

Lake Gem Mary

WBID 3168W1

Hydrologic & Nutrient Budget and Water Quality Management Plan

Final Report

January 2019

Prepared for:



Orange County, Florida

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ACKNOWLEDGEMENTS

A report of this magnitude requires the cooperation of many people to bring it to a successful completion. The continued interest and support of the Board of County Commissioners is gratefully acknowledged. The direction, assistance and guidance of the Environmental Protection Division, specifically the Water Sciences Section, throughout the project development were greatly appreciated.

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EXECUTIVE SUMMARY

Lake Gem Mary is an urban lake, approximately 14 acres in size, and is located in the Boggy Creek Drainage Basin, three miles southeast of downtown Orlando in the Southern Oaks area. The majority of the watershed surrounding Lake Gem Mary is located within Orange County; however, approximately 18% of the watershed is located within the City of Orlando jurisdiction. A Hydrologic & Nutrient Budget and Water Quality Management Plan (Study) was performed to evaluate existing water quality data for the lake, collect and analyze current water quality data, estimate hydrologic information for the watershed, estimate nutrient inputs to the lake and outputs from the lake, and prepare recommendations for water quality improvements within the watershed. This study was prepared for the Orange County Environmental Protection Division (OCEPD) by Cribb Philbeck Weaver Group (CPWG), TEAM Engineering (TEAM) and Environmental Research & Design, Inc. (ERD).

Waterbodies within the State of Florida are divided by the Florida Department of Environmental Protection (FDEP) into five separate groups for planning purposes, with Lake Gem Mary categorized in Group 4 “Kissimmee River”, specifically the Upper Kissimmee Planning Unit. FDEP issued Lake Gem Mary a unique waterbody identification number (WBID) 3168W1. The Kissimmee River planning group is a separate group from Lake Okeechobee (designated as Group 1); however, the Kissimmee River, including Lake Gem Mary, is included in the Lake Okeechobee Basin Management Action Plan (BMAP).

The lake was initially verified as impaired for nutrients based on the Trophic State Index, and was included on the Verified List of impaired waters for the Kissimmee River. Between 2009 and 2013, the FDEP developed numeric nutrient criterion (NNC) as the basis for nutrient impairment for surface water. Because Lake Gem Mary nutrient impairment was based on TSI, the FDEP formally delisted the lake from the Verified List of Impaired Waters in June 2017.

The Lake Gem Mary watershed area is developed, with residential and institutional (former Naval Research Facility) land uses. The area surrounding the lake was constructed prior to implementation of regulations requiring stormwater treatment. There are currently no stormwater treatment areas located within the Lake Gem Mary watershed. Historical data for Lake Gem Mary indicates that the lake water quality is within the upper mesotrophic to lower eutrophic range. A

year-long field reconnaissance was performed to evaluate the physical characteristics of Lake Gem Mary. A summary of Lake Gem Mary's bathymetric characteristics is presented in the table below.

Bathymetric Parameter¹	Value
Surface Area	14.1 acres
Total Volume	252 ac-ft
Mean Depth	17.9 ft
Maximum Depth	32 ft
Shoreline Length	2,828 ft
Shoreline Development	2,780 ft

1-Based upon a water surface elevation of 89.78 (NAVD 88)

Work efforts for this study were initiated by CPWG during September 2015 to assist in developing a Water Management Action Plan for Lake Gem Mary to maintain water quality compliance with the NNC. The primary objective of the year-long study was to quantify and record current water quality in the lake, evaluate potential pollutant loadings to and from the lake, and identify opportunities for water quality improvements within the lake and surrounding watershed.

A field monitoring program was conducted between October 2015 and September 2016 to collect water quality data for use in developing hydrologic and nutrient budgets for the lake. The hydrologic budget includes estimated inputs from direct rainfall on the lake, stormwater runoff, and groundwater seepage. The nutrient budget includes inputs from bulk precipitation, stormwater runoff (direct runoff and through stormwater sewer systems), groundwater seepage, and internal recycling. A detailed evaluation of sediment characteristics in Lake Gem Mary was also conducted which included physical and chemical characterization of surficial sediments and evaluation of internal phosphorus recycling.

RECOMMENDATIONS

The recommended water quality improvement options for Lake Gem Mary are summarized below and discussed in detail in the last section of this report. Water quality improvement options were evaluated to target sources which are identified as contributors of nutrient loadings to the lake. The

evaluated options include both structural and non-structural approaches to controlling and reducing pollutant inputs into Lake Gem Mary.

Sediment Inactivation

Sediment phosphorus inactivation is a lake restoration technique which is designed to substantially reduce sediment phosphorus release by combining available phosphorus in the sediments with a metal salt to form an insoluble precipitate, rendering the sediment phosphorus unavailable for release into the overlying water column. The largest contributor of TP to Lake Gem Mary, approximately 56%, occurs due to internal recycling of nutrients in the sediments accumulated on the bottom of the lake. Since the overall contribution of phosphorus to Lake Gem Mary from sediments is significant, the objective of sediment inactivation is to control the sediment release of phosphorus, resulting in improvements to the lake's water quality.

On-Site Sanitary Treatment and Disposal Maintenance

Failing or non-maintained on-site sanitary treatment and disposal systems (OSTDs), also known as septic tanks, can contribute substantially more nutrients to waterbodies than well-maintained OSTDs. Since the majority of residents in the watershed use OSTD systems, homeowners should be made aware of recommended, regular maintenance activities for OSTDs.

Sanitary Sewer

A majority of the existing homes within the Lake Gem Mary watershed are serviced by on-site OSTDs. An average septic tank will leach 3 kg/year of TP and 18 kg/year of TN to the lake. The cost/benefit ratio for installing sanitary sewer in this area is high, therefore, if sanitary sewer becomes available in the area, homeowners should connect as their OSTD systems fail.

Rear Yard Swales and Berms

Stormwater runoff from the rear yards around the lake can be intercepted by swales and berms, allowing the runoff to be infiltrated into the ground rather than directly discharging into the lake. Runoff originating from lawns and landscaped areas has the potential to contribute significant loadings of both nutrients and pesticides into Lake Gem Mary. Untreated stormwater runoff from lawns and landscaped areas contains TP concentrations which are many times greater than concentrations commonly observed in Lake Gem Mary. As the runoff migrates through the

vegetation and surficial soils, a large portion of the pollutant mass is attenuated and is prevented from reaching the lake.

Inlet Baskets

Development within the Lake Gem Mary watershed was constructed prior to water quality treatment requirements. Stormwater runoff from the residential areas along the north and east portions of the watershed flow to the streets where it is collected by curb inlets and discharged directly to the lake.

Installation of inlet baskets in the residential areas of the watershed would collect leaves, floatable trash, grass clippings, and other debris present in the stormwater runoff prior to discharge into the lake.

Baffle Boxes

Nutrient separating baffle boxes, on average, remove 16% TP and 19% TN. Biological Activated Media such as Bold & Gold can be added to baffle boxes to increase their nutrient removal efficiencies. Potential locations for baffle box installation include the Orange County School Board facility (Naval Research facility) on the west side of the lake and along Gatlin Avenue along the south side of the lake. Installation of the baffle boxes would reduce TP, TN and TSS pollutant load to the lake, and would remove floating debris and vegetation from entering the lake.

Non-Structural Techniques

Non-structure techniques that can reduce nutrient loads to Lake Gem Mary include: Florida Yards and Neighborhoods Program, Street Sweeping, Public Education and enforcement of the Orange County Fertilizer Ordinance. Public meetings and the use of education pamphlets are two ways to interact with the homeowners living in the watershed.

A summary of available options with pollutant load removal and initial capital costs (except street sweeping costs which are annual costs) are summarized in the following table.

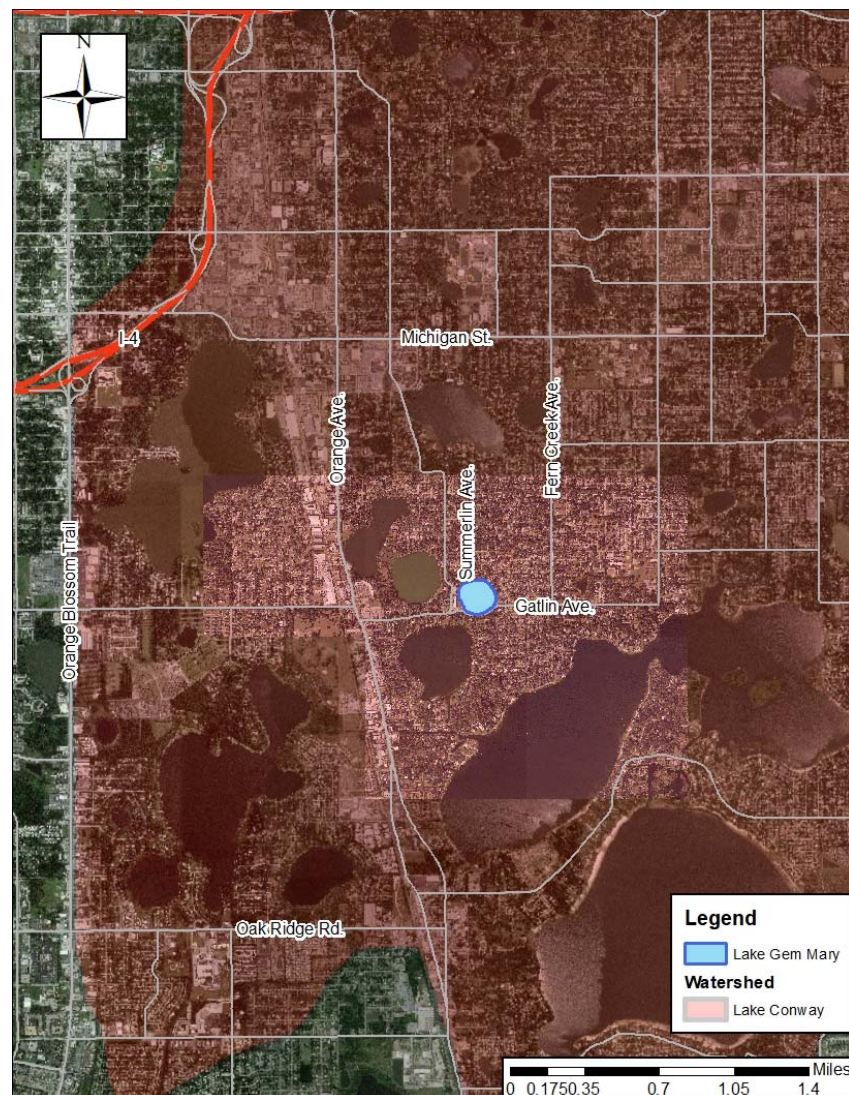
Option	Description	TP Removal (kg/yr)	TN Removal (kg/yr)	Cost
1	Sediment Inactivation	476	NA	\$117,594
2	Sanitary Sewer	78.3	324.8	\$800,000
3	On-Site Sanitary Treatment and Disposal Maintenance	74.4	162.4	\$200,000
4a	Rear Yard Swales and Berms	1.25	7.5	\$100,000
4b	Rear Yard Swales and Berms with BAM	2.61	9	\$177,000
5	Inlet Baskets	6.6	18	\$14,300
6a	Baffle Boxes for Sub-basins 1 & 2	0.42	2.97	\$80,000
6b	Baffle Boxes for Sub-basins 8	0.12	1.24	\$80,000
6c	Baffle Boxes for Sub-basins 1 & 2 with Bold & Gold	2.13	10.45	\$100,000
6d	Baffle Boxes for Sub-basins 8 with Bold & Gold	0.63	4.36	\$100,000
7	Florida Yards and Neighborhoods	NA	NA	NA
8a	Street Sweeping – Existing every 6 weeks (PW) /2 weeks (EPD)	0.88	3.68	\$764
8b	Street Sweeping - every 2 weeks	1.47	6.17	\$1,638
8c	Street Sweeping - once weekly	2.9	12.35	\$3,275
8d	Street Sweeping - twice weekly	5.9	24.78	\$6,552
9	Public Education	0.84	3.72	NA
10	Proper Landscape and Fertilizer Usage	NA	NA	NA

NA = Unable to Quantify TP and TN removal from the proposed Management Option

1.1. GENERAL DESCRIPTION

This report provides a summary of work efforts performed by Cribb Philbeck Weaver Group (CPWG), Team Engineering (TEAM) and Environmental Research & Design, Inc. (ERD) for the Orange County Environmental Protection Division (OCEPD) to develop hydrologic and nutrient budgets, along with a water quality management plan, for Lake Gem Mary. Lake Gem Mary is an urban lake, approximately 14-acres in size, and located approximately 3 miles southeast of downtown Orlando in the Southern Oaks area. A location map for Lake Gem Mary is provided in Figure 1-1. The Lake Gem Mary watershed is partially within Orlando City limits as presented in Figure 1-2.

Figure 1-1: Lake Gem Mary Location Map



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The watershed area immediately surrounding the lake is developed, with residential and institutional (formerly Naval Research Facility) land uses. Development within the Lake Gem Mary watershed was constructed prior to implementation of regulations requiring stormwater treatment and therefore contains no stormwater treatment areas. Historical water quality in Lake Gem Mary has been somewhat variable, primarily within upper mesotrophic to lower eutrophic range.

According to the Florida Department of Environmental Protection (FDEP), Lake Gem Mary is classified as a Class 3F waterbody. This designation means that the “water use class is freshwater for fish consumption, recreation, propagation and maintenance of a healthy, well-balanced population of fish and wildlife.”

1.2. IMPAIRED WATERS DESIGNATION

Section 303(d) of the Clean Water Act (CWA) requires states to submit lists of surface waterbodies that do not meet applicable water quality standards. These waterbodies are defined as “impaired waters” and Total Maximum Daily Loads (TMDLs) must be established for these waters on a prioritized schedule. The FDEP has established a series of guidelines to identify impaired waters which may require the establishment of TMDLs. Waterbodies within the State of Florida are divided into five separate groups for planning purposes, with Lake Gem Mary categorized in Group 4 “Kissimmee River”, specifically the Upper Kissimmee Planning Unit. Although the Kissimmee River is categorized as a separate group from Lake Okeechobee (Group 1), the Kissimmee River, including Lake Gem Mary, is included in the Lake Okeechobee Basin Management Action Plan (BMAP). Orange County could become a stakeholder in the Lake Okeechobee BMAP if Lake Gem Mary is designated as impaired.

The lake was initially verified as impaired for nutrients based on the Trophic State Index, and was included on the Verified List of impaired waters for the Kissimmee River. The Trophic State Index (TSI) values in the lake exceeded the threshold of 40 TSI units in 2003, 2004, and 2007. For assessment purposes, the FDEP divided the Upper Kissimmee Planning Unit into water assessment polygons with a unique waterbody identification (WBID) number. The WBID for Lake Gem Mary is 3168W1.

Between 2009 and 2013, the FDEP developed numeric nutrient criterion (NNC) as the basis for nutrient impairment for surface water. Because Lake Gem Mary nutrient impairment was based on TSI, the FDEP formally delisted the lake from the Verified List of Impaired Waters in June 2017.

1.3. PREVIOUS STUDIES

In July 1996, a Contamination Assessment Plan was prepared for the Naval Research Laboratory Underwater Sound Reference Detachment at Lake Gem Mary to provide the rationale for performing field activities associated with collecting data to evaluate the presence of petroleum hydrocarbons at the site. The report indicates that there is no known evidence of a release of petroleum hydrocarbons at the facility, but recommends collection of surface water and sediment samples to confirm that there were no impacts from activities at the facility.

In April 1997, an Environmental Baseline Survey was prepared as a result of the Base Realignment and Closure Act of 1995 and the subsequent relocation of the Naval Research Facility (NRF) to Rhode Island. The report was based on information obtained through records search, interviews and visual inspections of the property. The environmental condition summary indicated that asbestos-containing materials were identified as pipe insulation in the basement and plaster wall treatment in the walls of Building 1, and lead-based paint used on Building 51. Soil analysis indicated that lead levels were below regulatory action levels (400 mg/kg). One underground, double-wall storage tank used to store heating oil was removed from site. The report classified the site as 7/GRAY meaning that additional investigation would be necessary due to tetrachloroethene exceedances.

In 2009, Orange County published the “2008 Water Quality Summary Report” which has basic information about Lake Gem Mary and historical information of various lakes across Orange County.

Various environmental investigations were conducted and reports prepared presenting the results of investigations and remediation activities conducted. The primary contaminant found at the site was tetrachloroethene (PCE) in groundwater on the south side of the NRF near Gatlin Avenue. In January 1999, a pilot-scale Air Sparging / Soil Vapor Extraction (AS/SVE) system was installed at the site to reduce the concentrations of PCE below regulatory action levels. In February 2000,

the AS/SVE system was shut off because PCE levels were reduced significantly after one year of operation. Subsequent monitoring showed an increase in PCE levels and the AS/SVE system was operated from January 2003 to July 2003. The AS/SVE was operated from February 2004 to April 2004 and again from December 2004 to January 2006. Subsequent quarterly sampling events showed PCE concentrations below regulatory action levels. In September 2007, a Final Groundwater Summary Report was submitted to the FDEP who recommend No Further Action.

1.4. WORK EFFORTS PERFORMED

Work efforts were initiated on this project by CPWG in September of 2015. The primary objective of this project was to quantify pollutant loadings to Lake Gem Mary and identify areas or opportunities where nutrient load reductions could be achieved to improve water quality within the lake. A field monitoring program was conducted by CPWG, Team, and ERD from October 2015-September 2016 to collect hydrologic and water quality data for use in developing hydrologic and nutrient budgets for the lake. The hydrologic budget includes estimated inputs from precipitation, stormwater runoff, and groundwater seepage. The nutrient budget includes inputs from bulk precipitation, stormwater runoff, groundwater seepage, and internal recycling. A detailed evaluation of sediment characteristics in Lake Gem Mary was also conducted which included physical and chemical characterization of surficial sediments and evaluation of internal phosphate recycling. Specific nutrient load reduction projects were evaluated and recommended to maximize load reductions to the lake and improve water quality. The work efforts described in this report were managed by Orange County Environmental Protection Division (OCEPD).

This report has been divided into six separate sections for presentation of the work efforts performed by CPWG. Section 1 contains an introduction to the report and provides a general overview of the work efforts performed. Current characteristics of Lake Gem Mary are discussed in Section 2, including lake bathymetry, sediment accumulation and characteristics, and water quality. A discussion of the drainage basin area is presented in Section 3, including the land uses and soil types. The hydrologic budget is presented in Section 4, as well as the field measured discharge rates and volumes. A nutrient budget, which includes inputs from total nitrogen (TN), total phosphate (TP), and total suspended solids (TSS), is presented in Section 5. Alternatives for management of water quality in Lake Gem Mary are discussed in Section 6. Appendices are also

attached which contain technical data and analyses used to support the information contained within the report.

2. LAKE GEM MARY'S PHYSICAL AND CHEMICAL CHARACTERISTICS

The physical and chemical characteristics of Lake Gem Mary discussed in this section include bathymetry, sediment characterization, and a discussion of historical and current water quality characteristics.

2.1. PHYSICAL CHARACTERISTICS

The Lake Gem Mary surface area is approximately 14 acres. An aerial view of Lake Gem Mary and the surrounding area is shown in Figure 2-1. Residential homes with yards directly connected to the lake are located along the north and east shore. Gatlin Avenue runs along the south shore separated from the lake by a vegetated strip. Commercial buildings with paved parking are located along the west shore. These buildings were initially owned by the US Navy and sold to Orange County through quitclaim deed in 2010.

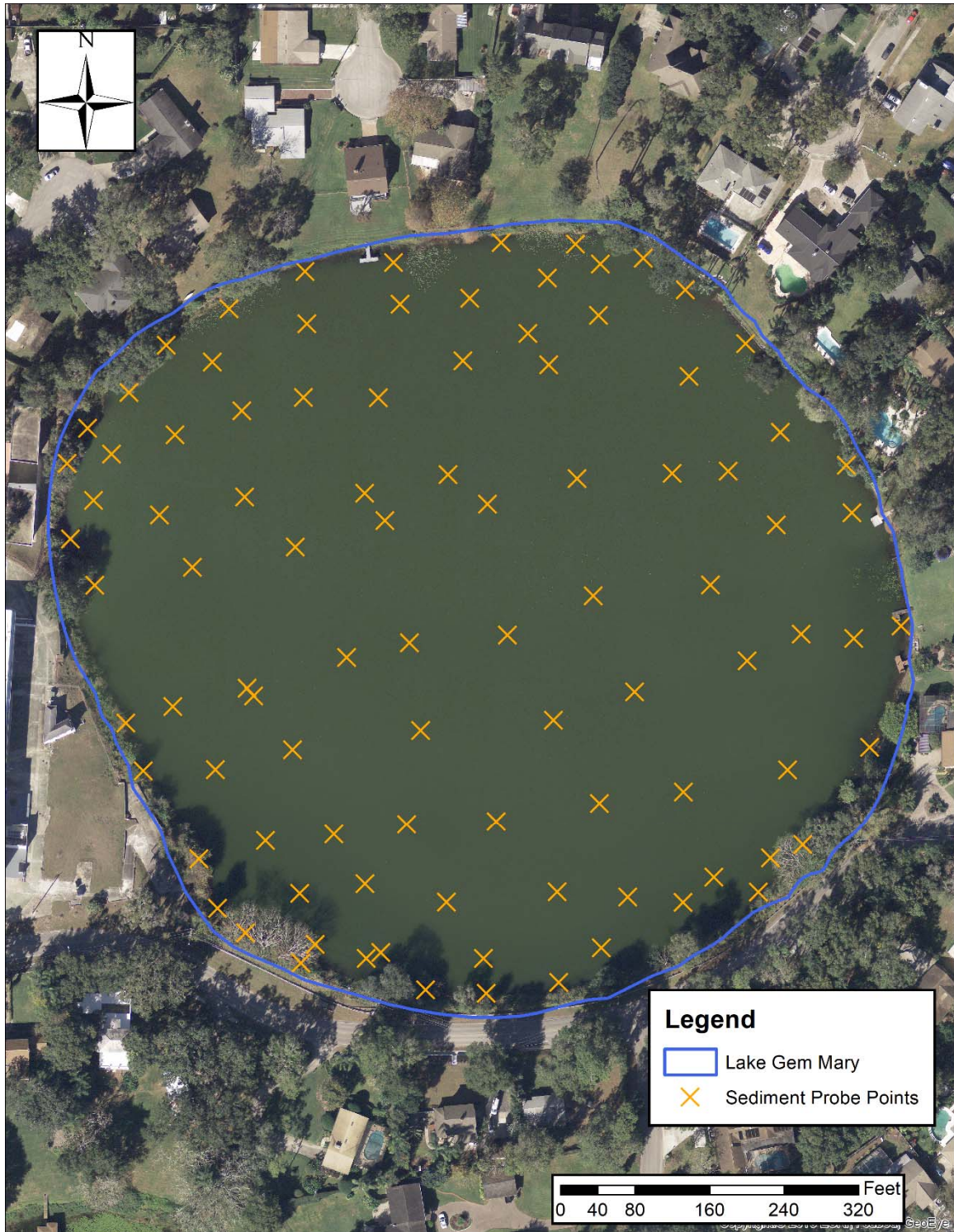
Surface water flow into Lake Gem Mary includes direct rainfall on the lake, direct stormwater runoff from adjacent properties, including City of Orlando streets and the parking areas for the historical US Navy property. Overflow from Lake Gem Mary discharges through a control structure on the south side of the lake and into Lake Gatlin.

A bathymetric survey of Lake Gem Mary was performed on September 24, 29, and 30, 2015 to evaluate the water column depth as well as thickness of unconsolidated sediments within the lake. Additional probing was performed on July 28, 2016 to evaluate the total thickness of the sediments within the lake. Measurements of water depth and sediment thickness were conducted at 95 individual sites in the lake during 2015 and at 21 individual sites in the lake during 2016, as shown in Figure 2-2. The northing and easting coordinates of each depth measurement site was identified using a portable GPS device (TopCon GRS-1). A staff gauge was installed in Lake Gem Mary at the time of the bathymetric survey and the reading on the staff gauge was compared to an existing survey point that Orange County established on a stormwater runoff flume on the south side of the lake. The surface water elevation of Lake Gem Mary during the bathymetric survey on September 30, 2015 was approximately 89.78 ft., NAVD88.

Figure 2-1: View of Lake Gem Mary and Surrounding Areas



Figure 2-2: Lake Gem Mary Probing Locations



Water depth at each data collection site was determined by lowering a 30-cm diameter stainless steel disk welded to a survey rod with graduated measurement lines until resistance from the sediment layer was encountered. The depth on the graduated line corresponding to the water surface was documented in a dedicated field book and is recorded as the water depth at each site.

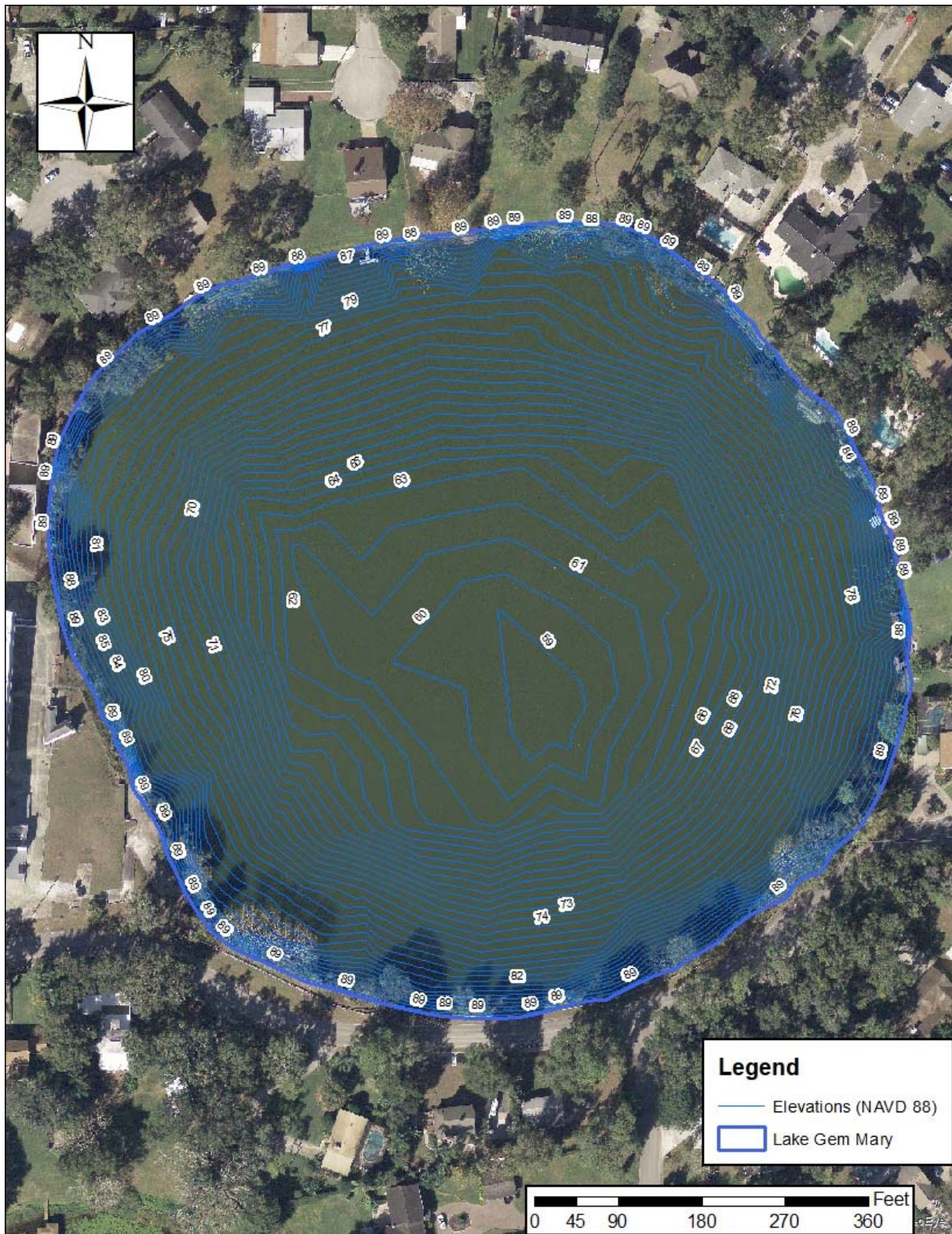
After each measurement of the water depth, a 5-pound weight, tied to non-elastic rope, was lowered into the water column at the same location and allowed to sink through the sediment until reaching a firmer material. The difference between the depth to the firmer material and the water depth at each site is defined as the thickness of unconsolidated organic sediments. Probing rods were used to push through the unconsolidated and consolidated muck until the hard surface of the lake bottom was reached. The difference between the depth to firm bottom material and the water depth at each site is defined as the total depth of sediments. The field data was converted into bathymetric maps illustrating both water depth and sediment depth in Lake Gem Mary using ArcMap 10.4. Estimates of water volume and sediment volume within Lake Gem Mary were generated using ArcMap 10.4.

A water depth contour map for Lake Gem Mary based on the field data collected by CPWG is shown in Figure 2-3. The bottom bathymetry in Lake Gem Mary is conical with fairly steep shoreline slopes. The deepest area within the lake is located in the southeast section of the lake at approximately 33 feet deep at the water elevation reported in September 2015. The bathymetric signature of Lake Gem Mary indicated on Figure 2-3 suggests that the lake originated as a result of one sinkhole feature.

Water elevations in Lake Gem Mary are regulated by an overflow weir constructed on the outfall structure to Lake Gatlin. The elevation of the overflow weir is calculated to be 90.0 feet, NAVD88, based on the survey datum from the nearby flume.

Stage-area-volume relationships for Lake Gem Mary are summarized in Table and are based upon the bathymetric survey performed by CPWG. The lake surface area of 14.1 acres based on a surface water elevation of 89.78 feet measured on September 30, 2015. The lake volume at this surface area is 252 ac-ft which corresponds to a mean water depth of approximately 17.9 feet. A summary of bathymetric characteristics of Lake Gem Mary is presented in Table 2-1.

Figure 2-3: Water Bathymetry Contours (Based on September 30, 2015 Field Investigation)



**Table 2-1: Depth-Area-Volume Relationship for Lake Gem Mary
(Elev. 89.78 NAVD88)**

Depth (ft)	EL (NAVD 88)	Area (ac)	Incremental Volume (ac-ft)	Cumulative Volume (ac-ft)
0-1	90-89	14.1	14	252
1-2	89-88	13.9	14	238
2-3	88-87	13.7	14	224
3-4	87-86	13.4	13	211
4-5	86-85	13.1	13	198
5-6	85-84	12.9	13	185
6-7	84-83	12.6	12	172
7-8	83-82	12.3	12	159
8-9	82-81	11.9	12	147
9-10	81-80	11.5	11	136
10-11	80-79	11.1	11	124
11-12	79-78	10.6	10	114
12-13	78-77	10.0	10	103
13-14	77-76	9.4	9	94
14-15	76-75	8.9	9	84
15-16	75-74	8.3	8	76
16-17	74-73	7.8	8	68
17-18	73-72	7.4	7	60
18-19	72-71	6.9	7	53
19-20	71-70	6.5	6	46
20-21	70-69	6.1	6	40
21-22	69-68	5.7	6	34
22-23	68-67	5.4	5	28
23-24	67-66	5.0	5	23
24-25	66-65	4.6	4	18
25-26	65-64	4.2	4	14
26-27	64-63	3.8	3	10
27-28	63-62	3.2	3	7
28-29	62-61	2.4	2	4
29-30	61-60	1.6	1	2
30-31	60-59	0.8	0	1
31-32	59-58	0.2	0	0
32	58	0.0	0	0

Table 2-1: Bathymetric Characteristics of Lake Gem Mary

Bathymetric Parameter¹	Value
Surface Area	14.1 acres
Total Volume	252 ac-ft
Mean Depth	17.9 ft
Maximum Depth	32 ft
Shoreline Length	2,828 ft
Shoreline Development	2,780 ft

¹ Based upon a water surface elevation of 89.78 ft. (NAVD88)

The shoreline length (i.e.-lake perimeter) is presented in Table 2-1 and is used to calculate the shoreline development index, a measure of the regularity of a lake's shoreline. The shoreline development index is a ratio of a lake's actual perimeter to the perimeter of a lake with the same area that is a perfect circle. Lakes which exhibit a high degree of shoreline irregularity provide a higher degree of aquatic organism habitat and often display a higher degree of diversity in the aquatic community. Shoreline development indices of 2 or more are often considered to provide a high degree of habitat. The shoreline development index for Lake Gem Mary is 1.0, indicating a regular shoreline area and a low degree of habitat, as the lake has a nearly circular shoreline.

A bathymetric contour map depicting the depth of unconsolidated organic sediments from the 2015 muck depth probes is shown on Figure 2-4. A bathymetric contour map depicting the total depth of organic sediments (unconsolidated and consolidated) in Lake Gem Mary is shown on Figure 2-5. Accumulation of organic muck primarily occurs in the lower elevations within the interior of the lake. Muck depths range from 0.5 feet along the perimeter of the lake to approximately 11.0 feet in the deeper section of the lake. The accumulated organic muck appears to be comprised primarily of dead algal cells and other partially decomposed vegetation, including grass clippings, as well as solids which have entered the lake from the surrounding drainage basin. It appears that most of the sediments slough to the deepest portion of the lake, probably due to the steepness of the shoreline slopes.

Figure 2-4: Unconsolidated Sediment Thickness Contours (feet) in Lake Gem Mary during September 2015

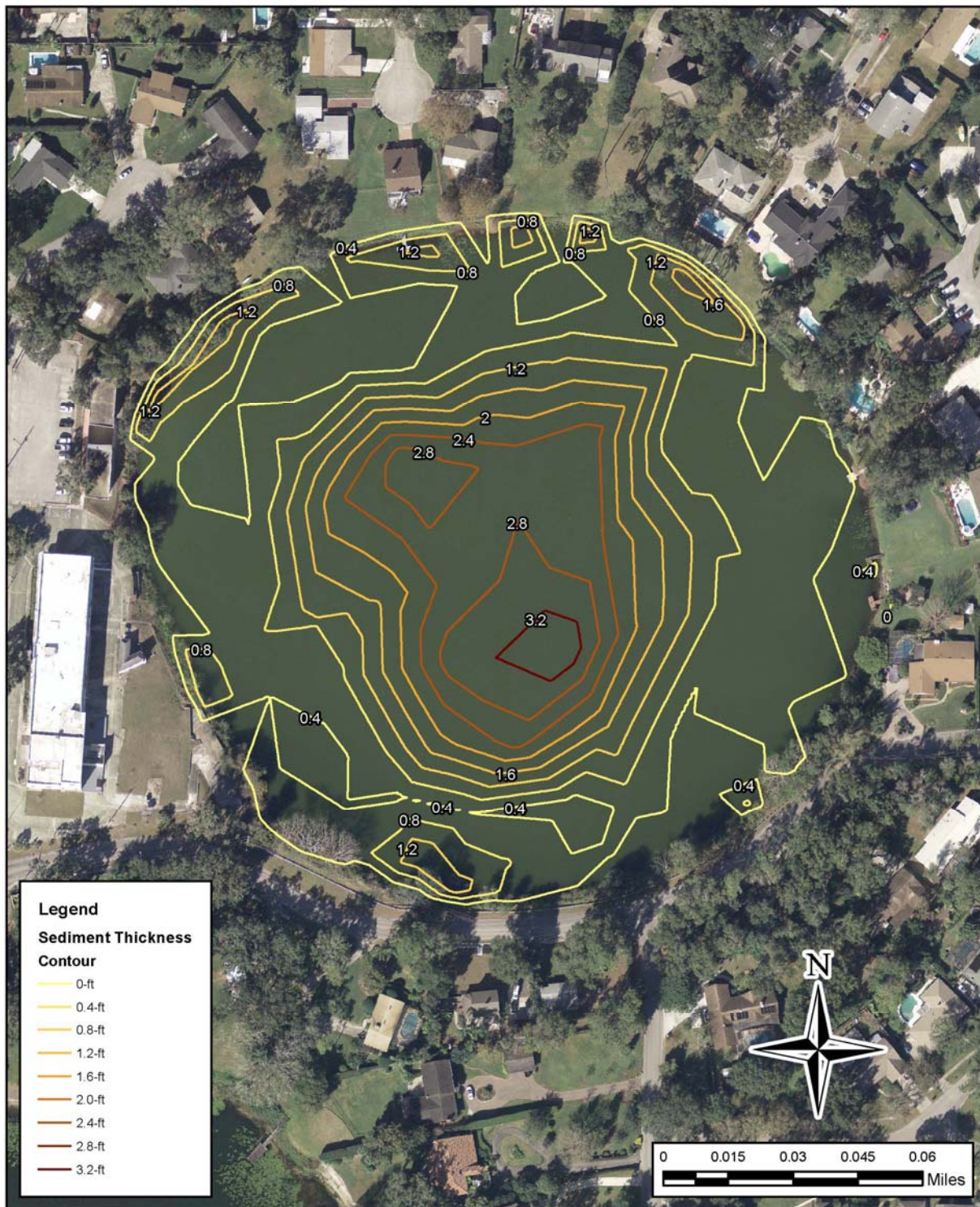
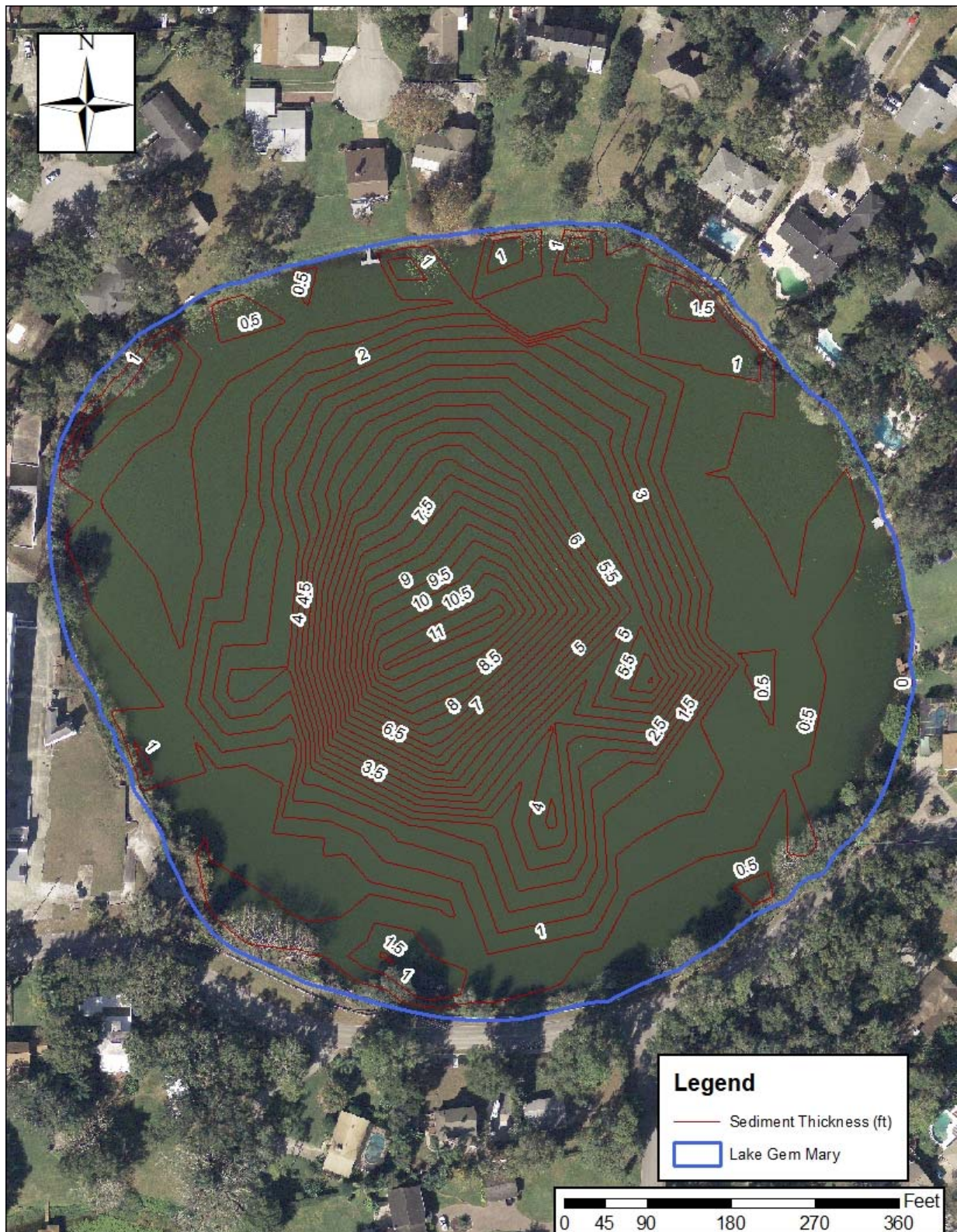


Figure 2-5: Total Sediment Thickness Contours (feet) in Lake Gem Mary during September 2015 and July 2016



Estimates of area-volume relationships for organic muck accumulation in the lake are presented in Table 2-2. Approximately 7.1 acres (50%) of the lake area around the shoreline have less than 1.0 feet of existing muck accumulation on the lake bottom. The majority of the muck accumulation ranges from 1.0 to 11.0 feet in depth and is located in the interior of the lake. Overall, Lake Gem Mary contains approximately 32 ac-ft (1,393,920 ft³) of organic sediments.

Table 2-2: Depth-Area-Volume Relationship for Organic Muck in Lake Gem Mary

Muck Depth (ft)	Area (ac)	Incremental Volume (ac-ft)	Cumulative Volume (ac-ft)
0-1	14.1	11	32
1-2	7.0	6	21
2-3	4.9	4	15
3-4	3.7	3	11
4-5	2.9	2	8
5-6	2.1	2	5
6-7	1.6	1	3
7-8	1.1	1	2
8-9	0.8	1	1
9-10	0.5	0	0
10-11	0.2	0	0
11+	0.0	0	0

2.2. SEDIMENT CHARACTERISTICS

Sediment core samples were collected from 6 sites across Lake Gem Mary on July 28, 2016. Based on the lake surface area of 14 acres, sediment samples were collected at a rate of one sample for every 2.33 acres of lake area. Locations of sediment sampling sites are illustrated in Figure 2-6.

2.2.1. SAMPLING TECHNIQUES

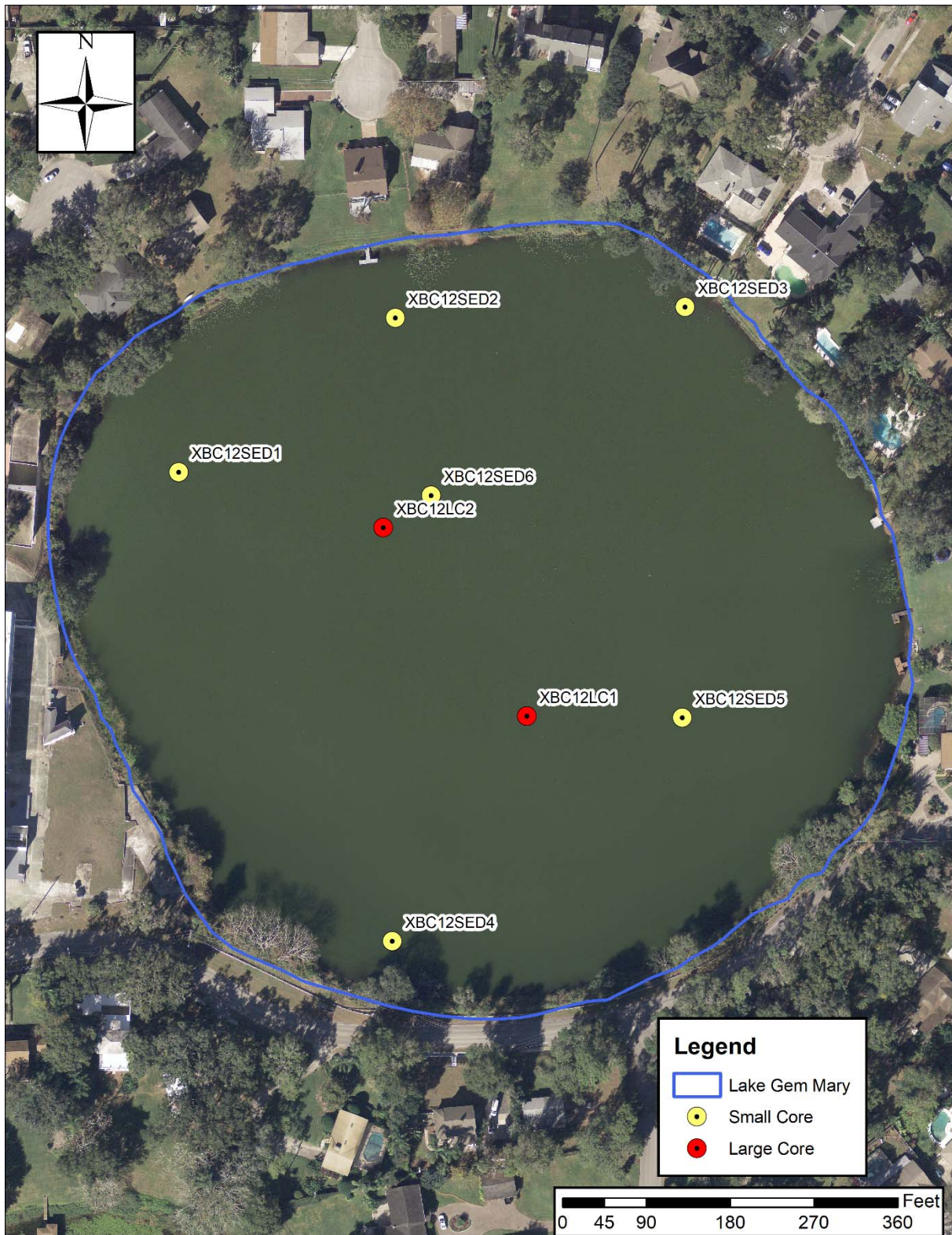
Sediment samples were collected at each of the 6 monitoring sites using a stainless steel split-spoon core device, which was pushed into the sediments at each location to a distance of approximately 15 to 20 cm. After retrieval of the sediment sample, any overlying water was decanted before the split-spoon device was opened to expose the collected sediment. Visual characteristics of each sediment core sample were recorded in a dedicated field book. The top 0-10 cm layer was sectioned off and placed into a polyethylene container for transport to the ERD laboratory for analysis. The polyethylene containers used 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 transported to the laboratory within 24 hours of collection for physical and chemical characterization.

2.2.2. SEDIMENT CHARACTERIZATION AND SPECIATION TECHNIQUES

Each of the 6 sediment core samples was analyzed for a variety of general parameters, including moisture content, organic content, sediment density, total nitrogen, and total phosphate. Methodologies used for preparation and analysis of the sediment samples for these parameters are outlined in Table 2-3.

In addition to general sediment characterization, a fractionation procedure for inorganic soil phosphate was conducted on the 6 collected sediment samples. The modified Chang and Jackson Procedure, as proposed by Peterson and Corey (1966), was used for phosphate fractionation. The Chang and Jackson Procedure allows the speciation of sediment phosphates into saloid-bound phosphates (defined as the sum of soluble plus easily exchangeable sediment phosphates), iron-bound phosphates, and aluminum-bound phosphates.

Figure 2-6: Lake Gem Mary Sediment Sample Sites



Saloid-bound phosphate is considered to be available under all conditions at all times. Iron-bound phosphates is relatively stable under aerobic environments, generally characterized by redox potentials greater than 200 millivolts (mV), Eh, while unstable under anoxic conditions, characterized by redox potential less than 200 mV. Aluminum-bound phosphates are considered to be stable under all redox potentials and natural pH conditions. A schematic of the Chang and Jackson Speciation Procedure for evaluating soil phosphates bounding is presented in Figure 2-7.

For purposes of estimating nutrient loads from sediment release, the potentially available inorganic phosphates in soils/sediments is represented by the sum of the soluble inorganic phosphates and easily exchangeable phosphate fractions (collectively termed saloid-bound phosphate), plus iron-bound phosphate which can become solubilized under reducing conditions. Aluminum-bound phosphate is generally considered to be unavailable in the pH range of approximately 5.5-7.5 under a wide range of redox conditions.

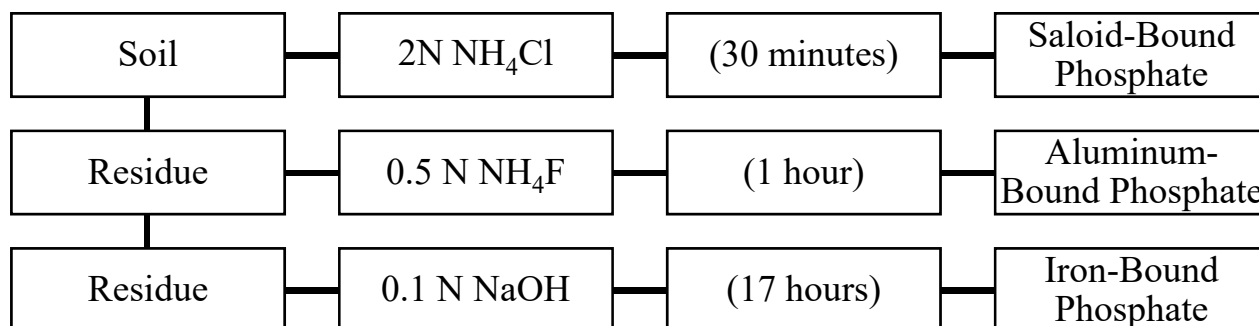
Table 2-3: Analytical Methods for Sediment Analyses

Measurement Parameter	Sample Preparation	Analysis Reference	Reference Prep/Anal *	Method Detection Limits (MDLs)
pH	EPA 9045	EPA 9045	3 / 3	0.01 pH units
Moisture Content	p. 3-54	p. 3-58	1 / 1	0.1%
Organic Content (Volatile Solids)	p. 3-52	pp. 3-52 to 3-53	1 / 1	0.1%
Total Phosphate	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.

Figure 2-7: Schematic of Chang and Jackson Speciation Procedure for Soil Phosphate Bonding



2.2.3. VISUAL CHARACTERISTICS

Visual characteristics of sediment core samples were recorded for each of the 6 sediment samples collected during July 2016. A summary of visual characteristics of the sediment core samples is presented in Table 2-4. In general, four sediment samples were collected near the perimeter of the lake in the shallow portion near existing stormwater outfalls. Two sediment samples were collected in the deeper portion of the lake. A surficial layer of sand with undecomposed organic matter was observed in three of the four shallow sites and muck in the surficial layer of the fourth shallow site. Muck was observed in two deeper sites. Loose to watery muck was observed in the surficial layer of the deeper sites with more consolidated muck beneath the surface layer, almost with a consistency similar to pudding. These layers, which reflect older organic deposits that are resistant to further degradation, are referred to as consolidated organic muck and typically do not re-suspend into the water column except during relatively vigorous wind or boating activity on the lake. Shallow shoreline areas of the lake are characterized by various types of brown fine to medium-coarse sand which appears to be the parent soil layer forming the original lake bottom. Photographs of some of the sediment characteristics are presented in Figure 2-8.

2.2.4. GENERAL CHARACTERISTICS

ERD Laboratory was used to analyze the collected sediment core samples for general sediment characteristics including pH, moisture content, organic content, sediment density, total nitrogen, and total phosphate. A summary of general characteristics measured in each of the 6 collected sediment core samples is presented in Table 2-5. Laboratory reports are provided in Appendix A. Isopleths were developed for the general sediment characteristics using the measurement results

shown in Table 2-5 to evaluate patterns occurring within Lake Gem Mary. The isopleths and descriptions are presented below.

Table 2-4: Visual Characteristics of Lake Gem Mary Sediment Cores collected July 28, 2016

Site Number	Depth of Collection below Surface (feet)	Layer (cm)	Visual Description of Sediment
XBC12SED1	13.4	0 – 10	Medium brown fine sand
		10 - 17	Medium brown fine sand with dark brown mottling
		17 – 30	Dark brown, medium coarse sand with some muck
XBC12SED2	11.3	0 – 18	Medium dark brown muck w/organic matter
		18 – 30	Medium brown fine sand
XBC12SED3	5.2	0 – 8	Organic matter – green grass evident
		8 - 13	Medium dark brown fine sand
		13 – 15	Light brown fine sand
XBC12SED4	12.5	0 – 8	Medium brown muck - loose
		8 – 11	Medium brown muck – consolidated
		11 - 18	Medium dark brown sandy muck
		18 – 23	Medium brown medium-coarse sand w/dark brown mottling
XBC12SED5	27.4	0 – 13	Dark brown muck – loose
		13 – 19	Dark brown sandy muck - consolidated
		19 – 28	Dark brown sandy muck w/ dark brown mottling
XBC12SED6	30.0	0 – 8	Very dark brown muck – loose & watery
		8 – 13	Very dark brown muck – gelatinous
		13 – 23	Very dark brown muck – consolidated
		23 - 30	Dark brown medium coarse sand

Figure 2-8: Photographs of Lake Gem Mary Sediment Samples



Sandy Sediments w/Some Mottling
XBC12SED1



Sandy Sediments w/Organic Matter
SBC12SED3



Brown Sandy Muck
XBC12SED4



Muck – Loose & Consolidated
XBC12SED6

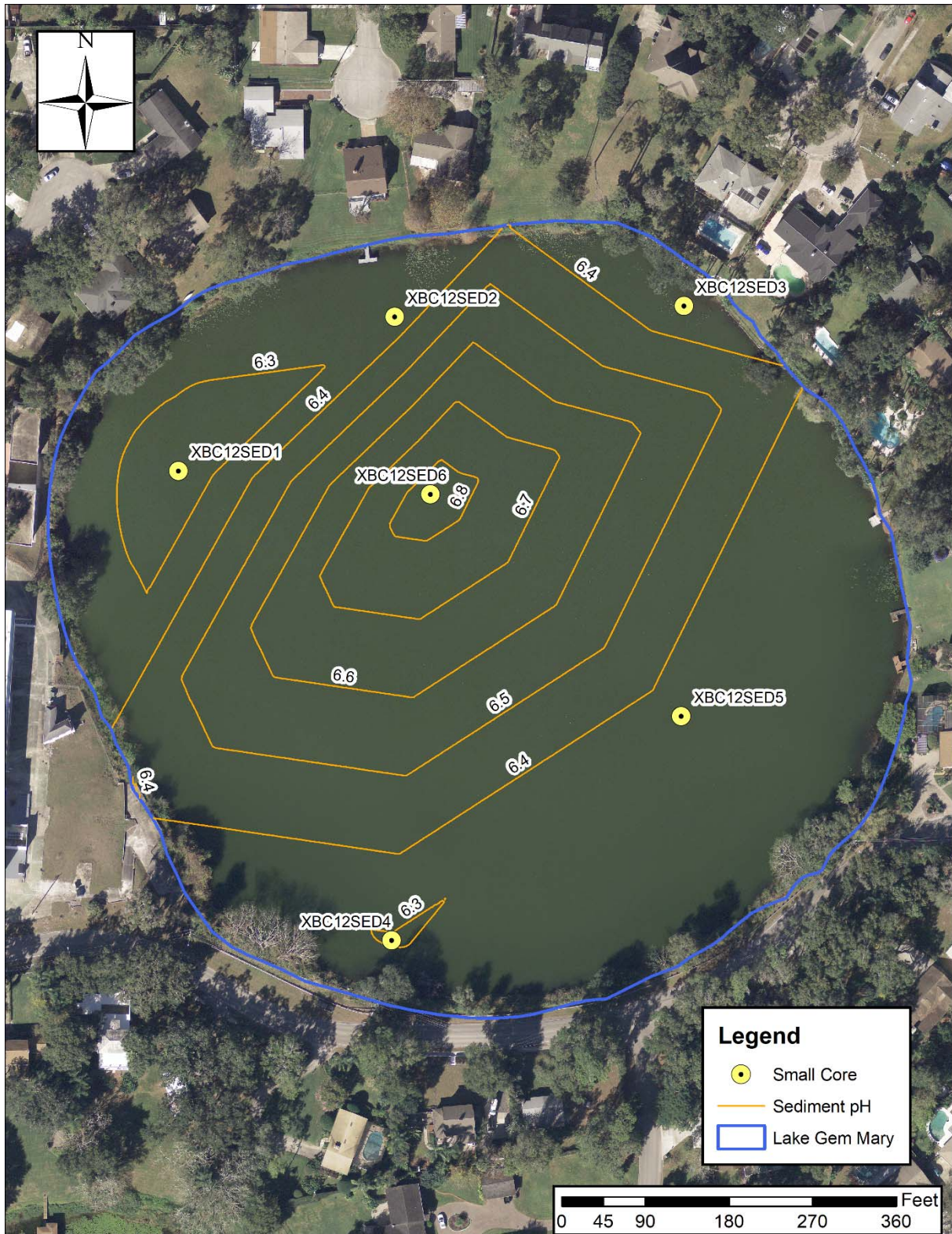
Table 2-5: General Characteristics of Sediment Core Samples from Lake Gem Mary

Site	Date	pH (s.u.)	Moisture Content (%)	Organic Content ¹ (%)	Wet Density (g/cm ³)	Total Nitrogen (µg/cm ³)	Total Phosphate (µg/cm ³)
XBC12SED1	7/28/16	6.2	26.2	2.4	2.1	6,599	1,130
XBC12SED2	7/28/16	6.3	39.2	2.5	1.9	13,795	2,932
XBC12SED3	7/28/16	6.3	46.5	11.0	1.7	13,417	6,048
XBC12SED4	7/28/16	6.3	44.2	6.6	1.8	13,200	2,335
XBC12SED5	7/28/16	6.3	77.8	15.0	1.3	11,640	7,082
XBC12SED6	7/28/16	6.9	91.4	36.6	1.1	9,056	8,179
Minimum		6.2	26.2	2.4	1.1	6,599	1,130
Geomean		6.4	45.4	7.9	1.6	10,924	3,734
Maximum		6.9	91.4	36.6	2.1	13,795	8,179

Note 1. Dry wt. basis

The sediments in Lake Gem Mary were found to be slightly acidic in pH, with measured pH values ranging from 6.2 to 6.9 and a geometric mean value of 6.4. Isopleths of pH in the top 10 cm of sediments in Lake Gem Mary are illustrated in Figure 2-9. The highest pH value was observed in one of the deeper sites within the interior of the lake.

Figure 2-9: Isopleth of pH (s.u.) in the Top 10 cm of Sediments



Measurements of sediment moisture content and organic content in Lake Gem Mary were variable throughout the lake; however, the isopleths of these two measurements were very similar in their overall pattern. Isopleths of sediment moisture content in Lake Gem Mary are illustrated in Figure 2-10. Sediment moisture content in excess of 50% are often indicative of highly organic sediments, while moisture contents less than 50% reflect mixtures of sand and muck. Areas of elevated moisture content are depicted in the two samples collected from the deeper areas within the interior of the lake where the majority of muck was observed. The measured sediment moisture content within Lake Gem Mary ranges from 26.2% to 91.4%, with an overall geometric mean value of 45.4%.

Isopleths of sediment organic content (dry wt. basis) in Lake Gem Mary are illustrated in Figure 2-11. Sediment organic content percentages in excess of 20% to 30% are generally indicative of organic muck-type sediments. Values less than this range typically represent sand or a mixture of sand with muck. The percent sediment organic content in the four shallow samples ranged from 2.4% to 11.0%, indicating sandy soils with little muck. The highest percentage of organic content in the Lake Gem Mary sediments was found in the two samples collected from the deeper sites within the interior of the lake. The measured sediment organic content within Lake Gem Mary ranges from 2.4% to 36.6%, with an overall geometric mean value of 7.9%.

Measured sediment density values are useful in evaluating the presence of muck in sediments within a lake. Isopleths of wet density in Lake Gem Mary sediments are presented in Figure 2-12. Sediments with calculated wet densities from 1.0 g/cm³ to 1.25 g/cm³ generally indicate organic muck type sediments, 1.25 g/cm³ to 2.0 g/cm³ indicate a sand/muck mixture and greater than 2.0 g/cm³ indicate sandy sediment conditions. The sediment density values measured in Lake Gem Mary sediments range from 1.1 g/cm³ to 2.1 g/cm³, with a geometric mean value of 1.6 g/cm³. The areas of low density measurements occurred in the two sites collected from the deeper areas of the lake. Sediments characterized by high densities are indicative of sandy sediments which are located in the shallow areas along the shoreline of the lake.

Figure 2-10: Isopleths of Moisture Content (%) in the Top 10 cm of Sediments

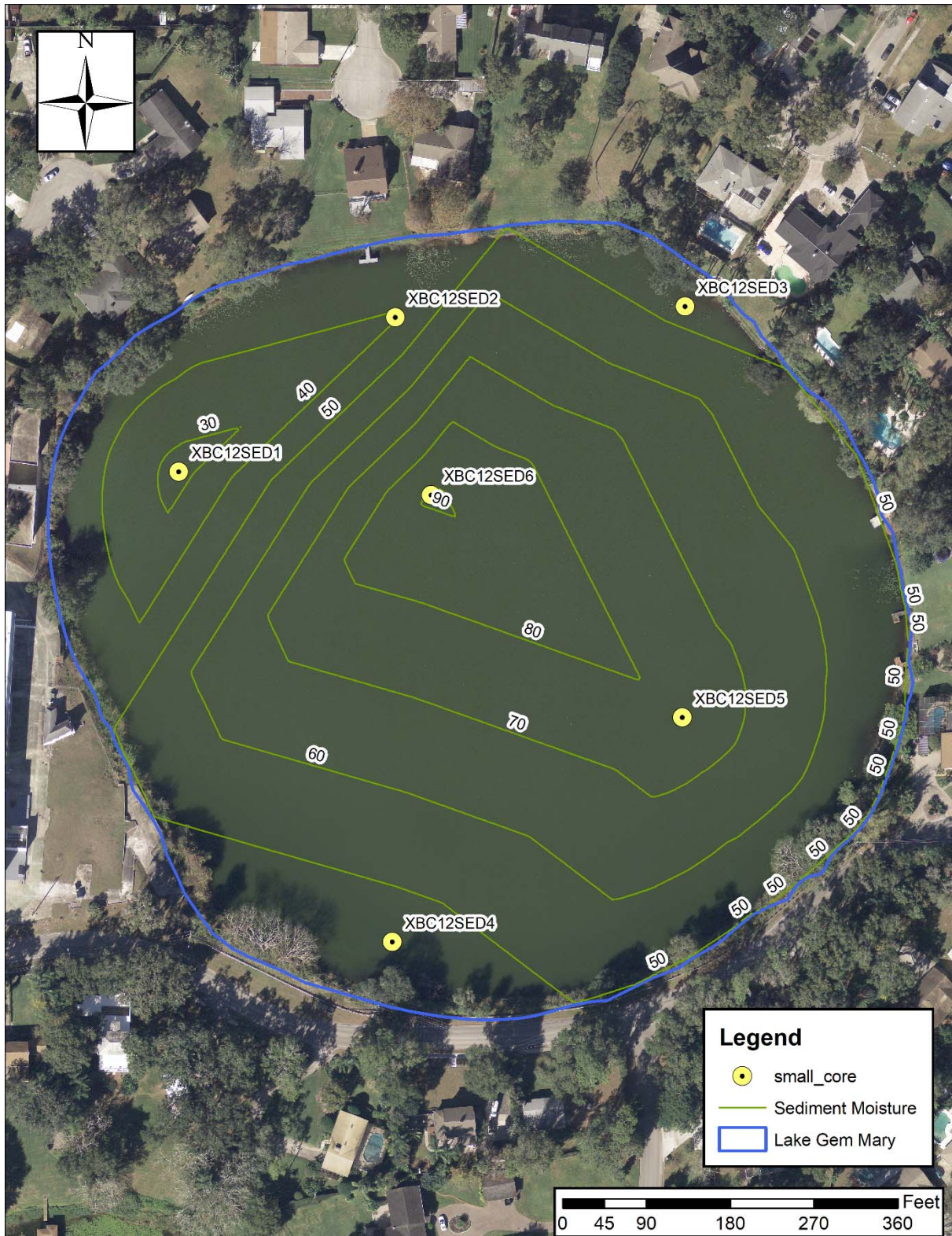


Figure 2-11: Isopleths of Organic Content (% dry wt.) in the Top 10 cm of Sediments

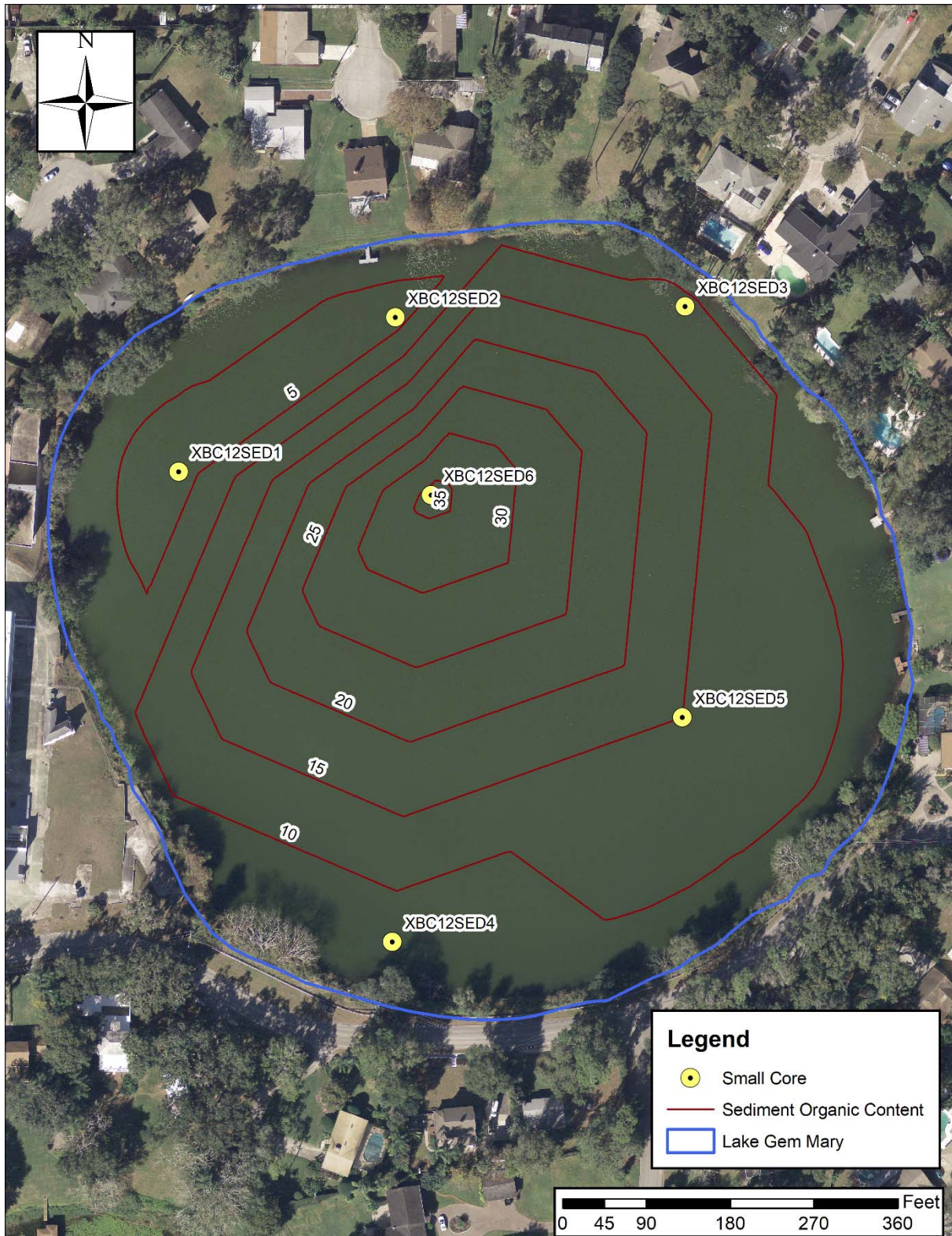
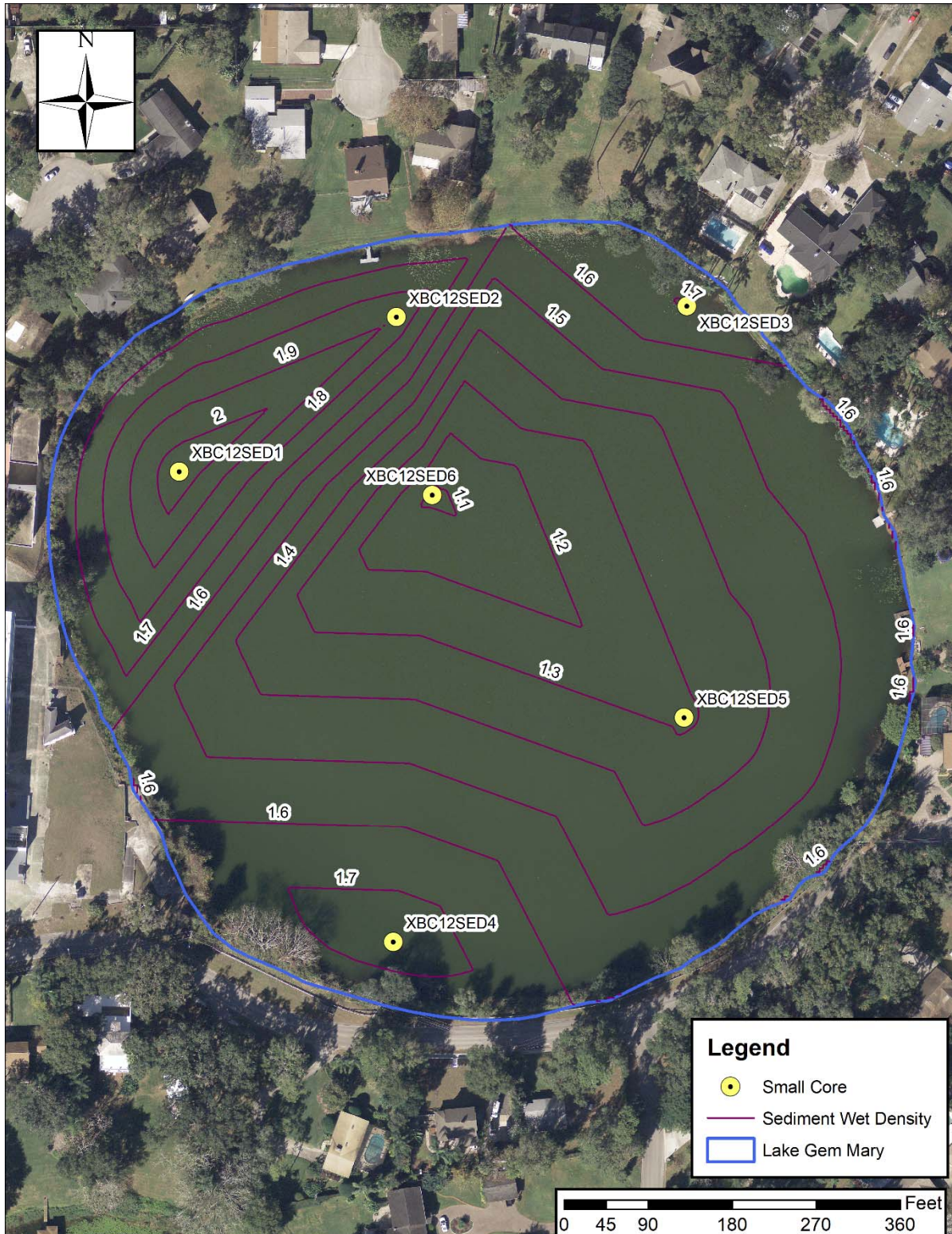


Figure 2-12: Isopleths of Wet Density (g/cm^3) in the Top 10 cm of Sediments



Analytical results for the collected sediment samples are summarized in Table 2-6. Total phosphate (TP) concentrations measured in the Lake Gem Mary sediment samples ranged from 1,130 $\mu\text{g}/\text{cm}^3$ to 8,179 $\mu\text{g}/\text{cm}^3$ with a geometric mean value of 3,734 $\mu\text{g}/\text{cm}^3$. In general, sandy sediments are often characterized by low TP concentrations, while highly organic muck type sediments are characterized by elevated TP concentrations. Isopleths of sediment phosphate concentrations in Lake Gem Mary are presented on Figure 2-13. The areas with the highest TP concentrations were observed in the two deeper sites within the interior of the lake. One of the sample sites near the east shoreline also had a high level of TP concentrations.

Total nitrogen (TN) concentrations measured in the lake sediment samples ranged from 6,599 $\mu\text{g}/\text{cm}^3$ to 13,795 $\mu\text{g}/\text{cm}^3$, with a geometric mean value of 10,924 $\mu\text{g}/\text{cm}^3$. Isopleths of sediment nitrogen concentrations in Lake Gem Mary are illustrated in Figure 2-14. In general, areas of observed elevated nitrogen concentrations were observed in three of the shallow sites along the shoreline and one of the deeper sites within the interior of the lake.

Figure 2-13: Isopleths of Total Phosphates ($\mu\text{g}/\text{cm}^3$) in the Top 10 cm of Sediments

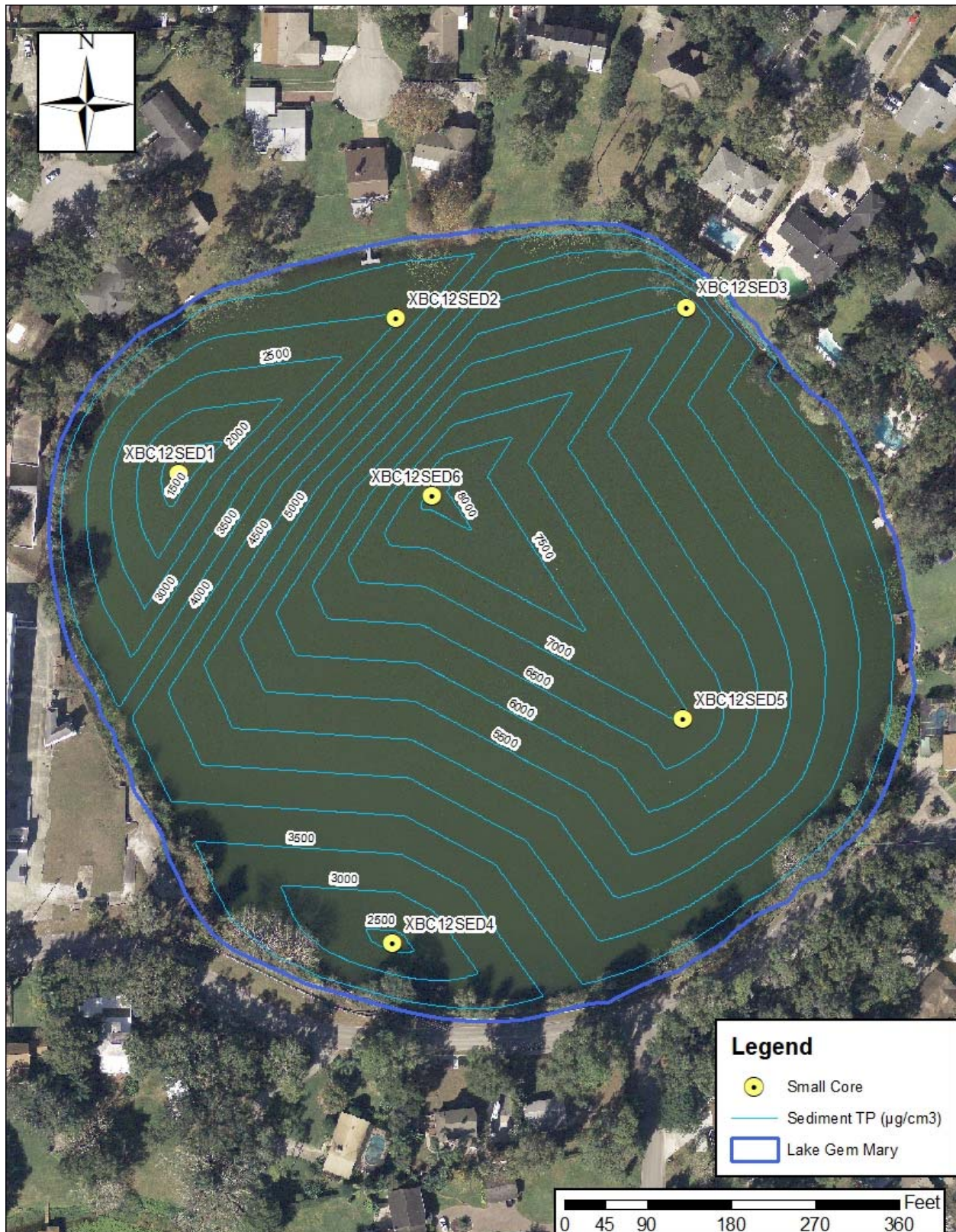
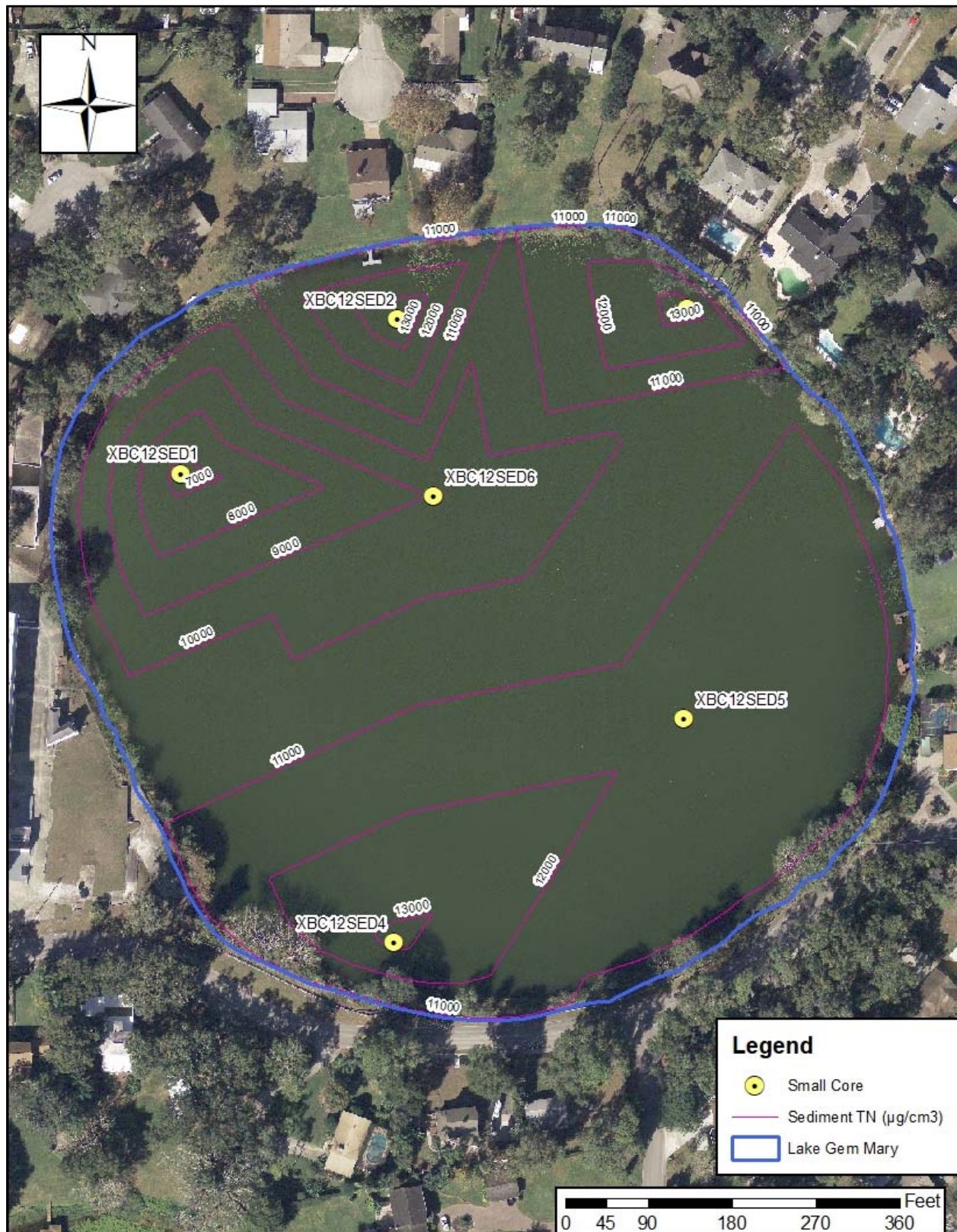


Figure 2-14: Isopleths of Total Nitrogen ($\mu\text{g}/\text{cm}^3$) in the Top 10 cm of Sediments



2.2.5. PHOSPHATE SPECIATION

As previously discussed, each of the sediment core samples were evaluated for phosphate speciation based upon the Chang and Jackson Procedure. The results of this analysis are used to estimate potential phosphate nutrient loading resulting from phosphate dissociation under aerobic and anaerobic conditions.

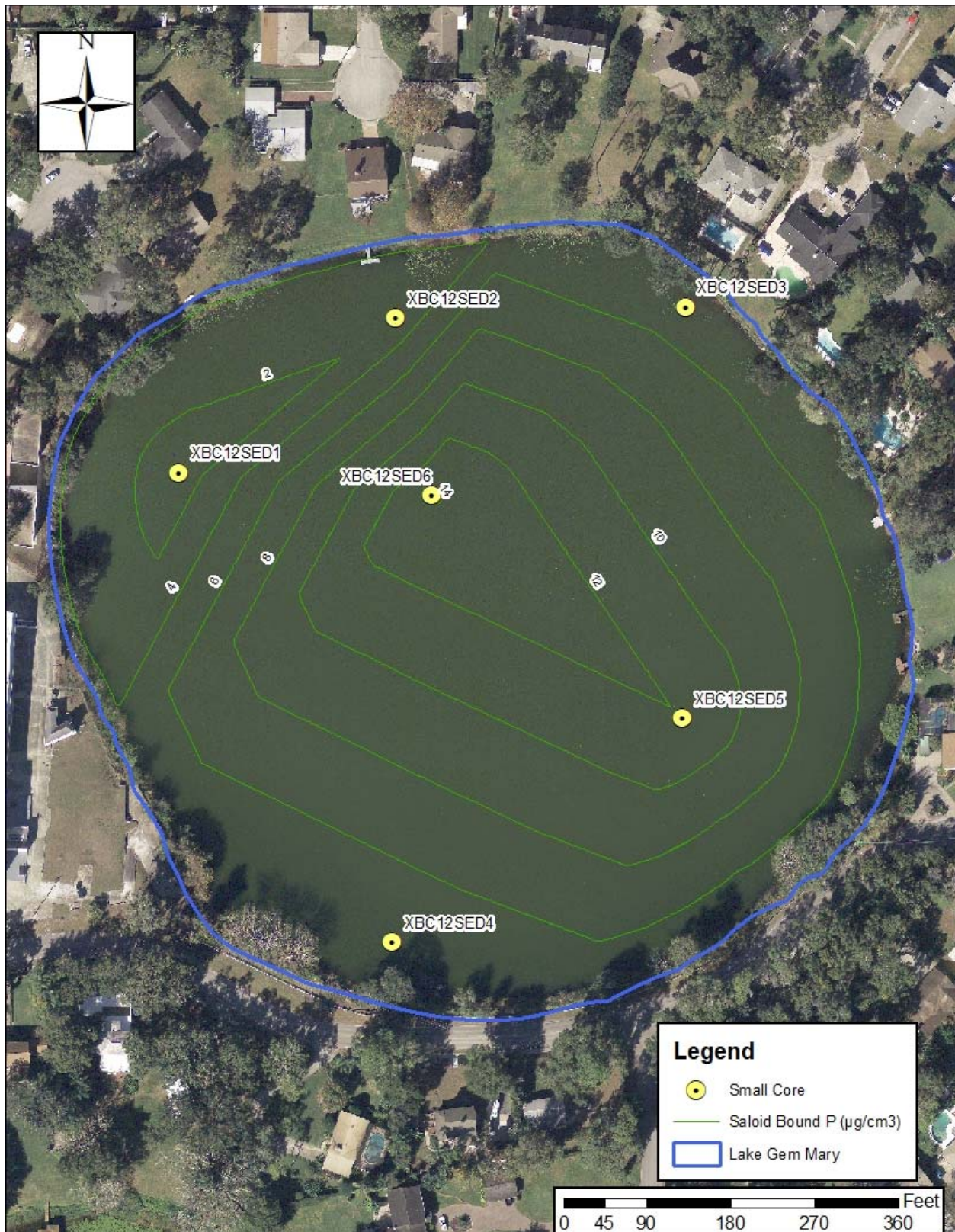
A summary of phosphate speciation in sediment core samples collected from Lake Gem Mary during July 2016 is presented in Table 2-6.

Table 2-6: Phosphate Speciation in Sediment Core Samples

Site	Saloid-Bound P ($\mu\text{g}/\text{cm}^3$ wet wt.)	Iron-Bound P ($\mu\text{g}/\text{cm}^3$ wet wt.)	Available P ($\mu\text{g}/\text{cm}^3$ wet wt.)	Percent of Sediment P Available by Weight	Al- Bound P ($\mu\text{g}/\text{cm}^3$ wet wt.)
XBC12SED1	0.8	62	62.8	6%	64
XBC12SED2	2.4	93	95.4	3%	71
XBC12SED3	4.8	58	62.8	1%	30
XBC12SED4	4.2	112	116.2	5%	98
XBC12SED5	11.9	81	92.9	1%	79
XBC12SED6	14.1	54	68.1	1%	65
Minimum	0.8	54	62.8	1%	30
Geomean	4.0	74	80.7	2%	64
Maximum	14.1	112	116.2	6%	98

Saloid-bound phosphate represents a sediment phosphate which is either soluble or easily exchangeable and is typically considered readily available for release from the sediments into the overlying water column. Measured values for saloid-bound sediment phosphate in core samples ranged from $0.8 \mu\text{g}/\text{cm}^3$ to $14.1 \mu\text{g}/\text{cm}^3$, with a geometric mean value of $4.3 \mu\text{g}/\text{cm}^3$. The saloid-bound phosphate concentrations appear to be relatively low in the samples collected near the shoreline while higher concentrations were observed in the sediment samples collected from the deeper sites within the interior of the lake. Isopleths of saloid-bound phosphates in the top 10 cm of sediments in Lake Gem Mary are illustrated in Figure 2-15.

Figure 2-15: Isopleths of Saloid-Bound Phosphates in the Top 10 cm of Sediments



Analytical results indicate that the iron-bound phosphate concentrations in the sediments of Lake Gem Mary appear to be an order of magnitude higher than the saloid-bound phosphate. Iron-bound sediment phosphate is relatively stable under oxidized conditions, but becomes unstable under anoxic (reducing) conditions, causing the iron-phosphate complex to dissociate releasing its phosphate ligands to the overlying water column. Iron-bound phosphate concentrations in the sediments of Lake Gem Mary ranged from 54 to 112 $\mu\text{g}/\text{cm}^3$, with a geometric mean value of 74 $\mu\text{g}/\text{cm}^3$. Since iron-bound phosphate can be released under anoxic conditions, the interior portions of Lake Gem Mary may have conditions favorable for release of iron-bound sediment phosphate into the water column. Isopleths of iron-bound phosphate in the sediments of Lake Gem Mary are illustrated in Figure 2-16. The highest concentration of iron-bound phosphate was observed in two of the shallow sites along the shoreline.

Total available phosphate represents the sum of the saloid-bound phosphate and iron-bound phosphate associations in each sediment core sample. The saloid-bound phosphate is immediately available and the iron-bound phosphate is available under reduced conditions; therefore, the sum of these concentrations represent the total phosphate which is potentially available within the sediments. This information can be used as a guide for future sediment inactivation projects. A summary of total available phosphate in each of the 6 collected sediment core samples is presented in Table 2-7. Total available phosphate concentrations within the lake sediments ranged from 62.8 $\mu\text{g}/\text{cm}^3$ to 116.2 $\mu\text{g}/\text{cm}^3$, with a geometric mean value of 80.7 $\mu\text{g}/\text{cm}^3$. Isopleths of total available phosphate in the top 10 cm of sediments in Lake Gem Mary are illustrated in Figure 2-17. The total available phosphate concentration in the sediments appear to be fairly uniform across the lake.

Available sediment phosphorus can also be expressed as a percentage of TP concentrations within the sediments by weight. The percentage of available phosphate in the sediments of Lake Gem Mary ranges from 1% to 6%, with a geometric mean value of 2%. This suggests that if the top 10 cm of sediments were removed from the entire 14.11 acres of Lake Gem Mary, a total of 461 kg of available phosphate (saloid and iron bound) could be removed based on a geometric mean available phosphate concentration of 80.7 $\mu\text{g}/\text{cm}^3$.

Aluminum-bound phosphates represents an unavailable species of phosphate in the sediments. Phosphate bound to aluminum is typically considered to be tightly bound under a wide range of

pH and redox conditions within lake sediments. Aluminum-bound phosphate concentrations in Lake Gem Mary range from 30 to 98 $\mu\text{g}/\text{cm}^3$, with a geometric mean value of 64 $\mu\text{g}/\text{cm}^3$. The geometric mean aluminum-bound phosphate concentration of 64 $\mu\text{g}/\text{cm}^3$ suggests that approximately 2% of the existing phosphate within the sediment is bound in sediment associations which are considered to be unavailable.

Figure 2-16: Isopleths of Iron-Bound Phosphate in the Top 10 cm of Sediments

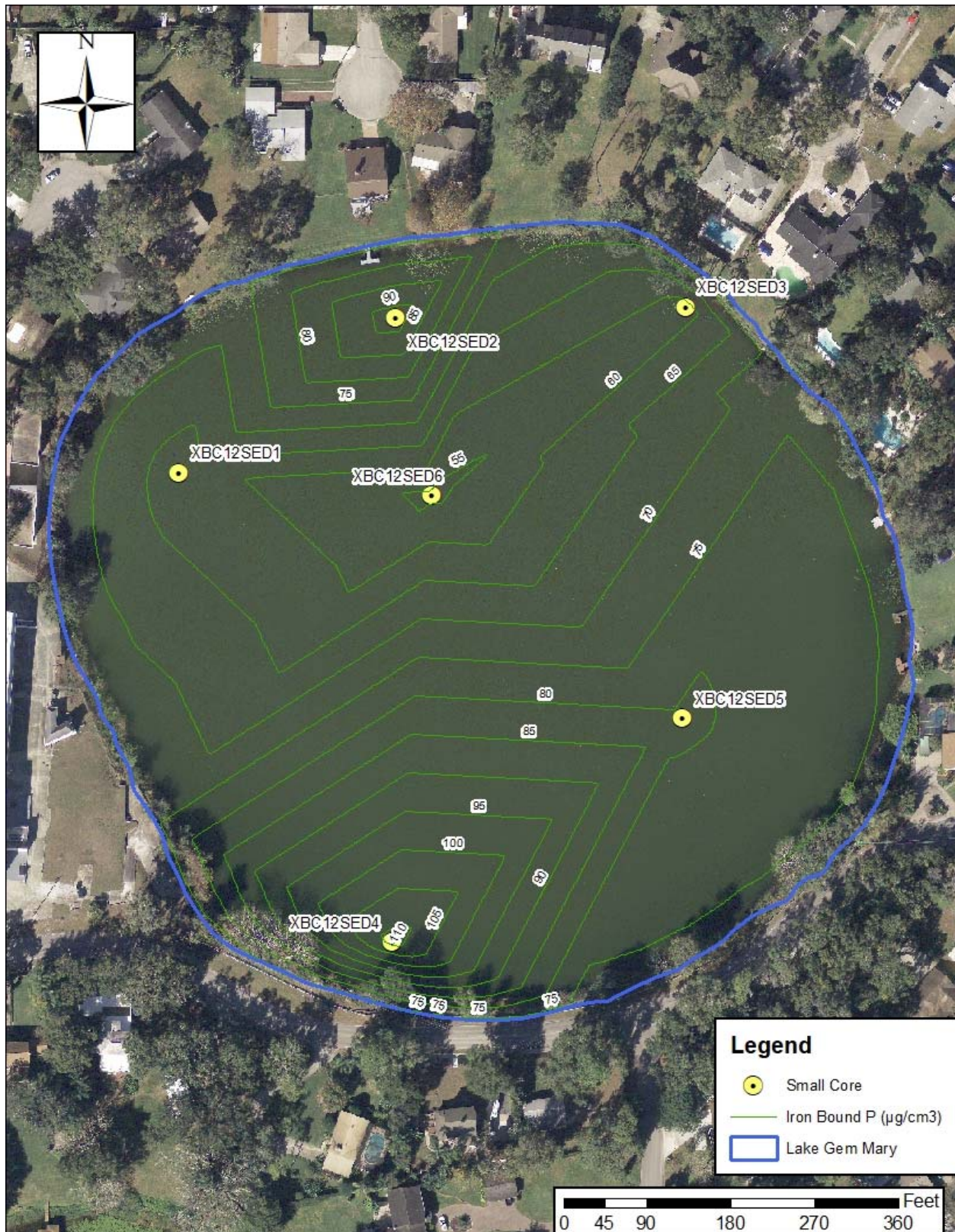
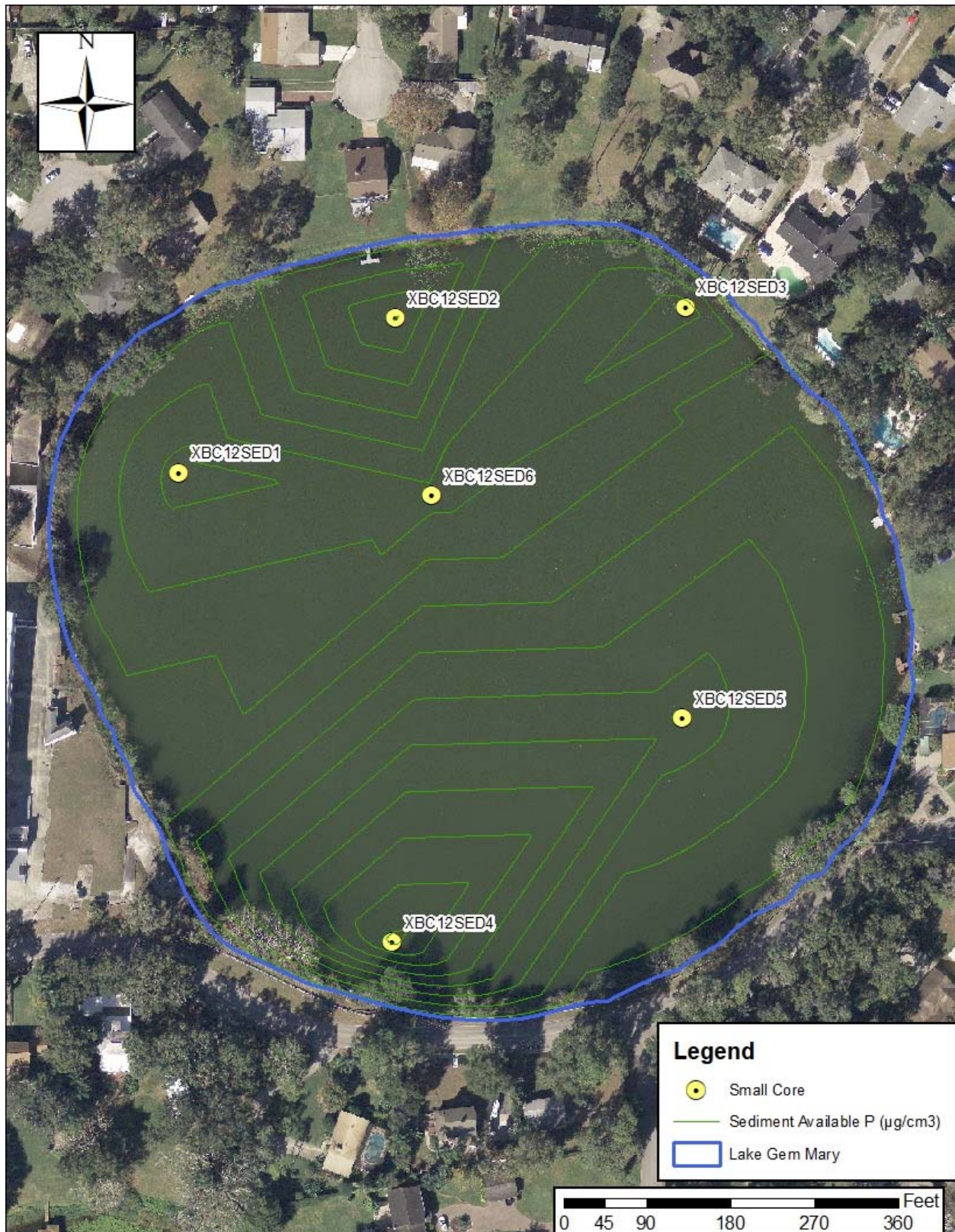


Figure 2-17: Isopleths of Total Available Phosphates in the Top 10 cm of Sediments



2.3. WATER QUALITY CHARACTERISTICS OF LAKE GEM MARY

2.3.1. HISTORICAL WATER QUALITY

Historical water quality monitoring has been conducted in Lake Gem Mary by the Orange County Environmental Protection Division (OCEPD) since February 1991. The OCEPD sample site, as shown in the Orange County Water Atlas, is located in the northeast portion of the lake. A summary of available historical water quality data for Lake Gem Mary is presented in Table 2-7. Samples were analyzed for physical and chemical parameters, including nutrients, chlorophyll-a, heavy metals and Secchi disk depth. Historical samples were collected at 0.5 meters below the surface.

Table 2-7: Summary of Historical Water Quality Data

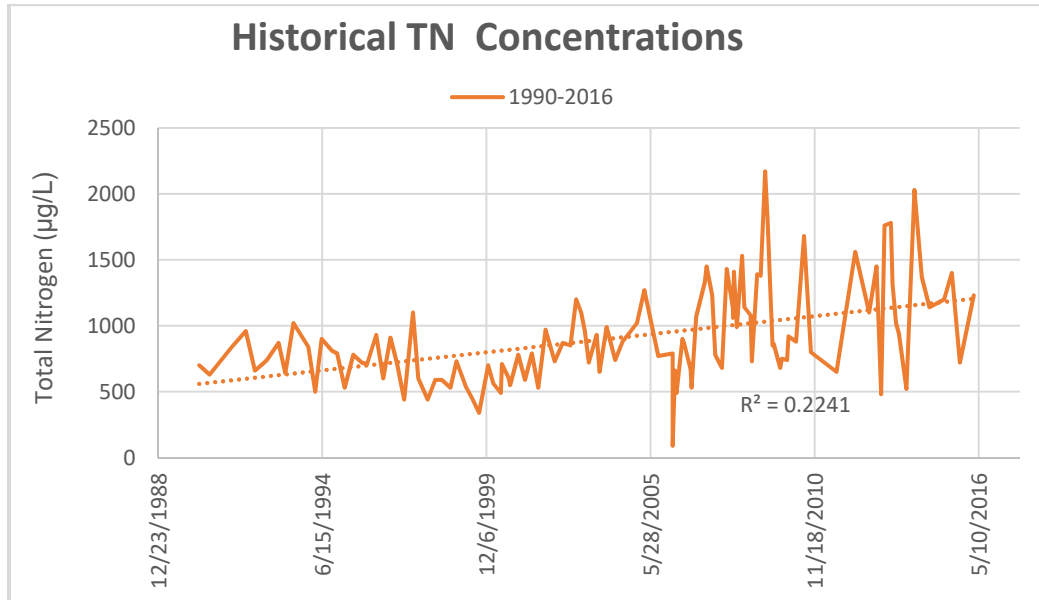
Data Source	Period of Record	Number of Sampling Events	Monitoring Frequency	Parameters Analyzed
Orange County Water Atlas	1969-1977	12	Between 1 and 2 samples per year	General Parameters, Nutrients, Microbiological Parameters, Metals-1970,1977
	1990-1999	47	Between 2 and 7 samples per year	TSI(Trophic State Index), General Parameters, Nutrients, Microbiological Parameters -1999, Metals-1994-99
	2000-2010	73	Between 4 and 8 samples per year	TSI, General Parameters, Nutrients, Microbiological Parameters, Metals
	2011-2016	39	Between 1 and 8 samples per year	TSI, General Parameters, Nutrients, Microbiological Parameters, Metals

Available historical data collected for Lake Gem Mary was downloaded from the Orange County Water Atlas and evaluated for total nitrogen (TN), total phosphate (TP), corrected chlorophyll-a, Secchi disk depth, the TN/TP ratio, dissolved oxygen, and TSI (Chl-a).

Historical data for TN concentrations are available from two sampling events in 1973, three separate times during the same sampling event in 1975, and 125 sampling events between 1990 and 2016. Due to the gap of time from the limited early samples and majority of sampling events, a graph of TN concentrations samples collected in Lake Gem Mary from 1990 to 2016 are presented in Figure 2-18. TN concentrations over the 27-year sampling period ranged between 90 µg/L and 2,170 µg/L. A simple linear regression method was used to develop a trend line for the

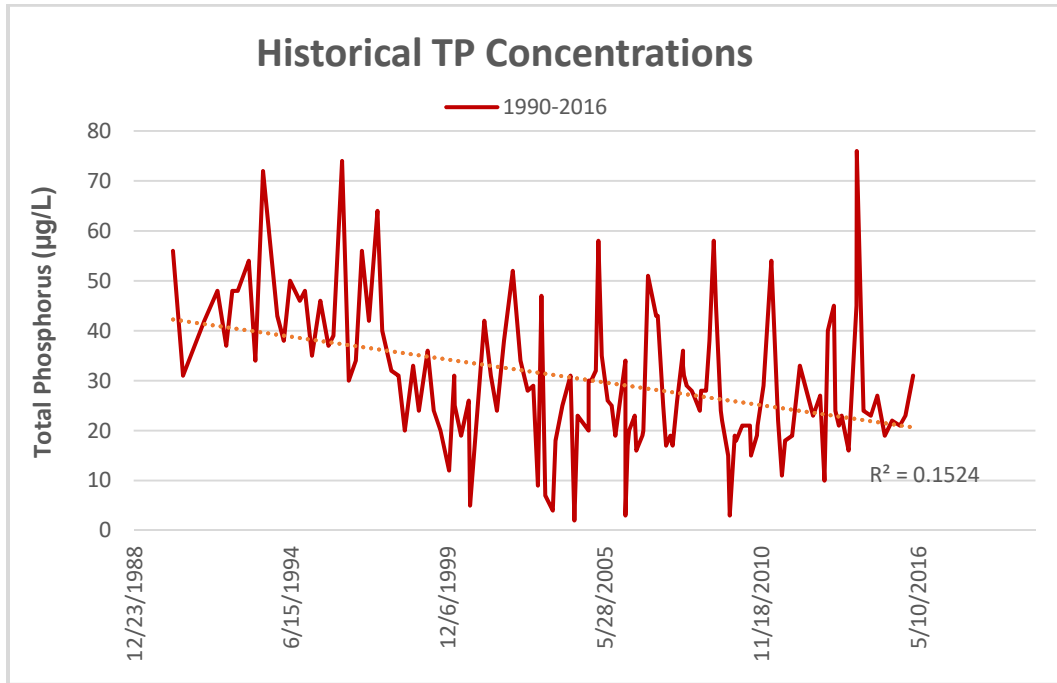
graphed data. While there are cyclic fluctuations in TN concentrations in the historical data, an overall trend of increasing TN concentrations is observed during the time period of record.

Figure 2-18: Historical Total Nitrogen Concentrations 1990 - 2016



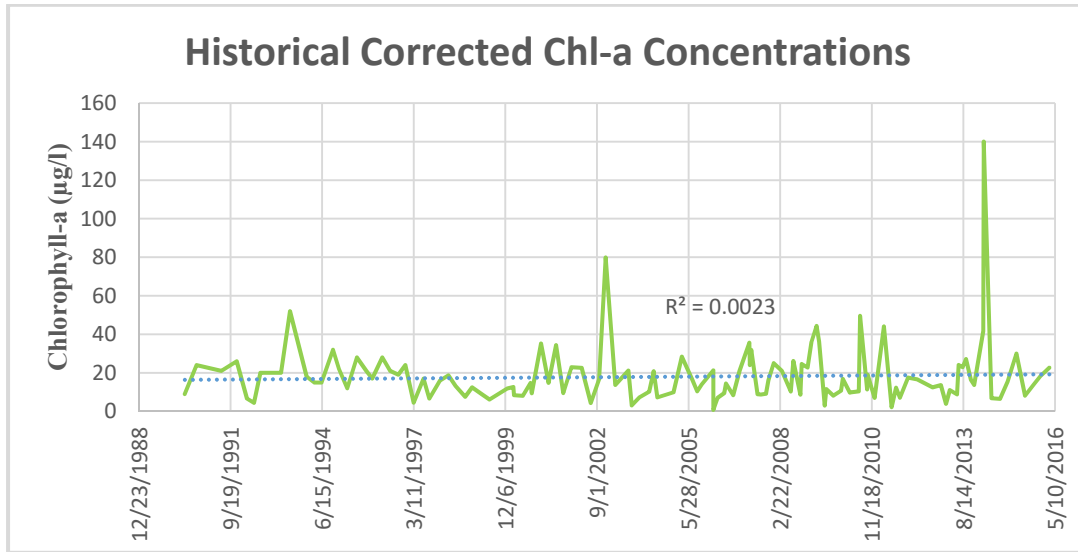
Historical data for Total Phosphorus (TP) concentrations are available from eight sampling events between 1969 and 1975, and 144 sampling events between 1990 and 2016. Due to the limited number of samples collected in the early years and the length of time between early sample events and when the majority of historical sampling events occurred, a graphical summary of historical trends in TP concentrations in Lake Gem Mary from 1990 and 2016 is presented in Figure 2-19. The measured TP concentrations vary over the monitoring period ranging from approximately 2 µg/L to 74 µg/L. An overall trend of decreasing TP concentrations is observed from 1990 to 2016.

Figure 2-19: Historical TP Concentrations 1990 - 2016



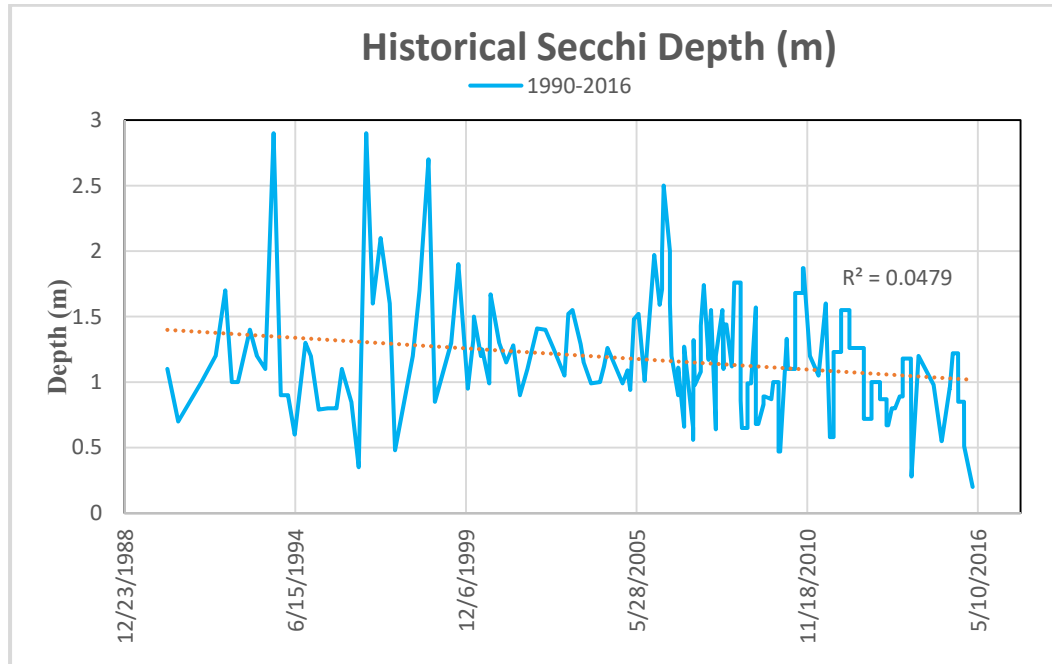
Historical data for corrected chlorophyll-a concentrations are available from 123 sampling events between 1990 and 2016 (some events had more than one sample collected at different times of the day). A graphical summary of historical concentrations of corrected chlorophyll-a concentrations in Lake Gem Mary is presented in Figure 2-20. The measured chlorophyll-a concentrations ranged from less than 0.8 µg/L to approximately 140 µg/L. A slight trend of increasing chlorophyll-a concentrations is observed over the 27-year monitoring period.

Figure 2-20: Historical Chlorophyll-a Concentrations 1990 - 2016



Historical data for Secchi disk depths are available from seven sampling events between 1970 and 1975, and 182 sampling events between 1990 and 2016. Due to the limited number of samples collected in the early years and the length of time between early sample events and when the majority of sampling events occurred, a graphical summary of measured Secchi disk depths in Lake Gem Mary from 1990-2016 is presented in Figure 2-21. The Secchi disk depth measurements ranged between 0.2 meters and 2.9 meters with the highest transparency observed in 1993. An overall trend of slightly decreasing Secchi disk depth is observed in the lake between 1990 and 2016.

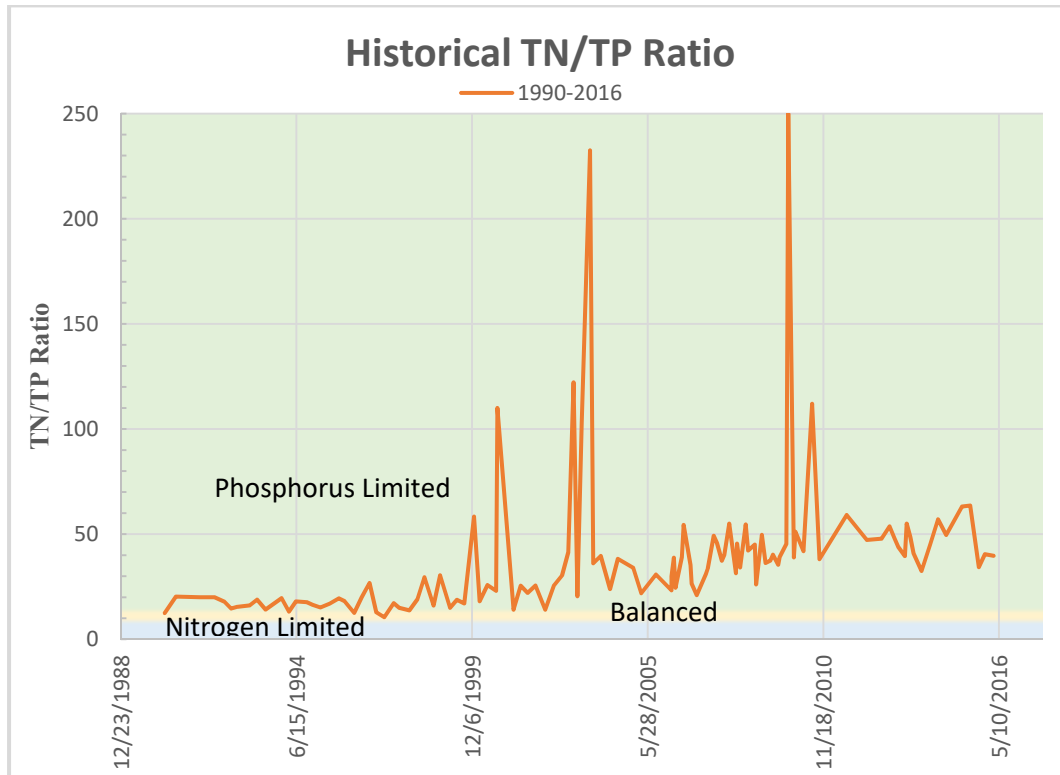
Figure 2-21: Historical Secchi Disk Depths 1990 - 2016



Nutrient limitation in a waterbody is often evaluated using the total nitrogen/total phosphate (TN/TP) ratio. The calculated TN/TP ratio is a numerical ratio of the measured water column concentrations of total nitrogen and total phosphate. This ratio is useful in evaluating the relative significance of nitrogen and phosphates 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 phosphates are 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 and 17 indicate nutrient-balanced conditions, with both nitrogen and phosphates considered important for limiting aquatic growth. Calculated TN/TP ratios in excess of 17 indicate phosphate-limited conditions, which suggests that nitrogen is abundant within the system and algal growth is limited by the availability of phosphates. This is the typical situation observed in many lakes in the Central Florida area. This condition indicates that inputs of phosphates into a lake system should be controlled to regulate the growth of algal biomass within the lake.

A summary of total nitrogen/total phosphate (TN/TP) ratios in Lake Gem Mary from 1990 to 2016 is presented in Figure 2-22.. Although the TN/TP ratios vary widely ranging between 10.5 and 250, it appears that the lake was mostly phosphate limited over the historical data range.

Figure 2-22: Calculated TN/TP Ratios for 1990 - 2016



Florida Trophic State Index (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. TSI values ranging between 50 and 60 indicate mesotrophic conditions, representing fair water quality characteristics. TSI values ranging between 60 and 70 indicate eutrophic conditions, representing poor water quality characteristics. TSI values in excess of 70 indicate hypereutrophic conditions, reflecting very poor water quality.

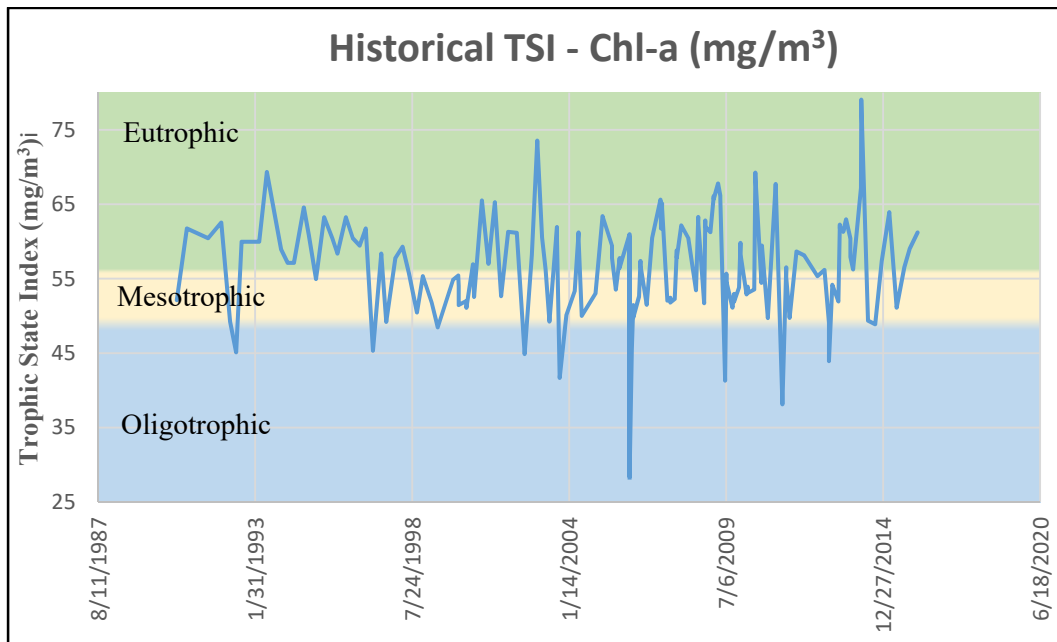
The TSI index was developed by Carlson (1977) as a relative measure of the degree of biological productivity in lakes. The TSI concept incorporates forcing functions such as nutrient supplies, light availability, seasonality, and other factors. Since the TSI value is intended to reflect the level

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-a data is not available. TSI calculations were performed for Lake Gem Mary's historical data from 1990 to 2016 using measured concentrations of chlorophyll-a according to the following relationship:

$$TSI (Chl - a) = 10(6 - \left[\frac{2.04 - 0.68 \cdot \ln(Chl - a)}{\ln 2} \right]) \text{ mg/m}^3$$

Calculated TSI values in Lake Gem Mary from 1990 to 2016 are presented in Figure 2-23. TSI conditions in Lake Gem Mary have ranged from oligotrophic to eutrophic conditions with the highest peaks observed in 2002 and 2014. Water quality within the lake has been highly variable during the monitoring period. However, the data suggests a slight trend of increasing TSI values over the historical sampling period.

Figure 2-23: Calculated TSI Conditions for 1990 - 2016



In addition to the concentration graphs prepared for the available data, the minimum, geometric mean, and maximum concentrations were calculated for total phosphate, total nitrogen, chlorophyll-a, and TN/TP ratios to evaluate seasonal variations that may occur in lake water quality.

Box and whisker plots of the monthly total nitrogen (TN) concentrations in Lake Gem Mary from 1990 to 2016 are presented in Figure 2-24. The central tendency of the historical TN concentrations ranged from 695 $\mu\text{g/L}$ to 1,150 $\mu\text{g/L}$, which are classified as eutrophic to hypereutrophic. Based on the box plot, TN concentrations fluctuate from month to month with the highest observed concentration occurring in March and the lowest concentration occurring in September. These trends may be directly related to rainfall events, the application of fertilizer in the watershed and the occurrence of algae blooms in the lake.

Box and whisker plots of the monthly total phosphate (TP) concentrations in Lake Gem Mary from 1990 to 2016 are presented in Figure 2-24. The central tendency of the historical TP concentrations has a range of 13 $\mu\text{g/L}$ to 36.5 $\mu\text{g/L}$, which is generally classified as eutrophic. There does not appear to be a clear seasonal trend in the monthly changes in TP concentrations from the historical data. Higher TP concentrations were observed during March, April, and June with the lowest concentration observed in May. These trends may be directly related to rainfall events, the application of fertilizer in the watershed and the occurrence of algae blooms in the lake.

Box and whisker plots of the monthly concentrations of corrected chlorophyll-a in Lake Gem Mary from 1990 to 2016 are presented in Figure 2-26. The central tendency of the historical concentrations of chlorophyll-a has range of 3.9 $\mu\text{g/L}$ to 28 $\mu\text{g/L}$. During certain months, such as January, February May and November only a few samples were collected, providing limited corrected chlorophyll-a concentrations for those months. The highest concentration was observed during March and the lowest concentration was observed during February.

Box and whisker plots of the monthly TN/TP ratios in Lake Gem Mary from 1990 to 2016 are illustrated in Figure 2-27. The central tendency of the historical TN/TP values has range of 22.9 to 64.3, indicating that Lake Gem Mary is phosphorus limited.

Figure 2-24: Box and Whisker Plot of Monthly TN Concentrations 1990 - 2016

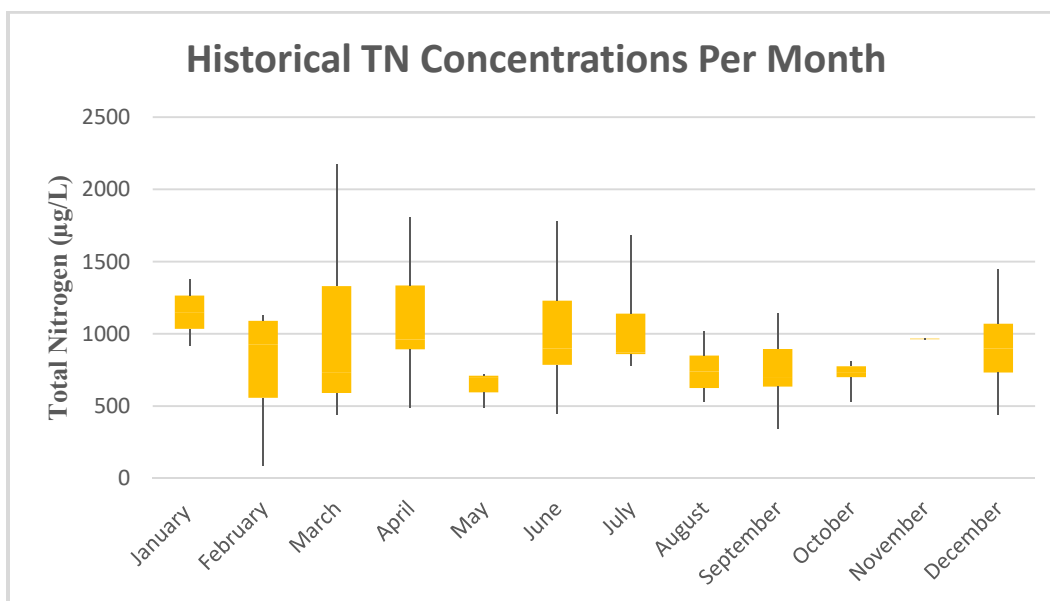


Figure 2-25: Box and Whisker Plot of Monthly TP Concentrations 1990 - 2016

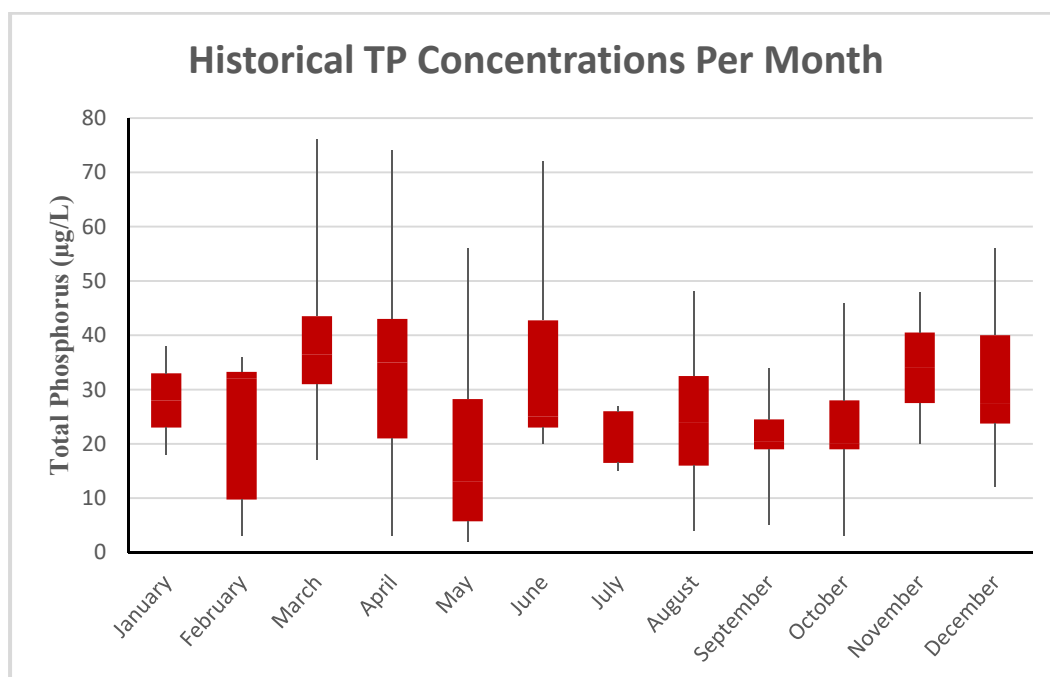


Figure 2-26: Box and Whisker Plot of Monthly Chlorophyll-a Concentrations 1990 – 2016

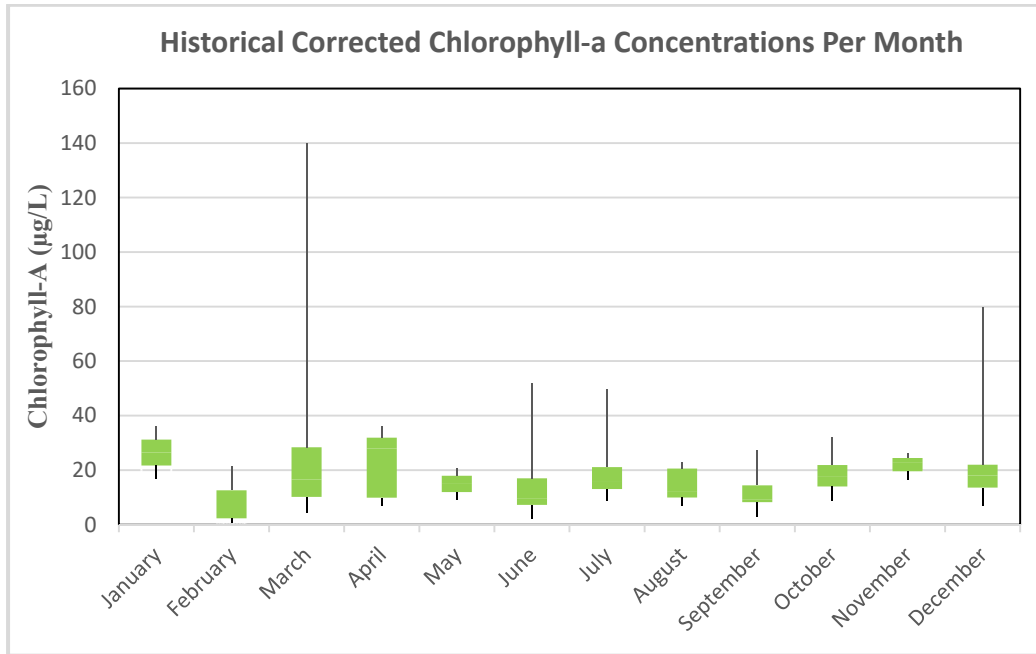
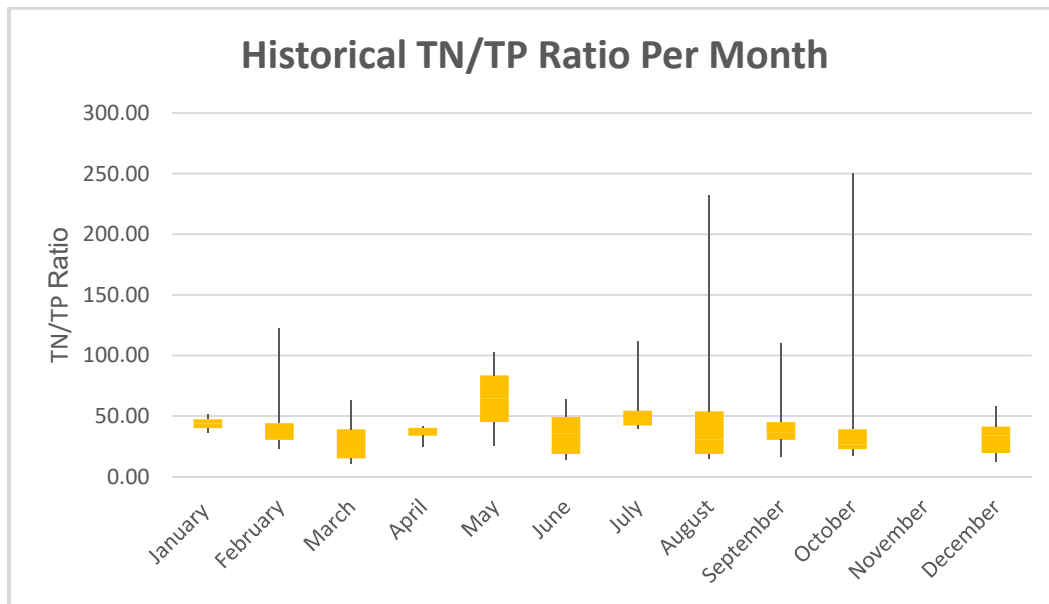


Figure 2-27: Box and Whisker Plot of Monthly TN/TP Ratio 1990 - 2016



Historically, the Florida Department of Environmental Protection (FDEP) based surface water impairment for dissolved oxygen on the concentration of DO analyzed in the water column. Therefore, the majority of historical analytical results for DO are based on concentration. In March

2013, the FDEP determined that the percent saturation of dissolved oxygen in the top two meters of the water column was a more accurate indicator of the health of a surface water body. The FDEP modified the criteria for DO impairment to be based on percent saturation instead of concentration. The majority of historical analytical results for dissolved oxygen in Lake Gem Mary are DO concentrations expressed in milligrams per liter (mg/L).

A total of 11 samples were collected between 1969 to 1975 and analyzed for dissolved oxygen. A total of 149 surface samples were collected between 1993 and 2016. Due to the limited number of samples collected in the early years and the length of time between the early sample events and when the majority of samples were collected, a graphical summary of historical trends in DO concentrations in Lake Gem Mary from 1993 and 2016 is presented in Figure 2-28. Most of the historical samples in Lake Gem Mary were collected 0.5 m below the surface; however, samples collected in 2015 and 2016 appear to be collected throughout the water column to the lake bottom. Only the top two meters of DO concentrations from all sample events are graphed in Figure 2-28. The dissolved oxygen concentrations over the 24 year sampling period in the top two meters of the water column ranged between 0.15 mg/L and 14.8 mg/L. For the purpose of this report, a dissolved oxygen concentration below 5.0 mg/L is defined as anoxic based upon data for the minimum required oxygen concentration with water temperatures at 20°C, as specified in the Environmental Protection Agency (EPA) report EPA-R3-73-019. Of the 149 historical dissolved oxygen concentrations measured in the top two meters of the water column, six of the measurements fell below the 5.0 mg/L threshold. This indicates that historically, the dissolved oxygen in the upper two meters of the water column was measured in the oxic range 96% of the time.

As shown in Figure 2-29, the monthly dissolved oxygen concentrations indicate that the lower concentrations have historically occurred between July and September with the highest concentrations in January through March, indicating that dissolved oxygen concentrations are temperature dependent. A few records of percent DO saturation were available in the historical database and are graphed in Figure 2-30. Samples were not collected consistently throughout the year and analysis is incomplete.

A summary of the historical water quality characteristics of Lake Gem Mary from 1969 to 2016 is given in Table 2-8 for parameters based upon the OCEPD data set. The entire data set is presented in the appendices and includes the mean, median, and geometric mean values for comparison.

Figure 2-28: Historic Dissolved Oxygen Concentrations for 1993 - 2016

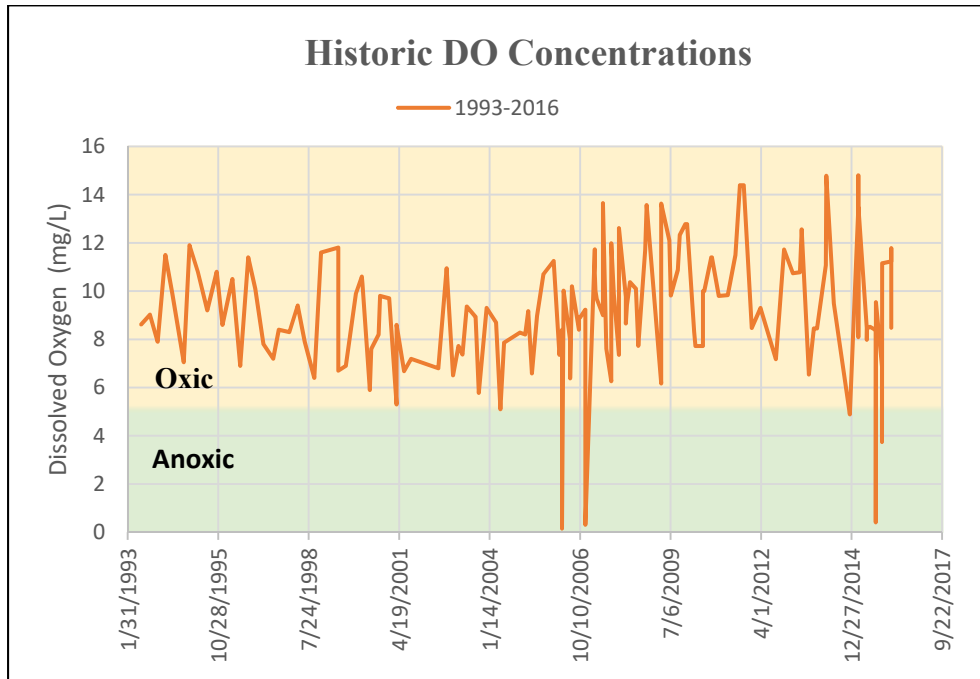


Figure 2-29: Historic Monthly Dissolved Oxygen Concentrations 1993 - 2016

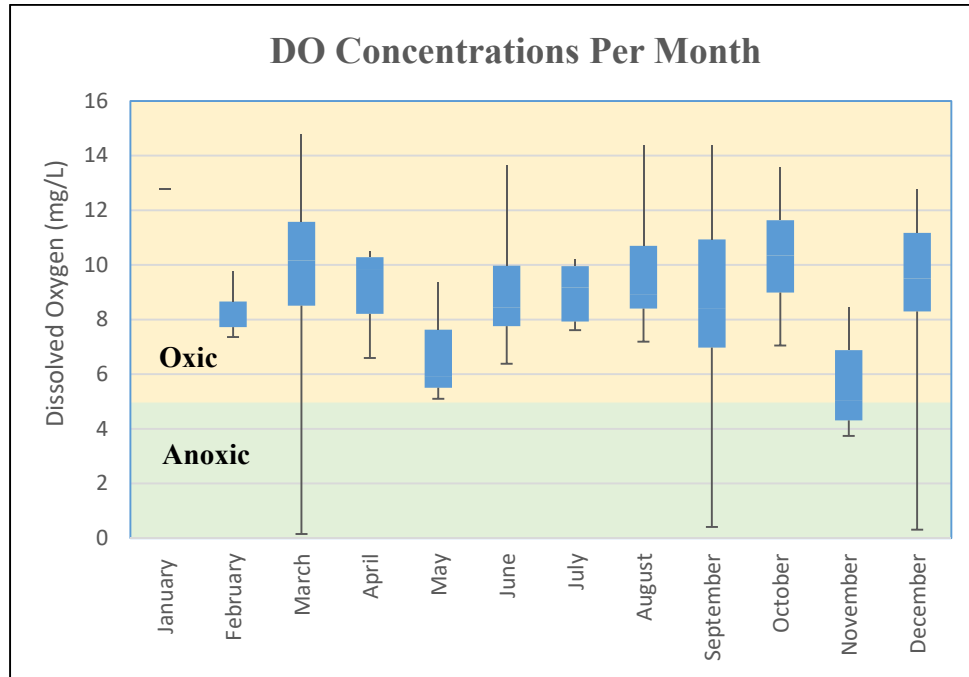


Figure 2-30: Historic Percent Dissolved Oxygen Saturation

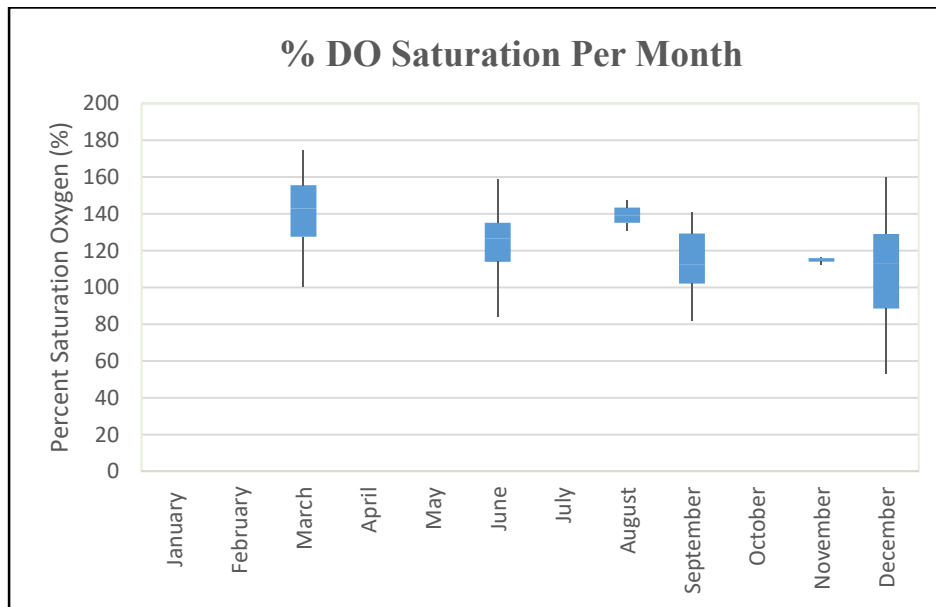


Table 2-8: Summary of Historical Water Quality Characteristics for 1969 - 2016

Parameter	Units	Geomean Concentration
Alkalinity	mg/L	42.0
Chlorophyll-a	mg/m ³	14.3
Conductivity	µmho/cm	274.4
Dissolved Oxygen	mg/L	8.8
Dissolved Oxygen	% Saturation.	114.8
pH	s.u.	8.1
Secchi Depth	m	1.1
Total Nitrogen (TN)	µg/L	857.3
Total Phosphate (TP)	µg/L	28.4
TSI	--	56.3

Note 1: Data from Orange County Water Atlas

2.3.2. CURRENT WATER QUALITY

2.3.2.1. MONITORING ACTIVITIES

A monthly surface water quality monitoring program was conducted in Lake Gem Mary between October 2015 and September 2016 at three fixed monitoring locations within the lake; one fixed location along the north shoreline (shallow depth), one fixed location in the western portion of the lake (medium depth) and one fixed location in the southeast portion of the lake (deep depth). Approximate locations of the surface water monitoring sites in Lake Gem Mary are shown in Figure 2-31. The water quality monitoring sites were selected to allow evaluation of horizontal variability in water quality characteristics, vertical variability in deep areas of Lake Gem Mary and general information on ambient water quality characteristics. Water quality monitoring was performed monthly for 12 months.

Monitoring and sampling was performed in accordance with FDEP's standard operating procedures outlined in DEP-SOP-001/01 titled "Department of Environmental Protection Standard Operating Procedures for Field Activities", dated March 1, 2014. Surface water samples in the lake were collected using a Van Dorn sampler consisting of a polyvinyl chloride (PVC) cylinder closed at both ends by rubber force cups. The cups are locked outside the cylinder to open the sampler. Once the desired depth of sample was reached, a weight was lowered to release the cups, retaining the sample in the cylinder. Surface samples (0.5 meters below water surface) and bottom samples (0.5 meters above the bottom sediment) were collected from the three Lake Gem Mary sites. Samples were field filtered and/or preserved as appropriate for the parameter to be analyzed,

stored on ice, and returned to the laboratory for chemical analyses. Laboratory measurement parameters are shown in Table 2-9, along with a summary of analytical methods and laboratory detection limits.

Table 2-9: Analytical Methods and Detection Limits for Laboratory Analyses Conducted by Environmental Research and Design, Inc.

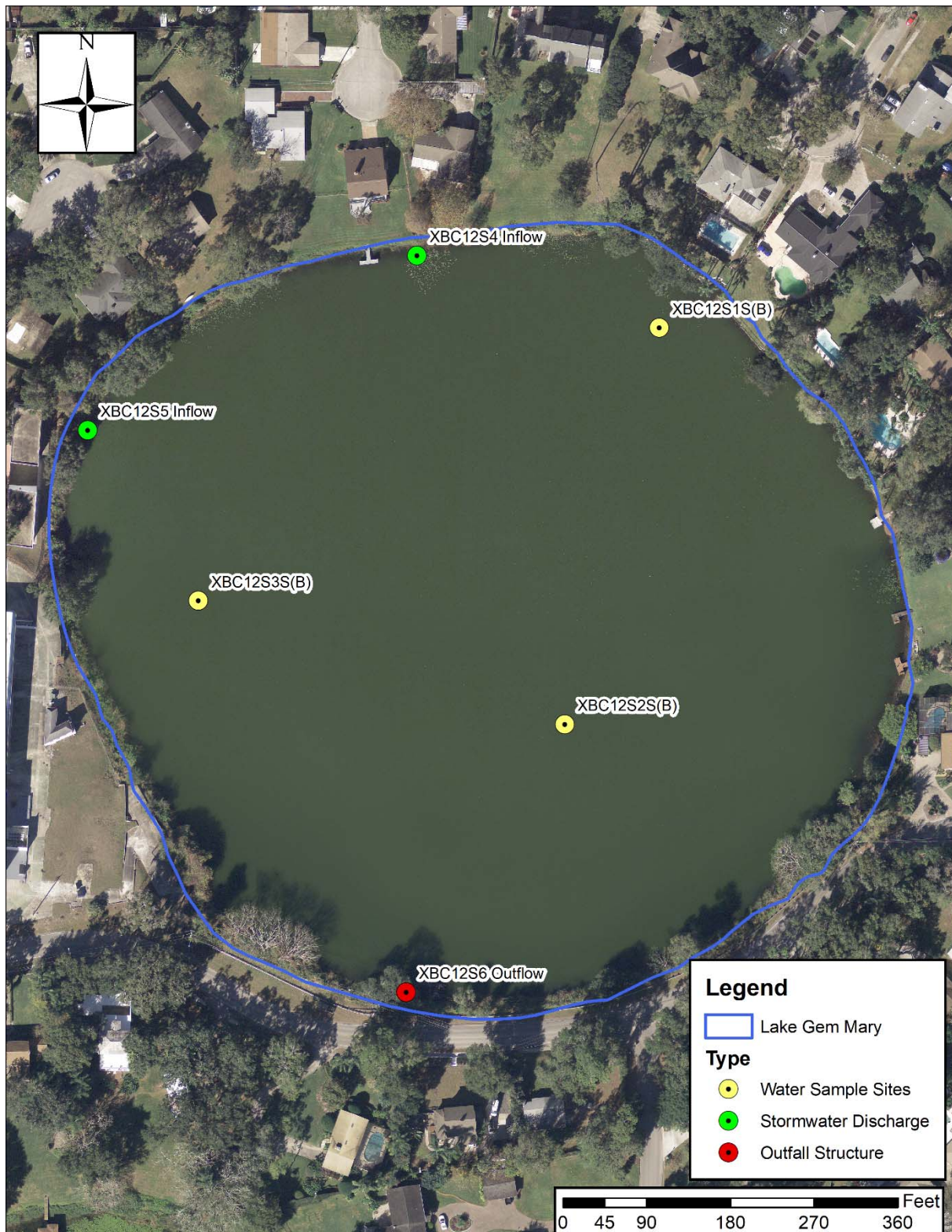
Measurement Parameter		Method ¹	Method Detection Limits (MDLs) ²
General Parameters	Hydrogen Ion (pH)	SM-21, Sec. 4500-H ⁺ B	N/A
	Alkalinity	SM-21, Sec. 2320 B	1.4 mg/L
	TSS	SM-21, Sec. 2540 D	0.7 mg/L
	Color	SM-21, Sec. 2120 C	1 Pt-Co Unit
	Specific Conductivity	SM-21, Sec. 2510 B	0.25µmho/cm
	Turbidity	SM-21, Sec. 2130 B	0.3 NTU
Nutrients	Ammonia-N (NH ₃ -N) Nitrate + Nitrite (NO _x -N)	SM-21, Sec. 4500-NH ₃ G	0.005 mg/L
		SM-21, Sec. 4500-NO ₃ F	0.005 mg/L
	Total Nitrogen	SM-21, Sec. 4500-N C	0.025 mg/L
	SRP (Orthophosphorus)	SM-21, Sec. 4500-P F	0.0006 mg/L
	Total Phosphorus	SM-21, Sec. 4500-P B.5	0.0018 mg/L
Biological Parameters	Chlorophyll-a	SM-19, Sec. 10200 H.1.3	0.1 mg/m ³

¹Standard Methods for Examination of Water and Wastewater, 21st Ed, 2005.

²MDLs are calculated based on the EPA method of determining detection limits.

During each monitoring event, vertical profiles of pH, temperature, conductivity, dissolved oxygen, ORP, and turbidity were conducted at each site. Field measurements were collected at 0.5 meter intervals below the surface to a depth of 0.5 meter above the bottom of each sampling site in the lake, except the October 2015 sampling event when only the surface and bottom field measurements were performed. Field measurements were performed using a calibrated YSI Data Sonde. A measurement of Secchi disk depth was also recorded at each site.

Figure 2-31: Surface Water Monitoring Sites



2.3.2.2. FIELD PROFILES

A listing of vertical field profiles collected in Lake Gem Mary from October 2015 through September 2016 is presented in Appendix B. A discussion of vertical field profiles collected at the three monitoring sites is given in the following sections.

2.3.2.2.1. SITE 1 – XBC12S1

The Site 1 monitoring location was established in the northeast portion of the lake. The total depth of the water column at Site 1 was approximately 3 meters during the yearlong study. The vertical field profile measurements for temperature, pH, conductivity, and dissolved oxygen collected during the monthly monitoring events were graphed to show variations during different seasons and at different depths in the water column, as shown in Figure 2-32, Figure 2-33, Figure 2-34, and Figure 2-35, respectively.

Temperature measurements were relatively uniform throughout the water column. Temperature differences were observed to be less than 1°C between top and bottom measurements collected during the November 2015, October 2015 and August 2016 and between 2°C and 4°C during the remaining months. No significant thermal stratification was observed at this site during the monitoring events.

Field measured pH values were relatively uniform in the upper 1.5 meters of the water column during most months. Below this depth, pH measurements began to decrease with increasing water depth. Water column pH varied from 7.0 to 8.0 except during February, April and May 2016 when pH exceeded 8.5 in the upper 1.5 meters.

Measured conductivity values were relatively uniform throughout the water column during the monitoring events. Increases in conductivity were observed during January, March and April 2016.

Figure 2-32: Site 1 Vertical Field Profile of Temperature

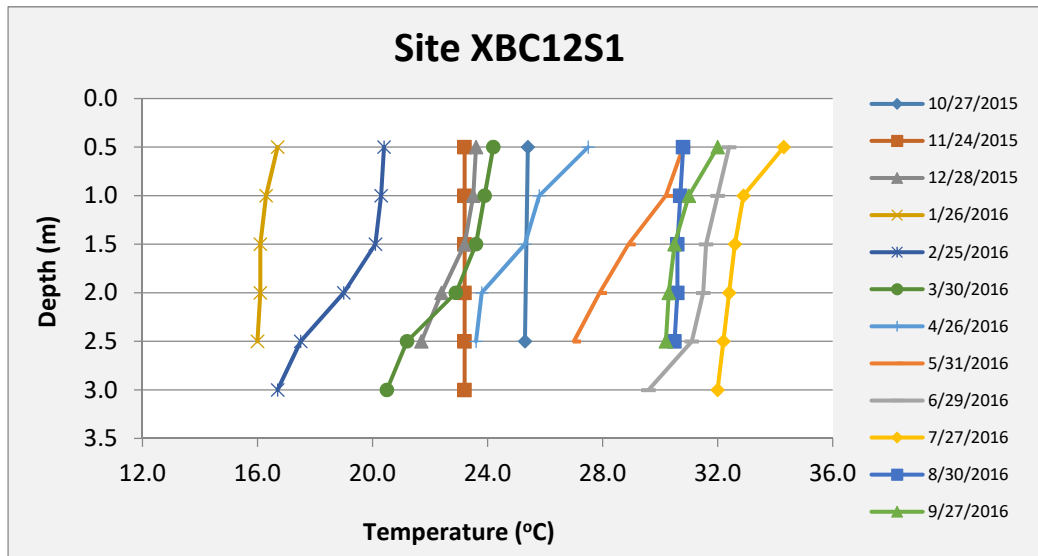


Figure 2-33: Site 1 Vertical Field Profile of pH

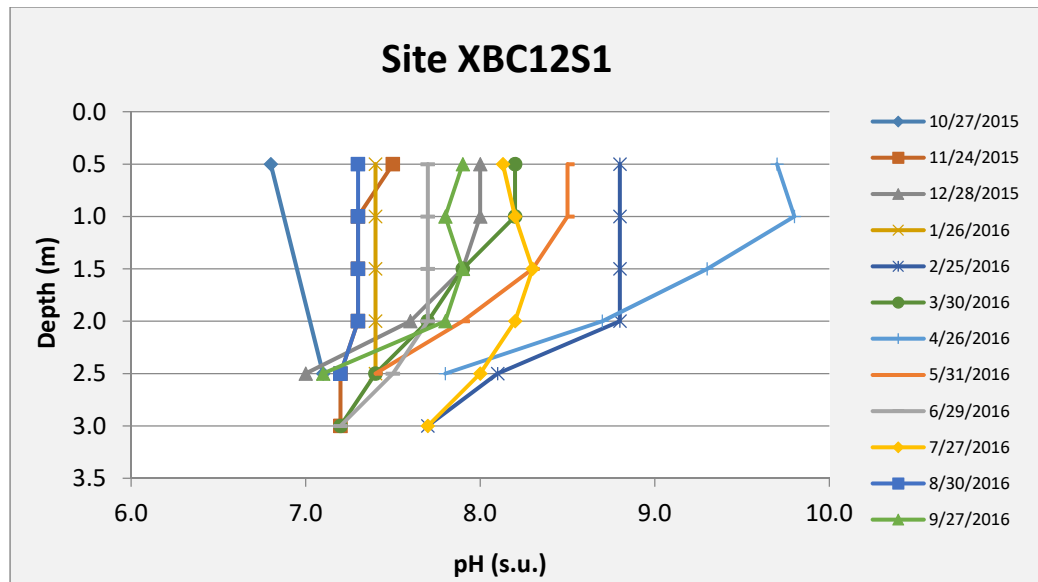
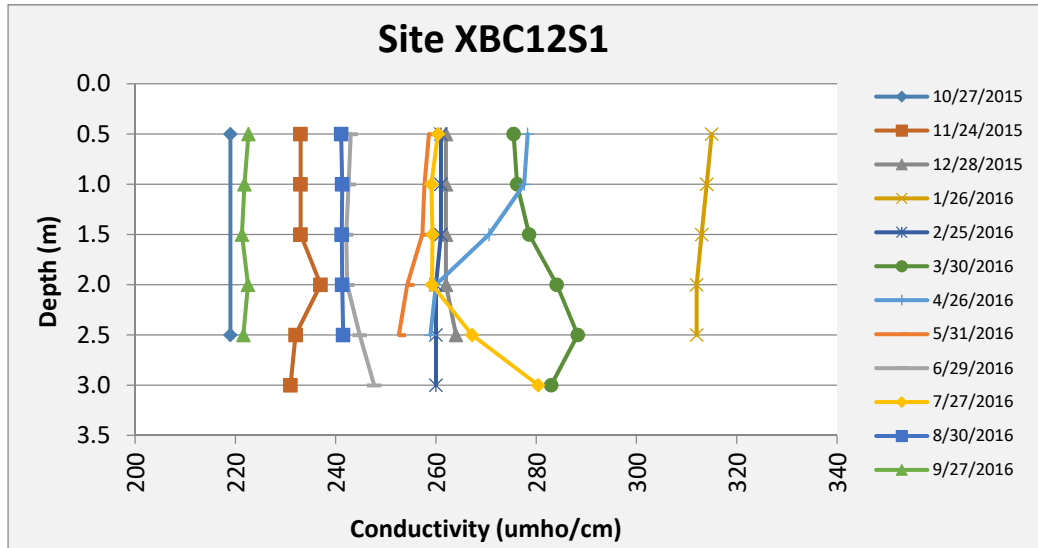


Figure 2-34: Site 1 Vertical Field Profile of Conductivity



Dissolved oxygen concentrations and percent saturation were collected during each of the monthly sampling events to a depth of approximately 3 meters, depending upon water depth at the time of sampling. Prior to 2013, the FDEP criteria for dissolved oxygen impairment for freshwater was a concentration of 5 mg/L. Historically, dissolved oxygen concentrations were collected to evaluate the health of a lake based on the concentration criterion.

Surface DO concentrations at Site 1 appeared to be uniform to 1 meter below the surface and then generally decreased with increasing water depth, as shown in Figure 2-35. DO concentrations below 5 mg/L were observed in 6 of the 12 sampling events at the water-sediment interface, indicating that internal recycling may be occurring, although an increase in conductivity near the water-sediment interface was not generally observed.

In March 2013, the FDEP prepared a Technical Support Document, *Derivation of Dissolved Oxygen Criteria to Protect Aquatic Life in Florida's Fresh and Marine Waters*, modifying the DO criteria based on data collected during a 2-year statewide freshwater DO study. The revised freshwater DO criteria uses the relationship between the daily average DO condition (percent saturation of DO) and the measure of stream aquatic life health (Stream Condition Index). FDEP selected DO percent saturation rather than concentration because saturation automatically accounts for the inherent relationship between temperature and DO. Based on the results of regional relationships observed in the 2-year DO study, daily average DO levels of 38% saturation for the

Peninsula of Florida (including Central Florida) were determined to support healthy, well-balanced biological communities.

The Central Florida DO criteria for Class III freshwater is expressed as “*No more than 10 percent of the daily average percent DO saturation values shall be below 38 percent saturation*”. When single event samples are used to assess the DO criteria, a “time-of-day” translation of the daily average criteria should be calculated. The time-of-day translation generates an equation relating DO saturation with the time the sample was collected and shown as a blue line in the percent DO saturation graphs presented below.

The Site 1 percent DO saturation values in the top two meters of the water column were graphed in relation to the time-of-day translation as directed in the FDEP Technical Support Document and shown in Figure 2-36. Dissolved oxygen saturation in 1 of the 48 values at Site 1 fell below the FDEP target saturation, or approximately 2% of the values. During this year of investigation, less than 10% of the DO saturation values fell below the target saturation; therefore, the lake would be classified as attainment for dissolved oxygen in accordance with the FDEP criteria.

Figure 2-35: Site 1 Vertical Field Profile of Dissolved Oxygen Concentrations

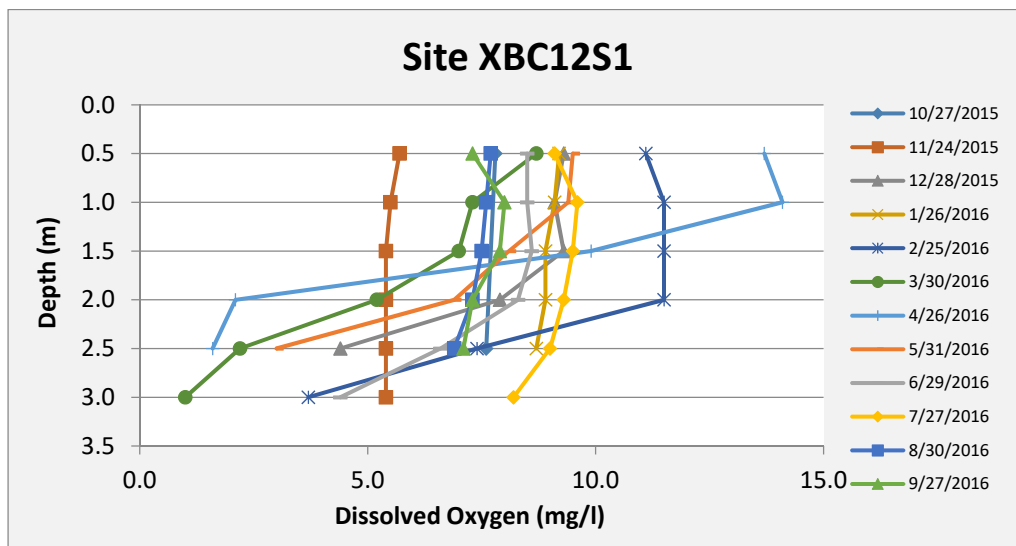
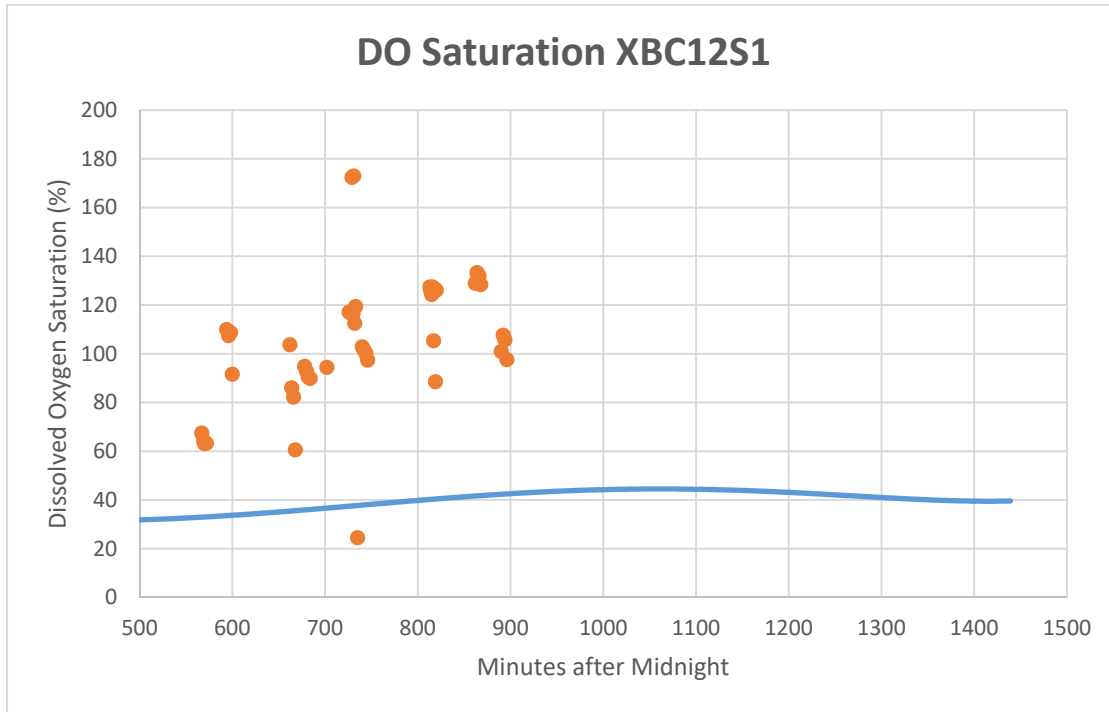


Figure 2-36: Time-of-Day Percent Dissolved Oxygen Saturation at Site 1



2.3.2.2.2. SITE 2 – XBC12S2

The Site 2 monitoring location was established in the western portion of the lake. The total depth of the water column at Site 2 ranged between 4.5 and 6.0 meters throughout the study. The vertical field profile measurements for temperature, pH, conductivity, and dissolved oxygen collected during the monthly monitoring events were graphed to show variations during different seasons and at different depths in the lake, as shown in Figure 2-37, Figure 2-38, Figure 2-39, and Figure 2-40, respectively.

Temperature measurements decreased with depth in the water column. Temperature differences were observed to be less than 1°C between top and bottom measurements collected during October 2015 and November 2015, between 2°C and 5°C during December 2015, January 2016, February 2016 and September 2016, and greater than 5°C during the warm months when surface water temperatures increased. No significant thermal stratification was observed during the monitoring events.

Field measured pH values were relatively uniform in the upper 1.5 meters of the water column during most months. Below this depth, pH measurements began to decrease with increasing water

depth. Water column pH varied from 7.0 to 8.5 except during February, March, April, and 2016 when pH exceeded 8.5 in the upper 2.0 meters.

Measured conductivity values were relatively uniform throughout the water column during six (6) of the monitoring events. Increases in conductivity were observed during January, March, and April 2016. During six (6) of the sampling events the conductivity increased as the probe got closer to the bottom of the lake.

Figure 2-37: Site 2 Vertical Field Profile of Temperature

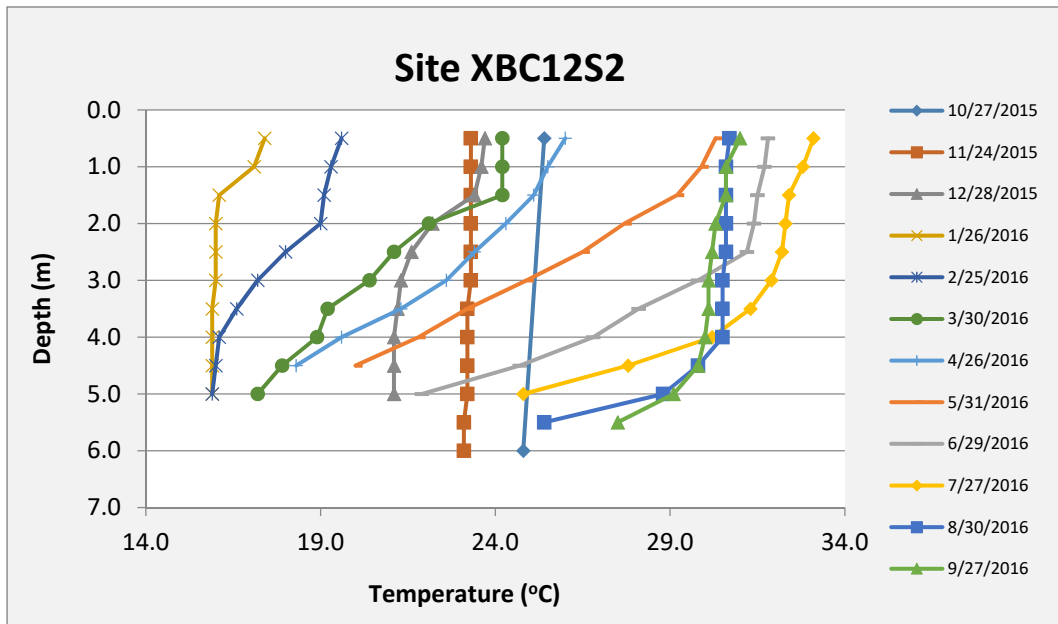


Figure 2-38: Site 2 Vertical Field Profile of pH

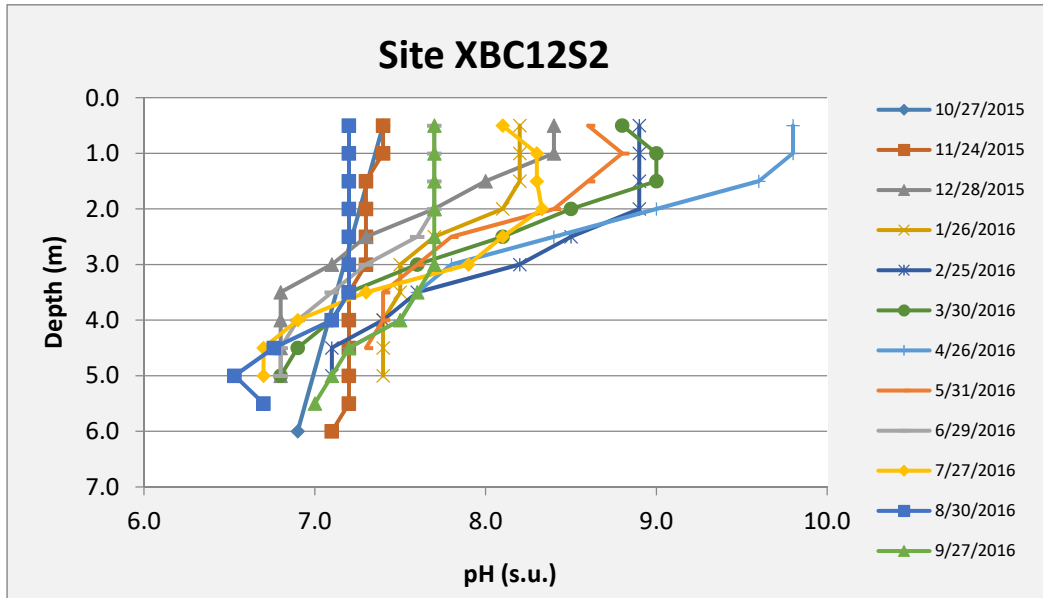
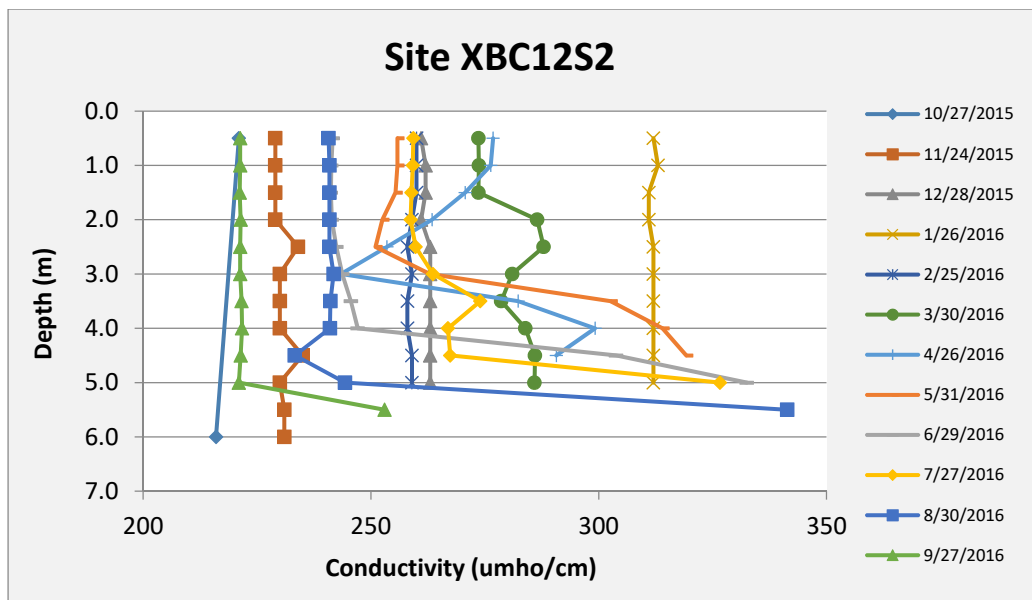


Figure 2-39: Site 2 Vertical Field Profile of Conductivity



Dissolved oxygen concentrations and percent saturation were collected during each of the monitoring events to a depth of approximately 4.5 – 6.0 meters, depending upon sample date and surface elevation of the lake. Surface DO concentrations appeared to be uniform to 1 meter below

the surface and then generally decreased with increasing water depth, as shown in Figure 2-40. DO concentrations less than 5 mg/L, were observed in 10 of the 12 sampling events at the water-sediment interface, indicating that internal recycling might be occurring. An increase in conductivity near the water-sediment interface was observed in 6 of the 12 sampling events and could be an indicator that internal recycling is occurring.

The Site 2 percent DO saturation values in the top two meters of the water column were graphed in relation to the time-of-day translation as directed in the FDEP Technical Support Document and shown in Figure 2-41. Dissolved oxygen saturation in the 48 values at Site 2 were above the FDEP target saturation. During this year of investigation, none of the DO saturation values fell below the target saturation; therefore, the lake would be classified as attainment for dissolved oxygen in accordance with the FDEP criteria.

Figure 2-40: Site 2 Vertical Field Profile of Dissolved Oxygen Concentrations

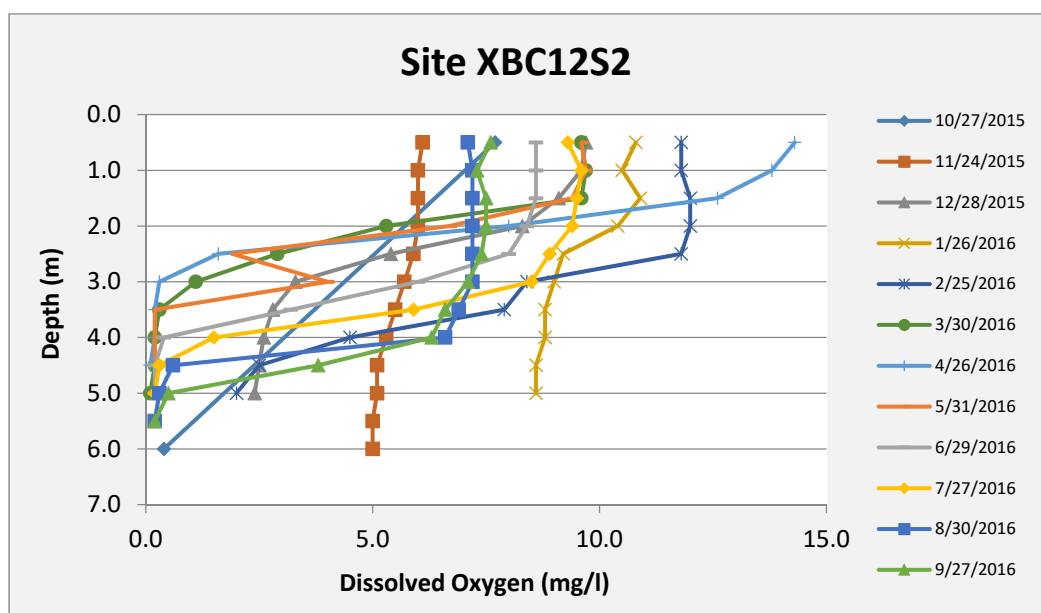
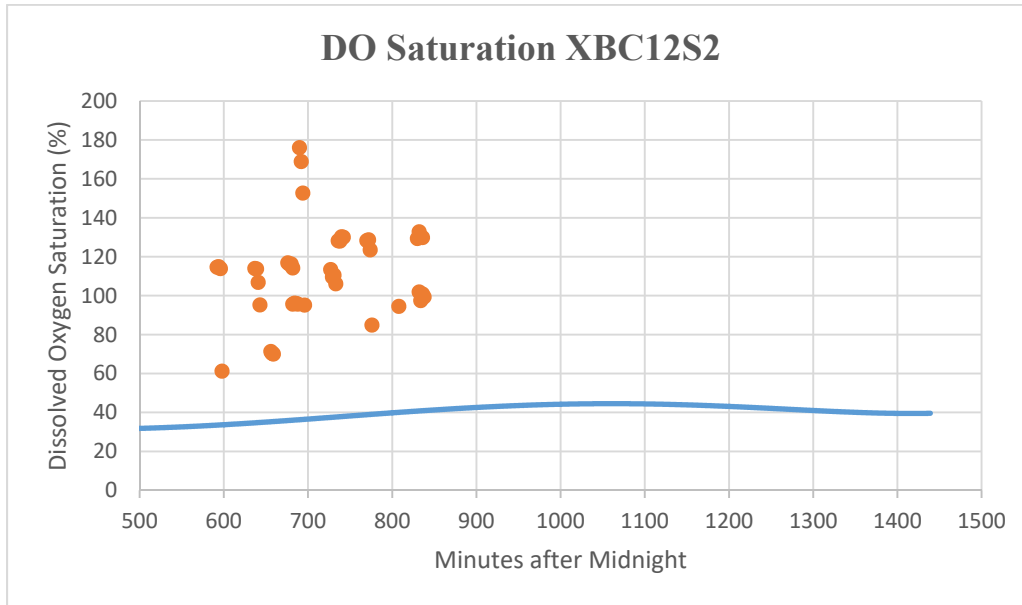


Figure 2-41: Time-of-Day Percent Dissolved Oxygen Saturation at Site 2



2.3.2.2.3. SITE 3 – XBC12S3

The Site 3 monitoring location was established in the southeast portion of the lake. The total depth of the water column at Site 3 was approximately 8.0 to 8.5 meters throughout the study. The vertical field profile measurements for temperature, pH, conductivity, and dissolved oxygen collected during the monthly monitoring event at Site 3 were graphed to show variations during different seasons and at different depths in the water column, as shown in Figure 2-42, Figure 2-43, Figure 2-44, and Figure 2-45, respectively.

Temperature measurements decreased with depth in the water column. Temperature differences were observed to be less than 5°C between top and bottom measurements collected during November 2015, December 2015, January 2016 and February 2016, between 5°C and 10°C during October 2015, March 2016 and April 2016, and greater than 10°C difference during May 2016 through September 2016 when surface water temperatures increased. No significant thermal stratification was observed during the monitoring events.

Field measured pH values were relatively uniform in the upper 1.5 meters of the water column during most months and decreased with increasing water depth. Water column pH varied from 7.0 to 8.0 October 2015, November 2015, June 2016, August 2016 and September 2016. Water column pH exceeded 8.0 in the upper layers of the water column during the remaining 7 months.

Measured conductivity values were relatively uniform for the top four (4) meters of the water column during the monitoring events. For nine (9) of the sampling events the conductivity increased after four (4) meters and continued increasing with depth. Conductivity in the water column was uniform for January and February 2016.

Figure 2-42: Site 3 Vertical Field Profile of Temperature

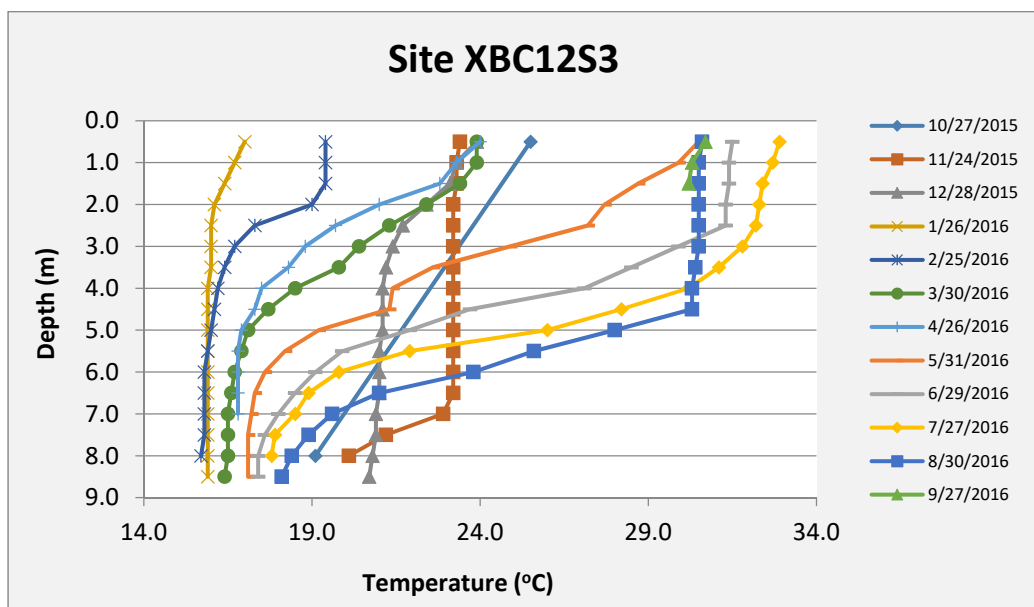


Figure 2-43: Site 3 Vertical Field Profile of pH

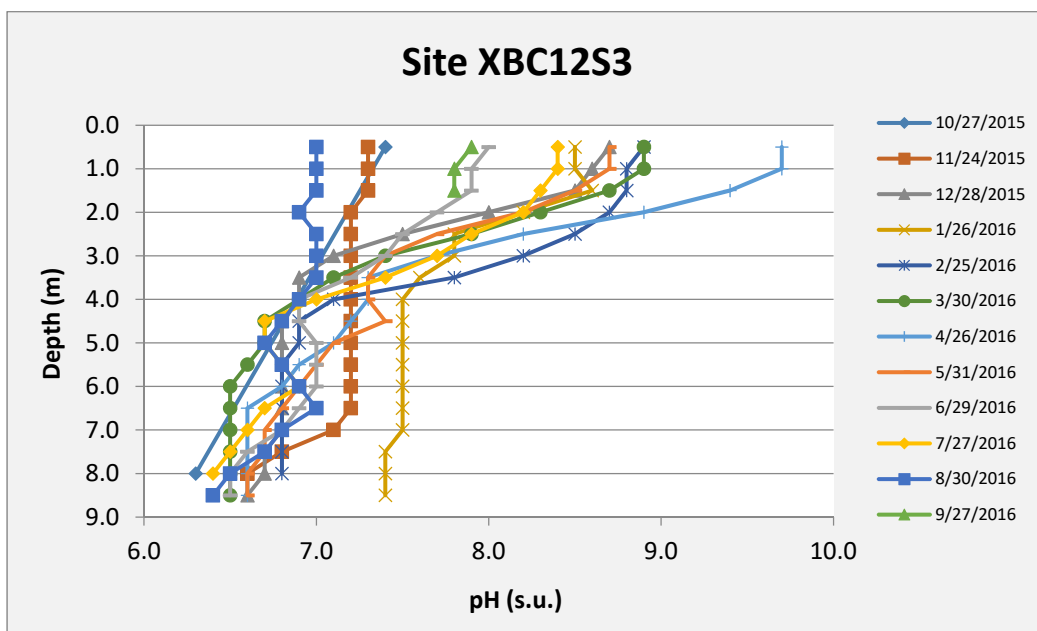
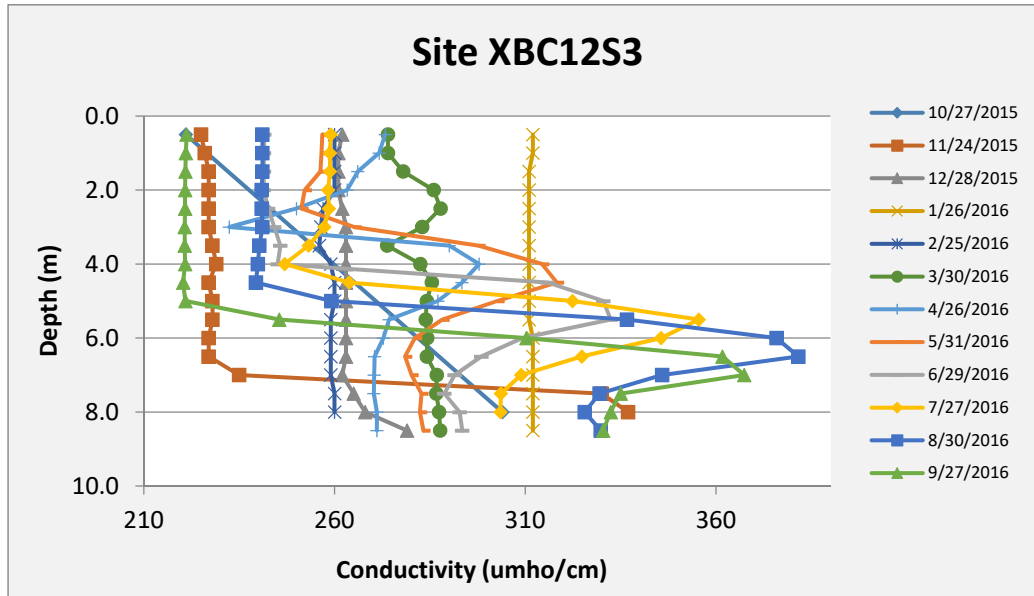


Figure 2-44: Site 3 Vertical Field Profile of Conductivity



Dissolved oxygen concentrations and percent saturation were collected during each of the monitoring events to a depth of approximately 8.0 – 8.5 meters, depending upon sample date and surface elevation of the lake. Surface DO concentrations appeared to be uniform to 1 meter below the surface and then generally decreased with increasing water depth, as shown in Figure 2-45. DO concentrations less than 5 mg/l, were observed in 11 of the 12 sampling events at the water-sediment interface, indicating that internal recycling may be occurring. An increase in conductivity near the water-sediment interface was observed in 10 of the 12 sampling events. An increase in conductivity in the lower portion of the water column can indicate a release of ions resulting from internal recycling of the bottom sediment within the area.

The Site 3 percent DO saturation values in the water column were graphed in relation to the time-of-day translation as directed in the FDEP Technical Support Document and shown in Figure 2-46. Dissolved oxygen saturation in the 48 values at Site 3 were above the FDEP target saturation. During this year of investigation, none of the DO saturation values fell below the target saturation; therefore, the lake would be classified as attainment for dissolved oxygen in accordance with the FDEP criteria.

Figure 2-45: Site 3 Vertical Field Profile of Dissolved Oxygen Concentrations

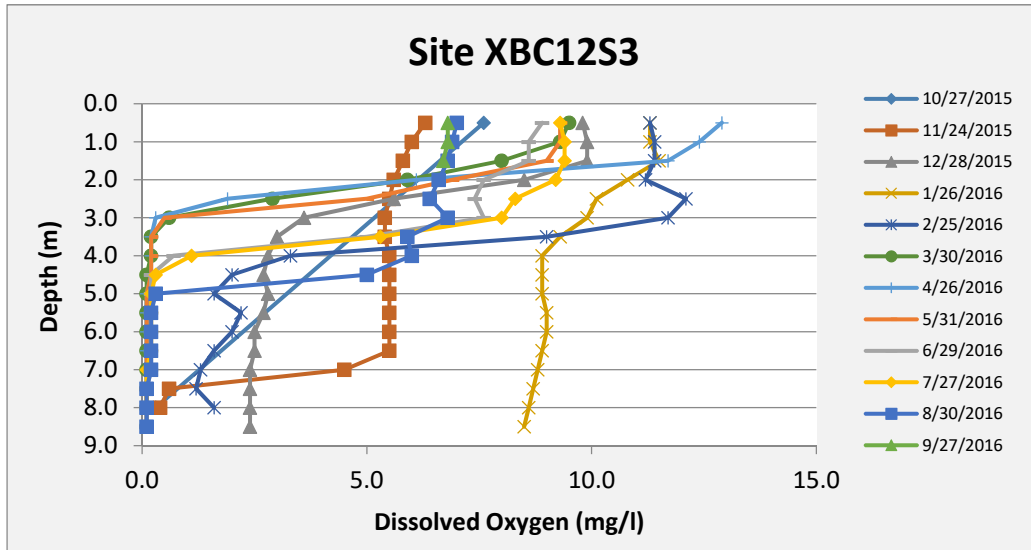
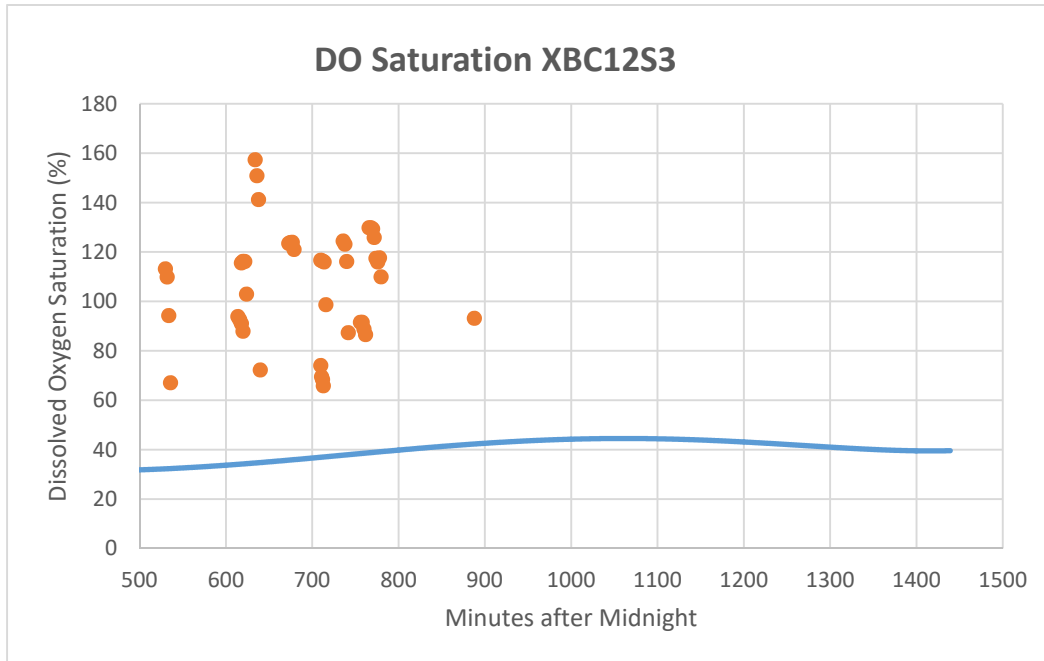


Figure 2-46: Time-of-Day Percent Dissolved Oxygen Saturation at Site 3

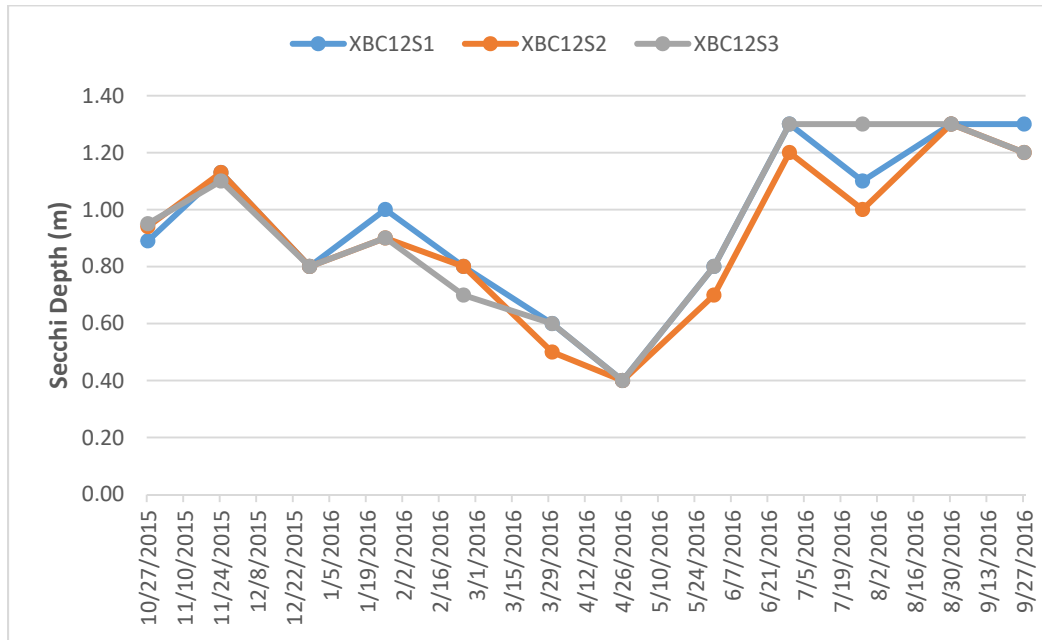


2.3.2.3. SECCHI DISK MEASUREMENTS

A Secchi disk depth measurement was collected at each of the three lake monitoring sites during the year-long study. A chart of the depths for each monitoring site was prepared as shown on Figure 2-47. Secchi disk depths within the monitoring sites fluctuated demonstrating dependence on rainfall within the watershed. The peak in January can be attributed to the 6.73" of measured

rainfall during the month. The rise in secchi depths for May and June correspond with measured rainfall of 6.61” and 9.79” total for each month respectively. The high levels of secchi depths in August and September correspond with monthly rainfall totals of 9.49” and 7.45”, respectively.

Figure 2-47: Secchi Disk Depth at Monitoring Sites



2.3.2.4. WATER QUALITY CHARACTERISTICS

Surface water monitoring was conducted in Lake Gem Mary on a monthly basis during the 12-month monitoring program at each of the three monitoring sites indicated in Figure 2-31. Two separate water samples were collected at each monitoring site, one at approximately 0.5 meters below the water surface (top sample) and the second at approximately 0.5 meters above the water-sediment interface (bottom sample). A total of 12 top and 12 bottom samples was collected at each of the monitoring sites. A listing of water quality characteristics measured at the monitoring sites between October 2015 and September 2016 is presented in Appendix C.

A summary of the geometric mean water quality characteristics at each of the monitoring sites in Lake Gem Mary between October 2015 and September 2016 is presented in Table 2-10. The values summarized in this table reflect the geometric mean values for the data collected at each site. Separate geometric mean values are provided for the surface and bottom samples.

Alkalinity concentration geometric means in the lake surface and bottom water samples ranged from 34.4 mg/l to 46.8 µg/l (as a function of carbonate), with higher concentrations in the bottom water samples. A low alkalinity value indicates a water body with a low buffering capacity.

Table 2-10: Geometric Mean Water Quality Characteristics for Lake Gem Mary November 2015 - October 2016

Parameter	Units	Northeast – Shallow Depth (S1)		West – Medium Depth (S2)		Southeast – Deepest Depth (S3)	
		Surface	Bottom	Surface	Bottom	Surface	Bottom
Alkalinity	mg/L	35.3	34.4	35.3	46.8	35.5	46.8
NH ₃	µg/L	12.4	75.7	7.7	206.0	7.6	1723.4
NO _x	µg/L	8.7	10.7	8.2	6.2	7.5	4.4
Dissolved Organic N	µg/L	585	533	628	504	609	755
Particulate N	µg/L	299	253	225	215	220	173
Total N	µg/L	1009	1015	949	1130	919	3110
SRP	µg/L	3.8	3.5	3.6	3.6	3.5	5.7
Dissolved Organic P	µg/L	8.8	9.9	10.9	10.0	9.8	11.0
Particulate P	µg/L	15.7	20.2	15.8	20.6	15.3	29.1
Total P	µg/L	33.8	37.6	34.1	38.4	32.8	50.7
Color	PCU	10.2	9.7	11.0	9.7	10.2	25
Chlorophyll-a	mg/m ³	26.2	24.8	28.9	45.3	28.8	22.6

The geometric mean concentrations of ammonia and NO_x (nitrite + nitrate) in the lake surface water samples were low while the lake bottom sample concentrations were higher. The dominant nitrogen species that was analyzed in the lake monitoring sites is dissolved organic nitrogen which comprises approximately 24% to 66% of the total nitrogen. Particulate nitrogen comprises approximately 6% to 30% of the total nitrogen measured at each site. The geometric mean TN concentrations in the samples collected from Lake Gem Mary ranged from 919 to 3,110 µg/L.

The dominant phosphate species analyzed in the lake monitoring locations was particulate phosphate. The geometric mean for particulate phosphate concentrations in the lake samples ranged from 15.3µg/L to 29.1 µg/L. The geometric mean of TP concentrations in the lake samples ranged from 32.8 µg/L to 50.7 µg/L.

The geometric mean for color concentrations in the lake were low enough in value that Lake Gem Mary will be classified as a low color lake. The geometric mean of surface color concentrations in Lake Gem Mary surface samples ranged from 9.7 PCU to 11.0 PCU.

The geometric mean for corrected chlorophyll-a concentrations in the lake surface samples ranged from 22.6 mg/m³ to 45.3 mg/m³. These values exceed the maximum concentrations specified in the numeric nutrient criteria published by FDEP.

A graphical comparison of the variability in measured surface concentrations of total nitrogen (TN) at each of the surface monitoring sites in Lake Gem Mary from October 2015 to September 2016 is presented in Figure 2-48. The measured TN concentrations within the lake surface waters increased slightly from March through June. The TN concentrations observed in XBC12S3B were significantly higher than the other sample sites during most months. Site XBC12S3B is the deepest sample site within Lake Gem Mary (approximately 30 feet below water surface) and located in an area where the unconsolidated muck is three feet thick. Based on analytical results, it appears that the higher TN exchange across the sediment/surface water interface occurs at site XBC12S3B. A box and whisker plot of the TN concentrations for each sampling site and a plot of TN concentrations per month are presented in Figure 2-48.

A graphical comparison of the variability in measured surface concentrations of total phosphorus (TP) at each of the surface monitoring sites in Lake Gem Mary from October 2015 to September 2016 is presented in Figure 2-49. The measured TP concentrations significantly increased during March, possibly due to algae bloom. The samples collected from the sediment/surface water interface in Lake Gem Mary exhibited higher TP concentrations than the surface waters. TP concentrations in the surface waters and in the two relatively shallow bottom sample sites (Sites 1 and 2) appear to be higher during the months when temperatures are higher. The TP concentrations observed at Site XBC12S3B were consistently higher than the other sample sites, possibly due to a higher TP exchange across the sediment-surface water interface. A box and whisker plot of the TP concentrations for each sampling site and a plot of TP concentrations per month are presented in Figure 2-49.

A graphical comparison of the variability in measured surface concentrations of chlorophyll-a in the surface waters of Lake Gem Mary from October 2015 to September 2016 is presented in Figure

2-50. The measured chlorophyll-a concentrations significantly increased during April, possibly due to phytoplankton response to the increased biological activity in the lake during March. A box plot and whisker plot of the chlorophyll-a concentrations for each sampling site and a plot of chlorophyll-a concentrations per month are presented in Figure 2-50.

Figure 2-48: Variability in Measured TN Concentrations

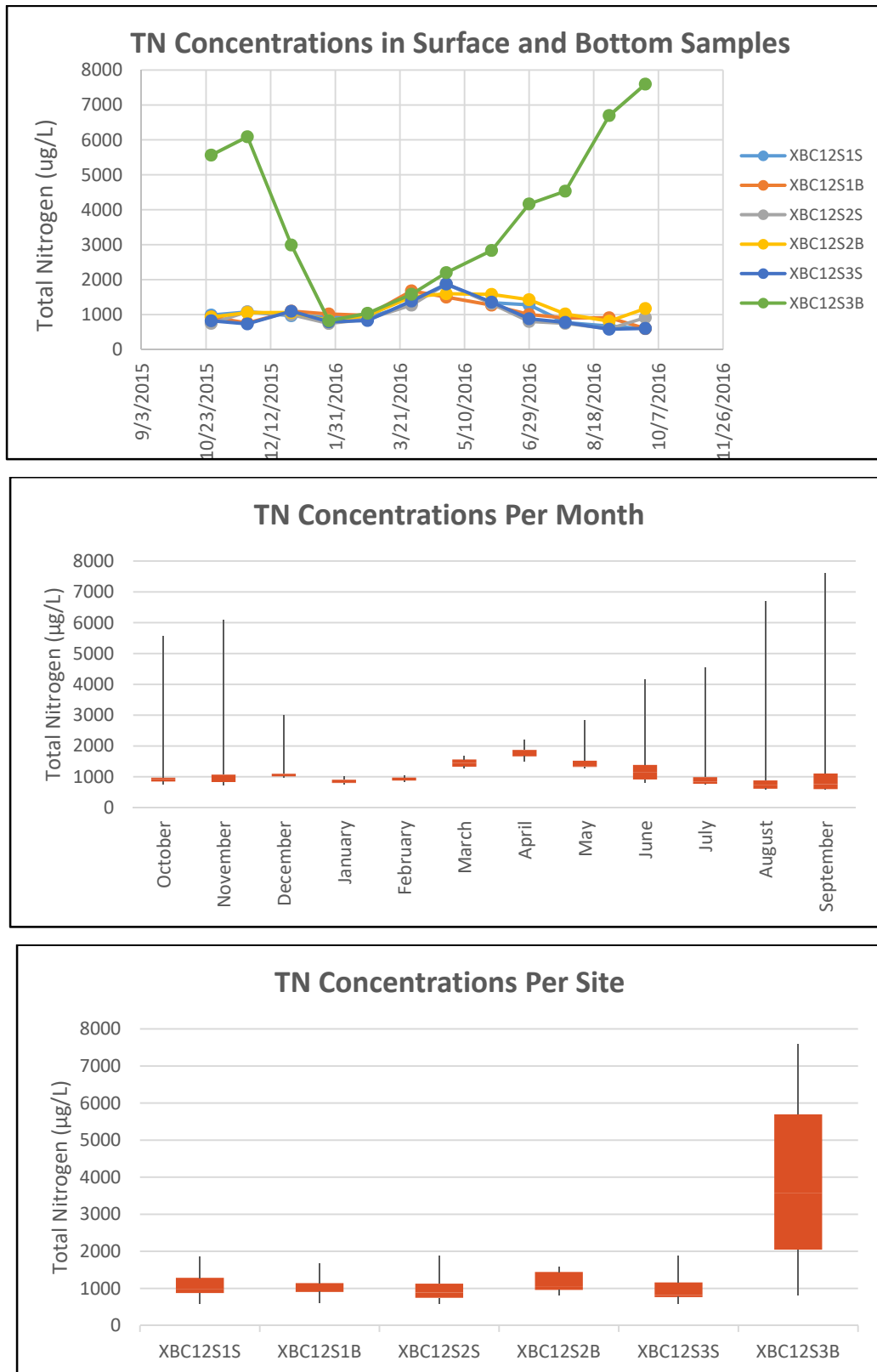


Figure 2-49: Variability in Measured TP Concentrations

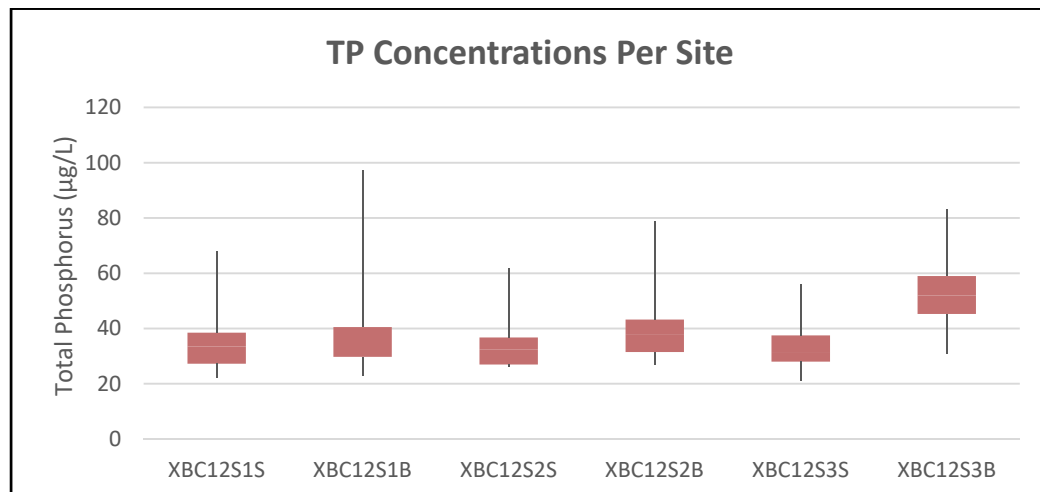
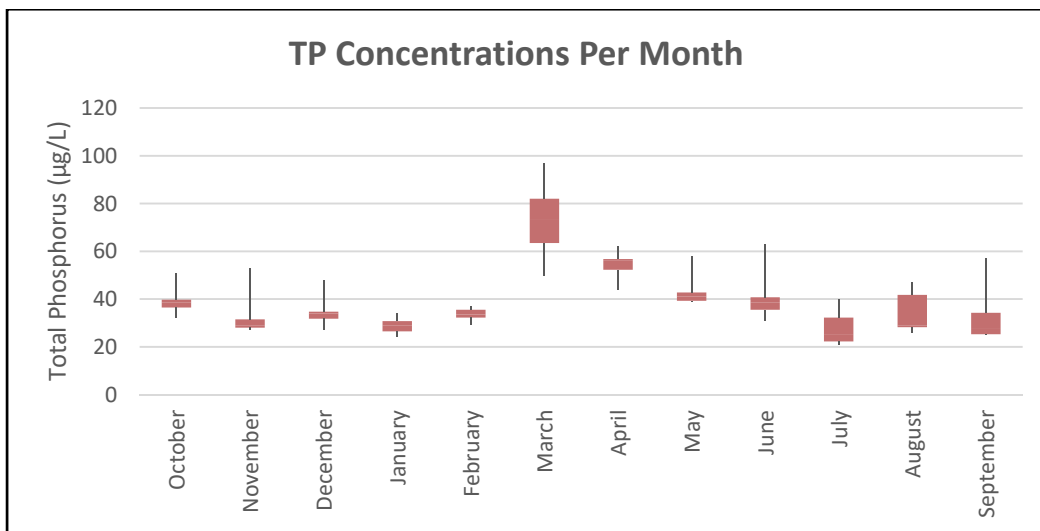
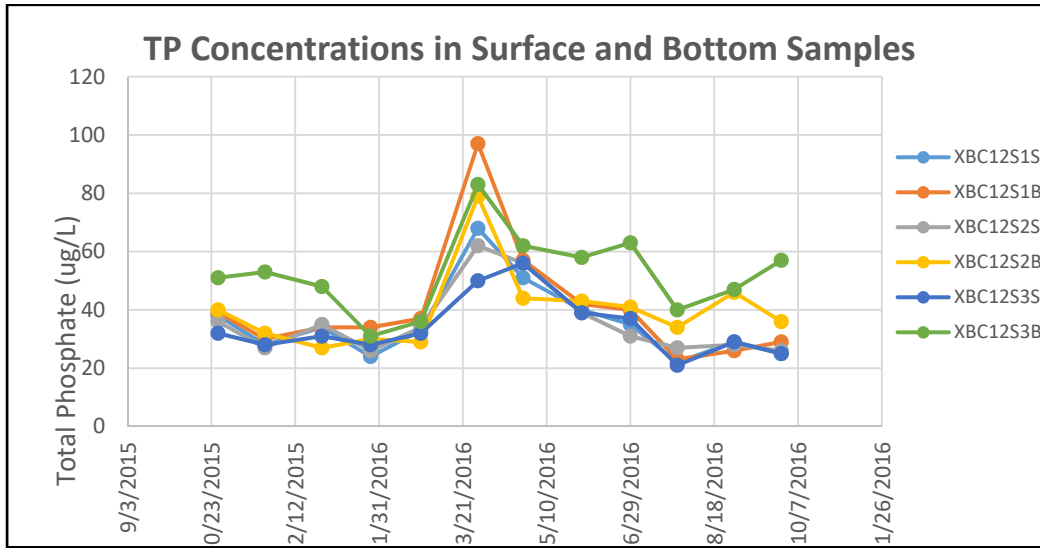
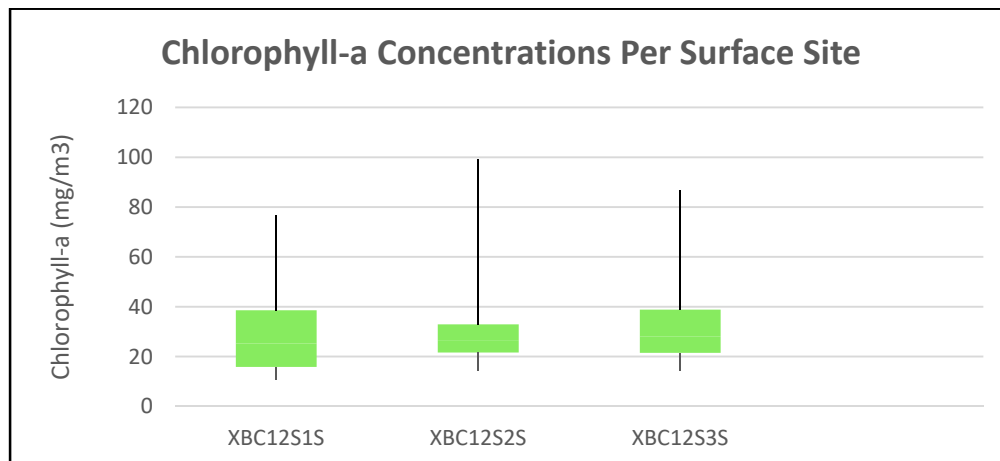
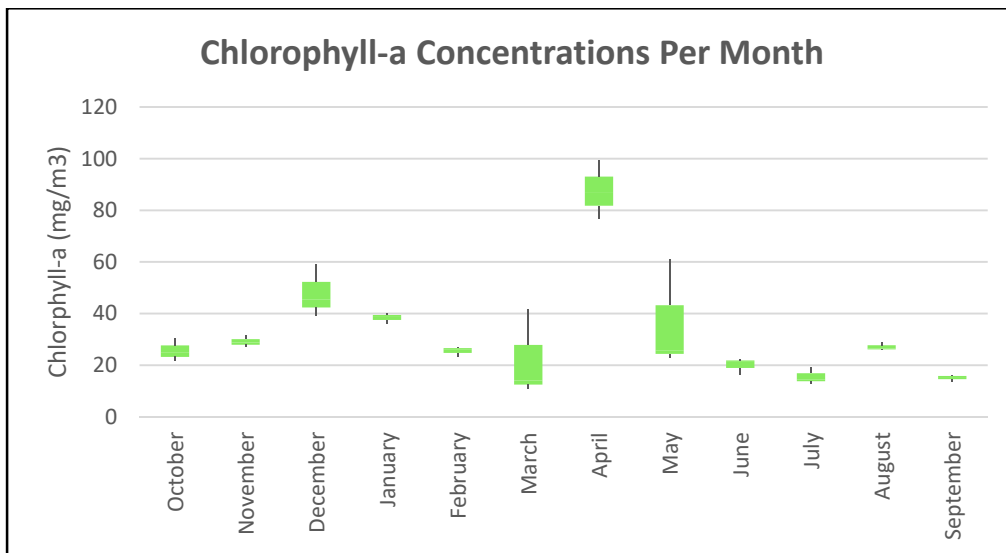
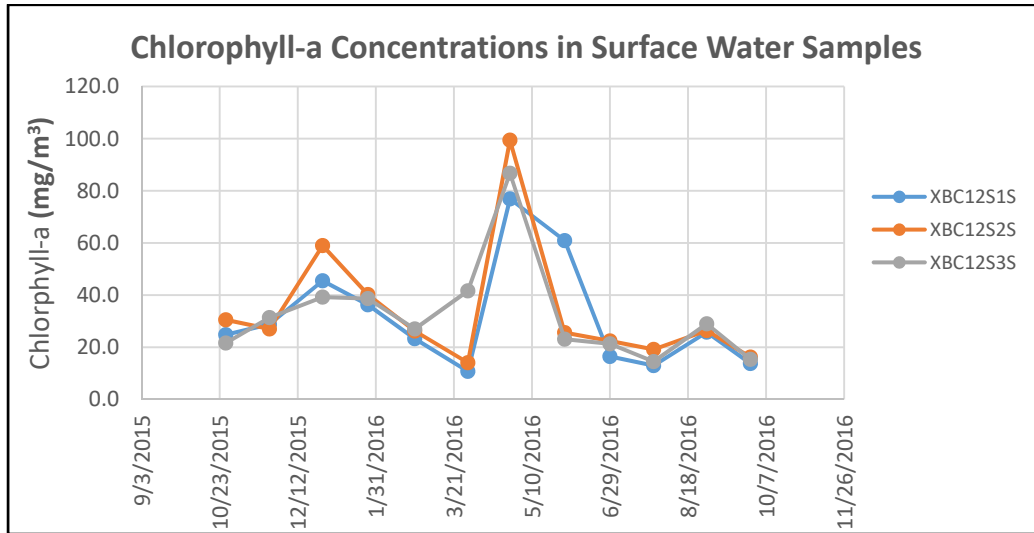
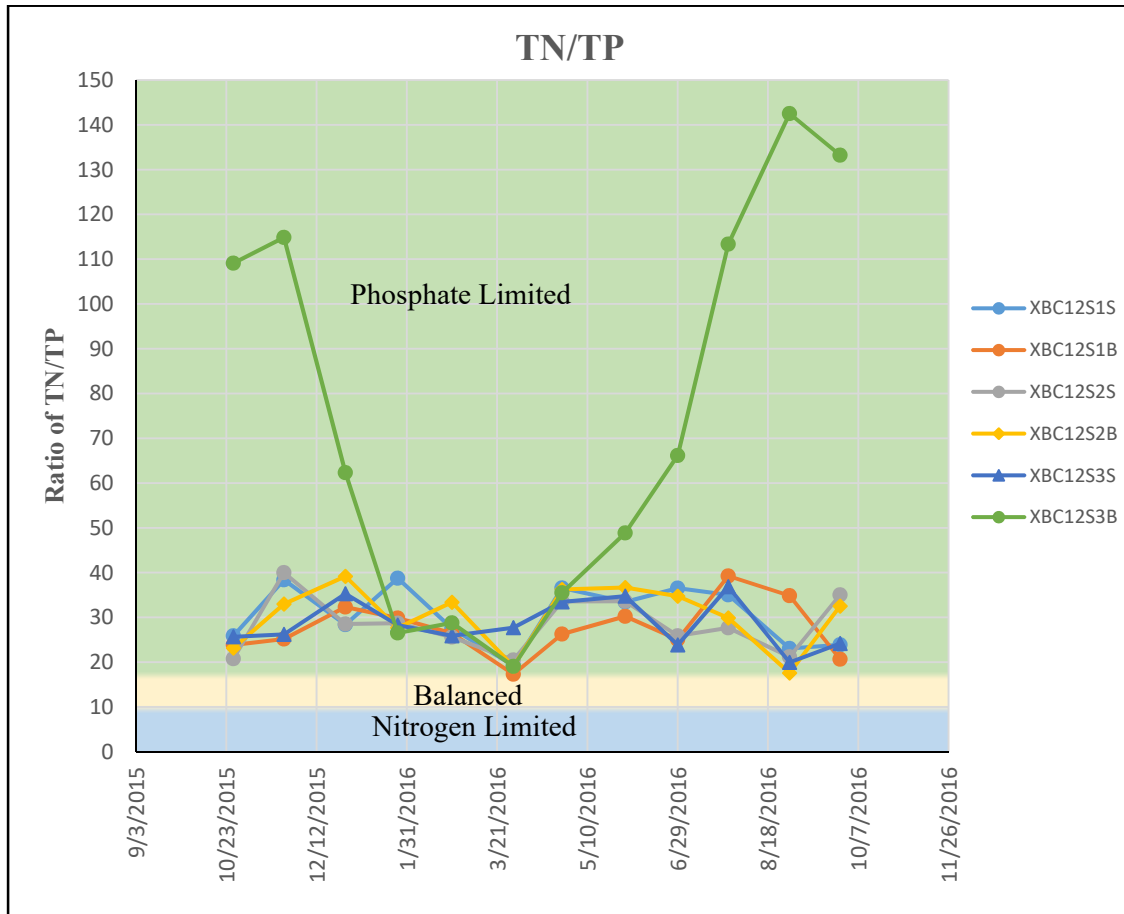


Figure 2-50: Variability in Measured Chlorophyll-a Concentrations



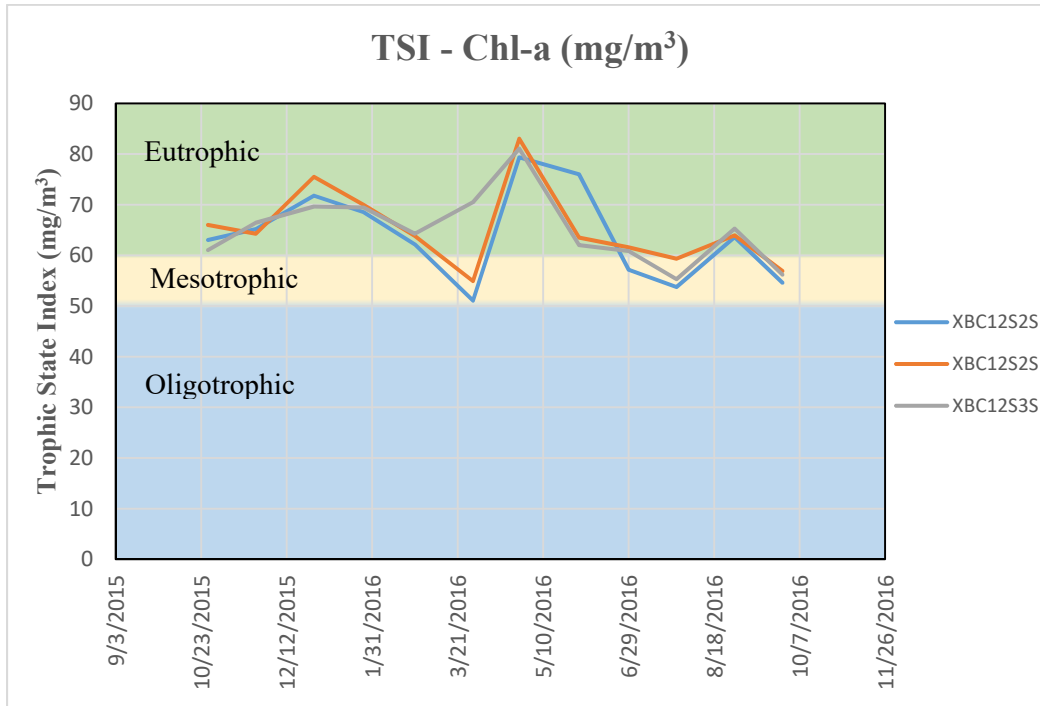
A graphical comparison of variability in TN/TP ratios at each of the monitoring sites during the field monitoring program is presented in Figure 2-51. In general, the three surface water samples and the three bottom water samples indicated that Lake Gem Mary is phosphate limited throughout the year-long study.

Figure 2-51: Ratio of TN/TP in Surface Water Samples



A graphical comparison of variability in TSI values based on chlorophyll-a at the three surface water monitoring sites during the 12-month field monitoring program is presented in Figure 2-52. The sites exhibited predominantly eutrophic conditions.

Figure 2-52: Trophic State Index (TSI) in Surface Water Samples



2.3.2.5. SUMMARY

The water quality monitoring conducted by CPWG provided monthly water quality characteristics within the surface and bottom samples of Lake Gem Mary. The historical water quality monitoring samples in Lake Gem Mary were collected primarily from the center of the lake (surface sample only). The historical water column concentrations of TN in Lake Gem Mary show an increasing trend over the last 26 years while TP concentrations show a slight decreasing trend. Chlorophyll-a concentrations show a slightly increasing trend over a 13-year period. Current data shows TN, TP and chlorophyll-a concentrations fluctuating during the 12-month study with surface concentrations showing a slight increase during the spring months.

The highest concentration of TN was observed in the deepest bottom sample (Site 3). The higher TP concentrations were observed in lake bottom samples, with peak concentrations occurring during March. The highest chlorophyll-a concentrations observed in the three lake surface samples occurred during April, the month after peak TP concentrations were observed in the lake. TN/TP ratio calculations indicate that the lake was phosphate limited during the study period. Trophic State Index calculations for the three surface sample sites ranged from mesotrophic to eutrophic conditions with values fluctuating throughout study period.

The Numeric Nutrient Criteria (NNC) was adopted by the FDEP on July 3, 2012 and updated in February 2016 to further assess the impairment of inland surface waters. The NNC establishes surface water impairment using different minimum and maximum values for TN, TP, and chlorophyll-a depending on the color of a water body. The geometric mean for color for the three surface water samples in Lake Gem Mary was 10 PCU, indicating a low color lake. The thresholds for a low color lake (≤ 40 PCU) with high alkalinity (≥ 20 mg/l as CaCO_3) are presented in Table 2-11. While the FDEP allows for an acceptable range of annual geometric means of TN and TP, the numeric interpretations for TN, TP, and chlorophyll-a cannot be exceeded more than once in any consecutive calendar three-year period. Based upon the measured concentrations during this year-long study, Lake Gem Mary is within the acceptable geometric mean for TN and TP, but exceeds the acceptable geometric mean for chlorophyll-a. NNC regulations and their relation to Lake Gem Mary is presented in Appendix D.

Table 2-11: Numeric Nutrient Criteria

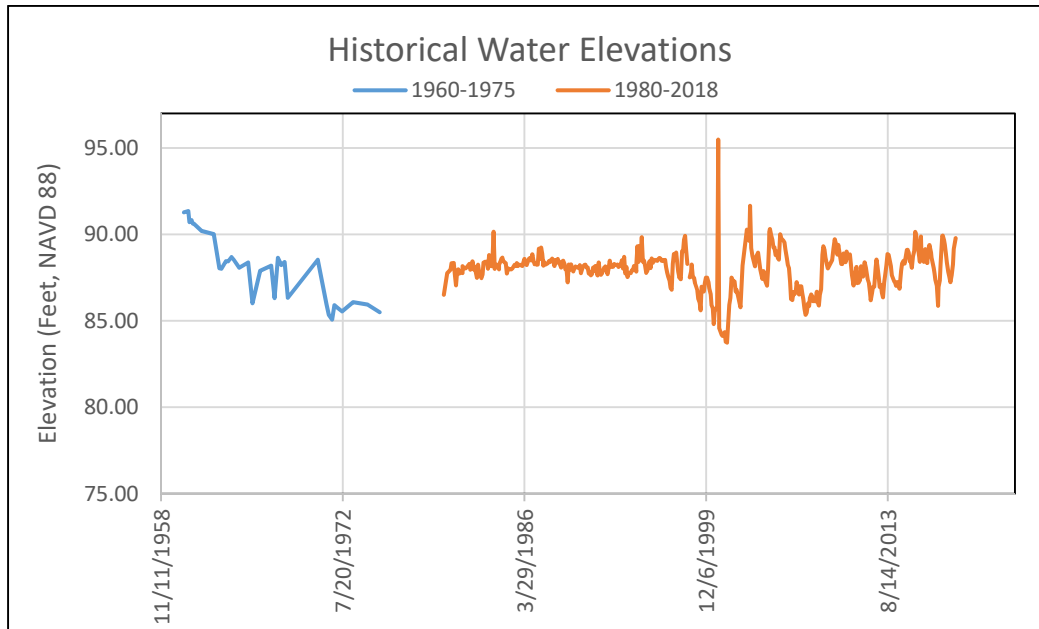
Parameter	Minimum Annual Geometric Mean	Maximum Annual Geometric Mean	Lake Gem Mary Geometric Mean*
TP (mg/l)	0.03	0.09	0.03
TN (mg/l)	1.05	1.91	0.96
Chlorophyll-a ($\mu\text{g/l}$)	N/A	20	27.9

* Based on surface sample data collected between October 2015 and September 2016

2.4. WATER LEVELS

Discharge from Lake Gem Mary is regulated by a concrete weir located on the outfall structure to Lake Gatlin at an elevation of 90.0 feet, NAVD 88 (see Figure 2-1 for outfall structure location). Historical water elevations were recorded in Lake Gem Mary from 1960 to 2018, with a 5-year gap between 1975 and 1980. A graphical summary of recorded surface water elevations available from Orange County is presented in Figure 2-53. Water Elevations in Lake Gem Mary fluctuated between 83.7 and 95.5 feet, NAVD 88, with the highest recorded elevation in 2000 and the lowest elevation recorded in 2001.

Figure 2-53: Historical Surface Water Elevations



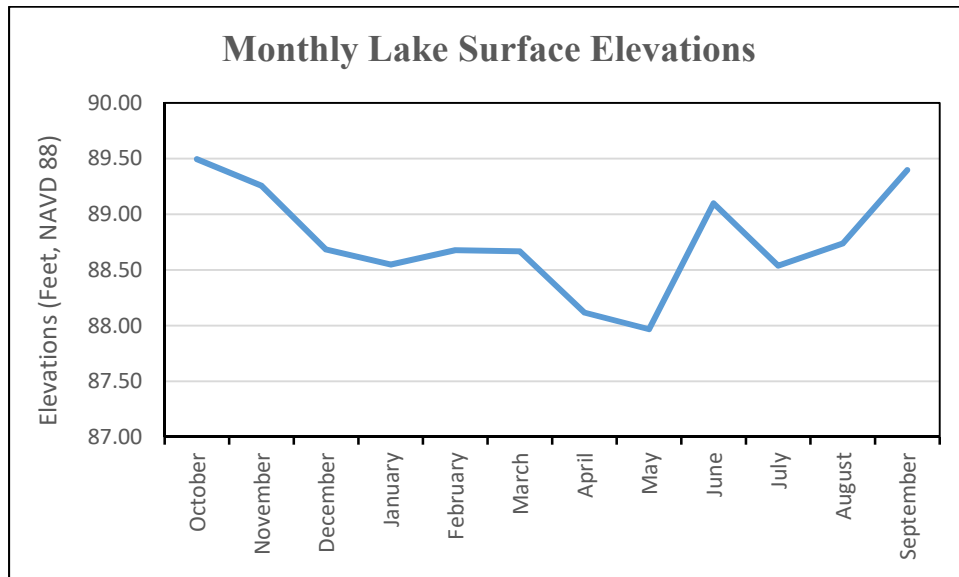
During October 2015 through September 2016, water elevation data was collected based on a disk set into a concrete flume structure on the south side of the lake and surveyed by Orange County. Water elevation data collected during the study for Lake Gem Mary is presented in Table 2-12. The monthly water elevations during the year-long study are graphically represented in Figure 2-54. Discharge from Lake Gem Mary to Lake Gatlin is controlled by a weir within an outfall structure at an elevation of 90.0 feet, NAVD 1988 (see Figure 2-1).

During the 12 monthly sampling events, there was no observed discharge of water from the Lake Gem Mary outfall structure. A site visit was performed after a large rain event during June 2016 and again in September 2016. Observations after these two rain events indicated that water elevations in the lake did not reach the elevation of the outfall weir and there was no observed discharge of water from the lake after the two storm events.

**Table 2-12: Surface Water Elevations of Lake Gem Mary
October 2015 – November 2016**

Date	Water Levels (feet – NAVD88)
	Lake Gem Mary
10/27/2015	89.50
11/24/2015	89.26
12/28/2015	88.68
1/26/2016	88.55
2/25/2016	88.68
3/30/2016	88.67
4/26/2016	88.12
5/31/2016	87.97
6/29/2016	89.10
7/27/2016	88.54
8/30/2016	88.74
9/27/2016	89.40

**Figure 2-54: Surface Water Elevations of Lake Gem Mary
December 2015 - October 2016**



3. CHARACTERISTICS OF THE LAKE GEM MARY DRAINAGE BASIN

Characteristics of the drainage basin area for Lake Gem Mary are summarized in this section, including information on drainage sub-basin delineation, topography, land use characteristics, soil types, stormwater treatment areas, and sewage disposal. A discussion of each of these elements is given in the following sections.

3.1. WATERSHED CHARACTERISTICS

Lake Gem Mary receives stormwater from the neighborhoods west, north, and east of it. The majority of the inflow from these neighborhoods is via the stormwater collection systems which each individually discharge into Lake Gem Mary. Basin delineation was performed based upon field reconnaissance, review of water management district files, discussions with area residents, and observation of drainage patterns during significant rain events. An overview of the drainage basin delineation for Lake Gem Mary is illustrated in Figure 3-1. A summary of areas discharging to Lake Gem Mary is given on Table 3-1. The sub-basins within the Lake Gem Mary drainage basin were established using the stormwater collection points; with areas that drained to the same outfall pipe being aggregated together. There was also a distinction made for areas that drained directly into Lake Gem Mary. The sub-basins were created to allow for direct comparison of the field measured values and the calculated values for parameters such as discharge volumes.

Table 3-1: Lake Gem Mary Drainage Basin Area

Basin Area (Acres)	Lake Area (Acres)	Lake to Basin Ratio
70.88	14.11	1.5

Governmental jurisdictions in the Lake Gem Mary watershed are illustrated in Figure 3-2. Jurisdiction within the watershed area is divided between the City of Orlando and unincorporated Orange County. The majority of the land surrounding Lake Gem Mary is within unincorporated Orange County with a sliver in the northeast portion of the lake falling within the limits of the City of Orlando.

Figure 3-1: Lake Gem Mary Watershed Map

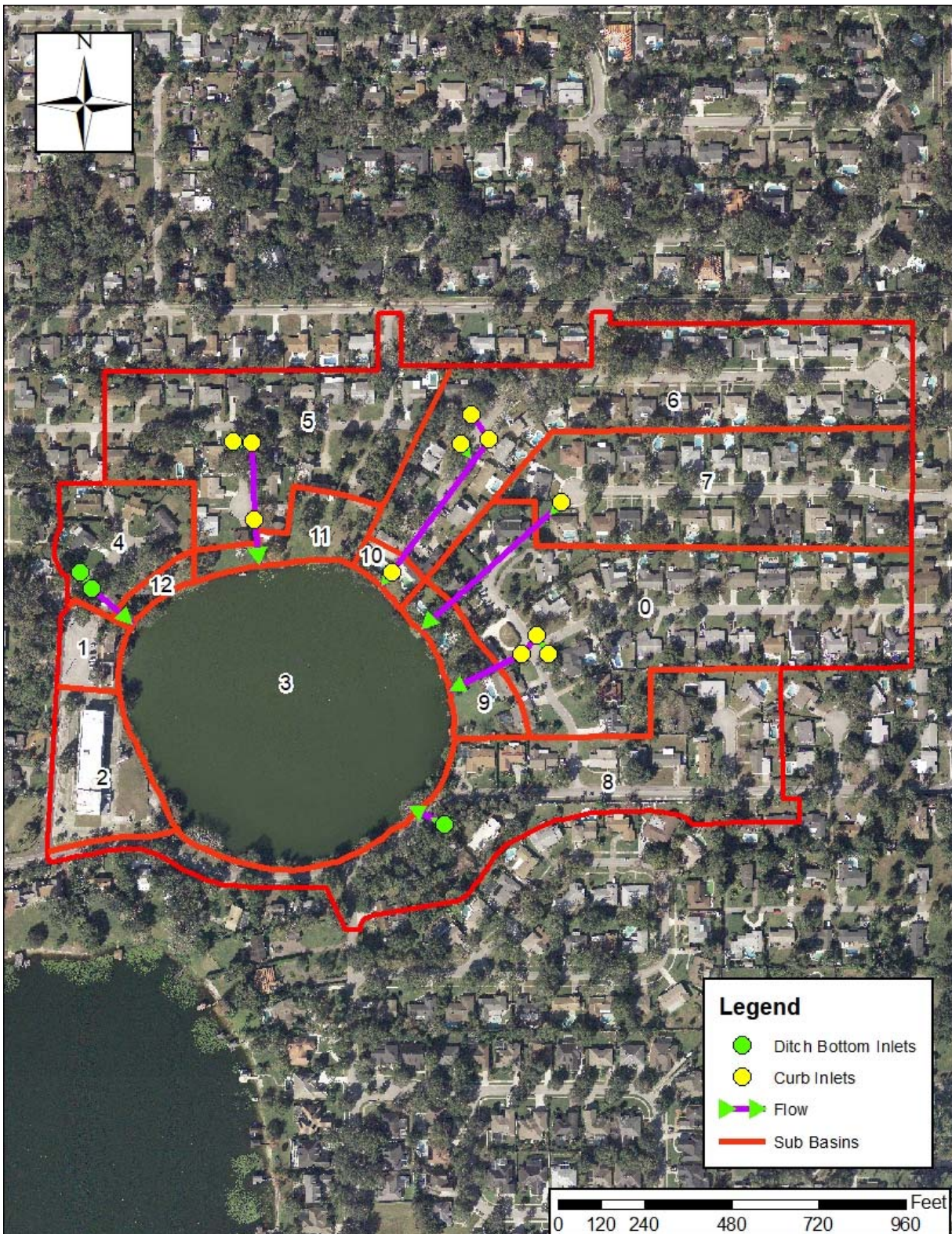
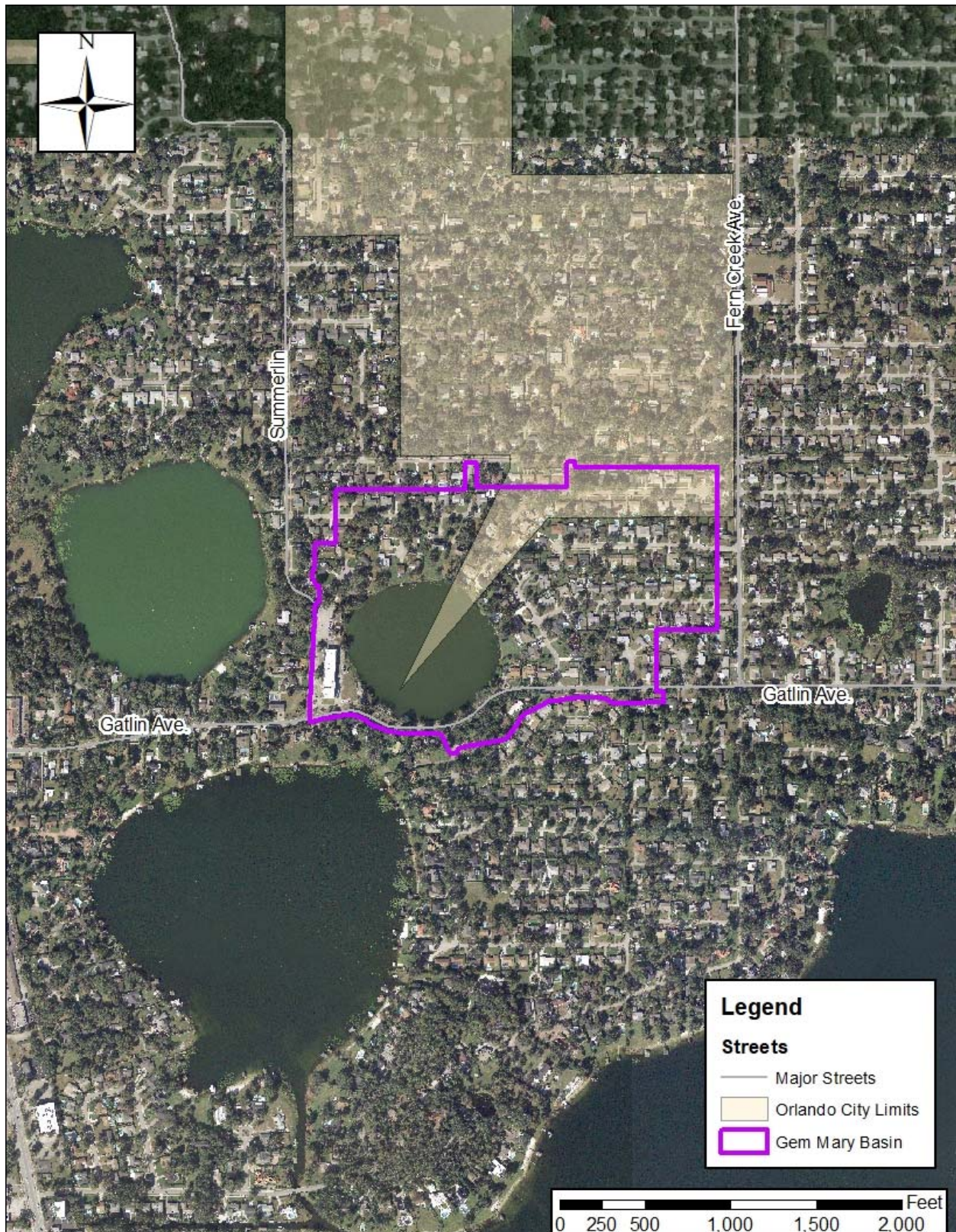


Figure 3-2: City of Orlando and Orange County Watershed Jurisdiction Map



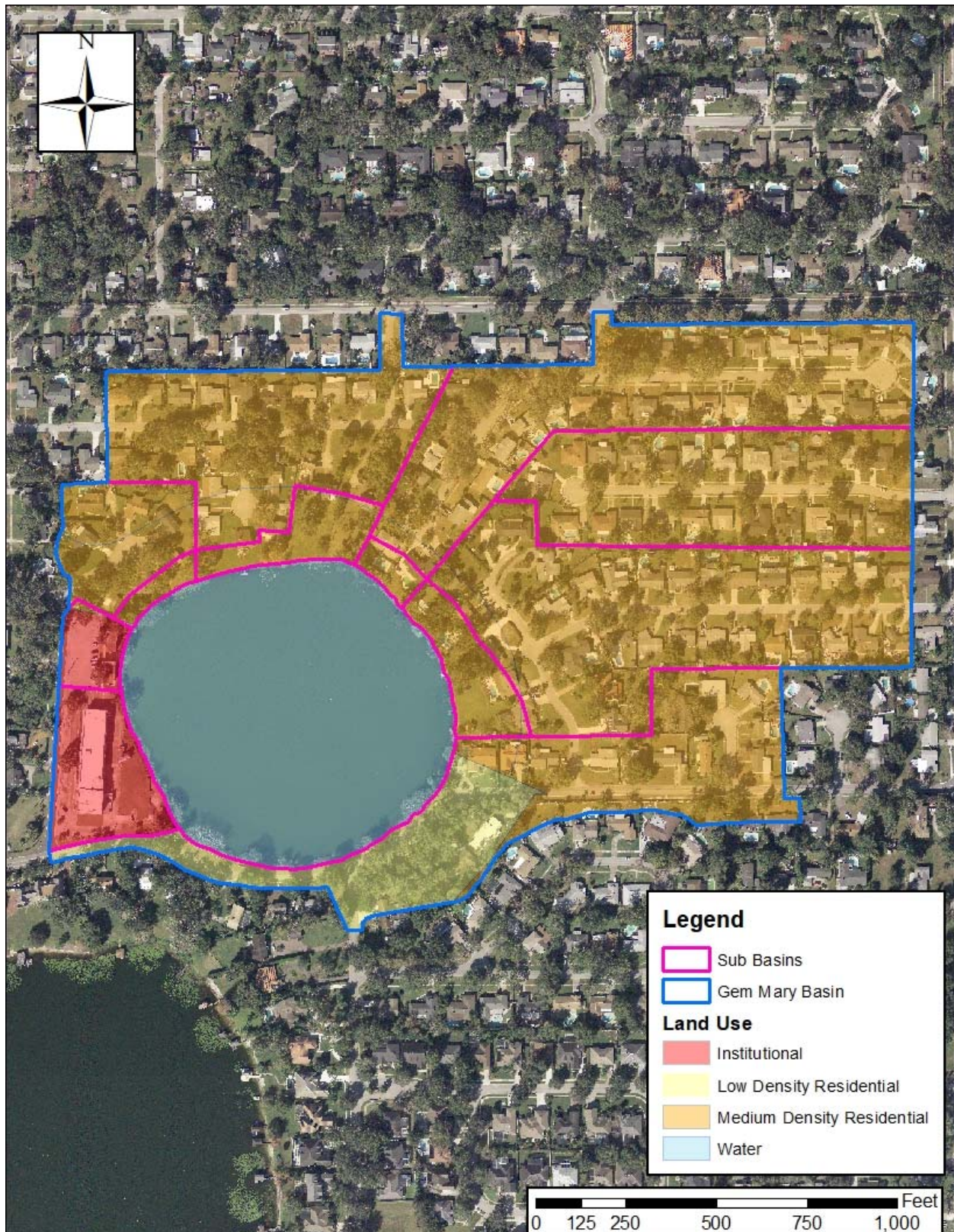
3.2. LAND USE

Land use information for the Lake Gem Mary watershed was obtained from the South Florida Water Management District's Land Cover Land Use 2008 GIS coverage. This information was used as a base map, and changes to the land use characterization data were identified using a combination of aerial photography and field reconnaissance. Land use within the basin was allocated to a series of general land use categories for which runoff characterization data are typically available. The resulting land use summary presented in Table 3-2 reflects conditions which currently exist within the Lake Gem Mary drainage basin. The dominant land use within the total watershed is medium-density residential, at about 70 percent, with water following next with approximately 20 percent. The remaining land use types account for 10 percent of the total watershed and each cover less than 6 percent of the total watershed. A breakdown of current general land use categories in the Lake Gem Mary drainage basin is presented in Figure 3-3.

Table 3-2: Land Use by Acreage and Percentage

Land use area	Area (acres)	Area (%)
Medium Density Residential	49.5	69.7%
Low Density Residential	4.0	5.7%
Institutional	3.3	4.7%
Water	14.1	19.9%
Watershed Basin Total	70.9	100.0%

Figure 3-3: Lake Gem Mary Land Use



3.3. SOILS

Information on soil types within the Lake Gem Mary drainage basin was obtained from the South Florida Water Management District GIS database. Soil information was extracted in the form of Hydrologic Soil Groups (HSG) which classifies soil types with respect to runoff-producing characteristics. Using this system, soils are classified into one of five groups for evaluation and modeling purposes. The chief consideration in each of the soil group types is the inherent capacity of bare soil to permit infiltration. A summary of the characteristics of each hydrologic soil group is given in Table 3-3.

A graphical depiction of hydrologic soil groups in drainage basin areas for Lake Gem Mary is given in Figure 3-4. A tabular summary of soil groups is given in Table 3-4. 79% of the watershed is Hydrologic Soil Group A, indicating a relatively low runoff potential.

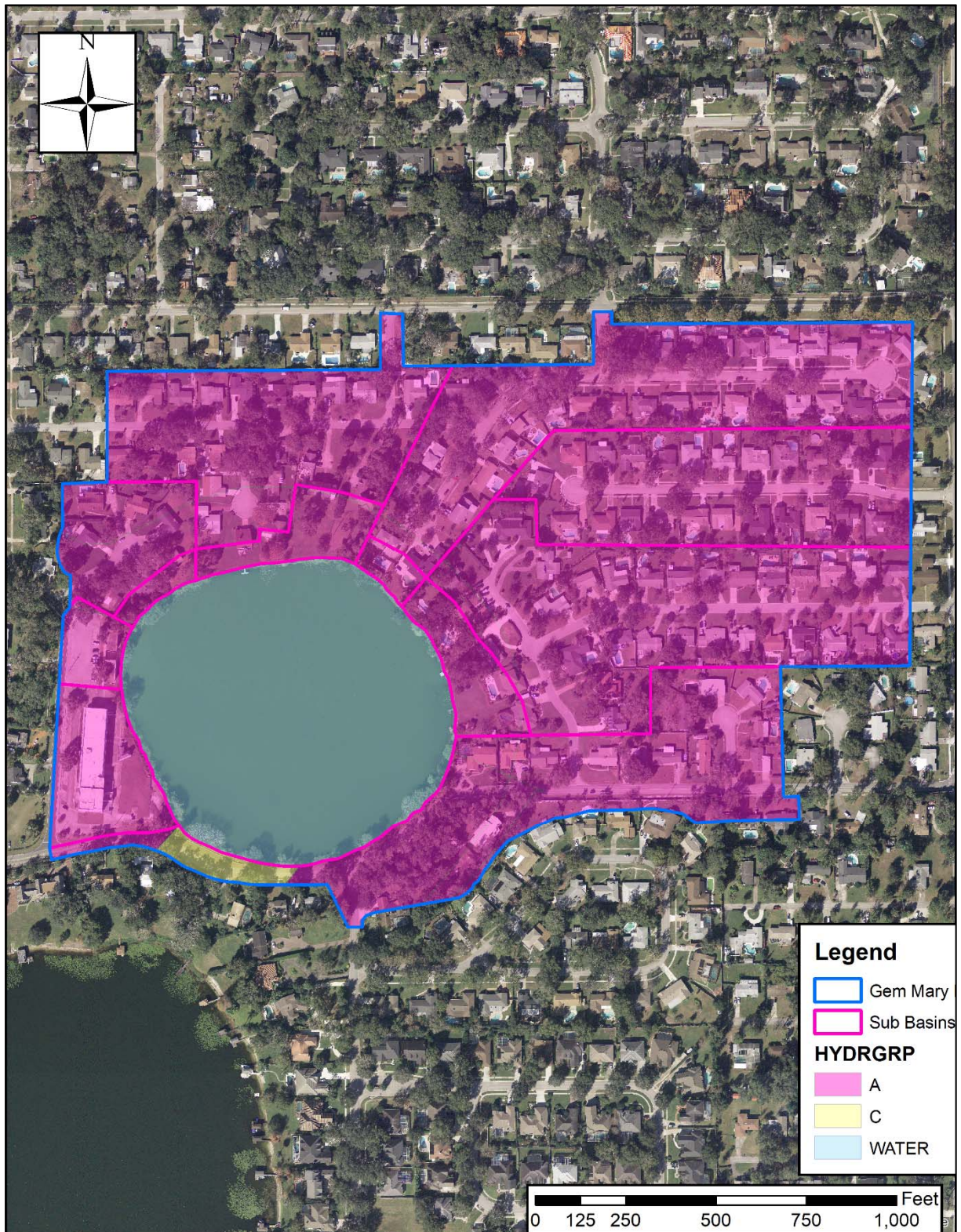
Table 3-3: Characteristics of SCS Hydrologic Soil Group Classification

Soil Group	Description	Runoff Potential	Infiltration Rate
A	Deep sandy soils	Very	High
B	Shallow sandy soils over low permeability layer	Low	Moderate
C	Sandy soil with high clay or organic content	Medium to high	Low
D	Clayey soils	Very high	Low to none
W	Wetland or hydric soils	--	--
A / D B / D	Shallow sandy soils with high water table under undeveloped conditions	Very high in undeveloped & Low in developed	Moderate - limited by water table in undeveloped condition

Table 3-4: Soils

Hydrological Soil Group	Gem Mary (acres)	Gem Mary (%)
A	56.2	79.2%
C	0.6	0.8%
W	14.1	20.0%
Watershed Basin Total	70.9	100.0%

Figure 3-4: Lake Gem Mary Soil Types



3.4. HYDROLOGIC CHARACTERISTICS

In addition to land use characteristics, information on hydrologic characteristics of the Lake Gem Mary drainage basin area was developed for use in modeling inputs of stormwater runoff. The initial step in evaluating hydrologic characteristics involved a review of the impervious area within the basin.

A composite curve number for the basin was obtained by using “Urban Hydrology of Small Watershed –TR-55” as published by United States Department of Agriculture. An intersection of land use, soils and basin data was used to develop the summary of hydrologic characteristics presented in the Appendix E.

The composite curve number value (CCN) is calculated by:

Equation 1: Composite Curve Number

$$CCN = \frac{\sum_1^n \left(CN_{n,m} * \sum_{m=1}^m Area_{n,m} \right)}{\sum_1^n \left(\sum_{m=1}^m Area_{n,m} \right)}$$

where:

CCN = Composite Curve Number,
CN_{n,m} = Curve Number for given land use, n, and HSG, m,
Area_{n,m} = area (acres) for land use, n, and HSG, m,
n = number of different land uses within the area, and
m = number of different HSGs within the area.

An area-weighted runoff coefficient is a computation that takes into account all the various land use and soil types within an area. The application determines the area associated with each land use/hydrologic soil group combination within the area, sums these up, and divides by the total area, as shown below. This value is computed for the basin.

Equation 2: Area Weighted Runoff Coefficient

$$C = \frac{\sum_{n=1}^n \left(C_{n,m} * \sum_{m=1}^m Area_{n,m} \right)}{\sum_{n=1}^n \left(\sum_{m=1}^m Area_{n,m} \right)}$$

where:

C = area-weighted runoff coefficient,
C_{n,m} = Curve Number for given land use, n, and HSG, m,
Area_{n,m} = area (acres) for land use, n, and HSG, m,
n = number of different land uses within the area, and
m = number of different HSGs within the area.

3.5. STORMWATER TREATMENT

The watershed was constructed prior to implementation of requirements for stormwater treatment systems and discharge untreated stormwater runoff directly into the lake.

3.6. SEWAGE DISPOSAL

Disposal of sanitary sewage within the Lake Gem Mary watershed occurs mostly through use of on-site sewage treatment and disposal systems (OSTDS), commonly known as septic tank systems. The portion of the watershed that falls within the City of Orlando jurisdiction appears to be on sanitary sewer. An OSTDS GIS coverage was provided by Orange County and updated using google earth and field observations. The number of OSTDS contributing nutrient load to the lake was assumed to be those systems within 300 feet of the lake and are summarized in Table 3-5. The loading from the Orange County School Board facility (previously owned by the Navy and operated as a Naval Research Facility) was assumed to be equivalent to 10 residences based on current work occupancy. Parcels with sewage disposal using OSTDS in the vicinity of Lake Gem Mary are illustrated in Figure 3-5.

An estimated 37.6 acres (66.2% of upland area) within the Lake Gem Mary watershed are covered with parcels that use OSTDS for wastewater treatment. The remaining area 19.2 acres (33.8%) of upland area appears to be serviced by City of Orlando central sewer. These areas are based upon the information illustrated in Figure 3-5.

The nutrient loading from OSTDS to receiving waterbodies is varied and is dependent on the number of people using the system, inputs to the system, water table elevation and/or groundwater

potential elevation, and soil characteristics. Several studies were reviewed to estimate the nutrient load from OSTDS including the following reports:

- The “Nutrient and Unionized Ammonia TMDLs for Lake Jesup (WBIDs 2981 and 2981A)” (March 2006) reported the nutrient load for household wastewater discharge into septic tanks as 1.46 kilograms/capita/ year for total phosphate (TP) and 4.61 kilograms/capita/year for total nitrogen (TN).
- The “Preliminary Evaluation of Septic Tank Influences on Nutrient Loading to the Lower St. Johns River and Its Tributaries” (June 2011) report concentrations of TP and TN in groundwater downstream of septic tanks to be 0.75 milligrams/liter (mg/l) and 7.687 mg/l, respectively.
- The University of Florida IFAS Extension reported 2.7 grams/capita/day of TP discharging into the septic system in “Onsite Sewage Treatment and Disposal Systems: Phosphorus” (July 2011).
- The University of Florida IFAS Extension reported 11.2 grams/capita/day of TN discharging into OSTDS in “Onsite Sewage Treatment and Disposal Systems: Nitrogen” (June 2011). These same two IFAS studies report that TP removal is generally 90% to 99% and TN removal is 10% to 50%.

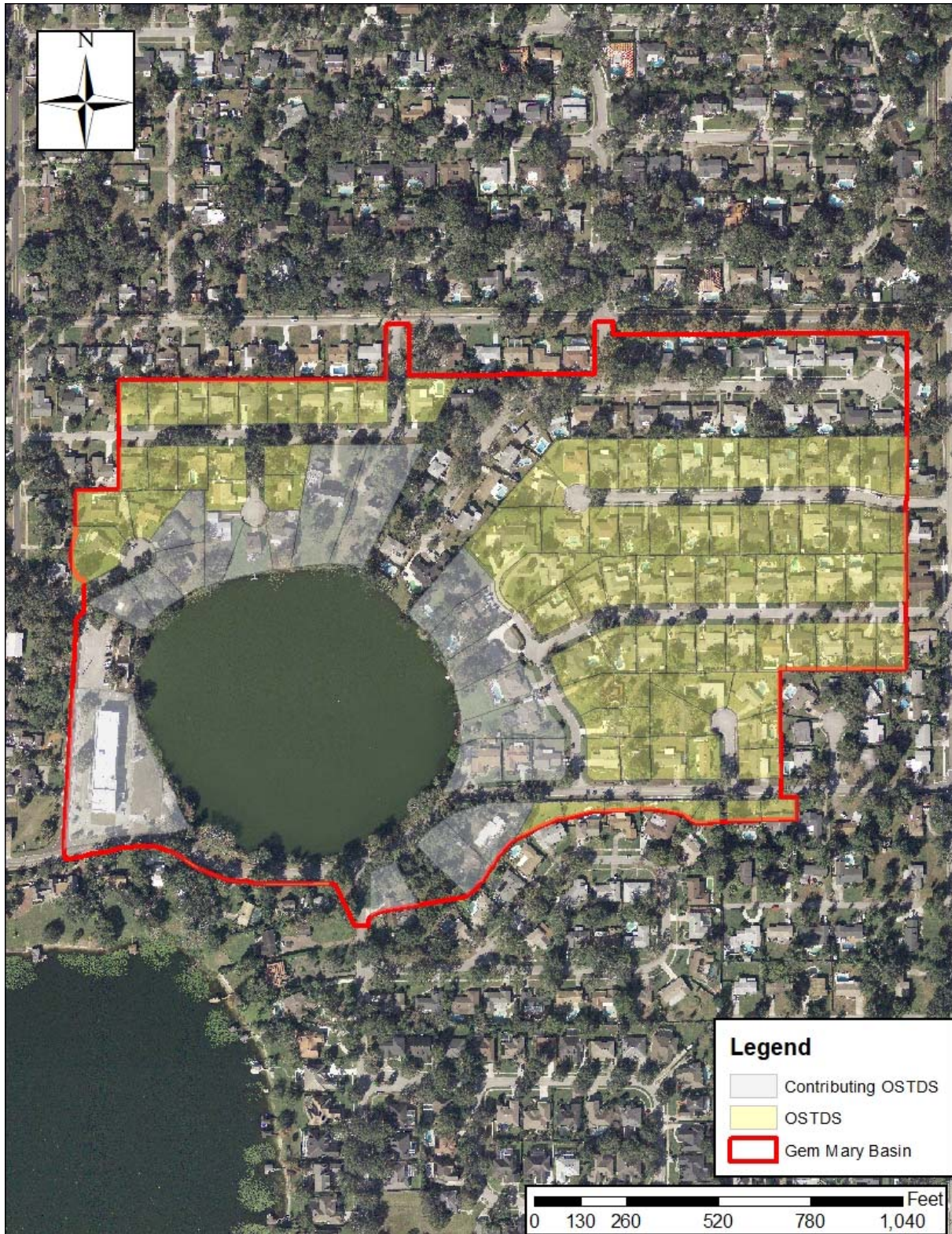
The IFAS data from 2011 is incorporated in this Study in order to estimate the nutrient pollutant load from the septic tanks located within 300 meters of the lake’s shoreline. It should be noted that current Orange County ordinances require a 150-ft septic tank setback from the normal high water elevation for all surface water bodies and 75-ft setback for the control elevation of all artificial water bodies. The assumed loading rates, removal rates and resulting nutrient loadings are averages reported by the IFAS report and are presented in Table 3-5.

The actual loading at Lake Gem Mary could be higher or lower depending on such characteristics as surrounding soil types, groundwater depths, per capita assumptions, distance of system from the shoreline, and septic system maintenance.

Table 3-5: Nutrient Loadings from Septic Tanks

Description	Lake Gem Mary
TP Loading	2.7 grams/capita/day
TN Loading	11.2 grams/capita/day
Number of OSTDS	19 houses
Equivalent OSTDS at School Board Property	10 houses
Total OSTDS	29 houses
Capita per OSTDS	2.74 people/house
TP Removal Rate	90%
TN Removal Rate	30%
TP Loading to OSTDS	78.3 Kg/year
TP Removed by OSTDS	70.5 Kg/Year
TP Loading to Lake Gem Mary	7.8 Kg/year (17.3 lbs/Year)
TN Loading to OSTDS	324.8 Kg/Year
TN Removed by OSTDS	97.4 Kg/Year
TN Loading to Lake Gem Mary	227.4 Kg/Year (501.3 lbs/yr)

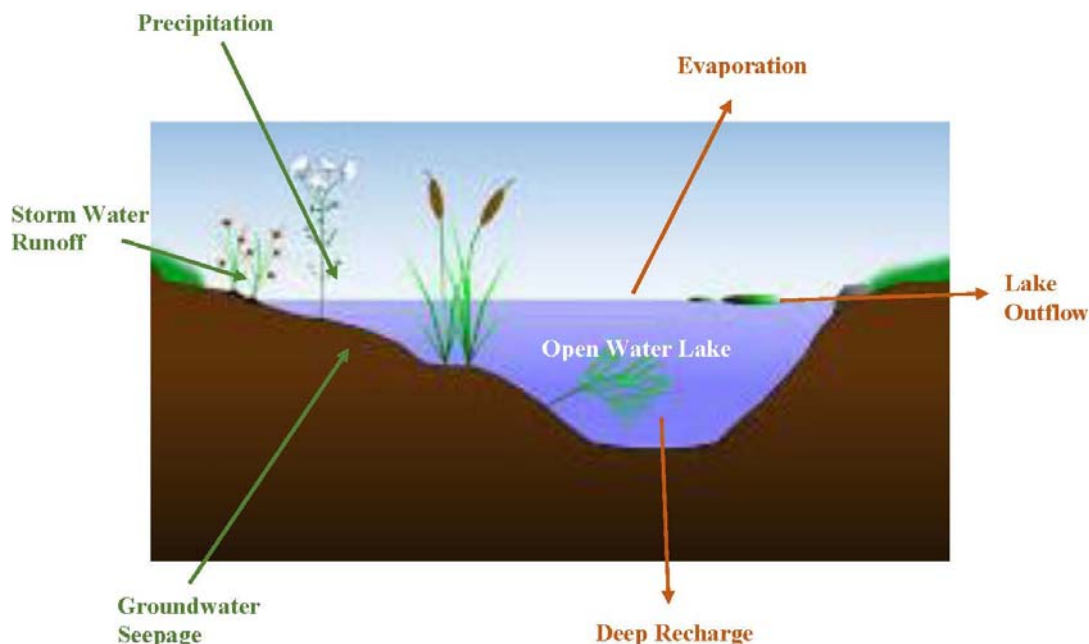
Figure 3-5: Parcels with Sewage Disposal Using On-Site Sewage Treatment & Disposal Systems



4. HYDROLOGICAL INPUTS AND LOSSES

An average annual hydrologic budget was developed for Lake Gem Mary which include inputs from direct precipitation, stormwater runoff, and groundwater seepage. Hydrologic losses are estimated for evaporation, deep recharge, and discharges through the outfall structure between Lake Gatlin and Lake Gem Mary (during the year-long study, water was not observed to overflow from Lake Gem Mary). In order to create the average annual hydrological budget, a computer model of the Lake Gem Mary watershed was first created. This model was then calibrated based upon the actual field measurements captured during the study. By adjusting the monthly delivered runoff volumes from monthly rainfall totals to match the measured volumes for the same rainfall events the computer model was calibrated. The calibrated model was then used to generate an average annual hydrologic budget. The hydrologic budget is used as an input for development of a nutrient budget as well as estimation of hydraulic residence time. A conceptual schematic of evaluated hydrologic inputs and losses in Lake Gem Mary is given in Figure 4-1. A discussion of identified hydrologic inputs and losses for Lake Gem Mary is given in the following sections.

Figure 4-1: Conceptual Schematic of Evaluated Hydrologic Inputs and Losses for Lake Gem Mary



4.1. HYDROLOGIC INPUTS

4.1.1. DIRECT PRECIPITATION

4.1.1.1. RAINFALL CHARACTERISTICS

Hydrologic inputs from direct precipitation to Lake Gem Mary are calculated based upon historical geometric mean monthly precipitation for the Lake Gem Mary area as provided by weather stations utilized by the South Florida Water Management District (SFWMD). The closest weather station is located at Orlando International Airport (MCO) which about 5 miles from the lake. A summary of average monthly rainfall near Lake Gem Mary is presented in Table 4-1. Mean monthly rainfall depths range from a low of 1.7 inches during November to a high of 8.1 inches in June, with an annual total of 51.2 inches.

Table 4-1: Summary of Average Monthly Rainfall, Recorded at Orlando International Airport (OIA) from 1991-2014

Month	Rainfall Depth (inches)
January	2.5
February	2.1
March	3.3
April	2.8
May	3.9
June	8.1
July	7.3
August	7.5
September	6.0
October	3.7
November	1.7
December	2.3
TOTAL	51.2

A rain gauge was installed at the western edge of Lake Gem Mary as part of this study. Rainfall data was collected from November 2015 to October 2016. The results in this data collected are presented in Table 4-2. The November 2015 to October 2016 rainfall was a higher rainfall period. It is 2.9 inches (5.6%) more than the MCO long-term mean total annual rainfall.

Table 4-2: Summary of Monthly Rainfall Collected in a Rain gauge installed at Lake Gem Mary from November 2015 to October 2016

Month	Rainfall Depth (inches)
November	0.14
December	0.65
January	6.73
February	1.39
March	4.14
April	1.72
May	6.61
June	9.79
July	1.39
August	9.49
September	7.45
October	4.53
Total	54.03

4.1.1.2. HYDROLOGICAL INPUTS

Estimated monthly hydrologic inputs from direct precipitation into Lake Gem Mary were calculated by multiplying the mean monthly rainfall at Lake Gem Mary (as summarized in Table 4-1) times the assumed lake surface area of 14.11 acres for Lake Gem Mary. A summary of estimated mean monthly hydrologic inputs to Lake Gem Mary from direct precipitation is given in Table 4-3. During an average annual rainfall year, direct precipitation contributes approximately 60.19 acre-feet of water to Lake Gem Mary. During the 2015-2016 study period the direct precipitation contributed 63.53 acre-feet.

Table 4-3: Estimated Mean Monthly Hydrologic Input to Lake Gem Mary from Direct Precipitation

Month	Monthly Rainfall (inches)¹	Hydrologic Inputs (ac-ft/month)
January	2.5	2.93
February	2.1	2.44
March	3.3	3.84
April	2.8	3.29
May	3.9	4.58
June	8.1	9.56
July	7.3	8.55
August	7.5	8.82
September	6.0	7.09
October	3.7	4.35
November	1.7	2.00
December	2.3	2.74
TOTALS	51.2	60.19

¹ 1991-2014 Rainfall Average

4.1.2. STORMWATER RUNOFF

Estimates of hydrologic inputs to Lake Gem Mary from stormwater runoff were calculated based upon the average rainfall data from OIA. The Lake Gem Mary watershed was divided into sub-basins based on observed runoff collection by stormwater infrastructure and on local topography, as shown in Figure 4-2. Sub-basin data was used for the purpose of developing both the hydrologic and nutrient budgets for the lake. Details of evaluation methods and results of the runoff modeling efforts are described in the following sections.

4.1.2.1. COMPUTATION METHODS

Estimates of volumetric inputs of stormwater runoff were generated for the areas discharging into Lake Gem Mary. The estimated runoff volumes were calculated for average annual rainfall conditions based upon hydrologic modeling of individual rain events. A runoff simulation model was developed and the historical rainfall data were used as the precipitation input data. This model provides an estimate of runoff inputs to Lake Gem Mary based on average rainfall conditions over the period from 1991-2014.

The SCS curve number methodology was used to provide estimates of the runoff volumes generated within the drainage basin area for the measured rain events from 1991-2014. The SCS methodology utilizes the hydrologic characteristics of the drainage basin, including impervious area, directly

connected impervious area, and soil curve numbers to estimate runoff volumes for modeled storm events. Hydrologic characteristics of the basin areas were determined based upon aerial photography and a field reconnaissance of the watershed areas. This information was previously discussed in Section 3 of this report.

After estimating the hydrologic characteristics of each basin area, the runoff volume is calculated by adding the rainfall excess from the non-directly connected impervious area (non-DCIA) portion of the watershed to the rainfall excess created from the DCIA portion of the watershed. Rainfall excess from the non-DCIA areas is calculated using the following set of equations:

$$\text{Soil Storage, } S = \left\{ \frac{1000}{n_{DCIA} CN} - 10 \right\}$$

$$n_{DCIA} CN = \frac{[CN * (100 - IMP) + 98 (IMP - DCIA)]}{100 - DCIA}$$

$$Q_{nDCIAi} = \frac{[(P_i - 0.2S)^2]}{[(P_i + 0.8S)]}$$

Where:

CN	=	Curve number for pervious area
IMP	=	Percent impervious area
DCIA	=	Percent directly connected impervious area
$n_{DCIA} CN$	=	Curve number for non-DCIA area
P_i	=	Rainfall event depth (inches)
Q_{nDCIAi}	=	Rainfall excess for non-DCIA for rainfall event (inches)

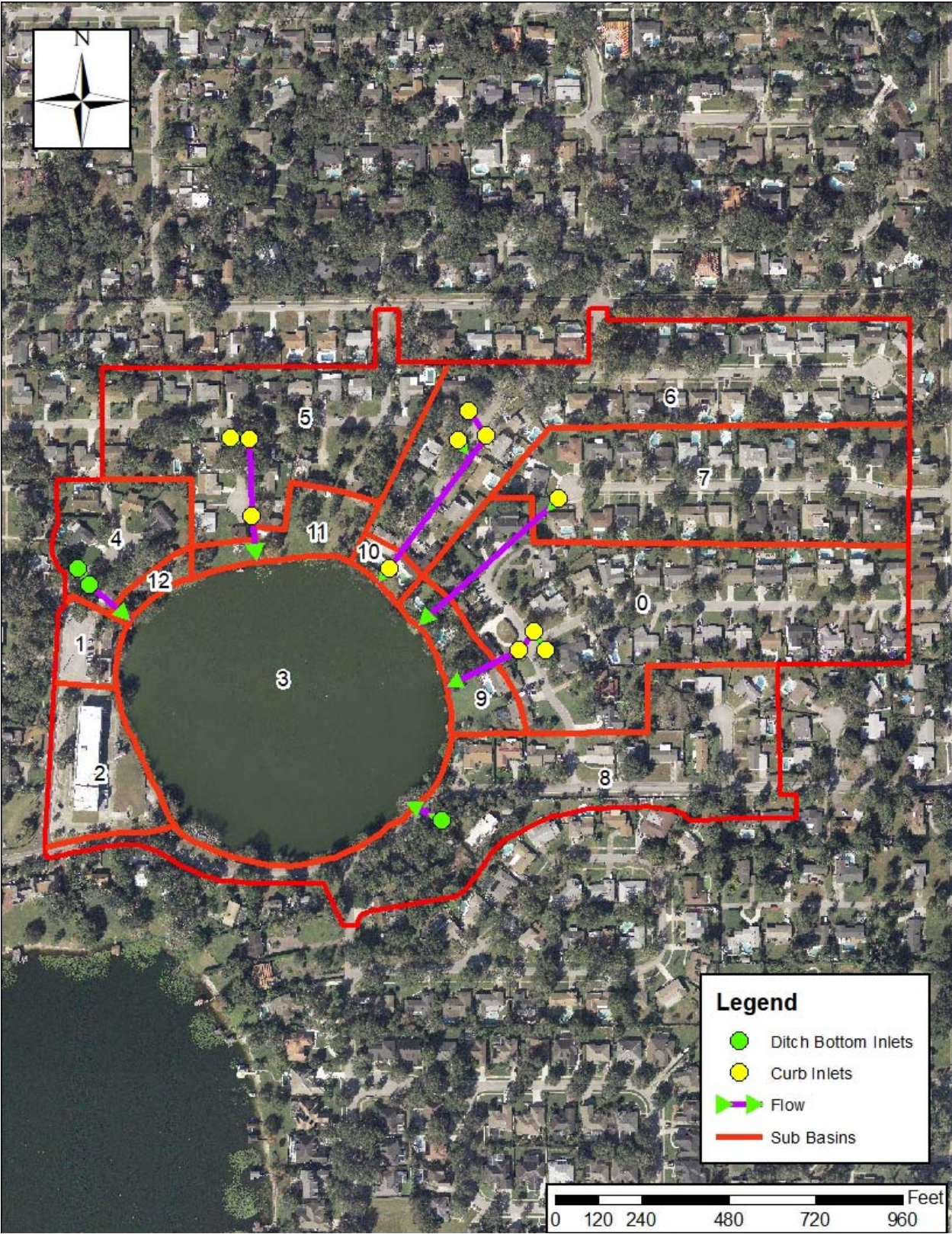
For the DCIA portion, rainfall excess is calculated using the following equation:

$$Q_{DCIAi} = (P_i - 0.1)$$

When P_i is less than 0.1, Q_{DCIAi} is equal to zero.

The methodology outlined above provides an estimate of the “generated” runoff volume for rainfall events in the basin over the 13-year period from 1991-2014. Given that the sub-basins within the Lake Gem Mary all discharge to the lake, the generated runoff would be equal to the delivered runoff. The sub-basins within the Lake Gem Mary watershed are presented in Figure 4-2.

Figure 4-2: Lake Gem Mary Sub-Basins with Stormwater Pipes



4.1.2.2. LAKE GEM MARY STORMWATER RUNOFF

A summary of estimated average annual runoff volumes which discharge into Lake Gem Mary are presented in Table 4-4. The generated runoff volume represents the modeled runoff volume within each sub-basin. Estimates of the generated and observed runoff coefficients (C value) are also provided for each drainage sub-basin. Shown in Table 4-5 is the calculated delivered runoff in acre-ft and percent total run off; aggregated by land use.

Table 4-4: Average Annual Runoff (1991-2014)

Delivered Runoff	22.42 ac-ft
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Table 4-5: Calculated Delivered Runoff (acre-ft) and Percentage of Total Generated Run off

Land Use Type	Volume (ac-ft)	Percent of Total
Low Density Residential	0.61	2.7%
Medium Density Residential	15.42	68.8%
Institutional	6.39	28.5%
Watershed Basin Total	22.42	100.0%

4.1.3. SHALLOW GROUNDWATER SEEPAGE

Field investigations were performed by to evaluate the quantity and quality of shallow groundwater seepage entering Lake Gem during the monitoring period from December 2015-January 2017. 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 estimated methods can only provide information on water quantity.

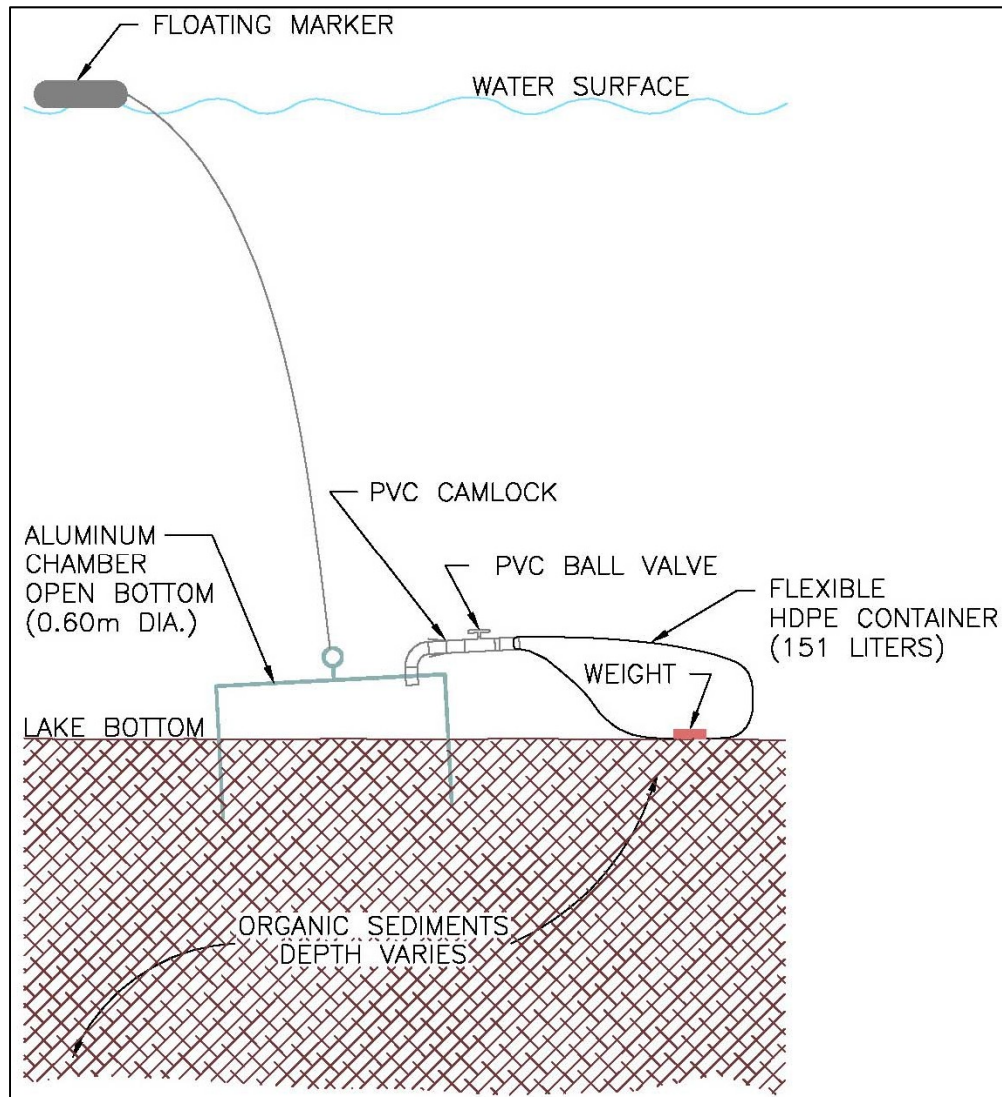
4.1.3.1. SEEPAGE METER CONSTRUCTION AND LOCATIONS

A schematic of a typical seepage meter installation used in Lake Gem Mary is given in Figure 4-3. Seepage meters were constructed from a 2-foot diameter aluminum container with a closed top and open bottom. Each seepage meter isolated a sediment area of approximately 3.14 ft². Seepage meters were inserted into the lake sediments to a depth of approximately 8-12 inches, 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. The 0.75- inch PVC fitting was 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. Light could potentially stimulate photosynthetic activity within the sample prior to collection and result in an undesirable alteration of the chemical characteristics of the sample.

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.

Figure 4-3: Typical Seepage Meter Installation



Note: Figure for seepage meter setup was prepared by ERD

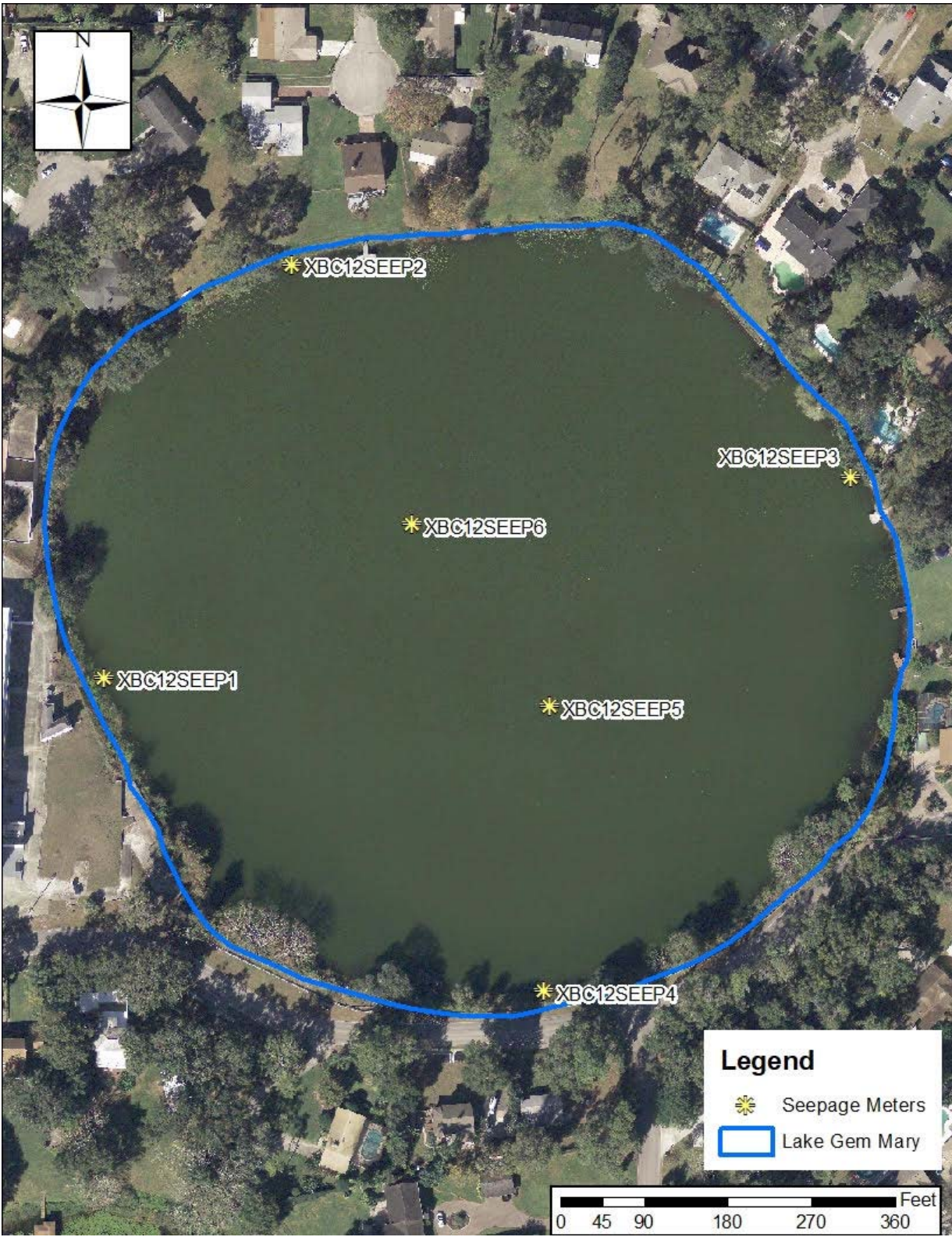
Each seepage meter was installed with a slight tilt toward the outlet point so that any gases which may be generated inside the seepage meter would exit into the collection container. A plastic-coated fishing weight was placed inside each of the collection bags to prevent the bags from floating up towards 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.

Six seepage meters were installed in Lake Gem Mary in December 2015. Locations for the seepage meters are indicated in Figure 4-4. Seepage inflow rates are often highest along the perimeter of a lake; therefore, the majority of the seepage meters in Lake Gem Mary were installed around the perimeter of the lake at a uniform water depth of approximately 5 feet. Seepage meters were also

installed in central portions of the lake at a depth of approximately 27 to 30 feet below the lake's surface.

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 2015-January 2017. During the initial monitoring event, the volume of seepage collected was recorded, and 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. Nine separate seepage monitoring events were conducted for evaluation of seepage quantity, with eight events conducted to evaluate seepage quality at each of the monitoring sites. Seepage meter XBC12SEEP3 was reinstalled in January, and therefore the first data record at this site was lost. A total of 47 samples were collected between the 6 sites over the duration of the monitoring program. The location of the replacement meter XBC12SEEP3 is approximated, since the typical buoy at the surface was not installed. The buoy was omitted due to security concerns for the meter.

Figure 4-4: Seepage Meter Locations



4.1.3.2. SEEPAGE METER SAMPLING PROCEDURES

After the initial installation of collection bags, site visits were performed at monthly (or bi-monthly) 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.

The first collected seepage sample was measured for volume and discarded due to potential for lake water mixing during the installation process. Following the initial purging, seepage meter samples were measured for total volume and collected for return to the laboratory for chemical analysis. On many occasions, seepage meter samples were turbid due to 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 and placed on ice for return to the laboratory for chemical analyses.

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 replacement/repair details.

A summary of seepage meter field measurements collected during the monitoring period from December 2015 through January 2017 is presented in the Appendix F. The data shows that Site XBC12SEEP3 contains missing data during March 2016 as a result of a missing or damaged seepage meter.

4.1.3.3. SEEPAGE INFLOW

A statistical summary of seepage inflow measurements is presented in Table 4-6. The seepage inflow at each meter location is calculated by dividing the total collected seepage volume (liters) by the total number of days during which the seepage sample was collected. The seepage inflow is then calculated by the area of the seepage meter to determine the inflow rate per square foot. The geometric mean

(geomean) seepage inflow rates measured in Lake Gem Mary during the study period ranged from 0.02 to 0.157 liters/day-ft², assuming that each meter has an area of 3.14 ft².

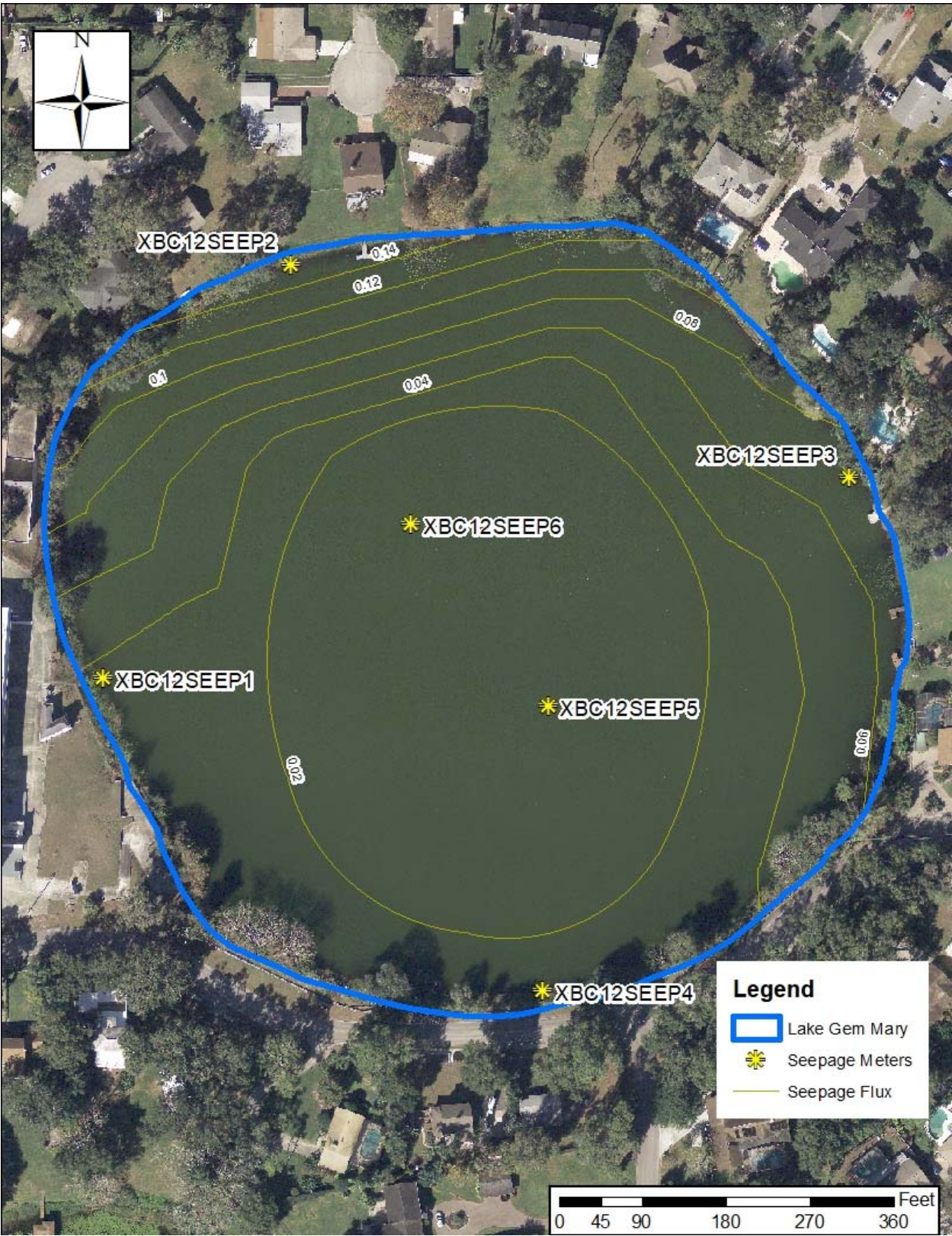
Table 4-6: Statistical Summary of Seepage Inflow Measurements (L/day) in Lake Gem Mary December 2015 - January 2017

Seepage Meter	Meter Depth (feet)	Volume Rate (liters per day)									GeoMean per Area (L/ft ² -day)
		1/29/2016	3/31/2016	6/3/2016	6/27/2016	7/31/2016	8/31/2016	9/30/2016	11/30/2016	1/25/2017	
XBC12SEEP1	5	0.076	0.060	0.066	0.219	0.316	0.177	0.183	0.041	0.094	0.035
XBC12SEEP2	5	0.569	1.544	0.414	0.531	0.485	0.524	1.683	0.086	0.241	0.157
XBC12SEEP3	5	0.257	N/A	0.105	0.177	0.890	1.234	0.425	0.057	0.049	0.071
XBC12SEEP4	5	0.063	0.198	0.117	0.146	0.390	0.024	0.042	0.012	0.027	0.021
XBC12SEEP5	27	0.243	0.105	0.020	0.073	0.051	0.113	0.042	0.078	0.067	0.023
XBC12SEEP6	30	0.160	0.052	0.020	0.052	0.051	0.105	0.042	0.107	0.063	0.020

N/A – Meter was damaged or missing and had to be replaced

The geomean seepage inflow rates are summarized in Table 4-6. The inflow rates were linked with the geographic coordinates for each site to generate an isopleth contour map for the geomean seepage inflow across the lake and is presented in Figure 4-5. A mix of GIS spatial analyst interpolation tools were used to create the contour maps presented in the report.

Figure 4-5: Lake Gem Mary Isopleths of Geomean Seepage Inflow Rates (Liters/ft²-day)



The highest observed seepage rates in the lake are 0.157 L/ft²-day and 0.071 L/ft²-day, and were observed at XBC12SEEP2 and XBC12SEEP3 along the north and east perimeters of the lake, respectively. The seepage rates along the south and west perimeters, and the deep portion of the lake have a relatively low seepage rate when compared to sites XBC12SEEP2 and XBC12SEEP3. The area of the lake with a seepage rate of approximately 0.020 to 0.035 liter/day-ft² is approximately 8.92 acres. The remaining area of the lake, approximately 5.19 acres, has a seepage rate between 0.021 and 0.023 L/day/ft²-day.

The seepage isopleths shown on Figure 4-5 were graphically integrated to obtain estimates of daily seepage influx into Lake Gem Mary. A summary of the results of this analysis is presented in Table 4-7. The aerial average of the geometric mean for seepage influx to Lake Gem Mary based on the field monitoring program was 0.044 liters/ft²-day. When multiplied by the lake's area, the resulting inflow flux volume is 0.022 ac-ft/day or 7.944 ac-ft/yr.

Table 4-7: Estimated Seepage Inflow to Lake Gem Mary from December 2015 - January 2017

Parameter	Units	Value
Lake Area	acres	14.11
Seepage Flux	liters/ft ² -day	0.044
Seepage Flux Over Lake Area	ac-ft/day ac-ft/year	0.022 7.944
Seepage/Surface Area Ratio	ft/yr	0.563

4.2. HYDROLOGIC LOSSES

Hydrologic losses from Lake Gem Mary occur as a result of evaporation from the lake surface, discharge through the outfall structure, and discharge from deeper portions of the lake bottom to underground aquifers. Estimated losses from each of these sources are discussed in the following sections.

4.2.1. EVAPORATION LOSSES

Estimates of monthly evaporation from Lake Gem Mary were generated based upon mean monthly evaporation data collected at the US Weather Bureau Lisbon Station over the 65-year period from 1948-2012. The Lisbon Station is at Burrell Lock and Dam on Haines Creek near Fruitland Park, Florida, approximately 37 miles northwest of Lake Gem Mary and appears to be the closest long-term evaporation monitoring site to the Central Florida area. A summary of mean monthly potential

evaporation (PET) for this site is presented in Table 4-8. For purposes of this project, the mean evaporation measured at the Lisbon site is assumed to be similar to evaporation at Lake Gem Mary.

Table 4-8: Mean Monthly Lake Evaporation at Lisbon Experimental Station Site

Month	Mean Pan Evaporation (inches)
January	2.50
February	2.88
March	4.31
April	5.28
May	6.30
June	6.26
July	6.34
August	5.86
September	4.70
October	3.75
November	2.76
December	2.34
Total	53.29

A summary of estimated evaporation losses from Lake Gem Mary is presented in Table 4-9. The values summarized in this table were obtained by multiplying the lake surface area of 14.11 acres by the estimated monthly lake evaporation values. Lake evaporation in Lake Gem Mary ranges from 2.76 ac-ft/month in December to 7.45 ac-ft/month in July. Overall, evaporation losses from Lake Gem Mary remove approximately 62.66 ac-ft of water each year.

Table 4-9: Estimate of Annual Hydrologic Losses from Surface Evaporation

Month	Lake Evaporation (inches)	Lake Evaporation (ac-ft)
January	2.5	2.94
February	2.88	3.39
March	4.31	5.07
April	5.28	6.21
May	6.3	7.41
June	6.26	7.36
July	6.34	7.45
August	5.86	6.89
September	4.7	5.53
October	3.75	4.41
November	2.76	3.25
December	2.35	2.76
Total	53.29	62.66

4.2.2. OUTFALL STRUCTURE

Discharge from Lake Gem Mary occurs through an outfall structure with a concrete weir that controls water elevations in the lake. Overflow from Lake Gem Mary discharges through the outfall structure and connecting culverts to Lake Gatlin. During the 12 monthly sampling events, water was not observed to flow over the weir within the outfall structure. After several large rain events, field visits to the outfall structure were performed. Observations after the rain events also indicated that water was not discharging from Lake Gem Mary.

4.2.3. DEEP RECHARGE

Lake Gem Mary is characterized by 15 feet of sediment in the deeper locations of the lake. The seepage meters placed in the top sediment layer measured an inflow rate of 0.02 L/ft²-day. This insignificant influx is attributed to the recycling of water stored in the sediment as a result of differential water pressure. Since Lake Gem Mary is a deep sinkhole lake (greater than 50 feet), it is believed that there is a strong connection to the underlying aquifer, which is evidenced by the deep recharge volume needed to complete the annual hydrologic budget. Specific measurements of deep recharge were not conducted as part of this project. Therefore, losses of water due to deep recharge are assumed as the difference between the identified inputs and outputs for the lake.

4.3. HYDROLOGIC BUDGET

A summary of identified hydrologic inputs to Lake Gem Mary on an average annual basis is presented in Table 4-10. The largest annual hydrologic input to Lake Gem Mary is direct rainfall to the lake, which contributes 66.5% of the annual hydrologic inputs. The second largest source of hydrologic input is stormwater runoff, which is 24.8%. Groundwater seepage accounts for only 8.7% of the total annual hydrological budget for Lake Gem Mary.

A summary of mean annual hydrologic losses from Lake Gem Mary is given in Table 4-11. Evaporation is the largest hydrologic loss accounting for 69.3% of the total losses. Delta Storage is the difference in lake volume between the start date (October 2015) of the study and the end date (September 2016). An initial water elevation in the lake was measured to be 89.5-ft and the ending water elevation was 89.4-ft. The approximate lake area at the initial elevation is 14.1 acres. The resulting reduction of water volume is $(89.5-89.6 \text{ ft}) \times (14.1 \text{ acres})$ or 1.4 ac-ft. Since the water budget assumes that total inflow minus total outflow equals delta storage, in this case 1.4 ac-ft becomes an output from the hydrologic budget. The hydrological inputs and outputs for Lake Gem Mary are presented in Figure 4-6 and 4-7.

Table 4-10: Mean Annual Hydrologic Inputs to Lake Gem Mary

Source	Volume (ac-ft)	Percent of Total
Groundwater Seepage	7.9	8.7%
Stormwater Runoff	22.4	24.8%
Direct Rainfall on Lake	60.2	66.5%
Total	90.5	100%

Table 4-11: Mean Hydrologic Losses from Lake Gem Mary

Source	Volume (ac-ft)	Percent of Total
Evaporation	62.7	69.3%
Outfall Discharge Structure ¹	0.0	0%
Delta Storage	1.4	1.5%
Deep Recharge	26.4	29.2%
Total	90.5	100%

¹ No observed discharges based on limited site visits, discharges could have occurred between site visits

Figure 4-6: Summary of Annual Hydrologic Inputs

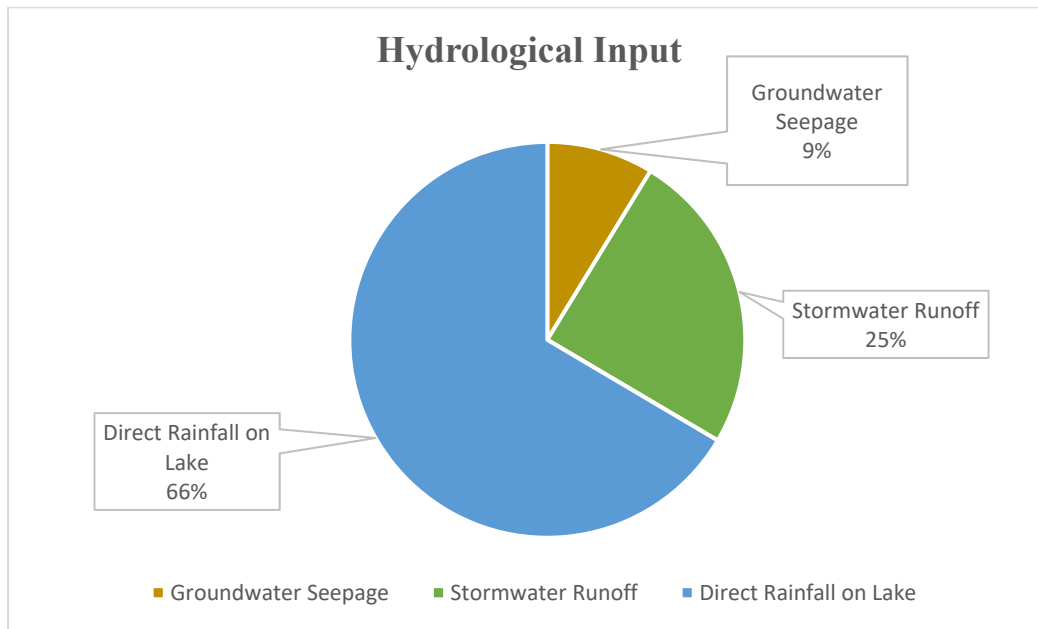
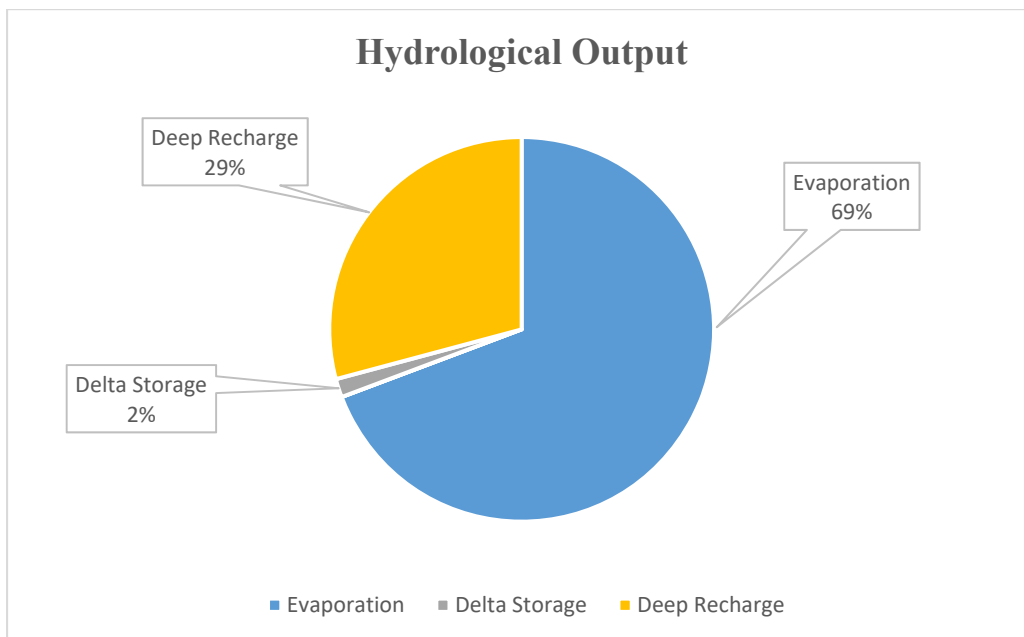


Figure 4-7: Summary of Annual Hydrologic Losses



4.4. WATER RESIDENCE TIME

Mean annual water residence time was calculated for Lake Gem Mary by dividing the estimated water volume for the lake (summarized in Table 4-12) by the calculated mean annual hydrologic inputs (summarized in Table 4-10). A summary of this information is presented in Table 4-12. Based upon this analysis, the calculated residence time in Lake Gem Mary is approximately 3.6 years or 1,314 days. This value is higher than the residence times commonly observed in Central Florida urban lakes.

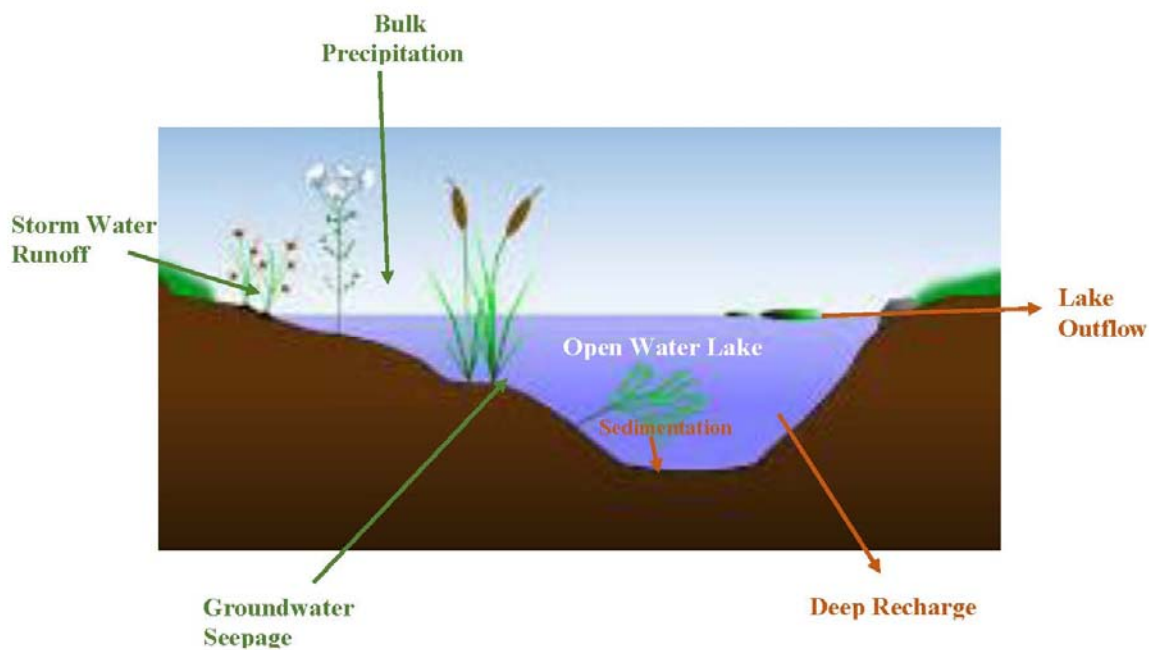
Table 4-12: Calculated Mean Annual Residence Time in Lake Gem Mary

Lake Volume (ac-ft.)	Annual Hydrologic Inputs (ac-ft.)	Residence Time	
		Years	Days
252	69.9	3.6	1,314

5. NUTRIENT INPUTS AND LOSSES

Lake Gem Mary receives nutrient inputs from a variety of sources which include bulk precipitation, stormwater runoff, shallow groundwater seepage, and internal recycling. A discussion of these inputs, along with calculated mass loadings, is given in the following sections. Information from each of these sources is used to generate an annual average nutrient budget for total nitrogen, total phosphate and TSS in Lake Gem Mary. A conceptual schematic of evaluated nutrient sources and sinks in Lake Gem Mary is given in Figure 5-1.

Figure 5-1: Conceptual Schematic of Evaluated Nutrient Inputs and Losses



5.1. CHARACTERISTICS OF NUTRIENT INPUTS

5.1.1. BULK PRECIPITATION

5.1.1.1. CHEMICAL CHARACTERISTICS

The chemical characteristics of bulk precipitation in the Central Florida area are based on the Butler Chain-of-Lakes study (ERD, 2005). A summary of the mean characteristics of measured concentrations for total nitrogen, total phosphate, and TSS in bulk precipitation at the Butler Chain-of-Lakes monitoring site is given in Table 5-1. For purposes of this evaluation, it is assumed that the bulk precipitation characteristics summarized in Table 5-1 are similar to bulk precipitation which falls on Lake Gem Mary.

Table 5-1: Mean Characteristics of Bulk Precipitation in Central Florida Area

Parameter	Units	Concentration
Total Nitrogen	µg/L	770
Total Phosphate	µg/L	61
TSS	mg/L	17.3

5.1.1.2. MASS LOADING

Estimates of annual mass loadings from bulk precipitation to Lake Gem Mary were calculated for TN, TP, and TSS based upon the assumed characteristics listed in Table 5-1 and the estimated annual average volumetric inputs from direct precipitation listed in Table 4-3. A summary of estimated mean annual loadings to Lake Gem Mary from bulk precipitation is presented in Table 5-2.

Table 5-2: Estimated Mean Annual Loading from Bulk Precipitation

Parameter	Mass Loading (kg/yr)
Total Nitrogen	38.2
Total Phosphate	3.0
TSS	857.8

5.1.2. STORMWATER RUNOFF

Procedures, calculations, and assumptions used to calculate the watershed's pollutant load contribution to Lake Gem Mary through stormwater runoff are presented in the following sections.

5.1.2.1. POLLUTANT LOAD COMPUTATION

The potential for stormwater runoff and pollutant loads from the watershed to the lake are determined by computing the area-weighted Runoff Coefficient (C) and Event Mean Concentrations (EMC) based on the areas of the watershed sub-basins, as previously discussed in Section 4 of this report.

5.1.2.2. AREA-WEIGHTED RUNOFF COEFFICIENT, C

The area-weighted runoff coefficient is a computation that takes into account the various land use and soil types within the watershed. The computation shown below determines the area associated with each land use/hydrologic soil group combination within the area, sums these up, and divides by the total area. This value is computed for each sub-basin.

$$C = \frac{\sum_1^n \left(C_{n,m} * \sum_{m=1}^m Area_{n,m} \right)}{\sum_1^n \left(\sum_{m=1}^m Area_{n,m} \right)}$$

where:

C = area-weighted runoff coefficient,

C_n = area-weighted runoff coefficient for a given land use, n,

Area_{n,m} = area (acres) for land use, n, and hydraulic soil group (HSG), m,

n = number of different land uses within the area, and

m = number of different HSGs within the area.

The curve number based runoff coefficients are shown in Table 5-3.

Table 5-3: Annual Runoff C-Factors

Curve Number	Annual Runoff C-Factor	Curve Number	Annual Runoff C-Factor
39	0.0006	71	0.0556
40	0.0008	72	0.0603
41	0.0010	73	0.0654
42	0.0013	74	0.0709
43	0.0017	75	0.0769
44	0.0021	76	0.0834
45	0.0025	77	0.0906
46	0.0031	78	0.0983
47	0.0037	79	0.1067
48	0.0044	80	0.1157
49	0.0051	81	0.1255
50	0.0060	82	0.1360
51	0.0069	83	0.1474
52	0.0079	84	0.1596
53	0.0090	85	0.1727
54	0.0102	86	0.1869
55	0.0116	87	0.2023
56	0.0130	88	0.2188
57	0.0146	89	0.2368
58	0.0164	90	0.2573
59	0.0182	91	0.2815
60	0.0202	92	0.3101
61	0.0223	93	0.3440
62	0.0246	94	0.3846
63	0.0270	95	0.4334
64	0.0297	96	0.4934
65	0.0327	97	0.5687
66	0.0359	98	0.6665
67	0.0393	99	0.8005
68	0.0430	100	1.0000
69	0.0469		
70	0.0511		

5.1.2.3. AREA-WEIGHTED EMC

The area-weighted EMC computation takes into account the various land uses within the lake's watershed. The area associated with each land use within the watershed is determined, summed up, and then divided by the total area, as shown in the computations below. The area weighted EMC value is computed for each land use.

$$EMC_x = \frac{\sum_1^n (EMC_n * Area_n)}{\sum_1^n Area_n}$$

where:

EMC_x = area-weighted EMC for the project for pollutant X(mg/L),
n = number of land uses within the area,
EMC_n = EMC (mg/L) for a given land use, and
Area_n = area (acres) for a given land use (the total area, A, could also be used here).

The EMC values used in this study were obtained from *Stormwater Chemistry and Water Quality: Estimating Pollutant Loadings and Evaluation of Best Management Practices for Water Quality Improvements*, Harper, H.H. (1999), as shown in Table 5-4.

Table 5-4: EMC values for Various Land Uses

Land Use	TN (mg/l)	TP (mg/l)	TSS (mg/l)
Agriculture	2.48	0.387	94.3
Cemeteries	1.15	0.074	7.8
Commercial/Shopping	1.23	0.17	59.2
Golf Course	2.00	0.306	33.0
Upland Non Forested	1.25	0.057	7.8
Institutional	1.98	0.339	69.7
Low Density Residential	1.77	0.177	20.4
Medium Density Residential	2.29	0.306	33.0
High Density Residential	2.42	0.49	77.8
Recreational	1.15	0.074	7.8
Water	0.490	0.013	17.3
Wetland	1.15	0.074	7.8
Transportation	1.64	0.22	37.3

Land use within the Lake Gem Mary watershed primarily consists of Low and Medium Density Residential, institutional and water, as discussed in Section 3.2 of this report.

5.1.2.4. ANNUAL POLLUTANT LOADS

Pollutant load to Lake Gem Mary due to stormwater runoff was calculated for each sub-basin within the watershed. Sub-basin locations within the watershed are presented in Figure 4-2. The pollutant loading was divided into direct stormwater runoff (parcels directly connected to the lake) and the runoff collected and conveyed by a stormwater system within the watershed, as shown in Table 5-5.

Table 5-5: Stormwater Runoff Pollutant Load to Lake Gem Mary

Basin	Pollutant Source	Area (acres)	TP (kg/yr)	TN (kg/yr)	TSS (kg/yr)
0	Stormwater Drainage System	11.7	1.4	10.3	148.0
1	Stormwater Drainage System	0.9	0.7	3.9	136.7
2	Direct Runoff	2.5	2.0	11.7	412.5
4	Stormwater Drainage System	2.5	0.3	2.2	31.3
5	Stormwater Drainage System	7.6	0.9	6.7	97.1
6	City of Orlando	10.2	1.2	8.9	128.8
7	Stormwater Drainage System	7.9	0.9	6.9	100.0
8	Stormwater Drainage System	9.8	0.8	6.5	89.6
9	Direct Runoff	1.5	0.2	1.3	19.3
10	Direct Runoff	0.4	0.0	0.4	5.3
11	Direct Runoff	1.4	0.2	1.3	18.0
12	Direct Runoff	0.4	0.0	0.3	4.9
City of Orlando Sub Total		10.2	1.2	8.9	128.8
Direct Runoff Sub Total		6.2	2.4	15.0	460.2
Stormwater Drainage System Sub Total		40.4	5.0	36.5	602.5
Total		56.8	8.6	60.5	1,191.5

The majority of the watershed is located within unincorporated Orange County; however, sub-basin 6 is located within the City of Orlando. The majority of the stormwater pollutant loading within the Lake Gem Mary watershed is discharged to the lake through a stormwater collection and conveyance system. The pollutant load model spreadsheet based on land uses and EMC values for each sub-basin is presented in Appendix E.

5.1.3. GROUNDWATER SEEPAGE

5.1.3.1. CHEMICAL CHARACTERISTICS

Nutrient influx from groundwater seepage was quantified using a total of six underwater seepage meters installed at various locations throughout Lake Gem Mary. A discussion of the hydrologic inputs resulting from groundwater seepage is presented in Section 4 of this report. Each of the collected groundwater seepage samples were analyzed for pH, alkalinity, conductivity, NO_x, TN, and TP. A listing of laboratory measurements conducted on seepage samples collected at each of the six sites is presented in Appendix F.

A summary of the geometric mean chemical characteristics of seepage samples collected in Lake Gem Mary from December 2015 to January 2017 is presented in Table 5-6. Seepage collected from Lake Gem Mary was found to be mostly neutral in pH, with measured conductivity values in the 200 to 300 µmho/cm range. A wide range of nitrogen concentrations; both NO_x and TN, was observed in seepage

samples, with geometric mean values ranging from 21 to 4,600 µg/L and 1,187 to 6,779 µg/L respectively. The geometric mean for TP concentrations in groundwater seepage were also highly variable, ranging from 28 to 265 µg/l between the various sites.

Table 5-6: Mean Characteristics of Ground Water Seepage Samples Collected December 2016 -January 2017

SITE	Number of Samples	pH (s.u)	Specific Conductivity (µmho/cm)	Alkalinity (mg/L)	NOx (µg/L)	Total Nitrogen (µg/L)	Total Phosphorus (µg/L)
XBC12SEEP1	8	7.0	260	35.7	228	1,187	28
XBC12SEEP2	8	6.9	249	35.3	602	1,378	172
XBC12SEEP3	7	6.6	284	26.6	4,600	6,779	47
XBC12SEEP4	8	7.1	286	50.2	509	1,608	39
XBC12SEEP5	8	7.1	362	88.4	27	4,974	236
XBC12SEEP6	8	7.0	341	88.5	21	6,190	265

* Note: Seepage Meter Site 3 is based on 7 samples because seepage meter was missing and was replaced.

Seepage samples collected from the lake were generally well buffered (above 20 mg/l), with the majority of geometric mean alkalinity values ranging from 35 to 88 mg/l. Therefore, as expected the pH was relatively stable. The seepage samples collected at XBC12SEEP3 had the highest geometric mean values for NOx and TN.

Isopleths of the geometric mean for pH values in groundwater seepage entering Lake Gem Mary are presented in Figure 5-2. In general, most pH values were neutral throughout the lake ranging between 6.6 and 7.1.

Isopleths of the geometric mean for alkalinity values in groundwater seepage entering Lake Gem Mary are presented in Figure 5-3. Areas of relatively elevated alkalinity were within the center portion of the lake. Around the shoreline of Lake Gem Mary, the alkalinity concentrations tended to be lower than the center of the lake.

Isopleths of the geometric mean for conductivity values in groundwater seepage entering Lake Gem Mary are presented in Figure 5-4. The most elevated concentrations of conductivity were observed in the center portion of the lake. The lower concentrations were generally observed along the shoreline.

Isopleths of the geometric mean for NOx concentrations in groundwater seepage entering Lake Gem Mary are presented in Figure 5-5. The most elevated concentrations of NOx were observed at Seepage Site XBC12SEEP3 on the eastern shore. The lowest concentrations were generally observed in the center of the lake.

Isopleths of the geometric mean for TN concentrations in groundwater seepage entering Lake Gem Mary are presented in Figure 5-6. The most elevated concentrations of TN were observed at the eastern shoreline. The lowest were observed along the western, northern, and southern shorelines of Lake Gem Mary.

Isopleths of the geometric mean for TP concentrations in groundwater seepage entering Lake Gem Mary are presented in Figure 5-7. The most elevated concentrations of TP were observed in the center of the lake. The lowest concentrations were observed along the western shoreline of the lake.

The concentration trends for the NO_x and TN seem to have an area of highest concentration near the eastern shoreline. The TP was observed to be the highest in the deepest portions of the lake.

Figure 5-2: Isopleths of Geometric Mean PH (s.u.) Values in Groundwater Seepage

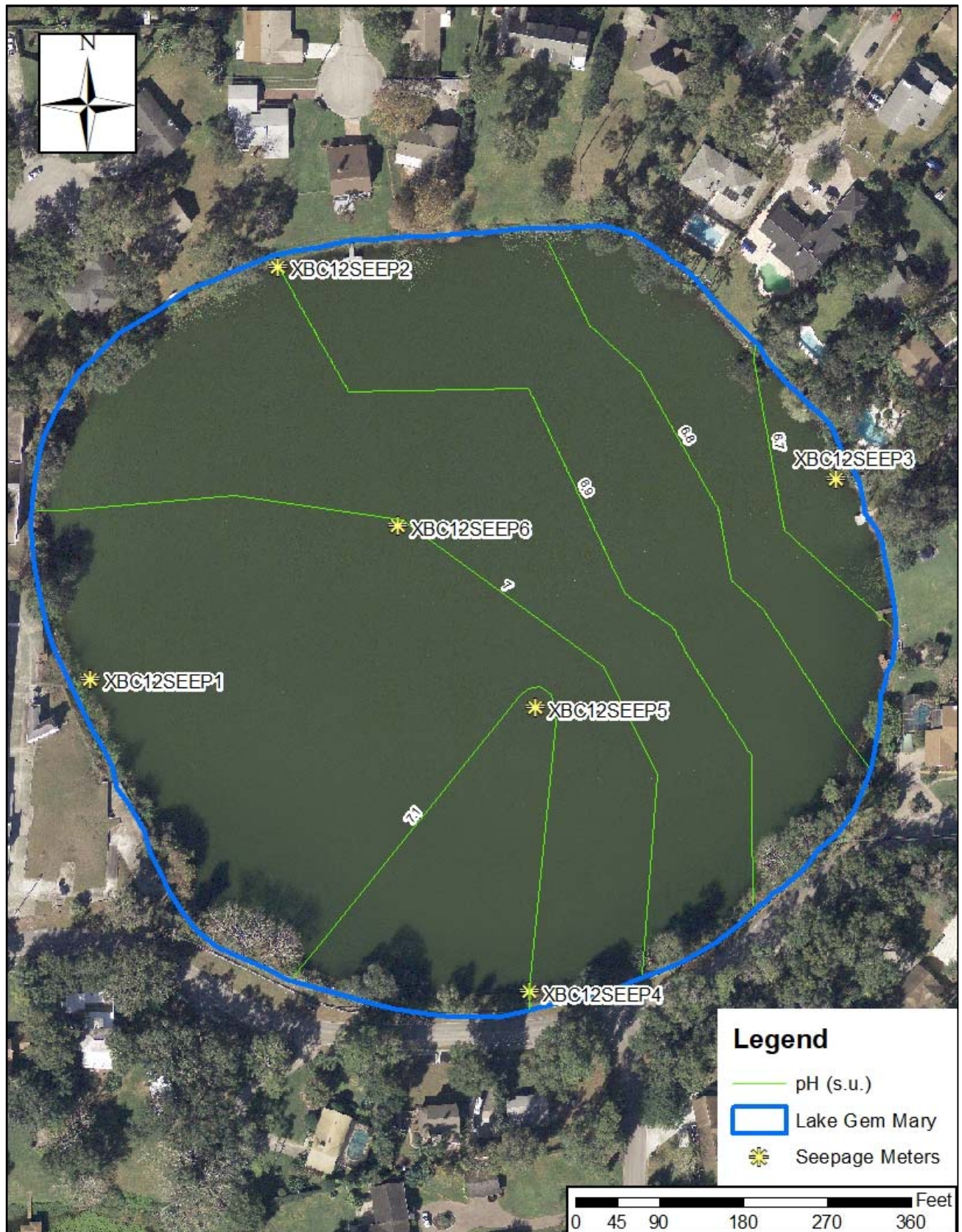


Figure 5-3: Isopleths of Geometric Mean Alkalinity (mg/L) Concentrations in Groundwater Seepage

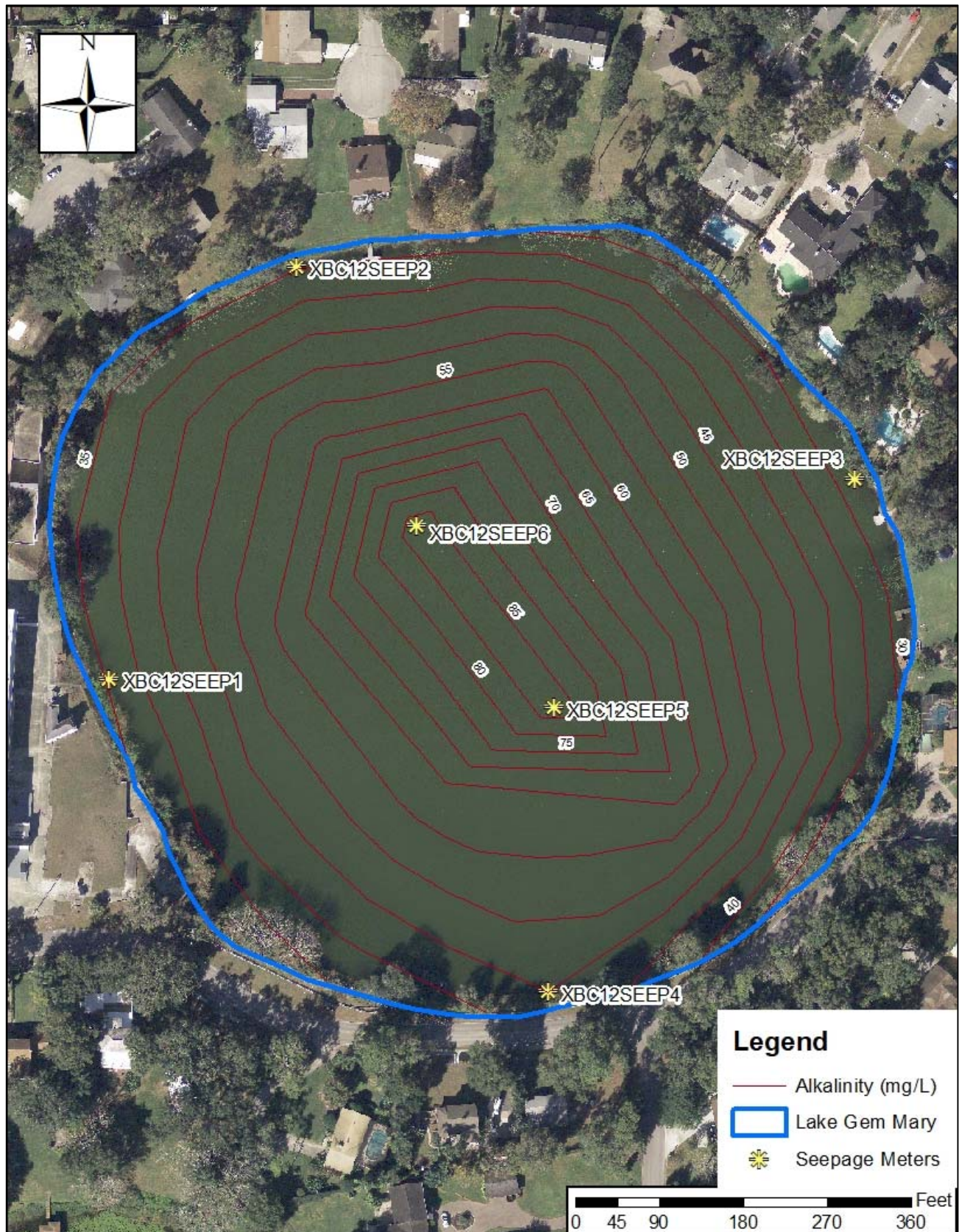


Figure 5-4: Isopleths of Geometric Mean Conductivity ($\mu\text{mho/cm}$) Values in Groundwater Seepage

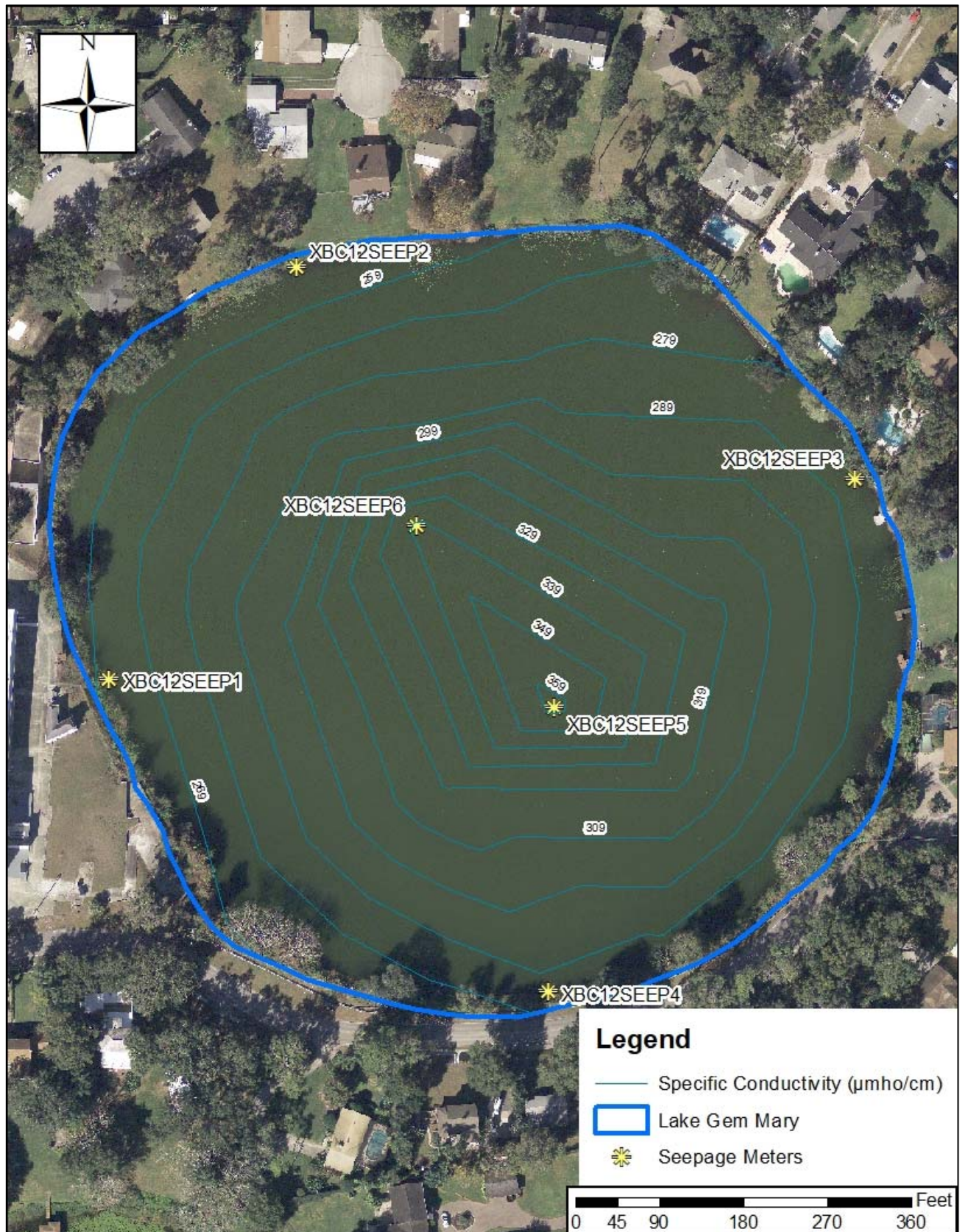


Figure 5-5: Isopleths of Geometric Mean NO_x (µg/L) Concentrations in Groundwater Seepage

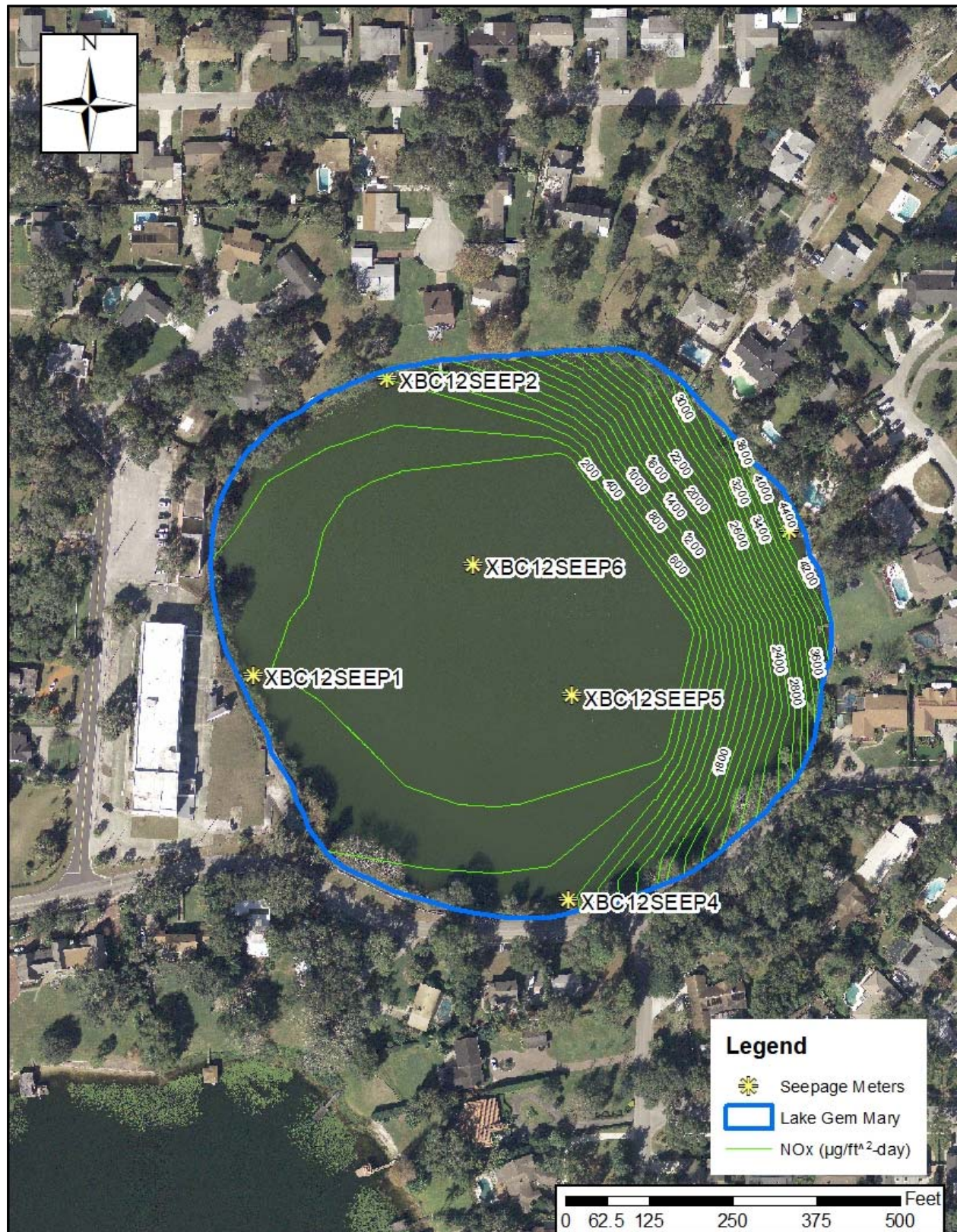


Figure 5-6: Isopleths of Geometric Mean TN ($\mu\text{g/L}$) Concentrations in Groundwater Seepage

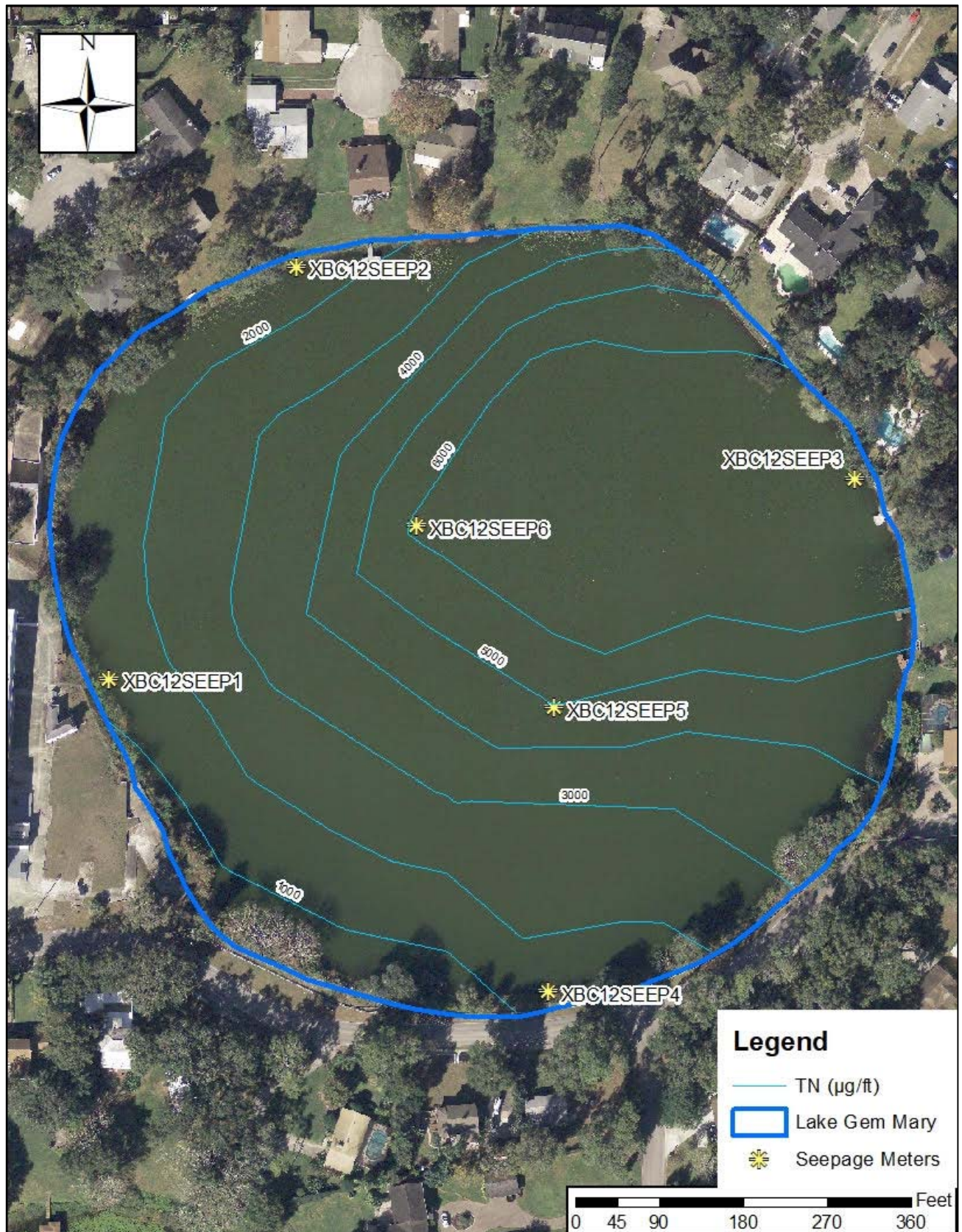
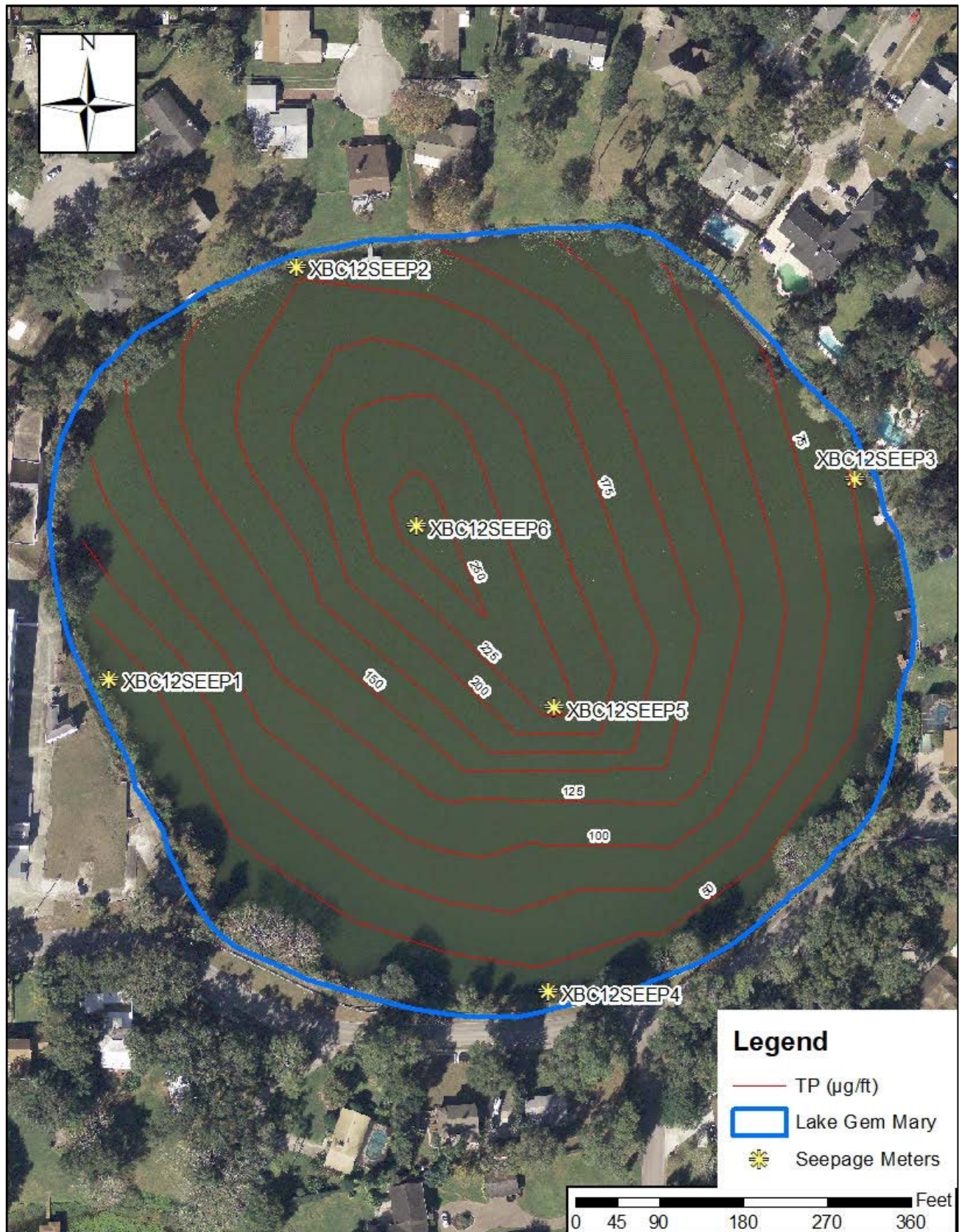


Figure 5-7: Isopleths of Geometric Mean TP ($\mu\text{g/L}$) Concentrations in Groundwater Seepage



5.1.3.2. MASS LOADING

Geometric mean seepage isopleths for NO_x influx, in $\mu\text{g}/\text{ft}^2\text{-day}$, were generated by combining the concentration isopleths for NO_x (presented in Figure 5-5) with the hydrologic isopleths for groundwater seepage (presented in Figure 4-5). This procedure results in estimates of NO_x influx in terms of mass NO_x per square feet 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 geomean seepage influx of NO_x into Lake Gem Mary are presented in Figure 5-8. In general, NO_x influx from groundwater seepage ranges from approximately 0.4 to 328 $\mu\text{g}/\text{ft}^2\text{-day}$. The most elevated concentrations of NO_x influx were observed along the eastern shoreline.

Isopleths of geomean seepage influx of Total Nitrogen (TN) into Lake Gem Mary are presented in Figure 5-9. In general, TN influx from groundwater seepage ranges from approximately 34 to 483 $\mu\text{g}/\text{ft}^2\text{-day}$. The most elevated concentrations of TN influx were observed along the eastern shoreline.

Geometric mean isopleths of Total Phosphate (TP) influx into Lake Gem Mary are presented in Figure 5-10. In general, TP influx into Lake Gem Mary ranges from approximately 0.8 to 27 $\mu\text{g}/\text{ft}^2\text{-day}$. The most elevated concentrations of TP influx were observed along the northern shoreline of the lake.

The isopleths depicted in Figure 5-9 and Figure 5-10 were integrated to develop estimates of the total influx of TN and TP from groundwater seepage into Lake Gem Mary during the field monitoring program from December 2015 to January 2017. A summary of estimated annual mass loadings of TN and TP to Lake Gem Mary from groundwater seepage is presented in Table 5-7.

Overall, groundwater seepage contributes approximately 29 kg/yr of TN and 0.8 kg/yr of TP to Lake Gem Mary. Calculated areal loadings of groundwater seepage are provided at the end of Table 5-7, which reflect the mass influx divided by the lake surface area.

Table 5-7: Estimated Annual Mass Loading from Groundwater Seepage

Parameter	Units	TN	TP
Geometric Mean Daily Flux	μg/ft ² -day	112.8	3.6
	g/day	79.3	2.3
Annual Loading	kg/yr	29	0.8
Areal Loading	kg/ac-yr	2.1	0.1

Figure 5-8: Isopleths of Geometric Mean NO_x ($\mu\text{g}/\text{ft}^2\text{-day}$) Influx from Groundwater Seepage

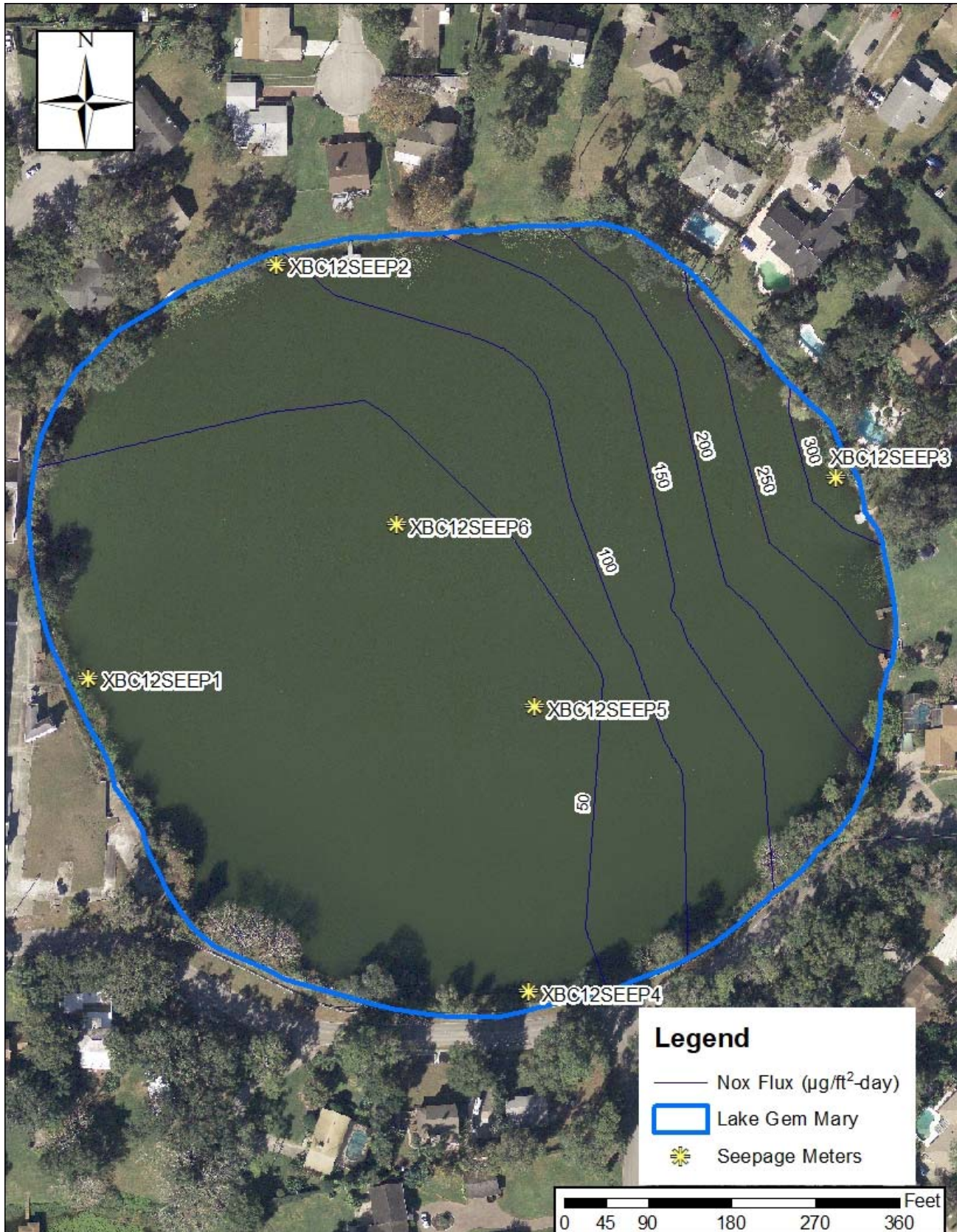


Figure 5-9: Isopleths of Geometric Mean TN ($\mu\text{g}/\text{ft}^2\text{-day}$) Influx from Groundwater Seepage

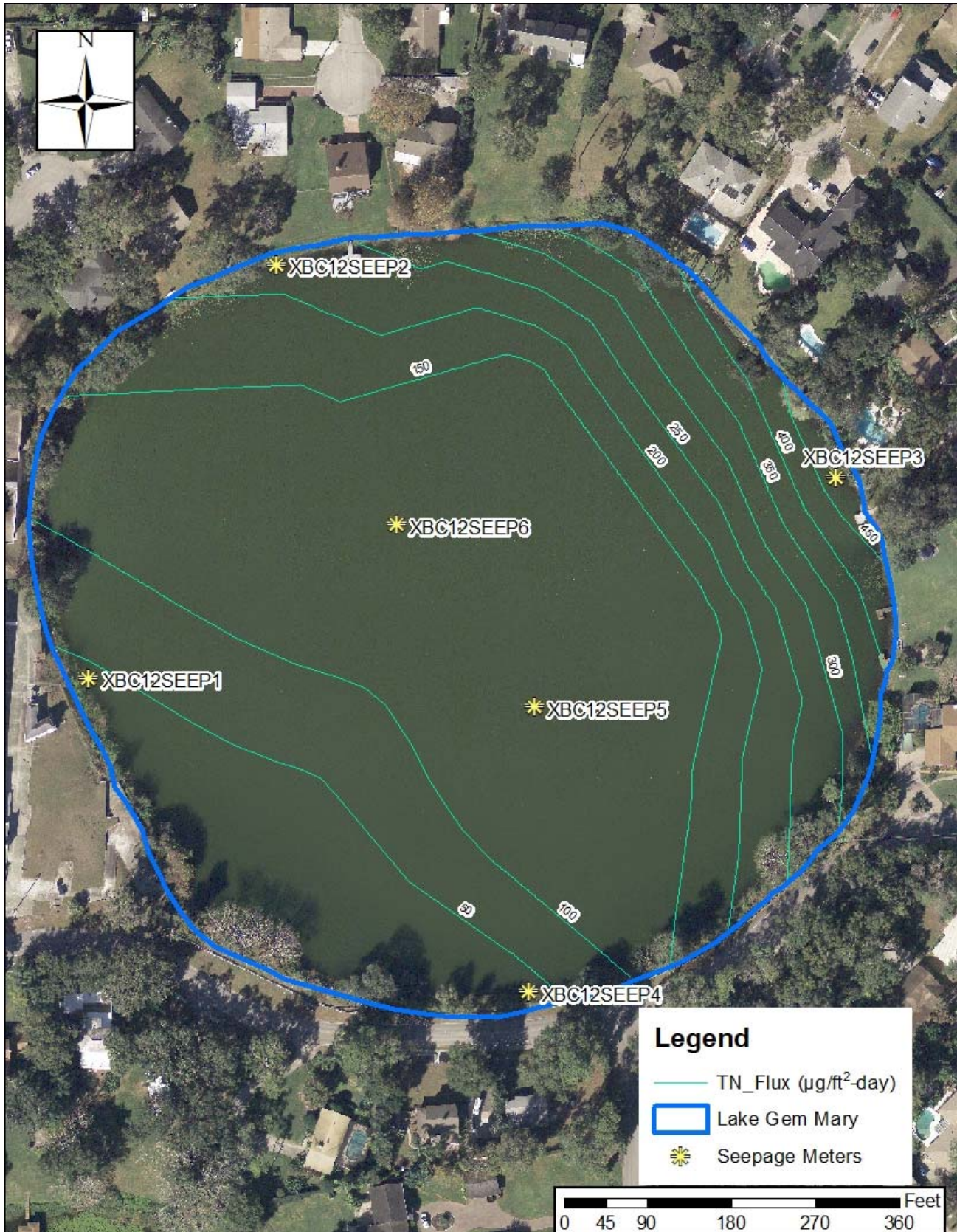
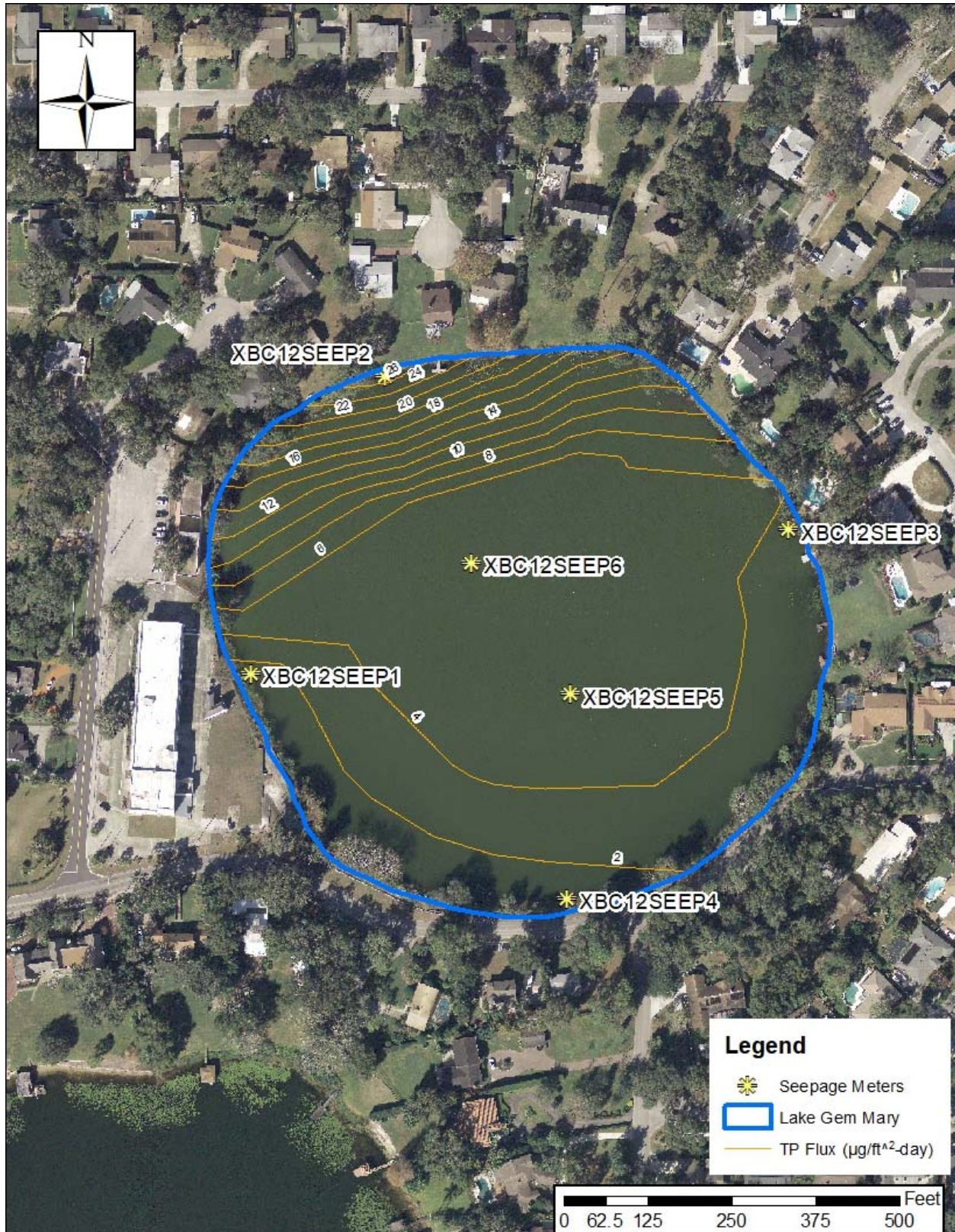


Figure 5-10: Isopleths of Geometric Mean TP ($\mu\text{g}/\text{ft}^2\text{-day}$) Influx from Groundwater Seepage



5.1.4. INTERNAL RECYCLING

The method used for quantification of internal loadings within Lake Gem Mary was to perform sediment nutrient release experiments. In this method, large diameter sediment cores are collected from various locations within the lake and incubated in the laboratory under a variety of conditions to simulate variability in the lake throughout the year. Changes in total phosphate concentrations are measured in the overlying sediments, and this information is extrapolated to an aerial release rate within the lake. This method allows for the estimating of internal loadings which provides a direct measurement of TP release from sediments to the lake.

Field and laboratory investigations were performed to quantify the mass of TP released as a result of internal recycling from the sediments to the overlying water column in Lake Gem Mary under both aerobic and anoxic conditions. Large diameter lake sediment core samples were collected at two locations in the lake and incubated under anoxic and aerobic conditions. Periodic measurements of TP and other water quality parameters were used to estimate total sediment phosphorus release under the evaluated conditions. This information is used to provide an estimate of the significance of mass loadings of total phosphate from lake sediments as part of the overall nutrient budget for the lake.

5.1.4.1. FIELD AND LABORATORY PROCEDURES

Sediment core samples were collected at two locations in Lake Gem Mary on April 7, 2016 using 4-inch diameter clear acrylic core tubes. Site XBC12LC1 (LC1) is located slightly south of the center of the lake and Site XBC12LC2 (LC2) is located slightly northwest of the center of the lake, as presented in Figure 5-12. The sediments at Site LC1 and Site LC2 consisted primarily of thick organic muck. Each of the acrylic tubes was driven into the sediments to the maximum possible depth using a large sledge hammer. A 4-inch x 4-inch wooden beam was placed on top of the acrylic core tube to evenly distribute the force of each sledge hammer blow and to prevent direct contact between the sledge hammer and the acrylic tube.

The acrylic tubes were penetrated into the sediments to depths ranging from approximately 2-6 ft, depending upon the physical characteristics of the sediments at each of the selected monitoring sites or until a firm bottom material was encountered. Each of the core tubes was retrieved intact, along with the overlying water column present at each of the collection sites. Upon retrieval, a rubber cap was attached to the bottom of each core tube to prevent loss of sediments. The collected water volume above the trapped sediments was carefully siphoned off until a water depth of 24 inches remained in each of the collected columns above the sediment-water interface. Each of the acrylic core tubes was then cut at a uniform height of 6 inches above the water level, leaving a 6-inch air space between the

water level and the top of the column. A 4-inch PVC cap was then placed on the top of each collected core tube. Each of the collected core tubes was then returned to the laboratory for incubation experimentation. All samples were transported in a vertical position to avoid mixing of the sediment layers.

After return to the laboratory, each of the core samples was attached to a laboratory work bench in a vertical position. Two separate 0.25-inch diameter holes were then drilled into the PVC cap attached to the top of each core sample. A 0.25-inch diameter semi-rigid polyethylene tube was inserted through one of the holes to a depth of approximately 2-3 inches above the sediment surface. An air stone diffuser was attached to the end of the tubing inside each core tube to introduce selected gases into the core tubes to induce aerobic or anoxic conditions.

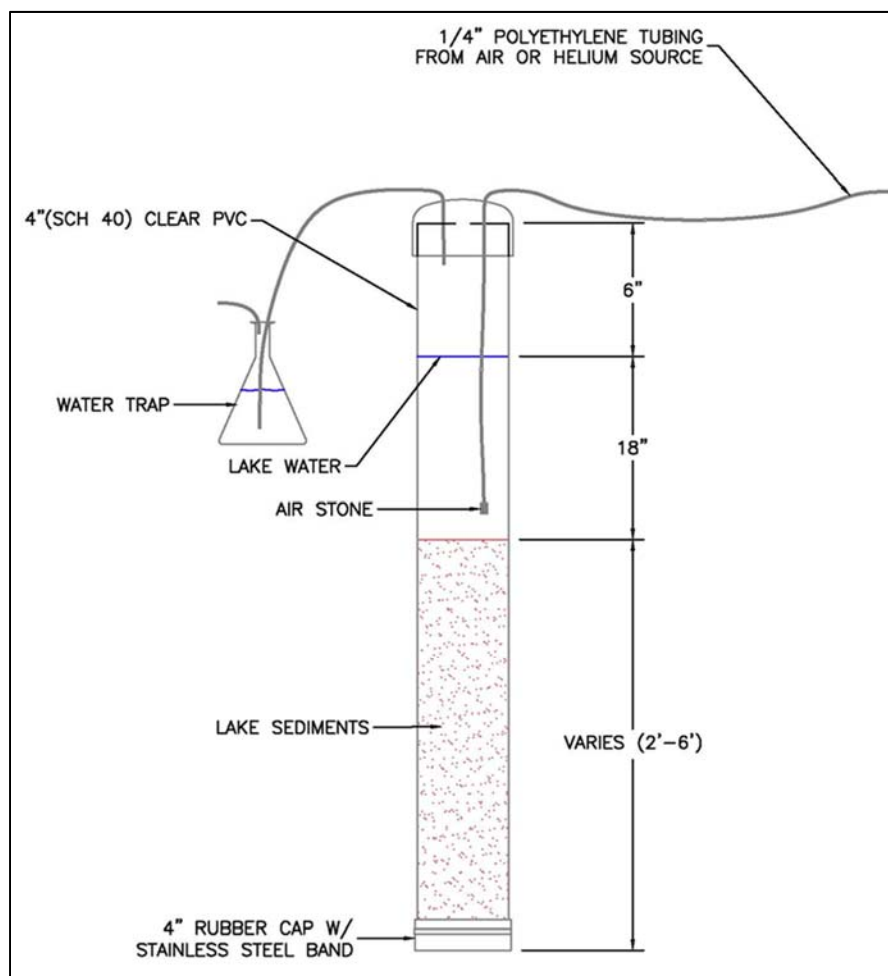
A separate piece of polyethylene tubing was inserted into the second hole in the top of each core tube, approximately 1 inch below the level of the cap, but well above the water level contained in each tube. The other end of the tubing was connected to a water trap to minimize loss of water from each column as a result of evaporation. This tubing also provided a point of exit for gases which were bubbled into each core tube. A schematic of the sediment incubation apparatus is presented in Figure 5-11.

After initial set-up of the incubation apparatus, a compressed stream of helium gas was introduced into each of the core tubes through the individual air stone diffusers. This process quickly created anoxic conditions within each of the core tubes. After anoxic conditions were established, as verified by an H_2S smell in the outflow from the water trap, the helium gas addition was reduced to 1-2 hours per day, generally in association with a sampling event to ensure completely mixed conditions within the tube. This process was continued in each of the core tubes for a period of 25 days. The gas addition was used to ensure that water within each of the core tubes was well mixed without disturbing the sediments, so that phosphates released from the sediments could be quantified as a function of changes in TP concentrations within the water column of each core tube. On approximately a 1-2 day interval, 20 ml of water was withdrawn from each of the columns using a 0.25-inch polyethylene tube and a plastic laboratory syringe. Each of the collected samples was immediately filtered using a 0.45 micron syringe type membrane filter and analyzed for soluble reactive phosphorus (SRP), TP, TN, and other significant laboratory parameters for research purposes.

At the conclusion of the experimentation under anoxic conditions, the compressed helium source was replaced with a compressed air source. Compressed air was gently bubbled through each of the columns to increase dissolved oxygen and create aerobic conditions within each tube. In general, creation of aerobic conditions, as indicated by measurements of redox potential (> 200 mv) within

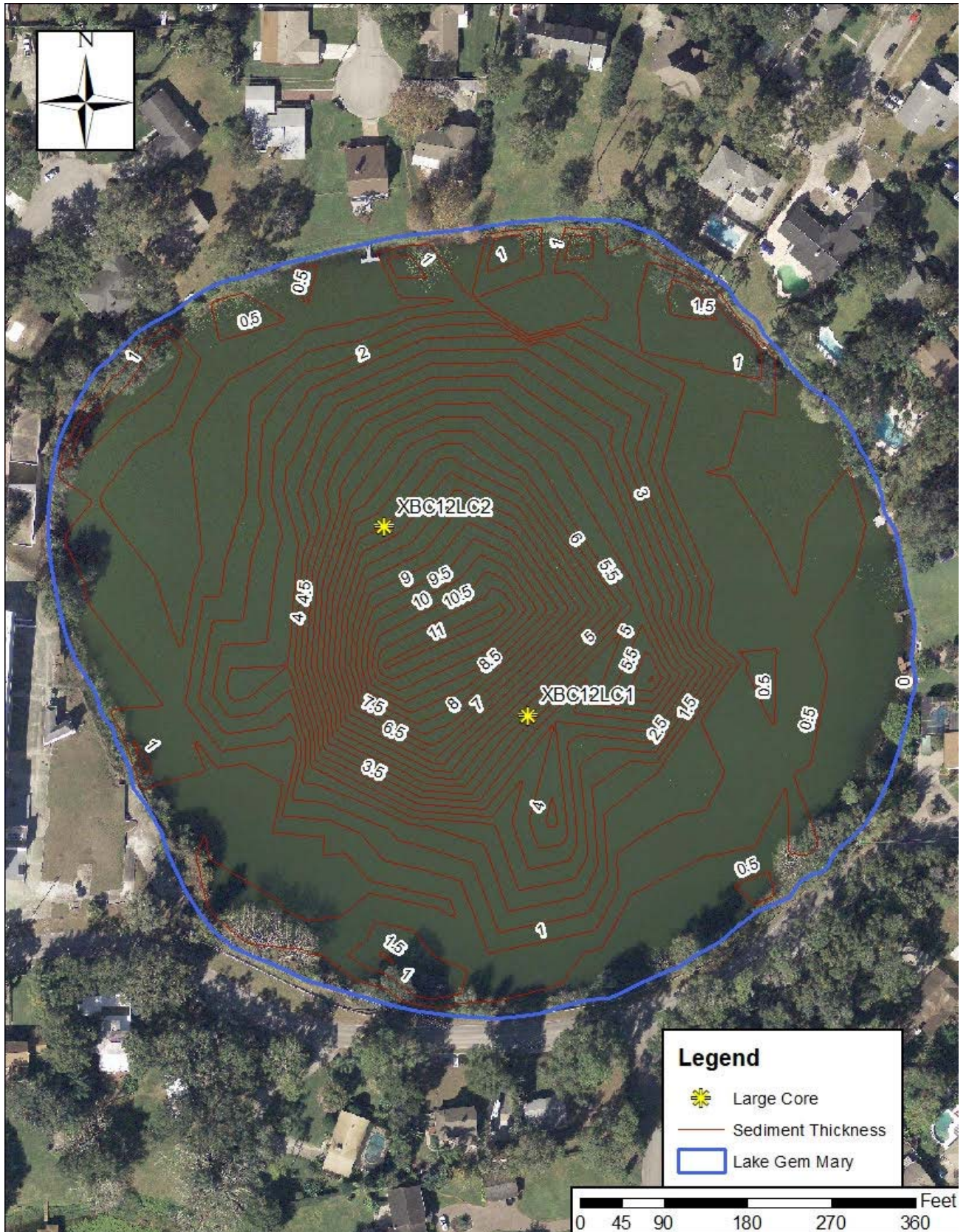
each of the columns, occurred after approximately 5-7 days. At the onset of aerobic conditions, sample collection was conducted at a 1-2 day interval from each of the 2 columns for a period of 22 days using the method previously outlined for anoxic conditions.

Figure 5-11: Schematic of Sediment Incubation Apparatus



Source: ERD 2016

Figure 5-12: Large Core Sediment Sample Locations



5.1.4.2. RESULTS OF LABORATORY TESTING

A graphical comparison of total phosphorus release from the isolation chamber experiments under aerobic and anoxic conditions is presented in Figure 5-13 and Figure 5-14. Changes in total phosphorus concentrations over time are provided for each of the two isolation chamber experiments under both aerobic and anoxic conditions. Concentration of SRP and TP remained constant for the first 10 days in the isolation chamber for all conditions. After the first 10 days the SRP concentration for oxic conditions began trending upwards. The anoxic conditions experienced a dip in the SRP concentrations after day 10, then the concentrations began to increase until day 26 when the concentrations began to decline. TP concentrations for both conditions began to rise after day 10, but after day 21 the anoxic conditions began to exhibit reductions in TP concentrations.

Figure 5-13: SRP Concentrations for Large Core Sediment Samples

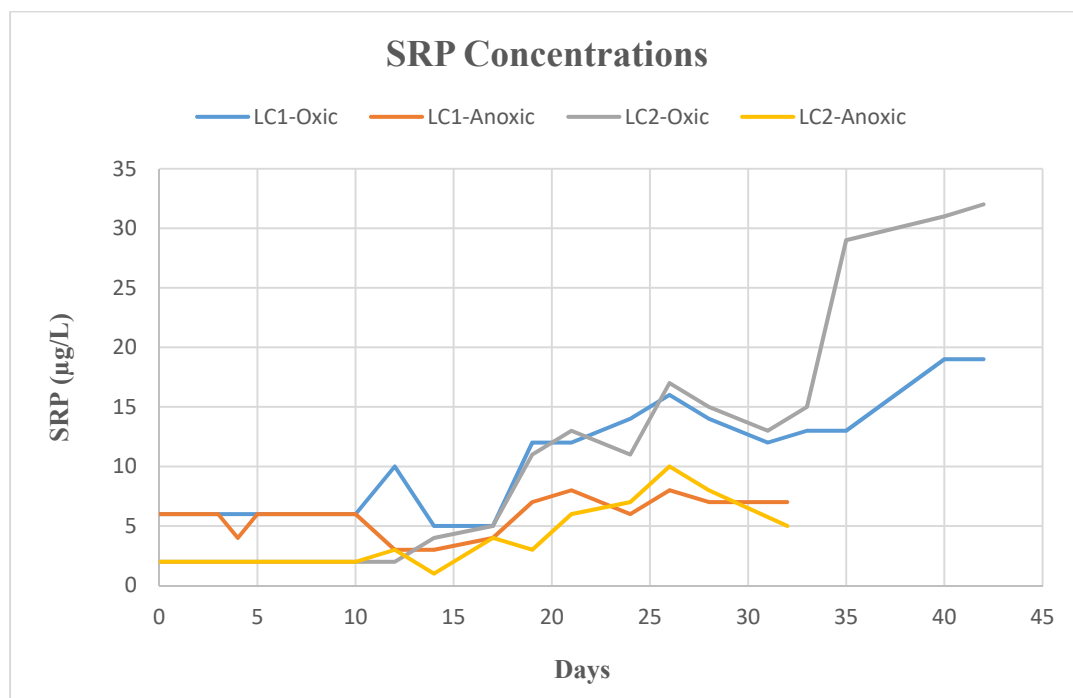
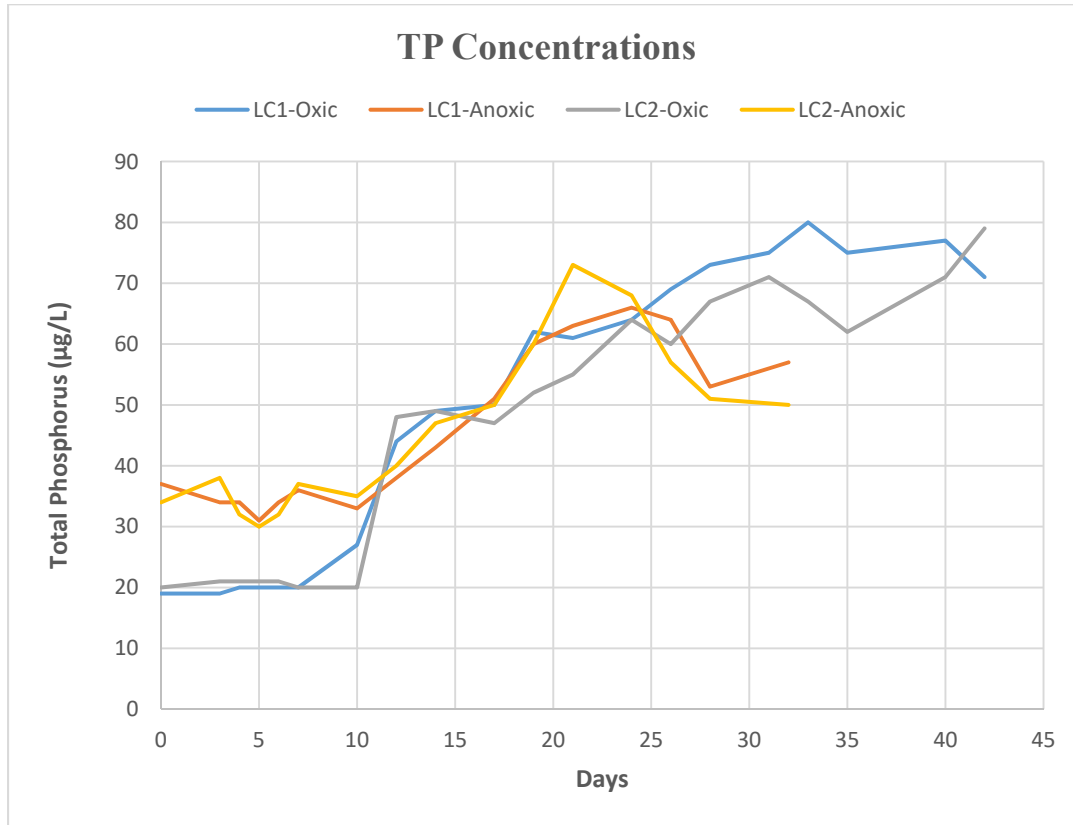


Figure 5-14: TP Concentration for Large Core Sediment Samples



5.1.4.3. MASS RELEASE

The results of the phosphate release experiments discussed in the previous section were extrapolated to estimate total sediment phosphorus release from Lake Gem Mary on an annual basis. The first step in this extrapolation process is to develop estimates of sediment release rates within each of the incubation chambers. The phosphate release rate in the incubation experiments is defined as the slope of the rising limb of the SRP and total phosphate release plots presented in Figure 5-15 and Figure 5-16. In all chambers, an initial delay in phosphate release occurred as anoxic or aerobic conditions were established within each chamber. In this case, the release rate is calculated using the data obtained between the start of the upward release trend and the total maximum phosphorus concentrations measured within a sample. In some experiments, TP concentrations began to decrease after reaching the maximum concentration, presumably due to biological uptake within the chamber. Regression relationships developed for estimation of sediment phosphate release rates in the incubation experiments under aerobic and anoxic conditions are also presented in Figure 5-15 and Figure 5-16.

Figure 5-15: SRP Concentrations and Rate of Release

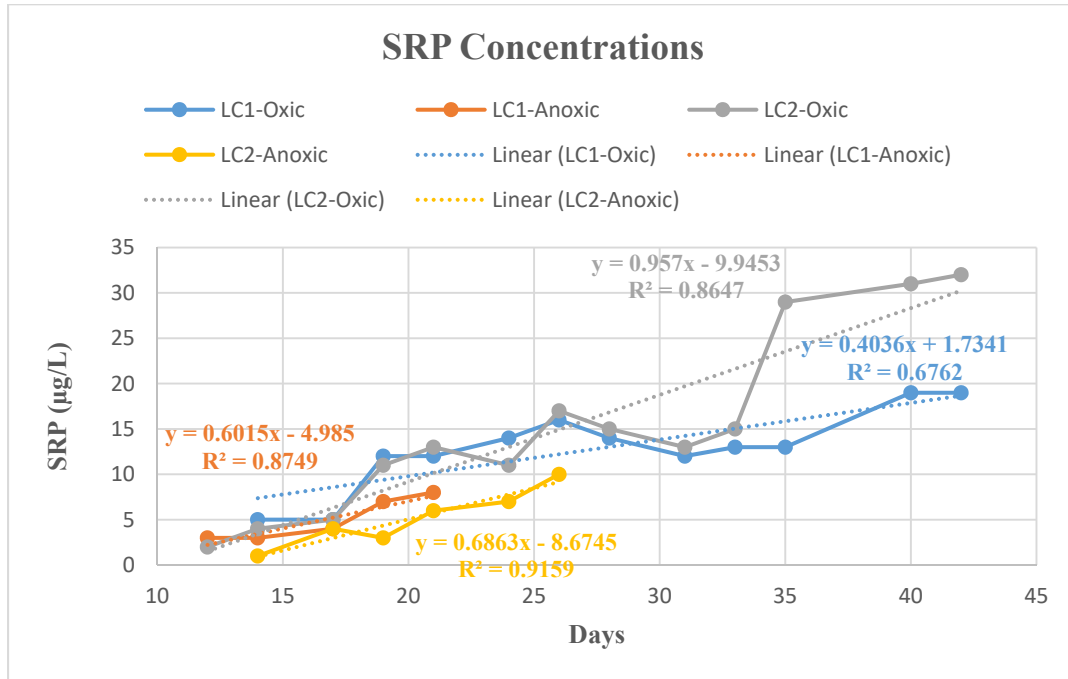
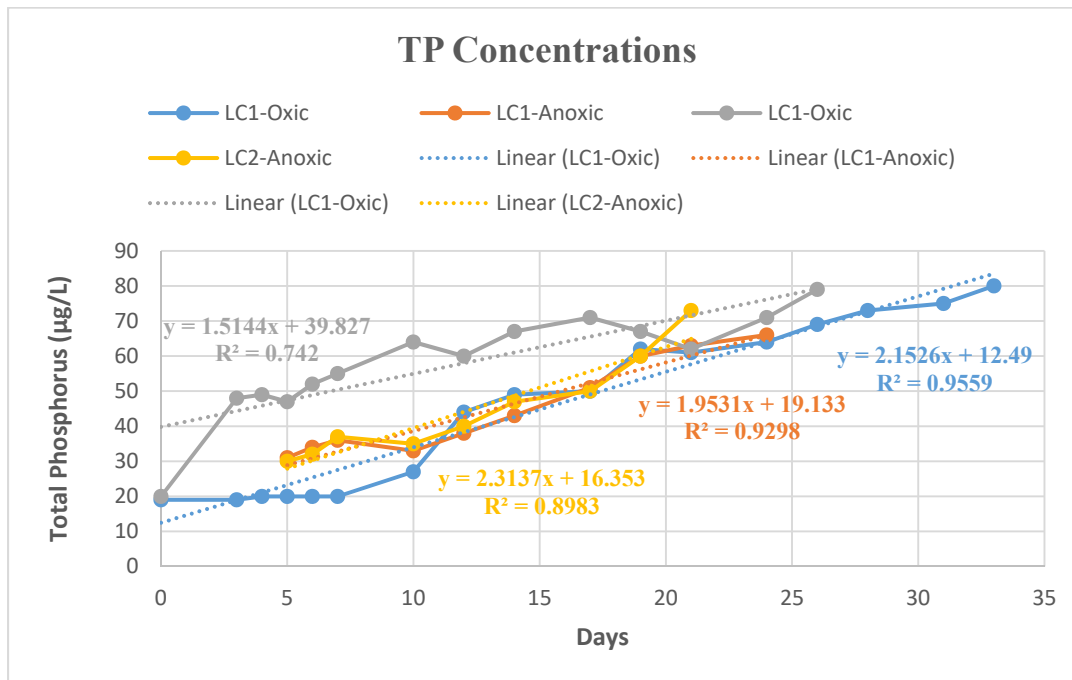


Figure 5-16: TP Concentrations and Rate of Release



Estimates of the areal extent and frequency of aerobic and anoxic conditions within the sediments of Lake Gem Mary were obtained from the vertical field profiles conducted in the lake from October 2015 to September 2016. These profiles (summarized in Figure 2-32 through Figure 2-45) provide seasonal patterns of dissolved oxygen concentrations in the lake. The percentage of events indicating

anoxic conditions at the water-sediment interface were calculated for each of the two monitoring sites and used to estimate the seasonal distribution of aerobic and anoxic conditions throughout the lake.

A summary of calculated total sediment phosphorus release rates during the isolation chamber experiments is presented in Table 5-8. Phosphate release rates are provided for each of the two isolation chamber core samples under both aerobic and anoxic conditions, with individual release rates provided for both SRP and TP. The phosphate release rates reflect the slope of the SRP and total phosphate release rate plots provided in Figure 5-15 and Figure 5-16. The calculated phosphate release rates are converted into a mass release per day by multiplying the volume of the water above the sediment and dividing by the surface area of the 4-inch diameter incubation chamber. This mass release is then converted into an aerial mass release in terms of mg/ft²-day. Under aerobic conditions, the mean mass release rate for SRP was 0.03 mg/ft²-day, with a mean release rate for TP of 0.09 mg/ft²-day. Under anoxic conditions, the mass release rates were 0.03 mg/ft²-day for SRP and a mean release rate of 0.11 mg/ft²-day for TP.

Table 5-8: Calculated Sediment Phosphate Release Rates During the Isolation Chamber Experiments

Condition	Site	Phosphorus (µg/L-day)		Water Volume (liters)	Mass Release µg/day		Mass Release mg/m ² -day		Mass Release mg/ft ² -day	
		SRP	TP		SRP	TP	SRP	TP	SRP	TP
Aerobic	LC1	0.40	2.15	4.44	1.78	9.55	0.22	1.18	0.02	0.11
	LC2	0.96	1.51	4.44	4.26	6.70	0.53	0.83	0.05	0.08
	Mean	0.68	1.83		3.02	8.13	0.37	1.00	0.03	0.09
Anoxic	LC1	0.60	1.95	4.44	2.66	8.66	0.33	1.07	0.03	0.10
	LC2	0.69	2.31	4.44	3.06	4.62	0.38	0.57	0.04	0.05
	Mean	0.65	2.13		2.86	9.46	0.35	1.17	0.03	0.11

A summary of calculated annual total sediment phosphorus release rates in Lake Gem Mary are presented in Table 5-9. The release is calculated using the mass release rates summarized in Table 5-8 for each of the two isolation chamber sites which is weighted by the fraction of aerobic and anoxic conditions assumed to occur within the lake, based upon the vertical field profiles summarized in Section 2. A review of Figure 2-45 for the deep sample site (XBC12S3B) within Lake Gem Mary shows that the lake exhibited anoxic conditions at the water-sediment interface during eleven of the twelve months during the year.

The measured aerobic and anoxic release rates are weighted by the estimated frequency of occurrence of aerobic (8%) and anoxic (92%) conditions within the lake to calculate estimates of mean annual phosphate release for SRP and TP, as shown in Table 5-9. Overall, the mean SRP release within Lake Gem Mary is estimated to be approximately 0.03 mg/ft²-day, with a total phosphorus release of 0.10 mg/ft²-day.

Table 5-9: Calculated Annual Total Sediment Phosphate Release

Site	Frequency of Condition		Weighted Phosphate Release (mg/ft ² -day)	
	Aerobic	Anoxic	SRP	TP
LC1	8%	92%	0.03	0.09
LC2	8%	92%	0.03	0.11
Mean	8%	92%	0.03	0.10
Annual Load (kg/yr)			7.4	24.0
Assumed Load (kg/yr) (average of SRP and TP)			15.7	

Estimates of annual phosphate loadings to Lake Gem Mary as a result of total sediment phosphorus release are provided in Table 5-9. When extended over the entire lake surface (14.11 acres), the weighted SRP release rate equates to an annual phosphate loading of approximately 7.4 kg/yr, with an annual total phosphate loading of 24.0 kg/yr. The actual total sediment phosphorus release in Lake Gem Mary probably lies somewhere between the annual load values for SRP and total phosphorus.

Research by Nurnberg (1998) has indicated that SRP comprises approximately 80% of the total phosphorus released from lake sediments, with the remaining fraction comprised primarily of organic phosphates. If this fraction were to be applied to SRP release in Lake Gem Mary, the resulting total phosphorus release is calculated to be 9.24 kg/yr, which is lower than the actual TP release. For this analysis an average of the SRP and TP release rates is used, yielding a phosphate release from sediments of approximately 15.7 kg/yr.

5.2. NUTRIENT LOSSES

Nutrient losses from Lake Gem Mary would occur as a result of discharge through the outfall structure. Pollutant mass which is not discharged through the outfall structure accumulates into the sediments of the lake. Since there was no discharge from the lake during the study, nutrient losses through the discharge structure are zero.

5.3. ANNUAL MASS BUDGETS

Estimated annual mass budgets were developed for TN, TP, and TSS entering Lake Gem Mary based upon the analyses presented in the previous sections. A discussion of estimated mass inputs and losses to Lake Gem Mary is given in the following sections. The nutrient loadings used in the following section are based upon the estimated loadings calculated using the land uses and soil types.

5.3.1. MASS INPUTS

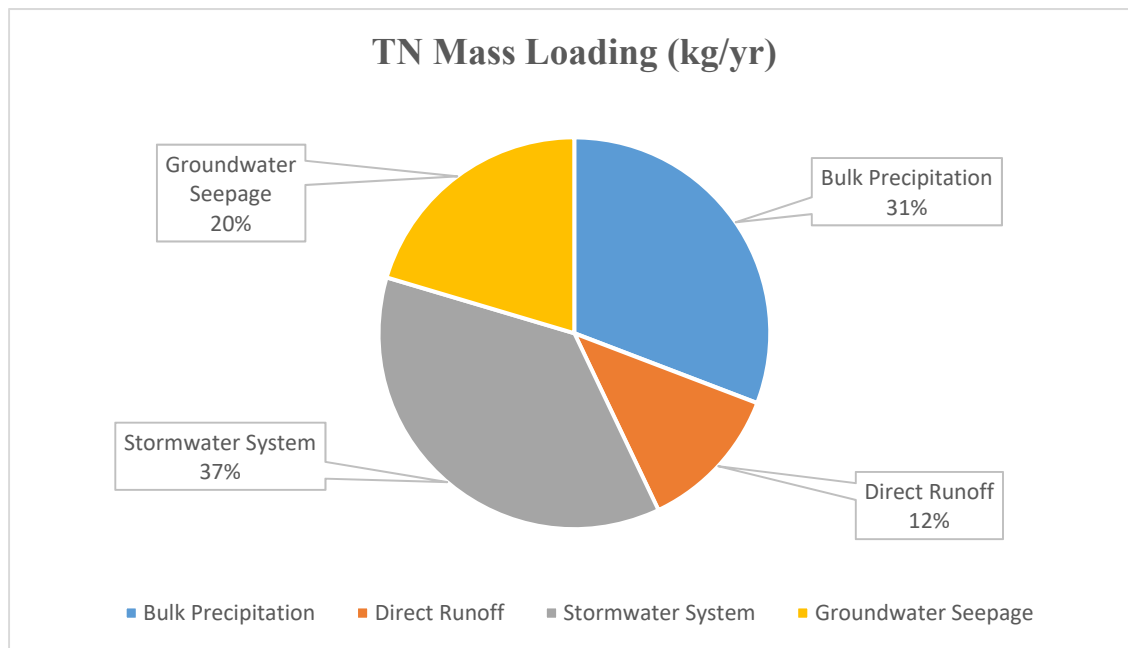
A summary of estimated annual mass loadings of TN, TP, and TSS entering Lake Gem Mary are presented in Table 5-10 and are based upon assumptions and analyses presented in previous sections. The allocation of annual mass loading from each sub-basin, including the City of Orlando sub-basin, is presented Table 5-5.

Table 5-10: Annual Mass Loadings of TN, TP, and TSS

Source	TN (kg/yr)	TP (kg/yr)	TSS (kg/yr)	TN (%)	TP (%)	TSS (%)
Bulk Precipitation	38.2	3.0	858	30.8%	10.7%	41.9%
Direct Runoff	15.0	2.4	460	12.1%	8.7%	22.4%
Stormwater System	45.5	6.2	731	36.7%	22.0%	35.7%
Groundwater Seepage	25.3	0.8	--	20.4%	2.8%	--
Internal Recycling	--	15.7	--	--	55.8%	--
Total	124.0	28.1	2,049	100%	100%	100%

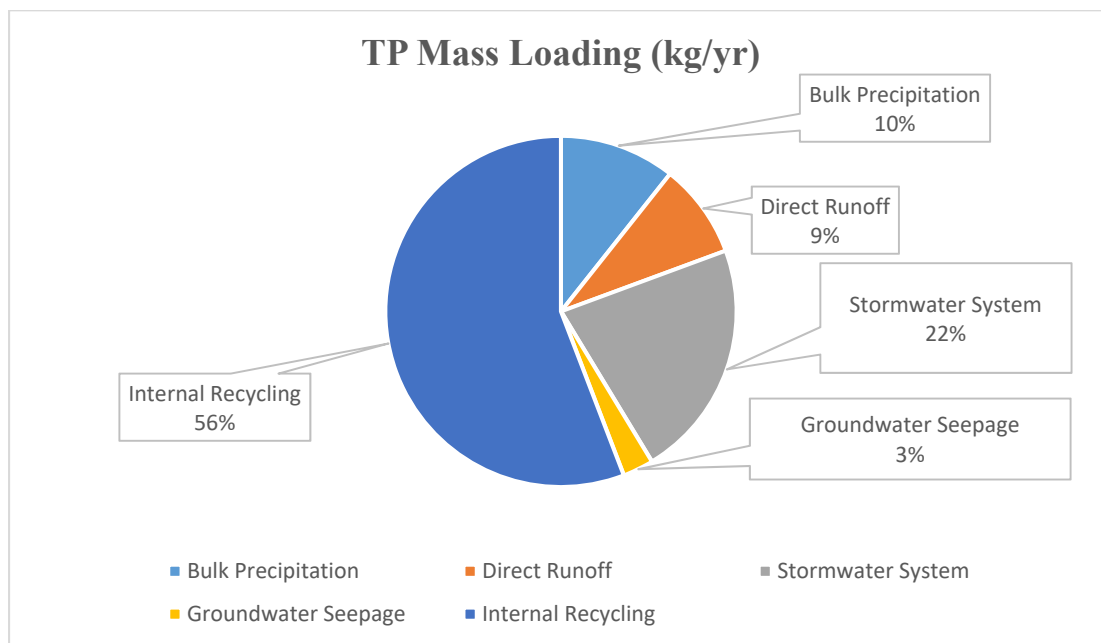
The largest contributor of TN to Lake Gem Mary on an annual basis is stormwater runoff (direct and from stormwater systems), contributing approximately 49% of the annual loading. Bulk precipitation accounts for 31% of the TN load into Lake Gem Mary. Figure 5-17 presents the TN mass loading into Lake Gem Mary.

Figure 5-17: TN Mass Loading (kg/yr) to Lake Gem Mary



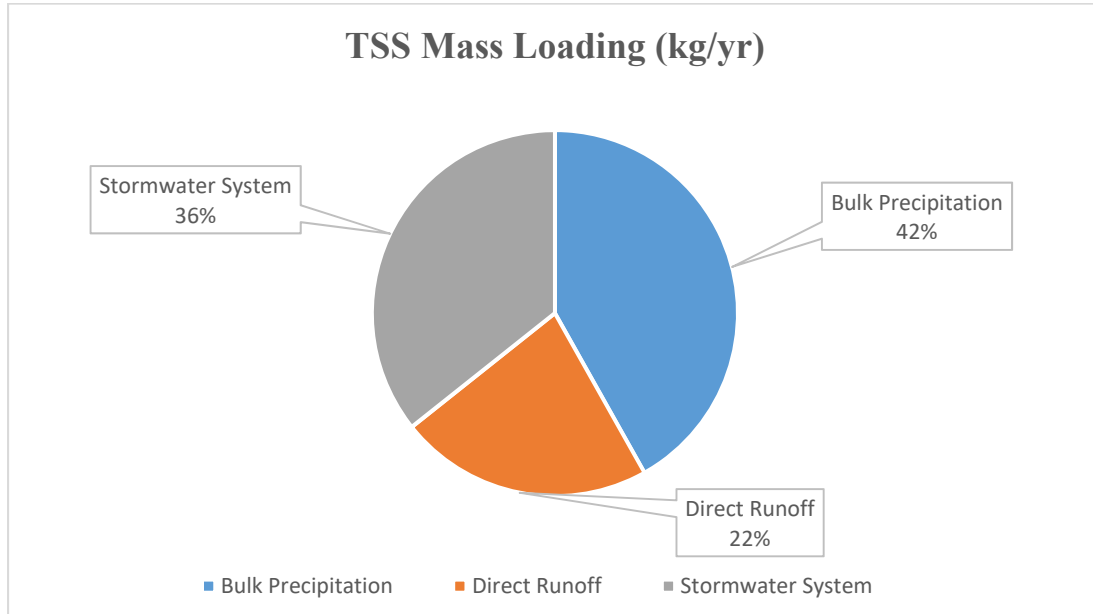
The largest contributor of TP loading into Lake Gem Mary appears to be internal recycling which accounts for 56%. The second largest contributor of TP into Lake Gem Mary is the stormwater at 31% of the total load. Figure 5-18 presents the TP mass loading into Lake Gem Mary.

Figure 5-18: TP Mass Loading (kg/yr) to Lake Gem Mary



The largest contributor of TSS is stormwater at 58% of the annual load. Bulk precipitation is the second largest contributor of TSS loading to Lake Gem Mary at 42% of the annual load, as shown in Figure 5-19.

Figure 5-19: TSS Mass Loading (kg/yr) to Lake Gem Mary



5.3.2. MASS LOSSES

The average annual precipitation was less than the precipitation measured during the year-long study. Therefore, it is assumed that Lake Gem Mary does not regularly discharge through the outfall structure and the mass losses from the lake are assumed to be zero. However, historical visual accounts indicate that Lake Gem Mary overflows to Lake Gatlin when a combination of high water elevations in the lake and/or extreme rain events occur.

6. EVALUATION OF WATER QUALITY IMPROVEMENT OPTIONS

In June 2017, the FDEP formerly delisted Lake Gem Mary from the Verified List of Impaired Waters. Study analytical results for surface water samples collected in Lake Gem Mary between October 2015 and September 2016 indicate that the concentrations of TP, TN and DO achieved compliance with the State's Numeric Nutrient Criteria (NNC). However, analytical results for chlorophyll-a in the collected surface water samples exceeded the criteria established by the NNC. During future review of the State's Impaired Water Body list, the FDEP may determine that Lake Gem Mary is impaired for nutrients based on the chlorophyll-a concentrations.

Water quality improvement options were evaluated to target sources which are identified as contributors of nutrient loadings to the lake. The evaluated options include both structural and non-structural approaches to controlling and reducing pollutant inputs into Lake Gem Mary. A discussion of general management philosophy and recommended water quality improvement projects is presented in the following sections.

6.1. MANAGEMENT PHILOSOPHY

Based on historical evaluation of water quality characteristics in Lake Gem Mary (Section 2), Trophic State Index (TSI) ratios indicate that Lake Gem Mary fluctuates between eutrophic and mesotrophic. As discussed in Section 5 and shown in Table 5-10, annual mass loadings of nutrients are largely attributed to stormwater runoff and internal recycling from the accumulated sediment at the bottom of the lake. Over time, the natural ability of the lake to assimilate the incoming nutrients and organic debris could diminish, resulting in a gradual degradation in water quality and the overall health of the aquatic system. Organic accumulation in the lake has resulted in increased sediments over time.

Activities intended to improve water quality within Lake Gem Mary depends on the active participation of the City of Orlando, Orange County, residents living within the watershed and businesses located within the watershed.

6.2. SEDIMENT INACTIVATION

The largest contributor of TP to Lake Gem Mary, (56%), occurs due to internal recycling of nutrients in the sediments accumulated on the bottom of the lake. Sediment phosphorus inactivation is a lake restoration technique which is designed to substantially reduce sediment phosphorus release by combining available phosphorus in the sediments with a metal salt to form an insoluble 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 a relatively inexpensive option for reducing sediment phosphorus release since removal of the existing sediments is not required.

6.2.1. GENERAL CONSIDERATIONS

Sediment phosphorus inactivation is most often performed using aluminum sulfate (an acidic aluminum salt commonly called alum) or sodium aluminate (an alkaline aluminum salt), which are applied at the surface in a liquid form using a boat or barge. The aluminum forms an insoluble precipitate of aluminum hydroxide which attracts phosphorus, bacteria, algae, and suspended solids within the water column, settling these constituents into the bottom sediments. Upon reaching the bottom sediments, the residual aluminum binds tightly with phosphorus within the sediments, forming a precipitate which remains stable under many conceivable conditions of pH or redox potential which could occur in a natural lake system. These sediment treatments have been shown to be effective from 2-20 years, depending upon the sediment accumulation rate within the lake from the remaining phosphorus sources.

A tabular summary of the chemical and physical characteristics of alum and sodium aluminate, both of which are commonly used in lake sediment inactivation projects, is presented in Table 6-1. Aluminum sulfate, commonly called alum, is the most widely used chemical for sediment inactivation, and has a density of approximately 11.12 lbs/gallon and contains 4.4% aluminum by weight. Sodium aluminate, which is often used as a pH buffer in alum treatments, has a density of 12.3 lbs/gallon and an aluminum content of 10.6% by weight, although this percentage varies slightly depending on the manufacturer.

Table 6-1: Characteristics of Common Treatment Chemicals

Chemical / Parameter		Units	Value
Alum	Density	lbs/gallon	11.12
	Aluminum Content	% Aluminum	4.4
Sodium Aluminate	Density	lbs/gallon	12.3
	Aluminum Content	% Aluminum	10.6

Based on the nutrient budget for Lake Gem Mary, internal recycling contributes approximately 56% of the phosphorus loading to the lake, with an additional 3% contributed by groundwater seepage. Phosphorus loadings from internal recycling and groundwater seepage can be controlled simultaneously through a carefully planned alum application. Therefore, the goal of the proposed sediment inactivation alum treatment for Lake Gem Mary is to provide simultaneous control for both internal recycling and groundwater seepage. Together, these sources contribute approximately 59% of the total phosphorus loading to the lake. Since the overall contribution of phosphorus to Lake Gem Mary from sediments is significant, controlling the sediment release of phosphorus has the potential to result in improvements in water quality within the lake.

6.2.2. CHEMICAL REQUIREMENTS

Sediment inactivation in Lake Gem Mary would involve the addition of liquid aluminum-based coagulants at the water surface. Upon entering the water, the coagulants form insoluble precipitates which settle onto the lake bottom while also clarifying the existing water column within the lake. The precipitate will combine with existing phosphorus within the sediments, primarily saloid- and iron-bound complexes, forming insoluble precipitates which will chemically bind with 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 aluminum to bind the saloid- and iron-bound phosphorus complexes 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 Lake Gem Mary were generated by graphically integrating the total available phosphorus isopleths presented in Figure 2-17, generated from the phosphorus speciation conducted on the collected sediment samples. Available phosphorus concentrations in Lake Gem Mary sediments

are generally high in value, although this does not necessarily correlate with a high phosphorus release rate. The top 0-10 cm layer of the sediments is considered to be the most active layer with respect to exchange of phosphorus between the sediments and the overlying water column. Inactivation of phosphorus within the 0-10 cm layer is typically sufficient to inactivate sediment release of phosphorus within a lake.

Prior research involving sediment inactivation has indicated that an excess of aluminum is required within the sediments to cause phosphorus to preferentially bind with aluminum rather than other available competing ions. Previous sediment inactivation projects have been conducted at molar Al:P ratios of 2, 3, 5, and 10, with recent sediment inactivation projects performed using a 10:1 ratio. Therefore, since the phosphorus concentration within the lake sediments appear to be normal to high, an Al:P ratio of 10:1 is assumed for inactivation of sediment phosphorus in Lake Gem Mary.

A summary of total estimated total available phosphorus in the sediments of Lake Gem Mary is presented in Table 6-2. On a mass basis, the sediments of Lake Gem Mary contain approximately 466 kg of available phosphorus in the top 10 cm which equates to approximately 14,428 moles of available phosphorus to be inactivated as part of the sediment inactivation process. Using an Al:P ratio of 10:1, sediment inactivation in Lake Gem Mary would require 144,277 moles of aluminum or approximately 17,573 gallons of alum, equivalent to approximately 4 tanker loads containing 4,500 gallons each, assuming that alum could be used as the sole inactivant without concern for pH depression. The equivalent aerial aluminum dose for this application would be 104.1 g Al/m².

Additional aluminum can 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. However, Lake Gem Mary's groundwater seepage input is low when compared to the internal recycling input. 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 6-2: Lake Gem Mary Sediment Inactivation Requirements

Available P Contour Interval ($\mu\text{g}/\text{cm}^3$)	Contour Interval Mid-Point ($\mu\text{g}/\text{cm}^3$)	Contour Area (acres)	Available Phosphorus		Alum Requirements (Al:P Ratio = 10:1)	
			kg	moles	moles Al	gallons alum
60-65	62.5	0.2	4	131	1,306	159
65-70	67.5	1.5	42	1,304	13,035	1,588
70-75	72.5	2.3	67	2,062	20,618	2,511
75-80	77.5	2.9	92	2,852	28,517	3,473
80-85	82.5	2.7	91	2,813	28,132	3,427
85-90	87.5	1.9	68	2,115	21,150	2,576
90-95	92.5	0.9	35	1,099	10,988	1,338
95-100	97.5	0.7	26	817	8,174	996
100-105	102.5	0.5	20	630	6,297	767
105-110	107.5	0.3	14	419	4,192	511
110-115	112.5	0.1	6	187	1,867	227
Overall Totals:		14.1	466	14,428	144,277	17,573

A summary of calculations of alum requirements for control of phosphorus loading from groundwater seepage entering Lake Gem Mary is presented in Table 6-3. Based on the field seepage monitoring program conducted during 2015 to 2016, phosphorus inflow to Lake Gem Mary from groundwater seepage is estimated to be approximately 0.8 kg/yr. This analysis assumes that control of groundwater seepage is desired for a period of approximately 10 years. Therefore, the total mass of phosphorus from groundwater seepage which must be inactivated is approximately 8 kg over the 10-year period. This mass of phosphorus equates to approximately 248 moles of total phosphorus. Assuming an Al:P ratio of 10:1 for adequate inactivation, control of 248 moles of total phosphorus will require approximately 2,478 moles of aluminum, or an equivalent alum volume of 302 gallons.

Table 6-3: Alum Requirements for Control of Phosphorus Loading from Groundwater Seepage in Lake Gem Mary

Parameter		Units	Value
Estimated Phosphorus Mass to be Controlled	Annual Phosphorus Loading from Seepage	kg/yr	0.8
	Desired Length of Control	years	10
	Total Phosphorus Mass to be Inactivated (based on 10 years)	kg	8
	Moles of Phosphorus to be Inactivated	moles	248
Alum Requirements	Inactivation Al:P ratio	--	10
	Moles of Aluminum Required	moles	2,478
	Alum Required	gallons	302

Note: Based on an Al:P ratio of 10:1

Previous alum surface applications performed for inactivation of sediment phosphorus release 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 6-9 months. Multiple applications provide less stress on aquatic organisms and allow a gradual transition for food webs from larger concentration of TP/chlorophyll-a or a lower concentration of TP/chlorophyll-a. 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.

The proposed alum treatment to Lake Gem Mary would add sufficient alum to control both internal recycling and intercept phosphorus loadings from groundwater seepage. Assuming that approximately 17,573 gallons of alum are needed for sediment inactivation and 302 gallons of alum are needed for interception of groundwater seepage, the total amount of alum to be added to Lake Gem Mary would be 17,875 gallons. This equates to a whole-lake dose of approximately 19.1 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 or a buffering compound would be needed to

neutralize the pH impacts from the alum addition. Due to the large quantity of alum required for Lake Gem Mary, four separate applications are proposed, with each application providing a whole-lake dose of approximately 4.8 mg Al/liter.

Based upon the surface water monitoring conducted during 2015 through 2016, the water column in Lake Gem Mary is moderately to poorly buffered, with measured alkalinity values ranging from approximately 30-85 mg/l, depending upon location within the lake. This level of alkalinity is insufficient to provide adequate buffering for even the relatively low estimated whole-lake dose of 4.8 mg Al/liter for each treatment. Therefore, each of the four recommended treatments will require a simultaneous application of alum and sodium aluminate. Sodium aluminate, an alkaline form of alum, is commonly used in these applications as the preferred buffering agent and is recommended for use in Lake Gem Mary. Sodium aluminate provides a high level of buffering, as well as supplemental aluminum ions, which reduces the total 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. Based on previous experience in lakes with similar water quality characteristics, the simultaneous addition of 1 gallon of sodium aluminate for every 2.5 gallons of alum is often sufficient to minimize pH reductions during the application process for lakes with water quality characteristics similar to Lake Gem Mary. Therefore, this ratio is assumed for Lake Gem Mary. 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 it can also reduce the amount of alum required for the inactivation project. The optimum alum/sodium aluminate ratio needs to be determined in a series of jar tests prior to the four proposed applications as the ratio may vary as the lake water chemistry may vary.

A summary of anticipated chemical requirements for the sediment inactivation treatments in Lake Gem Mary is given in Table 6-4. Assuming an alum/sodium aluminate ratio of 2.5:1, the required mass of aluminum for sediment inactivation can be achieved using approximately 25,645 gallons of alum and 10,258 gallons of sodium aluminate. When these quantities are divided into the four

separate treatments, each treatment will require the addition of 6,411 gallons of alum (1.5 tankers) and 2,564 gallons of sodium aluminate (0.6 tankers). The applied water column dose of aluminum for each of the four treatments will be approximately 4.8 mg Al/liter.

Table 6-4: Chemical Requirements for Sediment Inactivation and Seepage Control in Lake Gem Mary

Parameter		Units	Value
Chemical Requirements	Aluminum Required	kg	3,967
	Alum/Sodium Aluminate Volume Ratio	--	2.5
	Alum	gallons	25,645
	Sodium Aluminate	gallons	10,258
	Aluminum Provided	kg	5,940
	Water Column Dose	mg Al/liter	19.1
	Areal Dose	g Al/m ²	104.1
Chemical Requirements/ Treatment	Number of Treatments	--	4
	Alum Required per Treatment	gallons tankers	6,411 1.5
	Sodium Aluminate Required per Treatment	gallons tankers	2,564 0.6
	Dose per Treatment	mg Al/liter	4.8

6.2.3. APPLICATION COSTS

A summary of estimated costs for the proposed sediment inactivation treatments in Lake Gem Mary is presented in Table 6-5. Each of the four proposed treatments will include application of approximately 6,411 gallons of alum and 2,564 gallons of sodium aluminate. Planning and mobilization costs are estimated to be approximately \$4,500 per treatment, with a chemical application fee of \$1,350 per tanker or partial tanker. Field monitoring for pH and alkalinity during the application is estimated at \$500 per treatment, with an additional \$4,800 per treatment for pre- and post-treatment laboratory analyses. The estimated overall cost for sediment inactivation in

Lake Gem Mary is \$29,399 per treatment or a total of \$117,594 for the four proposed treatments, as shown in Table 6-5.

Table 6-5: Estimated Costs for Sediment Inactivation and Seepage Control in Lake Gen Mary

Parameter		Quantity per Treatment	Units	Unit Cost	Cost per Treatment	Total Cost
Alum	Quantity	6,411	gallons	\$0.60	\$3,847	\$15,386
	Number of Tankers	2	tankers	--	--	--
Sodium Aluminate	Quantity	2,564	gallons	\$5.50	\$14,102	\$56,408
	Number of Tankers	1	tankers	--	--	--
Labor Costs	Planning/Mobilization	1	each	\$5,000.00	\$5,000	\$20,000
	Chemical Application	3	tankers	\$1,500.00	\$4,500	\$18,000
Monitoring/ Lab Testing	Field Monitoring	1	each	\$750.00	\$750	\$3,000
	Lab Analyses- Pre/Post (at 2 sites)	4	samples	\$300.00	\$1,200	\$4,800
Total					\$ 29,399	\$ 117,594

6.2.4. 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.

Many sediment inactivation projects have been conducted in the State of Florida since 1992 with sufficient pre- and post-water quality data to evaluate the effectiveness of the alum sediment inactivation process. It appears that a properly planned and executed alum treatment project for Lake Gem Mary would maintain a continuous level of effectiveness for a minimum of approximately 10-15 years.

6.3. SANITARY SEWER

The majority of existing homes along the perimeter of Lake Gem Mary are serviced by on-site sewage treatment and disposal facilities (OSTDs), commonly known as septic tanks, see Figure 3-5. Based on 2011 IFAS data for TN and TP loading from OSTDs shown in Table 3-5, a pollutant load reduction of 78.3 kg/year of TP and 324.8 kg/year of TN could be expected if the OSTDs were converted to a central sewer system. While these numbers based on literature results are significant, the analytical results from the collection of ground-water samples from the six on-site seepage meters do not show significant concentrations of TN and TP. It is recommended that homeowners connect to the sanitary sewer as it becomes available in their area.

If the County chooses to install a sanitary system in the Lake Gem Mary watershed, the nearest sanitary sewer connection is owned and operated by the City of Orlando. The closest manhole is located at the intersection of Northglenn Drive and Appleton Avenue. The manhole location and potential sewer lines necessary to connect to the sanitary system are presented in Figure 6-1. The estimated construction costs to install sanitary sewer and a lift station as shown in Table 6-6. The estimated pollutant removal cost is presented in Table 6-7.

Table 6-6: Central Sewer Cost Estimate

Alternative	Amount	Unit Cost	Total
Gravity System Piping (feet)	3,000	\$150	\$525,000
Laterals	19	\$1,000	\$19,000
Manholes	7	\$8,000	\$56,000
Lift Station	1	\$150,000	\$200,000
Total			\$800,000

Table 6-7: Central Sewer Pollutant Removal Estimate

Number of Houses	19
Total TP Removed per Year	78.3
Total TN removed per Year	324.8
Cost per Kg of TP Removed*	\$10,217
Cost per Kg of TN Removed*	\$2,463.05

* Assuming that construction costs are \$800,000

Figure 6-1: Sanitary Sewer Alternative



6.4. ON-SITE SANITARY TREATMENT AND DISPOSAL MAINTENANCE

Failing or non-maintained on-site sanitary treatment and disposal systems (OSTDs) also known as septic systems, can contribute substantially more nutrients to waterbodies than well-maintained OSTDs. The EPA's "A Homeowner's Guide to Septic Systems" is presented in Appendix H. The document discusses important issues for homeowners, including:

- "Your septic system is your responsibility";
- "How does it work?";
- "Why should I maintain my septic system?";
- "How do I maintain my septic system?"; and
- "What can make my system fail?"

A septic tank inspection may include: locating the system, uncovering access holes, flushing toilets, checking for signs of back up, measuring scum and sludge layers, identifying any leaks, inspecting mechanical components, and pumping the tank if necessary. Steps to maintain a septic system include:

- Inspect and pump frequently;
- Use water efficiently;
- Watch what goes down the drains; and
- Care for the drainfield.

If a central sewer system is not installed in the neighborhoods surrounding Lake Gem Mary, the existing OSTDs could be replaced with advanced septic treatment system. These systems are generally pumped systems to provide additional separation between the drainfield and the groundwater elevation. Very often these systems include a biological activated media (BAM) filter which will reduce the discharge of nutrients from a OSTD. A cost of \$10,000 is estimated to replace an existing septic system with an advanced OSTD. There are 19 homes and one institution surrounding Lake Gem Mary for an estimated cost of \$200,000 to retrofit or replace the existing OSTDs. The estimated removal efficiencies are 95% and 50% for TP and TN, respectively.

6.5. REAR YARD SWALES AND BERMS

Runoff originating from lawns and landscaped areas has the potential to contribute significant loadings of both nutrients and pesticides into Lake Gem Mary. Untreated stormwater runoff from lawns and landscaped areas contains TP concentrations which are many times greater than concentrations commonly observed in Lake Gem Mary. As a result, a relatively small volume of untreated rear yard runoff can impact a large quantity of adjacent water. As shown in Table 5-10, runoff originating from direct overland flow into Lake Gem Mary contributes approximately 8.7% (2.4 kg/yr) of the annual TP loadings to the lake.

6.5.1. EXISTING CONDITIONS AND ISSUES

A requirement for rear yard berms and swales to contain overland runoff is contained in Section 34-132 of the Orange County Municipal Code, titled “Subdivision Construction Plans”. The requirement for berms and swales consists of a single sentence located in paragraph c (2) which states “... Pollution abatement swales shall be provided upland of streams and canals and the normal high water elevation in all lakes. ...” However, this section of the Municipal Code does not provide design criteria or guidelines for the berm and swale. Since the reference to berms and swales is located in a section titled “Subdivision Construction Plans”, the requirement applies only to construction of new subdivisions and does not apply to pre-existing homes or new single-family homes constructed on individual lots which are not part of a designated subdivision. This provision also does not apply to redevelopment (demolition and reconstruction) of an existing single-family lot.

Design guidelines for the rear yard swale and berm systems should achieve the same level of treatment as a stormwater management system designed for the remaining portions of the development. The design of stormwater management systems in Florida is regulated by Chapter 62-25 of the Florida Administrative Code titled “Regulation of Stormwater Discharge”. This statute establishes minimum design and performance standards for stormwater management systems, including design criteria for swales which are for water quality treatment. Chapter 62-25 requires that stormwater management systems be designed “to achieve at least an 80%

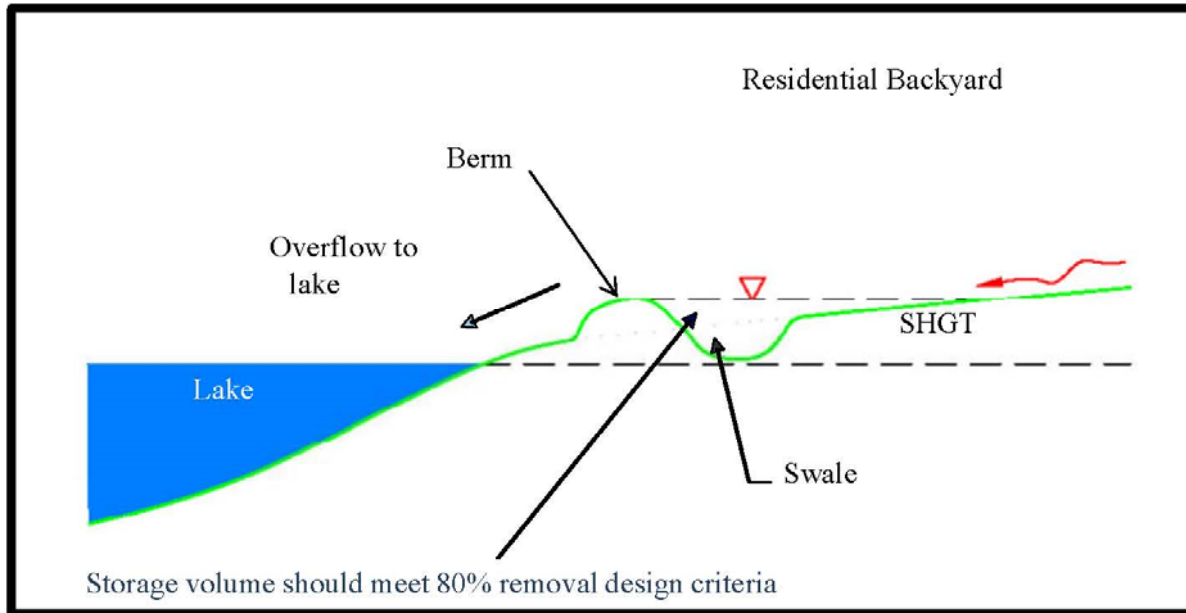
reduction of the average annual load of pollutants that would cause or contribute to violations of State water quality standards”.

Design calculations to achieve 80% pollutant load reductions for swale and infiltration systems were developed as part of the ongoing Statewide Stormwater Rule development. As part of this process, a series of continuous simulations were conducted to evaluate retention depths necessary to achieve 80% load reductions for various combinations of curve number and directly connected impervious percentages (DCIA) for various meteorological regions within the State. To achieve an 80% removal rate, one inch of stormwater would need to be retained in the swale system. It is unlikely that an existing development can be retrofitted to achieve 1-inch stormwater retention; therefore, calculations are based on 0.5 inches of retention over each parcel, providing approximately 52% reductions of TP and TN. These tabular values are included in the Statewide Stormwater Rule as well as in the 2007 report by Harper and Baker titled “Evaluation of Current Stormwater Design Criteria within the State of Florida”. This methodology has been reviewed and approved by FDEP and the State’s Water Management Districts. It is recommended that this methodology be used to establish volumetric requirements for rear yard berm and swale systems.

During November 2007, CDM Smith prepared a report for OCEPD titled “Orange County Swale and Berm Design Criteria Report”. This report contains many general guidelines regarding swale design concerning distance from shorelines, relationship to the seasonal high groundwater table, check dams, stability and erosion control criteria, and other general information which is useful in designing swale and berm systems. However, volumetric requirements should be calculated using the methodology referenced previously.

The objective of a berm and swale system is to intercept runoff from a rear yard area, causing the runoff to be infiltrated into the ground rather than directly discharging into the adjacent waterbody. As the runoff migrates through the vegetation and surficial soils, a large portion of the pollutant mass is attenuated and is prevented from reaching the adjacent waterbody. Since these systems act primarily as retention areas, it is important that the area used for the swales be constructed above the seasonal high groundwater table elevation (SHGWT). If the bottom of the swale is not maintained above the SHGWT, the infiltration area will assume wetland characteristics and will gradually lose its ability to store and treat the required pollution abatement volume. A schematic of a recommended berm and swale design is presented in Figure 6-2.

Figure 6-2: Schematic of Recommended Rear Yard Swale and Berm Design

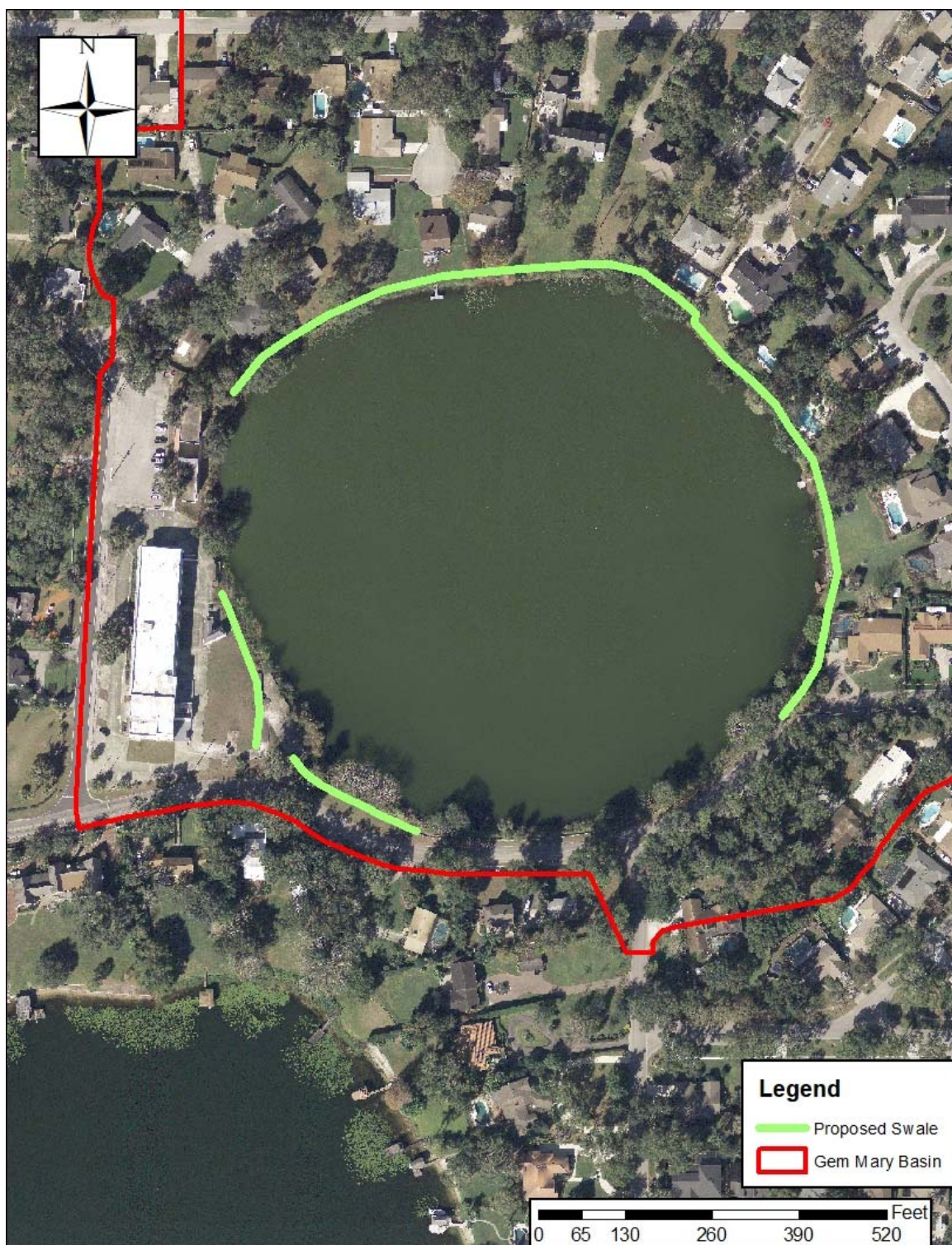


One of the common criticisms of berm and swale systems concerns ongoing maintenance of the areas. Where swale systems are used, bottom portions of the swale can become wet for extended periods, making mowing and maintenance activities difficult. Mowing of the berms can also be difficult, particularly if the berm is constructed with steep side slopes. Maintenance concerns for the berms can be eliminated by constructing a more gradual side slope, such as 6(H):1(V), or flatter. In addition, the area between the berm and the lake shoreline should be planted with low or no-maintenance vegetation to reduce erosion, eliminate mowing and maintenance activities, and reduce pollutant load to the lake.

A field review was performed to evaluate the lake front properties adjacent to the Lake Gem Mary to determine if a berm and swale system exists along the lake shore. There was no evidence of a swale and berm system along the vegetated shore of Lake Gem Mary. Portions of the shoreline at the Naval Research Facility are paved and portion of the shoreline along Gatlin Avenue is too narrow to install a swale and berm system. Swales can be constructed along approximately 2,000 linear feet of the shoreline. The location of proposed swales along the shoreline of Lake Gem Mary is presented in Figure 6-3.

While the construction of swales and berms are assumed to capture 52% of the direct runoff and thereby, 52% of the TP in the direct runoff, different soil types have different abilities to capture TP. To prevent entrainment of TP in groundwater entering Lake Gem Mary from the swales, the addition of biological activated media (BAM) such as Bold and Gold CTS in the soil at the bottom of the swale can provide 90% TP removal and 60% TN removal. Using a cost of \$50 per linear foot, the cost of swale construction is estimated to be \$100,000. The cost to install a one-foot depth of CTS in a 10-foot wide swale approximately 2000 feet around the perimeter of Lake Gem Mary is estimated to be \$77,000. The total cost of the swales and berms constructed with CTS is \$177,000. Assuming the swale will function for 10-years without significant repairs, the cost per kg TP removed over a 10-year period is \$15,733 kg/yr ($\$177,000 / (1.25 \times 10 \times 0.9)$).

Figure 6-3: Lake Gem Mary Proposed Swale Locations

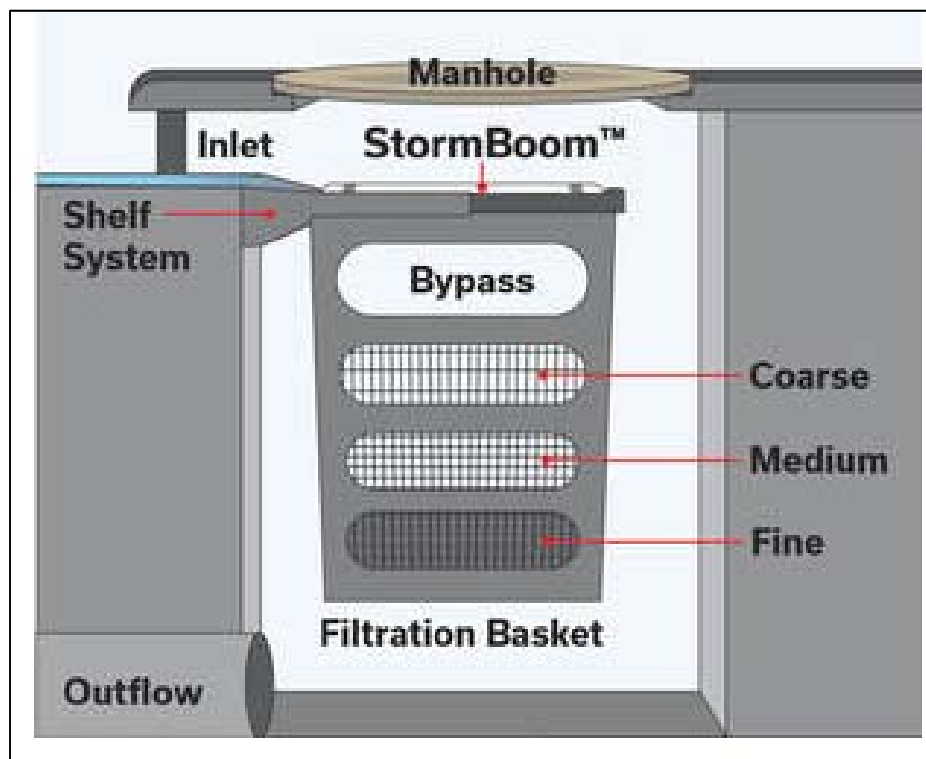


6.6. INLET BASKETS

Development within the Lake Gem Mary watershed was constructed prior to water quality treatment requirements. Stormwater runoff from the residential areas along the north and east portions of the watershed flow to the streets where it is collected by curb inlets and discharged directly to the lake.

Installation of inlet baskets in the residential areas of the watershed would collect leaves, floatable trash, grass clippings, and other debris present in the stormwater runoff prior to discharge into the lake. Curb inlet baskets (CIBs) and grate inlet baskets (GIBs), also referred to as catch basin basket inserts, are a retrofit-type BMP designed to filter pollutants from stormwater before the pollutants enter the storm sewer and ultimately the lake. These units are installed in individual inlets or grate inlets and are made of durable material, such as stainless steel and high-strength plastic. High Capacity Curb Inlet Baskets™ are used in deep catch basins where the primary access is a manhole, such as those in the Lake Gem Mary watershed. A schematic of the high capacity CIB is presented in Figure 6-4.

Figure 6-4: Schematic of High Capacity Curb Inlet Basket



The high capacity CIB filter uses a shelf system to direct stormwater flow through the filter positioned directly under the access manhole. The multi-stage filtration system captures different size pollutants and debris during a storm event. Under high volume flows, water can bypass the filter. A hydrocarbon absorption sock is installed around the top of the CIB to reduce oils and grease in stormwater runoff.

The installed CIBs are relatively inexpensive with an installed cost of approximately \$1,000 to \$1,100/unit. Maintenance is relatively simple, requiring approximately 5-10 minutes to clean each unit with a vacuum-type truck. Recommended cleaning of the CIBs is monthly.

Locations of proposed curb and grate inlet baskets in the Lake Gem Mary watershed are illustrated in Figure 6-5. Literature values indicated a TP removal rate of 4.4/kg/curb mile/year and TN removal rate of 12.0/kg/curb mile/year. Biological Activated Media (BAM) can be added to inlet baskets to increase their pollutant removal efficiencies. Pollutant removal efficiencies for inlet baskets retrofitted with BAM are reported to be between 71% to 96% for TP and 65% to 96% for TN. Estimated nutrient removal and costs that can be expected with inlet basket installation without BAM usage are presented in Table 6-8.

Table 6-8: Inlet Basket Pollutant Removal and Costs

Description	Amount
Road Length (miles)	1.5
TP Removal kg/curb mile/year	4.4
TN Removal kg/curb mile/year	12
TP Removed (Kg/yr)	6.6
TN Removed (Kr/yr)	18.0
Number of Inlets	13
Cost Per Inlet Basket	\$1,100
Construction Cost	\$14,300
TP Cost per Kg Removed*	\$216.67
TN Cost per Kg Removed*	\$79.44

* Based on 10-year life cycle for Inlet Baskets

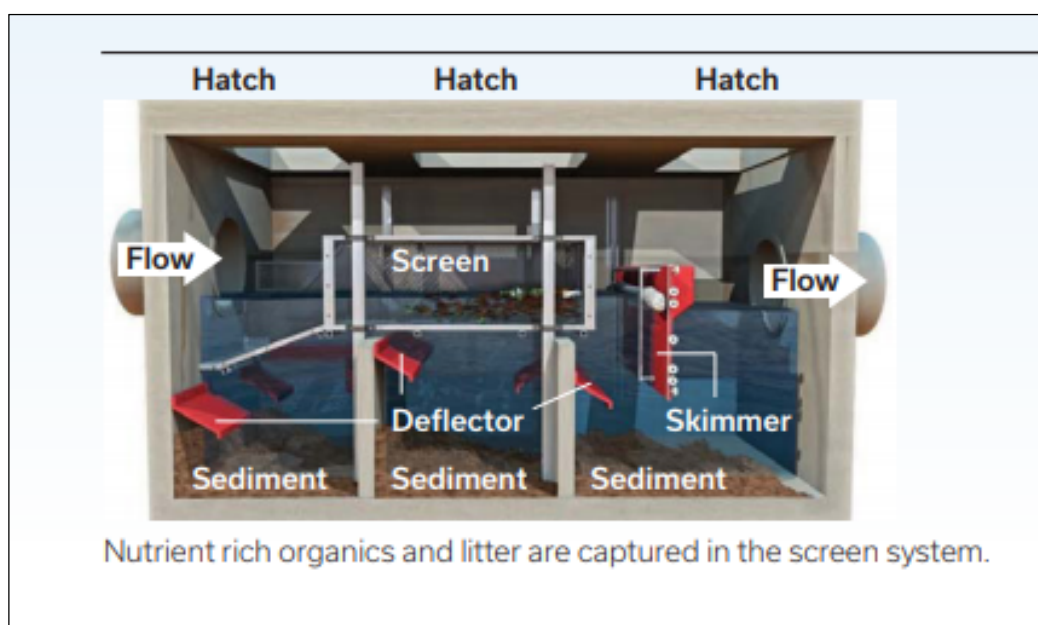
Figure 6-5: Inlet Basket Locations



6.7. BAFFLE BOXES

Baffle boxes are designed to collect sediment and floating debris from flowing water. Second generation baffle boxes are also designed for removal of nutrients by using a screened basket inside the structure to keep the collected vegetation/debris out of the water table, reducing the decomposition and release of nutrients. A schematic of a nutrient removing baffle box is presented in Figure 6-6.

Figure 6-6: Nutrient Separating Baffle Box



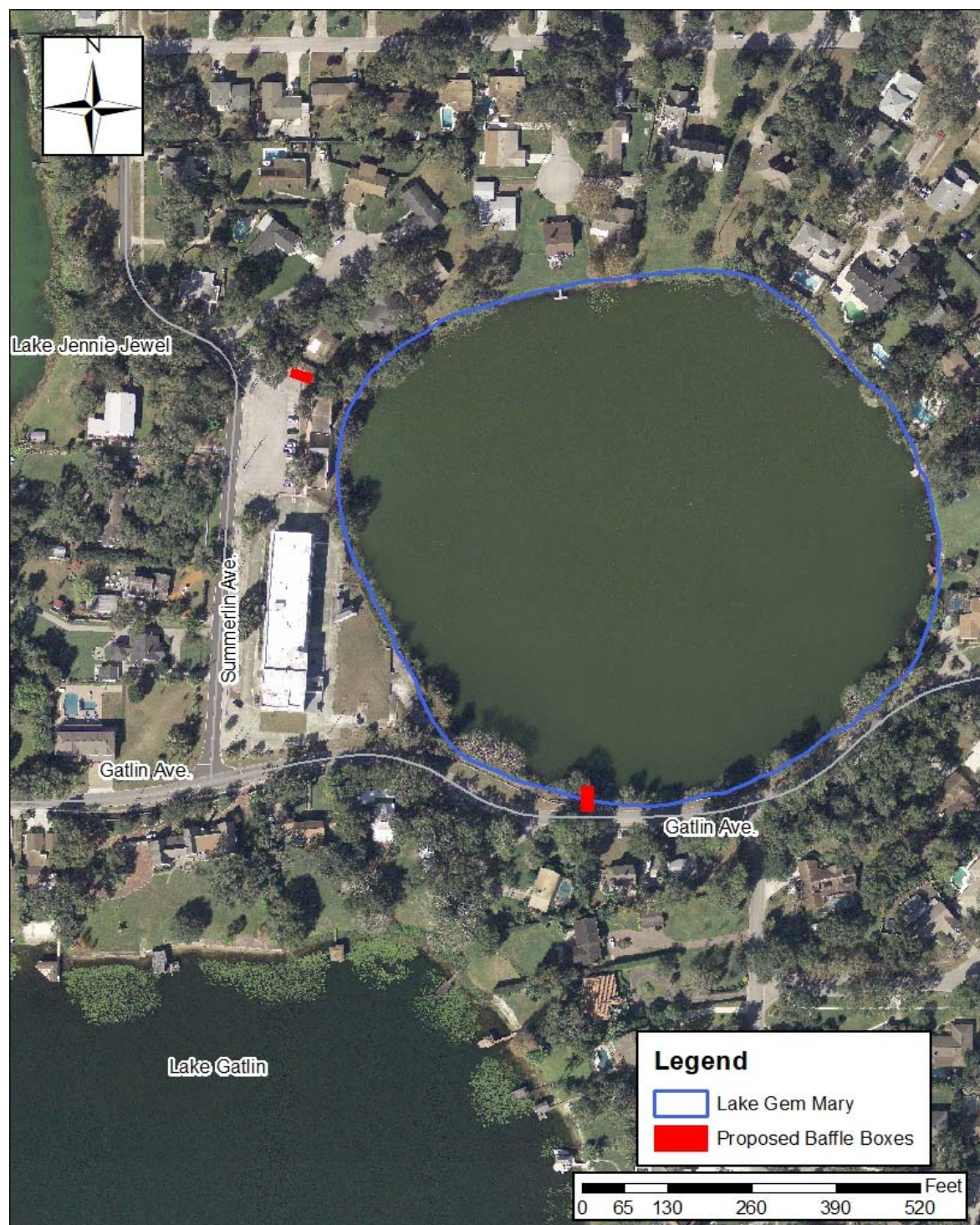
Schematic attributed to Suntree Technologies

FDEP accepts removal efficiencies of 15.5% for TP and 19.05% for TN from nutrient separating baffle boxes as part of the “*Basin Management Action Plan for the Implementation of Total Maximum Daily Load for Total Phosphorus by the Florida Department of Environmental Protection in Lake Okeechobee*” (2014). Biological activated media (BAM), such as Bold & Gold, can be added to baffle boxes to increase their nutrient removal capabilities during base flow. Typically, base flow rates of 4 cfs or less can be treated with Bold & Gold, with a bypass flow system used during peak flow rates. Test results show that removal efficiencies of 79% for TP and 67% for TN can be achieved using Bold & Gold to treat the base flow.

There are two recommended locations within the Lake Gem Mary watershed for baffle box installation. The first location is at the Orange County School Board facility (previously the

Naval Research Facility), identified as sub-basins 1 and 2 on Figure 4-2. These two sub-basins are almost 100% impervious area and stormwater runoff discharges from the parking area through a grated ditch bottom inlet to the lake. The recommended location for the baffle box is along the north boundary of the parking area where the DBI is currently located. A second location recommended for baffle box installation is along Gatlin Avenue (south of the lake), identified as sub-basin 8 on Figure 4-2. The location is near the existing flume that allows the entire road within the watershed to drain directly into the lake. The recommended baffle box locations are shown in Figure 6-7.

Figure 6-7: Nutrient Separating Baffle Box



Based on the relatively small size of the sub-basin drainage areas and anticipated inlet stormwater pipe size of 24 inches, a 5-ft X 10.5-ft baffle box is recommended at each site. Peak flow capacity for each baffle box is up to 30cfs. Estimated pollutant loading from each of the sub-basins are

presented in Table 5-5. The estimated pollutant removal and associated costs for each recommended baffle box site are presented in Table 6-9. The estimated pollutant removal and associated costs for each recommended baffle box site including Bold & Gold are presented in Table 6-10.

Table 6-9: Baffle Boxes at Sub-Basin 1, 2 & 8

Sub-Basins 1 & 2 with Baffle Box

Description	Amount
TP Load kg/yr	2.7
TN Load kg/yr	15.6
TSS Load kg/yr	549.2
TP Removal Efficiency*	15.5%
TN Removal Efficiency*	19.1%
TSS Removal Efficiency**	80%
TP Removed (kg/yr)	0.42
TN Removed (kg/yr)	2.97
TSS Removed (kg/yr)	439.36
Baffle Box Cost & Installation	\$80,000
TP Cost per Kg Removed	\$191,159
TN Cost per Kg Removed	\$26,920
TSS Cost per Kg Removed	\$182

Sub-Basins 8 with Baffle Box

Description	Amount
TP Load kg/yr	0.8
TN Load kg/yr	6.5
TSS Load kg/yr	89.6
TP Removal Efficiency*	15.5%
TN Removal Efficiency*	19.1%
TSS Removal Efficiency**	80%
TP Removed (kg/yr)	0.12
TN Removed (kg/yr)	1.24
TSS Removed (kg/yr)	71.68
Baffle Box Cost & Installation	\$80,000
TP Cost per Kg Removed	\$645,161
TN Cost per Kg Removed	\$64,607
TSS Cost per Kg Removed	\$1,116

Table 6-10: Baffle Boxes at Sub-Basin 1, 2 & 8 with Bold & Gold

Sub-Basins 1 & 2 with Baffle Box and Bold & Gold

Description	Amount
TP Load kg/yr	2.7
TN Load kg/yr	15.6
TSS Load kg/yr	549.2
TP Removal Efficiency*	79.0%
TN Removal Efficiency*	67.0%
TSS Removal Efficiency**	95%
TP Removed (kg/yr)	2.13
TN Removed (kg/yr)	10.45
TSS Removed (kg/yr)	521.74
Baffle Box Cost & Installation	\$100,000
TP Cost per Kg Removed	\$46,882
TN Cost per Kg Removed	\$9,568
TSS Cost per Kg Removed	\$192

Sub-Basins 8 with Baffle Box and Bold & Gold

Description	Amount
TP Load kg/yr	0.8
TN Load kg/yr	6.5
TSS Load kg/yr	89.6
TP Removal Efficiency*	79.0%
TN Removal Efficiency*	67.0%
TSS Removal Efficiency**	95%
TP Removed (kg/yr)	0.63
TN Removed (kg/yr)	4.36
TSS Removed (kg/yr)	85.12
Baffle Box Cost & Installation	\$100,000
TP Cost per Kg Removed	\$158,228
TN Cost per Kg Removed	\$22,962
TSS Cost per Kg Removed	\$1,175

6.8. NON-STRUCTURAL TECHNIQUES

The Lake Gem Mary drainage basin is 100% developed, and opportunities for stormwater treatment are limited within the basin. Non-structural techniques can support nutrient load reduction entering Lake Gem Mary when structural techniques are not possible. Non-structural techniques that may support nutrient reduction in stormwater runoff include enforcement of the County's fertilizer ordinance, street sweeping, promoting good landscape practices with homeowners and stormwater management.

Source reduction programs have the potential to provide effective reduction of pollutant concentrations in stormwater, particularly for nutrients and suspended solids. Source reduction techniques, such as street sweeping and public education, are capable of reducing loadings of pollutants entering receiving waterbodies by reducing pollutant accumulation within the watershed. Non-structural techniques are discussed in the following sections.

6.8.1. FLORIDA YARDS AND NEIGHBORHOODS

The Florida Yards and Neighborhoods (FYN) Program is a project of the Florida Department of Environmental Protection and is presented by the University of Florida's IFAS extension and the

Southwest Florida Water Management District. These organizations have developed the Florida-Friendly Landscaping program to educate Floridians about science-based, environmentally friendly, landscaping practices and to encourage them to conserve and protect our water resources by applying 9 basic principles:

- 1) Right Plant, Right Place: Plants selected to suit a specific site will require minimal amounts of water, fertilizers and pesticides.
- 2) Water Efficiently: Irrigate only when your lawn needs water. Efficient watering is the key to a healthy yard and conservation of limited resources.
- 3) Fertilize Appropriately: Less is often best.
- 4) Mulch: Maintain two to three inches of mulch to help retain soil moisture, prevent erosion and suppress weeds.
- 5) Attract Wildlife: Plants that provide food, water and shelter can conserve Florida's diverse wildlife.
- 6) Manage Yard Pests Responsibly: Unwise use of pesticides can harm people, pets, beneficial organisms and the environment.
- 7) Recycle: Grass clippings, leaves, and yard trimmings composted and recycled on site provide nutrients to the soil and reduce waste disposal.
- 8) Reduce Stormwater Runoff: Water running off the yard can carry pollutants such as fertilizer, pesticides, soil and debris that can harm water quality. Reduction of this runoff will help prevent pollution.
- 9) Protect the Waterfront: Waterfront property, whether on a river, stream, pond, bay or beach, is very fragile and should be carefully protected to maintain freshwater and marine ecosystems.

Homeowners around the lake should be encouraged to implement these principles to improve the water quality of the lake. An important aspect of the FYN program is education. If residents do not know the importance of these principals, then they cannot implement these. Distributing information in homeowner association newsletters, newspapers and other public announcements

(PSAs), such as informational pamphlets, educational presentations, and informative stormwater websites are recommended.

6.8.2. STREET SWEEPING

Street sweeping is an effective best management practice (BMP) for reducing total suspended solids and associated pollutant wash-off from urban streets. Street sweeping is well suited to an urban environment where little land is available for installation of structural controls. Street sweeping can be extremely effective in commercial business districts, industrial sites, residential areas with significant tree cover and intensely developed areas in close proximity to receiving waters.

Street sweeping involves the use of machines that pick-up contaminants from the street surface and deposit them in a self-contained bin or hopper. Mechanical sweepers are the most commonly used sweeping devices and consist of a series of brooms which rotate at high speeds, forcing debris from the street and gutter into a collection hopper. Water is often sprayed on the surface for dust control during the sweeping process. The effectiveness of mechanical sweepers is a function of a number of factors, including: (1) particle size distribution of accumulated surface contaminants; (2) sweeping frequency; (3) number of passes during each sweeping event; (4) equipment speed; and (5) pavement conditions. Unfortunately, mechanical sweepers perform relatively poorly for collection of particle sizes <100 microns which are commonly associated with total phosphate loadings in stormwater runoff.

Street sweeping is currently performed throughout the Lake Gem Mary watershed that has curb and gutter. Gatlin Avenue along the south side of the lake does not have curb and gutter, and is not currently swept.

The efficiency of street sweepers is highly dependent upon the sweeping interval. To achieve a 20% annual removal of TP, street sweeping should be performed twice a week. Since the average interval between storms in the Central Florida area is approximately three days, a sweeping frequency of once every three days is recommended to yield to a 20% removal of TP. Street sweeping tasks in the Lake Gem Mary watershed are divided between the Environmental Protection Division (EPD), and Roads and Drainage. EPD usually conducts sweeping operations once every two weeks, removing an estimated 10% of TP; approximately 0.7 lb TP/curb mile per

year. Roads and Drainage usually conducts sweeping operations once every six weeks, removing an estimated 5% of TP; approximately 0.35 lb TP/curb mile per year. The pollutant removal efficiency of street sweeping at varying time intervals is presented in Table 6-11.

Table 6-11: Removal Efficiency per Street Sweep Frequency

Street Sweep Frequency	% of Total TP Load	TP lbs/curb mile	TN lbs/curb mile
Every 6 Weeks	5%	0.35	1.46
Every 2 Weeks	10%	0.7	2.94
Weekly	15%	1.4	5.88
Twice Weekly	20%	2.81	11.8

(Based on *Quantifying Nutrient Loads Associated with Urban Particulate Matter (PM) and Biogenic/Litter Recovery Through Current MS4 Source Control and Maintenance Practices* (Florida Stormwater Association Educational Foundation, 2011))

Street sweeping activities can be particularly effective during periods of high leaf fall by removing solid leaf material and the associated nutrient loadings from roadside areas where they can easily become transported by stormwater flow. Previous research has indicated that leaves release large quantities of both TN and TP into surface water within 24-48 hours after becoming saturated in an aquatic environment. Loadings to waterbodies from leaf fall are often the most significant loadings during the fall and winter months. Increasing street sweeping during heavy leaf fall is recommended in the Lake Gem Mary drainage basin.

Capital costs for street sweepers range from approximately \$70,000-\$150,000, with the lower end of the range associated with mechanical street sweepers and the higher end of the range associated with vacuum-type sweepers. The useful life span is typically 4-8 years, with an operating cost of approximately \$80/hour.

The current street sweeping operations occur once every 2 to 6 weeks within the Lake Gem Mary watershed. This frequency will result in an annual reduction of approximately 0.9 kg/yr TP and 3.7 kg/yr TN, as shown in Table 6-12. If street sweeping frequency by Roads and Drainage and

EPD were increased to twice weekly for all roads within the watershed, then estimated removal of TP and TN would be 5.9 kg/yr TP and 24.8 kg/yr TN removal, as shown in Table 6-13.

Table 6-12: Cost Analysis for Existing Street Sweeping in Watershed

Description	Roads and Drainage (Sweeping Every 6 Weeks)	EPD (Sweeping Every 2 Weeks)	Total
Road Length (mile)	0.84	0.21	1.05
Curb Length (mile)	1.68	0.42	2.1
TP Removal kg/curb mile/year	0.35	0.7	-
TN Removal kg/curb mile/year	1.46	2.92	-
TP Removed (kg/yr)	0.588	0.294	0.882
TN Removed (kg/yr)	2.4528	1.2264	3.6792
Cost Per curb mile	\$30	\$30	-
Times Swept per Year	8.7	26.0	-
Total Cost/Year	\$436.80	\$327.60	\$764.40
TP Cost per Kg Removed	\$742.86	\$1,114.29	\$866.67
TN Cost per Kg Removed	\$178.08	\$267.12	\$207.76

Table 6-13: Cost Analysis for Increased Frequency of Street Sweeping in Watershed

Description	Every Two Weeks	Weekly	Twice Weekly
Road Length (mile)	1.05	1.05	1.05
Curb Length (mile)	2.1	2.1	2.1
TP Removal kg/curb mile/year	0.7	1.4	2.81
TN Removal kg/curb mile/year	2.94	5.88	11.8
TP Removed (kg/yr)	1.47	2.94	5.901
TN Removed (kg/yr)	6.174	12.348	24.78
Cost Per curb mile	\$30	\$30	\$30
Times Swept/Year	26.0	52.0	104.0
Total Cost/Year	\$1,638.00	\$3,276.00	\$6,552.00
TP Cost/Kg Removed	\$1,114.29	\$1,114.29	\$1,110.32
TN Cost/Kg Removed	\$265.31	\$265.31	\$264.41

6.8.3. PUBLIC EDUCATION

Public education is an important tool for reducing nonpoint source pollution in a watershed. Many residents appear to be unaware of the direct link between watershed activities and the water quality in adjacent waterbodies. The more a resident or business owner understands the relationship between nonpoint source loadings and receiving water quality, the more that person may be willing to implement source controls.

Several national studies have indicated that it is an extremely worthwhile and cost-effective activity to periodically remind property owners of the potential for water quality degradation which can occur due to misapplication of fertilizers and pesticides. Periodic information pamphlets can be distributed by hand or enclosed with water and sewer bills which will reach virtually all residents within the watershed. These educational brochures should emphasize that taxpayer funds are currently being used to treat nonpoint source water pollution and that homeowners have the opportunity to reduce this tax burden by modifying their daily activities. A comprehensive public education program should concentrate, at a minimum, on the following topics:

1. Relationship between land use, stormwater runoff, and pollutants
2. Functions of stormwater treatment systems
3. How to reduce stormwater runoff volume
4. Impacts of water fowl and pets on runoff characteristics and surface water quality
5. County stormwater program goals and regulations
6. Responsible use of fertilizer, pesticides and herbicides
7. Elimination of illicit connections to the stormwater system
8. Controlling erosion and turbidity
9. Proper operation and maintenance of stormwater systems
10. Prevent grass clippings from being blown into stormwater inlets

The public education program can be implemented in a variety of ways, including homeowner and business seminars, newsletters, performing special projects with local schools (elementary, middle and high schools), Earth Day celebrations, brochures, and special signage at stormwater treatment

construction sites. Many people do not realize that storm sewers eventually drain to area lakes. Many cities and counties in Florida have implemented a signage program which places a small engraved plaque on each storm sewer inlet indicating "Do Not Dump, Drains to Lake". It is recommended that an aggressive public education program be implemented in the Lake Gem Mary watershed which incorporates all of the elements discussed previously.

Anticipated load reductions for implementation of public education programs are difficult to predict and depend highly upon the degree of implementation by the homeowners within the basin. The Lake Okeechobee BMAP (December 2014) allows a 1% to 6% reduction in both TN and TP based on the extent of the public education program. The impacts of public education programs also depend, to a large extent, on the degree to which water quality within the Lake Gem Mary basin is currently being impacted by uneducated and uninformed activities by current homeowners. Assuming a 3 percent reduction, 3.72 kg/year of TN and 0.84 kg/year of TP would be removed through an effective public education program.

6.8.4. PROPER LANDSCAPE AND FERTILIZER USAGE

6.8.4.1. EXISTING CONDITIONS AND ISSUES

Improper landscape and lawn maintenance, including blowing grass clippings, leaves, and other vegetation debris onto paved or roadway surfaces, or directly into a waterbody, as well as improper application of both granular and liquid fertilizers to impervious surfaces and roadways appear to be a large source of pollutants to Lake Gem Mary. When grass clippings and fertilizers are introduced onto impervious surfaces, they become available for mobilization by stormwater runoff during rain events, causing them to be deposited into the nearest waterbody during storm events. These types of lawn maintenance practices are needless and irresponsible activities which have the potential to significantly increase nutrient loadings to Lake Gem Mary, as well as other waterbodies in Orange County where these activities occur. At best, these activities occur as a result of lack of information and education, while at worst, they represent a disregard for water quality consequences in a misguided attempt to reduce labor time and costs.

Orange County has regulated fertilizer application since 2009 and updated the Fertilizer Management Ordinance in 2017. As a result of impairment to the County's surface waters, groundwater, and springs caused by excessive nutrients, the County has determined that the

improper use of fertilizers on land creates a risk of contributing to adverse effects on surface and groundwater. The Orange County Fertilizer Management Ordinance can be found in the Orange County Muni-Code, Part1, Chapter 15, Article XVII, Section 15-800.

The Fertilizer Management Ordinance regulates proper use and application of fertilizer, training requirements, and restricted application periods in the County. The following restrictions are included in the Ordinance.

- No fertilizer containing nitrogen or phosphorus shall be applied to turf or landscape plants during a period for which the National Weather Service has issued any of the following advisories for any portion of the County: a severe thunderstorm warning or watch, flood warning or watch, tropical storm warning or watch, or hurricane warning or watch.
- No fertilizer containing phosphorus shall be applied to turf or landscape plants. Provided, however, where phosphorus deficiency has been demonstrated in the soil by a soil analysis test performed by a laboratory using University of Florida's Institute of Food and Agricultural Sciences ("UF/IFAS") approved methodology, phosphorus may then be applied at a rate no greater than one-quarter (0.25) of one (1) pound of phosphorus per one thousand (1,000) square feet per application, not to exceed one-half (0.5) pound of phosphorus per one thousand (1,000) square feet per year. Any person who obtains such a soil analysis test showing a phosphorus deficiency may apply phosphorus and shall provide the test results to the Orange County Environmental Protection Division, Attention: Manager within thirty (30) days of receipt of results.
- No person, except applicators certified pursuant to Section 15-809, shall apply fertilizer containing nitrogen or phosphorus to turf or landscape plants during the restricted season from June 1 through September 30.
- No fertilizer containing nitrogen shall be applied unless at least fifty (50) percent of its nitrogen content is slow release as indicated on the Guaranteed Analysis label, with no more than one (1) pound total nitrogen per one thousand (1,000) square feet of area per application. This requirement shall change to at least sixty-five (65) percent slow release if the product is readily available on the local commercial market by July 1, 2020.

- No fertilizer shall be applied within fifteen (15) feet of any wetland or surface waters, including but not limited to a lake, pond, stream, water body, water course, or canal.
- No fertilizer shall be deposited, washed, swept, or blown off, intentionally or inadvertently, onto any impervious surface, public right-of-way, public property, stormwater drain, ditch, conveyance, or water body. Any fertilizer applied, spilled, or deposited, either intentionally or accidentally, on any impervious surface shall be immediately and completely removed to the greatest extent practicable. Fertilizer released on an impervious surface must be immediately contained and either legally applied to turf or landscape plants or any other legal site, or returned to the original or other appropriate container.
- A low-maintenance zone is strongly recommended, though not required, for all areas within ten (10) feet of the normal high water elevation of any lake, pond, stream, water body, water course or canal, or any wetland, excluding permitted stormwater ponds. Low-maintenance zones should be planted and managed in such a way as to minimize the need for watering, mowing, and other active maintenance. No mowed or cut vegetative material may be deposited or left remaining in this zone or deposited in the water. Care should be taken to prevent over-spray of aquatic weed control products in this zone.
- Grass clippings and/or vegetative material/debris shall not be deposited, washed, swept, or blown off, intentionally or inadvertently, onto any impervious surface, public right-of-way, stormwater drain, ditch, conveyance, or water body.
- No commercial applicator shall cause fertilizer to be applied, except at his or her own residence, without a valid limited certification for urban landscape commercial fertilizer application from the Florida Department of Agriculture and Consumer Services, as specified in Section 15-809.
- Certified applicators must show proof of training on all vehicles used during applications.

6.8.4.2. RECOMMENDATIONS

Although the Fertilizer Management Ordinance has been adopted and implemented in Orange County, there appear to be many homeowners and lawn care professionals in the Lake Gem Mary watershed who are either unaware or ignore the existing ordinance. This ordinance does not

appear to impose a significant hardship on landscape companies since it appears to be just as easy to blow the clippings and vegetation back onto the lawn surface rather than into the adjacent roadway or drainage system. When the yard waste is returned into the landscaped areas, it will decompose and provide additional sources of nutrients to the vegetation rather than the receiving waterbody.

The existing Fertilizer Management Ordinance, if fully observed, would virtually eliminate water quality impacts from fertilizer and landscaping activities. However, in spite of the ordinance, instances of improper fertilizer application and discharge of vegetation debris onto paved surfaces appear to be relatively routine activities. Therefore, it is recommended that an educational pamphlet on the importance of observing the fertilizer ordinance be delivered to each homeowner living near Lake Gem Mary. Additionally, OCEPD staff should schedule a meeting and invite all homeowners in the watershed to discuss issues with lake cleanup efforts and how fertilizer and grass clippings runoff plays an important role in the degradation of water quality in the lake. During the presentation, OCEPD can make the homeowners aware that the County intends to enforce the Fertilizer Management Ordinance and issue citations when violations are observed during routine job-related activities.

6.9. RECOMMENDED MANAGEMENT OPTIONS

A summary of recommended management options for Lake Gem Mary is presented in Table 6-14. These recommendations are based upon the discussions and evaluations provided in previous sections. Many of the recommended management options have relatively low associated costs, such as developing ordinances, restricting lawn maintenance activities and public education. Each of the recommended management options have the potential to result in improvements in water quality characteristics in Lake Gem Mary. It is recommended that the management options be implemented as funding sources and opportunities become available.

Table 6-14: Lake Management Option Costs

Option	Description	TP Removed (kg/yr)	TN Removed (kg/yr)	Cost
1	Sediment Inactivation	476	NA	\$117,594
2	Sanitary Sewer	78.3	324.8	\$800,000
3	On-Site Sanitary Treatment and Disposal Maintenance	74.4	162.4	\$200,000
4a	Rear Yard Swales and Berms	1.25	7.5	\$100,000
4b	Rear Yard Swales and Berms with BAM	2.61	9	\$177,000
5	Inlet Baskets	6.6	18	\$14,300
6a	Baffle Boxes for Sub-basins 1 & 2	0.42	2.97	\$80,000
6b	Baffle Boxes for Sub-basins 8	0.12	1.24	\$80,000
6c	Baffle Boxes for Sub-basins 1 & 2 with Bold & Gold	2.13	10.45	\$100,000
6d	Baffle Boxes for Sub-basins 8 with Bold & Gold	0.63	4.36	\$100,000
7	Florida Yards and Neighborhoods	NA	NA	NA
8a	Street Sweeping – Existing every 6 weeks (PW) /2 weeks (EPD)	0.88	3.68	\$764
8b	Street Sweeping - every 2 weeks	1.47	6.17	\$1,638
8c	Street Sweeping - once weekly	2.9	12.35	\$3,275
8d	Street Sweeping - twice weekly	5.9	24.78	\$6,552
9	Public Education	0.84	3.72	NA
10	Proper Landscape and Fertilizer Usage	NA	NA	NA

NA = Unable to Quantify TP and TN removal from the proposed Management Option

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APPENDICES

APPENDIX A

SMALL CORE SEDIMENT SAMPLES

NOVEMBER 2015 THROUGH OCTOBER 2016

SMALL CORE SEDIMENT SAMPLES

Site	Date	pH (s.u.)	Moisture content (%)	Organic Content (%)	Wet Density (g/cm ³)	Total Nitrogen (µg/cm ³)	Total Phosphorus (µg/cm ³)	Saloid Bound P	Aluminum Bound P	Iron Bound P
XBC12S1	7/28/2016	6.21	26.2	2.4	2.08	6599	1130	0.8	64	62
XBC12S2	7/28/2016	6.34	39.2	2.5	1.89	13795	2932	2.4	71	93
XBC12S3	7/28/2016	6.33	46.5	11	1.71	13417	6048	4.8	30	58
XBC12S4	7/28/2016	6.29	44.2	6.6	1.78	13200	2335	4.2	98	112
XBC12S5	7/28/2016	6.34	77.8	15	1.28	11640	7082	11.9	79	81
XBC12S6	7/28/2016	6.86	91.4	36.6	1.08	9056	8179	14.1	65	54
	Mean	6.4	54.2	12.4	1.6	11284.5	4617.7	6.4	67.8	76.7
	Median	6.3	45.4	8.8	1.7	12420.0	4490.0	4.5	68.0	71.5
	Geomean	6.4	49.7	7.9	1.6	10924.1	3733.9	4.3	64.0	74.0

APPENDIX B

FIELD PROFILE DATA

NOVEMBER 2015 THROUGH OCTOBER 2016

Site 1 Vertical Field Profile collected in Lake Gem Mary

Location	Site	Date	Depth (meter)	Temp (°C)	SpCond (umho/cm)	pH Units	DO (mg/L)	DO (%)	ORP (mV)	Turbidity (NTU)	Secchi (meter)
Site 1	XBC12S1S	10/27/2015	0.5	25.4	219	6.8	7.8	94.4	136.5	0.1	0.89
	XBC12S1S	10/27/2015	1.0	25.3	219	6.9	7.7	93.5	144.2	0.1	0.89
	XBC12S1S	10/27/2015	1.5	25.3	219	7.1	7.6	92.1	157.2	0.1	0.89
	XBC12S1S	10/27/2015	2.0	25.3	219	7.1	7.6	92.1	163.8	0.1	0.89
	XBC12S1B	10/27/2015	2.5	25.3	219	7.1	7.6	93.1	169.7	0.1	0.89
	XBC12S1S	11/24/2015	0.5	23.2	233	7.5	5.7	67.4	92.8	0.1	1.13
	XBC12S1	11/24/2015	1.0	23.2	233	7.3	5.5	64.3	105.8	0.2	1.13
	XBC12S1	11/24/2015	1.5	23.2	233	7.3	5.4	63.1	112.6	0.8	1.13
	XBC12S1	11/24/2015	2.0	23.2	237	7.3	5.4	63.2	116.8	0.2	1.13
	XBC12S1	11/24/2015	2.5	23.2	232	7.2	5.4	63.1	121.9	0.1	1.13
	XBC12S1B	11/24/2015	3.0	23.2	231	7.2	5.4	63.1	124.0	1.4	1.13
	XBC12S1S	12/28/2015	0.5	23.6	262	8.0	9.3	109.9	28.3	2.2	0.80
	XBC12S1	12/28/2015	1.0	23.5	262	8.0	9.1	107.4	30.0	1.6	0.80
	XBC12S1	12/28/2015	1.5	23.2	262	7.9	9.3	108.7	33.8	0.1	0.80
	XBC12S1	12/28/2015	2.0	22.4	262	7.6	7.9	91.6	40.1	0.1	0.80
	XBC12S1B	12/28/2015	2.5	21.7	264	7.0	4.4	51.4	55.6	0.1	0.80
	XBC12S1S	1/26/2016	0.5	16.7	315	7.4	9.2	94.8	292.0	4.0	1.00
	XBC12S1	1/26/2016	1.0	16.3	314	7.4	9.1	92.8	293.4	4.1	1.00
	XBC12S1	1/26/2016	1.5	16.1	313	7.4	8.9	90.4	297.9	4.2	1.00

Location	Site	Date	Depth (meter)	Temp (°C)	SpCond (umho/cm)	pH Units	DO (mg/L)	DO (%)	ORP (mV)	Turbidity (NTU)	Secchi (meter)
	XBC12S1	1/26/2016	2.0	16.1	312	7.4	8.9	89.9	300.3	4.5	1.00
	XBC12S1B	1/26/2016	2.5	16.0	312	7.4	8.7	88.0	302.8	5.1	1.00
	XBC12S1S	2/25/2016	0.5	20.4	261	8.8	11.1	125.7	234.5	8.9	0.8
	XBC12S1	2/25/2016	1.0	20.3	261	8.8	11.5	127.4	233.3	8.4	0.8
	XBC12S1	2/25/2016	1.5	20.1	261	8.8	11.5	126.7	236.7	8.3	0.8
	XBC12S1	2/25/2016	2.0	19.0	260	8.8	11.5	126.1	240.4	6.4	0.8
	XBC12S1	2/25/2016	2.5	17.5	260	8.1	7.4	77.8	261.9	5.4	0.8
	XBC12S1B	2/25/2016	3.0	16.7	260	7.7	3.7	37.7	261.6	4.9	0.8
	XBC12S1S	3/30/2016	0.5	24.2	276	8.2	8.7	103.7	152.1	9.6	0.6
	XBC12S1	3/30/2016	1.0	23.9	276	8.2	7.3	86.0	162.7	8.2	0.6
	XBC12S1	3/30/2016	1.5	23.6	279	7.9	7.0	82.2	166.6	7.5	0.6
	XBC12S1	3/30/2016	2.0	22.9	284	7.7	5.2	60.5	171.2	6.0	0.6
	XBC12S1	3/30/2016	2.5	21.2	288	7.4	2.2	25.6	176.6	4.4	0.6
	XBC12S1B	3/30/2016	3.0	20.5	283	7.2	1.0	8.9	177.0	4.6	0.6
	XBC12S1S	4/26/2016	0.5	27.5	278	9.7	13.7	172.4	103.6	18.0	0.4
	XBC12S1	4/26/2016	1.0	25.8	278	9.8	14.1	173.0	108.3	17.9	0.4
	XBC12S1	4/26/2016	1.5	25.3	271	9.3	9.9	119.4	123.9	14.6	0.4
	XBC12S1	4/26/2016	2.0	23.8	260	8.7	2.1	24.5	141.3	6.7	0.4
	XBC12S1B	4/26/2016	2.5	23.6	259	7.8	1.6	19.1	135.9	6.4	0.4
	XBC12S1S	5/31/2016	0.5	30.8	259	8.5	9.5	127.4	91.2	5.6	0.8
	XBC12S1	5/31/2016	1.0	30.2	258	8.5	9.4	124.3	97.0	5.7	0.8
	XBC12S1	5/31/2016	1.5	28.9	257	8.3	8.1	105.3	11.6	2.6	0.8

Location	Site	Date	Depth (meter)	Temp (°C)	SpCond (umho/cm)	pH Units	DO (mg/L)	DO (%)	ORP (mV)	Turbidity (NTU)	Secchi (meter)
	XBC12S1	5/31/2016	2.0	27.9	254	7.9	6.9	88.5	117.1	2.2	0.8
	XBC12S1B	5/31/2016	2.5	27.0	253	7.4	3.0	37.5	124.6	1.1	0.8
	XBC12S1S	6/29/2016	0.5	32.4	243	7.7	8.5	117.1	98.5	1.4	1.3
	XBC12S1	6/29/2016	1.0	32.0	243	7.7	8.5	116.8	107.0	1.6	1.3
	XBC12S1	6/29/2016	1.5	31.6	242	7.7	8.6	116.4	104.8	1.5	1.3
	XBC12S1	6/29/2016	2.0	31.5	242	7.7	8.3	112.5	108.7	1.8	1.3
	XBC12S1	6/29/2016	2.5	31.1	245	7.5	6.6	88.8	116.3	2.2	1.3
	XBC12S1B	6/29/2016	3.0	29.6	248	7.2	4.4	57.0	122.7	3.2	1.3
	XBC12S1S	7/27/2016	0.5	34.3	260	8.1	9.1	128.9	123.7	0.4	1.1
	XBC12S1	7/27/2016	1.0	32.9	259	8.2	9.6	133.3	126.9	0.5	1.1
	XBC12S1	7/27/2016	1.5	32.6	259	8.3	9.5	131.9	130.2	0.6	1.1
	XBC12S1	7/27/2016	2.0	32.4	259	8.2	9.3	128.4	133.7	0.5	1.1
	XBC12S1	7/27/2016	2.5	32.2	267	8.0	9.0	123.6	139.3	0.6	1.1
	XBC12S1B	7/27/2016	3.0	32.0	280	7.7	8.2	112.9	147.9	0.7	1.1
	XBC12S1S	8/30/2016	0.5	30.8	241	7.3	7.7	102.8	123.8	1.2	1.3
	XBC12S1	8/30/2016	1.0	30.7	241	7.3	7.6	101.5	126.8	1.2	1.3
	XBC12S1	8/30/2016	1.5	30.6	241	7.3	7.5	100.2	128.5	1.2	1.3
	XBC12S1	8/30/2016	2.0	30.6	241	7.3	7.3	97.4	130.4	1.2	1.3
	XBC12S1B	8/30/2016	2.5	30.5	242	7.2	6.9	91.5	132.9	1.2	1.3
	XBC12S1S	9/27/2016	0.5	32.0	223	7.9	7.3	100.9	183.3	1.0	1.3
	XBC12S1	9/27/2016	1.0	31.0	222	7.8	8.0	107.6	185.8	1.3	1.3
	XBC12S1	9/27/2016	1.5	30.5	221	7.9	7.9	105.7	187.9	1.3	1.3

Location	Site	Date	Depth (meter)	Temp (°C)	SpCond (umho/cm)	pH Units	DO (mg/L)	DO (%)	ORP (mV)	Turbidity (NTU)	Secchi (meter)
	XBC12S1	9/27/2016	2.0	30.3	223	7.8	7.3	97.6	194.8	1.3	1.3
	XBC12S1B	9/27/2016	2.5	30.2	222	7.1	7.1	94.0	202.3	1.3	1.3

Site 2 Vertical Field Profile collected in Lake Gem Mary

Location	Site	Date	Depth (meter)	Temp (°C)	SpCond (umho/cm)	pH Units	DO (mg/L)	DO (%)	ORP (mV)	Turbidity (NTU)	Secchi (meter)
Site 2	XBC12S2S	10/27/2015	0.5	25.4	221	7.4	7.7	94.5	111.9	0.1	0.94
	XBC12S2S	10/27/2015	1.0	25.4	220	7.4	7.7	94.4	122.0	0.1	0.94
	XBC12S2S	10/27/2015	1.5	25.4	220	7.3	7.7	94.3	130.0	0.1	0.94
	XBC12S2S	10/27/2015	2.0	25.4	220	7.3	7.8	94.6	146.0	0.1	0.94
	XBC12S2S	10/27/2015	2.5	25.4	220	7.3	7.7	94.1	164.9	0.1	0.94
	XBC12S2S	10/27/2015	3.0	25.4	220	7.3	7.7	93.6	172.3	0.1	0.94
	XBC12S2S	10/27/2015	3.5	25.4	220	7.4	7.7	93.2	179.5	0.1	0.94
	XBC12S2S	10/27/2015	4.0	25.4	220	7.4	7.6	93.0	185.0	0.1	0.94
	XBC12S2S	10/27/2015	4.5	25.3	220	7.4	7.3	89.1	190.8	0.1	0.94
	XBC12S2S	10/27/2015	5.0	25.3	219	7.3	7.0	84.7	196.0	0.1	0.94
	XBC12S2S	10/27/2015	5.5	25.0	215	7.1	1.3	15.8	209.6	0.1	0.94
	XBC12S2B	10/27/2015	6.0	24.8	216	6.9	0.4	4.5	162.0	0.1	0.94
	XBC12S2S	11/24/2015	0.5	23.3	229	7.4	6.1	71.3	122.9	0.0	1.13
	XBC12S2	11/24/2015	1.0	23.3	229	7.4	6.0	70.5	131.5	0.1	1.13
	XBC12S2	11/24/2015	1.5	23.3	229	7.3	6.0	70.2	139.8	0.1	1.13
	XBC12S2	11/24/2015	2.0	23.3	229	7.3	6.0	70.0	151.6	0.1	1.13
	XBC12S2	11/24/2015	2.5	23.3	234	7.3	5.9	69.2	160.7	0.1	1.13
	XBC12S2	11/24/2015	3.0	23.3	230	7.3	5.7	66.9	169.5	0.1	1.13
	XBC12S2	11/24/2015	3.5	23.2	230	7.2	5.5	64.1	179.1	0.1	1.13
	XBC12S2	11/24/2015	4.0	23.2	230	7.2	5.3	62.0	184.0	0.6	1.13
	XBC12S2	11/24/2015	4.5	23.2	235	7.2	5.1	59.7	190.1	0.2	1.13
	XBC12S2	11/24/2015	5.0	23.2	230	7.2	5.1	60.0	181.3	0.1	1.13

Location	Site	Date	Depth (meter)	Temp (°C)	SpCond (umho/cm)	pH Units	DO (mg/L)	DO (%)	ORP (mV)	Turbidity (NTU)	Secchi (meter)
	XBC12S2	11/24/2015	5.5	23.1	231	7.2	5.0	58.8	153.0	0.3	1.13
	XBC12S2B	11/24/2015	6.0	23.1	231	7.1	5.0	58.2	144.0	1.4	1.13
	XBC12S2S	12/28/2015	0.5	23.7	261	8.4	9.7	114.0	81.7	2.9	0.80
	XBC12S2	12/28/2015	1.0	23.6	262	8.4	9.6	113.7	77.8	3.3	0.80
	XBC12S2	12/28/2015	1.5	23.4	262	8.0	9.1	106.8	80.2	1.5	0.80
	XBC12S2	12/28/2015	2.0	22.2	261	7.7	8.3	95.2	84.9	1.0	0.80
	XBC12S2	12/28/2015	2.5	21.6	263	7.3	5.4	60.7	87.5	0.0	0.80
	XBC12S2	12/28/2015	3.0	21.3	263	7.1	3.3	38.5	90.3	0.1	0.80
	XBC12S2	12/28/2015	3.5	21.2	263	6.8	2.8	32.0	94.3	0.1	0.80
	XBC12S2	12/28/2015	4.0	21.1	263	6.8	2.6	29.6	96.2	0.1	0.80
	XBC12S2	12/28/2015	4.5	21.1	263	6.8	2.5	27.9	94.3	0.1	0.80
	XBC12S2B	12/28/2015	5.0	21.1	263	6.8	2.4	27.2	82.6	0.1	0.80
	XBC12S2S	1/26/2016	0.5	17.4	312	8.2	10.8	113.4	303.0	5.0	0.90
	XBC12S2	1/26/2016	1.0	17.1	313	8.2	10.5	109.5	306.1	4.9	0.90
	XBC12S2	1/26/2016	1.5	16.1	311	8.2	10.9	110.5	305.9	4.9	0.90
	XBC12S2	1/26/2016	2.0	16.0	311	8.1	10.4	106.1	310.1	5.1	0.90
	XBC12S2	1/26/2016	2.5	16.0	312	7.7	9.2	93.7	314.0	4.7	0.90
	XBC12S2	1/26/2016	3.0	16.0	312	7.5	9.0	90.7	313.9	4.4	0.90
	XBC12S2	1/26/2016	3.5	15.9	312	7.5	8.8	89.5	314.1	4.7	0.90
	XBC12S2	1/26/2016	4.0	15.9	312	7.4	8.8	88.6	314.5	5.1	0.90
	XBC12S2	1/26/2016	4.5	15.9	312	7.4	8.6	87.6	314.9	5.0	0.90
	XBC12S2B	1/26/2016	5.0	15.9	312	7.4	8.6	87.4	314.8	5.5	0.90
	XBC12S2S	2/25/2016	0.5	19.6	260	8.9	11.8	128.2	231.6	7.0	0.8
	XBC12S2	2/25/2016	1.0	19.3	260	8.9	11.8	128.0	235.4	6.1	0.8

Location	Site	Date	Depth (meter)	Temp (°C)	SpCond (umho/cm)	pH Units	DO (mg/L)	DO (%)	ORP (mV)	Turbidity (NTU)	Secchi (meter)
	XBC12S2	2/25/2016	1.5	19.1	260	8.9	12.0	130.2	236.0	5.9	0.8
	XBC12S2	2/25/2016	2.0	19.0	259	8.9	12.0	130.0	238.6	5.6	0.8
	XBC12S2	2/25/2016	2.5	18.0	258	8.5	11.8	125.0	245.2	4.9	0.8
	XBC12S2	2/25/2016	3.0	17.2	259	8.2	8.4	86.9	252.2	4.9	0.8
	XBC12S2	2/25/2016	3.5	16.6	258	7.6	7.9	81.2	251.8	4.7	0.8
	XBC12S2	2/25/2016	4.0	16.1	258	7.4	4.5	45.8	257.1	3.8	0.8
	XBC12S2	2/25/2016	4.5	16.0	259	7.1	2.5	25.3	259.3	3.5	0.8
	XBC12S2B	2/25/2016	5.0	15.9	259	7.1	2.0	19.9	260.3	3.6	0.8
	XBC12S2S	3/30/2016	0.5	24.2	274	8.8	9.6	114.6	146.0	9.7	0.5
	XBC12S2	3/30/2016	1.0	24.2	274	9.0	9.7	114.9	148.3	9.9	0.5
	XBC12S2	3/30/2016	1.5	24.2	274	9.0	9.6	113.9	151.8	9.8	0.5
	XBC12S2	3/30/2016	2.0	22.1	287	8.5	5.3	61.2	171.2	5.5	0.5
	XBC12S2	3/30/2016	2.5	21.1	288	8.1	2.9	32.3	177.2	4.2	0.5
	XBC12S2	3/30/2016	3.0	20.4	281	7.6	1.1	11.6	180.8	3.5	0.5
	XBC12S2	3/30/2016	3.5	19.2	279	7.2	0.3	2.7	120.1	4.4	0.5
	XBC12S2	3/30/2016	4.0	18.9	284	7.1	0.2	1.9	91.7	4.1	0.5
	XBC12S2	3/30/2016	4.5	17.9	286	6.9	0.2	1.5	54.0	3.5	0.5
	XBC12S2B	3/30/2016	5.0	17.2	286	6.8	0.1	1.4	18.5	3.4	0.5
	XBC12S2S	4/26/2016	0.5	26.0	277	9.8	14.3	176.0	113.5	16.5	0.4
	XBC12S2	4/26/2016	1.0	25.5	276	9.8	13.8	168.9	118.3	19.1	0.4
	XBC12S2	4/26/2016	1.5	25.1	271	9.6	12.6	152.7	125.9	16.8	0.4
	XBC12S2	4/26/2016	2.0	24.3	263	9.0	8.0	95.1	144.7	11.8	0.4
	XBC12S2	4/26/2016	2.5	23.4	254	8.4	1.6	18.9	158.8	5.3	0.4
	XBC12S2	4/26/2016	3.0	22.6	243	7.8	0.3	3.8	135.2	5.5	0.4
	XBC12S2	4/26/2016	3.5	21.3	282	7.6	0.2	2.7	28.4	4.0	0.4

Orange County
Lake Gem Mary Watershed
Appendix

Location	Site	Date	Depth (meter)	Temp (°C)	SpCond (umho/cm)	pH Units	DO (mg/L)	DO (%)	ORP (mV)	Turbidity (NTU)	Secchi (meter)
	XBC12S2	4/26/2016	4.0	19.6	299	7.5	0.2	1.7	-56.2	3.2	0.4
	XBC12S2B	4/26/2016	4.5	18.3	291	7.2	0.1	1.3	-68.4	2.6	0.4
	XBC12S2S	5/31/2016	0.5	30.3	256	8.6	9.6	128.3	80.5	4.9	0.7
	XBC12S2	5/31/2016	1.0	29.9	256	8.8	9.7	128.7	83.9	3.9	0.7
	XBC12S2	5/31/2016	1.5	29.2	255	8.6	9.4	123.5	91.1	2.5	0.7
	XBC12S2	5/31/2016	2.0	27.7	253	8.4	6.7	84.9	109.3	1.6	0.7
	XBC12S2	5/31/2016	2.5	26.5	251	7.8	1.9	23.5	113.4	0.9	0.7
	XBC12S2	5/31/2016	3.0	24.9	263	7.6	4.0	4.9	112.0	4.3	0.7
	XBC12S2	5/31/2016	3.5	23.2	303	7.4	0.2	2.9	109.1	6.5	0.7
	XBC12S2	5/31/2016	4.0	21.8	314	7.4	0.2	2.6	81.6	6.9	0.7
	XBC12S2B	5/31/2016	4.5	20.0	319	7.3	0.2	1.7	-62.3	10.4	0.7
	XBC12S2S	6/29/2016	0.5	31.8	242	7.7	8.6	116.8	68.8	1.8	1.2
	XBC12S2	6/29/2016	1.0	31.7	241	7.7	8.6	116.2	73.5	1.7	1.2
	XBC12S2	6/29/2016	1.5	31.5	241	7.7	8.6	116.3	77.5	1.7	1.2
	XBC12S2	6/29/2016	2.0	31.4	241	7.7	8.4	114.2	84.1	1.7	1.2
	XBC12S2	6/29/2016	2.5	31.2	242	7.6	8.0	108.2	92.4	1.9	1.2
	XBC12S2	6/29/2016	3.0	29.8	244	7.3	6.0	78.9	100.4	2.9	1.2
	XBC12S2	6/29/2016	3.5	28.1	246	7.1	3.2	40.9	105.4	3.5	1.2
	XBC12S2	6/29/2016	4.0	26.8	247	6.9	0.4	4.6	106.5	5.7	1.2
	XBC12S2	6/29/2016	4.5	24.7	304	6.8	0.2	2.8	104.8	10.6	1.2
	XBC12S2B	6/29/2016	5.0	21.9	333	6.8	0.2	2.0	31.3	19.0	1.2
	XBC12S2S	7/27/2016	0.5	33.1	259	8.1	9.3	129.3	106.6	0.5	1.0
	XBC12S2	7/27/2016	1.0	32.8	259	8.3	9.6	132.8	109.1	0.5	1.0
	XBC12S2	7/27/2016	1.5	32.4	259	8.3	9.5	130.2	113.2	0.5	1.0

Orange County
Lake Gem Mary Watershed
Appendix

Location	Site	Date	Depth (meter)	Temp (°C)	SpCond (umho/cm)	pH Units	DO (mg/L)	DO (%)	ORP (mV)	Turbidity (NTU)	Secchi (meter)
	XBC12S2	7/27/2016	2.0	32.3	259	8.3	9.4	129.8	115.9	0.5	1.0
	XBC12S2	7/27/2016	2.5	32.2	260	8.1	8.9	122.4	123.0	0.5	1.0
	XBC12S2	7/27/2016	3.0	31.9	264	7.9	8.5	116.7	127.6	0.8	1.0
	XBC12S2	7/27/2016	3.5	31.3	274	7.3	5.9	79.8	138.4	0.7	1.0
	XBC12S2	7/27/2016	4.0	30.2	267	6.9	1.5	19.2	140.4	0.9	1.0
	XBC12S2	7/27/2016	4.5	27.8	267	6.7	0.3	0.3	138.4	4.7	1.0
	XBC12S2B	7/27/2016	5.0	24.8	327	6.7	0.2	0.2	135.6	5.6	1.0
	XBC12S2S	8/30/2016	0.5	30.7	241	7.2	7.1	95.6	79.2	1.2	1.3
	XBC12S2	8/30/2016	1.0	30.6	241	7.2	7.2	96.1	85.0	1.3	1.3
	XBC12S2	8/30/2016	1.5	30.6	241	7.2	7.2	96.0	90.1	1.2	1.3
	XBC12S2	8/30/2016	2.0	30.6	241	7.2	7.2	95.6	94.9	1.2	1.3
	XBC12S2	8/30/2016	2.5	30.6	241	7.2	7.2	95.8	101.8	1.2	1.3
	XBC12S2	8/30/2016	3.0	30.5	242	7.2	7.2	95.6	106.3	1.2	1.3
	XBC12S2	8/30/2016	3.5	30.5	241	7.2	6.9	92.7	110.1	1.1	1.3
	XBC12S2	8/30/2016	4.0	30.5	241	7.1	6.6	88.2	113.8	1.2	1.3
	XBC12S2	8/30/2016	4.5	29.8	233	6.8	0.6	8.4	121.8	3.3	1.3
	XBC12S2	8/30/2016	5.0	28.8	244	6.5	0.3	4.0	80.1	4.5	1.3
	XBC12S2B	8/30/2016	5.5	25.4	341	6.7	0.2	2.7	65.0	9.9	1.3
	XBC12S2S	9/27/2016	0.5	31.0	221	7.7	7.6	101.9	221.4	1.3	1.2
	XBC12S2	9/27/2016	1.0	30.6	221	7.7	7.3	97.4	123.5	1.4	1.2
	XBC12S2	9/27/2016	1.5	30.6	221	7.7	7.5	100.8	132.2	1.5	1.2
	XBC12S2	9/27/2016	2.0	30.3	221	7.7	7.5	99.3	142.6	1.3	1.2
	XBC12S2	9/27/2016	2.5	30.2	221	7.7	7.4	97.9	153.1	1.3	1.2
	XBC12S2	9/27/2016	3.0	30.1	221	7.7	7.1	94.6	158.9	1.3	1.2
	XBC12S2	9/27/2016	3.5	30.1	222	7.6	6.6	86.8	168.6	1.3	1.2

Location	Site	Date	Depth (meter)	Temp (°C)	SpCond (umho/cm)	pH Units	DO (mg/L)	DO (%)	ORP (mV)	Turbidity (NTU)	Secchi (meter)
	XBC12S2	9/27/2016	4.0	30.0	222	7.5	6.3	84.1	177.9	1.3	1.2
	XBC12S2	9/27/2016	4.5	29.8	221	7.2	3.8	47.5	184.0	1.3	1.2
	XBC12S2	9/27/2016	5.0	29.1	221	7.1	0.5	6.1	156.7	3.8	1.2
	XA42S2B	9/27/2016	5.5	27.5	253	7.0	0.2	3.0	102.9	5.1	1.2

Site 3 Vertical Field Profile collected in Lake Gem Mary

Location	Site	Date	Depth (meter)	Temp (°C)	SpCond (umho/cm)	pH Units	DO (mg/L)	DO (%)	ORP (mV)	Turbidity (NTU)	Secchi (meter)
Site 3	XBC12S3S	10/27/2015	0.5	25.5	221	7.4	7.6	93.1	81.0	0.1	0.95
	XBC12S3S	10/27/2015	1.0	25.4	220	7.4	7.4	90.7	106.1	0.1	0.95
	XBC12S3S	10/27/2015	1.5	25.4	218	7.3	7.2	88.1	173.0	0.1	0.95
	XBC12S3S	10/27/2015	2.0	25.3	218	7.3	7.0	85.4	131.2	0.1	0.95
	XBC12S3S	10/27/2015	2.5	25.3	219	7.3	7.0	84.9	142.9	0.1	0.95
	XBC12S3S	10/27/2015	3.0	25.3	219	7.3	7.0	85.7	149.3	0.1	0.95
	XBC12S3S	10/27/2015	3.5	25.3	218	7.3	7.3	89.0	153.3	0.1	0.95
	XBC12S3S	10/27/2015	4.0	25.3	218	7.3	7.4	89.4	155.9	0.1	0.95
	XBC12S3S	10/27/2015	4.5	25.3	220	7.3	7.1	86.2	163.7	0.1	0.95
	XBC12S3S	10/27/2015	5.0	25.3	220	7.3	6.6	80.0	170.8	0.1	0.95
	XBC12S3S	10/27/2015	5.5	25.2	220	7.3	6.0	73.3	173.8	0.1	0.95
	XBC12S3S	10/27/2015	6.0	25.0	216	7.1	1.6	19.7	155.1	0.1	0.95
	XBC12S3S	10/27/2015	6.5	24.0	265	7.0	0.4	5.3	-107.5	0.1	0.95
	XBC12S3S	10/27/2015	7.0	21.1	313	6.8	0.3	3.4	-165.2	0.1	0.95
	XBC12S3S	10/27/2015	7.5	19.1	304	6.3	0.3	3.2	-144.5	0.1	0.95
	XBC12S3S	11/24/2015	0.5	23.4	225	7.3	6.3	74.0	155.1	0.1	1.10
	XBC12S3	11/24/2015	1.0	23.3	226	7.3	6.0	69.5	176.9	0.1	1.10
	XBC12S3	11/24/2015	1.5	23.3	227	7.3	5.8	68.3	188.5	0.1	1.10
	XBC12S3	11/24/2015	2.0	23.2	227	7.2	5.6	65.8	197.7	0.1	1.10
	XBC12S3	11/24/2015	2.5	23.2	227	7.2	5.5	64.1	205.4	0.1	1.10
	XBC12S3	11/24/2015	3.0	23.2	227	7.2	5.4	63.3	211.6	0.0	1.10
	XBC12S3	11/24/2015	3.5	23.2	228	7.2	5.4	62.8	218.0	0.1	1.10
	XBC12S3	11/24/2015	4.0	23.2	229	7.2	5.5	64.0	226.9	0.1	1.10
	XBC12S3	11/24/2015	4.5	23.2	227	7.2	5.5	64.3	233.6	0.3	1.10

Location	Site	Date	Depth (meter)	Temp (°C)	SpCond (umho/cm)	pH Units	DO (mg/L)	DO (%)	ORP (mV)	Turbidity (NTU)	Secchi (meter)
	XBC12S3	11/24/2015	5.0	23.2	228	7.2	5.5	64.0	239.8	0.1	1.10
	XBC12S3	11/24/2015	5.5	23.2	228	7.2	5.5	63.9	245.5	0.0	1.10
	XBC12S3	11/24/2015	6.0	23.2	227	7.2	5.5	64.2	249.8	0.1	1.10
	XBC12S3	11/24/2015	6.5	23.2	227	7.2	5.5	64.8	253.2	0.1	1.10
	XBC12S3	11/24/2015	7.0	22.9	235	7.1	4.5	51.6	-16.7	2.5	1.10
	XBC12S3	11/24/2015	7.5	21.2	330	6.8	0.6	6.8	-176.3	4.5	1.10
	XBC12S3B	11/24/2015	8.0	20.1	337	6.6	0.4	3.9	-185.2	4.0	1.10
	XBC12S3S	12/28/2015	0.5	23.9	262	8.7	9.8	116.6	58.8	2.2	0.80
	XBC12S3	12/28/2015	1.0	23.3	261	8.6	9.9	116.3	62.4	1.2	0.80
	XBC12S3	12/28/2015	1.5	23.1	261	8.5	9.9	115.9	65.8	0.0	0.80
	XBC12S3	12/28/2015	2.0	22.4	261	8.0	8.5	98.6	74.7	0.0	0.80
	XBC12S3	12/28/2015	2.5	21.7	262	7.5	5.6	64.4	81.8	0.1	0.80
	XBC12S3	12/28/2015	3.0	21.4	263	7.1	3.6	41.0	85.0	0.1	0.80
	XBC12S3	12/28/2015	3.5	21.2	263	6.9	3.0	33.7	98.1	0.1	0.80
	XBC12S3	12/28/2015	4.0	21.1	263	6.9	2.8	31.2	100.1	0.1	0.80
	XBC12S3	12/28/2015	4.5	21.1	263	6.8	2.7	30.6	102.2	0.1	0.80
	XBC12S3	12/28/2015	5.0	21.1	263	6.8	2.8	31.6	104.1	0.1	0.80
	XBC12S3	12/28/2015	5.5	21.0	263	6.8	2.7	30.2	105.6	0.1	0.80
	XBC12S3	12/28/2015	6.0	21.0	263	6.8	2.5	28.1	107.0	0.1	0.80
	XBC12S3	12/28/2015	6.5	21.0	263	6.8	2.5	27.5	106.9	0.1	0.80
	XBC12S3	12/28/2015	7.0	20.9	262	6.8	2.4	27.0	105.2	0.1	0.80
	XBC12S3	12/28/2015	7.5	20.9	265	6.7	2.4	26.7	-14.3	0.1	0.80
	XBC12S3	12/28/2015	8.0	20.8	268	6.7	2.4	26.5	-57.8	0.1	0.80
	XBC12S3B	12/28/2015	8.5	20.7	279	6.6	2.4	26.4	-90.9	0.9	0.80
	XBC12S3S	1/26/2016	0.5	17.0	312	8.5	11.3	117.4	296.7	4.8	0.90

Location	Site	Date	Depth (meter)	Temp (°C)	SpCond (umho/cm)	pH Units	DO (mg/L)	DO (%)	ORP (mV)	Turbidity (NTU)	Secchi (meter)
	XBC12S3	1/26/2016	1.0	16.7	312	8.5	11.3	115.9	298.9	5.0	0.90
	XBC12S3	1/26/2016	1.5	16.4	311	8.6	11.5	117.6	297.2	4.9	0.90
	XBC12S3	1/26/2016	2.0	16.1	311	8.2	10.8	109.9	303.4	5.2	0.90
	XBC12S3	1/26/2016	2.5	16.0	311	7.8	10.1	102.0	306.3	4.9	0.90
	XBC12S3	1/26/2016	3.0	16.0	311	7.8	9.9	99.8	306.4	5.5	0.90
	XBC12S3	1/26/2016	3.5	16.0	311	7.6	9.3	93.8	307.9	4.9	0.90
	XBC12S3	1/26/2016	4.0	15.9	311	7.5	8.9	90.1	308.2	4.8	0.90
	XBC12S3	1/26/2016	4.5	15.9	311	7.5	8.9	90.0	308.0	5.8	0.90
	XBC12S3	1/26/2016	5.0	15.9	311	7.5	8.9	91.2	308.5	5.0	0.90
	XBC12S3	1/26/2016	5.5	15.9	311	7.5	9.0	91.4	308.8	5.0	0.90
	XBC12S3	1/26/2016	6.0	15.9	312	7.5	9.0	90.8	309.2	4.6	0.90
	XBC12S3	1/26/2016	6.5	15.9	312	7.5	8.9	90.5	309.7	4.6	0.90
	XBC12S3	1/26/2016	7.0	15.9	312	7.5	8.8	89.2	310.4	4.2	0.90
	XBC12S3	1/26/2016	7.5	15.9	312	7.4	8.7	87.7	310.8	4.6	0.90
	XBC12S3	1/26/2016	8.0	15.9	312	7.4	8.6	86.8	310.9	4.6	0.90
	XBC12S3B	1/26/2016	8.5	15.9	312	7.4	8.5	86.4	307.0	5.4	0.90
	XBC12S3S	2/25/2016	0.5	19.4	260	8.9	11.3	123.4	215.9	8.1	0.7
	XBC12S3	2/25/2016	1.0	19.4	260	8.8	11.4	123.8	217.9	8.4	0.7
	XBC12S3	2/25/2016	1.5	19.4	260	8.8	11.4	123.9	219.3	7.9	0.7
	XBC12S3	2/25/2016	2.0	19.0	260	8.7	11.2	121.0	221.4	7.9	0.7
	XBC12S3	2/25/2016	2.5	17.3	257	8.5	12.1	126.4	228.1	4.8	0.7
	XBC12S3	2/25/2016	3.0	16.7	256	8.2	11.7	120.9	231.4	4.7	0.7
	XBC12S3	2/25/2016	3.5	16.4	256	7.8	9.0	99.9	238.6	5.1	0.7
	XBC12S3	2/25/2016	4.0	16.2	259	7.1	3.3	33.1	244.5	3.9	0.7
	XBC12S3	2/25/2016	4.5	16.1	260	6.9	2.0	20.7	246.9	3.9	0.7
	XBC12S3	2/25/2016	5.0	16.0	260	6.9	1.6	15.6	248.3	3.8	0.7

Location	Site	Date	Depth (meter)	Temp (°C)	SpCond (umho/cm)	pH Units	DO (mg/L)	DO (%)	ORP (mV)	Turbidity (NTU)	Secchi (meter)
	XBC12S3	2/25/2016	5.5	15.9	259	6.8	2.2	21.3	249.7	3.7	0.7
	XBC12S3	2/25/2016	6.0	15.8	259	6.8	2.0	20.0	251.1	3.6	0.7
	XBC12S3	2/25/2016	6.5	15.8	259	6.8	1.6	16.5	252.2	3.6	0.7
	XBC12S3	2/25/2016	7.0	15.8	259	6.8	1.3	12.9	253.6	3.4	0.7
	XBC12S3	2/25/2016	7.5	15.8	260	6.8	1.2	12.1	254.1	3.8	0.7
	XBC12S3B	2/25/2016	8.0	15.7	260	6.8	1.6	16.4	253.8	3.6	0.7
	XBC12S3S	3/30/2016	0.5	23.9	274	8.9	9.5	113.1	228.8	9.7	0.6
	XBC12S3	3/30/2016	1.0	23.9	274	8.9	9.3	109.8	230.9	9.6	0.6
	XBC12S3	3/30/2016	1.5	23.4	278	8.7	8.0	94.2	237.0	8.0	0.6
	XBC12S3	3/30/2016	2.0	22.4	286	8.3	5.9	67.0	247.0	6.5	0.6
	XBC12S3	3/30/2016	2.5	21.3	288	7.9	2.9	32.8	253.3	4.1	0.6
	XBC12S3	3/30/2016	3.0	20.4	283	7.4	0.6	6.8	256.9	3.9	0.6
	XBC12S3	3/30/2016	3.5	19.8	274	7.1	0.2	2.5	245.1	3.6	0.6
	XBC12S3	3/30/2016	4.0	18.5	283	6.9	0.2	1.8	186.3	3.8	0.6
	XBC12S3	3/30/2016	4.5	17.7	286	6.7	0.1	1.4	115.0	3.2	0.6
	XBC12S3	3/30/2016	5.0	17.1	284	6.7	0.1	1.3	92.0	3.0	0.6
	XBC12S3	3/30/2016	5.5	16.9	284	6.6	0.1	1.2	63.8	2.9	0.6
	XBC12S3	3/30/2016	6.0	16.7	284	6.5	0.1	1.1	50.3	2.6	0.6
	XBC12S3	3/30/2016	6.5	16.6	284	6.5	0.1	1.0	37.2	2.7	0.6
	XBC12S3	3/30/2016	7.0	16.5	287	6.5	0.1	1.0	9.6	3.0	0.6
	XBC12S3	3/30/2016	7.5	16.5	287	6.5	0.1	1.0	-4.6	2.9	0.6
	XBC12S3	3/30/2016	8.0	16.5	287	6.5	0.1	0.9	-12.5	3.2	0.6
	XBC12S3B	3/30/2016	8.5	16.4	288	6.5	0.1	0.8	-27.3	3.4	0.6

Location	Site	Date	Depth (meter)	Temp (°C)	SpCond (umho/cm)	pH Units	DO (mg/L)	DO (%)	ORP (mV)	Turbidity (NTU)	Secchi (meter)
Site 3	XBC12S3S	4/26/2016	0.5	25.4	273	9.7	12.9	157.3	251.8	17.3	0.4
	XBC12S3	4/26/2016	1.0	25.3	272	9.7	12.4	150.8	253.5	16.1	0.4
	XBC12S3	4/26/2016	1.5	24.8	266	9.4	11.7	141.2	257.7	13.9	0.4
	XBC12S3	4/26/2016	2.0	24.0	263	8.9	6.1	72.2	278.4	8.9	0.4
	XBC12S3	4/26/2016	2.5	23.3	250	8.2	1.9	21.7	284.4	5.0	0.4
	XBC12S3	4/26/2016	3.0	22.8	232	7.7	0.3	3.4	268.7	5.8	0.4
	XBC12S3	4/26/2016	3.5	21.0	290	7.3	0.2	2.2	120.0	3.5	0.4
	XBC12S3	4/26/2016	4.0	19.7	298	7.3	0.2	1.7	59.8	3.3	0.4
	XBC12S3	4/26/2016	4.5	18.8	293	7.2	0.2	1.6	25.1	2.8	0.4
	XBC12S3	4/26/2016	5.0	18.3	287	7.1	0.1	1.4	5.7	2.3	0.4
	XBC12S3	4/26/2016	5.5	17.5	274	6.9	0.1	1.3	-14.6	2.0	0.4
	XBC12S3	4/26/2016	6.0	17.3	273	6.8	0.1	1.2	-17.3	2.0	0.4
	XBC12S3	4/26/2016	6.5	16.9	271	6.6	0.1	1.1	-39.7	2.1	0.4
	XBC12S3	4/26/2016	7.0	16.8	270	6.6	0.1	1.1	-47.0	2.1	0.4
	XBC12S3	4/26/2016	7.5	16.8	270	6.6	0.1	1.0	-54.1	2.2	0.4
	XBC12S3	4/26/2016	8.0	16.8	271	6.6	0.1	1.0	-64.9	2.2	0.4
	XBC12S3B	4/26/2016	8.5	16.8	271	6.6	0.1	1.0	-77.7	2.4	0.4
										2.4	
	XBC12S3S	5/31/2016	0.5	30.5	257	8.7	9.3	124.4	175.2	4.9	0.8
	XBC12S3	5/31/2016	1.0	29.9	257	8.7	9.3	123.1	178.2	5.3	0.8
	XBC12S3	5/31/2016	1.5	28.7	256	8.5	9.0	116.1	184.1	2.2	0.8
	XBC12S3	5/31/2016	2.0	27.7	252	8.2	6.9	87.3	193.9	1.7	0.8
	XBC12S3	5/31/2016	2.5	27.2	251	7.7	5.0	63.2	198.3	1.3	0.8
	XBC12S3	5/31/2016	3.0	24.9	265	7.4	0.5	5.5	200.4	2.8	0.8
	XBC12S3	5/31/2016	3.5	22.6	298	7.3	0.2	2.7	197.8	3.7	0.8
	XBC12S3	5/31/2016	4.0	21.4	314	7.3	0.2	2.2	172.6	7.3	0.8

Location	Site	Date	Depth (meter)	Temp (°C)	SpCond (umho/cm)	pH Units	DO (mg/L)	DO (%)	ORP (mV)	Turbidity (NTU)	Secchi (meter)
	XBC12S3	5/31/2016	4.5	21.3	318	7.4	0.2	1.8	38.8	11.9	0.8
	XBC12S3	5/31/2016	5.0	19.2	303	7.1	0.1	1.4	-43.2	4.1	0.8
	XBC12S3	5/31/2016	5.5	18.2	288	7.0	0.1	1.2	-59.4	1.5	0.8
	XBC12S3	5/31/2016	6.0	17.6	281	6.9	0.1	1.2	-74.0	1.2	0.8
	XBC12S3	5/31/2016	6.5	17.3	279	6.8	0.1	1.2	-84.5	1.8	0.8
	XBC12S3	5/31/2016	7.0	17.2	280	6.7	0.1	1.2	-93.6	2.4	0.8
	XBC12S3	5/31/2016	7.5	17.1	283	6.7	0.1	1.0	-101.2	3.1	0.8
	XBC12S3	5/31/2016	8.0	17.1	282	6.6	0.1	1.0	-107.1	3.4	0.8
	XBC12S3B	5/31/2016	8.5	17.1	283	6.6	0.1	1.1	-111.3	3.6	0.8
	XBC12S3S	6/29/2016	0.5	31.5	242	8.0	8.9	115.5	152.0	1.7	1.3
	XBC12S3	6/29/2016	1.0	31.4	242	7.9	8.6	116.2	154.0	1.6	1.3
	XBC12S3	6/29/2016	1.5	31.4	242	7.9	8.6	116.1	156.6	1.6	1.3
	XBC12S3	6/29/2016	2.0	31.3	241	7.7	7.6	102.9	162.3	1.7	1.3
	XBC12S3	6/29/2016	2.5	31.3	243	7.5	7.4	100.1	169.0	1.9	1.3
	XBC12S3	6/29/2016	3.0	29.9	244	7.4	7.6	101.6	172.6	2.9	1.3
	XBC12S3	6/29/2016	3.5	28.5	246	7.2	5.0	64.0	177.6	3.3	1.3
	XBC12S3	6/29/2016	4.0	27.1	245	6.9	0.7	7.7	179.3	4.1	1.3
	XBC12S3	6/29/2016	4.5	23.7	316	6.9	0.2	2.8	176.6	11.3	1.3
	XBC12S3	6/29/2016	5.0	21.9	331	7.0	0.2	2.0	136.2	13.7	1.3
	XBC12S3	6/29/2016	5.5	19.9	332	7.0	0.2	1.9	-13.2	14.3	1.3
	XBC12S3	6/29/2016	6.0	19.1	309	7.0	0.2	1.7	-48.0	6.6	1.3
	XBC12S3	6/29/2016	6.5	18.5	299	6.9	0.2	1.6	-58.3	5.8	1.3
	XBC12S3	6/29/2016	7.0	18.0	292	6.8	0.2	1.5	-70.6	5.4	1.3
	XBC12S3	6/29/2016	7.5	17.6	289	6.6	0.1	1.4	-79.9	5.6	1.3
	XBC12S3	6/29/2016	8.0	17.4	293	6.5	0.1	1.3	-84.2	5.9	1.3

Location	Site	Date	Depth (meter)	Temp (°C)	SpCond (umho/cm)	pH Units	DO (mg/L)	DO (%)	ORP (mV)	Turbidity (NTU)	Secchi (meter)
	XBC12S3B	6/29/2016	8.5	17.4	294	6.5	0.1	1.4	-87.0	7.1	1.3
	XBC12S3S	7/27/2016	0.5	32.9	259	8.4	9.3	129.8	216.2	0.5	1.3
	XBC12S3	7/27/2016	1.0	32.7	259	8.4	9.4	129.8	216.7	0.5	1.3
	XBC12S3	7/27/2016	1.5	32.4	259	8.3	9.4	129.3	217.4	0.6	1.3
	XBC12S3	7/27/2016	2.0	32.3	258	8.2	9.2	125.8	218.9	0.6	1.3
	XBC12S3	7/27/2016	2.5	32.2	259	7.9	8.3	114.3	223.7	0.7	1.3
	XBC12S3	7/27/2016	3.0	31.8	257	7.7	8.0	108.7	226.2	0.7	1.3
	XBC12S3	7/27/2016	3.5	31.1	253	7.4	5.3	72.0	230.4	0.8	1.3
	XBC12S3	7/27/2016	4.0	30.2	247	7.0	1.1	14.3	233.5	0.8	1.3
	XBC12S3	7/27/2016	4.5	28.2	264	6.7	0.3	3.6	232.2	2.6	1.3
	XBC12S3	7/27/2016	5.0	26.0	322	6.7	0.2	2.5	230.9	5.7	1.3
	XBC12S3	7/27/2016	5.5	21.9	356	6.8	0.2	2.1	31.7	9.4	1.3
	XBC12S3	7/27/2016	6.0	19.8	346	6.9	0.2	1.8	-68.2	3.8	1.3
	XBC12S3	7/27/2016	6.5	18.9	325	6.7	0.2	1.6	-81.3	2.2	1.3
	XBC12S3	7/27/2016	7.0	18.5	309	6.6	0.1	1.5	-81.4	2.0	1.3
	XBC12S3	7/27/2016	7.5	17.9	304	6.5	0.1	1.4	-84.4	1.9	1.3
	XBC12S3	7/27/2016	8.0	17.8	304	6.4	0.1	1.5	-85.6	2.3	1.3
	XBC12S3S	8/30/2016	0.5	30.6	241	7.0	7.0	93.8	254.5	1.2	1.3
	XBC12S3	8/30/2016	1.0	30.5	241	7.0	6.9	92.6	254.5	1.2	1.3
	XBC12S3	8/30/2016	1.5	30.5	241	7.0	6.8	91.0	254.5	1.2	1.3
	XBC12S3	8/30/2016	2.0	30.5	241	6.9	6.6	87.9	241.2	1.3	1.3
	XBC12S3	8/30/2016	2.5	30.5	241	7.0	6.4	86.0	246.8	1.1	1.3
	XBC12S3	8/30/2016	3.0	30.5	241	7.0	6.8	90.5	249.0	1.2	1.3
	XBC12S3	8/30/2016	3.5	30.4	240	7.0	5.9	78.6	248.3	1.2	1.3
	XBC12S3	8/30/2016	4.0	30.3	240	6.9	6.0	79.7	205.6	1.2	1.3

Location	Site	Date	Depth (meter)	Temp (°C)	SpCond (umho/cm)	pH Units	DO (mg/L)	DO (%)	ORP (mV)	Turbidity (NTU)	Secchi (meter)
	XBC12S3	8/30/2016	4.5	30.3	239	6.8	5.0	66.4	215.9	1.2	1.3
	XBC12S3	8/30/2016	5.0	28.0	259	6.7	0.3	3.6	178.0	5.7	1.3
	XBC12S3	8/30/2016	5.5	25.6	337	6.8	0.2	2.2	126.2	9.5	1.3
	XBC12S3	8/30/2016	6.0	23.8	376	6.9	0.2	1.8	19.4	16.4	1.3
	XBC12S3	8/30/2016	6.5	21.0	382	7.0	0.2	1.7	-76.2	8.8	1.3
	XBC12S3	8/30/2016	7.0	19.6	346	6.8	0.2	1.6	-78.4	6.7	1.3
	XBC12S3	8/30/2016	7.5	18.9	330	6.7	0.1	1.5	-77.7	6.3	1.3
	XBC12S3	8/30/2016	8.0	18.4	326	6.5	0.1	1.4	-76.9	6.7	1.3
	XBC12S3B	8/30/2016	8.5	18.1	330	6.4	0.1	1.5	-78.7	9.0	1.3
	XBC12S3S	9/27/2016	0.5	31.1	221	7.9	6.8	91.5	310.4	1.1	1.2
	XBC12S3	9/27/2016	1.0	30.7	221	7.8	6.8	91.5	315.0	1.1	1.2
	XBC12S3	9/27/2016	1.5	30.3	221	7.8	6.7	88.8	319.5	1.3	1.2
	XBC12S3	9/27/2016	2.0	30.2	221	7.7	6.5	86.5	324.4	1.3	1.2
	XBC12S3	9/27/2016	2.5	30.1	221	7.6	6.4	84.4	329.0	1.2	1.2
	XBC12S3	9/27/2016	3.0	30.1	221	7.6	5.9	78.8	332.3	1.2	1.2
	XBC12S3	9/27/2016	3.5	30.1	221	7.5	5.7	76.0	334.1	1.3	1.2
	XBC12S3	9/27/2016	4.0	30.0	221	7.5	5.5	73.2	335.8	1.3	1.2
	XBC12S3	9/27/2016	4.5	29.9	220	7.4	3.0	39.8	342.8	1.2	1.2
	XBC12S3	9/27/2016	5.0	29.3	221	7.3	0.6	8.4	329.1	2.3	1.2
	XBC12S3	9/27/2016	5.5	27.7	246	7.1	0.2	3.0	383.5	3.9	1.2
	XBC12S3	9/27/2016	6.0	25.8	310	7.1	0.2	2.5	199.0	10.4	1.2
	XBC12S3	9/27/2016	6.5	23.6	362	7.1	0.2	2.2	93.5	13.2	1.2
	XBC12S3	9/27/2016	7.0	22.2	367	7.2	0.2	2.0	-275.9	7.1	1.2
	XBC12S3	9/27/2016	7.5	20.0	335	6.9	0.2	1.9	-271.1	5.0	1.2
	XBC12S3	9/27/2016	8.0	19.8	332	6.8	0.2	1.9	-266.1	5.1	1.2

Location	Site	Date	Depth (meter)	Temp (°C)	SpCond (umho/cm)	pH Units	DO (mg/L)	DO (%)	ORP (mV)	Turbidity (NTU)	Secchi (meter)
	XBC12S3B	9/27/2016	8.5	18.9	330	6.6	0.2	1.9	-254.5	6.2	1.2

APPENDIX C

LABORATORY DATA FOR SURFACE WATER SAMPLES

NOVEMBER 2015 THROUGH OCTOBER 2016

XBC12S1S															
Date Collected															
	October	November	December	January	February	March	April	May	June	July	August	September	MEAN	MEDAIN	GEOMEAN
Alkalinity (mg/L)	38	41.4	41.2	42	40.4	43.4	38.5	29.4	29.6	33.2	25.7	27.6	35.9	38.3	35.3
Qualifier	-	-	-	-	-	-	-	-	-	-	-	-			
Ammonia (µg/L)	2.5	100	2.5	49	2.5	2.5	2.5	12	27	31	96	30	29.8	19.5	12.4
Qualifier	U	-	U	-	U	U	U	-	-	-	-	-			
NOX (µg/L)	2.5	2.5	122	151	25	51	2.5	13	2.5	2.5	2.5	2.5	31.6	2.5	8.7
Qualifier	U	U	-	-	-	-	U	I	U	U	U	U			
Diss. Total N (µg/L)	684	775	751	705	329	670	831	1016	787	692	575	339	679.5	698.5	648.6
Qualifier	-	-	-	-	-	-	-	-	-	-	-	-			
Diss. Org. N (µg/L)	679	672.5	626.5	505	301.5	616.5	826	991	757.5	658.5	476.5	306.5	618.1	642.5	584.8
Qualifier	-	-	-	-	-	-	-	-	-	-	-	-			
Part. N (µg/L)	300	300	214	225	579	638	1034	322	492	79	94	258	377.9	300.0	298.6
Qualifier	-	-	-	-	-	-	-	-	-	-	-	-			
Total N (µg/L)	984	1075	965	930	908	1308	1865	1338	1279	771	669	597	1057.4	974.5	1008.6
Qualifier	-	-	-	-	-	-	-	-	-	-	-	-			
SRP (µg/L)	3	1	11	2	1	4	9	9	7	7	1	8	5.3	5.5	3.8
Qualifier	-	I	-	I	I	-	-	-	-	-	I	-			
Diss. Total P (µg/L)	15	9	16	9	2	15	21	28	29	18	12	17	15.9	15.5	13.5
Qualifier	-	-	-	-	I	-	-	-	-	-	-	-			
Diss. Org. P (µg/L)	12	8	5	7	1	11	12	19	22	11	11	9	10.7	11.0	8.8
Qualifier	-	-	-	-	-	-	-	-	-	-	-	-			
Part. P (µg/L)	23	19	18	15	31	53	30	12	6	4	17	8	19.7	17.5	15.7
Qualifier	-	-	-	-	-	-	-	-	-	-	-	-			
Total P (µg/L)	38	28	34	24	33	68	51	40	35	22	29	25	35.6	33.5	33.8
Qualifier	-	-	-	-	-	-	-	-	-	-	-	-			
Chyl- a (mg/m³)	24.8	28.8	45.5	36.3	23.3	10.8	76.9	60.9	16.5	13	25.8	13.8	31.4	25.3	26.2
Qualifier	-	-	-	-	-	-	-	-	-	-	-	-			
TSS (mg/L)	4.4	3.2	3.6	5.3	7.2	9.6	7.2	5	2.8	2.5	4.3	2.2	4.8	4.4	4.3
Qualifier	-	-	-	-	-	-	-	-	-	-	-	I			
Color (PCU)	11	11	11	11	11	9	15	8	11	9	9	8	10.3	11.0	10.2
Qualifier	-	-	-	-	-	-	-	-	-	-	-	-			

XBC12S1B															
Date Collected															
	October	November	December	January	February	March	April	May	June	July	August	September	MEAN	MEDAIN	GEOMEAN
Alkalinity (mg/L)	39.2	42.6	43.6	40.6	41.6	40.0	30.2	27.2	29.3	31.6	26.5	28.1	35.0	35.4	34.4
Qualifier	-	-	-	-	-	-	-	-	-	-	-	-			
Ammonia (µg/L)	20	89	192	62	329	217	119	96	30	56	61	20	107.6	75.5	75.7
Qualifier	-	-	-	-	-	-	-	-	-	-	-	-			
NOX (µg/L)	2.5	9	60	73	36	58	2.5	14	2.5	20	2.5	2.5	23.5	11.5	10.7
Qualifier	U	I	-	-	-	-	U	I	U	-	U	U			
Diss. Total N (µg/L)	574	614	740	483	597	841	760	873	982	805	659	439	697.3	699.5	679.0
Qualifier	-	-	-	-	-	-	-	-	-	-	-	-			
Diss. Org. N (µg/L)	551.5	516	488	348	232	566	638.5	763	949.5	729	595.5	416.5	566.1	558.8	533.4
Qualifier	-	-	-	-	-	-	-	-	-	-	-	-			
Part. N (µg/L)	356	141	359	532	382	838	738	397	20	98	247	160.0	355.7	357.5	253.3
Qualifier	-	-	-	-	-	-	-	-	-	-	-	-			
Total N (µg/L)	930	755	1099	1015	979	1679	1498	1270	1002	903	906	599	1052.9	990.5	1015.5
Qualifier	-	-	-	-	-	-	-	-	-	-	-	-			
SRP (µg/L)	3	1	4	2	1	4	9	9	7	8	1	7	4.7	4.0	3.5
Qualifier	-	I	-	I	I	-	-	-	-	-	I	-			
Diss. Total P (µg/L)	16	13	5	19	1	15	22	28	29	14	11	16	15.8	15.5	12.4
Qualifier	-	-	I	-	U	-	-	-	-	-	-	-			
Diss. Org. P (µg/L)	13	12	1	17	-	11	13	19	22	6	10	9	12.1	12.0	9.9
Qualifier	-	-	-	-	-	-	-	-	-	-	-	-			
Part. P (µg/L)	23	17	29	15	36	82	35	14	11	9	15	13	24.9	16.0	20.2
Qualifier	-	-	-	-	-	-	-	-	-	-	-	-			
Total P (µg/L)	39	30	34	34	37	97	57	42	40	23	26	29	40.7	35.5	37.6
Qualifier	-	-	-	-	-	-	-	-	-	-	-	-			
Chyl- a (mg/m³)	-	-	-	-	-	8.1	57.4	30.6	29.1	24.5	23.1	24.6	28.2	24.6	24.8
Qualifier	-	-	-	-	-	-	-	-	-	-	-	-			
TSS (mg/L)	4.4	3.5	2.9	6.8	6	5.2	4.2	3.5	3.6	2.6	3.1	3.2	4.1	3.6	3.9
Qualifier	-	-	-	-	-	-	-	-	-	-	-	-			
Color (PCU)	-	-	-	-	-	8	14	9	11	9	10	8	9.9	9.0	9.7
Qualifier	-	-	-	-	-	-	-	-	-	-	-	-			

XBC12S2S															
Date Collected															
	October	November	December	January	February	March	April	May	June	July	August	September	MEAN	MEDAIN	GEOMEAN
Alkalinity (mg/L)	39.2	41.0	44.0	39.6	39.4	40.2	39.2	30.0	29.6	32.8	27.1	27.4	35.8	39.2	35.3
Qualifier	-	-	-	-	-	-	-	-	-	-	-	-			
Ammonia (µg/L)	7	77	2.5	15	2.5	2.5	2.5	2.5	33	29	2.5	22	16.5	4.8	7.7
Qualifier	I	-	U	-	U	U	U	U	-	-	U	-			
NOX (µg/L)	2.5	8	95	69	8	57	2.5	15	2.5	2.5	2.5	2.5	22.3	5.3	8.2
Qualifier	U	I	-	-	I	-	U	-	U	U	U	U			
Diss. Total N (µg/L)	510	839	917	670	324	720	1304	836	732	599	417	603	705.9	695.0	664.2
Qualifier	-	-	-	-	-	-	-	-	-	-	-	-			
Diss. Org. N (µg/L)	500.5	754	819.5	586	313.5	660.5	1299	818.5	696.5	567.5	412	578.5	667.2	623.3	627.9
Qualifier	-	-	-	-	-	-	-	-	-	-	-	-			
Part. N (µg/L)	238	241	82	76	546	550	575	475	70	148	177	308.0	290.5	239.5	224.7
Qualifier	-	-	-	-	-	-	-	-	-	-	-	-			
Total N (µg/L)	748	1080	999	746	870	1270	1879	1311	802	747	594	911	996.4	890.5	948.7
Qualifier	-	-	-	-	-	-	-	-	-	-	-	-			
SRP (µg/L)	3	1	12	1	1	5	7	9	8	7	1	7	5.2	6.0	3.6
Qualifier	-	I	-	I	I	-	-	-	-	-	I	-			
Diss. Total P (µg/L)	16	7	29	9	7	18	23	27	25	14	13	15	16.9	15.5	15.2
Qualifier	-	-	-	-	-	-	-	-	-	-	-	-			
Diss. Org. P (µg/L)	13	6	17	8	6	13	16	18	17	7	12	8	11.8	12.5	10.9
Qualifier	-	-	-	-	-	-	-	-	-	-	-	-			
Part. P (µg/L)	20	20	6	17	27	44	33	12	6	13	15	11	18.7	16.0	15.8
Qualifier	-	-	-	-	-	-	-	-	-	-	-	-			
Total P (µg/L)	36	27	35	26	34	62	56	39	31	27	28	26	35.6	32.5	34.1
Qualifier	-	-	-	-	-	-	-	-	-	-	-	-			
Chyl- a (mg/m³)	30.5	27	59	40.2	26.2	14.1	99.4	25.6	22.4	19.2	26.4	16.2	33.9	26.3	28.9
Qualifier	-	-	-	-	-	-	-	-	-	-	-	-			
TSS (mg/L)	3	3.1	5.5	4.8	6.8	10.7	6.4	5.5	2.6	2.1	2.9	3.2	4.7	4.0	4.2
Qualifier	-	-	-	-	-	-	-	-	-	I	-	-			
Color (PCU)	12	10	12	11	11	11	17	8	11	9	13	9	11.2	11.0	11.0
Qualifier	-	-	-	-	-	-	-	-	-	-	-	-			

XBC12S2B															
Date Collected															
	October	November	December	January	February	March	April	May	June	July	August	September	MEAN	MEDAIN	GEOMEAN
Alkalinity (mg/L)	38.6	42.0	42.2	41.2	42.2	44.2	62.2	69.4	29.3	64.2	63.9	40.0	48.3	42.2	46.8
Qualifier	-	-	-	-	-	-	-	-	-	-	-	-			
Ammonia (µg/L)	65	142	343	42	390	514	695	823	624	125	78	63	325.3	242.5	206.0
Qualifier	-	-	-	-	-	-	-	-	-	-	-	-			
NOX (µg/L)	2.5	2.5	38	63	40	21	2.5	2.5	2.5	2.5	2.5	2.5	15.2	2.5	6.2
Qualifier	U	U	-	-	-	-	U	U	U	U	U	U			
Diss. Total N (µg/L)	657	801	1004	818	639	975	1401	1252	1041	577	549	708	868.5	809.5	832.2
Qualifier	-	-	-	-	-	-	-	-	-	-	-	-			
Diss. Org. N (µg/L)	589.5	656.5	623	713	209	440	703.5	426.5	414.5	449.5	468.5	642.5	528.0	529.0	503.6
Qualifier	-	-	-	-	-	-	-	-	-	-	-	-			
Part. N (µg/L)	270	255	54	12	329	531	194	325	383	439	261	463.0	293.0	297.5	215.4
Qualifier	-	-	-	-	-	-	-	-	-	-	-	-			
Total N (µg/L)	927	1056	1058	830	968	1506	1595	1577	1424	1016	810	1171	1161.5	1057.0	1129.8
Qualifier	-	-	-	-	-	-	-	-	-	-	-	-			
SRP (µg/L)	3	1	4	2	1	4	8	12	7	7	1	11	5.1	4.0	3.6
Qualifier	-	I	-	I	I	-	-	-	-	-	I	-			
Diss. Total P (µg/L)	16	9	15	15	3	17	26	27	30	17	15	14	17.0	15.5	14.9
Qualifier	-	-	-	-	I	-	-	-	-	-	-	-			
Diss. Org. P (µg/L)	13	8	11	13	2	13	18	15	23	10	14	3	11.9	13.0	10.0
Qualifier	-	-	-	-	-	-	-	-	-	-	-	-			
Part. P (µg/L)	24	23	12	15	26	62	18	16	11	17	31	22	23.1	20.0	20.6
Qualifier	-	-	-	-	-	-	-	-	-	-	-	-			
Total P (µg/L)	40	32	27	30	29	79	44	43	41	34	46	36	40.1	38.0	38.4
Qualifier	-	-	-	-	-	-	-	-	-	-	-	-			
Chyl- a (mg/m³)	-	-	-	-	-	7.9	8.5	88.9	92.8	113	104	60	67.9	88.9	45.3
Qualifier	-	-	-	-	-	-	-	-	-	-	-	-			
TSS (mg/L)	4	3.8	1.7	7.2	4.7	3.4	1.5	2.9	3.3	5.2	4.6	2.7	3.8	3.6	3.4
Qualifier	-	-	I	-	-	-	I	-	-	-	-	-			
Color (PCU)	-	-	-	-	-	7	14	7	10	11	12	9	10.0	10.0	9.7
Qualifier	-	-	-	-	-	-	-	-	-	-	-	-			

XBC12S3S															
Date Collected															
	October	November	December	January	February	March	April	May	June	July	August	September	MEAN	MEDAIN	GEOMEAN
Alkalinity (mg/L)	39.8	43.6	41.8	40.0	39.6	41.8	39.4	28.4	28.0	32.1	28.4	29.2	36.0	39.5	35.5
Qualifier	-	-	-	-	-	-	-	-	-	-	-	-			
Ammonia (µg/L)	2.5	49	2.5	2.5	10	2.5	2.5	7	37	26	2.5	46	15.8	4.8	7.6
Qualifier	U	-	U	U	I	U	U	I	-	-	U	-			
NOX (µg/L)	2.5	2.5	84	68	10	30	2.5	9	2.5	2.5	8	2.5	18.7	5.3	7.5
Qualifier	U	U	-	-	I	-	U	I	U	U	I	U			
Diss. Total N (µg/L)	554	668	935	578	427	677	893	964	812	624	460	443	669.6	646.0	644.5
Qualifier	-	-	-	-	-	-	-	-	-	-	-	-			
Diss. Org. N (µg/L)	549	616.5	848.5	507.5	407	644.5	888	948	772.5	595.5	449.5	394.5	635.1	606.0	609.4
Qualifier	-	-	-	-	-	-	-	-	-	-	-	-			
Part. N (µg/L)	268	66	159	214	401	708	980	391	70	150	119	161.0	307.3	187.5	220.4
Qualifier	-	-	-	-	-	-	-	-	-	-	-	-			
Total N (µg/L)	822	734	1094	792	828	1385	1873	1355	882	774	579	604	976.8	825.0	919.1
Qualifier	-	-	-	-	-	-	-	-	-	-	-	-			
SRP (µg/L)	3	1	12	1	1	4	6	9	8	7	1	7	5.0	5.0	3.5
Qualifier	-	I	-	I	I	-	-	-	-	-	I	-			
Diss. Total P (µg/L)	15	8	19	9	4	18	20	27	31	16	14	13	16.2	15.5	14.3
Qualifier	-	-	-	-	I	-	-	-	-	-	-	-			
Diss. Org. P (µg/L)	12	7	7	8	3	14	14	18	23	9	13	6	11.2	10.5	9.8
Qualifier	-	-	-	-	-	-	-	-	-	-	-	-			
Part. P (µg/L)	17	20	12	19	28	32	36	12	6	5	15	12	17.8	16.0	15.3
Qualifier	-	-	-	-	-	-	-	-	-	-	-	-			
Total P (µg/L)	32	28	31	28	32	50	56	39	37	21	29	25	34.0	31.5	32.8
Qualifier	-	-	-	-	-	-	-	-	-	-	-	-			
Chyl- a (mg/m³)	21.6	31.4	39.2	38.7	27	41.6	86.7	23.1	21.3	14.5	29	15.4	32.5	28.0	28.8
Qualifier	-	-	-	-	-	-	-	-	-	-	-	-			
TSS (mg/L)	3.2	1.7	4.1	5.4	5.6	9.7	5.4	5.7	2.4	3.7	3.7	3.1	4.5	3.9	4.1
Qualifier	-	I	-	-	-	-	-	-	-	-	-	-			
Color (PCU)	12	10	12	11	11	10	16	7	10	9	8	9	10.4	10.0	10.2
Qualifier	-	-	-	-	-	-	-	-	-	-	-	-			

XBC12S3B															
Date Collected															
	October	November	December	January	February	March	April	May	June	July	August	September	MEAN	MEDAIN	GEOMEAN
Alkalinity (mg/L)	10.4	42.8	43.4	38.8	41.8	50.6	50.2	29.7	65.0	81.1	91.9	95.8	53.5	46.8	46.8
Qualifier	-	-	-	-	-	-	-	-	-	-	-	-			
Ammonia (µg/L)	3966	5444	1628	59	436	995	1187	2192	3177	3730	4714	5251	2731.6	2684.5	1723.4
Qualifier	-	-	-	-	-	-	-	-	-	-	-	-			
NOX (µg/L)	2.5	2.5	2.5	66	38	2.5	2.5	2.5	2.5	2.5	6	2.5	11.0	2.5	4.4
Qualifier	U	U	U	-	-	U	U	U	U	U	I	U			
Diss. Total N (µg/L)	5243	6050	2607	465	961	1453	1875	2688	3916	4509	6352	7166	3607.1	3302.0	2784.8
Qualifier	-	-	-	-	-	-	-	-	-	-	-	-			
Diss. Org. N (µg/L)	1274.5	603.5	976.5	340	487	455.5	685.5	493.5	736.5	776.5	1632	1912.5	864.5	711.0	754.8
Qualifier	-	-	-	-	-	-	-	-	-	-	-	-			
Part. N (µg/L)	321	38	385	357	75	128	326	146	251	25	346	428.0	235.5	286.0	172.9
Qualifier	-	-	-	-	-	-	-	-	-	-	-	-			
Total N (µg/L)	5564	6088	2992	822	1036	1581	2201	2834	4167	4534	6698	7594	3842.6	3579.5	3109.8
Qualifier	-	-	-	-	-	-	-	-	-	-	-	-			
SRP (µg/L)	11	8	4	1	1	4	9	9	10	12	7	13	7.4	8.5	5.7
Qualifier	-	-	-	I	I	-	-	-	-	-	-	-			
Diss. Total P (µg/L)	18	12	9	10	24	15	24	40	33	19	18	25	20.6	18.5	18.8
Qualifier	-	-	-	-	-	-	-	-	-	-	-	-			
Diss. Org. P (µg/L)	7	4	5	9	23	11	15	31	23	7	11	12	13.2	11.0	11.0
Qualifier	-	-	-	-	-	-	-	-	-	-	-	-			
Part. P (µg/L)	33	41	39	21	12	68	38	18	30	21	29	32	31.8	31.0	29.1
Qualifier	-	-	-	-	-	-	-	-	-	-	-	-			
Total P (µg/L)	51	53	48	31	36	83	62	58	63	40	47	57	52.4	52.0	50.7
Qualifier	-	-	-	-	-	-	-	-	-	-	-	-			
Chyl- a (mg/m³)	-	-	-	-	-	5.9	12	37.6	24.3	32.9	52.3	27.2	27.5	27.2	22.6
Qualifier	-	-	-	-	-	-	-	-	-	-	-	-			
TSS (mg/L)	3.9	6.5	4.9	5.8	4.9	4.4	2.1	5.8	5.7	5.5	5.3	6.1	5.1	5.4	4.9
Qualifier	-	-	-	-	-	-	I	-	-	-	-	-			
Color (PCU)	-	-	-	-	-	9	16	9	15	92	52	65	36.9	16.0	25.0
Qualifier	-	-	-	-	-	-	-	-	-	-	-	-			

APPENDIX D

NUMERIC NUTRIENT CRITERIA (NNC)

NOVEMBER 2015 THROUGH OCTOBER 2016

The Numeric Nutrient Criteria (NNC) was adopted in Florida on July 3, 2012, and updated in February 2016 to further assess the impairment of inland waters. The NNC utilizes different minimum and maximum values for TN, TP, and Chlorophyll-a based upon the color of the water. The geometric mean for color within Lake Gem Mary was 11 PCU and the geometric mean alkalinity was 38.7. The thresholds for a low Color lake (≤ 40 PCU) and high Alkalinity lake (≥ 20 mg/L) are presented in Table D-1 along with the Site Specific NNC for Lake Gem Mary.

The minimum annual geometric mean for Total Phosphorus (TP) is 0.03 mg/L and TN is 1.05 mg/L. The Maximum annual geometric mean for TP is 0.09 mg/L, TN is 1.91 mg/L and chlorophyll-a is 20 μ g/L. The Lake Gem Mary Interpretation of the Numeric Nutrient Criteria is TP of 0.03 (mg/L) and TN 1.05, the minimum Annual Geometric Mean for lakes ≤ 40 Platinum Cobalt Units and ≥ 20 mg/L of ammonia. Following code 62-302.531 “if the annual geometric mean chlorophyll *a* exceeds the values in the table below for the lake type, then the applicable numeric interpretations for TN and TP shall be the minimum values in the table below”.

Table D-1: Florida Adopted Numeric Nutrient Criteria (July 2012)

Long Term Geometric Mean Lake Color and Alkalinity	Annual Geometric Mean Chlorophyll <i>a</i>	Minimum calculated numeric interpretation		Maximum calculated numeric interpretation	
		Annual Geometric Mean Total	Annual Geometric Mean Total	Annual Geometric Mean Total	Annual Geometric Mean Total
		Phosphorus	Nitrogen	Phosphorus	Nitrogen
≥ 40 Platinum Cobalt Units	20 µg/L	0.05 mg/L	1.27 mg/L	0.16 mg/L ¹	2.23 mg/L
≤ 40 Platinum Cobalt Units and ≥ 20 mg/L CaCO ₃	20 µg/L	0.03 mg/L	1.05 mg/L	0.09 mg/L	1.91 mg/L
≤ 40 Platinum Cobalt Units and ≤ 20 mg/L CaCO ₃	6 µg/L	0.01 mg/L	0.51 mg/L	0.03 mg/L	0.93 mg/L

Lake Gem Mary Numeric Nutrient Criteria

Test Performed	Minimum Annual Geometric Mean	Maximum Annual Geometric Mean	Lake Gem Mary Annual Geometric Mean
Total Phosphorus (mg/L)	0.03	0.09	0.03
Total Nitrogen (mg/L)	1.05	1.91	1.05
Chlorophyll-a (µg/L)	N/A	20	28.46

APPENDIX E

CALCULATED RUNOFF VOLUMES

Basin	Land Use	Stormwater Treatment	Area (acres)	DCIA (%)	Non-DCIA CN Value	Runoff C Value	Generated Runoff Volume (ac-ft)	Runoff Volume Reduction Factor	Delivered Runoff Volume (ac-ft)	TP EMC (mg/l)	TN EMC (mg/l)	TSS EMC (mg/l)	TP (kg/yr)	TN (kg/yr)	TSS (kg/yr)	Direct runoff into Lake
0	Medium Density Residential	No	11.137	15	54	0.1253	5.95	41.7	3.47	0.306	2.29	33.0	1.31	9.81	141.32	No
0	Medium Density Residential	No	0.525	15	54	0.1253	0.28	41.7	0.16	0.306	2.29	33.0	0.06	0.46	6.66	No
1	Institutional	No	0.818	40	89	0.4527	1.58	0.0	1.58	0.339	1.98	69.7	0.66	3.86	135.77	No
1	Medium Density Residential	No	0.041	15	54	0.1253	0.02	0.0	0.02	0.306	2.29	33.0	0.01	0.06	0.89	No
2	Low Density Residential	No	0.001	5	51	0.0457	0.00	0.0	0.00	0.177	1.77	20.4	0.00	0.00	0.01	Yes
2	Low Density Residential	No	0.000	5	79	0.1525	0.00	0.0	0.00	0.177	1.77	20.4	0.00	0.00	0.00	Yes
2	Institutional	No	2.484	40	89	0.4527	4.80	0.0	4.80	0.339	1.98	69.7	2.01	11.72	412.52	Yes
4	Medium Density Residential	No	1.091	15	54	0.1253	0.58	41.7	0.34	0.306	2.29	33.0	0.13	0.96	13.84	No
4	Low Density Residential	No	0.000	5	51	0.0457	0.00	41.7	0.00	0.177	1.77	20.4	0.00	0.00	0.00	No
4	Medium Density Residential	No	1.373	15	54	0.1253	0.73	41.7	0.43	0.306	2.29	33.0	0.16	1.21	17.42	No
5	Medium Density Residential	No	6.803	15	54	0.1253	3.64	41.7	2.12	0.306	2.29	33.0	0.80	5.99	86.32	No
5	Medium Density Residential	No	0.845	15	54	0.1253	0.45	41.7	0.26	0.306	2.29	33.0	0.10	0.74	10.73	No
6	Medium Density Residential	No	9.852	15	54	0.1253	5.27	41.7	3.07	0.306	2.29	33.0	1.16	8.68	125.02	No
6	Medium Density Residential	No	0.301	15	54	0.1253	0.16	41.7	0.09	0.306	2.29	33.0	0.04	0.27	3.82	No
7	Medium Density Residential	No	7.883	15	54	0.1253	4.21	41.7	2.46	0.306	2.29	33.0	0.93	6.94	100.03	No
8	Low Density Residential	No	0.574	5	51	0.0457	0.11	41.7	0.07	0.177	1.77	20.4	0.01	0.14	1.64	No
8	Medium Density Residential	No	5.530	15	54	0.1253	2.96	41.7	1.72	0.306	2.29	33.0	0.65	4.87	70.18	No
8	Low Density Residential	No	0.593	5	79	0.1525	0.39	41.7	0.23	0.177	1.77	20.4	0.05	0.49	5.67	No
8	Low Density Residential	No	2.838	5	51	0.0457	0.55	41.7	0.32	0.177	1.77	20.4	0.07	0.70	8.12	No
8	Medium Density Residential	No	0.310	15	54	0.1253	0.17	41.7	0.10	0.306	2.29	33.0	0.04	0.27	3.94	No
9	Medium Density Residential	No	0.039	15	54	0.1253	0.02	41.7	0.01	0.306	2.29	33.0	0.00	0.03	0.49	Yes
9	Medium Density Residential	No	1.483	15	54	0.1253	0.79	41.7	0.46	0.306	2.29	33.0	0.17	1.31	18.82	Yes
10	Medium Density Residential	No	0.421	15	54	0.1253	0.22	41.7	0.13	0.306	2.29	33.0	0.05	0.37	5.34	Yes
11	Medium Density Residential	No	0.070	15	54	0.1253	0.04	41.7	0.02	0.306	2.29	33.0	0.01	0.06	0.89	Yes
11	Medium Density Residential	No	1.352	15	54	0.1253	0.72	41.7	0.42	0.306	2.29	33.0	0.16	1.19	17.15	Yes
12	Low Density Residential	No	0.009	5	51	0.0457	0.00	41.7	0.00	0.177	1.77	20.4	0.00	0.00	0.03	Yes
12	Medium Density Residential	No	0.386	15	54	0.1253	0.21	41.7	0.12	0.306	2.29	33.0	0.05	0.34	4.90	Yes
Total							33.85		22.41				8.6	60.5	1,191.5	

APPENDIX F

SEEPAGE METER DATA

NOVEMBER 2015 THROUGH OCTOBER 2016

Characteristics of Seepage Meters Collected in Lake Gem Mary from November 2015 through October 2016

Sample Site		XHB62 SEEP 1	XHB62 SEEP 2	XHB62 SEEP 3	XHB62 SEEP 4	XHB62 SEEP 5	XHB62 SEEP 6	XHB62 SEEP 7	XHB62 SEEP 8	XHB62 SEEP 9
Specific Conductance	Min	160	150	24	140	160	140	170	160	160
	Max	230	160	200	160	190	220	240	200	260
	Median	180	155	190	155	165	140	185	160	210
	Mean	187.5	155	152.8	152.5	170.0	166.7	195	172	210
	GeoMean	185.7	154.9	122.6	152.3	169.6	162.8	193.3	171.3	206.0
Alkalinity	Min	17	1.7	18	22	29	11	27	33	27
	Max	65	35	32	31	48	58	86	53	72
	Median	40	18.35	28	29	39.5	16	50	42.5	48
	Mean	40.5	18.35	26.4	27.75	39.0	28.3	53.25	42.75	48.8
	GeoMean	35.8	7.7	25.9	27.5	38.4	21.7	49.1	42.0	44.1
NOx	Min	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	Max	0.58	0.92	0.03	2.90	0.03	0.65	0.21	0.69	0.93
	Median	0.23	0.43	0.02	0.03	0.01	0.01	0.02	0.01	0.01
	Mean	0.26	0.45	0.02	0.85	0.02	0.22	0.07	0.15	0.32
	GeoMean	0.08	0.16	0.01	0.12	0.02	0.04	0.03	0.03	0.05
Nitrogen, Kjeldahl	Min	0.85	0.75	1	1	0.47	0.59	1.3	0.98	1.1
	Max	2.5	0.76	2.5	2.5	0.89	3.4	4.1	1.7	5.4
	Median	1.265	0.76	1.6	1.7	0.73	2.2	1.3	1.4	2.8
	Mean	1.47	0.76	1.675	1.86	0.7	2.1	2.0	1.4	3.1
	GeoMean	1.3	0.8	1.6	1.8	0.7	1.6	1.7	1.3	2.6
TN	Min	0.93	0.76	1	1.6	0.47	1.2	1.3	0.98	1.1
	Max	2.5	1.7	2.5	3.9	0.92	3.4	4.3	1.9	5.4
	Median	1.75	1.2	1.6	2.5	0.7	2.2	1.3	1.5	3.7
	Mean	1.7325	1.22	1.675	2.7	0.7	2.27	2.1	1.50	3.4
	GeoMean	1.6	1.2	1.6	2.6	0.7	2.1	1.8	1.5	2.8
TP	Min	0.02	0.04	0.03	0.07	0.02	0.08	0.04	0.05	0.04
	Max	0.15	0.11	0.09	0.22	0.03	0.19	0.11	0.11	0.25
	Median	0.09	0.10	0.07	0.14	0.02	0.10	0.07	0.06	0.19
	Mean	0.08	0.08	0.06	0.15	0.02	0.12	0.07	0.07	0.16
	GeoMean	0.06	0.07	0.06	0.14	0.02	0.11	0.06	0.07	0.12

APPENDIX G

LARGE CORE SAMPLES

NOVEMBER 2015 THROUGH OCTOBER 2016

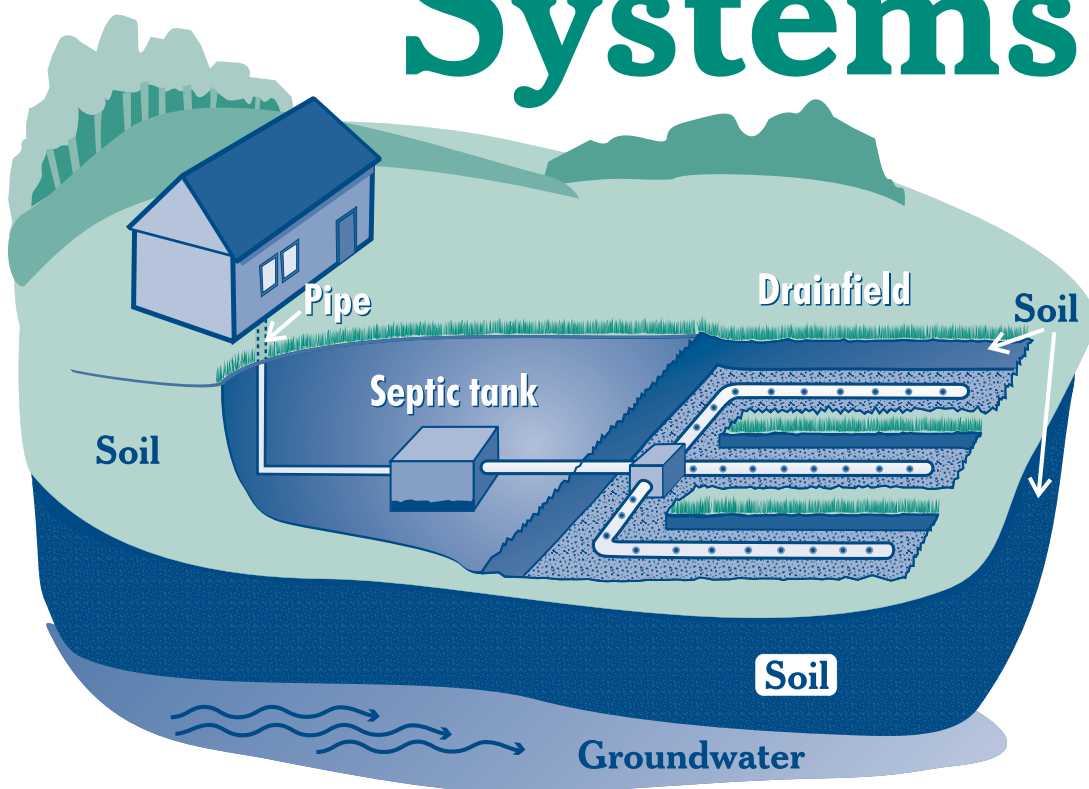
LARGE CORE SAMPLES

Site	Condition	Value Used	Nitrogen (µg/L)			Phosphorus (µg/L)	
			Ammonia	NOx	TN	SRP	TP
Large Core Samples Site 1	Aerobic	Mean	474	597	1645	10	49.75
		Median	538	373	1656	11	55.5
		Geomean	146.66	121.79	1616.37	9.29	43.17
	Anoxic	Mean	196	156	987	6	45.875
		Median	174	94	965	6	40.5
		Geomean	73.79	66.55	976.71	5.58	44.24
Large Core Samples Site 2	Aerobic	Mean	301	712	1574	11	46.8
		Median	106	889	1666	8	50.5
		Geomean	106.31	155.17	1539.64	6.35	41.31
	Anoxic	Mean	275	163	1101	4	45.875
		Median	140	102	1089	3	43.5
		Geomean	101.51	61.46	1089.58	3.11	44.16

APPENDIX H

EPA's "A HOMEOWNER GUIDE TO SEPTIC SYSTEMS"

A Homeowner's Guide to Septic Systems



What's Inside

Your septic system is your responsibility	1
How does it work?	1
Why should I maintain my septic system?	4
How do I maintain my septic system?	5
What can make my system fail?	9
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Your Septic System is your responsibility!

Did you know that as a homeowner you're responsible for maintaining your septic system? Did you know that maintaining your septic system protects your investment in your home? Did you know that you should periodically inspect your system and pump out your septic tank?

If properly designed, constructed and maintained, your septic system can provide long-term, effective treatment of household wastewater. If your septic system isn't maintained, you might need to replace it, costing you thousands of dollars. A malfunctioning system can contaminate groundwater that might be a source of drinking water. And if you sell your home, your septic system must be in good working order.

This guide will help you care for your septic system. It will help you understand how your system works and what steps you can take as a homeowner to ensure your system will work properly. To help you learn more, consult the resources listed at the back of this booklet.

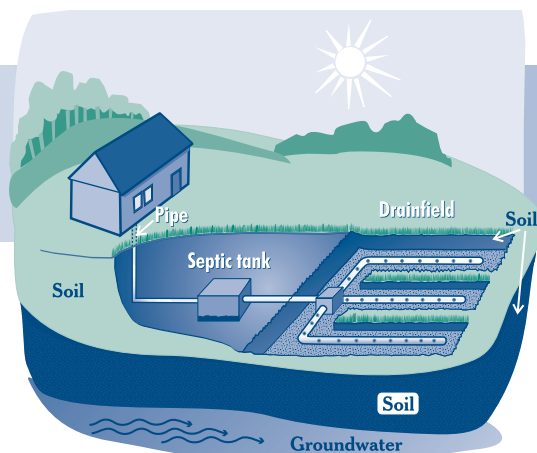
Top Four Things You Can Do to Protect Your Septic System

1. Regularly inspect your system and pump your tank as necessary.
2. Use water efficiently.
3. Don't dispose of household hazardous wastes in sinks or toilets.
4. Care for your drainfield.

How does it work?

Components

A typical septic system has four main components: a pipe from the home, a septic tank, a drainfield, and the soil. Microbes in the soil digest or remove most contaminants from wastewater before it eventually reaches groundwater.



Typical septic system

Septic system aliases:

- On-lot system
- Onsite system
- Individual sewage disposal system
- Onsite sewage disposal system
- Onsite wastewater treatment system

Pipe from the home

All of your household wastewater exits your home through a pipe to the septic tank.

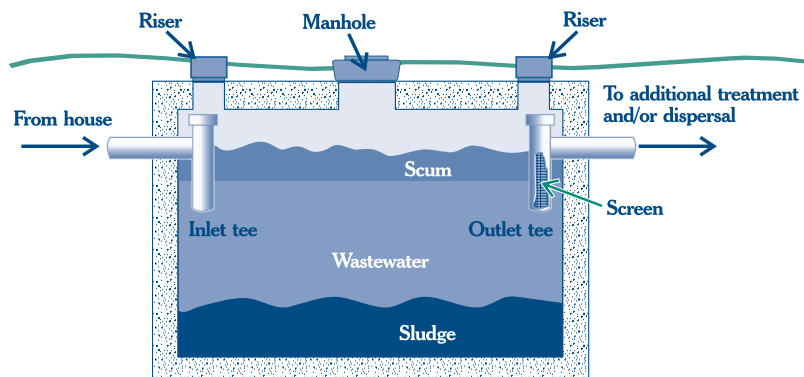
Septic tank

The septic tank is a buried, watertight container typically made of concrete, fiberglass, or polyethylene. It holds the wastewater long enough to allow solids to settle out (forming sludge) and oil and grease to float to the surface (as scum). It also allows partial decomposition of the solid materials. Compartments and a T-shaped outlet in the

septic tank prevent the sludge and scum from leaving the tank and traveling into the drainfield area. Screens are also recommended to keep solids from entering the drainfield.

Newer tanks generally have risers with lids at the ground surface to allow easy location, inspection, and pumping of the tank.

Typical single-compartment septic tank with ground-level inspection risers and screen

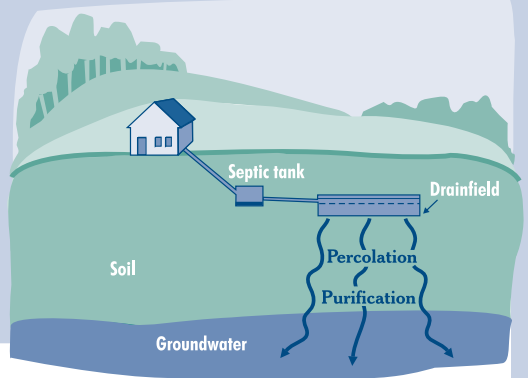


Tip

To prevent buildup, sludge and floating scum need to be removed through periodic pumping of the septic tank. Regular inspections and pumping are the best and cheapest way to keep your septic system in good working order.

Finding Your System

Your septic tank, drainfield, and reserve drainfield should be clearly designated on the “as-built” drawing for your home. (An “as-built” drawing is a line drawing that accurately portrays the buildings on your property and is usually filed in your local land records.) You might also see lids or manhole covers for your septic tank. Older tanks are often hard to find because there are no visible parts. An inspector/pumper can help you locate your septic system if your septic tank has no risers.



Drainfield

The wastewater exits the septic tank and is discharged into the drainfield for further treatment by the soil. The partially treated wastewater is pushed along into the drainfield for further treatment every time new wastewater enters the tank.

If the drainfield is overloaded with too much liquid, it will flood, causing sewage to flow to the ground surface or create backups in plumbing fixtures and prevent treatment of all wastewater.

A reserve drainfield, required by many states, is an area on your property suitable for a new drainfield system if your current drainfield fails. Treat this area with the same care as your septic system.

Soil

Septic tank wastewater flows to the drainfield, where it percolates into the soil, which provides final treatment by removing harmful bacteria, viruses, and nutrients. Suitable soil is necessary for successful wastewater treatment.

Alternative systems

Because many areas don't have soils suitable for typical septic systems, you might have or need an alternative system. You might also have or need an alternative system if there are too many typical septic systems in one area or the systems are too close to groundwater or surface waters. Alternative septic

systems use new technology to improve treatment processes and might need special care and maintenance. Some alternative systems use sand, peat, or plastic media instead of soil to promote wastewater treatment. Other systems might use wetlands, lagoons, aerators, or disinfection devices. Float switches, pumps, and other electrical or mechanical components are often used in alternative systems. Alternative systems should be inspected annually. Check with your local health department or installer for more information on operation and maintenance needs if you have or need an alternative system.

Why should I maintain my septic system?

When septic systems are properly designed, constructed, and maintained, they effectively reduce or eliminate most human health or environmental threats posed by pollutants in household wastewater. However, they require regular maintenance or they can fail. Septic systems need to be monitored to ensure that they work properly throughout their service lives.

Saving money

A key reason to maintain your septic system is to save money! Failing septic systems are expensive to repair or replace, and poor maintenance is often the culprit. Having your septic system inspected regularly is a bargain when you consider the cost of replacing the entire system. Your system will need pumping depending on how many people live in the house and the size of the system. An unusable septic system or one in disrepair will lower your property value and could pose a legal liability.

Protecting health and the environment

Other good reasons for safe treatment of sewage include preventing the spread of infection and disease and protecting water resources. Typical pollutants in household wastewater are nitrogen, phosphorus, and disease-

causing bacteria and viruses. If a septic system is working properly, it will effectively remove most of these pollutants.

With one-fourth of U.S. homes using septic systems, more than 4 billion gallons of wastewater per day is dispersed below the ground's surface. Inadequately treated sewage from septic systems can be a cause of ground-water contamination. It poses a significant threat to drinking water and human health because it can contaminate drinking water wells and cause diseases and infections in people and animals. Improperly treated sewage that contaminates nearby surface waters also increases the chance of swimmers contracting a variety of infectious diseases. These range from eye and ear infections to acute gastrointestinal illness and diseases like hepatitis.

How do I maintain my septic system?

Inspect and pump frequently

You should have a typical septic system inspected at least every 3 years by a professional and your tank pumped as recommended by the inspector (generally every 3 to 5 years). Alternative systems with electrical float switches, pumps, or mechanical components need to be inspected more often, generally once a year. Your service provider should inspect for leaks and look at the scum and sludge layers in your septic tank. If the bottom of the scum layer is within 6 inches of the bottom of the outlet tee or the top of the sludge layer is within 12 inches of the outlet tee, your tank needs to be pumped. Remember to note the sludge and scum levels determined by your service provider in your operation and maintenance records. This information will help you decide how often pumping is necessary.

What Does an Inspection Include?

- Locating the system.
- Uncovering access holes.
- Flushing the toilets.
- Checking for signs of back up.
- Measuring scum and sludge layers.
- Identifying any leaks.
- Inspecting mechanical components.
- Pumping the tank if necessary.

Four major factors influence the frequency of pumping: the number of people in your household, the amount of wastewater generated (based on the number of people in the household and the amount of water used), the volume of solids in the wastewater (for example, using a garbage disposal increases the amount of solids), and septic tank size.

Some makers of septic tank additives claim that their products break down the sludge in septic tanks so the tanks never need to be pumped. Not everyone agrees on the effectiveness of additives. In fact, septic tanks already contain the microbes they need for effective treatment. Periodic pumping is a much better way to ensure that septic systems work properly and provide many years of service. Regardless, every septic tank requires periodic pumping.

In the service report, the pumper should note any repairs completed and whether the tank is in good condition. If the pumper recommends additional repairs he or she can't perform, hire someone to make the repairs as soon as possible.

Use water efficiently

Average indoor water use in the typical single-family home is almost 70 gallons per person per day. Leaky toilets can waste as much as 200 gallons each day. The more water a household conserves, the less water enters the septic system. Efficient water use can improve the operation of the septic system and reduce the risk of failure.

High-efficiency toilets

Toilet use accounts for 25 to 30 percent of household water use. Do you know how many gallons of water your toilet uses to empty the bowl? Most older homes have toilets with 3.5- to 5-gallon reservoirs, while newer high-efficiency toilets use 1.6 gallons of water or less per flush. If you have problems with your septic system being flooded with household water, consider reducing the volume of water in the toilet tank if you don't have a high-efficiency model or replacing your existing toilets with high-efficiency models.



Faucet aerators and high-efficiency showerheads

Faucet aerators help reduce water use and the volume of water entering your septic system. High-efficiency showerheads or shower flow restrictors also reduce water use.

Water fixtures

Check to make sure your toilet's reservoir isn't leaking into the bowl. Add five drops of liquid food coloring to the reservoir before bed. If the dye is in the bowl the next morning, the reservoir is leaking and repairs are needed.

A small drip from a faucet adds many gallons of unnecessary water to your system every day. To see how much a leak adds to your water usage, place a cup under the drip for 10 minutes. Multiply the amount of water in the cup by 144 (the number of minutes in 24 hours, divided by 10). This is the total amount of clean water traveling to your septic system each day from that little leak.



Use Water Efficiently!

- **Install high-efficiency showerheads**
- **Fill the bathtub with only as much water as you need**
- **Turn off faucets while shaving or brushing your teeth**
- **Run the dishwasher and clothes washer only when they're full**
- **Use toilets to flush sanitary waste only (not kitty litter, diapers, or other trash)**
- **Make sure all faucets are completely turned off when not in use**
- **Maintain your plumbing to eliminate leaks**
- **Install aerators in the faucets in your kitchen and bathroom**
- **Replace old dishwashers, toilets, and clothes washers with new, high-efficiency models.**

For more information on water conservation, please visit www.epa.gov/owm/water-efficiency/index.htm

Watch your drains

What goes down the drain can have a major impact on how well your septic system works.

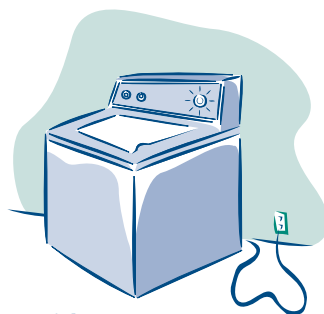
Waste disposal

What shouldn't you flush down your toilet? Dental floss, feminine hygiene products, condoms, diapers, cotton swabs, cigarette butts, coffee grounds, cat litter, paper towels, and other kitchen and bathroom items that can clog and potentially damage septic system components if they become trapped. Flushing household chemicals, gasoline, oil, pesticides, antifreeze, and paint can stress or destroy the biological treatment taking place in the system or might contaminate surface waters and groundwater. If your septic tank pumper is concerned about quickly accumulating scum layers, reduce the flow of floatable materials like fats, oils, and grease into your tank or be prepared to pay for more frequent inspections and pumping.

Washing machines

By selecting the proper load size, you'll reduce water waste. Washing small loads of laundry on the large-load cycle wastes precious water and energy. If you can't select load size, run only full loads of laundry.

Doing all the household laundry in one day might seem like a time-saver, but it could be harmful to your septic system. Doing load after load does not allow your septic tank time to adequately treat wastes. You could be flooding your drainfield without allowing sufficient recovery time. Try to spread water usage throughout the week. A new Energy Star clothes washer uses 35 percent less energy and 50 percent less water than a standard model.



Care for your drainfield

Your drainfield is an important part of your septic system. Here are a few things you should do to maintain it:

- Plant only grass over and near your septic system. Roots from nearby trees or shrubs might clog and damage the drainfield.
- Don't drive or park vehicles on any part of your septic system. Doing so can compact the soil in your drainfield or damage the pipes, tank, or other septic system components.
- Keep roof drains, basement sump pump drains, and other rainwater or surface water drainage systems away from the drainfield. Flooding the drainfield with excessive water slows down or stops treatment processes and can cause plumbing fixtures to back up.

What can make my system fail?

If the amount of wastewater entering the system is more than the system can handle, the wastewater backs up into the house or yard and creates a health hazard.

You can suspect a system failure not only when a foul odor is emitted but also when partially treated wastewater flows up to the ground surface. By the time you can smell or see a problem, however, the damage might already be done.

By limiting your water use, you can reduce the amount of wastewater your system must treat. When you have your system inspected and pumped as needed, you reduce the chance of system failure.

A system installed in unsuitable soils can also fail. Other failure risks include tanks that are inaccessible for maintenance, drainfields that are paved or parked on, and tree roots or defective components that interfere with the treatment process.

Failure symptoms

The most obvious septic system failures are easy to spot. Check for pooling water or muddy soil around your septic system or in your basement. Notice whether your toilet or sink backs up when you flush or do laundry. You might also notice strips of bright green grass over the drainfield. Septic systems also fail when partially treated wastewater comes into contact with

groundwater. This type of failure is not easy to detect, but it can result in the pollution of wells, nearby streams, or other bodies of water. Check with a septic system professional and the local health department if you suspect such a failure.

Stop, look, and smell!

Failure causes

Household toxics

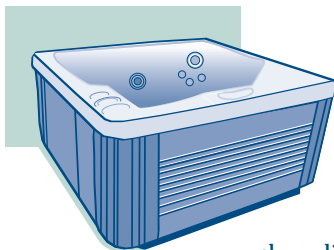
Does someone in your house use the utility sink to clean out paint rollers or flush toxic cleaners? Oil-based paints, solvents, and large volumes of toxic cleaners should not enter your septic system. Even latex paint cleanup waste should be minimized. Squeeze all excess paint and stain from brushes and rollers on several layers of newspaper before rinsing. Leftover paints and wood stains should be taken to your local household hazardous waste collection center. Remember that your septic system contains a living collection of organisms that digest and treat waste.

Household cleaners

For the most part, your septic system's bacteria should recover quickly after small amounts of household cleaning products have entered the system. Of course, some cleaning products are less toxic to your system than others. Labels can help key you into the potential toxicity of various products. The word "Danger" or "Poison" on a label indicates that the product is highly hazardous. "Warning" tells you the product is moderately hazardous. "Caution" means the product is slightly hazardous. ("Nontoxic" and "Septic Safe"



are terms created by advertisers to sell products.) Regardless of the type of product, use it only in the amounts shown on the label instructions and minimize the amount discharged into your septic system.



Hot tubs

Hot tubs are a great way to relax. Unfortunately, your septic system was not designed to handle large quantities of water from your hot tub. Emptying hot tub water into your septic system stirs the solids in the tank and pushes them out into the drainfield, causing it to clog and fail. Draining your hot tub into a septic system or over the drainfield can overload the system. Instead, drain cooled hot tub water onto turf or landscaped areas well away from the septic tank and drainfield, and in accordance with local regulations. Use the same caution when draining your swimming pool.

Water Purification Systems

Some freshwater purification systems, including water softeners, unnecessarily pump water into the septic system. This can contribute hundreds of gallons of water to the septic tank, causing agitation of solids and excess flow to the drainfield. Check with your licensed plumbing professional about alternative routing for such freshwater treatment systems.

Garbage disposals

Eliminating the use of a garbage disposal can reduce the amount of grease and solids entering the septic tank and possibly clogging the drainfield. A garbage disposal grinds up kitchen scraps, suspends them in water, and sends the mixture to the septic tank. Once in the septic tank, some of the materials are broken down by bacterial action, but most of the grindings have to be pumped out of the tank. Using a garbage disposal frequently can significantly increase the accumulation of sludge and scum in your septic tank, resulting in the need for more frequent pumping.

**Not in My
Septic System!**

X Cloggers
diapers, cat litter, cigarette
filters, coffee grounds,
grease, feminine hygiene
products, etc.

X Killers
household chemicals,
gasoline, oil, pesticides,
antifreeze, paint, etc.

Improper design or installation

Some soils provide excellent wastewater treatment; others don't. For this reason, the design of the drainfield of a septic system is based on the results of soil analysis. Homeowners and system designers sometimes underestimate the significance of good soils or believe soils can handle any volume of wastewater applied to them. Many failures can be attributed to having an undersized drainfield or high seasonal groundwater table. Undersized septic tanks—another design failure—allow solids to clog the drainfield and result in system failure.

If a septic tank isn't watertight, water can leak into and out of the system. Usually, water from the environment leaking into the system causes hydraulic overloading, taxing the system beyond its capabilities and causing inadequate treatment and sometimes sewage to flow up to the ground surface. Water leaking out of the septic tank is a significant health hazard because the leaking wastewater has not yet been treated.

Even when systems are properly designed, failures due to poor installation practices can occur. If the drainfield is not properly leveled, wastewater can overload the system. Heavy equipment can damage the drainfield during installation which can lead to soil compaction and reduce the wastewater infiltration rate. And if surface drainage isn't diverted away from the field, it can flow into and saturate the drainfield.

For more information

Local Health Department

EPA Onsite/Decentralized Management Homepage

www.epa.gov/owm/septic

EPA developed this Web site to provide tools for communities investigating and implementing onsite/decentralized management programs. The Web site contains fact sheets, program summaries, case studies, links to design and other manuals, and a list of state health department contacts that can put you in touch with your local health department.

National Small Flows Clearinghouse

www.nesc.wvu.edu

Funded by grants from EPA, the NSFC helps America's small communities and individuals solve their wastewater problems. Its activities include a Web site, online discussion groups, a toll-free assistance line (800-624-8301), informative publications, and a free quarterly newsletter and magazine.

Rural Community Assistance Program

www.rcap.org

RCAP is a resource for community leaders and others looking for technical assistance services and training related to rural drinking water supply and wastewater treatment needs, rural solid waste programs, housing, economic development, comprehensive community assessment and planning, and environmental regulations.

National Onsite Wastewater Recycling Association, Inc.

www.nowra.org

NOWRA is a national professional organization to advance and promote the onsite wastewater industry. The association promotes the need for regular service and educates the public on the need for properly designed and maintained septic systems.

Septic Yellow Pages

www.septicyellowpages.com

The Septic Yellow Pages provides listings by state for professional septic pumpers, installers, inspectors, and tank manufacturers throughout the United States. This Web site is designed to answer simple septic system questions and put homeowners in contact with local septic system professionals.

National Association of Wastewater Transporters

www.nawt.org

NAWT offers a forum for the wastewater industry to exchange ideas and concerns. The NAWT Web site lists state associations and local inspectors and pumpers.



EPA-832-B-02-005
December 2002
Revised March 2005

Additional copies can be obtained from:
U.S. EPA Publications Clearinghouse
P.O. Box 42419
Cincinnati, OH 45241

Telephone: 800-490-9198
Fax: 513-489-8695

Office of Water
U.S. Environmental Protection Agency

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Septic System Dos and Don'ts

(adapted from National Small Flows Clearinghouse)

Dos

- Check with the local regulatory agency or inspector/pumper if you have a garbage disposal unit to make sure that your septic system can handle this additional waste.
- Check with your local health department before using additives. Commercial septic tank additives do not eliminate the need for periodic pumping and can be harmful to the system.
- Use water efficiently to avoid overloading the septic system. Be sure to repair leaky faucets or toilets. Use high-efficiency fixtures.
- Use commercial bathroom cleaners and laundry detergents in moderation. Many people prefer to clean their toilets, sinks, showers, and tubs with a mild detergent or baking soda.
- Check with your local regulatory agency or inspector/pumper before allowing water softener backwash to enter your septic tank.
- Keep records of repairs, pumpings, inspections, permits issued, and other system maintenance activities.
- Learn the location of your septic system. Keep a sketch of it with your maintenance record for service visits.
- Have your septic system inspected and pumped as necessary by a licensed inspector/contractor.
- Plant only grass over and near your septic system. Roots from nearby trees or shrubs might clog and damage the drainfield.

Don'ts

- Your septic system is not a trash can. Don't put dental floss, feminine hygiene products, condoms, diapers, cotton swabs, cigarette butts, coffee grounds, cat litter, paper towels, latex paint, pesticides, or other hazardous chemicals into your system.
- Don't use caustic drain openers for a clogged drain. Instead, use boiling water or a drain snake to open clogs.
- Don't drive or park vehicles on any part of your septic system. Doing so can compact the soil in your drainfield or damage the pipes, tank, or other septic system components.