Performance Efficiency Evaluation of the Booker Lake Alum Stormwater Treatment System

Final Report
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SECTION 1

INTRODUCTION

This document provides a summary of work efforts conducted by Environmental Research & Design, Inc. (ERD) for the City of St. Petersburg (City) to conduct a performance efficiency evaluation of the Booker Lake Alum Stormwater Treatment (ATS) system. This facility was constructed by the City, with cooperative funding from the Florida Department of Environmental Protection (FDEP) through a Section 319(h) Grant to reduce pollutant loadings discharging from the Booker Lake watershed into Tampa Bay.

The Booker Lake ATS facility is designed to reduce pollutant loadings from a watershed of approximately 1,437 acres which consists primarily of residential, commercial, industrial, and transportation land uses, much of which currently have no existing stormwater treatment. The Booker Lake ATS facility injects liquid alum into the incoming stormwater flows, providing significant removals for TSS, heavy metals, nutrients, and bacteria, with the accumulated alum floc retained within Booker Lake. Alum injection was selected for treating inflows into Booker Lake due to the lack of available land for traditional stormwater BMPs, the high removal efficiencies achieved by alum for the target pollutants, and the substantially lower pollutant mass removal costs for alum compared with traditional BMPs.

1.1 Receiving Waters Designation

The ultimate receiving water for discharges from Booker Lake is Tampa Bay which covers more than 400 square miles and is the largest open water estuary within the State of Florida. Tampa Bay has been designated by EPA as an Estuary of National Significance and as a State priority waterbody under the Surface Water Improvement and Management Program (SWIM). The segment of Tampa Bay which receives inflows from Booker Creek is included on the Section 303(d) list of impaired waters. Runoff from urban and residential areas comprises the largest source of nutrients to Tampa Bay, particularly total nitrogen, and accounted for approximately 63% of the total nitrogen loading to Tampa Bay over the period from 1999-2003. The Booker Lake ATS facility is designed to reduce nutrient loading to Tampa Bay and assist in improving the existing impaired conditions.

1.2 Project Description

A general location map for Booker Lake is given on Figure 1-1. Booker Lake is located within the city limits of St. Petersburg on the west side of I-275, approximately 1.8 miles northwest of downtown St. Petersburg, in a densely developed area of residential, commercial, industrial, and transportation land uses. The lake is bordered on the north by 13th Avenue North, on the south by 9th Avenue North, on the west by 25th Street North, and on the east by I-275.

Figure 1-1. General Location Map for Booker Lake.

An aerial overview of Booker Lake is given on Figure 1-2. Booker Lake is approximately 13.0 acres in size and receives largely untreated stormwater runoff from watershed areas located north and west of the lake. Runoff enters Booker Lake through two primarily inflows, identified as the northern channel and western channel on Figure 1-2. Discharges from the lake occur through an outfall structure located on the southeast corner of the lake which passes beneath I-275 and forms the headwaters of Booker Creek which ultimately discharges into Tampa Bay. Park facilities are located north of the lake and an exercise trail was constructed around the perimeter of the lake.

A bathymetric contour map of Booker Lake was developed for the City during 2004 by a private surveying consultant. A copy of the bathymetric contour map for Booker Lake is given on Figure 1-3. The elevation values indicated on Figure 1-3 are based upon the City of St. Petersburg datum. Shoreline areas of the lake exhibit a relatively mild slope, with central portions of the lake exhibiting water depths ranging from approximately 14-17 ft.

A summary of elevation-area-volume relationships for Booker Lake is given in Table 1-1. At the normal water level of 130.4 ft (St. Petersburg datum), Booker Lake has a surface area of approximately 13.02 acres and a water volume of 146.4 ac-ft. The mean depth in Booker Lake, calculated by dividing the lake volume by the surface area, is approximately 11.2 ft. This value is typical of waterbody depths commonly observed in southwest Florida.

Figure 1-2. Overview of Booker Lake.

TABLE 1-1

ELEVATION-AREA-VOLUME RELATIONSHIPS FOR BOOKER LAKE

ELEVATION (ft)	AREA (acres)	VOLUME (ac-ft)	ELEVATION (ft)	AREA (acres)	VOLUME (ac-ft)
130.4	13.02	146.4	121	7.93	38.5
130	13.02	133.4	120	7.35	30.9
129	12.63	120.5	119	6.75	23.8
128	12.17	108.1	118	6.13	17.4
127	11.46	96.3	117	5.45	11.6
126	10.80	85.2	116	4.56	6.61
125	10.16	74.7	115	3.02	2.82
124	9.57	64.8	114	1.31	0.66
123	9.05	55.5	113	0.00	0.0
122	8.51	46.8			

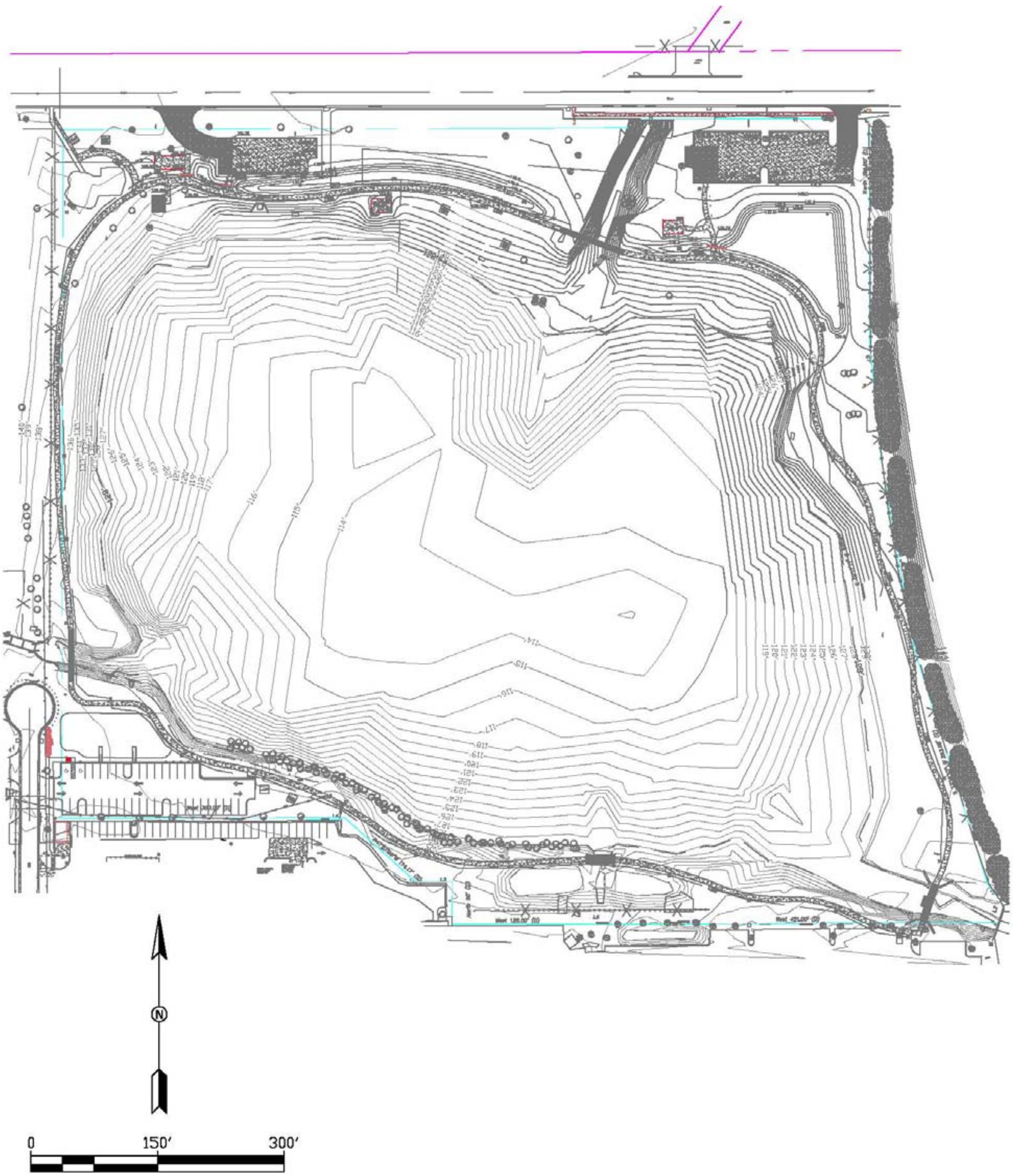


Figure 1-3. Bathymetric Contour Map for Booker Lake.
(Elevations based on City of St. Petersburg datum).

1.3 Watershed Characteristics

An overview of watershed areas discharging to Booker Lake is given on Figure 1-4, based upon information provided to ERD by the City. Watershed areas for the lake extend primarily north and west of Booker Lake. A tabular summary of sub-basin areas discharging to Booker Lake is given on Table 1-2. Watershed sizes range from 22.22-283.54 acres, with a total combined watershed area of 1437.3 acres.

TABLE 1-2

SUMMARY OF SUB-BASINS DISCHARGING TO BOOKER LAKE

BASIN	AREA (acres)
B-1	142.59
B-2	189.57
B-3	86.54
B-4	22.22
B-5	104.15
B-6	174.09
B-6A	74.60
B-7	117.91
B-8	150.61
B-9	91.43
B-10	283.54
Total:	**1437.25**

Runoff generated within the watershed areas discharges into Booker Lake through either the northern or western channels (depicted on Figure 1-2). The primary piping systems for the western and northern channels are interconnected in multiple places, and it is difficult to define the specific basin areas which discharge to either of the inflows for a given rain event. Each of the two channels maintains a relatively constant baseflow component which exists throughout much of the year. This inflow volume is in addition to the volume of runoff estimated through modeling techniques.

An overview of current land use in the Booker Lake drainage basin is given in Figure 1-5, with a tabular summary provided in Table 1-3. The largest land use within the Booker Lake basin is high-density residential which covers 55.3% of the basin area. Approximately 15.8% of the basin is industrial, with 14.6% in commercial activities and services and 4.7% in transportation. Each of the remaining land use categories occupies approximately 3% or less each of the drainage basin area.

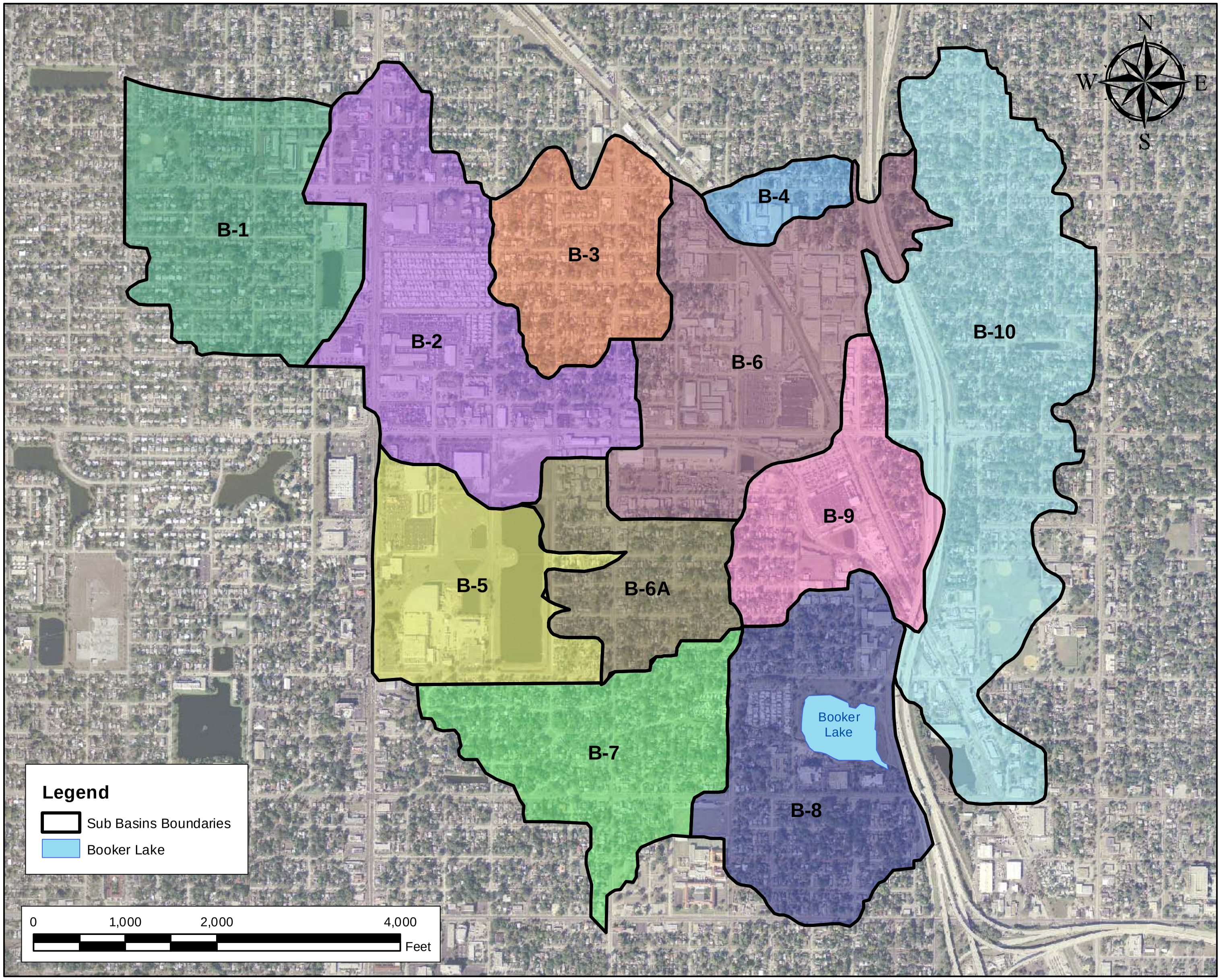


Figure 1-4. Watershed Areas Discharging to Booker Lake.

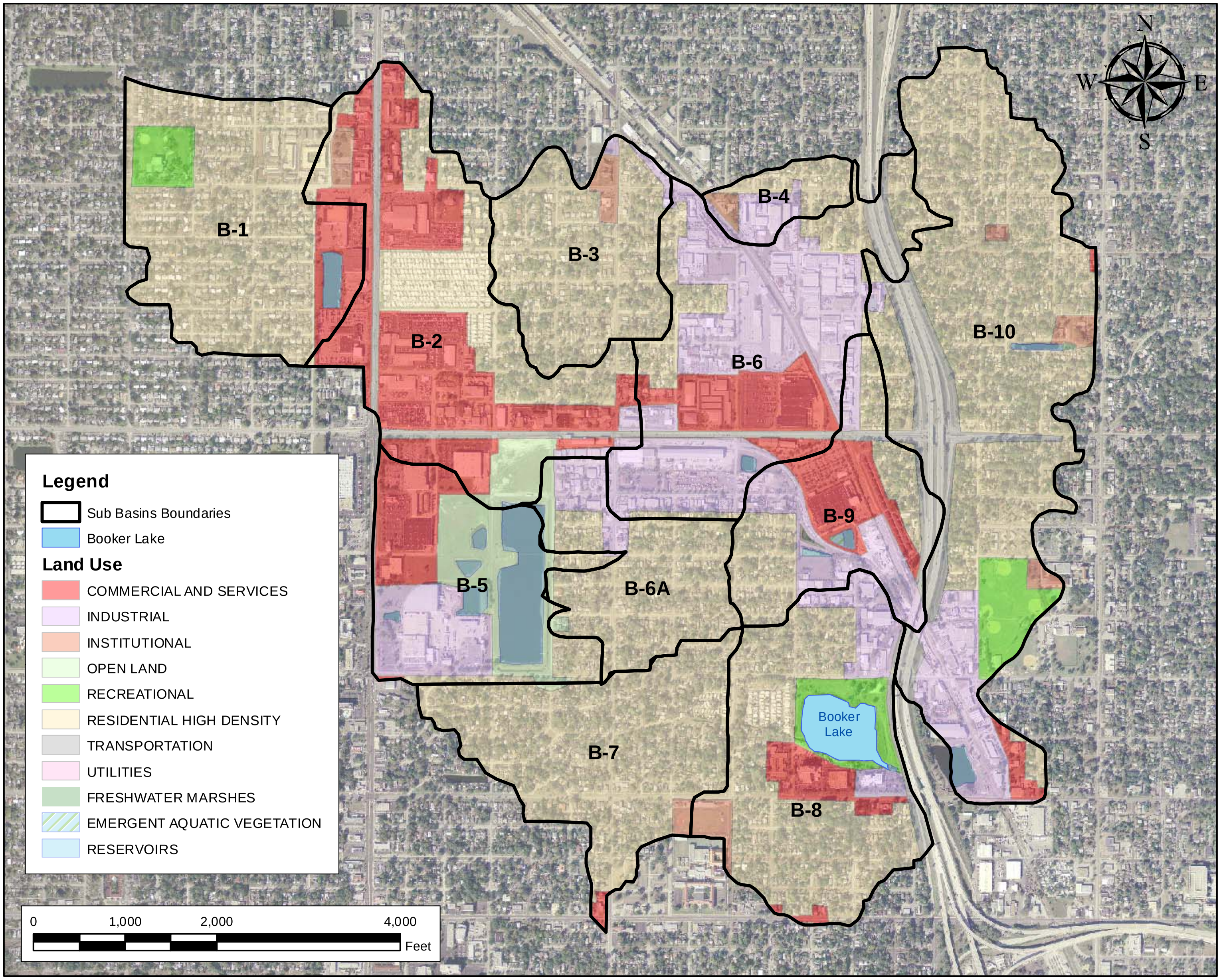


Figure 1-5. Land Use in the Booker Lake Drainage Basin.

TABLE 1-3

CURRENT LAND USE CHARACTERISTICS IN THE BOOKER LAKE DRAINAGE BASIN

LAND USE	AREA (acres)	PERCENT OF TOTAL (%)
High-Density Residential	794.51	55.3
Commercial and Services	209.30	14.6
Industrial	227.58	15.8
Institutional	22.89	1.6
Recreational	37.18	2.6
Open Land	36.38	2.5
Reservoirs	40.28	2.8
Freshwater Marshes	0.21	< 0.1
Emergent Aquatic Vegetation	0.35	< 0.1
Transportation	67.12	4.7
Utilities	0.99	0.1
Total:	**1437.25**	**100.0**

An overview of hydrologic soil groups (HSG) in the Booker Lake drainage basin is given on Figure 1-6, with a tabular summary provided in Table 1-4. Approximately 82.5% of the basin area is covered with soils classified in HSG D which reflect fine sands with a low potential for infiltration and high rate of runoff. Approximately 15.2% of the basin area is covered by soils in HSG C which reflect a moderate infiltration rate and a moderate to high degree of runoff. In general, soils within the Booker Lake drainage basin are characterized by low infiltration rates and high runoff potentials.

TABLE 1-4

HYDROLOGIC SOIL GROUPS IN THE BOOKER LAKE DRAINAGE BASIN

HSG TYPE	AREA (acres)	PERCENT OF TOTAL (%)
B/D	6.47	0.5
C	218.80	15.2
D	1186.02	82.5
W	25.96	1.8
Total:	**1437.25**	**100.0**

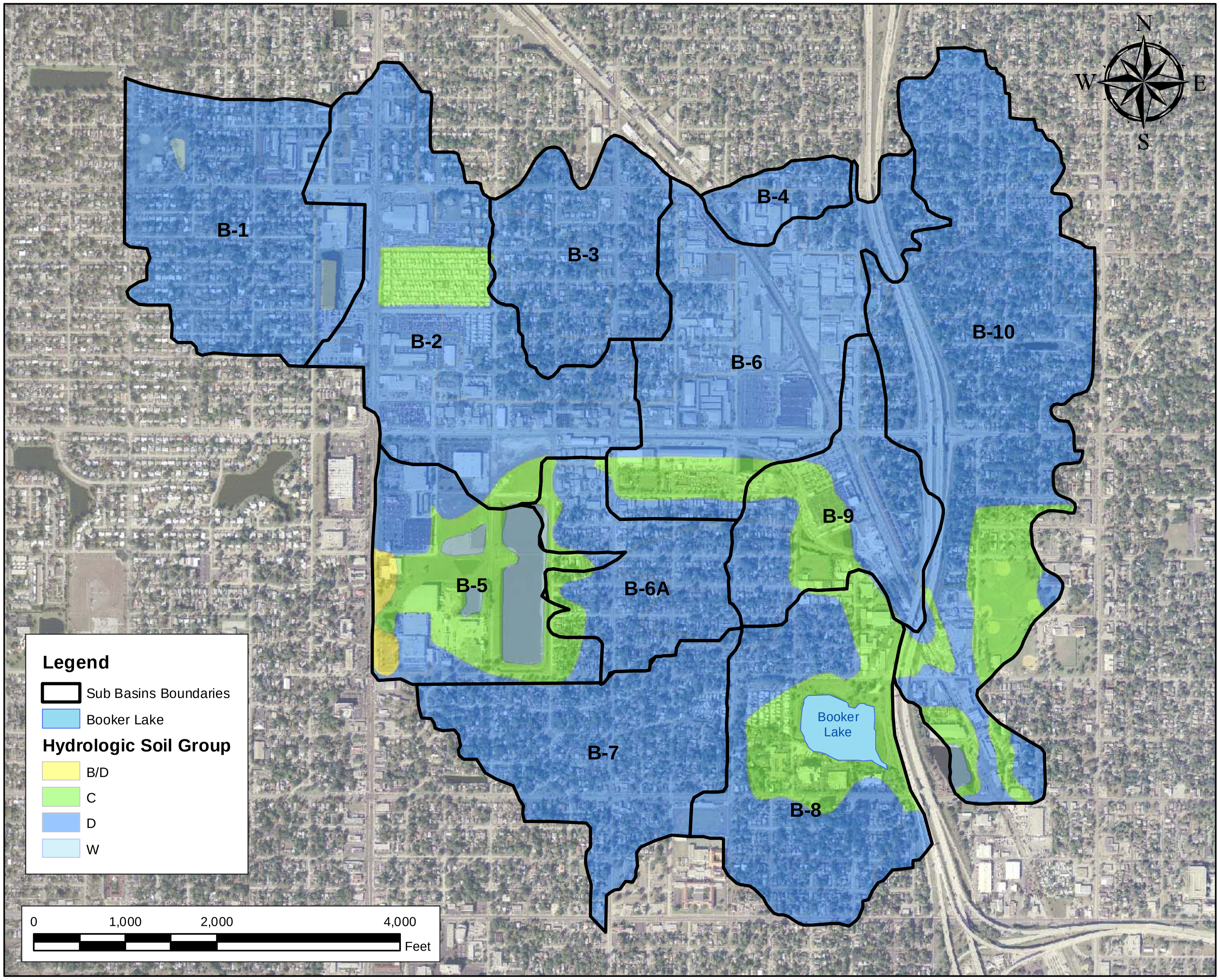


Figure 1-6. Hydrologic Soil Groups in the Booker Lake Drainage Basin.

A SWMM model (Version 4.4) of the Booker Lake watershed, originally developed by PBS&J, was provided to ERD by the City for use with this project. This model was used by ERD to simulate inflows through the northern and western channel into Booker Lake during a wide range of rain events which were then used to estimate annual inflows into the lake through each of the two channels. A summary of the results of the SWMM modeling is given in Table 1-5. On an average annual basis, the northern inflow channel contributes approximately 272.2 ac-ft of runoff each year to Booker Lake, with 377.5 ac-ft/yr contributed by the western channel. Overall, the western channel contributes approximately 58% of the annual inflows to Booker Lake, with 42% contributed by the northern channel. Approximately 649.7 ac-ft/yr of runoff is discharged to Booker Lake from the two inflows. These values do not include baseflows which occur throughout much of the year.

TABLE 1-5

SUMMARY OF ANNUAL SWMM MODEL INFLOWS TO BOOKER LAKE

CHANNEL	AVERAGE ANNUAL INFLOW (ac-ft/yr)	PERCENT OF TOTAL (%)
Northern	272.2	42
Western	377.5	58
Total:	**649.7**	**100**

Baseflow inputs into Booker Lake from the northern inflow channel originate primarily as a result of gradual bleed-down of stormwater detention basins and depressional areas throughout the basin, along with groundwater infiltration into the extensive stormsewer system. Baseflow inputs into Booker Lake through the western channel are also contributed by bleed-down of stormwater management systems and groundwater inflow into the stormsewer system. However, significant baseflows also originate within the western channel as a result of the periodic pumped drawdown of Lake Emerald which is a 16.5-acre waterbody located northwest of Booker Lake. Excess water in Lake Emerald is pumped into the western inflow for Booker Lake and provides the single largest baseflow component for the western channel. However, the annual quantity of water which is pumped from Lake Emerald to Booker Lake is not known. Therefore, in addition to the 649.7 ac-ft/yr of runoff which discharges to Booker Lake, an additional unknown quantity of baseflow also discharges to the lake.

1.4 Characteristics of Inflows to Booker Lake

A field stormwater monitoring program was conducted by ERD in the Booker Lake watershed from July-October 2005 to quantify the characteristics of raw stormwater runoff discharging into Booker Lake and to collect composite runoff samples for use in laboratory jar testing using alum. Stormwater monitoring was conducted in the two primary inflows into Booker Lake, referred to previously as the northern and western channels, upstream from the point of inflow to Booker Lake, using Sigma Model 900 automatic sequential stormwater collectors with integral flow meters. Three composite runoff and four composite baseflow samples were collected at the northern channel inflow, with four composite stormwater and three composite baseflow samples collected at the western channel inflow. The collected samples were analyzed in the ERD Laboratory for general parameters, nutrients, and microbiological parameters, and jar testing was conducted to evaluate responses to various alum doses. A complete listing of the results of the stormwater and baseflow monitoring efforts and the laboratory jar testing is given in Appendix A.

A summary of mean chemical characteristics of stormwater and baseflow samples collected at the northern and western inflow channel from July-October 2005 is given in Table 1-6. Both stormwater and baseflow samples were approximately neutral in pH and moderately to well buffered, based upon measured alkalinity values. Runoff entering Booker Lake through the 13^{th} Avenue location (northern channel), was found to contain elevated levels of nitrates, total nitrogen, total phosphorus, TSS, and extremely elevated levels of fecal coliform bacteria. Baseflow collected in the northern inflow channel contained substantially lower concentrations for virtually all of the measured parameters, although nitrate concentrations in the baseflow were still relatively elevated in value.

Runoff entering Booker Lake through the western inflow channel contained more moderate concentrations of virtually all of the measured parameters, compared with the northern inflow channel. Baseflow discharges through the western channel contained relatively elevated levels of both nitrate and total nitrogen, with relatively modest concentrations for each of the remaining measured parameters.

1.5 Work Efforts Performed by ERD

A Quality Assurance Project Plan (QAPP) was developed by ERD during April 2005 which provides details concerning the proposed field monitoring and laboratory analyses. The QAPP was reviewed and approved by FDEP. Pre-construction field monitoring was conducted in Booker Lake by ERD from July 2005-June 2006. Construction of the ATS facility was completed during June 2011, and post-treatment monitoring was conducted from November 2011-October 2012.

This report has been divided into five separate sections to summarize the work efforts conducted by ERD. Section 1 contains an introduction to the report and a brief summary of work efforts performed by ERD. A description of the Booker Lake ATS facility is given in Section 2. Section 3 provides a detailed discussion of the methodologies used for field and laboratory evaluations. Section 4 includes a discussion of the water quality monitoring results, with a summary provided in Section 5. Appendices are attached which contain data and supporting documentation for the results and conclusions of this project.

TABLE 1-6

CHARACTERISTICS OF PRE-TREATMENT STORMWATER AND BASEFLOW ENTERING BOOKER LAKE

PARAMETER	UNITS	13th AVENUE (Northern Inflow Channel)		24th STREET (Western Inflow Channel)	
		Stormwater	Baseflow	Stormwater	Baseflow
pH	s.u.	7.71	7.59	7.68	7.25
Conductivity	µmho/cm	260	375	204	284
Alkalinity	mg/l	106	155	80	108
Ammonia	µg/l	276	97	173	261
Nitrates	µg/l	973	671	424	677
Diss. Organic N	µg/l	142	351	176	151
Particulate N	µg/l	337	84	224	341
Total N	µg/l	1,727	1,203	996	1,430
SRP	µg/l	136	11	51	18
Diss. Organic P	µg/l	89	6	17	18
Particulate P	µg/l	163	13	148	54
Total P	µg/l	388	28	216	91
Turbidity	NTU	29.0	1.8	11.0	1.8
TSS	mg/l	54.8	3.1	17.7	1.8
BOD	mg/l	3.4	2.9	3.3	2.9
Color	Pt-Co	35	34	18	21
Diss. Al	µg/l	54	65	59	39
Fecal Coliform	cfu/100 ml	18,877	45	874	374

1.6 <u>Project Costs and Funding</u>

Funding for the Booker Lake alum treatment system was provided jointly by the City of St. Petersburg and FDEP. A summary of funding amounts and sources for the Booker Lake ATS is given on Table 1-7. The overall total cost of the project was approximately $1,060,000, with $424,000 (40%) contributed by the City and $636,000 (60%) contributed by FDEP through 319(h) funding. Funds contributed by the City included the survey of the project site, engineering design, project management, grant administration, water quality monitoring, the educational component of the system, and a portion of the construction costs. Funds contributed by FDEP were used exclusively for construction of the system. All but $4,000 of the funds contributed by the City was paid for through the St. Petersburg Stormwater Utility.

TABLE 1-7

FUNDING AMOUNTS AND SOURCES FOR THE BOOKER LAKE ATS FACILITY (SOURCE: DEP Agreement No. G0135)

TASK	319(h) FUNDS ($)	NON-FEDERAL MATCH FUNDS* ($)
1. Survey Project Site	0	35,000 (SP SU)
2. Engineering Design	0	240,000 (SP SU)
3. Prepare, Send, Receive, Evaluate, and Award Construction Bid	0	4,000 (Gen Rev)
4. Construction of Stormwater Facilities	636,000	90,000 (SP SU)
5. Post-Award Grant Administration	0	15,000 (SP SU)
6. Water Quality Monitoring Program	0	30,000 (SP SU)
7. Education Component	0	10,000 (SP SU)
Total:	**$ 636,000 (60%)**	**$ 424,000 (40%)**
TOTAL PROJECTED COST:	**$ 1,060,000**	

*SP SU: St. Petersburg Stormwater Utility
Gen Rev: St. Petersburg General Revenue Funds

SECTION 2

BOOKER LAKE ATS SYSTEM

This section provides a description of the Booker Lake ATS design and operational characteristics. Details of the facility are discussed in the following sections.

2.1 Process Chemistry of Alum

Alum is produced by dissolving aluminum ore in sulfuric acid and water. The most common aluminum sources used for production of alum are chemical grade bauxite, high aluminum clays, and aluminum trihydrate. Bauxite and bauxitic clays are used to produce the standard grade alum most commonly used for coagulation. The purity of alum will vary with aluminum and acid sources used in the production process. However, bauxite and bauxitic clays are low in metal contaminants, and alum solutions are typically low in virtually all heavy metals. Aluminum chloride is generated in a similar manner by dissolving aluminum ore in hydrochloric acid.

When aluminum sulfate is added to water, aluminum hydrous oxides are precipitated according to the following stoichiometric coagulation reaction:

$$Al_2(SO_4)_3 + 18H_2O + 3Ca(HCO_3)_2 = Al(OH)_{3(s)} + 3CaSO_4 + 6CO_{2(g)} + 18H_2O$$

In this reaction, calcium carbonate is used to represent the alkalinity needed to form $Al(OH)_{3(s)}$. According to this relationship, 1 mg/l of alum requires 0.45 mg/l of alkalinity as $CaCO_3$ and releases 0.9 mg/l of $CO_{2(g)}$ as $CaCO_3$. The alum coagulation reaction is frequently abbreviated to include just significant products and reactants.

The addition of alum to water results in the production of chemical precipitates which remove pollutants by two primary mechanisms. Removal of suspended solids, algae, phosphorus, heavy metals and bacteria occurs primarily by enmeshment and adsorption onto aluminum hydroxide precipitate according to the following net reaction:

$$Al^{+3} + 6H_2O = Al(OH)_{3(s)} + 3H_3O^+$$

Removal of additional dissolved phosphorus occurs as a result of direct formation of $AlPO_4$ by:

$$Al^{+3} + HnPO_4^{n-3} = AlPO_{4(s)} + nH^+$$

The aluminum hydroxide precipitate, $Al(OH)_3$, is a gelatinous floc which attracts and adsorbs colloidal particles onto the growing floc, thus clarifying the water. Phosphorus removal or entrapment can occur by several mechanisms, depending on the solution pH. Inorganic phosphorus is also effectively removed by adsorption to the $Al(OH)_3$ floc. Removal of particulate phosphorus is most effective in the pH range of 6-8 where maximum floc occurs (Cooke and Kennedy, 1981). At higher pH values, OH^- begins to compete with phosphate ions for aluminum ions, and aluminum hydroxide-phosphate complexes begin to form. At lower pH values and higher inorganic phosphorus concentrations, the formation of aluminum phosphate ($AlPO_4$) is favored.

ERD pioneered the concept of using chemical coagulants for treatment of stormwater and tributary inflows during the mid-1980s. Alum stormwater treatment systems provide a cost-effective and highly efficient method for treatment of stormwater runoff in an urban setting. Currently, there are more than 60 operational alum stormwater treatment systems within the State of Florida.

2.2 Description of the ATS Design

An overview of main components of the Booker Lake Regional ATS Facility is given on Figure 2-1. Controls and pumps for the ATS facility are located in a concrete block structure on the east side of the lake adjacent to I-275. An overview of the control building is given on Figure 2-2. The building contains two separate rooms, with one room used to house the pumps and electronic controls, and the second room used to house the 8,000-gallon FRP alum storage tank.

Ultrasonic flow measurement devices were installed in both the northern and western inflow channels, upstream from the point of discharge into Booker Lake. These flow meters generate estimates of discharge from the inflow channels based upon depth of water using the Manning Equation and provide a continuous measurement of discharges through each of the two inflow channels under both storm and baseflow conditions. The flow meters generate 4-20 mA signals which are transmitted back to the building by telemetry and are used to pace the chemical feed pumps to inject liquid alum at a constant dose of 7.5 mg Al/liter, regardless of the rate of the incoming runoff or baseflow. The alum is transported to each of the two points of injection using a water carrier pump. Water is pumped from Booker Lake, and alum is injected into the carrier flow which assists in the preliminary mixing of the alum with water. The alum/water mixture is then injected into each of the two inflow channels. Photographs of the injection of the alum/water mixture into the two inflow channels are given on Figure 2-3.

An overview of control panels for the ATS facility is given on Figure 2-4. Separate control panels are provided for each of the two chemical metering pumps and the individual flow sensors. Operation of the system is controlled by a Programmable Logic Controller (PLC) which controls and coordinates all system components, including operation of the chemical metering pumps, carrier pump, and system operational status. The PLC allows a wide degree of control over system start-up, operation, and shut-down. The PLC stores all operational data for the system, including stormwater inflow rates and volumes, alum use, and system status.

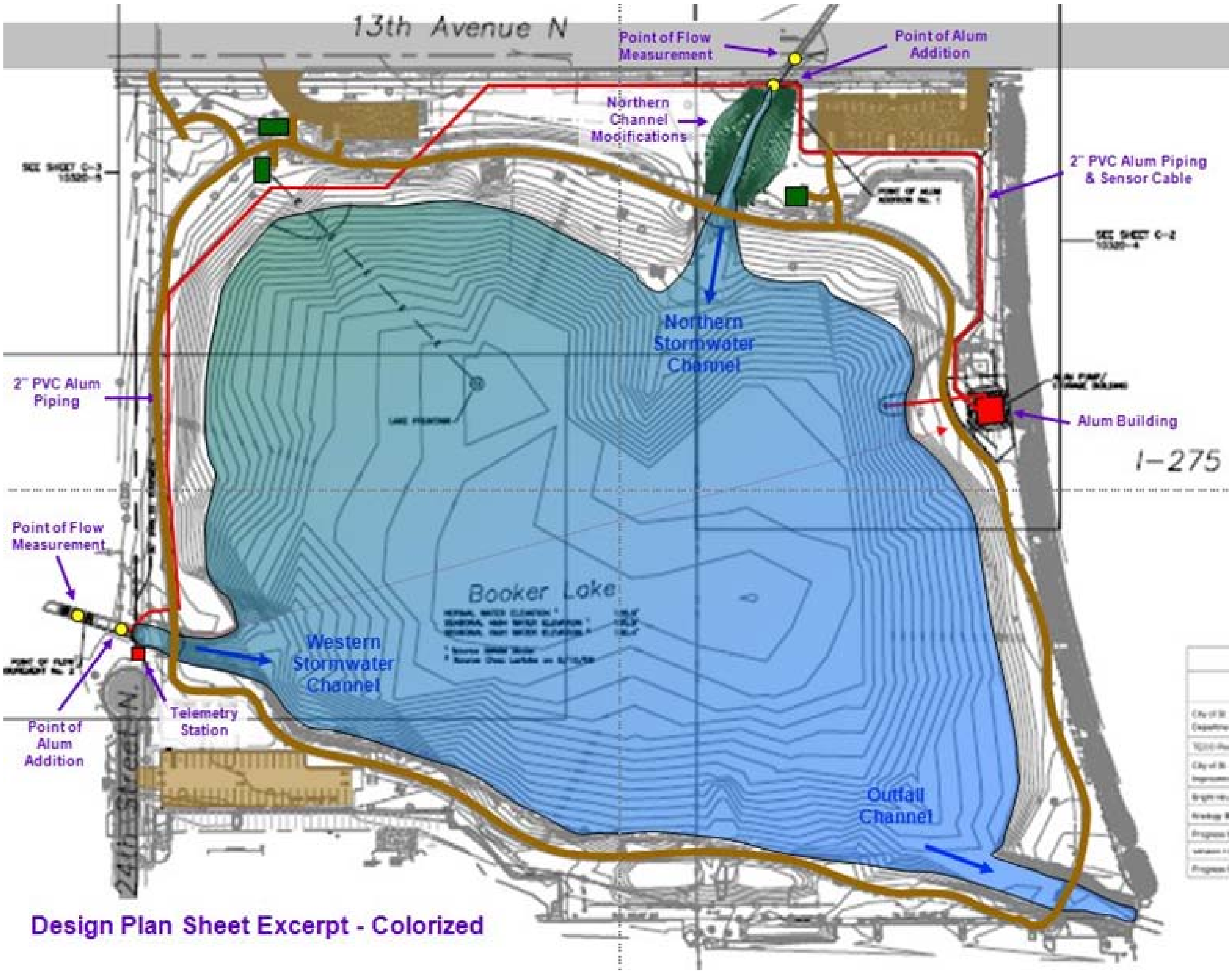


Figure 2-1. Major Components of the Booker Lake Regional ATS Facility.

Figure 2-2. Control Building.

Western Channel

Northern Channel

Figure 2-3. Discharges of Alum/Water Mixture at the Two Injection Points.

Figure 2-4.   Overview of Alum System Control Panels.

Figure 2-5.   Overview of Alum System Pumping and Piping.

An overview of alum system pumping and piping is given on Figure 2-5. The system has two progressive cavity pumps which introduce alum in a flow proportioned manner into the carrier feeds for each of the two inflows. The piping system includes backpressure valves and magnetic meters for accurately measuring the volume of alum which has been dispensed. The system also contains a calibration chamber to calibrate the alum flow meters and pumping rates. A photograph of the alum pump calibration chamber is given on Figure 2-6.

Figure 2-6. Alum Pump Calibration Chamber.

A SWMM model was provided to ERD by the City for use in estimating inflows to Booker Lake through the western and northern inflow channels on an average annual basis. The alum treatment system is capable of providing full alum treatment for inflows up to 100 cfs in each of the two channels. Modeling was conducted using the SWMM model to estimate the average annual stormwater volume which would be treated if the first 100 cfs of typical storm events receive full alum addition. The SWMM model indicated that the proposed ATS facility would be capable of treating up to 98.5% of the runoff generated annual inflows to Booker Lake through the northern and western inflow channels, or approximately 640 ac-ft/yr. Based upon the alum addition rate of 7.5 mg Al/liter determined through laboratory jar testing of collected stormwater and baseflow samples, the Booker Lake ATS facility will require approximately 26,697 gallons of liquid alum on an average annual basis to provide treatment for 640 ac-ft/yr of runoff.

The estimated annual alum volume does not include treatment of additional inflows from baseflow in the two channels. In an effort to reduce annual alum usage, the treatment system is set-up to largely ignore low discharge baseflow inputs to Booker Lake, including most of the pumped inflows from Lake Kenwood, although higher level baseflow discharges may be treated at times. Baseflow in the northern channel is ignored by programming the system to activate only when discharges exceed a pre-determined, but adjustable, flow rate assumed to represent baseflow conditions. Baseflow through the western channel is highly variable, and can reach fairly large flow rates when pumping from Lake Emerald is occurring. Baseflow through this inflow is ignored by programming the western channel to inject alum only when the northern channel is injecting which indicates storm event conditions.

Alum floc generated as a result of treatment of stormwater and baseflow accumulates within the sediments of Booker Lake. Portions of Booker Lake below elevation 120.0 ft are designated as floc storage areas. As indicated on Table 1-1, the volume of Booker Lake below elevation 120.0 is approximately 30.9 ac-ft. When the floc accumulation reaches this level, the floc will be removed using a manually operated portable dredge unit designed to operate at a relatively low flow rate of 300-400 gpm. Once the floc is dredged, it will be disposed of by addition to the sanitary sewer system or processed using a rapid dewatering system with the dewatered solids trucked off-site for disposal.

Relationships between alum floc production and alum treatment dose have been developed by Harper (1990) based upon alum treatment of stormwater and baseflow with a wide variety of chemical characteristics. At a dose of 7.5 mg Al/liter, the alum floc production rate is approximately 0.2% of the treated stormwater runoff flow. Using this value, the estimated annual floc volume generated as a result of treating inflows through the northern and western channels is approximately 1.3 ac-ft/yr. Therefore, approximately 23.8 years of storage is available within Booker Lake below elevation 120 for storage of alum floc.

2.3 Effectiveness of Alum for Reducing Runoff and Baseflow Loadings

Once alum has been identified as an option in a stormwater management or retrofit project, extensive laboratory testing must be performed to verify the feasibility of alum treatment and to establish process design parameters. The feasibility of alum treatment for a particular stormwater stream is typically evaluated in a series of laboratory jar tests conducted on representative runoff samples collected from the project watershed area. This laboratory testing is an essential part of the evaluation process necessary to determine design, maintenance, and operational parameters such as the optimum coagulant dose required to achieve the desired water quality goals, chemical pumping rates and pump sizes, the need for additional chemicals to buffer receiving water pH, post-treatment water quality characteristics, floc formation and settling characteristics, floc accumulation, annual chemical costs and storage requirements, ecological effects, and maintenance procedures. In addition to determining the optimum coagulant dose, jar tests can also be used to determine floc strength and stability, required mixing intensity and duration, and establish design criteria for floc settling.

As discussed in Section 1.4, a field monitoring program was conducted by ERD from July-October 2005 to identify the characteristics of stormwater and baseflow inputs into Booker Lake and to collect composite samples of runoff and baseflow for use in laboratory jar tests using alum. A summary of mean removal efficiencies for alum treatment of stormwater and baseflow collected from the northern and western channels of Booker Lake from July-October 2005 is given in Table 2-1. Mean removal efficiencies for total nitrogen in stormwater runoff collected from the two inflow channels ranged from 27-28%, with mean removal efficiencies for total phosphorus ranging from 82-98%, and 80-96% removal for TSS.

Laboratory removal efficiencies for baseflow samples collected from the northern and western inflow channels were somewhat lower than removal efficiencies observed for treatment of stormwater runoff. Baseflow entering Booker Lake from both the northern and western channels was found to be low in both nutrients and suspended solids. As a result of the initial low raw concentrations, the water quality improvements obtained using alum treatment were not as dramatic as removal efficiencies obtained for treatment of stormwater runoff which exhibited much higher raw concentrations.

A summary of assumed removal efficiencies for treatment of stormwater runoff from both the northern and western channels is given at the bottom of Table 2-1. Since field operational conditions are less controlled than laboratory jar tests, a slightly lower removal efficiency is assumed for the alum treatment system than the removal efficiencies observed during the jar testing process. For purposes of estimating pollutant load reductions for the Booker Lake ATS facility, a removal of 25% is assumed for total nitrogen, with a 90% removal for total phosphorus, and a 90% removal for TSS. Although laboratory jar testing was conducted on baseflow samples collected from the northern and western channels, the annual volumetric inputs of baseflow are not known, and the system is programmed to largely ignore baseflow inputs. Therefore, estimates of annual loadings and load reductions are not included for the baseflow components.

TABLE 2-1

SUMMARY OF MEAN REMOVAL EFFICIENCIES FOR ALUM TREATMENT OF STORMWATER AND BASEFLOW ENTERING BOOKER LAKE FROM JULY-OCTOBER 2005

INFLOW	INFLOW TYPE	ALUM DOSE (mg Al/liter)	NUMBER OF TESTS	MEAN REMOVAL EFFICIENCY (%)		
				Total Nitrogen	Total Phosphorus	TSS
Northern Channel	Stormwater	7.5	4	27	98	96
	Baseflow	7.5	3	8	82	80
Western Channel	Stormwater	7.5	3	28	97	87
	Baseflow	7.5	4	13	96	63
Assumed Removal Efficiency for Stormwater:				**25**	**90**	**90**

2.4 Runoff Generated Loadings to Booker Lake

A summary of estimated annual mass loadings of total nitrogen, total phosphorus, and TSS to Booker Lake from stormwater runoff is given on Table 2-2. Estimated annual mass loadings were calculated by multiplying the modeled runoff inflow volumes for the northern and western channels (summarized in Table 1-5) and the mean pre-treatment runoff characteristics for the northern and western channels (summarized in Table 1-6). On an annual basis, the northern and western channels contribute approximately 1,043 kg of total nitrogen, 231 kg of total phosphorus, and 26,636 of TSS each year. These annual loadings do not include the additional loadings to Booker Lake provided by baseflow inputs since the annual volume of the baseflow inputs is not known.

TABLE 2-2

ESTIMATED ANNUAL MASS LOADINGS OF TOTAL NITROGEN, TOTAL PHOSPHORUS, AND TSS TO BOOKER LAKE FROM STORMWATER RUNOFF

INFLOW	RUNOFF VOLUME (ac-ft/yr)	ASSUMED INFLOW CONCENTRATION			ANNUAL MASS LOADING (kg/yr)		
		Total N (μg/l)	Total P (μg/l)	TSS (mg/l)	Total N	Total P	TSS
Northern Channel	272.2	1,727	388	54.8	580	130	18,396
Western Channel	377.5	996	216	17.7	464	101	8,240
Total:	**649.7**				**1,043**	**231**	**26,636**

2.5 Anticipated Load Reductions from the ATS Facility

Estimated annual mass load reductions for alum treatment of stormwater runoff are summarized in Table 2-3. The calculated load reductions reflect the assumed removal efficiencies for stormwater treatment provided at the bottom of Table 2-1. Overall, the Booker Lake ATS facility is expected to remove approximately 261 kg/yr of total nitrogen, 208 kg/yr of total phosphorus, and 23,973 kg/yr of TSS.

TABLE 2-3

ESTIMATED ANNUAL MASS LOAD REDUCTIONS FOR ALUM TREATMENT OF STORMWATER RUNOFF

INFLOW	ASSUMED REMOVAL EFFICIENCY (%)			ANNUAL LOAD REDUCTION (kg/yr)		
	Total N (μg/l)	Total P (μg/l)	TSS (mg/l)	Total N	Total P	TSS
Northern Channel	25	90	90	145	117	16,556
Western Channel	25	90	90	116	91	7,416
Total:				**261**	**208**	**23,973**

SECTION 3

FIELD AND LABORATORY ACTIVITIES

Field and laboratory investigations were conducted by ERD to evaluate the effectiveness of the Booker Lake ATS facility. Pre-construction field monitoring was conducted from July 2005-June 2006 which included evaluation of surface water quality, sediment characteristics, and benthic communities. Post-treatment monitoring was conducted from November 2011-October 2012, following completion of the alum stormwater treatment facility, to document changes in water quality, sediment characteristics, and benthic communities, as well as floc accumulation rates. Laboratory analyses were conducted on the collected pre- and post-treatment samples to assist in quantifying the pollutant removal effectiveness of the treatment system. Specific details of monitoring efforts conducted to evaluate the performance efficiency of the Booker Lake ATS facility are given in the following sections.

3.1 Surface Water Monitoring

Surface water monitoring was conducted in Booker Lake under both pre- and post-treatment conditions to evaluate the performance efficiency of the Booker Lake ATS facility. Under pre-treatment conditions, surface water monitoring was conducted at 3 separate locations in Booker Lake to evaluate horizontal variability in water quality characteristics within the lake. The locations of the pre-treatment surface water monitoring sites are illustrated on Figure 3-1. Pre-treatment surface water monitoring was conducted at each of the 3 sites on a monthly basis over the period from July 2005-June 2006, with a total of 12 separate monthly monitoring events conducted to evaluate pre-treatment characteristics.

During each monthly surface water monitoring event, surface water samples were collected at each of the 3 monitoring sites at a water depth equivalent to one-half of the measured Secchi disk depth at the time of sample collection. The surface water samples were collected using a portable submersible pump which operated on 12-volt DC power. The pump was lowered to the appropriate depth, and surface water was pumped from the selected water depth through polyethylene tubing into the appropriate collection container. The collected samples were placed in ice and returned to the ERD Laboratory for analyses. Measurements of Secchi disk depth were conducted during each monitoring event using a standard 10-cm diameter disk.

During each monthly monitoring event, vertical field profiles of pH, temperature, specific conductivity, dissolved oxygen, and oxidation-reduction potential (ORP) were conducted at each of the 3 monitoring sites using a Hydrolab Datasonde 4a water quality monitor. Field measurements were conducted at depths of 0.25 m and 0.5 m, and continued at 0.5 m intervals to the lake bottom at each site. This information is used to evaluate potential stratification and anoxic conditions in bottom portions of the lake.

Figure 3-1. Pre-Treatment Surface Water Monitoring Sites in Booker Lake.

After reviewing the results of the pre-treatment surface water monitoring program, it was concluded that Booker Lake is a well-mixed waterbody, and chemical characteristics of the surface water can be evaluated by monitoring at a single location. Therefore, the post-treatment monitoring program was conducted only at a single monitoring site near the geographic center of Booker Lake. The location of the post-treatment surface water monitoring site is indicated on Figure 3-2. Post-treatment surface water monitoring was conducted from November 2011-October 2012, with samples collected on a monthly basis, with a total of 12 separate monthly monitoring events. Monitoring techniques used for collection of surface water samples and vertical field profiles were identical to the techniques used for collection of the pre-treatment data.

In addition to the routine monthly surface water monitoring, a Hydrolab Model MS5 recording datasonde unit was installed in Booker Lake upstream from the outfall structure at the location indicated on Figure 3-2. The datasonde was suspended at approximately mid-depth in the water column using a buoy and anchor system. The unit was programmed to collect measurements of pH, temperature, and specific conductivity at 15-minute intervals, with the data stored into internal memory within the unit. During each monthly monitoring event, the data were downloaded from the datasonde unit and the internal batteries were replaced. The primary purpose of the datasonde was to record pH values within Booker Lake to ensure that the alum treatment process did not reduce pH levels in Booker Lake to undesirable levels. A photograph of the datasonde unit is given on Figure 3-3. The Datasonde was calibrated and cleaned during each of the monthly events. In general, the calibration remained very stable between the monthly calibration events.

Figure 3-2. Post-Treatment Surface Water Monitoring Sites in Booker Lake.

Figure 3-3. Photograph of the Datasonde Unit Installed in Booker Lake.

3.2 Sediment Monitoring

Collection of sediment core samples was conducted in Booker Lake under pre- and post-treatment conditions to evaluate potential changes in sediment characteristics resulting from operation of the Booker Lake ATS facility. Sediment monitoring was conducted under both pre- and post-treatment conditions at each of the 3 surface water monitoring sites indicated on Figure 3-1.

3.2.1 Sampling Techniques

Sediment samples were collected at each of the 3 monitoring sites using a stainless steel split-spoon core device, which was penetrated into the sediments at each location to a minimum distance of approximately 0.5 m. After retrieval of the sediment sample, any overlying water was carefully decanted before the split-spoon device was opened to expose the collected sample. Visual characteristics of each sediment core sample were recorded, and the 0-10 cm layer was carefully sectioned off and placed into a polyethylene container for transport to the ERD laboratory. The polyethylene containers utilized for storage of the collected samples were filled completely to minimize air space in the storage container above the composite sediment sample.

Triplicate core samples were collected at each site for both pre- and post-treatment monitoring events. Under pre-treatment conditions, the 0-10 cm layers for each of the triplicate samples were combined together to form a single composite sample for each of the 3 monitoring sites, forming a total of 3 pre-treatment sediment core samples. During the post-treatment sediment monitoring event, each of the triplicate core samples were placed into separate bottles and analyzed separately, resulting in a total of 9 individual core samples which were analyzed individually. Each of the collected pre- and post-treatment samples was stored on ice and returned to the ERD laboratory for physical and chemical characterization.

3.2.2 Sediment Characterization and Speciation Techniques

The collected pre- and post-treatment sediment core samples was analyzed for a variety of general parameters, including moisture content, organic content, sediment density, total nitrogen, and total phosphorus. Methodologies utilized for preparation and analysis of the sediment samples for these parameters are outlined in Table 3-1.

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

TABLE 3-1

ANALYTICAL METHODS FOR SEDIMENT ANALYSES

MEASUREMENT PARAMETER	SAMPLE PREPARATION	ANALYSIS REFERENCE	REFERENCE PREP./ANAL.*	METHOD DETECTION LIMITS (MDLs)
pH	EPA 903	EPA 903	3 / 3	0.01 pH units
Moisture Content	p. 3-54	p. 3-58	1 / 1	0.1%
Organic Content (Volatile Solids)	p. 3-52	pp. 3-52 to 3-53	1 / 1	0.1%
Total Phosphorus	pp. 3-227 to 3-228 (Method C)	EPA 365.4	1 / 2	0.005 mg/kg
Total Nitrogen	p. 3-201	pp. 3-201 to 3-204	1 / 1	0.010 mg/kg
Specific Gravity (Density)	p. 3-61	pp. 3-61 to 3-62	1 / 1	NA

*REFERENCES:

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

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

Saloid-bound phosphorus is considered to be available under all conditions at all times. Iron-bound phosphorus is relatively stable under aerobic environments, generally characterized by redox potentials greater than 200 mv (E_h), while unstable under anoxic conditions, characterized by redox potential less than 200 mv. Aluminum-bound phosphorus is considered to be stable under all conditions of redox potential and natural pH conditions. A schematic of the Chang and Jackson Speciation Procedure for evaluating soil phosphorus bounding is given in Figure 3-4.

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

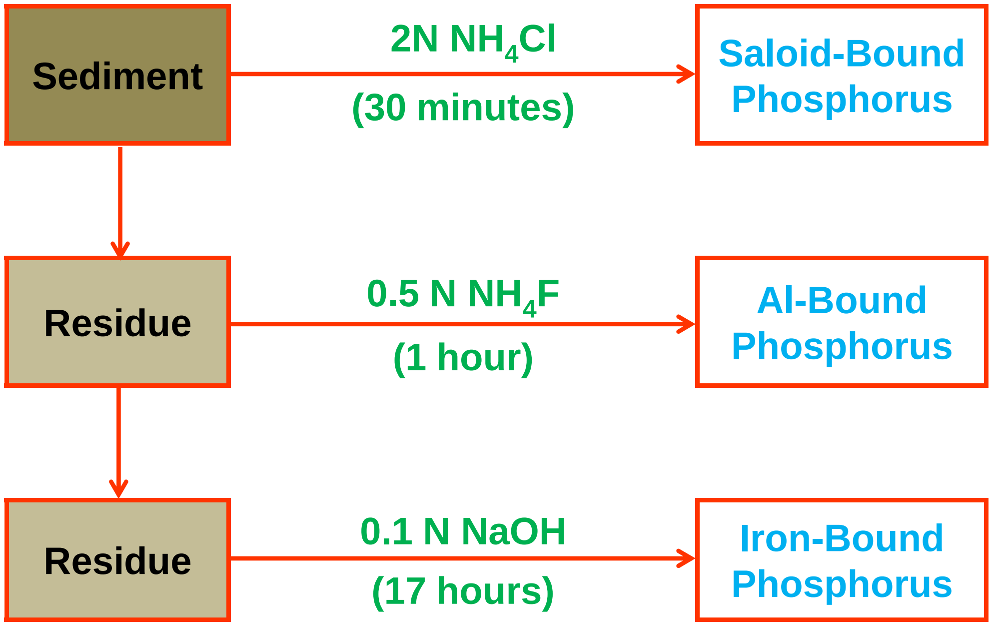


Figure 3-4. Schematic of Chang and Jackson Speciation Procedure for Evaluating Soil Phosphorus Bonding.

3.3 Collection of Benthic Samples

Benthic monitoring was conducted in Booker Lake under pre- and post-treatment conditions to evaluate potential impacts on benthic populations from operation of the Booker Lake ATS facility. Pre-construction benthic monitoring was conducted in Booker Lake during July 2005 and January 2006 to evaluate benthic populations under summer and winter conditions. Post-treatment benthic monitoring was conducted during January and August 2012.

Locations of the pre- and post-treatment benthic monitoring sites in Booker Lake are indicated on Figure 3-5. Sample collection for the pre- and post-treatment benthic monitoring event was performed by ERD, with sample identification conducted by Mr. Mark Vogel, formerly employed by the Florida Fish and Game Commission and the Orange County Environmental Protection Division, and currently employed by USGS.

Sample collection was performed using a 6-inch x 6-inch stainless steel Eckman dredge. Three separate dredge samples were collected at each sample site. Each of the collected samples was placed into a wash bucket with a 500 µm stainless steel sieve screen. The samples were washed to remove silt and fine sand and stored in individual bottles for subsequent analysis. This procedure formed a total of nine separate benthic samples (3 sites x 3 samples/site) for analysis from each of the pre- and post-treatment monitoring events. Each of the benthic samples was preserved and shipped to Mr. Vogel for evaluation. In order to maintain uniform procedures and sample methodologies between the monitoring events, specifics concerning monitoring techniques, sieve size, preservation and shipping methods were provided to ERD by Mr. Vogel.

Figure 3-5. Pre- and Post-Treatment Benthic Monitoring Sites in Booker Lake.

3.4 Monitoring for Floc Accumulation

Field monitoring was conducted by ERD under post-treatment conditions to evaluate the rate of floc accumulation in Booker Lake resulting from treatment of inflows from the northern and western channels. Monitoring for floc accumulation was conducted at 10 separate locations in Booker Lake using underwater staff gauges installed by ERD. Locations of the underwater staff gauge sites are illustrated on Figure 3-6. The staff gauges consisted of stainless steel rulers (approximately 3" wide and 4' long) which were attached to 1.5-inch aluminum fence post piping. Each of the pipes was inserted firmly into the sediments such that the stainless steel staff gauges extended approximately 1 ft below the sediment surface and 3 ft above the sediment surface. Each of the pipes was extended to near the water surface to assist in locating each of the staff gauge monitoring sites.

On approximately a bimonthly basis, readings were collected of the elevation of the top sediment layer at each of the staff gauge locations. The readings were conducted by gently lowering an underwater video camera at each site and recording the relative sediment elevation. The use of the underwater camera minimized disturbances to the sediments which would have potentially impacted the measured values. Changes in each of the relative sediment depths are used to evaluate the distribution of the alum floc within Booker Lake.

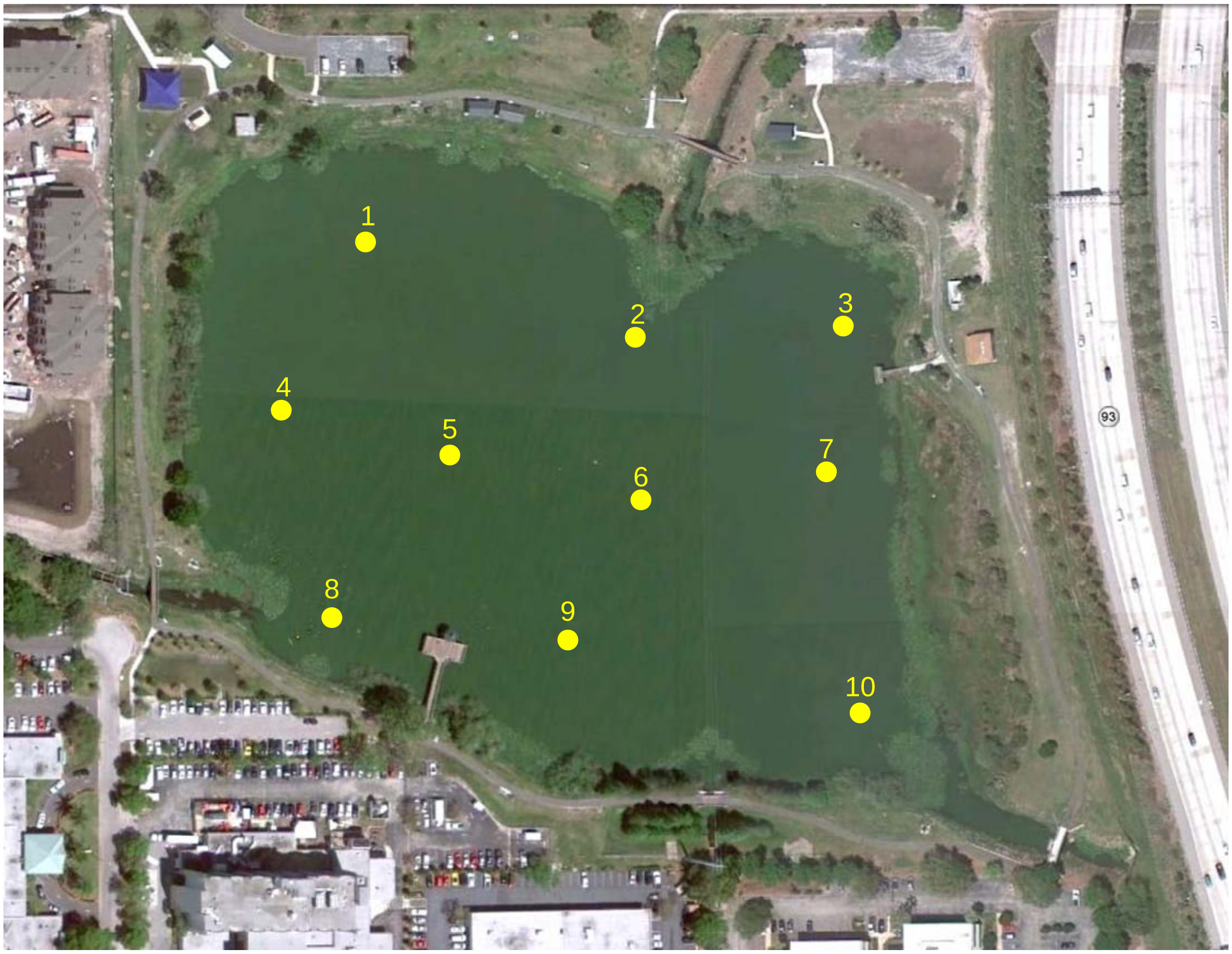


Figure 3-6. Locations of Underwater Staff Gauges Installed in Booker Lake.

3.5 Laboratory Analyses

A summary of laboratory methods and MDLs for analyses conducted on water samples collected during this project is given in Table 3-2. All laboratory analyses were conducted in the ERD Laboratory which is NELAC-certified (No. E1031026). Details on field operations, laboratory procedures, and quality assurance methodologies are provided in the Quality Assurance Project Plan (QAPP), outlining the specific field and laboratory procedures to be conducted for this project, were submitted to and approved by FDEP prior to initiation of any field and laboratory activities.

TABLE 3-2

ANALYTICAL METHODS AND DETECTION LIMITS FOR LABORATORY ANALYSES

PARAMETER	METHOD OF ANALYSIS	METHOD DETECTION LIMITS (MDLs)[1]
pH	SM-21, Sec. 4500-H^+ B[2]	N/A
Conductivity	SM-21, Sec. 2510 B	0.2 µmho/cm
Alkalinity	SM-21, Sec. 2320 B	0.5 mg/l
Ammonia	SM-21, Sec. 4500-NH_3 G	0.005 mg/l
NO_x	SM-21, Sec. 4500-NO_3 F	0.005 mg/l
Total Nitrogen	SM-21, Sec. 4500-N C	0.01 mg/l
Soluble Reactive Phosphorus (ORP)	SM-21, Sec. 4500-P F	0.001 mg/l
Total Phosphorus	SM-21, Sec. 4500-P B.5	0.001 mg/l
Turbidity	SM-21, Sec. 2130 B	0.3 NTU
Color	SM-21, Sec. 2120 C	1 Pt-Co Unit
TSS	SM-21, Sec. 2540 D	0.7 mg/l
Chlorophyll-a[3]	SM-21, Sec. 10200 H.1,3	1 mg/m^3
BOD	SM-21, Sec. 5210 B	2 mg/l
Fecal Coliform	SM-21, Sec. 9222 D	1 cfu
Diss. Aluminum	SM-21, Sec. 3500-Al E	4 µg/l

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

3.6 Routine Data Analysis and Compilation

All data generated during this project, including field measurements, water quality information, sediment characteristics, and datasonde downloads were entered into a computerized database and double-checked for accuracy. Data collected during this project were analyzed using a variety of statistical methods and software.

3.7 Quality Assurance

Supplemental samples (such as equipment blanks and duplicate samples) were collected during the field monitoring program for quality assurance purposes. In addition, a number of supplemental laboratory analyses were performed to evaluate precision and accuracy of the collected data. Overall, more than 1000 additional laboratory analyses were conducted for quality assurance purposes. A summary of the QA data collected as part of this project is given in Appendix D.

SECTION 4

RESULTS OF FIELD MONITORING AND LABORATORY ANALYSES

This section provides a summary of the results of field monitoring and laboratory analyses conducted at Booker Lake before and after construction of the alum stormwater treatment system. Pre- and post-treatment comparisons are provided for water quality, sediments, observed floc accumulation rates, and benthic communities. Pre-treatment monitoring was conducted from July 2005-June 2006, with post-treatment monitoring conducted from November 2011-October 2012. A discussion of the results of the monitoring activities is given in the following sections. Information is also provided on the operational status of the Booker Lake ATS during the field monitoring program.

4.1 Operational Status of the ATS Facility During the Field Monitoring Program

The Booker Lake ATS facility includes a programmable logic controller (PLC) that provides a record of the operational status of the system at one minute intervals and provides information on operational parameters such as water level readings in the various channels, calculated storm flows, alum pumping requirements based upon the calculated discharge rates through the western and northern channels, and the actual pumped rate of alum addition. This information is stored onto an SD card which can be retrieved and downloaded onto a laptop computer in an Excel format. The data stored on the SD card were retrieved approximately mid-way through the 12-month field monitoring program and at the completion of the field monitoring program.

A graphical summary of days with verified system operation, based upon the information contained on the SD card, is given in Figure 4-1. Continuous operational data are available from 11/1/11-1/8/12 and from 7/13/12-10/31/12. System operation was evaluated by reviewing the stored data for measured water levels in the western and northern channels along with the theoretical and actual alum pumping rates. The alum treatment system is assumed to be operational on days when water level measurements in one or both of the two inflow channels exhibit a trend of either increasing or decreasing elevations, combined with actual operation of the alum injection pump. This analysis does not include an evaluation of whether or not the alum pumping system was dispensing the appropriate amount of alum. The system is also assumed to be operational during periods of low flow conditions when the depth transducers in the two channels appear to be measuring reasonable values, although the calculated inflow rates may be too low to energize the alum addition system.

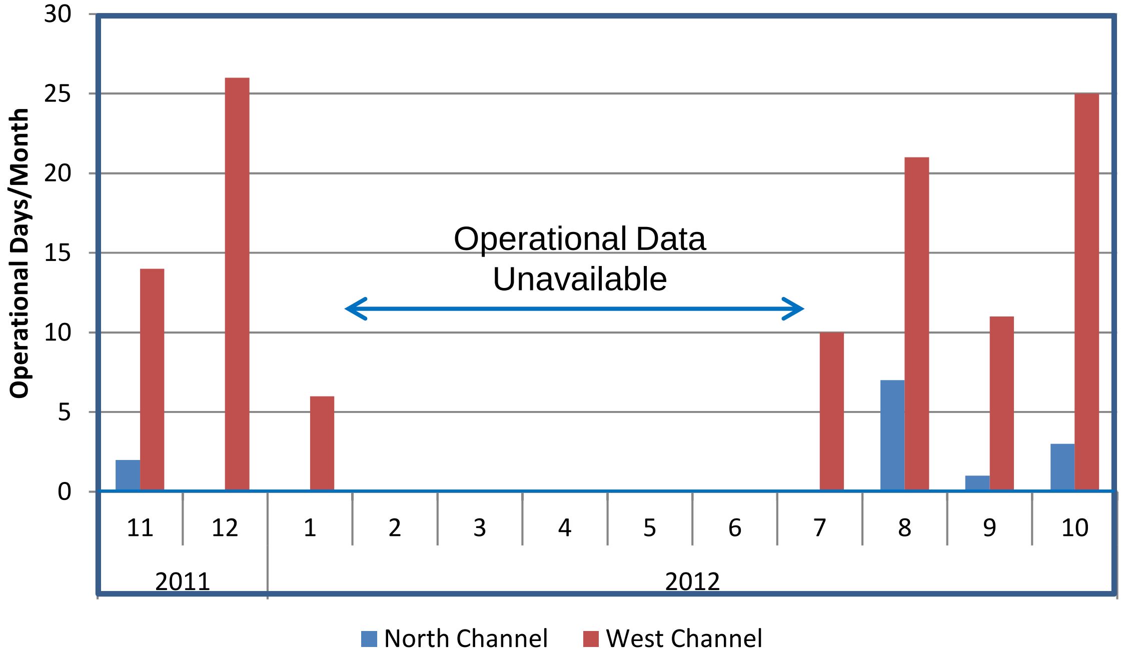


Figure 4-1. Summary of Days with Verified System Operation.

Unfortunately, operational data are not available over the period from 1/8/12-7/13/12. It is not known whether the missing data suggests that the system was turned off and inoperable or if the stored data were lost. As a result, no conclusions can be drawn regarding the operational status of the system during this period. Overall, information necessary to evaluate system performance is available for approximately 179 of the 365 days included in the field monitoring program.

As indicated on Figure 4-1, alum addition to the west channel was verified during the months of November, December, and January, along with the period from July-October. Of the 179 days included in this period, the western channel alum addition system appeared to be operational for approximately 113 days, or approximately 63% of the available period of record. The operational status of the west channel injection system over the period of missing data from 1/8/12-7/13/12 is not known. Based upon the review of the operational data, the north inflow channel appeared to be operational during approximately 13 of the 179 days for which data are available, reflecting approximately 7% of the time.

Based upon the information summarized in Figure 4-1, it appears that operation of the Booker Lake alum treatment system was sporadic at best. Verifiable operation of the north channel alum addition system is only available for approximately 7% of the period for which data are available, with an operational effectiveness of 63% for the west channel. Unfortunately, the reasons for the poor operational status of the Booker Lake ATS facility are not known. The data do not provide sufficient information to determine the cause of the poor performance, such as equipment problems, poor operational techniques, or lack of sufficient alum within the tank which would cause a low-level shut-down of both injection points. The fact that the system only operated during a portion of the 12-month field monitoring program must be considered when reviewing the results of the post-treatment monitoring program.

4.2 Surface Water Characteristics

4.2.1 Vertical Field Profiles

As discussed in Section 3, vertical field profiles were collected under both pre- and post-treatment conditions in Booker Lake. A complete listing of vertical field profiles collected in Booker Lake under pre- and post-treatment conditions is given in Appendix B, with pre-treatment profiles provided in Appendix B.1 and post-treatment profiles provided in Appendix B.2.

4.2.1.1 Pre-Treatment Vertical Profiles

A graphical compilation of pre-treatment vertical field profiles collected at Booker Lake Site 1 from July 2005-June 2006 is given on Figure 4-2. Relatively isograde temperature profiles were observed in Booker Lake during the vast majority of the field monitoring events, with virtually uniform temperature measurements throughout the entire water column. This type of temperature profile is often indicative of a well-mixed waterbody. Classic thermal stratification, defined as a temperature decrease of 1^{o}C or more within a 1 m portion of the water column, was observed only during 2 of the 12 events (March and July). Surface temperature measurements at Site 1 during the field monitoring program ranged from approximately 15-31^{o}C. Overall, the temperature profiles for Site 1 (exhibited on Figure 4-2) indicate a well-mixed water column through much of the year.

Surface pH measurements at Site 1 in Booker Lake ranged from approximately 7.4-8.6 during the field monitoring program. Relatively isograde pH profiles were observed in top portions of the water column to a depth of approximately 2-3 m during most events. Below this depth, water column pH decreased steadily, reaching values ranging from 6.7-7.7 near the water-sediment interface.

Measured surface conductivity values at Site 1 under pre-treatment conditions ranged from approximately 230-400 μmho/cm. Relatively isograde conductivity profiles were observed during virtually all of the monitoring events to a water depth of approximately 3-4 m. Below this depth, increases in specific conductivity were observed near the water-sediment interface during 6 of the 12 monitoring events, suggesting that internal recycling may occur during portions of the year at Site 1.

Measured dissolved oxygen concentrations at Site 1 in Booker Lake were highly variable during the field monitoring program, with surface measurements ranging from approximately 3-11 mg/l. Dissolved oxygen concentrations were generally uniform in upper portions of the water column to a depth of approximately 2-3 m, followed by a relatively rapid decrease in concentrations, with anoxic conditions (defined as dissolved oxygen concentrations less than 1 mg/l) at the water-sediment interface during 9 of the 12 monitoring events. The areas of low dissolved oxygen concentrations at Site 1 correspond closely with the areas of increasing conductivity in lower portions of the water column, indicating that internal recycling is occurring within the sediments at Site 1 under anoxic conditions during a portion of each year. Surface dissolved oxygen concentrations less than the applicable Class III criterion of 5 mg/l, outlined in Section 302 FAC, were observed during 2 of the 12 monitoring events (March and May).

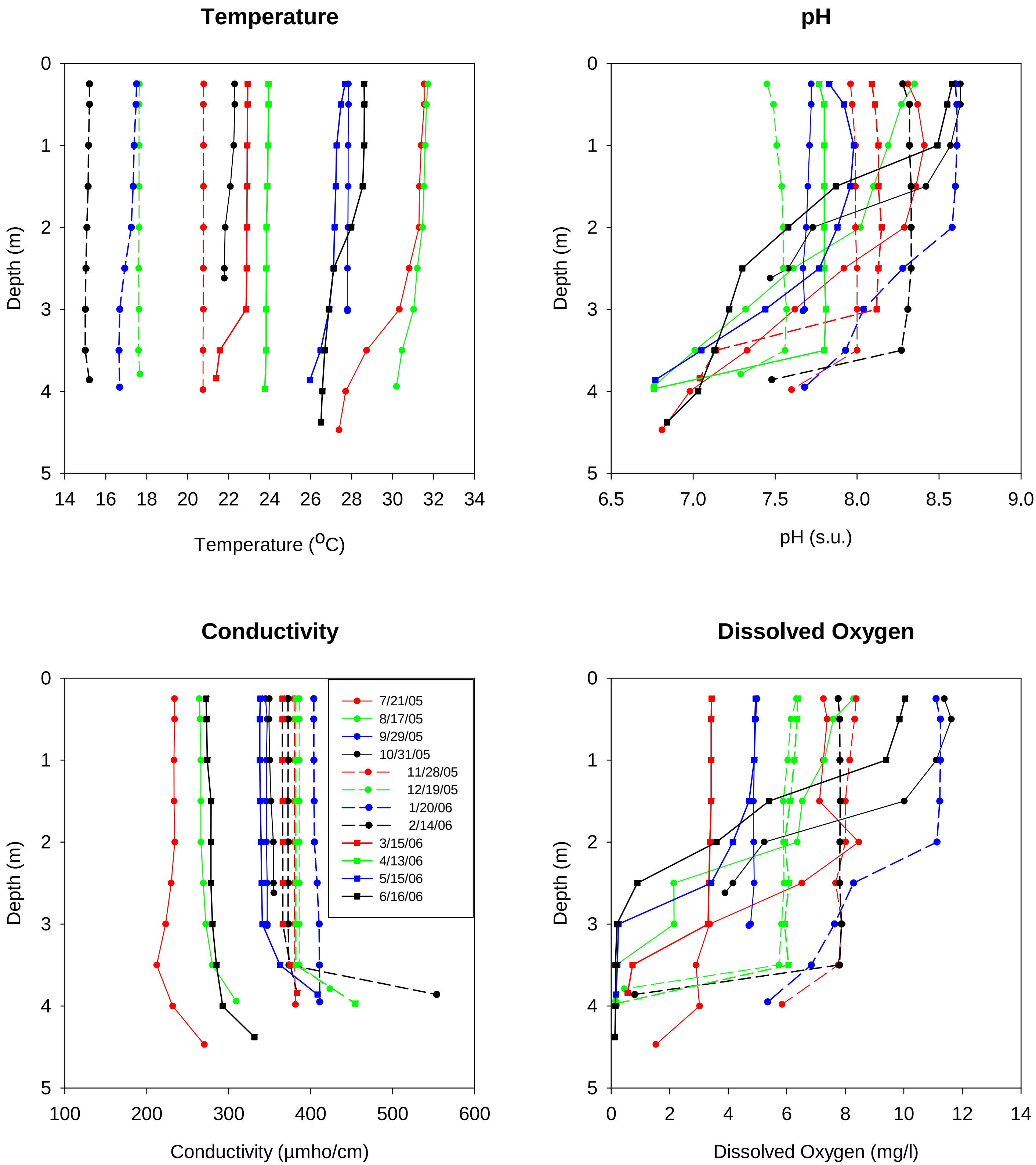


Figure 4-2. Pre-Treatment Vertical Field Profiles Collected at Booker Lake Site 1 from July 2005-June 2006.

A graphical summary of pre-treatment vertical field profiles collected at Booker Lake Site 2 from July 2005-June 2006 is given on Figure 4-3. As indicated on Figure 3-2, pre-treatment Site 2 is located near the center of Booker Lake. Temperature profiles observed at Site 2 are virtually identical to the temperature profiles observed at Site 1, with largely isograde temperature profiles observed during each of the 12 monthly monitoring events. Significant thermal stratification at Site 2 was observed only during November 2005 when thermal stratification was also observed at Site 1. In general, the water column at Site 2 appears to be well-mixed with little vertical change in temperature during most portions of the year.

Vertical pH profiles at Site 2 also appear to be similar to the vertical pH profiles observed at Site 1. Surface pH measurements at Site 2 ranged from approximately 7.5-8.7 during the field monitoring program. During approximately half of the field monitoring events, pH profiles were relatively isograde, with uniform pH measurements throughout the entire water column with the exception of areas near the water-sediment interface. On the remaining monitoring dates, pH measurements exhibited a relatively steady decrease in value with increasing water depth, reaching values ranging from 6.6-7.4 near the water-sediment interface. Monitoring events which exhibited the trend of gradually decreasing values from top to bottom within the water column occurred primarily during summer and early fall conditions.

Relatively isograde conductivity profiles were observed at Site 2 which appear to be very similar to the vertical profiles for conductivity observed at Site 1. Isograde conductivity values were observed throughout the water column during each of the 12 monitoring events, with substantial increases in conductivity observed near the water-sediment interface during 4 of the 12 monitoring events. The observed increases in conductivity near the water-sediment interface are an indication of likely internal recycling from the sediments of Booker Lake into the overlying water column during portions of the year.

Similar to the trends observed at Site 1, dissolved oxygen concentrations at Site 2 were highly variable, with surface dissolved oxygen concentrations ranging from approximately 3-12 mg/l. During approximately 9 of the 12 monitoring events at Site 2, relatively uniform dissolved oxygen concentrations were observed throughout the water column with rapid decreases in dissolved oxygen observed near the water-sediment interface. During the remaining monitoring events, dissolved oxygen concentrations decreased steadily from the surface to the bottom, with near-anoxic conditions observed at the water-sediment interface. The monitoring events with anoxic conditions in lower portions of the water column correspond closely to the events which exhibited increases in conductivity at the water-sediment interface. Surface dissolved oxygen concentrations less than the Class III criterion of 5 mg/l, outlined in Section 302 FAC, were observed during 2 of the 12 monitoring events.

A graphical summary of vertical field profiles collected at Site 3 in Booker Lake from July 2005-June 2006 is given on Figure 4-4. As indicated on Figure 3-1, monitoring Site 3 is located near the outfall channel for Booker Lake on the southeast portion of the lake. Temperature profiles measured at Site 3 exhibited relatively isograde characteristics during virtually all of the field monitoring events, with measured surface temperatures ranging from approximately 15-32^{o}C during the field monitoring program. Classic thermal stratification was observed at Site 3 only during one of the monitoring events (July 2005). In general, the temperature profiles observed at Site 3 are virtually identical to the temperature profiles observed at Sites 1 and 2.

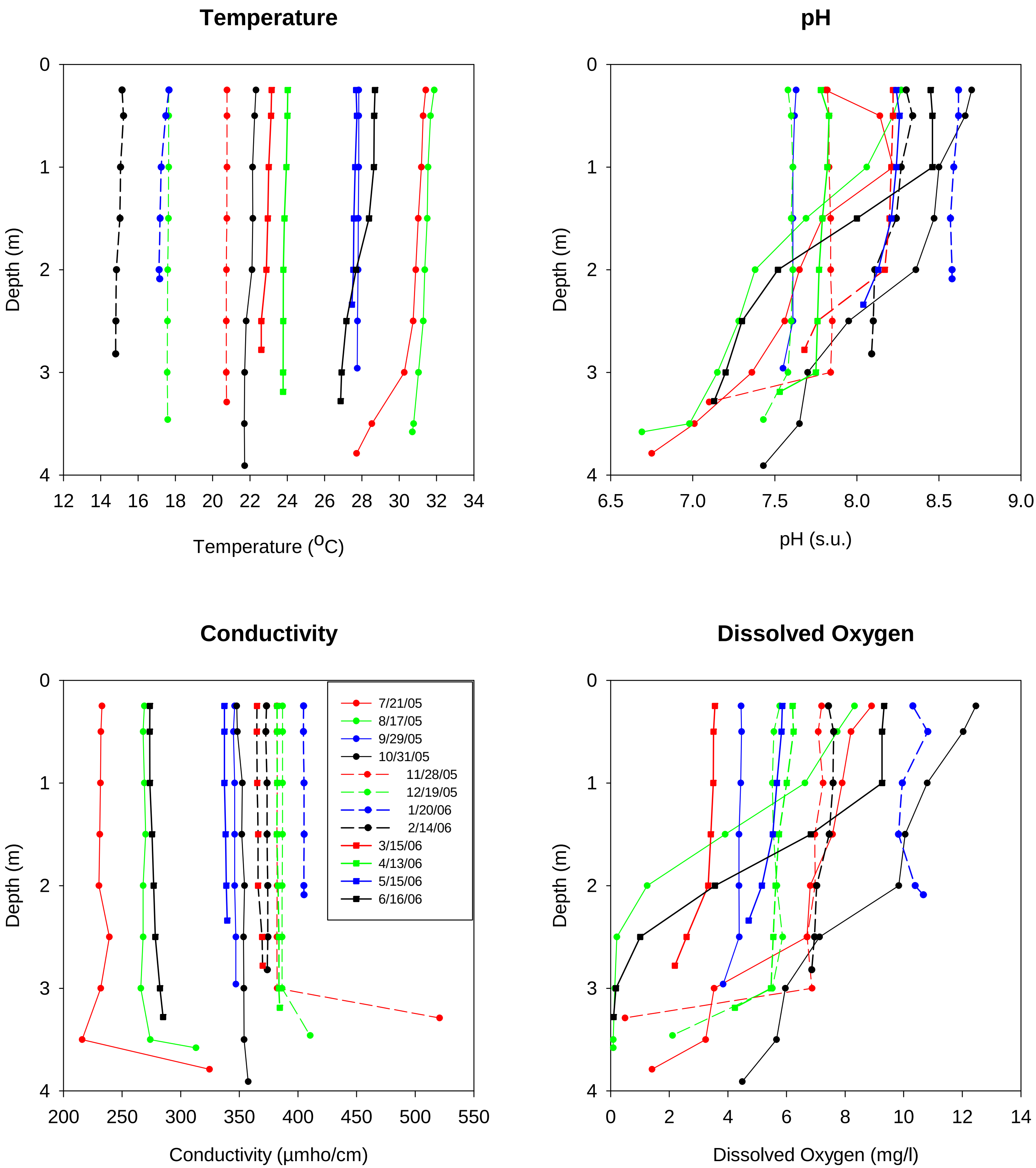


Figure 4-3. Pre-Treatment Vertical Field Profiles Collected at Booker Lake Site 2 from July 2005-June 2006.

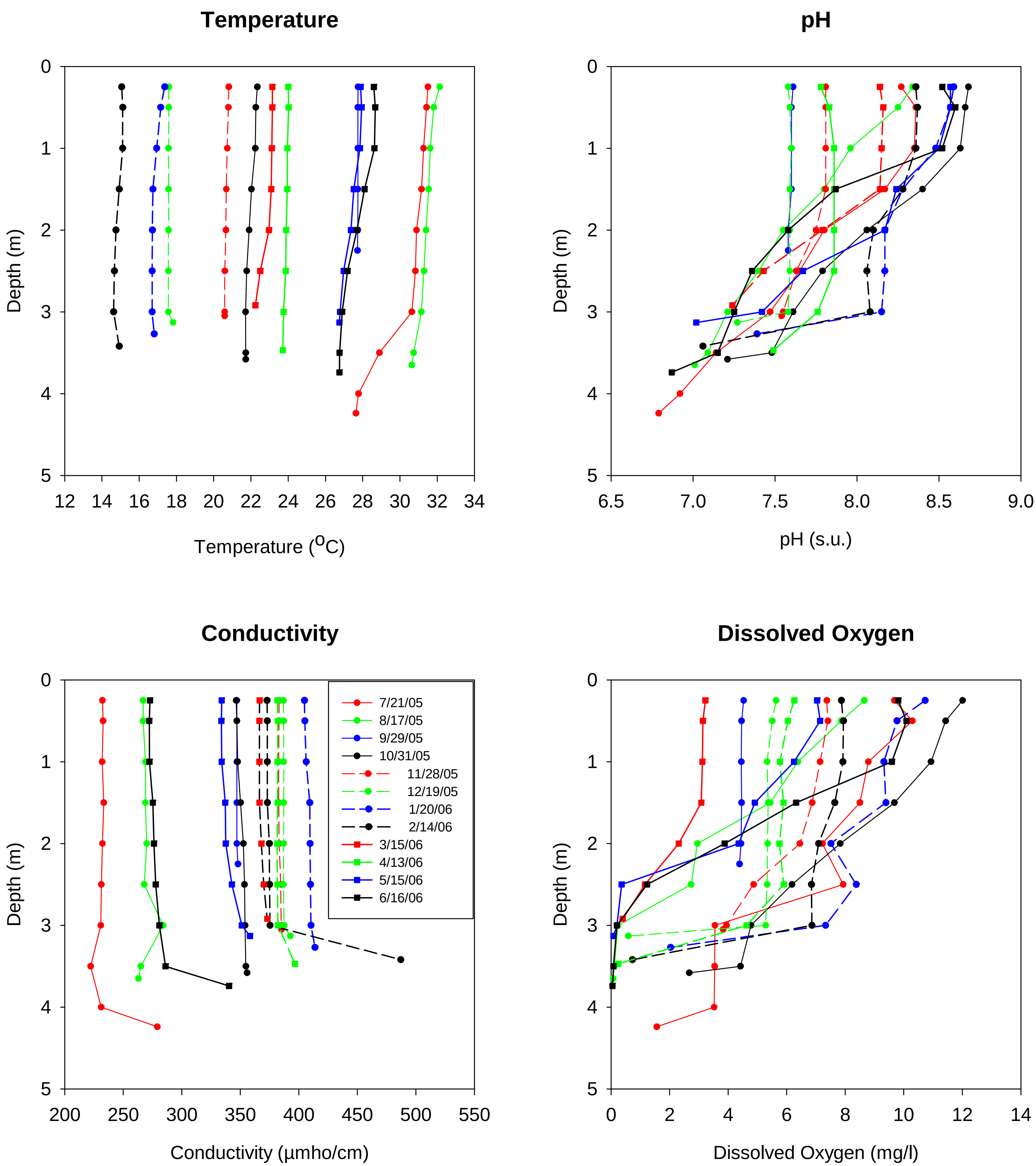


Figure 4-4. Pre-Treatment Vertical Field Profiles Collected at Booker Lake Site 3 from July 2005-June 2006.

Measured surface pH values at Site 3 ranged from approximately 7.6-8.7 during the field monitoring program. In general, pH profiles observed at Site 3 are very similar to the pH profiles observed at Sites 1 and 2. Relatively uniform pH measurements were observed in upper portions of the water column to a depth of approximately 2 m. Below this depth, pH values decreased steadily with increasing water depth, reaching pH measurements near the water-sediment interface ranging from 6.7-7.2.

Measured conductivity profiles at Site 3 are also similar to the profiles measured at Sites 1 and 2. Relatively isograde conductivity measurements were observed throughout the water column with the exception of areas immediately adjacent to the water-sediment interface, with significant increases in conductivity observed in lower portions of the water column during 6 of 12 monitoring events, suggesting that internal recycling is significant at Site 3 in Booker Lake during at least a portion of the year. Monitoring events which exhibited the observed increases in conductivity near the water-sediment interface occurred primarily during summer and early-fall conditions.

Measured surface dissolved oxygen concentrations at Site 3 in Booker Lake ranged from approximately 3-12 mg/l during the field monitoring program. Relatively uniform dissolved oxygen concentrations were observed in upper portions of the water column to a depth of approximately 1-2 m. Below this depth, gradual decreases in dissolved oxygen were observed with increasing water depth. Anoxic conditions were observed at the water-sediment interface during 10 of the 12 monitoring events, suggesting that low levels of dissolved oxygen are a chronic problem near the water-sediment interface in this portion of the lake throughout much of the year. Dissolved oxygen concentrations less than the minimum criterion of 5 mg/l, outlined in Section 302 FAC, were observed at Site 3 during 2 of the 12 monitoring events.

4.2.1.2 Post-Treatment Vertical Profiles

A graphical compilation of post-treatment vertical field profiles collected in Booker Lake from November 2011-October 2012 is given on Figure 4-5. As discussed previously, due to the similarities in field measurements observed between the three pre-treatment monitoring sites, post-treatment monitoring was conducted at only a single location near the center of Booker Lake.

In general, vertical field profiles of temperature in Booker Lake under post-treatment conditions from November 2011-October 2012 appear to be virtually identical to the temperature profiles observed under pre-treatment conditions. Relatively isograde temperature profiles were observed during 10 of the 12 monthly monitoring events. Classic thermal stratification was observed on only one occasion during July 2012. The post-treatment temperature profiles suggest that Booker Lake continues to be a relatively well-mixed waterbody under post-treatment conditions.

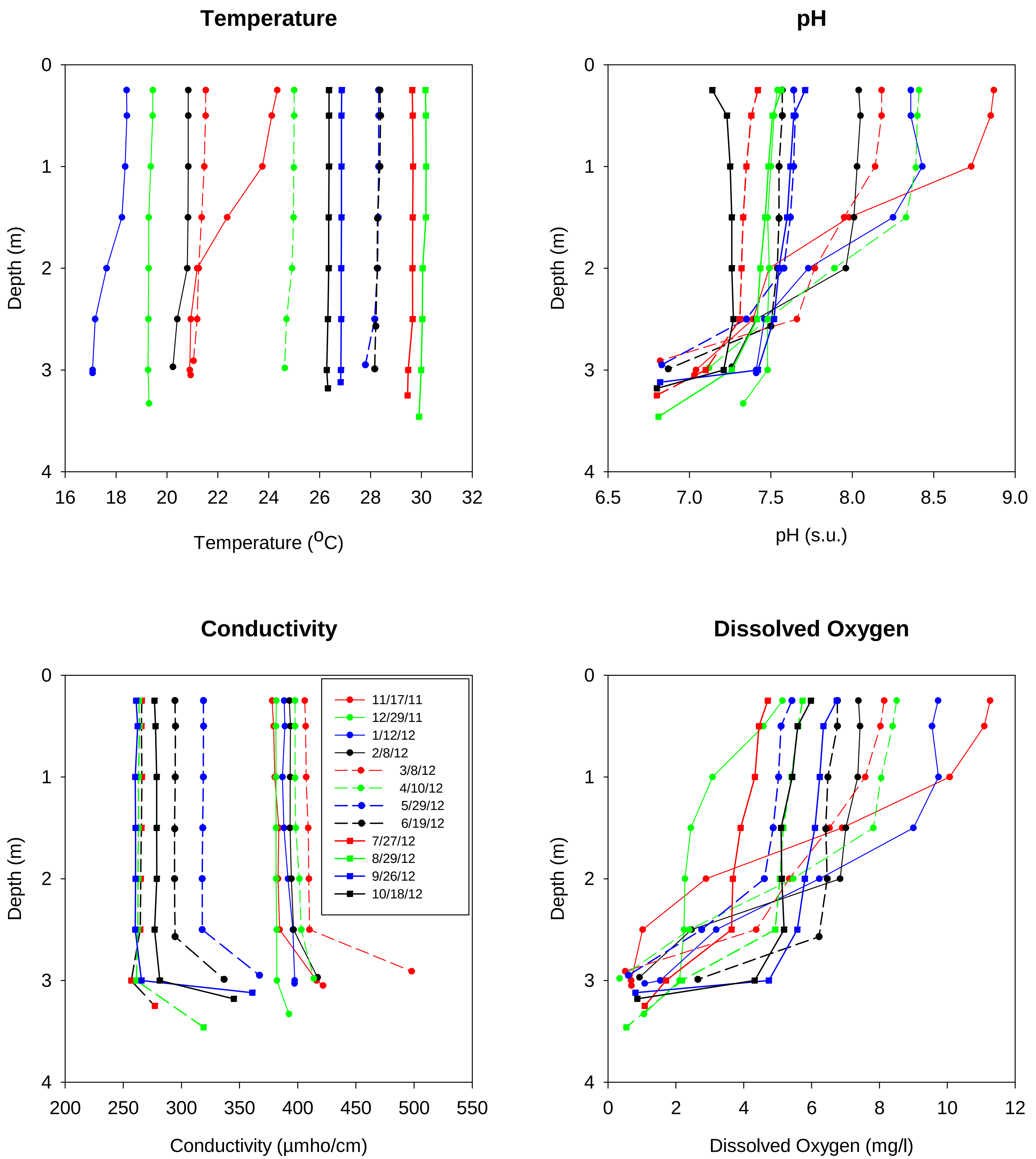


Figure 4-5. Post-Treatment Vertical Field Profiles Collected in Booker Lake from November 2011-October 2012.

Measured surface pH values in Booker Lake under post-treatment conditions ranged from approximately 7.1-8.8. Relatively isograde pH profiles were observed in upper portions of the water column, extending to depths of approximately 1-2.5 m, followed by a gradual decrease in pH with increasing water depth. Measured pH values near the water-sediment interface under post-treatment conditions ranged from approximately 6.7-7.3. Although measured pH values appear to be relatively similar between pre- and post-treatment conditions, the area of isograde pH conditions appears to extend deeper into the water column under post-treatment conditions compared with pre-treatment conditions. In addition, a majority of pH profiles under post-treatment conditions appear to be concentrated in a relatively narrow pH range of approximately 7.1-7.6.

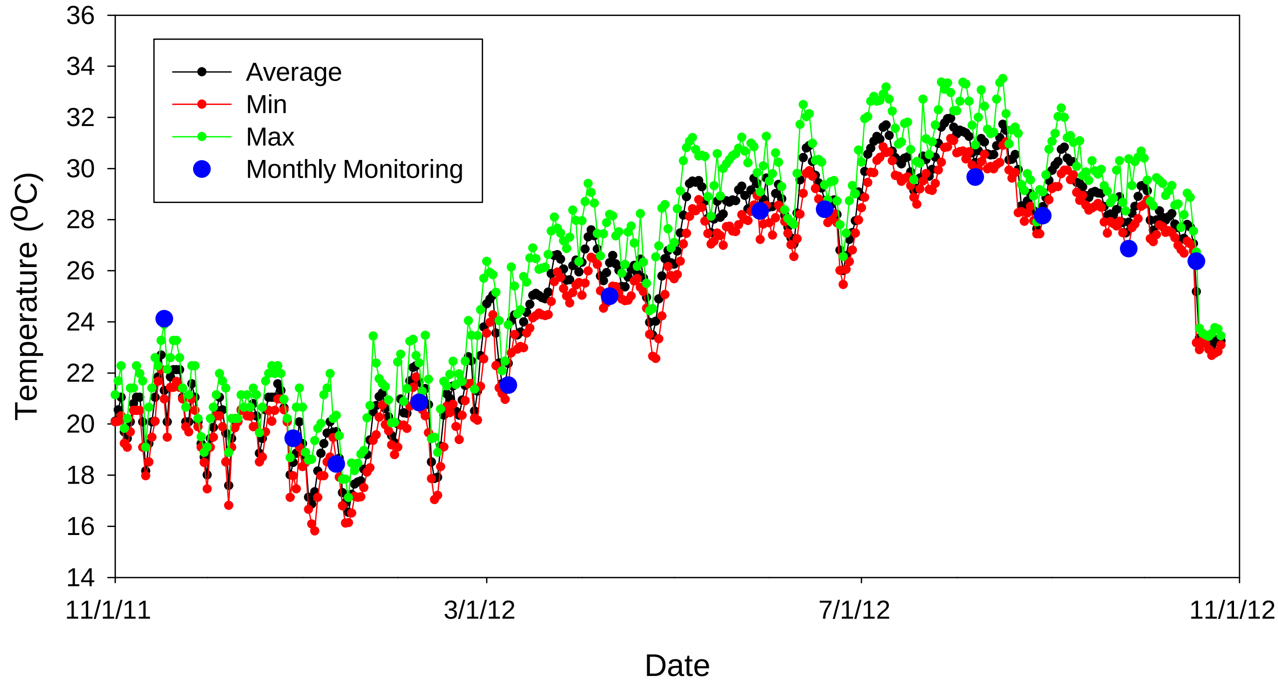
Conductivity profiles in Booker Lake during the post-treatment conditions exhibited isograde characteristics throughout virtually the entire water column. Measured conductivity values ranged from approximately 250-400 μmho/cm, and appear to be slightly higher in value than conductivity values observed under pre-treatment conditions. Conductivity increases near the water-sediment interface were observed during each of the 12 post-treatment monitoring events, suggesting that internal recycling is occurring, at least in central portions of the lake.

Vertical dissolved oxygen profiles in Booker Lake under post-treatment conditions appear to be relatively similar to profiles observed under pre-treatment conditions with a few notable exceptions. Only one of the 12 post-treatment monitoring events was characterized by surface dissolved oxygen concentrations less than 5 mg/l. Relatively uniform dissolved oxygen concentrations occurred within the water column to depths ranging from approximately 1.5-2.5 m, followed by a gradual decrease in dissolved oxygen with increasing water depth. Under pre-treatment conditions, dissolved oxygen concentrations near 0 mg/l were observed on multiple occasions at water depths of approximately 2.5 m or greater. However, under post-treatment conditions, dissolved oxygen concentrations in lower portions of the water column were generally higher in value, never reaching a value near 0 mg/l.

In general, post-treatment vertical field profiles are characterized by a more uniform water column pH, with isograde pH conditions extending to deeper water depths than observed under pre-treatment conditions. Isograde conductivity profiles were observed on each of the 12 post-treatment monitoring events, with increases in conductivity observed near the water-sediment interface. Dissolved oxygen concentrations under post-treatment conditions appear to be generally higher in value, particularly near the water-sediment interface, with no measured concentrations near 0 mg/l under post-treatment conditions.

As discussed in Section 3.1, continuous measurements of temperature, pH, and specific conductivity were conducted near the outfall for Booker Lake using a YSI recording datasonde unit. This unit provided measurements of the characteristics of water discharging from Booker Lake to downstream waterbodies.

A graphical summary of field measurements of temperature and pH in Booker Lake collected by the YSI datasonde from November 2011-October 2012 is given on Figure 4-6. Three separate graphical lines are provided for each of the evaluated parameters which reflect minimum daily values, maximum daily values, and average daily values for each of the monitored parameters. The results of monthly values obtained from the vertical field profiles collected near this location are also included on Figure 4-5 for corroboration purposes. In general, the measurements collected as part of the vertical profile measurement match very closely with the information collected by the YSI datasonde.



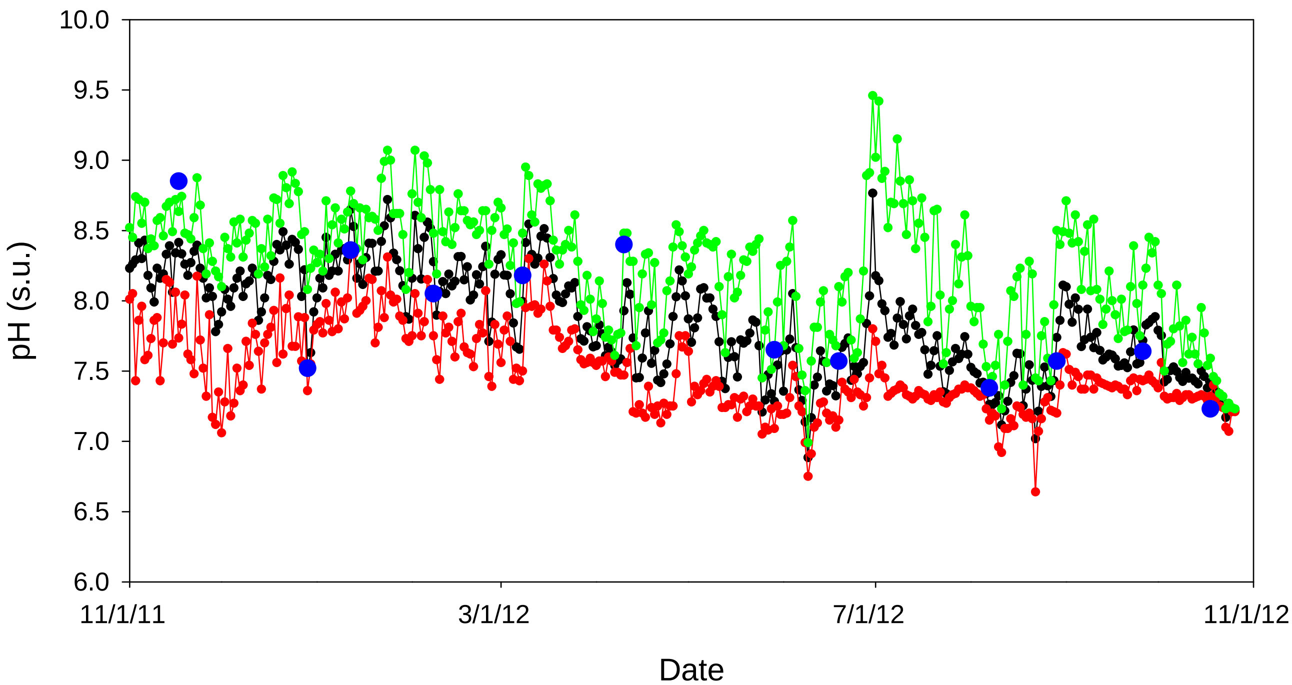


Figure 4-6. Field Measurements of Temperature and pH in Booker Lake Collected by the YSI Datasonde from November 2011-October 2012.

Measured temperature values in Booker Lake recorded by the datasonde unit ranged from approximately 16-34^{o}C during the 12-month post-treatment monitoring program. The measured temperature values appear to reflect seasonal patterns which would be expected in a lake in southwest Florida.

Measured pH values by the datasonde unit ranged from approximately 7-9 throughout a majority of the field monitoring program. The minimum pH value recorded by the datasonde was approximately 6.7 units which is above the minimum criterion of 6.0 for freshwater Class III waterbodies. Therefore, no violations of the pH criterion were observed during the post-treatment field monitoring program. The vast majority of measured pH values ranged from approximately 7.0-8.5 which is similar to pH values commonly observed in urban lakes.

A graphical summary of continuous field measurements of conductivity in Booker Lake collected by the YSI datasonde from November 2011-October 2012 is given on Figure 4-7. During the period from November 2011-June 2012, conductivity measurements in Booker Lake ranged from approximately 375-425 μmho/cm and appeared to remain relatively constant over time. However, beginning in June 2012, a decrease in conductivity was observed within Booker Lake for the remainder of the field monitoring program, with measured conductivity values ranging from approximately 200-300 μmho/cm. Conductivity values during this period were also highly variable as opposed to the relatively consistent conductivity values observed during the first 8 months of the field monitoring program. The reason for the apparent decreases in conductivity in Booker Lake is not known at this time, although the change in conductivity could be related to high quantities of inflow with substantially lower conductivity values.

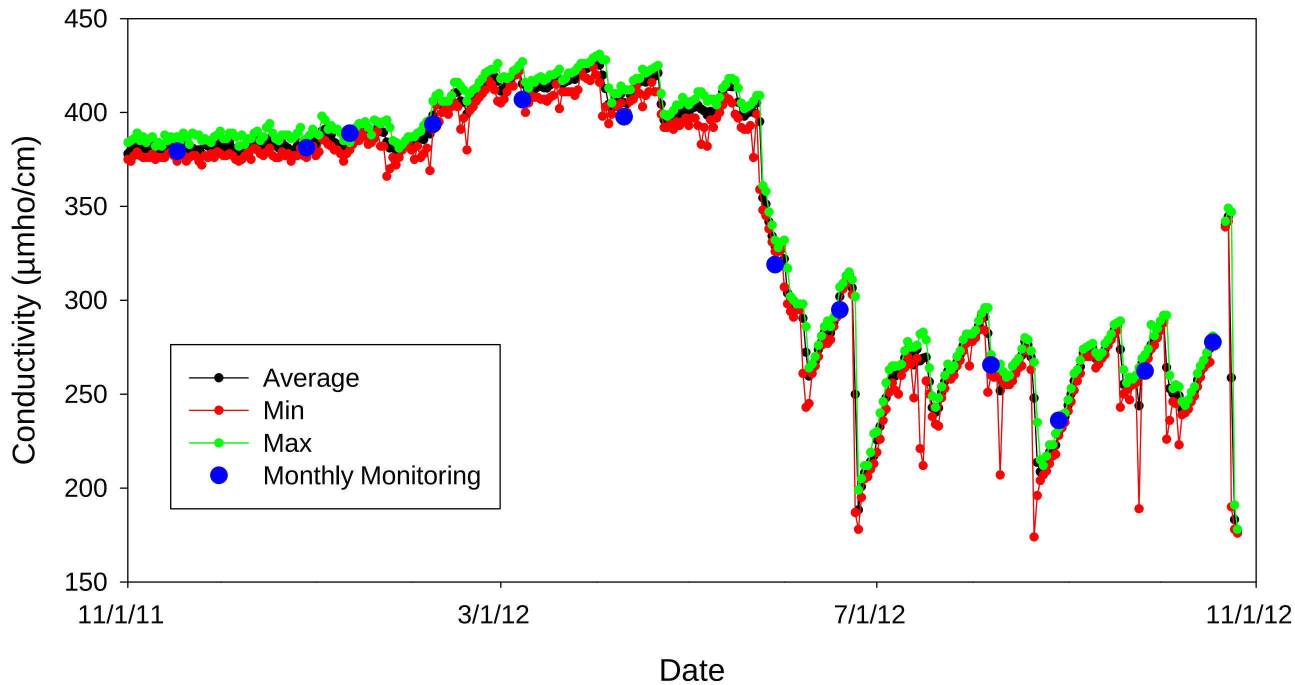


Figure 4-7. Continuous Field Measurements of Conductivity in Booker Lake Collected by the YSI Datasonde from November 2011-October 2012.

4.2.2 Chemical Characteristics of Pre- and Post-Treatment Surface Water

As discussed in Section 3.1, surface water monitoring was conducted in Booker Lake over a 12-month period during both pre- and post-treatment conditions to evaluate changes in water quality characteristics resulting from the alum stormwater treatment system. Pre-treatment surface water monitoring was conducted at each of the 3 monitoring sites indicated on Figure 3-1, with post-treatment surface water monitoring conducted at a single site near the geographic center of the lake. A total of 12 separate monthly monitoring events was conducted during both pre- and post-treatment programs. A summary of the water quality characteristics of Booker Lake under pre- and post-treatment conditions is given in the following sections.

4.2.2.1 Pre-Treatment Characteristics

A tabular summary of the chemical characteristics of pre-treatment surface water samples collected in Booker Lake from June 2005-June 2006 is given on Table 4-1. Measured values are provided for each collected sample at each of the 3 pre-treatment surface water monitoring sites. Summary statistics are provided for each of the 3 surface water monitoring sites which includes minimum value, maximum value, median value, and geometric mean value. Since environmental data commonly exhibit log-normal distributions, the geometric mean is used in this evaluation as the primary measure of central tendency for each of the data sets.

A graphical summary of temporal variability in pre-treatment concentrations of pH, alkalinity, conductivity, and TSS in Booker Lake from July 2005-June 2006 is given on Figure 4-8. Individual values are provided for measurements collected at each of the 3 pre-treatment monitoring sites to assist in evaluating horizontal variability in water quality characteristics.

Measured water quality characteristics at each of the 3 pre-treatment monitoring sites were extremely close in value for each of the parameters included in Figure 4-8, with the possible exception of one of the TSS measurements conducted at Site 3. Measured pH values at the 3 monitoring sites ranged from approximately 7.5-8.6, with no distinct seasonal patterns. Measured alkalinity values at the 3 monitoring sites were extremely close in value, ranging from 80-150 mg/l. Surface water in Booker Lake appears to be moderately to well-buffered based upon the measured alkalinity values.

Extremely close agreement was also obtained between conductivity measurements collected at each of the 3 monitoring sites, with measured conductivity values ranging from approximately 240-400 μmho/cm which is typical of conductivity values commonly observed in urban lakes in southwest Florida. Measured TSS values in Booker Lake were generally approximately 10-15 mg/l or less throughout much of the year. More elevated spikes in TSS concentrations were observed during late-fall and early-winter conditions, and may be related to a blue-green algal bloom which is common in Florida lakes during this period.

A graphical summary of temporal variability in pre-treatment concentrations of nitrogen species in Booker Lake from July 2005-June 2006 is given on Figure 4-9. Measured concentrations of nitrogen species were highly variable during the pre-treatment surface water monitoring program, particularly for ammonia. However, a relatively close agreement is apparent for measured concentrations between the 3 monitoring sites for each individual monitoring date.

TABLE 4-1

CHEMICAL CHARACTERISTICS OF PRE-TREATMENT SURFACE WATER SAMPLES COLLECTED IN BOOKER LAKE FROM JUNE 2005 – JUNE 2006

Sample Location Site	Date Collected	pH (s.u.)	Alk. (mg/l)	NH_3 (µg/l)	NO_x (µg/l)	Diss. Org. N (µg/l)	Part. N (µg/l)	Total N (µg/l)	SRP (µg/l)	Diss. Org. P (µg/l)	Part. P (µg/l)	Total P (µg/l)	Turb. (NTU)	Color (Pt-Co)	Chyl-a (mg/m^3)	TSS (mg/l)	BOD (mg/l)	Fecal (cfu/100 ml)	Al (µg/l)	Chloride (mg/l)
	6/27/05	8.31	78.0	298	7	46	322	673	3	7	49	59	8.7	16	32.9	4.1	4.3	176	21	16.3
	7/21/05	8.36	80.6	61	7	408	206	682	9	8	73	90	4.2	25	58.9	5.1	2.2	2,440	17	15.6
	8/17/05	8.23	90.4	161	<5	172	419	754	2	6	65	73	3.3	27	96.0	5.2	6.0	1,835	39	16.9
	9/29/05	7.71	114	89	<5	351	510	952	2	10	63	75	4.3	34	24.5	6.2	<2.0	72	44	22.2
	10/30/05	8.56	136	320	<5	232	1,185	1,739	1	18	133	152	6.1	38	159.0	15.7	3.3	240	21	24.6
	11/28/05	7.98	142	48	<5	651	489	1,190	1	20	119	140	4.2	32	147.0	8.7	4.5	13	<15	27.5
	12/19/05	7.50	142	418	154	271	642	1,485	5	6	130	141	5.4	25	58.7	18.1	3.8	42	35	29.1
	1/20/06	8.61	151	34	<5	398	803	1,237	<1	2	127	130	7.3	23	70.3	17.4	6.4	21	<15	30.3
1	2/14/06	8.31	130	89	72	351	743	1,255	3	15	92	110	7.7	26	81.3	8.8	5.5	12	116	27.4
	3/15/06	8.12	127	264	<5	118	441	825	2	7	106	115	6.7	25	49.6	15.0	3.1	18	66	30.9
	4/13/06	7.79	128	70	<5	373	546	991	6	12	119	137	7.6	22	39.3	9.2	5.6	124	39	31.6
	5/15/06	7.92	105	37	6	564	738	1,345	1	23	102	126	5.4	39	44.3	9.4	5.9	123	52	33.1
	6/16/06	8.37	93.6	65	13	389	377	844	3	42	83	128	3.5	5	90.8	10.3	3.5	180	103	22.6
	Minimum Value:	**7.50**	**78.0**	**34**	**6**	**46**	**206**	**673**	**1**	**2**	**49**	**59**	**3.3**	**5**	**24.5**	**4.1**	**2.2**	**12**	**17**	**15.6**
	Maximum Value:	**8.61**	**151**	**418**	**154**	**651**	**1,185**	**1,739**	**9**	**42**	**133**	**152**	**8.7**	**39**	**159.0**	**18.1**	**6.4**	**2,440**	**116**	**33.1**
	Median Value	**8.23**	**127**	**89**	**10**	**351**	**510**	**991**	**3**	**10**	**102**	**126**	**5.4**	**25**	**58.9**	**9.2**	**4.4**	**123**	**39**	**27.4**
	Geometric Mean:	**8.13**	**114**	**106**	**19**	**279**	**521**	**1,029**	**2**	**10**	**93**	**109**	**5.5**	**24**	**63.6**	**9.2**	**4.3**	**99**	**42**	**24.5**
	6/27/05	8.11	76.8	259	<5	10	572	843	2	10	54	66	7.7	17	44.3	3.7	4.9	124	19	16.7
	7/21/05	7.99	80.8	109	12	368	201	690	7	10	69	86	4.0	27	70.9	6.7	<2.0	2,320	39	15.0
	8/17/05	8.06	98.6	69	<5	893	263	1,227	3	10	106	119	4.8	26	165.0	4.8	8.2	1,055	39	19.0
	9/29/05	7.62	114	227	8	659	358	1,252	1	14	57	72	4.6	35	21.0	6.6	2.1	96	19	22.9
	10/30/05	8.58	135	336	28	256	1,359	1,979	1	20	108	129	5.9	45	155.0	8.9	3.3	232	35	25.3
	11/28/05	7.83	139	158	10	344	15	527	2	5	111	118	4.7	33	115.0	10.2	4.9	28	<15	27.1
	12/19/05	7.60	144	470	151	293	556	1,470	8	6	127	141	7.1	24	53.1	25.2	5.8	34	21	29.9
	1/20/06	8.60	150	37	<5	402	788	1,229	<1	5	126	132	7.7	26	67.9	17.2	6.2	40	31	23.3
2	2/14/06	8.29	132	26	58	456	610	1,150	3	11	86	100	7.5	26	84.0	8.3	4.8	13	79	27.6
	3/15/06	8.21	127	148	<5	237	409	796	2	7	100	109	6.5	26	49.6	12.8	2.9	18	83	30.2
	4/13/06	7.81	132	36	<5	402	615	1,055	8	16	131	155	6.9	27	41.8	8.9	5.4	140	21	31.2
	5/15/06	8.24	106	41	<5	600	800	1,443	1	28	110	139	5.0	40	63.1	10.1	6.5	72	76	32.3
	6/16/06	8.34	96.8	60	40	368	464	932	3	43	104	150	3.5	24	96.7	11.2	4.7	214	70	22.4
	Minimum Value:	**7.60**	**76.8**	**26**	**8**	**10**	**15**	**527**	**1**	**5**	**54**	**66**	**3.5**	**17**	**21.0**	**3.7**	**2.1**	**13**	**19**	**15.0**
	Maximum Value:	**8.60**	**150**	**470**	**151**	**893**	**1,359**	**1,979**	**8**	**43**	**131**	**155**	**7.7**	**45**	**165.0**	**25.2**	**8.2**	**2,320**	**83**	**32.3**
	Median Value	**8.11**	**127**	**109**	**28**	**368**	**556**	**1,150**	**3**	**10**	**106**	**119**	**5.9**	**26**	**67.9**	**8.9**	**4.9**	**96**	**37**	**25.3**
	Geometric Mean:	**8.09**	**115**	**103**	**27**	**306**	**394**	**1,062**	**3**	**12**	**96**	**113**	**5.7**	**28**	**68.6**	**9.2**	**4.7**	**102**	**38**	**24.2**
	6/27/05	8.33	78.2	315	<5	85	169	571	3	6	63	72	5.9	15	48.2	4.1	4.9	108	17	16.7
	7/21/05	8.29	81.0	52	<5	528	10	592	6	7	71	84	4.1	26	80.7	7.5	<2.0	2,300	134	14.7
	8/17/05	8.09	94.8	57	7	1,023	55	1,142	4	5	89	98	5.7	25	162.0	7.2	8.8	1,527	55	19.0
	9/29/05	7.60	117	243	8	154	510	915	2	11	65	78	4.5	37	22.5	5.4	<2.0	112	25	22.4
	10/30/05	8.59	135	377	<5	131	823	1,333	<1	11	110	122	5.6	38	135.0	7.9	3.9	112	21	23.0
	11/28/05	7.81	143	175	23	301	489	988	1	7	96	104	4.5	33	66.3	14.7	4.3	16	<15	24.2
	12/19/05	7.59	141	409	156	314	485	1,364	6	11	116	133	7.5	24	49.9	49.6	5.0	36	19	30.0
	1/20/06	8.48	152	39	9	371	843	1,262	<1	4	129	134	7.6	25	70.7	17.5	5.3	15	59	28.2
3	2/14/06	8.34	130	61	68	370	643	1,142	1	15	78	94	6.8	26	77.4	8.7	4.8	13	89	26.9
	3/15/06	8.15	126	81	<5	299	493	875	4	11	121	136	7.1	26	47.6	13.4	2.9	25	15	30.6
	4/13/06	7.83	133	53	<5	386	592	1,033	9	16	116	141	6.1	27	35.6	8.8	5.5	172	35	30.6
	5/15/06	8.47	105	38	<5	562	947	1,549	1	27	119	147	6.2	41	104.0	12.8	8.7	68	32	32.9
	6/16/06	8.38	92.2	62	7	384	545	998	4	39	163	206	3.6	26	97.9	10.2	3.8	128	70	22.2
	Minimum Value:	**7.59**	**78.2**	**38**	**7**	**85**	**10**	**571**	**1**	**4**	**63**	**72**	**3.6**	**15**	**22.5**	**4.1**	**2.9**	**13**	**15**	**14.7**
	Maximum Value:	**8.59**	**152**	**409**	**156**	**1,023**	**947**	**1,549**	**9**	**39**	**163**	**206**	**7.6**	**41**	**162.0**	**49.6**	**8.8**	**2,300**	**134**	**32.9**
	Median Value	**8.29**	**126**	**62**	**9**	**370**	**510**	**1,033**	**4**	**11**	**110**	**122**	**5.9**	**26**	**70.7**	**8.8**	**4.9**	**108**	**34**	**24.2**
	Geometric Mean:	**8.14**	**115**	**103**	**19**	**315**	**338**	**1,019**	**3**	**11**	**99**	**114**	**5.6**	**28**	**67.4**	**10.4**	**5.0**	**88**	**37**	**24.1**

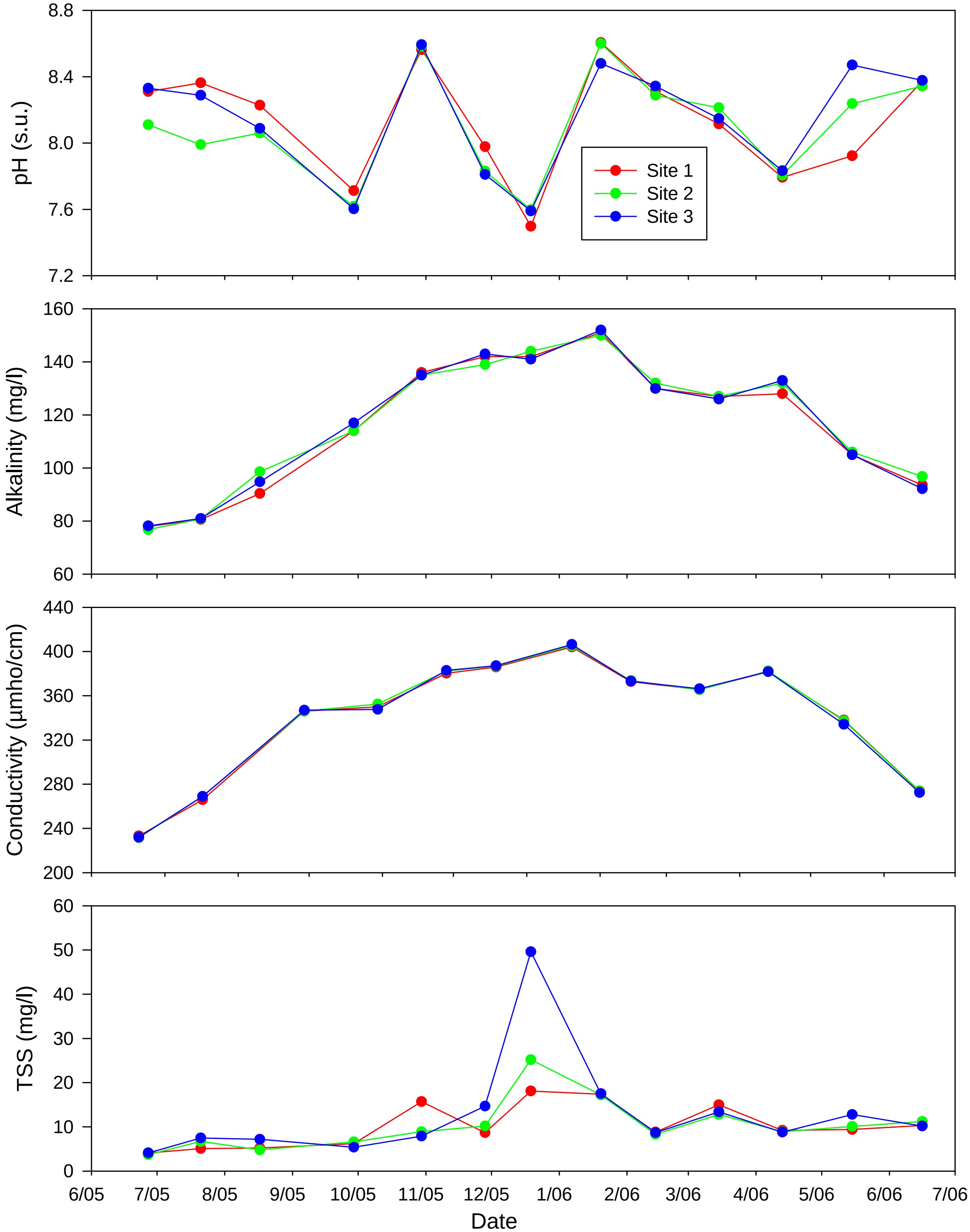


Figure 4-8. Variability in Pre-Treatment Concentrations of pH, Alkalinity, Conductivity, and TSS in Booker Lake from July 2005-June 2006.

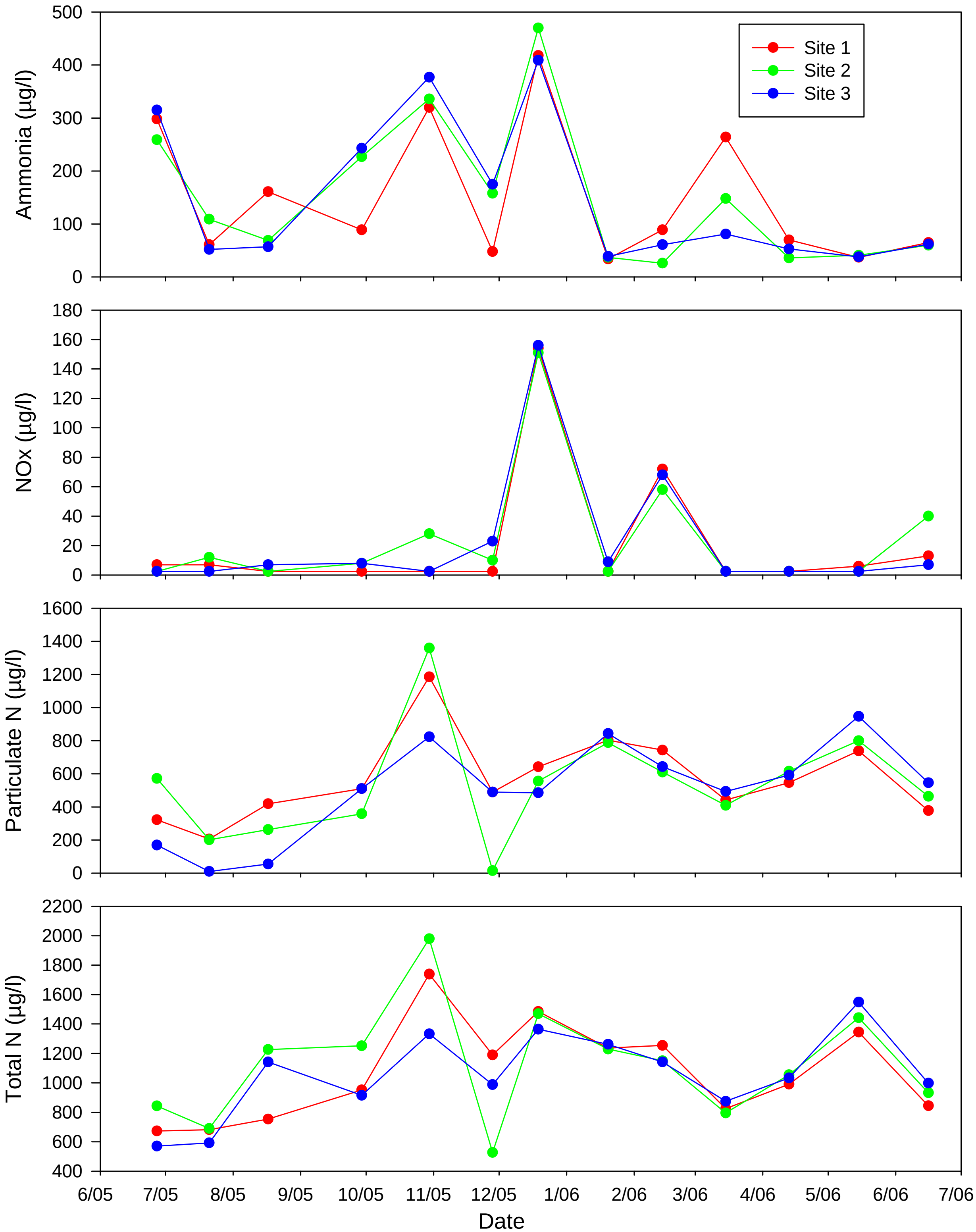


Figure 4-9. Variability in Pre-Treatment Concentrations of Nitrogen Species in Booker Lake from July 2005-June 2006.

Measured concentrations of ammonia in Booker Lake surface water samples ranged from approximately 10-480 μg/l during the field monitoring program. The highest degree of variability appears to occur during fall and early-winter conditions. This type of variability in ammonia concentration during fall and early-winter conditions is sometimes related to release of ammonia from internal recycling from the frequent turnover events that commonly occur during this portion of the year.

Measured concentrations of NO_x were generally low in value throughout most of the pre-treatment field monitoring program, with most values ranging from near zero to approximately 30 μg/l. However, spikes in NO_x concentrations were observed during late-fall and late-winter conditions in Booker Lake, although the magnitude of the observed spikes is relatively low.

Measured concentrations of particulate nitrogen in Booker Lake were highly variable during the pre-treatment field monitoring program, with measured concentrations ranging from near zero to 1400 μg/l. The lowest observed concentrations of particulate nitrogen under pre-treatment conditions occurred during the wet season conditions, with more elevated concentrations observed during dry season conditions. This type of pattern is often observed in lakes with significant internal recycling which fuels algal growth during fall and winter conditions. Particulate nitrogen is clearly the dominant nitrogen species present in Booker Lake, comprising approximately 60-70% of the total nitrogen measured during the individual monitoring events.

Measured concentrations of total nitrogen in Booker Lake were also highly variable during the pre-treatment field monitoring program, with measured concentrations ranging from approximately 600-2000 μg/l. The temporal trends for total nitrogen are very similar to the trends exhibited by particulate nitrogen since this is the dominant nitrogen species in Booker Lake. In general, total nitrogen concentrations appear to be lowest during wet season conditions, with more elevated values observed during fall and winter conditions. The observed concentrations of total nitrogen in Booker Lake are typical of nitrogen concentrations commonly observed in eutrophic urban lakes.

A graphical summary of temporal variability in pre-treatment concentrations of phosphorus species in Booker Lake from July 2005-June 2006 is given on Figure 4-10. Similar to the trends observed for the previously discussed water quality parameters, measured concentrations of phosphorus species appear to be similar in value between the 3 monitoring sites during a given monitoring event.

Measured concentrations of soluble reactive phosphorus (SRP) were highly variable during the pre-treatment monitoring program, with measured values ranging from 1-9 μg/l. Although these values are small in comparison to total phosphorus concentrations, the measured SRP concentrations in Booker Lake are substantially elevated compared with SRP values commonly observed in urban lakes which typically are less than 2-4 μg/l. Significant spikes in SRP concentrations were observed at each of the 3 monitoring sites during December 2005 and April 2006. These observed increases in concentrations may be related to a significant rain event or, more likely, evidence of upwelling of nutrients released from the lake sediments.

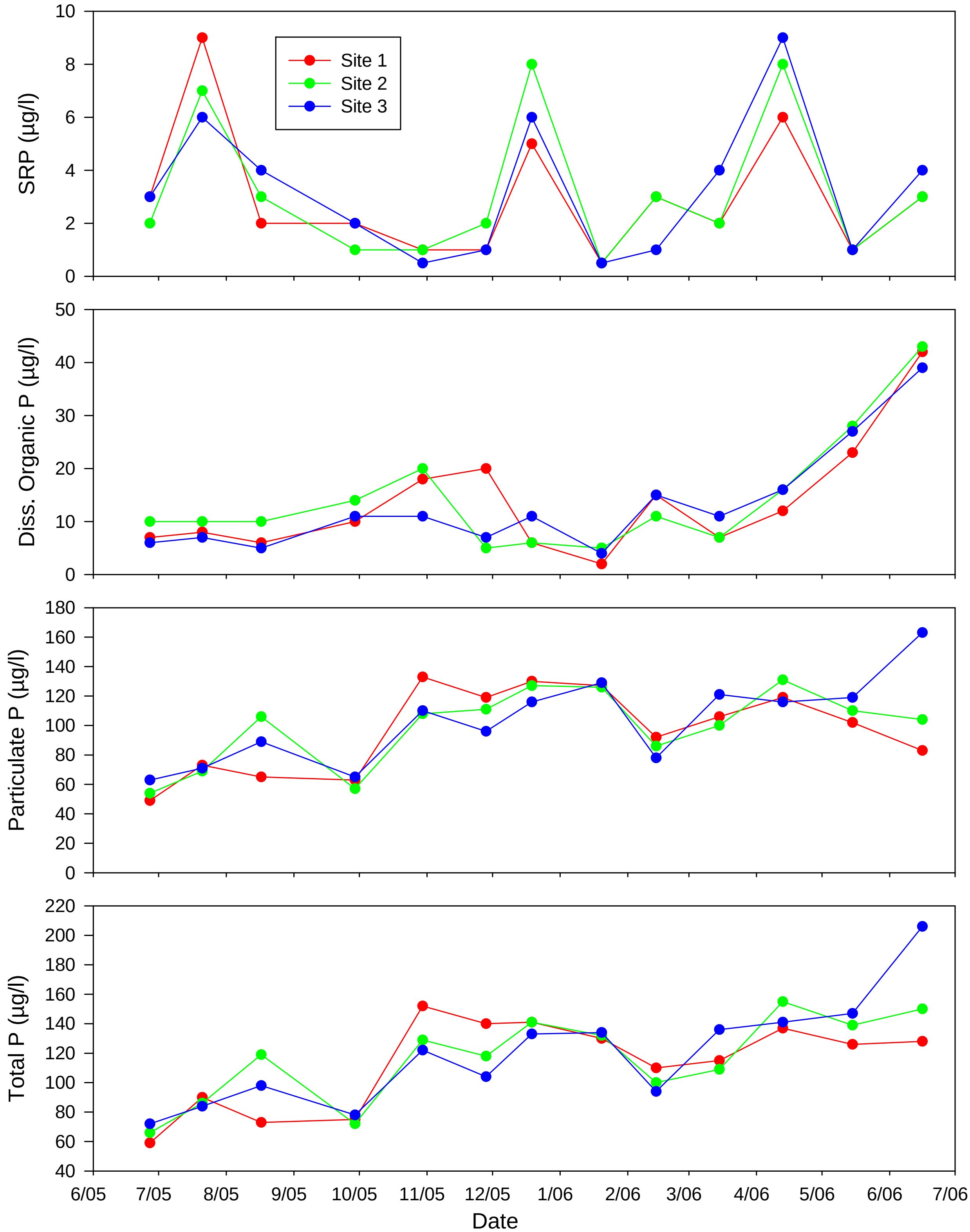


Figure 4-10. Variability in Pre-Treatment Concentrations of Phosphorus Species in Booker Lake from July 2005-June 2006.

Measured concentrations of dissolved organic phosphorus were generally low in value throughout the initial 8-9 months of the field monitoring program, with measured values ranging from near 0 to 20 μg/l. A steady increase in dissolved organic phosphorus was observed in Booker Lake beginning in April 2006 and continuing until the end of the pre-treatment monitoring program in June 2006. Measured concentrations of dissolved organic phosphorus were extremely close in value between the 3 monitoring sites.

Measured concentrations of particulate phosphorus in Booker Lake ranged from approximately 50-160 μg/l during the field monitoring program. In general, particulate phosphorus concentrations appear to be slightly greater during dry season conditions compared with wet season conditions. This type of pattern is often associated with internal recycling processes in eutrophic lakes. Particulate phosphorus is clearly the dominant form of phosphorus in Booker Lake, comprising 80-90% of the total phosphorus measured during each monitoring event.

Measured concentrations of total phosphorus exhibit a temporal pattern which is virtually identical to the pattern exhibited by particulate phosphorus. In general, total phosphorus concentrations in Booker Lake appear to be greatest during dry season conditions, with lower values measured during wet season conditions. The observed total phosphorus concentrations in Booker Lake are extremely elevated in value and much greater than total phosphorus concentrations commonly observed in urban lakes.

A graphical summary of temporal variability in pre-treatment concentrations of chlorophyll-a, Secchi disk depth, and dissolved aluminum in Booker Lake from July 2005-June 2006 is given on Figure 4-11. Measured concentrations of chlorophyll-a in Booker Lake ranged from approximately 20-160 mg/m^3 during the pre-treatment monitoring program, although the majority of values appear to range between 40-100 mg/m^3. Spikes in chlorophyll-a were observed during August 2005, presumably resulting from stormwater loadings to the lake, and from November-December 2005 which may be associated with nutrients introduced from internal recycling. Chlorophyll-a concentrations during the remaining portions of the pre-treatment monitoring program were relatively consistent in value.

Measured Secchi disk depth in Booker Lake under pre-treatment conditions ranged from approximately 0.5-1 m, with higher Secchi disk depth readings observed during wet season conditions and lower readings observed during dry season conditions. Recorded measurements between the 3 monitoring sites were extremely close in value throughout the entire field monitoring program. Measured concentrations of dissolved aluminum in Booker Lake were highly variable during the pre-treatment monitoring program, with measured concentrations ranging from 10-140 μg/l, although the majority of measured values were less than 80 μg/l.

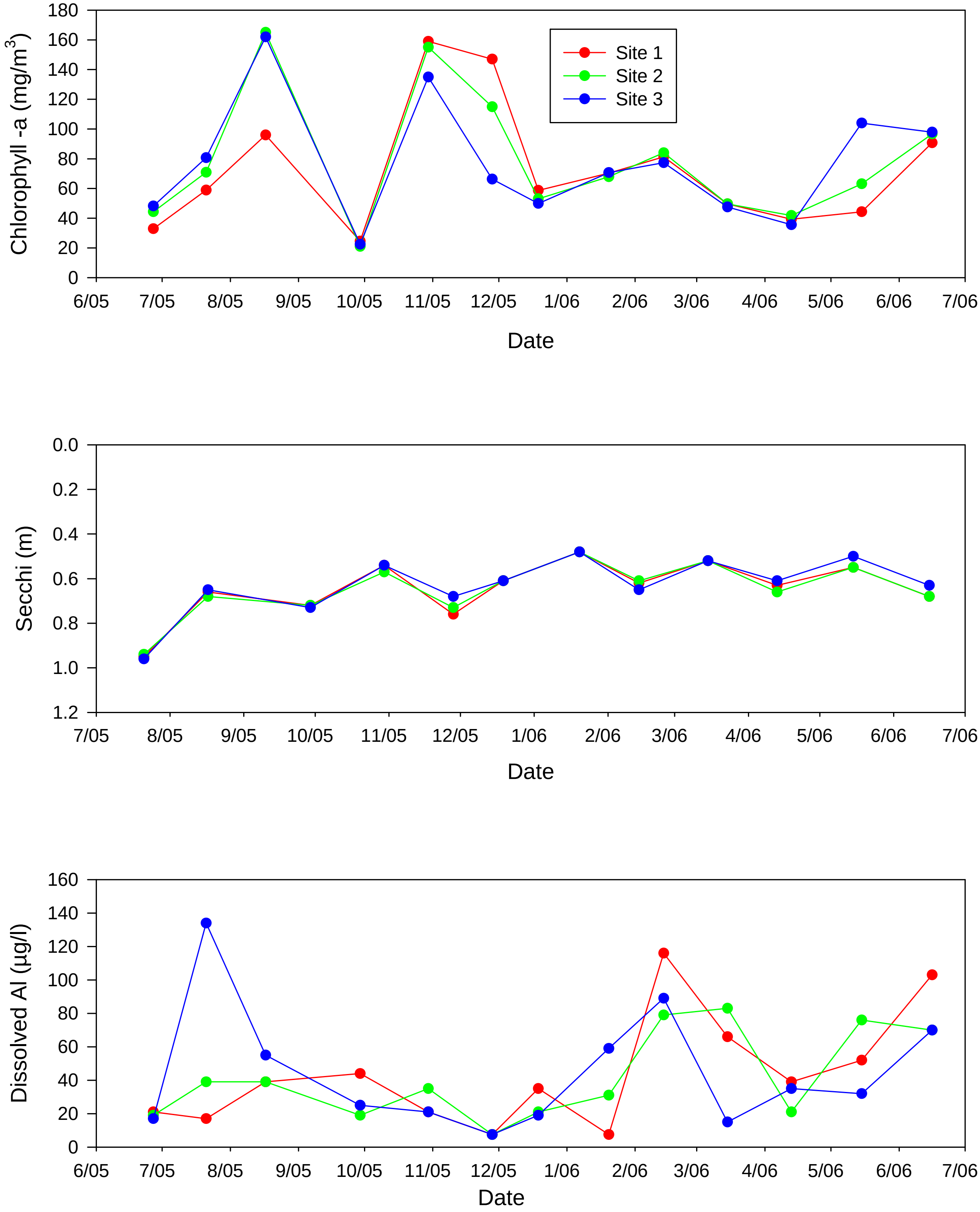


Figure 4-11. Variability in Pre-Treatment Concentrations of Chlorophyll-a, Secchi Disk Depth, and Dissolved Aluminum in Booker Lake from July 2005-June 2006.

In summary, pre-treatment water quality in Booker Lake is characterized by a relatively high degree of variability in concentrations for virtually all of the measured parameters which is a common characteristic of eutrophic waterbodies. Booker Lake contained highly variable and sometimes elevated concentrations of ammonia which, when combed with elevated pH values observed at times, could generate toxic levels of unionized ammonia. Measured total nitrogen concentrations within the lake were highly variable during the pre-treatment monitoring program, although the measured values are typical of total nitrogen concentrations commonly observed in urban lakes. Highly variable concentrations were observed for species of phosphorus, with particularly elevated levels for SRP and total phosphorus. The measured concentrations of total phosphorus in Booker Lake are substantially greater in value than phosphorus concentrations observed in eutrophic waterbodies. Measured concentrations of chlorophyll-a were also highly variable, with peaks in concentrations under both wet season and dry season conditions. Patterns of nutrient concentrations, chlorophyll-a, and Secchi disk depths in Booker Lake suggest that nutrient loadings, particularly for phosphorus, may be greater during dry season conditions. Increases in phosphorus loadings during dry season conditions often suggest the presence of internal recycling or a significant groundwater influence, particularly in view of the high levels of phosphorus in Pinellas County soils.

4.2.2.2 Post-Treatment Characteristics

A tabular summary of the chemical characteristics of post-treatment surface water samples collected in Booker Lake from November 2011-October 2012 is given on Table 4-2. As discussed previously, surface water monitoring under post-treatment conditions was conducted at a single monitoring location near the center of the lake since the pre-treatment field monitoring program indicated that Booker Lake is well-mixed. Summary statistics are provided which include minimum value, maximum value, median value, and geometric mean value. Since environmental data commonly exhibit log-normal distributions, the geometric mean is used in this evaluation as the primary measure of central tendency for each of the data sets.

A graphical summary of temporal variability in post-treatment concentrations of pH, alkalinity, conductivity, and TSS in Booker Lake from November 2011-October 2012 is given on Figure 4-12. Measured pH values in Booker Lake under post-treatment conditions ranged from approximately 7-8.2 and appear to be slightly lower than pH values measured during pre-treatment conditions. No significant seasonal trend is apparent in measured pH values within the lake.

Measured alkalinity values in Booker Lake under post-treatment conditions are similar in value to alkalinity measurements conducted under pre-treatment conditions, with more elevated concentrations during fall and winter conditions and lower alkalinity measurements during other portions of the year. A similar pattern is also exhibited by conductivity which appears to have more elevated values during dry season conditions compared with wet season conditions. This same pattern was observed under pre-treatment conditions. Measured TSS concentrations in Booker Lake were substantially lower in value during the post-treatment program than measured during the pre-treatment program, although a peak in concentration as high as 20 mg/l was observed on one occasion.

TABLE 4-2

CHEMICAL CHARACTERISTICS OF POST-TREATMENT SURFACE WATER SAMPLES COLLECTED IN BOOKER LAKE FROM NOVEMBER 2011 – OCTOBER 2012

Sample Location Site	Date Collected	pH (s.u.)	Alk. (mg/l)	NH_3 (µg/l)	NO_x (µg/l)	Diss. Org. N (µg/l)	Part. N (µg/l)	Total N (µg/l)	SRP (µg/l)	Diss. Org. P (µg/l)	Part. P (µg/l)	Total P (µg/l)	Turb. (NTU)	Color (Pt-Co)	Chyl-a (mg/m^3)	TSS (mg/l)	BOD (mg/l)	Fecal (cfu/100 ml)	Al (µg/l)
Middle	11/17/11	8.23	120	18	3	645	177	843	1	1	84	86	6.7	27	53.9	13.0	4.9	58	50
	12/29/11	7.09	135	285	59	410	150	904	3	2	85	90	5.6	28	31.6	6.2	5.2	78	53
	1/12/12	7.54	132	205	136	219	113	673	2	1	55	58	6.8	23	138	12.8	5.1	81	43
	2/8/12	7.51	133	66	6	230	248	550	3	9	114	126	6.5	28	104	10.9	4.8	46	71
	3/8/12	7.53	137	10	4	141	322	477	3	6	93	102	9.6	22	102	20.0	5.7	57	104
	4/10/12	8.16	134	3	3	175	233	414	3	9	48	60	5.8	29	33.6	10.4	4.0	20	131
	5/29/12	7.35	98.8	53	3	108	139	303	1	6	52	59	4.4	23	14.5	6.9	3.8	30	159
	6/19/12	7.49	92.4	37	3	194	227	461	2	1	53	56	4.9	17	63.1	8.6	5.0	35	132
	8/7/12	7.11	82.6	253	89	141	262	745	3	3	34	40	5.5	21	26.2	7.2	3.3	50	95
	8/29/12	7.02	79.2	8	32	126	189	355	3	3	28	34	3.7	20	50.0	3.0	3.1	39	109
	9/26/12	7.44	92.6	3	11	187	157	358	2	3	39	44	4.8	30	51.2	8.8	3.8	25	168
	10/18/12	7.54	96.8	65	29	147	160	401	3	4	21	28	3.8	21	37.3	6.5	3.0	73	112
	Minimum Value:	**7.02**	**79.2**	**3**	**3**	**108**	**113**	**303**	**1**	**1**	**21**	**28**	**3.7**	**17**	**14.5**	**3.0**	**3.0**	**20**	**43**
	Maximum Value:	**8.23**	**137**	**285**	**136**	**645**	**322**	**904**	**3**	**9**	**114**	**126**	**9.6**	**30**	**138**	**20.0**	**5.7**	**81**	**168**
	Median Value	**7.50**	**109**	**45**	**9**	**181**	**183**	**469**	**3**	**3**	**53**	**59**	**5.6**	**23**	**50.6**	**8.7**	**4.4**	**48**	**107**
	Geometric Mean:	**7.49**	**109**	**33**	**12**	**197**	**190**	**508**	**2**	**3**	**52**	**59**	**5.5**	**24**	**49.0**	**8.6**	**4.2**	**45**	**94**

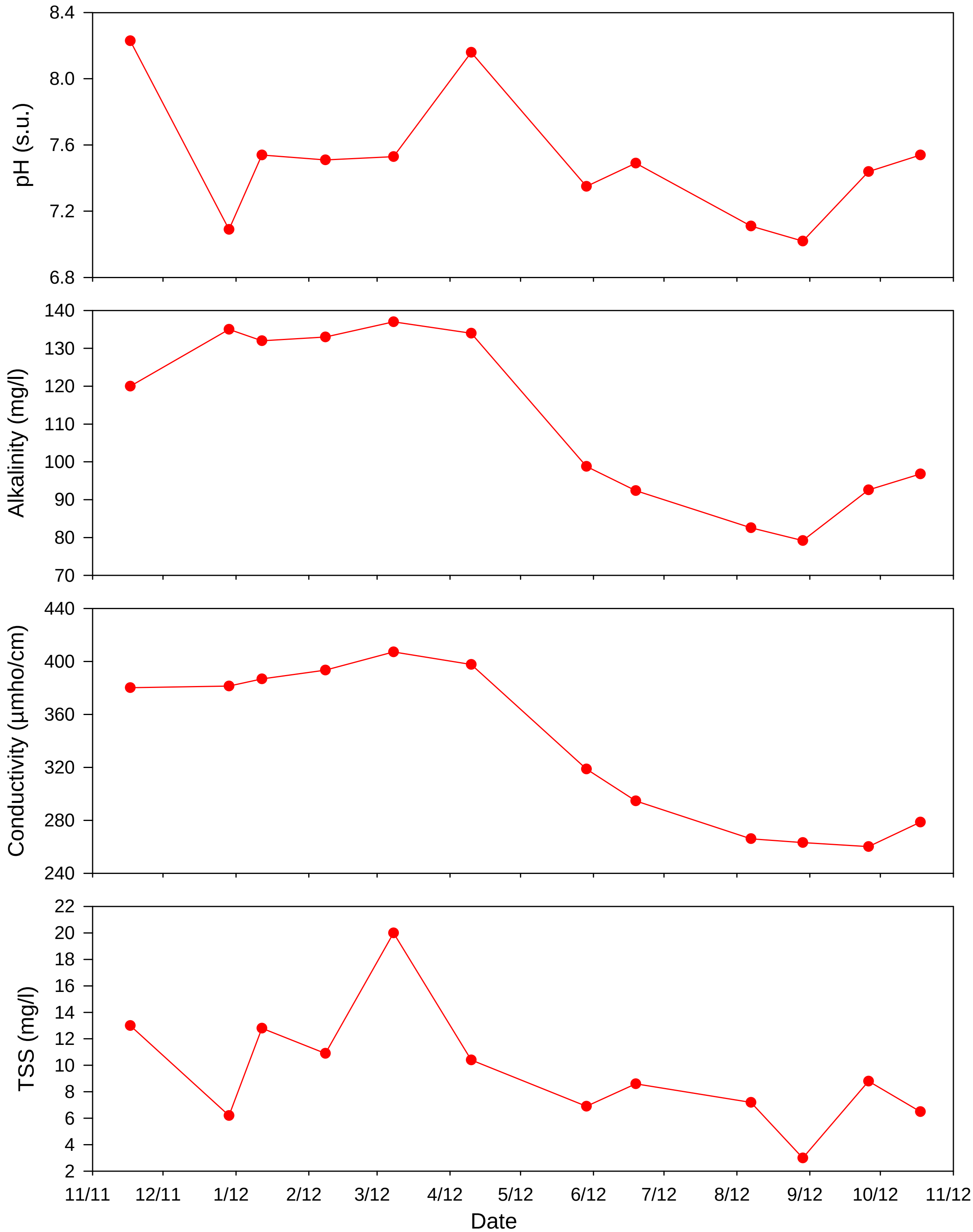


Figure 4-12. Variability in Post-Treatment Concentrations of pH, Alkalinity, Conductivity, and TSS in Booker Lake from November 2011-October 2012.

A graphical summary of temporal variability in post-treatment concentrations of nitrogen species in Booker Lake from November 2011-October 2012 is given on Figure 4-13. Under post-treatment conditions, ammonia concentrations exhibited peaks in value during late-fall/ early-winter and during the summer season, with measured concentrations ranging from approximately 250-300 μg/l. During remaining portions of the year, ammonia concentrations in Booker Lake were typically less than 50 μg/l. A similar pattern was also observed for concentrations of NO_x, with peaks during late-fall/winter conditions and during the summer rainy season, although the observed peak concentrations were only moderate in value. During other portions of the year, measured concentrations of NO_x were generally less than 40 mg/l, reflecting extremely low concentrations. Measured concentrations of particulate nitrogen under post-treatment conditions ranged from approximately 100-300 μg/l, with peak concentrations observed during late-winter and summer conditions, although the relative increase in concentrations for particulate nitrogen is not as great as the observed increases for ammonia and NO_x.

Measured concentrations of total nitrogen in Booker Lake during the post-treatment monitoring program ranged from approximately 300-900 μg/l. The most elevated total nitrogen concentrations were observed during late-fall/early-winter and summer conditions, similar to the peaks exhibited by ammonia and NO_x. However, measured concentrations of total nitrogen under post-treatment conditions were generally low in value in comparison with nitrogen concentrations commonly observed in urban lakes.

A graphical summary of temporal variability in post-treatment concentrations of phosphorus species in Booker Lake from November 2011-October 2012 is given on Figure 4-14. In general, SRP concentrations were low in value under post-treatment conditions, with measured values ranging from 1-3 μg/l. Concentrations of dissolved organic phosphorus were also low in value, ranging from 1-9 μg/l. Moderate concentrations of particulate phosphorus were observed during the post-treatment monitoring program, with measured values ranging from approximately 20-110 μg/l. However, the majority of measured concentrations were less than 50 μg/l.

Trends in total phosphorus concentrations generally mimic the trends exhibited by particulate phosphorus since particulate phosphorus is the dominant phosphorus species present under post-treatment conditions, representing more than 90% of the total phosphorus present during most of the monitoring events. In general, post-treatment total phosphorus concentrations were low in value, particularly during the final 6 months of the field monitoring program.

Temporal trends in post-treatment concentrations of chlorophyll-a, Secchi disk depth, and dissolved aluminum in Booker Lake from November 2011-October 2012 are summarized on Figure 4-15. Measured concentrations of chlorophyll-a exhibited a peak in late-fall/early-winter, with concentrations reaching approximately 140 mg/m^3. However, during much of the remaining portion of the year, chlorophyll-a concentrations were generally 60 mg/m^3 or less, reflecting moderately elevated values. Measured Secchi disk depths under post-treatment conditions ranged from approximately 0.4-1.0 m, reflecting poor to moderate water clarity. Water clarity was poorest during fall and winter conditions, with the greatest transparency observed during wet season conditions.

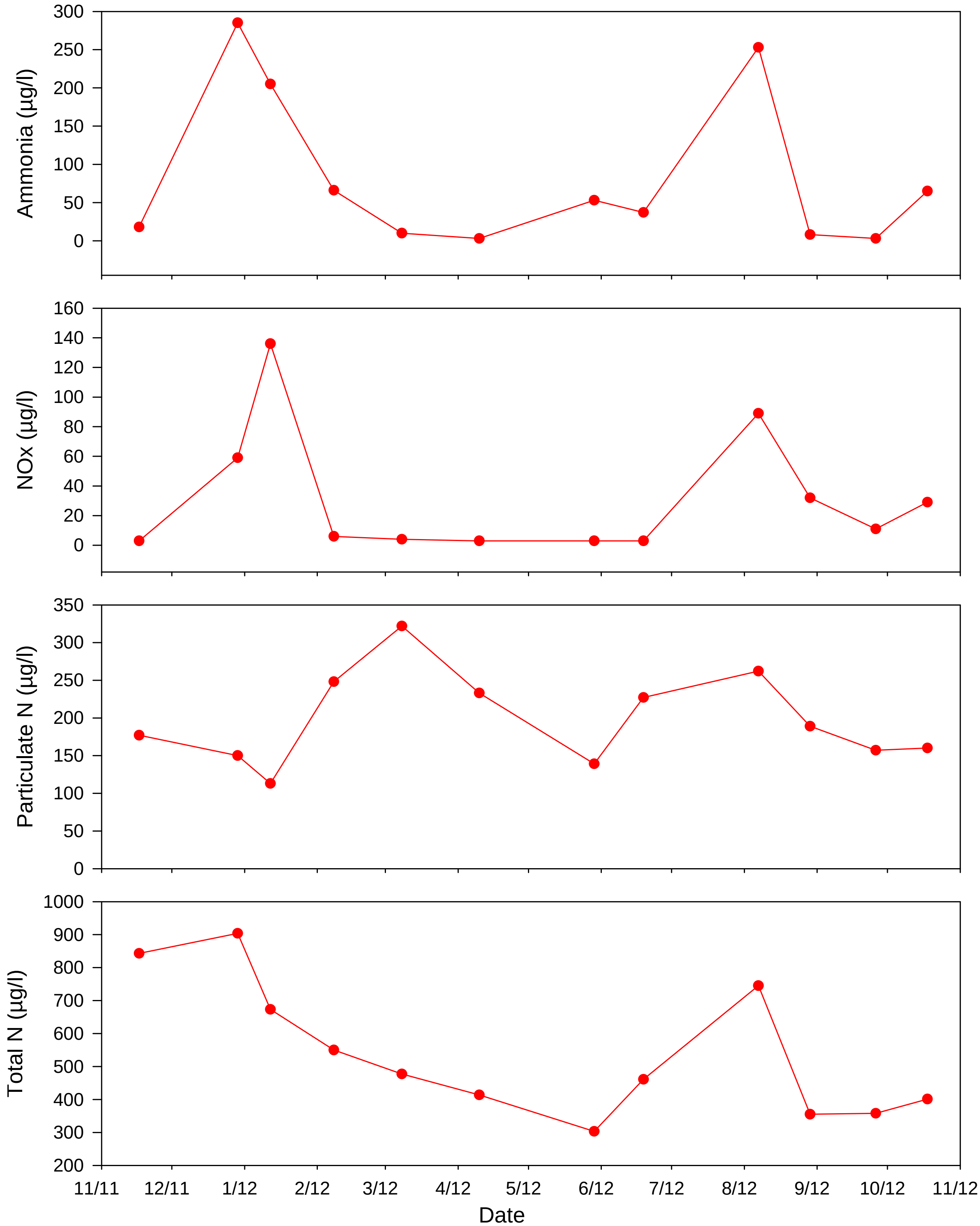


Figure 4-13. Variability in Post-Treatment Concentrations of Nitrogen Species in Booker Lake from November 2011-October 2012.

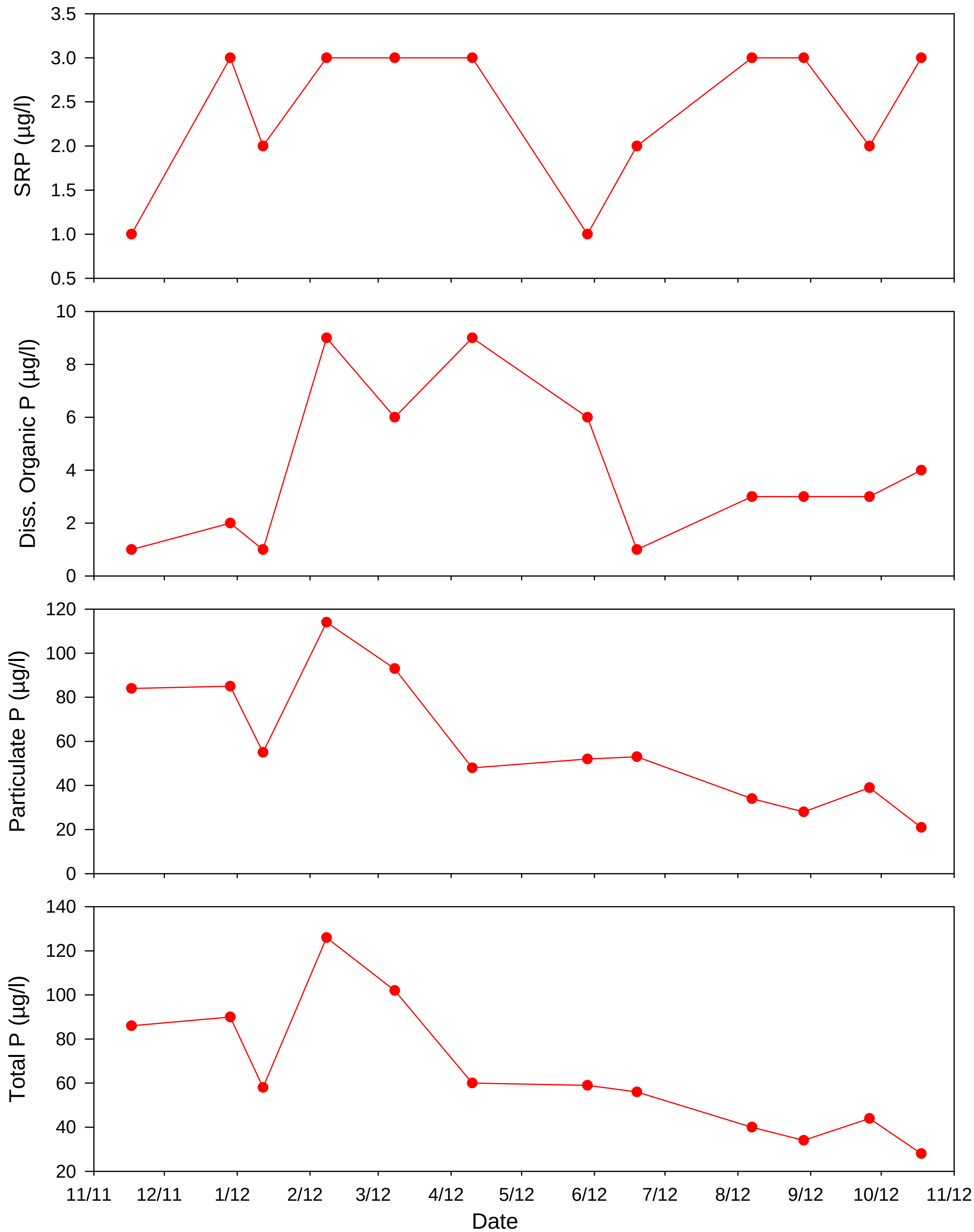


Figure 4-14. Variability in Post-Treatment Concentrations of Phosphorus Species in Booker Lake from November 2011-October 2012.

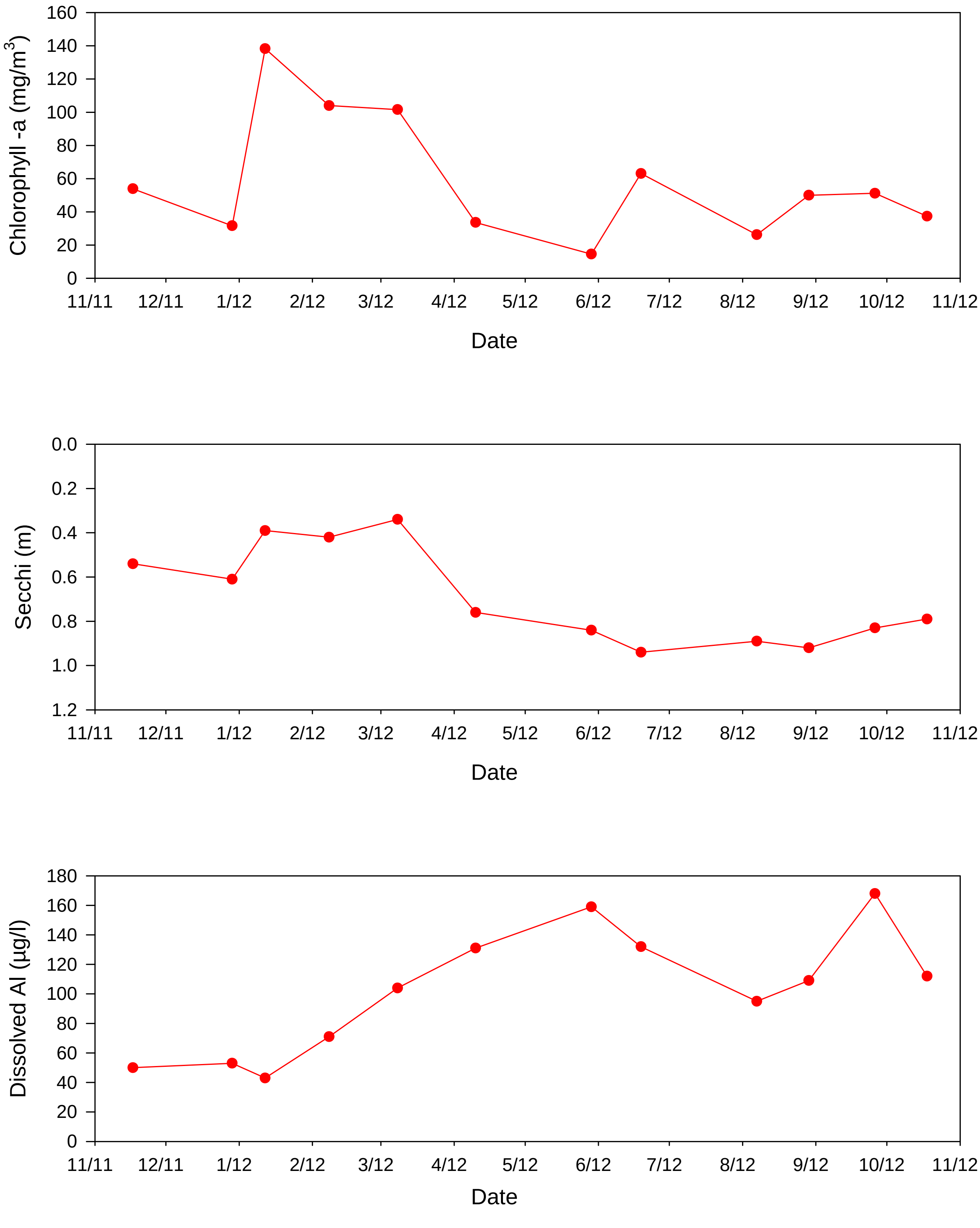


Figure 4-15. Variability in Post-Treatment Concentrations of Chlorophyll-a, Secchi Disk Depth, and Dissolved Aluminum in Booker Lake from November 2011-October 2012.

Measured concentrations of dissolved aluminum in Booker Lake under post-treatment conditions ranged from approximately 40-160 μg/l, although the vast majority of measured values were less than 120 μg/l. The observed concentrations for dissolved aluminum are moderate to low in value and well below concentrations which would create toxicity concerns in Florida lakes.

4.2.2.3 Comparison of Pre- vs. Post-Characteristics

A graphical comparison of pre- vs. post-treatment concentrations of pH, alkalinity, conductivity, and TSS in Booker Lake is given on Figure 4-16. Under post-treatment conditions, measured pH values in Booker Lake ranged from approximately 7.0-8.3, with pre-treatment pH measurements ranging from 7.6-8.6. Post-treatment pH values were lower in value than pre-treatment measurements during 10 of the 12 monitoring events. Since the addition of alum results in a reduction in pH, the observed lower pH values under post-treatment conditions are presumably due to addition of alum to the lake.

Measured alkalinity values under pre- and post-treatment conditions were very similar during the initial 6-7 months of field monitoring. However, during summer and fall conditions, measured alkalinity values were slightly lower under post-treatment conditions, presumably resulting from alkalinity consumption by the alum addition. The minimum measured alkalinity value in Booker Lake was approximately 80 mg/l under both pre- and post-treatment conditions, reflecting moderately well-buffered conditions.

Measured conductivity values in Booker Lake appear to be relatively similar under both pre- and post-treatment conditions, with more elevated conductivity values observed under post-treatment conditions during 6 of the monitoring events and more elevated conductivity values under pre-treatment conditions during the remaining events. In general, the alum treatment system does not appear to have had a significant impact on the measured conductivity values in Booker Lake.

Measured concentrations of TSS in Booker Lake appear to be relatively similar under pre- and post-treatment conditions during a majority of the monitoring events. With the exception of the December monitoring event, there appears to be no significant difference between TSS measurements conducted under pre- vs. post-treatment conditions.

A graphical comparison of pre- vs. post-treatment concentrations of nitrogen species in Booker Lake is given on Figure 4-17. Measured concentrations of ammonia, particulate nitrogen, and total nitrogen were generally lower in value under post-treatment conditions than observed under pre-treatment conditions, with the exception of monitoring conducted during July. For total nitrogen, post-treatment concentrations appear to be substantially lower in value than the pre-treatment measurements. It appears that the alum treatment system provided reductions in concentrations of ammonia, particulate nitrogen, and total nitrogen, with no significant change in measured concentrations of NO_x.

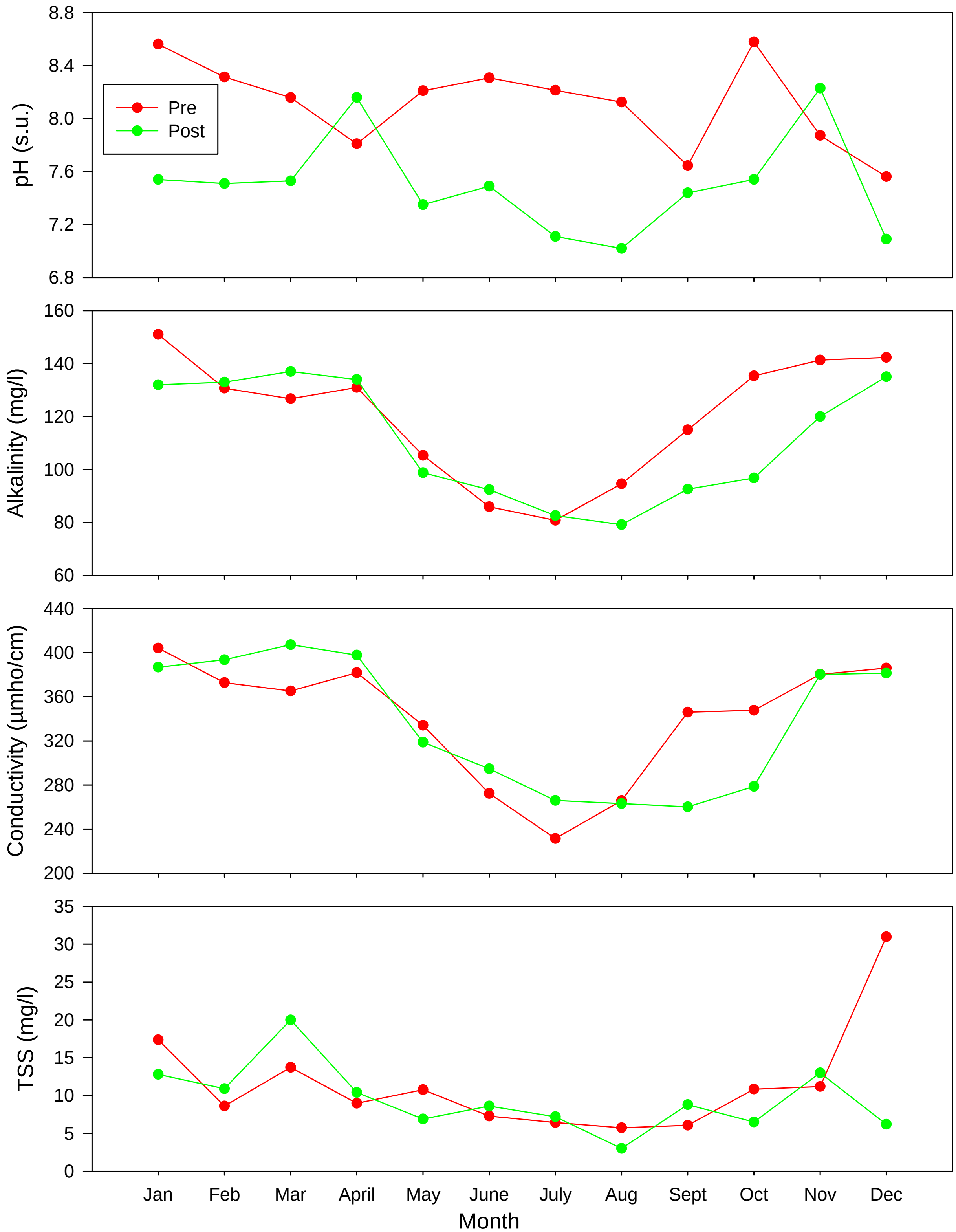


Figure 4-16. Comparison of Pre- vs. Post-Treatment Concentrations of pH, Alkalinity, Conductivity, and TSS in Booker Lake.

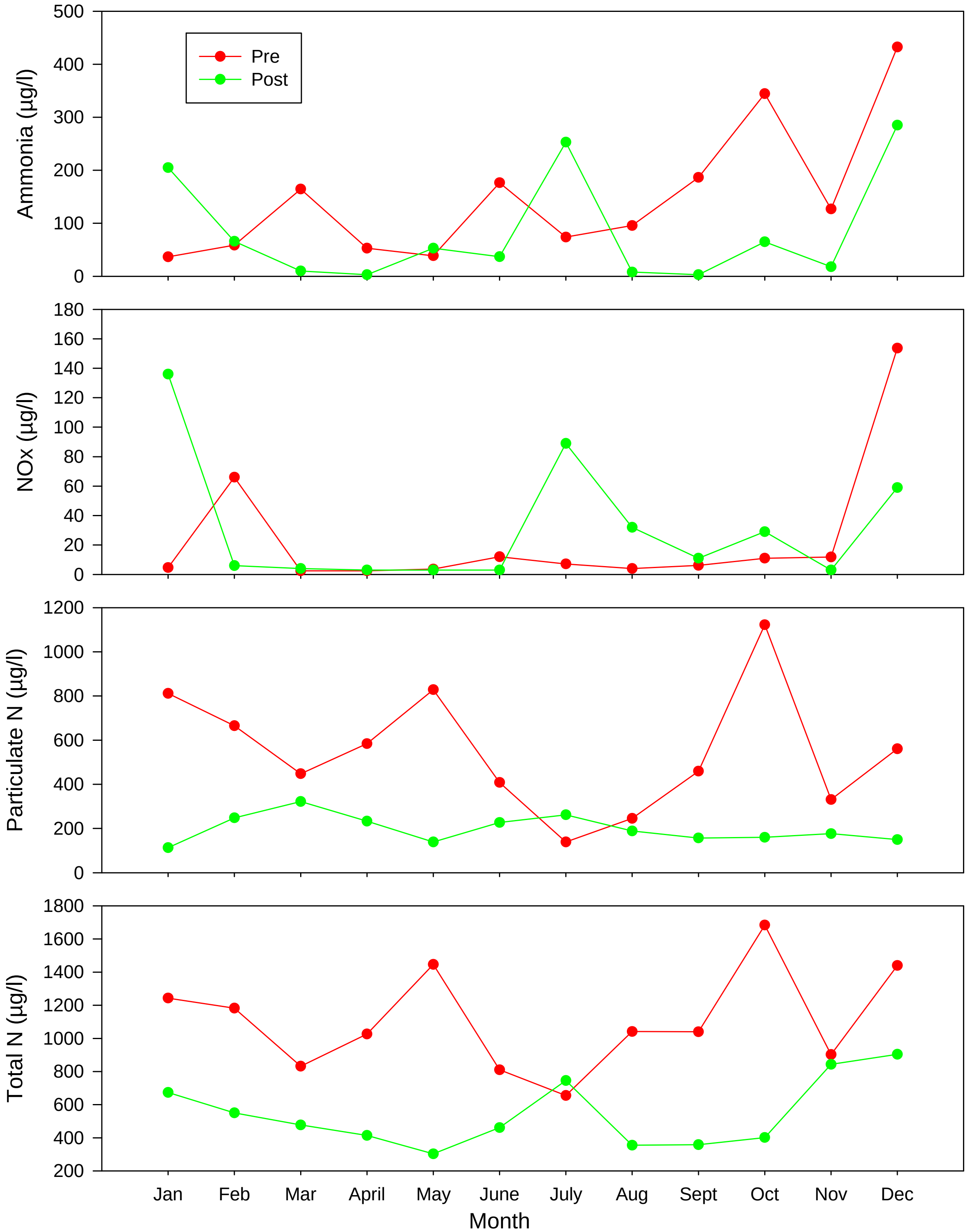


Figure 4-17. Comparison of Pre- vs. Post-Treatment Concentrations of Nitrogen Species in Booker Lake.

A graphical comparison of pre- vs. post-treatment concentrations of phosphorus species in Booker Lake is given on Figure 4-18. Post-treatment concentrations for SRP, dissolved organic phosphorus, particulate phosphorus, and total phosphorus are all lower in value during a majority of the monitoring events compared with pre-treatment conditions. The observed differences in phosphorus concentrations under pre- and post-treatment conditions are particularly visible for dissolved organic phosphorus, particulate phosphorus, and total phosphorus. Post-treatment concentrations of total phosphorus in Booker Lake ranged from approximately 25-120 μg/l, with pre-treatment concentrations ranging from approximately 80-140 μg/l.

A graphical comparison of pre- vs. post-treatment concentrations of chlorophyll-a, Secchi disk depth, and dissolved aluminum in Booker Lake is given on Figure 4-19. During the first few months of the field monitoring program, post-treatment concentrations of chlorophyll-a were higher in value than pre-treatment concentrations. However, beginning in April, post-treatment chlorophyll-a concentrations were substantially lower in value than the pre-treatment values. A similar pattern was also observed for Secchi disk depth, with lower Secchi disk depths observed under post-treatment conditions during the initial few months of the monitoring program, followed by substantially greater Secchi disk depths under post-treatment conditions for much of the remainder of the monitoring program.

Pre-treatment concentrations of dissolved aluminum in Booker Lake ranged from approximately 10-100 μg/l. Under post-treatment conditions, dissolved aluminum concentrations ranged from 40-170 μg/l, reflecting an increase under post-treatment conditions. However, although slight increases in dissolved aluminum were observed, the resulting absolute concentrations are well below any documented toxicity levels for Florida fauna or flora.

A comparison of mean pre- and post-treatment characteristics in Booker Lake is given on Table 4-3. The data summarized in Table 4-3 reflect mean values for the entire 12-month pre- and post-treatment monitoring programs. Reductions in concentrations were observed under post-treatment conditions for each of the measured parameters, with the exception of dissolved aluminum which exhibited a slight increase. Measured concentrations of pH decreased by approximately 8% under post-treatment conditions, with a 5% decrease in alkalinity. Substantial reductions were observed for nitrogen species, with a 68% reduction in ammonia, 42% reduction in NO_x, 34% reduction in dissolved organic nitrogen, 55% reduction in particulate nitrogen, and 51% in total nitrogen.

Similar removal efficiencies were also observed for measured phosphorus species, with a 15% reduction in SRP, 72% reduction in dissolved organic phosphorus, 45% reduction in particulate phosphorus, and 47% reduction in total phosphorus. Alum is well known for its ability to remove inorganic phosphorus, and the observed relatively low removal efficiencies for phosphorus appear to be related to the sporadic operation of the system. Alum treatment of runoff entering Booker Lake resulted in a 2% reduction in turbidity, 10% reduction in color, 26% reduction in chlorophyll-a, and a 10% reduction in TSS. For chlorophyll-a, post-treatment concentrations decreased from 66.6 mg/m^3 under pre-treatment conditions to 49.0 mg/m^3 under post-treatment conditions. Measured BOD concentrations were reduced by approximately 10%, with a 53% reduction in fecal coliform bacteria. Removal efficiencies for these parameters are also substantially lower than commonly observed and are also likely related to the sporadic system operation. The only parameter which exhibited an increase in concentration was dissolved aluminum, which increased from 39 mg/l to 94 mg/l. However, the observed increased concentrations of aluminum are well below concentrations which would cause toxicity issues to flora or fauna in the State of Florida.

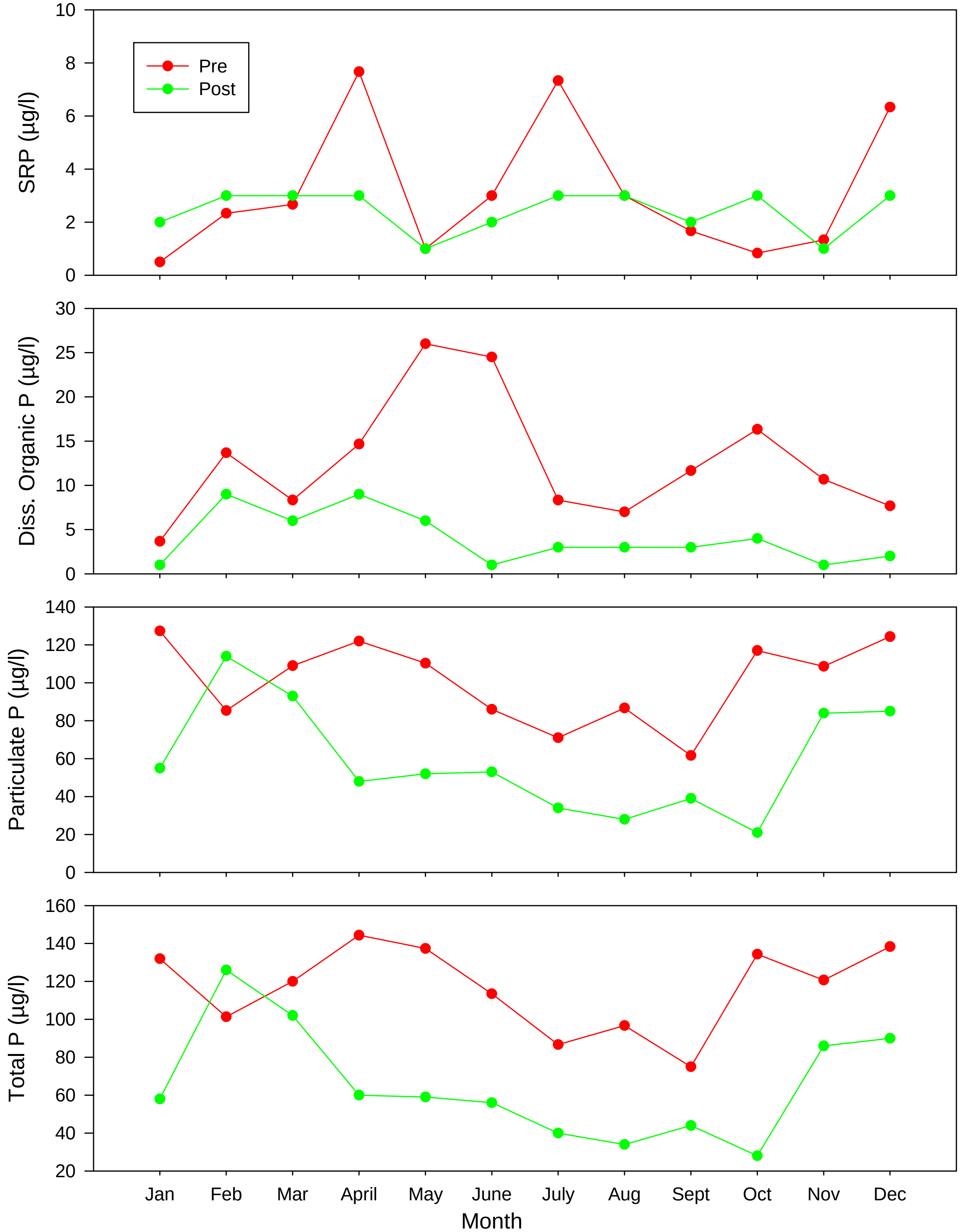


Figure 4-18. Comparison of Pre- vs. Post-Treatment Concentrations of Phosphorus Species in Booker Lake.

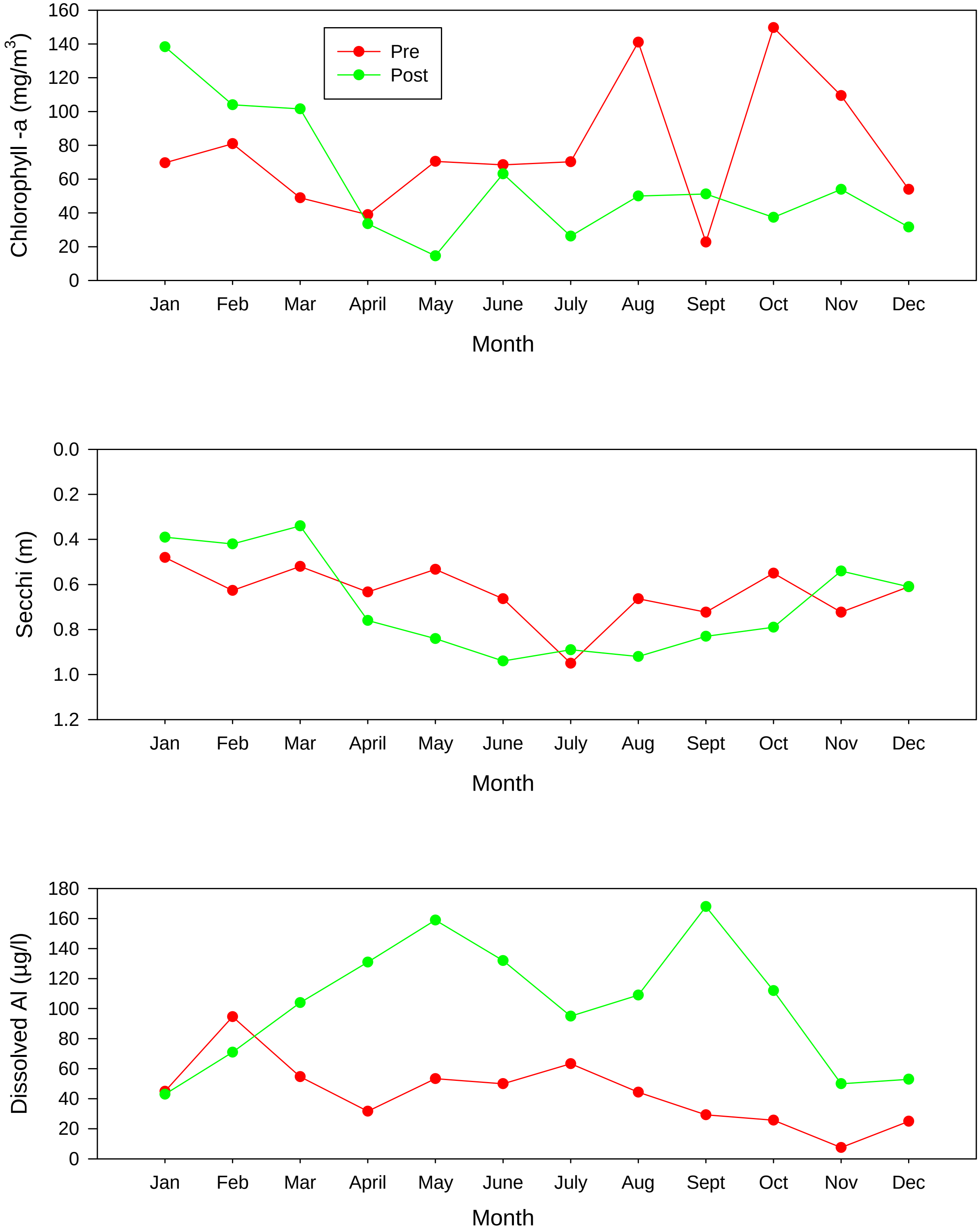


Figure 4-19. Comparison of Pre- vs. Post-Treatment Concentrations of Chlorophyll-a, Secchi Disk Depth, and Dissolved Aluminum in Booker Lake.

TABLE 4-3

COMPARISON OF MEAN PRE- AND POST-TREATMENT CHARACTERISTICS IN BOOKER LAKE

PARAMETER	UNITS	PRE-TREATMENT[1] (7/05-6/06)	POST-TREATMENT[1] (11/11-10/12)	PERCENT CHANGE (%)
pH	s.u.	8.12	7.49	-8
Alkalinity	mg/l	115	109	-5
NH_3	µg/l	104	33	-68
NO_x	µg/l	21	12	-42
Diss. Organic N	µg/l	300	197	-34
Particulate N	µg/l	418	190	-55
Total N	µg/l	1,037	508	-51
SRP	µg/l	3	2	-15
Diss. Organic P	µg/l	11	3	-72
Particulate P	µg/l	96	52	-45
Total P	µg/l	112	59	-47
Turbidity	NTU	5.6	5.5	-2
Color	Pt-Co	26	24	-10
Chlorophyll-a	mg/m^3	66.6	49.0	-26
TSS	mg/l	9.6	8.6	-10
BOD	mg/l	4.7	4.2	-10
Fecal Coliform	cfu/100 ml	97	45	-53
Aluminum	µg/l	39	94	139

1. Includes all data collected during the pre- and post-treatment monitoring programs

4.3 Sediment Characteristics

This section provides a discussion of the physical and chemical characteristics of sediment samples collected in Booker Lake under pre- and post-treatment conditions.

4.3.1 Pre-Treatment Sediment Characteristics

As discussed in Section 3.2, pre-treatment sediment core samples were collected in Booker Lake at each of the 3 monitoring locations indicated on Figure 3-1 on July 21, 2005 near the beginning of the pre-treatment field monitoring program. Triplicate core samples were collected at each of the 3 monitoring sites, with the triplicate samples combined together to form a single composite sediment sample for each of the 3 monitoring sites. Each of the collected pre-treatment sediment samples was evaluated for general characteristics and nutrients.

A summary of the characteristics of pre-treatment sediment core samples collected in Booker Lake on July 21, 2005 is given on Table 4-4. The collected sediment samples were slightly acidic, with measured pH values ranging from 6.42-6.59 and an overall geometric mean of 6.48. The pre-treatment sediment samples were characterized by elevated moisture contents ranging from 65.9-79.2%, with an overall geometric mean of 73.6%. Sediments with moisture contents in this range are commonly associated with organic muck type sediments. Measured organic contents within the sediments ranged from 19.2-40.4%, with an overall geometric mean of 25.2%. Sediments with organic contents in this range are also characteristic of highly organic muck type sediments. Measured sediment densities were also low in value, ranging from 1.19-1.41 g/cm^3 with an overall geometric mean of 1.29 g/cm^3. Sediments with measured densities less than approximately 1.5 g/cm^3 are also indicative of organic muck type sediments.

TABLE 4-4

CHARACTERISTICS OF PRE-TREATMENT SEDIMENT CORE SAMPLES COLLECTED IN BOOKER LAKE ON JULY 21, 2005

SITE	pH (s.u.)	MOISTURE CONTENT (%)	ORGANIC CONTENT (%)	DENSITY (g/cm^3)	TOTAL NITROGEN (μg/cm^3)	TOTAL PHOSPHORUS (μg/cm^3)
1	6.44	65.9	19.2	1.41	638	548
2	6.42	76.3	20.7	1.28	589	507
3	6.59	79.2	40.4	1.19	585	407
Geometric Mean	**6.48**	**73.6**	**25.2**	**1.29**	**604**	**483**

Relatively low levels of total nitrogen were measured in the pre-treatment Booker Lake sediment core samples, with values ranging from 585-638 g/cm^3 and an overall geometric mean of 604 g/cm^3. Sediment nitrogen concentrations in this range are somewhat lower than nitrogen concentrations commonly observed in lake sediments. Measured phosphorus concentrations in the pre-treatment Booker Lake sediment core samples ranged from 407-548 g/cm^3, with an overall geometric mean of 483 g/cm^3. Phosphorus concentrations in this range are typical of concentrations commonly observed in urban lakes.

Overall, the pre-treatment sediment characteristics in Booker Lake are similar to characteristics commonly observed in sediments of eutrophic lakes. The pre-treatment samples were characterized by elevated levels of moisture content and organic content and low wet density values, all of which are consistent with organic muck.

4.3.2 Post-Treatment Sediment Characteristics

Post-treatment sediment core samples were collected in Booker Lake on October 18, 2012 near the completion of the post-treatment monitoring program. During the post-treatment sediment monitoring event, each of the triplicate core samples was placed into separate bottles and analyzed separately, resulting in a total of 9 individual core samples submitted for analysis. The post-treatment sediment core samples were collected from the same monitoring locations indicated on Figure 3-1. Laboratory analyses were conducted for general sediment characteristics, along with sediment phosphorus speciation.

A summary of the characteristics of post-treatment sediment core samples collected in Booker Lake is given on Table 4-5. Mean values for each of the triplicate samples collected at the 3 monitoring locations are provided at the bottom of Table 4-5, along with an overall geometric mean for the post-treatment sediment characteristics. Post-treatment sediments collected in Booker Lake were slightly acidic, with mean pH values measured at each of the 3 monitoring sites ranging from 6.47-6.49. The post-treatment sediment core samples were also characterized by substantially elevated moisture contents, with mean values for the 3 sites ranging from 73.6-79.7%, and elevated organic contents, ranging from 21.1-30.4% between the 3 monitoring sites. The elevated concentrations observed for moisture content and organic content are indicative of organic muck type sediments. Measured wet densities for the three monitoring sites ranged from 1.21-1.3 g/cm^3, also indicative of highly organic sediments.

TABLE 4-5

CHARACTERISTICS OF POST-TREATMENT SEDIMENT CORE SAMPLES COLLECTED IN BOOKER LAKE ON OCTOBER 18, 2012

SITE		pH	MOISTURE CONTENT (%)	ORGANIC CONTENT (%)	DENSITY (g/cm^3)	TOTAL N (µg/cm^3)	TOTAL P (µg/cm^3)	SALOID-BOUND P (µg/cm^3)	IRON-BOUND P (µg/cm^3)	TOTAL AVAILABLE P		Al-BOUND P (µg/cm^3)
										(µg/cm^3)	% of TP	
1-A		6.45	65.9	15.8	1.43	524	459	13	66	79	17	256
1-B		6.49	76.3	23.6	1.27	540	473	9	65	74	16	246
1-C		6.46	79.2	25.0	1.23	500	435	11	63	73	17	234
2-A		6.47	82.9	28.4	1.18	519	393	11	57	69	17	200
2-B		6.51	79.0	24.4	1.24	536	334	10	51	61	18	195
2-C		6.50	72.4	20.9	1.33	523	373	12	55	67	18	222
3-A		6.46	80.7	32.4	1.20	526	449	12	61	73	16	227
3-B		6.53	80.4	31.2	1.20	548	404	8	57	65	16	200
3-C		6.49	77.5	27.8	1.24	527	310	8	55	63	20	180
Mean Values	**1**	**6.47**	**73.6**	**21.1**	**1.31**	**521**	**456**	**11**	**65**	**76**	**17**	**245**
	2	**6.49**	**78.0**	**24.4**	**1.25**	**526**	**366**	**11**	**55**	**65**	**18**	**205**
	3	**6.49**	**79.6**	**30.4**	**1.21**	**534**	**383**	**9**	**58**	**67**	**17**	**201**
Overall Mean		**6.48**	**77.0**	**25.0**	**1.26**	**527**	**400**	**10**	**59**	**69**	**17**	**216**

Measured sediment concentrations of total nitrogen were relatively consistent between the 3 post-treatment monitoring sites, ranging from 521-534 $\mu g/cm^3$. Total nitrogen concentrations in this range are somewhat lower than nitrogen concentrations commonly observed in urban lakes. Measured total phosphorus concentrations in the post-treatment sediments ranged from 366-456 $\mu g/cm^3$ between the 3 monitoring sites which are typical of values commonly observed in urban lakes.

As discussed in Section 3.2.2, a fractionation procedure for inorganic sediment phosphorus was also conducted on the post-treatment sediment core samples collected from Booker Lake. Saloid-bound phosphorus (reflecting phosphorus which is soluble or easily exchangeable within the sediments) ranged from 9-11 $\mu g/cm^3$ between the 3 monitoring sites. Values in this range are typical of saloid-bound phosphorus concentrations commonly observed in untreated lake sediments. Iron-bound phosphorus concentrations in the sediments ranged from 55-65 $\mu g/cm^3$ which is also typical of the range of iron-bound phosphorus concentrations observed in untreated lake sediments. Total available phosphorus (defined as the sum of saloid plus iron-bound phosphorus) ranged from 65-76 $\mu g/cm^3$ which is also typical of values commonly observed in untreated lake sediments. Overall, the available phosphorus within the sediments reflected approximately 17-18% of the total phosphorus present within the sediments.

Aluminum-bound phosphorus concentrations in the post-treatment sediment core samples ranged from 201-245 $\mu g/cm^3$. These values are substantially greater than aluminum-bound phosphorus concentrations observed in urban lakes and indicate that approximately half of the phosphorus within the sediments in bound with aluminum. Since these elevated aluminum-bound concentrations were observed throughout the entire lake, it is unlikely that these values were significantly impacted by accumulation of alum floc within the sediments and appear to indicate a high natural bonding of sediment phosphorus with aluminum in Booker Lake which appears to be unrelated to the alum treatment system.

4.3.3 Comparison of Pre- vs. Post-Treatment Sediment Characteristics

A comparison of pre- and post-treatment sediment characteristics in Booker Lake is given on Table 4-6. Mean values are provided for measured sediment characteristics at each of the 3 sites under pre- and post-treatment conditions as well as overall mean values for each of the two monitoring events. Operation of the alum treatment system does not appear to have resulted in any measurable change in sediment pH at any of the 3 monitoring sites, with mean sediment pH values under pre- and post-treatment conditions each equal to 6.48. Operation of the alum stormwater treatment system resulted in slight increases in measured moisture contents at Sites 1 and 2, with no measurable change in moisture content in sediments collected at Site 3. Overall, the pre-treatment sediment core samples were characterized by a mean moisture content of 73.6% compared with a mean moisture content of 77.0% for the post-treatment samples. Although this difference is not statistically significant, introduction of alum floc into sediments has been shown to result in slight increases in moisture content due to the relatively high moisture content of alum floc.

TABLE 4-6

COMPARISON OF PRE- AND POST-TREATMENT SEDIMENT CHARACTERISTICS IN BOOKER LAKE

SITE	CONDITION	pH	MOISTURE CONTENT (%)	ORGANIC CONTENT (%)	DENSITY (g/cm^3)	TOTAL NITROGEN ($\mu g/cm^3$)	TOTAL PHOSPHORUS ($\mu g/cm^3$)
1	Pre	6.44	65.9	19.2	1.41	638	548
	Post	6.47	73.6	21.1	1.31	521	456
2	Pre	6.42	76.3	20.7	1.28	589	507
	Post	6.49	78.0	24.4	1.25	526	366
3	Pre	6.59	79.2	40.4	1.19	585	407
	Post	6.49	79.6	30.4	1.21	534	383
Overall Mean	**Pre**	**6.48**	**73.6**	**25.2**	**1.29**	**604**	**483**
	Post	**6.48**	**77.0**	**25.0**	**1.26**	**527**	**400**

Similar to the trends observed for moisture content, slight increases in organic content were observed at Sites 1 and 2, although a reduction in organic content was observed at Site 3. Overall, the pre-treatment mean sediment organic content was approximately 25.2% compared with a post-treatment organic content of 25.0%. In general, operation of the alum treatment system does not appear to have significantly impacted organic content within the sediments of Booker Lake.

Slight reductions in sediment density were observed at Sites 1 and 2 under post-treatment conditions, with no significant change in measured density values at Site 3. The observed reductions in sediment density at Sites 1 and 2 are likely related to the additional moisture content of the alum floc which may have accumulated in these areas. Overall, the pre-treatment mean wet sediment density was 1.29 g/cm^3 compared with a post-treatment wet density of 1.26 g/cm^3.

Measured sediment nitrogen concentrations in Booker Lake were relatively similar under pre- and post-treatment conditions. Sediment nitrogen concentrations are often highly variable in lakes, and the observed differences in pre- and post-treatment sediment nitrogen concentrations are within the normal range of variability anticipated when collecting and analyzing lake sediments for nitrogen. The pre-treatment mean total sediment nitrogen concentration was 604 $\mu g/cm^3$ compared with a post-treatment mean total nitrogen concentration of 527 $\mu g/cm^3$. Since there is no conceivable mechanism by which alum should alter sediment nitrogen concentrations, the observed differences in concentrations are likely related to ordinary variability within the lake.

Measured concentrations of total phosphorus were relatively similar in Booker Lake under both pre- and post-treatment conditions. Since alum floc binds with sediment phosphorus, but does not eliminate it, there should be no significant difference between measured phosphorus concentrations under pre- and post-treatment conditions. The measured mean total phosphorus concentration under pre-treatment concentrations was 483 $\mu g/cm^3$ compared with a post-treatment mean phosphorus sediment concentration of 400 $\mu g/cm^3$. These apparent differences are likely due to normal variability in collection and analysis of sediment phosphorus.

In general, operation of the alum treatment system for Booker Lake has not resulted in any significant changes to sediment characteristics within the lake. Addition of the alum floc has had no impact on pH, although a slight increase in moisture content may have occurred. Virtually no change is apparent in measured organic contents within the lake sediments. Measured concentrations of total nitrogen and total phosphorus in the lake sediments are relatively similar under pre- and post-treatment conditions.

4.4 Floc Accumulation

As discussed in Section 3.4, field monitoring was conducted by ERD under post-treatment conditions to evaluate the rate of floc accumulation in Booker Lake resulting from treatment of inflows from the northern and western channels. Underwater staff gauges were installed at 10 separate locations, as indicated on Figure 3-6, and measurements of relative sediment depth were made on approximately a monthly-bimonthly basis using an underwater video camera.

A tabular summary of field measurements of underwater staff gauge readings in Booker Lake from November 2011-October 2012 is given on Table 4-7. The values summarized in this table reflect the relative sediment elevations at each of the 10 underwater staff gauge sites in Booker Lake. The initial values recorded on November 17, 2011 reflect the relative sediment elevation prior to addition of alum floc to the lake. The underwater staff gauge measurements are listed in units of inches and reflect the staff gauge reading at the top of the sediment surface at the beginning of the post-treatment monitoring program. The values summarized in Table 4-7 are not intended to represent any data or elevation.

TABLE 4-7

FIELD MEASUREMENTS OF UNDERWATER STAFF GAUGES IN BOOKER LAKE FROM NOVEMBER 2011 - OCTOBER 2012

SITE	SEDIMENT LEVEL BY DATE (inches)								CHANGE IN DEPTH (inches)[1]
	11/17/11	1/1/12	2/8/12	3/8/12	4/10/12	6/19/12	9/26/12	10/18/12	
1	16.0	16.0	16.3	16.5	16.0	16.3	16.8	16.5	0.6
2	17.8	17.8	17.5	17.8	--	--	17.5	17.3	-0.4
3	26.8	26.8	26.3	26.5	--	--	26.5	26.0	-0.5
4	9.0	9.0	9.3	9.3	9.0	9.5	9.8	9.5	0.6
5	19.0	19.0	19.3	19.3	--	19.0	19.5	19.3	0.4
6	20.0	20.0	19.8	19.8	--	19.5	19.3	19.8	-0.5
7	38.5	38.5	38.3	38.3	--	--	38.8	39.3	0.5
8	6.0	6.0	--	6.5	6.5	6.3	6.0	6.5	0.3
9	8.8	8.8	--	9.0	9.5	9.0	9.3	9.3	0.5
10	43.0	43.0	--	43.3	43.5	43.3	43.5	43.8	0.6
								Overall Mean Change:	**0.2**

1. Change in mean values between the initial two dates and final two dates of the monitoring period.

A graphical summary of changes in measured sediment surface levels in Booker Lake from November 2011-October 2012 is given on Figure 4-20. Changes in monitored sediment depths are plotted for each of the 10 underwater staff gauge sites in terms of increases or decreases in sediment depth from the initial measurements conducted on November 17, 2011. The relative elevations of the sediment surface fluctuated at each of the 10 monitoring sites during the 12-month monitoring period within a range of ±0.5 inches. Organic muck sediments in eutrophic lakes are somewhat fluid in nature, and small fluctuations in sediment elevations are commonly observed in these lakes. Much of the variability in measurements indicated on Figure 4-20 is likely due to movement of the surficial fluid layer of sediments within the lake. However, no distinct trend of either increasing or decreasing sediment levels are apparent at any of the 10 individual monitoring sites.

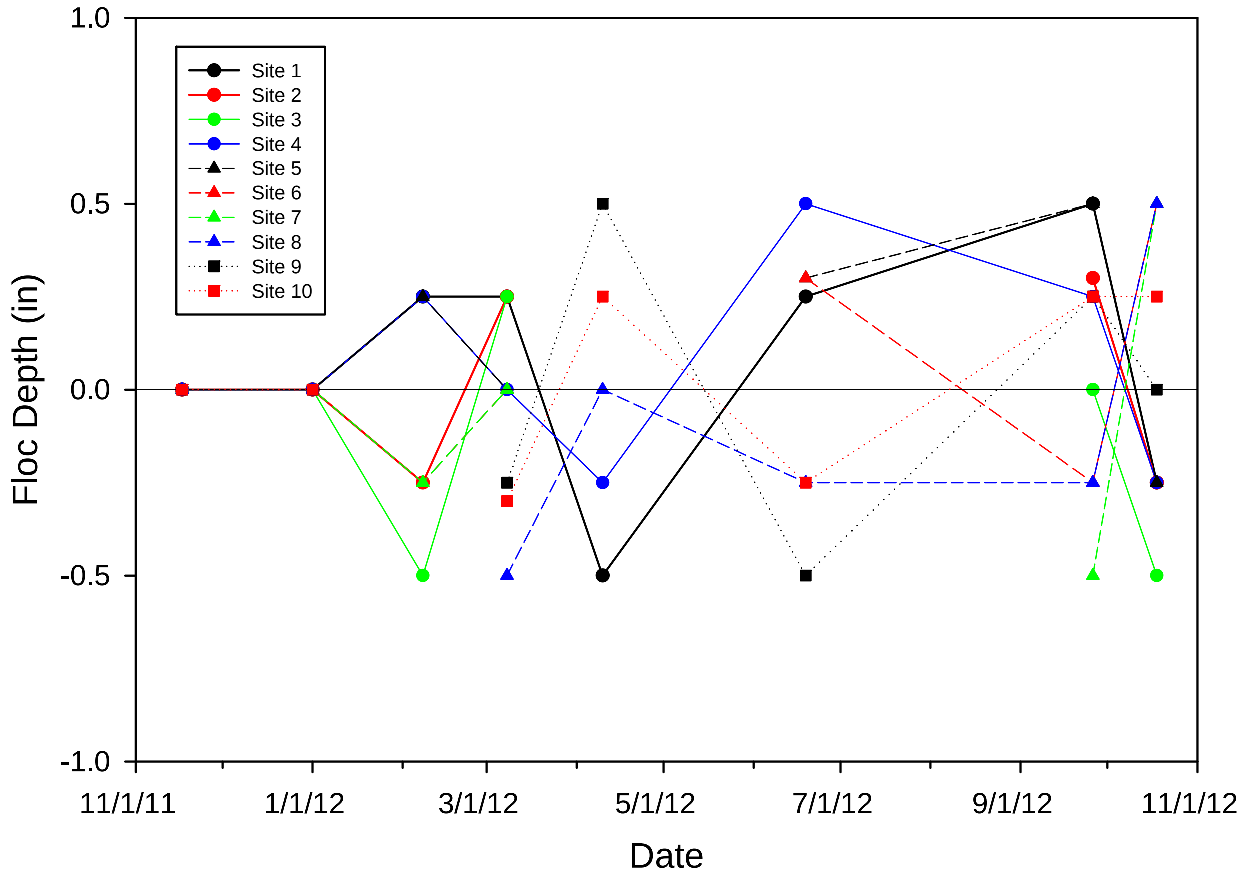


Figure 4-20. Change in Measured Sediment Levels in Booker Lake from November 2011-October 2012.

Estimates of the relative change in sediment elevations in Booker Lake from the beginning to the end of the 12-month monitoring period are summarized in the final column of Table 4-17. These values reflect the change in relative sediment elevations between the initial two monitoring dates and the final two monitoring dates of the 12-month period. Increases in sediment elevations, ranging from 0.3-0.6 inches, were observed at Sites 1, 4, 5, 7, 8, 9, and 10. Decreases in relative sediment elevation, ranging from 0.4-0.5 inches, were recorded at Sites 2, 3, and 6. Based upon this analysis, the sediment elevation in Booker Lake increased by an average of 0.2 inches during the 12-month field monitoring program. The observed overall mean increase of approximately 0.2 inches is equivalent to approximately 0.44 cm which is about half of the mean sediment elevation increase of approximately 1 cm/year commonly observed in lakes receiving alum treatment of stormwater runoff.

4.5 Benthic Monitoring

As discussed in Section 3.3, benthic monitoring was conducted in Booker Lake under pre- and post-treatment conditions to evaluate potential impacts to benthic populations from operation of the Booker Lake ATS facility. Benthic monitoring was conducted during both winter and summer conditions to document changes in benthic populations on a seasonal basis. Pre-treatment benthic monitoring was conducted during July 2005 (summer season) and January 2006 (winter season), with post-treatment benthic monitoring conducted during January 2012 (winter season) and August 2012 (summer season), and individual reports were prepared for each of the four benthic monitoring events. Reports describing the results of the pre-treatment benthic monitoring events are provided in Appendix C.1, with the results of the post-treatment benthic monitoring events provided in Appendix C.2.

During summer season pre-treatment conditions, a total of 3 separate benthic species were identified at the monitoring sites during July 2005 compared with 8 different species identified during the September 2012 post-treatment event. A slight increase in organism density was observed at Site 1 under post-treatment conditions, with a slight decrease in overall organism density observed at Site 2. No benthic organisms were observed at Site 3 during the pre-treatment summer monitoring event, but under post-treatment conditions the phantom midge *Chaoborus punctipennis* was present. Increases in mean Shannon Diversity Index were observed at each of the 3 monitoring sites under post-treatment conditions compared with pre-treatment conditions. The data suggests that addition of alum floc to the sediments has made the environment more favorable for benthic organisms, resulting in an increase in the number of species at 2 of the 3 monitoring sites and an increase in Shannon Diversity Index at each of the 3 post-treatment monitoring sites under summer conditions.

During the post-treatment winter monitoring event, substantial increases in the number of benthic species occurred at monitoring Sites 1 and 3 compared with pre-treatment conditions, with a reduction in benthic species observed at Site 2. Overall organism density increased at Site 1 from 1,911 organisms/m^2 during pre-treatment conditions to 4,534 organisms/m^2 under post-treatment conditions. A similar increase in the density of benthic organisms was observed at Site 3. The only site which exhibited a decrease in overall benthic density under post-treatment conditions was Site 2 which was reduced from 9,275 organisms/m^2 during January 2006 to 3,363 organisms/m^2 during January 2012.

The benthic results discussed previously are virtually identical to the results of benthic monitoring conducted on previous alum treatment projects where the floc discharges to the receiving waterbody. Benthic communities appear to progress through a 3-year cycle, with an initial increase in the number of species present after approximately one year, although some sites may exhibit a slight reduction in overall organism density caused by the reduction in available nutrients resulting from bonding between phosphorus and the alum floc in the sediments. During year 2 following introduction of an alum treatment system, increases in both the number of species and organism densities continue to occur. During year 3, the benthic population appears to reflect a revised community structure with more clean water organisms and carnivores present compared with polluted water organisms and detritivores which are mostly present under pre-treatment conditions.

4.6 Estimated Mass Load Reductions

A summary of estimated annual mass load reductions for the Booker Lake ATS facility is given on Table 4-8. Estimates of annual mass loadings to the lake under pre-treatment conditions are calculated based upon the information summarized on Table 2-2. Removal efficiencies by the alum treatment system are based upon the percent change in water quality characteristics in Booker Lake under pre- and post-treatment conditions, as summarized in Table 4-3.

TABLE 4-8

ESTIMATED ANNUAL MASS LOAD REDUCTIONS FOR THE BOOKER LAKE ATS FACILITY

INFLOW	RUNOFF VOLUME (ac-ft/yr)	ANNUAL MASS LOADING (kg/yr)			REMOVAL BY ATS (%)			ANNUAL MASS LOAD REDUCTION (kg/yr)		
		Total N	Total P	TSS	Total N	Total P	TSS	Total N	Total P	TSS
Northern Channel	272	580	130	18,396	51	47	10	296	61	1,840
Western Channel	378	464	101	8,240	51	47	10	237	47	824
TOTAL:	**650**	**1,044**	**231**	**26,636**				**532**	**109**	**2,664**
Projected Annual Mass Load Reduction:								261	208	23,973
Fraction of Projected Reduction Achieved:								2.04	0.52	0.11

Annual mass load reductions for the Booker Lake ATS facility are approximately 532 kg/yr for total nitrogen, 109 kg/yr for total phosphorus, and 2,644 kg/yr for TSS. The observed annual load reductions for total phosphorus and TSS are substantially lower than the anticipated load reductions summarized on Table 2-3. The difference between the observed and predicted load reductions is likely related to the sporadic operational status of the facility during the field monitoring program. It is interesting to note that the ATS facility achieved twice the anticipated load reduction for total nitrogen, even though the system was operated on a sporadic basis. The observed load reduction for total phosphorus is approximately 52% of the anticipated load reduction, while the load reduction for TSS is only 11% of the anticipated mass reduction.

SECTION 5

SUMMARY

An alum stormwater treatment system was constructed for Booker Lake to provide alum treatment of significant inflows from stormwater and baseflow entering the lake through two separate channels, identified as the western and northern channels. The sub-basin area discharging to Booker Lake through the two inflow channels is approximately 1,437 acres of high-density residential, commercial, and industrial land use activities. Based upon hydrologic modeling of the Booker Lake watershed conducted by ERD using a SWMM Model provided by the City, runoff inflows contribute approximately 600 ac-ft/yr to Booker Lake. This value does not include significant baseflows which also enter Booker Lake throughout much of the year. Construction of the ATS facility was completed during June 2011. The overall total cost of the project was approximately $1,256,000, with approximately 40% contributed by the City and 60% contributed by FDEP through a 319(h) Grant.

Pre- and post-treatment field monitoring for water quality, sediments, floc accumulation rates, and benthic communities were conducted to evaluate the performance efficiency of the Booker Lake ATS facility. Pre-treatment monitoring was conducted from July 2005-June 2006, with post-treatment monitoring conducted from November 2011-October 2012. During the field monitoring program, the ATS facility appeared to operate sporadically, with normal system operation occurring approximately 63% of the time within the west channel and 7% of the time in the north channel based upon a period of 179 days during which detailed operational data are available.

In general, post-treatment vertical field profiles in Booker Lake were characterized by a more uniform water column pH, with isograde pH conditions extending to deeper water depths than observed under pre-treatment conditions. Isograde conductivity profiles were observed during each of the 12 post-treatment monitoring events. Dissolved oxygen concentrations under post-treatment conditions were generally higher in value, particularly near the water-sediment interface, with no apparent anoxic conditions observed under post-treatment conditions.

Although the system operation may have been sporadic, reductions in concentrations for virtually all measured parameters were observed under post-treatment conditions compared with pre-treatment conditions. Measured nitrogen species were reduced from 34-68%, with an overall total nitrogen reduction of approximately 51% in Booker Lake. Measured reductions for phosphorus species ranged from 15-72% with an overall concentration decrease of approximately 47% under post-development conditions. Measured concentrations of color were reduced by approximately 10%, with a 26% reduction in chlorophyll-a and a 53% reduction in fecal coliform bacteria. The ATS facility generated substantial improvements in water quality in Booker Lake even though the operation of the system was somewhat sporadic.

Mean values for measured sediment characteristics in Booker Lake were virtually identical under pre- and post-treatment conditions. Operation of the alum treatment system does not appear to have resulted in measurable change in sediment pH at any of the 3 monitoring sites. Slight increases were observed in measured moisture contents at 2 of the 3 sediment sites which may be explained by the additional moisture content of alum floc compared with lake sediments. Virtually no changes were observed in measured organic content or in sediment concentrations of total nitrogen or total phosphorus. In general, operation of the ATS for Booker Lake did not result in any significant changes to sediment characteristics throughout the lake.

Estimates of floc accumulation rates in Booker Lake were conducted by ERD using a series of 10 separate underwater staff gauges which were used to generate estimates of relative sediment depth. Field monitoring of the underwater staff gauges was conducted on approximately a monthly or bi-monthly basis using an underwater video camera to avoid sediment disturbances. Seven of the 10 monitoring sites exhibited increases in sediment depth, ranging from 0.3-0.6 inches, while 3 of the 10 monitoring sites exhibited decreases, ranging from 0.4-0.5 inches. Overall, sediment depth in Booker Lake increased by approximately 0.2 inches (0.44 cm) during the 12-month field monitoring program.

As discussed previously, benthic monitoring was conducted in Booker Lake under pre- and post-treatment conditions, with separate samples collected during summer and winter conditions for both pre- and post-treatment programs. In general, the results of the pre- and post-treatment monitoring events are similar to the results of benthic monitoring conducted on previous alum stormwater treatment systems. Increases in the number of benthic species occurred under both winter and summer conditions under post-treatment conditions compared with pre-treatment conditions. However, increases in organism densities were observed at some sites, while decreases in organism densities were observed at other sites. Benthic communities generally go through a 3-year cycle after introduction of alum floc into the sediments, with steady increases in the number of species and organism densities over time. Increases in Shannon Diversity Indices were also observed under post-treatment conditions at each of the 3 post-treatment monitoring sites.

Based upon the observed changes in water quality within Booker Lake, the ATS facility achieved load reductions of 261 kg/yr for total nitrogen, 109 kg/yr for total phosphorus, and 2,664 kg/yr for TSS. Mass load reductions would likely be greater if the system were operated on a more reliable schedule.

APPENDICES

APPENDIX A

BOOKER LAKE STORMWATER, BASEFLOW, AND JAR TEST DATA

Booker Lake Stormwater and Baseflow Jar Test Data

Site	Type	Dose	Date	pH (raw)	pH (1 min)	pH (1 hr)	pH (24 hr)	Cond (µmho/cm)	Alkalinity (mg/l)	Ammonia (µg/l)	NOx (µg/l)	Diss Org N (µg/l)	Part. N (µg/l)	Total N (µg/l)	SRP (µg/l)	Diss Org P (µg/l)	Part. P (µg/l)	Total P (µg/l)	Turbidity (NTU)	TSS (mg/l)	BOD (mg/l)	Color (Pt-Co)	Diss Al (µg/l)	Chloride (mg/l)	Fecal (cfu/100 ml)
13th St	Stormwater	Raw	7/9/05	7.42	7.42	7.42	7.42	149	65.5	175	444	104	559	1,282	260	256	286	802	39.0	84.2	4.6	32	30	5.0	54,000
13th St	Stormwater	5.0 mg/l	7/13/05	7.42	6.25	6.50	7.31	182	43.2	94	448	97	30	669	<1	1	4	6	0.6	<0.7	<2.0	6	55	5.8	200
13th St	Stormwater	7.5 mg/l	7/13/05	7.42	5.81	6.32	7.15	196	35.6	108	440	77	26	651	<1	1	3	5	0.4	<0.7	<2.0	5	55	5.0	220
13th St	Stormwater	10.0 mg/l	7/13/05	7.42	5.21	5.99	6.99	206	27.3	112	435	50	5	602	<1	1	2	4	0.2	<0.7	<2.0	3	39	6.6	101
13th St	Stormwater	Raw	7/21/05	7.67	7.67	7.67	7.67	317	123	128	1,271	274	137	1,810	77	1	89	167	24.3	39.7	2.1	42	117	30.0	2,500
13th St	Stormwater	5.0 mg/l	7/25/06	7.67	7.00	6.86	7.56	341	99	73	1,265	207	75	1,620	<1	10	1	12	0.7	0.8	4.7	14	131	26.3	9
13th St	Stormwater	7.5 mg/l	7/25/06	7.67	6.67	6.64	7.43	341	85.6	70	1,253	182	30	1,535	<1	5	1	7	0.2	1.4	4.8	8	66	26.0	3
13th St	Stormwater	10.0 mg/l	7/25/06	7.67	6.46	6.50	7.34	360	78	70	1,277	172	24	1,543	<1	5	1	7	0.2	2.0	5.0	8	65	27.2	4
13th St	Stormwater	Raw	10/5/05	8.04	8.04	8.04	8.04	313	130	524	1,205	47	314	2,090	70	11	113	194	23.6	40.4	<2.0	30	14	25.9	132
13th St	Stormwater	5.0 mg/l	10/18/05	8.04	6.87	6.84	7.61	333	108	<5	1,270	128	329	1,729	<1	<1	4	4	0.5	2.3	<2.0	13	67	16.7	6
13th St	Stormwater	7.5 mg/l	10/18/05	8.04	6.64	6.63	7.49	345	95	38	1,287	124	299	1,748	<1	<1	1	1	0.3	2.7	2.7	8	68	36.0	<1
13th St	Stormwater	10.0 mg/l	10/18/05	8.04	6.49	6.40	7.39	345	91.6	<5	1,284	123	330	1,739	<1	<1	1	1	0.3	2.8	2.9	6	86	25.3	<1
13th St	Baseflow	Raw	7/24/05	8.20	8.20	8.20	8.20	315	125	73	990	264	22	1,349	21	<1	9	30	1.2	2.6	<2.0	22	129	35.7	<1
13th St	Baseflow	5.0 mg/l	7/25/06	8.20	6.58	6.87	7.84	415	123	97	1,011	161	39	1,308	<1	<1	1	1	0.2	<0.7	4.2	5	108	36.9	<1
13th St	Baseflow	7.5 mg/l	7/25/06	8.20	6.45	6.80	7.76	424	109	103	1,017	130	46	1,296	<1	<1	1	1	0.2	<0.7	4.9	2	97	35.2	5
13th St	Baseflow	10.0 mg/l	7/25/06	8.20	6.32	6.70	7.68	433	94.2	120	1,015	80	32	1,247	<1	<1	<1	<1	0.1	1.3	5.3	<1	60	36.2	3
13th St	Baseflow	Raw	10/5/05	7.37	7.37	7.37	7.37	390	164	21	780	593	221	1,615	7	7	30	44	2.5	5.4	<2.0	36	32	35.9	14
13th St	Baseflow	5.0 mg/l	10/18/05	7.37	6.79	6.81	7.48	401	139	21	853	365	49	1,288	<1	<1	1	1	0.3	2.0	2.8	15	80	35.8	6
13th St	Baseflow	7.5 mg/l	10/18/05	7.37	6.69	6.72	7.40	399	125	97	870	243	79	1,289	<1	<1	1	1	0.3	1.2	3.0	11	73	34.7	<1
13th St	Baseflow	10.0 mg/l	10/18/05	7.37	6.56	6.58	7.28	417	114	<5	857	151	103	1,114	<1	<1	1	1	0.2	1.6	2.9	8	66	35.1	<1
13th St	Baseflow	Raw	12/19/05	7.21	7.21	7.21	7.21	334	175	84	540	317	50	991	3	2	9	14	2.0	1.4	<2.0	38	34	36.7	95
13th St	Baseflow	5.0 mg/l	12/21/05	7.21	6.68	6.88	7.90	433	155	162	557	242	18	979	2	<1	2	4	0.4	1.7	<2.0	16	130	27.9	19
13th St	Baseflow	7.5 mg/l	12/21/05	7.21	6.57	6.79	7.80	440	139	118	545	282	39	984	1	2	3	6	0.5	<0.7	<2.0	12	113	36.9	5
13th St	Baseflow	10.0 mg/l	12/21/05	7.21	6.55	6.76	7.74	452	125	177	545	149	34	905	1	3	<1	4	0.3	<0.7	<2.0	9	84	37.2	4
13th St	Baseflow	Raw	2/14/06	7.56	7.56	7.56	7.56	459	155	209	373	231	42	855	11	9	4	24	1.6	<0.7	2.9	38	66	37.8	27
13th St	Baseflow	5.0 mg/l	2/17/06	7.56	6.72	6.78	7.37	462	134	201	381	123	63	768	3	2	1	6	0.6	1.4	<2.0	16	144	38.0	5
13th St	Baseflow	7.5 mg/l	2/17/06	7.56	6.64	6.69	7.31	466	125	200	351	158	77	786	1	4	1	6	0.6	2.1	<2.0	12	85	37.8	<1
13th St	Baseflow	10.0 mg/l	2/17/06	7.56	6.53	6.65	7.25	476	107	205	378	152	4	739	<1	<1	6	7	0.5	2.6	2.2	9	81	38.6	<1
24th St	Stormwater	Raw	7/9/05	7.67	7.67	7.67	7.67	214	77.2	152	120	235	133	640	19	46	50	115	3.6	13.3	3.3	23	30	14.6	3,200
24th St	Stormwater	5.0 mg/l	7/13/05	7.67	6.52	6.70	7.31	230	49.9	148	119	110	18	395	<1	1	1	3	0.4	<0.7	<2.0	4	39	16.4	13
24th St	Stormwater	7.5 mg/l	7/13/05	7.67	6.22	6.46	7.14	237	38	151	107	111	23	392	<1	1	1	3	0.3	<0.7	<2.0	3	30	16.1	3
24th St	Stormwater	10.0 mg/l	7/13/05	7.67	5.96	6.14	6.93	242	28.1	175	106	117	1	399	<1	2	1	4	0.1	<0.7	<2.0	2	71	16.6	12
24th St	Stormwater	Raw	7/21/05	7.52	7.52	7.52	7.52	213	81.4	44	439	236	91	810	75	2	34	111	3.0	8.4	<2.0	16	79	17.2	3
24th St	Stormwater	5.0 mg/l	7/25/06	7.52	6.67	6.67	7.34	218	56	63	444	117	46	670	<1	4	1	6	0.1	2.3	5.4	1	76	17.0	<1
24th St	Stormwater	7.5 mg/l	7/25/06	7.52	6.37	6.38	7.16	230	39.6	26	446	116	29	617	<1	6	1	8	0.1	0.8	5.8	1	107	17.6	<1
24th St	Stormwater	10.0 mg/l	7/25/06	7.52	6.08	6.11	6.94	230	30.4	35	439	101	27	602	<1	4	2	7	0.1	<0.7	5.6	<1	105	17.8	<1
24th St	Stormwater	Raw	7/24/05	7.86	7.86	7.86	7.86	179	68.2	105	631	154	204	1,094	70	10	86	166	9.4	47.8	<2.0	12	118	10.5	281
24th St	Stormwater	5.0 mg/l	7/25/06	7.86	6.47	6.80	7.34	198	42.2	66	637	69	65	837	<1	<1	<1	<1	0.1	6.7	5.0	4	102	12.9	1
24th St	Stormwater	7.5 mg/l	7/25/06	7.86	6.16	6.52	7.09	197	24.8	87	643	31	37	798	<1	<1	<1	<1	0.1	4.9	5.0	1	134	12.3	<1
24th St	Stormwater	10.0 mg/l	7/25/06	7.86	5.92	6.33	6.74	204	20.4	82	631	3	19	735	<1	<1	1	1	0.2	4.3	4.6	<1	134	12.9	1
24th St	Stormwater	Raw	10/5/05	7.66	7.66	7.66	7.66	210	91.6	390	505	77	467	1,439	38	9	423	470	27.8	1.2	<2.0	19	9	15.2	11
24th St	Stormwater	5.0 mg/l	10/18/05	7.66	6.62	6.69	7.37	220	61.2	410	538	121	81	1,150	<1	<1	1	1	0.3	3.0	3.2	2	10	15.1	<1
24th St	Stormwater	7.5 mg/l	10/18/05	7.66	6.40	6.45	7.27	242	56.2	424	547	76	91	1,138	<1	<1	1	1	0.3	1.8	2.9	2	47	14.9	<1
24th St	Stormwater	10.0 mg/l	10/18/05	7.66	6.13	6.22	7.06	245	41.4	346	546	78	64	1,034	<1	<1	1	1	0.4	2.9	2.9	1	14	11.3	<1
24th St	Baseflow	Raw	10/5/05	7.16	7.16	7.16	7.16	334	120	550	770	84	925	2,329	10	11	60	81	1.8	1.4	<2.0	16	62	35.4	33
24th St	Baseflow	5.0 mg/l	10/18/05	7.16	6.70	6.76	7.33	351	87.8	585	863	201	526	2,175	<1	<1	1	1	0.3	1.6	2.8	5	58	34.2	<1
24th St	Baseflow	7.5 mg/l	10/18/05	7.16	6.46	6.51	7.16	349	76.6	444	830	132	598	2,004	<1	<1	1	1	0.2	0.8	2.7	8	22	36.7	1
24th St	Baseflow	10.0 mg/l	10/18/05	7.16	6.32	6.34	7.06	357	62.6	243	830	160	176	1,409	<1	<1	1	1	0.3	<0.7	2.8	5	26	34.5	<1
24th St	Baseflow	Raw	12/19/05	7.21	7.21	7.21	7.21	182	105	146	689	153	43	1,031	6	41	57	104	2.1	1.7	<2.0	24	15	39.1	880
24th St	Baseflow	5.0 mg/l	12/21/05	7.21	6.38	6.54	7.57	204	78.2	123	694	66	110	993	2	2	<1	5	0.3	<0.7	<2.0	5	68	38.5	60
24th St	Baseflow	7.5 mg/l	12/21/05	7.21	6.19	6.41	7.33	209	63	125	705	42	40	912	2	1	<1	4	0.2	<0.7	<2.0	3	39	39.5	44
24th St	Baseflow	10.0 mg/l	12/21/05	7.21	6.11	6.21	7.16	213	51.8	99	701	77	47	924	1	2	1	4	0.2	<0.7	<2.0	4	50	39.9	14
24th St	Baseflow	Raw	2/14/06	7.37	7.37	7.37	7.37	335	98.2	88	571	216	54	929	38	3	46	87	1.5	2.4	2.9	23	40	34.4	208
24th St	Baseflow	5.0 mg/l	2/17/06	7.37	6.72	6.83	7.27	340	73.6	82	514	279	19	894	<1	5	1	7	0.4	0.8	<2.0	7	77	34.8	5
24th St	Baseflow	7.5 mg/l	2/17/06	7.37	6.65	6.79	7.17	356	53.6	85	585	142	3	815	1	3	1	5	0.5	0.8	<2.0	5	60	35.3	5
24th St	Baseflow	10.0 mg/l	2/17/06	7.37	6.58	6.67	7.14	358	49.8	87	591	123	16	817	1	4	1	6	0.6	1.0	<2.0	5	56	34.7	1

APPENDIX B

VERTICAL FIELD PROFILES
COLLECTED IN BOOKER LAKE DURING
PRE- AND POST-TREATMENT MONITORING

B.1 Pre-Treatment Monitoring
B.2 Post-Treatment Monitoring

B.1 Pre-Treatment Monitoring

Vertical Field Profiles Collected in Booker Lake from July 2005 - June 2006

Site	Date	Time	Level (m)	Temp (°C)	pH (s.u.)	SpCond (µmho/cm)	DO (mg/l)	DO (%Sat)	Redox (mV)	Secchi (m)
Site 1	7/21/05	10:32	0.25	31.54	8.31	234	7.3	100	447	0.95
		10:32	0.50	31.55	8.37	234	7.4	102	459	
		10:33	1.00	31.40	8.41	233	7.3	100	477	
		10:34	1.50	31.31	8.36	233	7.1	98	480	
		10:35	2.00	31.29	8.29	234	8.5	116	483	
		10:36	2.50	30.80	7.92	230	6.5	89	465	
		10:36	3.00	30.33	7.62	223	3.4	45	442	
		10:37	3.50	28.73	7.33	212	2.9	38	404	
		10:38	4.00	27.71	6.98	232	3.0	39	279	
		10:39	4.47	27.39	6.81	270	1.5	20	222	
Site 2	7/21/05	10:07	0.25	31.42	7.81	233	8.9	120	601	0.94
		10:09	0.50	31.28	8.14	232	8.2	111	619	
		10:10	1.00	31.19	8.22	232	7.9	106	625	
		10:11	1.50	31.02	7.79	231	7.6	103	607	
		10:12	2.00	30.89	7.65	230	6.8	93	601	
		10:13	2.50	30.75	7.56	239	6.7	91	597	
		10:14	3.00	30.27	7.36	232	3.5	48	584	
		10:15	3.50	28.53	7.01	216	3.2	42	389	
		10:17	3.79	27.71	6.75	325	1.4	18	213	
Site 3	7/21/05	10:20	0.25	31.50	8.27	232	9.7	133	463	0.96
		10:21	0.50	31.43	8.36	233	10.3	142	481	
		10:22	1.00	31.27	8.35	232	8.8	121	490	
		10:23	1.50	31.16	8.17	233	8.5	116	487	
		10:24	2.00	30.89	7.80	232	7.2	98	472	
		10:25	2.50	30.83	7.65	231	7.9	108	467	
		10:26	3.00	30.64	7.47	231	3.6	48	453	
		10:27	3.50	28.90	7.14	222	3.5	47	367	
		10:28	4.00	27.78	6.92	231	3.5	45	265	
		10:29	4.24	27.64	6.79	279	1.6	20	226	
Site 1	8/17/05	9:25	0.25	31.73	8.35	264	8.3	113	601	0.66
		9:26	0.50	31.65	8.27	265	7.6	104	597	
		9:27	1.00	31.59	8.19	266	7.3	99	593	
		9:27	1.50	31.53	8.10	266	6.5	89	590	
		9:28	2.00	31.46	8.02	266	6.4	86	578	
		9:29	2.50	31.20	7.61	269	2.1	29	559	
		9:30	3.00	31.03	7.32	272	2.2	29	530	
		9:31	3.50	30.46	7.01	280	0.2	2	278	
		9:32	3.94	30.19	6.76	309	0.2	2	240	
Site 2	8/17/05	9:38	0.25	31.88	8.27	269	8.3	114	507	0.68
		9:38	0.50	31.68	8.22	268	7.7	105	514	
		9:39	1.00	31.55	8.06	269	6.6	90	511	
		9:40	1.50	31.50	7.69	270	3.9	53	497	
		9:41	2.00	31.37	7.38	268	1.3	17	477	
		9:42	2.50	31.29	7.28	268	0.2	3	465	
		9:43	3.00	31.03	7.15	266	0.1	2	405	
		9:44	3.50	30.77	6.98	274	0.1	1	298	
		9:44	3.58	30.70	6.69	313	0.1	1	257	

Vertical Field Profiles Collected in Booker Lake from July 2005 - June 2006

Site	Date	Time	Level (m)	Temp (°C)	pH (s.u.)	SpCond (µmho/cm)	DO (mg/l)	DO (%Sat)	Redox (mV)	Secchi (m)
Site 3	8/17/05	9:58	0.25	32.13	8.34	267	8.7	119	510	0.65
		9:59	0.50	31.81	8.25	267	7.9	108	518	
		10:00	1.00	31.63	7.96	269	6.4	87	512	
		10:01	1.50	31.54	7.80	269	5.4	74	508	
		10:02	2.00	31.40	7.55	270	3.0	40	497	
		10:03	2.50	31.29	7.40	268	2.7	37	490	
		10:04	3.00	31.15	7.21	284	0.2	3	465	
		10:05	3.50	30.73	7.09	265	0.1	2	390	
		10:05	3.65	30.64	7.01	263	0.1	1	332	
Site 1	9/29/05	9:23	0.25	27.84	7.72	345	5.0	64	360	0.72
		9:24	0.50	27.85	7.72	347	4.9	63	360	
		9:25	1.00	27.83	7.71	346	4.9	62	359	
		9:26	1.50	27.83	7.70	346	4.9	62	361	
		9:27	2.00	27.82	7.69	346	4.9	62	360	
		9:27	2.50	27.80	7.67	347	4.9	62	360	
		9:29	3.00	27.80	7.68	347	4.8	61	361	
		9:29	3.02	27.80	7.67	347	4.7	60	360	
Site 2	9/29/05	9:32	0.25	27.83	7.63	346	4.5	57	360	0.72
		9:33	0.50	27.83	7.62	345	4.5	57	361	
		9:34	1.00	27.83	7.61	346	4.4	57	360	
		9:35	1.50	27.81	7.61	346	4.4	56	360	
		9:35	2.00	27.79	7.61	346	4.4	56	360	
		9:36	2.50	27.76	7.61	347	4.4	56	360	
		9:37	2.96	27.75	7.55	347	3.8	49	351	
Site 3	9/29/05	9:41	0.25	27.75	7.61	347	4.5	58	351	0.73
		9:42	0.50	27.74	7.60	347	4.5	57	350	
		9:42	1.00	27.74	7.60	347	4.5	57	351	
		9:43	1.50	27.74	7.60	347	4.5	57	352	
		9:44	2.00	27.73	7.58	347	4.4	57	353	
		9:45	2.25	27.72	7.58	348	4.4	56	351	
Site 1	10/31/05	8:44	0.25	22.29	8.63	350	11.4	156	356	0.54
		8:45	0.50	22.30	8.63	349	11.6	159	361	
		8:45	1.00	22.25	8.57	350	11.1	152	360	
		8:46	1.50	22.08	8.42	352	10.0	136	355	
		8:47	2.00	21.83	7.73	355	5.2	71	323	
		8:48	2.50	21.79	7.58	355	4.2	56	261	
		8:49	2.62	21.79	7.47	355	3.9	53	188	
Site 2	10/31/05	8:27	0.25	22.32	8.70	348	12.5	171	428	0.57
		8:28	0.50	22.25	8.66	348	12.0	164	426	
		8:29	1.00	22.14	8.50	353	10.8	147	419	
		8:30	1.50	22.15	8.47	352	10.1	137	418	
		8:30	2.00	22.11	8.36	354	9.8	134	414	
		8:31	2.50	21.79	7.95	354	7.1	97	394	
		8:34	3.00	21.71	7.70	354	6.0	81	384	
		8:34	3.50	21.70	7.65	354	5.7	77	381	
		8:35	3.91	21.71	7.43	358	4.5	61	195	

Vertical Field Profiles Collected in Booker Lake from July 2005 - June 2006

Site	Date	Time	Level (m)	Temp (°C)	pH (s.u.)	SpCond (µmho/cm)	DO (mg/l)	DO (%Sat)	Redox (mV)	Secchi (m)
Site 3	10/31/05	8:53	0.25	22.34	8.68	347	12.0	165	324	0.54
		8:53	0.50	22.26	8.66	347	11.4	156	329	
		8:54	1.00	22.23	8.63	348	10.9	149	337	
		8:55	1.50	22.03	8.40	350	9.7	132	334	
		8:57	2.00	21.90	8.06	353	7.8	106	323	
		8:57	2.50	21.77	7.79	354	6.2	84	313	
		8:58	3.00	21.71	7.61	354	4.8	65	305	
		9:00	3.50	21.72	7.48	355	4.4	60	195	
		9:01	3.58	21.72	7.21	356	2.7	36	156	
Site 1	11/28/05	9:05	0.25	20.78	7.96	380	8.4	111	407	0.76
		9:05	0.50	20.76	7.97	380	8.3	111	407	
		9:06	1.00	20.77	7.99	380	8.2	108	407	
		9:07	1.50	20.77	7.99	380	8.0	106	407	
		9:07	2.00	20.77	7.99	380	8.0	106	407	
		9:08	2.50	20.76	8.00	380	7.7	102	408	
		9:09	3.00	20.76	8.00	381	7.9	105	408	
		9:09	3.50	20.75	8.00	381	7.8	103	408	
		9:11	3.98	20.75	7.60	382	5.8	80	171	
Site 2	11/28/05	9:29	0.25	20.77	7.82	382	7.2	96	327	0.73
		9:30	0.50	20.77	7.83	382	7.1	94	328	
		9:30	1.00	20.77	7.83	382	7.3	96	330	
		9:31	1.50	20.76	7.84	382	7.0	93	332	
		9:32	2.00	20.74	7.84	382	7.0	92	333	
		9:33	2.50	20.73	7.85	382	6.7	89	335	
		9:33	3.00	20.73	7.84	382	6.9	91	336	
		9:35	3.29	20.75	7.10	521	0.5	7	81	
Site 3	11/28/05	9:47	0.25	20.81	7.81	383	7.4	98	282	0.68
		9:47	0.50	20.79	7.81	383	7.4	98	287	
		9:48	1.00	20.73	7.81	383	7.1	95	292	
		9:48	1.50	20.68	7.81	383	6.9	91	294	
		9:49	2.00	20.66	7.75	383	6.5	86	294	
		9:50	2.50	20.60	7.63	385	4.9	65	288	
		9:51	3.00	20.59	7.55	385	3.9	52	243	
		9:52	3.05	20.59	7.54	385	3.8	51	251	
Site 1	12/19/05	9:35	0.25	17.64	7.45	386	6.3	79	411	0.61
		9:36	0.50	17.63	7.49	386	6.2	77	411	
		9:36	1.00	17.63	7.51	386	6.0	75	412	
		9:37	1.50	17.63	7.54	386	5.9	73	412	
		9:38	2.00	17.63	7.55	386	5.9	74	413	
		9:39	2.50	17.61	7.55	386	5.9	74	412	
		9:40	3.00	17.62	7.57	386	5.8	73	413	
		9:40	3.50	17.60	7.56	386	5.7	71	409	
		9:43	3.79	17.67	7.29	424	0.5	6	118	

Vertical Field Profiles Collected in Booker Lake from July 2005 - June 2006

Site	Date	Time	Level (m)	Temp (°C)	pH (s.u.)	SpCond (µmho/cm)	DO (mg/l)	DO (%Sat)	Redox (mV)	Secchi (m)
Site 2	12/19/05	9:46	0.25	17.64	7.58	387	5.8	72	242	0.61
		9:47	0.50	17.64	7.60	387	5.6	70	256	
		9:48	1.00	17.64	7.61	387	5.5	69	262	
		9:48	1.50	17.63	7.60	387	5.6	69	267	
		9:49	2.00	17.59	7.61	387	5.7	71	274	
		9:50	2.50	17.58	7.60	387	5.9	73	282	
		9:51	3.00	17.56	7.58	387	5.5	69	286	
		9:55	3.46	17.59	7.43	410	2.1	26	157	
Site 3	12/19/05	9:58	0.25	17.59	7.58	387	5.6	70	244	0.61
		9:59	0.50	17.59	7.59	387	5.5	69	258	
		10:00	1.00	17.58	7.60	387	5.3	66	267	
		10:01	1.50	17.58	7.59	387	5.4	67	271	
		10:02	2.00	17.58	7.59	387	5.4	67	276	
		10:02	2.50	17.57	7.59	387	5.3	66	281	
		10:03	3.00	17.57	7.58	387	5.3	66	281	
		10:06	3.13	17.82	7.27	393	0.6	7	165	
Site 1	1/20/06	10:45	0.25	17.51	8.60	404	11.1	138	425	0.48
		10:46	0.50	17.48	8.61	404	11.3	140	425	
		10:48	1.00	17.39	8.61	404	11.3	140	425	
		10:49	1.50	17.34	8.60	404	11.2	139	426	
		10:50	2.00	17.25	8.58	405	11.1	138	426	
		10:52	2.50	16.93	8.28	408	8.3	102	412	
		10:54	3.00	16.69	8.04	410	7.6	93	401	
		10:56	3.50	16.65	7.93	411	6.8	84	397	
		10:59	3.95	16.68	7.68	411	5.4	65	217	
Site 2	1/20/06	11:04	0.25	17.66	8.62	405	10.3	129	349	0.48
		11:05	0.50	17.49	8.62	405	10.8	135	359	
		11:07	1.00	17.24	8.59	405	10.0	123	368	
		11:10	1.50	17.18	8.57	405	9.8	121	375	
		11:12	2.00	17.13	8.58	405	10.4	128	380	
		11:17	2.09	17.16	8.58	405	10.7	132	386	
Site 3	1/20/06	11:22	0.25	17.37	8.59	405	10.7	133	394	0.48
		11:23	0.50	17.16	8.57	405	9.8	121	395	
		11:24	1.00	16.94	8.48	406	9.3	115	392	
		11:25	1.50	16.74	8.28	409	9.4	115	383	
		11:27	2.00	16.71	8.17	410	7.5	92	380	
		11:28	2.50	16.70	8.17	410	8.4	103	381	
		11:29	3.00	16.70	8.15	410	7.3	90	382	
		11:32	3.27	16.81	7.39	414	2.0	25	190	
Site 1	2/14/06	11:08	0.25	15.21	8.28	372	7.8	92	405	0.62
		11:09	0.50	15.21	8.32	373	7.8	93	406	
		11:10	1.00	15.16	8.32	373	7.8	93	406	
		11:11	1.50	15.14	8.33	372	7.8	93	406	
		11:12	2.00	15.08	8.33	373	7.8	92	407	
		11:13	2.50	15.04	8.33	373	7.8	92	407	
		11:13	3.00	15.01	8.31	373	7.9	93	406	
		11:14	3.50	15.00	8.27	374	7.8	92	405	
		11:19	3.86	15.20	7.48	554	0.8	9	58	

Vertical Field Profiles Collected in Booker Lake from July 2005 - June 2006

Site	Date	Time	Level (m)	Temp (°C)	pH (s.u.)	SpCond (µmho/cm)	DO (mg/l)	DO (%Sat)	Redox (mV)	Secchi (m)
Site 2	2/14/06	11:24	0.25	15.14	8.30	373	7.4	88	270	0.61
		11:25	0.50	15.22	8.34	373	7.6	90	292	
		11:27	1.00	15.06	8.27	374	7.6	90	299	
		11:28	1.50	15.03	8.24	374	7.5	88	305	
		11:29	2.00	14.84	8.11	374	7.0	83	306	
		11:30	2.50	14.81	8.10	374	7.0	82	310	
		11:33	2.82	14.80	8.09	374	6.9	81	290	
Site 3	2/14/06	11:39	0.25	15.06	8.36	373	7.9	93	327	0.65
		11:40	0.50	15.12	8.37	373	7.9	94	335	
		11:41	1.00	15.11	8.36	373	7.9	94	340	
		11:43	1.50	14.93	8.28	373	7.6	90	338	
		11:44	2.00	14.75	8.10	375	7.1	83	334	
		11:46	2.50	14.67	8.06	375	6.9	80	334	
		11:47	3.00	14.63	8.08	375	6.9	80	337	
		11:52	3.42	14.93	7.06	487	0.7	9	145	
Site 1	3/15/06	9:50	0.25	22.93	8.09	366	3.4	48	343	0.52
		9:51	0.50	22.92	8.11	366	3.4	47	343	
		9:52	1.00	22.91	8.13	366	3.4	47	343	
		9:52	1.50	22.90	8.13	366	3.4	47	343	
		9:54	2.00	22.89	8.15	366	3.4	47	344	
		9:55	2.50	22.88	8.13	366	3.3	46	345	
		9:55	3.00	22.85	8.12	366	3.3	46	345	
		9:57	3.50	21.57	7.14	375	0.7	10	85	
		9:58	3.84	21.39	7.04	384	0.6	8	69	
Site 2	3/15/06	10:12	0.25	23.16	8.22	365	3.6	50	250	0.52
		10:13	0.50	23.13	8.22	365	3.5	49	252	
		10:14	1.00	23.00	8.21	365	3.5	49	254	
		10:15	1.50	22.95	8.20	366	3.4	47	255	
		10:16	2.00	22.88	8.17	366	3.3	46	257	
		10:17	2.50	22.61	7.76	369	2.6	36	263	
		10:19	2.78	22.61	7.68	370	2.2	30	241	
Site 3	3/15/06	10:30	0.25	23.15	8.14	367	3.2	45	267	0.52
		10:31	0.50	23.15	8.16	366	3.1	44	265	
		10:32	1.00	23.12	8.15	366	3.1	43	267	
		10:33	1.50	23.09	8.14	366	3.1	43	268	
		10:34	2.00	22.97	7.79	368	2.3	32	274	
		10:36	2.50	22.50	7.43	370	1.2	16	276	
		10:38	2.92	22.24	7.24	373	0.4	5	143	

Vertical Field Profiles Collected in Booker Lake from July 2005 - June 2006

Site	Date	Time	Level (m)	Temp (°C)	pH (s.u.)	SpCond (µmho/cm)	DO (mg/l)	DO (%Sat)	Redox (mV)	Secchi (m)
Site 1	4/13/06	9:02	0.25	23.94	7.77	382	6.4	76	320	0.63
		9:03	0.50	23.94	7.80	382	6.4	75	319	
		9:04	1.00	23.92	7.80	382	6.3	74	319	
		9:05	1.50	23.89	7.80	382	6.1	73	320	
		9:06	2.00	23.85	7.80	382	5.9	70	321	
		9:07	2.50	23.84	7.80	382	6.1	72	321	
		9:08	3.00	23.83	7.81	382	5.9	70	321	
		9:09	3.50	23.83	7.80	382	6.1	72	322	
		9:13	3.97	23.77	6.76	455	0.2	2	109	
Site 2	4/13/06	9:16	0.25	24.02	7.78	382	6.2	74	179	0.66
		9:17	0.50	24.01	7.83	382	6.2	74	190	
		9:18	1.00	23.95	7.82	382	6.0	71	201	
		9:19	1.50	23.85	7.79	382	5.7	68	209	
		9:19	2.00	23.79	7.77	383	5.6	67	217	
		9:20	2.50	23.78	7.76	384	5.6	66	222	
		9:23	3.00	23.77	7.75	384	5.5	65	215	
		9:25	3.19	23.77	7.53	385	4.2	50	119	
Site 3	4/13/06	9:28	0.25	24.00	7.78	382	6.3	74	167	0.61
		9:29	0.50	24.02	7.83	382	6.0	72	178	
		9:30	1.00	23.96	7.86	382	5.8	69	186	
		9:30	1.50	23.95	7.86	382	5.9	70	194	
		9:31	2.00	23.89	7.86	382	5.8	68	200	
		9:31	2.50	23.87	7.86	382	5.9	70	205	
		9:32	3.00	23.75	7.76	382	4.6	55	209	
		9:34	3.47	23.71	7.49	397	0.3	3	123	
Site 1	5/15/06	9:37	0.25	27.68	7.83	339	4.9	63	277	0.55
		9:38	0.50	27.48	7.92	338	4.9	62	273	
		9:39	1.00	27.27	7.98	338	4.9	62	271	
		9:40	1.50	27.23	7.96	339	4.7	59	271	
		9:41	2.00	27.17	7.88	340	4.2	53	272	
		9:42	2.50	27.12	7.77	340	3.4	43	273	
		9:43	3.00	26.91	7.44	341	0.3	3	160	
		9:44	3.50	26.48	7.05	363	0.2	3	-14	
		9:45	3.86	25.97	6.77	409	0.2	2	-37	
Site 2	5/15/06	9:52	0.25	27.69	8.24	337	5.9	75	198	0.55
		9:54	0.50	27.73	8.26	337	5.8	74	206	
		9:55	1.00	27.64	8.24	337	5.7	72	212	
		9:56	1.50	27.57	8.21	338	5.5	70	215	
		9:57	2.00	27.54	8.13	339	5.2	65	219	
		9:58	2.34	27.46	8.04	340	4.7	60	220	
Site 3	5/15/06	10:09	0.25	27.89	8.57	334	7.0	90	225	0.50
		10:10	0.50	27.94	8.57	334	7.1	91	227	
		10:12	1.00	27.85	8.50	334	6.3	80	230	
		10:13	1.50	27.52	8.24	337	4.9	62	236	
		10:14	2.00	27.37	8.17	338	4.4	55	237	
		10:15	2.50	26.98	7.67	343	0.4	5	223	
		10:16	3.00	26.79	7.42	351	0.2	3	31	
		10:17	3.13	26.75	7.02	358	0.1	1	7	

Vertical Field Profiles Collected in Booker Lake from July 2005 - June 2006

Site	Date	Time	Level (m)	Temp (°C)	pH (s.u.)	SpCond (µmho/cm)	DO (mg/l)	DO (%Sat)	Redox (mV)	Secchi (m)
Site 1	6/16/06	8:30	0.25	28.61	8.58	273	10.0	130	262	0.68
		8:31	0.50	28.62	8.55	273	9.9	127	263	
		8:32	1.00	28.61	8.49	274	9.4	121	265	
		8:33	1.50	28.54	7.87	279	5.4	70	274	
		8:34	2.00	27.98	7.58	278	3.6	46	279	
		8:36	2.50	27.13	7.30	278	0.9	11	285	
		8:37	3.00	26.89	7.22	280	0.2	3	267	
		8:37	3.50	26.69	7.13	285	0.2	2	118	
		8:38	4.00	26.57	7.03	293	0.2	2	58	
		8:39	4.38	26.51	6.84	331	0.1	2	37	
Site 2	6/16/06	8:44	0.25	28.70	8.45	274	9.3	121	171	0.68
		8:45	0.50	28.66	8.46	274	9.3	120	187	
		8:46	1.00	28.64	8.46	274	9.3	120	197	
		8:47	1.50	28.38	8.00	276	6.8	88	205	
		8:48	2.00	27.69	7.52	277	3.6	45	207	
		8:49	2.50	27.17	7.30	278	1.0	13	196	
		8:50	3.00	26.91	7.20	282	0.2	2	145	
		8:52	3.28	26.86	7.13	285	0.1	1	93	
Site 3	6/16/06	8:55	0.25	28.60	8.52	273	9.8	127	175	0.63
		8:57	0.50	28.67	8.60	272	10.1	131	190	
		8:57	1.00	28.63	8.52	272	9.6	124	200	
		8:59	1.50	28.10	7.87	275	6.3	81	212	
		9:00	2.00	27.69	7.58	276	3.9	49	214	
		9:01	2.50	27.18	7.36	278	1.2	16	210	
		9:01	3.00	26.90	7.25	281	0.2	3	155	
		9:02	3.50	26.76	7.15	286	0.1	1	87	
		9:03	3.74	26.75	6.87	340	0.1	1	56	

B.2 Post-Treatment Monitoring

Vertical Field Profiles Collected in Booker Lake from November 2011 - October 2012

Site	Date	Time	Depth (m)	Temp (°C)	pH (s.u.)	Cond (µmho/cm)	DO (mg/L)	% Sat (%)	ORP (mV)	Secchi Depth (m)
Middle	11/17/11	12:36	0.25	24.34	8.87	378	11.3	135	391	0.54
		12:37	0.50	24.12	8.85	379	11.1	132	393	
		12:38	1.00	23.75	8.73	380	10.1	117	390	
		12:38	1.50	22.37	7.98	384	6.9	80	362	
		12:39	2.00	21.19	7.49	383	2.9	33	342	
		12:40	2.50	20.94	7.39	384	1.0	11	320	
		12:41	3.00	20.90	7.04	416	0.7	8	104	
		12:41	3.05	20.93	7.03	422	0.7	8	96	
Middle	12/29/11	10:42	0.25	19.45	7.54	382	5.1	56	415	0.61
		10:43	0.50	19.44	7.52	381	4.6	50	413	
		10:44	1.00	19.37	7.50	381	3.1	33	410	
		10:45	1.50	19.29	7.48	381	2.4	26	409	
		10:46	2.00	19.28	7.49	381	2.3	25	407	
		10:46	2.50	19.27	7.48	382	2.2	24	406	
		10:47	3.00	19.26	7.48	382	2.1	23	405	
		10:49	3.33	19.30	7.33	392	1.1	12	321	
Middle	1/12/12	8:34	0.25	18.42	8.36	388	9.7	104	414	0.39
		8:35	0.50	18.43	8.36	389	9.6	102	412	
		8:36	1.00	18.36	8.43	387	9.7	104	413	
		8:36	1.50	18.23	8.25	388	9.0	96	405	
		8:38	2.00	17.63	7.73	392	6.2	65	384	
		8:38	2.50	17.18	7.46	396	3.2	33	374	
		8:39	3.00	17.08	7.41	397	1.5	16	263	
		8:41	3.03	17.08	7.41	397	1.1	11	251	
Middle	2/8/12	8:57	0.25	20.84	8.04	393	7.4	83	503	0.42
		8:58	0.50	20.84	8.05	394	7.4	83	503	
		8:59	1.00	20.84	8.03	394	7.4	83	502	
		9:00	1.50	20.83	8.01	393	7.0	79	501	
		9:01	2.00	20.80	7.96	395	6.8	77	498	
		9:01	2.50	20.41	7.41	396	2.5	27	429	
		9:03	2.97	20.24	7.26	417	0.9	10	206	
Middle	3/8/12	8:50	0.25	21.53	8.18	406	8.1	92	482	0.34
		8:51	0.50	21.52	8.18	407	8.0	91	481	
		8:51	1.00	21.47	8.14	407	7.6	86	479	
		8:52	1.50	21.37	7.95	409	6.5	74	471	
		8:53	2.00	21.25	7.77	410	5.3	60	466	
		8:54	2.50	21.19	7.66	410	4.4	49	462	
		8:56	2.91	21.05	6.82	498	0.5	6	116	
Middle	4/10/12	8:45	0.25	25.00	8.41	398	8.5	103	517	0.76
		8:46	0.50	25.00	8.40	398	8.4	102	515	
		8:47	1.01	24.99	8.39	398	8.1	98	513	
		8:48	1.50	24.98	8.33	398	7.8	95	509	
		8:49	2.00	24.92	7.89	401	5.5	66	492	
		8:50	2.50	24.70	7.48	403	2.4	29	475	
		8:52	2.98	24.63	7.12	414	0.3	4	180	

Vertical Field Profiles Collected in Booker Lake from November 2011 - October 2012

Site	Date	Time	Depth (m)	Temp (°C)	pH (s.u.)	Cond (µmho/cm)	DO (mg/L)	% Sat (%)	ORP (mV)	Secchi Depth (m)
Middle	5/29/12	9:31	0.25	28.32	7.64	319	5.4	70	355	0.84
		9:32	0.50	28.33	7.65	319	5.1	66	357	
		9:33	1.00	28.32	7.64	319	5.0	65	357	
		9:34	1.50	28.30	7.62	318	4.9	63	357	
		9:34	2.00	28.28	7.58	318	4.6	59	356	
		9:35	2.50	28.17	7.35	318	2.8	35	345	
		9:36	2.95	27.80	6.83	367	0.6	8	107	
Middle	6/19/12	9:19	0.25	28.37	7.57	294	6.8	87	409	0.94
		9:20	0.50	28.40	7.57	295	6.8	87	409	
		9:21	1.00	28.37	7.55	295	6.5	83	408	
		9:22	1.51	28.28	7.55	294	6.4	83	409	
		9:23	2.00	28.27	7.54	294	6.5	83	410	
		9:24	2.57	28.21	7.50	295	6.2	80	409	
		9:26	2.99	28.17	6.87	337	2.7	34	219	
Middle	7/27/12	9:33	0.25	29.64	7.42	266	4.7	62	408	0.89
		9:34	0.50	29.66	7.38	266	4.5	59	407	
		9:34	1.00	29.67	7.35	266	4.3	57	406	
		9:35	1.50	29.66	7.33	266	3.9	52	405	
		9:36	2.00	29.65	7.32	265	3.7	48	405	
		9:37	2.50	29.66	7.31	265	3.6	48	405	
		9:37	3.00	29.48	7.10	257	1.7	23	397	
		9:38	3.25	29.46	6.80	277	1.1	14	383	
Middle	8/29/12	8:59	0.25	30.16	7.57	264	5.7	74	409	0.92
		9:00	0.50	30.18	7.51	264	5.6	73	408	
		9:00	1.00	30.19	7.49	263	5.4	70	407	
		9:01	1.50	30.18	7.47	263	5.2	67	407	
		9:02	2.00	30.05	7.44	263	5.1	66	407	
		9:03	2.50	30.04	7.42	263	4.9	64	407	
		9:03	3.00	29.99	7.26	261	2.2	28	308	
		9:04	3.46	29.91	6.81	319	0.5	7	192	
Middle	9/26/12	8:25	0.25	26.87	7.71	261	6.7	85	365	0.83
		8:26	0.50	26.86	7.64	262	6.4	80	367	
		8:26	1.00	26.86	7.62	260	6.2	78	369	
		8:27	1.50	26.86	7.60	261	6.1	76	370	
		8:28	2.00	26.85	7.55	261	5.8	73	370	
		8:29	2.50	26.85	7.52	260	5.6	70	369	
		8:29	3.00	26.84	7.42	266	4.7	59	355	
		8:31	3.12	26.83	6.82	361	0.8	10	283	
Middle	10/18/12	8:03	0.25	26.37	7.14	277	6.0	74	397	0.79
		8:04	0.50	26.37	7.23	278	5.6	69	400	
		8:05	1.00	26.37	7.25	279	5.4	67	400	
		8:06	1.50	26.36	7.26	279	5.1	63	399	
		8:06	2.00	26.36	7.26	279	5.1	64	399	
		8:07	2.50	26.33	7.27	277	5.2	65	399	
		8:08	3.00	26.28	7.21	281	4.3	54	387	
		8:10	3.18	26.33	6.80	345	0.9	11	236	

APPENDIX C

PRE- AND POST-TREATMENT BENTHIC MONITORING REPORTS

C.1 Pre-Treatment Summer and Winter Season Monitoring Events
C.2 Post-Treatment Summer and Winter Season Monitoring Events

C.1 Pre-Treatment Summer and Winter Season Monitoring Events

RESULTS OF PRE-CONSTRUCTION BENTHIC MONITORING PERFORMED IN BOOKER LAKE DURING JULY 2005

July 2006

Prepared For:

City of St. Petersburg

Prepared By:

Environmental Research & Design, Inc.
3419 Trentwood Blvd., Suite 102
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and

Mr. Mark Vogel

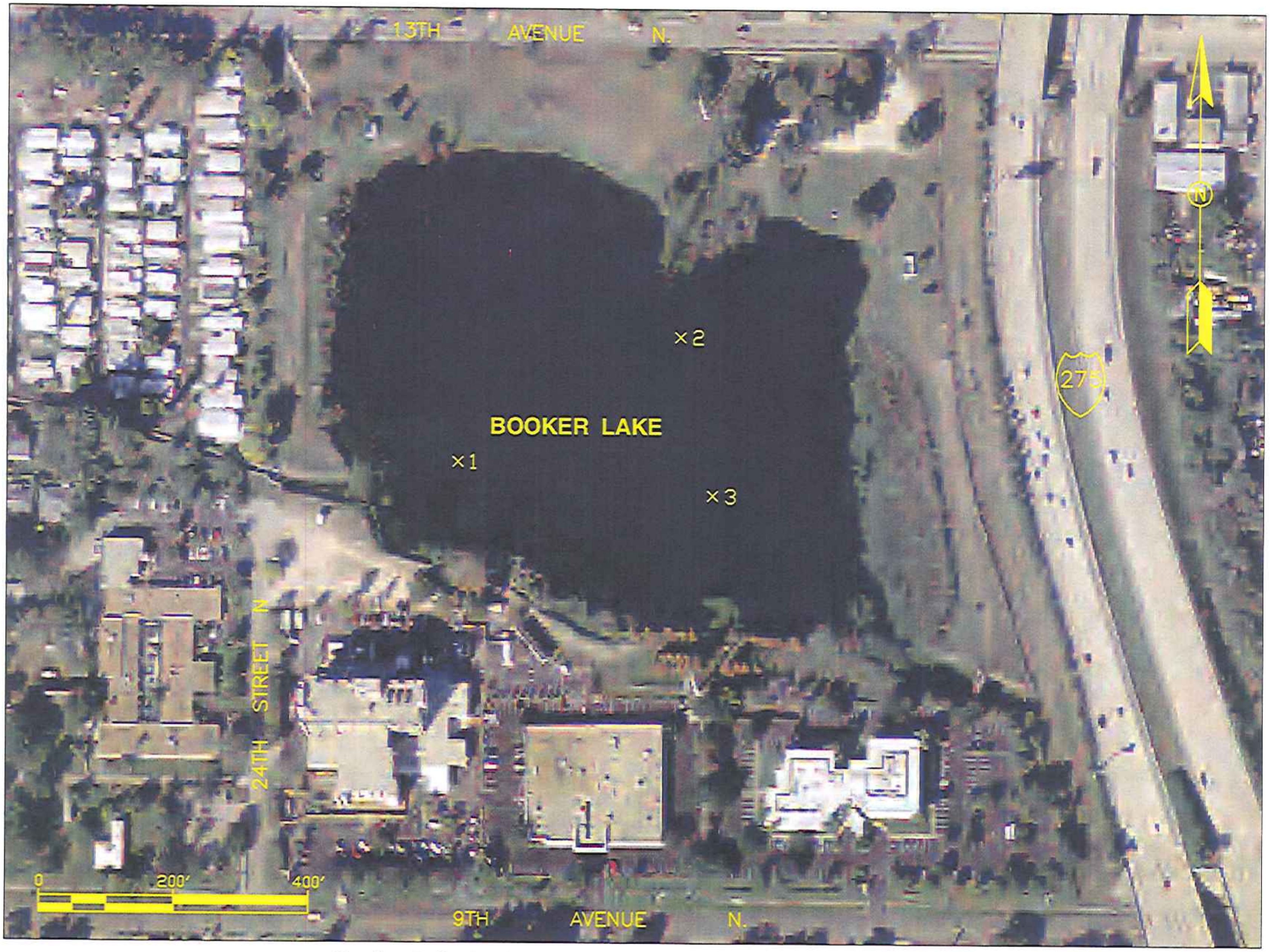
1.0 Introduction

This report summarizes the results of the initial pre-construction benthic monitoring event performed in Booker Lake in conjunction with the proposed alum stormwater treatment system to treat runoff inputs entering along the northeast and southwest shores of the lake. Two pre-construction benthic monitoring events will be performed in Booker Lake. The initial pre-construction monitoring event, discussed in this report, was conducted on July 21, 2005. The second pre-construction monitoring event will be conducted in January 2006. Sample collection for the pre-construction benthic monitoring events was performed by Environmental Research & Design, Inc. (ERD), with sample identification performed by Mr. Mark Vogel, formerly with the Florida Fish and Game Commission and the Orange County Environmental Protection Department.

2.0 Benthic Collection Procedures

Field personnel from ERD performed benthic monitoring at three sites within Booker Lake on July 21, 2005. The locations of the monitoring sites are indicated on Figure 1. The monitoring sites indicated on Figure 1 will be used for collection of both pre- and post-construction benthic samples.

Sample collection was performed using a 6-inch x 6-inch stainless steel Eckman dredge. Three separate dredge samples were collected at each sample site and placed into a wash bucket with a 500 μm stainless steel sieve screen. The samples were washed to remove silt and fine sand and stored in individual bottles for subsequent analysis. This procedure formed a total of nine separate benthic samples (3 sites x 3 samples/site) to be submitted for analysis. Each of the benthic samples was preserved and shipped to Mr. Mark Vogel for evaluation. In order to maintain uniform procedures and sample methodologies between the monitoring events, specifics concerning monitoring techniques, sieve size, preservation and shipping methods were provided to ERD by Mr. Vogel.



Booker Lake Surface Water and Benthic Monitoring Sites.

3.0 Water Column Characteristics

During the collection process for benthic organisms, physical-chemical profiles of temperature, pH, specific conductivity, dissolved oxygen and ORP were conducted at the water surface and at 0.5 m intervals to the lake bottom at each monitoring site. A summary of physical-chemical profiles collected at monitoring sites in Booker Lake on July 21, 2005 is given in Appendix A.

The water column within Booker Lake on July 21, 2005 was highly stratified at each of the three monitoring sites, with stratified conditions occurring at depths from 2.5-3.5 m. Temperature differences of approximately 3-4 °C were observed between surface and bottom locations at each site. Upper portions of the water column at each site were found to be well oxygenated, with concentrations typically in excess of 5 mg/l. However, after a depth of approximately 2.5-3 m, dissolved oxygen concentrations decrease rapidly, reaching values ranging from 1.4-1.6 mg/l near the water-sediment interface.

Measured pH values at the surface range from 7.81-8.31 units. In general, water column pH decreases with increasing water depth, with a more rapid rate of decrease in lower portions of the water column. Bottom pH measurements range from 6.75-6.81.

Oxidized conditions, indicated by ORP values in excess of 200 mv, were observed in upper portions of the water column at each site. However, ORP values appear to approach 200 mv at bottom measurements performed at each site. A large increase in specific conductivity was also observed near the water-sediment interface, suggesting a significant amount of internal recycling at each of the three sites. Measured Secchi disk depths range from 0.94-0.96 m, indicating moderately poor water column transparency at the time of the monitoring event.

4.0 Results of Benthic Identification

Benthic identification bench sheets for Booker Lake, summarizing the results of analyses conducted on replicate samples at each site, are provided in Appendix B. A comparison of species observed in Booker Lake at the three monitoring sites is given in Table 1. Three separate benthic species were identified in monitoring performed within the lake. Of the measured species, *Chironomus* sp. and *Limnodrilus hoffmeisteri* were simultaneously observed at Sites 1 and 2. No benthic species were found in any of the replicate samples collected at Site 3.

TABLE 1

COMPARISON OF BENTHIC SPECIES OBSERVED IN BOOKER LAKE DURING THE JULY 1005 PRE-CONSTRUCTION MONITORING EVENT

SPECIES	PRE-CONSTRUCTION (1/20/06)		
	Site 1	Site 2	Site 3
Chaoborus punctipennis	X	X	
Limnodrilus hoffmeisteri	X	X	
Urnatella gracilis	X		
TOTAL:	3	2	0

A summary of pre-construction macroinvertebrate assemblages at Site 1 in Booker Lake during July 2005 is given in Table 2. The existing organism density at monitoring Site 1 is low in value, with only three significant species observed at this site. The benthic community at Site 1 can be described as a depauperate community characterized by low densities and low diversity. The aquatic worm, *Limnodrilus hoffmeisteri*, was the most common species observed at this site, comprising 82.6% of the total organism density. The remaining species observed at this site consist of the phantom midge, *Chaoborus punctipennis*, and a single specimen of *Urnatella gracilis*.

A summary of pre-construction macroinvertebrate assemblages at Site 2 in Booker Lake during July 2005 is given in Table 3. The benthic population at Site 2 is similar to the assemblage at Site 1. Two species were observed at this site, with *Limnodrilus hoffmeisteri* comprising 71.9% of the population and *Chaoborus punctipennis* comprising 28.1% of the total organisms found at this site.

TABLE 2

SUMMARY OF PRE-CONSTRUCTION MACROINVERTEBRATE ASSEMBLAGE AT SITE 1 IN BOOKER LAKE DURING JULY 2005

PRE-CONSTRUCTION (7/21/05)		
TAXA	**MEAN ($\#/m^2$)**	**%**
Urnatella gracilis	15	2.2
Chaoborus punctipennis	104	15.2
Limnodrilus hoffmeisteri	563	82.6
Mean Total Taxa		2
Mean Total Organisms/m^2		682
Mean Shannon Diversity		0.46
Mean Eveness		0.66

TABLE 3

SUMMARY OF PRE-CONSTRUCTION MACROINVERTEBRATE ASSEMBLAGE AT SITE 2 IN BOOKER LAKE DURING JULY 2005

PRE-CONSTRUCTION (7/21/05)		
TAXA	**MEAN ($\#/m^2$)**	**%**
Chaoborus punctipennis	400.1	28.1
Limnodrilus hoffmeisteri	1022.4	71.9
Mean Total Taxa		2
Mean Total Organisms/m^2		1422
Mean Shannon Diversity		0.58
Mean Eveness		0.82

No benthic species were found in any of the replicate samples collected at Site 3. This is an extremely unusual situation in Florida lakes and suggests that harsh conditions must exist at this location in order to exclude all benthic organisms. It appears that the high summer water temperatures, combined with the high organic content of the sediments, severely limit the types of organisms that can survive in this environment.

APPENDICES

APPENDIX A

PHYSICAL-CHEMICAL PROFILES COLLECTED IN BOOKER LAKE ON JULY 21, 2005

Location	Site	Date	Time	Level (m)	Temp (°C)	pH (s.u.)	SpCond (µmho/cm)	TDS (mg/l)	DO (mg/l)	DO (%Sat)	Redox (mV)	Turb (NTU)	Secchi (m)
Booker	Site 1	7/21/05	103226	0.25	31.54	8.31	234	150	7.3	100	447	11.8	0.95
Booker	Site 1	7/21/05	103254	0.50	31.55	8.37	234	150	7.4	102	459	8.7	0.95
Booker	Site 1	7/21/05	103358	1.00	31.40	8.41	233	149	7.3	100	477	5.1	0.95
Booker	Site 1	7/21/05	103439	1.50	31.31	8.36	233	149	7.1	98	480	4.8	0.95
Booker	Site 1	7/21/05	103517	2.00	31.29	8.29	234	150	8.5	116	483	4.7	0.95
Booker	Site 1	7/21/05	103604	2.50	30.80	7.92	230	147	6.5	89	465	5.4	0.95
Booker	Site 1	7/21/05	103655	3.00	30.33	7.62	223	143	3.4	45	442	9.1	0.95
Booker	Site 1	7/21/05	103732	3.50	28.73	7.33	212	136	2.9	38	404	12.2	0.95
Booker	Site 1	7/21/05	103832	4.00	27.71	6.98	232	148	3.0	39	279	15.5	0.95
Booker	Site 1	7/21/05	103923	4.47	27.39	6.81	270	173	1.5	20	222	> 1000	0.95
Booker	Site 2	7/21/05	100759	0.25	31.42	7.81	233	149	8.9	120	601	7.8	0.94
Booker	Site 2	7/21/05	100905	0.50	31.28	8.14	232	148	8.2	111	619	7.7	0.94
Booker	Site 2	7/21/05	101011	1.00	31.19	8.22	232	148	7.9	106	625	5.9	0.94
Booker	Site 2	7/21/05	101134	1.50	31.02	7.79	231	148	7.6	103	607	5.8	0.94
Booker	Site 2	7/21/05	101235	2.00	30.89	7.65	230	147	6.8	93	601	5.7	0.94
Booker	Site 2	7/21/05	101321	2.50	30.75	7.56	239	153	6.7	91	597	5.3	0.94
Booker	Site 2	7/21/05	101416	3.00	30.27	7.36	232	148	3.5	48	584	10.9	0.94
Booker	Site 2	7/21/05	101542	3.50	28.53	7.01	216	138	3.2	42	389	13.0	0.94
Booker	Site 2	7/21/05	101724	3.79	27.71	6.75	325	208	1.4	18	213	> 1000	0.94
Booker	Site 3	7/21/05	102059	0.25	31.50	8.27	232	149	9.7	133	463	5.5	0.96
Booker	Site 3	7/21/05	102159	0.50	31.43	8.36	233	149	10.3	142	481	5.9	0.96
Booker	Site 3	7/21/05	102255	1.00	31.27	8.35	232	148	8.8	121	490	5.5	0.96
Booker	Site 3	7/21/05	102334	1.50	31.16	8.17	233	149	8.5	116	487	5.2	0.96
Booker	Site 3	7/21/05	102446	2.00	30.89	7.80	232	149	7.2	98	472	5.1	0.96
Booker	Site 3	7/21/05	102530	2.50	30.83	7.65	231	148	7.9	108	467	5.2	0.96
Booker	Site 3	7/21/05	102631	3.00	30.64	7.47	231	148	3.6	48	453	6.3	0.96
Booker	Site 3	7/21/05	102725	3.50	28.90	7.14	222	142	3.5	47	367	11.0	0.96
Booker	Site 3	7/21/05	102823	4.00	27.78	6.92	231	148	3.5	45	265	18.1	0.96
Booker	Site 3	7/21/05	102907	4.24	27.64	6.79	279	179	1.6	20	226	> 1000	0.96

APPENDIX B

BENTHIC IDENTIFICATION SHEETS FOR BOOKER LAKE

Raw Data

Booker Lake	7/21/05				
ORDER	FAMILY	GENUS/SPECIES (FBI)		Site1	
			Rep1	Rep 2	Rep 3
Urnitellida		*Urnatella gracilis* (0)	P	0	0
Diptera	Chaoboridae	*Chaoborus punctipennis* (0)	2	1	4
Oligochaeta	Tubificidae	*Limnodrilus hoffmeisteri* (0)	2	20	16
		Mean Total Taxa		2	
		Mean Total Organisms/sq. m		667	
		Mean Diversity		0.46	
		Mean Eveness		0.66	

Booker Lake	7/21/05				
ORDER	FAMILY	GENUS/SPECIES (FBI)		Site2	
			Rep1	Rep 2	Rep 3
Diptera	Chaoboridae	*Chaoborus punctipennis* (0)	7	7	13
Oligochaeta	Tubificidae	*Limnodrilus hoffmeisteri* (0)	4	34	31
		Mean Total Taxa		2	
		Mean Total Organisms/sq. m		1422	
		Mean Diversity		0.58	
		Mean Eveness		0.82	

Booker Lake	7/21/05				
ORDER	FAMILY	GENUS/SPECIES (FBI)		Site3	
			Rep1	Rep 2	Rep 3
		Mean Total Taxa		0	
		Mean Total Organisms/sq. m		0	
		Mean Diversity		0	
		Mean Eveness		0	

RESULTS OF PRE-CONSTRUCTION BENTHIC MONITORING PERFORMED IN BOOKER LAKE DURING JANUARY 2006

July 2006

Prepared For:

City of St. Petersburg

Prepared By:

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Orlando, FL 32812

and

Mr. Mark Vogel

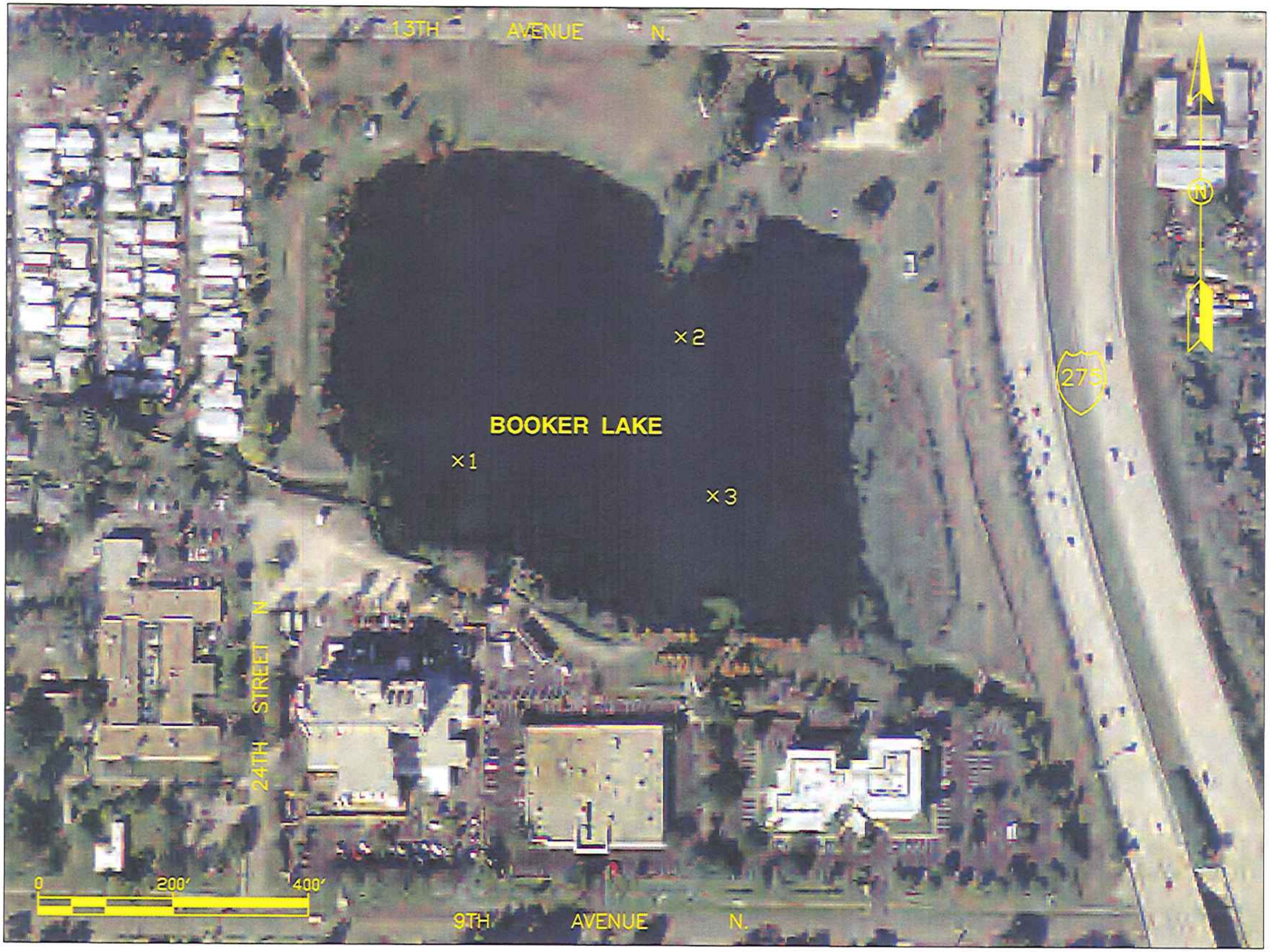
1.0 Introduction

This report summarizes the results of the second pre-construction benthic monitoring event performed in Booker Lake in conjunction with the proposed alum stormwater treatment system to treat runoff inputs entering along the northeast and southwest shores of the lake. Two pre-construction benthic monitoring events have now been performed in Booker Lake. The initial pre-construction monitoring event was conducted in July 2005. The second pre-construction monitoring event, discussed in this report, was conducted on January 20, 2006. Sample collection for the pre-construction benthic monitoring events was performed by Environmental Research & Design, Inc. (ERD), with sample identification performed by Mr. Mark Vogel, formerly with the Florida Fish and Game Commission and the Orange County Environmental Protection Department.

2.0 Benthic Collection Procedures

Field personnel from ERD performed benthic monitoring at three sites within Booker Lake on January 20, 2006. The locations of the monitoring sites are indicated on Figure 1. The monitoring sites indicated on Figure 1 will be used for collection of both pre- and post-construction benthic samples.

Sample collection was performed using a 6-inch x 6-inch stainless steel Eckman dredge. Three separate dredge samples were collected at each sample site and placed into a wash bucket with a 500 μm stainless steel sieve screen. The samples were washed to remove silt and fine sand and stored in individual bottles for subsequent analysis. This procedure formed a total of nine separate benthic samples (3 sites x 3 samples/site) to be submitted for analysis. Each of the benthic samples was preserved and shipped to Mr. Mark Vogel for evaluation. In order to maintain uniform procedures and sample methodologies between the monitoring events, specifics concerning monitoring techniques, sieve size, preservation and shipping methods were provided to ERD by Mr. Vogel.



Booker Lake Surface Water and Benthic Monitoring Sites.
Figure 1.

3.0 Water Column Characteristics

During the collection process for benthic organisms, physical-chemical profiles of temperature, pH, specific conductivity, dissolved oxygen and ORP were conducted at the water surface and at 0.5 m intervals to the lake bottom at each monitoring site. A summary of physical-chemical profiles collected at monitoring sites in Booker Lake on January 20, 2006 is given in Appendix A.

The water column within Booker Lake on January 20, 2006 appeared to be relatively well mixed at each of the three sites. The temperature difference between surface and bottom layers at each site was less than 1°C. Measured pH values in the top 1 m at each site ranged from 8.59-8.62, with a decrease of approximately 0.1-1.2 unit near the bottom at each site. The water column was well oxygenated at each site, with concentrations greater than 2 mg/l near the water-sediment interface at all sites.

Oxidized conditions, indicated by ORP values in excess of 200 mv, were observed throughout the entire water column at Sites 1 and 2, with reduced conditions observed near the bottom at Site 3. No significant specific conductivity increases were observed near the bottom at any of the sites, suggesting a low internal recycling. The measured Secchi disk depths at the monitoring sites averaged 0.48 m, indicating poor water column transparency at the time of the monitoring event.

4.0 Results of Benthic Identification

Benthic identification bench sheets for Booker Lake, summarizing the results of analyses conducted on replicate samples at each site, are provided in Appendix B. A comparison of species observed in Booker Lake at the three monitoring sites is given in Table 1. A total of 20 separate benthic species was identified in monitoring performed within the lake. Of the measured species, only *Chironomus* sp. and *Limnodrilus hoffmeisteri* were simultaneously observed at each of the three sites.

TABLE 1

COMPARISON OF BENTHIC SPECIES OBSERVED IN BOOKER LAKE DURING THE JANUARY 2006 PRE-CONSTRUCTION MONITORING EVENT

SPECIES	PRE-CONSTRUCTION (1/20/06)		
	Site 1	Site 2	Site 3
Aulodrilus pigueti		X	
Caenis diminuta		X	
Chaoborus punctipennis	X		X
Chironomus sp.	X	X	X
Cladopelma sp.		X	
Cordylophora lacustris		X	
Cryptochironomus sp.		X	
Dero sp.		X	
Glyptotendipes sp.		X	
Goeldichironomus sp.		X	
Helobdella stagnalis		X	
Hyalella azteca		X	
Hyalopyrgus aequicostatus		X	
Limnodrilus hoffmeisteri	X	X	X
Melanoides tuberculata		X	
unid. Nematode		X	
Perithemis tenera		X	
Planorbella scalaris		X	
Procladius sp.	X		
Pyrogophorus platyrachis		X	
unid. Sphaeriid		X	
Utterbackia imbecilis		X	
TOTAL:	4	20	3

A summary of pre-construction macroinvertebrate assemblages at Site 1 in Booker Lake during January 2006 is given in Table 2. The existing organism density at monitoring Site 1 is low in value, with only four significant species observed at this site. The benthic community at Site 1 can be described as a depauperate community characterized by low densities and low diversity. The aquatic worm, *Limnodrilus hoffmeisteri*, was the most common species observed at this site, comprising 80.6% of the total organism density. The remaining species observed at this site consist of pollution tolerant midges and the phantom midge, *Chaoborus punctipennis*. In general, the taxa found at Site 1 during January 2006 is comparable to those found in July 2005.

TABLE 2

SUMMARY OF PRE-CONSTRUCTION MACROINVERTEBRATE ASSEMBLAGE AT SITE 1 IN BOOKER LAKE DURING JANUARY 2006

PRE-CONSTRUCTION (1/20/06)		
TAXA	**MEAN (#/m^2)**	**%**
Procladius sp.	44.5	2.3
Chaoborus punctipennis	119	6.2
Chironomus sp.	207	10.9
Limnodrilus hoffmeisteri	1541	80.6
Mean Total Taxa		3
Mean Total Organisms/m^2		1,911
Mean Shannon Diversity		0.71
Mean Eveness		0.60

A summary of pre-construction macroinvertebrate assemblages at Site 2 in Booker Lake during January 2006 is given in Table 3. The benthic population at Site 2 is somewhat better than the assemblage at Site 1. Species composition at Site 2 during January 2006 is improved from that observed during July 2005. The total taxa found at Site 2 increased from two in July 2005 to ten in January 2006, with the vast majority of these species consisting of organisms which are highly tolerant to low dissolved oxygen levels. The serrated crown snail, *Pyrogophorus platyrachis*, was the most abundant species, comprising approximately 76.5% of the organisms found at this site.

The second most abundant species was *Melanoides tuberculata*, which is an exotic red-rimmed snail. This species comprised approximately 6.9% of the organisms present. Only three of the total taxa observed at this site are considered to be pollution tolerant. These species include the mayfly, *Caenis diminuta*, the freshwater mussel, *Utterbackia imbecilis*, and the scud, *Hyalella azteca*. Each of these is assigned a score of 1 on the Florida Biotic Index.

TABLE 3

SUMMARY OF PRE-CONSTRUCTION MACROINVERTEBRATE ASSEMBLAGE AT SITE 2 IN BOOKER LAKE DURING JANUARY 2006

PRE-CONSTRUCTION (1/20/06)		
TAXA	**MEAN (#/m^2)**	**%**
Dero sp.	14.8	0.2
Helobdella stagnalis	14.8	0.2
Caenis diminuta	29.6	0.3
Cryptochironomus sp.	29.6	0.3
Glyptotendipes sp.	29.6	0.3
Hyalella azteca	29.6	0.3
Hyalopyrgus aequicostatus	29.6	0.3
Perithemis tenera	29.6	0.3
Planorbella scalaris	29.6	0.3
Utterbackia imbecilis	29.6	0.3
Unid. Nematode	29.6	0.3
Aulodrilus pigueti	44.5	0.5
Cladopelma sp.	59.3	0.6
Goeldichironomus sp.	88.9	1.0
Chironomus sp.	252	2.7
Unid. Sphaeriid	326	3.5
Limnodrilus hoffmeisteri	445	4.8
Melanoides tuberculata	637	6.0
Pyrogophorus platyrachis	7097	76.5
Mean Total Taxa		10
Mean Total Organisms/m^2		9,275
Mean Shannon Diversity		1.23
Mean Eveness		0.61

A summary of pre-construction macroinvertebrate assemblages at Site 3 in Booker Lake during January 2006 is given in Table 4. In general, macroinvertebrate populations at Site 3 have improved since the initial pre-construction monitoring event performed in July 2005. No benthic species were observed in any of the replicate samples collected during the July 2005 event. However, during January 2006, three taxa were collected at Site 3. Each of the three species observed at this site are considered to be highly pollutant tolerant. The dominant species observed at this site is the aquatic worm, *Limnodrilus hoffmeisteri*, which comprised 68.2% of the total organisms measured at this site.

TABLE 4

SUMMARY OF PRE-CONSTRUCTION MACROINVERTEBRATE ASSEMBLAGE AT SITE 3 IN BOOKER LAKE DURING JANUARY 2006

PRE-CONSTRUCTION (1/20/06)		
TAXA	**MEAN ($\#/m^2$)**	**%**
Chaoborus punctipennis	88.9	13.6
Chironomus sp.	119	18.2
Limnodrilus hoffmeisteri	445	68.2
Mean Total Taxa		2
Mean Total Organisms/m^2		652
Mean Shannon Diversity		0.46
Mean Eveness		0.47

APPENDICES

APPENDIX A

PHYSICAL-CHEMICAL PROFILES COLLECTED IN BOOKER LAKE ON JANUARY 20, 2006

Location	Site	Date	Time	Level (m)	Temp (°C)	pH (s.u.)	SpCond (μmho/cm)	TDS (mg/l)	DO (mg/l)	DO (%Sat)	Redox (mV)	Turb (NTU)	Secchi (m)
Booker	Site 1	1/20/06	10:45	0.25	17.51	8.60	404	258	11.1	138	425	14.2	0.48
Booker	Site 1	1/20/06	10:46	0.50	17.48	8.61	404	258	11.3	140	425	14.1	0.48
Booker	Site 1	1/20/06	10:48	1.00	17.39	8.61	404	259	11.3	140	425	13.8	0.48
Booker	Site 1	1/20/06	10:49	1.50	17.34	8.60	404	259	11.2	139	426	13.8	0.48
Booker	Site 1	1/20/06	10:50	2.00	17.25	8.58	405	259	11.1	138	426	13.9	0.48
Booker	Site 1	1/20/06	10:52	2.50	16.93	8.28	408	261	8.3	102	412	20.7	0.48
Booker	Site 1	1/20/06	10:54	3.00	16.69	8.04	410	263	7.6	93	401	21.6	0.48
Booker	Site 1	1/20/06	10:56	3.50	16.65	7.93	411	263	6.8	84	397	26.3	0.48
Booker	Site 1	1/20/06	10:59	3.95	16.68	7.68	411	263	5.4	65	217	780.9	0.48
Booker	Site 2	1/20/06	11:04	0.25	17.66	8.62	405	259	10.3	129	349	13.9	0.48
Booker	Site 2	1/20/06	11:05	0.50	17.49	8.62	405	259	10.8	135	359	13.8	0.48
Booker	Site 2	1/20/06	11:07	1.00	17.24	8.59	405	259	10.0	123	368	13.8	0.48
Booker	Site 2	1/20/06	11:10	1.50	17.18	8.57	405	259	9.8	121	375	13.9	0.48
Booker	Site 2	1/20/06	11:12	2.00	17.13	8.58	405	259	10.4	128	380	14.4	0.48
Booker	Site 2	1/20/06	11:17	2.09	17.16	8.58	405	259	10.7	132	386	14.3	0.48
Booker	Site 3	1/20/06	11:22	0.25	17.37	8.59	405	259	10.7	133	394	13.7	0.48
Booker	Site 3	1/20/06	11:23	0.50	17.16	8.57	405	259	9.8	121	395	13.8	0.48
Booker	Site 3	1/20/06	11:24	1.00	16.94	8.48	406	260	9.3	115	392	13.8	0.48
Booker	Site 3	1/20/06	11:25	1.50	16.74	8.28	409	262	9.4	115	383	14.6	0.48
Booker	Site 3	1/20/06	11:27	2.00	16.71	8.17	410	262	7.5	92	380	16.4	0.48
Booker	Site 3	1/20/06	11:28	2.50	16.70	8.17	410	262	8.4	103	381	16.0	0.48
Booker	Site 3	1/20/06	11:29	3.00	16.70	8.15	410	263	7.3	90	382	17.6	0.48
Booker	Site 3	1/20/06	11:32	3.27	16.81	7.39	414	265	2.0	25	190	>1000	0.48

APPENDIX B

BENTHIC IDENTIFICATION SHEETS FOR BOOKER LAKE

Raw Data

Booker Lake	1/20/2006				
ORDER	FAMILY	GENUS/SPECIES (LI)		Site1	
			Rep1	Rep 2	Rep 3
Diptera	Chaoboridae	*Chaoborus punctipennis* (0)	6	2	0
Diptera	Chironomidae	*Chironomus* (0) sp.	4	6	4
Diptera	Chironomidae	*Procladius* (1) sp.	0	1	2
Oligochaeta	Tubificidae	*Limnodrilus hoffmeisteri* (0)	50	44	10
		Mean Total Taxa		3	
		Mean Total Organisms/sq. m		1911	
		Mean Diversity		0.71	
		Mean Eveness		0.60	
ORDER	FAMILY	GENUS/SPECIES (LI)		Site2	
			Rep1	Rep 2	Rep 3
Cnidaria	Clavidae	*Cordylophora lacustris* (0)	0	0	P
Nematoda		unid. Nematode (0)	0	0	2
Pelycepoda	Unionidae	*Utterbackia imbecilis* (1)	0	1	1
	Sphaeriidae	unid. Sphaeriid (0)	0	0	22
Gastropoda	Hydrobiidae	*Pyrogophorus platyrachis* (0)	6	42	431
	Hydrobiidae	*Hyalopyrgus aequicostatus* (0)	0	0	2
	Thiaridae	*Melanoides tuberculata* (0)	2	13	28
	Planorbidae	*Planorbella scalaris* (0)	0	0	2
Amphipoda	Hyalellidae	*Hyalella azteca* (0)	0	0	2
Epheroptera	Caenidae	*Caenis diminuta* (0)	0	0	2
Odonata	Libelluidae	*Perithemis tenera* (0)	0	0	2
Diptera	Chironomidae	*Chironomus* (0) sp.	6	0	11
	Chironomidae	*Cladopelma* (0) sp.	4	0	0
	Chironomidae	*Cryptochironomus* (0) sp.	2	0	0
	Chironomidae	*Glyptotendipes* (0) sp.	0	2	0
	Chironomidae	*Goeldichironomus* (0) sp.	0	4	2
Oligochaeta	Tubificidae	*Aulodrilus pigueti* (0)	0	0	3
	Tubificidae	*Dero* (0) sp.	1	0	0
	Tubificidae	*Limnodrilus hoffmeisteri* (0)	7	2	21
	Glossophoniidae	*Helobdella stagnalis* (0)	0	0	1
		Mean Total Taxa		10	
		Mean Total Organisms/sq. m		9275	
		Mean Diversity		1.23	
		Mean Eveness		0.61	
ORDER	FAMILY	GENUS/SPECIES (FBI)		Site3	
			Rep1	Rep 2	Rep 3
Diptera	Chaoboridae	*Chaoborus punctipennis* (0)	6	0	0
Diptera	Chironomidae	*Chironomus* (0) sp.	6	2	0
Oligochaeta	Tubificidae	*Limnodrilus hoffmeisteri* (0)	12	18	0
		Mean Total Taxa		2	
		Mean Total Organisms/sq. m		652	
		Mean Diversity		0.46	
		Mean Eveness		0.47	

C.2 Post-Treatment Summer and Winter Season Monitoring Events

RESULTS OF POST-CONSTRUCTION BENTHIC MONITORING PERFORMED IN BOOKER LAKE DURING JANUARY 2012

July 2012

Prepared For:

City of St. Petersburg

Prepared By:

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and

Mr. Mark Vogel

1.0 Introduction

This report summarizes the results of the January 2012 winter season post-construction benthic monitoring event performed in Booker Lake in conjunction with the alum stormwater treatment system which treats runoff inputs entering along the northeast and southwest shores of the lake. Pre-construction benthic monitoring events were performed in Booker Lake during July 2005 (summer season) and January 2006 (winter season). Sample collection for both the pre- and post-construction benthic monitoring events was performed by Environmental Research & Design, Inc. (ERD), with sample identification performed by Mr. Mark Vogel, formerly with the Florida Fish and Game Commission and the Orange County Environmental Protection Department.

2.0 Benthic Collection Procedures

Field personnel from ERD performed benthic monitoring at three sites within Booker Lake

Figure 2-2 Pre & Post Treatment Benthic Monitoring Site

Figure 1. Booker Lake Surface Water and Benthic Monitoring Sites.

Sample collection was performed using a 6-inch x 6-inch stainless steel Eckman dredge. Three separate dredge samples were collected at each sample site and placed into a wash bucket with a 500 μm stainless steel sieve screen. The samples were washed to remove silt and fine sand and stored in individual bottles for subsequent analysis. This procedure formed a total of nine separate benthic samples (3 sites x 3 samples/site) to be submitted for analysis. Each of the benthic samples was preserved and shipped to Mr. Mark Vogel for evaluation. In order to maintain uniform procedures and sample methodologies between the monitoring events, specifics concerning monitoring techniques, sieve size, preservation and shipping methods were provided to ERD by Mr. Vogel.

3.0 Results of Benthic Identification

Benthic identification bench sheets for the January 2012 monitoring event, summarizing the results of analyses conducted on replicate samples at each site, are provided in Appendix A. A comparison of species observed in Booker Lake at the three monitoring sites is given in Table 1. Twelve separate benthic species were identified at the three post-treatment monitoring sites compared with 20 species identified in the January 2006 pre-treatment event. Of the measured species, *Chironomus* sp., *Limnodrilus hoffmeisteri, Procladius* sp.*, Chironomus* sp.*, and Ilyodrilus templetoni* were simultaneously observed at all sites.

TABLE 1

COMPARISON OF BENTHIC SPECIES OBSERVED IN BOOKER LAKE DURING THE JANUARY 2012 WINTER SEASON POST-CONSTRUCTION MONITORING EVENT

SPECIES	POST-CONSTRUCTION (1/12/12)		
	Site 1	Site 2	Site 3
Chaoborus punctipennis	X	X	X
Limnodrilus hoffmeisteri	X	X	X
Cladopelma sp.		X	X
Dero sp.	X	X	
Nematoda		X	X
Goeldichironomus sp.		X	
Procladius sp.	X	X	X
Chironomus sp.	X	X	X
Tanypus sp.	X		
Ilyodrilus templetoni	X	X	X
Nais sp.			X
TOTAL:	**7**	**9**	**8**

A summary of post-construction winter season macroinvertebrate assemblages at Site 1 in Booker Lake during January 2012 is given in Table 2. The post-treatment winter organism density at monitoring Site 1 was 4,534 organisms/m^2 compared with a pre-treatment density of 1,911 organisms/m^2, indicating a substantial increase in overall density. The aquatic worm, *Limnodrilus hoffmeisteri*, was the most common species observed at this site during January 2012, comprising 80.6% of the total organism density under pre-treatment winter conditions and 92.2% under post-treatment winter conditions, indicating little change in benthic species at this site. The mean Shannon Diversity Index for the winter season post-treatment benthic assemblage at Site 1 decreased to a value of 0.35 compared with a pre-treatment mean Shannon Diversity Index of 0.71 for the January 2006 monitoring event.

TABLE 2

SUMMARY OF POST-CONSTRUCTION MACROINVERTEBRATE ASSEMBLAGE AT SITE 1 IN BOOKER LAKE DURING JANUARY 2012

TAXA	MEAN (#/m^2)	%
Limnodrilus hoffmeisteri	4,178.3	92.2
Procladius sp.	148.2	3.3
Chaoborus punctipennis	103.7	2.3
Chironomus sp.	29.6	0.7
Tanypus sp.	29.6	0.7
Dero sp.	29.6	0.7
Ilyodrilus templetoni	14.8	0.3
Mean Total Taxa	4.6	
Mean Total Organisms/m^2	4,534	
Mean Shannon Diversity	0.35	
Mean Eveness	0.24	

A summary of post-construction macroinvertebrate assemblages at Site 2 in Booker Lake during January 2012 is given in Table 3. Nine separate species were observed at this site during January 2012, with *Limnodrilus hoffmeisteri* comprising 65.7% of the population and *Procladius* sp. comprising 20.7% of the total organisms found at this site. Seven additional taxa were found at Site 2 under post-treatment winter season conditions. During the pre-treatment monitoring event conducted in January 2006, 19 separate species were present at this site, all of which are considered to be tolerant of highly organic sediments. The overall organism density was reduced from 9,275 organisms/m^2 during January 2006 to 4,534 organisms/m^2 during January 2012 which indicates a reduction in available nutrients. The mean Shannon Diversity Index for the post-treatment winter season benthic assemblage at Site 2 was 1.09 compared with a pre-treatment mean Shannon Diversity Index of 1.23 for the January 2006 monitoring event.

TABLE 3

SUMMARY OF POST-CONSTRUCTION MACROINVERTEBRATE ASSEMBLAGE AT SITE 2 IN BOOKER LAKE DURING JANUARY 2012

TAXA	MEAN (#/m^2)	%
Limnodrilus hoffmeisteri	2207.7	65.7
Procladius sp.	696.4	20.7
Dero sp.	148.2	4.4
Chaoborus punctipennis	133.4	4.0
Cladopelma sp.	74.1	2.2
Chironomous sp.	44.5	1.3
Nematoda.	29.6	0.9
Ilyodrilus templetoni	14.8	0.4
Goeldichironomus sp.	14.8	0.4
Mean Total Taxa	6.3	
Mean Total Organisms/m^2	3363	
Mean Shannon Diversity	1.09	
Mean Eveness	0.59	

A summary of winter season post-treatment macroinvertebrate assemblages at Site 3 in Booker Lake during January 2012 is given in Table 4. A total of eight separate species was observed at this site which was dominated by *Limnodrilus hoffmeisteri*, indicating that conditions have become more favorable for maintaining benthic populations. The overall organism density of 2,000 organisms/m^2 during January 2012 reflects a large increase over the density of 652 organisms/m^2 in January 2006.

TABLE 4

SUMMARY OF POST-CONSTRUCTION MACROINVERTEBRATE ASSEMBLAGE AT SITE 3 IN BOOKER LAKE DURING JANUARY 2012

TAXA	MEAN (#/m^2)	%
Limnodrilus hoffmeisteri	1259	62.9
Procladius sp.	548.2	27.4
Chironomous sp.	59.3	3.0
Cladopelma sp.	44.5	2.2
Chaoborus punctipennis	44.5	2.2
Nais sp.	14.8	0.7
Nematoda.	14.8	0.7
Ilyodrilus templetoni	14.8	0.3
Mean Total Taxa	5.3	
Mean Total Organisms/m^2	2000	
Mean Shannon Diversity	0.76	
Mean Eveness	0.59	

APPENDIX A

BENTHIC IDENTIFICATION SHEETS FOR BOOKER LAKE

Raw Data

Booker Lake Site 1

	Rep 1	Rep 2	Rep 3
Limnodrilus hoffmeisteri	63	120	99
Procladius sp.	1	2	7
Ilyodrilus templetoni	0	1	0
Chironomus sp.	0	1	1
Chaoborus punctipennis	3	1	3
Tanypus sp.	0	2	0
Dero sp.	0	2	0

Booker Lake Site 2

	Rep 1	Rep 2	Rep 3
Nematoda	0	2	0
Limnodrilus hoffmeisteri	65	21	63
Dero sp.	2	1	7
Ilyodrilus templetoni	1	0	0
Chironomus sp.	1	1	1
Chaoborus punctipennis	2	5	2
Goeldichironomus sp.	0	0	1
Procladius sp.	22	12	13
Cladopelma sp.	0	3	2

Booker Lake Site 3

	Rep 1	Rep 2	Rep 3
Limnodrilus hoffmeisteri	0	81	4
Procladius sp.	13	21	3
Cladopelma sp.	1	2	0
Chironomus sp.	1	2	1
Chaoborus punctipennis	0	2	1
Nais sp.	0	1	0
Nematoda	0	1	0
Ilyodrilus templetoni	0	1	0

RESULTS OF POST-CONSTRUCTION BENTHIC MONITORING PERFORMED IN BOOKER LAKE DURING AUGUST 2012

December 2012

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City of St. Petersburg

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and

Mr. Mark Vogel

1.0 Introduction

This report summarizes the results of the summer season post-construction benthic monitoring event performed in Booker Lake in conjunction with the alum stormwater treatment system which treats runoff inputs entering along the northeast and southwest shores of the lake. Pre-construction benthic monitoring events were performed in Booker Lake during July 2005 (summer season) and January 2006 (winter season). Sample collection for both the pre- and post-construction benthic monitoring events was performed by Environmental Research & Design, Inc. (ERD), with sample identification performed by Mr. Mark Vogel, formerly with the Florida Fish and Game Commission and the Orange County Environmental Protection Department.

2.0 Benthic Collection Procedures

Field personnel from ERD performed benthic monitoring at three sites within Booker Lake

Figure 2-2 Pre & Post Treatment Benthic Monitoring Site

Figure 1. Booker Lake Surface Water and Benthic Monitoring Sites.

Sample collection was performed using a 6-inch x 6-inch stainless steel Eckman dredge. Three separate dredge samples were collected at each sample site and placed into a wash bucket with a 500 μm stainless steel sieve screen. The samples were washed to remove silt and fine sand and stored in individual bottles for subsequent analysis. This procedure formed a total of nine separate benthic samples (3 sites x 3 samples/site) to be submitted for analysis. Each of the benthic samples was preserved and shipped to Mr. Mark Vogel for evaluation. In order to maintain uniform procedures and sample methodologies between the monitoring events, specifics concerning monitoring techniques, sieve size, preservation and shipping methods were provided to ERD by Mr. Vogel.

3.0 Results of Benthic Identification

Benthic identification bench sheets for the August 2012 monitoring event, summarizing the results of analyses conducted on replicate samples at each site, are provided in Appendix A. A comparison of species observed in Booker Lake at the three monitoring sites is given in Table 1. Eight separate benthic species were identified at the three post-treatment monitoring sites compared with three species identified in the July 2005 pre-treatment event. Of the measured species, *Chironomus* sp. and *Limnodrilus hoffmeisteri* were simultaneously observed at Sites 1 and 2. One benthic species was observed at Site 3 during August 2012 compared with no benthic species found in any of the replicate samples collected at Site 3 during the July 2005 pre-treatment event.

TABLE 1

COMPARISON OF BENTHIC SPECIES OBSERVED IN BOOKER LAKE DURING THE AUGUST 2012 POST-CONSTRUCTION MONITORING EVENT

SPECIES	POST-CONSTRUCTION (8/7/12)		
	Site 1	Site 2	Site 3
Chaoborus punctipennis	X	X	X
Limnodrilus hoffmeisteri	X	X	
Polypedilum Illinoense	X		
Glyptotendipes sp.		X	
Dero sp.		X	
Aulodrilus pigueti		X	
Bratislavia unidentata		X	
TOTAL:	**3**	**6**	**1**

A summary of post-construction macroinvertebrate assemblages at Site 1 in Booker Lake during August 2012 is given in Table 2. The post-treatment summer organism density at monitoring Site 1 was 770 organisms/m^2 compared with a pre-treatment density of 682 organisms/m^2. Only three significant species were observed at this site under both pre- and post-treatment summer conditions. The pre- and post-construction benthic community at Site 1 can be described as a depauperate community characterized by low densities and low diversity. The aquatic worm, *Limnodrilus hoffmeisteri*, was the most common species observed at this site during August 2012, comprising 82.6% of the total organism density under pre-treatment conditions and 82.7% under post-treatment conditions, indicating little change in benthic communities at this site. The remaining species observed at this site during August 2012 consist of the phantom midge, *Chaoborus punctipennis*, and a single specimen of *Polypedilum Illinoense.* The mean Shannon Diversity Index for the post-treatment benthic assemblage at Site 1 has increased to a value of 0.52 compared with a pre-treatment mean Shannon Diversity Index of 0.46 for the July 2005 monitoring event.

TABLE 2

SUMMARY OF POST-CONSTRUCTION MACROINVERTEBRATE ASSEMBLAGE AT SITE 1 IN BOOKER LAKE DURING AUGUST 2012

TAXA	MEAN (#/m^2)	%
Limnodrilus hoffmeisteri	637.1	82.7
Chaoborus punctipennis	118.5	15.4
Polypedilum Illinoense	14.8	1.9
Mean Total Taxa	2.3	
Mean Total Organisms/m^2	770	
Mean Shannon Diversity	0.52	
Mean Eveness	0.33	

A summary of post-construction macroinvertebrate assemblages at Site 2 in Booker Lake during August 2012 is given in Table 3. Six separate species were observed at this site during August 2012, with *Limnodrilus hoffmeisteri* comprising 76.0% of the population and *Chaoborus punctipennis* comprising 8.0% of the total organisms found at this site. Four additional taxa were found at Site 2 under post-treatment conditions, including three aquatic worms and one midge (*Glyptotendipes* sp.). During the pre-treatment monitoring event conducted in July 2005, only *Chaoborus punctipennis* and *Limnodrilus hoffmeisteri* were present at this site. Each of the six species found at Site 2 are considered to be tolerant of highly organic sediments. The overall organism density was reduced from 1422 organisms/m^2 during July 2005 to 370 organisms/m^2 during August 2012 which indicates a reduction in available nutrients. The mean Shannon Diversity Index for the post-treatment benthic assemblage at Site 2 was 0.8 compared with a pre-treatment mean Shannon Diversity Index of 0.58 for the July 2005 monitoring event, indicating a more diverse environment under post-treatment conditions.

TABLE 3

SUMMARY OF POST-CONSTRUCTION MACROINVERTEBRATE ASSEMBLAGE AT SITE 2 IN BOOKER LAKE DURING AUGUST 2012

TAXA	MEAN (#/m^2)	%
Limnodrilus hoffmeisteri	281.5	76.0
Chaoborus punctipennis	29.6	8.0
Glyptotendipes sp.	14.8	4.0
Dero sp.	14.8	4.0
Aulodrilus pigueti	14.8	4.0
Bratislavia unidentata	14.8	4.0
Mean Total Taxa	3.0	
Mean Total Organisms/m^2	370	
Mean Shannon Diversity	0.8	
Mean Eveness	0.7	

A summary of post-treatment macroinvertebrate assemblages at Site 3 in Booker Lake during August 2012 is given in Table 4. Only one organism was observed at this site, the phantom midge *Chaoborus punctipennis*. However, no organisms were collected at this site during July 2005, indicating that conditions have become more favorable for maintaining benthic populations. The overall organism density of 237 organisms/m^2 reflects a relatively low value.

TABLE 4

SUMMARY OF POST-CONSTRUCTION MACROINVERTEBRATE ASSEMBLAGE AT SITE 3 IN BOOKER LAKE DURING AUGUST 2012

TAXA	MEAN (#/m^2)	%
Chaoborus punctipennis	237.1	100.0
Mean Total Taxa	1.0	
Mean Total Organisms/m^2	237	
Mean Shannon Diversity	0.0	
Mean Eveness	0.0	

Substrates at each of the three monitoring sites were dominated by coarse woody debris intermixed with fine sand. The unconsolidated nature of this material will naturally limit the number of species that can exist within the lake.

APPENDIX A

BENTHIC IDENTIFICATION SHEETS FOR BOOKER LAKE

Raw Data

Booker Lake Site 1			
	Rep 1	Rep 2	Rep 3
Limnodrilus hoffmeisteri	9	7	27
Chaoborus punctipennis	6	1	1
Polypedilum Illinoense	0	0	1
Booker Lake Site 2			
	Rep 1	Rep 2	Rep 3
Limnodrilus hoffmeisteri	13	4	2
Aulodrilus pigueti	1	0	0
Glyptotendipes sp	1	0	0
Dero sp	0	0	1
Chaoborus punctipennis	0	1	1
Bratislavia unidentata	0	0	1
Booker Lake Site 3			
	Rep 1	Rep 2	Rep 3
Chaoborus punctipennis	6	6	4

APPENDIX D

LABORATORY QA/QC DATA

D.1 Sample Duplicate Analyses
D.2 Matrix Spike Recovery
D.3 Continuing Calibration Verification (CCV) Study
D.4 Laboratory Calibration Standards (LCS) Study
D.5 Lab Method Blank Recovery

D.1 Sample Duplicate Analyses

Sample Duplicate Recovery Study

Booker Lake ATS Evaluation

Parameter	Units	Sample ID	Sample Description	Date Collected	Date Analyzed	Repeat 1	Repeat 2	Mean	s	% Relative Std. Deviation (RSD)	Acceptance Range (% RSD)
pH	s.u.	05-1468	13th St. 7.5 mg/l	06/14/05	06/14/05	7.27	7.25	7.26	0.0	0.19	0-2
pH	s.u.	05-1473	24th St. 10.0 mg/l	06/14/05	06/14/05	6.80	6.84	6.82	0.0	0.41	0-2
pH	s.u.	05-1813	24th St. 5.0 mg/l	07/13/05	07/09/05	7.45	7.43	7.44	0.0	0.19	0-2
pH	s.u.	05-1815	24th St. 10.0 mg/l	07/13/05	07/13/05	6.89	6.92	6.91	0.0	0.31	0-2
pH	s.u.	05-2051	24th St. 10.0 mg/l	08/05/05	08/05/05	6.94	6.92	6.93	0.0	0.20	0-2
pH	s.u.	05-2198	24th St. Raw	07/24/05	07/24/05	7.86	7.90	7.88	0.0	0.36	0-2
pH	s.u.	05-2201	24th St. 10.0 mg/l	08/23/05	08/23/05	6.74	6.72	6.73	0.0	0.21	0-2
pH	s.u.	05-2972	24th St. 5.0 mg/l	10/18/05	10/18/05	7.33	7.32	7.33	0.0	0.10	0-2
pH	s.u.	05-3731	24th St. 10.0 mg/l	12/21/05	12/21/05	7.46	7.45	7.46	0.0	0.09	0-2
pH	s.u.	11-4510	Booker	11/17/11	11/22/11	8.23	8.20	8.22	0.0	0.26	0-2
pH	s.u.	12-0743	Booker	03/08/12	03/12/12	7.53	7.59	7.56	0.0	0.56	0-2
pH	s.u.	12-1075	Booker	04/10/12	04/12/12	8.16	8.20	8.18	0.0	0.35	0-2
pH	s.u.	12-1424	Booker	06/19/12	06/20/12	7.49	7.46	7.48	0.0	0.28	0-2
pH	s.u.	12-1690	Booker	08/07/12	08/08/12	7.91	7.94	7.93	0.0	0.27	0-2
pH	s.u.	12-1831	Booker	08/29/12	09/04/12	7.02	7.09	7.06	0.0	0.70	0-2
Alkalinity	mg/l	05-1872	Site #3 Field Dup	07/21/05	07/25/05	81.4	81.0	81	0.3	0.35	0-2.8
Alkalinity	mg/l	05-2201	24th St. 10.0 mg/l	08/23/05	08/25/05	20.4	20.4	20	0.0	0.00	0-2.8
Alkalinity	mg/l	05-1468	13th St. 7.5 mg/l	06/14/05	06/14/05	82.5	82.6	83	0.1	0.09	0-2.8
Alkalinity	mg/l	05-1473	24th St. 10.0 mg/l	06/14/05	06/14/05	38.0	37.4	38	0.4	1.13	0-2.8
Alkalinity	mg/l	05-1813	24th St. 5.0 mg/l	07/13/05	07/09/05	49.9	49.6	50	0.2	0.43	0-2.8
Alkalinity	mg/l	05-1815	24th St. 10.0 mg/l	07/13/05	07/13/05	28.1	29.0	29	0.6	2.23	0-2.8
Alkalinity	mg/l	05-1796	Site #3 Field Dup	07/08/05	07/10/05	77.8	78.8	78	0.7	0.90	0-2.8
Alkalinity	mg/l	05-2051	24th St. 10.0 mg/l	08/05/05	08/08/05	30.4	30.2	30	0.1	0.47	0-2.8
Alkalinity	mg/l	05-2047	13th St. 10.0 mg/l	08/05/05	08/08/05	78.0	78.6	78	0.4	0.54	0-2.8
Alkalinity	mg/l	11-4510	Booker	11/17/11	11/22/11	120	121	121	0.7	0.59	0-2.8
Alkalinity	mg/l	12-0743	Booker	03/08/12	03/12/12	137	136	137	0.7	0.52	0-2.8
Alkalinity	mg/l	12-1075	Booker	04/10/12	04/12/12	134	135	135	0.7	0.53	0-2.8
Alkalinity	mg/l	12-1424	Booker	06/19/12	06/20/12	92.4	91.4	92	0.7	0.77	0-2.8
Alkalinity	mg/l	12-1690	Booker	08/07/12	08/08/12	82.6	83.8	83	0.8	1.02	0-2.8
Alkalinity	mg/l	12-1831	Booker	08/29/12	09/04/12	79.2	80.2	80	0.7	0.89	0-2.8

Sample Duplicate Recovery Study

Booker Lake ATS Evaluation

Parameter	Units	Sample ID	Sample Description	Date Collected	Date Analyzed	Repeat 1	Repeat 2	Mean	s	% Relative Std. Deviation (RSD)	Acceptance Range (% RSD)
Conductivity	µΩ	05-1469	13th St. 10.0 mg/l	06/14/05	07/02/05	356	360	358	2.8	0.79	0-2.8
Conductivity	µΩ	05-1473	24th St. 10.0 mg/l	06/14/05	07/02/05	278	274	276	2.8	1.02	0-2.8
Conductivity	µΩ	05-1809	13th St. 5.0 mg/l	07/13/05	08/08/05	182	185	184	2.1	1.16	0-2.8
Conductivity	µΩ	05-2044	13th St. Raw	07/21/05	08/08/05	317	313	315	2.8	0.90	0-2.8
Conductivity	µΩ	05-2203	Down Basin #9	08/20/05	09/10/05	204	203	204	0.7	0.35	0-2.8
Conductivity	µΩ	05-2980	13th St. 5.0 mg/l	10/18/05	11/03/05	333	327	330	4.2	1.29	0-2.8
Conductivity	µΩ	05-2974	24th St 10.0mg/l	10/18/05	11/03/05	357	356	357	0.7	0.20	0-2.8
Conductivity	µΩ	05-2982	13th St. 10.0 mg/l	10/18/05	11/03/05	345	348	347	2.1	0.61	0-2.8
Conductivity	µΩ	05-2967	13th St. Raw	10/05/05	11/03/05	390	387	389	2.1	0.55	0-2.8
Conductivity	µΩ	11-4510	Booker	11/17/11	11/22/11	326	332	329	4.2	1.29	0-2.8
Conductivity	µΩ	12-1690	Booker	08/07/12	08/09/12	249	246	248	2.1	0.86	0-2.8
Conductivity	µΩ	12-1831	Booker	08/29/12	09/20/12	663	670	667	4.9	0.74	0-2.8
Turbidity	NTU	05-1470	24th St. Raw	06/10/05	06/15/05	7.4	7.3	7	0.1	0.96	0 - 7.2
Turbidity	NTU	05-1473	24th St. 10.0 mg/l	06/14/05	06/15/05	0.1	0.1	0	0.0	0.00	0 - 7.2
Turbidity	NTU	05-1469	13th St. 10.0 mg/l	06/14/05	06/15/05	0.2	0.2	0	0.0	0.00	0 - 7.2
Turbidity	NTU	05-1796	Site #3 Field Dup	07/08/05	07/09/05	2.5	2.4	2	0.0	1.72	0 - 7.2
Turbidity	NTU	05-1872	Site #3 Field Dup	07/21/05	07/22/05	4.2	4.1	4	0.1	1.70	0 - 7.2
Turbidity	NTU	05-1869	Site #1	07/21/05	07/22/05	4.2	4.2	4	0.0	0.00	0 - 7.2
Turbidity	NTU	05-2051	24th St 10.0mg/l	08/05/05	08/05/05	0.1	0.1	0	0.0	0.00	0 - 7.2
Turbidity	NTU	05-2047	13th St. 10.0 mg/l	08/05/05	08/05/05	0.2	0.2	0	0.0	0.00	0 - 7.2
Turbidity	NTU	05-2146	Site #3	08/17/05	08/19/05	5.7	5.6	6	0.1	1.25	0 - 7.2
Turbidity	NTU	11-4510	Booker	11/17/11	11/18/11	6.7	6.5	7	0.1	2.14	0 - 7.2
Turbidity	NTU	12-0743	Booker	03/08/12	03/08/12	9.6	10.0	10	0.3	2.89	0 - 7.2
Turbidity	NTU	12-1075	Booker	04/10/12	04/11/12	5.8	5.7	6	0.1	1.23	0 - 7.2
Turbidity	NTU	12-1424	Booker	06/19/12	06/20/12	4.9	4.5	5	0.3	6.02	0 - 7.2
Turbidity	NTU	12-1690	Booker	08/07/12	08/08/12	5.5	5.7	6	0.1	2.53	0 - 7.2
Turbidity	NTU	12-1811	Booker	08/29/12	08/30/12	3.7	3.9	4	0.1	3.72	0 - 7.2

Sample Duplicate Recovery Study

Booker Lake ATS Evaluation

Parameter	Units	Sample ID	Sample Description	Date Collected	Date Analyzed	Repeat 1	Repeat 2	Mean	s	% Relative Std. Deviation (RSD)	Acceptance Range (% RSD)
TSS	mg/L	05-1470	24th St. Raw	06/10/05	06/19/05	5.9	6.0	6	0.1	1.19	0 - 18.7
TSS	mg/L	05-1796	Site #3 Field Dup	07/08/05	07/12/05	4.0	4.1	4	0.1	1.75	0 - 18.7
TSS	mg/L	05-1871	Site #3	07/21/05	07/23/05	7.5	7.0	7	0.4	4.88	0 - 18.7
TSS	mg/L	05-1869	Site #1	07/21/05	07/23/05	5.1	5.4	5	0.2	4.04	0 - 18.7
TSS	mg/L	05-2047	13th St. 10.0 mg/l	08/05/05	08/08/05	2.0	2.0	2	0.0	0.00	0 - 18.7
TSS	mg/L	05-2146	Site #3	08/17/05	08/22/05	7.2	7.0	7	0.1	1.99	0 - 18.7
TSS	mg/L	05-2201	24th St. 10.0 mg/l	08/23/05	08/24/05	4.3	4.3	4	0.0	0.00	0 - 18.7
TSS	mg/L	11-4510	Booker	11/17/11	11/22/11	13.0	13.2	13	0.1	1.08	0 - 18.7
TSS	mg/L	12-0743	Booker	03/08/12	03/08/12	20.0	17.5	19	1.8	9.43	0 - 18.7
TSS	mg/L	12-1075	Booker	04/10/12	04/12/12	10.4	11.1	11	0.5	4.60	0 - 18.7
TSS	mg/L	12-1158	Booker	05/29/12	05/30/12	6.9	7.4	7	0.4	4.94	0 - 18.7
TSS	mg/L	12-1424	Booker	06/19/12	06/21/12	8.6	9.3	9	0.5	5.53	0 - 18.7
TSS	mg/L	12-1690	Booker	08/07/12	08/08/12	7.2	6.2	7	0.7	10.55	0 - 18.7
TSS	mg/L	12-2306	Booker	10/18/12	10/21/12	6.5	5.7	6	0.6	9.27	0 - 18.7
BOD	mg/L	05-1469	13th St. 10.0 mg/l	06/14/05	06/15/05	2.6	2.6	3	0.0	0.00	0-20
BOD	mg/L	05-1796	Site #3 Field Dup	07/08/05	07/09/05	5.9	5.6	6	0.2	3.66	0-20
BOD	mg/L	05-1813	24th St. 5.0 mg/l	07/13/05	07/15/05	2.0	1.7	2	0.2	12.86	0-20
BOD	mg/L	05-1871	Site #3	07/21/05	07/21/05	2.0	2.0	2	0.0	0.36	0-20
BOD	mg/L	05-2050	24th St. 7.5 mg/l	08/05/05	08/06/05	5.8	5.8	6	0.1	0.98	0-20
BOD	mg/L	05-2198	24th St. Raw	07/24/05	07/25/05	1.4	1.3	1	0.1	4.80	0-20
BOD	mg/L	11-4510	Booker	11/17/11	11/18/11	9.0	7.8	8	0.8	10.10	0-20
BOD	mg/L	12-0110	Booker	01/12/12	01/14/12	5.1	5.0	5	0.1	1.40	0-20
BOD	mg/L	12-0743	Booker	03/08/12	03/08/12	5.4	5.7	6	0.2	3.82	0-20
BOD	mg/L	12-1332	Booker	05/29/12	05/31/12	3.8	3.8	4	0.0	0.56	0-20
BOD	mg/L	12-1424	Booker	06/19/12	06/21/12	5.0	4.6	5	0.3	5.89	0-20
BOD	mg/L	12-1690	Booker	08/07/12	08/09/12	3.3	2.9	3	0.3	8.80	0-20
BOD	mg/L	12-2306	Booker	10/18/12	10/20/12	3.0	3.0	3	0.0	0.71	0-20

Sample Duplicate Recovery Study

Booker Lake ATS Evaluation

Parameter	Units	Sample ID	Sample Description	Date Collected	Date Analyzed	Repeat 1	Repeat 2	Mean	s	% Relative Std. Deviation (RSD)	Acceptance Range (% RSD)
Chlorophyll-a	mg/L	05-1796	Site #3 Field Dup	07/08/05	07/09/05	46.8	47.1	47	0.2	0.45	0-18.5
Chlorophyll-a	mg/L	05-1872	Site #3 Field Dup	07/21/05	07/22/05	59.9	58.5	59	1.0	1.67	0-18.5
Chlorophyll-a	mg/L	05-3130	Site #3 F.D.	11/04/05	11/06/05	134.0	141.0	138	4.9	3.60	0-18.5
Chlorophyll-a	mg/L	05-3398	Site #3	11/28/05	11/29/05	66.1	66.4	66	0.2	0.32	0-18.5
Chlorophyll-a	mg/L	05-3701	Site #3	12/19/05	12/19/05	49.9	50.6	50	0.5	0.99	0-18.5
Chlorophyll-a	mg/L	11-4969	Booker	12/30/11	12/30/11	31.6	32.0	32	0.3	0.89	0-18.5
Chlorophyll-a	mg/L	12-0110	Booker	01/12/12	01/13/12	138.3	139.9	139	1.1	0.81	0-18.5
Chlorophyll-a	mg/L	12-0401	Booker	02/07/12	02/08/12	104.0	106.0	105	1.4	1.35	0-18.5
Chlorophyll-a	mg/L	12-0743	Booker	03/07/12	03/08/12	101.6	104.5	103	2.1	1.99	0-18.5
Chlorophyll-a	mg/L	12-1075	Booker	04/09/12	04/10/12	33.6	32.0	33	1.1	3.45	0-18.5
Chlorophyll-a	mg/L	12-1332	Booker	05/29/12	05/30/12	14.5	11.3	13	2.3	17.54	0-18.5
Chlorophyll-a	mg/L	12-1424	Booker	06/18/12	06/20/12	63.1	57.2	60	4.2	6.94	0-18.5
Chlorophyll-a	mg/L	12-1690	Booker	08/08/12	08/08/12	26.2	25.2	26	0.7	2.75	0-18.5
Chlorophyll-a	mg/L	12-1831	Booker	08/28/12	08/29/12	50.0	47.7	49	1.6	3.33	0-18.5
Chlorophyll-a	mg/L	12-2020	Booker	09/25/12	09/26/12	51.2	52.0	52	0.6	1.10	0-18.5
Chlorophyll-a	mg/L	12-2306	Booker	10/18/12	10/19/12	37.3	36.1	37	0.8	2.31	0-18.5
Fecal	mg/L	05-1796	Site #3 Field Dup	07/08/05	07/08/05	60	110	2	35.4	0.26	0-0.33
Fecal	mg/L	05-1870	Site #1	07/21/05	07/21/05	232	230	2	1.4	0.00	0-0.33
Fecal	mg/L	05-3130	Site #3 F.D.	11/04/05	11/04/05	148	136	2	8.5	0.04	0-0.33
Fecal	mg/L	05-3699	Site #2	12/19/05	12/19/05	34	26	2	5.7	0.12	0-0.33
Fecal	mg/L	05-3731	24th St-10.0mg/l	12/21/05	12/21/05	11	17	1	4.2	0.19	0-0.33
Fecal	mg/L	12-0110W	Booker	01/12/12	01/12/12	42	39	2	2.1	0.03	0-0.33
Fecal	mg/L	12-0401W	Booker	02/08/12	02/08/12	23	21	1	1.4	0.04	0-0.33
Fecal	mg/L	12-0743W	Booker	03/08/12	03/08/12	30	27	1	2.1	0.05	0-0.33
Fecal	mg/L	12-1075W	Booker	04/10/12	04/10/12	10	11	1	0.7	0.04	0-0.33
Fecal	mg/L	12-1332W	Booker	05/29/12	05/29/12	18	17	1	0.7	0.02	0-0.33
Fecal	mg/L	12-1424W	Booker	06/19/12	06/19/12	18	17	1	0.7	0.02	0-0.33
Fecal	mg/L	12-1690W	Booker	08/07/12	08/07/12	25	23	1	1.4	0.04	0-0.33
Fecal	mg/L	12-1831W	Booker	08/29/12	08/29/12	20	19	1	0.7	0.02	0-0.33
Fecal	mg/L	12-2020W	Booker	09/26/12	09/26/12	18	17	1	0.7	0.02	0-0.33
Fecal	mg/L	12-2306W	Booker	10/18/12	10/18/12	38	35	2	2.1	0.04	0-0.33

Sample Duplicate Recovery Study

Booker Lake ATS Evaluation

Parameter	Units	Sample ID	Sample Description	Date Collected	Date Analyzed	Repeat 1	Repeat 2	Mean	s	% Relative Std. Deviation (RSD)	Acceptance Range (% RSD)
Chloride	mg/L	05-1468	13th St. 7.5 mg/l	06/14/05	07/12/05	28.6	28.3	28	0.2	0.75	0-5
Chloride	mg/L	05-1870	Site #2	07/21/05	11/17/05	15.0	14.7	15	0.2	1.43	0-5
Chloride	mg/L	05-2044	13th St. Raw	07/21/05	11/17/05	30.0	30.8	30	0.6	1.86	0-5
Chloride	mg/L	05-2201	24th St. 10.0 mg/l	08/23/05	11/17/05	12.9	13.1	13	0.1	1.09	0-5
Chloride	mg/L	05-2771	Site #3 F.D.	10/05/05	11/17/05	23.3	23.0	23	0.2	0.92	0-5
Chloride	mg/L	05-2974	24th St. 10.0 mg/l	10/18/05	11/17/05	34.5	35.5	35	0.7	2.02	0-5
Chloride	mg/L	05-3127	Site #1	11/04/05	11/17/05	24.6	25.8	25	0.8	3.37	0-5
Chloride	mg/L	05-3699	Site #2	12/21/05	01/06/06	29.9	29.0	29	0.6	2.16	0-5
SRP	µg/l	11-4510F	Booker	11/17/11	11/18/11	0	0	0	0.0	0.00	0-5
SRP	µg/l	12-0110F	Booker	01/12/12	01/13/12	2	3	2	0.0	0.28	0-5
SRP	µg/l	12-1332F	Booker	05/29/12	06/11/12	1	2	1	0.0	0.47	0-5
SRP	µg/l	12-1424F	Booker	06/19/12	06/20/12	2	3	2	0.0	0.28	0-5
SRP	µg/l	12-1690F	Booker	08/07/12	08/08/12	13	12	13	0.4	3.34	0-5
SRP	µg/l	12-1831F	Booker	08/29/12	08/31/12	3	3	3	0.0	0.00	0-5
NOx	µg/l	11-4510F	Booker	11/17/11	11/18/11	2	1	1	0.1	4.88	0-4
NOx	µg/l	12-0110F	Booker	01/12/12	01/13/12	136	138	137	0.7	0.52	0-4
NOx	µg/l	12-1332F	Booker	05/29/12	06/11/12	1	1	1	0.0	0.00	0-4
NOx	µg/l	12-1424F	Booker	06/19/12	06/20/12	3	2	2	0.0	0.28	0-4
NOx	µg/l	12-1690F	Booker	08/07/12	08/08/12	89	90	90	0.7	0.79	0-4
NOx	µg/l	12-1831F	Booker	08/29/12	08/31/12	32	31	32	0.4	1.34	0-4

Sample Duplicate Recovery Study

Booker Lake ATS Evaluation

Parameter	Units	Sample ID	Sample Description	Date Collected	Date Analyzed	Repeat 1	Repeat 2	Mean	s	% Relative Std. Deviation (RSD)	Acceptance Range (% RSD)
Total N	µg/l	05-1469P	Booker 13th St. 10.0 mg/l	06/14/05	07/13/05	1,655	1,637	1646	12.7	0.77	0-10
Total N	µg/l	05-1810P	13th St. 7.5 mg/l	07/13/05	08/09/05	651	651	651	0.0	0.00	0-10
Total N	µg/l	05-1812FP	Raw	07/09/05	08/09/05	507	499	503	5.7	1.12	0-10
Total N	µg/l	05-1793P	Site #1	07/08/05	08/09/05	2,679	2,633	2656	32.5	1.22	0-10
Total N	µg/l	05-1869FP	Site #1	07/21/05	08/20/05	476	476	476	0.0	0.00	0-10
Total N	µg/l	05-2050P	24th St. 7.5 mg/l	08/05/05	09/08/05	617	602	610	10.6	1.74	0-10
Total N	µg/l	05-2145FP	Site #2 Field Dup	08/17/05	09/13/05	447	448	448	0.7	0.16	0-10
Total N	µg/l	05-2197P	13th St. 10.0 mg/l	08/23/05	10/10/05	1,347	1,308	1328	27.6	2.08	0-10
Total N	µg/l	05-2199FP	24th St 5.0 mg/l	08/23/05	10/10/05	837	780	809	40.3	4.99	0-10
Total N	µg/l	05-3396FP	Site #2 F.D.	11/28/05	01/25/06	879	953	916	52.3	5.71	0-10
Total N	µg/l	05-3725P	13th St-5.0mg/l	12/21/05	01/25/06	961	956	959	3.5	0.37	0-10
Total N	µg/l	05-3727FP	13th St-10.0mg/l	12/21/05	01/25/06	905	901	903	2.8	0.31	0-10
Total N	µg/l	05-2972P	24th St-5.0mg/l	10/18/05	01/30/06	2,475	2,460	2468	10.6	0.43	0-10
Total N	µg/l	05-2976FP	24th St-5.0mg/l	10/18/05	01/30/06	669	761	715	65.1	9.10	0-10
Total N	µg/l	05-3130P	Site #3 F.D.	11/04/05	01/30/06	1,346	1,438	1392	65.1	4.67	0-10
Total N	µg/l	05-3130P	Site #3 F.D.	11/04/05	01/30/06	1,346	1,438	1392	65.1	4.67	0-10
Total N	µg/l	11-4510fp	Booker	11/17/11	02/08/12	666	655	661	7.8	1.18	0-10
Total N	µg/l	12-1332P	Booker	05/29/12	06/14/12	303	302	303	0.7	0.23	0-10
Total N	µg/l	12-1424FP	Booker	06/19/12	06/26/12	334	353	344	13.4	3.91	0-10
Total N	µg/l	12-1690FP	Booker	08/07/12	08/13/12	328	358	343	21.2	6.18	0-10

Sample Duplicate Recovery Study

Booker Lake ATS Evaluation

Parameter	Units	Sample ID	Sample Description	Date Collected	Date Analyzed	Repeat 1	Repeat 2	Mean	s	% Relative Std. Deviation (RSD)	Acceptance Range (% RSD)
Total P	µg/l	05-1469P	Booker 13th St. 10.0 mg/l	06/14/05	07/13/05	7	6	6	0.0	0.11	0-10
Total P	µg/l	05-1812FP	Raw	07/09/05	08/09/05	5	6	5	0.4	6.73	0-10
Total P	µg/l	05-1793P	Site #1	07/08/05	08/09/05	65	64	65	0.7	1.10	0-10
Total P	µg/l	05-1869FP	Site #1	07/21/05	08/20/05	17	19	18	1.1	5.98	0-10
Total P	µg/l	05-2050P	24th St. 7.5 mg/l	08/05/05	09/08/05	8	10	9	0.7	7.94	0-10
Total P	µg/l	05-2145FP	Site #2 Field Dup	08/17/05	09/13/05	12	12	12	0.0	0.00	0-10
Total P	µg/l	05-2197P	13th St. 10.0 mg/l	08/23/05	10/10/05	0	0	0	0.0	0.00	0-10
Total P	µg/l	05-2199FP	24th St 5.0 mg/l	08/23/05	10/10/05	0	0	0	0.0	0.00	0-10
Total P	µg/l	05-3396FP	Site #2 F.D.	11/28/05	01/25/06	15	16	16	0.7	4.56	0-10
Total P	µg/l	05-3725P	13th St-5.0mg/l	12/21/05	01/25/06	0	0	0	0.0	0.00	0-10
Total P	µg/l	05-3727FP	13th St-10.0mg/l	12/21/05	01/25/06	0	0	0	0.0	0.00	0-10
Total P	µg/l	05-2972P	24th St-5.0mg/l	10/18/05	01/30/06	0	0	0	0.0	0.00	0-10
Total P	µg/l	05-2976FP	24th St-5.0mg/l	10/18/05	01/30/06	0	0	0	0.0	0.00	0-10
Total P	µg/l	05-3130P	Site #3 F.D.	11/04/05	01/30/06	118	131	125	9.2	7.38	0-10
Total P	µg/l	11-4510fp	Booker	11/17/11	02/08/12	1	2	1	0.0	0.47	0-10
Total P	µg/l	12-1332P	Booker	05/29/12	06/14/12	59	60	60	0.7	1.19	0-10
Total P	µg/l	12-1424FP	Booker	06/19/12	06/26/12	3	4	3	0.0	0.20	0-10
Total P	µg/l	12-1690FP	Booker	08/07/12	08/13/12	4	5	5	0.1	3.23	0-10
Ammonia	µg/l	05-1468	Booker 13th St. 7.5 mg/l	06/14/05	07/07/05	219	233	226	9.9	4.38	0-10
Ammonia	µg/l	05-1793	Booker Lake Site 1	07/08/05	07/29/05	298	312	305	9.9	3.25	0-10
Ammonia	µg/l	05-2146	Booker Lake Site 3	08/17/05	08/29/05	76	74	75	1.4	1.89	0-10
Ammonia	µg/l	05-2197P	Booker 13th St. 10.0 mg/l	08/23/13	09/10/05	220	209	215	7.8	3.63	0-10
Ammonia	µg/l	05-2970P	Booker 13th St-10.0mg/l	10/18/05	10/25/05	0	0	0	0.1	141.42	0-10
Ammonia	µg/l	05-2980P	Booker 13th St-5.0mg/l	10/18/05	10/25/05	0	0	0	0.1	141.42	0-10
Ammonia	µg/l	05-3700P	Booker Site 2 F.D.	12/19/05	12/26/05	1,797	1,796	1797	0.7	0.04	0-10
Ammonia	µg/l	05-3726P	Booker 13th St - 7.5mg/l	12/21/05	01/05/06	418	396	407	15.6	3.82	0-10
Ammonia	µg/l	12-0401P	Booker	02/08/12	02/15/12	66	72	69	4.2	6.15	0-10
Ammonia	µg/l	12-0743P	Booker	03/08/12	03/16/12	10	8	9	0.7	7.94	0-10
Ammonia	µg/l	12-1332P	Booker	05/29/12	05/30/12	53	48	51	3.5	7.00	0-10
Ammonia	µg/l	12-1424P	Booker	06/19/12	06/20/12	37	38	38	0.7	1.89	0-10
Ammonia	µg/l	12-1690P	Booker	08/07/12	08/08/12	253	253	253	0.0	0.00	0-10

Sample Duplicate Recovery Study

Booker Lake ATS Evaluation

Parameter	Units	Sample ID	Sample Description	Date Collected	Date Analyzed	Repeat 1	Repeat 2	Mean	s	% Relative Std. Deviation (RSD)	Acceptance Range (% RSD)
Color	PCU	05-1796	Site #3 Field Dup	07/08/05	07/08/05	18	18	18	0.0	0.00	0-5
Color	PCU	05-1870	Site #2	07/21/05	07/21/05	28	27	28	0.7	2.57	0-5
Color	PCU	05-1872	Site #3 Field Dup	07/21/05	07/21/05	27	28	28	0.7	2.57	0-5
Color	PCU	05-03130	Site #3 F.D.	11/04/05	11/04/05	38	38	38	0.0	0.00	0-5
Color	PCU	05-03395	Site #2	11/28/05	11/28/05	33	33	33	0.0	0.00	0-5
Color	PCU	05-03398	Site #3	11/28/05	11/28/05	33	33	33	0.0	0.00	0-5
Color	PCU	05-03699	Site #2	12/19/05	12/19/05	24	24	24	0.0	0.00	0-5
Color	PCU	05-03701	Site #3	12/19/05	12/19/05	24	24	24	0.0	0.00	0-5
Color	PCU	05-03731	24th St-10.0mg/l	12/21/05	12/21/05	4	4	4	0.0	0.00	0-5
Color	PCU	11-4510F	Booker	11/17/11	11/18/11	27	27	27	0.0	0.00	0-5
Color	PCU	11-4969F	Booker	12/29/11	12/29/11	28	28	28	0.0	0.00	0-5
Color	PCU	12-0401F	Booker	02/08/12	02/08/12	28	28	28	0.0	0.00	0-5
Color	PCU	12-0743F	Booker	03/08/12	03/09/12	22	22	22	0.0	0.00	0-5
Color	PCU	12-1075F	Booker	04/10/12	04/12/12	29	29	29	0.0	0.00	0-5
Color	PCU	12-1424F	Booker	06/19/12	06/21/12	17	17	17	0.0	0.00	0-5
Color	PCU	12-1690F	Booker	08/07/12	08/09/12	21	20	21	0.7	3.45	0-5
Color	PCU	12-1831F	Booker	08/29/12	08/31/12	20	20	20	0.0	0.00	0-5
Color	PCU	12-2306F	Booker	10/18/12	10/19/12	21	21	21	0.0	0.00	0-5

D.2 Matrix Spike Recovery

Matrix Spike Recovery Study

Booker Lake ATS Evaluation

Parameter	Units	Sample ID	Sample Description	Date Collected	Date Received	Date Analyzed	Initial Conc.	Initial Volume (ml)	Spike Conc.	Spike Volume Added (ml)	Dilution Factor	Theor. Conc.	Measured Conc.	Percent Recovery (%)	Acceptance Range (%)
Alkalinity	mg/l	12-0743	Booker	03/08/12	03/08/12	03/12/12	137	50	1000	0.5	1	147.0	146	99%	91-105
Alkalinity	mg/l	12-1075	Booker	04/10/12	04/10/12	04/12/12	134	50	1000	0.4	1	142.0	142	100%	91-105
Turbidity	NTU	11-4510	Booker	11/17/11	11/17/11	11/18/11	6.7	50	4000	0.5	1	46.7	47.3	101%	87.4 - 110
Turbidity	NTU	12-0743	Booker	03/08/12	03/08/12	03/08/12	9.6	50	4000	0.125	1	19.6	19.6	100%	87.4 - 110
Turbidity	NTU	12-1075	Booker	04/10/12	04/10/12	04/11/12	5.8	50	4000	0.25	1	25.8	24.6	95%	87.4 - 110
Turbidity	NTU	12-1424	Booker	06/19/12	06/19/12	06/20/12	4.9	50	4000	0.25	1	24.9	24.7	99%	87.4 - 110
Turbidity	NTU	12-1690	Booker	08/07/12	08/07/12	08/08/12	5.5	50	4000	0.5	1	45.5	45.2	99%	87.4 - 110
Turbidity	NTU	12-1811	Booker	08/29/12	08/29/12	08/30/12	3.7	50	4000	0.5	1	43.7	44.2	101%	87.4 - 110
Chloride	mg/l	05-1471	24th St. 5.0 mg/L	06/14/05	06/14/05	06/14/05	22.9	50	500	0.5	1	27.9	28.2	101%	90-110
Chloride	mg/l	05-2771	Site #3 F.D.	10/05/05	10/05/05	11/17/05	23.3	50	500	0.5	1	28.3	27.8	98%	90-110
Chloride	mg/l	05-2974	24th St. 10.0 mg/l	10/18/05	10/18/05	11/17/05	34.5	50	500	0.5	1	39.5	40.8	103%	90-110
Chloride	mg/l	05-3699	Site #2	12/21/05	12/21/05	01/06/06	29.9	50	500	0.5	1	34.9	34.2	98%	90-110
BOD	mg/l	05-1796	Site #3 Field Dup	07/08/05	07/08/05	07/09/05	5.94	300	500	6	1	206	175	85%	83-111
BOD	mg/l	05-1872	Site #3 Field Dup	07/21/05	07/21/05	07/22/05	2.78	300	500	6	1	203	208	98%	83-111
BOD	mg/l	05-2051	24th St. 10.0 mg/l	08/05/05	08/05/05	08/06/05	5.6	300	500	6	1	206	213	103%	83-111
BOD	mg/l	11-4510	Booker	11/17/11	11/17/11	11/18/11	13	300	500	6	1	211	196	98%	83-111
BOD	mg/l	12-110	Booker	01/12/12	01/12/12	01/14/12	83	300	500	6	1	281	290	98%	83-111
BOD	mg/l	12-743	Booker	03/08/12	03/08/12	03/08/12	94.5	300	500	6	1	293	264	98%	83-111
BOD	mg/l	12-1332	Booker	05/29/12	05/29/12	05/31/12	63.5	300	500	6	1	262	266	98%	83-111
BOD	mg/l	12-1424	Booker	06/19/12	06/19/12	06/21/12	76.5	300	500	6	1	275	283	98%	83-111
SRP	µg/l	11-4510F	Booker	11/17/11	11/17/11	11/18/11	0	10	10000	0.15	1	150	151	101%	90-110
SRP	µg/l	12-0110F	Booker	01/12/12	01/12/12	01/13/12	2	10	3260	0.2	1	67	61	91%	90-110
SRP	µg/l	12-1332F	Booker	05/29/12	05/29/12	06/11/12	1	10	10000	0.075	1	76	78	103%	90-110
SRP	µg/l	12-1424F	Booker	06/19/12	06/19/12	06/20/12	2	10	10000	0.1	1	102	101	99%	90-110
SRP	µg/l	12-1690F	Booker	08/07/12	08/07/12	08/08/12	13	10	10000	0.3	1	313	292	93%	90-110
SRP	µg/l	12-1831F	Booker	08/29/12	08/29/12	08/31/12	3	10	10000	0.3	1	303	318	105%	90-110
NOx	µg/l	11-4510F	Booker	11/17/11	11/17/11	11/18/11	2	10	10000	0.15	1	152	156	103%	90-110
NOx	µg/l	12-0110F	Booker	01/12/12	01/12/12	01/13/12	136	10	1000	0.2	1	156	155	99%	90-110
NOx	µg/l	12-1332F	Booker	05/29/12	05/29/12	06/11/12	1	10	10000	0.075	1	76	81	107%	90-110
NOx	µg/l	12-1424F	Booker	06/19/12	06/19/12	06/20/12	3	10	10000	0.1	1	103	94	91%	90-110
NOx	µg/l	12-1690F	Booker	08/07/12	08/07/12	08/08/12	89	10	10000	0.3	1	389	391	101%	90-110
NOx	µg/l	12-1831F	Booker	08/29/12	08/29/12	08/31/12	32	10	10000	0.3	1	332	334	101%	90-110

Matrix Spike Recovery Study

Booker Lake ATS Evaluation

Parameter	Units	Sample ID	Sample Description	Date Collected	Date Received	Date Analyzed	Initial Conc.	Initial Volume (ml)	Spike Conc.	Spike Volume Added (ml)	Dilution Factor	Theor. Conc.	Measured Conc.	Percent Recovery (%)	Acceptance Range (%)
Total N	µg/l	05-1469P	13th St. 10.0 mg/l	06/14/05	06/14/05	07/13/05	1655	5	10000	0.5	1	2655	2640	99%	90-110
Total N	µg/l	05-1810P	13th St. 7.5 mg/l	07/13/05	07/13/05	08/09/05	651	5	10000	0.5	1	1651	1592	96%	90-110
Total N	µg/l	05-1812FP	Raw	07/09/05	07/13/05	08/09/05	507	5	10000	0.5	1	1507	1503	100%	90-110
Total N	µg/l	05-1793P	Site #1	07/08/05	07/08/05	08/09/05	2679	5	10000	0.5	1	3679	3594	98%	90-110
Total N	µg/l	05-1869FP	Site #1	07/21/05	07/21/05	08/20/05	476	5	10000	0.75	1	1976	2033	103%	90-110
Total N	µg/l	05-2050P	24th St. 7.5 mg/l	08/05/05	08/05/05	09/08/05	617	5	10000	1	1	2617	2756	105%	90-110
Total N	µg/l	05-2145FP	Site #2 Field Dup	08/17/05	08/17/05	09/13/05	447	5	10000	1	1	2447	2479	101%	90-110
Total N	µg/l	05-2197P	13th St. 10.0 mg/l	08/23/05	08/23/05	10/10/05	1347	5	10000	1	1	3347	3371	101%	90-110
Total N	µg/l	05-2199FP	24th St 5.0 mg/l	08/23/05	08/23/05	10/10/05	837	5	10000	1	1	2837	2761	97%	90-110
Total N	µg/l	05-3396FP	Site #2 F.D.	11/28/05	11/28/05	01/25/06	879	5	10000	0.5	1	1879	1973	105%	90-110
Total N	µg/l	05-3725P	13th St-5.0mg/l	12/21/05	12/21/05	01/25/06	961	5	10000	0.5	1	1961	1945	99%	90-110
Total N	µg/l	05-3727FP	13th St-10.0mg/l	12/21/05	12/21/05	01/25/06	905	5	10000	0.5	1	1905	1940	102%	90-110
Total N	µg/l	05-2972P	24th St-5.0mg/l	10/18/05	10/18/05	01/30/06	2475	5	100000	0.5	1	12475	12317	99%	90-110
Total N	µg/l	05-2976FP	24th St-5.0mg/l	10/18/05	10/18/05	01/30/06	669	5	100000	0.5	1	10669	10536	99%	90-110
Total N	µg/l	05-3130P	Site #3 F.D.	11/04/05	11/04/05	01/30/06	1346	5	100000	0.5	1	11346	11413	101%	90-110
Total N	µg/l	11-4510fp	Booker	11/17/11	11/17/11	02/08/12	666	5	10000	0.20	1	1066	1054	99%	90-110
Total N	µg/l	12-1332P	Booker	05/29/12	05/29/12	06/14/12	303	5	10000	0.05	1	403	421	104%	90-110
Total N	µg/l	12-1424FP	Booker	06/19/12	06/19/12	06/26/12	334	5	10000	0.10	1	534	481	90%	90-110
Total N	µg/l	12-1690FP	Booker	08/07/12	08/07/12	08/13/12	328	5	10000	0.50	1	1328	1240	93%	90-110
Total P	µg/l	05-1469P	13th St. 10.0 mg/l	06/14/05	06/14/05	07/13/05	7	5	10000	0.10	1	207	194	94%	90-110
Total P	µg/l	05-1810P	13th St. 7.5 mg/l	07/13/05	07/13/05	08/09/05	5	5	10000	0.10	1	205	99	48%	90-110
Total P	µg/l	05-1812FP	Raw	07/09/05	07/13/05	08/09/05	65	5	10000	0.15	1	365	162	44%	90-110
Total P	µg/l	05-1793P	Site #1	07/08/05	07/08/05	08/09/05	59	5	10000	0.10	1	259	157	61%	90-110
Total P	µg/l	05-1869FP	Site #1	07/21/05	07/21/05	08/20/05	17	5	10000	0.10	1	217	210	97%	90-110
Total P	µg/l	05-2050P	24th St. 7.5 mg/l	08/05/05	08/05/05	09/08/05	8	5	10000	0.10	1	208	189	91%	90-110
Total P	µg/l	05-2145FP	Site #2 Field Dup	08/17/05	08/17/05	09/13/05	12	5	10000	0.10	1	212	196	92%	90-110
Total P	µg/l	05-2197P	13th St. 10.0 mg/l	08/23/05	08/23/05	10/10/05	0	5	10000	0.10	1	200	190	95%	90-110
Total P	µg/l	05-2199FP	24th St 5.0 mg/l	08/23/05	08/23/05	10/10/05	0	5	10000	0.10	1	200	189	95%	90-110
Total P	µg/l	05-3396FP	Site #2 F.D.	11/28/05	11/28/05	01/25/06	15	5	10000	0.50	1	1015	1030	101%	90-110
Total P	µg/l	05-3725P	13th St-5.0mg/l	12/21/05	12/21/05	01/25/06	0	5	10000	0.5	1	1000	1044	104%	90-110
Total P	µg/l	05-3727FP	13th St-10.0mg/l	12/21/05	12/21/05	01/25/06	0	5	10000	0.5	1	1000	1033	103%	90-110
Total P	µg/l	05-2972P	24th St-5.0mg/l	10/18/05	10/18/05	01/30/06	0	5	10000	0.5	1	1000	1030	103%	90-110
Total P	µg/l	05-2976FP	24th St-5.0mg/l	10/18/05	10/18/05	01/30/06	0	5	10000	0.5	1	1000	1018	102%	90-110
Total P	µg/l	05-3130P	Site #3 F.D.	11/04/05	11/04/05	01/30/06	118	5	10000	0.5	1	1118	1183	106%	90-110
Total P	µg/l	11-4510fp	Booker	11/17/11	11/17/11	02/08/12	1	5	10000	0.2	1	401	427	106%	90-110
Total P	µg/l	12-1332P	Booker	05/29/12	05/29/12	06/14/12	59	5	10000	0.1	1	259	269	104%	90-110
Total P	µg/l	12-1424FP	Booker	06/19/12	06/19/12	06/26/12	3	5	10000	0.1	1	203	192	95%	90-110
Total P	µg/l	12-1690FP	Booker	08/07/12	08/07/12	08/13/12	4	5	10000	0.3	1	604	610	101%	90-110

Matrix Spike Recovery Study

Booker Lake ATS Evaluation

Parameter	Units	Sample ID	Sample Description	Date Collected	Date Received	Date Analyzed	Initial Conc.	Initial Volume (ml)	Spike Conc.	Spike Volume Added (ml)	Dilution Factor	Theor. Conc.	Measured Conc.	Percent Recovery (%)	Acceptance Range (%)
Ammonia	µg/l	05-1468	Booker 13th St. 7.5 mg/l	06/14/05	06/14/05	07/07/05	219	10	10000	0.50	1	719	2849	396%	80-120
Ammonia	µg/l	05-1793	Booker Lake Site 1	07/08/05	07/08/05	07/29/05	298	10	10000	2.00	1	2298	2120	92%	80-120
Ammonia	µg/l	05-2146	Booker Lake Site 3	08/17/05	08/17/05	08/29/05	76	10	10000	1.75	1	1826	1757	96%	80-120
Ammonia	µg/l	05-2197P	Booker 13th St. 10.0 mg/l	08/23/13	08/23/13	09/10/05	220	10	10000	2.00	1	2220	2310	104%	80-120
Ammonia	µg/l	05-2970P	Booker 13th St-10.0mg/l	10/18/05	10/18/05	10/25/05	0	10	10000	1.00	1	1000	1060	106%	80-120
Ammonia	µg/l	05-2980P	Booker 13th St-5.0mg/l	10/18/05	10/18/05	10/25/05	0	10	10000	0.15	1	150	1535	1023%	80-120
Ammonia	µg/l	05-3700P	Booker Site 2 F.D.	12/19/05	12/19/05	12/26/05	1797	10	10000	1.50	1	3297	3159	96%	80-120
Ammonia	µg/l	05-3726P	Booker 13th St - 7.5mg/l	12/21/05	12/21/05	01/05/06	418	10	10000	1.0	1	1418	845	60%	80-120
Ammonia	µg/l	12-0401P	Booker	02/08/12	02/08/12	02/15/12	66	10	10000	0.2	1	266	239	90%	80-120
Ammonia	µg/l	12-1332P	Booker	05/29/12	05/29/12	05/30/12	53	10	100000	0.8	1	8053	8325	103%	80-120
Ammonia	µg/l	12-1424P	Booker	06/19/12	06/19/12	06/20/12	37	10	10000	0.1	1	137	134	98%	80-120
Ammonia	µg/l	12-1690P	Booker	08/07/12	08/07/12	08/08/12	253	10	10000	0.3	1	553	559	101%	80-120

D.3 Continuing Calibration Verification (CCV) Study

Continuing Calibration Verification (CCV) Study

Booker Lake ATS Evaluation

Parameter	Units	Sample Description	Date Prepared	Date Analyzed	Actual Conc.	Measured Conc.	Percent Accuracy (%)	Acceptance Range (% RSD)
Alkalinity	mg/l	CCV	11/22/11	11/22/11	8.60	8.80	102%	91 - 105
Alkalinity	mg/l	CCV	03/12/12	03/12/12	8.40	8.60	102%	91 - 105
Alkalinity	mg/l	CCV	04/12/12	04/12/12	8.60	8.60	100%	91 - 105
Alkalinity	mg/l	CCV	06/20/12	06/20/12	8.60	8.80	102%	91 - 105
Alkalinity	mg/l	CCV	08/08/12	08/08/12	8.40	8.20	98%	91 - 105
Alkalinity	mg/l	CCV	09/04/12	09/04/12	8.40	8.60	102%	91 - 105
Conductivity	μΩ	CCV	11/22/11	11/22/11	8.60	8.80	102%	91 - 105
Conductivity	μΩ	CCV	08/09/12	08/09/12	8.60	8.80	102%	91 - 105
Conductivity	μΩ	CCV	09/20/12	09/20/12	8.60	8.60	100%	91 - 105
Turbidity	NTU	CCV	11/18/11	11/18/11	6.2	6	97%	91 - 105
Turbidity	NTU	CCV	03/08/12	03/08/12	6.4	6.2	97%	91 - 105
Turbidity	NTU	CCV	04/11/12	04/11/12	6.6	6.4	97%	91 - 105
Turbidity	NTU	CCV	06/20/12	06/20/12	6.6	6.6	100%	91 - 105
Turbidity	NTU	CCV	08/08/12	08/08/12	6.6	6.40	97%	91 - 105
Turbidity	NTU	CCV	08/30/12	08/30/12	6.2	6.2	100%	91 - 105
TSS	mg/L	CCV	11/22/11	11/22/11	30.2	30.4	101%	87.4-110
TSS	mg/L	CCV	03/08/12	03/08/12	30.2	30.2	100%	87.4-110
TSS	mg/L	CCV	04/12/12	04/12/12	30.1	30.0	100%	87.4-110
TSS	mg/L	CCV	05/30/12	05/30/12	30.0	29.6	99%	87.4-110
TSS	mg/L	CCV	06/21/12	06/21/12	30.2	30.9	102%	87.4-110
TSS	mg/L	CCV	08/08/12	08/08/12	30.2	31.2	103%	87.4-110
TSS	mg/L	CCV	10/21/12	10/21/12	30.3	30.9	102%	87.4-110
BOD	mg/L	CCV	06/15/05	06/15/05	30.2	29.9	99%	87.4-110
BOD	mg/L	CCV	07/09/05	07/09/05	30.0	30.8	103%	87.4-110
BOD	mg/L	CCV	11/18/11	11/18/11	30.0	30.3	101%	87.4-110
BOD	mg/L	CCV	01/14/12	01/14/12	30.0	30.7	102%	87.4-110
BOD	mg/L	CCV	03/08/12	03/08/12	30.2	30.2	100%	87.4-110
BOD	mg/L	CCV	05/31/12	05/31/12	30.2	29.0	96%	87.4-110
BOD	mg/L	CCV	06/21/12	06/21/12	30.1	29.9	99%	87.4-110
BOD	mg/L	CCV	08/09/12	08/09/12	40.5	39.1	97%	87.4-110
BOD	mg/L	CCV	10/20/12	10/20/12	40.5	39.1	97%	87.4-110
SRP	μg/l	CCV	11/18/11	11/18/11	100	99	99%	90-110
SRP	μg/l	CCV	01/13/12	01/13/12	100	103	103%	90-110
SRP	μg/l	CCV	06/11/12	06/11/12	100	97	97%	90-110
SRP	μg/l	CCV	06/20/12	06/20/12	100	105	105%	90-110
SRP	μg/l	CCV	08/08/12	08/08/12	150	153	102%	90-110
SRP	μg/l	CCV	08/31/12	08/31/12	150	161	107%	90-110

Continuing Calibration Verification (CCV) Study

Booker Lake ATS Evaluation

Parameter	Units	Sample Description	Date Prepared	Date Analyzed	Actual Conc.	Measured Conc.	Percent Accuracy (%)	Acceptance Range (% RSD)
NOx	μg/l	CCV	11/18/11	11/18/11	150	151	101%	90-110
NOx	μg/l	CCV	01/13/12	01/13/12	150	155	103%	90-110
NOx	μg/l	CCV	06/11/12	06/11/12	150	153	102%	90-110
NOx	μg/l	CCV	06/20/12	06/20/12	150	146	97%	90-110
NOx	μg/l	CCV	08/08/12	08/08/12	150	148	99%	90-110
NOx	μg/l	CCV	08/31/12	08/31/12	100	103	103%	90-110
Total N	μg/l	CCV	02/08/12	02/08/12	1000	917	92%	85-115
Total N	μg/l	CCV	06/14/12	06/14/12	1000	950	95%	85-115
Total N	μg/l	CCV	06/26/12	06/26/12	2000	1929	96%	85-115
Total N	μg/l	CCV	08/13/12	08/13/12	2000	1910	96%	85-115
Total P	μg/l	CCV	07/13/05	07/13/05	2000	1910	96%	85-115
Total P	μg/l	CCV	08/09/05	08/09/05	2000	1928	96%	85-115
Total P	μg/l	CCV	08/09/05	08/09/05	2000	1950	98%	85-115
Total P	μg/l	CCV	02/08/12	02/08/12	1250	1236	99%	85-115
Total P	μg/l	CCV	06/14/12	06/14/12	1000	996	100%	85-115
Total P	μg/l	CCV	06/26/12	06/26/12	2000	1797	90%	85-115
Total P	μg/l	CCV	08/13/12	08/13/12	2000	1877	94%	85-115
Ammonia	μg/l	CCV	02/15/12	02/15/12	2000	1976	99%	85-115
Ammonia	μg/l	CCV	03/16/12	03/16/12	2000	2071	104%	85-115
Ammonia	μg/l	CCV	05/30/12	05/30/12	2000	2097	105%	85-115
Ammonia	μg/l	CCV	06/20/12	06/20/12	2000	2036	102%	85-115
Ammonia	μg/l	CCV	08/08/12	08/08/12	2000	2034	102%	85-115
Color	PCU	CCV	11/18/11	11/18/11	7232	6826	94%	90-110
Color	PCU	CCV	12/29/11	12/29/11	1000	952	95%	90-110
Color	PCU	CCV	02/08/12	02/08/12	1000	905	91%	90-110
Color	PCU	CCV	03/09/12	03/09/12	8000	8363	105%	90-110
Color	PCU	CCV	04/12/12	04/12/12	8000	8473	106%	90-110
Color	PCU	CCV	06/21/12	06/21/12	8000	8426	105%	90-110
Color	PCU	CCV	08/09/12	08/09/12	8000	7800	98%	90-110
Color	PCU	CCV	08/31/12	08/31/12	8000	8345	104%	90-110
Color	PCU	CCV	10/19/12	10/19/12	1000	958	96%	90-110

D.4 Laboratory Calibration Standards (LCS) Study

Laboratory Calibration Standards (LCS) Recovery Study
Booker Lake ATS Evaluation

Parameter	Units	Sample Description	Date Prepared	Date Analyzed	Actual Conc.	Measured Conc.	Percent Recovery (%)	Acceptance Range
Alkalinity	mg/l	LCS	03/12/12	03/12/12	10.8	10.6	98%	91 - 109
Alkalinity	mg/l	LCS	04/12/12	04/12/12	10.8	10.2	94%	91 - 109
Turbidity	NTU	LCS	11/18/11	11/18/11	8.8	8.8	100%	91 - 109
Turbidity	NTU	LCS	03/08/12	03/08/12	8.6	8.8	98%	91 - 109
Turbidity	NTU	LCS	04/11/12	04/11/12	8.6	8.4	95%	91 - 109
Turbidity	NTU	LCS	06/20/12	06/20/12	6.4	6.2	97%	91 - 109
Turbidity	NTU	LCS	08/08/12	08/08/12	6.4	6.2	97%	91 - 109
Turbidity	NTU	LCS	08/30/12	08/30/12	6.4	6.6	103%	91 - 109
SRP	mg/l	LCS	11/18/11	11/18/11	200	191	96%	87.4 - 110
SRP	mg/l	LCS	01/13/12	01/13/12	200	198	99%	87.4 - 110
SRP	mg/l	LCS	06/11/12	06/11/12	200	197	99%	90-110
SRP	mg/l	LCS	06/20/12	06/20/12	200	203	102%	90-110
SRP	mg/l	LCS	08/08/12	08/08/12	200	211	106%	90-110
SRP	mg/l	LCS	08/31/12	08/31/12	200	212	106%	90-110
NOx	mg/l	LCS	11/18/11	11/18/11	200	211	106%	90-110
NOx	mg/l	LCS	01/13/12	01/13/12	200	204	102%	90-110
NOx	mg/l	LCS	06/11/12	06/11/12	200	200	100%	90-110
NOx	mg/l	LCS	06/20/12	06/20/12	200	205	102%	90-110
NOx	mg/l	LCS	08/08/12	08/08/12	200	199	99%	90-110
NOx	mg/l	LCS	08/31/12	08/31/12	200	198	99%	90-110
Total N	mg/l	LCS	02/08/12	02/08/12	3000	2923	97%	85-115
Total N	mg/l	LCS	06/14/12	06/14/12	3000	2948	98%	90-110
Total N	mg/l	LCS	06/26/12	06/26/12	3000	3174	106%	90-110
Total N	mg/l	LCS	08/13/12	08/13/12	3000	3129	104%	90-110
Total P	mg/l	LCS	07/13/05	07/13/05	100	93	93%	90-110
Total P	mg/l	LCS	08/09/05	08/09/05	100	91	91%	90-110
Total P	mg/l	LCS	08/09/05	08/09/05	100	94	94%	90-110
Total P	mg/l	LCS	02/08/12	02/08/12	100	93	93%	90-110
Total P	mg/l	LCS	06/14/12	06/14/12	100	90	90%	90-110
Total P	mg/l	LCS	06/26/12	06/26/12	100	96	96%	90-110
Total P	mg/l	LCS	08/13/12	08/13/12	100	94	94%	90-110
Ammonia	mg/l	LCS	02/15/12	02/15/12	3000	3048	102%	80-120
Ammonia	mg/l	LCS	05/30/12	05/30/12	3000	3069	102%	80-120
Ammonia	mg/l	LCS	06/20/12	06/20/12	3000	3061	102%	80-120
Ammonia	mg/l	LCS	08/08/12	08/08/12	3000	3115	104%	80-120

D.5 Lab Method Blank Recovery

Lab Method Blank Recovery

Booker Lake ATS Evaluation

Parmeter	Units	Sample Description	Date Prepared	Date Analyzed	Measured Value	Acceptance Range
pH	s.u.	Blank	06/14/05	06/14/05	5.81	5.50-5.90
pH	s.u.	Blank	06/14/05	06/14/05	5.73	5.50-5.90
pH	s.u.	Blank	07/09/05	07/09/05	5.79	5.50-5.90
pH	s.u.	Blank	07/13/05	07/13/05	5.79	5.50-5.90
pH	s.u.	Blank	08/05/05	08/05/05	5.78	5.50-5.90
pH	s.u.	Blank	07/24/05	07/24/05	5.74	5.50-5.90
pH	s.u.	Blank	08/23/05	08/23/05	5.79	5.50-5.90
pH	s.u.	Blank	10/18/05	10/18/05	5.81	5.50-5.90
pH	s.u.	Blank	12/21/05	12/21/05	5.75	5.50-5.90
pH	s.u.	Blank	11/22/11	11/22/11	5.81	5.50-5.90
pH	s.u.	Blank	03/12/12	03/12/12	5.71	5.50-5.90
pH	s.u.	Blank	04/12/12	04/12/12	5.79	5.50-5.90
pH	s.u.	Blank	06/20/12	06/20/12	5.79	5.50-5.90
pH	s.u.	Blank	08/08/12	08/08/12	5.82	5.50-5.90
pH	s.u.	Blank	09/04/12	09/04/12	5.71	5.50-5.90
Alkalinity	mg/l	Blank	07/25/05	07/25/05	<1	<1
Alkalinity	mg/l	Blank	08/25/05	08/25/05	<1	<1
Alkalinity	mg/l	Blank	06/14/05	06/14/05	<1	<1
Alkalinity	mg/l	Blank	06/14/05	06/14/05	<1	<1
Alkalinity	mg/l	Blank	07/09/05	07/09/05	<1	<1
Alkalinity	mg/l	Blank	07/13/05	07/13/05	<1	<1
Alkalinity	mg/l	Blank	07/10/05	07/10/05	<1	<1
Alkalinity	mg/l	Blank	08/08/05	08/08/05	<1	<1
Alkalinity	mg/l	Blank	08/08/05	08/08/05	<1	<1
Alkalinity	mg/l	Blank	11/22/11	11/22/11	<1	<1
Alkalinity	mg/l	Blank	03/12/12	03/12/12	<1	<1
Alkalinity	mg/l	Blank	04/12/12	04/12/12	<1	<1
Alkalinity	mg/l	Blank	06/20/12	06/20/12	<1	<1
Alkalinity	mg/l	Blank	08/08/12	08/08/12	<1	<1
Alkalinity	mg/l	Blank	09/04/12	09/04/12	<1	<1

Lab Method Blank Recovery

Booker Lake ATS Evaluation

Parmeter	Units	Sample Description	Date Prepared	Date Analyzed	Measured Value	Acceptance Range
Conductivity	μΩ	Blank	07/02/05	07/02/05	<0.3	<0.3
Conductivity	μΩ	Blank	07/02/05	07/02/05	<0.3	<0.3
Conductivity	μΩ	Blank	08/08/05	08/08/05	<0.3	<0.3
Conductivity	μΩ	Blank	08/08/05	08/08/05	<0.3	<0.3
Conductivity	μΩ	Blank	09/10/05	09/10/05	<0.3	<0.3
Conductivity	μΩ	Blank	11/03/05	11/03/05	<0.3	<0.3
Conductivity	μΩ	Blank	11/03/05	11/03/05	<0.3	<0.3
Conductivity	μΩ	Blank	11/03/05	11/03/05	<0.3	<0.3
Conductivity	μΩ	Blank	11/03/05	11/03/05	<0.3	<0.3
Conductivity	μΩ	Blank	11/22/11	11/22/11	<0.3	<0.3
Conductivity	μΩ	Blank	08/09/12	08/09/12	<0.3	<0.3
Conductivity	μΩ	Blank	09/20/12	09/20/12	<0.3	<0.3
Turbidity	NTU	Blank	06/15/05	06/15/05	<0.4	<0.4
Turbidity	NTU	Blank	06/15/05	06/15/05	<0.4	<0.4
Turbidity	NTU	Blank	06/15/05	06/15/05	<0.4	<0.4
Turbidity	NTU	Blank	07/09/05	07/09/05	<0.4	<0.4
Turbidity	NTU	Blank	07/22/05	07/22/05	<0.4	<0.4
Turbidity	NTU	Blank	07/22/05	07/22/05	<0.4	<0.4
Turbidity	NTU	Blank	08/05/05	08/05/05	<0.4	<0.4
Turbidity	NTU	Blank	08/05/05	08/05/05	<0.4	<0.4
Turbidity	NTU	Blank	08/19/05	08/19/05	<0.4	<0.4
Turbidity	NTU	Blank	11/18/11	11/18/11	<0.4	<0.4
Turbidity	NTU	Blank	03/08/12	03/08/12	<0.4	<0.4
Turbidity	NTU	Blank	04/11/12	04/11/12	<0.4	<0.4
Turbidity	NTU	Blank	06/20/12	06/20/12	<0.4	<0.4
Turbidity	NTU	Blank	08/08/12	08/08/12	<0.4	<0.4
Turbidity	NTU	Blank	08/30/12	08/30/12	<0.4	<0.4

Lab Method Blank Recovery

Booker Lake ATS Evaluation

Parmeter	Units	Sample Description	Date Prepared	Date Analyzed	Measured Value	Acceptance Range
TSS	mg/L	Blank	06/19/05	06/19/05	<0.6	<0.6
TSS	mg/L	Blank	07/12/05	07/12/05	<0.6	<0.6
TSS	mg/L	Blank	07/18/05	07/18/05	<0.6	<0.6
TSS	mg/L	Blank	07/18/05	07/18/05	<0.6	<0.6
TSS	mg/L	Blank	07/23/05	07/23/05	<0.6	<0.6
TSS	mg/L	Blank	07/23/05	07/23/05	<0.6	<0.6
TSS	mg/L	Blank	08/08/05	08/08/05	<0.6	<0.6
TSS	mg/L	Blank	08/22/05	08/22/05	<0.6	<0.6
TSS	mg/L	Blank	08/24/05	08/24/05	<0.6	<0.6
TSS	mg/L	Blank	11/22/11	11/22/11	<0.6	<0.6
TSS	mg/L	Blank	03/08/12	03/08/12	<0.6	<0.6
TSS	mg/L	Blank	04/12/12	04/12/12	<0.6	<0.6
TSS	mg/L	Blank	05/30/12	05/30/12	<0.6	<0.6
TSS	mg/L	Blank	06/21/12	06/21/12	<0.6	<0.6
TSS	mg/L	Blank	08/08/12	08/08/12	<0.6	<0.6
TSS	mg/L	Blank	10/21/12	10/21/12	<0.6	<0.6
BOD	mg/L	Blank	06/15/05	06/15/05	<2.0	<2.0
BOD	mg/L	Blank	07/09/05	07/09/05	<2.0	<2.0
BOD	mg/L	Blank	07/15/05	07/15/05	<2.0	<2.0
BOD	mg/L	Blank	07/21/05	07/21/05	<2.0	<2.0
BOD	mg/L	Blank	08/06/05	08/06/05	<2.0	<2.0
BOD	mg/L	Blank	07/25/05	07/25/05	<2.0	<2.0
BOD	mg/L	Blank	11/18/11	11/18/11	<2.0	<2.0
BOD	mg/L	Blank	01/14/12	01/14/12	<2.0	<2.0
BOD	mg/L	Blank	03/08/12	03/08/12	<2.0	<2.0
BOD	mg/L	Blank	05/31/12	05/31/12	<2.0	<2.0
BOD	mg/L	Blank	06/21/12	06/21/12	<2.0	<2.0
BOD	mg/L	Blank	08/09/12	08/09/12	<2.0	<2.0
BOD	mg/L	Blank	10/20/12	10/20/12	<2.0	<2.0

Lab Method Blank Recovery
Booker Lake ATS Evaluation

Parmeter	Units	Sample Description	Date Prepared	Date Analyzed	Measured Value	Acceptance Range
Chlorophyll-a	mg/L	Blank	07/09/05	07/09/05	<1.0	<1.0
Chlorophyll-a	mg/L	Blank	07/22/05	07/22/05	<1.0	<1.0
Chlorophyll-a	mg/L	Blank	11/06/05	11/06/05	<1.0	<1.0
Chlorophyll-a	mg/L	Blank	11/29/05	11/29/05	<1.0	<1.0
Chlorophyll-a	mg/L	Blank	12/19/05	12/19/05	<1.0	<1.0
Chlorophyll-a	mg/L	Blank	12/30/11	12/30/11	<1.0	<1.0
Chlorophyll-a	mg/L	Blank	01/13/12	01/13/12	<1.0	<1.0
Chlorophyll-a	mg/L	Blank	02/08/12	02/08/12	<1.0	<1.0
Chlorophyll-a	mg/L	Blank	03/08/12	03/08/12	<1.0	<1.0
Chlorophyll-a	mg/L	Blank	04/10/12	04/10/12	<1.0	<1.0
Chlorophyll-a	mg/L	Blank	05/30/12	05/30/12	<1.0	<1.0
Chlorophyll-a	mg/L	Blank	06/20/12	06/20/12	<1.0	<1.0
Chlorophyll-a	mg/L	Blank	08/08/12	08/08/12	<1.0	<1.0
Chlorophyll-a	mg/L	Blank	08/29/12	08/29/12	<1.0	<1.0
Chlorophyll-a	mg/L	Blank	09/26/12	09/26/12	<1.0	<1.0
Chlorophyll-a	mg/L	Blank	10/19/12	10/19/12	<1.0	<1.0
Fecal	mg/L	Blank	07/08/05	07/08/05	1 cfu	1 cfu
Fecal	mg/L	Blank	07/21/05	07/21/05	1 cfu	1 cfu
Fecal	mg/L	Blank	11/04/05	11/04/05	1 cfu	1 cfu
Fecal	mg/L	Blank	12/19/05	12/19/05	1 cfu	1 cfu
Fecal	mg/L	Blank	12/21/05	12/21/05	1 cfu	1 cfu
Fecal	mg/L	Blank	01/12/12	01/12/12	1 cfu	1 cfu
Fecal	mg/L	Blank	02/08/12	02/08/12	1 cfu	1 cfu
Fecal	mg/L	Blank	03/08/12	03/08/12	1 cfu	1 cfu
Fecal	mg/L	Blank	04/10/12	04/10/12	1 cfu	1 cfu
Fecal	mg/L	Blank	05/29/12	05/29/12	1 cfu	1 cfu
Fecal	mg/L	Blank	06/19/12	06/19/12	1 cfu	1 cfu
Fecal	mg/L	Blank	08/07/12	08/07/12	1 cfu	1 cfu
Fecal	mg/L	Blank	08/29/12	08/29/12	1 cfu	1 cfu
Fecal	mg/L	Blank	09/26/12	09/26/12	1 cfu	1 cfu
Fecal	mg/L	Blank	10/18/12	10/18/12	1 cfu	1 cfu

Lab Method Blank Recovery

Booker Lake ATS Evaluation

Parmeter	Units	Sample Description	Date Prepared	Date Analyzed	Measured Value	Acceptance Range
Chloride	mg/L	Blank	07/12/05	07/12/05	<1.0	<1.0
Chloride	mg/L	Blank	11/17/05	11/17/05	<1.0	<1.0
Chloride	mg/L	Blank	11/17/05	11/17/05	<1.0	<1.0
Chloride	mg/L	Blank	11/17/05	11/17/05	<1.0	<1.0
Chloride	mg/L	Blank	11/17/05	11/17/05	<1.0	<1.0
Chloride	mg/L	Blank	11/17/05	11/17/05	<1.0	<1.0
Chloride	mg/L	Blank	11/17/05	11/17/05	<1.0	<1.0
Chloride	mg/L	Blank	01/06/06	01/06/06	<1.0	<1.0
SRP	µg/l	Blank	11/18/11	11/18/11	<1.0	<1.0
SRP	µg/l	Blank	01/13/12	01/13/12	<1.0	<1.0
SRP	µg/l	Blank	06/11/12	06/11/12	<1.0	<1.0
SRP	µg/l	Blank	06/20/12	06/20/12	<1.0	<1.0
SRP	µg/l	Blank	08/08/12	08/08/12	<1.0	<1.0
SRP	µg/l	Blank	08/31/12	08/31/12	<1.0	<1.0
NOx	µg/l	Blank	11/18/11	11/18/11	<1.0	<1.0
NOx	µg/l	Blank	01/13/12	01/13/12	<1.0	<1.0
NOx	µg/l	Blank	06/11/12	06/11/12	<1.0	<1.0
NOx	µg/l	Blank	06/20/12	06/20/12	<1.0	<1.0
NOx	µg/l	Blank	08/08/12	08/08/12	<1.0	<1.0
NOx	µg/l	Blank	08/31/12	08/31/12	<1.0	<1.0

Lab Method Blank Recovery

Booker Lake ATS Evaluation

Parmeter	Units	Sample Description	Date Prepared	Date Analyzed	Measured Value	Acceptance Range
Total N	μg/l	Blank	07/13/05	07/13/05	<1.0	<1.0
Total N	μg/l	Blank	08/09/05	08/09/05	<1.0	<1.0
Total N	μg/l	Blank	08/09/05	08/09/05	<1.0	<1.0
Total N	μg/l	Blank	08/09/05	08/09/05	<1.0	<1.0
Total N	μg/l	Blank	08/20/05	08/20/05	<1.0	<1.0
Total N	μg/l	Blank	09/08/05	09/08/05	<1.0	<1.0
Total N	μg/l	Blank	09/13/05	09/13/05	<1.0	<1.0
Total N	μg/l	Blank	10/10/05	10/10/05	<1.0	<1.0
Total N	μg/l	Blank	10/10/05	10/10/05	<1.0	<1.0
Total N	μg/l	Blank	01/25/06	01/25/06	<1.0	<1.0
Total N	μg/l	Blank	01/25/06	01/25/06	<1.0	<1.0
Total N	μg/l	Blank	01/25/06	01/25/06	<1.0	<1.0
Total N	μg/l	Blank	01/30/06	01/30/06	<1.0	<1.0
Total N	μg/l	Blank	01/30/06	01/30/06	<1.0	<1.0
Total N	μg/l	Blank	01/30/06	01/30/06	<1.0	<1.0
Total N	μg/l	Blank	01/30/06	01/30/06	<1.0	<1.0
Total N	μg/l	Blank	02/08/12	02/08/12	<1.0	<1.0
Total N	μg/l	Blank	06/14/12	06/14/12	<1.0	<1.0
Total N	μg/l	Blank	06/26/12	06/26/12	<1.0	<1.0
Total N	μg/l	Blank	08/13/12	08/13/12	<1.0	<1.0
Total P	μg/l	Blank	07/13/05	07/13/05	<1.0	<1.0
Total P	μg/l	Blank	08/09/05	08/09/05	<1.0	<1.0
Total P	μg/l	Blank	08/09/05	08/09/05	<1.0	<1.0
Total P	μg/l	Blank	08/20/05	08/20/05	<1.0	<1.0
Total P	μg/l	Blank	09/08/05	09/08/05	<1.0	<1.0
Total P	μg/l	Blank	09/13/05	09/13/05	<1.0	<1.0
Total P	μg/l	Blank	10/10/05	10/10/05	<1.0	<1.0
Total P	μg/l	Blank	10/10/05	10/10/05	<1.0	<1.0
Total P	μg/l	Blank	01/25/06	01/25/06	<1.0	<1.0
Total P	μg/l	Blank	01/25/06	01/25/06	<1.0	<1.0
Total P	μg/l	Blank	01/25/06	01/25/06	<1.0	<1.0
Total P	μg/l	Blank	01/30/06	01/30/06	<1.0	<1.0
Total P	μg/l	Blank	01/30/06	01/30/06	<1.0	<1.0
Total P	μg/l	Blank	01/30/06	01/30/06	<1.0	<1.0
Total P	μg/l	Blank	02/08/12	02/08/12	<1.0	<1.0
Total P	μg/l	Blank	06/14/12	06/14/12	<1.0	<1.0
Total P	μg/l	Blank	06/26/12	06/26/12	<1.0	<1.0
Total P	μg/l	Blank	08/13/12	08/13/12	<1.0	<1.0

Lab Method Blank Recovery

Booker Lake ATS Evaluation

Parmeter	Units	Sample Description	Date Prepared	Date Analyzed	Measured Value	Acceptance Range
Ammonia	μg/l	Blank	07/07/05	07/07/05	<1.0	<1.0
Ammonia	μg/l	Blank	07/29/05	07/29/05	<1.0	<1.0
Ammonia	μg/l	Blank	08/29/05	08/29/05	<1.0	<1.0
Ammonia	μg/l	Blank	09/10/05	09/10/05	<1.0	<1.0
Ammonia	μg/l	Blank	10/25/05	10/25/05	<1.0	<1.0
Ammonia	μg/l	Blank	10/25/05	10/25/05	<1.0	<1.0
Ammonia	μg/l	Blank	12/26/05	12/26/05	<1.0	<1.0
Ammonia	μg/l	Blank	01/05/06	01/05/06	<1.0	<1.0
Ammonia	μg/l	Blank	02/15/12	02/15/12	<1.0	<1.0
Ammonia	μg/l	Blank	03/16/12	03/16/12	<1.0	<1.0
Ammonia	μg/l	Blank	05/30/12	05/30/12	<1.0	<1.0
Ammonia	μg/l	Blank	06/20/12	06/20/12	<1.0	<1.0
Ammonia	μg/l	Blank	08/08/12	08/08/12	<1.0	<1.0
Color	PCU	Blank	07/08/05	07/08/05	<1.0	<1.0
Color	PCU	Blank	07/21/05	07/21/05	<1.0	<1.0
Color	PCU	Blank	07/21/05	07/21/05	<1.0	<1.0
Color	PCU	Blank	11/04/05	11/04/05	<1.0	<1.0
Color	PCU	Blank	11/28/05	11/28/05	<1.0	<1.0
Color	PCU	Blank	11/28/05	11/28/05	<1.0	<1.0
Color	PCU	Blank	12/19/05	12/19/05	<1.0	<1.0
Color	PCU	Blank	12/19/05	12/19/05	<1.0	<1.0
Color	PCU	Blank	12/21/05	12/21/05	<1.0	<1.0
Color	PCU	Blank	11/18/11	11/18/11	<1.0	<1.0
Color	PCU	Blank	12/29/11	12/29/11	<1.0	<1.0
Color	PCU	Blank	02/08/12	02/08/12	<1.0	<1.0
Color	PCU	Blank	03/09/12	03/09/12	<1.0	<1.0
Color	PCU	Blank	04/12/12	04/12/12	<1.0	<1.0
Color	PCU	Blank	06/21/12	06/21/12	<1.0	<1.0
Color	PCU	Blank	08/09/12	08/09/12	<1.0	<1.0
Color	PCU	Blank	08/31/12	08/31/12	<1.0	<1.0
Color	PCU	Blank	10/19/12	10/19/12	<1.0	<1.0