SWEETWATER COVE LAKE LYNGBYA NUTRIENT SOURCE EVALUATION

Final Report – December 2015

Prepared For:

Seminole County, Florida

Prepared By:

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SECTION 1

INTRODUCTION

This report provides a summary of work efforts performed by Environmental Research & Design, Inc. (ERD) for the Seminole County Watershed Management Division to evaluate potential nutrient sources and environmental factors responsible for stimulation of the ongoing excessive growth of Lyngbya in the lower lobe of the Sweetwater Cove Lake system. A location map for Sweetwater Cove Lake is given on Figure 1-1. Sweetwater Cove is located approximately 20 miles north of Orlando along the southern boundary of the Wekiva Preserve.

The objective of this project is to identify potential sources of nutrient loadings fueling the Lyngbya outbreaks and to provide recommendations for interception or inactivation of nutrient loadings before becoming available for uptake by algae. This project evaluated nutrient sources resulting from groundwater seepage as well as measurement of nutrient content and bonding mechanisms in existing sediments. Groundwater seepage meters were installed in areas within the lower lobe with and without Lyngbya growth to evaluate the significance of seepage inflows as a potential source of nutrient loadings. In addition, sediment core samples were collected throughout the lower lobe of Sweetwater Cove to determine if the sediments may also be linked to the observed Lyngbya growth. Recommendations were developed for managing nutrient loadings in areas of persistent Lyngbya growth.

1.1 Characteristics of Sweetwater Cove

An overview of Sweetwater Cove and associated hydrologic features is given on Figure 1-2. Sweetwater Cove Lake consists of three interconnected waterbodies which receive inflows from Sweetwater Creek. Sweetwater Creek provides drainage for multiple residential communities and contains several connecting tributaries. A wastewater treatment plant, operated by Sanlando Utilities, discharged treated secondary effluent to Sweetwater Creek until 2013 when an alternate disposal technique was adopted. Under current conditions, the plant is permitted for wet weather discharges into Sweetwater Creek when the sewage flows received by the facility exceed the capacity of the on-site infiltration basins.

An overview of drainage flow patterns for Sweetwater Cove Lake is given on Figure 1-3. Sweetwater Cove Lake is divided into three separate waterbodies identified as the upper, middle, and lower lobes of Sweetwater Cove Lake. The general flow pattern within the lakes originates with the inflow of Sweetwater Creek into the southern portion of the upper lobe. Under normal flow conditions, water discharges from the upper lobe to the middle lobe, finally reaching the lower lobe of Sweetwater Cove Lake. The lower lobe has a water surface area of approximately 4.55 acres and shallow water depths ranging from approximately 2-4 ft. Water level elevations within the lower lobe, as well as in other portions of Sweetwater Cove Lake, are controlled at

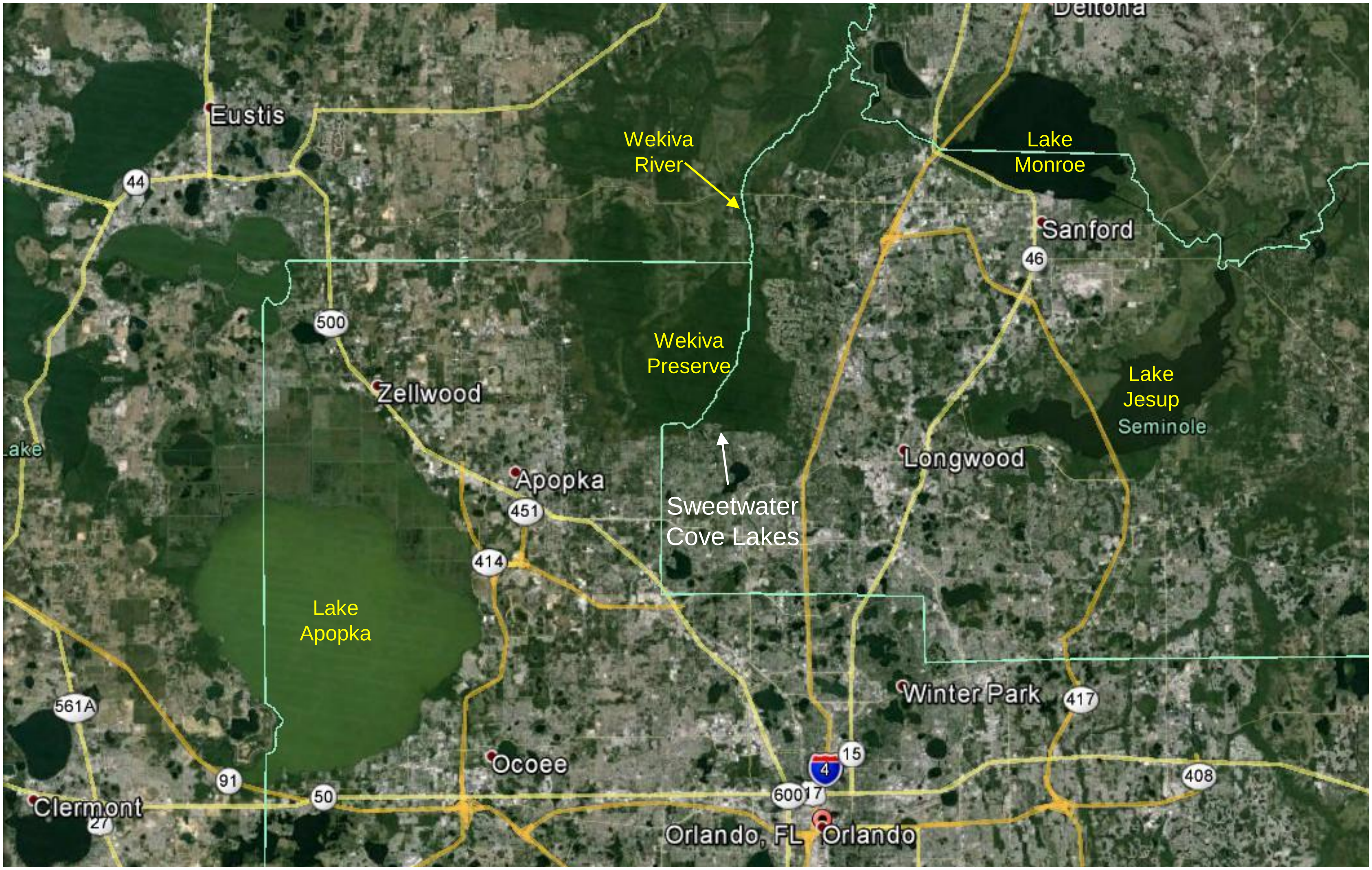


Figure 1-1. Location Map for Sweetwater Cove.

Figure 1-2. Overview of Sweetwater Cove and Hydrologic Features.

Figure 1-3. Overview of Drainage Flow Patterns for Sweetwater Cove Lake.

elevation 20.9 ft by a semicircular concrete weir structure, approximately 57.2 ft in length, located in the northeast portion of the lower lobe. Discharges through the outfall structure flow northward into the Rock Springs Run State Preserve. Under high water level conditions, water can also discharge from the upper lobe over a high level overflow weir which connects directly with the Wekiva River. The work efforts outlined in this document were conducted exclusively within the lower lobe of Sweetwater Cove Lake.

In addition to inflows from upstream waterbodies, the lower lobe also receives direct inputs of untreated stormwater runoff from residential areas surrounding the lake. Locations of stormwater inflows into the lower lobe are illustrated on Figure 1-4. In effect, the lower lobe serves as the stormwater treatment system for the adjacent residential community.

1.2 Characteristics of Lyngbya

Lyngbya is a filamentous cyanobacteria which is composed of a single series of cells surrounded by a tough covering or sheath. The sheaths of Lyngbya are hair-like or filamentous in appearance which can vary in size and length and are often crowded together in thick tangled mats. There are over 60 different species of Lyngbya, most of which live on bottom substrates in fresh, brackish, and marine waters. Lyngbya can thrive at extreme temperatures ranging from near-freezing lakes and streams to hot springs. This alga also contains photosynthetic accessory pigments that permit growth in extremely low-light conditions. Due to its ability to fix atmospheric nitrogen, Lyngbya can grow in waters with extremely low nitrogen concentrations, and the growth of Lyngbya is typically regulated by the availability of phosphorus within the waterbody.

Lyngbya is primarily a benthic algae which grows in dense mats on the bottom of nutrient-enriched lakes and springs. Benthic mats of Lyngbya commonly exhibit a black or dark gray appearance. During photosynthesis, gases are produced that often cause the mats to rise to the surface, forming the green to yellow floating Lyngbya mats commonly observed in eutrophic lake systems. Photographs of floating mats of Lyngbya and microscopic Lyngbya filaments are given on Figure 1-5. Lyngbya common in southeastern ponds and lakes is a particularly large species which is most frequently referred to as *Lyngbya wollei* (recently renamed *Microseria wollei*) or by the common name “Giant Lyngbya”.

Lyngbya thrives in warm, slightly alkaline waters with abundant nutrients, and the growth of Lyngbya has accelerated in Florida springs in the past several decades. Lyngbya interferes with many beneficial uses of waterbodies, including fishing, swimming, and boating, and produces volatile organic compounds which can taint the taste of water and fish and cause episodes of contact dermatitis in humans. Since Lyngbya interferes with oxygen diffusion through the water column, anaerobic bacteria (such as sulfur bacteria) often thrive inside the Lyngbya mat which can release an odor of hydrogen sulfide when disturbed.

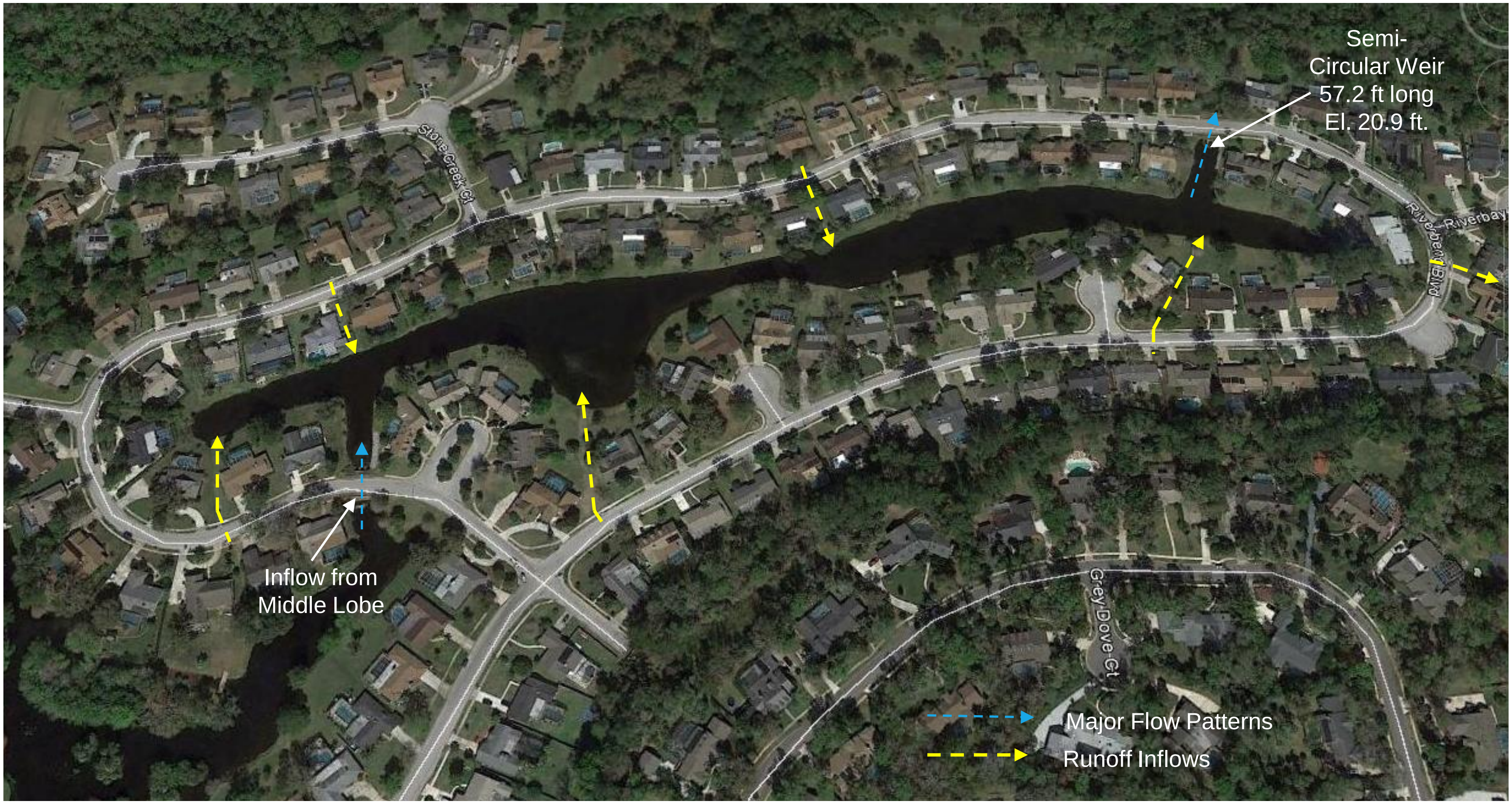


Figure 1-4. Significant Hydrologic Inputs and Losses to the Lower Lobe.

a. Floating Surface Mat of Lyngbya b. Microscopic Lyngbya Filaments

Figure 1-5. Photographs of Lyngbya Algae.

Control of Lyngbya is extremely difficult due to the tough sheath covering which protects the internal algal cells from the impacts of most current herbicides. In addition, since a large portion of the plant biomass is generally on the bottom of the waterbody, penetration of herbicides into lower portions of the dense algal mat becomes difficult. Grass carp do not prefer to eat Lyngbya, although they will turn to this species when other food sources become exhausted. Studies indicate that mechanical harvesting of Lyngbya is not only expensive but generally ineffective and may actually cause spreading of the plant to other areas of the waterbody.

1.3 <u>Ongoing Management Efforts</u>

For the past several years, Seminole County has conducted ongoing efforts to control the excessive growth of emergent vegetation and Lyngbya in lower Sweetwater Cove. A photograph of a portion of the lower lobe during 2012 is given on Figure 1-6. At that time, the lower lobe had become almost completely covered with emergent aquatic vegetation with few remaining areas of open water. Based upon concerns voiced by residents, Seminole County undertook a project to excavate and remove the existing nuisance and exotic emergent vegetation and deepen portions of the lower lobe to reduce the opportunity for recolonization of the emergent vegetation.

Figure 1-6. Photograph of the Lower Lobe During 2012.

Construction activities were initiated during July 2013 and completed in December 2013. Areas identified for selective excavation and deepening of the water column are illustrated on Figure 1-7 and include the extreme eastern and western portions of the lower lobe along with the small cove located on the south side of the lower lobe. Photographs of excavation activities in the lower lobe are illustrated on Figure 1-8, with a photograph of the "spyder" excavation machine shown on Figure 1-8a and the lower lobe during excavation activities shown on Figure 1-8b. A photograph of the lower lobe following excavation during 2014 is given on Figure 1-9. The excavation project was successful in converting the lower lobe from a system dominated by emergent nuisance/exotic vegetation to an open water system.

Figure 1-7. Approximate Areas for Selective Excavation.

a. Photo of Spyder excavation machine

b. Lower lobe during excavation activities

Figure 1-8. Excavation Activities in the Lower Lobe.

Figure 1-9. Lower Lobe Following Excavation.

After completion of the vegetation removal and excavation activities in the lower lobe, Seminole County also conducted replanting of the emergent littoral zone vegetation along selected portions of the shoreline. Shoreline vegetation is an essential part of any healthy lake ecosystem. Vegetation provides many important functions, such as protection from erosion of shoreline areas and contributing to a diverse ecological community which is an important factor in maintaining good water quality characteristics. Shoreline vegetation also consumes nutrients, leaving fewer nutrients available for algal growth and reduces the formation and accumulation of organic muck. A photograph of a shoreline area following planting is given on Figure 1-10a, and a photograph of mature shoreline vegetation (approximately 12 months following installation) is given on Figure 1-10b.

Shortly after completion of the previously described activities in the lower lobe, the lake began to experience patches of floating Lyngbya in isolated stagnant areas of the lake. At times, large areas of the lower lobe would become completely covered with floating Lyngbya which, in addition to being aesthetically unpleasing, isolated portions of the water column from atmospheric exchange. Photographs of floating Lyngbya in the lower lobe are given on Figure 1-11.

a. Area following planting

b. Mature vegetation

Figure 1-10. Aquatic Plantings in Lower Sweetwater Cove.

Figure 1-11. Photo of Lyngbya Growth in the Lower Lobe.

Seminole County has made multiple attempts to address the Lyngbya issue within the lower lobe. During December 2013, Seminole County attempted to remove the floating Lyngbya mats using an aquatic harvester typically used for removal of Hydrilla or other nuisance species. A photograph of the harvester used for Lyngbya removal in the lower lobe is given on Figure 1-12. The harvester was moderately successful in removing Lyngbya from the water surface, but significant areas of floating Lyngbya mats returned within a few months following removal. Seminole County has also attempted to control the growth of Lyngbya using bi-monthly herbicide treatments as well as using an application protocol developed by the Florida Wildlife Commission (FWC). A more detailed discussion of attempts to control algae growth using the FWC protocol is given in a subsequent section.

Figure 1-12. Harvester Used for Lyngbya Removal.

1.4 Work Efforts Performed by ERD

Work efforts were initiated on this project by ERD during January 2015. The primary objective of this project is to identify potential sources of nutrient loadings fueling the ongoing Lyngbya outbreaks and to provide recommendations for potential Lyngbya control. A field monitoring program was conducted by ERD from January-June 2015 to collect surface water samples in lower Sweetwater Cove and to evaluate hydrologic and nutrient loadings from groundwater seepage entering the lake. In addition, sediment samples were collected and analyzed for general parameters, nutrients, and phosphorus speciation to assist in identifying potential impacts of sediments on Lyngbya growth. Recommendations were developed for methods of controlling Lyngbya growth in lower Sweetwater Cove.

This report has been divided into six separate sections for presentation of the work efforts performed by ERD. Section 1 contains an introduction to the report, a description of Sweetwater Cove Lake, a discussion of the characteristics of Lyngbya, and a general overview of the work efforts performed by ERD. Measured water quality characteristics of lower Sweetwater Cove are discussed in Section 2. A discussion of sediment characteristics is given in Section 3, and a summary of the results from the field seepage monitoring program is presented in Section 4. Section 5 contains a discussion of the results of the FWC Lyngbya treatment protocol used in the lower lobe. Alternatives for management of Lyngbya in lower Sweetwater Cove are discussed in Section 6. Appendices are also attached which contain technical data and analyses used to support the information contained within the report.

SECTION 2

WATER QUALITY CHARACTERISTICS OF LOWER SWEETWATER COVE LAKE

An overview of current water quality characteristics in lower Sweetwater Cove is provided in this section based on field monitoring conducted by ERD from January-June 2015. Discussions are provided in the following sections for the results of measurements of field profiles and chemical characteristics of surface water within the lake.

2.1 Monitoring Activities

A monthly surface water quality monitoring program was conducted in lower Sweetwater Cove by ERD from January-June 2015 at four fixed monitoring locations. Approximate locations of the surface water monitoring sites in lower Sweetwater Cove are indicated on Figure 2-1. The water quality monitoring sites were selected to provide general information on ambient water quality and allow evaluation of horizontal and vertical variability in water quality characteristics. Water quality monitoring was conducted on approximately a monthly basis, with a total of five monitoring events conducted during the 6-month monitoring program.

Sample collection procedures followed methods outlined in DEP-SOP-001/01 titled "Department of Environmental Protection Standard Operating Procedures for Field Activities" dated March 1, 2014. Surface water samples were collected using a battery-powered peristaltic pump constructed of plastic and stainless steel. Two separate samples were collected at each site during each monitoring event. The first sample was collected at a depth equal to 50% of the Secchi disk depth at the time of sample collection. The second sample was collected at a depth of 0.25 m above the sediment/water interface. Each of the collected samples was preserved as appropriate for the parameter to be analyzed, stored in ice, and returned to the ERD Laboratory for chemical analyses. A listing of laboratory measurements performed on the collected samples is given in Table 2-1, along with a summary of analytical methods and laboratory detection limits.

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

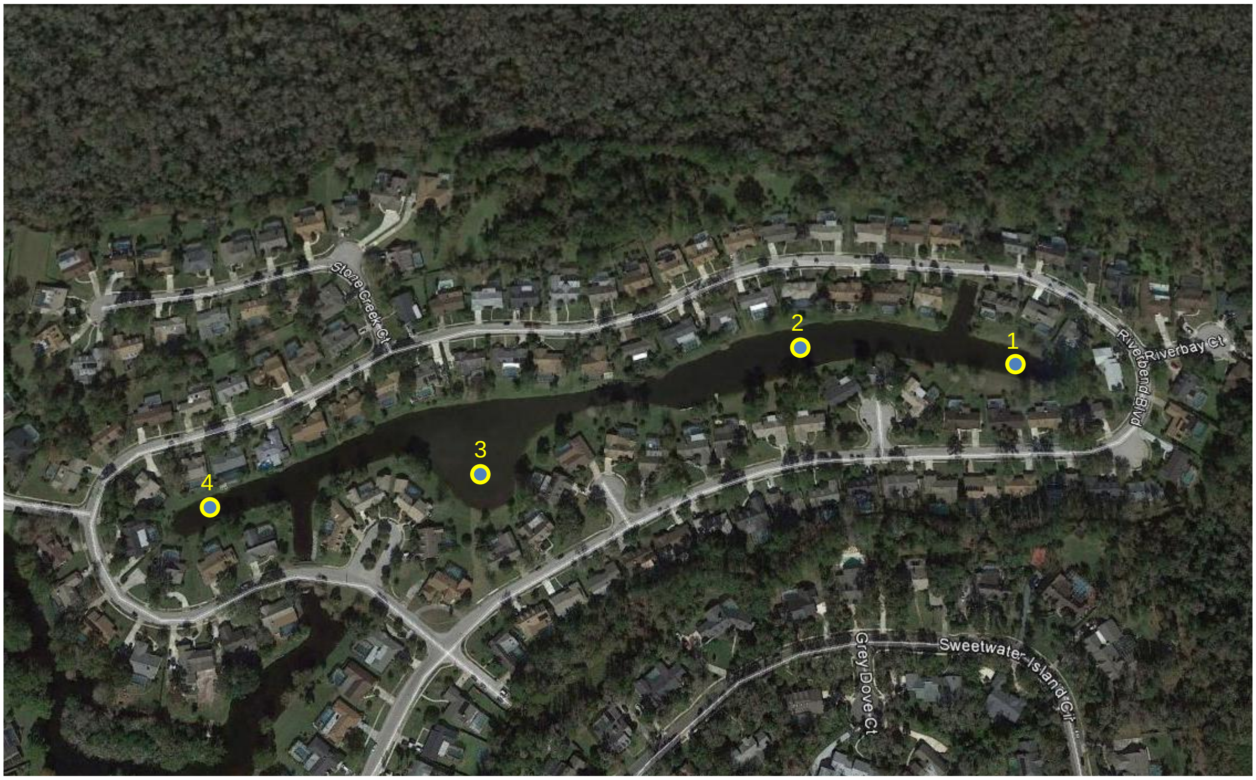


Figure 2-1. Water Quality Monitoring Sites in Lower Sweetwater Cove.

TABLE 2-1

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

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

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

2.2 Field Profiles

A complete listing of vertical field profiles collected in lower Sweetwater Cove from January-June 2015 is given in Appendix A.1, and a summary of mean measurements collected at the four sites for each event is given in Table 2-2. The mean values summarized in this table reflect vertical geometric mean values for all measurements collected at a given site on a given date. A discussion of vertical field profiles collected at each of the four monitoring sites is given in the following sections.

TABLE 2-2

MEAN WATER COLUMN FIELD MEASUREMENTS COLLECTED IN LOWER SWEETWATER COVE FROM JANUARY - JUNE 2015

DATE	SITE	PARAMETER						
		Temperature (^oC)	pH (s.u.)	Conductivity (µmho/cm)	Diss. Oxygen (mg/l)	Diss. Oxygen (% Sat.)	ORP (mv)	Secchi Depth (m)
1/12/15	1	17.32	7.43	295	7.0	73	451	0.81 (B)*
	2	17.08	7.42	306	6.0	62	469	0.93 (B)
	3	16.91	7.35	311	6.5	68	487	1.11 (B)
	4	17.03	7.21	304	4.3	44	528	0.82 (B)
2/10/15	1	16.55	7.60	310	6.6	68	509	0.64 (B)
	2	17.16	7.30	310	6.6	68	450	0.75 (B)
	3	17.31	7.36	302	7.6	79	437	0.88 (B)
	4	16.96	7.28	292	5.1	53	427	0.58 (B)
3/20/15	1	24.08	7.18	363	2.7	32	574	0.83 (B)
	2	24.40	7.22	358	3.7	44	443	0.79 (B)
	3	24.25	7.30	359	4.2	50	456	1.24 (B)
	4	24.10	7.27	364	3.5	41	446	0.93 (B)
5/27/15	1	27.60	8.54	425	2.2	27	411	0.29
	2	28.31	9.10	409	4.4	57	317	0.27
	3	28.41	9.28	408	5.7	73	331	0.29
	4	28.16	8.34	428	2.8	37	338	0.28
6/30/15	1	28.55	6.77	266	2.2	28	470	0.71 (B)
	2	28.34	7.09	257	2.5	32	397	0.99 (B)
	3	28.35	7.16	254	2.6	34	403	1.29 (B)
	4	28.55	7.16	257	3.0	39	409	0.64 (B)

*B = Secchi disk visible on bottom

2.2.1 Temperature

Graphical summaries of vertical field profiles of temperature, pH, conductivity, dissolved oxygen, and oxidation-reduction potential (ORP) measured at each of the four monitoring sites in lower Sweetwater Cove are given in Figures 2-2 through 2-5, for Sites 1, 2, 3, and 4, respectively. In general, relatively uniform temperature measurements were observed at each of the four monitoring locations within lower Sweetwater Cove during each of the five surface water monitoring events. The observed isograde profiles for temperature are likely related to the shallow water column within the lake. Temperature differences between top and bottom measurements at each of the four sites were typically less than 0.5^{o}C during most events. No evidence of significant thermal stratification was observed at any of the monitoring sites during any of the events. As indicated on Table 2-2, mean water column temperatures at the four surface water monitoring sites were within 0.7^{o}C during most events, suggesting relatively minimal horizontal variability in temperature.

2.2.2 pH

Measured pH values in lower Sweetwater Cove were highly variable, with surface (0.25 m) pH measurements ranging from 6.69-9.28 during the 6-month field monitoring program. With the exception of Site 1, measured pH profiles were virtually identical at each of the four monitoring sites during the months of January, February, March, and June, with surface pH measurements ranging from approximately 7.0-7.5 during this period. However, a somewhat larger range of surface pH values was observed during January, February, March, and June at Site 1, with surface measurements ranging from approximately 6.6-7.6. A slight decrease in pH was observed with increasing water depth during most events, although differences between top and bottom pH measurements were typically less than 0.2 units.

Measurements of pH conducted during May 2015 were substantially higher in value at each of the four monitoring sites, with surface measurements on this date ranging from 8.96-9.31. Measured pH values in this range are often indicative of a high level of algal production. Decreases in pH with increasing water depth were more significant during the May 2015 event than observed for the remaining events, with pH differences between top and bottom measurements ranging from 0.5-1.0 unit or more at most sites. Mean water column pH values between the individual sites were typically within 0.5 units, providing evidence of minimal horizontal variability in pH. Overall, with the exception of the June monitoring event at Site 1, surface water within Sweetwater Cove was characterized by alkaline conditions.

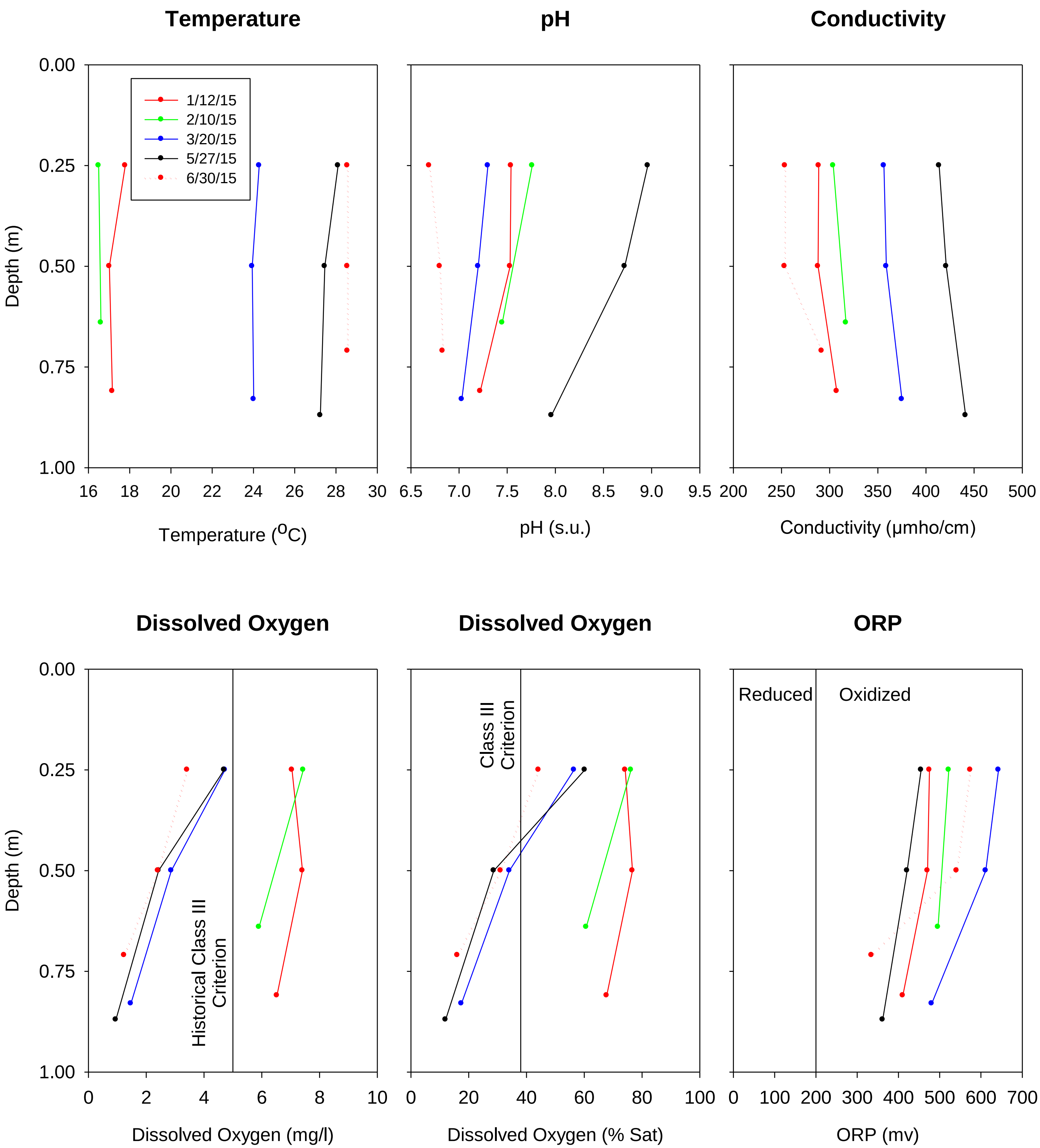


Figure 2-2. Vertical Field Profiles Collected at Site 1 in Lower Sweetwater Cove from January-June 2015.

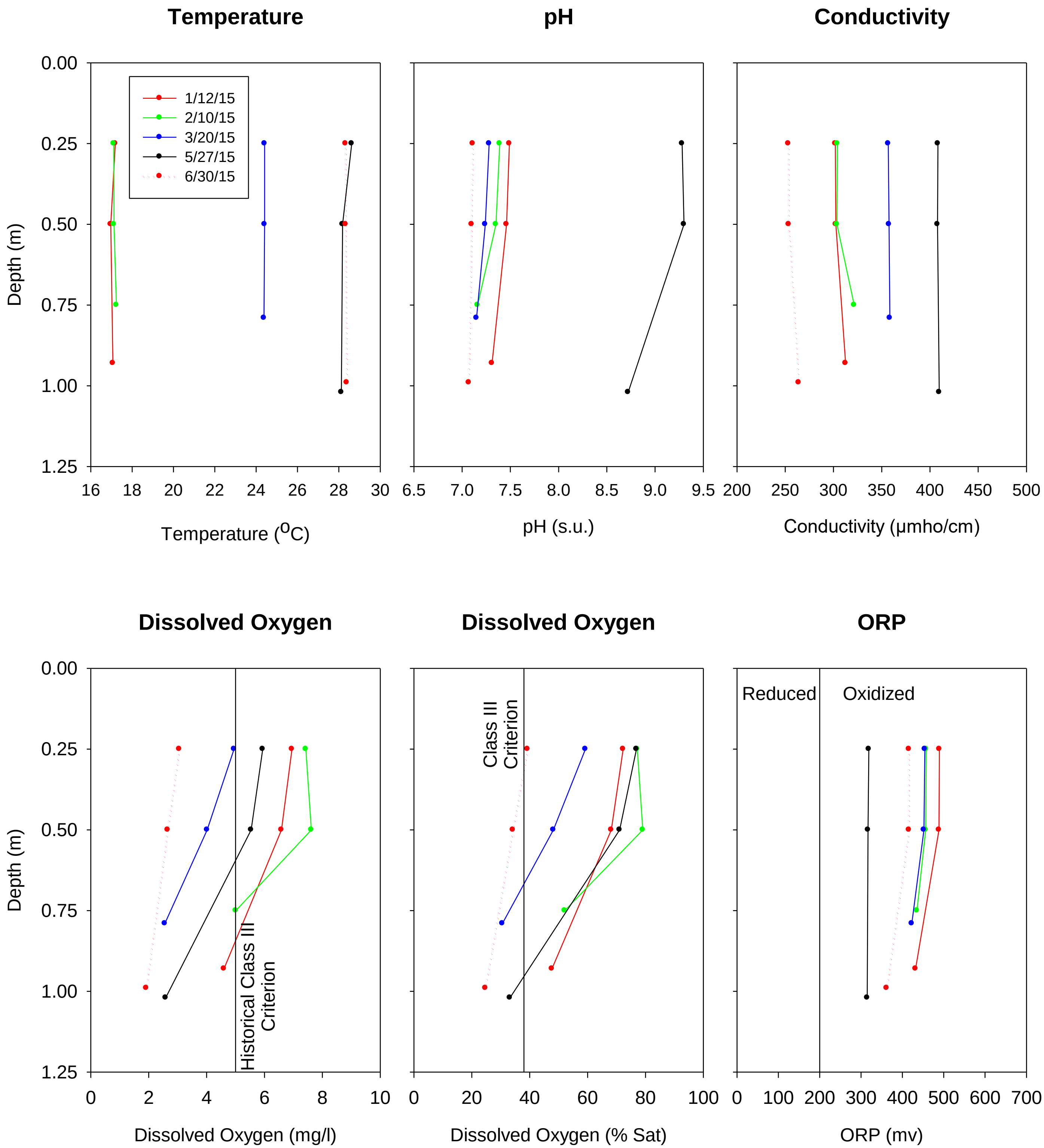


Figure 2-3. Vertical Field Profiles Collected at Site 2 in Lower Sweetwater Cove from January-June 2015.

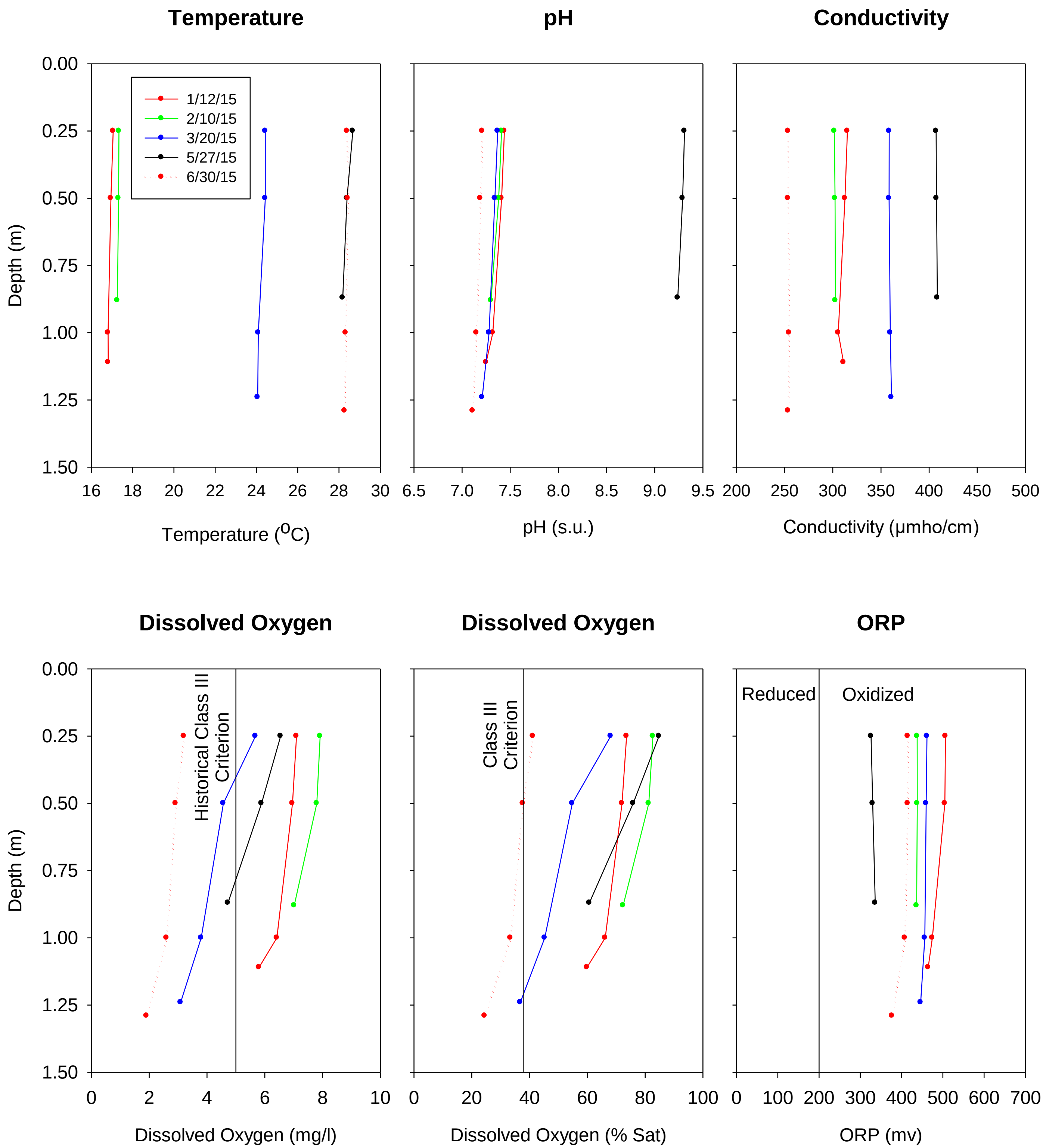


Figure 2-4. Vertical Field Profiles Collected at Site 3 in Lower Sweetwater Cove from January-June 2015.

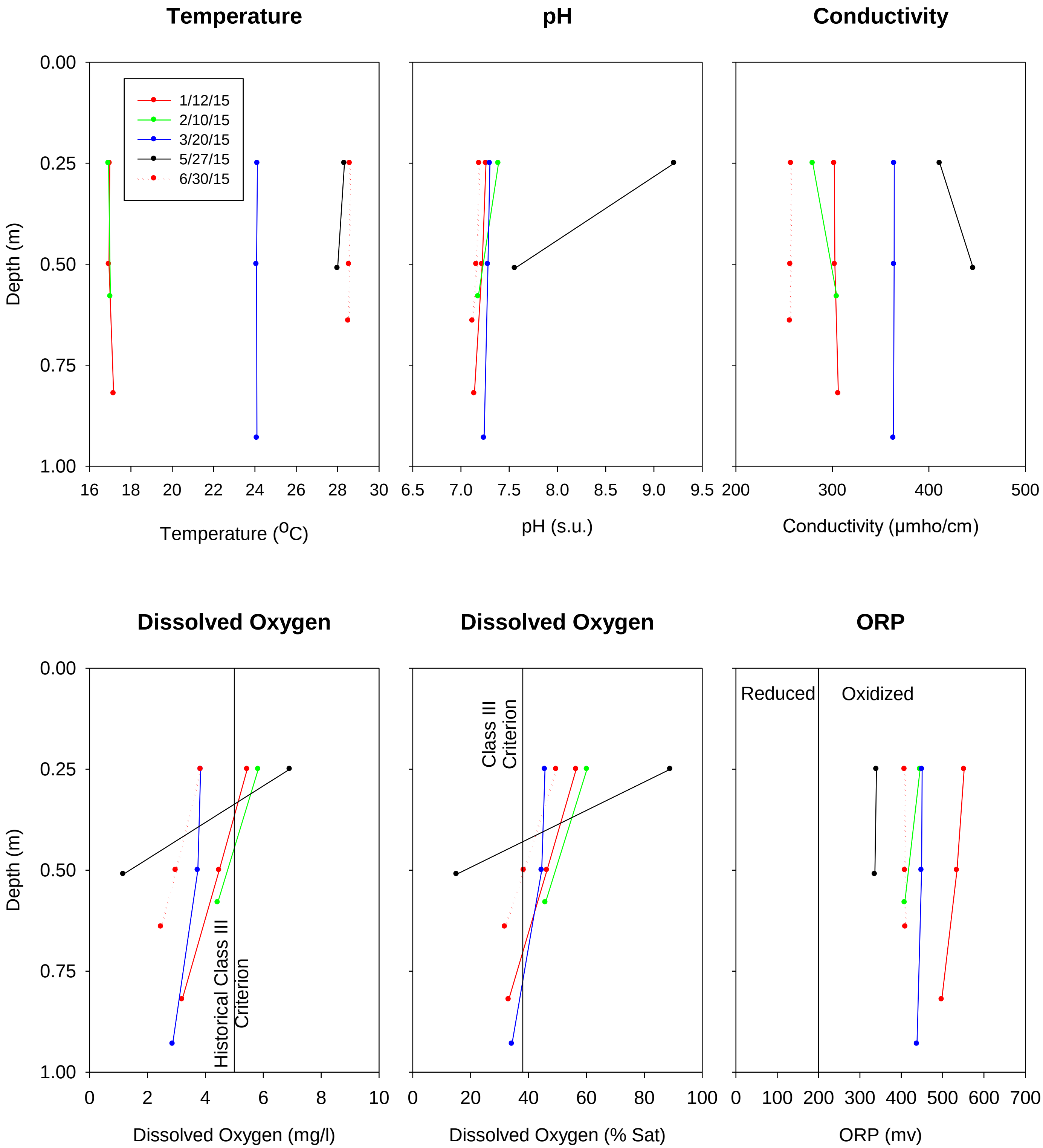


Figure 2-5. Vertical Field Profiles Collected at Site 4 in Lower Sweetwater Cove from January-June 2015.

2.2.3 Conductivity

Measured conductivity values in lower Sweetwater Cove were highly variable during the field monitoring program, with surface measurements ranging from approximately 250-400 μmho/cm. The observed high degree of variability is likely related to the relatively small water volume contained within lower Sweetwater Cove which can be replaced relatively rapidly during high flow conditions from the upstream lakes. A slight trend of increasing conductivity with increasing water depth was observed during most events, although differences between top and bottom conductivity measurements were generally small. The dense growth of Lyngbya on the bottom of lower Sweetwater Cove may temporarily trap nutrient flux from sediments and groundwater beneath the algal mat, making this influx difficult to detect during routine field monitoring activities. However, conductivity increases near the water-sediment interface were observed at Site 1 during January and June, at Site 2 during February, and at Site 4 during February and May 2015, suggesting that influx of nutrients may occur from the bottom sediments which is temporarily trapped by the dense algal mats and slowly diffused into the water column.

2.2.4 Dissolved Oxygen

Measured concentrations of dissolved oxygen in lower Sweetwater Cove were also highly variable during the field monitoring program from January-June 2015, with surface measurements ranging from 3.1-7.9 mg/l. In general, the highest levels of dissolved oxygen (mean values ranging from 4.3-7.6 mg/l) were observed during January and February, with lower concentrations (mean values ranging from 2.2-5.7 mg/l) observed during the remaining months. A general trend of decreasing concentrations of dissolved oxygen with depth was observed at each of the four sites during each monitoring event, with bottom dissolved oxygen measurements ranging from 1.0-7.0 mg/l.

The standard for dissolved oxygen in Class III freshwater systems (defined as waterbodies used for recreation and wildlife) has historically been 5 mg/l, and this concentration is indicated on Figures 2-2 through 2-5 for reference purposes. Based upon this historical criterion, violations of the 5 mg/l standard would have occurred during 3 of the 5 events at Site 1, 2 of the 5 events at Site 2, 1 of the 5 events at Site 3, and 2 of the 5 events at Site 4. However, FDEP has recently adopted a revised dissolved oxygen criterion which is based upon oxygen saturation rather than a specific concentration. The revised Class III criterion for dissolved oxygen saturation in freshwater systems requires that the daily average percent dissolved oxygen saturation shall not be below 38% in the top 2 m of a waterbody in more than 10% of the locations monitored. Based upon this revised dissolved oxygen criterion, and the mean water column saturation values summarized in Table 2-2, dissolved oxygen in lower Sweetwater Cove appears to have violated the oxygen saturation criterion during 3 of the 5 events at Site 1, 1 of the 5 events at Site 2, 1 of the 5 events at Site 3, and 2 of the 5 events at Site 4. Violations of the current Class III criterion were observed primarily at Site 1 which is located in an isolated cove on the east end of lower Sweetwater Cove. Overall, with the exception of Site 1, the water column in lower Sweetwater Cove appears to contain adequate dissolved oxygen to support the existing wildlife within the lake.

2.2.5 Oxygen-Reduction Potential (ORP)

ORP is a measure of the availability of free electrons within the water column. Since many chemical and biological reactions involve exchange of electrons, ORP can be used as an indication of the type of biological reactions present or favored at a given time. In general, measurements of ORP were relatively uniform throughout the water column at a majority of the monitoring sites during the field monitoring program, although a slight trend of decreasing ORP with increasing water depth was observed during some of the individual field measurements. However, each of the monitoring sites maintained oxidized conditions throughout the water column during each monitoring event. In general, ORP values greater than 200 mv indicate oxidized conditions within the water column, while ORP values less than 200 mv indicate reduced conditions which can possibly lead to degraded water quality characteristics. Evidence of reduced conditions near the water-sediment interface was not observed during any field monitoring event in lower Sweetwater Cove.

2.2.6 Secchi Disk Depth

In general, measured Secchi disk depths exceeded the water column depth at each of the four monitoring sites during the January, February, March, and June monitoring events. However, substantially lower Secchi disk depths (ranging from 0.29-0.7 m) were observed at the four monitoring sites on May 27, 2015. This monitoring event corresponded with a significant algal bloom within the lower Sweetwater Cove which restricted light penetration into the water column.

2.3 Laboratory Measurements

A complete listing of laboratory measured values for general parameters, biological parameters, and nutrients measured in lower Sweetwater Cove is given in Table 2-3. A discussion of measured water quality characteristics in lower Sweetwater Cove is given in the following sections.

2.3.1 General Parameters (Alkalinity, Color, and Turbidity)

2.3.1.1 Alkalinity

Alkalinity is a direct measurement of the buffering capacity available within a waterbody and indicates the ability of the lake to resist changes in pH caused by internal or external impacts. In general, surface water within lower Sweetwater Cove was moderately to well buffered, with measured alkalinity values ranging from approximately 59-117 mg/l. Measured alkalinity values in lakes are typically a reflection of the characteristics of the watershed surrounding the lake as well as significant inflows from upstream lakes or tributaries.

TABLE 2-3

CHEMICAL CHARACTERISTICS OF SURFACE WATER SAMPLES COLLECTED IN LOWER SWEETWATER COVE FROM JANUARY – JUNE 2015

DATE	SITE	DEPTH	PARAMETER																
			pH (s.u.)	Alkalinity (mg/l)	Conductivity (µmho/cm)	NH_3 (µg/l)	NO_x (µg/l)	Dissolved Organic Nitrogen (µg/l)	Particulate Nitrogen (µg/l)	Total Nitrogen (µg/l)	SRP (µg/l)	Dissolved Organic Phosphorus (µg/l)	Particulate Phosphorus (µg/l)	Total Phosphorus (µg/l)	Turbidity (NTU)	Color (Pt-Co units)	Chlorophyll-a (mg/m^3)	TN/TP Ratio	TSI Value
1/12/15	1	Top	7.39	73.8	298	87	25	447	29	588	149	13	10	172	1.3	35	6.8	3.4	44
		Bottom	7.31	72.6	297	90	22	411	129	653	158	16	11	185	1.3	37	5.4	3.5	41
	2	Top	7.24	77.2	311	85	51	591	89	817	135	5	14	154	1.2	35	3.4	5.3	34
		Bottom	7.14	67.6	315	87	50	501	115	753	148	19	13	180	1.8	36	4.2	4.2	37
	3	Top	7.24	77.8	332	86	69	809	90	1,054	131	2	10	143	1.7	36	1.6	7.4	24
		Bottom	7.27	78.4	320	100	61	693	74	927	139	6	11	156	2.2	36	2.6	6.0	31
	4	Top	7.22	81.8	312	188	30	625	98	941	106	38	19	163	1.3	35	8.3	5.8	47
		Bottom	7.34	82.4	318	191	30	585	202	1,008	135	7	35	177	1.4	36	15.0	5.7	56
2/10/15	1	Top	7.25	82.4	314	138	293	283	145	860	115	3	25	144	2.0	37	9.8	6.0	50
		Bottom	7.30	81.4	316	116	295	337	107	855	117	2	19	138	1.9	38	9.9	6.2	50
	2	Top	7.41	88.6	319	59	423	286	128	896	103	14	16	133	11.1	35	8.2	6.7	47
		Bottom	7.33	82.2	316	59	424	296	160	940	104	19	12	135	3.6	35	13.5	7.0	54
	3	Top	7.53	86.8	316	77	451	247	121	895	103	9	15	127	6.3	36	2.7	7.0	31
		Bottom	7.32	82.8	318	63	450	325	34	873	106	11	15	132	2.6	37	7.1	6.6	45
	4	Top	7.21	84.4	289	187	149	326	185	847	96	20	11	128	4.8	35	10.1	6.6	50
		Bottom	7.49	83.4	292	188	157	315	201	862	97	20	18	135	10.4	36	18.6	6.4	59
3/20/15	1	Top	7.22	85.0	390	65	27	616	352	1,061	459	232	17	708	2.8	42	68.9	1.5	78
		Bottom	7.31	87.2	388	73	34	589	446	1,142	479	160	100	739	2.5	42	72.5	1.5	78
	2	Top	7.23	83.4	390	105	102	557	205	970	514	190	51	755	3.3	43	7.8	1.3	46
		Bottom	7.39	86.4	386	106	100	599	203	1,008	510	207	45	762	4.1	42	8.8	1.3	48
	3	Top	7.40	85.4	389	118	234	587	265	1,204	548	150	81	779	3.9	40	6.3	1.5	43
		Bottom	7.42	85.8	388	114	230	593	216	1,153	553	175	50	778	3.0	39	10.4	1.5	51
	4	Top	7.39	94.2	394	166	205	608	224	1,203	579	224	96	899	2.1	41	5.4	1.3	41
		Bottom	7.44	93.0	394	200	161	580	277	1,219	579	161	96	836	4.7	42	8.9	1.5	48
5/27/15	1	Top	8.63	116	471	4	3	562	1,062	1,631	4	54	265	324	12.7	49	117	5.0	85
		Bottom	7.89	117	476	2	3	726	950	1,680	9	53	276	339	14.5	57	239	5.0	96
	2	Top	8.89	116	472	3	3	637	1,093	1,736	4	51	195	250	14.9	54	116	7.0	85
		Bottom	8.03	116	470	1	3	683	1,597	2,284	5	54	339	399	18.3	57	160	5.7	90
	3	Top	8.17	107	472	4	3	635	1,433	2,075	5	56	284	344	18.0	57	151	6.0	89
		Bottom	7.79	115	473	5	3	582	1,092	1,682	5	55	317	377	18.6	59	236	4.5	96
	4	Top	7.74	116	475	2	3	735	1,308	2,049	5	56	263	324	19.3	57	236	6.3	95
		Bottom	7.76	115	476	1	3	737	1,287	2,028	3	57	261	321	20.8	59	239	6.3	96
6/30/15	1	Top	7.17	58.4	284	15	3	457	324	799	38	7	37	82	3.3	52	17.0	9.7	58
		Bottom	6.97	60.0	312	10	3	481	166	660	37	9	34	80	3.8	54	10.9	8.3	51
	2	Top	7.09	63.0	286	6	3	478	237	724	44	6	33	83	2.8	55	8.6	8.7	48
		Bottom	6.94	59.2	299	4	3	436	179	622	43	9	2	54	3.0	55	6.8	11.5	44
	3	Top	7.18	59.0	281	28	3	436	197	664	61	4	27	92	2.2	57	10.7	7.2	51
		Bottom	7.05	59.4	288	28	7	500	191	726	63	4	31	98	3.1	57	13.1	7.4	54
	4	Top	7.02	61.8	285	39	7	472	92	610	85	8	16	109	1.5	58	7.4	5.6	46
		Bottom	7.10	60.4	287	49	9	482	74	614	85	15	8	108	1.9	44	9.6	5.7	49

Measured alkalinity values during the January, February, and March 2015 monitoring events were relatively similar in value, ranging from approximately 70-95 mg/l. Little horizontal variability was observed in measured alkalinity values at the four monitoring sites during a given monitoring event. However, it appears that alkalinity values within the lake are significantly impacted by inflows from upstream lakes, as evidenced by the substantial increase in alkalinity observed during the May 2015 monitoring event (with surface alkalinity values of approximately 116 mg/l), followed by a substantial reduction in alkalinity of approximately 50% during the June 2015 monitoring event. The data suggest that inflows into lower Sweetwater Cove have significant impacts on alkalinity within the lake, although the lake does not appear to exhibit significant horizontal or vertical variability in alkalinity measurements on any given monitoring date.

2.3.1.2 Color

Color is a measure of dissolved organic molecules in the water column, typically derived from humic acids, tannins, and lignins. The presence of color in a waterbody does not necessarily indicate the presence of pollution. However, excessive color may result in lower pH values. In addition, some color-causing compounds can act as natural algicides restricting the growth of certain algal species. High levels of color can also cause stratification in a waterbody, leading to low dissolved oxygen and additional water quality concerns.

Measured color concentrations in lower Sweetwater Cove appear to exhibit a lower degree of variability than observed for alkalinity and field parameters, with the majority of measured values ranging from approximately 35-60 Pt-Co units. Similar to the trend observed for alkalinity, color measurements were relatively uniform in value during the January and February monitoring events, with a slight increase in color observed during March. More substantial increases in color values were observed during the May and June monitoring events, presumably as a result of colored inflows from upstream lakes. Measured color values appear to exhibit a relatively low degree of horizontal and vertical variability within lower Sweetwater Cove during any given monitoring date. No substantial difference was observed in measured color concentrations between surface and bottom samples.

2.3.1.3 Turbidity

Turbidity is a measure of suspended particles in a water column of a lake contributed by both organic sources (such as algae) as well as inorganic sources (such as colloids and sediment material). As indicated on Table 2-3, measured turbidity values in Sweetwater Cove were relatively low and consistent in value during the January, March, and June monitoring events, with the vast majority of measured turbidity values less than 4 NTU during these events. No substantial differences were observed between surface and bottom turbidity measurements during these events. However, during the February 2015 monitoring event, elevated levels of turbidity were observed at Sites 2 and 3, with relatively large differences between surface and bottom measurements at most sites. During the May 2015 monitoring event, turbidity values increased substantially at all sites, presumably due to the significant algal bloom which occurred within the lake at that time. Measured turbidity values within lower Sweetwater Cove during May 2015 ranged from approximately 13-21 NTU.

Similar to the trends observed for alkalinity and color, no significant horizontal or vertical variability was observed within lower Sweetwater Cove for turbidity during any given monitoring event, with the possible exception of the February 2015 event which was discussed previously.

2.3.2 Nutrients

2.3.2.1 Nitrogen Species

Nitrogen is an important building block for the production of phytoplankton and in regulating the overall productivity of some freshwater systems. Ammonia (NH_4^+) and nitrate (NO_3^-) are the most stable and significant inorganic forms of nitrogen which are readily available for assimilation into phytoplankton. Once these inorganic molecules are assimilated by phytoplankton, they are converted into organic nitrogen in the form of living biomass tissue. As the organic matter dies and decomposes, ammonia and nitrate are released and are available to enter the nutrient cycle once again.

Sweetwater Cove exhibited highly variable concentrations of both ammonia and NO_x during the field monitoring program. During the January 2015 monitoring event, measured surface (top) concentrations of ammonia ranged from 85-188 μg/l, with surface NO_x concentrations ranging from 25-69 μg/l, both of which are similar to concentrations commonly observed in urban lakes. Measured concentrations for each of these parameters increased during the February 2015 monitoring event, particularly for NO_x where concentrations increased by approximately 3- to 10-fold, depending upon the site. Reductions in measured concentrations for ammonia and NO_x occurred during the March 2015 event, although with NO_x concentrations were still relatively elevated compared with the January 2015 event. However, during the May and June 2015 monitoring events, water column concentrations of both ammonia and NO_x were virtually depleted, presumably as a result of significant algal production which was observed during these two months. The growth of algae in Sweetwater Cove was likely limited during May and June 2015 by the available concentrations of ammonia and NO_x within the lake.

In contrast to the trends observed for ammonia and NO_x, measured concentrations of dissolved organic nitrogen were relatively consistent during the field monitoring program, with only minimal variability in concentrations between the five monitoring events. The observed concentrations of dissolved organic nitrogen in Sweetwater Cove during the five monitoring events are typical of concentrations commonly observed in urban lakes.

Measured concentrations of particulate nitrogen in Sweetwater Cove were highly variable during the field monitoring program. Particulate nitrogen concentrations increased during each monthly monitoring event from May-June 2015, with the most elevated concentrations of particulate nitrogen observed during the May monitoring event. The observed particulate nitrogen is primarily due to algal biomass which reached substantially elevated levels during May 2015. Water column concentrations of particulate nitrogen increased approximately 10-fold between the January and May monitoring events. A 50-60% reduction in particulate nitrogen concentrations was observed between the May and June events.

In general, measured concentrations of total nitrogen appeared to exhibit a trend similar to the trends observed for dissolved organic and particulate nitrogen since these are the dominant nitrogen species present during most events. Total nitrogen concentrations increased steadily from May-June 2015, reaching peak concentrations during the May event, ranging from 1,631-2,075 μg/l, reflecting substantially elevated values. The vast majority of the elevated total nitrogen concentrations observed during the May 2015 event were a result of particulate nitrogen. Similar to the trends observed for particulate nitrogen, total nitrogen decreased by 50-60% between the May and June monitoring events.

2.3.2.2 Phosphorus Species

In general, a high degree of variability was observed in measured concentrations for all phosphorus species between the five surface water monitoring events. Measured concentrations of soluble reactive phosphorus (SRP) during January 2015 ranged from 131-149 μg/l in the surface (top) samples, reflecting extremely elevated values. SRP concentrations decreased slightly during the February monitoring event, with values ranging from 96-115 μg/l. However, a substantial increase in SRP concentrations was observed during the March 2015 event, with measured SRP values ranging from 459-579 μg/l, reflecting extremely elevated values for a freshwater system and likely due to discharges of treated effluent from the wastewater treatment plant located on Sweetwater Creek. SRP concentrations decreased by approximately 1-2 orders of magnitude during May 2015 to values more commonly observed in urban lakes. A 10-fold increase in SRP concentrations was observed at most sites between the May and June monitoring events.

Unlike the trends observed for dissolved organic nitrogen, concentrations of dissolved organic phosphorus were highly variable throughout the field monitoring program. Measured concentrations of dissolved organic phosphorus were relatively similar in value during January and February 2015, with typical values less than approximately 20 μg/l. However, substantial increases in dissolved organic phosphorus occurred within Sweetwater Cove during March 2015, with approximately a 10-fold increase in concentrations at most sites. The observed increases in both SRP and dissolved organic phosphorus during March 2015 suggest a significant influx of phosphorus loadings into the lake which may be related to discharges from the wastewater treatment plant located on Sweetwater Creek upstream of the upper lobe. Measured concentrations of dissolved organic phosphorus decreased during the May 2015 event although the measured values were still approximately 2-4 times higher than observed during January and February. Concentrations of dissolved organic phosphorus further decreased during the June 2015 monitoring event to values equal to or less than measurements observed during January and February.

A relatively high degree of variability was also observed in concentrations of particulate phosphorus in Sweetwater Cove. In general, trends in particulate phosphorus in Sweetwater Cove appear to mimic the trends observed for particulate nitrogen. Relatively low levels of particulate nitrogen were observed during the January and February monitoring events and correspond with the relatively low degree of algal productivity within the lake at that time. However, substantial increases in particulate phosphorus were observed during March, with additional increases observed during May 2015, both of which correspond to increases in both particulate nitrogen and chlorophyll-a. Particulate phosphorus concentrations decreased during the June 2015 monitoring event, corresponding to decreases in particulate nitrogen and chlorophyll-a.

Overall, measured concentrations of total phosphorus were also highly variable during the field monitoring program. Concentrations of total phosphorus were relatively similar during the January and February monitoring events, with most measured concentrations ranging from approximately 130-180 mg/l. Values in this range are extremely elevated and 5-10 times greater than total phosphorus concentrations typically observed in urban lakes. A substantial increase in total phosphorus was observed during March 2015 primarily as a result of increases in SRP. Concentrations of total phosphorus decreased during May in contrast to the observed substantial increase in total nitrogen. The dominant phosphorus form during the May event was particulate phosphorus which corresponds to the elevated chlorophyll-a values also measured on this date. During June 2015, total phosphorus concentrations decreased to values of approximately 80-110 μg/l which, although still substantially elevated in value, were the lowest values measured in lower Sweetwater Cove during this monitoring program.

2.3.3 Chlorophyll-a

In general, measured concentrations of chlorophyll-a observed patterns similar to the patterns previously described for total nitrogen and total phosphorus. Low to moderate levels of chlorophyll-a values were observed in lower Sweetwater Cove during January and February 2015. Chlorophyll-a concentrations increased within the lake during March 2015, particularly at Site 1. However, an additional substantial increase in chlorophyll-a concentrations was observed during the May 2015 event, with measured values ranging from approximately 117-236 mg/m^3, reflecting extremely elevated values similar to concentrations typically measured in Lake Jesup and Lake Apopka. However, during June 2015, chlorophyll-a concentrations decreased substantially within lower Sweetwater Cove, approaching the lower values observed during January and February.

2.3.4 Nutrient Limitation

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

Calculated TN/TP ratios are included in Table 2-3 for each of the samples collected during the field monitoring program. In general, the vast majority of calculated TN/TP ratios are less than 10, suggesting nitrogen-limited conditions within Sweetwater Cove throughout the field monitoring program. However, for lower Sweetwater Cove, the calculated TN/TP ratios provide an incorrect representation of nutrient dynamics within the lake. Of the five surface water monitoring events conducted in lower Sweetwater Cove, limiting concentrations of ammonia and NO_x were observed only during the May and June events, with more than adequate concentrations of inorganic nitrogen present during June, February, and March. In lower Sweetwater Cove, the low calculated TN/TP ratios are not a result of low availability of nitrogen but appear to be more related to elevated concentrations of total phosphorus in the denominator of the ratio which results in an artificially low nutrient ratio calculation. In addition, true nitrogen limitation may not be possible in lakes dominated by nitrogen-fixing cyanobacteria since these species can supplement water column concentrations of inorganic nitrogen by fixing nitrogen from the atmosphere. Therefore, the low observed TN/TP ratios in Sweetwater Cove more likely suggest that water column concentrations of total phosphorus (denominator) are too high rather than total nitrogen concentrations (numerator) being too low and reductions in primary productivity are best achieved by controlling concentrations of total phosphorus rather than total nitrogen.

2.3.5 Trophic State Index

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

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

TSI is a summary statistic which incorporates measured concentrations of significant parameters in lake systems and is often considered the best overall indicator of the health of a lake system. Calculated TSI values less than 50 indicate oligotrophic conditions, representing lakes with low nutrient loadings and good to excellent water quality characteristics. Calculated TSI values from 50-60 indicate mesotrophic or fair water quality characteristics. Calculated TSI values between 60-70 indicate eutrophic or poor water quality characteristics, with hypereutrophic conditions, reflecting very poor water quality, indicated by TSI values in excess of 70.

TSI values were calculated for each of the individual samples collected in Sweetwater Cove during the field monitoring program are provided in the final column of Table 2-3. TSI values in Sweetwater Cove were highly variable during the field monitoring program, ranging from oligotrophic to extremely hypereutrophic conditions. However, the TSI value only measures biological productivity of algae suspended in the water column of the lake. Since a large portion of the algal productivity in lower Sweetwater Cove occurs as a result of benthic algae and floating algal mats, neither of which are included in chlorophyll measurements of water column samples, the TSI values do not provide a correct reflection of actual algal productivity in Sweetwater Cove. It appears obvious from the abundant growth of benthic and floating algal species (such as Lyngbya) that Sweetwater Cove is clearly a hypereutrophic waterbody throughout most of the year in spite of the calculated TSI values in Table 2-3.

2.4 Vertical Variability in Water Quality Characteristics

Separate samples were collected from surface and bottom portions of the water column at each of the four monitoring sites in lower Sweetwater Cove during each of the five individual monitoring events to evaluate vertical variability in water quality characteristics. A summary of overall geometric mean values for top and bottom samples collected in lower Sweetwater Cove from January-June 2015 is given on Table 2-4. The values summarized in Table 2-4 reflect the overall geometric mean values for all top and bottom samples collected at each of the four monitoring sites during the five monitoring events.

In general, measured water quality characteristics at the four monitoring sites appear to be relatively similar for the top and bottom samples. The bottom samples were characterized by slightly lower values for pH which is typical in urban lakes. However, no consistent trend of higher or lower concentrations in bottom samples were observed for pH, alkalinity, or conductivity.

No significant trends of either higher or lower concentrations were observed in bottom samples for either ammonia or NO_x. However, measured bottom concentrations of dissolved organic nitrogen and particulate nitrogen were greater in value than surface measurements at 3 of the 4 monitoring sites. A similar pattern was also observed for total nitrogen, with slightly higher concentrations measured in bottom samples compared with surface samples at 3 of the 4 sites. Similar trends were also observed for phosphorus species, with higher concentrations of SRP measured in bottom samples at 3 of the 4 monitoring sites and for dissolved organic phosphorus at 2 of the 4 monitoring sites. However, overall, measured concentrations of total phosphorus in bottom samples were slightly higher in value than concentrations measured in surface samples at each of the four sites. The observed increases in total phosphorus in the bottom samples were generally minimal, with less than 5% difference in overall geometric mean concentrations between top and bottom sites.

TABLE 2-4

OVERALL GEOMETRIC MEAN VALUES FOR TOP AND BOTTOM SAMPLES COLLECTED IN LOWER SWEETWATER COVE FROM JANUARY – JUNE 2015

PARAMETER	UNITS	SITE							
		1		2		3		4	
		Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom
pH	s.u.	7.60	7.45	7.66	7.47	7.58	7.45	7.39	7.51
Alkalinity	mg/l	88.0	88.1	90.2	86.4	88.6	89.5	93.2	92.6
Conductivity	μmho/cm	362	363	368	367	373	370	360	363
Ammonia	μg/l	41	35	34	27	42	44	60	48
NO_x	μg/l	28	29	51	50	68	66	41	39
Diss. Organic Nitrogen	μg/l	458	493	495	496	522	528	549	530
Particulate Nitrogen	μg/l	200	277	225	278	253	156	270	347
Total Nitrogen	μg/l	967	1,017	1,054	1,130	1,239	1,119	1,184	1,211
SRP	μg/l	76	96	75	80	77	80	74	68
Diss. Organic Phosphorus	μg/l	27	23	28	45	21	28	56	34
Particulate Phosphorus	μg/l	33	49	39	39	43	40	48	63
Total Phosphorus	μg/l	274	283	249	293	264	279	279	283
Turbidity	NTU	3	3	5	5	5	4	4	6
Color	Pt-Co	40	43	41	42	41	42	41	42
Chlorophyll-a	mg/m^3	27.1	31.0	12.6	16.8	8.0	14.6	18.1	27.8

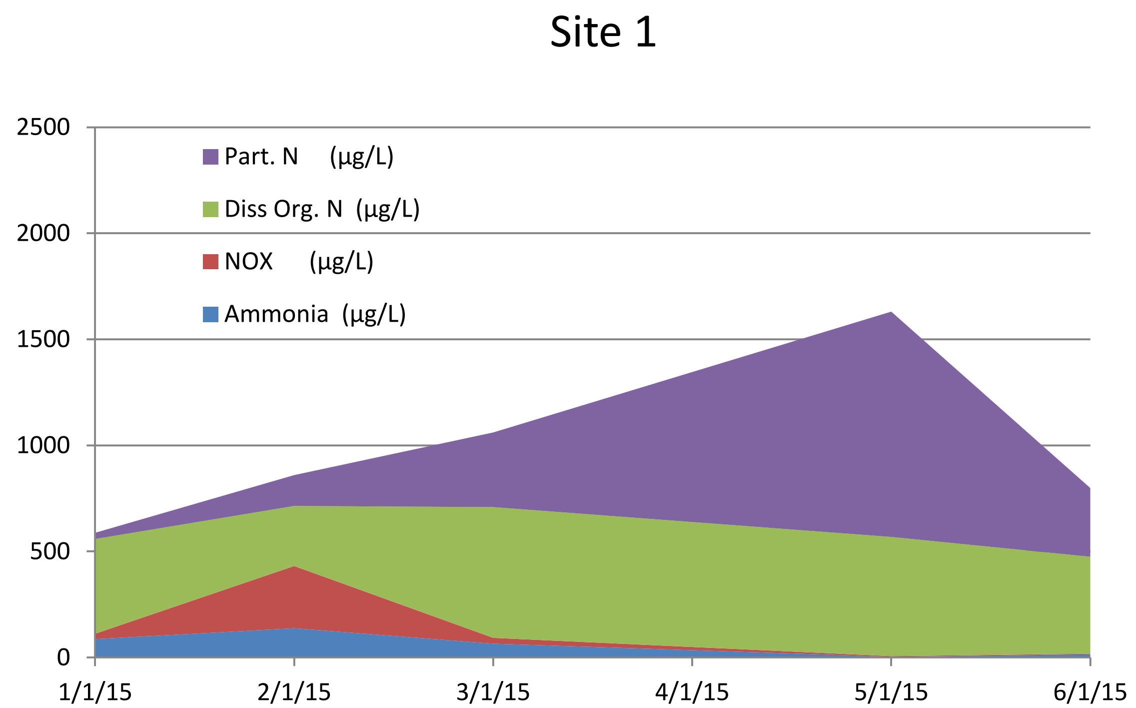
No significant differences were observed for concentrations of either turbidity or color between top and bottom samples at any of the four monitoring sites. In contrast, chlorophyll-a concentrations were consistently higher in bottom samples than observed in top samples at each of the four sites. Differences in measured concentrations of chlorophyll-a between top and bottom samples were greater in magnitude than the observed differences for other parameters listed previously.

Overall, with the possible exception of chlorophyll-a, no significant vertical variability was observed in water quality characteristics in lower Sweetwater Cove during the field monitoring program. This finding is not surprising due to the shallow water depth within the lower lobe and the relatively consistent flow-through of water from upstream lakes. No significant horizontal variability in water quality characteristics was observed in lower Sweetwater Cove for any of the measured nutrient species.

2.5 Temporal Variability

A graphical summary of temporal variability in measured forms of nitrogen in lower Sweetwater Cove from January-June 2015 is given on Figure 2-6. During the initial two months of the field monitoring program (January-February), the dominant nitrogen forms at each of the four monitoring sites were NO_x and dissolved organic nitrogen. Concentrations of NO_x decreased in value at most sites during March 2015, with a corresponding increase in dissolved organic nitrogen. During the May 2015 monitoring event, the dominant nitrogen species within the lake was particulate nitrogen which was comprised primarily of algal cells produced during the heavy algal bloom observed at this time. Measured concentrations of ammonia, NO_x, and particulate nitrogen decreased at each site during June, with the dominant species at this time being dissolved organic nitrogen.

A graphical summary of temporal variability in measured forms of phosphorus in lower Sweetwater Cove from January-June 2015 is given on Figure 2-7. SRP was the dominant phosphorus species within the lake during January, February, and March, representing 75-95% of the phosphorus present during these three monitoring events. However, SRP concentrations decreased substantially during May, presumably as a result of phosphorus uptake from the large algal bloom present during this event. This decrease in SRP resulted in a corresponding decrease in total phosphorus. The dominant phosphorus species during the May 2015 monitoring event was particulate phosphorus which reflected phosphorus in the cells of algae. A slight increase in SRP, combined with a decrease in particulate phosphorus, was observed during the June monitoring event.



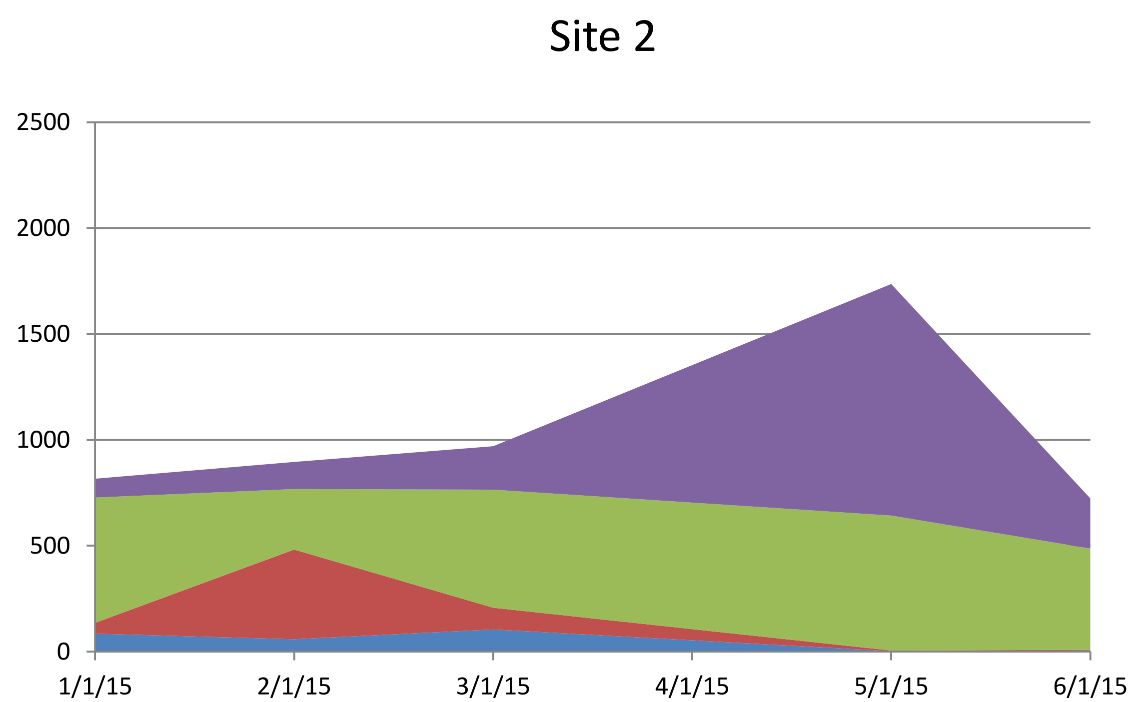
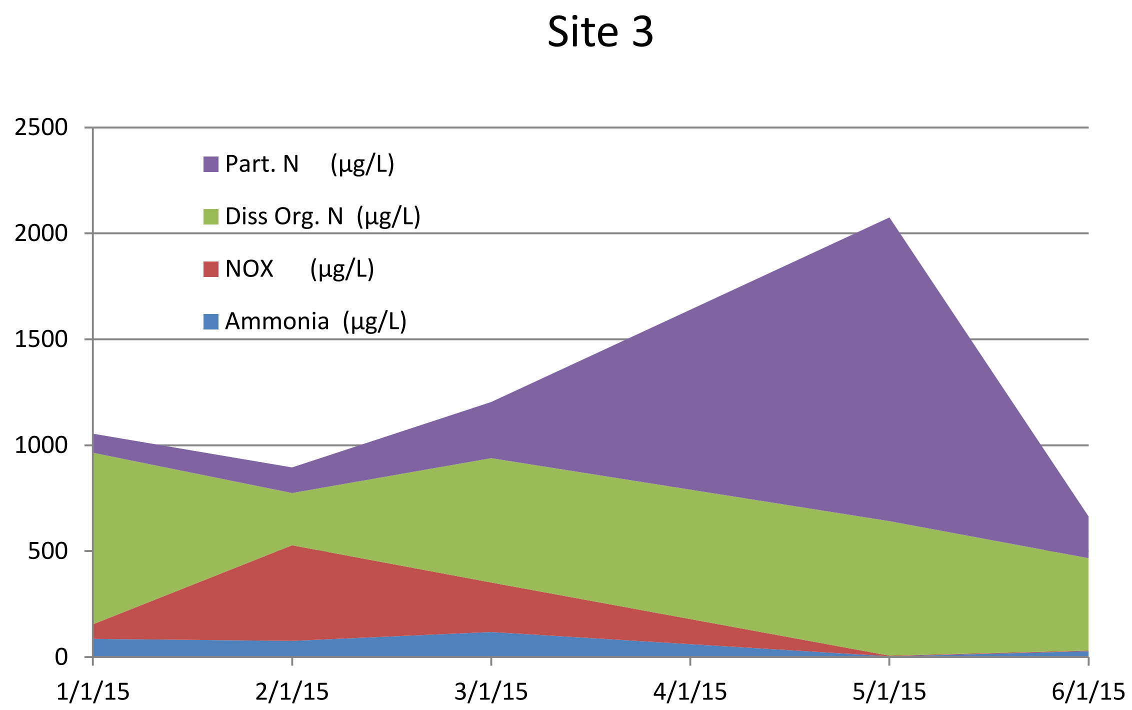


Figure 2-6. Temporal Variability in Measured Forms of Nitrogen in Lower Sweetwater Cove from January-June 2015.



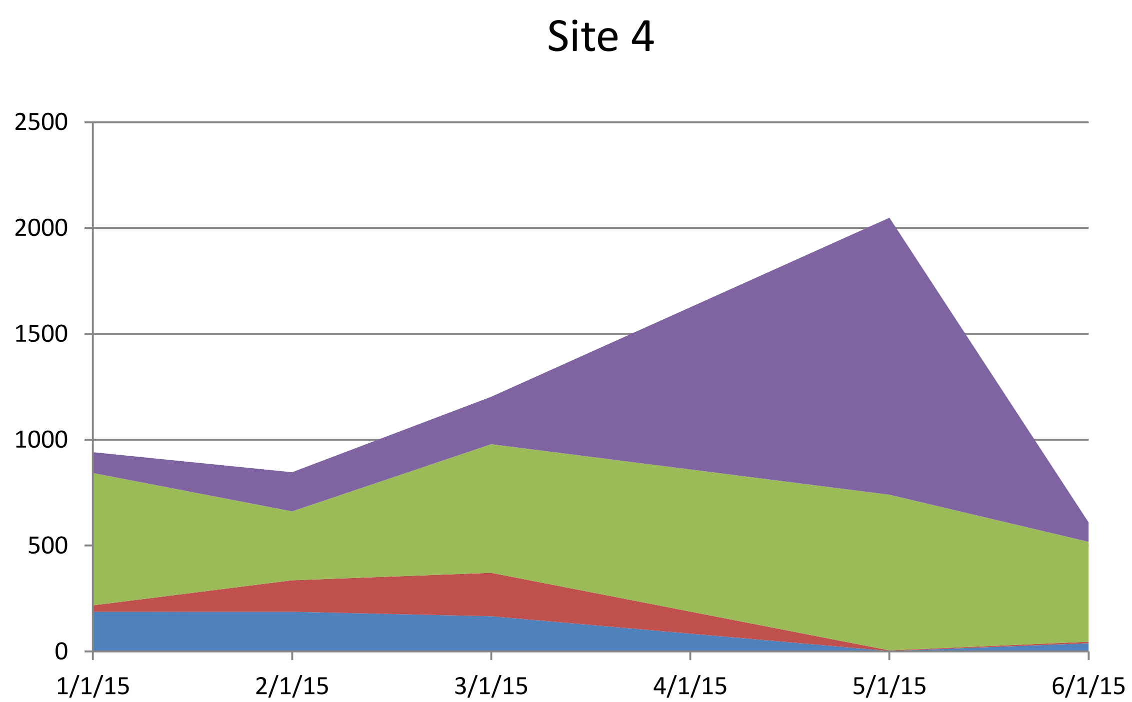
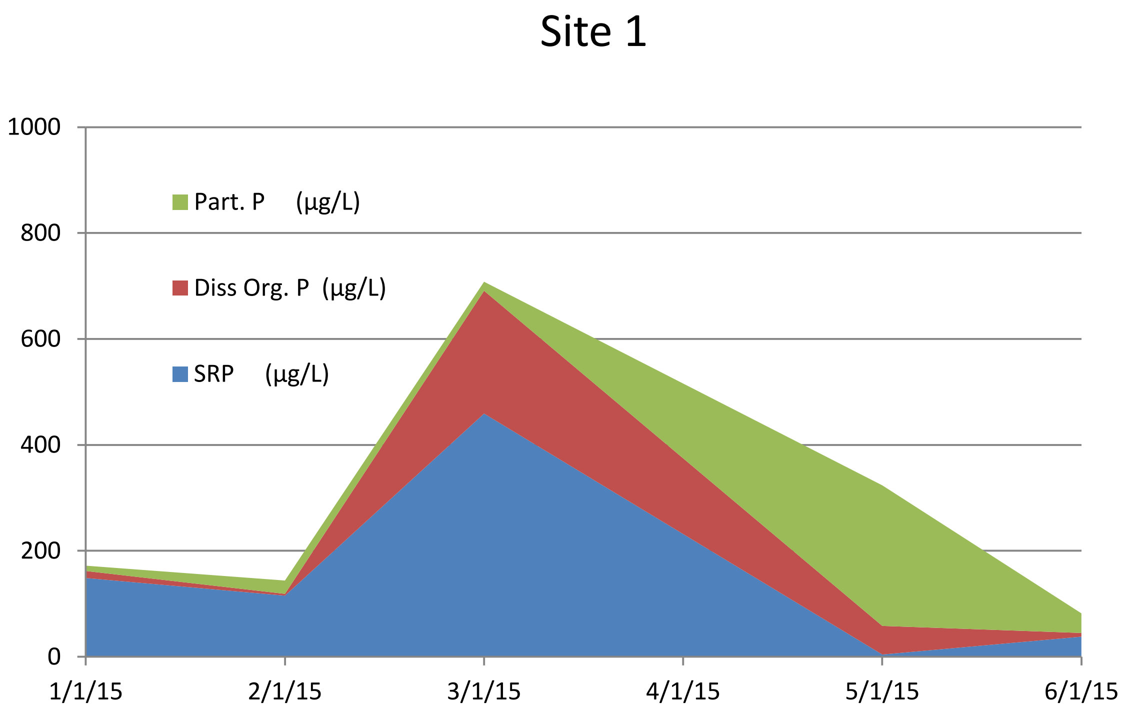


Figure 2-6. (Continued) Temporal Variability in Measured Forms of Nitrogen in Lower Sweetwater Cove from January-June 2015.



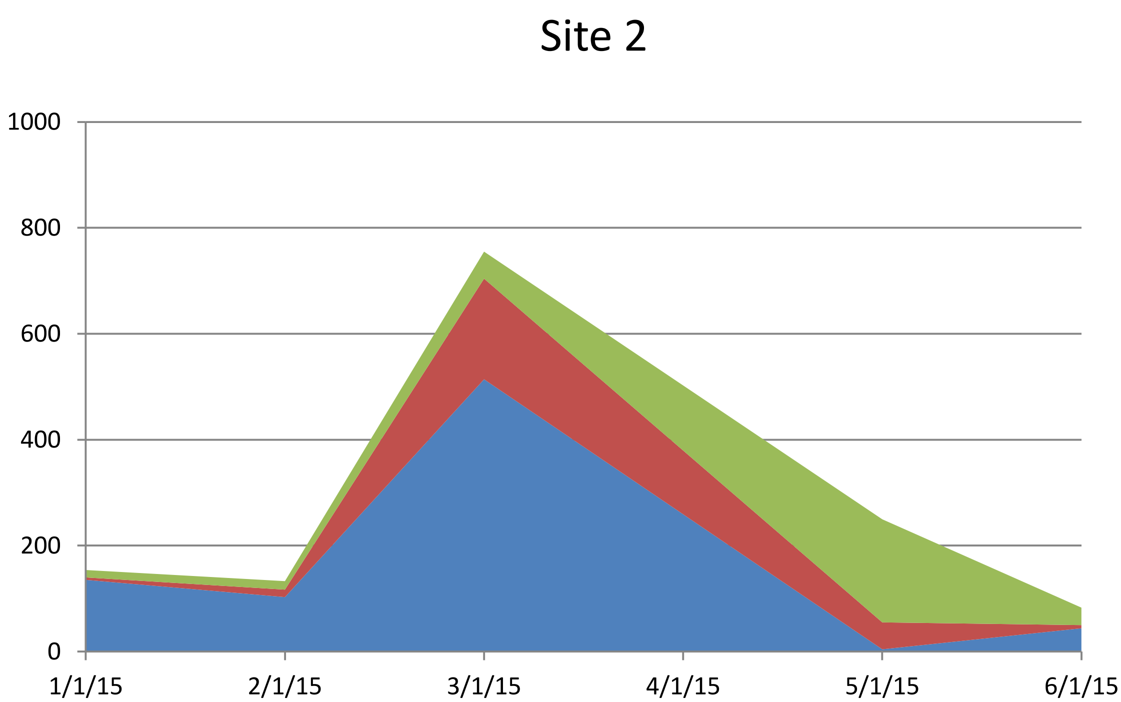
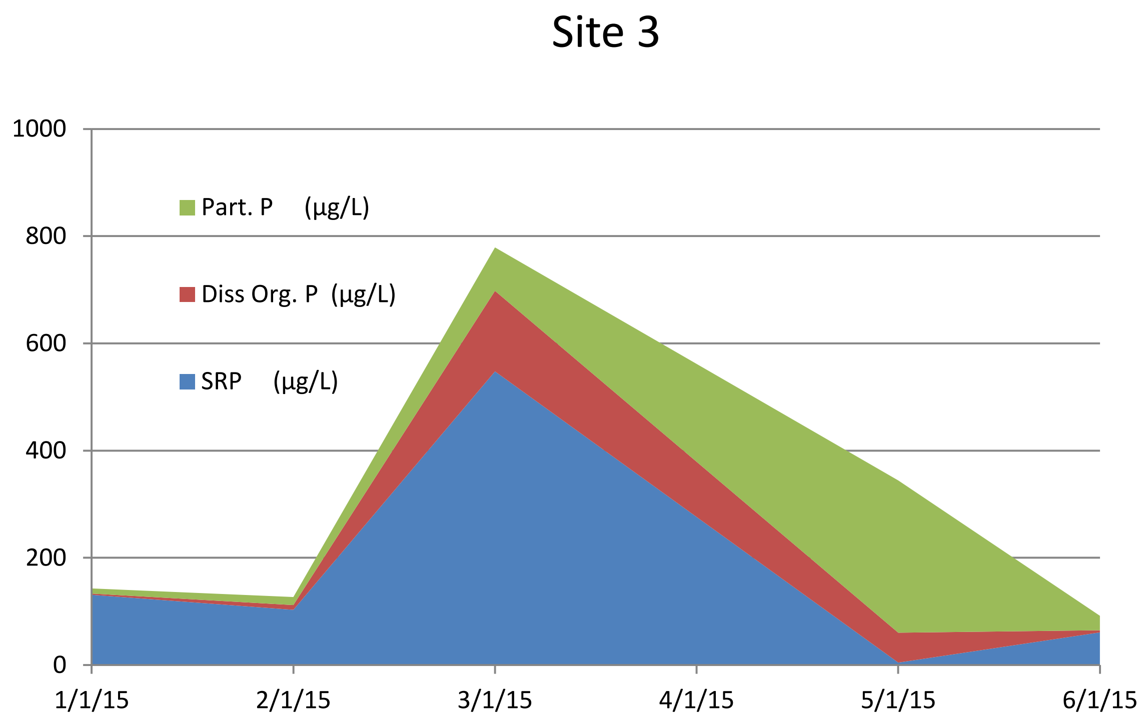


Figure 2-7. Temporal Variability in Measured Forms of Phosphorus in Lower Sweetwater Cove from January-June 2015.



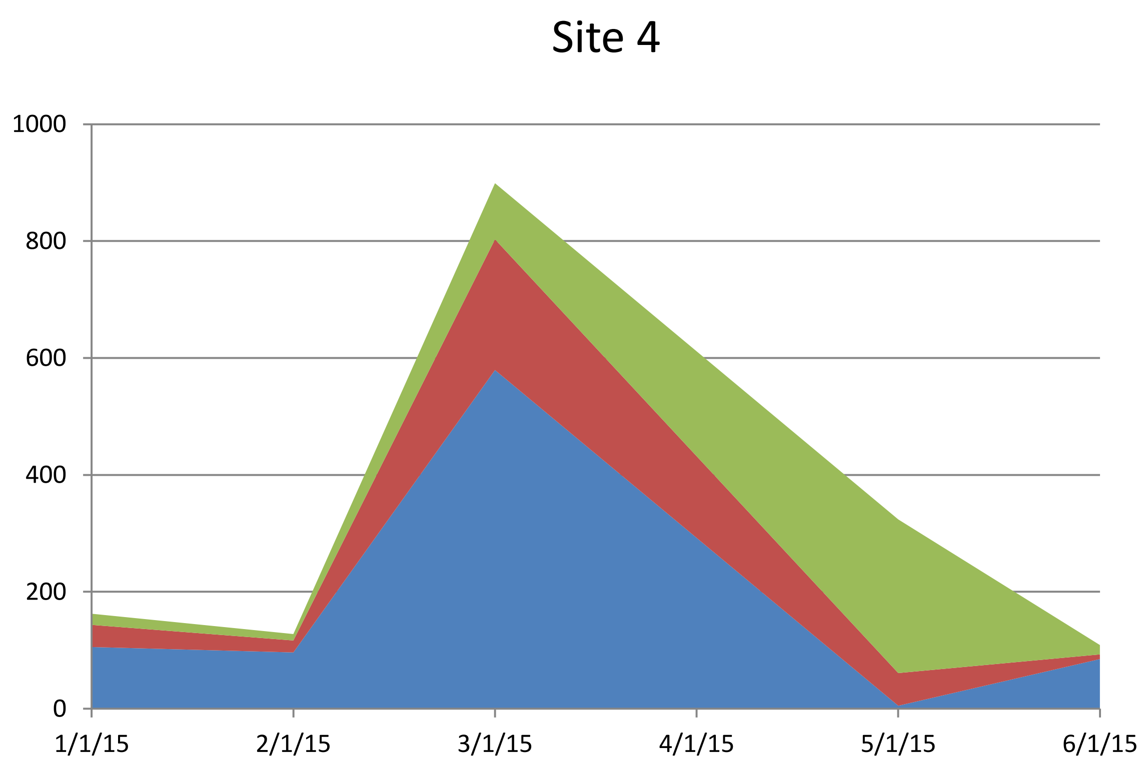


Figure 2-7. (Continued) Temporal Variability in Measured Forms of Phosphorus in Lower Sweetwater Cove from January-June 2015.

SECTION 3

CHARACTERISTICS OF SEDIMENTS IN THE LOWER LOBE OF SWEETWATER COVE LAKE

Sediment core samples were collected by ERD in the lower lobe of Sweetwater Cove Lake to evaluate the characteristics of existing sediments and potential impacts on water quality within the lake. Sediment core samples were collected at 20 separate locations within the lower lobe on January 7, 2015. Locations of sediment monitoring sites in the west half of the lower lobe of Sweetwater Cove Lake are indicated on Figure 3-1, with monitoring sites in the east half indicated on Figure 3-2. Based on the lake surface area of 4.55 acres, sediment samples were collected at an average rate of one sample for every 0.46 acres of lake area.

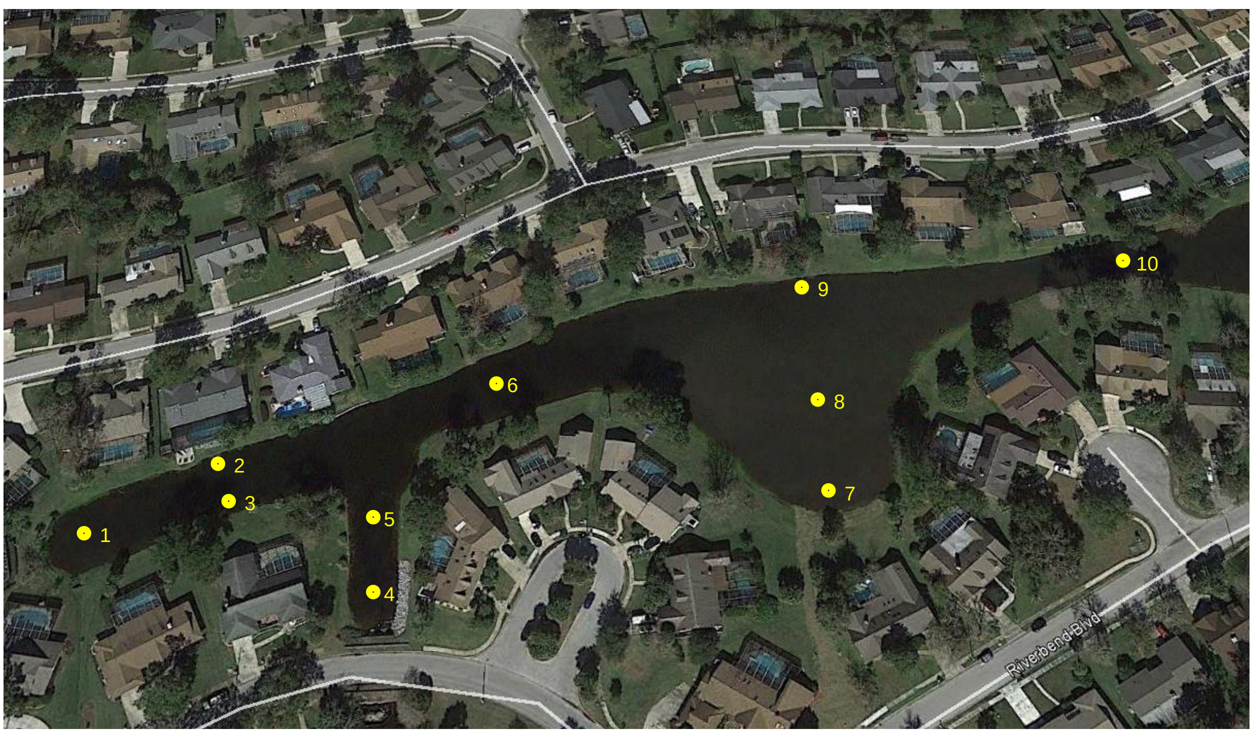


Figure 3-1. Locations of Sediment Monitoring Sites in the West Half of the Lower Lobe of Sweetwater Cove Lake.

Figure 3-2. Locations of Sediment Monitoring Sites in the East Half of the Lower Lobe of Sweetwater Cove Lake.

3.1 Sampling Techniques

Sediment samples were collected at each of the 20 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 20 monitoring sites. The polyethylene containers utilized for storage of the collected samples were filled completely to minimize air space in the storage container above the sediment sample. The collected samples were stored on ice and returned to the ERD laboratory for physical and chemical characterization.

3.2 Sediment Characterization and Speciation Techniques

Each of the 20 sediment core samples was analyzed for a variety of general parameters and nutrients, 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 3-1.

TABLE 3-1

ANALYTICAL METHODS FOR SEDIMENT ANALYSES

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

*REFERENCES:

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

In addition to general sediment characterization, a fractionation procedure for inorganic soil phosphorus was conducted on each of the 20 collected sediment samples. The modified Chang and Jackson Procedure, as proposed by Peterson and Corey (1966), was used for phosphorus fractionation. The Chang and Jackson Procedure allows the speciation of sediment phosphorus 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 organic fractions.

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 3-3.

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.

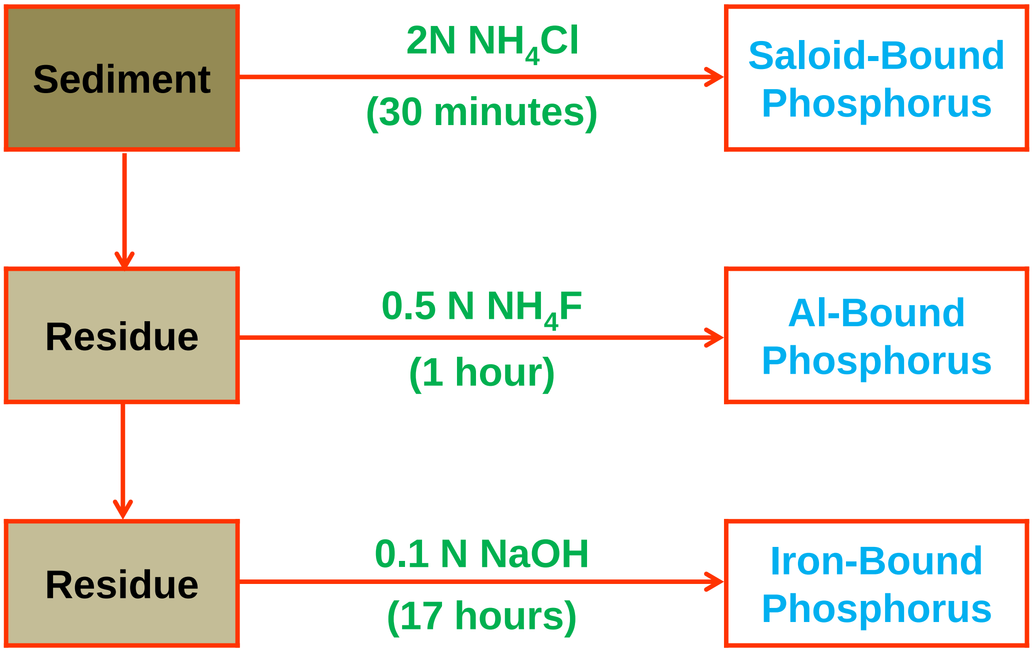


Figure 3-3. Schematic of Chang and Jackson Speciation Procedure for Evaluating Soil Phosphorus Bonding.

3.3 Sediment Characteristics

3.3.1 Visual Characteristics

Visual characteristics of sediment core samples were recorded for each of the 20 sediment samples collected in the lower lobe of Sweetwater Cove Lake on January 7, 2015. A summary of visual characteristics of sediment core samples is given in Table 3-2. In general, a surficial layer of unconsolidated organic muck was observed in the lower lobe at 18 of the 20 monitoring sites, with measured muck depths ranging from 3-41 cm. This unconsolidated surficial layer is 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. Consolidated organic muck, comprised of recalcitrant organic matter and commonly observed in urban lake sediments below the unconsolidated organic muck, was not observed in the lower lobe, possibly due to the age of the waterbody and periodic desiccation events. Layers beneath the organic muck consist of various types of light to brown fine sand which is the parent soil layer which forms the original lake bottom. Photographs of sediment characteristics in the lower lobe of Sweetwater Cove Lake are given in Figure 3-4. Evidence of iron deposits is visible in several of the core photographs.

TABLE 3-2

VISUAL CHARACTERISTICS OF SEDIMENT CORE SAMPLES COLLECTED IN THE LOWER LOBE OF SWEETWATER COVE LAKE ON JANUARY 7, 2015

SITE	TIME	LAYER (cm)	VISUAL APPEARANCE
1	11:53	0 – 25 25 - >41	Dark brown unconsolidated organic muck Fine brown sand with organics
2	11:46	0 – 16 16 - >22	Dark brown unconsolidated organic muck Fine brown sand with organics
3	11:40	0 – 3 3 – 17 17 - >19	Dark brown unconsolidated organic muck Fine brown sand with organics Light brown fine sand
4	11:34	0 – 15 15 - >31	Dark brown unconsolidated organic muck with detritus Fine brown sand with organics
5	11:26	0 – 3 3 - >12	Dark brown unconsolidated organic muck Fine brown sand with organics
6	11:18	0 – 29 > 29	Dark brown unconsolidated organic muck Light brown hard sand
7	11:10	0 – 13 13 - >21	Dark brown unconsolidated organic muck Fine brown sand with organics
8	11:04	0 – 4 4 - >13	Dark brown unconsolidated organic muck Fine brown sand with organics
9	10:58	0 – 2 2 - >21	Dark brown unconsolidated organic muck Fine brown sand with organics
10	10:51	0 – 18 18 - >26	Dark brown unconsolidated organic muck Light brown fine sand
11	10:41	0 – 2 2 - >11	Dark brown unconsolidated organic muck Fine brown sand with organics
12	10:35	0 – 41 41 - >48	Dark brown unconsolidated organic muck Fine brown sand with organics
13	10:28	0 – 4 4 - >12	Dark brown unconsolidated organic muck Fine brown sand with organics
14	10:13	0 – 31 31 – 49 49 - >56	Dark brown unconsolidated organic muck Fine brown sand with organics Light brown fine sand
15	9:56	0 – 8 8 - >14	Dark brown unconsolidated organic muck Light brown fine sand
16	9:50	0 – 6 6 - >20	Dark brown unconsolidated organic muck Light brown fine sand
17	9:40	0 – 5 5 – 10 10 - >24	Fine brown sand with organics Dark brown unconsolidated organic muck with algae Fine brown sand with organics
18	10:21	0 – 12 12 - >25	Dark brown unconsolidated organic muck Light brown fine sand
19	9:37	0 - >12	Fine brown sand with organics
20	9:24	0 - >16	Fine brown sand with organics

Site 1

Site 2

Site 3

Site 4

Site 5

Site 6

Figure 3-4. Photographs of Sediment Core Samples Collected in the Lower Lobe of Sweetwater Cove Lake on January 7, 2015.

Site 7

Site 8

Site 9

Site 10

Site 11

Site 12

Figure 3-4. (Continued) Photographs of Sediment Core Samples Collected in the Lower Lobe of Sweetwater Cove Lake on January 7, 2015.

Site 13

Site 14

Site 15

Site 16

Site 17

Site 18

Figure 3-4. (Continued) Photographs of Sediment Core Samples Collected in the Lower Lobe of Sweetwater Cove Lake on January 7, 2015.

Site 19

Site 20

Figure 3-4. (Continued) Photographs of Sediment Core Samples Collected in the Lower Lobe of Sweetwater Cove Lake on January 7, 2015.

3.3.2 General Sediment Characteristics

After return to the ERD Laboratory, the collected sediment core samples were evaluated for general sediment characteristics and nutrients, including pH, moisture content, organic content, sediment density, total nitrogen, and total phosphorus. A summary of characteristics measured in each of the 20 collected sediment core samples is given in Table 3-3. Isopleth maps of sediment characteristics were developed for the lower lobe for each of the measured sediment parameters. However, due to the linear shape of the lower lobe, some of the contour plots exhibit somewhat unusual shapes.

In general, sediments in the lower lobe were found to be slightly acidic in pH, with measured pH values ranging from 5.97-6.96 and a geometric mean value of 6.70. These values are typical of pH measurements commonly observed in eutrophic urban lakes. Isopleths of pH in the top 10 cm of sediments in the lower lobe are illustrated on Figure 3-5, based upon the information provided in Table 3-3. The majority of areas within the lower lobe are characterized by pH values ranging from approximately 6.1-6.9. Somewhat lower pH values were observed in the eastern portion of the lake, with measured pH values ranging from approximately 6.1-6.5.

Measurements of sediment moisture content and organic content in the lower lobe were highly variable throughout the lake. Many of the collected sediment samples are characterized by a relatively high moisture content and organic content, suggesting that these surficial sediments are comprised primarily of organic muck. In contrast, other sediment core samples are characterized by low values for both moisture content and organic content, suggesting areas of primarily sandy sediments.

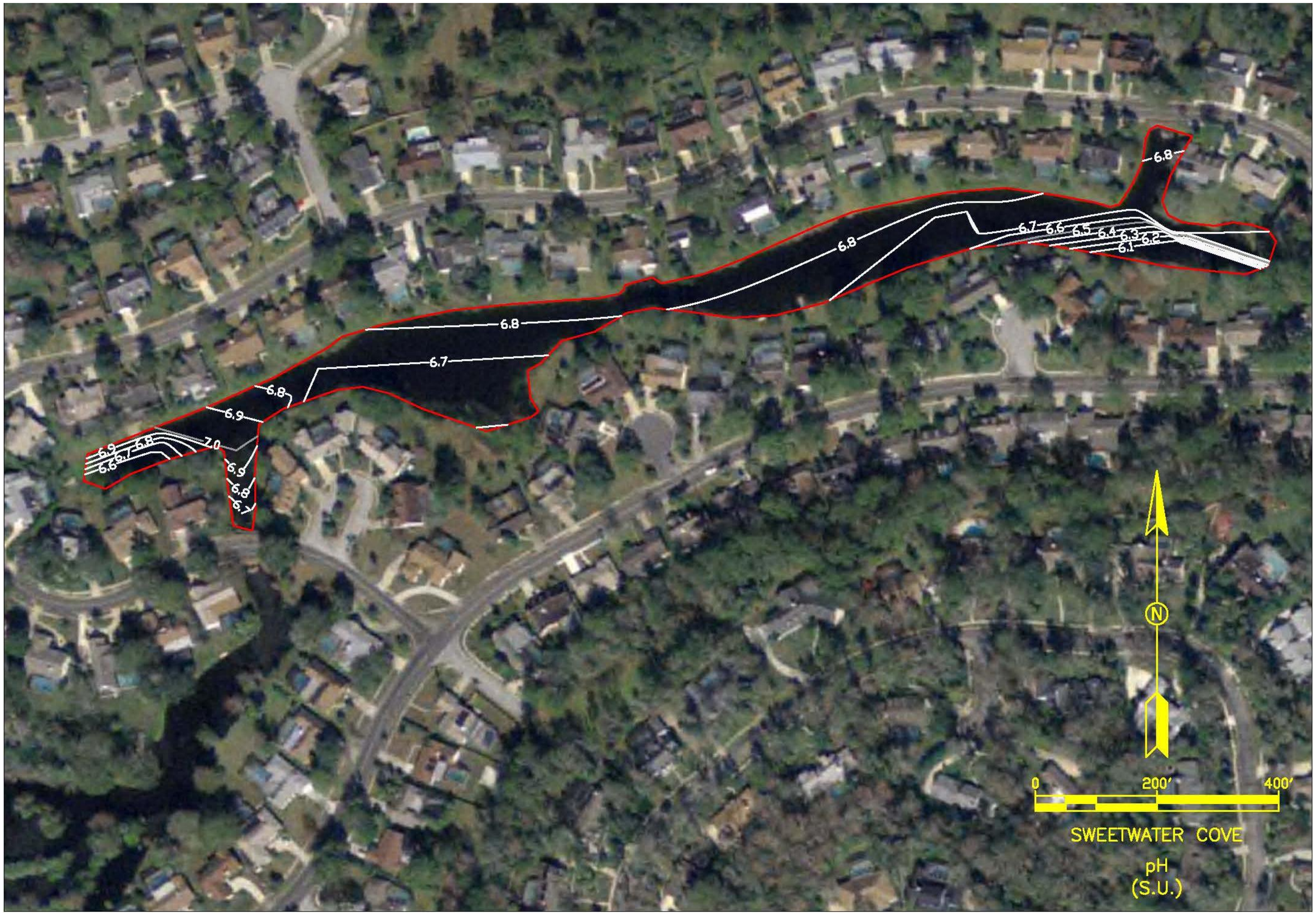


Figure 3-5. Isopleths of pH (s.u.) in the Top 10 cm of Sediments in the Lower Lobe of Sweetwater Cove Lake.

TABLE 3-3

GENERAL CHARACTERISTICS OF SEDIMENT CORE SAMPLES COLLECTED IN THE LOWER LOBE OF SWEETWATER COVE LAKE ON JANUARY 7, 2015

SITE	pH (s.u.)	MOISTURE CONTENT (%)	ORGANIC CONTENT[1] (%)	WET DENSITY (g/cm^3)	TOTAL NITROGEN (μg/cm^3)	TOTAL PHOSPHORUS (μg/cm^3)
1	6.51	85.9	22.1	1.16	1,851	166
2	6.67	53.0	7.0	1.65	872	160
3	6.96	45.9	2.1	1.79	875	99
4	6.65	55.8	6.3	1.62	1,546	374
5	6.95	37.9	3.4	1.90	871	119
6	6.66	73.9	13.2	1.34	1,426	190
7	6.75	73.9	13.2	1.34	1,395	119
8	6.67	63.5	8.3	1.50	505	88
9	6.82	40.2	2.0	1.88	960	96
10	6.84	65.7	8.1	1.47	1,515	225
11	6.74	39.7	1.5	1.89	778	96
12	6.71	86.8	18.8	1.16	1,508	166
13	6.80	40.6	3.2	1.86	1,172	120
14	6.62	92.7	32.3	1.07	1,761	172
15	6.70	48.0	3.2	1.76	986	161
16	6.81	52.5	4.8	1.68	1,058	126
17	6.72	45.9	2.8	1.79	1,056	114
18	6.73	82.0	12.7	1.24	1,702	178
19	5.97	29.5	1.1	2.05	234	64
20	6.73	38.9	2.6	1.89	370	106
Minimum:	**5.97**	**29.5**	**1.1**	**1.07**	**234**	**64**
Maximum:	**6.96**	**92.7**	**32.3**	**2.05**	**1,851**	**374**
Geometric Mean:	**6.70**	**54.7**	**5.5**	**1.57**	**1,005**	**136**

1. Dry wt. basis

Isopleths of sediment moisture content in the lower lobe sediments are illustrated in Figure 3-6 based upon the information provided in Table 3-3. Areas of elevated moisture content (> 50%) are present throughout most of the lower lobe. Sediment moisture contents in excess of 50% are often indicative of highly organic sediments, while moisture contents less than 50% reflect mixtures of sand and muck. Mixtures of muck and sand are located primarily in the primary inflow canal and in the eastern end of the lake.

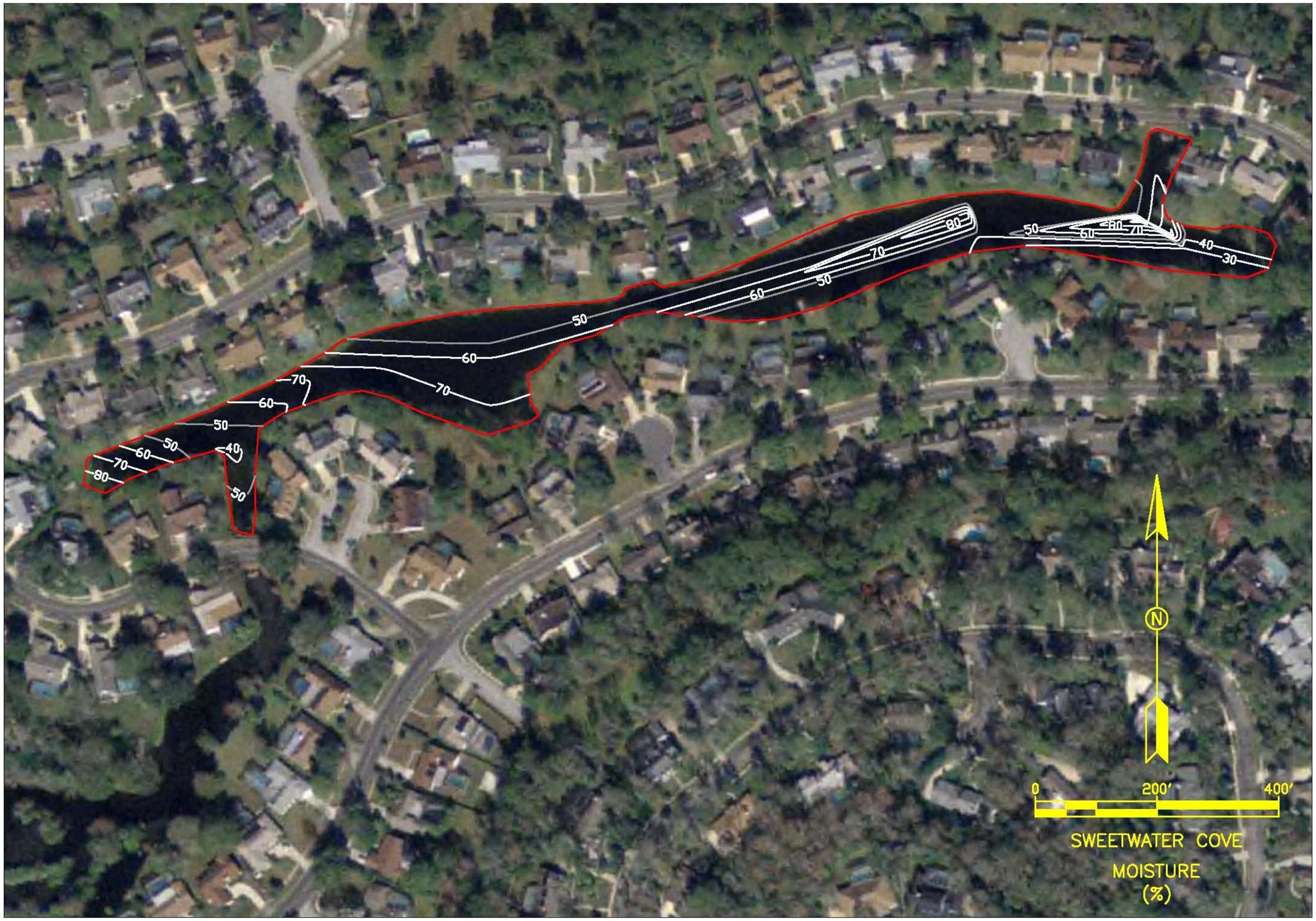


Figure 3-6. Isopleths of Moisture Content (%) in the Top 10 cm of Sediments in the Lower Lobe of Sweetwater Cove Lake.

Isopleths of sediment organic content (dry wt. basis) in the lower lobe are illustrated on Figure 3-7 based upon the information provided in Table 3-3. In general, sediment organic content percentages in excess of 20-30% are often indicative of organic muck type sediments, with values less than 20% representing either sand or mixtures of muck and sand. Based upon these criteria, areas of concentrated organic muck are apparent in both eastern and western portions of the lower lobe. Measured sediment organic content within the lower lobe ranged from 1.1-32.3%, with an overall geometric mean value of 5.5%. Although organic muck was observed at most sites, some of the muck accumulation was relatively thin, and the collected sediment sample contained a mixture of muck and the parent sand layer in the 0-10 cm layer that was collected which resulted in a lower composite organic content.

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 g/cm^3 and 1.25 g/cm^3 are often indicative of organic muck type sediments, while sediment densities of approximately 2.0 g/cm^3 or greater are indicative of sandy sediment conditions. Values between 1.25 g/cm^3 and 2.0 g/cm^3 indicate mixtures of sand and muck. Measured sediment density values in the lower lobe sediments ranged from 1.07-2.05 g/cm^3, with a mean density of 1.57 g/cm^3.

Isopleths of wet density in the lower lobe sediments are given in Figure 3-8. In general, the measured wet density values indicate a mixture of organic muck and sand in many areas of the lower lobe which is consistent with the thin organic sediment layers present throughout the lower lobe.

Measured concentrations of total phosphorus in the lower lobe sediments were found to be highly variable throughout the lake, with values ranging from 64-374 μg/cm^3, and an overall geometric mean value of 136 μg/cm^3. In general, sandy sediments are often characterized by low total phosphorus concentrations, while highly organic muck type sediments are characterized by elevated total phosphorus concentrations.

Isopleths of sediment phosphorus concentrations in the lower lobe of are presented on Figure 3-9, based on information provided in Table 3-3. Areas of elevated sediment phosphorus concentrations are apparent along the primary flow path from the inflow channel to the outfall canal.

Similar to the trends observed for sediment phosphorus concentrations, sediment nitrogen concentrations are also highly variable throughout the lower lobe. Measured sediment nitrogen concentrations in the lake range from 234-1,851 μg/cm^3, with a geometric mean value of 1,005 μg/cm^3. Measured sediment nitrogen concentrations in the lower lobe appear to be similar to values commonly observed in urban lakes.

Isopleths of sediment nitrogen concentrations in the lower lobe are illustrated on Figure 3-10. In general, areas of elevated nitrogen concentrations are similar to the patterns exhibited by total phosphorus, with more elevated concentrations present in areas of accumulated organic muck.

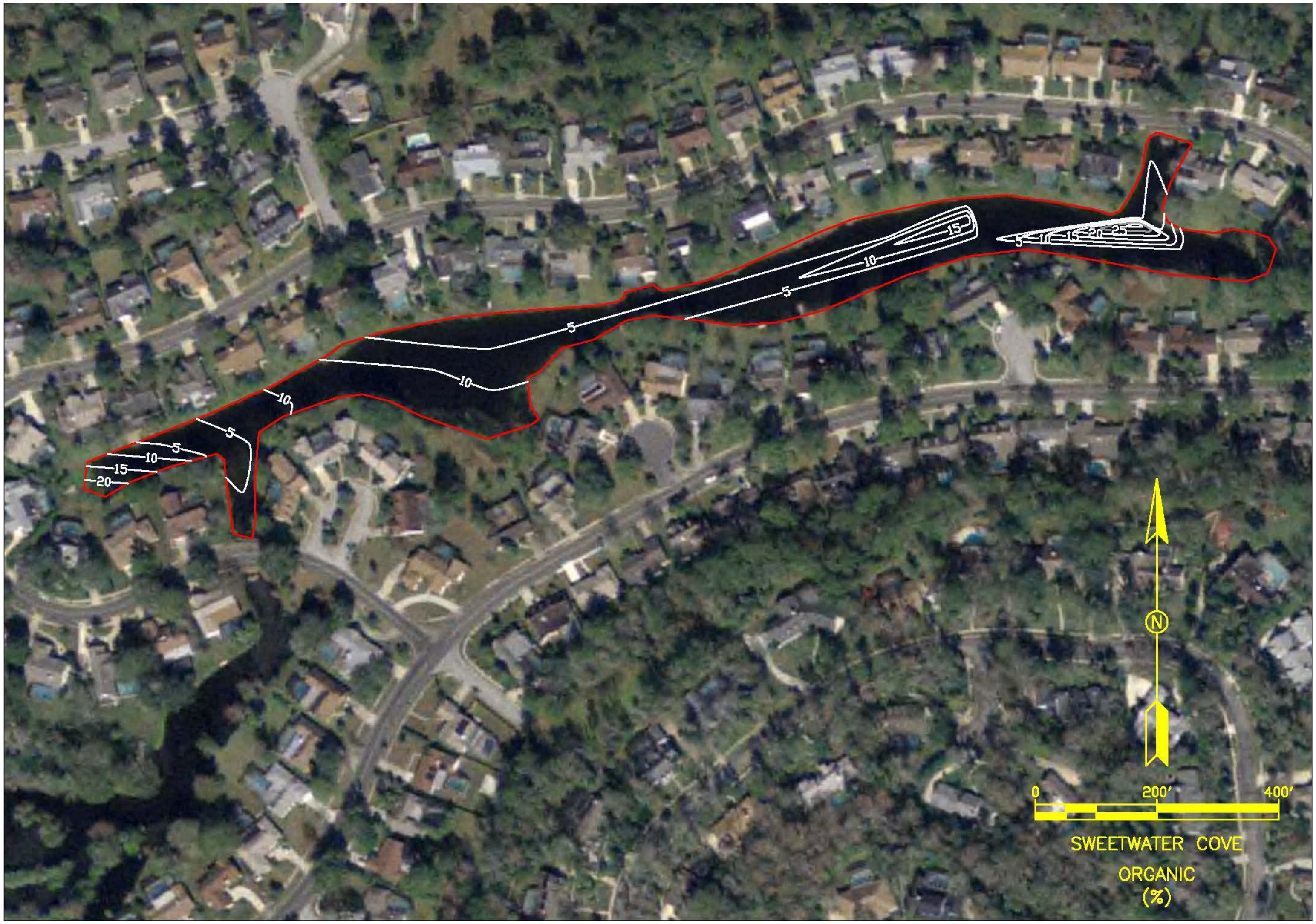


Figure 3-7. Isopleths of Organic Content (% dry wt.) in the Top 10 cm of Sediments in the Lower Lobe of Sweetwater Cove Lake.

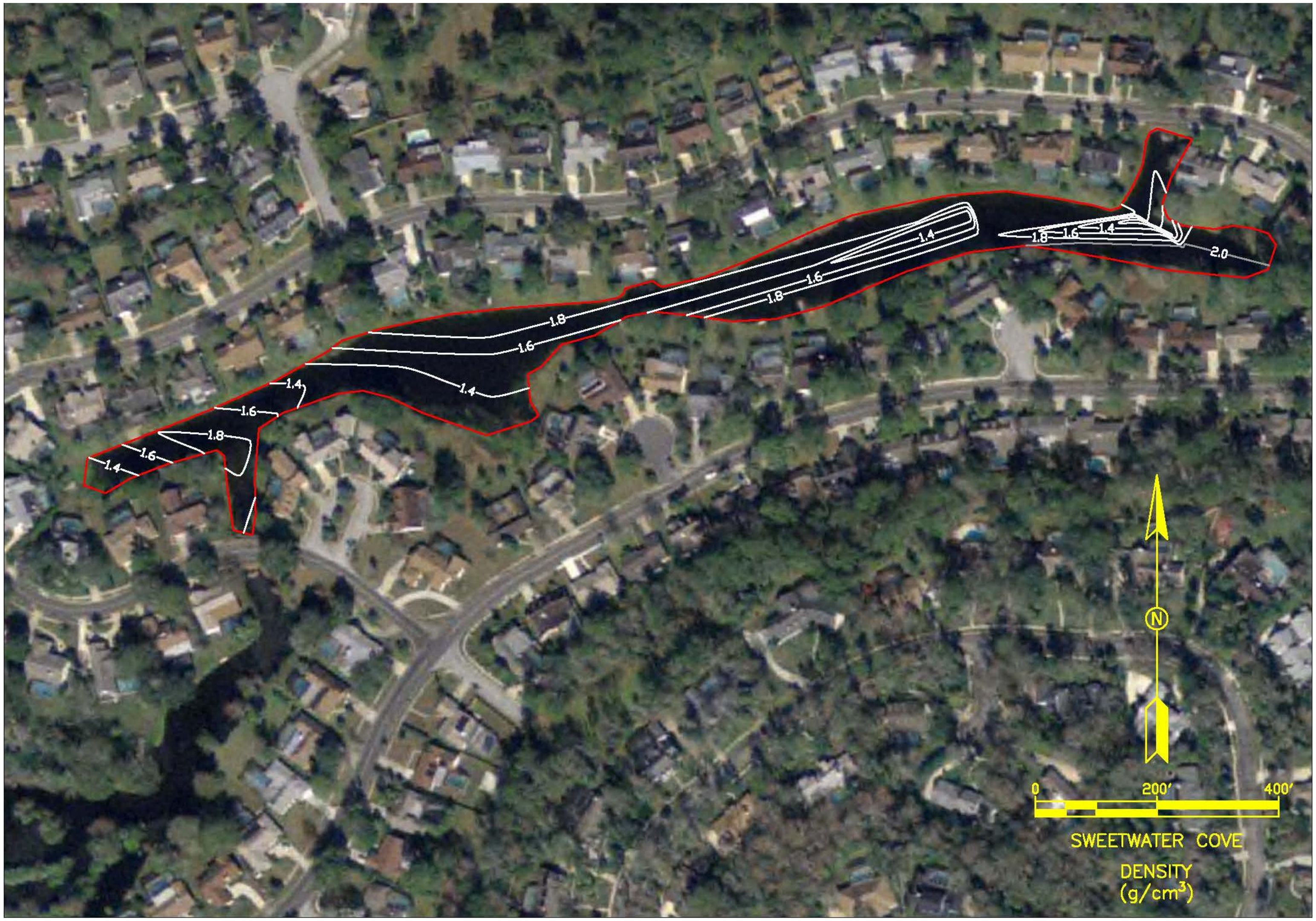


Figure 3-8. Isopleths of Wet Density (g/cm^3) in the Top 10 cm of Sediments in the Lower Lobe of Sweetwater Cove Lake.

Figure 3-9. Isopleths of Total Phosphorus ($\mu g/cm^3$) in the Top 10 cm of Sediments in the Lower Lobe of Sweetwater Cove Lake.

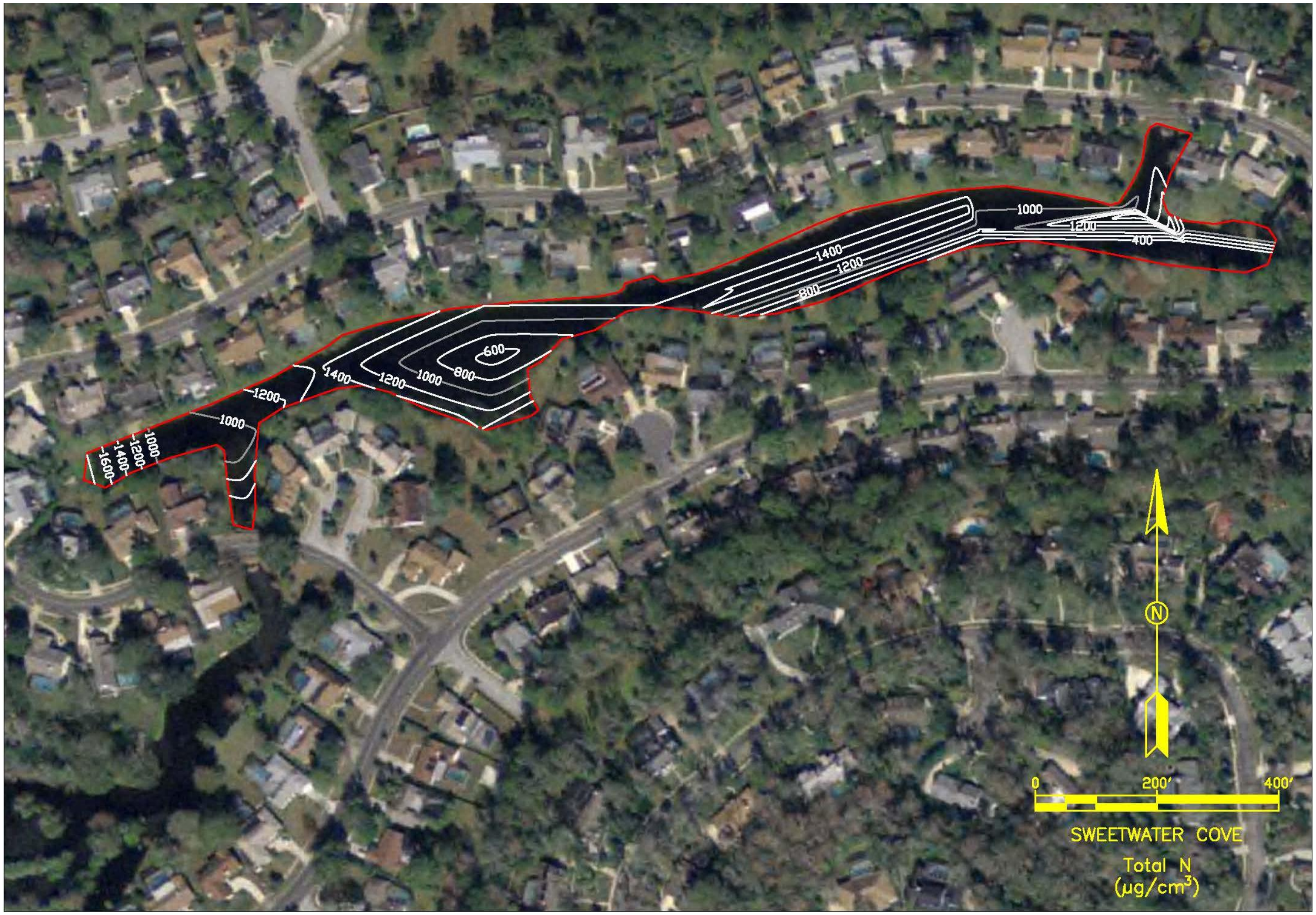


Figure 3-10. Isopleths of Total Nitrogen (µg/cm^3) in the Top 10 cm of Sediments in the Lower Lobe of Sweetwater Cove Lake.

3.3.3 Phosphorus Speciation

As discussed in Section 3.2, each of the collected sediment core samples was evaluated for phosphorus speciation based upon the Chang and Jackson speciation procedure. This procedure allows phosphorus within the sediments to be speciated with respect to bonding mechanisms. This information is useful in evaluating the stability of phosphorus in the sediments and the potential for release of phosphorus under anoxic conditions.

A summary of phosphorus speciation in sediment core samples collected from the lower lobe of Sweetwater Cove Lake during January 2015 is given in Table 3-4. Saloid-bound phosphorus represents sediment phosphorus which is either soluble or easily exchangeable and is typically considered readily available for release from the sediments into the overlying water column. As seen in Table 3-4, saloid-bound phosphorus concentrations range from low to elevated in value throughout the sediments of the lower lobe. Measured values for saloid-bound sediment phosphorus range from 0.2-45.0 $\mu g/cm^3$, with a mean value of 11.3 $\mu g/cm^3$. This value is somewhat higher than saloid-bound concentrations commonly observed by ERD in urban lakes, suggesting a large amount of easily available sediment phosphorus. Isopleths of saloid-bound phosphorus in the top 10 cm of sediments in the lower lobe are illustrated on Figure 3-11. Areas of elevated saloid-bound phosphorus are apparent throughout the lower lobe.

In general, iron-bound phosphorus associations in the sediments of the lower lobe appear to be low to moderate in value. Iron-bound sediment phosphorus is relatively stable under oxidized conditions, but becomes unstable under a reduced environment, causing the iron-phosphorus bonds to separate and release the bound phosphorus directly into the water column. Iron-bound phosphorus concentrations in the sediments of the lower lobe range from 12-62 $\mu g/cm^3$, with a geometric mean value of 28 $\mu g/cm^3$. Since iron-bound phosphorus can be released under anoxic conditions, portions of the lower lobe may have conditions favorable for release of iron-bound sediment phosphorus into the water column throughout much of the year. The mean iron-bound phosphorus concentration of 28 $\mu g/cm^3$ is lower than iron-bound sediment concentrations commonly measured by ERD in urban lakes. Isopleths of iron-bound phosphorus in the sediments of the lower lobe are illustrated on Figure 3-12. Areas of elevated iron-bound phosphorus are present in central and western portions of the lower lobe.

Total available phosphorus represents the sum of the saloid-bound phosphorus and iron-bound phosphorus associations in each sediment core sample. Since the saloid-bound phosphorus is immediately available, and the iron-bound phosphorus is available under reduced conditions, the sum of these speciations represents the total phosphorus which is potentially available within the sediments. This information can be utilized as a guide for future sediment inactivation projects.

A summary of total available phosphorus in each of the 20 collected sediment core samples is given in Table 3-4. Total available phosphorus concentrations within the sediments range from 17-80 $\mu g/cm^3$, with a mean value of 45 $\mu g/cm^3$. The mean sediment total available phosphorus in the lower lobe is slightly lower than values commonly observed by ERD in urban lakes but still reflects a large pool of available phosphorus.

TABLE 3-4

PHOSPHORUS SPECIATION IN SEDIMENT CORE SAMPLES COLLECTED IN THE LOWER LOBE OF SWEETWATER COVE LAKE ON JANUARY 7, 2015

SITE	SEDIMENT PHOSPHORUS SPECIATION (µg/cm^3)			TOTAL AVAILABLE SEDIMENT PHOSPHORUS	
	Saloid-Bound	Iron-Bound	Aluminum-Bound	µg/cm^3	% of Total
1	12.7	23	46	36	25
2	12.7	56	121	68	71
3	28.2	17	56	46	82
4	6.5	25	90	32	14
5	8.3	34	54	42	67
6	28.9	33	69	62	44
7	4.4	12	24	17	19
8	0.4	52	44	52	89
9	19.6	28	55	48	93
10	18.8	62	77	80	52
11	15.2	14	30	29	58
12	34.6	41	67	75	53
13	16.8	27	34	44	68
14	23.4	20	36	44	27
15	33.6	23	66	56	62
16	12.2	38	55	51	67
17	18.1	20	25	38	60
18	45.0	24	98	69	48
19	0.2	26	37	27	86
20	15.2	34	48	49	87
Minimum:	**0.2**	**12**	**24**	**17**	**14**
Maximum:	**45**	**62**	**121**	**80**	**93**
Geometric Mean:	**11.3**	**28**	**52**	**45**	**52**

Isopleths of total available phosphorus in the top 10 cm of sediments in the lower lobe are illustrated on Figure 3-13. Areas of elevated total available phosphorus are apparent throughout the lower lobe. The isopleths presented on Figure 3-13 can be utilized directly as a guide for future sediment inactivation activities.

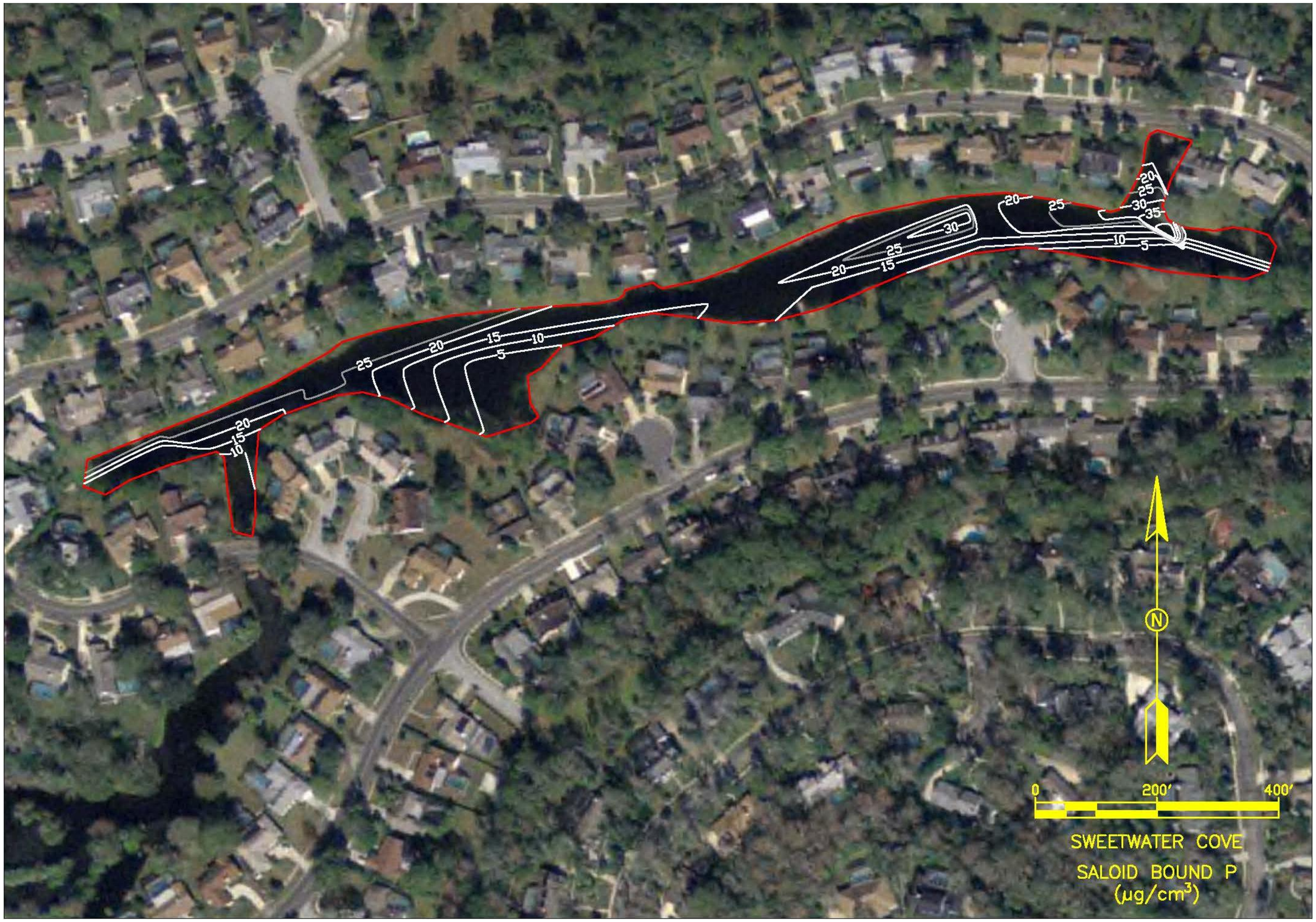


Figure 3-11. Isopleths of Saloid-Bound Phosphorus (µg/cm^3) in the Top 10 cm of Sediments in the Lower Lobe of Sweetwater Cove Lake.

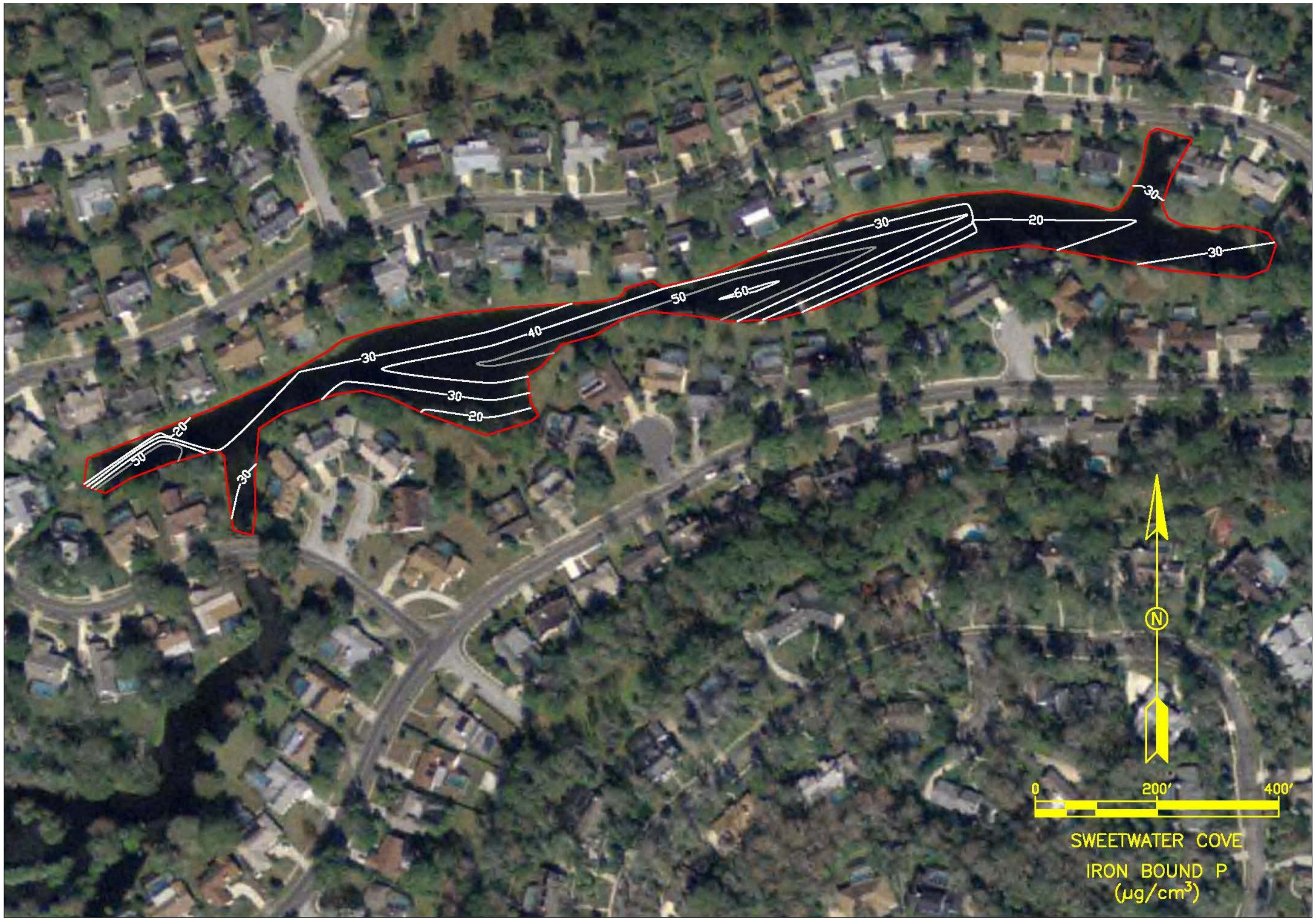


Figure 3-12. Isopleths of Iron-Bound Phosphorus (μg/cm^3) in the Top 10 cm of Sediments in the Lower Lobe of Sweetwater Cove Lake.

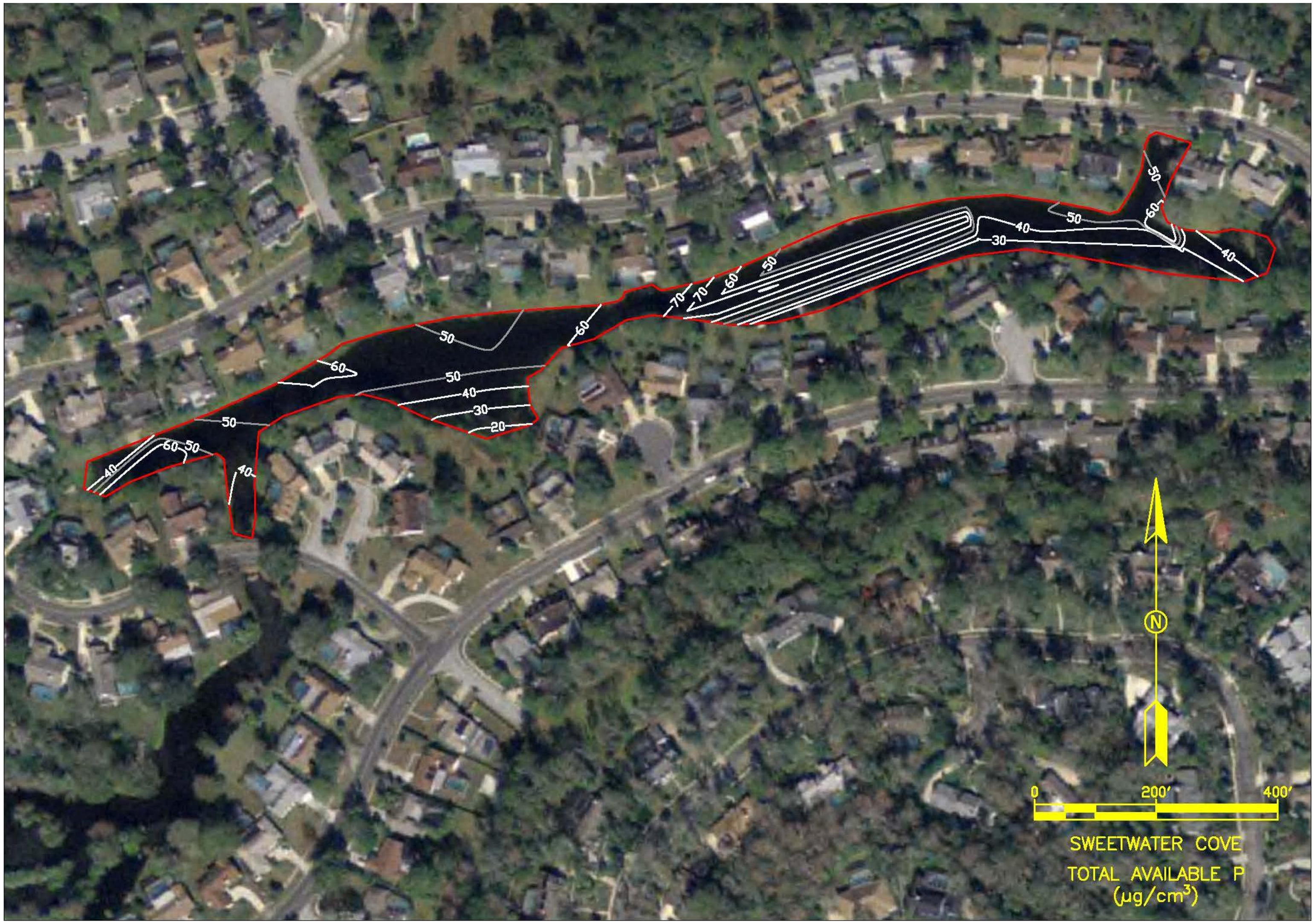


Figure 3-13. Isopleths of Total Available Phosphorus (µg/cm^3) in the Top 10 cm of Sediments in the Lower Lobe of Sweetwater Cove Lake.

Available sediment phosphorus is also expressed in Table 3-4 as a percentage of total phosphorus concentrations within the sediments. The percentage of available phosphorus within the sediments of the lower lobe ranges from 14-93%, with a mean value of 52%. This suggests that, on an average basis, approximately 52% of the existing accumulation of phosphorus within the lake is potentially available for release into the overlying water column as a result of sediment agitation or anoxic conditions.

Aluminum-bound phosphorus represents an unavailable species of phosphorus within the lake sediments. Phosphorus bound with aluminum is typically considered to be inert under a wide range of pH and redox conditions within lake sediments. Aluminum-bound phosphorus concentrations in the lower lobe range from 14-93 $\mu g/cm^3$, with a median value of 52 $\mu g/cm^3$. These values are similar to aluminum-bound phosphorus concentrations observed by ERD in other lake systems. The mean aluminum-bound phosphorus concentration of 52 $\mu g/cm^3$ suggests that approximately 40% of the existing phosphorus within the sediments is bound in sediment associations which are considered to be unavailable for release into the water column.

SECTION 4

SHALLOW GROUNDWATER SEEPAGE

Field investigations were performed by ERD to evaluate the quantity and quality of shallow groundwater seepage entering the lower lobe of Sweetwater Cove Lake during the monitoring period from December 2014-June 2015. Groundwater seepage was quantified using a series of underwater seepage meters installed at locations throughout the lake. Seepage meters provide a mechanism for direct measurement of groundwater inflow into a lake by isolating a portion of the lake bottom so that groundwater seeping up through the bottom sediments into the lake can be collected and characterized. Use of the direct seepage meter measurement technique avoids errors, assumptions, and extensive input data required when indirect techniques are used, such as the Gross Water Budget or Subtraction Method, as well as computer modeling and flow net analyses.

The seepage meter technique has been recommended by the U.S. Environmental Protection Agency (EPA) and has been established as an accurate and reliable technique in field and tank test studies (Lee, 1977; Erickson, 1981; Cherkauer and McBride, 1988; Belanger and Montgomery, 1992). With installation of adequate numbers of seepage meters and proper placement, seepage meters are a very effective tool to estimate groundwater-surface water interactions. One distinct advantage of seepage meters is that seepage meters can provide estimates of both water quantity and quality entering a lake system, whereas indirect methods can only provide information on water quantity.

4.1 Seepage Meter Construction and Locations

A schematic of a typical seepage meter installation used in the lower lobe is given in Figure 4-1. Seepage meters were constructed from a 2-ft diameter aluminum container with a closed top and open bottom. Each seepage meter isolated a sediment area of approximately 3.14 ft^2. Seepage meters were inserted into the lake sediments to a depth of approximately 8-12 inches, depending on sediment characteristics, isolating a portion of the lake bottom. Approximately 3-6 inches of water was trapped inside the seepage meter above the lake bottom.

A 0.75-inch PVC fitting was threaded into the top of each aluminum container and attached to a female quick-disconnect PVC camlock fitting. A flexible polyethylene bag, with an approximate volume of 40 gallons, was attached to the seepage meters using a quick-disconnect PVC male camlock fitting with a terminal ball valve. Each of the collection bags was constructed of black polyethylene to prevent light penetration into the bag which could potentially stimulate photosynthetic activity within the sample prior to collection and result in an alteration of the chemical characteristics of the sample.

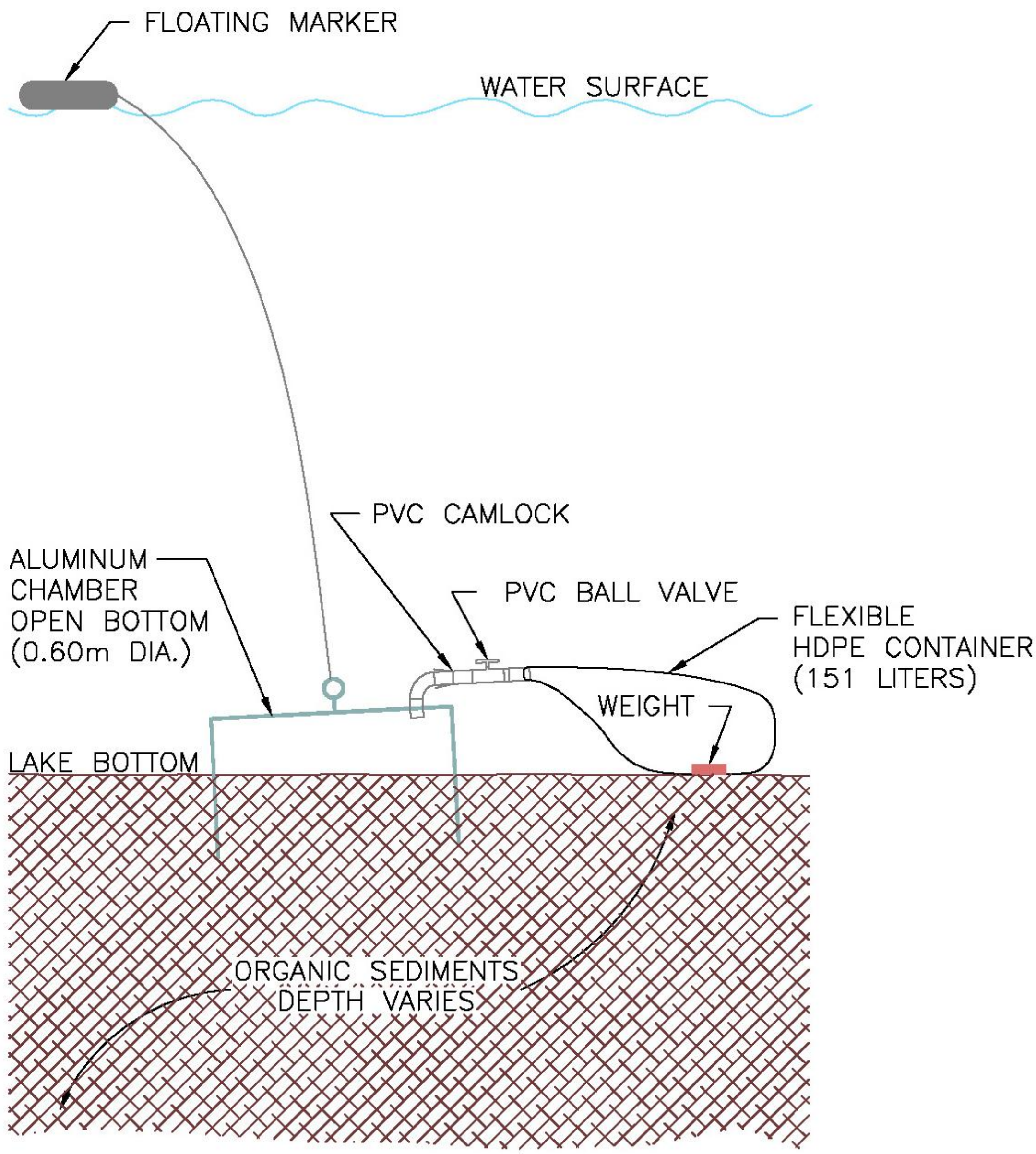


Figure 4-1. Typical Seepage Meter Installation.

Prior to attachment to the seepage meter, all air was removed from inside the polyethylene collection bag, and the PVC ball valve was closed so that lake water would not enter the collection container prior to attachment to the seepage meter. A diver then connected the collection bag to the seepage meter using the PVC camlock fitting. After attaching the collection bag to the seepage meter, the PVC ball valve was then opened. As groundwater influx occurs into the open bottom of the seepage meter, it is collected inside the flexible polyethylene bag.

Each seepage meter was installed with a slight tilt toward the outlet point so that any gases generated inside the seepage meter would exit into the collection container. A plastic-coated fishing weight was placed inside each of the collection bags to prevent the bags from floating up towards the water surface as a result of trapped gases. The location of each seepage meter was indicated by a floating marker in the lake which was attached to the seepage meter using a coated wire cable.

Ten (10) seepage meters were installed in the lower lobe on December 5, 2014. Locations for the seepage meters are indicated on Figure 4-2. Since seepage inflow is often most variable around the perimeter of a lake, the majority of the seepage meters were installed around the perimeter of the lower lobe. Although seepage meters were also installed in central portions of the lake.

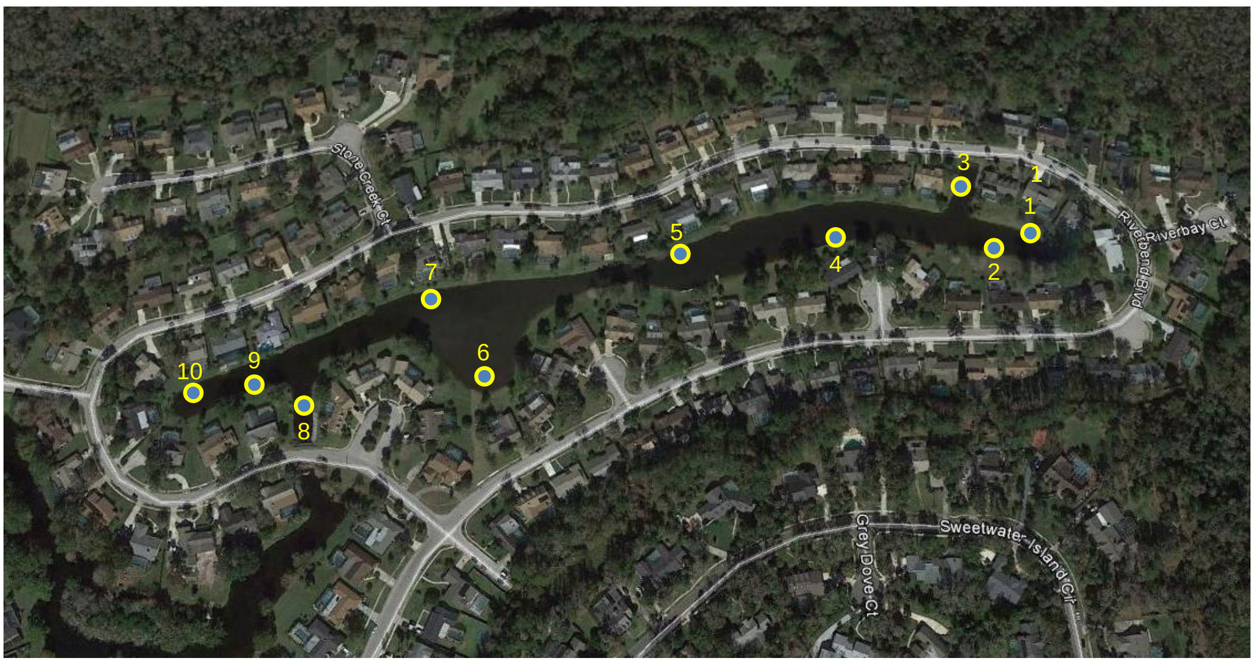


Figure 4-2. Locations of Seepage Monitoring Sites in the Lower Lobe of Sweetwater Cove Lake.

Collection bags were installed on each of the seepage meters at the time of installation, and the monitoring program was initiated. Each of the seepage meters was monitored on approximately a monthly to bi-monthly basis, depending on rainfall, from December 2014-June 2015. During the initial monitoring event (January 2015), the volume of seepage collected was recorded, but the sample was discarded since the water within the collection bag represented a combination of seepage and the initial lake water trapped at the time of installation. During all subsequent events, samples were collected for analysis of seepage characteristics. Four separate seepage monitoring events were conducted for evaluation of seepage quantity, with three events conducted to evaluate seepage quality at each of the monitoring sites. A total of 29 seepage samples was collected for lab analyses between the 10 sites over the 207-day monitoring program.

4.2 Seepage Meter Sampling Procedures

After the initial installation of collection bags, site visits were performed at periodic intervals to collect the seepage samples. During the collection process, a diver was used to close the PVC ball valve and remove the collection bag from the seepage meter using the quick-disconnect camlock fitting. The collection bag was placed onto the boat and the contents were emptied into a polyethylene container. The volume of seepage collected in the container was measured using either a 4-liter graduated cylinder or a 20-liter graduated polyethylene bucket, depending on the collected volume.

Following the initial purging event, seepage meter samples were collected for return to the laboratory for chemical analysis. On many occasions seepage meter samples were found to contain turbidity or particles originating from the sediments isolated within the seepage meter. Since these contaminants are not part of the seepage flow, all seepage meter samples collected for chemical analyses were field-filtered using a 0.45 micron disposable glass fiber filter typically used for filtration of groundwater samples. A new filter was used for each seepage sample. Seepage samples were filtered immediately following collection using a battery operated peristaltic pump at a flow rate of approximately 0.25 liter/minute. The filtered seepage samples were placed in ice for return to the ERD laboratory for further chemical analyses.

A summary of field measurements of seepage inflow over the monitoring period from December 2014-June 2015 is given in Appendix B.1. During collection of the seepage samples, information was recorded on the time of sample collection, the total volume of seepage collected at each site, and general observations regarding the condition of the seepage collection bags and meter replacement/repair details. The seepage inflow rate at each location is calculated by dividing the total collected seepage volume (liters) by the area of the seepage meter (0.27 m^2) and the time (days) over which the seepage sample was collected.

4.3 Seepage Inflow

A statistical summary of seepage inflow measurements collected in the lower lobe is given in Table 4-1. In general, mean seepage rates measured at the monitoring sites range from 0.43-1.14 liters/m^2-day, with the majority of mean values ranging from approximately 0.5-0.9 liters/m^2-day.

The mean seepage values summarized on Table 4-1 were combined with the geographic coordinates for each seepage meter site to generate an isopleth contour map for mean seepage inflow into the lower lobe using the Autodesk Land Desktop 2007 Module for AutoCAD. Isopleths of mean seepage inflow into the lower lobe from December 2014-June 2015 are given in Figure 4-3. The range of seepage values indicated on this figure is from <0.5 to 1 liter/m^2-day. Much of the area within the lower lobe appears to exhibit relatively low seepage inflow, with large portions of the lake area indicating seepage of approximately 0.5-0.75 liter/m^2-day or less. Areas of more elevated seepage inflow were observed in the southern cove and in the outfall canal, with seepage rates equal to 0.75 liter/m^2-day or more. Most of the areas with elevated seepage inflow are located adjacent to sub-basin areas with permeable soils and a slightly steeper topography which enhances the potential for migration of groundwater into the adjacent receiving water.

TABLE 4-1

STATISTICAL SUMMARY OF SEEPAGE INFLOW MEASUREMENTS IN THE LOWER LOBE OF SWEETWATER COVE LAKE FROM DECEMBER 2014 – JUNE 2015

SITE	NUMBER OF SAMPLES	MINIMUM VALUE (liters/m^2-day)	MAXIMUM VALUE (liters/m^2-day)	MEAN VALUE (liters/m^2-day)
1	4	0.42	0.90	0.72
2	4	0.27	0.81	0.44
3	3	0.68	1.43	1.14
4	4	0.38	0.84	0.55
5	3	0.59	0.76	0.54
6	4	0.71	1.51	0.89
7	4	0.38	0.73	0.49
8	4	0.39	1.04	0.71
9	4	0.44	0.81	0.58
10	4	0.30	0.76	0.43

The seepage isopleths indicated on Figure 4-3 were graphically integrated to obtain estimates of mean daily seepage influx into the lower lobe. A summary of the results of this analysis is given in Table 4-2. The mean seepage influx to the lower lobe during the 207-day field monitoring program was 0.63 liters/m^2-day which is equivalent to approximately 0.0094 ac-ft/day or 0.43 ac-ft during the 207-day monitoring period. However, it should be noted that the seepage monitoring program was conducted during typical dry season conditions, and the calculated mean and annual seepage rates would likely be greater if the monitoring had included wet season conditions.

TABLE 4-2

ESTIMATED SEEPAGE INFLOW TO THE LOWER LOBE OF SWEETWATER COVE LAKE FROM DECEMBER 2014-JUNE 2015

PARAMETER	UNITS	VALUE
Lake Area	acres	4.55
Mean Seepage Inflow	liters/m^2-day ac-ft/day ac-ft	0.63 0.0094 1.95
Seepage/Surface Area Ratio	ft/yr	0.43

Figure 4-3. Isopleths of Mean Seepage Inflow into the Lower Lobe of Sweetwater Cove Lake from December 2014-June 2015.

The calculated seepage/surface area ratio for the lower lobe is provided in the final row of Table 4-2. This value provides an estimate of seepage inflow in terms of a water depth over the entire lake surface and provides a method for comparing relative seepage inflow between lakes without consideration of lake area. During the field monitoring program, seepage inflow into the lower lobe contributed a water volume equivalent to 0.43 ft over the entire surface area of the lake. This value is somewhat lower than areal seepage influx rates measured by ERD in other Central Florida lakes which typically range from 1-2 liters/m^2-day.

4.4 Chemical Characteristics

After the initial purging event, each of the collected groundwater seepage samples was analyzed in the ERD Laboratory for pH, alkalinity, conductivity, total nitrogen, and total phosphorus. A complete listing of laboratory measurements conducted on seepage samples collected at each of the 10 sites is given in Appendix B.2.

A summary of mean chemical characteristics of seepage samples collected in the lower lobe from December 2014-June 2015 is given in Table 4-3. The mean values listed in Table 4-3 reflect geometric (log-normal) mean values for all values of a particular parameter collected at each site. Seepage collected from the lower lobe was found to be slightly alkaline to neutral in pH, with measured conductivity values similar to values commonly observed in urban runoff. A wide range of nitrogen concentrations was observed in seepage samples, with mean measured values ranging from 1,588-6,017 μg/l. Mean total phosphorus concentrations in groundwater seepage were also highly variable, ranging from 417-1,492 μg/l between the various sites. The observed mean concentrations of both total nitrogen and total phosphorus in seepage samples entering the lower lobe appear to be somewhat higher, particularly for total phosphorus, than seepage inflow values measured by ERD in other urban lakes in the Central Florida area.

Seepage samples collected from the lake were generally well buffered, with the majority of mean alkalinity values greater than 100 mg/l. A substantially lower mean alkalinity value of 66.4 mg/l was observed at seepage site 10 which is located on the extreme west end of the lake. This site also exhibited a lower mean pH value than the other sites and was characterized by the lowest mean conductivity value of any of the 10 seepage sites. Seepage collected at this site was also characterized by the lowest mean concentrations of total nitrogen and total phosphorus. It appears that seepage characteristics at this site are impacted by different factors than other sites.

Isopleths of mean pH values in groundwater seepage entering the lower lobe from December 2014-June 2015 are illustrated on Figure 4-4. In general, the most elevated pH values were observed in central portions of the eastern and western portions of the lake, with the lowest measured pH values observed in central and extreme eastern and western portions of the lake. The measured pH values illustrated on Figure 4-3 are slightly higher than pH values observed by ERD in groundwater seepage entering other lakes in the Central Florida area.

Figure 4-4. Isopleths of Mean pH Values in Groundwater Seepage Entering the Lower Lobe of Sweetwater Cove Lake from December 2014-June 2015.

TABLE 4-3

MEAN CHARACTERISTICS OF GROUNDWATER SEEPAGE SAMPLES COLLECTED IN THE LOWER LOBE OF SWEETWATER COVE LAKE FROM DECEMBER 2014-JUNE 2015

SITE	pH (s.u.)	ALKALINITY (mg/l)	CONDUCTIVITY (μmho/cm)	TOTAL N (μg/l)	TOTAL P (μg/l)
1	7.33	181	416	5,250	1,492
2	7.47	140	479	6,017	1,378
3	7.58	149	400	3,372	641
4	7.64	130	405	4,500	1,006
5	7.24	91.5	395	2,068	507
6	7.53	100	327	3,181	690
7	7.44	133	430	4,208	1,025
8	7.75	140	463	4,219	936
9	7.51	125	446	5,565	1,374
10	7.15	66.4	393	1,588	417
Mean Values:	**7.46**	**126**	**416**	**3,997**	**947**

Isopleths of mean alkalinity values in groundwater seepage entering the lower lobe from December 2014-June 2015 are illustrated on Figure 4-5. Areas of more elevated alkalinity were observed in the eastern portions of the lower lobe, with the lowest alkalinity values observed in the central and western portions of the lower lobe.

Isopleths of mean conductivity values in groundwater seepage entering the lower lobe from December 2014-June 2015 are illustrated on Figure 4-6. The most elevated levels of conductivity were observed in eastern and western portions of the lower lobe, with lower concentrations generally observed in central portions of the lake.

Isopleths of mean total nitrogen concentrations in groundwater seepage entering the lower lobe from December 2014-June 2015 are illustrated on Figure 4-7. The most elevated concentrations of total nitrogen were observed along the eastern and central-western portions of the lake, with the lowest values generally observed in central and extreme western portions of the lake.

Isopleths of mean total phosphorus concentrations in groundwater seepage entering the lower lobe from December 2014-June 2015 are illustrated on Figure 4-8. Areas of elevated total phosphorus concentrations are apparent in the eastern and central-western portions of the lake. In general, phosphorus concentrations in groundwater seepage entering the lower lobe appear to be substantially higher in value than concentrations measured by ERD in other Central Florida Lakes. The pattern of elevated total phosphorus concentrations exhibited on Figure 4-8 is similar to the pattern of elevated nitrogen concentrations exhibited on Figure 4-7.

Figure 4-5. Isopleths of Mean Alkalinity Values in Groundwater Seepage Entering the Lower Lobe of Sweetwater Cove Lake from December 2014-June 2015.

Figure 4-6. Isopleths of Mean Conductivity Values in Groundwater Seepage Entering the Lower Lobe of Sweetwater Cove Lake from December 2014-June 2015.

Figure 4-7. Isopleths of Mean Total Nitrogen Values in Groundwater Seepage Entering the Lower Lobe of Sweetwater Cove Lake from December 2014-June 2015.

Figure 4-8. Isopleths of Mean Total Phosphorus Values in Groundwater Seepage Entering the Lower Lobe of Sweetwater Cove Lake from December 2014-June 2015.

4.5 Mass Loadings

Mean seepage isopleths for nitrogen influx, in terms of μg/m^2-day, were generated by combining the concentration isopleths for total nitrogen (provided on Figure 4-7) with the hydrologic isopleths for groundwater seepage (summarized on Figure 4-3). This procedure results in estimates of nitrogen influx in terms of mass of nitrogen per square meter of lake surface per day. For purposes of this analysis, "influx" or "flux" is defined as the areal mass input or loading per unit of time.

Isopleths of mean seepage influx of total nitrogen into the lower lobe are illustrated on Figure 4-9. In general, nitrogen influx from groundwater seepage into the lower lobe ranges from approximately 500-3,500 μg/m^2-day. The most elevated levels of nitrogen influx were observed in eastern and central-western portions of the lake, with substantially lower nitrogen influx in central and extreme western portions of the lake.

Mean isopleths of phosphorus influx into the lower lobe are illustrated on Figure 4-10. These isopleths were generated by combining the phosphorus concentration isopleths (summarized on Figure 4-8) with the seepage inflow isopleths (summarized on Figure 4-3). In general, phosphorus influx into the lower lobe ranges from approximately 200-900 μg/m^2-day. These values are somewhat higher than phosphorus influx measured by ERD in other Central Florida lakes. The most elevated values of phosphorus influx are located in eastern and central-western portions of the lake, similar to those exhibited on Figure 4-7 for nitrogen influx. The lowest seepage influx values, ranging from approximately 200-500 μg/m^2-day, were measured in central and central-western portions of the lake.

The isopleths summarized on Figures 4-9 and 4-10 were integrated to develop estimates of the total influx of nitrogen and phosphorus from groundwater seepage into the lower lobe during the field monitoring program from December 2014-June 2015. A summary of estimated annual mass loadings of total nitrogen and total phosphorus to the lower lobe from groundwater seepage is given in Table 4-4. Based on the results of the field monitoring program, groundwater seepage contributes approximately 16.2 kg/yr of total nitrogen and 3.76 kg/yr of total phosphorus to the lower lobe. However, as discussed previously, the seepage monitoring program was conducted during typical dry season conditions. If the field monitoring program had included wet season conditions as well, it is likely that the estimated annual loadings for total nitrogen and total phosphorus would be somewhat larger.

Calculated areal loadings of groundwater seepage are provided at the bottom of Table 4-4 which reflect the mass influx divided by the lake surface area. The mean total nitrogen influx of 3.56 kg/ac-yr entering the lower lobe is lower than the mean seepage influx of total nitrogen measured by ERD in other Central Florida lakes. The mean areal total phosphorus influx from groundwater seepage entering the lower lobe of 0.83 kg/ac-yr is similar to mean areal phosphorus loadings commonly measured by ERD in eutrophic urban lakes. Although the measured concentrations of both total nitrogen and total phosphorus were elevated, the low seepage volumetric inflow rate resulted in loading estimates similar to other urban lakes.

Figure 4-9. Isopleths of Mean Total Nitrogen Influx from Groundwater Seepage to the Lower Lobe of Sweetwater Cove Lake from December 2014-June 2015.

Figure 4-10. Isopleths of Mean Total Phosphorus Influx from Groundwater Seepage to the Lower Lobe of Sweetwater Cove Lake from December 2014-June 2015.

TABLE 4-4

ESTIMATED ANNUAL MASS LOADINGS TO THE LOWER LOBE OF SWEETWATER COVE LAKE FROM GROUNDWATER SEEPAGE

PARAMETER	UNITS	TOTAL NITROGEN	TOTAL PHOSPHORUS
Mean Daily Flux	μg/m^2-day g/day	2,413 44.5	558 10.3
Annual Loading	kg/yr	16.2	3.76
Areal Loading	kg/ac-yr g/m^2-yr	3.56 0.88	0.83 0.204

SECTION 5

LYNGBYA TREATMENT DURING MAY 2015

During May 2015, a test trial of a new Lyngbya herbicide treatment protocol was conducted in the lower lobe by the Florida Fish and Wildlife Conservation Commission (FWC) in conjunction with the Seminole County Lake Management Program. A discussion of the application protocol and water quality impacts is given in the following sections.

5.1 Application Protocol and Details

During May 2015, FWC conducted a test trial of a new Lyngbya herbicide treatment protocol in conjunction with the Seminole County Lake Management Program. The protocol was developed by Dr. Rogers at Clemson University using in-situ lab results. A copy of the application protocol is given in Appendix C. The experimental treatment was conducted throughout the most western portion of the lower lobe.

The treatment was initiated on May 19, 2015 by first adding 600 pounds of PAK 27 (totaling 100 pounds/ac-ft) and allowing the product to settle and react overnight. A photograph of application of the PAK 27 is given on Figure 5-1. PAK 27 is a peroxide-based formula which provides algae control through oxidation of organic matter.

Figure 5-1. Application of PAK 27. (Photo taken on May 19, 2015)

On May 20, 2015, 32 gallons of Captain XTR (a chelated copper compound) were applied to the lower lobe at a rate of approximately 0.992 ppm or 5.3 gallons/ac-ft of water. A photograph of the application of Captain XTR is given on Figure 5-2.

Figure 5-2. Applicator Applying Captain XTR. (Photo taken on May 20, 2015)

During the overnight hours of May 20-21, the Sanlando Utilities Wastewater Treatment Facility (located on Sweetwater Creek south of Wekiva Springs Road) discharged a reported volume of 2 million gallons of treated effluent into Sweetwater Creek. On the morning of May 21, 2015, a small fish kill was reported in the lower lobe. A photograph of a typical shoreline area in the lower lobe illustrating the fish kill on the morning of May 21, 2015 is given on Figure 5-3. Approximately 400 dead fish were noted within the lower lobe, some of which were still on the bottom of the lower lobe on May 22, 2015.

The Seminole County Lake Management Program, in conjunction with ERD, conducted field and laboratory evaluations to document ambient water quality within the lower lobe in an attempt to understand the cause of the fish kill. Field monitoring was conducted within the lower lobe as well as an upstream background location to evaluate potential causes for the fish kill. The results of these evaluations are summarized in the following section.

Figure 5-3. Photo of Fish Kill Following Treatment. (Photo taken on May 21, 2015)

5.2 Results of Field and Laboratory Monitoring

Field and laboratory monitoring was conducted by ERD in the lower lobe on May 22, 2015 to evaluate ambient water quality characteristic following the Lyngbya treatment. Locations for surface water monitoring sites are indicated on Figure 5-4. Surface water monitoring was conducted in the inflow channel, middle, and outflow channel for the lower lobe. In addition, surface water monitoring was conducted in an upstream portion of the middle lobe as a background site.

5.2.1 Monitoring Protocol

Vertical field profiles of temperature, pH, conductivity, TDS, dissolved oxygen concentration, dissolved oxygen saturation, and ORP were conducted at water depths of 0.25 m and 0.5 m, continuing at 0.5 m intervals to the lake bottom at each site. A measurement of Secchi disk depth was also conducted at each of the four sites. Surface water samples were collected at each site approximately mid-way within the water column and returned to the ERD Laboratory for evaluation of general parameters, nutrients, microbiological parameters, and total copper. The field monitoring and laboratory analyses were conducted using the methods and protocol used by ERD for routine water quality monitoring in the lower lobe outlined in Section 2.1. In addition to the parameters and analytical methods summarized in Table 2-1, additional parameters of BOD, fecal coliform, E. Coli, and total copper were added for the samples collected on May 22, 2015. A summary of analytical methods and detection limits for these additional parameters, which were also conducted in the ERD Laboratory, is given in Table 5-1.

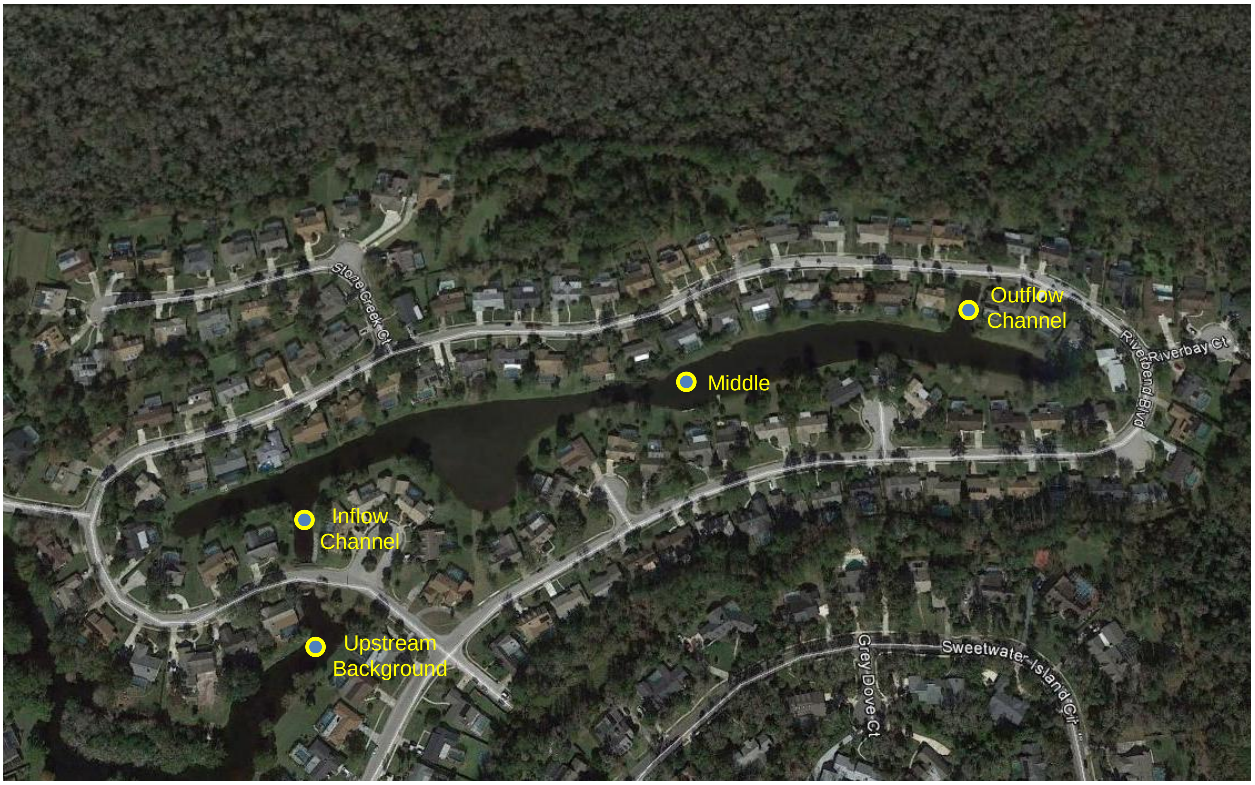


Figure 5-4. Surface Water Monitoring Sites for Post-Treatment Monitoring.

TABLE 5-1

ANALYTICAL METHODS AND DETECTION LIMITS FOR SUPPLEMENTAL LABORATORY ANALYSES CONDUCTED BY ERD ON SAMPLES COLLECTED ON MAY 22, 2015

MEASUREMENT PARAMETER	METHOD[1]	METHOD DETECTION LIMITS[2] (MDL)
BOD	SM-21, Sec. 5210 B	2.0 mg/l
Fecal Coliform	SM-21, Sec. 9222 D	1 cfu/100 ml
E. Coli	EPA-83, Sec. 1603	1 cfu/100 ml
Total Copper	EPA 220.1	2 µg/l

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

5.2.2 Vertical Field Profiles

A summary of vertical field measurements collected in the lower lobe and upstream background location on May 22, 2015 is given in Table 5-2. Measured water depths at the four monitoring sites ranged from 0.54-1.47 m. In general, temperature measurements conducted at the three lower lobe monitoring sites were relatively similar within the water column at each of the three sites, with little change in temperature with increasing water depth. However, water temperatures dropped substantially below a depth of 0.5 m at the upstream background site, with approximately 3.6°C difference in water temperature between top and bottom measurements in a 1.47 m deep water column.

TABLE 5-2

VERTICAL FIELD MEASUREMENTS COLLECTED IN THE LOWER LOBE ON MAY 22, 2015

SITE	PARAMETER								
	Time	Depth (m)	Temp. (°C)	pH (s.u.)	Conductivity (µmho/cm)	TDS (mg/l)	Diss. Oxygen (mg/l)	Diss. Oxygen (% Sat.)	ORP (mv)	Secchi Disk Depth (m)
Inflow Channel	7:27	0.25	28.67	8.63	402	257	2.5	33	482	0.49
	7:28	0.54	28.65	8.59	400	256	1.8	23	479	
Middle	7:36	0.25	28.99	8.51	410	262	1.3	17	481	0.78 (bottom)
	7:36	0.50	28.93	8.42	418	267	0.8	11	468	
	7:37	0.78	28.86	8.01	436	279	0.6	8	410	
Outflow Channel	8:08	0.25	29.72	8.45	418	267	1.7	22	463	0.59 (bottom)
	8:09	0.50	29.64	8.32	417	267	0.7	9	454	
	8:09	0.60	29.67	8.23	421	270	0.5	7	435	
Upstream Background	8:36	0.25	28.34	9.15	395	253	7.1	92	488	0.63
	8:37	0.50	28.41	9.16	395	253	7.0	91	488	
	8:38	1.00	25.61	8.33	329	210	2.0	25	446	
	8:38	1.47	24.77	7.70	307	196	0.6	7	368	

Measured pH values at the three monitoring sites in the lower lobe were somewhat elevated, ranging from approximately 8.0-8.6 s.u. A general decrease in pH was observed with increasing water depth at each site. Slightly higher pH values were observed at the upstream background site, with surface pH values in excess of 9.1 s.u. A relatively rapid drop in pH was observed at this site below a water depth of 0.5 m.

Measured conductivity values in the lower lobe were similar to values commonly measured by ERD during the routine field monitoring program. A slight trend of increasing conductivity with increasing water depth was observed at the middle and outflow channel sites. A slightly lower conductivity value was observed at the upstream background site, with substantial decreases in conductivity observed below a depth of approximately 0.5 m. The observed lower values for temperature, pH, and conductivity at depths below 0.5 m at the upstream background site suggest an isolated layer of water below the surface layers at this site.

Measured dissolved oxygen concentrations in the lower lobe were extremely low in value, with measured values ranging from 0.5-2.5 mg/l and oxygen saturation values ranging from 7-33%. Each of the sites in the lower lobe failed to meet the minimum dissolved oxygen saturation criterion outlined in Chapter 62-302 FAC of 38% for freshwater lakes in the central peninsula part of the state. The observed concentrations of dissolved oxygen were not adequate for long-term support of aquatic organisms and may be at least partially responsible for the observed fish kill within the lower lobe. Substantially higher dissolved oxygen concentrations were observed at the upstream background site, with a surface concentration of approximately 7 mg/l, although oxygen concentrations at this site decreased rapidly below a depth of 0.5 m. In spite of the low levels of dissolved oxygen, measurements of ORP indicated oxidized conditions at each of the four sites.

5.2.3 Chemical Characteristics

A summary of the results of lab analyses conducted on samples collected at each of the four monitoring sites on May 22, 2015 is given in Table 5-3. Each of the samples was collected at approximately mid-depth in the water column at each site. Surface water within the lower lobe was well buffered on the monitoring date, with alkalinity values ranging from 108-120 mg/l. A slightly lower alkalinity value of 105 mg/l was measured at the upstream background site.

Samples collected in Sweetwater Cove and at the upstream background site were characterized by low levels of both ammonia and NO_x. The dominant nitrogen species observed at each of the monitoring sites was particulate nitrogen which comprised approximately 70% of the total nitrogen measured at each site. Measured concentrations of total nitrogen at the lower lobe monitoring sites ranged from 1,486-2,010 μg/l, with a substantially lower value of 784 μg/l measured at the upstream background site. The enhanced concentrations of total nitrogen in the lower lobe compared with the upstream background site may be related to oxidation of the organic matter within the lake and subsequent release of nitrogen species.

Measured concentrations of SRP in the lower lobe were substantially elevated in value compared with values commonly observed by ERD in urban lakes, although SRP concentrations substantially in excess of the values measured on May 22, 2015 have been observed in the lower lobe on multiple occasions. Nevertheless, the measured SRP concentrations indicate a substantial source of available inorganic phosphorus within the water column. The dominant phosphorus species measured at each of the monitoring sites was particulate phosphorus which comprised approximately 70% of the total phosphorus measured at each site. Measured concentrations of total phosphorus in the lower lobe ranged from 345-404 μg/l compared with a concentration of 204 μg/l at the upstream background site. The measured concentrations of total phosphorus in the lower lobe are approximately 44-98% greater than the total phosphorus concentration measured at the upstream background site.

TABLE 5-3

RESULTS OF LAB ANALYSES CONDUCTED ON SWEETWATER COVE SAMPLES COLLECTED ON MAY 22, 2015

PARAMETER	UNITS	SITE			
		Inflow Channel	Middle	Outflow Channel	Upstream Background
Alkalinity	mg/l	108	111	120	105
Ammonia	µg/l	11	15	17	18
NO_x	µg/l	< 5	< 5	< 5	23
Diss. Organic Nitrogen	µg/l	384	542	628	253
Particulate Nitrogen	µg/l	1,161	1,450	838	490
Total Nitrogen	µg/l	1,559	2,010	1,486	784
SRP	µg/l	37	48	42	31
Diss. Organic Phosphorus	µg/l	56	53	57	30
Particulate Phosphorus	µg/l	252	303	294	143
Total Phosphorus	µg/l	345	404	393	204
Hardness	mg/l	126	122	124	126
Color	Pt-Co	55	61	66	46
BOD	mg/l	10.7	9.8	10.3	10.4
Fecal Coliform	cfu/100 ml	100	20	7	5
E. Coli	cfu/100 ml	67	13	1	5
Copper	µg/l	< 2	50	80	< 2

Measured concentrations of BOD were highly elevated at each of the four monitoring sites, with measured values ranging from 9.8-10.7 mg/l. Measured BOD concentrations were relatively similar in the lower lobe and at the upstream background site. The observed BOD concentrations on May 22, 2015 are substantially higher than values commonly observed in urban lakes and represent a significant oxygen demand within the water column of the lake. The specific cause of the elevated BOD values is difficult to determine. A potential source of BOD within the water column could be the volume of sewage effluent discharged into Sweetwater Creek and Sweetwater Cove Lake which occurred approximately 6-8 hours prior to the monitoring event. However, the volume of sewage released would receive substantial dilution within the significantly larger volume of the water within the three lobes which would dilute BOD concentrations in the sewage discharge.

Measured concentrations of fecal coliform and E. Coli bacteria were highly variable at each of the four monitoring sites. However, no violations of applicable criteria for either fecal coliform or E. Coli were observed during the monitoring event.

Measured concentrations of copper at each of the four monitoring sites are provided in the final row of Table 5-3. Concentrations of copper in the inflow to the lower lobe and at the background monitoring site were extremely low in value and less than the detection limit of 2 μg/l for the test. However, extremely elevated copper concentrations of 50 μg/l and 80 μg/l were observed at the middle monitoring site and at the outfall canal, respectively, within the lower lobe. The Class III criterion for copper is a hardness-based standard which varies depending upon the associated hardness concentration. Measured hardness values in Sweetwater Cove ranged from 122-126 mg/l, and a hardness of approximately 125 mg/l is assumed for this analysis. Based upon the assumed hardness value, the applicable Class III copper standard would be approximately 11 μg/l which is substantially exceeded at 2 of the 3 lower lobe monitoring sites. The observed concentrations of copper would likely exhibit acute toxicity to a wide variety of aquatic organisms within a relatively short contact period. The observed elevated values for copper may also be at least partly responsible for the observed fish kill within the lake. The fact that elevated copper concentrations were not observed in the inflow channel suggest that water from the middle lobe is being flushed out by inflows from the upstream lakes, and the copper remaining from the application is now located in the middle and outflow portions of the lower lobe.

5.3 **Evaluation of Treatment Success**

A photograph of observed conditions in the lower lobe on May 29, 2015, approximately 9 days after treatment (DAT) is given on Figure 5-5. Prolific growth of Lyngbya was observed throughout many portions of the lower lobe. Although some of the Lyngbya appeared to be in distress and may have eventually died, large portions of the Lyngbya mat still exhibit a healthy green coloration.

A photograph of the conditions in the lower lobe on June 15, 2015, approximately 25 DAT, is given on Figure 5-6. Lyngbya growth is still evident throughout large portions of the lower lobe and appears to have expanded in coverage since the photograph taken on May 29, 2015. Although portions of the Lyngbya growth appear to be in distress, the majority of the observed growth appears to be in a healthy condition.

Figure 5-5. Conditions in the Lower Lobe on May 29, 2015

Figure 5-6. Conditions in the Lower Lobe on June 2015.

SECTION 6

EVALUATION OF WATER QUALITY IMPROVEMENT OPTIONS

A general discussion of potential water quality management and improvement options for lower Sweetwater Cove is presented in this section. Although detailed hydrologic and nutrient budgets have not been developed for the lower lobe, the evaluated water quality improvement options are designed to target sources which have been identified as likely contributors of nutrient loadings to the lake and, particularly, sources likely to be fueling the ongoing and persistent growth of Lyngbya within the lake. A discussion of general management philosophy and potential water quality improvement options is given in the following sections.

6.1 Management Philosophy

Based upon the results of evaluations summarized in previous sections, it appears that lower Sweetwater Cove is primarily a hypereutrophic waterbody which experiences highly variable water quality characteristics and nutrient loadings. Algal productivity within the lake is concentrated primarily in benthic growths of Lyngbya which periodically rise to the water surface, creating unsightly floating algal mats. The algae receive nutrients both from the sediments when in a benthic state and from the water column when floating, and control of nutrient loadings from each of these sources is probably necessary to adequately control Lyngbya growth within the lake. Existing sediment accumulations of organic muck within the lower lobe are less than accumulations commonly observed in urban lakes due to the periodic desiccation of the lower lobe during periods of low rainfall. However, the sediments which are present contain moderate to elevated levels of both nitrogen and phosphorus. In addition, seepage influx into the lower lobe contains extremely elevated levels of nutrients, particularly for total phosphorus, which may be the dominant nutrient source for benthic algae within the lake.

As discussed in Section 2, calculated TN/TP ratios suggest that the lower lobe is primarily a nitrogen-limited ecosystem, although this indication is more related to elevated levels of total phosphorus than limiting amounts of inorganic nitrogen. Lyngbya is a nitrogen-fixing cyanobacteria and can extract nitrogen from the atmosphere when inorganic nitrogen becomes low, suggesting that nitrogen limitation is not possible for this species. Therefore, the most appropriate method for reducing nutrient availability within Sweetwater Cove would be to control phosphorus rather than nitrogen.

The growth of cyanobacteria is favored at low nutrient TN/TP ratios, generally less than approximately 7, and these conditions were present within lower Sweetwater Cove Lake during most of the field monitoring events. As nutrient ratios increase above 7, species of green algae begin to be preferred, and at higher TN/TP ratios, diatoms become dominant. Therefore, control of phosphorus loadings entering lower Sweetwater Cove Lake would not only reduce the availability of nutrients but result in changes in TN/TP ratios which would favor less objectionable green algae and diatoms.

Although a nutrient budget has not been conducted for lower Sweetwater Cove, it appears highly likely that the most significant nutrient loadings to the water column originate from upstream lakes which receive inflows from Sweetwater Creek. As indicated on Table 2-3, water column concentrations of SRP were both substantially elevated in value and highly variable in concentration throughout the field monitoring program, presumably resulting from inflows from Sweetwater Creek which migrated through the upstream lakes and eventually reached lower Sweetwater Cove. Lower Sweetwater Cove is also impacted by direct stormwater runoff, although it appears intuitive that the annual loadings from upstream waterbodies would substantially exceed inputs from stormwater runoff on an annual basis. Therefore, control of water column phosphorus concentrations in Sweetwater Cove could be best achieved by reducing phosphorus concentrations in upstream waterbodies which discharge to the lower lobe.

Management options are provided in subsequent sections for control of nutrient loadings to the water column as well as loadings originating through sediments. Control of both water column and sediment loadings of phosphorus has the largest potential to reduce nutrient availability, raise N/P nutrient ratios, reduce algal productivity, and cause a change in algal species from blue-green to more acceptable green algal species.

6.2 Control of Sediment Loadings by Sediment Inactivation

6.2.1 Theory

Sediment phosphorus inactivation is a nutrient reduction technique which is designed to substantially reduce sediment phosphorus release by combining available phosphorus in the sediments with a metal salt to form an insoluble inert precipitate, rendering the sediment phosphorus unavailable for release into the overlying water column. Although salts of aluminum calcium and iron have been used for sediment inactivation in previous projects, aluminum salts are the clear compounds of choice for this application. Inactivation of sediment phosphorus using aluminum is often a substantially less expensive option for reducing sediment phosphorus release, compared with dredging, 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 will not be re-released under any conceivable condition of pH or redox potential which could occur in a natural lake system. Sediment inactivation treatments in Florida have been shown to be effective from 8 years to greater than 20 years, depending upon the sediment accumulation rate within the lake from the remaining phosphorus sources.

Based upon the field monitoring program conducted by ERD, it appears likely that the existing Lyngbya benthic mats in lower Sweetwater Cove receive significant phosphorus loadings from internal recycling of phosphorus from the sediments as well as influx of groundwater seepage. Lyngbya is also capable of extracting phosphorus directly from the sediments without release from internal recycling. Therefore, since the benthic mats are in direct contact with the sediments, the primary sediment related inputs originate from internal recycling or groundwater seepage rather than from the water column due to the significantly higher levels of phosphorus typically available through sediment benthic processes. Therefore, control of phosphorus loadings from sediments and internal recycling is essential to reducing the growth of Lyngbya in lower Sweetwater Cove. The goal of the proposed sediment inactivation treatment for lower Sweetwater Cove is to provide sufficient aluminum to provide simultaneous long-term control for phosphorus loadings from both internal recycling and groundwater seepage. Once the Lyngbya rises to the surface, the water column becomes the most significant phosphorus source to the floating mats, and options for control of water column phosphorus concentrations are discussed in a subsequent section.

6.2.2 Chemical Requirements

Sediment inactivation in the lower lobe of Sweetwater Cove Lake would involve addition of liquid aluminum sulfate at the water surface. 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, 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 the lower lobe of Sweetwater Cove Lake were generated by graphically integrating the total available phosphorus isopleths presented on Figure 3-13. The top 0-10 cm layer of the sediments is considered to be the primary 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 create a driving force which causes phosphorus to preferentially bind with aluminum rather than other available competing agents such as iron. 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.

Recent research conducted by ERD and others suggests that the required Al:P ratio for sediment inactivation is impacted by the concentration of available phosphorus within the sediment. As concentrations of available phosphorus decrease, a larger driving force is required to force phosphorus bonding with aluminum rather than other ions. As a result, higher Al:P ratios may be required for lakes with lower concentrations of total available sediment phosphorus, generally considered to be in the range of 50 $\mu g/cm^3$ or less. As indicated in Table 3-4, the geometric mean concentration of available sediment phosphorus in the lower lobe is 45 $\mu g/cm^3$ which suggests that a higher aluminum to phosphorus ratio may be required. Therefore, the proposed Al:P ratio for the lower lobe is increased to 15:1 to ensure adequate bonding between phosphorus and aluminum ions. However, the somewhat lower mean concentration for available sediment phosphorus in the lower lobe of 45 $\mu g/cm^3$ does not suggest that sediment phosphorus release is not significant within the lake. As indicated in the final column of Table 3-4, approximately 52% of the total phosphorus contained within the sediments of the lower lobe is potentially available for release into the overlying water column.

A summary of estimated total available phosphorus in the sediments of the lower lobe is given in Table 6-1. On a mass basis, the sediments of the lower lobe contain approximately 89 kg of available phosphorus in the top 10 cm. On a molar basis, this equates to approximately 2,879 moles of phosphorus to be inactivated as part of the sediment inactivation process. A summary of alum requirements for sediment inactivation is also provided in Table 6-1. Using an Al:P ratio of 15:1, sediment inactivation in the lower lobe would require approximately 5,258 gallons of alum, equivalent to approximately 1.2 tankers of alum containing 4,500 gallons. The equivalent aerial aluminum dose for this application would be 63.2 g Al/m^2 which is typical of application rates commonly used in Central Florida lakes.

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 through multiple applications of aluminum to the waterbody spaced at intervals of approximately 4-12 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.

Additional aluminum can also be added to the sediments to create an active absorption mechanism for other phosphorus inputs into the water column as a result of groundwater seepage. Inputs of phosphorus from groundwater seepage into a lake can easily exceed inputs from internal recycling in only a few annual cycles. Carefully planned applications of alum can provide an abundance of aluminum which can intercept groundwater inputs of phosphorus over a period of many years. As a result, alum applications can be used to eliminate phosphorus from the combined inputs resulting from internal recycling as well as groundwater seepage.

TABLE 6-1

LOWER SWEETWATER COVE SEDIMENT INACTIVATION REQUIREMENTS

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
< 20	15	0.02	0.1	5	68	8
20-30	25	0.50	5.1	164	2,455	299
30-40	35	0.61	8.6	279	4,181	509
40-50	45	1.24	23	726	10,896	1,327
50-60	55	1.32	29	949	14,236	1,733
60-70	65	0.67	18	570	8,557	1,042
70-80	75	0.19	5.8	186	2,785	339
>80	85	0.00	0.0	0.4	6	1
Overall Totals:		**4.55**	**89**	**2,879**	**43,184**	**5,258**

Areal Aluminum Dose (g Al/m^2):	63.2
Number of Tankers:	1.2
Lake Volume (ac-ft):	18.2
Water Column Aluminum Dose (mg/l):	51.9

A summary of calculations of alum requirements for control of phosphorus loading from groundwater seepage entering the lower lobe is given in Table 6-2. Based on the field seepage monitoring program conducted by ERD, phosphorus inflow to the lower lobe of Sweetwater Cove Lake from groundwater seepage is conservatively estimated to be approximately 3.76 kg/yr based on extrapolating the measured daily influx rate to an annual cycle. However, as discussed in Section 4.5, this measurement was conducted during dry season conditions and includes only a portion of an annual cycle. Therefore, the seepage loading estimate is increased by 50% to 5.64 kg/yr in order to account for the lack of wet season measurements. This analysis assumes that control of groundwater seepage is desired for a period of approximately 15 years to match the typical longevity of sediment inactivation projects. Therefore, the total mass of phosphorus from groundwater seepage which must be inactivated is approximately 84.6 kg over the 15-year period, equivalent to approximately 2,729 moles of total phosphorus. Assuming an Al:P ratio of 15:1 for adequate inactivation, control of 2,729 moles of total phosphorus will require approximately 40,935 moles of aluminum. This equates to an alum volume of 4,985 gallons.

TABLE 6-2

CALCULATION OF ALUM REQUIREMENTS FOR CONTROL OF PHOSPHORUS LOADING FROM GROUNDWATER SEEPAGE

PARAMETER		UNITS	VALUE
Estimated Phosphorus Mass to be Controlled	Seepage Phosphorus Loading	g/m^2-yr	0.306
	Annual Phosphorus Loading from Seepage	kg/yr	5.64
	Desired Length of Control	years	15
	Total Phosphorus Mass to be Inactivated	kg	84.6
	Moles of Phosphorus to be Inactivated	moles	2,729
Alum Requirements	Inactivation Al:P Ratio	--	15
	Moles of Aluminum Required	moles	40,935
	Alum Required	gallons	4,985
	Number of Tankers at 4,500 Gallons Each	--	1.1
	Mean Water Column Dose	mg Al/liter	49.2

1. Based on an Al:P ratio of 15:1

The proposed alum treatment to the lower lobe would add sufficient alum to control both internal recycling and intercept phosphorus loadings from groundwater seepage over an anticipated period of 15 years. Assuming that approximately 5,258 gallons of alum are needed for sediment inactivation and 4,984 gallons of alum are needed for interception of groundwater seepage, the total amount of alum to be added to the lower lobe would be 10,242 gallons. Based on an assumed lake volume of 13.7 ac-ft, the proposed alum addition equates to a whole-lake alum dose of approximately 101 mg Al/liter which far exceeds the available buffering capacity in the lake to withstand potential reductions in water column pH. As a result, the proposed application would need to be divided into a series of multiple applications and/or a buffering compound would be needed to neutralize the pH impacts from the alum addition.

The most common approach to reducing the impacts from large water column doses of aluminum is to use a buffering compound in addition to the alum to neutralize the anticipated undesirable pH impacts, reducing the number of required repeat applications. Due to the large amount of alum required for the lower lobe in comparison with the water column, a minimum of four applications is recommended to ensure a uniform coating over the lake bottom and to spread out potential impacts to the lake. Sodium aluminate (SA), an alkaline form of alum, is commonly used in these applications as the buffering agent. Sodium aluminate provides a high level of buffering, as well as supplemental aluminum ions, which reduces the amount of alum required during the application process. If alum and sodium aluminate are used in combination, changes in pH within the lake during the application process can be easily controlled.

The specific ratio of alum and sodium aluminate required to control water column pH varies based on the characteristics of each lake and is often determined in a series of laboratory jar test experiments. Although the alum/SA ratio for a lake depends on many factors and must be determined independently in a series of jar tests, the simultaneous addition of 1 gallon of sodium aluminate for every 3 gallons of alum is often sufficient to create neutral pH conditions during the application process, and this assumption is used for purposes of this analysis. One gallon of alum provides approximately 8.21 moles of available aluminum for sediment inactivation, while one gallon of sodium aluminate provides 21.46 moles of aluminum. Therefore, the use of sodium aluminate not only provides pH buffering, but also reduces the amount of alum required for the inactivation project.

The total estimated alum volume for inactivation of internal recycling and control of seepage inputs in the lower lobe at an Al:P ratio of 15:1, without the use of supplemental buffering agents, is approximately 10,243 gallons or 2,271 kg of aluminum. If sodium aluminate is used as a buffering agent and applied at an alum/SA ratio of 3:1, the total chemical requirements necessary to generate an equivalent total mass of aluminum are 5,450 gallons of alum combined with 1,817 gallons of sodium aluminate. A summary of proposed alum requirements to control internal recycling and groundwater seepage in the lower lobe is given in Table 6-3. The treatment should be divided into a minimum of four separate applications, with approximately one-fourth of the required chemical volume for alum and sodium aluminate applied during each application. Each treatment would be applied using a boat or barge to spread the chemicals over the lake surface. The recommended overall chemical volumes are indicated in Table 6-3 along with chemical requirements for each of the four individual treatments. However, as indicated previously, the specific alum/SA ratio would need to be verified in the lab prior to a proposed application.

TABLE 6-3

SUMMARY OF CHEMICAL REQUIREMENTS FOR CONTROL OF SEDIMENT PHOSPHORUS RELEASE AND GROUNDWATER SEEPAGE ENTERING THE LOWER LOBE OF SWEETWATER COVE LAKE

PARAMETER		UNITS	VALUE
Chemical Requirements	Aluminum Required	kg	2,271
	Alum/Sodium Aluminate Volume Ratio	--	3
	Alum	gallons	5,450
	Sodium Aluminate	gallons	1,817
	Aluminum Provided	kg	2,284
	Water Column Dose	mg Al/liter	101.7
	Areal Dose	g Al/liter^2	123.9
Chemical Requirements per Treatment	Number of Treatments	--	4
	Alum requirement per Treatment	gallons tankers	1,363 0.30
	Sodium Aluminate Required per Treatment	gallons tankers	454 0.12
	Dose per Treatment	mg Al/liter	25.4

6.2.3 Application Details

Sediment inactivation in lower Sweetwater Cove will be a very difficult and tedious operation compared with sediment inactivation projects routinely conducted by ERD. Due to the shallow water depth, the application of the alum and sodium aluminate must be conducted in an extremely precise manner to maintain the desired pH conditions within the lake. Alum is a strong acid, and sodium aluminate is an extremely strong base, and even a slight error in the application ratio for the two chemicals can rapidly result in undesirably high or low pH conditions within the lake. Therefore, the application must be conducted in a slow and highly controlled manner, with relatively precise chemical metering pumps required to accurately dose the proper amount of alum and sodium aluminate into the carrier water stream. Alum and sodium aluminate cannot be mixed prior to application to the water column, so two separate injection systems will be required and must be capable of operating simultaneously. Due to the shallow water column throughout the lake, the application will need to be conducted with a boat with a shallow water draft which is also capable of supporting the weight of two separate chemical storage tanks and associated pumps, valves, and control equipment.

A second factor impacting a successful alum application to lower Sweetwater Cove is the existing floating mats of Lyngbya within the lake. The current density of these mats limits navigability in portions of the lower lobe, and the vast majority of the floating mats would need to be removed prior to any proposed chemical application. Control of Lyngbya growth in lower Sweetwater Cove has been challenging, and previous attempts at control of the Lyngbya growth have been only partially successful. If the current growth cannot be removed through chemical means, then manual harvesting may be required prior to the alum application.

6.2.4 Application Costs

A summary of estimated application costs for sediment inactivation and control of groundwater seepage in the lower lobe is given in Table 6-4. This estimate assumes an alum volume of 6,150 gallons and a sodium aluminate volume of 1,538 gallons will be applied during a total of four separate applications. It is assumed that the alum will be purchased directly by the County at contract price, with the sodium aluminate provided by the application contractor. For purposes of this estimate, the typical alum contract price of approximately $0.50/gallon (full load) is increased to $0.75/gallon to account for the partial shipment.

Planning and mobilization costs are estimated to be approximately $5000 per application, which includes initial planning, mobilization of equipment to the site, demobilization at the completion of the application process, and clean-up. A unit application rate of $4,000 is assumed which includes labor costs, water quality monitoring, expenses, equipment rental, insurance, mileage, and application equipment fees. The estimated cost for sediment inactivation and control of groundwater seepage in the lower lobe is $58,984 or approximately $14,746 per application.

TABLE 6-4

ESTIMATED APPLICATION COSTS FOR SEDIMENT INACTIVATION AND CONTROL OF GROUNDWATER SEEPAGE IN THE LOWER LOBE OF SWEETWATER COVE
(Based on 4 separate treatments)

PARAMETER		AMOUNT REQUIRED/ APPLICATION	UNIT COST/ APPLICATION	COST/ APPLICATION ($)	TOTAL COST ($) (4 applications)
Chemicals	Alum	1,363 gallons	$0.75/gallon[1]	1,022	4,088
	Sodium Aluminate	454 gallons	$6.00/gallon	2,724	10,896
Labor	Planning/Mobilization	1 each	$5,000/application	5,000	20,000
	Chemical Application	1 each	$5,000/application[2]	5,000	20,000
Lab Testing		Pre-/Post-samples	$1,000/event	1,000	4,000
			TOTAL:	**$ 14,746**	**$ 54,984**

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

6.2.5 Longevity of Treatment

After initial 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 30-90 days, reaching maximum consolidation during that time. 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.

At least 35 previous sediment inactivation projects have been conducted by ERD in the State of Florida since 1992. Approximately half of these waterbodies have sufficient pre- and post-water quality data to evaluate the effectiveness of the alum sediment inactivation process. None of the 17 waterbodies for which water quality data are available have shown any signs of a decrease in the effectiveness of the sediment inactivation project, some of which were conducted more than 15 years ago. As a result, it appears that a properly planned and executed alum treatment project for the lower lobe would maintain a continuous level of effectiveness for a minimum of 10-15 years.

6.3 Control of Upstream Inflows

As discussed in Section 2, water quality characteristics in lower Sweetwater Cove are highly variable and generally elevated in value for both total nitrogen and total phosphorus. The measured concentrations for SRP during January, February, and March 2015 were substantially higher in value than concentrations measured by ERD in any other waterbody within the State of Florida, and it is highly unlikely that the observed elevated SRP values could have originated from normal waterbody inputs of stormwater runoff and groundwater seepage. The most likely source of the elevated SRP values observed in lower Sweetwater Cove, along with the highly variable and often elevated levels of inorganic nitrogen, is inflow from Sweetwater Creek which contains inputs of secondary treated effluent from the Sanlando Utilities Wastewater Treatment Plant (WWTP). These elevated nutrient concentrations stimulate the growth of algae in upper, middle, and lower portions of Sweetwater Cove throughout the year. However, the deeper water present in the upper lobe limits the type of algae present compared with the shallow water column present in lower Sweetwater Cove.

Unfortunately, no reliable information currently exists on the inflow rates from Sweetwater Creek into Sweetwater Cove Lake. Discharge rates through Sweetwater Creek are regulated by a variety of factors including antecedent rainfall conditions and the quantity of discharges from the Sanlando Utilities WWTP, and each of these sources impact not only the quantity but also the quality of the discharges. During the field monitoring program conducted by ERD, continuous discharges were observed through the outfall structure located in the northeast portion of the lower lobe, indicating a continuous flow through the interconnected lakes.

Due to the virtually continuous flow of water through the Sweetwater Cove Lake system and the general lack of available land for construction of stormwater BMPs, it is unlikely that any common stormwater BMP, such as a wet pond, could be constructed in available land areas which would make a significant impact on water quality characteristics in lower Sweetwater Cove. The only type of treatment system which could potentially provide nutrient reductions for the volume of inflow from Sweetwater Creek is an alum inflow treatment system. A conceptual schematic of a proposed alum addition system for Sweetwater Creek is given on Figure 6-1. Flow monitoring would occur at the box culvert which passes beneath Wekiva Springs Road, and liquid alum would be injected into the flow on a flow-proportioned basis. The upper lobe of Sweetwater Cove Lake contains relatively deep areas extending to depths of approximately 10-15 ft which could be used for floc settling and accumulation. After the floc settling occurs, the treated water would then pass into the middle lobe and lower lobe with substantially lower nutrient concentrations. Components for the alum addition system could be constructed either above-ground or below-ground in existing right-of-way areas. ERD recently completed 60% design drawings for a similar underground system for Haines City, and the estimated construction cost was $250,000. However, this idea is only conceptual at this time, and a substantially more detailed study will be needed to determine feasibility, construction costs, annual O&M costs, and floc accumulation rates.

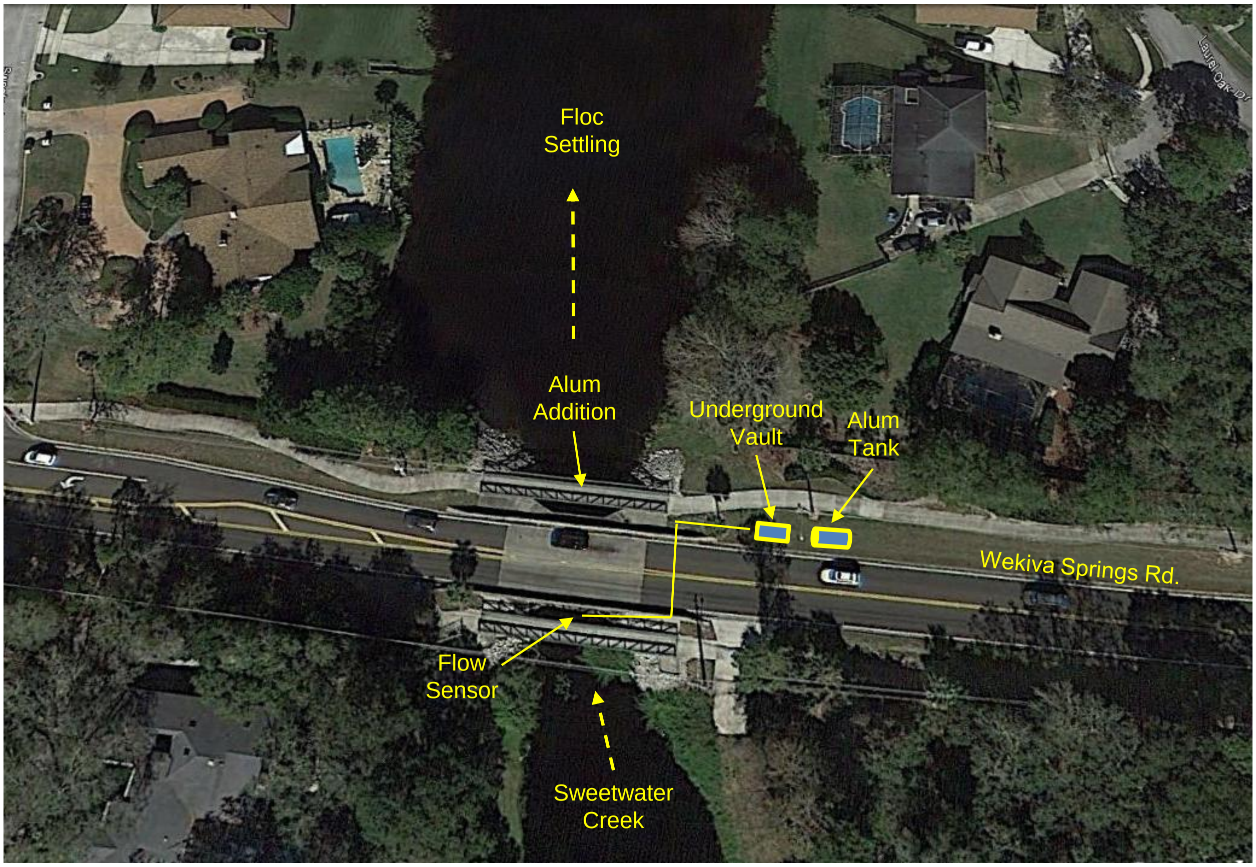


Figure 6-1. Conceptual Schematic of an Alum Addition System for Sweetwater Creek.

Potential locations for underground or above-ground alum treatment components are illustrated on Figures 6-2 and 6-3, respectively. A substantial grassed right-of-way exists on both sides of Wekiva Springs Road which could be used to bury an underground vault and alum storage tank, provided that significant utility conflicts do not exist. The treatment system components could also be installed in a small above-ground facility which could be constructed in existing right-of-way areas on the south side of Wekiva Springs Road adjacent to Sweetwater Creek. ERD has multiple new designs for treatment facilities which reduce required space and overall construction costs.

It is highly likely that an alum inflow treatment would provide substantial reductions in nutrient loadings reaching the lower lobe, and since it is believed that inflows from upstream waterbodies contribute the largest volumetric and mass loadings to the lower lobe, then the anticipated reductions in loadings should substantially improve water quality within the lower lobe, reduce the TN/TP ratio, and remove the existing favorable conditions for Lyngbya growth. However, this idea is only conceptual at this time, and a more thorough evaluation and preliminary design will be necessary to evaluate the feasibility of this option.

Figure 6-2. Potential Locations for Underground Alum Treatment System Components.

Figure 6-3. Potential Locations for Above-ground Alum Treatment System Components.

6.4 Rear Yard Berms and Swales

Rear yard areas on lake front homes have the potential to contribute significant loadings of nutrients and pesticides directly into a lake with no significant treatment of any kind. Even if stormwater management systems are built to control runoff generated within a lake front residential community, rear yard runoff often discharges directly into the lake without the benefit of treatment processes within the stormwater management systems. Rear yard areas often have a steeper slope than front yard areas, further increasing the potential for runoff and pollutant transport from these areas.

A reliable and inexpensive method of controlling rear yard runoff is a berm and swale system. The objective of a berm and swale system is to intercept runoff from the rear yard area, causing this volume to be infiltrated into the ground rather than directly discharging into the adjacent waterbody. As the intercepted runoff migrates through the vegetation and surficial soils, a large portion of the pollutant mass is attenuated and is prevented from reaching the adjacent water. Since these systems act primarily as retention areas, it is important that the area utilized for infiltration be constructed above the seasonal high groundwater table elevation. If the bottom of the infiltration area is not maintained above the seasonal high groundwater table elevation (SHGWT), the retention area will assume wetland characteristics and will gradually lose its ability to evacuate the required pollution abatement volume.

The volume of water retained by a rear yard swale or berm system is directly proportional to the performance efficiency of the system for reducing loadings discharging into the waterbodies. The minimum design criteria for retention systems constructed in the St. Johns River Water Management District is storage of the first 0.5-inch of runoff. This volume is calculated by multiplying the area of each parcel which discharges to the rear of the lot (rather than the front) times 0.50 inches over this area. The resulting volume represents the amount of water which should be retained in the rear yard and dictates the design of the swale and berm. A schematic of a recommended berm and swale design is given in Figure 6-4.

One of the common criticisms of berm and swale systems concerns ongoing maintenance of the areas. Where swale systems are used, bottom portions of the swale can become wet for extended periods, making mowing and maintenance activities difficult. Mowing of bermed areas can also be difficult, particularly if the berm is constructed with steep side slopes. However, virtually all of the maintenance concerns for bermed areas can be eliminated by constructing the berm with more gradual side slopes, such as 6(H):1(V) or flatter, and by designing the bottom of the swale portion above the seasonal high water level (SHWL) of the lake.

Berm and swale systems could provide an inexpensive method of reducing discharges of direct runoff from rear yards and landscaped areas into the lower lobe. However, the quantity of nutrient loadings discharging to the lower lobe from rear yard areas is not known, and the anticipated load reductions and corresponding water quality improvements cannot be determined at this time.

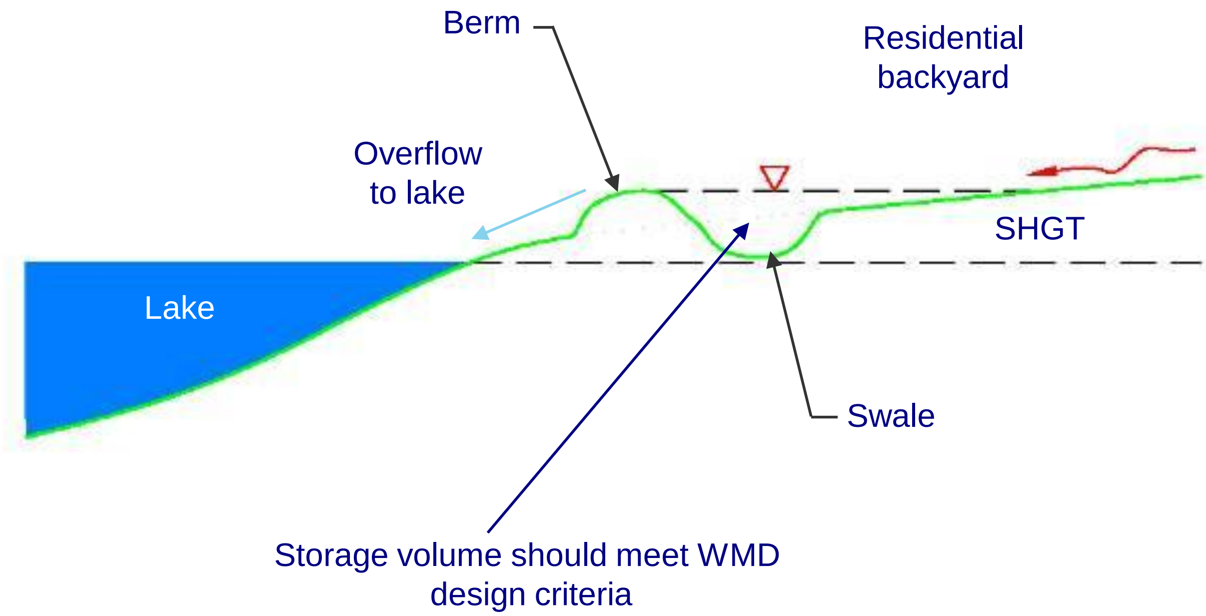


Figure 6-4. Schematic of Recommended Rear Yard Swale and Berm Design.

6.5 Vegetated Shorelines

6.5.1 Existing Conditions and Issues

Shoreline areas surrounding the lower lobe contain a wide variety of both species and density of aquatic vegetation which range from natural vegetated shorelines, to planted shorelines, to bare shorelines. Some of the shoreline residents have planted native plant species along their shoreline, while others maintain a cleared shoreline where virtually all aquatic vegetation has been removed from shoreline areas adjacent to their properties. Many areas exist where the rear lawn extends to the water's edge with no emergent shoreline vegetation at all. Photographs of current shoreline vegetation in the lower lobe are given on Figure 6-5.

A recent study conducted by ERD on the Butler Chain-of-Lakes indicated that shoreline areas which are non-vegetated are susceptible to erosion and resuspension of sediment material as a result of wave activity caused by boats or wind. Shoreline vegetation also contributes to a diverse ecological community which is an important factor in maintaining good water quality characteristics within the water column. Shoreline vegetation consumes nutrients, leaving fewer nutrients available for algal growth, reducing the formation and accumulation of organic muck. Shoreline vegetation also assists in providing treatment for runoff generated in rear yards. In general, shoreline vegetation provides an extremely beneficial function in lake ecosystems and should be maintained to the maximum extent possible. Ideal shoreline vegetation consists of a combination of emergent vegetation to filter runoff generated pollutants from upland areas and submergent vegetation to assist in removing pollutants which seep through the shallow shoreline areas.

Figure 6-5. Examples of Shoreline Areas in the Lower Lobe of Sweetwater Cove.

Seminole County maintains a series of education brochures on aquatic plant management and revegetation. The document titled “Plants for Lake Front Revegetation”, developed by the Bureau of Invasive Management of FDEP, provides a detailed description of native aquatic plants, including photographs, physical characteristics, and planting requirements. A copy of this publication is given in Appendix D.1. Another publication, titled “A Guide on How to Plant Your Lake Front”, was developed by the Seminole County Department of Public Works and contains information material on selecting desirable planting species, where to plant various species, shoreline preparation, planting techniques, and vegetation maintenance. A copy of this publication is given in Appendix D.2. Another excellent reference document is the Seminole County publication titled “A Citizen’s Guide to Lake Management” produced by the Seminole County Lake Management Program. This document provides an overview of potential sources to lakes, aquatic plant and invasive aquatic species, shoreline alteration, and a discussion of beneficial native plant species. A copy of this publication is included in Appendix D.3.

Since 2013, Seminole County has held multiple shoreline restoration events within the lower lobe of Sweetwater Cove. Each of these events was sponsored by Seminole County Watershed Management and the SERV Program, in conjunction with shoreline residents. The aquatic plants are provided by Seminole County, and County personnel provide instruction and assistance in installation of aquatic shoreline vegetation. More than 20,000 aquatic plants have been planted in the lower lobe as part of this program.

An overview of parcels participating in the shoreline restoration projects is given on Figure 6-6. At this time, more than half of the current parcels located on the lower lobe have participated in the shoreline revegetation project. Similar shoreline restoration events have been conducted for the upper and middle lobes of Sweetwater Cove Lake.

6.6 Recommendations

A summary of recommendations designed to reduce available nutrient loadings within lower Sweetwater Cove to control the current nuisance growth of Lyngbya is summarized in Table 6-5. The listed nutrient management recommendations are designed to reduce existing nutrient pathways from both sediments and the water column to reduce nutrient source availability to Lyngbya, alter the water column nutrient ratio to an area of more favorable green algae and diatoms, and develop a more diverse ecological community within the lower lobe. The listed recommendations are conceptual at this point since detailed hydrologic and nutrient budgets have not been conducted. The management recommendations are based upon anticipated primary sources for sediment and water column nutrient loadings.

TABLE 6-5

RECOMMENDED NUTRIENT MANAGEMENT OPTIONS FOR LOWER SWEETWATER COVE LAKE

NUTRIENT SOURCE / ISSUE	RECOMMENDATIONS
Water Column Nutrient Loadings	Conduct a feasibility evaluation for an alum treatment system to treat nutrient inflows from Sweetwater Creek
Sediment Nutrient Loadings	Conduct a whole-lake alum treatment to control sediment nutrient loadings
Rear Yard Runoff	Construct rear yard berms and swales on all waterfront parcels on the lower lobe
Vegetated Shorelines	Conduct educational workshop on benefits of shoreline vegetation; County to provide assistance with re-vegetation of all shoreline areas

Figure 6-6. Parcels Participating in the Shoreline Restoration Projects.

APPENDICES

APPENDIX A

VERTICAL FIELD PROFILES COLLECTED AT SURFACE WATER MONITORING SITES IN SWEETWATER COVE FROM JANUARY – JUNE 2015

Field Measurements Collected in Sweetwater Cove

Lake	Site	Date	Time	Depth (m)	Temp. (°C)	pH (s.u.)	Conductivity (µmho/cm)	TDS (mg/L)	Diss. O_2 (mg/L)	Diss. O_2 (% Sat)	ORP (mV)	Secchi Depth (m)
Sweetwater Cove	Site 1	1/12/15	10:27	0.25	17.79	7.54	289	185	7.1	74	475	0.81 (B)
			10:28	0.50	17.02	7.53	288	184	7.4	77	471	
			10:30	0.81	17.16	7.22	307	197	6.5	68	411	
Sweetwater Cove	Site 2	1/12/15	10:09	0.25	17.19	7.49	302	193	7.0	72	489	0.93 (B)
			10:10	0.50	16.97	7.46	303	194	6.6	68	489	
			10:11	0.93	17.07	7.31	313	200	4.6	48	432	
Sweetwater Cove	Site 3	1/12/15	9:44	0.25	17.06	7.44	315	202	7.1	74	507	1.11 (B)
			9:45	0.50	16.95	7.41	313	200	7.0	72	505	
			9:46	1.00	16.81	7.32	306	196	6.4	66	475	
			9:47	1.11	16.82	7.25	311	199	5.8	60	465	
Sweetwater Cove	Site 4	1/12/15	9:22	0.25	16.98	7.26	302	193	5.5	57	552	0.82 (B)
			9:23	0.50	16.94	7.22	303	194	4.5	46	535	
			9:24	0.82	17.17	7.14	306	196	3.2	33	498	
Sweetwater Cove	Site 1	2/10/15	9:35	0.25	16.50	7.76	304	194	7.4	76	522	0.64 (B)
			9:36	0.64	16.61	7.45	317	203	5.9	61	496	
Sweetwater Cove	Site 2	2/10/15	9:51	0.25	17.11	7.39	304	195	7.4	77	458	0.75 (B)
			9:52	0.50	17.12	7.35	304	194	7.6	79	456	
			9:53	0.75	17.24	7.16	321	206	5.0	52	435	
Sweetwater Cove	Site 3	2/10/15	10:05	0.25	17.34	7.41	302	193	7.9	83	438	0.88 (B)
			10:06	0.50	17.32	7.38	302	194	7.8	81	438	
			10:07	0.88	17.26	7.30	303	194	7.0	72	436	
Sweetwater Cove	Site 4	2/10/15	10:22	0.25	16.92	7.39	280	179	5.8	60	446	0.58 (B)
			10:24	0.58	17.01	7.18	305	195	4.4	46	408	

Field Measurements Collected in Sweetwater Cove

Lake	Site	Date	Time	Depth (m)	Temp. (°C)	pH (s.u.)	Conductivity (µmho/cm)	TDS (mg/L)	Diss. O_2 (mg/L)	Diss. O_2 (% Sat)	ORP (mV)	Secchi Depth (m)
Sweetwater Cove	Site 1	3/20/15	7:19	0.25	24.28	7.30	356	228	4.7	57	642	0.83 (B)
			7:19	0.50	23.94	7.20	359	230	2.9	34	612	
			7:20	0.83	24.01	7.03	375	240	1.5	18	481	
Sweetwater Cove	Site 2	3/20/15	7:31	0.25	24.41	7.28	357	228	5.0	59	454	0.79 (B)
			7:32	0.50	24.41	7.24	358	229	4.0	48	452	
			7:34	0.79	24.38	7.15	359	229	2.6	31	423	
Sweetwater Cove	Site 3	3/20/15	7:52	0.25	24.43	7.37	359	230	5.7	68	461	1.24 (B)
			7:53	0.50	24.43	7.34	358	229	4.6	55	460	
			7:54	1.00	24.09	7.28	360	230	3.8	45	456	
			7:55	1.24	24.06	7.21	361	231	3.1	37	446	
Sweetwater Cove	Site 4	3/20/15	8:01	0.25	24.12	7.30	364	233	3.8	46	450	0.93 (B)
			8:02	0.50	24.08	7.28	364	233	3.7	45	449	
			8:02	0.93	24.10	7.24	363	233	2.9	34	438	
Sweetwater Cove	Site 1	5/27/15	7:53	0.25	28.10	8.96	414	265	4.7	60	455	0.29
			7:54	0.50	27.46	8.72	421	270	2.4	29	421	
			7:54	0.87	27.24	7.96	441	282	1.0	12	362	
Sweetwater Cove	Site 2	5/27/15	8:17	0.25	28.62	9.28	408	261	5.9	77	319	0.27
			8:18	0.50	28.18	9.30	408	261	5.5	71	317	
			8:19	1.02	28.12	8.72	410	262	2.6	33	315	
Sweetwater Cove	Site 3	5/27/15	8:26	0.25	28.67	9.31	407	261	6.6	85	326	0.29
			8:26	0.50	28.39	9.29	408	261	5.9	76	330	
			8:27	0.87	28.18	9.24	409	261	4.7	61	336	
Sweetwater Cove	Site 4	5/27/15	8:36	0.25	28.33	9.21	411	263	6.9	89	340	0.28
			8:37	0.51	28.00	7.56	446	285	1.2	15	336	

Field Measurements Collected in Sweetwater Cove

Lake	Site	Date	Time	Depth (m)	Temp. (°C)	pH (s.u.)	Conductivity (µmho/cm)	TDS (mg/L)	Diss. O_2 (mg/L)	Diss. O_2 (% Sat)	ORP (mV)	Secchi Depth (m)
Sweetwater Cove	Site 1	6/30/15	6:38	0.25	28.55	6.69	254	162	3.4	44	574	0.71 (B)
			6:38	0.50	28.55	6.80	253	162	2.4	31	541	
			6:39	0.71	28.56	6.83	292	187	1.2	16	335	
Sweetwater Cove	Site 2	6/30/15	6:47	0.25	28.32	7.11	253	162	3.1	39	416	0.99 (B)
			6:48	0.50	28.33	7.10	254	162	2.7	34	416	
			6:48	0.99	28.38	7.07	264	169	1.9	25	362	
Sweetwater Cove	Site 3	6/30/15	6:56	0.25	28.39	7.21	254	162	3.2	41	415	1.29 (B)
			6:57	0.50	28.42	7.19	254	162	2.9	38	415	
			6:57	1.00	28.32	7.15	255	163	2.6	33	408	
			6:58	1.29	28.27	7.11	254	162	1.9	25	377	
Sweetwater	Site 4	6/30/15	7:02	0.25	28.59	7.19	257	165	3.8	50	408	0.64 (B)
			7:03	0.50	28.55	7.16	257	164	3.0	38	409	
			7:04	0.64	28.52	7.12	256	164	2.5	32	410	

APPENDIX B

CHARACTERISTICS OF GROUNDWATER SEEPAGE COLLECTED IN SWEETWATER COVE FROM JANUARY – JUNE 2015

B.1 Volumetric Seepage Measurements

B.2 Chemical Characteristics of Seepage Samples

B.1 Volumetric Seepage Measurements

Seepage Meter Field Measurements

Location: **Sweetwater Cove** **Site:** **1**

Date Installed: **12/5/14** **Chamber Diameter:** **0.58 m** **Sediment Area Covered:** **0.27 m^2**

Date	Time Collected	Volume Collected (liters)	Previous Collection Event		Seepage Time (days)	Seepage (liters/m^2-day)	Comments / Observations
			Date	Time			
12/5/14	12:10	- - -	- - -	- - -	- - -	- - -	Bags Installed
1/7/15	12:46	3.8	12/5/14	12:10	33.0	0.42	Measured volume, no sample collected
2/10/15	11:40	5.3	1/7/15	12:46	34.0	0.57	Sample collected, bag in good condition
3/20/15	10:13	6.5	2/10/15	11:40	37.9	0.63	Sample collected, bag in good condition
6/30/15	9:37	24.8	3/20/15	10:13	102.0	0.90	Sample collected, bag in good condition
					Mean:	**0.72**	

Seepage Meter Field Measurements

Location: **Sweetwater Cove** **Site:** **2**

Date Installed: **12/5/14** **Chamber Diameter:** **0.58 m** **Sediment Area Covered:** **0.27 m^2**

Date	Time Collected	Volume Collected (liters)	Previous Collection Event		Seepage Time (days)	Seepage (liters/m^2-day)	Comments / Observations
			Date	Time			
12/5/14	12:00	- - -	- - -	- - -	- - -	- - -	Bags Installed
1/7/15	12:41	3.5	12/5/14	12:00	33.0	0.39	Measured volume, no sample collected
2/10/15	11:35	5.5	1/7/15	12:41	34.0	0.60	Sample collected, bag in good condition
3/20/15	10:07	8.3	2/10/15	11:35	37.9	0.81	Sample collected, bag in good condition
6/30/15	9:19	7.5	3/20/15	10:07	102.0	0.27	Sample collected, bag in good condition
					Mean:	**0.44**	

Seepage Meter Field Measurements

Location: **Sweetwater Cove** **Site:** **3**

Date Installed: **12/5/14** **Chamber Diameter:** **0.58 m** **Sediment Area Covered:** **0.27 m^2**

Date	Time Collected	Volume Collected (liters)	Previous Collection Event		Seepage Time (days)	Seepage (liters/m^2-day)	Comments / Observations
			Date	Time			
12/5/14	12:20	- - -	- - -	- - -	- - -	- - -	Bags Installed
1/7/15	12:51	12.8	12/5/14	12:20	33.0	1.43	Measured volume, no sample collected
2/10/15	11:46	12.3	1/7/15	12:51	- - -	- - -	Sample collected, bag in good condition
3/20/15	10:18	9.5	2/10/15	11:46	37.9	0.93	Sample collected, bag in good condition
6/30/15	9:25	18.8	3/20/15	10:18	102.0	0.68	Sample collected, bag in good condition
					Mean:	**1.14**	

Seepage Meter Field Measurements

Location: Sweetwater Cove **Site: 4**

Date Installed: 12/5/14 **Chamber Diameter: 0.58 m** **Sediment Area Covered: 0.27 m^2**

Date	Time Collected	Volume Collected (liters)	Previous Collection Event		Seepage Time (days)	Seepage (liters/m^2-day)	Comments / Observations
			Date	Time			
12/5/14	11:52	- - -	- - -	- - -	- - -	- - -	Bags Installed
1/7/15	12:37	7.5	12/5/14	11:52	33.0	0.84	Measured volume, no sample collected
2/10/15	11:30	5.3	1/7/15	12:37	34.0	0.57	Sample collected, bag in good condition
3/20/15	10:03	7.5	2/10/15	11:30	37.9	0.73	Sample collected, bag in good condition
6/30/15	9:11	10.5	3/20/15	10:03	102.0	0.38	Sample collected, bag in good condition
					Mean:	**0.55**	

Seepage Meter Field Measurements

Location: Sweetwater Cove **Site: 5**

Date Installed: 12/5/14 **Chamber Diameter: 0.58 m** **Sediment Area Covered: 0.27 m^2**

Date	Time Collected	Volume Collected (liters)	Previous Collection Event		Seepage Time (days)	Seepage (liters/m^2-day)	Comments / Observations
			Date	Time			
12/5/14	11:48	- - -	- - -	- - -	- - -	- - -	Bags Installed
1/7/15	12:34	5.3	12/5/14	11:48	33.0	0.59	Measured volume, no sample collected
2/10/15	11:24	- - -	1/7/15	12:34	34.0	- - -	Bag damaged, no sample, bag replaced
3/20/15	9:55	7.8	2/10/15	11:24	37.9	0.76	Sample collected, bag in good condition
6/30/15	9:03	17.3	3/20/15	9:55	102.0	0.63	Sample collected, bag in good condition
					Mean:	**0.54**	

Seepage Meter Field Measurements

Location: Sweetwater Cove **Site: 6**

Date Installed: 12/5/14 **Chamber Diameter: 0.58 m** **Sediment Area Covered: 0.27 m^2**

Date	Time Collected	Volume Collected (liters)	Previous Collection Event		Seepage Time (days)	Seepage (liters/m^2-day)	Comments / Observations
			Date	Time			
12/5/14	11:08	- - -	- - -	- - -	- - -	- - -	Bags Installed
1/7/15	12:29	7.3	12/5/14	11:08	33.1	0.81	Measured volume, no sample collected
2/10/15	11:18	7.5	1/7/15	12:29	34.0	0.82	Sample collected, bag in good condition
3/20/15	9:50	15.5	2/10/15	11:18	37.9	1.51	Sample collected, bag in good condition
6/30/15	8:58	19.5	3/20/15	9:50	102.0	0.71	Sample collected, bag in good condition
					Mean:	**0.89**	

Seepage Meter Field Measurements

Location: Sweetwater Cove **Site: 7**

Date Installed: 12/5/14 **Chamber Diameter: 0.58 m** **Sediment Area Covered: 0.27 m^2**

Date	Time Collected	Volume Collected (liters)	Previous Collection Event		Seepage Time (days)	Seepage (liters/m^2-day)	Comments / Observations
			Date	Time			
12/5/14	11:01	- - -	- - -	- - -	- - -	- - -	Bags Installed
1/7/15	12:24	6.5	12/5/14	11:01	33.1	0.73	Measured volume, no sample collected
2/10/15	11:12	3.5	1/7/15	12:24	33.9	0.38	Sample collected, bag in good condition
3/20/15	9:43	6.8	2/10/15	11:12	37.9	0.66	Sample collected, bag in good condition
6/30/15	8:48	10.8	3/20/15	9:43	102.0	0.39	Sample collected, bag in good condition
					Mean:	**0.49**	

Seepage Meter Field Measurements

Location: Sweetwater Cove **Site: 8**

Date Installed: 12/5/14 **Chamber Diameter: 0.58 m** **Sediment Area Covered: 0.27 m^2**

Date	Time Collected	Volume Collected (liters)	Previous Collection Event		Seepage Time (days)	Seepage (liters/m^2-day)	Comments / Observations
			Date	Time			
12/5/14	10:50	- - -	- - -	- - -	- - -	- - -	Bags Installed
1/7/15	12:17	9.3	12/5/14	10:50	33.1	1.04	Measured volume, no sample collected
2/10/15	11:06	9.3	1/7/15	12:17	34.0	1.01	Sample collected, bag in good condition
3/20/15	9:39	10.5	2/10/15	11:06	37.9	1.03	Sample collected, bag in good condition
6/30/15	8:41	10.8	3/20/15	9:39	102.0	0.39	Sample collected, bag in good condition
					Mean:	**0.71**	

Seepage Meter Field Measurements

Location: Sweetwater Cove **Site: 9**

Date Installed: 12/5/14 **Chamber Diameter: 0.58 m** **Sediment Area Covered: 0.27 m^2**

Date	Time Collected	Volume Collected (liters)	Previous Collection Event		Seepage Time (days)	Seepage (liters/m^2-day)	Comments / Observations
			Date	Time			
12/5/14	10:41	- - -	- - -	- - -	- - -	- - -	Bags Installed
1/7/15	12:14	6.5	12/5/14	10:41	33.1	0.73	Measured volume, no sample collected
2/10/15	11:02	5.3	1/7/15	12:14	33.9	0.57	Sample collected, bag in good condition
3/20/15	9:34	8.3	2/10/15	11:02	37.9	0.81	Sample collected, bag in good condition
6/30/15	8:34	12.3	3/20/15	9:34	102.0	0.44	Sample collected, bag in good condition
					Mean:	**0.58**	

Seepage Meter Field Measurements

Location: **Sweetwater Cove** **Site:** **10**

Date Installed: **12/5/14** **Chamber Diameter:** **0.58 m** **Sediment Area Covered:** **0.27 m^2**

Date	Time Collected	Volume Collected (liters)	Previous Collection Event		Seepage Time (days)	Seepage (liters/m^2-day)	Comments / Observations
			Date	Time			
12/5/14	10:32	- - -	- - -	- - -	- - -	- - -	Bags Installed
1/7/15	12:11	3.3	12/5/14	10:32	33.1	0.36	Measured volume, no sample collected
2/10/15	10:55	2.8	1/7/15	12:11	33.9	0.30	Sample collected, bag in good condition
3/20/15	9:26	7.8	2/10/15	10:55	37.9	0.76	Sample collected, bag in good condition
6/30/15	8:25	10.5	3/20/15	9:26	102.0	0.38	Sample collected, bag in good condition
					Mean:	**0.43**	

B.2 Chemical Characteristics of Seepage Samples

Chemical Characteristics of Groundwater Seepage Samples
Collected in Sweetwater Cove

Sample Location	Date Collected	pH (s.u.)	Alkalinity (mg/L)	Cond. (µmho/cm)	Total N (µg/L)	Total P (µg/L)
Site #1 SP	2/10/15	7.39	234	293	12,483	3,777
Site #1 SP	3/20/15	7.29	300	787	8,214	3,960
Site #1 SP	6/30/15	7.30	84.2	312	1,411	222
Minimum Value:		**7.29**	**84.2**	**293**	**1,411**	**222**
Maximum Value:		**7.39**	**300**	**787**	**12,483**	**3,960**
Geometric Mean:		**7.33**	**181**	**416**	**5,250**	**1,492**
Site #2 SP	2/10/15	7.61	204	593	12,924	3,810
Site #2 SP	3/20/15	7.60	189	627	10,597	2,437
Site #2 SP	6/30/15	7.22	71.6	296	1,591	282
Minimum Value:		**7.22**	**71.6**	**296**	**1,591**	**282**
Maximum Value:		**7.61**	**204**	**627**	**12,924**	**3,810**
Geometric Mean:		**7.47**	**140**	**479**	**6,017**	**1,378**
Site #3 SP	2/10/15	7.67	168	617	3,881	915
Site #3 SP	3/20/15	7.53	156	428	3,796	798
Site #3 SP	6/30/15	7.55	125	243	2,602	360
Minimum Value:		**7.53**	**125.0**	**243**	**2,602**	**360**
Maximum Value:		**7.67**	**168**	**617**	**3,881**	**915**
Geometric Mean:		**7.58**	**149**	**400**	**3,372**	**641**
Site #4 SP	2/10/15	7.71	170	410	6,375	2,334
Site #4 SP	3/20/15	7.68	171	551	8,826	1,889
Site #4 SP	6/30/15	7.52	76.0	295	1,620	231
Minimum Value:		**7.52**	**76.0**	**295**	**1,620**	**231**
Maximum Value:		**7.71**	**171**	**551**	**8,826**	**2,334**
Geometric Mean:		**7.64**	**130**	**405**	**4,500**	**1,006**
Site #5 SP	3/20/15	7.43	119	460	4,461	1,203
Site #5 SP	6/30/15	7.05	70.4	339	959	214
Minimum Value:		**7.05**	**70.4**	**339**	**959**	**214**
Maximum Value:		**7.43**	**119**	**460**	**4,461**	**1,203**
Geometric Mean:		**7.24**	**91.5**	**395**	**2,068**	**507**

Chemical Characteristics of Groundwater Seepage Samples
Collected in Sweetwater Cove

Sample Location	Date Collected	pH (s.u.)	Alkalinity (mg/L)	Cond. (μmho/cm)	Total N (μg/L)	Total P (μg/L)
Site #6 SP	2/10/15	7.72	125	289	3,657	987
Site #6 SP	3/20/15	7.46	121	435	4,851	1,115
Site #6 SP	6/30/15	7.42	66.0	278	1,815	298
Minimum Value:		**7.42**	**66.0**	**278**	**1,815**	**298**
Maximum Value:		**7.72**	**125**	**435**	**4,851**	**1,115**
Geometric Mean:		**7.53**	**100**	**327**	**3,181**	**690**
Site #7 SP	2/10/15	7.61	202	506	5,644	1,984
Site #7 SP	3/20/15	7.47	167	545	7,301	1,774
Site #7 SP	6/30/15	7.23	69.2	289	1,809	306
Minimum Value:		**7.23**	**69.2**	**289**	**1,809**	**306**
Maximum Value:		**7.61**	**202**	**545**	**7,301**	**1,984**
Geometric Mean:		**7.44**	**133**	**430**	**4,208**	**1,025**
Site #8 SP	2/10/15	7.71	150	424	4,292	1,059
Site #8 SP	3/20/15	7.97	176	507	5,339	1,212
Site #8 SP	6/30/15	7.57	105	463	3,278	639
Minimum Value:		**7.57**	**105.0**	**424**	**3,278**	**639**
Maximum Value:		**7.97**	**176**	**507**	**5,339**	**1,212**
Geometric Mean:		**7.75**	**140**	**463**	**4,219**	**936**
Site #9 SP	2/10/15	7.56	153	492	9,133	2,998
Site #9 SP	3/20/15	7.69	182	623	10,317	2,756
Site #9 SP	6/30/15	7.29	70.6	290	1,829	314
Minimum Value:		**7.29**	**70.6**	**290**	**1,829**	**314**
Maximum Value:		**7.69**	**182**	**623**	**10,317**	**2,998**
Geometric Mean:		**7.51**	**125**	**446**	**5,565**	**1,374**
Site #10 SP	2/10/15	6.91	54.6	414	1,694	317
Site #10 SP	3/20/15	7.32	76.0	508	1,090	448
Site #10 SP	6/30/15	7.24	70.6	289	2,170	510
Minimum Value:		**6.91**	**54.6**	**289**	**1,090**	**317**
Maximum Value:		**7.32**	**76**	**508**	**2,170**	**510**
Geometric Mean:		**7.15**	**66**	**393**	**1,588**	**417**

APPENDIX C

APPLICATION PROTOCOL
DEVELOPED BY DR. ROGERS

Responses of *Lyngbya sp*. sampled from Sweetwater Cove Lake in Seminole County, FL., to exposures of Cutrine® Plus, Algimycin-PWF®, and Phycomycin SCP® followed by Algimycin-PWF®,

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Responses of *Lyngbya sp*. from Sweetwater Cove Lake, Fl, to exposures of Cutrine® Plus, Algimycin-PWF®, and Phycomycin SCP® followed by Algimycin-PWF®

- For treatment of *Lyngbya* sp. in Sweetwater Cove Lake, FL an application of Phycomycin SCP® at the maximum label rate of 36.6 mg / L (**100lbs/acre-ft.)** followed one day later by Algimycin-PWF® at 1.0 mg Cu / L (**5.31 gallons/acre-ft**.) should yield visible results (*i.e.* algae color change from green/brown to brown) within 10 days after application.

Recommendation:

Apply Phycomycin SCP® at 100lbs/acre-ft, then one day later apply Algimycin-PWF® at 5.31 gallons/acre-ft to gain effective control of *Lyngbya sp.* from Sweetwater Cove Lake, FL.

The algaecide should be applied directly to the *Lyngbya* mat and proportional to the amount of biomass present. Always read and follow the label recommendations, and use caution when applying the algaecide to reduce the probability of adverse effects to non-target organisms.

If you need assistance with this treatment, please contact Mr. Harry Knight. Always follow label recommendations.

Sample Origin: Sweetwater Cove Lake, FL
Site Contact Representative: Gloria Eby
Phone: 407-665-2439
Applied Biochemist Contact: Harry Knight
Phone: (256) 796-8704
Date Received: 17 December 2014
Experimental Period: 17--29 December 2014

Tests Completed:

Exposures of Cutrine® Plus, Algimycin-PWF®, and Phycomycin SCP® followed by Algimycin-PWF® to *Lyngbya sp.*

- The algal samples labeled “representative” and “composite” were approximately the same based on microscopic analysis. Therefore, tests were completed using the “composite” algal sample.

Formulations Tested:

Cutrine® Plus--10 day test duration

Algimycin-PWF®--10 day test duration

Phycomycin SCP® followed one day after by Algimycin-PWF®-- 10 day test duration

Types of Algae:

Lyngbya sp. (Cyanobacteria)

Initial Chlorophyll-*a* Concentration:

894 µg chlorophyll *a* / 0.5 g algae

Initial water characteristics:

Water Characteristics	Sweetwater Cove Lake
pH (S.U.)	7.1
Dissolved Oxygen (mg O_2 / L)	8.3
Alkalinity (mg $CaCO_3$ / L)	60
Hardness (mg $CaCO_3$ / L)	110
Conductivity (µS)	390
Temperature (°C)	20

Appendices

Appendix A

Responses of *Lyngbya sp.* sampled from Sweetwater Cove Lake in Seminole County, FL to exposures of Phycomycin SCP® followed by Algimycin-PWF®

Sample Origin: Sweetwater Cove Lake, FL
Site Contact Representative: Gloria Eby
Phone: 407-665-2439
Applied Biochemist Contact: Harry Knight
Phone: (256) 796-8704
Date Received: 17 December 2014
Experimental Period: 17--29 December 2014

Types of algae:

Lyngbya sp. (Cyanobacteria)

Initial Chlorophyll-*a* Concentration:

894 µg chlorophyll-*a*/ 0.5g algae

Experimental Conditions:

- Maintained at 20 ± 2°C
- 16-h light / 8-h dark photoperiod
- Light intensity of ~3077 lux

Experiment Details:

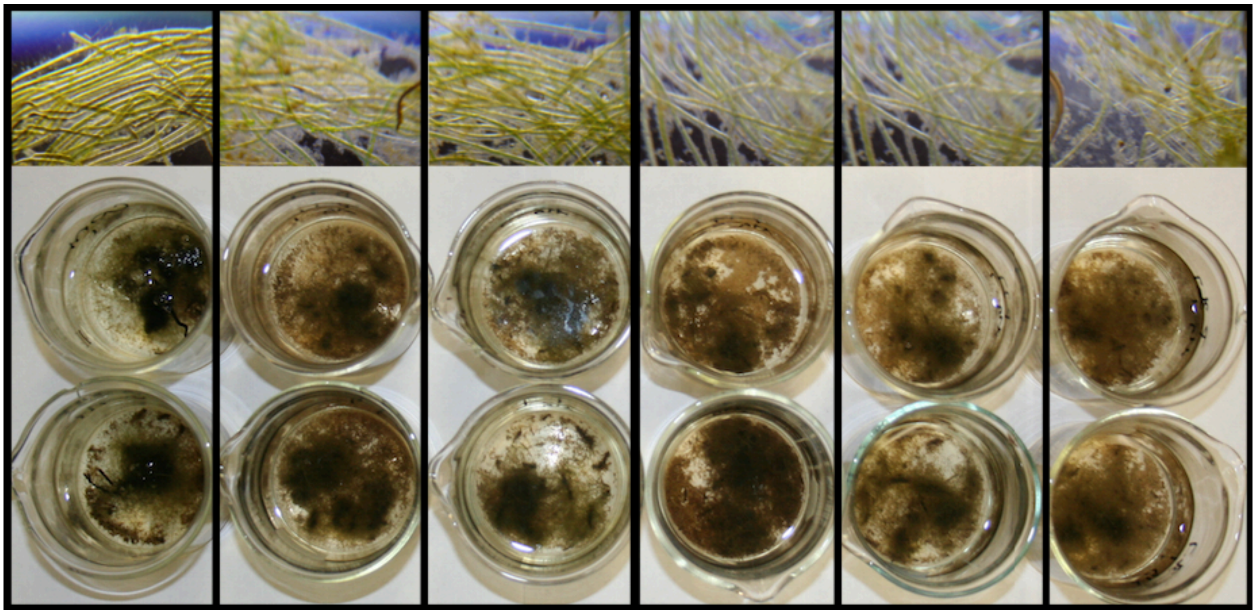
- The experimental objective was to obtain control of the *Lyngbya sp.* sampled from Sweetwater Cove Lake in Seminole County, FL.
- Exposures were conducted in 150 mL of the site water in 250 mL beakers.
- Experiments were initiated by exposing 0.5 g (wet weight) of algae to a series of exposures of Phycomycin SCP® (7.7, 63, 133, 189, 257 mg / 0.5g algae) followed one day later by a series of exposures of Algimycin-PWF® (0.7, 2.1, 3.5, 4.9, 7.0 mg Cu as Algimycin-PWF® / 0.5g algae).
- Two replicates of each exposure concentration, along with two replicates of untreated controls, were tested.
- Calculations for the mass of algaecide applied per 0.5 gram of algae were based on the assumption that the average depth of the lake is 7 ft.
- Observations of algal responses were continued for 10 days.

<u>Phycomycin SCP® followed by Algimycin-PWF® Results (see Table 1 and Figure 1)</u>:

Table 1. Responses of *Lyngbya sp.* sampled from Sweetwater Cove Lake in untreated controls and exposure concentrations of Phycomycin SCP® followed by Algimycin-PWF®.

Phycomycin SCP® followed by Algimycin-PWF® (mg SCP / 0.5g algae and mg Cu as Algimycin-PWF® / 0.5g algae)	Day 7 Visual Observations	Avg. Day 7 Chlorophyll-*a* (µg chl-*a*/ 0.5g algae)
Control	Algal mass in beakers was a dark green/brown color; individual cells were a light green color.	1340
7.7 mg SCP / 0.5g algae followed by 0.7 mg Cu as Algimycin-PWF®/ 0.5g algae	Algal mass in beakers was a dark green/brown color; individual cells were a light green color.	1473
63 mg SCP / 0.5g algae followed by 2.1 mg Cu as Algimycin-PWF®/ 0.5g algae	Algal mass in beakers was a dark green/brown color; individual cells were a light green color.	1797
133 mg SCP / 0.5g algae followed by 3.5 mg Cu as Algimycin-PWF®/ 0.5 algae	Algal mass in beakers was a brown color; individual cells were bleached were a light green/yellow color.	1232
189 mg SCP / 0.5g algae followed by 4.9 mg Cu as Algimycin-PWF®/ 0.5g algae	Algal mass in beakers was a brown color; individual cells were bleached were a light green/yellow color.	1565
257 mg SCP / 0.5g algae followed by 7.0 mg Cu as Algimycin-PWF®/ 0.5g algae	Algal mass in beakers was a brown color; individual cells were bleached were a light green/yellow color.	1089

If a treatment of Phycomycin SCP® followed one day later by Algimycin-PWF® is chosen for treatment of the *Lyngbya sp.* sampled from Sweetwater Cove Lake we recommend the maximum label rate of 36.6 mg Phycomycin SCP® / L (**100lbs/acre ft.)** followed one day later by 1.0 mg Cu / L as Algimycin-PWF® (**5.31 gallons/acre ft**.)



Untreated Control	7.7 mg SCP / 0.5g algae followed by 0.7 mg Cu as Algimycin-PWF®/ 0.5g algae	63 mg SCP / 0.5g algae followed by 2.1 mg Cu as Algimycin-PWF®/ 0.5g algae	133 mg SCP / 0.5g algae followed by 3.5 mg Cu as Algimycin-PWF®/ 0.5g algae	189 mg SCP / 0.5g algae followed by 4.9 mg Cu as Algimycin-PWF®/ 0.5g algae	257 mg SCP / 0.5g algae followed by 7.0 mg Cu as Algimycin-PWF®/ 0.5g algae

Figure 1. Post-exposure images (top = micro; bottom = macro) of the algal assemblage in untreated controls and exposure concentrations of Phycomycin SCP® followed one day later by Algimycin-PWF®.

Appendix B

Responses of *Lyngbya sp.* sampled from Sweetwater Cove Lake in Seminole County, FL to exposures of Algimycin-PWF®

Sample Origin: Sweetwater Cove Lake, FL
Site Contact Representative: Gloria Eby
Phone: 407-665-2439
Applied Biochemist Contact: Harry Knight
Phone: (256) 796-8704
Date Received: 17 December 2014
Experimental Period: 17--29 December 2014

Types of algae:

Lyngbya sp. (Cyanobacteria)

Initial Chlorophyll-*a* Concentration:

894 µg chlorophyll-*a*/ 0.5g algae

Experimental Conditions:

- Maintained at 20 ± 2°C
- 16-h light / 8-h dark photoperiod
- Light intensity of ~3077 lux

Experiment Details:

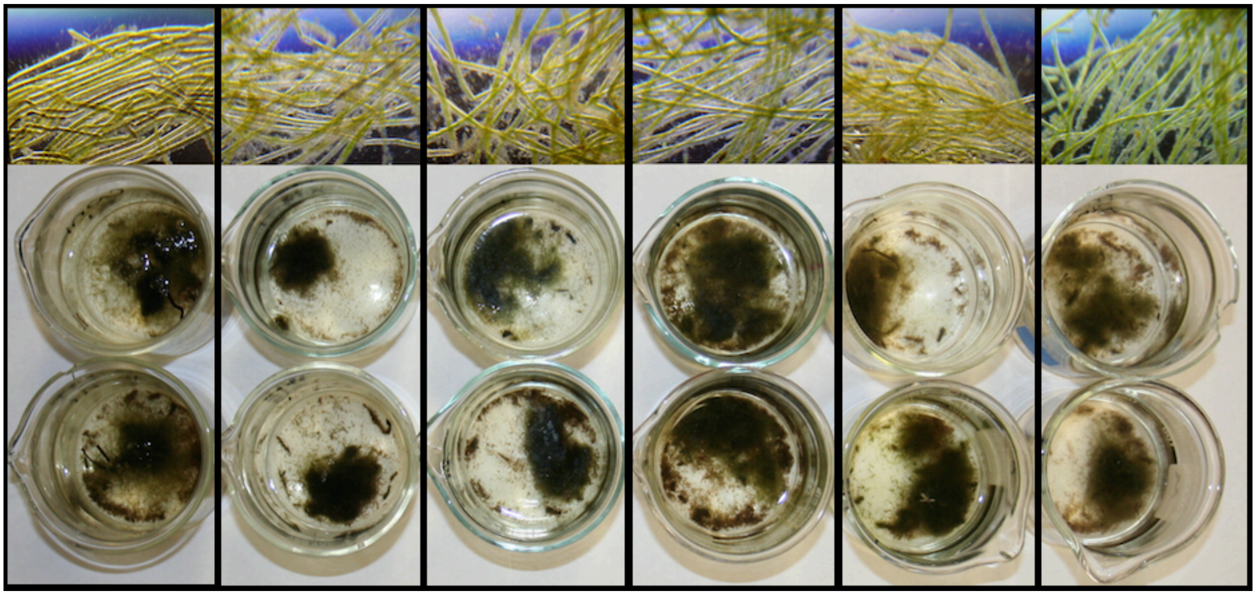
- The experimental objective was to obtain control of the *Lyngbya sp.* sampled from Sweetwater Cove Lake in Seminole County, FL.
- Exposures were conducted in 150 mL of the site water in 250 mL beakers.
- Experiments were initiated by exposing 0.5 g (wet weight) of algae to a series of exposures of Algimycin-PWF® (0.7, 2.1, 3.5, 4.9, 7.0 mg Cu as Algimycin-PWF®/ 0.5g algae)
- Two replicates of each exposure concentration, along with two replicates of untreated controls, were tested.
- Calculations for the mass of algaecide applied per 0.5 gram of algae were based on the assumption that the average depth of the lake is 7 ft.
- Observations of algal responses were continued for 10 days.

<u>Algimycin-PWF® Results (see Table 2 and Figure 2)</u>:

Table 2. Responses of *Lyngbya sp.* sampled from Sweetwater Cove Lake in untreated controls and exposure concentrations of Algimycin-PWF®

Algimycin-PWF® (mg Cu as Algimycin-PWF® / 0.5g algae)	Day 10 Visual Observations	Avg. Day 7 Chlorophyll-*a* (µg chl-*a*/ 0.5g algae)
Control	Algal mass in beakers was a dark green/brown color; individual cells were a light green color.	1340
0.7 mg Cu as Algimycin-PWF® /0.5g algae	Algal mass in beakers was a dark green/brown color; individual cells were a light green color.	885
2.1 mg Cu as Algimycin-PWF® /0.5g algae	Algal mass in beakers was a dark green/brown color; individual cells were a light green color.	1316
3.5 mg Cu as Algimycin-PWF® /0.5g algae	Algal mass in beakers was a dark green/brown color; individual cells were a light green color.	1696
4.9 mg Cu as Algimycin-PWF® /0.5g algae	Algal mass in beakers was a dark green/brown color; individual cells were a light green color.	1039
7.0 mg Cu as Algimycin-PWF® /0.5g algae	Algal mass in beakers was a dark green/brown color; individual cells were a light green color.	1326

We do not recommend Algimycin-PWF® alone for treatment of the *Lyngbya sp.* sampled from Sweetwater Cove Lake.



Untreated Control	0.7 mg Cu as Algimycin-PWF® /0.5g algae	2.1 mg Cu as Algimycin-PWF® /0.5g algae	3.5 mg Cu as Algimycin-PWF® /0.5g algae	4.9 mg Cu as Algimycin-PWF® /0.5g algae	7.0 mg Cu as Algimycin-PWF®/0.5g algae

Figure 2. Post-exposure images (top = micro; bottom = macro) of the algal assemblage in untreated controls and exposure concentrations of Algimycin-PWF®.

Appendix C

Responses of *Lyngbya sp.* sampled from Sweetwater Cove Lake in Seminole County, FL to exposures of Cutrine® Plus

Sample Origin: Sweetwater Cove Lake, FL
Site Contact Representative: Gloria Eby
Phone: 407-665-2439
Applied Biochemist Contact: Harry Knight
Phone: (256) 796-8704
Date Received: 17 December 2014
Experimental Period: 17--29 December 2014

Types of algae:

Lyngbya sp. (Cyanobacteria)

Initial Chlorophyll-*a* Concentration:

894 µg chlorophyll-*a*/ 0.5g algae

Experimental Conditions:

- Maintained at 20 ± 2°C
- 16-h light / 8-h dark photoperiod
- Light intensity of ~3077 lux

Experiment Details:

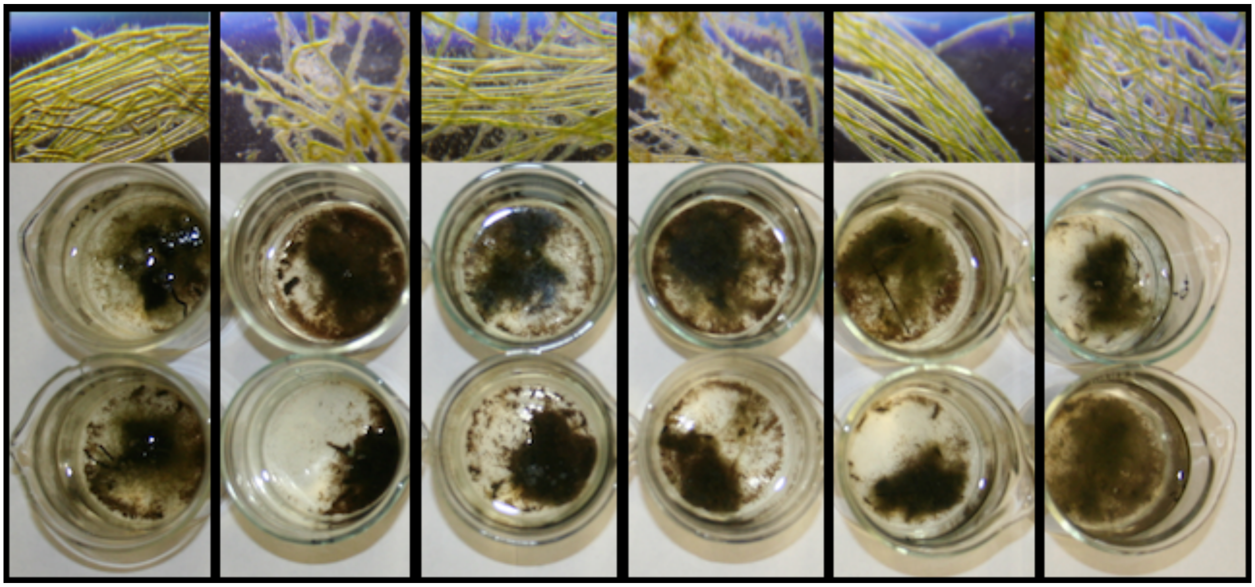
- The experimental objective was to obtain control of the *Lyngbya sp.* sampled from Sweetwater Cove Lake in Seminole County, FL.
- Exposures were conducted in 150 mL of the site water in 250 mL beakers.
- Experiments were initiated by exposing 0.5 g (wet weight) of algae to a series of exposures of Cutrine® Plus (0.7, 2.1, 3.5, 4.9, and 7.0 mg Cu as Cutrine® Plus / 0.5 g algae).
- Two replicates of each exposure concentration, along with two replicates of untreated controls, were tested.
- Calculations for the mass of algaecide applied per 0.5 gram of algae were based on the assumption that the average depth of the lake is 7 ft.
- Observations of algal responses were continued for 10 days.

Cutrine® Plus Results (see Table 3 and Figure 3):

Table 3. Responses of *Lyngbya sp.* sampled from Sweetwater Cove Lake in untreated controls and exposure concentrations of Cutrine® Plus.

Cutrine® Plus (mg Cu as Cutrine® Plus / 0.5g algae)	Day 10 Visual Observations	Avg. Day 7 Chlorophyll-*a* (µg chl-*a*/ 0.5g algae)
Control	Algal mass in beakers was a dark green/brown color; individual cells were a light green color.	1340
0.7 mg Cu as Cutrine® Plus /0.5g algae	Algal mass in beakers was a dark green/brown color; individual cells were a light green color.	1438
2.1 mg Cu as Cutrine® Plus/0.5g algae	Algal mass in beakers was a dark green/brown color; individual cells were a light green color.	882
3.5 mg Cu as Cutrine® Plus /0.5g algae	Algal mass in beakers was a dark green/brown color; individual cells were a light green color.	981
4.9 mg Cu as Cutrine® Plus /0.5g algae	Algal mass in beakers was a dark green/brown color; individual cells were a light green color.	1955
7.0 mg Cu as Cutrine® Plus /0.5g algae	Algal mass in beakers was a dark green/brown color; individual cells were a light green color.	1177

We do not recommend Cutrine® Plus for treatment of the *Lyngbya sp.* sampled from Sweetwater Cove Lake



Untreated Control	0.7 mg Cu as Cutrine®Plus /0.5g algae	2.1 mg Cu as Cutrine® Plus /0.5g algae	3.5 mg Cu as Cutrine® Plus /0.5g algae	4.9 mg Cu as Cutrine® Plus /0.5g algae	7.0 mg Cu as Cutrine® Plus /0.5g algae

Figure 3. Post-exposure images (top = micro; bottom = macro) of the algal assemblage in untreated controls and exposure concentrations of Cutrine® Plus.

APPENDIX D

LAKE MANAGEMENT EDUCATIONAL MATERIALS AVAILABLE THROUGH SEMINOLE COUNTY

D.1 Plants for Lakefront Revegetation

D.2 A Guide on How to Plant Your Lakefront

D.3 Citizen’s Guide to Lake Management

D.4 How You Can Protect Central Florida Waterways

D.5 Seminole Education, Restoration, and Volunteer (SERV) Program

D.1 Plants for Lakefront Revegetation

Florida Department of Environmental Protection
Bureau of Invasive Plant Management Circular 4

Plants For
Lakefront Revegetation

By: John Rodgers
Bureau of Invasive Plant Management
South Gulf Office
8302 Laurel Fair Circle, Suite 140, Tampa, FL 33610

Seminole County's continued effort to provide its citizens with vital information about our water resources, the County has been authorized by the Bureau of Invasive Plant Management of the Florida Department of Environmental Protection to reprint the Department's, *"Plants for Lakefront Revegetation"* by John Rodgers. This publication is an excellent guide for waterfront owners to design their pond, lake, and stream/river property. As you landscape your lawn, this publication provides information needed to select beneficial native aquatic and wetland plants to aquascape your waterfront property.

Please note, the cost range for each plant identified in this guide is a suggested rate at the time of printing and is subject to change.

The benefits of revegetation with native plants have been widely published. The following is a summary of the advantages of replanting a shoreline:

1. Food source for wildlife.
2. Protective cover for small fish and other animals.
3. Source of nesting material for reptiles, birds, and small mammals.
4. Shade for fish and humans (cypress trees).
5. Erosion control and soil stabilization.
6. Aesthetics and landscaping appeal.
7. Animal attractor.
8. Nutrient uptake.
9. Plant competition for preventing encroachment of invasive exotics such as hydrilla.
10. Living surface for small insects and other invertebrates important to fisheries.

The plants listed in this document are species that can be used to provide one or more of the above. Below is a brief explanation of the terms used in this document:

Average Height: Typical height of the plant from substrate to top of leaves (not flowers).
Leaf Type: Shape of mature leaves.
Leaf Size: Length of mature leaves.
Flower Type: Arrangement and/or number of flowers per stem or stalk.
Flower Color: Color of the plant's flowers.
Flowering Season: Spring (April, May, June), summer (July, Aug, Sept), fall (Oct, Nov, Dec), and winter (Jan, Feb, Mar).
Habitat: Most common areas where plant is found.
Wildlife Value: Animals that utilize the plant.
Distribution: Location within the state – South, Central, and North Florida.
Overwinter: Survivability, leaf drop, or leaf burn occurrence.
Common Uses: Reasons why plant is used – erosion control, landscape, fish habitat, nesting, etc.
Soil: Suggested planting substrate such as sand or muck.
Light: Shade or sun preference.
Salinity: Tolerance to brackish water (low – freshwater, medium – brackish, high – estuaries).
Propagation: How a plant reproduces or spreads. Rhizomes are underground stems that produce daughter plants.
Pest Problems: Insect, small mammal or reptile damage, and grass carp if they have been stocked in the waterbody.
Growth Rate: Slow, medium, or fast growth.
Water Depth: Typical recommended water depth of planting (not the maximum depth a plant can survive).
Density: Typical recommended spacing of plantings.
Planting: Planting suggestions to improve survivability.
Survivability: Low, medium or high.
Cost: Retail and wholesale cost per plant (does not include labor). Cost is dependent on the quantity, size, and time of year purchased. These cost figures are an average based on several sources checked in 2001-2002.

HIBISCUS

(Hibiscus coccineus (red) • *Hibiscus laevis* (white to pink) • *Hibiscus moscheutos* (white to cream) • *Hibiscus grandiflorus* (light-pink))

DESCRIPTION

Average Height: 5 to 6 ft
Leaf Type: Ovate, some strongly lobed
Leaf Size: 4 to 6”
Flower Type: Single flower per leaf axil, numerous on plant
Flower Color: Red. white or pink
Flowering Season: Spring to summer
Habitat: Marshes, edges of streams and lakes
Wildlife Value: Shelter for small birds; butterfly attractor
Distribution: Statewide
Overwinter: Leaves and stems die back; resprout in spring
Common Uses: Flowering shrub

PLANTING REQUIREMENTS

Soil: Sand to muck, prefers acid soils
Light: Medium to high
Salinity: Low (except H. coccineus and H. grandiflorus, occasionally in brackish marshes)
Propagation: Seeds (and cuttings)
Pest Problems: None
Growth Rate: Medium to fast
Water Depth: Moist soils and seasonal wet areas
Density: 5 ft apart
Planting: Trim branches to avoid leggy appearance and to promote bloom production
Survivability: High (using small potted plants)

Cost:	Retail	$ 15.00	3 gal	
	Wholesale	$ 4.00 - 6.00	3 gal	(250 minimum order)

HIBISCUS

Hibiscus coccineus (red) • *Hibiscus laevis* (white to pink)
Hibiscus moscheutos (white to cream) • *Hibiscus grandiflorus* (light-pink)

BALD CYPRESS

(Taxodium distichum)

DESCRIPTION

Average Height: 60 to 80 ft
Leaf Type: Tiny on green, feather-like branchlets
Leaf Size: 1/4” to 3/8” long
Flower Type: No flowers; seeds formed in small, round female cones
Flower Color: Cones green to brown; pollen formed in long delicate cones
Flowering Season: Pollen released in spring
Habitat: Marshes, rivers, lakes
Wildlife Value: Habitat for fish and other aquatic animals; birds nest in upper branches; wood ducks and mammals feed on seeds
Distribution: Statewide
Overwinter: Branchlets drop during late fall to early winter (one of a few deciduous conifers)
Common Uses: Either along the shoreline or offshore; frequently grouped in clusters of 3 or more, good shade tree during spring through fall

PLANTING REQUIREMENTS

Soil: Sand to muck
Light: Medium to high
Salinity: Low to medium (brackish)
Propagation: Seeds
Pest Problems: None
Growth Rate: Medium, about 1 to 2 ft/yr
Water Depth: Upland to 36” of water
Density: 10 ft apart
Planting: Grows well in dry (if watered frequently during establishment) to wet soil; don’t plant in too deep of water to increase survivability (seeds must be unflooded to germinate)
Survivability: High with small trees

Cost:	Retail	$ 15.00	3 gal	5-6 ft	
		$ 25.00	7 gal	6-8 ft	
		$ 50.00	15 gal	8-10 ft	
	Wholesale	$ 4.00 – 5.35	3 gal	5-6 ft	(100 minimum order)
		$ 14.00 – 15.00	7 gal	6-8 ft	(100 minimum order)
		$ 35.00 – 40.00	15 gal	8-10 ft	(100 minimum order)

BALD CYPRESS

Taxodium distichum

GOLDEN CANNA

(Canna flaccida)

DESCRIPTION

Average Height: 3 to 4 ft
Leaf Type: Lance shape
Leaf Size: 12 to 18" long
Flower Type: A few large flowers on a short spike
Flower Color: Yellow
Flowering Season: Mid spring to summer
Habitat: Marshes, ponds, and lake margins
Wildlife Value: Butterfly attractor
Distribution: South, Central and North Florida (west to Franklin County)
Overwinter: Hard freeze will brown upper leaves (lower leaves will remain green), but will not kill plant
Common Uses: Ornamental plant with large, showy flowers producing season-long color

PLANTING REQUIREMENTS

Soil: Sand to muck
Light: Medium to high
Salinity: Low
Propagation: Seeds and rhizomes
Pest Problems: Insect (aphids) leaf damage, not a preferred grass carp plant
Growth Rate: Fast
Water Depth: Dry, moist soils to intermittent flooding
Density: 18" apart
Planting: Will survive in low sunlight, but requires full sun to produce blooms
Survivability: High

Cost:			
Retail	$ 6.00	1 gal	
Wholesale	$ 0.25 – 0.45	bareroot	(1000 minimum order)
	$ 1.50	1gal	(1000 minimum order)

GOLDEN CANNA

(Canna flaccida)

ALLIGATOR FLAG

(Thalia geniculata)

DESCRIPTION

Average Height: 6 to 8 ft
Leaf Type: Lance shape
Leaf Size: 1 to 2 1/2 ft long
Flower Type: Panicled spikes
Flower Color: Purple
Flowering Season: Spring to summer
Habitat: Marshes, rivers
Wildlife Value: Habitat for aquatic animals; butterfly attractor; ducks and mammals feed on seeds
Distribution: Statewide
Overwinter: Dies back in winter; resprouts from rhizomes during spring
Common Uses: Can be used in partial shade areas and as protective cover for wildlife

PLANTING REQUIREMENTS

Soil: Sand to muck
Light: Low/medium to high
Salinity: Low
Propagation: Seeds and rhizomes
Pest Problems: Insect (aphids and spider mites) leaf damage, not a preferred grass carp plant
Growth Rate: Fast
Water Depth: Moist soils and intermittent flooding
Density: 3 ft apart
Planting: Strong winds can cause some leaf damage in unprotected areas
Survivability: High

Cost:	Retail	$ 4.50	1 gal	
	Wholesale	$ 0.40 – 0.57	bareroot	(1000 minimum order)

ALLIGATOR FLAG

(Thalia geniculata)

SOUTHERN BLUE-FLAG

(Iris virginica)

DESCRIPTION

Average Height: 2 to 2 1/2 ft
Leaf Type: Ribbon shape, or strap-like
Leaf Size: 2 to 2 1/2 ft long
Flower Type: Single flower at a time on short spike
Flower Color: Blue to blue-purple
Flowering Season: Spring
Habitat: Marshes, ponds and streams
Wildlife Value: Habitat for small aquatic animals; butterfly attractor
Distribution: Central and North Florida
Overwinter: Evergreen
Common Uses: Ornamental plant with showy flowers, especially when planted in dense groupings

PLANTING REQUIREMENTS

Soil: Sand to muck
Light: Medium to high
Salinity: Low
Propagation: Seeds; rhizomes
Pest Problems: Infrequent caterpillar and aphid damage; not a preferred grass carp plant
Growth Rate: Medium
Water Depth: Water's edge, moist soils to intermittent flooding
Density: 1 to 2 ft apart
Planting: Will survive in low sunlight, but requires full sun to produce blooms
Survivability: High

Cost:	Retail	$ 3.50	1 gal	
	Wholesale	$ 0.25 – 0.30	bareroot	(1000 minimum order)
		$ 1.75 – 2.00	1gal	(1000 minimum order)

SOUTHERN BLUE-FLAG

(Iris virginica)

SWAMP LILY

(Crinum americanum)

DESCRIPTION

Average Height: 2 ft
Leaf Type: Ribbon shape, or strap-like
Leaf Size: 12 to 24” long
Flower Type: 2 to 6 flowers on long stalk
Flower Color: White
Flowering Season: Spring to summer
Habitat: Marshes, rivers
Wildlife Value: Habitat for small aquatic animals; ducks and mammals feed on seeds
Distribution: Statewide
Overwinter: Hard freeze will cause leaves to turn yellow and burn, but will not kill plant
Common Uses: Along shoreline as a border plant; showy fragrant flowers

PLANTING REQUIREMENTS

Soil: Sand to muck
Light: Low to medium
Salinity: Low to medium (brackish)
Propagation: Seeds
Pest Problems: None, not a preferred grass carp plant
Growth Rate: Medium
Water Depth: Edge to 3” of water, seasonal wet areas
Density: 2 ft apart
Planting: Make sure leaves are above water and not in an area flooded all year; in nature, it’s usually found in partial or deep shade
Survivability: High

Cost:	Retail	$ 4.00	1 gal	
	Wholesale	$ 0.40 – 0.50	bareroot	(1000 minimum order)
		$ 1.50 – 2.00	1 gal	(1000 minimum order)
		$ 3.50 - 5.00	3 gal	(1000 minimum order)

SWAMP LILY

(Crinum americanum)

DUCK POTATO

(Sagittaria latifolia)

DESCRIPTION

Average Height: 2 1/2 ft
Leaf Type: Arrowhead shape
Leaf Size: 7 to 10" long
Flower Type: In whorls of 3 flowers on tall flowering stalk
Flower Color: White
Flowering Season: Spring to fall
Habitat: Marshes, rivers, lakes
Wildlife Value: Habitat for fish and other aquatic animals; butterfly attractor; waterbirds and mammals feed on seeds and tubers
Distribution: Statewide
Overwinter: Hard freeze will brown margins of leaves, but will not kill plant
Common Uses: Along edge of shoreline, usually landward of arrowhead and pickerelweed

PLANTING REQUIREMENTS

Soil: Sand to muck
Light: Low to high
Salinity: Low
Propagation: Seeds and rhizomes
Pest Problems: Leaf spots and aphid damage occasionally; not a preferred grass carp plant
Growth Rate: Medium
Water Depth: Edge to 6" of water
Density: 2 ft apart
Planting: Make sure leaves are above water; plant landward of Sagittaria lancifolia
Survivability: High
Cost: Retail $ 3.50 1 gal
Wholesale $ 0.35 – 0.55 bareroot (1000 minimum order)

DUCK POTATO

(Sagittaria latifolia)

ARROWHEAD

(Sagittaria lancifolia)

DESCRIPTION

Average Height: 3 ft
Leaf Type: Lance shape
Leaf Size: 9 to 12" long
Flower Type: In whorls of 3 flowers on tall flowering stalk
Flower Color: White
Flowering Season: Spring to fall
Habitat: Marshes, rivers, lakes
Wildlife Value: Habitat for fish and other aquatic animals; butterfly attractor; ducks and mammals feed on seeds and tubers
Distribution: Statewide
Overwinter: Hard freeze will brown margins of leaves, but will not kill plant
Common Uses: Along shoreline, it's light-green leaves and white flowers are a good contrast to the dark-green leaves and purple flowers of pickerelweed

PLANTING REQUIREMENTS

Soil: Sandy to muck
Light: Medium to high
Salinity: Low to medium (brackish)
Propagation: Seeds and rhizomes
Pest Problems: Weevils infrequently feed on flowering stalks; yellowing of leaves during late fall; not a preferred grass carp plant
Growth Rate: Medium
Water Depth: 6 to 12" of water
Density: 1 to 2 ft apart
Planting: Make sure leaves are above water; tends to grow in slightly shallower water than pickerelweed
Survivability: High

Cost:	Retail	$ 2.50	1 gal	
	Wholesale	$ 0.25 – 0.55	bareroot	(1000 minimum order)
		$ 1.25	4" pot	(1000 minimum order)

ARROWHEAD

(Sagittaria lancifolia)

PICKERELWEED

(Pontederia cordata)

DESCRIPTION

Average Height: 3 ft
Leaf Type: Lance to heart shape
Leaf Size: 7 to 10” long
Flower Type: Spike
Flower Color: Purple
Flowering Season: Spring to fall
Habitat: Marshes, rivers, lakes
Wildlife Value: Habitat for fish and other aquatic animals; stems provide surface for apple snail attachment; butterfly attractor; ducks and mammals feed on seeds
Distribution: Statewide
Overwinter: Hard freeze will brown leaves, but will not kill plant
Common Uses: Along shoreline as a border plant, provides good erosion control

PLANTING REQUIREMENTS

Soil: Sand or muck
Light: Medium to high
Salinity: Low
Propagation: Seeds and rhizomes
Pest Problems: Not a preferred grass carp plant; insect (borer and weevil) damage on leaves and stems is not uncommon, but usually will not kill plant
Growth Rate: Medium
Water Depth: 6 to 18” of water
Density: 1 to 2 ft apart
Planting: Make sure leaves are above water; tends to grow in slightly deeper water than arrowhead
Survivability: High
Cost:

Retail	$ 2.25	1 gal	
Wholesale	$ 0.25 – 0.45	bareroot	(1000 minimum order)
	$ 1.25	4” pot	(1000 minimum order)

PICKERELWEED

(Pontederia cordata)

SAND CORD GRASS

(Spartina bakeri)

DESCRIPTION

Average Height: 4 1/2 ft
Leaf Type: Rolled or curled grass leaves
Leaf Size: 10 to 30" long
Flower Type: Narrow cluster of small spikes
Flower Color: Bronze
Flowering Season: Summer to fall
Habitat: Marshes, lakes
Wildlife Value: Habitat for small animals; waterfowl and songbirds feed on seeds
Distribution: Statewide
Overwinter: Hard freezes may cause some leaf browning
Common Uses: Along shoreline in fresh and brackish waters; good erosion control

PLANTING REQUIREMENTS

Soil: Sand to muck
Light: Medium to high
Salinity: Low to medium (brackish to saline tidal marshes)
Propagation: Seeds and rhizomes (division)
Pest Problems: None
Growth Rate: Medium
Water Depth: Dry to moist soils; can survive in dry soils and extended flooded areas for long periods of time
Density: 3 ft apart
Planting: Establish at or above shoreline in moist soils
Survivability: High

Cost: Retail	$ 3.50	1 gal	
	$ 8.50	3 gal	
Wholesale	$ 0.35	bareroot	(1000 minimum order)
	$ 1.40 – 1.75	1 gal	(1000 minimum order)
	$ 3.50 - 4.00	3 gal	(1000 minimum order)

SAND CORD GRASS

(Spartina bakeri)

SOFT RUSH

(Juncus effusus)

DESCRIPTION

Average Height: 3 to 4 ft
Leaf Type: Leaves inconspicuous; stems green, round, tubular
Leaf Size: Blades absent; stems elongated with stiff green bract rising above flower cluster
Flower Type: Cluster of spikelets
Flower Color: Greenish-brown
Flowering Season: Summer
Habitat: Marshes
Wildlife Value: Habitat (shelter and nesting) for aquatic mammals and birds; ducks and small mammals feed on seeds
Distribution: Statewide
Overwinter: Evergreen
Common Uses: Along shoreline in fresh and brackish water areas; good erosion control plant

PLANTING REQUIREMENTS

Soil: Sandy to muck
Light: Medium to high
Salinity: Low to medium (brackish)
Propagation: Seeds and rhizomes
Pest Problems: None; not a preferred grass carp plant
Growth Rate: Medium
Water Depth: Moist soils; can survive extended flooding
Density: 3 ft apart
Planting: Can be sectioned into individual plants or clumps
Survivability: High

Cost:	Retail	$	5.00	1 gal	
	Wholesale	$	0.25 - 0.30	bareroot	(1000 minimum order)
		$	1.50 – 1.80	1 gal	(1000 minimum order)

SOFT RUSH

(Juncus effusus)

SPIKERUSH

(Eleocharis cellulosa & interstincta)

DESCRIPTION

Average Height: 2 1/2 ft
Leaf Type: Leaves inconspicuous; stems green, round, tubular
Leaf Size: Blades are absent, stems elongated
Flower Type: Small short spike with scales, not showy
Flower Color: Yellow-brown
Flowering Season: Spring to fall
Habitat: Marshes, lakes
Wildlife Value: Habitat for fish and other aquatic animals; ducks and mammals feed on seed head
Distribution: Statewide
Overwinter: Yellowing of stems
Common Uses: Adds diversity to shoreline plants and attracts wildlife

PLANTING REQUIREMENTS

Soil: Sand to muck
Light: Medium to high
Salinity: Low to medium (brackish)
Propagation: Seeds and rhizomes
Pest Problems: None; not a preferred grass carp plant
Growth Rate: Medium
Water Depth: 6 to 12" of water
Density: 2 ft apart
Planting: Prefers shallow water areas, clumps soon send out rhizomes
Survivability: High

Cost: Retail	$	2.50	1 gal	
Wholesale	$	0.25 to 0.45	bareroot	(1000 minimum order)

SPIKERUSH

(Eleocharis cellulosa & interstincta)

PASPALIDIUM GRASS

(Paspalidium geminatum)

DESCRIPTION

Average Height: 3 ft
Leaf Type: A grass; leaves with sheaths and blades
Leaf Size: 8 to 12” long
Flower Type: Spikelet seed head
Flower Color: Green
Flowering Season: All year
Habitat: Marshes, rivers, and lakes
Wildlife Value: Excellent habitat for fish and other aquatic animals
Distribution: Statewide
Overwinter: Stems and leaves may brown in hard freeze
Common Uses: Planted in shallows beyond shoreline plants such as pickerelweed to improve fisheries

PLANTING REQUIREMENTS

Soil: Sand to muck
Light: Medium to high
Salinity: Low
Propagation: Seeds and rhizomes
Pest Problems: None, not a preferred grass carp plant
Growth Rate: Medium
Water Depth: 12 to 18” of water
Density: 2 ft apart
Planting: Leaves must be above water; place rhizomes on top or slightly below soil; weigh down if necessary in windy areas
Survivability: Medium to high

Cost: Retail	$ 3.00	1 gal	
Wholesale	$ 0.45 – 0.55	2” pot	(1000 minimum order)

PASPALIDIUM GRASS

(Paspalidium geminatum)

MAIDENCANE

(Panicum hemitomon)

DESCRIPTION

Average Height: 3 ft
Leaf Type: A grass; leaves with sheaths and blades
Leaf Size: 7 to 11" long
Flower Type: Spikelet seed head
Flower Color: Green
Flowering Season: Summer
Habitat: Marshes, rivers, lakes
Wildlife Value: Excellent habitat for fish and other aquatic animals, especially invertebrates; seeds fed upon by songbirds
Distribution: Statewide
Overwinter: Stems and leaves may brown in hard freeze
Common Uses: Planted in shallows beyond shoreline plants such as pickerelweed to improve fisheries

PLANTING REQUIREMENTS

Soil: Sand to muck
Light: Medium to high
Salinity: Low
Propagation: Seeds and rhizomes
Pest Problems: None, not a preferred grass carp plant
Growth Rate: Medium
Water Depth: 12 to 18" of water
Density: 2 ft apart
Planting: Make sure leaves are above water and rhizomes are firmly in soil
Survivability: Medium to high
Cost:

Retail	$	2.25	1 gal	
Wholesale	$	0.25 - 0.40	bareroot	(1000 minimum order)
	$	0.45 - 0.55	2" pot	(1000 minimum order)
	$	0.75 - 0.80	4" pot	(1000 minimum order)

MAIDENCANE

(Panicum hemitomon)

JOINTED FLAT SEDGE

(Cyperus articulatus)

DESCRIPTION

Average Height: 5 ft
Leaf Type: Leaves inconspicuous; stems green, round, tubular
Leaf Size: Blades are absent, stems elongated
Flower Type: Cluster of spikelets
Flower Color: Light-brown
Flowering Season: Summer to fall
Habitat: Marshes, rivers, lakes
Wildlife Value: Habitat for fish and other aquatic animals; songbirds feed on seeds
Distribution: Statewide
Overwinter: Some browning of stems
Common Uses: Offshore, planted in deeper water

PLANTING REQUIREMENTS

Soil: Sand to muck
Light: Medium to high
Salinity: Low to medium (brackish)
Propagation: Seeds and rhizomes
Pest Problems: None; not a preferred grass carp plant
Growth Rate: Medium
Water Depth: 18 to 30” of water
Density: 3 ft apart
Planting: Use small plants versus large mature plants; place between shoreline plants and bulrush/water lily plants; stems are frequently bent over mid-way to prevent whipping of plants in windy areas; new stems will sprout.
Survivability: High

Cost:			
Retail	$ 4.00	1 gal	
Wholesale	$ 0.60 – 0.85	bareroot	(1000 minimum order)

JOINTED FLAT SEDGE

(Cyperus articulatus)

BULRUSH

(Scirpus californicus & validus)

DESCRIPTION

Average Height: *S. californicus* – 6 to 9 ft
S. validus – 4 to 5 ft
Leaf Type: Leaves inconspicuous. Stems green, round tubular, tall
Leaf Size: Reduced sheaths with blades absent.
Flower Type: Spikelets, not showy
Flower Color: Brown
Flowering Season: Spring to fall
Habitat: Marshes, rivers, lakes
Wildlife Value: Excellent habitat for fish and other aquatic animals; stems provide surface for apple snail and invertebrate attachment; ducks, songbirds and mammals feed on seeds
Distribution: Statewide
Overwinter: Generally evergreen
Common Uses: Plant offshore in deeper water to improve fisheries and for songbird/wading bird habitat

PLANTING REQUIREMENTS

Soil: Sandy or muck
Light: Medium to high
Salinity: Low to medium (brackish)
Propagation: Seeds and rhizomes
Pest Problems: At times insect damage can be heavy, especially during early fall; not a preferred grass carp plant
Growth Rate: Medium
Water Depth: 24 to 36" of water
Density: 3 ft apart
Planting: Use small plants versus large mature plants; stems are frequently bent over mid-way to prevent whipping of plants in windy areas; weigh down plants in deeper water; seeds can be spread in shallow muddy areas
Survivability: Medium

Cost:				
	Retail	$ 2.60	1 gal	
	Wholesale	$ 0.35 – 0.45	bareroot	(1000 minimum order)

BULRUSH

(Scirpus californicus & validus)

YELLOW WATER LILY

(Nymphaea mexicana)

DESCRIPTION

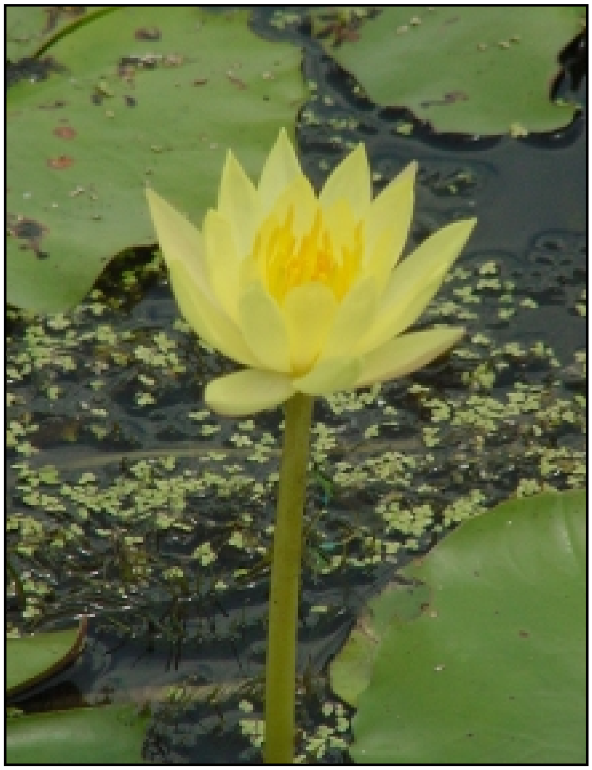
Average Height: Floating leaves
Leaf Type: Roundish heart shapes
Leaf Size: 6” to 8” wide
Flower Type: Single flower per stem
Flower Color: Yellow
Flowering Season: Summer
Habitat: Marshes, lakes and quiet streams
Wildlife Value: Habitat and shade for fish and other aquatic animals; mammals feed on tender stems
Distribution: Statewide
Overwinter: Perennial, majority of the leaves die off; overwintering rhizomes or stolons develop in late fall and occasionally produce small leaves.
Common Uses: Deep water plant used to improve fisheries, showy yellow blooms attractive

PLANTING REQUIREMENTS

Soil: Sand to muck
Light: Medium to high
Salinity: Low
Propagation: Seeds and rhizomes
Pest Problems: Insect leaf damage; turtles and small mammals feed on the leaves; not a preferred grass carp plant
Growth Rate: Medium
Water Depth: 24” to 36” of water
Density: 5 ft apart
Planting: Place rhizome cluster just below soil (trim off stolons)
Survivability: Medium
Cost: Retail $ 16.00 1 gal (multi-leaf)
Wholesale $ 2.50 - 3.00 bareroot (1000 minimum order)

YELLOW WATER LILY

(Nymphaea mexicana)



FRAGRANT WATER LILY

(Nymphaea odorata)

DESCRIPTION

Average Height: Floating leaves
Leaf Type: Large, roundish heart shapes
Leaf Size: 10 to 18" wide
Flower Type: Single flower per stem
Flower Color: White
Flowering Season: Spring to fall
Habitat: Marshes, lakes, and quiet streams
Wildlife Value: Habitat and shade for fish and other aquatic animals; invertebrates attach on underside of leaves; ducks and mammals feed on seeds and stems
Distribution: Statewide
Overwinter: Evergreen
Common Uses: Deep water plant for fisheries; showy sweet-scented flowers aesthetically pleasing

PLANTING REQUIREMENTS

Soil: Sand to muck
Light: Medium to high
Salinity: Low
Propagation: Seeds and rhizomes
Pest Problems: Insect and fungal leaf damage; ducks, turtles and small mammals feed on the leaves; not a preferred grass carp plant
Growth Rate: Medium
Water Depth: 30 to 36" of water
Density: 5 ft apart
Planting: Use a 18 to 24" long rhizome for planting, place on soil, weight down; leaf tear damage may occur in windy areas
Survivability: High

Cost:	Retail	$ 16.00	1 gal
	Wholesale	$ 0.90 – 1.20	bareroot (1000 minimum order

FRAGRANT WATER LILY

(Nymphaea odorata)

SPATTERDOCK

(Nuphar luteua/advena)

DESCRIPTION

Average Height: Floating leaf or extending several inches above water surface
Leaf Type: Heart shaped, longer than wide
Leaf Size: 10 to 13" long
Flower Type: Single, ovoid shape flower per stem
Flower Color: Yellow
Flowering Season: Late winter to summer
Habitat: Marshes, rivers, lakes
Wildlife Value: Habitat and shade for fish and other aquatic animals; waterbirds feed on seeds
Distribution: Statewide
Overwinter: No freeze damage (see pest problem below)
Common Uses: Deep water plant; good plant for fisheries

PLANTING REQUIREMENTS

Soil: Sand to muck
Light: Medium - high
Salinity: Low
Propagation: Seeds and rhizomes
Pest Problems: Heavy insect damage to leaves and upper stems during winter; not a preferred grass carp plant
Growth Rate: Fast in muck
Water Depth: 30 to 36" of water
Density: 5 ft apart
Planting: Use small plant with submersed leaves or use 8 to 12" length rhizome for planting; place on soil, weigh down, leaves may die off soon after planting with new sprouts occurring in several weeks
Survivability: High

Cost:	Retail	$ 12.00	1 gal	
	Wholesale	$ 1.00 – 1.10	bareroot	(1000 minimum order)

SPATTERDOCK

(Nuphar luteua/advena)

TAPE-GRASS, EEL-GRASS

(Vallisneria americana)

DESCRIPTION

Average Height: Plants submersed, 6 inches tall to several feet (horizontal length in flowing water)
Leaf Type: Ribbon shape
Leaf Size: 6 inches to several feet (in flowing water)
Flower Type: Single flower per stalk; only female flowers seen at surface
Flower Color: White, tiny green tube
Flowering Season: Spring to summer
Habitat: Rivers, lakes
Wildlife Value: Excellent habitat for fish and other aquatic animals including invertebrates; waterfowl feed on leaves and flowers
Distribution: Statewide
Overwinter: Evergreen
Common Uses: Excellent submersed species for fisheries; good competitor to invasive species such as hydrilla; reduces turbidity from sediments

PLANTING REQUIREMENTS

Soil: Sand to muck
Light: Low to high
Salinity: Low to medium (brackish)
Propagation: Seeds, rhizomes and winter buds
Pest Problems: Not a preferred grass carp plant; turtles feed on leaves
Growth Rate: Medium
Water Depth: 12” to 36” of water
Density: 2 ft apart
Planting: Plant in shallow water for best results; fence in area to prevent turtles from eating leaves; plant winter vegetative buds by burying them into the sediment 2 to 3” deep; make sure filamentous algae doesn’t cover water surface and shade out eel-grass
Survivability: Low

Cost:	Retail	$ 1.00 bareroot
	Wholesale	$ 0.25 – 0.30 bareroot (1000 minimum order)

TAPE-GRASS, EEL-GRASS

(Vallisneria americana)

D.2 A Guide on How to Plant Your Lakefront

SEMINOLE COUNTY

FLORIDA'S NATURAL CHOICE

A Guide on How to Plant Your Lakefront

Seminole County Department of Public Works
Roads-Stormwater Division
177 Bush Loop • Sanford, FL 32773
407-665-7623

How to Plant Your Lakefront




Introduction:

Lakefront homeowners have a direct impact on the water quality, aquatic habitat and the overall health of their waterbody. Nutrients enter a waterbody by way of stormwater runoff, septic tanks (especially improperly maintained septic tanks) or excess fertilizer run off from lawns to name just a few sources. All of these contribute to the decline in health of urban and neighborhood lakes. Excess nutrients in a waterbody can speed up the natural aging of a lake through a process called eutrophication. Eutrophication can lead to negative effects such as algae blooms (a great increase of phytoplankton in a waterbody) and the depletion of oxygen in the waterbody, which can result in fish kills. This guide will detail one simple method to minimize these nutrient impacts on your waterbody and protect it for the future.

Having a healthy ecosystem of shoreline plants plays an important role in improving and maintaining the quality of your lake. While many people enjoy a white sandy beach along their shoreline, this unfortunately allows nutrients from the yard and surrounding areas to flow directly into the lake. Shoreline plants act as a buffer and help reduce the amount of runoff that can reach your lake. Appropriate shoreline plants also helps reduce shoreline erosion. Having native aquatic plants along the shoreline (or littoral zone) can protect and improve the ecological health of your waterbody and provide a great view at the same time!

This guide details how to plant the littoral zone by identifying:

- *species of beneficial native plants to use,*
- *the correct zone in which to plant,*
- *the tools needed for aquatic planting,*
- *preparation of the shoreling before planting,*
- *planting techniques, and*
- *maintenance of the shoreline after planting.*

Native and Exotic Plant Species:

While many plants can and will grow along the shoreline, selecting the correct species and then planting it in the appropriate place (zone) is important to its long term survival and success of your shoreline project. Exotic/invasive species, because of their rapid growth, can completely take over an area and prevent the establishment of more beneficial and desirable native species. Exotic species alter the landscape of Florida and renders habitat unsuitable to native species that are critical to the balance of a lake's ecosystem. There are many ways to remove exotic/invasive species and some are identified in the "Preparation of Your Shoreline" section of this guide. Although there are numerous types of exotic and invasive plants, the following are species most commonly encountered by lakefront homeowners.

Undesirable invasive and/or exotic species:

Primrose Willow (*Lugwigia peruviana*)

(A) Alligator Weed (*Alternanthera philoxeroides*)

(B) Torpedo Grass (*Panicum repens*)

Water Hyacinth (*Eichhornia crassipes*)

(C) Water Lettuce (*Pistia Stratiotes*)

(D) Wild Taro (*Colocasia esculenta*)

Para Grass (*Urochloa mutica*)

Native aquatic plants provide the most benefit in terms of habitat creation and protecting the health of a waterbody by absorbing nutrients out of the water column and lake bottom soils. Some of the most commonly used beneficial native aquatic plant species are listed on the next page. Check the phone book and Internet for local aquatic plant nurseries where you can purchase your own native shoreline plants.

Desirable Native Species:

Thalia (*Thalia geniculata*)

(B) Canna (*Canna flaccida*)

Burr Marigold (*Bidens laevis*)

Crinum (*Crinum americanum*)

Iris (*Iris virginica*)

Soft Rush (*Juncus effusus*)

Spike Rush (*Eleocharis sp.*)

(C) Pickerelweed (*Pontederia cordata*)

(A) Duck Potato (*Sagittaria lancifolia*)

(D) Saw Grass (*Cladium jamaicense*)

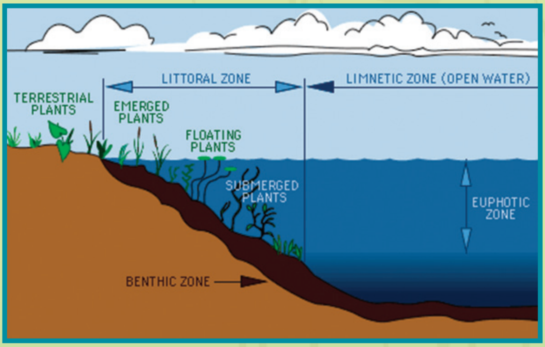
Bulrush (*Scirpus validus*)

Maidencane (*Panicum hemitomon*)

Planting Zones:

In order for aquatic plants to survive and flourish, you must first determine which plant species is most appropriate for the desired planting zone. Different aquatic plant species are adapted to different ranges of water depth, soil moisture and inundation period (length of time submerged underwater). Each species should be planted within the zone for which it is best suited. Your aquatic plant nursery or local lake management staff can help you identify the proper zone for the type of plants that you have.

Typical Lake Zones



Step 1 - Preparation of Your Shoreline:

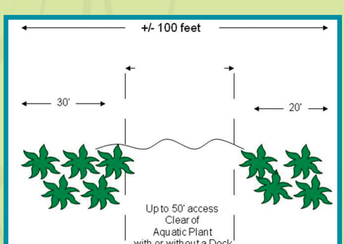
The first step in preparing your shoreline is to identify and remove the undesirable exotic species from the area.

There are two ways to remove undesirable vegetation, mechanical/physical removal and chemical removal.

Mechanical/physical removal means the use of any machinery, hand tools or hands to physically harvest the plant material. Hand removal will be sufficient for most residential lakefront properties. The tools needed for hand removal will include shovels, clippers, rakes and string trimmers (weed whacker or weed eater). In situations where vegetation is too dense for hand removal, like large areas of cattails or primrose willow, you may want to hire a contractor to remove this vegetation with heavy equipment.

Florida Fish and Wildlife Conservation Commission (FWC) Aquatic Plant Management guidelines allow homeowners to clear non-woody plants (no trees) from 50% or 50 feet of their shoreline (whichever is less) by physical or mechanical means in order to create an "access corridor." This allows for navigation to open water and does not require a permit from the FWC. A permit <u>**is**</u> required for the use of herbicides <u>**and**</u> for the removal of any plants outside the "access corridor." A FWC permit is free. If you think that you may need a permit, or are not sure, please contact your FWC regional biologist at (407) 858-6170 for assistance. For more FWC permitting information, please visit:

http://myfwc.com/nonnatives/invasiveplants/FieldOperationPermits.htm






Chemical removal includes spraying unwanted vegetation with a herbicide that is approved for aquatic use. Once vegetation is treated with a herbicide, it will need to be removed after it has died. Treating vegetation with a herbicide greatly reduces the effort of removal. A shoreline should be treated no sooner than two weeks before planned removal, and several months before in most cases. Contractors that provide these services are readily available. Check the phone book and Internet for local contractors.

Step 2 - Planting:

Planting usually requires only the most basic and common garden tools, although a few specialized tools will make the job easier. One very handy tool to use during planting is a plant anchor. Plant anchors are used to hold down the plants underwater in the soil once planted, preventing them from floating to the surface. This is especially helpful on lakes where there is a lot of watercraft activity.




Tools recommended:

Shovel	Dirt Rake	Plant Anchors
Clippers	Machete	Hand Trowel
Rake	String Trimmer (Weed Whacker)	

It is important to install aquatic plants as deep into the soil as possible to help prevent them from “floating or popping” back up to the surface. Six to eight inches is the standard depth to dig the hole in the lake bottom, and deeper when possible.

Plants obtained from a nursery or contractor may be small juvenile plants, known as a bareroot plant. These plants are typically anywhere from six inches to a few feet long, depending on the species. It is not necessary to plant bareroot plants one at a time. Three or four of the same plant species can be combined together into one hole, which will expand into a cluster of plants. Planting in clusters and not rows will improve the survival rate of the plants.

When using plant anchors on plants, pack dirt tightly into the hole, then insert plant anchors around the cluster, one from each side. It is not necessary to plant the entire shoreline. The clustered plants will fill in and expand into the space between clusters. This will also help reduce the need for maintenance over time.




Step 3 - Maintenance:

- *Routine maintenance of the restored/revegetated area needs to be done in order to prevent regrowth of exotic species and to allow expansion of the desirable native species.*
- *Maintenance will need to be done more frequently in the beginning, when the plants are first getting established.*
- *Planted vegetation that is found floating (i.e. "popped up") should be replanted and secured.*
- *Large exotic species like cattail and primrose willow are easier to hand remove when the plants are young and small.*
- *It is important to be sure to try to remove all of the roots of undesirable plants to prevent regrowth.*
- *Spot spraying exotics with herbicides may be done as long as you are careful not to spray the new native plants.*
- *Once the desirable native species have become established and adequate coverage is achieved, the maintenance requirements will be minimal.*
- *The desirable native species recommended in this guide should be hardy and able to withstand normal fluctuations in water levels.*
- *Desirable natives do not require fertilizers or pesticide spray.*

Seminole County
Florida's Natural Choice

Seminole County Water Quality Section
Department of Public Works • Roads-Stormwater Division
177 Bush Loop • Sanford, FL 32773

Water Quality Program
(407) 665-7623
www.seminole.wateratlas.usf.edu

Lake Management Program
(407) 665-7623
www.seminole.wateratlas.usf.edu/lmp

How to Plant Your Lakefront

D.3 Citizen's Guide to Lake Management

Seminole County Lake Management Program

A Citizens' Guide to Lake Management

SEMINOLE COUNTY
FLORIDA'S NATURAL CHOICE

Seminole County Department of Public Works • Roads-Stormwater Division
177 Bush Loop • Sanford, FL 32773 • 407-665-2439


OVERVIEW OF THE SEMINOLE COUNTY LAKE MANAGEMENT PROGRAM

The water quality of the lakes, which to most people is a matter of how clear the water is, directly relates to the quality of water coming into the lakes from their surrounding watersheds. Increasing development pressure and poor management practices around lakes has raised concerns about water quality and impacts on our lakes.

Often property owners find that they do not have all the resources to properly manage their lake. The Seminole County Lake Management Program (SCLMP) offers options that are understandable and responsive to undesirable lake conditions affecting water quality and biological habitats for insects, fish, birds and other wildlife.

The term "Environmental Stewardship" is taking active participation to care for natural resources ensuring that they are sustainably managed for current and future generations. By becoming a lake steward, citizens actively care for the needs of their lake. SCLMP promotes remediation of undesirable lake conditions by facilitating stewardships (lake associations) and partnerships among various stakeholders including fellow neighbors, landowners, community groups and local and state government professionals, working together protecting/improving/managing your lake.

SCLMP provides the following resources for unincorporated County lakes:

- *Conducts detailed lake assessment and restoration studies*
- *Provides actions to control invasive aquatic plants*
- *Prepares reports analyzing the condition of County lakes*
- *Provides public education, volunteer monitoring and technical assistance to lake groups and lakeside residents*
- *Provides technical assistance with aquatic plant management*
- *Provides funding resource options*
- *Brings other local and state agencies and management professionals to establish the best management plan*

The development of a successful Lake Management Program is dependent on active community participation. SCLMP is very active in meeting with property owners, lake associations and professional officials to promote and assist in various lake management projects. It's the cumulative effect of all of our efforts that will help protect our watershed.

Contact Us: For more information about this program, please contact:

Lake Management Program Coordinator
Department of Public Works
Roads-Stormwater Division
177 Bush Loop • Sanford, FL 32773
Phone: (407) 665-2439
E-mail: geby@seminolecountyfl.gov

HOW *YOU* CAN PROTECT SEMINOLE COUNTY'S WATERWAYS

Many of our daily activities can cause pollution to our lakes. This includes: lawn maintenance services that do not shield grass clippings from moving into the lake, excess fertilizing, use of phosphorus-containing fertilizer, leaf-litter accumulation in street gutters from surrounding private neighborhoods and altered shorelines. Each of these activities greatly affects the nutrient levels of the lake since the basic elemental make-up of these components is nitrogen and phosphorus. As the materials break down, they are washed into the lake during storm events and irrigation. This input of excess nitrogen and phosphorus leads to an excess in algae production and degrades water quality. By reducing the pollution sources around the lake and continuing to encourage native aquatic plant communities (to help uptake nutrients) within the lake, this nutrient cycle can be slowed to a more productive rate for your lake.

To help prevent these negative impacts to the lakes, follow these simple suggestions:

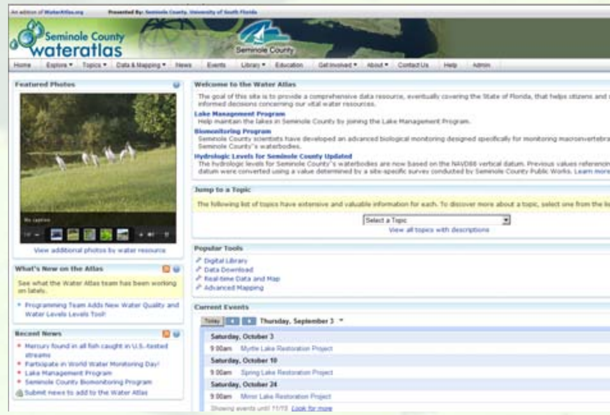
- ***Fertilize and spray sparingly*** - *These substances can be very detrimental when they are carried to the lakes by stormwater runoff. When fertilizers and pesticides are applied to a lawn, keep them away from the driveway and streets so they don't run into the storm drain. Assurance a 25-foot buffer between the fertilized area and the water body. Most people fertilize and spray more than is necessary.*
- ***Be careful with grass and leaves*** - *Grass clippings and leaves can add nutrients (nitrogen and phosphorous) to lakes. Don't blow them into the street or lake; instead, blow them back into the lawn, which provides nutrients for your lawn.*
- ***Maintain lakefronts*** - *Aquatic plants provide habitat, food and shelter for fish and wildlife. Plants also reduce erosion and filter stormwater runoff, which helps to protect water quality. A portion of the lakefront (the lesser of 50 feet or 50 percent, with a permit) can be cleared for boating and swimming, but aquatic vegetation should be maintained.*
- ***Wash cars and boats in the yard*** - *If vehicles are washed on a paved surface, the detergents (phosphates) can run into the street and end up in the lake. Detergents add nutrients, which aid the growth of algae within the lake.*
- ***Don't Litter*** - *Trash, food wrappers and litter in the streets can get into lakes and cause harm to fish and wildlife. It also destroys the beautiful natural view.*
- ***Protect against erosion*** - *Exposed soil on construction sites and earthen stockpiles can wash into the storm drains, which run into the lakes. Make sure barriers, such as silt fencing or turbidity screens, are erected to prevent the soil from discharging into the lake.*
- ***Be a responsible boater*** - *Oil, gasoline and trash deposited in lakes by boaters are harmful to the lake and the wildlife. Use caution when operating boats near the shore because waves can erode the shoreline and disturb wildlife.*
- ***Use lake-friendly surface cover*** - *Surfaces such as pavers, porous stone, gravel and mulch are much better for walkways and driveways than asphalt or concrete. If you do have a paved area, divert the runoff into a separate area, such as a grassy swale that allows the water to soak into the ground rather than discharging directly into the storm drain or lake.*
- ***Keep septic tanks and drain fields away from the lakes*** - *Keep septic tanks and drain fields away from the water's edge and make sure that they are working properly. Use low phosphorous detergents if you have a septic tank. Septic tanks and the drain field must be 75 feet from the surface water.*
- ***Conserve water*** - *Using less water in homes, yards, businesses and agriculture can help conserve water. Observe water guidelines. Consider the right plant for the right site characteristics. Effective watering conserves water and reduces runoff.*
- ***Properly maintain vehicles*** - *Automobiles and other vehicles that leak oil, gas and other fluids pollute the lakes when these materials are washed down the storm drain. Keep driveways and parking areas pollutant free. Properly dispose of motor oil at the County landfill.*
- ***Obtain the proper permits for shoreline structures*** - *Structures such as docks, seawalls and boardwalks require an application and proper*

HOW *YOU* CAN PROTECT SEMINOLE COUNTY'S WATERWAYS (Continued)

permits. A private landowner must obtain a permit from the Florida Department of Environmental Protection (DEP), and a homeowners' association or community area must obtain a permit from the St. Johns River Water Management District. A zoning clearance and building permit must also be obtained from Seminole County or a local municipality.

- ***Report suspicious activities*** *- Keep an eye out for activities that might be harmful to lakes. Chemical spills or dumping, wetland or shoreline destruction, wildlife harassment or any other suspicious activity should be reported to local environmental officials. For more information, contact the Seminole County Sheriff's Office-Special Operations Division at (407) 665-6600 or report water pollution to (407) 665-7623.*

Paper towels - 2 to 4 weeks
Newspapers - 6 weeks
Cardboard box - 2 months
Apple core - 2 months
Cigarette butt - up to 12 years
Painted wood - 13 years
Styrofoam cup - 50 years
Aluminum can - 200 years
Plastic drink bottle - 450 years
Glass bottles - Undetermined



Seminole County and the University of South Florida have developed an interactive web application using the County's Geographic Information System (GIS) database to provide water quality data, lake management data, hydrology, weather data, ecological, watershed, historical information, bathymetric maps, fishing reports, comprehensive mapping capability, aerial photographs, lesson plans for educators, volunteer opportunities and a way to report illicit discharges.

Seminole County has been monitoring the water quality in the majority of the unincorporated County lakes since 1999 and has hydrological data on some of our waterbodies since the 1930's. This data is complied into the atlas under the specific water body page.

The atlas was developed as a "One-Stop Information Shop for All Water Resources" to provide citizens, environmental professionals, planners and others with current and historical water resource data and other related information on Seminole County waterbodies. To access this information, log on to our Web site:

www.seminole.wateratlas.org

AQUATIC PLANTS AND *INVASIVE* AQUATIC PLANTS

Plants are an important part of a healthy, diverse aquatic ecosystem. Aquatic plants play a vital role in maintaining the integrity of lakes, ponds, streams and rivers for fish, wildlife, other organisms and human enjoyment. Specific roles of aquatic plants include:

- *Habitat and food for fish, invertebrates, amphibians and water fowl*
- *Food for other wild life and mammals*
- *Spawning area for fish, invertebrates and amphibians*
- *Oxygen production*
- *Erosion protection of river banks and lake shorelines*
- *Water quality improvement through nutrient uptake and slowing of sediment transport*

The natural balance between vegetation and other aquatic organisms is disrupted when invasive or non-native (exotic) plants from other lakes are introduced and become nuisance weeds. Once introduced, these noxious or harmful plants can displace native plants(which are important sources of food and shelter for wildlife) and can interfere with recreational activities such as fishing, boating and swimming; property values; and the enjoyment of the natural beauty of Seminole County's water resources. Often property owners find that they do not have all the resources to properly manage their lake. The Seminole County Lake Management Program offers options that are understandable and responsive to undesirable lake conditions affecting water quality and biological habitats for insects, fish, birds, etc.

Basic Components of the Seminole County Lake Management Program include:

- ***Provide biological and water quality diagnosis*** *- to assess the extent of eutrophication and evaluate trends in water quality conditions.*

- ***Conduct watershed assessment*** *- a detailed evaluation of important watershed features, such as land uses and soil types, is conducted to identify active or potential sources of pollution that need to be addressed to protect and improve lake water quality.*

- ***Develop lake management plan*** *- the results of the water quality diagnosis and watershed assessment are used to evaluate methods to remediate undesirable lake conditions and to manage pollution sources in the lake watershed. The plan identifies the most effective ways to achieve water quality objectives.*

- ***Provide plan implementation*** *- the lake management plan may involve one or more of a variety of technologies including sediment dredging, weed harvesting, artificial aeration, grass carp fish and aquatic herbicide treatments. Watershed management invariably involves the implementation of best management practices for non-point sources or pollution. (Examples are improved lawn fertilization practices, routine catch basin clean outs and installation of storm water treatment technology.) SCLMP provides oversight and assistance to guide recommended lake management activities.*

WHERE DO I NEED A PERMIT? *WHEN IN DOUBT, ASK . . .*

Aquatic Planting Permitting:

For any lake greater than 10 acres, Florida Fish and Wildlife Conservation Commission (FWC) Aquatic Plant Management guidelines allow for homeowners to clear non-woody plants (no trees) from 50% or 50 feet of their shoreline (whichever is less) by physical or mechanical means to create an access corridor which allows for navigation to open water without a permit from the State. However, a permit from FWC is required for the use of herbicides and for the removal of any plants outside this access corridor. This FWC permit is free and should you feel (based upon the above guidelines) you may require a permit, please contact your FWC regional biologist at (407) 275-4004 for assistance. For more FWC permitting information, please visit:

http://myfwc.com/nonnatives/invasiveplants/FieldOperationPermits.htm

Shoreline Alteration Permitting: (Docks, Seawalls, Dredge and Fill):

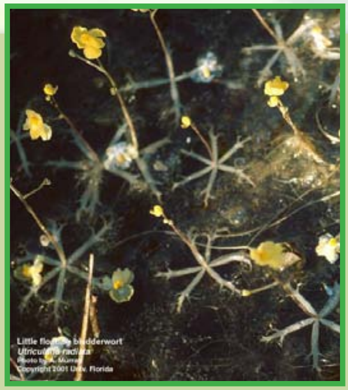
Florida Department of Environmental Protection (FDEP) Environmental Resource Permitting Section (ERP) requires permits for any structure construction, dredging (excavating) or filling of any materials within wetlands or surface water areas, unless it otherwise meets specific criteria for an exemption. Since processing applications for these activities are more in-depth, there is a cost associated with this type of permitting. For more ERP permitting information, please call (407) 893-7863 or visit: **www.dep.state.fl.us/water/wetlands**.

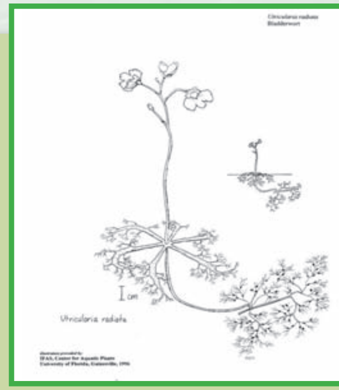
Additionally, Seminole County requires a building permit for docks and seawalls. Please contact the Planning and Development Department's Development Review Division at (407) 665-7331 (**www.seminolecountyfl.gov/pd/devrev/wetlands.asp**) prior to construction or your local municipality for requirements.

Manmade "beaches" are prohibited by local and state regulations.

Since these are constructed by importing sand and clearing of the lake's shoreline, thus reducing shoreline function, it is a violation impacting the floodplain, increasing erosion and sediment/nutrient loading to lakes.

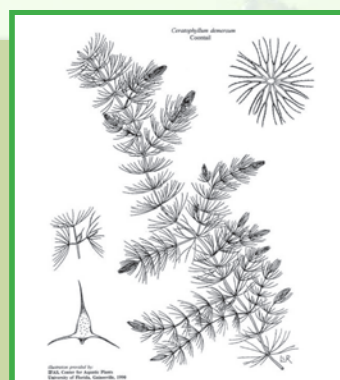
Bladderwort





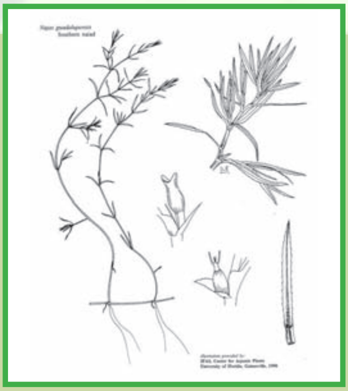
Bladderworts (*Utricularia sp.*) are submersed free-floating plants. There are about 200 species in the world, ranging in size from a few inches to several feet long. Tiny bladders attached to the leaves trap and digest very tiny animals. Utricularia species occurs almost always (estimated probability 99%) under natural conditions in wetlands. Bladderwort flowers are usually bright yellow (but sometimes lavender, depending on species); the flowers have two "lip-like" petals of about equal size. Flowers are on long stalks that emerge several inches above the water.

Coontail



Coontail (***Ceratophyllum demersum***) has no roots and is free floating. It grows in sluggish waters. Because its feathery leaves are arranged in whorls on the stem, this plant resembles a raccoon's tail. The fan-shaped leaves are best observed in the water. Each leaf has several small teeth on the midribs. These tiny teeth give the plant a rough feel when pulled through the hand. Coontail's flowers are very small and rarely seen.

Southern Naid



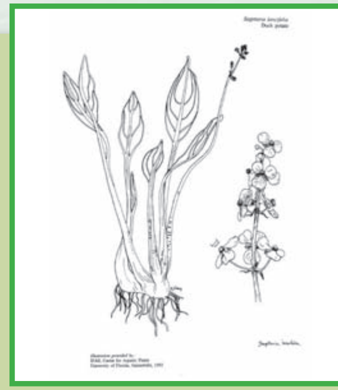
Southern naiad (***Najas guadalupensis***) is a submersed plant with very long stems and many branches. All naiads have very narrow, inch-long leaves that have definite teeth on their margins. Southern naiad leaves are less then 1/16 inch wide. With a hand lens, very tiny teeth can be seen along the leaf margins. Naiad leaves are arranged oppositely on the stem or sometimes in whorls of three. The leaves are deep green to purplish-green. The flowers are very small and inconspicuous.

Eelgrass/ Tape Grass

Eelgrass/Tape Grass (*Vallisneria americana*) is a submersed plant that spreads by runners and sometimes forms tall underwater meadows and is commonly found growing in lakes and streams in most of Florida (Wunderlin, 2003). *Vallisneria americana* blooms all year and occurs almost always (estimated probability 99%) under natural conditions in wetlands. Eelgrass leaves arise in clusters from their roots. They are about one inch wide and can be several feet long. Single white female flowers grow to the water surface on very long, spiraling stalks.

COMMON *NATIVE* PLANTS IN FLORIDA
Emersed Plants

Duck Potato



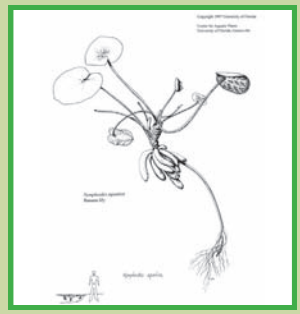
Duck potato (*Sagittaria lancifolia*) is an emersed plant. Its large leaves and conspicuous flowers make it easy to find in the wild. It grows commonly in swamps, ditches, lakes and stream margins. Duck potato has large, firm, lance-shaped leaves, which are typically four inches wide and up to two feet long. The leaf bases taper to the stem. The leaves grow as a fan-like rosette from underground the rhizomes. Duck potato flowers are typical sagittaria flowers: showy and white with three petals. Flowers are extended on thick stalks that are often a foot or more above the leaves.

Pickerel-weed

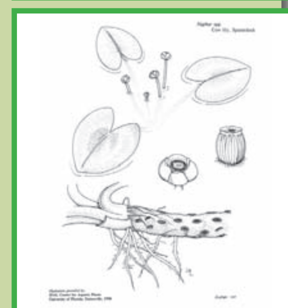
Pickerelweed (*Pontederia cordata*) is a very common emersed plant that is commonly found growing in streams, marshes, ditches, ponds and lake margins nearly throughout Florida (Wunderlin, 2003). It is a prolific grower that can cover large areas. Pickerelweed blooms from spring to summer and typically grows to about two to three feet tall. Its leaves are large, up to five inches wide and are usually twice as long. Leaf shapes are variable, but are usually lance-shaped. The easiest way to recognize pickerelweed is by its spike of violet-blue flowers.


Water Lillies

Nymphaea odorata



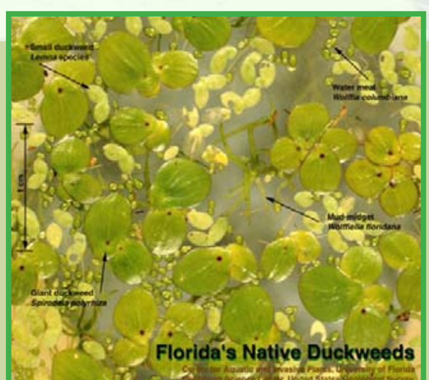
Nymphoides aquatic

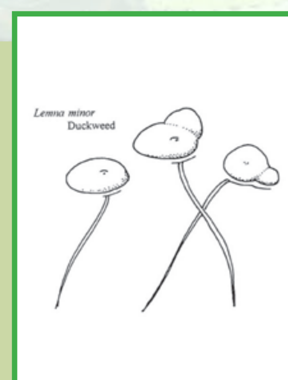


Nuphar lutea subsp. advena

Water lilies (***Nymphaea odorata, Nymphoides aquatic, Nuphar lutea subsp. advena***) are often recognized by their floating leaves. There are about 40 species of water lily in the world, plus numerous hybrids and varieties. Water lily leaves are nearly circular in shape. The leaves arise on stalks from long rhizomes in the mud. Fragrant water lily flowers are showy white and aromatic. Flowers of unusual color and shape are characteristic of hybrid water lilies.

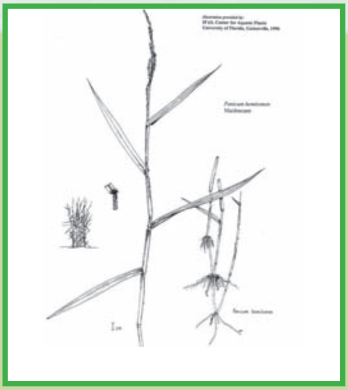
Florida's Duckweed





Duckweeds are common plants in Florida. Although very small, they are nonetheless sometimes quite noticeable when they cover a pond in dense masses. These are very small flowering plants indeed; in fact, water meal (*Wolffia spp.*), at 1 to 1.5 mm long, is the smallest flowering plant on earth! Types of Native Duckweeds include: *Spirodela polyrhiza* - Giant duckweed, *Lemna valdiviana* - Small duckweed, *Wolffia columbiana* - Water meal, *Wolffiella gladiata* (syn. *W. floridana*) - Mud-midget.

Maidencane



Maidencane (*Panicum hemitomon*) is a valuable and common native that can form large stands in the water or even on dry banks. It may be confused with torpedo grass, para grass, cupscale grass or blue maidencane. It provides food, protection and nesting material for wildlife. Maidencane is a grass with extensive rhizomes and narrow stems up to six feet long. The smooth leaf blades are flat or folded, pointed at the tips and up to one inch wide and 12 inches long. Inflorescence (flowers) are erect, narrow, spike-like and range from four to 12 inches long.

Saw-Grass

Saw-grass (*Cladium jamaicense*), aptly named for its small sharp teeth on the leaf blades, is a large sedge that occurs throughout the southeastern U.S. growing in fresh- and brackish-water wetlands where it provides food and shelter to water birds and other animals (Kartesz, 1999). Two species of Cladium exist in Florida (Wunderlin, 2003).


Bald Cypress

Bald cypress (*Taxodium distichum*) grows to be a huge tree in Florida and the southeast. Although it is reported as far north as New York (Kartesz, 1999). It is commonly found growing in lakes, swamps, floodplains and along streams (Wunderlin, 2003). Bald cypress occurs almost always (estimated probability 99%) under natural conditions in wetlands. *Taxodium distichum* leaves are linear and spread on the branchlets.

Taxodium distichum

Taxodium ascendens

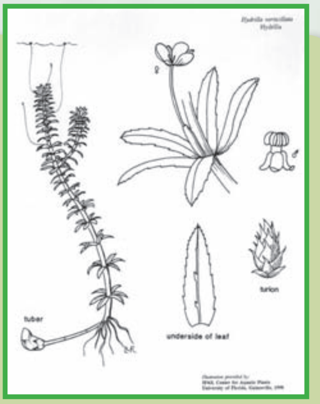
Pond Cypress

Pond cypress (***Taxodium ascendens***) doesn't grow as tall or as robustly; it is the cypress of the Everglades. It commonly occurs in flatwood pond and lake margins throughout Florida and only in the southeastern coastal states (Wunderlin, 2003). Pond cypress leaves are awl-shaped and press against the branchlets (appressed), with branchlets generally ascending. *Taxodium ascendens* occurs almost always under natural conditions in wetlands.

Dahoon Holly

Dahoon holly (*Ilex cassine*), an evergreen, is native to Florida's swamps, margins and other wetlands, growing to be a large shrub or a medium-sized tree, sometimes much larger. It is found throughout Florida and occurs in all southeastern U.S. coastal states. It flowers in the spring; later it has bright red to orange-red drupes. There are 13 species and varieties of Ilex in Florida.

Hydrilla



Hydrilla (*Hydrilla verticillata*) is a submersed plant. It can grow to the surface and form dense mats and may be found in all types of water bodies. Hydrilla stems are slender, branched and up to 25 feet long. Hydrilla's small leaves are strap-like and pointed. They grow in whorls of four to eight around the stem. The leaf margins are distinctly saw-toothed with one or more sharp teeth along the length of the leaf mid-rib. Hydrilla produces tiny white flowers on long stalks. It also produces 1/4 inch turions at the leaf axils and potato-like tubers attached to the roots in the mud. Hydrilla is an invisible menace, in-visible that is, until it fills the lake or river that it infests, "topping out" at the surface. Hydrilla can grow an inch a day. When hydrilla invades, ecologically-important native submersed plants such as pondweeds (*Potamogeton spp.*), tapegrass (*Vallisneria americana*) and coontail (*Ceratophyllum demersum*) are shaded out by hydrilla's thick mats or are sim-ply outcompeted and eliminated (van Dijk 1985).

Be sure to check your boat and trailer for "hitchhikers" when entering or leaving a waterbody.

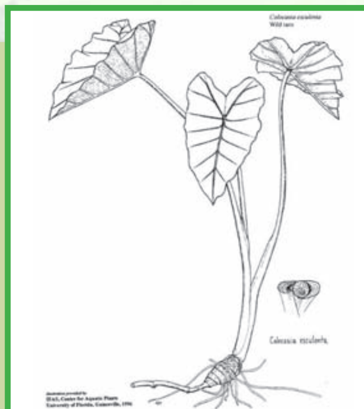
Millions of dollars are spent each year on herbicides and mechanical harvesters in Florida alone in an effort to place hydrilla under "maintenance control." Hydrilla spreads to new waters mainly as fragments on boats and trailers.

Alligator Weed

Alligator weed (*Alternanthera philoxeroides*) is an emersed plant. It can grow in a variety of habitats, including dry land, but is usually found in water. It may form sprawling mats over the water or along shorelines.

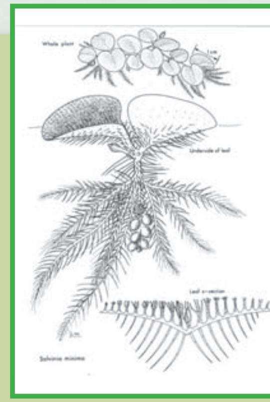
Stems are pinkish and can become hollow when larger. Flowers are reduced in round white heads on long stalks; each flower has four to five thin, papery bracts, five stamens, one pistil.

Wild Taro



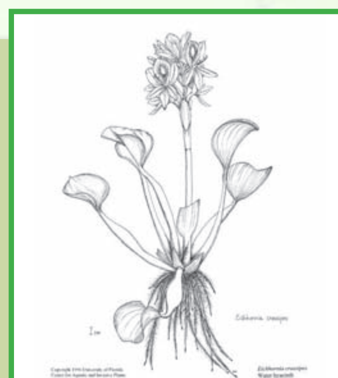
Wild taro (*Colocasia esculenta*) is a non-native emersed plant, having been imported from the Pacific Islands. It occurs in and out of water. Wild taro leaves are medium to large-size. They are arrowhead-shaped with heart-shaped leaf bases. The leaves can grow up to two feet long. They are dark, velvety green and water repellent. Wild taro leaves are peltate: the leaf stem attaches more-or-less to the middle of the underside of the leaf. Leaf stems grow up to four feet tall. Flowers occur in small finger-like spikes.

Salvinia



Salvinia (*Salvinia minima*) are floating ferns, thus also referred to as water ferns. There are 10 species of Salvinia in the world, none of which are native to the United States. This species is about 3/4 inch in width. Salvinia has joined oval leaves which are covered with stiff hairs. It has root-like structures which are actually modified fronds.

Water Hyacinth

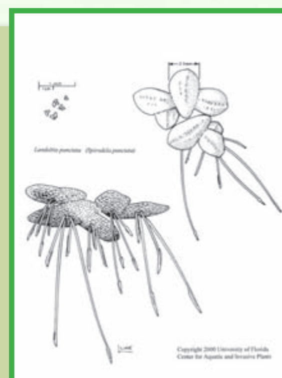


Water hyacinth (*Eichhornia crassipes*) is a floating plant. This invasive nuisance plant often jams rivers and lakes with uncounted thousands of tons of floating plant matter. A healthy acre of water hyacinths can weigh up to 200 tons. The plants vary in size from a few inches to over three feet tall with showy lavender flowers and dark feathery roots. Water hyacinth leaves are rounded and leathery, attached to spongy and sometimes inflated stalks.

Water Lettuce

Water lettuce (*Pistia stratiotes*) is a floating plant. Experts disagree as to whether water lettuce is a native or has been introduced. It occurs in lakes, rivers and canals, occasionally forming large dense mats. As its name implies, water lettuce resembles a floating open head of lettuce. Water lettuce has very thick leaves which are a light dull green, hairy and ridged. There are no leaf stalks. Water lettuce roots are light colored and feathery. Its flowers are inconspicuous.

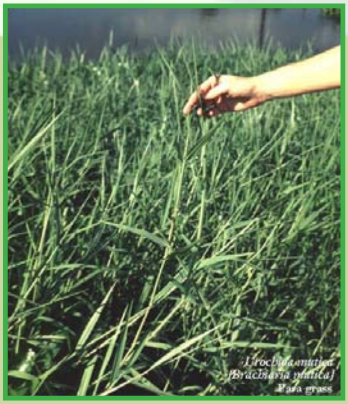
Dotted Duckweed



Dotted duckweed (*Landoltia punctata, syn. S. punctata*) is a new name for this duckweed, which used to be known as *Spirodela punctata*. It looks very similar to the native giant duckweed, *Spirodela polyrhiza*. It is frequently found growing in rivers, ponds, lakes and sloughs nearly throughout the state and blooms all year (Wunderlin, 2003). *Landoltia punctata* can grow into dense masses in stagnant water bodies. *Landoltia punctata* usually has two leaves attached together. The leaves are shoe-shaped, which makes it resemble a large Lemna species. *Landoltia punctata* has two to five roots descending from each leaf.

This plant is easily confused with the native plant, giant duckweed, *Spirodela polyrhiza*. Landoltia duckweed is smaller than *Spirodela polyrhiza*, is more shoe-shaped, does not have a red dot on top, usually only has up to four roots and sometimes has a red margin on the underneath of the leaves. The native giant duckweed is larger, has rounder leaves, some have a red dot on the top, has up to nine or more roots and is dark red underneath the leaves.

Para Grass



Para grass (*Brachiaria mutica*) is in the family Poaceae, along with other familiar grasses such as St. Augustine, Bermuda and Centipede grass. Stems will often root at the base and can reach up to eight feet in height, having hairy nodes and sheaths. Leaf blades are four to 12 inches long and 1/2 an inch wide. Although there are many flower heads produced by para grass, seed production is very poor with poor seed viability.

Torpedo Grass

Torpedo grass (*Panicum repens*) is a highly invasive exotic weed from Australia and is often mistaken for native maidencane. It grows rapidly and extensively throughout Florida, along canal ditches and banks and along shores of lakes, often extending into the water to form large floating mats. It also grows terrestrially and may be found in pastures, grovelands and even sand dunes. The plants are erect or leaning up to about three feet tall. Its stems are rigid with narrow leaves which are only 1/16 to 1/4 inch wide and two to 10 inches long. The inflorescence (flower) is three to nine inches long, branched and somewhat open, with branches pointing upward.


Brazilian Pepper Tree

Brazilian pepper tree (*Schinus terebinthifolius*) is one of the most aggressive of the invasive non-indigenous plants in Florida. It is invading aquatic and terrestrial habitats, greatly reducing the quality of native biotic communities in the state. Brazilian pepper is a small tree, growing up to 30 feet tall with a short trunk usually hidden by dense intertwining branches. The leaves have a reddish, sometimes winged midrib with three to 13 finely-toothed leaflets which are one to two inches long. The leaves smell of turpentine when crushed. Flowers are white. The fruits are in clusters, glossy, green and juicy at first, becoming bright red as they ripen. The skin dries to become a papery shell surrounding the seed.

Chinese Tallow

Characteristics that make **Chinese tallow (*Sapium sebiferum*)** a popular ornamental are its fast growth rate, attractive fall color and its ability to resist damage from pests. It is a small to medium-sized tree that grows to about 20 feet tall, but some specimens can reach 40-50 feet. It is freely branching with leaves arranged alternately on branches. The flowers of Chinese tallow are attractive to bees and other insects and are borne in spikes roughly eight inches long. Fruit ripens from August to November. Chinese tallow trees are deciduous with a strong, deep taproot. This enables young trees to withstand periods of drought. Seeds are spread by many species of birds, and moving water can also serve as a mechanism for seed dispersal.

HELPFUL RESOURCES

Other Resources to Help With Your Questions:

Boating Safety and Regulations: http://www.myfwc.com/SAFETY/Safety_Boat_Safety_index.htm

Seminole County MSBU Program: Funding format for Aquatic Weed Control or Lake Restoration (407) 665-7185 or www.seminolecountyfl.gov/fs/msbu/msbuprogbroch.asp

Florida Yard & Neighborhood Program (FYN) Program: For more information or to schedule a Florida Yards & Neighborhoods presentation, call (407) 665-5575, Web site: www.seminolecountyfl.gov/fyn, e-mail: fyn@seminolecountyfl.gov

Seminole County Watershed Atlas: Comprehensive Web site for lakes and rivers that includes water quality, hydrology, history and events. (407) 665-2424 or visit the Web site: www.seminole.wateratlas.org

Seminole County Lake Management Program: (407) 665-2439 or visit the Web site dedicated to lakes www.seminole.wateratlas.usf.edu/LakeManagement

Watershed Action Volunteers (WAV) Program: For volunteering opportunities, call (407) 665-2457 or visit www.seminolecountyfl.gov/pw/roadstorm/education_wav.asp; e-mail: wavsem@seminolecountyfl.gov

Plant and Fish Information:

Aquatic Plant (Permit/Herbicides):

Florida Fish and Wildlife Conservation Commission (FWC) Aquatic Plant Management Permit Application: www.myfwc.com/nonnatives/InvasivePlants/docs/20%20Application-07-26-05.pdf

FWC Invasive Plant Management Section: (407) 275-4004 or www.myfwc.com/WILDLIFEHABITATS/InvasivePlants_index.htm

Why You Need an FWC Aquatic Plant Management Permit:
http://plants.ifas.ufl.edu/guide/permit.html

Use of Herbicides for Aquatic Plant Management: http://plants.ifas.ufl.edu/guide/herbcons.html

Listing of the Eight Aquatic Herbicides Registered for Florida's Waters: http://plants.ifas.ufl.edu/guide/sup3herb.html

Other Aquatic Plant Resources (Identification/ Management/Nurseries):

Plant Management in Florida's Waters:
http://plants.ifas.ufl.edu/guide/index.html

UF's Center for Aquatic and Invasive Plant Identification: http://plants.ifas.ufl.edu/plants&animals.html

USF's Plant Atlas: www.plantatlas.usf.edu

UF Herbarium (digital images of plants): www.flmnh.ufl.edu/herbarium/cat/imagesearch.asp?srchproject=IN

Plants for Lakefront Revegetation (PDF): www.seminole.wateratlas.usf.edu/upload/documents/651_Lakefront%20Revegetation.pdf

Native Aquatic Plant Nursery List (PDF): www.seminole.wateratlas.usf.edu/upload/documents/Native%20Aquatic%20Plant%20Nursery%20List.pdf

Triploid Grass Carp Fish (Permits/Information):

Florida Fish and Wildlife Conservation Commission (FWC) - Triploid Grass Carp Permitting: (352) 357-2951 or www.myfwc.com/License/FreshwaterPermit_grasscarp.htm

Triploid Grass Carp Vendor/Supplier List: http://myfwc.com/freepermits/tgc-internet/tg_vendorlist.asp

Use of Biological Controls for Aquatic Plant Management: http://plants.ifas.ufl.edu/guide/biocons.html

Report a Fish Kill or Pollution:

FWC Fish Kill Hotline: (800) 636-0511 or http://research.myfwc.com/fishkill/submit.asp

Report Water Pollution: (407) 665-7623 or www.seminole.wateratlas.usf.edu/forms/pollution.asp

Seminole County Water Quality Section

Department of Public Works • Roads-Stormwater Division

177 Bush Loop • Sanford, FL 32773

Water Quality Program

(407) 665-2424 or (407) 665-2456

www.seminole.wateratlas.usf.edu

Lake Management Program

(407) 665-2439 • www.seminole.wateratlas.usf.edu/lmp

Report Water Pollution

(407) 665-7632

www.seminole.wateratlas.usf.edu/forms/pollution.asp

Watershed Action Volunteer Program

A Program of the St. Johns River Water Management Program

177 Bush Loop • Sanford, FL 32773

Seminole County WAV Coordinator:

Web site: www.seminolecountyfl.gov/pw/roadstorm/education_wav.asp or www.sjrwmd.com/education/wav/

E-mail: wavsem@seminolecountyfl.gov

Phone: (407) 665-2457

Florida Yards & Neighborhood Program

250 West County Home Road • Sanford, FL 32773

Web site: www.seminolecountyfl.gov/fyn

E-mail: fyn@seminolecountyfl.gov

Phone: (407) 665-5575

Photo and Illustrations: All plant specimen photos and illustrations provided by the University of Florida/ IFAS Center for Aquatic and Invasive Plants. Used with permission. For Additional information on Florida's aquatic and invasive plants, log on to http://plants.ifas.ufl.edu.

D.4 How You Can Protect Central Florida Waterways

How does Pointless Personal Pollution impact our waters?

- Nutrients from fertilizers, septic tanks and animal waste can cause excessive growth of algae and aquatic weeds.
- Heavy metals and pesticides from road runoff or from yards and farms can kill aquatic organisms and contaminate sediments.
- Sewage, garbage and litter reduce oxygen in the water to levels that can kill aquatic life.
- Sediments from soil erosion clog fish gills and shellfish filter systems, cutting off their oxygen supplies.

SEMINOLE COUNTY
FLORIDA'S NATURAL CHOICE

Reporting Illicit Discharges

Please report any wastewater or other polluting material that you see being discharged into a street, alley, stormdrain, lake or river. Violations that are reported while they are in progress can often be quickly corrected and may result in little or no pollution entering a lake. You may submit a report through Seminole County's Watershed Atlas at :

www.seminole.wateratlas.org

If you want to be part of the solution, and need additional information, you can contact any of the following organizations:

Florida Department of Environmental Protection
Nonpoint Source Management Section
2600 Blair Stone Road • Tallahassee FL 32399
(850) 245-7508

Seminole County Government
Environmental Services/Solid Waste Management
(407) 665-2262

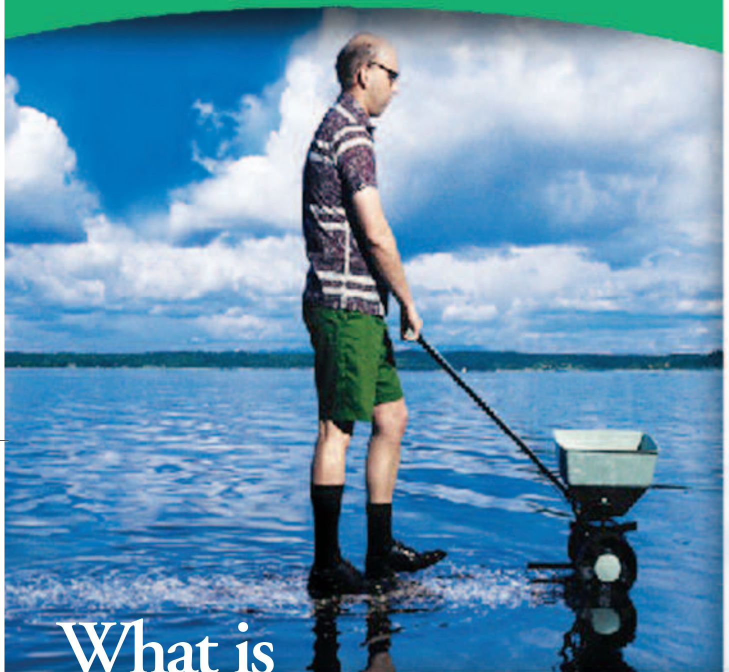
Seminole County Government
Public Works Department/Roads–Stormwater
Water Quality Section
(407) 665-2461

Florida Yards & Neighborhoods
(407) 665-5575

SEMINOLE COUNTY
FLORIDA'S NATURAL CHOICE

"How You Can Protect Central Florida Waterways"

“Wherever you live, your daily activities could end up polluting Florida waters.”



What is Pointless Personal Pollution?

Pointless Personal Pollution, also known as nonpoint source pollution, is difficult to identify and treat. This is because many of our daily activities can cause this pollution, and it can travel by many different routes into the ground and surface waters.

Pollutants from our homes, businesses and farms are major contributors to the pollution of Florida’s surface and ground waters. This pollution is washed into the state’s waters by rain or irrigation water.

What can I do to reduce Pointless Personal Pollution?

SHOP WISELY:
Buy products labeled biodegradable, non-toxic, non-phosphorus, or water soluble. These products decompose quickly and will not pollute surface or ground waters.

STORE PRODUCTS SAFELY:
Keep toxic products in original containers, closed and clearly marked, in safe storage places. This will prevent spillage that could reach ground or surface waters. It may also help prevent an accidental poisoning if you have children or pets.

PROPERLY MAINTAIN SEPTIC SYSTEMS:
Inspect systems regularly and have the system pumped out as needed. Avoid caustic cleaners, chemicals, solvents, fats, oils and greases. These might destroy waste-reducing bacteria or clog absorption fields, causing runoff of inadequately treated waste during storms and compromising the ground or surface waters.

LAWN & GARDEN CARE:
Use garden and lawn chemicals wisely. Follow package directions carefully, and only use pesticides, herbicides and fertilizers when other methods fail. Do not apply if rain is in the forecast. Excessive fertilizers and chemicals wash off the property and into surface and ground waters.

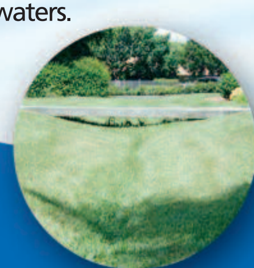
Keep irrigation water on the lawn and garden (not on paved surfaces).

Divert rain spouts to unpaved areas or swales, and wash vehicles where water will drain to vegetated areas. This allows runoff to soak into the soil and not wash off the property into nearby waterbodies after picking up pollutants.

Compost leaves, grass and shrub clippings should be used as mulch to supplement fertilizers. Do not rake these materials into roadways or swales. These materials decompose, returning nutrients to the soil so you use less fertilizer. Do not place yard debris in roads or swales. This will block drainage flows and end up in your nearest waterbodies.

AUTOMOTIVE CARE
Don’t drain used motor oil into stormdrains. Take used motor oil and antifreeze to service stations to recycle them. These products are toxic and add pollutants to surface waters if placed or washed into stormdrains.

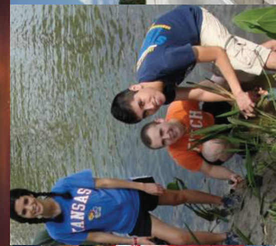
Service your car regularly. Have your car inspected and maintained regularly. This will prevent leakage of motor oil, antifreeze and other fluids that can end up in the nearest waterbody. Well-maintained vehicles reduce air emissions that also can contaminate surface waters.



“Unlike many other types of pollution, WE cause this pollution, and WE can stop it.”

D.5 Seminole Education, Restoration, and Volunteer (SERV) Program

Seminole County
Florida's Natural Choice



Working together to protect Seminole County's natural resources

SERV Program:

Our mission is to actively restore, preserve and protect the waterways and natural areas of Seminole County through education and volunteer projects.

We need your help to keep Seminole County "Florida's Natural Choice!"

For More Information, Contact:
Seminole County Public Works
Roads-Stormwater Division
Attn: SERV Coordinator
177 Bush Loop
Sanford, FL 32773
407-665-2457
407-665-2458 - Fax
Email: serv@seminolecountyfl.gov

www.seminole.wateratlas.org
www.seminolecountyfl.gov

Seminole County
Florida's Natural Choice

Public Works Department
Roads-Stormwater Division
177 Bush Loop
Sanford, FL 32773

Please place stamp here.

Public Works Department
Roads-Stormwater Division
ATTN: SERV Coordinator
177 Bush Loop
Sanford, FL 32773

Join our volunteer program and leave your mark by improving Seminole County's natural resources!

Help restore the ecosystems and habitats of your lakes, rivers and natural lands by joining our hands-on volunteer program.

Volunteer in a beautiful outdoor setting, removing invasive species and planting beneficial native plants along our waterbodies and natural lands areas, cleaning up our waterways and roadways, or helping to reduce pollution by labeling storm drains throughout the County.

SEMINOLE COUNTY
FLORIDA'S NATURAL CHOICE

SERV Opportunities:

- *Lake Restoration Projects*
- *Invasive Plant Removal Projects*
- *Waterway Cleanups*
- *Storm Drain Marking Projects*
- *Adopt-A-Road*
- *Adopt-A-River*
- *Education and Outreach Activities*

Benefits of Becoming a SERV:

- *Work alongside biologists and gain valuable field experience.*
- *Gain leadership skills.*
- *Earn community service hours. This is an approved Bright Futures Community Service Organization.*
- *Boost up your resume – add new skills through volunteering and stand out to potential employers.*
- *Give back to the environment – protect the quality of our valuable resources.*
- *Leave your mark - know that you made a difference.*
- *Work in an exciting, outdoor setting.*
- *Have FUN!*

SERV

Volunteer Application Form

YES! I want to get involved in the SERV Program!

Date ______________________

Name ______________________

Organization ______________________

Street Address ______________________

City, State, Zip ______________________

Phone ______________________

E-mail ______________________

Times/Dates Available ______________________

Number of Volunteers in your Group ______________________

SERV
Seminole Education, Restoration & Volunteer Program

END OF REPORT