SILVER LAKE SEDIMENT INACTIVATION ANALYSIS AND EVALUATION

EVALUATION PHASE RESULTS

Final Report -- September 2013

Prepared For:

Pinellas County
400 South Fort Harrison Avenue
Clearwater, FL 33756
Pinellas County P.O. No. 227551

Prepared By:

Environmental Research and Design, Inc.
3419 Trentwood Blvd., Suite 102
Belle Isle (Orlando), FL 32812-4864
Phone: 407-855-9465

TABLE OF CONTENTS

Section **Page**

LIST OF TABLES **LT-1**
LIST OF FIGURES **LF-1**

1. INTRODUCTION **1-1**

1.1 Background 1-1

2. BATHYMETRIC AND SEDIMENT CHARACTERISTICS OF SILVER LAKE **2-1**

2.1 Lake Bathymetry 2-1
2.2 Sediment Collection / Characterization 2-6
  2.2.1 Sampling Techniques 2-6
  2.2.2 Sediment Characterization and Speciation Techniques 2-8
2.3 Sediment Characteristics 2-10
  2.3.1 Visual Characteristics 2-10
  2.3.2 General Sediment Characteristics 2-10
  2.3.3 Sediment Phosphorus Speciation 2-14

3. INSTALLATION AND MONITORING OF LIMNO-CORRALS **3-1**

3.1 Installation Details 3-1
3.2 Calculation of Sediment Inactivation Doses 3-9
3.3 Incubation Experiment Start-Up 3-15
3.4 Monitoring Protocol 3-20

4. RESULTS **4-1**

4.1 Field Parameters 4-1
  4.1.1 Temperature 4-1
  4.1.2 pH 4-3
  4.1.3 Conductivity 4-3
  4.1.4 Dissolved Oxygen 4-6
  4.1.5 Oxidation-Reduction Potential (ORP) 4-6
  4.1.6 Secchi Disk Depth 4-9

TABLE OF CONTENTS -- CONTINUED

Section **Page**

4.2 Chemical Characteristics of Monitored Limno-Corrals 4-11
    4.2.1 General Parameters (pH, Alkalinity, Turbidity, and Color) 4-11
        4.2.1.1 pH 4-11
        4.2.1.2 Alkalinity 4-13
        4.2.1.3 Turbidity 4-13
        4.2.1.4 Color 4-14
        4.2.1.5 Statistical Comparison 4-15
    4.2.2 Nitrogen Species 4-15
        4.2.2.1 Ammonia 4-15
        4.2.2.2 NO_x 4-18
        4.2.2.3 Particulate Nitrogen 4-18
        4.2.2.4 Total Nitrogen 4-19
        4.2.2.5 Statistical Comparison 4-19
    4.2.3 Phosphorus Species 4-19
        4.2.3.1 SRP 4-19
        4.2.3.2 Dissolved Organic Phosphorus 4-22
        4.2.3.3 Particulate Phosphorus 4-22
        4.2.3.4 Total Phosphorus 4-22
        4.2.3.5 Statistical Comparison 4-23
    4.2.4 Chlorophyll-a 4-23
4.3 Statistical Comparisons 4-26
4.4 Evaluation of Post-Treatment Sediment Phosphorus Release 4-30
    4.4.1 Field and Laboratory Procedures 4-30
    4.4.2 Results of Laboratory Testing 4-32
    4.4.3 Mass Release Rates 4-35
4.5 Impacts on Nitrogen Loadings 4-38
4.6 Summary 4-39

5. SEDIMENT INACTIVATION PLAN 5-1

5.1 Alum Sediment Inactivation 5-1
    5.1.1 General Considerations 5-1
    5.1.2 Floc Settling and Stability 5-2
    5.1.3 Chemical Requirements 5-3
    5.1.4 Longevity of Treatment 5-6
5.2 Sediment Removal 5-6
    5.2.1 Dredging Methods 5-7
    5.2.2 Containment Area Requirements 5-8
    5.2.3 Dredging Costs 5-9
5.3 Recommendations 5-9

6. CITED REFERENCES 6-1

TABLE OF CONTENTS -- CONTINUED

Appendices

A. Construction Drawings for Detention Pond 1 (Silver Lake)

B. Product Information Sheets

- B.1 Phoslock
- B.2 Alum and Sodium Aluminate

C. Field Data Collected in the Isolation Chambers from October 12, 2012-January 11, 2013

- C.1 Vertical Field Profiles
- C.2 Photosynthetically Active Radiation (PAR)

D. Laboratory Analyses of Isolation Chamber Samples Collected from October 12, 2012-January 13, 2013

- D.1 Laboratory Results of Limno-Corral Studies
- D.2 Calculated Concentrations of Un-ionized Ammonia in the Silver Lake Limno-Corral Experiments

E. Results of Sediment Phosphorus Release Experiments Conducted on Silver Lake Core Samples

- E.1 Laboratory Analyses
- E.2 Regression Relationships of Sediment Phosphorus Release

LIST OF TABLES

Table No. / Description		Page
2-1	Stage-Area-Volume Relationships for Silver Lake	2-3
2-2	Area-Volume Relationships for Organic Muck in Silver Lake	2-6
2-3	Analytical Methods for Sediment Analyses	2-8
2-4	General Characteristics of Sediment Core Samples Collected in Silver Lake on March 28, 2012	2-12
2-5	Summary of Phosphorus Speciation in Sediment Core Samples Collected in Silver Lake on March 28, 2012	2-20
3-1	Mean Water Depths in the Silver Lake Limno-Corral Structures	3-9
3-2	Electronegativities of Common Chemical Inactivants	3-11
3-3	Alum Dosing Calculations for Limno-Corral Studies	3-13
3-4	Phoslock Dosing Calculations for Limno-Corral Studies	3-14
3-5	Comparison of Costs for Inactivation Chemicals Used in the Limno-Corral Experiments	3-15
3-6	Analytical Methods and Detection Limits for Field Measurements of Surface Water	3-20
3-7	Analytical Methods and Detection Limits for Laboratory Analyses	3-22
4-1	Summary of Mean Field Parameters Measured in the Silver Lake Isolation Chambers from October 12, 2012-January 11, 2013	4-11
4-2	Turbidity Measurements Collected in the Isolation Chambers 30 Minutes Following Chemical Additions	4-13
4-3	Mean Characteristics of Limno-Corral Chambers in Silver Lake from October 2012-January 2013	4-26
4-4	Percent Change in Mean Characteristics in the Limno-Corral Chambers in Silver Lake from October 2012-January 2013	4-28

LIST OF TABLES -- CONTINUED

Table No. / Description **Page**

4-5 ANOVA Comparison of Water Quality Characteristics in the Silver Lake Limno-Corrals 4-29

4-6 Measured Sediment Release Rates for SRP, Total Phosphorus, and Total Nitrogen in the Silver Lake Core Samples Under Anoxic Conditions 4-35

4-7 Summary of Mean Sediment Release Rates for SRP, Total Phosphorus, and Total Nitrogen in the Silver Lake Core Samples Under Anoxic Conditions 4-37

4-8 Relative Inhibition of Sediment Release by Alum and Phoslock Compared with the Control Core Samples 4-38

5-1 Summary of Sediment Available Phosphorus and Inactivation Requirements for Silver Lake 5-4

5-2 Estimated Application Costs for Sediment Inactivation in Silver Lake 5-6

5-3 Summary of Dredging Design Assumptions and Containment Area Requirements for Silver Lake 5-8

5-4 Estimated Costs for Hydraulic Dredging of Silver Lake 5-9

LIST OF FIGURES

Figure No. / Description		Page
1-1	Location Map for the Joe's Creek Watershed	1-2
1-2	Delineation of the Joe's Creek Watershed	1-3
1-3	Typical Characteristics of Silver Lake	1-4
2-1	Bathymetric Probing Locations in Silver Lake	2-2
2-2	Water Depth Contours in Silver Lake on March 28, 2012	2-4
2-3	Depth Contours of Unconsolidated Organic Sediments in Silver Lake	2-5
2-4	Locations for Collection of Sediment Core Samples in Silver Lake on March 28, 2012	2-7
2-5	Schematic of Chang and Jackson Speciation Procedure for Evaluating Soil Phosphorus Bonding	2-9
2-6	Photographs of Typical Sediment Characteristics in Silver Lake	2-11
2-7	Isopleths of Organic Content in the Top 10 cm of Sediments in Silver Lake	2-13
2-8	Isopleths of Total Nitrogen Concentrations in the Top 10 cm of Sediments in Silver Lake	2-15
2-9	Isopleths of Total Phosphorus Concentrations in the Top 10 cm of Sediments in Silver Lake	2-16
2-10	Isopleths of Saloid-Phosphorus Concentrations in the Top 10 cm of Sediments in Silver Lake	2-17
2-11	Isopleths of Iron-Bound Phosphorus Concentrations in the Top 10 cm of Sediments in Silver Lake	2-18
2-12	Isopleths of Total Available Phosphorus Concentrations in the Top 10 cm of Sediments in Silver Lake	2-19
2-13	Isopleths of Aluminum-Bound Phosphorus Concentrations in the Top 10 cm of Sediments in Silver Lake	2-21

LIST OF FIGURES -- CONTINUED

Figure No. / Description **Page**

3-1 Locations for the Six Limno-Corrals in Silver Lake 3-2

3-2 Typical Isolation Chamber Installation 3-3

3-3 Assembled Isolation Chambers Prior to Installation in Silver Lake 3-3

3-4 Monofilament Lines Used for Bird Exclusion 3-4

3-5 Initial Set of Installed Limno-Corrals Prior to Height Adjustment and Bag Attachment 3-5

3-6 Completed Limno-Corrals with Floating Isolation Bags 3-6

3-7 Digital Water Level Recorder and Debris Mark Following Significant Rain Event 3-6

3-8 Evidence of Overtopping of the Limno-Corral Structures Following a Significant Rain Event 3-7

3-9 Completed Limno-Corrals 3-8

3-10 Locations and Chamber Designations for the Final Set of Limno-Corral Structures 3-8

3-11 Significant Reactions at the Water-Sediment Interface 3-10

3-12 Phoslock Product Label 3-16

3-13 Photographs of Alum Addition to the Chambers 3-16

3-14 Photographs of Phoslock Addition to the Chambers 3-17

3-15 Comparison of Isolation Chambers Following Chemical Additions 3-18

3-16 Photographs of Alum and Phoslock Chambers for Experiment #2 After 24 Hours 3-18

3-17 Photographs of Alum and Phoslock Chambers for Experiment #3 After 24 Hours 3-19

4-1 Summary of Vertical Temperature Profiles Collected in the Isolation Chamber Experiments from October 12, 2012-January 11, 2013 4-2

4-2 Summary of Vertical pH Profiles Collected in the Isolation Chamber Experiments from October 12, 2012-January 11, 2013 4-4

LIST OF FIGURES -- CONTINUED

Figure No. / Description		Page
4-3	Summary of Vertical Conductivity Profiles Collected in the Isolation Chamber Experiments from October 12, 2012-January 11, 2013	4-5
4-4	Summary of Vertical Dissolved Oxygen Profiles Collected in the Isolation Chamber Experiments from October 12, 2012-January 11, 2013	4-7
4-5	Summary of Oxidation-Reduction Potential (ORP) Profiles Collected in the Isolation Chamber Experiments from October 12, 2012-January 11, 2013	4-8
4-6	Summary of Measured Secchi Disk Depths in the Isolation Chambers and Open Lake from October 12, 2012-January 11, 2013	4-9
4-7	Temporal Variability in Measured Concentrations of pH, Alkalinity, Turbidity, and Color in the Isolation Chambers from October 12, 2012-January 11, 2013	4-12
4-8	Statistical Comparison of Measured Concentrations of pH, Alkalinity, Turbidity, and Color in the Silver Lake Isolation Chambers	4-16
4-9	Temporal Variability in Measured Concentrations of Nitrogen Species in the Isolation Chambers from October 12, 2012-January 11, 2013	4-17
4-10	Statistical Comparison of Measured Concentrations of Nitrogen Species in the Silver Lake Isolation Chambers	4-20
4-11	Temporal Variability in Measured Concentrations of Phosphorus Species in the Isolation Chambers from October 12, 2012-January 11, 2013	4-21
4-12	Statistical Comparison of Measured Concentrations of Phosphorus Species in the Silver Lake Isolation Chambers	4-24
4-13	Temporal Variability in Measured Concentrations of Chlorophyll-a in the Isolation Chambers from October 12, 2012-January 11, 2013	4-25
4-14	Statistical Comparison of Measured Concentrations of Chlorophyll-a in the Silver Lake Isolation Chambers	4-25
4-15	Schematic of Sediment Incubation Apparatus	4-31
4-16	Changes in Concentrations of NH_3 and NO_x in Silver Lake Sediment Core Samples Incubated Under Anoxic Conditions	4-33

LIST OF FIGURES -- CONTINUED

Figure No. / Description **Page**

4-17 Changes in Concentrations of Total Nitrogen in Silver Lake Sediment Core Samples Incubated Under Anoxic Conditions 4-34

4-18 Changes in Concentrations of SRP and Total Phosphorus in Silver Lake Sediment Core Samples Incubated Under Anoxic Conditions 4-36

5-1 Settling Processes for Alum Floc in a Shallow Lake 5-3

SECTION 1

INTRODUCTION

1.1 Background

This document provides a summary of field and laboratory efforts conducted by Environmental Research & Design, Inc. (ERD) for the Pinellas County Department of Environmental Management (County) as part of the Silver Lake Sediment Inactivation Analysis and Evaluation project under P.O. No. 404489. A Project Work Plan was previously prepared by ERD and approved by the County which provides details of the field and laboratory work efforts to be performed to evaluate and select a sediment inactivant for use in Silver Lake. The current document provides a discussion and summary of the field and laboratory testing outlined in the Project Work Plan document.

Silver Lake is located in the headwaters of Joe's Creek in south-central Pinellas County. The Joe's Creek watershed is a 9256-acre drainage basin which includes portions of the cities of Pinellas Park, St. Petersburg, and Kenneth City. A location map for the Joe's Creek watershed is given on Figure 1-1. The dominant land use categories in the Joe's Creek watershed include residential, commercial, industrial, and recreational open space. The main channel of Joes Creek is divided into a tidal segment (WBID 1668E) and a freshwater segment (WBID 1668A), with Silver Lake located in the headwaters of the freshwater segment. A delineation of the Joe's Creek watershed, indicating the location of Silver Lake, is given on Figure 1-2.

Although referred to as a lake, Silver Lake is actually an 8.44-acre expanded area of open water along the path of Joe's Creek. Silver Lake was constructed during the mid-1980s as a flood control project. The area was originally identified as Joe's Creek Detention Area No. 1, but later came to be referred to as Silver Lake. Available construction drawings for Silver Lake are included in Appendix A.

Typical characteristics of Silver Lake are illustrated on Figure 1-3. Shoreline areas of Silver Lake are densely vegetated with a variety of emergent macrophytes. Silver Lake collects a substantial quantity of floating litter and organic matter during storm events which occur within the basin. Water level elevation in Silver Lake fluctuates rapidly during significant storm events, with rapid 3-4 ft increases in water level elevations during large storm events.

A nutrient source evaluation study for the Joe's Creek watershed was completed by ERD for Pinellas County during 2010 which concluded that the sediments in Silver Lake may be a significant source of phosphorus to Joe's Creek, and inactivation of sediment phosphorus using aluminum was recommended. The evaluation also indicated a substantial decrease in measured concentrations of NO_x between the inlet and outlet of Silver Lake, suggesting that significant nitrogen removal occurs within the lake.

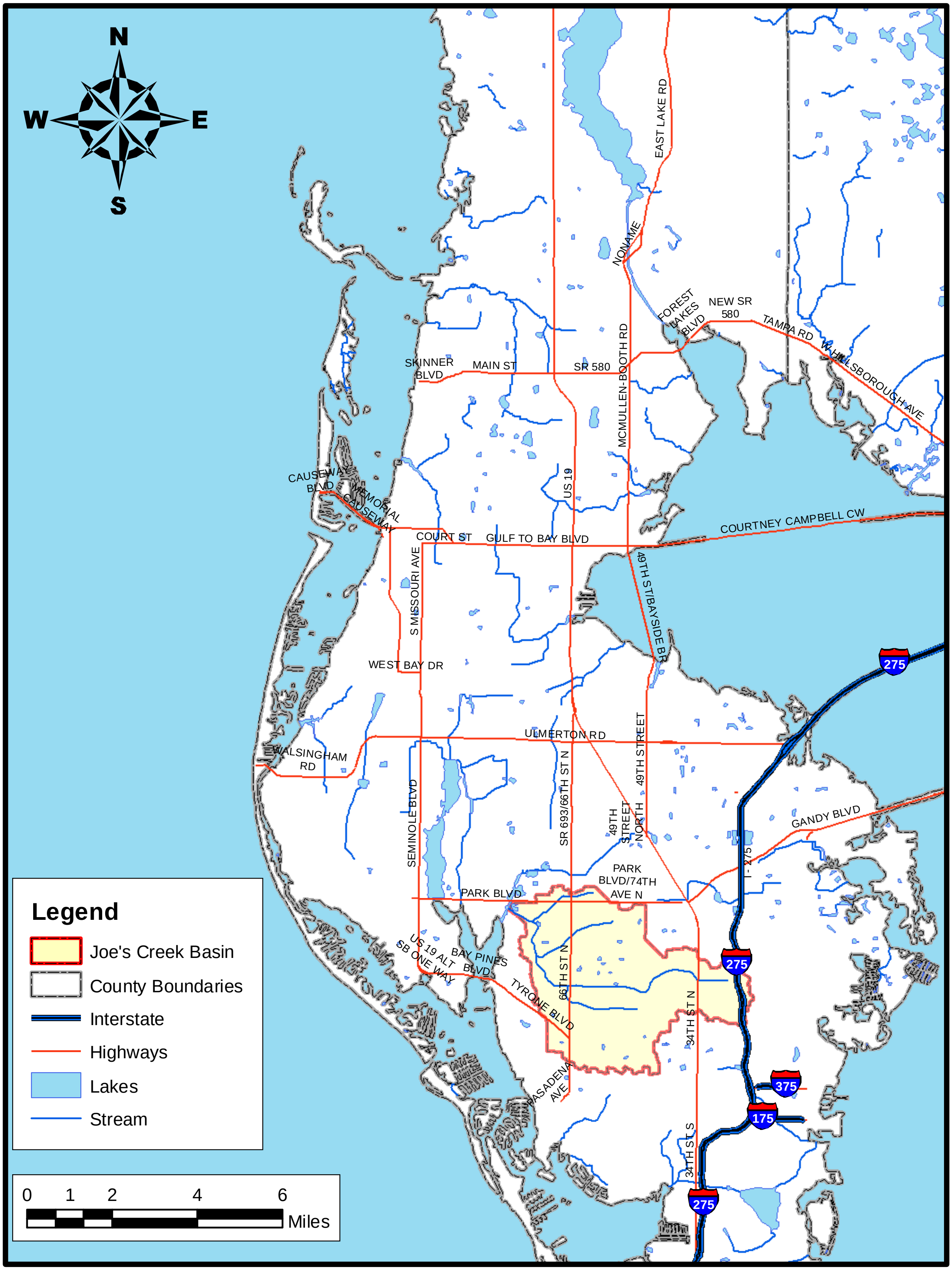


Figure 1-1. Location Map for the Joe’s Creek Watershed.

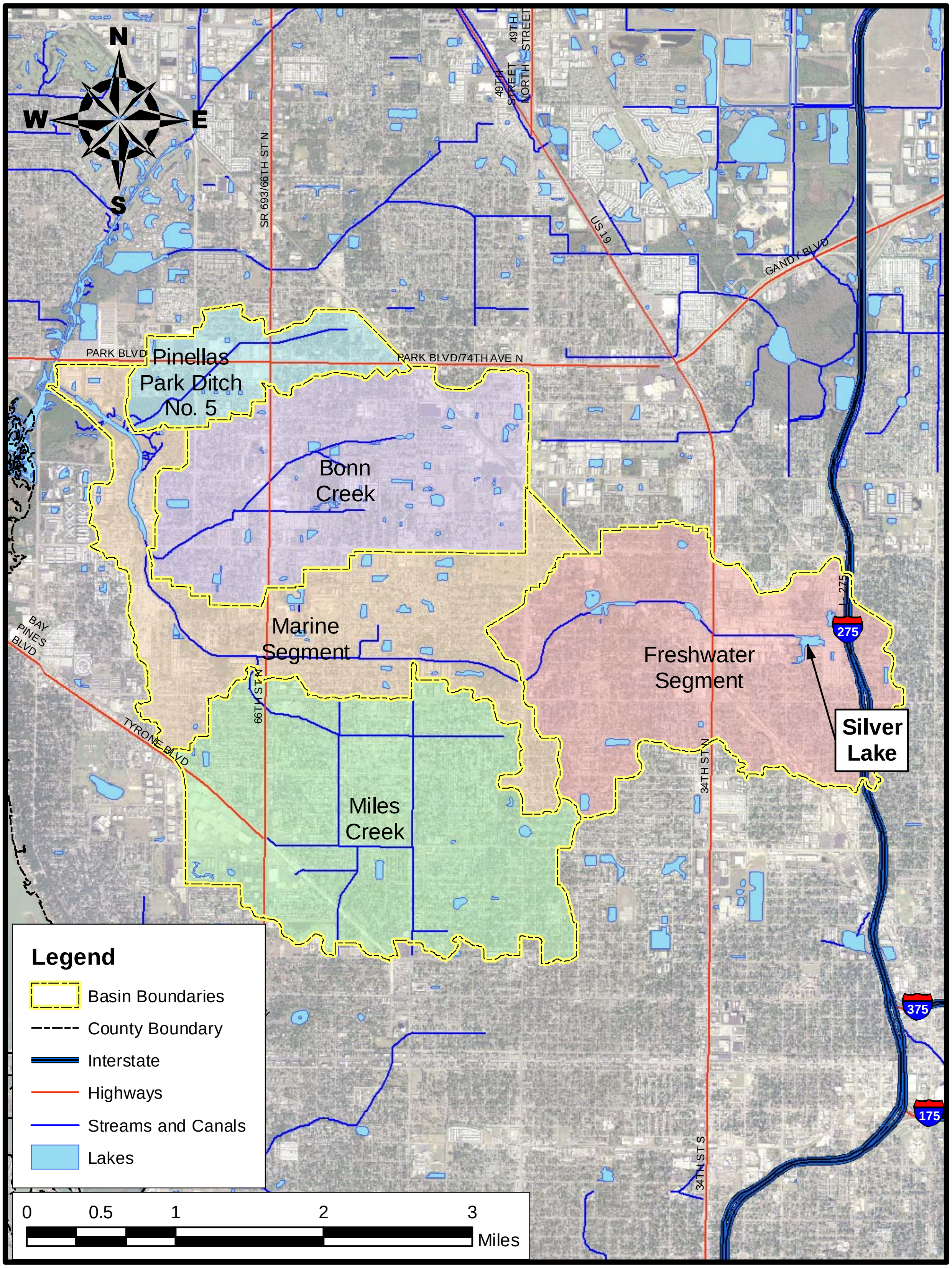


Figure 1-2. Delineation of the Joe’s Creek Watershed.

Shoreline vegetation on west end of pond

Floating litter and organic matter

Main portion of the pond

Shoreline vegetation on south side of pond

Figure 1-3. Typical Characteristics of Silver Lake.

The scope of work for this project is divided into three separate phases. Phase I, referred to as the Evaluation Phase, consists of field monitoring, and laboratory analyses conducted in Silver Lake to identify the significance of internal recycling and potential water quality impacts from a proposed sediment inactivation project. Phase I includes collection of sediment core samples, development of bathymetric and muck depth maps, installation and monitoring of limno-corrals, preparation of draft and final reports, and a review meeting with the County. This document represents the Final Report for the Phase I-Evaluation Phase work efforts.

Phase II, referred to as the Implementation Phase, consists of work efforts necessary to conduct and complete a proposed sediment inactivation project for Silver Lake. This phase includes initial laboratory jar testing, pre- and post-treatment water quality monitoring, as well as planning, mobilization, set-up, and application of the chemical coagulant.

Phase III, referred to as the Post-Treatment Monitoring Phase, consists of a 6-month surface water quality monitoring program to document changes in water quality characteristics resulting from the sediment inactivation project. At the end of the 6-month monitoring program, sediment core samples will be collected in Silver Lake at the locations used during the Evaluation Phase and evaluated for general characteristics and phosphorus speciation. Changes in phosphorus speciation between the pre- and post-treatment samples will be used, in conjunction with the pre- and post-water quality monitoring results, to document the overall success of the project.

SECTION 2

BATHYMETRIC AND SEDIMENT CHARACTERISTICS OF SILVER LAKE

Phase I field monitoring efforts include collection and analysis of sediment core samples, development of bathymetric and muck depth maps, and installation and monitoring of limno-corrals. Work efforts involved for collection and analysis of sediment core samples and development of bathymetric and muck depth maps were conducted prior to development of the Project Work Plan since bathymetric and sediment characteristics within Silver Lake impact the selected locations for installation of the limno-corrals. A discussion of lake bathymetry and sediment characteristics is repeated in the following sections since sediment characteristics are important in evaluating the results of the limno-corral testing and in determining the quantity of chemical requirements for sediment inactivation. The results of the limno-corral studies are provided in a subsequent section.

2.1 Lake Bathymetry

A bathymetric survey of Silver Lake was conducted by ERD on March 28, 2012 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 74 individual sites in Silver Lake. Probing locations used for the bathymetric study are indicated on Figure 2-1. Each of the data collection sites were identified in the field by longitude and latitude coordinates using a portable GPS device.

Water depth at each of the data collection sites was determined by lowering a 20-cm diameter Secchi disk attached to a graduated line until resistance from the sediment layer was encountered. The depth on the graduated line corresponding to the water surface was recorded in the field and is defined as the water depth at each site. After measurement of the water depth at each site, a 1.5-inch graduated aluminum pole was then lowered into the water column and forced into the sediments until a firm bottom material, typically sand or clay, was encountered. The depth corresponding to the water surface is defined as the depth to the firm lake bottom. The difference between the depth to the firm lake bottom and the water depth at each site is defined as the depth of unconsolidated sediments.

The generated field data was converted into bathymetric maps for both water depth and unconsolidated sediment depth in Silver Lake using AutoCAD 2007. Estimates of water volume and unconsolidated sediment volume within Silver Lake were generated using the Autodesk Land Desktop 2007 Module.

Figure 2-1. Bathymetric Probing Locations in Silver Lake.

A water depth contour map for Silver Lake, based upon the field monitoring conducted on March 28, 2012, is given on Figure 2-2. In general, water depths in Silver Lake range from approximately 1-7 ft, with the majority of central portions of the lake exhibiting water depths of 6-7 ft. Water depths range from approximately 1-3 ft in the southern extension of Silver Lake.

Stage-area-volume relationships for Silver Lake are summarized on Table 2-1 based upon the bathymetric survey performed by ERD. At the surface water elevation present on March 28, 2012, the area of Silver Lake was approximately 8.44 acres, with a volume of 26.8 ac-ft, corresponding to a mean water depth of approximately 3.2 ft.

TABLE 2-1

STAGE-AREA-VOLUME RELATIONSHIPS FOR SILVER LAKE

DEPTH (feet)	AREA (acres)	VOLUME (ac-ft)
0	8.44	26.8
1	6.87	19.1
2	5.54	12.9
3	4.04	8.12
4	2.65	4.77
5	2.01	2.44
6	1.41	0.73
7	0.05	0
Average Depth = 3.2 ft		

The construction drawings for the pond (page 2 in Appendix A) indicate that the southern, western, western-central, and northern-central portions of the pond were to be constructed as shallow littoral areas with water depths ranging from 1-2 ft. However, water depth contours illustrated on Figure 2-2 do not indicate these littoral zones, and no planted littoral zone areas currently exist within the lake. It is not known if the littoral areas were never constructed or eroded away over time.

A bathymetric contour map of the depth of unconsolidated organic sediments in Silver Lake is given in Figure 2-3. Deep pockets of organic muck, extending to depths of approximately 4-5 ft, are present in central portions of the lake as well as eastern portions of the lake near the flow path for the inflow from Joe’s Creek. Muck depths in western and southern portions of Silver Lake typically range from approximately 0-1 ft. Based on the contours on Figure 2-3, the primary flow path in Silver Lake appears to be from the inflow on the southeast side of the lake to the outflow on the northwest side.

Estimates of area-volume relationships for organic muck accumulations in Silver Lake are given on Table 2-2. Overall, Silver Lake contains approximately 9.90 ac-ft of unconsolidated organic sediments which is sufficient to cover the entire lake bottom to a depth of approximately 1.17 ft.

Figure 2-2. Water Depth Contours in Silver Lake on March 28, 2012.

Figure 2-3. Depth Contours of Unconsolidated Organic Sediments in Silver Lake.

TABLE 2-2

AREA-VOLUME RELATIONSHIPS FOR ORGANIC MUCK IN SILVER LAKE

DEPTH (feet)	AREA (acres)	VOLUME (ac-ft)
0	8.44	9.90
1	2.90	4.23
2	1.70	1.93
3	0.83	0.67
4	0.24	0.13
5	0.02	0.00
Average Depth = 1.17 ft		

According to the original construction drawings for the pond, a sediment sump area was constructed near the point of inflow for Joe’s Creek which appears to be in the general area of the deepest deposits of organic muck indicated on Figure 2-3. Most of the accumulated muck within Silver Lake has deposited in the eastern half of the lake. Two additional areas of accumulated organic muck are present along the north shoreline in the general flow path for the lake. These areas likely reflect deposition of finer particles which were transported a greater distance within the lake. The observed areas of deposition in Silver Lake follow a pattern which is commonly observed in urban lakes and stormwater ponds.

2.2 Sediment Collection / Characterization

Sediment core samples were collected in Silver Lake by ERD to evaluate the characteristics of existing sediments and potential impacts on water quality within the lake. Sediment core samples were collected at 15 separate locations within the lake on March 28, 2012 by ERD personnel. Locations of sediment sampling sites in Silver Lake are illustrated on Figure 2-4. Based on the lake surface area of 8.44 acres, sediment samples were collected at a rate of one sample for every 0.56 acres of lake area.

2.2.1 Sampling Techniques

Sediment core samples were collected at each of the 15 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 15 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.

Figure 2-4. Locations for Collection of Sediment Core Samples in Silver Lake on March 28, 2012.

2.2.2 Sediment Characterization and Speciation Techniques

Each of the 15 collected sediment core samples was analyzed for a variety of general parameters, including moisture content, organic content, sediment density, total nitrogen, and total phosphorus. Methodologies utilized for preparation and analysis of the sediment samples for these parameters are outlined in Table 2-3.

TABLE 2-3

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 modified fractionation procedure for inorganic soil phosphorus was conducted on each of the 35 collected sediment samples. The modified Chang and Jackson Procedure, as proposed by Peterson and Corey (1966), 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 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 soil phosphorus bounding is given in Figure 2-5.

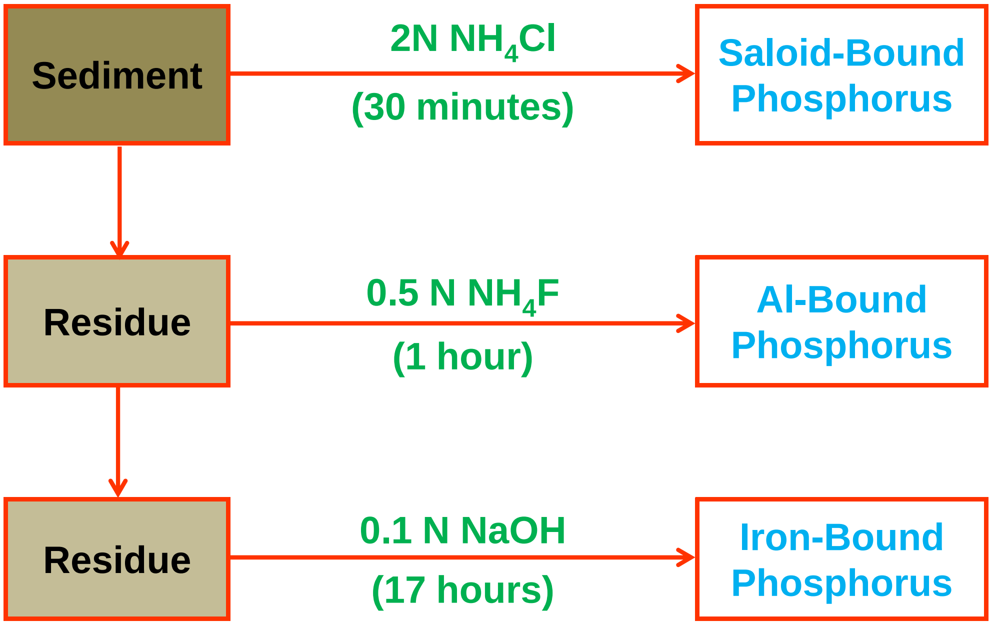


Figure 2-5. Schematic of Chang and Jackson Speciation Procedure for Evaluating Soil Phosphorus Bonding.

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.

2.3 Sediment Characteristics

2.3.1 Visual Characteristics

In general, virtually all of the sediment core samples collected in Silver Lake had a surficial layer of unconsolidated organic muck comprised primarily of fresh organic material, such as dead algal cells, and detritus which has accumulated onto the bottom of the lake and is easily disturbed by wind action or boating activities. This surficial layer of unconsolidated organic muck was observed at approximately 90% of the sediment core monitoring sites. The organic muck becomes more consolidated beneath the unconsolidated surficial layer, with a consistency similar to pudding which reflects older organic deposits which are resistant to further degradation. These more consolidated layers typically do not resuspend into the water column except during relatively vigorous wind activity on the lake. In most portions of the lake, the organic muck layer overlies tan to brown sand which appears to be the parent material of the lake.

Visual characteristics of sediment core samples were documented by photographing typical characteristics of sediment samples collected in Silver Lake during March 2012. Photographs of typical sediment characteristics in Silver Lake are given on Figure 2-6. Typical organic muck type sediments overlying gray sand are illustrated on the top of Figure 2-6, with examples of sediments consisting primarily of light brown sand with a thin organic layer illustrated on the bottom of Figure 2-6. Site 12 (which consists primarily of brown sand intermixed with organic matter) is located on the west side of the pond near the current boat launch area and is away from the primary flow path for the pond. Light brown sand with a relatively thin organic layer was observed at Site 7 which is located in western-central portions of Silver Lake. This monitoring location appears to be just outside of the areas of unconsolidated organic sediments indicated on Figure 2-3. It is worth noting that Site 7 is located where the shallow littoral shelf appears in the plans so, if the littoral shelf were constructed, it would be expected that this site would have less accumulation of organic muck compared to the deeper surrounding areas. However, since there is no evidence that the littoral shelf was ever constructed, the low observed organic layer at this site is likely just a result of being slightly outside of the primary flow path within the lake. Sediment monitoring Sites 8 and 12 also appear to be located in the area of the proposed shallow littoral shelf. However, the relatively low rate of sediment deposition observed at these sites is more likely related to the fact that these sites are not along the primary flow path within the lake. A very granular sediment material which resembles residue from erosion of roadway pavement was collected at Site 9 which (as indicated on Figure 2-4) is located near the point of inflow for Joe’s Creek into Silver Lake.

2.3.2 General Sediment Characteristics

A tabular summary of measured general characteristics of sediment core samples collected in Silver Lake on March 28, 2012 is given on Table 2-4. Measured pH values in Silver Lake sediments range from approximately neutral to slightly acidic, ranging from 5.92-6.89, with an overall geometric mean of 6.49. The measured sediment pH values in Silver Lake are typical of pH measurements commonly observed in the sediments of eutrophic urban lakes.

Organic muck overlying brown sand

Organic muck overlying brown sand

Granular sediment material

Organic muck overlying brown sand

Organic muck overlying gray sand

Organic muck overlying gray sand

Brown sand with organics

Light brown sand with thin organic layer

Figure 2-6. Photographs of Typical Sediment Characteristics in Silver Lake.

TABLE 2-4

GENERAL CHARACTERISTICS OF SEDIMENT CORE SAMPLES COLLECTED IN SILVER LAKE ON MARCH 28, 2012

SITE	pH (s.u.)	MOISTURE CONTENT (%)	DENSITY (g/cm^3)	ORGANIC CONTENT (%)	TOTAL N ($\mu g/cm^3$)	TOTAL P ($\mu g/cm^3$)
1	6.47	31.7	1.99	3.4	362	1,057
2	6.24	76.9	1.26	23.9	639	2,644
3	6.65	44.3	1.78	6.8	201	706
4	6.68	71.6	1.34	19.5	407	2,459
5	6.64	68.1	1.34	28.4	406	1,282
6	6.27	85.8	1.12	41.4	575	2,633
7	6.87	26.1	2.10	0.4	276	288
8	6.89	26.7	2.09	0.9	392	1,300
9	6.84	29.0	2.02	4.2	344	809
10	6.29	86.3	1.13	38.9	735	2,042
11	6.36	88.7	1.11	37.9	491	1,858
12	6.86	22.0	2.16	0.9	315	283
13	6.39	68.2	1.42	11.1	661	1,327
14	6.06	59.7	1.56	6.7	1,049	1,605
15	5.92	28.9	2.04	2.2	750	863
Mean:	**6.49**	**48.3**	**1.58**	**6.8**	**463**	**1164**

Measurement of sediment moisture content and organic content in Silver Lake sediments were highly variable throughout the lake. Approximately half of the collected sediment core samples were characterized by elevated values for both moisture content and organic content, suggesting areas of accumulated organic muck. The remaining sediment core samples were characterized by low to moderate levels of moisture content and organic content, suggesting that these sediment samples are comprised primarily of fine sand or a mixture of sand and organic muck. Measured sediment moisture contents in the collected samples ranged from 22.0-85.8%, with an overall geometric mean of 48.3%. Measured sediment organic contents ranged from 0.4-41.4%, with an overall geometric mean of 6.8%.

Measured sediment density values are also useful in evaluating the general characteristics of sediments within a lake. Sediments with calculated wet densities between 1.0-1.25 g/cm^3 are indicative of highly organic muck type sediments, while sediment densities of approximately 2.0 g/cm^3 or greater are indicative of sandy sediment conditions. Density values between 1.25-2.0 g/cm^3 indicate mixtures of sand and muck. Measured sediment density values in Silver Lake ranged from 1.11-2.16 g/cm^3, with an overall geometric mean of 1.58 g/cm^3.

Isopleths of organic content in the top 10 cm of sediments in Silver Lake are illustrated in Figure 2-7. Organic content is often an indicator of accumulation patterns of organic matter discharges into the lake. The most elevated levels of organic content appear to occur in central portions of Silver Lake, suggesting that this may be a primary area of deposition for inputs from Joe’s Creek.

Figure 2-7.   Isopleths of Organic Content (% dry wt.) in the Top 10 cm of Sediments in Silver Lake.

Measured sediment nitrogen concentrations in Silver Lake ranged from 201-1049 µg/cm^3, with an overall geometric mean of 463 µg/cm^3, reflecting concentrations which are low in value and approximately ¼-½ of the total nitrogen concentrations commonly observed in urban lake sediments. Isopleths of total nitrogen concentrations in the top 10 cm of sediments in Silver Lake are illustrated on Figure 2-8. Sediment nitrogen concentrations appear to be lowest along the primary flow path within Silver Lake which begins at the Joe's Creek inflow, moving through northern-central portions of the lake to the lake outfall on the northwest corner.

In contrast, total phosphorus concentrations within the sediments of Silver Lake appear to be substantially elevated and approximately 2-3 times greater than concentrations commonly observed in lake sediments. Measured sediment phosphorus concentrations in Silver Lake ranged from 288-2644 µg/cm^3, with an overall geometric mean of 1164 µg/cm^3. Isopleths of sediment phosphorus concentrations (µg/cm^3) in the top 10 cm of sediments in Silver Lake are illustrated on Figure 2-9. The most elevated sediment phosphorus concentrations appear to occur along the primary flow path for the lake. The accumulation of total phosphorus corresponds roughly with the areas of elevated organic content indicated on Figure 2-7 and suggest that phosphorus inputs into the system appear to accumulate primarily in eastern and northern portions of the lake.

2.3.3 Sediment Phosphorus Speciation

The results of sediment phosphorus speciation conducted on each of the collected core samples are given on Table 2-5. In general, saloid-bound phosphorus concentrations within the sediments appear to be relatively low in value, with measured values ranging from 0.4-4.2 µg/cm^3, and an overall geometric mean of 1.4 µg/cm^3. Isopleths of saloid phosphorus concentrations (µg/cm^3) in the top 10 cm of sediments in Silver Lake are given on Figure 2-10. The most elevated saloid-bound phosphorus concentrations appear to occur in central portions of Silver Lake along with areas within the southern extension of the lake.

Moderate to somewhat elevated concentrations of iron-bound phosphorus were observed within the lake sediments which can be potentially mobilized under anoxic conditions. Measured iron-bound phosphorus concentrations in Silver Lake sediments ranged from 7-98 µg/cm^3, with an overall geometric mean of 51 µg/cm^3. Isopleths of iron-bound phosphorus concentrations in the top 10 cm of sediments in Silver Lake are illustrated on Figure 2-11. The most elevated concentrations of iron-bound phosphorus in Silver Lake sediments are located along the primary flow path in the lake from the inlet to the lake outlet. Somewhat elevated sediment iron-bound phosphorus concentrations were also observed in the southern canal area.

The sum of the saloid-bound and iron-bound associations reflects total available phosphorus which ranged from 8.2-102 µg/cm^3, with an overall geometric mean of 53 µg/cm^3. This value is near the lower end of the range of available phosphorus concentrations commonly observed in urban lakes. Isopleths of total available phosphorus in the top 10 cm of sediments in Silver Lake are illustrated on Figure 2-12. The most elevated region of total available phosphorus within the lake appears to occur in central portions of the lake in the general area where elevated sediment phosphorus concentrations and elevated organic content was observed. An area of somewhat elevated available phosphorus concentrations occurs in the outfall channel near the water control structure for the lake.

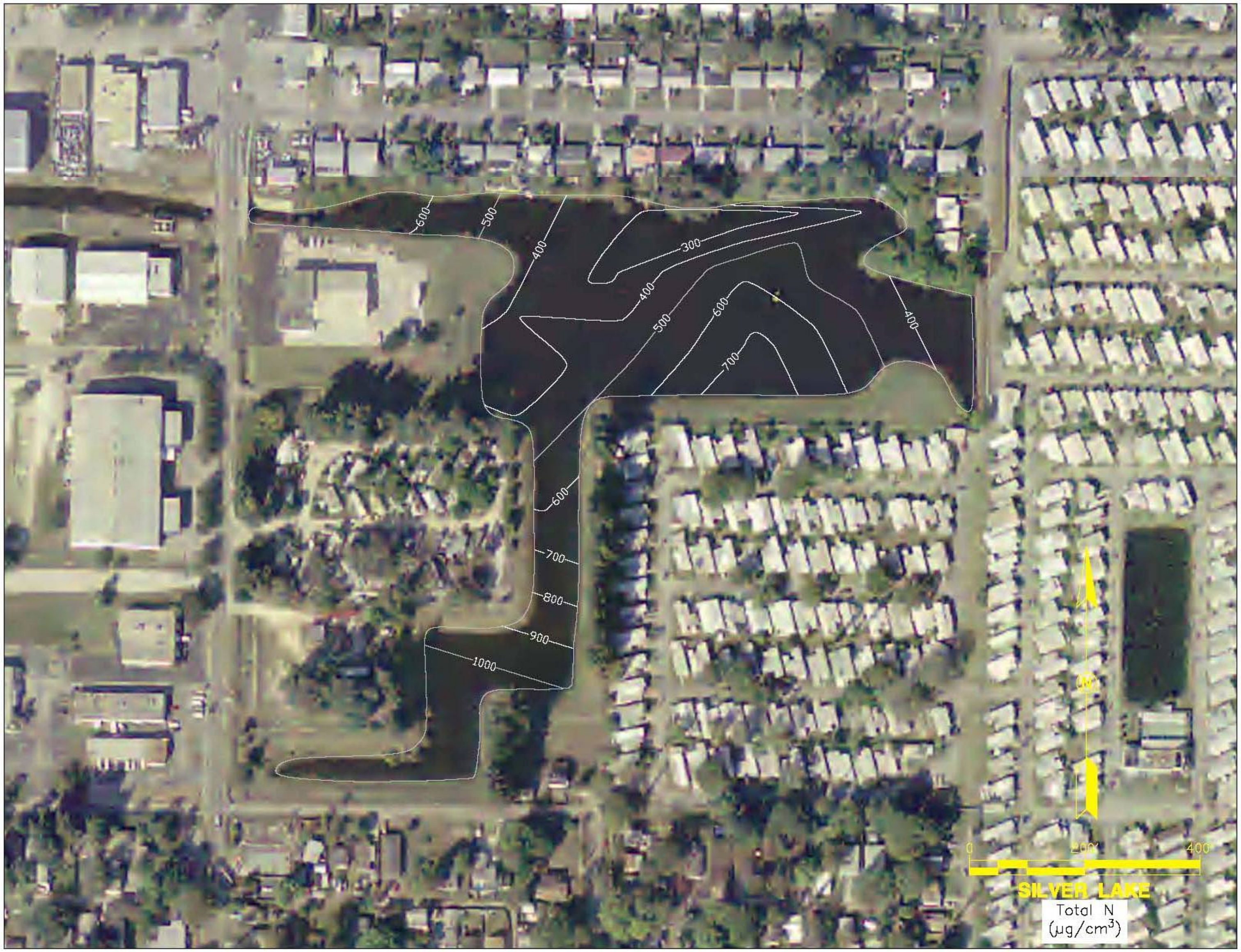


Figure 2-8. Isopleths of Total Nitrogen Concentrations (µg/cm^3) in the Top 10 cm of Sediments in Silver Lake.

Figure 2-9. Isopleths of Total Phosphorus Concentrations (µg/cm^3) in the Top 10 cm of Sediments in Silver Lake.

Figure 2-10. Isopleths of Saloid Phosphorus Concentrations (µg/cm^3) in the Top 10 cm of Sediments in Silver Lake.

Figure 2-11. Isopleths of Iron-Bound Phosphorus Concentrations ($\mu g/cm^3$) in the Top 10 cm of Sediments in Silver Lake.

Figure 2-12. Isopleths of Total Available Phosphorus Concentrations ($\mu g/cm^3$) in the Top 10 cm of Sediments in Silver Lake.

TABLE 2-5

SUMMARY OF PHOSPHORUS SPECIATION IN SEDIMENT CORE SAMPLES COLLECTED IN SILVER LAKE ON MARCH 28, 2012

SITE	SEDIMENT P SPECIATION (μg/cm^3)				
	Saloid P	Fe-Bound P	Total Available P	Percent Available (%)	Al-Bound P
1	1.2	44	45	4.3	86
2	2.4	90	92	3.5	153
3	1.9	96	98	13.9	121
4	1.0	84	85	3.5	107
5	0.4	57	58	4.5	64
6	3.3	98	102	3.9	154
7	1.0	7	8	2.8	9
8	1.3	10	11	0.8	45
9	0.6	44	45	5.6	39
10	2.0	88	90	4.4	112
11	1.5	81	82	4.4	113
12	0.8	39	40	14.1	18
13	4.2	89	93	7.0	185
14	3.0	51	54	3.4	111
15	0.6	53	54	6.3	82
MEAN	**1.4**	**51**	**53**	**4.5**	**74**

Aluminum-bound phosphorus reflects phosphorus within the sediments which is bound in an unavailable form with aluminum. Aluminum-bound phosphorus concentrations in the sediments of Silver Lake were highly variable, ranging from 9-185 μg/cm^3, with an overall geometric mean value of 74 μg/cm^3. Isopleths of aluminum-bound phosphorus concentrations in the sediments of Silver Lake are illustrated on Figure 2-13. These isopleths reflect sediment phosphorus which is unavailable for release into the overlying water column. Since the objective of sediment inactivation is to decrease sediment bonding with potentially available forms such as saloid and iron-bound phosphorus, and increase the amount of phosphorus bound with unavailable forms, the isopleths indicated on Figure 2-13 will be compared with isopleths of sediment characteristics conducted after the proposed sediment inactivation process to evaluate the overall success in converting available sediment phosphorus into unavailable forms.

Information is also provided in Table 2-5 on the percent of sediment phosphorus which is potentially available. This value is calculated as the ratio of the total available phosphorus to total phosphorus concentrations within the sediments at each site. Overall, approximately 4.5% of the total phosphorus within the sediments of Silver Lake is potentially available for release into the overlying water column.

Figure 2-13. Isopleths of Aluminum-Bound Phosphorus Concentrations (µg/cm^3) in the Top 10 cm of Sediments in Silver Lake.

SECTION 3

INSTALLATION AND MONITORING OF LIMNO-CORRALS

Six isolation chamber structures were installed in Silver Lake during October 2012 and monitored for a period of 91 days to evaluate water quality impacts from sediment inactivation using alum and Phoslock. A discussion of methods and protocols used for installation and monitoring of the limno-corral structures is given in the following sections.

3.1 Installation Details

Based on the results of the sediment characterization and speciation evaluations, discussed in Sections 2.3.2 and 2.3.3, it appears that the most elevated levels of total available phosphorus occur near western-central portions of Silver Lake. As a result, these areas likely have the largest sediment phosphorus release and the largest impact on phosphorus loadings from the sediments into the overlying water column within the lake, and provide the best locations for the proposed limno-corrals to evaluate mechanisms for reducing internal phosphorus release under worst case conditions.

Three duplicate sets of isolation chambers, also referred to in this document as limno-corrals, were installed in Silver Lake to evaluate water quality impacts from the existing sediments as well as proposed sediment inactivation techniques. An isolation chamber provides a mechanism for isolating a portion of the sediments and water column within the lake. If other factors are held constant, equilibrium water quality characteristics achieved within isolation chambers are directly regulated by water-sediment interactions. Approximate locations for the installed limno-corrals are given on Figure 3-1.

Isolation chambers are designed to totally isolate a column of water so that equilibrium water quality characteristics can be evaluated without interference from other processes within the lake. A schematic of a typical isolation chamber is given in Figure 3-2. Each isolation chamber is supported by a 6-ft diameter x 4-ft tall aluminum cylinder, with a thickness of approximately 0.25 in, which is placed into the existing muck sediments to a depth of approximately 2-3 ft. A 6-ft tall tubular aluminum frame with three support legs is attached to the aluminum cylinder which extends above the lake water level. A double-layer fiberglass-reinforced 10 mil polyethylene bag, with a diameter of approximately 2 m (6.5 ft), is then placed over the aluminum frame. The double-layer bag is secured to the aluminum cylinder using a ratchet-type tie-down strap as shown on Figure 3-2. A 4-inch lip, welded to the top of the aluminum ring, prevents the double-layer bag from sliding off the aluminum ring. A photograph of the assembled isolation chambers prior to installation in Silver Lake is given in Figure 3-3.

Figure 3-1. Locations for the Six Limno-Corrals in Silver Lake.

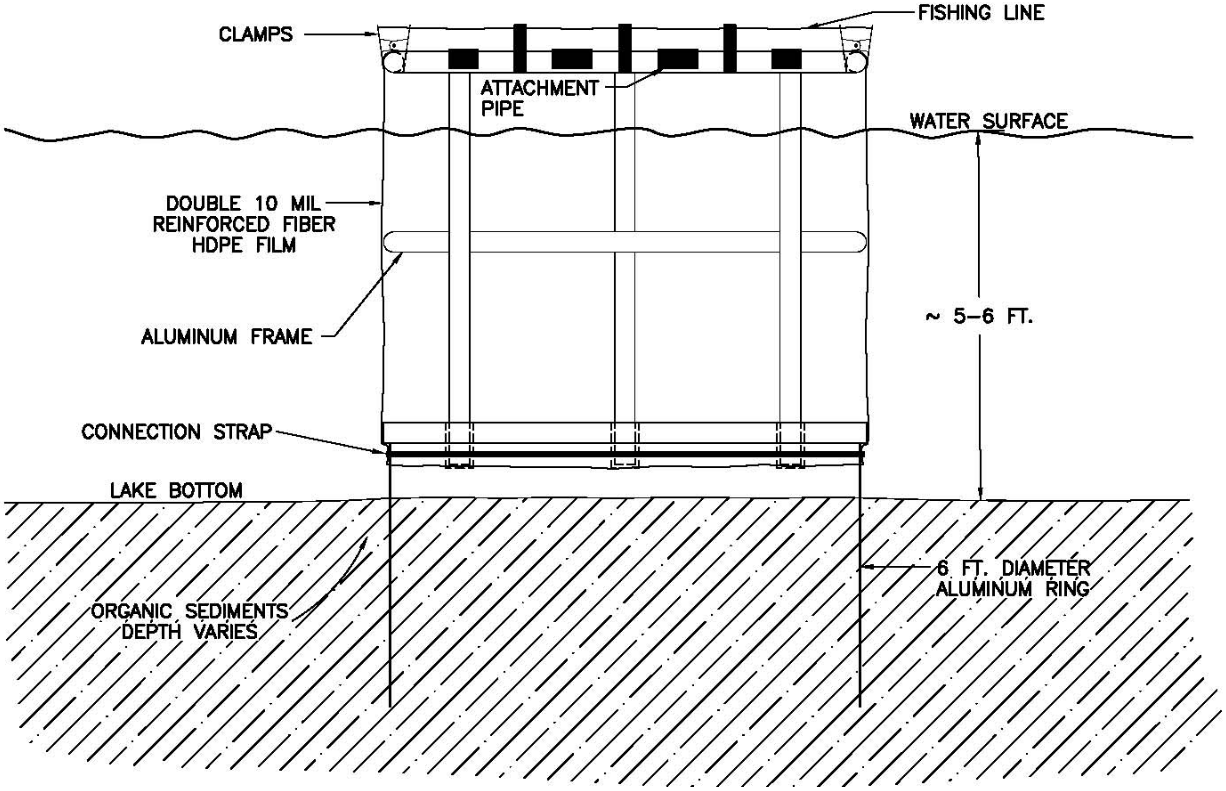


Figure 3-2. Typical Isolation Chamber Installation.

Figure 3-3. Assembled Isolation Chambers Prior to Installation in Silver Lake.

Each of the circular cylinders was inserted into the sediments approximately 2-3 ft to the firm lake bottom, with the isolation chambers spaced approximately 5 ft apart. The aluminum frames were then adjusted so that the circular top portion of the frame extended approximately 12-18 inches above the top of the water surface. Each chamber was initially installed with the polyethylene bag in a lowered position. After adjusting the tubular frame to the proper height above the water surface, the bag was raised and attached to the top of the frame. Excess bag material was folded over the top of the aluminum frame into the center of the isolation chamber. The bags were connected to the aluminum frame using short sections of 1.5-inch diameter vacuum hose which was slit along one side. Each small hose section was stretched open and placed over the bag and aluminum frame. When released, the hose section snaps closed, providing a firm attachment for the bag at the top of the aluminum frame.

Spring-loaded clamps were attached at nine equally spaced locations around the top of the circular frame. A double strand of monofilament fishing line was then stretched between each of the clamps in a circular pattern around the top of the frame. Previous isolation chamber research conducted by ERD indicated that the top of the isolation chamber frames are used by birds for roosting, and inputs of bird wastes into the isolation chamber can substantially affect the results of ongoing experiments. Monofilament line placed above the top of the aluminum frame helps prevent birds from landing on the frame and using it as a roost. A photograph of the monofilament lines used for bird exclusion is given on Figure 3-4.

Figure 3-4.

Monofilament Lines
Used for Bird Exclusion.

Three duplicate sets of isolation chambers were installed in Silver Lake in an area with a water depth ranging from approximately 6-7 ft. One of the duplicate sets of isolation chambers was treated with alum using a dose based upon the total available phosphorus concentrations illustrated on Figure 2-12. The second set of duplicate isolation chambers received Phoslock for sediment inactivation, with the dose also based upon the total available phosphorus concentrations illustrated on Figure 2-12. The final two chambers received no chemical additions and served as controls to evaluate potential water quality impacts from the sediments within the lake under existing conditions.

Limno-corrals were installed in Silver Lake by ERD on three separate occasions as part of this project. The first set of limno-corrals was installed on July 6, 2012. A photograph of the originally installed limno-corrals, prior to final height adjustment of the top aluminum ring and attachment of the bag enclosures, is given on Figure 3-5. Chemical additions to the installed limno-corrals occurred on July 7, 2012, and monitoring was initiated. However, representatives of the County requested that the installed limno-corrals be removed and reinstalled using the dose calculation recommended by the Phoslock representative. In addition, approximately one week after installation of the isolation chambers, a large storm event caused water levels in Silver Lake to rise and overtop the chambers, invalidating the experiment. Therefore, after several weeks of monitoring, the initial set of limno-corrals was removed from Silver Lake.

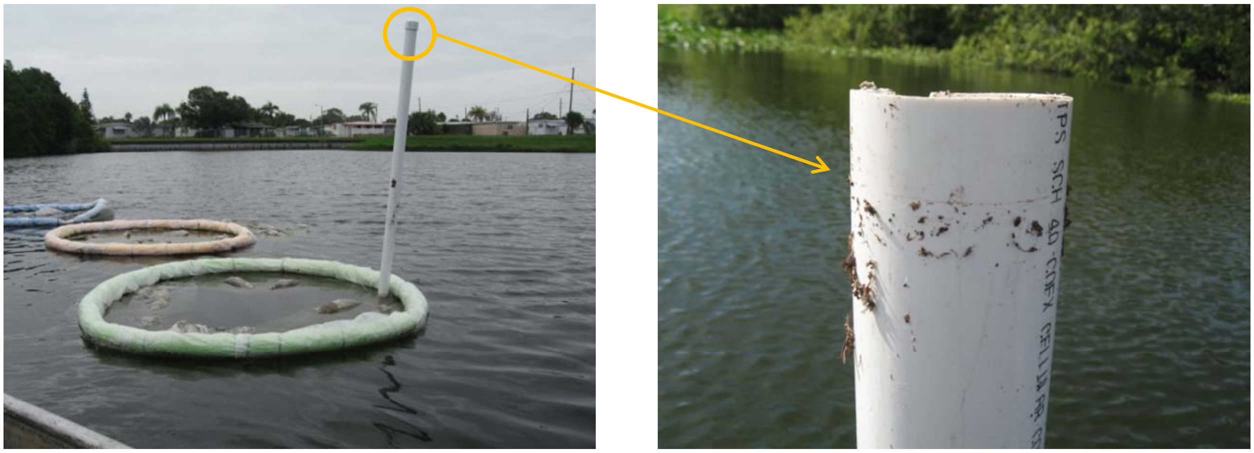
Figure 3-5.

Initial Set of
Installed Limno-Corrals
Prior to Height Adjustment
and Bag Attachment.

During the brief period of monitoring conducted by ERD on the initial set of limno-corrals, it became apparent that Silver Lake exhibited relatively large fluctuations in water surface elevations resulting from rain events that occur within the watershed. Therefore, to reduce the likelihood of lake water overtopping the limno-corral structure and compromising the experiment, the chamber design was modified so that the tops of each of the isolation bags were attached to tubular floats commonly used as pool toys. Photographs of the installed limno-corrals are given on Figure 3-6. The floats allowed the top of the isolation bags to float up and down with changes in water level elevations within Silver Lake. The limno-corrals were color-coded, with the two control chambers equipped with **green** floats, the two Phoslock chambers equipped with **orange** chambers, and the two alum addition chambers fitted with **blue** floats. The floats were designed to accommodate a 3-4 ft increase in water surface elevations within Silver Lake without overtopping into the isolation chambers. A digital water level recorder was installed inside a 2-inch PVC pipe, inserted into one of the control chambers, to provide continuous measurements of water surface elevations in Silver Lake. The second set of limno-corrals was installed in Silver Lake on August 3, 2012, with the chambers moved slightly south to avoid areas where the initial chambers were located.

After installation of the limno-corrals and addition of the chemical doses, field monitoring was initiated and conducted for a period of approximately 30 days. At that time, a significant rain event occurred within the Joe’s Creek drainage basin which caused a rapid rise in water elevation within Silver Lake. A photograph of the digital water level recorder installed in the control chamber is given on Figure 3-7. Based upon the debris mark on the riser pipe for the water level recorder, it appears that water level elevations within Silver Lake increased by approximately 4-5 ft during the storm event. The actual increase in water level is not known since the digital water level recorder was ruined when the data storage unit became submerged.

Figure 3-6. Completed Limno-Corrals with Floating Isolation Bags.



Digital water level recorder

Pond water level following storm event

Figure 3-7. Digital Water Level Recorder and Debris Mark Following Significant Rain Event.

Since the floats were designed to accommodate a water level change of approximately 3-4 ft, evidence of overtopping of the top floats was apparent for all of the isolation chambers. Photographs providing evidence of overtopping of the limno-corral structures are given on Figure 3-8. Floating debris and litter were observed in each of the limno-corrals as well as on top of each of the individual floats. Since it was apparent that overtopping of the limno-corral structures had occurred, the monitoring program was halted and the limno-corral structures were removed from the lake.

Floating debris from overtopping

Floating trash

Debris around top of float

Evidence of overtopping

Figure 3-8. Evidence of Overtopping of the Limno-Corral Structures Following a Significant Rain Event.

The third set of limno-corral structures was installed in Silver Lake on October 12, 2012. For this installation, the limno bag design was modified from the floating design illustrated on Figure 3-6 to a rigid design created by extending the tubular frame from the bottom solid cylinder structure to a height of approximately 4 ft above the lake surface elevation. This height was determined to be the maximum distance above the normal water level which would allow for access into the limno bags for the routine monitoring program. A photograph of the completed limno-corrals is given on Figure 3-9. This design was used for the remainder of the field monitoring program.

Locations and chamber designations for the final set of limno-corral structures is given on Figure 3-10. The base photograph is from an aerial photo dated March 2013. The three chambers which were still in Silver Lake at the time of the photo are clearly visible, and locations of the remaining chambers have been added. Chambers which received alum are designated as A-1 and A-2 for the two replicate chambers, with chambers receiving Phoslock designated as P-1 and P-2. The replicate control chambers are referred to as C-1 and C-2.

Figure 3-9.

Completed Limno-Corrals.

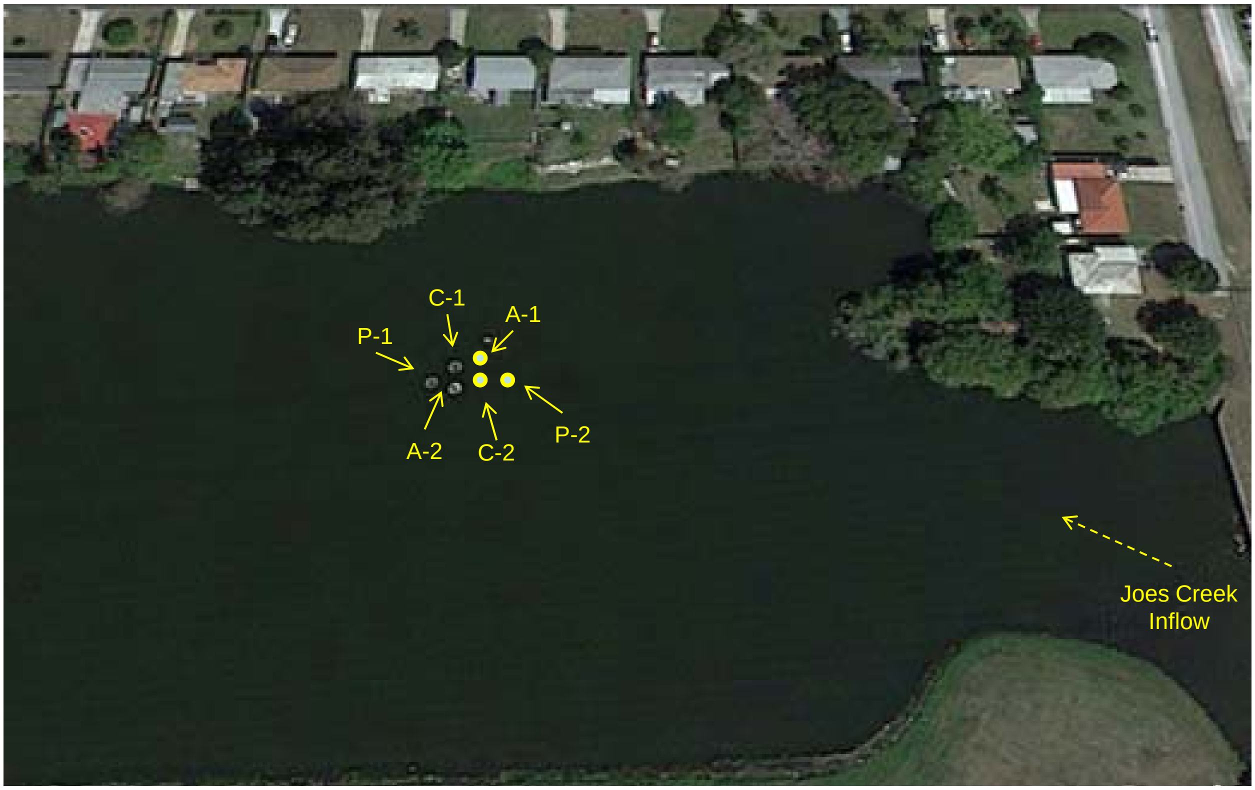


Figure 3-10. Locations and Chamber Designations for the Final Set of Limno-Corral Structures.

A summary of mean water depths in the Silver Lake limno-corral structures for the third and final set of limno-corrals is given in Table 3-1. The values summarized in this table reflect the geometric mean of the water depths measured in each of the isolation chambers during collection of vertical field profiles. Water depths in each of the isolation chambers and in the open lake were relatively similar in value, with an overall mean water depth of approximately 1.89 m in the alum treated chambers, 1.76 m in the Phoslock treated chambers, 1.85 m in the control chambers, and 1.92 m in the open lake.

TABLE 3-1

MEAN WATER DEPTHS IN THE SILVER LAKE LIMNO-CORRAL STRUCTURES

CHAMBER	WATER DEPTH (m)
A-1	1.82
A-2	1.95
P-1	1.69
P-2	1.82
C-1	1.73
C-2	1.96
Lake	1.92

3.2 Calculation of Sediment Inactivation Doses

An overview of significant reactions at the water-sediment interface under oxygenated and anoxic conditions is given on Figure 3-11. When particulate matter settles into the bottom sediments of a lake, microbial processes begin to breakdown the material and phosphorus which was contained in the particulate matter is released into the sediments in a soluble form. Most lake sediments contain an abundance of iron which, under oxygenated conditions, forms an insoluble precipitate of ferric phosphorus ($FePO_4$). This precipitate remains stable, and the phosphorus largely unavailable, as long as the sediments maintain an oxygenated environment. However, under anoxic conditions, iron undergoes an oxidation-reduction reaction where insoluble ferric (Fe^{+3}) iron is converted into soluble ferrous (Fe^{+2}) iron according to the following relationship:

$$\underset{\text{(insoluble)}}{\mathbf{Fe^{+3}}} + \mathbf{1e^{-}} \rightarrow \underset{\text{(soluble)}}{\mathbf{Fe^{+2}}}$$

As the iron becomes soluble, the iron-phosphorus bond breaks apart and soluble phosphorus is released into the sediment layer where it diffuses into the overlying water column by a first-order concentration gradient-based diffusion process. This soluble phosphorus accumulates in lower portions of the water column until circulated into the main body of the lake where it is available for stimulation of algal growth.

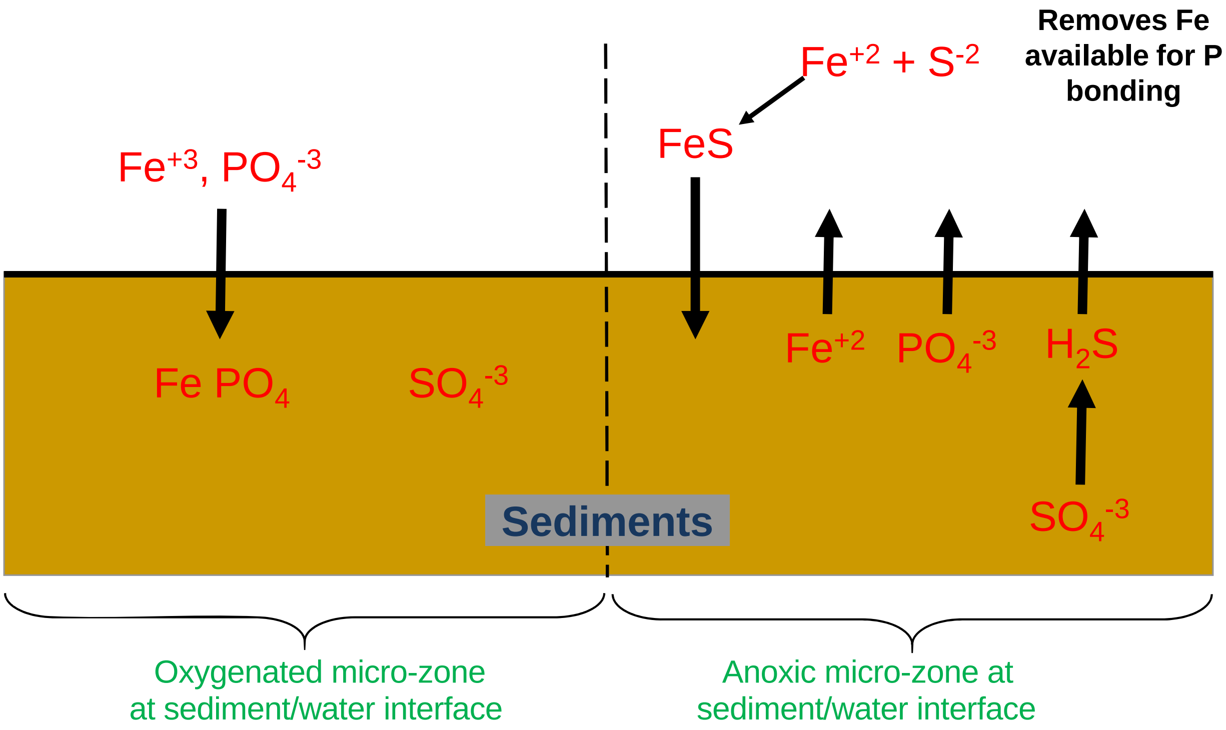


Figure 3-11. Significant Reactions at the Water-Sediment Interface.

In contrast to iron, elements such as aluminum, calcium, and lanthanum are capable of bonding with phosphorus in associations which are stable under a wide range of environmental conditions, effectively removing the phosphorus from the lake cycle on a permanent or semi-permanent basis, depending on the element. The most common form of soluble phosphorus in sediments is the phosphate ion (PO_4^{-3}) which carries a triple negative charge. Metal ions such as iron, aluminum, calcium, and lanthanum, all carry positive charges which attract the negatively charged phosphate ion, forming a polar bond. The relative ability of an atom to attract the available electrons in the phosphate molecule to itself is predicted by the electronegativity of the atom. Electronegativity is simply a relative measure of the ability of an atom, when in a molecule, to attract electrons. The higher the electronegativity value, the stronger the attraction for electrons.

A summary of electronegativities of common chemical inactivants is given on Table 3-2. Iron has an electronegativity of 1.8, which is greater than the electronegativities of the other listed elements, and a negatively charged ion such as phosphate would be more attracted to bonding with iron than the other listed elements due to the higher electronegativity of the iron atom. According to the listed electronegativities, aluminum (with an electronegativity of 1.6) would be less reactive to phosphorus than iron, with calcium (electronegativity value of 1.3) less reactive than either aluminum or iron, and lanthanum (electronegativity value of 1.1) less reactive with phosphate than calcium, aluminum, or iron.

TABLE 3-2

ELECTRONEGATIVITIES OF COMMON CHEMICAL INACTIVANTS

ELEMENT	ELECTRONEGATIVITY (Pauling Scale)
Fe	1.8
Al	1.6
Ca	1.3
La	1.1

When conducting sediment inactivation using aluminum, the difference in electronegativities between iron (1.8) and aluminum (1.6), dictate that phosphorus would preferentially bond with iron rather than aluminum. Therefore, the standard protocol for sediment inactivation calls for applying an abundance of aluminum into the sediments to overcome the preferential bonding between iron and phosphate and allow the phosphate in the sediments to form insoluble, inert bonds with aluminum. Most sediment inactivation projects are conducted using an overabundance of aluminum which is equivalent to 5-10 times the number of moles of available phosphorus present within the sediments to create an artificial driving force to increase the opportunity for phosphorus to bond with aluminum rather than iron. By extrapolation, using calcium as an inactivant would require a higher dose than is currently used for aluminum due to the lower reactivity between calcium and phosphorus compared with aluminum and phosphate. Similarly, an even higher molar ratio would be required for lanthanum due to the substantially lower electronegativity of lanthanum compared with iron and aluminum. Estimation of the inactivant mass required for sediment inactivation is not only a function of the available phosphorus within the sediments but also the relative reactivity of the element selected for inactivation.

The applied cation:phosphorus ratio is an important variable for estimating the dosage required to inactivate saloid- and iron-bound phosphorus in sediments for control of internal phosphorus loadings in lakes. The ratio provides an abundance of the cation element in the sediments to provide a driving force to cause the released phosphate ions to preferentially bind with the cation rather than with iron or another unstable association.

A variety of Al:P ratios have been used in previous alum sediment inactivation projects. James (2011) reports that much larger cation:phosphorus ratios are needed at lower doses of iron-bound sediment phosphorus than at higher doses. At extremely low iron-bound phosphorus concentrations, Al:P ratios required to bind 90% of the iron-bound phosphorus may exceed 150:1, with molar ratios of approximately 20:1 or less are required at higher iron-bound phosphorus concentrations. Rydin and Welch (1998) recommend a range of cation:phosphorus ratios based upon whether the treatment is assuming a 4 cm active sediment zone or a 10 cm sediment depth zone. Ratios for an assumed 4 cm inactivation depth range from 11-27, with ratios for the 10 cm depth ranging from approximately 3-11. ERD currently assumes 10:1 ratios for Florida lake systems which have been shown to reduce sediment phosphorus release by approximately 90% in evaluated lakes.

Alum and Phoslock differ significantly in their specificity for removal of various phosphorus forms. Phoslock appears to be relatively specific for dissolved inorganic phosphorus (SRP), with little affinity for removal of particulate phosphorus, dissolved organic phosphorus, or chlorophyll-a. Alum is not only specific for SRP but also provides virtually complete removal of particulate phosphorus and chlorophyll-a, with a 40-50% removal of dissolved organic phosphorus. These differences in the specificity for various phosphorus forms are apparent in the results of the limno-corral experiments discussed in Section 4.

When estimating the mass of a compound required for sediment inactivation, ERD assumes an active sediment depth of approximately 10 cm which is based upon the assumption that the top 10 cm of lake sediments are actively involved in internal recycling since phosphorus can mobilize from the sediments by diffusion to approximately this depth. Below this depth, upwards diffusion is relatively restricted and contributes little to the overall phosphorus loading resulting from sediment release. Therefore, when estimating inactivant doses, it is assumed that the top 10 cm of the sediments will be inactivated.

As indicated on Figure 3-1, the area of Silver Lake where the isolation chambers were installed is characterized by available sediment phosphorus concentrations ranging from 90-100 $\mu g/cm^3$. If this concentration is extrapolated over the area of the chamber and extended to a depth of 10 cm, the resulting mass of available phosphorus is approximately 23.4 g or 0.76 moles of phosphorus. Using an applied Al:P ratio of 10:1 (commonly used by ERD on sediment inactivation projects), a total of 7.56 moles of aluminum is required to inactivate the available phosphorus. This is equivalent to approximately 3483 ml of commercial strength liquid alum and results in a mean water column dose of 47.6 mg Al/liter. This dose is well in excess of the alum dose that can be added to Silver Lake without undesirable depression of the water column pH. Therefore, the required mass of aluminum was divided between alum and sodium aluminate, which acts as a buffering compound, to maintain a pH value of 6.0 within the isolation chambers following the alum addition. The sum of the aluminum provided by the alum and the aluminum provided by the sodium aluminate is equivalent to the required 7.56 moles of aluminum or 204 g of aluminum. This dose was added to each of the two limno-corral structures which received alum sediment inactivation. A summary of calculations used to estimate the mass of aluminum required for sediment inactivation is given on Table 3-3.

Based upon the methodology outlined previously for aluminum, the lanthanum dose should also be calculated as a ratio of lanthanum to available phosphorus in the sediments except that the applied molar Al:P ratio should be well in excess of the 10:1 ratio used for aluminum due to the substantially lower electronegativity and reactivity of lanthanum compared with aluminum. In response to comments regarding electronegativity and potential reactivity of lanthanum compared with aluminum and other inactivants, the Phoslock representative indicated that “Phoslock does behave differently, as designed, to more specifically and preferentially interact with free phosphorus species not general binding to many constituents. As Phoslock (La^{+3}) is exposed to PO_4^{-3} (in water column during settling, the pore water and sediments over time), the La^{+3} will preferentially bind with the trivalent cation PO_4^{-3} and form a highly stable bond as the naturally occurring mineral rhabdophane.”

TABLE 3-3

ALUM DOSING CALCULATIONS FOR LIMNO-CORRAL STUDIES

PARAMETER	UNITS	VALUE
Sediment Available Phosphorus Concentration	$\mu g/cm^3$	100
Diameter of Chamber	inches m	68 1.73
Area of Chamber	m^2	2.34
Inactivation Depth	cm	10
Inactivation Volume	m^3	0.23
Phosphorus Mass to be Inactivated	g	23.4
Moles of Phosphorus to be Inactivated	--	0.76
Applied Al:P Ratio	--	10
Moles Al Required	--	7.56
Mass Al Required	g	204.1
Equivalent Alum Volume	ml	3,483
Water Depth	ft	6
Chamber Volume	m^3 gallons	4.29 1,177
Alum Water Column Dose	mg Al/liter	47.6
Dose Contributed by Alum	mg Al/liter	20.0
Dose Contributed by AS	mg Al/liter	27.6
Alum Volume Required	ml	1,463
Sodium Aluminate Volume Required	ml	756
Aluminum Areal Dose	$g\ Al/m^2$	87.1

In the initial set of limno-corral experiments described previously, a 10:1 inactivant:P ratio was used to provide a comparison of the effectiveness of sediment inactivation using aluminum and lanthanum when the inactivation requirements are calculated using the same methodology. Based upon the assumed La:P ratio of 10:1, sediment inactivation within each of the two isolation chambers receiving the Phoslock treatment would require 47.2 pounds of Phoslock to be applied to each chamber. This dose was added to each of the two Phoslock chambers during the initial limno-corral experiment conducted in July 2012.

After ERD initiated the original field monitoring program, representatives from the County discussed the inactivation dose calculations used by ERD with the Phoslock representative. The representative provided a reference to Phoslock removal in a beaker containing a phosphorus solution with no competing ions, during which 1 g of Phoslock (which is approximately 4.9% lanthanum by weight) removed 0.011 g of soluble phosphorus from the solution water under equilibrium conditions. The Phoslock representative indicated that lanthanum is "different" from other inactivants, and indicated that an La:P ratio of 1:1 is adequate for sediment inactivation using lanthanum in apparent opposition to current sediment inactivation theory as well as basic chemical principles. However, as directed by the County, ERD conducted the second and third limno-corral experiments using the La:P ratio of 1:1 recommended by the representative. This resulted in 4.72 lbs of Phoslock applied to each of the chambers receiving Phoslock additions. A summary of calculations used to estimate the Phoslock mass added to the limno-corral structures is given on Table 3-4.

TABLE 3-4

PHOSLOCK DOSING CALCULATIONS FOR LIMNO-CORRAL STUDIES

PARAMETER	UNITS	VALUE
P Removal by Phoslock	p P/g Phoslock	0.011
Applied La:P Ratio	--	1
Mass of Phoslock Required	kg	2.13
Phoslock Lanthanum Content	% by weight	4.9
Applied La:P Ratio	--	1
Moles La Required	--	0.76
Mass La Required:	--	105
Mass Phoslock Required	kg lb	2.14 4.72
Phoslock Water Column Dose	mg/l	500
Phoslock Areal Dose	g/m^2	914
Lanthanum Areal Dose	g/m^2	44.8

A comparison of costs for inactivation chemicals used for the alum and Phoslock limno-corral chambers is given on Table 3-5. Each of the alum chambers received 1.463 liters of alum and 0.756 liters of sodium aluminate. At a unit cost of \$0.60/gallon and \$2.50/gallon for sodium aluminate, the total estimated chemical cost for the alum inactivation in each chamber is approximately \$0.73. Each of the Phoslock chambers required 4.72 lbs of Phoslock product even using the La:P ratio of 1:1. The Phoslock material used by ERD was purchased directly from SePRO with a 40 lb pail purchased for \$175, equivalent to a unit cost of \$4.38/lb. The resulting overall cost for the Phoslock product was approximately \$20.65, approximately 28 times greater than the chemical cost for alum and sodium aluminate. If the 10:1 ratio had been used for lanthanum as recommended by ERD, the cost of the Phoslock product would have been 280 times greater than the cost for alum and sodium aluminate.

TABLE 3-5

COMPARISON OF COSTS FOR INACTIVATION CHEMICALS USED IN THE LIMNO-CORRAL EXPERIMENTS

INACTIVANT		QUANTITY USED	UNIT COST	TOTAL COST
Aluminum	Alum	1.463 liters	$ 0.60/gallon	$ 0.23
	Sodium Aluminate	0.756 liters	$ 2.50/gallon	$ 0.50
			Total:	**$ 0.73**
Phoslock		4.72 lbs	$ 4.38/lb	$ 20.65
			Total:	**$ 20.65**

In response to the comparison of cost for inactivation chemicals used in the limno-corral experiments, SePRO comments that the unit cost of $4.38/pound for Phoslock as purchased by ERD would be substantially lower if a whole-lake project were to be conducted. Phoslock pricing for professional uses varies based on a project-by-project basis but is generally in the range of $1.70-1.90/pound. At an assumed cost of $1.80/pound, the 4.72 pounds of Phoslock used by ERD in the limno-corral experiments would have cost approximately $8.50 which is approximately 12 times the listed costs for alum and sodium aluminate of approximately $0.73. This comparison reflects chemical costs only and does not include labor involved in the applications.

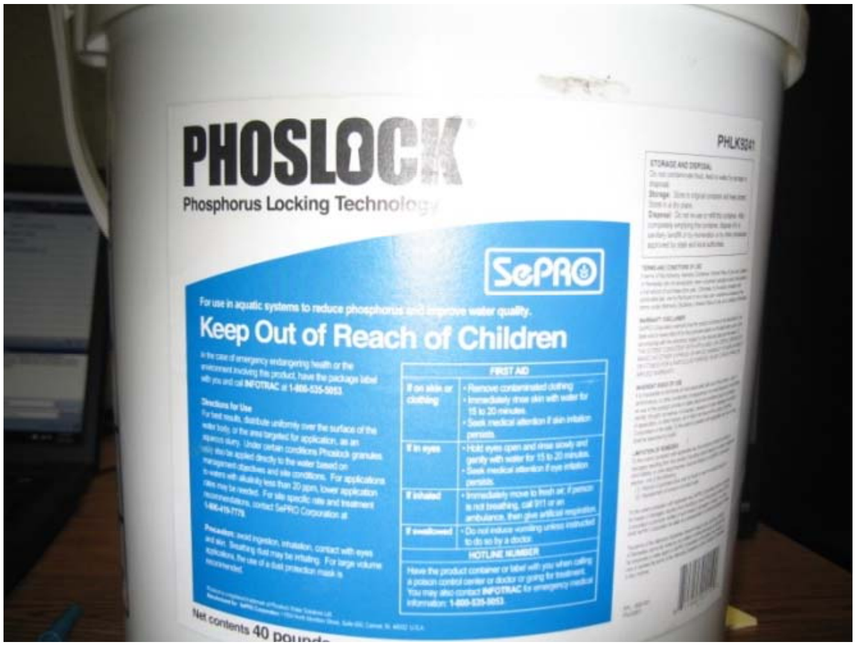
3.3 Incubation Experiment Start-Up

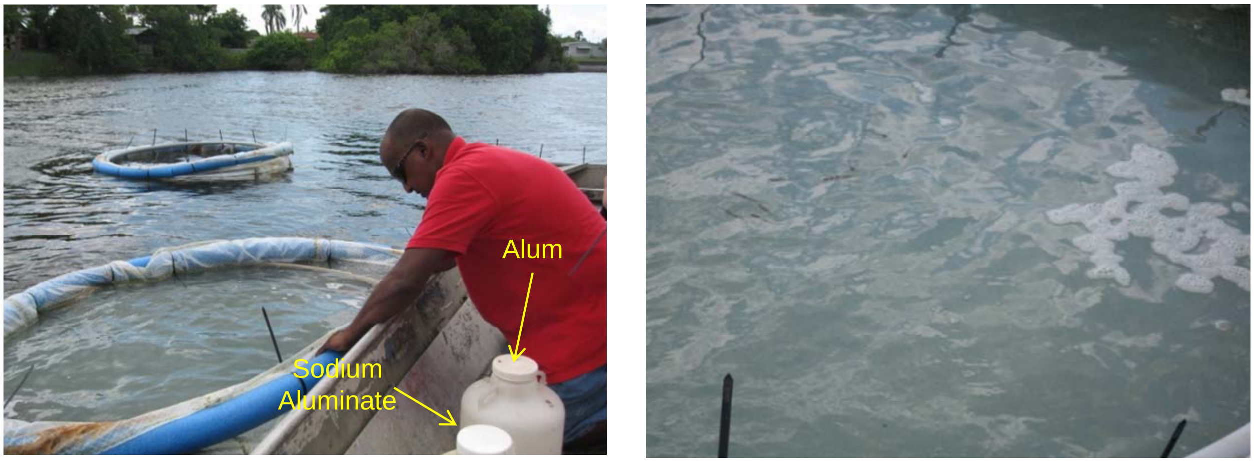
After installation of the six limno-corrals was completed, the appropriate chemical doses were added to the alum and Phoslock chambers to initiate the field monitoring program. A photograph of the Phoslock product label is given on Figure 3-12, and a product specification sheet for Phoslock is provided in Appendix B.1. According to the specification sheet, Phoslock contains approximately 4.9% lanthanum by weight. The alum and sodium aluminate used in the limno-corral experiments were obtained from existing stock of these products maintained by ERD for experimental purposes. Product information sheets for alum and sodium aluminate are provided in Appendix B.2.

Photographs of the addition of alum and sodium aluminate to the isolation chambers are given on Figure 3-13. The quantity of alum listed on Table 3-2 (1.463 liters) was added to a 5-gallon bucket of lake water and pre-mixed prior to addition to the isolation chamber. Similarly, the required volume of sodium aluminate (0.756 liters) was added to a second bucket containing 5 gallons of lake water and well mixed. The chemical addition occurred by first adding the alum into the isolation chamber, followed approximately 30 seconds later by the addition of the sodium aluminate solution. The water within the isolation chamber was then thoroughly mixed using a plastic paddle. Formation of the floc began rapidly, with relatively large floc particles produced which exhibited a relatively rapid settling characteristic. A period of 24 hours was allowed following addition of the alum and sodium aluminate to allow complete settling of the floc prior to initiation of the field monitoring program.

Figure 3-12.

Phoslock Product Label.





Alum and sodium aluminate mixtures

Alum floc formation

Figure 3-13. Photographs of Alum Addition to the Chambers.

Photographs of the process used for Phoslock addition to each of the two incubation chambers are given on Figure 3-14. The required Phoslock mass to be added to each of the two chambers (4.72 lbs) was weighed beforehand in the ERD Laboratory and placed into separate containers. The required Phoslock mass for a given chamber was added to approximately 5 gallons of lake water and mixed vigorously with a plastic paddle. The Phoslock slurry was then added to the appropriate chamber and thoroughly mixed into the chamber using the plastic paddle. After addition of the Phoslock product to each of the two isolation chambers, a settling period of 24 hours was allowed before initiating the post-treatment monitoring program. The photographs illustrated on Figure 3-13 were actually taken during the second of the three limno-corral experimental set-ups since the low profile of the floating Styrofoam rings greatly simplified the process of photographing both individual chambers and groups of chambers.

Phoslock added to lake water and mixed

Phoslock slurry added to chamber

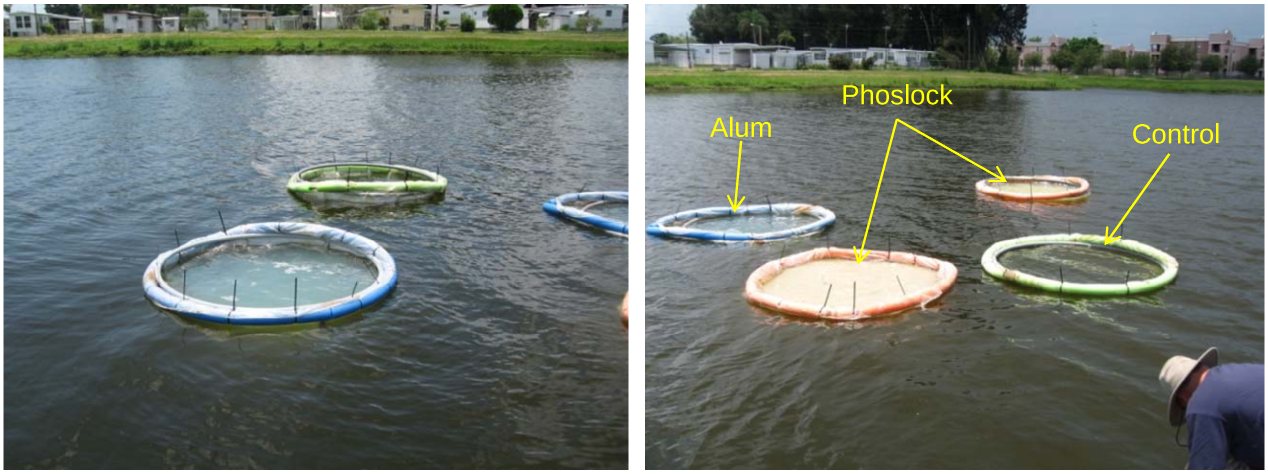
Immediately after Phoslock addition

Slurry mixed into chamber with paddle

Figure 3-14. Photographs of Phoslock Addition to the Chambers.

Photographic comparisons of the visual appearance of each of the isolation chambers following the chemical additions is given on Figure 3-15. Each of the chambers to which alum was added exhibited a bluish-white color. The chambers to which Phoslock was added exhibited a tan colored turbidity which gradually settled out over the initial 24-hour period.

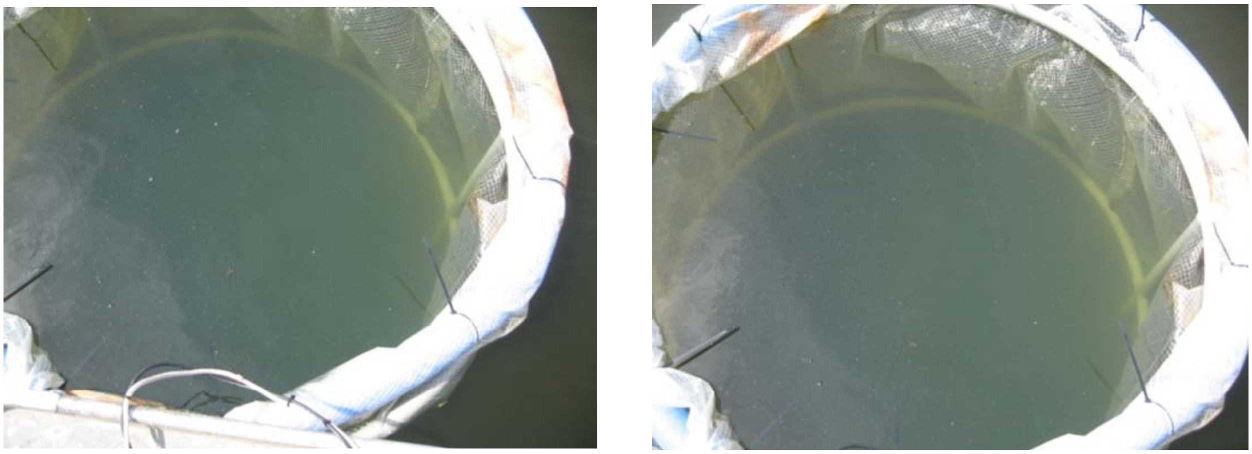
Photographs of the alum and Phoslock chambers for Experiment #2 after the initial 24-hour settling period are given on Figure 3-16. The water column within each of the two alum chambers was relatively clear with the lake bottom visible in each of the two chambers. The two chambers to which Phoslock was added still exhibited a moderate level of turbidity approximately 24 hours after the Phoslock addition, with relatively poor water column visibility.



Chamber following alum addition

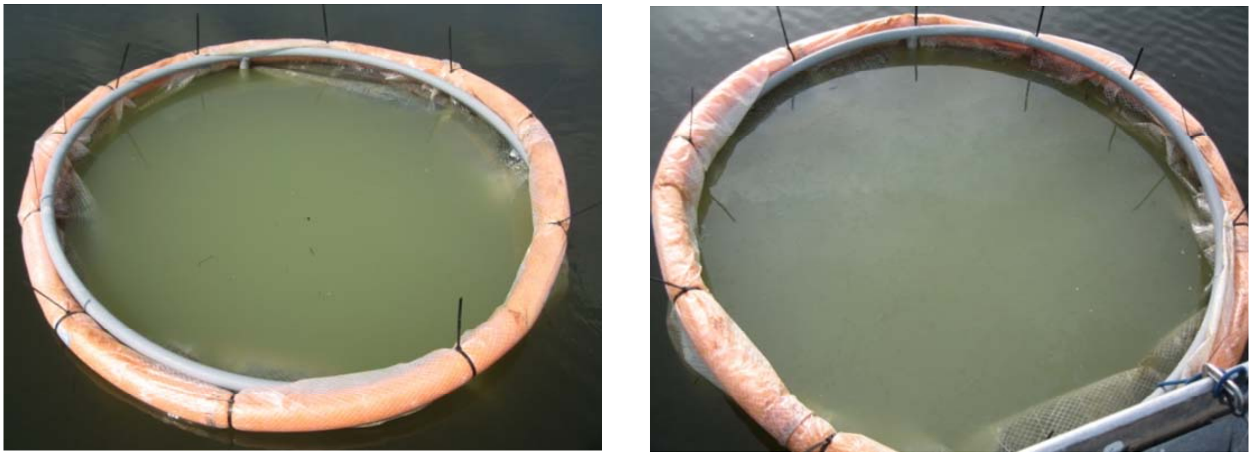
Comparison of final chambers

Figure 3-15. Comparison of Isolation Chambers Following Chemical Additions.



Alum chamber #1 – 24 hours

Alum chamber #2 – 24 hours

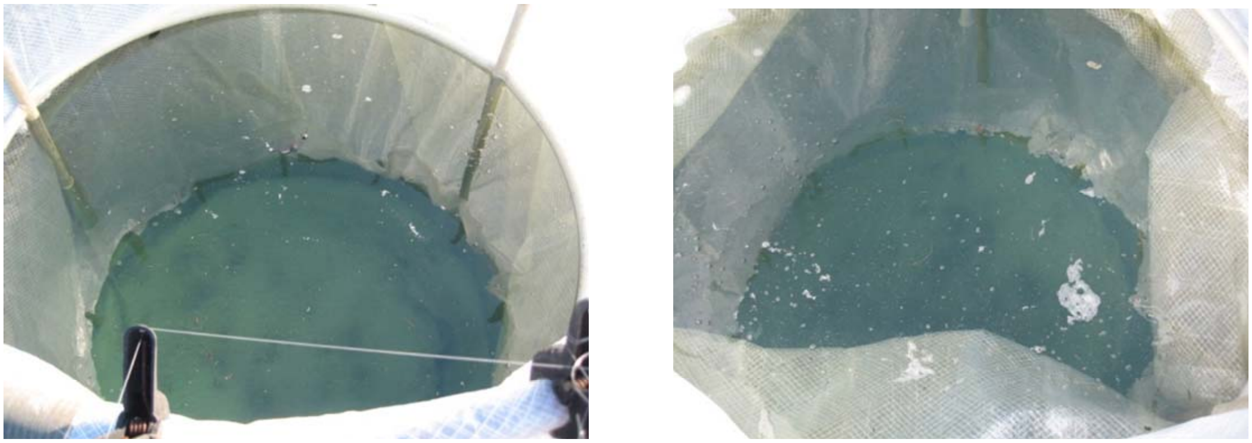


Phoslock chamber #1 – 24 hours

Phoslock Chamber #2 – 24 hours

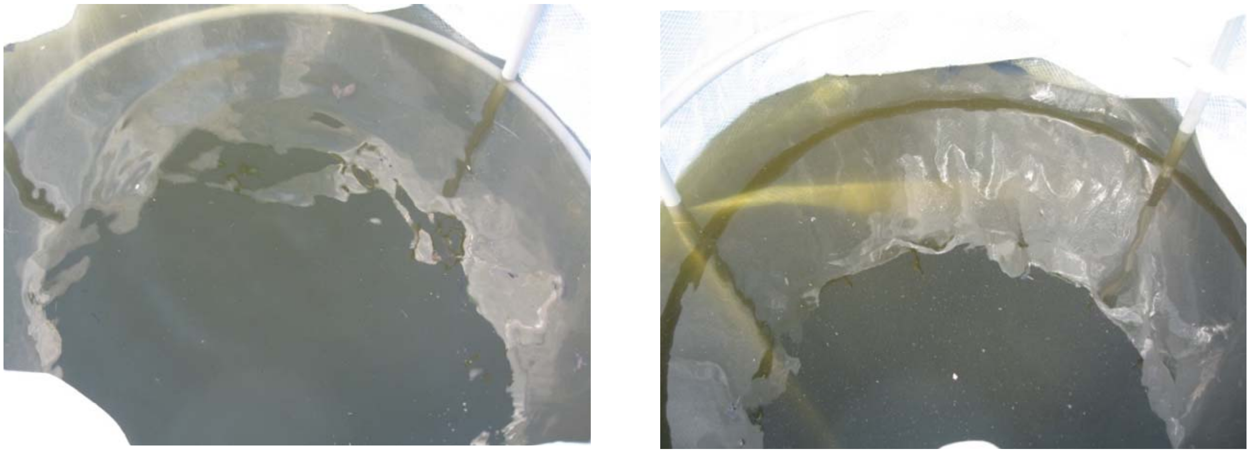
Figure 3-16. Photographs of Alum and Phoslock Chambers for Experiment #2 after 24 Hours.

Photographs of the alum and Phoslock chambers for Experiment #3 after the initial 24-hour settling period are given on Figure 3-17. Each of the two chambers which received alum addition was exceptionally clear after 24 hours, with the bottom of the accumulated alum floc clearly visible in each of the two chambers. Each of the Phoslock chambers exhibited slightly enhanced water column clarity compared with the control, although the bottom of the chamber was not visible in either of the two enclosures. The photographs illustrated on Figure 3-17 represent the final experiment which forms the basis of the results and conclusions obtained from the comparison of the two inactivant materials.



Alum chamber #1 – 24 hours

Alum chamber #2 – 24 hours



Phoslock chamber #1 – 24 hours

Phoslock Chamber #2 – 24 hours

Figure 3-17. Photographs of Alum and Phoslock Chambers for Experiment #3 after 24 Hours.

3.4 Monitoring Protocol

Initial water quality samples were collected within each of the isolation chambers and lake water following installation of the isolation chambers. The calculated amounts of alum and Phoslock were then added to the appropriate chambers, as described in Section 3.3. Routine monitoring was initiated 24 hours after the addition of the alum and Phoslock. During each routine monitoring event, vertical field profiles were collected within each isolation chamber and in open lake water adjacent to the isolation chambers on each monitoring date. Field measurements of pH, specific conductivity, temperature, dissolved oxygen, and ORP were collected at depths of 0.25 m, 0.5 m, and at 0.5 m intervals to the lake bottom within each isolation chamber and in the open lake using a Hydrolab H2O water quality monitor. A measurement of Secchi disk depth was also conducted in each isolation chamber and in the open lake adjacent to the chambers. In addition to the general parameters, field measurements of photosynthetically active radiation (PAR) were conducted in each of the isolation chambers and within the open lake water during each biweekly monitoring event. PAR measurements were conducted at water depths of 0.2, 0.4, 0.6, 0.8, 1.0 m, and at 0.5 m intervals to the bottom at each site. A summary of analytical methods and detection limits for field measurements is given in Table 3-6.

TABLE 3-6

ANALYTICAL METHODS AND DETECTION LIMITS FOR FIELD MEASUREMENTS ON SURFACE WATER

MEASUREMENT PARAMETER	METHOD	METHOD DETECTION LIMITS (MDLs)
pH	DEP-SOP-001/01, Sec. FT1100	NA
Temperature	DEP-SOP-001/01, Sec. FT1400	NA
Conductivity	DEP-SOP-001/01, Sec. FT1200	0.3 μmho/cm
Diss. Oxygen	DEP-SOP-001/01, Sec. FT1500	0.3 mg/l
Secchi Disk Depth	DEP-SOP-001/01, Sec. FT1720	NA
Photosynthetically Active Radiation (PAR)	DEP-SOP-001/01, Sec. FT1710	NA

Composite surface water samples were collected from each chamber using a portable submersible pump. A single composite sample was collected by combining equal aliquots of water collected from the top (0.5 m), bottom (0.5 m from bottom), and middle of the water column in each chamber. Water samples were also collected from the open lake water adjacent to the chambers using the same methodology. All field monitoring was conducted in accordance with DEP-SOP-001, "FDEP Standard Operating Procedure for Field Activities," dated March 31, 2008. Samples used for chemical analysis of dissolved nutrients were filtered in the field immediately following sample collection using a syringe apparatus with a 0.45 micron glass fiber disposable filter.

The limno-corrals were impacted from nutrient inputs from all potential sources (bulk precipitation, groundwater seepage, and sediment processes) except runoff inputs. Based on an assumed water depth of 6-7 ft and a diameter of 6 ft for the limno-corrals, each chamber contained a water volume of approximately 1500 gallons. To assist in simulating nutrient inputs from runoff, a volume of Joe’s Creek inflow was added to each limno-corral on a biweekly basis equivalent to 5% of the volume of water contained in each limno-corral or approximately 75 gallons. The experimental protocol resulted in the addition of 75 gallons of Joe’s Creek water to each of the limno-corrals on a biweekly basis during a total of 7 post-treatment monitoring events. The total volume added to each of the limno-corrals during the monitoring program was approximately 525 gallons, equivalent to approximately to 35% of the original limno-corral volume. This addition rate was selected based upon the assumed additional capacity within each of the limno-corral structures.

The water which was added to the limno-corrals was collected at the box culvert inflow into Silver Lake, which typically maintains a constant flow even in the absence of rain events, and placed in a 150-gallon tank inside the work boat. All of the initial water quality monitoring and sample collection activities were completed in the 6 chambers before the inflow water was added. The water was allowed to drain by gravity from the tank into each limno-corral to minimize disturbance of the bottom sediments. The chamber was then mixed using a plastic paddle. At the completion of the mixing, field measurements of pH, conductivity, temperature, dissolved oxygen, and ORP were repeated.

Each of the collected surface water samples was returned to the ERD Laboratory and evaluated for general parameters and nutrients. A summary of laboratory methods and MDLs for analyses conducted on water samples collected during this project is given in Table 3-7. All laboratory analyses were conducted in the ERD Laboratory (NELAC Certification No. E1031026).

Field monitoring was conducted in each of the limno-corrals on a biweekly basis for approximately three months, with a total of 7 post-treatment monitoring events conducted at each site. Including the initial pre-treatment sampling event, 8 sets of water quality samples were collected from the limno-corrals and Silver Lake surface water. This process generated a total of 56 individual samples for laboratory analysis (8 events x 7 samples/event).

TABLE 3-7

ANALYTICAL METHODS AND DETECTION LIMITS FOR LABORATORY ANALYSES

PARAMETER	METHOD OF ANALYSIS	METHOD DETECTION LIMITS (MDLs)[1]
pH	SM-21, Sec. 4500-H^+ B[2]	N/A
Alkalinity	SM-21, Sec. 2320 B	0.5 mg/l
Ammonia	SM-21, Sec. 4500-NH_3 G	0.005 mg/l
NO_x	SM-21, Sec. 4500-NO_3 F	0.005 mg/l
Total Nitrogen	SM-21, Sec. 4500-N C	0.01 mg/l
Soluble Reactive Phosphorus (ORP)	SM-21, Sec. 4500-P F	0.001 mg/l
Total Phosphorus	SM-21, Sec. 4500-P B.5	0.001 mg/l
Turbidity	SM-21, Sec. 2130 B	0.3 NTU
Color	SM-21, Sec. 2120 C	1 Pt-Co Unit
Chlorophyll-a[3]	SM-21, Sec. 10200 H.1,3	1 mg/m^3

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

SECTION 4

RESULTS

A series of isolation chamber experiments was conducted in Silver Lake to evaluate the relative effectiveness of alum and Phoslock for inactivation of sediment phosphorus release. Six limno-corral isolation chambers were installed in Silver Lake, with one pair of the isolation chambers dosed with alum, one pair dosed with Phoslock, and the remaining pair used as a control. The isolation chambers were dosed with the appropriate chemicals and field monitoring was conducted on approximately a 2-3 week interval over a 91-day period from October 12, 2012-January 11, 2013. Field monitoring intervals typically ranged from 11-15 days, although an interval of 21 days occurred between the November 2012 monitoring events due to the Thanksgiving holiday. A discussion of the results of these monitoring efforts is given in the following sections.

4.1 Field Parameters

A complete listing of physical-chemical field profiles collected in each of the isolation chambers from October 12, 2012-January 11, 2013 is given in Appendix C.1, and a discussion of the measured physical-chemical profiles is given in the following sections. Field profiles of PAR are included in Appendix C.2 for reference purposes, but the PAR data are not discussed in the text.

4.1.1 Temperature

A summary of vertical temperature profiles collected in the isolation chambers from October 12, 2012-January 11, 2013 is given on Figure 4-1. Separate profiles are included for field measurements collected in each of the two alum treated chambers, the two Phoslock treated chambers, the two control chambers, as well as in the open lake.

In general, relatively isograde temperature profiles were observed in each of the isolation chambers, as well as in the open lake water, throughout the field monitoring program. No significant difference was observed in temperature measurements within the isolation chambers or in the open lake, with no significant change in temperature with increasing water depth.

Each of the plots provided in Figure 4-1 have the same horizontal temperature scale which allows a comparison of seasonal changes in temperature during the field monitoring program. The water temperature at the start of the isolation chamber testing on October 12, 2012 was approximately 27^{o}C. Water temperature within the lake continued a steady decline over time, reaching a minimum temperature of approximately 17.5 ^{o}C on December 27, 2012, before rebounding upward on the final monitoring date of January 11, 2013. Based upon the profiles summarized on Figure 4-1, it appears that neither the alum nor Phoslock additions had any significant impact on water column temperature.

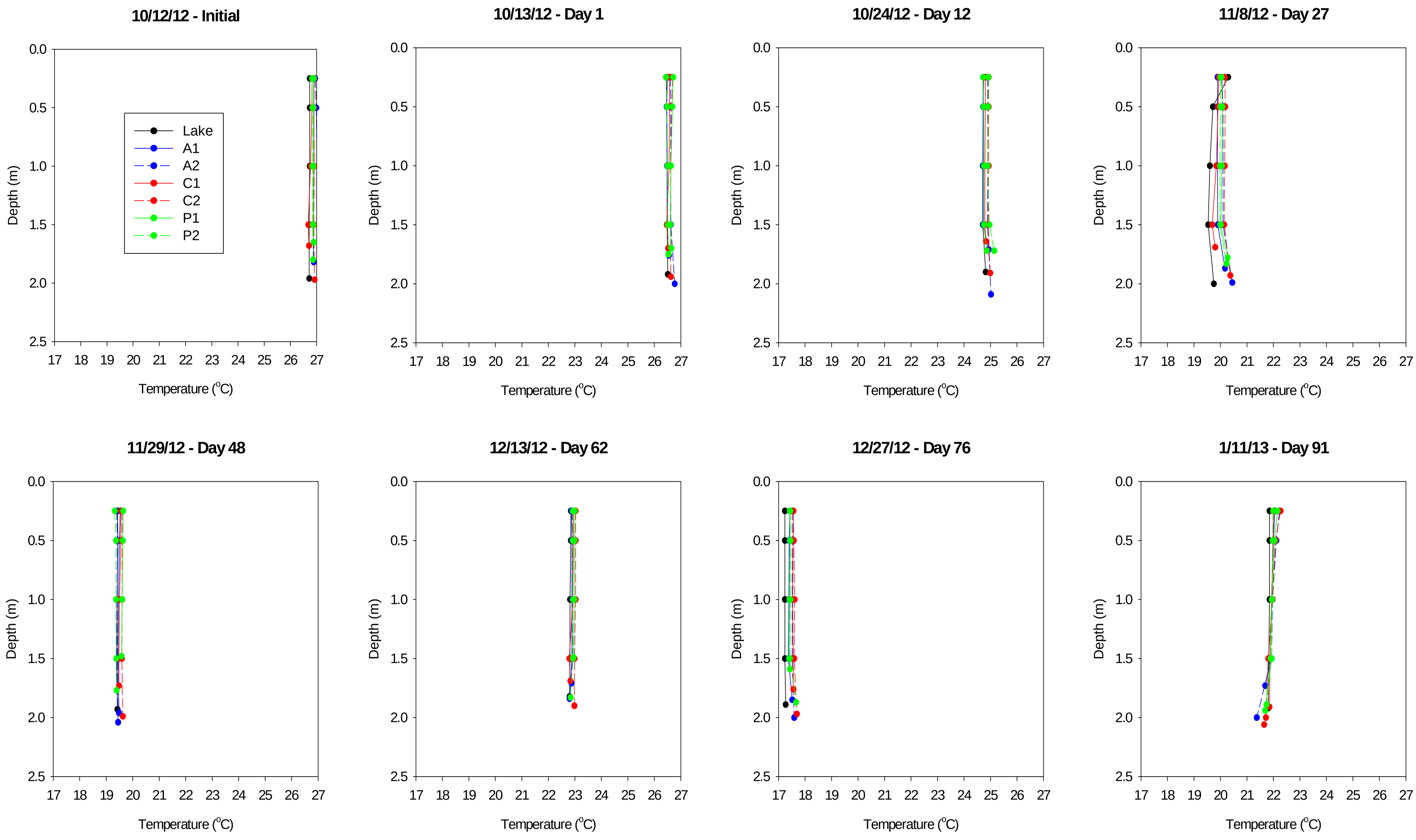


Figure 4-1. Summary of Vertical Temperature Profiles Collected in the Isolation Chamber Experiments from October 12, 2012-January 11, 2013.

4.1.2 pH

A graphical comparison of vertical field profiles of pH measured in Silver Lake isolation chambers from October 12, 2012-January 11, 2013 is given on Figure 4-2. The pH profiles illustrated for October 12 reflect conditions in each of the isolation chambers and in the open lake prior to chemical additions. The measured pH profiles prior to chemical addition were relatively similar, with measured surface pH values ranging from approximately 6.8-7.2. Relatively isograde pH profiles were observed in each of the isolation chambers and in the open lake from the water surface to a depth of approximately 1.5 m. Below this depth, a slight decrease in pH was measured near the water-sediment interface at each of the monitoring sites.

The pH profiles collected on October 13 reflect conditions approximately 24 hours following the chemical additions. No significant change in water column pH appears to have occurred in the Phoslock or control chambers as well as in the open lake. However, the measured pH value in the alum treated chambers decreased to approximately 6.0 which was the target pH based upon the mixture of alum and sodium aluminate which was used. By day 12 of the field monitoring program, the alum, control, and open lake sites exhibited relatively similar pH profiles, with surface values ranging from 6.5-7.2. Somewhat higher pH values were observed in the two Phoslock chambers, with one of the chambers exhibiting a surface pH of 7.3 and a surface pH of 8.3 in the other Phoslock chamber. As discussed in a subsequent section, the Phoslock chambers on day 12 also were characterized by substantially higher concentrations of dissolved oxygen than observed at the remaining sites. The combination of elevated pH and high dissolved oxygen concentration is often indicative of an algal bloom condition.

However, by day 27, the measured pH profiles in the isolation chambers and in the open lake were similar to the initial measurements conducted prior to chemical addition. This same general pattern for pH was maintained throughout the remainder of the 91-day incubation period.

4.1.3 Conductivity

A graphical summary of vertical conductivity profiles collected in the isolation chamber experiments from October 12, 2012-January 11, 2013 is given in Figure 4-3. The initial conductivity measurements in each of the isolation chambers as well as the open lake were virtually identical, with isograde conductivity profiles observed within the top 1.5 m of the water column at each site. Slight increases in conductivity were observed in lower layers of virtually all of the isolation chambers. The larger increase in conductivity observed in the alum treated chambers is due to the release of sulfate ions during alum addition. Sulfate ions have a large impact on conductivity to the double ionic charge of the sulfate ion.

Conductivity measurements collected approximately 24 hours following the chemical additions were virtually identical for the control and open water monitoring sites. A slight increase in conductivity of approximately 5% was observed in the Phoslock chambers, with a substantially greater conductivity increase observed in the alum treated chamber. The same general pattern exhibited on day 1 was maintained throughout most of the 91-day monitoring program. By day 48, the measured conductivity values in the two alum treated chambers were virtually identical and continued in this fashion for the remainder of the field monitoring program. A slight gradual decrease in conductivity values was observed in each of the two alum treated isolation chambers over time. Conductivity profiles in the remaining chambers were virtually unchanged from day 1 to the end of the field monitoring program.

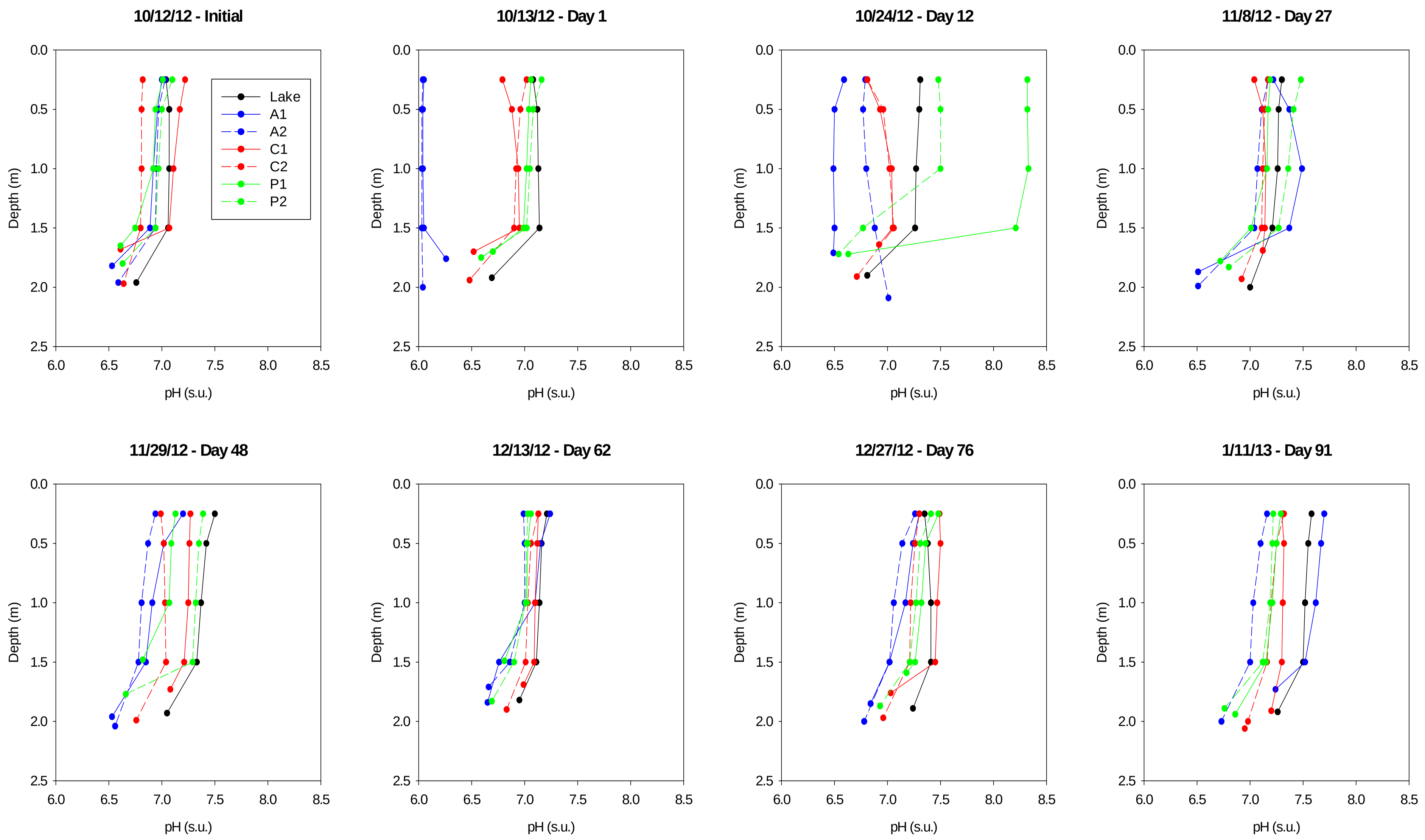


Figure 4-2. Summary of Vertical pH Profiles Collected in the Isolation Chamber Experiments from October 12, 2012-January 11, 2013.

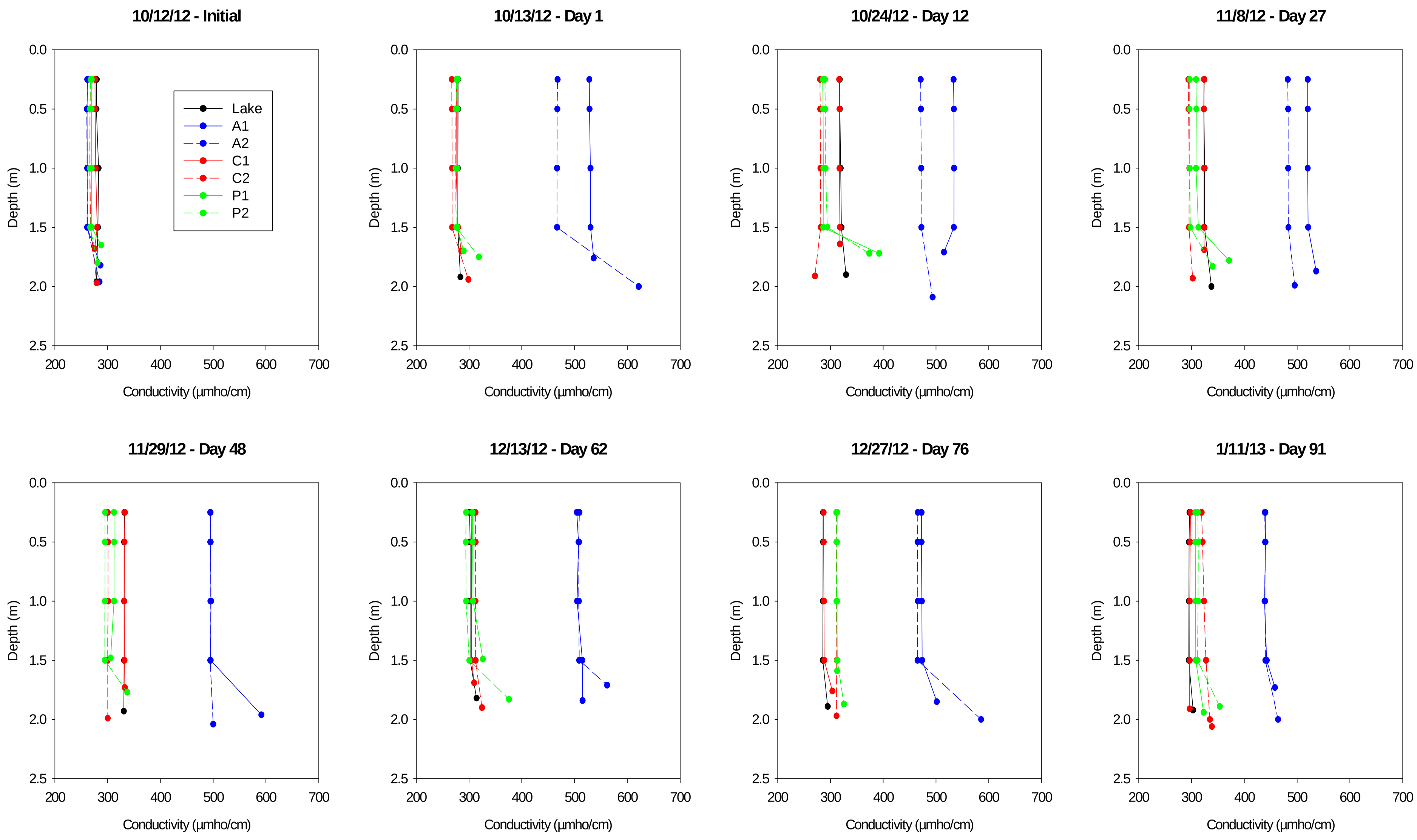


Figure 4-3. Summary of Vertical Conductivity Profiles Collected in the Isolation Chamber Experiments from October 12, 2012-January 11, 2013.

4.1.4 Dissolved Oxygen

A summary of vertical dissolved oxygen profiles collected in the isolation chamber experiments from October 12, 2012-January 11, 2013 is given on Figure 4-4. Initial surface (0.25 m) dissolved oxygen concentrations prior to chemical addition ranged from approximately 4.4-6.9 mg/l in the individual chambers and open lake. Dissolved oxygen concentrations at each of the monitoring sites were relatively isograde from the water surface to a depth of approximately 1.5 m. Below this depth, rapid decreases in dissolved oxygen were observed in each of the chambers and in the open lake near the water-sediment interface. The control chambers appeared to have a slightly greater dissolved oxygen concentration initially than was observed in the alum or Phoslock chambers or in the open water.

After approximately 24 hours following the chemical additions, measured dissolved oxygen concentrations in the isolation chambers and open water ranged from approximately 5-7 mg/l, with a relatively close range of values observed between each of the monitoring sites. Rapid decreases in dissolved oxygen were observed at each of the monitoring sites at the water-sediment interface. On monitoring day 12, the alum, control, and open water sites exhibited very similar dissolved oxygen concentrations ranging from approximately 5-6 mg/l. As discussed previously, substantially more elevated dissolved oxygen concentrations were observed in the Phoslock chambers, combined with the more elevated pH values summarized in Figure 4-2. A general increase in dissolved oxygen concentrations was observed at each of the monitoring sites on November 8 which is likely related to the substantial decrease in water temperature which occurred between the day 12 and day 27 monitoring events. The highest dissolved oxygen concentrations on November 8 were observed in the alum treated chambers.

Measured dissolved oxygen concentrations in the isolation chambers exhibited relatively similar patterns between days 48 and 91. Surface dissolved oxygen concentrations in the isolation chambers ranged from approximately 4-8 mg/l during this period, with relatively similar patterns of dissolved oxygen concentrations observed at each of the monitoring sites. Decreases in dissolved oxygen concentrations near the water-sediment interface were observed throughout the field monitoring program, with the possible exception of day 76 when the observed decreases near the water-sediment interface were substantially reduced, presumably due to the low water temperature which existed on this date.

4.1.5 Oxidation-Reduction Potential (ORP)

A summary of oxidation-reduction potential (ORP) profiles collected in the isolation chamber experiments from October 12, 2012-January 11, 2013 is given on Figure 4-5. A vertical line is included on each of the plots at 200 mV (E_h) which is generally considered to be the boundary between aerobic and anoxic conditions. ORP profiles conducted following installation of the isolation chambers but before chemical additions (10/12/12) indicate either aerobic or slightly reduced conditions in the first meter of the water column in each of the chambers. ORP values decreased below this depth in all chambers, with reduced conditions observed near the water-sediment interface in each chamber. Surface dissolved oxygen concentrations in each of the chambers during the initial monitoring event were approximately 4 mg/l, decreasing to less than 1 mg/l near the water-sediment interface.

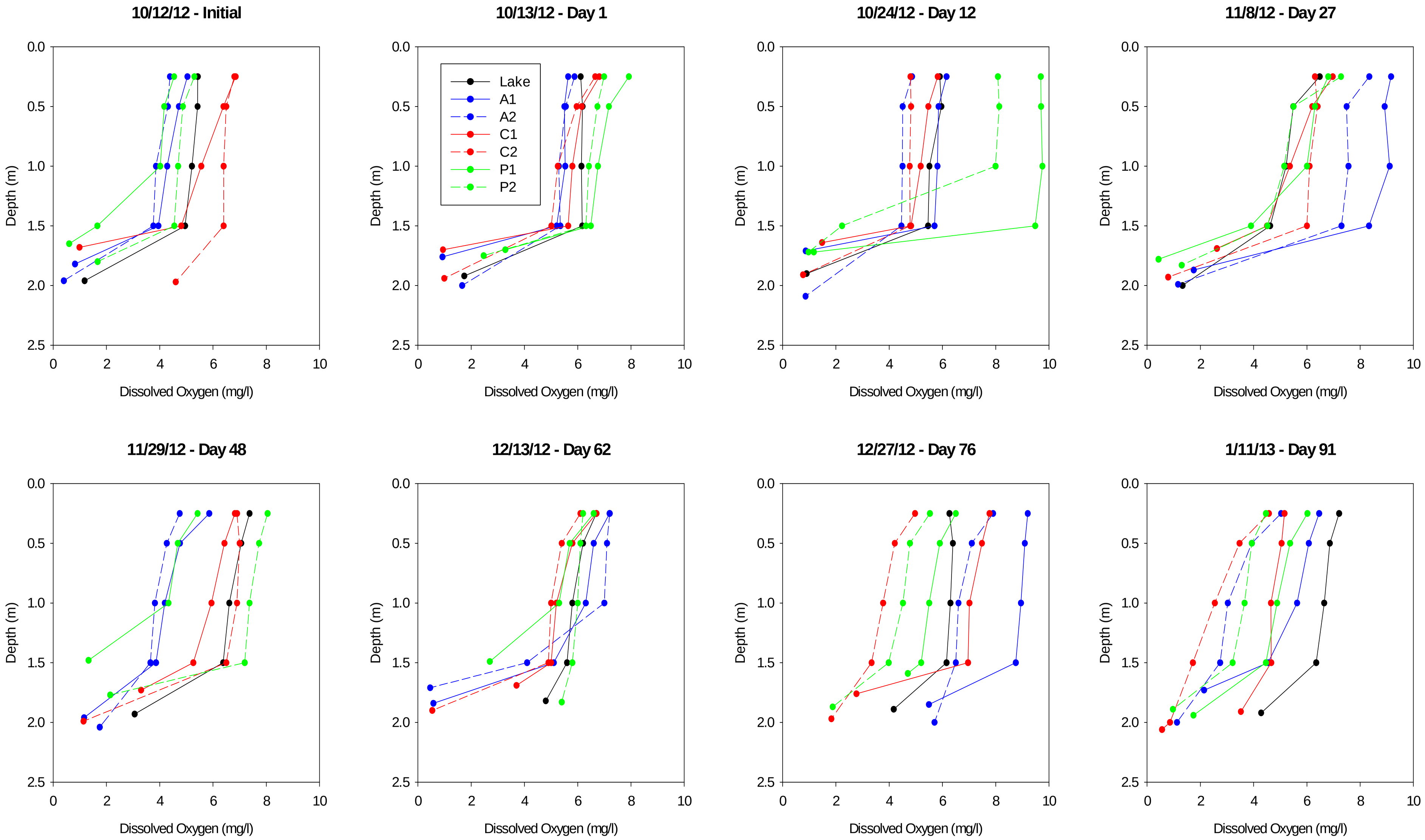


Figure 4-4. Summary of Vertical Dissolved Oxygen Profiles Collected in the Isolation Chamber Experiments from October 12, 2012-January 11, 2013.

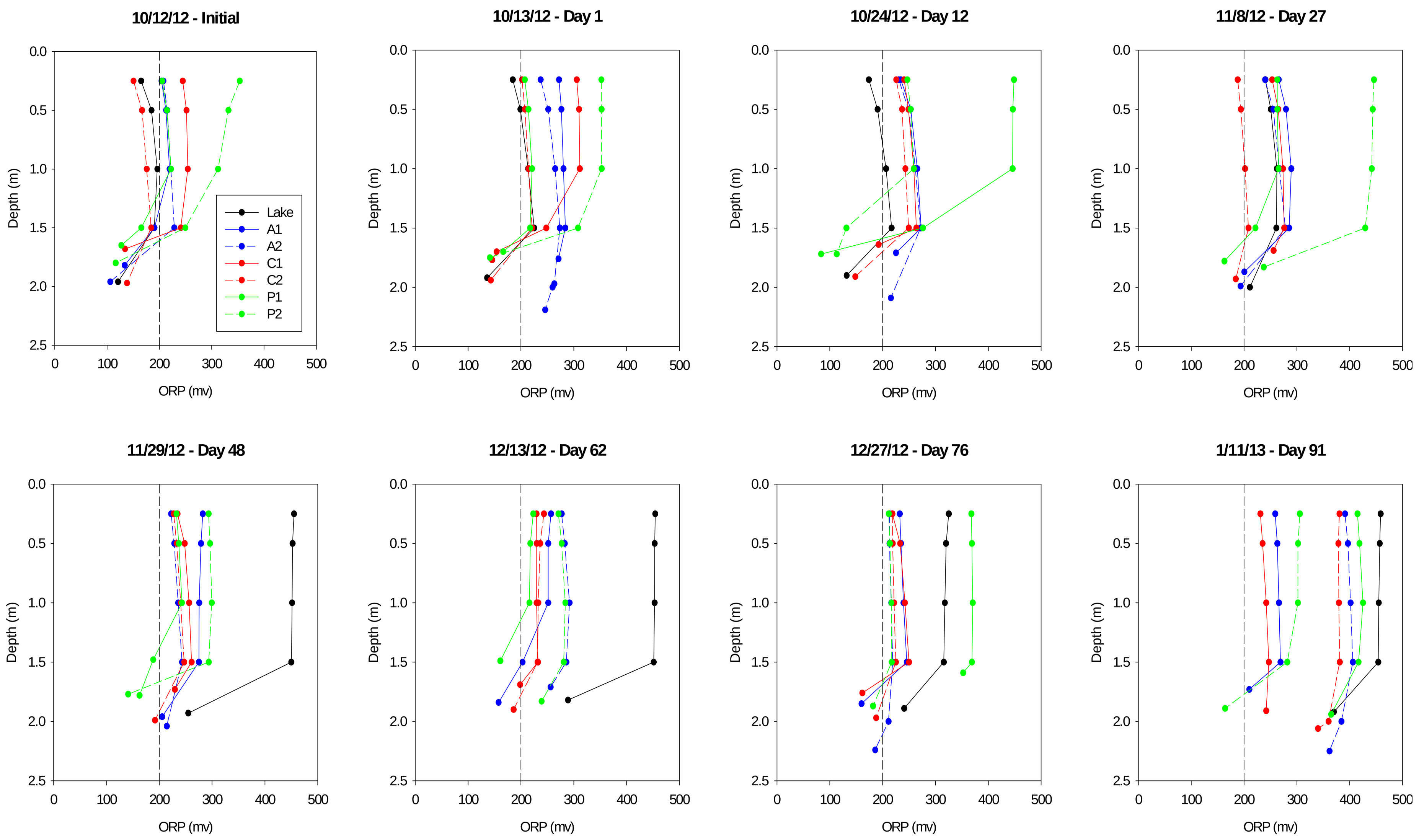


Figure 4-5. Summary of Oxidation-Reduction Potential (ORP) Profiles Collected in the Isolation Chamber Experiments from October 12, 2012-January 11, 2013.

Following addition of the chemical inactivants, redox conditions in the alum treated chambers improved substantially, with aerobic conditions observed throughout the entire water column in each of the two alum treated chambers. Reduced conditions (indicated by ORP values less than 200 mV) were observed near the water-sediment interface in the Phoslock and control chambers as well as within the open lake. A similar condition occurred on day 12 with aerobic conditions observed in the upper portions of the water column in each of the isolation chambers, although a slightly reduced condition was observed in upper portions of the water column within the open lake. The alum treated isolation chambers still maintained oxidized conditions throughout the water column, with reduced conditions observed in lower portions of the water column in each of the remaining chambers. ORP profiles collected on day 27 are similar to profiles measured on day 12 in upper portions of the water column. However, the reduced conditions observed in lower portions of the water column in the control, Phoslock, and open lake sites observed during day 12 have improved to borderline oxidized/reduced conditions at most sites. This general pattern is maintained in the isolation chambers on day 48, with oxidized conditions observed in the alum treated chambers throughout the entire water column and in one of the two Phoslock treated chambers. The same general pattern was maintained throughout the remainder of the monitoring program, although bottom redox conditions in the control and Phoslock chambers improved to oxidized conditions near the end of the field monitoring program.

4.1.6 Secchi Disk Depth

A graphical summary of measured Secchi disk depths in the isolation chambers and the open lake during the field monitoring program from October 12, 2012-January 11, 2013 is given on Figure 4-6. Prior to chemical additions, measured Secchi disk depths in each of the isolation chambers as well as the open lake were relatively similar in value, ranging from 0.60-0.62 m. A rapid, immediate improvement in water clarity was observed in the two alum treated isolation chambers, with measured Secchi disk depths of 1.76 m and 2.19 m measured 24-hours following chemical addition. No significant change in Secchi disk depth was observed in either the Phoslock or control chambers during the 24-hour monitoring event. Measured Secchi disk depths in the open lake and in control chamber C-1 were virtually identical throughout the entire monitoring period. A higher degree of variability in Secchi disk depth was measured in control chamber C-2 which exhibited periodic increases in Secchi disk depth.

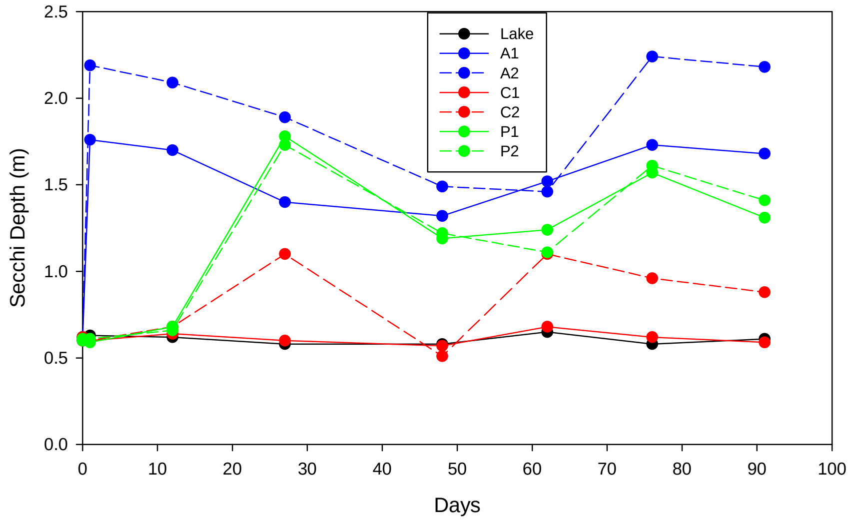


Figure 4-6.

Summary of Measured Secchi Disk Depths in the Isolation Chambers and Open Lake from October 12, 2012-January 11, 2013.

Following chemical addition, the alum treated chambers maintained excellent water clarity throughout the entire field monitoring program, with measured values ranging from 1.32-1.76 m in chamber A-1, and from 1.46-2.24 m in chamber A-2. With the exception of measurements conducted on day 27, the measured Secchi disk depths in the alum treated chambers were consistently higher in value than measurements conducted in the Phoslock chambers.

In the Phoslock chambers, the Secchi disk measurements conducted on day 12 were similar to the original values prior to chemical addition. Visual improvements in water clarity were not observed until day 27 of the field monitoring program. The lack of water clarity, combined with the elevated values for both pH, dissolved oxygen, and chlorophyll-a measured in the Phoslock chambers in day 12, suggest that an algal bloom event may have occurred in the Phoslock chamber following the chemical addition. However, beginning on day 27, water clarity in the Phoslock chambers improved, although the alum treated chambers exhibited a higher water clarity than the Phoslock chambers throughout the field monitoring program with the exception of day 27.

A tabular summary of mean values for field parameters measured in the Silver Lake isolation chambers during the field monitoring program is given in Table 4-1. The values summarized in this table reflect the mean of all measurements collected for each parameter and water depth with the exception of the measurements conducted near the water-sediment interface. The listed values for the control and lake samples reflect means calculated using all of the collected profiles. The listed values for the alum and Phoslock chambers include all measurements except the initial readings prior to chemical addition.

Measured temperature values in the isolation chambers and open lake were relatively similar in value, with mean temperatures ranging from 21.76-21.99 ^{o}C. Mean measured pH values were also relatively similar in value, ranging from 6.82-7.33. Measured conductivity values in the Phoslock, control, and lake samples were similar in value, ranging from 297-306 μmho/cm. However, somewhat higher conductivity values, ranging from 484-500 μmho/cm, were observed in the alum treated chambers. Measured dissolved oxygen concentrations were relatively similar between the isolation chambers and open lake, with mean dissolved oxygen concentrations ranging from 5-6.6 mg/l, with percent dissolved oxygen saturation values ranging from 57-74%. All measured ORP values in the isolation chambers were in excess of 200 mV, indicating oxidized conditions during the experimental period. However, substantial differences were observed in measured Secchi disk depths in the isolation chambers and open lake. The lowest measured Secchi disk depth was observed in the open lake, with a mean of 0.61 m. Mean Secchi disk depth in the control chambers ranged from 0.61-0.83 m, with a mean Secchi disk depth of 1.19 m in each of the two Phoslock chambers. The highest Secchi disk depths were observed in the alum treatment chambers, with mean values ranging from 1.59-1.93 m.

TABLE 4-1

SUMMARY OF MEAN FIELD PARAMETERS MEASURED IN THE SILVER LAKE ISOLATION CHAMBERS FROM OCTOBER 12, 2012-JANUARY 11, 2013

CHAMBER	TEMPERATURE (^{o}C)	pH (s.u.)	CONDUCTIVITY (μmho/cm)	DISSOLVED OXYGEN (mg/l)	% SATURATED D.O.	ORP (mV)	SECCHI DISK DEPTH (m)
A-1	21.83	7.13	500	6.6	74	262	1.59
A-2	21.93	6.82	484	5.3	61	273	1.93
P-1	21.97	7.33	301	6.4	74	308	1.19
P-2	21.87	7.23	297	5.9	67	299	1.19
C-1	21.85	7.16	306	5.9	67	253	0.61
C-2	21.99	7.08	300	5.0	57	250	0.83
Lake	21.76	7.31	305	6.2	70	334	0.61

4.2 Chemical Characteristics of Monitored Limno-Corrals

A complete listing of the laboratory measured chemical characteristics of surface water samples collected from each of the isolation chambers from October 12, 2012-January 11, 2013 is given in Appendix D.1. As discussed in Section 3, samples collected from the isolation chambers and the open lake reflect a composite of water collected from top, middle, and bottom portions of the water column. A discussion of short- and long-term water quality characteristics in each of the isolation chambers is given in the following sections.

4.2.1 General Parameters (pH, Alkalinity, Turbidity, and Color)

A graphical summary of temporal variability in laboratory measured concentrations of pH, alkalinity, turbidity, and color in the Silver Lake isolation chambers from October 12, 2012-January 11, 2013 is given on Figure 4-7.

4.2.1.1 pH

In general, measured pH values in the control, Phoslock, and lake samples were relatively consistent in value during the field monitoring program. An initial decrease in pH was observed in the alum treated samples, although by day 62, the alum treated chambers exhibited pH values similar to those measured at the remaining sites.

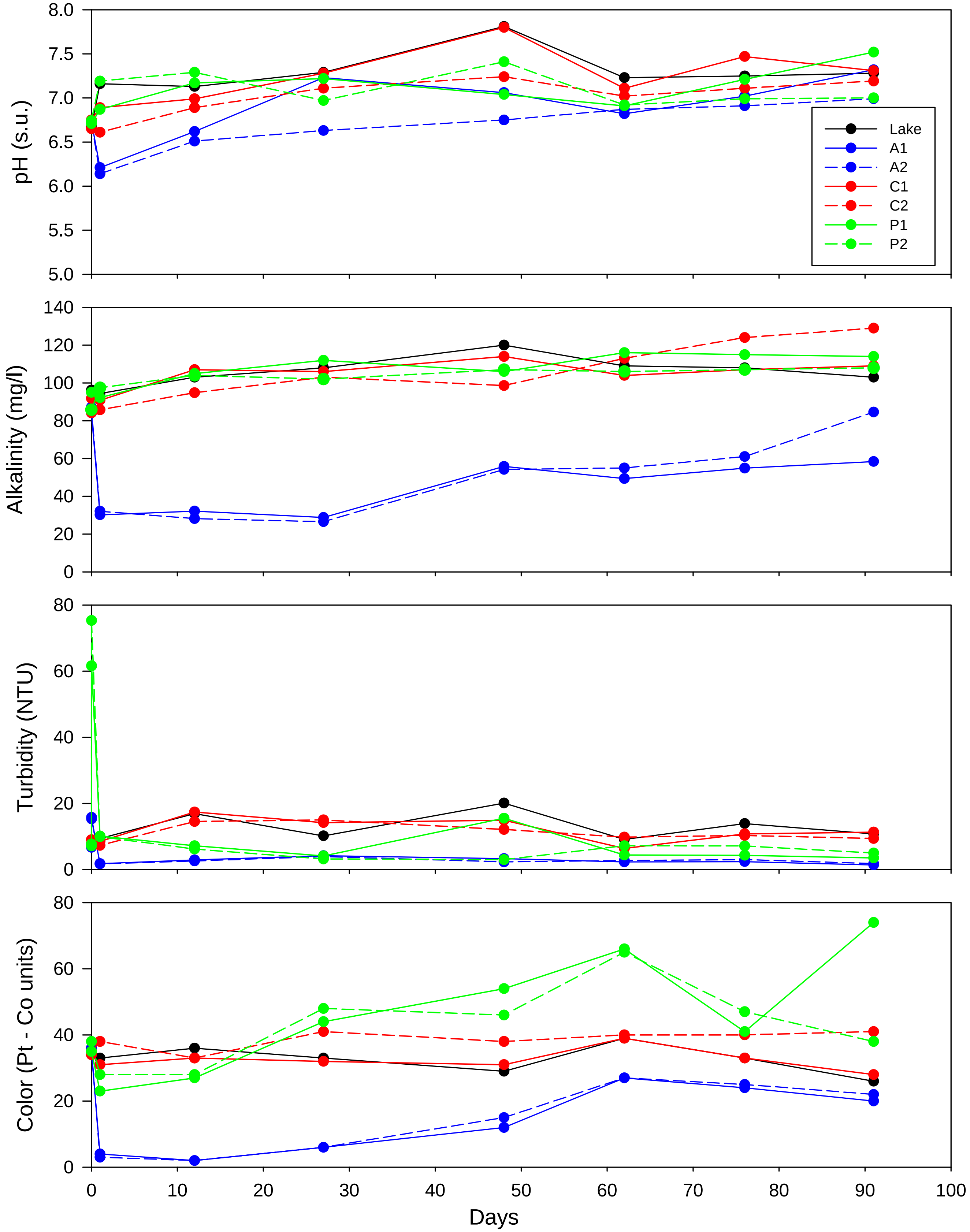


Figure 4-7. Temporal Variability in Laboratory Measured Concentrations of pH, Alkalinity, Turbidity, and Color in the Isolation Chambers from October 12, 2012-January 11, 2013.

4.2.1.2 Alkalinity

Initial alkalinity measurements in the isolation chambers and lake water ranged from approximately 85-95 mg/l, reflecting relatively well buffered conditions. The addition of Phoslock to the isolation chambers had minimal impact on measured alkalinity in the chambers. Relatively consistent alkalinity values were observed in the control, Phoslock, and lake samples throughout the field monitoring program. However, the addition of alum and sodium aluminate resulted in a rapid decrease in alkalinity to approximately 30 mg/l, measured 24 hours following chemical addition. The measured alkalinity values in the alum treated chambers increased gradually over time, reaching concentrations ranging from 58-85 mg/l by the end of the field monitoring program. The observed depression in alkalinity in the alum treated chambers is typical of alkalinity reductions commonly observed when using alum.

4.2.1.3 Turbidity

Measured turbidity values in the isolation chambers prior to chemical addition ranged from approximately 6.7-9.0 NTU. Immediately following the addition of the alum and Phoslock inactivants, increases in turbidity were observed in the alum treated chambers due to the alum floc, with turbidity increases in the Phoslock chambers resulting from the addition of the clay slurry. The experimental protocol for the project indicated that turbidity monitoring would be conducted only during the routine monitoring events. However, in view of the changes in turbidity which occurred during and following addition of the inactivants, turbidity measurements were conducted in each of the chambers approximately 30 minutes following chemical additions. A comparison of turbidity measurements collected in the isolation chambers approximately 30 minutes following chemical additions for each of the three isolation chamber experiments is given on Table 4-2. As discussed previously, the initial experiment was conducted using comparable 10:1 doses for aluminum and lanthanum. No significant increase in turbidity was observed in the alum chambers following the chemical addition. However, substantially elevated turbidity measurements, ranging from 755-757 NTU, were measured in the Phoslock chambers approximately 30 minutes after the initial chemical addition. These values are substantially in excess of the Class III surface water criterion of 29 NTU above background outlined in Chapter 302 of the Florida Administrative Code (FAC).

TABLE 4-2

TURBIDITY MEASUREMENTS COLLECTED IN THE ISOLATION CHAMBERS 30 MINUTES FOLLOWING CHEMICAL ADDITIONS

EXPERIMENT NUMBER	DOSE BASIS	MEASURED TURBIDITY (NTU) 30 MINUTES FOLLOWING CHEMICAL ADDITION		
		Control Chambers	Alum Chambers	Phoslock Chambers
1 (7/7/12)	Alum (10:1) Phoslock (10:1)	#1: 14.4 #2: 12.8	#1: 13.7 #2: 8.0	#1: 755 #2: 757
2 (8/3/12)	Alum (10:1) Phoslock (1:1)	#1: 7.5 #2: 8.1	#1: 17.2 #2: 20.4	#1: 113 #2: 102
3 (10/12/12)	Alum (10:1) Phoslock (1:1)	#1: 7.3 #2: 9.0	#1: 15.3 #2: 15.8	#1: 61.6 #2: 75.3

During the second experiment (conducted on August 3, 2012), alum was added at a 10:1 ratio, while the Phoslock addition was reduced to a 1:1 ratio. The alum addition on this date resulted in slight increases in turbidity within the alum treated chambers approximately 30 minutes following chemical addition. More substantial increases in turbidity were observed in the Phoslock treated chambers, with turbidity measurements ranging from 102-113 NTU.

The final isolation chamber experiment (initiated on October 12, 2012) was also conducted at an alum to phosphorus ratio of 10:1 and a Phoslock to phosphorus ratio of 1:1. During this experiment, increases in turbidity were observed in the alum treated chambers, compared to the control chambers, with measured turbidity values ranging from 15.3-15.8 NTU. Substantially higher turbidity values were measured in the Phoslock chambers, with measured turbidity values ranging from 61.6-75.3 NTU. These values also exceed the Class III criterion of 29 NTU above background. The 30-minute turbidity readings in each of the chambers are included on Figure 4-7.

In general, the addition of alum to the isolation chambers did not result in any exceedances of the Class III turbidity criterion during any of the three tests. However, turbidity measurements in the Phoslock chambers following the chemical additions indicated exceedances of the Class III turbidity criterion in all chambers on all dates. These data suggest that addition of Phoslock may result in a temporary violation of the Class III criterion for turbidity which would likely require a temporary waiver of the Class III turbidity standards from FDEP if Phoslock was to be used in a whole-lake application.

As indicated on Figure 4-8, an initial decrease in turbidity in the alum treated chambers was observed after 24 hours which continued throughout the majority of the 91-day monitoring program. The Phoslock chambers exhibited an initial increase in turbidity which decreased slowly over time. Turbidity measurements in the Phoslock chambers exceeded the turbidity measurements in the alum treated chambers on virtually all of the monitoring dates but were less than the control and lake on most monitoring dates. Measured turbidity values in the open lake and control chambers were relatively similar.

4.2.1.4 Color

Measured color concentrations in the isolation chambers ranged from approximately 34-38 Pt-Co units prior to chemical addition. Following the addition of alum, a substantial reduction in color occurred within the alum treated chambers which slowly increased throughout the field monitoring program. No significant change was observed in color concentrations within either the Phoslock or control chambers. Color within the Phoslock chambers appeared to increase steadily over time, with concentrations which were consistently greater than the control chambers throughout most of the monitoring period. The observed increases in color within the isolation chambers appear to be related to the repeated addition of Joe’s Creek water, which typically exhibits moderate color levels, into the isolation chambers.

4.2.1.5 Statistical Comparison

A statistical comparison of measured concentrations of pH, alkalinity, turbidity, and color in the Silver Lake isolation chambers is given on Figure 4-8 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 5 and 95 percentiles for the data sets. Individual values which fall outside of the 5-95 percentile range are indicated as **red dots**. Information summarized for the control and lake samples reflect all of the data collected during the 91-day field monitoring program. However, data summarized for the alum and Phoslock chambers does not include the initial sample collected prior to chemical addition since these samples reflect conditions prior to chemical additions.

As indicated on Figure 4-8, pH measurements in the Phoslock, control, and lake monitoring sites were relatively similar during the field monitoring program, with slightly lower pH values measured in the alum treated chambers. A similar pattern is also apparent for alkalinity, with relatively similar alkalinity values measured in the Phoslock, control, and lake chambers and lower alkalinity measurements in the alum treatment chambers. Relatively similar concentrations of turbidity were measured in the control and lake samples, with slightly lower turbidity measurements in the Phoslock chambers and the lowest turbidity measurements observed in the alum treated chambers. Measured color values in the Phoslock, control, and lake chambers were relatively similar in value, with a substantially lower color measured in the alum treated chambers.

4.2.2 Nitrogen Species

4.2.2.1 Ammonia

A graphical summary of temporal variability in measured concentrations of nitrogen species in the isolation chambers from October 12, 2012-January 11, 2013 is given on Figure 4-9. Initial concentrations of ammonia in the alum and Phoslock chambers ranged from approximately 200-400 μg/l, while initial ammonia concentrations in the control chambers were 10 μg/l or less. The initial higher ammonia concentrations observed in the alum and Phoslock chambers are probably related to sediment disturbances during installation of the limno-corral structures which caused small amounts of ammonia to be released from the anoxic sediments.

Ammonia concentrations in both the alum and Phoslock chambers increased steadily over time, reaching peak values in excess of 1000 μg/l by day 27. Following this date, ammonia concentrations in the Phoslock chambers remained at these elevated levels for the remainder of the field monitoring program. However, ammonia concentrations in the alum chambers exhibited a steady decrease, returning to near the original concentrations by the end of the field monitoring program. Ammonia concentrations in the control chambers as well as in the open lake were extremely low in value throughout the entire field monitoring program. Release of ammonia from anoxic sediments is a common occurrence in lakes and the observed elevated values are likely a result of ordinary sediment processes. The lack of ammonia build-up in the control chamber may be due to the continuous uptake by biological activity which was substantially reduced in the alum and Phoslock chambers.

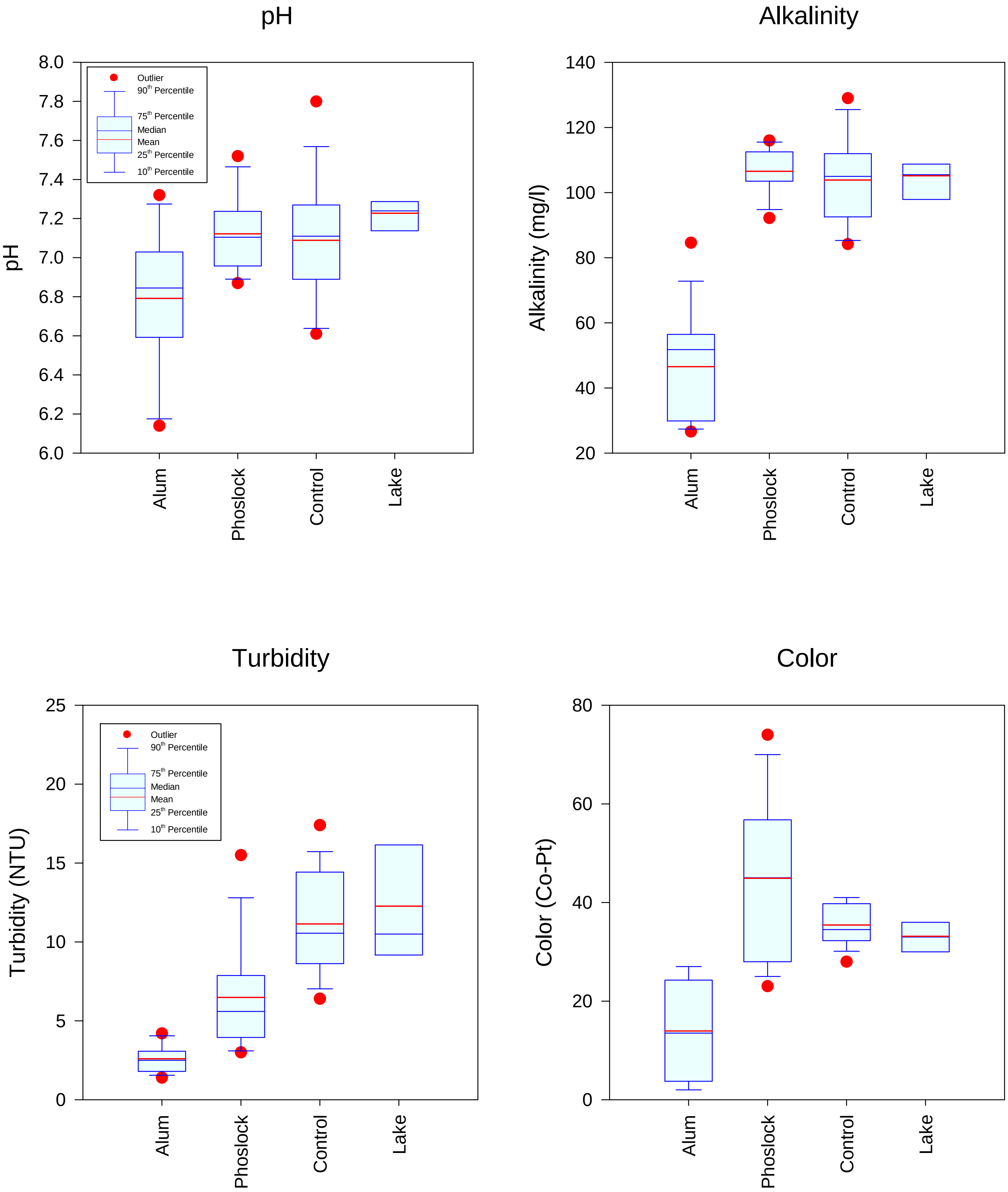


Figure 4-8. Statistical Comparison of Measured Concentrations of pH, Alkalinity, Turbidity, and Color in the Silver Lake Isolation Chambers.

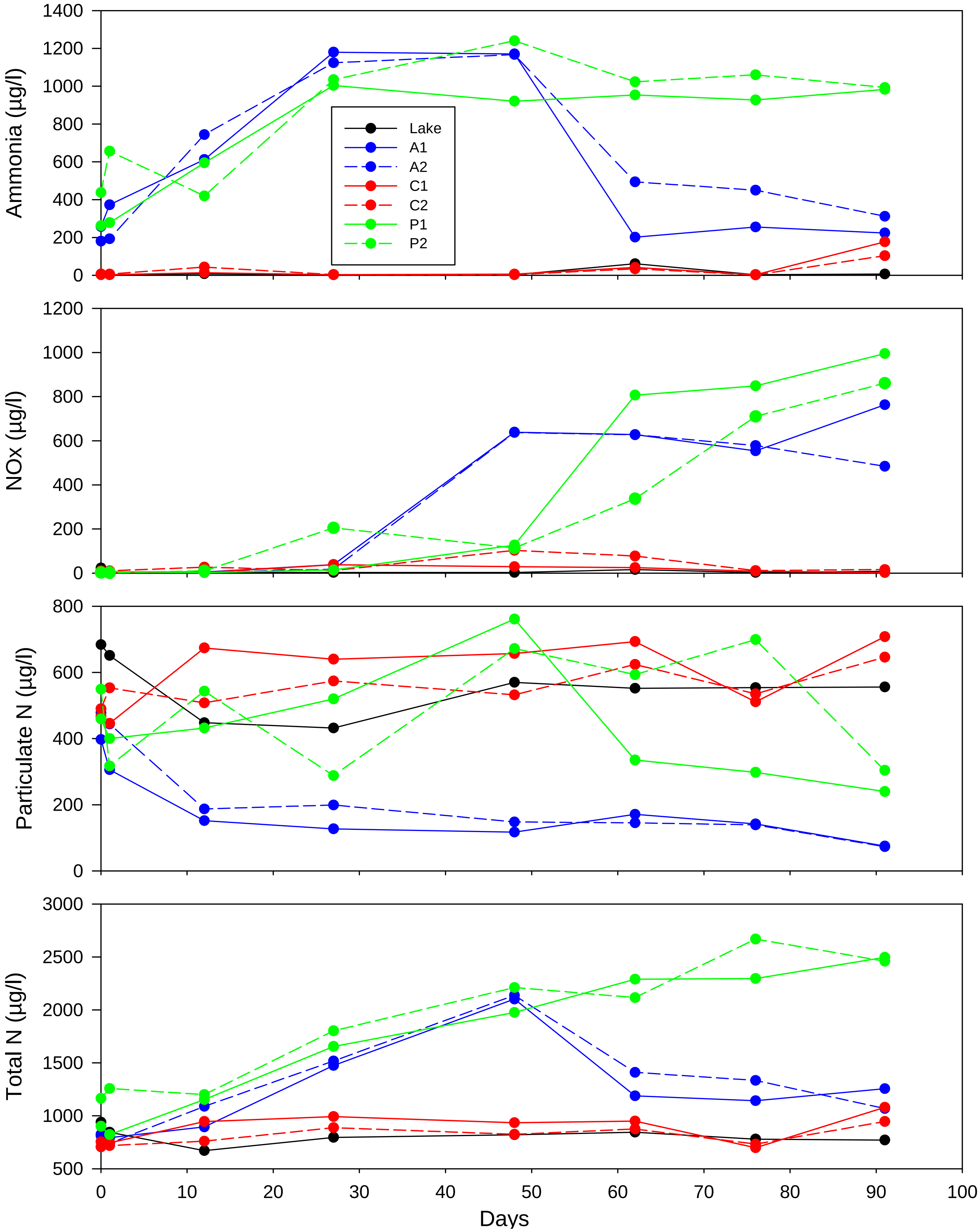


Figure 4-9. Temporal Variability in Measured Concentrations of Nitrogen Species in the Isolation Chambers from October 12, 2012-January 11, 2013.

Calculated concentrations for un-ionized ammonia in the isolation chambers are given in Appendix D.2. These calculations were conducted to evaluate potential for elevated levels of un-ionized ammonia given the high concentrations of ammonia observed in some of the isolation chambers. Calculations for un-ionized ammonia were conducted using the standard FDEP protocol which incorporates measurements for pH, temperature, and total ammonia. Measurements of total ammonia were obtained from the composite water samples collected in each of the isolation chambers, summarized in Appendix D. Input values for pH and temperature are based upon the vertical field profiles summarized in Appendix C.1 at a water depth of 1 m.

As seen in Appendix D.2, concentrations of un-ionized ammonia were generally low in value, with only one exceedances of the 20 µg/l criterion which occurred in Phoslock chamber 1 on October 24, 2012. No other exceedances of the un-ionized ammonia criterion were observed in any chamber on any monitoring date.

4.2.2.2 NO$_x$

Water column concentrations of NO$_x$ were initially extremely low in value in all of the isolation chambers as well as in the open lake, with concentrations typically less than 10 µg/l. No significant changes in NO$_x$ concentrations were observed during the first several weeks of the field monitoring program. However, beginning after approximately 30 days, increases in NO$_x$ concentrations were observed in both the alum and Phoslock chambers. By the end of the 91-day field monitoring program, NO$_x$ concentrations in the Phoslock chambers had increased to values of 995 µg/l and 861 µg/l. Increases in NO$_x$ concentrations also occurred in the alum treated chambers, although the magnitude of the final NO$_x$ concentrations was less than that observed for Phoslock. No significant changes were noted in NO$_x$ concentrations in the control chambers or within the open lake. Since processes responsible for release of both ammonia and NO$_x$ from lake sediments are biologically-mediated, the addition of the alum and Phoslock to the sediments appears to have provided conditions which increase the activity of organisms responsible for the conversion and release of ammonia and NO$_x$.

4.2.2.3 Particulate Nitrogen

Measured concentrations of particulate nitrogen in the isolation chambers were initially moderate in value, with pre-treatment concentrations ranging from approximately 200-500 µg/l. The addition of alum resulted in immediate and long-term reductions in particulate nitrogen concentrations which persisted throughout the field monitoring program. However, the addition of Phoslock did not appear to reduce particulate nitrogen concentrations for the first two months of the field monitoring program. During this time, virtually no difference was observed in particulate nitrogen concentrations measured in the Phoslock, control, or lake monitoring sites. However, beginning on day 62, one of the Phoslock chambers began to exhibit lower concentrations of particulate nitrogen, although still somewhat greater in value than concentrations achieved using alum. A similar reduction in particulate nitrogen concentrations was observed in the second Phoslock isolation chamber beginning on the final day of the field monitoring program.

4.2.2.4 Total Nitrogen

Overall, virtually no change was observed during the monitoring program in concentrations of total nitrogen in the control or in lake monitoring sites. Total nitrogen concentrations in both the Phoslock and alum chambers increased steadily for the first 40-50 days of the field monitoring program. After this date, nitrogen concentrations in the alum treated chambers began to decrease, reaching concentrations similar to the control chambers by the end of the field monitoring program. However, nitrogen concentrations in the Phoslock chambers continued to increase during the field monitoring program, approaching concentrations of approximately 2500 μg/l by day 91.

In summary, increases in total nitrogen concentrations occurred in both the alum and Phoslock treated chambers during the first half of the field monitoring program, due primarily to increases in ammonia and to a lesser extent NO_x. However, after this point, total nitrogen concentrations in the alum treated chambers began to decrease, while nitrogen concentrations in the Phoslock chambers continued to increase.

4.2.2.5 Statistical Comparison

A statistical comparison of measured concentrations of nitrogen species in the Silver Lake isolation chambers is given on Figure 4-10. Relatively elevated concentrations of both ammonia and NO_x were observed in the alum and Phoslock treated chambers, with concentrations near detection limits for these parameters in the control and lake samples. Measured concentrations of particulate nitrogen were similar in value in both the control and lake samples, with slightly lower particulate nitrogen concentrations observed in the Phoslock chambers and much lower particulate nitrogen concentrations observed in the alum treated chambers. Overall, measured total nitrogen concentrations in the control and lake samples were similar in value, with a slightly greater total nitrogen concentration in the alum treated chambers and a substantially greater total nitrogen concentration in the Phoslock chambers.

4.2.3 Phosphorus Species

4.2.3.1 SRP

A graphical summary of temporal variability in measured concentrations of phosphorus species in the isolation chambers from October 12, 2012-January 11, 2013 is given on Figure 4-11. Initially, each of the isolation chambers was characterized by SRP concentrations ranging from 6-8 μg/l. The addition of alum resulted in an immediate reduction in SRP to concentrations ranging from 2-3 μg/l, while the addition of Phoslock resulted in SRP concentrations ranging from 5-6 μg/l after 24 hours. The alum treated chambers maintained the initially observed low concentrations of SRP throughout the field monitoring program. However, increases in SRP concentrations were observed in the Phoslock chambers during much of the incubation period, although a final decrease in SRP concentrations occurred in the Phoslock chambers during the final monitoring event. In general, measured concentrations of SRP in the Phoslock chambers were similar to values measured in the control chambers.

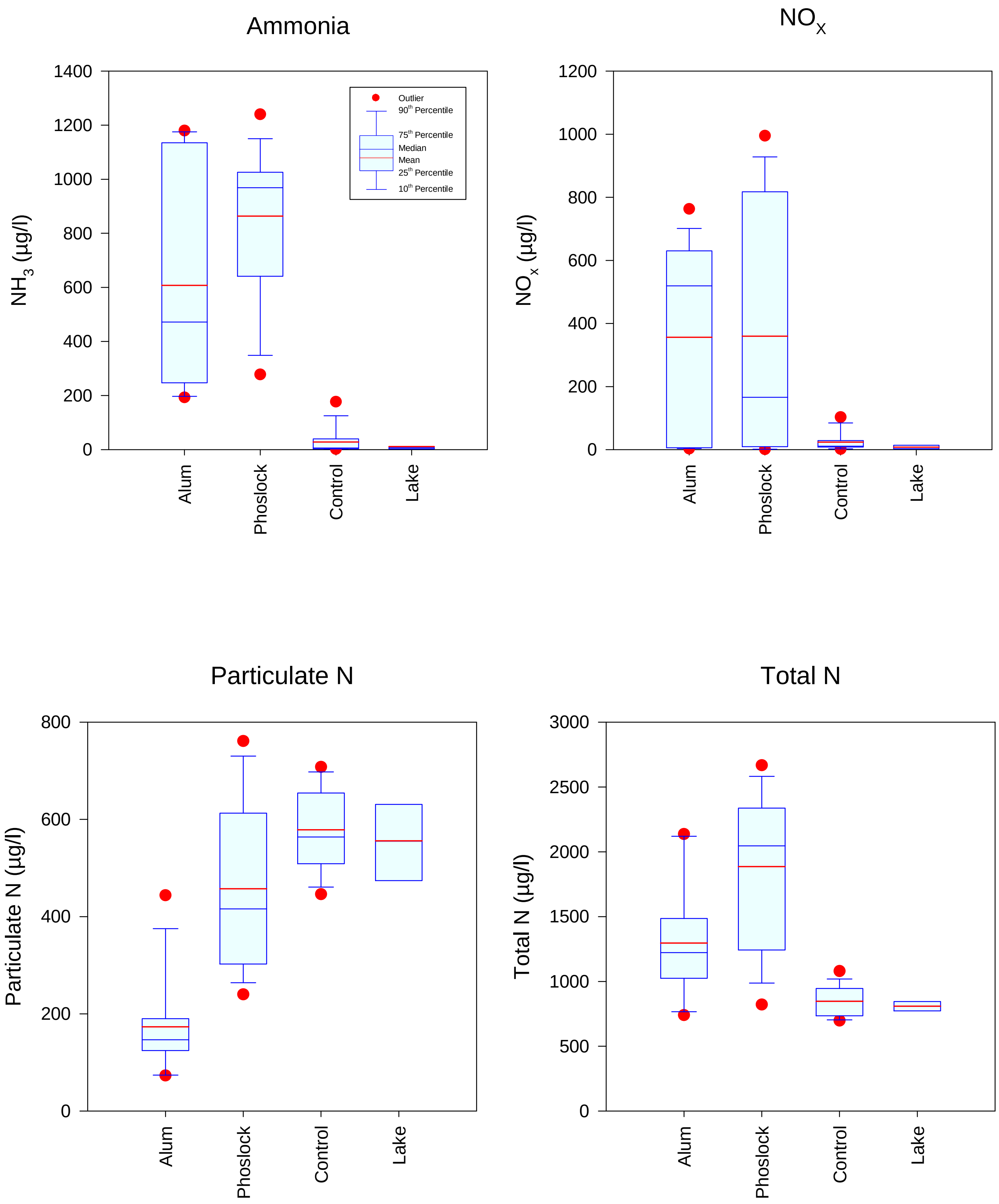


Figure 4-10. Statistical Comparison of Measured Concentrations of Nitrogen Species in the Silver Lake Isolation Chambers.

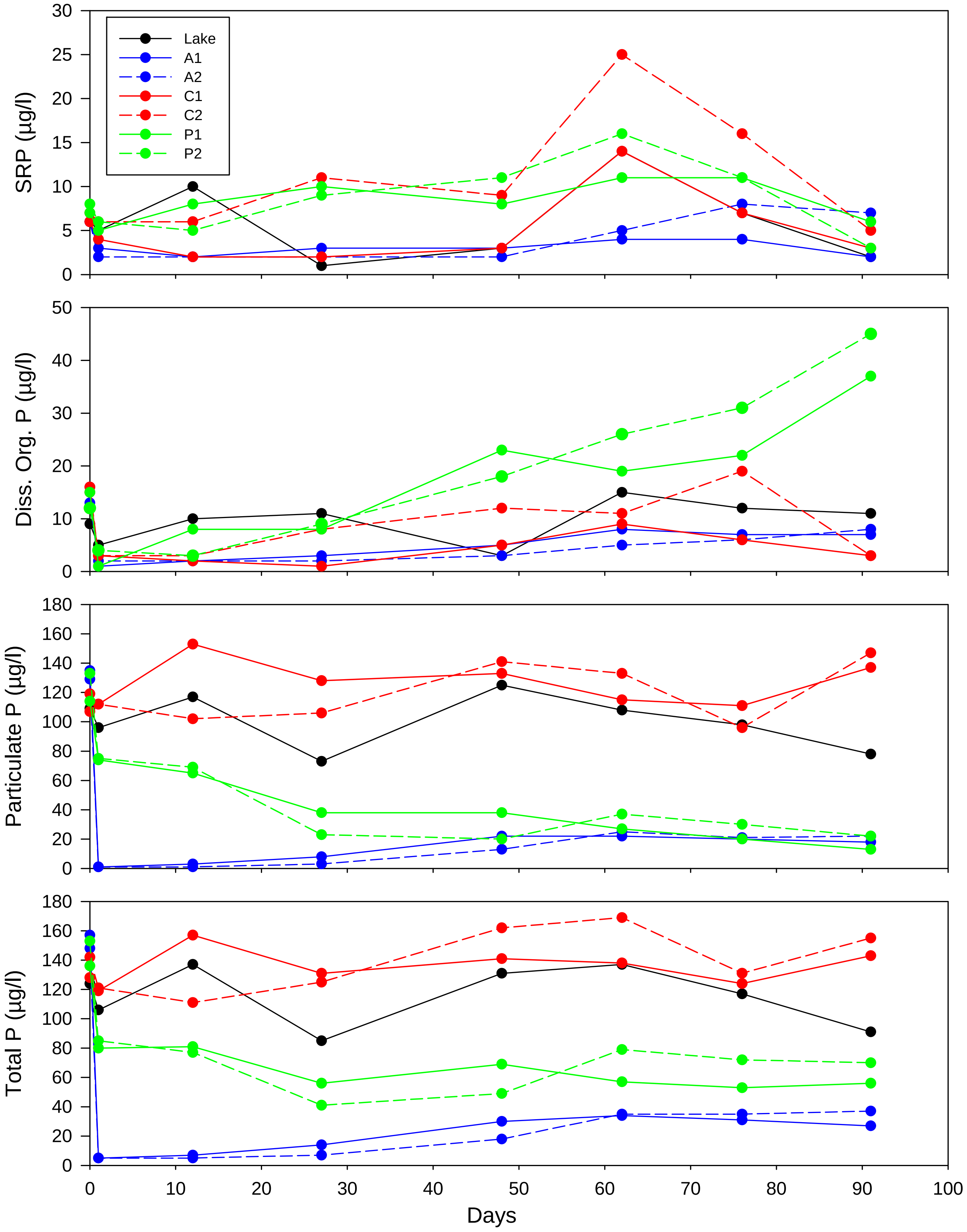


Figure 4-11. Temporal Variability in Measured Concentrations of Phosphorus Species in the Isolation Chambers from October 12, 2012-January 11, 2013.

4.2.3.2 Dissolved Organic Phosphorus

Initial concentrations of dissolved organic phosphorus in the isolation chambers were relatively low in value, ranging from approximately 9-16 µg/l. Substantial decreases in dissolved organic phosphorus were observed following alum addition, with reduced concentrations remaining throughout the 91-day monitoring program. Dissolved organic phosphorus concentrations in the control chambers and in the open lakes were approximately twice the concentrations observed in the alum treated chambers, on an average basis. However, dissolved organic phosphorus concentrations in the Phoslock chambers exhibited a steady increase in value over time, reaching values ranging from 37-45 µg/l at the end of the field monitoring program, with an apparent trend of continuing increases in values.

4.2.3.3 Particulate Phosphorus

Initial concentrations of particulate phosphorus in the isolation chambers were extremely elevated in value, ranging from 107-135 µg/l between the individual chambers. A rapid initial reduction in particulate phosphorus occurred in the alum treated chambers, with measured values on day 1 and day 12 ranging from 1-3 µg/l, eventually reaching equilibrium concentrations of particulate phosphorus ranging from approximately 20-25 µg/l. In the Phoslock treated chambers, an initial reduction in particulate phosphorus was observed, although the degree of reduction was substantially less than observed for alum. Further gradual decreases in particulate phosphorus were observed in the Phoslock chambers, until approximately day 62 when the particulate phosphorus concentrations in the alum and Phoslock chambers appeared to be relatively similar. No significant change in particulate phosphorus concentrations were observed in the control or lake samples during the field monitoring program.

4.2.3.4 Total Phosphorus

Initial concentrations of total phosphorus in the isolation chambers ranged from 128-157 µg/l. Overall, the addition of alum resulted in rapid and dramatic decreases in total phosphorus concentrations in the isolation chambers. A gradual increase in phosphorus concentrations occurred over time, reaching equilibrium total phosphorus concentrations ranging from 27-37 µg/l by the end of the field monitoring program. An initial decrease in total phosphorus was also observed in the Phoslock chambers, although the degree of concentration reduction was substantially less than observed using alum. Further reductions in total phosphorus occurred in the Phoslock chambers through day 27 of the field monitoring program, after which total phosphorus concentrations remained relatively constant throughout the remainder of the field monitoring program. No significant changes in total phosphorus concentrations were observed during the 91-day monitoring program in either the control or lake samples.

Overall, alum addition was successful in producing both immediate and prolonged reductions in total phosphorus concentrations in the isolation chambers for the duration of the monitoring program. The equilibrium total phosphorus concentrations of 27-37 µg/l achieved in the alum treated chambers are substantially lower than the equilibrium total phosphorus concentrations of 56-70 µg/l observed in the Phoslock chambers.

4.2.3.5 Statistical Comparison

A statistical comparison of measured concentrations of phosphorus species in the Silver Lake isolation chambers is given on Figure 4-12. The measured concentrations of SRP in the Phoslock, control, and lake samples were relatively similar in value throughout the field monitoring program, with substantially lower SRP values measured in the alum treated chambers. Measured concentrations of dissolved organic phosphorus were relatively similar in the control and lake samples, with a slightly higher value measured in the Phoslock chambers and a slightly lower concentration measured in the alum treated chambers. Particulate phosphorus concentrations were highly variable between the various monitoring sites, with substantially elevated values observed in both the control and lake samples, somewhat lower particulate phosphorus concentrations in the Phoslock chambers, and the lowest particulate phosphorus concentrations observed in the alum treated chambers. A similar pattern is also present for total phosphorous, with elevated concentrations of total phosphorus in both the control and lake samples, lower concentrations in the Phoslock chambers, and the lowest concentrations in the alum treated chambers.

4.2.4 Chlorophyll-a

A graphical summary of temporal variability in measured concentrations of chlorophyll-a in the isolation chambers from October 12, 2012-January 11, 2013 is given on Figure 4-13. Initial chlorophyll-a concentrations in the isolation chambers ranged from approximately 45.6-65.3 μg/l. The addition of alum resulted in immediate reductions in chlorophyll-a concentrations to values of approximately 1 μg/l or less. The addition of Phoslock had little impact on chlorophyll-a concentrations after 24 hours and actually resulted in increases in chlorophyll-a concentrations in Chamber P-2 by day 12. However, after day 12, chlorophyll-a concentrations decreased to values similar to those in the alum treated chambers, with measured chlorophyll-a values of 58.0 mg/m^3 and 82.1 mg/m^3 in the replicate chambers. The chlorophyll-a value of 82.1 mg/m^3 in the Phoslock chamber was the highest chlorophyll-a value measured in the chambers or open lake during the field monitoring program. No significant changes were observed in chlorophyll-a concentrations in the control or lake samples during the field monitoring program.

A statistical comparison of measured concentrations of chlorophyll-a in the Silver Lake isolation chambers is given on Figure 4-14. Measured chlorophyll-a concentrations in the control and lake samples were relatively similar in value. Chlorophyll-a concentrations in the Phoslock chambers were highly variable throughout the field monitoring program. The observed high variability in measured chlorophyll-a concentrations in the Phoslock chambers is due to the elevated concentrations of chlorophyll-a observed in the Phoslock chambers during the first two monitoring events where it appears that an algal bloom may have occurred within the chambers. However, following this event, chlorophyll-a concentrations in the Phoslock chambers decreased substantially and were similar to the alum treated chambers for the remaining duration of the field monitoring program. However, consistently lower concentrations of chlorophyll-a were observed in the alum treated chambers throughout the entire field monitoring period.

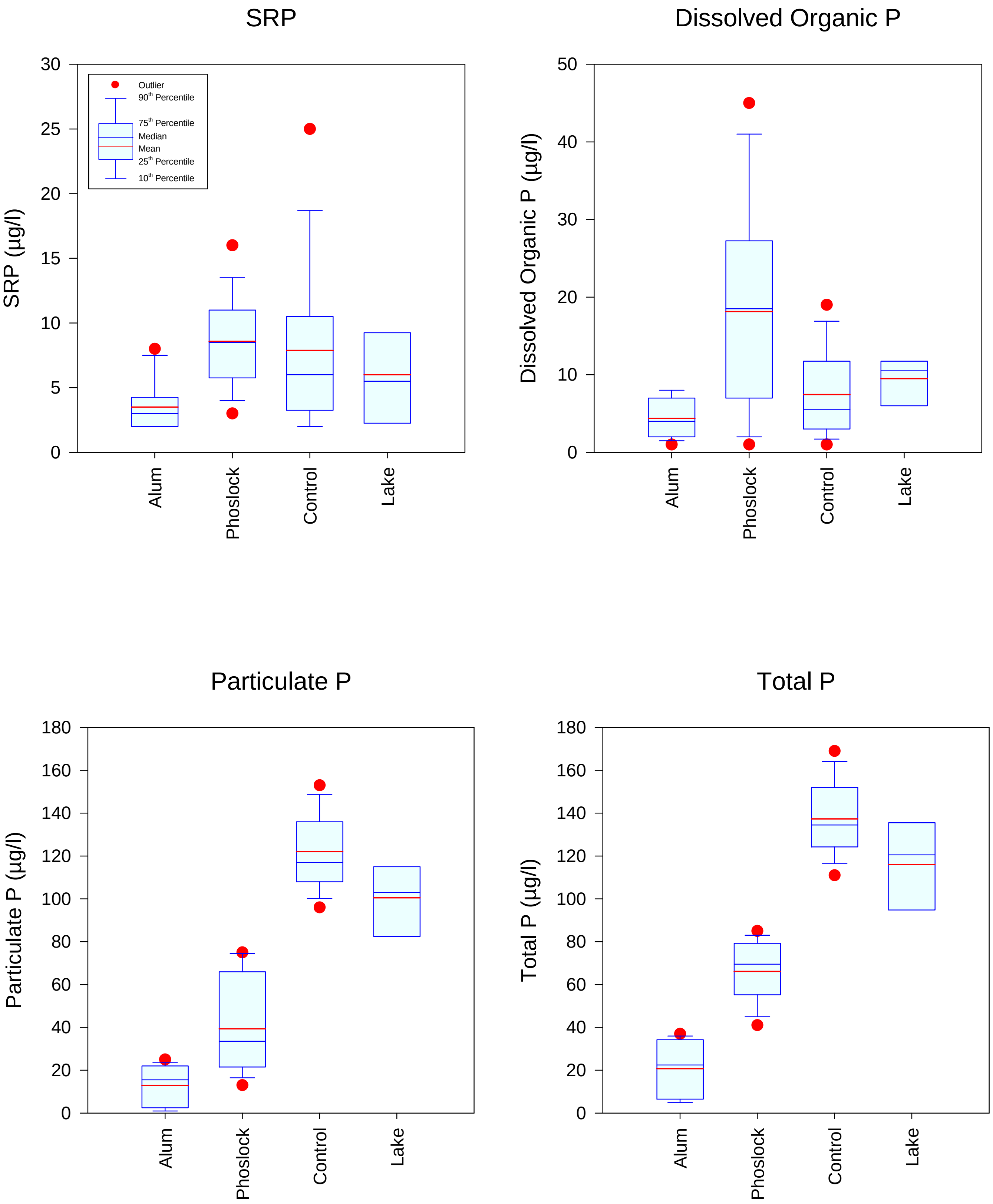


Figure 4-12. Statistical Comparison of Measured Concentrations of Phosphorus Species in the Silver Lake Isolation Chambers.

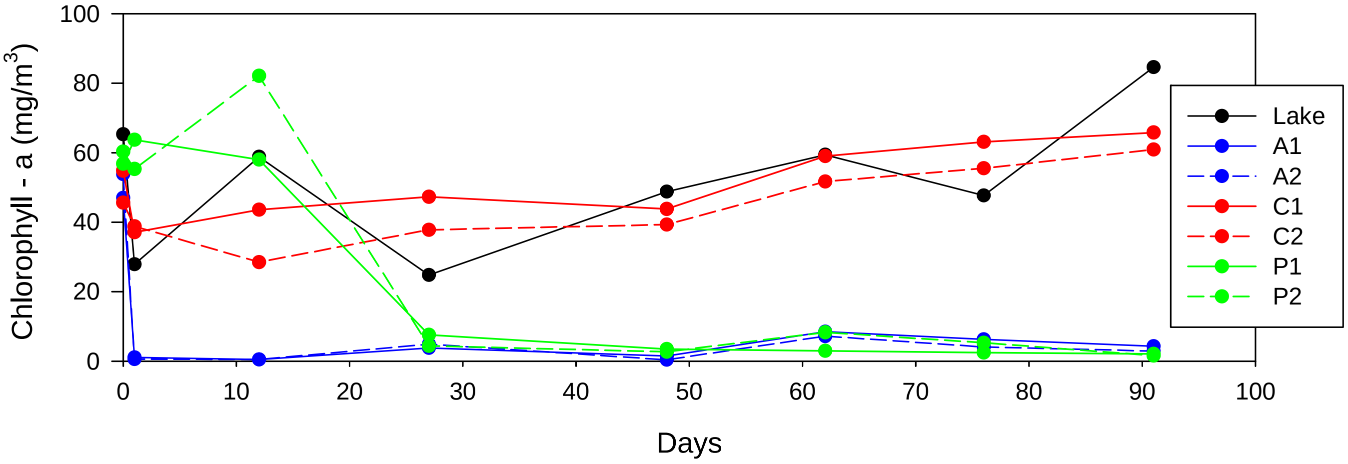


Figure 4-13. Temporal Variability in Measured Concentrations of Chlorophyll-a in the Isolation Chambers from October 12, 2012-January 11, 2013.

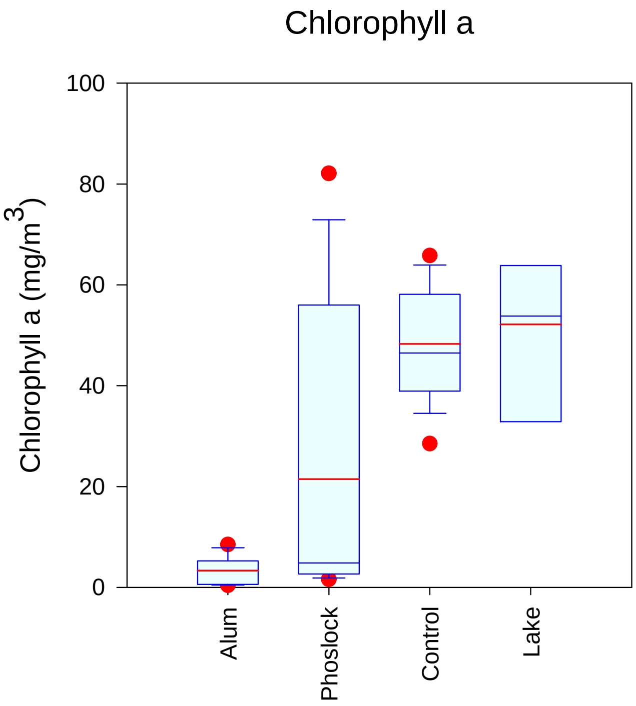


Figure 4-14. Statistical Comparison of Measured Concentrations of Chlorophyll-a in the Silver Lake Isolation Chambers.

4.3 Statistical Comparisons

A tabular comparison of mean characteristics of limno-corral chambers in Silver Lake from October 2012-January 2013 is given on Table 4-3. Geometric mean values are provided for each evaluated parameter in the alum, control, Phoslock, and lake monitoring sites. The mean values summarized for the control and lake samples reflect the geometric mean of all data collected at these sites. The geometric mean values listed for the alum and Phoslock chambers reflect all data beginning on day 1 and continuing through day 91 but exclude the initial samples collected prior to chemical addition since these samples do not reflect the impacts of the chemical additions.

TABLE 4-3

MEAN CHARACTERISTICS OF LIMNO-CORRAL CHAMBERS IN SILVER LAKE FROM OCTOBER 2012-JANUARY 2013

PARAMETER	UNITS	ALUM CHAMBERS	CONTROL CHAMBERS	PHOSLOCK CHAMBERS	LAKE SAMPLES
pH	s.u.	6.78	7.08	7.12	7.22
Alkalinity	mg/l	43.7	103	106	105
NH_3	µg/l	493	10	810	5
NO_x	µg/l	97	15	84	5
Diss. Organic N	µg/l	156	211	198	229
Particulate N	µg/l	155	573	429	550
Total N	µg/l	1,237	840	1,789	805
SRP	µg/l	3	7	8	5
Diss. Organic P	µg/l	4	6	12	9
Particulate P	µg/l	8	121	34	99
Total P	µg/l	16	136	65	114
Turbidity	NTU	2.5	10.7	5.8	11.7
Color	Pt-Co	10	35	42	33
Chlorophyll-a	mg/m^3	2.2	47.3	8.2	48.6

Mean pH values in the isolation chambers and open lake were relatively similar in value, ranging from 6.78-7.22, with the lowest pH value measured in the alum chambers and the highest pH value measured in the open lake. Mean measured alkalinity values in the control, Phoslock, and lake samples are relatively similar in value, with a somewhat lower mean alkalinity value measured in the alum chambers. Mean measured turbidity values in the control and lake samples averaged 10.7 NTU and 11.7 NTU, respectively, compared with a mean of 2.5 NTU in the alum chambers and 5.7 NTU in the Phoslock chambers. Measured color concentrations in the control and lake samples were relatively similar in value, ranging from 33-35 Pt-Co units. A slightly higher mean color concentration of 42 Pt-Co units was measured in the Phoslock chambers, with a substantially lower color of 10 Pt-Co units measured in the alum chambers.

The addition of alum and Phoslock resulted in increases in both ammonia and NO_x compared with the control and lake samples, with substantially higher ammonia concentrations measured in the Phoslock chambers compared with the alum chambers. Measured concentrations of dissolved organic nitrogen were relatively similar in the control, Phoslock, and lake samples, with a somewhat lower mean value observed in the alum chambers. A similar pattern is also apparent for particulate nitrogen, with relatively similar mean concentrations measured in the control, Phoslock, and lake samples, and substantially lower concentrations observed in the alum samples. Overall, total nitrogen concentrations in the control and lake samples were relatively similar in value, with mean concentrations ranging from 805-840 μg/l. A somewhat higher mean total nitrogen concentration of 1,237 μg/l was measured in the alum chambers, with an even higher mean concentration of 1,789 μg/l measured in the Phoslock chambers.

Extremely low levels of SRP, dissolved organic phosphorus, particulate phosphorus, and total phosphorus were measured in the alum treated chambers, with an overall mean total phosphorus concentration of 16 μg/l. More elevated mean concentrations of each of these parameters occurred in the Phoslock chambers which exhibited an overall mean total phosphorus concentration of 65 μg/l. Mean total phosphorus concentrations in the control and lake samples were 136 μg/l and 114 μg/l, respectively.

The addition of both alum and Phoslock resulted in substantial reductions in measured concentrations of chlorophyll-a, with an overall mean of 2.2 mg/m^3 for alum and 8.2 mg/m^3 for Phoslock. The overall mean chlorophyll-a concentrations for the control and lake were relatively similar, with mean values of 47.3 mg/m^3 and 48.6 mg/m^3, respectively.

A summary of percent change in mean characteristics in the limno-corral chambers in Silver Lake from October 2012-January 2013 is given in Table 4-4. The values summarized in this table reflect the percent change for the alum and Phoslock treated chambers compared with the control chambers. For total nitrogen, the alum treated chambers exhibited a mean increase of approximately 47%, with a 113% increase observed in the Phoslock chambers. The alum treated chambers exhibited a 53% reduction in SRP, 36% reduction in dissolved organic phosphorus, 94% reduction in particulate phosphorus, and 88% reduction in total phosphorus. In comparison, the Phoslock treated chambers exhibited a 19% increase in SRP, 114% increase in dissolved organic phosphorus, 72% decrease in particulate phosphorus, and 53% decrease in total phosphorus. The alum treated chambers also exhibited a 77% reduction in turbidity, 73% reduction in color, and 95% reduction in concentrations of chlorophyll-a. In contrast, the Phoslock chambers exhibited a 46% reduction in turbidity, 20% increase in color, and 83% reduction in chlorophyll-a.

TABLE 4-4

PERCENT CHANGE IN MEAN CHARACTERISTICS IN THE LIMNO-CORRAL CHAMBERS IN SILVER LAKE FROM OCTOBER 2012-JANUARY 2013

CHAMBERS	PERCENT CHANGE FROM CONTROL (%)							
	Total N	SRP	Diss. Org. P	Part. P	Total P	Turbidity	Color	Chlorophyll-a
Alum	47	-53	-36	-94	-88	-77	-73	-95
Phoslock	113	19	114	-72	-53	-46	20	-83

An additional statistical comparison was conducted using analysis of variance (ANOVA) to identify statistically significant differences in water quality characteristics between the treated and control isolation chambers in Silver Lake. ANOVA comparisons were conducted using the GLM procedure of SAS. The data sets were evaluated for normality and equality of variances prior to testing. The calculated model significance level is provided, with values of 0.05 or less indicating statistically significant differences at the 0.05 level of significance or better, and values in excess of 0.05 indicating a lack of statistical significance. Mean values are provided for each set of isolation chambers, as well as the open lake. The results of a Tukey grouping analysis are also provided which identify statistically similar treatment types. Mean concentrations for each parameter are listed from highest to lowest for each treatment type.

A summary of the results of the ANOVA comparisons of water quality characteristics in the Silver Lake limno-corrals is given on Table 4-5. Measured values for pH and alkalinity were statistically similar in the lake, control, and Phoslock chambers, with significantly lower values for these parameters observed in the alum treated chambers. For ammonia and NO_x, both Phoslock and alum exhibited statistically higher concentrations for these parameters than observed in either the control or lake. However, dissolved organic nitrogen concentrations in the lake, control, and Phoslock sites were statistically similar, with a significantly lower concentration in the alum treated chambers. For particulate nitrogen, the control and lake samples were statistically similar, with a statistically lower concentration in the Phoslock chamber and in the alum chamber. For total nitrogen, the Phoslock concentrations were statistically greater than any of the other monitoring sites. Total nitrogen concentrations measured in the alum and control chambers were statistically similar, with a statistically lower total nitrogen concentration measured in the lake samples.

Measured concentrations of SRP were found to be statistically similar in the Phoslock, control, and lake samples, with statistically lower SRP concentrations in the alum treated samples. Concentrations of dissolved organic phosphorus were statistically similar in the Phoslock and lake samples, with statistically lower dissolved organic phosphorus concentrations in the control and alum treated samples. For both particulate phosphorus and total phosphorus, each of the data sets were statistically different from one another, with the most elevated concentrations observed in the control chambers, followed by the lake, Phoslock, and alum treated chambers which exhibited the lowest concentrations for each of the two parameters.

TABLE 4-5
ANOVA COMPARISON OF WATER QUALITY CHARACTERISTICS IN THE SILVER LAKE LIMNO-CORRALS

PARAMETER	UNITS	MODEL SIGNIFICANCE LEVEL	CHAMBER	MEAN CONCENTRATION	TUKEY GROUPING
pH	s.u.	0.0006	Lake	7.31	A
			Control	7.14	A
			Phoslock	7.12	A
			Alum	6.79	B
Alkalinity	mg/l	0.0001	Phoslock	107	A
			Lake	106	A
			Control	106	A
			Alum	46.5	B
Ammonia	µg/l	0.0001	Phoslock	863	A
			Alum	607	A
			Control	32	B
			Lake	13	B
NO_x	µg/l	0.0011	Phoslock	360	A
			Alum	356	A
			Control	26	B
			Lake	6	B
Diss. Organic N	µg/l	0.0128	Lake	234	A
			Control	213	A
			Phoslock	205	A
			Alum	159	B
Particulate N	µg/l	0.0001	Control	593	A
			Lake	538	A
			Phoslock	457	B
			Alum	173	C
Total N	µg/l	0.0001	Phoslock	1,886	A
			Alum	1,296	B
			Control	863	B
			Lake	790	C
SRP	µg/l	0.0174	Phoslock	8.6	A
			Control	8.1	A
			Lake	6.0	A
			Alum	3.5	B
Diss. Organic P	µg/l	0.0002	Phoslock	18	A
			Lake	10	A
			Control	6	B
			Alum	4	B
Particulate P	µg/l	0.0001	Control	123	A
			Lake	99	B
			Phoslock	39	C
			Alum	13	D
Total P	µg/l	0.0001	Control	138	A
			Lake	115	B
			Phoslock	66	C
			Alum	21	D
Turbidity	NTU	0.0001	Lake	12.9	A
			Control	11.6	A
			Phoslock	6.5	B
			Alum	2.6	B
Color	Pt-Co	0.0001	Phoslock	45	A
			Control	36	B
			Lake	33	B
			Alum	14	C
Chlorophyll-a	mg/m^3	0.0001	Lake	50.3	A
			Control	48.0	A
			Phoslock	21.4	B
			Alum	3.3	C
Secchi Disk Depth	m	0.0001	Alum	1.76	A
			Phoslock	1.19	B
			Control	0.72	C
			Lake	0.61	C

For turbidity, both the Phoslock and alum treated chambers were statistically lower in value than either the lake or control. For color, Phoslock exhibited a statistically higher concentration than any of the other chambers. Statistically similar color concentrations were observed in both the control and lake samples, with a statistically lower color concentration observed in the alum chamber. Measured concentrations of chlorophyll-a were statistically similar in the lake and control chambers, with the Phoslock chamber statistically lower than the lake and control, and the alum chambers statistically lower than the Phoslock chambers. For Secchi disk depth, alum was statistically higher in value than either Phoslock, control, or lake. Phoslock was statistically higher than either the control or lake which appeared to be statistically similar in value.

4.4 Evaluation of Post-Treatment Sediment Phosphorus Release

At the conclusion of the field monitoring program, ERD conducted additional field and laboratory investigations to quantify the comparative mass of phosphorus released as a result of internal recycling from the sediments to the overlying water column in each of the isolation chambers and in the open lake. Large diameter undisturbed lake sediment core samples were collected from each isolation chamber and the open lake and incubated under anoxic conditions. Periodic measurements of orthophosphorus and other water quality parameters were used to estimate sediment phosphorus release under the evaluated conditions. This information is utilized to provide a comparison of the alum and Phoslock inactivants for reducing sediment phosphorus release.

4.4.1 Field and Laboratory Procedures

Sediment core samples were collected from each of the six isolation chambers and in the open lake using 4-inch diameter clear acrylic core tubes. Each of the acrylic tubes was driven into the sediments to the maximum possible depth using a large sledge hammer. A 4-inch x 4-inch wooden beam was placed on top of the acrylic core tube to evenly distribute the force of each sledge hammer blow and to prevent direct contact between the sledge hammer and the acrylic tube. The acrylic tubes were penetrated into the sediments to depths ranging from approximately 4-5 ft at each of the seven sites or until a firm bottom material was encountered. Each of the core tubes was retrieved intact, along with the overlying water column present at each of the collection sites. Upon retrieval, rubber caps were attached to the bottom and top of each core tube to prevent loss of sediments during transport. Each of the collected core tubes was then transported to the ERD laboratory for incubation experimentation. All samples were transported in a vertical position to avoid mixing of the sediment layers.

After return to the laboratory, each of the seven collected core samples was attached to a laboratory work bench in a vertical position. The collected water volume above the sediments was carefully siphoned off until a water depth of 24 inches remained in each of the collected columns above the sediment-water interface. A 4-inch PVC cap was then placed on the top of each collected core tube. Two separate 1/4-inch diameter holes were then drilled into the PVC cap. A 1/4-inch diameter semi-rigid polyethylene tube was inserted through one of the holes to a depth of approximately 2-3 inches above the sediment surface. An air stone diffuser was attached to the end of the tubing inside each core tube. This system was used to introduce selected gases into the core tubes to encourage aerobic or anoxic conditions.

A separate piece of polyethylene tubing was inserted into the second hole in the top of each core tube, approximately 1 inch below the level of the cap, but well above the water level contained in each tube. The other end of the tubing was connected to a water trap to minimize loss of water from each column as a result of evaporation. This tubing also provided a point of exit for gases which were bubbled into each core tube. A schematic of the sediment incubation apparatus is given in Figure 4-15.

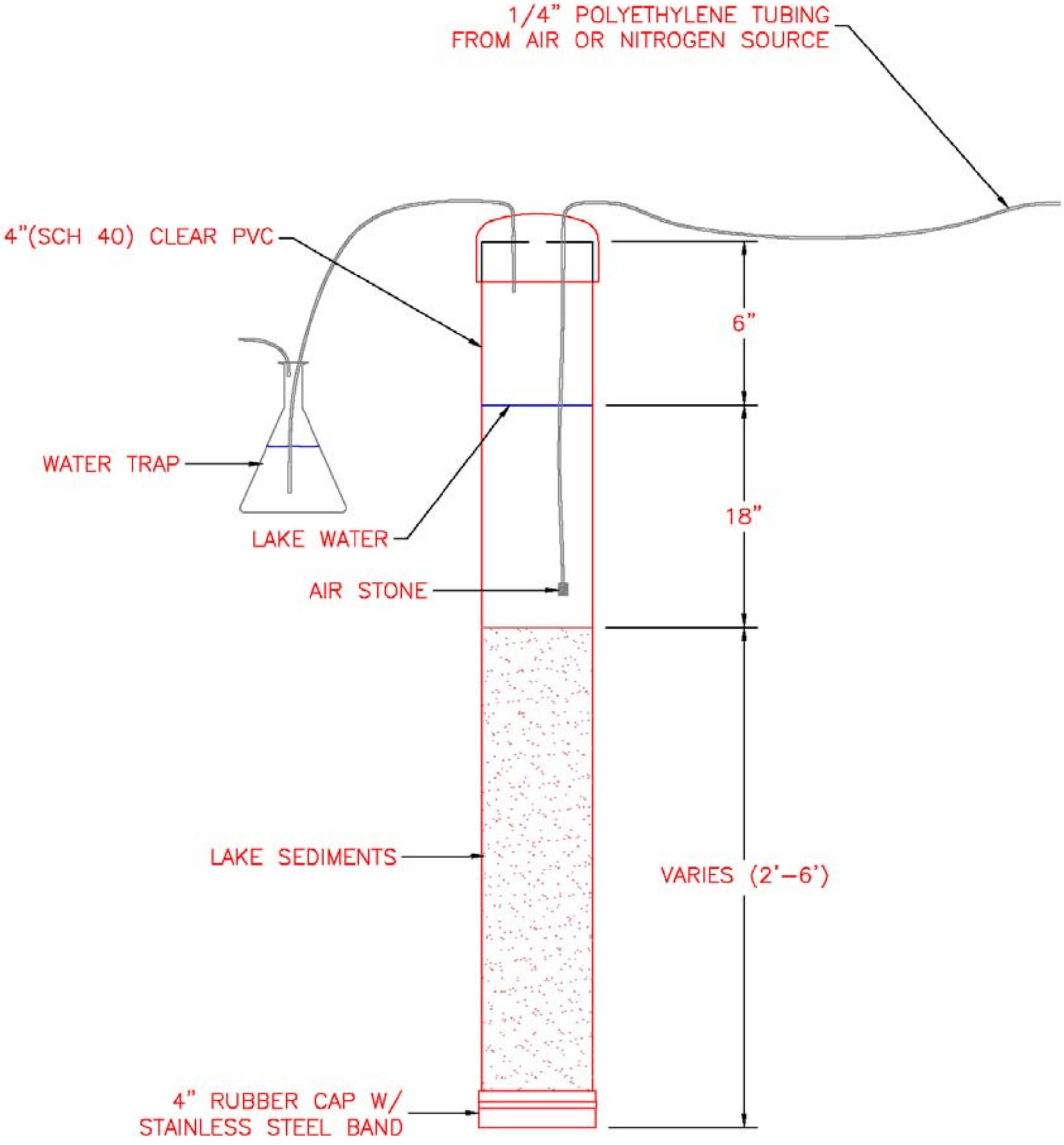


Figure 4-15. Schematic of Sediment Incubation Apparatus.

After initial set-up of the incubation apparatus, nitrogen gas was gently bubbled through each of the six columns to remove existing dissolved oxygen and create anoxic conditions within each tube. This process quickly created anoxic conditions within each of the core tubes and was continued in each of the core tubes for a period of approximately 30 days. In general, creation of anoxic conditions, as indicated by measurements of redox potential (< 200 mv) within each of the columns, occurred after approximately 1-2 days. Introduction of the nitrogen gas caused the water within each of the core tubes to be mixed without disturbing the sediments, so that phosphorus released from the sediments could be quantified as a function of changes in phosphorus concentrations within the water column of each core tube.

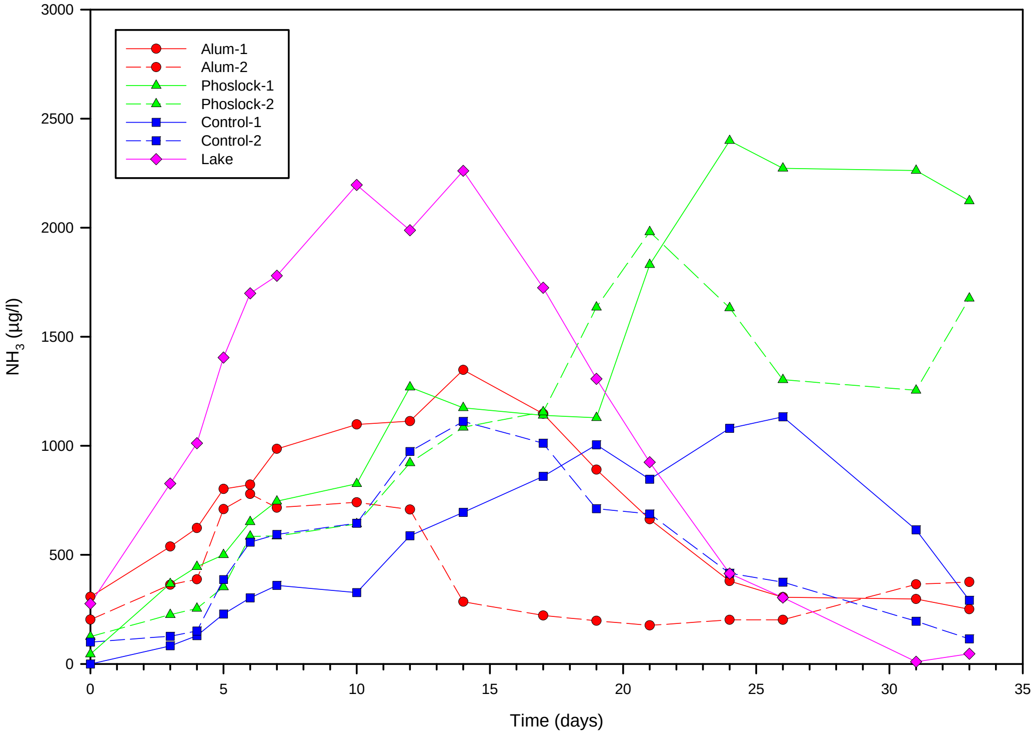
On approximately a 1-2 day interval, 20 ml of water was withdrawn from each of the columns using a 1/4-inch polyethylene tube and a plastic laboratory syringe. Each of the collected samples was immediately filtered using a 0.45 micron syringe mount membrane filter and analyzed for orthophosphorus, total phosphorus, and nitrogen species. Collection of the large diameter (4-inch) sediment core samples was performed during February 2013. Experimentation under aerobic conditions was initiated on February 21, 2013 and continued until April 1, 2013.

4.4.2 Results of Laboratory Testing

Each of the samples collected as part of the sediment incubation experiments was analyzed in the ERD Laboratory for NH_3, NO_x, total nitrogen, SRP, and total phosphorus. A total of 112 separate samples was collected as part of the incubation experiments conducted under anoxic conditions. A complete listing of the results of laboratory analyses conducted on sediment incubation samples under anoxic conditions is given in Appendix E.1.

A graphical comparison of changes in concentrations of ammonia and NO_x in the Silver Lake sediment core samples incubated under anoxic conditions is given on Figure 4-16. Concentrations of ammonia within each of the seven sediment core samples increased rapidly over the first 10-15 days of the incubation period. Relatively similar release rates of ammonia were observed over this period for the alum, Phoslock, and control sediment core samples, with a somewhat higher rate of release observed for the sediment core sample collected in the open lake. After approximately 10-15 days, ammonia concentrations in the alum, control, and lake core samples began to decrease, reaching final concentrations which were near the original starting concentrations. In contrast, release of ammonia continued to occur in the Phoslock chambers, although evidence of a slight decrease in ammonia concentrations is apparent in the Phoslock core samples near the end of the monitoring period.

Measured concentrations of NO_x were initially low in value in each of the sediment core samples, although a somewhat higher initial NO_x concentration was observed in the open lake sediment core sample. Measured NO_x concentrations remained relatively low in value during the first 5-10 days of the field monitoring program. However, beginning on day 10, increases in NO_x concentrations were observed in each of the two alum treated sediment core tube, one of the Phoslock core tubes, and one of the control core tubes. On day 17, increases in NO_x concentrations began to occur in the second Phoslock core tube and in the open lake core tube. Increases in NO_x concentrations in the second control chamber were delayed until approximately day 26 when rapid increases in NO_x concentrations were observed in this chamber as well. Measured NO_x concentrations in each of the seven core tube samples appeared to be approaching near-equilibrium concentrations at the end of the incubation period.



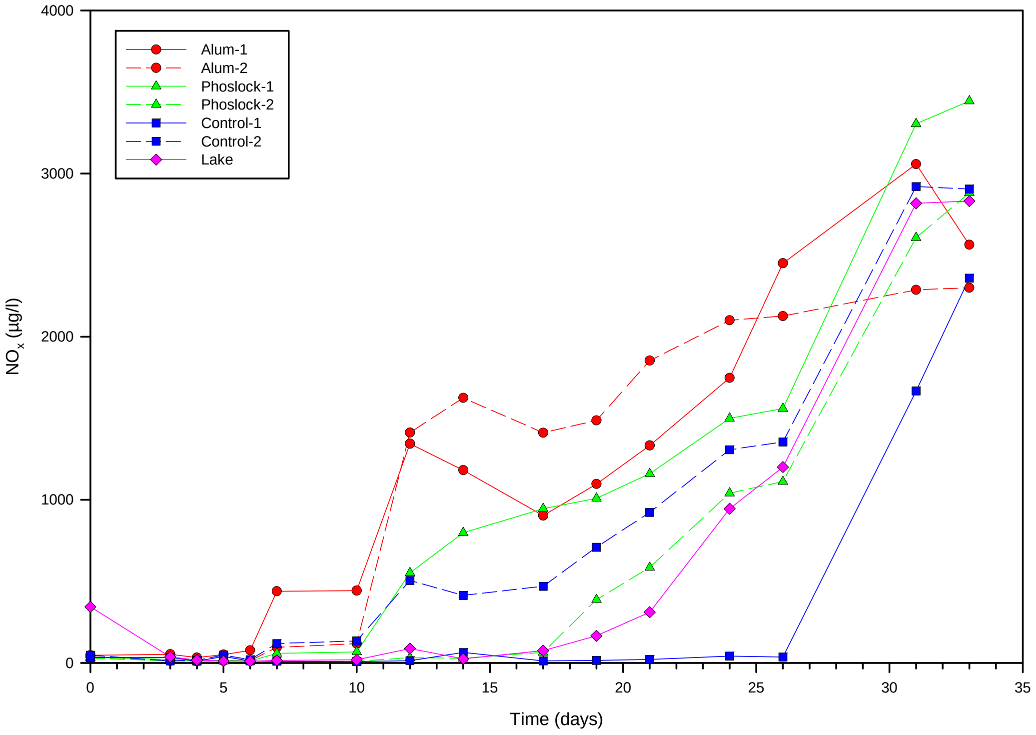


Figure 4-16. Changes in Concentrations of NH_3 and NO_x in Silver Lake Sediment Core Samples Incubated Under Anoxic Conditions.

At least a portion of the observed increases in NO_x concentrations may be related to nitrification processes which convert ammonia into NO_x. Since the ammonia observed in the core sample tubes originates from the sediments, the observed increases in NO_x after day 10, combined with the leveling off of ammonia release from the sediments, may be an indication that redox conditions have improved within the sediments from reduced to oxidized conditions which favors the release of NO_x rather than ammonia.

It is significant to note that the observed release of ammonia from the sediments occurred in each of the seven sediment core chambers throughout the laboratory incubation period. The observed similarity in release rates for ammonia from both the treated and non-treated sediment core samples suggests that release of ammonia from the sediments is an ongoing process in Silver Lake and not a phenomenon which is mediated by the addition of either alum or Phoslock. In the open lake, the ammonia is quickly diluted into the overlying water column where it becomes available for uptake through biological activity, and as a result, does not accumulate within the water column as observed in the sediment core chambers.

A graphical comparison of changes in concentrations of total nitrogen in the Silver Lake sediment core samples incubated under anoxic conditions is given on Figure 4-17. In general, gradual increases in concentrations of total nitrogen were observed in each of the seven sediment core chambers throughout the incubation period. Release rates for the alum, control, and lake core samples appear to be relatively similar, with a slightly higher degree of sediment release of nitrogen observed in the two Phoslock chambers. The release patterns for total nitrogen observed on Figure 4-17 suggests that nitrogen release is a phenomenon which is occurring in each of the sediment core chambers and not specifically related to the addition of either alum or Phoslock.

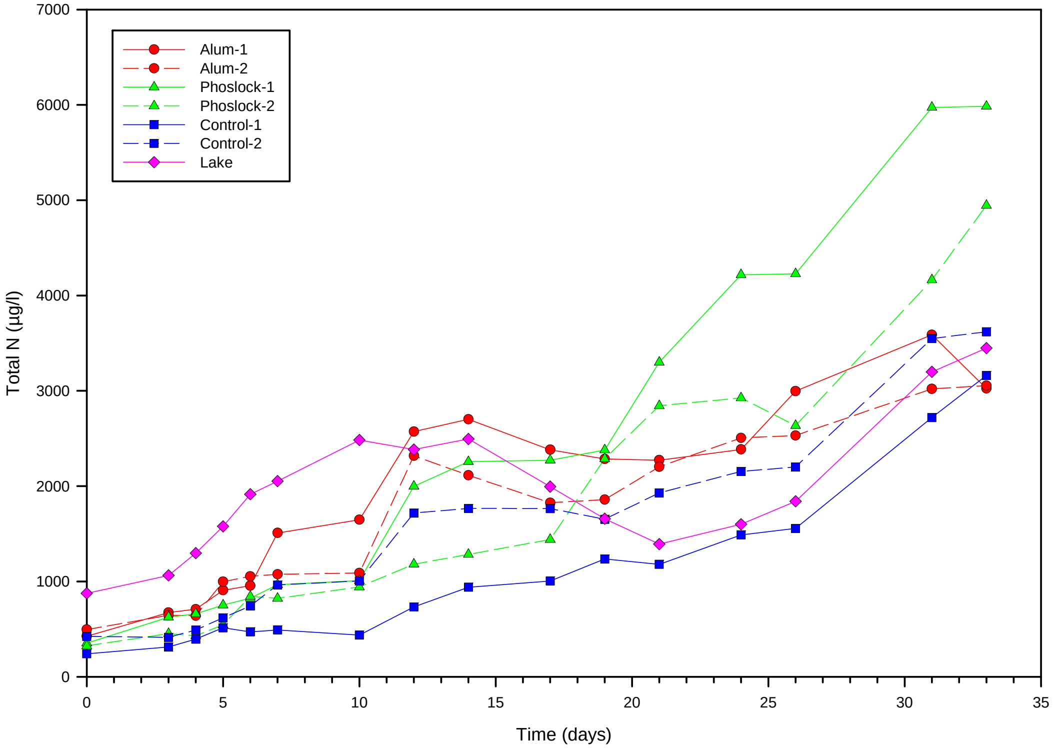


Figure 4-17. Changes in Concentrations of Total Nitrogen in Silver Lake Sediment Core Samples Incubated Under Anoxic Conditions.

A graphical comparison of changes in concentrations of SRP and total phosphorus in the Silver Lake sediment core samples incubated under anoxic conditions is given on Figure 4-18. Initial concentrations of SRP were low in value in each of the seven core sample chambers at the start of the incubation program. Rapid increases in SRP concentrations, indicating significant release from the anoxic sediments, were observed in each of the two control core samples as well as in the open lake. Substantially lower measured concentrations of SRP were observed in the Phoslock and alum treated sediment core samples, with very little change in SRP concentrations observed in the two alum treated core samples, and a slightly higher release rate observed in the Phoslock core samples. Overall, measured SRP concentrations in the alum treated chambers were approximately one-half to one-third of the SRP concentrations observed in the Phoslock treated chambers.

A similar pattern is also apparent for measured concentrations of total phosphorus. Substantial increases in total phosphorus over time were observed in the control and lake sediment core chambers, with substantially lower amounts of total phosphorus released from the Phoslock and alum treated chambers. The measured concentrations of total phosphorus in the alum treated chambers were approximately one-third to one-half of the concentrations observed in the Phoslock treated chambers.

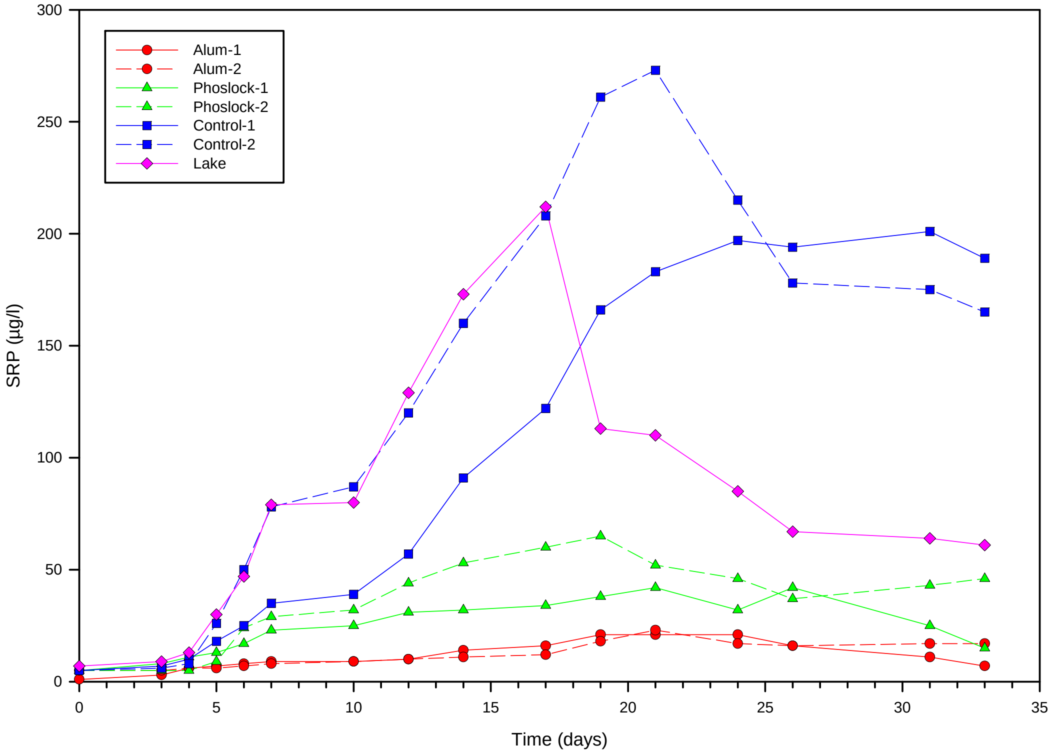
4.4.3 Mass Release Rates

Mass release rates for phosphorus and nitrogen can be calculated as the slope of the rising limb for each of the concentration plots summarized on Figures 4-16 through 4-18. Regression analyses were conducted over the rising limb for each of the data sets summarized in Appendix E.1. A summary of this analysis is given in Appendix E.2. Calculated release rates are provided for SRP, total phosphorus, and total nitrogen in Table 4-6. Release rates for SRP and total phosphorus in the alum treated chambers are typically less than 1 µg/l per day, while release rates in the Phoslock treated chambers range from approximately 2-4 µg/l per day. Phosphorus release rates in the control chamber were substantially higher, ranging from 9-15 µg/l per day, with 13-14.4 µg/l per day released in the lake sediment sample.

TABLE 4-6

MEASURED SEDIMENT RELEASE RATES FOR SRP, TOTAL PHOSPHORUS, AND TOTAL NITROGEN IN THE SILVER LAKE CORE SAMPLES UNDER ANOXIC CONDITIONS

CHAMBER	RELEASE RATE (µg/l per day)		
	SRP	Total Phosphorus	Total Nitrogen
A-1	0.88	1.09	94.7
A-2	0.82	0.76	130
P-1	1.79	2.06	177
P-2	3.91	4.33	131
C-1	9.06	9.46	82.3
C-2	14.23	14.62	93.8
Lake	13.15	14.43	130



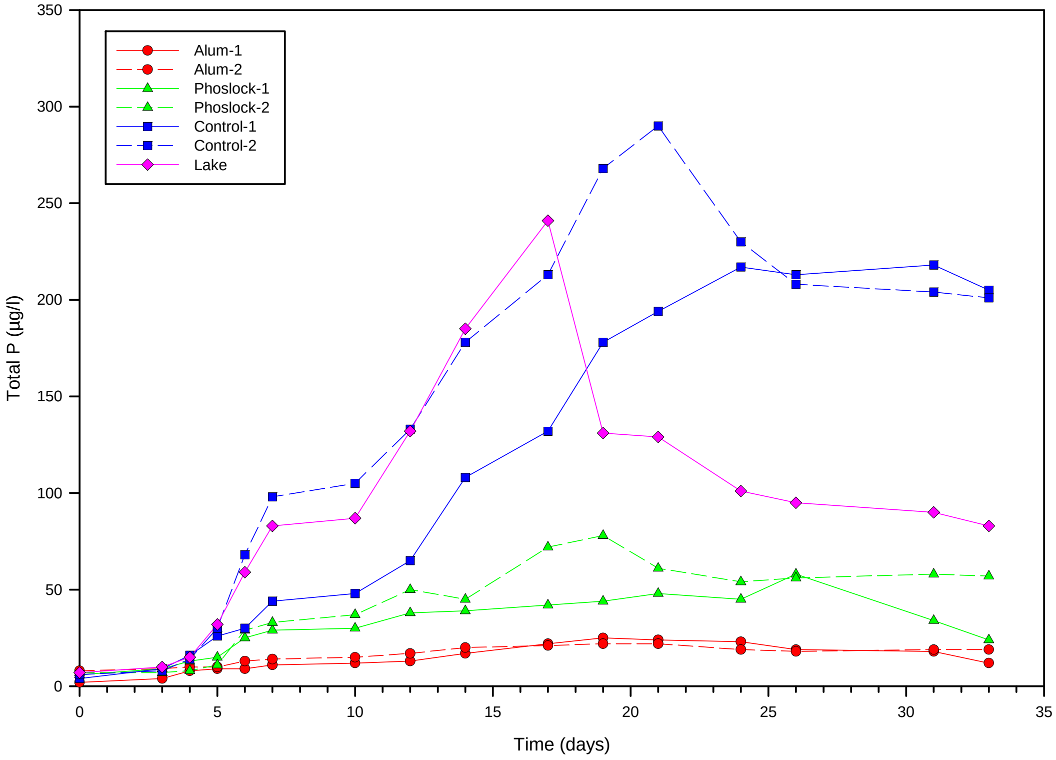


Figure 4-18. Changes in Concentrations of SRP and Total Phosphorus in Silver Lake Sediment Core Samples Incubated Under Anoxic Conditions.

A summary of mean sediment release rates for SRP, total phosphorus, and total nitrogen in the Silver Lake core samples incubated under anoxic conditions is given in Table 4-7. The values summarized in this table reflect the geometric mean of the individual release rates for the chambers summarized in Table 4-6. Mean release rates for SRP and total phosphorus in alum treated sediments were 0.85 µg/l per day and 0.91 µg/l per day, respectively. Mean phosphorus release rates in the Phoslock chambers for SRP and total phosphorus were 2.64 µg/l per day and 2.99 µg/l per day, respectively. Substantially higher release rates for SRP and total phosphorus were observed in the control cores, ranging from approximately 11-12 µg/l per day, with a release rate of 13-14 µg/l per day in the open lake core sample. Substantially higher release rates were observed for total nitrogen in each of the seven core sample experiments, ranging from 88 µg/l per day in the control core samples to 152 µg/l per day in the Phoslock treated core samples.

TABLE 4-7

SUMMARY OF MEAN SEDIMENT RELEASE RATES FOR SRP, TOTAL PHOSPHORUS, AND TOTAL NITROGEN IN THE SILVER LAKE CORE SAMPLES UNDER ANOXIC CONDITIONS

TREATMENT	**RELEASE RATE (µg/l per day)**		
	SRP	**Total Phosphorus**	**Total Nitrogen**
Alum	0.85	0.91	111
Phoslock	2.64	2.99	152
Control	11.36	11.76	88
Lake	13.15	14.43	130

A comparison of relative inhibition of sediment nutrient release by alum and Phoslock compared with the control core samples is given in Table 4-8. The values summarized in this table reflect the mean release rates for SRP, total phosphorus, and total nitrogen (summarized in Table 4-7) expressed as a percentage of the control. Release of SRP and total phosphorus in the alum treated samples were approximately 7.5% and 7.7%, respectively, of the release measured in the control chambers. In the Phoslock treated chambers, the SRP and total phosphorus release increased to 23-25% of the control chambers. Release of nitrogen from the lake sediments in the alum treated chambers was approximately 126% of the control release, with 173% of the nitrogen control release observed in the Phoslock treated chambers. However, as discussed previously, the higher net nitrogen release observed with the two inactivants is likely a continuous occurrence in Silver Lake and the build-up of nitrogen in these chambers is due to a lack of significant uptake mechanisms compared with the control.

TABLE 4-8

RELATIVE INHIBITION OF SEDIMENT RELEASE BY ALUM AND PHOSLOCK COMPARED WITH THE CONTROL CORE SAMPLES

TREATMENT	FRACTION OF CONTROL RELEASE (%)		
	SRP	**Total Phosphorus**	**Total Nitrogen**
Alum	7.5	7.7	126
Phoslock	23	25	173

The data summarized in this section from the sediment core incubation experiments suggest that alum treated sediments provide a substantially lower rate of phosphorus release than Phoslock treated sediments using the Phoslock dosage rates recommended by the Phoslock representative. The phosphorus release rates in the alum treated sediments were approximately one-third of the release rates observed for phosphorus in the Phoslock treated chambers. Increases in sediment nitrogen release were also observed in the alum and Phoslock treated chambers compared with the control.

4.5 Impacts on Nitrogen Loadings

Since Silver Lake discharges to Joe's Creek which is a tributary to an estuarine waterbody, loadings of nitrogen are a potential concern since many estuarine waterbodies are considered to be nitrogen-limited. The limno-corral experiments indicated increases in concentrations of ammonia and NO_x within the alum treated and Phoslock treated chambers, with no significant increase in nitrogen concentrations in the control and in-lake samples. However, during the sediment incubation studies discussed in Section 4.4, significant release of ammonia and NO_x was observed in each of the collected sediment samples, including the alum, Phoslock, control, and lake sites. ERD has frequently observed large releases of ammonia from anoxic sediments in both field and laboratory investigations, and significant ongoing release of ammonia from Silver Lake sediments appears likely. It is possible that the observed increases in ammonia and NO_x in the isolation chamber experiments simply reflects the ongoing process of ammonia release from sediments within Silver Lake.

Due to the ongoing high rate of algal productivity which appears to occur in Silver Lake, the released ammonia and NO_x is relatively quickly absorbed, and accumulation resulting in increased concentrations does not occur in the open lake to the extent that it occurred in the in-lake isolation chambers and the sediment incubation experiments. Other than a change in redox condition which would cause release of NO_x rather than ammonia, there is no known physical or chemical mechanism by which alum or Phoslock would result in increases of sediment nitrogen. ERD has conducted more than 40 sediment inactivation projects within the State of Florida, and increases in total nitrogen concentrations has never been observed in any of these treatments. In contrast, long-term nitrogen reductions of approximately 30-40% are commonly observed in alum treated lakes.

4.6 Summary

Based upon the results discussed in the previous sections, both the alum and Phoslock treated chambers resulted in reductions in measured concentrations for total phosphorus, turbidity, and chlorophyll-a, with resulting increases in Secchi disk depth. However, the water quality improvements achieved within the alum treated chambers were clearly superior to the improvements achieved in the Phoslock treated chambers. Based upon the geometric mean values summarized in Table 4-3, the equilibrium SRP concentration for Phoslock was approximately 2-3 times greater than the concentration in the alum treated chambers, with a 3-fold higher concentration for dissolved organic phosphorus, a 4-fold greater concentration of particulate phosphorus, and a 4-fold higher concentration of total phosphorus.

However, this study may not provide an accurate comparison of potential impacts from alum and Phoslock since the alum dose was calculated based upon the traditional sediment inactivation dose, while the Phoslock dose was calculated based upon the recommendation of the sales representative for Phoslock removal in an aqueous phosphorus solution. The experimental results may have been different if the Phoslock dose had been calculated using the standard methodology developed by ERD which has been used for all other sediment inactivation projects in Florida and many others throughout the U.S. The only potential drawback to the use of alum are the reductions in pH and alkalinity which can be controlled through proper application techniques and timing.

Therefore, based upon the evaluations discussed previously, ERD recommends that alum be used for the subsequent sediment inactivation program to be conducted in Silver Lake. Based upon the limno-corral experiments and the sediment core incubation studies, alum was clearly superior in retaining phosphorus within the sediments, reducing concentrations of chlorophyll-a, and improving water clarity based upon measured Secchi disk depth.

It should be noted that both Phoslock and alum resulted in increases in measured concentrations of total nitrogen in the enclosures compared with the control or lake samples due primarily to increases in ammonia and NO_x. However, as indicated on Figure 4-7, the increases in ammonia in the alum treated chambers appear to be temporary since ammonia concentrations in the alum treated and control chambers were similar at the end of the 91-day monitoring period. In contrast, ammonia concentrations in the Phoslock treated chambers remained relatively constant at an elevated concentration of approximately 1000 μg/l. A similar pattern was also observed for measured concentrations of NO_x in the alum and Phoslock treated chambers, with the alum chambers appearing to level off in concentration while the Phoslock treated chambers continued an upward increase. However, overall, total nitrogen concentrations at the end of the incubation period were virtually identical in the alum and control chambers, while the Phoslock chambers remained elevated.

SECTION 5

SEDIMENT INACTIVATION PLAN

Based on the comparison of alum and Phoslock for sediment inactivation in Silver Lake (discussed in the previous sections), aluminum sulfate was superior for sediment inactivation within Silver Lake. Therefore, the sediment inactivation plan discussed in this section is based upon alum as the selected chemical. Although outside the Scope of Services for this project, dredging of the organic muck from the lake bottom may have an effect similar to sediment inactivation and provides an additional benefit of removing accumulated material from the lake. Therefore, a brief discussion of dredging is also provided in this section.

5.1 Alum Sediment Inactivation

5.1.1 General Considerations

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 generally the clear compounds of choice for this application. Inactivation of sediment phosphorus is a substantially less expensive option for reducing sediment phosphorus release since removal of the existing sediments is not required.

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. After reaching the bottom sediments, the residual aluminum binds tightly with phosphorus within the sediments, forming an inert precipitate which is stable under any conceivable condition of pH or redox potential which could occur in a natural lake system. These sediment treatments have been shown to be effective from 5-20 years, depending upon the sediment accumulation rate within the lake from the remaining phosphorus sources.

5.1.2 Floc Settling and Stability

One of the concerns raised during this project is the potential for the alum floc layer to resuspend as a result of inflows into Silver Lake from Joe's Creek and potential discharge of floc through the outfall structure to downstream portions of Joe's Creek. A schematic of settling processes for alum floc in a shallow lake is given on Figure 5-1. Sediments in shallow lakes, including Silver Lake, generally consist of a surficial layer of unconsolidated organic muck, which varies in thickness from several inches to several feet, and is typically characterized by a density of approximately 1.02 g/cm^3. Beneath this surficial layer, these sediments become more consolidated with a consistency similar to thick pudding, and are characterized by densities ranging from approximately 1.1-1.2 g/cm^3.

When alum is added to the surface of a lake, an aluminum hydroxide floc is formed which initially settles onto the surface of the unconsolidated sediment layer. Alum floc is typically characterized by a density of approximately 1.05 g/cm^3, and as a result, begins to migrate into the less dense layer of unconsolidated sediments. Based upon visual observations conducted by ERD during previous alum inactivation projects, migration of alum floc into the unconsolidated organic sediment layer occurs within approximately 1-4 weeks following addition. As the floc migrates downward, it becomes completely incorporated into the unconsolidated organic muck sediments and becomes a part of the sediments rather than a distinct separate layer overlying the unconsolidated sediments. Resuspension of the alum floc would only occur with an event which is sufficient to disturb the unconsolidated organic sediment layer within the lake. However, the disturbed floc and sediment layer will quickly settle back into the existing sediments. Even if an event of sufficient magnitude to disturb the sediment layers were to occur, and alum floc were to be discharged downstream, the alum floc is absolutely inert and poses no danger to any water quality or biological criteria.

Mobilization of the existing muck sediments in Silver Lake would require a flow velocity at the water-sediment interface of approximately 1-1.5 fps based upon standard erosive velocities. Silver Lake is approximately 335 ft in width in a north-south direction perpendicular to the flow path from Joe's Creek to the outfall of the pond. The most restrictive portion of Silver Lake occurs in the channel which extends from the lake to the weir structure where the channel is approximately 75 ft in width. Based upon the water depth contours illustrated on Figure 2-2, the normal water depth in the outfall canal is approximately 3 ft, although this depth would be substantially greater during an extreme storm event. For purposes of this analysis, a water depth of approximately 4 ft is assumed under high flow conditions.

In order to exceed the scour velocity of 1.5 fps at the water-sediment interface in this most restrictive portion of Silver Lake, a discharge in excess of approximately 450 cfs would be required (75 ft wide x 4 ft deep x 1.5 fps). A USGS gauging station is located in Joe's Creek near the weir structure downstream from the SWFWMD treatment pond, approximately 1.5 miles downstream from Silver Lake. The greatest discharge measured at this site over the available period of record which includes 1985-1991 and from 2000-present was 250 cfs although the vast majority of flow rates appear to be equal to 50 cfs or less. If the maximum monitored flow rate in Joe's Creek substantially downstream from Silver Lake is 250 cfs, it appears highly unlikely that sufficient scour velocity would develop within Silver Lake even in the most restrictive outfall channel portions of the lake to mobilize lake sediments containing alum floc and cause these to discharge from the lake. If scour were a frequent occurrence in Silver Lake, evidence of these processes would be readily apparent on the depth contour profiles collected by ERD and summarized in Figure 2-2.

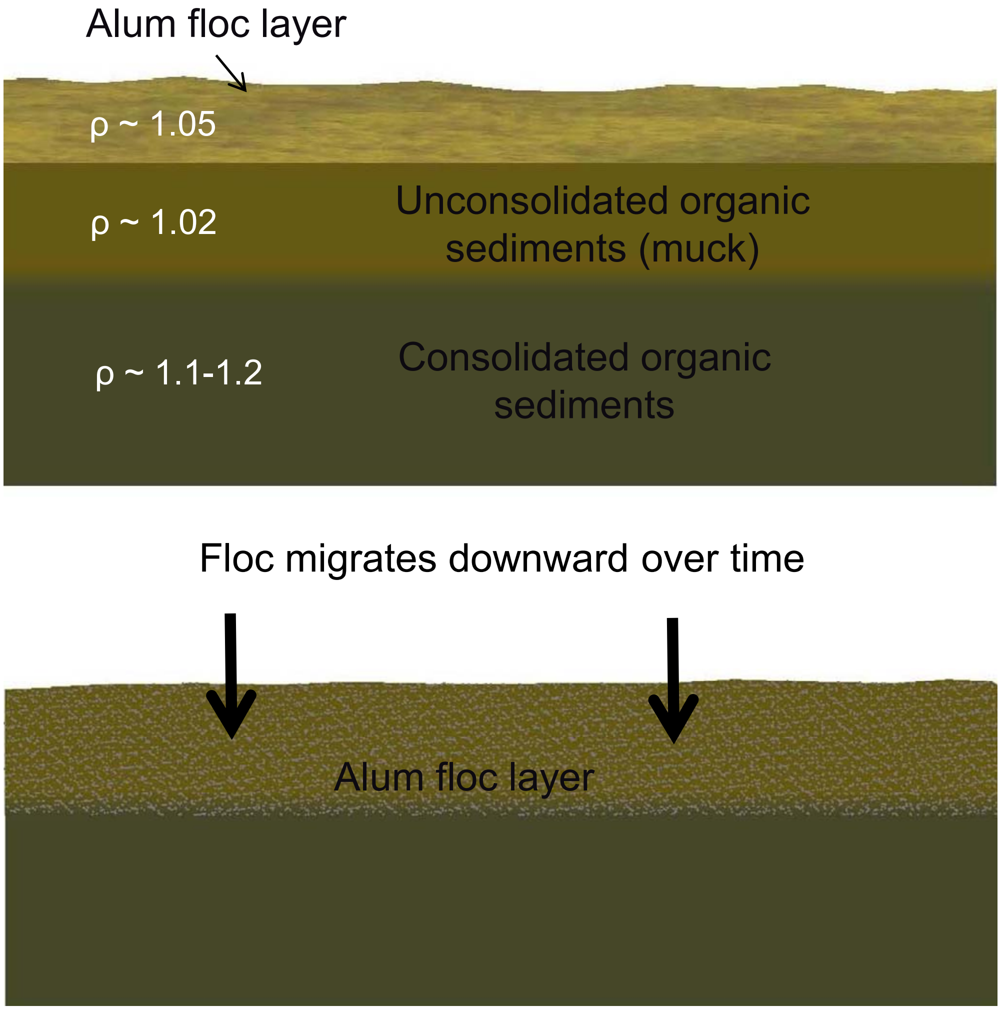


Figure 5-1. Settling Processes for Alum Floc in a Shallow Lake.

5.1.3 Chemical Requirements

Sediment inactivation in Silver Lake would involve addition of liquid aluminum sulfate at the water surface using an application boat. Upon entering the water, the alum would form insoluble precipitates which would settle onto the bottom while also clarifying the existing water column within the lake. Upon entering the sediments, the alum will combine with existing phosphorus within the sediments, primarily saloid- and iron-bound associations, forming insoluble inert precipitates which will bind the phosphorus in an inert crystalline structure, making it unavailable for release into the overlying water column. 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.

Estimates of the mass of total available phosphorus within the top 0-10 cm layer of the sediments in Silver Lake were generated by graphically integrating the total available phosphorus isopleths presented on Figure 2-12. The top 0-10 cm layer of the sediments is considered to be an 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 inactivate sediment release of phosphorus within a lake. 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 agents. 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.

A summary of estimated total available phosphorus in the sediments of Silver Lake is given in Table 5-1. On a mass basis, the sediments of Silver Lake contain approximately 209 kg of available phosphorus in the top 10 cm, equivalent to approximately 6,730 moles of phosphorus to be inactivated as part of the sediment inactivation process. Using an Al:P ratio of 10:1, sediment inactivation in Silver Lake would require approximately 8,195 gallons of alum, equivalent to approximately 1.8 tankers. The equivalent aerial aluminum dose for this application would be 53.2 g Al/m^2, with a water column dose of 55.0 mg Al/liter.

TABLE 5-1

SUMMARY OF SEDIMENT AVAILABLE PHOSPHORUS AND INACTIVATION REQUIREMENTS FOR SILVER LAKE

AVAILABLE P CONTOUR INTERVAL (μg/cm^3)	CONTOUR INTERVAL MID-POINT (μg/cm^3)	CONTOUR AREA (acres)	AVAILABLE PHOSPHORUS		ALUM REQUIREMENTS (Al:P Ratio = 10:1)	
			kg	moles	moles Al	gallons alum
0-10	5	0.01	0	1	9	1
10-20	15	0.26	2	51	507	62
20-30	25	0.33	3	106	1,064	130
30-40	35	0.36	5	164	1,637	199
40-50	15	0.97	6	189	1,895	231
50-60	55	1.99	44	1,430	14,303	1,742
60-70	65	0.93	25	793	7,929	966
70-80	75	1.06	32	1,042	10,423	1,269
80-90	85	1.44	50	1,603	16,031	1,952
90-100	95	1.05	41	1,308	13,078	1,592
100-110	105	0.03	1	43	425	52
Overall Totals:		**8.44**	**209**	**6,730**	**67,301**	**8,195**

The chemical additions to Silver Lake would be applied at the surface using an application boat with a spreader bar to distribute the alum over the water surface. The alum would be pre-mixed with lake water in approximately a 5:1 (lake water to alum) ratio to assist in mixing the alum with the water. The isopleths of available phosphorus illustrated on Figure 2-12 would be used as an application guide, with more alum applied in areas with high concentrations of available phosphorus and less alum applied in areas with low concentrations. The lake will be divided into multiple sections with specific quantities of alum added to each section based on the quantity of available sediment phosphorus.

Previous alum surface applications performed for inactivation of sediment phosphorus release by ERD have indicated that the greatest degree of improvement in surface water characteristics and the highest degree of inactivation of sediment phosphorus release are achieved when the total recommended alum addition occurs through multiple applications of aluminum to the waterbody spaced at intervals of approximately 3-6 months. Each subsequent application results in additional improvements in water column quality and additional aluminum floc added to the sediments for long-term inactivation of sediment phosphorus release.

As indicated in Section 2, Silver Lake is a shallow waterbody with an average depth of approximately 3.1 ft. Due to the shallow depth and relatively small water volume, the proposed alum addition for sediment inactivation would result in a mean water column aluminum dose of 55.0 mg Al/liter if the application were to be conducted as a single event. However, this alum dose substantially exceeds the buffering capacity of the lake to withstand changes in water column pH. As a result, the applied dose must be divided into multiple applications to minimize impacts on pH and to eliminate the need for a supplemental buffering compound, such as sodium aluminate, to buffer the pH which would be necessary if the proposed alum volume were to be added at one time. Based upon the available alkalinity in Silver Lake, which ranged from 94-120 mg/l during the field monitoring program, the recommended quantity of aluminum for sediment inactivation should be divided into a minimum of four separate applications, with approximately 2,050 gallons of alum added during each of the four applications. If four separate applications are conducted, the mean water column aluminum dose during each of the four applications would be approximately 13.75 mg Al/liter which can likely be tolerated given the relatively well buffered nature of the Silver Lake water.

Generally, ERD recommends that multiple applications be spaced at intervals of approximately 2-3 months. Due to the short residence time within the lake, the treated lake water from one application will have been replaced with new inflows from Joe’s Creek by the time of the next application which will also restore the original alkalinity within the lake water.

A summary of estimated application costs for sediment inactivation is given in Table 5-2. This estimate assumes an alum volume of 8195 gallons will be applied during four separate applications, with approximately 2050 gallons added per application. Planning and mobilization costs are estimated to be approximately $4000 per application, which includes initial planning, mobilization of equipment to the site, demobilization at the completion of the application process, and clean-up. An application rate of $1500/tanker or partial tanker is assumed which includes labor costs, water quality monitoring, expenses, equipment rental, insurance, mileage, and application equipment fees. Fees are also included for analysis of pre- and post-treatment water samples. The estimated cost for sediment inactivation in Silver Lake is $36,300 or approximately $9075 per application.

TABLE 5-2

ESTIMATED APPLICATION COSTS FOR SEDIMENT INACTIVATION IN SILVER LAKE

(Based on 4 separate treatments)

PARAMETER		AMOUNT REQUIRED PER TREATMENT	UNIT COST/ TREATMENT	COST/ TREATMENT	TOTAL COST
Chemicals	Alum	2050 gallons	1.50/gallon[1]	$ 3,075	$ 12,300
Labor	Planning and Mobilization	4 applications	$4000/application	$ 4,000	$ 16,000
	Chemical Application	1 each	$1500[2]	$ 1,500	$ 6,000
Lab Testing		Pre/Post Samples x 4 events	$ 500/event	$ 500	$ 2,000
			TOTAL:	**$ 9,075**	**$ 36,300**

1. Assumed contract cost
2. Includes raw labor, water quality monitoring, insurance, expenses, application equipment, mileage, and rentals

5.1.4 Longevity of Treatment

After each application, the alum precipitate will form a visible floc layer on the surface of the sediments within the lake. This floc layer will continue to consolidate for approximately 30 days, reaching maximum consolidation during that time (Harper, 1990). Due to the unconsolidated nature of the sediments in much of the lake, it is anticipated that a large portion of the floc will migrate into the existing sediments rather than accumulate on the surface as a distinct layer. This process is beneficial since it allows the floc to sorb soluble phosphorus during migration through the surficial sediments. Any floc remaining on the surface will provide a chemical barrier for adsorption of phosphorus which may be released from the sediments.

ERD has conducted more than 40 sediment inactivation projects in the State of Florida with a wide variety of waterbody sizes, depths, and water quality characteristics. Each of these treatments has resulted in substantial improvements in water quality characteristics. The observed improvements in water quality have lasted from a minimum of 5-7 years to more than 15 years in a majority of the applications. Therefore, sediment inactivation in Silver Lake would be expected to sequester significant amounts of sediment phosphorus for a minimum of approximately 10 years.

5.2 Sediment Removal

Another potential management option for improving water quality in Silver Lake is sediment removal through a whole-lake dredging project which is designed to remove the existing organic muck, leaving the original parent bottom material of the lake. This option will eliminate most, but probably not all, of the water quality impacts from the existing sediments, with added benefits of increasing water depth, water volume, and lake residence time. In general, increasing residence time within a waterbody increases the opportunity for biological uptake, resulting in better equilibrium water quality characteristics and lower rates of discharge to downstream waterbodies.

A decision to remove accumulated lake bottom sediments generally occurs when there is sufficient evidence that the accumulated sediments are having an adverse impact on habitat, water quality, recreation, or navigation. The existing sediments in Silver Lake do not appear to have a direct impact on recreation or navigation within the lake, but field and laboratory work conducted by ERD has demonstrated an adverse impact of sediments on existing water quality.

5.2.1 Dredging Methods

Sediment removal by dredging can be accomplished by either mechanical or hydraulic dredging methods. Mechanical dredging most frequently involves either partially or completely draining the lake to expose the sediments to drying conditions. Conventional earth moving equipment, such as bulldozers, scrapers, backhoes, and draglines, are then used to remove the dried sediments. The sediment material is stockpiled on the shore and then hauled away in dump trucks to a disposal location.

However, given the significant volume of inflow contributed to Silver Lake through Joe’s Creek, any potential mechanical dredging project would need to be carefully scheduled to occur during dry season conditions. The inflow into Silver Lake from Joe’s Creek would need to be isolated using a sheetpile structure, and any runoff which occurs during the dredging project would need to be pumped around the facility to a downstream portion of Joe’s Creek. A substantial dewatering effort would also be required to remove the existing water from the lake and provide sufficient drying of the bottom sediments to allow earth-moving equipment to work within the lake. However, if sufficient dewatering and sediment drying could be achieved, a mechanical dredging operation would be ideal since the accumulated sediment is readily visible and can be easily removed to the parent bottom material.

Another potential option for dredging in Silver Lake would be hydraulic dredging. A hydraulic dredge excavates and pumps material from the lake bottom through a temporary HDPE pipeline to an off-site location, which is often several thousand feet to several miles away, or if the sediment volume is sufficiently small, the slurry could be pumped into geotubes located on the banks of the lake. Proprietary dewatering systems are also available which can often dewater the dredge slurry directly on-site.

The head of the dredging unit is equipped with a cutter with steel blades to dislodge the sediments, and a centrifugal pump is used to “suck up” the muck and water mixture, forming a slurry. Control of the dredging depth occurs by manipulation of the suction head in both a vertical and horizontal direction. Since lake water is removed along with the sediment, hydraulic dredging slurries are commonly 80-90% water. An advantage of hydraulic dredging is that it is generally faster than mechanical dredging and creates less turbidity in the dredged waterbody. Hydraulic dredging is also often the most cost-effective method for large dredging projects, but can result in elevated removal costs for small projects.

5.2.2 Containment Area Requirements

If hydraulic dredging were selected as an option for Silver Lake, the dredged sediment material from the bottom of the lake would be pumped to a disposal area where the sediments will be allowed to dewater and dry out over time. The disposal area must be sufficient in size to hold not only the dried dredged sediments, but also the large volume of pumped sediment/water slurry that occurred during the actual dredging process. When lake sediments are formed into a slurry by the dredge, the volume of the sediments tends to increase temporarily which is referred to as the “bulking factor”. This additional volume must also be considered when designing the disposal basin. Bulking factors ranging from 1.2-1.5 are typical, with a factor of 1.5 assumed for Silver Lake.

A summary of dredging design assumptions and containment area requirements for hydraulic dredging in Silver Lake is given on Table 5-3. As discussed previously, the lake contains approximately 9.90 ac-ft of sediments which would be removed during the dredging process. This volume is equivalent to approximately 15,972 yd^3. Assuming a bulking factor of 1.5, the total volume of sediment/water slurry which must be contained within the containment area increases to 23,958 yd^3.

TABLE 5-3

SUMMARY OF DREDGING DESIGN ASSUMPTIONS AND CONTAINMENT AREA REQUIREMENTS FOR SILVER LAKE

PARAMETER	UNITS	VALUE
Existing Sediment Volume	ac-ft ft^3 yd^3	9.90 431,244 15,972
Assumed Bulking Factor	--	1.5
Containment Area Volume	ac-ft ft^3 yd^3	14.85 646,866 23,958
Assumed Containment Area Depth, with 1 ft Freeboard	ft	5
Required Containment Area	acres	3.7

Containment areas are commonly constructed on relatively flat ground, with a berm constructed around the perimeter to contain the dredged slurry. To minimize stability issues associated with the containment berm, the depth of the dredged slurry is frequently limited to approximately 3-4 ft. An additional freeboard of approximately 1 ft would also be incorporated into the design to provide an average berm height of approximately 5 ft with a maximum slurry depth of 4 ft. Based upon these criteria, the required containment area for hydraulic dredging of Silver Lake would be approximately 3.7 ac. Assuming an additional 20% area for roadways and access to various portions of the containment area, the total required site area would be approximately 5 acres. This parcel would ideally be located close to Silver Lake, although remote locations can also be utilized at an increased unit cost.

5.2.3 Dredging Costs

A summary of estimated costs for hydraulic dredging of Silver Lake is given on Table 5-4. Costs for hydraulic dredging typically range from approximately \$5-15/yd^3 which includes the actual dredging, pumping of the dredged slurry to the containment area, construction of containment area berms, construction of a return water discharge from the containment area, and expenses for treatment of the dredged slurry to meet discharge requirements. For purposes of estimating costs for Silver Lake, an assumed dredging cost of \$15/yd^3 is used due to the relatively small size of the job.

TABLE 5-4

ESTIMATED COSTS FOR HYDRAULIC DREDGING OF SILVER LAKE

PARAMETER	UNITS	VALUE
Assumed Dredging Cost	\$/yd^3	15.00
Dredging Cost	\$	239,580
Assumed Land Costs	\$/acre	50,000
Land Costs (if required)	\$	250,000
Engineering/Design	\$	75,000
Total Cost (with Land)	\$	564,580
Total Cost (without Land)	\$	314,580

The estimated dredging cost for removal of 15,972 yd^3 of material from Silver Lake is approximately \$239,580. This value does not include any cost associated with land purchase which may be required for the containment area. Assuming that land purchase is required at a unit cost of \$50,000/ac, the land cost for the 5-acre parcel would be approximately \$250,000. An additional \$75,000 is included for engineering, design and testing during the dredging feasibility analysis phase. The estimated total project cost with land purchase is approximately \$564,580 or \$314,580 without land purchase.

5.3 Recommendations

Based on the information summarized in previous sections, inactivation of Silver Lake sediments with alum appears to be the least costly alternative for managing sediment nutrient release within the lake. Alum sediment inactivation is a low-cost method of reducing sediment impacts on water quality without the expense of sediment removal. Sediment removal through either mechanical or hydraulic dredging is estimated to cost approximately \$314,580, assuming no additional land purchase is required, or \$564,580 if a 5-acre parcel is purchased for use as a dredged spoils containment area.

SECTION 6

CITED REFERENCES

APHA/AWWA/WEF. (2005). *Standard Methods for the Examination of Water and Wastewater*, 21st Ed.

Harper, H.H. (1990). "Long-Term Performance Evaluation of the Alum Stormwater Treatment System at Lake Ella, Florida." Final Report Prepared for the Florida Department of Environmental Protection, Contract No. WM339.

Hynes, H.B.N., and Greib, B.J. (1970). "Movement of Phosphate and Other Ions From and Through Lake Muds." *J. Fish. Res. Bd. Canada 27,* pp. 653-668.

James, W.F. (2011). "Variations in the Aluminum:Phosphorus Binding Ratio and Alum Dosage Considerations for Half Moon Lake, Wisconsin." *Lake and Water Management 27,* 2, pp. 128-137.

Peterson, G.W., and Corey, R.B. (1966). "A Modified Chang and Jackson Procedure for Routine Fractionation of Inorganic Soil Phosphates." *Soil Sci. Soc. Amer. Proc. 30,* pp. 563-565.

Rydin, E., and Welch, E.B. (1998). "Aluminum Dose Required to Inactivate Phosphate in Lake Sediments." *Wat. Res. 32,* pp. 2969-2976.

U.S. EPA. (1983). *Methods for Chemical Analysis of Water and Wastes*. EPA 600/4-79-020.

U.S. EPA. (1990). *Test Methods for Evaluating Solid Wastes, Physical-Chemical Methods,* 3rd Ed.. EPA-SW-846.

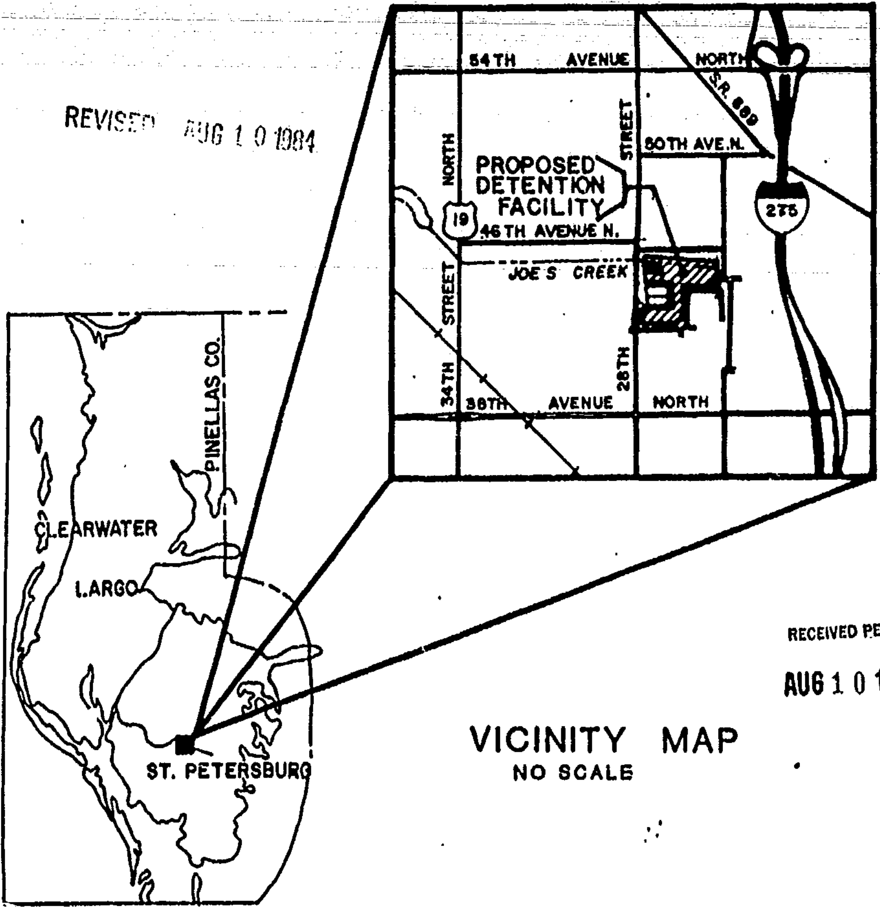
U.S. EPA/Corps of Engineers. (1981). *Procedures for Handling and Chemical Analysis of Sediments and Water Samples*. EPA/CE-81-1.

APPENDICES

APPENDIX A

CONSTRUCTION DRAWINGS FOR DETENTION POND 1 (SILVER LAKE)

REVISED AUG 1 0 1984



RECEIVED PERM

AUG 1 0 1984

VICINITY MAP

NO SCALE

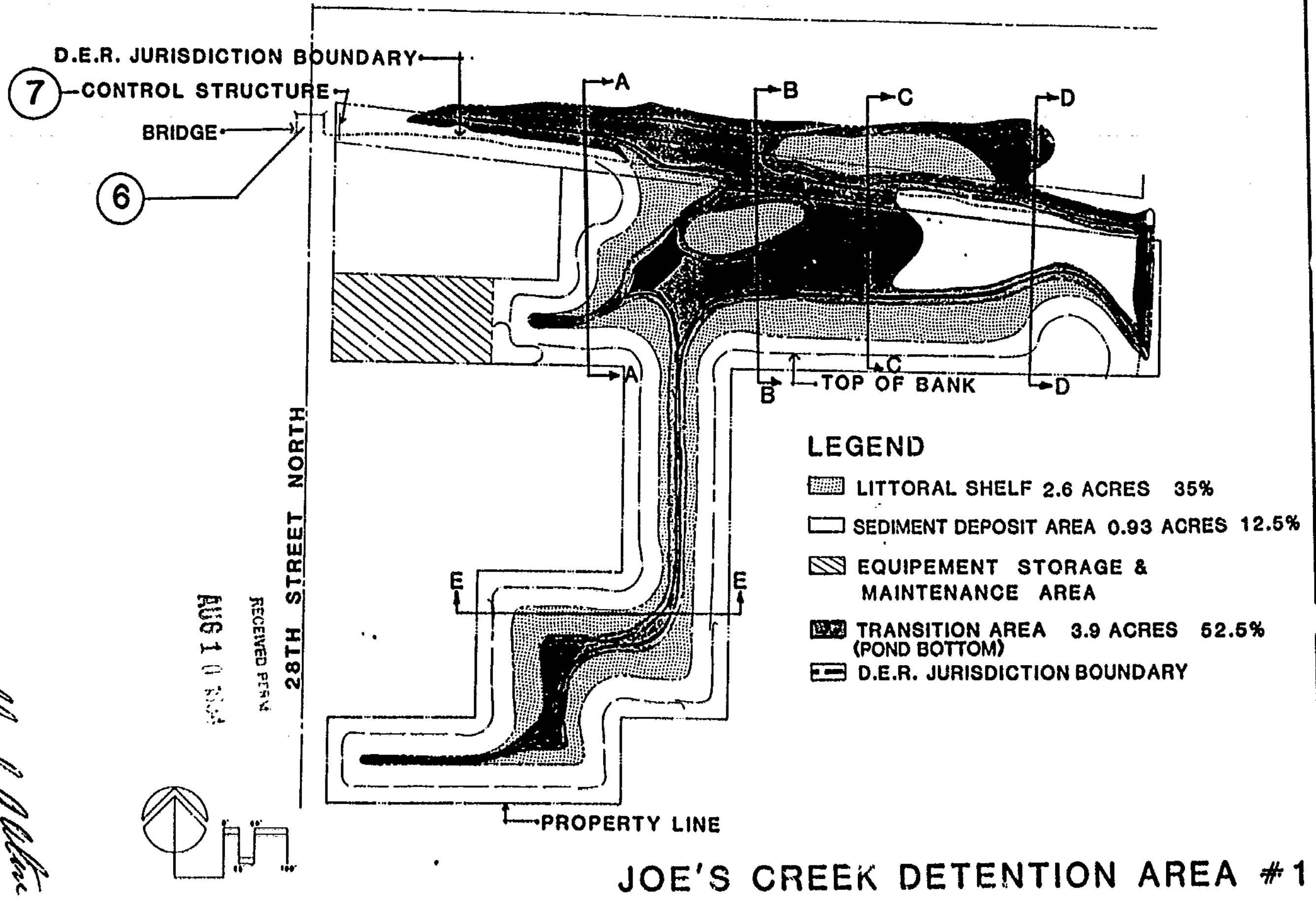
PROPOSED STORMWATER DETENTION FACILITY #1

PURPOSE: STORMWATER
DETENTION FACILITY
IN PINELLAS COUNTY
STATE OF FLORIDA

APPLICATION BY: PINELLAS COUNTY
DEPARTMENT OF PUBLIC WORKS
CLEARWATER, FLORIDA 33516
SHEET 1 OF 15 DATE 2/16/84

Charles A Otero
8/9/84

REVISED AUG 1 . 1984



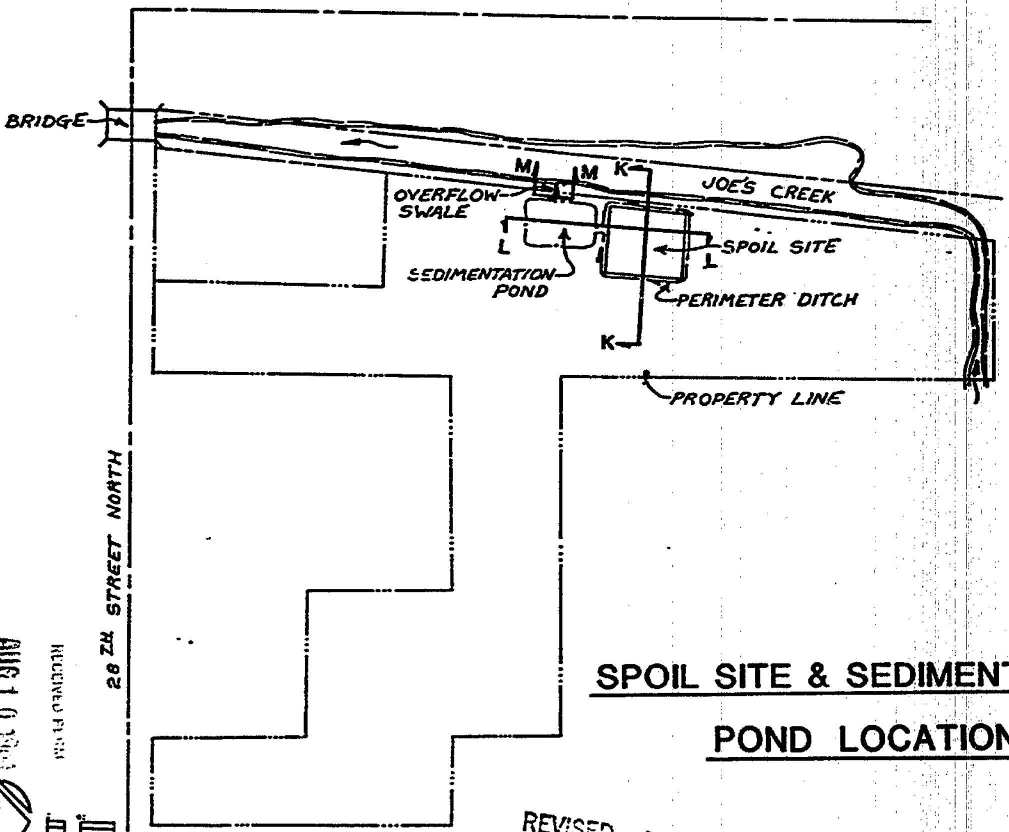
RECEIVED PERM
AUG 1 0 1984

8/9/84

SHEET 8 OF 35 DATE: 2/16/8

JOE'S CREEK DETENTION AREA #1
INDEX TO CROSS SECTION

PURPOSE: STORMWATER
DETENTION FACILITY
IN PINELLAS COUNTY
STATE OF FLORIDA



SPOIL SITE & SEDIMENTATION POND LOCATION

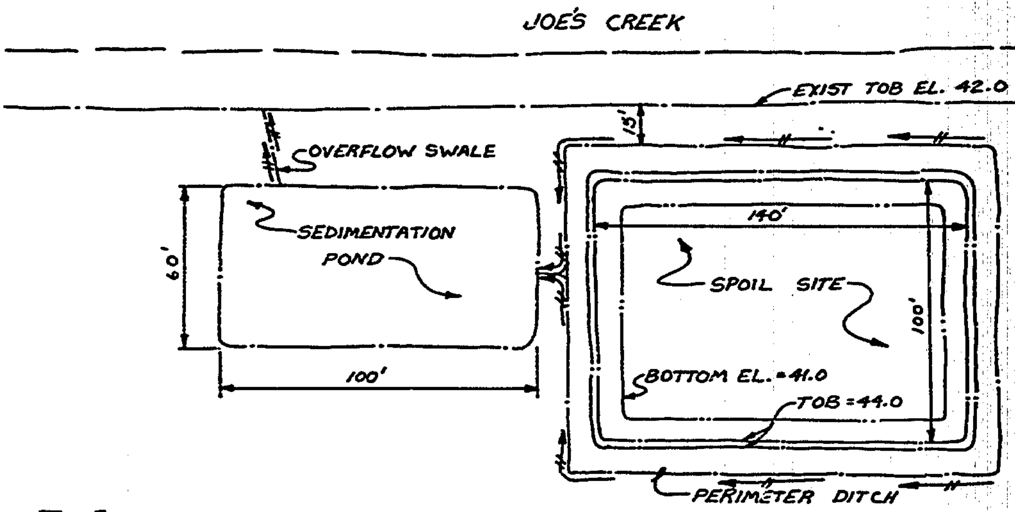
RECEIVED
AUG 10 1984

REVISED AUG 10 1984

APPLICATION BY: PINELLAS COUNTY
DEPARTMENT OF PUBLIC WORKS
CLEARWATER, FLORIDA 33516
SHEET 13 [illegible] DATE 2/16/84

8/9/84

PURPOSE: STORMWATER
DETENTION FACILITY
IN PINELLAS COUNTY
STATE OF FLORIDA



SPOIL SITE & SEDIMENTATION POND DETAIL

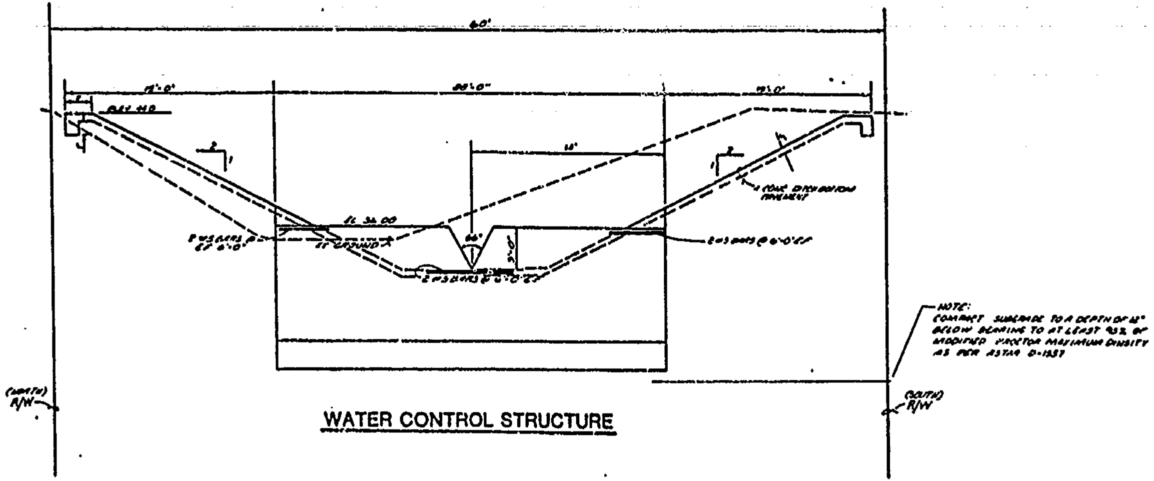
SCALE: 1":50'

RECEIVED PERM
AUG 10 1984

REVISED AUG 10 1984

APPLICATION BY: PINELLAS COUNTY
DEPARTMENT OF PUBLIC WORKS
CLEARWATER, FLORIDA 33516
SHEET 14 OF 16 DATE [illegible]16.84

8/9/84



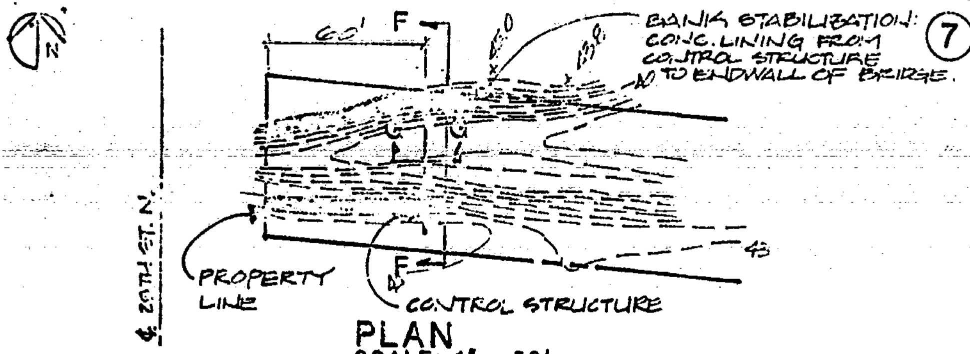
WATER CONTROL STRUCTURE

REVISED AUG 1 0 1984

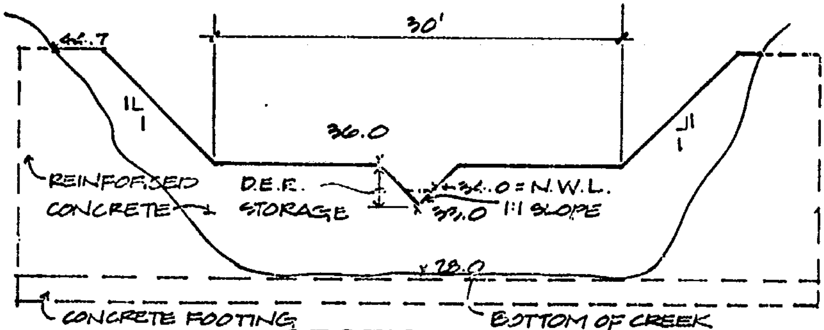
SHEET 9 OF 15 DATE 2/16/84

WATER CONTROL STRUCTURE

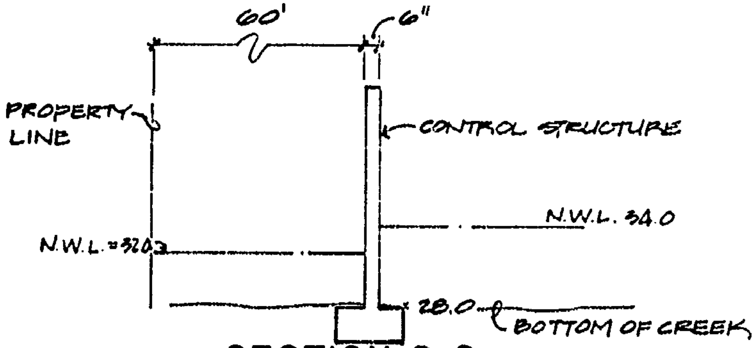
⑦



PLAN
SCALE: 1" = 50'



SECTION F•F
NO SCALE



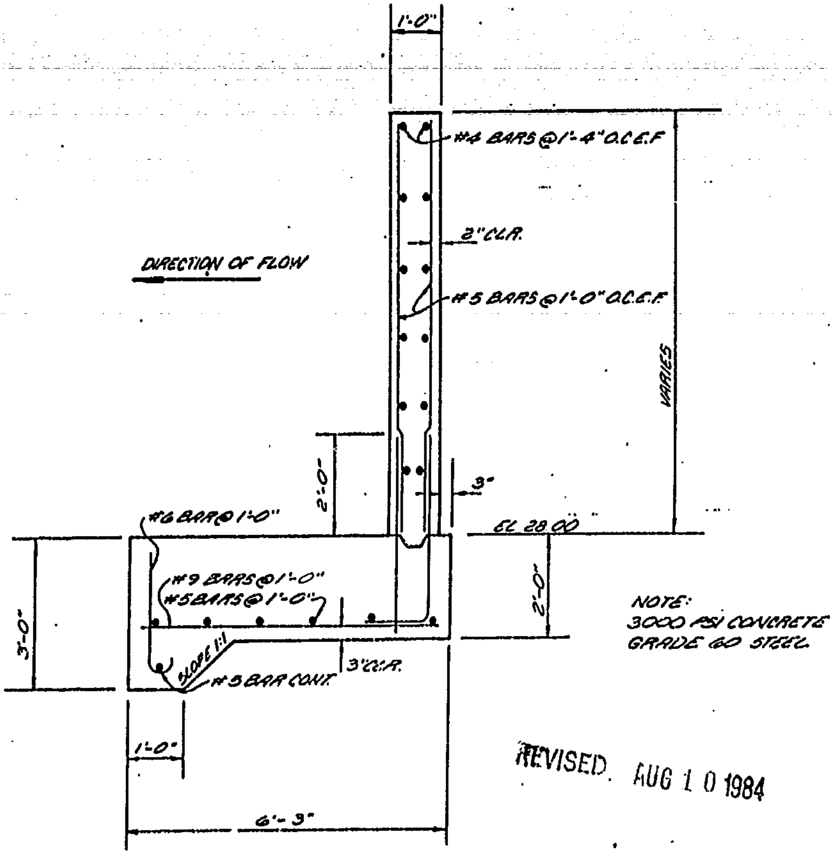
SECTION G•G
NO SCALE

CONTROL STRUCTURE DETAILS

PURPOSE: STORMWATER
DETENTION FACILITY
IN PINELLAS COUNTY
STATE OF FLORIDA

APPLICATION BY: PINELLAS COUNTY
DEPARTMENT OF PUBLIC WORKS
CLEARWATER, FLORIDA 33516
SHEET 15 OF 15 DATE [illegible]

2/17/84



NOTE:
3000 PSI CONCRETE
GRADE 60 STEEL

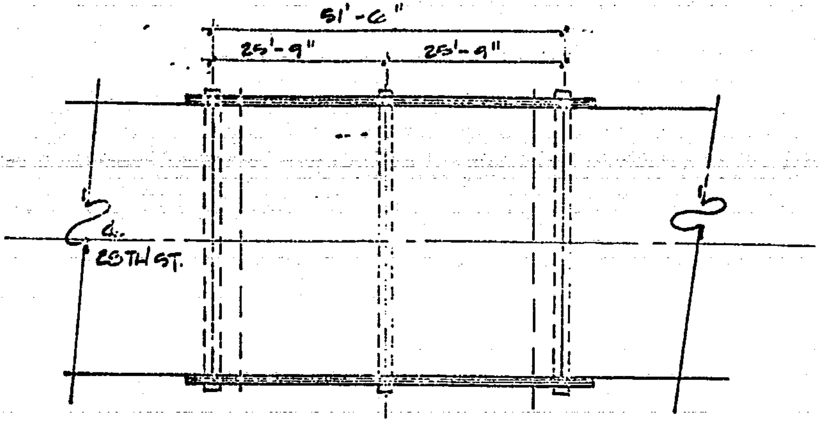
REVISED AUG 1 0 1984

TYPICAL SECTION THRU
WATER CONTROL STRUCTURE

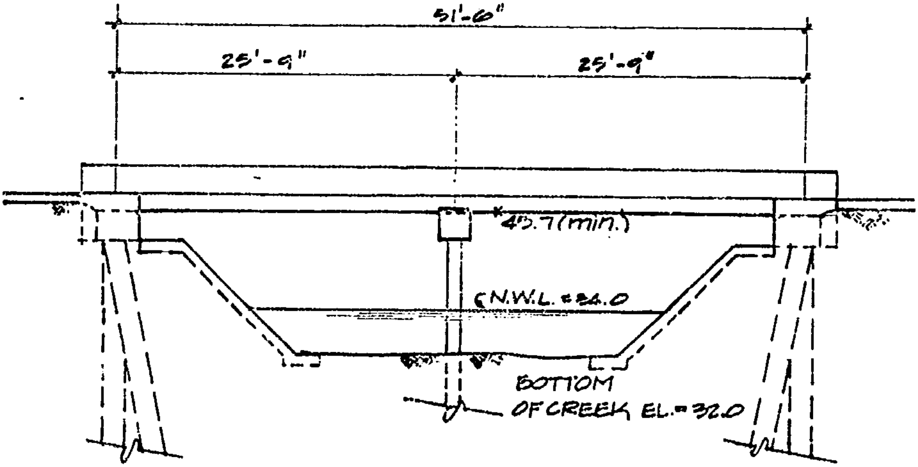
RECEIVED PERMI
AUG 1 0 1984

SHEET 10 OF 15 DATE 2/16/84

⑥



PLAN
NO SCALE



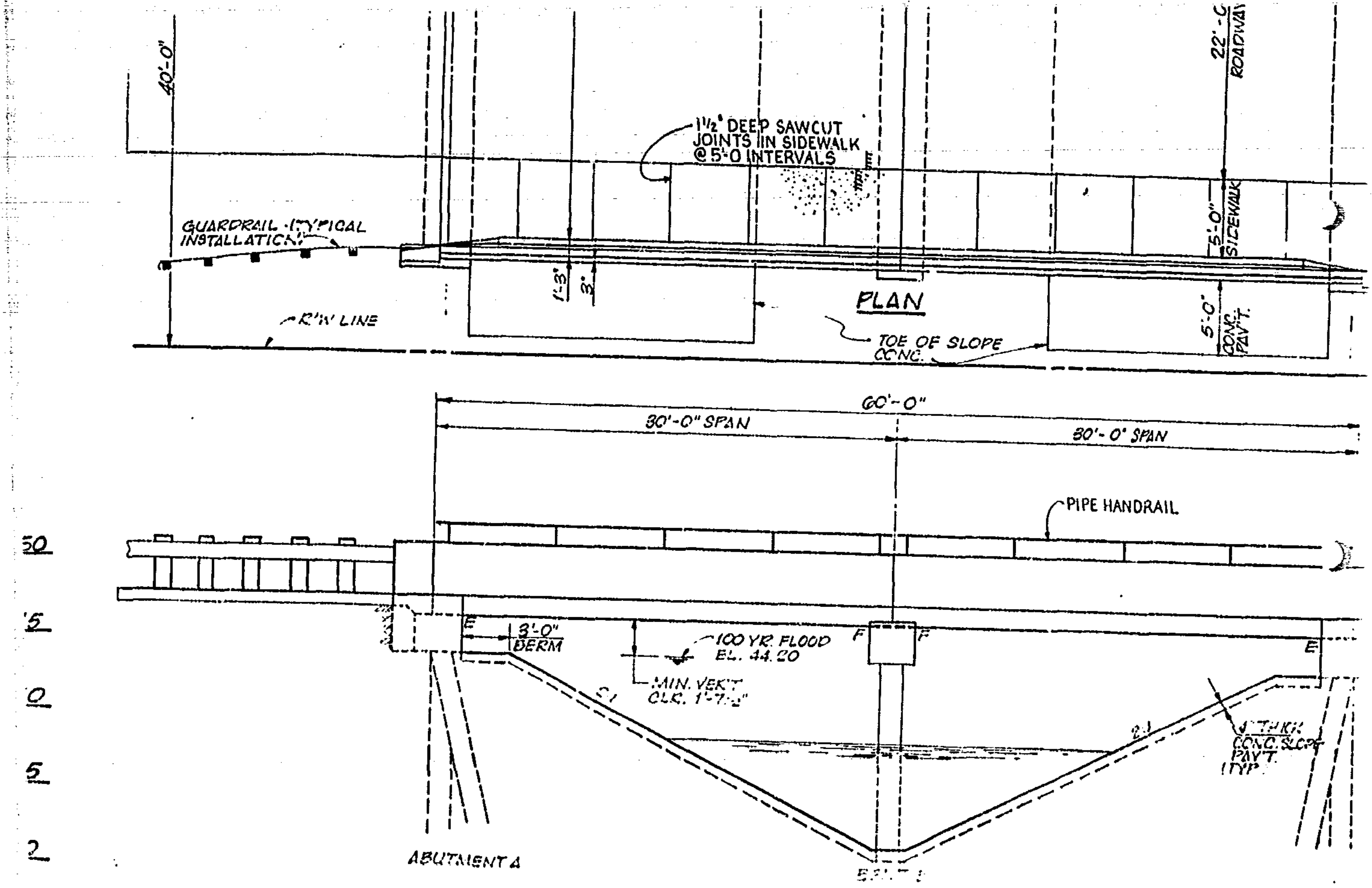
ELEVATION
NO SCALE

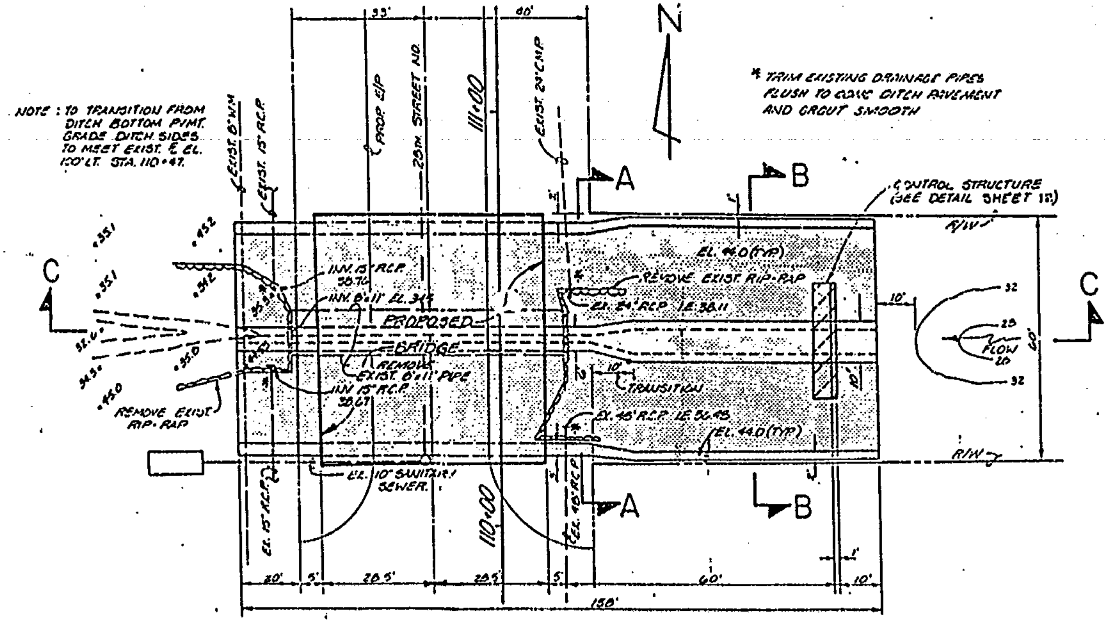
BRIDGE DETAILS

PURPOSE: STORMWATER
DETENTION FACILITY
IN: PINELLAS COUNTY
STATE OF FLORIDA

APPLICATION BY: PINELLAS COUNTY
DEPARTMENT OF PUBLIC WORKS
CLEARWATER, FLORIDA 33516
SHEET 12 OF 15 DATE 2/[illegible]/84

2/29/84


40'-0"
1½" DEEP SAWCUT JOINTS IN SIDEWALK @ 5'-0 INTERVALS
22'-0
ROADWAY
GUARDRAIL (TYPICAL INSTALLATION)
5'-0"
SIDEWALK
1'-3"
3"
PLAN
R/W LINE
TOE OF SLOPE CONC.
5'-0"
CONC. PAV'T.
60'-0"
30'-0" SPAN
30'-0" SPAN
PIPE HANDRAIL
50
5
0
5
2
E
3'-0"
BERM
100 YR. FLOOD EL. 44.20
MIN. VERT. CLR. 1'-7½"
F
F
E
2:1
2:1
4" THK. CONC. SLOPE PAV'T. (TYP.)
ABUTMENT A

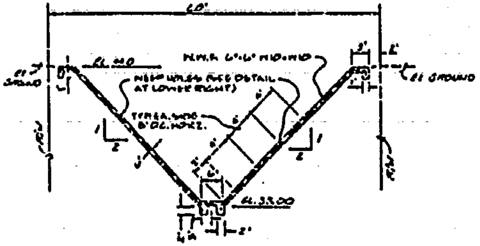


CONCRETE DITCH BOTTOM PAVEMENT

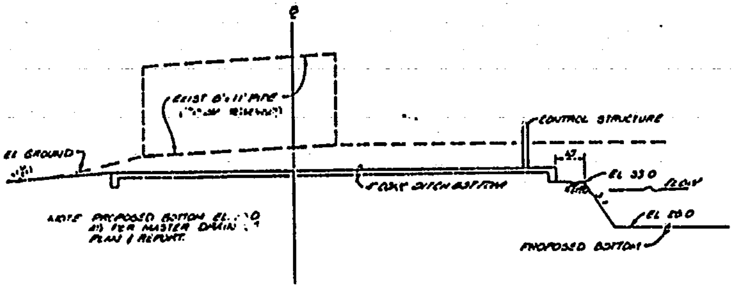
SHEET 11 OF 15 DATE 2/16/84

8/17/84

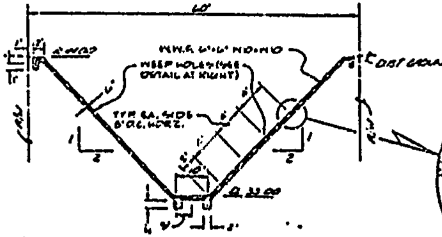
CONCRETE DITCH BOTTOM PAVEMENT

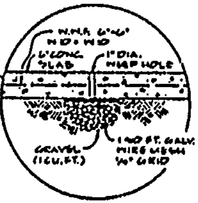


SECTION A-A
NTS



SECTION C-C
NTS





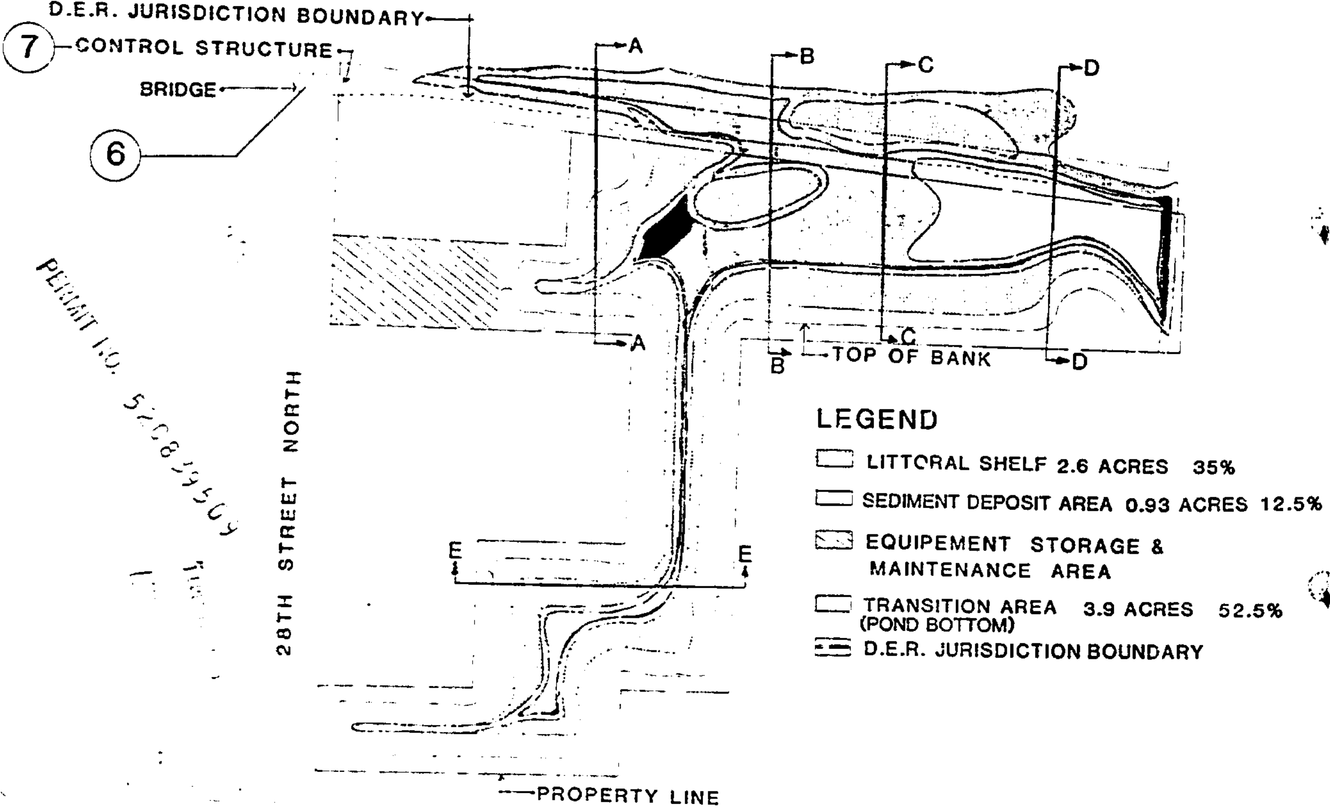
SECTION B-B
NTS

RECEIVED PERMIT
AUG 10 1984

REVISED AUG 10 1984

SHEET 12 OF 15 DATE 2/16/84

SECTIONS THRU DITCH BOTTOM PAVEMENT

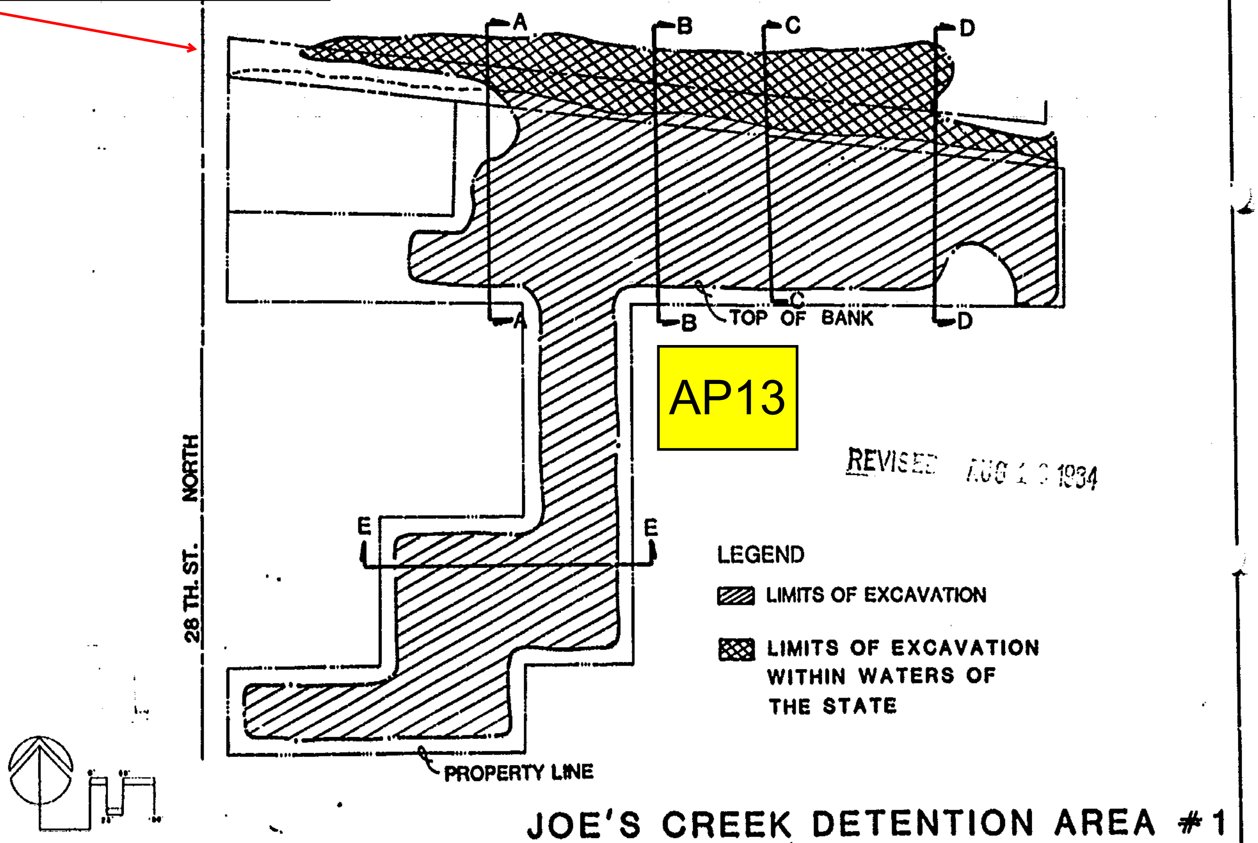


PERMIT NO. 520839509

JOE'S CREEK DETENTION AREA #1
INDEX TO CROSS SECTION

SHEET 20 OF 19 DATE: 2/10/8

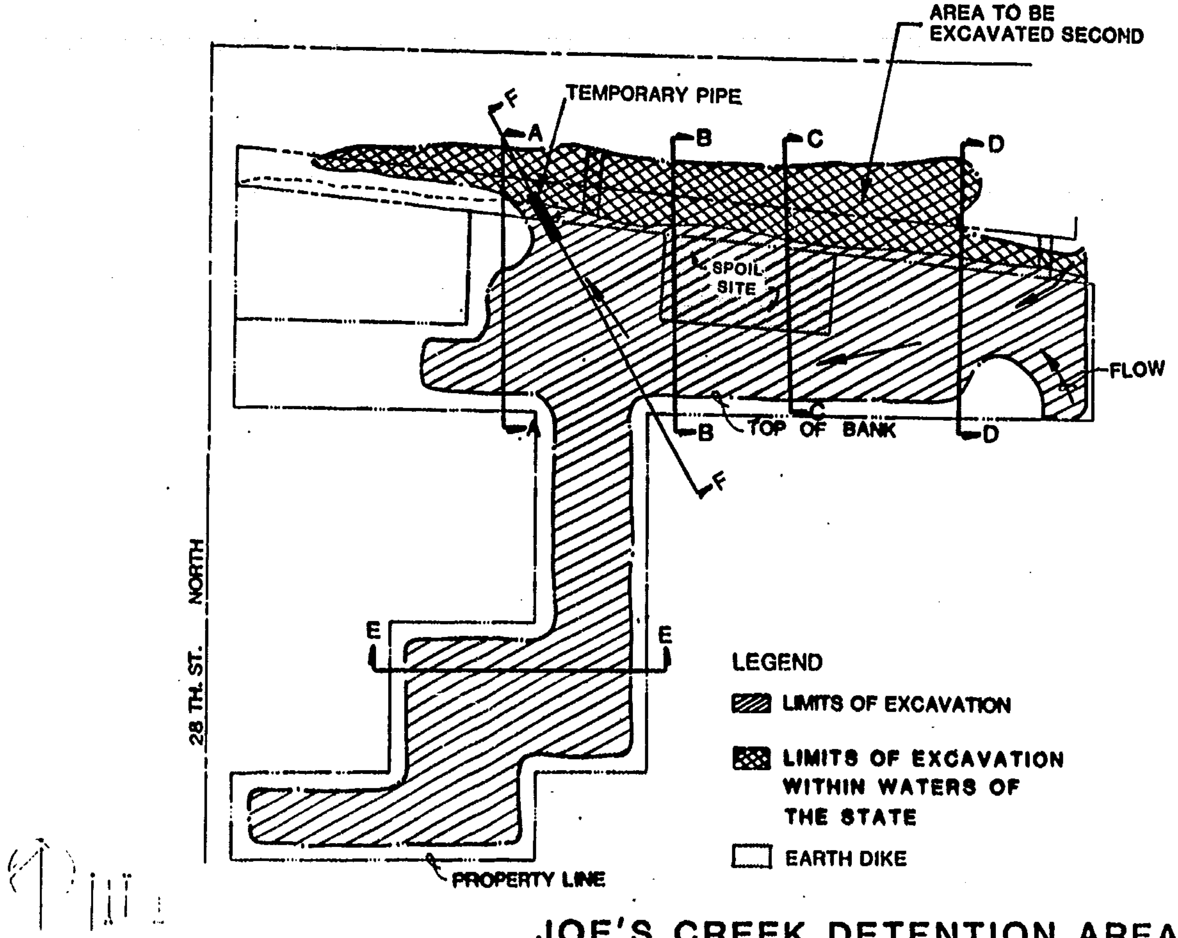
Outfall Structure at Bridge



AP13

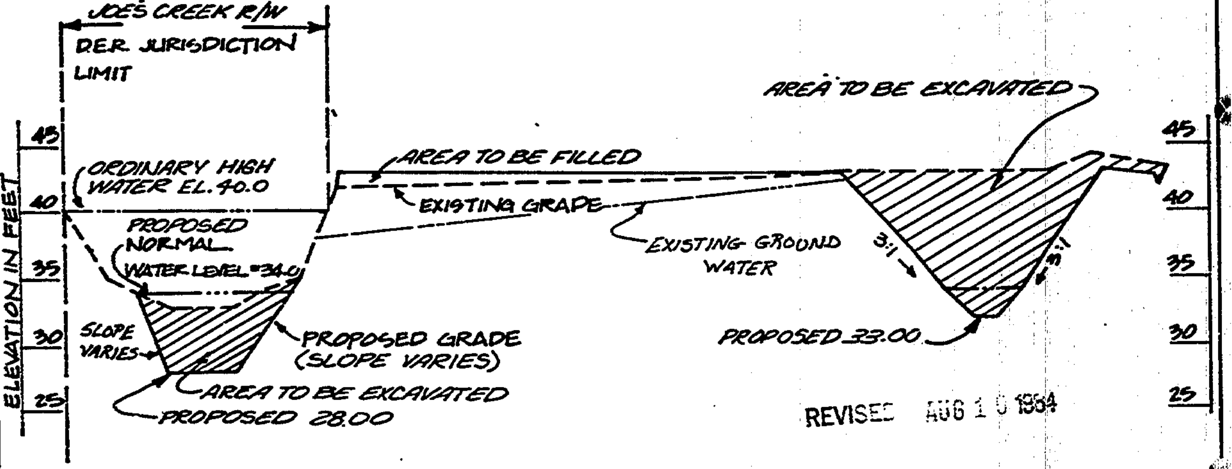
JOE'S CREEK DETENTION AREA # 1
INDEX TO CROSS SECTION

SHEET 3 OF 15 DATE 2/16/84



JOE'S CREEK DETENTION AREA # 1
INDEX TO CROSS SECTION

ALL ELEV. ARE REFERENCED TO NVGD



REVISED AUG 10 1984

CROSS SECTION VIEW – SECTION A•A

SCALE: HORIZ. 1" = 50'
VERT. 1" = 10'

NOTE: OHW BASED ON
FIELD INVESTIGATION
ON EXIST. VEGETATION.

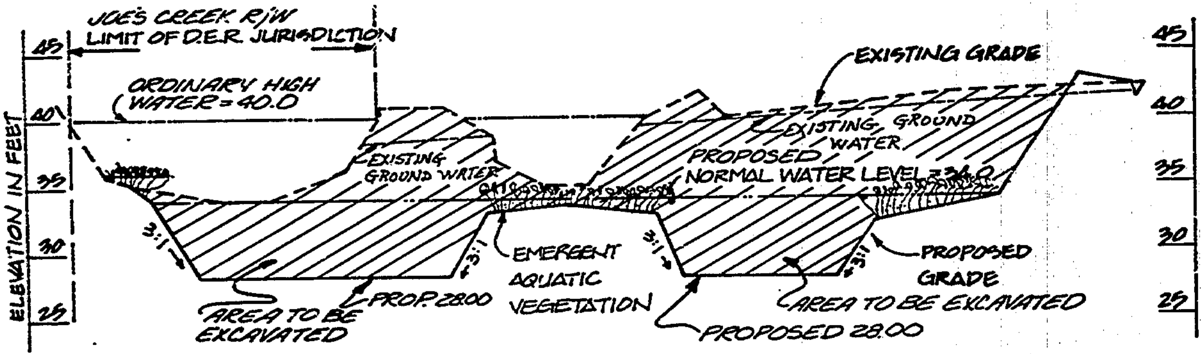
RECEIVED PERMIT
AUG 10 1984

▨ AREA TO BE EXCAVATED
☐ AREA TO BE FILLED

PURPOSE: STORMWATER
DETENTION FACILITY
IN PINELLAS COUNTY
STATE OF FLORIDA

APPLICATION BY: PINELLAS COUNTY
DEPARTMENT OF PUBLIC WORKS
CLEARWATER, FLORIDA 33516
SHEET 4 OF 15 DATE 2/13/84

ALL ELEV. ARE REFERENCED TO NVGD



REVISED AUG 1 0 1984

CROSS SECTION - SECTION B•B

SCALE: HORIZ. 1" = 50'
VERT. 1" = 10'

▨ AREA TO BE EXCAVATED

☐ AREA TO BE FILLED

PURPOSE: STORMWATER
DETENTION FACILITY
IN PINELLAS COUNTY
STATE OF FLORIDA

APPLICATION BY: PINELLAS COUNTY
DEPARTMENT OF PUBLIC WORKS
CLEARWATER, FLORIDA 33516
SHEET 5 OF 15 DATE 2/16/84

8/9/84

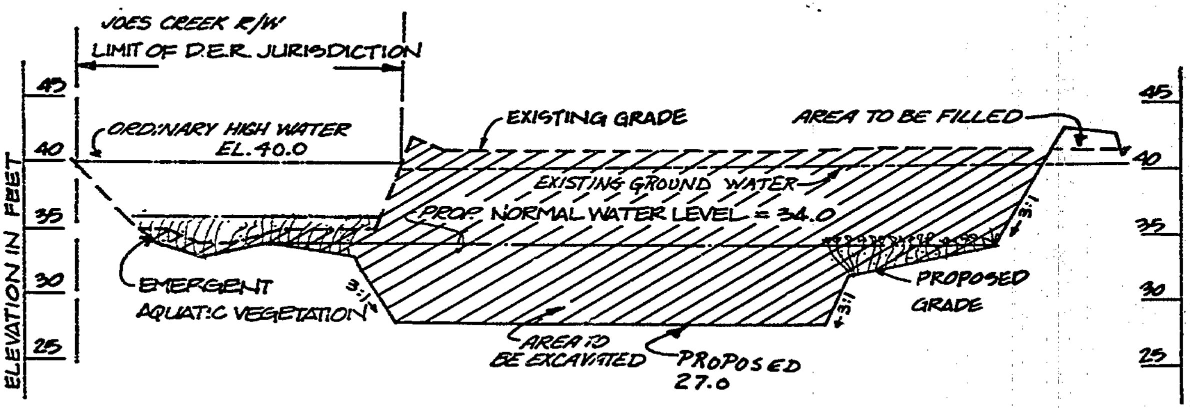
AUG 1 0 1984

PURPOSE: STORMWATER
DETENTION FACILITY
IN PINELLAS COUNTY
STATE OF FLORIDA

APPLICATION BY: PINELLAS COUNTY
DEPARTMENT OF PUBLIC WORKS,
CLEARWATER, FLORIDA 33616
SHEET 6 OF 15 DATE 8/9/84

8/9/84

ALL ELEV. ARE REFERENCED TO NVGD



REVISED AUG 10 1984

RECEIVED PERM
AUG 10 1984

CROSS SECTION VIEW – SECTION C•C

SCALE: HORIZ. 1" = 50'
VERT. 1" = 10'

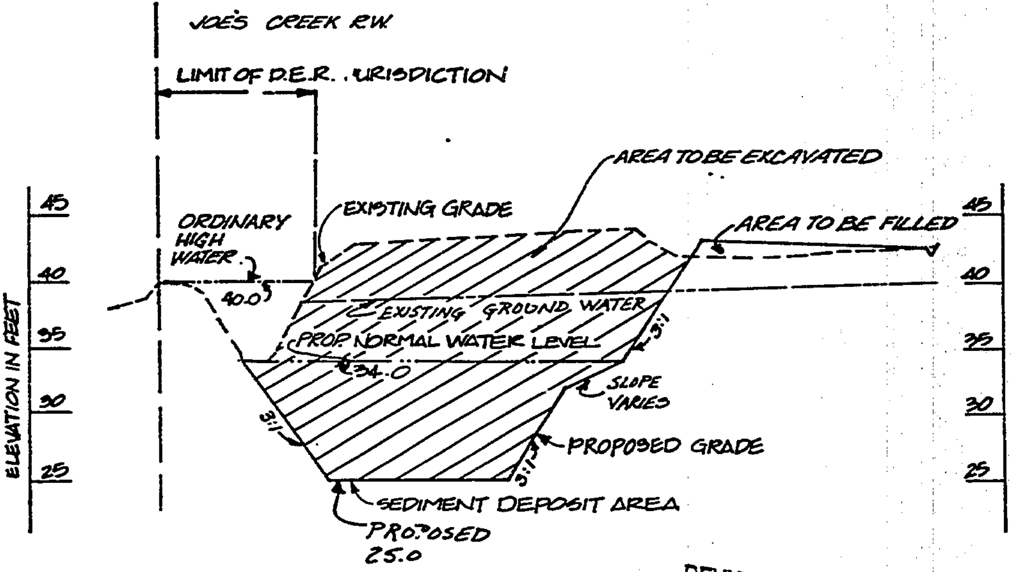
▨ AREA TO BE EXCAVATED
☐ AREA TO BE FILLED

PURPOSE: STORMWATER
DETENTION FACILITY
IN PINELLAS COUNTY
STATE OF FLORIDA

APPLICATION BY: PINELLAS COUNTY
DEPARTMENT OF PUBLIC WORKS
CLEARWATER, FLORIDA 33516
SHEET 7 OF 15 DATE 7/16/84

8/9/84

ALL ELEV. ARE REFERENCED TO NVGD



REVISED AUG 10 1984

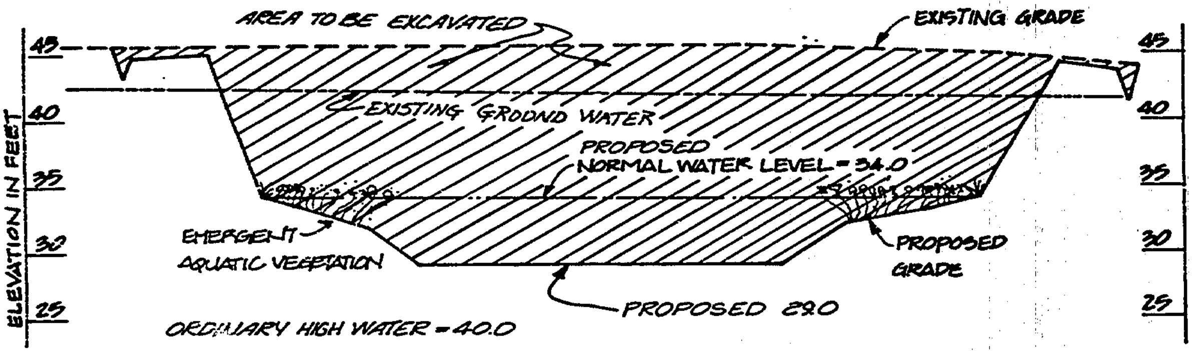
CROSS SECTION VIEW – SECTION D•D

SCALE: HORIZ. 1" = 50'
VERT. 1" = 10'

▨ AREA TO BE EXCAVATED
☐ AREA TO BE FILLED

PURPOSE: STORMWATER
DETENTION FACILITY
IN PINELLAS COUNTY
STATE OF FLORIDA

ALL ELEV. ARE REFERENCED TO NVGD



REVISED AUG 10 1984

CROSS SECTION – SECTION E•E

SCALE: HORIZ. 1" = 50'
VERT. 1" = 10'

RECEIVED PERM.
AUG 10 1984

▨ AREA TO BE EXCAVATED
☐ AREA TO BE FILLED

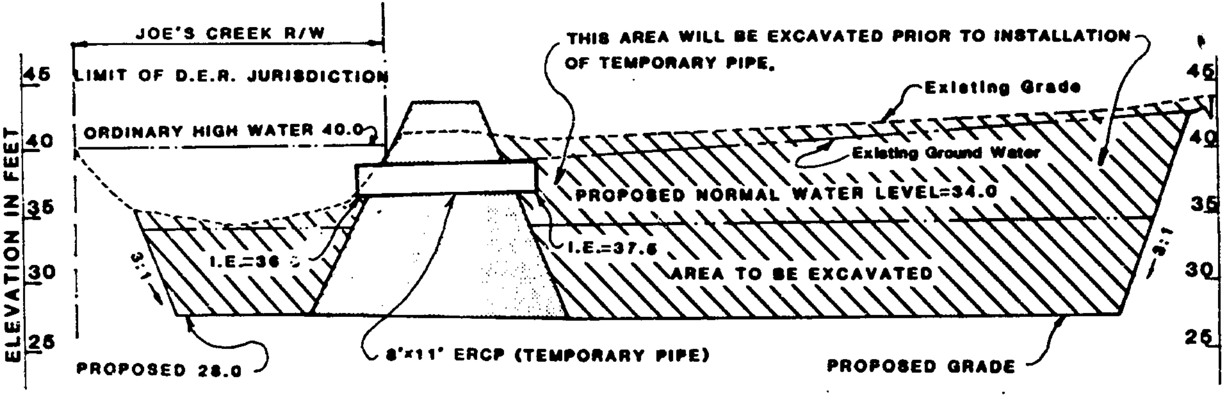
APPLICATION BY: PINELLAS COUNTY
DEPARTMENT OF PUBLIC WORKS
CLEARWATER, FLORIDA 33516
SHEET 8 OF 15 DATE 2/10/84.

8/9/84

PURPOSE: STORMWATER
DETENTION FACILITY
IN PINELLAS COUNTY
STATE OF FLORIDA

APPILCATION BY: PINELLAS COUNTY
DEPARTMENT OF PUBLIC WORKS
CLEARWATER, FLORIDA 33516
SHEET 6 OF 6 DATE:2/16/85

ALL ELEV. ARE REFERENCED TO NVGD



SECTION F–F

SCALE: HORIZ.1"=50'
VERT.1"=10'

LEGEND

▨ AREA TO BE EXCAVATED

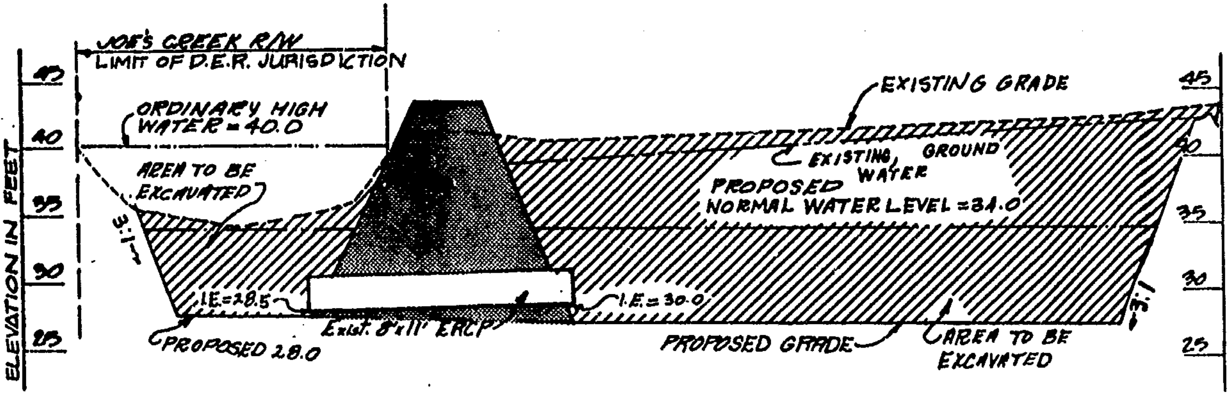
☐ AREA TO BE FILLED

░ EARTH DIKE

PURPOSE: STORMWATER
DETENTION FACILITY
IN PINELLAS COUNTY
STATE OF FLORIDA

APPLICATION BY: PINELLAS COUNTY
DEPARTMENT OF PUBLIC WORKS
CLEARWATER, FLORIDA 33516
SHEET 6 OF 6 DATE 2/16/84

ALL ELEV. ARE REFERENCED TO NVGD

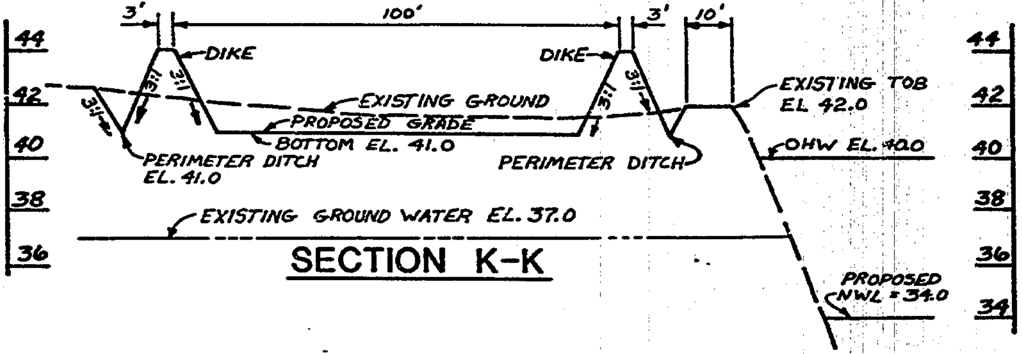


CROSS SECTION VIEW – SECTION F•F

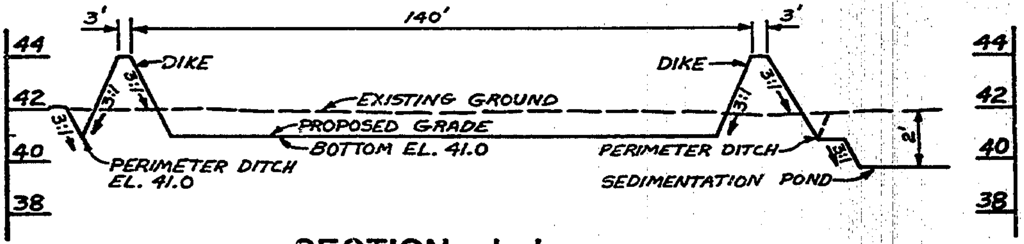
SCALE: HORIZ. 1" = 50'
VERT. 1" = 10'

▨ AREA TO BE EXCAVATED
▩ AREA TO BE FILLED
☐ EARTH DIKE

PURPOSE: STORMWATER
DETENTION FACILITY
IN PINELLAS COUNTY
STATE OF FLORIDA

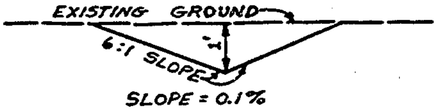


SECTION K-K



SECTION L-L

SCALE: 1" = 30' HORIZ.
1" = 5' VERT.



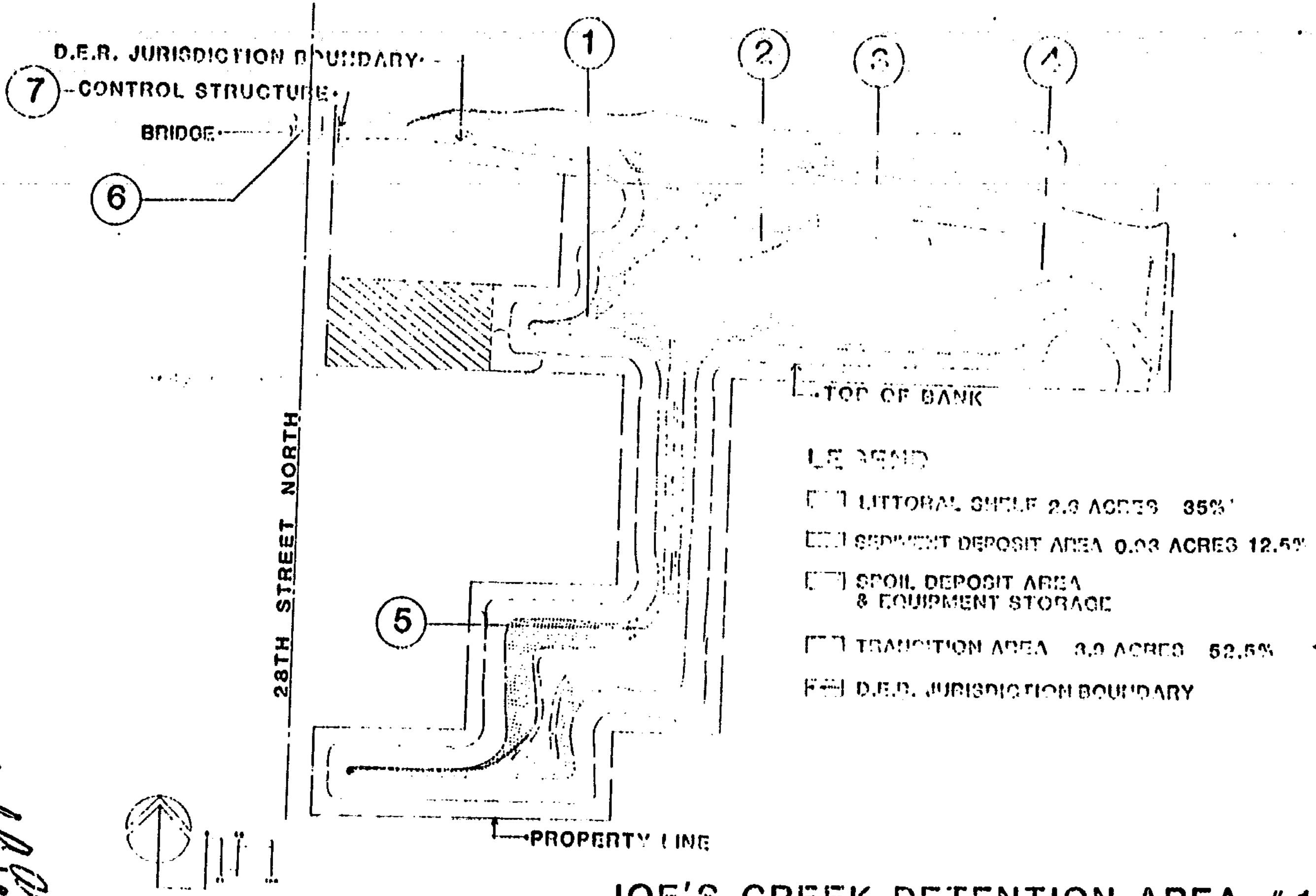
SECTION M-M

NTS

REVISED AUG 1 0 1984

APPLICATION BY: PINELLAS COUNTY
DEPARTMENT OF PUBLIC WORKS
CLEARWATER, FLORIDA 33516
SHEET 15 OF 16 DATE 16/84

8/9/84



LEGEND

[ ] LITTORAL SHELF 2.0 ACRES 35%

[ ] SEDIMENT DEPOSIT AREA 0.93 ACRES 12.5%

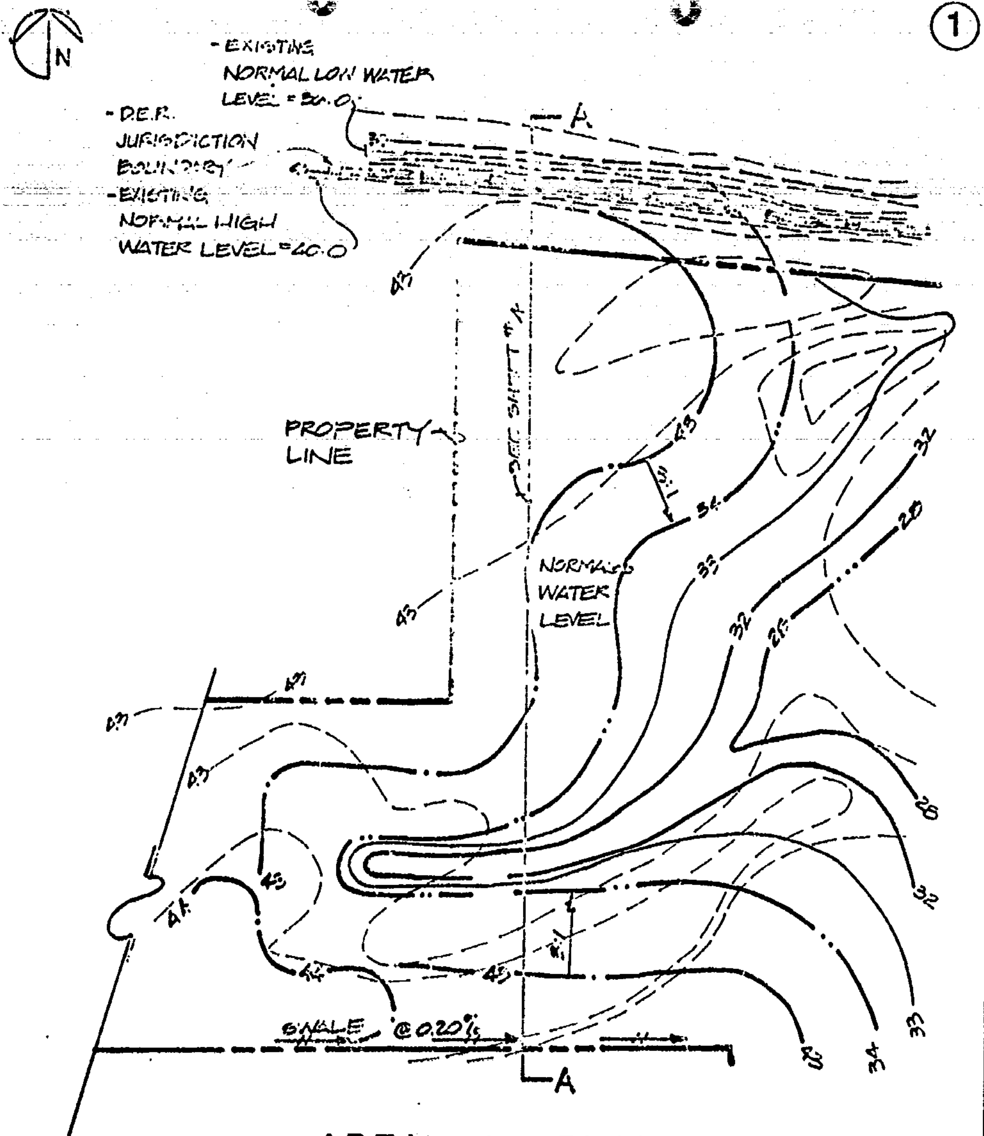
[ ] SPOIL DEPOSIT AREA
& EQUIPMENT STORAGE

[ ] TRANSITION AREA 3.0 ACRES 52.5%

[ ] D.E.R. JURISDICTION BOUNDARY

JOE'S CREEK DETENTION AREA #1
INDEX TO AREA ENLARGEMENTS

SHEET 15 DATE: 2/16/84



AREA #1 - PLAN

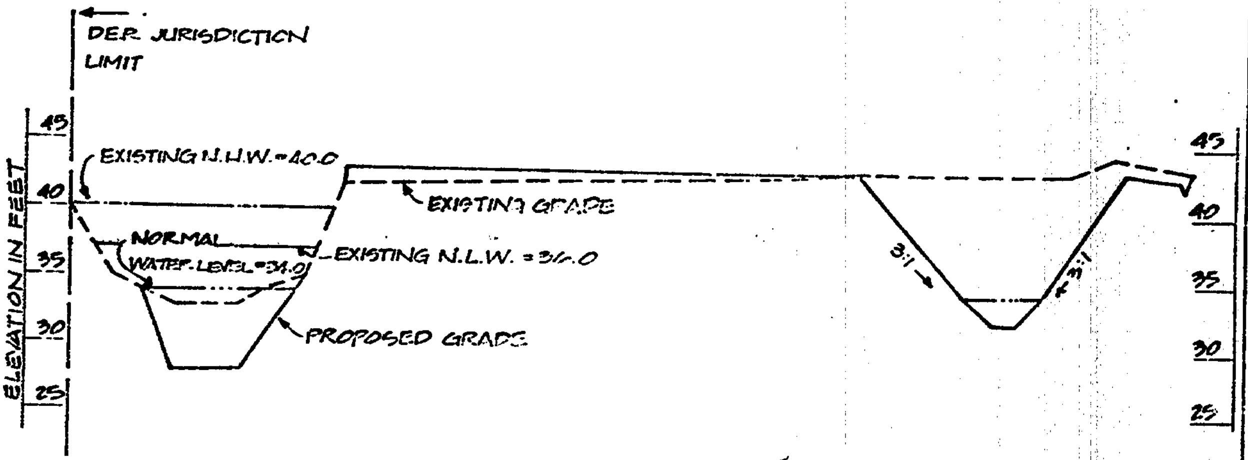
SCALE: 1" = 50'

PURPOSE: STORMWATER
DETENTION FACILITY
IN: PINELLAS COUNTY
STATE OF FLORIDA

APPLICATION BY: PINELLAS COUNTY
DEPARTMENT OF PUBLIC WORKS
CLEARWATER, FLORIDA 33[illegible]
SHEET 3 OF 15 DATE 2[illegible]

2/29/84

PURPOSE: STORMWATER
DETENTION FACILITY
IN PINELLAS COUNTY
STATE OF FLORIDA

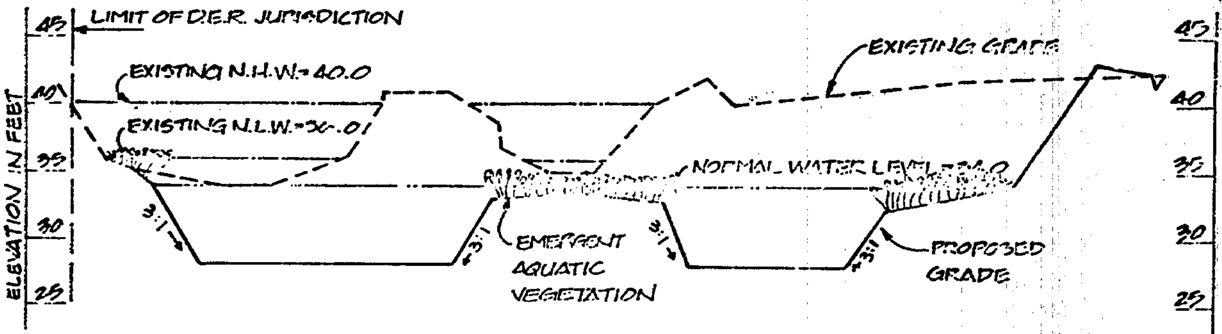


AREA #1 - SECTION A-A

SCALE: HORIZ. 1" = 50'
VERT. 1" = 10'

APPLICATION BY: PINELLAS COUNTY
DEPARTMENT OF PUBLIC WORKS
CLEARWATER, FLORIDA 33516
SHEET 4 OF 15 DATE 2/18/8

PURPOSE: STORMWATER
DETENTION FACILITY
IN: PINELLAS COUNTY
STATE OF FLORIDA



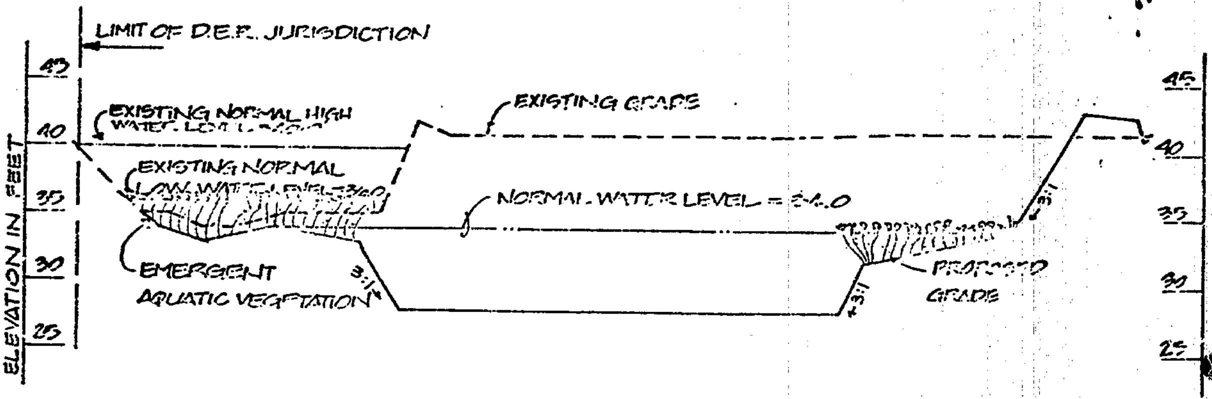
AREA #2 - SECTION B•B

SCALE: HORIZ. 1" = 50'
VERT. 1" = 10'

APPLICATION BY: PINELLAS COUNTY
DEPARTMENT OF PUBLIC WORKS
CLEARWATER, FLORIDA 33516
SHEET 6 OF 16 DATE 2/18/8

②

PURPOSE: STORMWATER DETENTION FACILITY IN PINELLAS COUNTY STATE OF FLORIDA



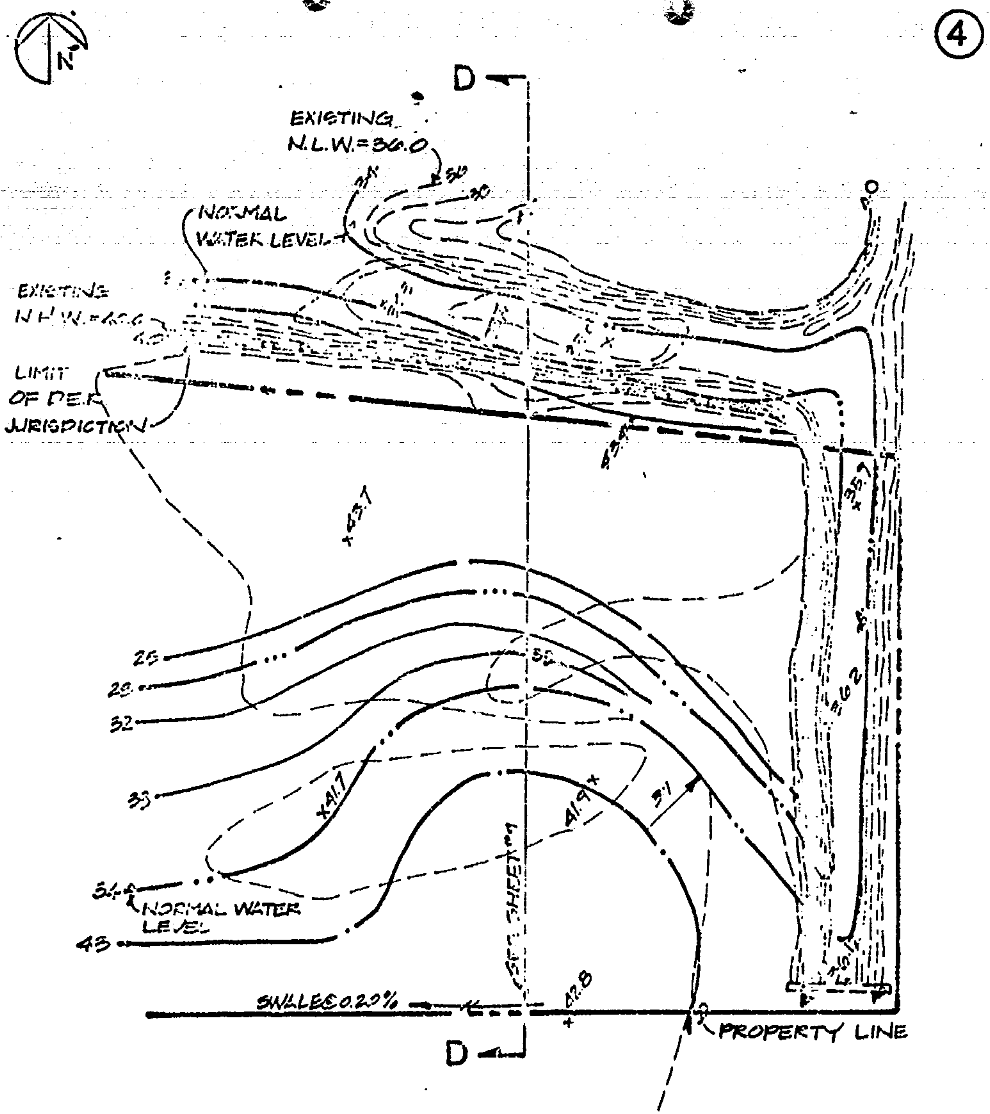
AREA #3 – SECTION C•C

SCALE: HORIZ. 1" = 50'
VERT. 1" = 10'

③

APPLICATION BY: PINELLAS COUNTY
DEPARTMENT OF PUBLIC WORKS
CLEARWATER, FLORIDA 33516
SHEET 7 OF 16 DATE 2/1[illegible]/84

2/14/84



AREA #4 - PLAN

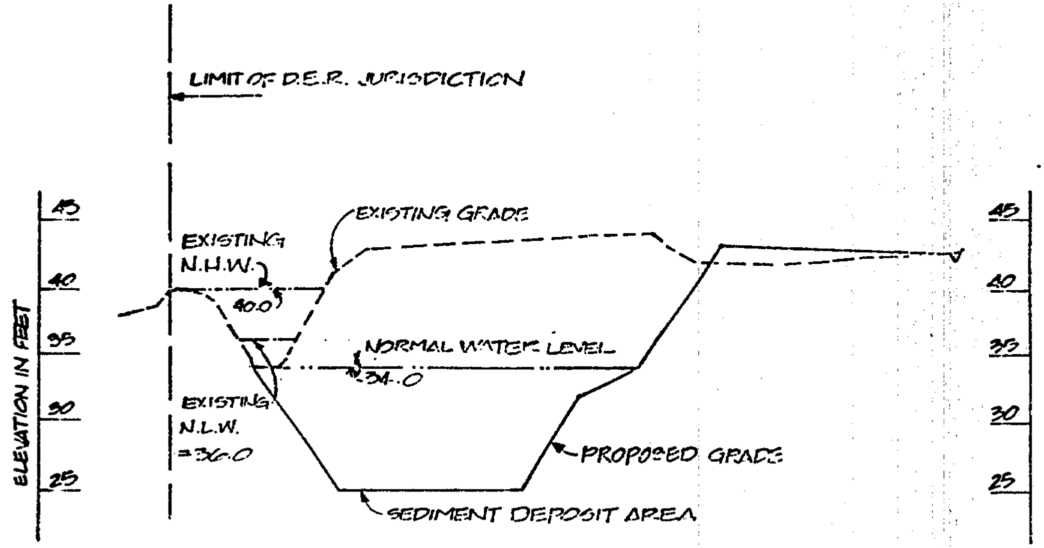
SCALE: 1" = 50'

PURPOSE: STORMWATER
DETENTION FACILITY
IN PINELLAS COUNTY
STATE OF FLORIDA

APPLICATION BY: PINELLAS COUNTY
DEPARTMENT OF PUBLIC WORKS
CLEARWATER, FLORIDA
SHEET 8 OF 16 DATE 2/ /84

2/29/84

PURPOSE: STORMWATER DETENTION FACILITY
IN: PINELLAS COUNTY
STATE OF FLORIDA

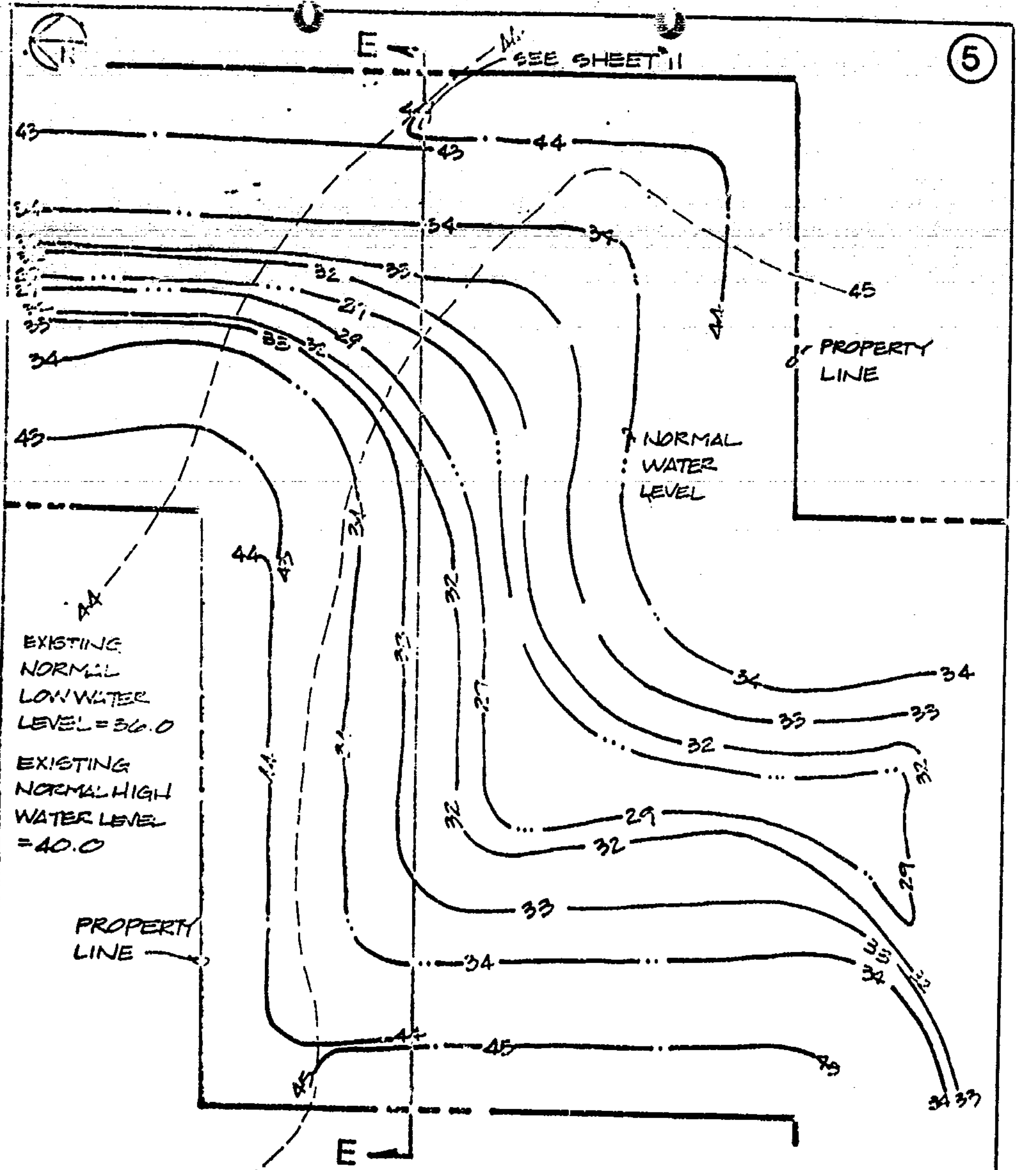


AREA #4 - SECTION D•D

SCALE: HORIZ. 1" = 50'
VERT. 1" = 10'.

APPLICATION BY: PINELLAS COUNTY
DEPARTMENT OF PUBLIC WORKS
CLEARWATER, FLORIDA 33516
SHEET 8 OF 16 DATE 2/29/84

④



EXISTING NORMAL LOW WATER LEVEL = 36.0

EXISTING NORMAL HIGH WATER LEVEL = 40.0

PROPERTY LINE

AREA #5 - PLAN

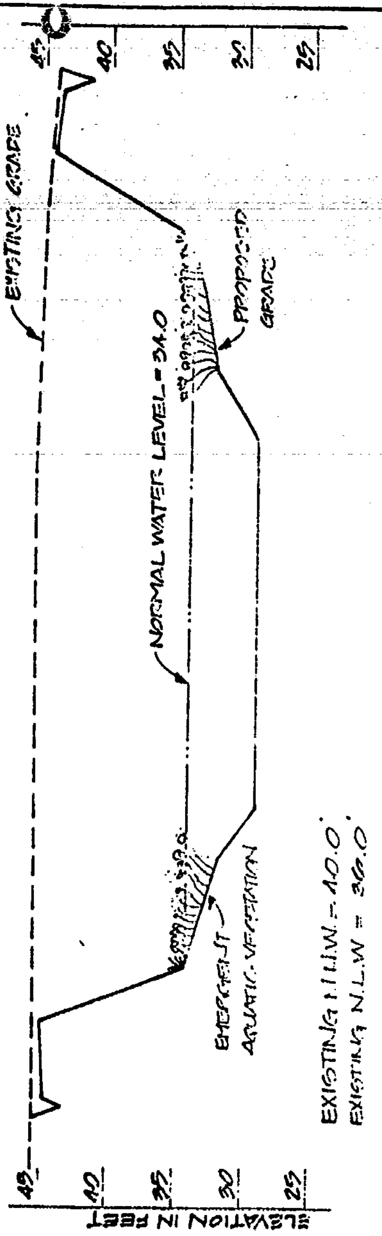
SCALE: 1" = 50'

PURPOSE: STORMWATER
DETENTION FACILITY
IN PINELLAS COUNTY
STATE OF FLORIDA

APPLICATION BY: PINELLAS COUNTY
DEPARTMENT OF PUBLIC WORKS
CLEARWATER, FLORIDA 33516
SHEET 10 OF 15 DATE 2/16/84

2/29/84

⑤



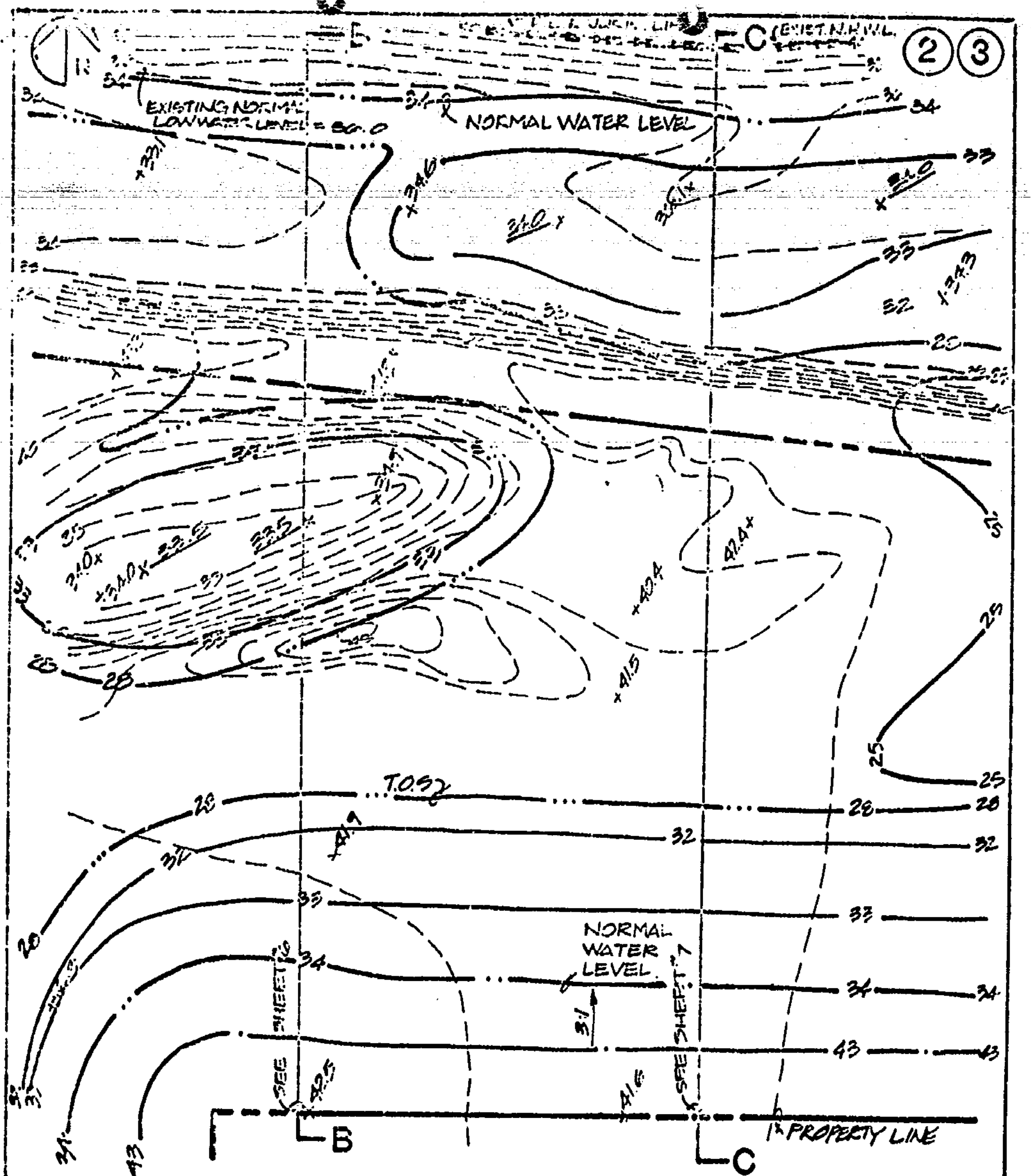
AREA #5 - SECTION E•E

SCALE: HORIZ. 1" = 50'
VERT. 1" = 10'

PURPOSE: STORMWATER
DETENTION FACILITY
IN PINELLAS COUNTY
STATE OF FLORIDA

APPLICATION BY: PINELLAS COUNTY
DEPARTMENT OF PUBLIC WORKS
CLEARWATER, FLORIDA
SHEET 11 OF 16 DATE

2/29/84



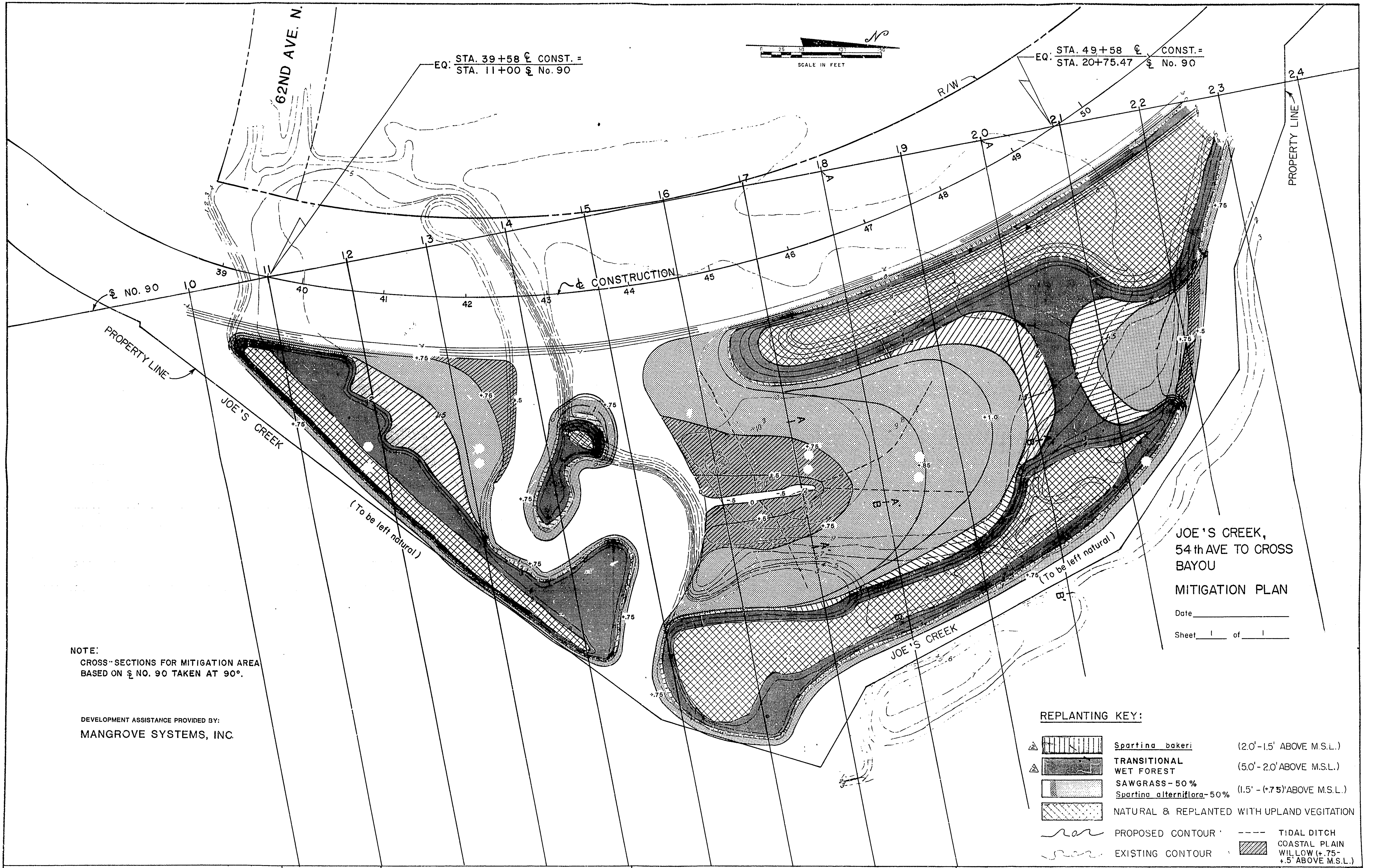
AREAS #2 & #3 - PLAN

SCALE: 1" = 50'

PURPOSE: STORMWATER
DETENTION FACILITY
IN: PINELLAS COUNTY
STATE OF FLORIDA

APPLICATION BY: PINELLAS COUNTY
DEPARTMENT OF PUBLIC WORKS
CLEARWATER, FLORIDA 33516
SHEET 5 OF 15 DATE 2/1/84

2/27/84



3	REVISED CONTOURS & REPLANTING PLAN	J.B.T.	4-17-85
2	REVISED PLANTING LIMITS PER J.B.T.	J.K.	7-17-84
1	CHANGED ℄ CHANNEL TO ℄ CONST., RESTATIONED	F.N.	8/83
	REVISIONS	BY	DATE

SURVEY BY	BY	DATE
DESIGNED	JBT	10-82
DRAWN	C.L.P.	10-20-82
CHECKED	JBT	9-16-84
APPROVED		

PINELLAS COUNTY, FLORIDA
ENGINEERING DEPARTMENT

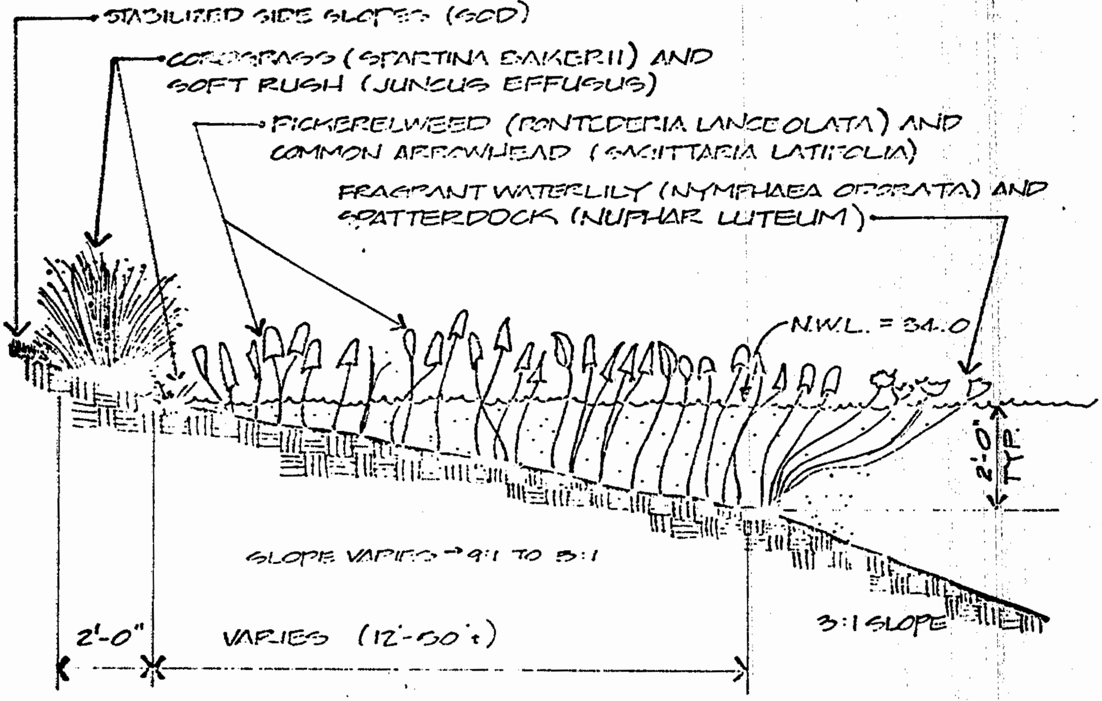
APPROVED BY
DIRECTOR OF ENGINEERING
DATE

JOE'S CREEK
MITIGATION AREA
(54TH AVE.N. TO CROSS BAYOU)

MITIGATION AREA
GRADING & REPLANTING PLAN

DATE 2-2-83
DRAWING № 2068
SHEET 30 OF 45

PURPOSE: STORMWATER DETENTION FACILITY
IN PINELLAS COUNTY
STATE OF FLORIDA



TYPICAL SECTION: LITTORAL SHELF

NO SCALE

APPLICATION BY: PINELLAS COUNTY
DEPARTMENT OF PUBLIC WORKS
CLEARWATER, FLORIDA
SHEET 14 OF 16 DATE

SUGGESTED AQUATIC PLANT LIST FOR LITTORAL SHELF

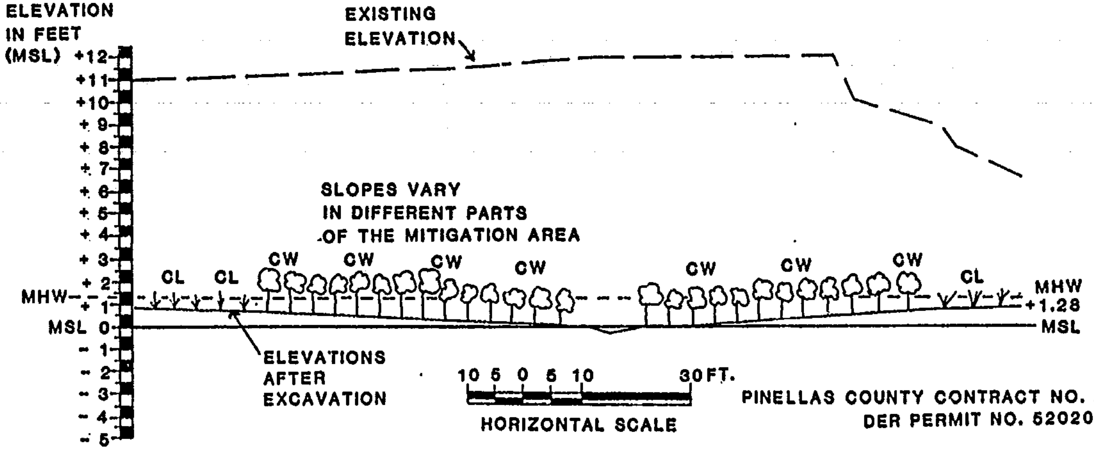
BOTANICAL NAME	COMMON NAME	SIZE/REMARKS	PLANT LOCATION (DEPTH FROM NWL)
SPARTINA BAKERII	CORDGRASS	18"-36" x 18"-36", DENSE CLUMP PLANTED UPLAND FROM NWL, PLANTED IN CLUMPS	EDGE MATERIAL
JUNCUS EFFUSUS	SOFT RUSH	12"-24" x 12"-24", MULTI-STEM(20)/ CLUMP, PLANTED IN CLUMPS	6" DEPTH TO EDGE
PONTEDERIA LANCEOLATA	PICKERELWEED	3-4 STEMS/PLANT, 12"-24" TALL	6" TO 2' DEPTH
SAGITTARIA LATIFOLIA	ARROWHEAD	4-6 STEMS/PLANT, 12"-24" TALL, PLANTED IN CLUMPS OF 3-5	6" TO 2' DEPTH
NUPHAR LUTEUM	SPATTERDOCK	3-5 PETIOLES/ PLANT, PETIOLES 18"-36" LONG, LEAVES 8"-12" LONG, PLANTED IN CLUMPS	2' TO 3' DEPTH
NYMPHAEA ODORATA	FRAGRANT WATER LILY	3-5 PETIOLES/ PLANT/PETIOLES 18"-36" LONG, LEAVES 6"-10" WIDE	2' TO 3' DEPTH

PURPOSE: STORMWATER
DETENTION FACILITY
IN PINELLAS COUNTY
STATE OF FLORIDA

APPLICATION BY: PINELLAS COUNTY
DEPARTMENT OF PUBLIC WORKS
CLEARWATER, FLORIDA 33[illegible]
SHEET 13 OF 15 DATE 2/[illegible]/84

2/27/84

JOE'S CREEK CHANNEL IMPROVEMENTS
MITIGATION AREA PLANTINGS - CROSS SECTION 17 A-A'



PINELLAS COUNTY CONTRACT NO. 2068
DER PERMIT NO. 520207219

MITIGATION PLANTS

SB - *SPARTINA BAKERI*
CL - SAWGRASS
CW - WILLOW

WM - WAX MYRTLE
SLO - SAND LIVE OAK
SP - SLASH PINE
PM - SAW PALMETTO
CP - CABBAGE PALM

UPLAND PLANTS

TRANSITIONAL WET FOREST

SW - SWAMP BAY
RM - RED MAPLE
LO - LAUREL OAK
PA - POP ASH
BB - BUTTONBUSH
SG - SWEETGUM

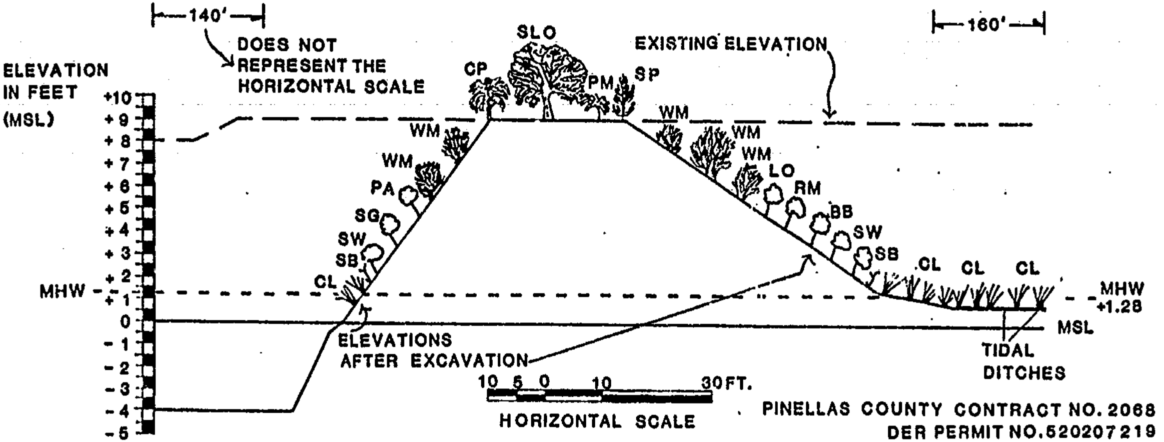
PINELLAS COUNTY
REQUESTED MITIGATION.

JOE'S CREEK,
ST. PETERSBURG, FL.,
PINELLAS COUNTY, FLORIDA.

INTER BAY MARINE,
CONSTRUCTION CO.

PREPARED BY:
MANGROVE SYSTEMS, INC.
28 MAR 85

JOE'S CREEK CHANNEL IMPROVEMENTS
MITIGATION AREA PLANTINGS - CROSS SECTION 18 A-A'



PINELLAS COUNTY CONTRACT NO. 2068
DER PERMIT NO.520207219

MITIGATION PLANTS

SB - <u>SPARTINA BAKERI</u>
CL - SAWGRASS
CW - WILLOW

UPLAND PLANTS:
WM - WAX MYRTLE
SLO - SAND LIVE OAK
SP - SLASH PINE
PM - SAW PALMETTO
CP - CABBAGE PALM

TRANSITIONAL WET FOREST:
SW SWAMP BAY
RM RED MAPLE
LO LAUREL OAK
PA POP ASH
BB BUTTONBUSH
SG SWEETGUM

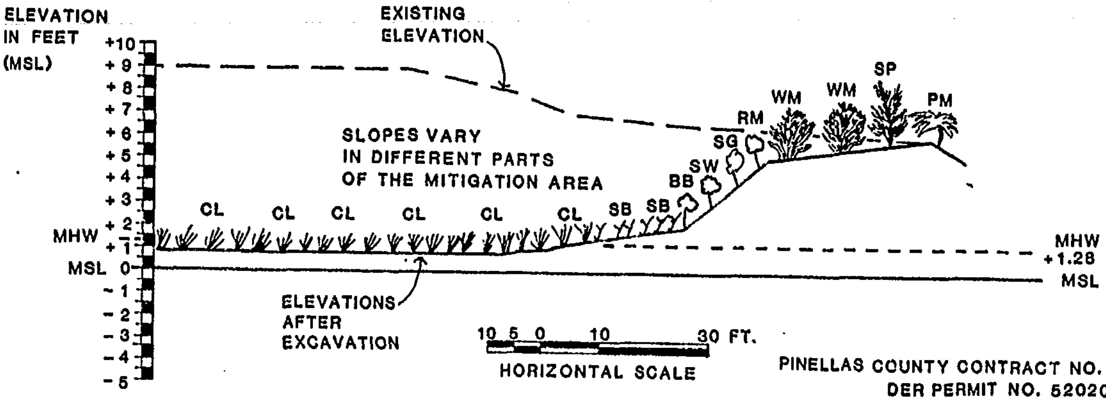
PINELLAS COUNTY
REQUESTED MITIGATION.

JOE'S CREEK,
ST. PETERSBURG, FL.,
PINELLAS COUNTY, FLORIDA.

INTER BAY MARINE,
CONSTRUCTION CO.

PREPARED BY:
MANGROVE SYSTEMS, INC.
28 MAR 85

JOE'S CREEK CHANNEL IMPROVEMENTS
MITIGATION AREA PLANTINGS - CROSS SECTION 18 B-B'



PINELLAS COUNTY CONTRACT NO. 2068
DER PERMIT NO. 520207219

MITIGATION PLANTS

SB – SPARTINA BAKERI
CL – SAWGRASS
CW – WILLOW

UPLAND PLANTS:
WM – WAX MYRTLE
SLO – SAND LIVE OAK
SP – SLASH PINE
PM – SAW PALMETTO
CP – CABBAGE PALM

TRANSITIONAL WET FOREST:
SW – SWAMP BAY
RM – RED MAPLE
LO – LAUREL OAK
PA – POP ASH
BB – BUTTONBUSH
SG – SWEETGUM

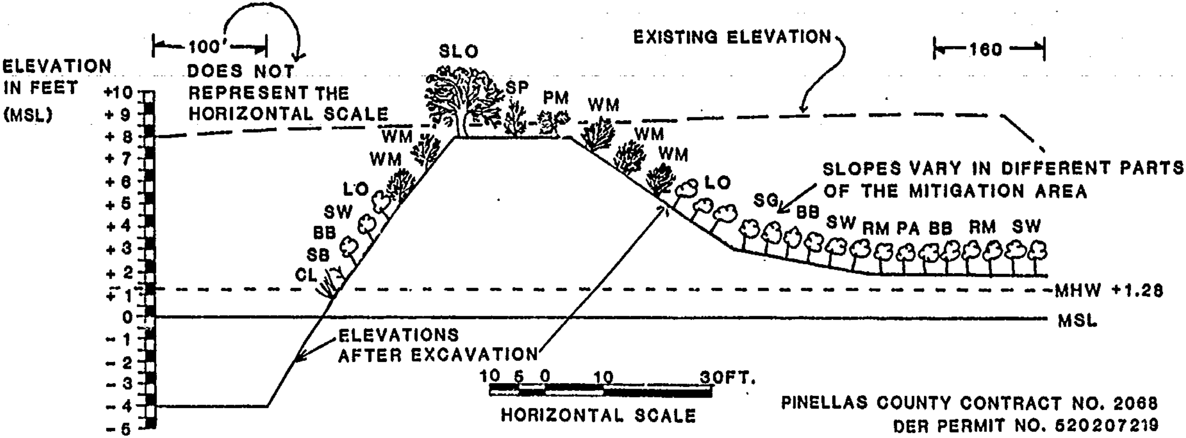
PINELLAS COUNTY
REQUESTED MITIGATION.

JOE'S CREEK
ST. PETERSBURG, FL.,
PINELLAS COUNTY, FLORIDA.

INTER BAY MARINE,
CONSTRUCTION CO.

PREPARED BY:
MANGROVE SYSTEMS, INC.
28 MAR 85

JOE'S CREEK CHANNEL IMPROVEMENTS
MITIGATION AREA PLANTINGS - CROSS SECTION 20 A-A'



PINELLAS COUNTY CONTRACT NO. 2068
DER PERMIT NO. 520207219

MITIGATION PLANTS

SB - SPARTINA BAKERI
CL - SAWGRASS
CW - WILLOW

UPLAND PLANTS:
WM - WAX MYRTLE
SLO - SAND LIVE OAK
SP - SLASH PINE
PM - SAW PALMETTO
CP - CABBAGE PALM

TRANSITIONAL WET FOREST:
SW - SWAMP BAY
RM - RED MAPLE
LO - LAUREL OAK
PA - POP ASH
BD - BUTTONBUSH
SG - SWEETGUM

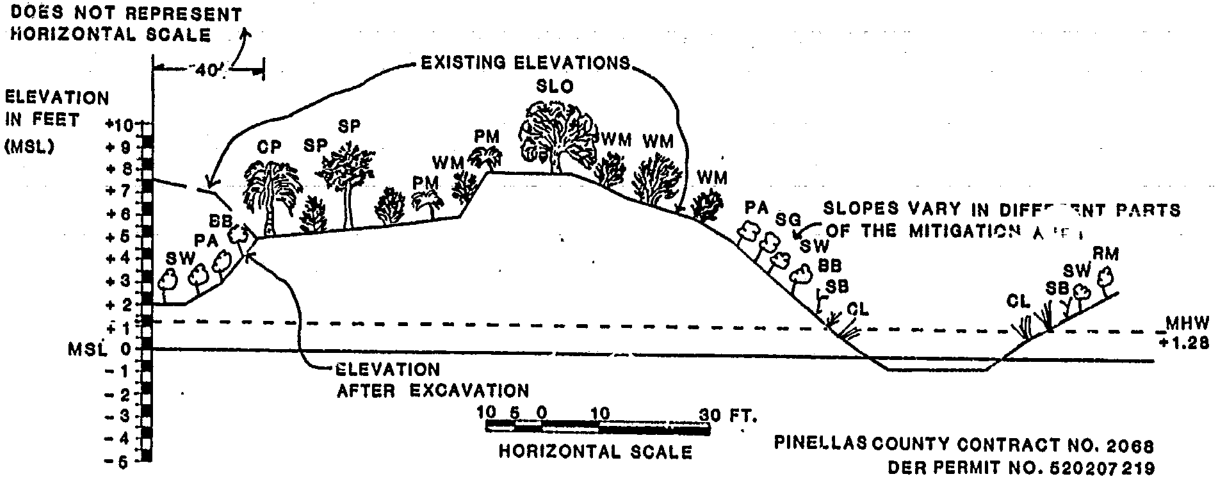
PINELLAS COUNTY
REQUESTED MITIGATION.

JOE'S CREEK,
ST. PETERSBURG, FL.,
PINELLAS COUNTY, FLORIDA.

INTER BAY MARINE,
CONSTRUCTION CO.

PREPARED BY:
MANGROVE SYSTEMS INC.
28 MAR 85

JOE'S CREEK CHANNEL IMPROVEMENTS
MITIGATION AREA PLANTINGS – CROSS SECTION 20 B–B'



PINELLAS COUNTY CONTRACT NO. 2068
DER PERMIT NO. 520207219

MITIGATION PLANTS

SB – *SPARTINA BAKERI*
CL – SAWGRASS
CW – WILLOW

UPLAND PLANTS:
WM – WAX MYRTLE
SLO – SAND LIVE OAK
SP – SLASH PINE
PM – SAW PALMETTO
CP – CABBAGE PALM

TRANSITIONAL WET FOREST:
SW – SWAMP BAY
RM – RED MAPLE
LO – LAUREL OAK
PA – POP ASH
BB – BUTTONBUSH
SG – SWEETGUM

PINELLAS COUNTY
REQUESTED MITIGATION.

JOE'S CREEK
ST. PETERSBURG, FL.
PINELLAS COUNTY, FLORIDA

INTER BAY MARINE
CONSTRUCTION CO.

PREPARED BY:
MANGROVE SYSTEMS INC.
28 MAR 85

APPENDIX B

PRODUCT INFORMATION SHEETS

B.1 Phoslock
B.2 Alum and Sodium Aluminate

B.1 Phoslock

Specimen Label

PHOSLOCK®

Phosphorus Locking Technology

SePRO

For use in aquatic systems to reduce phosphorus and improve water quality.

Keep Out of Reach of Children

In the case of emergency endangering health or the environment involving this product, have the package label with you and call **INFOTRAC** at **1-800-535-5053**.

Directions for Use

For best results, distribute uniformly over the surface of the waterbody, or the area targeted for application, as an aqueous slurry. Under certain conditions Phoslock granules may also be applied directly to the water based on management objectives and site conditions. For applications to waters with alkalinity less than 20 ppm, lower application rates may be needed. For site specific rate and treatment recommendations, contact SePRO Corporation at **1-800-419-7779**.

NSF/ANSI 60

Tested and certified against NSF/ANSI 60 by Water Quality Association (WQA). The maximum application rate is 80 ppm when applied to drinking water.

NSF/ANSI 60

Precaution: avoid ingestion, inhalation, contact with eyes and skin. Breathing dust may be irritating. For large volume applications, the use of a dust protection mask is recommended.

FIRST AID	
If on skin or clothing	• Remove contaminated clothing • Immediately rinse skin with water for 15 to 20 minutes. • Seek medical attention if skin irritation persists.
If in eyes	• Hold eyes open and rinse slowly and gently with water for 15 to 20 minutes. • Seek medical attention if eye irritation persists.
If inhaled	• Immediately move to fresh air; if person is not breathing, call 911 or an ambulance, then give artificial respiration.
If swallowed	• Do not induce vomiting unless instructed to do so by a doctor.
HOTLINE NUMBER	
Have the product container or label with you when calling a poison control center or doctor or going for treatment. You may also contact **INFOTRAC** for emergency medical information: **1-800-535-5053**.	

Specimen Label

PHOSLOCK®

Phosphorus Locking Technology

STORAGE AND DISPOSAL

Do not contaminate food, feed or water by storage or disposal.

Storage: Store in original container and keep closed. Store in a dry place.

Disposal: Do not re-use or refill this container. After completely emptying the container, dispose of in a sanitary landfill or by incineration or by other procedures approved by state and local authorities.

TERMS AND CONDITIONS OF USE

If terms of the following *Warranty Disclaimer, Inherent Risks of Use,* and *Limitation of Remedies* are not acceptable, return unopened package at once to the seller for a full refund of purchase price paid. Otherwise, to the extent consistent with applicable law, use by the buyer or any other user constitutes acceptance of the terms under *Warranty Disclaimer, Inherent Risks of Use,* and *Limitation of Remedies.*

WARRANTY DISCLAIMER

SePRO Corporation warrants that the product conforms to the description on the label and is reasonably fit for the purposes stated on the label when used in strict accordance with the directions, subject to the inherent risks set forth below.
TO THE EXTENT CONSISTENT WITH APPLICABLE LAW, SEPRO CORPORATION MAKES NO OTHER EXPRESS OR IMPLIED WARRANTY OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE OR ANY OTHER EXPRESS OR IMPLIED WARRANTY.

INHERENT RISKS OF USE

It is impossible to eliminate all risks associated with use of this product. Lack of performance, or other unintended consequences may result because of such factors as use of the product contrary to label, abnormal conditions (such as excessive rainfall, drought, tornadoes, hurricanes), presence of other materials, the manner of application, or other factors, all of which are beyond the control of SePRO Corporation or the seller. To the extent consistent with applicable law, all such risks shall be assumed by buyer.

LIMITATION OF REMEDIES

To the extent consistent with applicable law, the exclusive remedy for losses or damages resulting from this product (including claims based on contract, negligence, strict liability, or other legal theories) shall be limited to, at SePRO Corporation's election, one of the following:

(1) Refund of purchase price paid by buyer or user for product bought, or
(2) Replacement of amount of product used.

To the extent consistent with applicable law, SePRO Corporation shall not be liable for losses or damages resulting from handling or use of this product unless SePRO Corporation is promptly notified of such losses or damages in writing. In no case shall SePRO Corporation be liable for consequential or incidental damages or losses.

The terms of the *Warranty Disclaimer, Inherent Risks of Use,* and this *Limitation of Remedies* cannot be varied by any written or verbal statements or agreements. No employee or sales agent of SePRO Corporation or the seller is authorized to vary or exceed the terms of the *Warranty Disclaimer* or this *Limitation of Remedies* in any manner.

FPL20111214

Manufactured for: SePRO Corporation 11550 North Meridian Street, Suite 600, Carmel, IN 46032 U.S.A.

Material Safety Data Sheet

Phoslock*

1 . Product and company identification

Product name : Phoslock*

Material uses : Used to remove phosphorus in a variety of natural environments such as ponds, lakes, reservoirs, lagoons, rivers, estuaries, dams, ornamental ponds and natural wetlands. Also inartificial environments including waste efflluents such as sewage and industrial efflluents and as a barrier within containment cells for leachable wastes.

Supplier/Manufacturer :
SePRO Corporation
11550 North Meridian Street
Suite 600
Carmel, IN 46032 U.S.A.
Tel: 317-580-8282
Toll free: 1-800-419-7779
Fax: 317-428-4577
Monday - Friday, 8am to 5pm E.S.T.
www.sepro.com

Responsible name : KMK Regulatory Services Inc.

In case of emergency : **INFOTRAC - 24-hour service 1-800-535-5053**

2 . Hazards identification

Physical state : Solid. [Granular powder.]

OSHA/HCS status : While this material is not considered hazardous by the OSHA Hazard Communication Standard (29 CFR 1910.1200), this MSDS contains valuable information critical to the safe handling and proper use of the product. This MSDS should be retained and available for employees and other users of this product.

Emergency overview : **NOT EXPECTED TO PRODUCE SIGNIFICANT ADVERSE HEALTH EFFECTS WHEN THE RECOMMENDED INSTRUCTIONS FOR USE ARE FOLLOWED.**

No known significant effects or critical hazards. Avoid prolonged contact with eyes, skin and clothing.

Potential acute health effects

Inhalation : No known significant effects or critical hazards.
Skin : No known significant effects or critical hazards.
Eyes : No known significant effects or critical hazards.

Potential chronic health effects

Chronic effects : No known significant effects or critical hazards.
Carcinogenicity : No known significant effects or critical hazards.
Mutagenicity : No known significant effects or critical hazards.
Teratogenicity : No known significant effects or critical hazards.
Developmental effects : No known significant effects or critical hazards.
Fertility effects : No known significant effects or critical hazards.

Over-exposure signs/symptoms

Inhalation : No specific data.
Ingestion : No specific data.
Skin : No specific data.
Eyes : No specific data.

Medical conditions aggravated by over-exposure : None known.

See toxicological information (Section 11)

3 . Composition/information on ingredients

Name	CAS number	%
No hazardous ingredient		

There are no ingredients present which, within the current knowledge of the supplier and in the concentrations applicable, are classified as hazardous to health or the environment and hence require reporting in this section.

4 . First aid measures

Eye contact : Immediately flush eyes with plenty of water for at least 15 to 20 minutes, occasionally lifting the upper and lower eyelids. Get medical attention if symptoms occur.

Skin contact : In case of contact, immediately flush skin with plenty of water for at least 15 to 20 minutes. Get medical attention if symptoms occur.

Inhalation : Move exposed person to fresh air. Get medical attention if symptoms occur.

Ingestion : Wash out mouth with water. Do not induce vomiting unless directed to do so by medical personnel. Never give anything by mouth to an unconscious person. Get medical attention if symptoms occur.

Protection of first-aiders : No action shall be taken involving any personal risk or without suitable training.

Notes to physician : No specific treatment. Treat symptomatically. Contact poison treatment specialist immediately if large quantities have been ingested or inhaled.

5 . Fire-fighting measures

Flammability of the product : No specific fire or explosion hazard.

Extinguishing media

Suitable : Use an extinguishing agent suitable for the surrounding fire.

Not suitable : None known.

Hazardous thermal decomposition products : No specific data.

Special protective equipment for fire-fighters : No special protection is required.

6 . Accidental release measures

Personal precautions : Put on appropriate personal protective equipment (see Section 8).

Environmental precautions : Avoid dispersal of spilled material and runoff and contact with soil, waterways, drains and sewers. Inform the relevant authorities if the product has caused environmental pollution (sewers, waterways, soil or air).

Spill : Prevent entry into sewers, water courses, basements or confined areas. Vacuum or sweep up material and place in a designated, labeled waste container. Dispose of via a licensed waste disposal contractor. Note: see section 1 for emergency contact information and section 13 for waste disposal.

7 . Handling and storage

Handling : Put on appropriate personal protective equipment (see Section 8). Eating, drinking and smoking should be prohibited in areas where this material is handled, stored and processed. Workers should wash hands and face before eating, drinking and smoking. Remove contaminated clothing and protective equipment before entering eating areas.

Storage : Store in accordance with local regulations. Store in original container protected from direct sunlight in a dry, cool and well-ventilated area, away from incompatible materials (see section 10) and food and drink. Keep container tightly closed and sealed until ready for use. Containers that have been opened must be carefully resealed and kept upright to prevent leakage. Do not store in unlabeled containers. Use appropriate containment to avoid environmental contamination.

8 . Exposure controls/personal protection

Consult local authorities for acceptable exposure limits.

		Applicators should refer to the product label for personal protective equipment.
Respiratory	:	Not required under normal conditions of use. Respirator selection must be based on known or anticipated exposure levels, the hazards of the product and the safe working limits of the selected respirator.
Hands	:	Not required under normal conditions of use. Use gloves appropriate for work or task being performed.
Eyes	:	Not required under normal conditions of use. Safety eyewear should be used when there is a likelihood of exposure. Recommended: Safety glasses with side shields.
Skin	:	No special protective clothing is required.
Environmental exposure controls	:	Emissions from ventilation or work process equipment should be checked to ensure they comply with the requirements of environmental protection legislation.

9 . Physical and chemical properties

Physical state	:	Solid. [Granular powder.]
Color	:	Brown. [Light]
pH	:	7 to 7.5 [Conc. (% w/w): 2%]
Boiling/condensation point	:	Not available.
Melting/freezing point	:	>1000°C (>1832°F)
Relative density	:	Not available.
Vapor pressure	:	Not available.
Solubility	:	Insoluble in water

10 . Stability and reactivity

Chemical stability	:	The product is stable.
Conditions to avoid	:	No specific data.
Materials to avoid	:	Reactive or incompatible with the following materials: oxidizing materials.
Hazardous decomposition products	:	Under normal conditions of storage and use, hazardous decomposition products should not be produced.
Possibility of hazardous reactions	:	Under normal conditions of storage and use, hazardous reactions will not occur.
Hazardous polymerization	:	Under normal conditions of storage and use, hazardous polymerization will not occur.

11 . Toxicological information

Acute toxicity	:	No known significant effects or critical hazards.
Chronic toxicity	:	No known significant effects or critical hazards.

12 . Ecological information

Environmental effects	:	No known significant effects or critical hazards.

13 . Disposal considerations

Waste disposal	:	The generation of waste should be avoided or minimized wherever possible. Avoid dispersal of spilled material and runoff and contact with soil, waterways, drains and sewers. Empty containers or liners may retain some product residues. Dispose of surplus and non-recyclable products via a licensed waste disposal contractor.

Disposal should be in accordance with applicable regional, national and local laws and regulations.

Refer to Section 7: HANDLING AND STORAGE and Section 8: EXPOSURE CONTROLS/PERSONAL PROTECTION for additional handling information and protection of employees.

14 . Transport information

DOT/IMDG/IATA : Not regulated.

15 . Regulatory information

HCS Classification : Not regulated.

U.S. Federal regulations : **TSCA 8(a) IUR Exempt/Partial exemption**: Not determined
United States inventory (TSCA 8b): Not determined.

SARA 302/304/311/312 extremely hazardous substances: No products were found.
SARA 302/304 emergency planning and notification: No products were found.
SARA 302/304/311/312 hazardous chemicals: No products were found.
SARA 311/312 MSDS distribution - chemical inventory - hazard identification: No products were found.

Clean Air Act (CAA) 112 accidental release prevention: No products were found.

Clean Air Act Section 112(b) Hazardous Air Pollutants (HAPs) : Not listed

Clean Air Act Section 602 Class I Substances : Not listed

Clean Air Act Section 602 Class II Substances : Not listed

DEA List I Chemicals (Precursor Chemicals) : Not listed

DEA List II Chemicals (Essential Chemicals) : Not listed

State regulations : **Connecticut Carcinogen Reporting**: None of the components are listed.
Connecticut Hazardous Material Survey: None of the components are listed.
Florida substances: None of the components are listed.
Illinois Chemical Safety Act: None of the components are listed.
Illinois Toxic Substances Disclosure to Employee Act: None of the components are listed.
Louisiana Reporting: None of the components are listed.
Louisiana Spill: None of the components are listed.
Massachusetts Spill: None of the components are listed.
Massachusetts Substances: None of the components are listed.
Michigan Critical Material: None of the components are listed.
Minnesota Hazardous Substances: None of the components are listed.
New Jersey Hazardous Substances: None of the components are listed.
New Jersey Spill: None of the components are listed.
New Jersey Toxic Catastrophe Prevention Act: None of the components are listed.
New York Acutely Hazardous Substances: None of the components are listed.
New York Toxic Chemical Release Reporting: None of the components are listed.
Pennsylvania RTK Hazardous Substances: None of the components are listed.
Rhode Island Hazardous Substances: None of the components are listed.

California Prop. 65

No products were found.

International regulations

Chemical Weapons Convention List Schedule I Chemicals : Not listed

Chemical Weapons Convention List Schedule II Chemicals : Not listed

Chemical Weapons Convention List Schedule III Chemicals : Not listed

16 . Other information

Label requirements : NOT EXPECTED TO PRODUCE SIGNIFICANT ADVERSE HEALTH EFFECTS WHEN THE RECOMMENDED INSTRUCTIONS FOR USE ARE FOLLOWED.

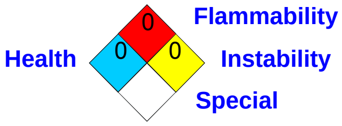
Hazardous Material Information System (U.S.A.) :

Health	0
Flammability	0
Physical hazards	0

Caution: HMIS® ratings are based on a 0-4 rating scale, with 0 representing minimal hazards or risks, and 4 representing significant hazards or risks Although HMIS® ratings are not required on MSDSs under 29 CFR 1910.1200, the preparer may choose to provide them. HMIS® ratings are to be used with a fully implemented HMIS® program. HMIS® is a registered mark of the National Paint & Coatings Association (NPCA). HMIS® materials may be purchased exclusively from J. J. Keller (800) 327-6868.

The customer is responsible for determining the PPE code for this material.

National Fire Protection Association (U.S.A.) :



Date of issue : 03/01/2011

Version : 1

Notice to reader

To the best of our knowledge, the information contained herein is accurate. However, neither the above-named supplier, nor any of its subsidiaries, assumes any liability whatsoever for the accuracy or completeness of the information contained herein.

Final determination of suitability of any material is the sole responsibility of the user. All materials may present unknown hazards and should be used with caution. Although certain hazards are described herein, we cannot guarantee that these are the only hazards that exist.

B.2 Alum and Sodium Aluminate

General Chemical

(800) 631-8050
www.GeneralChemical.com

Liquid Alum

PRODUCT DATA SHEET

CHARACTERISTICS

Liquid Alum is a clear, light green or yellow to colorless solution. It is a cationic inorganic coagulant and flocculant suitable for industrial and municipal water and wastewater treatment applications.

NSF/ANSI Standard 60: Drinking Water Chemicals - Health Effects; Certified

TYPICAL PROPERTIES

Formula: Aqueous solution of aluminum sulfate
C.A.S. 10043-01-3 (Aluminum sulfate)

pH (neat)	2.0 - 2.4
Specific Gravity @ 70^{o}F (21^{o}C)	1.335
Freezing Point	4^{o}F (-16^{o}C)
Density, lbs/gal., U.S.	11.14
Aluminum as Al, %	4.2 - 4.4
Aluminum as Al_2O_3, %	8.0 - 8.4
Aluminum as $Al_2(SO_4)_3 \cdot 14H_2O$ (Dry Alum), %	46 - 49

PRODUCT USES

Municipal and industrial water and wastewater treatment for the removal of turbidity, color, suspended solids and phosphorus. Sludge compaction and volume reduction. Lagoon treatment. Oily wastewater clarification and dissolved air flotation. Emulsion breaking. Fixing rosin sizes on paper fibers. Paper machine drainage and retention aid. Paper machine pitch control.

SHIPPING CONTAINERS

Bulk transport
275 gal. one way container
Bulk car
55 gal. plastic drum

SHIPPING REGULATIONS

DOT Classification: Corrosive Liquid, Acidic, Inorganic, N.O.S. (Contains Aluminum Sulfate)
Hazard Class: 8 DOT ID Number: UN 3264 Packing Group: III
RQ = 5000 Lbs. (CASRN formula basis)

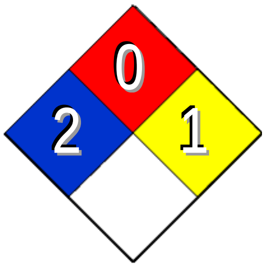
PRODUCT SAFETY INFORMATION

Liquid Alum may cause irritation to the skin, eyes and respiratory tract. Avoid contact with skin, eyes and clothing. Anyone procuring, using or disposing of these products or their containers must be familiar with the appropriate safety and handling precautions. Such information may be found in the **Material Safety Data Sheets (MSDS)** for these products or you may contact General Chemical Technical Service. In the event of an emergency with these products, call the 24 hour **Emergency Number: USA (CHEMTREC) 800-424-9300** or **Canada (CANUTEC) 613-996-6666**. For additional information contact:

Syracuse Technical Center
(315) 478-2323
(800) 255-7589 Outside NY

Water Chemicals Group
(973) 515-0900
(800) 631-8050 Customer Service

MATERIAL SAFETY DATA SHEET

NFPA	HMIS	PPE	Symbol(s)
			 Regulated

Current Issue Date: November 30, 2012	Revision Number: 0

1. PRODUCT AND COMPANY IDENTIFICATION

Product Name:	**Liquid Alum**
Other/Generic Names:	Aluminum Sulfate, Alum, Alun 48, Aluminum Sulphate 48%
Recommended Use:	Water treatment. Various industrial uses.
Manufacturer:	General Chemical, LLC 90 East Halsey Road Parsippany, NJ 07054 General Chemical Performance Products Ltd. 90 East Halsey Road Parsippany, NJ 07054
For More Information:	Customer Service US ONLY: 800-631-8050 (Monday – Friday 9:00AM – 4:30PM) Customer Service CANADA ONLY: 866-543-3896 (Monday – Friday 9:00AM – 4:30PM)
Emergency Telephone Number:	US ONLY - CALL CHEMTREC: 800-424-9300 (24 Hours/Day, 7 Days/Week) CANADA ONLY - CALL CANUTEC: 613-996-6666 (24 Hours/Day, 7 Days/Week)

2. HAZARDS IDENTIFICATION

EMERGENCY OVERVIEW: A clear, light green or amber liquid with a negligible odor. Can irritate the skin and eyes. May be harmful if swallowed. Not flammable, but may release toxic vapors if decomposed in a fire.

OSHA Status: This material is considered hazardous by the OSHA Hazard Communication Standard (29 CFR 1910.1200)

Potential Health Affects

Skin:	May cause skin irritation.
Eyes:	May strongly irritate or burn the eyes.
Inhalation:	Product mists may cause irritation to the respiratory tract.
Ingestion:	May irritate the gastrointestinal tract. Concentrated solutions may cause burns to the digestive tract.
Delayed Effects:	None known.

3. COMPOSITION/INFORMATION ON INGREDIENTS

Component	CAS No	Weight %
Aluminum sulfate	10043-01-3	~48.5 (dry basis)
Water	7732-18-5	Balance

4. FIRST AID MEASURES

Eye Contact	Immediately flush eyes with water for at least 15 minutes. Get medical attention if irritation persists.
Skin Contact	Flush with plenty of water, removing contaminated clothing. If irritation develops, get medical attention.
Inhalation	Remove to fresh air. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. Get prompt medical attention.
Ingestion	Do not induce vomiting. Immediately give large quantities of water. Get medical attention immediately.
Notes to Physician	Treat symptomatically

5. FIRE-FIGHTING MEASURES

Flammable Properties

FLASH POINT:	Not Flammable
FLASH POINT METHOD:	Not Applicable
AUTOIGNITION TEMPERATURE:	Not Applicable
UPPER FLAME LIMIT (VOLUME % IN AIR):	Not Applicable
LOWER FLAME LIMIT (VOLUME % IN AIR):	Not Applicable
FLAME PROPAGATION RATE (SOLIDS):	Not Applicable
OSHA FLAMMABILITY CLASS:	Not Applicable
SUITABLE EXTINGUISHING MEDIA:	Water spray, foam, carbon dioxide or dry chemical
UNSUITABLE EXTINGUISHING MEDIA:	No information available

Explosion Limits

Hazardous Combustion Products	No information available
Impact sensitivity	No information available
Sensitivity to static discharge	No information available
Specific Hazards Arising from the Chemical	Keep product and empty container away from heat and sources of ignition.
Protective Equipment and Precautions for Firefighters	Wear self-contained breathing apparatus (SCBA) and full protective equipment. Use water spray to keep containers cool.

6. ACCIDENTAL RELEASE MEASURES

IN CASE OF SPILL OR OTHER RELEASE	Dilute small spills or leaks cautiously with plenty of water. Neutralize any further residue with alkali such as soda ash, lime or limestone. Adequate ventilation is required if soda ash or limestone is used, because of the consequent release of carbon dioxide gas. Large spills should be diked up with soda ash and neutralized as above. Collect liquid and/or residue and dispose of in accordance with applicable regulations.

7. HANDLING AND STORAGE

Handling	Keep container tightly closed when not in use. Avoid contact with skin, eyes, and clothing. Avoid breathing vapors or mists. Remove contaminated clothing and wash thoroughly after handling.
Storage	Keep storage container tightly closed. Store in a cool, dry, well-ventilated area or cabinet. Isolate from incompatible substances. Store and ship in plastic or rubber-lined containers.

8. EXPOSURE CONTROLS/PERSONAL PROTECTION

Component	ACGIH TLV	OSHA PEL	Ontario TWAEV	Mexico OEL (TWA)	NIOSH IDLH
Aluminum sulfate	2 mg/m^3	2 mg/m^3		TWA: 2 mg/m^3	

Engineering Measures	Use local exhaust to keep airborne concentrations below the permissible exposure limits.

Personal Protective Equipment

Eye/Face Protection	Wear hard hard (or other head covering) and chemical safety goggles. Do not wear contact lenses.
Skin Protection	Wear appropriate personal protective clothing to prevent skin contact. If prolonged or repeated contact is anticipated, all clothing should be impervious to liquid.
Respiratory Protection	A respiratory protection program that meets OSHA 1910.134 and ANSI Z88.2 or applicable federal/provincial requirements must be followed whenever workplace conditions warrant respirator use. NIOSH's "Respirator Decision Logic" may be useful in determining the suitability of various types of respirators.
General Hygiene Considerations	To identify additional Personal Protective Equipment (PPE) requirements, it is recommended that a hazard assessment in accordance with the OSHA PPE Standard (29CFR 1910.132) be conducted before using this product. Eyewash and safety showers are recommended.

9. PHYSICAL AND CHEMICAL PROPERTIES

Appearance	Clear, light green or amber liquid
Color	Clear, light green or amber
Chemical Formula	~48.5% $Al_2(SO_4)_3$ $14H_2O$ in water
Odor	None
Odor Threshold	No information available
Physical State	Liquid
pH	2.0-2.4
Flash Point	Not flammable
Autoignition Temperature	Not applicable
Boiling Point/Range	101 ^oC / 214 ^oF
Melting Point/Range	-16^oC /4^oF
Flammability Limits in Air	No information available
Explosive Properties	No information available
Oxidizing Properties	No information available
Evaporation Rate	Not determined
Vapor Pressure	Not applicable
Vapor Density	Not applicable
Specific Gravity	1.335
Partition Coefficient (n-octano/water)	No information available
Viscosity	No information available
Molecular Weight	594 for $Al_2(SO_4)_3$ $14H_2O$
Water Solubility	100%
VOC Content (%)	0

10. STABILITY AND REACTIVITY

Chemical Stability	Normally stable. If evaporated to dryness, residue should not be exposed to elevated temperatures (above 760°C), as this will yield toxic and corrosive gases.
Incompatible Products	Alkalis and water reactive materials such as oleum: causes exothermic reactions.
Hazardous Decomposition Products	At elevated temperatures, sulfur oxides may be formed. These are toxic and corrosive and are oxidizers. Sulfur trioxide is also a fire hazard. The loss of these gases leaves a caustic residue.
Possibility of Hazardous Reactions	Will not occur.

11. TOXICOLOGICAL INFORMATION

Acute Toxicity

Component Information

Component	LD50 Oral	LD50 Dermal	LC50 Inhalation
Aluminum sulfate	1930 mg/kg (rat) 6207 mg/kg (mouse		

Irritation	No information available
Corrosivity	No information available
Sensitization	No information available

Chronic Toxicity

Carcinogenicity	There are no known carcinogenic chemicals in this product.
Mutagenic Effects	No information available
Reproductive Effects	No information available
Developmental Effects	No information available
Teratogenicty	No information available
Target Organ Effects	No information available
Other Adverse Effects	No information available
Endocrine Disruptor Information	No information available

12. ECOLOGICAL INFORMATION

Ecotoxicity

Contains no substances known to be hazardous to the environment or not degradable in waste water treatment plants.

Component	Freshwater Algae	Freshwater Fish	Microtex	Water Flea
Aluminum sulfate		LC50 = 100 mg/L Carassius auratus 96 h LC50 = 37 mg/L Gambusia affinis 96 h		EC50 = 136 mg/L 15 min

Persistence and Degradability	No information available
Bioaccumulation	No information available
Mobility in Environmental Media	No information available
Other adverse affects	**Aluminum sulfate component:** 14 ppm/36 hr/fundulus/fatal/fresh water; 240 ppm/48 hr/mosquito fish/TLm/water type not specified; TLm Mosquito fish, 235 ppm, 96 hours; LC50 Largemouth bass, 250 ppm, 96 hours

13. DISPOSAL CONSIDERATIONS

Waste Disposal Methods	Dispose of waste in accordance with all federal, state, and local regulations.
Contaminated Packaging	Empty containers should be taken for local recycling, recovery or waste disposal.

14. TRANSPORT INFORMATION

DOT	Regulated
Proper Shipping Name	Corrosive liquid, acidic, inorganic, n.o.s. (contains aluminum sulfate)
Hazard Class	8
UN-No	UN3264
Packing Group	PGIII
TDG	Regulated
Hazard Class	8
UN-No	UN3264
Packing Group	PGIII

15. REGULATORY INFORMATION

International Inventories

TSCA	Yes
DSL	Yes
ELINCS	No
EINECS	Yes
ENCS	Yes
CHIINA	Yes
KECL	Yes
PICCS	Yes
AICS	Yes

U.S. Federal Regulations

SARA 313

Section 313 of Title III of the Superfund Amendments and Reauthorization Act of 1986 (SARA). This product contains the following chemicals which are subject to the reporting requirements of the Act and Title 40 of the Code of Federal Regulations, Part 372: None

SARA 311/312 Hazardous Categorization

Chronic Health Hazard	No
Acute Health Hazard	Yes
Fire Hazard	No
Sudden Release of Pressure Hazard	No
Reactive Hazard	No

Clean Water Act

Component	CWA – Reportable Quantities	CWA – Toxic Pollutants	CWA – Priority Pollutants	CWA – Hazardous Substances
Aluminum sulfate	5000 lb			X

CERCLA

Component	CERCLA RQ (lb)	SARA TPQ (lb)
Aluminum sulfate	5000 lb	

U.S. State Regulations

California Proposition 65

This product does not contain any Proposition 65 chemicals.

State Right-to-Know

Component	**Massachusetts**	**New Jersey**	**Pennsylvania**	**Illinois**	**Rhode Island**
Aluminum sulfate	X	X	X		

Other International Regulations

Mexico	No information available
Canada	This product has been classified in accordance with the hazard criteria of the Controlled Products Regulations (CPR) and the MSDS contains all the information required by the CPR.

WHMIS Hazard Class	
E Corrosive material	
D2B Toxic materials	

16. OTHER INFORMATION

Current Issue Date:	November 30, 2012
Previous Issue Date:	November 1, 2011
Revision Summary:	Convert to GC Template

Disclaimer:

All information, statements, data, service and/or recommendations, including, without limitation, those relating to storage, loading/unloading, piping and transportation (collectively referred to herein as “information”) are believed to be accurate and reliable. However, no representation or warranty, express or implied, is made as to its completeness, accuracy, fitness for a particular purpose or any other matter, including, without limitation, that the practice or application of any such information is free of patent infringement or other intellectual property misappropriation. General Chemical, LLC is not engaged in the business of providing technical, operational, engineering or safety information for a fee, and therefore; any such information provided herein has been furnished as an accommodation and without charge. All information provided herein is intended for use by persons having requisite knowledge, skill, and experience in the chemical industry. General Chemical, LLC shall not be responsible or liable for the use, application or implementation of the information, provided herein, and all such information is to be used at the risk, and in the sole judgment and discretion, of such persons, their employees, advisors and agents.

End of MSDS

Sodium aluminate

MSDS No. 132
4/30/2013

Safety Data Sheet

Section 1 - Chemical Product and Company Identification

Product/Chemical Name:	Sodium aluminate, solution	**Manufacturer:** USALCO, LLC 2601 Cannery Ave Baltimore, MD 21226 Phone 410-354-0100 (7:00am 5:00pm) FAX 410-354-1021
Chemical Family:	Inorganic salt	
General Use:	Water Treatment Chemical	
Emergency Contact:	800-282-5322	

HMIS	
H	**3**
F	**0**
R	**0**
PPE†	

†Sec. 11

Section 2 - Composition / Information on Ingredients

Ingredient Name	CAS Number	% wt
Sodium aluminate	1302-42-7	31-45
Sodium hydroxide	1310-73-2	3-9
Water	7732-18-5	52-66

	OSHA PEL		ACGIH TLV		NIOSH REL		NIOSH
Ingredient	**TWA**	**STEL**	**TWA**	**STEL**	**TWA**	**STEL**	**IDLH**
Sodium aluminate	none estab.	2 mg/m^3 *as aluminum*	none estab.	2 mg/m^3 *as aluminum*	none estab.	2 mg/m^3 *as aluminum*	none estab.

Section 3 - Emergency Overview

Description:	Viscous colorless to amber liquid with no or very mild odor. Not flammable. Not volatile
Hazards:	Corrosive; pH 14. Causes burns. Harmful by contact with skin and if swallowed. Risk of serious damage to eyes. Not flammable, but may release toxic vapors if decomposed in a fire.

Section 4 - First Aid Procedures

Overview:	Direct contact can cause corrosive burns and permanent injury.
Inhalation:	(mist or spray) Remove from exposure; seek medical treatment if any symptoms occur.
Eye Contact:	Immediately flush with large amounts of water for at least 15 minutes, occasionally lifting upper and lower lids. Seek medical attention.
Skin Contact:	Remove contaminated clothing and flush contact area with large amounts of water for at least 15 minutes. Seek medical attention if any symptoms are present.
Ingestion:	Do not induce vomiting, drink milk or water and immediately seek medical attention.

After first aid, get appropriate in-plant, paramedic, or community medical support.

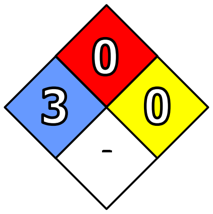
Section 5 - Physical and Chemical Properties

Physical State:	Liquid	**Water Solubility:**	Complete
Characteristics	Clear to amber liquid	**Melting/Freezing Point:**	0° to 12° F (-18° to -11°C)
Odor:	Odorless	**Boiling Point:**	220-240°F (104-116 °C)
Vapor Pressure:	Not applicable	**% Volatile:**	0.0
Specific Gravity (H_2O=1, at 4 °C):	1.44-1.56	**Viscosity:**	>2000 cps. @ 20°F 200-800 cps. @ 68°F
Vapor Density (Air=1):	Not applicable	**pH:**	14.0

Section 6 - Fire-Fighting Measures

Flash Point:	NA
Burning Rate:	NA
Autoignition Temperature:	NA
LEL:	NA
UEL:	NA
Flammability:	Not flammable
Extinguishing Media:	NA
Unusual Fire or Explosion Hazards:	None
Hazardous Combustion Products:	None
Fire-Fighting Instructions:	Do not release runoff from fire control methods to sewers or waterways.

NFPA



Section 7 - Stability and Reactivity

Stability:	Will generate heat on contact with water and will hydrolyze to sodium hydroxide and aluminum hydroxide.
Polymerization:	Hazardous polymerization does not occur.
Chemical Incompatibilities:	Incompatible with acids.
Hazardous Decomposition Products:	None.

Section 8 - Health Hazard Information

Primary Entry Routes:	Ingestion, contact
Target Organs:	N/A
Acute Effects:	Chemical (caustic) burns
Eye:	Chemical burn
Skin:	Chemical burn
Ingestion:	Burns, nausea, vomiting, diarrhea, stomach pain
Carcinogenicity:	IARC, NTP, and OSHA do not list Sodium aluminate as a carcinogen
Medical Conditions Aggravated by Long-Term Exposure:	Skin rashes
Chronic Effects:	IARC, NTP, and OSHA do not list

Section 9 - Spill, Leak, and Disposal Procedures

Spill /Leak Procedures:	Wear appropriate personal protective equipment. Do not come in contact with spilled material.
Small Spills:	Neutralize with sodium bicarbonate or weak acid solution.
Large Spills:	Dike and transfer spill to container for reuse and reprocessing. Can flush contaminated areas with large amounts of water and direct rinsing to chemical sewer or collect for treatment.
Cleanup:	Recover liquid when possible. Wash impacted areas with water to remove residues.
Regulatory Requirements:	Waste Sodium aluminate is not a RCRA listed hazardous waste. Waste material can be a RCRA Characteristic Waste (D002) if not neutralized.
Disposal:	Contact your supplier or a licensed contractor for detailed recommendations. Follow applicable Federal, State, and local regulations.
Container Cleaning and Disposal:	Rinse with water, dispose of containers in accordance with State and local regulations.

Section 10 - Regulatory Information

EPA Regulations:	
RCRA Hazardous Waste Classification:	D002 (Corrosive) if the pH of the waste is ≥12.5
CERCLA Hazardous Substance (40 CFR 302.4):	Not listed CWA, Sec. 311 (b)(4)
CERCLA Reportable Quantity (RQ):	Not listed
SARA 311/312 Codes:	Immediate (acute) health hazard
SARA Toxic Chemical (40 CFR 372.65):	Not listed
SARA EHS (Extremely Hazardous Substance) (40 CFR 355):	Not listed
OSHA Regulations:	
Air Contaminant (29 CFR 1910.1000, Table Z-1, Z-1-A):	Not listed
OSHA Specifically Regulated Substance (29CFR 1910.):	Not listed
State Regulations:	USALCO, LLC has not determined regulatory requirements for individual states.

Section 11 - Exposure Controls / Personal Protection

Ventilation:	Under normal conditions, Sodium aluminate solution will not generate mists or vapors. No special ventilation is recommended.
Respiratory Protection:	Seek professional advice prior to respirator selection and use. Follow OSHA respirator regulations (29 CFR 1910.134) and, if necessary, wear a MSHA/NIOSH-approved respirator. Select respirator based on its suitability to provide adequate worker protection for given working conditions, level of airborne contamination, and presence of sufficient oxygen. For emergency or non-routine operations (cleaning spills, reactor vessels, or storage tanks), wear an SCBA. Warning! Air-purifying respirators do not protect workers in oxygen-deficient atmospheres. If respirators are used, OSHA requires a written respiratory protection program that includes at least: medical certification, training, fit-testing, periodic environmental monitoring, maintenance, inspection, cleaning, and convenient, sanitary storage areas.
Protective Clothing/Equipment:	Wear chemically protective gloves, boots, aprons, and gauntlets to prevent prolonged or repeated skin contact. Wear protective chemical safety goggles, per OSHA eye- and face-protection regulations (29 CFR 1910.133). Contact lenses are not eye protective devices. Appropriate eye protection must be worn instead of, or in conjunction with contact lenses.
Safety Stations:	Make emergency eyewash stations, safety/quick-drench showers, and washing facilities available in work area.
Contaminated Equipment:	Separate contaminated work clothes from street clothes. Launder before reuse. Remove this material from your shoes and clean personal protective equipment.
Comments:	Never eat, drink, or smoke in work areas. Practice good personal hygiene after using this material, especially before eating, drinking, smoking, using the toilet, or applying cosmetics.

Section 12 - Special Precautions and Comments

Handling Precautions:	Ensure that all containers are labeled in accordance with OSHA regulations. Avoid skin and eye contact. Wear appropriate protective clothing. Material is slippery; use caution if walking on spilled material.
Storage Requirements:	Keep containers tightly closed when not in use.

Section 13 - DOT Transportation Data (49 CFR 172.101)

Proper Shipping Name:	UN1819, Sodium aluminate, solution, 8, II	**Packaging Authorizations**	
		a) Exceptions:	173.154
		b) Non-bulk Packaging:	173.203
Shipping Symbols:	-	**c) Bulk Packaging:**	173.241
Hazard Class:	8	**Quantity Limitations**	
DOT No.:	UN1819	**a) Passenger, Aircraft, or Railcar:**	1 L
Packing Group:	II	**b) Cargo Aircraft Only:**	30 L
Label:	Corrosive	**Vessel Stowage Requirements**	
Special Provisions (172.102):	IB3,T4,TP1	**a) Location:**	A
2008 Emergency Response Guidebook:	Guide 154	**b) Other:**	52

Prepared By: Craig T. Owen
Effective Date: 2/1/2012 **Supercedes:** NA

APPENDIX C

FIELD DATA COLLECTED IN THE ISOLATION CHAMBERS FROM OCTOBER 12, 2012 TO JANUARY 11, 2013

C.1 Vertical Field Profiles
C.2 Photosynthetically Active Radiation (PAR)

C.1 Vertical Field Profiles

Vertical Profiles Collected in Silver Lake from October 2012 - January 2013

Site	Date	Time	Depth (m)	Temp (°C)	pH (s.u.)	Cond (µmho/cm)	DO (mg/L)	% Sat (%)	ORP (mV)	Secchi (m)
Prior to Alum Addition										
A-1	10/12/12	8:56	0.25	26.90	7.00	262	5.0	63	204	0.61
		8:57	0.5	26.90	6.96	261	4.7	59	213	
		8:58	1.0	26.89	6.92	261	4.3	54	219	
		8:59	1.5	26.87	6.89	261	4.0	50	191	
		9:00	1.8	26.89	6.53	286	0.8	10	134	
Day 1 - Initial										
A-1	10/13/12	8:27	0.25	26.45	6.05	528	5.6	70	272	1.76
		8:28	0.5	26.47	6.04	528	5.5	64	277	
		8:29	1.0	26.49	6.04	530	5.5	64	281	
		8:30	1.5	26.48	6.05	530	5.2	65	284	
		8:31	1.8	26.55	6.26	536	0.9	12	271	
Day 1 - Following Inflow Addition										
A-1	10/13/12	8:41	0.25	26.48	6.05	530	5.3	66	265	-
		8:42	0.5	26.49	6.04	530	5.4	68	270	
		8:43	1.0	26.48	6.04	531	5.3	66	275	
		8:44	1.5	26.48	6.05	530	5.2	65	278	
		8:45	1.7	26.56	6.25	551	1.1	14	271	
Day 12 - Initial										
A-1	10/24/12	9:01	0.25	24.72	6.59	533	6.2	74	234	1.70
		9:02	0.5	24.72	6.50	534	5.9	71	253	
		9:03	1.0	24.72	6.49	534	5.8	71	266	
		9:05	1.5	24.72	6.50	534	5.7	69	273	
		9:06	1.7	24.93	6.49	515	0.9	11	225	
Day 12 - Following Inflow Addition										
A-1	10/24/12	10:13	0.25	24.87	6.88	532	6.6	80	265	-
		10:13	0.5	24.83	6.76	532	6.1	74	263	
		10:14	1.0	24.83	6.79	533	6.0	72	269	
		10:15	1.5	24.83	6.85	561	4.3	52	246	
		10:16	1.8	25.10	6.48	599	0.9	11	219	
Day 27 - Initial										
A-1	11/8/12	9:53	0.25	19.89	7.22	520	9.2	101	266	1.40
		9:53	0.5	19.89	7.37	520	8.9	98	279	
		9:54	1.0	19.89	7.49	520	9.1	100	289	
		9:55	1.5	19.90	7.37	521	8.3	92	285	
		9:57	1.9	20.17	6.51	536	1.8	19	201	
Day 27 - Following Inflow Addition										
A-1	11/8/12	11:12	0.25	20.11	7.47	521	9.7	107	252	-
		11:12	0.5	20.08	7.64	521	9.5	105	262	
		11:14	1.0	19.98	7.80	521	9.6	106	275	
		11:14	1.5	19.96	7.71	521	8.6	94	277	
		11:16	1.7	20.27	6.57	499	2.6	28	162	

Vertical Profiles Collected in Silver Lake from October 2012 - January 2013

Site	Date	Time	Depth (m)	Temp (°C)	pH (s.u.)	Cond (µmho/cm)	DO (mg/L)	% Sat (%)	ORP (mV)	Secchi (m)
Day 48 - Initial										
A-1	11/29/12	10:15	0.25	19.53	7.20	495	5.9	64	283	1.32
		10:16	0.5	19.50	7.02	495	4.8	52	279	
		10:17	1.0	19.46	6.91	496	4.2	46	276	
		10:18	1.5	19.45	6.85	495	3.9	42	275	
		10:19	2.0	19.48	6.53	591	1.2	13	206	
Day 48 - Following Inflow Addition										
A-1	11/29/12	11:28	0.25	19.88	6.97	498	6.1	67	275	-
		11:29	0.5	19.64	6.89	498	4.8	52	283	
		11:30	1.0	19.55	6.84	495	4.1	45	295	
		11:31	1.5	19.48	6.78	496	3.7	40	402	
		11:33	1.9	19.53	6.54	523	1.1	12	371	
Day 62 - Initial										
A-1	12/13/12	9:31	0.25	22.88	7.24	504	7.2	84	257	1.52
		9:32	0.5	22.90	7.15	508	6.6	77	252	
		9:33	1.0	22.89	7.10	505	6.3	73	252	
		9:34	1.5	22.89	6.76	515	5.1	59	203	
		9:35	1.8	22.80	6.65	515	0.6	2	158	
Day 62 - Following Inflow Addition										
A-1	12/13/12	9:53	0.25	22.92	7.16	513	7.0	82	233	-
		9:53	0.5	22.91	7.11	512	6.4	75	230	
		9:55	1.0	22.92	7.05	513	6.2	72	227	
		9:55	1.5	22.91	7.01	512	5.8	68	222	
		9:56	1.9	22.80	6.65	518	0.8	9	177	
Day 76 - Initial										
A-1	12/27/12	10:40	0.25	17.43	8.30	473	9.2	96	232	1.73
		10:41	0.5	17.40	8.29	473	9.1	95	235	
		10:42	1.0	17.39	8.27	473	9.0	94	240	
		10:43	1.5	17.37	8.22	474	8.8	91	246	
		10:46	1.9	17.52	7.02	502	5.5	58	160	
Day 76 - Following Inflow Addition										
A-1	12/27/12	10:55	0.25	17.45	7.90	471	9.1	95	231	-
		10:56	0.5	17.45	8.07	472	8.8	92	239	
		10:57	1.0	17.42	8.15	473	8.7	91	245	
		10:58	1.5	17.39	8.10	473	8.1	85	249	
		11:01	1.8	17.73	6.90	483	3.1	32	132	
Day 91 - Initial										
A-1	1/11/13	9:35	0.25	22.05	7.70	440	6.5	74	259	1.68
		9:36	0.5	22.00	7.67	440	6.1	70	263	
		9:37	1.0	21.93	7.62	439	5.6	64	266	
		9:38	1.5	21.88	7.52	442	4.6	52	269	
		9:40	1.7	21.69	7.24	458	2.1	24	210	

Vertical Profiles Collected in Silver Lake from October 2012 - January 2013

Site	Date	Time	Depth (m)	Temp (°C)	pH (s.u.)	Cond (µmho/cm)	DO (mg/L)	% Sat (%)	ORP (mV)	Secchi (m)
Prior to Alum Addition										
A-2	10/12/12	8:02	0.25	26.95	7.03	262	4.4	55	208	0.60
		8:03	0.5	26.99	6.97	261	4.3	54	215	
		8:04	1.0	27.01	6.95	261	3.9	49	222	
		8:05	1.5	27.01	6.94	262	3.8	47	229	
		8:07	2.0	27.01	6.59	285	0.4	5	106	
Day 1 - Initial										
A-2	10/13/12	8:15	0.25	26.61	6.04	468	5.9	73	237	2.19
		8:16	0.5	26.62	6.03	467	5.6	69	252	
		8:17	1.0	26.62	6.03	467	5.3	66	265	
		8:18	1.5	26.63	6.03	467	5.4	67	274	
		8:19	2.0	26.77	6.04	622	1.7	21	260	
		8:20	2.2	26.77	6.11	622	0.7	9	246	
Day 1 - Following Inflow Addition										
A-2	10/13/12	8:34	0.25	26.62	6.05	467	5.1	64	271	-
		8:35	0.5	26.62	6.05	467	4.8	60	275	
		8:36	1.0	26.62	6.04	466	4.7	58	278	
		8:37	1.5	26.62	6.05	466	4.6	58	282	
		8:38	2.0	26.88	6.18	506	1.1	14	263	
Day 12 - Initial										
A-2	10/24/12	8:39	0.25	24.89	6.79	471	4.9	59	231	2.09
		8:40	0.5	24.89	6.77	472	4.5	55	249	
		8:41	1.0	24.89	6.80	472	4.5	54	262	
		8:42	1.5	24.89	6.88	472	4.5	54	272	
		8:43	2.1	25.02	7.01	494	0.9	10	216	
Day 12 - Following Inflow Addition										
A-2	10/24/12	10:25	0.25	24.99	6.86	472	4.9	59	358	-
		10:26	0.5	24.97	6.61	472	4.6	56	386	
		10:27	1.0	24.94	6.52	473	4.6	56	409	
		10:28	1.5	24.92	6.50	474	4.5	55	422	
		10:29	2.0	25.04	6.48	666	0.8	10	375	
		10:30	2.2	25.08	6.35	690	0.6	7	366	
Day 27 - Initial										
A-2	11/8/12	9:44	0.25	20.05	7.17	482	8.3	92	240	1.89
		9:45	0.5	20.10	7.11	483	7.5	83	255	
		9:46	1.0	20.10	7.07	483	7.6	84	267	
		9:46	1.5	20.10	7.04	484	7.3	81	278	
		9:49	2.0	20.45	6.51	496	1.2	13	194	
Day 27 - Following Inflow Addition										
A-2	11/8/12	11:05	0.25	20.20	7.04	483	7.3	81	213	-
		11:06	0.5	20.19	7.03	483	7.3	81	228	
		11:07	1.0	20.14	7.01	484	7.1	78	243	
		11:08	1.5	20.10	7.00	484	6.9	76	251	
		11:10	1.9	20.28	6.60	492	2.7	30	208	

Vertical Profiles Collected in Silver Lake from October 2012 - January 2013

Site	Date	Time	Depth (m)	Temp (°C)	pH (s.u.)	Cond (µmho/cm)	DO (mg/L)	% Sat (%)	ORP (mV)	Secchi (m)
Day 48 - Initial										
A-2	11/29/12	9:23	0.25	19.40	6.94	495	4.8	52	223	1.49
		9:24	0.5	19.42	6.87	495	4.3	47	228	
		9:25	1.0	19.42	6.81	495	3.8	42	236	
		9:26	1.5	19.42	6.78	495	3.7	40	243	
		9:28	2.0	19.45	6.56	500	1.8	19	214	
Day 48 - Following Inflow Addition										
A-2	11/29/12	11:02	0.25	19.79	7.90	495	7.8	85	244	-
		11:03	0.5	19.72	7.52	496	6.5	72	234	
		11:04	1.0	19.59	7.23	495	5.3	57	230	
		11:05	1.5	19.48	7.03	495	4.4	48	231	
		11:06	2.0	19.52	6.66	605	2.5	27	176	
		11:06	2.1	19.57	6.56	673	1.4	15	160	
Day 62 - Initial										
A-2	12/13/12	9:37	0.25	22.90	6.99	509	7.2	84	277	1.46
		9:38	0.5	22.90	7.00	508	7.1	83	283	
		9:39	1.0	22.90	7.00	508	7.0	82	292	
		9:40	1.5	22.90	6.86	509	4.1	48	286	
		9:41	1.7	22.88	6.66	562	0.5	6	256	
Day 62 - Following Inflow Addition										
A-2	12/13/12	10:00	0.25	22.93	6.87	512	6.9	80	232	-
		10:01	0.5	22.93	6.93	514	7.0	82	243	
		10:01	1.0	22.92	6.95	513	6.9	80	251	
		10:02	1.5	22.92	6.95	512	6.7	78	256	
		10:03	1.7	22.91	6.74	518	0.7	8	249	
Day 76 - Initial										
A-2	12/27/12	9:49	0.25	17.52	7.26	466	7.9	83	213	2.24
		9:50	0.5	17.52	7.14	465	7.1	74	213	
		9:51	1.0	17.52	7.06	466	6.6	69	216	
		9:52	1.5	17.52	7.02	465	6.5	68	219	
		9:53	2.0	17.59	6.78	585	5.7	70	211	
		9:54	2.2	17.79	6.74	670	4.0	42	186	
Day 76 - Following Inflow Addition										
A-2	12/27/12	10:00	0.25	17.51	7.19	462	8.8	92	295	-
		10:01	0.5	17.51	7.10	462	7.9	83	296	
		10:02	1.0	17.50	7.04	463	7.4	77	300	
		10:03	1.5	17.50	7.00	462	7.2	75	303	
		10:04	2.0	17.52	6.89	475	6.7	70	303	
		10:05	2.2	17.89	6.74	496	1.1	12	290	
Day 91 - Initial										
A-2	1/11/13	10:22	0.25	22.23	7.16	439	5.0	58	391	2.18
		10:23	0.5	22.11	7.10	440	3.9	45	397	
		10:24	1.0	21.97	7.03	439	3.0	35	402	
		10:25	1.5	21.93	7.00	440	2.7	31	406	
		10:26	2.0	21.37	6.73	464	1.1	13	384	
		10:27	2.3	21.28	6.72	553	0.7	8	362	

Vertical Profiles Collected in Silver Lake from October 2012 - January 2013

Site	Date	Time	Depth (m)	Temp (°C)	pH (s.u.)	Cond (µmho/cm)	DO (mg/L)	% Sat (%)	ORP (mV)	Secchi (m)
Prior to Phoslock Addition										
P-1	10/12/12	8:22	0.25	26.89	7.01	270	4.5	57	206	0.61
		8:23	0.5	26.88	6.94	270	4.2	52	215	
		8:24	1.0	26.88	6.92	270	4.0	50	222	
		8:25	1.5	26.87	6.75	270	1.7	21	166	
		8:26	1.7	26.89	6.61	288	0.6	8	127	
Day 1 - Initial										
P-1	10/13/12	9:25	0.25	26.71	7.06	279	7.9	99	207	0.59
		9:26	0.5	26.68	7.04	278	7.2	90	214	
		9:27	1.0	26.63	7.02	278	6.8	84	221	
		9:28	1.5	26.61	6.99	278	6.5	81	217	
		9:30	1.7	26.65	6.70	290	3.3	41	167	
Day 1 - Following Inflow Addition										
P-1	10/13/12	9:39	0.25	26.73	7.00	278	7.6	95	179	-
		9:40	0.5	26.72	7.03	276	6.9	86	191	
		9:41	1.0	26.62	7.01	278	6.5	81	203	
		9:43	1.5	26.60	6.97	279	6.9	87	205	
		9:45	1.8	26.63	6.77	281	3.3	41	170	
Day 12 - Initial										
P-1	10/24/12	8:16	0.25	24.72	8.32	285	9.7	117	449	0.68
		8:17	0.5	24.74	8.32	286	9.7	117	447	
		8:18	1.0	24.75	8.33	287	9.8	118	446	
		8:19	1.5	24.75	8.21	286	9.5	114	276	
		8:21	1.7	24.86	6.63	392	1.2	14	84	
Day 12 - Following Inflow Addition										
P-1	10/24/12	10:38	0.25	25.09	7.47	290	8.9	108	174	-
		10:39	0.5	25.03	7.52	292	8.5	103	184	
		10:40	1.0	24.92	7.48	292	7.9	96	192	
		10:41	1.5	24.92	6.87	297	3.6	44	132	
		10:41	1.8	25.20	6.47	413	0.9	11	110	
Day 27 - Initial										
P-1	11/8/12	10:07	0.25	20.04	7.19	309	6.8	75	263	1.78
		10:08	0.5	20.07	7.17	309	6.3	70	263	
		10:09	1.0	20.05	7.16	309	6.0	66	265	
		10:10	1.5	20.02	7.01	313	3.9	43	222	
		10:11	1.8	20.27	6.72	371	0.4	4	163	
Day 27 - Following Inflow Addition										
P-1	11/8/12	11:26	0.25	20.21	7.20	308	7.0	77	256	-
		11:27	0.5	20.18	7.18	309	6.5	72	254	
		11:28	1.0	20.11	7.16	310	6.0	66	255	
		11:29	1.5	20.09	6.80	337	4.2	46	197	
		11:29	1.8	20.33	6.79	407	0.9	10	166	

Vertical Profiles Collected in Silver Lake from October 2012 - January 2013

Site	Date	Time	Depth (m)	Temp (°C)	pH (s.u.)	Cond (µmho/cm)	DO (mg/L)	% Sat (%)	ORP (mV)	Secchi (m)
Day 48 - Initial										
P-1	11/29/12	9:45	0.25	19.64	7.13	312	5.4	59	233	1.19
		9:46	0.5	19.63	7.09	312	4.7	51	237	
		9:47	1.0	19.60	7.07	312	4.3	47	243	
		9:49	1.5	19.58	6.82	306	1.3	15	189	
Day 48 - Following Inflow Addition										
P-1	11/29/12	11:15	0.25	19.84	7.17	311	6.0	66	224	-
		11:16	0.5	19.76	7.15	311	5.2	57	229	
		11:17	1.0	19.63	7.10	311	4.2	46	231	
		11:18	1.5	19.61	6.92	319	3.1	34	213	
		11:19	1.7	19.63	6.75	326	1.4	15	166	
Day 62 - Initial										
P-1	12/13/12	11:02	0.25	23.00	7.06	307	6.6	77	223	1.24
		11:03	0.5	22.99	7.03	307	5.7	67	218	
		11:04	1.0	22.98	7.02	308	5.3	62	216	
		11:05	1.5	22.95	6.81	326	2.7	32	161	
Day 62 - Following Inflow Addition										
P-1	12/13/12	11:14	0.25	22.96	7.12	307	7.2	84	205	-
		11:15	0.5	22.99	7.05	307	5.7	67	198	
		11:16	1.0	22.99	7.02	306	5.4	63	198	
		11:17	1.5	22.96	6.81	321	2.8	33	163	
Day 76 - Initial										
P-1	12/27/12	8:43	0.25	17.43	7.48	313	6.5	68	368	1.57
		8:44	0.5	17.43	7.36	312	5.9	62	369	
		8:45	1.0	17.41	7.32	313	5.5	57	371	
		8:46	1.5	17.40	7.26	313	5.2	54	369	
		8:48	1.6	17.43	7.18	313	4.7	49	352	
Day 76 - Following Inflow Addition										
P-1	12/27/12	9:12	0.25	17.37	7.37	313	6.8	71	282	-
		9:13	0.5	17.43	7.31	313	6.1	64	278	
		9:13	1.0	17.43	7.23	313	5.7	60	274	
		9:15	1.5	17.44	7.23	314	5.3	55	273	
		9:16	1.8	17.49	7.03	317	4.0	42	224	
Day 91 - Initial										
P-1	1/11/13	10:00	0.25	22.15	7.29	307	6.0	69	415	1.31
		10:00	0.5	22.04	7.25	307	5.4	62	419	
		10:02	1.0	21.94	7.21	308	4.9	56	425	
		10:03	1.5	21.89	7.15	308	4.5	51	417	
		10:04	1.9	21.69	6.86	323	1.7	20	365	

Vertical Profiles Collected in Silver Lake from October 2012 - January 2013

Site	Date	Time	Depth (m)	Temp (°C)	pH (s.u.)	Cond (µmho/cm)	DO (mg/L)	% Sat (%)	ORP (mV)	Secchi (m)
Prior to Phoslock Addition										
P-2	10/12/12	7:45	0.25	26.83	7.10	268	5.3	66	354	0.60
		7:46	0.5	26.84	7.00	267	4.9	61	332	
		7:47	1.0	26.84	6.97	266	4.7	59	312	
		7:47	1.5	26.85	6.94	267	4.6	57	250	
		7:49	1.8	26.86	6.63	281	1.7	21	117	
Day 1 - Initial										
P-2	10/13/12	7:53	0.25	26.44	7.16	277	7.0	87	352	0.61
		7:54	0.5	26.48	7.08	275	6.7	84	353	
		7:55	1.0	26.50	7.05	275	6.4	80	353	
		7:56	1.5	26.51	7.02	276	6.3	79	308	
		7:58	1.8	26.53	6.59	319	2.5	31	141	
Day 1 - Following Inflow Addition										
P-2	10/13/12	8:05	0.25	26.52	6.98	278	6.2	78	370	-
		8:06	0.5	26.51	7.00	276	6.2	78	382	
		8:07	1.0	26.51	7.01	276	6.2	77	395	
		8:08	1.5	26.51	7.01	277	5.8	73	306	
		8:09	1.8	26.56	6.53	397	1.2	15	223	
Day 12 - Initial										
P-2	10/24/12	9:19	0.25	24.92	7.48	290	8.1	98	247	0.66
		9:20	0.5	24.91	7.50	290	8.1	98	253	
		9:21	1.0	24.89	7.50	291	8.0	97	259	
		9:22	1.5	24.96	6.77	294	2.2	27	132	
		9:23	1.7	25.14	6.54	374	1.0	12	113	
Day 12 - Following Inflow Addition										
P-2	10/24/12	10:18	0.25	24.98	8.21	284	11.3	136	219	-
		10:19	0.5	24.86	8.21	286	10.4	124	221	
		10:20	1.0	24.81	8.17	287	10.1	121	227	
		10:21	1.5	24.81	8.13	289	9.7	117	233	
		10:23	1.8	24.96	6.66	395	1.2	15	94	
Day 27 - Initial										
P-2	11/8/12	9:39	0.25	20.00	7.48	297	7.3	80	446	1.73
		9:39	0.5	20.00	7.41	296	5.5	61	444	
		9:40	1.0	19.98	7.36	297	5.2	57	442	
		9:41	1.5	19.99	7.27	298	4.5	50	430	
		9:42	1.8	20.23	6.80	340	1.3	14	237	
Day 27 - Following Inflow Addition										
P-2	11/8/12	11:01	0.25	20.44	7.41	297	6.4	71	332	-
		11:01	0.5	20.23	7.37	296	5.6	62	330	
		11:02	1.0	20.12	7.33	297	5.0	55	330	
		11:03	1.5	20.11	7.30	297	4.6	51	329	
		11:04	1.9	20.30	6.83	328	1.9	21	229	

Vertical Profiles Collected in Silver Lake from October 2012 - January 2013

Day 48 - Initial

Site	Date	Time	Depth (m)	Temp (°C)	pH (s.u.)	Cond (µmho/cm)	DO (mg/L)	% Sat (%)	ORP (mV)	Secchi (m)
P-2	11/29/12	9:10	0.25	19.32	7.39	295	8.1	87	294	1.22
		9:10	0.5	19.37	7.35	295	7.7	84	296	
		9:11	1.0	19.37	7.32	295	7.4	80	300	
		9:12	1.5	19.38	7.29	295	7.2	78	294	
		9:14	1.8	19.39	6.66	337	2.1	23	141	

Day 48 - Following Inflow Addition

Site	Date	Time	Depth (m)	Temp (°C)	pH (s.u.)	Cond (µmho/cm)	DO (mg/L)	% Sat (%)	ORP (mV)	Secchi (m)
P-2	11/29/12	10:55	0.25	19.66	7.56	294	8.6	94	329	-
		10:56	0.5	19.64	7.49	294	7.8	84	327	
		10:57	1.0	19.47	7.40	295	7.2	79	324	
		10:58	1.5	19.47	7.34	295	6.3	69	322	
		11:00	1.8	19.54	7.02	310	4.7	51	247	

Day 62 - Initial

Site	Date	Time	Depth (m)	Temp (°C)	pH (s.u.)	Cond (µmho/cm)	DO (mg/L)	% Sat (%)	ORP (mV)	Secchi (m)
P-2	12/13/12	8:51	0.25	22.92	7.03	295	6.2	77	271	1.11
		8:52	0.5	22.92	7.02	294	6.1	71	277	
		8:53	1.0	22.93	7.01	295	6.0	70	284	
		8:54	1.5	22.93	6.90	301	5.8	68	281	
		8:55	1.8	22.84	6.69	376	5.4	63	239	

Day 62 - Following Inflow Addition

Site	Date	Time	Depth (m)	Temp (°C)	pH (s.u.)	Cond (µmho/cm)	DO (mg/L)	% Sat (%)	ORP (mV)	Secchi (m)
P-2	12/13/12	9:12	0.25	22.89	7.23	297	6.6	77	261	-
		9:12	0.5	22.89	7.12	296	5.8	68	251	
		9:13	1.0	22.91	7.06	296	5.4	63	244	
		9:13	1.5	22.92	6.96	299	5.0	58	219	
		9:14	1.8	22.84	6.71	348	4.6	54	176	

Day 76 - Initial

Site	Date	Time	Depth (m)	Temp (°C)	pH (s.u.)	Cond (µmho/cm)	DO (mg/L)	% Sat (%)	ORP (mV)	Secchi (m)
P-2	12/27/12	10:14	0.25	17.44	7.41	312	5.5	58	212	1.61
		10:15	0.5	17.45	7.31	312	4.8	50	214	
		10:16	1.0	17.45	7.27	312	4.5	47	217	
		10:17	1.5	17.43	7.21	313	4.0	42	217	
		10:19	1.9	17.66	6.93	326	1.9	20	182	

Day 76 - Following Inflow Addition

Site	Date	Time	Depth (m)	Temp (°C)	pH (s.u.)	Cond (µmho/cm)	DO (mg/L)	% Sat (%)	ORP (mV)	Secchi (m)
P-2	12/27/12	10:27	0.25	17.45	7.41	314	5.5	57	203	-
		10:28	0.5	17.46	7.33	314	4.8	50	205	
		10:29	1.0	17.45	7.27	314	4.6	48	208	
		10:30	1.5	17.44	7.24	315	4.2	44	212	
		10:31	1.9	17.70	6.97	316	2.2	23	183	

Day 91 - Initial

Site	Date	Time	Depth (m)	Temp (°C)	pH (s.u.)	Cond (µmho/cm)	DO (mg/L)	% Sat (%)	ORP (mV)	Secchi (m)
P-2	1/11/13	8:44	0.25	21.99	7.22	312	4.5	51	306	1.41
		8:45	0.5	21.97	7.21	313	3.9	45	302	
		8:46	1.0	21.95	7.19	313	3.7	42	302	
		8:47	1.5	21.93	7.12	311	3.2	36	282	
		8:48	1.9	21.74	6.76	354	1.0	11	164	

Vertical Profiles Collected in Silver Lake from October 2012 - January 2013

Site	Date	Time	Depth (m)	Temp (°C)	pH (s.u.)	Cond (µmho/cm)	DO (mg/L)	% Sat (%)	ORP (mV)	Secchi (m)
Prior to Chemical Additions										
C-1	10/12/12	8:41	0.25	26.83	7.22	276	6.9	86	245	0.62
		8:43	0.5	26.82	7.17	276	6.4	80	252	
		8:44	1.0	26.77	7.11	278	5.6	70	254	
		8:45	1.5	26.68	7.07	280	4.8	60	241	
		8:47	1.7	26.71	6.61	276	1.0	12	134	
Day 1 - Initial										
C-1	10/13/12	8:51	0.25	26.58	6.79	276	6.8	85	306	0.60
		8:52	0.5	26.58	6.88	276	6.2	77	310	
		8:53	1.0	26.56	6.94	276	5.8	72	312	
		8:54	1.5	26.47	6.95	279	5.6	70	248	
		8:55	1.7	26.52	6.52	285	0.9	12	154	
Day 1 - Following Inflow Addition										
C-1	10/13/12	9:00	0.25	26.61	6.98	277	6.5	81	174	-
		9:01	0.5	26.61	7.00	277	6.4	79	187	
		9:02	1.0	26.58	7.01	276	6.1	76	196	
		9:03	1.5	26.49	7.02	278	6.0	74	204	
		9:06	1.8	26.50	6.75	274	2.0	25	146	
Day 12 - Initial										
C-1	10/24/12	9:09	0.25	24.81	6.81	317	5.8	70	241	0.64
		9:09	0.5	24.80	6.93	317	5.5	66	249	
		9:11	1.0	24.79	7.04	317	5.2	63	259	
		9:12	1.5	24.79	7.05	318	4.8	58	264	
		9:13	1.6	24.83	6.92	318	1.5	18	192	
Day 12 - Following Inflow Addition										
C-1	10/24/12	10:44	0.25	25.01	7.22	318	6.4	77	149	-
		10:44	0.5	24.90	7.21	319	5.5	66	160	
		10:45	1.0	24.80	7.19	318	5.1	62	169	
		10:46	1.5	24.78	7.18	319	4.7	57	179	
		10:48	1.7	24.80	7.05	315	3.2	39	169	
Day 27 - Initial										
C-1	11/8/12	10:01	0.25	19.94	7.04	324	7.0	77	253	0.60
		10:01	0.5	19.91	7.12	323	6.2	68	265	
		10:02	1.0	19.84	7.15	324	5.4	59	274	
		10:03	1.5	19.69	7.14	324	4.5	49	276	
		10:05	1.7	19.80	7.12	324	2.6	29	256	
Day 27 - Following Inflow Addition										
C-1	11/8/12	11:18	0.25	20.14	7.12	323	7.2	79	212	-
		11:19	0.5	19.98	7.18	323	6.1	67	227	
		11:20	1.0	19.83	7.19	324	5.3	58	239	
		11:21	1.5	19.71	7.18	324	4.5	49	244	
		11:23	1.7	19.75	7.13	330	3.0	32	243	

Vertical Profiles Collected in Silver Lake from October 2012 - January 2013

Site	Date	Time	Depth (m)	Temp (°C)	pH (s.u.)	Cond (µmho/cm)	DO (mg/L)	% Sat (%)	ORP (mV)	Secchi (m)
Day 48 - Initial										
C-1	11/29/12	9:54	0.25	19.56	7.27	333	6.8	74	235	0.57
		9:56	0.5	19.55	7.26	332	6.4	70	248	
		9:57	1.0	19.50	7.25	332	5.9	65	257	
		9:58	1.5	19.48	7.21	332	5.3	57	261	
		10:00	1.7	19.48	7.08	333	3.3	36	230	
Day 48 - Following Inflow Addition										
C-1	11/29/12	11:08	0.25	19.82	7.11	332	7.1	78	197	-
		11:09	0.5	19.74	7.20	331	6.7	73	217	
		11:10	1.0	19.55	7.20	332	5.4	59	223	
		11:11	1.5	19.49	7.18	332	5.1	55	227	
		11:12	1.7	19.49	7.12	332	3.5	38	216	
Day 62 - Initial										
C-1	12/13/12	10:11	0.25	22.95	7.13	305	6.7	78	230	0.68
		10:12	0.5	22.95	7.12	305	5.8	68	230	
		10:13	1.0	22.92	7.10	305	5.2	61	230	
		10:15	1.5	22.79	7.09	305	5.0	58	232	
		10:16	1.7	22.83	6.99	310	3.7	43	198	
Day 62 - Following Inflow Addition										
C-1	12/13/12	10:22	0.25	22.96	7.07	305	6.6	77	166	-
		10:23	0.5	22.95	7.09	305	6.4	75	177	
		10:24	1.0	22.94	7.11	304	6.2	72	188	
		10:25	1.5	22.84	7.09	305	6.0	70	193	
		10:27	1.7	22.88	7.02	305	4.1	48	184	
Day 76 - Initial										
C-1	12/27/12	11:09	0.25	17.70	7.49	287	7.8	82	218	0.62
		11:10	0.5	17.55	7.50	287	7.5	78	233	
		11:11	1.0	17.23	7.47	288	7.0	73	242	
		11:12	1.5	17.09	7.45	288	7.0	72	250	
		11:14	1.8	17.22	7.03	304	2.8	29	162	
Day 76 - Following Inflow Addition										
C-1	12/27/12	11:23	0.25	17.94	7.47	289	8.2	87	230	-
		11:24	0.5	17.61	7.50	287	7.9	83	244	
		11:25	1.0	17.23	7.49	289	7.5	78	252	
		11:26	1.5	17.12	7.46	289	7.0	73	258	
		11:30	1.9	17.49	6.94	235	3.8	40	171	
Day 91 - Initial										
C-1	1/11/13	9:13	0.25	22.01	7.30	298	5.2	59	231	0.59
		9:14	0.5	21.99	7.32	298	5.1	58	235	
		9:15	1.0	21.93	7.31	297	4.7	53	242	
		9:15	1.5	21.87	7.30	297	4.7	53	247	
		9:17	1.9	21.85	7.20	297	3.5	40	242	

Vertical Profiles Collected in Silver Lake from October 2012 - January 2013

Site	Date	Time	Depth (m)	Temp (°C)	pH (s.u.)	Cond (µmho/cm)	DO (mg/L)	% Sat (%)	ORP (mV)	Secchi (m)
Prior to Chemical Additions										
C-2	10/12/12	8:09	0.25	26.91	6.82	268	6.8	95	151	0.60
		8:10	0.5	26.90	6.81	267	6.5	82	167	
		8:11	1.0	26.91	6.81	267	6.4	80	176	
		8:12	1.5	26.90	6.80	268	6.4	80	184	
		8:13	2.0	26.92	6.64	279	4.6	58	138	
Day 1 - Initial										
C-2	10/13/12	9:12	0.25	26.69	7.02	268	6.7	83	202	0.60
		9:13	0.5	26.66	6.96	268	6.0	75	208	
		9:14	1.0	26.62	6.92	268	5.3	66	214	
		9:16	1.5	26.61	6.90	268	5.0	62	221	
		9:17	1.9	26.63	6.48	299	1.0	12	143	
Day 1 - Following Inflow Addition										
C-2	10/13/12	9:32	0.25	26.69	6.95	268	6.9	87	186	-
		9:33	0.5	26.67	6.93	268	6.2	78	198	
		9:34	1.0	26.61	6.91	268	5.7	71	206	
		9:35	1.5	26.59	6.89	269	4.9	62	213	
		9:37	1.9	26.63	6.51	294	0.8	10	147	
Day 12 - Initial										
C-2	10/24/12	8:45	0.25	24.93	6.81	280	4.8	58	226	0.68
		8:46	0.5	24.93	6.96	281	4.8	58	237	
		8:47	1.0	24.93	7.02	281	4.8	58	243	
		8:48	1.5	24.92	7.06	282	4.8	58	249	
		8:50	1.9	24.99	6.71	271	0.8	9	148	
Day 12 - Following Inflow Addition										
C-2	10/24/12	10:32	0.25	25.10	6.91	281	5.7	70	173	-
		10:33	0.5	25.03	7.01	281	5.3	64	181	
		10:33	1.0	24.95	7.04	282	4.9	59	186	
		10:34	1.5	24.93	7.06	283	4.6	56	193	
		10:35	2.0	25.02	6.64	298	0.8	9	134	
Day 27 - Initial										
C-2	11/8/12	10:14	0.25	20.17	7.17	294	6.3	70	188	1.10
		10:15	0.5	20.18	7.14	295	6.4	71	194	
		10:16	1.0	20.16	7.12	296	6.1	67	202	
		10:17	1.5	20.14	7.11	295	6.0	66	208	
		10:18	1.9	20.37	6.92	302	0.8	9	184	
Day 27 - Following Inflow Addition										
C-2	11/8/12	11:32	0.25	20.33	7.16	295	6.9	77	189	-
		11:33	0.5	20.30	7.15	296	6.0	67	195	
		11:33	1.0	20.20	7.13	296	5.5	61	199	
		11:34	1.5	20.11	7.12	296	5.0	55	204	
		11:36	2.0	20.23	6.97	303	1.0	11	183	

Vertical Profiles Collected in Silver Lake from October 2012 - January 2013

Day 48 - Initial

Site	Date	Time	Depth (m)	Temp (°C)	pH (s.u.)	Cond (µmho/cm)	DO (mg/L)	% Sat (%)	ORP (mV)	Secchi (m)
C-2	11/29/12	9:30	0.25	19.60	6.99	300	6.9	75	227	0.51
		9:31	0.5	19.60	7.02	301	7.0	77	233	
		9:32	1.0	19.60	7.03	301	6.9	75	241	
		9:33	1.5	19.59	7.04	300	6.5	71	247	
		9:35	2.0	19.63	6.76	300	1.1	12	192	

Day 48 - Following Inflow Addition

Site	Date	Time	Depth (m)	Temp (°C)	pH (s.u.)	Cond (µmho/cm)	DO (mg/L)	% Sat (%)	ORP (mV)	Secchi (m)
C-2	11/29/12	11:22	0.25	19.85	7.07	300	6.7	74	177	-
		11:22	0.5	19.78	7.08	300	6.5	71	185	
		11:23	1.0	19.63	7.07	301	5.8	63	191	
		11:24	1.5	19.62	7.06	301	5.5	60	198	
		11:25	1.9	19.64	6.77	336	1.2	13	150	

Day 62 - Initial

Site	Date	Time	Depth (m)	Temp (°C)	pH (s.u.)	Cond (µmho/cm)	DO (mg/L)	% Sat (%)	ORP (mV)	Secchi (m)
C-2	12/13/12	10:35	0.25	23.03	7.13	312	6.1	71	244	1.10
		10:36	0.5	23.03	7.06	313	5.4	63	236	
		10:37	1.0	23.03	7.03	312	5.0	58	233	
		10:38	1.5	22.99	7.01	313	4.9	57	232	
		10:38	1.9	22.98	6.83	325	0.5	6	186	

Day 62 - Following Inflow Addition

Site	Date	Time	Depth (m)	Temp (°C)	pH (s.u.)	Cond (µmho/cm)	DO (mg/L)	% Sat (%)	ORP (mV)	Secchi (m)
C-2	12/13/12	10:45	0.25	23.03	7.01	312	5.9	69	121	-
		10:46	0.5	23.03	7.01	312	5.9	69	129	
		10:47	1.0	23.02	7.00	311	5.8	68	134	
		10:48	1.5	23.01	6.98	312	5.7	67	134	
		10:49	2.0	22.99	6.79	323	0.4	11	116	

Day 76 - Initial

Site	Date	Time	Depth (m)	Temp (°C)	pH (s.u.)	Cond (µmho/cm)	DO (mg/L)	% Sat (%)	ORP (mV)	Secchi (m)
C-2	12/27/12	9:25	0.25	17.56	7.30	311	5.0	52	218	0.96
		9:26	0.5	17.58	7.26	312	4.2	44	219	
		9:27	1.0	17.61	7.22	312	3.8	40	222	
		9:28	1.5	17.59	7.21	312	3.3	35	225	
		9:29	2.0	17.69	6.96	312	1.8	19	188	

Day 76 - Following Inflow Addition

Site	Date	Time	Depth (m)	Temp (°C)	pH (s.u.)	Cond (µmho/cm)	DO (mg/L)	% Sat (%)	ORP (mV)	Secchi (m)
C-2	12/27/12	9:36	0.25	17.56	7.21	312	4.8	50	201	-
		9:37	0.5	17.58	7.20	312	4.0	42	203	
		9:38	1.0	17.59	7.18	312	3.6	37	205	
		9:39	1.5	17.61	7.18	312	3.3	35	209	
		9:41	2.0	17.66	7.02	313	1.8	19	185	

Day 91 - Initial

Site	Date	Time	Depth (m)	Temp (°C)	pH (s.u.)	Cond (µmho/cm)	DO (mg/L)	% Sat (%)	ORP (mV)	Secchi (m)
C-2	1/11/13	10:45	0.25	22.27	7.32	319	4.6	53	381	0.88
		10:46	0.5	22.08	7.25	321	3.5	40	379	
		10:47	1.0	21.97	7.20	324	2.5	29	380	
		10:48	1.5	21.81	7.16	328	1.7	20	381	
		10:49	2.0	21.72	6.98	335	0.9	10	360	
		10:50	2.1	21.65	6.95	339	0.6	6	340	

Vertical Profiles Collected in Silver Lake from October 2012 - January 2013

Site	Date	Time	Depth (m)	Temp (°C)	pH (s.u.)	Cond (µmho/cm)	DO (mg/L)	% Sat (%)	ORP (mV)	Secchi (m)
Prior to Chemical Additions										
Lake	10/12/12	7:50	0.25	26.74	7.04	279	5.4	68	165	0.62
		7:51	0.5	26.74	7.07	279	5.4	68	185	
		7:52	1.0	26.74	7.07	283	5.2	65	196	
		7:53	1.5	26.72	7.06	282	5.0	62	190	
		7:54	2.0	26.72	6.76	279	1.2	15	121	
Day 1										
Lake	10/13/12	7:59	0.25	26.49	7.08	279	6.1	76	185	0.63
		8:00	0.5	26.47	7.12	279	6.2	77	199	
		8:01	1.0	26.48	7.13	279	6.1	77	214	
		8:02	1.5	26.48	7.14	279	6.2	77	225	
		8:04	1.9	26.51	6.69	284	1.7	22	136	
Day 12										
Lake	10/24/12	8:24	0.25	24.74	7.31	317	5.9	71	174	0.62
		8:25	0.5	24.73	7.30	318	6.0	72	190	
		8:26	1.0	24.71	7.27	319	5.5	67	207	
		8:26	1.5	24.71	7.26	321	5.5	66	217	
		8:28	1.9	24.82	6.81	330	0.9	11	132	
Day 27										
Lake	11/8/12	10:21	0.25	20.29	7.30	324	6.5	72	240	0.58
		10:22	0.5	19.72	7.27	324	5.5	60	251	
		10:22	1.0	19.60	7.26	325	5.2	57	262	
		10:23	1.5	19.54	7.21	325	4.6	50	261	
		10:25	2.0	19.75	7.00	338	1.3	15	211	
Day 48										
Lake	11/29/12	8:52	0.25	19.42	7.50	332	7.4	80	455	0.58
		8:52	0.5	19.44	7.42	331	7.1	77	452	
		8:53	1.0	19.41	7.37	331	6.6	72	451	
		8:54	1.5	19.40	7.33	331	6.4	69	450	
		8:56	1.9	19.42	7.05	331	3.1	33	255	
Day 62										
Lake	12/13/12	8:44	0.25	22.85	7.21	301	6.7	78	454	0.65
		8:45	0.5	22.85	7.16	302	6.2	72	453	
		8:46	1.0	22.82	7.14	302	5.8	68	453	
		8:46	1.5	22.82	7.11	302	5.6	65	451	
		8:48	1.8	22.80	6.95	314	4.8	56	289	
Day 76										
Lake	12/27/12	8:50	0.25	17.24	7.35	286	6.3	65	325	0.58
		8:51	0.5	17.24	7.38	286	6.4	67	320	
		8:52	1.0	17.24	7.41	286	6.3	66	318	
		8:53	1.5	17.24	7.41	286	6.2	64	316	
		8:56	1.9	17.27	7.24	295	4.2	43	241	
Day 91										
Lake	1/11/13	8:38	0.25	21.85	7.58	296	7.2	82	459	0.61
		8:38	0.5	21.85	7.55	295	6.9	78	457	
		8:40	1.0	21.85	7.52	295	6.7	76	455	
		8:40	1.5	21.83	7.50	295	6.4	73	454	
		8:42	1.9	21.81	7.26	303	4.3	49	370	

C.2   Photosynthetically Active Radiation (PAR)

Lake Silver Water Quality Monitoring Program
Photosynthetically Active Radiation (PAR)

Site	Date	Time	Depth (m)	Raw Underwater PAR (µmol s^1 m^2)	Ln(Raw) PAR	Air Raw (µmol s^1 m^2)	Air Corrected PAR (µmol s^1 m^2)	Ln(Corrected)	Air Corrected Kd
Lake	10/12/12	9:40	0.2	342.34	5.836	746.21	342.34	5.836	3.740
Lake	10/12/12	9:40	0.4	217.37	5.382	771.03	210.37	5.349	
Lake	10/12/12	9:40	0.6	77.70	4.353	771.57	75.15	4.319	
Lake	10/12/12	9:41	0.8	35.51	3.570	773.33	34.26	3.534	
Lake	10/12/12	9:41	1.0	17.27	2.849	786.66	16.39	2.796	
Lake	10/12/12	9:42	1.5	3.19	1.161	784.34	3.04	1.111	
P-1	10/12/12	9:45	0.2	237.93	5.472	787.03	237.93	5.472	3.157
P-1	10/12/12	9:45	0.4	97.27	4.577	802.12	95.44	4.558	
P-1	10/12/12	9:46	0.6	54.48	3.998	803.98	53.33	3.977	
P-1	10/12/12	9:46	0.8	28.79	3.360	808.78	28.01	3.333	
P-1	10/12/12	9:47	1.0	16.41	2.798	808.97	15.96	2.770	
P-1	10/12/12	9:47	1.5	3.59	1.279	798.22	3.54	1.265	
C-1	10/12/12	10:00	0.2	364.60	5.899	931.21	364.60	5.899	3.575
C-1	10/12/12	10:00	0.4	122.74	4.810	936.84	122.00	4.804	
C-1	10/12/12	10:01	0.6	60.39	4.101	939.66	59.84	4.092	
C-1	10/12/12	10:01	0.8	28.27	3.342	940.62	27.99	3.332	
C-1	10/12/12	10:02	1.0	17.29	2.850	940.47	17.12	2.840	
C-1	10/12/12	10:02	1.5	3.03	1.107	944.44	2.98	1.093	
A-1	10/12/12	10:14	0.2	325.35	5.785	1018.10	325.35	5.785	3.410
A-1	10/12/12	10:14	0.4	141.10	4.949	1022.00	140.56	4.946	
A-1	10/12/12	10:15	0.6	55.89	4.023	1021.30	55.71	4.020	
A-1	10/12/12	10:15	0.8	39.95	3.688	1022.50	39.78	3.683	
A-1	10/12/12	10:16	1.0	15.88	2.765	1029.80	15.70	2.754	
A-1	10/12/12	10:16	1.5	3.73	1.316	1031.80	3.68	1.303	
A-2	10/12/12	10:19	0.2	287.81	5.662	984.37	287.81	5.662	3.506
A-2	10/12/12	10:19	0.4	137.46	4.923	984.86	137.39	4.923	
A-2	10/12/12	10:20	0.6	79.68	4.378	993.37	78.96	4.369	
A-2	10/12/12	10:20	0.8	33.83	3.521	999.78	33.31	3.506	
A-2	10/12/12	10:21	1.0	15.56	2.745	1002.60	15.28	2.726	
A-2	10/12/12	10:21	1.5	3.24	1.174	1003.20	3.18	1.155	
P-2	10/12/12	10:25	0.2	348.20	5.853	1051.40	348.20	5.853	3.475
P-2	10/12/12	10:26	0.4	196.01	5.278	1059.10	194.58	5.271	
P-2	10/12/12	10:26	0.6	74.06	4.305	1066.00	73.04	4.291	
P-2	10/12/12	10:27	0.8	48.43	3.880	1066.80	47.73	3.865	
P-2	10/12/12	10:27	1.0	20.26	3.009	1079.90	19.73	2.982	
P-2	10/12/12	10:28	1.5	4.09	1.409	1084.50	3.97	1.378	
C-2	10/12/12	10:32	0.2	304.63	5.719	1094.70	304.63	5.719	3.129
C-2	10/12/12	10:32	0.4	217.27	5.381	1100.60	216.11	5.376	
C-2	10/12/12	10:33	0.6	91.00	4.511	1108.20	89.89	4.499	
C-2	10/12/12	10:33	0.8	62.73	4.139	1109.00	61.92	4.126	
C-2	10/12/12	10:34	1.0	26.40	3.273	1109.80	26.04	3.260	
C-2	10/12/12	10:34	1.5	5.91	1.776	1117.50	5.79	1.756	

Lake Silver Water Quality Monitoring Program
Photosynthetically Active Radiation (PAR)

Site	Date	Time	Depth (m)	Raw Underwater PAR (µmol s^{1} m^{2})	Ln(Raw) PAR	Air Raw (µmol s^{1} m^{2})	Air Corrected PAR (µmol s^{1} m^{2})	Ln(Corrected)	Air Corrected Kd
Lake	10/13/12	11:09	0.2	577.95	6.359	1335.20	577.95	6.359	3.102
Lake	10/13/12	11:09	0.4	265.07	5.580	1331.30	265.85	5.583	
Lake	10/13/12	11:10	0.6	148.63	5.001	1344.00	147.66	4.995	
Lake	10/13/12	11:10	0.8	73.01	4.291	1346.60	72.39	4.282	
Lake	10/13/12	11:11	1.0	43.88	3.781	1363.90	42.96	3.760	
Lake	10/13/12	11:11	1.5	10.03	2.305	1365.70	9.80	2.283	
A-1	10/13/12	11:16	0.2	532.30	6.277	1361.20	532.30	6.277	0.783
A-1	10/13/12	11:17	0.4	491.66	6.198	1367.50	489.39	6.193	
A-1	10/13/12	11:17	0.6	436.18	6.078	1364.50	435.13	6.076	
A-1	10/13/12	11:18	0.8	384.88	5.953	1375.60	380.85	5.942	
A-1	10/13/12	11:18	1.0	330.42	5.800	1380.00	325.92	5.787	
A-1	10/13/12	11:19	1.5	197.30	5.285	1393.20	192.77	5.261	
P-2	10/13/12	11:22	0.2	1183.40	7.076	1407.00	1183.40	7.076	0.884
P-2	10/13/12	11:22	0.4	663.51	6.498	1443.60	646.69	6.472	
P-2	10/13/12	11:23	0.6	434.36	6.074	1365.70	447.50	6.104	
P-2	10/13/12	11:23	0.8	420.76	6.042	1389.20	426.15	6.055	
P-2	10/13/12	11:24	1.0	384.53	5.952	1367.20	395.72	5.981	
P-2	10/13/12	11:25	1.5	301.43	5.709	1329.60	318.98	5.765	
A-2	10/13/12	11:28	0.2	694.52	6.543	1439.50	694.52	6.543	3.035
A-2	10/13/12	11:28	0.4	334.41	5.812	1432.70	336.00	5.817	
A-2	10/13/12	11:29	0.6	146.82	4.989	1429.20	147.88	4.996	
A-2	10/13/12	11:29	0.8	72.49	4.283	1234.60	84.52	4.437	
A-2	10/13/12	11:30	1.0	39.38	3.673	1269.40	44.66	3.799	
A-2	10/13/12	11:30	1.5	3.16	1.150	337.72	13.46	2.599	
P-1	10/13/12	11:34	0.2	605.70	6.406	1393.10	605.70	6.406	0.640
P-1	10/13/12	11:34	0.4	429.24	6.062	1540.70	388.12	5.961	
P-1	10/13/12	11:35	0.6	376.20	5.930	1625.10	322.49	5.776	
P-1	10/13/12	11:35	0.8	349.66	5.857	1623.90	299.96	5.704	
P-1	10/13/12	11:36	1.0	339.02	5.826	1620.30	291.48	5.675	
P-1	10/13/12	11:36	1.5	237.21	5.469	1425.00	231.90	5.446	
C-1	10/13/12	11:39	0.2	724.86	6.586	1464.50	724.86	6.586	3.459
C-1	10/13/12	11:40	0.4	375.71	5.929	1487.90	369.80	5.913	
C-1	10/13/12	11:40	0.6	112.03	4.719	1507.30	108.85	4.690	
C-1	10/13/12	11:41	0.8	58.88	4.076	1519.60	56.75	4.039	
C-1	10/13/12	11:41	1.0	27.42	3.311	1497.60	26.81	3.289	
C-1	10/13/12	11:42	1.5	9.32	2.233	1506.30	9.06	2.204	
C-2	10/13/12	11:46	0.2	500.59	6.216	1522.20	500.59	6.216	3.110
C-2	10/13/12	11:46	0.4	308.06	5.730	1543.00	303.91	5.717	
C-2	10/13/12	11:47	0.6	145.54	4.980	1557.60	142.23	4.957	
C-2	10/13/12	11:47	0.8	96.64	4.571	1548.90	94.98	4.554	
C-2	10/13/12	11:48	1.0	45.90	3.826	1532.80	45.58	3.820	
C-2	10/13/12	11:48	1.5	9.10	2.208	1559.70	8.88	2.184	

Lake Silver Water Quality Monitoring Program
Photosynthetically Active Radiation (PAR)

Site	Date	Time	Depth (m)	Raw Underwater PAR (µmol s^1 m^2)	Ln(Raw) PAR	Air Raw (µmol s^1 m^2)	Air Corrected PAR (µmol s^1 m^2)	Ln(Corrected)	Air Corrected Kd
P-1	10/24/12	10:54	0.2	250.32	5.523	720.15	250.32	5.523	3.902
P-1	10/24/12	10:54	0.4	133.77	4.896	728.19	132.29	4.885	
P-1	10/24/12	10:55	0.6	71.09	4.264	739.00	69.28	4.238	
P-1	10/24/12	10:55	0.8	38.46	3.650	747.03	37.07	3.613	
P-1	10/24/12	10:56	1.0	19.22	2.956	747.96	18.50	2.918	
P-1	10/24/12	10:56	1.5	1.51	0.414	752.25	1.45	0.371	
C-1	10/24/12	11:00	0.2	163.64	5.098	731.64	163.64	5.098	4.858
C-1	10/24/12	11:01	0.4	76.59	4.338	727.97	76.98	4.343	
C-1	10/24/12	11:01	0.6	22.99	3.135	723.26	23.25	3.146	
C-1	10/24/12	11:02	0.8	8.68	2.161	721.60	8.80	2.175	
C-1	10/24/12	11:02	1.0	4.14	1.420	721.23	4.20	1.435	
C-1	10/24/12	11:03	1.5	0.30	-1.207	721.23	0.30	-1.192	
C-2	10/24/12	11:07	0.2	179.59	5.191	752.46	179.59	5.191	2.745
C-2	10/24/12	11:08	0.4	83.66	4.427	756.87	83.17	4.421	
C-2	10/24/12	11:08	0.6	53.33	3.977	760.11	52.80	3.966	
C-2	10/24/12	11:09	0.8	42.48	3.749	768.41	41.59	3.728	
C-2	10/24/12	11:09	1.0	19.05	2.947	764.19	18.76	2.932	
C-2	10/24/12	11:10	1.5	4.59	1.524	768.98	4.49	1.502	
A-2	10/24/12	11:13	0.2	374.80	5.926	761.14	374.80	5.926	1.613
A-2	10/24/12	11:13	0.4	336.51	5.819	756.74	338.47	5.824	
A-2	10/24/12	11:14	0.6	229.38	5.435	753.72	231.64	5.445	
A-2	10/24/12	11:14	0.8	145.27	4.979	757.83	145.90	4.983	
A-2	10/24/12	11:15	1.0	82.63	4.414	752.06	83.63	4.426	
A-2	10/24/12	11:15	1.5	55.82	4.022	752.33	56.48	4.034	
P-2	10/24/12	11:19	0.2	185.46	5.223	756.51	185.46	5.223	3.056
P-2	10/24/12	11:19	0.4	99.00	4.595	747.47	100.20	4.607	
P-2	10/24/12	11:20	0.6	44.23	3.789	734.12	45.58	3.820	
P-2	10/24/12	11:20	0.8	23.14	3.141	728.56	24.03	3.179	
P-2	10/24/12	11:21	1.0	13.77	2.622	723.37	14.40	2.667	
P-2	10/24/12	11:21	1.5	3.32	1.200	710.69	3.54	1.263	
A-1	10/24/12	11:24	0.2	400.87	5.994	668.30	400.87	5.994	1.037
A-1	10/24/12	11:25	0.4	336.33	5.818	677.23	331.90	5.805	
A-1	10/24/12	11:25	0.6	288.76	5.666	684.51	281.92	5.642	
A-1	10/24/12	11:26	0.8	245.84	5.505	703.06	233.69	5.454	
A-1	10/24/12	11:26	1.0	196.81	5.282	722.54	182.04	5.204	
A-1	10/24/12	11:27	1.5	117.97	4.770	755.88	104.30	4.647	
Lake	10/24/12	11:32	0.2	244.78	5.500	803.22	244.78	5.500	3.742
Lake	10/24/12	11:32	0.4	127.90	4.851	815.19	126.02	4.836	
Lake	10/24/12	11:33	0.6	65.69	4.185	826.23	63.86	4.157	
Lake	10/24/12	11:33	0.8	32.61	3.485	832.10	31.48	3.449	
Lake	10/24/12	11:34	1.0	13.25	2.584	846.55	12.57	2.531	
Lake	10/24/12	11:34	1.5	2.11	0.749	856.76	1.98	0.684	

Lake Silver Water Quality Monitoring Program
Photosynthetically Active Radiation (PAR)

Site	Date	Time	Depth (m)	Raw Underwater PAR (µmol s^{1} m^{2})	Ln(Raw) PAR	Air Raw (µmol s^{1} m^{2})	Air Corrected PAR (µmol s^{1} m^{2})	Ln(Corrected)	Air Corrected Kd
C-2	11/8/12	11:41	0.2	544.20	6.299	1254.70	544.20	6.299	1.759
C-2	11/8/12	11:42	0.4	165.95	5.112	1318.60	157.91	5.062	
C-2	11/8/12	11:43	0.6	163.33	5.096	1316.90	155.62	5.047	
C-2	11/8/12	11:44	0.8	113.36	4.731	1313.80	108.26	4.685	
C-2	11/8/12	11:44	1.0	93.13	4.534	1303.10	89.67	4.496	
C-2	11/8/12	11:45	1.5	40.45	3.700	1306.60	38.84	3.659	
P-1	11/8/12	11:48	0.2	340.32	5.830	1518.90	340.32	5.830	3.364
P-1	11/8/12	11:48	0.4	230.98	5.442	1467.80	239.02	5.477	
P-1	11/8/12	11:49	0.6	63.20	4.146	1476.50	65.02	4.175	
P-1	11/8/12	11:49	0.8	47.14	3.853	1469.10	48.74	3.887	
P-1	11/8/12	11:50	1.0	24.65	3.205	1465.70	25.54	3.240	
P-1	11/8/12	11:50	1.5	4.36	1.472	1470.30	4.50	1.505	
C-1	11/8/12	11:53	0.2	131.77	4.881	1520.70	131.77	4.881	6.061
C-1	11/8/12	11:53	0.4	53.74	3.984	1509.20	54.15	3.992	
C-1	11/8/12	11:54	0.6	29.56	3.387	1502.30	29.93	3.399	
C-1	11/8/12	11:54	0.8	7.65	2.034	1514.90	7.68	2.038	
C-1	11/8/12	11:55	1.0	1.72	0.543	1513.80	1.73	0.548	
C-1	11/8/12	11:55	1.5	0.06	-2.886	1516.80	0.06	-2.883	
A-1	11/8/12	11:59	0.2	402.39	5.997	1428.60	402.39	5.997	1.894
A-1	11/8/12	11:59	0.4	350.32	5.859	1445.30	346.27	5.847	
A-1	11/8/12	12:00	0.6	260.21	5.561	1455.10	255.47	5.543	
A-1	11/8/12	12:00	0.8	185.77	5.225	1459.80	181.80	5.203	
A-1	11/8/12	12:01	1.0	106.90	4.672	1433.20	106.56	4.669	
A-1	11/8/12	12:01	1.5	36.81	3.606	1412.60	37.23	3.617	
A-2	11/8/12	12:05	0.2	398.55	5.988	1433.90	398.55	5.988	2.675
A-2	11/8/12	12:05	0.4	347.73	5.851	1460.80	341.33	5.833	
A-2	11/8/12	12:06	0.6	202.60	5.311	1470.20	197.60	5.286	
A-2	11/8/12	12:06	0.8	98.74	4.592	1448.70	97.73	4.582	
A-2	11/8/12	12:07	1.0	44.64	3.799	1460.00	43.84	3.781	
A-2	11/8/12	12:07	1.5	16.36	2.795	1468.20	15.97	2.771	
P-2	11/8/12	12:10	0.2	255.71	5.544	1430.50	255.71	5.544	2.077
P-2	11/8/12	12:11	0.4	216.79	5.379	1435.40	216.05	5.376	
P-2	11/8/12	12:11	0.6	154.44	5.040	1447.10	152.67	5.028	
P-2	11/8/12	12:12	0.8	93.04	4.533	1441.40	92.34	4.525	
P-2	11/8/12	12:12	1.0	63.14	4.145	1434.30	62.97	4.143	
P-2	11/8/12	12:13	1.5	18.41	2.913	1419.90	18.55	2.920	
Lake	11/8/12	12:18	0.2	305.71	5.723	1433.20	305.71	5.723	4.493
Lake	11/8/12	12:18	0.4	190.31	5.249	1434.50	190.14	5.248	
Lake	11/8/12	12:19	0.6	82.67	4.415	1436.00	82.51	4.413	
Lake	11/8/12	12:19	0.8	40.11	3.692	1438.00	39.98	3.688	
Lake	11/8/12	12:20	1.0	18.86	2.937	1441.80	18.75	2.931	
Lake	11/8/12	12:20	1.5	0.88	-0.124	1448.00	0.87	-0.135	

Lake Silver Water Quality Monitoring Program
Photosynthetically Active Radiation (PAR)

Site	Date	Time	Depth (m)	Raw Underwater PAR (µmol s^1 m^2)	Ln(Raw) PAR	Air Raw (µmol s^1 m^2)	Air Corrected PAR (µmol s^1 m^2)	Ln(Corrected)	Air Corrected Kd
P-2	11/29/12	11:40	0.2	143.98	4.970	1068.50	143.98	4.970	2.171
P-2	11/29/12	11:40	0.4	96.05	4.565	1014.90	101.12	4.616	
P-2	11/29/12	11:41	0.6	49.32	3.898	986.00	53.44	3.979	
P-2	11/29/12	11:41	0.8	37.76	3.631	1003.20	40.22	3.694	
P-2	11/29/12	11:42	1.0	24.63	3.204	996.16	26.42	3.274	
P-2	11/29/12	11:42	1.5	8.11	2.094	1014.40	8.55	2.146	
A-2	11/29/12	11:46	0.2	325.55	5.786	984.99	325.55	5.786	3.894
A-2	11/29/12	11:47	0.4	196.38	5.280	986.21	196.14	5.279	
A-2	11/29/12	11:47	0.6	63.51	4.151	989.48	63.22	4.147	
A-2	11/29/12	11:48	0.8	28.92	3.364	982.38	28.99	3.367	
A-2	11/29/12	11:48	1.0	14.52	2.676	981.37	14.58	2.679	
A-2	11/29/12	11:49	1.5	2.31	0.837	985.79	2.31	0.836	
C-2	11/29/12	11:52	0.2	128.35	4.855	1021.00	128.35	4.855	2.869
C-2	11/29/12	11:52	0.4	66.63	4.199	994.47	68.41	4.225	
C-2	11/29/12	11:53	0.6	45.61	3.820	1000.20	46.56	3.841	
C-2	11/29/12	11:53	0.8	25.13	3.224	1012.40	25.34	3.232	
C-2	11/29/12	11:54	1.0	12.10	2.493	1009.80	12.24	2.504	
C-2	11/29/12	11:54	1.5	3.08	1.126	1008.30	3.12	1.138	
P-1	11/29/12	11:58	0.2	104.70	4.651	1004.90	104.70	4.651	2.194
P-1	11/29/12	11:58	0.4	39.49	3.676	1043.20	38.04	3.639	
P-1	11/29/12	11:59	0.6	26.37	3.272	1078.60	24.56	3.201	
P-1	11/29/12	11:59	0.8	19.71	2.981	1077.70	18.38	2.911	
P-1	11/29/12	12:00	1.0	12.37	2.515	1105.20	11.25	2.420	
P-1	11/29/12	12:00	1.5	6.23	1.829	1258.70	4.97	1.604	
C-1	11/29/12	12:05	0.2	169.11	5.131	1053.80	169.11	5.131	4.726
C-1	11/29/12	12:05	0.4	73.45	4.297	1042.90	74.22	4.307	
C-1	11/29/12	12:06	0.6	21.42	3.064	1039.80	21.71	3.078	
C-1	11/29/12	12:06	0.8	8.77	2.172	1031.70	8.96	2.193	
C-1	11/29/12	12:07	1.0	3.55	1.266	1004.90	3.72	1.314	
C-1	11/29/12	12:07	1.5	0.36	-1.012	1010.00	0.38	-0.970	
A-1	11/29/12	12:11	0.2	223.52	5.410	1021.90	223.52	5.410	1.951
A-1	11/29/12	12:11	0.4	137.97	4.927	1020.40	138.17	4.929	
A-1	11/29/12	12:12	0.6	88.69	4.485	1016.40	89.17	4.491	
A-1	11/29/12	12:12	0.8	59.56	4.087	1027.70	59.22	4.081	
A-1	11/29/12	12:13	1.0	43.22	3.766	1031.50	42.82	3.757	
A-1	11/29/12	12:13	1.5	17.38	2.855	1033.20	17.19	2.844	
Lake	11/29/12	12:17	0.2	607.84	6.410	1059.30	607.84	6.410	4.160
Lake	11/29/12	12:17	0.4	274.55	5.615	1066.80	272.62	5.608	
Lake	11/29/12	12:18	0.6	97.65	4.581	1073.00	96.41	4.569	
Lake	11/29/12	12:18	0.8	50.21	3.916	1070.30	49.70	3.906	
Lake	11/29/12	12:19	1.0	18.46	2.916	1072.60	18.23	2.903	
Lake	11/29/12	12:19	1.5	2.87	1.054	1073.60	2.83	1.041	

Lake Silver Water Quality Monitoring Program
Photosynthetically Active Radiation (PAR)

Site	Date	Time	Depth (m)	Raw Underwater PAR (µmol s^1 m^2)	Ln(Raw) PAR	Air Raw (µmol s^1 m^2)	Air Corrected PAR (µmol s^1 m^2)	Ln(Corrected)	Air Corrected Kd
P-2	12/13/12	10:24	0.2	168.61	5.128	659.98	168.61	5.128	3.104
P-2	12/13/12	10:24	0.4	111.83	4.717	665.08	110.97	4.709	
P-2	12/13/12	10:25	0.6	62.76	4.139	666.20	62.18	4.130	
P-2	12/13/12	10:25	0.8	29.34	3.379	666.39	29.06	3.369	
P-2	12/13/12	10:26	1.0	13.36	2.592	636.77	13.85	2.628	
P-2	12/13/12	10:26	1.5	3.08	1.126	592.46	3.44	1.234	
A-2	12/13/12	10:59	0.2	279.45	5.633	1146.50	279.45	5.633	2.483
A-2	12/13/12	11:00	0.4	124.96	4.828	1144.40	125.19	4.830	
A-2	12/13/12	11:00	0.6	99.17	4.597	1146.00	99.21	4.597	
A-2	12/13/12	11:01	0.8	57.29	4.048	1123.70	58.45	4.068	
A-2	12/13/12	11:01	1.0	40.16	3.693	1031.20	44.65	3.799	
A-2	12/13/12	11:02	1.5	9.07	2.205	1143.10	9.10	2.208	
A-1	12/13/12	11:06	0.2	217.28	5.381	1201.40	217.28	5.381	3.023
A-1	12/13/12	11:06	0.4	133.34	4.893	1221.70	131.12	4.876	
A-1	12/13/12	11:07	0.6	64.71	4.170	1215.50	63.96	4.158	
A-1	12/13/12	11:07	0.8	26.26	3.268	1069.90	29.48	3.384	
A-1	12/13/12	11:08	1.0	14.84	2.698	834.34	21.37	3.062	
A-1	12/13/12	11:08	1.5	3.60	1.282	991.09	4.37	1.475	
C-1	12/13/12	11:33	0.2	169.78	5.135	891.44	169.78	5.135	3.360
C-1	12/13/12	11:33	0.4	64.58	4.168	1075.50	53.53	3.980	
C-1	12/13/12	11:34	0.6	31.93	3.464	1261.60	22.56	3.116	
C-1	12/13/12	11:34	0.8	18.28	2.906	1026.60	15.87	2.765	
C-1	12/13/12	11:35	1.0	9.32	2.232	992.30	8.37	2.125	
C-1	12/13/12	11:35	1.5	1.97	0.680	1027.00	1.71	0.538	
C-2	12/13/12	11:55	0.2	170.56	5.139	841.81	170.56	5.139	2.518
C-2	12/13/12	11:56	0.4	83.67	4.427	692.23	101.75	4.623	
C-2	12/13/12	11:56	0.6	39.05	3.665	518.15	63.44	4.150	
C-2	12/13/12	11:57	0.8	28.66	3.355	541.29	44.57	3.797	
C-2	12/13/12	11:58	1.0	19.78	2.985	574.42	28.99	3.367	
C-2	12/13/12	11:58	1.5	5.42	1.689	775.29	5.88	1.772	
Lake	12/13/12	12:22	0.2	117.38	4.765	475.40	117.38	4.765	3.330
Lake	12/13/12	12:22	0.4	82.36	4.411	485.13	80.71	4.391	
Lake	12/13/12	12:23	0.6	47.39	3.858	506.90	44.45	3.794	
Lake	12/13/12	12:23	0.8	19.76	2.984	518.58	18.11	2.897	
Lake	12/13/12	12:24	1.0	12.86	2.554	553.11	11.05	2.403	
Lake	12/13/12	12:24	1.5	2.63	0.968	733.01	1.71	0.535	
P-1	12/13/12	12:28	0.2	203.03	5.313	1241.10	203.03	5.313	2.001
P-1	12/13/12	12:28	0.4	105.88	4.662	907.49	144.80	4.975	
P-1	12/13/12	12:29	0.6	41.28	3.720	547.31	93.60	4.539	
P-1	12/13/12	12:30	0.8	26.97	3.295	495.35	67.56	4.213	
P-1	12/13/12	12:30	1.0	16.29	2.791	475.13	42.55	3.751	
P-1	12/13/12	12:31	1.5	5.57	1.718	452.09	15.30	2.728	

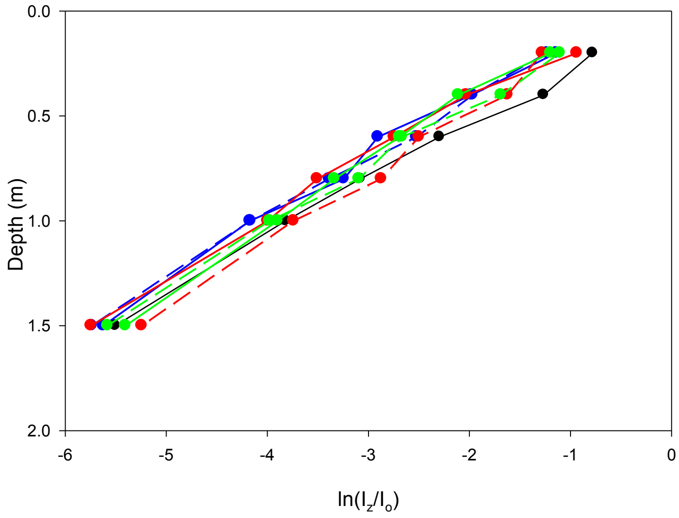
Lake Silver Water Quality Monitoring Program
Photosynthetically Active Radiation (PAR)

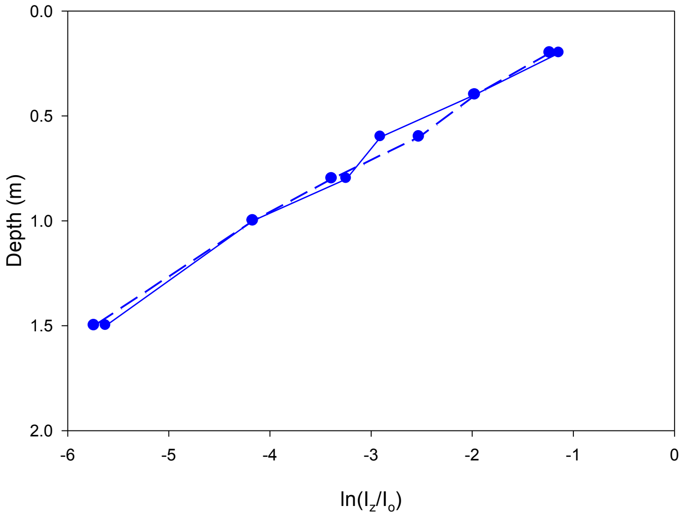
Site	Date	Time	Depth (m)	Raw Underwater PAR (µmol s^1 m^2)	Ln(Raw) PAR	Air Raw (µmol s^1 m^2)	Air Corrected PAR (µmol s^1 m^2)	Ln(Corrected)	Air Corrected Kd
P-1	12/27/12	10:22	0.2	61.54	4.120	753.98	61.54	4.120	1.748
P-1	12/27/12	10:22	0.4	40.82	3.709	760.06	40.50	3.701	
P-1	12/27/12	10:23	0.6	27.91	3.329	770.81	27.30	3.307	
P-1	12/27/12	10:23	0.8	19.75	2.983	771.86	19.29	2.960	
P-1	12/27/12	10:24	1.0	13.34	2.590	761.19	13.21	2.581	
P-1	12/27/12	10:24	1.5	6.42	1.859	763.16	6.34	1.847	
Lake	12/27/12	10:29	0.2	112.76	4.725	716.90	112.76	4.725	5.224
Lake	12/27/12	10:29	0.4	61.12	4.113	711.39	61.60	4.121	
Lake	12/27/12	10:30	0.6	20.50	3.020	705.37	20.83	3.036	
Lake	12/27/12	10:30	0.8	7.66	2.035	711.26	7.72	2.043	
Lake	12/27/12	10:31	1.0	2.39	0.870	712.33	2.40	0.877	
Lake	12/27/12	10:31	1.5	0.14	-1.949	696.64	0.15	-1.921	
C-2	12/27/12	10:48	0.2	95.66	4.561	708.11	95.66	4.561	2.554
C-2	12/27/12	10:49	0.4	81.47	4.400	758.20	76.08	4.332	
C-2	12/27/12	10:49	0.6	48.41	3.880	752.75	45.53	3.818	
C-2	12/27/12	10:50	0.8	20.50	3.020	768.08	18.90	2.939	
C-2	12/27/12	10:50	1.0	13.20	2.580	762.55	12.26	2.506	
C-2	12/27/12	10:51	1.5	4.50	1.504	756.84	4.21	1.437	
A-2	12/27/12	11:12	0.2	208.56	5.340	898.14	208.56	5.340	2.032
A-2	12/27/12	11:13	0.4	178.20	5.183	909.85	175.91	5.170	
A-2	12/27/12	11:13	0.6	110.56	4.706	920.85	107.83	4.681	
A-2	12/27/12	11:14	0.8	79.57	4.377	933.69	76.54	4.338	
A-2	12/27/12	11:15	1.0	49.42	3.900	939.72	47.23	3.855	
A-2	12/27/12	11:15	1.5	16.82	2.823	938.82	16.09	2.779	
P-2	12/27/12	11:37	0.2	159.71	5.073	997.97	159.71	5.073	2.521
P-2	12/27/12	11:37	0.4	82.01	4.407	991.50	82.55	4.413	
P-2	12/27/12	11:38	0.6	57.53	4.052	993.97	57.76	4.056	
P-2	12/27/12	11:38	0.8	37.44	3.623	991.59	37.68	3.629	
P-2	12/27/12	11:39	1.0	24.10	3.182	997.58	24.11	3.183	
P-2	12/27/12	11:39	1.5	5.32	1.672	994.73	5.34	1.675	
A-1	12/27/12	12:04	0.2	284.52	5.651	1213.80	284.52	5.651	1.885
A-1	12/27/12	12:05	0.4	219.38	5.391	1198.60	222.16	5.403	
A-1	12/27/12	12:05	0.6	122.28	4.806	1179.90	125.79	4.835	
A-1	12/27/12	12:05	0.8	76.85	4.342	1161.70	80.30	4.386	
A-1	12/27/12	12:06	1.0	52.10	3.953	1148.70	55.05	4.008	
A-1	12/27/12	12:06	1.5	26.20	3.266	1169.60	27.18	3.303	
C-1	12/27/12	12:33	0.2	96.65	4.571	1228.50	96.65	4.571	4.890
C-1	12/27/12	12:33	0.4	49.12	3.894	1223.20	49.34	3.899	
C-1	12/27/12	12:34	0.6	27.04	3.297	1283.00	25.89	3.254	
C-1	12/27/12	12:34	0.8	9.03	2.200	1259.60	8.81	2.175	
C-1	12/27/12	12:35	1.0	2.78	1.024	1243.60	2.75	1.011	
C-1	12/27/12	12:35	1.5	0.20	-1.631	1275.70	0.19	-1.669	

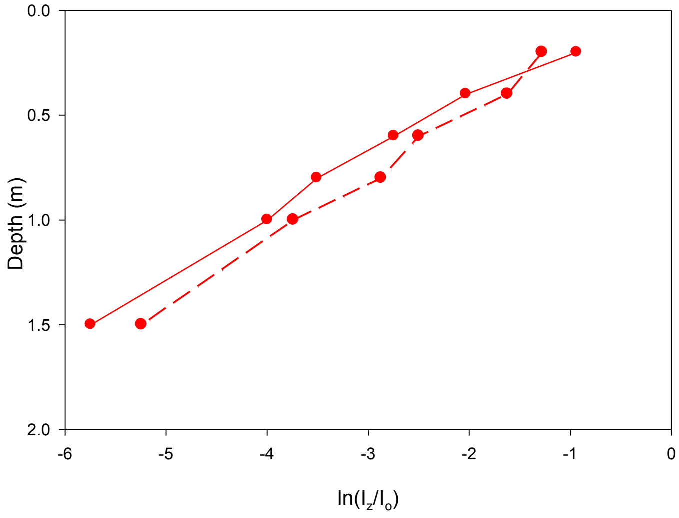
Lake Silver Water Quality Monitoring Program
Photosynthetically Active Radiation (PAR)

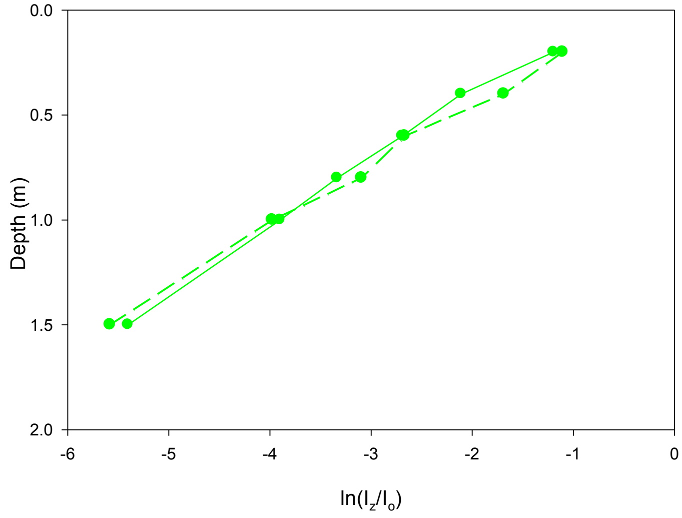
Site	Date	Time	Depth (m)	Raw Underwater PAR (μmol s^1 m^2)	Ln(Raw) PAR	Air Raw (μmol s^1 m^2)	Air Corrected PAR (μmol s^1 m^2)	Ln(Corrected)	Air Corrected Kd
Lake	1/11/13	10:10	0.2	238.42	5.474	482.07	238.42	5.474	3.614
Lake	1/11/13	10:10	0.4	175.34	5.167	488.02	173.20	5.154	
Lake	1/11/13	10:11	0.6	81.35	4.399	485.29	80.81	4.392	
Lake	1/11/13	10:11	0.8	37.05	3.612	462.56	38.61	3.653	
Lake	1/11/13	10:12	1.0	19.71	2.981	423.84	22.41	3.110	
Lake	1/11/13	10:12	1.5	1.91	0.647	397.98	2.31	0.838	
P-2	1/11/13	10:15	0.2	109.45	4.695	400.63	109.45	4.695	2.081
P-2	1/11/13	10:15	0.4	68.59	4.228	399.12	68.84	4.232	
P-2	1/11/13	10:16	0.6	51.30	3.938	400.74	51.28	3.937	
P-2	1/11/13	10:17	0.8	29.98	3.401	419.65	28.62	3.354	
P-2	1/11/13	10:17	1.0	16.82	2.823	425.59	15.84	2.762	
P-2	1/11/13	10:18	1.5	8.46	2.135	423.81	7.99	2.079	
C-1	1/11/13	10:37	0.2	140.94	4.948	857.83	140.94	4.948	3.817
C-1	1/11/13	10:37	0.4	37.99	3.637	856.69	38.04	3.639	
C-1	1/11/13	10:38	0.6	22.24	3.102	862.69	22.12	3.096	
C-1	1/11/13	10:38	0.8	9.17	2.216	871.13	9.03	2.200	
C-1	1/11/13	10:39	1.0	3.79	1.333	869.26	3.74	1.320	
C-1	1/11/13	10:39	1.5	0.90	-0.102	866.40	0.89	-0.112	
A-1	1/11/13	11:00	0.2	121.87	4.803	770.46	121.87	4.803	2.747
A-1	1/11/13	11:00	0.4	97.11	4.576	758.74	98.61	4.591	
A-1	1/11/13	11:01	0.6	54.11	3.991	739.94	56.34	4.031	
A-1	1/11/13	11:01	0.8	20.48	3.020	760.32	20.76	3.033	
A-1	1/11/13	11:02	1.0	10.69	2.370	763.35	10.79	2.379	
A-1	1/11/13	11:02	1.5	4.57	1.520	756.40	4.66	1.539	
P-1	1/11/13	11:24	0.2	152.54	5.027	1008.50	152.54	5.027	3.104
P-1	1/11/13	11:24	0.4	63.18	4.146	1011.40	63.00	4.143	
P-1	1/11/13	11:25	0.6	22.52	3.114	1006.70	22.56	3.116	
P-1	1/11/13	11:25	0.8	13.49	2.602	1010.00	13.47	2.600	
P-1	1/11/13	11:26	1.0	8.21	2.105	1016.30	8.14	2.097	
P-1	1/11/13	11:26	1.5	2.52	0.925	1011.30	2.52	0.922	
A-2	1/11/13	11:48	0.2	82.11	4.408	1069.10	82.11	4.408	2.130
A-2	1/11/13	11:48	0.4	69.28	4.238	1062.90	69.68	4.244	
A-2	1/11/13	11:49	0.6	42.85	3.758	1067.40	42.92	3.759	
A-2	1/11/13	11:49	0.8	31.00	3.434	1065.60	31.10	3.437	
A-2	1/11/13	11:50	1.0	21.05	3.047	1077.70	20.89	3.039	
A-2	1/11/13	11:50	1.5	5.29	1.666	1065.40	5.31	1.670	
C-2	1/11/13	12:12	0.2	174.02	5.159	1192.50	174.02	5.159	2.605
C-2	1/11/13	12:12	0.4	90.25	4.503	1182.60	91.00	4.511	
C-2	1/11/13	12:13	0.6	66.42	4.196	1195.30	66.26	4.194	
C-2	1/11/13	12:13	0.8	38.04	3.639	1197.60	37.88	3.634	
C-2	1/11/13	12:14	1.0	19.45	2.968	1193.80	19.43	2.967	
C-2	1/11/13	12:14	1.5	5.87	1.769	1201.80	5.82	1.762	

Silver Lake Water Quality Monitoring Program
Photosynthetically Active Radiation (PAR)
October 12, 2012

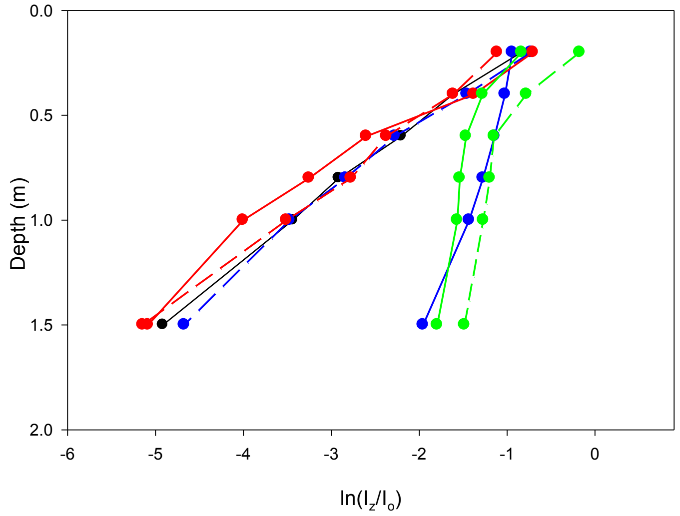

10/12/12 - Initial

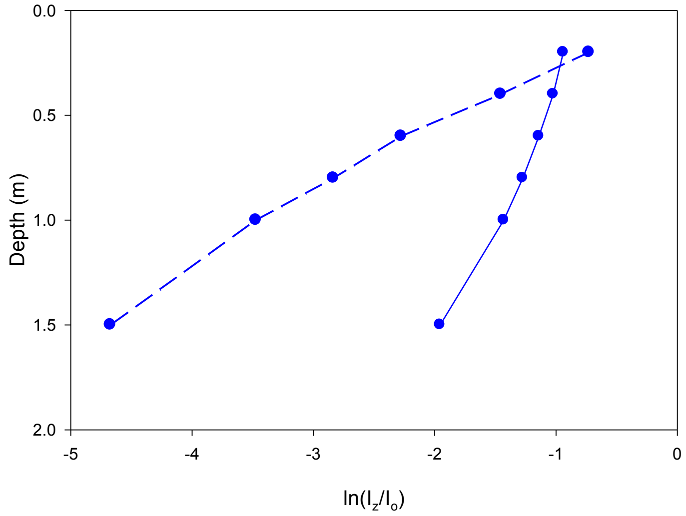

Alum Chambers

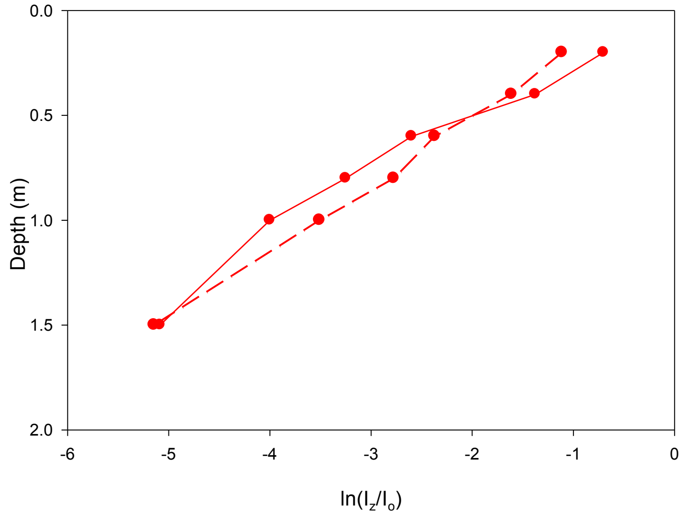

Control Chambers

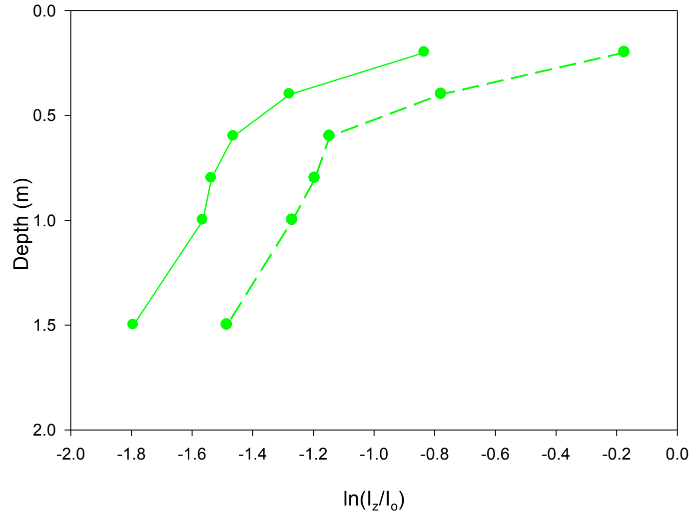

Phoslock Chambers

Silver Lake Water Quality Monitoring Program
Photosynthetically Active Radiation (PAR)
October 13, 2012

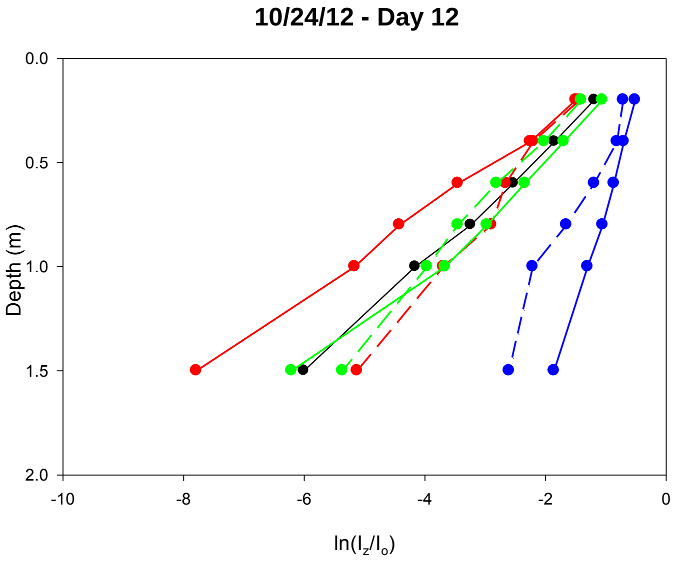

10/13/12 - Day 1

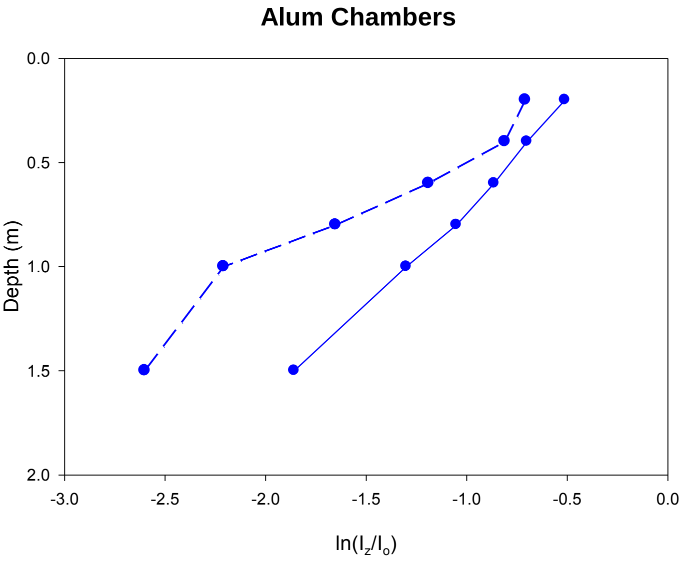

Alum Chambers

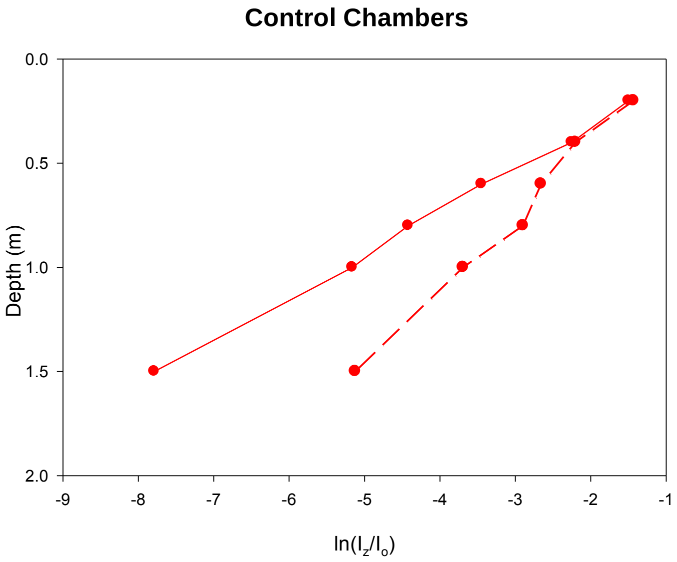

Control Chambers

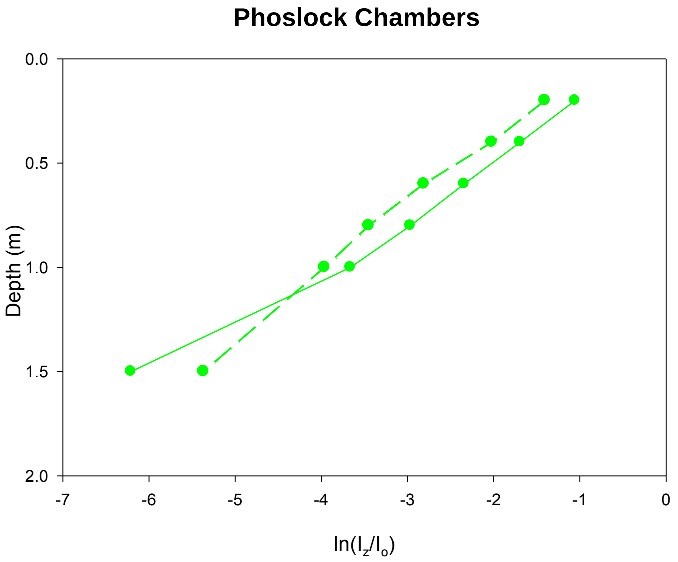

Phoslock Chambers

Silver Lake Water Quality Monitoring Program
Photosynthetically Active Radiation (PAR)
October 24, 2012



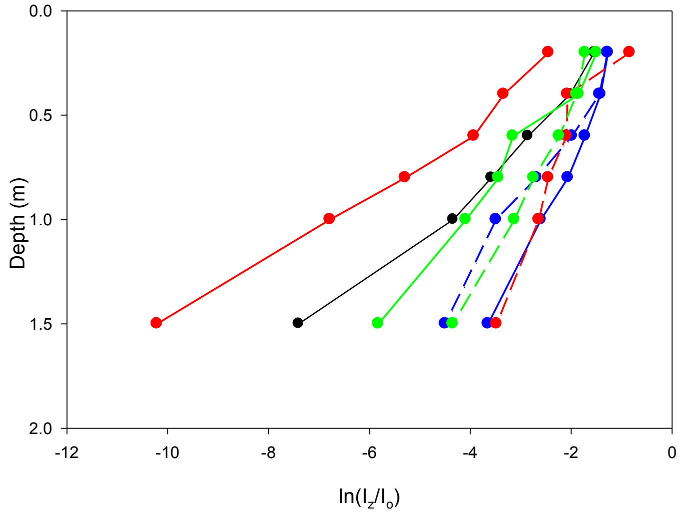




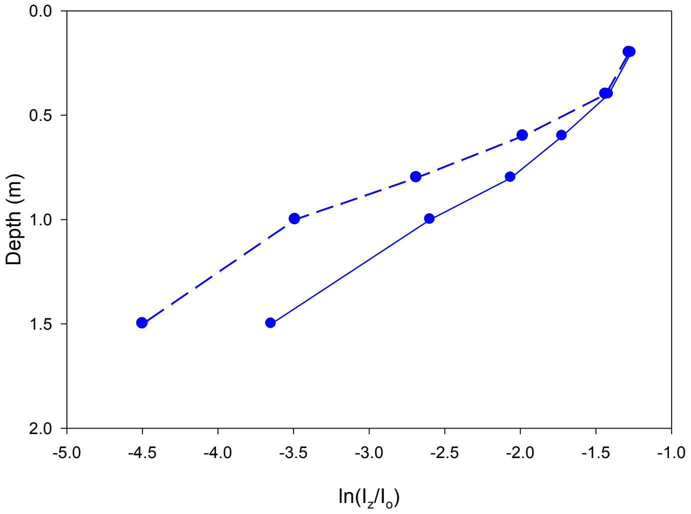


Silver Lake Water Quality Monitoring Program
Photosynthetically Active Radiation (PAR)
November 8, 2012

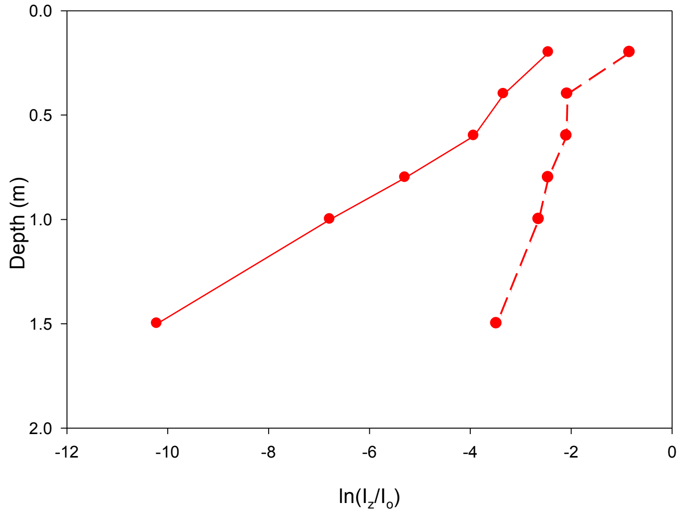
11/8/12 - Day 27



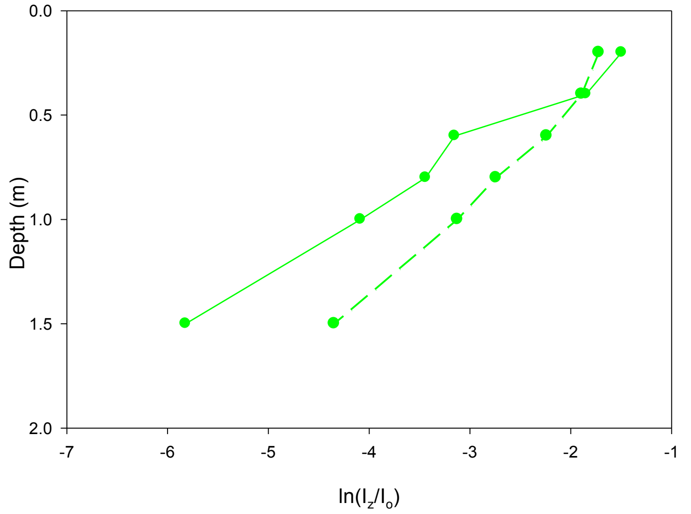
Alum Chambers



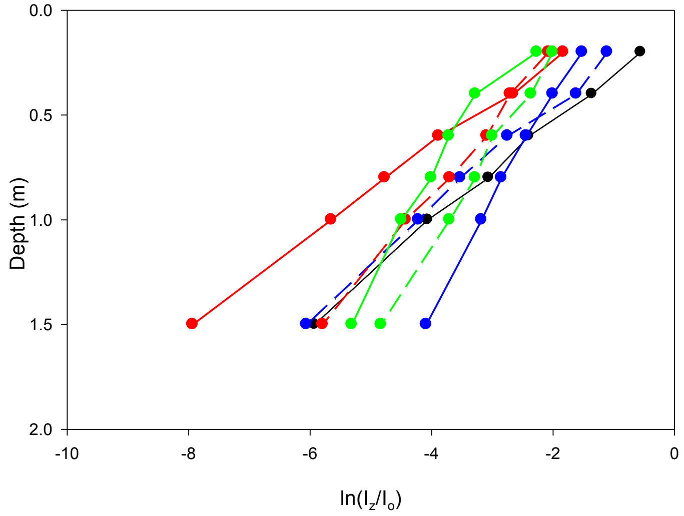
Control Chambers



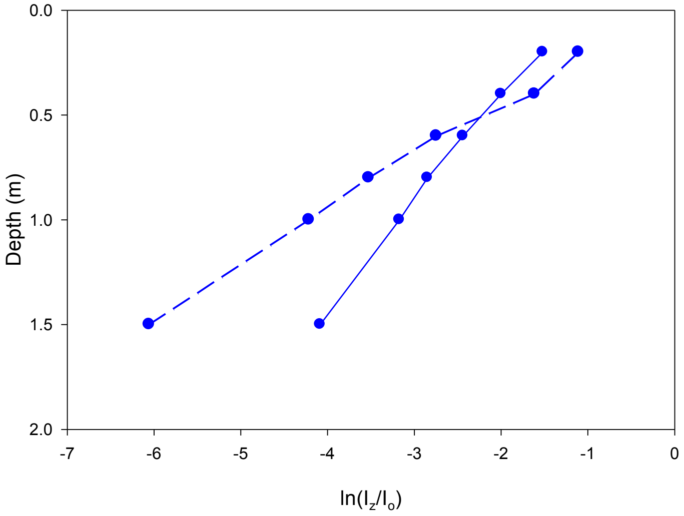
Phoslock Chambers



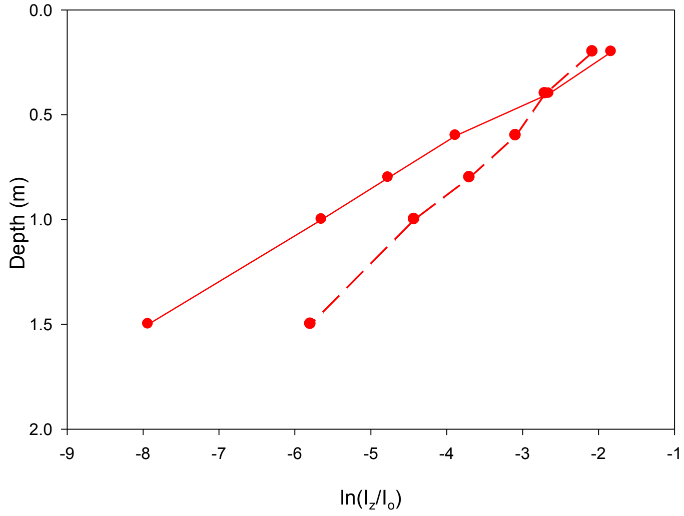
Silver Lake Water Quality Monitoring Program
Photosynthetically Active Radiation (PAR)
November 29, 2012



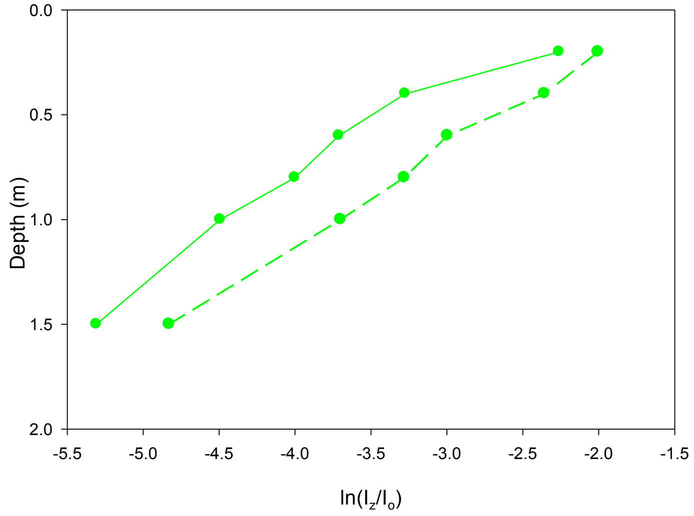
11/29/12 - Day 48



Alum Chambers

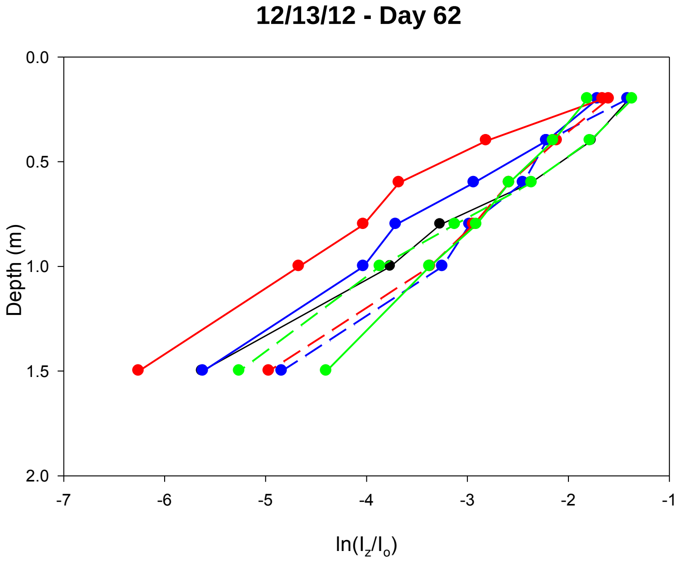


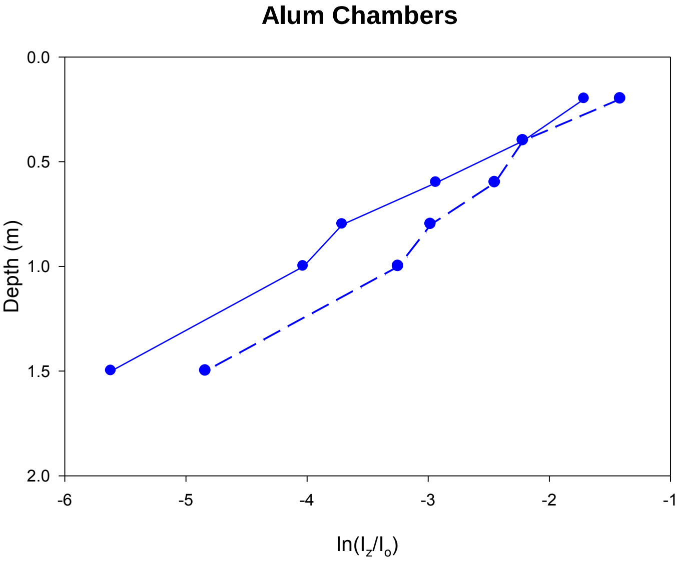
Control Chambers

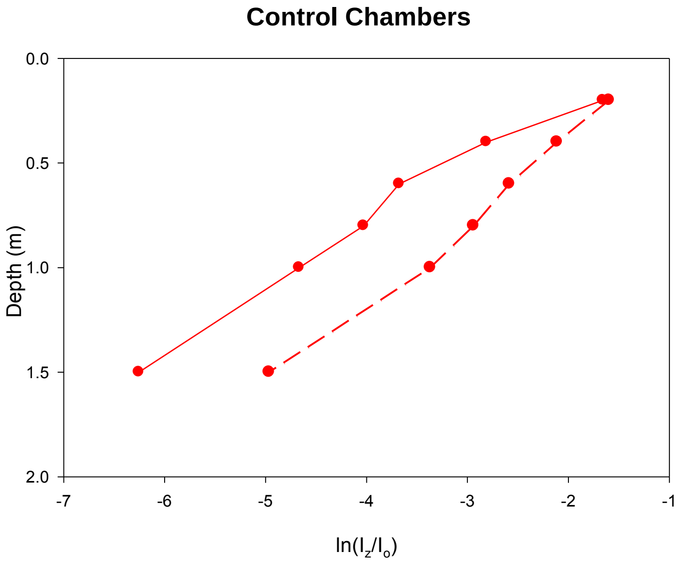


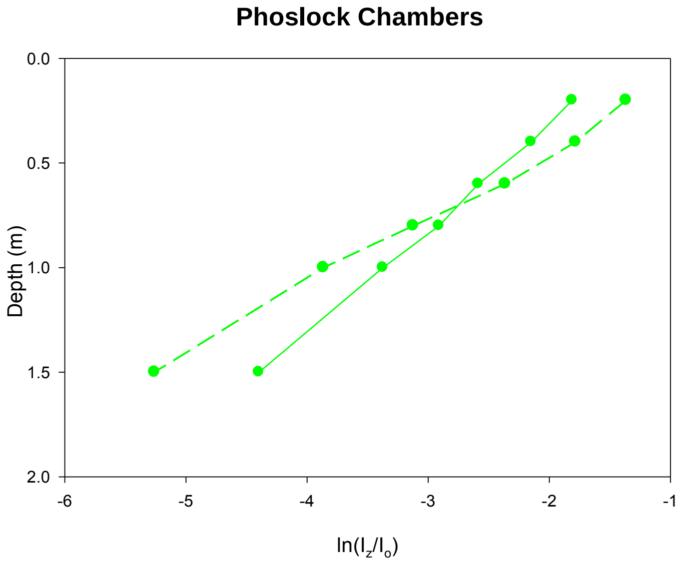
Phoslock Chambers

Silver Lake Water Quality Monitoring Program
Photosynthetically Active Radiation (PAR)
December 13, 2012

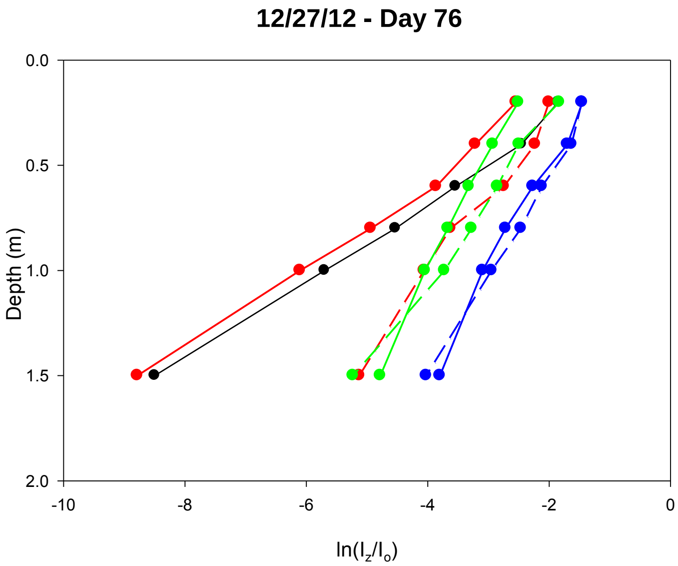


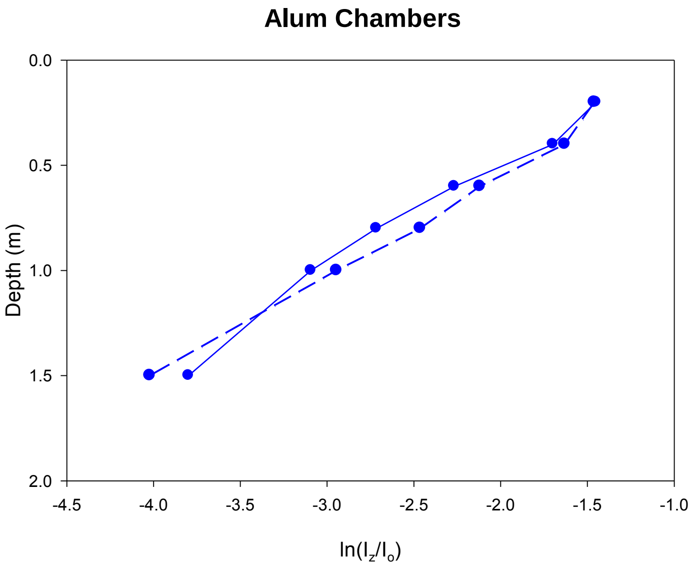


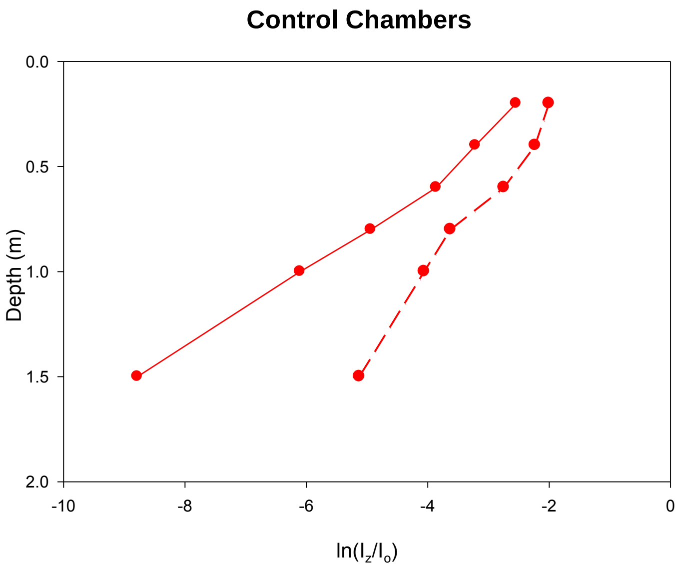


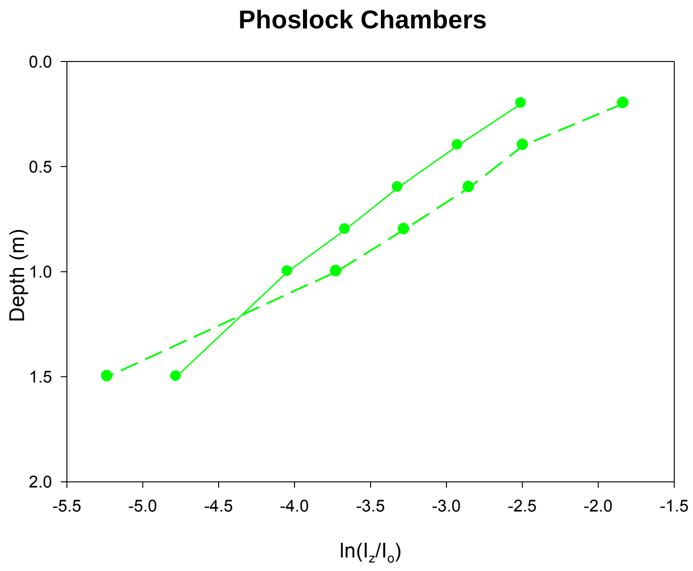


Silver Lake Water Quality Monitoring Program
Photosynthetically Active Radiation (PAR)
December 27, 2012

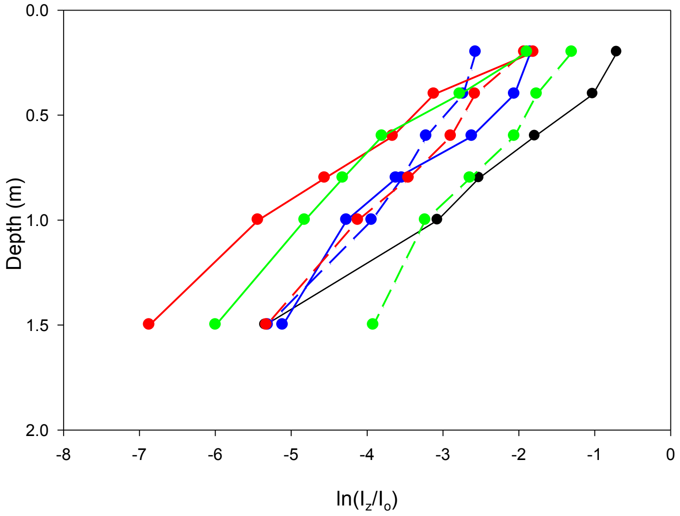


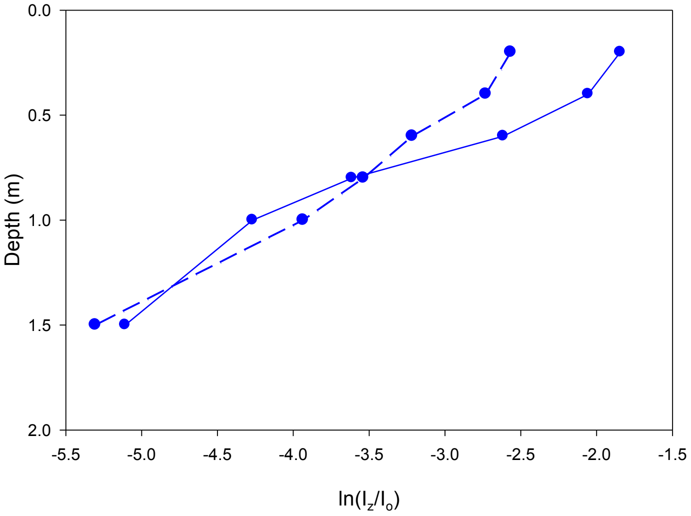


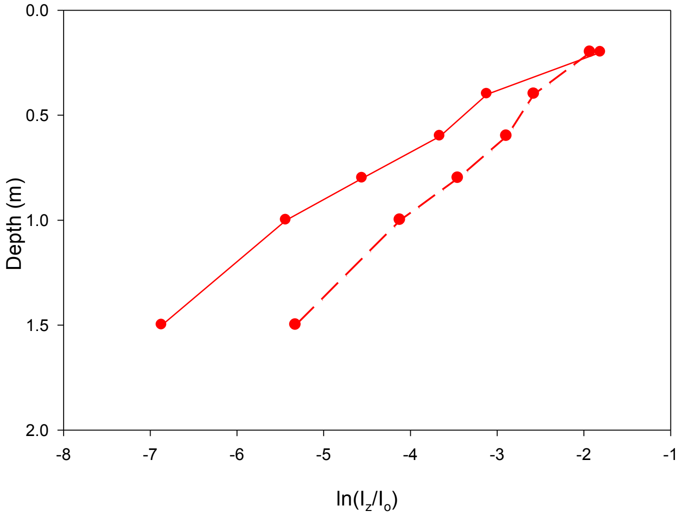


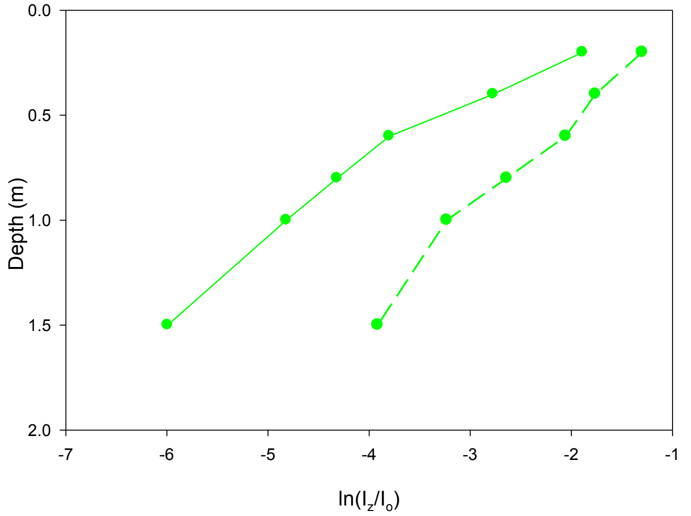


Silver Lake Water Quality Monitoring Program
Photosynthetically Active Radiation (PAR)
January 11, 2013


1/11/13 - Day 91


Alum Chambers


Control Chambers


Phoslock Chambers

APPENDIX D

LABORATORY ANALYSES OF ISOLATION CHAMBER SAMPLES COLLECTED FROM OCTOBER 12, 2012 TO JANUARY 11, 2013

D.1 Laboratory Results of Limno-Corral Studies
D.2 Calculated Concentrations of Un-Ionized Ammonia in the Silver Lake Limno-Corral Experiments

D.1 Laboratory Results of Limno-Corral Studies

Results of Limno-corral Studies Conducted in Silver Lake from October 2012 - January 2013

Site	Date Collected	pH (s.u.)	Alkalinity (mg/l)	NH3 (µg/l)	NOX (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)	Total P (µg/l)	Turbidity (NTU)	Color (Pt-Co)	Chyl- a (mg/m³)
Alum - 1	10/12/12	6.73	84.2	257	2	168	397	824	6	16	135	157	7.8	35	47.0
Alum - 1	10/13/12	6.21	30.2	373	6	108	306	793	3	1	1	5	1.8	4	1.1
Alum - 1	10/24/12	6.62	32.2	612	5	126	152	895	2	2	3	7	2.9	2	0.5
Alum - 1	11/8/12	7.23	28.8	1,180	39	129	127	1,475	3	3	8	14	4.2	6	3.8
Alum - 1	11/29/12	7.06	55.8	1,171	639	175	117	2,102	3	5	22	30	3.3	12	1.5
Alum - 1	12/13/12	6.82	49.4	201	628	188	171	1,188	4	8	22	34	2.3	27	8.5
Alum - 1	12/27/12	7.02	54.9	255	554	191	142	1,142	4	7	20	31	2.4	24	6.3
Alum - 1	1/11/13	7.32	58.4	224	763	194	75	1,256	2	7	18	27	1.4	20	4.3
Minimum Value:		**7.32**	**84.2**	**1,180**	**763**	**194**	**397**	**2,102**	**6**	**16**	**135**	**157**	**7.8**	**35**	**47.0**
Maximum Value:		**6.21**	**28.8**	**201**	**2**	**108**	**75**	**793**	**2**	**1**	**1**	**5**	**1.4**	**2**	**0.5**
Median Value:		**6.92**	**52.2**	**315**	**297**	**172**	**147**	**1,165**	**3**	**6**	**19**	**29**	**2.7**	**16**	**4.1**
Geometric Mean:		**6.87**	**46.2**	**418**	**67**	**156**	**163**	**1,151**	**3**	**5**	**12**	**22**	**2.9**	**11**	**3.7**
Alum - 2	10/12/12	6.73	87.2	180	3	150	478	811	6	13	129	148	6.7	36	53.8
Alum - 2	10/13/12	6.14	32.1	193	5	98	444	740	2	2	1	5	1.7	3	0.6
Alum - 2	10/24/12	6.51	28.2	744	3	154	187	1,088	2	2	1	5	2.6	2	0.5
Alum - 2	11/8/12	6.63	26.6	1,124	18	176	199	1,517	2	2	3	7	3.9	6	4.9
Alum - 2	11/29/12	6.75	54.2	1,167	637	185	148	2,137	2	3	13	18	2.3	15	0.4
Alum - 2	12/13/12	6.87	55.0	494	627	143	145	1,409	5	5	25	35	2.7	27	7.2
Alum - 2	12/27/12	6.91	61.0	450	578	166	139	1,333	8	6	21	35	3.0	25	4.1
Alum - 2	1/11/13	6.99	84.6	312	484	199	73	1,068	7	8	22	37	1.8	22	2.9
Minimum Value:		**6.99**	**87.2**	**1,167**	**637**	**199**	**478**	**2,137**	**8**	**13**	**129**	**148**	**6.7**	**36**	**53.8**
Maximum Value:		**6.14**	**26.6**	**180**	**3**	**98**	**73**	**740**	**2**	**2**	**1**	**5**	**1.7**	**2**	**0.4**
Median Value:		**6.74**	**54.6**	**472**	**251**	**160**	**168**	**1,211**	**4**	**4**	**17**	**27**	**2.7**	**19**	**3.5**
Geometric Mean:		**6.69**	**48.8**	**469**	**56**	**156**	**190**	**1,198**	**4**	**4**	**9**	**20**	**2.8**	**11**	**2.7**

Results of Limno-corral Studies Conducted in Silver Lake from October 2012 - January 2013

Site	**Date Collected**	**pH (s.u.)**	**Alkalinity (mg/l)**	**NH3 (µg/l)**	**NOX (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)**	**Total P (µg/l)**	**Turbidity (NTU)**	**Color (Pt-Co)**	**Chyl- a (mg/m^3)**
Control - 1	10/12/12	6.75	91.8	3	8	275	467	753	6	15	107	128	7.3	34	54.8
Control - 1	10/13/12	6.89	90.8	3	3	292	446	744	4	3	112	119	8.5	31	37.1
Control - 1	10/24/12	6.99	107	14	3	255	674	946	2	2	153	157	17.4	33	43.6
Control - 1	11/8/12	7.28	106	3	38	311	640	992	2	1	128	131	14.2	32	47.3
Control - 1	11/29/12	7.80	114	6	29	243	657	935	3	5	133	141	14.9	31	43.8
Control - 1	12/13/12	7.11	104	42	25	190	693	950	14	9	115	138	6.4	39	59.0
Control - 1	12/27/12	7.47	107	3	9	175	511	698	7	6	111	124	10.8	33	63.1
Control - 1	1/11/13	7.31	109	177	2	193	708	1,080	3	3	137	143	11.3	28	65.8
Minimum Value:		**7.80**	**114**	**177**	**38**	**311**	**708**	**1,080**	**14**	**15**	**153**	**157**	**17.4**	**39**	**65.8**
Maximum Value:		**6.75**	**90.8**	**3**	**2**	**175**	**446**	**698**	**2**	**1**	**107**	**119**	**6.4**	**28**	**37.1**
Median Value:		**7.20**	**107**	**5**	**9**	**249**	**649**	**941**	**4**	**4**	**122**	**135**	**11.1**	**33**	**51.1**
Geometric Mean:		**7.19**	**103**	**9**	**9**	**237**	**591**	**878**	**4**	**4**	**124**	**135**	**10.8**	**32**	**50.9**
Control - 2	10/12/12	6.65	84.2	7	10	199	490	706	7	16	119	142	9.0	35	45.6
Control - 2	10/13/12	6.61	85.8	6	10	149	553	718	6	3	112	121	7.3	38	38.8
Control - 2	10/24/12	6.89	94.8	43	27	182	508	760	6	3	102	111	14.5	33	28.5
Control - 2	11/8/12	7.11	103	3	11	299	574	887	11	8	106	125	15.0	41	37.8
Control - 2	11/29/12	7.24	98.6	3	103	186	532	824	9	12	141	162	12.1	38	39.3
Control - 2	12/13/12	7.02	113	34	77	139	624	874	25	11	133	169	9.8	40	51.7
Control - 2	12/27/12	7.11	124	2	11	184	535	732	16	19	96	131	10.3	40	55.5
Control - 2	1/11/13	7.19	129	103	16	181	646	946	5	3	147	155	9.4	41	60.9
Minimum Value:		**7.24**	**129**	**103**	**103**	**299**	**646**	**946**	**25**	**19**	**147**	**169**	**15.0**	**41**	**60.9**
Maximum Value:		**6.61**	**84.2**	**2**	**10**	**139**	**490**	**706**	**5**	**3**	**96**	**111**	**7.3**	**33**	**28.5**
Median Value:		**7.07**	**101**	**7**	**14**	**183**	**544**	**792**	**8**	**10**	**116**	**137**	**10.1**	**39**	**42.5**
Geometric Mean:		**6.97**	**103**	**10**	**21**	**185**	**555**	**802**	**9**	**7**	**118**	**138**	**10.6**	**38**	**43.6**

Results of Limno-corral Studies Conducted in Silver Lake from October 2012 - January 2013

Site	Date Collected	pH (s.u.)	Alkalinity (mg/l)	NH3 (µg/l)	NOX (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)	Total P (µg/l)	Turbidity (NTU)	Color (Pt-Co)	Chyl- a (mg/m³)
Phoslock - 1	10/12/12	6.71	95.0	262	6	174	459	901	7	15	114	136	7.1	35	56.8
Phoslock - 1	10/13/12	6.87	92.2	278	7	137	400	822	5	1	74	80	10.1	23	63.7
Phoslock - 1	10/24/12	7.17	105	595	2	124	432	1,153	8	8	65	81	7.2	27	58.0
Phoslock - 1	11/8/12	7.22	112	1,004	14	116	520	1,654	10	8	38	56	4.1	44	7.6
Phoslock - 1	11/29/12	7.04	106	921	127	167	761	1,976	8	23	38	69	15.5	54	3.5
Phoslock - 1	12/13/12	6.91	116	954	807	194	335	2,290	11	19	27	57	4.4	66	3.0
Phoslock - 1	12/27/12	7.21	115	927	849	222	298	2,296	11	22	20	53	4.3	41	2.5
Phoslock - 1	1/11/13	7.52	114	983	995	278	240	2,496	6	37	13	56	3.5	74	2.1
Minimum Value:		**7.52**	**116**	**1,004**	**995**	**278**	**761**	**2,496**	**11**	**37**	**114**	**136**	**15.5**	**74**	**63.7**
Maximum Value:		**6.71**	**92.2**	**262**	**2**	**116**	**240**	**822**	**5**	**1**	**13**	**53**	**3.5**	**23**	**2.1**
Median Value:		**7.11**	**109**	**924**	**71**	**171**	**416**	**1,815**	**8**	**17**	**38**	**63**	**5.8**	**43**	**5.6**
Geometric Mean:		**7.08**	**107**	**657**	**56**	**170**	**407**	**1,568**	**8**	**12**	**39**	**70**	**6.2**	**42**	**9.8**
Phoslock - 2	10/12/12	6.74	85.8	438	2	175	549	1,164	8	12	133	153	7.7	38	60.3
Phoslock - 2	10/13/12	7.19	97.4	656	1	283	317	1,257	6	4	75	85	9.9	28	55.3
Phoslock - 2	10/24/12	7.29	104	420	10	226	543	1,199	5	3	69	77	6.2	28	82.1
Phoslock - 2	11/8/12	6.97	102	1,034	205	275	288	1,802	9	9	23	41	3.2	48	4.4
Phoslock - 2	11/29/12	7.41	107	1,240	114	185	672	2,211	11	18	20	49	3.0	46	2.7
Phoslock - 2	12/13/12	6.92	106	1,023	337	163	593	2,116	16	26	37	79	7.2	65	8.3
Phoslock - 2	12/27/12	6.99	107	1,060	710	199	699	2,668	11	31	30	72	7.1	47	5.3
Phoslock - 2	1/11/13	7.00	108	993	861	302	304	2,460	3	45	22	70	5.0	38	1.6
Minimum Value:		**7.41**	**108**	**1,240**	**861**	**302**	**699**	**2,668**	**16**	**45**	**133**	**153**	**9.9**	**65**	**82.1**
Maximum Value:		**6.74**	**85.8**	**420**	**1**	**163**	**288**	**1,164**	**3**	**3**	**20**	**41**	**3.0**	**28**	**1.6**
Median Value:		**7.00**	**105**	**1,008**	**160**	**213**	**546**	**1,959**	**9**	**15**	**34**	**75**	**6.7**	**42**	**6.8**
Geometric Mean:		**7.06**	**102**	**799**	**56**	**220**	**468**	**1,772**	**8**	**13**	**41**	**73**	**5.7**	**41**	**11.1**

Results of Limno-corral Studies Conducted in Silver Lake from October 2012 - January 2013

Site	Date Collected	pH (s.u.)	Alkalinity (mg/l)	NH3 (µg/l)	NOX (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)	Total P (µg/l)	Turbidity (NTU)	Color (Pt-Co)	Chyl- a (mg/m^3)
Lake	10/12/12	6.67	96.2	3	23	230	684	940	6	9	109	124	7.7	36	65.3
Lake	10/13/12	7.16	94.4	3	3	187	651	844	5	5	96	106	9.4	33	27.9
Lake	10/24/12	7.13	103	8	3	212	448	671	10	10	117	137	16.9	36	58.8
Lake	11/8/12	7.29	108	3	3	358	432	796	1	11	73	85	10.2	33	24.8
Lake	11/29/12	7.81	120	3	3	245	570	821	3	3	125	131	20.1	29	48.8
Lake	12/13/12	7.23	109	61	16	216	552	845	14	15	108	137	9.1	39	59.4
Lake	12/27/12	7.25	108	3	3	219	554	779	7	12	98	117	13.9	33	47.7
Lake	1/11/13	7.28	103	7	8	200	556	771	2	11	78	91	10.8	26	84.6
Minimum Value:		**7.81**	**120.0**	**61**	**23**	**358**	**684**	**940**	**14**	**15**	**125**	**137**	**20.1**	**39**	**84.6**
Maximum Value:		**6.67**	**94.4**	**3**	**3**	**187**	**432**	**671**	**1**	**3**	**73**	**85**	**7.7**	**26**	**24.8**
Median Value:		**7.24**	**105.5**	**3**	**3**	**218**	**555**	**809**	**6**	**11**	**103**	**121**	**10.5**	**33**	**53.8**
Geometric Mean:		**7.22**	**104.9**	**5**	**5**	**229**	**550**	**805**	**5**	**9**	**99**	**114**	**11.7**	**33**	**48.6**

Calculated Percent Change from Initial Conditions in the Silver Lake Limno-Corral Experiments

Site	Date Collected	pH (s.u.)	Alkalinity (mg/l)	NH3 (µg/l)	NOX (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)	Total P (µg/l)	Turbidity (NTU)	Color (Pt-Co)	Chyl- a (mg/m³)
Alum - 1	10/12/12	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Alum - 1	10/13/12	-8	-64	45	200	-36	-23	-4	-50	-94	-99	-97	-77	-89	-98
Alum - 1	10/24/12	-2	-62	138	150	-25	-62	9	-67	-88	-98	-96	-63	-94	-99
Alum - 1	11/8/12	7	-66	359	1850	-23	-68	79	-50	-81	-94	-91	-46	-83	-92
Alum - 1	11/29/12	5	-34	356	31850	4	-71	155	-50	-69	-84	-81	-58	-66	-97
Alum - 1	12/13/12	1	-41	-22	31300	12	-57	44	-33	-50	-84	-78	-71	-23	-82
Alum - 1	12/27/12	4	-35	-1	27600	14	-64	39	-33	-56	-85	-80	-69	-31	-87
Alum - 1	1/11/13	9	-31	-13	38050	15	-81	52	-67	-56	-87	-83	-82	-43	-91
Alum - 2	10/12/12	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Alum - 2	10/13/12	-9	-63	7	67	-35	-7	-9	-67	-85	-99	-97	-75	-92	-99
Alum - 2	10/24/12	-3	-68	313	0	3	-61	34	-67	-85	-99	-97	-61	-94	-99
Alum - 2	11/8/12	-1	-69	524	500	17	-58	87	-67	-85	-98	-95	-42	-83	-91
Alum - 2	11/29/12	0	-38	548	21133	23	-69	164	-67	-77	-90	-88	-66	-58	-99
Alum - 2	12/13/12	2	-37	174	20800	-5	-70	74	-17	-62	-81	-76	-60	-25	-87
Alum - 2	12/27/12	3	-30	150	19167	11	-71	64	33	-54	-84	-76	-55	-31	-92
Alum - 2	1/11/13	4	-3	73	16033	33	-85	32	17	-38	-83	-75	-73	-39	-95
Control - 1	10/12/12	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Control - 1	10/13/12	2	-1	0	-63	6	-4	-1	-33	-80	5	-7	16	-9	-32
Control - 1	10/24/12	4	17	367	-63	-7	44	26	-67	-87	43	23	138	-3	-20
Control - 1	11/8/12	8	15	0	375	13	37	32	-67	-93	20	2	95	-6	-14
Control - 1	11/29/12	16	24	100	263	-12	41	24	-50	-67	24	10	104	-9	-20
Control - 1	12/13/12	5	13	1300	213	-31	48	26	133	-40	7	8	-12	15	8
Control - 1	12/27/12	11	17	0	13	-36	9	-7	17	-60	4	-3	48	-3	15
Control - 1	1/11/13	8	19	5800	-75	-30	52	43	-50	-80	28	12	55	-18	20
Control - 2	10/12/12	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Control - 2	10/13/12	-1	2	-14	0	-25	13	2	-14	-81	-6	-15	-19	9	-15
Control - 2	10/24/12	4	13	514	170	-9	4	8	-14	-81	-14	-22	61	-6	-38
Control - 2	11/8/12	7	22	-57	10	50	17	26	57	-50	-11	-12	67	17	-17
Control - 2	11/29/12	9	17	-57	930	-7	9	17	29	-25	18	14	34	9	-14
Control - 2	12/13/12	6	34	386	670	-30	27	24	257	-31	12	19	9	14	13
Control - 2	12/27/12	7	47	-71	10	-8	9	4	129	19	-19	-8	14	14	22
Control - 2	1/11/13	8	53	1371	60	-9	32	34	-29	-81	24	9	4	17	34

Calculated Percent Change from Initial Conditions in the Silver Lake Limno-Corral Experiments

Site	Date Collected	pH (s.u.)	Alkalinity (mg/l)	NH3 (µg/l)	NOX (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)	Total P (µg/l)	Turbidity (NTU)	Color (Pt-Co)	Chyl- a (mg/m^3)
Phoslock - 1	10/12/12	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Phoslock - 1	10/13/12	2	-3	6	17	-21	-13	-9	-29	-93	-35	-41	42	-34	12
Phoslock - 1	10/24/12	7	11	127	-67	-29	-6	28	14	-47	-43	-40	1	-23	2
Phoslock - 1	11/8/12	8	18	283	133	-33	13	84	43	-47	-67	-59	-42	26	-87
Phoslock - 1	11/29/12	5	12	252	2017	-4	66	119	14	53	-67	-49	118	54	-94
Phoslock - 1	12/13/12	3	22	264	13350	11	-27	154	57	27	-76	-58	-38	89	-95
Phoslock - 1	12/27/12	7	21	254	14050	28	-35	155	57	47	-82	-61	-39	17	-96
Phoslock - 1	1/11/13	12	20	275	16483	60	-48	177	-14	147	-89	-59	-51	111	-96
Phoslock - 2	10/12/12	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Phoslock - 2	10/13/12	7	14	50	-50	62	-42	8	-25	-67	-44	-44	29	-26	-8
Phoslock - 2	10/24/12	8	21	-4	400	29	-1	3	-38	-75	-48	-50	-19	-26	36
Phoslock - 2	11/8/12	3	19	136	10150	57	-48	55	13	-25	-83	-73	-58	26	-93
Phoslock - 2	11/29/12	10	25	183	5600	6	22	90	38	50	-85	-68	-61	21	-96
Phoslock - 2	12/13/12	3	24	134	16750	-7	8	82	100	117	-72	-48	-6	71	-86
Phoslock - 2	12/27/12	4	25	142	35400	14	27	129	38	158	-77	-53	-8	24	-91
Phoslock - 2	1/11/13	4	26	127	42950	73	-45	111	-63	275	-83	-54	-35	0	-97
Lake	10/12/12	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lake	10/13/12	7	-2	0	-87	-19	-5	-10	-17	-44	-12	-15	22	-8	-57
Lake	10/24/12	7	7	167	-87	-8	-35	-29	67	11	7	10	119	0	-10
Lake	11/8/12	9	12	0	-87	56	-37	-15	-83	22	-33	-31	32	-8	-62
Lake	11/29/12	17	25	0	-87	7	-17	-13	-50	-67	15	6	161	-19	-25
Lake	12/13/12	8	13	1933	-30	-6	-19	-10	133	67	-1	10	18	8	-9
Lake	12/27/12	9	12	0	-87	-5	-19	-17	17	33	-10	-6	81	-8	-27
Lake	1/11/13	9	7	133	-65	-13	-19	-18	-67	22	-28	-27	40	-28	30

D.2 Calculated Concentrations of Un-Ionized Ammonia in the Silver Lake Limno-Corral Experiments

Calculated Concentrations of Unionized Ammonia in the Silver Lake Limno-Corral Experiments

Site	**Date Collected**	**pH (s.u.)**	**Temperature (°C)**	**NH3 (µg/l)**	**Unionized NH3 (µg/l)**
Alum - 1	10/12/12	6.92	26.89	257	1.7
Alum - 1	10/13/12	6.04	26.49	373	0.3
Alum - 1	10/24/12	6.49	24.72	612	1.3
Alum - 1	11/8/12	7.49	19.89	1,180	17.2
Alum - 1	11/29/12	6.91	19.46	1,171	4.4
Alum - 1	12/13/12	7.10	22.89	201	1.5
Alum - 1	12/27/12	7.17	17.39	255	1.5
Alum - 1	1/11/13	7.62	21.93	224	5.1
Alum - 2	10/12/12	6.95	27.01	180	1.3
Alum - 2	10/13/12	6.03	26.62	193	0.2
Alum - 2	10/24/12	6.80	24.89	744	3.2
Alum - 2	11/8/12	7.07	20.10	1,124	6.4
Alum - 2	11/29/12	6.81	19.42	1,167	3.5
Alum - 2	12/13/12	7.00	22.90	494	2.9
Alum - 2	12/27/12	7.06	17.52	450	2.1
Alum - 2	1/11/13	7.03	21.97	312	1.8
Control - 1	10/12/12	7.11	26.77	3	0.03
Control - 1	10/13/12	6.94	26.56	3	0.02
Control - 1	10/24/12	7.04	24.79	14	0.10
Control - 1	11/8/12	7.15	19.84	3	0.02
Control - 1	11/29/12	7.25	19.50	6	0.05
Control - 1	12/13/12	7.10	22.92	42	0.31
Control - 1	12/27/12	7.47	17.53	3	0.04
Control - 1	1/11/13	7.31	21.93	177	1.98
Control - 2	10/12/12	6.81	26.91	7	0.04
Control - 2	10/13/12	6.92	26.62	6	0.04
Control - 2	10/24/12	7.02	24.93	43	0.31
Control - 2	11/8/12	7.12	20.16	3	0.02
Control - 2	11/29/12	7.03	19.60	3	0.01
Control - 2	12/13/12	7.03	23.03	34	0.22
Control - 2	12/27/12	7.22	17.61	2	0.01
Control - 2	1/11/13	7.20	21.97	103	0.90

Calculated Concentrations of Unionized Ammonia in the Silver Lake Limno-Corral Experiments

Site	**Date Collected**	**pH (s.u.)**	**Temperature (°C)**	**NH3 (µg/l)**	**Unionized NH3 (µg/l)**
Phoslock - 1	10/12/12	6.92	26.88	262	1.7
Phoslock - 1	10/13/12	7.02	26.63	278	2.2
Phoslock - 1	10/24/12	8.33	24.75	595	76.9
Phoslock - 1	11/8/12	7.16	20.05	1,004	7.0
Phoslock - 1	11/29/12	7.07	19.60	921	5.0
Phoslock - 1	12/13/12	7.02	22.98	954	5.9
Phoslock - 1	12/27/12	7.32	17.41	927	7.6
Phoslock - 1	1/11/13	7.21	21.97	983	8.8
Phoslock - 2	10/12/12	6.97	26.84	438	3.2
Phoslock - 2	10/13/12	7.05	26.50	656	5.6
Phoslock - 2	10/24/12	7.50	24.89	420	8.9
Phoslock - 2	11/8/12	7.36	19.98	1,034	11.3
Phoslock - 2	11/29/12	7.32	19.37	1,240	11.8
Phoslock - 2	12/13/12	7.01	22.93	1,023	6.2
Phoslock - 2	12/27/12	7.27	17.45	1,060	7.8
Phoslock - 2	1/11/13	7.19	21.95	993	8.5
Lake	10/12/12	7.07	26.74	3	0.03
Lake	10/13/12	7.13	26.48	3	0.03
Lake	10/24/12	7.27	24.71	8	0.10
Lake	11/8/12	7.26	19.60	3	0.03
Lake	11/29/12	7.37	19.41	3	0.03
Lake	12/13/12	7.14	22.82	61	0.49
Lake	12/27/12	7.41	17.24	3	0.03
Lake	1/11/13	7.52	21.85	7	0.13

APPENDIX E

RESULTS OF SEDIMENT PHOSPHORUS RELEASE EXPERIMENTS CONDUCTED ON SILVER LAKE CORE SAMPLES

E.1 Laboratory Analyses
E.2 Regression Relationships of Sediment Phosphorus Release

E.1 Laboratory Analyses

Results of Sediment Release Studies Conducted on Silver Lake Sediments

Sample Description	Condition	Date Collected	Time (Days)	NH_3-N (µg/L)	NO_X-N (µg/L)	Organic N (µg/L)	Total N (µg/L)	SRP (µg/L)	Total P (µg/L)
Alum-1	Anoxic	2/22/13	0	308	47	71	426	1	2
Alum-1	Anoxic	2/25/13	3	538	53	83	674	3	4
Alum-1	Anoxic	2/26/13	4	623	33	53	709	6	8
Alum-1	Anoxic	2/27/13	5	802	51	56	909	7	9
Alum-1	Anoxic	2/28/13	6	822	77	57	956	8	9
Alum-1	Anoxic	3/1/13	7	986	439	85	1,510	9	11
Alum-1	Anoxic	3/4/13	10	1,098	443	107	1,648	9	12
Alum-1	Anoxic	3/6/13	12	1,113	1,344	115	2,572	10	13
Alum-1	Anoxic	3/8/13	14	1,348	1,182	172	2,702	14	17
Alum-1	Anoxic	3/11/13	17	1,147	903	332	2,382	16	22
Alum-1	Anoxic	3/13/13	19	891	1,097	298	2,286	21	25
Alum-1	Anoxic	3/15/13	21	663	1,333	277	2,273	21	24
Alum-1	Anoxic	3/18/13	24	380	1,748	258	2,386	21	23
Alum-1	Anoxic	3/20/13	26	306	2,450	241	2,997	16	19
Alum-1	Anoxic	3/25/13	31	298	3,058	233	3,589	11	18
Alum-1	Anoxic	3/27/13	33	251	2,563	212	3,026	7	12
Alum-2	Anoxic	2/22/13	0	203	37	256	496	5	8
Alum-2	Anoxic	2/25/13	3	363	13	270	646	5	9
Alum-2	Anoxic	2/26/13	4	388	11	241	640	6	10
Alum-2	Anoxic	2/27/13	5	710	13	274	997	6	10
Alum-2	Anoxic	2/28/13	6	779	14	261	1,054	7	13
Alum-2	Anoxic	3/1/13	7	716	95	265	1,076	8	14
Alum-2	Anoxic	3/4/13	10	741	118	229	1,088	9	15
Alum-2	Anoxic	3/6/13	12	708	1,412	199	2,319	10	17
Alum-2	Anoxic	3/8/13	14	285	1,625	204	2,114	11	20
Alum-2	Anoxic	3/11/13	17	222	1,411	193	1,826	12	21
Alum-2	Anoxic	3/13/13	19	198	1,486	175	1,859	18	22
Alum-2	Anoxic	3/15/13	21	177	1,853	174	2,204	23	22
Alum-2	Anoxic	3/18/13	24	202	2,100	204	2,506	17	19
Alum-2	Anoxic	3/20/13	26	202	2,126	204	2,532	16	18
Alum-2	Anoxic	3/25/13	31	365	2,287	369	3,021	17	19
Alum-2	Anoxic	3/27/13	33	376	2,300	379	3,055	17	19

Results of Sediment Release Studies Conducted on Silver Lake Sediments

Sample Description	Condition	Date Collected	Time (Days)	NH_3-N (µg/L)	NO_X-N (µg/L)	Organic N (µg/L)	Total N (µg/L)	SRP (µg/L)	Total P (µg/L)
Phoslock-1	Anoxic	2/22/13	0	45	34	275	354	5	6
Phoslock-1	Anoxic	2/25/13	3	368	22	237	627	8	9
Phoslock-1	Anoxic	2/26/13	4	446	11	205	662	11	13
Phoslock-1	Anoxic	2/27/13	5	500	11	242	753	13	15
Phoslock-1	Anoxic	2/28/13	6	652	12	162	826	17	25
Phoslock-1	Anoxic	3/1/13	7	746	58	163	967	23	29
Phoslock-1	Anoxic	3/4/13	10	826	67	117	1,010	25	30
Phoslock-1	Anoxic	3/6/13	12	1,269	552	178	1,999	31	38
Phoslock-1	Anoxic	3/8/13	14	1,174	798	285	2,257	32	39
Phoslock-1	Anoxic	3/11/13	17	1,140	945	188	2,273	34	42
Phoslock-1	Anoxic	3/13/13	19	1,129	1,009	242	2,380	38	44
Phoslock-1	Anoxic	3/15/13	21	1,830	1,160	311	3,301	42	48
Phoslock-1	Anoxic	3/18/13	24	2,399	1,500	319	4,218	32	45
Phoslock-1	Anoxic	3/20/13	26	2,272	1,560	396	4,228	42	58
Phoslock-1	Anoxic	3/25/13	31	2,262	3,305	407	5,974	25	34
Phoslock-1	Anoxic	3/27/13	33	2,123	3,444	418	5,985	15	24
Phoslock-2	Anoxic	2/22/13	0	125	29	171	325	5	7
Phoslock-2	Anoxic	2/25/13	3	226	12	216	454	5	7
Phoslock-2	Anoxic	2/26/13	4	255	10	165	430	5	8
Phoslock-2	Anoxic	2/27/13	5	353	18	175	546	9	11
Phoslock-2	Anoxic	2/28/13	6	585	11	248	844	24	29
Phoslock-2	Anoxic	3/1/13	7	586	10	227	823	29	33
Phoslock-2	Anoxic	3/4/13	10	642	10	291	943	32	37
Phoslock-2	Anoxic	3/6/13	12	922	32	228	1,182	44	50
Phoslock-2	Anoxic	3/8/13	14	1,085	28	171	1,284	53	45
Phoslock-2	Anoxic	3/11/13	17	1,155	65	221	1,441	60	72
Phoslock-2	Anoxic	3/13/13	19	1,635	388	265	2,288	65	78
Phoslock-2	Anoxic	3/15/13	21	1,981	585	279	2,845	52	61
Phoslock-2	Anoxic	3/18/13	24	1,632	1,041	254	2,927	46	54
Phoslock-2	Anoxic	3/20/13	26	1,303	1,112	220	2,635	37	56
Phoslock-2	Anoxic	3/25/13	31	1,254	2,607	304	4,165	43	58
Phoslock-2	Anoxic	3/27/13	33	1,676	2,881	388	4,945	46	57

Results of Sediment Release Studies Conducted on Silver Lake Sediments

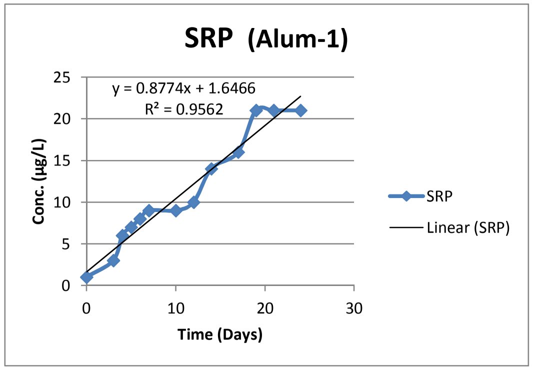
Sample Description	Condition	Date Collected	Time (Days)	NH_3-N (µg/L)	NO_X-N (µg/L)	Organic N (µg/L)	Total N (µg/L)	SRP (µg/L)	Total P (µg/L)
Control-1	Anoxic	2/22/13	0	0	33	209	242	5	4
Control-1	Anoxic	2/25/13	3	83	34	197	314	7	9
Control-1	Anoxic	2/26/13	4	130	11	254	395	10	16
Control-1	Anoxic	2/27/13	5	229	40	246	515	18	26
Control-1	Anoxic	2/28/13	6	303	12	157	472	25	30
Control-1	Anoxic	3/1/13	7	360	10	122	492	35	44
Control-1	Anoxic	3/4/13	10	327	9	103	439	39	48
Control-1	Anoxic	3/6/13	12	588	14	132	734	57	65
Control-1	Anoxic	3/8/13	14	695	64	182	941	91	108
Control-1	Anoxic	3/11/13	17	860	13	133	1,006	122	132
Control-1	Anoxic	3/13/13	19	1,005	15	217	1,237	166	178
Control-1	Anoxic	3/15/13	21	847	21	313	1,181	183	194
Control-1	Anoxic	3/18/13	24	1,080	42	367	1,489	197	217
Control-1	Anoxic	3/20/13	26	1,133	36	388	1,557	194	213
Control-1	Anoxic	3/25/13	31	615	1,667	439	2,721	201	218
Control-1	Anoxic	3/27/13	33	292	2,359	511	3,162	189	205
Control-2	Anoxic	2/22/13	0	100	47	277	424	5	6
Control-2	Anoxic	2/25/13	3	127	12	275	414	6	8
Control-2	Anoxic	2/26/13	4	151	16	324	491	8	14
Control-2	Anoxic	2/27/13	5	387	48	184	619	26	30
Control-2	Anoxic	2/28/13	6	558	20	166	744	50	68
Control-2	Anoxic	3/1/13	7	594	119	250	963	78	98
Control-2	Anoxic	3/4/13	10	645	135	226	1,006	87	105
Control-2	Anoxic	3/6/13	12	974	505	239	1,718	120	133
Control-2	Anoxic	3/8/13	14	1,112	414	241	1,767	160	178
Control-2	Anoxic	3/11/13	17	1,012	470	282	1,764	208	213
Control-2	Anoxic	3/13/13	19	712	709	232	1,653	261	268
Control-2	Anoxic	3/15/13	21	688	923	319	1,930	273	290
Control-2	Anoxic	3/18/13	24	416	1,307	432	2,155	215	230
Control-2	Anoxic	3/20/13	26	375	1,354	472	2,201	178	208
Control-2	Anoxic	3/25/13	31	196	2,920	433	3,549	175	204
Control-2	Anoxic	3/27/13	33	115	2,905	600	3,620	165	201

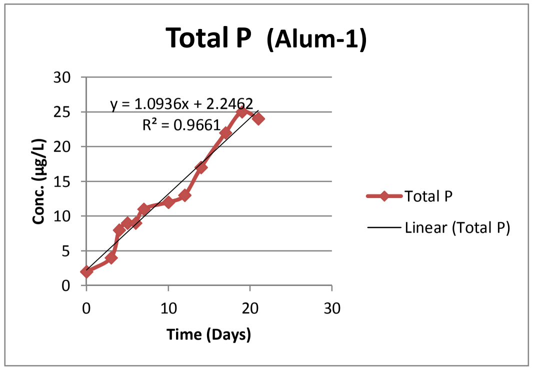
Results of Sediment Release Studies Conducted on Silver Lake Sediments

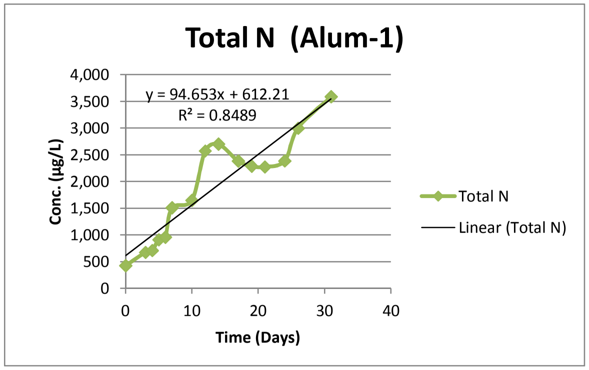
Sample Description	Condition	Date Collected	Time (Days)	NH_3-N (µg/L)	NO_X-N (µg/L)	Organic N (µg/L)	Total N (µg/L)	SRP (µg/L)	Total P (µg/L)
Lake	Anoxic	2/22/13	0	277	344	256	877	7	7
Lake	Anoxic	2/25/13	3	827	37	201	1,065	9	10
Lake	Anoxic	2/26/13	4	1,012	17	269	1,298	13	15
Lake	Anoxic	2/27/13	5	1,405	12	162	1,579	30	32
Lake	Anoxic	2/28/13	6	1,699	11	206	1,916	47	59
Lake	Anoxic	3/1/13	7	1,780	16	258	2,054	79	83
Lake	Anoxic	3/4/13	10	2,196	20	269	2,485	80	87
Lake	Anoxic	3/6/13	12	1,988	88	309	2,385	129	132
Lake	Anoxic	3/8/13	14	2,261	25	209	2,495	173	185
Lake	Anoxic	3/11/13	17	1,725	75	196	1,996	212	241
Lake	Anoxic	3/13/13	19	1,307	166	186	1,659	113	131
Lake	Anoxic	3/15/13	21	925	311	156	1,392	110	129
Lake	Anoxic	3/18/13	24	415	945	241	1,601	85	101
Lake	Anoxic	3/20/13	26	304	1,201	337	1,842	67	95
Lake	Anoxic	3/25/13	31	10	2,818	371	3,199	64	90
Lake	Anoxic	3/27/13	33	47	2,832	570	3,449	61	83

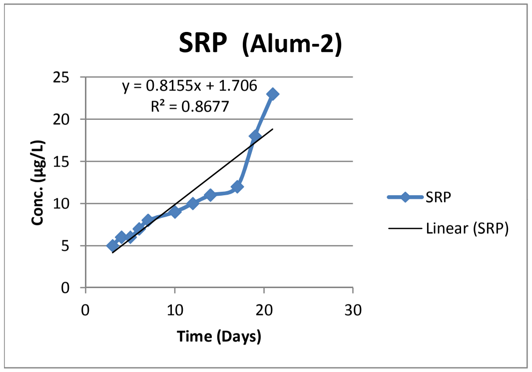
E.2 Regression Relationships of Sediment Phosphorus Release

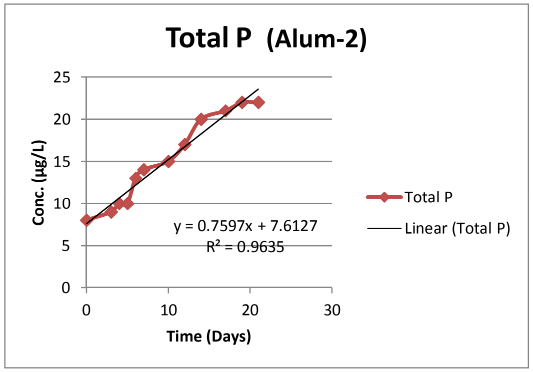
Regression Plots for Sediment Release Studies Conducted on Silver Lake Sediments

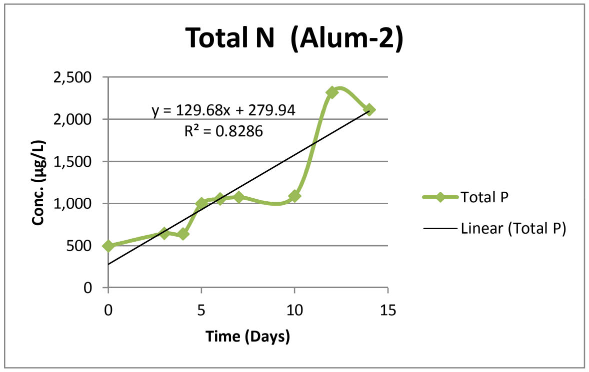




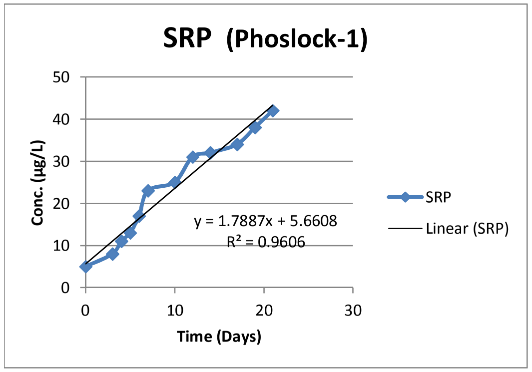


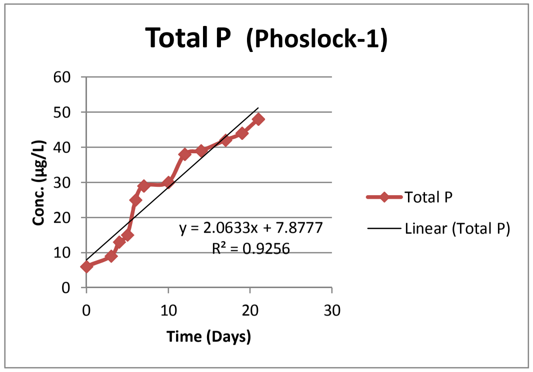


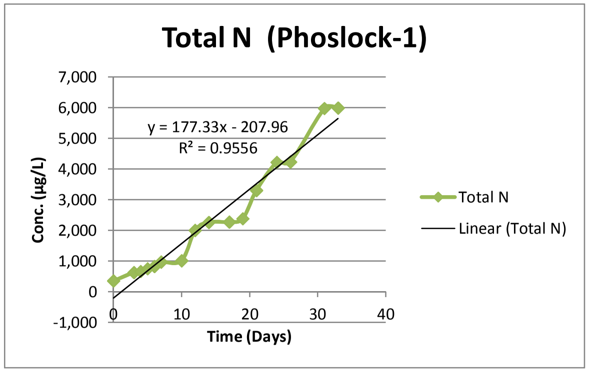


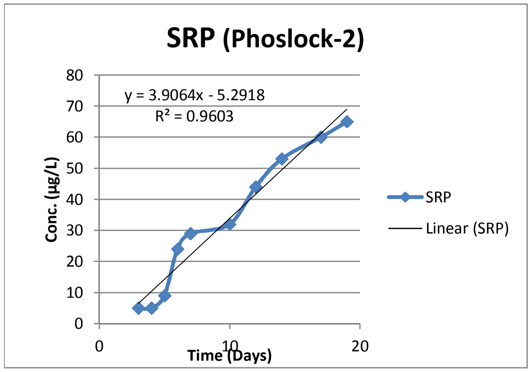


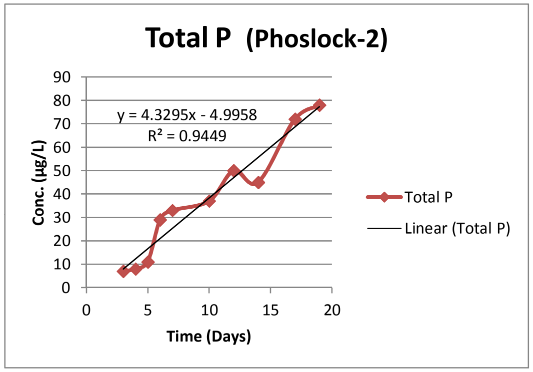
Regression Plots for Sediment Release Studies Conducted on Silver Lake Sediments

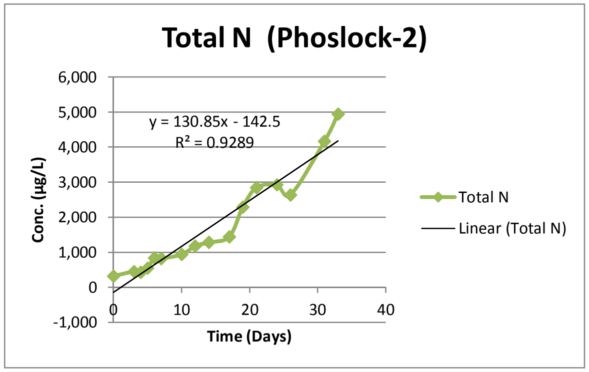

SRP (Phoslock-1)


Total P (Phoslock-1)

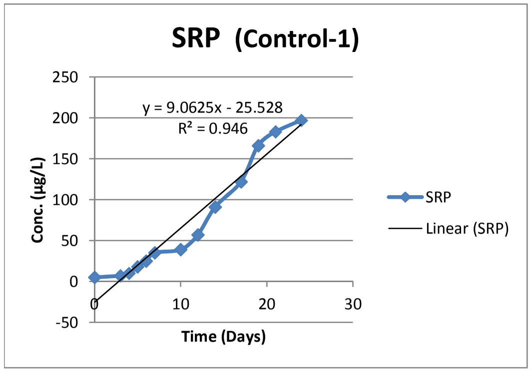

Total N (Phoslock-1)

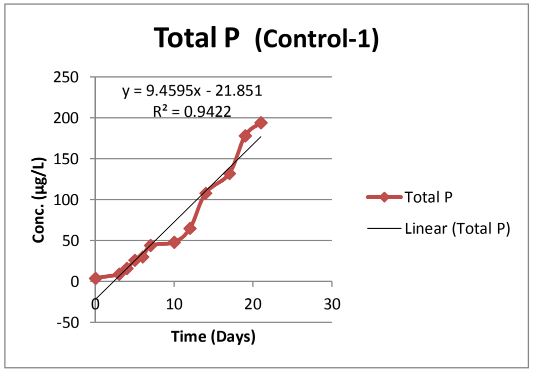

SRP (Phoslock-2)

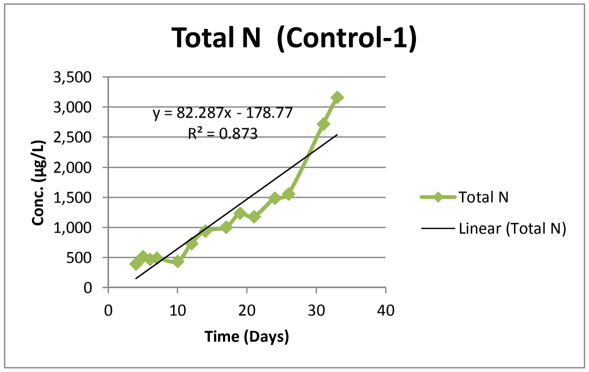

Total P (Phoslock-2)

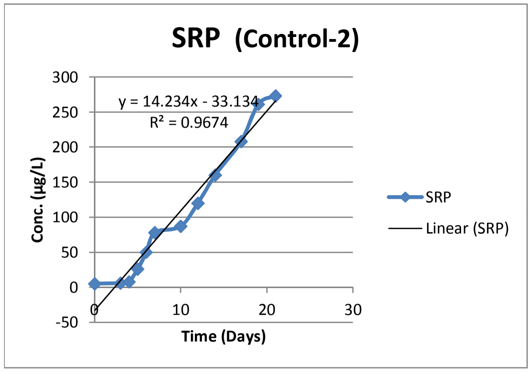

Total N (Phoslock-2)

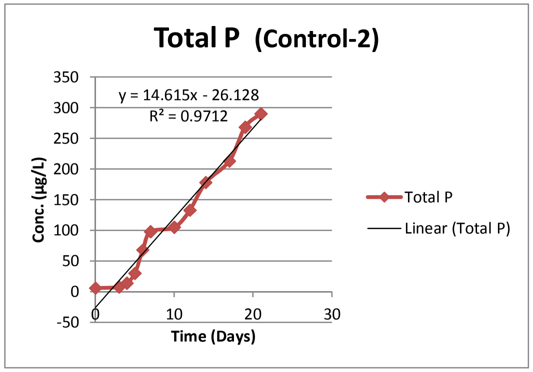
Regression Plots for Sediment Release Studies Conducted on Silver Lake Sediments

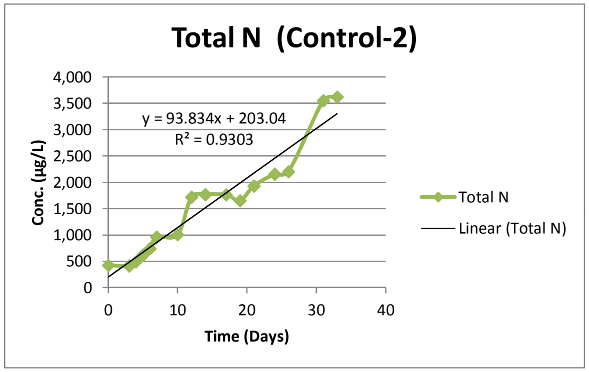












Regression Plots for Sediment Release Studies Conducted on Silver Lake Sediments