8.00	52.0	270	0.040		0.900		0.001	0.025		60	1.3	8.2	27.60	5.0	2.0
Jessamine M	8/21/91	7.30	45.0	231	0.010		1.210		0.005	0.015		30	1.3	5.6	29.40	7.0	2.2
Jessamine M	11/13/91	7.20	52.0	226	0.070		0.890		0.005	0.026		20	1.2	8.7	18.50	7.0	4.5
Jessamine M	2/19/92	6.20	46.0	242	0.040	0.107	0.710	0.857	0.007	0.019		10	2.0	9.3	20.30	1.0	2.4
Jessamine M	5/20/92	7.50	51.0		0.040	0.015	0.770	0.825	0.005	0.005		25	1.2	8.0	26.00	1.0	3.6
Jessamine M	8/19/92	8.10	48.0	213	0.010	0.016	0.780	0.806	0.005	0.014		20	1.0	7.9	29.70	2.0	3.5
Jessamine M	11/11/92	7.50	50.0	208	0.010	0.015	1.050	1.075	0.007	0.025		20	1.0	7.8	22.30	2.0	4.1
Jessamine M	2/17/93	7.50	46.0	209	0.010	0.045	0.750	0.805	0.005	0.019		20	2.3	8.7	18.80	1.0	1.4
Jessamine M	6/22/93	8.60	45.0	206	0.010	0.015	1.180	1.205	0.006	0.022			1.1	8.8	29.00	5.0	6.0
Jessamine M	8/25/93	7.40	46.0	207	0.010	0.015	0.950	0.975	0.006	0.016			1.2	7.0	30.00		4.3
Jessamine M	3/7/94	7.60	44.0	231	0.010	0.025		0.035	0.005	0.022			2.4	8.0	20.95	2.0	2.5
Jessamine M	6/13/94	8.30	44.0	212	0.030	0.015	0.990	1.035	0.005	0.005			0.5	8.6	29.82	8.0	5.3
Jessamine M	9/19/94	7.60	45.0	188	0.030	0.015	0.940	0.985	0.005	0.030			0.8	7.5	27.89	8.0	5.5
Jessamine M	11/21/94	7.70	47.0	202	0.010	0.015		0.025	0.005	0.007			3.0	8.7	22.99	1.0	4.0
Jessamine M	3/13/95	7.36	43.9	190	0.023	0.015	3.077	3.115	0.005	0.029			1.8	8.3	19.00	3.0	2.2
Jessamine M	7/10/95	8.64	49.0	243						0.005			1.0	5.7	30.95		5.3
Jessamine M	10/2/95	7.46		204						0.009			1.0	5.2	29.14		3.0
Jessamine M	12/11/95	6.90	62.0	211						0.030			1.0	5.2	18.45	7.0	4.0
Jessamine M	1/3/96	7.15	59.0	185	0.170	0.020	0.530	0.720	0.007	0.014			1.5	8.4	17.11	3.0	3.8
Jessamine M	4/3/96		49.0		0.010	0.016	1.400	1.426	0.005	0.006		20				2.0	1.1
Jessamine M	7/3/96	8.44	44.0	180	0.010	0.015	1.000	1.025	0.009	0.011		20	1.5	8.3	29.30	9.0	4.1
Jessamine M	10/2/96	7.34	48.0	205	0.010	0.016	1.000	1.026	0.006	0.012		15	1.0	6.4	27.99	4.0	4.0
Jessamine M	2/17/97	7.42	44.0	230	0.010	0.015	0.800	0.825	0.005	0.014		15	1.3	7.7	18.65	2.0	3.1
Jessamine M	4/30/97	8.34	54.0	201	0.100	0.015	1.000	1.115	0.005	0.013		10	0.8	8.9	24.65	4.0	4.5
Jessamine M	8/11/97	8.47	50.0	211	0.100	0.015	1.100	1.215	0.009	0.009		15	1.0	8.1	31.71	6.0	3.7
Jessamine M	11/11/97	8.20	54.0	218	0.100	0.015	1.300	1.415	0.005	0.018		20	1.0	9.1	22.36	11.0	6.3
Jessamine M	3/25/98	7.50	54.6	207	0.010	0.025	0.600	0.635	0.005	0.014		20	2.2	9.5	20.26	5.0	1.7
Jessamine M	6/17/98	8.59	54.6	228	0.020	0.015	0.900	0.935	0.005	0.016		15	1.3	7.7	31.80	6.0	3.4
Jessamine M	9/15/98	8.06	55.0	232	0.010	0.015	1.100	1.125	0.011	0.014		15	0.7	7.6	28.62	3.5	5.6
Jessamine M	12/1/98	7.59	55.7	228	0.010	0.015	0.800	0.825	0.005	0.007		10	0.7	7.5	24.16	6.0	3.5
Jessamine M	1/27/99	8.01	58.0	228	0.010	0.015	1.000	1.025	0.005	0.014		20	1.5	8.3	20.66	6.0	4.2
Jessamine M	4/12/99	8.22	62.0	244	0.010	0.015	0.960	0.985	0.005	0.015		10	1.9	7.7	25.19	4.0	1.9
Jessamine M	7/14/99	8.72	56.0	221	0.017	0.015	0.890	0.922	0.005	0.012		10	1.0	7.9	30.50	5.0	2.9
Jessamine M	10/4/99	8.19	58.0	236	0.010	0.015	1.100	1.125	0.008	0.020		10	0.8	9.3	27.77	11.0	3.7
Jessamine M	3/15/00	7.80	60.0	235	0.012	0.015	0.780	0.807	0.005	0.016	5.4	10	2.0	7.7	21.76	1.0	2.1

Historical Water Quality Data for Lake Jessamine

Lake	Date	pH (s.u.)	Alkalinity (mg/l)	Conductivity (µmho/cm)	Ammonia (mg/l)	NOx (mg/l)	Organic N (mg/l)	Total N (mg/l)	SRP (mg/l)	Total P (mg/l)	Chlorophyll-a (mg/m^3)	Color (PCU)	Secchi (m)	Diss.O_2 (mg/l)	Temp. (^oC)	TSS (mg/l)	Turbidity (NTU)
Jessamine M	6/26/01																
Jessamine M	9/24/01	8.16	58.4	235	0.014	0.010	0.990	1.014	0.005	0.015	16.0	15	2.0	8.5	28.54	6.5	3.2
Jessamine M	12/4/01	9.26	64.6		0.023	0.010	1.100	1.133	0.005	0.015	13.7	25				5.5	3.1
Jessamine M	2/11/02	6.97	65.5	239	0.017	0.010	0.810	0.837	0.005	0.014	4.1	15	1.8	8.0	18.70	3.5	2.5
Jessamine M	4/24/02	8.31	64.5	219	0.017	0.010	1.300	1.327	0.005	0.016	10.7	15	0.5	9.2	27.57	6.0	4.8
Jessamine M	8/6/02	6.45	51.0	212	0.015	0.010	0.740	0.765	0.005	0.012	3.0	15	1.5	6.6	30.45	1.0	1.4
Jessamine M	11/14/02	6.38	61.2	206	0.013	0.010	0.990	1.013	0.005	0.016	9.1	15	1.0	6.6	23.61	1.5	2.7
Jessamine M	2/5/03	5.87	51.0	193	0.019	0.130	0.610	0.759	0.005	0.016		10	3.2	9.5	15.92	1.0	0.9
Jessamine M	5/29/03	7.50	52.5	225	0.020	0.007	0.550	0.577	0.003	0.013		10	3.1	7.6	28.66	2.0	1.1
Jessamine M	8/28/03	7.97	55.0	209	0.020	0.006	0.690	0.716	0.003	0.009	6.7	5	1.5	7.7	29.74	3.0	2.8
Jessamine M	10/23/03		45.0		0.020	0.004	0.730	0.754	0.003	0.016	10.2	5				5.5	2.8
Jessamine M	2/10/04	6.53	54.0	208	0.024	0.004	0.320	0.348	0.003	0.013	3.2	5	2.0	9.1	19.23	4.0	2.2
Jessamine M	3/23/04	6.16	52.0	208	0.032	0.004	0.187	0.223	0.003	0.014	3.5	5	2.0	8.3	21.18	1.0	1.4
Jessamine M	5/11/04	8.10	50.0	208	0.020	0.004	1.220	1.244	0.003	0.004	6.7	13	1.4	8.5	26.30	4.0	2.9
Jessamine M	6/30/04	7.80	47.0	200	0.020	0.004	0.500	0.524	0.007	0.002	13.2	10	1.0	6.8	30.80	1.5	4.1
Jessamine M	8/10/04	7.30	49.0	210	0.020	0.004	0.670	0.694	0.003	0.007	2.9	13	1.5	6.7	30.70	2.5	1.8
Jessamine M	9/29/04	7.98	49.0	183	0.020	0.020	0.450	0.490	0.010	0.020	6.6	100	2.6	8.3	27.64	5.0	2.7
Jessamine M	11/9/04	7.09	52.0	182	0.020	0.020	0.580	0.620	0.020	0.014	10.9	100	1.2	6.7	23.59	10.0	2.4
Jessamine M	1/12/05	7.90	54.0	193	0.020	0.020	0.460	0.500	0.003	0.011	5.1	25	2.3	9.5	20.70	5.0	1.9
Jessamine M	4/11/05	6.40	52.0	194	0.020	0.030	0.460	0.510	0.007	0.012	2.3	18	2.8	7.5	23.20	1.0	1.0
Jessamine M	7/11/05	7.26	50.0	195	0.020	0.020	0.770	0.810	0.003	0.026	18.9	21	1.0	6.6	28.85	5.0	5.3
Jessamine M	10/20/05	7.60	56.0	198	0.020	0.003	0.530	0.553	0.002	0.024	18.1	12	0.9	7.9	27.20	6.0	5.5
Jessamine M	1/9/06	6.30	55.0	206	0.020	0.061	0.670	0.751	0.002	0.019	9.1	14	1.5	8.4	16.20	5.0	4.4
Jessamine M	4/6/06	8.20	56.0	214	0.020	0.004	0.630	0.654	0.004	0.013	3.4	14	2.7	8.4	23.82	2.0	1.0
Jessamine M	8/3/06	8.20	61.0	217	0.020	0.004	0.780	0.804	0.004	0.013	10.3	12	1.1	7.5	31.60	4.0	3.9
Jessamine M	10/9/06	7.90	62.0	213	0.020	0.004	0.800	0.824	0.004	0.022	13.1	16	1.1	7.4	26.70	6.0	3.8
Jessamine M	1/11/07	7.60	61.0	219	0.020	0.004	0.730	0.754	0.004	0.018	7.9	14	1.8	6.3	18.90	3.0	3.8
Jessamine M	4/11/07	7.80	65.0	225	0.020	0.004			0.004	0.023	6.6	9	2.1	8.3	21.20	2.0	2.1
Jessamine M	9/26/07	7.80	59.0	229	0.020	0.005	1.090	1.115	0.002	0.017	22.8	10	0.9	6.9	28.30	6.0	4.3
Jessamine M	10/17/07	7.60	60.0	230	0.020	0.005	1.010	1.035	0.002	0.022	15.6	10	1.0	6.7	27.00	4.0	5.0
Jessamine M	1/29/08	7.60	64.0	230	0.020	0.003	0.850	0.873	0.003	0.018	11.5	7	1.4	6.7	16.80	5.0	4.4
Jessamine M	4/16/08	7.70	66.0	233	0.020	0.003	0.870	0.893	0.007	0.012	12.1	8	0.9	6.9	21.00	4.0	4.3
Jessamine M	7/29/08	7.70	63.0	236	0.030	0.008	1.210	1.248	0.003	0.016	22.6	10	0.9	7.1	30.20	6.0	4.7
Jessamine M	10/22/08	7.30	58.0	223	0.030	0.005	1.200	1.235	0.004	0.022	29.9	10	0.9	6.6	24.70	7.0	5.4
Jessamine M	1/14/09	7.60	64.0	237	0.030	0.005	1.180	1.215	0.002	0.022	14.2	6	1.4	7.9	18.30	6.0	4.1
Jessamine M	4/6/09	8.10	63.0	243	0.030	0.003	0.800	0.833	0.002	0.015	6.4	9	1.7	8.8	23.90	3.0	2.7
Jessamine M	7/8/09	8.10		228							14.3	11	1.2	6.8	29.30		
Jessamine M	10/7/09	8.30	59.0	222	0.020	0.003	1.470	1.493	0.002	0.005	22.8	7	0.9	8.8	28.70	5.0	3.0
Jessamine M	1/12/10	7.40	60.0	224	0.020	0.115	0.895	1.030	0.002	0.017	7.0		1.7	11.1	10.00	5.0	4.0
Jessamine M	4/13/10	8.10	55.0	104	0.020	0.004	0.816	0.840	0.002	0.020	4.6		3.4	8.8	23.30	4.0	1.0
Jessamine M	7/6/10	7.60	52.0	214	0.020	0.004	0.996	1.020	0.002	0.012	7.7		1.0	6.8	29.10	3.0	3.2
Jessamine M	10/12/10	8.10	56.0	222	0.020	0.003	0.707	0.730	0.002	0.011	11.6		1.1	7.9	26.00	6.0	2.5

Historical Water Quality Data for Lake Jessamine

Lake	Date	pH (s.u.)	Alkalinity (mg/l)	Conductivity (µmho/cm)	Ammonia (mg/l)	NOx (mg/l)	Organic N (mg/l)	Total N (mg/l)	SRP (mg/l)	Total P (mg/l)	Chlorophyll-a (mg/m^3)	Color (PCU)	Secchi (m)	Diss.O_2 (mg/l)	Temp. (^oC)	TSS (mg/l)	Turbidity (NTU)
Jessamine M	1/11/11	8.00	61.0	228	0.020	0.003	0.977	1.000	0.003	0.015	12.4		1.7	10.0	15.30	4.0	2.6
Jessamine M	4/11/11	8.70	58.0	223	0.020	0.003	0.807	0.830	0.003	0.010	10.7		0.5	9.9	26.70	4.0	3.7
Jessamine M	7/5/11	8.30	52.0	228	0.020	0.005	0.735	0.760	0.003	0.007	6.3		2.0	8.4	29.70	1.0	1.7
Jessamine M	10/17/11	7.90		215							10.6		1.6	8.2	25.60		
Jessamine M	1/24/12	8.30	59.0	226	0.020	0.005	0.635	0.660	0.003	0.016	9.5		1.2	10.3	18.70	2.0	5.7
Jessamine M	4/10/12	8.40	65.0	220	0.020	0.005	1.335	1.360	0.003	0.025	32.0		0.5	8.7	24.60	10.0	5.6
Jessamine M	7/17/12	8.00	64.0	245	0.020	0.005	1.245	1.270	0.003	0.028	23.0		0.8	7.2	29.30	8.0	4.5
Jessamine M	10/8/12	8.00	52.0	250	0.020	0.005	0.975	1.000	0.003	0.007	17.9		1.0	8.0	28.70	5.0	2.5
Values for period from 2000 - 2012	**count**	**49**	**48**	**48**	**48**	**48**	**47**	**47**	**48**	**48**	**48**	**38**	**48**	**48**	**48**	**48**	**48**
	min	**5.87**	**45.0**	**104**	**0.012**	**0.003**	**0.187**	**0.223**	**0.002**	**0.002**	**2.3**	**5**	**0.5**	**6.3**	**10.00**	**1.0**	**0.9**
	max	**9.26**	**66.0**	**250**	**0.032**	**0.130**	**1.470**	**1.493**	**0.020**	**0.028**	**32.0**	**100**	**3.4**	**11.1**	**31.60**	**10.0**	**5.7**
	median	**7.80**	**58.0**	**220**	**0.020**	**0.005**	**0.800**	**0.824**	**0.003**	**0.015**	**10.5**	**11**	**1.4**	**7.9**	**25.80**	**4.0**	**3.0**
	geo mean	**7.63**	**56.9**	**214**	**0.020**	**0.007**	**0.774**	**0.812**	**0.003**	**0.014**	**9.4**	**12**	**1.4**	**7.9**	**23.94**	**3.5**	**2.8**

Historical Water Quality Data for Lake Jessamine

Lake	Date	pH (s.u.)	Alkalinity (mg/l)	Conductivity (μmho/cm)	Ammonia (mg/l)	NOx (mg/l)	Organic N (mg/l)	Total N (mg/l)	SRP (mg/l)	Total P (mg/l)	Chlorophyll-a (mg/m^3)	Color (PCU)	Secchi (m)	Diss.O_2 (mg/l)	Temp. (^oC)	TSS (mg/l)	Turbidity (NTU)
Jessamine NE	6/13/94	7.70	43.0	220	0.080	0.015	1.170	1.265	0.005	0.005			0.5	8.2	29.86		6.0
Jessamine NE	7/10/95	8.40	54.0	255						0.005			0.8	5.2	31.20		6.4
Jessamine NE	10/2/95	7.37		212						0.023			1.0	5.4	29.24		4.5
Jessamine NE	12/11/95	6.63	62.0	223						0.035			1.0	5.8	18.57	10.0	6.7
Jessamine NE	1/3/96	6.75	56.0	194	0.053	0.075	1.017	1.145	0.013	0.024			1.0	8.1	17.60	3.0	6.5
Jessamine NE	4/3/96	7.05	47.0	201								15	2.0	8.3	20.79	4.0	3.2
Jessamine NE	6/12/96	5.65		171	0.070		0.730	0.800	0.055	0.061			1.0	4.6	26.19	13.0	
Jessamine NE	10/2/96	7.60	44.0	206	0.010	0.016	1.100	1.126	0.007	0.013		15	1.0	7.4	28.26	8.0	3.8
Jessamine NE	2/17/97	7.30	23.0	233	0.010	0.015	0.900	0.925	0.005	0.018		15	1.3	7.4	18.95	9.0	5.8
Jessamine NE	4/30/97	8.35	58.0	203	0.010	0.015	1.300	1.325	0.005	0.017		15	0.5	9.2	24.57	5.0	3.1
Jessamine NE	8/11/97	8.50	47.0	212	0.010	0.015	1.300	1.325	0.013	0.016		15	0.8	8.9	31.63	7.0	5.3
Jessamine NE	11/11/97	8.10	53.0	220	0.010	0.015	1.300	1.325	0.005	0.017		20	1.0	9.1	22.19	14.0	5.8
Jessamine NE	3/25/98	7.26	65.3	216	0.010	0.086	0.500	0.596	0.005	0.014		15	1.7	9.3	20.68	7.5	1.4
Jessamine NE	6/17/98	8.24	54.6	238	0.020	0.015	0.800	0.835	0.005	0.018		16	1.2	7.5	32.24	6.0	3.5
Jessamine NE	9/15/98	8.25	50.0	241	0.020	0.015	1.300	1.335	0.016	0.018		20	0.8	8.3	28.92	12.0	4.7
Jessamine NE	12/1/98	7.68	54.6	234	0.010	0.015	1.100	1.125	0.005	0.009		15	0.7	8.2	24.29	7.0	3.4
Jessamine NE	1/27/99	7.99	55.0	232	0.010	0.015	1.300	1.325	0.005	0.017		30	1.0	8.8	20.83	10.0	4.8
Jessamine NE	4/12/99	8.42	64.0	250	0.010	0.015	1.200	1.225	0.009	0.017		10	0.6	7.5	25.49	4.0	4.7
Jessamine NE	7/14/99	8.26	54.0	232	0.034	0.015	1.100	1.149	0.005	0.014		15	0.8	7.9	30.71	6.0	4.7
Jessamine NE	10/4/99	7.40	54.0	237	0.010	0.015	1.200	1.225	0.008	0.031		10	0.8	8.5	28.04	7.0	3.6
Jessamine NE	3/15/00	7.53	58.0	237	0.010	0.015	0.930	0.955	0.005	0.015	7.0	10	1.3	7.3	22.05	4.0	2.2
Jessamine NE	6/26/01	8.41	56.5	231	0.016	0.010	1.100	1.126	0.005	0.014	10.2	15	1.0	8.0	32.01	3.0	4.5
Jessamine NE	9/24/01	7.10	56.8	239	0.015	0.010	0.990	1.015	0.005	0.015	12.8	20	1.8	7.1	28.63	7.5	2.5
Jessamine NE	12/4/01	6.91	64.1		0.026	0.010	0.970	1.006	0.005	0.019	13.4	25	1.3	7.0	28.81	5.0	3.2
Jessamine NE	2/11/02	6.01	64.0	239	0.017	0.010	0.810	0.837	0.005	0.016	3.2	15	2.0	8.2	18.93	2.0	2.0
Jessamine NE	4/24/02	7.73	62.5	219	0.021	0.010	1.200	1.231	0.005	0.015	8.9	15	1.0	7.9	27.47	6.0	4.1
Jessamine NE	8/6/02	6.58	55.5	217	0.014	0.010	0.880	0.904	0.005	0.015	6.3	15	1.5	6.7	30.48	1.0	1.8
Jessamine NE	11/14/02	6.17	53.6	207	0.013	0.010	0.770	0.793	0.005	0.018	12.1	15	1.0	6.8	23.61	3.0	3.0
Jessamine NE	2/5/03	5.79	49.0	198	0.038	0.180	0.670	0.888	0.005	0.021		15	2.5	8.7	16.18	1.0	0.9
Jessamine NE	5/29/03	7.36	51.0	228	0.020	0.006	0.700	0.726	0.003	0.016		10	2.2	7.6	29.16	3.3	1.4
Jessamine NE	8/28/03	7.77	49.0	219	0.020	0.006	0.890	0.916	0.003	0.013	6.9	10	1.0	7.8	29.97	3.8	7.0
Jessamine NE	10/23/03		50.0		0.020	0.002	0.840	0.862	0.003	0.018	14.3	10				6.5	3.6
Jessamine NE	2/10/04	5.96	54.0	210	0.029	0.004	0.290	0.323	0.003	0.020	7.1	5	1.7	8.0	18.99	3.0	3.3
Jessamine NE	3/23/04	6.17	51.0	210	0.033	0.004	0.750	0.787	0.003	0.021	5.3	5	1.5	8.1	21.45	4.5	2.5
Jessamine NE	5/11/04	8.30	50.0	211	0.020	0.004	1.390	1.414	0.003	0.002	28.8	13	0.6	8.9	26.30	8.5	11.0
Jessamine NE	6/30/04	6.50	47.0	204	0.026	0.004	0.570	0.600	0.003	0.003	10.8	10	1.0	6.5	31.00	1.5	2.1
Jessamine NE	8/10/04	6.70	49.0	212	0.020	0.004	0.810	0.834	0.003	0.009	8.9	13	1.4	6.4	30.50	4.5	1.8
Jessamine NE	9/29/04	8.03	49.0	185	0.020	0.020	0.430	0.470	0.010	0.020	8.0	100	1.6	8.2	27.86	5.0	2.8
Jessamine NE	11/9/04	6.92	51.0	186	0.020	0.020	0.620	0.660	0.020	0.011	13.3	125	1.2	7.1	23.44	14.0	2.4
Jessamine NE	1/12/05	7.10	50.0	199	0.020	0.060	0.560	0.640	0.003	0.010	3.3	25	2.5	8.5	20.40	4.0	1.4
Jessamine NE	4/11/05	6.40	48.0	199	0.020	0.030	0.420	0.470	0.003	0.011	1.6	18	3.2	6.9	23.40	1.0	0.9
Jessamine NE	7/11/05	7.27	48.0	197	0.020	0.020	0.690	0.730	0.003	0.025	17.3	21	1.1	6.7	29.05	4.0	4.8
Jessamine NE	10/20/05	7.20	53.0	199	0.060	0.003	0.470	0.533	0.002	0.024	17.8	12	0.9	7.8	27.50	6.0	5.1
Jessamine NE	1/9/06	6.10	53.0	206	0.020	0.028	0.640	0.688	0.002	0.023	4.7	14	2.2	8.3	16.00	3.0	2.7
Jessamine NE	4/6/06	8.30	54.0	215	0.030	0.004	0.590	0.624	0.004	0.015	3.3	15	3.0	8.6	24.33	2.0	0.9

Historical Water Quality Data for Lake Jessamine

Lake	Date	pH (s.u.)	Alkalinity (mg/l)	Conductivity (µmho/cm)	Ammonia (mg/l)	NOx (mg/l)	Organic N (mg/l)	Total N (mg/l)	SRP (mg/l)	Total P (mg/l)	Chlorophyll-a (mg/m^3)	Color (PCU)	Secchi (m)	Diss.O_2 (mg/l)	Temp. (^oC)	TSS (mg/l)	Turbidity (NTU)
Jessamine NE	8/3/06	8.00	57.0	220	0.020	0.004	0.860	0.884	0.004	0.018	13.1	18	1.0	7.8	31.80	5.0	4.7
Jessamine NE	10/9/06	8.00	61.0	219	0.020	0.004	0.880	0.904	0.004	0.023	14.2	23	1.0	7.6	26.70	5.0	3.6
Jessamine NE	1/11/07	7.30	59.0	222	0.030	0.011	0.590	0.631	0.006	0.015	3.4	15	2.5	6.4	18.90	1.0	1.6
Jessamine NE	4/11/07	7.50	61.0	225	0.020	0.004		0.024	0.004	0.012	3.8	9	3.0	8.4	21.40	1.0	1.0
Jessamine NE	9/26/07	7.40	61.0	237	0.020	0.005	1.160	1.185	0.002	0.016	19.9	11	0.9	7.0	28.30	7.0	4.5
Jessamine NE	10/17/07	7.40	62.0	234	0.020	0.005	1.020	1.045	0.002	0.020	14.2	13	1.1	6.9	27.10	5.0	4.2
Jessamine NE	1/29/08	7.40	62.0	231	0.050	0.058	0.800	0.908	0.003	0.013	6.2	8	3.0	6.1	16.80	2.0	1.9
Jessamine NE	4/16/08	7.65	64.0	233	0.020	0.003	0.620	0.643	0.003	0.010	3.3	9	2.6	7.2	21.30	1.0	1.3
Jessamine NE	7/29/08	7.30	61.0	238	0.030	0.005	1.170	1.205	0.003	0.017	20.0	12	1.0	6.4	30.70	4.0	4.0
Jessamine NE	10/22/08	7.00	56.0	224	0.030	0.005	1.180	1.215	0.003	0.019	24.6	11	0.9	6.8	24.60	6.0	4.1
Jessamine NE	1/14/09	7.70	62.0	238	0.030	0.005	1.210	1.245	0.002	0.028	13.4	6	1.3	8.7	18.30	7.0	4.7
Jessamine NE	4/6/09	7.80	61.0	246	0.030	0.003	0.820	0.853	0.002	0.025	4.1	9	2.0	8.2	24.50	2.0	2.5
Jessamine NE	7/8/09	7.80		232							13.0	13	1.3	6.7	29.60		
Jessamine NE	10/7/09	7.80	47.0	224	0.020	0.007	1.190	1.217	0.002	0.012	13.3	10	1.3	8.4	28.90	4.0	2.0
Jessamine NE	1/12/10	7.20	56.0	226	0.030	0.117	0.933	1.080	0.002	0.009	1.8		3.4	11.1	9.60	1.0	1.1
Jessamine NE	4/13/10	7.80	54.0	106	0.020	0.004	0.826	0.850	0.002	0.012	3.6		3.2	8.6	23.60	3.0	1.0
Jessamine NE	7/6/10	7.30	52.0	219	0.020	0.006	0.864	0.890	0.002	0.009	6.0		2.1	5.8	29.40		
Jessamine NE	10/12/10	7.60	51.0	219	0.020	0.003	0.637	0.660	0.002	0.010	4.9		2.2	7.5	25.90	2.0	1.2
Jessamine NE	1/11/11	7.60	59.0	232	0.020	0.031	0.809	0.860	0.003	0.014	3.2		2.5	9.4	15.70	3.0	1.0
Jessamine NE	4/11/11	8.40	50.0	222	0.020	0.003	0.697	0.720	0.003	0.009	3.0		4.2	9.7	26.60	4.0	1.2
Jessamine NE	7/5/11	7.90	53.0	233	0.020	0.005	0.565	0.590	0.003	0.006	3.4		2.9	8.2	30.10	1.0	1.0
Jessamine NE	10/17/11	7.50		217							7.5		1.8	7.7	25.70		
Jessamine NE	1/24/12	8.00	58.0	23	0.030	0.007	0.730	0.767	0.003	0.013	5.3		1.4	10.0	18.80	4.0	2.7
Jessamine NE	4/10/12	7.90	64.0	225	0.020	0.005	1.420	1.445	0.003	0.038	24.4		0.5	8.4	25.10	11.0	7.9
Jessamine NE	7/17/12	7.40		246				0.940		0.013	25.8		0.6	6.2	29.70		
Jessamine NE	10/8/12	7.50	50.0	247	0.020	0.005	0.920	0.945	0.003		19.1		0.9	7.8	28.80	5.0	3.2
	count	**50**	**48**	**49**	**48**	**48**	**47**	**49**	**48**	**48**	**49**	**39**	**50**	**50**	**50**	**47**	**47**
Values for period from 2000 - 2012	**min**	**5.79**	**47.0**	**23**	**0.010**	**0.002**	**0.290**	**0.024**	**0.002**	**0.002**	**1.6**	**5**	**0.5**	**5.8**	**9.60**	**1.0**	**0.9**
	max	**8.41**	**64.1**	**247**	**0.060**	**0.180**	**1.420**	**1.445**	**0.020**	**0.038**	**28.8**	**125**	**4.2**	**11.1**	**32.01**	**14.0**	**11.0**
	median	**7.40**	**54.0**	**220**	**0.020**	**0.006**	**0.810**	**0.860**	**0.003**	**0.015**	**8.0**	**13**	**1.5**	**7.8**	**26.10**	**4.0**	**2.5**
	geo mean	**7.30**	**54.9**	**207**	**0.022**	**0.008**	**0.788**	**0.775**	**0.003**	**0.014**	**8.0**	**14**	**1.5**	**7.6**	**24.29**	**3.3**	**2.4**

Historical Water Quality Data for Lake Jessamine

Lake	Date	pH (s.u.)	Alkalinity (mg/l)	Conductivity (µmho/cm)	Ammonia (mg/l)	NOx (mg/l)	Organic N (mg/l)	Total N (mg/l)	SRP (mg/l)	Total P (mg/l)	Chlorophyll-a (mg/m^3)	Color (PCU)	Secchi (m)	Diss.O_2 (mg/l)	Temp. (^oC)	TSS (mg/l)	Turbidity (NTU)
Jessamine SW	6/13/94	7.80	42.0	195	0.020	0.015	0.700	0.735	0.008	0.005			0.5	9.3	30.36		4.0
Jessamine SW	7/10/95	8.26	50.0	229		0.025		0.025	0.045	0.006			1.0	5.1	31.18		2.6
Jessamine SW	10/2/95	7.33		203						0.018			1.0	4.9	29.04		2.9
Jessamine SW	12/11/95	7.01	74.0	216						0.048			1.0	5.8	18.68	10.0	4.3
Jessamine SW	1/3/96	7.24	72.0	192	0.015	0.015	0.785	0.815	0.008	0.031			1.5	8.0	18.06	6.0	5.5
Jessamine SW	4/3/96		55.0									15				3.0	1.4
Jessamine SW	10/2/96	7.26	56.0	194	0.010	0.015	1.000	1.025	0.007	0.019		20	1.0	6.3	28.01	4.0	3.5
Jessamine SW	2/17/97	7.35	46.0	294	0.010	0.015	0.700	0.725	0.005	0.021		15	1.3	6.9	18.63	8.0	3.7
Jessamine SW	4/30/97	8.03	59.0	209	0.010	0.015	1.000	1.025	0.005	0.018		15	1.0	8.2	25.29	3.0	4.6
Jessamine SW	8/11/97	8.80	55.0	215	0.010	0.015	1.100	1.125	0.009	0.009		20	0.8	9.1	31.93	6.0	5.2
Jessamine SW	11/11/97	8.20	64.0	227	0.010	0.015	1.300	1.325	0.005	0.018		20	1.0	9.1	22.25	12.0	4.2
Jessamine SW	3/25/98	7.34	65.3	217	0.010	0.015	0.600	0.625	0.005	0.016		25	1.5	8.7	20.67	7.0	2.0
Jessamine SW	6/17/98	9.57	56.7	232	0.020	0.015	1.800	1.835	0.007	0.020		25	0.4	10.4	32.51	18.0	
Jessamine SW	9/15/98	8.25	62.0	236	0.010	0.015	1.100	1.125	0.013	0.019		20	0.8	8.2	28.62	11.0	4.3
Jessamine SW	12/1/98	7.83	67.2	236	0.010	0.016	0.600	0.626	0.005	0.009		15	0.7	8.1	23.99	8.0	3.6
Jessamine SW	1/27/99	8.20	66.0	234	0.010	0.015	1.400	1.425	0.005	0.019		20	1.1	8.5	20.56	6.0	3.2
Jessamine SW	4/12/99	8.16	70.0	251	0.010	0.015	0.840	0.865	0.005	0.020		15	0.9	7.3	25.64	8.0	4.3
Jessamine SW	7/14/99	8.66	60.0	214	0.021	0.015	0.960	0.996	0.005	0.027		15	0.9	7.6	30.71	4.0	3.5
Jessamine SW	10/4/99	7.51	64.0	228	0.010	0.015	1.100	1.125	0.006	0.025		15	0.8	8.0	27.82	10.0	3.1
Jessamine SW	3/15/00	7.71	37.0	235	0.013	0.025	0.710	0.748	0.005	0.017	4.8	20	1.5	7.4	22.06	3.0	3.1
Jessamine SW	6/26/01	8.99	58.2	207	0.019	0.010	1.200	1.229	0.005	0.023	25.2	15	0.5	8.7	31.91	9.0	7.8
Jessamine SW	9/24/01	6.93	64.3	223	0.015	0.010	0.830	0.855	0.005	0.020	14.2	25	1.5	7.6	28.55	4.5	2.4
Jessamine SW	12/4/01	6.81	70.4		0.022	0.013	0.970	1.005	0.005	0.023	17.8	20	1.3	9.5	22.73	6.0	3.1
Jessamine SW	2/11/02	6.91	69.2	238	0.017	0.010	0.780	0.807	0.005	0.019	5.1	15	1.8	8.1	19.06	2.5	2.2
Jessamine SW	4/24/02	8.09	64.0	215	0.016	0.010	1.100	1.126	0.005	0.019	10.4	15	0.8	8.5	27.54	6.5	4.5
Jessamine SW	8/6/02	6.44	59.1	208	0.012	0.010	0.710	0.732	0.005	0.017	3.0	20	1.5	7.0	30.40	2.5	1.9
Jessamine SW	11/14/02	5.87	62.7	205	0.011	0.014	1.500	1.525	0.005	0.019	9.0	20	1.2	7.1	23.15	2.0	2.2
Jessamine SW	2/5/03	5.71	54.5	188	0.024	0.093	0.640	0.757	0.005	0.019		15	3.1	9.5	16.28	1.0	0.8
Jessamine SW	5/29/03	7.85	56.0	226	0.020	0.009	0.720	0.749	0.003	0.022		10	2.6	7.6	28.93	4.8	1.2
Jessamine SW	8/28/03	8.08	61.0	216	0.020	0.006	0.870	0.896	0.003	0.017	12.2	5	1.1	8.0	29.65	3.0	4.9
Jessamine SW	10/23/03		59.0		0.020	0.004	0.710	0.734	0.003	0.019	8.1	10				5.3	4.3
Jessamine SW	2/10/04	6.77	60.0	211	0.023	0.004	0.630	0.657	0.003	0.014	1.4	10	2.9	8.9	19.64	2.5	1.0
Jessamine SW	3/23/04	6.18	56.0	209	0.033	0.004	0.260	0.297	0.003	0.016	2.7	5	2.5	8.3	21.42	2.5	0.9
Jessamine SW	5/11/04	8.20	47.0	191	0.020	0.004	0.880	0.904	0.003		2.2	10	3.0	8.3	26.40	4.0	0.8
Jessamine SW	6/30/04	7.60	55.0	209	0.020	0.004	0.870	0.894	0.009	0.004	8.4	13	1.4	6.4	31.00	1.5	2.5
Jessamine SW	8/10/04	6.80	52.0	207	0.020	0.004	0.710	0.734	0.003	0.009	6.0	13	2.0	7.1	30.50	2.0	1.6
Jessamine SW	9/29/04	8.10	51.0	171	0.020	0.020	0.460	0.500	0.010	0.020	4.2	100	1.7	8.4	27.37	5.0	2.0
Jessamine SW	11/9/04	8.28	52.0	157	0.020	0.020	0.470	0.510	0.020	0.010	2.6	75	2.5	8.9	23.58	17.0	0.7

Historical Water Quality Data for Lake Jessamine

Lake	Date	pH (s.u.)	Alkalinity (mg/l)	Conductivity (µmho/cm)	Ammonia (mg/l)	NOx (mg/l)	Organic N (mg/l)	Total N (mg/l)	SRP (mg/l)	Total P (mg/l)	Chlorophyll-a (mg/m^3)	Color (PCU)	Secchi (m)	Diss.O_2 (mg/l)	Temp. (^oC)	TSS (mg/l)	Turbidity (NTU)
Jessamine SW	1/12/05	8.40	54.0	184	0.020	0.020	0.650	0.690	0.003	0.014	3.3	25	3.0	9.3	20.70	4.0	1.2
Jessamine SW	4/11/05	7.40	52.0	188	0.020	0.020	0.430	0.470	0.003	0.011	1.2	18	2.0	7.8	23.40	1.0	1.0
Jessamine SW	7/11/05	6.86	62.0	206	0.020	0.020	1.330	1.370	0.003	0.071	56.6	38	0.6	5.9	28.62	12.0	14.0
Jessamine SW	10/20/05	7.10	60.0	200	0.020	0.004	0.550	0.574	0.002	0.036	25.2	14	0.9	6.7	27.10	9.0	7.8
Jessamine SW	1/9/06	6.90	58.0	209	0.020	0.007	0.800	0.827	0.002	0.033	7.4	18	1.1	8.5	16.10	7.0	5.9
Jessamine SW	10/22/08	7.23	62.0	237	0.030	0.005	1.120	1.155	0.003	0.022						12.0	5.4
Jessamine SW	1/14/09	7.70	63.0	243	0.030	0.005	1.305	1.340	0.002	0.024	13.3	1	1.4	7.8	17.80	5.0	4.7
Jessamine SW	4/6/09	8.30	64.0	227	0.030	0.003	0.737	0.770	0.002	0.016	6.3	1	1.8	8.8	24.40	1.0	2.0
Jessamine SW	7/8/09	8.10	60.0	221	0.020	0.003	1.417	1.440	0.002	0.016	13.6	1	1.4	6.2	29.50	4.0	3.9
Jessamine SW	10/7/09	8.30	59.0	226	0.020	0.003	1.327	1.350	0.002	0.019	18.8	1	1.0	9.2	28.70	3.0	2.5
Jessamine SW	1/12/10	7.50	64.0	202	0.020	0.063	1.257	1.340	0.002	0.024	4.7	1	1.6	11.4	9.80	5.0	3.0
Jessamine SW	4/13/10	8.00	58.0	219	0.020	0.004	0.946	0.970	0.002	0.017	7.9	1	1.7	8.6	23.30	5.0	1.8
Jessamine SW	7/6/10	7.50						1.680		0.027	35.7	2	0.5	5.6	29.10		
Jessamine SW	10/12/10							0.860		0.020	12.7	1					
Jessamine SW	7/5/11	8.60	60.0	228	0.020	0.005	0.615	0.640	0.003	0.013	9.0	1	1.2	8.8	30.10	4.0	2.2
Jessamine SW	10/17/11	7.70	52.0	210	0.020	0.005	0.775	0.800	0.003	0.021	13.0	1	1.3	8.0	25.40	6.0	3.0
Jessamine SW	1/24/12	8.20	60.0	224	0.020	0.005	1.035	1.060	0.003	0.027	9.6	1	1.0	10.3	18.90	6.0	6.0
Jessamine SW	4/10/12	8.80	64.0	217	0.020	0.005	1.365	1.390	0.003	0.026	48.9	1	0.5	9.4	24.80	13.0	8.2
Jessamine SW	7/17/12	7.60	66.0	242	0.020	0.007	1.133	1.160	0.003	0.033	19.7	1	0.8	6.4	29.80	9.0	4.7
Jessamine SW	10/8/12	7.80	55.0	247	0.020	0.005	0.785	0.810	0.003	0.011	15.3	1	1.0	7.9	28.80	5.0	2.9
Values for period from 2000 - 2012	**count**	**37**	**37**	**35**	**37**	**37**	**37**	**39**	**37**	**38**	**36**	**38**	**36**	**36**	**36**	**37**	**37**
	min	**5.71**	**37.0**	**157**	**0.011**	**0.003**	**0.260**	**0.297**	**0.002**	**0.004**	**1.2**	**1**	**0.5**	**5.6**	**9.80**	**1.0**	**0.7**
	max	**8.99**	**70.4**	**247**	**0.033**	**0.093**	**1.500**	**1.680**	**0.020**	**0.071**	**56.6**	**100**	**3.1**	**11.4**	**31.91**	**17.0**	**14.0**
	median	**7.70**	**59.1**	**211**	**0.020**	**0.006**	**0.800**	**0.855**	**0.003**	**0.019**	**9.0**	**10**	**1.4**	**8.2**	**25.90**	**4.8**	**2.5**
	geo mean	**7.51**	**58.0**	**212**	**0.020**	**0.008**	**0.825**	**0.876**	**0.003**	**0.019**	**8.6**	**6**	**1.4**	**8.0**	**24.27**	**4.2**	**2.7**

APPENDIX B

PRE- AND POST- ALUM TREATMENT FIELD AND LABORATORY ANALYSES COLLECTED IN LAKE JESSAMINE

B-1. Field Profiles and Data
B-2. Lab Analyses

B-1. Field Profiles and Data

Field Measurements Collected in Lake Jessamine as Part of the Alum Treatments

Site	Date	Time	Depth (m)	Temp. (^oC)	pH (s.u.)	SpCond (µmho/cm)	TDS (mg/l)	DO (mg/l)	DO% (% Sat.)	ORP (mV)	Secchi (m)
Pre Alum - 1st Application											
North	7/17/12	9:57	0.25	29.81	7.75	252	161	6.9	89	390	0.51
		9:58	0.50	29.79	7.74	252	161	6.7	88	388	
		9:59	1.00	29.71	7.65	252	161	6.3	83	386	
		9:59	1.50	29.54	7.64	251	161	6.3	83	386	
		10:00	2.00	29.52	7.66	251	161	6.2	81	387	
		10:01	2.50	29.47	7.64	252	161	6.0	79	386	
		10:02	3.00	29.36	7.40	252	161	4.8	62	376	
		10:02	3.50	29.29	7.36	252	161	4.5	59	376	
		10:03	3.95	28.92	7.23	254	162	3.8	50	187	
Middle	7/17/12	10:12	0.25	29.51	8.20	252	161	7.2	94	356	0.53
		10:13	0.50	29.51	8.22	253	162	7.0	92	354	
		10:14	1.00	29.51	8.23	252	161	7.0	91	354	
		10:14	1.50	29.43	8.24	252	161	6.8	89	354	
		10:15	2.00	29.34	8.22	252	161	6.7	87	355	
		10:15	2.50	29.32	8.20	252	161	6.8	88	355	
		10:16	3.00	29.28	8.13	253	162	6.6	87	353	
		10:17	3.50	29.23	8.10	252	161	6.5	85	353	
		10:17	4.00	28.74	7.37	252	161	2.8	36	319	
		10:18	4.50	27.92	7.18	256	164	1.7	22	175	
		10:18	5.00	26.52	7.07	267	171	1.2	15	109	
		10:19	5.50	26.02	7.03	272	174	0.9	11	88	
		10:19	6.00	25.80	7.00	274	176	0.7	9	74	
		10:20	6.40	25.75	6.91	289	185	0.6	7	60	
South	7/17/12	10:35	0.25	30.05	8.00	247	158	6.8	90	297	0.51
		10:36	0.50	30.05	8.02	248	159	6.6	88	298	
		10:36	1.00	29.92	8.03	247	158	6.4	85	299	
		10:37	1.50	29.83	8.06	248	159	6.5	86	301	
		10:38	2.00	29.76	8.07	248	159	6.4	85	303	
		10:39	2.50	29.71	8.09	248	158	6.3	83	307	
		10:39	3.00	29.58	7.93	248	159	6.1	80	302	
		10:41	3.34	29.48	7.17	263	168	1.1	14	129	

Field Measurements Collected in Lake Jessamine as Part of the Alum Treatments

Site	Date	Time	Depth (m)	Temp. (°C)	pH (s.u.)	SpCond (µmho/cm)	TDS (mg/l)	DO (mg/l)	DO% (% Sat.)	ORP (mV)	Secchi (m)

During 1st Application

Site	Date	Time	Depth (m)	Temp. (°C)	pH (s.u.)	SpCond (µmho/cm)	TDS (mg/l)	DO (mg/l)	DO% (% Sat.)	ORP (mV)	Secchi (m)
Zone 2	7/18/12	9:59	0.25	29.13	8.00	248	159	7.4	97	382	
Zone 2	7/18/12	11:28	0.44	29.25	8.15	252	161	7.8	102	387	
Zone 2	7/18/12	12:16	0.39	29.56	7.58	261	167	8.0	106	366	
Zone 2	7/18/12	12:54	0.24	29.83	8.35	253	162	8.0	105	380	
Zone 2	7/18/12	13:25	0.39	29.81	8.26	253	162	7.9	105	377	
Zone 1	7/18/12	13:56	0.33	29.81	8.15	257	164	7.8	103	372	
Zone 1	7/18/12	13:58	0.33	29.92	7.84	257	165	7.7	102	353	
Zone 1	7/18/12	14:02	0.34	29.98	8.12	256	164	7.8	103	367	
Zone 2	7/18/12	14:20	0.28	30.48	7.10	276	176	7.7	103	293	
Zone 3	7/18/12	14:20	0.37	30.41	7.10	287	183	9.3	124	280	
Zone 2	7/19/12	9:39	0.29	29.49	7.75	259	166	9.2	121	383	
Zone 2	7/19/12	9:52	0.37	29.48	7.75	258	165	9.1	122	379	
Zone 2	7/19/12	10:32	0.29	29.81	7.71	257	164	9.4	124	372	
Zone 2	7/19/12	11:28	0.41	29.71	7.84	254	163	7.8	103	378	
Zone 1	7/19/12	13:17	0.36	30.29	7.78	262	167	8.5	113	346	
Zone 1	7/19/12	13:38	0.34	30.30	7.71	257	164	8.9	119	337	
Zone 3	7/19/12	14:06	0.40	31.10	7.65	261	167	8.2	111	347	
Zone 3	7/19/12	14:58	0.39	31.10	7.64	261	167	8.1	110	349	
Zone 2	7/20/12	7:58	0.40	29.87	7.78	267	171	9.8	130	358	
Zone 2	7/20/12	8:28	0.42	29.76	7.82	259	166	8.3	110	373	
Zone 2	7/20/12	9:31	0.34	29.50	7.74	261	167	7.7	101	372	
Zone 1	7/20/12	9:51	0.38	29.79	7.70	262	167	7.6	100	373	
Zone 2	7/20/12	10:35	0.36	30.34	7.78	261	167	10.0	133	359	
Zone 2	7/20/12	11:02	0.37	30.29	7.64	261	167	10.6	141	352	
Zone 1	7/20/12	11:37	0.38	30.30	7.53	265	169	11.0	147	344	
Zone 2	7/20/12	12:22	0.36	30.80	7.58	269	172	8.3	111	338	
Zone 3	7/20/12	13:05	0.46	31.10	7.54	267	171	7.7	105	335	
Zone 3	7/20/12	13:46	0.44	31.64	7.79	264	169	8.4	115	360	
Zone 2	7/23/12	9:28	0.45	30.00	7.74	265	170	6.8	90	397	
Zone 1	7/23/12	9:33	0.41	30.05	7.45	272	174	7.4	90	388	
Zone 2	7/23/12	12:14	0.40	30.41	7.48	268	172	7.1	95	373	
Zone 3	7/23/12	13:03	0.38	30.28	7.51	271	173	7.2	94	371	
Zone 3	7/23/12	13:46	0.35	30.41	7.46	266	170	7.0	92	385	
Zone 1	7/24/12	8:52	0.42	29.76	7.48	265	169	6.8	90	382	
Zone 2	7/24/12	13:09	0.36	30.42	7.49	272	174	7.0	94	362	
Zone 3	7/24/12	13:48	0.36	30.45	7.46	271	174	7.7	102	361	
Zone 2	7/26/12	8:29	0.46	29.91	7.61	278	178	7.3	96	390	
Zone 2	7/26/12	9:36	0.47	30.09	7.64	272	174	7.2	95	396	
Zone 1	7/26/12	12:58	0.38	31.45	7.66	277	177	7.8	105	368	
Zone 3	7/26/12	13:05	0.42	30.84	7.65	277	177	8.4	113	377	
Zone 3	7/26/12	14:09	0.40	30.87	7.52	277	177	8.0	108	371	
Zone 2	7/27/12	9:39	0.51	30.91	7.55	277	178	7.7	104	378	
Zone 1	7/27/12	10:45	0.38	30.55	7.70	277	177	8.4	112	396	
Zone 3	7/27/12	11:36	0.36	30.47	7.56	277	177	8.2	104	374	
Zone 5	7/27/12	12:41	0.45	30.84	7.61	271	173	7.8	109	386	
Zone 4	7/27/12	13:58	0.47	30.66	7.43	273	175	8.3	111	361	
Zone 2	7/30/12	9:35	0.41	31.64	7.56	284	182	7.2	99	351	
Zone 1	7/30/12	10:44	0.42	31.87	7.44	283	181	8.0	110	350	
Zone 3	7/30/12	11:26	0.37	31.56	7.34	286	183	7.9	107	364	
Zone 5	7/30/12	12:22	0.41	31.73	7.52	272	174	7.7	105	376	
Zone 4	7/30/12	12:59	0.32	31.51	7.34	292	187	7.9	108	377	
Zone 3	7/30/12	13:28	0.46	31.47	7.45	292	187	7.5	102	384	

Field Measurements Collected in Lake Jessamine as Part of the Alum Treatments

Site	Date	Time	Depth (m)	Temp. (°C)	pH (s.u.)	SpCond (µmho/cm)	TDS (mg/l)	DO (mg/l)	DO% (% Sat.)	ORP (mV)	Secchi (m)
Post 1st Application (16 tankers Alum and 4 tankers Sodium Aluminate)											
North	7/31/12	12:42	0.25	31.76	7.15	283	181	7.6	103	413	0.94
		12:43	0.50	31.68	7.34	283	181	7.7	105	417	
		12:44	1.00	31.35	7.44	283	181	7.9	107	419	
		12:45	1.50	31.21	7.46	283	181	7.9	107	418	
		12:45	2.00	30.94	7.43	284	182	7.8	105	415	
		12:46	2.50	30.88	7.43	284	181	7.8	105	415	
		12:47	3.00	30.80	7.39	283	181	7.3	98	414	
		12:48	3.50	30.46	7.27	283	181	6.3	84	398	
		12:49	4.00	29.39	6.71	286	183	1.9	25	68	
		12:50	4.11	29.42	6.70	285	182	1.4	18	51	
Middle	7/31/12	13:03	0.25	31.19	7.58	284	182	7.5	102	277	0.96
		13:04	0.50	31.14	7.60	283	181	7.7	104	282	
		13:05	1.00	31.17	7.61	284	182	7.7	104	287	
		13:05	1.50	31.07	7.64	284	182	8.0	107	294	
		13:06	2.00	30.90	7.65	284	182	7.9	106	300	
		13:07	2.50	30.82	7.62	284	182	7.8	105	302	
		13:08	3.00	30.73	7.59	283	181	7.5	101	303	
		13:08	3.50	30.37	7.47	282	181	6.8	91	299	
		13:09	4.00	29.66	7.14	274	175	3.8	50	277	
		13:10	4.50	28.67	6.98	272	174	2.4	31	146	
		13:10	5.00	27.45	6.92	279	178	1.9	24	94	
		13:11	5.50	26.96	6.90	282	181	1.6	20	71	
		13:11	6.00	26.02	6.74	302	193	1.3	17	36	
		13:12	6.15	26.01	6.59	347	222	1.1	14	11	
South	7/31/12	13:26	0.25	31.61	7.56	272	174	6.9	94	249	0.92
		13:27	0.50	31.62	7.58	272	174	7.0	95	259	
		13:28	1.00	31.60	7.58	272	174	7.2	98	266	
		13:28	1.50	31.51	7.59	272	174	7.3	99	272	
		13:29	2.00	30.96	7.59	274	175	7.4	99	277	
		13:30	2.50	30.74	7.54	273	175	7.0	94	279	
		13:31	3.00	30.62	7.30	270	173	5.5	73	268	
		13:34	3.28	30.30	7.01	318	204	1.7	23	149	

Field Measurements Collected in Lake Jessamine as Part of the Alum Treatments

Pre Alum - 2nd Application

Site	Date	Time	Depth (m)	Temp. (°C)	pH (s.u.)	SpCond (μmho/cm)	TDS (mg/l)	DO (mg/l)	DO% (% Sat.)	ORP (mV)	Secchi (m)
North	10/15/12	11:36	0.25	27.75	7.75	247	158	8.2	104	346	0.73
		11:37	0.50	27.63	7.72	247	158	7.9	100	345	
		11:37	1.00	27.24	7.69	246	158	7.9	100	344	
		11:38	1.50	26.99	7.68	246	158	7.8	98	344	
		11:39	2.00	26.96	7.70	246	157	7.6	96	346	
		11:40	2.50	26.93	7.68	245	157	7.5	95	345	
		11:40	3.00	26.82	7.59	246	157	7.0	88	342	
		11:41	3.50	26.73	7.46	247	158	6.3	79	338	
		11:42	4.00	26.67	7.39	246	157	6.3	79	336	
		11:44	4.18	26.68	7.12	247	158	4.8	60	191	
Middle	10/15/12	11:59	0.25	27.69	7.85	249	160	8.4	107	313	0.72
		12:00	0.50	27.58	7.94	249	160	8.1	103	319	
		12:01	1.00	27.15	8.02	248	159	8.0	101	323	
		12:02	1.50	27.06	8.04	249	159	7.9	100	325	
		12:03	2.00	26.95	8.02	249	159	7.8	98	326	
		12:04	2.50	26.90	7.99	249	159	7.6	96	325	
		12:05	3.00	26.87	7.94	248	159	7.3	91	326	
		12:06	3.50	26.83	7.86	248	159	7.1	89	323	
		12:07	4.00	26.72	7.75	249	159	6.7	83	321	
		12:08	4.50	26.63	7.64	248	159	6.3	79	317	
		12:09	5.00	26.62	7.58	248	159	6.1	76	316	
		12:10	5.50	26.60	7.52	248	159	6.2	78	315	
		12:11	6.00	26.60	7.49	249	159	6.3	79	316	
		12:13	6.50	26.57	7.46	248	159	5.8	73	316	
		12:15	6.78	26.56	6.77	276	177	2.1	26	200	
South	10/15/12	12:27	0.26	27.95	7.74	247	158	7.9	101	287	0.76
		12:27	0.50	27.56	7.82	247	158	7.6	96	293	
		12:29	1.00	27.40	7.90	247	158	7.8	98	298	
		12:29	1.50	26.99	7.92	247	158	7.6	95	301	
		12:30	2.00	26.77	7.90	247	158	7.2	91	302	
		12:31	2.50	26.68	7.81	246	158	7.4	93	301	
		12:32	3.00	26.61	7.70	247	158	6.8	85	298	
		12:33	3.50	26.57	7.56	247	158	6.1	76	293	
		12:36	3.66	26.63	7.27	279	178	1.9	24	256	

Field Measurements Collected in Lake Jessamine as Part of the Alum Treatments

Site	Date	Time	Depth (m)	Temp. (°C)	pH (s.u.)	SpCond (µmho/cm)	TDS (mg/l)	DO (mg/l)	DO% (% Sat.)	ORP (mV)	Secchi (m)

During 2nd Application

Zone 2	10/22/12	7:28	0.25	20.89	7.43	269	172	12.1	136	454
Zone 2	10/22/12	9:29	0.30	20.93	7.39	268	172	10.3	115	453
Zone 1	10/22/12	11:41	0.24	21.72	7.23	270	172	9.6	110	418
Zone 3	10/22/12	12:40	0.33	21.79	7.32	253	162	10.1	115	425
Zone 3	10/22/12	13:40	0.32	21.78	7.31	265	170	10.4	116	424
Zone 2	10/23/12	8:35	0.29	20.39	7.31	263	168	9.9	110	434
Zone 2	10/23/12	10:41	0.22	21.73	7.25	256	164	10.4	118	420
Zone 1	10/23/12	11:35	0.24	20.42	7.31	264	169	9.6	107	434
Zone 3	10/23/12	12:35	0.27	20.43	7.31	264	169	9.4	104	433
Zone 3	10/23/12	14:35	0.26	20.42	7.30	263	169	9.1	100	432
Zone 2	10/24/12	8:53	0.32	19.35	7.42	266	170	11.6	127	457
Zone 2	10/24/12	10:35	0.34	19.33	7.36	268	172	9.4	102	455
Zone 1	10/24/12	12:41	0.22	21.74	7.28	251	161	9.9	112	422
Zone 1	10/24/12	13:54	0.32	19.34	7.35	267	171	9.6	104	455
Zone 3	10/24/12	14:35	0.27	20.41	7.31	263	168	9.9	109	434
Zone 2	10/25/12	9:06	0.27	19.82	7.19	264	169	10.0	109	429
Zone 2	10/25/12	11:12	0.27	19.84	7.22	264	169	10.2	112	431
Zone 1	10/25/12	12:03	0.29	19.83	7.25	265	170	9.7	107	432
Zone 3	10/25/12	13:07	0.37	19.82	7.25	265	170	9.7	106	432
Zone 3	10/25/12	14:02	0.36	19.47	7.33	260	166	9.8	107	432
Zone 2	10/29/12	9:03	0.27	19.64	6.82	265	170	10.1	111	415
Zone 2	10/29/12	11:03	0.27	19.69	6.85	266	170	10.8	111	416
Zone 1	10/29/12	12:26	0.28	19.70	6.90	265	170	9.9	108	417
Zone 3	10/29/12	13:04	0.26	19.73	6.95	264	169	10.6	116	419
Zone 3	10/29/12	14:04	0.39	19.80	7.10	264	169	10.7	117	426
Zone 2	10/31/12	8:43	0.35	19.30	7.62	261	167	8.7	95	460
Zone 2	10/31/12	10:31	0.32	19.92	7.56	256	164	13.1	144	406
Zone 1	10/31/12	13:41	0.34	19.90	7.20	251	160	9.5	108	417
Zone 3	10/31/12	12:31	0.31	19.92	7.57	256	164	11.1	122	407
Zone 3	10/31/12	14:32	0.33	19.90	7.61	259	166	9.0	99	406
Zone 2	11/1/12	8:16	0.40	20.25	7.30	268	171	9.7	108	423
Zone 1	11/1/12	10:16	0.25	20.34	7.35	267	171	9.5	106	424
Zone 3	11/1/12	11:19	0.23	20.38	7.32	269	172	12.6	140	420
Zone 5	11/1/12	12:21	0.24	20.27	7.29	270	173	13.0	144	418
Zone 4	11/1/12	13:21	0.24	20.14	7.27	268	171	10.7	118	417
Zone 2	11/2/12	8:40	0.23	20.85	7.40	269	172	9.4	105	428
Zone 1	11/2/12	9:55	0.25	20.82	7.37	268	171	9.3	104	427
Zone 3	11/2/12	11:40	0.26	20.80	7.35	268	171	9.1	102	427
Zone 5	11/2/12	13:41	0.25	20.84	7.34	268	172	9.3	104	427
Zone 2	11/5/12	8:41	0.34	21.66	7.18	269	172	8.8	100	414
Zone 2	11/5/12	9:43	0.25	21.65	7.16	269	172	8.3	94	414
Zone 1	11/5/12	11:23	0.23	21.72	7.10	258	165	8.5	97	412
Zone 3	11/5/12	13:42	0.24	21.70	7.15	281	180	8.6	98	414
Zone 2	11/6/12	8:11	0.21	21.27	7.34	275	176	10.6	120	447
Zone 1	11/6/12	9:12	0.23	21.30	7.25	260	167	9.8	111	442
Zone 3	11/6/12	10:15	0.44	21.21	7.09	279	178	9.4	106	435
Zone 5	11/6/12	11:15	0.21	21.24	7.00	279	179	9.9	112	433
Zone 4	11/6/12	12:16	0.30	21.22	6.95	276	176	8.9	100	430
Zone 2	11/6/12	13:17	0.26	21.21	6.98	276	176	8.4	94	431
Zone 1	11/6/12	10:17	0.22	21.20	7.00	275	176	8.7	98	431

Post 2nd Application (16 tankers Alum and 3 tankers Sodium Aluminate)

Field Measurements Collected in Lake Jessamine as Part of the Alum Treatments

Site	Date	Time	Depth (m)	Temp. (°C)	pH (s.u.)	SpCond (µmho/cm)	TDS (mg/l)	DO (mg/l)	DO% (% Sat.)	ORP (mV)	Secchi (m)
North	11/9/12	8:34	0.25	19.59	7.56	268	171	8.2	90	421	1.32
		8:35	0.50	19.59	7.49	268	171	7.8	86	420	
		8:36	1.00	19.59	7.43	269	172	7.7	84	419	
		8:37	1.50	19.58	7.40	268	172	7.6	83	418	
		8:37	2.00	19.58	7.36	268	172	7.4	81	418	
		8:38	2.50	19.58	7.34	268	172	7.3	80	417	
		8:39	3.00	19.57	7.32	268	172	7.4	81	417	
		8:40	3.50	19.54	7.31	268	172	7.4	80	416	
		8:40	4.00	19.51	7.27	269	172	7.2	79	382	
		8:43	4.09	19.51	7.20	268	171	3.4	37	281	
Middle	11/9/12	8:59	0.25	19.67	7.35	272	174	8.5	93	351	2.36
		9:00	0.50	19.66	7.31	273	175	8.0	87	352	
		9:00	1.00	19.67	7.28	273	174	7.8	85	353	
		9:01	1.50	19.67	7.26	273	175	7.8	85	355	
		9:02	2.00	19.67	7.24	273	175	7.6	83	356	
		9:03	2.50	19.65	7.23	273	175	7.5	83	358	
		9:04	3.00	19.65	7.22	274	175	7.4	81	360	
		9:05	3.50	19.63	7.21	274	175	7.3	80	362	
		9:06	4.00	19.55	7.20	275	176	7.3	80	364	
		9:07	4.50	19.57	7.20	274	175	7.3	80	366	
		9:08	5.00	19.38	7.21	274	175	7.4	81	367	
		9:09	5.50	19.30	7.20	275	176	6.9	75	359	
		9:13	5.52	19.30	7.19	274	175	3.3	36	337	
South	11/9/12	9:23	0.25	19.70	7.39	262	167	7.9	86	360	1.95
		9:24	0.50	19.69	7.40	262	168	7.7	84	361	
		9:25	1.00	19.68	7.40	263	168	7.3	80	362	
		9:26	1.50	19.67	7.41	262	168	7.3	79	365	
		9:27	2.00	19.66	7.40	263	168	7.2	79	366	
		9:28	2.50	19.63	7.41	263	168	7.1	77	369	
		9:29	3.00	19.57	7.40	263	168	6.9	75	369	
		9:30	3.50	19.53	7.39	263	168	7.1	77	371	
		9:34	3.90	19.74	7.20	313	200	1.4	15	332	

Field Measurements Collected in Lake Jessamine as Part of the Alum Treatments

Post 3rd Application (18 tankers Alum and 4 tankers Sodium Aluminate)

Site	Date	Time	Depth (m)	Temp. (^oC)	pH (s.u.)	SpCond (μmho/cm)	TDS (mg/l)	DO (mg/l)	DO% (% Sat.)	ORP (mV)	Secchi (m)
North	6/18/13	12:06	0.25	29.96	7.54	282	181	7.1	94	418	2.43
		12:06	0.50	29.96	7.50	282	181	7.1	94	419	
		12:07	1.00	29.86	7.48	282	181	7.1	94	422	
		12:08	1.50	29.79	7.46	282	181	7.2	95	424	
		12:08	2.00	29.58	7.42	282	181	6.8	89	424	
		12:09	2.50	29.46	7.39	282	181	6.6	87	426	
		12:10	3.00	29.33	7.36	282	181	6.5	85	427	
		12:11	3.50	29.26	7.35	283	181	6.6	87	427	
		12:12	4.00	29.07	7.30	283	181	5.5	71	428	
		12:13	4.50	28.58	7.16	283	181	2.2	27	424	
		12:13	4.71	28.42	7.03	290	185	1.2	15	341	
Middle	6/18/13	12:28	0.25	29.50	7.36	290	185	7.4	98	371	2.96
		12:29	0.50	29.47	7.33	291	186	7.3	95	375	
		12:29	1.00	29.40	7.31	291	186	7.2	94	378	
		12:30	1.50	29.33	7.31	291	186	7.0	92	383	
		12:31	2.00	29.28	7.30	291	186	7.0	91	385	
		12:31	2.50	29.19	7.29	292	186	6.9	90	388	
		12:32	3.00	29.13	7.28	292	187	7.0	91	391	
		12:33	3.50	29.02	7.27	292	187	6.9	89	394	
		12:34	4.00	28.92	7.25	292	187	6.6	86	397	
		12:35	4.50	28.88	7.23	292	187	6.5	84	398	
		12:36	5.00	28.40	7.20	287	182	5.9	76	401	
		12:36	5.50	27.25	7.15	285	181	3.7	47	401	
		12:37	6.00	26.93	7.05	285	181	2.3	29	399	
		12:38	6.50	26.68	7.00	285	181	1.7	21	397	
		12:39	7.00	26.22	6.91	287	182	0.2	2	346	
		12:39	7.50	25.54	6.65	363	240	0.1	1	186	
		12:40	7.58	25.39	6.65	395	259	0.1	1	157	
South	6/18/13	12:54	0.25	30.04	7.31	270	173	7.3	97	313	1.98
		12:55	0.50	30.00	7.33	270	173	7.2	95	320	
		12:56	1.00	29.95	7.35	271	173	7.0	92	326	
		12:56	1.50	29.84	7.36	271	173	7.1	93	332	
		12:57	2.00	29.29	7.37	271	173	6.9	91	337	
		12:57	2.50	29.17	7.36	271	173	6.7	88	340	
		12:58	3.00	29.01	7.35	273	174	6.5	84	343	
		12:59	3.50	28.93	7.32	275	176	6.4	83	346	
		13:01	3.81	28.78	7.16	304	195	1.1	15	286	

B-2. Lab Analyses

Characteristics of Pre and Post Treatment Samples Collected in Lake Jessamine

Pre/Post	Site	Date	pH (s.u.)	Alkalinity (mg/L)	Ammonia (µg/L)	NO_X (µg/L)	Diss. Org. N (µg/L)	Part. N (µg/L)	Total N (µg/L)	SRP (µg/L)	Diss. Org. P (µg/L)	Part. P (µg/L)	TP (µg/L)	Tur (NTU)	Color (Pt-Co)	Chl a (mg/m^3)	Diss Al (µg/L)
								Application 1									
Pre	North - Top	7/17/12	7.11	66.0	< 5	5	215	585	808	5	5	26	36	4.6	25	30.0	46
	North - Bottom	7/17/12	7.05	61.6	< 5	< 5	201	659	863	6	4	12	22	4.3	21	19.5	39
	Middle - Top	7/17/12	7.43	63.2	< 5	11	225	382	621	5	4	6	15	3.7	18	16.7	63
	Middle - Bottom	7/17/12	6.88	73.0	< 5	5	556	387	951	6	6	9	21	6.6	18	25.4	39
	South - Top	7/17/12	7.39	63.2	< 5	< 5	381	256	643	5	4	6	15	3.6	18	20.0	55
	South - Bottom	7/17/12	7.55	65.4	< 5	< 5	204	300	508	6	5	2	13	3.5	21	23.1	52
Post	North - Top	7/31/12	7.38	50.4	< 5	< 5	365	325	696	< 1	4	11	15	2.8	8	16.7	330
	North - Bottom	7/31/12	7.27	49.8	< 5	< 5	357	354	717	< 1	3	10	13	2.6	10	15.0	182
	Middle - Top	7/31/12	7.39	50.2	< 5	< 5	221	349	576	1	1	3	5	2.0	9	5.7	189
	Middle - Bottom	7/31/12	7.07	63.8	< 5	< 5	471	308	785	1	2	3	6	4.0	9	8.4	35
	South - Top	7/31/12	7.32	54.8	< 5	< 5	290	116	408	< 1	4	3	7	2.5	9	9.2	229
	South - Bottom	7/31/12	7.42	54.8	< 5	< 5	310	170	486	1	2	5	8	3.1	9	14.4	169
	Pre	**Top - Mean**	**7.31**	**64.13**	**< 5**	**8**	**274**	**408**	**691**	**5**	**4**	**13**	**22**	**4.0**	**20**	**22.2**	**55**
		Bottom - Mean	**7.16**	**66.67**	**< 5**	**< 5**	**320**	**449**	**774**	**6**	**5**	**8**	**19**	**4.8**	**20**	**22.7**	**43**
	Post	**Top - Mean**	**7.36**	**51.80**	**< 5**	**< 5**	**292**	**263**	**560**	**1**	**3**	**6**	**9**	**2.4**	**9**	**10.5**	**249**
		Bottom - Mean	**7.25**	**56.13**	**< 5**	**< 5**	**379**	**277**	**663**	**1**	**2**	**6**	**9**	**3.2**	**9**	**12.6**	**129**
								Application 2									
Pre	North - Top	10/15/12	6.97	47.4	13	< 5	372	229	617	2	1	4	7	3.1	19	15.4	103
	North - Bottom	10/15/12	6.96	46.4	18	< 5	333	239	593	3	1	6	10	3.1	13	22.0	90
	Middle - Top	10/15/12	7.16	52.8	11	< 5	320	195	529	2	2	4	8	3.1	9	19.0	153
	Middle - Bottom	10/15/12	7.25	53.2	16	< 5	332	298	649	2	2	5	9	3.2	10	20.9	109
	South - Top	10/15/12	7.24	50.4	12	< 5	341	269	625	2	2	4	8	2.9	13	17.4	147
	South - Bottom	10/15/12	7.37	53.4	10	< 5	328	206	547	2	1	3	6	4.1	12	18.7	115
Post	North - Top	11/9/12	7.16	41.0	< 5	< 5	220	181	407	1	1	2	4	2.5	7	16.9	102
	North - Bottom	11/9/12	6.99	40.0	< 5	< 5	271	165	442	1	1	2	4	2.7	6	17.8	85
	Middle - Top	11/9/12	7.19	37.8	< 5	< 5	238	145	389	1	1	1	3	2.2	5	2.5	81
	Middle - Bottom	11/9/12	7.37	36.0	< 5	< 5	222	225	453	1	1	2	4	2.2	6	7.5	79
	South - Top	11/9/12	7.41	47.2	< 5	< 5	157	161	324	1	1	2	4	3.3	7	13.9	113
	South - Bottom	11/9/12	7.24	42.8	< 5	< 5	263	209	478	1	1	2	4	2.7	7	9.0	129
	Pre	**Top - Mean**	**7.12**	**50.20**	**< 5**	**< 5**	**344**	**231**	**590**	**2**	**2**	**4**	**8**	**3.0**	**14**	**17.3**	**134**
		Bottom - Mean	**7.19**	**51.00**	**< 5**	**< 5**	**331**	**248**	**596**	**2**	**1**	**5**	**8**	**3.5**	**12**	**20.5**	**105**
	Post	**Top - Mean**	**7.25**	**42.00**	**< 5**	**< 5**	**205**	**162**	**373**	**1**	**1**	**2**	**4**	**2.7**	**6**	**11.1**	**99**
		Bottom - Mean	**7.20**	**39.60**	**< 5**	**< 5**	**252**	**200**	**458**	**1**	**1**	**2**	**4**	**2.5**	**6**	**11.4**	**98**

Characteristics of Pre and Post Treatment Samples Collected in Lake Jessamine

Application 3

Pre/Post	Site	Date	pH (s.u.)	Alkalinity (mg/L)	Ammonia (µg/L)	NO_X (µg/L)	Diss. Org. N (µg/L)	Part. N (µg/L)	Total N (µg/L)	SRP (µg/L)	Diss. Org. P (µg/L)	Part. P (µg/L)	TP (µg/L)	Tur (NTU)	Color (Pt-Co)	Chl a (mg/m^3)	Diss Al (µg/L)
Pre	North - Top	6/3/13	7.16	39.8	3	3	449	110	565	2	< 1	3	5	3.8	16	14.5	123
	North - Bottom	6/3/13	7.12	37.1	3	3	397	143	546	1	< 1	3	4	3.5	16	25.2	109
	Middle - Top	6/3/13	7.33	35.5	3	3	413	218	637	1	< 1	4	5	2.9	15	22.1	133
	Middle - Bottom	6/3/13	7.07	40.5	3	3	414	260	680	1	< 1	3	4	3.1	16	20.8	119
	South - Top	6/3/13	7.11	38.5	3	3	497	191	694	1	< 1	4	5	4.2	15	18.9	154
	South - Bottom	6/3/13	7.08	39.6	3	3	447	229	682	1	< 1	3	5	3.5	14	20.6	132
Post	North - Top	6/18/13	6.96	30.4	< 5	< 5	418	117	541	< 1	< 1	2	2	2.2	6	10.7	108
	North - Bottom	6/18/13	6.93	30.0	< 5	< 5	350	142	498	1	< 1	1	2	2.6	6	17.8	94
	Middle - Top	6/18/13	6.99	28.2	< 5	< 5	301	85	392	1	< 1	1	2	1.5	6	3.4	93
	Middle - Bottom	6/18/13	6.55	35.4	55	< 5	338	214	610	1	< 1	1	2	2.5	6	17.0	52
	South - Top	6/18/13	6.84	33.4	< 5	< 5	329	225	560	< 1	< 1	3	3	2.6	8	12.3	118
	South - Bottom	6/18/13	6.88	33.2	< 5	< 5	372	130	508	< 1	< 1	4	3	2.8	6	13.2	100
	Pre	**Top - Mean**	**7.20**	**37.94**	**< 5**	**< 5**	**453**	**173**	**632**	**1**	**< 1**	**4**	**5**	**3.6**	**15**	**18.5**	**137**
		Bottom - Mean	**7.09**	**39.08**	**< 5**	**< 5**	**419**	**211**	**636**	**1**	**< 1**	**3**	**4**	**3.4**	**15**	**22.2**	**120**
	Post	**Top - Mean**	**6.93**	**30.67**	**< 5**	**< 5**	**349**	**142**	**498**	**< 1**	**< 1**	**2**	**2**	**2.1**	**7**	**8.8**	**106**
		Bottom - Mean	**6.79**	**32.87**	**20**	**< 5**	**353**	**162**	**539**	**1**	**< 1**	**2**	**2**	**2.6**	**6**	**16.0**	**82**

APPENDIX C

VISUAL CHARACTERISTICS OF SEDIMENT CORE SAMPLES COLLECTED IN LAKE JESSAMINE

C-1. December 2010 (Pre-Treatment)
C-2. September 2013 (Post-Treatment)

C-1. December 2010 (Pre-Treatment)

VISUAL CHARACTERISTICS OF SEDIMENT CORE SAMPLES COLLECTED IN LAKE JESSAMINE ON DECEMBER 16, 2010

SITE NO.	LAYER (cm)	VISUAL APPEARANCE
1	0 - 22 22 - >28	brown fine sand brown fine sand with organics
2	0 - 7 7 - >22	dark brown consolidated organic muck brown fine sand with organics
3	0 - 1 1 - 26 26 - >29	dark brown unconsolidated organic muck dark brown consolidated organic muck brown fine sand with organics
4	0 - 1 1 - >26	dark brown unconsolidated organic muck brown fine sand with organics
5	0 - 1 1 - 30 30 - >53	dark brown unconsolidated organic muck dark brown consolidated organic muck brown fine sand with organics
6	0 - >18	brown fine sand with organics
7	0 - 6 6 - 20 20 - >28	dark brown unconsolidated organic muck dark brown consolidated organic muck brown fine sand with organics
8	0 - 12 12 - >24	dark brown consolidated organic muck brown fine sand with organics
9	0 - 3 3 - >18	dark brown consolidated organic muck brown fine sand with organics
10	0 - 8 8 - >17	dark brown unconsolidated organic muck brown fine sand with organics
11	0 - 3 3 - >17	dark brown unconsolidated organic muck brown fine sand with organics
12	0 - >28	brown fine sand with organics
13	0 - 8 8 - >16	dark brown consolidated organic muck brown fine sand with organics
14	0 - 19 19 - >23	dark brown consolidated organic muck brown fine sand with organics
15	0 - 2 2 - >27	brown fine sand with organics brown fine sand
16	0 - 30 30 - >42	dark brown consolidated organic muck brown fine sand with organics
17	0 - 3 3 - >67	dark brown unconsolidated organic muck dark brown consolidated organic muck
18	0 - >16	brown fine sand with organics
19	0 - 6 6 - >19	dark brown consolidated organic muck brown fine sand with organics
20	0 - 1 1 - 9 9 - >23	dark brown unconsolidated organic muck dark brown consolidated organic muck brown fine sand with organics
21	0 - 1 1 - >25	dark brown unconsolidated organic muck brown fine sand with organics
22	0 - 2 2 - >56	dark brown unconsolidated organic muck dark brown consolidated organic muck
23	0 - >26	brown fine sand with organics
24	0 - >14	brown fine sand with organics

VISUAL CHARACTERISTICS OF SEDIMENT CORE SAMPLES COLLECTED IN LAKE JESSAMINE ON DECEMBER 16, 2010 (Continued)

SITE NO.	LAYER (cm)	VISUAL APPEARANCE
25	0 - 1	dark brown unconsolidated organic muck
	1 - >23	brown fine sand with organics
26	0 - >17	brown fine sand with organics
27	0 - >12	brown fine sand
28	0 - >12	brown fine sand
29	0 - >12	brown fine sand
30	0 - >10	brown fine sand with organics
31	0 - 7	brown fine sand
	7 - >14	brown fine sand with organics
32	0 - 8	dark brown unconsolidated organic muck
	8 - >23	brown fine sand with organics
33	0 - 2	dark brown unconsolidated organic muck
	2 - 10	dark brown consolidated organic muck
	10 - >24	brown fine sand with organics
34	0 - 2	dark brown unconsolidated organic muck
	2 - 26	dark brown consolidated organic muck
	26 - >33	brown fine sand with organics
35	0 - 9	dark brown unconsolidated organic muck
	9 - >16	brown fine sand with organics
36	0 - 10	dark brown unconsolidated organic muck
	10 - 30	dark brown consolidated organic muck
	30 - >47	brown fine sand with organics
37	0 - 5	dark brown unconsolidated organic muck
	5 - >21	brown fine sand with organics
38	0 - 10	dark brown unconsolidated organic muck
	10 - >21	brown fine sand with organics
39	0 - 4	dark brown unconsolidated organic muck
	4 - 30	dark brown consolidated organic muck
	30 - >44	brown fine sand with organics
40	0 - 2	dark brown unconsolidated organic muck
	2 - 15	dark brown consolidated organic muck
	15 - >32	brown fine sand with organics
41	0 - 1	dark brown unconsolidated organic muck
	1 - >60	dark brown consolidated organic muck
42	0 - 1	dark brown unconsolidated organic muck
	1 - 20	dark brown consolidated organic muck
	20 - >37	brown fine sand with organics

C-2. September 2013 (Post-Treatment)

VISUAL CHARACTERISTICS OF SEDIMENT CORE SAMPLES COLLECTED IN LAKE JESSAMINE ON SEPTEMBER 27, 2013

SITE NO.	LAYER (cm)	VISUAL APPEARANCE
1	0 - 23	brown fine sand with organics
2	0 - 1 1 - >24	dark brown unconsolidated organic muck brown fine sand with organics
3	0 - 0.5 0.5 - 24 24 - >32	dark brown unconsolidated organic muck dark brown consolidated organic muck brown fine sand with organics
4	0 - 0.5 0.5 - >28	dark brown unconsolidated organic muck brown fine sand with organics
5	0 - 2 2 - 34 34 - >49	dark brown unconsolidated organic muck dark brown consolidated organic muck brown fine sand with organics
6	0 - >21	brown fine sand with organics
7	0 - 2 2 - 25 25 - >27	dark brown unconsolidated organic muck brown fine sand with organics brown fine sand
8	0 - 10 10 - >16	dark brown consolidated organic muck brown fine sand with organics
9	0 - 1 1 - >17	dark brown consolidated organic muck brown fine sand with organics
10	0 - 5 5 - >16	dark brown unconsolidated organic muck brown fine sand with organics
11	0 - 1 1 - >26	dark brown unconsolidated organic muck brown fine sand with organics
12	0 - 2 2 - >24 24 - >51	dark brown unconsolidated organic muck dark brown consolidated organic muck brown fine sand with organics
13	0 - 3 3 - >28	dark brown consolidated organic muck brown fine sand with organics
14	0 - 11 11 - >26	dark brown consolidated organic muck brown fine sand with organics
15	0 - >27	brown fine sand with organics
16	0 - 3 3 - 26 26 - >36	dark brown unconsolidated organic muck dark brown consolidated organic muck brown fine sand with organics
17	0 - 2 21 - >26	dark brown unconsolidated organic muck dark brown consolidated organic muck
18	0 - >17	brown fine sand with organics
19	0 - 3 3 - >18	dark brown consolidated organic muck brown fine sand with organics
20	0 - >12	white sand
21	0 - 3 3 - 46 46 - >54	dark brown unconsolidated organic muck dark brown consolidated organic muck brown fine sand with organics
22	0 - 3 3 - >52	dark brown unconsolidated organic muck dark brown consolidated organic muck

VISUAL CHARACTERISTICS OF SEDIMENT CORE SAMPLES COLLECTED IN LAKE JESSAMINE ON SEPTEMBER 27, 2013 (Continued)

SITE NO.	LAYER (cm)	VISUAL APPEARANCE
23	0 - >24	brown fine sand with organics
24	0 - 3	dark brown unconsolidated organic muck
	3 - >19	brown fine sand with organics
25	0 - >18	brown fine sand with organics
26	0 - >22	brown fine sand with organics
27	0 - >10	brown fine sand with organics
28	0 - 4	brown fine sand with organics
	4 - >20	brown fine sand
29	0 - >11	brown fine sand with organics
30	0 - >12	brown fine sand with organics
31	0 - >17	brown fine sand with organics
32	0 - 2	dark brown unconsolidated organic muck
	2 - >21	brown fine sand with organics
33	0 - 1	dark brown unconsolidated organic muck
	1 - 8	dark brown consolidated organic muck
	8 - >19	brown fine sand with organics
34	0 - 3	dark brown unconsolidated organic muck
	3 - 30	dark brown consolidated organic muck
	30 - >35	brown fine sand with organics
35	0 - >14	brown fine sand with organics
36	0 - 3	dark brown unconsolidated organic muck
	3 - 26	dark brown consolidated organic muck
	26 - 52	brown fine sand with organics
	52 - 64	clay
37	0 - >12	brown fine sand with organics
38	0 - >0.5	dark brown unconsolidated organic muck
	0.5 - >13	brown fine sand with organics
39	0 - 1	dark brown unconsolidated organic muck
	1 - 11	dark brown consolidated organic muck
	11 - >32	brown fine sand with organics
40	0 - 0.5	dark brown unconsolidated organic muck
	0.5 - >15	brown fine sand with organics
41	0 - 2	dark brown unconsolidated organic muck
	2 - >50	dark brown consolidated organic muck
42	0 - 0.5	dark brown unconsolidated organic muck
	0.5 - >8	dark brown consolidated organic muck