
Final Report

Conceptual Design of C-43 Water Quality Treatment Area Nutrient Removal/Reduction Test Facility

Prepared for
South Florida Water Management District

Date
October 2012

Prepared by
Wetland Solutions, Inc.



CERTIFICATION

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Acronyms

AGP	Algal Growth Potential
AN	Ammonia N
BAN	Biologically Available N
BOD	Biochemical Oxygen Demand
BMAP	Basin Management Action Plan
C*	Irreducible background concentration
COD	Chemical Oxygen Demand
CRE	Caloosahatchee River and Estuary
DIN	Dissolved Inorganic Nitrogen
DO	Dissolved Oxygen
DON	Dissolved Organic Nitrogen
EMV	Emergent Macrophyte Vegetation
F.A.C.	Florida Administrative Code
FAV	Floating Aquatic Vegetation
FDEP	Florida Department of Environmental Protection
HLR	Hydraulic Loading Rate
N	Nitrogen
nHRT	Nominal Hydraulic Residence Time
NH ₃ -N	Unionized form of AN
NH ₄ -N	Ammonium Nitrogen
NO _x -N	Nitrate+Nitrite Nitrogen
NNC	Numeric Nutrient Criteria
O&M	Operation and Maintenance
OW	Open Water
PAC	Periphytic Algal-Dominated Community
PSTA	Periphyton Stormwater Treatment Area
SAV	Submerged Aquatic Vegetation
SFWMD	South Florida Water Management District
SRP	Soluble Reactive Phosphorus
STAs	Stormwater Treatment Areas
TKN	Total Kjeldahl Nitrogen
TMDL	Total Maximum Daily Loads
TN	Total Nitrogen
TON	Total Organic Nitrogen
TP	Total Phosphorus
TSS	Total Suspended Solids
USEPA	United States Environmental Protection Agency
WQTA	Water Quality Treatment Area
WSI	Wetland Solutions, Inc.

Section 1.0 Introduction

1.1 Background

Elevated concentrations of nitrogen and phosphorus in the Caloosahatchee River and Estuary (CRE or “Study Area”) are contributing to water quality impairments in this system as evidenced by excessive algae blooms and decreased water clarity and dissolved oxygen content (Knight and Steele 2005). The reduction of nutrient concentrations and loads to these water bodies was required by the Northern Everglades and Estuaries Protection Program passed by the Florida Legislature and signed into law in 2007, and by CRE Total Maximum Daily Loads (TMDL) published by the Florida Department of Environmental Protection (FDEP) (Bailey *et al.* 2009) [Rule 62-304.800, Florida Administrative Code (F.A.C.)]. FDEP is currently in the planning stages of the Caloosahatchee Estuary Basin Management Action Plan (BMAP) which is the roadmap to implement the TMDL. Concurrent with the BMAP planning, FDEP is revising the estuary TMDL and developing several tributary and freshwater Caloosahatchee River TMDLs.

In order to decrease nutrient loading to the downstream estuary, the South Florida Water Management District (District or SFWMD) and Lee County have been partnering on the C-43 Water Quality Treatment Area Testing Facility Project (the “C-43 WQTA Project”). The purpose of the C-43 WQTA Project is to investigate and demonstrate cost effective strategies for reducing loadings of total nitrogen (TN) and other constituents, including total phosphorus (TP) and total suspended solids (TSS) to the C-43 Canal (Caloosahatchee River) to improve water quality in the downstream estuarine ecosystems. The District also anticipates that the C-43 WQTA Project will generate strategies that can be applied to estuaries throughout south Florida.

Through a decade of successful operation of Stormwater Treatment Areas (STAs), the District has built an extensive expertise in TP removal from storm water runoff using wetland treatment systems. However, the mechanisms for TN removal via wetland treatment systems have not been studied to the same extent. The existing data from STAs mostly indicate that currently designed wetland treatment systems are not optimized to reduce TN (especially dissolved organic nitrogen, DON) although they can remove dissolved inorganic nitrogen (DIN) with high efficiency, which accounts for, at most, 20% of the TN present in the CRE system. Thus, the District initiated a project to identify the best option(s) for achieving the C-43 WQTA Project’s goals of nutrient reduction in CRE and to design a test facility prior to construction of the full-scale C-43 WQTA Project.

Those efforts were conducted under contract by CH2M HILL (2008, 2009, 2010) and subsequent review by a panel of natural treatment technology experts (WSI 2010) and resulted in several deliverables and recommendations, including the selection of constructed wetland treatment systems as the most cost-effective and feasible approach for advanced nutrient removal in the C-43 Basin. As a preliminary step, the recommended plan included design, construction, and operation of a multi-scale test/demonstration facility on a 1,750-acre parcel (“Boma” property see Figure 1) purchased by the District and Lee County for the proposed C-43 WQTA. This test/demonstration facility is intended to provide the basis for design of full-scale constructed treatment wetlands to assist with ultimate compliance with the CRE TMDL.

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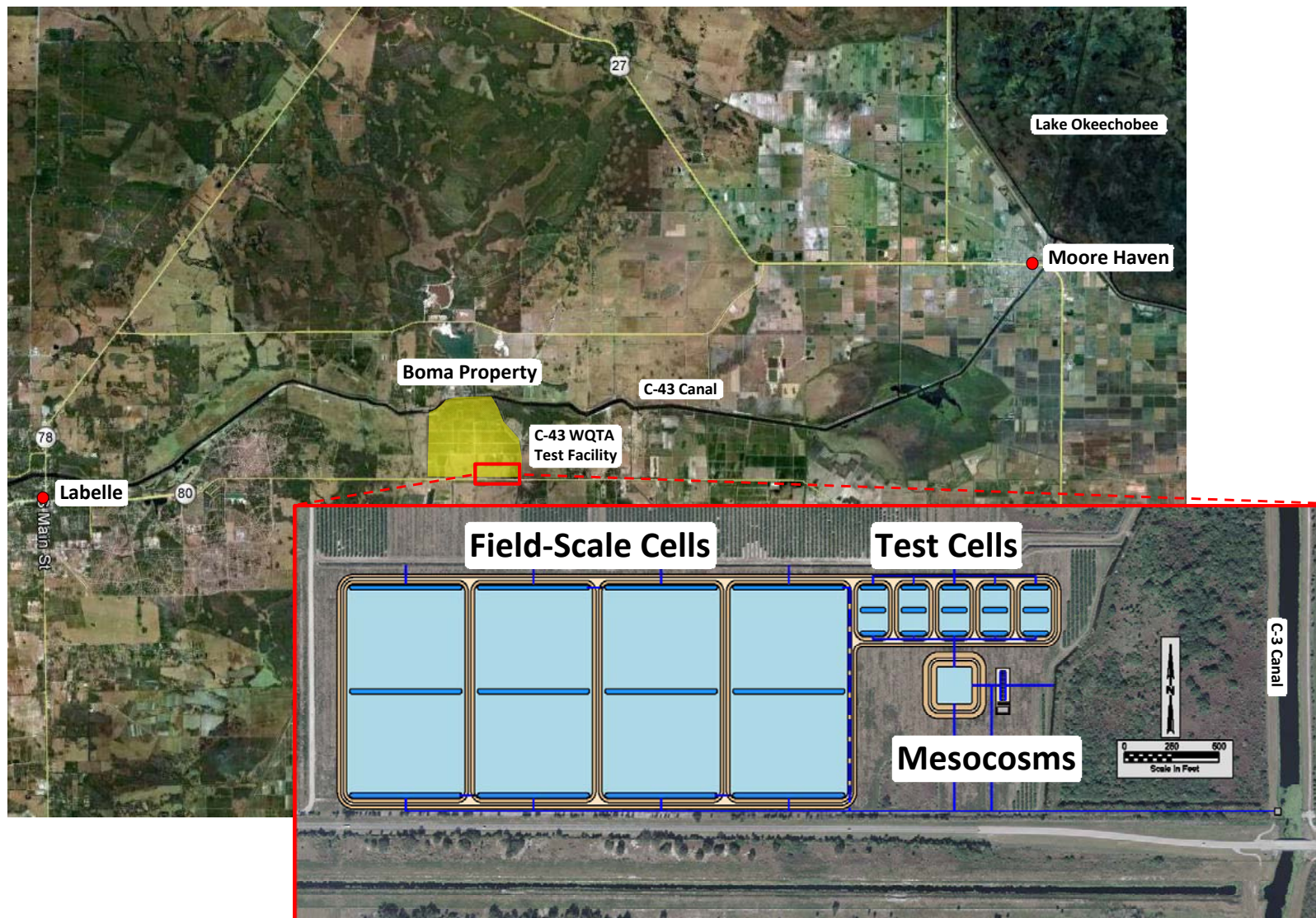


Figure 1. Location and Conceptual layout of the Proposed C-43 Water Quality Treatment Area Test Facility on the Boma Property

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Following those preliminary efforts, Wetland Solutions, Inc. (WSI) was selected by the District to provide additional technical support to develop the detailed C-43 WQTA Project Testing Plan, including an updated conceptual design of the proposed test facilities and an operational testing plan. The C-43 WQTA Testing Plan is intended to provide the flexibility to test multiple nitrogen removal approaches to determine which are most cost effective and to develop defensible design criteria for full-scale C-43 WQTA Project implementation. The conceptual design includes a recommended suite of testing scales including: laboratory bioassays, experimental mesocosms, and field-scale wetland plots. Each platform scale includes testing plans, scientific rationales, and estimated costs for construction, operation and maintenance (O&M), and testing in the proposed conceptual plan.

1.2 Project Goals and Objectives

The goal of this project is to develop a conceptual design for a test facility comprised of mesocosms and test cells that: 1) is based on a thorough review of applicable Florida treatment wetland performance experience; 2) will test and demonstrate wetland technologies that have the highest potential to effectively remove and/or reduce background TN loading from the facility's C-43 inflows; 3) identify the range of hydrological loading rates per unit area to achieve optimal nutrient removal/reduction rates; and 4) is implementable and cost effective on larger scales and/or applicable to other south Florida estuarine systems. The principal project objective is to prepare a conceptual design that can be used to proceed to final design, preparation of construction documents and a final test plan, and operation of the proposed C-43 WQTA Test Facility.

The C-43 WQTA Test Facility Conceptual Design Project has four tasks:

1. Project Management and Communication
2. Evaluation of Total Nitrogen Reduction Options
3. Conceptual Design of the Testing Facility
4. Final Report and Project Close-Out

WSI previously completed Tasks 1 through 3 (copies appended to this report). This Final Report provides an Executive Summary of the work completed for those three tasks as well as appended copies of the complete reports for each task. This Final Report provides a stand-alone summary of the technical basis and conceptual design for the proposed C-43 WQTA Test Facility.

Project Management and Coordination

Mr. Eric Gonzalez, P.E. was the District's Project Manager and served as the principal point of communication between the District and WSI on all contract and technical matters related to the C-43 WQTA Project.

WSI's Project Manager and Principal Scientist was Robert L. Knight, Ph.D. Dr. Knight served as the principal point of contact on all contract and technical matters between WSI and the District.

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Chris Keller, P.E. was WSI's Assistant Project Manager and Senior Engineer for the C-43 WQTA Project. Mr. Keller directed all engineering aspects of the project and assisted Dr. Knight with project management, data analysis, and report preparation.

Dr. Knight and Mr. Keller were in-turn assisted by key WSI staff, including Senior Scientist Debra Segal, M.S. for technical quality control, Assistant Scientist Ron Clarke, M.S. for water quality and data analysis issues, and Assistant Engineer Scott Knight, P.E. for engineering support.

All project deliverables were prepared in a consistent editorial format and delivered to the District by electronic mail. All work products were initially submitted and labeled as Draft, revised as agreed upon by the District and WSI, and resubmitted as Final documents. The schedule for actual and realized project deliverable dates is included below as Table 1. The full project work plan is included as Attachment A.

A Project Kick-Off Meeting was held at the District's West Palm Beach Headquarters on January 4, 2012. At the kick-off meeting the District's project manager and administrative/technical review staff provided guidance to WSI concerning the goals, objectives, and scope of the project. Subsequent project meetings to discuss project deliverables and revisions to the draft reports were held by teleconference on April 2 and August 20, 2012.

C-43 WQTA Test Facility Conceptual Design – Task 4

Table 1. C-43 WQTA Test Facility Conceptual Design Project Tasks, Deliverables, and Key Dates

TASK	DELIVERABLE	DUE DATE	ACTUAL DATE
Task 1.1: Project Kickoff Meeting	Power Point presentation	One week before kickoff meeting	1/3/2012 – Power Point submitted 1/4/2012 – kickoff meeting in West Palm Beach
Task 1.2: Project Work Plan	District-approved final project work plan	1/17/2012	1/2/2012 draft submitted 1/18/2012 – WMD comments 1/20/2012 – final accepted
Task 2.1: Draft Evaluation of Options for Reduction of Total Nitrogen	Electronic copy of draft report summarizing relevant options for reduction of total nitrogen	2/28/2012	2/27/2012 – draft submitted 3/27/2012 – WMD comments
Task 2.2: Draft Evaluation of Options for Reduction of TN Meeting	Project meeting between contractor and the district project team	Within 2 weeks of draft submission	4/2/2012 – teleconference review meeting 4/10/2012 – WMD addl. comments 4/12/2012 – revised draft submitted 4/23/2012; 5/2/2012; 5/11/2012 – WMD addl. comments
Task 2.3: Final Evaluation of Options for Reduction of TN	Electronic copies of final documentation summarizing the evaluation of relevant options for reduction of TN	5/9/2012	5/13/2012 – final Task 2 report accepted
Task 3.1: Draft Conceptual Design Report	Electronic copy of draft report detailing the conceptual design of mesocosms and the nutrient removal/reduction test facility	6/30/2012	6/28/2012 – draft submitted
Task 3.2: Final Conceptual Design	Electronic copy of the district approved final report detailing the final conceptual design of mesocosms and the nutrient removal/reduction test facility	8/15/2012	7/12/2012 – WMD comments received 7/30/2012 – revised draft submitted 8/16/2012 – addl. WMD comments received 8/20/2012 – pre-meeting teleconference 8/20/2012 – teleconference review meeting 8/24/2012 – final Task 3 report accepted
Task 4.1: Draft Final project Report	Draft final project report	9/1/2012	
Task 4.2: Draft Final Project Report Meeting	Draft final project report meeting	9/15/2012	
Task 4.3: Final Project Report	District approved final project report	9/25/2012	9/26/12 – WMD comments to Draft Final received 10/1/12 – Final Project Report submitted

Section 2.0 Evaluation of Treatment Wetland Total Nitrogen Reduction Technologies

2.1 Background

Surface-flow constructed treatment wetlands include a broad variety of technologies that rely on the use of aquatic and wetland plants and associated microbial communities to provide water quality benefits. All constructed treatment wetlands have the following basic characteristics: treatment processes that primarily rely on the growth of hydrophytes (aquatic and wetland plants) and associated microbial biogeochemical processes; and the need for relatively large land areas necessary to utilize sunlight as the primary energy source for the treatment process. The Task 2 report (Attachement B) provides a detailed discussion of these processes.

The different types of surface-flow constructed treatment wetlands are generally similar in design with the exception of water regime (depth and duration of flooding), sediment or substrate type, and the selection of the appropriate plant community that is adapted to the selected water regime. A considerable variety of hydrophytic plant species are available for use in constructed surface flow treatment wetlands in south Florida.

Treatment wetlands have been proven effective for the removal of a wide range of inorganic and organic pollutants. For the proposed C-43 WQTA project the pollutants of principal concern are nitrogen (N) forms – total nitrogen (TN), total organic N (TON), ammonia N (AN), and nitrate+nitrite N ($\text{NO}_x\text{-N}$). Pollutants of secondary interest for the C-43 WQTA Project are phosphorus (P) forms – total phosphorus (TP), inorganic or soluble reactive phosphorus (SRP), particulate P, and organic P; and total suspended solids (TSS). While wetlands constructed for TN reduction will provide benefits for removal of many of the other pollutants such as organics and trace metals, those ancillary benefits were not explicitly considered.

To-date there have been limited efforts to design treatment wetlands to optimize nitrogen removal at TN concentrations less than about 3 mg/L (Kadlec and Knight 1996; Kadlec and Wallace 2009). A few Florida municipal treatment wetlands do have TN permit limits in the range from 1.6 to 2.3 mg/L (Titusville Blue Heron and Orlando Easterly Wetland, respectively). TN mass reduction goals for the CRE TMDL are 23% of current loads. Based on ambient TN concentrations measured between S-77 and S-79 (1.61 to 1.79 mg/L), this may result in the need to achieve TN concentration targets as low as 1.24 mg/L. Because of this focus on very low TN concentrations this report summarizes TN removal performance data from full-scale treatment wetlands that operate at relatively low TN levels, and especially those that have demonstrated the capability to achieve TN concentrations less than 1 mg/L.

2.2 Summary of Nitrogen Chemistry Relevant to Treatment Wetlands

The focus of the C-43 WQTA Project is the use of constructed treatment wetlands for removal of TN, with particular reference to the removal of various forms of TON. This section provides a brief summary of nitrogen chemistry. Figure 2 shows the aquatic nitrogen cycle.

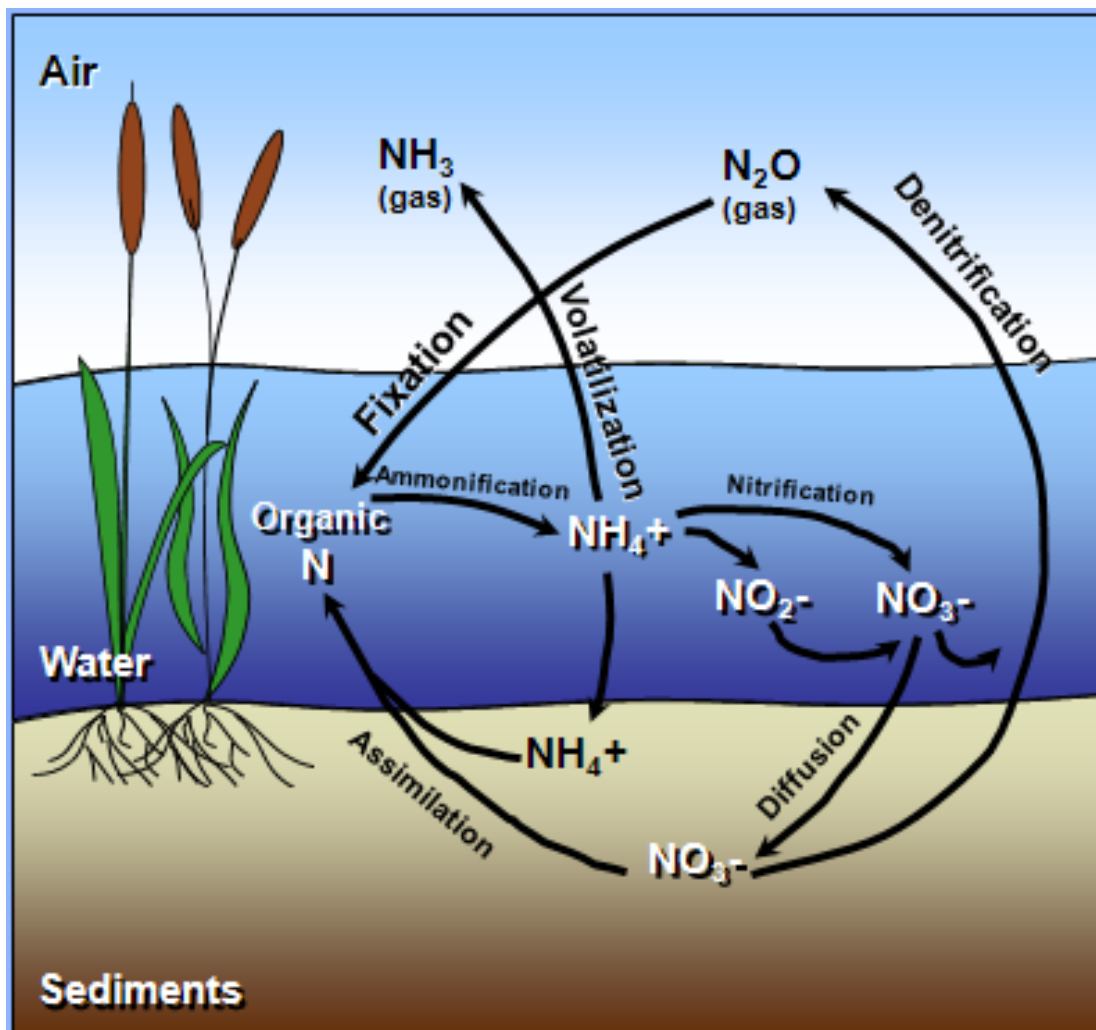


Figure 2. Aquatic Nitrogen Cycle (CH2M HILL 2008)

Nitrogen has five different oxidation states that commonly occur in nature. These range from the most oxidized form - nitrate N (oxidation state +5), to nitrite N (+3), to nitrous oxide (+1), to di-nitrogen gas (0), to ammonium N (-3) and organic N (-3). Di-nitrogen gas (N_2) is the ultimate sink for much of the TN transformed by treatment wetlands. Nitrogen gas makes up about 78% of the atmosphere and due to its triple bond it is relatively stable with the exception of N-fixation processes such as lightning and a small number of plant species that have developed enzyme and energy systems necessary to convert this gas back to dissolved ammonia. Industrial fixation of N_2 has been greatly accelerated by the use of fossil fuel energies and is at least

partially responsible for worldwide increases in agricultural production and the resulting global imbalance of nitrogen in the environment and eutrophication of surface waters.

Nitrogen pollution in water frequently occurs as one or more of the four non-gaseous forms of nitrogen and is often assessed as the total combined aqueous form - TN. However the actual mix of individual nitrogen forms in polluted waters is very important for assessing impacts in the receiving water and treatment options for reducing the concentration and load of TN.

For example, TON is derived from organic pollution, often resulting from the discharge of domestic and some industrial wastewaters and from runoff from agricultural areas. Organic N in wastewater and runoff can degrade by physical and microbial mineralization to AN. Other important sources of TON in runoff result from the oxidation and decomposition of organic (peat or mucky) soils and dead plant and animal materials.

Ammonia N may also be high in human and animal wastewaters and in agricultural and urban runoff when liquid ammonia fertilizer is used. Ammonia N is in turn chemically reactive in surface waters where its bacterial transformation exerts a high demand for dissolved oxygen. The unionized form of AN ($\text{NH}_3\text{-N}$) is acutely and chronically toxic to sensitive aquatic organisms. In most aquatic environments most of the AN is in the ionized form known as ammonium ($\text{NH}_4\text{-N}$). Ammonia N is a plant growth nutrient and can stimulate algal blooms. In aerobic aquatic systems, AN can be microbially converted by the process termed “nitrification” to nitrite N which is subsequently converted to nitrate N.

Nitrate and nitrite N are often contained in wastewater and stormwater. Municipal and industrial wastewaters that have received advanced secondary treatment in activated sludge systems commonly discharge TN predominately as $\text{NO}_x\text{-N}$. Nitrate and nitrite N are also commonly found in runoff from agricultural and urban areas that use inorganic fertilizers. Nitrite is unstable in aquatic systems and readily converts to nitrate N. For this reason, the two oxidized nitrogen forms are often considered together. Nitrate N is also a plant growth nutrient and can stimulate algal blooms. Nitrate N is readily converted by the microbial denitrification process in constructed treatment wetlands to di-nitrogen gas.

All of these forms of nitrogen are continuously transformed from one compound to another and back again in biological systems, including constructed treatment wetlands. Organic and AN forms release energy when utilized and serve as food for adapted microbes and higher organisms. Oxidized forms of nitrogen ($\text{NO}_x\text{-N}$) provide oxygen for microbial metabolism in anaerobic environments and organic energy sources (primarily reduced carbon from wetland plants) are necessary to fuel these transformations. Most of the microbial nitrogen conversions are dependent upon enzymes and catalysts that are relatively specific to the individual conversion processes. Because of the inter-conversion of nitrogen forms in wetlands, it is necessary to consider a reaction sequence when examining the rate and ultimate fate of various incoming water sources.

2.3 Pollutant Sources and Forms in the C-43 Study Area

A number of authors have estimated the inputs of nitrogen to the CRE study area (Bailey *et al.* 2009; WSI 2007a; Knight and Steele 2005; JEI 2003; and Doering and Chamberlain 2004). The principal sources of TN to C-43 and the Caloosahatchee Estuary include inflows from Lake Okeechobee, the Upper Caloosahatchee Watershed, and the Tidal Caloosahatchee Watershed (Figure 2). Table 2 provides a summary of long-term flows, N, P, and TSS concentrations, and loads at the three principal C-43 water control structures for the period-of-record from January 1981 through October 2011.

The water entering the C-43 canal from Lake Okeechobee at S-77 has an average TN concentration of 1.76 mg/L and is predominantly in the organic form (average 89%). Nitrate+nitrite N makes up the next most abundant fraction (average 0.114 mg/L [6.5%]). Ammonia N averages 0.075 mg/L (4.3% of TN).

The average TN concentration in C-43 decreases slightly with travel distance downstream. The mean TN concentration at S-78 is 1.64 mg/L and 1.61 mg/L at S-79. The fraction of the TN in the TON form also declines from 89% at S-77 to 85% at S-78 and 78% at S-79. These data indicate that as the distance downstream increases from S-77 to S-79, on average the proportion of the more easily removed inorganic N forms increases. On an average concentration basis, TON at S-77 is reduced by about 20% by the time it reaches S-79. However, due to the increase in water volume from the watershed the total TON load increases on average by about 917 MT/yr (83%) with distance downstream between S-77 and S-79.

Total suspended solids concentrations decline along C-43 from an average of 8.5 mg/L at S-77 to 3.4 mg/L at S-79. TSS loads also decline between S-77 and S-79 on average from 9,593 MT/yr to 6,751 MT/yr respectively.

In contrast to TN and TSS, TP concentrations increase with travel distance downstream, from an average of 0.094 mg/L at S-77 to 0.14 mg/L at S-79 (49% increase). The average TP load also increases between these stations from 61 to 235 MT/yr.

These data illustrate the observation that the concentrations of TN and TSS generally decrease as water travels along the C-43 Canal and that the fraction of organic nitrogen also declines along this waterway. The estimated average TSS load also declines downstream while the TN mass load increases significantly. TP concentrations and loads increase with distance downstream.

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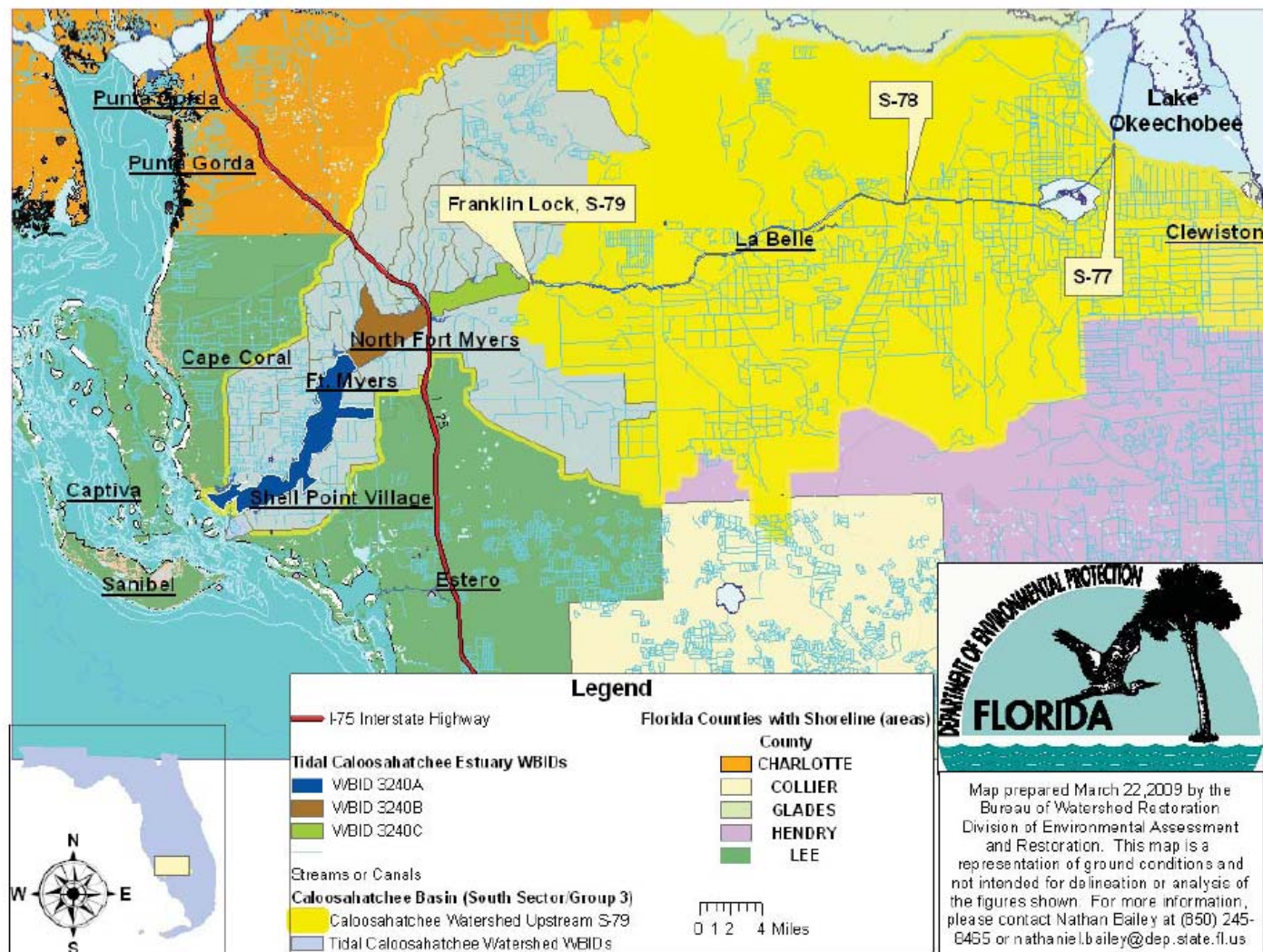


Figure 3. Location of Lake Okeechobee, the Upper Caloosahatchee Watershed above S-79, the Tidal Caloosahatchee Watershed, and Surface Water Stations Referenced in the Report (Bailey *et al.* 2009).

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Table 2. Caloosahatchee River Flows and Nutrient Concentrations and Cumulative Loads at Structures S-77, S-78, S-79 (SFWMD DBHYDRO, January 1981 - October 2011). Values are Averages of Monthly Data (“n” refers to the number of months in each average)

Structure	Stats	Total Flow cfs	TP		TN		ON		TKN		NOx-N		NH ₄ -N		TSS	
			mg/L	MT/yr	mg/L	MT/yr	mg/L	MT/yr	mg/L	MT/yr	mg/L	MT/yr	mg/L	MT/yr	mg/L	MT/yr
S-77	Avg	755	0.094	60.8	1.76	1,235	1.57	1,105	1.65	1,149	0.114	84.5	0.075	42.9	8.46	9,593
	Median	164	0.075	13.3	1.65	331	1.50	309	1.56	316	0.056	7.26	0.048	6.90	6.00	1,204
	Min	-879	0.020	0.010	0.294	0.190	0.245	0.178	0.250	0.182	0.002	0.008	0.005	0.004	0.500	0.685
	Max	8,330	0.392	0,846	8.12	16,842	4.38	16,607	4.75	16,743	6.65	1,780	1.13	1,001	103	299,635
	StdDev	1,415	0.060	117	0.633	2,274	0.482	2,047	0.519	2,117	0.344	227	0.097	103	9.76	25,546
	N	560	449	410	450	411	447	408	451	412	450	411	447	408	402	364
S-78	Avg	997	0.131	115	1.64	1,465	1.40	1,252	1.45	1,327	0.195	150	0.059	72.2	4.43	7,267
	Median	357	0.117	44.4	1.50	610	1.30	0,515	1.34	0,531	0.096	40	0.040	10.6	3.00	1,128
	Min	0.229	0.039	0.029	0.349	0.429	0.245	0.43	0.250	0.43	0.002	0.001	0.005	0.002	0.500	1.43
	Max	8,724	0.561	0,904	11.4	13,295	3.34	10,448	3.37	11,059	9.85	3,092	0.390	0,750	36.0	227,476
	StdDev	1,527	0.066	170	0.825	2,205	0.437	1,912	0.447	2,005	0.703	344	0.060	128	5.00	23,025
	N	466	203	185	199	181	195	177	202	184	201	183	197	179	183	174
S-79	Avg	1,730	0.140	235	1.61	2,532	1.26	2,021	1.31	2,146	0.308	409	0.045	92.4	3.44	6,751
	Median	798	0.128	114	1.46	1,425	1.15	1,018	1.19	1,057	0.256	170	0.033	22.9	1.50	1,944
	Min	0.00	0.051	0.52	0.330	5.44	0.210	3.91	0.250	4.01	0.002	0.197	0.003	0.039	0.500	2.54
	Max	10,928	0.460	1,973	10.8	13,276	5.05	10,549	5.06	11,124	9.63	7,351	0.279	811	22.0	72,006
	StdDev	2,169	0.062	298	0.802	2,902	0.468	2,407	0.464	2,530	0.692	699	0.042	146	3.41	11,998
	N	546	199	194	197	192	191	186	199	194	198	193	192	187	193	188

S-77 DBKEY: P1022 (01/1965-12/2005); 15635 (01/2006-08/2011)

S-78 DBKEY: 00857 (07/1971-09/2003); WN161 (10/2003-04/2010)

S-79 DBKEY: 00865 (05/1966-10/2011)

2.4 Wetland Design Considerations

2.4.1 Surface-Flow Constructed Treatment Wetland Categories

The Task 2 report (see Attachment B) provides a detailed discussion of the treatment wetland design elements of importance for TN removal. This section describes the variety of plant communities utilized in wetland and aquatic treatment systems.

Five general plant community types typically can be found in constructed treatment wetlands and STAs:

- Emergent macrophyte vegetation (EMV)
- Submerged aquatic vegetation (SAV)
- Floating aquatic vegetation (FAV)
- Attached and floating algal-dominated systems algae (PSTA or periphyton stormwater treatment area)
- Open water (OW)

When used in full-scale water quality treatment systems, none of these plant communities are routinely harvested. Thus their nutrient removal performance is based on natural biogeochemical processes, including aerobic and anaerobic decomposition, nitrification and denitrification, volatilization, and burial in recalcitrant sediments (peat).

The dominant plant community in most existing constructed treatment wetlands is EMV (Kadlec and Knight 1996). EMV wetlands typically have average water depths less than 1 meter (m) and the dominant plants are rooted in the wetland sediments. EMV wetlands typically have low dissolved oxygen concentrations in the water column. This plant community type has been found to be highly reliable for nutrient removal in most applications and is likely to be the first choice for constructed water quality treatment wetlands in the C-43 basin southwest of Lake Okeechobee. Key nitrogen transformation/reduction processes, including mineralization of TON, nitrification of AN, and denitrification of NO_x-N have been demonstrated at relatively high rates in EMV systems.

The use of SAV as a dominant plant community was first carefully evaluated for enhanced phosphorus concentration reduction south of Lake Okeechobee in the District's EAA STAs. SAV may or may not be rooted and most plant biomass is within the water column and below the water surface. For this reason, the primary productivity of these systems generally results in high daily concentrations of dissolved oxygen. Water depths in SAV cells are typically greater than 1 m and may be up to 6 m deep or more. SAV systems are expected to incorporate all of the nitrogen reduction processes listed above for EMV systems, but with higher or lower effective rate constants.

FAV communities have been used extensively in treatment ponds throughout the southern U.S. and data are available from California and Texas for nutrient removal in ponds dominated by either water hyacinth or duckweed. A few pilot-scale FAV systems have been monitored in south Florida. Historically, the Everglades Nutrient Removal Project's (ENRP) Buffer Cell included about 39% cover by a FAV plant community. FAV is generally not rooted and these

systems typically have deeper water conditions than EMV and SAV systems (greater than 2 m). This water depth is generally effective at excluding significant colonization of these systems by EMV plants. FAV systems typically shade out other plants and algae in the water column and have very low levels of dissolved oxygen. FAV systems are expected to incorporate all of the nitrogen reduction processes listed above for EMV systems, but with higher or lower effective rate constants.

Algal-dominated wetlands include relatively shallow systems with attached and/or floating filamentous algae. This algae community may be called *aufwuchs*, periphyton, epiphytic, benthic, or floating. PSTA has been a convenient descriptor for this highly variable treatment wetland plant community. POP (periphyton-enhanced oxidative photodegradation) systems also fit into this category. Typical water depths in algal-dominated treatment systems are less than 0.6 m. Since algal productivity occurs in the water column, PSTA systems have high daily concentrations of dissolved oxygen. This category does not include the Algal Turf Scrubber™ technology since those systems are highly managed through continuous harvesting and biomass disposal. PSTA systems are expected to incorporate all of the nitrogen reduction processes listed above for EMV systems, but with higher or lower effective rate constants.

Open Water (OW) treatment wetlands include a variety of ponds and lakes where floating aquatic plants are excluded by use of herbicides and/or wind fetch (large dimensions). These open water systems typically have average water depths greater than 2 m and are dominated by planktonic (free-floating) unicellular and colonial algae species. Treatment ponds and open water areas in treatment wetlands are typically aerobic near the surface of the water column due to high algal productivity, but also may be anaerobic at the level of the sediments due to high sediment oxygen demand. OW systems are expected to incorporate all of the nitrogen reduction processes listed above for EMV systems, but with higher or lower effective rate constants.

Following initial plant establishment and startup, plant community composition in all of these wetland alternatives often deviates from plan and follows a course dictated by the multiple environmental influences of water depth and flooding duration, water quality, pre-existing seed bank in site soils, weather, herbivorous insects, and other fauna and plant diseases. These shifts are not necessarily detrimental to wetland water quality treatment performance. In light of minimizing unproductive costs, maintenance activities in constructed wetlands should be limited to only what is necessary to maintain the desired wetland plant community type – not a preordained list of “desirable” plant species.

2.4.2 Optimizing the Total Nitrogen Treatment Process

The ability of a constructed, wetland-based treatment system to reduce TN concentrations can be summarized as follows:

- In a treatment wetland or a series of wetland-based treatment steps, the removal of TN from a polluted water source will only occur through a sequential biological process;
- The rate of this overall TN removal process is limited by its slowest intermediate step;
- To achieve effective TN removal in a treatment wetland it is essential that no step in the N sequential transformation is omitted;

- It is also essential to maximize the efficiency of each N transformation step to the extent possible allowed by optimal biological process rates.

The preliminary step or steps in the N transformation process should be focused on TON mineralization. When biologically-available TON is converted to AN early in the wetland process, this will allow greater time for nitrification and denitrification in the downstream portions of the wetland treatment system. However, since some forms of biologically-available TON are more recalcitrant than others, it is necessary to provide continuing favorable conditions for TON mineralization throughout the downstream wetland treatment train. The Expert Panel recommended that the District consider developing an analytical indicator to rapidly assess the biological availability of TON in the CRE system (WSI 2010). It was suggested that this test might be based on a modification of the commonly-used analytical procedure to measure TKN, e.g., a modified digestion sequence using something less reactive than the sulfuric acid that mineralizes TON to AN in the TKN test.

Treatment wetland (i.e., STA) design is not one-dimensional and multiple constraints must be met simultaneously in order to create a successful project (Kadlec and Wallace 2009; WSI 2009). Owners and operators of wetland systems frequently inquire as to the optimum value for any particular variable that is under the designer's control. The reality of wetland design and behavior is that all of the key design parameters are inter-related and any adjustment to one may cause a response in one or more of the others. In many cases, the reaction of one variable to the manipulation of another is counterproductive to water quality improvement processes. For this reason it is recommended that the District consider development of a dynamic model for nitrogen removal as part of the long-term application of treatment wetlands for meeting water quality goals in the CRE and other south Florida estuarine systems.

2.5 Performance Summary for Florida Treatment Wetlands

2.5.1 Reference Wetland Sites for Performance Evaluation

Design and operational data from full-scale Florida treatment wetlands were reviewed for this evaluation (Table 3 and Figure 4). These projects cover a very broad range of conditions, including inflow nitrogen and phosphorus concentrations and forms, soils diversity, loading rates, and effluent concentrations. This performance evaluation was empirical in that it compared actual operational data for these systems and did not rely on model estimates. The full evaluation of relevant Florida treatment wetland performance was evaluated as part of task 2 and is included in Attachment B.

2.5.2 Performance Evaluation and Factors Affecting Performance

Table 3 summarizes the average inflow and outflow concentrations for nitrogen, phosphorus, and total suspended solids for each of the Florida treatment wetland systems included in the performance summary. The long-term average inflow TN concentrations for these systems ranged from 0.83 to 10.1 mg/L and the period-of-record (POR) outflow TN concentrations ranged from 0.79 to 3.5 mg/L. The long-term average inflow TP concentrations for these systems ranged from 0.02 to 5.42 mg/L and the POR outflow TP concentrations ranged from 0.01 to 5.00 mg/L. The long-term average inflow TSS concentrations for these systems ranged from 0.60 to 29.2 mg/L and the POR outflow TSS concentrations ranged from 0.20 to 21.3 mg/L. Additional findings related to plant community and substrate conditions are described below.

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Table 3. Summary of Design Criteria and Operational Performance for Existing Treatment Sites

System	Sub- strate	Plant Com.	Area (ha)	HLR (cm/d)	TP (mg/L)		NOx-N (mg/L)		NH ₄ -N (mg/L)		TKN (mg/L)		TON (mg/L)		TN (mg/L)		TSS (mg/L)		POR	
					In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out		
Phase I Apopka Marsh Flow-Way																				
	Cell B1	PEAT	EMV	67.99	11.31	0.119	0.087	0.027	0.010	0.081	0.660	3.98	2.94	3.90	2.29	4.00	2.96	21.50	1.47	11-03 12-09
	Cell B2	PEAT	EMV	45.73	13.82	0.101	0.074	0.026	0.012	0.159	0.761	3.68	3.06	3.52	2.30	3.71	3.07	11.32	1.68	11-03 12-09
	Cell C1	PEAT	EMV	74.06	11.75	0.116	0.096	0.028	0.016	0.104	0.759	3.93	3.14	3.83	2.38	3.96	3.16	19.48	1.17	11-03 12-09
	Cell C2	PEAT	EMV	73.25	10.51	0.111	0.109	0.031	0.024	0.122	0.533	3.62	3.08	3.50	2.54	3.65	3.10	13.03	1.56	11-03 12-09
C-43 West Storage Reservoir Test Cell																				
	Cell 1	SAND	OPEN	1.82	5.15	0.141	0.033	0.192	0.126	0.047	0.025	1.03	0.95	0.98	0.93	1.22	1.08	5.17	5.08	6-06 5-07
	Cell 2	SAND	OPEN	1.82	5.15	0.141	0.040	0.192	0.099	0.047	0.039	1.03	0.92	0.98	0.88	1.22	1.02	5.17	5.27	6-06 5-07
C-44 Reservoir / Stormwater Treatment Area Test Cell 1																				
	STA Cell 1	SAND	EMV	1.74	3.35	0.060	0.076	0.028	0.019	0.089	0.106	0.80	1.16	0.71	1.05	0.83	1.17	11.55	14.58	7-06 12-06
	STA Cell 2	SAND	EMV	1.74	7.82	0.060	0.031	0.028	0.025	0.089	0.074	0.80	0.81	0.71	0.74	0.83	0.84	11.55	8.07	7-06 12-06
	Test Cell 1	SAND	OPEN	1.50	3.59	0.053	0.017	0.028	0.013	0.116	0.096	0.88	0.78	0.76	0.69	0.90	0.79	29.25	7.27	7-06 6-07
	Test Cell 2	SAND	OPEN	1.50	4.60	0.053	0.026	0.028	0.013	0.116	0.118	0.88	0.94	0.76	0.82	0.90	0.95	29.25	21.29	7-06 6-07
City of Lakeland Wetland Treatment System Cells																				
	Cell 1	CLAY	EMV	81.40	3.84	5.416	5.001	6.289	1.528	1.081	0.641	3.83	2.01	2.68	1.42	10.11	3.50	8.25	1.49	1-87 9-08
	Cell 2	CLAY	EMV	77.33	3.43	4.995	4.406	1.530	0.730	0.643	0.246	2.01	1.16	1.42	0.91	3.50	1.84	1.49	1.52	1-87 9-08
	Cell 3	CLAY	EMV	166.9	2.07	4.406	4.192	0.730	0.194	0.246	0.182	1.16	1.06	0.91	0.88	1.84	1.87	1.52	3.19	1-87 9-08
	Cell 4	CLAY	EMV	30.53	9.02	4.192	4.085	0.194	0.169	0.182	0.127	1.06	1.06	0.88	0.93	1.87	1.21	3.19	3.27	1-87 9-08
	Cell 5	CLAY	SAV	93.61	1.12	3.862	3.412	0.210	0.205	0.171	0.166	1.14	1.46	0.97	1.30	1.29	1.64	3.03	20.71	1-87 9-08
	Cell 6	CLAY	FAV	19.94	6.89	3.412	3.034	0.205	0.220	0.166	0.302	1.46	1.57	1.30	1.27	1.64	1.79	20.71	7.87	1-87 9-08
	Cell 7	CLAY	FAV	14.25	7.80	3.034	2.898	0.220	0.181	0.302	0.178	1.57	1.32	1.27	1.14	1.79	1.51	7.87	5.97	1-87 9-08
Orlando Easterly Wetlands	SAND	EMV			0.265	0.064	0.850	0.038	0.523	0.058	1.38	0.85	0.85	0.80	2.23	0.87	1.93	2.65	1-88 11-11	
SFWMD Field-Scale PSTA Cells																				
	FS-1	LR	PSTA	2.08	8.37	0.030	0.022	0.163	0.104	0.103	0.082	1.45	1.89	1.43	1.81	1.48	1.92	8.01	1.99	8-01 12-02
	FS-2	LR	PSTA	2.08	12.07	0.031	0.015	0.180	0.133	0.097	0.071	1.61	1.61	1.63	1.65	1.72	1.75	9.67	4.19	9-01 12-02
	FS-3	LR	PSTA	2.08	9.27	0.030	0.015	0.155	0.113	0.099	0.134	1.69	1.77	1.69	1.76	1.73	1.81	5.00	3.35	8-01 12-02
	FS-4	PEAT	PSTA	2.08	11.03	0.033	0.026	0.203	0.193	0.127	0.101	1.42	1.55	1.41	1.60	1.56	1.61	3.04	4.47	11-01 12-02
SFWMD Porta-PSTA Mesocosms Treatments																				
	Treatment 1	PEAT	PSTA	0.0006	7.17	0.021	0.018	0.064	0.022	0.029	0.026	1.17	1.17	1.14	1.14	1.24	1.17	2.02	3.72	4-99 1-00
	Treatment 2	LR	PSTA	0.0006	7.11	0.022	0.018	0.061	0.035	0.037	0.028	1.24	1.22	1.20	1.20	1.30	1.27	2.12	4.48	4-99 1-00
	Treatment 3	PEAT	PSTA	0.0006	7.18	0.025	0.018	0.047	0.014	0.033	0.024	1.52	1.47	1.48	1.21	1.57	1.49	2.49	2.93	4-99 2-01
	Treatment 4	LR	PSTA	0.0006	7.49	0.025	0.016	0.046	0.020	0.034	0.025	1.58	1.57	1.55	1.38	1.63	1.60	2.66	3.47	4-99 2-01
	Treatment 5	LR	PSTA	0.0006	13.84	0.023	0.018	0.059	0.020	0.034	0.026	1.33	1.30	1.29	1.14	1.39	1.31	1.99	3.17	4-99 3-00
	Treatment 6	LR	PSTA	0.0006	5.54	0.023	0.018	0.059	0.026	0.035	0.029	1.34	1.29	1.31	1.19	1.41	1.32	1.86	3.56	4-99 3-00
	Treatment 7	SAND	PSTA	0.0006	7.36	0.025	0.018	0.044	0.096	0.034	0.029	1.48	1.66	1.45	1.41	1.53	1.74	2.85	2.33	4-99 2-01
	Treatment 8	SAND	PSTA	0.0006	7.32	0.020	0.021	0.062	0.023	0.032	0.023	1.33	1.14	1.30	1.12	1.40	1.15	2.01	3.84	4-99 1-00
	Treatment 9	PEAT	OPEN	0.0006	7.32	0.024	0.019	0.063	0.025	0.032	0.077	1.32	1.42	1.29	1.25	1.39	1.42	1.71	4.15	4-99 3-00
	Treatment 10	LR	OPEN	0.0006	7.14	0.024	0.016	0.053	0.017	0.035	0.069	1.32	1.28	1.29	1.16	1.38	1.28	2.94	5.09	4-99 3-00
	Treatment 11	LR	PSTA	0.0018	7.78	0.025	0.020	0.045	0.027	0.035	0.026	1.60	1.66	1.57	1.45	1.65	1.67	2.47	4.80	4-99 2-01
	Treatment 12	PEAT	PSTA	0.0018	7.63	0.025	0.020	0.043	0.013	0.034	0.026	1.53	1.49	1.50	1.30	1.58	1.49	2.60	4.70	4-99 2-01
	Treatment 13	PEAT	PSTA	0.0006	8.14	0.028	0.017	0.022	0.010	0.032	0.121	1.99	2.15	1.96	2.32	2.01	2.16	4.90	4.39	4-00 2-01
	Treatment 14	LR	PSTA	0.0006	8.03	0.028	0.015	0.023	0.010	0.032	0.014	2.11	1.71	2.07	2.02	2.13	1.68	5.47	2.60	4-00 2-01
	Treatment 15	LR	PSTA	0.0006	7.40	0.028	0.017	0.023	0.012	0.032	0.024	2.01	2.10	1.98	2.41	1.97	2.11	4.67	3.33	4-00 2-01
	Treatment 16	LR	PSTA	0.0006	15.69	0.025	0.017	0.034	0.008	0.042	0.020	2.16	2.33	2.12	2.32	2.20	2.33	2.67	2.50	5-00 2-01
	Treatment 17	SAND	PSTA	0.0006	7.49	0.028	0.016	0.020	0.002	0.033	0.012	2.10	2.03	2.07	2.09	2.12	2.06	4.00	3.13	4-00 2-01
	Treatment 18	NONE	OPEN	0.0006	8.11	0.028	0.016	0.021	0.002	0.033	0.036	2.62	2.01	2.58	2.16	2.64	2.01	4.00	2.60	4-00 2-01
	Treatment 19	NONE	PSTA	0.0006	7.84	0.027	0.014	0.021	0.003	0.034	0.027	2.11	2.34	2.07	1.96	2.13	2.34	3.80	4.22	4-00 2-01
SFWMD PSTA Test Cells Treatments																				
	Treatment 1	PEAT	PSTA	0.26	4.57	0.025	0.026	0.068	0.028	0.068	0.022	1.93	1.17	1.86	1.15	1.96	1.18	2.94	2.68	2-99 1-00
	Treatment 2	LR	PSTA	0.26	4.65	0.024	0.018	0.068	0.019	0.069	0.027	1.86	1.47	1.79	1.30	1.89	1.42	3.11	4.13	2-99 3-00
	Treatment 3	LR	PSTA	0.26	4.03	0.024	0.023	0.072	0.022	0.064	0.021	1.90	1.53	1.83	1.28	1.95	1.47	2.82	6.02	2-99 3-00
	Treatment 4	PEAT	PSTA	0.24	5.08	0.023	0.032	0.071	0.010	0.086	0.028	2.38	2.34	2.30	2.41	2.45	2.50	3.35	4.48	4-00 3-01
	Treatment 5	LR	PSTA	0.24	5.14	0.023	0.012	0.071	0.002	0.086	0.017	2.37	2.36	2.29	2.39	2.44	2.37	3.36	3.86	4-00 3-01
	Treatment 6	LR	PSTA	0.25	5.35	0.023	0.019	0.057	0.002	0.098	0.030	2.57	2.58	2.47	2.88	2.63	2.58	2.77	2.67	5-00 3-01
STA-1E																				
	Cell 3	SAND	EMV	214.5	7.28	0.139	0.155	0.173	0.021	0.099	0.035	1.32	1.32	1.22	1.28	1.49	1.34	11.41	4.22	5-06 1-12
	Cell 4N	SAND	SAV	257.4	6.38	0.155	0.066	0.021	0.020	0.035	0.043	1.32	1.63	1.28	1.58	1.34	1.65	4.22	4.84	5-06 1-12
	Cell 4S	PEAT	SAV	292.0	6.92	0.070	0.030	0.058	0.031	0.183	0.052	1.62	1.37	1.44	1.32	1.68	1.40	4.80	3.30	5-06 1-12
	Cell 5	SAND	EMV	209.2	3.25	0.217	0.241	0.396	0.068	0.193	0.122	2.26	2.26	2.06	2.13	2.65	2.32	9.76	9.75	5-06 1-12
	Cell 6	PEAT	SAV	417.7	3.27	0.170	0.147	0.126	0.120	0.124	0.134	2.55	3.00	2.43	2.86	2.68	3.12	8.79	7.89	5-06 1-12
	Cell 7	PEAT	EMV	166.3	3.55	0.172	0.134	0.716	0.185	0.297	0.131	2.88	2.68	2.58	2.55	3.60	2.87	16.96	8.31	5-06 1-12
STA-1W																				
	Cell 1	PEAT	EMV	603.0	8.46	0.133	0.109	0.533	0.325	0.598	0.202	2.92	2.72	2.32	2.52	3.45	3.04	0.60	0.20	6-00 1-08
	Cell 1A	PEAT	EMV	301.5	10.21	0.135	0.110	0.926	0.244	0.499	0.149	2.74	2.39	2.24	2.24	3.67	2.64	11.97	9.60	5-08 1-12
	Cell 1B+3	PEAT	SAV	716.7	5.40	0.109	0.031	0.087	0.050	0.093	0.136	2.27	2.22	2.18	2.08	2.36	2.27	3.80	3.17	5-08 1-12
	Cell 2	PEAT	EMV	380.8	6.44	0.128	0.110	0.842	0.411	0.485	0.125	3.05	2.72	2.56	2.59	3.89	3.13	17.40	8.63	6-00 11-04
	Cell 3	PEAT	EMV	415.2	9.31	0.102	0.078	0.248	0.135	0.149	0.184	2.60	2.21	2.45	2.02	2.85	2.34	8.69	3.33	6-00 1-08
	Cell 4	PEAT	SAV	144.9	18.39	0.110	0.053	0.411	0.146	0.125	0.040	2.72	2.09	2.59	2.05					

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Table 3 Cont. - Summary of Design Criteria and Operational Performance for Existing Treatment Sites

System	Sub- strate	Plant Com.	Area (ha)	HLR (cm/d)	TP (mg/L)		NOx-N (mg/L)		NH ₄ -N (mg/L)		TKN (mg/L)		TON (mg/L)		TN (mg/L)		TSS (mg/L)		POR
					In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	
STA-2																			
Cell 1A	PEAT	EMV	805.0	2.41	0.060	0.013	0.685	0.018	0.380	0.032	2.45	2.13	2.07	2.10	3.14	2.15	8.55	2.96	3-02 5-05
Cell 1B	PEAT	EMV	805.0	2.39	0.090	0.017	0.840	0.033	0.315	0.027	2.54	1.99	2.22	1.96	3.38	2.02	8.12	3.00	6-05 2-12
Cell 2	PEAT	EMV	898.0	3.97	0.089	0.029	0.844	0.147	0.315	0.076	2.61	2.19	2.30	2.12	3.46	2.34	9.81	3.13	3-02 2-12
Cell 3	PEAT	SAV	898.0	3.86	0.084	0.019	0.824	0.190	0.270	0.046	2.54	2.22	2.27	2.18	3.36	2.41	7.22	3.02	3-02 2-12
Cell 4	PEAT	SAV	769.7	1.19	0.095	0.028	0.633	0.069	0.190	0.229	2.51	2.73	2.32	2.50	3.15	2.80	11.13	4.51	2-08 2-12
STA-3/4																			
Cell 1A	PEAT	EMV	1229.8	4.61	0.084	0.042	1.052	0.077	0.230	0.069	2.26	2.13	2.03	2.07	3.32	2.21	10.29	3.19	5-05 1-12
Cell 1B	PEAT	SAV	1411.5	5.40	0.036	0.019	0.078	0.022	0.070	0.071	2.14	2.05	2.07	1.98	2.22	2.08	3.13	3.09	5-05 2-12
Cell 2A	PEAT	EMV	1028.7	4.65	0.066	0.030	1.490	0.135	0.150	0.073	2.16	2.03	2.01	1.95	3.64	2.16	8.35	3.06	5-05 1-12
Cell 2B	PEAT	SAV	1171.2	4.54	0.028	0.021	0.134	0.028	0.072	0.084	2.05	1.95	1.98	1.87	2.18	1.98	3.08	3.02	5-05 2-12
Cell 3A	PEAT	EMV	871.3	6.17	0.051	0.025	1.562	0.148	0.112	0.052	2.08	2.04	1.97	1.99	3.64	2.19	7.55	3.00	4-08 2-12
Cell 3B	PEAT	SAV	982.2	10.04	0.025	0.018	---	---	---	---	---	---	---	---	---	---	---	---	4-08 11-11
STA-5																			
Cell 1A	PEAT	EMV	337.9	3.09	0.128	0.131	0.056	0.021	0.396	0.057	1.89	1.69	1.50	1.63	1.95	1.71	4.28	3.57	4-08 2-12
Cell 1B	PEAT	SAV	493.7	3.80	0.090	0.049	0.017	0.017	0.074	0.220	1.72	1.97	1.64	1.75	1.74	1.98	3.67	3.69	4-08 1-12
Cell 2A	PEAT	EMV	337.9	3.54	0.137	0.063	0.078	0.015	0.110	0.046	1.57	1.45	1.46	1.41	1.64	1.47	4.88	3.07	4-08 2-12
Cell 2B	PEAT	SAV	493.7	2.66	0.101	0.072	---	---	---	---	---	---	---	---	---	---	---	---	4-08 2-12
Cell 3A	PEAT	EMV	405.5	0.68	0.223	0.101	0.078	0.040	0.078	0.061	1.52	1.86	1.44	1.80	1.60	1.90	4.15	5.63	4-08 2-12
Cell 3B	PEAT	SAV	397.8	0.83	0.079	0.042	0.029	0.005	0.047	0.022	1.35	1.52	1.30	1.50	1.38	1.53	3.98	4.07	4-08 2-12
Center Flow-way	PEAT	EMV	831.6	2.58	0.152	0.143	0.047	0.018	0.241	0.051	1.65	1.52	1.41	1.47	1.70	1.54	2.80	1.78	5-00 3-08
North Flow-way	PEAT	EMV	803.3	3.48	0.106	0.123	0.063	0.027	0.326	0.067	1.67	1.58	1.35	1.51	1.74	1.61	1.68	3.00	5-00 3-08
STA-6																			
Cell 3	PEAT	EMV	99.00	2.89	0.068	0.033	0.105	0.008	0.099	0.030	1.56	1.36	1.47	1.34	1.67	1.37	4.26	2.99	10-02 2-12
Cell 5	PEAT	EMV	253.0	2.46	0.080	0.023	0.112	0.008	0.133	0.049	1.63	1.48	1.49	1.43	1.74	1.49	4.98	3.03	10-02 2-12
Section 2	PEAT	SAV	561.3	3.13	0.105	0.044	0.100	0.006	0.176	0.043	1.60	1.41	1.43	1.37	1.70	1.42	6.22	3.13	5-08 10-11
Taylor Creek Pilot STA																			
TC STA	SAND	EMV	57.47	7.29	0.320	0.229	0.172	0.009	0.100	0.120	1.57	1.55	1.47	1.43	1.74	1.56	5.19	3.27	6-08 1-12
City of Titusville, Blue Heron Wetland																			
BHW	SAND	EMV	101.6	0.65	0.493	0.077	2.485	0.042	0.438	0.284	1.60	1.16	1.16	0.87	4.02	1.19	0.97	1.30	1-97 12-11
Wellington Aquatics Pilot Test Facility																			
Cell E1	SAND	EMV	0.055	26.97	0.348	0.209	0.094	0.080	---	---	1.33	1.07	---	---	1.42	1.15	27.9	1.56	11-01 2-03
Cell E2	SAND	SAV	0.044	19.08	0.209	0.090	0.080	0.080	---	---	1.07	1.01	---	---	1.15	1.09	1.56	1.81	11-01 2-03
Cell E3	LR	PSTA	0.049	19.82	0.090	0.043	0.080	0.062	---	---	1.01	1.02	---	---	1.09	1.09	1.81	2.40	11-01 2-03
Cell W1	SAND	FAV	0.047	33.49	0.348	0.081	0.094	0.085	---	---	1.33	0.84	---	---	1.42	0.93	27.9	1.13	11-01 2-03
Cell W2	SAND	EMV	0.055	13.30	0.081	0.029	0.085	0.083	---	---	0.84	0.83	---	---	0.93	0.91	1.13	0.94	11-01 2-03
Cell W3	LR	PSTA	0.049	11.77	0.029	0.022	0.083	0.062	---	---	0.83	0.96	---	---	0.91	1.02	0.94	1.15	11-01 2-03

POR = Period-of-Record

Substrate: LR = Lime Rock

HLR = Hydraulic Loading Rate

Period of record averages are reported as arithmetic means; Monthly time series data presented in Appendix B are arithmetic means with the exception of the following sites which are reported as flow-weighted means: STA-1E, STA-1W, STA-2, STA-3/4, STA-5, STA-6, Taylor Creek Pilot STA

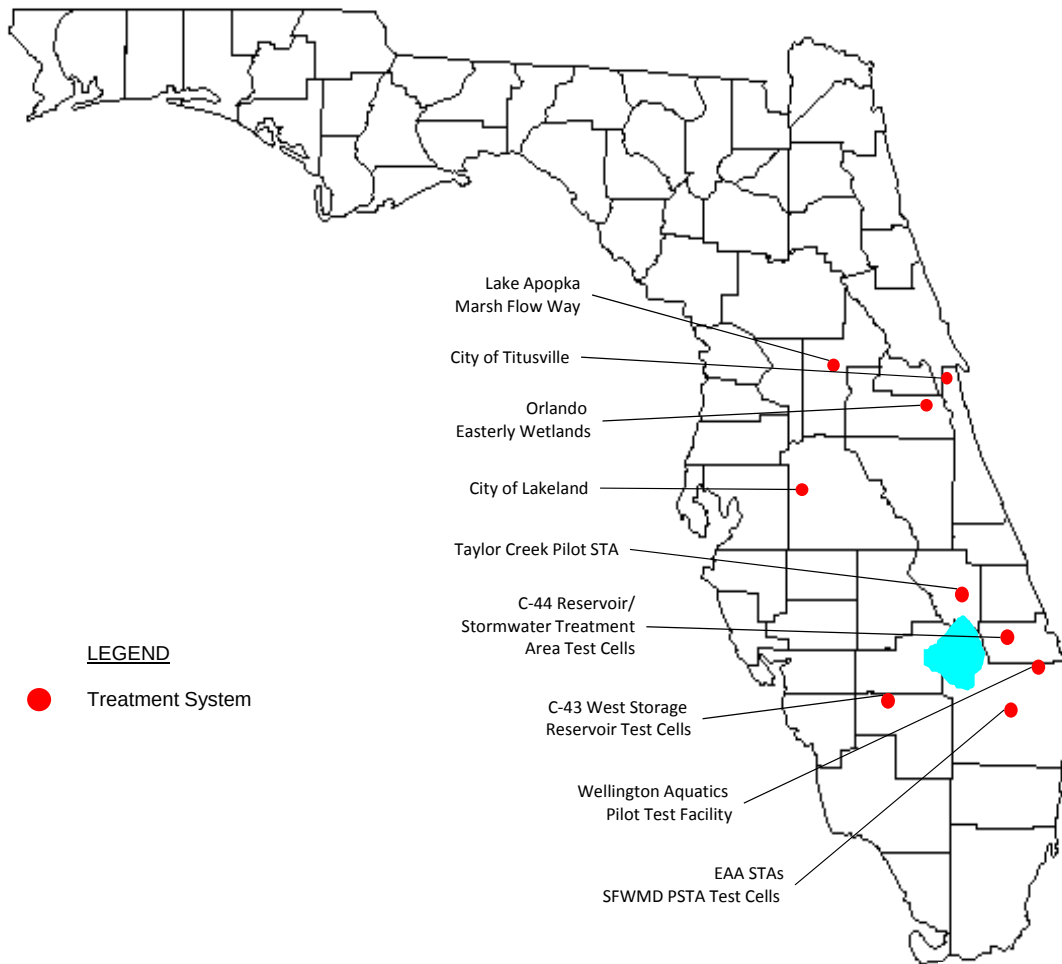


Figure 4. Location of Selected Florida Treatment Wetland Sites

2.5.2.1 Nitrate + Nitrite Nitrogen

Most treatment wetlands are successful at removal of $\text{NO}_x\text{-N}$. Baseline or C^* concentration are close to analytical detection limits (less than 0.01 mg/L). In terms of optimal plant community type, EMV, PSTA, OW, and SAV wetlands appear to be similar for removal of $\text{NO}_x\text{-N}$ while FAV is least effective. In terms of optimal substrate for $\text{NO}_x\text{-N}$ removal peat, sand, and limerock appear to be similar while clay was inferior.

2.5.2.2 Ammonia Nitrogen

Ammonia nitrogen is effectively removed in lightly-loaded treatment wetlands. Typical C^* concentrations are approximately 0.02 mg/L. In terms of optimal plant communities, PSTA appeared to be the best, followed by OW, SAV, and EMV, and FAV was the least effective plant community. Substrate type had a noticeable effect of AN removal with limerock performing the best, followed by similar effects for peat and sandy soils, and with clay least effective.

2.5.2.3 Organic Nitrogen

The lowest TON outflow concentrations typically observed in these treatment wetlands were about 0.6 mg/L. These low concentrations were most likely to be observed in EMV and OW systems built on sandy soils. PSTA and FAV were less effective especially on clay and limerock soils. SAV and peat soils were the least effective combination to achieve low TON concentrations.

2.5.2.4 Total Nitrogen

The lowest TN outflow concentrations observed were essentially all in the reduced forms (TON and AN) and equal to about 0.7 mg/L. As with TKN and TON, TN was most efficiently reduced in EMV and OW systems built on sandy soils. Periphyton, FAV, and SAV were less effective plant communities and clay, limerock, and organic peat were less effective substrates to efficiently achieve low TN outflow concentrations.

2.5.2.5 Total Phosphorus

There is considerable evidence that TP is most effectively removed by SAV-dominated wetlands at inlet TP concentrations in the range between about 50 and 300 ppb (Walker 2010). Emergent wetlands are likely more effective for TP removal at higher inlet TP concentrations (>300 ppb) and periphyton-dominated wetlands are more effective than SAV systems at lower inlet TP concentrations (<50 ppb). The lowest TP concentrations practically achievable in any type of treatment wetlands are in the range of 10 to 15 ppb. The most favorable substrate for achieving very low TP concentrations and for the highest removal rates appears to be calcareous substrates such as limerock. Organic substrates appear to be next most favorable for effective TP reduction, followed in last place by sandy soils.

2.5.2.6 Total Suspended Solids

The lowest TSS concentration typically attained by these Florida treatment wetlands was about 1 mg/L. For TSS reduction PSTA and EMV were the most effective plant communities, followed by SAV, with OW and FAV least favorable. There was essentially no observed effect of substrate type on TSS reduction effectiveness.

2.6 Treatment Wetland System Merits and Limitations

The five treatment wetland options described in Section 2.4 were evaluated for their overall cost effectiveness for removal of TN, TP, and TSS in the C-43 Basin in southwest Florida (Table 4). Evaluation factors included:

- TN, TP, and TSS removal rates;
- Estimated C* values by pollutant and sediment type; and
- Order-of-magnitude cost per unit treatment area and volume.

These rankings were used to support selection of alternative test facility configurations and are not intended to provide a final alternative evaluation for full-scale project implementation. That evaluation should be conducted once additional operational, performance, and cost data are developed at the proposed C-43 WQTA Test Facility for each of the highest ranked alternatives.

The treatment wetland alternative analysis resulted in a general order of preference based on cost and pollutant removal performance of EMV>SAV>PSTA>>FAV>>OW. The three treatment wetland unit processes that hold most promise include: a very shallow (<15 cm) emergent wetland marsh for mineralization of TON and nitrification of AN, a classic emergent wetland (about 30 to 45 cm deep) for denitrification, and a deeper water mixed wetland or slough dominated by a mix of FAV, SAV, and tolerant rooted plants for long hydraulic residence time and conversion of biologically-available DON to DIN. This comparison indicated that there is not likely to be a large difference in overall TN cost effectiveness between these three wetland plant community types. Each of these types of wetlands has somewhat similar biogeochemical cycles, dependence on adequate surface area for treatment, and production of ample organic carbon required for effective denitrification of NO_x-N. However, where there are differences in performance and cost between wetland alternatives, those differences were used to prioritize testing resources.

Two additional aquatic unit processes that are recommended for less intensive investigation are an OW treatment system that tests ultraviolet processes for converting recalcitrant DON to biologically-available DON, and an algal-dominated plant community on a limestone substrate (PSTA) to evaluate the feasibility for other unknown enzymatic benefits of these simple plants.

The C-43 WQTA Expert Panel report (WSI 2010) came to a similar conclusion that, if the District was limited to a single wetland technology, the EMV would be most likely to achieve the lowest TN, TP, and TSS concentrations with the smallest footprint and the lowest construction cost. A full-scale nitrogen-removal WQTA facility may be a combination of technologies in series with each sized to provide the greatest overall cost effectiveness for the reduction of TN in the CRE.

Table 4. C-43 WQTA Wetland Plant Community Alternatives Comparison including Pros and Cons

Wetland Type	Rank	Target Water Depth (ft)	Est. Cost w/o Land (\$/ha)	PROS	CONS
EMV	1	2	\$38,000	Highly complex microbial community, high TON mineralization, high denitrification, moderate P removal, high TSS removal, lowest cost, wide experience and applicability	Limited aerobic zone, limited photodegradation
SAV	2	4	\$66,000	Highly complex microbial community, high P removal, aerobic water column	Susceptible to vegetation loss due to high wind and extended drought conditions, limited data available for N removal on sandy soils, limited denitrification
PSTA	3	3	\$52,00	Aerobic water column including DO supersaturation, potential for photodegradation, able to achieve very low P	Lower removal rates for all N and P forms, requires adequate calcium availability for P removal
FAV	4	6	\$94,000	Moderate to high levels of N and P removal	Limited reaeration, highly anaerobic water column, may require plant harvesting, high cost
OW	5	8	\$121,500	Optimal photodegradation for TON mineralization, highly aerobic at surface	Lowest N and P removal rates, limited experience for achieving low N concentrations, higher cost

Section 3.0 C-43 WQTA Test Facility Conceptual Design

3.1 Introduction

The objective of Task 3 was to recommend a conceptual design of a test facility capable of removing TN with an emphasis on removing various TN fractions, including organic and inorganic forms. The proposed C-43 WQTA test facility conceptual plan includes a discussion and rationale for the use of bioassays and mesocosms as compared to larger test cells, recommended test cell treatments, a preliminary operations and monitoring plan, and estimated costs for design, construction, and operation of the proposed test facility. The full description of the recommended C-43 WQTA Testing Facility conceptual design and testing plan is included as Attachment C.

Experimentation of alternative wetland/aquatic plant communities arranged in different sequences is recommended in the testing facility at the mesocosm level, larger scale test cells, or both. First consideration was be given to treatment trains comprised of conventional wetland and/or aquatic plant community cells that are optimized for the treatment of total nitrogen through natural microbial and photodegradation processes.

Should the operation and sampling of the testing facility reveal that these different treatment trains cannot be effectively replicated throughout the watershed to achieve the CRE TMDL, other less conventional TN removal technologies might ultimately be considered.

3.2 Priority Test Questions

The primary goal of the proposed C-43 WQTA Project is the cost-effective removal of TN, with particular reference to the removal of various forms of TON. Secondary goals include ancillary reductions in the concentrations of TP and TSS in the C-43 canal. There are two principal test questions:

- To what level can various alternative constructed treatment wetland plant communities lower the concentration of TN in the C-43 Basin?
- What will be the combined footprint of full-scale treatment facilities required to achieve the goals of the CRE TMDL?

Mass balances will be prepared for all test units to help understand the fate of these pollutants in light of the various design and operational treatments used at the Test Facility. Due to the complex chemistry of nitrogen in surface waters, evaluation of TN removal must include the measurement of the full suite of nitrogen sources, sinks, and transformations that will occur in the treatment unit.

The Task 2 literature review (WSI 2012) and the expert panel report (WSI 2010) both indicated that selection of appropriate soil conditions or possible soil amendments may be critical for achieving the very low TN concentrations required to meet the CRE TMDL. Soil type and previous exposure to nutrients are an important component of the recommended C-43 WQTA Test Facility conceptual design.

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A number of design and operational considerations are important for effective pollutant removal in treatment wetlands. The Test Facility will evaluate the potential for the most effective plant community types listed above to provide N, P, and TSS removal. In addition to initial site preparation and planting, propagation and maintenance of these different plant communities is largely influenced by water depth. For this reason water depth, hydroperiod, and initial plant establishment are key considerations in setting up the Test Facility. Also, inclusion of multiple vegetation zones in series will be incorporated to provide a variety of processes within single test cells.

Other key design and operational considerations that are included in the recommended testing plan include:

- Levee height (to allow for testing of a wide range of water depths as well as to retain all inflows and outflows to control structures, including peak rainfall inputs)
- Aspect ratio (the average length divided by the average width of the flow path)
- Inclusion of deep zones (their depth, width, percent of treatment area)
- Hydraulic loading rate (the average rate of water application over the wetted treatment area expressed as rainfall equivalent, reported as cm/d or m/yr)
- Hydraulic residence time (nominally the inflow divided by the water volume of the wetland, reported as days)
- Loading frequency (the frequency and duration of pumped inputs, reported as #/yr)
- Inlet pollutant load (the pollutant concentrations multiplied by the hydraulic loading rate, reported as kg/ha/d)

The suggested testing approach focuses on the inputs and outputs of materials in these natural treatment systems. Process-level studies to detail the many physical, chemical, and biological processes in these test units are not part of the recommended testing plan. If time and budget are available for process studies, then those may be added when the final C-43 WQTA testing plan is prepared.

Finally, there are analytical considerations that are important to this project. For example, due to the complexity and possible recalcitrance of nitrogen forms, a variety of analytical tests are available but not all are necessary for project success. The simplest TN series is recommended for all test systems, including total Kjeldahl nitrogen (TKN – the sum of organic and ammonia N), total ammonia N (a combination of ionized ammonium [NH₄-N] and unionized ammonia [NH₃-N]), and total nitrate+nitrite N (NO_x-N). Since AN and nitrate+nitrite N are dissolved compounds there is generally no need to look at filtered (particulate) and filtrate (dissolved) fractions. However, organic N is generally present in both particulate and dissolved forms and this distinction is important for data interpretation. Filtered and unfiltered samples should be evaluated for total and dissolved TKN to highlight the relative proportions of these two fractions.

There is currently no recognized analytical test to fractionate total organic N (TON) from biologically available N (BAN). As used in this report, BAN includes all biologically available N forms, including organic and inorganic compounds. In response to the Expert Panel's recommendation, this test plan recommends further evaluation of the scope and cost to develop

a prototype analytical procedure to estimate the BAN fraction of the TON. The Expert Panel conceptualized this test as a modified TKN test with one or more milder oxidants to breakdown the more tractable organic nitrogen compounds to ammonia. The efficacy of this test would be determined through mesocosm and laboratory bioassays.

When possible, standard analytical tests will be used for determination of concentrations of the other pollutants of concern (i.e., TP and TSS). These tests may be modified if needed to obtain adequate sensitivity to detect low concentrations of nutrients and solids.

3.3 Testing Scale

The most appropriate scale for the individual Test Facility components is dependent upon the specific questions to be answered, scale-up issues needed to implement a full-scale project, and cost. Some questions will be answered at a single test scale while others may be answered at multiple scales to provide confirmation that test scale is or is not a critical issue.

Three physical testing scales are recommended for the proposed C-43 WQTA Testing Facility:

- Mesocosm units (generally less than 10 to 40 m² [108 to 430 ft²]) are appropriate for testing multiple design elements more cost effectively than building many larger test units. The primary limitation with smaller mesocosm scale test units is that they have unrealistic edge-to-area (surface area-to-volume) ratios compared to full-scale treatment systems. Mesocosms are considered to be an appropriate scale to test the effects of antecedent soil chemistry on C^{*}_{TN}, plant community effects on C^{*}_{TN}, plant- and microbial-level biogeochemical processes (biomass production, nutrient storages, nutrient biotransformations, enzyme production, plant uptake kinetics, etc.). Mesocosms are also an appropriate scale for replicated experiments and development of preliminary pollutant removal kinetics (that will be confirmed at larger scales).
- Test Cells refer to larger, in-ground test systems, generally in the range of 500 to 4,000 m² (0.12 to 1 ac) and are less affected by high surface to volume ratios and provide more realistic plant growth conditions in native soils. Test Cells are small enough to be replicated, although stochastic effects still lead to relatively high variation between cells. Test Cells are most applicable to verification of preliminary findings from Mesocosm scale research. Test Cells may also be the most appropriate scale to develop more robust data sets for performance model calibration/validation. It is important to note that Test Cells are not suitable as the only intermediate scale prior to design and operation of full-scale treatment wetlands.
- Field-Scale treatment wetland test systems are typically in the range of 4,000 to 400,000 m² (1 to 100 ac). These systems are generally not replicated due to their size and cost. When used, they are typically the last stage of work prior to implementation at Full-Scale. Depending on their size, Field-Scale systems may provide realistic data concerning pollutant removal rates and kinetics, effects of soil and climate variation, and construction costs. Their value for Full-Scale design is roughly proportional to their size. Smaller Field-Scale cells do not simulate actual Full-Scale hydraulics very well and therefore are not as reliable for understanding of Full-Scale treatment wetland mixing, head loss, and volumetric efficiency issues.

3.4 Test Facility Description and Treatments

3.4.1 Test Facility Components

The recommended C-43 WQTA Test Facility will include the following components (Table 5 and Figures 4 and 5):

- Pump Station (9,300 m³/d or 1,700 gpm maximum capacity)
- Supply Force Main (30-cm [12-in] diameter HDPE; 1,900-m length [6,250 ft])
- Mesocosm Head Tank (7 m³ [247 ft³])
- Head Cell (4,000 m² [1 ac] and 12,200 m³ [430,510 ft³])
- Mesocosms (8 at 12 m² each [129 ft²])
- Test Cells (5 at 4,000 m² [1 ac])
- Field-Scale Cells (4 at 62,700 m² [15.5 ac])
- Cell Inlet Piping, Control Valves, and Flow Meters
- Miscellaneous Water Control and Monitoring Structures

Table 5. Proposed C-43 WQTA Test Facility plan

Scale	Unit ID	Description	Plant Community ¹	Substrate ²	Water Depth (cm)	Area (m ²)	Dimensions (m)
Mesocosm	M-1	EMV sand	EMV	Sand	30	12	2.4 x 4.9
Mesocosm	M-2	SAV sand	SAV	Sand	60	12	2.4 x 4.9
Mesocosm	M-3	FAV sand	FAV	Sand	90	12	2.4 x 4.9
Mesocosm	M-4	Algae limestone	Algae	Limestone	60	12	2.4 x 4.9
Mesocosm	M-5	OW sand	OW	Sand	90	12	2.4 x 4.9
Mesocosm	M-6	FAV control	FAV	None	90	12	2.4 x 4.9
Mesocosm	M-7	Algae control	Algae	None	60	12	2.4 x 4.9
Mesocosm	M-8	OW control	OW	None	90	12	2.4 x 4.9
Test Cell	TC-1	EMV shallow	EMV	Native sand	15	4,000	50 x 80
Test Cell	TC-2	EMV deep	EMV	Native sand	45	4,000	50 x 80
Test Cell	TC-3	SAV/FAV	SAV/FAV	Native sand	90	4,000	50 x 80
Test Cell	TC-4	Algae/OW	Algae/OW	Limestone	120	4,000	50 x 80
Test Cell	TC-5	MIX	EMV/SAV/FAV/Algae	Native sand	30-90	4,000	50 x 80
Field-Scale	FS-1	EMV shallow	EMV	Native sand	15	62,700	190 x 330
Field-Scale	FS-2	EMV deep	EMV	Native sand	45	62,700	190 x 330
Field-Scale	FS-3	SAV/FAV	SAV/FAV	Native sand	90	62,700	190 x 330
Field-Scale	FS-4	MIX	EMV/SAV/FAV/Algae	Native sand	30-90	62,700	190 x 330

Notes:

¹ Plant Communities: EMV (emergent vegetation), SAV (submerged aquatic vegetation), FAV (floating aquatic vegetation), Algae (filamentous and macro algae), OW (open water), MIX (mixed plant community)

² Substrate: sand (imported, rinsed, medium-grained sand), native sand (on-site soils), limestone (#57 limerock or equivalent)

3.4.1.1 Mesocosms

Eight pre-fabricated fiberglass Mesocosms (2.4x4.9 m [8x16 ft] each) will be installed on a level pad of crushed limestone (Figure 7). A single plastic Head Tank (700 m³ [25,000 ft³]) will be centrally located to provide a constant head inflow to the Mesocosms. The Head Tank will

receive inputs from a temporary gas-powered pump until completion of the Head Cell and main pump station. The eight Mesocosm tanks will be plumbed for parallel operation. Four of the Mesocosms will receive 30 cm (12 in) of clean (washed) medium-grain sand. One Mesocosm unit will receive 30 cm (12 in) of #57 limestone. Three of the Mesocosms will be “controls” with no substrate. Cattails and bulrush are combined in the deeper EMV treatments while a combination of cattails and spikerush are recommended in shallower EMV treatments. Plant communities in the Mesocosms will be managed by physical removal of unwanted plants. Individual Mesocosm test unit design criteria and treatments are specified in Attachment C.

3.4.1.2 Test Cells

Five in-ground 4,000 m² (1 ac) (50x80 m [164x262 ft]) Test Cells will be constructed using earthen embankments (6). Four of these Test Cells will have native soil fill. One Test Cell will be over-excavated and backfilled with 30 cm (12 in) of #57 limestone. Design embankment heights in all five Test Cells will be 1.8 m (6 feet) and constructed with 3:1 side slopes and top width of 4.2 m (14 ft). The maximum water depth proposed in this test plan is 120 cm (about 4 feet), resulting in a minimum of about 60 cm (2 feet) of freeboard in all of the Test Cells. The five Test Cells will be designed only for parallel operation. Embankment properties will be further considered during the design phase to minimize “cross-talk” between cells.

Cattails and bulrush are combined in the deeper EMV treatments while a combination of cattails and spikerush are recommended in shallower EMV treatments. There is no plant removal or harvesting anticipated in the Test Cells. Individual Test Cell unit design criteria and treatments are specified in Attachment C.

3.4.1.3 Field-Scale Cells

Four in-ground Field-Scale Cells will be constructed for parallel and series operation (Figures 4 and 5). These cells will each have a wet area of about 62,700 m² (190x330 m [15.5 ac]) and will have native soil fill. Design embankment height in all cells will be 6 feet with 3:1 side slopes. The maximum water depth proposed in the Field-Scale Cells is 90 cm (about 3 feet), resulting in a minimum of about 90 cm (3 feet) of freeboard in all of the Field-Scale Cells. Inlet and outlet plumbing will allow parallel and series flow as illustrated in Figure 4.

Cattails and bulrush are combined in the deeper EMV treatments while a combination of cattails and spikerush are recommended in shallower EMV treatments. Use of rooted plant windbreaks in the FAV/SAV Field-Scale Cell will be considered during final design. There is no plant removal or harvesting anticipated in the Field-Scale Cells. Individual Field-Scale test unit design criteria and treatments are specified in Attachment C.

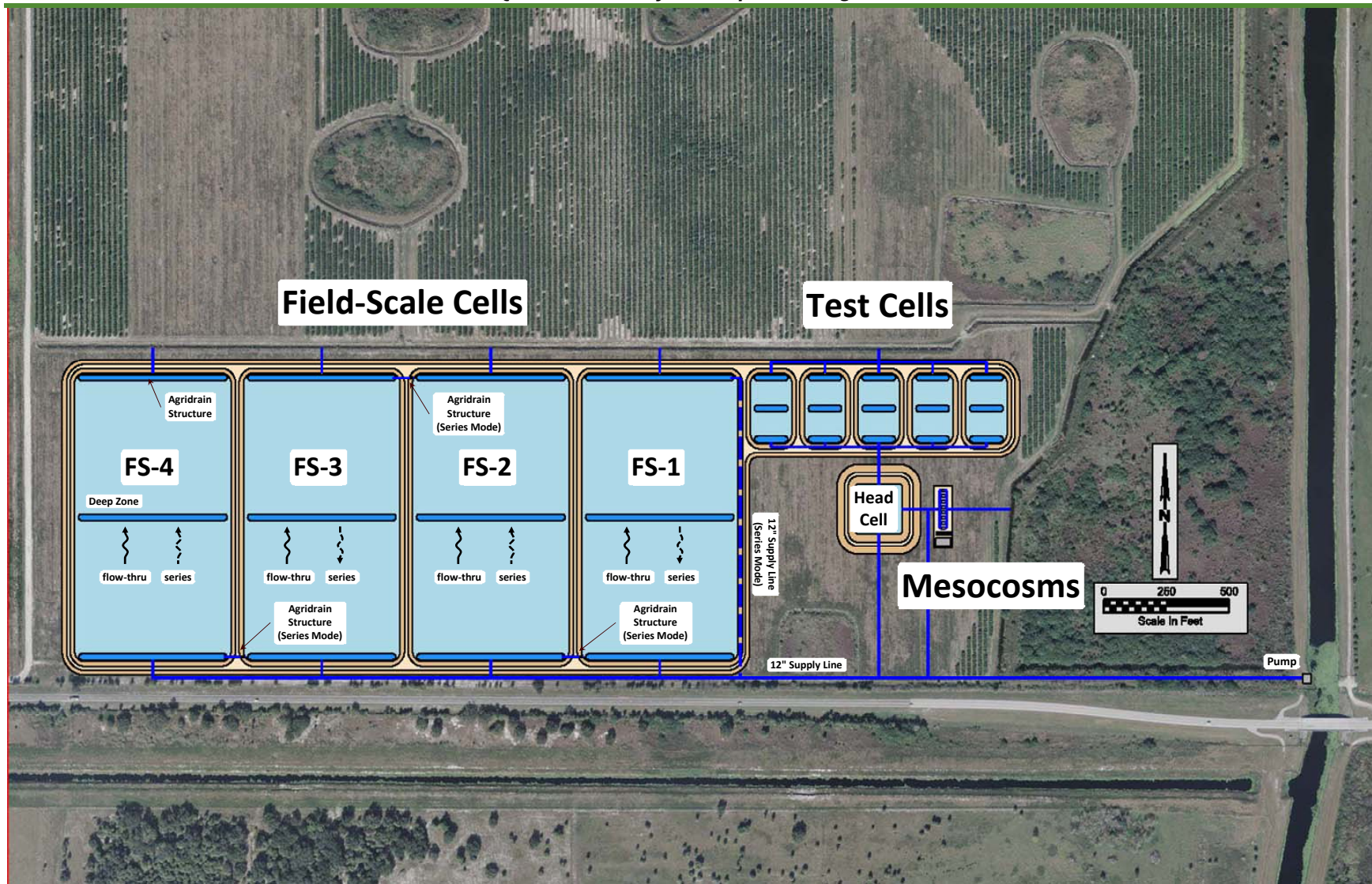


Figure 5. Proposed C-43 WQTA Test Facility Site plan

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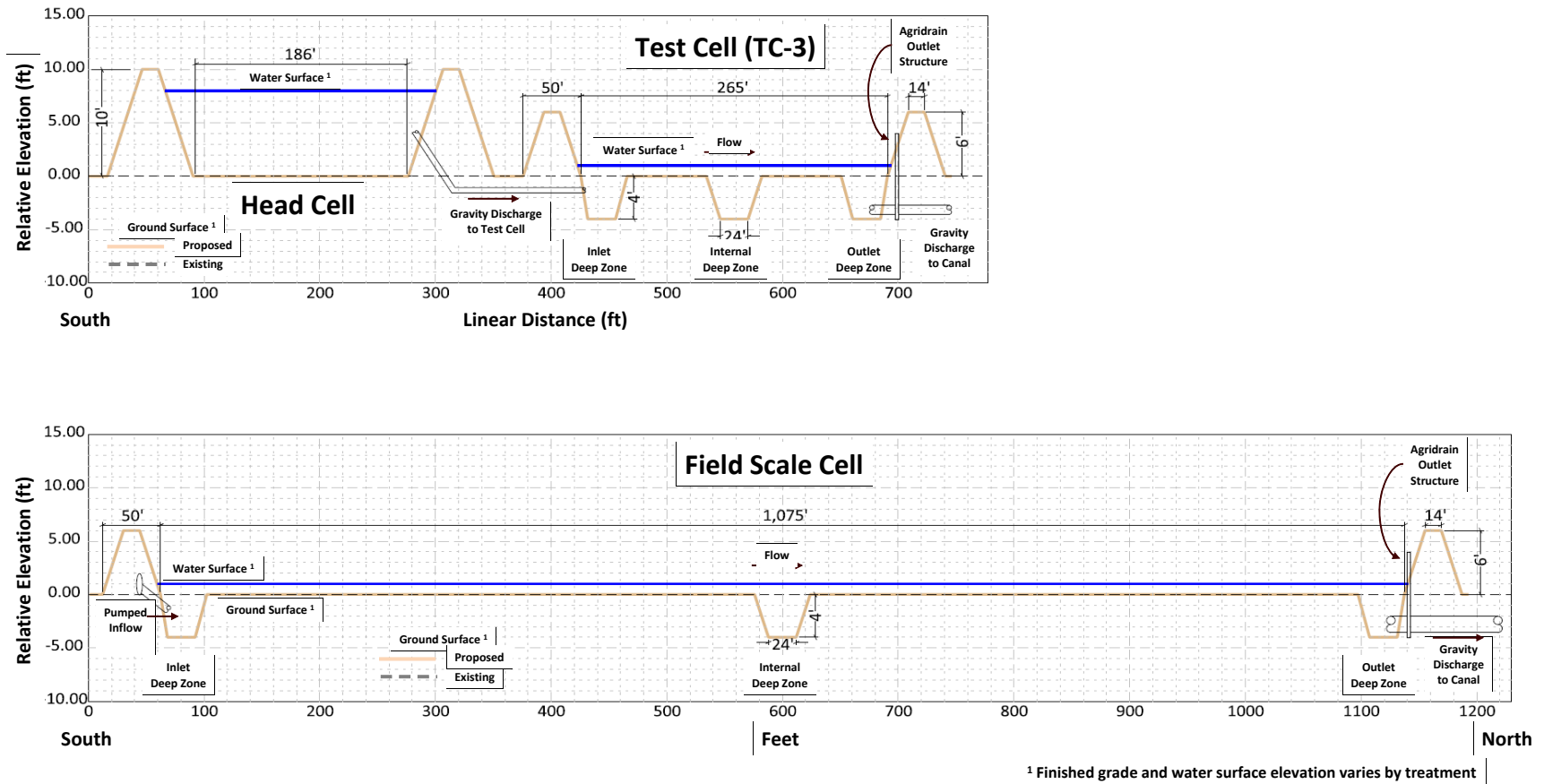


Figure 6. Proposed C-43 Test Facility Typical Cross Sections

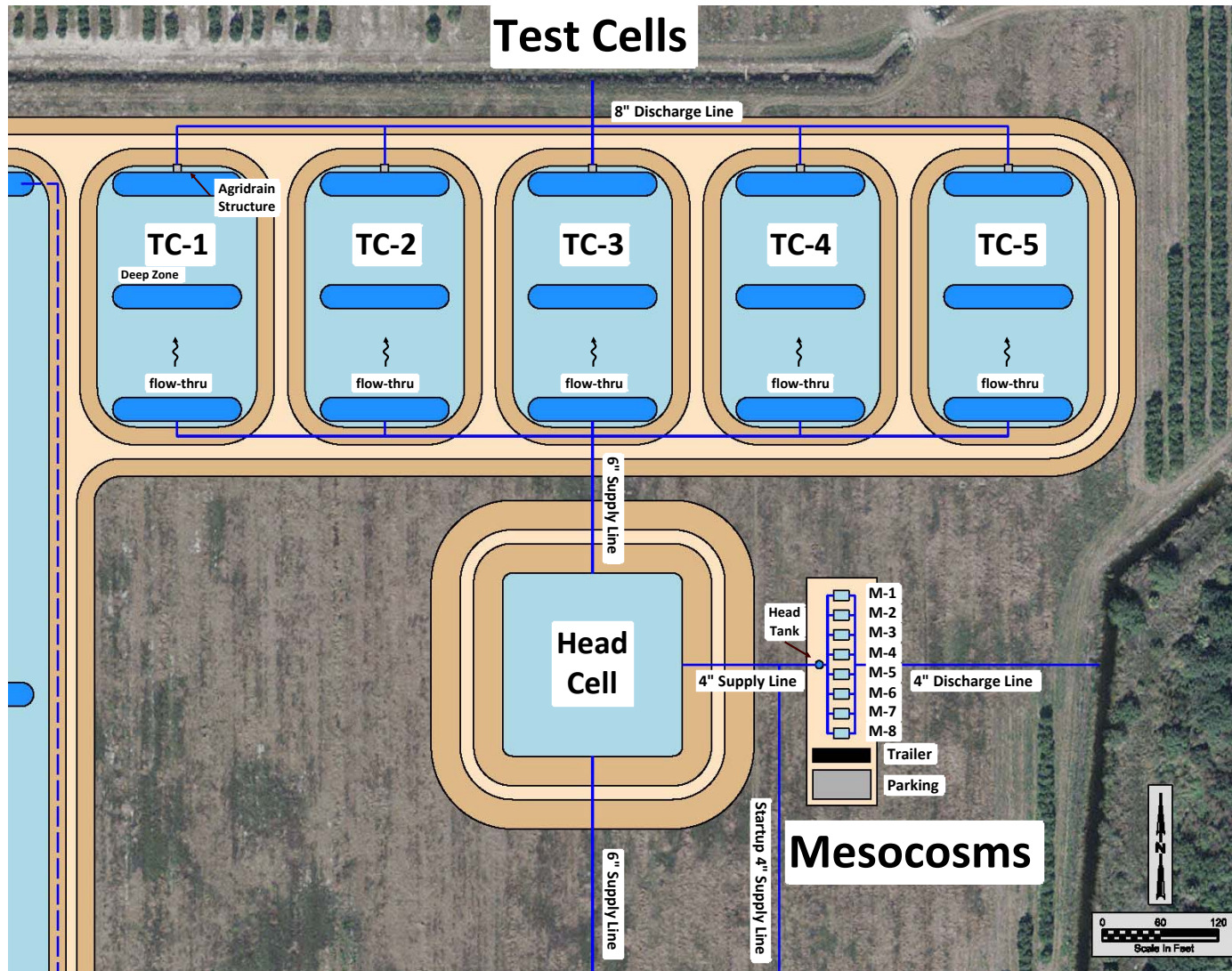


Figure 7. Proposed C-43 WQTA Test Facility Site plan – Test Cells and Mesocosms

3.5 Experimental Treatments

A total of 84 unique treatments are recommended for the proposed test program. These include 48 treatments at the Mesocosm scale, 20 treatments at the Test Cell scale, and 16 treatments at the Field-Scale units.

3.5.1 Mesocosm Treatments

Table 6 summarizes the forty-eight (48) proposed Mesocosm treatments, including their unit and treatment identification labels, their proposed duration in months, their mode of operation, their target plant community, their principal substrate, their design water depth, their design hydraulic loading rate (HLR), their nominal hydraulic residence time (nHRT), their physical dimensions, and their key test variables.

The eight Mesocosms will receive different treatments during each of six sequential six- to 10-month operational phases. It is expected that the Mesocosm construction will require about three months and that these systems will be operational after a Phase 1 six-month construction/startup period (Treatment IDs M1-1 through M8-1 construction and plant grow-in). The remaining five Mesocosm treatments will require an estimated 3.5 years to complete.

3.5.2 Test Cell Treatments

Table 7 summarizes the 20 proposed Test Cell treatments, including their unit and treatment identification labels, their proposed duration in months, their mode of operation, their target plant community, their principal substrate, their design water depth, their design hydraulic loading rate (HLR), their nominal hydraulic residence time (nHRT), their physical dimensions, and their key test variables.

The five Test Cells will receive different treatments during each of four sequential twelve-month operational phases. It is expected that the Test Cell construction will require up to six months to complete and that these systems will be operational after a Phase 1 twelve-month batch-mode startup period (Treatment IDs TC1-1 through TC5-1 construction and plant grow-in). The large-scale treatments are each twelve months to allow adequate time for internal biological readjustments following changes in HLR, water depth, or nHRT. A four-year operational time span is generally supported as adequate based on the evidence from the full-scale treatment wetlands reviewed in the Task 2 report.

3.5.3 Field-Scale Treatments

Table 8 summarizes the 16 proposed Field-Scale treatments, including their unit and treatment identification labels, their proposed duration in months, their mode of operation, their target plant community, their principal substrate, their design water depth, their design hydraulic loading rate (HLR), their nominal hydraulic residence time (nHRT), their physical dimensions, and their key test variables.

The four Field-Scale Cells will receive different treatments during each of four sequential twelve-month operational phases. It is expected that the Field-Scale Cell construction and plant grow-in will require up to twelve months for completion, and that these systems will not be fully operational until the end of the Phase 1 startup period. Three additional 12-month Field-Scale treatments are planned for an estimated total study duration of four years.

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Table 6. Proposed C-43 Test Facility Mesocosm Treatments

Unit ID	Treat ID	Phase	Duration (months)	Description	Mode ¹	Plant Community ²	Substrate ³	Water Depth (cm)	HLR ⁴ (cm/d)	Mean nHRT ⁵ (d)	Area (m ²)	Dimensions (m)	Key Test Variables ⁶
M-1	M1-1	1	6	EMV sand startup	Startup	EMV	Sand	30	0	--	12	2.4 x 4.9	C* _{TN} ; BAN
M-2	M2-1	1	6	SAV sand startup	Startup	SAV	Sand	60	0	--	12	2.4 x 4.9	C* _{TN} ; BAN
M-3	M3-1	1	6	FAV sand startup	Startup	FAV	Sand	90	0	--	12	2.4 x 4.9	C* _{TN} ; BAN
M-4	M4-1	1	6	Algae limestone startup	Startup	Algae	Limestone	60	0	--	12	2.4 x 4.9	C* _{TN} ; BAN
M-5	M5-1	1	6	OW sand startup	Startup	OW	Sand	90	0	--	12	2.4 x 4.9	C* _{TN} ; BAN
M-6	M6-1	1	6	FAV control startup	Startup	FAV	None	90	0	--	12	2.4 x 4.9	C* _{TN} ; BAN
M-7	M7-1	1	6	Algae control startup	Startup	Algae	None	60	0	--	12	2.4 x 4.9	C* _{TN} ; BAN
M-8	M8-1	1	6	OW control startup	Startup	OW	None	90	0	--	12	2.4 x 4.9	C* _{TN} ; BAN
M-1	M1-2	2	6	EMV sand batch	Batch	EMV	Sand	30	0	--	12	2.4 x 4.9	C* _{TN} ; BAN
M-2	M2-2	2	6	SAV sand batch	Batch	SAV	Sand	60	0	--	12	2.4 x 4.9	C* _{TN} ; BAN
M-3	M3-2	2	6	FAV sand batch	Batch	FAV	Sand	90	0	--	12	2.4 x 4.9	C* _{TN} ; BAN
M-4	M4-2	2	6	Algae limestone batch	Batch	Algae	Limestone	60	0	--	12	2.4 x 4.9	C* _{TN} ; BAN
M-5	M5-2	2	6	OW sand batch	Batch	OW	Sand	90	0	--	12	2.4 x 4.9	C* _{TN} ; BAN
M-6	M6-2	2	6	FAV control batch	Batch	FAV	None	90	0	--	12	2.4 x 4.9	C* _{TN} ; BAN
M-7	M7-2	2	6	Algae control batch	Batch	Algae	None	60	0	--	12	2.4 x 4.9	C* _{TN} ; BAN
M-8	M8-2	2	6	OW control batch	Batch	OW	None	90	0	--	12	2.4 x 4.9	C* _{TN} ; BAN
M-1	M1-3	3	10	EMV sand low flow-thru	Flow-Thru	EMV	Sand	30	1.5	20	12	2.4 x 4.9	N-k values
M-2	M2-3	3	10	SAV sand low flow-thru	Flow-Thru	SAV	Sand	60	1.5	40	12	2.4 x 4.9	N-k values
M-3	M3-3	3	10	FAV sand low flow-thru	Flow-Thru	FAV	Sand	90	1.5	60	12	2.4 x 4.9	N-k values
M-4	M4-3	3	10	Algae limestone low flow-thru	Flow-Thru	Algae	Limestone	60	1.5	40	12	2.4 x 4.9	N-k values
M-5	M5-3	3	10	OW sand low flow-thru	Flow-Thru	OW	Sand	90	1.5	60	12	2.4 x 4.9	N-k values
M-6	M6-3	3	10	FAV control low flow-thru	Flow-Thru	FAV	None	90	1.5	60	12	2.4 x 4.9	N-k values
M-7	M7-3	3	10	Algae control low flow-thru	Flow-Thru	Algae	None	60	1.5	40	12	2.4 x 4.9	N-k values
M-8	M8-3	3	10	OW control low flow-thru	Flow-Thru	OW	None	90	1.5	60	12	2.4 x 4.9	N-k values
M-1	M1-4	4	10	EMV sand medium flow-thru	Flow-Thru	EMV	Sand	30	3	10	12	2.4 x 4.9	N-k values
M-2	M2-4	4	10	SAV sand medium flow-thru	Flow-Thru	SAV	Sand	60	3	20	12	2.4 x 4.9	N-k values
M-3	M3-4	4	10	FAV sand medium flow-thru	Flow-Thru	FAV	Sand	90	3	30	12	2.4 x 4.9	N-k values
M-4	M4-4	4	10	Algae limestone medium flow-thru	Flow-Thru	Algae	Limestone	60	3	20	12	2.4 x 4.9	N-k values
M-5	M5-4	4	10	OW sand medium flow-thru	Flow-Thru	OW	Sand	90	3	30	12	2.4 x 4.9	N-k values
M-6	M6-4	4	10	FAV control medium flow-thru	Flow-Thru	FAV	None	90	3	30	12	2.4 x 4.9	N-k values
M-7	M7-4	4	10	Algae control medium flow-thru	Flow-Thru	Algae	None	60	3	20	12	2.4 x 4.9	N-k values
M-8	M8-4	4	10	OW control medium flow-thru	Flow-Thru	OW	None	90	3	30	12	2.4 x 4.9	N-k values
M-1	M1-5	5	10	EMV sand high flow-thru	Flow-Thru	EMV	Sand	30	6	5	12	2.4 x 4.9	N-k values
M-2	M2-5	5	10	SAV sand high flow-thru	Flow-Thru	SAV	Sand	60	6	10	12	2.4 x 4.9	N-k values
M-3	M3-5	5	10	FAV sand high flow-thru	Flow-Thru	FAV	Sand	90	6	15	12	2.4 x 4.9	N-k values
M-4	M4-5	5	10	Algae limestone high flow-thru	Flow-Thru	Algae	Limestone	60	6	10	12	2.4 x 4.9	N-k values
M-5	M5-5	5	10	OW sand high flow-thru	Flow-Thru	OW	Sand	90	6	15	12	2.4 x 4.9	N-k values
M-6	M6-5	5	10	FAV control high flow-thru	Flow-Thru	FAV	None	90	6	15	12	2.4 x 4.9	N-k values
M-7	M7-5	5	10	Algae control high flow-thru	Flow-Thru	Algae	None	60	6	10	12	2.4 x 4.9	N-k values
M-8	M8-5	5	10	OW control high flow-thru	Flow-Thru	OW	None	90	6	15	12	2.4 x 4.9	N-k values
M-1	M1-6	6	6	EMV sand batch	Batch	EMV	Sand	30	0	--	12	2.4 x 4.9	C* _{TN} ; BAN
M-2	M2-6	6	6	SAV sand batch	Batch	SAV	Sand	60	0	--	12	2.4 x 4.9	C* _{TN} ; BAN
M-3	M3-6	6	6	FAV sand batch	Batch	FAV	Sand	90	0	--	12	2.4 x 4.9	C* _{TN} ; BAN
M-4	M4-6	6	6	Algae limestone batch	Batch	Algae	Limestone	60	0	--	12	2.4 x 4.9	C* _{TN} ; BAN
M-5	M5-6	6	6	OW sand batch	Batch	OW	Sand	90	0	--	12	2.4 x 4.9	C* _{TN} ; BAN
M-6	M6-6	6	6	FAV control batch	Batch	FAV	None	90	0	--	12	2.4 x 4.9	C* _{TN} ; BAN
M-7	M7-6	6	6	Algae control batch	Batch	Algae	None	60	0	--	12	2.4 x 4.9	C* _{TN} ; BAN
M-8	M8-6	6	6	OW control batch	Batch	OW	None	90	0	--	12	2.4 x 4.9	C* _{TN} ; BAN

Notes:

¹ Operational Mode: startup (includes construction time), batch (make-up water only), flow-thru [at average hydraulic loading rate (HLR)], series (cells-in-series), pulsed (dynamic flow rates)

² Plant Communities: EMV (emergent vegetation), SAV (submerged aquatic vegetation), FAV (floating aquatic vegetation), Algae (filamentous and macro algae), OW (open water), MIX (mixed plant community)

³ Substrate: sand (imported, rinsed, medium-grained sand), native sand (on-site soils), limestone (#57 limerock or equivalent)

⁴ HLR (hydraulic loading rate = flow/area)

⁵ nHRT (nominal hydraulic residence time = water depth/HLR)

⁶ Test Variables: C* (lowest-achievable background concentration), BAN (biologically available nitrogen as determined by treatment system and analytical test), N-kvalues (first-order removal rate constants for TN fractions, including TN, NH₃-N, NO₃+NO₂-N)

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Table 7. Proposed C-43 Test Facility Test Cell Treatments

Unit ID	Treat ID	Phase	Duration (months)	Description	Mode ¹	Plant Community ²	Substrate ³	Water Depth (cm)	HLR ⁴ (cm/d)	Mean nHRT ⁵ (d)	Area (m ²)	Dimensions (m)	Key Test Variables ⁶
TC-1	TC1-1	1	12	EMV shallow startup	Startup	EMV	Native sand	15	0	--	4,000	50 x 80	C* _{TN} ; BAN
TC-2	TC2-1	1	12	EMV deep startup	Startup	EMV	Native sand	45	0	--	4,000	50 x 80	C* _{TN} ; BAN
TC-3	TC3-1	1	12	SAV/FAV startup	Startup	SAV/FAV	Native sand	90	0	--	4,000	50 x 80	C* _{TN} ; BAN
TC-4	TC4-1	1	12	Algae/OW startup	Startup	Algae/OW	Limestone	120	0	--	4,000	50 x 80	C* _{TN} ; BAN
TC-5	TC5-1	1	12	MIX startup	Startup	EMV/SAV/FAV/Algae	Native sand	30-90	0	--	4,000	50 x 80	C* _{TN} ; BAN
TC-1	TC1-2	2	12	EMV shallow low flow-thru	Flow-Thru	EMV	Native sand	15	1.5	10	4,000	50 x 80	N-k values
TC-2	TC2-2	2	12	EMV deep low flow-thru	Flow-Thru	EMV	Native sand	45	1.5	30	4,000	50 x 80	N-k values
TC-3	TC3-2	2	12	SAV/FAV low flow-thru	Flow-Thru	SAV/FAV	Native sand	90	1.5	60	4,000	50 x 80	N-k values
TC-4	TC4-2	2	12	Algae/OW low flow-thru	Flow-Thru	Algae/OW	Limestone	120	1.5	80	4,000	50 x 80	N-k values
TC-5	TC5-2	2	12	MIX low flow-thru	Flow-Thru	EMV/SAV/FAV/Algae	Native sand	30-90	1.5	40	4,000	50 x 80	N-k values
TC-1	TC1-3	3	12	EMV shallow medium flow-thru	Flow-Thru	EMV	Native sand	15	3	5	4,000	50 x 80	N-k values
TC-2	TC2-3	3	12	EMV deep medium flow-thru	Flow-Thru	EMV	Native sand	45	3	15	4,000	50 x 80	N-k values
TC-3	TC3-3	3	12	SAV/FAV medium flow-thru	Flow-Thru	SAV/FAV	Native sand	90	3	30	4,000	50 x 80	N-k values
TC-4	TC4-3	3	12	Algae/OW medium flow-thru	Flow-Thru	Algae/OW	Limestone	120	3	40	4,000	50 x 80	N-k values
TC-5	TC5-3	3	12	MIX medium flow-thru	Flow-Thru	EMV/SAV/FAV/Algae	Native sand	30-90	3	20	4,000	50 x 80	N-k values
TC-1	TC1-4	4	12	EMV shallow high flow-thru	Flow-Thru	EMV	Native sand	15	6	2.5	4,000	50 x 80	N-k values
TC-2	TC2-4	4	12	EMV deep high flow-thru	Flow-Thru	EMV	Native sand	45	6	7.5	4,000	50 x 80	N-k values
TC-3	TC3-4	4	12	SAV/FAV high flow-thru	Flow-Thru	SAV/FAV	Native sand	90	6	15	4,000	50 x 80	N-k values
TC-4	TC4-4	4	12	Algae/OW high flow-thru	Flow-Thru	Algae/OW	Limestone	120	6	20	4,000	50 x 80	N-k values
TC-5	TC5-4	4	12	MIX high flow-thru	Flow-Thru	EMV/SAV/FAV/Algae	Native sand	30-90	6	10	4,000	50 x 80	N-k values

Notes:

¹ Operational Mode: startup (includes construction time), batch (make-up water only), flow-thru [at average hydraulic loading rate (HLR)], series (cells-in-series), pulsed (dynamic flow rates)

² Plant Communities: EMV (emergent vegetation), SAV (submerged aquatic vegetation), FAV (floating aquatic vegetation), Algae (filamentous and macro algae), OW (open water), MIX (mixed plant community)

³ Substrate: sand (imported, rinsed, medium-grained sand), native sand (on-site soils), limestone (#57 limrock or equivalent)

⁴ HLR (hydraulic loading rate = flow/area)

⁵ nHRT (nominal hydraulic residence time = water depth/HLR); average depth of 60 cm used to calculate nHRT for TC5

⁶ Test Variables: C* (lowest-achievable background concentration), BAN (biologically available nitrogen as determined by treatment system and analytical test), N-kvalues (first-order removal rate constants for TN fractions, including TN, NH₃-N, NO₃+NO₂-N)

Table 8. Proposed C-43 Test Facility Field-Scale treatments

Unit ID	Treat ID	Phase	Duration (months)	Description	Mode ¹	Plant Community ²	Substrate ³	Water Depth (cm)	HLR ⁴ (cm/d)	Mean nHRT ⁵ (d)	Area (m ²)	Dimensions (m)	Key Test Variables ⁶
FS-1	FS1-1	1	12	EMV shallow startup	Startup	EMV	Native sand	15	0	--	62,700	190 x 330	C* _{TN} ; BAN
FS-2	FS2-1	1	12	EMV deep startup	Startup	EMV	Native sand	45	0	--	62,700	190 x 330	C* _{TN} ; BAN
FS-3	FS3-1	1	12	SAV/FAV startup	Startup	SAV/FAV	Native sand	90	0	--	62,700	190 x 330	C* _{TN} ; BAN
FS-4	FS4-1	1	12	MIX startup	Startup	EMV/SAV/FAV/Algae	Native sand	30-90	0	--	62,700	190 x 330	C* _{TN} ; BAN
FS-1	FS1-2	2	12	EMV shallow flow-thru	Flow-Thru	EMV	Native sand	15	1.5	10	62,700	190 x 330	N-k values
FS-2	FS2-2	2	12	EMV deep flow-thru	Flow-Thru	EMV	Native sand	45	1.5	30	62,700	190 x 330	N-k values
FS-3	FS3-2	2	12	SAV/FAV flow-thru	Flow-Thru	SAV/FAV	Native sand	90	1.5	60	62,700	190 x 330	N-k values
FS-4	FS4-2	2	12	MIX flow-thru	Flow-Thru	EMV/SAV/FAV/Algae	Native sand	30-90	1.5	40	62,700	190 x 330	N-k values
FS-1	FS1-3	3	12	EMV shallow series	Series	EMV	Native sand	15	6	2.5	62,700	190 x 330	N-k values
FS-2	FS2-3	3	12	EMV deep series	Series	EMV	Native sand	45	6	7.5	62,700	190 x 330	N-k values
FS-3	FS3-3	3	12	SAV/FAV series	Series	SAV/FAV	Native sand	90	6	15	62,700	190 x 330	N-k values
FS-4	FS4-3	3	12	MIX series	Series	EMV/SAV/FAV/Algae	Native sand	30-90	6	10	62,700	190 x 330	N-k values
System		3	12		Series		Native sand	15-90	1.5	35	250,800	190x1320	N-k values
FS-1	FS1-4	4	12	EMV shallow series pulsed	Series/Pulsed	EMV	Native sand	15	2-12	1.3-7.5	62,700	190 x 330	N-k values
FS-2	FS2-4	4	12	EMV deep series pulsed	Series/Pulsed	EMV	Native sand	45	2-12	3.8-23	62,700	190 x 330	N-k values
FS-3	FS3-4	4	12	SAV/FAV series pulsed	Series/Pulsed	SAV/FAV	Native sand	90	2-12	7.5-45	62,700	190 x 330	N-k values
FS-4	FS4-4	4	12	MIX series pulsed	Series/Pulsed	EMV/SAV/FAV/Algae	Native sand	30-90	2-12	5-30	62,700	190 x 330	N-k values
System		4	12		Series/Pulsed		Native sand	15-90	0.5-3	17.5-105	250,800	190x1320	N-k values

Notes:

¹ Operational Mode: startup (includes construction time), batch (make-up water only), flow-thru [at average hydraulic loading rate (HLR)], series (cells-in-series), pulsed (dynamic flow rates)

² Plant Communities: EMV (emergent vegetation), SAV (submerged aquatic vegetation), FAV (floating aquatic vegetation), Algae (filamentous and macro algae), OW (open water), MIX (mixed plant community)

³ Substrate: sand (imported, rinsed, medium-grained sand), native sand (on-site soils), limestone (#57 limrock or equivalent)

⁴ HLR (hydraulic loading rate = flow/area)

⁵ nHRT (nominal hydraulic residence time = water depth/HLR); average depth of 60 cm used to calculate nHRT for FS5

⁶ Test Variables: C* (lowest-achievable background concentration), BAN (biologically available nitrogen as determined by treatment system and analytical test), N-kvalues (first-order removal rate constants for TN fractions, including TN, NH₃-N, NO₃+NO₂-N)

3.6 Project Implementation and Estimated Cost

This report recommends a five to six-year period for implementation and completion of the C-43 WQTA Test Facility project (Figure 8). Key phases of the proposed timeline of activities necessary to complete this project include the following (some phases can be completed concurrently):

- System Final Design and Contracting (6 to 12 months)
- System Construction and Startup (12 months)
- System Operation and Monitoring (36 months)
- Final Data Analysis and Reporting (12 months)
- Abandonment and Decommissioning (6 months)

Assuming data are favorable and adequate, the next step after this testing period should be full-scale C-43 WQTA project implementation.

The proposed C-43 WQTA Test Facility described in this report will require a significant financial investment to implement. Cost impacts associated with all of the conceptual design elements were considered, including the selection of monitoring stations, parameter lists, and sample collection frequency and the duration of the proposed study. Costs for this test program could be reduced by cutting back on both the size and complexity of the various test units as well as reducing the sampling and analysis efforts. Costs could also be increased by adding design complexity and numbers of sampling stations, increasing sampling frequency and project duration, and increasing lists of analytical parameters to be sampled. Since no target testing budget was provided by the District, the sampling design recommendations in this report are based on WSI's best professional judgment and will need to be refined by the District in light of actual budget constraints. A final testing plan will need to be prepared as part of the final engineering design of the C-43 WQTA Test Facility. This revised plan will be necessary to incorporate any changes made to test unit sizes, flow rates, lay-out, and treatment schedule.

Table 9 provides a summary of the conceptual-level capital (engineering and construction) estimated cost for the proposed test facilities. Attachment C provides an expanded summary table with the cost basis for each line item as well as additional relevant cost data. The estimated total capital cost for the C-43 WQTA Test Facility as proposed is \$5.06 million with \$340,000 estimated for engineering and permitting and \$4.72 million for construction.

Operation and maintenance (O&M) cost estimates include both routine O&M as well as the costs for sample collection and preliminary data analysis. It is estimated that two full-time staff will be needed to effectively operate the C-43 WQTA Test Facility and complete all of the O&M and site/data management functions described in this plan. Estimated burdened (3.0 multiplier) rates for these two full-time employees are \$225,000 and \$135,000 per year, respectively, for an estimated total annual labor cost of about \$360,000. Costs for higher-level personnel management and data analysis/reporting are not included in this estimate. Estimated costs for electric power consumption and facility maintenance were not included in the conceptual plan.

Total estimated analytical costs are approximately \$1.6 million for the 4-year study period (Table 10). Analytical costs by system scale are estimated to be \$418,000 for the Mesocosms,

\$444,000 for the Test Cells, and \$763,000 for the Field-Scale Cells. Detailed costs by testing scale are included in Attachment C. These analytical costs do not include trace metals or organics.

3.7 Recommendations for Further Consideration

3.7.1 Rapid Assessment of Biologically-Available Nitrogen

The District may wish to consider using the C-43 WQTA Test Facility as a platform for developing a new analytical or biological test for rapid estimation of BAN. Such a test could ultimately allow screening of raw water sources for BAN as a first step in full-scale compliance with the CRE TMDL. Two possible approaches to developing a rapid assessment test are described in the Task 3 report (Attachment C). These two alternative approaches should be critically examined and discussed by District and FDEP staff before inclusion in the C-43 WQTA Test Facility Project. Development of a BAN rapid assessment protocol as part of this project might help with data interpretation and subsequent adaptive management but is not considered critical for developing design guidance and achieving project success. Additional effort beyond the scope of the conceptual plan will be needed to provide a cost estimate for one or both of these suggested assessment methods. For example, development of this cost estimate would include development of a detailed scope of work and budget in cooperation with a research-level analytical laboratory. If a BAN rapid assessment technique can be developed cost effectively within the project budget, then it is recommended. Costs for development of rapid BAN assessment methods are not included in this report.

3.7.2 Development of a Dynamic Nitrogen Model

The District routinely uses the Dynamic Model for Stormwater Treatment Areas Version 2 (DMSTA2, Walker and Kadlec 2008) to design STAs for phosphorus removal and to forecast future performance based on changes in dominant vegetation community, expansions of treatment area, and/or changing inflow volumes and concentrations. The DMSTA2 provides an excellent framework to begin the development of a dynamic nitrogen model because it already includes a highly flexible water balance component. In theory, the phosphorus dynamics module could be replaced with a nitrogen module. Data sets from the proposed project, and other systems, could be used to calibrate the nitrogen module for the different vegetation community types.

Development of a dynamic nitrogen model is not critical for full-scale design. For example, early STA design relied on a steady-state model that was calibrated based on the data from existing south Florida wetlands. However the ability to optimize the full-scale C-43 WQTA design would likely be improved by development of a dynamic nitrogen model using the detailed data collected from the proposed test facility. Additional effort beyond this conceptual design will be needed to provide a realistic cost estimate for model development. If determined to be cost effective and within the overall project budget, it is recommended that the District plan to develop a dynamic nitrogen model, based on DMSTA2, concurrently with the construction and operation of the C-43 Test Facility. It is reasonable to assume that the proposed nitrogen model could be developed and tested within the same five to six year time span of this testing project. Estimation of the cost for a dynamic nitrogen model were not part of this project.

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Figure 8. Proposed C-43 Water Quality Treatment and Demonstration Project Schedule

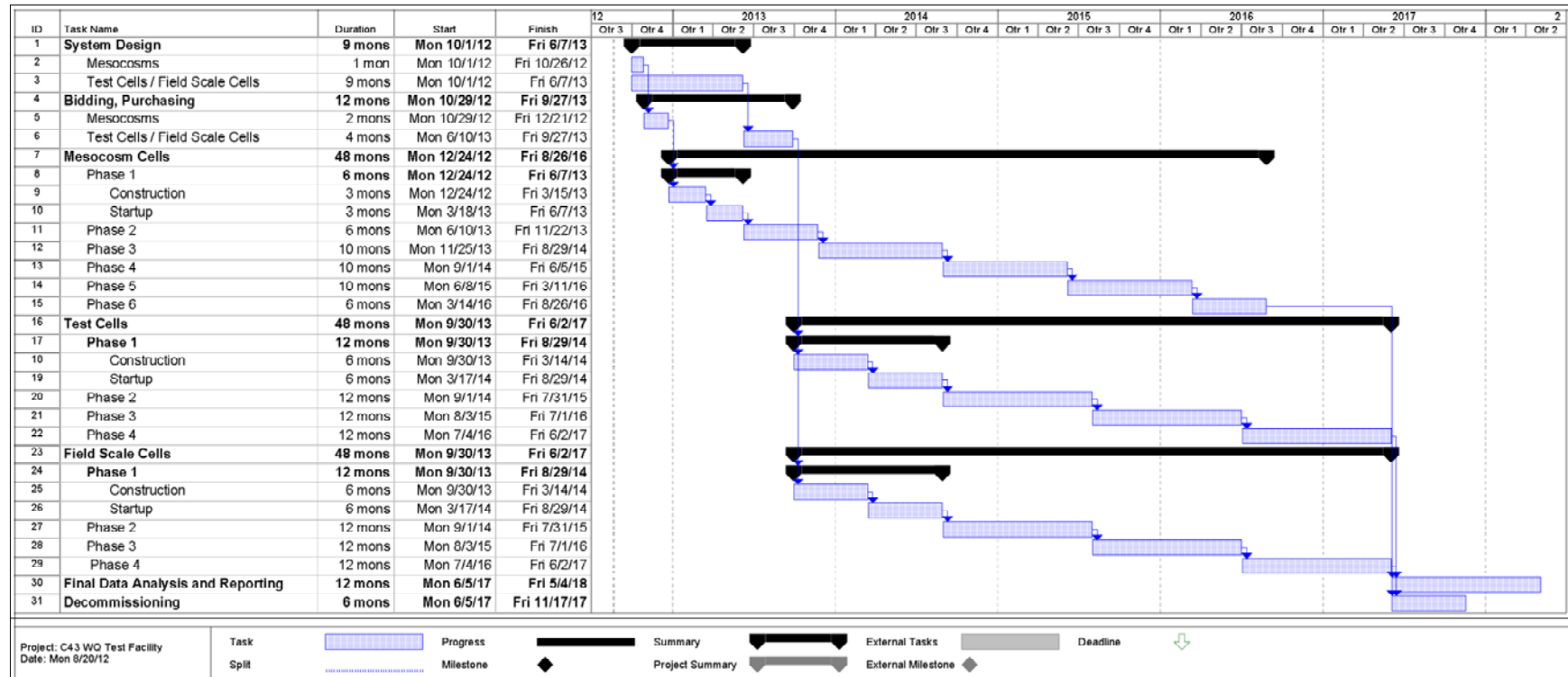


Table 9. C-43 Test Facility Conceptual Capital and Operational Cost Estimate

Category	Amount
Earthwork	\$ 1,353,000
Sitework	\$ 956,933
Buildings	\$ 70,000
Pumping Facilities	\$ 152,500
Piping and Appurtenances	\$ 423,250
Electrical	\$ 100,000
Wetland Vegetation	\$ 190,000
Miscellaneous Equipment	\$ 126,700
Construction Total	\$ 3,372,383
Overhead	\$ 337,238
Profit	\$ 168,619
Mobilization/Demobilization/Bonding	\$ 168,619
Contingency	\$ 674,477
Engineering and Permitting	\$ 337,238
Capital Cost Total	\$ 5,058,575

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Table 10. C-43 Test Facility Analytical Laboratory Cost Estimate

Parameter	Number of Samples				Analytical Cost			
	Mesocosms	Test Cells	Field Scale Cells	Total	Mesocosms	Test Cells	Field Scale Cells	Total
Field Sampling	28,288	15,600	12,480	56,368	\$ -	\$ -	\$ -	\$ -
Surface Water Quality	30,067	29,069	46,733	105,869	\$ 369,965	\$ 367,987	\$ 640,531	\$ 1,378,483
Rainfall / Atmospheric Inputs	749	749	749	2,246	\$ 9,504	\$ 9,504	\$ 9,504	\$ 28,512
Tracer Study	0	1,440	1,152	2,592	\$ -	\$ 43,200	\$ 34,560	\$ 77,760
Biological Analyses	3,328	2,576	1,328	7,232	\$ -	\$ -	\$ 40,000	\$ 40,000
Sediments	1,075	672	1,075	2,822	\$ 38,093	\$ 23,808	\$ 38,093	\$ 99,994
Totals	63,507	50,106	63,517	177,130	\$ 417,562	\$ 444,499	\$ 762,688	\$ 1,624,749

Section 4.0 References

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- Wetland Solutions, Inc. (WSI). 2010. Inc. 2010 C-43 Water Quality Treatment Area-Technical Expert Review Panel Consolidated Report. Prepared for the South Florida Water Management District. August 2010. 13pp.
- Wetland Solutions, Inc. (WSI). 2012. Final Task 2 Report - Evaluation of Total Nitrogen Reduction Options for the C-43 Water Quality Treatment Area Test Facility. Prepared for the South Florida Water Management District.



Attachment A

C-43 WQTA Test Facility Conceptual Design Project Management Plan (Task 1)

Final Project Work Plan

Conceptual Design of C-43 Water Quality Treatment Area Test Facility

Prepared for
South Florida Water Management District

Date
January 20, 2012

Prepared by
Wetland Solutions, Inc.



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Section 1.0 Introduction

1.1 Background

Elevated concentrations of nitrogen and phosphorus in the Caloosahatchee River and Estuary (CRE) are contributing to impairment of beneficial uses in this system as evidenced by excessive algae blooms and decreased water clarity and dissolved oxygen content (Knight and Steele, 2005). The reduction of nutrient concentrations and loads to these water bodies was required by the Northern Everglades and Estuaries Protection Program passed by the Florida Legislature and signed into law in 2007, and by CRE Total Maximum Daily Loads (TMDL) adopted by the Florida Department of Environmental Protection (FDEP) (Bailey *et al.* 2009). Currently, the US Environmental Protection Agency (EPA) is developing estuarine numeric nutrient criteria (NNC) for the South Florida Estuaries to ensure healthy and well-balanced coastal ecosystems.

In order to increase nutrient reductions to the downstream estuary, the South Florida Water Management District (District) and Lee County have been partnering on the C-43 Water Quality Treatment Area Testing Facility Project (the “C-43 WQTA Project”). The purpose of the C-43 WQTA Project is to investigate and demonstrate cost effective strategies for reducing concentrations and loadings of total nitrogen (TN) and other constituents including total phosphorus (TP) and total suspended solids to the C-43 Canal to improve water quality in the downstream estuarine ecosystems. The District also anticipated that the C-43 WQTA Project will generate strategies that can be applied to estuaries throughout South Florida.

Through a decade of successful operation of Stormwater Treatment Areas (STAs), the District has built an extensive expertise in TP removal from storm water runoff using wetland treatment systems. However the mechanisms for TN removal via wetland treatment systems have not been studied to the same extent. The existing data from STAs mostly indicate that currently designed wetland treatment systems are not optimized to reduce TN (especially dissolved organic nitrogen, DON) although they can remove dissolved inorganic nitrogen (DIN) with high efficiency, which accounts for, at most, 20% of the TN present in the CRE system. Thus the District contracted with CH2M HILL to identify the best option(s) for achieving the C-43 WQTA Project’s goals of nutrient reduction in CRE and to design a test facility prior to construction of the full-scale C-43 WQTA Project. CH2M HILL completed three tasks from 2007-2009, including:

- Initial Data Collection and TN Reduction Technologies Assessment;
- Water Quality Evaluation and Characterization of DON; and
- C-43 WQTA Project Test Facility Conceptual Plan Development.

CH2M HILL’s efforts resulted in several deliverables and recommendations, such as developing constructed wetland treatment systems as the most cost-effective means for nutrient removal. The recommended plan included design, construction, and operation of a multi-scale test/demonstration facility on a 1,750-acre parcel (see Exhibit 1) purchased by the District and Lee County for the proposed WQTA. This test/demonstration facility is intended to provide the basis for design of constructed wetlands to assist with ultimate compliance of the CRE TMDL.

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CH2MHill proposed a process that would convert bioavailable nitrogen into non-bioavailable forms. The TMDL, however, makes no distinction between the two nitrogen forms and includes TN only. Therefore the District is seeking expertise from Wetland Solutions, Inc. (WSI). WSI to provide additional technical support to develop the detailed C-43 WQTA Project Testing Plan, including a conceptual design of the proposed test facilities and an operational testing plan. This project plan is intended to provide the flexibility to test multiple nitrogen removal approaches to determine which approaches are most effective.



EXHIBIT 1

Location of the C-43 Water Quality Treatment and Demonstration Project (top panel) and layout of the test and demonstration cells (bottom panel). (CH2M HILL 2009).

1.2 Project Goals and Objectives

The goal of this project is to develop a conceptual design of a test facility comprised of mesocosms and test cells that: 1) will effectively remove and/or reduce TN from the CRE by a minimum of 23% but preferably 30% (as required by FDEP's TMDL) below existing levels; 2) is based on a review of available information and sound science; and 3) is implementable and cost effective on larger scales and/or applicable to other South Florida estuarine systems. This project is Phase I of a two-phase project. Phase 2 will be focused on the design of a full-scale test facility, and construction and operations and maintenance (O&M) for this facility.

The objective of this work is for WSI, with recognized experts in the field of nitrogen and nutrient removal using constructed wetlands, to develop a conceptual design for a cost-effective testing facility including all necessary testing plans. WSI will conduct a thorough evaluation of relevant treatment options to remove TN using constructed wetlands, propose a conceptual design which is based on sound science, provide a conceptual design of the testing systems and provide estimated probable construction, operating, and testing costs of the proposed design.

1.3 Project Work Plan

This Project Work Plan describes WSI's understanding of the District's goals and objectives for the C-43 WQTA test facility conceptual design, the responsibilities of WSI's staff, the methods, and materials that will be used to achieve these goals and objectives, the preparation of deliverables provided by WSI to the District, and the project schedule of tasks and deliverables.

Section 2.0 Project Team and Accomplishment of Work

2.1 Project Management Structure

The District Project Manager is Eric Gonzalez, P.E.. Mr. Gonzalez will be the principal point of contact between the District and WSI on all contract and technical matters related to the C-43 WQTA Project.

Mr. Gonzalez's contact information:

- Telephone: 561-682-6391
- Fax: 561-682-5831
- Email: ergonzal@sfwmd.gov

The WSI Project Manager and Principal Scientist is Robert L. Knight, Ph.D. Dr. Knight will be the principal point of contact on all contract and technical matters between WSI and the District.

Dr. Knight's contact information:

- Office phone: 386-462-1003
- Cell phone: 352-538-6620
- Fax: 386-462-3196
- Email: bknight@wetlandsolutionsinc.com

WSI's Assistant Project Manager and Senior Engineer for the C-43 WQTA Project is Chris Keller, P.E. Mr. Keller will assist Dr. Knight as needed on contract, deliverable, and invoicing issues and will oversee engineering aspects of this project.

Mr. Keller's contact information:

- Office phone: 386-462-9286
- Cell phone: 352-262-3098
- Fax: 386-462-3196
- Email: ckeller@wetlandsolutionsinc.com

Dr. Knight and Mr. Keller will be assisted as needed by key WSI staff, including Senior Scientist Debra Segal, M.S. for technical quality control, Assistant Scientist Ron Clarke, M.S. for water quality and data analysis issues and Assistant Engineer Scott Knight, P.E. for engineering support. Resumes of all participating WSI staff are included in Section 5 of this document.

2.2 Conduct of Work

Dr. Knight and Mr. Keller will be the primary WSI staff working to complete this project in a satisfactory manner. Mr. Clarke and Mr. Knight will provide technical support as needed. Ms.



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Segal will provide editorial quality control on all deliverables and Dr. Knight will provide final technical and overall quality control on all deliverables provided by WSI to the District.

All project deliverables will be prepared in the editorial format utilized for this Project Work Plan. All work products will be delivered to the District by electronic mail. All work products will be submitted and labeled as Draft, revised as agreed upon by the District and WSI, and as Final documents. An approximate schedule for all project deliverables is included below in Section 3: Project Scope of Services.

Section 3.0 Project Scope of Services

3.1 Task 1: Project Management/Communication

The objective of this task is to provide active and effective communication between District and WSI staff working on this project. This communication is critical to accomplishment of the project goals and objectives and to finish the project on time and in budget. The methods to accomplish this objective include five project meetings, teleconference calls as needed, and electronic mail communications on a regular basis.

3.1.1 Subtask 1.1: WSI will conduct a Project kick-off meeting at the District headquarters in West Palm Beach, Florida within two (2) weeks after Contract execution date or as agreed upon with the District Project Manager. At this time, WSI shall introduce key staff needed to complete this work, provide résumés, identify the contract Project Managers and define WSI's chain of command. Additionally, WSI shall make a Power Point presentation to the District scientists including a detailed overview of the C-43 WQTA Project objectives, plans, methods, schedule and required deliverables. Based on this kick-off meeting and discussions, WSI shall prepare a detailed Project Work Plan that describes the objectives for each task in detail, the major questions being addressed by each task, the rationale for the task and detailed methods that incorporate conclusions reached during the kick-off meeting. In addition, the deliverables expected for each task will be specified. This final work plan will be evaluated and must be approved by District Project Manager.

- Deliverable 1.1: Power Point presentation that will be presented at the kick-off meeting to District scientists.

3.1.2 Subtask 1.2: WSI will submit a draft Project Work Plan to the District Project Manager within two (2) weeks after the Contract execution date, with details for completing this Project including, but not limited to:

- Description of the Project (reflecting WSI's understanding of District goals and objectives and associated tasks);
- How the tasks will be accomplished (methodologies);
- Format(s) of documentation to be provided to the District; and
- Schedule of tasks/deliverables.

Review and comment of the draft Project Work Plan will be completed by the District team, including the District Project Manager and other District scientists, and returned to WSI two (2) weeks after receipt of the Draft Work Plan by the District. WSI shall incorporate all changes provided by the District into a Final Project Work Plan. The District-approved Final Project Work Plan shall become a binding document for this Contract once the District's Project Manager has agreed to it in writing. WSI shall proceed with the performance of this Contract in accordance with the approved Final Work Plan and the requirements of the Statement of Work. In the event of any conflict between the Statement of Work and this Final Work Plan, the Statement of Work shall take precedence.

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- Deliverable 1.2.1: Electronic copy (in MS Word form) of the draft Project Work Plan shall be submitted within two (2) weeks after the Contract execution.
- Deliverable 1.2.2: Electronic copy (in MS Word form) of the Final Work Plan shall be submitted within five (5) weeks after the Contract execution.

3.2 Task 2: Evaluation of Total Nitrogen Reduction Options

The objective of this task is to provide an up-to-date summary of information related to the use of constructed wetland technologies for TN removal with an emphasis on the removal of various TN fractions, including inorganic and organic forms. This evaluation will primarily draw information from the WSI Expert Panel report as well as the reports prepared previously for the District by CH2M HILL. More recent literature on TN removal in constructed treatment wetlands will also be reviewed and summarized. If necessary to provide a scientifically sound evaluation, existing studies and empirical data on TN reduction from existing STAs will be evaluated. The potential to degrade and remove organic nitrogen fractions is of particular interest for this evaluation since these are the most recalcitrant forms of nitrogen and are the principal nitrogen fraction in the CRE system.

WSI will evaluate relevant treatment options for reduction of TN and principal nitrogen fractions using constructed wetland systems by comparing and summarizing scientific merits and limitations and associated costs of each treatment system. The District is particularly interested in consideration of treatment options discussed in the “C-43 Water Quality Treatment Area- Technical Expert Review Panel Consolidated Report”. The results of this evaluation will be discussed between WSI and the District Project Team at a Project Meeting, to be held at District Headquarters. Approval of Final Task 2 Deliverables by the District Project Team is required for initiation of Task 3 - Conceptual Design of Nitrogen Removal Technologies for the C-43 Test Facility.

- Deliverable 2.1: Electronic copy (in MS Word form) of a draft report summarizing the evaluation of relevant options for reduction of TN;
- Deliverable 2.2: Project Meeting between WSI and the District Project Team, to be held at District Headquarters; and
- Deliverable 2.3: Electronic copy (in MS Word form) of final documentation summarizing the evaluation of relevant options for reduction of TN.

3.3 Task 3: Conceptual Design

The objective of this task is to revise and refine the WQTA Test Facility preliminary design prepared by CH2M HILL in 2009 based on the updated and focused technology evaluation completed in Task 2 above. The previous plan recommended testing several treatment alternatives that are theoretical and currently unsupported by preliminary research. The WSI Conceptual Design will be based on constructed wetland alternatives that have demonstrated capabilities to provide the desired level of TN reduction needed for the CRE TMDL. This increased focus is necessary to keep this project on schedule and in budget. This conceptual design will include two major components: 1) summary of the effectiveness of mesocosms to provide process-level data that will be useful for test cell design and operation and 2) conceptual design of the larger test cells needed to provide reliable performance data for full-

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scale project implementation. The rationale for this two-step process is that mesocosms can be implemented more rapidly and with greater cost efficiency than larger test cells. If WSI and the District conclude that mesocosms should be included in this test facility plan, then the mesocosm test system conceptual design will be completed first to accelerate that portion of the project.

WSI will develop a conceptual design of the recommended test facility for the removal/reduction of TN/Biologically Available Nitrogen, which includes but is not limited to, bioassays (sub-meter), experimental mesocosms (sub-acre), and wetland plots (acres). This conceptual design shall include testing plans, scientific rationales, and estimated costs for construction, operation, and testing in the proposed design. WSI's recommended test facility plan will consider cost-effectiveness (i.e. low, mid, high), with corresponding incremental benefits for each. The goal is to recommend one option with the highest estimated return on investment.

Based on the recommendations provided by the expert panel, the District wishes to incorporate mesocosms as one of the elements of the treatment facility. The first order of work is for WSI to validate or rebut the use of experimental mesocosms to test proposed treatment technologies. Should WSI validate the use of mesocosms, then WSI shall proceed first with the conceptual design of a mesocosm system that will operate independently from the rest of the testing facility. Should WSI rebut the use of mesocosms, then WSI shall submit a detailed explanation based on sound science and shall obtain the District's concurrence. The results of this evaluation will be discussed between WSI and the District Project Team at a Project Meeting, to be held at District Headquarters

- Deliverable 3.1: Electronic copy of the Draft Report detailing the Conceptual Design (or rebuttal) of mesocosms;
- Deliverable 3.2: Electronic copy of the District Approved, Final Report detailing the Final Conceptual Design of mesocosms;
- Deliverable 3.3: Electronic copy of the Draft Report detailing the Conceptual Design of Nutrient Removal/Reduction Test Facility; and
- Deliverable 3.4: Electronic copy of the District Approved, Final Report detailing the Conceptual Design of Test Facility.

3.4 Task 4: Final Report and Project Close-Out

3.4.1 Subtask 4.1: Draft Final Report

WSI will provide two (2) hard copies and one electronic copy of a draft Final Report, which includes Task 2 and Task 3 deliverables, for District review. Within ten (10) working days of receipt of the Draft Final report, District personnel will review and forward, in letter format, recommended revisions to the Draft report for incorporation into the Final report.

3.4.2 Subtask 4.2: Final Project Meeting

During the two (2) week period of District review, WSI will present the findings of this work to the District and interested stakeholders (e.g., Lee County). At this meeting, participants can discuss the results and recommendations of the Final Report.

3.4.3 Subtask 4.3: Final Report

WSI will provide five (5) hard copies and one electronic copy of the Final Report for the District incorporating all the comments received from the District Project Manager.

- Deliverable 4.1: Electronic copy (in MS Word form) of draft final project report
- Deliverable 4.2: A draft final project report meeting
- Deliverable 4.3: Electronic copy (in MS Word form) of District approved final project report

3.5 Hardware and Software

WSI will be responsible for providing the hardware and software necessary to complete the above tasks for any staff located off-site. Software products will be compatible with Microsoft Office 2007 version.

3.6 Evaluation Criteria for Acceptance of Deliverables

For each deliverable, WSI shall submit one (1) electronic copy of data products (graphs, tables, etc. All draft and final reports shall be written in clear and concise English, and shall be submitted to the District Project Manager only after an internal editorial review has been completed by WSI. The District Project Manager's review shall be strictly for the purpose of assessing the content of the material in these reports. The District Project Manager may return documents to WSI in order to seek clarification or corrections and WSI shall be responsible for re-submitting revised documents to the District Project Manager on schedule.

WSI is responsible for performing all work and submitting all deliverables on or before the deadlines specified in Exhibit "D" SUMMARY OF DELIVERABLE SCHEDULE AND PAYMENTS. Any requests for extensions of Project Schedule Deadlines as specified in Exhibit "D" SUMMARY OF DELIVERABLE SCHEDULE AND PAYMENTS to the Contract shall be submitted by WSI by electronic mail, with justification, to the District's Project Manager. The District's Project Manager can verbally authorize any reasonable changes in the schedule of deliverables.

Any manuscripts, technical publications, presentation slides, or other documents resulting from or related to the work performed under this Contract will be submitted to the District for review and approval prior to publication by WSI in any forum or format. This paragraph will survive the expiration or termination of the Project Contract.

3.7 Schedule of Deliverables

Exhibit 2 provides a summary of the schedule of deliverables for the C-43 WQTA Test Facility Conceptual Design Project. The project authorization date was December 12, 2011. The project completion date is expected to be no later than September 25, 2012.

EXHIBIT 2
Schedule of Deliverables

TASK	DELIVERABLE	DUE DATE
Task 1.1: Project Kickoff Meeting	Power Point presentation that will be presented at the kick-off meeting to the District Project Team.	One (1) week in advance of the Kickoff Meeting
Task 1.2: Project Work Plan	District Approved Final Project Work Plan.	Five (weeks after contract execution (1/17/2012) 2/28/2012
Task 2.1: Draft Evaluation of Options for Reduction of Total Nitrogen	Electronic copies of a draft report summarizing the evaluation of relevant options for reduction of Total Nitrogen	
Task 2.2: Draft Evaluation of Options for Reduction of Total Nitrogen Meeting	Project Meeting between Contractor and the District Project Team, to be held at District Headquarters	Within 2 weeks of submission of draft report
Task 2.3: Final Evaluation of Options for Reduction of Total Nitrogen	Electronic copies of a final documentation summarizing the evaluation of relevant options for reduction of Total Nitrogen	3/30/2012
Task 3.1: Draft conceptual design (or rebuttal) of mesocosms and meeting	Electronic copies of the Draft Report detailing the Conceptual Design (or rebuttal) of mesocosms	4/13/2012
Task 3.2 Final conceptual design of mesocosms	Electronic copies of the District Approved, Final Report detailing the Final Conceptual Design of mesocosms	5/15/2012
Task 3.3: Draft conceptual design of test facility and meeting	Electronic copies of the Draft Report detailing the Conceptual Design of Nutrient Removal/Reduction Test Facility	5/30/2012
Task 3.4: Final conceptual design of test facility and meeting	Electronic copies of the District Approved, Final Report detailing the Conceptual Design of Test Facility	6/29/2012
Task 4.1: Draft Final Project Report	Draft Final Project Report	8/01/2012
Task 4.2: Draft Final Project Report Meeting	Draft Final Project Report Meeting	8/10/2012
Task 4.3: Final Project Report	District Approved Final Project Report	9/25/2012

Section 4.0 References

Bailey, N., W. Magley, J. Mandrup-Poulsen, K. O'Donnell and R. Peets. 2009 Nutrient TMDL for the Caloosahatchee Estuary (WBIDs 3240A, 3240B, and 3240C). Florida Department of Environmental Protection. TMDL Report. 119 pp.

CH2MHill. 2009. Organic Nitrogen Methodology Screening Analysis (Draft). Technical Memorandum prepared for the South Florida Water Management District. 32 pp.

CH2MHill. 2008. Total Nitrogen Reduction Technologies Review. Technical Memorandum prepared for the South Florida Water Management District. 43 pp.

Knight, R.L. and J. Steele 2005. Caloosahatchee River/Estuary Nutrient Issues. White Paper. Prepared for the South Florida Water Management District. Prepared by Wetland Solutions, Inc., Gainesville, FL.

Wetland Solutions. 2010. Inc. 2010 C-43 Water quality treatment Area-Technical Export Review Panel consolidated Report. 13pp

Section 5.0 WSI Key Personnel

Robert L. Knight, Ph.D.

Robert L. Knight, Ph.D. is a consulting environmental scientist. He is the founder and president of Wetland Solutions, Inc., and specializes in projects related to treatment wetlands, wetland and aquatic ecology, surface water quality, and environmental studies.

Education

Ph.D., Systems Ecology, University of Florida, Department of Environmental Engineering and Center for Wetlands 1980

M.S.P.H., Environmental Chemistry and Biology, University of North Carolina School of Public Health 1973

B.A., Zoology, University of North Carolina 1970



Professional Registration

Certified Professional Wetland Scientist, #466, Society of Wetland Scientists

Distinguishing Qualifications

- Internationally recognized authority in treatment wetland technology and aquatic ecology and co-author of the first comprehensive wetland treatment system design handbook
- Over 30 years of professional environmental experience in wetland and aquatic ecology including consulting and research experience with more than 200 projects assessing environmental impacts of human activities and designing solutions
- Graduate professor at the University of Florida teaching Wetlands for Water Quality Treatment and Springs Ecology
- Served as principal author on more than 100 technical reports on treatment wetland permitting, design, and operation, including the North American Treatment Wetland Database, assessment of the habitat values of treatment wetlands, and industry-wide reviews of the use of treatment wetlands for the pulp and paper industry, the petroleum industry, and concentrated livestock facilities.
- Principal investigator for research and development of a new technology using periphyton for agricultural stormwater treatment in the Florida Everglades. Developed research plan, coordinated and led Scientific Review Committee, and directed mesocosm research and data analysis.
- Senior wetland process consultant for design of Okeechobee Stormwater Treatment Areas (STAs), Ten Mile Creek Reservoir and STA, and STA-3/4 in the Florida Everglades. Applied revised design model and design parameters considering infiltration, background phosphorus conditions, updated phosphorus performance data, and appropriate hydraulic model.

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- Designed and implemented a comprehensive monitoring program in the Wekiva River, Rock Springs Run, Juniper Creek, and Alexander Springs Creek to quantify necessary pollutant load reduction goals
- Served as lead co-principal investigator on the 50-year Silver Springs Retrospective Study to provide a quantitative comparison between current and historical environmental conditions in the upper Silver River and to project possible future impacts
- Developed quantitative methods for assessing minimum flows and levels for Volusia County Blue Spring and Blue Spring Run that would protect ecological resource values from significant harm
- Led a team of scientists and engineers assessing the environmental impacts of groundwater withdrawals throughout the northern Tampa Bay area and developed methods for quantitative ecological inventories and developing minimum flows and levels in regional wetlands and aquatic ecosystems

Relevant Experience

Dr. Knight's professional experience includes all aspects of environmental study, including design and implementation of field studies, data analysis and interpretation, water quality modeling, project management, quality assurance and review, environmental systems overview analysis and computer modeling, and impact analysis, prediction, and assessment. He is experienced in a wide range of applied research problems in aquatic, wetland, and terrestrial environments and has completed environmental assessments nationwide.

Dr. Knight has conducted numerous studies on the feasibility of using constructed and natural wetlands for the assimilation of municipal, industrial, and agricultural wastewaters. He has played a major role in site investigations of existing wetland disposal systems and in the development of design and management criteria for new wetland and land treatment systems. Dr. Knight has been instrumental in the research and development of the periphyton-based stormwater treatment area (PSTA) technology, has evaluated the use of submerged aquatic vegetation (SAV) for phosphorus control, provided senior review on the use of chemical treatment/wetland hybrid systems for phosphorus removal, and designed and directed research on the use of deep water zones for enhancing treatment wetland performance.

State and federal environmental agencies have called on Dr. Knight to provide state-of-the-art knowledge about wetland advanced treatment technology. He was the manager on projects to provide a technology assessment for surface flow wetlands, and prepared a literature review and database on wetlands used for treatment of concentrated livestock wastewaters. He has prepared a literature review on the habitat value of treatment wetlands and prepared a data base to summarize wildlife, human use, and toxicity data from treatment wetlands. He was the leader of the U.S. Environmental Protection Agency (EPA)-sponsored team that developed a standardized data base for treatment wetlands operational data. Dr. Knight has taught numerous short courses on the permitting and design of wetland treatment systems and frequently makes presentations to scientific conferences concerning wetland systems. As a result of this experience, he was invited to be the lead author of a chapter on wetland system design for the Water Environment Federation's Natural Systems Manual of Practice; he authored a chapter for the EPA's revised design manual on constructed wetlands; and he is the

coauthor (with Dr. Robert Kadlec) of the first definitive work on wetland treatment system design: *Treatment Wetlands*, first edition, published by Lewis Publishers.

Dr. Knight has led design efforts on 20 full-scale wetland treatment systems and has developed and implemented 12 pilot wetland treatment system projects. For a number of these projects, he led workshops to identify project goals and to prepare project conceptual designs prior to detailed engineering. Following design and implementation of wastewater to wetland projects, Dr. Knight has prepared sampling protocols and trained client staff to conduct all essential field monitoring. In some projects where clients have taken charge of monitoring, Dr. Knight provides essential data interpretation and trouble-shooting consultation.

Dr. Knight has over 35 years of experience as an aquatic and wetland ecologist. His doctoral work included an ecological evaluation of Silver Springs and Silver River. He is currently providing on-going water resource value monitoring services for the St. Johns River Water Management District as required by the Volusia Blue Spring Minimum Flow Regime. Dr. Knight and WSI are currently assessing the ecological condition of 12 artesian springs, including the Ichetucknee Springs System for the Florida Fish and Wildlife Conservation Commission. Dr. Knight recently completed quantitative assessments of a minimum flow regime for the protection of water and human-use resource values (WRVs) for the Wekiva River and Rock Springs Run, a 50-year retrospective study of the ecological health of Silver Springs, and a multi-year study establishing pollutant load reduction goals (PLRGs) for the Wekiva River and Rock Springs Run. Dr. Knight helped to assess the effects of nitrate on spring ecosystems in conjunction with UF's Water Institute.

Dr. Knight has conducted many field studies of water quality and surface water hydrology in natural surface waters. He has extensive taxonomic and ecological experience with phytoplankton and periphyton in Florida surface waters and has quantified communities of aquatic and wetland plants, including submersed aquatic vegetation, floating aquatic plants, and emergent woody and herbaceous plant species. He has also evaluated populations of benthic macroinvertebrates, fish, reptiles and amphibians, birds, and mammals associated with aquatic and wetland ecosystems. He has provided numerous assessments of the quantitative relationships between water regime and ecological structure and function in aquatic and wetland ecosystems.

His research experience in wetland ecology in the southeastern United States includes floodplain and riparian forests; coastal plain and inland isolated wetlands, such as pocosins, cypress heads, cypress strands, wet prairies, and freshwater marshes; and coastal wetlands, including *Juncus* and *Spartina* salt marshes, mangrove wetlands, and seagrass beds. His work in wetlands includes botanical studies, wildlife inventories, water quality studies, nutrient assimilation studies, endangered species surveys, hydrological studies, wetland soil surveys, and dredge and fill permitting.

Dr. Knight has extensive experience in the study and analysis of the water quality of natural lakes, streams, wetlands, and estuaries. He has designed and implemented numerous water quality monitoring programs and has assessed the impacts associated with urban development and construction activities on water quality. He has provided recommendations concerning nutrient control and eutrophication abatement for lakes and canals throughout the United States. His lake management expertise also includes identification and control of excessive aquatic plant growths through chemical and biological means. He has conducted field

verification studies of the algal assay procedure, studied the effects of power plant entrainment on phytoplankton, and provided taxonomy and enumeration of phytoplankton and periphyton from rivers and streams. His professional experience includes extensive work on the effects of toxic metals and discharges on streams and wetlands.

Publications

Dr. Knight has written numerous technical papers on wetland ecology, ecosystem metabolism, phytoplankton and periphyton ecology, springs ecology, and heavy metal dynamics in aquatic systems. Representative papers, chapters, and a book include the following:

Knight, R.L., B. Gu, R.A. Clarke, and J.M. Newman. 2003. Long-term phosphorus removal in Florida aquatic systems dominated by submerged aquatic vegetation. *Ecological Engineering* 20: 45-63.

Knight, R.L., R.A. Clarke, and R.K. Bastian. Treatment Wetlands as Habitat for Wildlife and Humans. Presented at the IWA Wetland Conference, Orlando, Florida. November 13-16, 2000.

Knight, R.L., W.E. Walton, G.O'Meara, W.K. Reisen, and R. Wass. Design Strategies for Effective Mosquito Control in Constructed Treatment Wetlands. Presented at the IWA Wetland Conference, Orlando, Florida. November 13-16, 2000.

Knight, R.L., V.W.E. Payne, R.E. Borer, R.A. Clarke, and J.H. Pries. Constructed Wetlands for Livestock Wastewater Management. *Ecological Engineering* 15: 41-55. 2000.

Knight, R.L., R.H. Kadlec, and H.M. Ohlendorf. The Use of Treatment Wetlands for Petroleum Industry Effluents. *Environmental Science & Technology* 33(7):973-980. 1999.

Knight, R.L., R. Adams, C. O'Brien, and E.R. Davis. Beltway 8 Wetland Water Quality Project – Constructed Wetlands for Stormwater Polishing and Wetland Mitigation Banking. *Transportation Research Record* No. 1626, Paper No. 98-1382, pp. 11-20. 1998.

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Chris Keller, P.E.

Mr. Keller is experienced in a wide range of environmental engineering disciplines, including water resources engineering, water quality and biological monitoring, water quality treatment, and environmental permitting. Mr. Keller has particular expertise in treatment wetlands design, performance optimization, water regime and hydrological analysis, data interpretation, and trouble shooting. Mr. Keller has also conducted tracer studies in wetland and lagoon systems ranging from 50 square feet to 900 acres in surface area.



Education

M.E., Environmental Engineering, University of Florida (1994)

Graduate Wetlands Certificate, University of Florida (1994)

B.S., Environmental Engineering, University of Florida (1992)

Professional Registrations

Professional Engineer: Florida (No. 54040)

Relevant Experience

Mr. Keller has prepared an independent analysis of operational data from STA-1E for the U.S. Army Corps of Engineers. This work included the preparation of period-of-record water and phosphorus mass balances and estimation of phosphorus removal rates. Follow-on work has included an analysis of potential remedial actions that could be taken to improve water quality performance.

Mr. Keller developed a detailed design guidance report for the SFWMD's stormwater treatment areas (STAs) in the Northern Lake Okeechobee Watershed. The report also included recommendations for optimal site conditions for STA construction.

Mr. Keller is proficient in use of the Dynamic Model for Stormwater Treatment Areas (DMSTA) model for estimation of P removal performance in south Florida STAs. Projects he has worked on include the Lake Okeechobee STAs, Nubbin Slough Nutrient Treatment Area, C-44 Storage Reservoir/STAs, expansions of STAs 5 and 6 in the Everglades Agricultural Area, proposed Lemkin Creek Water Quality Treatment Area, and proposed STAs within the C-43 Basin.

Mr. Keller assisted with a variety of tasks for the Lake Okeechobee Watershed Project. These tasks included the following:

- evaluating optimum hydraulic loading rates to maximize phosphorus load reduction while protecting STA structure and function
- recalibration of DMSTA (with W. Walker) for lakes and wetlands north of the Everglades Agricultural Area
- comparing phosphorus performance estimates generated with DMSTA and DMSTA version 2

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- conducting a literature review to estimate long-term sediment accretion rates in treatment wetlands
- preliminary phosphorus removal estimates (DMSTA) for potential STAs in the Lake Okeechobee Watershed
- review of estimated watershed flows and loads generated with the OASIS model
- assisting with the integration of OASIS and DMSTA to rank potential projects in the Lake Okeechobee Watershed
- updating the Water Quality Ranking Tool to prioritize potential projects in the Lake Okeechobee Watershed

Mr. Keller has prepared a dynamic model for estimation of nitrogen removal in south Florida treatment wetlands. This model fractionates inlet nitrogen forms and tracks performance for ammonia, nitrate, organic, and total nitrogen.

Mr. Keller prepared detailed water quality reports for both the C-44 and C-43 reservoir test cell projects. Each report summarized approximately 1 year of monthly data collected from a total of four 5-acre reservoir cells. These reports included water and nutrient mass balances and calculations of nutrient removal rates that might be achievable in the proposed full-scale reservoirs.

Mr. Keller provided engineering design assistance and water quality performance modeling for the 125-acre Sweetwater Branch/Paynes Prairie Sheetflow Restoration Project in Gainesville, FL. Project elements include in-line trash and sediment removal facilities, three constructed wetland cells to cleanse a combined flow of stormwater runoff and reclaimed water, and a distribution channel to spread water across a mile-wide portion of Paynes Prairie.

Mr. Keller has provided senior engineering design guidance for several large-scale treatment wetland projects in Texas. These include the East Fork Constructed Wetland Treatment System (North Texas Municipal Water District), the Richland Chambers Phase II Wetland Expansion Project (Tarrant Regional Water District), and the City of Beaumont Cattail Marsh.

Mr. Keller has provided senior engineering design guidance for large-scale wetland restoration projects in Arizona including the Tres Rios Environmental Restoration Project (Phase II) and the Va Shly'ay Akimel-Salt River Ecosystem Restoration Project.

Mr. Keller designed a multi-phase project for Gainesville Regional Utilities to demonstrate the feasibility of using constructed treatment wetlands as a means of further polishing reclaimed water while providing a reuse alternative that recharges groundwater levels. The Infiltrating Wetlands Demonstration Project has been implemented to compare the denitrification capacity and infiltration rates in wetlands dominated by emergent vegetation, open water ponds, and traditional rapid infiltration basins (RIBs). Mr. Keller provided design guidance and construction oversight for the project and is conducting monitoring and data analysis at the Kanapaha Middle School (KMS) and the Kanapaha Water Reclamation Facility (KWRF).

Mr. Keller designed a pilot-scale treatment wetland system for the remediation of a groundwater source with high nitrate-nitrogen concentrations. The pilot system consisted of three parallel cells, two of which were operated with supplemental carbon sources (hay mulch and MicroC-G™) to accelerate the denitrification process. At the conclusion of the 14-month study, Mr. Keller prepared a final report that summarized water and nitrogen mass balances,



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estimated nitrate removal kinetics, and provided scale-up calculations and cost estimates for full-scale implementation.

Mr. Keller assisted with an analysis of stormwater pollutant loadings to Lake Parker in Lakeland, Florida. He assisted with delineation of drainage sub-basins, calculation of hydrologic parameters required for modeling the volume of annual stormwater runoff, and selection of the most cost-effective stormwater treatment technologies to reduce pollutant loadings to the lake. Mr. Keller managed the permitting and design of the Lake Parker Southwest Basin Water Quality Enhancement Project, a series of wetlands designed to capture and treat urban runoff discharging to the lake.

Mr. Keller developed conceptual and final designs for several other natural stormwater treatment systems for the City of Lakeland. Two projects, the Buckingham Road Wetland Study and the Lake Parker Tributary Swamp Conceptual Design, evaluated the use of existing, dehydrated forested swamps for stormwater retention and treatment. Mr. Keller designed the Anchor Park Stormwater Treatment Wetland Project for the City of Lakeland which involves the creation of a wetland system to treat stormwater that discharges to Lake Hollingsworth. Mr. Keller also provided senior design assistance for the development of construction plans to convert an existing wet detention system to a wetland treatment system for the Griffin Road sub-basin.

Mr. Keller has provided senior wetland design assistance and water quality modeling for the Lake Hancock Outfall Treatment Wetland in Polk County, Florida. This design was particularly challenging because of the high content of organic nitrogen in this eutrophic lake and the highly variable flow regime at the outlet of the lake. Mr. Keller prepared water quality modeling estimates, design drawings for the wetland planting plan, wetland planting specifications, and elements of the operations and maintenance plan. Another component of the Project was a site-specific investigation of wetland plant establishment and recruitment on the clay soils. Mr. Keller designed a six-cell system to evaluate vegetative community development (planting versus natural recruitment on scraped and excavated substrates) and exotic species (cogon grass) control methods that could be applied to the full-scale project. Mr. Keller evaluated vegetative community composition, water budget, and water quality for a 1-year study period and prepared a report summarizing the findings.

For the SWFWMD, Mr. Keller prepared a technical review of the McIntosh Park Enhanced Stormwater Treatment Wetland facility. Following construction, the system experienced widely variable hydrology and significant mortality of planted vegetation. Mr. Keller evaluated the project design criteria, design documentation, and available hydrologic data and then constructed a detailed water balance to estimate the long-term wetland hydrology. Mr. Keller recommended modifications that could be implemented to improve wetland hydrology and decrease vegetation management issues. In parallel with this effort, Mr. Keller prepared a preliminary feasibility analysis to evaluate whether reclaimed water from Plant City could be used as a supplemental source of water for the wetland system.

Mr. Keller developed a conceptual design for a 40-acre demonstration treatment wetland adjacent to the eastern boundary of Everglades National Park. The design was prepared for the U.S. Army Corps of Engineers to evaluate the phosphorus removal effectiveness of engineered wetland ecosystems.



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Mr. Keller led the final design of a pilot-scale treatment wetland system for the Village of Wellington, Florida. The design combined several different wetland ecosystem types to evaluate the lower limit of phosphorus removal from polluted stormwater. The Village of Wellington Aquatics Pilot Program was the first operational research-scale treatment system to combine floating aquatic plant, emergent marsh, submerged aquatic vegetation, and periphyton ecosystems in series.

Mr. Keller assisted with two projects for the South Florida Water Management District's Ecologically Engineered Systems Research Division. These projects, the Periphyton-based Stormwater Treatment Area (PSTA) and the Managed Wetlands Treatment System (MWTS), are research and demonstration projects designed to assess supplemental technologies to reduce phosphorus loadings in agricultural runoff that discharges to the Everglades. Both projects involved the construction, operation, and performance evaluation of mesocosm-scale and field-scale pilot treatment wetland systems. Mr. Keller assembled the mesocosm-scale system, performed routine water quality monitoring tasks, and led tracer studies to determine the hydraulic characteristics of the various research platforms.

Mr. Keller developed the preliminary and 50% designs for the 150-acre Green Cay Wetlands in Palm Beach County, Florida. The design blended various native wetland habitats with significant public access and educational components.

Mr. Keller completed the design for a 5-acre treatment wetland to be constructed at Cathedral Caverns State Park in Alabama. He was responsible for sizing the wetland to meet specific effluent standards, modeling seasonal variation in wetland performance, and developing design drawings and specifications.

Mr. Keller assisted with the design of the Wakodahatchee Wetlands, a 40-acre constructed wetland treatment system in Palm Beach County, Florida. He evaluated acceptable hydraulic loading rates and modeled the expected treatment performance of the emergent marsh system. Mr. Keller also assisted with development of the planting plan, design of hydraulic control structures, and preparation of construction drawings and specifications. He has also assisted with a feasibility study to create a network of treatment wetland flow-ways through 25 square miles of agricultural land in western Palm Beach County.

Mr. Keller assisted the City of Lakeland with the design of a bypass structure for its wetland treatment system (WTS). The construction of the bypass provided significant operational flexibility, enabling the City to control concentrations of algal solids in the WTS effluent without resorting to the use of algaecides. He has also provided the City with technical assistance, planning, and data interpretation for a lithium chloride tracer study at the WTS.

Mr. Keller assisted with the permit renewal of the Deer Park wetlands treatment system, a 146-acre natural cypress dome system in Pasco County, Florida. This project included analysis of water quality data, nutrient removal modeling to determine possible impacts to the receiving waters, and preparation of an Operations and Monitoring plan.

Mr. Keller assisted with the establishment of baseline monitoring programs for several proposed natural treatment wetlands in northern Florida. He performed both biological and water quality sampling within the wetlands and in the receiving water bodies. Mr. Keller has also performed vegetation, biological, and water quality monitoring for an impounded natural treatment wetland in central Florida.

Mr. Keller has prepared numerous feasibility studies to evaluate the potential application of treatment wetlands technology for municipal and industrial wastewaters, stormwater, and contaminated ground water throughout the United States. Mr. Keller has also designed and permitted several mitigation wetlands in Florida.

Journal Publications / Presentations

Keller, C.H. and J.S. Bays. Hydraulic Considerations and Performance Modeling for Treatment Wetland Design. Presented at the American Ecological Engineering Society's 3rd Annual Meeting - Designing Green Partnerships of Nature and Humanity, College Park, Maryland. May 28-30, 2003.

C.H. Keller. Ecological Engineering in the Consulting Profession: Connecting the Theory with the Practice. Presented at the American Ecological Engineering Society's 2nd Annual Meeting - Ecological Engineering: Implementing the Profession, Burlington, Vermont. April 28-30, 2002.

Zarbock, H.W., C.H. Keller, and A. Adams. Ecological Considerations in Decision Support Systems for Water Resources Enhancement. Presented at AWRA's Decision Support Systems for Water Resources Management, Snowbird, Utah. June 27-30, 2001.

Majer-Newman, J., T. Lynch, and C.H. Keller. Comparison of Tracer Studies from Stormwater Treatment Area 1 West (STA-1W) Test Cells and Mesocosm Tanks. Presented at the Seventh Symposium on Biogeochemistry of Wetlands, Durham, North Carolina. June 17-20, 2001.

Martin, J.R., C.H. Keller, R.A. Clarke, Jr., and R.L. Knight. Long-term Performance Summary for the Boot Wetland Treatment System. Presented at the International Water Association's Seventh International Conference on Wetland Systems for Water Pollution Control, Lake Buena Vista, Florida. November 11-16, 2000.

Keller, C.H. and J.S. Bays. Tracer Studies for Treatment Wetlands. Presented at the Society of Wetland Scientists 21st Annual Meeting – Millennium Wetland Event, Quebec, Canada. August 6-12, 2000.

Bays, J.S., G. Dernlan, H. Hadjimiry, K. Vaith, and C.H. Keller. Treatment Wetlands for Multiple Functions: Wakodahatchee Wetlands, Palm Beach County, Florida. Presented at WEFTEC 2000.

Keller, C.H., J.S. Bays, R.H. Kadlec, and D.P. Gleckler. Lithium Chloride Tracer Study for Treated Municipal Wastewater in Lakeland, Florida. Presented at Wetlands for Wastewater Recycling Conference, Baltimore, Maryland. November 3-5, 1999.

Keller, C.H., J.S. Bays, and D.P. Gleckler. Effluent TSS Improvement at the Lakeland Wetland Treatment System, Florida. Presented at the Society of Wetland Scientists 19th Annual Meeting, Anchorage, Alaska. June 8-12, 1998.

Bays, J.S., C.H. Keller, and R.L. Knight. Structure of an Arid Riparian Ecosystem Receiving Treated Wastewater. Presented at the Society of Wetland Scientists 19th Annual Meeting, Anchorage, Alaska. June 8-12, 1998.

Bays, J.S., C.H. Keller, T.R. Sear, and G.W. Medley. Implementation of the Lake Parker Southwest Basin Water Quality Enhancement Project; Lakeland, Florida. Proceeding of the Fifth Biennial Stormwater Research Conference. Tampa, Florida. November 5-7, 1997.

Ronald A. Clarke, M.S.

Mr. Clarke has 15 years of experience in a number of environmental disciplines, including data management and analyses, water quality and biological monitoring, spring ecology, water quality treatment, and environmental permitting.

Education

M.S., Soil and Water Science, University of Florida (1995)

B.S., Soil and Water Science, University of Florida (1992)

Selected Experience

Mr. Clarke managed water quality and biological monitoring efforts at the SFWMD C-43 and C-44 storage reservoir test cell projects. Monitoring included surface and groundwater sampling within the inflow water supply canal, the test cells, in seepage canals, in wetland test cells (C-44 only), and in surrounding monitoring wells. Test cell sampling included vertical and spatial sampling as well as installation and maintenance of continuous recording multi-parameter data sondes. Mr. Clarke prepared the project QAPP and was responsible for quality control efforts and all data reporting and analysis.

Mr. Clarke has conducted baseline and operational monitoring for a 480-acre natural wetland that receives treated wastewater from the Beaufort-Jasper Water and Sewer Authority in SC. Monitoring activities include wetland hydrology, surface water quality, benthic invertebrates, fish, and wetland plant community composition. He maintains the large database that contains over ten years of environmental data. More recently, 600-acres of additional land has been added to the project for future wastewater application. Mr. Clarke is currently collecting and interpreting baseline data (hydrology, water quality, plant communities, amphibians, and reptiles) for the expansion area and is also evaluating the effects of logging road removal on system hydrology and vegetative restoration efforts.

Mr. Clarke assembled and installed hydrologic monitoring equipment throughout the NASA VAB Hydrologic Restoration & Treatment Wetland (Kennedy Space Center), which consisted of piezometers, automated water level recorders, and staff gauges. Mr. Clarke maintained large database consisting of baseline and five years of operational data. Mr. Clarke analyzed, tabulated, and graphed multiple annual hydrologic and water quality data sets including water level fluctuations; inflows from stormwater and rainfall; discharge from weir, evapotranspiration; infiltration; and pollutant inputs and assimilation rates.

Mr. Clarke assisted with wetland monitoring at GRU Murphree Wellfield; Gainesville. He installed hydrologic monitoring equipment (i.e., piezometers, automated water level recorders, and staff gauges) at eight wetland monitoring sites at Gainesville's Murphree Wellfield. Mr. Clarke downloaded water level data and analyzed hydrologic data to determine changes in the surficial water level at the wetland sites over time, in response to rainfall events, and in proximity to the municipal wells. Mr. Clarke maintains the large hydrologic database for GRU and provides on-going technical input regarding hydrologic monitoring and equipment operation, and provides troubleshooting when needed.



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Mr. Clarke assisted with the Wekiva River Pollutant Load Reduction Goal project for the St. Johns River Water Management District. In this project he designed and conducted field sampling efforts, collected stage, discharge, water quality, sediment, plant community, and ecosystem-level data, and prepared all data analyses and reports.

Mr. Clarke assisted with the Silver Springs 50-Year Retrospective Study conducted for the St. Johns River Water Management District and the Florida Department of Environmental protection. He conducted one year of field data collection, including methods development, field sampling for water quality, macroinvertebrate emergence rates, macrophyte and particulate export rates, and ecosystem metabolism. Mr. Clarke developed an ACCESS™ database for historical and recent data related to Silver Springs.

Mr. Clarke assisted with the Blue Spring Water Resource and Human-Use Value Assessment. He conducted all of the data collection and analyses for this project and assisted with field sampling and report preparation.

Mr. Clarke conducted all of the data collection and analysis of the study of phosphorus assimilation in lakes dominated by submerged aquatic vegetation (SAV) for the South Florida Water Management District. He also was the principal data analyst for the Blue Spring minimum flows and levels project conducted for the St. Johns River Water Management District.

Mr. Clarke provided database management for two projects for the South Florida Water Management District's Ecologically Engineered Systems Research Division. These projects, the Periphyton-based Stormwater Treatment Area (PSTA) and the Managed Wetlands Treatment System (MWTS), are research and demonstration projects designed to assess supplemental wetland-based technologies to reduce phosphorus loadings in agricultural runoff that discharges to the Everglades.

Mr. Clarke assisted with the establishment of baseline monitoring programs for several treatment wetlands, including:

- The Boot Wetland, a 115-acre natural cypress dome wetland in central Florida receiving secondarily treated municipal wastewater since 1984.
- The Blacks Ford Swamp, a 311-acre natural receiving wetland located in northeast Florida receiving treated municipal wastewater since 1999. Mr. Clarke was involved in the baseline monitoring and wetland delineation of the Blacks Ford Swamp and continues to provide assistance with operational monitoring.
- The Harris County Beltway 8 Constructed Wetlands for Highway Runoff Treatment, a 180-acre treatment wetland located in Harris County, Texas to provide renovation of runoff from the Sam Houston Tollroad and to create a public amenity and wildlife habitat.
- The Pace Swamp, a 144-acre natural mixed hardwood swamp in northwest Florida receiving treated municipal wastewater since 1999.

Mr. Clarke assisted in the baseline data collection, including surface water quality sampling, ecological monitoring and identification of hydrologic indicators for several Demonstration Pilot Projects for the St. Johns River Water Management District. These pilot projects are part of

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the Avoidance of Impacts and Alternative Water Supply Strategies in the St. Johns River Water Management District. Two of the projects involved the direct discharge of raw groundwater to impacted wetlands, surface water diversion of storm water, and surface water retention through the removal of drainage ditching. These studies provided an assessment of the feasibility of avoiding projected impacts to native vegetation resulting from the projected increases in groundwater withdrawals.

Mr. Clarke led database design and management efforts for a number of environmental studies including bird monitoring in Port Arthur, TX, and Alachua County, FL Solid Waste Transfer Station; water supply wellfield monitoring for St. Petersburg, FL; and in the Treatment Wetlands North American Database version 2 (NADB v2).

Publications

Mr. Clarke has co-authored a number of technical publications related to water quality, aquatic ecology, and wetlands.

Munch, D. A., E. J. Philips, M. S. Allen, R. L. Knight, R. Clarke, and S. Knight. 2007. Fifty-Year Retrospective Study of the Ecology of Silver Springs, Florida. SJRWMD. SJ2007-SP4

Knight, R.L., B. Gu, R.A. Clarke, and J.M. Newman. 2003. Long-term phosphorus removal in Florida aquatic systems dominated by submerged aquatic vegetation. *Ecol. Eng.* 20: 45-63.

Knight, R.L., R.A. Clarke, and R.K. Bastian. 2000. Treatment Wetlands as Habitat for Wildlife and Humans. Presented at the IWA Wetland Conference, Orlando, Florida. November 13-16.

Martin, J.R, R.A. Clarke, and R.L. Knight. 2000. Ecological Characteristics of a Natural Wetland Receiving Secondary Effluent. IWA, Orlando, Florida. November 13-16.

Martin, J.R, C.H. Keller, R.A. Clarke, and R.L. Knight. 2000. Long-Term Performance Summary for the Boot Wetland Treatment System. IWA, Orlando, Florida. November 13-16.

Bays, J.S., R.L. Knight, L. Wenkert, R.A. Clarke, and S. Gong. 2000. Progress in the Research and Demonstration of Everglades Periphyton-Based Stormwater Treatment Areas. Presented at the IWA Wetland Conference, Orlando, Florida. November 13-16.

Knight, R.L, V.W.E. Payne Jr., R.E. Borer, R.A. Clarke, and J.H. Pries. 2000. Constructed Wetlands for Livestock Wastewater Management. *Ecological Engineering*. 15: 41-55.

Pries, J.H., R.E. Borer, R.A. Clarke, and R.L. Knight. 1999. Performance and Design Considerations of Treatment Wetland Systems for Livestock Wastewater Management in Cold Climate Regions in the Northern United States and Southern Canada.

Clarke, R.A., C.D. Stanley, B.W. MacLeod, and B.L. McNeal. 1997. Relationship of Seasonal Water Quality to Chlorophyll a Concentrations in Lake Manatee, Florida. *Lake and Reserv. Manage.* 13(3): 253-258.

Debra Segal, M.S.

Ms. Segal has more than 20 years' experience providing ecological services throughout Florida. She is an invited speaker at the Florida Chamber's annual Environmental Permitting Short Course and speaks on wetlands delineations and Environmental Resource Permitting. She has also provided wetlands-related lectures at various seminars and wetland classes at UF. Ms. Segal has been instrumental in permitting numerous projects throughout Florida. She has performed wetland delineations, wildlife surveys, UMAM analysis, and overall ecological assessments for all types of projects. She is a hydric soil scientist and has performed soil assessments for wellfield monitoring, minimum flows and levels, wetland delineations, and wetland restoration projects. She has designed and permitted numerous wetland creation, restoration, and enhancement projects throughout Florida. She has overseen construction and implementation of many of these wetland projects and performed post-construction monitoring and reporting.



Education

M.S., Environmental Engineering Sciences, University of Florida (1987)

B.S., Soils and Land Use, University of Florida (1983)

Relevant Experience

Sweetwater Branch Sheetflow Wetland and Paynes Prairie Hydrologic Enhancement Project, Gainesville Regional Utilities and the City of Gainesville, Wetland Permitting Task Manager – Gainesville Regional Utilities and the City of Gainesville plan to implement the largest water resources project in Gainesville's history by constructing a large-scale sheetflow wetland that will improve water quality and hydrologic conditions in Paynes Prairie by treating wastewater and stormwater and sheet-flowing the water onto Paynes Prairie. Wetland permitting will be complicated and potentially controversial as over 200 acres of wetlands will be temporarily or permanently impacted in an area classified as an Aquatic Preserve and a State Park. As wetlands permitting task manager conducted a detailed ecological site assessment of the 500+ acre site with regards to habitat mapping, wetland delineations, and wildlife survey. Performed UMAM analysis for multiple wetland impact scenarios and with multiple wetland types. Assisted in the design of the 125-acre sheetflow emergent marsh that will treat polluted water from an urban stream and discharge the water onto Paynes Prairie. Attended multiple field and office pre-application meetings with regulatory staff from SJRWMD, ACOE, and Alachua County. Developed ecological support material for the permit application that included descriptions of the 11 on-site habitats; wildlife on and surrounding the project site; hydrologic conditions within the multiple wetland communities; jurisdictional wetlands and overall wetland conditions; detailed UMAM spreadsheets with calculations of wetland impacts and wetland functional loss and proposed wetland creation and wetland functional gain; vegetation planting plans for the emergent marsh treatment wetland; post-construction vegetation and wildlife monitoring plans; and sections of the O&M plan as related to vegetation management of the emergent marsh. The 30 percent project design is nearing completion and the permit applications are anticipated to be submitted in the fall.



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Lake Hancock Large-Scale Outfall Treatment Wetland, Southwest Florida Water Management District, Ecology and Permitting Task Manager - Conducted a detailed wildlife survey, wetland jurisdictional assessment, and habitat assessment for a roughly 1,500 acre site for a large-scale (1,000 ac.) treatment wetland. The treatment wetland is designed as a flow-through treatment system to improve water quality in the discharge water of the highly eutrophic Lake Hancock before water discharges to the Peace River and flows down to the Charlotte Harbor estuary. Delineated wetlands and obtained field verification from state (SWFWMD) and federal (ACOE) agencies. Mapped the various habitats throughout the site. Prepared the ecological-related items for the Environmental Resource Permit application. Conducted pre-application field and office meetings with regulatory staff and other stakeholders.

Ecological Monitoring for the Consumptive Use Permit at the Murphree Wellfield, Gainesville Regional Utilities, Project Manager - Assisting Gainesville Regional Utilities with hydrologic and wetland monitoring at designated wetland stations at the Murphree Wellfield in Gainesville in response to requirements for the Consumptive Use Permit. Monitored vegetation, soils, and hydrology at eight wetland monitoring stations and produced annual monitoring reports. Assisted GRU in development and maintenance of their hydrologic database to incorporate additional water level monitoring stations and to include all historic water level data from their existing monitoring program. Also assisted GRU in equipment troubleshooting and in the collection of field quality control measurements to more accurately report water level elevations in the monitoring wetlands.

Consumptive Use Permitting (for Creek and Reservoir Withdrawals) and Ecological Investigations, Georgia Pacific, Wetland Task Manager - Conducted detailed ecological investigations and assisted in producing the permit application support material to renew Georgia Pacific's (GP) Consumptive Use Permit (CUP) for the Palatka paper mill with the SJRWMD. CUP permitting conditions required GP to switch from large withdrawals of groundwater to increased surface water withdrawals. Surface water withdrawals included construction of a new reservoir and increased stream withdrawals from Etonia Creek. As lead wetland scientist, conducted numerous ecological investigations to provide the ecological support data for the CUP application. These investigations included delineating wetlands within the reservoir footprint, evaluating isolated wetlands within the predicted influence area of the existing GP wellfield, performing wildlife surveys within the Etonia Creek study area, and conducting wetland evaluations in the extensive floodplain forest upstream and downstream of the Etonia Creek dam. Assisted in establishing Minimum Flows and Levels in Etonia Creek that would be protective of floodplain vegetation and fish populations during surface water withdrawals. Fish surveys were also conducted by electroshocking upstream and downstream of the dam prior to and after lowering the creek levels. Produced the ecological and wetlands-related information for the CUP application. Attended numerous field meetings with SJRWMD staff and participated in pre-application meetings during the CUP process.

Minimum Flows and Levels, St. Johns River Water Management District (SJRWMD), Project Manager - Provided technical expertise to the SJRWMD in support of their Minimum Flows and Levels (MFL) Program. Conducted detailed soil investigations at more than 35 lakes, creeks, rivers, and wetlands throughout most of the SJRWMD 17-county area. Analyzed and described soils at multiple locations within each transect and transects generally extended from the uplands down through the wetlands. Detailed soil descriptions included describing each soil



C-43 WQTA Test Facility Conceptual Design – Work Plan

horizon with respect to texture, color, thickness, structure, and presence of hydric soil indicators. Produced soil reports for each of the 35+ MFL evaluation sites. Combined soils data with vegetation data and modeling results to assist in determining elevations for Frequent High Water, Minimum Average Water, and Frequent Low Water.

Griffin/Ellsworth Floodplain Enhancement Plan, Southwest Florida Water Management District - Project Manager. Developed a detailed floodplain enhancement plan for a segment of Saddle Creek in Polk County that has been degraded and converted to improved pasture. The goal of the enhancement plan is to enhance wildlife use along the creek, especially for migratory birds. Conducted a detailed vegetation, soil, and topographic assessment of the 184-acre site. Identified and mapped all areas based on hydrologic conditions and denoted those areas as hydric, mesic, and upland. Developed a detailed vegetation planting plan that consisted of plant species, size, spacing, costs, scheduling, installation methods, site preparation monitoring, and maintenance. Attended project meetings and coordinated with various stakeholders to implement this enhancement plan as a wetland mitigation project for Polk County.

Scott L. Knight, P.E.

Mr. Knight is a water resources engineer with 5 years of experience in the fields of environmental and water resources engineering both in consulting and municipal government. His experience includes environmental work including biological assessments, water quality sampling, and water quality modeling. His water resources experience includes hydrologic and hydraulic modeling, stream flow measurement, and consumptive use modeling. His experience has also included water rights law in Colorado and he is familiar with the contentious issues of quantity and the regional struggle for water resources.



Education

Doctor of Philosophy, Expected 2015, Environmental Engineering and Sciences, University of Florida

M.E., Environmental Engineering and Sciences, University of Florida (2005)

B.S., Environmental Engineering and Sciences, University of Florida (2004)

Professional Registration

Professional Engineer: Colorado (No. 43823); Florida (No. 72207)

Relevant Experience

India Agricultural Research Institute, Treatment Wetland Design Evaluation and Recommendations, 2011, Prepared a review of a subsurface flow treatment wetland design. Evaluated hydraulic loading, treatment performance, and potential overloading. Made recommendations on sizing and configuration to meet desired water quality goals. Drafted a memo proposing an alternate treatment configuration.

Three Sisters Treatment Wetland Design, Ongoing 2011, Assisted with development of a conceptual treatment wetland to treat stormwater runoff from an urban area. Worked on modeling of runoff from the contributing urban watershed to determine available flows. Assisted with inflow and outflow options to optimize stormwater capture volume.

Periphyton Stormwater Treatment Area 1 East Treatment Evaluation, 2010-11, Assisted with evaluation of the treatment performance at STA-1E. Worked on nitrogen mass balance and data analysis. Assisted with assessment of rainfall water quality for the site.

Kanapaha Groundwater Recharge Wetlands, Ongoing 2010-11, Assisted with data analysis and sampling of surface and ground water in wetlands. Developed study plan for future phase of study. Developed water budget for future phase of study to estimate infiltration rate of wetland cell.

Alachua County CR 231 Wetland Assessment, Delineation, and Mapping, Prepared GIS field maps for 5-mile roadway resurfacing project in Alachua County. Assisted with wetland jurisdictional assessment and wetland flagging. Delineated and flagged 28 wetlands along CR 231. Assisted with preparation of report and graphics.



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Columbia County Cannon Creek Wetland Assessment, Assisted with wetland jurisdictional assessment and wetland flagging for proposed drainage improvements along Cannon Creek in Columbia County. Also assisted with wetland permitting of drainage improvements.

Union County Wetland Assessment and Permitting, Prepared GIS field maps that depicted potential hydrologic and ecological features within and surrounding a 5-acre project site that was proposed for development. Assisted with the hydrologic and ecological field assessments including jurisdictional wetlands. Assisted with wetland permitting and assessment of off-site potential wetland mitigations areas.

Brantner Ditch Capacity and Loss Study, City of Aurora, CO, Project Manager – Developed a hydraulic model for the Brantner Ditch in Brighton, CO. This is an irrigation ditch with municipal interests. A study was completed to evaluate the capacity of the ditch, constrictions, and ditch loss. This project consisted of three flow measurements to develop percent loss along the ditch during multiple seasons. A HEC-RAS model was completed for the approximately 20 miles of ditch. This model included more than 700 cross-sections, bridges, and other structures. The model was used to determine constrictions and approximate capacity of the ditch.

Floodplain Map Modernization, South West Florida Water Management District (SWFWMD), Engineer Intern – Collaborated on development of hydrologic and hydraulic modeling integrated with GIS applications to develop updated maps for multiple watersheds within the SWFWMD. This work included the use of high resolution (LiDAR) elevation data to map catchments and develop models of predicted flow paths and potential floodplains.

Watershed Management Modeling, Marion County, FL, Engineer Intern – Collaborated on the development of updated floodplains for watersheds within the county using updated high resolution imagery and elevation data. Prepared hydrologic and hydraulic models to estimate inundation for 100-year and 500-year single and multiple day rainfall events. Developed maps displaying updated floodplains and connections.



Attachment B

C-43 WQTA Test Facility Existing Wetland Performance Evaluation (Task 2)

Final Task 2 Report

Evaluation of Total Nitrogen Reduction Options for the C-43 Water Quality Treatment Area Test Facility

Prepared for
South Florida Water Management District

Date
May 2012

Prepared by
Wetland Solutions, Inc.



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Acronyms

AN	Ammonia N
ANAMMOX	Anaerobic ammonium oxidation
BHWTS	Blue Heron Wetland Treatment System
BOD	Biochemical Oxygen Demand
C*	Irreducible background concentration
CaCO ₃	Calcium Carbonate
COD	Chemical Oxygen Demand
CRE	Caloosahatchee River and Estuary
DIN	Dissolved Inorganic Nitrogen
DMSTA2	Dynamic Model for Stormwater Treatment Areas Version 2
DO	Dissolved Oxygen
DON	Dissolved Organic Nitrogen
EAA	Everglades Agricultural Area
EMV	Emergent Macrophyte Vegetation
ENP	Everglades National Park
ENRP	Everglades Nutrient Removal Project
USEPA	US Environmental Protection Agency
FAC	Facultative
FAP	Floating Aquatic Plants
FDEP	Florida Department of Environmental Protection
HLR	Hydraulic Loading Rate
MDL	Minimum Detection Limit
N ₂ O	Nitrous Oxide
NH ₃ -N	Unionized form of AN
NH ₄ -N	Ammonium Nitrogen
NO _x -N	Nitrate+Nitrite Nitrogen
OBL	Obligate
OEW	Orlando Easterly Wetlands
OW	Open Water
POR	Period of Record
Porta-PSTAs	Portable Experimental PSTA Mesocosms
PSTA	Periphyton Stormwater Treatment Area
SAV	Submerged Aquatic Vegetation
SFWMD	South Florida Water Management District
SJRWMD	St. John's River Water Management District
SRP	Soluble Reactive Phosphorus
STAs	Stormwater Treatment Areas
SWFWMD	Southwest Florida Water Management District
TCSTA	Taylor Creek STA
TKN	Total Kjeldahl Nitrogen
TMDL	Total Maximum Daily Loads



TN	Total Nitrogen
TON	Total Organic Nitrogen
TP	Total Phosphorus
TSS	Total Suspended Solids
UPL	Upland
WCA	Water Conservation Areas
WQTA	Water Quality Treatment Area
WSI	Wetland Solutions, Inc.

Section 1.0 Introduction

1.1 Background

Elevated concentrations of nitrogen and phosphorus in the Caloosahatchee River and Estuary (CRE) are contributing to water quality impairments in this system as evidenced by excessive algae blooms and decreased water clarity and dissolved oxygen content (Knight and Steele 2005). The reduction of nutrient concentrations and loads to these water bodies was required by the Northern Everglades and Estuaries Protection Program passed by the Florida Legislature and signed into law in 2007, and by CRE Total Maximum Daily Loads (TMDL) published by the Florida Department of Environmental Protection (FDEP) (Bailey *et al.* 2009) [Rule 62-304.800, Florida Administrative Code (F.A.C.)]. FDEP is currently in the planning stages of the Caloosahatchee Estuary Basin Management Action Plan (BMAP) which is the roadmap to implement the TMDL. Concurrent with the BMAP planning, FDEP is revising the estuary TMDL and developing several tributary and freshwater Caloosahatchee River TMDLs.

The development of numeric nutrient criteria (NNC) is another water quality process with the potential to influence future nutrient targets in the Caloosahatchee River and Estuary. The United States Environmental Protection Agency (USEPA) and FDEP both have their own rulemaking processes that may or may not be reconciled during design or construction of the test facility. The future of both federal and state criteria implementation is therefore uncertain at this time and the details of this dynamic process are beyond the scope of this report.

In order to increase nutrient reductions to the downstream estuary, the South Florida Water Management District (District or SFWMD) and Lee County have been partnering on the C-43 Water Quality Treatment Area Testing Facility Project (the “C-43 WQTA Project”). The purpose of the C-43 WQTA Project is to investigate and demonstrate cost effective strategies for reducing loadings of total nitrogen (TN) and other constituents including total phosphorus (TP) and total suspended solids (TSS) to the C-43 Canal (Caloosahatchee River) to improve water quality in the downstream estuarine ecosystems. The District also anticipated that the C-43 WQTA Project will generate strategies that can be applied to estuaries throughout south Florida.

Through a decade of successful operation of Stormwater Treatment Areas (STAs), the District has built an extensive expertise in TP removal from storm water runoff using wetland treatment systems. However, the mechanisms for TN removal via wetland treatment systems have not been studied to the same extent. The existing data from STAs mostly indicate that currently designed wetland treatment systems are not optimized to reduce TN (especially dissolved organic nitrogen, DON) although they can remove dissolved inorganic nitrogen (DIN) with high efficiency, which accounts for, at most, 20% of the TN present in the CRE system. Thus, the District contracted with CH2M HILL to identify the best option(s) for achieving the C-43 WQTA Project’s goals of nutrient reduction in CRE and to design a test facility prior to construction of the full-scale C-43 WQTA Project. CH2M HILL completed three tasks from 2007-2009, including:

- Initial Data Collection and TN Reduction Technologies Assessment;

- Water Quality Evaluation and Characterization of DON; and
- C-43 WQTA Project Test Facility Conceptual Plan Development.

CH2M HILL's efforts resulted in several deliverables and recommendations, such as developing constructed wetland treatment systems as the most cost-effective means for nutrient removal. The recommended plan included design, construction, and operation of a multi-scale test/demonstration facility on a 1,750-acre parcel (see Exhibit 1) purchased by the District and Lee County for the proposed WQTA. This test/demonstration facility is intended to provide the basis for design of constructed wetlands to assist with ultimate compliance of the CRE TMDL.

Wetland Solutions, Inc. (WSI) has been selected to provide additional expert technical support to develop the detailed C-43 WQTA Project Testing Plan, including a conceptual design of the proposed test facilities and an operational testing plan. This project plan is intended to provide the flexibility to test multiple nitrogen removal approaches to determine which approaches are most effective.



Exhibit 1 - Location of the C-43 Water Quality Treatment and Demonstration Project (top panel) and layout of the test and demonstration cells (bottom panel). (CH2M HILL 2009).

1.2 Project Goals and Objectives

The goal of this project is to develop a conceptual design of a test facility comprised of mesocosms and test cells that: 1) will test and demonstrate wetland technologies that have the potential to effectively remove and/or reduce background TN loading from the facility's C-43 inflows; 2) identifies the range of hydrological loading rates per unit area to achieve optimal removal/reduction rates; 3) is based on a review of available information and sound science; and 4) is implementable and cost effective on larger scales and/or applicable to other south

Florida estuarine systems. Phase 2 will be focused on the design of a full-scale test facility, and construction and operation and maintenance (O&M) for this facility.

The objective of this work is for WSI, with expertise in the field of nitrogen and nutrient removal using constructed wetlands, to develop a conceptual design for a testing facility including testing plans. WSI will conduct an evaluation of relevant treatment options to remove TN using constructed wetlands, propose a conceptual design, which is based on sound science, provide a conceptual design of the testing systems and provide estimated probable construction, operating, and testing costs of the proposed design.

The C-43 WQTA Test Facility Conceptual Design Project has three tasks:

1. Project Management and Communication
2. Evaluation of Total Nitrogen Reduction Options
3. Conceptual Design

This report provides the results of Task 2, namely an updated evaluation of the constructed wetland alternatives for total nitrogen load reduction in the C-43 Basin.

1.3 Evaluation of Total Nitrogen Reduction Options

The objective of this task is to provide a summary of information related to the use of constructed wetland technologies for TN removal with an emphasis on the removal of various TN fractions, including inorganic and organic forms. This evaluation will primarily draw information from the WSI Expert Panel report (WSI 2010) as well as the *Total Nitrogen Reduction Technologies Review* previously conducted by CH2M HILL for the District (CH2M HILL 2008). More recent literature and operational data on TN removal in Florida constructed treatment wetlands has been reviewed and is also summarized. The potential to degrade and remove organic nitrogen fractions in constructed wetland environments is of particular interest for this evaluation since these are the most recalcitrant forms of nitrogen and constitute the principal nitrogen fraction in the CRE system. The CH2M HILL and Expert Panel reports provide a relatively detailed description of the various passive environmental processes that can result in the breakdown of organic nitrogen. The reader is advised to review those documents to learn more about individual nitrogen-removal processes.

This report evaluates relevant treatment options for reduction of TN using constructed wetland systems by comparing and summarizing scientific merits and limitations and associated costs of each treatment system. Based on guidance from District staff, this report focuses attention on the treatment options discussed in the *C-43 Water Quality Treatment Area - Technical Expert Review Panel Consolidated Report* prepared by WSI (2010). The results of this evaluation were discussed by WSI and the District Project Team on April 2, 2012 by teleconference. Approval of the Final Task 2 report by the District Project Team is required for initiation of *Task 3 - Conceptual Design of Nitrogen Removal Technologies for the C-43 Test Facility*. This Task 2 report does not provide detailed design guidance for a full-scale C-43 WQTA. It is intended that design guidance for the proposed full-scale C-43 WQTA will be the outcome of monitoring and analysis of data from the C-43 Test Facility.

Task 3 of this project will include the conceptual plan for the C-43 WQTA test facility. The proposed test facility conceptual plan will include a discussion and rationale for the use of mesocosms as compared to larger test cells, recommended test cell treatments, a preliminary operations and monitoring plan, and estimated costs for design, construction, and operation of the proposed test facility. Experimentation of alternative wetland/aquatic plant communities arranged in different sequences will be conducted in the testing facility at the mesocosm level, larger scale test cells, or both. First consideration will be given to treatment trains comprised of conventional wetland and/or aquatic plant community cells that are optimized for the treatment of total nitrogen through natural microbial and photodegradation processes. Should the operation and sampling of the testing facility reveal that these different treatment trains are not as effective as needed to achieve the TN TMDL, other less-conventional TN removal technologies might be considered at that time.

Section 2.0 General Description of Treatment Wetland Technologies

2.1 Background

Constructed treatment wetlands include a broad variety of technologies that rely on the use of aquatic and wetland plants and associated microbial communities to provide water quality benefits. All constructed treatment wetlands have the following basic characteristics in common:

- One or more shallow (water depths typically average less than three feet) basins that receive, hold, and release water to be treated;
- Treatment process that primarily relies on the growth of hydrophytes (aquatic and wetland plants) and associated microbial biogeochemical processes; and
- Relatively large land area requirement necessary to utilize solar input as the primary energy source for the treatment process.

There are two basic hydrologic variants of constructed treatment wetlands:

- Surface flow wetlands that route water aboveground; and
- Subsurface flow wetlands where water is primarily below ground.

Subsurface flow constructed wetlands have significant hydrologic and cost constraints and are not discussed further in this technology evaluation.

The different types of surface flow constructed treatment wetlands are generally similar in design with the exception of water regime (depth and duration of flooding) and the selection of the appropriate plant community that is adapted to the selected water regime. A considerable variety of hydrophytic plant species are available for use in constructed surface flow treatment wetlands in south Florida. Plant selection for constructed treatment wetlands is based on a number of considerations, including:

- Growth form/habit (floating, submerged, rooted, emergent, etc.);
- Flooding tolerance (saturated soil only, periodic flooding, continuous flooding, etc.);
- Salinity tolerance (strictly freshwater, mildly tolerant, halophyte, etc.);
- Pollution tolerance (oligotrophic, mesotrophic, eutrophic, etc.);
- Resistance to frost (intolerant or tolerant);
- Seasonality (annual, perennial, seasonal, etc.);
- Resistance to pests; and
- Value for wildlife habitat (cover, food, nesting, etc.).

By definition, treatment wetlands are constructed to provide water quality treatment. This implies the presence of pollution or wastes above ambient levels in the water source requiring treatment. Water sources that are commonly treated using wetland technologies include:

- Municipal wastewater;
- Domestic wastewater;
- Urban stormwater;
- Non-point source stormwater;
- Commercial and industrial wastewaters;
- River and lake waters; and
- Polluted groundwaters.

Treatment wetlands have been proven effective for the removal of a wide range of inorganic and organic pollutants. The following pollutants are being attenuated by constructed treatment wetlands, roughly in order of the number of applications worldwide:

- Biochemical oxygen demand (BOD);
- Total suspended solids (TSS);
- Nitrogen (N) forms – total nitrogen (TN), total organic N (TON), ammonia N (AN), and nitrate+nitrite N (NO_x-N);
- Chemical oxygen demand (COD);
- Phosphorus (P) forms – total phosphorus (TP), inorganic or soluble reactive phosphorus (SRP), particulate P, and organic P;
- Trace metals (e.g., arsenic, cadmium, chromium, copper, lead, nickel, silver, and zinc); and
- Trace organics (e.g., pesticides, petroleum, aromatic hydrocarbons, alcohols, aliphatic hydrocarbons, volatile organics, etc.).

The focus of this report is the use of constructed treatment wetlands for reduction of TN concentrations and loads. Pollutants of secondary interest for the C-43 WQTA Project are TSS and TP, and are briefly discussed in this report. While wetlands constructed for TN reduction will provide benefits for removal of many of the other pollutants listed above, they are not explicitly considered further in this document.

2.2 Summary of Nitrogen Chemistry Relevant to Treatment Wetlands

The focus of this report is the use of constructed treatment wetlands for removal of TN, with particular reference to the removal of various forms of TON. This section provides a brief summary of nitrogen chemistry. The reader who needs more information about this subject is referred to the detailed discussion of wetland nitrogen chemistry provided by Kadlec and Wallace (2009) and Reddy and DeLaune (2008).

Nitrogen has five different oxidation states that commonly occur in nature. These range from the most oxidized form - nitrate N (oxidation state +5), to nitrite N (+3), to nitrous oxide (+1), to di-nitrogen gas (0), to ammonium N (-3) and organic N (-3). Di-nitrogen gas (N_2) is the ultimate sink for much of the TN transformed by treatment wetlands. Nitrogen gas makes up about 78% of the atmosphere and due to its triple bond it is relatively stable with the exception of N-fixation processes such as lightning and a small number of plant species that have developed enzyme and energy systems necessary to convert this gas back to dissolved ammonia. Industrial fixation of N_2 has been greatly accelerated by the use of fossil fuel energies and is at least partially responsible for worldwide increases in agricultural production and the resulting global imbalance of nitrogen in the environment and eutrophication of surface waters.

Nitrogen pollution in water frequently occurs as one or more of the four non-gaseous forms of nitrogen and is often assessed as the total combined aqueous form - TN. However the actual mix of individual nitrogen forms in polluted waters is very important for assessing impacts in the receiving water and treatment options for reducing the concentration and load of TN.

For example, TON is derived from organic pollution, often resulting from the discharge of domestic and some industrial wastewaters and from runoff from agricultural areas. Organic N in wastewater and runoff can degrade by physical and microbial mineralization to AN. Other important sources of TON in runoff result from the oxidation and decomposition of organic (peat or mucky) soils and dead plant and animal materials.

Ammonia N may also be high in human and animal wastewaters and in agricultural and urban runoff when liquid ammonia fertilizer is used. Ammonia N is in turn chemically reactive in surface waters where its bacterial transformation exerts a high demand for dissolved oxygen. The unionized form of AN (NH_3 -N) is acutely and chronically toxic to sensitive aquatic organisms. In most aquatic environments most of the AN is in the ionized form known as ammonium (NH_4 -N). Ammonia N is a plant growth nutrient and can stimulate algal blooms. In aerobic aquatic systems, AN can be microbially converted by the process termed “nitrification” to nitrite N which is subsequently converted to nitrate N.

Nitrate and nitrite N are often contained in wastewater and stormwater. Municipal and industrial wastewaters that have received advanced secondary treatment in activated sludge systems commonly discharge TN predominately as NO_x -N. Nitrate and nitrite N are also commonly found in runoff from agricultural and urban areas that use inorganic fertilizers. Nitrite is unstable in aquatic systems and readily converts to nitrate N. For this reason, the two oxidized nitrogen forms are often considered together. Nitrate N is also a plant growth nutrient and can stimulate algal blooms. Nitrate N is readily converted by the microbial denitrification process in constructed treatment wetlands to di-nitrogen gas.

All of these forms of nitrogen are continuously transformed from one compound to another and back again in biological systems, including constructed treatment wetlands. Organic and AN forms release energy when utilized and serve as food for adapted microbes and higher organisms. Oxidized forms of nitrogen (NO_x -N) provide oxygen for microbial metabolism in anaerobic environments and organic energy sources (primarily reduced carbon from wetland plants) are necessary to fuel these transformations. Most of the microbial nitrogen conversions are dependent upon enzymes and catalysts that are relatively specific to the individual conversion processes. Because of the inter-conversion of nitrogen forms in wetlands, it is

necessary to consider a reaction sequence when examining the rate and ultimate fate of various incoming water sources.

To-date there have been limited efforts to design treatment wetlands to optimize nitrogen removal at TN concentrations less than about 3 mg/L (Kadlec and Wallace 2009). A few Florida municipal treatment wetlands do have TN permit limits in the range from 1.6 to 2.3 mg/L (Titusville Blue Heron and Orlando Easterly Wetland, respectively). TN mass reduction goals for the CRE TMDL are 23% of current loads. Based on ambient TN concentrations measured between S-77 and S-79 (1.61 to 1.79 mg/L), this may result in the need to achieve TN concentration targets as low as 1.24 mg/L, less than one half of the 3 mg/L limit for most advanced wastewater treatment projects in Florida. Because of this focus on very low TN concentrations this report summarizes a selection of data from full-scale treatment wetlands that operate at relatively low TN levels, and especially those that have demonstrated the capability to achieve TN concentrations less than 1 mg/L.

2.3 Pollutant Sources and Forms in the C-43 Study Area

A number of authors have estimated the inputs of nitrogen to the Caloosahatchee River/Estuary (CRE) system (Bailey et al. 2009; WSI 2007a; Knight and Steele 2005; JEI 2003; and Doering and Chamberlain 2004). An actual nutrient budget for the Caloosahatchee Watershed has not been done to the same level of detail as that for phosphorus inputs to the Lake Okeechobee Watershed (Hiscock *et al.* 2003). Collectively, the authors identify the following as the principal sources of TN inputs to the study area:

- Atmospheric inputs as rainfall and dryfall, including nitrogen fixation;
- Inputs as fertilizer N;
- Inputs from Lake Okeechobee;
- Inputs in animal and human food;
- Wastewater discharges;
- Mixing with the Gulf of Mexico waters;
- Release of nitrogen from soil oxidation and subsidence.

The following discussion takes a closer look at these TN inputs and their potential contributions of TN loading to the freshwater portion of the river. Before proceeding with that discussion however it is worth pointing out that the water quality data at S-79 was collected every other month while the water quality data for the ambient Caloosahatchee River Estuary sampling was collected every month. The loads and concentrations calculated for S-79 therefore may not be as accurate as those upstream (i.e. S-77 and S-78). Additionally, flow estimates may not reflect all the source data for a structure but are acceptable for comparing the estimated volumes of water that travels through the structures from Lake Okeechobee and the surrounding watershed.

Atmospheric TN inputs include all N forms (particulate, dissolved, inorganic, and organic) and typically average about 10 to 20 kilograms per hectare per year (kg/ha/yr) in the U.S. (Kadlec and Wallace 2009). No known atmospheric TN input estimates specific to south Florida were found. For the C-43 watershed area above the S-79 (2,413 km²) this is equivalent to an estimated

average loading rate ranging from about 2,413 to 4,826 metric tons per year (MT/yr). There is uncertainty on what portion of the TN atmospheric inputs actually reach the C-43 canal. It is likely that a large percentage of atmospheric TN inputs to the C-43 watershed are assimilated or denitrified and never reach the surface waters in the C-43 Canal.

Average annual fertilizer nitrogen inputs to Glades and Hendry Counties were reported by the Florida Department of Agriculture and Consumer Services as 12,625 MT/yr for the 2009-2010 period. Only a portion of these counties' surface area is tributary to the C-43 canal. Much of the N present in fertilizer nitrogen is taken up in crops, assimilated or denitrified and never reaches the river. While estimating the amount of fertilizer nitrogen reaching the river has not been done, there have been estimates of nutrient loading from different land use types in the Caloosahatchee Watershed. In work done for a recent SFWMD document (CRWPP 2012), nutrient loading from watershed contributions upstream of S-79 were estimated at 1,624 Mt/yr based on a 1996-2010 POR. The land use in this area is primarily agricultural (67 percent) followed by natural areas (27 percent).

The estimated average TN input from Lake Okeechobee at S-77 for the period of record between 1965 and 2011 was 1,235 MT/yr. Inputs of total nitrogen associated with Lake Okeechobee discharges are highly variable from year-to-year and have ranged from 190 to 16,842 MT/yr. Animal and human feed related nitrogen loads to the CRE have not been estimated. With the exception of benthic flux analysis in the estuary, internal TN loads to the freshwater portion of the river from soil oxidation and subsidence and the decomposition of plant and animal wastes have not been estimated as well. Neither have TN loads been estimated from the mixing with Gulf of Mexico waters and waste water discharges which inherently are not easily quantifiable.

During extreme conditions of high rainfall and resulting high water releases from Lake Okeechobee, that source likely dominates the TN mass budget for this watershed. The dominant sources of N loads to the CRE are likely to affect the relative proportions of chemical forms of N that will need to be removed by a wetland treatment system.

Of particular interest to the C-43 WQTA Project are the total nitrogen loads and concentrations recorded at the three principal monitoring points in the C-43 Canal, namely S-77, S-78, and S-79 (Exhibit 2). Exhibit 3 provides a summary of these loads and concentrations of the various fractions of TN, as well as TP and TSS, observed at these stations over the period-of-record (POR January 1981-October 2011). Historically, water quality samples at S77 have been collected on at least a monthly basis, depending on flowing conditions. Sampling at this station is scheduled to occur two times during a month. During the first sampling event of the month, samples are only collected if the structure is flowing. Water quality samples are collected regardless if the structure is flowing during the second sampling event of the month. In contrast, water quality samples have been collected on more irregular frequencies at S78 and S79. Typically, water quality samples have been collected approximately once every other month at these two structures. Starting with 2010, samples at these three structures are collected on a weekly basis. Water quality means and extremes for monthly averages are included in Exhibit 3 and reflect the full range of seasonal and annual variation.

The TN entering the C-43 system from Lake Okeechobee has an average concentration of 1.76 mg/L (range 0.29 to 8.12 mg/L) and is predominantly in the organic form (average 1.57 mg/L [89%], range 0.24 to 4.38 mg/L). Nitrate+nitrite N makes up the next most abundant fraction

(average 0.114 mg/L [6.5%], range 0.002 to 6.65 mg/L). Ammonia N averages 0.075 mg/L (4.3% of TN) with an observed range from 0.005 to 1.13 mg/L.

Average TN in C-43 decreases slightly with travel distance downstream. The mean TN concentration at S-78 is 1.64 mg/L and 1.61 mg/L at S-79. The fraction of the TN in the TON form also declines from 89% at S-77 to 85% at S-78 and 78% at S-79. These data indicate that as the distance downstream increases from S-77 to S-79 on average the proportion of the more easily removed inorganic forms increases. On an average concentration basis, the concentration of TON in the C-43 at S-77 is reduced by about 20% by the time it reaches S-79. However, the total TON load increases on average by about 917 MT/yr (83%) with distance downstream between S-77 and S-79.

Total suspended solids concentrations decline along the C-43 from an average of 8.5 mg/L at S-77 to 3.4 mg/L at S-79. TSS loads also decline between S-77 and S-79 on average from 9,593 MT/yr to 6,751 MT/yr respectively.

In contrast to TN and TSS, TP concentrations increase with travel distance downstream, from an average of 0.094 mg/L at S-77 to 0.14 mg/L at S-79 (49% increase). The average TP load also increases between these stations from 61 to 235 MT/yr.

These data illustrate the observation that the concentrations of TN and TSS generally decrease as water travels along the C-43 Canal and that the fraction of organic nitrogen also declines along this waterway. The estimated average TSS load also declines downstream while the TN mass load increases significantly. TP concentrations and loads increase with distance downstream.

2.4 Discussion of Nitrogen Removal Processes in Treatment Wetlands

Total nitrogen concentrations are reduced in treatment wetlands through a sequence of chemical and microbial processes (Kadlec and Wallace 2009). Organic N must be mineralized to inorganic N forms before it can be further oxidized and ultimately removed via denitrification. This section briefly summarizes each of the basic unit processes that occur in treatment wetlands designed for N removal.

2.4.1 Organic Nitrogen Removal

Organic N in the environment may be in simple forms (e.g., urea and uric acid) or moderately to highly complex organic molecules that include amines, amides, purines, and pyrimidines. Organic N primarily in the form of amino acids comprises from 1-7% of the dry weight of plants and animals (Kadlec and Wallace 2009). Urea and uric acid are readily converted in treatment wetlands to AN by chemical or microbial hydrolyzation. More complex organic N forms are often associated with aromatic organic molecules and have varying resistance to mineralization. Some of the more recalcitrant forms of TON, which have half-lives of months to years, require conditioning (i.e. cleaving of amine groups from complex organic molecules) and development of specific microbial communities (i.e. adaptation) that are capable of metabolizing complex TON molecules.

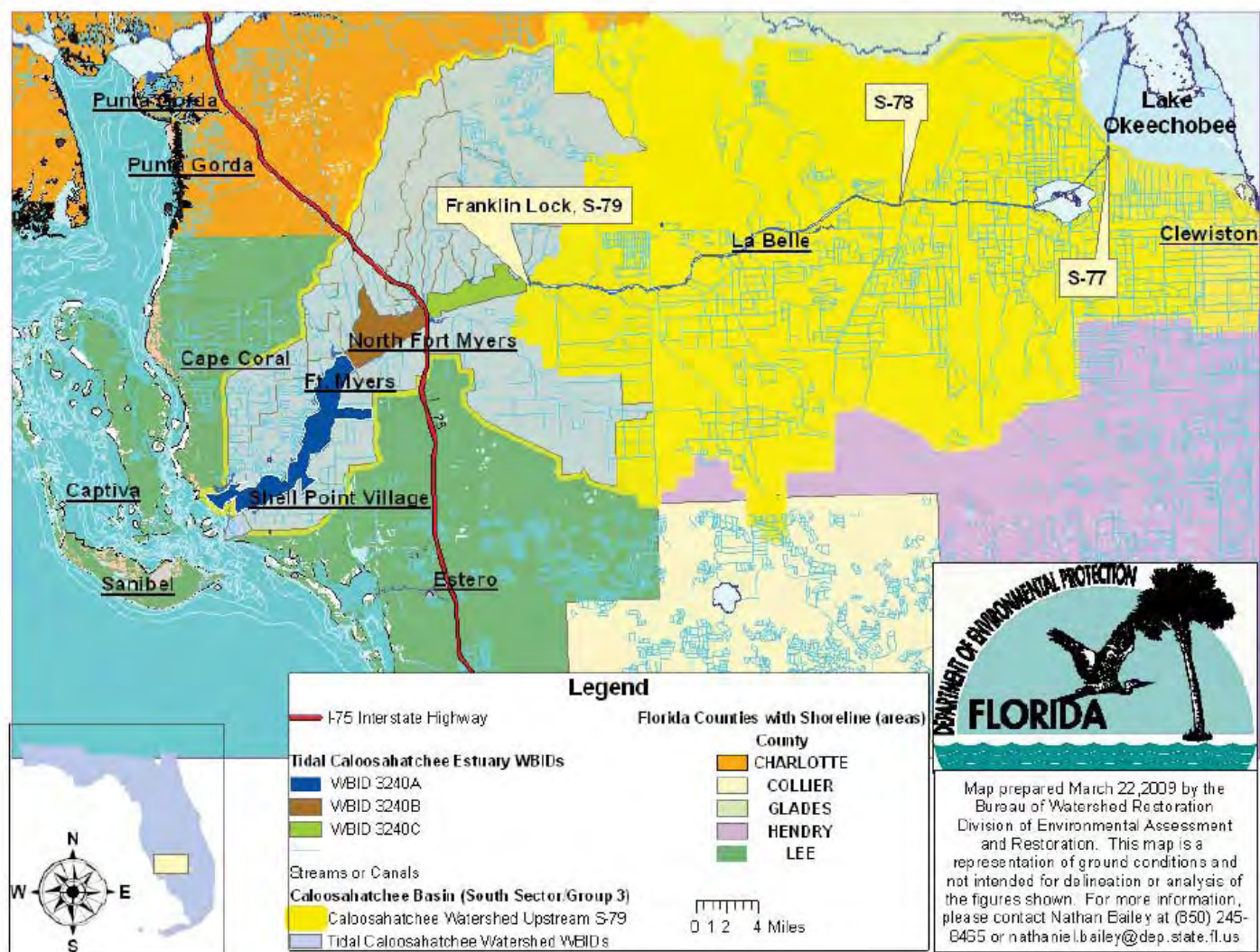


Exhibit 2 - Location of the C-43 Water Discharge and Quality Sampling Stations Referenced in Exhibit 3. (Bailey et al. 2009).

Exhibit 3 - Caloosahatchee River Flows and Nutrient Concentrations and Cumulative Loads at Structures S-77, S-78, S-79 (SFWMD DBHYDRO, January 1981 - October 2011). Values are Averages of Monthly Data (n refers to the number of months in each average)

Structure	Stats	Flow cfs	TP		TN		ON		TKN		NOx-N		NH ₄ -N		TSS	
			mg/L	MT/yr	mg/L	MT/yr	mg/L	MT/yr	mg/L	MT/yr	mg/L	MT/yr	mg/L	MT/yr	mg/L	MT/yr
S-77	Avg	755	0.094	60.8	1.76	1,235	1.57	1,105	1.65	1,149	0.114	84.5	0.075	42.9	8.46	9,593
	Median	164	0.075	13.3	1.65	331	1.50	309	1.56	316	0.056	7.26	0.048	6.90	6.00	1,204
	Min	-879	0.020	0.010	0.294	0.190	0.245	0.178	0.250	0.182	0.002	0.008	0.005	0.004	0.500	0.685
	Max	8,330	0.392	0,846	8.12	16,842	4.38	16,607	4.75	16,743	6.65	1,780	1.13	1,001	103	299,635
	StdDev	1,415	0.060	117	0.633	2,274	0.482	2,047	0.519	2,117	0.344	227	0.097	103	9.76	25,546
	N	560	449	410	450	411	447	408	451	412	450	411	447	408	402	364
S-78	Avg	997	0.131	115	1.64	1,465	1.40	1,252	1.45	1,327	0.195	150	0.059	72.2	4.43	7,267
	Median	357	0.117	44.4	1.50	610	1.30	0,515	1.34	0,531	0.096	40	0.040	10.6	3.00	1,128
	Min	0.229	0.039	0.029	0.349	0.429	0.245	0.43	0.250	0.43	0.002	0.001	0.005	0.002	0.500	1.43
	Max	8,724	0.561	0,904	11.4	13,295	3.34	10,448	3.37	11,059	9.85	3,092	0.390	0,750	36.0	227,476
	StdDev	1,527	0.066	170	0.825	2,205	0.437	1,912	0.447	2,005	0.703	344	0.060	128	5.00	23,025
	N	466	203	185	199	181	195	177	202	184	201	183	197	179	183	174
S-79	Avg	1,730	0.140	235	1.61	2,532	1.26	2,021	1.31	2,146	0.308	409	0.045	92.4	3.44	6,751
	Median	798	0.128	114	1.46	1,425	1.15	1,018	1.19	1,057	0.256	170	0.033	22.9	1.50	1,944
	Min	0.00	0.051	0.52	0.330	5.44	0.210	3.91	0.250	4.01	0.002	0.197	0.003	0.039	0.500	2.54
	Max	10,928	0.460	1,973	10.8	13,276	5.05	10,549	5.06	11,124	9.63	7,351	0.279	811	22.0	72,006
	StdDev	2,169	0.062	298	0.802	2,902	0.468	2,407	0.464	2,530	0.692	699	0.042	146	3.41	11,998
	N	546	199	194	197	192	191	186	199	194	198	193	192	187	193	188

S-77 DBKEY: P1022 (01/1965-12/2005); 15635 (01/2006-08/2011)

S-78 DBKEY: 00857 (07/1971-09/2003); WN161 (10/2003-04/2010)

S-79 DBKEY: 00865 (05/1966-10/2011)

2.4.2 Ammonia Nitrogen Removal

Ammonia N is highly reactive in wetland environments. Ammonia N is the generally preferred form of N for plant uptake and assimilation into plant organic matter. Ammonia N is nitrified to $\text{NO}_x\text{-N}$ in aerobic wetland environments that have high microbial populations. Aerated ponds and wetland deep zones are not particularly effective for this conversion because of the relative absence of suspended or attached nitrifying bacteria. Shallow wetlands with high water velocity generally provide enough dissolved oxygen by diffusion from the atmosphere to provide higher rates of nitrification. Alkalinity is consumed in the nitrification process and low alkalinity can result in diminished rates of AN conversion to $\text{NO}_x\text{-N}$. Additional AN removal processes that are known to occur in treatment wetlands include ammonia volatilization, anaerobic ammonium oxidation (anammox) and other related anaerobic pathways (Kadlec and Wallace 2009). Ammonia N must be in the unionized form to be susceptible to volatilization and this is somewhat limited to very high pH and temperature conditions that do not typically occur in treatment wetlands. Open-water pond areas dominated by phytoplanktonic algae are likely to have the highest rates of AN volatilization (Kadlec and Wallace 2009). Anammox and related AN transformation processes appear to rely on $\text{NO}_x\text{-N}$ as an electron acceptor, thereby competing with denitrification in treatment wetlands (see below) and having lower kinetic rate constants than aerobic nitrification. For this reason, the anammox biogeochemical pathway is not currently considered responsible for a significant amount of AN removal in wetland treatment systems with light to moderate AN loading rates.

2.4.3 Nitrate+Nitrite Nitrogen Removal

Nitrate+nitrite N is highly reactive in anaerobic wetland environments, especially at the interface between the detritus/sediments with the water column. Assimilatory nitrate reduction consists of the conversion of nitrate to ammonia and subsequent cell synthesis. In dissimilatory nitrate reduction, anaerobic bacteria use these forms of nitrogen to provide electron acceptors (oxygen) for their decomposition of organic carbon to carbon dioxide. Organic carbon produced by the decaying plants and dead microbes in the wetland sediments and detritus layers provide the energy resource for this heterotrophic process. There is extensive evidence in the literature that most nitrate disappearance in full-scale treatment wetlands is primarily due to the denitrification reaction rather than due to undocumented internal storages of the compound (Kadlec and Wallace 2009). Denitrification is generally the ultimate nitrogen sink in treatment wetlands since the byproducts are gases – namely nitrous oxide (N_2O) and N_2 . The denitrification process in treatment wetlands is generally considered to be complete, with little to no N_2O (a potential air pollutant) produced. Di-nitrogen gas is relatively inert and is the dominant gas in the earth's atmosphere.

2.5 Design Considerations

2.5.1 Optimizing the Total Nitrogen Treatment Process

The above discussion can be summarized as follows:

- In a treatment wetland or a series of wetland-based treatment steps, the removal of TN from a polluted water source will only occur through a sequential biological process;

- The rate of this overall TN removal process is limited by its slowest intermediate step;
- To achieve effective TN removal in a treatment wetland it is essential that no step in the N sequential transformation is omitted;
- It is also essential to maximize the efficiency of each N transformation step to the extent possible allowed by optimal biological process rates.

Based on this summary, it is concluded that the preliminary step or steps in the N transformation process should be focused on TON mineralization. TON in the source waters to the proposed C-43 WQTA Project are thought to be particularly recalcitrant (CH2M HILL 2009). When biologically-available TON is converted to AN early in the wetland process, this will allow greater time for nitrification and denitrification in the downstream portions of the wetland treatment system. However, since some forms of biologically-available TON are more recalcitrant than others, it is necessary to provide continuing favorable conditions for TON mineralization throughout the downstream wetland treatment train. The Expert Panel recommended that the District consider developing an analytical indicator to rapidly assess the biological availability of TON in the CRE system (WSI 2010). It was suggested that this test might be based on a modification of the commonly-used analytical procedure to measure TKN, e.g., a modified digestion sequence using something less reactive than the sulfuric acid that mineralizes TON to AN in the TKN test.

The Expert Panel also concluded that five unit processes that hold most promise included: a very shallow (<15 cm) emergent wetland marsh for nitrification, a classic emergent wetland (about 30 to 45 cm deep) for denitrification, a deeper water mixed wetland or slough dominated by a mix of FAP, SAV, and tolerant rooted plants for long hydraulic residence time and conversion of BDON to DIN, an innovative POP (Periphyton-enhanced Oxidative Photodegradation) mixed open water wetland system with pulsed operation for physical DON degradation, and a final polishing emergent marsh for removal of DIN and algal solids. With the exception of POP, these unit processes are considered conventional and likely candidates for evaluation in the testing facility. Since WSI was unable to locate any data or information about full-scale applications for the POP unit process, it is considered to be “unconventional” (experimental) and is not evaluated further in this report. However, the periphyton-dominated treatment process discussed below shares a similar algal-dominated plant community with POP and, if evaluated in the test facility, a periphyton-dominated process can be manipulated to simulate POP.

In most treatment wetlands receiving pretreated municipal wastewater, nitrification of AN is the rate-limiting step. While this is not expected for the C-43 WQTA Project source water, it indicates that for those forms of TON that can be readily decomposed in a wetland, the most limiting transformation is likely to be nitrification of AN. For this reason, it will be important to optimize the nitrification process beginning near the front end of the treatment wetland process train. Ammonia is the principal ingredient needed for nitrification. For AN removal in treatment wetlands there are two potential constraints of primary interest – adequate dissolved oxygen (DO) and alkalinity. From 4.3 to 4.6 grams of O₂ are required for each gram of AN oxidized in the nitrification process (Kadlec and Wallace 2009). This oxygen is typically supplied from the oxygen in the atmosphere by the physical process of oxygen diffusion. One empirical method used to reduce DO limitations is to increase oxygen diffusion by increasing

water velocity. For a given hydraulic loading rate, shallow, narrow, and longer wetlands have the highest velocities.

Alkalinity is also consumed during the nitrification of AN, resulting in a loss of about 7.1 g of alkalinity (as calcium carbonate [CaCO₃]) per gram of AN nitrified (Kadlec and Wallace 2009). Alkalinity is critical to buffer the pH of a treatment wetland used for nitrification. This is because the nitrification process produces hydrogen ions, which must be neutralized by the wetland to maintain the optimum pH range for nitrification (reported to be from 7.2 to 9.0 in wastewater treatment systems by Metcalf and Eddy 1991). For this analysis, it is assumed that alkalinity is high enough in C-43 source waters (average values of 116 to 148 mg/L as calcium carbonate from S-77 to S-79) that it is not likely to limit the removal of the relatively low concentrations of AN expected.

Denitrification is typically the last microbial N transformation needed in treatment wetlands. In addition to the reactant (nitrate N), the availability of reduced organic carbon is essential for this biogeochemical process. Kadlec and Wallace (2009) estimate an average organic carbon requirement of about 3.0 grams of organic matter per gram of nitrate N. Denitrification is favored under anaerobic conditions. With these two considerations in mind, the optimal treatment wetland system for denitrification is generally thought to be a system with high organic carbon production in close proximity to anaerobic conditions suitable for the growth of denitrifying bacteria. These conditions are met in almost all well-vegetated treatment wetlands.

There are also other variables that will be important in design of a full-scale C-43 WQTA for lowering concentrations of TN. One factor of high importance will be the seasonal and annual variability of source water chemistry. Depending on the origin of flow, water in the C-43 shows considerable variability as evidenced by the data summarized in Exhibit 3. This variability and the ability of a full-scale WQTA system is an important consideration in preliminary design and is not discussed further in this report. Other design criteria of importance that will be developed based on results from the proposed C-43 WQTA Test Facility will include: hydraulic loading rate, water depth, plant community composition, and soil suitability.

Possible operational strategies for a full-scale C-43 WQTA will also need to be considered during final design. The occurrence of dry-outs or controlled burns on plant community composition and mobilization of nutrients are important operational issues. More information on a variety of possible management strategies will be provided in the Task 3 report that describes the recommended operations plan for the Test Facility.

2.5.2 Treatment Wetland Plant Communities

Plant communities in existing treatment wetlands have been described in a number of available publications (Kadlec and Wallace 2009, Kadlec and Knight 1996, Vymazal *et al.* 1998). The use of the term “treatment wetland” is inclusive in this report. All low energy “natural” aquatic treatment systems are included under the treatment wetland epithet. This includes wetlands and aquatic ecosystems dominated by a range of non-vascular to vascular vegetation, including open water systems dominated by planktonic algae, systems dominated by masses of filamentous algae, and wetlands dominated by vascular plant communities including rooted, submerged, and floating aquatic herbaceous (non-woody) plants. In this sense, the following ecosystem types are included in this definition: pond, slough, and marsh. Forested wetlands

(swamps) are not included in this discussion since they have not shown as much promise for water quality performance as wetland systems dominated by herbaceous plant species (Kadlec and Knight 1996).

In general, similar or identical plant types and species are utilized in treatment wetlands worldwide. Specific plant species recommended for use in south Florida, and particularly in treatment wetlands to be developed in the vicinity of the C-43 basin are well known, both from experience with the Everglades Agricultural Area (EAA) STAs south of Lake Okeechobee and from a variety of full and pilot-scale constructed wetlands in south and central Florida north of the Lake (e.g., Taylor Creek STA, the Periphyton Stormwater Treatment Area (PSTA) test projects, Lakeland Constructed Wetland, Apopka Wetland, Titusville Blue Heron Wetland, and Orlando Easterly Wetland in Orange County).

Five general plant community types typically can be found in constructed treatment wetlands and STAs:

- Emergent macrophyte vegetation (EMV)
- Submerged aquatic vegetation (SAV)
- Floating aquatic plants (FAP)
- Attached and floating algal-dominated systems algae (PSTA or periphyton stormwater treatment area)
- Open water (OW)

The dominant plant community in most constructed treatment wetlands is EMV (Kadlec and Knight 1996). EMV wetlands typically have average water depths less than 1 meter (m) and the dominant plants are rooted in the wetland sediments. Since the majority of plant productivity in these wetlands takes place above the water level, EMV wetlands typically have low dissolved oxygen concentrations in the water column. This plant community type has been found to be highly reliable for nutrient removal in most applications and is likely to be the first choice for constructed water quality treatment wetlands in the C-43 basin southwest of Lake Okeechobee. All nitrogen reduction processes, including mineralization or TON, nitrification of AN, and denitrification of NO_x-N have been demonstrated in EMV systems.

The use of SAV as a dominant plant community was first carefully evaluated for enhanced phosphorus concentration reduction south of Lake Okeechobee in the District's EAA STAs. Now this plant community is being used extensively at those locations. One large constructed wetland in central Florida (Orlando Easterly Project) has converted EMV to SAV in some downstream cells in an effort to enhance TP removal rates. SAV may or may not be rooted and most plant biomass is within the water column and below the water surface. For this reason, the primary productivity of these systems generally results in high daily concentrations of dissolved oxygen. Water depths in SAV cells are typically greater than 1 m and may be up to 6 or more meters deep. SAV systems are expected to incorporate all of the nitrogen reduction processes listed above for EMV systems, but with higher or lower effective rate constants as evaluated below.

Floating Aquatic Vegetation plant communities have been used extensively in treatment ponds throughout the southern U.S. and data are available from California and Texas for nutrient removal in ponds dominated by either water hyacinth or duckweed. A few pilot-scale FAP systems have been monitored in south Florida. Historically, the Everglades Nutrient Removal Project's (ENRP) Buffer Cell included about 39% cover by a FAP plant community. FAP is generally not rooted and these systems typically have deeper water conditions than EMV and SAV systems (greater than 2 m) and this water depth is generally effective at excluding significant colonization of these systems by EMV plants. FAP systems typically shade out other plants and algae in the water column and have very low levels of dissolved oxygen. FAP systems are expected to incorporate all of the nitrogen reduction processes listed above for EMV systems, but with higher or lower effective rate constants as evaluated below.

Algal-dominated wetlands include relatively shallow systems with attached and/or floating filamentous algae. This algae community may be called *aufwuchs*, periphyton, epiphytic, benthic, or floating. PSTA is used as a convenient descriptor for this highly variable treatment wetland plant community. POP (periphyton-enhanced oxidative photodegradation) systems also fit into this category. Typical water depths in algal-dominated treatment systems are less than 0.6 m. Since algal productivity occurs in the water column, these PSTA systems have high daily concentrations of dissolved oxygen. This category does not include the Algal Turf Scrubber technology since those systems are highly managed through continuous harvesting and biomass disposal. PSTA systems are expected to incorporate all of the nitrogen reduction processes listed above for EMV systems, but with higher or lower effective rate constants as evaluated below.

Open water treatment wetlands include a variety of shallow ponds and lakes where floating aquatic plants are excluded by use of herbicides and/or wind fetch (large dimensions). These open water systems typically have average water depths greater than 2 m and are dominated by planktonic (free-floating) unicellular and colonial algae species. Treatment ponds and open water areas in treatment wetlands are typically aerobic near the surface of the water column due to high algal productivity, but also may be anaerobic at the level of the sediments due to high sediment oxygen demand. OW systems are expected to incorporate all of the nitrogen reduction processes listed above for EMV systems, but with higher or lower effective rate constants as evaluated below.

2.5.3 Wetland Plant Community Maintenance

In most treatment wetlands, a specific plant community is initially specified by the designer, planted following the completion of site grading, and watered during establishment with site water. While survival of planted species is not typically 100%, these species can be established with care in relatively predictable plant assemblages or monospecific stands. In the EAA STAs, plant community establishment has generally relied on little to no planting and natural recruitment of adapted wetland plant species following construction and site hydration. For SAV systems, emergent macrophytes are increasingly being planted to keep SAV species in place and to improve system hydraulics.

Following initial plant establishment and startup, plant community composition often deviates from plan and follows a course dictated by the multiple environmental influences of water depth and flooding duration, water quality, pre-existing seed bank in site soils, weather,

herbivorous insects, and other fauna and plant diseases. Over time, all plant communities in treatment wetlands tend to deviate from the original planned assemblage unless they are rigorously maintained. These shifts are not necessarily detrimental to wetland water quality treatment performance. In light of minimizing unproductive costs, maintenance activities in constructed wetlands should be limited to only as much as necessary to maintain the desired wetland plant community type – not a preordained list of “desirable” plant species.

Emergent and submerged aquatic plant communities have been identified as being most desirable for STA performance south of Lake Okeechobee. The actual plant communities occurring in the existing STAs and in most other treatment wetlands are much more complex than indicated by general terms such as “emergent” or “submerged aquatic”. A total of 121 plant species (not including algae) have been reported from the EAA STAs (Chimney 2012, in press). Exhibit 4 provides an edited list of the dominant plant species currently recorded from the existing south Florida STAs. When possible all plant species in this list are categorized into three groups based on their origin (native or exotic), their general tolerance to flooding as indicated by the classification scheme developed by the U.S. Fish and Wildlife Service (ranging from obligate [OBL] at the wet end of the hydrologic spectrum, through facultative [FAC, FACW, and FACU] in the middle, and to upland [UPL] at the driest end of the spectrum), and their growth habit (emergent, submerged, floating, shrub = woody, or vines). While most of these species are herbaceous (soft plant tissues) a few are woody (such as willow, primrose willow, wax myrtle, and elderberry). This list primarily includes obligate and facultative wetland plant species and does not include upland plant species that have been observed in the STAs along the levee side slopes and under highly unfavorable conditions of extended drought.

2.5.4 Emergent Wetland Plant Communities

The majority of wetlands constructed for water quality improvement worldwide and in the U.S. have targeted an emergent plant community (Kadlec and Knight 1996). Dominant species used in these EMV designs have included:

- *Typha* spp. (cattail)
- *Phragmites communis* (common reed)
- *Schoenoplectus* (*Scirpus*) spp. (bulrush)

These particular plant species have been favored worldwide in treatment wetlands for two primary reasons: they are highly tolerant of continuous inundation (at least in the root zone) and they are highly productive and produce a large amount of fixed carbon that is essential for most of the water quality purification microbial processes that occur in treatment wetlands. The published literature for treatment wetlands shows no consistent preference for any single emergent plant species for phosphorus removal but does indicate that wetlands with emergent plants are significantly more effective than systems without plants (open water). An EMV plant community was favored in early south Florida STA designs due to the proven track record of this plant community type in dozens of constructed wetlands designed for phosphorus removal and due to its occurrence in Water Conservation Area (WCA) 2A which was used as a data source for initial STA process design (Kadlec and Newman 1992).

The ENRP Project was the prototype for all later STA designs and principally relied on natural recruitment by cattail (primarily *Typha domingensis*). A variety of other emergent wetland plant species were purposely planted in the ENRP, but this practice was found to be cost-prohibitive and unnecessary for meeting Phase 1 Everglades Construction Project phosphorus removal goals. While cattail-dominated treatment wetlands are highly effective for water quality improvement, tolerant of a wide range of water levels and hydraulic loading rates, and require minimal maintenance, cattail monocultures are not typical in the STAs. In addition to dominance of the plant community by cattails, a mix of emergent and floating plant species is typical of all of the existing south Florida STA EMV cells. Bulrush species (*Schoenoplectus* [*Scirpus*] spp.) have been recorded in STA 1-W and STA 1-E where they were purposely planted and common reed has not been reported from any of the south Florida STAs. For these reasons, cattails are the primary species of choice in EMV STA cells south of Lake Okeechobee.

Cattails dominated three of the original four cells in the ENRP for more than five years following construction and initial vegetation recruitment. Experience gained in the ENRP and in its later incarnation as STA 1-W indicated that cattail would continue to dominate the wetland plant community as long as water depths were adequate but not too deep. Long-term periods with high hydraulic loading rates to STA 1-W resulted in prolonged water depths greater than 2 feet in STA 1-W cells 1-3 and the gradual attrition of the dominant cattail community until water levels were subsequently lowered. There is good evidence from STA 1-W that an emergent wetland plant community will shift to an ecosystem dominated by floating and/or submerged aquatic species when water depths consistently exceed about 2 feet.

Colonization and disturbance history are also important in establishing an emergent wetland plant community. Natural recruitment of cattail and other desirable wetland emergent species is retarded in the presence of an existing upland plant community such as exotic grasses or shrubs. With careful site preparation and water management during construction, cattail recruitment can be optimized (GGI 2005). Once an emergent plant community dominated by cattails is established it is resilient to invasion by upland plant species during droughts. However, an EMV plant community with poor cover and open un-vegetated areas is susceptible to invasion by competitive upland plant species following an extended drought.

In summary, the target EMV plant community is dominated by a high cover of cattail. Based on the list presented in Exhibit 4 and from experience from other Florida constructed treatment wetlands, other emergent plant species that could also contribute to high primary productivity and plant cover in STA emergent zones include the following:

- *Eleocharis* spp. (spikerush)
- *Schoenoplectus* spp. (bulrush)
- *Cladium jamaicense* (sawgrass)
- *Pontederia cordata* (pickerelweed)
- *Panicum hemitomonum* (maidencane)
- *Sagittaria* spp. (duck potato/arrowhead)

However, due to the hydrological and water quality conditions in continuously-flooded EMV treatment wetlands, only the first three of these species, spikerush, bulrush, and sawgrass, are likely to be candidates as suitable alternative dominants in south Florida. The last three plant species in this list (pickerelweed, maidencane, and duck potato) are all intolerant of continuous deep flooding.

2.5.5 Submerged Aquatic Vegetation Wetland Plant Community

Following construction in 1994, Cell 4 of the ENRP/STA 1-W was intentionally treated with herbicides to encourage a non-emergent wetland plant community. The original intention was to create an open water/mixed marsh/periphyton dominated system that was similar to plant communities in WCA 2A and in the natural Everglades wetland mosaic that were known to predominate in areas of low phosphorus concentrations. The actual result of herbicide applications in Cell 4 was the creation of a deep-water wetland dominated by two submerged aquatic plant species, *Najas guadalupensis* (southern naiad) and *Ceratophyllum demersum* (coontail). After about five years of operation of Cell 4 with this SAV plant community, phosphorus removal results were remarkable in this cell, both in terms of the first-order area-based phosphorus removal rate constant and with respect to the lowest achievable P concentration.

Concurrent research in a variety of experimental mesocosms helped to verify and refine these full-scale results and subsequently led the District to an across-the-board program to replace downstream cattail emergent cells in all of the STAs with SAV cells. This re-engineering has had mixed success as various unexpected consequences of wetland plant ecology have been experienced by the District. *Hydrilla verticillata* (hydrilla), an exotic and invasive species, has been found to be highly competitive with the desired SAV species (southern naiad and coontail) and is now tolerated, although not preferred, in SAV cells. Herbicide control of hydrilla has not been effective in the STAs (Toth, pers. comm. 2008). All SAV plant communities were adversely affected by high water velocities induced by excessive hydraulic loading rates or by high winds during hurricanes. Use of transverse emergent plant zones at frequent intervals across SAV-dominated STA cells has been adopted as a reasonable method to counteract wind or velocity-induced wholesale movement of SAV. SAV plant species are also easily impacted by continuous shading due to highly colored inflow waters and by floating aquatic plants such as *Eichhornia crassipes* (water hyacinth) and *Hydrocotyle* spp. (pennywort). Perhaps the most significant challenge for maintenance of SAV-dominated plant communities in south Florida STAs is drought management. Most SAV species cannot withstand extensive periods of dryout and may be totally replaced by open-water conditions following a drought. Even after a short period of dry down, most SAV plant communities require an extended period of several months to re-establish pre-drought plant biomass levels. Wholesale loss of SAV plant species during a drought may require costly re-inoculation when adequate water inflows are re-established.

Exhibit 4 - Dominant Plants Occurring in the Everglades Agricultural Area STAs (Data assembled by Mike Chimney 2012)

SPECIES	COMMON NAME	STA-1E	STA-1W	STA-2	STA-3/4	STA-5	STA-6	ORIGIN	HABITAT	COMMUNITY TYPE
<i>Acrostichum danaeifolium</i>	giant leather fern		X	X				NAT	OBL	EMV
<i>Alternanthera philoxeroides</i>	alligatorweed	X	X		X	X	X	EXO	OBL	EMV
<i>Amaranthus australis</i>	southern amaranth; southern waterhemp	X	X			X		NAT	OBL	EMV
<i>Azolla caroliniana</i>	Carolina mosquitofern	X	X	X	X	X		NAT	OBL	FAP
<i>Bacopa caroliniana</i>	lemon bacopa; blue waterhyssop		X		X			NAT	OBL	EMV
<i>Bacopa monnieri</i>	herb-of-grace; smooth waterhyssop		X		X			NAT	OBL	EMV
<i>Ceratophyllum demersum</i>	coontail	X	X	X	X	X		NAT	OBL	SAV
<i>Chara sp.</i>	muskgrass	X	X	X	X	X	X	NAT	OBL	SAV
<i>Cladium jamaicense</i>	Jamaica swamp sawgrass		X	X	X		X	NAT	OBL	EMV
<i>Commelina sp.</i>	dayflower	X	X					-	FACW	EMV
<i>Cyperus esculentus</i>	yellow nutgrass; chufa flatsedge	X	X					EXO	FAC	EMV
<i>Cyperus sp.</i>	sedge		X		X	X		-	FACW	EMV
<i>Eichhornia crassipes</i>	common water hyacinth		X			X		EXO	OBL	FAP
<i>Eleocharis interstincta</i>	knotted spikerush	X	X		X		X	NAT	OBL	EMV

Exhibit 4 - Dominant Plants Occurring in the Everglades Agricultural Area STAs (Data assembled by Mike Chimney 2012)

SPECIES	COMMON NAME	STA-1E	STA-1W	STA-2	STA-3/4	STA-5	STA-6	ORIGIN	HABITAT	COMMUNITY TYPE
<i>Eleocharis sp.</i>	spikerush		X	X				NAT	OBL	EMV
<i>Equisetum sp.</i>	horsetail; scouring rush		X			X		-	FACW	EMV
<i>Eupatorium capillifolium</i>	dogfennel		X			X		NAT	FAC	EMV
<i>Hydrilla verticillata</i>	waterhyme; hydrilla	X	X	X	X	X		EXO	OBL	SAV
<i>Hydrocotyle sp.</i>	marshpennywort	X	X		X	X		-	FACW	EMV
<i>Ipomoea cordatotriloba</i>	tievine		X			X		NAT	FACU	EMV
<i>Lemna sp.</i>	duckweed	X	X	X	X	X	X	NAT	OBL	FAP
<i>Limnobium spongia</i>	American spongeplant; frog's-bit		X			X		NAT	OBL	FAP
<i>Ludwigia peruviana</i>	Peruvian primrosewillow	X	X		X	X		EXO	OBL	EMV
<i>Ludwigia repens</i>	creeping primrosewillow; red ludwigia	X	X	X	X	X		NAT	OBL	SAV
<i>Mikania scandens</i>	climbing hempvine		X		X	X	X	NAT	FACW	VINE
<i>Myrica cerifera</i>	southern bayberry; wax myrtle			X	X			NAT	FAC	EMV
<i>Najas guadalupensis</i>	southern waternymph; southern naiad	X	X	X	X	X		NAT	OBL	SAV
<i>Nuphar advena</i>	spatterdock; yellow pondlily				X	X		NAT	OBL	FAP

Exhibit 4 - Dominant Plants Occurring in the Everglades Agricultural Area STAs (Data assembled by Mike Chimney 2012)

SPECIES	COMMON NAME	STA-1E	STA-1W	STA-2	STA-3/4	STA-5	STA-6	ORIGIN	HABITAT	COMMUNITY TYPE
<i>Nymphaea odorata</i>	American white waterlily; fragrant waterlily		X	X	X	X	X	NAT	OBL	FAP
<i>Nymphoides aquatica</i>	big floatingheart; banana lily	X			X	X		NAT	OBL	FAP
<i>Panicum hemitomon</i>	maidencane	X	X	X	X	X	X	NAT	OBL	EMV
<i>Panicum repens</i>	torpedograss	X	X	X	X	X	X	EXO	FACW	EMV
<i>Panicum sp.</i>	-	X	X		X	X		-	FACW	-
<i>Phyla nodiflora</i>	turkey tangle fogfruit; capeweed	X	X					NAT	FAC	EMV
<i>Pistia stratiotes</i>	water lettuce	X	X	X	X	X		NAT	OBL	FLT
<i>Pluchea odorata</i>	sweetscent		X		X			NAT	FACW	EMV
<i>Polygonum sp.</i>	smartweed; knotweed	X	X	X	X	X	X	-	OBL	EMV
<i>Pontederia cordata</i>	pickerelweed		X	X	X	X	X	NAT	OBL	EMV
<i>Potamogeton sp.</i>	pondweed		X	X	X	X		-	OBL	SAV
<i>Sagittaria kurziana</i>	springtape; strap-leaf sagittaria		X		X			NAT	OBL	SAV
<i>Sagittaria lancifolia</i>	bulltongue arrowhead; duck potato	X	X	X	X	X	X	NAT	OBL	EMV
<i>Sagittaria latifolia</i>	broadleaf arrowhead; duck potato		X	X			X	NAT	OBL	EMV

Exhibit 4 - Dominant Plants Occurring in the Everglades Agricultural Area STAs (Data assembled by Mike Chimney 2012)

SPECIES	COMMON NAME	STA-1E	STA-1W	STA-2	STA-3/4	STA-5	STA-6	ORIGIN	HABITAT	COMMUNITY TYPE
<i>Sagittaria sp.</i>	arrowhead				X		X	-	OBL	-
<i>Salix caroliniana</i>	carolina willow; coastalplain willow	X	X	X	X	X	X	NAT	OBL	EMV
<i>Salvinia minima</i>	water spangles; water fern		X	X	X	X	X	EXO	OBL	FAP
<i>Sambucus nigra</i>	American elder; elderberry		X			X		NAT	FACW	EMV
<i>Sarcostemma clausum</i>	white twinevine		X	X	X	X	X	NAT	FACW	VINE
<i>Spirodela polyrhiza</i>	common duckweed; giant duckweed		X			X		NAT	OBL	FAP
<i>Typha domingensis</i>	southern cattail	X	X	X	X	X	X	NAT	OBL	EMV
<i>Typha sp.</i>	cattail	X	X	X	X	X	X	-	OBL	EMV
<i>Urochloa mutica</i>	paragrass					X	X	EXO	FACW	EMV
<i>Utricularia floridana</i>	Florida yellow bladderwort			X		X	X	NAT	OBL	SAV
<i>Utricularia sp.</i>	bladderwort	X	X		X	X	X	NAT	OBL	SAV
Taxa Counts		26	47	26	37	39	22			

In summary, the most desirable SAV species in the STAs are southern naiad and coontail. Other SAV species such as *Potamogeton* spp. (pondweed) and *Sagittaria kurtziana* (strap-leaf sagittaria) that occur rarely and at low densities in the STAs are not considered viable substitutes for the two species listed above. Other subdominant SAV plant species such as *Utricularia* spp. (bladderwort) and the macroalga *Chara* spp. (muskgrass) are also found in the south Florida SAV plant communities and occasionally occur at high densities. However, these species do not prefer habitats with elevated phosphorus concentrations and these species are not expected to provide acceptable phosphorus removal rates.

2.5.6 Floating Aquatic Vegetation Wetland Plant Community

The two floating aquatic plant species that have been most widely used in nutrient removal treatment wetlands are water hyacinth (*Eichornia crassipes*) and a variety of duckweed and related small-leaved species (*Lemna minor*, *Lemna* spp., *Spirodela*, etc.). Other floating leaved wetland plants that are often found in treatment wetlands include pennywort (*Hydrocotyle* spp.), frog's bit (*Limnobium spongia*), water lettuce (*Pistia stratiodes*), water lily (*Nymphaea* spp.), and spatterdock (*Nuphar luteum*). Pennywort, water lily, and spatterdock are all rooted plants capable of growing in deeper water locations (up to about 2 m). The other species can grow at greater water depths as long as they are not continually dispersed by wind and currents.

FAP species are particularly effective at shading the underlying water column, preventing the growth of planktonic or attached algae. The water column in FAP treatment systems is typically dark and low in dissolved oxygen. Aerobic treatment processes such as nitrification of AN are severely limited in FAP systems.

2.5.7 Periphyton-Dominated Wetlands

Periphyton-dominated stormwater treatment area (PSTA) systems have been extensively studied in south Florida (CH2M HILL 2003a; Kadlec and Walker 2003; Goforth 2011; WSI and Anamar 2011). Periphyton is a complex plant community composed of blue-green algae, green algae, diatoms, fungi, bacteria, micro- and macroinvertebrates, and detrital material that colonize submerged surfaces in aquatic systems. Everglades periphyton occurs as benthic mats growing underwater on the sediment surface (epipelon); benthic mats that have become unattached from the sediments and rise to the water surface forming floating mats (metaphyton); or attached to the surface of rocks (epilithic) or plant surfaces (epiphyton). The taxonomic composition of Everglades periphyton varies as a function of water chemistry and hydroperiod. Calcareous periphyton, which is recognized by a prevalence of filamentous blue-green algae and diatoms, dominate in areas of the Everglades with short hydroperiods (short periods of inundation followed by dessication), low TP concentrations (<20 ppb), high calcium concentrations (>50 milligrams per liter [mg/L]), and relatively high pH (6.9 to 7.5). At the other end of the environmental spectrum that includes longer hydroperiods, lower calcium concentrations (<5 mg/L), lower pH (5 to 7), and higher TP concentrations (>20 to 50 ppb), periphyton assemblages are often dominated by a greater percentage of species of filamentous green algae and desmids.

Peat soils were found to encourage undesirable colonization by emergent vegetation and discouraged the colonization by periphyton. Shellrock, sand, and limerock soils were all found

to be viable options for development of periphyton biomass. It was anticipated that some level of macrophyte management would be required in PSTAs built on any substrate.

Based on this review of existing published results and findings (WSI and Anamar 2011), the success of PSTA relies on the following principal design and operational considerations:

- Construction of a relatively shallow, level impoundment (less than about 60 cm in average water depth);
- Use of a substrate/sediment that has very low antecedent concentrations of available P;
- Moderate to low (< 20 ppb) inflow phosphorus concentrations;
- Adequate dissolved calcium available in the source water and/or in the substrate; and
- Maintenance of a relatively low density of emergent or floating vegetation.

2.5.8 Open Water Systems

Areas of perennially deep (greater than 1 m) open water in south Florida are typically dominated by floating aquatic plants, submerged aquatic plants, or planktonic algae (phytoplankton). These three plant community types are somewhat mutually exclusive due to their competition for nutrients and light. Floating aquatic plant dominance is optimized by smaller open water areas that have less wind fetch. Larger open water systems (with dimensions greater than a few hundred m) tend to be free of floating aquatic vegetation unless there are barriers that help to anchor the plants against windy conditions. These barriers may be islands, relic trees in impoundments, and even topped-out submerged aquatic vegetation. In relatively large open-water areas such as lakes and reservoirs, phytoplankton dominates the plant community. These unicellular and colonial algae are free floating and can form massive algal blooms under conditions of high nutrients. Water quality in these systems is characterized by highly variable concentrations of dissolved oxygen and pH and production of large amounts of total suspended solids.

2.5.9 Hydrologic Optima and Tolerance Ranges for Target Treatment Wetland Plant Communities

All wetland plants exhibit tolerance to a range of hydrologic conditions. The optimal portion of this range can be considered the zone where a given plant species is able to maximize its net primary production, resulting in the greatest amount of accumulated plant tissue in a given growing season. The range of tolerance to flooding may be considered as the portion of the water regime between low and high water conditions where the plant is actually found in natural field conditions (under competitive stress from other plants and due to grazing by wildlife). While many wetland plants in the absence of competing species actually have their highest growth rates in saturated but unflooded conditions, in the competitive environment that occurs in constructed wetlands, the optimal plant growth may occur in deeper water due to exclusion of upland plant species that would otherwise compete for sunlight and nutrients.

Plant tolerance to a range of hydrologic conditions can best be observed by looking for zonation of plant communities over a vertical gradient. Ideal data sets are most likely to be collected from bowl-shaped wetlands and lakes with long periods of hydrologic data collection. In such an ideal study site plant communities typically follow a progression of upland species at the

highest elevations, through facultative and obligate wetland species with distance down gradient. Plant community zonation in response to water depth variation may be much more difficult to observe in relatively level wetlands where water depth does not vary along a gradient but is more stochastic.

Based on previous reviews (Kadlec and Knight 1996; WSI 2009) the following specific depth ranges and average are suggested for each of these plant communities:

- EMV – average 45 to 60 cm
- PSTA – 60 to 90 cm
- SAV – 90 to 120 cm
- FAP – 1 to 2 m
- OW – >2 m

Currently, there is no single publication that summarizes plant gradient studies and tolerance ranges in Florida or that synthesizes these data into a general model that can be used to predict plant survival under a range of water regimes. Until such a comprehensive synthesis is available, it is still advantageous to analyze relevant local data to develop general hydrologic tolerance ranges for the target EMV and SAV wetland plant communities.

2.5.10 Other Treatment Wetland Plant Community Design Considerations

Treatment wetland (i.e., STA) design is not one-dimensional and multiple constraints must be met in order to create a successful project (Kadlec and Wallace 2009; WSI 2009). Owners and operators of wetland systems frequently inquire as to the optimum value for any particular variable that is under the designer's control. The reality of wetland design and behavior is that all of the key design parameters are inter-related and any adjustment to one may cause a response in one or more of the others. In many cases, the reaction of one variable to the manipulation of another is counteractive to water quality improvement processes. For example, increasing aspect ratio presumably to improve hydraulic efficiency and pollutant removal effectiveness will, at some threshold inflow rate, increase frictional losses to the point that hydrologic impacts to the wetland vegetation occur and pollutant removal actually decreases. At the other end of the spectrum, lowering hydraulic loading rates to levels that minimize outflow pollutant concentrations could starve the wetland for water if evapotranspiration and seepage demands are not met.

Section 3.0 Performance Summary for Florida Treatment Wetlands

3.1 Background

Florida has long been a leader in the engineering, operation, and optimization of treatment wetlands. Starting with the Cypress Dome Natural Treatment Wetland project in the mid-1970s, a dozen other natural treatment wetlands, the first two large constructed treatment wetlands in 1987 (Lakeland and Orlando) and at least a half dozen other municipal systems, the south Florida Stormwater Treatment Areas (STAs), and dozens of large and small-scale urban and agricultural stormwater treatment wetlands, Florida systems include a broad range of treatment wetland alternatives. Treatment wetland data reviewed for this evaluation are limited to Florida systems because they have reported very complete and intensive water quality and operational data and because they are most similar to the proposed C-43 WQTA treatment wetland project in terms of climatic variables, incoming water quality, soil properties, and biological communities.

Exhibit 5 lists the treatment wetland systems evaluated for this summary. Exhibit 6 provides a map showing the locations of these pilot and full-scale treatment wetland projects in central and south Florida. These projects cover a very broad range of conditions, including inflow nitrogen and phosphorus concentrations and forms, soils diversity, loading rates, and effluent concentrations. This performance evaluation is empirical in that it compares actual operational data for these systems and does not rely on model estimates. Pollutant-specific kinetic rate constants based on the k-C* model of Kadlec and Knight (1996) and the p-k-C* model of Kadlec and Wallace (2009) do not include the level of detail needed for this evaluation since they do not separate systems by plant community dominants, water depth, presence of open water, and site soil conditions. Calibrated values for a variety of treatment wetland plant communities are available for removal of TP using the Dynamic Model for Stormwater Treatment Areas version 2 (DMSTA2) supported by Walker and Kadlec (2008).

The reader is cautioned that there is some operational and analytical uncertainty in the data used for these analyses. This uncertainty is variable between data sets and could not be quantified by WSI for this evaluation. For example, Minimum Detection Limits (MDLs) may vary in some labs from year-to-year and researchers may report levels less than the MDL using different protocols. In some cases flow-weighted means were reported and in others only arithmetic means were available. These uncertainties result in statistical errors of unknown magnitude at the lower pollutant concentrations. One half of the MDL was used by WSI in generating statistics when researchers identified values below the MDL. The various treatment wetlands described below also have a wide range of design and operational variation that is incompletely known. The purpose of this analysis is to look at a large body of empirical data from a wide variety of Florida full-scale treatment wetland systems. Using this approach it is assumed that important data trends can be observed and that, if data trends are not obvious, they are probably not important or reproducible. Also, it is not likely to be productive for this evaluation of wetland treatment options to dwell too much on the inter-annual behavior of treatment wetlands experiencing a wide range of environmental variables. For these reasons

WSI does not attempt to offer informed conclusions about why treatment systems had positive nutrient removal performance in some years and negative removals in other years.

Exhibit 5 - Summary of Design Criteria for Existing Treatment Sites Evaluated

System	Area (ha)	HLR (cm/d)	Period-of-Record		Substrate	Vegetation
Phase I Apopka Marsh Flow-Way						
Cell B1	67.99	11.31	Nov-03	Dec-09	PEAT	EMERGENT
Cell B2	45.73	13.82	Nov-03	Dec-09	PEAT	EMERGENT
Cell C1	74.06	11.75	Nov-03	Dec-09	PEAT	EMERGENT
Cell C2	73.25	10.51	Nov-03	Dec-09	PEAT	EMERGENT
C-43 West Storage Reservoir Test Cell						
Cell 1	1.82	5.15	Jun-06	May-07	SAND	OPEN
Cell 2	1.82	5.15	Jun-06	May-07	SAND	OPEN
C-44 Reservoir / Stormwater Treatment Area Test Cells						
STA Cell 1	1.74	3.35	Jul-06	Dec-06	SAND	EMERGENT
STA Cell 2	1.74	7.82	Jul-06	Dec-06	SAND	EMERGENT
Test Cell 1	1.50	3.59	Jul-06	Jun-07	SAND	OPEN
Test Cell 2	1.50	4.60	Jul-06	Jun-07	SAND	OPEN
City of Lakeland Wetland Treatment System Cell 1						
Cell 1	81.40	3.84	Jan-87	Sep-08	CLAY	EMERGENT
Cell 2	77.33	3.43	Jan-87	Sep-08	CLAY	EMERGENT
Cell 3	166.87	2.07	Jan-87	Sep-08	CLAY	EMERGENT
Cell 4	30.53	9.02	Jan-87	Sep-08	CLAY	EMERGENT
Cell 5	93.61	1.12	Jan-87	Sep-08	CLAY	SAV
Cell 6	19.94	6.89	Jan-87	Sep-08	CLAY	FAP
Cell 7	14.25	7.80	Jan-87	Sep-08	CLAY	FAP
Orlando Easterly Wetlands	485.64	1.15	Jan-88	Nov-11	SAND	EMERGENT
SFWMD Field-Scale PSTA Cells						
FS-1	2.08	8.37	Aug-01	Dec-02	LIME ROCK	PSTA
FS-2	2.08	12.07	Sep-01	Dec-02	LIME ROCK	PSTA
FS-3	2.08	9.27	Aug-01	Dec-02	LIME ROCK	PSTA
FS-4	2.08	11.03	Nov-01	Dec-02	PEAT	PSTA
SFWMD Porta-PSTA Mesocosms Treatments						
Treatment 1	0.0006	7.17	Apr-99	Jan-00	PEAT	PSTA
Treatment 2	0.0006	7.11	Apr-99	Jan-00	LIME ROCK	PSTA
Treatment 3	0.0006	7.18	Apr-99	Feb-01	PEAT	PSTA
Treatment 4	0.0006	7.49	Apr-99	Feb-01	LIME ROCK	PSTA
Treatment 5	0.0006	13.84	Apr-99	Mar-00	LIME ROCK	PSTA
Treatment 6	0.0006	5.54	Apr-99	Mar-00	LIME ROCK	PSTA
Treatment 7	0.0006	7.36	Apr-99	Feb-01	SAND	PSTA
Treatment 8	0.0006	7.32	Apr-99	Jan-00	SAND	PSTA
Treatment 9	0.0006	7.32	Apr-99	Mar-00	PEAT	OPEN
Treatment 10	0.0006	7.14	Apr-99	Mar-00	LIME ROCK	OPEN
Treatment 11	0.0018	7.78	Apr-99	Feb-01	LIME ROCK	PSTA
Treatment 12	0.0018	7.63	Apr-99	Feb-01	PEAT	PSTA
Treatment 13	0.0006	8.14	Apr-00	Feb-01	PEAT	PSTA
Treatment 14	0.0006	8.03	Apr-00	Feb-01	LIME ROCK	PSTA
Treatment 15	0.0006	7.40	Apr-00	Feb-01	LIME ROCK	PSTA
Treatment 16	0.0006	15.69	May-00	Feb-01	LIME ROCK	PSTA
Treatment 17	0.0006	7.49	Apr-00	Feb-01	SAND	PSTA
Treatment 18	0.0006	8.11	Apr-00	Feb-01	NONE	OPEN
Treatment 19	0.0006	7.84	Apr-00	Feb-01	NONE	PSTA
SFWMD PSTA Test Cells Treatments						
Treatment 1	0.26	4.57	Feb-99	Jan-00	PEAT	PSTA
Treatment 2	0.26	4.65	Feb-99	Mar-00	LIME ROCK	PSTA
Treatment 3	0.26	4.03	Feb-99	Mar-00	LIME ROCK	PSTA
Treatment 4	0.24	5.08	Apr-00	Mar-01	PEAT	PSTA
Treatment 5	0.24	5.14	Apr-00	Mar-01	LIME ROCK	PSTA
Treatment 6	0.25	5.35	May-00	Mar-01	LIME ROCK	PSTA
STA-1E						
Cell 3	214.48	7.28	May-06	Jan-12	SAND	EMERGENT
Cell 4N	257.35	6.38	May-06	Jan-12	SAND	SAV
Cell 4S	291.98	6.92	May-06	Jan-12	PEAT	SAV
Cell 5	209.19	3.25	May-06	Jan-12	SAND	EMERGENT
Cell 6	417.65	3.27	May-06	Jan-12	PEAT	SAV
Cell 7	166.33	3.55	May-06	Jan-12	PEAT	EMERGENT

Exhibit 5 Cont. - Summary of Design Criteria for Existing Treatment Sites Evaluated

System	Area (ha)	HLR (cm/d)	Period-of-Record		Substrate	Vegetation
STA-1W						
Cell 1	602.99	8.46	Jun-00	Jan-08	PEAT	EMERGENT
Cell 1A	301.51	10.21	May-08	Jan-12	PEAT	EMERGENT
Cell 1B+3	716.70	5.40	May-08	Jan-12	PEAT	SAV
Cell 2	380.82	6.44	Jun-00	Nov-04	PEAT	EMERGENT
Cell 3	415.22	9.31	Jun-00	Jan-08	PEAT	EMERGENT
Cell 4	144.88	18.39	Jun-00	Nov-04	PEAT	SAV
North Flow-way	1155.38	3.08	Jun-00	Feb-12	PEAT	SAV
West Flow-way	525.69	3.36	Feb-08	Feb-12	PEAT	SAV
STA-2						
Cell 1A	805.00	2.41	Mar-02	May-05	PEAT	EMERGENT
Cell 1B	805.00	2.39	Jun-05	Feb-12	PEAT	EMERGENT
Cell 2	898.00	3.97	Mar-02	Feb-12	PEAT	EMERGENT
Cell 3	898.00	3.86	Mar-02	Feb-12	PEAT	SAV
Cell 4	769.71	1.19	Feb-08	Feb-12	PEAT	SAV
STA-3/4						
Cell 1A	1229.84	4.61	May-05	Jan-12	PEAT	EMERGENT
Cell 1B	1411.55	5.40	May-05	Feb-12	PEAT	SAV
Cell 2A	1028.71	4.65	May-05	Jan-12	PEAT	EMERGENT
Cell 2B	1171.16	4.54	May-05	Feb-12	PEAT	SAV
Cell 3A	871.29	6.17	Apr-08	Feb-12	PEAT	EMERGENT
Cell 3B	982.17	10.04	Apr-08	Nov-11	PEAT	SAV
STA-5						
Cell 1A	337.91	3.09	Apr-08	Feb-12	PEAT	EMERGENT
Cell 1B	493.72	3.80	Apr-08	Jan-12	PEAT	SAV
Cell 2A	337.91	3.54	Apr-08	Feb-12	PEAT	EMERGENT
Cell 2B	493.72	2.66	Apr-08	Feb-12	PEAT	SAV
Cell 3A	405.50	0.68	Apr-08	Feb-12	PEAT	EMERGENT
Cell 3B	397.81	0.83	Apr-08	Feb-12	PEAT	SAV
Center Flow-way	831.63	2.58	May-00	Mar-08	PEAT	EMERGENT
North Flow-way	803.30	3.48	May-00	Mar-08	PEAT	EMERGENT
STA-6						
Cell 3	99.00	2.89	Oct-02	Feb-12	PEAT	EMERGENT
Cell 5	253.00	2.46	Oct-02	Feb-12	PEAT	EMERGENT
Section 2	561.30	3.13	May-08	Oct-11	PEAT	SAV
Taylor Creek Pilot STA	57.47	7.29	Jun-08	Jan-12	SAND	EMERGENT
City of Titusville, Blue Heron Wetland	101.56	0.65	Jan-97	Dec-11	SAND	EMERGENT
Wellington Aquatics Pilot Test Facility						
Cell E1	0.055	26.97	Nov-01	Feb-03	SAND	EMERGENT
Cell E2	0.044	19.08	Nov-01	Feb-03	SAND	SAV
Cell E3	0.049	19.82	Nov-01	Feb-03	LIME ROCK	PSTA
Cell W1	0.047	33.49	Nov-01	Feb-03	SAND	FAP
Cell W2	0.055	13.30	Nov-01	Feb-03	SAND	EMERGENT
Cell W3	0.049	11.77	Nov-01	Feb-03	LIME ROCK	PSTA

HLR = Hydraulic Loading Rate

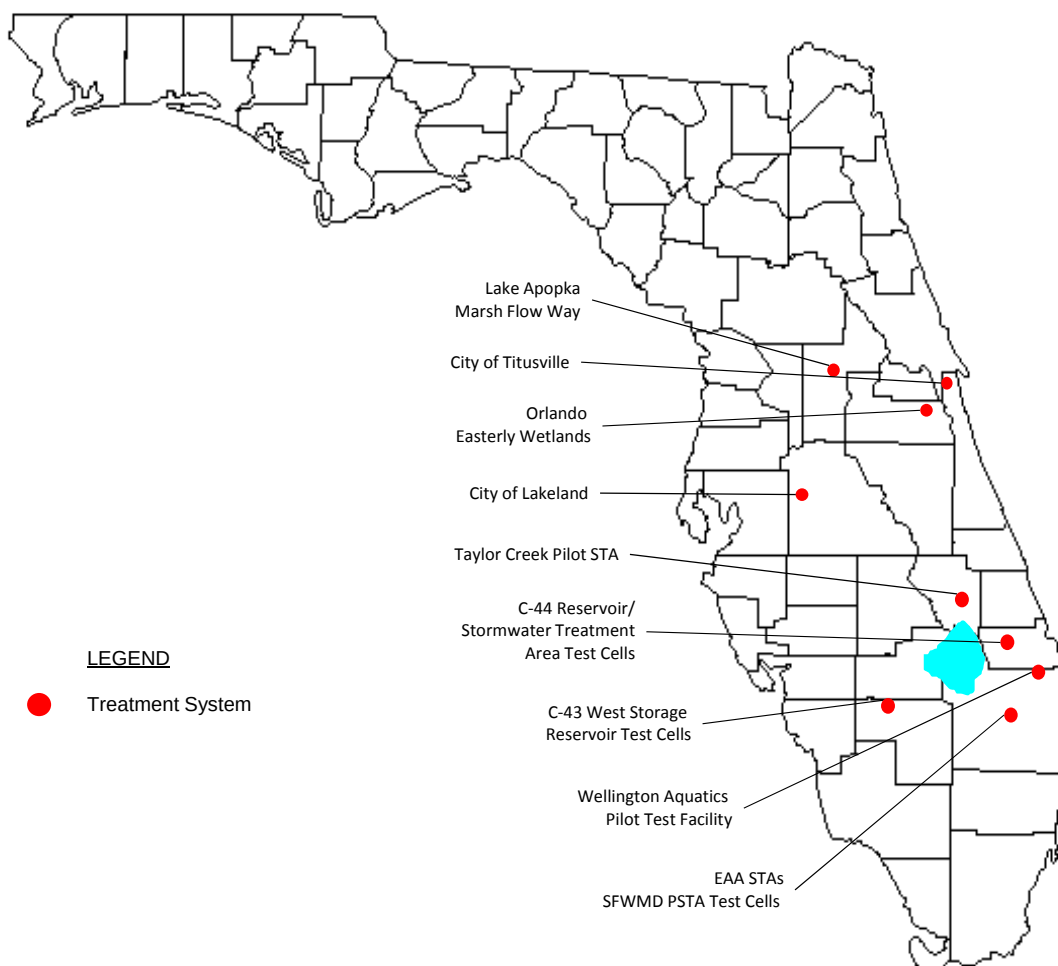


Exhibit 6 - Location of Reviewed Florida Treatment Wetland Sites

3.2 Description of Florida Treatment Wetlands Reviewed for Performance Evaluation

3.2.1 Everglades Agricultural Area Stormwater Treatment Areas

The SFWMD has constructed massive treatment wetland projects, the STAs, to improve water quality in discharges to the Water Conservation Areas (WCAs) and Everglades National Park (ENP). To date, the SFWMD has constructed six STAs south of Lake Okeechobee, each ranging in size from approximately 2,250 acres (910 ha) to over 16,500 acres (6,680 ha). Exhibit 7 provides a map of the Everglades Agricultural Area (EAA) and the locations of these six STAs. Exhibit 8 provides site plans, cell configurations, and structure locations for each of the EAA STAs.

The EAA STAs were largely constructed on land that was formerly used for agricultural operations such as sugar-cane production, sod production, and citrus groves. Existing substrates ranged from sandy mineral soils to very thick organic peat soils to exposed limestone caprock. The majority of the vegetation in the STAs was established through volunteer recruitment. Existing STA plant communities are diverse with a mixture of emergent wetland vegetation including cattails and bulrush, submerged aquatic vegetation such as southern naiad and coontail, and floating aquatic plant species such as water hyacinth and duckweed.

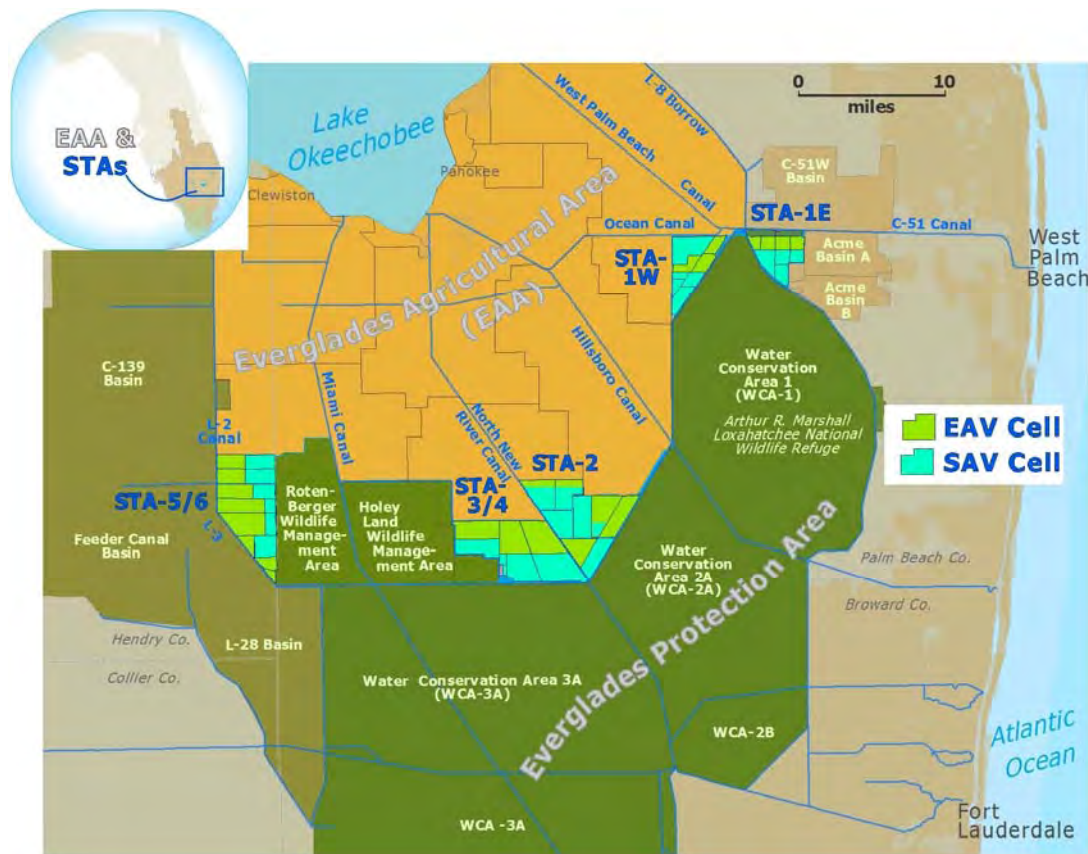


Exhibit 7 - Location of Stormwater Treatment Areas (SFWMD SFER 2011)

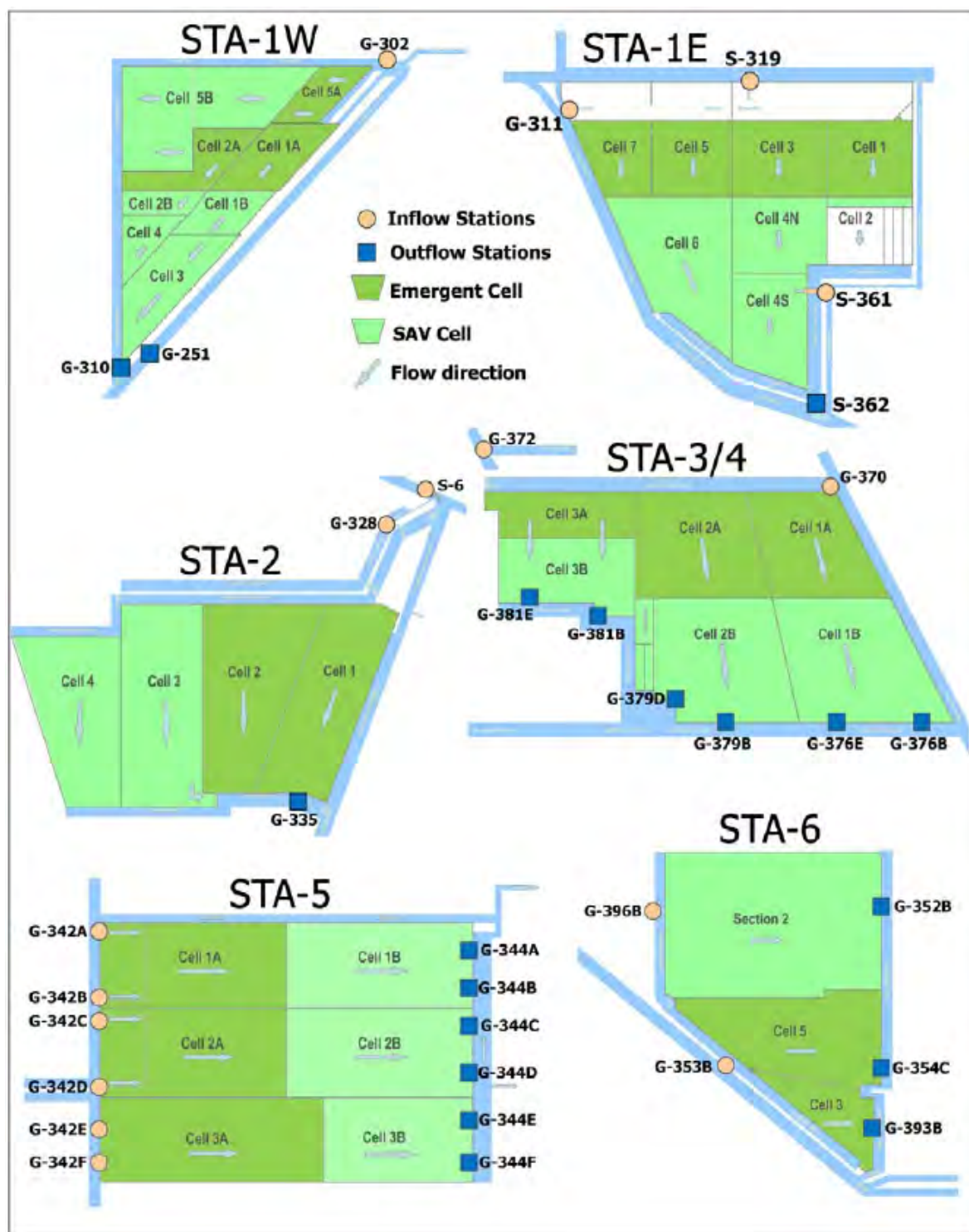


Exhibit 8 - Stormwater Treatment Areas Inlet and Outlet Structures and Cell Configuration (SFWMD SFER 2011)

3.2.1.1 STA-1E

STA-1 East (STA-1E) was permitted for approximately 5,132 acres (2,077 ha) of effective treatment area arranged in three flow-ways (WSI and Anamar 2011). STA-1E has been operated for multiple purposes including water treatment and water treatment research. The eastern flow-way contains Cells 1 and 2; the central flow-way contains Cell 3 upstream, Cell 4N in the center, and Cell 4S downstream; and the western flow-way contains Cells 5 and 7 upstream and Cell 6 downstream. Cells 1 and 2 have been operated by the USACE for the purpose of testing PSTA; data from this flow-way are not discussed in this report. The current effective area of STA-1E including the PSTA test cells is 3,199 acres (SFWMD 2011). Flow-through operations in the center and western flow-way began in the summer of 2004. Flow from STA-1E is discharged to Loxahatchee National Wildlife Refuge.

The design flow rate to STA-1E (including Cells 1 and 2) is about 111 mgd (420,000 m³/d). The system-wide, period-of-record (POR) (May 2006-January 2012) average inflow was 78 mgd (301,000 m³/d), excluding Cells 1 and 2. Within this STA, Cells 3, 4N, and 5 have sandy soils and Cells 4S, 6, and 7 have peat soils (Appendix A). Vegetation consists primarily of EMV in Cells 3, 5, and 7 and primarily SAV in Cells 4N, 4S, and 6. Exhibit 9 shows the long-term average nutrient and solids inflow and outflow concentration data for each cell with monthly time series data presented in Appendix B. It should be noted that some of the cells in many of these treatment wetlands are arranged in series and that the sum of the individual cell inflows is therefore greater than the overall site inflow.

3.2.1.2 STA-1W

STA-1 West (STA-1W) contains approximately 6,670 acres (2,700 ha) of effective treatment area arranged in three flow-ways (Goforth *et al.* 2004). The eastern flow-way (EFW) contains Cells 1A, 1B, and 3; the western flow-way (WFW) contains Cells 2A, 2B, and 4; and the northern flow-way (NFW) consists of Cells 5A and 5B. Flow-through operations in Cells 1 through 4 began in August 1994 when the system was operating as a full-scale prototype, the ENRP, for future STAs. The system has been referred to as STA-1W since Cell 5 began operations in July 2000. In 2004, additional modifications were made to divide Cells 1 and 2 to create Cells 1A and 1B in the footprint of Cell 1 and Cells 2A and 2B in the footprint of Cell 2. Flow from STA-1W is discharged to Water Conservation Area 1A.

The design flow rate to STA-1W exceeds 128 mgd (483,000 m³/d). During the POR, the system-wide average flow was 87.2 mgd (330,000 m³/d). In this STA, all cells were constructed on peat (Appendix A) with Cells 1A, 2A, 3, and 5A dominated by EMV plant communities and Cells 1B, 2B, 4, and 5B predominantly containing SAV plant communities. Exhibit 10 shows the POR (June 2000 - February 2012) average inflow and outflow nutrient and solids concentrations by cell with monthly time series data presented in Appendix B.

C-43 WQTA Test Facility Conceptual Design – TN Reduction Options

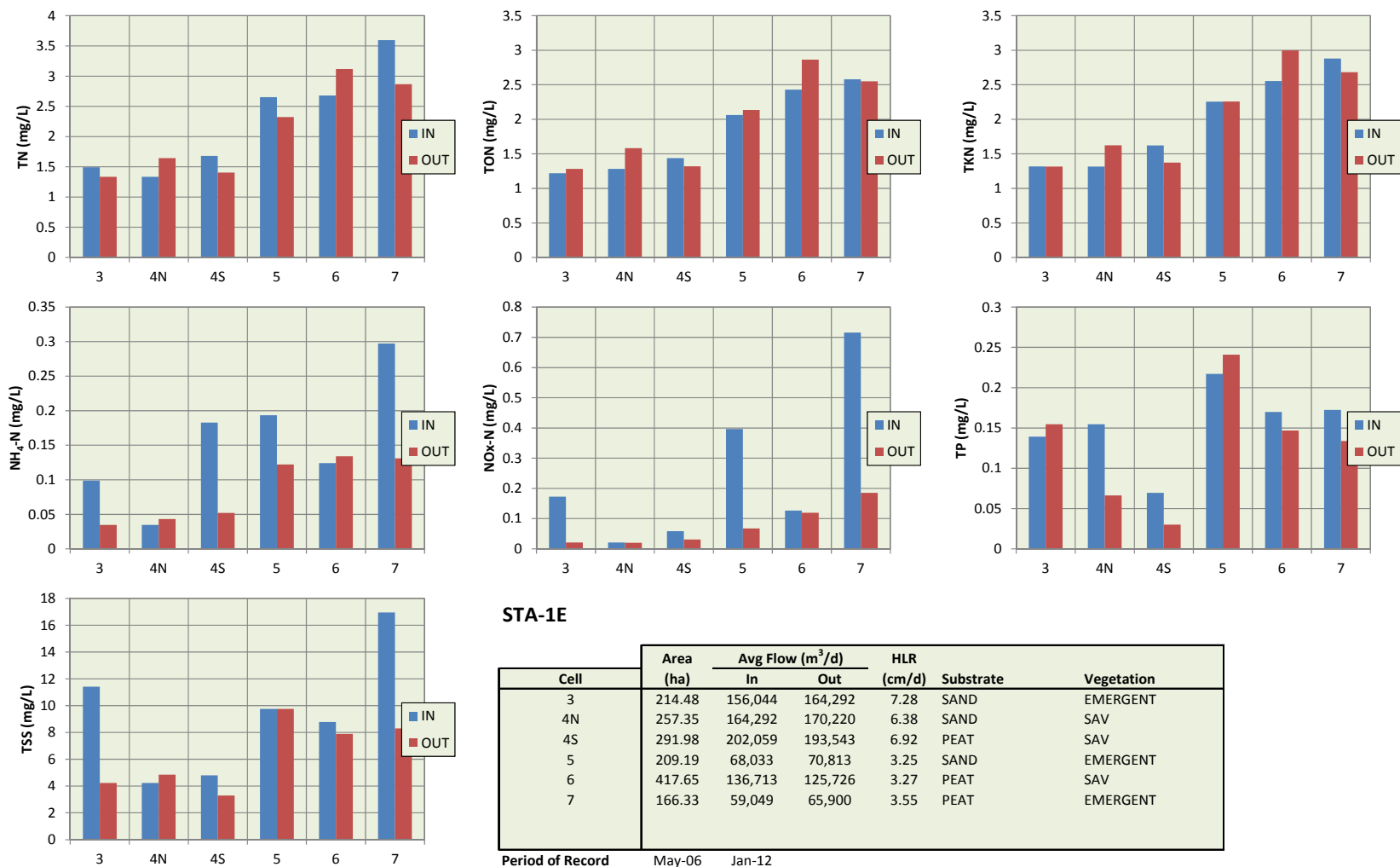


Exhibit 9 - STA-1E Long-term Average Water Quality Summary

C-43 WQTA Test Facility Conceptual Design – TN Reduction Options

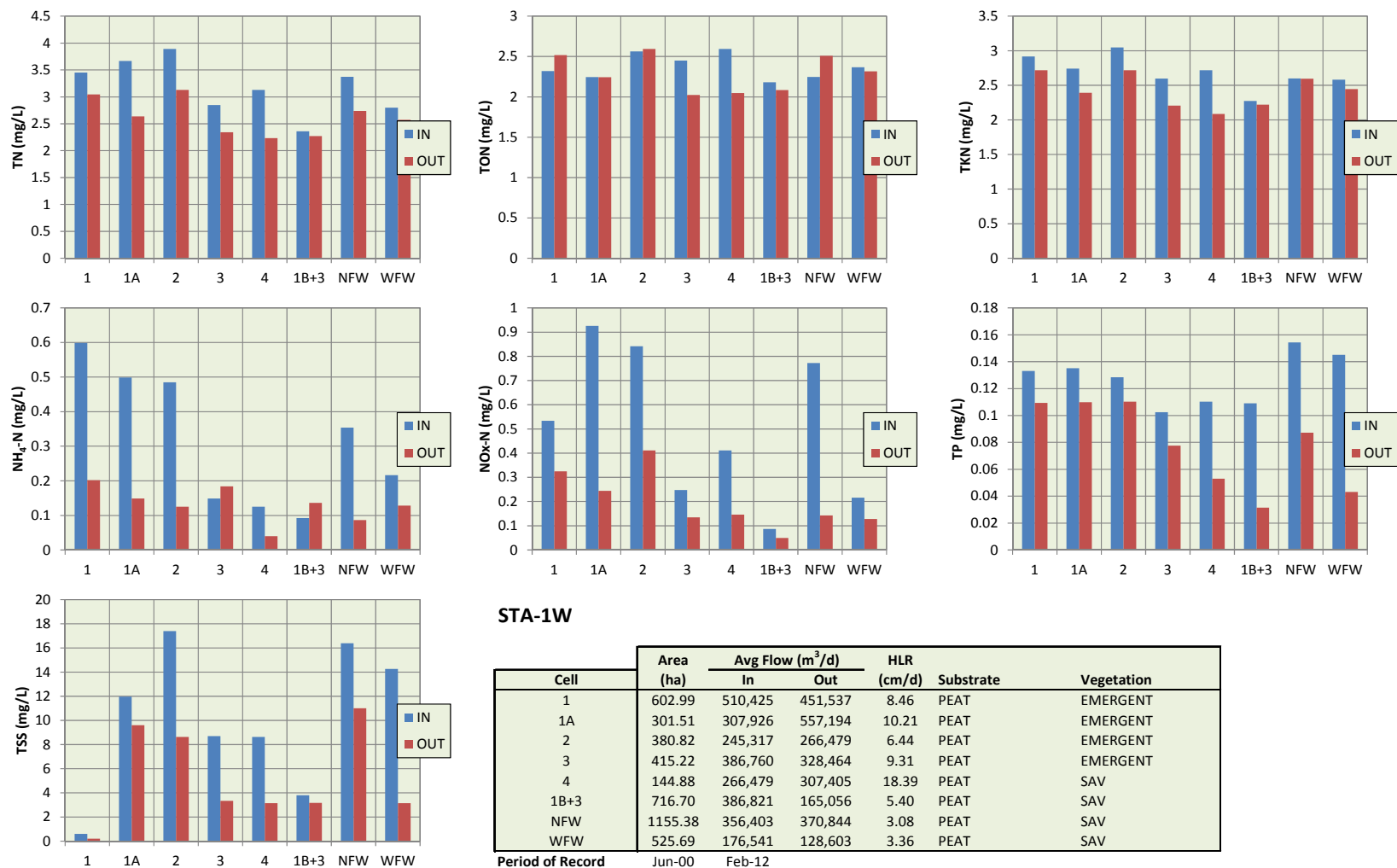


Exhibit 10 - STA-1W Long-term Average Water Quality Summary

3.2.1.3 STA-2

STA-2 contains approximately 8,240 acres (3,335 ha) of treatment area arranged in four parallel cells (SFWMD 2011) and began operation in mid-1999. All four cells were constructed on peat soils (Appendix A) with Cells 1 and 2 dominated by EMV plant communities and Cells 3 and 4 predominantly containing SAV plant communities. Cells 1A and 1B represent different time periods for Cell 1 (A = March 2002 – May 2005; B = June 2005 – February 2012).

The design flow for STA-2 is approximately 208 mgd (787,000 m³/d). Exhibit 11 shows POR (March 2002 to February 2012) average inflow and outflow concentration data for nutrient and solids by cell with monthly time series data presented in Appendix B.

3.2.1.4 STA-3/4

STA-3/4 is the largest of the existing STAs, with 16,543 acres of treatment area (SFWMD 2011). STA-3/4 has three flow-ways: the east flow-way is made up of Cells 1A and 1B, the central flow-way is made up of Cells 2A and 2B, and the west flow-way is Cells 3A and 3B. A 400-acre portion of Cell 2B has been converted to a PSTA demonstration project and is operated independently for water quality performance.

Lessons learned from earlier STA designs were incorporated into the design for STA-3/4 which was placed into operation in October 2003. These included compartmentalization of the system into a greater number of cells, back-filling farm ditches that channelize flow, and growing plants during the construction phase rather than following the completion of construction.

As with most of the STAs, the upstream cells (1A, 2A, and 3A) are dominated by EMV, and the downstream cells (1B, 2B, and 3B) are primarily SAV vegetation. Peat soils are the primary soil type for all of STA-3/4 (Appendix A).

During the POR, inflows have averaged 418 mgd (1,583,000 m³/d). Exhibit 12 shows the POR (May 2005 to February 2012) average inflow and outflow concentration data for nutrient and solids by cell with monthly time series data presented in Appendix B.

C-43 WQTA Test Facility Conceptual Design – TN Reduction Options

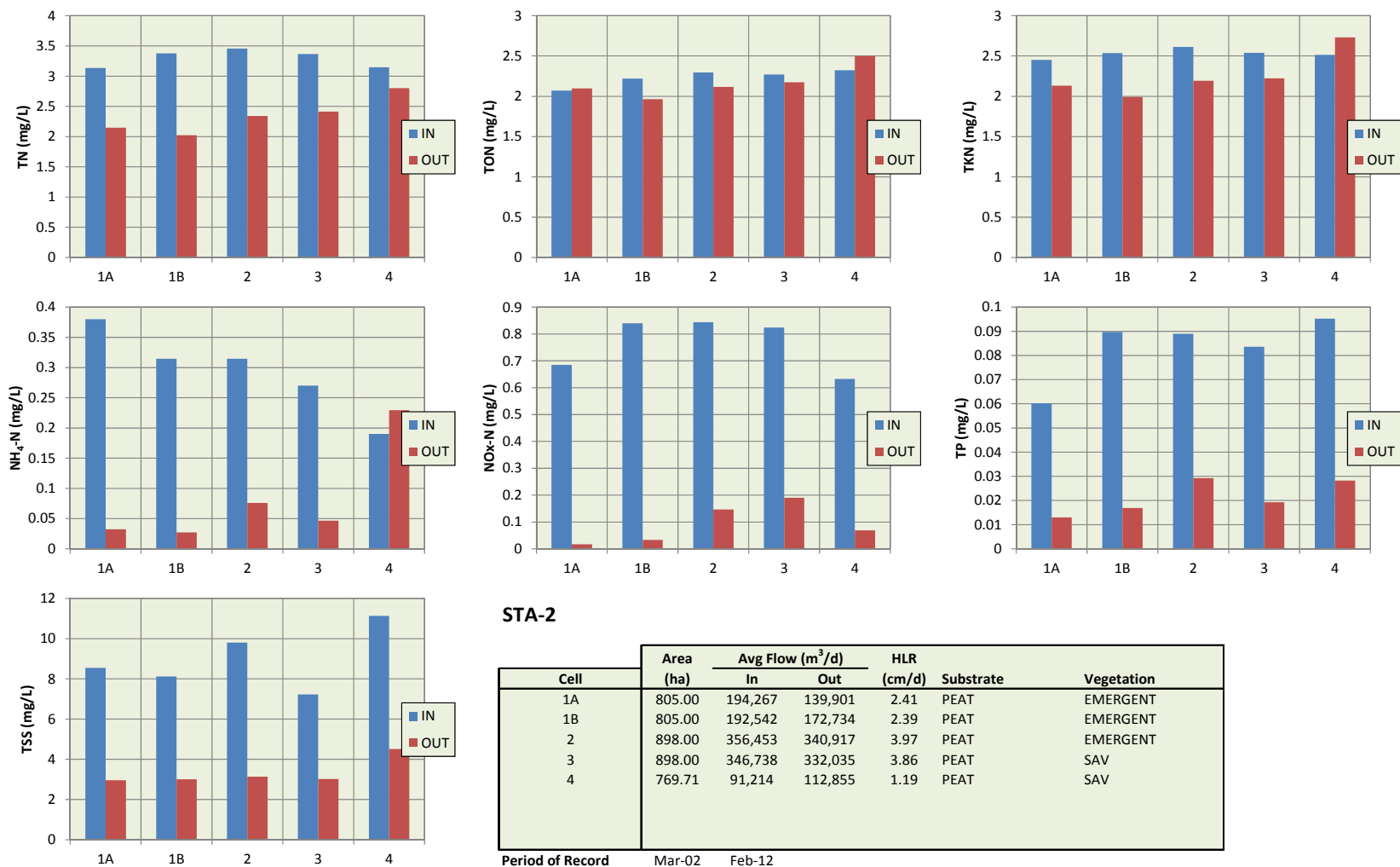


Exhibit 11 - STA-2 Long-term Average Water Quality Summary

C-43 WQTA Test Facility Conceptual Design – TN Reduction Options

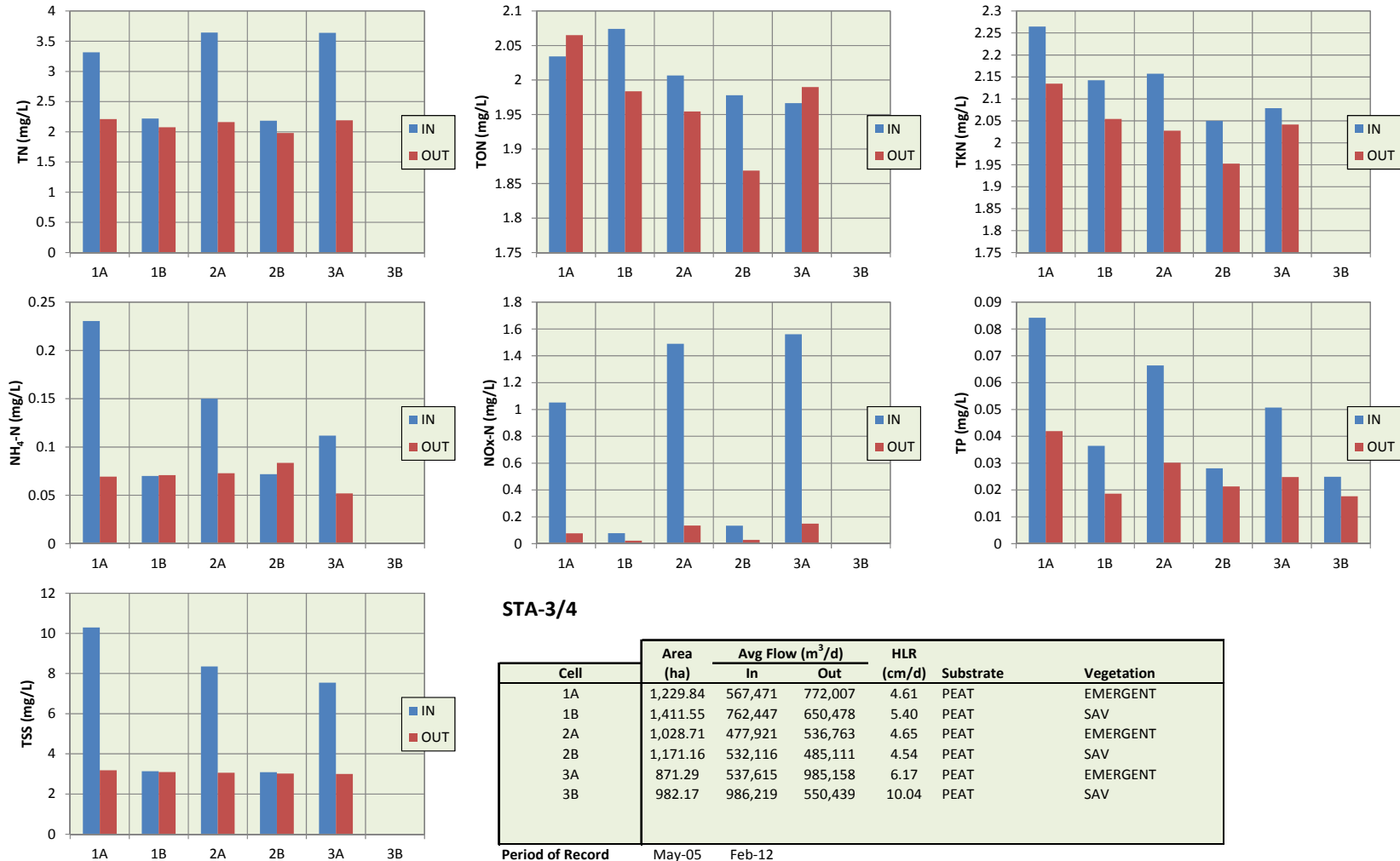


Exhibit 12 - STA-3/4 Long-term Average Water Quality Summary

3.2.1.5 STA-5

STA-5 contains 4,082 acres (1,652 ha) of effective treatment area arranged in three parallel flow-ways. The POR average inflow volume has been 67 mgd (252,000 m³/d). This STA has a northern flow-way (NFW - Cells 1A and 1B), a central flow-way (CFW - Cells 2A and 2B), and a southern flow-way (SFW - Cells 3A and 3B). The upstream cells (1A, 2A, and 3A) are primarily dominated by EMV while the downstream cells (1B, 2B, and 3B) are SAV dominated. The majority of the soils beneath the STA-5 are organic peat soils (Appendix A). Treated water is discharged to either the Rotenberger Wildlife Management Area or the Miami Canal, where the majority of the water moves south to the northwest corner of WCA-3A.

Exhibit 13 shows the POR (May 2000 to February 2012) average inflow and outflow concentration data for nutrient and solids by cell with monthly time series data presented in Appendix B. Water quality data from Cell 2B was not available at the time of this report.

3.2.1.6 STA-6

STA-6 is currently the smallest of the STAs at 2,257 acres (913 ha). STA-6 consists of three parallel cells and has a design flow of 4.8 mgd (18,300 m³/d). Section 1 (Cells 3 and 5) went into operation in late 1997. STA-6 Section 2, constructed in 2007, added approximately 1,400 acres to the treatment system. STA-6 discharges to either Rotenberger Wildlife Management Area or the Miami Canal, where the majority of the water moves south to the northwest corner of WCA-3A. Cells 3 and 5 are operated as emergent wetland cells with Section 2 operated as an SAV dominated cell. All of STA-6 is dominated by organic peat soils (Appendix A).

Exhibit 14 shows POR (October 2002 to October 2011) monthly average inflow and outflow concentration data for nutrient and solids by cell with monthly time series data presented in Appendix B.

C-43 WQTA Test Facility Conceptual Design – TN Reduction Options

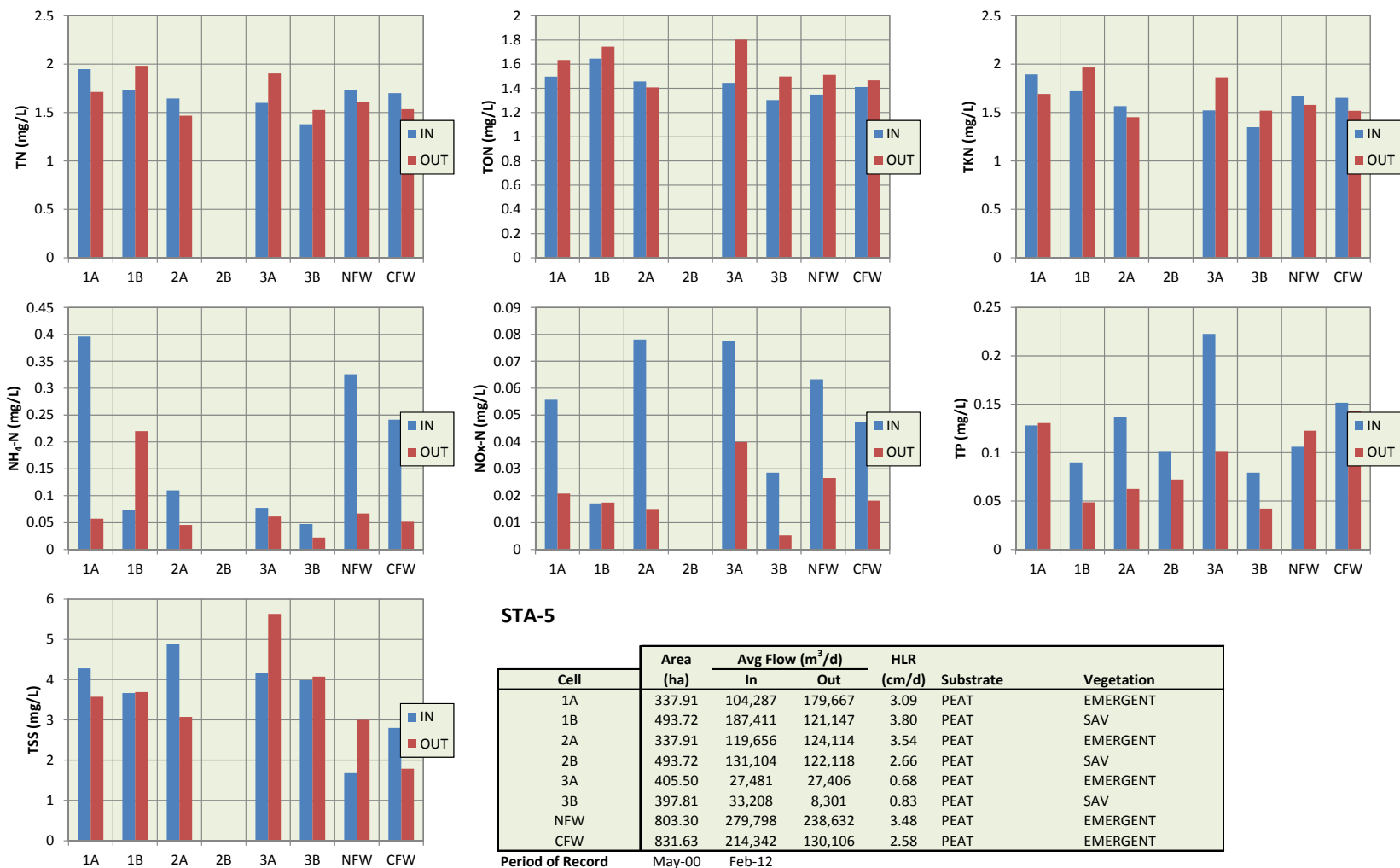


Exhibit 13 - STA-5 Long-term Average Water Quality Summary

C-43 WQTA Test Facility Conceptual Design – TN Reduction Options

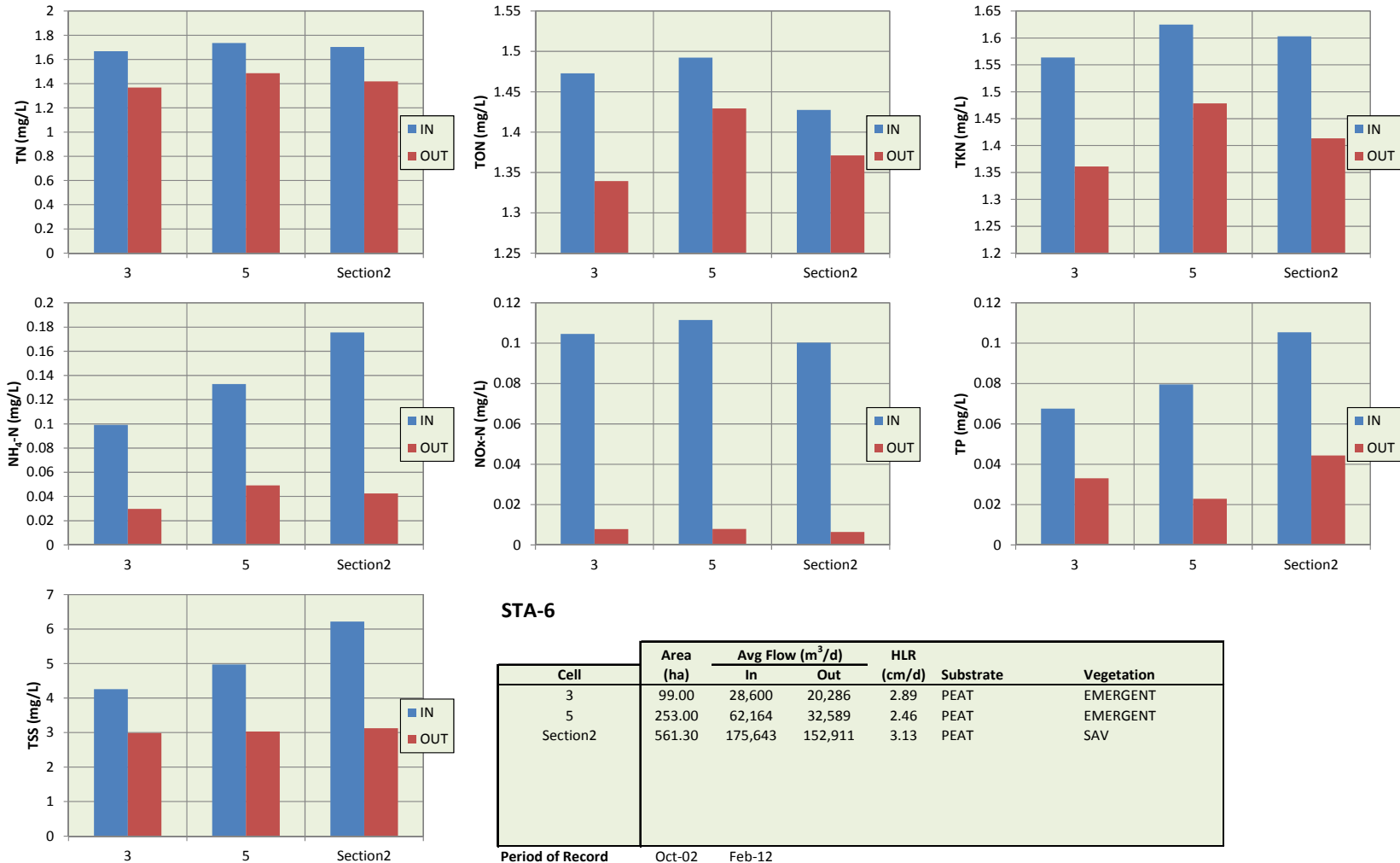


Exhibit 14 - STA-6 Long-term Average Water Quality Summary

3.2.2 City of Lakeland Wetland Treatment System

The City of Lakeland Wetland Treatment System is a 1,400-acre (565 ha) site consisting of 7 cells built on a former phosphate mine (Exhibit 15). Cells 1 through 4 are shrub and emergent marsh wetlands. Cell 5 includes emergent marsh, but is primarily a shallow lake. Deep-water systems such as Lakeland's Cell 5 typically grow phytoplanktonic algae that increase concentrations of TSS and atmospheric-fixed TON. Cells 6 and 7 are deep lakes and have experienced temporal changes in water hyacinth coverage. The Lakeland site receives up to 12 mgd (45,425 m³/d) of treated municipal effluent from the Glendale Wastewater Treatment Plant.

The site began operation in 1987, but underwent a series of modifications in the early- and mid-1990's to control elevated TSS concentrations caused by algal blooms in the deeper lake cells. Modifications included the use of Aquashade® to limit algal production in Cells 6 and 7, lowering of control elevations in several cells to promote the growth of emergent vegetation, and construction of a bypass to provide the option to discharge directly from Cell 4. Typically, all permit limits are now met at the discharge from Cell 4 (Exhibit 16 and Appendix B).

The operating permit for the Lakeland system requires effluent BOD and TSS concentrations of 5 mg/L or less and TN of 3 mg/L or less. There is no TP standard in the current permit, in recognition of the high background TP levels exhibited at the site.



Exhibit 15 - Site plan of the Lakeland Wetland Treatment System

C-43 WQTA Test Facility Conceptual Design – TN Reduction Options

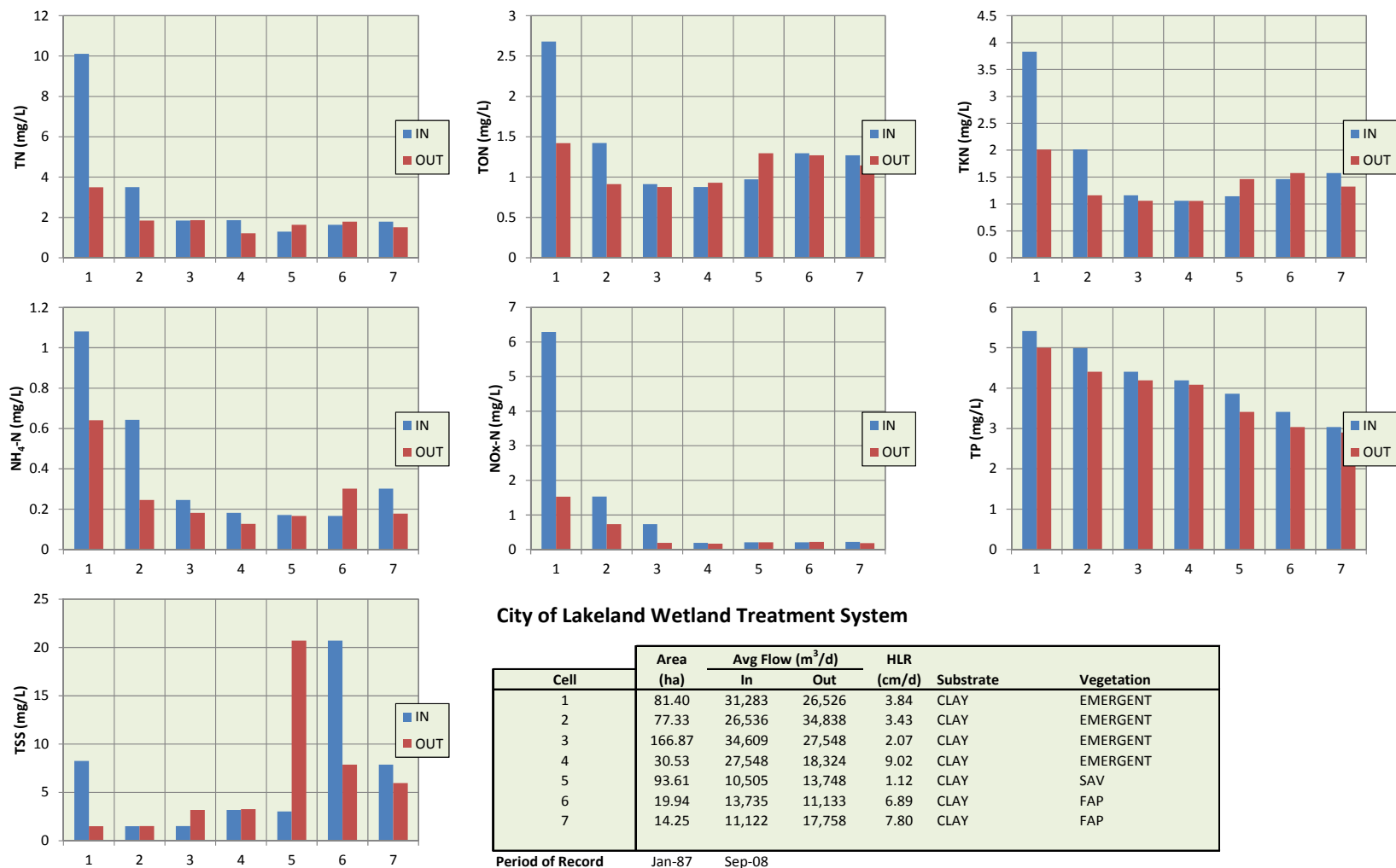


Exhibit 16 - Lakeland Wetland Treatment System Long-term Average Water Quality Summary

3.2.3 Orlando Easterly Wetland

The 1,200-acre (485 ha) Orlando Easterly Wetlands (OEW) began operation in 1987, and polishes advanced treated municipal effluent from the City of Orlando's Iron Bridge Water Reclamation Facility. The OEW is divided into 17 cells ranging in size from 14 to 186 acres (5.6 to 75 ha). Exhibit 17 shows the layout of the OEW system.

The OEW site was historically used as improved cattle pasture and consists of sandy soils underlain by clay (Appendix A). The wetland was created by constructing earthen berms and planting over 2 million aquatic plants (USEPA, 1993).

Water is pumped 17 miles (27 km) from the Iron Bridge Water Pollution Control Facility to a splitter box that routes flow into three parallel treatment trains. Each train consists of deep marsh cells (approximately 3 feet in depth) initially planted with cattail and bulrush, followed by mixed emergent marsh cells, and finally a hardwood swamp. Bird rookeries in the hardwood swamp areas and antecedent soil TP concentrations contributed to a net release of TP from the system during the first several years following startup.

Operators have used a variety of techniques to control vegetation and sediment accumulation, including prescribed burning, periodic draw downs, herbicide application, and excavation.

Exhibit 18 shows POR (January 1988 to November 2011) monthly average inflow and outflow concentrations for nutrients and solids with monthly time series data presented in Appendix B. The long-term average inflow and outflow TN concentrations were 2.23 mg/L and 0.87 mg/L, respectively, a 61 percent reduction. The long-term average inflow and outflow TP concentrations were 0.27 mg/L and 0.06 mg/L, respectively, a 78 percent reduction. Inflow and outflow TSS concentrations were 2.0 mg/L and 2.7 mg/L, reflecting the high quality of the applied wastewater. This type of TSS increase is indicative of phytoplankton growth and is commonly seen in treatment wetlands with excessive open water areas near the outflow. The POR average flow and hydraulic loading rate were 14.7 mgd (55,700 m³/d) and 1.15 cm/d.



Exhibit 17 - Site Plan of the Orlando Easterly Wetlands

C-43 WQTA Test Facility Conceptual Design – TN Reduction Options

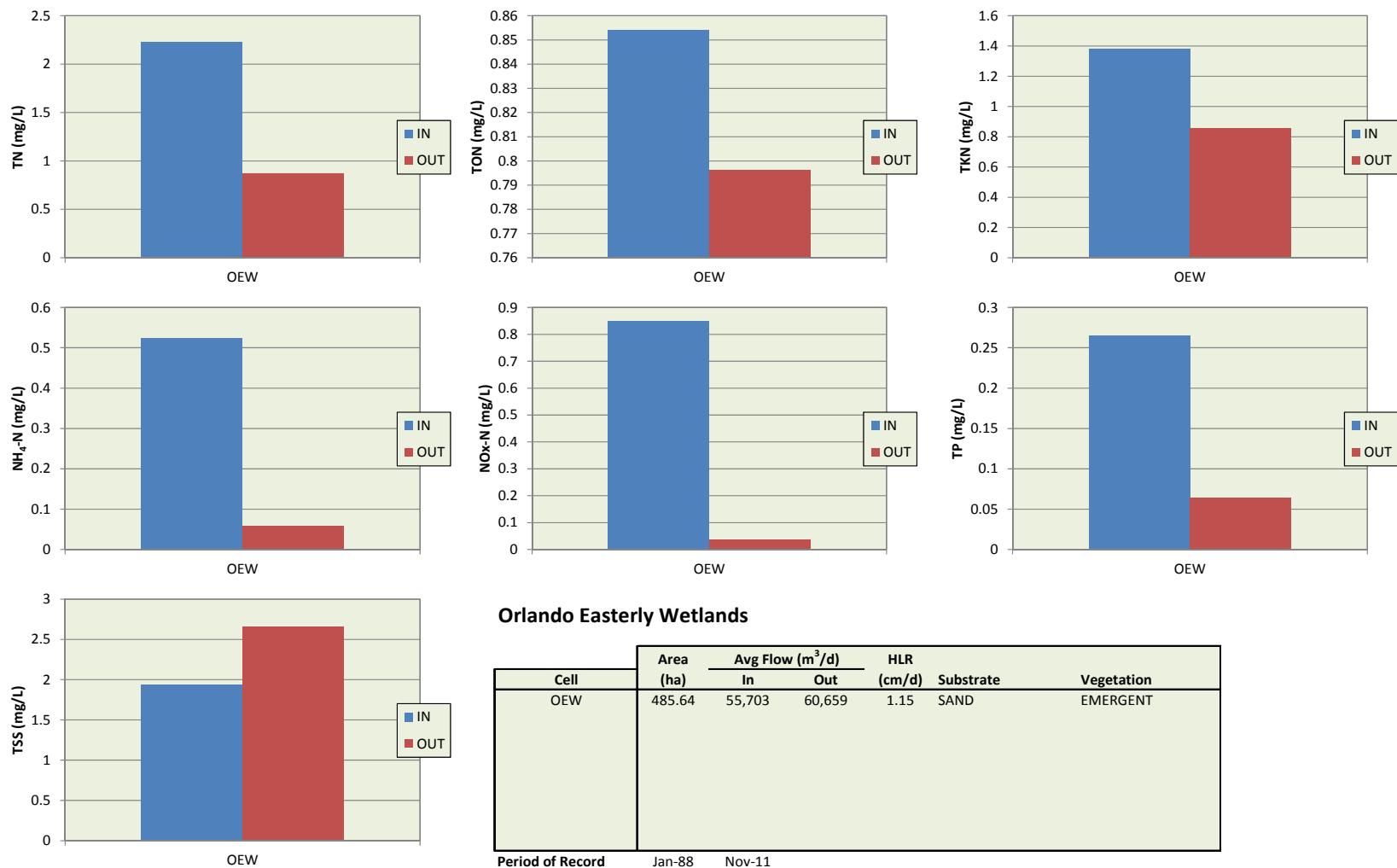


Exhibit 18 - Orlando Easterly Wetlands Long-term Average Water Quality Summary

3.2.4 City of Titusville, Blue Heron Wetland Treatment System

The Blue Heron Wetland Treatment System (BHWTS) is located in Brevard County and receives treated municipal effluent from the City of Titusville's Blue Heron Water Reclamation Plant. The BHWTS consists of about 264 acres (107 ha) divided into seven cells (three deep marsh cells [Cells 1-3], one pond cell [Cell 4], and three shallow marsh cells [Cells 5-7]). Exhibit 19 shows the layout of the BHWTS.

The BHWTS was constructed on land that historically formed part of the floodplain wetlands adjacent to the St. Johns River is dominated by sandy soils (Appendix A). Development and agricultural drainage activities over the past 50 years significantly altered the site, and the construction of the WTS re-established portions of the historic ecological communities that were found on the site. The potential habitat value of the WTS site was enhanced by not grading the soil surface to uniform elevations throughout each of the cells. The uneven nature of the cell bottom allows different plant communities to develop and be maintained throughout the deep and shallow marsh cells.

Water flows by gravity through the seven cells to a collection system along the south side of the site, and then is discharged to the Addison Canal, which is a primary tributary to the St. Johns River.

Exhibit 20 shows POR (January 1997 to December 2011) monthly average inflow and outflow concentrations for nutrients and solids with monthly time series data presented in Appendix B. The long-term average inflow and outflow TN concentrations were 4.02 mg/L and 1.19 mg/L, respectively, a 70 percent reduction. The long-term average inflow and outflow TP concentrations were 0.49 mg/L and 0.08 mg/L, respectively, a 84 percent reduction. Inflow and outflow TSS concentrations were 1.0 mg/L and 1.3 mg/L, respectively. This type of TSS increase is indicative of phytoplankton growth and is commonly seen in treatment wetlands with excessive open water areas near the outflow. The average flow and HLR were 1.8 mgd (6,611 m³/d) and 0.65 cm/d, respectively.

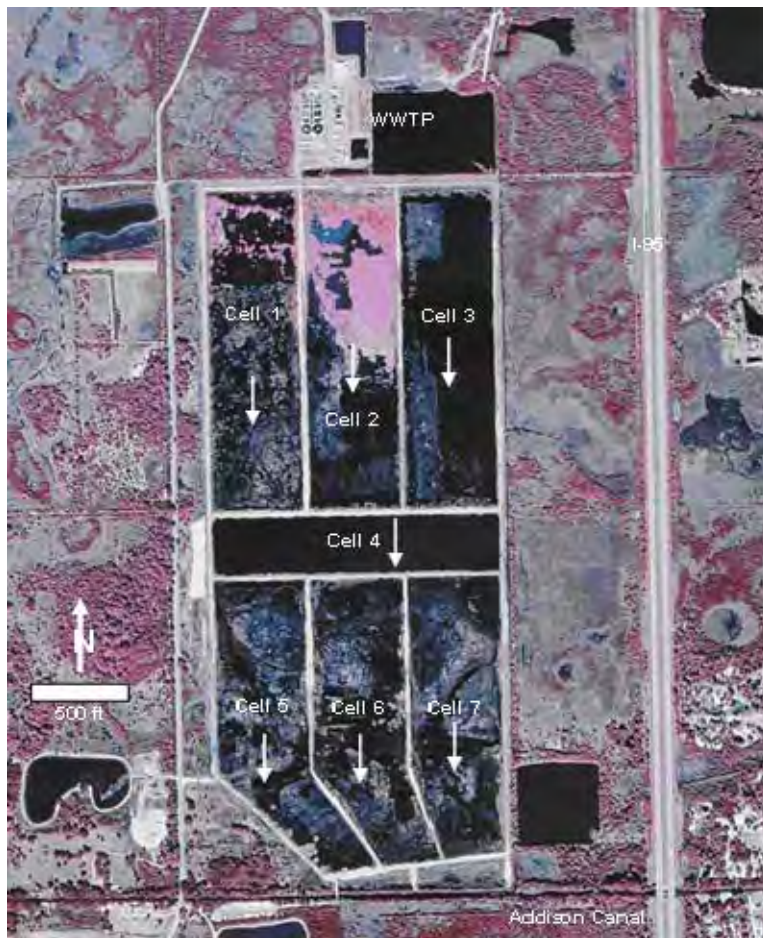


Exhibit 19 - Site Plan of the Blue Heron Wetland Treatment System

C-43 WQTA Test Facility Conceptual Design – TN Reduction Options

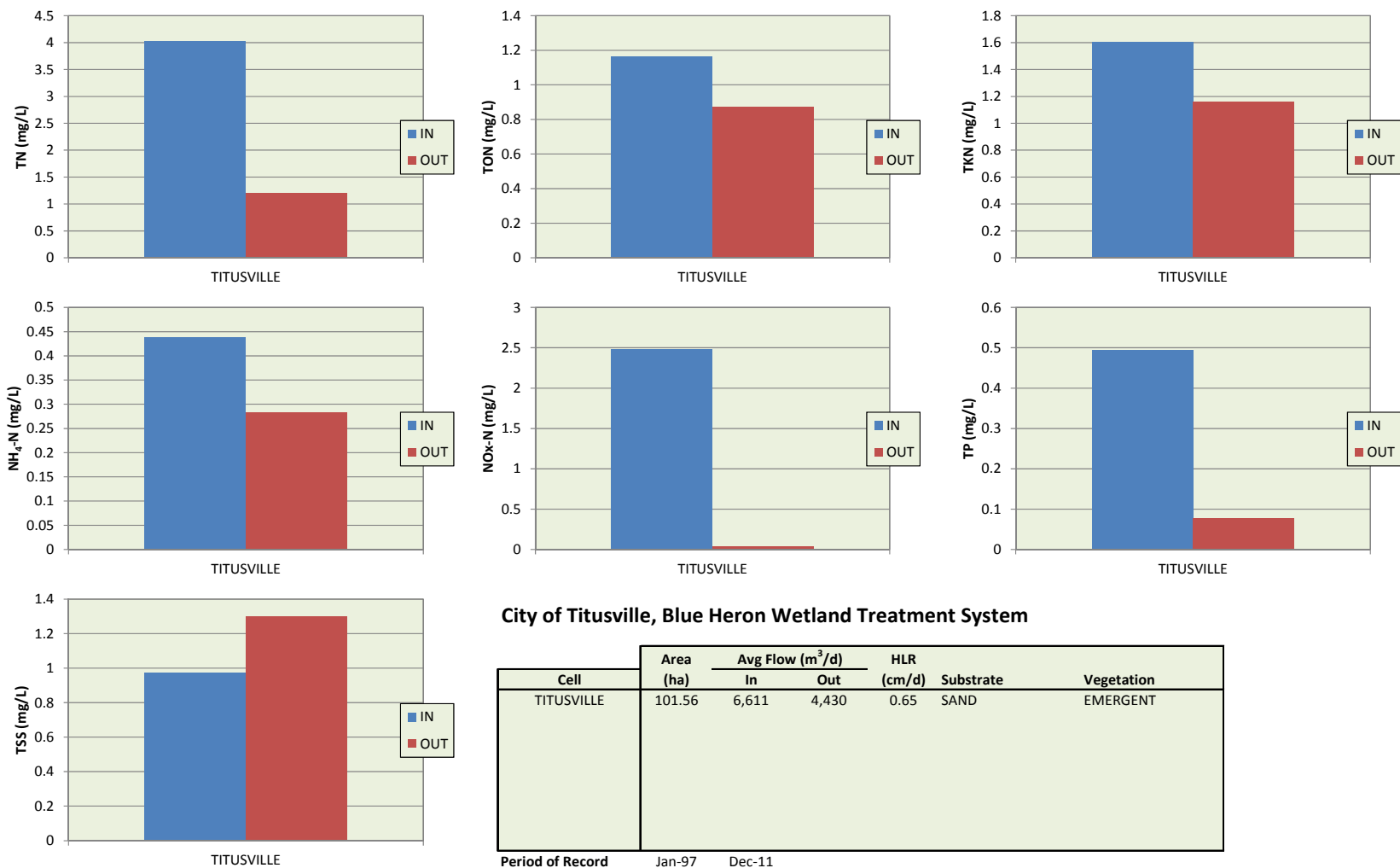


Exhibit 20 - Blue Heron Wetland Treatment System Long-term Average Water Quality Summary

3.2.5 Lake Apopka Marsh Flow Way Project

The St. John's River Water Management District's (SJRWMD) Phase I Lake Apopka Marsh Flow Way project began in November 2003, with the construction of a 660-acre (267 ha) full-scale facility that was designed to remove suspended sediments and particulate nutrients from lake water. The Lake Apopka Flow-Way was constructed on floodplain muck farmland soils on the northwest shore of Lake Apopka (Appendix A). Exhibit 21 shows a schematic of the Lake Apopka full-scale project.

Upon initial flooding, outflow nutrient concentrations exceeded inflow concentrations due to the release of soluble soil nutrients, however positive removal efficiencies were observed after vegetation biomass cycles stabilized, pools of labile P were depleted, and new sediments were deposited over the existing substrate.

Exhibit 22 shows POR (November 2003 – December 2009) monthly average inflow and outflow concentration data from the four Phase I Cells (B1, B2, C1, and C2). Average TN concentrations have declined from 4.0 mg/L at the inlets to 3.0 mg/L (25% concentration reduction) at the cell outlets. Long-term average TP concentrations have declined with inlet concentrations of 0.12 mg/L and outlet concentration of 0.09 mg/L (25% concentration reduction). Inflow and outflow TSS concentrations were 20.5 mg/L and 1.3 mg/L, respectively, for an average concentration removal efficiency of about 94 percent



Exhibit 21 - Site Plan for the Lake Apopka Marsh Flow-Way Project

C-43 WQTA Test Facility Conceptual Design – TN Reduction Options

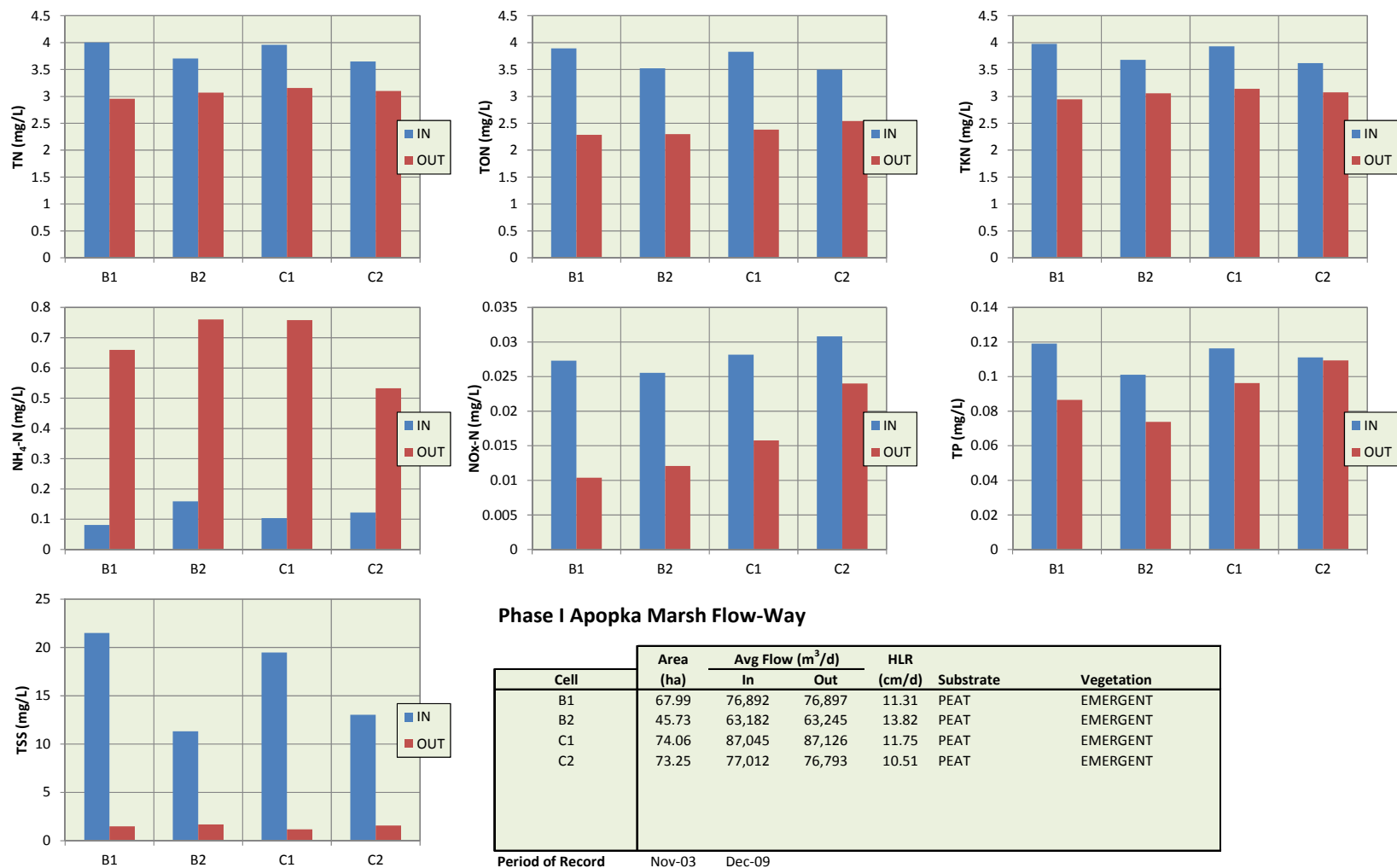


Exhibit 22 - Lake Apopka Marsh Flow-Way Project Long-term Average Water Quality Summary

3.2.6 Taylor Creek STA

The construction and operation of the Taylor Creek STA (TCSTA) in the Lake Okeechobee Watershed is a major component of the Lake Okeechobee Protection Plan. The Plan seeks to restore and protect Lake Okeechobee by achieving and maintaining compliance with lake water quality standards. The Plan's innovative restoration program is designed to reduce total phosphorus loads and implement long-term solutions, in accordance to the lake's Total Maximum Daily Load.

The Taylor Creek STA is one of the two pilot-scale STAs to be implemented north of the lake with flow-through operations starting in June 2008. The STA was inactive from February 2009 through September 2010 while repairs were being made on a culvert at the outfall structure.

The Taylor Creek STA is located about 1.4 miles (2.2 km) north of the city of Okeechobee in central Okeechobee County. It is bordered on the east by U.S. 441 and by Taylor Creek on the west (Exhibit 23). The site is approximately 142 acres (57 ha) in total area and the STA has a treatment area of about 118 acres (48 ha). The STA is divided into two cells operated in series and dominated by emergent vegetation on sandy soils (Appendix A).



Exhibit 23 - Site Plan of the Taylor Creek Pilot STA

Exhibit 24 shows POR (June 2008 to January 2012) monthly average inflow and outflow concentrations for nutrients and solids with monthly time series data presented in Appendix B. The long-term average inflow and outflow TN concentrations were 1.74 mg/L and 1.56 mg/L respectively, a 10 percent reduction. The long-term average inflow and outflow TP concentrations were 0.32 mg/L and 0.23 mg/L, respectively, a 28 percent reduction. Inflow and outflow TSS concentrations were 5.19 mg/L and 3.27 mg/L, respectively, a 37 percent reduction. The average flow and HLR were 11.1 mgd (41,879 m³/d) and 7.29 cm/d, respectively.

3.2.7 Periphyton-based Stormwater Treatment Areas

From 1999 to 2002 the District conducted research focused on determining the effectiveness and design criteria of Periphyton-based Stormwater Treatment Areas (PSTA) to support reduction of phosphorus loads in surface waters entering the EAA and ultimately meet the Everglades TP criterion of 10 ppb (CH2M Hill 2003a).

A multi-phase approach was developed to include an experimental phase of 24 portable experimental mesocosms (Porta-PSTAs), three experimental Test Cells (PSTA Test Cells), and a demonstration phase of four 5-acre (2 ha) Field Scale PSTA cells. A summary of the PSTA design criteria and experimental treatments are summarized in Exhibit 25.

3.2.7.1 Porta-PSTA Mesocosms

Twenty-four Porta-PSTA fiberglass mesocosms were installed at the STA-1W Supplemental Technology Research Compound and became operational in April 1999. The Porta-PSTA mesocosms included two sizes (22 at 6m x 1m and 2 at 6m x 3m) operated at various target water depths (30 and 60 cm) and loading rates (6 and 12 cm/d). The mesocosms were planted with a low density of macrophytes (*Eleocharis*) to provide periphyton mat stability within various substrates (organic soils, calcareous material, and sand). Exhibit 26 through Exhibit 28 summarize POR (April 1999 to February 2001) monthly average inflow and outflow concentrations for nutrients and solids with monthly time series data presented in Appendix B. Average outflow TP concentrations as low as 11 to 15 ppb were achieved in the calcareous and sand substrate treatments, while more internal P loading and higher outflow TP concentrations were observed in the peat substrate treatments (CH2M HILL 2003a). The Porta-PSTA mesocosms generally reduced concentrations of TN and TON in STA source water and achieved low NO_x-N concentrations (generally less than 0.04 mg/L).

C-43 WQTA Test Facility Conceptual Design – TN Reduction Options

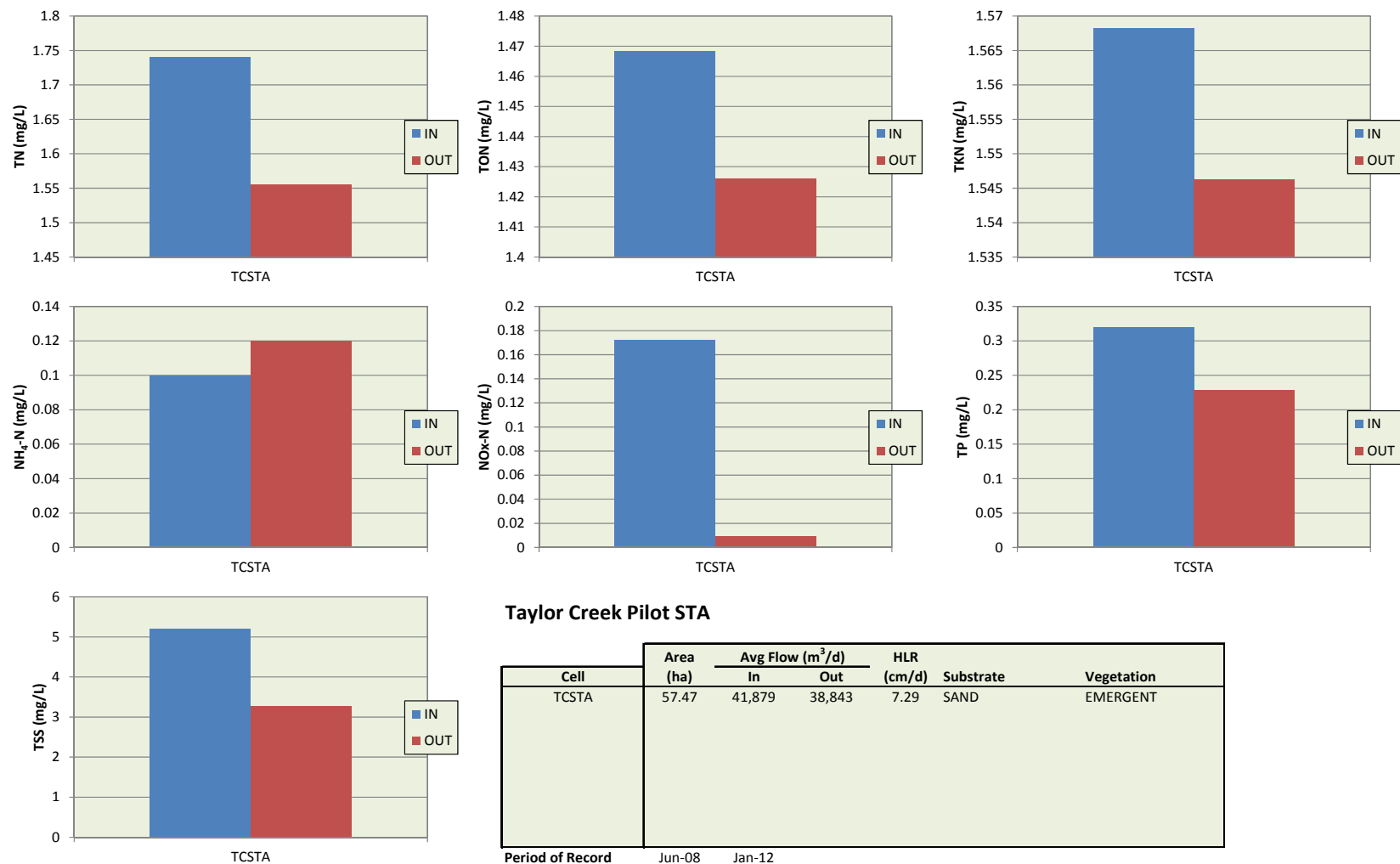


Exhibit 24 - Taylor Creek STA Long-term Average Water Quality Summary

Exhibit 25 - PSTA Treatment Summary Table

PSTA Treatment	Phase	Cells	Area (m ²)	Substrate Type	Target Wtr Depth (cm)	Target HLR (cm/d)	Target Depth:Width Ratio	Other Considerations
Porta-PSTA Mesocosms								
PP-1	1	9, 11, 18	6	Peat	60	6	0.6	macrophytes
PP-2	1	4, 7, 8	6	Shellrock	60	6	0.6	macrophytes
PP-3	1, 2	12, 14, 17	6	Peat	30	6	0.3	macrophytes
PP-4	1, 2	3, 5, 10	6	Shellrock	30	6	0.3	macrophytes
PP-5	1	2, 13, 16	6	Shellrock	60	12	0.6	macrophytes
PP-6	1	1, 6, 15	6	Shellrock	0-60	0-12	0-0.6	macrophytes
PP-7	1, 2	19	6	Sand	30	6	0.3	macrophytes
PP-8	1	20	6	Sand	60	6	0.6	macrophytes
PP-9	1	21	6	Peat	60	6	0.6	Aquashade; no macrophytes
PP-10	1	22	6	Shellrock	60	6	0.6	Aquashade; no Macrophytes
PP-11	1, 2	23	18	Shellrock	30	6	0.1	macrophytes
PP-12	1, 2	24	18	Peat	30	6	0.1	macrophytes
PP-13	2	9, 11, 18	6	peat (Ca)	30	6	0.3	macrophytes
PP-14	2	4, 7, 8	6	Limerock	30	6	0.3	macrophytes
PP-15	2	2, 13, 16	6	Shellrock	30	6	0.3	macrophytes; recirculation
PP-16	2	1, 6, 15	6	Shellrock	0-30	0-6	0-0.3	macrophytes
PP-17	2	20	6	sand (HCl)	30	6	0.3	macrophytes
PP-18	2	21	6	None	30	6	0.3	no macrophytes
PP-19	2	22	6	Aquamat	30	6	0.3	no macrophytes
Test Cell PSTAs								
STC-1	1	13	2,240	Peat	60	6	0.02	macrophytes
STC-2	1	8	2,240	Shellrock	60	6	0.02	macrophytes
STC-3	1	3	2,240	shellrock	0-60	0-12	0-0.02	macrophytes
STC-4	2	13	2,240	peat (Ca)	30	6	0.01	macrophytes
STC-5	2	8	2,240	shellrock	30	6	0.01	macrophytes
STC-6	2	13	2,240	shellrock	0-30	0-12	0-0.01	macrophytes
Field-Scale PSTAs								
FSC-1	3	1	20,790	Limerock/Peat	0-60	0-12	0.005	macrophytes
FSC-2	3	2	20,790	Limerock/Peat	0-60	0-12	0.014	macrophytes
FSC-3	3	3	20,790	Caprock	0-60	0-12	0.005	macrophytes
FSC-4	3	4	20,790	Peat	0-60	0-12	0.005	macrophytes

Notes:

PP = Porta-PSTA

STC = South Test Cell

FSC = Field-Scale Cell

C-43 WQTA Test Facility Conceptual Design – TN Reduction Options

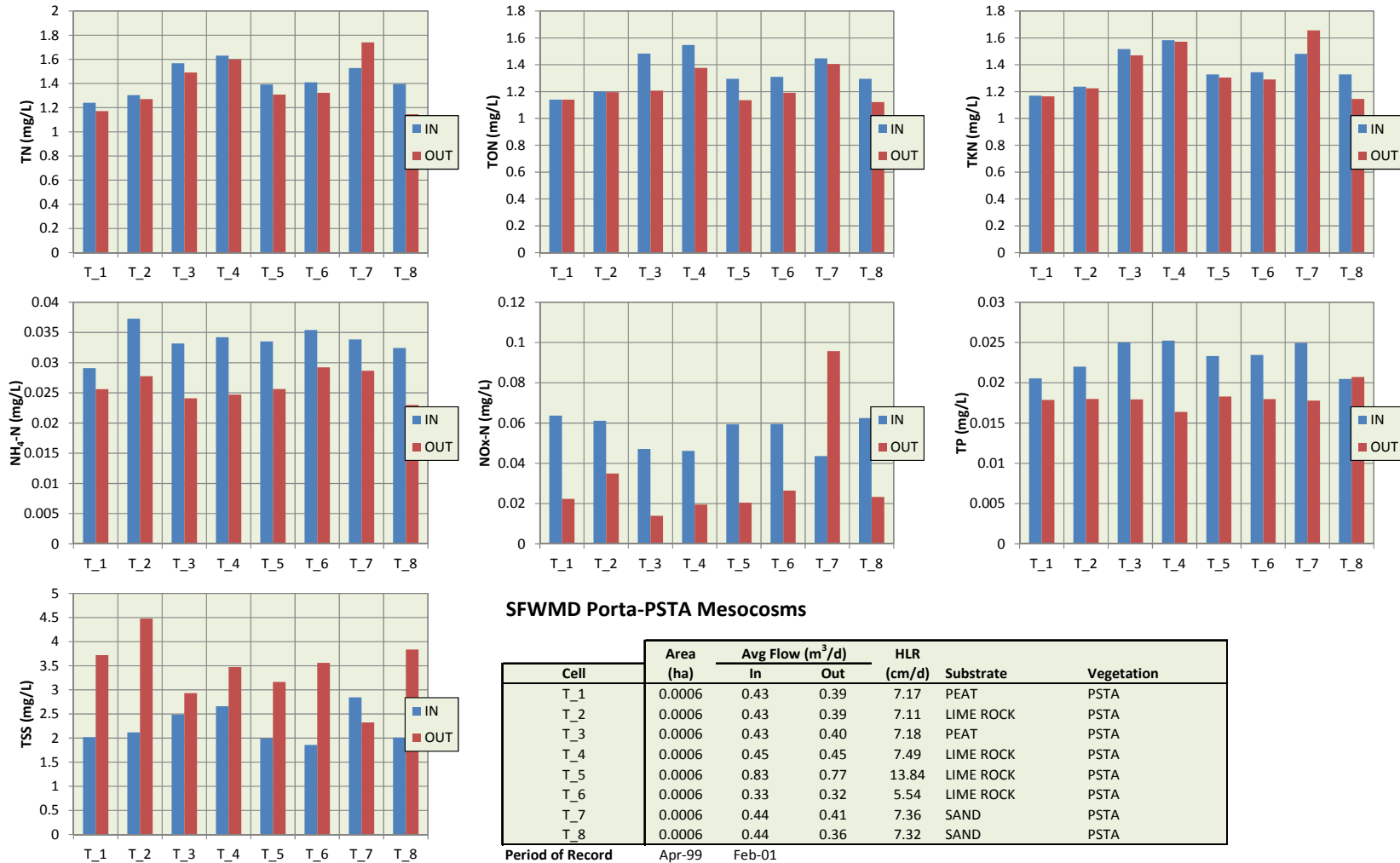


Exhibit 26 - SFWMD Porta-PSTA Mesocosm (Treatments) Long-term Average Water Quality Summary

C-43 WQTA Test Facility Conceptual Design – TN Reduction Options

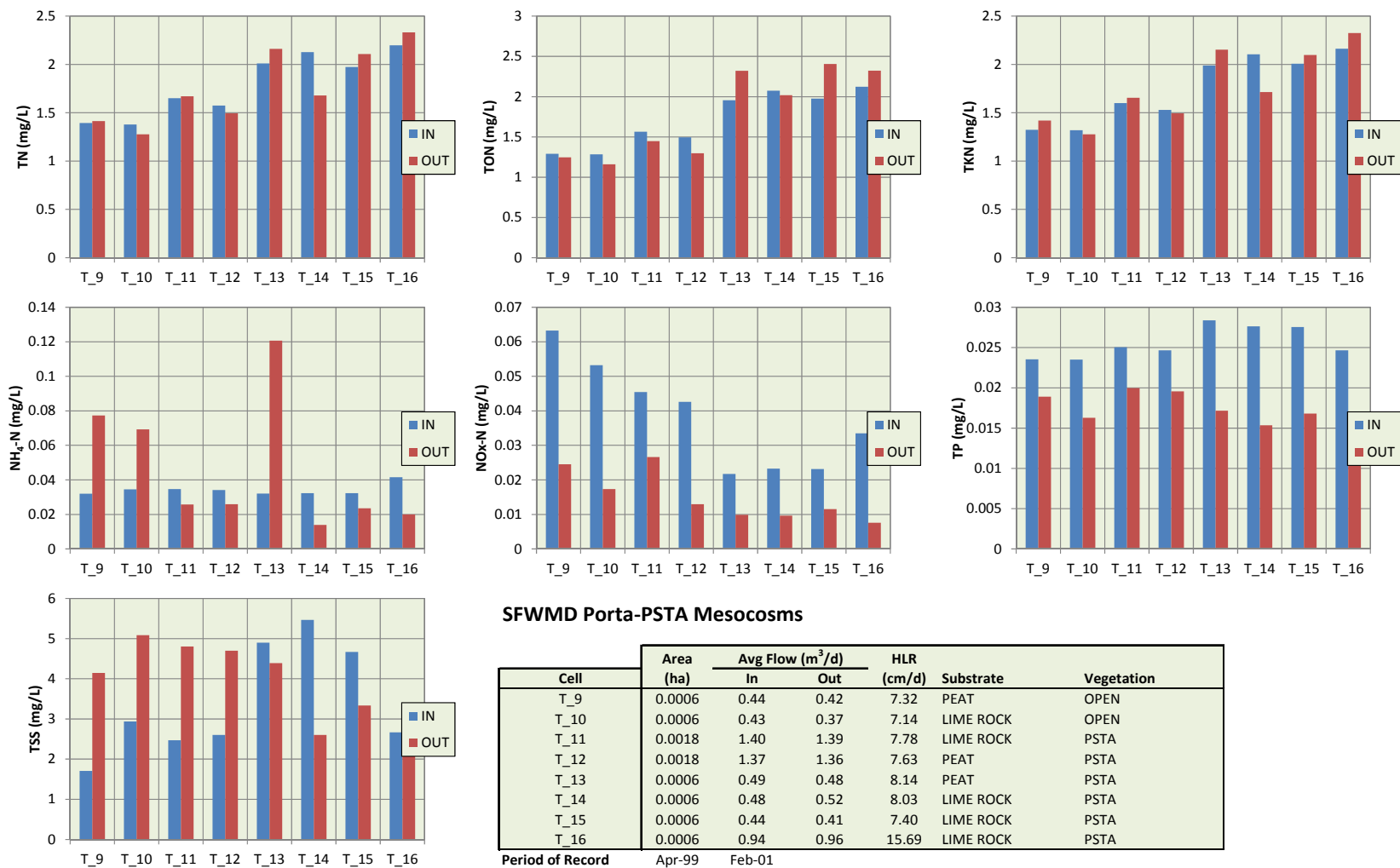


Exhibit 27 - SFWMD Porta-PSTA Mesocosm (Treatments) Long-term Average Water Quality Summary

C-43 WQTA Test Facility Conceptual Design – TN Reduction Options

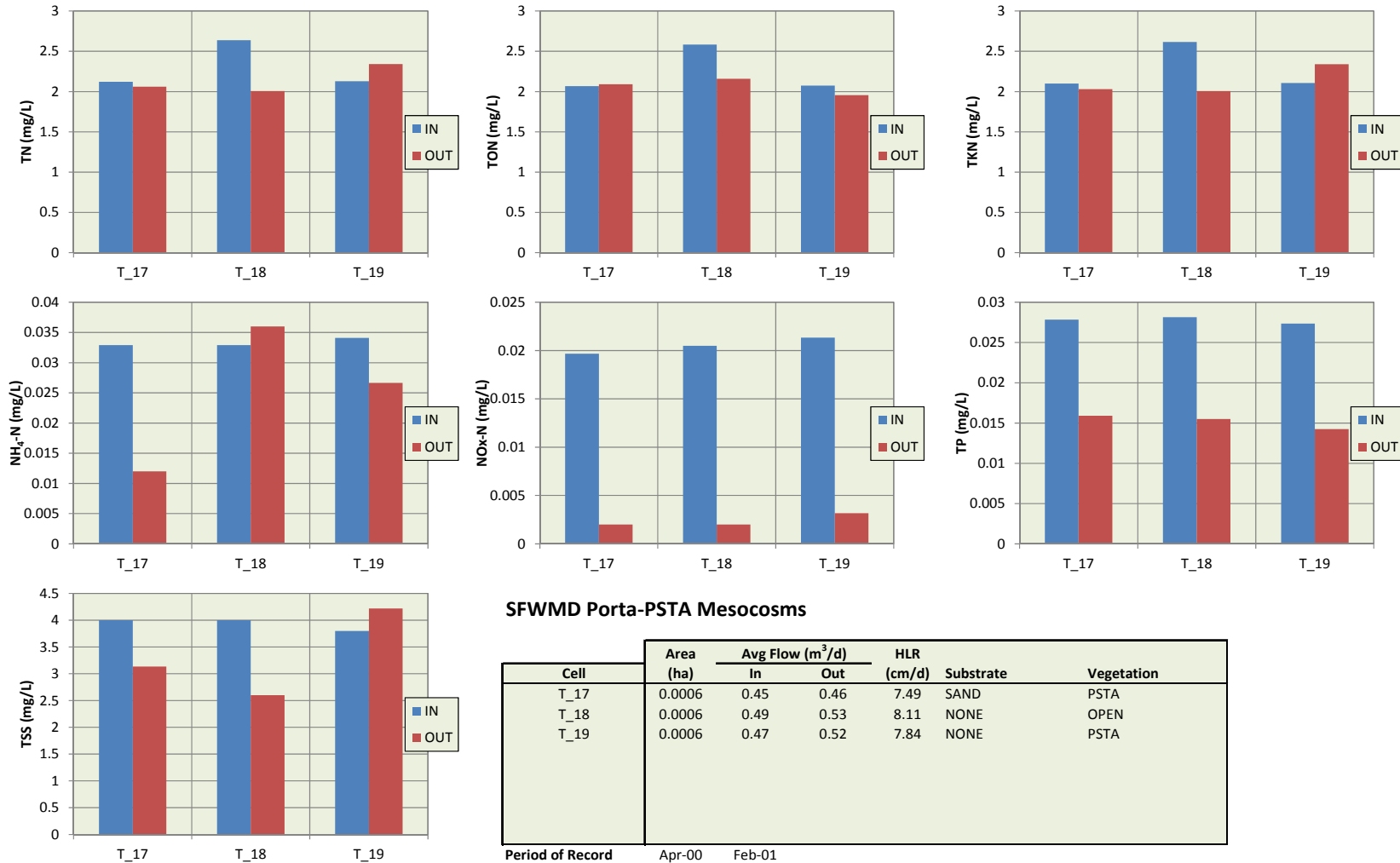


Exhibit 28 - SFWMD Porta-PSTA Mesocosm (Treatments) Long-term Average Water Quality Summary

3.2.7.2 South STA-1W PSTA Test Cells

The South STA-1W Test Cells consist of fifteen 0.5-acre (2,020 m²) full-lined parallel cells receiving flows from STA-1W Cell 3 by means of a single head cell. The District assigned three Test Cells for PSTA Research (cells 3, 8, and 13). Organic and calcareous material substrates were placed over the liners and the Test Cells were planted with a low density of macrophytes (*Eleocharis*) for periphyton mat stability. The Test Cells were operated at various target water depths (30 and 60 cm) and loading rates (6 and 12 cm/d). Exhibit 29 shows POR (February 1999 to March 2001) monthly average inflow and outflow concentrations for nutrients and solids with monthly time series data presented in Appendix B. As noted above, the calcareous substrate treatments achieved lower average TP concentrations in comparison to the peat substrate. The South STA PSTA Test Cells generally reduced concentrations of TN and TON in STA source water and achieved low NO_x-N concentrations (generally less than 0.02 mg/L).

3.2.7.3 Field-Scale PSTA Cells

Four Field-Scale PSTA cells were constructed west of STA-2 Cell 3, each about 5 acres in surface area (3 – 61m x 317m, 1 – 21m x 951m). Two cells had compact limerock placed over the native peat soils, one cell had the peat removed to expose the underlying caprock, and the remaining cell had the unaltered native peat soils. The Field-Scale PSTA Cells were also planted with a low density of macrophytes (*Eleocharis*) for periphyton mat stability and operated at variable water depths (< 60 cm) and loading rates (< 12 cm/d). Exhibit 30 shows POR (August 2001 to December 2002) monthly average inflow and outflow concentrations for nutrients and solids with monthly time series data presented in Appendix B. As noted above for the other PSTA cells, the calcareous substrate cells achieved lower average TP concentrations in comparison to the peat substrate. The presence of underlying and adjacent peat soils resulted in a net increase of TON in all cells, even those covered by limerock and in the cell where the peat was removed to caprock. Inorganic nitrogen concentrations (AN and NO_x-N) were generally reduced in the Field-Scale PSTA cells.

C-43 WQTA Test Facility Conceptual Design – TN Reduction Options

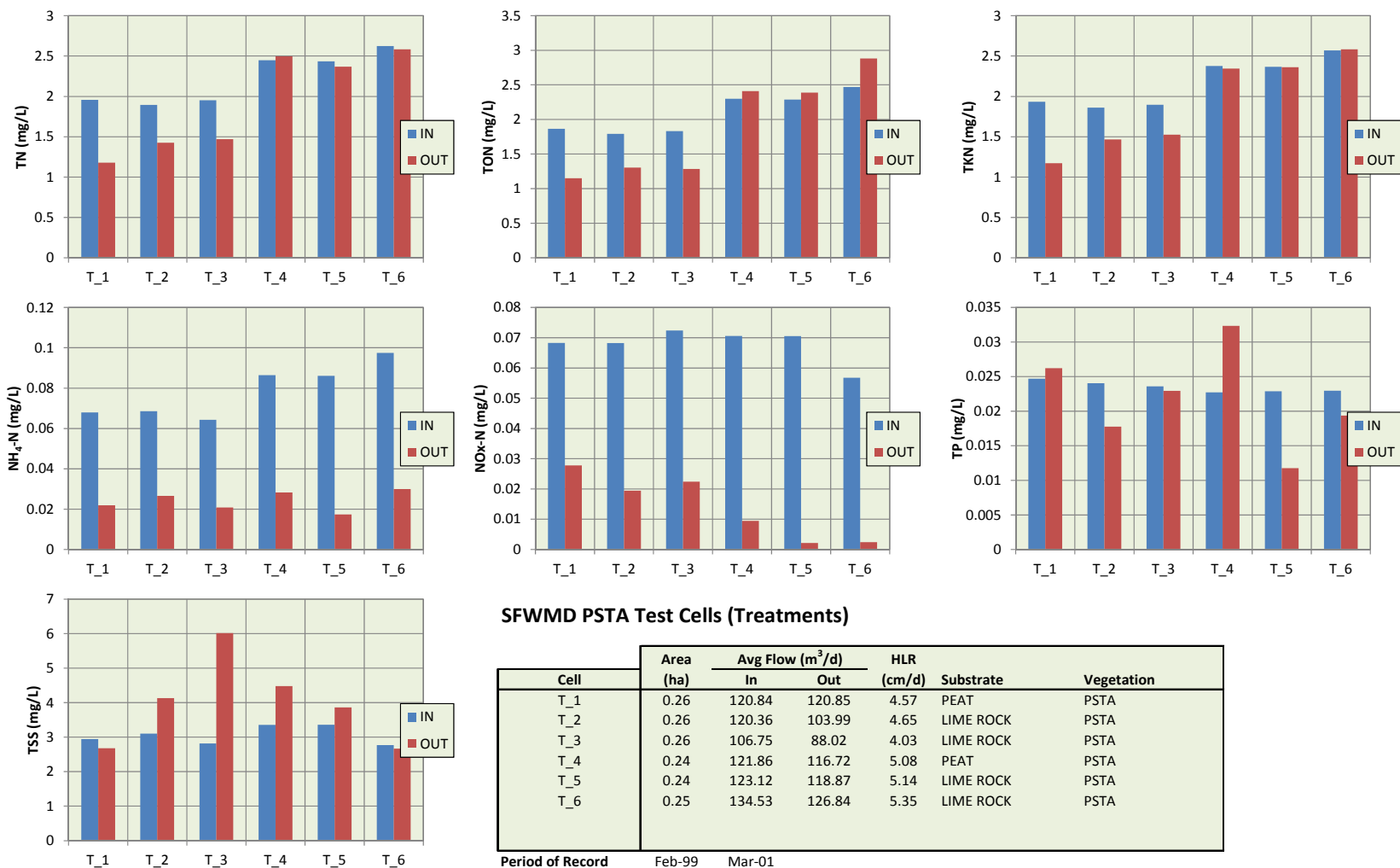


Exhibit 29 - SFWMD PSTA Test Cells (Treatments) Long-term Average Water Quality Summary

C-43 WQTA Test Facility Conceptual Design – TN Reduction Options

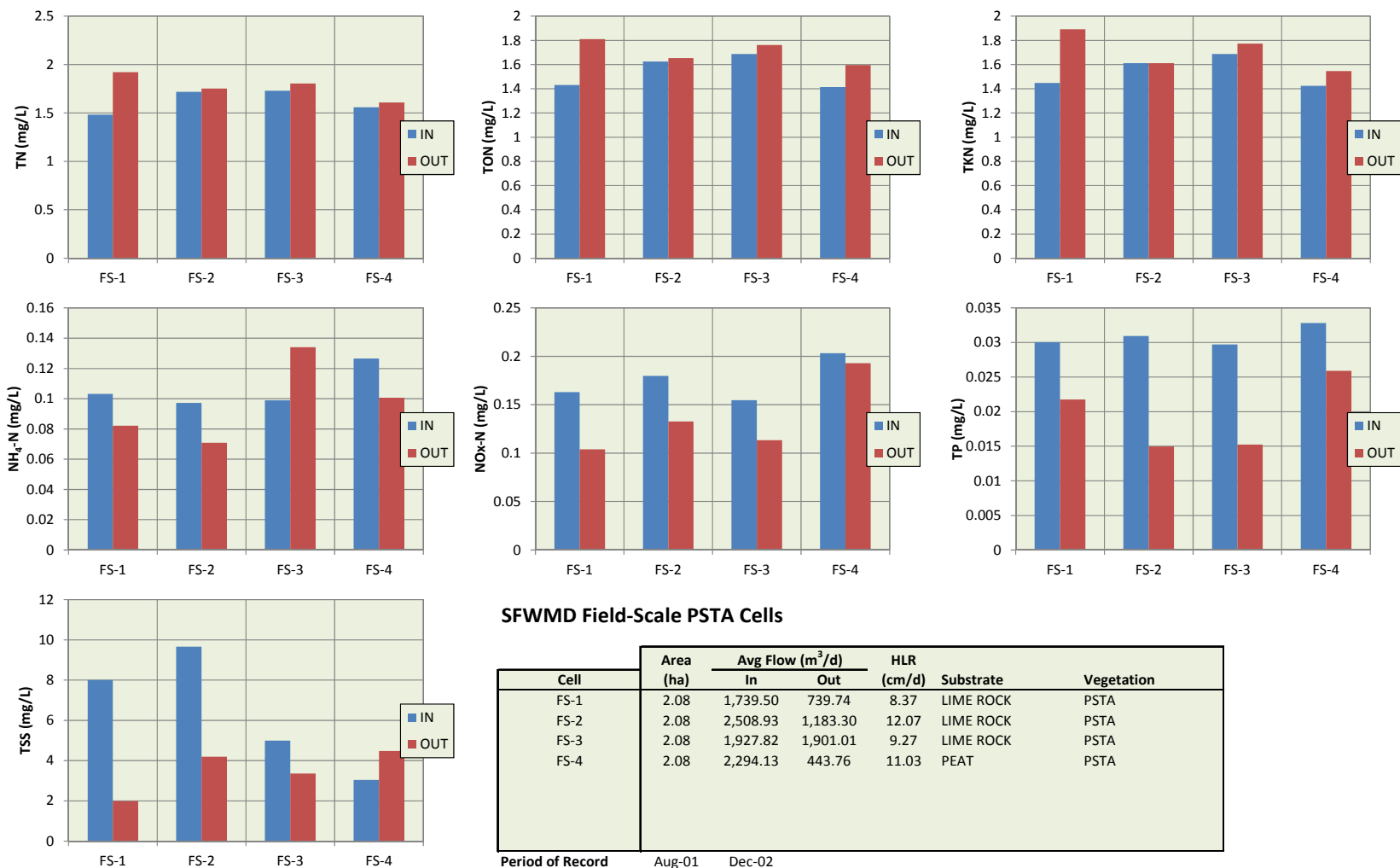


Exhibit 30 - SFWMD Field-Scale PSTA Cells Long-term Average Water Quality Summary

3.2.8 Wellington Aquatics Pilot Test Facility

The Village of Wellington initiated the Aquatics Pilot Program to demonstrate how well natural treatment wetlands may work to meet the anticipated 10 ppb Everglades Forever Act phosphorus threshold requirement. The Village of Wellington is responsible for the surface water management of a 13.6-square mile (3,500 ha) area within the Village (CH2M HILL 2003b). The Wellington Aquatics Pilot Test Facility is a 2.0-acre (8,000 m²) site consisting of six cells operated in two parallel treatment series (East and West) of three cells each (Exhibit 31). The West series included a FAP cell followed by an EMV cell and finally a PSTA cell. The East series included an EMV cell followed by a SAV cell and finally a PSTA cell.

Exhibit 32 shows POR (November 2001 to February 2003) monthly average inflow and outflow concentrations for nutrients and solids with monthly time series data presented in Appendix B. Inflow to the East and West series averaged 149 m³/d and 156 m³/d, respectively. Phosphorus concentrations were reduced by approximately 86 percent in the East series and 94 percent in the West series (CH2M HILL 2003b). Concentrations of TN and NO_x-N were lowered slightly in the Wellington Test Facility treatments.

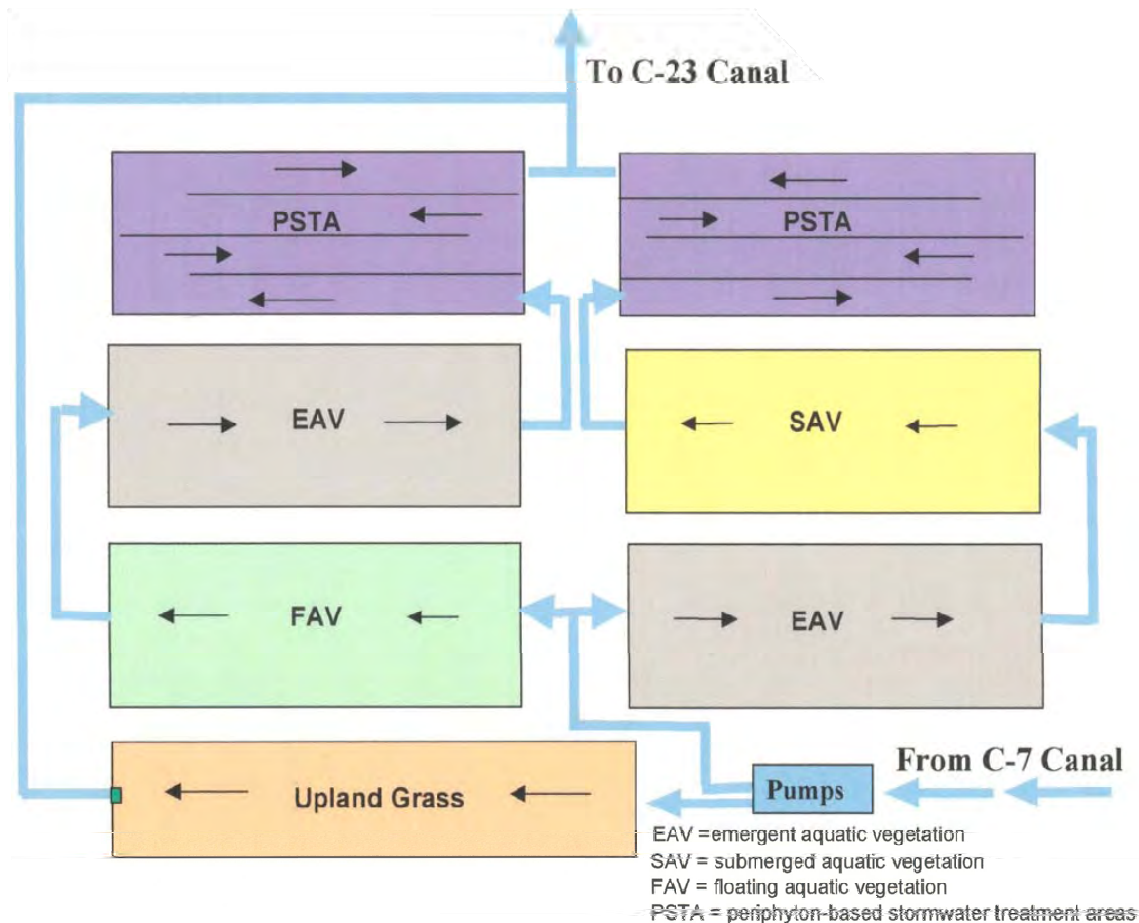


Exhibit 31 - Site Plan of the Wellington Aquatics Pilot Test Facility Showing the East (right side of drawing) and West Flow-Paths.

C-43 WQTA Test Facility Conceptual Design – TN Reduction Options

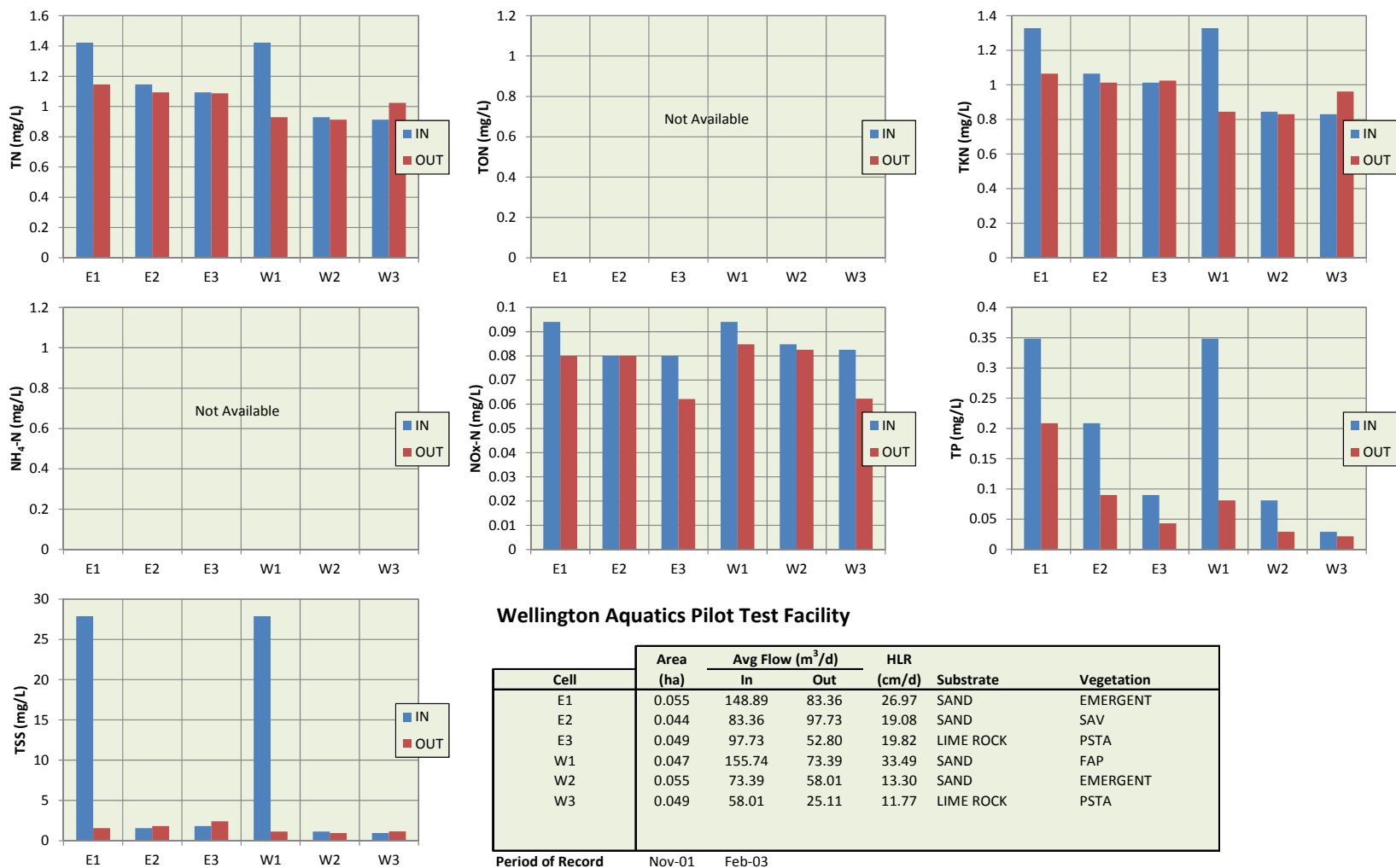


Exhibit 32 - Wellington Aquatics Pilot Test Facility Long-term Average Water Quality Summary for the East (E1 through E3) and West (W1 through W3) Flow Paths

3.2.9 C-43 West Storage Reservoir Test Cells

The C-43 West Storage Reservoir Project is an important component of the Comprehensive Everglades Restoration Program and is expected to capture and store approximately 170,000 acre-feet (210 million m³) of water during Florida's rainy season. Initially, in response to a concern raised to the District about the accuracy of seepage estimates for the full-scale Project, the District implemented a C-43 Storage Reservoir Test Cell Program. This Test Cell Program consisted of two test cells constructed within the footprint of the Project reservoir (Exhibit 33). Although the primary purpose of this Test Cell Program is to evaluate two different methods of reducing seepage, the test cells were utilized to provide a limited evaluation of water quality benefits and liabilities associated with reservoir start-up and operation (WSI 2007a).

The C-43 West Storage Reservoir Test Cells are located in Hendry County about 30 miles east of Fort Myers. Two Test Cells were constructed between March and June 2006, with initial pumping to fill the cells beginning on June 2006. The Test Cells were constructed with a wetted area of approximately 2.5 acres (1 ha) at the inside toe of slope and 4.5 acres (1.8 ha) at the target maximum water depth of 19 feet (5.8 m). These test cells were operated with no surface outflows (pumping was controlled within a target range of stages and all outflows were by evapotranspiration and leakage).

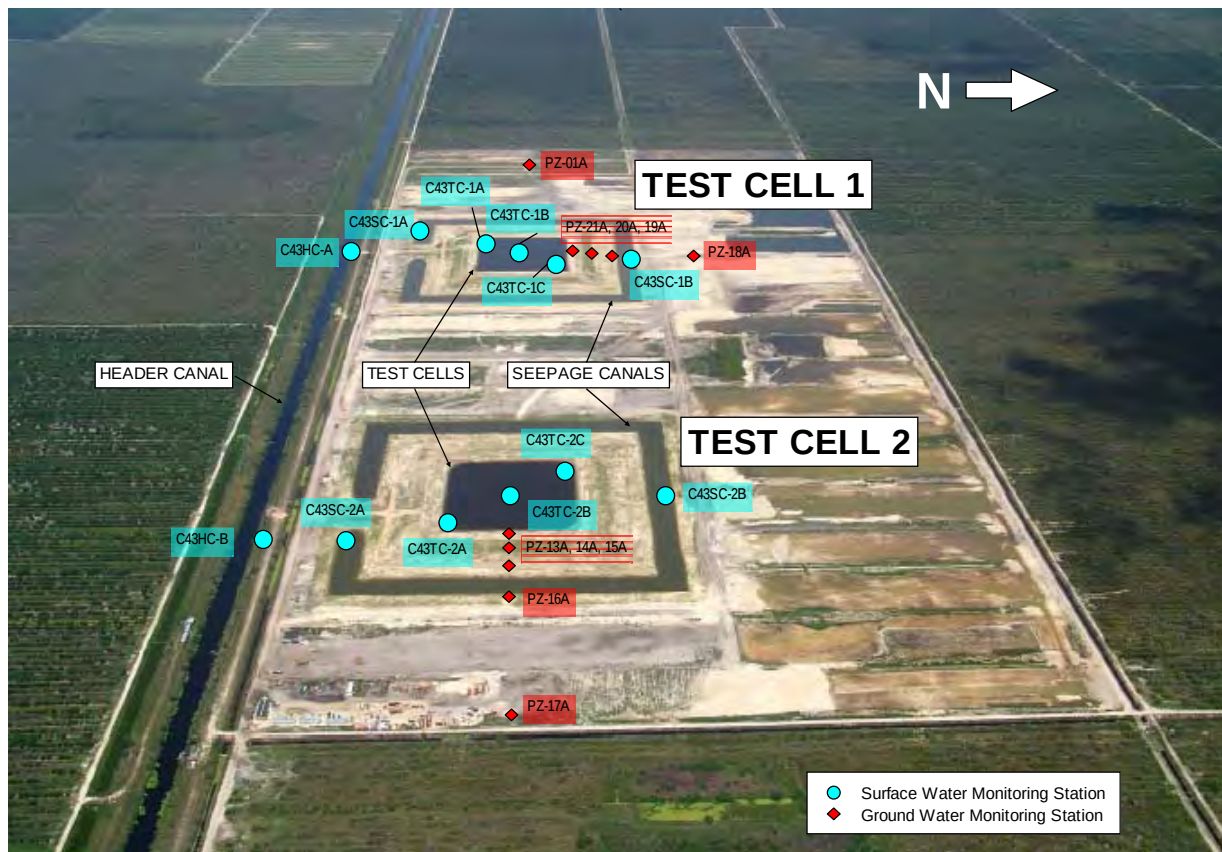


Exhibit 33 - Site Plan of the C-43 West Storage Reservoir Test Cells

Exhibit 34 shows POR (June 2006 to May 2007) monthly average inflow and outflow concentrations for nutrients and solids with monthly time series data presented in Appendix B. Nutrient concentrations were generally reduced through the Test Cells with an 14 percent long-term average reduction of TN (1.22 to 1.05 mg/L) and an average 74 percent reduction for TP (0.141 to 0.037 mg/L). The long-term average TSS was relatively unchanged with a concentration of 5.17 mg/L at the inflow and within the Test Cells. TSS was being produced in these OW cells due to growth of phytoplankton.

3.2.10 C-44 Reservoir/Stormwater Treatment Area Test Cells

The C-44 Reservoir/Stormwater Treatment Area Project is one component of the proposed Comprehensive Everglades Restoration Plan Indian River Lagoon South Integrated Project Implementation Report and Environmental Impact Statement (USACE and SFWMD 2004). The proposed C-44 Storage Reservoir/ STA Project is expected to retain and treat watershed runoff flows from the C-44 Canal (St. Lucie Canal) and possibly the C-23 Canal prior to discharge either to the St. Lucie River through S-80 or to Lake Okeechobee through S-308. The site for the C-44 Storage Reservoir/STA project is located north of the C-44 Canal about mid-way between Lake Okeechobee and the St. Lucie River in Martin County.

A test cell program was implemented in early 2006 to achieve the following objectives; assessment of storage reservoir seepage rates, water quality conditions during storage reservoir startup (initial flooding response), storage reservoir nutrient removal rates in response to reservoir water depth and hydraulic residence time, STA seepage rates, STA vegetation establishment from planting vs. natural recruitment, water quality conditions during STA startup (initial flooding response), and STA nutrient removal performance.

Two reservoir test cells and two STA test cells were constructed between March 2006 and June 2006 (Exhibit 35). Initial pumping began between mid-May and mid-June 2006, with the actual dates varying by cell. The reservoir test cells were constructed with a wetted area of approximately 2.2 acres (0.9 ha) at the inside toe of slope and 3.7 acres (1.5 ha) at the target maximum water depth of 15 feet (4.6 m). The STA cells were constructed with a wetted area of about 4.3 acres (1.7 ha) each at a target depth of about 1 foot (0.3 m) in the marsh zones (WSI 2007b). These test cells were operated with no surface outflows (pumping was controlled within a target range of stages and all outflows were by evapotranspiration and leakage).

Exhibit 36 shows POR (July 2006 to June 2007) monthly average inflow and outflow concentrations for nutrients and solids with monthly time series data presented in Appendix B. Nutrient concentrations were generally low in the Test Cells with an average TN concentration of 0.87 mg/L (3 percent reduction) and a TP average of 0.022 mg/L (58 percent reduction). TSS concentrations were reduced but still fairly high with an average inflow concentration of 29.3 mg/L and an outflow average of 14.3 mg/L (51 percent reduction). The C-44 STA-2 was the only STA cell that displayed a long-term average TP and TSS reduction [TP - 0.060 to 0.031 mg/L (48 percent), TSS - 11.6 to 8.1 mg/L (30 percent)]. The TN concentration was unchanged or increased in both STA Cells, apparently as a result of TN release from the pre-existing site soils.

C-43 WQTA Test Facility Conceptual Design – TN Reduction Options

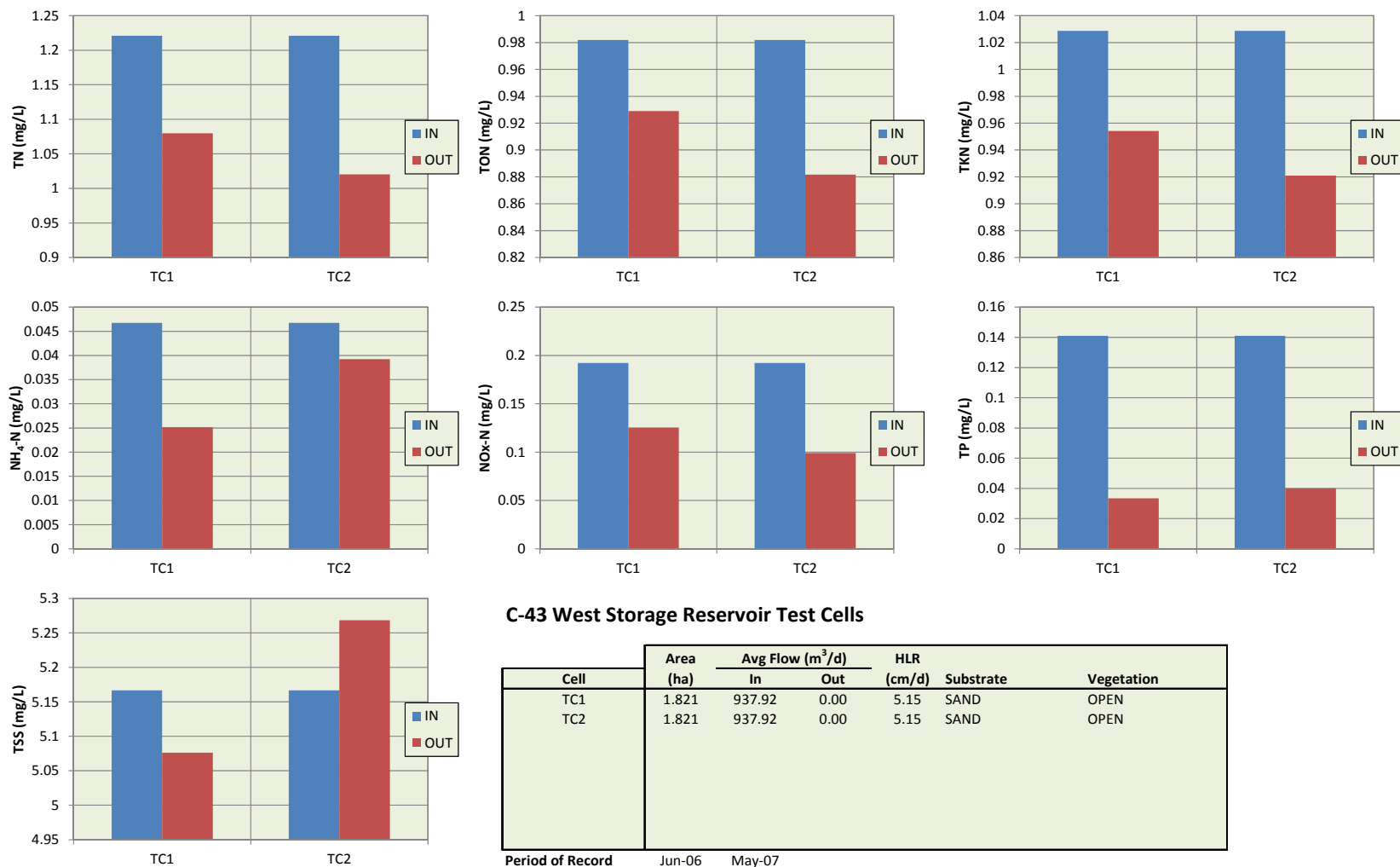


Exhibit 34 - C-43 West Storage Reservoir Test Cells Long-term Average Water Quality Summary

C-43 WQTA Test Facility Conceptual Design – TN Reduction Options

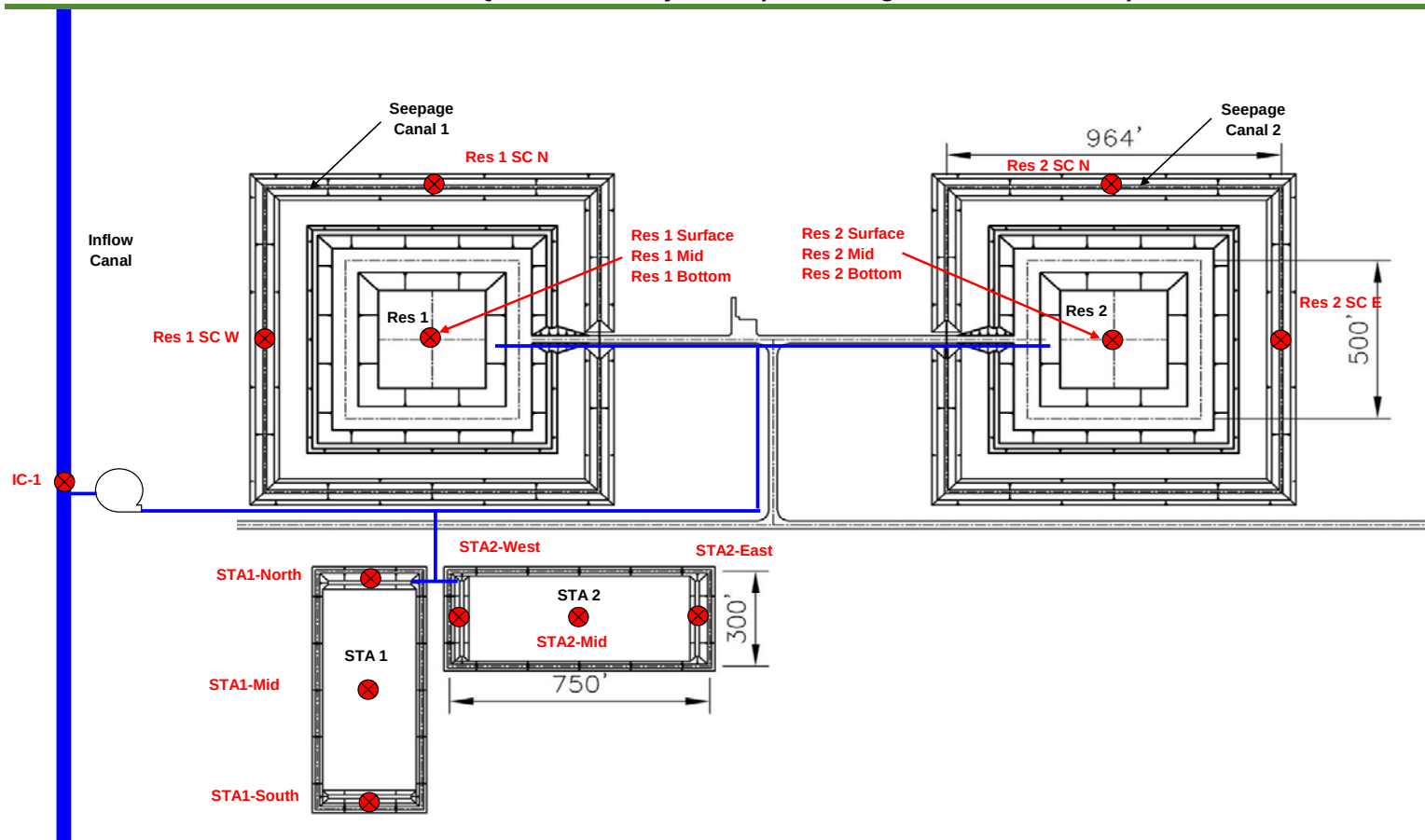
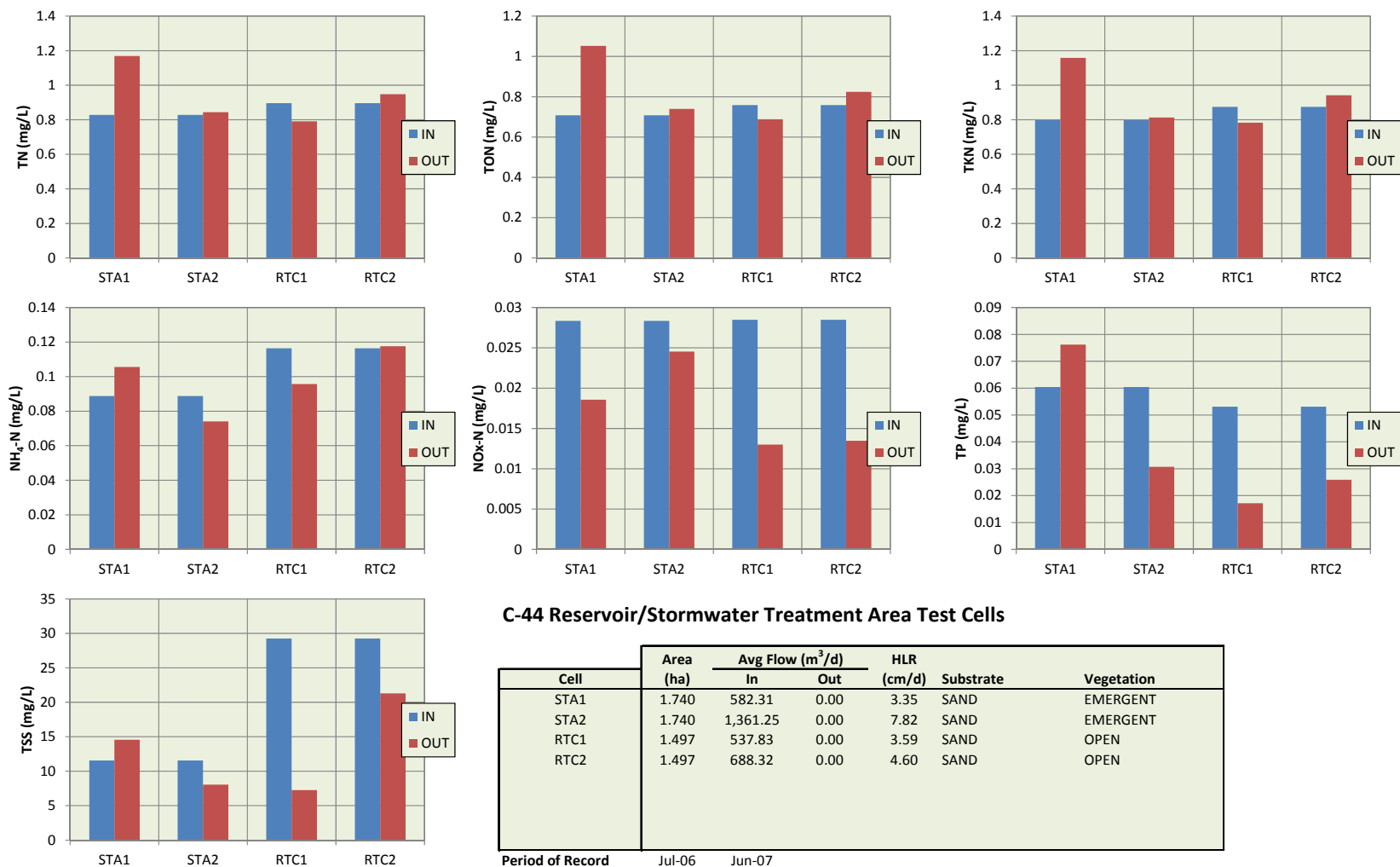


Exhibit 35 - Site Plan of the C-44 Reservoir/Stormwater Treatment Area Test Cells

C-43 WQTA Test Facility Conceptual Design – TN Reduction Options



C-44 Reservoir/Stormwater Treatment Area Test Cells

Cell	Area (ha)	Avg Flow (m ³ /d)		HLR (cm/d)	Substrate	Vegetation
		In	Out			
STA1	1.740	582.31	0.00	3.35	SAND	EMERGENT
STA2	1.740	1,361.25	0.00	7.82	SAND	EMERGENT
RTC1	1.497	537.83	0.00	3.59	SAND	OPEN
RTC2	1.497	688.32	0.00	4.60	SAND	OPEN

Period of Record Jul-06 Jun-07

Exhibit 36 - C-44 Reservoir/Stormwater Treatment Area Test Cells Long-term Average Water Quality Summary

3.3 Analysis of Design Factors Affecting Treatment Wetland Removal of Nitrogen Fractions

3.3.1 Site

Exhibit 37 summarizes the average inflow and outflow concentrations for nitrogen, phosphorus, and total suspended solids for each of the Florida treatment wetland systems included in this performance summary. The long-term average inflow TN concentrations for these systems ranged from 0.83 to 10.1 mg/L and the POR outflow TN concentrations ranged from 0.79 to 3.5 mg/L. The long-term average inflow total Kjeldahl nitrogen (TKN) concentrations for these systems ranged from 0.80 to 3.98 mg/L and the POR outflow TKN concentrations ranged from 0.78 to 3.14 mg/L. The long-term average inflow TON concentrations for these systems ranged from 0.71 to 3.90 mg/L and the POR outflow TON concentrations ranged from 0.69 to 2.88 mg/L. The long-term average inflow AN concentrations for these systems ranged from 0.03 to 1.08 mg/L and the POR outflow AN concentrations ranged from 0.01 to 0.76 mg/L. The long-term average inflow NO_x-N concentrations for these systems ranged from 0.02 to 6.29 mg/L and the POR outflow NO_x-N concentrations ranged from 0.00 to 1.53 mg/L. The long-term average inflow TP concentrations for these systems ranged from 0.02 to 5.42 mg/L and the POR outflow TP concentrations ranged from 0.01 to 5.00 mg/L. The long-term average inflow TSS concentrations for these systems ranged from 0.60 to 29.2 mg/L and the POR outflow TSS concentrations ranged from 0.20 to 21.3 mg/L.



C-43 WQTA Test Facility Conceptual Design – TN Reduction Options

Exhibit 37 - Average Inflow / Outflow Water Quality Concentrations by Treatment Wetland Site

System	Substrate	Vegetation	TP (mg/L)		NOx-N (mg/L)		NH ₄ -N (mg/L)		TKN (mg/L)		TON (mg/L)		TN (mg/L)		TSS (mg/L)		Period-of-Record	
			In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out		
Phase I Apopka Marsh Flow-Way																		
Cell B1	PEAT	EMERGENT	0.119	0.087	0.027	0.010	0.081	0.660	3.98	2.94	3.90	2.29	4.00	2.96	21.50	1.47	Nov-03	Dec-09
Cell B2	PEAT	EMERGENT	0.101	0.074	0.026	0.012	0.159	0.761	3.68	3.06	3.52	2.30	3.71	3.07	11.32	1.68	Nov-03	Dec-09
Cell C1	PEAT	EMERGENT	0.116	0.096	0.028	0.016	0.104	0.759	3.93	3.14	3.83	2.38	3.96	3.16	19.48	1.17	Nov-03	Dec-09
Cell C2	PEAT	EMERGENT	0.111	0.109	0.031	0.024	0.122	0.533	3.62	3.08	3.50	2.54	3.65	3.10	13.03	1.56	Nov-03	Dec-09
C-43 West Storage Reservoir Test Cell																		
Cell 1	SAND	OPEN	0.141	0.033	0.192	0.126	0.047	0.025	1.03	0.95	0.98	0.93	1.22	1.08	5.17	5.08	Jun-06	May-07
Cell 2	SAND	OPEN	0.141	0.040	0.192	0.099	0.047	0.039	1.03	0.92	0.98	0.88	1.22	1.02	5.17	5.27	Jun-06	May-07
C-44 Reservoir / Stormwater Treatment Area Test Cell 1																		
STA Cell 1	SAND	EMERGENT	0.060	0.076	0.028	0.019	0.089	0.106	0.80	1.16	0.71	1.05	0.83	1.17	11.55	14.58	Jul-06	Dec-06
STA Cell 2	SAND	EMERGENT	0.060	0.031	0.028	0.025	0.089	0.074	0.80	0.81	0.71	0.74	0.83	0.84	11.55	8.07	Jul-06	Dec-06
Test Cell 1	SAND	OPEN	0.053	0.017	0.028	0.013	0.116	0.096	0.88	0.78	0.76	0.69	0.90	0.79	29.25	7.27	Jul-06	Jun-07
Test Cell 2	SAND	OPEN	0.053	0.026	0.028	0.013	0.116	0.118	0.88	0.94	0.76	0.82	0.90	0.95	29.25	21.29	Jul-06	Jun-07
City of Lakeland Wetland Treatment System Cells																		
Cell 1	CLAY	EMERGENT	5.416	5.001	6.289	1.528	1.081	0.641	3.83	2.01	2.68	1.42	10.11	3.50	8.25	1.49	Jan-87	Sep-08
Cell 2	CLAY	EMERGENT	4.995	4.406	1.530	0.730	0.643	0.246	2.01	1.16	1.42	0.91	3.50	1.84	1.49	1.52	Jan-87	Sep-08
Cell 3	CLAY	EMERGENT	4.406	4.192	0.730	0.194	0.246	0.182	1.16	1.06	0.91	0.88	1.84	1.87	1.52	3.19	Jan-87	Sep-08
Cell 4	CLAY	EMERGENT	4.192	4.085	0.194	0.169	0.182	0.127	1.06	1.06	0.88	0.93	1.87	1.21	3.19	3.27	Jan-87	Sep-08
Cell 5	CLAY	SAV	3.862	3.412	0.210	0.205	0.171	0.166	1.14	1.46	0.97	1.30	1.29	1.64	3.03	20.71	Jan-87	Sep-08
Cell 6	CLAY	FAP	3.412	3.034	0.205	0.220	0.166	0.302	1.46	1.57	1.30	1.27	1.64	1.79	20.71	7.87	Jan-87	Sep-08
Cell 7	CLAY	FAP	3.034	2.898	0.220	0.181	0.302	0.178	1.57	1.32	1.27	1.14	1.79	1.51	7.87	5.97	Jan-87	Sep-08
Orlando Easterly Wetlands	SAND	EMERGENT	0.265	0.064	0.850	0.038	0.523	0.058	1.38	0.85	0.85	0.80	2.23	0.87	1.93	2.65	Jan-88	Nov-11
SFWMD Field-Scale PSTA Cells																		
FS-1	LIME ROCK	PSTA	0.030	0.022	0.163	0.104	0.103	0.082	1.45	1.89	1.43	1.81	1.48	1.92	8.01	1.99	Aug-01	Dec-02
FS-2	LIME ROCK	PSTA	0.031	0.015	0.180	0.133	0.097	0.071	1.61	1.61	1.63	1.65	1.72	1.75	9.67	4.19	Sep-01	Dec-02
FS-3	LIME ROCK	PSTA	0.030	0.015	0.155	0.113	0.099	0.134	1.69	1.77	1.69	1.76	1.73	1.81	5.00	3.35	Aug-01	Dec-02
FS-4	PEAT	PSTA	0.033	0.026	0.203	0.193	0.127	0.101	1.42	1.55	1.41	1.60	1.56	1.61	3.04	4.47	Nov-01	Dec-02
SFWMD Porta-PSTA Mesocosms Treatments																		
Treatment 1	PEAT	PSTA	0.021	0.018	0.064	0.022	0.029	0.026	1.17	1.17	1.14	1.14	1.24	1.17	2.02	3.72	Apr-99	Jan-00
Treatment 2	LIME ROCK	PSTA	0.022	0.018	0.061	0.035	0.037	0.028	1.24	1.22	1.20	1.20	1.30	1.27	2.12	4.48	Apr-99	Jan-00
Treatment 3	PEAT	PSTA	0.025	0.018	0.047	0.014	0.033	0.024	1.52	1.47	1.48	1.21	1.57	1.49	2.49	2.93	Apr-99	Feb-01
Treatment 4	LIME ROCK	PSTA	0.025	0.016	0.046	0.020	0.034	0.025	1.58	1.57	1.55	1.38	1.63	1.60	2.66	3.47	Apr-99	Feb-01
Treatment 5	LIME ROCK	PSTA	0.023	0.018	0.059	0.020	0.034	0.026	1.33	1.30	1.29	1.14	1.39	1.31	1.99	3.17	Apr-99	Mar-00
Treatment 6	LIME ROCK	PSTA	0.023	0.018	0.059	0.026	0.035	0.029	1.34	1.29	1.31	1.19	1.41	1.32	1.86	3.56	Apr-99	Mar-00
Treatment 7	SAND	PSTA	0.025	0.018	0.044	0.096	0.034	0.029	1.48	1.66	1.45	1.41	1.53	1.74	2.85	2.33	Apr-99	Feb-01
Treatment 8	SAND	PSTA	0.020	0.021	0.062	0.023	0.032	0.023	1.33	1.14	1.30	1.12	1.40	1.15	2.01	3.84	Apr-99	Jan-00
Treatment 9	PEAT	OPEN	0.024	0.019	0.063	0.025	0.032	0.077	1.32	1.42	1.29	1.25	1.39	1.42	1.71	4.15	Apr-99	Mar-00
Treatment 10	LIME ROCK	OPEN	0.024	0.016	0.053	0.017	0.035	0.069	1.32	1.28	1.29	1.16	1.38	1.28	2.94	5.09	Apr-99	Mar-00
Treatment 11	LIME ROCK	PSTA	0.025	0.020	0.045	0.027	0.035	0.026	1.60	1.66	1.57	1.45	1.65	1.67	2.47	4.80	Apr-99	Feb-01
Treatment 12	PEAT	PSTA	0.025	0.020	0.043	0.013	0.034	0.026	1.53	1.49	1.50	1.30	1.58	1.49	2.60	4.70	Apr-99	Feb-01
Treatment 13	PEAT	PSTA	0.028	0.017	0.022	0.010	0.032	0.121	1.99	2.15	1.96	2.32	2.01	2.16	4.90	4.39	Apr-00	Feb-01
Treatment 14	LIME ROCK	PSTA	0.028	0.015	0.023	0.010	0.032	0.014	2.11	1.71	2.07	2.02	2.13	1.68	5.47	2.60	Apr-00	Feb-01
Treatment 15	LIME ROCK	PSTA	0.028	0.017	0.023	0.012	0.032	0.024	2.01	2.10	1.98	2.41	1.97	2.11	4.67	3.33	Apr-00	Feb-01
Treatment 16	LIME ROCK	PSTA	0.025	0.017	0.034	0.008	0.042	0.020	2.16	2.33	2.12	2.32	2.20	2.33	2.67	2.50	May-00	Feb-01
Treatment 17	SAND	PSTA	0.028	0.016	0.020	0.002	0.033	0.012	2.10	2.03	2.07	2.09	2.12	2.06	4.00	3.13	Apr-00	Feb-01
Treatment 18	NONE	OPEN	0.028	0.016	0.021	0.002	0.033	0.036	2.62	2.01	2.58	2.16	2.64	2.01	4.00	2.60	Apr-00	Feb-01
Treatment 19	NONE	PSTA	0.027	0.014	0.021	0.003	0.034	0.027	2.11	2.34	2.07	1.96	2.13	2.34	3.80	4.22	Apr-00	Feb-01



C-43 WQTA Test Facility Conceptual Design – TN Reduction Options

Exhibit 37 (Cont.) Average Inflow / Outflow Water Quality Concentrations by Treatment Wetland Site

System	Substrate	Vegetation	TP (mg/L)		NOx-N (mg/L)		NH ₄ -N (mg/L)		TKN (mg/L)		TON (mg/L)		TN (mg/L)		TSS (mg/L)		Period-of-Record	
			In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out		
SFWMD PSTA Test Cells Treatments																		
Treatment 1	PEAT	PSTA	0.025	0.026	0.068	0.028	0.068	0.022	1.93	1.17	1.86	1.15	1.96	1.18	2.94	2.68	Feb-99	Jan-00
Treatment 2	LIME ROCK	PSTA	0.024	0.018	0.068	0.019	0.069	0.027	1.86	1.47	1.79	1.30	1.89	1.42	3.11	4.13	Feb-99	Mar-00
Treatment 3	LIME ROCK	PSTA	0.024	0.023	0.072	0.022	0.064	0.021	1.90	1.53	1.83	1.28	1.95	1.47	2.82	6.02	Feb-99	Mar-00
Treatment 4	PEAT	PSTA	0.023	0.032	0.071	0.010	0.086	0.028	2.38	2.34	2.30	2.41	2.45	2.50	3.35	4.48	Apr-00	Mar-01
Treatment 5	LIME ROCK	PSTA	0.023	0.012	0.071	0.002	0.086	0.017	2.37	2.36	2.29	2.39	2.44	2.37	3.36	3.86	Apr-00	Mar-01
Treatment 6	LIME ROCK	PSTA	0.023	0.019	0.057	0.002	0.098	0.030	2.57	2.58	2.47	2.88	2.63	2.58	2.77	2.67	May-00	Mar-01
STA-1E																		
Cell 3	SAND	EMERGENT	0.139	0.155	0.173	0.021	0.099	0.035	1.32	1.32	1.22	1.28	1.49	1.34	11.41	4.22	May-06	Jan-12
Cell 4N	SAND	SAV	0.155	0.066	0.021	0.020	0.035	0.043	1.32	1.63	1.28	1.58	1.34	1.65	4.22	4.84	May-06	Jan-12
Cell 4S	PEAT	SAV	0.070	0.030	0.058	0.031	0.183	0.052	1.62	1.37	1.44	1.32	1.68	1.40	4.80	3.30	May-06	Jan-12
Cell 5	SAND	EMERGENT	0.217	0.241	0.396	0.068	0.193	0.122	2.26	2.26	2.06	2.13	2.65	2.32	9.76	9.75	May-06	Jan-12
Cell 6	PEAT	SAV	0.170	0.147	0.126	0.120	0.124	0.134	2.55	3.00	2.43	2.86	2.68	3.12	8.79	7.89	May-06	Jan-12
Cell 7	PEAT	EMERGENT	0.172	0.134	0.716	0.185	0.297	0.131	2.88	2.68	2.58	2.55	3.60	2.87	16.96	8.31	May-06	Jan-12
STA-1W																		
Cell 1	PEAT	EMERGENT	0.133	0.109	0.533	0.325	0.598	0.202	2.92	2.72	2.32	2.52	3.45	3.04	0.60	0.20	Jun-00	Jan-08
Cell 1A	PEAT	EMERGENT	0.135	0.110	0.926	0.244	0.499	0.149	2.74	2.39	2.24	2.24	3.67	2.64	11.97	9.60	May-08	Jan-12
Cell 1B+3	PEAT	SAV	0.109	0.031	0.087	0.050	0.093	0.136	2.27	2.22	2.18	2.08	2.36	2.27	3.80	3.17	May-08	Jan-12
Cell 2	PEAT	EMERGENT	0.128	0.110	0.842	0.411	0.485	0.125	3.05	2.72	2.56	2.59	3.89	3.13	17.40	8.63	Jun-00	Nov-04
Cell 3	PEAT	EMERGENT	0.102	0.078	0.248	0.135	0.149	0.184	2.60	2.21	2.45	2.02	2.85	2.34	8.69	3.33	Jun-00	Jan-08
Cell 4	PEAT	SAV	0.110	0.053	0.411	0.146	0.125	0.040	2.72	2.09	2.59	2.05	3.13	2.23	8.63	3.14	Jun-00	Nov-04
North Flow-way	PEAT	SAV	0.154	0.087	0.773	0.143	0.354	0.086	2.60	2.59	2.25	2.51	3.37	2.74	16.39	11.00	Jun-00	Feb-12
West Flow-way	PEAT	SAV	0.145	0.043	0.216	0.128	0.216	0.128	2.58	2.45	2.37	2.32	2.80	2.57	14.26	3.13	Feb-08	Feb-12
STA-2																		
Cell 1A	PEAT	EMERGENT	0.060	0.013	0.685	0.018	0.380	0.032	2.45	2.13	2.07	2.10	3.14	2.15	8.55	2.96	Mar-02	May-05
Cell 1B	PEAT	EMERGENT	0.090	0.017	0.840	0.033	0.315	0.027	2.54	1.99	2.22	1.96	3.38	2.02	8.12	3.00	Jun-05	Feb-12
Cell 2	PEAT	EMERGENT	0.089	0.029	0.844	0.147	0.315	0.076	2.61	2.19	2.30	2.12	3.46	2.34	9.81	3.13	Mar-02	Feb-12
Cell 3	PEAT	SAV	0.084	0.019	0.824	0.190	0.270	0.046	2.54	2.22	2.27	2.18	3.36	2.41	7.22	3.02	Mar-02	Feb-12
Cell 4	PEAT	SAV	0.095	0.028	0.633	0.069	0.190	0.229	2.51	2.73	2.32	2.50	3.15	2.80	11.13	4.51	Feb-08	Feb-12
STA-3/4																		
Cell 1A	PEAT	EMERGENT	0.084	0.042	1.052	0.077	0.230	0.069	2.26	2.13	2.03	2.07	3.32	2.21	10.29	3.19	May-05	Jan-12
Cell 1B	PEAT	SAV	0.036	0.019	0.078	0.022	0.070	0.071	2.14	2.05	2.07	1.98	2.22	2.08	3.13	3.09	May-05	Feb-12
Cell 2A	PEAT	EMERGENT	0.066	0.030	1.490	0.135	0.150	0.073	2.16	2.03	2.01	1.95	3.64	2.16	8.35	3.06	May-05	Jan-12
Cell 2B	PEAT	SAV	0.028	0.021	0.134	0.028	0.072	0.084	2.05	1.95	1.98	1.87	2.18	1.98	3.08	3.02	May-05	Feb-12
Cell 3A	PEAT	EMERGENT	0.051	0.025	1.562	0.148	0.112	0.052	2.08	2.04	1.97	1.99	3.64	2.19	7.55	3.00	Apr-08	Feb-12
Cell 3B	PEAT	SAV	0.025	0.018	---	---	---	---	---	---	---	---	---	---	---	---	Apr-08	Nov-11
STA-5																		
Cell 1A	PEAT	EMERGENT	0.128	0.131	0.056	0.021	0.396	0.057	1.89	1.69	1.50	1.63	1.95	1.71	4.28	3.57	Apr-08	Feb-12
Cell 1B	PEAT	SAV	0.090	0.049	0.017	0.017	0.074	0.220	1.72	1.97	1.64	1.75	1.74	1.98	3.67	3.69	Apr-08	Jan-12
Cell 2A	PEAT	EMERGENT	0.137	0.063	0.078	0.015	0.110	0.046	1.57	1.45	1.46	1.41	1.64	1.47	4.88	3.07	Apr-08	Feb-12
Cell 2B	PEAT	SAV	0.101	0.072	---	---	---	---	---	---	---	---	---	---	---	---	Apr-08	Feb-12
Cell 3A	PEAT	EMERGENT	0.223	0.101	0.078	0.040	0.078	0.061	1.52	1.86	1.44	1.80	1.60	1.90	4.15	5.63	Apr-08	Feb-12
Cell 3B	PEAT	SAV	0.079	0.042	0.029	0.005	0.047	0.022	1.35	1.52	1.30	1.50	1.38	1.53	3.98	4.07	Apr-08	Feb-12
Center Flow-way	PEAT	EMERGENT	0.152	0.143	0.047	0.018	0.241	0.051	1.65	1.52	1.41	1.47	1.70	1.54	2.80	1.78	May-00	Mar-08
North Flow-way	PEAT	EMERGENT	0.106	0.123	0.063	0.027	0.326	0.067	1.67	1.58	1.35	1.51	1.74	1.61	1.68	3.00	May-00	Mar-08



C-43 WQTA Test Facility Conceptual Design – TN Reduction Options

Exhibit 37 (Cont.) Average Inflow / Outflow Water Quality Concentrations by Treatment Wetland Site

System	Substrate	Vegetation	TP (mg/L)		NOx-N (mg/L)		NH ₄ -N (mg/L)		TKN (mg/L)		TON (mg/L)		TN (mg/L)		TSS (mg/L)		Period-of-Record	
			In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out		
STA-6																		
Cell 3	PEAT	EMERGENT	0.068	0.033	0.105	0.008	0.099	0.030	1.56	1.36	1.47	1.34	1.67	1.37	4.26	2.99	Oct-02	Feb-12
Cell 5	PEAT	EMERGENT	0.080	0.023	0.112	0.008	0.133	0.049	1.63	1.48	1.49	1.43	1.74	1.49	4.98	3.03	Oct-02	Feb-12
Section 2	PEAT	SAV	0.105	0.044	0.100	0.006	0.176	0.043	1.60	1.41	1.43	1.37	1.70	1.42	6.22	3.13	May-08	Oct-11
Taylor Creek Pilot STA	SAND	EMERGENT	0.320	0.229	0.172	0.009	0.100	0.120	1.57	1.55	1.47	1.43	1.74	1.56	5.19	3.27	Jun-08	Jan-12
City of Titusville, Blue Heron Wetland	SAND	EMERGENT	0.493	0.077	2.485	0.042	0.438	0.284	1.60	1.16	1.16	0.87	4.02	1.19	0.97	1.30	Jan-97	Dec-11
Wellington Aquatics Pilot Test Facility																		
Cell E1	SAND	EMERGENT	0.348	0.209	0.094	0.080	---	---	1.33	1.07	---	---	1.42	1.15	27.9	1.56	Nov-01	Feb-03
Cell E2	SAND	SAV	0.209	0.090	0.080	0.080	---	---	1.07	1.01	---	---	1.15	1.09	1.56	1.81	Nov-01	Feb-03
Cell E3	LIME ROCK	PSTA	0.090	0.043	0.080	0.062	---	---	1.01	1.02	---	---	1.09	1.09	1.81	2.40	Nov-01	Feb-03
Cell W1	SAND	FAP	0.348	0.081	0.094	0.085	---	---	1.33	0.84	---	---	1.42	0.93	27.9	1.13	Nov-01	Feb-03
Cell W2	SAND	EMERGENT	0.081	0.029	0.085	0.083	---	---	0.84	0.83	---	---	0.93	0.91	1.13	0.94	Nov-01	Feb-03
Cell W3	LIME ROCK	PSTA	0.029	0.022	0.083	0.062	---	---	0.83	0.96	---	---	0.91	1.02	0.94	1.15	Nov-01	Feb-03

Notes:

Period of record averages are reported as arithmetic means; Monthly time series data presented in Appendix B are arithmetic means with the exception of the following sites which are reported as flow-weighted means: STA-1E, STA-1W, STA-2, STA-3/4, STA-5, STA-6, Taylor Creek Pilot STA

Exhibit 38 summarizes the annual average mass loading rate vs. outflow concentrations for TP in the Florida treatment wetlands included in this evaluation. All annual data presented below are arithmetic means by calendar year. Outflow TP concentration appears to be a function of TP mass loading rate with considerable intra-site and year-to-year variability. The Lakeland system built on a former phosphate mine had the highest TP loading rates and resulting outflow TP concentrations. The PSTA test systems, STA-2, STA-3/4, and the open-water reservoir test cells typically had the lowest TP inflow loads and TP outflow concentrations.

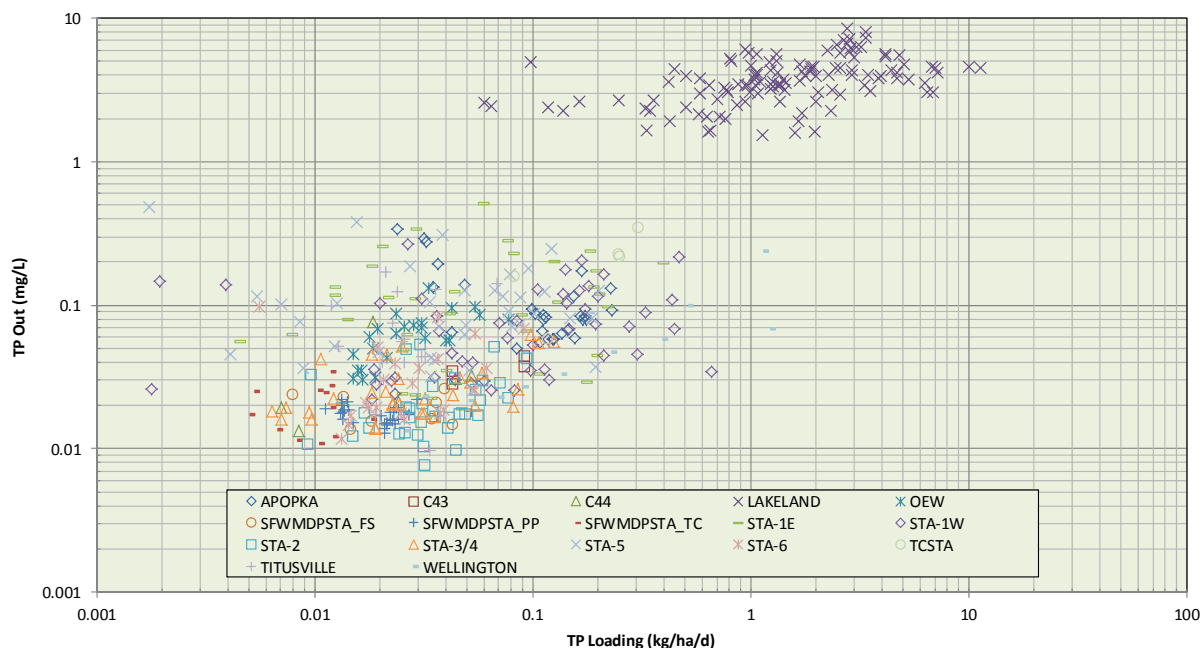


Exhibit 38 - Annual TP Mass Loading vs. Outlet Concentration by Site

Exhibit 39 summarizes the annual average mass loading rate vs. outflow concentrations for NO_x-N in the Florida treatment wetlands included in this evaluation. Outflow NO_x-N concentration is clearly a function of NO_x-N mass loading rate with considerable intra-site and year-to-year variability. The Lakeland treatment wetland system built on a former phosphate mine had the highest NO_x-N loading rates and resulting outflow NO_x-N concentrations. The majority of the treatment wetland systems evaluated were able to achieve very low NO_x-N concentrations, often below 0.01 mg/L.

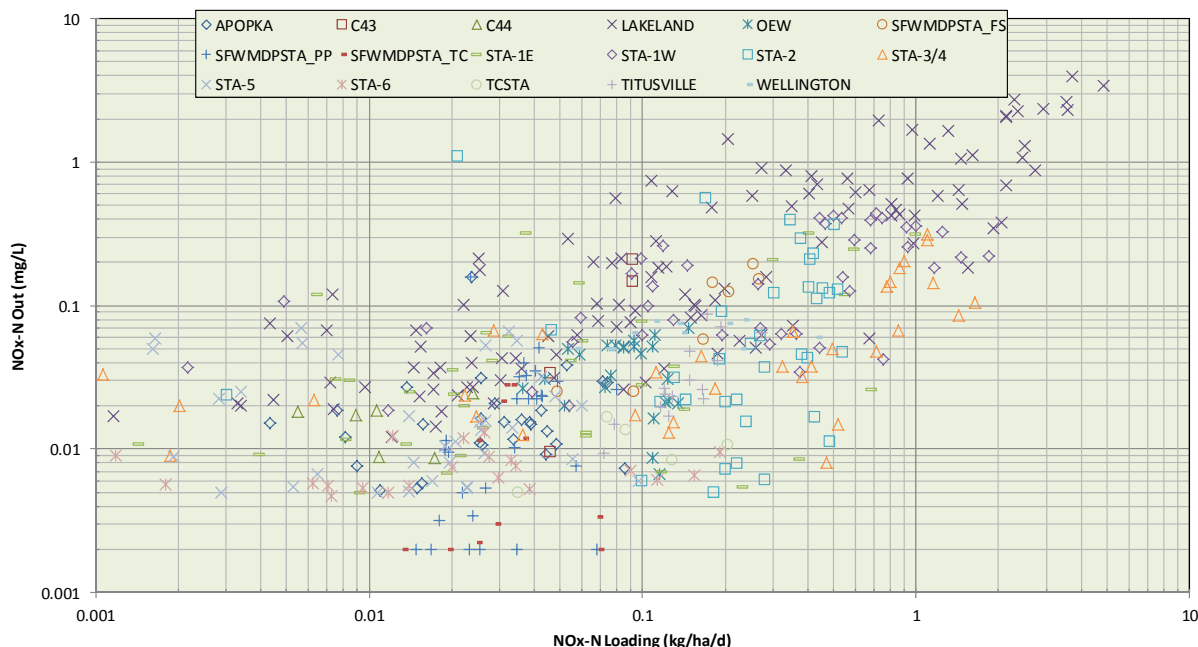


Exhibit 39 - Annual NOx-N Mass Loading vs. Outlet Concentration by Site

Exhibit 40 summarizes the annual average mass loading rate vs. outflow concentrations for AN in the Florida treatment wetlands included in this evaluation. At the inflow loads included in this analysis there does not appear to be a strong effect on outflow AN concentration. However, there is a considerable intra-site and year-to-year variability for AN performance at these sites. The Lakeland and Apopka wetland systems generally have the highest AN loading rates and resulting outflow AN concentrations. Very low outflow AN concentrations (<0.1 mg/L) were typical of the remaining wetland systems across the range of AN mass loading rates summarized.

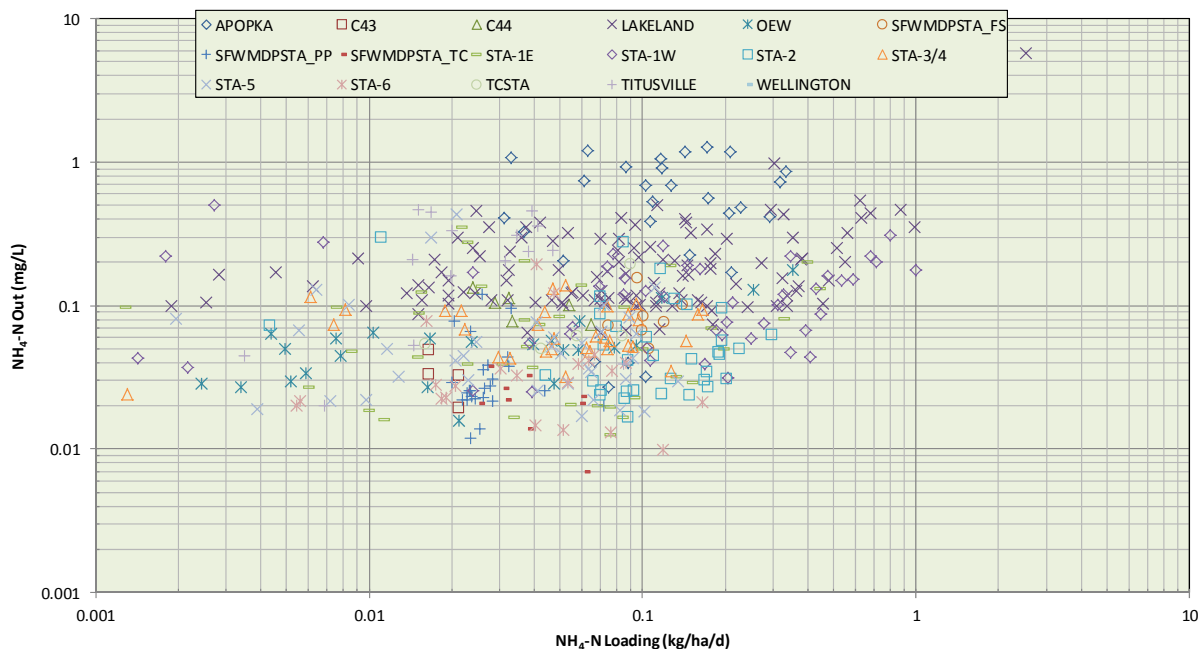


Exhibit 40 - Annual AN Mass Loading vs. Outlet Concentration by Site

Exhibit 41 summarizes the annual average mass loading rate vs. outflow concentrations for TKN in the Florida treatment wetlands included in this evaluation. Above a TKN loading rate of about 0.1 kg/ha/d, outflow TKN concentration is a function of TKN mass loading rate with considerable intra-site and year-to-year variability. The Lake Apopka treatment wetland system built on a former muck farm had the highest TKN loading rates and resulting outflow TKN concentrations. The wetlands with the lowest outflow TKN concentrations included the PSTA test systems, the Orlando Easterly wetland, the C-43 and C-44 test cells, Lakeland, and STA-1E.

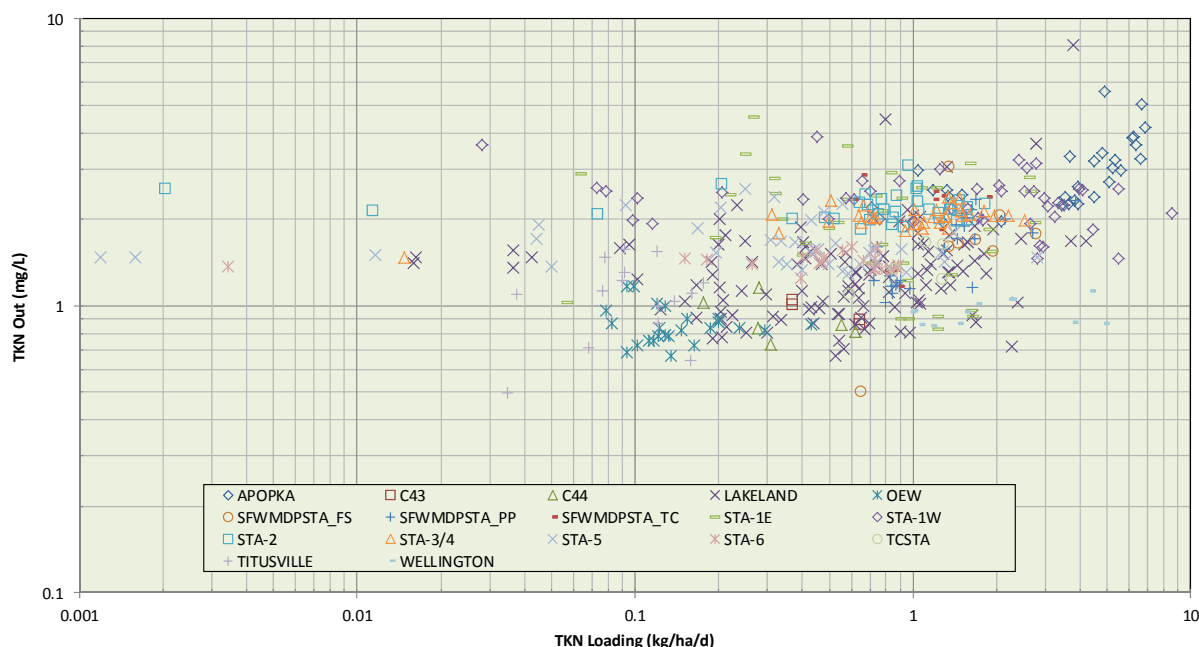


Exhibit 41 - Annual TKN Mass Loading vs. Outlet Concentration by Site

Exhibit 42 summarizes the annual average mass loading rate vs. outflow concentrations for TON in the Florida treatment wetlands included in this evaluation. Organic N loading rates do not exceed about 10 kg TON/ha/d for these data and within this range, most of the wetland TON outflow concentrations are in the range of 1 to 2 mg/L. This is the general TON background typical of treatment wetlands worldwide. Kadlec and Knight (1996) recommend an TON C* value (irreducible or wetland background concentration) of 1.5 mg/L. Of particular interest to the C-43 WQTA project is the observation that some of the Florida systems consistently achieve TON concentrations consistently lower than 1.5 mg/L. These systems include the Orlando Easterly Wetland, Lakeland, and the C-43 and C-44 reservoir test cell projects. Of the EAA STAs, STA-1E and STA-6 achieve the lowest TON concentrations, typically less than 1.5 mg/L. Three of these wetland cells were constructed on sandy or clayey soils. The effects of soil type on TON C* values is examined further below.

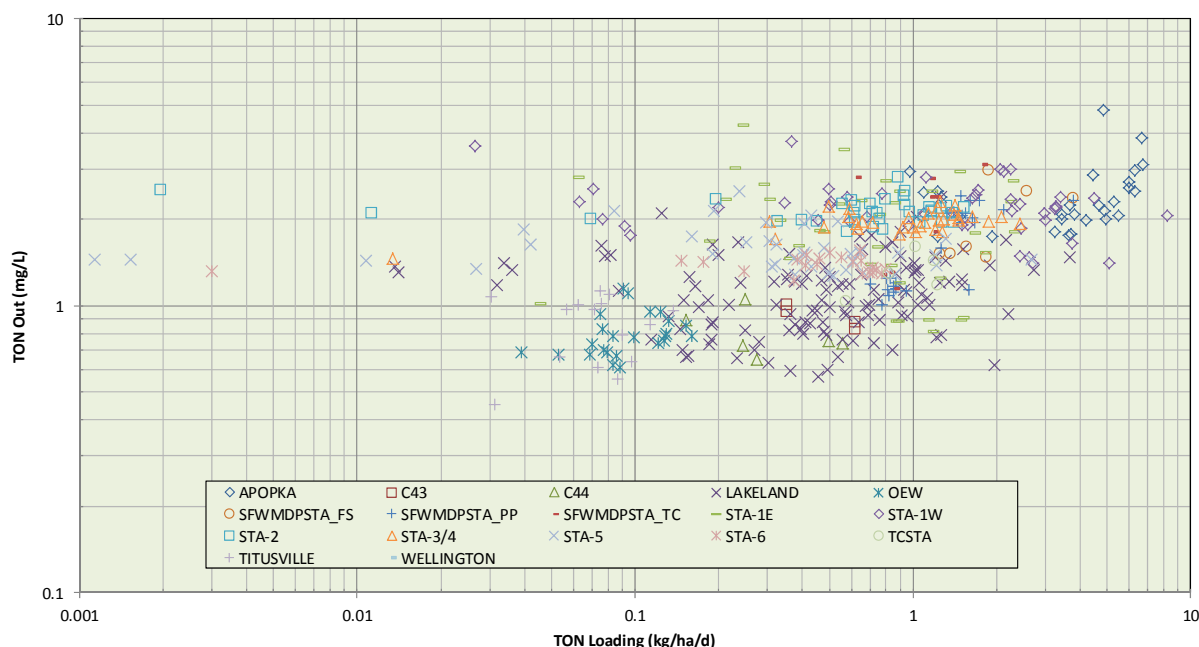


Exhibit 42 - Annual TON Mass Loading vs. Outlet Concentration by Site

Exhibit 43 summarizes the annual average mass loading rate vs. outflow concentrations for TN in the Florida treatment wetlands included in this evaluation. Due to the generally low inorganic N fraction remaining in wetland outflows, outflow TN concentrations are similar to the TON data reviewed above. Kadlec and Knight (1996) estimated a TN C^* of 1.5 mg/L. These data support that estimate for wetland systems loaded less than about 2 kg TN/ha/d. However, these data also clearly illustrate the potential to lower TN concentrations to less than 1 mg/L (as low as 0.6 mg/L on an annual average basis) in a variety of full-scale constructed aquatic and wetland treatment systems

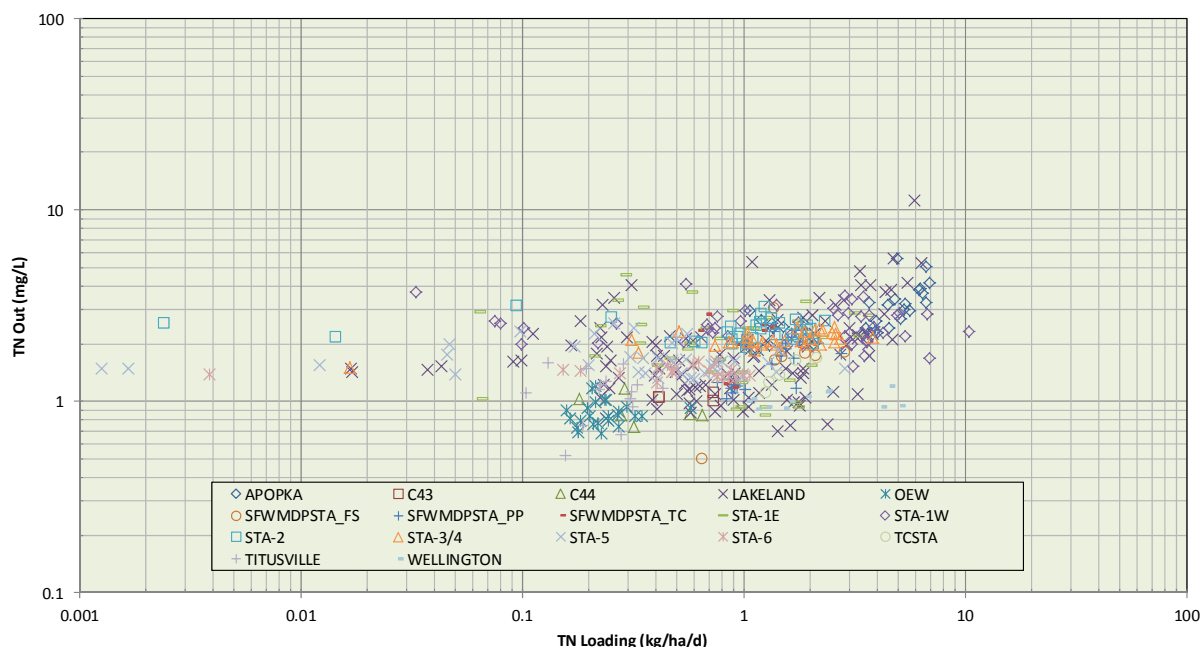


Exhibit 43 - Annual TN Mass Loading vs. Outlet Concentration by Site

Exhibit 44 summarizes the annual average mass loading rate vs. outflow concentrations for TSS in the Florida treatment wetlands included in this evaluation. Within the range of TSS loadings included in this analysis, outflow TSS concentration is largely independent of inflow loads. The central tendency of these TSS data is an outflow concentration of about 5 mg/L, with a range from 1 to 10 mg/L. The wetland systems with the lowest TSS outflow concentrations include Wellington, STA-1W, and the Porta PSTAs. These reported TSS concentrations may be an artifact of differing minimum reporting methods since they are below the typical analytical TSS detection level of 3 mg/L.

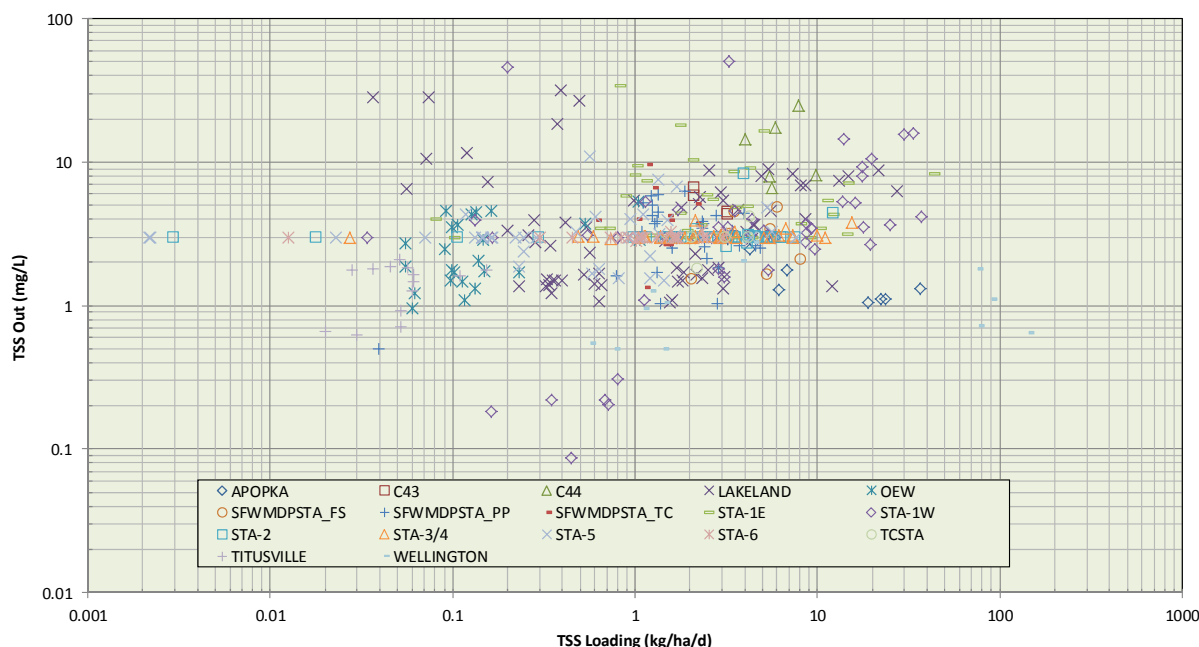


Exhibit 44 - Annual TSS Mass Loading vs. Outlet Concentration by Site

3.3.2 Inflow Concentration

Kadlec and Wallace (2009) note that C^* values are sometimes related to inflow concentrations for most pollutants in treatment wetlands. The apparent explanation for this phenomenon is that in most treatment systems there is some water that short circuits and has shorter effective hydraulic residence times and receives less treatment. Exhibit 45 through Exhibit 51 illustrate the effect of higher inflow pollutant concentrations on observed outflow concentrations for Florida systems. The effect is most notable for pollutants with slower reaction rates such as TP. Exhibit 45 illustrates that the achievable outflow TP is about 10 to 20 ppb lower for wetlands receiving the lowest inflow TP concentrations. Exhibit 46 for $\text{NO}_x\text{-N}$ does not show this effect as strongly as TP since wetland systems receiving higher inflow $\text{NO}_x\text{-N}$ concentrations can often attain outflow concentrations as low as the systems receiving lower inflow concentrations. For the more resistant N fractions (AN [Exhibit 47] and TON [Exhibit 49]) and for TN (Exhibit 50) there is an apparent effect of inflow concentration on achievable outflow C^* values. From these data it is concluded that as long as treatment wetland inflow TON and TN values are generally less than about 3 to 6 mg/L it is possible to achieve even the lowest outflow concentrations.

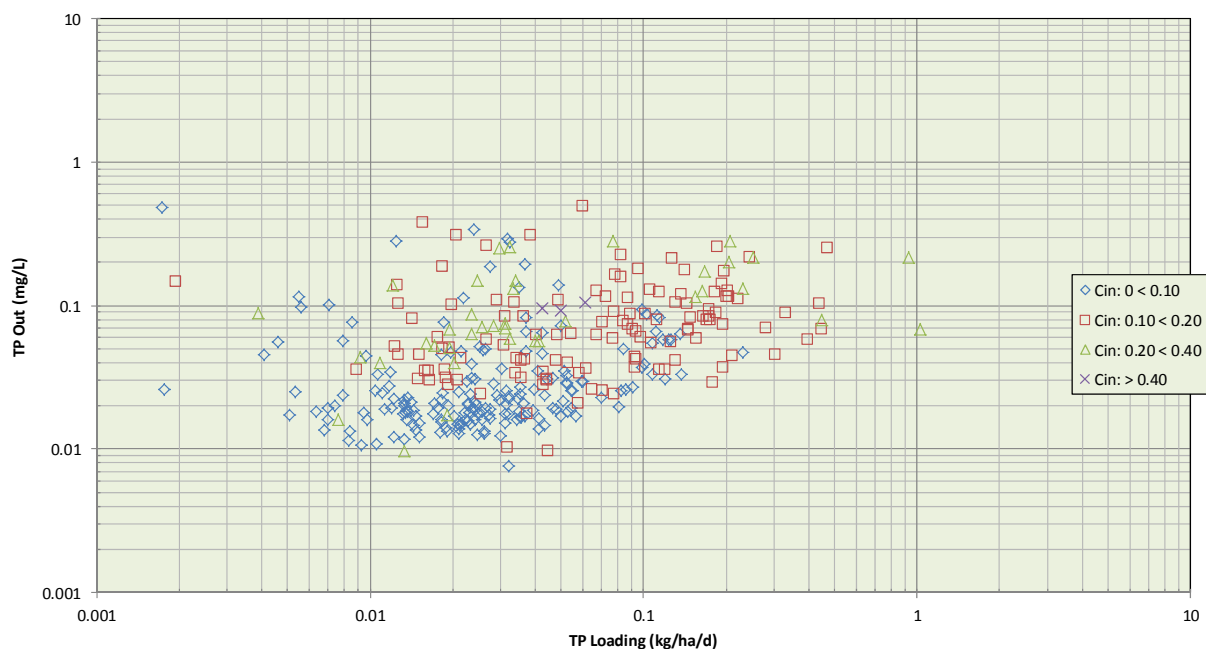


Exhibit 45 - Annual TP Mass Loading vs. Outlet Concentration by Inlet Concentration Range (TP < 0.561 mg/L)

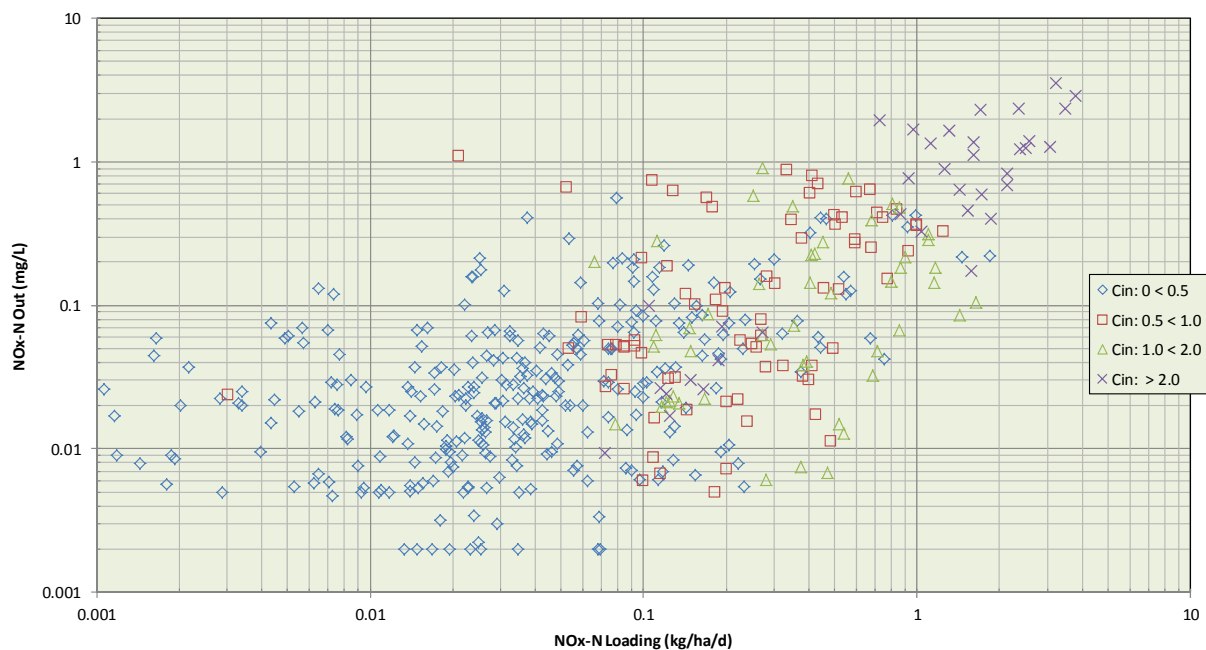


Exhibit 46 - Annual NOx-N Mass Loading vs. Outlet Concentration by Inlet Concentration Range (TN < 11 mg/L)

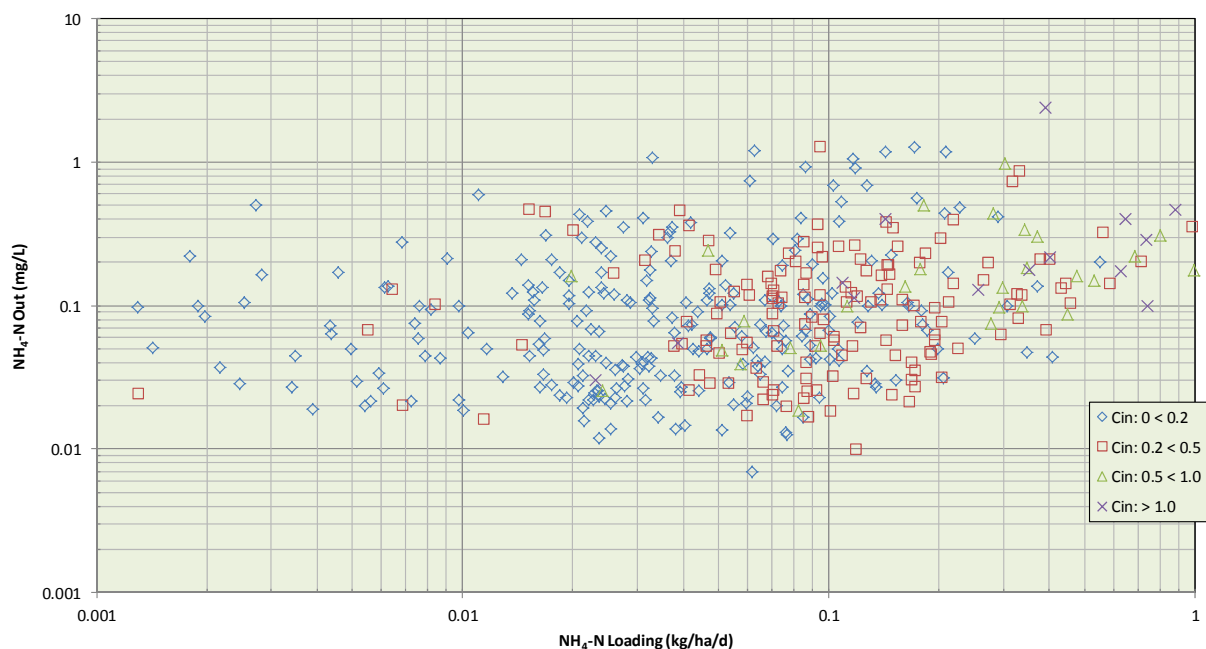


Exhibit 47 - Annual AN Mass Loading vs. Outlet Concentration by Inlet Concentration Range (TN < 11 mg/L)

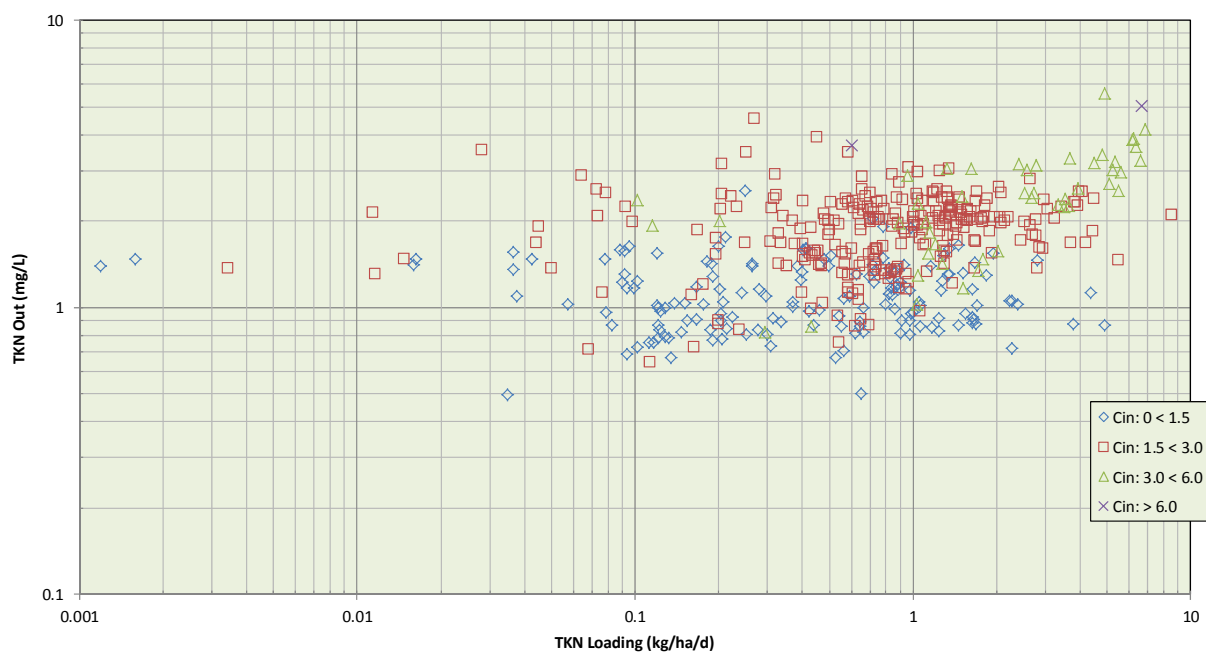


Exhibit 48 - Annual TKN Mass Loading vs. Outlet Concentration by Inlet Concentration Range (TN < 11 mg/L)

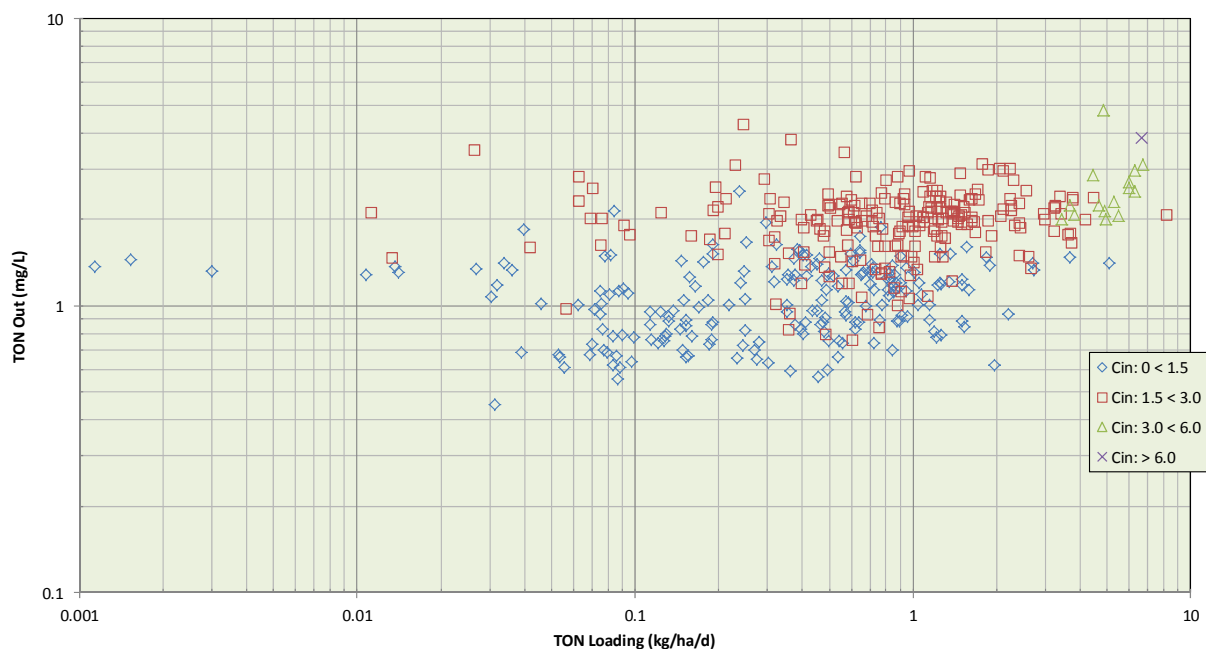


Exhibit 49 - Annual TON Mass Loading vs. Outlet Concentration by Inlet Concentration Range (TN < 11 mg/L)

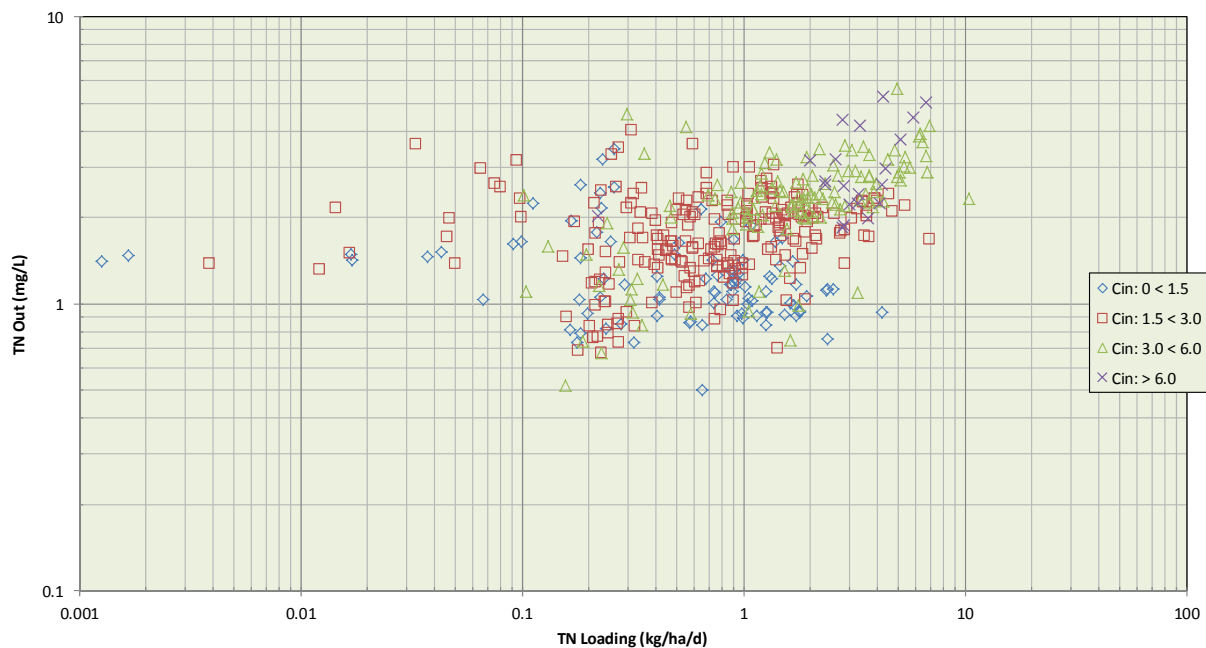


Exhibit 50 - Annual TN Mass Loading vs. Outlet Concentration by Inlet Concentration Range (TN < 11 mg/L)



Exhibit 51 - Annual TSS Mass Loading vs. Outlet Concentration by Inlet Concentration Range (TSS < 103 mg/L)

3.3.3 Vegetation

Exhibit 52 shows the relationship between TP loading and TP outflow concentration by vegetation type. The data show that the lowest outflow concentrations were observed in the PSTA and Open Water (OW) systems. It should be noted however, that the OW systems were all from relatively short-duration studies with mostly low inflow TP concentrations. The OW systems from the Porta-PSTA and C-44 projects received water with average inflow TP concentrations of 0.053 mg/L and 0.028 mg/L, respectively, while the C-43 test cells received water with 0.141 mg/L TP. Based on these short-term studies, it is more likely that the TP performance of the OW systems is a function of the low TP loading rate and start-up phenomena (e.g., adsorption to sediments) than it is to an inherently superior removal rate. The general performance curves support previous work that has shown the lowest TP concentrations are achieved in PSTA systems, followed by SAV and EMV.

Exhibit 53 shows cumulative frequency distributions of the monthly average outflow TP concentrations by vegetation type and indicates that the general order of performance (from highest to lowest outflow TP concentration) is FAP>EMV>SAV>OW>PSTA. A significant difference was found between vegetation types with the highest and lowest median outflow concentrations (Kruskal-Wallis test, $P < 0.001$). Again, the data for the OW systems are only reflective of relatively lightly loaded systems.

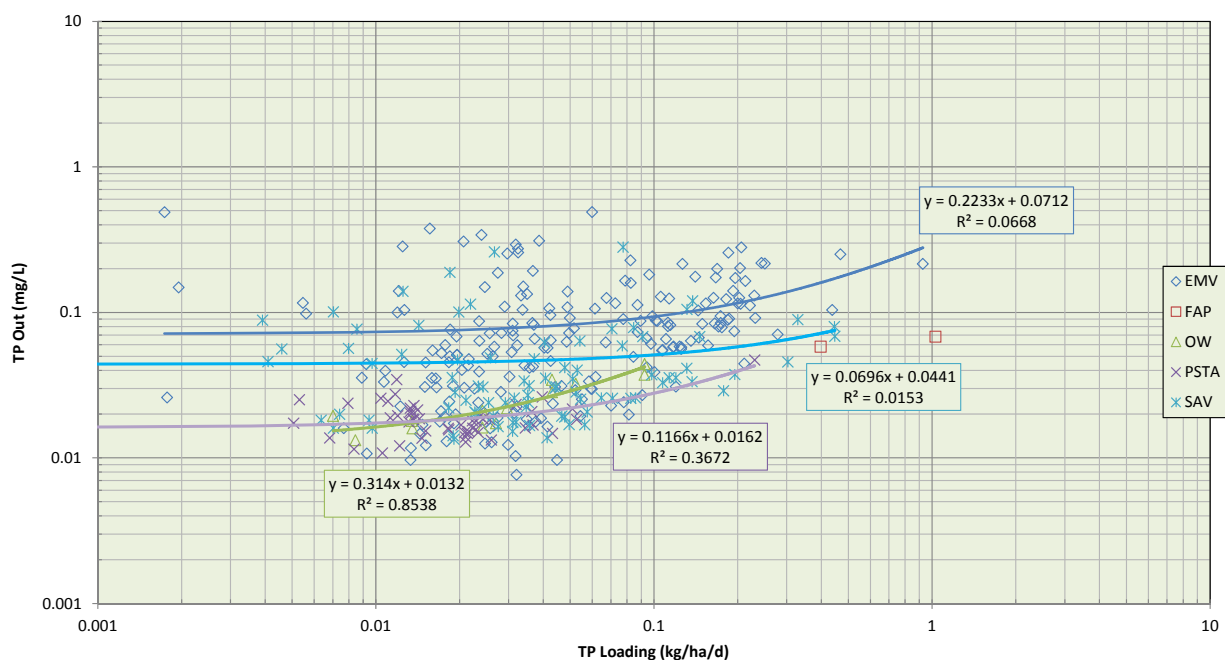


Exhibit 52 - Annual TP Mass Loading vs. Outlet Concentration by Vegetation Type (Inlet TP < 0.561 mg/L)

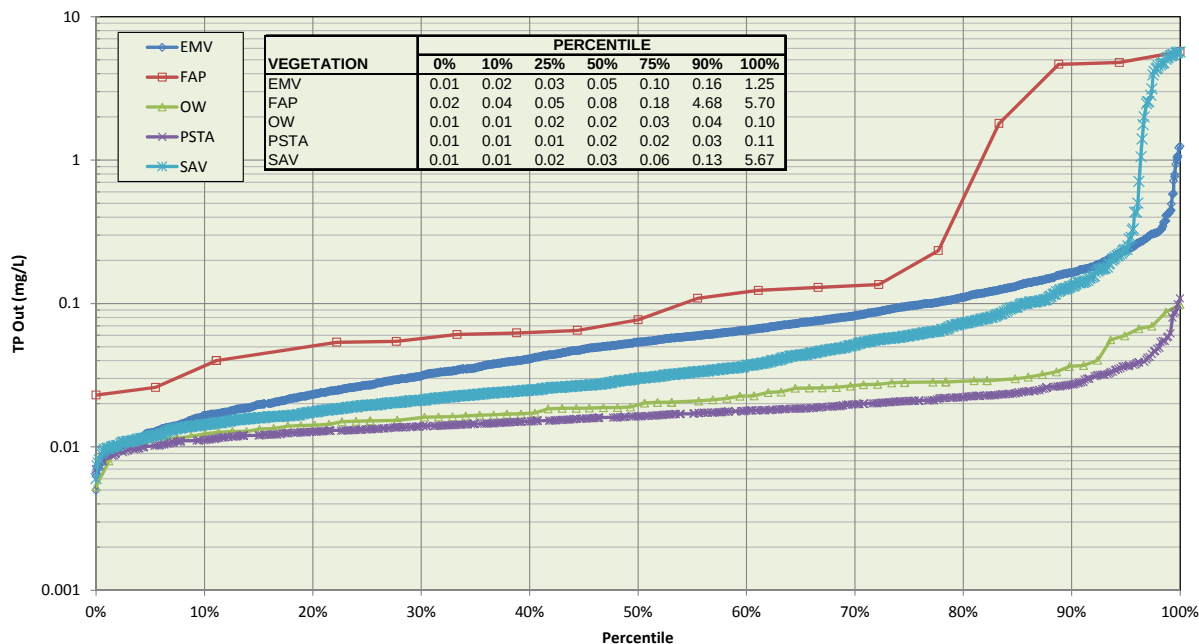


Exhibit 53 - Monthly Average TP Outflow Concentration Percentiles by Vegetation Type (Inlet TP < 0.561 mg/L)

Exhibit 54 shows the relationship between NO_x-N loading and outflow concentration by vegetation type. These data show that the lowest NO_x-N outflow concentrations were observed

in the EMV, PSTA, and SAV treatment wetland systems. The highest NO_x-N concentrations were typically measured in the FAP treatment wetland systems. Exhibit 55 shows frequency distributions of the monthly average outflow NO_x-N concentrations by vegetation type and indicates that the general order of performance (from highest to lowest outflow concentration) is FAP>SAV>EMV>OW>PSTA. A significant difference was found between vegetation types with the highest and lowest median outflow concentrations (Kruskal-Wallis test, P<0.001). Again, the data for the OW systems are only reflective of relatively lightly loaded systems.

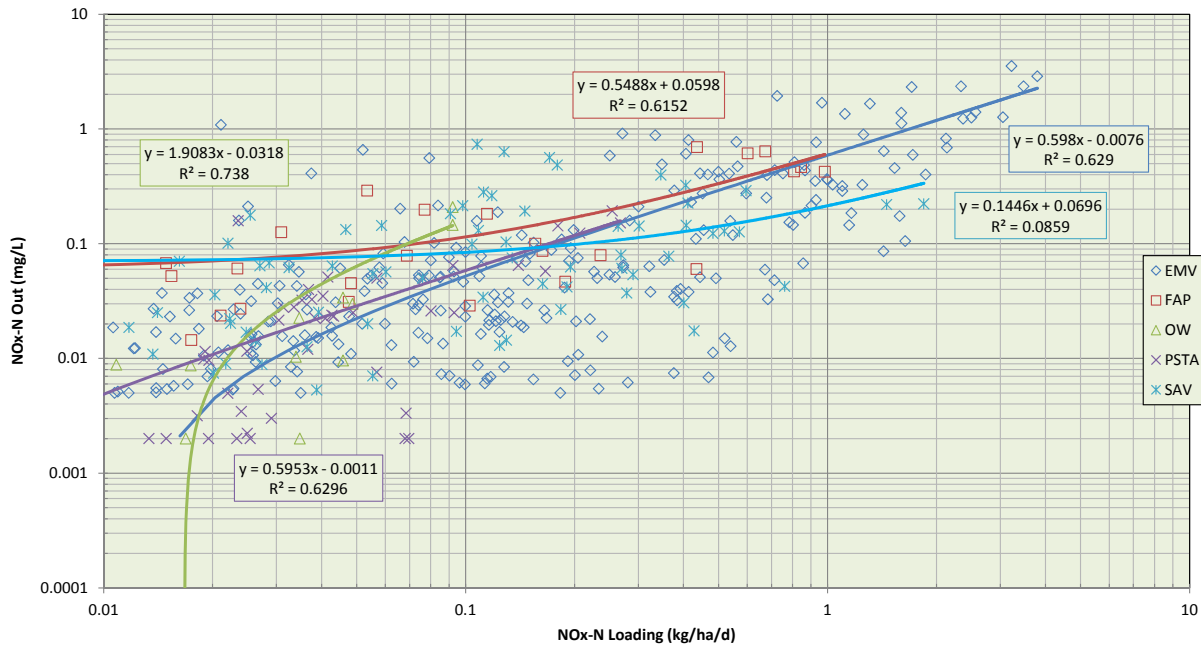


Exhibit 54 - Annual NO_x-N Mass Loading vs. Outlet Concentration by Vegetation Type (Inlet TN < 11 mg/L)

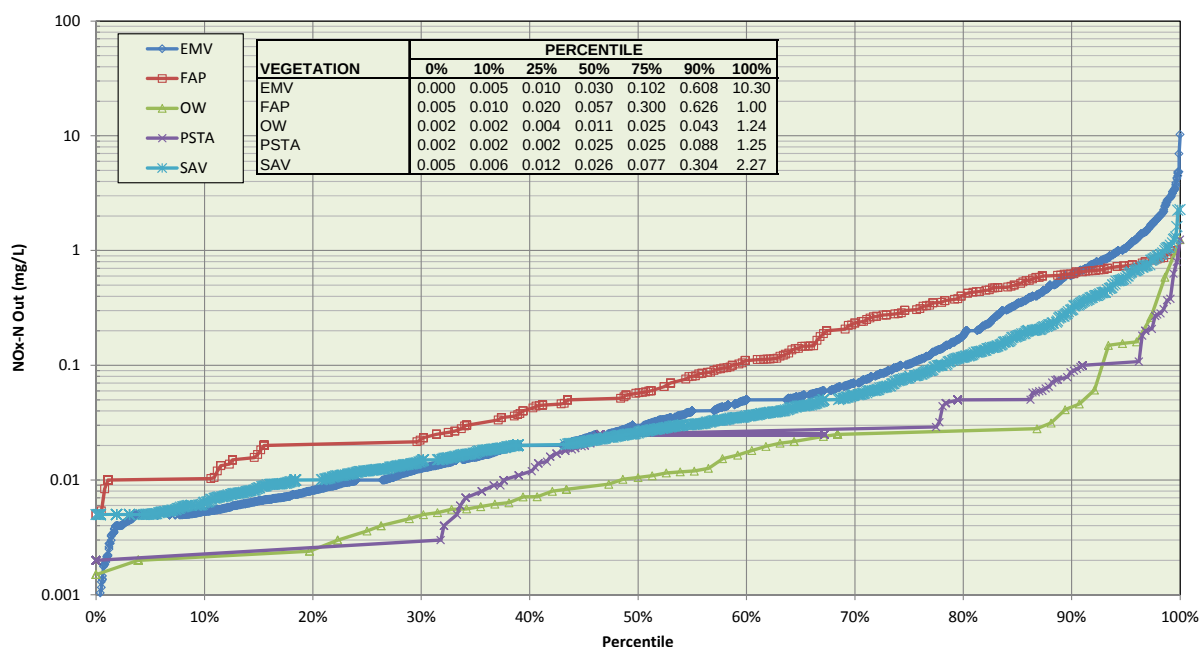


Exhibit 55 - Monthly Average NO_x-N Outflow Concentration Percentiles by Vegetation Type (Inlet TN < 11 mg/L)

Exhibit 56 shows the relationship between AN loading and outflow concentration by vegetation type. These data show that the lowest AN outflow concentrations were observed in the PSTA and SAV treatment wetland systems. The highest AN concentrations were typically measured in the FAP treatment wetland systems. EMV treatment wetlands were intermediate in their ability to reduce AN concentrations. Exhibit 57 shows frequency distributions of the monthly average outflow AN concentrations by vegetation type and indicates that the general order of performance (from highest to lowest outflow concentration) is FAP>EMV>SAV>OW>PSTA. A significant difference was found between vegetation types with the highest and lowest median outflow concentrations (Kruskal-Wallis test, $P < 0.001$). Again, the data for the OW systems are only reflective of relatively lightly loaded systems.

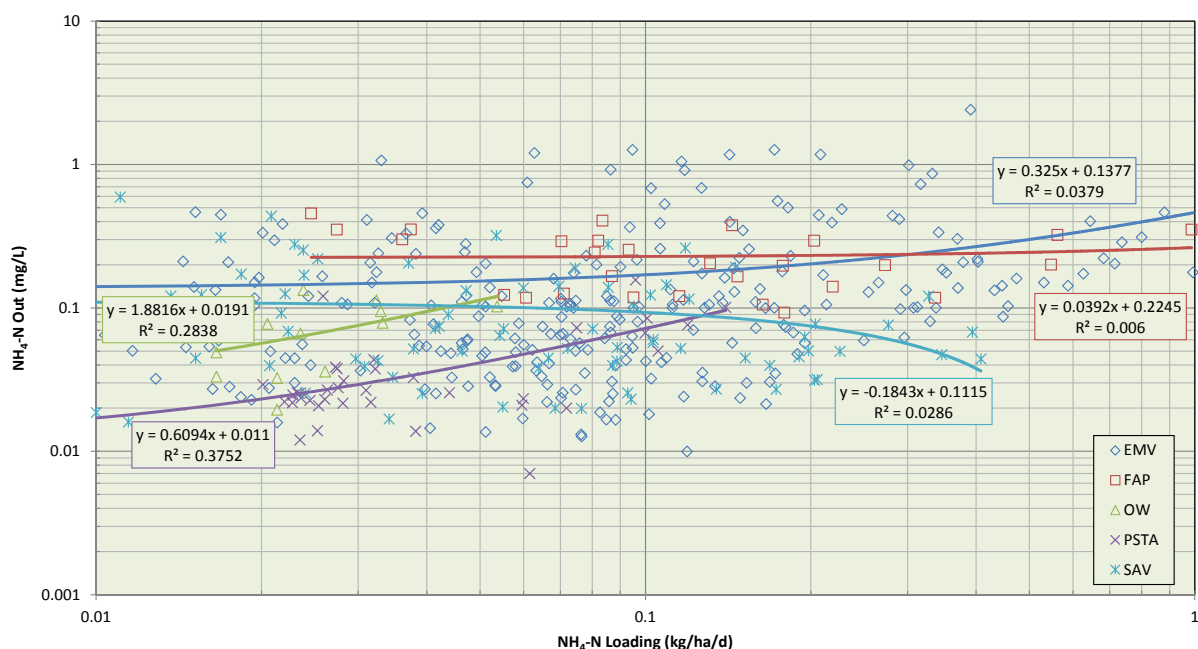


Exhibit 56 - Annual AN Mass Loading vs. Outlet Concentration by Vegetation Type (Inlet TN < 11 mg/L)

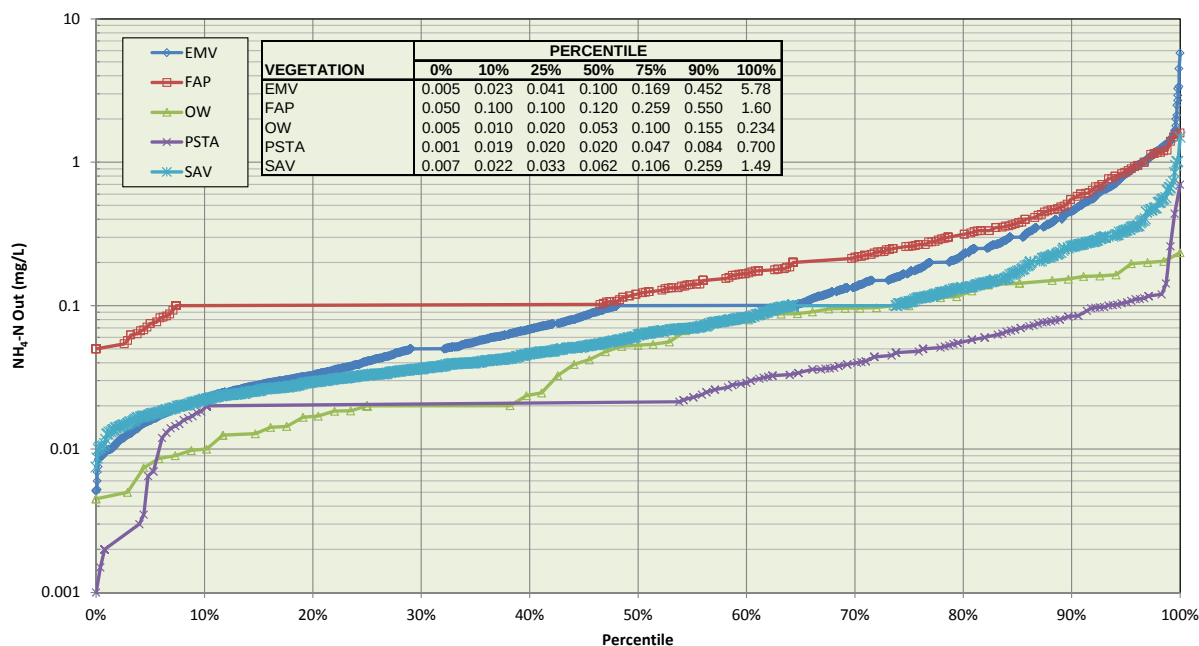


Exhibit 57 - Monthly Average AN Outflow Concentration Percentiles by Vegetation Type (Inlet TN < 11 mg/L)

Exhibit 58 shows the relationship between TKN loading and outflow concentration by vegetation type. These data show that the lowest TKN outflow concentrations were observed in

the OW and EMV treatment wetland systems. The highest TKN concentrations were typically measured in the SAV treatment wetland systems. This may be due to the fact that most existing SAV treatment wetlands are located in the EAA and are typically sited on organic soils. The PSTA and FAP treatment wetlands were intermediate in their ability to reduce TKN concentrations. Exhibit 59 shows frequency distributions of the monthly average outflow TKN concentrations by vegetation type and indicates that the general order of performance (from highest to lowest outflow concentration) is SAV>FAP>PSTA>EMV>OW. A significant difference was found between vegetation types with the highest and lowest median outflow concentrations (Kruskal-Wallis test, $P < 0.001$). Again, the data for the OW systems are reflective of relatively lightly loaded systems.

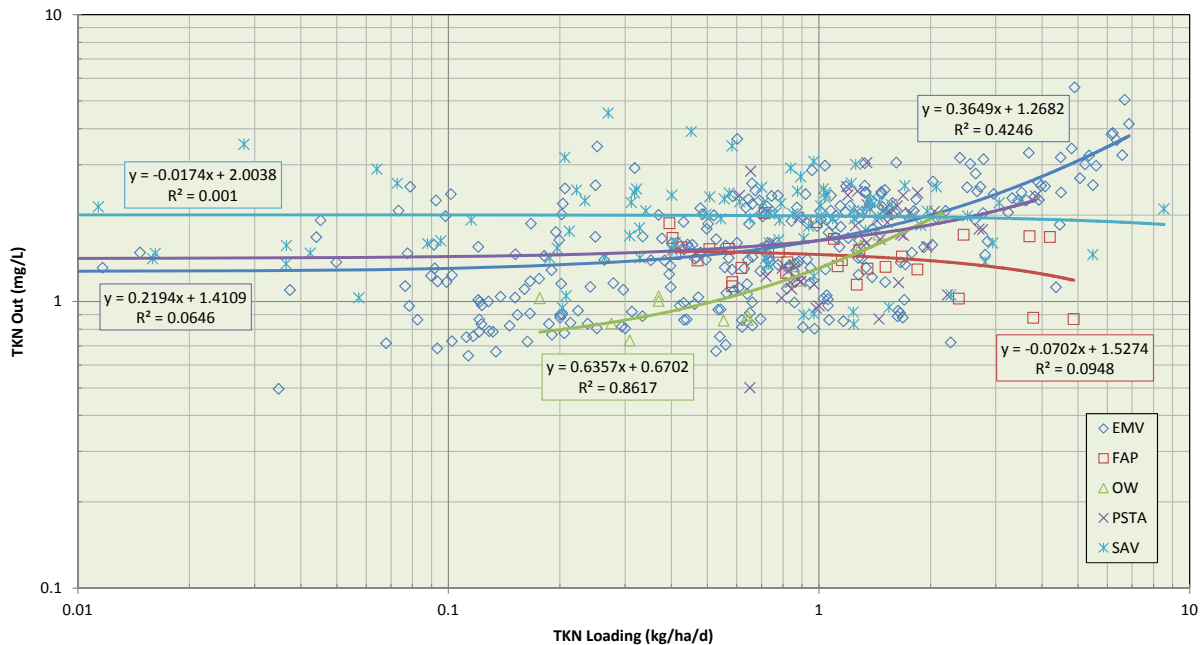


Exhibit 58 - Annual TKN Mass Loading vs. Outlet Concentration by Vegetation Type (Inlet TN < 11 mg/L)

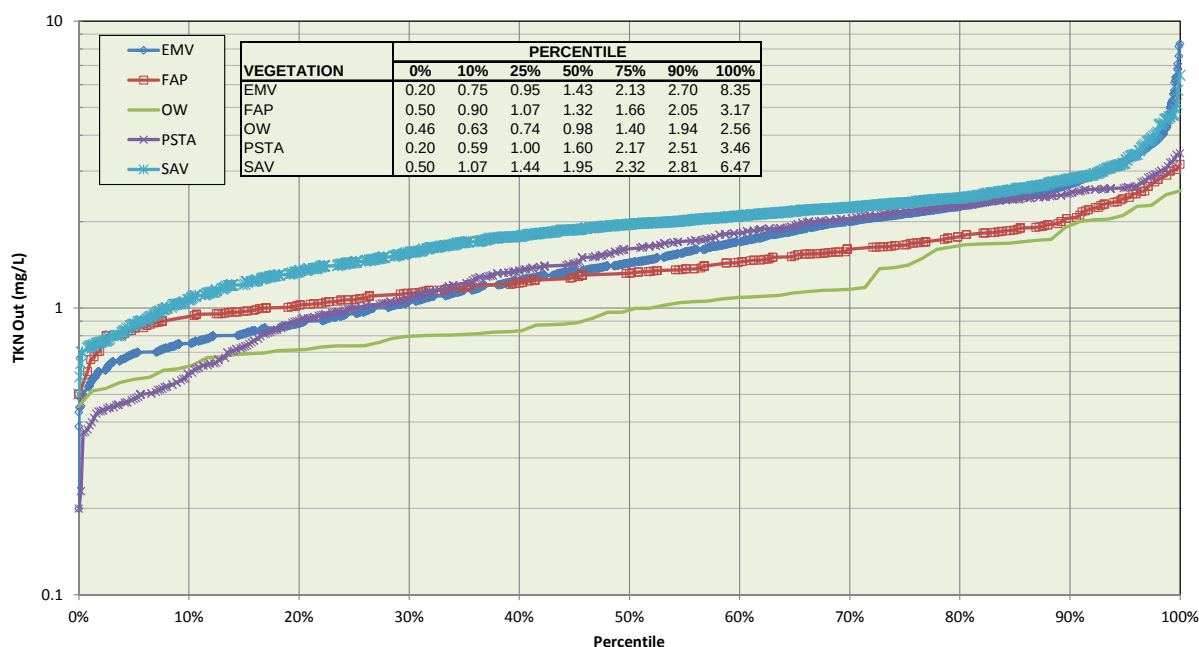


Exhibit 59 - Monthly Average TKN Outflow Concentration Percentiles by Vegetation Type (Inlet TN < 11 mg/L)

Exhibit 60 shows the relationship between TON loading and outflow concentration by vegetation type. These data show that the lowest TON outflow concentrations were observed in the OW and EMV treatment wetland systems. The highest TON concentrations were typically measured in the SAV treatment wetland systems. The PSTA and FAP treatment wetlands were intermediate in their ability to reduce TON concentrations. Exhibit 61 shows frequency distributions of the monthly average outflow TON concentrations by vegetation type and indicates that the general order of performance (from highest to lowest outflow concentration) is SAV>PSTA>FAP>EMV>OW. A significant difference was found between vegetation types with the highest and lowest median outflow concentrations (Kruskal-Wallis test, $P < 0.001$). Again, the data for the OW systems are reflective of relatively lightly loaded systems.

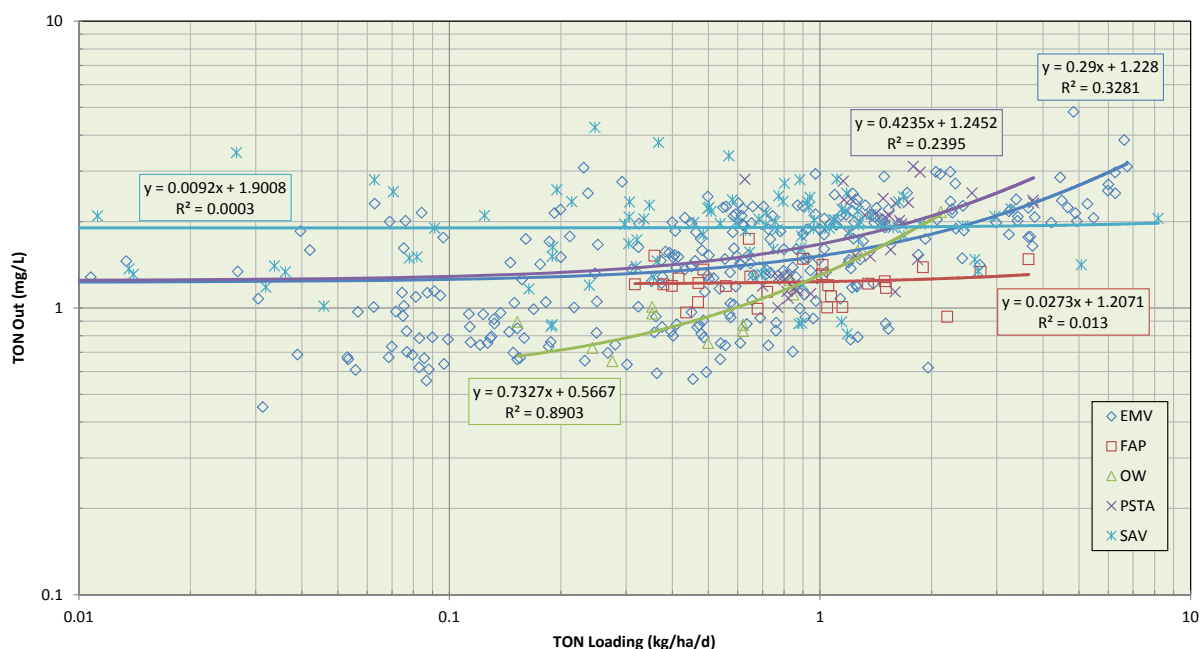


Exhibit 60 - Annual TON Mass Loading vs. Outlet Concentration by Vegetation Type (Inlet TN < 11 mg/L)

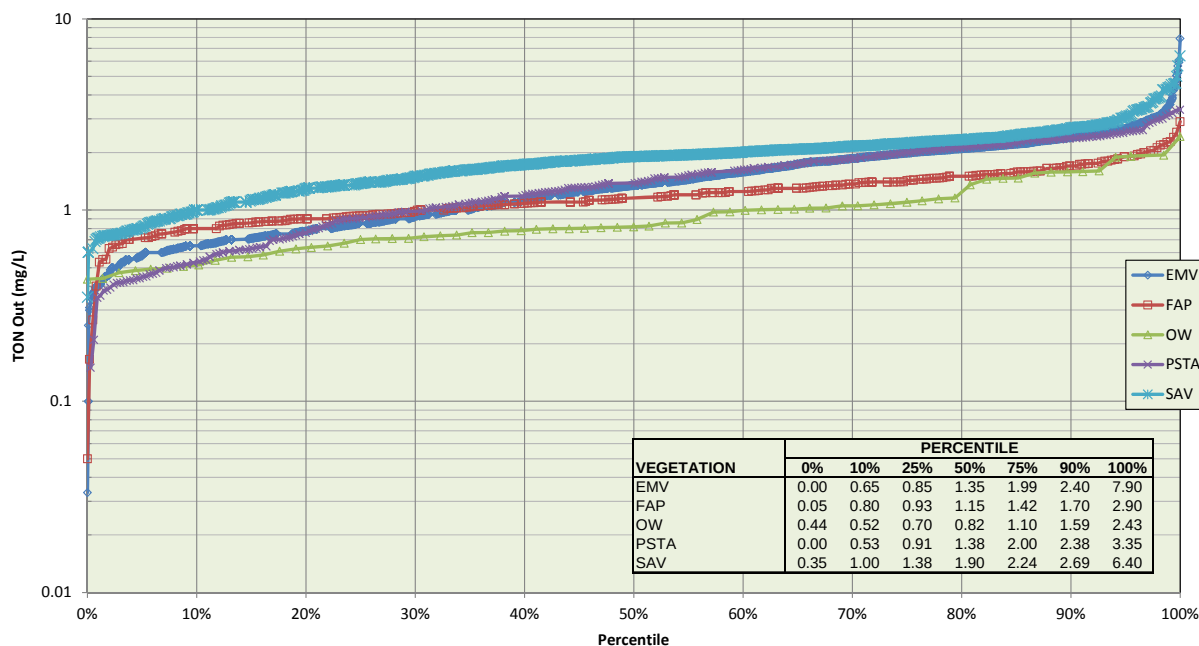


Exhibit 61 - Monthly Average TON Outflow Concentration Percentiles by Vegetation Type (Inlet TN < 11 mg/L)

Exhibit 62 shows the relationship between TN loading and outflow concentration by vegetation type. These data show that the lowest TN outflow concentrations were observed in the OW and

EMV treatment wetland systems. The highest TN concentrations were typically measured in the SAV treatment wetland systems. The PSTA and FAP treatment wetlands were intermediate in their ability to reduce TN concentrations. Exhibit 63 shows frequency distributions of the monthly average outflow TN concentrations by vegetation type and indicates that the general order of performance (from highest to lowest outflow concentration) is SAV>PSTA>FAP>EMV>OW. A significant difference was found between vegetation types with the highest and lowest median outflow concentrations (Kruskal-Wallis test, $P < 0.001$). Again, the data for the OW systems are reflective of relatively lightly loaded systems.

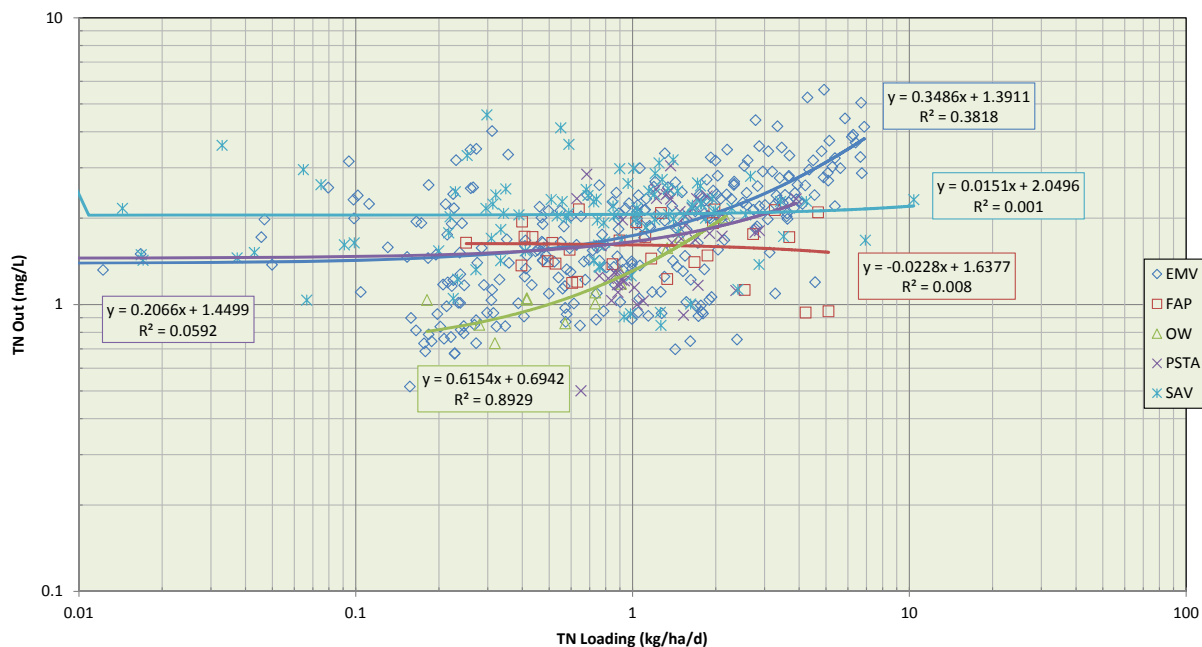


Exhibit 62 - Annual TN Mass Loading vs. Outlet Concentration by Vegetation Type (Inlet TN < 11 mg/L)

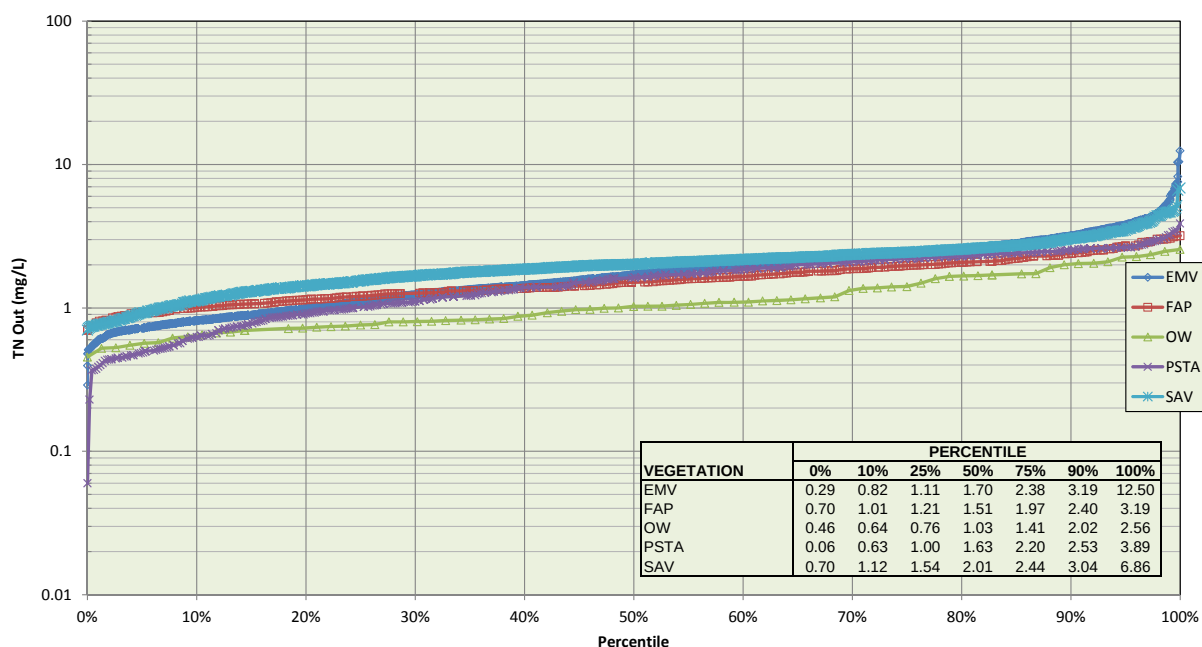


Exhibit 63 - Monthly Average TN Outflow Concentration Percentiles by Vegetation Type (Inlet TN < 11 mg/L)

Exhibit 64 shows the relationship between TSS loading and outflow concentration by vegetation type. These data show that the lowest TSS outflow concentrations were observed in the PSTA and EMV treatment wetland systems. The highest TSS concentrations were typically measured in the FAP and OW treatment wetland systems. The SAV treatment wetlands were intermediate in their ability to reduce TSS concentrations. Exhibit 65 shows frequency distributions of the monthly average outflow TSS concentrations by vegetation type and indicates that the general order of performance (from highest to lowest outflow concentration) is FAP>OW>SAV>PSTA>EMV. A significant difference was found between vegetation types with the highest and lowest median outflow concentrations (Kruskal-Wallis test, $P < 0.001$).

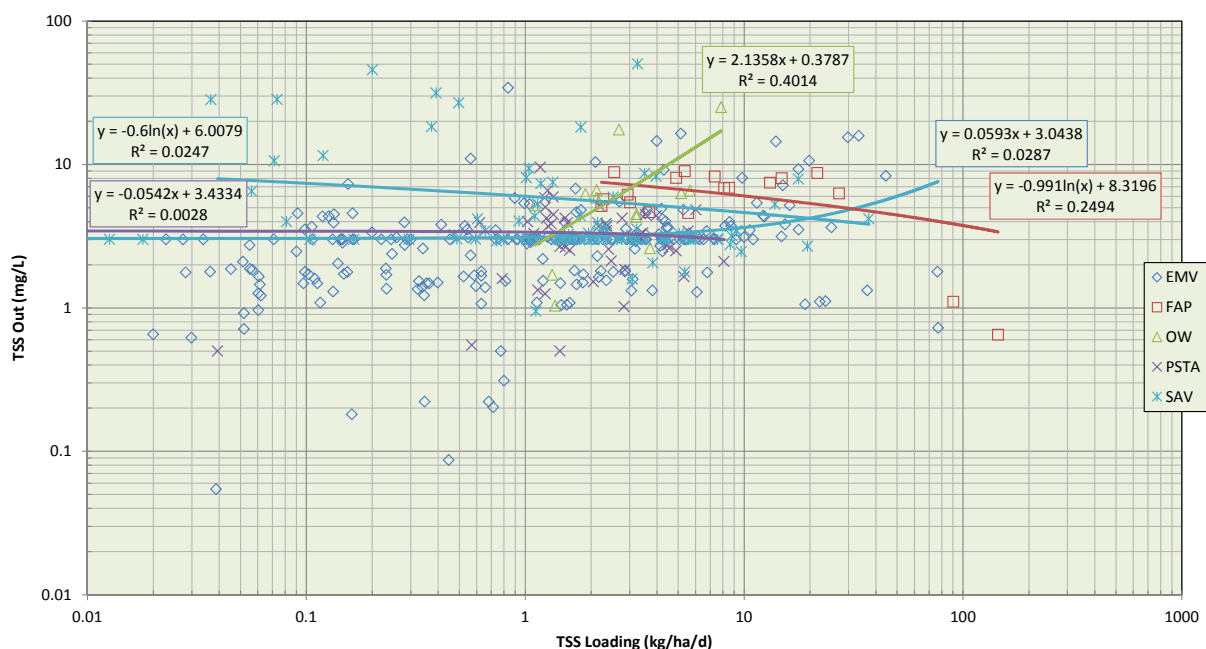


Exhibit 64 - Annual TSS Mass Loading vs. Outlet Concentration by Vegetation Type (Inlet TN < 103 mg/L)

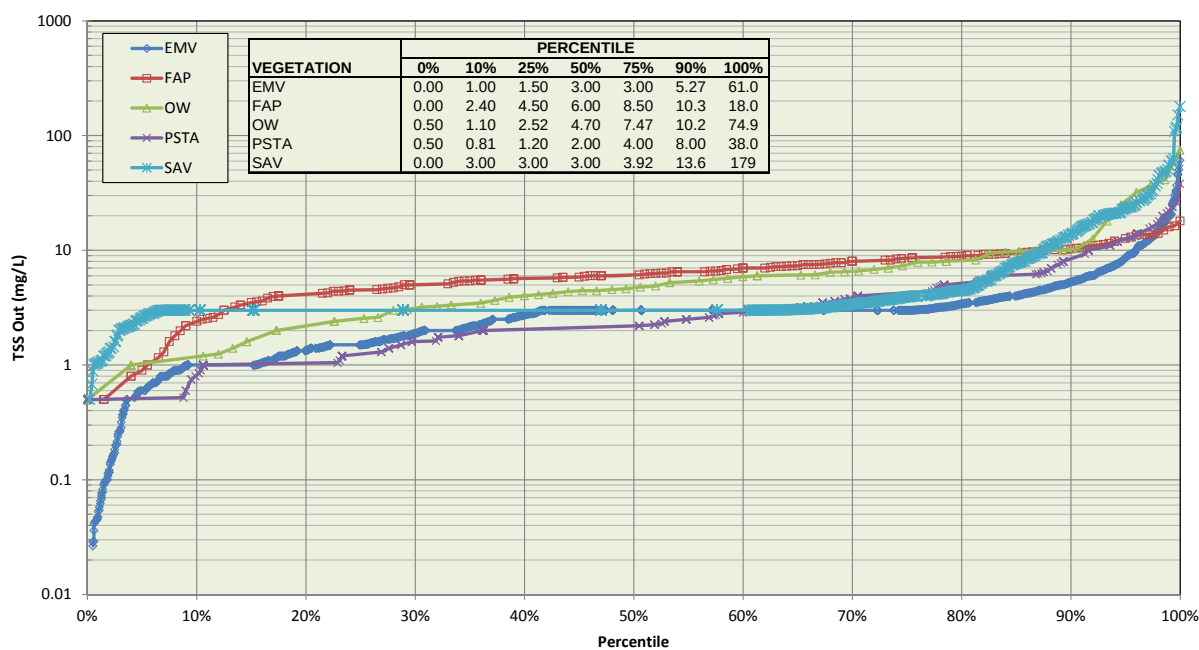


Exhibit 65 - Monthly Average TSS Outflow Concentration Percentiles by Vegetation Type (Inlet TSS < 103 mg/L)

3.3.4 Substrate

Examination of these Florida treatment wetland operational performance data indicate a possible relationship between TON C* concentrations and soil type. This section explores that phenomenon for each of the pollutants of interest.

Exhibit 66 illustrates the observed relationship between TP mass loading to Florida treatment wetlands vs. TP outflow concentrations for three basic substrate types: peat or organic soils, sandy soils (low organic), and calcareous soils. This graph and the cumulative probability distribution illustrated in Exhibit 67 clearly show the beneficial effect of using a calcium-rich substrate in treatment wetlands designed for TP reduction. Somewhat surprisingly, peat-based soils had slightly lower TP outflow concentrations as a function of TP loading rates than sandy soils.

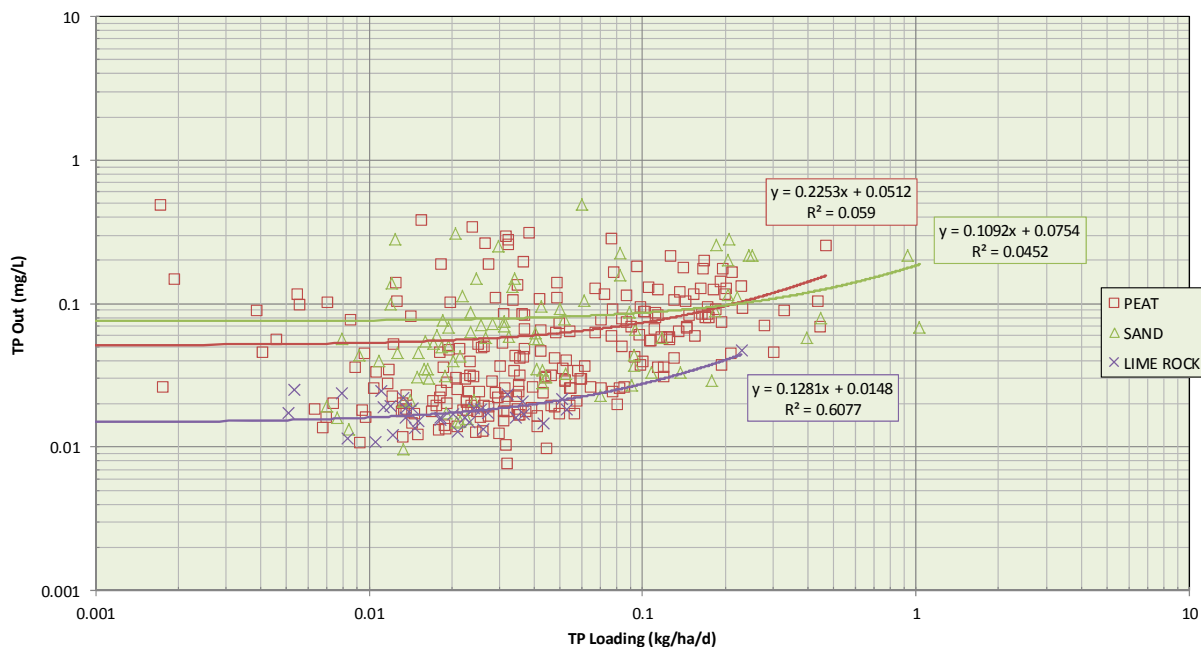


Exhibit 66 - Annual TP Mass Loading vs. Outlet Concentration by Substrate Type (Inlet TP < 0.561 mg/L)

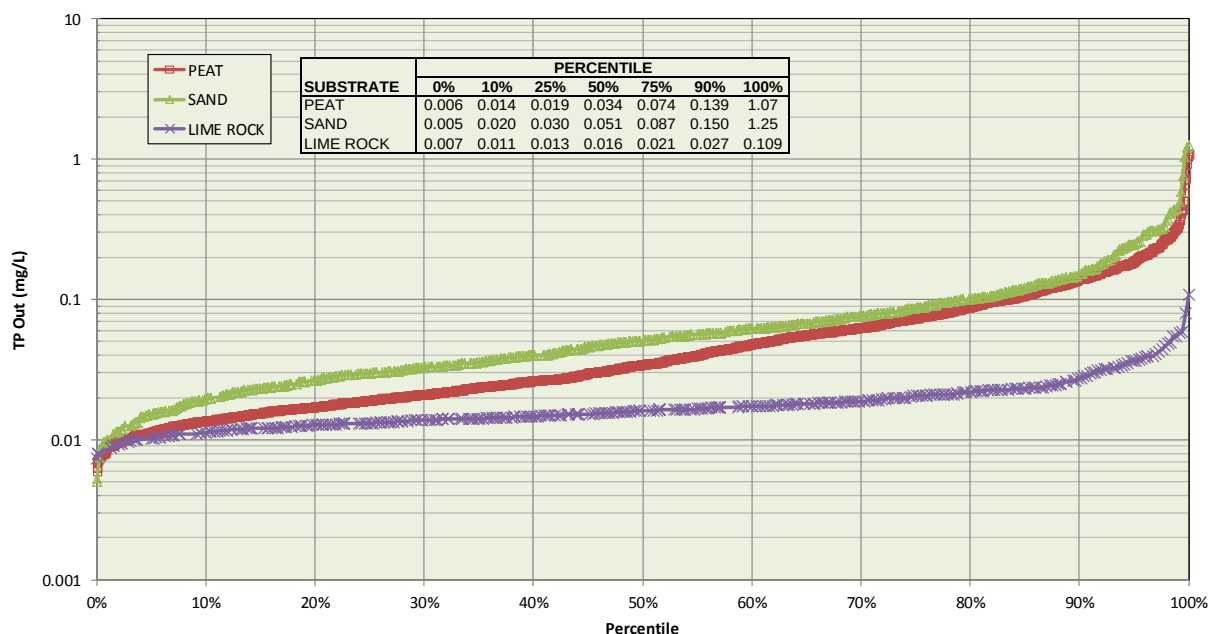


Exhibit 67 - Monthly Average TP Outflow Concentration Percentiles by Substrate Type (Inlet TP < 0.561 mg/L)

Exhibit 68 and Exhibit 69 provide the same information about the effect of substrate type on NO_x-N removal in Florida treatment wetlands. These data indicate that peat, sand, and limerock substrates have about equal potential to achieve low NO_x-N concentrations. Clayey soils appear to have a much lower potential for NO_x-N concentration reduction.

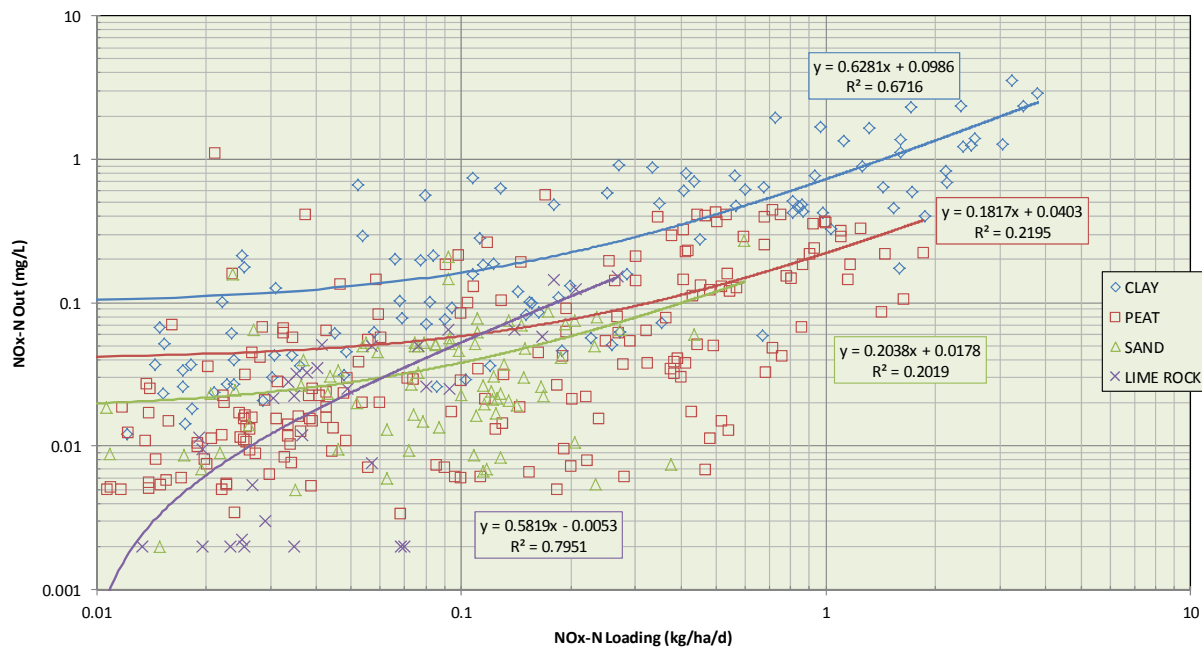


Exhibit 68 - Annual NO_x-N Mass Loading vs. Outlet Concentration by Substrate Type (Inlet TN < 11 mg/L)

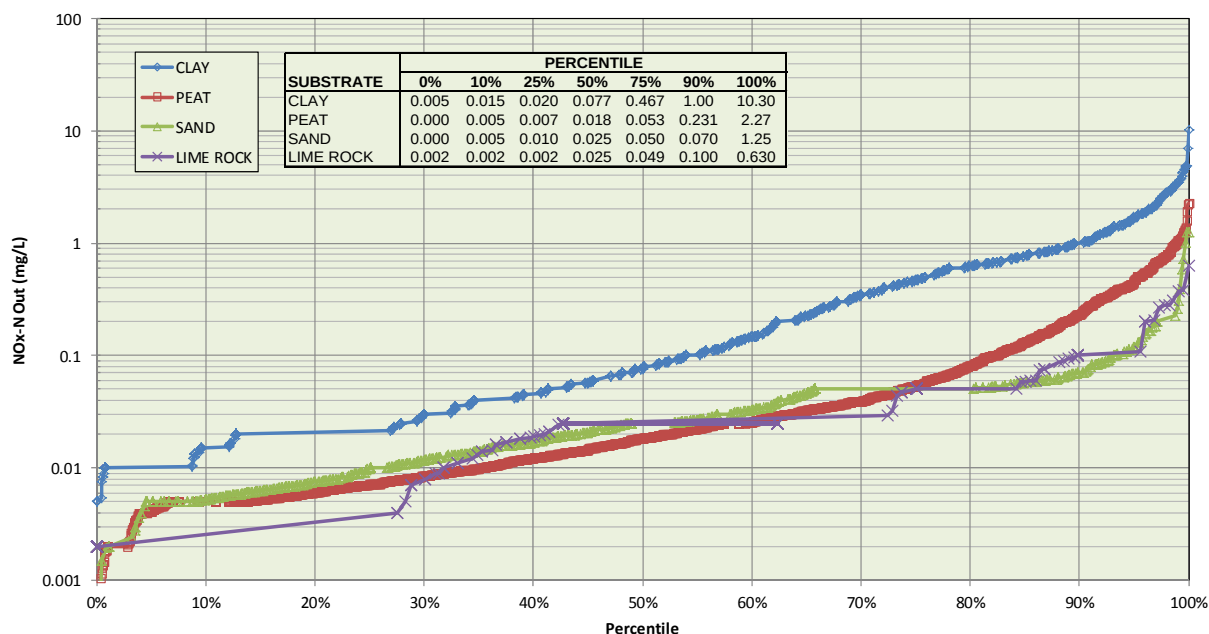


Exhibit 69 - Monthly Average NO_x-N Outflow Concentration Percentiles by Substrate Type (Inlet TN < 11 mg/L)

Exhibit 70 and Exhibit 71 provide the same analysis for AN in Florida treatment wetlands. The limerock-based systems achieved the lowest AN concentration. Peat and sand-based treatment wetlands were somewhat less effective and the clay-based system had the highest AN outflow concentrations at a given AN mass loading rate.

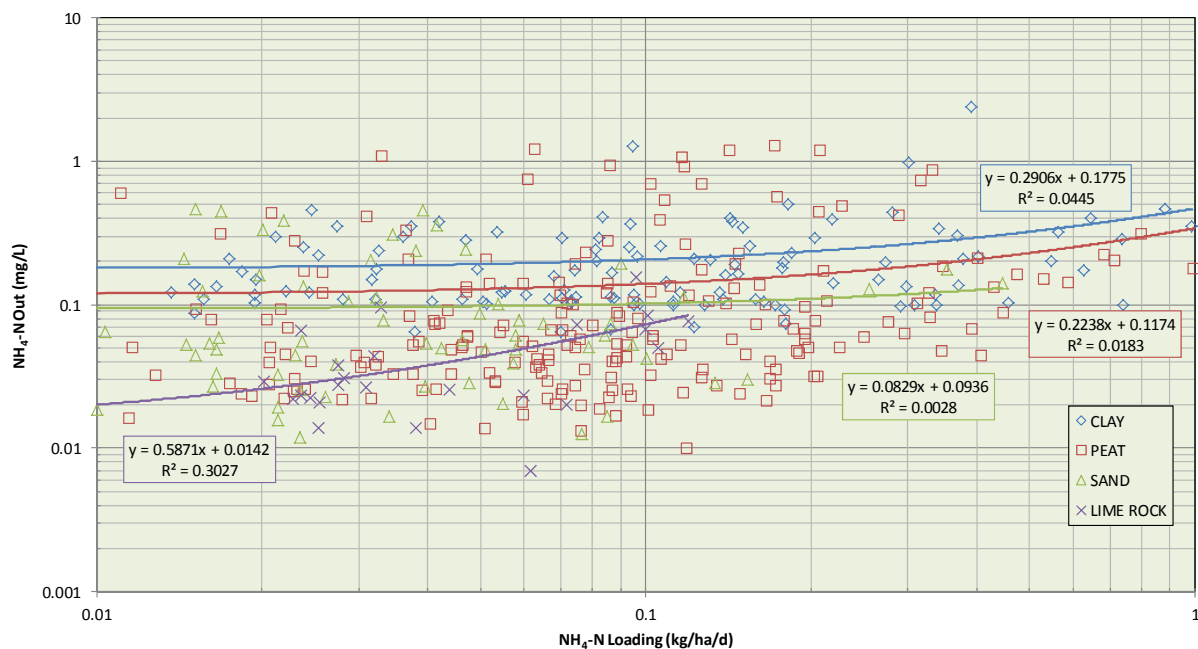


Exhibit 70 - Annual NH₄-N Mass Loading vs. Outlet Concentration by Substrate Type (Inlet TN < 11 mg/L)

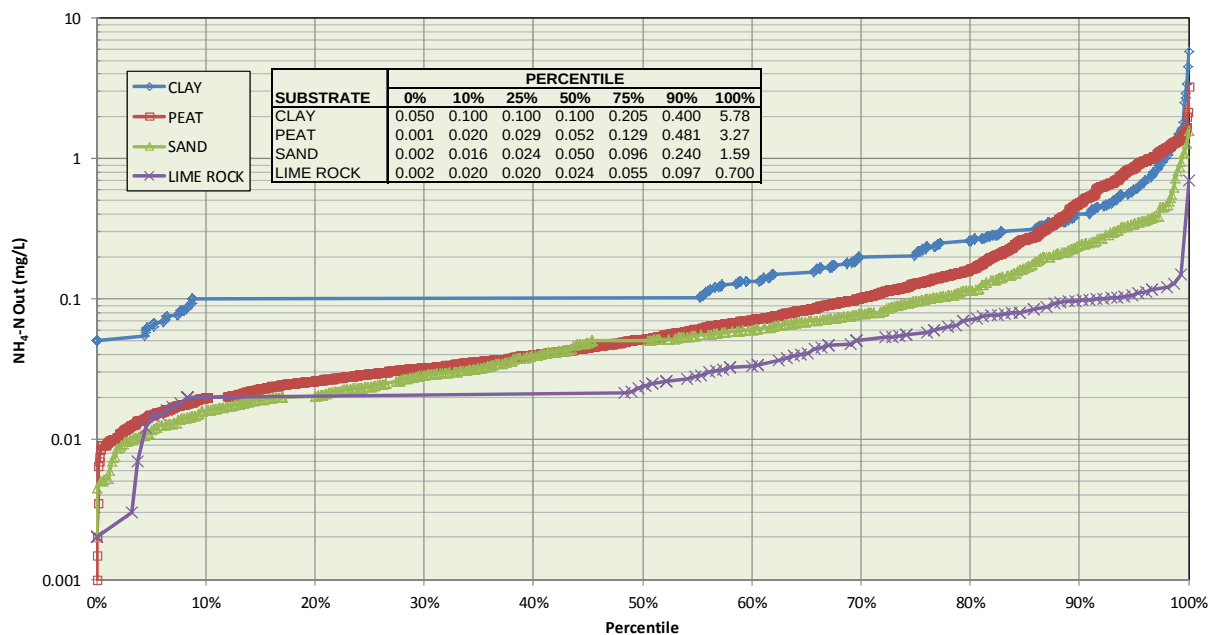


Exhibit 71 - Monthly Average NH₄-N Outflow Concentration Percentiles by Substrate Type (Inlet TN < 11 mg/L)

Exhibit 72 and Exhibit 73 provide the same analysis for TKN removal in Florida treatment wetlands. There appears to be a clear substrate effect on the removal of this pollutant with lowest TKN concentrations obtained in wetlands built on sandy soils, followed in order by clay, limerock, and peat substrates.

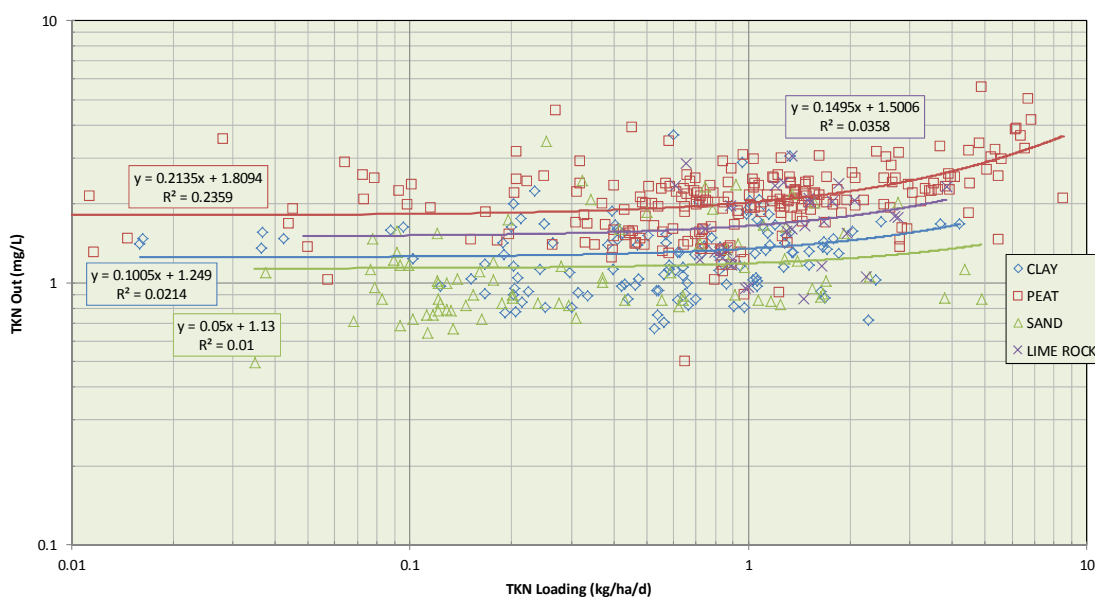


Exhibit 72 - Annual TKN Mass Loading vs. Outlet Concentration by Substrate Type (Inlet TN < 11 mg/L)

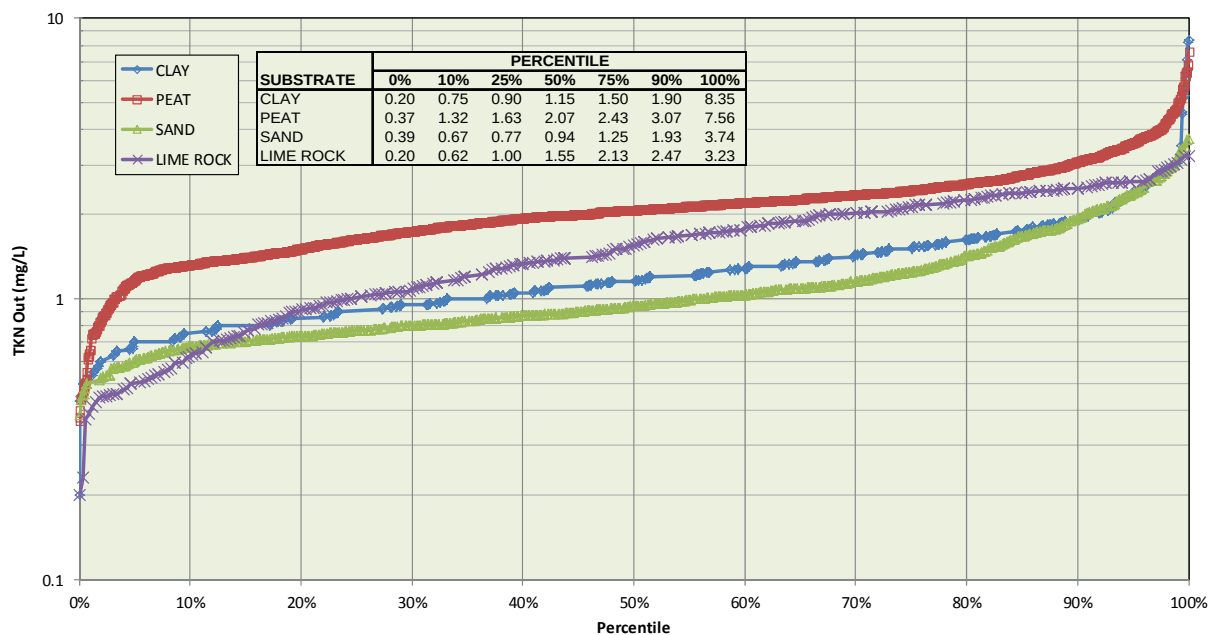


Exhibit 73 - Monthly Average TKN Outflow Concentration Percentiles by Substrate Type (Inlet TN < 11 mg/L)

Exhibit 74 and Exhibit 75 provide the same analysis for TON removal in Florida treatment wetlands. The effect of substrate on TON is similar to that described above for TKN. The lowest TON concentrations are obtained in wetlands built on sandy soils, followed in order by clay, limerock, and peat substrates. There is not as much difference between the sandy and the clayey soils for TON as there was for TKN.

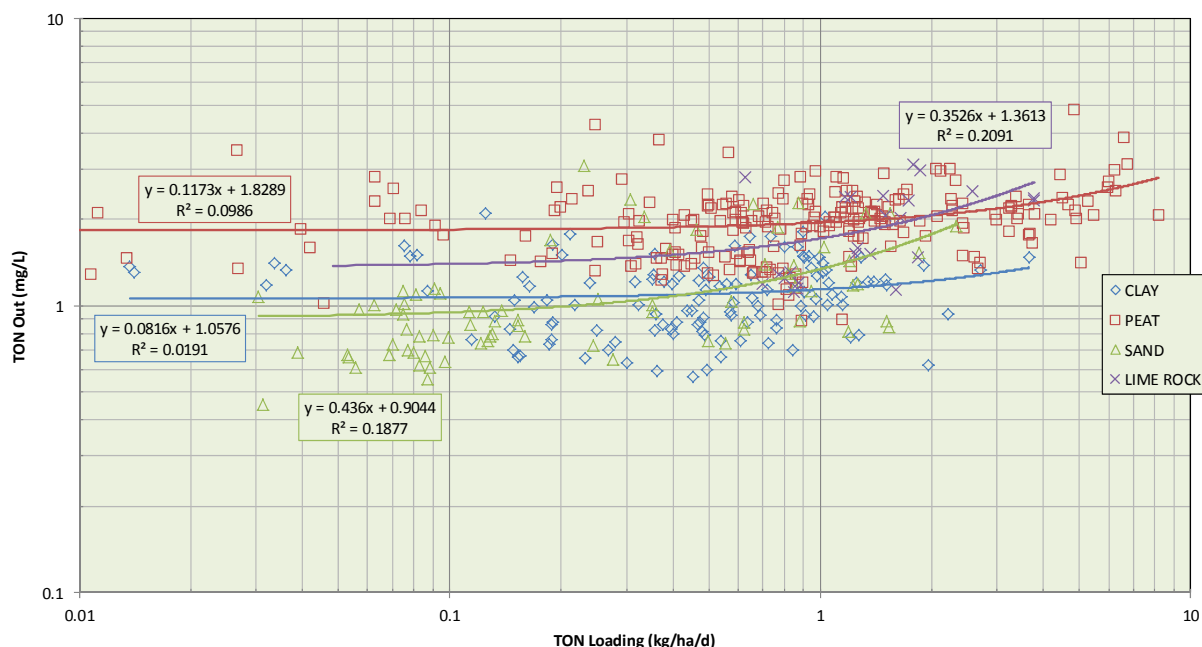


Exhibit 74 - Annual TON Mass Loading vs. Outlet Concentration by Substrate Type (Inlet TN < 11 mg/L)

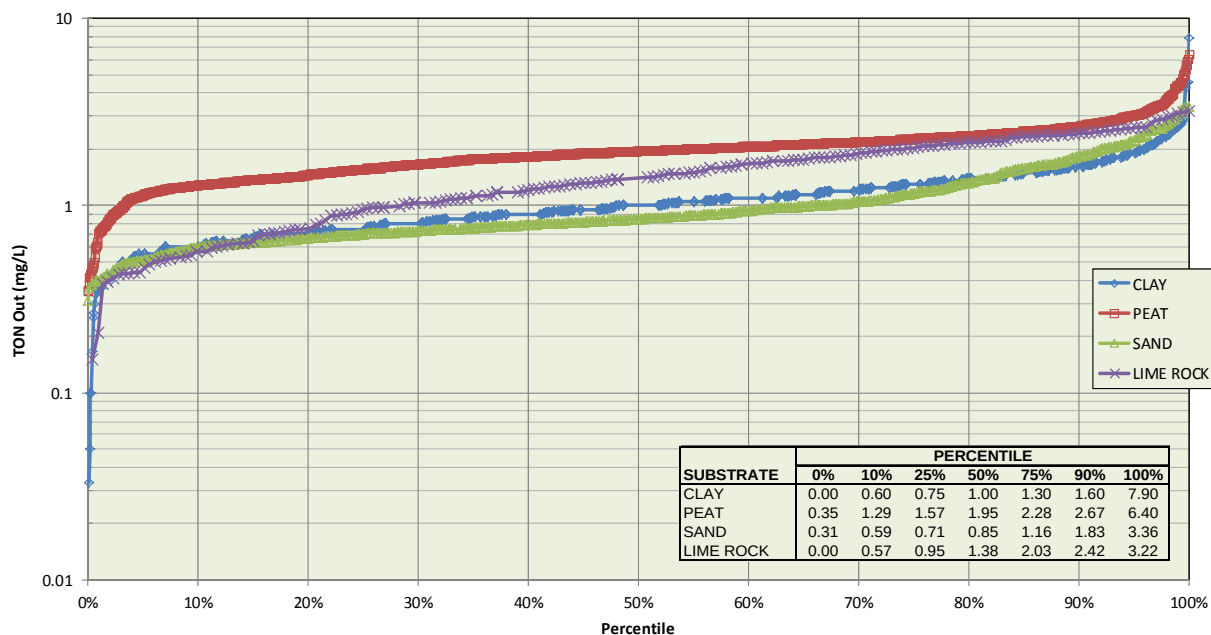


Exhibit 75 - Monthly Average TON Outflow Concentration Percentiles by Substrate Type (Inlet TN < 11 mg/L)

Exhibit 76 and Exhibit 77 provide the same analysis for TN removal in Florida treatment wetlands. As with TKN and TON, there appears to be a fairly clear substrate effect on the

removal of this pollutant with lowest TN concentrations obtained in wetlands built on sandy soils, followed by similar TN concentrations for limerock and clayey soils, and highest concentrations over peat soils.

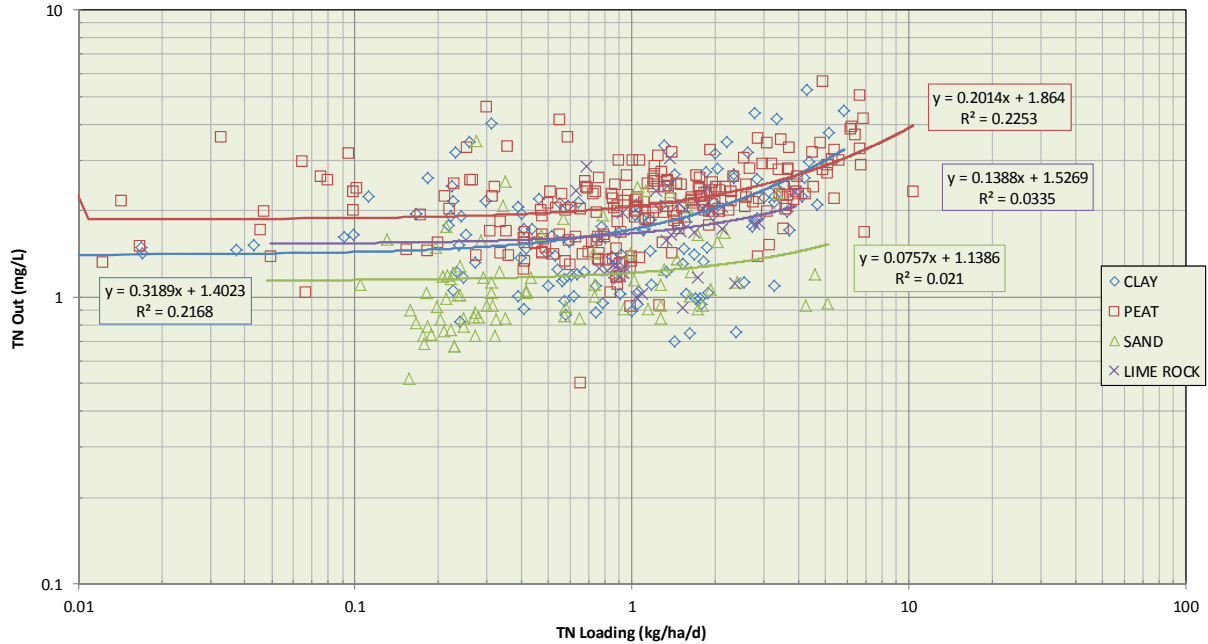


Exhibit 76 - Annual TN Mass Loading vs. Outlet Concentration by Substrate Type (Inlet TN < 11 mg/L)

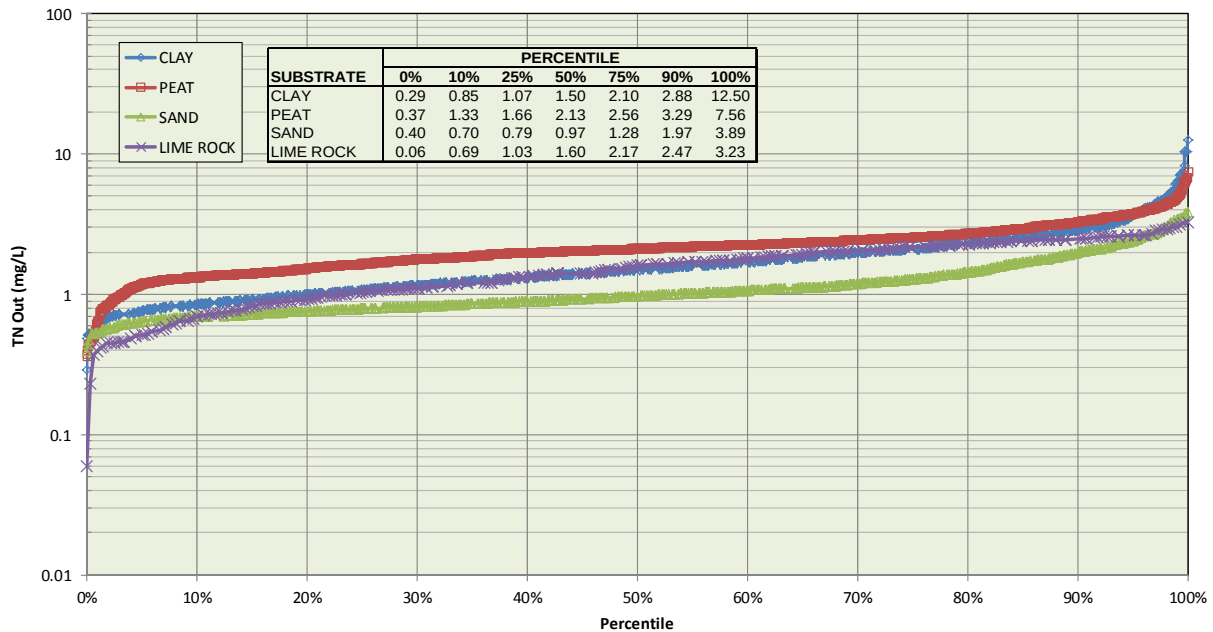


Exhibit 77 - Monthly Average TN Outflow Concentration Percentiles by Substrate Type (Inlet TN < 11 mg/L)

Exhibit 78 and Exhibit 79 illustrate that substrate does not have a very significant effect on the ability of treatment wetlands to achieve low TSS concentrations. The peat substrate best-fit line at low TSS concentrations is a model artifact.

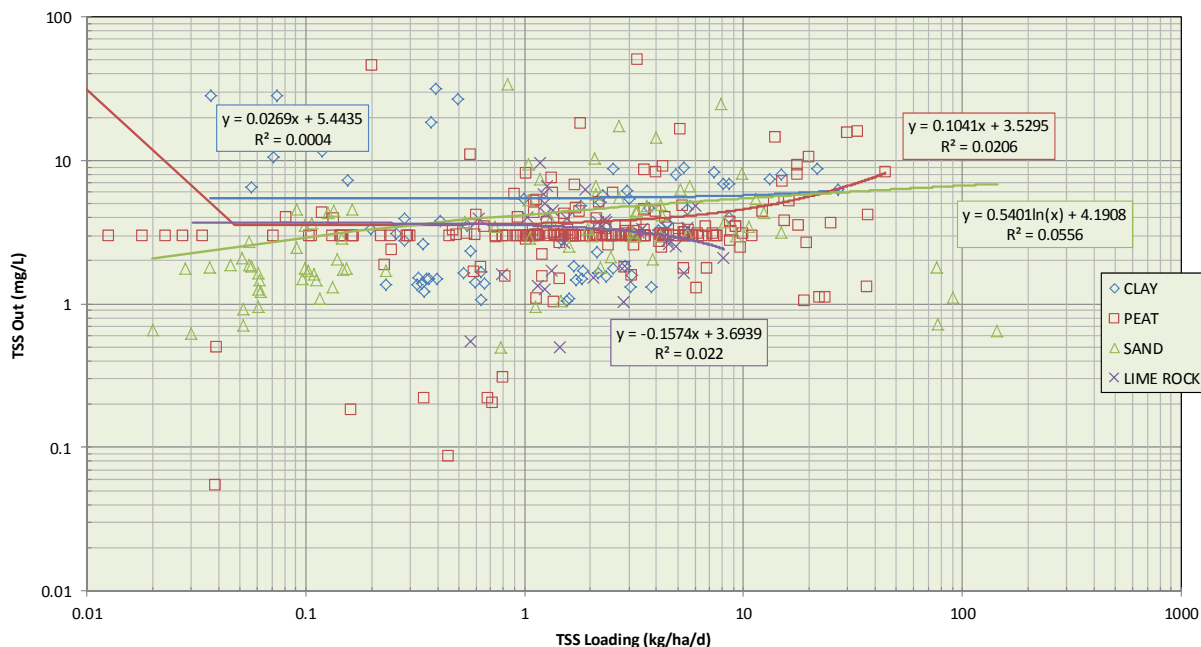


Exhibit 78 - Annual TSS Mass Loading vs. Outlet Concentration by Substrate Type (Inlet TSS < 103 mg/L)

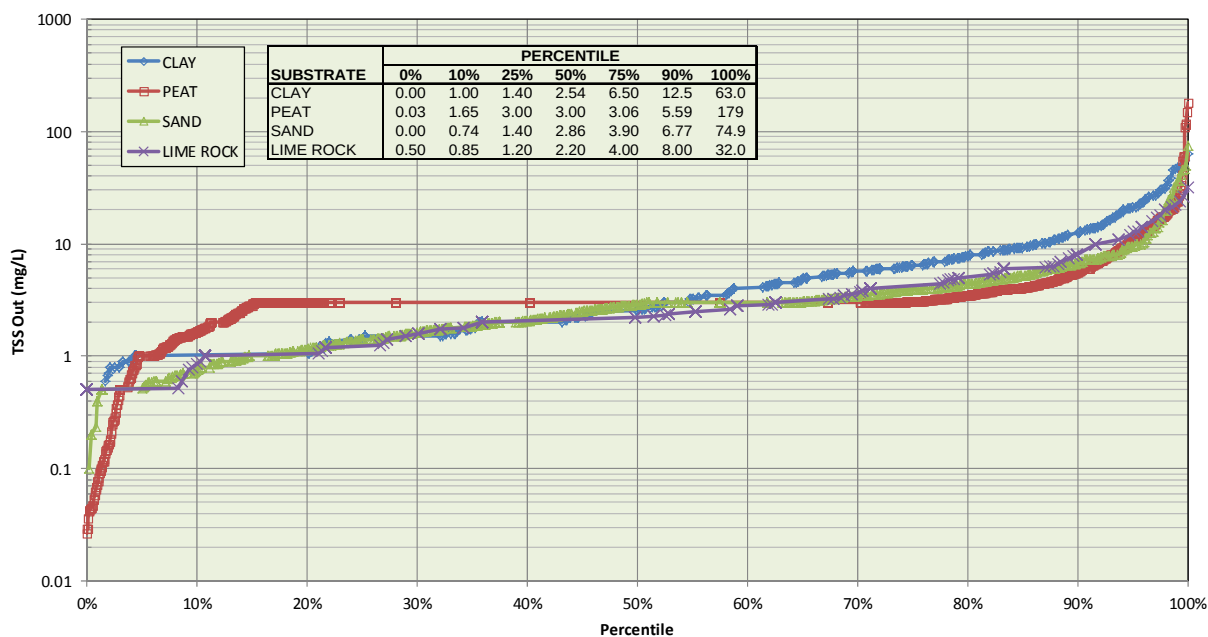


Exhibit 79 - Monthly Average TSS Outflow Concentration Percentiles by Substrate Type (Inlet TSS < 103 mg/L)

3.4 Summary of Design Factors Affecting Treatment Wetland Performance

This section provides a review of extensive operational data from existing constructed treatment wetlands in central and south Florida. This data summary leads to the following general conclusions for each of the parameter groups of interest in this report:

3.4.1 Total Phosphorus

There is considerable evidence that TP is most effectively removed by SAV-dominated wetlands at intermediate TP concentrations in the range between about 50 and 300 ppb (Walker 2010). Emergent wetlands are likely more effective for TP removal at higher inlet TP concentrations (>300 ppb) and periphyton-dominated wetlands are more effective than SAV systems at lower inlet TP concentrations (<50 ppb). The lowest TP concentrations practically achievable in any type of treatment wetlands are in the range of 10 to 15 ppb. The most favorable substrate for achieving very low TP concentrations and for the highest removal rates appears to be calcareous substrates such as limerock. Organic substrates appear to be next most favorable for effective TP reduction, followed in last place by sandy soils. The relationship between lower TP outflow concentrations and the presence of organic soils may just be a result of the SFWMD's preference for use of this plant community within the EAA where incoming TP concentrations tend to be lower than in other Florida treatment marshes.

3.4.2 Nitrate + Nitrite Nitrogen

Most treatment wetlands are successful at removal of $\text{NO}_x\text{-N}$. Baseline or C^* concentration are close to analytical detection limits (less than 0.01 mg/L). In terms of optimal plant community type, EMV, PSTA, OW, and SAV wetlands appear to be similar for removal of $\text{NO}_x\text{-N}$ while FAP is least effective. In terms of optimal substrate for $\text{NO}_x\text{-N}$ removal peat, sand, and limerock appear to be similar while clay was inferior.

3.4.3 Ammonia Nitrogen

Ammonia nitrogen is effectively removed in lightly-loaded treatment wetlands. Typical C^* concentrations are approximately 0.02 mg/L. In terms of optimal plant communities, PSTA appeared to be the best, followed by OW, SAV, and EMV, and FAP was the least effective plant community. Substrate type had a noticeable effect of AN removal with limerock performing the best, followed by similar effects for peat and sandy soils, and with clay least effective.

3.4.3 Total Kjeldahl Nitrogen

The lowest typical TKN outflow concentrations observed in these Florida treatment wetlands was approximately 0.7 mg/L, considerably lower than the Global C^* value of 1.5 mg/L reported by Kadlec and Knight (1996). The most effective plant communities for TKN reduction appear to be OW and EMV. PSTA and FAP were less effective, followed by SAV as the least effective wetland category. In terms of substrate, sand was clearly better than clay, followed by limerock, and finally by peat.

3.4.4 Organic Nitrogen

The lowest TON outflow concentrations typically observed in these treatment wetlands were about 0.6 mg/L. These low concentrations were most likely to be observed in EMV and OW systems built on sandy soils. PSTA and FAP were less effective especially on clay and limerock soils. SAV and peat soils were the least effective combination to achieve low TON concentrations.

3.4.5 Total Nitrogen

The lowest TN outflow concentrations observed were essentially all in the reduced forms (TON and AN) and equal to about 0.7 mg/L. As with TKN and TON, TN was most efficiently reduced in EMV and OW systems built on sandy soils. Periphyton, FAP, and SAV were less effective plant communities and clay, limerock, and organic peat were less effective substrates to efficiently achieve low TN outflow concentrations.

3.4.6 Total Suspended Solids

The lowest TSS concentration typically attained by these Florida treatment wetlands was about 1 mg/L. For TSS reduction PSTA and EMV were the most effective plant communities, followed by SAV, with OW and FAP least favorable. There was essentially no observed effect of substrate type on TSS reduction effectiveness.

Section 4.0 Summary of Treatment Wetland System Merits and Limitations

4.1 Introduction

This section summarizes evaluation criteria for the effectiveness of various treatment wetland options for removal of TN, TP, and TSS in the C-43 Basin in southwest Florida. The five treatment wetland alternatives that are evaluated include the following categories: EMV, FAP, SAV, PSTA, and OW.

Evaluation factors include:

- TN, TP, and TSS removal rates;
- Estimated C* values by pollutant and sediment type; and
- Order-of-magnitude cost per unit treatment area and volume.

It is expected that each of the five basic wetland plant community types will have a range of positive and negative attributes for specific treatment functions of importance. This section gives a general ranking for these options based on each of the evaluation factors listed above. These rankings are intended to support selection of alternative test facility configurations and are not intended to provide a final alternative evaluation for full-scale project implementation. That evaluation should be conducted later once additional operational, performance, and cost data are developed at the C-43 WQTA Test Facility for each of the highest ranked alternatives.

4.2 Estimated Construction Costs

Kadlec and Wallace (2009) report a median cost of about \$100,000 per hectare for surface flow constructed treatment wetlands. However, economy of scale greatly reduces the cost per acre for larger wetlands. Kadlec and Wallace (2009) report a surface flow wetland capital cost relationship with wetland area:

$$C = 194A^{0.690} \quad R^2 = 0.29$$

Where:

C = cost in \$1,000 U.S.

A = effective wetted area in hectares

This cost curve indicates that a 405-ha (1,000-acre) constructed surface flow wetland would have an estimated capital cost of about \$12,220,000 or \$30,164 per ha (\$12,207 per acre). Actual STA construction costs in south Florida may be greater or lower than this number for a number of site-specific reasons, including site topography and local earthwork costs.

To date, two STAs (Taylor Creek and Nubbin Slough) have been constructed in the Lake Okeechobee Watershed and a third is currently under construction (Lakeside Ranch). Six STAs have been constructed in the EAA in various phases and others are constructed (Ten Mile Creek) or planned (C-44 and C-43) in other watersheds. Cost data were previously compiled by WSI (WSI 2009) from Basis of Design Reports (BODRs) and bid tabulations for Nubbin Slough (USACE 2004), C-44 (HDR 2006), STA-2 Cell 4 (Brown and Caldwell 2005), STA-5 Cell 3 (URS 2005a), STA-6 Section 2 (URS 2005), and Lakeside Ranch (CDM 2007), and used to estimate order-of-magnitude unit costs for key components of STA construction. These costs provide a useful range of unit costs for comparing STA cost-effectiveness as a function of the design variables discussed in this document. It is recognized that these costs are dated and have not been normalized (to 2012 dollars for example). It is also recognized that BODR-level costs may vary significantly from the final engineer's estimates or bid tabulations and are somewhat dependent on total treatment wetland area (economy of scale). Based on the WSI (2009) review of South Florida STA construction costs and recognition of the differences between projects, the average unit cost for STA wetland construction (excluding the cost of land) was approximately \$38,000 per ha (\$15,300 per acre). This is the estimated average cost for an STA with a design water depth of about 2 feet.

WSI (2009) also estimated unit costs for various construction items related to the STAs described above. The average cost of excavation was estimated by WSI (2009) to be about \$4.60 per m³ (\$3.50 per cubic yard). For deeper wetland alternatives, these crude cost estimates can be extrapolated for the range of deeper wetland alternatives considered in this report. Each additional foot of design water depth greater than 60 cm (2 feet) over an area of 0.4 ha (one acre) will add about 1,233 m³ (one ac-ft or 1,613 cubic yards) of additional excavation at an estimated cost of about \$14,000 per ha (\$5,650 per acre). This estimate does not account for the possible need for de-watering during deeper excavations and therefore is probably low. While hydraulic residence time in these treatment wetlands is directly related to effective hydraulic volume, Kadlec and Knight (1996) conclude that treatment performance in a variety of wetland systems is more a function of wetted surface area than volume.

4.3 Performance Comparison

The detailed Florida treatment wetland data summarized in Section 3 of this report were compared on the basis of cost and expected effectiveness (Exhibit 80). These comparisons are based on the assumption that site soils for the C-43 WQTA Project will be sandy or calcareous in nature and will therefore avoid the potentially high C* effect for TON resulting from organic and clayey soils. The subsurface profiles, which are limited to the southeast portion of the site and are included in the site exploration report by Dunkelberger Engineering (2009), support this assumption.

The comparison leads to a general order of preference based on cost and pollutant removal performance of EMV>SAV>PSTA>>FAP>>OW. This comparison also indicates that there is not likely to be a large difference in overall TN cost effectiveness between the top three wetland plant community types: EMV, PSTA, and SAV. Each of these types of wetlands has somewhat similar biogeochemical cycles, dependence on adequate

surface area for treatment, and production of ample organic carbon required for effective denitrification of NO_x-N. However, where there are differences in performance and cost between wetland alternatives, those differences will be used to prioritize testing resources.

The C-43 WQTA Expert Panel report (WSI 2010) came to a similar conclusion that, if the District was limited to a single wetland technology, the EMV would be most likely to achieve the lowest TN, TP, and TSS concentrations with the smallest footprint and the lowest construction cost. It is too early however for the District to determine what limit, if any, ought to exist for the number of wetland technologies to be used in the WQTA. A full-scale nitrogen-removal WQTA facility may be a combination of technologies in series with each sized to provide the greatest overall cost effectiveness for the reduction of TN in the CRE.

The next task in this project will develop a test facility design that evaluates each of the promising wetland technologies, both individually and in combination.

Exhibit 80 - C-43 WQTA Wetland Plant Community Alternatives Comparison including Pros and Cons

Wetland Type	Target Water Depth (ft)	Est. Cost w/o Land (\$/ha)	PROS	CONS
EMV	2	\$38,000	Highly complex microbial community, high TON mineralization, high denitrification, moderate P removal, high TSS removal, lowest cost, wide experience and applicability	Limited aerobic zone, limited photodegradation
PSTA	3	\$52,00	Aerobic water column including DO supersaturation, potential for photodegradation, able to achieve very low P	Lower removal rates for all N and P forms, requires adequate calcium availability for P removal
SAV	4	\$66,000	Highly complex microbial community, high P removal, aerobic water column	Susceptible to vegetation loss due to high wind and extended drought conditions, limited data available for N removal on sandy soils
FAP	6	\$94,000	Moderate to high levels of N and P removal	Limited reaeration, highly anaerobic water column, may require plant harvesting, high cost
OW	8	\$121,500	Optimal photodegradation for TON mineralization, highly aerobic	Lowest N and P removal rates, limited experience for achieving low N concentrations, high cost

Section 5.0 References

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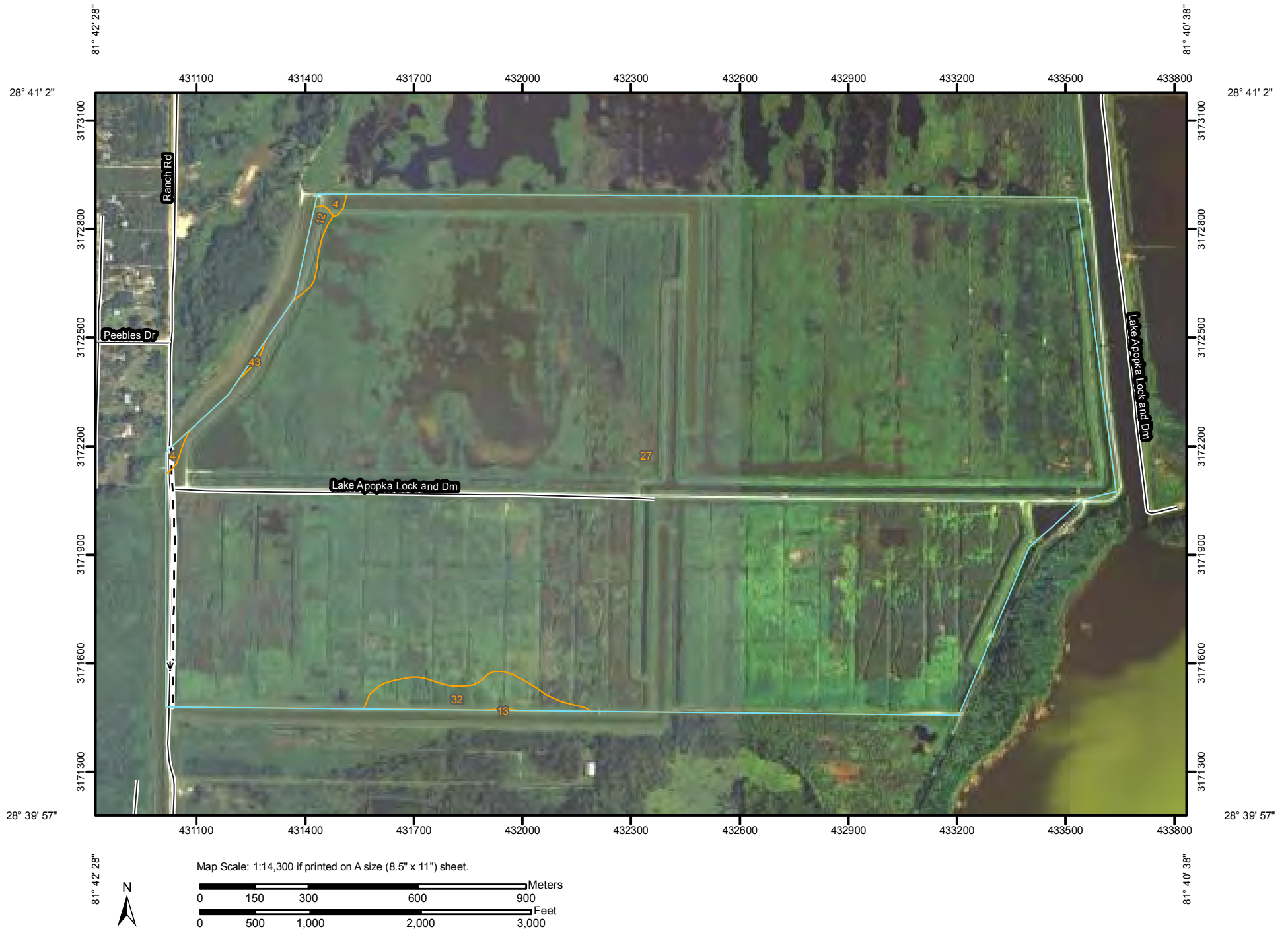
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Appendix A

USDA Natural Resources Conservation Service - Soil Survey

Soil Map—Lake County Area, Florida (Lake Apopka)



Soil Map—Lake County Area, Florida
(Lake Apopka)

MAP LEGEND

Area of Interest (AOI)

 Area of Interest (AOI)

Soils

 Soil Map Units

Special Point Features

-  Blowout
-  Borrow Pit
-  Clay Spot
-  Closed Depression
-  Gravel Pit
-  Gravelly Spot
-  Landfill
-  Lava Flow
-  Marsh or swamp
-  Mine or Quarry
-  Miscellaneous Water
-  Perennial Water
-  Rock Outcrop
-  Saline Spot
-  Sandy Spot
-  Severely Eroded Spot
-  Sinkhole
-  Slide or Slip
-  Sodic Spot
-  Spoil Area
-  Stony Spot



Very Stony Spot



Wet Spot



Other

Special Line Features



Gully



Short Steep Slope



Other

Political Features



Cities

Transportation



Rails



Interstate Highways



US Routes



Major Roads



Local Roads

MAP INFORMATION

Map Scale: 1:14,300 if printed on A size (8.5" × 11") sheet.

The soil surveys that comprise your AOI were mapped at 1:20,000.

Please rely on the bar scale on each map sheet for accurate map measurements.

Source of Map: Natural Resources Conservation Service

Web Soil Survey URL: <http://websoilsurvey.nrcs.usda.gov>

Coordinate System: UTM Zone 17N NAD83

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Lake County Area, Florida

Survey Area Data: Version 9, May 3, 2011

Date(s) aerial images were photographed: 9/9/2007; 8/30/2007

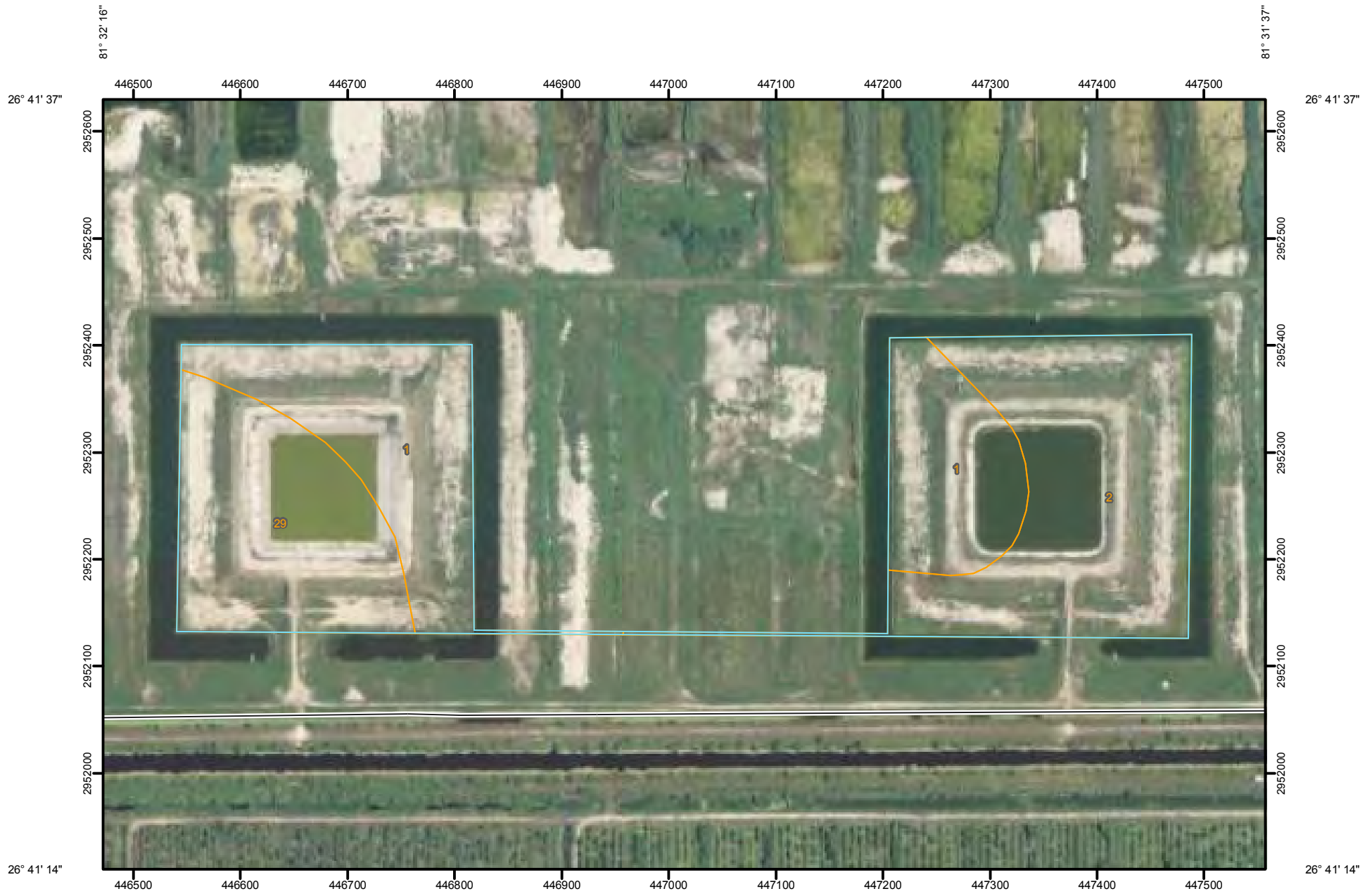
The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.



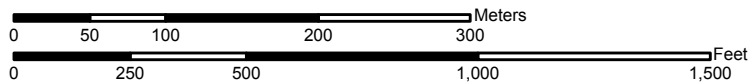
Map Unit Legend

Lake County Area, Florida (FL607)			
Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
4	Anclole and Myakka soils	1.5	0.2%
12	Cassia sand	2.5	0.3%
13	Emeralda fine sand	0.1	0.0%
27	Everglades muck, depressional	807.3	98.2%
32	Oklawaha muck	10.3	1.2%
43	St. Lucie sand, 0 to 5 percent slopes	0.2	0.0%
Totals for Area of Interest		821.9	100.0%

Soil Map—Hendry County, Florida (C-43)



Map Scale: 1:5,150 if printed on A size (8.5" x 11") sheet.



MAP LEGEND

Area of Interest (AOI)

 Area of Interest (AOI)

Soils

 Soil Map Units

Special Point Features

-  Blowout
-  Borrow Pit
-  Clay Spot
-  Closed Depression
-  Gravel Pit
-  Gravelly Spot
-  Landfill
-  Lava Flow
-  Marsh or swamp
-  Mine or Quarry
-  Miscellaneous Water
-  Perennial Water
-  Rock Outcrop
-  Saline Spot
-  Sandy Spot
-  Severely Eroded Spot
-  Sinkhole
-  Slide or Slip
-  Sodic Spot
-  Spoil Area
-  Stony Spot



Very Stony Spot



Wet Spot



Other

Special Line Features



Gully



Short Steep Slope



Other

Political Features



Cities

Transportation



Rails



Interstate Highways



US Routes



Major Roads



Local Roads

MAP INFORMATION

Map Scale: 1:5,150 if printed on A size (8.5" × 11") sheet.

The soil surveys that comprise your AOI were mapped at 1:24,000.

Warning: Soil Map may not be valid at this scale.

Enlargement of maps beyond the scale of mapping can cause misunderstanding of the detail of mapping and accuracy of soil line placement. The maps do not show the small areas of contrasting soils that could have been shown at a more detailed scale.

Please rely on the bar scale on each map sheet for accurate map measurements.

Source of Map: Natural Resources Conservation Service

Web Soil Survey URL: <http://websoilsurvey.nrcs.usda.gov>

Coordinate System: UTM Zone 17N NAD83

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Hendry County, Florida

Survey Area Data: Version 10, Jan 13, 2010

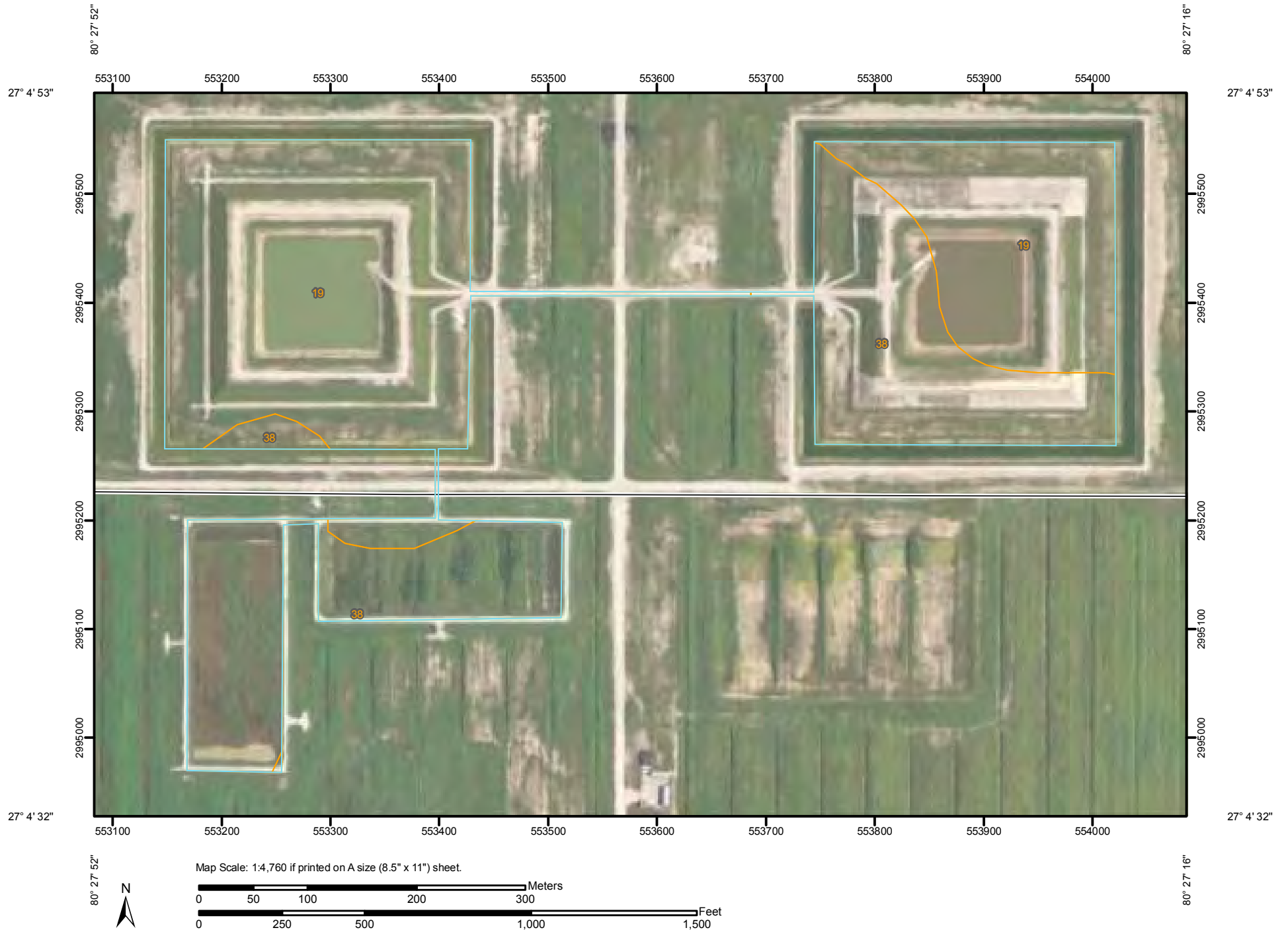
Date(s) aerial images were photographed: 8/10/2007

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Map Unit Legend

Hendry County, Florida (FL051)			
Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
1	Boca sand	14.2	37.3%
2	Pineda sand, limestone substratum	14.2	37.1%
29	Oldsmar sand, limestone substratum	9.8	25.7%
Totals for Area of Interest		38.2	100.0%

Soil Map—Martin County, Florida
(C-44)



MAP LEGEND

Area of Interest (AOI)

 Area of Interest (AOI)

Soils

 Soil Map Units

Special Point Features

-  Blowout
-  Borrow Pit
-  Clay Spot
-  Closed Depression
-  Gravel Pit
-  Gravelly Spot
-  Landfill
-  Lava Flow
-  Marsh or swamp
-  Mine or Quarry
-  Miscellaneous Water
-  Perennial Water
-  Rock Outcrop
-  Saline Spot
-  Sandy Spot
-  Severely Eroded Spot
-  Sinkhole
-  Slide or Slip
-  Sodic Spot
-  Spoil Area
-  Stony Spot



Very Stony Spot



Wet Spot



Other

Special Line Features



Gully



Short Steep Slope



Other

Political Features



Cities

Transportation



Rails



Interstate Highways



US Routes



Major Roads



Local Roads

MAP INFORMATION

Map Scale: 1:4,760 if printed on A size (8.5" × 11") sheet.

The soil surveys that comprise your AOI were mapped at 1:20,000.

Warning: Soil Map may not be valid at this scale.

Enlargement of maps beyond the scale of mapping can cause misunderstanding of the detail of mapping and accuracy of soil line placement. The maps do not show the small areas of contrasting soils that could have been shown at a more detailed scale.

Please rely on the bar scale on each map sheet for accurate map measurements.

Source of Map: Natural Resources Conservation Service

Web Soil Survey URL: <http://websoilsurvey.nrcs.usda.gov>

Coordinate System: UTM Zone 17N NAD83

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Martin County, Florida

Survey Area Data: Version 9, Jan 13, 2010

Date(s) aerial images were photographed: 8/4/2007

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Map Unit Legend

Martin County, Florida (FL085)			
Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
19	Winder sand, depressional	29.6	60.1%
38	Floridana fine sand, depressional	19.6	39.9%
Totals for Area of Interest		49.2	100.0%

Soil Map—Polk County, Florida (Lakeland)



MAP LEGEND

Area of Interest (AOI)

 Area of Interest (AOI)

Soils

 Soil Map Units

Special Point Features

-  Blowout
-  Borrow Pit
-  Clay Spot
-  Closed Depression
-  Gravel Pit
-  Gravelly Spot
-  Landfill
-  Lava Flow
-  Marsh or swamp
-  Mine or Quarry
-  Miscellaneous Water
-  Perennial Water
-  Rock Outcrop
-  Saline Spot
-  Sandy Spot
-  Severely Eroded Spot
-  Sinkhole
-  Slide or Slip
-  Sodic Spot
-  Spoil Area
-  Stony Spot



Very Stony Spot



Wet Spot



Other

Special Line Features



Gully



Short Steep Slope



Other

Political Features



Cities

Transportation



Rails



Interstate Highways



US Routes



Major Roads



Local Roads

MAP INFORMATION

Map Scale: 1:20,200 if printed on A size (8.5" × 11") sheet.

The soil surveys that comprise your AOI were mapped at 1:20,000.

Please rely on the bar scale on each map sheet for accurate map measurements.

Source of Map: Natural Resources Conservation Service

Web Soil Survey URL: <http://websoilsurvey.nrcs.usda.gov>

Coordinate System: UTM Zone 17N NAD83

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Polk County, Florida

Survey Area Data: Version 7, Jan 26, 2010

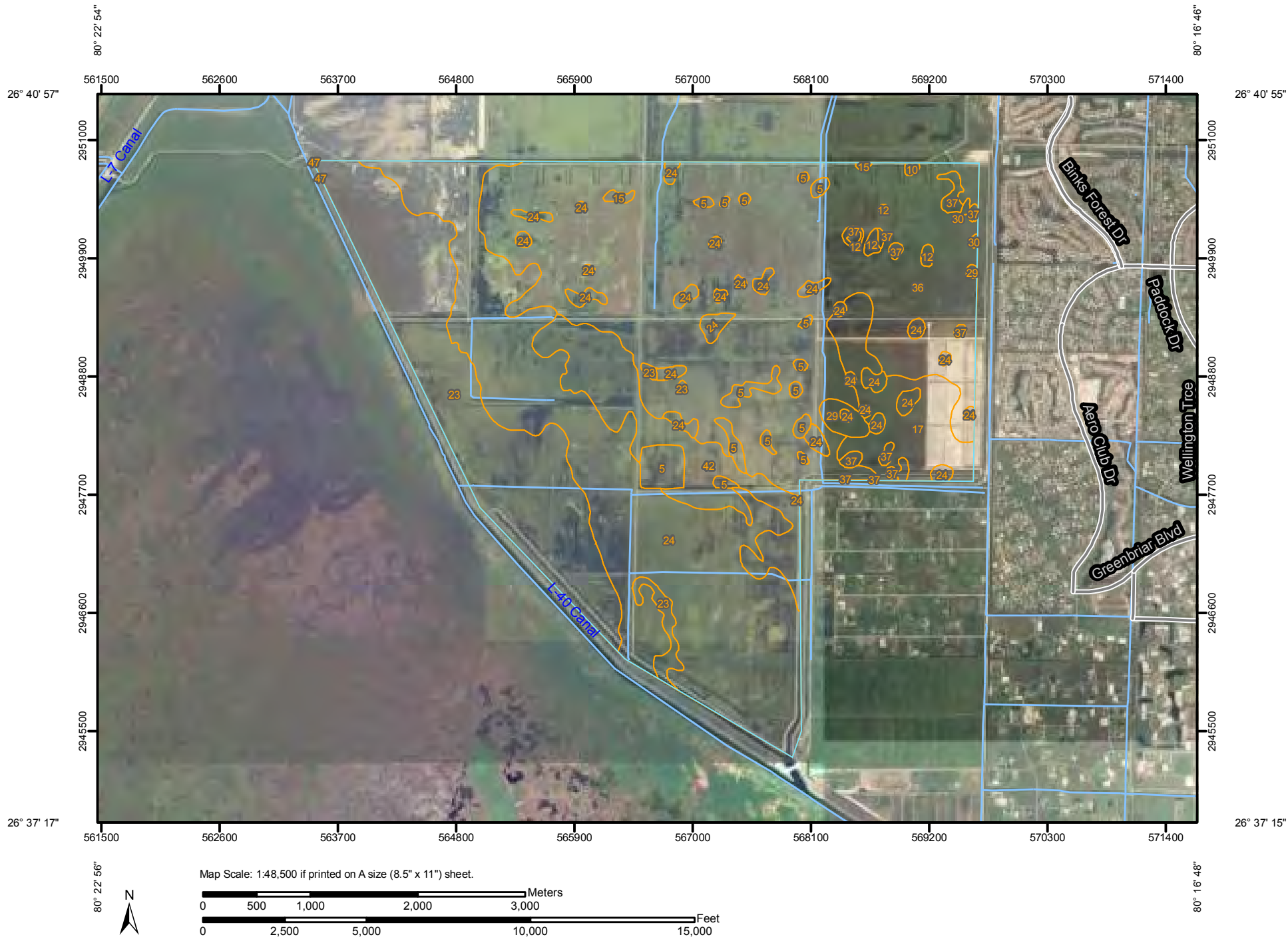
Date(s) aerial images were photographed: 8/11/2007

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Map Unit Legend

Polk County, Florida (FL105)			
Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
8	Hydraquents, clayey	918.0	67.5%
11	Arents-Water complex	26.3	1.9%
12	Neilhurst sand, 1 to 5 percent slopes	81.3	6.0%
68	Arents, 0 to 5 percent slopes	156.6	11.5%
99	Water	178.4	13.1%
Totals for Area of Interest		1,360.7	100.0%

Soil Map—Palm Beach County Area, Florida (STA-1E)



Soil Map—Palm Beach County Area, Florida
(STA-1E)

MAP LEGEND

Area of Interest (AOI)

 Area of Interest (AOI)

Soils

 Soil Map Units

Special Point Features

-  Blowout
-  Borrow Pit
-  Clay Spot
-  Closed Depression
-  Gravel Pit
-  Gravelly Spot
-  Landfill
-  Lava Flow
-  Marsh or swamp
-  Mine or Quarry
-  Miscellaneous Water
-  Perennial Water
-  Rock Outcrop
-  Saline Spot
-  Sandy Spot
-  Severely Eroded Spot
-  Sinkhole
-  Slide or Slip
-  Sodic Spot
-  Spoil Area
-  Stony Spot



Very Stony Spot



Wet Spot



Other

Special Line Features



Gully



Short Steep Slope



Other

Political Features



Cities

Water Features



Streams and Canals

Transportation



Rails



Interstate Highways



US Routes



Major Roads

MAP INFORMATION

Map Scale: 1:48,500 if printed on A size (8.5" × 11") sheet.

The soil surveys that comprise your AOI were mapped at 1:20,000.

Please rely on the bar scale on each map sheet for accurate map measurements.

Source of Map: Natural Resources Conservation Service

Web Soil Survey URL: <http://websoilsurvey.nrcs.usda.gov>

Coordinate System: UTM Zone 17N NAD83

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Palm Beach County Area, Florida

Survey Area Data: Version 7, Jan 13, 2010

Date(s) aerial images were photographed: 8/7/2007

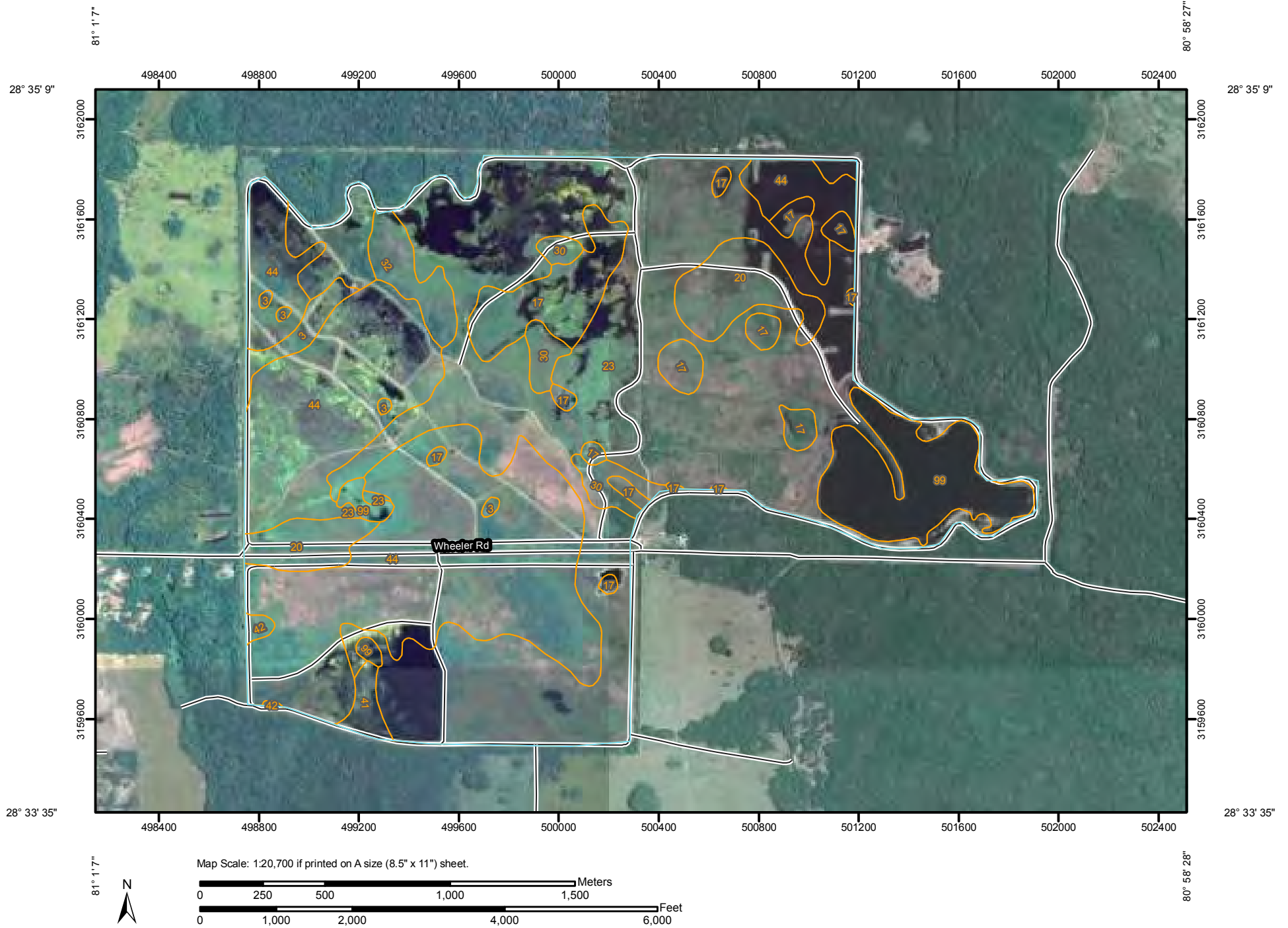
The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.



Map Unit Legend

Palm Beach County Area, Florida (FL611)			
Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
5	Arents-Urban land complex, organic substratum	109.8	2.1%
10	Boca fine sand	3.3	0.1%
12	Chobee fine sandy loam	15.0	0.3%
15	Floridana fine sand	7.8	0.2%
17	Holopaw fine sand	243.0	4.7%
23	Okeechobee muck	818.9	15.8%
24	Okeelanta muck	1,456.4	28.1%
29	Pineda fine sand	28.0	0.5%
30	Pinellas fine sand	4.0	0.1%
36	Riviera fine sand	2,119.1	40.9%
37	Riviera fine sand, depressional	47.3	0.9%
42	Tequesta muck	331.5	6.4%
47	Udorthents, 2 to 35 percent slopes	0.2	0.0%
Totals for Area of Interest		5,184.7	100.0%

Soil Map—Orange County, Florida (OEW)



MAP LEGEND

Area of Interest (AOI)

 Area of Interest (AOI)

Soils

 Soil Map Units

Special Point Features

-  Blowout
-  Borrow Pit
-  Clay Spot
-  Closed Depression
-  Gravel Pit
-  Gravelly Spot
-  Landfill
-  Lava Flow
-  Marsh or swamp
-  Mine or Quarry
-  Miscellaneous Water
-  Perennial Water
-  Rock Outcrop
-  Saline Spot
-  Sandy Spot
-  Severely Eroded Spot
-  Sinkhole
-  Slide or Slip
-  Sodic Spot
-  Spoil Area
-  Stony Spot



Very Stony Spot



Wet Spot



Other

Special Line Features



Gully



Short Steep Slope



Other

Political Features



Cities

Transportation



Rails



Interstate Highways



US Routes



Major Roads



Local Roads

MAP INFORMATION

Map Scale: 1:20,700 if printed on A size (8.5" × 11") sheet.

The soil surveys that comprise your AOI were mapped at 1:20,000.

Please rely on the bar scale on each map sheet for accurate map measurements.

Source of Map: Natural Resources Conservation Service

Web Soil Survey URL: <http://websoilsurvey.nrcs.usda.gov>

Coordinate System: UTM Zone 17N NAD83

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Orange County, Florida

Survey Area Data: Version 7, Apr 5, 2011

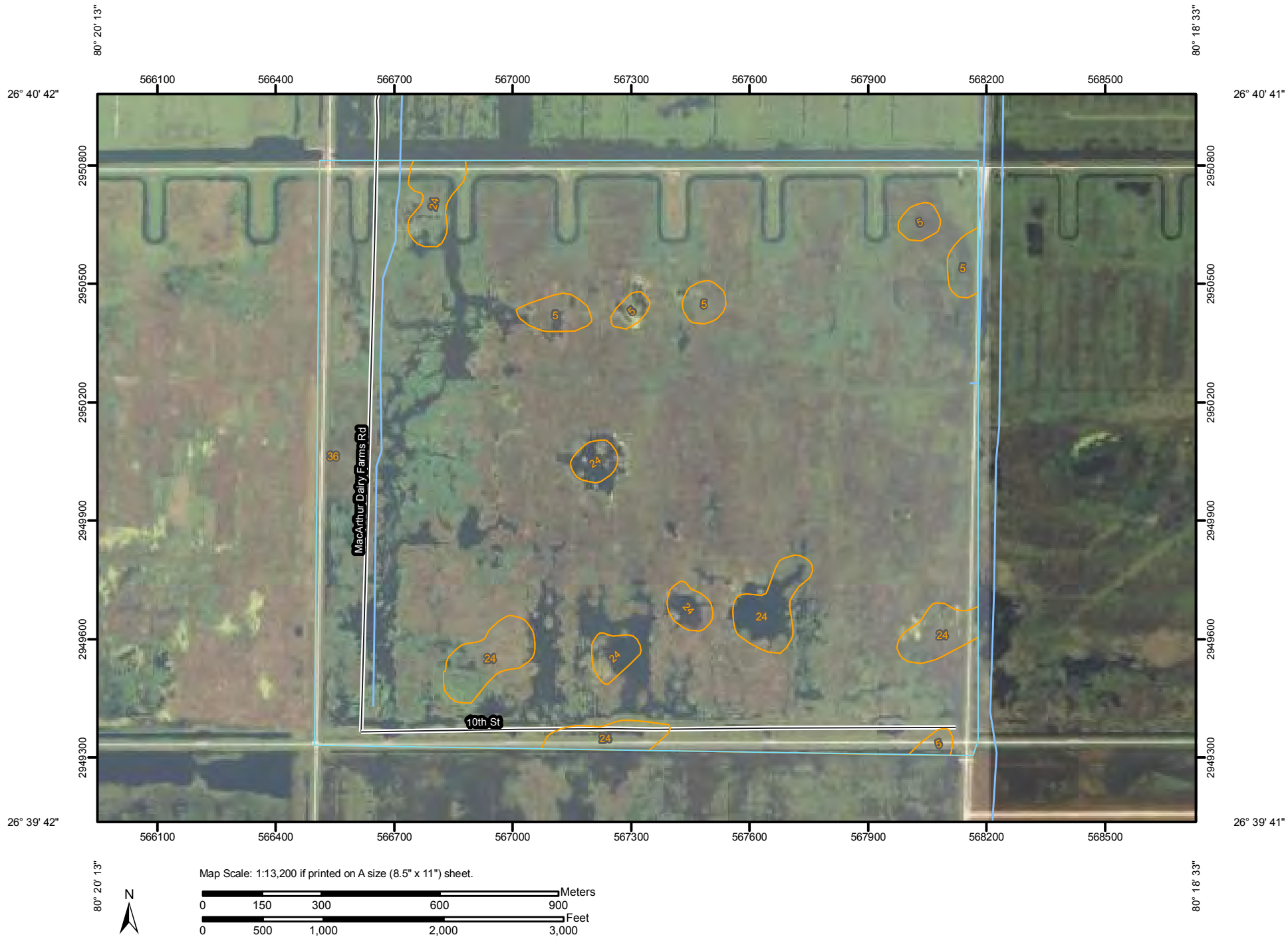
Date(s) aerial images were photographed: 6/9/2007

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Map Unit Legend

Orange County, Florida (FL095)			
Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
3	Basinger fine sand, depressional	13.9	1.1%
17	Floridana mucky fine sand, depressional	73.6	6.0%
20	Immokalee fine sand	55.9	4.6%
23	Malabar fine sand	560.1	45.7%
30	Pineda fine sand	21.1	1.7%
32	Pinellas fine sand	20.5	1.7%
41	Samsula-Hontoon-Basinger association, depressional	8.0	0.7%
42	Sanibel muck	2.8	0.2%
44	Smyrna fine sand	392.9	32.0%
99	Water	77.5	6.3%
Totals for Area of Interest		1,226.2	100.0%

Soil Map—Palm Beach County Area, Florida
(STA-1E Cell 3)



Soil Map—Palm Beach County Area, Florida
(STA-1E Cell 3)

MAP LEGEND

Area of Interest (AOI)

 Area of Interest (AOI)

Soils

 Soil Map Units

Special Point Features

-  Blowout
-  Borrow Pit
-  Clay Spot
-  Closed Depression
-  Gravel Pit
-  Gravelly Spot
-  Landfill
-  Lava Flow
-  Marsh or swamp
-  Mine or Quarry
-  Miscellaneous Water
-  Perennial Water
-  Rock Outcrop
-  Saline Spot
-  Sandy Spot
-  Severely Eroded Spot
-  Sinkhole
-  Slide or Slip
-  Sodic Spot
-  Spoil Area
-  Stony Spot



Very Stony Spot



Wet Spot



Other

Special Line Features



Gully



Short Steep Slope



Other

Political Features



Cities

Water Features



Streams and Canals

Transportation



Rails



Interstate Highways



US Routes



Major Roads



Local Roads

MAP INFORMATION

Map Scale: 1:13,200 if printed on A size (8.5" × 11") sheet.

The soil surveys that comprise your AOI were mapped at 1:20,000.

Please rely on the bar scale on each map sheet for accurate map measurements.

Source of Map: Natural Resources Conservation Service

Web Soil Survey URL: <http://websoilsurvey.nrcs.usda.gov>

Coordinate System: UTM Zone 17N NAD83

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Palm Beach County Area, Florida

Survey Area Data: Version 7, Jan 13, 2010

Date(s) aerial images were photographed: 8/7/2007

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.



Map Unit Legend

Palm Beach County Area, Florida (FL611)			
Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
5	Arents-Urban land complex, organic substratum	12.9	2.1%
24	Okeelanta muck	36.5	5.9%
36	Riviera fine sand	569.4	92.0%
Totals for Area of Interest		618.8	100.0%

Soil Map—Palm Beach County Area, Florida
(STA-1E Cell 4N)



Soil Map—Palm Beach County Area, Florida
(STA-1E Cell 4N)

MAP LEGEND

Area of Interest (AOI)

 Area of Interest (AOI)

Soils

 Soil Map Units

Special Point Features

-  Blowout
-  Borrow Pit
-  Clay Spot
-  Closed Depression
-  Gravel Pit
-  Gravelly Spot
-  Landfill
-  Lava Flow
-  Marsh or swamp
-  Mine or Quarry
-  Miscellaneous Water
-  Perennial Water
-  Rock Outcrop
-  Saline Spot
-  Sandy Spot
-  Severely Eroded Spot
-  Sinkhole
-  Slide or Slip
-  Sodic Spot
-  Spoil Area
-  Stony Spot



Very Stony Spot



Wet Spot



Other

Special Line Features



Gully



Short Steep Slope



Other

Political Features



Cities

Water Features



Streams and Canals

Transportation



Rails



Interstate Highways



US Routes



Major Roads



Local Roads

MAP INFORMATION

Map Scale: 1:13,800 if printed on A size (8.5" × 11") sheet.

The soil surveys that comprise your AOI were mapped at 1:20,000.

Please rely on the bar scale on each map sheet for accurate map measurements.

Source of Map: Natural Resources Conservation Service

Web Soil Survey URL: <http://websoilsurvey.nrcs.usda.gov>

Coordinate System: UTM Zone 17N NAD83

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Palm Beach County Area, Florida

Survey Area Data: Version 7, Jan 13, 2010

Date(s) aerial images were photographed: 8/7/2007

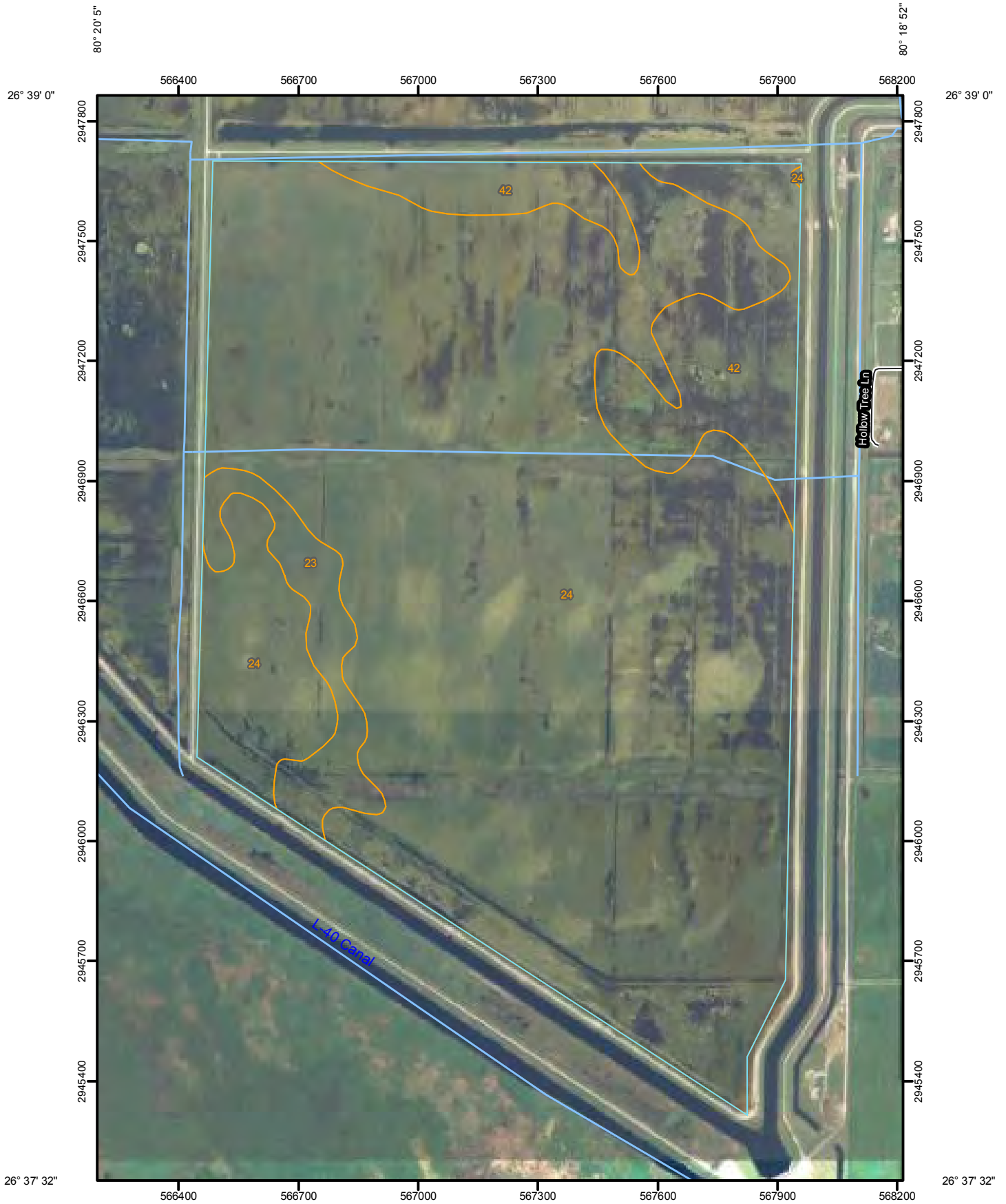
The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.



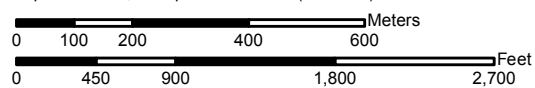
Map Unit Legend

Palm Beach County Area, Florida (FL611)			
Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
5	Arents-Urban land complex, organic substratum	94.3	15.0%
23	Okeechobee muck	5.8	0.9%
24	Okeelanta muck	31.0	4.9%
36	Riviera fine sand	409.1	65.0%
42	Tequesta muck	88.7	14.1%
Totals for Area of Interest		628.9	100.0%

Soil Map—Palm Beach County Area, Florida
(STA-1E Cell 4S)



Map Scale: 1:12,900 if printed on A size (8.5" x 11") sheet.



Soil Map—Palm Beach County Area, Florida
(STA-1E Cell 4S)

MAP LEGEND

Area of Interest (AOI)

 Area of Interest (AOI)

Soils

 Soil Map Units

Special Point Features

-  Blowout
-  Borrow Pit
-  Clay Spot
-  Closed Depression
-  Gravel Pit
-  Gravelly Spot
-  Landfill
-  Lava Flow
-  Marsh or swamp
-  Mine or Quarry
-  Miscellaneous Water
-  Perennial Water
-  Rock Outcrop
-  Saline Spot
-  Sandy Spot
-  Severely Eroded Spot
-  Sinkhole
-  Slide or Slip
-  Sodic Spot
-  Spoil Area
-  Stony Spot



Very Stony Spot



Wet Spot



Other

Special Line Features



Gully



Short Steep Slope



Other

Political Features



Cities

Water Features



Streams and Canals

Transportation



Rails



Interstate Highways



US Routes



Major Roads



Local Roads

MAP INFORMATION

Map Scale: 1:12,900 if printed on A size (8.5" × 11") sheet.

The soil surveys that comprise your AOI were mapped at 1:20,000.

Please rely on the bar scale on each map sheet for accurate map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL: <http://websoilsurvey.nrcs.usda.gov>
Coordinate System: UTM Zone 17N NAD83

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Palm Beach County Area, Florida
Survey Area Data: Version 7, Jan 13, 2010

Date(s) aerial images were photographed: 8/7/2007

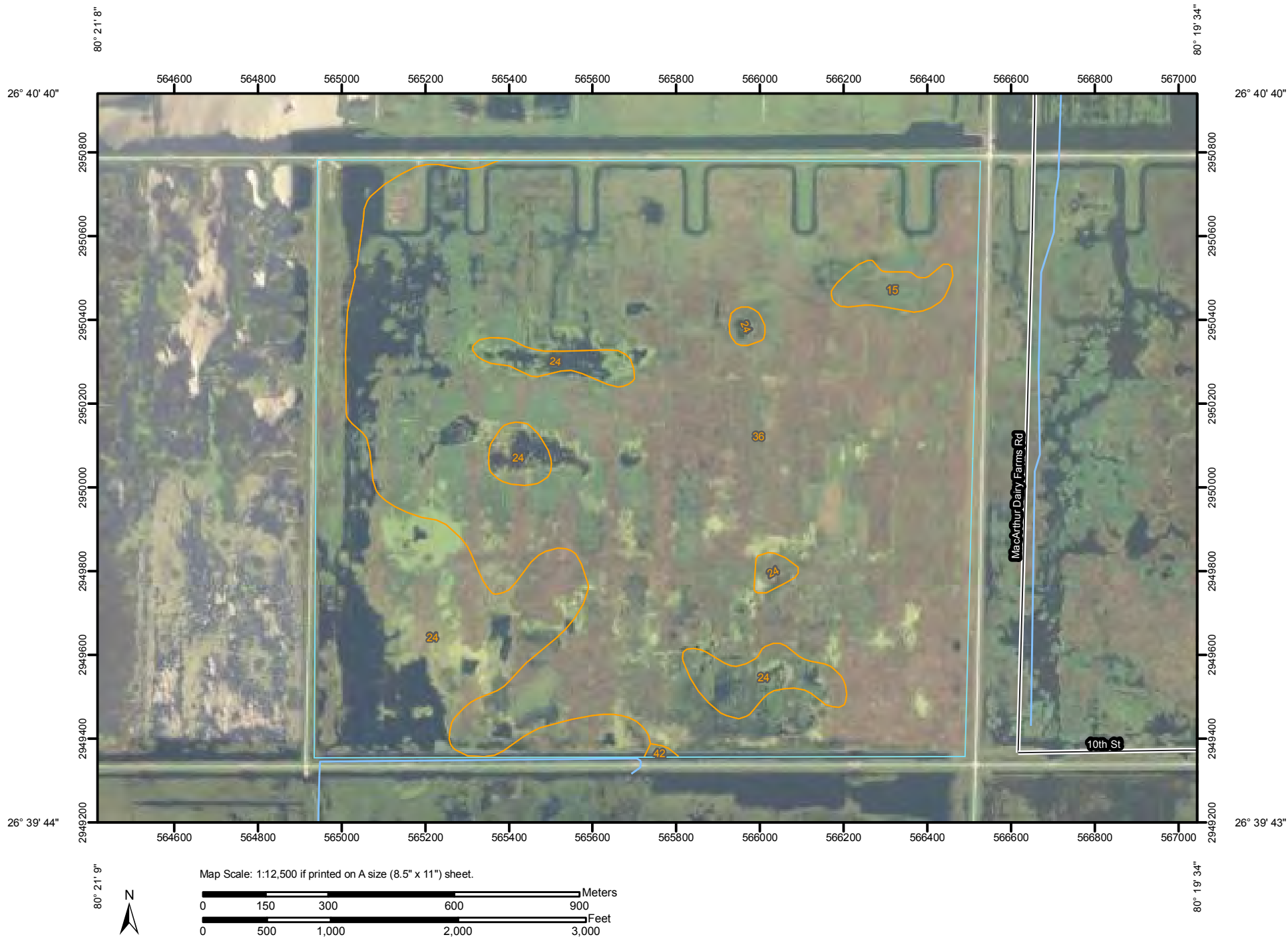
The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.



Map Unit Legend

Palm Beach County Area, Florida (FL611)			
Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
23	Okeechobee muck	29.4	4.1%
24	Okeelanta muck	606.7	85.1%
42	Tequesta muck	76.6	10.7%
Totals for Area of Interest		712.7	100.0%

Soil Map—Palm Beach County Area, Florida
(STA-1E Cell 5)



MAP LEGEND

Area of Interest (AOI)

 Area of Interest (AOI)

Soils

 Soil Map Units

Special Point Features

-  Blowout
-  Borrow Pit
-  Clay Spot
-  Closed Depression
-  Gravel Pit
-  Gravelly Spot
-  Landfill
-  Lava Flow
-  Marsh or swamp
-  Mine or Quarry
-  Miscellaneous Water
-  Perennial Water
-  Rock Outcrop
-  Saline Spot
-  Sandy Spot
-  Severely Eroded Spot
-  Sinkhole
-  Slide or Slip
-  Sodic Spot
-  Spoil Area
-  Stony Spot



Very Stony Spot



Wet Spot



Other

Special Line Features



Gully



Short Steep Slope



Other

Political Features



Cities

Water Features



Streams and Canals

Transportation



Rails



Interstate Highways



US Routes



Major Roads



Local Roads

MAP INFORMATION

Map Scale: 1:12,500 if printed on A size (8.5" × 11") sheet.

The soil surveys that comprise your AOI were mapped at 1:20,000.

Please rely on the bar scale on each map sheet for accurate map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL: <http://websoilsurvey.nrcs.usda.gov>
Coordinate System: UTM Zone 17N NAD83

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Palm Beach County Area, Florida
Survey Area Data: Version 7, Jan 13, 2010

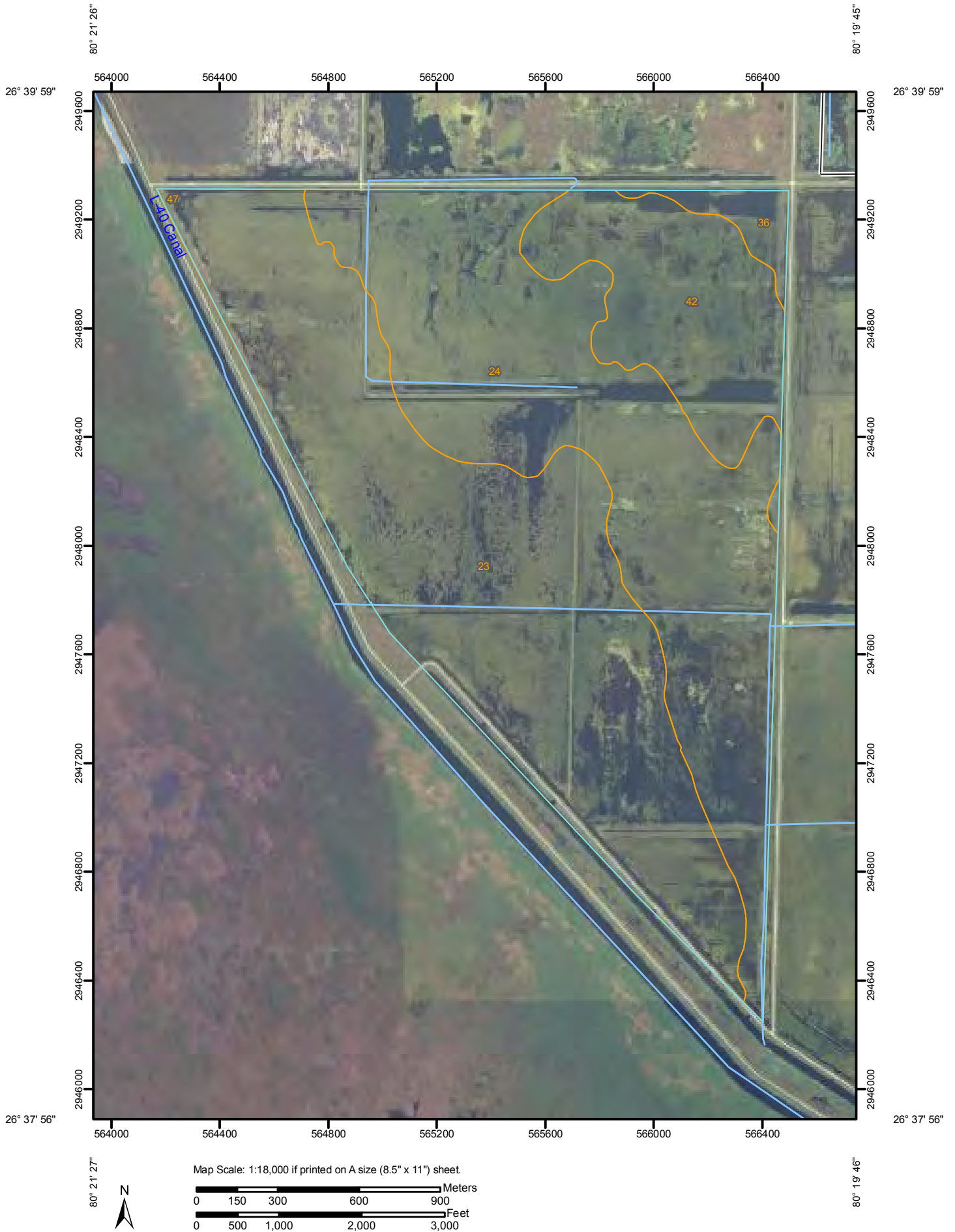
Date(s) aerial images were photographed: 8/7/2007

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Map Unit Legend

Palm Beach County Area, Florida (FL611)			
Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
15	Floridana fine sand	5.9	1.1%
24	Okeelanta muck	119.9	21.7%
36	Riviera fine sand	426.5	77.2%
42	Tequesta muck	0.4	0.1%
Totals for Area of Interest		552.7	100.0%

Soil Map—Palm Beach County Area, Florida
(STA-1E Cell 6)



MAP LEGEND

Area of Interest (AOI)

 Area of Interest (AOI)

Soils

 Soil Map Units

Special Point Features

-  Blowout
-  Borrow Pit
-  Clay Spot
-  Closed Depression
-  Gravel Pit
-  Gravelly Spot
-  Landfill
-  Lava Flow
-  Marsh or swamp
-  Mine or Quarry
-  Miscellaneous Water
-  Perennial Water
-  Rock Outcrop
-  Saline Spot
-  Sandy Spot
-  Severely Eroded Spot
-  Sinkhole
-  Slide or Slip
-  Sodic Spot
-  Spoil Area
-  Stony Spot



Very Stony Spot



Wet Spot



Other

Special Line Features



Gully



Short Steep Slope



Other

Political Features



Cities

Water Features



Streams and Canals

Transportation



Rails



Interstate Highways



US Routes



Major Roads



Local Roads

MAP INFORMATION

Map Scale: 1:18,000 if printed on A size (8.5" × 11") sheet.

The soil surveys that comprise your AOI were mapped at 1:20,000.

Please rely on the bar scale on each map sheet for accurate map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL: <http://websoilsurvey.nrcs.usda.gov>
Coordinate System: UTM Zone 17N NAD83

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Palm Beach County Area, Florida
Survey Area Data: Version 7, Jan 13, 2010

Date(s) aerial images were photographed: 8/7/2007

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Map Unit Legend

Palm Beach County Area, Florida (FL611)			
Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
23	Okeechobee muck	469.3	46.2%
24	Okeelanta muck	391.6	38.5%
36	Riviera fine sand	18.7	1.8%
42	Tequesta muck	137.2	13.5%
47	Udorthents, 2 to 35 percent slopes	0.1	0.0%
Totals for Area of Interest		1,016.9	100.0%

Soil Map—Palm Beach County Area, Florida
(STA-1E Cell 7)



MAP LEGEND

Area of Interest (AOI)

 Area of Interest (AOI)

Soils

 Soil Map Units

Special Point Features

-  Blowout
-  Borrow Pit
-  Clay Spot
-  Closed Depression
-  Gravel Pit
-  Gravelly Spot
-  Landfill
-  Lava Flow
-  Marsh or swamp
-  Mine or Quarry
-  Miscellaneous Water
-  Perennial Water
-  Rock Outcrop
-  Saline Spot
-  Sandy Spot
-  Severely Eroded Spot
-  Sinkhole
-  Slide or Slip
-  Sodic Spot
-  Spoil Area
-  Stony Spot



Very Stony Spot



Wet Spot



Other

Special Line Features



Gully



Short Steep Slope



Other

Political Features



Cities

Water Features



Streams and Canals

Transportation



Rails



Interstate Highways



US Routes



Major Roads



Local Roads

MAP INFORMATION

Map Scale: 1:12,000 if printed on A size (8.5" × 11") sheet.

The soil surveys that comprise your AOI were mapped at 1:20,000.

Please rely on the bar scale on each map sheet for accurate map measurements.

Source of Map: Natural Resources Conservation Service

Web Soil Survey URL: <http://websoilsurvey.nrcs.usda.gov>

Coordinate System: UTM Zone 17N NAD83

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Palm Beach County Area, Florida

Survey Area Data: Version 7, Jan 13, 2010

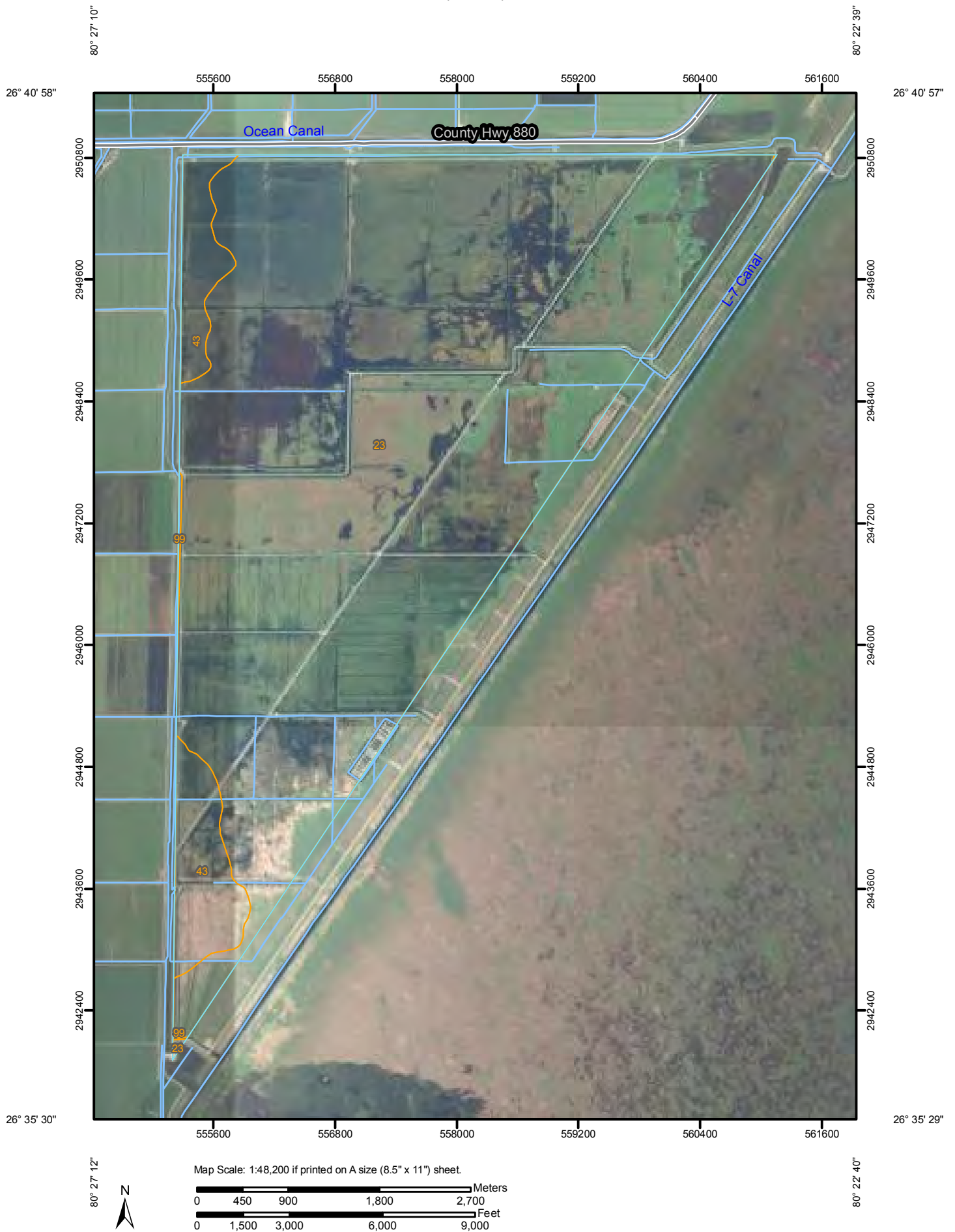
Date(s) aerial images were photographed: 8/7/2007

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Map Unit Legend

Palm Beach County Area, Florida (FL611)			
Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
23	Okeechobee muck	284.9	71.4%
24	Okeelanta muck	113.3	28.4%
47	Udorthents, 2 to 35 percent slopes	0.9	0.2%
Totals for Area of Interest		399.1	100.0%

Soil Map—Palm Beach County Area, Florida, and Water Conservation Area, Florida
(STA-1W)



Soil Map—Palm Beach County Area, Florida, and Water Conservation Area, Florida
(STA-1W)

MAP LEGEND

Area of Interest (AOI)

 Area of Interest (AOI)

Soils

 Soil Map Units

Special Point Features

-  Blowout
-  Borrow Pit
-  Clay Spot
-  Closed Depression
-  Gravel Pit
-  Gravelly Spot
-  Landfill
-  Lava Flow
-  Marsh or swamp
-  Mine or Quarry
-  Miscellaneous Water
-  Perennial Water
-  Rock Outcrop
-  Saline Spot
-  Sandy Spot
-  Severely Eroded Spot
-  Sinkhole
-  Slide or Slip
-  Sodic Spot
-  Spoil Area
-  Stony Spot



Very Stony Spot



Wet Spot



Other

Special Line Features



Gully



Short Steep Slope



Other

Political Features



Cities

Water Features



Streams and Canals

Transportation



Rails



Interstate Highways



US Routes



Major Roads

MAP INFORMATION

Map Scale: 1:48,200 if printed on A size (8.5" × 11") sheet.

The soil surveys that comprise your AOI were mapped at 1:20,000.

Please rely on the bar scale on each map sheet for accurate map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL: <http://websoilsurvey.nrcs.usda.gov>
Coordinate System: UTM Zone 17N NAD83

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Palm Beach County Area, Florida
Survey Area Data: Version 7, Jan 13, 2010

Soil Survey Area: Water Conservation Area, Florida
Survey Area Data: Not available

Your area of interest (AOI) includes more than one soil survey area. These survey areas may have been mapped at different scales, with a different land use in mind, at different times, or at different levels of detail. This may result in map unit symbols, soil properties, and interpretations that do not completely agree across soil survey area boundaries.

Date(s) aerial images were photographed: 8/7/2007

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

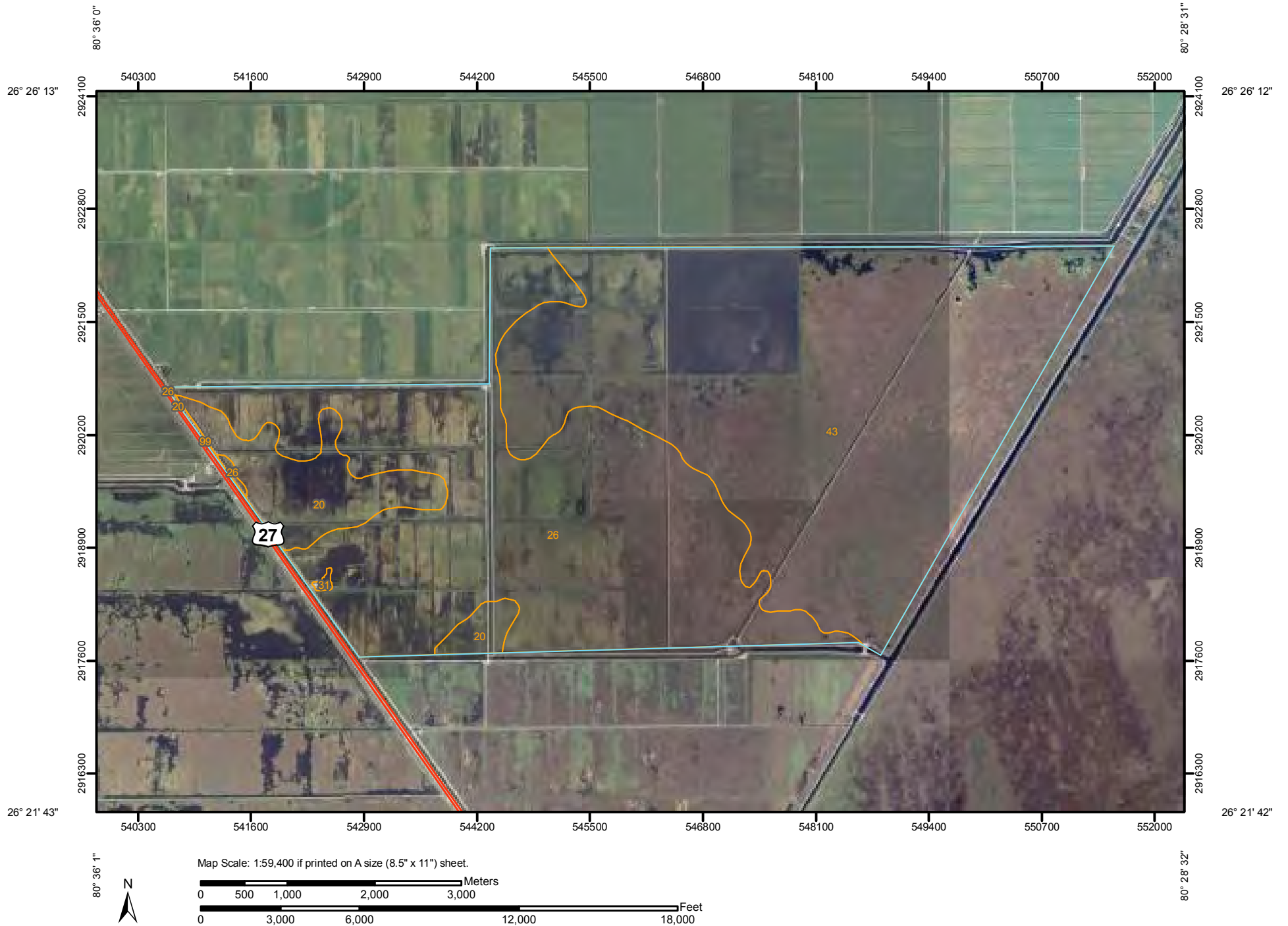


Map Unit Legend

Palm Beach County Area, Florida (FL611)			
Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
23	Okeechobee muck	5,996.4	92.8%
43	Terra Ceia muck	455.6	7.1%
99	Water	8.0	0.1%
Subtotals for Soil Survey Area		6,460.0	100.0%
Totals for Area of Interest		6,459.9	100.0%

Water Conservation Area, Florida (FL615)			
Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
No soil data available for this soil survey area.			
Subtotals for Soil Survey Area		—	—
Totals for Area of Interest		6,459.9	100.0%

Soil Map—Palm Beach County Area, Florida, and Water Conservation Area, Florida
(STA-2)



Soil Map—Palm Beach County Area, Florida, and Water Conservation Area, Florida
(STA-2)

MAP LEGEND

Area of Interest (AOI)

 Area of Interest (AOI)

Soils

 Soil Map Units

Special Point Features

-  Blowout
-  Borrow Pit
-  Clay Spot
-  Closed Depression
-  Gravel Pit
-  Gravelly Spot
-  Landfill
-  Lava Flow
-  Marsh or swamp
-  Mine or Quarry
-  Miscellaneous Water
-  Perennial Water
-  Rock Outcrop
-  Saline Spot
-  Sandy Spot
-  Severely Eroded Spot
-  Sinkhole
-  Slide or Slip
-  Sodic Spot
-  Spoil Area
-  Stony Spot



Very Stony Spot



Wet Spot



Other

Special Line Features



Gully



Short Steep Slope



Other

Political Features



Cities

Transportation



Rails



Interstate Highways



US Routes



Major Roads

MAP INFORMATION

Map Scale: 1:59,400 if printed on A size (8.5" × 11") sheet.

The soil surveys that comprise your AOI were mapped at 1:20,000.

Please rely on the bar scale on each map sheet for accurate map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL: <http://websoilsurvey.nrcs.usda.gov>
Coordinate System: UTM Zone 17N NAD83

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Palm Beach County Area, Florida
Survey Area Data: Version 7, Jan 13, 2010

Soil Survey Area: Water Conservation Area, Florida
Survey Area Data: Not available

Your area of interest (AOI) includes more than one soil survey area. These survey areas may have been mapped at different scales, with a different land use in mind, at different times, or at different levels of detail. This may result in map unit symbols, soil properties, and interpretations that do not completely agree across soil survey area boundaries.

Date(s) aerial images were photographed: 8/7/2007

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

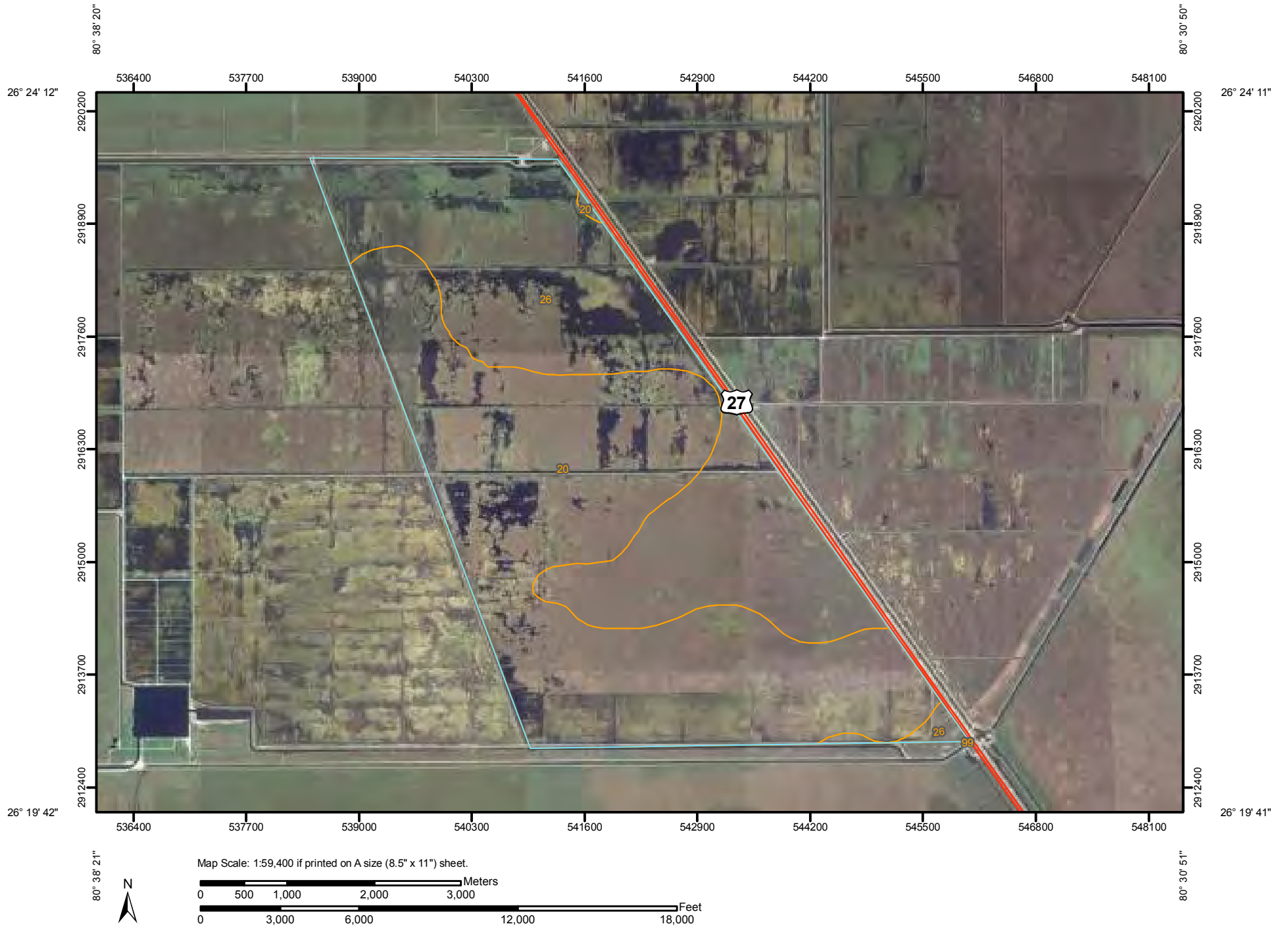


Map Unit Legend

Palm Beach County Area, Florida (FL611)			
Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
20	Lauderhill muck	606.2	7.0%
26	Pahokee muck	3,421.0	39.3%
31	Pits, 0 to 5 percent slopes	7.7	0.1%
43	Terra Ceia muck	4,660.9	53.5%
99	Water	9.5	0.1%
Subtotals for Soil Survey Area		8,705.3	100.0%
Totals for Area of Interest		8,705.1	100.0%

Water Conservation Area, Florida (FL615)			
Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
No soil data available for this soil survey area.			
Subtotals for Soil Survey Area		—	—
Totals for Area of Interest		8,705.1	100.0%

Soil Map—Palm Beach County Area, Florida, and Water Conservation Area, Florida
(STA-3/4 Cell 1AB)



Soil Map—Palm Beach County Area, Florida, and Water Conservation Area, Florida
(STA-3/4 Cell 1AB)

MAP LEGEND

Area of Interest (AOI)

 Area of Interest (AOI)

Soils

 Soil Map Units

Special Point Features

-  Blowout
-  Borrow Pit
-  Clay Spot
-  Closed Depression
-  Gravel Pit
-  Gravelly Spot
-  Landfill
-  Lava Flow
-  Marsh or swamp
-  Mine or Quarry
-  Miscellaneous Water
-  Perennial Water
-  Rock Outcrop
-  Saline Spot
-  Sandy Spot
-  Severely Eroded Spot
-  Sinkhole
-  Slide or Slip
-  Sodic Spot
-  Spoil Area
-  Stony Spot



Very Stony Spot



Wet Spot



Other

Special Line Features



Gully



Short Steep Slope



Other

Political Features



Cities

Transportation



Rails



Interstate Highways



US Routes



Major Roads

MAP INFORMATION

Map Scale: 1:59,400 if printed on A size (8.5" × 11") sheet.

The soil surveys that comprise your AOI were mapped at 1:20,000.

Please rely on the bar scale on each map sheet for accurate map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL: <http://websoilsurvey.nrcs.usda.gov>
Coordinate System: UTM Zone 17N NAD83

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Palm Beach County Area, Florida
Survey Area Data: Version 7, Jan 13, 2010

Soil Survey Area: Water Conservation Area, Florida
Survey Area Data: Not available

Your area of interest (AOI) includes more than one soil survey area. These survey areas may have been mapped at different scales, with a different land use in mind, at different times, or at different levels of detail. This may result in map unit symbols, soil properties, and interpretations that do not completely agree across soil survey area boundaries.

Date(s) aerial images were photographed: 8/5/2007; 8/7/2007

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

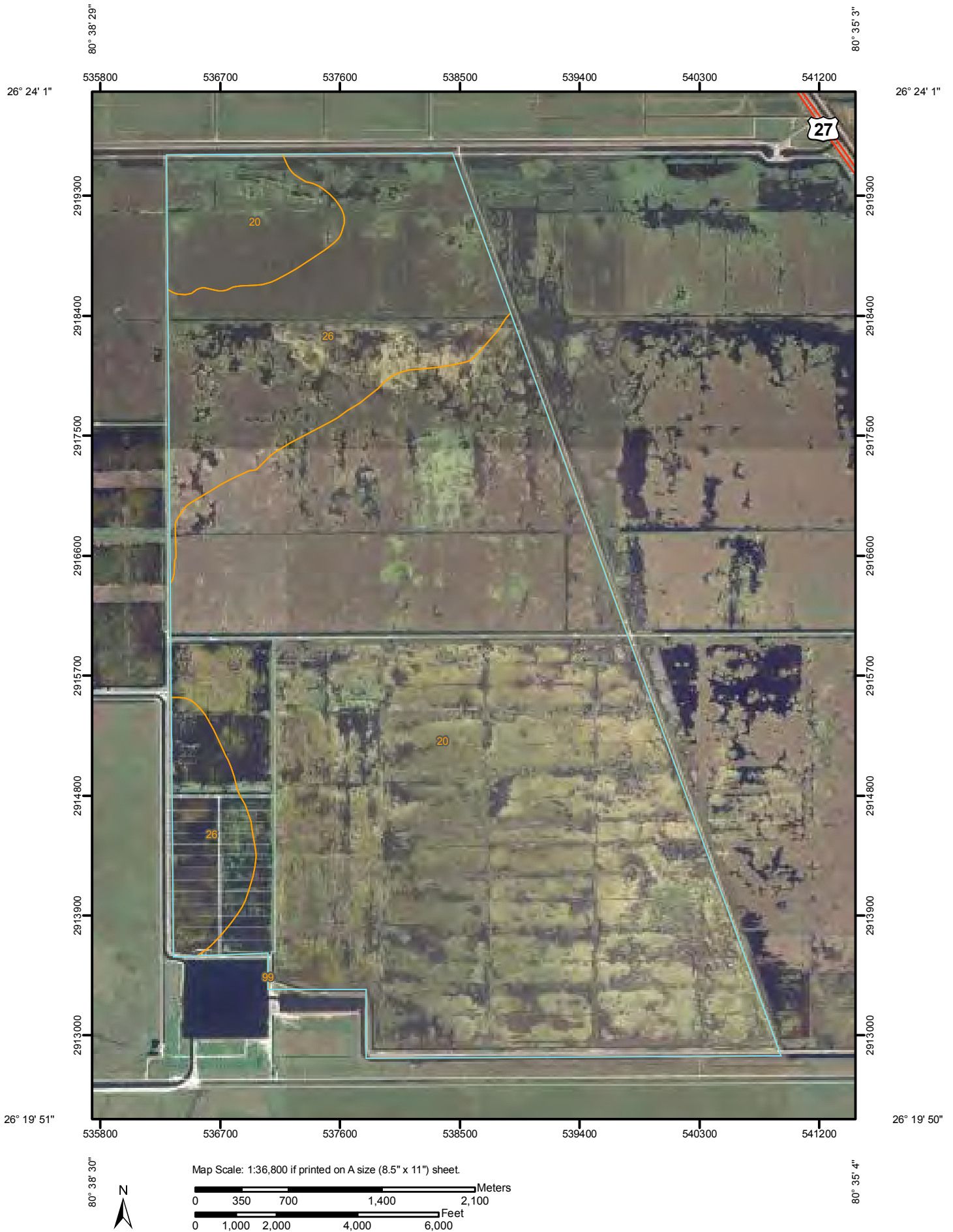


Map Unit Legend

Palm Beach County Area, Florida (FL611)			
Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
20	Lauderhill muck	3,721.2	56.1%
26	Pahokee muck	2,915.4	43.9%
99	Water	0.1	0.0%
Subtotals for Soil Survey Area		6,636.7	100.0%
Totals for Area of Interest		6,637.1	100.0%

Water Conservation Area, Florida (FL615)			
Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
No soil data available for this soil survey area.			
Subtotals for Soil Survey Area		—	—
Totals for Area of Interest		6,637.1	100.0%

Soil Map—Palm Beach County Area, Florida, and Water Conservation Area, Florida
(STA-3/4 Cell 2AB)



Soil Map—Palm Beach County Area, Florida, and Water Conservation Area, Florida
(STA-3/4 Cell 2AB)

MAP LEGEND

Area of Interest (AOI)

 Area of Interest (AOI)

Soils

 Soil Map Units

Special Point Features

-  Blowout
-  Borrow Pit
-  Clay Spot
-  Closed Depression
-  Gravel Pit
-  Gravelly Spot
-  Landfill
-  Lava Flow
-  Marsh or swamp
-  Mine or Quarry
-  Miscellaneous Water
-  Perennial Water
-  Rock Outcrop
-  Saline Spot
-  Sandy Spot
-  Severely Eroded Spot
-  Sinkhole
-  Slide or Slip
-  Sodic Spot
-  Spoil Area
-  Stony Spot



Very Stony Spot



Wet Spot



Other

Special Line Features



Gully



Short Steep Slope



Other

Political Features



Cities

Transportation



Rails



Interstate Highways



US Routes



Major Roads

MAP INFORMATION

Map Scale: 1:36,800 if printed on A size (8.5" × 11") sheet.

The soil surveys that comprise your AOI were mapped at 1:20,000.

Please rely on the bar scale on each map sheet for accurate map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL: <http://websoilsurvey.nrcs.usda.gov>
Coordinate System: UTM Zone 17N NAD83

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Palm Beach County Area, Florida
Survey Area Data: Version 7, Jan 13, 2010

Soil Survey Area: Water Conservation Area, Florida
Survey Area Data: Not available

Your area of interest (AOI) includes more than one soil survey area. These survey areas may have been mapped at different scales, with a different land use in mind, at different times, or at different levels of detail. This may result in map unit symbols, soil properties, and interpretations that do not completely agree across soil survey area boundaries.

Date(s) aerial images were photographed: 8/5/2007; 8/7/2007

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.



Map Unit Legend

Palm Beach County Area, Florida (FL611)			
Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
20	Lauderhill muck	4,245.4	78.7%
26	Pahokee muck	1,146.3	21.3%
99	Water	0.2	0.0%
Subtotals for Soil Survey Area		5,391.9	100.0%
Totals for Area of Interest		5,392.1	100.0%

Water Conservation Area, Florida (FL615)			
Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
No soil data available for this soil survey area.			
Subtotals for Soil Survey Area		—	—
Totals for Area of Interest		5,392.1	100.0%

Soil Map—Palm Beach County Area, Florida
(STA-3/4 Cell 3AB)



MAP LEGEND

Area of Interest (AOI)

 Area of Interest (AOI)

Soils

 Soil Map Units

Special Point Features

-  Blowout
-  Borrow Pit
-  Clay Spot
-  Closed Depression
-  Gravel Pit
-  Gravelly Spot
-  Landfill
-  Lava Flow
-  Marsh or swamp
-  Mine or Quarry
-  Miscellaneous Water
-  Perennial Water
-  Rock Outcrop
-  Saline Spot
-  Sandy Spot
-  Severely Eroded Spot
-  Sinkhole
-  Slide or Slip
-  Sodic Spot
-  Spoil Area
-  Stony Spot



Very Stony Spot



Wet Spot



Other

Special Line Features



Gully



Short Steep Slope



Other

Political Features



Cities

Transportation



Rails



Interstate Highways



US Routes



Major Roads

MAP INFORMATION

Map Scale: 1:35,200 if printed on A size (8.5" × 11") sheet.

The soil surveys that comprise your AOI were mapped at 1:20,000.

Please rely on the bar scale on each map sheet for accurate map measurements.

Source of Map: Natural Resources Conservation Service

Web Soil Survey URL: <http://websoilsurvey.nrcs.usda.gov>

Coordinate System: UTM Zone 17N NAD83

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Palm Beach County Area, Florida

Survey Area Data: Version 7, Jan 13, 2010

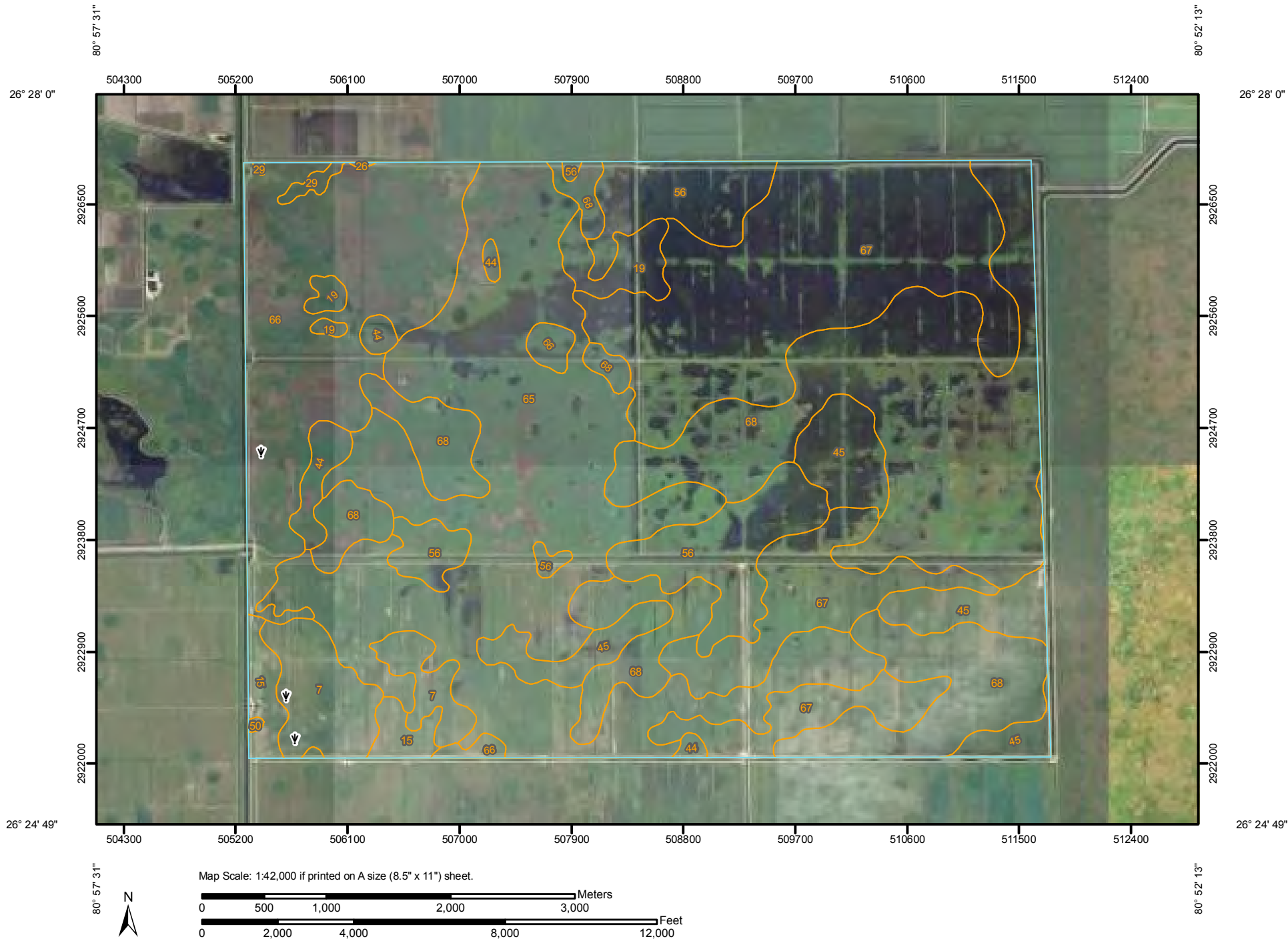
Date(s) aerial images were photographed: 8/5/2007; 8/7/2007

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Map Unit Legend

Palm Beach County Area, Florida (FL611)			
Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
20	Lauderhill muck	1,102.0	24.2%
26	Pahokee muck	3,458.6	75.8%
Totals for Area of Interest		4,560.7	100.0%

Soil Map—Hendry County, Florida (STA-5)



Soil Map—Hendry County, Florida
(STA-5)

MAP LEGEND

Area of Interest (AOI)

 Area of Interest (AOI)

Soils

 Soil Map Units

Special Point Features

-  Blowout
-  Borrow Pit
-  Clay Spot
-  Closed Depression
-  Gravel Pit
-  Gravelly Spot
-  Landfill
-  Lava Flow
-  Marsh or swamp
-  Mine or Quarry
-  Miscellaneous Water
-  Perennial Water
-  Rock Outcrop
-  Saline Spot
-  Sandy Spot
-  Severely Eroded Spot
-  Sinkhole
-  Slide or Slip
-  Sodic Spot
-  Spoil Area
-  Stony Spot



Very Stony Spot



Wet Spot



Other

Special Line Features



Gully



Short Steep Slope



Other

Political Features



Cities

Transportation



Rails



Interstate Highways



US Routes



Major Roads

MAP INFORMATION

Map Scale: 1:42,000 if printed on A size (8.5" × 11") sheet.

The soil surveys that comprise your AOI were mapped at 1:24,000.

Please rely on the bar scale on each map sheet for accurate map measurements.

Source of Map: Natural Resources Conservation Service

Web Soil Survey URL: <http://websoilsurvey.nrcs.usda.gov>

Coordinate System: UTM Zone 17N NAD83

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Hendry County, Florida

Survey Area Data: Version 10, Jan 13, 2010

Date(s) aerial images were photographed: 6/23/2007; 6/20/2007

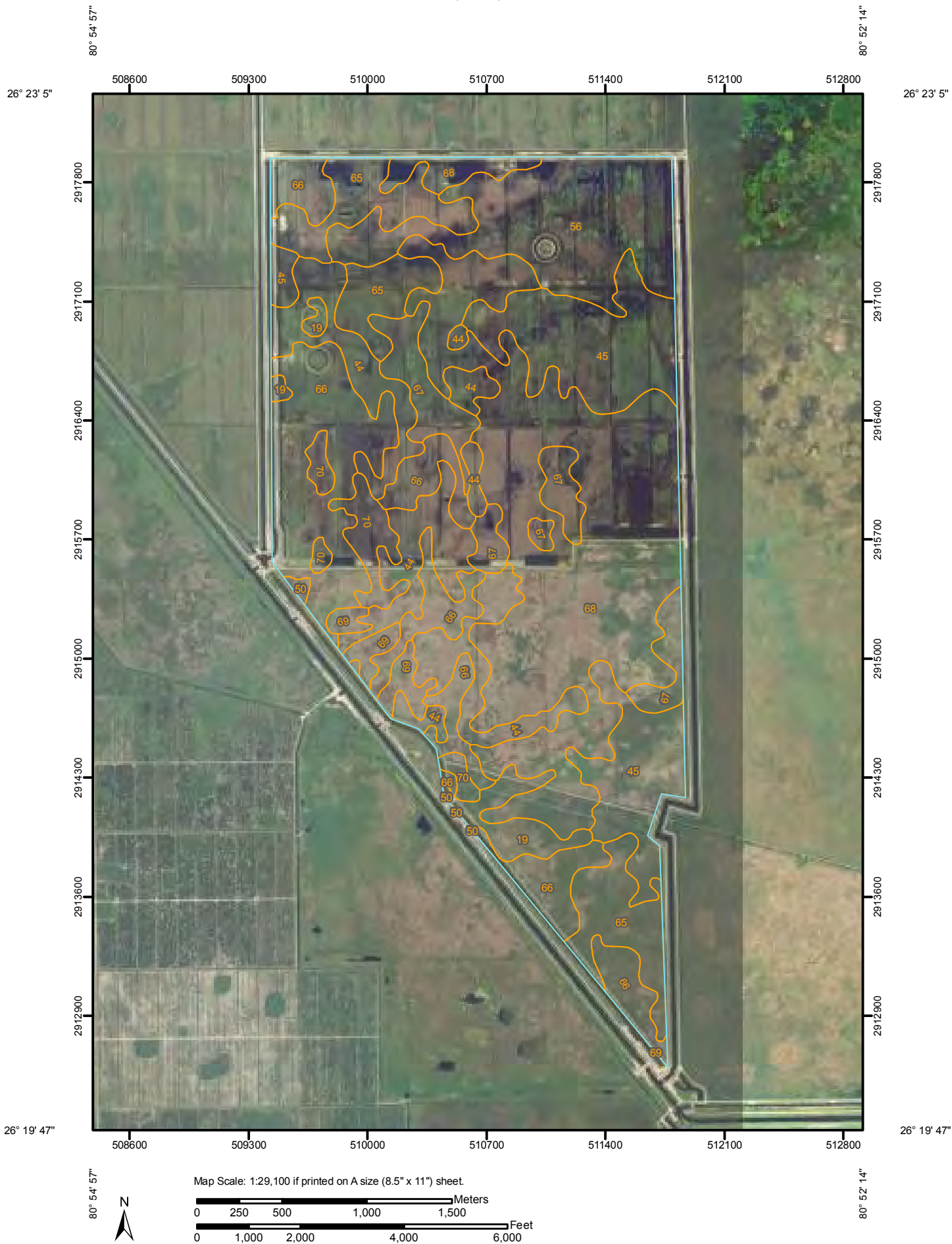
The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.



Map Unit Legend

Hendry County, Florida (FL051)			
Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
7	Immokalee sand	261.1	3.4%
15	Myakka sand	111.5	1.5%
19	Gator muck	115.5	1.5%
26	Holopaw sand, limestone substratum	1.6	0.0%
29	Oldsmar sand, limestone substratum	16.8	0.2%
44	Jupiter fine sand	92.4	1.2%
45	Pahokee muck	387.7	5.1%
50	Delray sand, depressional	2.9	0.0%
56	Terra Ceia muck	538.6	7.1%
65	Plantation muck	1,825.2	24.1%
66	Margate sand	909.7	12.0%
67	Lauderhill muck	1,501.3	19.8%
68	Dania muck	1,818.9	24.0%
Totals for Area of Interest		7,583.1	100.0%

Soil Map—Hendry County, Florida (STA-6)



Soil Map—Hendry County, Florida
(STA-6)

MAP LEGEND

Area of Interest (AOI)

 Area of Interest (AOI)

Soils

 Soil Map Units

Special Point Features

-  Blowout
-  Borrow Pit
-  Clay Spot
-  Closed Depression
-  Gravel Pit
-  Gravelly Spot
-  Landfill
-  Lava Flow
-  Marsh or swamp
-  Mine or Quarry
-  Miscellaneous Water
-  Perennial Water
-  Rock Outcrop
-  Saline Spot
-  Sandy Spot
-  Severely Eroded Spot
-  Sinkhole
-  Slide or Slip
-  Sodic Spot
-  Spoil Area
-  Stony Spot



Very Stony Spot



Wet Spot



Other

Special Line Features



Gully



Short Steep Slope



Other

Political Features



Cities

Transportation



Rails



Interstate Highways



US Routes



Major Roads

MAP INFORMATION

Map Scale: 1:29,100 if printed on A size (8.5" × 11") sheet.

The soil surveys that comprise your AOI were mapped at 1:24,000.

Please rely on the bar scale on each map sheet for accurate map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL: <http://websoilsurvey.nrcs.usda.gov>
Coordinate System: UTM Zone 17N NAD83

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Hendry County, Florida
Survey Area Data: Version 10, Jan 13, 2010

Date(s) aerial images were photographed: 6/23/2007; 6/20/2007

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.



Map Unit Legend

Hendry County, Florida (FL051)			
Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
19	Gator muck	51.9	2.3%
44	Jupiter fine sand	258.1	11.3%
45	Pahokee muck	276.8	12.1%
50	Delray sand, depressional	4.0	0.2%
56	Terra Ceia muck	244.3	10.7%
65	Plantation muck	203.9	8.9%
66	Margate sand	379.7	16.6%
67	Lauderhill muck	122.6	5.4%
68	Dania muck	647.7	28.3%
69	Denaud-Gator mucks	37.4	1.6%
70	Denaud muck	58.5	2.6%
Totals for Area of Interest		2,284.9	100.0%

Soil Map—Hendry County, Florida
(STA-6 Cell 3)



MAP LEGEND

Area of Interest (AOI)

 Area of Interest (AOI)

Soils

 Soil Map Units

Special Point Features

-  Blowout
-  Borrow Pit
-  Clay Spot
-  Closed Depression
-  Gravel Pit
-  Gravelly Spot
-  Landfill
-  Lava Flow
-  Marsh or swamp
-  Mine or Quarry
-  Miscellaneous Water
-  Perennial Water
-  Rock Outcrop
-  Saline Spot
-  Sandy Spot
-  Severely Eroded Spot
-  Sinkhole
-  Slide or Slip
-  Sodic Spot
-  Spoil Area
-  Stony Spot



Very Stony Spot



Wet Spot



Other

Special Line Features



Gully



Short Steep Slope



Other

Political Features



Cities

Transportation



Rails



Interstate Highways



US Routes



Major Roads



Local Roads

MAP INFORMATION

Map Scale: 1:9,660 if printed on A size (8.5" × 11") sheet.

The soil surveys that comprise your AOI were mapped at 1:24,000.

Warning: Soil Map may not be valid at this scale.

Enlargement of maps beyond the scale of mapping can cause misunderstanding of the detail of mapping and accuracy of soil line placement. The maps do not show the small areas of contrasting soils that could have been shown at a more detailed scale.

Please rely on the bar scale on each map sheet for accurate map measurements.

Source of Map: Natural Resources Conservation Service

Web Soil Survey URL: <http://websoilsurvey.nrcs.usda.gov>

Coordinate System: UTM Zone 17N NAD83

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Hendry County, Florida

Survey Area Data: Version 10, Jan 13, 2010

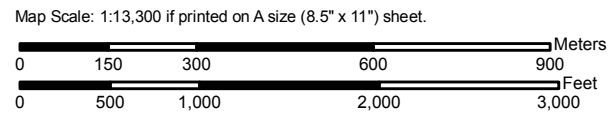
Date(s) aerial images were photographed: 6/20/2007

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Map Unit Legend

Hendry County, Florida (FL051)			
Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
19	Gator muck	35.5	14.5%
45	Pahokee muck	28.7	11.7%
65	Plantation muck	76.3	31.2%
66	Margate sand	70.2	28.7%
68	Dania muck	28.1	11.5%
69	Denaud-Gator mucks	0.1	0.0%
70	Denaud muck	5.8	2.4%
Totals for Area of Interest		244.8	100.0%

Soil Map—Hendry County, Florida
(STA-6 Cell 5)



MAP LEGEND

Area of Interest (AOI)

 Area of Interest (AOI)

Soils

 Soil Map Units

Special Point Features

-  Blowout
-  Borrow Pit
-  Clay Spot
-  Closed Depression
-  Gravel Pit
-  Gravelly Spot
-  Landfill
-  Lava Flow
-  Marsh or swamp
-  Mine or Quarry
-  Miscellaneous Water
-  Perennial Water
-  Rock Outcrop
-  Saline Spot
-  Sandy Spot
-  Severely Eroded Spot
-  Sinkhole
-  Slide or Slip
-  Sodic Spot
-  Spoil Area
-  Stony Spot



Very Stony Spot



Wet Spot



Other

Special Line Features



Gully



Short Steep Slope



Other

Political Features



Cities

Transportation



Rails



Interstate Highways



US Routes



Major Roads



Local Roads

MAP INFORMATION

Map Scale: 1:13,300 if printed on A size (8.5" × 11") sheet.

The soil surveys that comprise your AOI were mapped at 1:24,000.

Please rely on the bar scale on each map sheet for accurate map measurements.

Source of Map: Natural Resources Conservation Service

Web Soil Survey URL: <http://websoilsurvey.nrcs.usda.gov>

Coordinate System: UTM Zone 17N NAD83

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Hendry County, Florida

Survey Area Data: Version 10, Jan 13, 2010

Date(s) aerial images were photographed: 6/20/2007

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Map Unit Legend

Hendry County, Florida (FL051)			
Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
19	Gator muck	3.4	0.5%
44	Jupiter fine sand	108.3	17.2%
45	Pahokee muck	81.0	12.9%
50	Delray sand, depressional	3.5	0.6%
66	Margate sand	80.6	12.8%
67	Lauderhill muck	30.4	4.8%
68	Dania muck	274.7	43.6%
69	Denaud-Gator mucks	36.3	5.8%
70	Denaud muck	11.2	1.8%
Totals for Area of Interest		629.3	100.0%

Soil Map—Hendry County, Florida
(STA-6 Section 2)



Soil Map—Hendry County, Florida
(STA-6 Section 2)

MAP LEGEND

Area of Interest (AOI)

 Area of Interest (AOI)

Soils

 Soil Map Units

Special Point Features

-  Blowout
-  Borrow Pit
-  Clay Spot
-  Closed Depression
-  Gravel Pit
-  Gravelly Spot
-  Landfill
-  Lava Flow
-  Marsh or swamp
-  Mine or Quarry
-  Miscellaneous Water
-  Perennial Water
-  Rock Outcrop
-  Saline Spot
-  Sandy Spot
-  Severely Eroded Spot
-  Sinkhole
-  Slide or Slip
-  Sodic Spot
-  Spoil Area
-  Stony Spot



Very Stony Spot



Wet Spot



Other

Special Line Features



Gully



Short Steep Slope



Other

Political Features



Cities

Transportation



Rails



Interstate Highways



US Routes



Major Roads



Local Roads

MAP INFORMATION

Map Scale: 1:20,900 if printed on A size (8.5" × 11") sheet.

The soil surveys that comprise your AOI were mapped at 1:24,000.

Please rely on the bar scale on each map sheet for accurate map measurements.

Source of Map: Natural Resources Conservation Service

Web Soil Survey URL: <http://websoilsurvey.nrcs.usda.gov>

Coordinate System: UTM Zone 17N NAD83

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Hendry County, Florida

Survey Area Data: Version 10, Jan 13, 2010

Date(s) aerial images were photographed: 6/20/2007

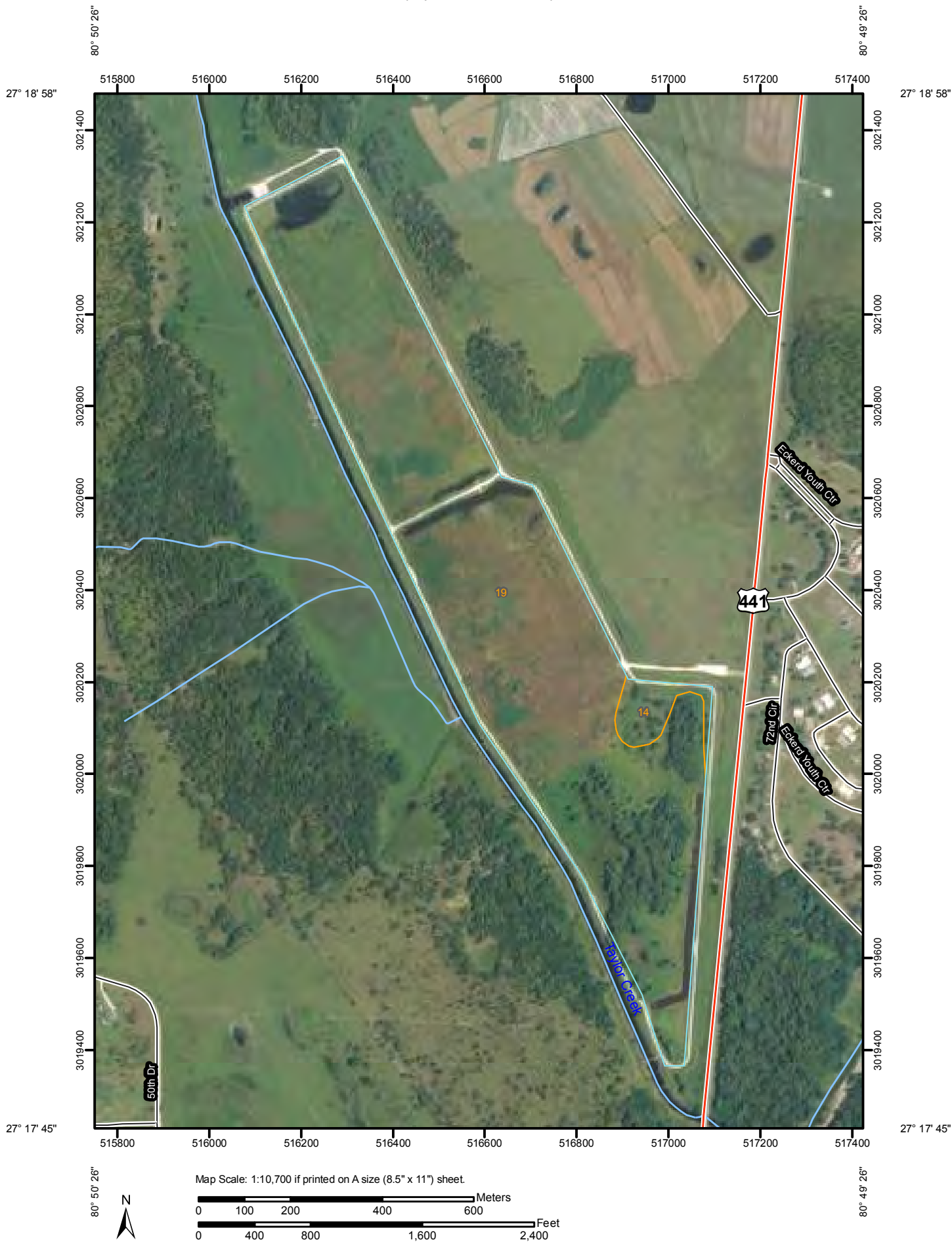
The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.



Map Unit Legend

Hendry County, Florida (FL051)			
Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
19	Gator muck	7.5	0.6%
44	Jupiter fine sand	142.3	10.5%
45	Pahokee muck	166.4	12.3%
56	Terra Ceia muck	240.3	17.8%
65	Plantation muck	126.1	9.3%
66	Margate sand	200.8	14.9%
67	Lauderhill muck	92.9	6.9%
68	Dania muck	335.4	24.8%
70	Denaud muck	38.9	2.9%
Totals for Area of Interest		1,350.6	100.0%

Soil Map—Okeechobee County, Florida
(Taylor Creek Pilot STA)



Soil Map—Okeechobee County, Florida
(Taylor Creek Pilot STA)

MAP LEGEND

Area of Interest (AOI)

 Area of Interest (AOI)

Soils

 Soil Map Units

Special Point Features

-  Blowout
-  Borrow Pit
-  Clay Spot
-  Closed Depression
-  Gravel Pit
-  Gravelly Spot
-  Landfill
-  Lava Flow
-  Marsh or swamp
-  Mine or Quarry
-  Miscellaneous Water
-  Perennial Water
-  Rock Outcrop
-  Saline Spot
-  Sandy Spot
-  Severely Eroded Spot
-  Sinkhole
-  Slide or Slip
-  Sodic Spot
-  Spoil Area
-  Stony Spot



Very Stony Spot



Wet Spot



Other

Special Line Features



Gully



Short Steep Slope



Other

Political Features



Cities

Water Features



Streams and Canals

Transportation



Rails



Interstate Highways



US Routes



Major Roads



Local Roads

MAP INFORMATION

Map Scale: 1:10,700 if printed on A size (8.5" × 11") sheet.

The soil surveys that comprise your AOI were mapped at 1:24,000.

Warning: Soil Map may not be valid at this scale.

Enlargement of maps beyond the scale of mapping can cause misunderstanding of the detail of mapping and accuracy of soil line placement. The maps do not show the small areas of contrasting soils that could have been shown at a more detailed scale.

Please rely on the bar scale on each map sheet for accurate map measurements.

Source of Map: Natural Resources Conservation Service

Web Soil Survey URL: <http://websoilsurvey.nrcs.usda.gov>

Coordinate System: UTM Zone 17N NAD83

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Okeechobee County, Florida

Survey Area Data: Version 7, Jan 13, 2010

Date(s) aerial images were photographed: 6/20/2007

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.



Map Unit Legend

Okeechobee County, Florida (FL093)			
Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
14	Myakka fine sand	4.6	3.3%
19	Floridana, Placid, and Okeelanta soils, frequently flooded	137.1	96.7%
Totals for Area of Interest		141.7	100.0%

Soil Map—Brevard County, Florida (Titusville)



Soil Map—Brevard County, Florida
(Titusville)

MAP LEGEND

Area of Interest (AOI)

 Area of Interest (AOI)

Soils

 Soil Map Units

Special Point Features

-  Blowout
-  Borrow Pit
-  Clay Spot
-  Closed Depression
-  Gravel Pit
-  Gravelly Spot
-  Landfill
-  Lava Flow
-  Marsh or swamp
-  Mine or Quarry
-  Miscellaneous Water
-  Perennial Water
-  Rock Outcrop
-  Saline Spot
-  Sandy Spot
-  Severely Eroded Spot
-  Sinkhole
-  Slide or Slip
-  Sodic Spot
-  Spoil Area
-  Stony Spot



Very Stony Spot



Wet Spot



Other

Special Line Features



Gully



Short Steep Slope



Other

Political Features



Cities

Transportation



Rails



Interstate Highways



US Routes



Major Roads



Local Roads

MAP INFORMATION

Map Scale: 1:9,080 if printed on A size (8.5" × 11") sheet.

The soil surveys that comprise your AOI were mapped at 1:24,000.

Warning: Soil Map may not be valid at this scale.

Enlargement of maps beyond the scale of mapping can cause misunderstanding of the detail of mapping and accuracy of soil line placement. The maps do not show the small areas of contrasting soils that could have been shown at a more detailed scale.

Please rely on the bar scale on each map sheet for accurate map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL: <http://websoilsurvey.nrcs.usda.gov>
Coordinate System: UTM Zone 17N NAD83

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Brevard County, Florida
Survey Area Data: Version 9, Apr 1, 2011

Date(s) aerial images were photographed: 8/10/2007

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

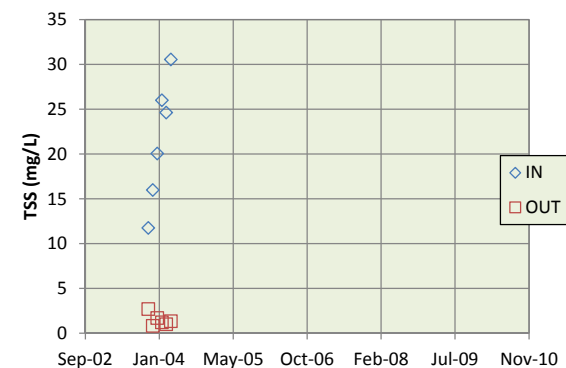
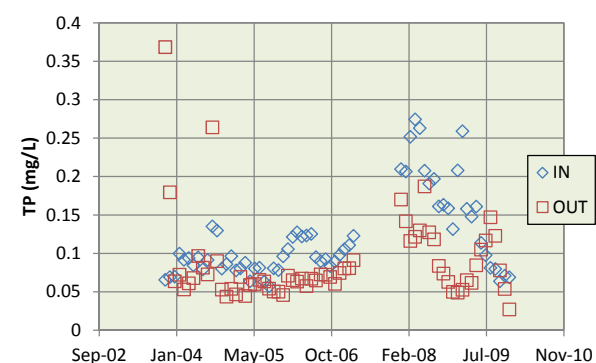
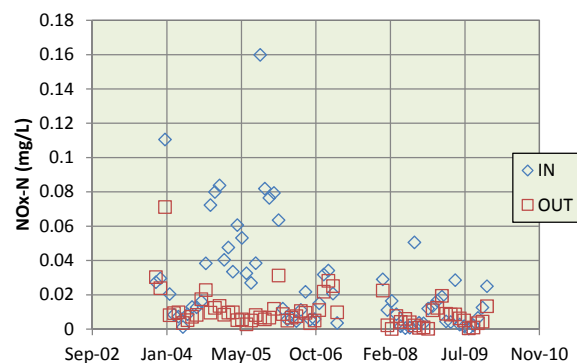
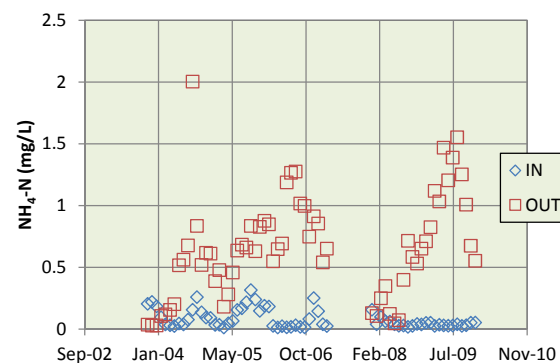
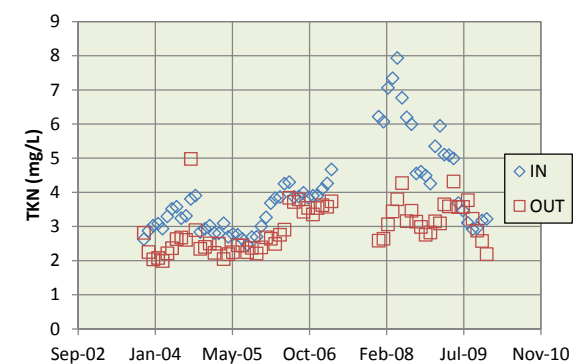
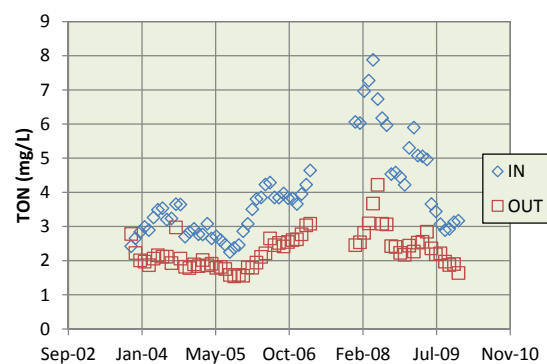
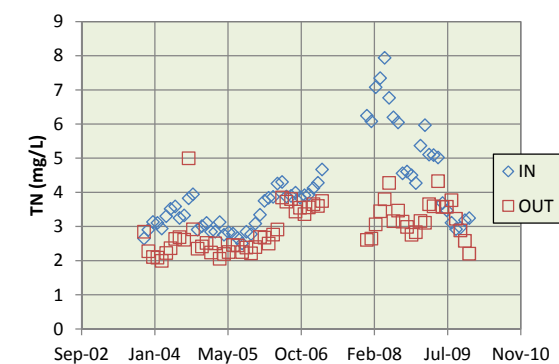


Map Unit Legend

Brevard County, Florida (FL009)			
Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
7	Basinger sand	1.6	0.6%
19	Riviera sand	49.1	17.6%
22	Floridana sand, depressional	1.7	0.6%
23	Floridana sand	147.8	53.1%
26	Holopaw sand	60.7	21.8%
47	Pineda sand	11.1	4.0%
67	Tomoka muck, undrained	6.6	2.4%
Totals for Area of Interest		278.5	100.0%

Appendix B

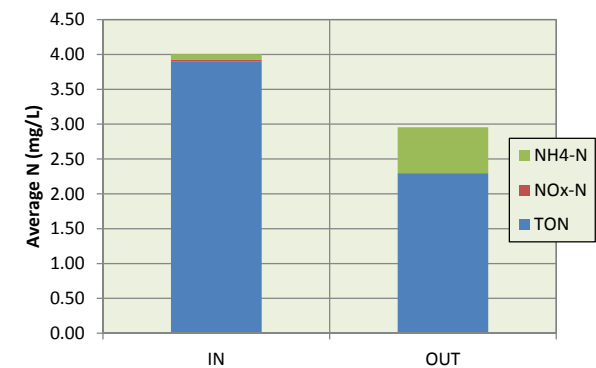
Florida Treatment Wetlands Monthly Water Quality Data



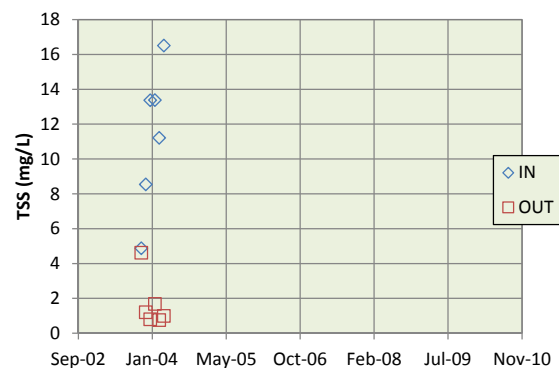
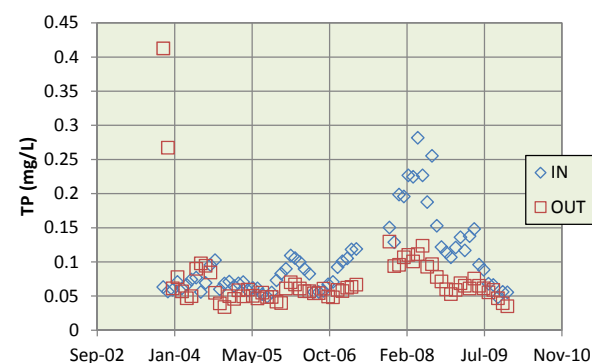
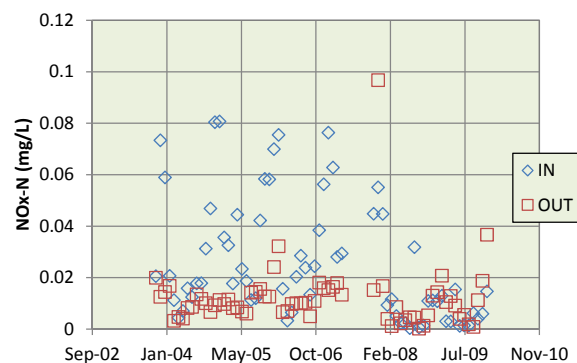
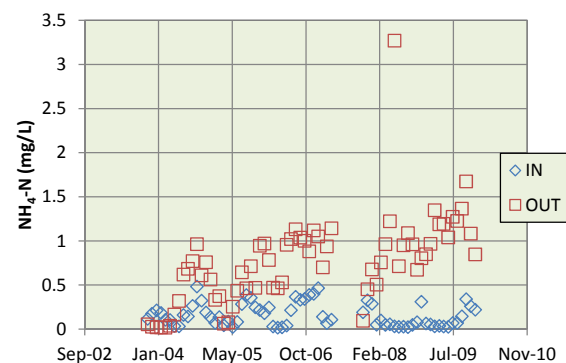
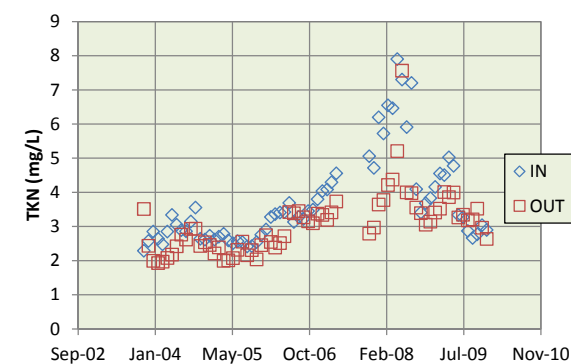
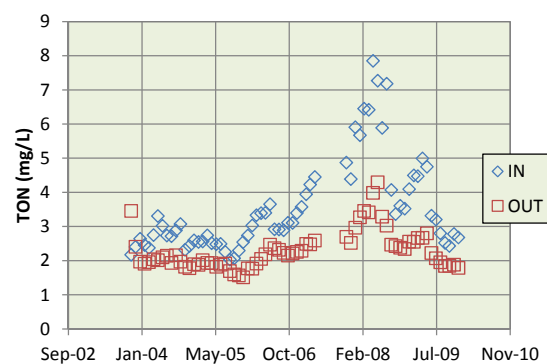
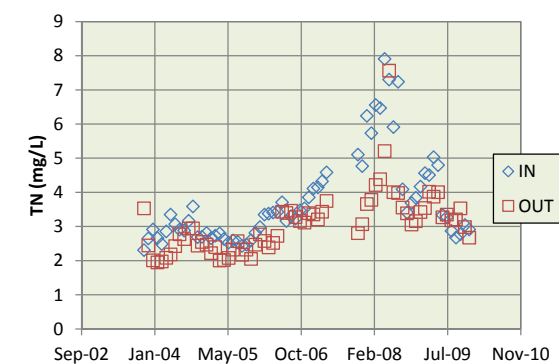
Long Term Average

	IN	OUT	Diff
TN	4.00	2.96	1.05
TON	3.90	2.29	1.61
TKN	3.98	2.94	1.03
NH ₄ -N	0.08	0.66	-0.58
NO _x -N	0.03	0.01	0.02
TP	0.12	0.09	0.03
TSS	21.50	1.47	20.03

Period of Record Nov-03 Dec-09



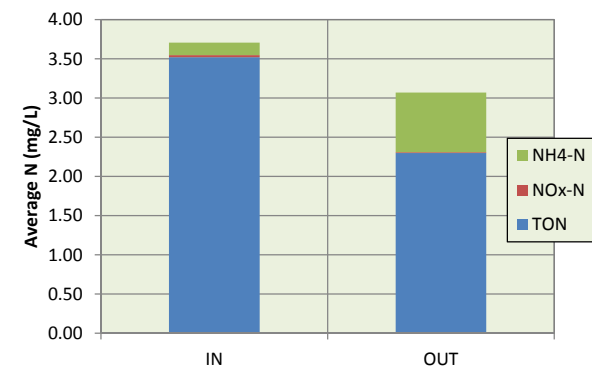
Phase I Apopka Marsh Flow-Way Cell B1 - Monthly Water Quality Data Summary



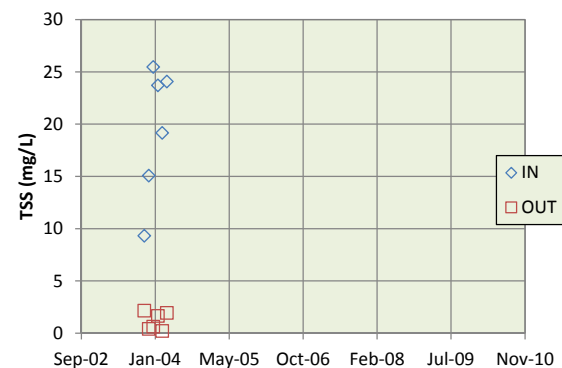
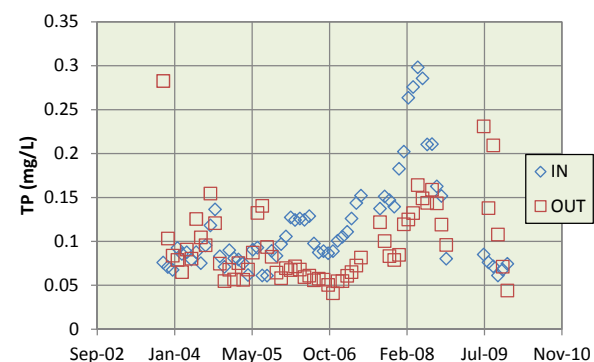
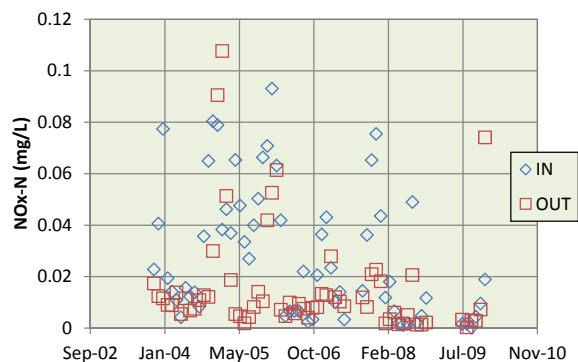
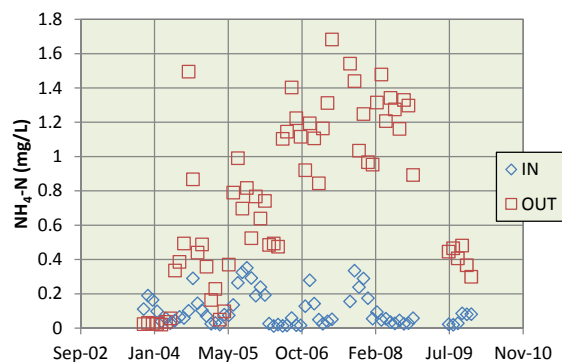
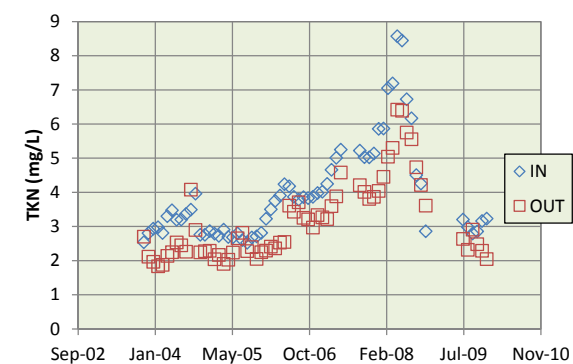
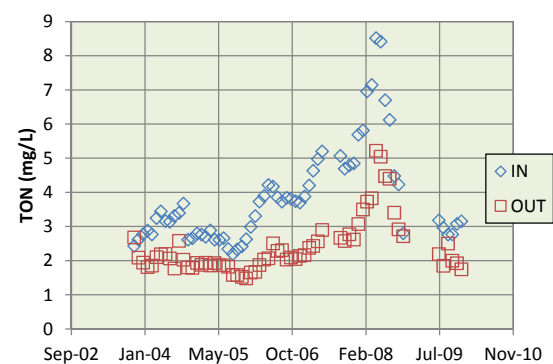
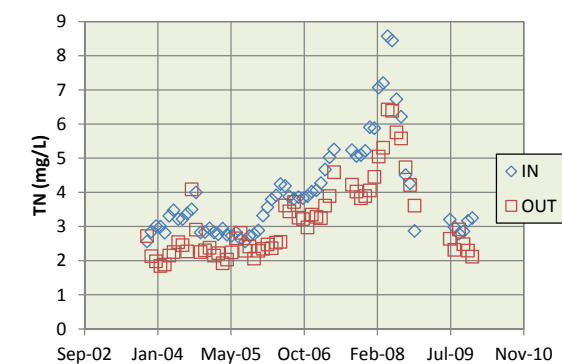
Long Term Average

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TN	3.71	3.07	0.64
TON	3.52	2.30	1.22
TKN	3.68	3.06	0.62
NH ₄ -N	0.16	0.76	-0.60
NO _x -N	0.03	0.01	0.01
TP	0.10	0.07	0.03
TSS	11.32	1.68	9.64

Period of Record Nov-03 Dec-09



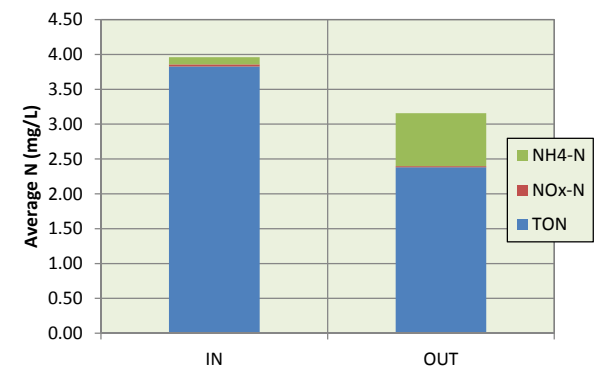
Phase I Apopka Marsh Flow-Way Cell B2 - Monthly Water Quality Data Summary



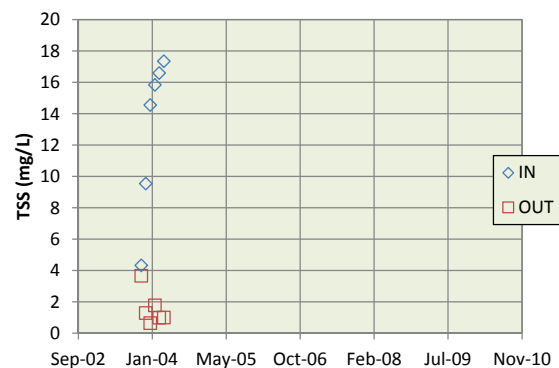
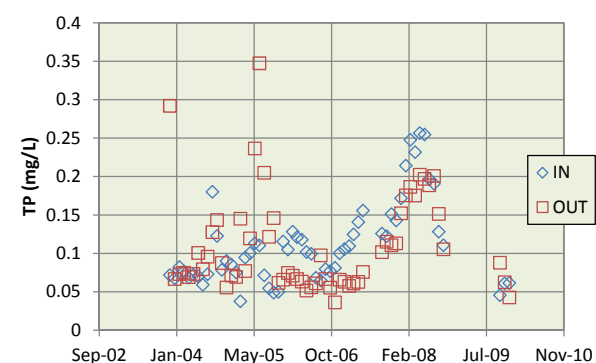
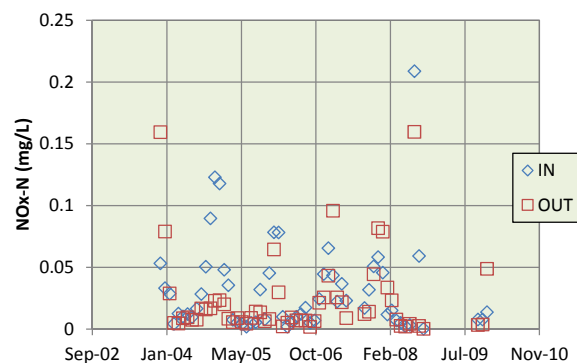
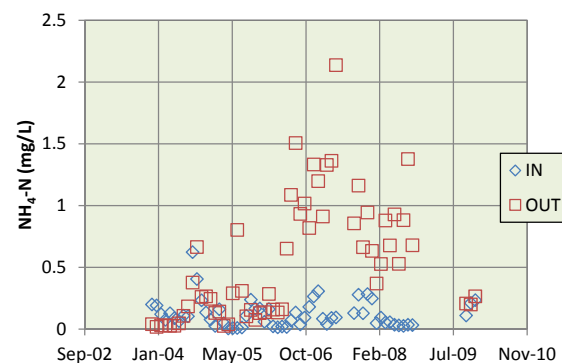
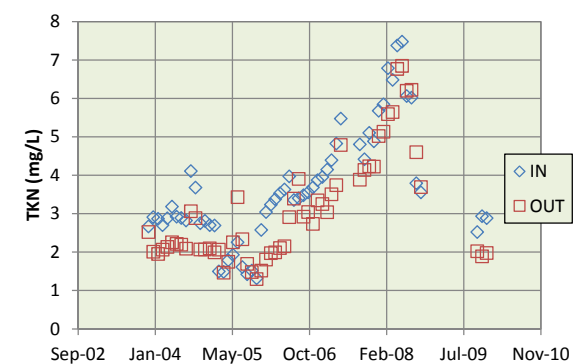
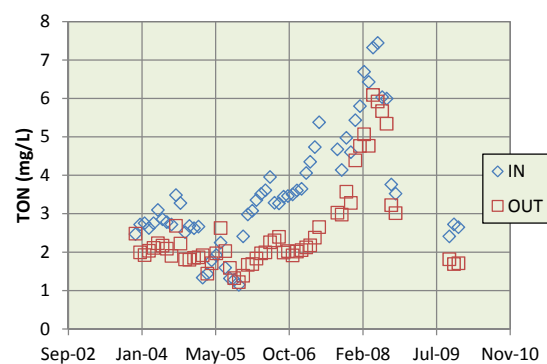
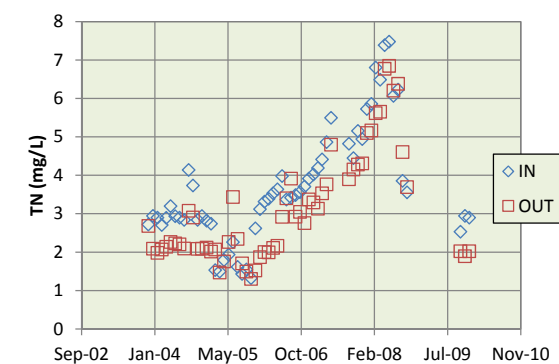
Long Term Average

	IN	OUT	Diff
TN	3.96	3.16	0.80
TON	3.83	2.38	1.45
TKN	3.93	3.14	0.79
NH ₄ -N	0.10	0.76	-0.65
NO _x -N	0.03	0.02	0.01
TP	0.12	0.10	0.02
TSS	19.48	1.17	18.30

Period of Record Nov-03 Dec-09



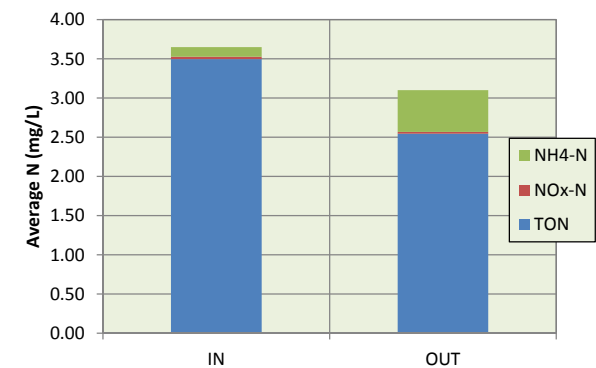
Phase I Apopka Marsh Flow-Way Cell C1 - Monthly Water Quality Data Summary



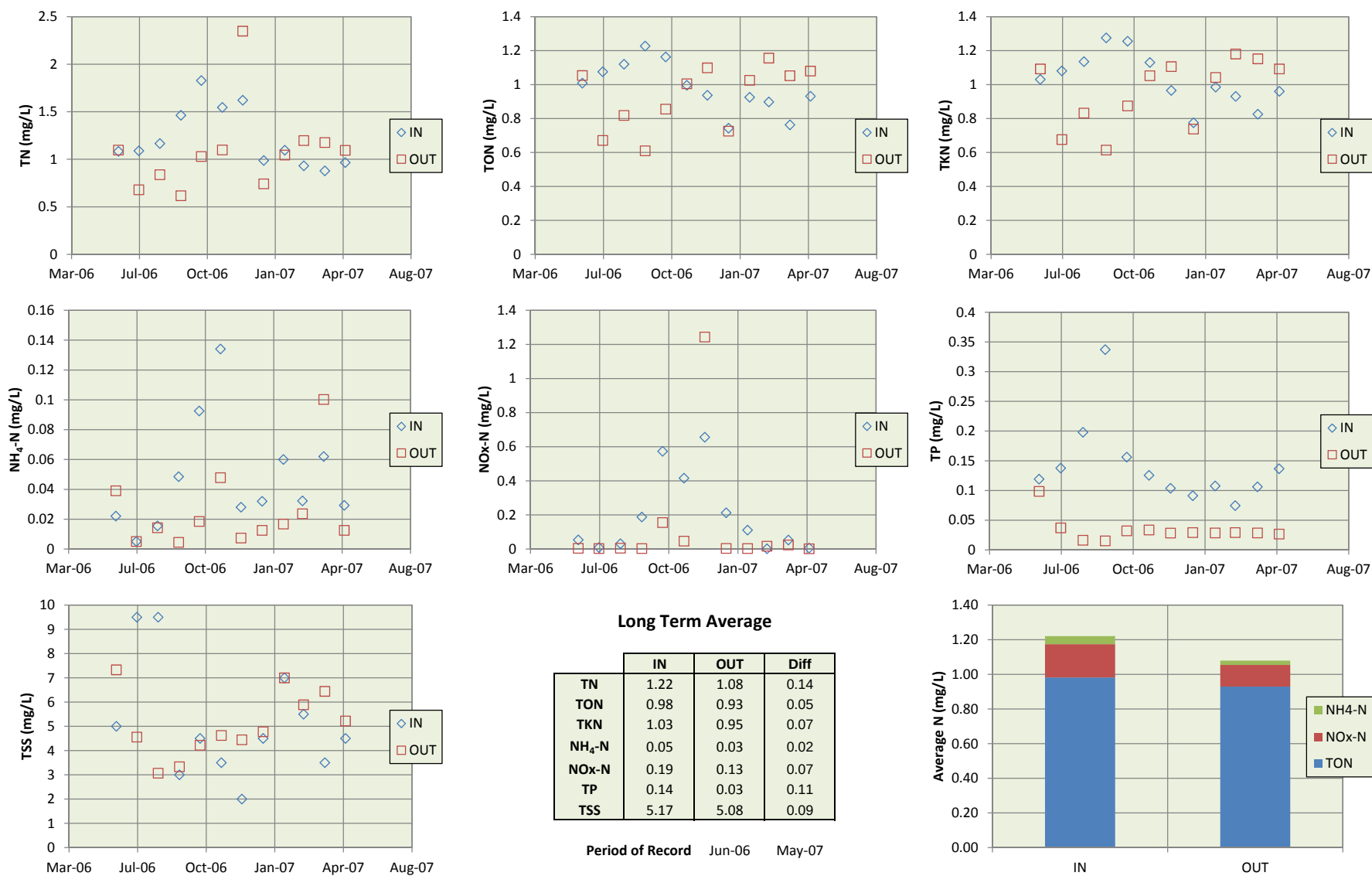
Long Term Average

	IN	OUT	Diff
TN	3.65	3.10	0.55
TON	3.50	2.54	0.95
TKN	3.62	3.08	0.54
NH ₄ -N	0.12	0.53	-0.41
NO _x -N	0.03	0.02	0.01
TP	0.11	0.11	0.00
TSS	13.03	1.56	11.47

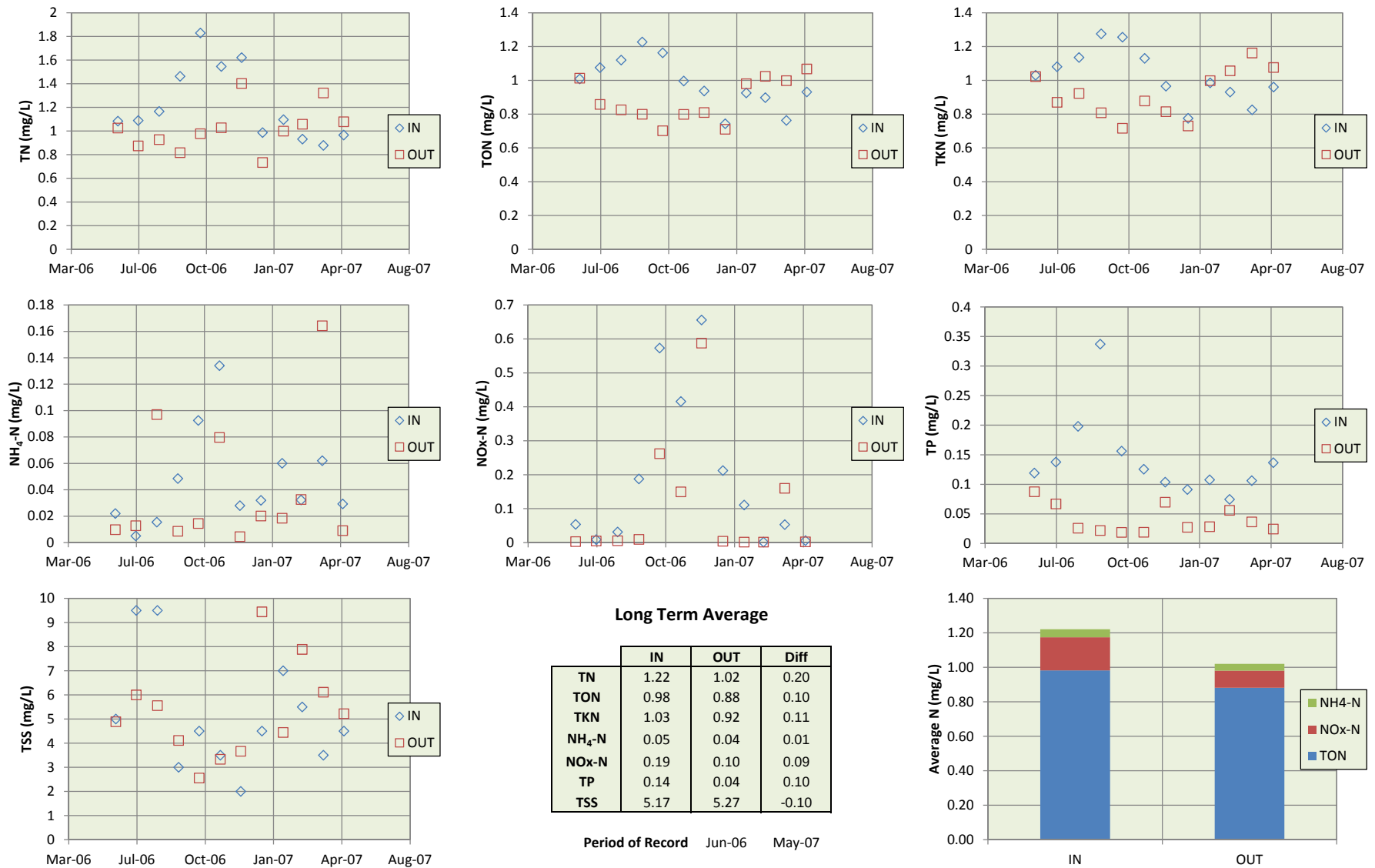
Period of Record Nov-03 Dec-09



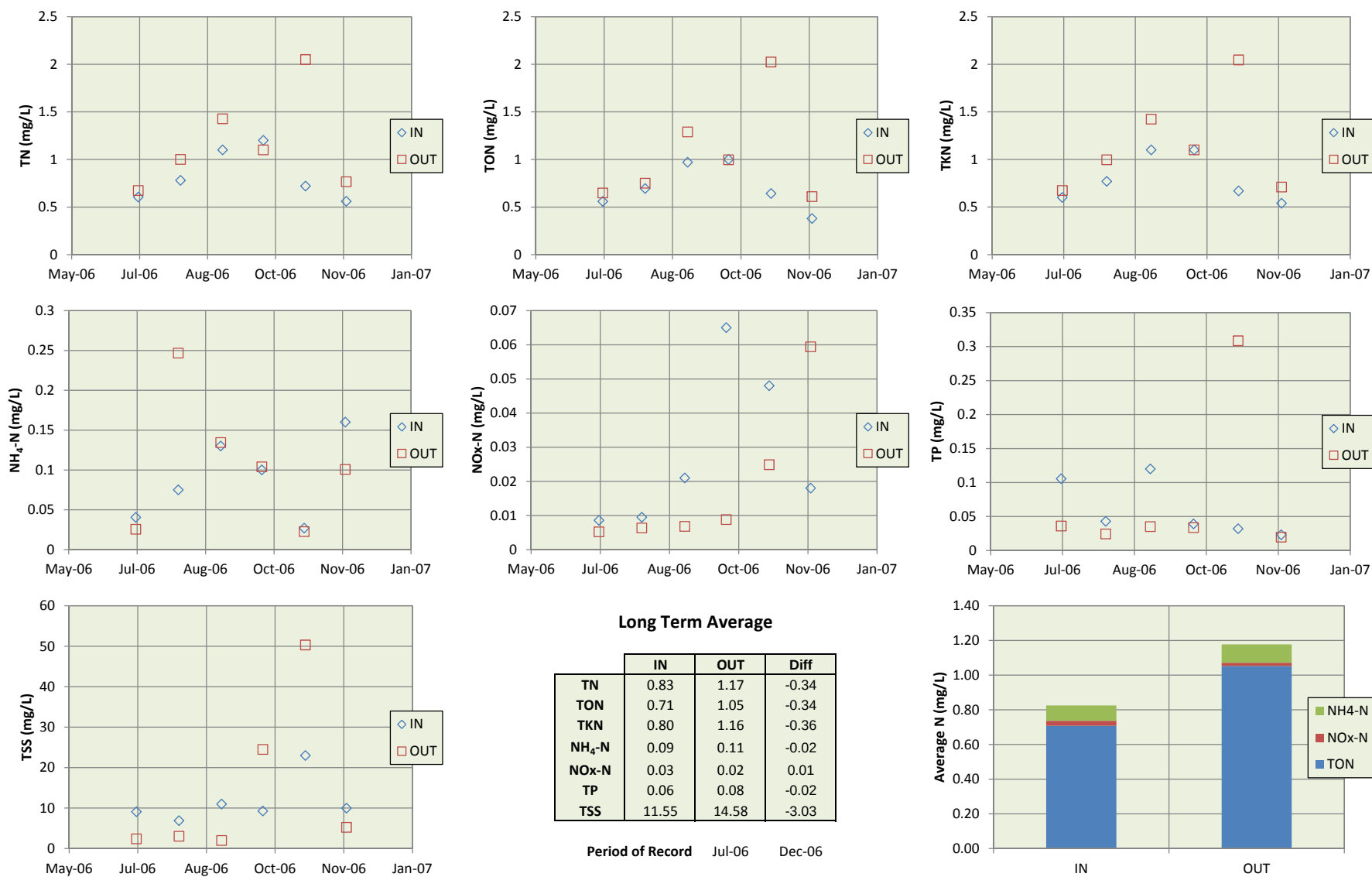
Phase I Apopka Marsh Flow-Way Cell C2 - Monthly Water Quality Data Summary



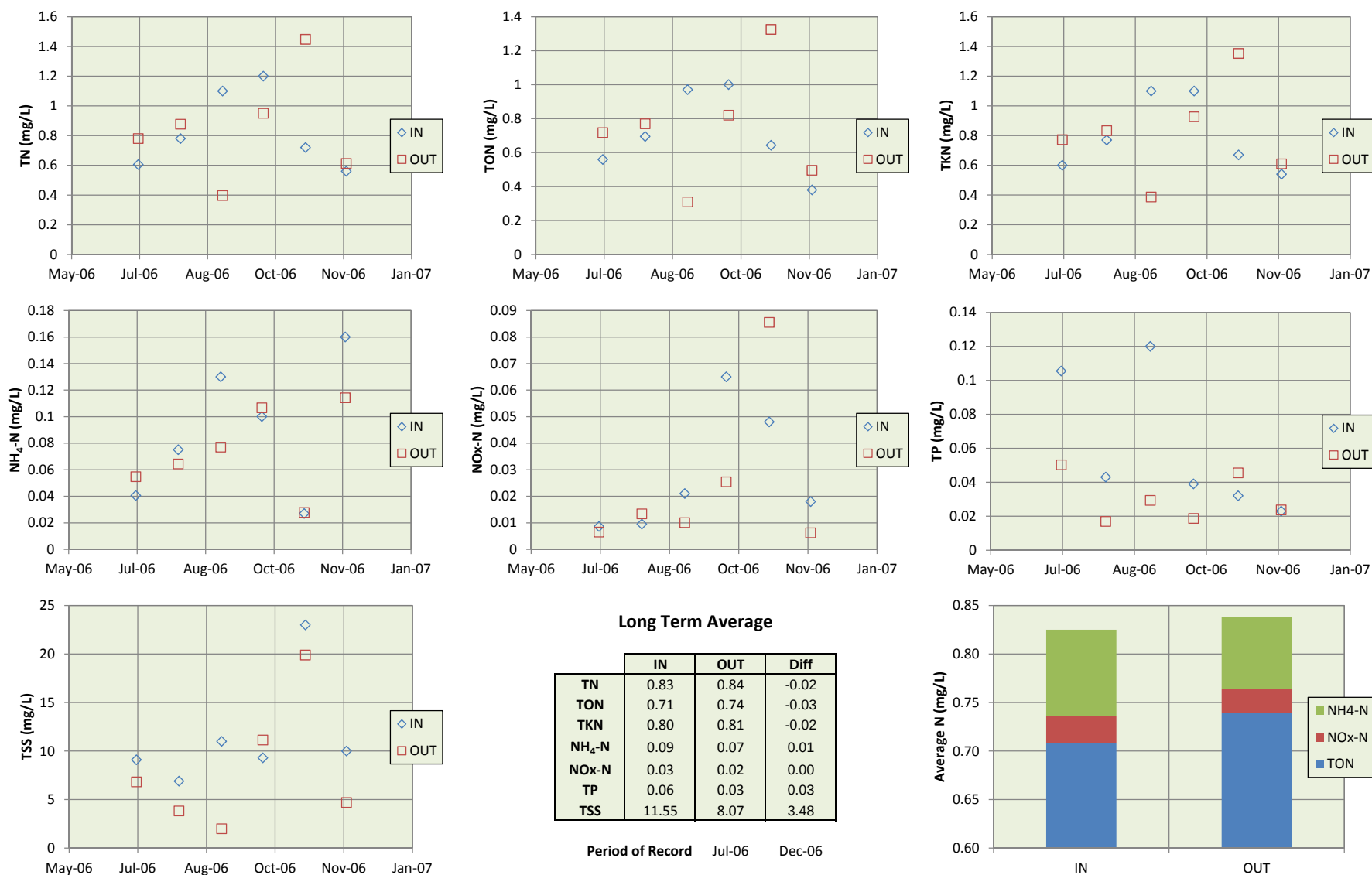
C-43 West Storage Reservoir Test Cell 1 - Monthly Water Quality Data Summary



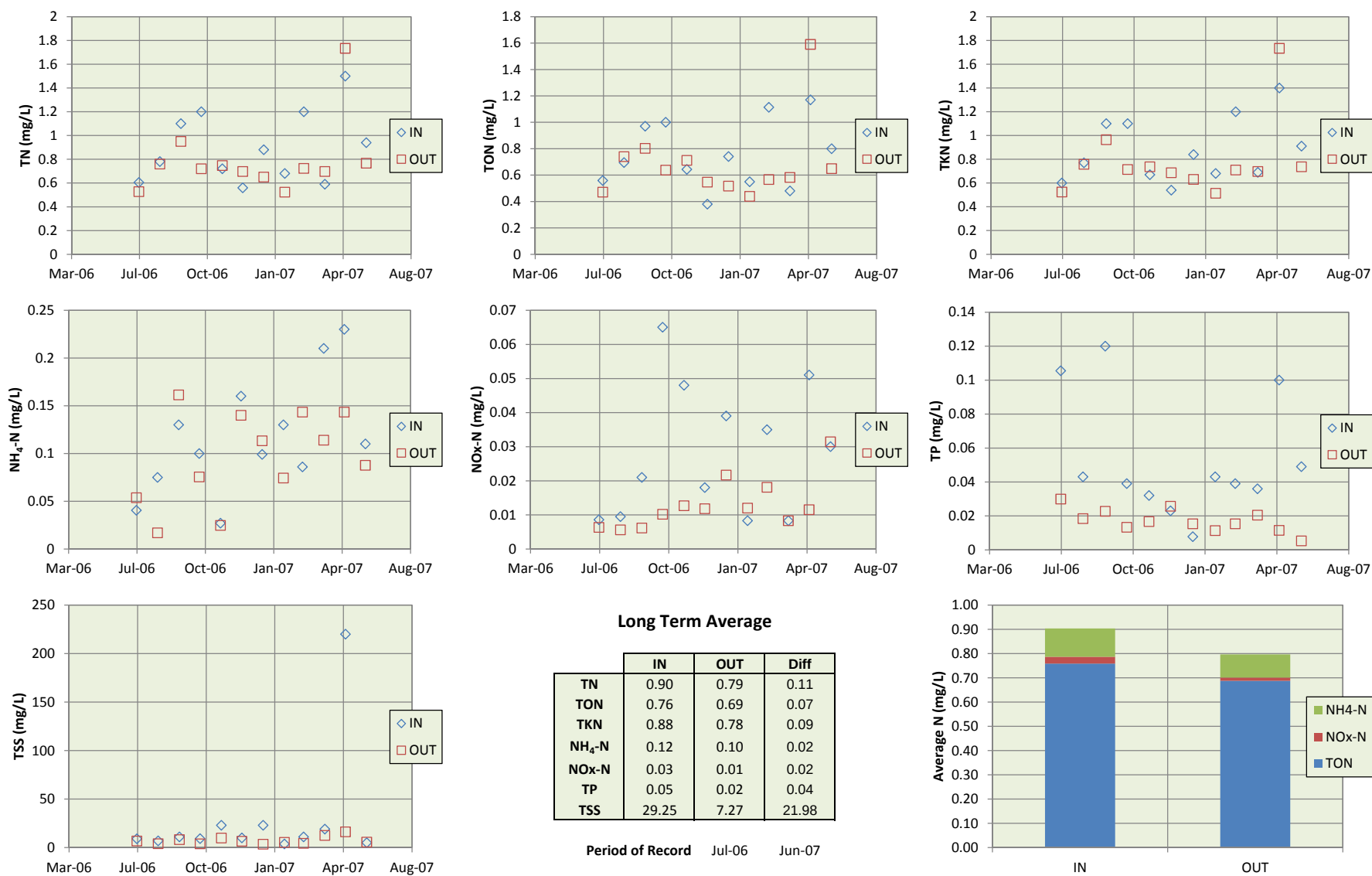
C-43 West Storage Reservoir Test Cell 2 - Monthly Water Quality Data Summary



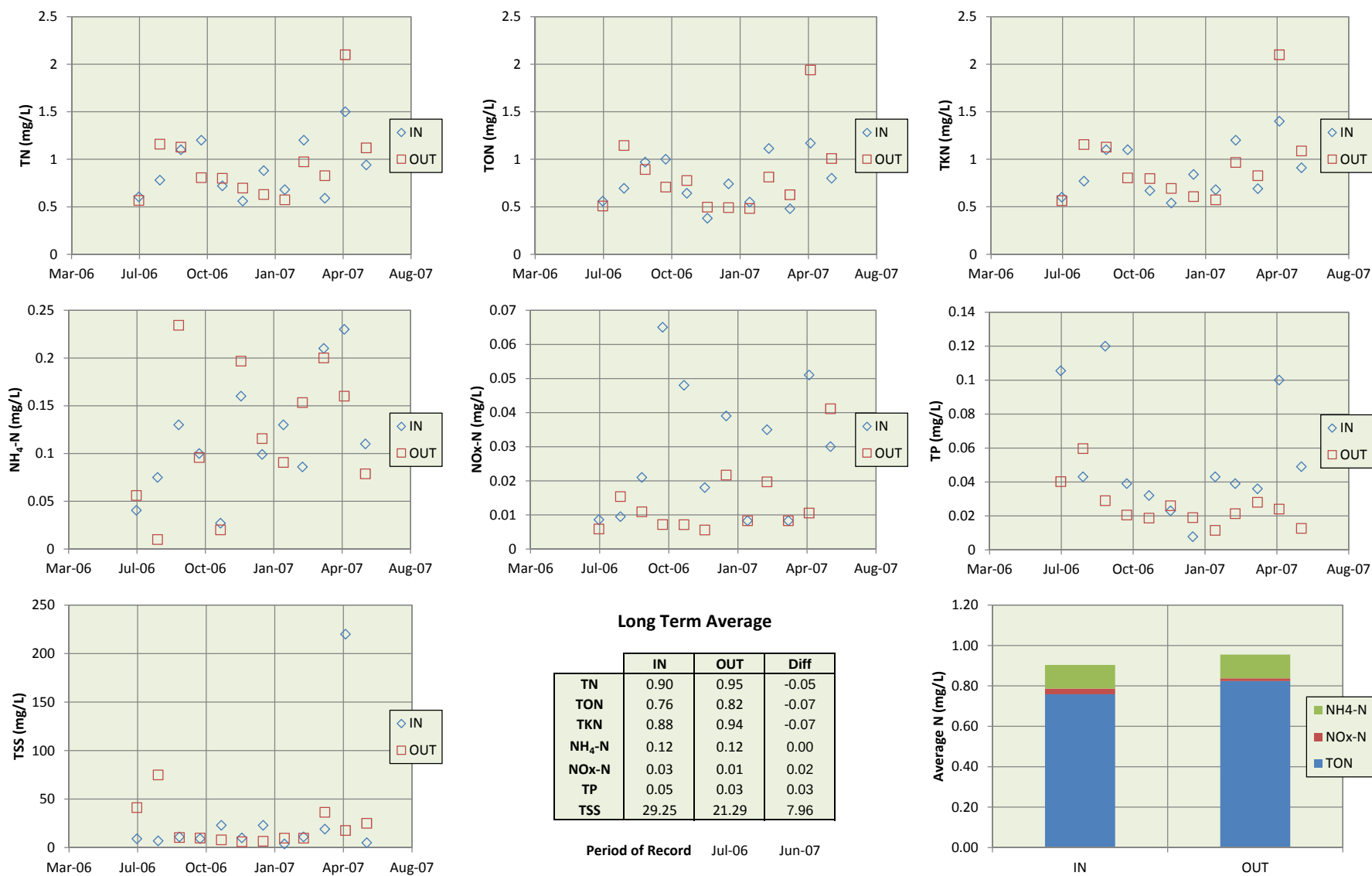
C-44 Stormwater Treatment Area Test Cell 1 - Monthly Water Quality Data Summary



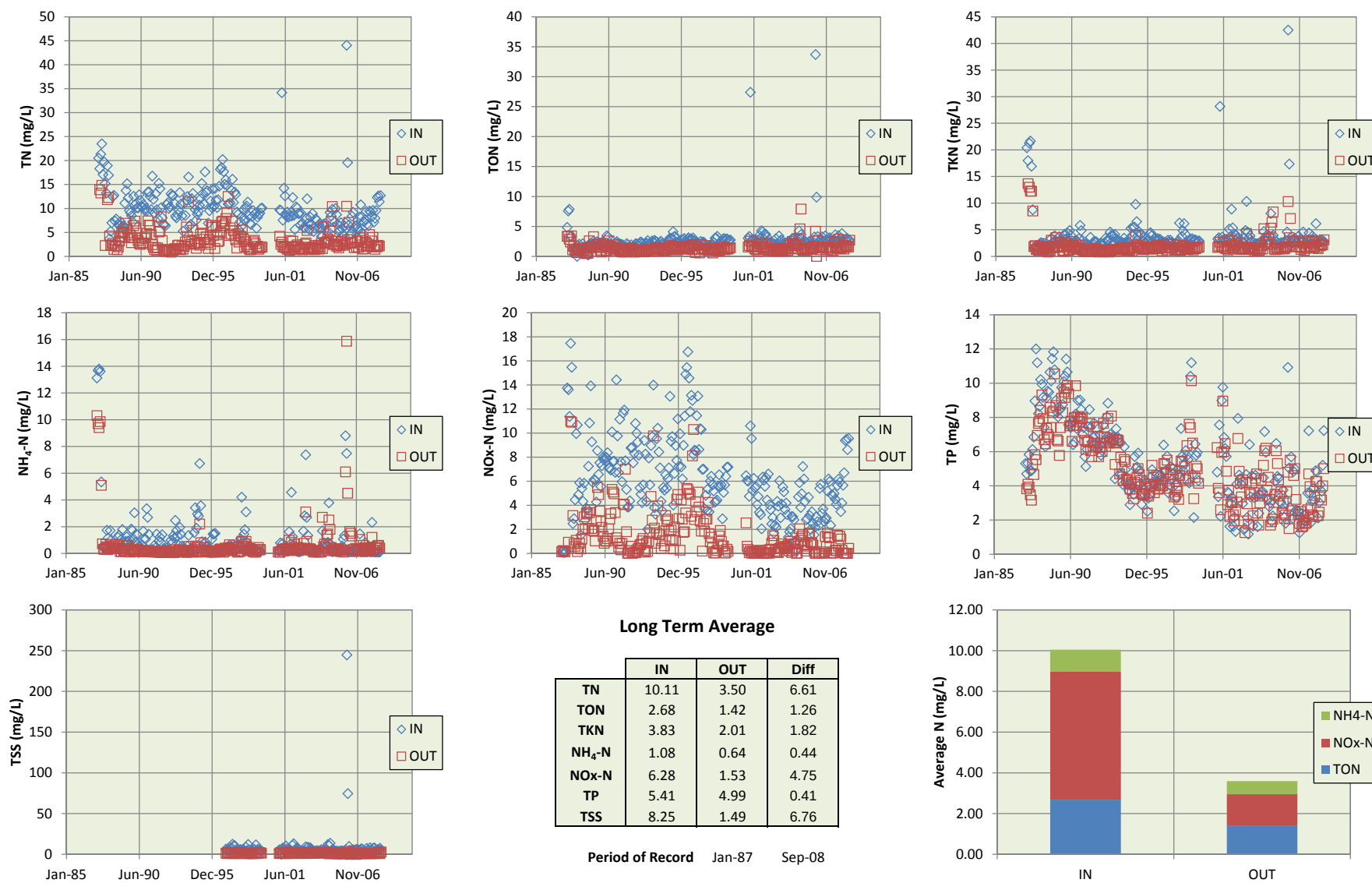
C-44 Stormwater Treatment Area Test Cell 2 - Monthly Water Quality Data Summary



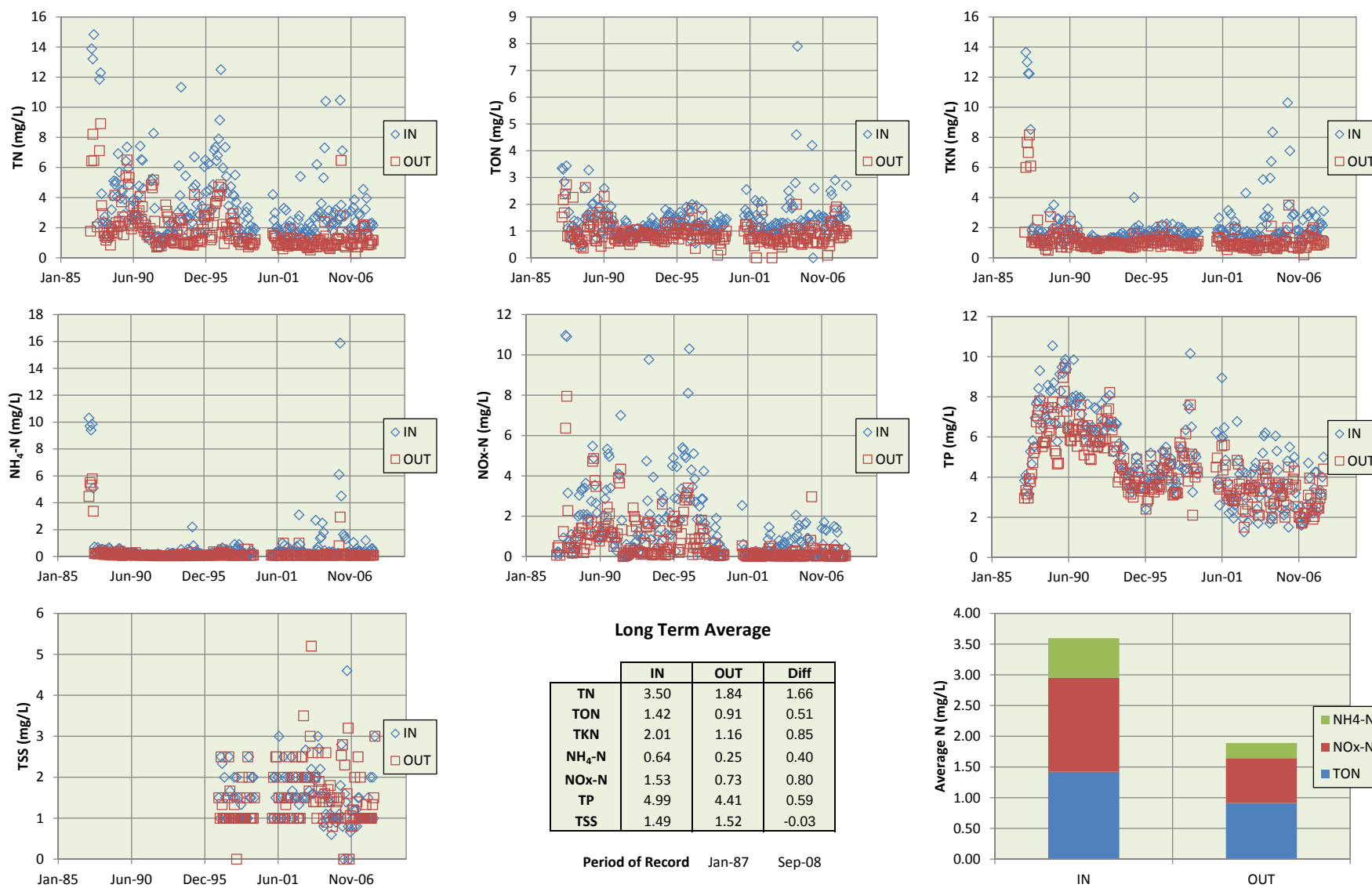
C-44 Reservoir Test Cell 1 - Monthly Water Quality Data Summary



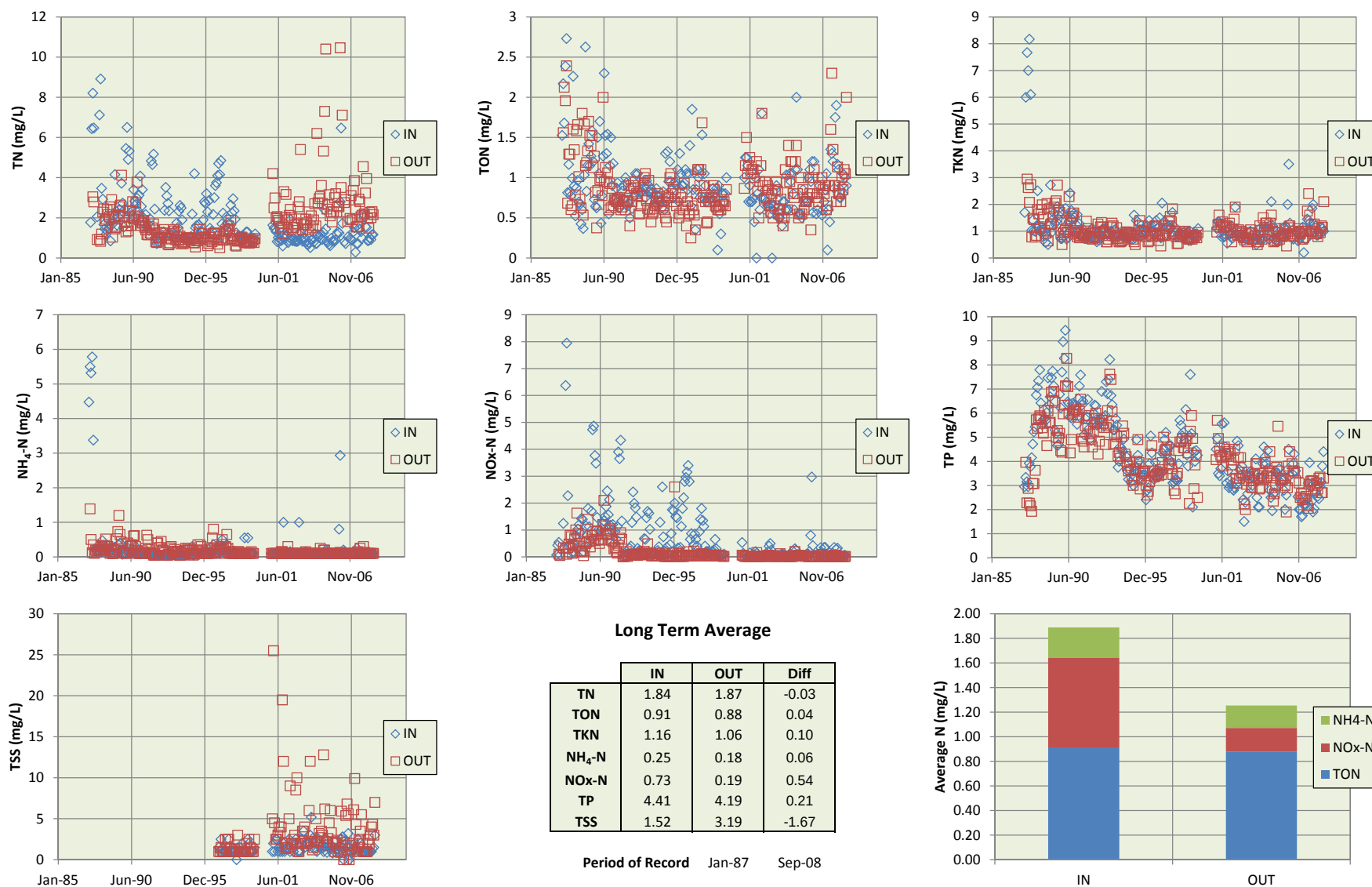
C-44 Reservoir Test Cell 2 - Monthly Water Quality Data Summary



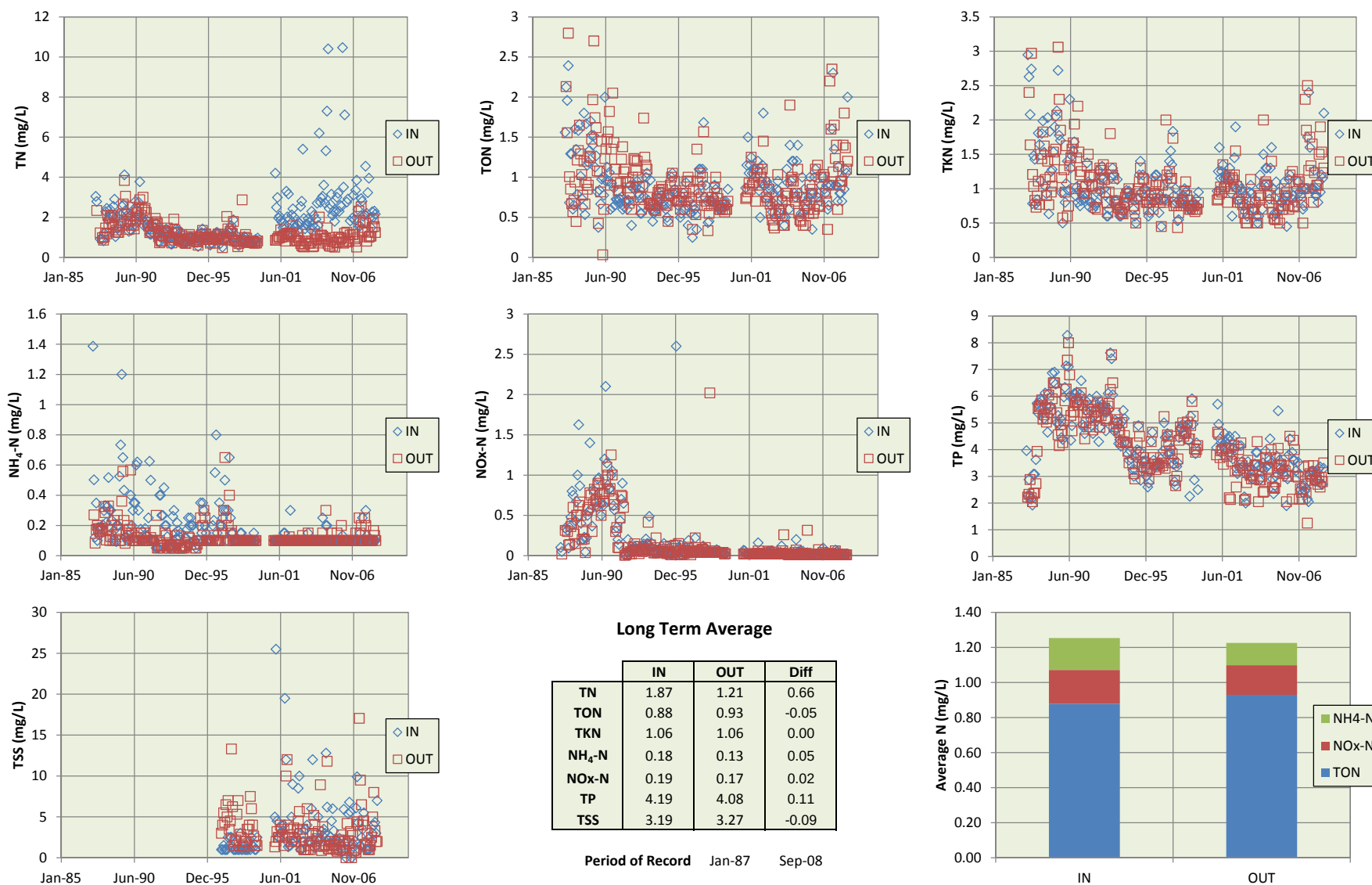
City of Lakeland Wetland Treatment System Cell 1 - Monthly Water Quality Data Summary



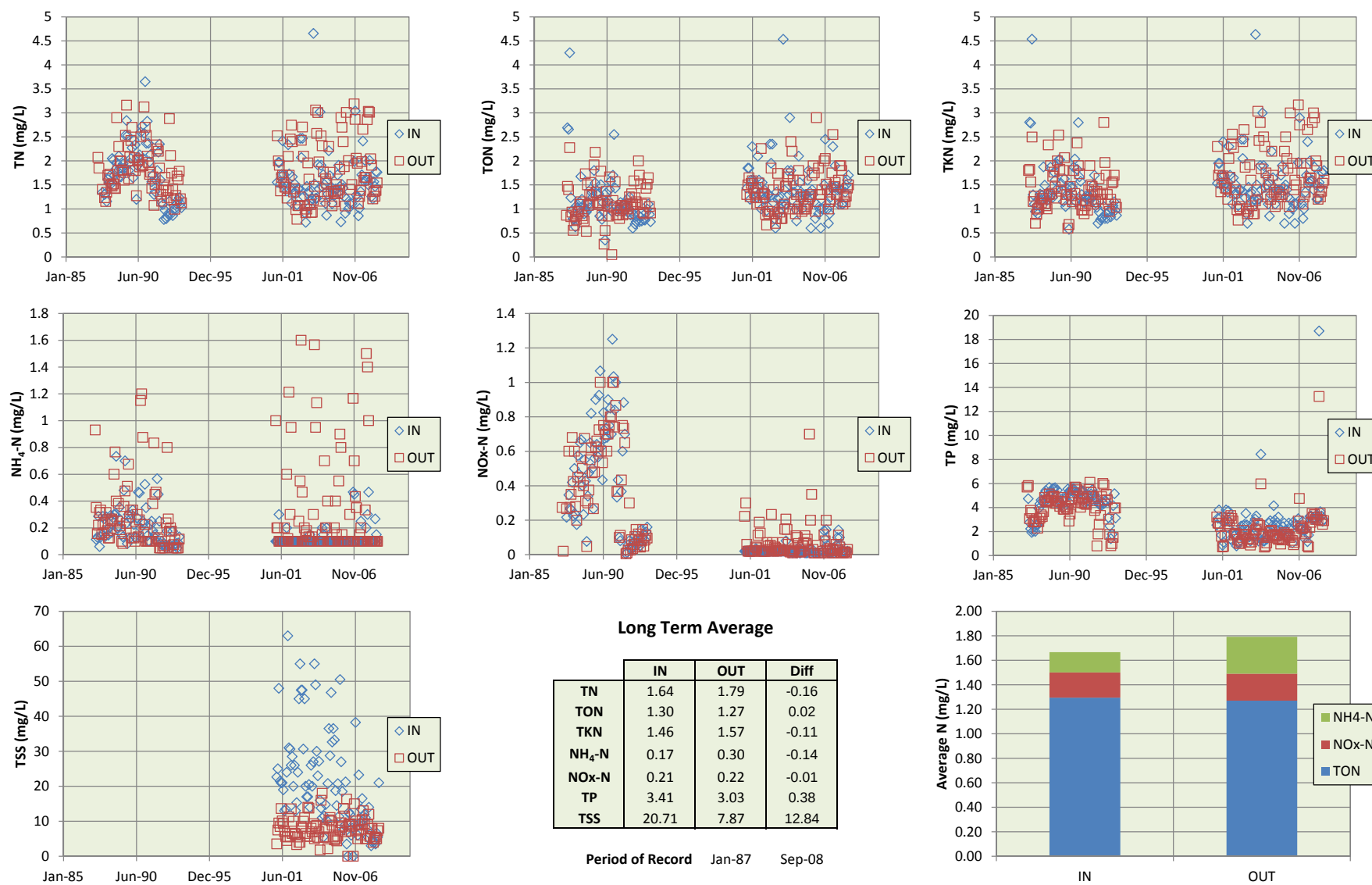
City of Lakeland Wetland Treatment System Cell 2 - Monthly Water Quality Data Summary



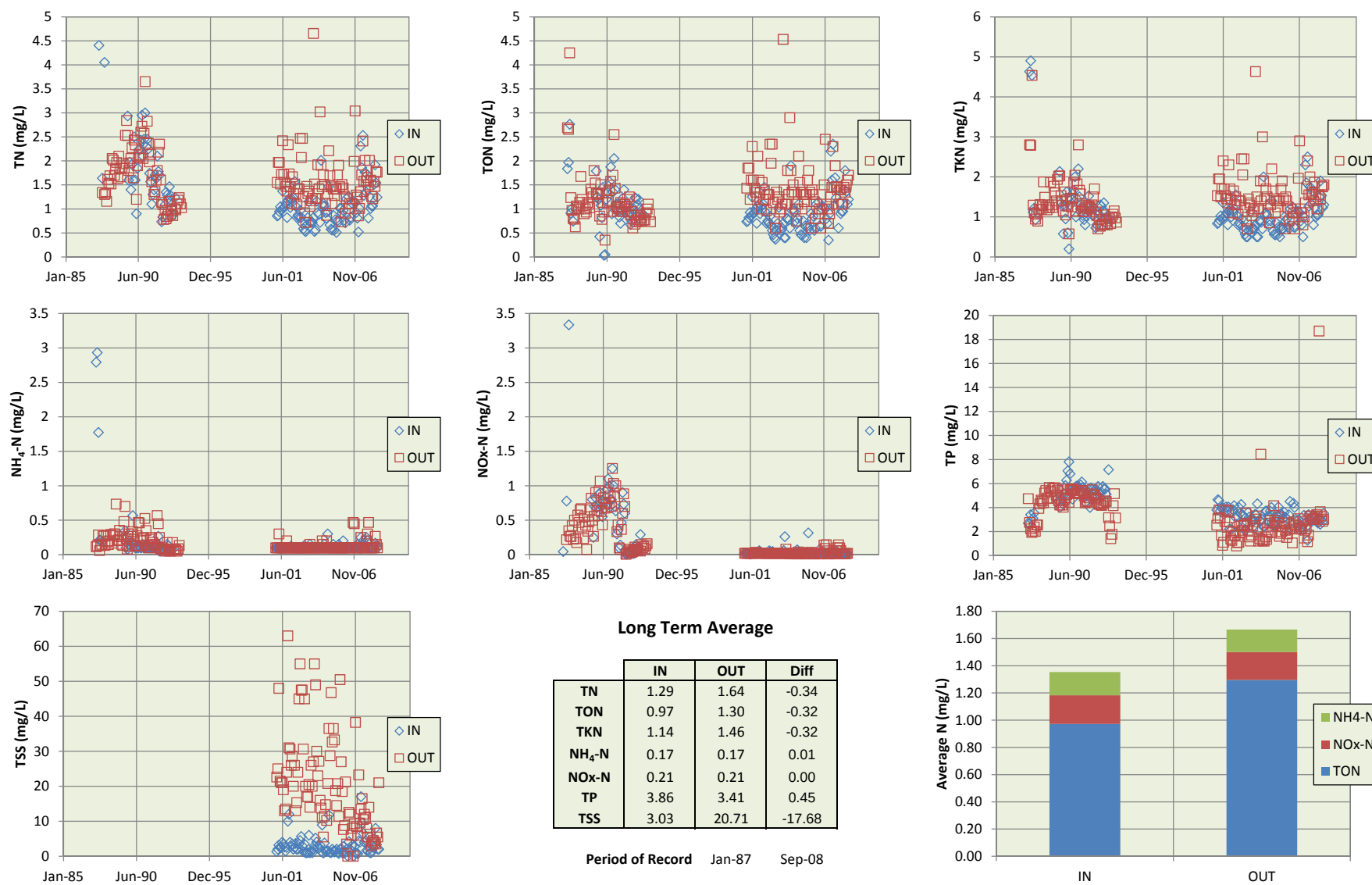
City of Lakeland Wetland Treatment System Cell 3 - Monthly Water Quality Data Summary



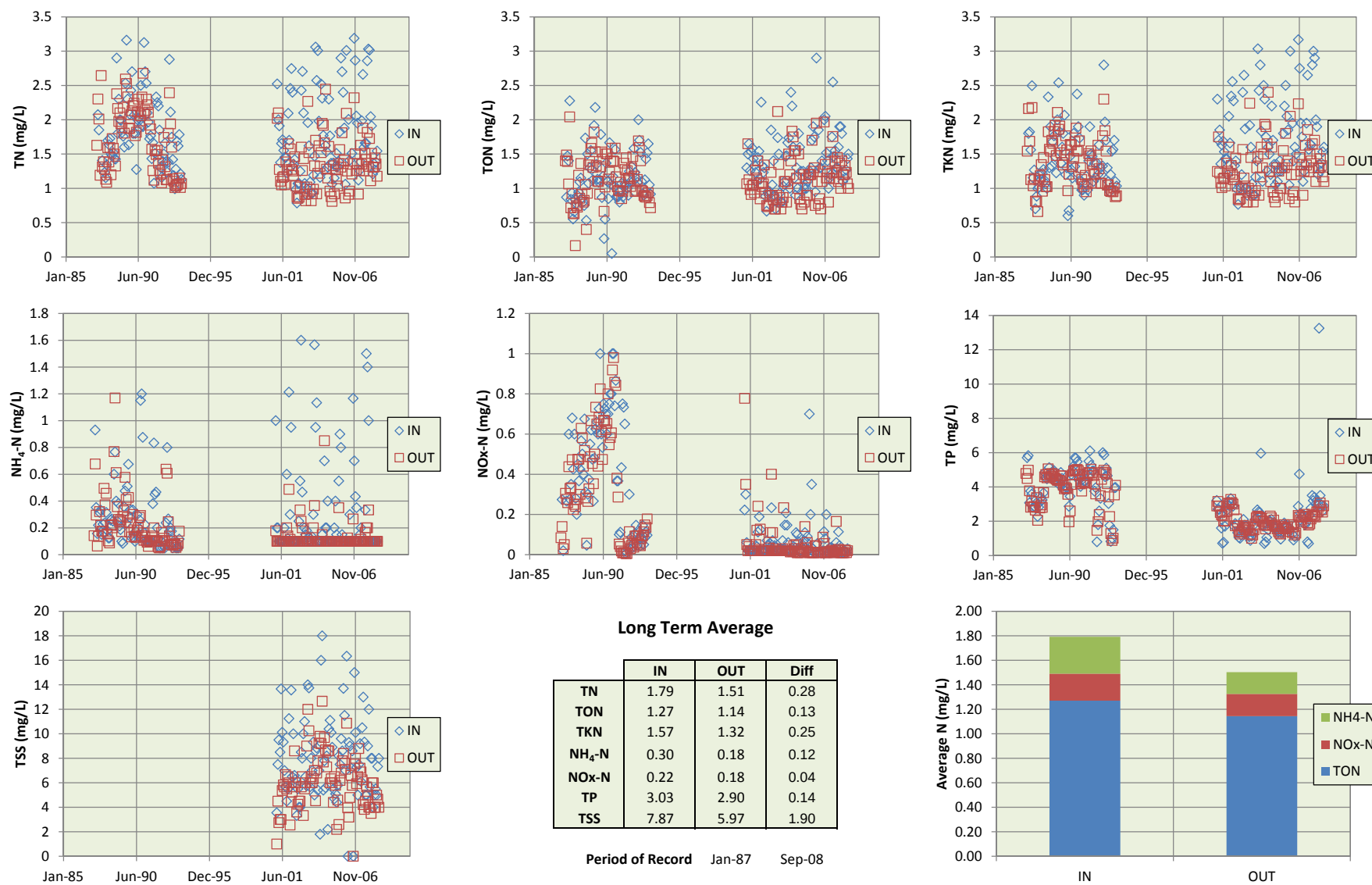
City of Lakeland Wetland Treatment System Cell 4 - Monthly Water Quality Data Summary



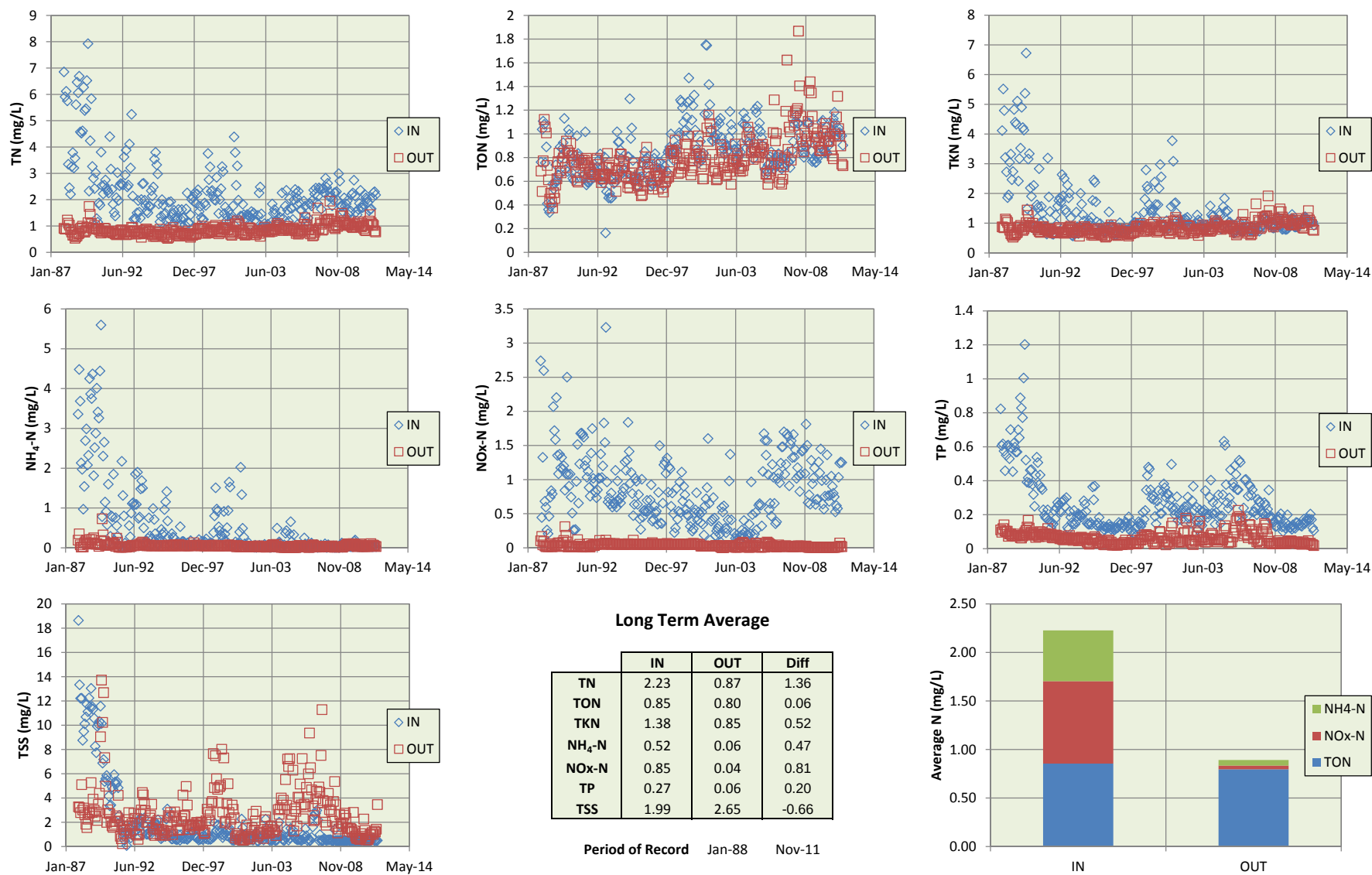
City of Lakeland Wetland Treatment System Cell 6 - Monthly Water Quality Data Summary



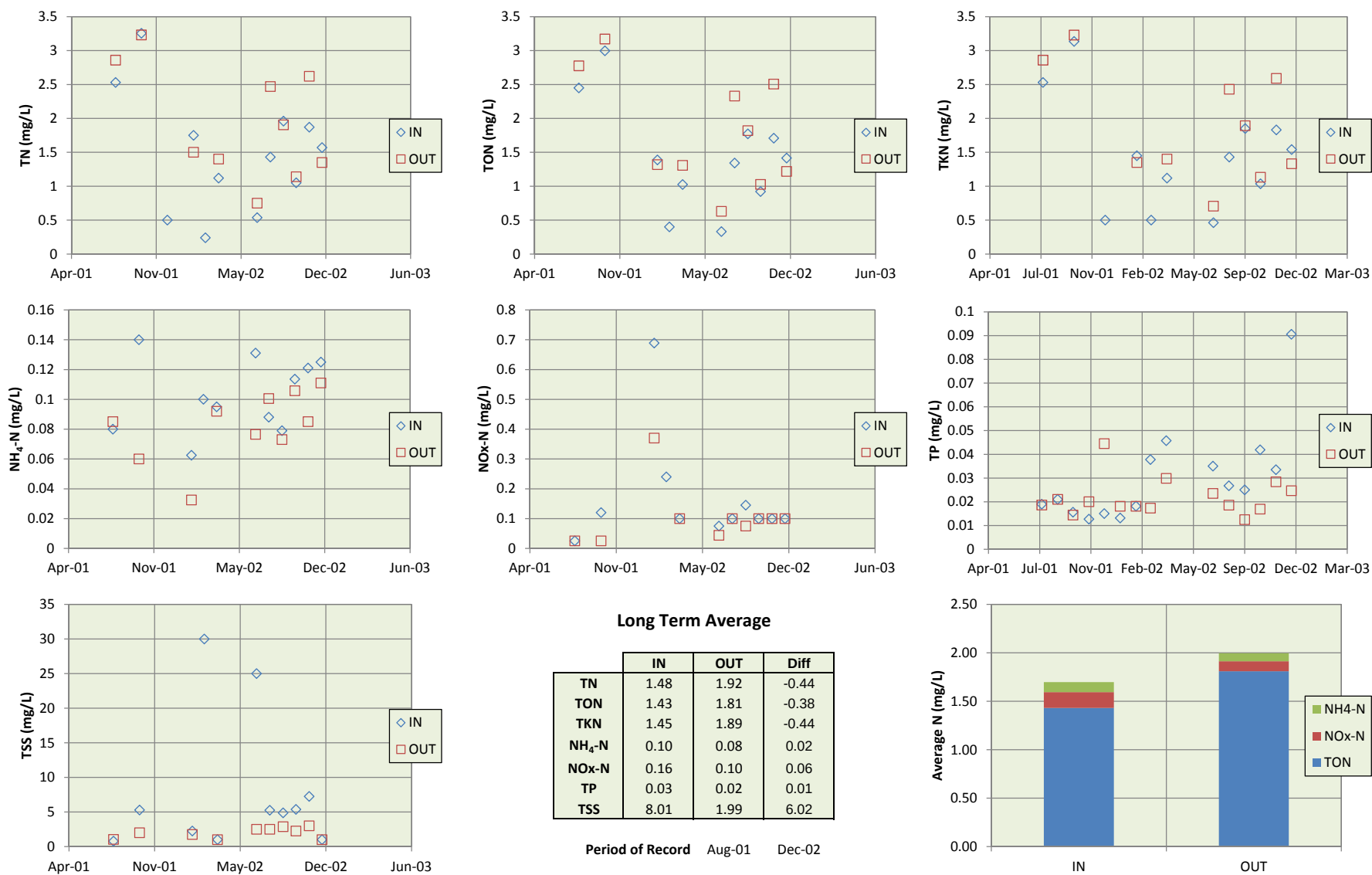
City of Lakeland Wetland Treatment System Cell 5 - Monthly Water Quality Data Summary



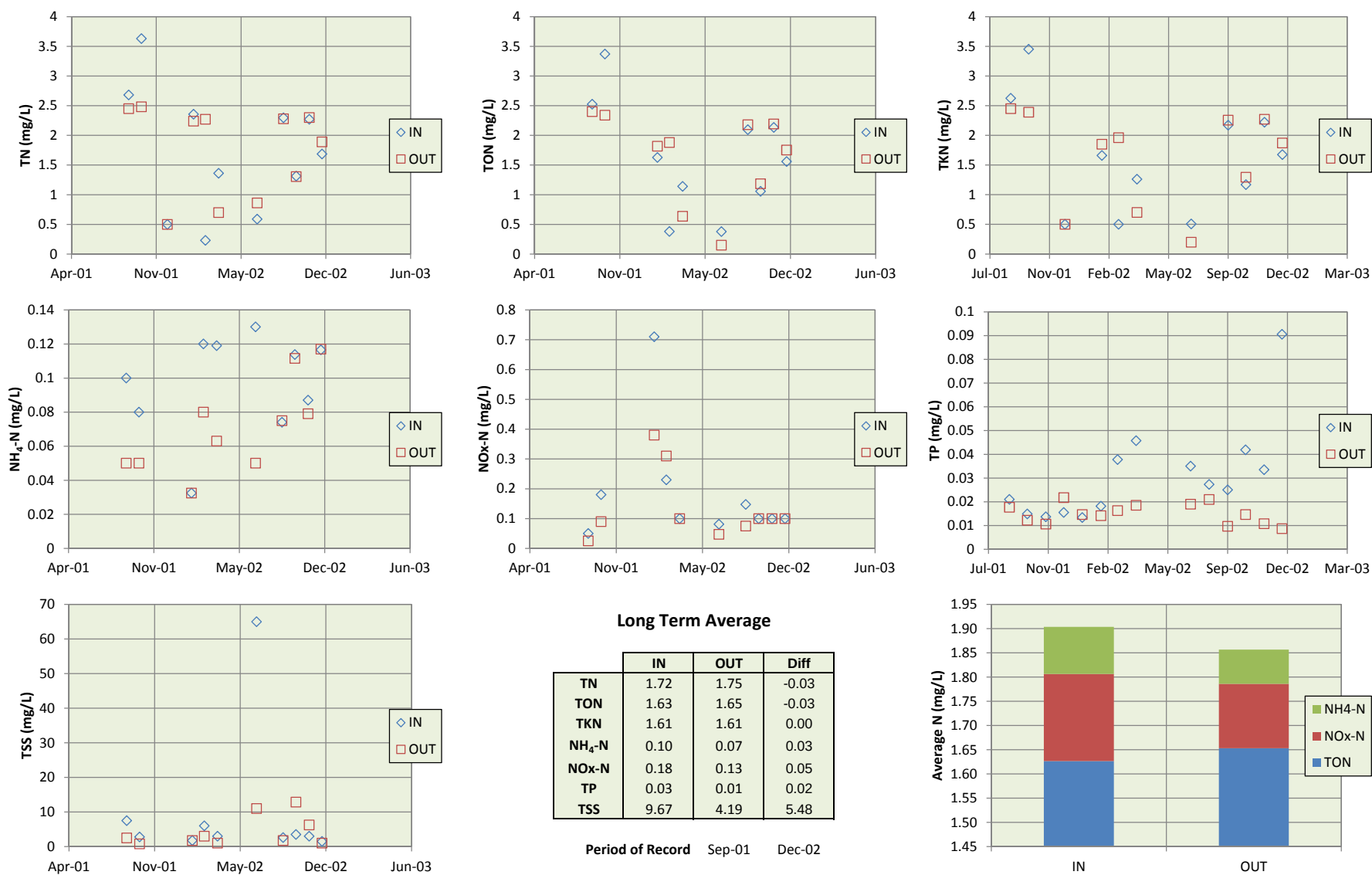
City of Lakeland Wetland Treatment System Cell 7 - Monthly Water Quality Data Summary



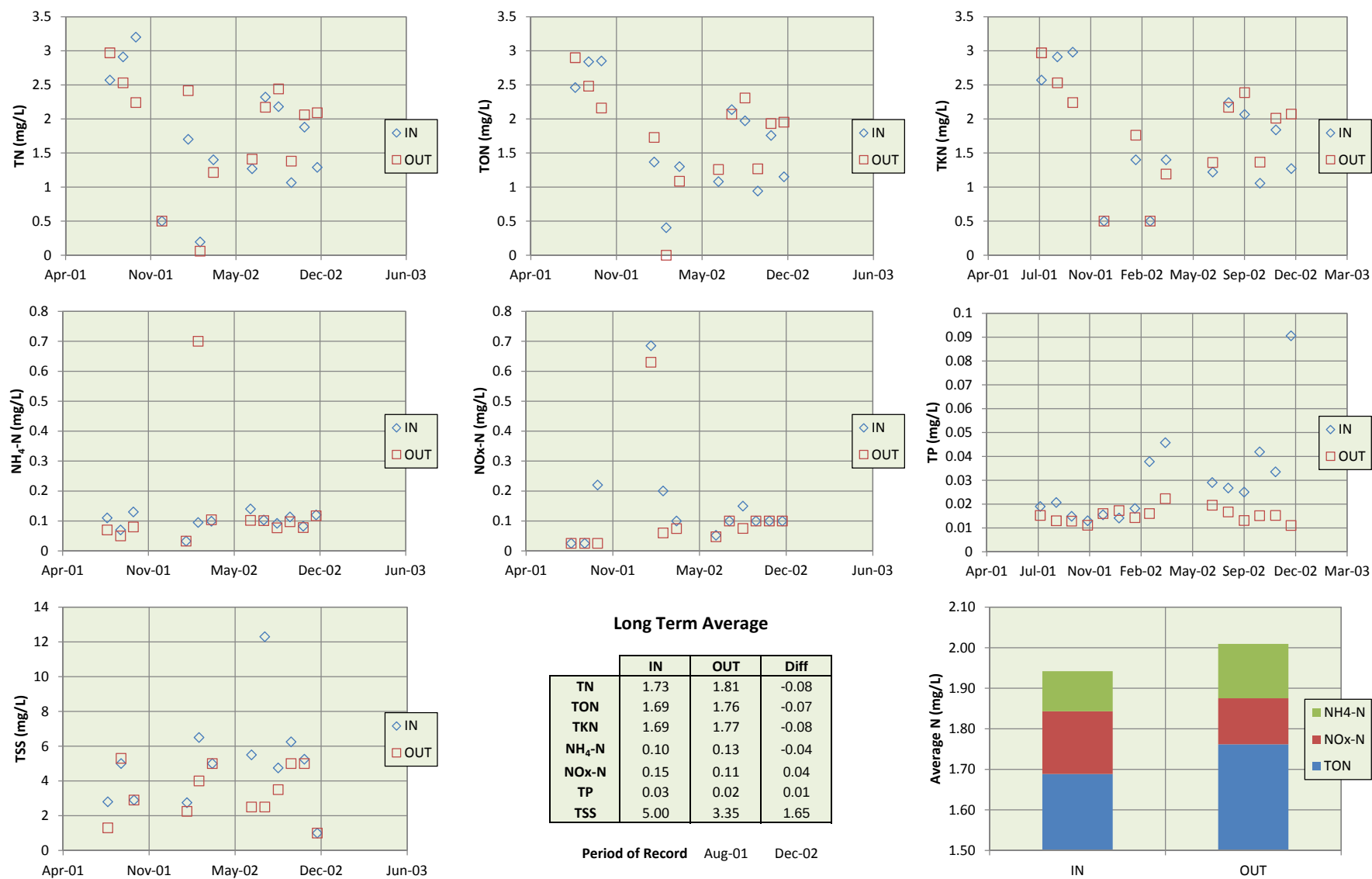
Orlando Easterly Wetlands - Monthly Water Quality Data Summary



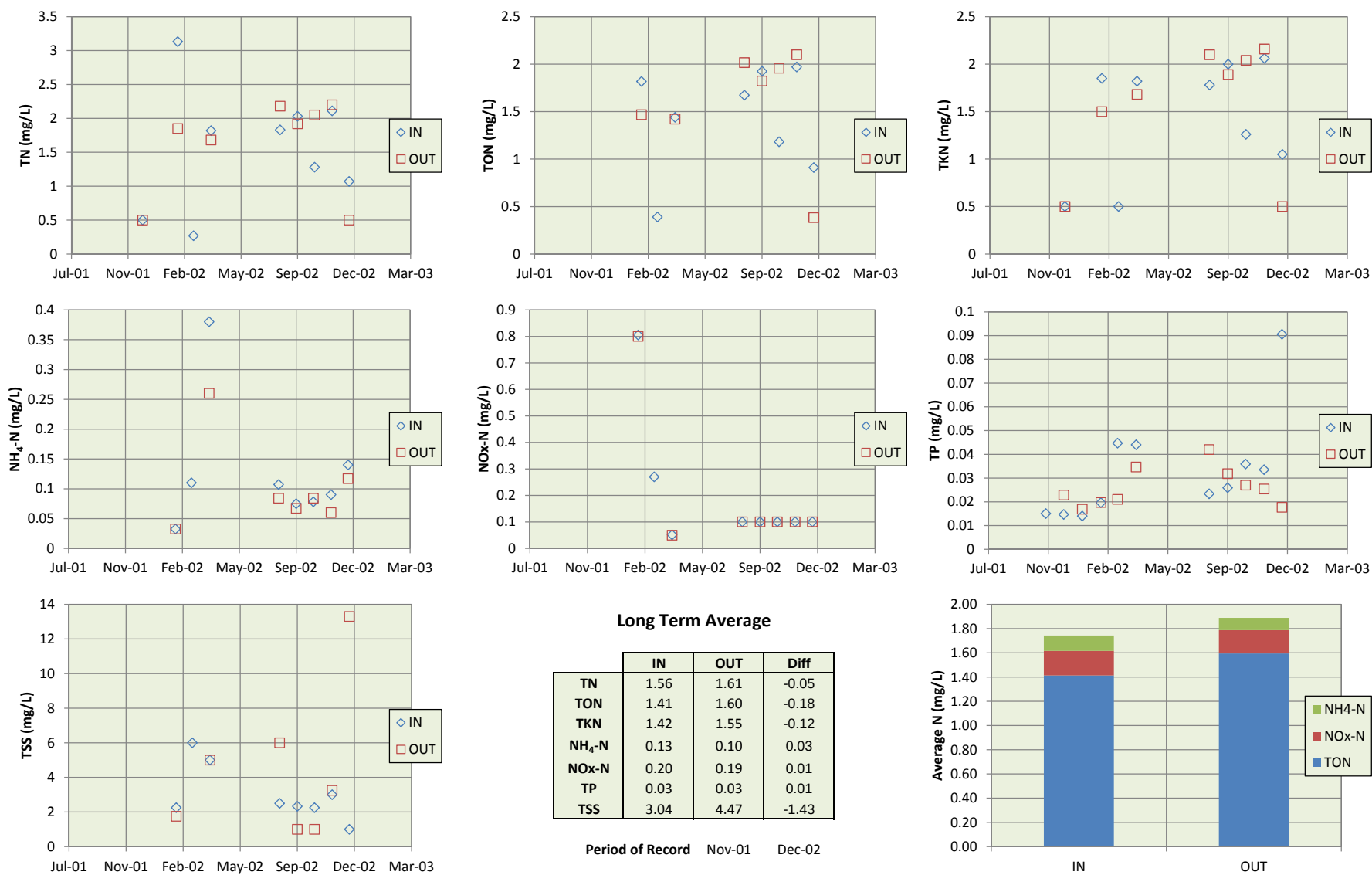
SFWMD Field-Scale PSTA Cell FS-1 - Monthly Water Quality Data Summary



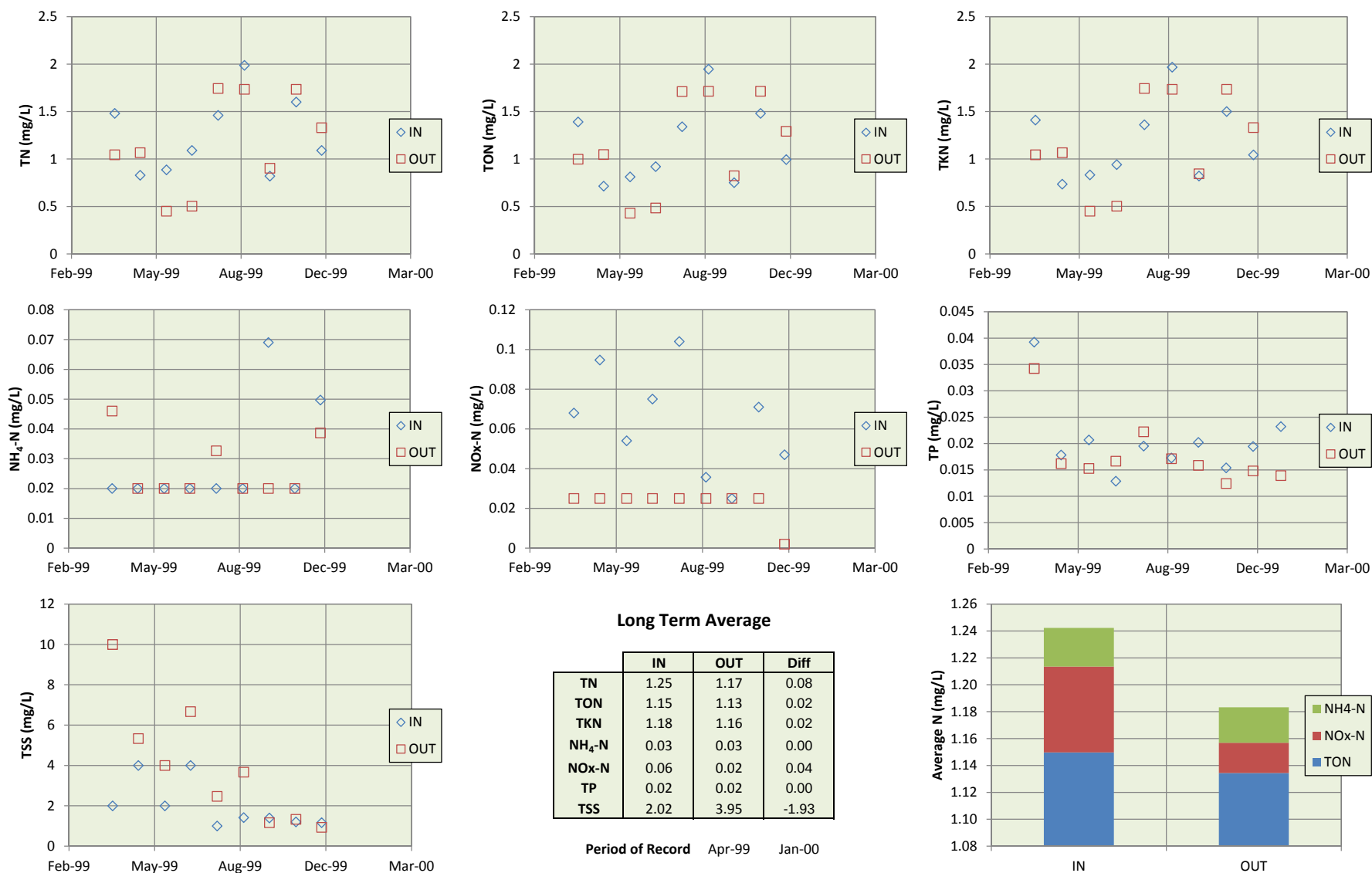
SFWMD Field-Scale PSTA Cell FS-2 - Monthly Water Quality Data Summary



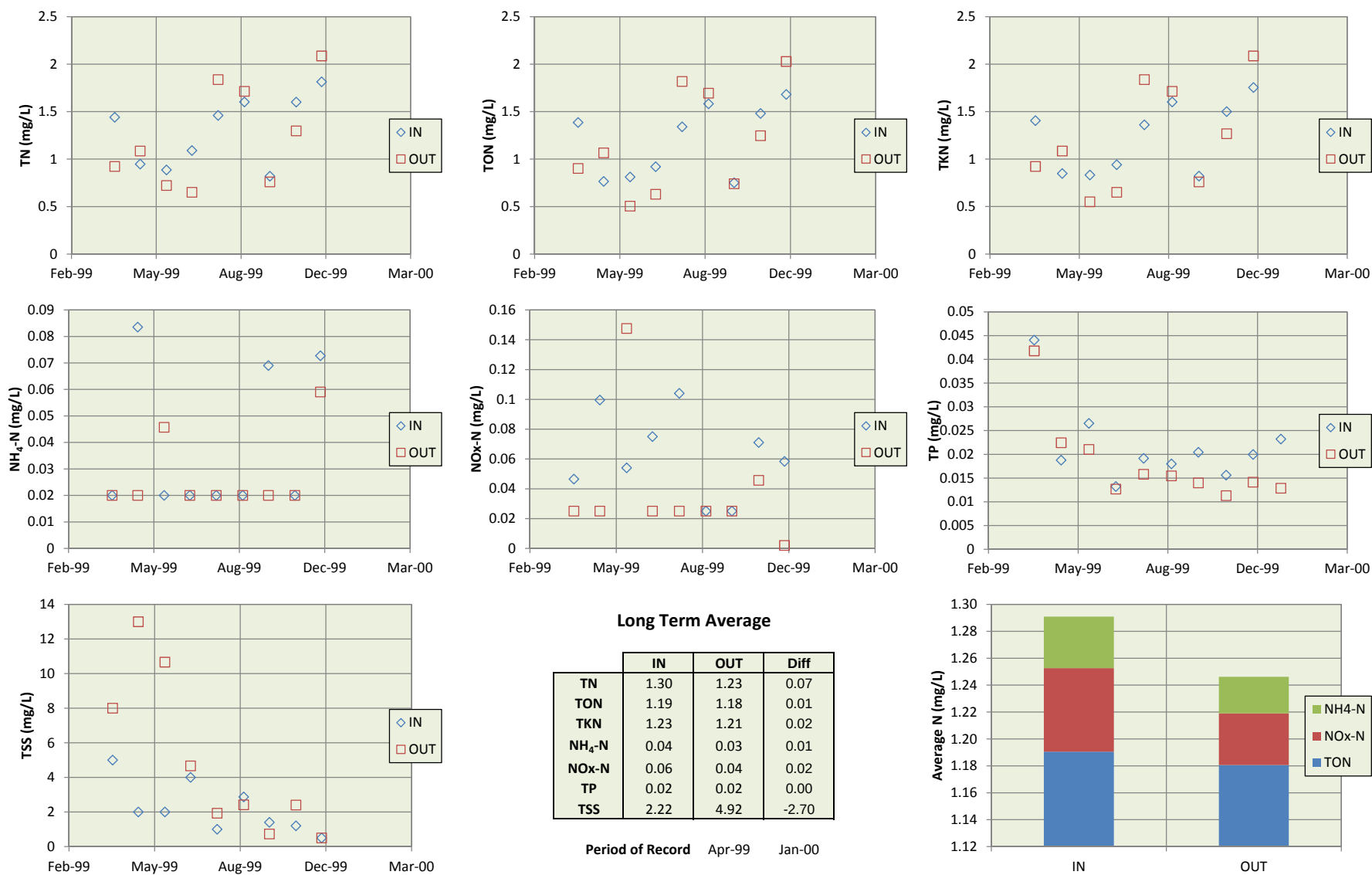
SFWMD Field-Scale PSTA Cell FS-3 - Monthly Water Quality Data Summary



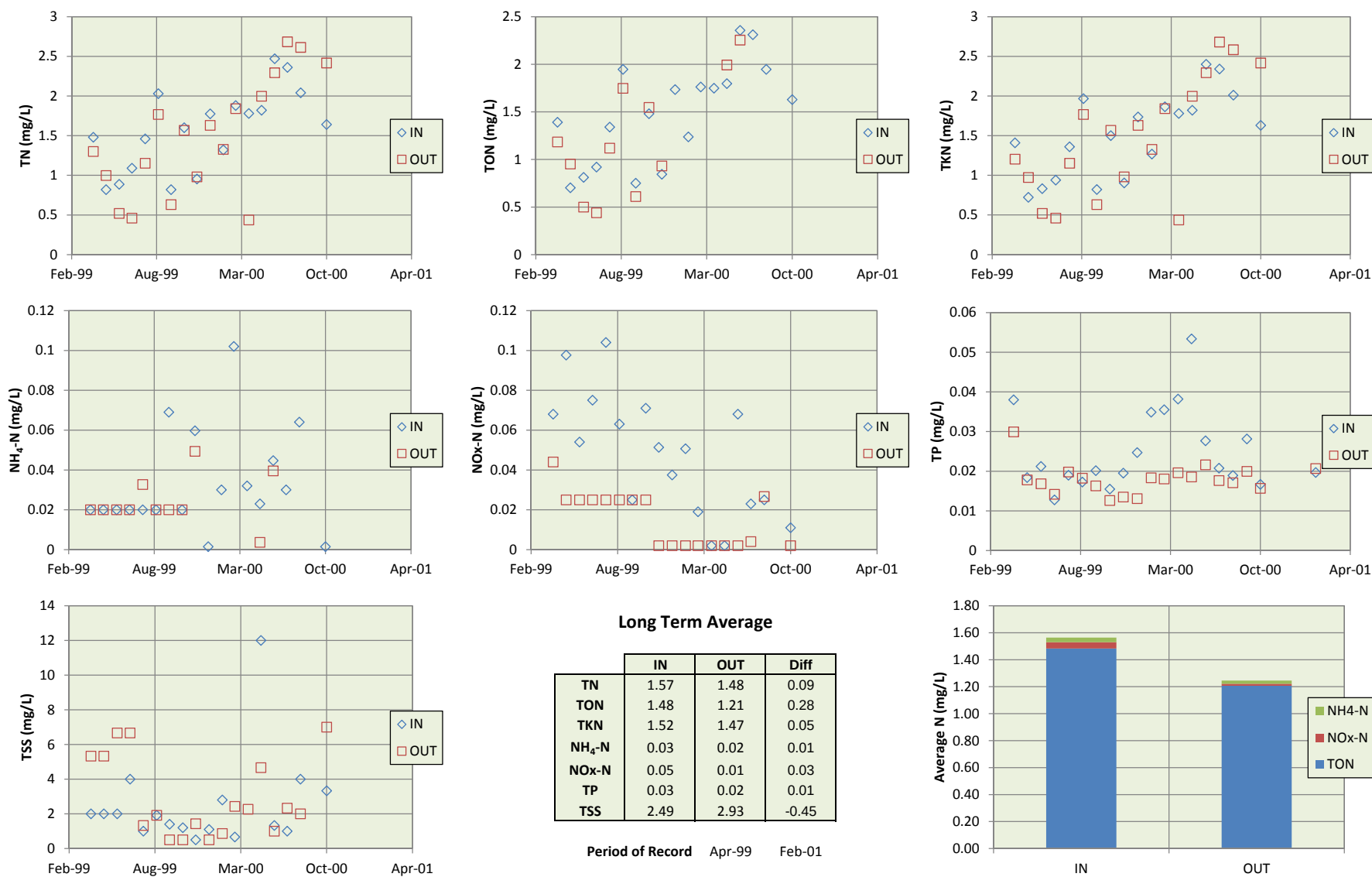
SFWMD Field-Scale PSTA Cell FS-4 - Monthly Water Quality Data Summary



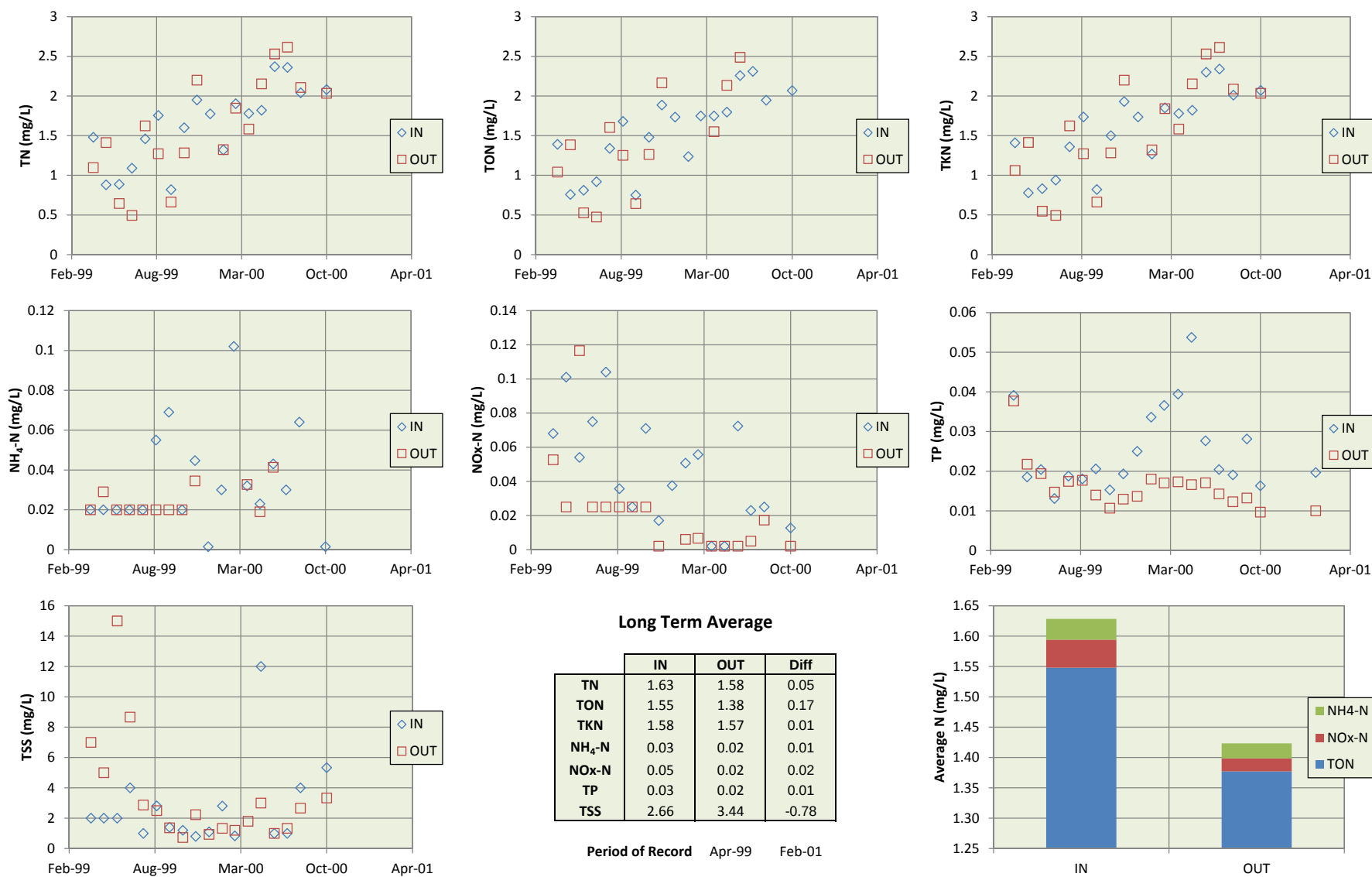
SFWM D Porta-PSTA Mesocosms Treatment 1 - Monthly Water Quality Data Summary



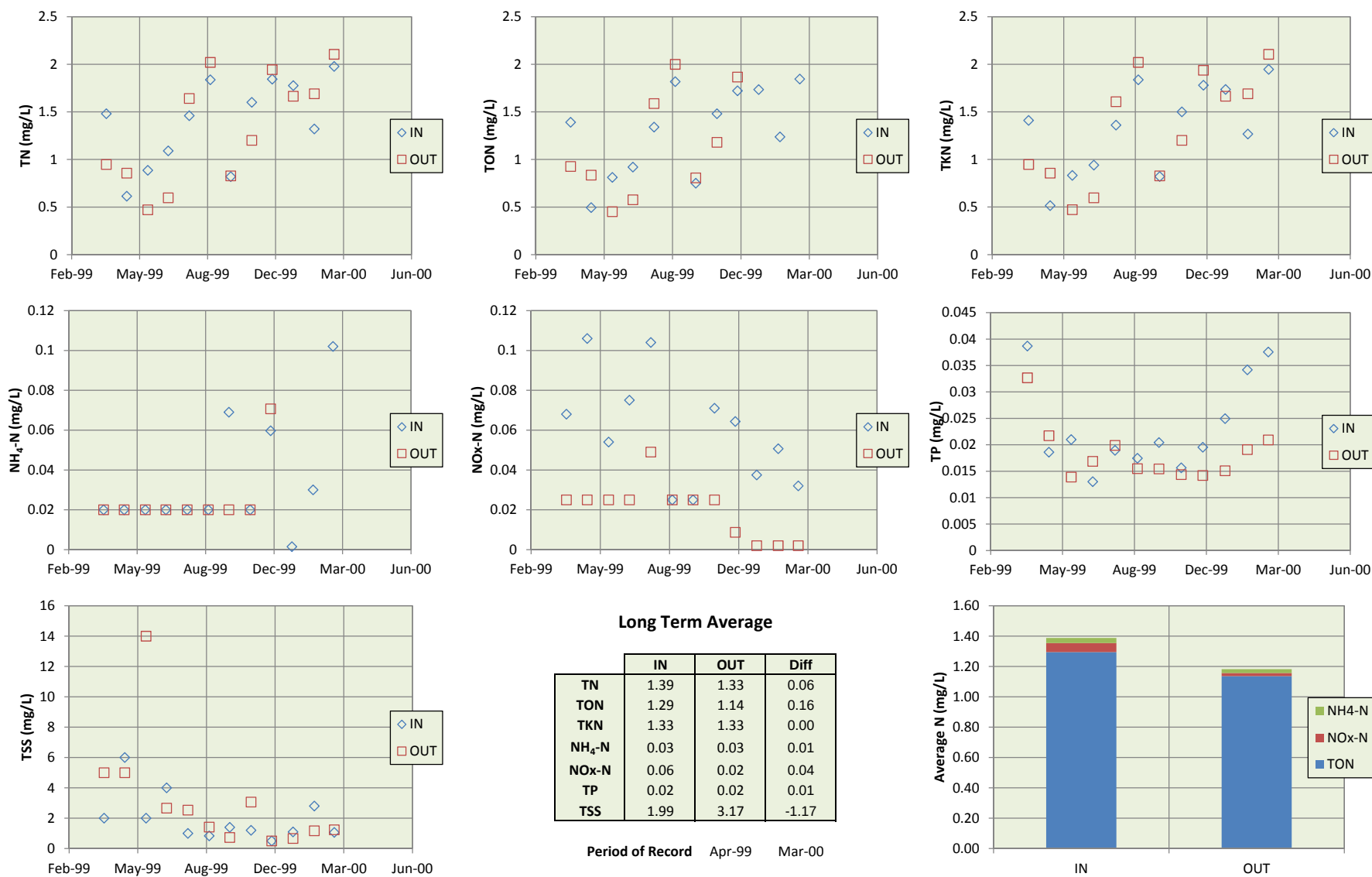
SFWMD Porta-PSTA Mesocosms Treatment 2 - Monthly Water Quality Data Summary



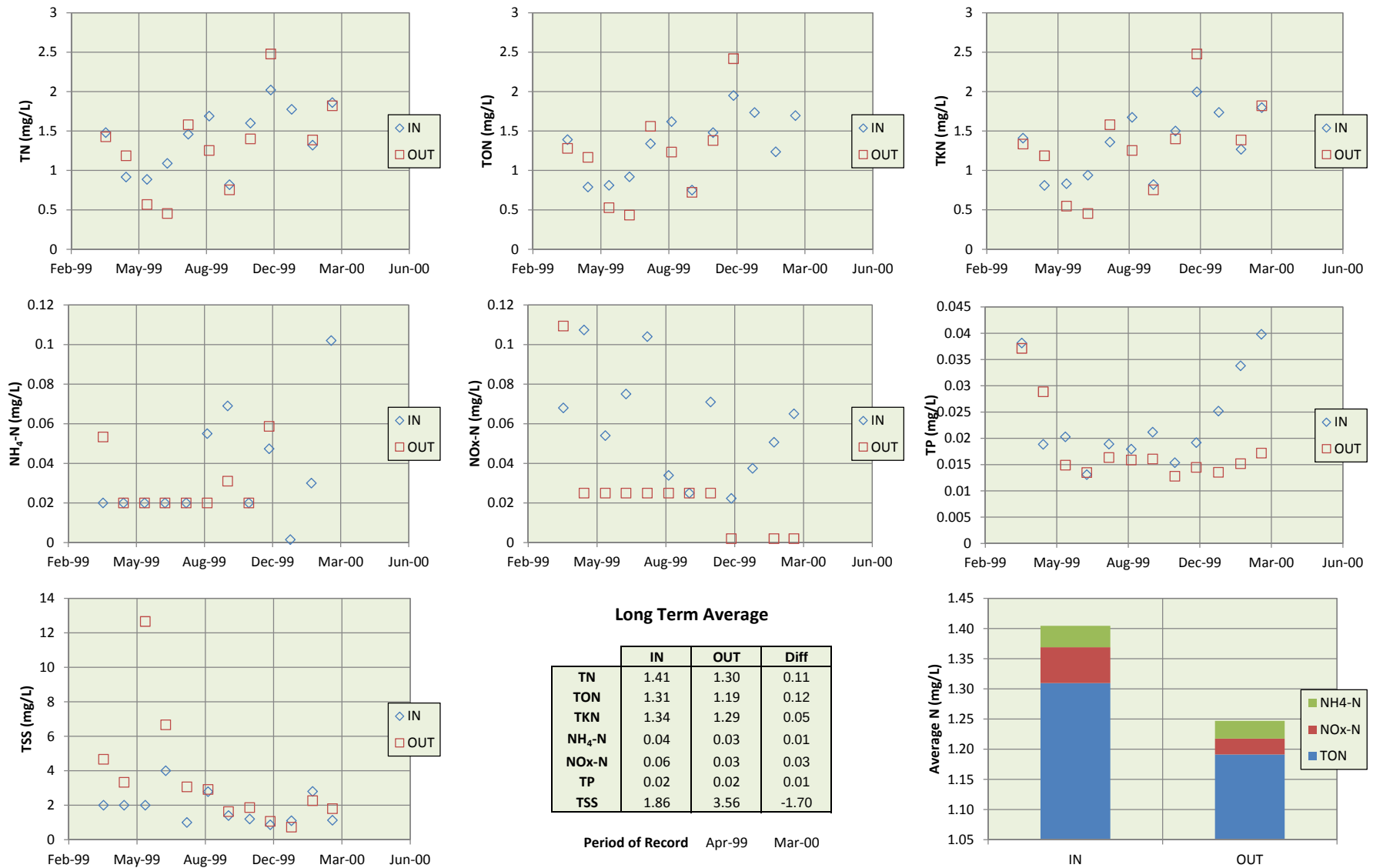
SFWMD Porta-PSTA Mesocosms Treatment 3 - Monthly Water Quality Data Summary



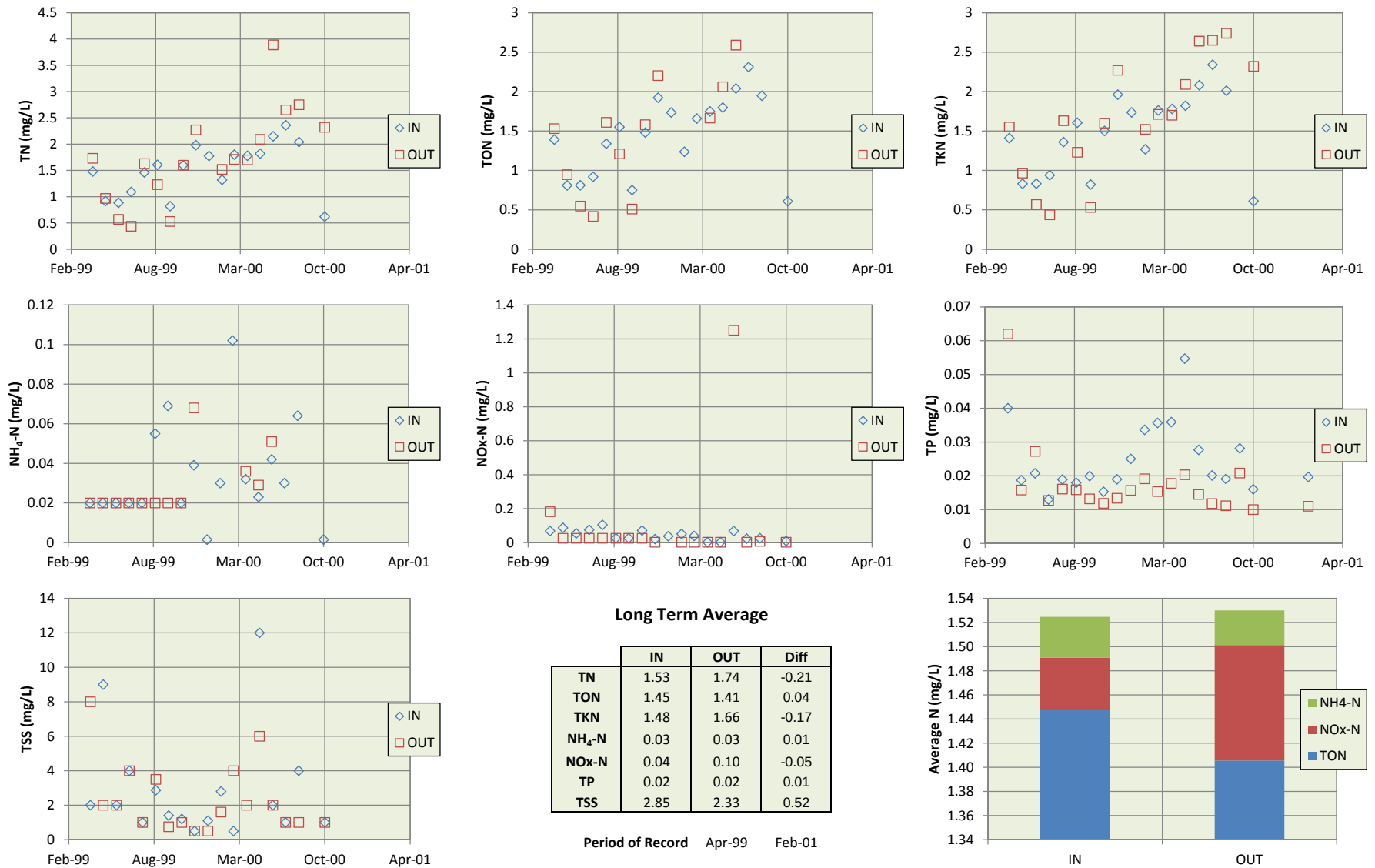
SFWMD Porta-PSTA Mesocosms Treatment 4 - Monthly Water Quality Data Summary



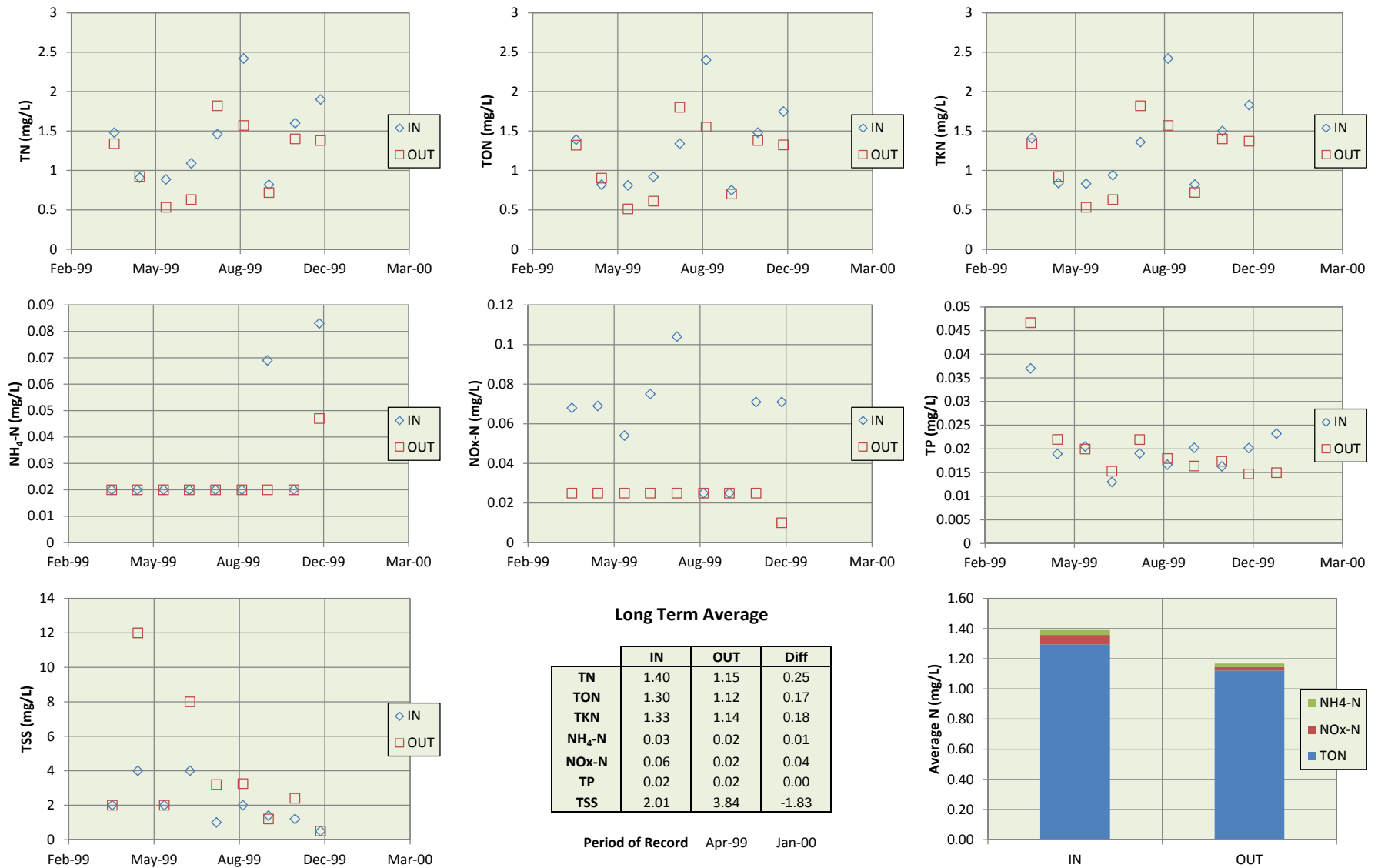
SFWMD Porta-PSTA Mesocosms Treatment 5 - Monthly Water Quality Data Summary



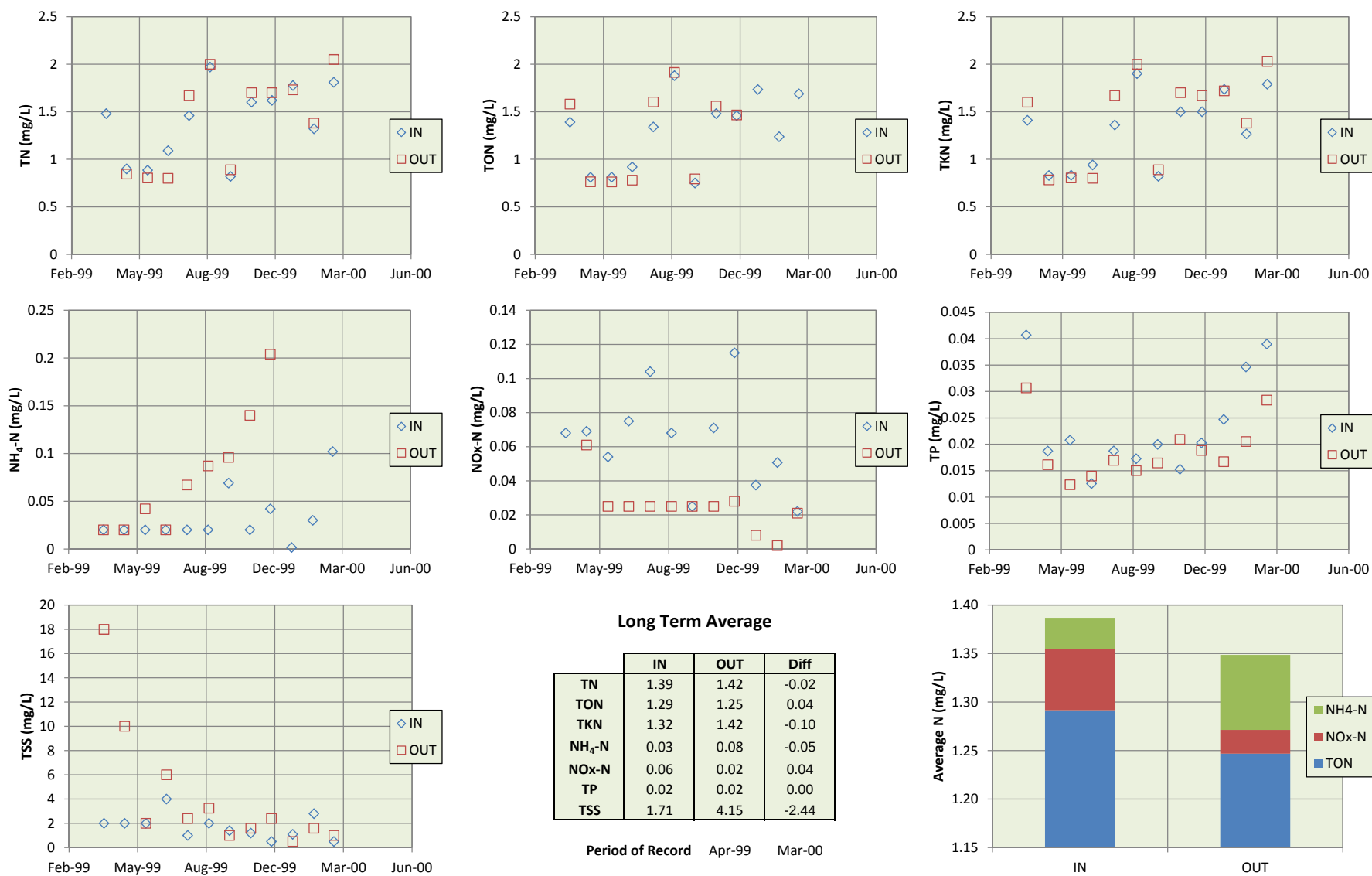
SFWMD Porta-PSTA Mesocosms Treatment 6 - Monthly Water Quality Data Summary



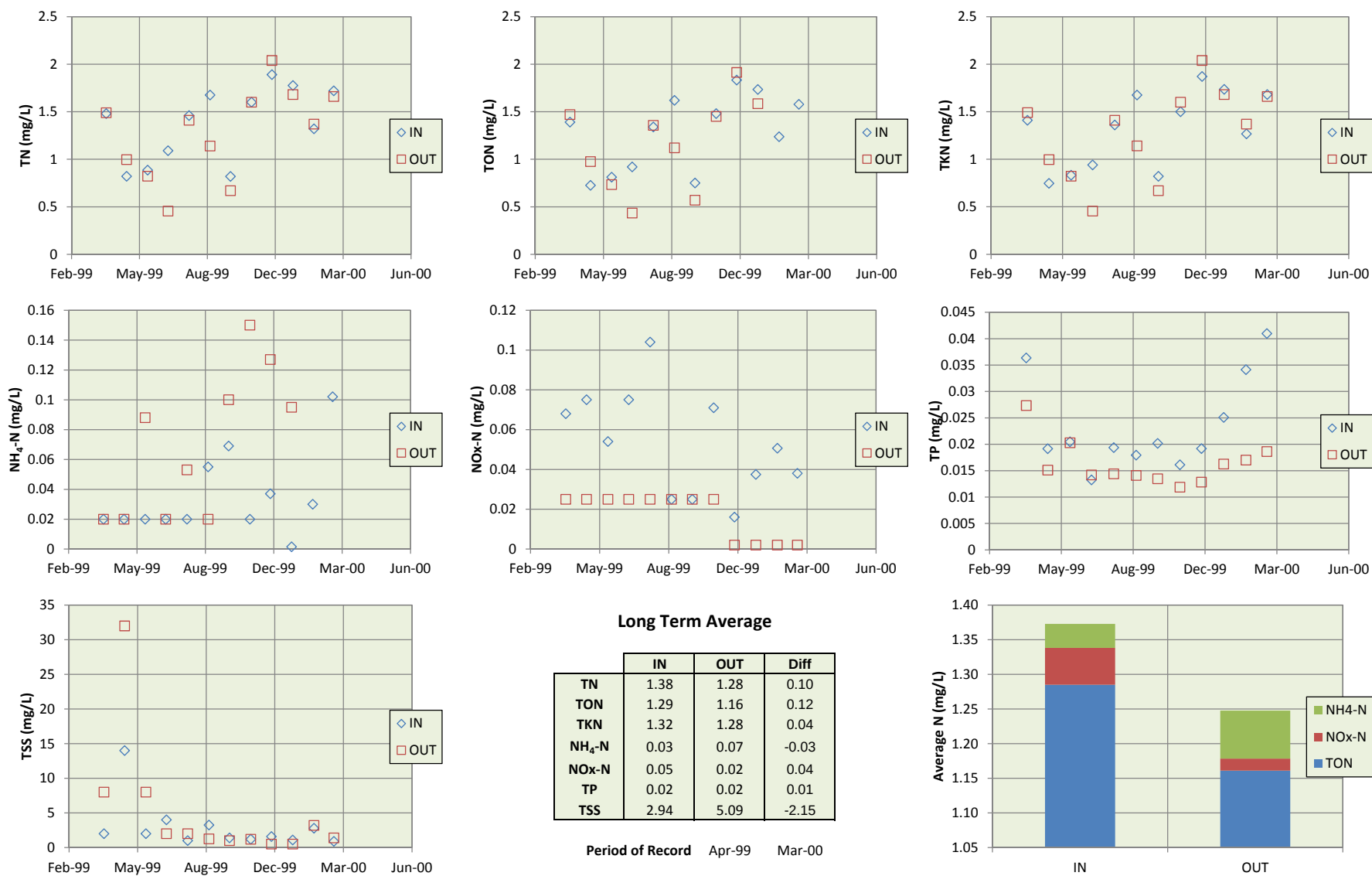
SFWMD Porta-PSTA Mesocosms Treatment 7 - Monthly Water Quality Data Summary



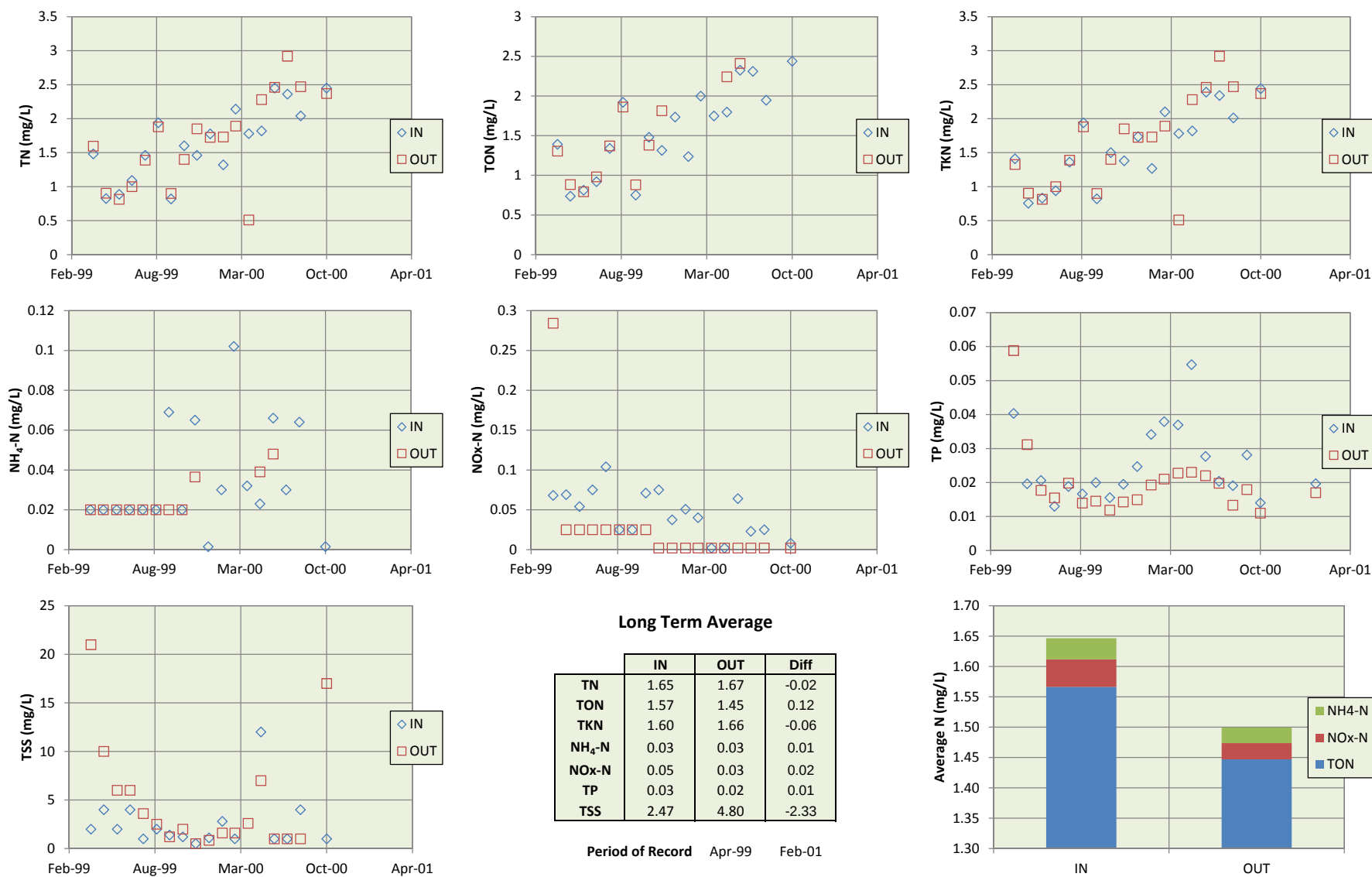
SFWMD Porta-PSTA Mesocosms Treatment 8 - Monthly Water Quality Data Summary



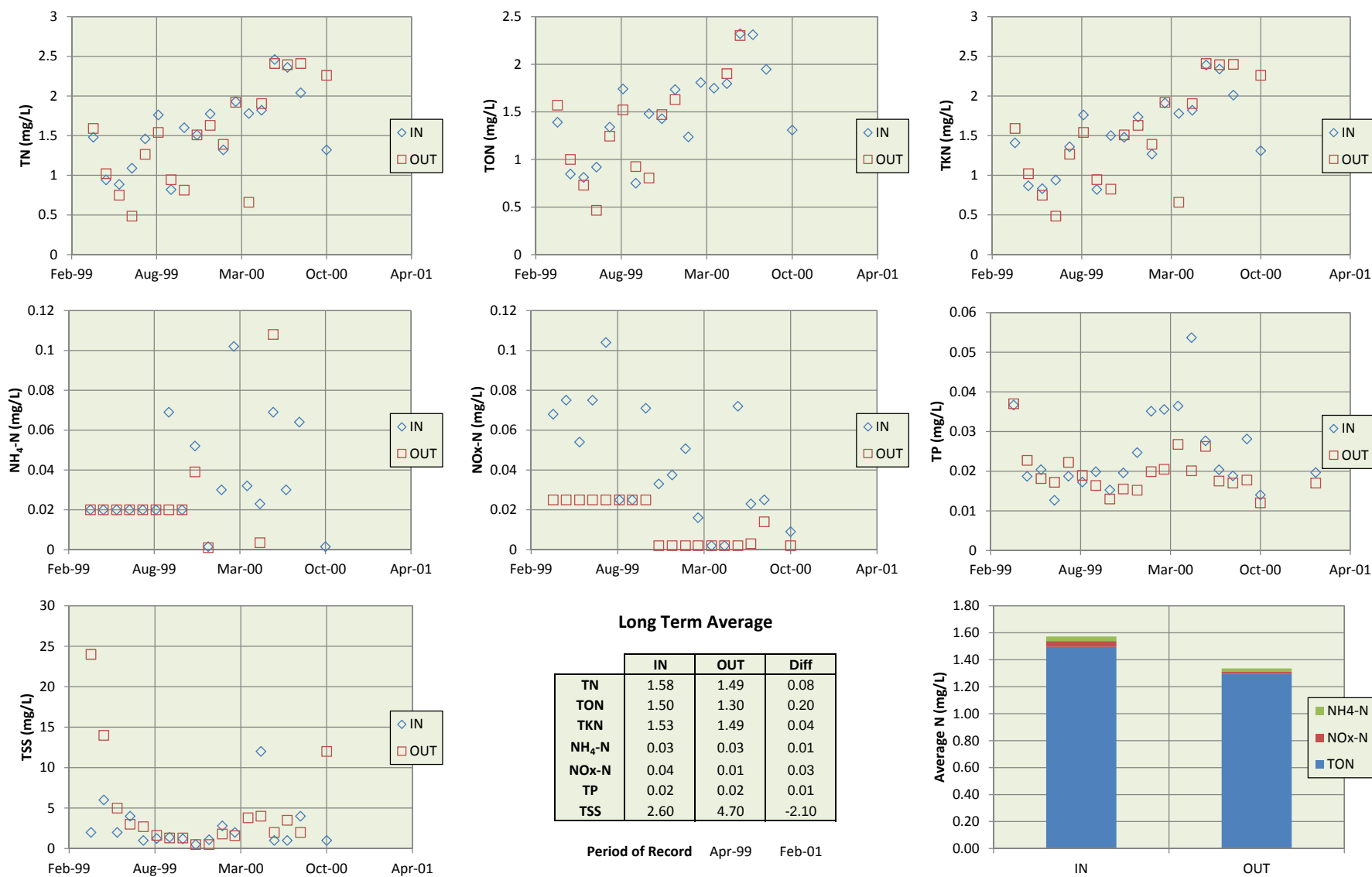
SFWMD Porta-PSTA Mesocosms Treatment 9 - Monthly Water Quality Data Summary



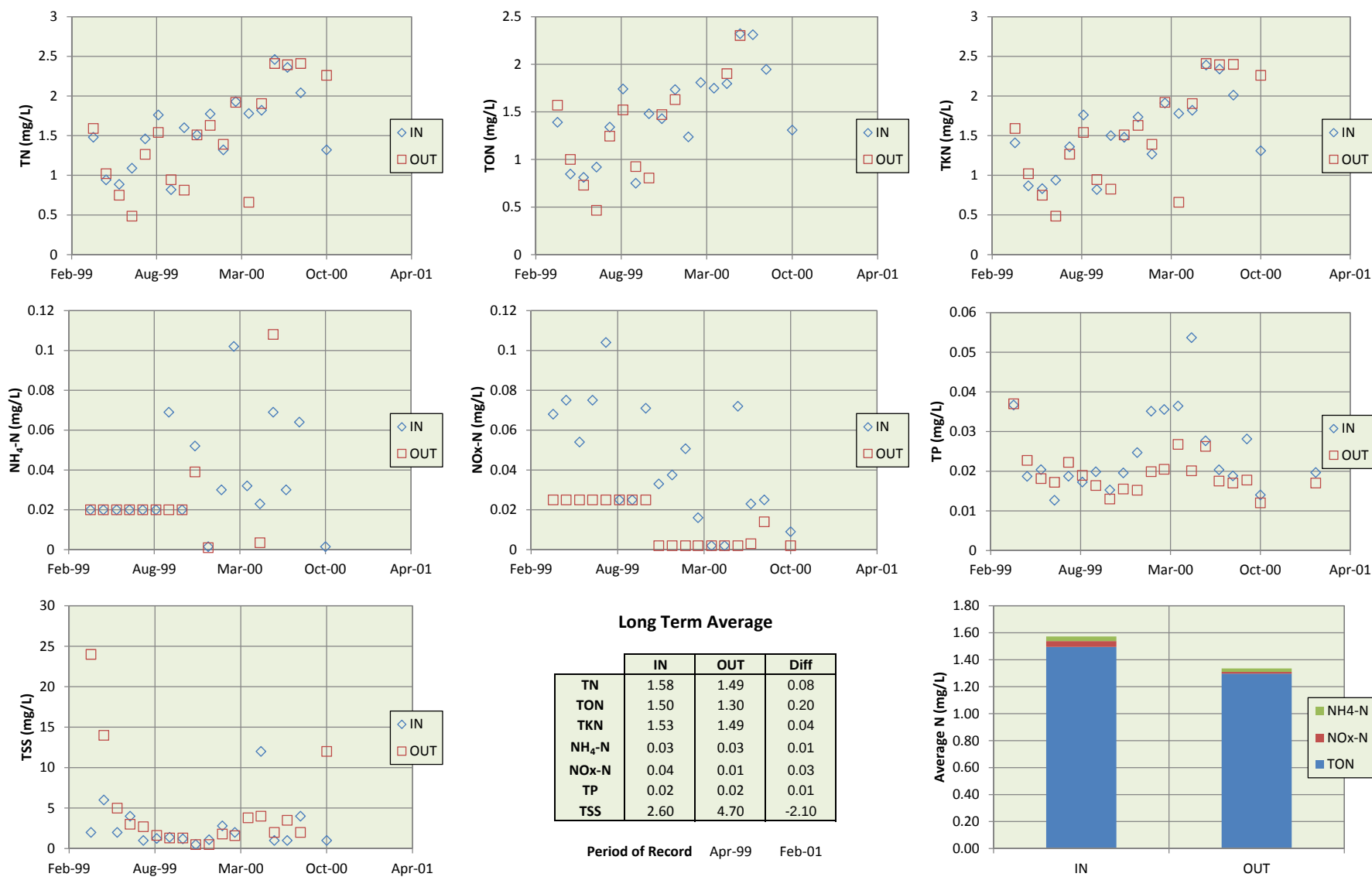
SFWMD Porta-PSTA Mesocosms Treatment 10 - Monthly Water Quality Data Summary



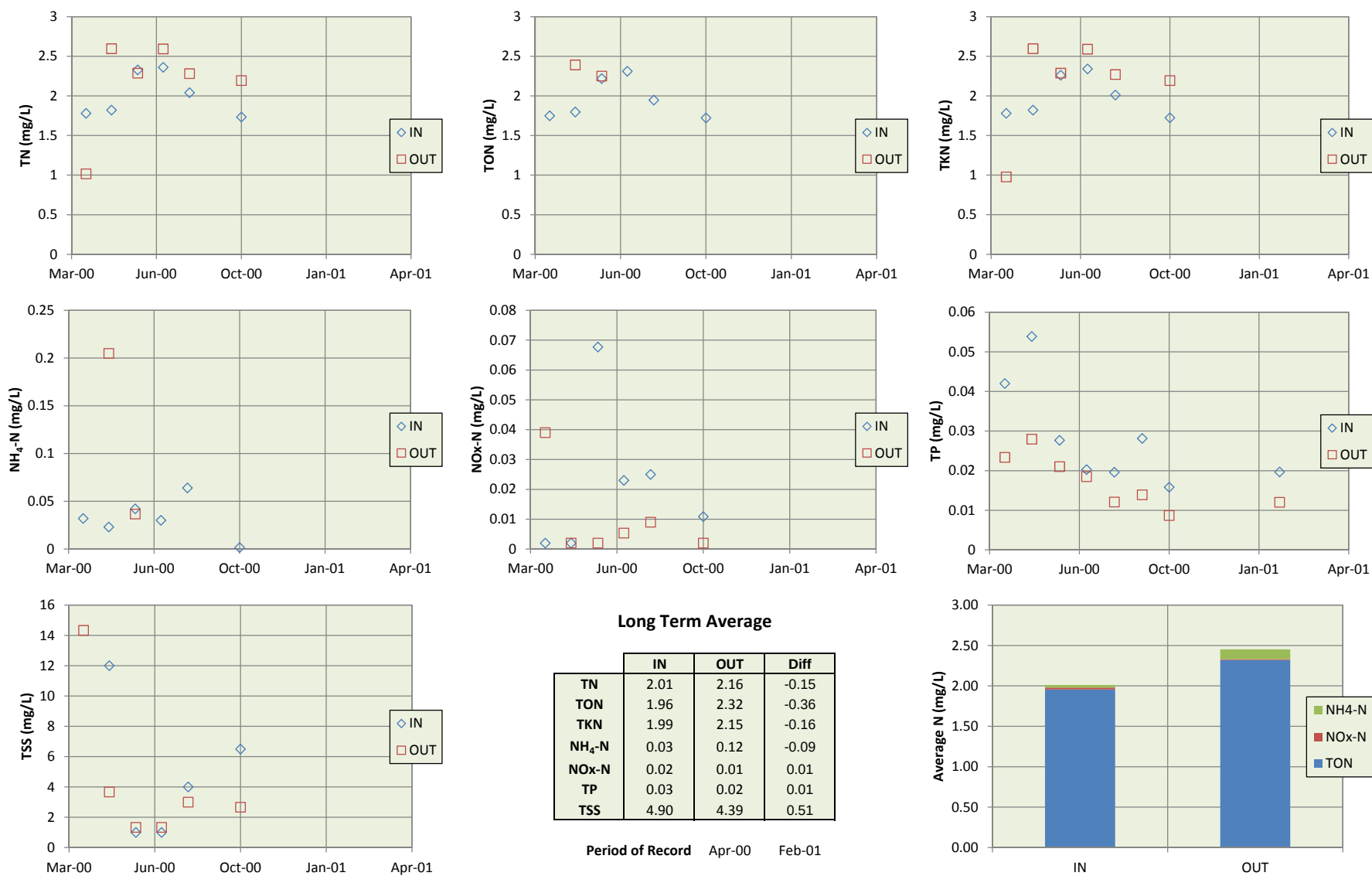
SFWMD Porta-PSTA Mesocosms Treatment 11 - Monthly Water Quality Data Summary



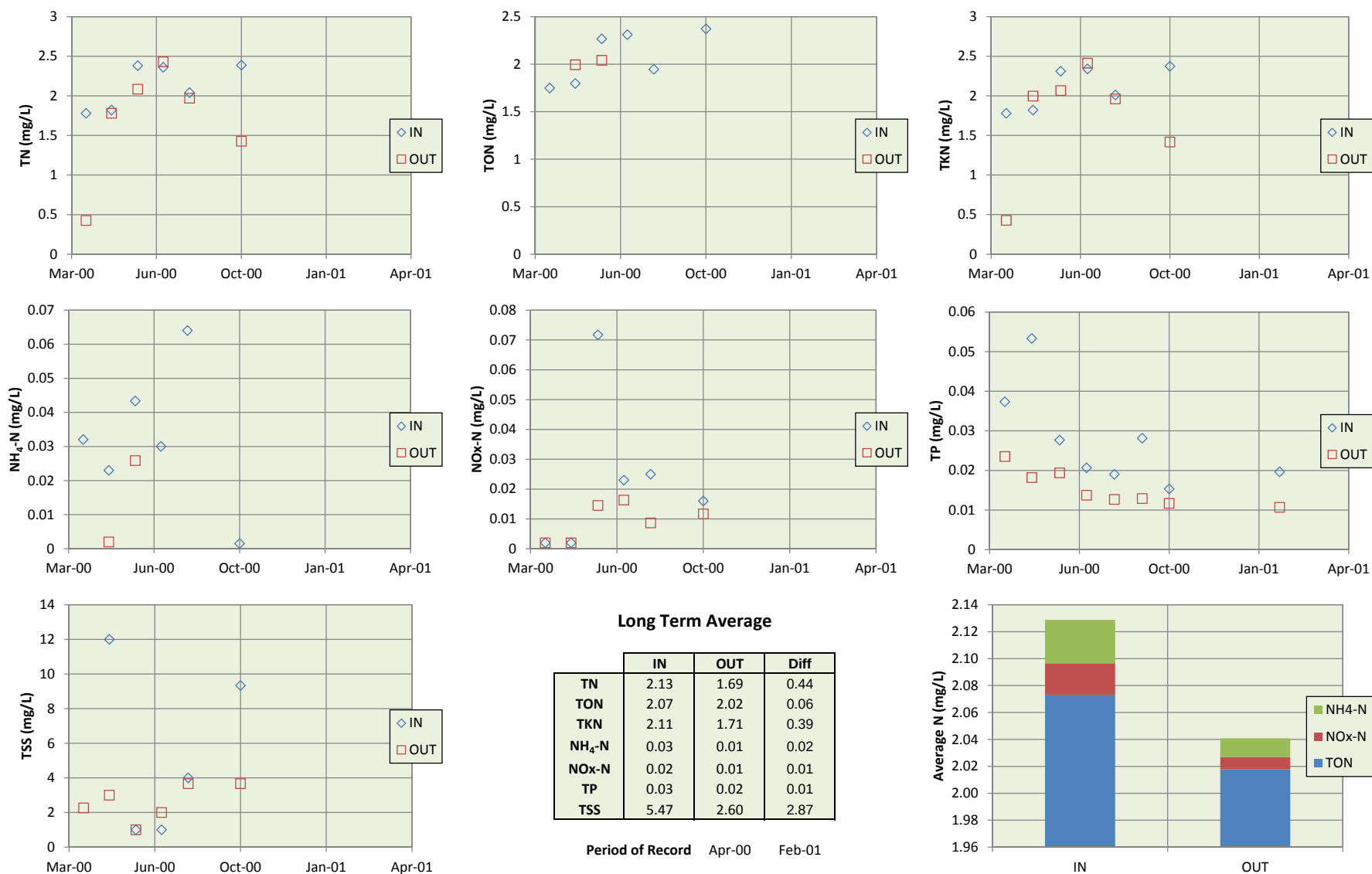
SFWMD Porta-PSTA Mesocosms Treatment 12 - Monthly Water Quality Data Summary



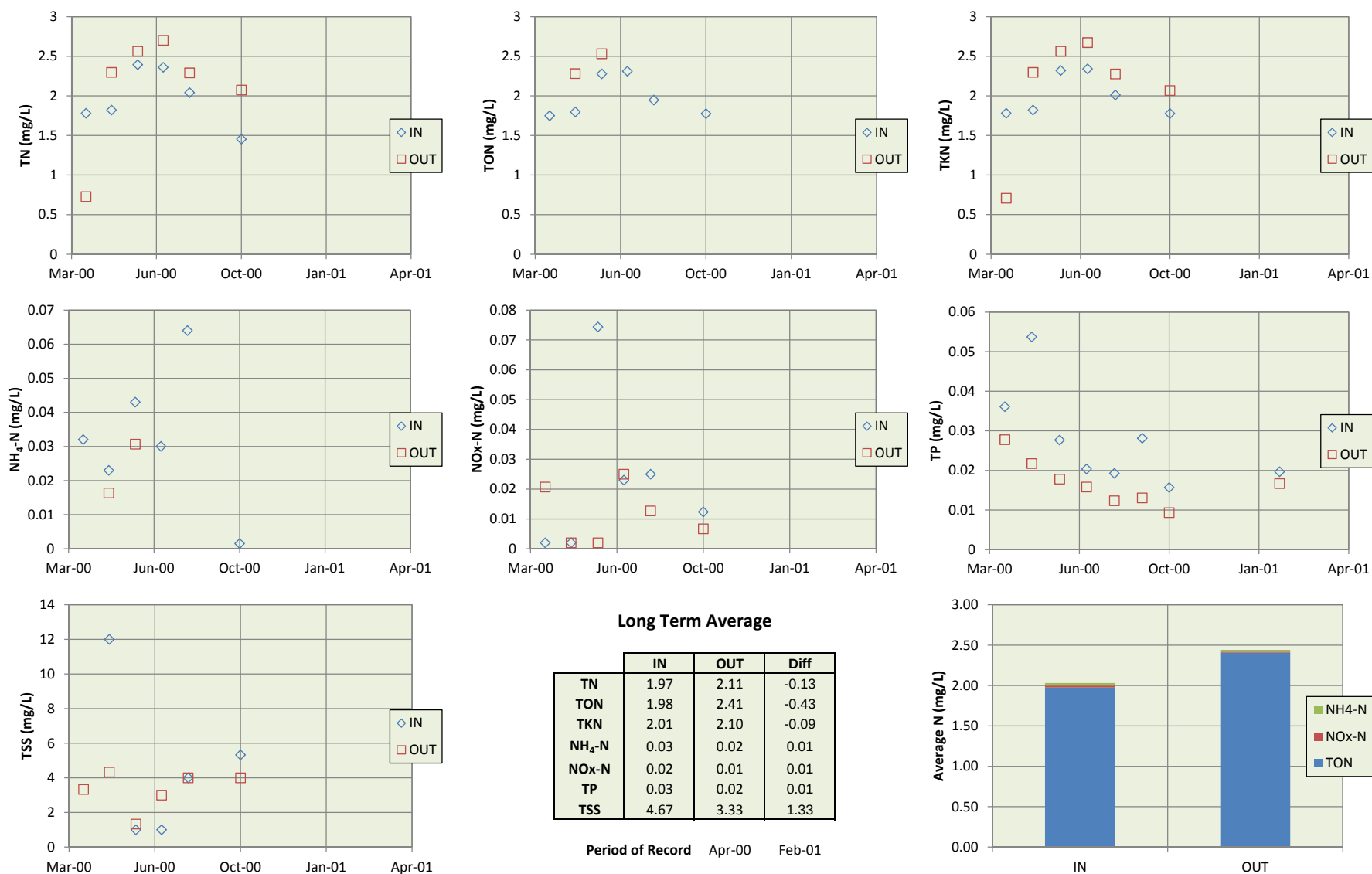
SFWMD Porta-PSTA Mesocosms Treatment 12 - Monthly Water Quality Data Summary



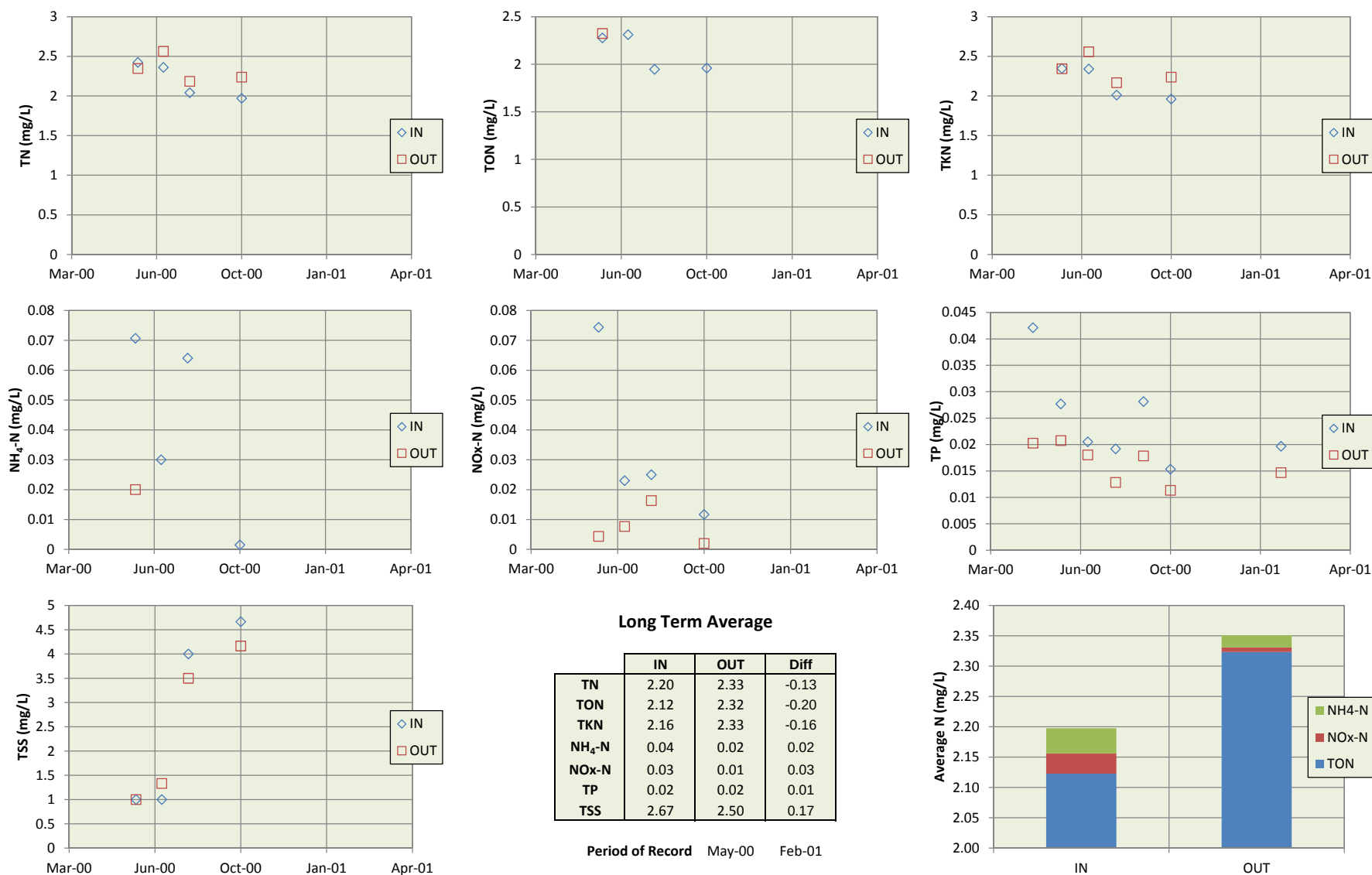
SFWMD Porta-PSTA Mesocosms Treatment 13 - Monthly Water Quality Data Summary



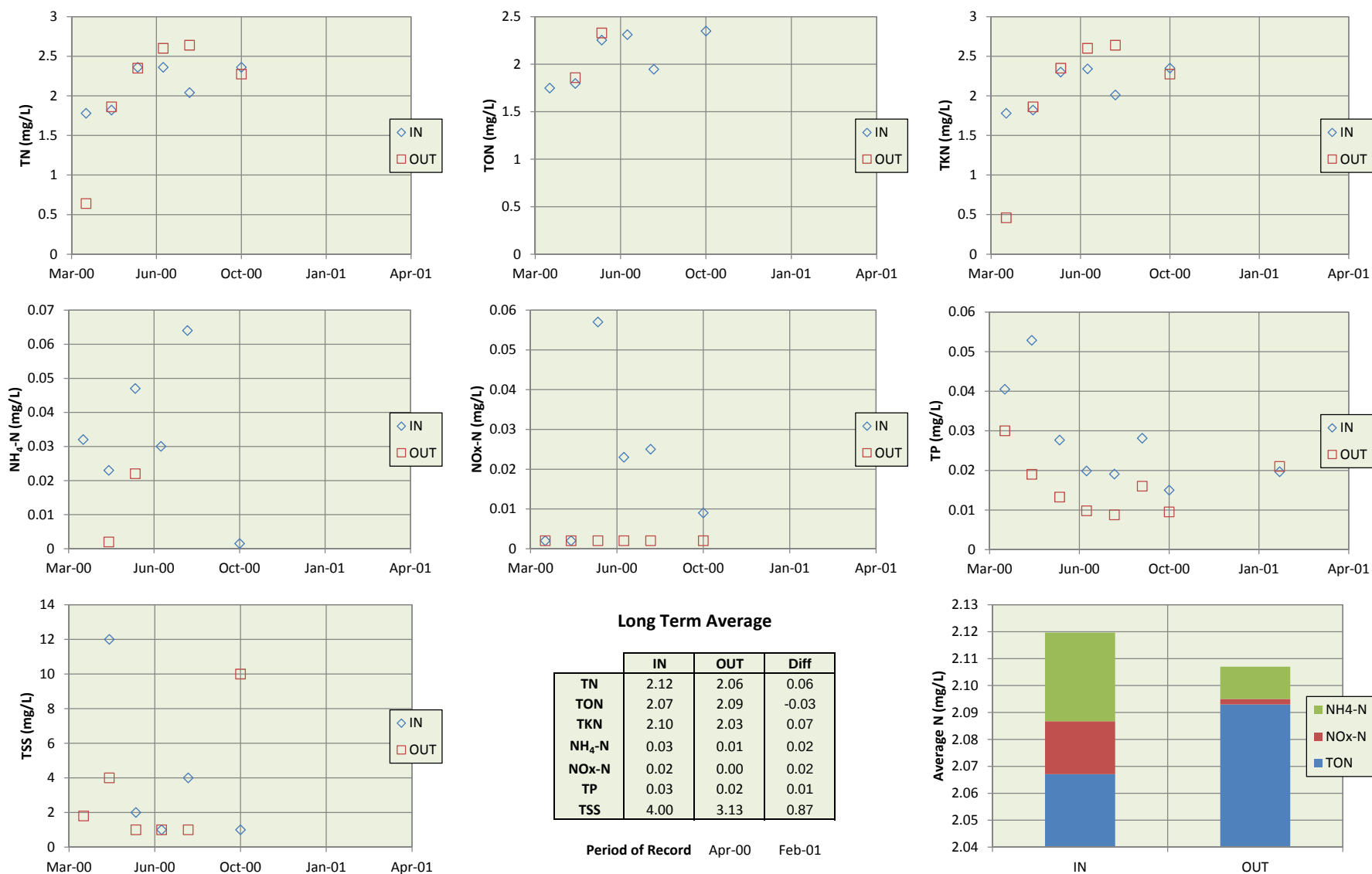
SFWMD Porta-PSTA Mesocosms Treatment 14 - Monthly Water Quality Data Summary



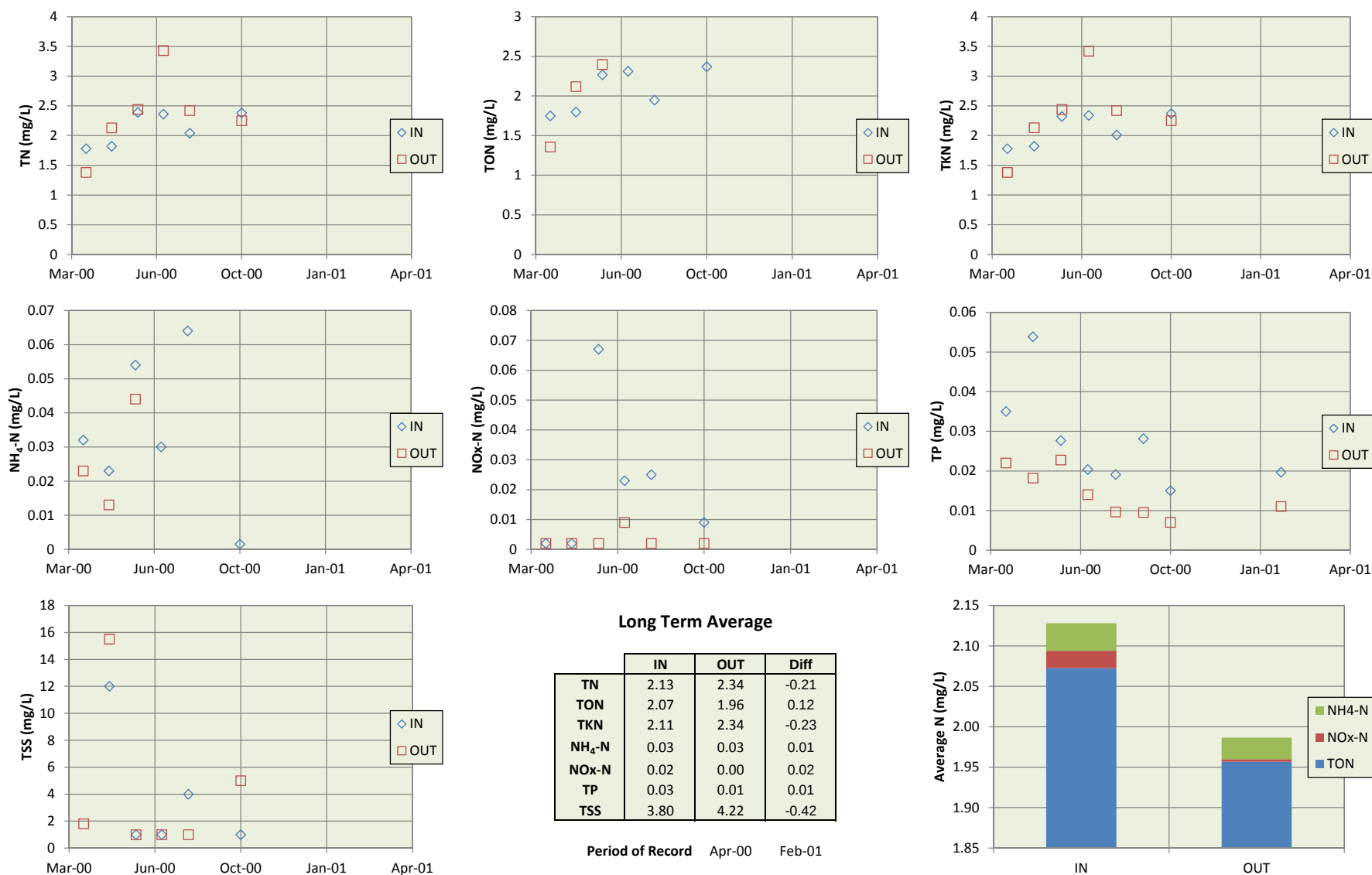
SFWM D Porta-PSTA Mesocosms Treatment 15 - Monthly Water Quality Data Summary



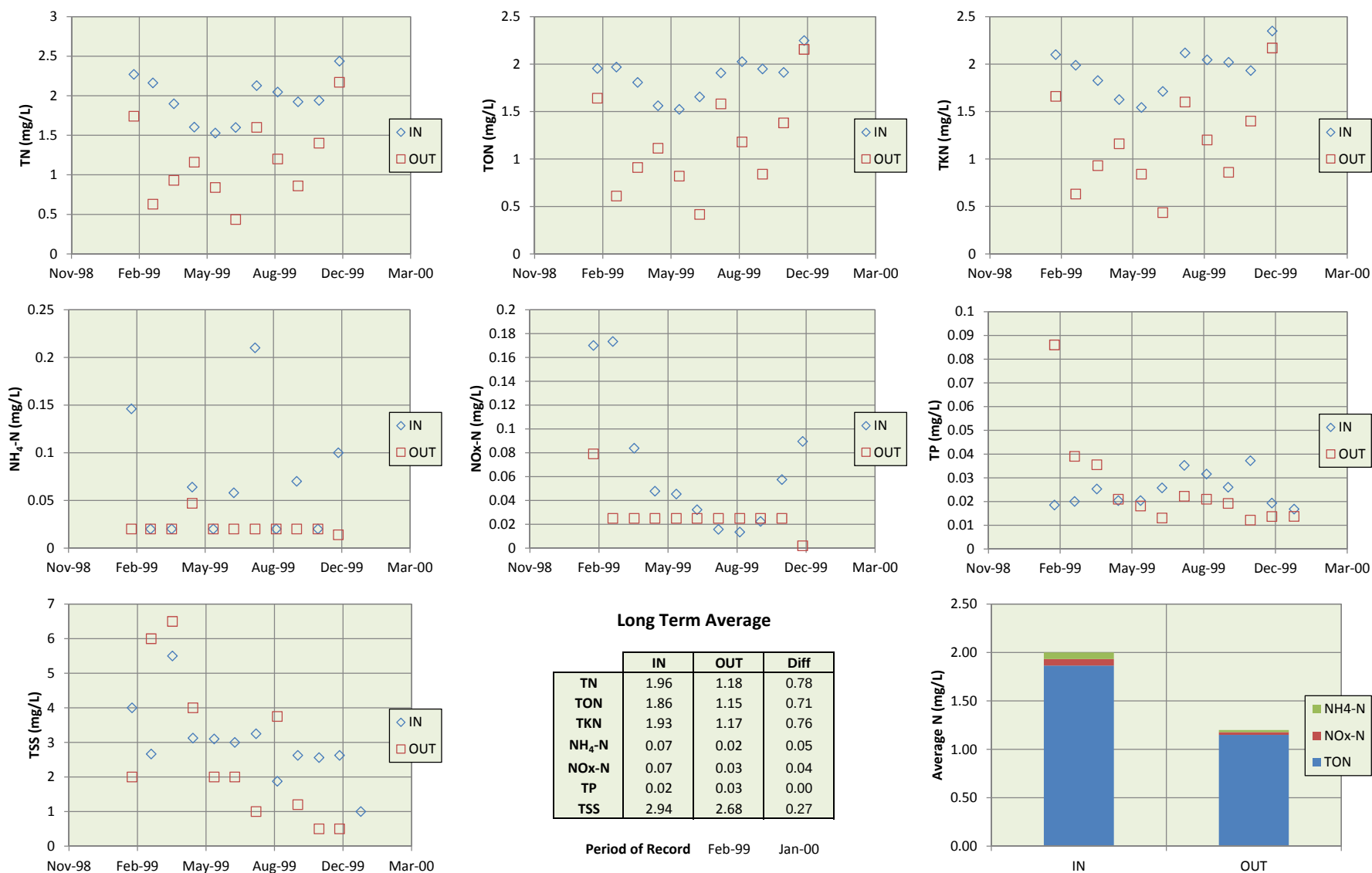
SFWMD Porta-PSTA Mesocosms Treatment 16 - Monthly Water Quality Data Summary



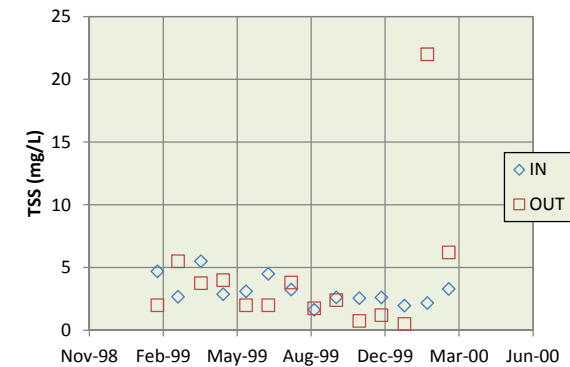
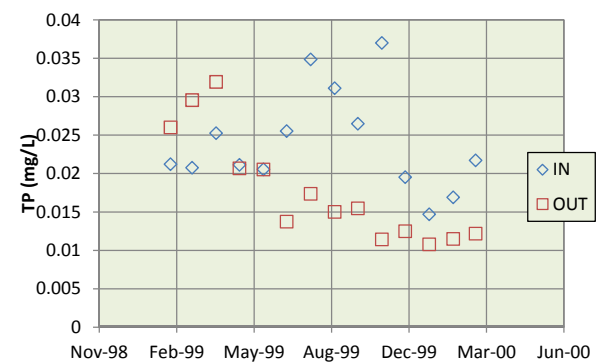
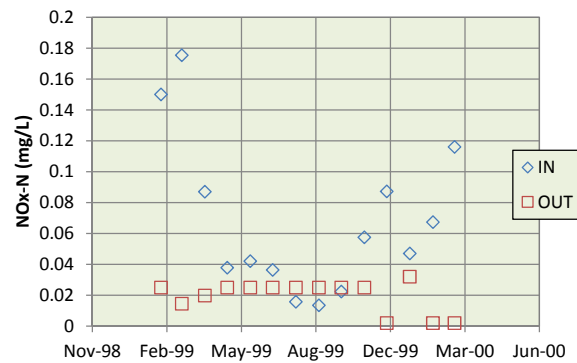
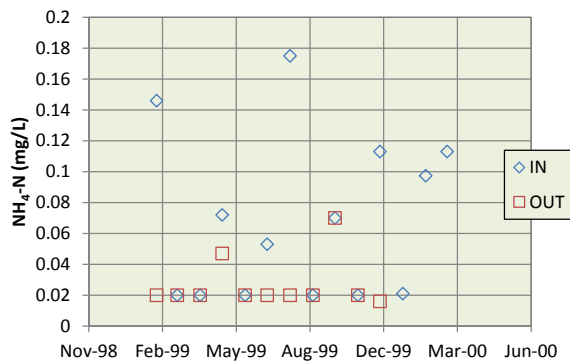
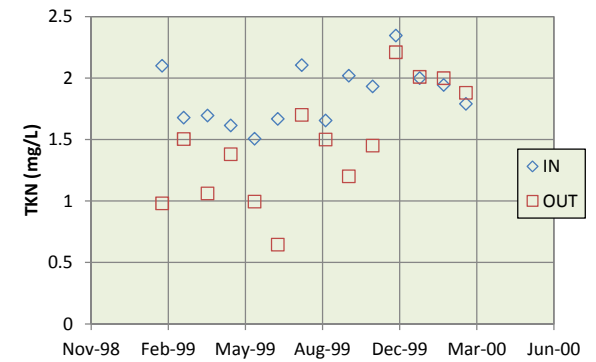
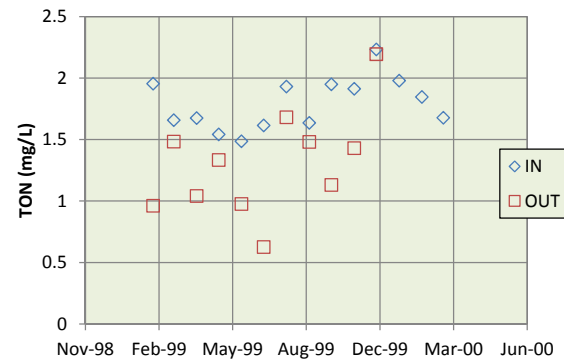
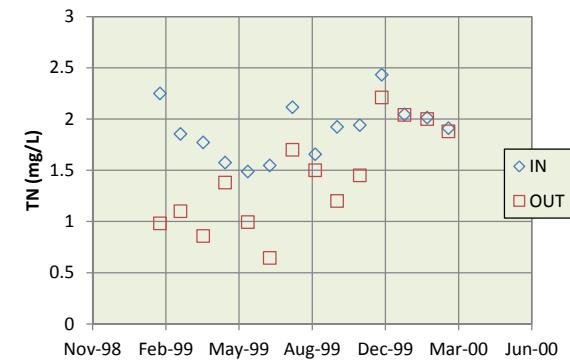
SFWMD Porta-PSTA Mesocosms Treatment 17 - Monthly Water Quality Data Summary



SFWMD Porta-PSTA Mesocosms Treatment 19 - Monthly Water Quality Data Summary



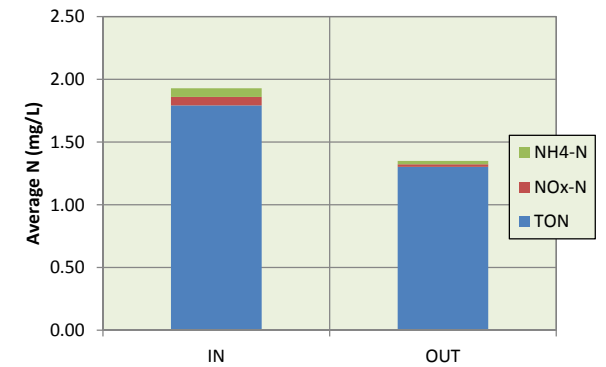
SFWMD PSTA Test Cells Treatment 1 - Monthly Water Quality Data Summary



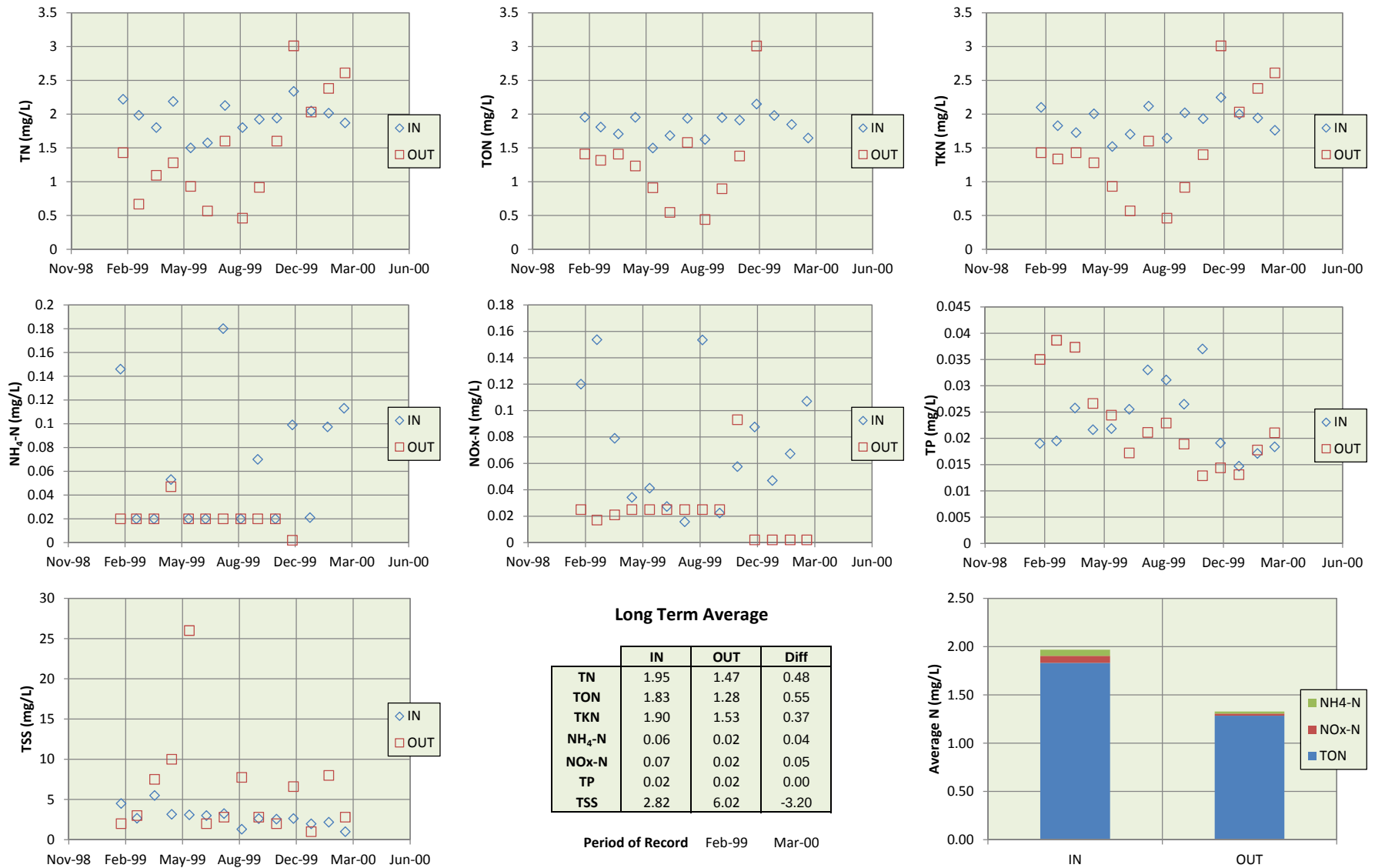
Long Term Average

	IN	OUT	Diff
TN	1.89	1.42	0.47
TON	1.79	1.30	0.49
TKN	1.86	1.47	0.40
NH ₄ -N	0.07	0.03	0.04
NO _x -N	0.07	0.02	0.05
TP	0.02	0.02	0.01
TSS	3.11	4.13	-1.03

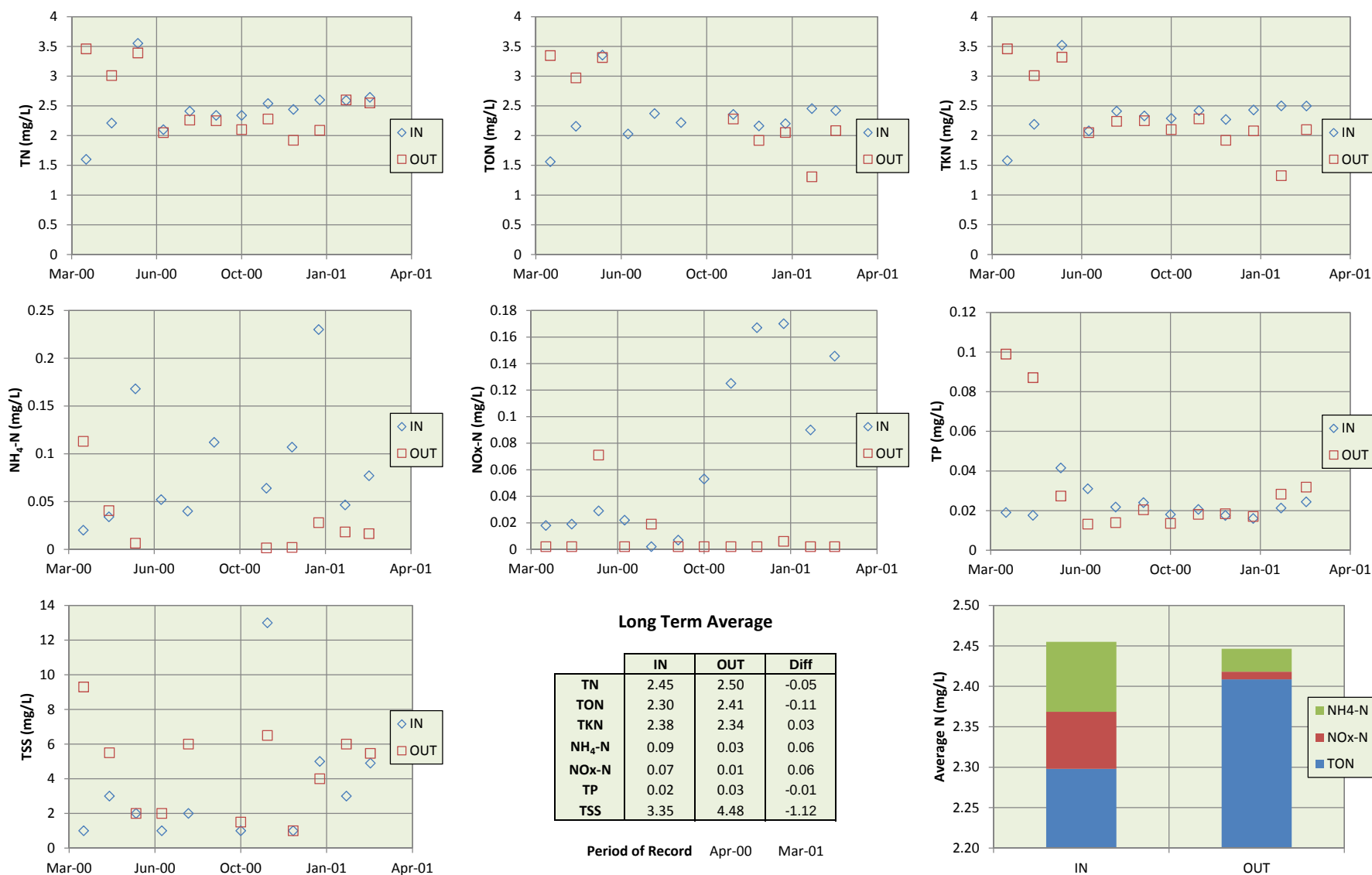
Period of Record Feb-99 Mar-00



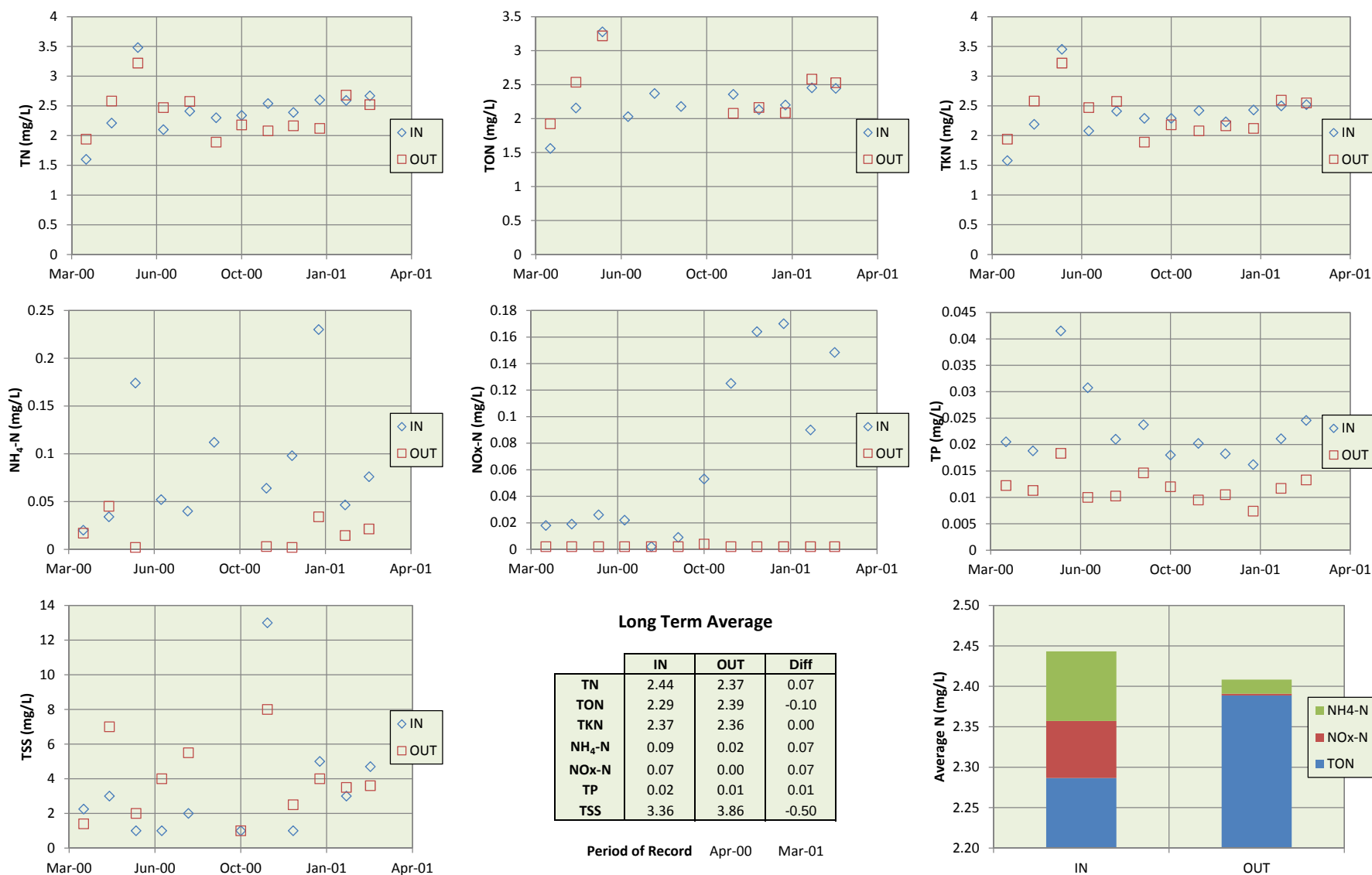
SFWMD PSTA Test Cells Treatment 2 - Monthly Water Quality Data Summary



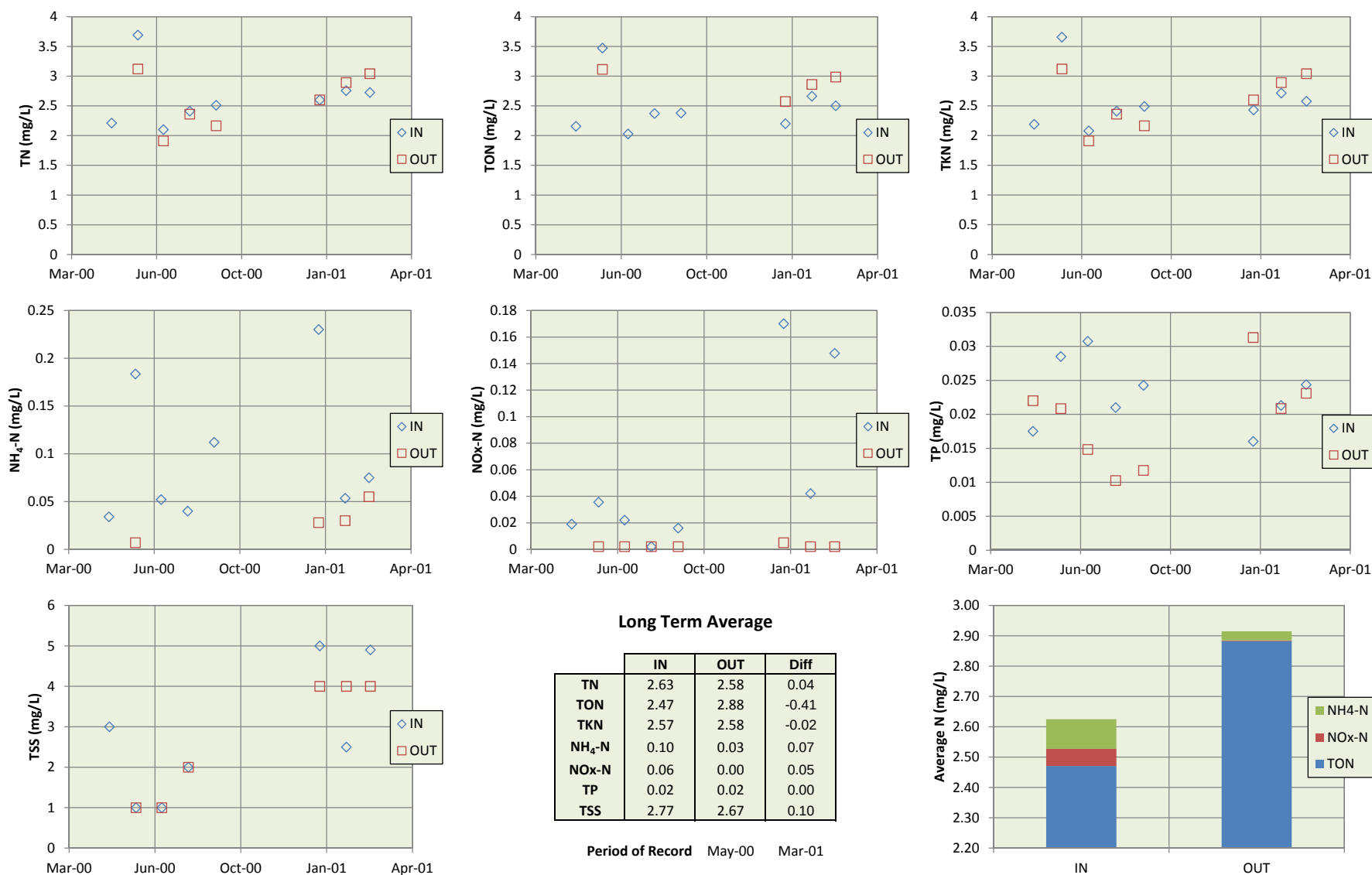
SFWMD PSTA Test Cells Treatment 3 - Monthly Water Quality Data Summary



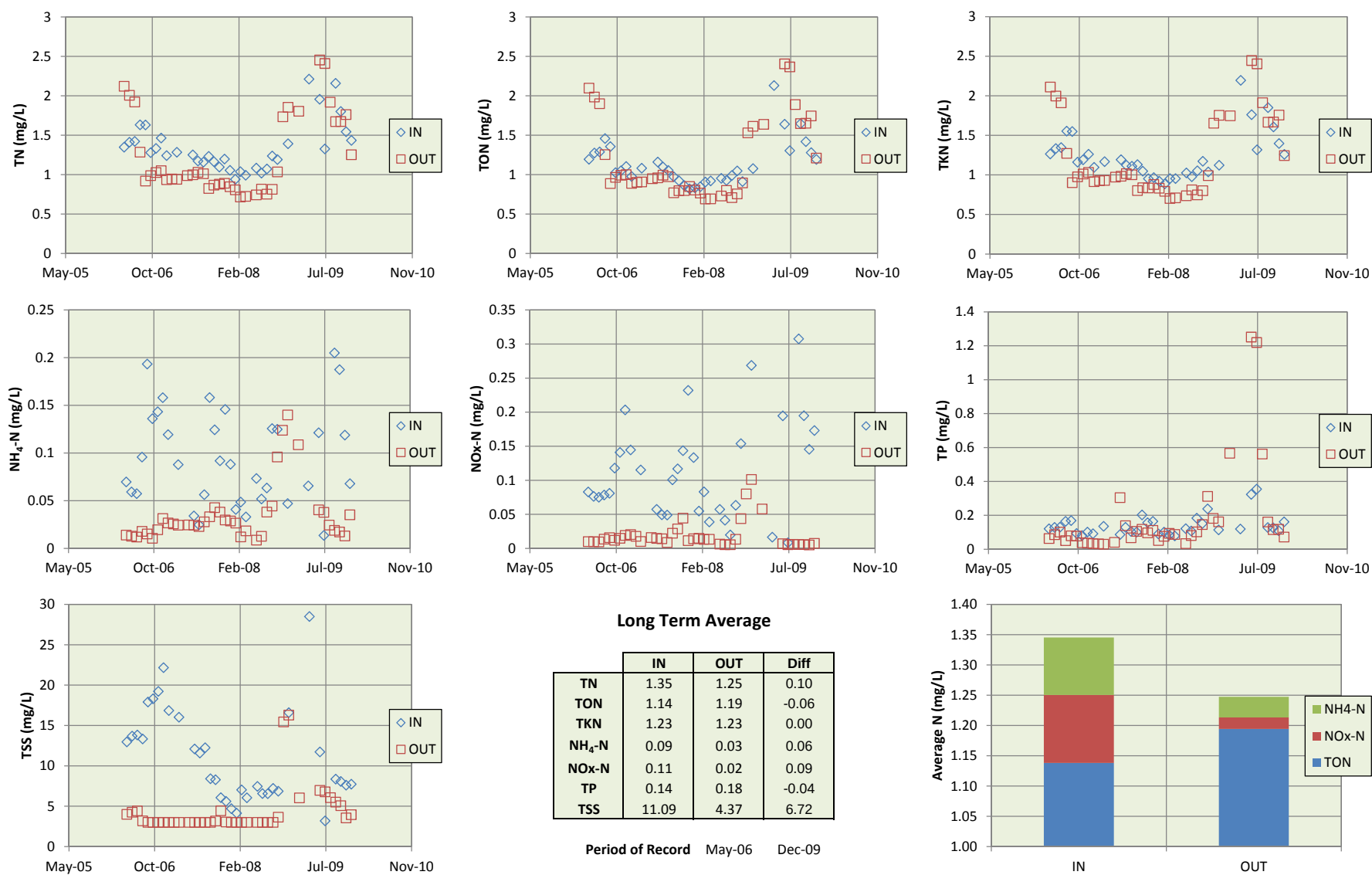
SFWMD PSTA Test Cells Treatment 4 - Monthly Water Quality Data Summary



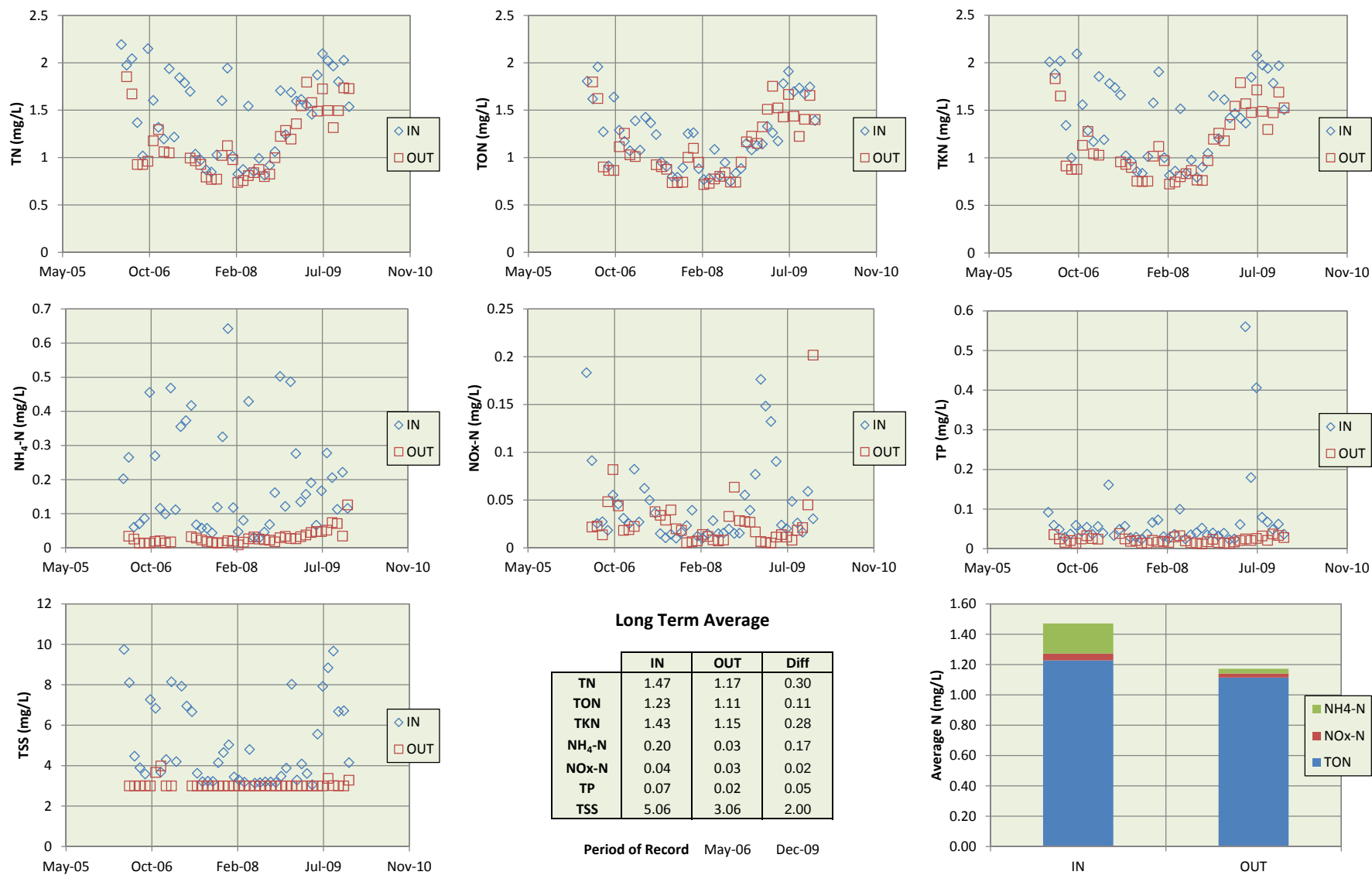
SFWMD PSTA Test Cells Treatment 5 - Monthly Water Quality Data Summary



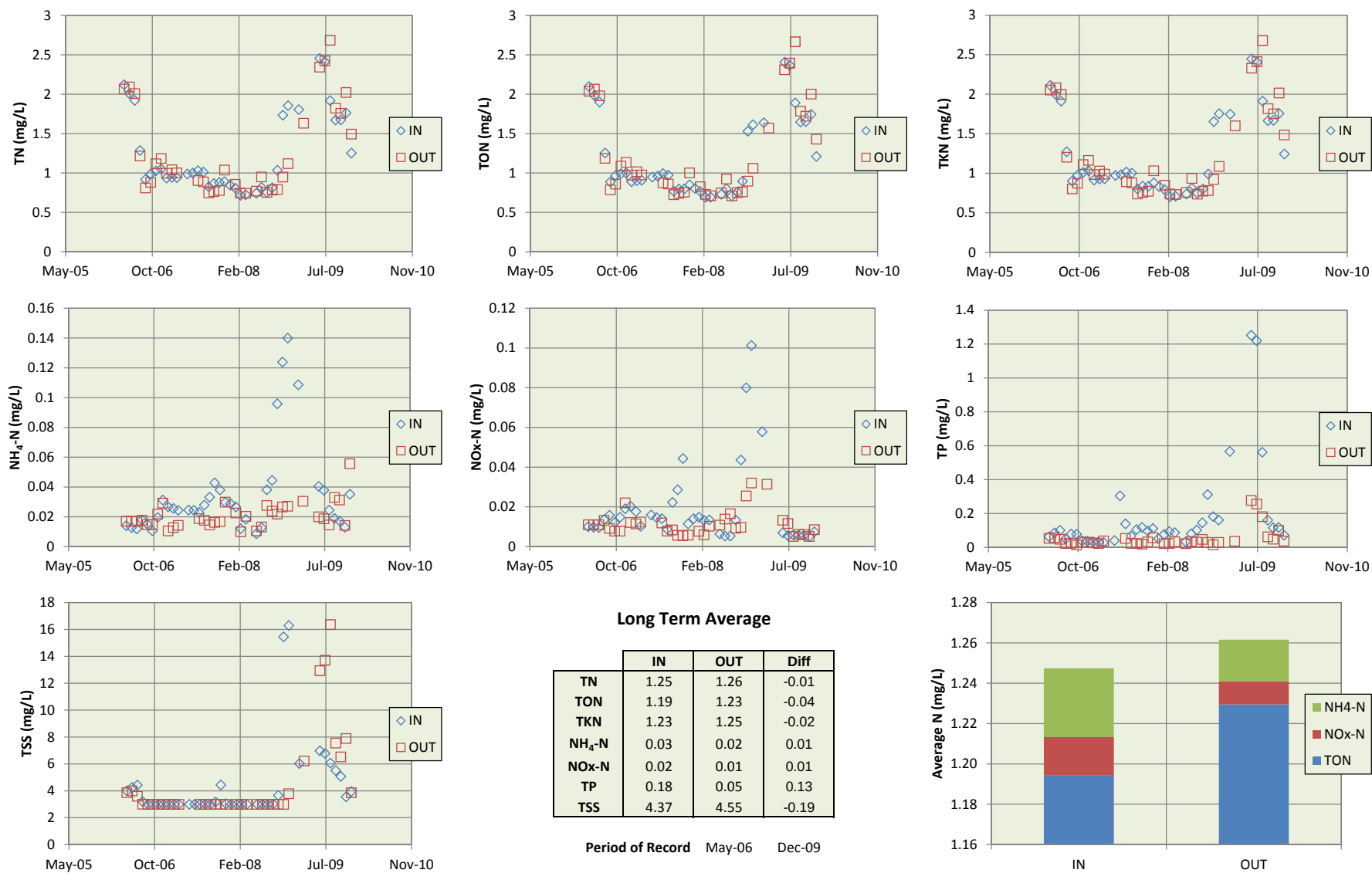
SFWMD PSTA Test Cells Treatment 6 - Monthly Water Quality Data Summary



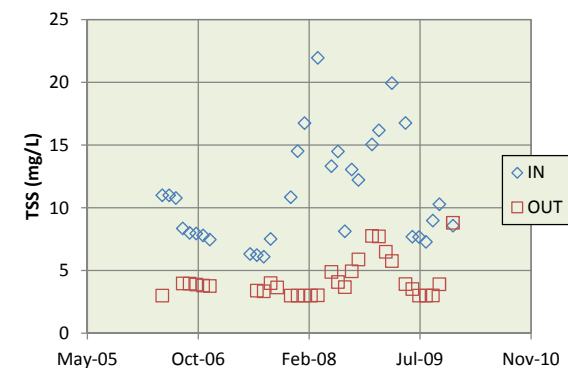
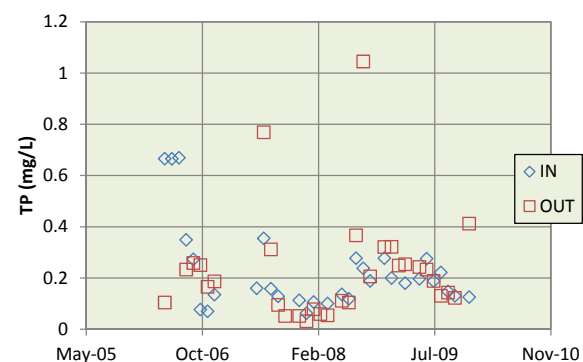
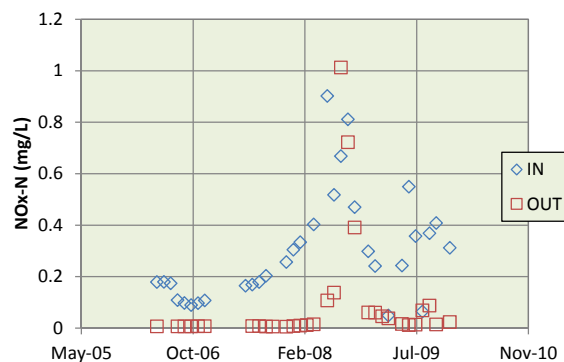
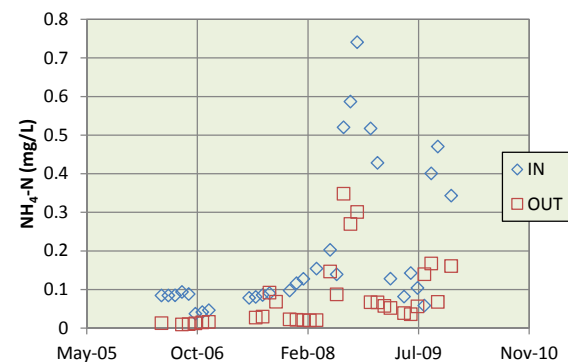
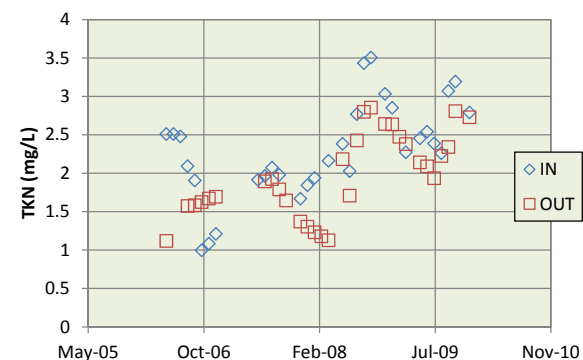
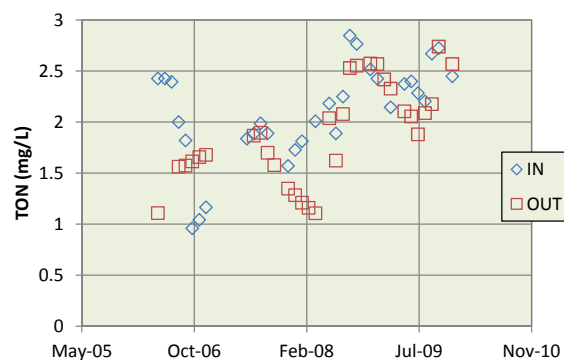
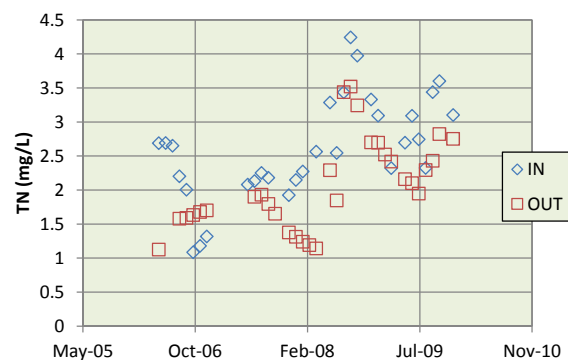
STA-1E Cell 3 - Monthly Water Quality Data Summary



STA-1E Cell 4S - Monthly Water Quality Data Summary



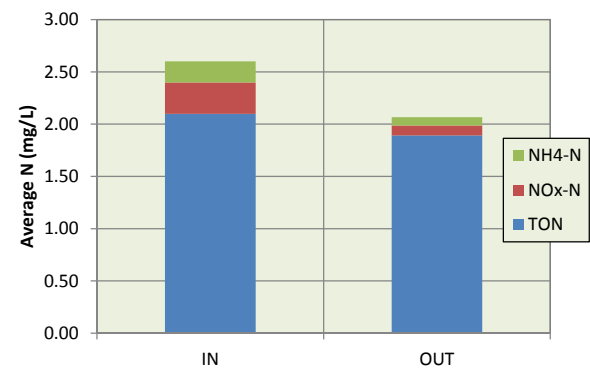
STA-1E Cell 4N - Monthly Water Quality Data Summary



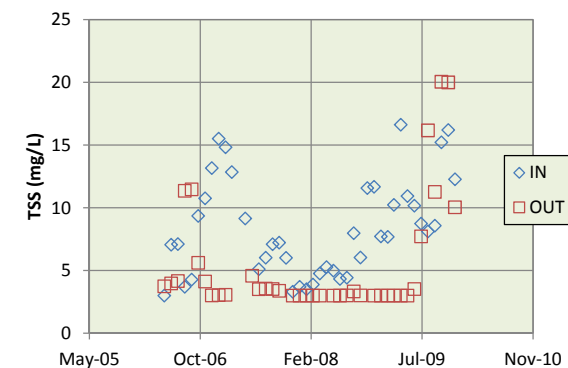
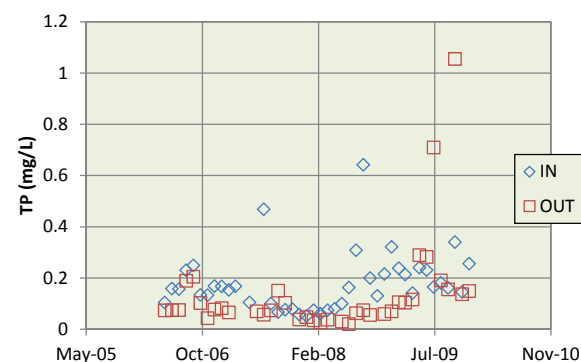
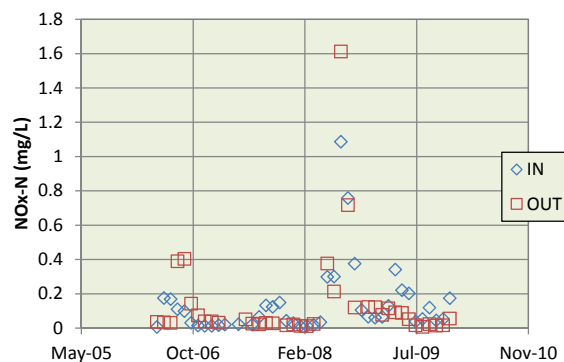
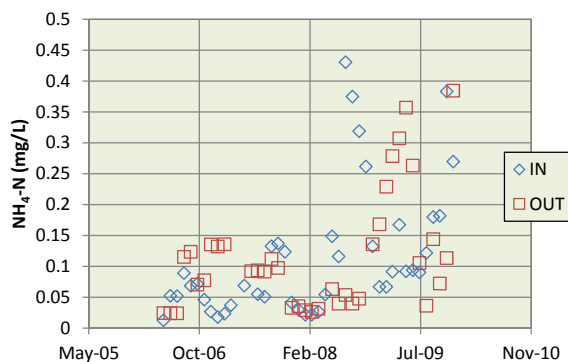
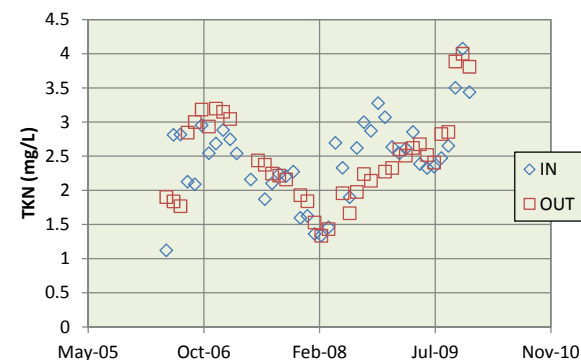
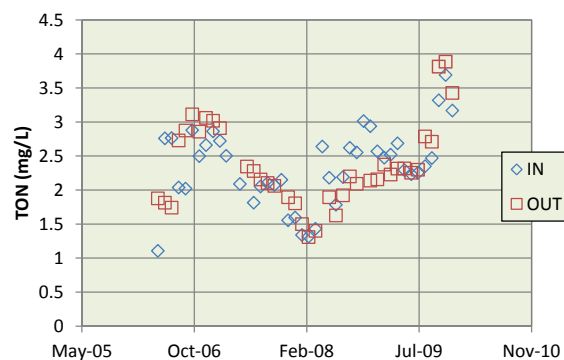
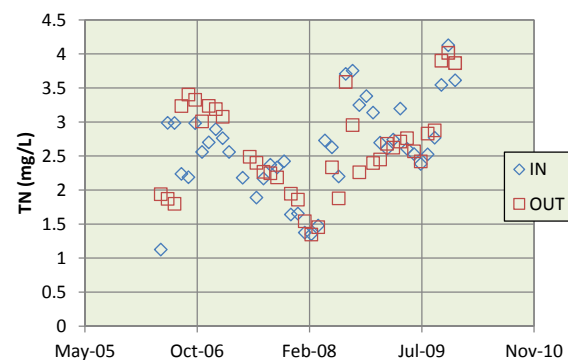
Long Term Average

	IN	OUT	Diff
TN	2.60	2.07	0.53
TON	2.10	1.89	0.21
TKN	2.30	1.97	0.33
NH ₄ -N	0.20	0.08	0.12
NO _x -N	0.30	0.09	0.21
TP	0.23	0.23	-0.01
TSS	11.04	4.26	6.77

Period of Record May-06 Dec-09



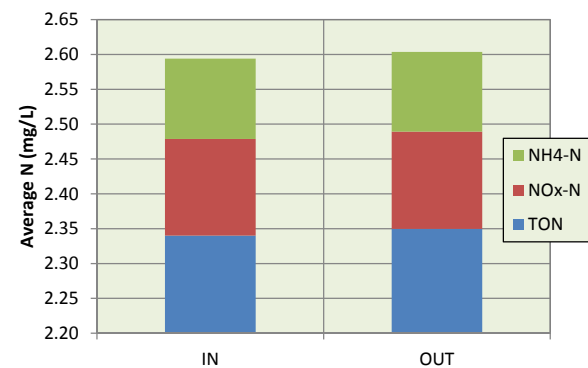
STA-1E Cell 5 - Monthly Water Quality Data Summary



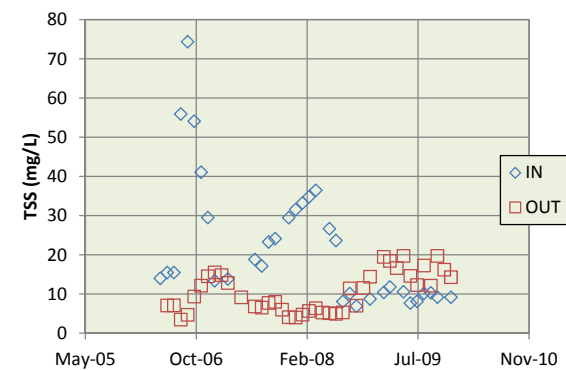
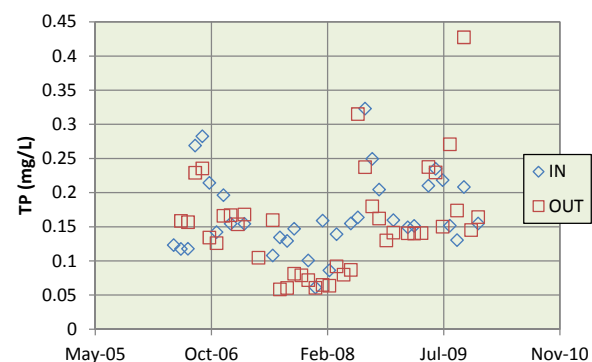
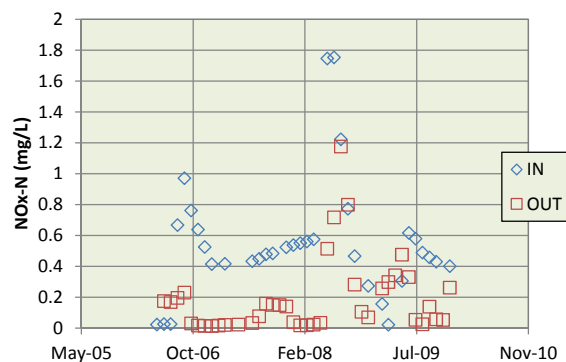
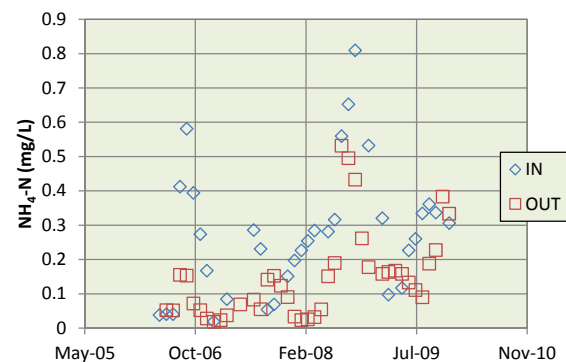
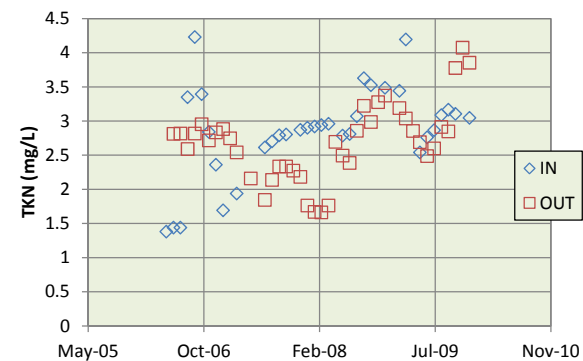
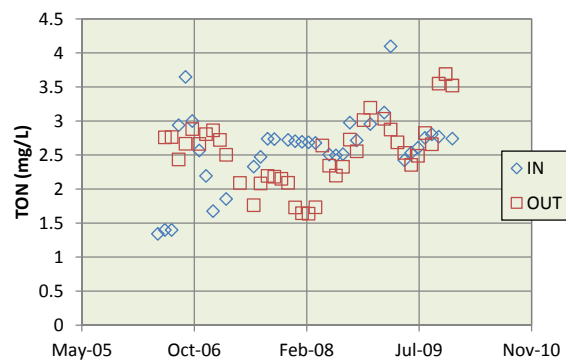
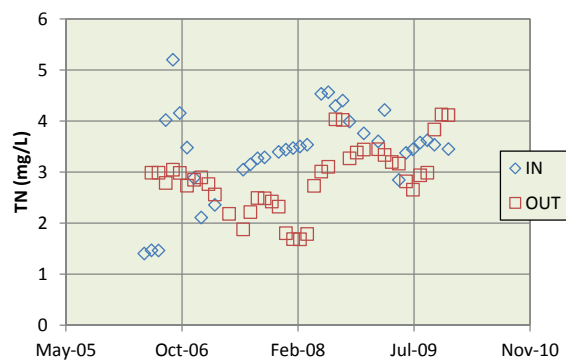
Long Term Average

	IN	OUT	Diff
TN	2.59	2.60	-0.01
TON	2.34	2.35	-0.01
TKN	2.46	2.46	-0.01
NH ₄ -N	0.12	0.11	0.00
NO _x -N	0.14	0.14	0.00
TP	0.18	0.14	0.04
TSS	8.34	5.51	2.83

Period of Record May-06 Dec-09



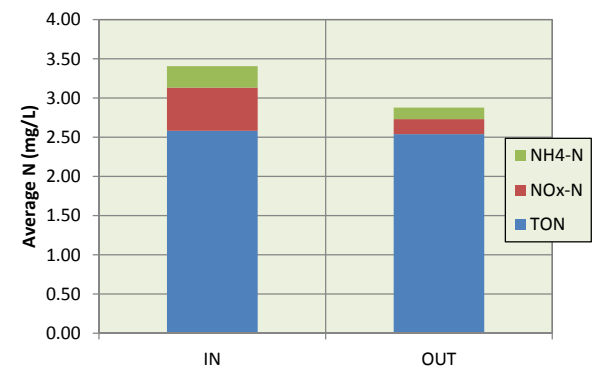
STA-1E Cell 6 - Monthly Water Quality Data Summary



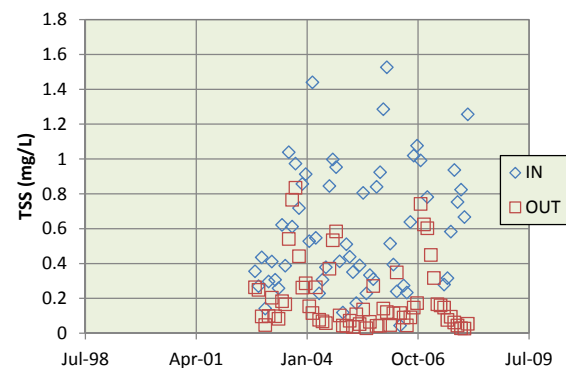
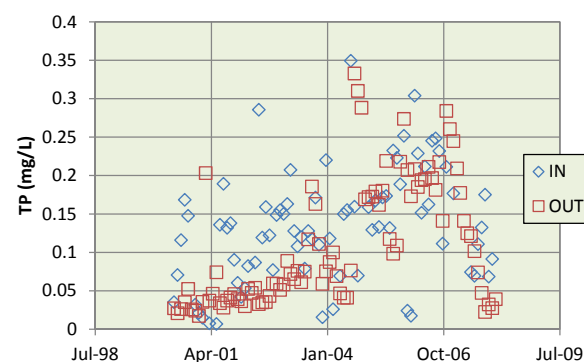
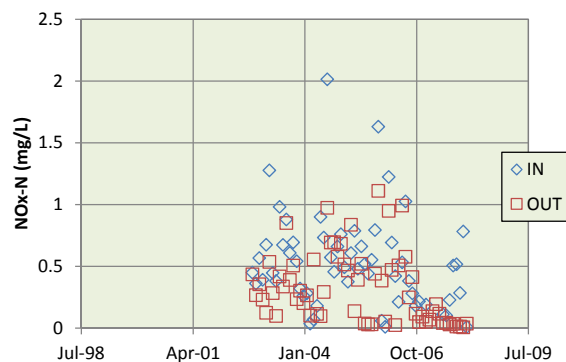
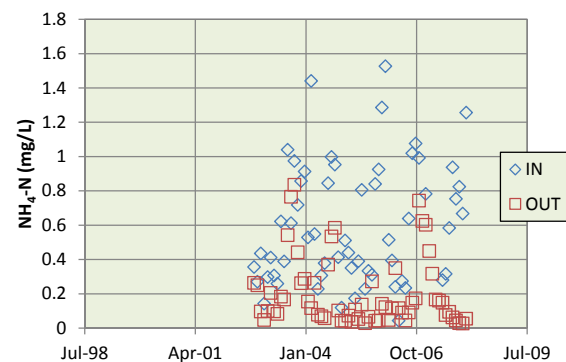
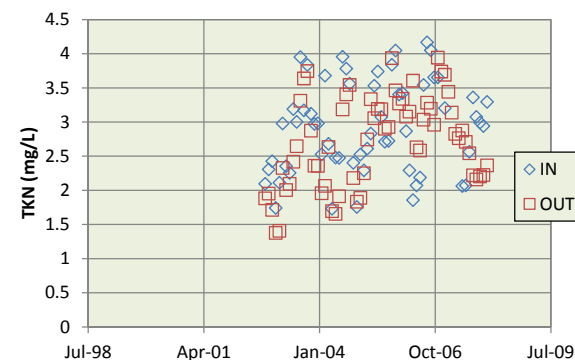
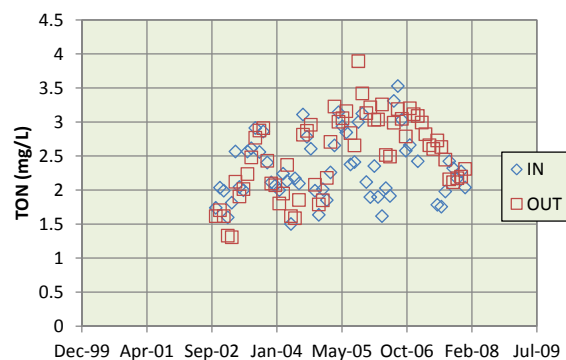
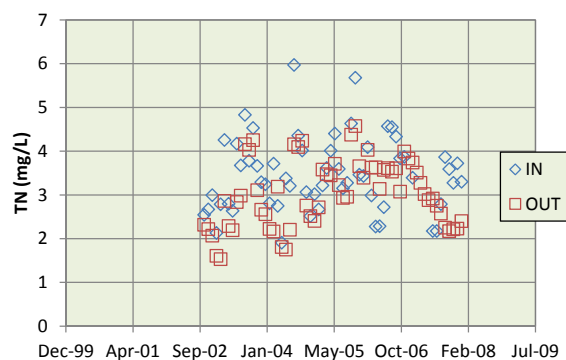
Long Term Average

	IN	OUT	Diff
TN	3.41	2.88	0.53
TON	2.58	2.54	0.04
TKN	2.86	2.69	0.17
NH ₄ -N	0.27	0.15	0.13
NO _x -N	0.55	0.19	0.36
TP	0.17	0.15	0.01
TSS	22.00	10.42	11.58

Period of Record May-06 Dec-09



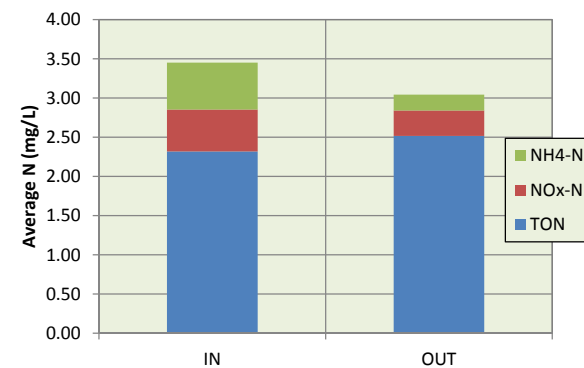
STA-1E Cell 7 - Monthly Water Quality Data Summary



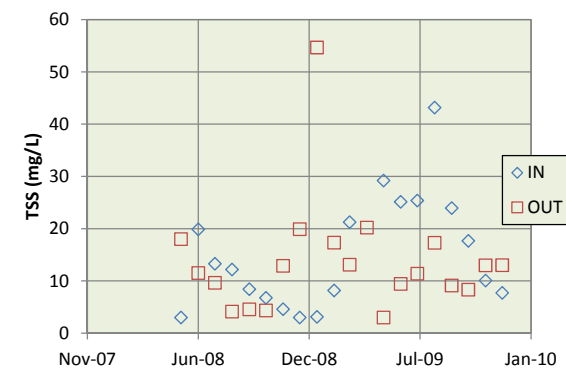
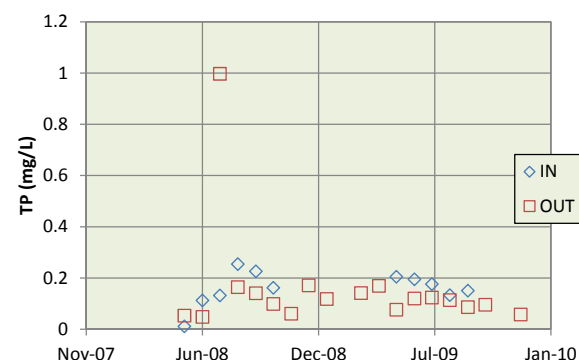
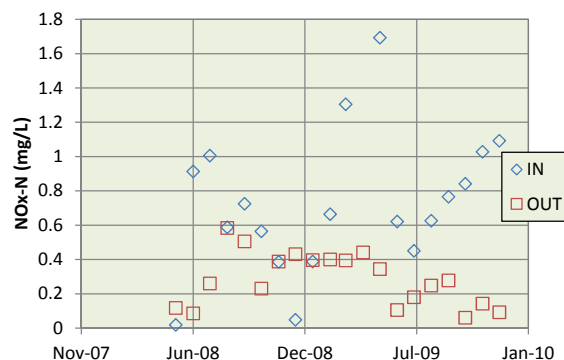
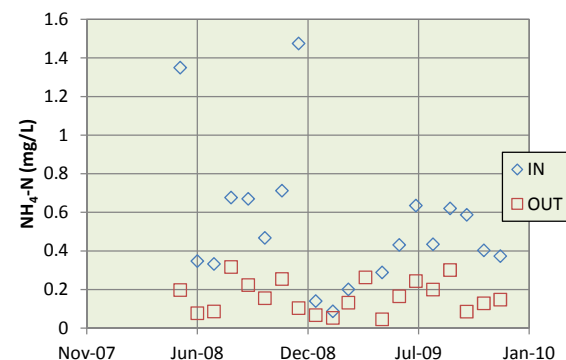
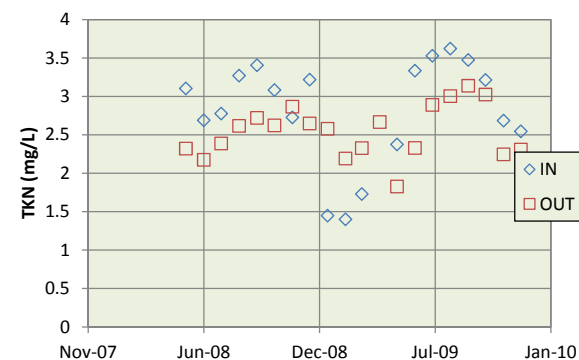
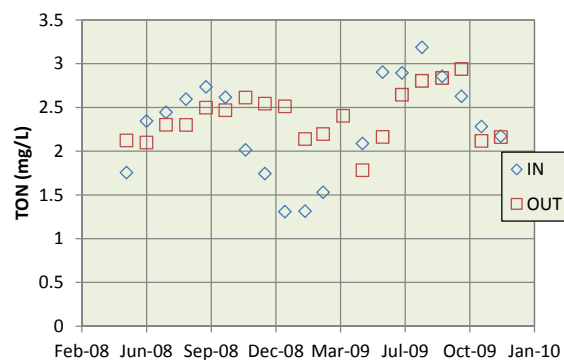
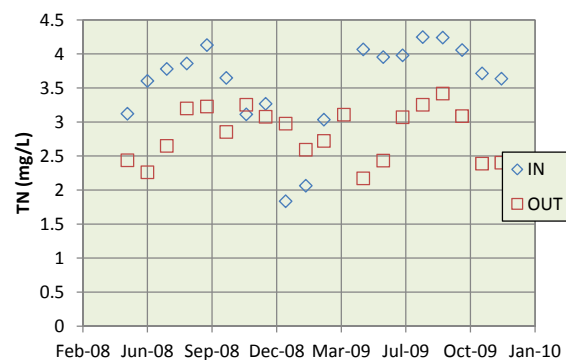
Long Term Average

	IN	OUT	Diff
TN	3.45	3.04	0.41
TON	2.32	2.52	-0.20
TKN	2.92	2.72	0.20
NH ₄ -N	0.60	0.20	0.40
NO _x -N	0.53	0.32	0.21
TP	0.13	0.11	0.02
TSS	0.60	0.20	0.40

Period of Record Jun-00 Jan-08



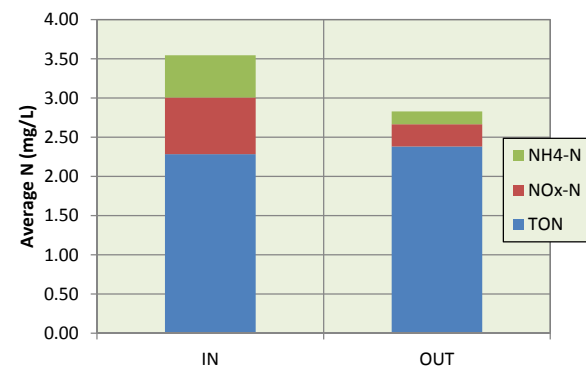
STA-1W Cell 1 - Monthly Water Quality Data Summary



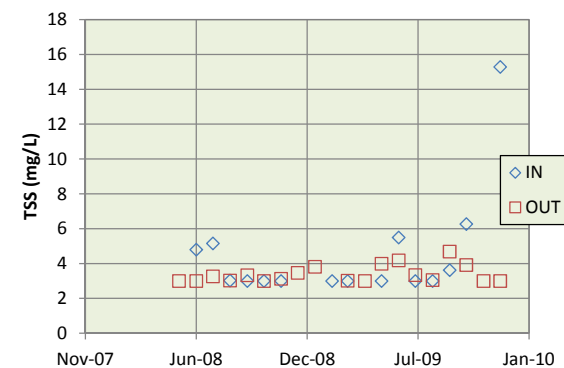
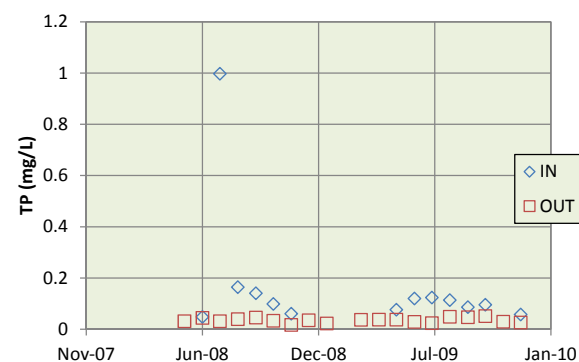
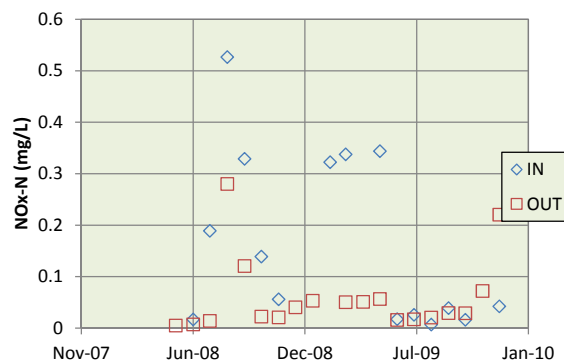
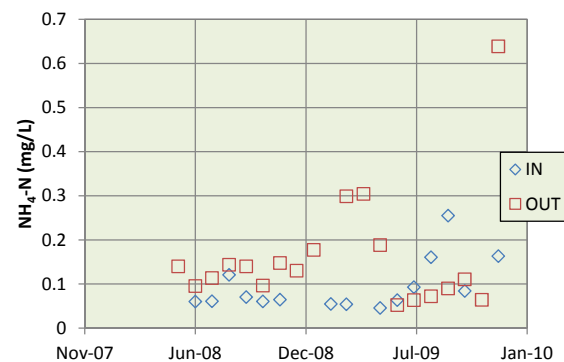
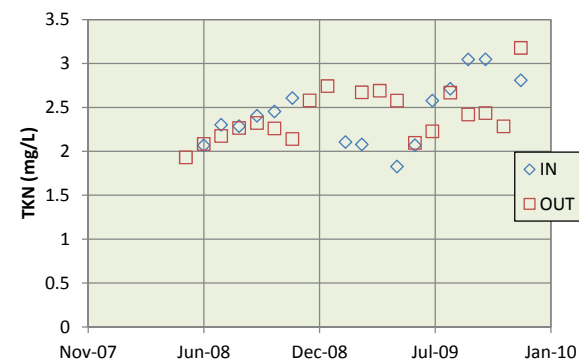
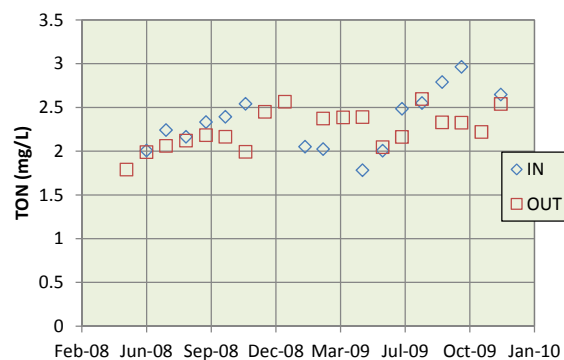
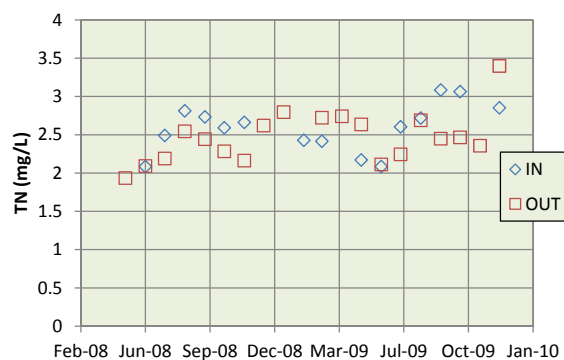
Long Term Average

	IN	OUT	Diff
TN	3.54	2.83	0.72
TON	2.28	2.38	-0.10
TKN	2.82	2.54	0.28
NH ₄ -N	0.54	0.16	0.38
NO _x -N	0.72	0.28	0.44
TP	0.16	0.16	0.00
TSS	15.06	13.75	1.31

Period of Record May-08 Dec-09



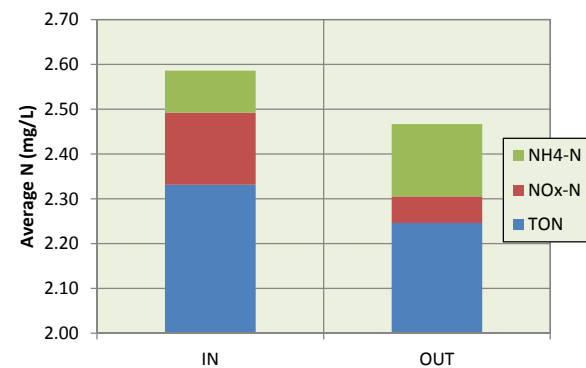
STA-1W Cell 1A - Monthly Water Quality Data Summary



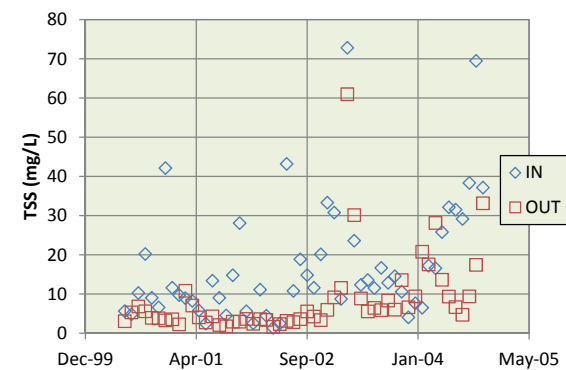
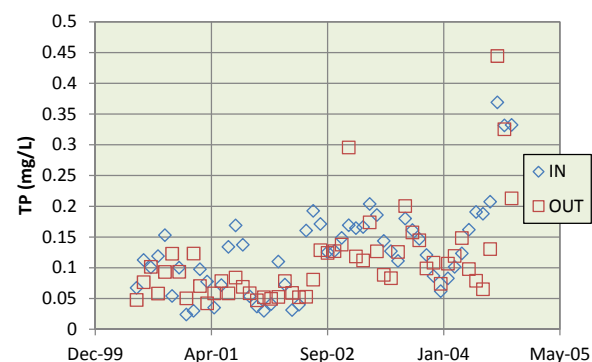
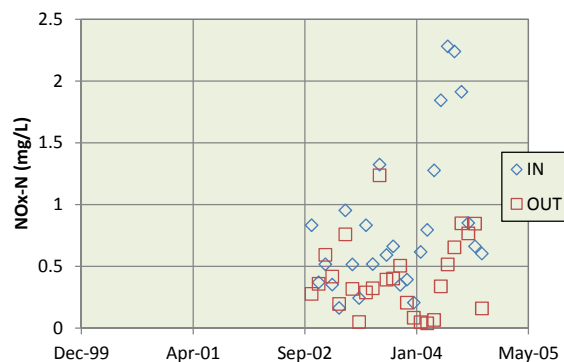
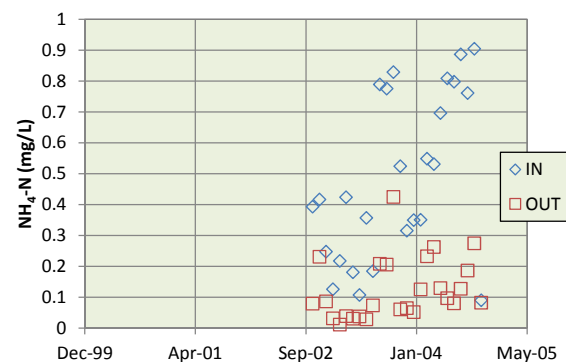
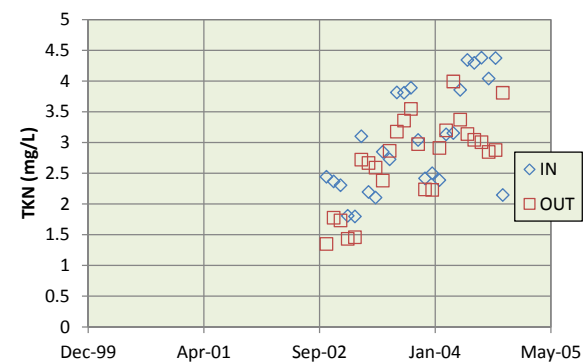
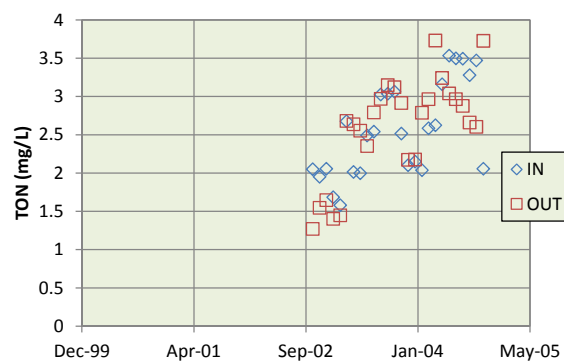
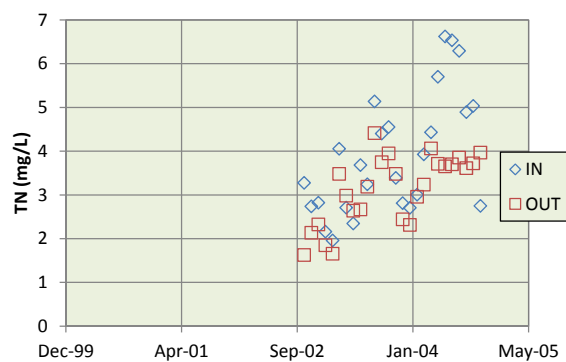
Long Term Average

	IN	OUT	Diff
TN	2.59	2.47	0.12
TON	2.33	2.25	0.09
TKN	2.43	2.41	0.02
NH ₄ -N	0.09	0.16	-0.07
NOx-N	0.16	0.06	0.10
TP	0.17	0.03	0.13
TSS	4.51	3.38	1.13

Period of Record May-08 Dec-09



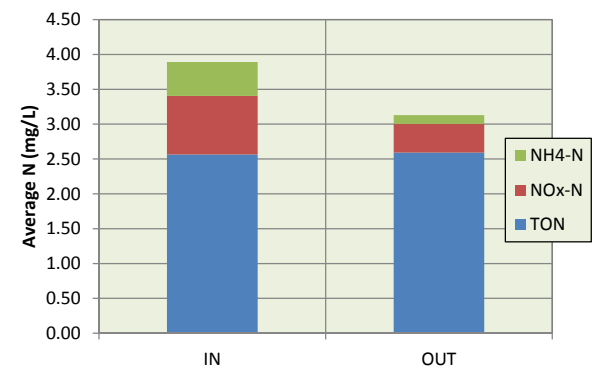
STA-1W Cell 1B+3 - Monthly Water Quality Data Summary



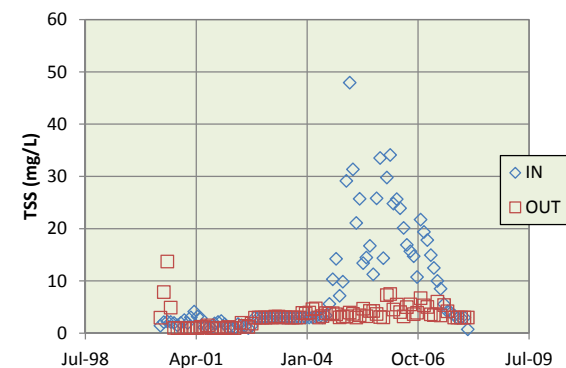
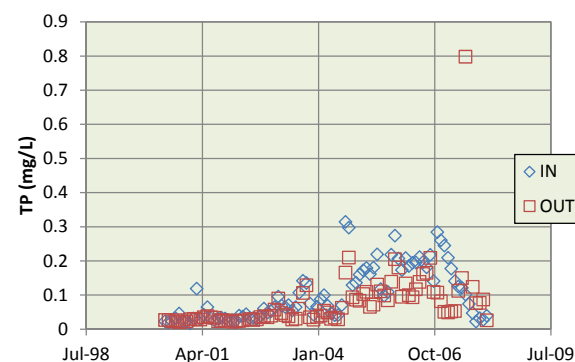
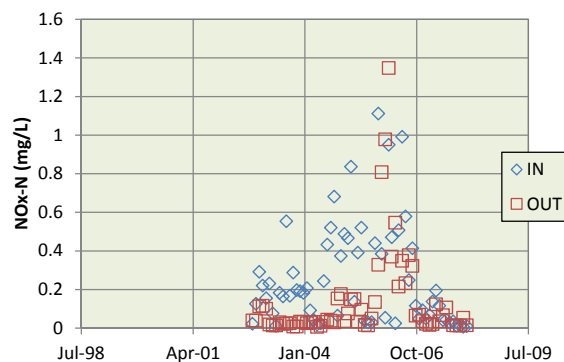
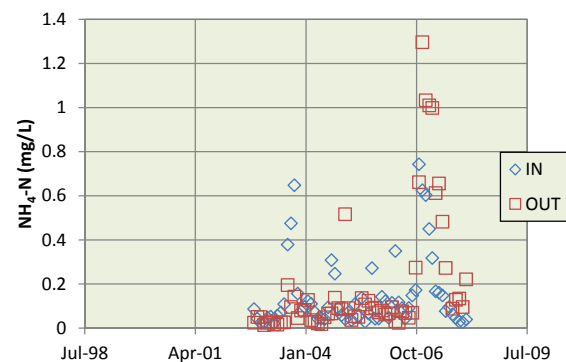
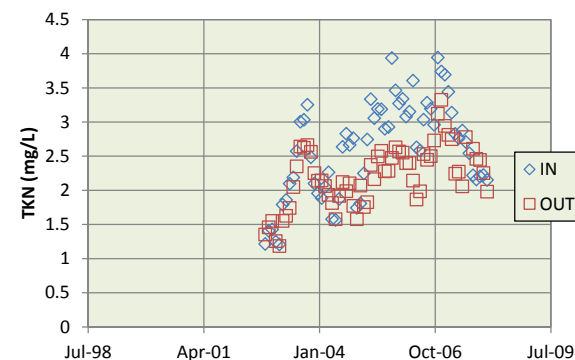
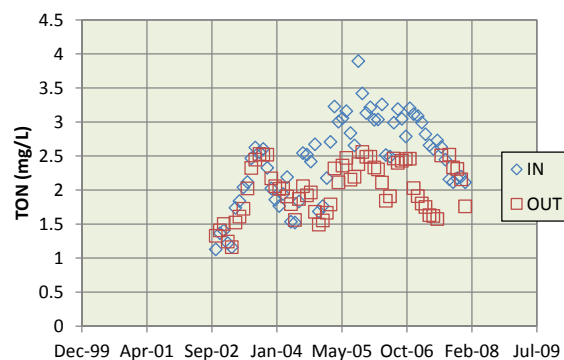
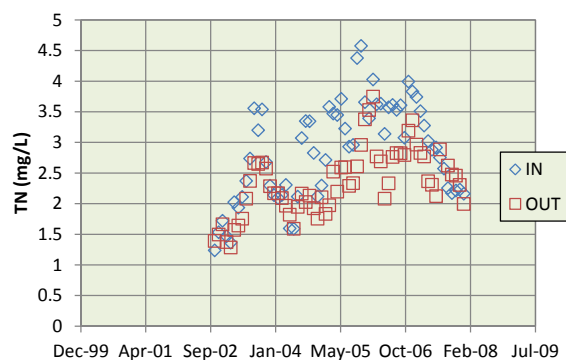
Long Term Average

	IN	OUT	Diff
TN	3.89	3.13	0.76
TON	2.56	2.59	-0.03
TKN	3.05	2.72	0.33
NH ₄ -N	0.48	0.13	0.36
NO _x -N	0.84	0.41	0.43
TP	0.13	0.11	0.02
TSS	17.40	8.63	8.77

Period of Record Jun-00 Nov-04



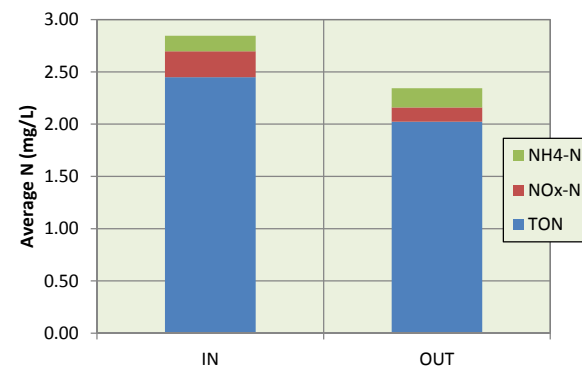
STA-1W Cell 2 - Monthly Water Quality Data Summary



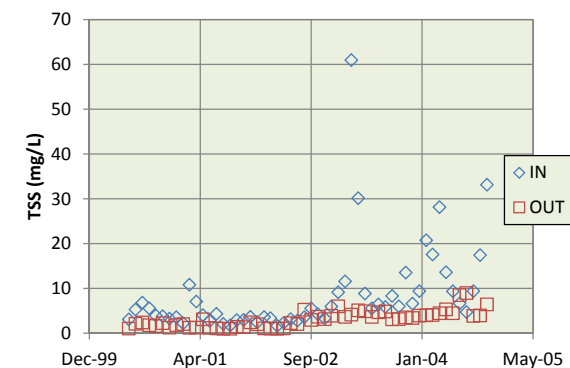
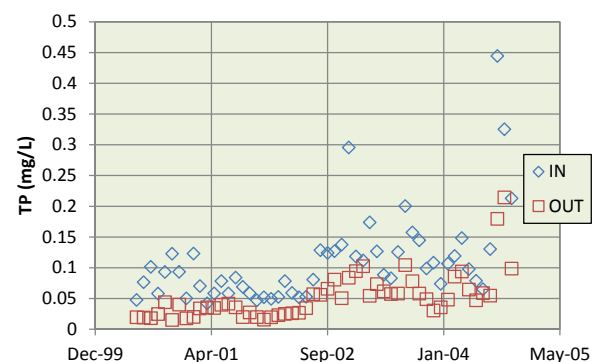
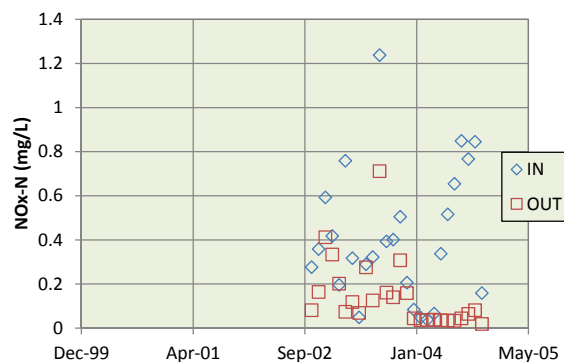
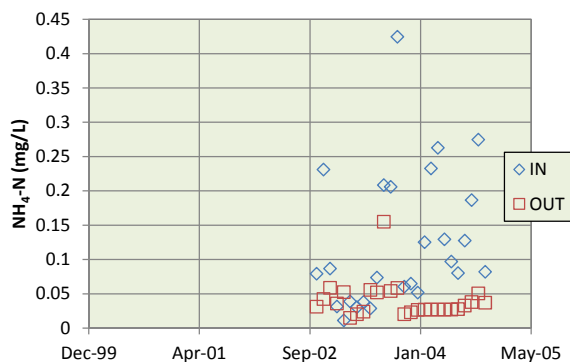
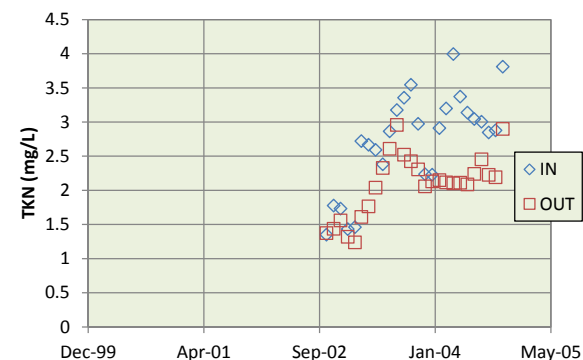
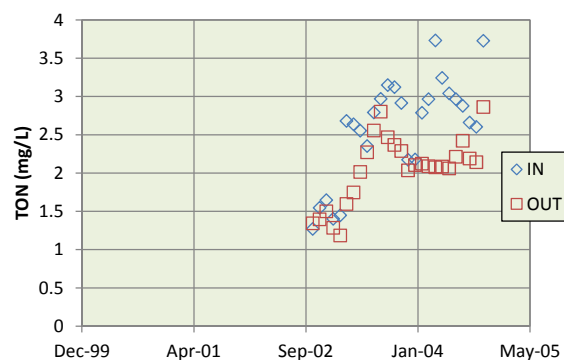
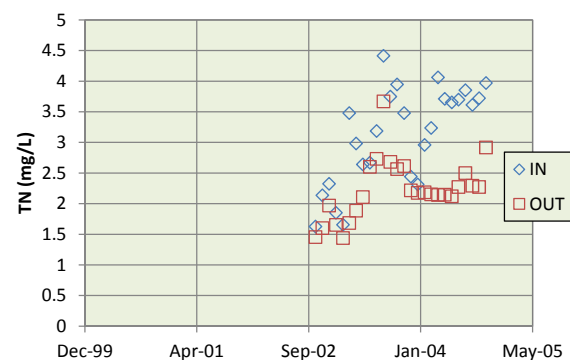
Long Term Average

	IN	OUT	Diff
TN	2.85	2.34	0.50
TON	2.45	2.02	0.42
TKN	2.60	2.21	0.39
NH ₄ -N	0.15	0.18	-0.04
NO _x -N	0.25	0.14	0.11
TP	0.10	0.08	0.02
TSS	8.69	3.33	5.37

Period of Record Jun-00 Jan-08



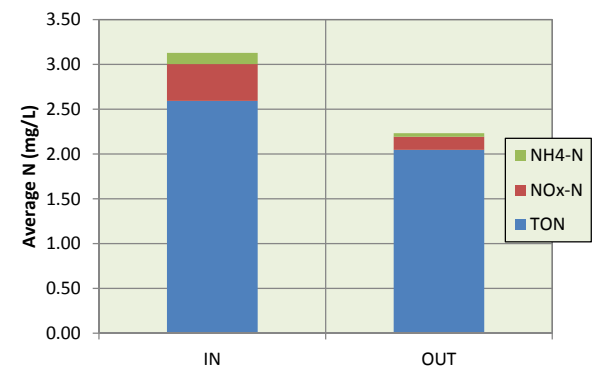
STA-1W Cell 3 - Monthly Water Quality Data Summary



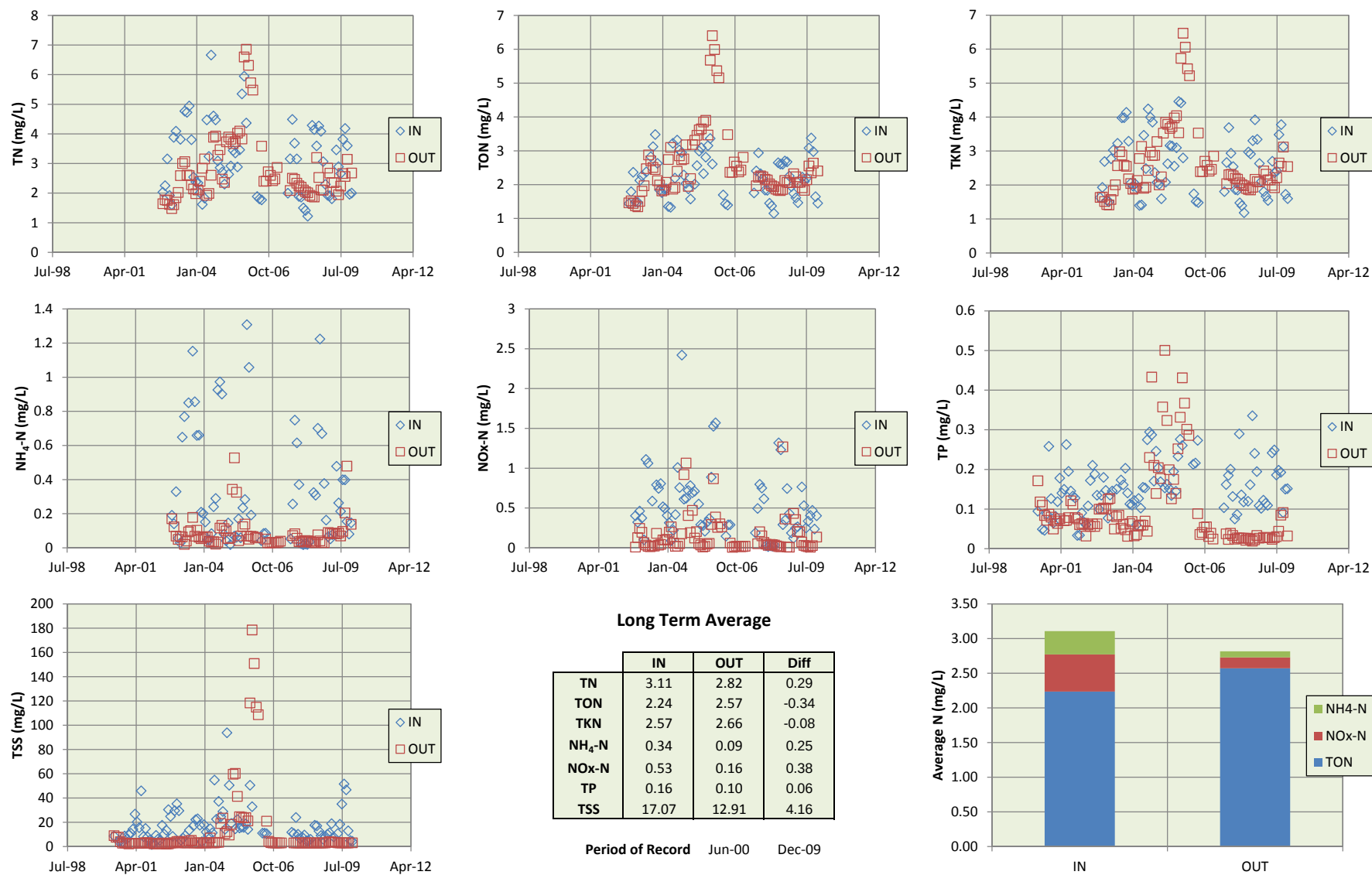
Long Term Average

	IN	OUT	Diff
TN	3.13	2.23	0.90
TON	2.59	2.05	0.55
TKN	2.72	2.09	0.63
NH ₄ -N	0.13	0.04	0.09
NO _x -N	0.41	0.15	0.26
TP	0.11	0.05	0.06
TSS	8.63	3.14	5.49

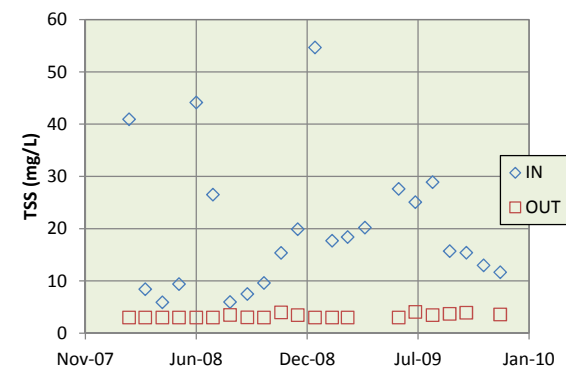
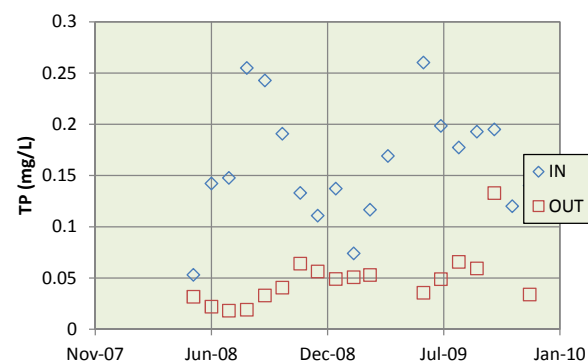
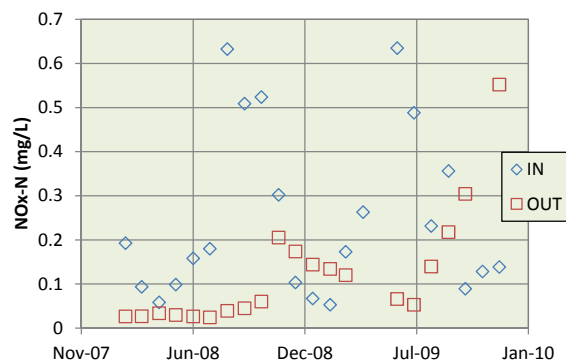
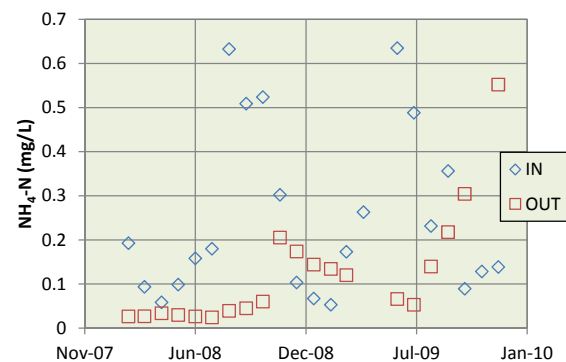
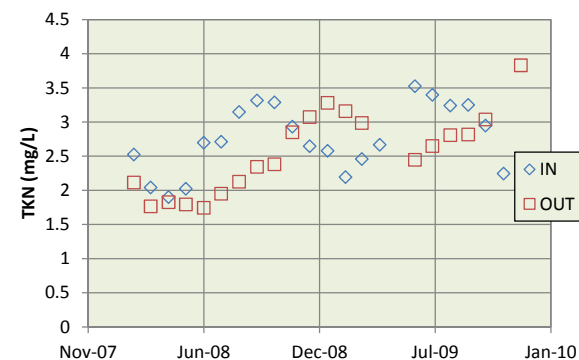
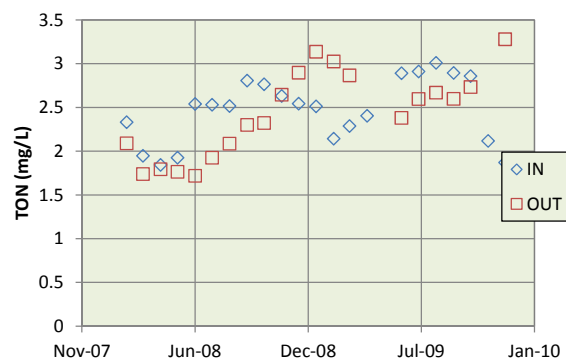
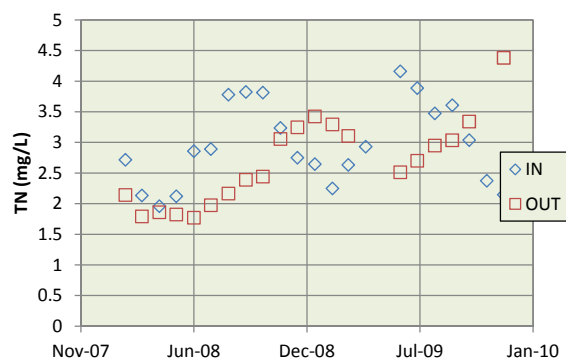
Period of Record Jun-00 Nov-04



STA-1W Cell 4 - Monthly Water Quality Data Summary



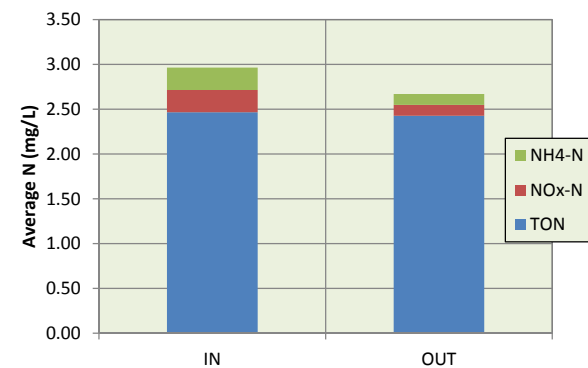
STA-1W North Flow-way - Monthly Water Quality Data Summary



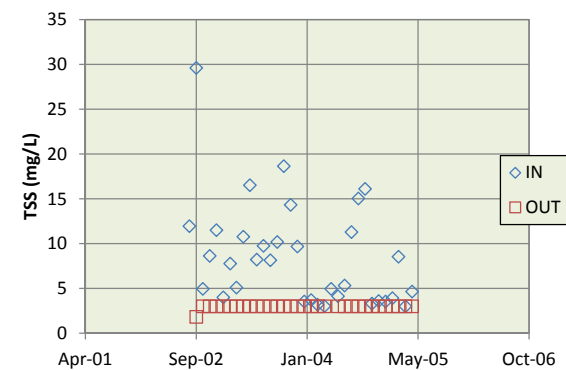
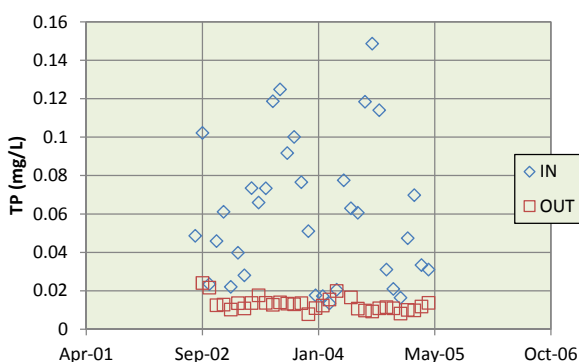
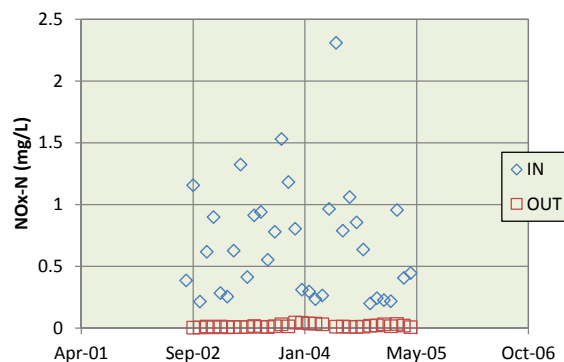
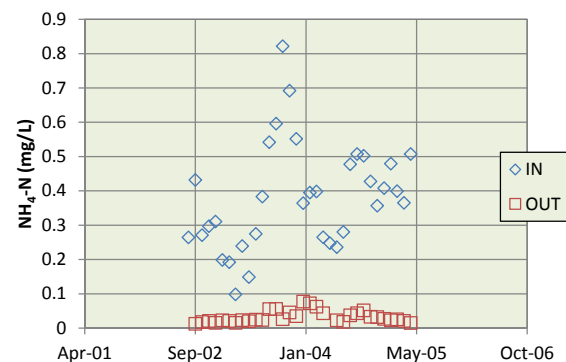
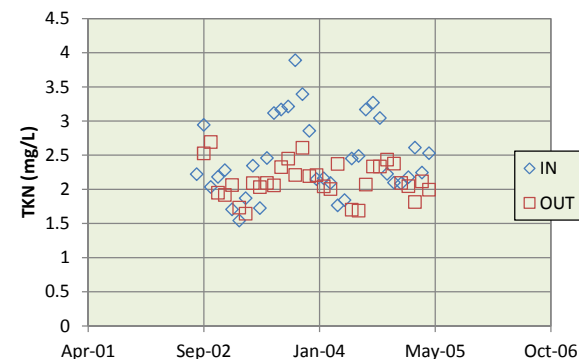
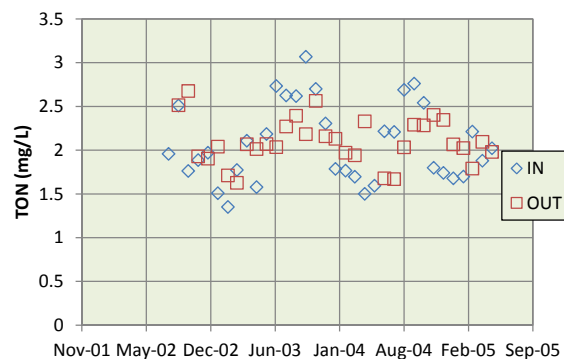
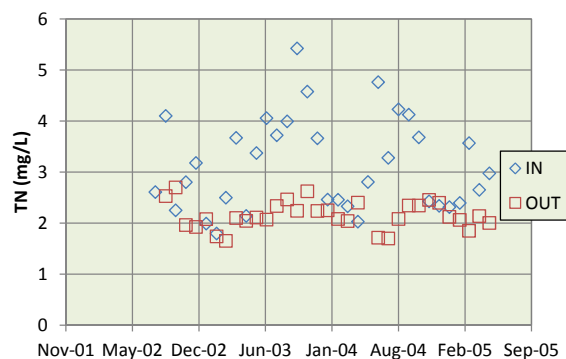
Long Term Average

	IN	OUT	Diff
TN	2.96	2.67	0.29
TON	2.47	2.43	0.04
TKN	2.72	2.55	0.17
NH ₄ -N	0.25	0.12	0.13
NO _x -N	0.25	0.12	0.13
TP	0.16	0.05	0.11
TSS	20.10	3.29	16.80

Period of Record Feb-08 Dec-09



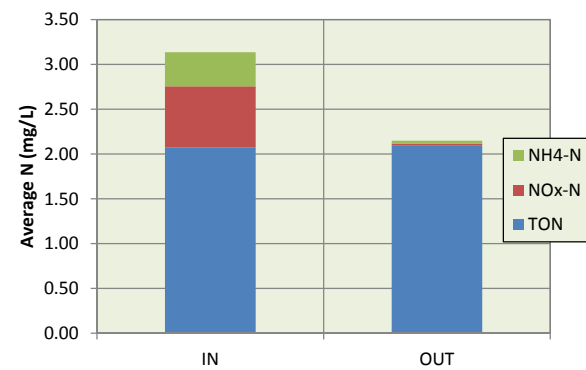
STA-1W West Flow-way - Monthly Water Quality Data Summary



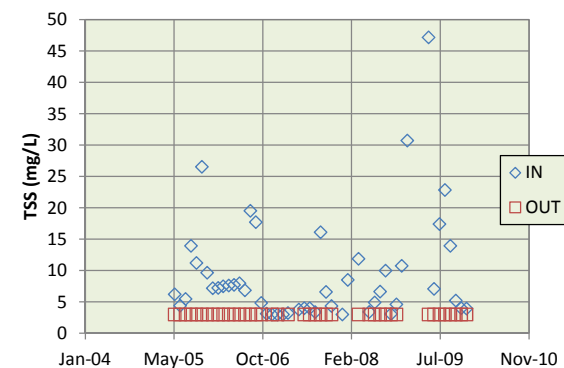
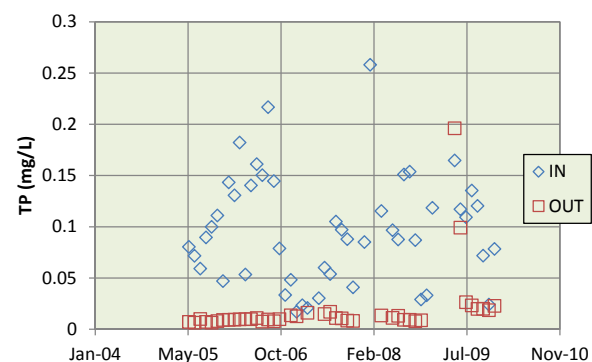
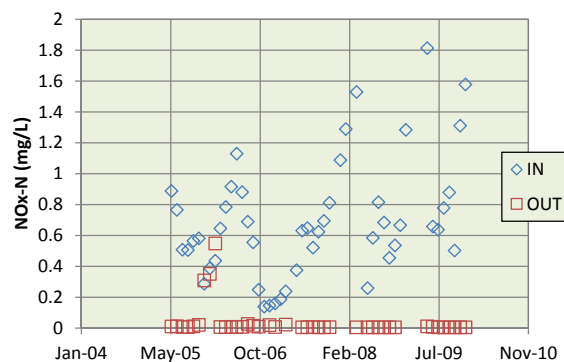
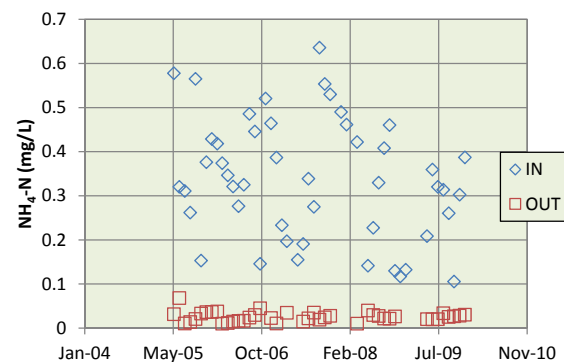
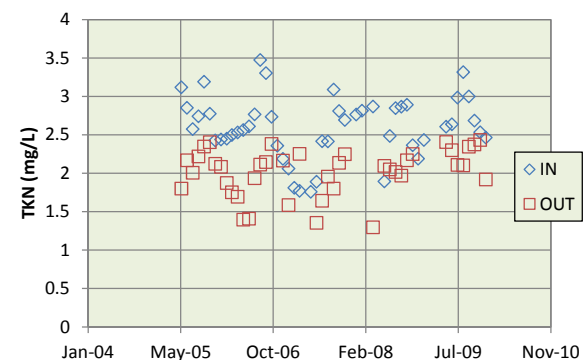
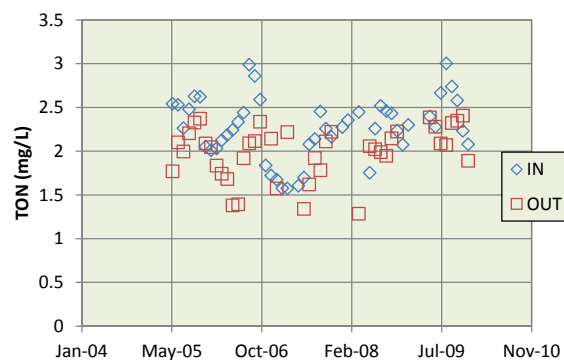
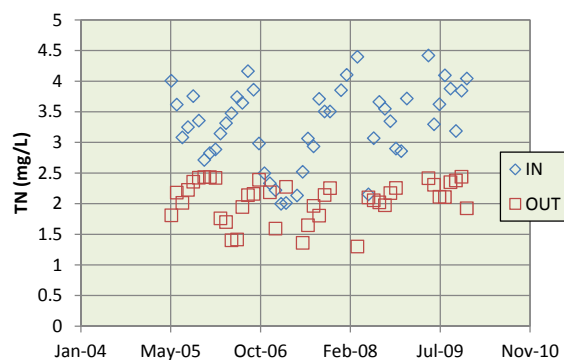
Long Term Average

	IN	OUT	Diff
TN	3.14	2.15	0.99
TON	2.07	2.10	-0.03
TKN	2.45	2.13	0.32
NH ₄ -N	0.38	0.03	0.35
NOx-N	0.68	0.02	0.67
TP	0.06	0.01	0.05
TSS	8.55	2.96	5.59

Period of Record Mar-02 May-05



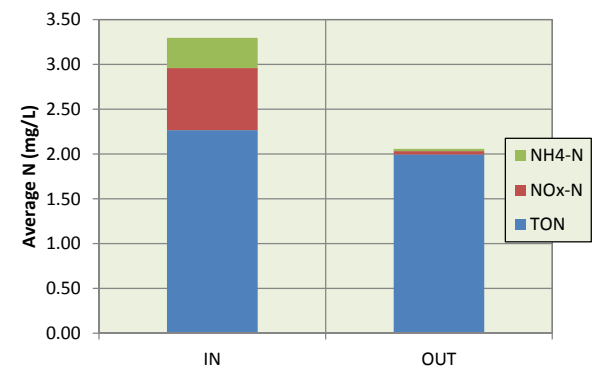
STA-2 Cell 1A - Monthly Water Quality Data Summary



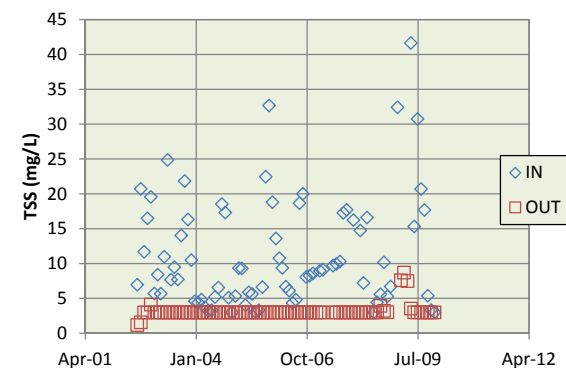
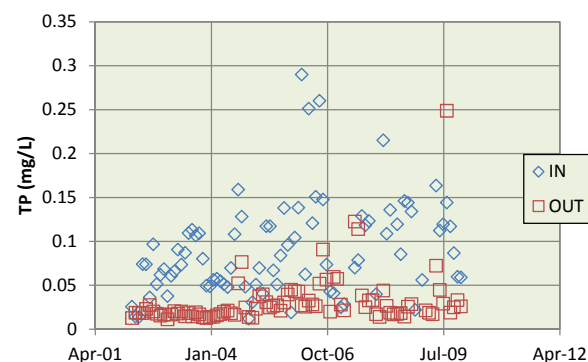
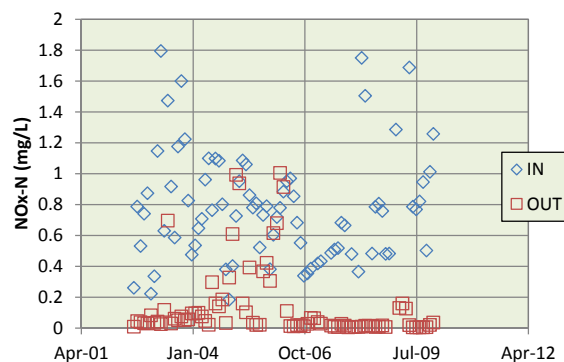
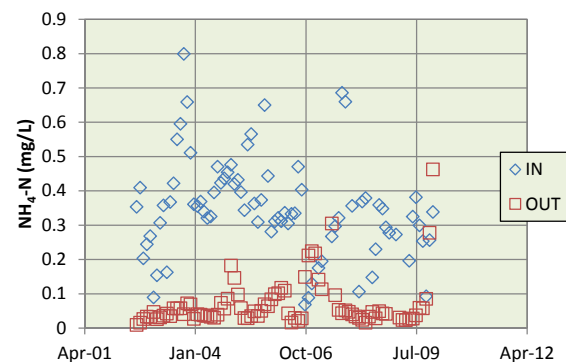
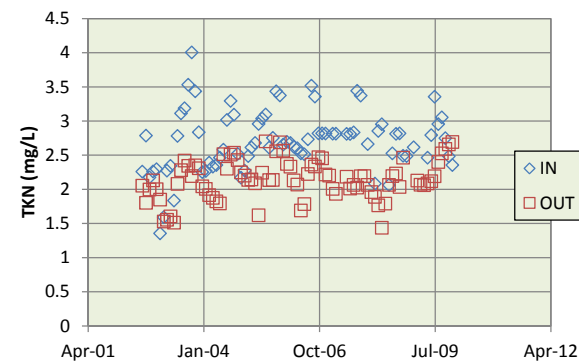
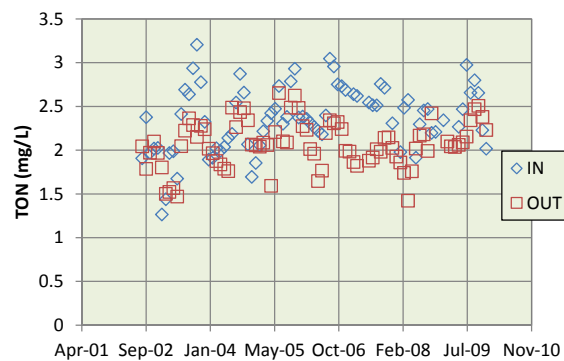
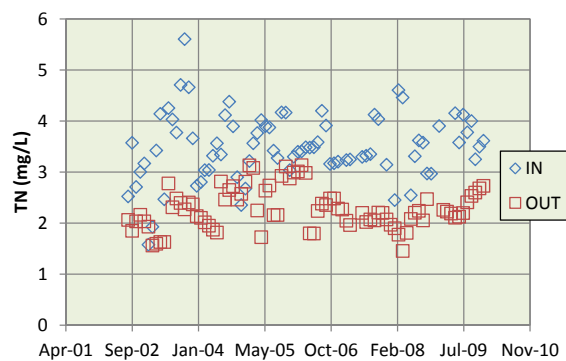
Long Term Average

	IN	OUT	Diff
TN	3.30	2.06	1.24
TON	2.27	1.99	0.27
TKN	2.60	2.02	0.58
NH ₄ -N	0.34	0.03	0.31
NO _x -N	0.69	0.04	0.66
TP	0.10	0.02	0.08
TSS	9.33	3.00	6.33

Period of Record Jun-05 Dec-09



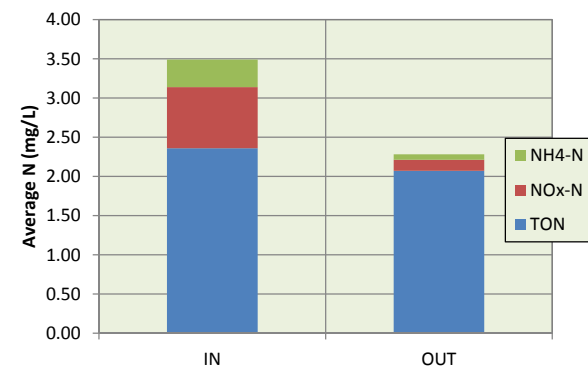
STA-2 Cell 1B - Monthly Water Quality Data Summary



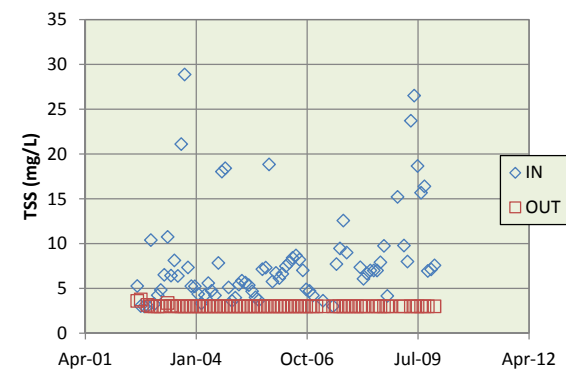
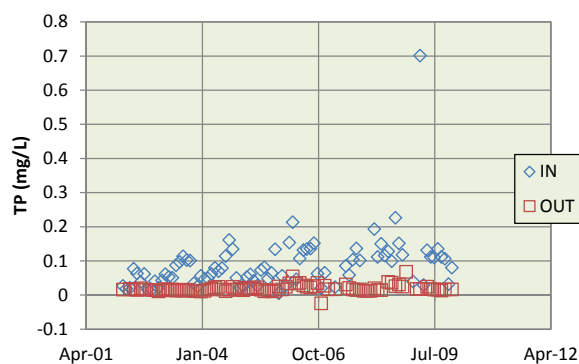
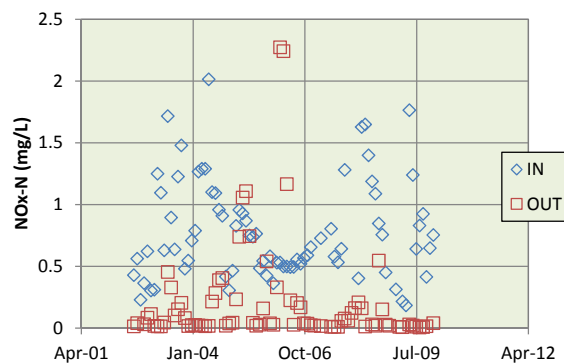
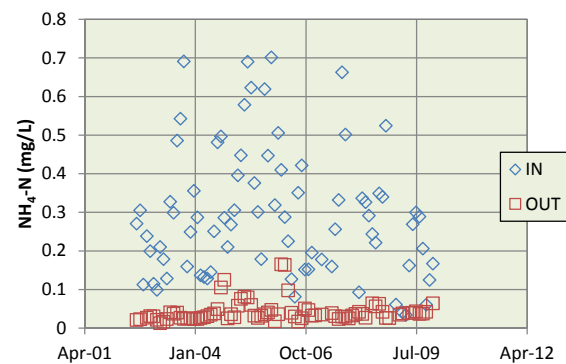
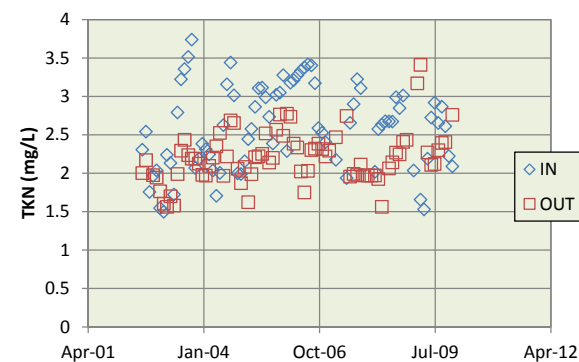
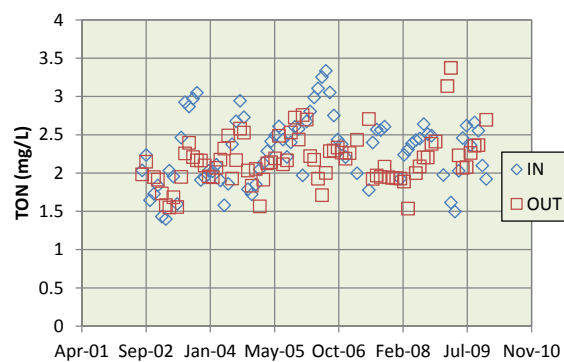
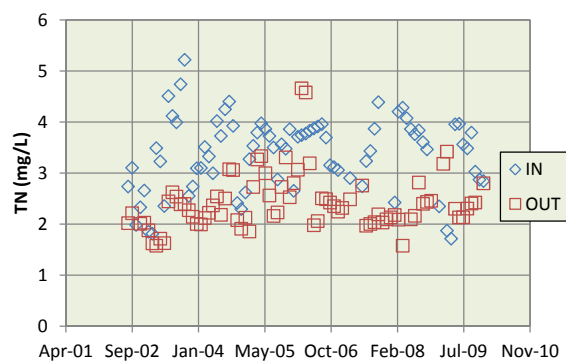
Long Term Average

	IN	OUT	Diff
TN	3.49	2.28	1.21
TON	2.36	2.07	0.29
TKN	2.71	2.14	0.57
NH ₄ -N	0.35	0.07	0.28
NO _x -N	0.78	0.14	0.64
TP	0.09	0.03	0.06
TSS	11.23	3.17	8.06

Period of Record Mar-02 Dec-09



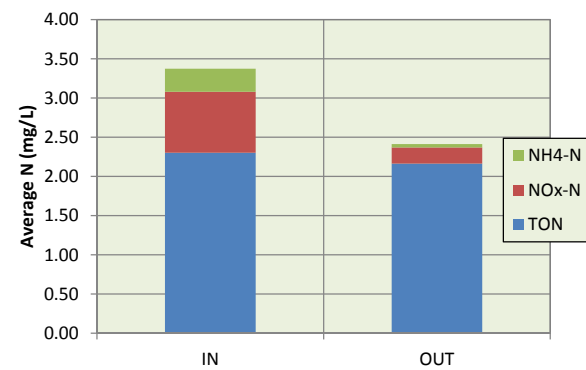
STA-2 Cell 2 - Monthly Water Quality Data Summary



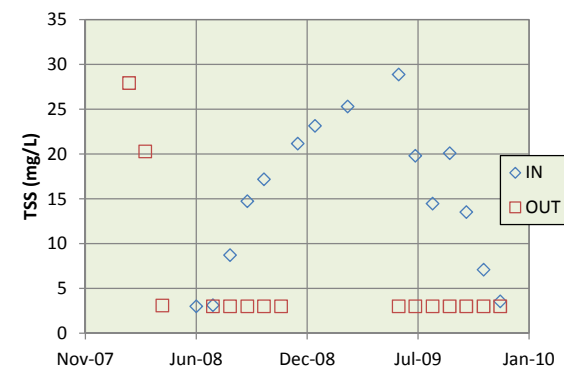
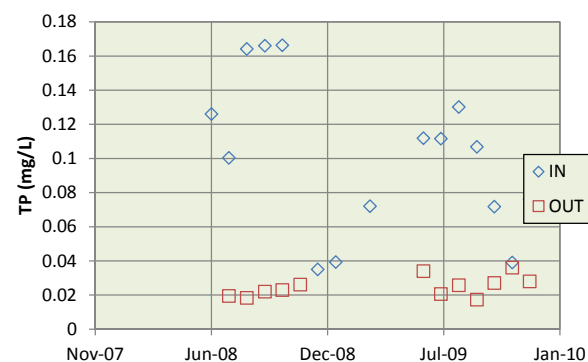
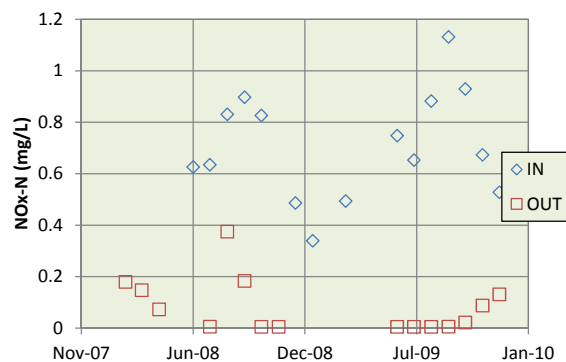
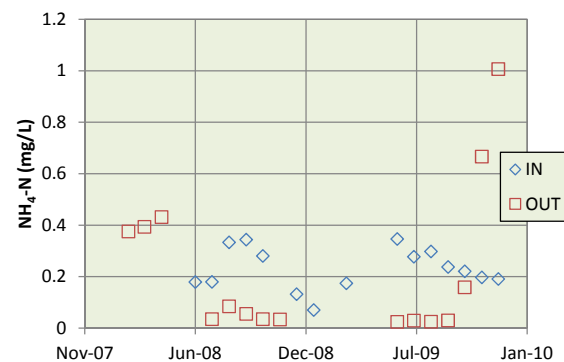
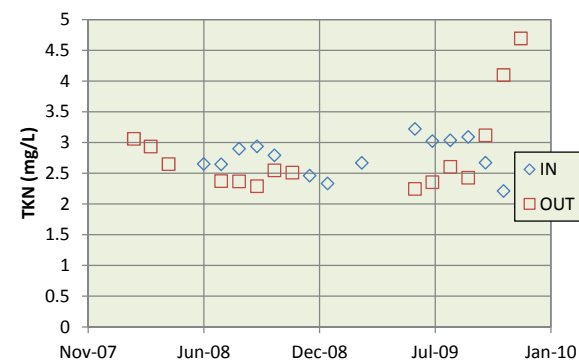
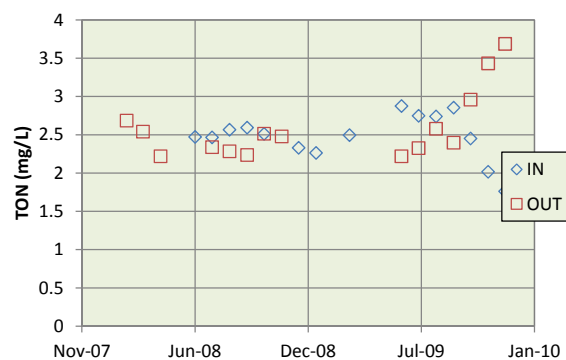
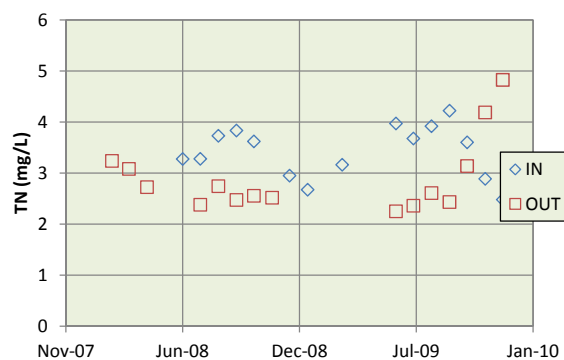
Long Term Average

	IN	OUT	Diff
TN	3.37	2.41	0.96
TON	2.30	2.16	0.14
TKN	2.60	2.20	0.39
NH ₄ -N	0.29	0.04	0.25
NOx-N	0.78	0.21	0.57
TP	0.09	0.02	0.07
TSS	8.17	3.03	5.15

Period of Record Mar-02 Dec-09



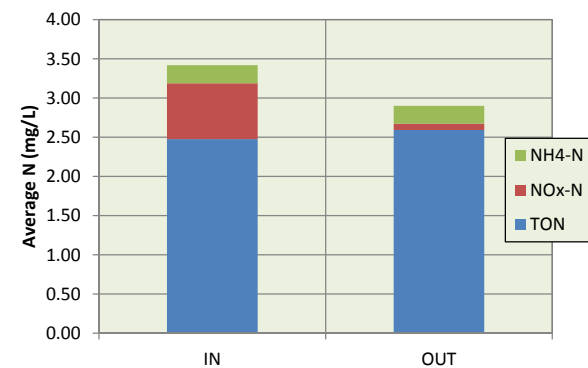
STA-2 Cell 3 - Monthly Water Quality Data Summary



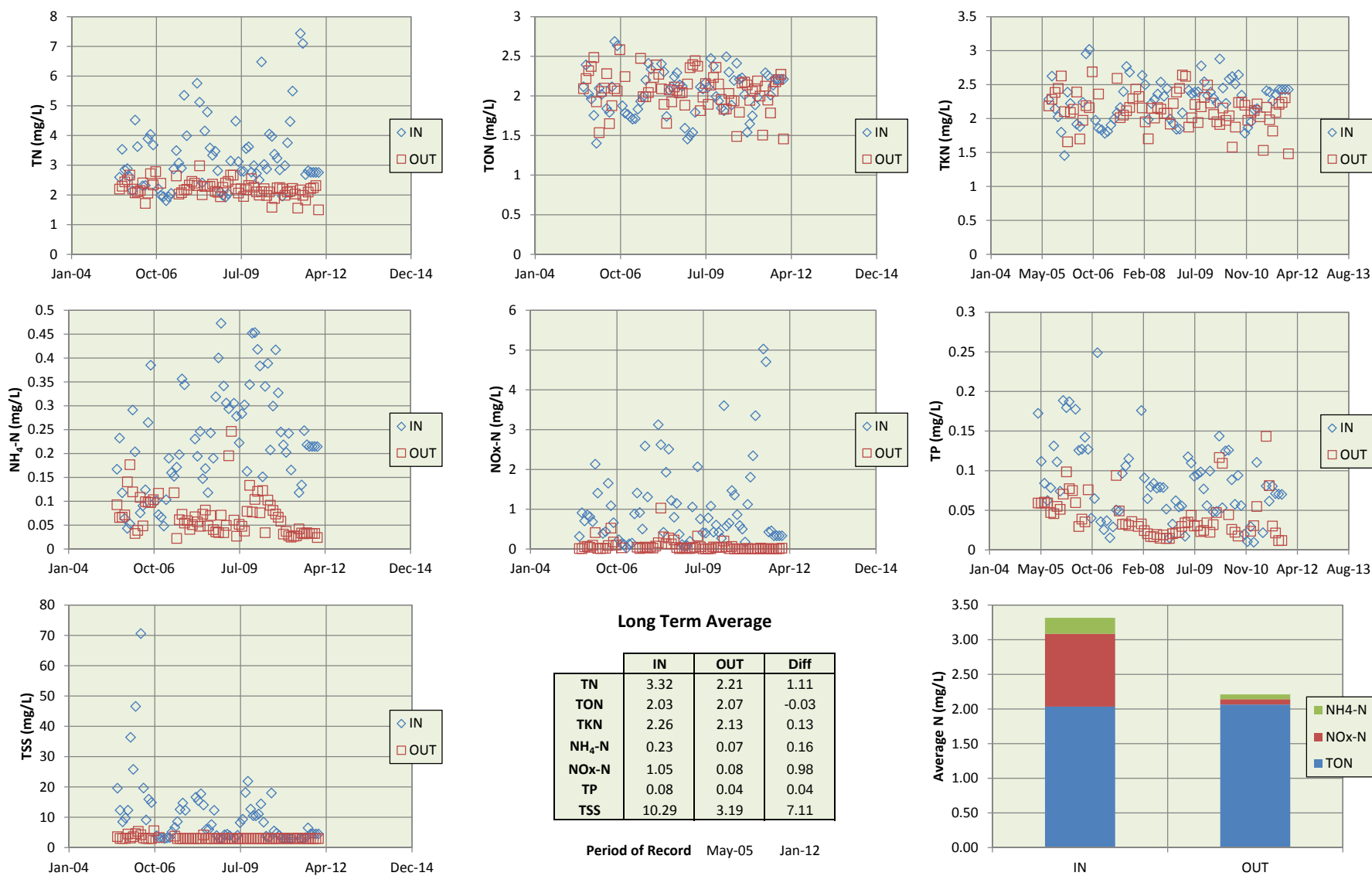
Long Term Average

	IN	OUT	Diff
TN	3.42	2.90	0.52
TON	2.48	2.59	-0.12
TKN	2.71	2.82	-0.11
NH ₄ -N	0.23	0.23	0.01
NO _x -N	0.71	0.08	0.63
TP	0.10	0.02	0.08
TSS	14.92	5.82	9.10

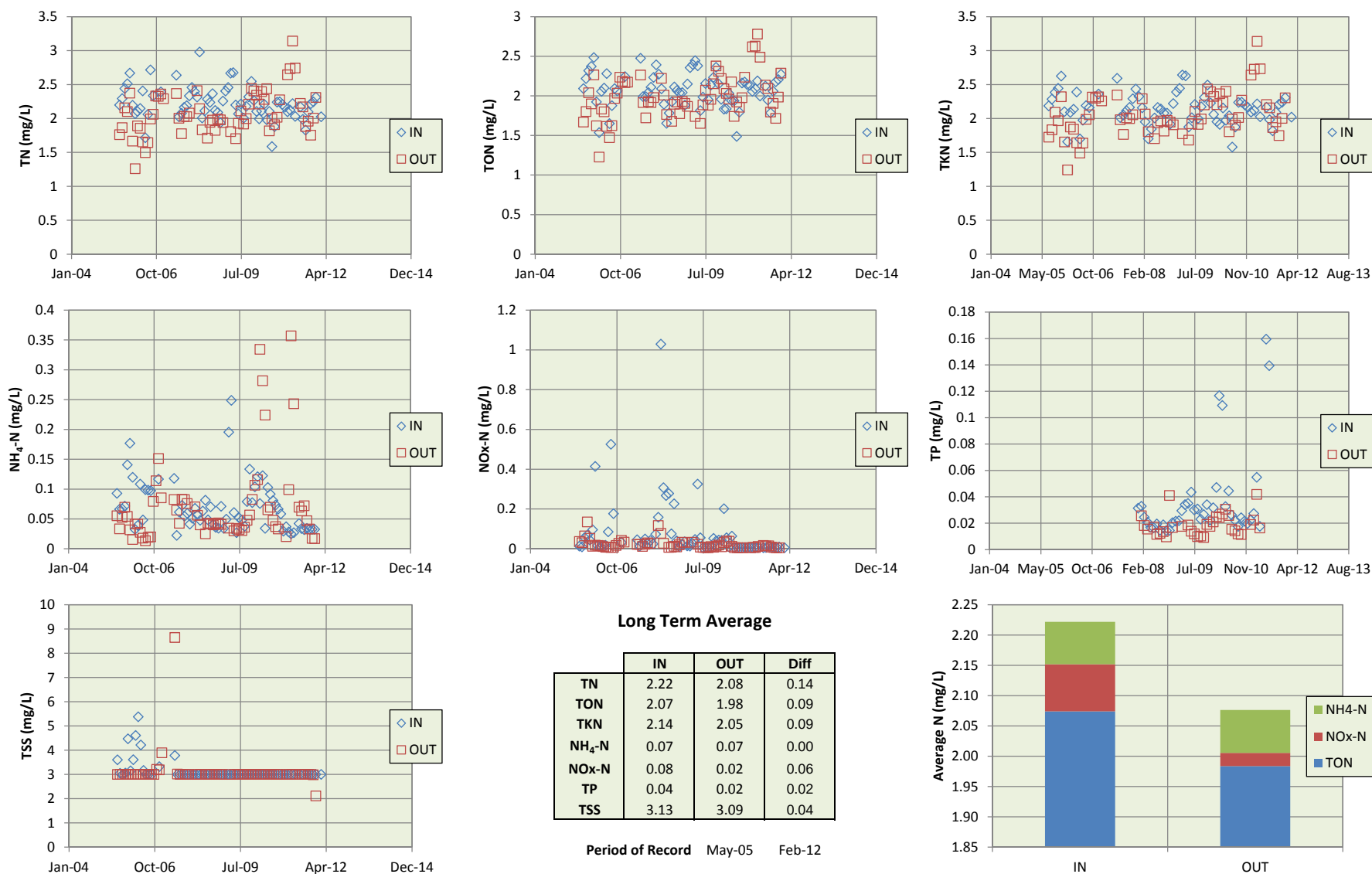
Period of Record Feb-08 Dec-09



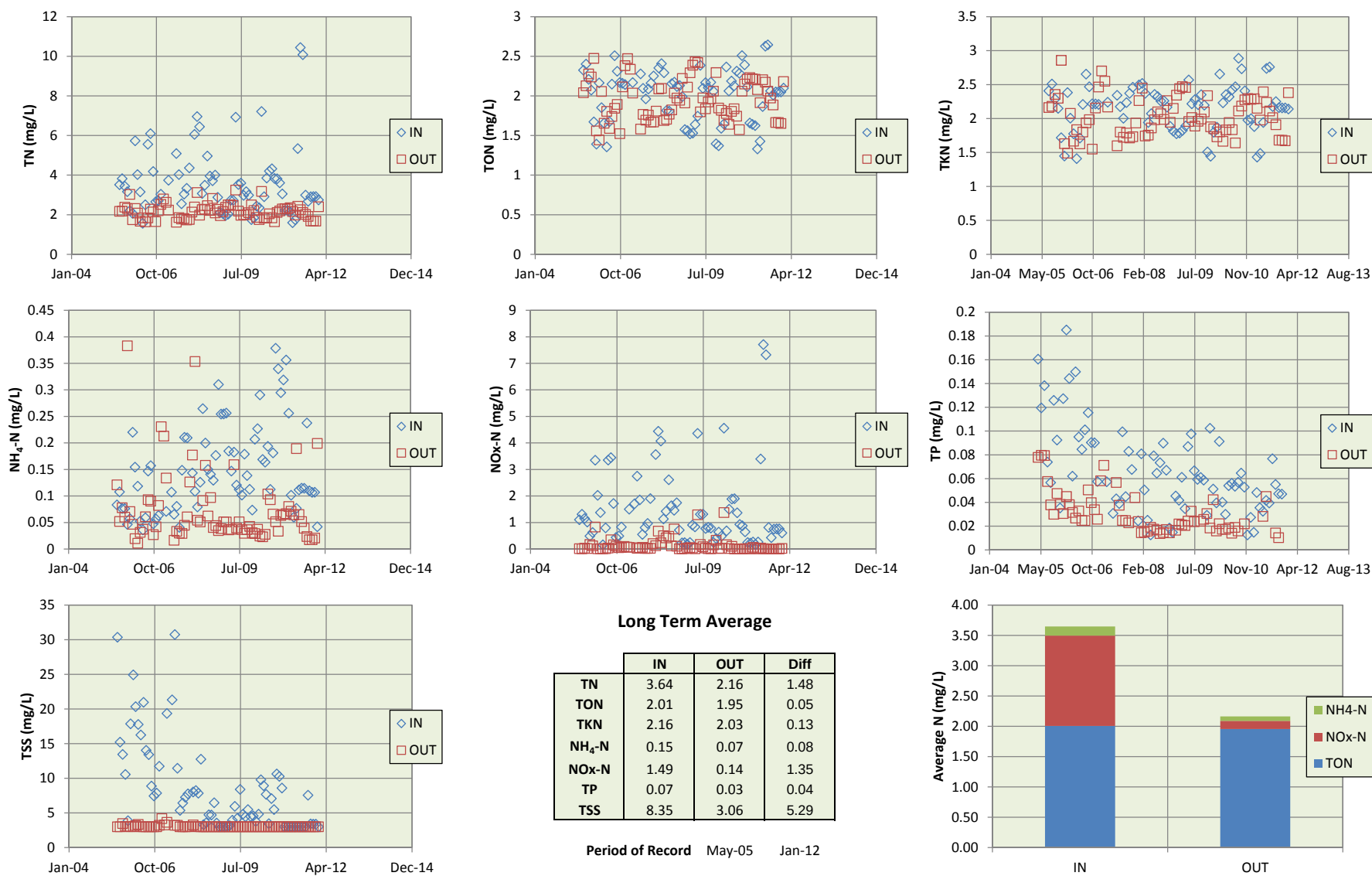
STA-2 Cell 4 - Monthly Water Quality Data Summary



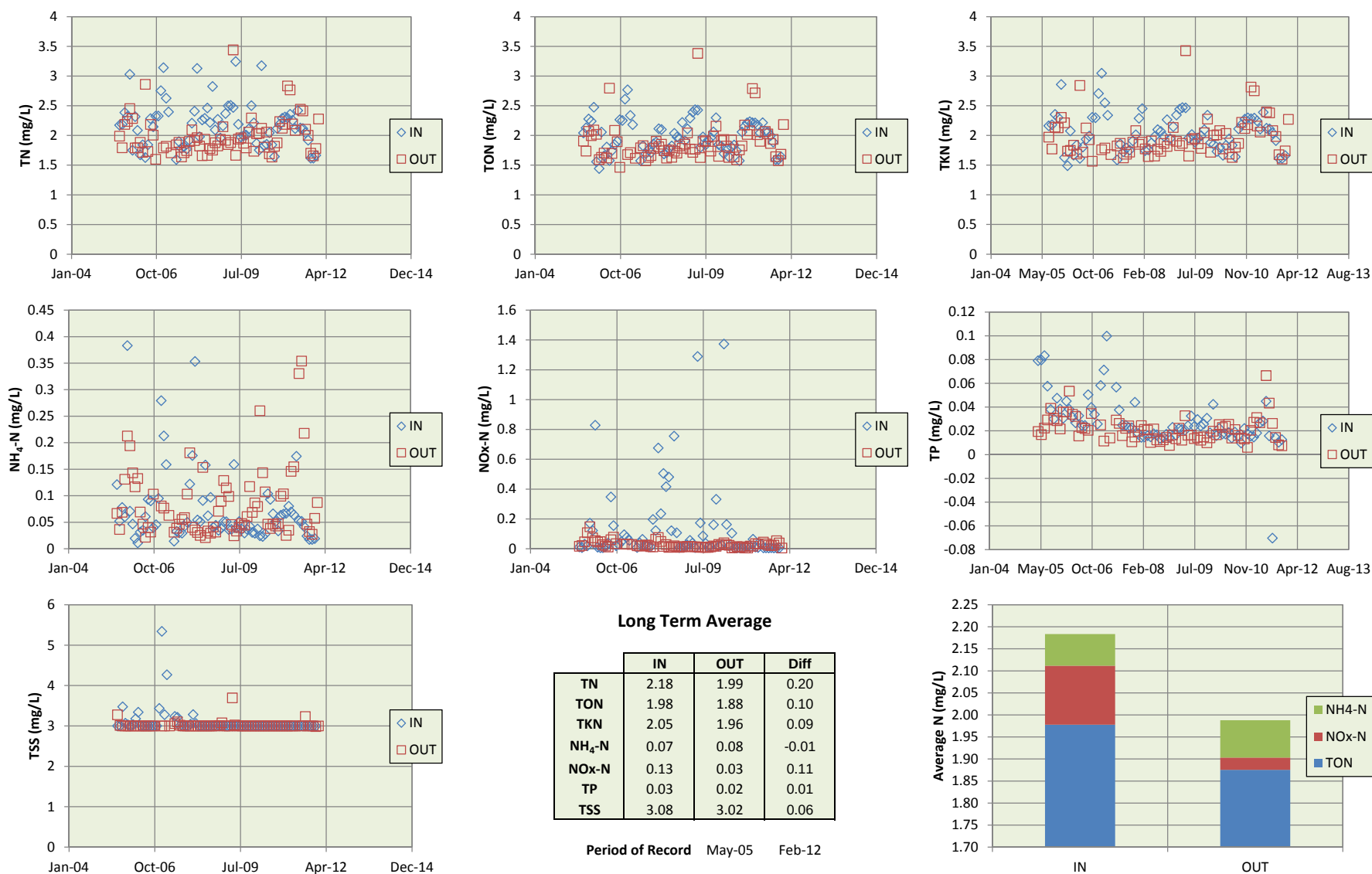
STA-3/4 Cell 1A - Monthly Water Quality Data Summary



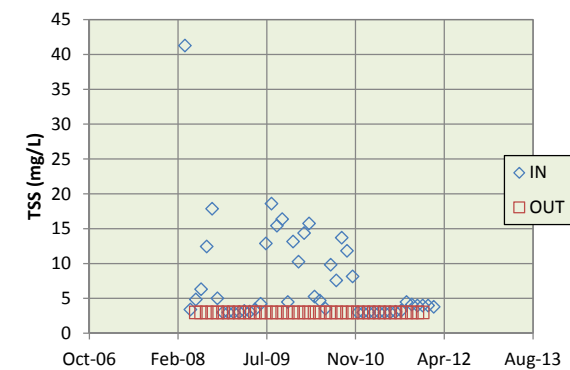
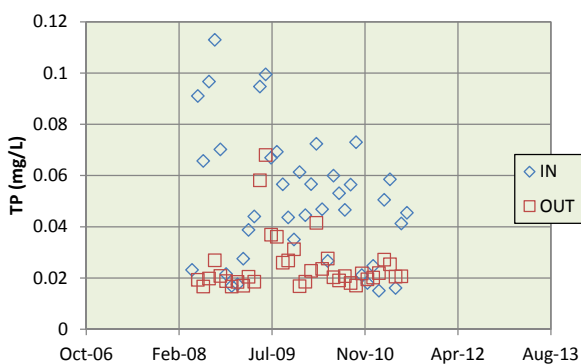
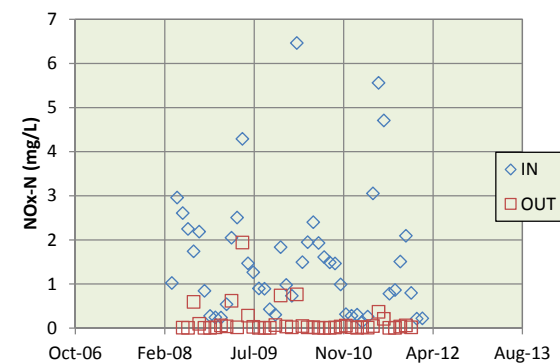
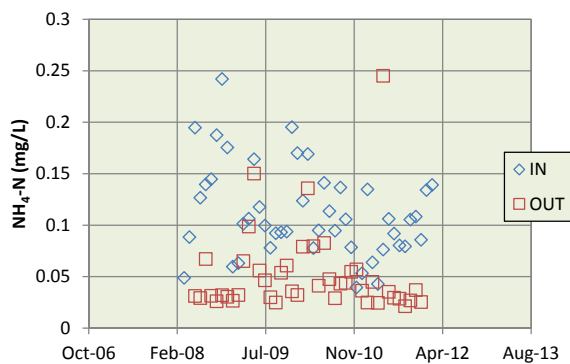
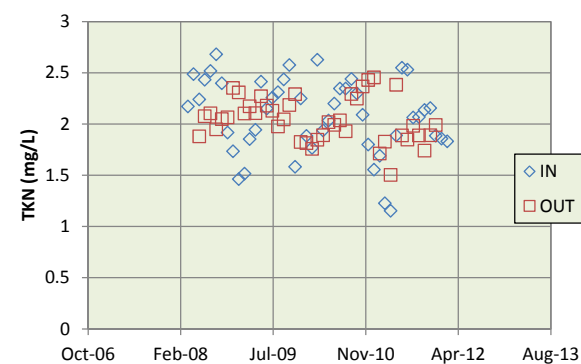
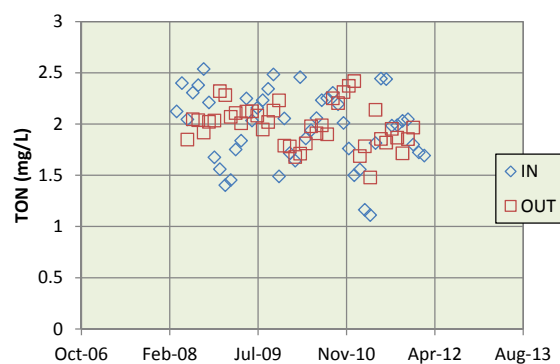
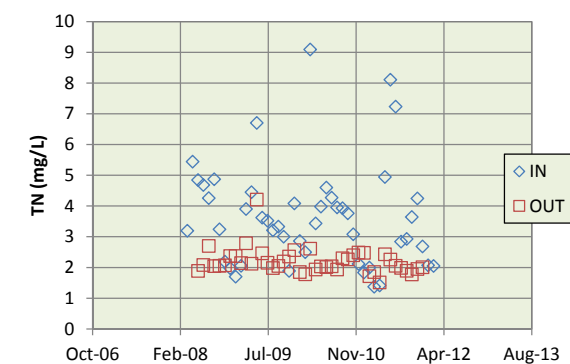
STA-3/4 Cell 1B - Monthly Water Quality Data Summary



STA-3/4 Cell 2A - Monthly Water Quality Data Summary



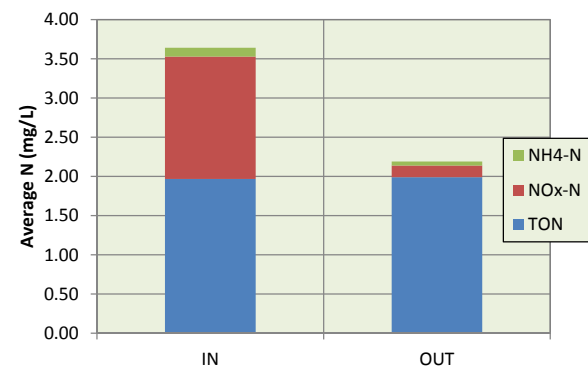
STA-3/4 Cell 2B - Monthly Water Quality Data Summary



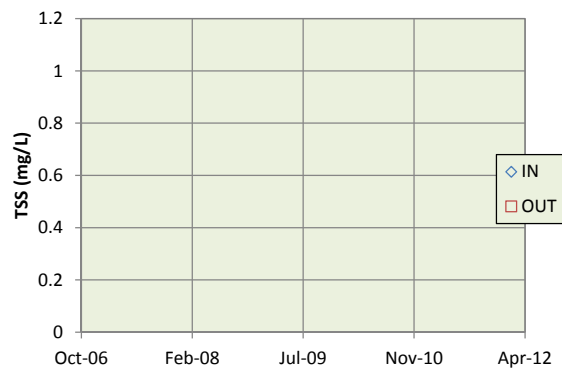
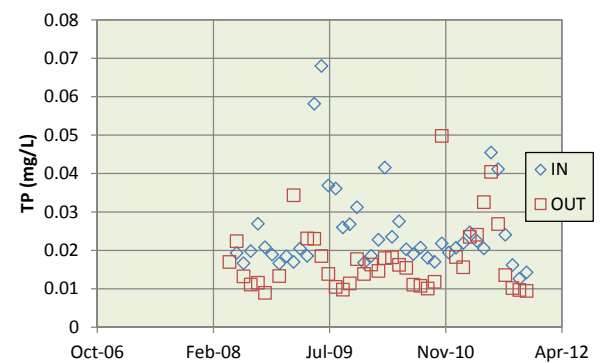
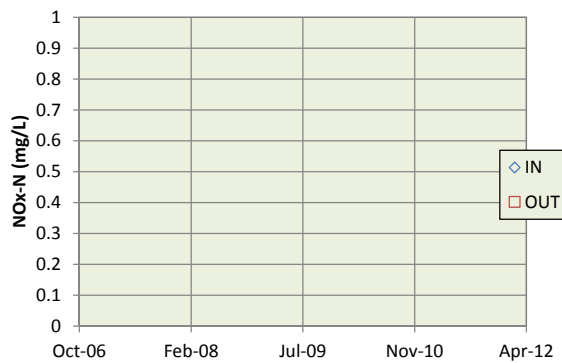
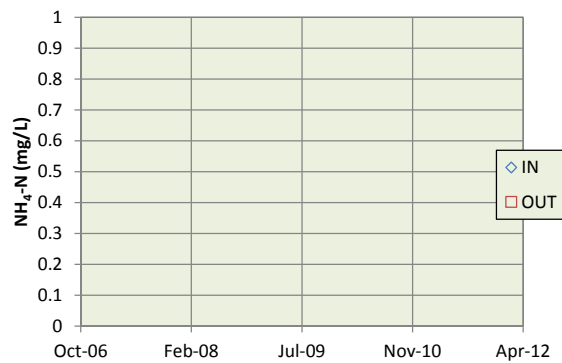
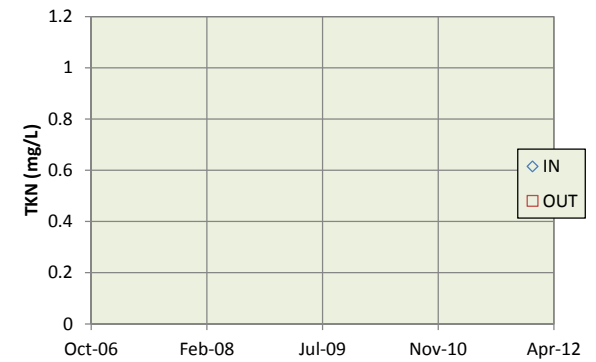
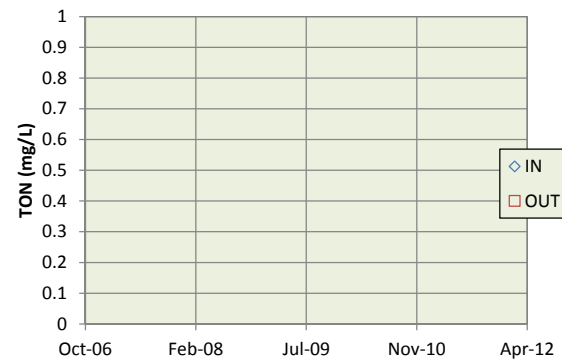
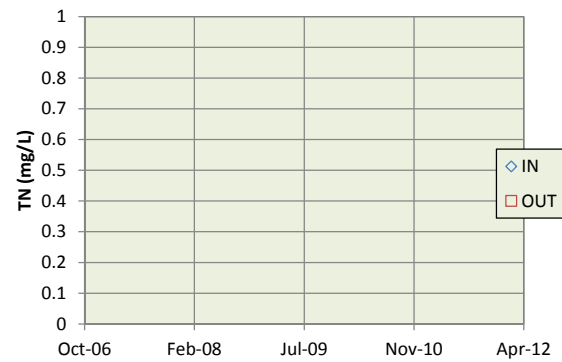
Long Term Average

	IN	OUT	Diff
TN	3.64	2.19	1.45
TON	1.97	1.99	-0.02
TKN	2.08	2.04	0.04
NH ₄ -N	0.11	0.05	0.06
NO _x -N	1.56	0.15	1.41
TP	0.05	0.02	0.03
TSS	7.55	3.00	4.55

Period of Record Apr-08 Feb-12



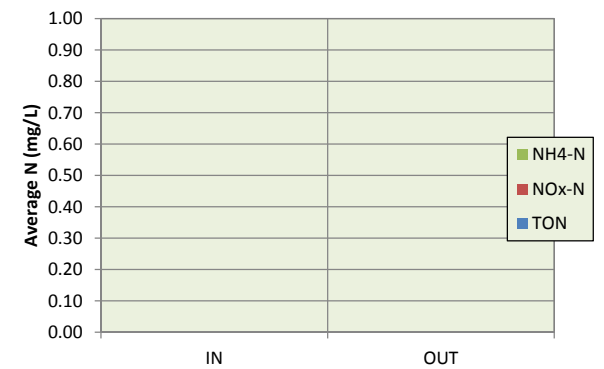
STA-3/4 Cell 3A - Monthly Water Quality Data Summary



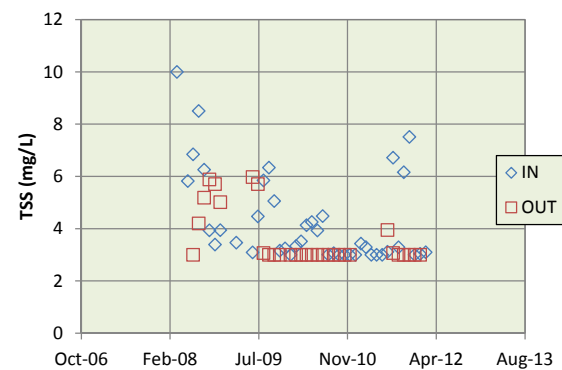
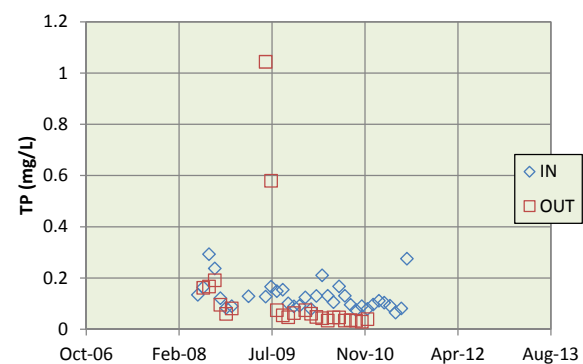
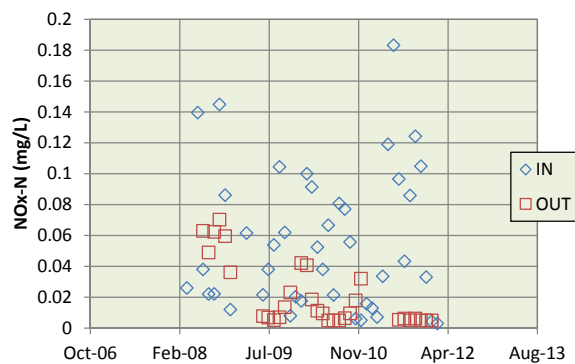
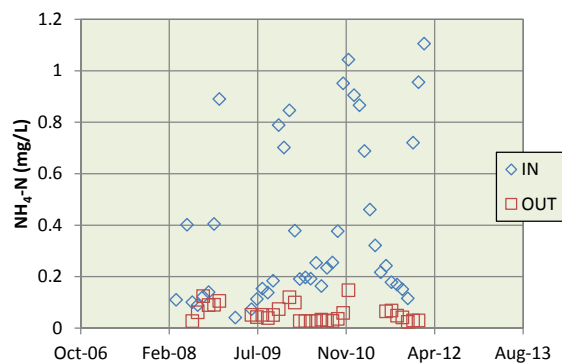
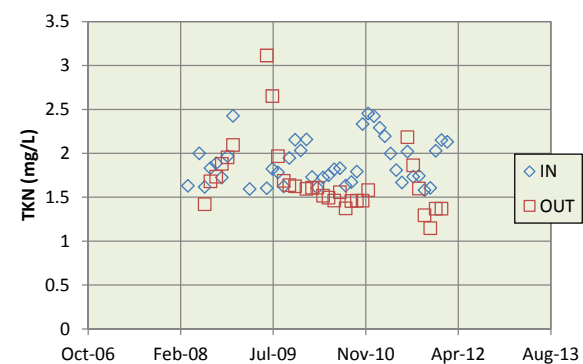
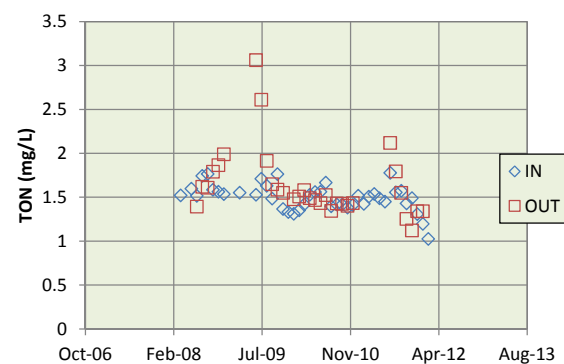
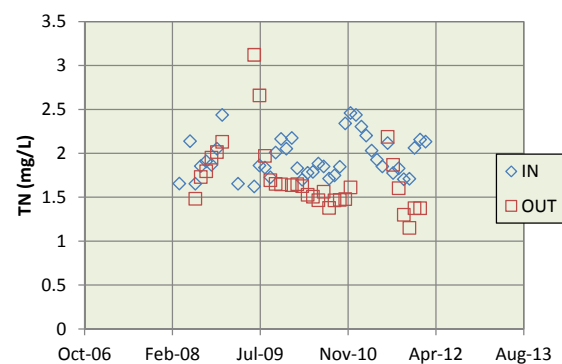
Long Term Average

	IN	OUT	Diff
TN	#DIV/0!	#DIV/0!	#DIV/0!
TON	#DIV/0!	#DIV/0!	#DIV/0!
TKN	#DIV/0!	#DIV/0!	#DIV/0!
NH ₄ -N	#DIV/0!	#DIV/0!	#DIV/0!
NO _x -N	#DIV/0!	#DIV/0!	#DIV/0!
TP	0.02	0.02	0.01
TSS	#DIV/0!	#DIV/0!	#DIV/0!

Period of Record Apr-08 Nov-11



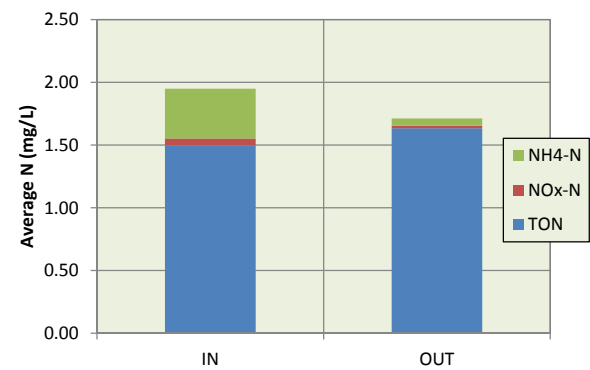
STA-3/4 Cell 3B - Monthly Water Quality Data Summary



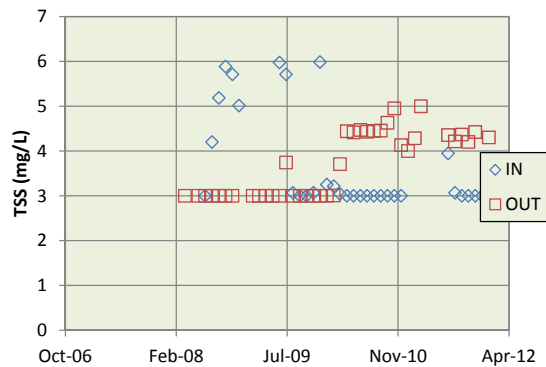
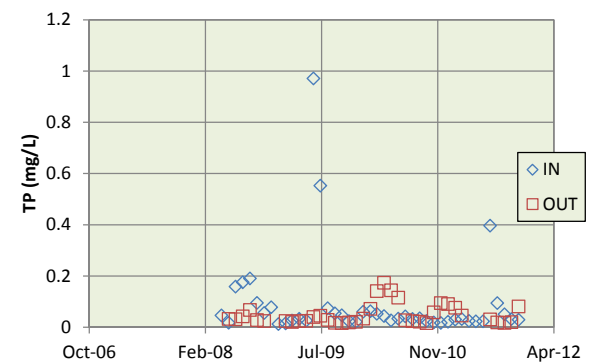
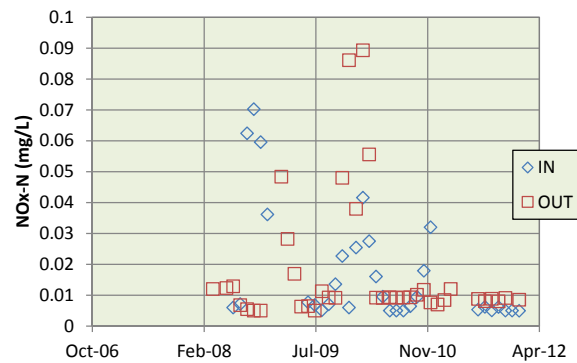
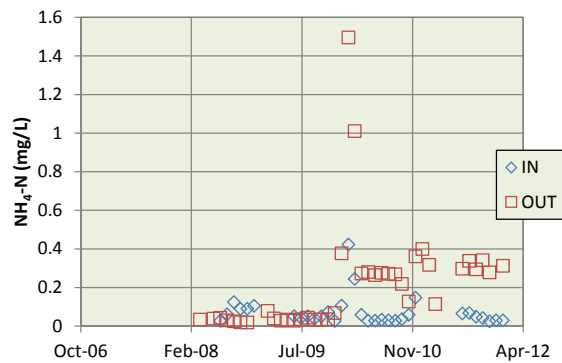
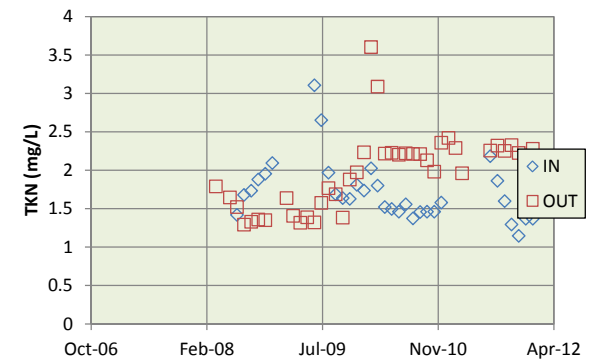
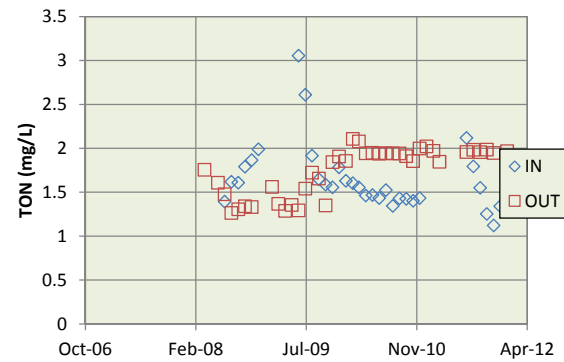
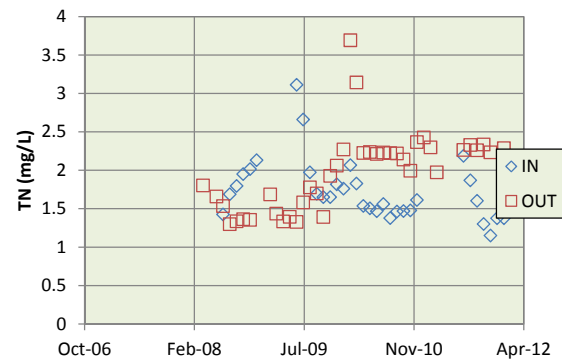
Long Term Average

	IN	OUT	Diff
TN	1.95	1.71	0.24
TON	1.50	1.63	-0.14
TKN	1.89	1.69	0.20
NH ₄ -N	0.40	0.06	0.34
NO _x -N	0.06	0.02	0.03
TP	0.13	0.13	0.00
TSS	4.28	3.57	0.71

Period of Record Apr-08 Feb-12



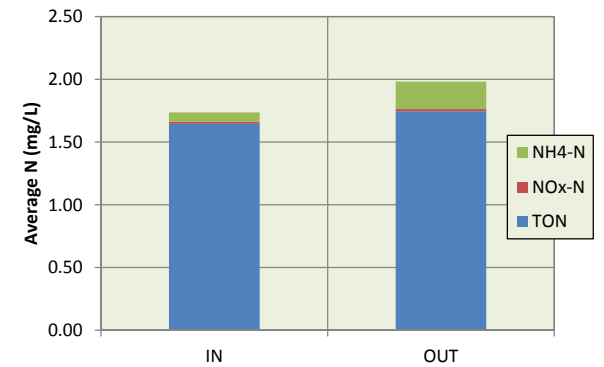
STA-5 Cell 1A - Monthly Water Quality Data Summary



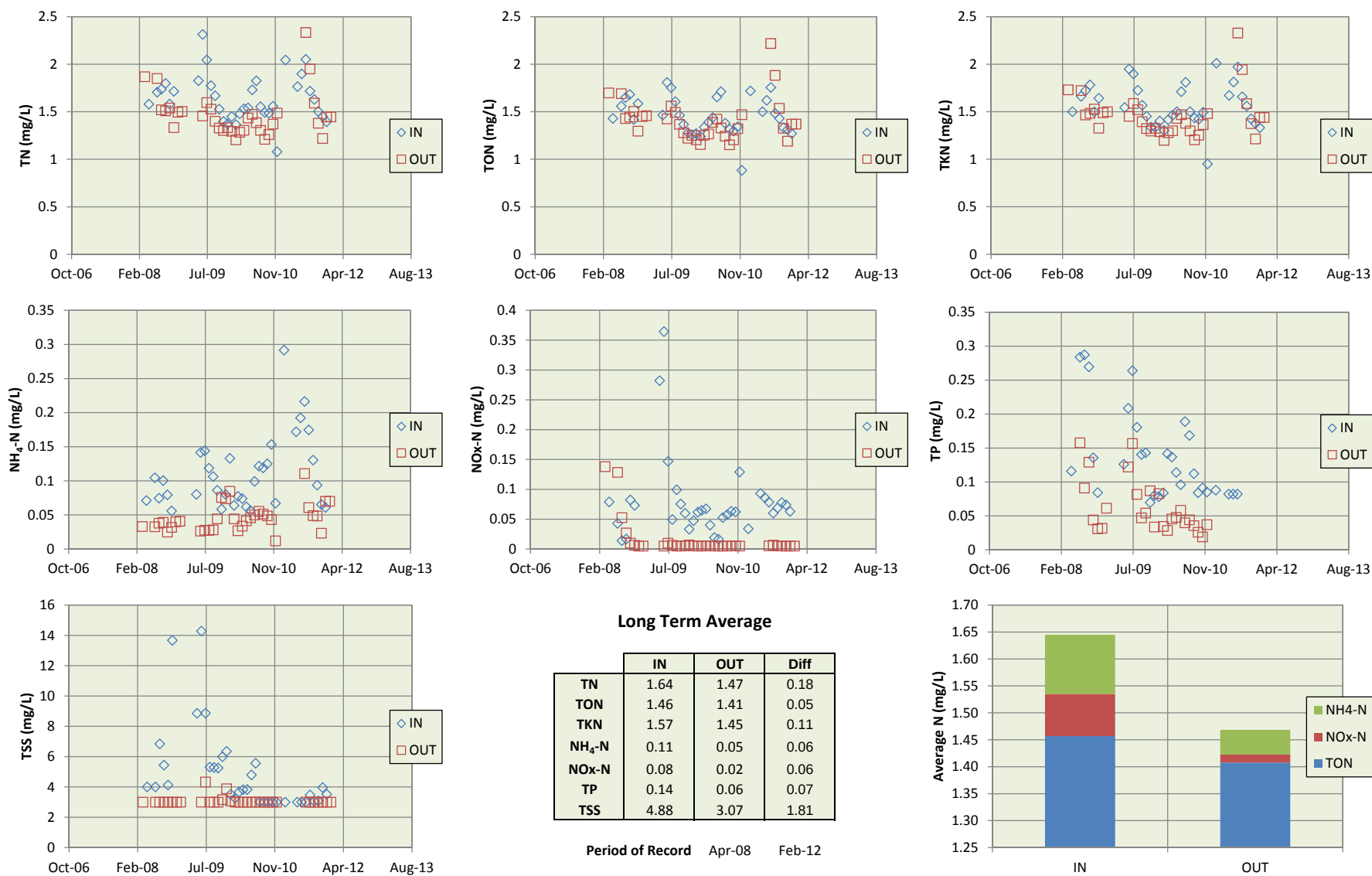
Long Term Average

	IN	OUT	Diff
TN	1.74	1.98	-0.25
TON	1.64	1.75	-0.10
TKN	1.72	1.97	-0.25
NH ₄ -N	0.07	0.22	-0.15
NO _x -N	0.02	0.02	0.00
TP	0.09	0.05	0.04
TSS	3.67	3.69	-0.03

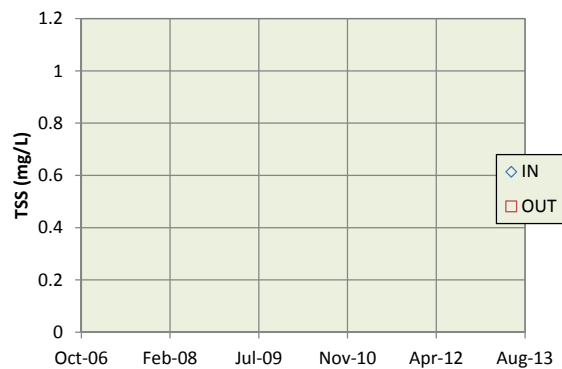
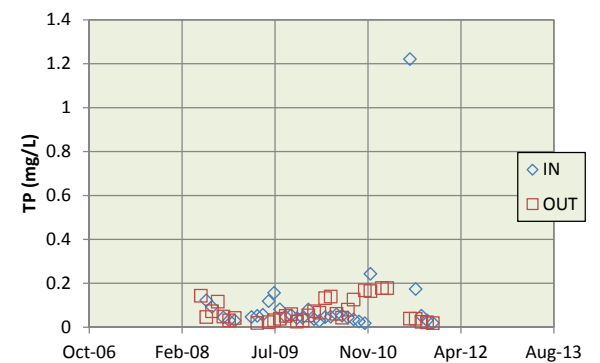
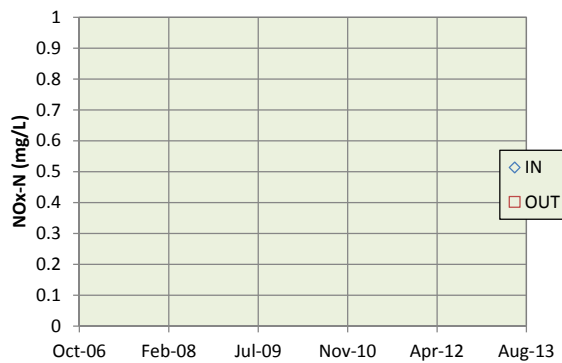
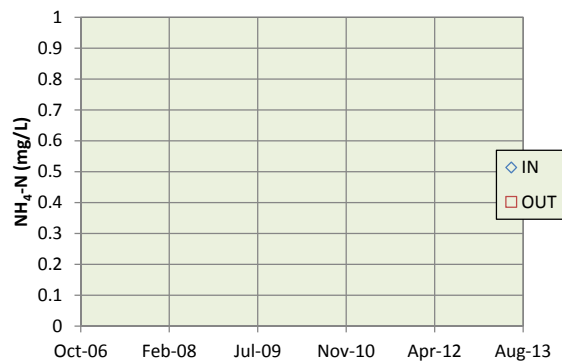
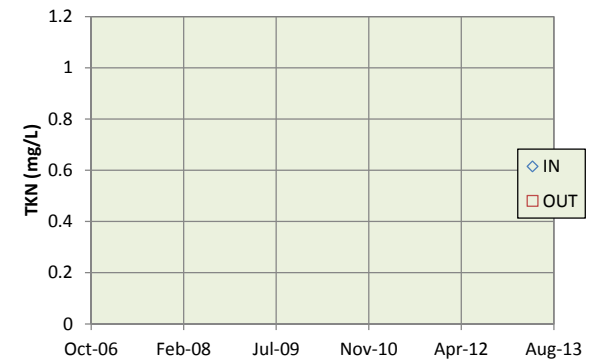
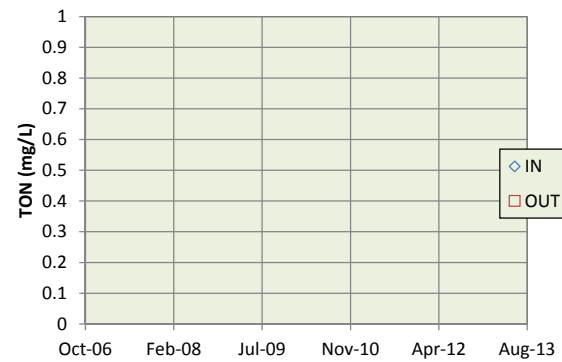
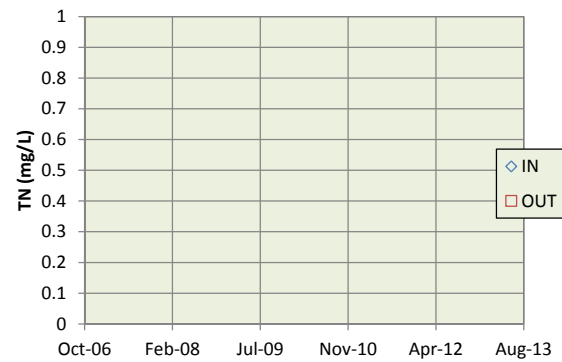
Period of Record Apr-08 Jan-12



STA-5 Cell 1B - Monthly Water Quality Data Summary



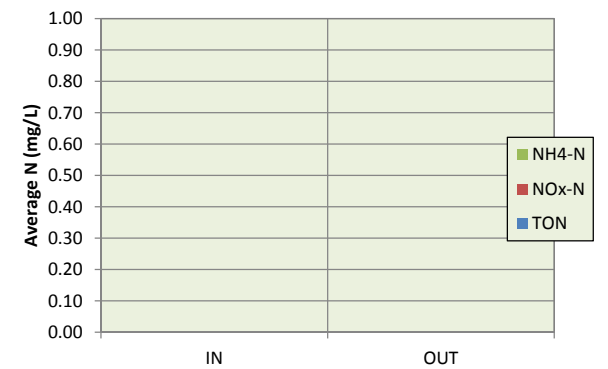
STA-5 Cell 2A - Monthly Water Quality Data Summary



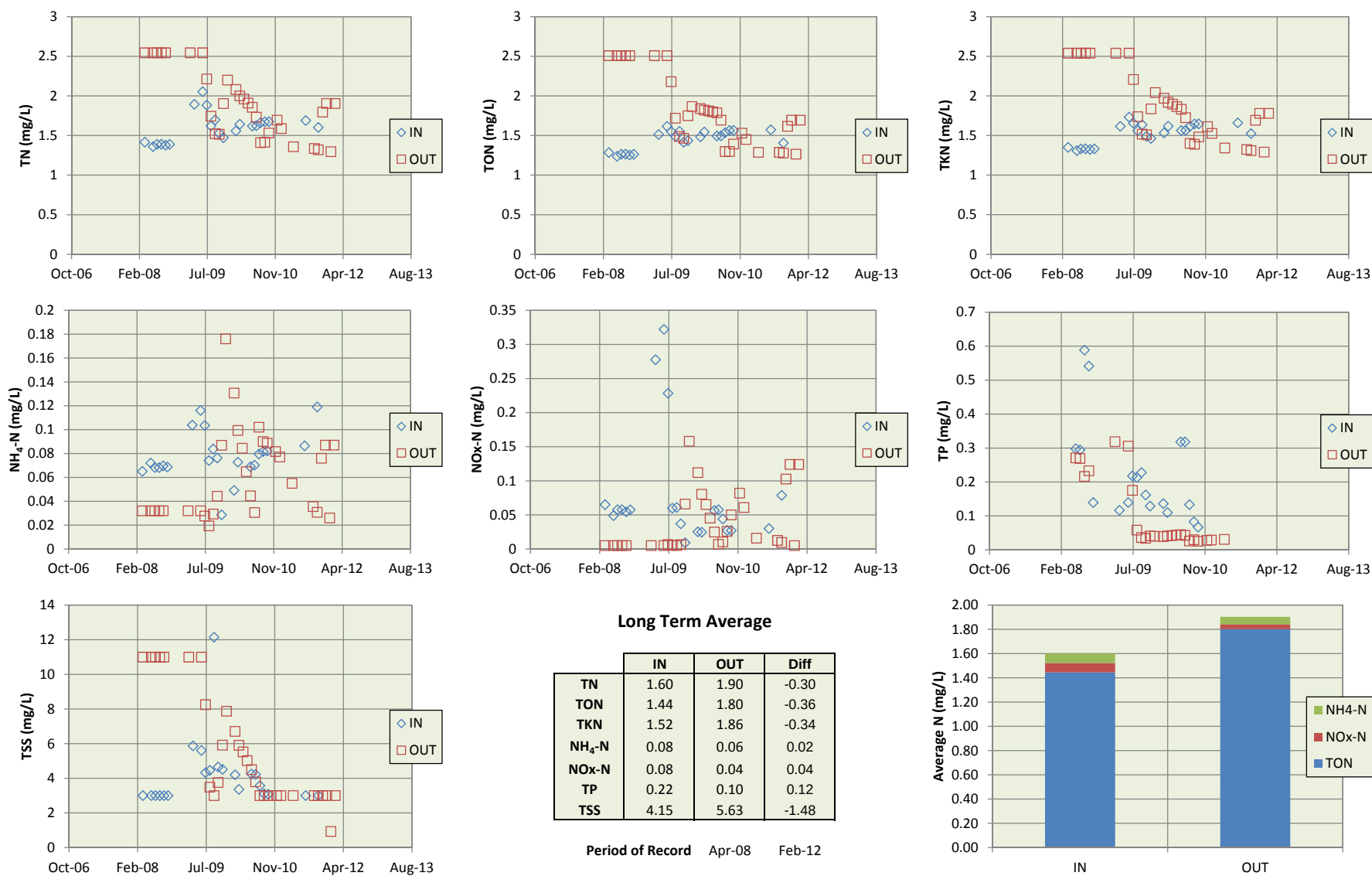
Long Term Average

	IN	OUT	Diff
TN	#DIV/0!	#DIV/0!	#DIV/0!
TON	#DIV/0!	#DIV/0!	#DIV/0!
TKN	#DIV/0!	#DIV/0!	#DIV/0!
NH ₄ -N	#DIV/0!	#DIV/0!	#DIV/0!
NO _x -N	#DIV/0!	#DIV/0!	#DIV/0!
TP	0.10	0.07	0.03
TSS	#DIV/0!	#DIV/0!	#DIV/0!

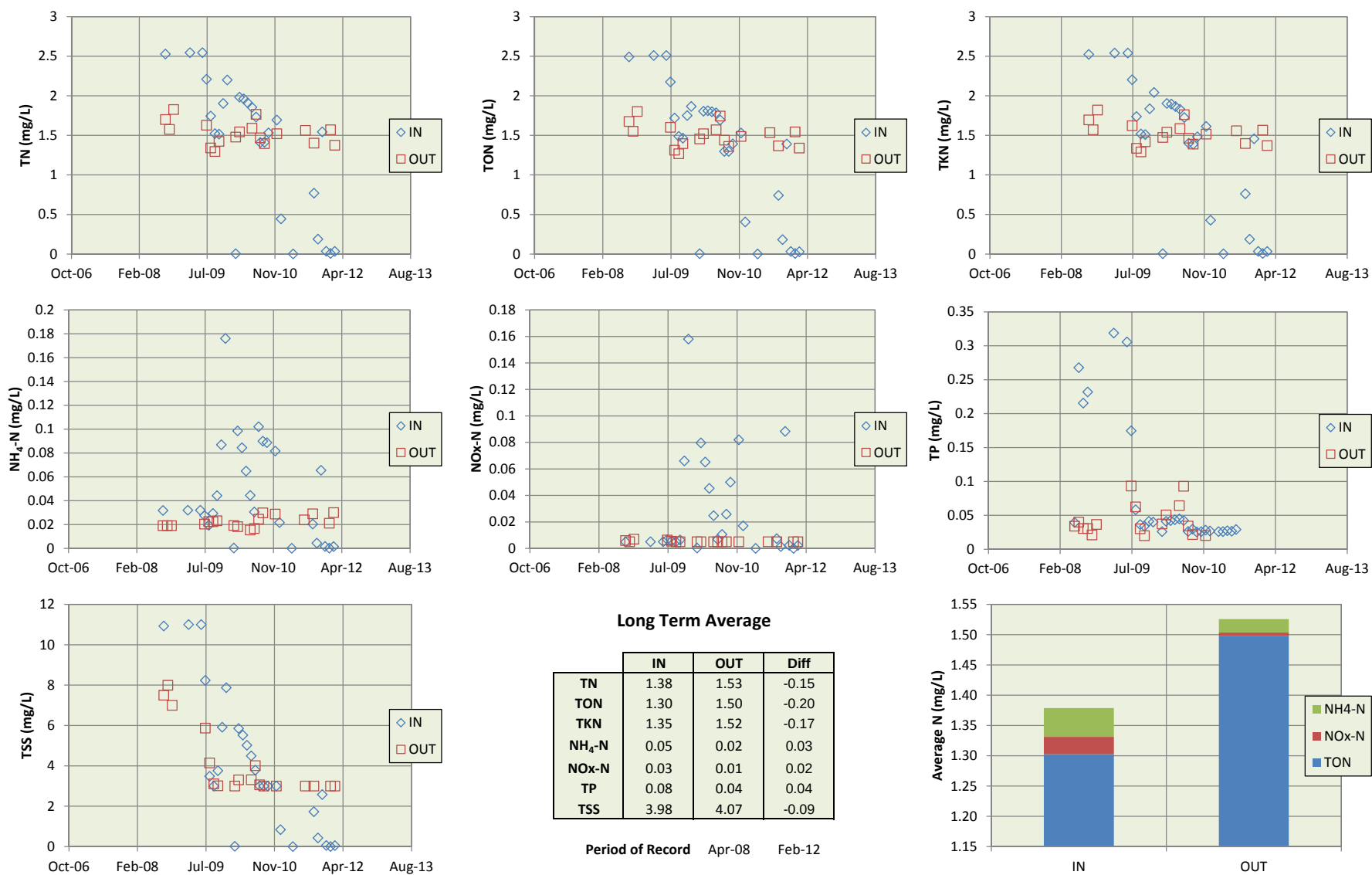
Period of Record Apr-08 Feb-12



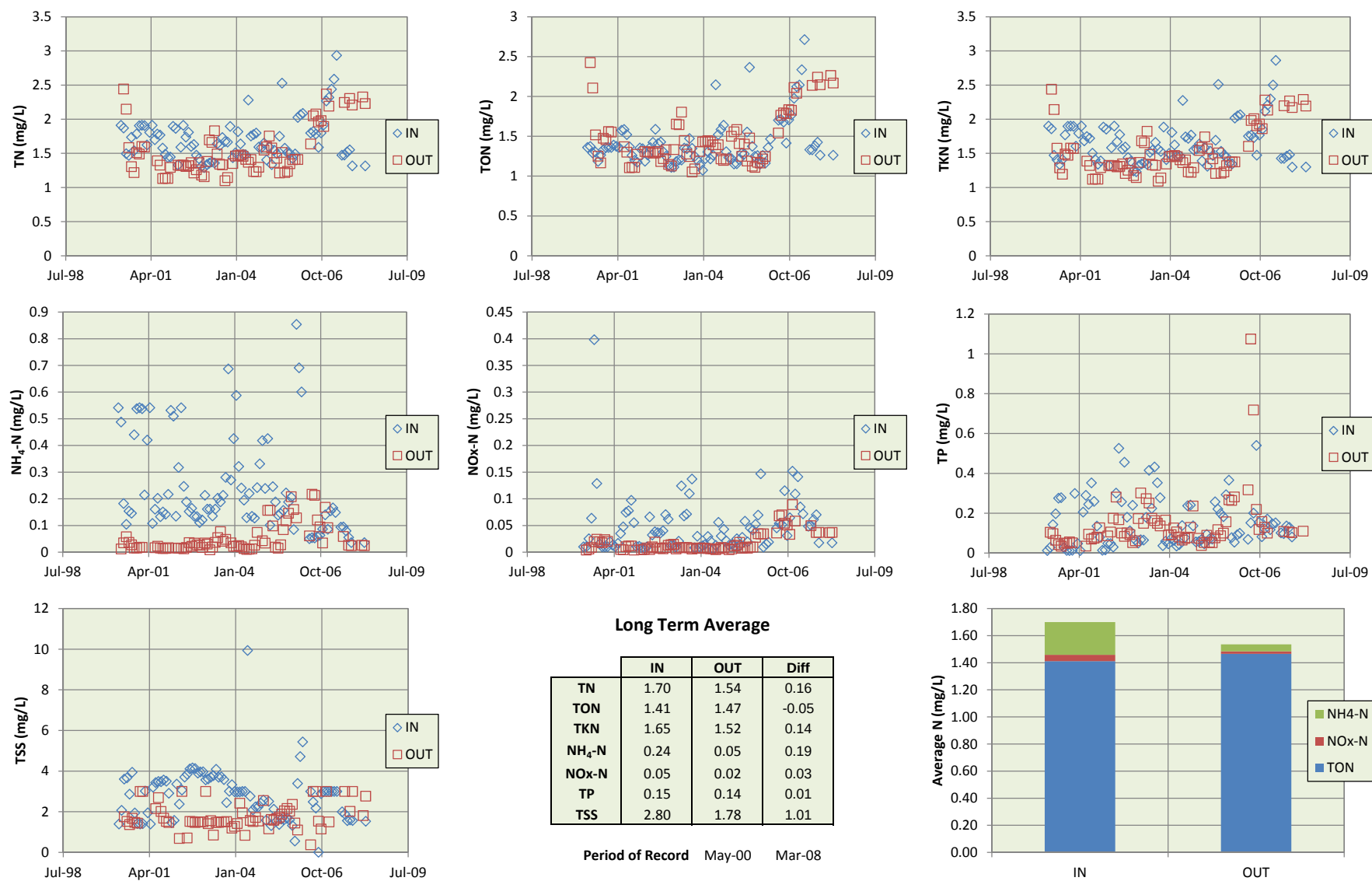
STA-5 Cell 2B - Monthly Water Quality Data Summary



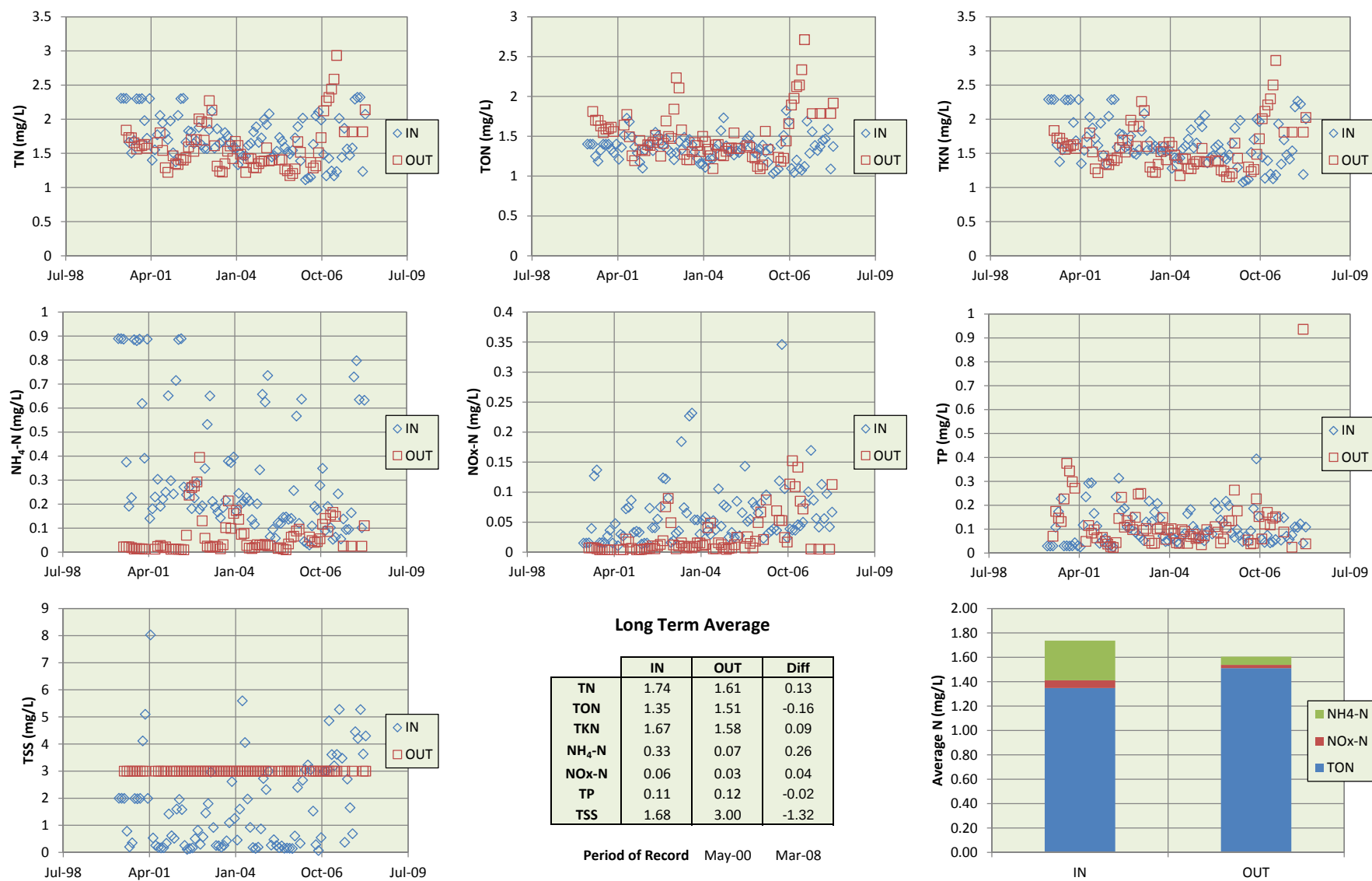
STA-5 Cell 3A - Monthly Water Quality Data Summary



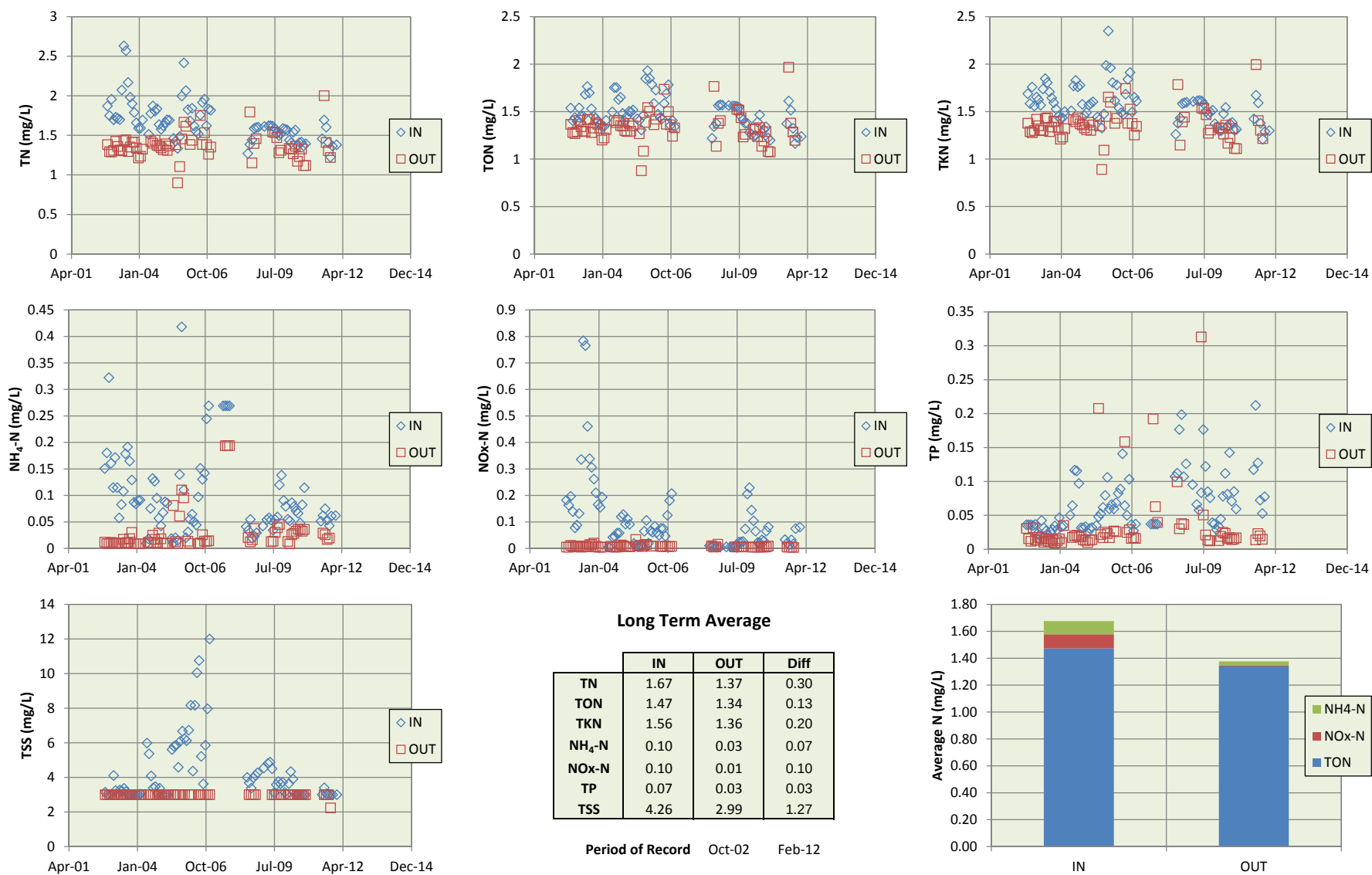
STA-5 Cell 3B - Monthly Water Quality Data Summary



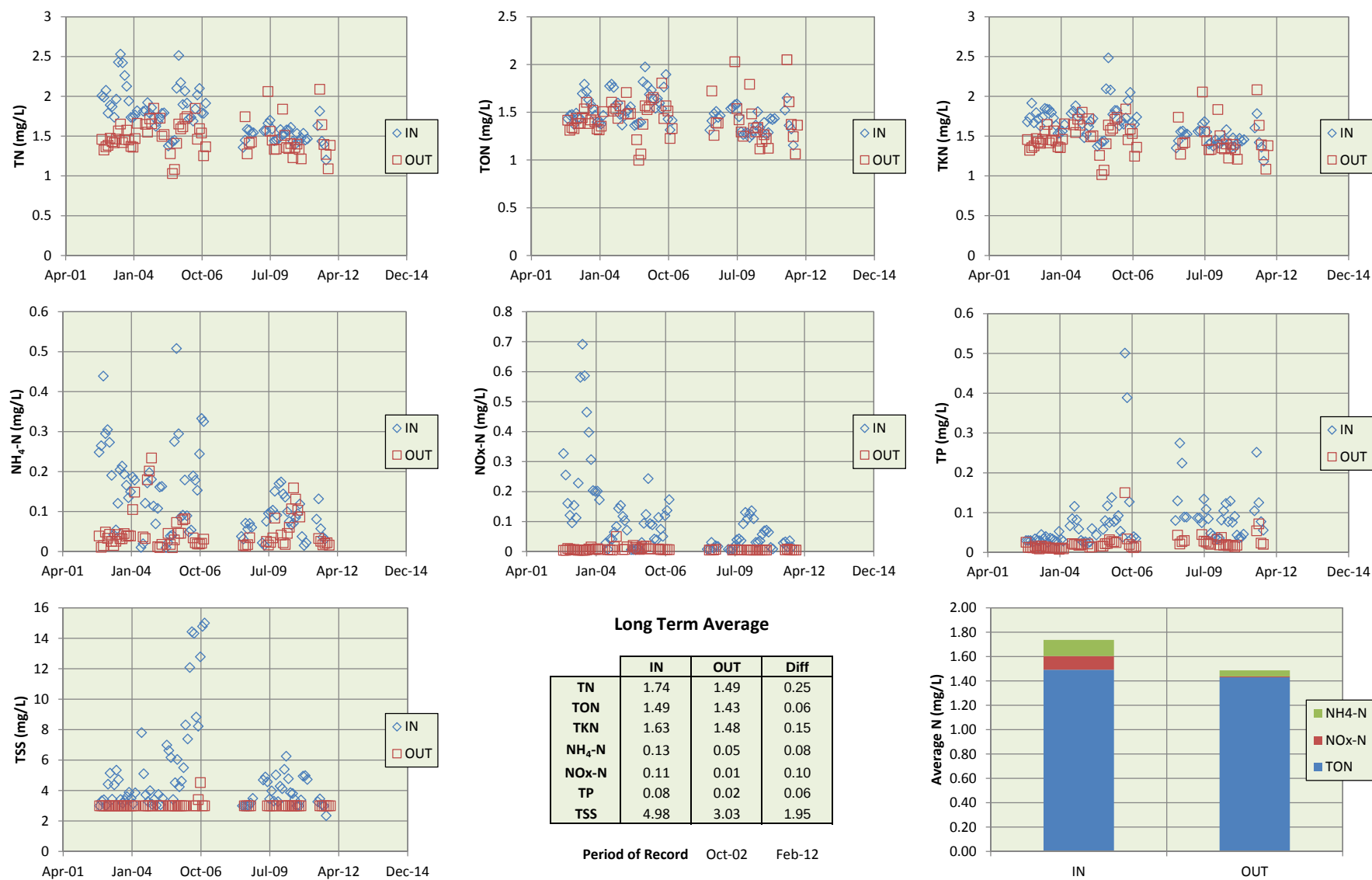
STA-5 Center Flow-way - Monthly Water Quality Data Summary



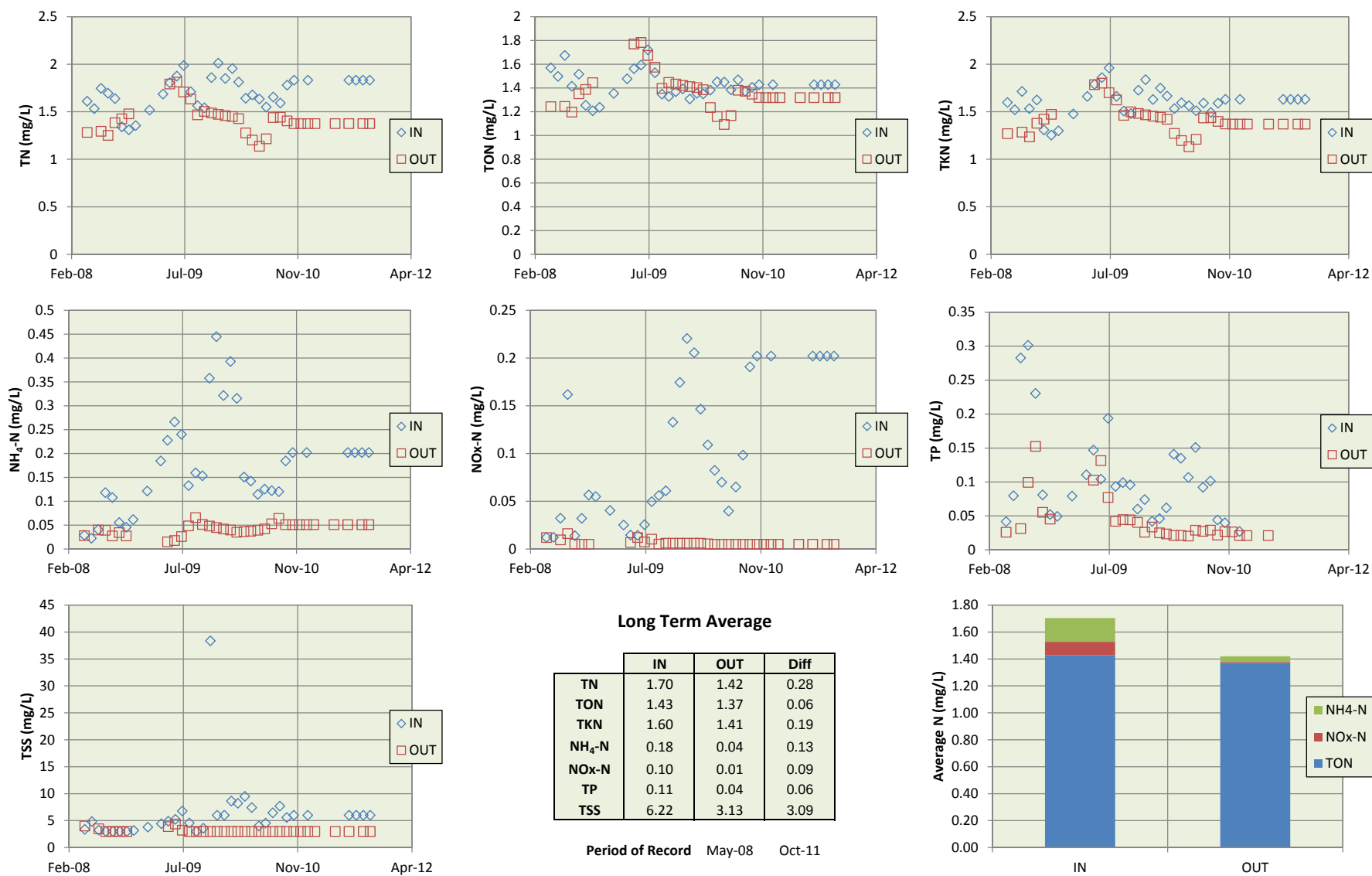
STA-5 North Flow-way - Monthly Water Quality Data Summary



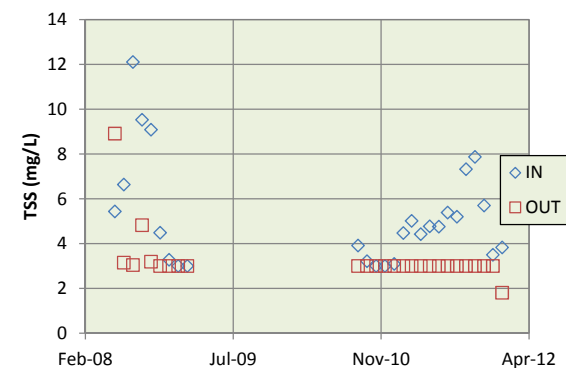
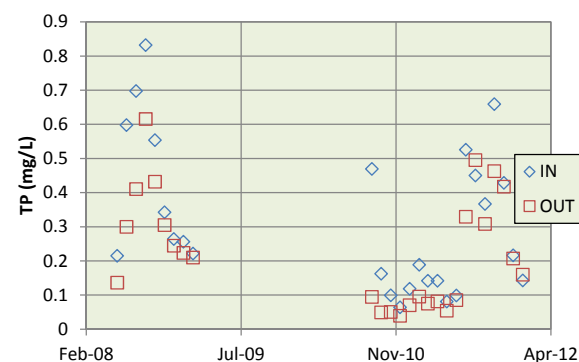
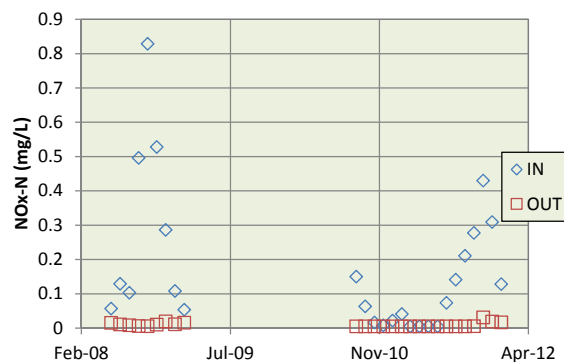
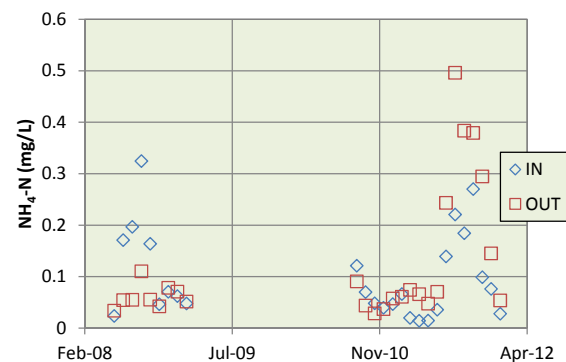
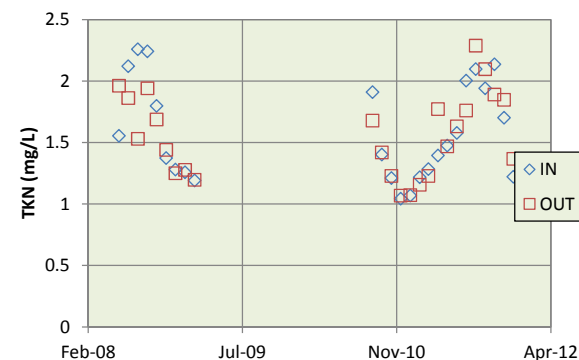
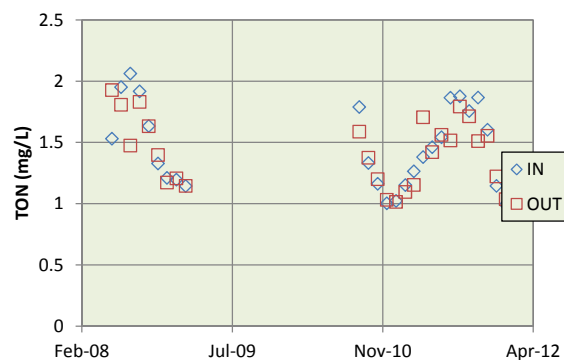
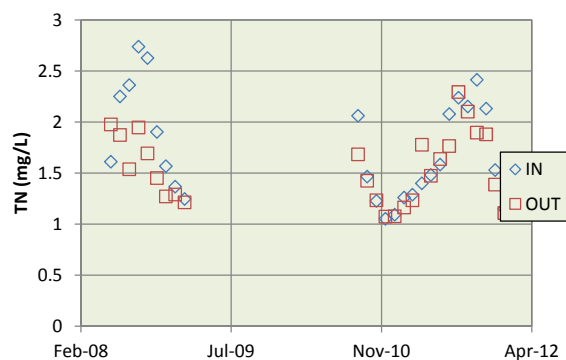
STA-6 Cell 3 - Monthly Water Quality Data Summary



STA-6 Cell 5 - Monthly Water Quality Data Summary



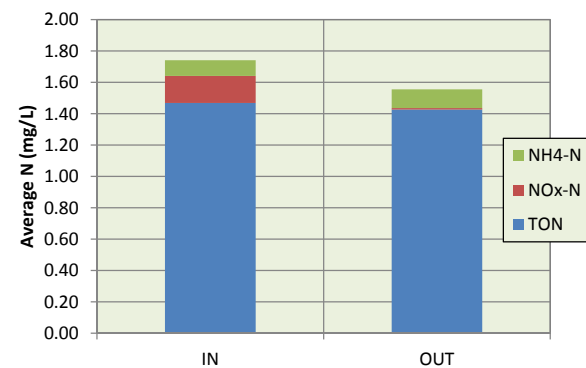
STA-6_Section 2 - Monthly Water Quality Data Summary



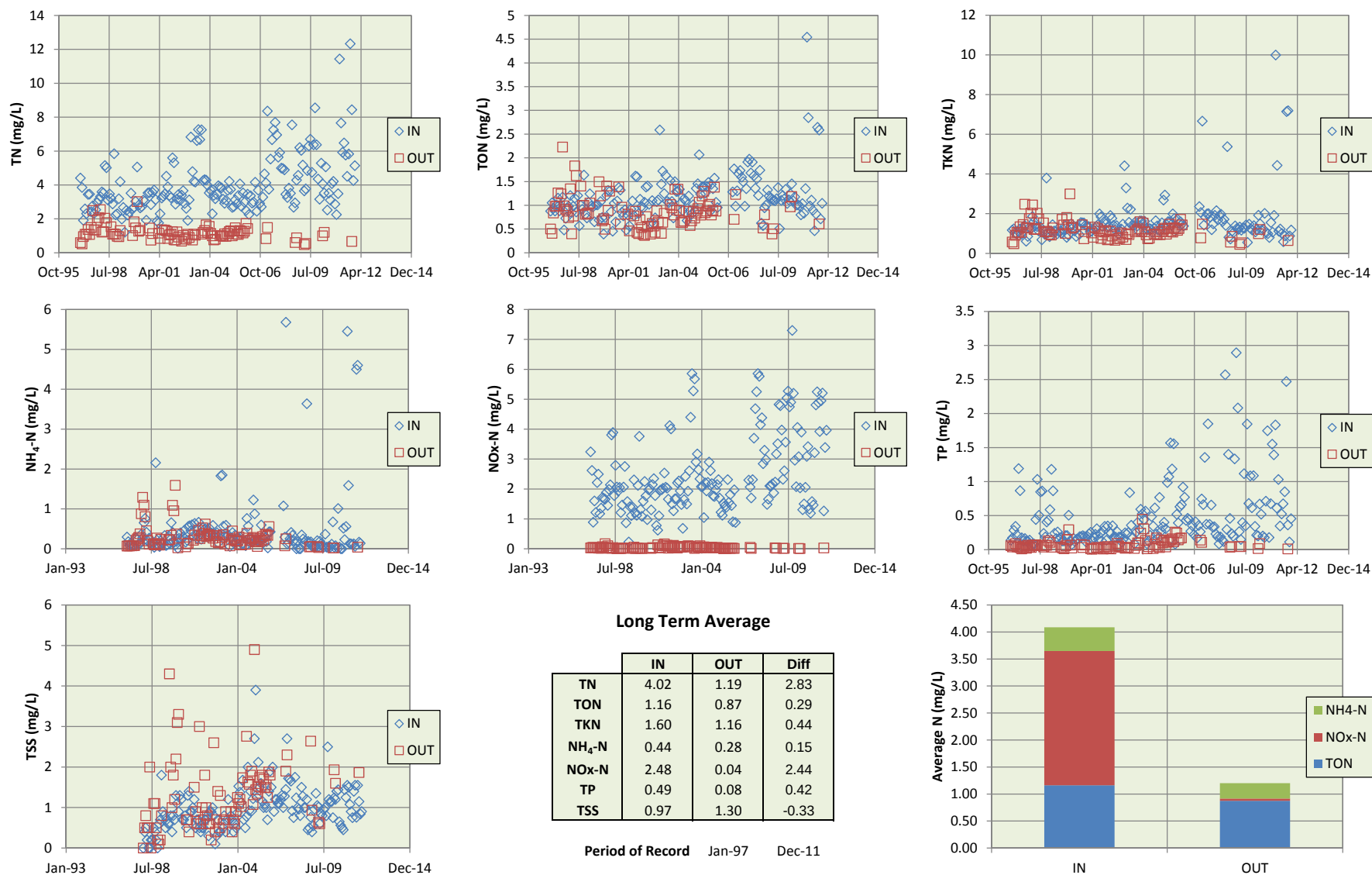
Long Term Average

	IN	OUT	Diff
TN	1.74	1.56	0.19
TON	1.47	1.43	0.04
TKN	1.57	1.55	0.02
NH ₄ -N	0.10	0.12	-0.02
NOx-N	0.17	0.01	0.16
TP	0.32	0.23	0.09
TSS	5.19	3.27	1.93

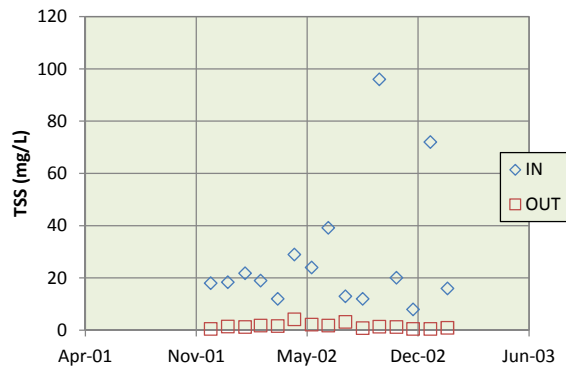
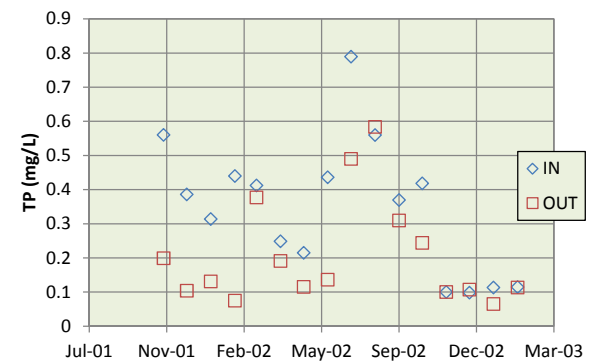
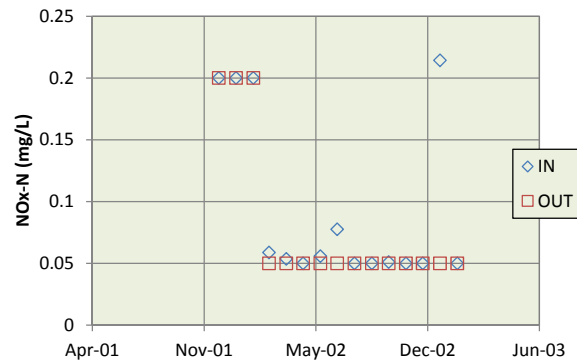
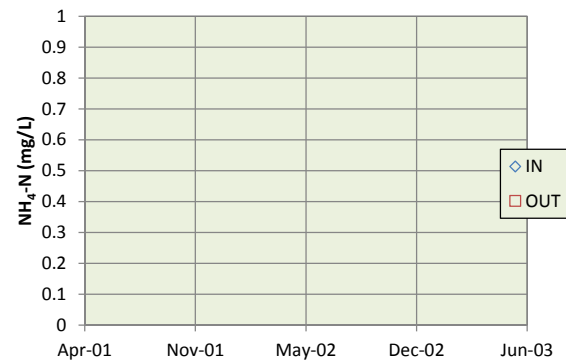
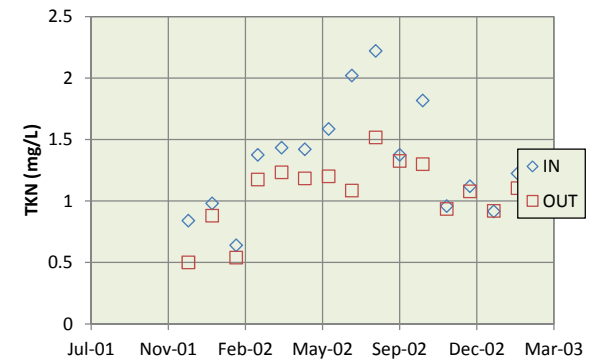
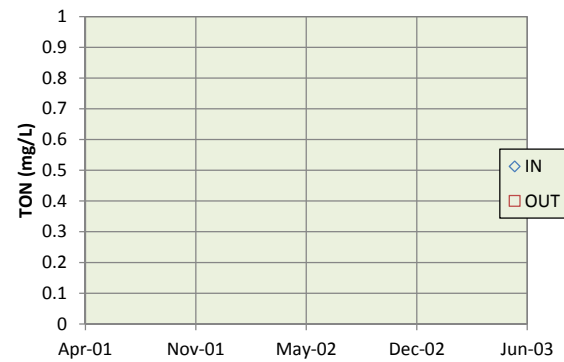
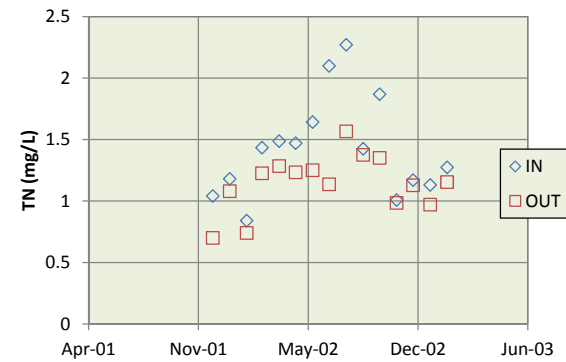
Period of Record Jun-08 Jan-12



Taylor Creek Pilot STA - Monthly Water Quality Data Summary



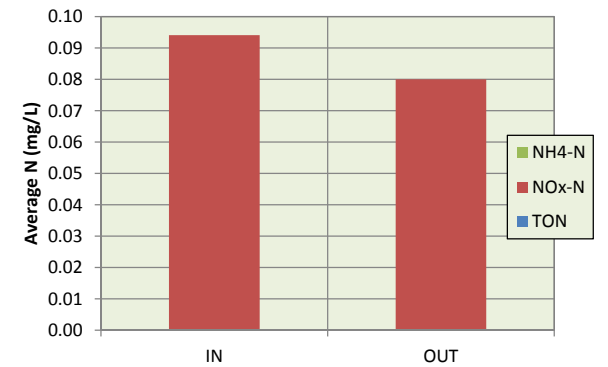
City of Titusville, Blue Heron Wetland Treatment System - Monthly Water Quality Data Summary



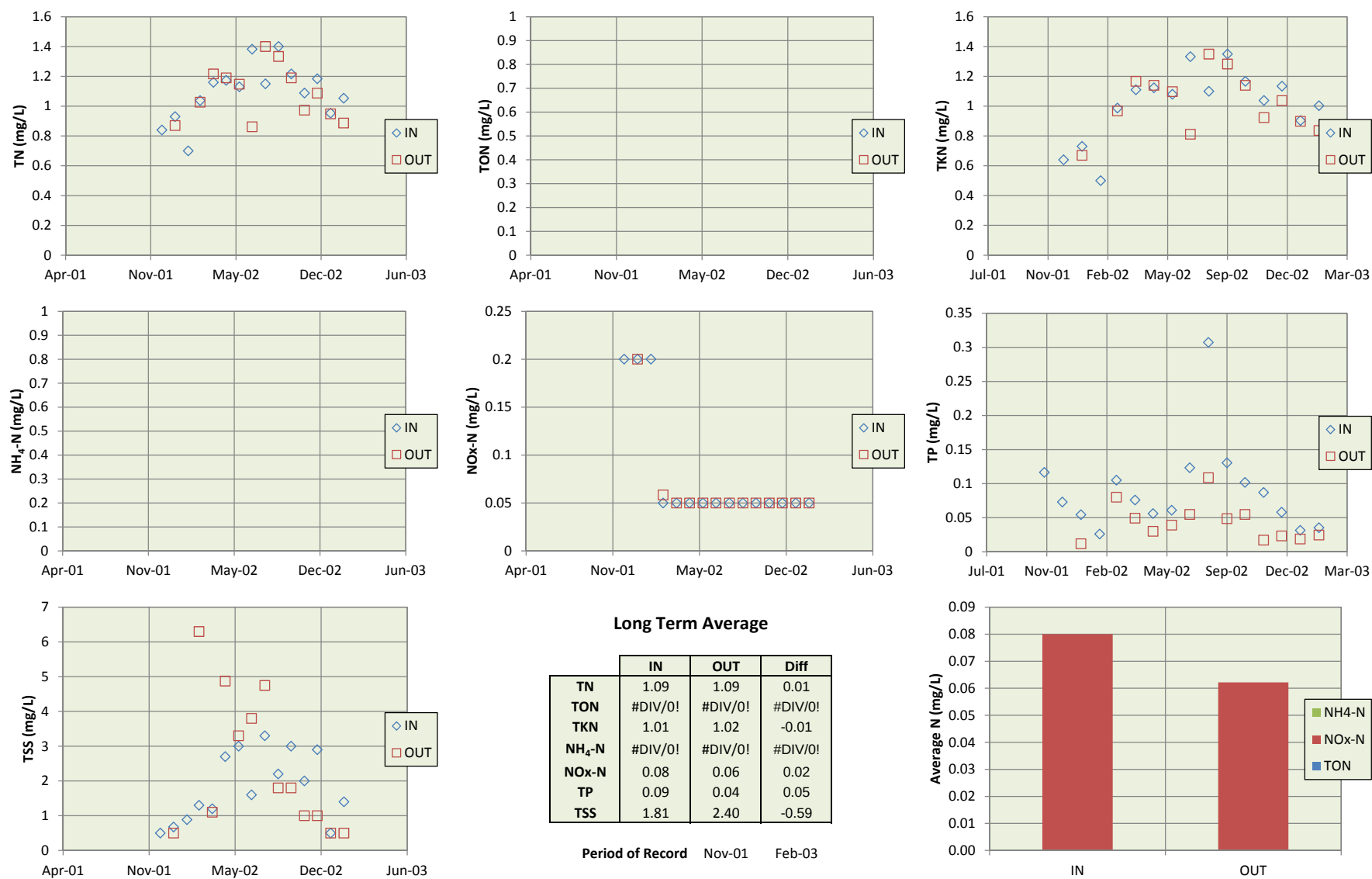
Long Term Average

	IN	OUT	Diff
TN	1.42	1.15	0.28
TON	#DIV/0!	#DIV/0!	#DIV/0!
TKN	1.33	1.07	0.26
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TP	0.35	0.21	0.14
TSS	27.90	1.56	26.34

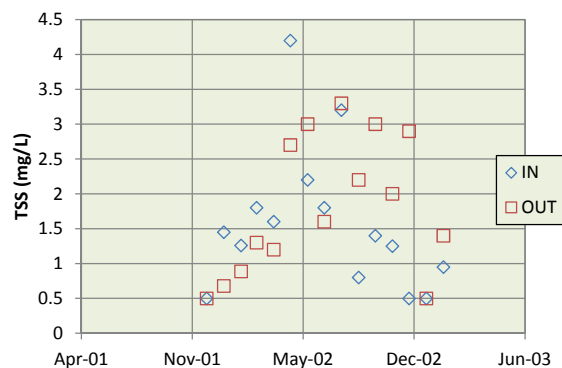
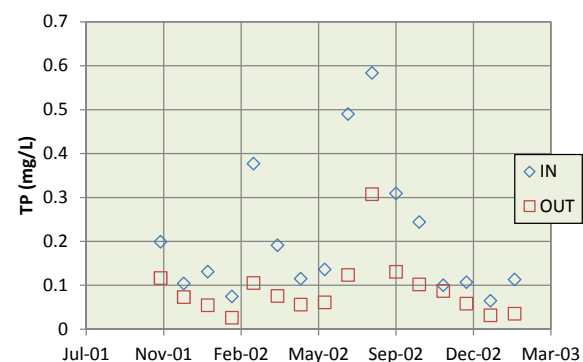
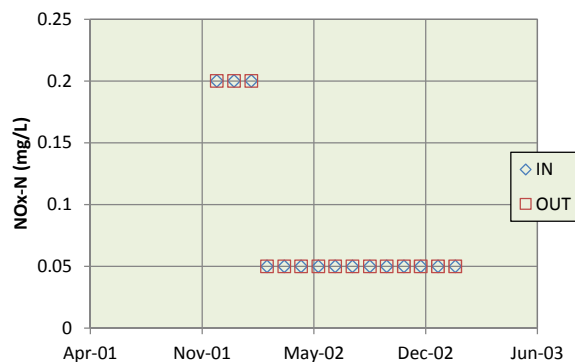
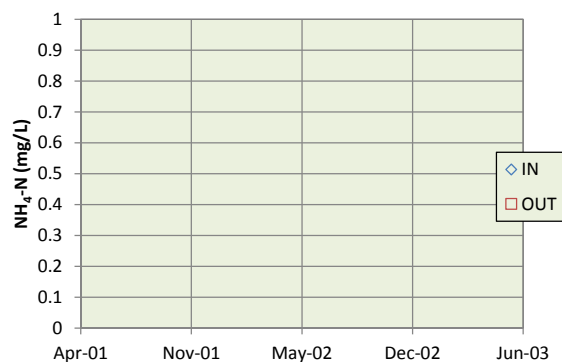
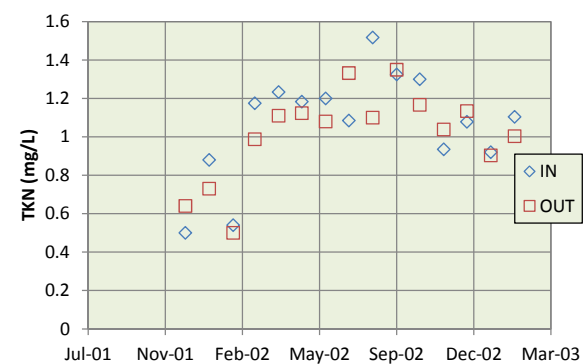
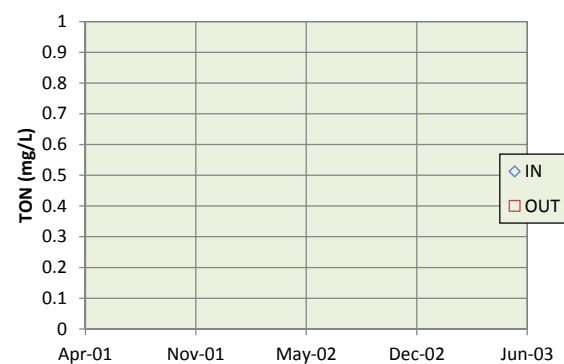
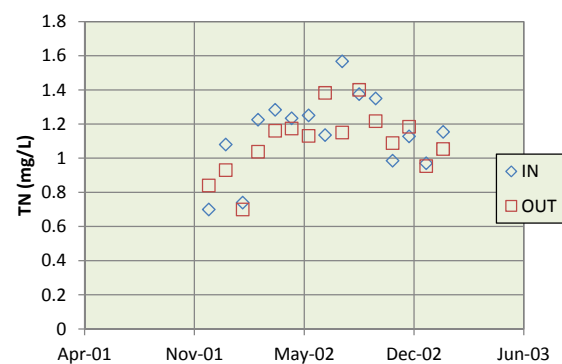
Period of Record Nov-01 Feb-03



Wellington Aquatics Pilot Test Facility Cell E1 - Monthly Water Quality Data Summary



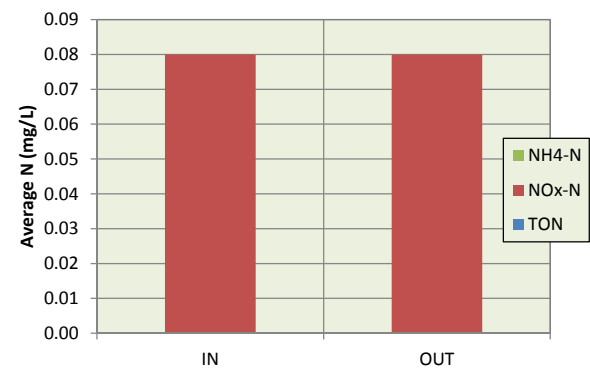
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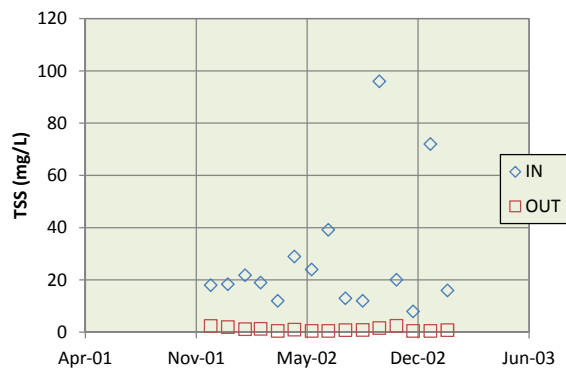
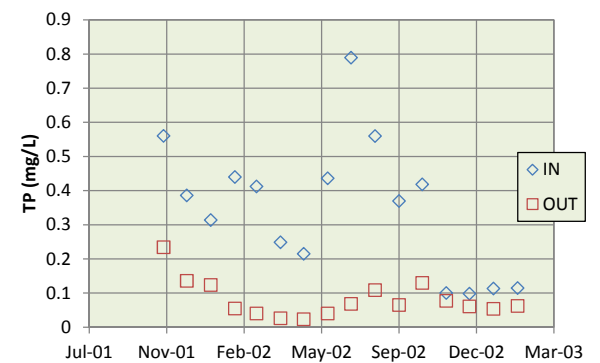
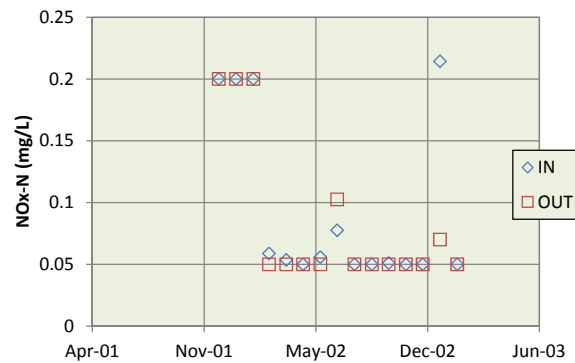
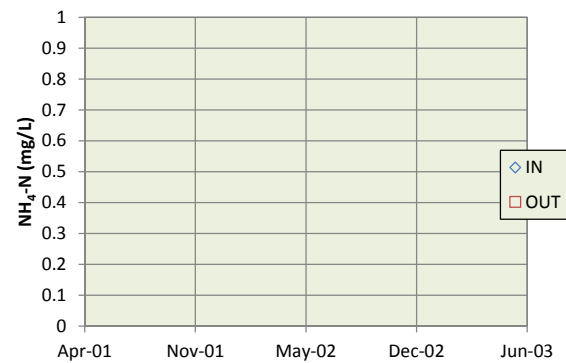
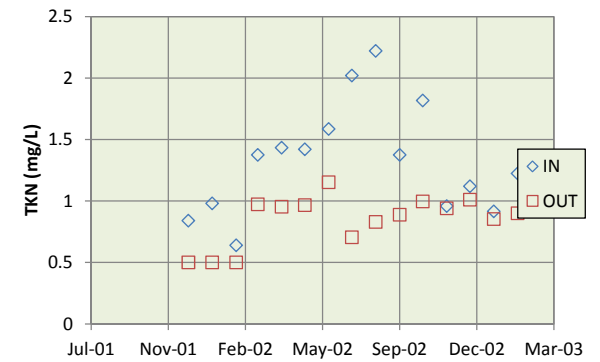
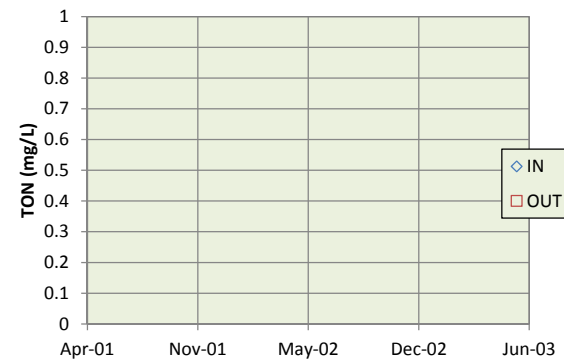
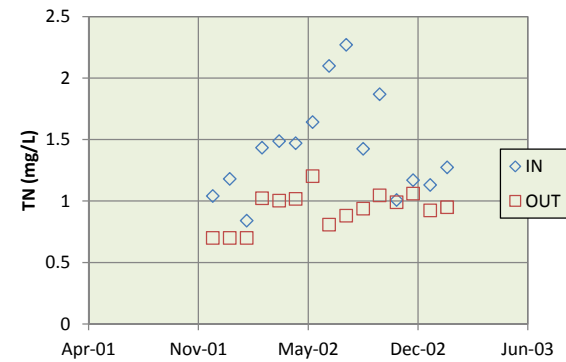
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TKN	1.07	1.01	0.05
NH ₄ -N	#DIV/0!	#DIV/0!	#DIV/0!
NO _x -N	0.08	0.08	0.00
TP	0.21	0.09	0.12
TSS	1.56	1.81	-0.25

Period of Record Nov-01 Feb-03



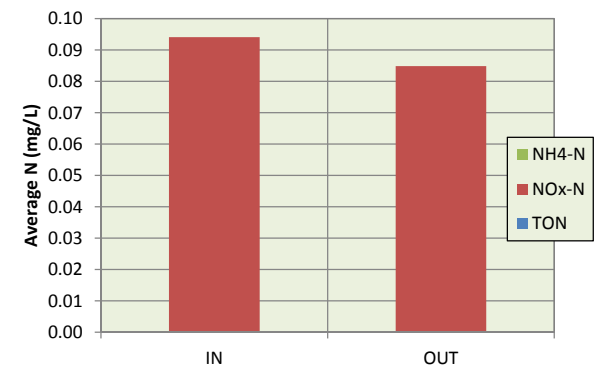
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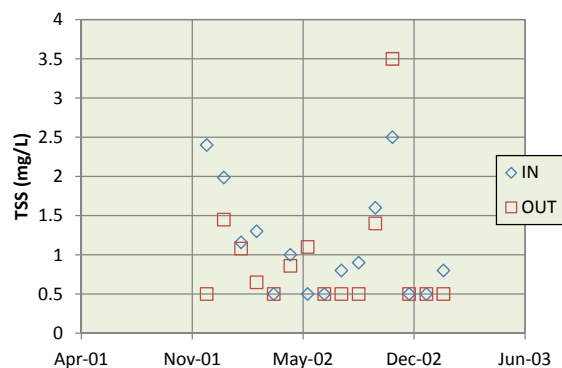
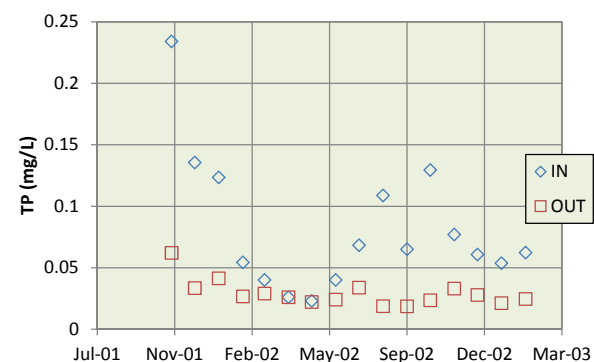
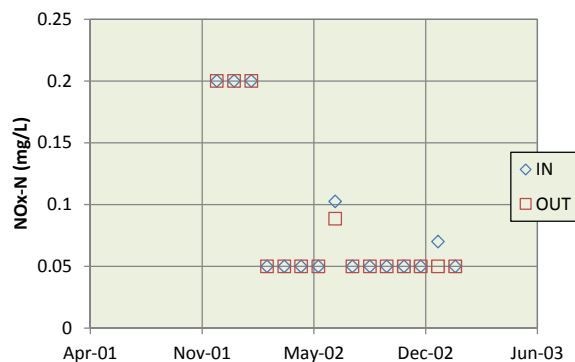
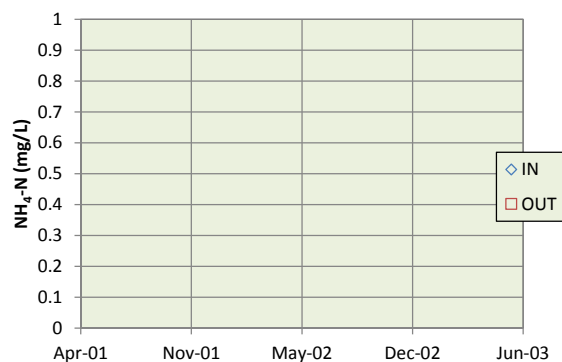
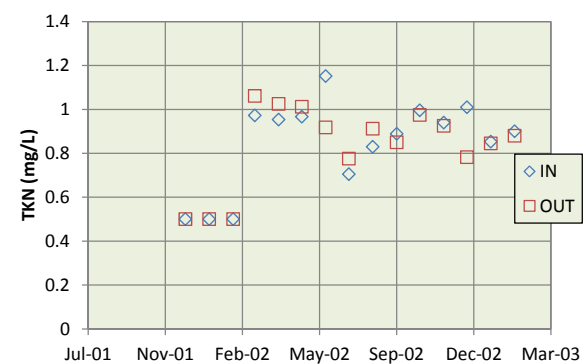
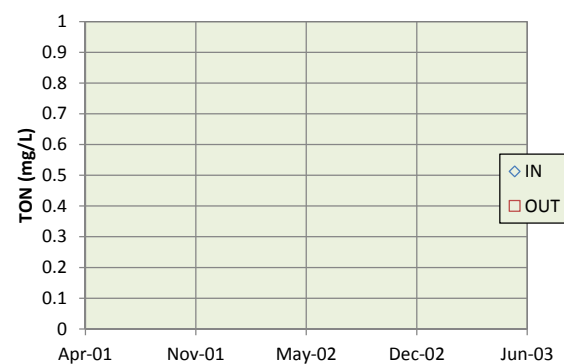
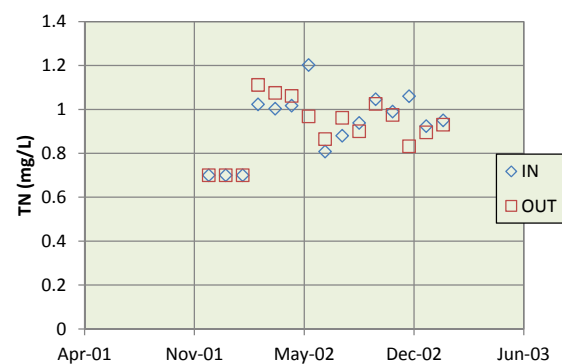
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NO _x -N	0.09	0.08	0.01
TP	0.35	0.08	0.27
TSS	27.90	1.13	26.77

Period of Record Nov-01 Feb-03



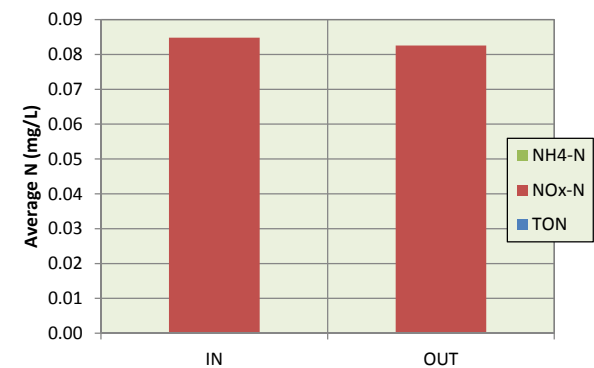
Wellington Aquatics Pilot Test Facility Cell W1 - Monthly Water Quality Data Summary



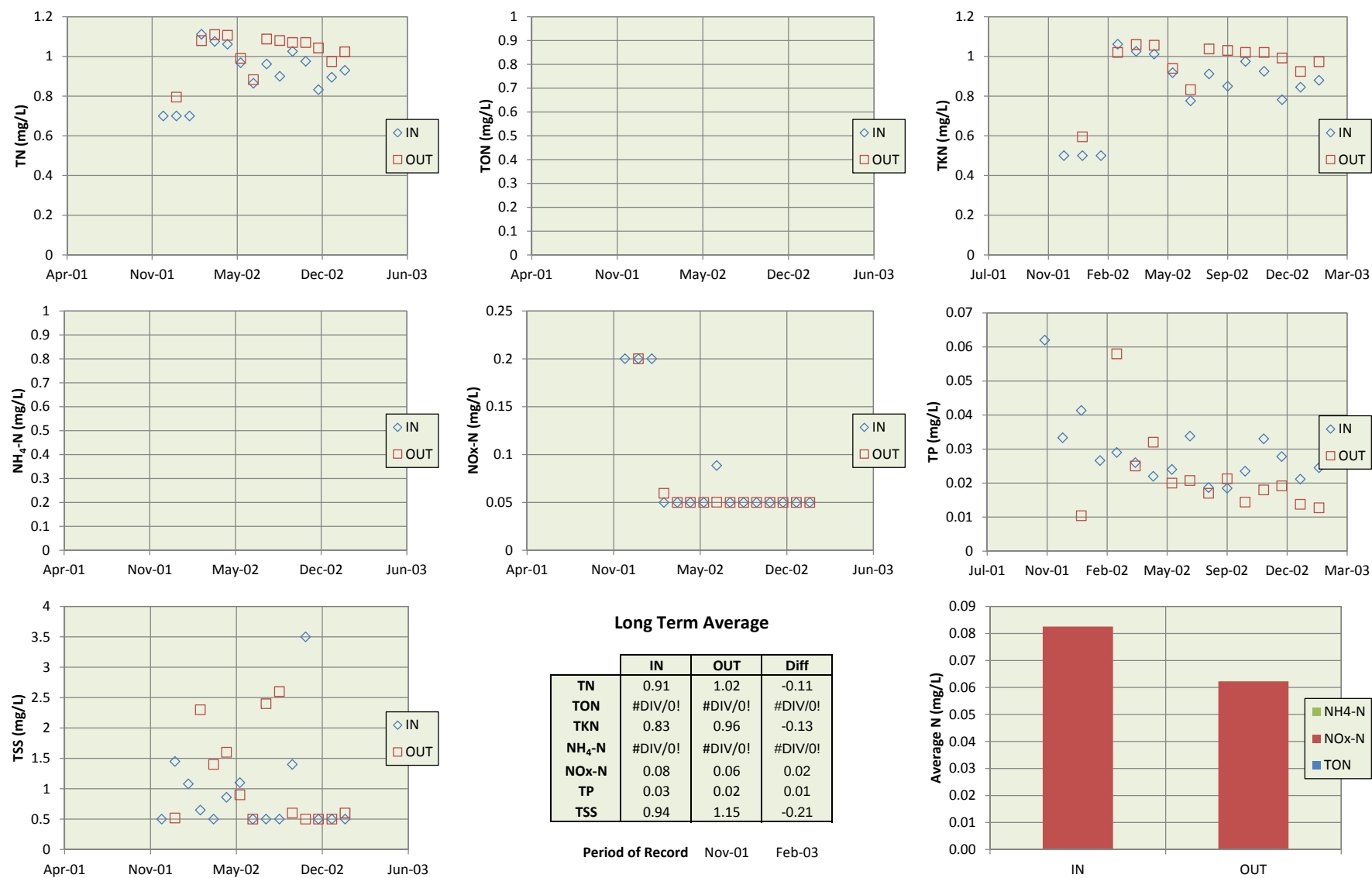
Long Term Average

	IN	OUT	Diff
TN	0.93	0.91	0.02
TON	#DIV/0!	#DIV/0!	#DIV/0!
TKN	0.84	0.83	0.01
NH ₄ -N	#DIV/0!	#DIV/0!	#DIV/0!
NO _x -N	0.08	0.08	0.00
TP	0.08	0.03	0.05
TSS	1.13	0.94	0.19

Period of Record Nov-01 Feb-03



Wellington Aquatics Pilot Test Facility Cell W2 - Monthly Water Quality Data Summary



Wellington Aquatics Pilot Test Facility Cell W3 - Monthly Water Quality Data Summary



Wetland
Solutions,
Inc.

C-43 WQTA Test Facility Conceptual Design – Task 4

Attachment C

C-43 WQTA Test Facility Conceptual Plan (Task 3)

Final Task 3 Report

Conceptual Design of C-43 Water Quality Treatment Area Nutrient Removal/Reduction Test Facility

Prepared for
South Florida Water Management District

Date
August 2012

Prepared by
Wetland Solutions, Inc.





CERTIFICATION

I hereby certify, as a Professional Engineer in the State of Florida, that the information in this document was assembled under my direct personal charge. This report is not intended or represented to be suitable for reuse by the South Florida Water Management District or others without specific verification or adaptation by the Engineer. This certification is made in accordance with the provisions of the Laws and Rules of the Florida Board of Professional Engineers under Chapter 61G15-29, Florida Administrative Code.

Christopher H. Keller, P.E.

Florida P.E. No. 54040

Wetland Solutions, Inc.

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Gainesville, FL 32609

Certificate of Authorization No. 28785

Date:

(Reproductions are not valid unless signed, dated, and embossed with Engineer's seal.)

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Acronyms

AGP	Algal Growth Potential
AN	Ammonia N
BAN	Biologically Available N
BOD	Biochemical Oxygen Demand
BMAP	Basin Management Action Plan
C*	Irreducible background concentration
COD	Chemical Oxygen Demand
CRE	Caloosahatchee River and Estuary
DIN	Dissolved Inorganic Nitrogen
DO	Dissolved Oxygen
DON	Dissolved Organic Nitrogen
EMV	Emergent Macrophyte Vegetation
F.A.C.	Florida Administrative Code
FAV	Floating Aquatic Vegetation
FDEP	Florida Department of Environmental Protection
HLR	Hydraulic Loading Rate
N	Nitrogen
nHRT	Nominal Hydraulic Residence Time
NH ₃ -N	Unionized form of AN
NH ₄ -N	Ammonium Nitrogen
NO _x -N	Nitrate+Nitrite Nitrogen
NNC	Numeric Nutrient Criteria
O&M	Operation and Maintenance
OW	Open Water
PAC	Periphytic Algal-Dominated Community
PSTA	Periphyton Stormwater Treatment Area
SAV	Submerged Aquatic Vegetation
SFWMD	South Florida Water Management District
SRP	Soluble Reactive Phosphorus
STAs	Stormwater Treatment Areas
TKN	Total Kjeldahl Nitrogen
TMDL	Total Maximum Daily Loads
TN	Total Nitrogen
TON	Total Organic Nitrogen
TP	Total Phosphorus
TSS	Total Suspended Solids
USEPA	United States Environmental Protection Agency
WQTA	Water Quality Treatment Area
WSI	Wetland Solutions, Inc.

Section 1.0 Introduction

1.1 Background

Elevated concentrations of nitrogen and phosphorus in the Caloosahatchee River and Estuary (CRE) are contributing to water quality impairments in this system as evidenced by excessive algae blooms and decreased water clarity and dissolved oxygen content (Knight and Steele 2005). The reduction of nutrient concentrations and loads to these water bodies was required by the Northern Everglades and Estuaries Protection Program passed by the Florida Legislature and signed into law in 2007, and by CRE Total Maximum Daily Loads (TMDL) published by the Florida Department of Environmental Protection (FDEP) (Bailey *et al.* 2009) [Rule 62-304.800, Florida Administrative Code (F.A.C.)]. FDEP is currently in the planning stages of the Caloosahatchee Estuary Basin Management Action Plan (BMAP) which is the roadmap to implement the TMDL. Concurrent with the BMAP planning, FDEP is revising the estuary TMDL and developing several tributary and freshwater Caloosahatchee River TMDLs.

The development of numeric nutrient criteria (NNC) is another water quality process with the potential to influence future nutrient targets in the CRE. The United States Environmental Protection Agency (USEPA) and FDEP both have their own rulemaking processes that may or may not be reconciled during design or construction of the test facility. The future of both federal and state criteria implementation is therefore uncertain at this time and the details of this dynamic process are beyond the scope of this report.

In order to increase nutrient reductions to the downstream estuary, the South Florida Water Management District (District or SFWMD) and Lee County have been partnering on the C-43 Water Quality Treatment Area Testing Facility Project (the “C-43 WQTA Project”). The purpose of the C-43 WQTA Project is to investigate and demonstrate cost effective strategies for reducing loadings of total nitrogen (TN) and other constituents, including total phosphorus (TP) and total suspended solids (TSS) to the C-43 Canal (Caloosahatchee River) to improve water quality in the downstream estuarine ecosystems. The District also anticipates that the C-43 WQTA Project will generate strategies that can be applied to estuaries throughout south Florida.

Through a decade of successful operation of Stormwater Treatment Areas (STAs), the District has built an extensive expertise in TP removal from storm water runoff using wetland treatment systems. However, the mechanisms for TN removal via wetland treatment systems have not been studied to the same extent. The existing data from STAs mostly indicate that currently designed wetland treatment systems are not optimized to reduce TN (especially dissolved organic nitrogen, DON) although they can remove dissolved inorganic nitrogen (DIN) with high efficiency, which accounts for, at most, 20% of the TN present in the CRE system. Thus, the District initiated a project to identify the best option(s) for achieving the C-43 WQTA Project’s goals of nutrient reduction in CRE and to design a test facility prior to construction of the full-scale C-43 WQTA Project.

Those efforts resulted in several deliverables and recommendations, such as developing constructed wetland treatment systems as the most cost-effective means for nutrient removal. The recommended plan included design, construction, and operation of a multi-scale



C-43 WQTA Test Facility Conceptual Design – Task 3

test/demonstration facility on a 1,750-acre parcel (“Boma” property see Figure 1) purchased by the District and Lee County for the proposed WQTA (CH2M HILL 2010). This test/demonstration facility is intended to provide the basis for design of constructed wetlands to assist with ultimate compliance of the CRE TMDL.

Wetland Solutions, Inc. (WSI) has been selected to provide additional expert technical support to develop the detailed C-43 WQTA Project Testing Plan, including a conceptual design of the proposed test facilities and an operational testing plan. The C-43 WQTA testing plan is intended to provide the flexibility to test multiple nitrogen removal approaches to determine which approaches are most effective.

1.2 Project Goals and Objectives

The goal of this project is to develop a conceptual design for a test facility comprised of mesocosms and test cells that: 1) will test and demonstrate wetland technologies that have the potential to effectively remove and/or reduce background TN loading from the facility’s C-43 inflows; 2) identify the range of hydrological loading rates per unit area to achieve optimal removal/reduction rates; 3) is based on a review of available information and sound science; and 4) is implementable and cost effective on larger scales and/or applicable to other south Florida estuarine systems.

The objective of this work is to develop a conceptual design for a testing facility. The C-43 WQTA Test Facility Conceptual Design Project has three tasks:

1. Project Management and Communication
2. Evaluation of Total Nitrogen Reduction Options
3. Conceptual Design of the Testing Facility

WSI has previously completed Tasks 1 and 2. This report provides the results of Task 3, namely an updated conceptual design for the proposed C-43 WQTA Test Facility based on the findings in the Task 2 report (WSI 2012). This conceptual design includes a recommended suite of testing scales including: laboratory bioassays, experimental mesocosms, and field-scale wetland plots. Each testing scale includes testing plans, scientific rationales, and estimated costs for construction, operation and maintenance (O&M), and testing in the proposed conceptual plan.

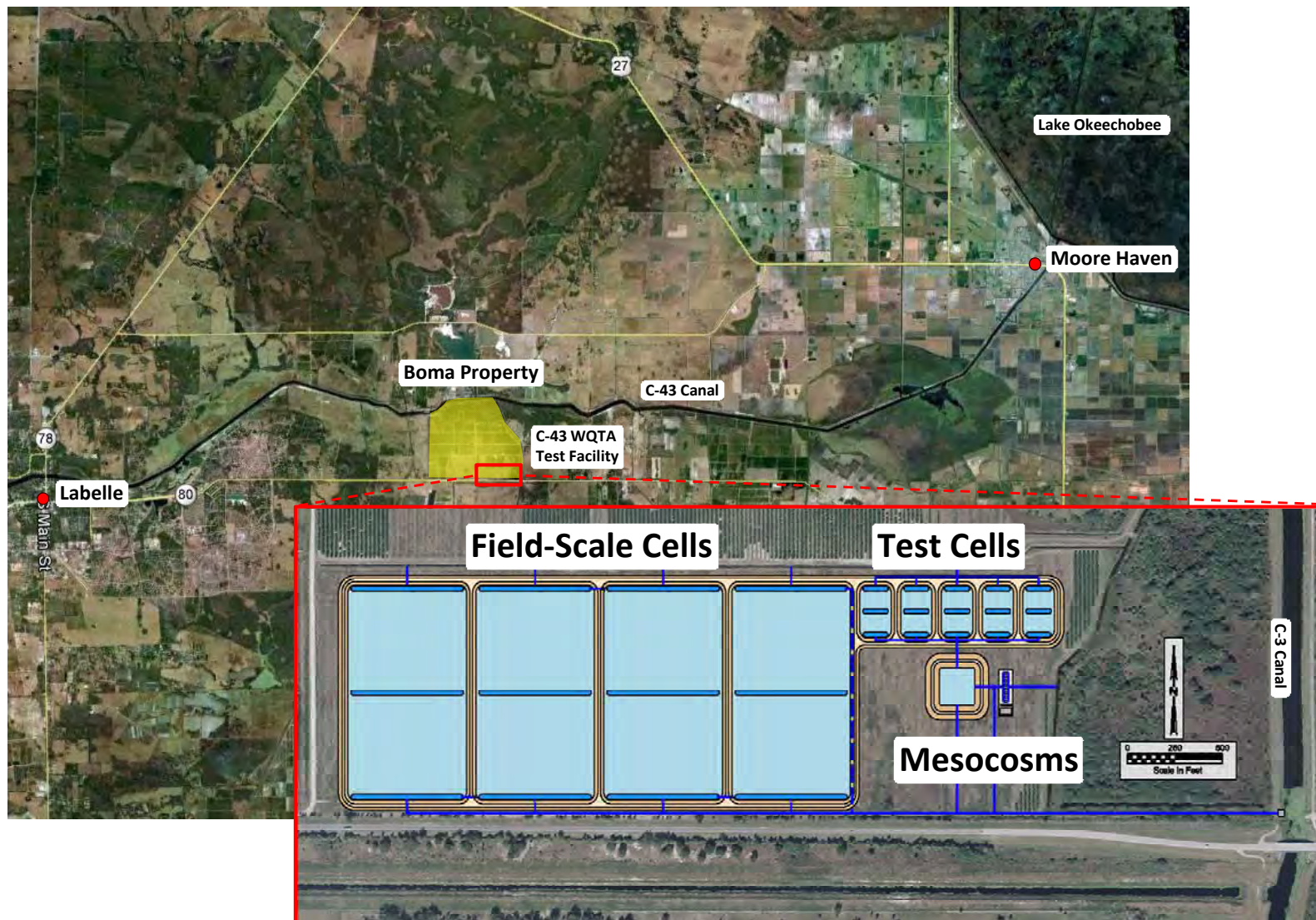


Figure 1. Location of the C-43 Water Quality Treatment and Demonstration Project

1.3 C-43 WQTA Test Facility Conceptual Design

The objective of this task is to recommend a conceptual design of a test facility capable of removing TN with an emphasis on removing various TN fractions, including organic and inorganic forms. This test facility conceptual plan will primarily be based on information presented in WSI (2012): *Evaluation of Total Nitrogen Reduction Options for the C-43 Water Quality Treatment Area Test Facility*. Two additional supporting documents include WSI (2010): *C-43 Water Quality Treatment Area – Technical Expert Review Panel Consolidated Report* and CH2M HILL (2010): *Draft C-43 Water Quality Treatment Area Project Conceptual Plan Technical Memorandum*.

Recent literature and operational data on TN, TP, and TSS removal in Florida constructed treatment wetlands were reviewed and summarized in WSI (2012). Five treatment wetland alternatives were evaluated, including:

- Emergent macrophyte vegetation (EMV)
- Submerged aquatic vegetation (SAV)
- Floating aquatic vegetation (FAV)
- Attached and floating algal-dominated systems (PSTA or periphyton stormwater treatment area)
- Open water (OW)

Evaluation factors included:

- TN, TP, and TSS removal rates;
- Estimated background (C*) values by pollutant and sediment type; and
- Order-of-magnitude cost per unit treatment area and volume.

Based on their review, WSI (2012) concluded that EMV-, SAV-, and PSTA-dominated wetlands are collectively preferred over FAV and OW treatment systems. These preliminary comparisons are based on the assumption that site soils for the C-43 WQTA Project will be sandy or calcareous in nature and will therefore avoid the potentially high C* effect for TON resulting from organic and clayey soils. Existing subsurface profiles, which are limited to the southeast portion of the BOMA test facility site, support this assumption.

This comparison indicated that there is not likely to be a large difference in overall TN cost effectiveness between the top three wetland plant community types: EMV, PSTA, and SAV. Each of these types of wetlands has somewhat similar biogeochemical cycles, dependence on adequate surface area for treatment, and production of ample organic carbon required for effective denitrification of NO_x-N. However, where there are differences in performance and cost between wetland alternatives, those differences are used in this Task 3 report to prioritize testing resources.

The C-43 WQTA Expert Panel report (WSI 2010) came to a similar conclusion that, if the District was limited to a single wetland technology, the EMV would be most likely to achieve the lowest TN, TP, and TSS concentrations with the smallest footprint and the lowest construction cost. It is too early however for the District to determine what limit, if any, ought to exist for the number of wetland technologies to be used in the WQTA. A full-scale nitrogen-removal WQTA



C-43 WQTA Test Facility Conceptual Design – Task 3

facility may be a combination of technologies in series with each sized to provide the greatest overall cost effectiveness for the reduction of TN in the CRE.

This Task 3 report details the conceptual plan for the C-43 WQTA test facility. The proposed test facility conceptual plan includes a discussion and rationale for the use of bioassays and mesocosms as compared to larger test cells, recommended test cell treatments, a preliminary operations and monitoring plan, and estimated costs for design, construction, and operation of the proposed test facility. Experimentation of alternative wetland/aquatic plant communities arranged in different sequences will be conducted in the testing facility at the mesocosm level, larger scale test cells, or both. First consideration will be given to treatment trains comprised of conventional wetland and/or aquatic plant community cells that are optimized for the treatment of total nitrogen through natural microbial and photodegradation processes. Should the operation and sampling of the testing facility reveal that these different treatment trains cannot be effectively replicated throughout the watershed to achieve the CRE TMDL, other less conventional TN removal technologies might ultimately be considered.

Section 2.0 General Constructed Treatment Wetland Testing Rationale

2.1 Background

Constructed treatment wetlands include a broad variety of technologies that rely on the use of aquatic and wetland plants and associated microbial communities to provide water quality benefits. All constructed treatment wetlands have the following basic characteristics in common:

- One or more shallow (water depths typically averaging less than three feet) basins that receive, hold, and release water to be treated;
- Treatment processes that primarily rely on the growth of hydrophytes (aquatic and wetland plants) and associated microbial and sediment biogeochemical processes; and
- Relatively large land area requirements necessary to utilize solar input and wind/atmospheric diffusion as the primary energy and raw materials inputs for the treatment process.

There are two basic hydrologic variants of constructed treatment wetlands:

- Surface flow wetlands that route water aboveground; and
- Subsurface flow wetlands where water is primarily below ground.

Subsurface flow constructed wetlands have significant hydrologic and cost constraints and were not considered to be a practical alternative for the C-43 WQTA project (WSI 2012).

The different types of surface flow constructed treatment wetlands are generally similar in design with the exception of water regime (depth and duration of flooding) and the selection of the appropriate plant community that is adapted to the selected water regime. A considerable variety of hydrophytic plant species are available for use in constructed surface flow treatment wetlands in south Florida. Plant selection for constructed treatment wetlands is based on a number of considerations, including:

- Growth form/habit (floating, submerged, rooted, emergent, etc.);
- Flooding tolerance (saturated soil only, periodic flooding, continuous flooding, etc.);
- Salinity tolerance (strictly freshwater, mildly tolerant, halophyte, etc.);
- Pollution tolerance (oligotrophic, mesotrophic, eutrophic, etc.);
- Resistance to frost (intolerant or tolerant);
- Seasonality (annual, perennial, seasonal, etc.);
- Resistance to pests; and
- Value for wildlife habitat (cover, food, nesting, etc.).

C-43 WQTA Test Facility Conceptual Design – Task 3

By definition, treatment wetlands are constructed to provide water quality treatment. This implies the presence of pollution or wastes above ambient levels in the water source requiring treatment. For the proposed C-43 WQTA Project, the water source is surface waters in the C-43 Canal (channelized Caloosahatchee River) and tributary canals and streams. Elevated concentrations of nitrogen are of principal concern due to the stimulation of algae growth in the CRE system. The primary sources for the elevated nitrogen concentrations in the C-43 Canal include:

- Inflow from Lake Okeechobee
- Fertilizer nitrogen inputs
- Inputs from livestock
- Inputs from domestic and municipal wastewater sources (septic tanks and package treatment plants)
- Releases from drained and tilled soils
- Atmospheric inputs

On average, inputs from the freshwater basin contribute an estimated 50% of the TN loads to the CRE, while Lake Okeechobee (28%), and the estuarine basin (about 21%), contribute less (Knight and Steele 2005).

Treatment wetlands have been proven effective for the removal of a wide range of inorganic and organic pollutants. The following pollutants are being attenuated by constructed treatment wetlands, roughly in order of the number of applications worldwide:

- Biochemical oxygen demand (BOD);
- Total suspended solids (TSS);
- Nitrogen (N) forms – total nitrogen (TN), total organic N (TON), ammonia N (AN), and nitrate+nitrite N ($\text{NO}_x\text{-N}$);
- Chemical oxygen demand (COD);
- Phosphorus (P) forms – total phosphorus (TP), inorganic or soluble reactive phosphorus (SRP), particulate P, and organic P;
- Trace metals (e.g., arsenic, cadmium, chromium, copper, lead, nickel, silver, and zinc); and
- Trace organics (e.g., pesticides, petroleum, aromatic hydrocarbons, alcohols, aliphatic hydrocarbons, volatile organics, etc.).

The focus of the proposed C-43 WQTA project is the use of constructed treatment wetlands for reduction of TN concentrations and loads. Pollutants of secondary interest for the C-43 WQTA Project are TSS and TP, and these and other pollutants listed above may also be included in the analytical sampling plan for the testing facility.

2.2 Priority Test Questions

The primary goal of the proposed C-43 WQTA Project is the cost-effective removal of TN, with particular reference to the removal of various forms of TON. Secondary goals include ancillary reductions in the concentrations of TP and TSS in the C-43 canal. This section describes the key technical questions that will be addressed by the C-43 WQTA Test Facility project.

There are two principal test questions:

- To what level can various alternative constructed treatment wetland plant communities lower the concentration of TN in the C-43 Basin?
- What will be the combined footprint of full-scale treatment facilities required to achieve the goals of the CRE TMDL?

The straight-forward method for answering the first question above is to lower hydraulic and nutrient loading rates to the point where the hydraulic residence time is long enough and the mass loading rate is low enough so that no additional concentration reduction occurs. The second question can be answered by running large-scale tests so that scale is not an issue and so a range of hydraulic and nutrient loading rates can lead to development of a sizing model that can be extrapolated to the regional watershed basin with time-varying flows and pollutant concentrations. A calibrated, dynamic model is the preferred outcome of this effort due to the varying flows and loads entering the CRE system.

Mass balances will be prepared for all test units to help understand the fate of these pollutants in light of the various design and operational treatments used at the Test Facility. Due to the complex chemistry of nitrogen in surface waters, evaluation of TN removal must include the measurement of the full suite of nitrogen sources, sinks, and transformations that will occur in the treatment unit. Since constructed wetlands are open to the atmosphere and are constructed on the surface of the land, two important sources of additional nitrogen may include atmospheric and sediment inputs. The influence of both nitrogen sources need to be assessed to prepare accurate nitrogen mass balances for the test units.

Direct atmospheric N inputs include both wetfall and dryfall. Wetfall in rain typically includes dissolved organic and inorganic nitrogen forms. Dryfall typically includes particulate organic forms of N. While atmospheric N inputs are expected to be relatively low in comparison to the C-43 water N inputs to the treatment units, this N source will be approximated based on rainfall estimates and periodic bulk rainfall sampling. Another possible atmospheric input of DON into the test units will be nitrogen fixation. This input is expected to be small and will only be assessed through residuals in the N mass balance estimates. Atmospheric inputs of P and particulate solids are also likely to occur at the test units and will be estimated through the bulk rainfall sampling.

The Task 2 report summarized the effects of soil types on C^*_N (background or lowest achievable outlet nitrogen concentration) in various types of treatment wetland systems. Treatment wetlands constructed on organic (peat) soils typically have higher C^*_N values than similar wetlands constructed on mineral (non-organic) soils. The C^*_N for N varies in response to the amount of easily soluble organic and inorganic N that occurs in the antecedent soils. The Task 2 literature review (WSI 2012) and the expert panel report (WSI 2010) both indicated that selection of appropriate soil conditions or possible soil amendments may be critical for achieving the

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very low TN concentrations required to meet the CRE TMDL. Soil type and previous exposure to nutrients should be an important component of the proposed technical evaluation of wetland treatment alternatives.

A number of design and operational considerations are important for effective pollutant removal in treatment wetlands. The Test Facility will evaluate the potential for the most effective plant community types listed above to provide N, P, and TSS removal. Based on the review of N removal data from existing systems, these highest performing plant communities include constructed ecosystems dominated by EMV, SAV, periphytic algae, and FAV. In addition to initial site preparation and planting, propagation and maintenance of these different plant communities is largely influenced by water depth. For this reason water depth, hydroperiod, and initial plant establishment are key considerations in setting up the Test Facility. Also, inclusion of multiple vegetation zones in series will be incorporated to provide a variety of processes within single test cells.

Other key design considerations that are included in this testing plan include:

- Levee height (to allow for testing of a wide range of water depths as well as to retain all inflows and outflows to control structures, including peak rainfall inputs)
- Aspect ratio (the average length divided by the average width of the flow path)
- Inclusion of deep zones (their depth, width, percent of treatment area)

Key operational considerations in all land-intensive water pollution treatment systems include the following:

- Hydraulic loading rate (the average rate of water application over the wetted treatment area expressed as rainfall equivalent, reported as cm/d or m/yr)
- Hydraulic residence time (nominally the inflow divided by the water volume of the wetland, reported as days)
- Loading frequency (the frequency and duration of pumped inputs, reported as #/yr)
- Inlet pollutant load (the pollutant concentrations multiplied by the hydraulic loading rate, reported as kg/ha/d)

This suggested approach focuses on the inputs and outputs of materials in these natural treatment systems. This “green box” approach has been found to provide reliable information for engineering design of full-scale water quality projects world-wide. Process-level studies to detail the many physical, chemical, and biological processes that will be occurring in these test units are not recommended. While it is certainly preferable to have this information, the cost in terms of schedule and dollars may not justify the ultimate benefit of the additional knowledge gained. If time and budget are available for process studies, then those may be added when the final C-43 WQTA testing plan is prepared.

Finally, there are analytical considerations that are important to this project. For example, due to the complexity and possible recalcitrance of nitrogen forms, a variety of analytical tests are available but not all are necessary for project success. The simplest TN series is recommended for all test systems, including total Kjeldahl nitrogen (TKN – the sum of organic and ammonia N), total ammonia N (a combination of ionized ammonium [NH₄-N] and unionized ammonia

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[NH₃-N]), and total nitrate+nitrite N (NO_x-N). Since ammonia and nitrate+nitrite N are dissolved compounds there is generally no need to look at filtered (particulate) and filtrate (dissolved) fractions. However, organic N is generally present in both particulate and dissolved forms and this distinction is important for data interpretation. Filtered and unfiltered samples should be evaluated for total and dissolved TKN to highlight the relative proportions of these two fractions.

There is currently no recognized analytical test to fractionate total organic N (TON) from biologically available N (BAN). As used in this report, BAN includes all biologically available N forms, including organic and inorganic compounds. In response to the Expert Panel's recommendation, this test plan recommends further evaluation of the scope and cost to develop a prototype analytical procedure to estimate the BAN fraction of the TON. The Expert Panel conceptualized this test as a modified TKN test with one or more milder oxidants to breakdown the more tractable organic nitrogen compounds to ammonia. The efficacy of this test would be determined through mesocosm and laboratory bioassays as described later in this report.

When possible, standard analytical tests will be used for determination of concentrations of the other pollutants of concern (i.e., TP and TSS). These tests will be modified as needed to obtain adequate sensitivity to detect low concentrations of nutrients and solids.

2.3 Testing Scale

The most appropriate scale for the individual Test Facility components is dependent upon the specific questions to be answered, scale-up issues needed to implement a full-scale project, and cost. Some questions will be answered at a single test scale while others may be answered at multiple scales to provide confirmation that test scale is or is not a critical issue.

Previous experience with the Everglades Advanced Treatment Technologies program indicates that smaller scale Mesocosm units (generally less than 10 to 40 m² [108 to 430 ft²]) are appropriate for testing multiple design elements more cost effectively than building many larger test units. The problem with smaller mesocosm scale test units is that they have unrealistic edge-to-area (surface area-to-volume) ratios compared to full-scale treatment systems. These "edge" effects are sometimes seen in unrealistic plant growth limitations due to shallow soil depth or high walls that result in shading; uncharacteristic cooling or heating by the surrounding environment due to the higher surface area to volume ratio; and the more pronounced influence of stochastic events that would not otherwise be noticed in a larger scale project (e.g., the "alligator in the bath tub" effect). Mesocosms are considered to be an appropriate scale to test the effects of antecedent soil chemistry on C*_{TN}, plant community effects on C*_{TN}, plant- and microbial-level biogeochemical processes (biomass production, nutrient storages, nutrient biotransformations, enzyme production, plant uptake kinetics, etc.). Mesocosms are also an appropriate scale for replicated experiments and development of preliminary pollutant removal kinetics (that will be confirmed at larger scales).

Test Cells refer to larger, in-ground test systems, generally in the range of 500 to 4,000 m² (0.12 to 1 ac) and are less affected by high surface to volume ratios and provide more realistic plant growth conditions in native soils. Test Cells are small enough to be replicated, although stochastic effects still lead to relatively high variation between cells. Test Cells are most applicable to verification of preliminary findings from Mesocosm scale research. For example, if

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Mesocosm data indicate that specific soil properties are critical to achieve low C^*_{TN} then Test Cells could be operated on actual native soils to verify those results prior to implementing the next larger scale. Test Cells may also be the most appropriate scale to develop more robust data sets for performance model calibration/validation. It is important to note that Test Cells are not suitable as the only intermediate scale prior to design and operation of full-scale treatment wetlands. This need is principally due to the issues related to Full-Scale systems concerning higher flow velocities and increased hydraulic head loss.

Field-Scale treatment wetland test systems are typically in the range of 4,000 to 400,000 m² (1 to 100 ac) Examples include the PSTA Field-Scale cells as well as the STA-3/4 PSTA cell. These systems are generally not replicated due to their size and cost. When used, they are typically the last stage of work prior to implementation at Full-Scale. Depending on their size, Field-Scale systems may provide realistic data concerning pollutant removal rates and kinetics, effects of soil and climate variation, and construction costs. Their value for Full-Scale design is roughly proportional to their size. Smaller Field-Scale cells do not simulate actual Full-Scale hydraulics very well and therefore are not as reliable for understanding of Full-Scale treatment wetland mixing, head loss, and volumetric efficiency issues.

Section 3.0 Test Facility Description and Treatments

3.1 Test Facility Components

The recommended C-43 WQTA Test Facility will include the following components:

- Pump Station (9,300 m³/d or 1,700 gpm maximum capacity)
- Supply Force Main (30-cm [12-in] diameter HDPE; 1,900-m length [6,250 ft])
- Mesocosm Head Tank (7 m³ [247 ft³])
- Head Cell (4,000 m² [1 ac] and 12,200 m³ [430,510 ft³])
- Mesocosms (8 at 12 m² each [129 ft²])
- Test Cells (5 at 4,000 m² [1 ac])
- Field-Scale Cells (4 at 62,700 m² [15.5 ac])
- Cell Inlet Piping, Control Valves, and Flow Meters
- Miscellaneous Water Control and Monitoring Structures

3.1.1 Pump Station and Inlet Force Mains

It is recommended that the intake pump station be located on the C-3 Canal and that the C-43 WQTA Test Facility be built in the southeast corner of the BOMA Site (Figure 2). Electricity must be provided at this site to allow use of electric pumps. The total length of the inlet pipeline is approximately 1,900 m (6,250 ft) (this includes the Head Cell supply and series flow inlet line to FS-1). The pump station is anticipated to include up to three 25-30 horsepower pumps to provide adequate water supply for the project, pending detailed seepage calculations to be performed during final design.

3.1.2 Testing Units

Three testing scales are recommended (Table 1): Mesocosms, Test Cells, and Field-Scale Cells. Mesocosms will be constructed of fiberglass (pre-fabricated). The number of recommended test systems was dictated by the questions to be answered at each scale and the construction and O&M cost for each size unit. Test Cells and Field-Scale Cells will be constructed on-site using native soils without liners. A 4,000 m² (1 ac) (12,200 m³ [3 ac-ft]) Head Cell will be constructed to provide continuous inflows to the Test Cells and Field-Scale Cells (Figure 2). This Head Cell will be constructed with a HDPE liner to reduce seepage losses and will have 3:1 side slopes and an average water depth of about 3 m (10 ft). Figure 3 shows typical cross sections through the Head Cell, a Test Cell, and a Field-Scale Cell.

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Table 1. Proposed C-43 WQTA Test Facility plan

Scale	Unit ID	Description	Plant Community ¹	Substrate ²	Water Depth (cm)	Area (m ²)	Dimensions (m)
Mesocosm	M-1	EMV sand	EMV	Sand	30	12	2.4 x 4.9
Mesocosm	M-2	SAV sand	SAV	Sand	60	12	2.4 x 4.9
Mesocosm	M-3	FAV sand	FAV	Sand	90	12	2.4 x 4.9
Mesocosm	M-4	Algae limestone	Algae	Limestone	60	12	2.4 x 4.9
Mesocosm	M-5	OW sand	OW	Sand	90	12	2.4 x 4.9
Mesocosm	M-6	FAV control	FAV	None	90	12	2.4 x 4.9
Mesocosm	M-7	Algae control	Algae	None	60	12	2.4 x 4.9
Mesocosm	M-8	OW control	OW	None	90	12	2.4 x 4.9
Test Cell	TC-1	EMV shallow	EMV	Native sand	15	4,000	50 x 80
Test Cell	TC-2	EMV deep	EMV	Native sand	45	4,000	50 x 80
Test Cell	TC-3	SAV/FAV	SAV/FAV	Native sand	90	4,000	50 x 80
Test Cell	TC-4	Algae/OW	Algae/OW	Limestone	120	4,000	50 x 80
Test Cell	TC-5	MIX	EMV/SAV/FAV/Algae	Native sand	30-90	4,000	50 x 80
Field-Scale	FS-1	EMV shallow	EMV	Native sand	15	62,700	190 x 330
Field-Scale	FS-2	EMV deep	EMV	Native sand	45	62,700	190 x 330
Field-Scale	FS-3	SAV/FAV	SAV/FAV	Native sand	90	62,700	190 x 330
Field-Scale	FS-4	MIX	EMV/SAV/FAV/Algae	Native sand	30-90	62,700	190 x 330

Notes:

¹ Plant Communities: EMV (emergent vegetation), SAV (submerged aquatic vegetation), FAV (floating aquatic vegetation), Algae (filamentous and macro algae), OW (open water), MIX (mixed plant community)

² Substrate: sand (imported, rinsed, medium-grained sand), native sand (on-site soils), limestone (#57 limerock or equivalent)

3.1.2.1 Mesocosms

Eight pre-fabricated fiberglass Mesocosms (2.4x4.9 m [8x16 ft] each) will be installed on a level pad of crushed limestone (Figure 4). A single plastic Head Tank (7 m³ [247 ft³]) will be centrally located to provide a constant head inflow to the Mesocosms. The Head Tank will receive inputs from a temporary gas-powered pump until completion of the Head Cell and main pump station. At that time, the Head Tank will receive inputs via gravity from a 10 cm (4 in) PVC supply line from the Head Cell. Excess water will be drained from the Head Tank by use of a fixed overflow from the tank to the return pipeline to an internal irrigation/drainage canal. The eight Mesocosm tanks will be plumbed for parallel operation using 5 cm (2 in) PVC piping and adjustable-level overflow pipes to the drain line. Four of the Mesocosms will receive 30 cm (12 in) of clean (washed) medium-grain sand. One Mesocosm unit will receive 30 cm (12 in) of #57 limestone. Limestone was found to be the best substrate to encourage the growth of calcareous blue green and macrophytic algal species in the Everglades Advanced Technology testing. On peat or mineral soils recruitment by rooted macrophytes precluded good colonization by the desired algal plant community. Three of the Mesocosms will be “controls” with no substrate.

Cattails and bulrush are combined in the deeper EMV treatments while a combination of cattails and spikerush are recommended in shallower EMV treatments. This plant selection is dictated by the general depth tolerance of each species. The purpose of planting these cells is to insure rapid plant colonization and stable water quality performance rather than to produce a specific mix of plant species. Considerable natural recruitment and resulting "self design" of wetland plant communities is anticipated in these test units in response to the controlled water regimes tested. Plant communities in the Mesocosms will be managed by physical removal of unwanted plants.

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Mesocosm M-1 will be planted with a mix (1:1) of cattails (*Typha* sp.) and bulrush (*Schoenoplectus* sp.) in a bed of washed sand. The planting density will be on 30-cm centers to provide rapid establishment and grow-in. The target water depth in this Mesocosm will be 30 cm.

Mesocosm M-2 will be planted with a mix of southern naiad (*Najas guadalupensis*) and coontail (*Ceratophyllum demersum*) above a bed of washed sand. The planting density will be 40 liters (10 gallons) of each plant species to provide rapid establishment and grow-in. The target water depth in this Mesocosm will be 60 cm (2 ft).

Mesocosm M-3 will be planted with a mix of water hyacinth (*Eichhornia crassipes*) and duckweed (*Lemna* sp.) above a bed of washed sand. The planting density will be 200 liters (50 gallons) of hyacinths and 4 liters (one gallon) of duckweed to provide rapid establishment and grow-in. This is a preliminary estimate that will allow good coverage of each species and will be adjusted based on the actual plant propagules at hand. The target water depth in this Mesocosm will be 90 cm (3 ft).

Mesocosm M-4 will be planted with a mix of filamentous algae (green and blue-green species) and macrophytic alga stonewort or muskgrass (*Chara* sp.) above a bed of #57 limestone. The planting density will be 40 liters (10 gallons) of each algae type to provide rapid establishment and grow-in. The target water depth in this Mesocosm will be 60 cm (2 ft).

Mesocosm M-5 will not be planted and any macroscopic colonizing plant species will be removed. This Mesocosm will include a bed of washed sand. The target water depth in this Mesocosm will be 90 cm.

Mesocosm M-6 will be planted with a mix of water hyacinth and duckweed with no sediment. The planting density will be 200 liters (50 gallons) of hyacinths and 4 liters (one gallon) of duckweed to provide rapid establishment and grow-in. This is a preliminary estimate that will allow good coverage of each species and will be adjusted based on the actual plant propagules at hand. The target water depth in this Mesocosm will be 90 cm (3 ft). This Mesocosm treatment is intended to provide a control without initial sediment to help separate benthic from plant community effects on nitrogen C* and k values.

Mesocosm M-7 will be planted with a mix of filamentous algae (green and blue-green species) and stonewort or muskgrass without a limestone bed. The planting density will be 40 liters (10 gallons) of each algae type to provide rapid establishment and grow-in. The target water depth in this Mesocosm will be 60 cm (2 ft). This Mesocosm treatment is intended to provide a control without initial sediment to help separate benthic from plant community effects on nitrogen C* and k values.

Mesocosm M-8 will not be planted and any macroscopic colonizing plant species will be removed. This Mesocosm will not include any initial sediment. The target water depth in this Mesocosm will be 90 cm (3 ft). This Mesocosm treatment is intended to provide a control without initial sediment to help separate benthic from plankton effects on nitrogen C* and k values.

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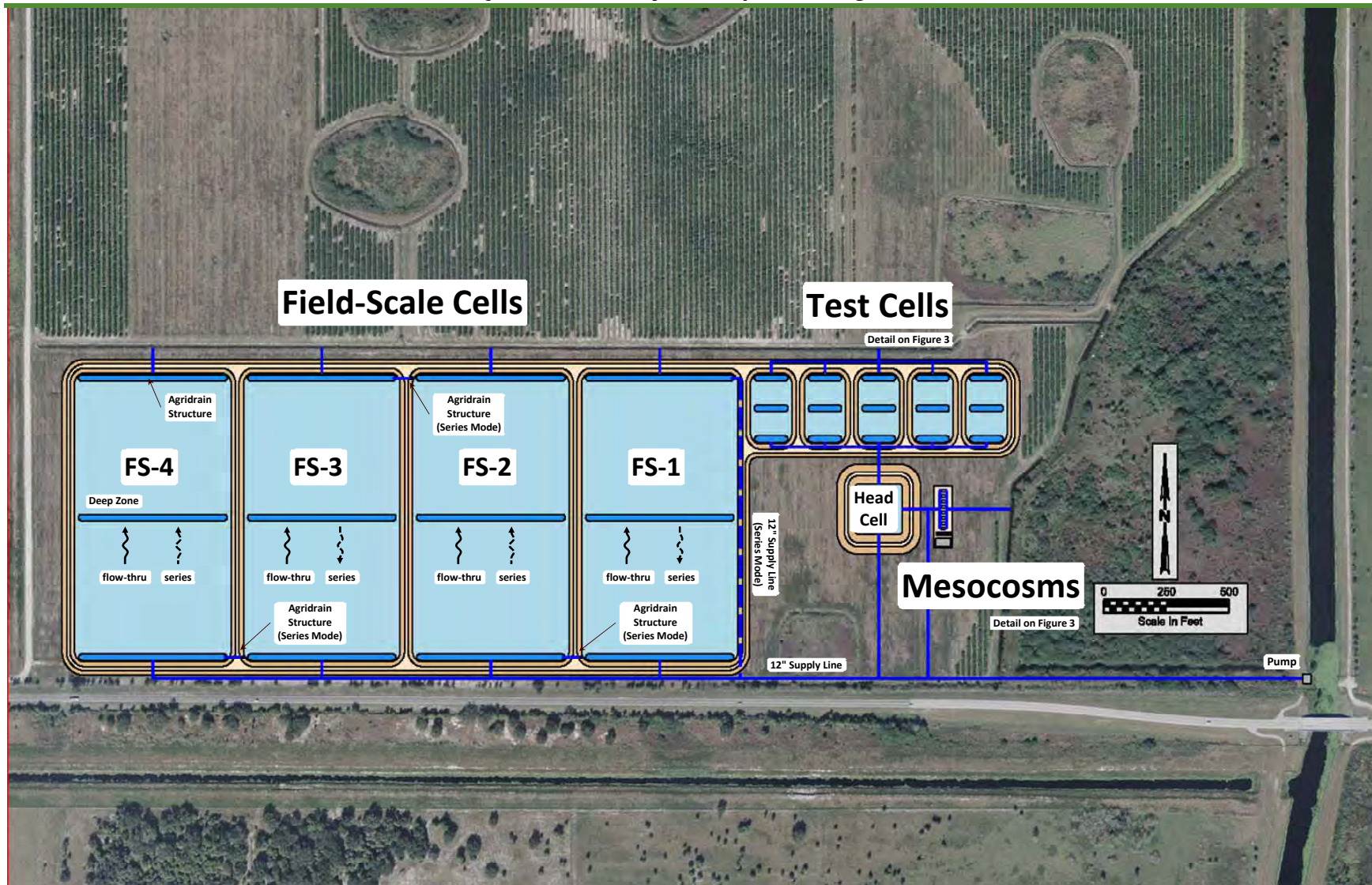


Figure 2. Proposed C-43 WQTA Test Facility Site plan



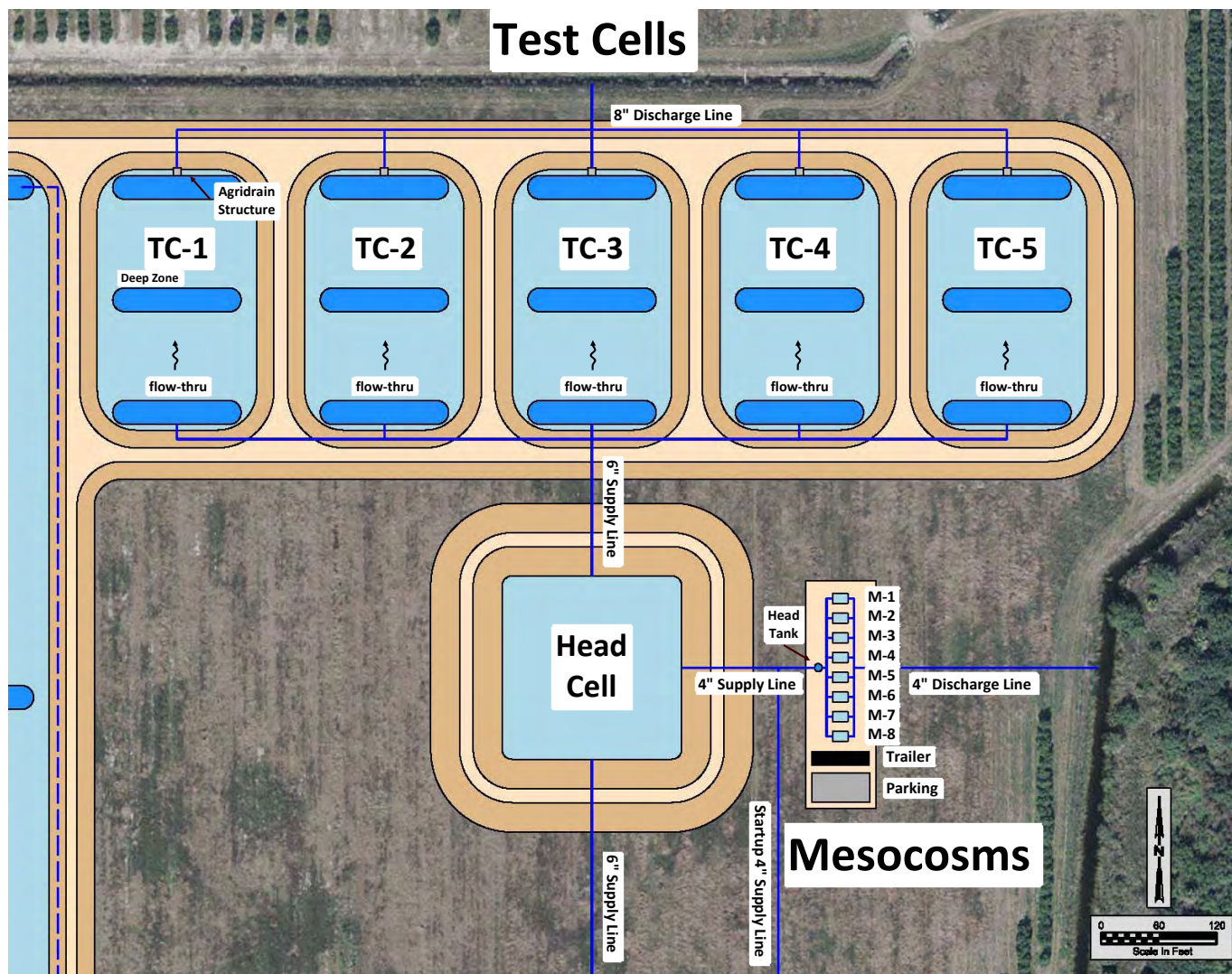


Figure 4. Proposed C-43 WQTA Test Facility Site plan – Test Cells and Mesocosms

3.1.2.2 Test Cells

Five in-ground 4,000 m² (1 ac) (50x80 m [164x262 ft]) Test Cells will be constructed using earthen embankments (Figure 4). Four of these Test Cells will have native soil fill. One Test Cell will be over-excavated and backfilled with 30 cm (12 in) of #57 limestone. Design embankment heights in all five Test Cells will be 1.8 m (6 feet) and constructed with 3:1 side slopes and top width of 4.2 m (14 ft). The maximum water depth proposed in this test plan is 120 cm (about 4 feet), resulting in a minimum of about 60 cm (2 feet) of freeboard in all of the Test Cells. While this height may not be necessary for the Test Cells experiencing shallower water conditions, this consistent cell height is recommended in all cells to allow flexible water depth operation in light of preliminary findings.

Water control structures in these Field-Scale Cells will include inlet, central, and outlet deep zones (bottom width 7.3 m [24 ft] with 3:1 side slopes) and outlet adjustable horizontal weirs (e.g. Agridrain™ or similar inline water control structures). The five Test Cells will be designed only for parallel operation. Embankment properties will be further considered during the design phase to minimize "cross-talk" between cells.

Cattails and bulrush are combined in the deeper EMV treatments while a combination of cattails and spikerush are recommended in shallower EMV treatments. This plant selection is dictated by the general depth tolerance of each species. The purpose of planting these cells is to insure rapid plant colonization and stable water quality performance rather than to produce a specific mix of plant species. Considerable natural recruitment and resulting "self design" of wetland plant communities is anticipated in these test units in response to the controlled water regimes tested. There is no plant removal or harvesting anticipated in the Test Cells. Plant biomass harvesting is not recommended in full-scale treatment wetlands (Kadlec and Wallace 2008) due to the cost and disruption of treatment processes.

Test Cell TC-1 will be planted with a mix (1:1) of cattails and spikerush (*Eleocharis* sp.) in a bed of native sand. The planting density will be on 60-cm (2 ft) centers to provide rapid establishment and grow-in. The target water depth in this Test Cell will be 15 cm (6 in).

Test Cell TC-2 will be planted with a mix (1:1) of cattails and bulrush in a bed of native sand. The planting density will be on 60-cm (2-ft) centers to provide rapid establishment and grow-in. The target water depth in this Test Cell will be 45 cm (18 in).

Test Cell TC-3 will be planted with an equal mix of southern naiad, coontail, water hyacinth, and duckweed over a bed of native sand. The planting density will be 400 liters (100 gallons) of each plant species to provide rapid establishment and grow-in. This is a preliminary estimate that will allow good coverage of each species and will be adjusted based on the actual plant propagules at hand. The target water depth in this Test Cell will be 90 cm.

Test Cell TC-4 will be planted with a mix of filamentous algae (green and blue-green species) and the macrophytic alga stonewort above a bed of #57 limestone. The planting density will be 400 liters (100 gallons) of each algae type to provide rapid establishment and grow-in. The target water depth in this Test Cell will be 120 cm (4 ft).

Test Cell TC-5 will be planted with a diverse mix of emergent wetland and aquatic plants, including spikerush, southern naiad, and stonewort over native soils. A diversity of opportunistic colonizing plant and algal species are expected and will be welcome in this MIX

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plant community. This plant diversity will be encouraged by engineering a range of water depths within TC-5. The desired range of water depths will be between 30 and 90 cm (1 to 3 ft).

3.1.2.3 Field-Scale Cells

Four in-ground Field-Scale Cells will be constructed for parallel and series operation (Figure 2). These cells will each have a wet area of about 62,700 m² (190x330 m [15.5 ac]) and will have native soil fill. Design embankment height in all cells will be 6 feet with 3:1 side slopes. The maximum water depth proposed in the Field-Scale Cells is 90 cm (about 3 feet), resulting in a minimum of about 90 cm (3 feet) of freeboard in all of the Field-Scale Cells. While this berm height will not be necessary during tests of shallower water plant communities such as EMV, this berm height is recommended in all cells to allow flexible water depth operation in light of preliminary findings. Water control structures in these Field-Scale Cells will include inlet, center, and outlet deep zones (bottom width 7.3 m [24 ft] with 3:1 side slopes) and outlet adjustable horizontal weirs. Inlet and outlet plumbing will allow parallel and series flow as illustrated in Figure 2.

Cattails and bulrush are combined in the deeper EMV treatments while a combination of cattails and spikerush are recommended in shallower EMV treatments. This plant selection is dictated by the general depth tolerance of each species. The purpose of planting these cells is to insure rapid plant colonization and stable water quality performance rather than to produce a specific mix of plant species. Considerable natural recruitment and resulting "self design" of wetland plant communities is anticipated in these test units in response to the controlled water regimes tested. Use of rooted plant windbreaks in the FAV/SAV Field-Scale Cell will be considered during final design. There is no plant removal or harvesting anticipated in the Field-Scale Cells.

Field-Scale Cell FS-1 will be planted with a mix (1:1) of cattails and spikerush in a bed of native sand. The planting density will be on 90-cm (3-ft) centers to provide rapid plant establishment and grow-in. The target water depth in this FS-1 will be 15 cm.

Field-Scale Cell FS-2 will be planted with a mix (1:1) of cattails and bulrush in a bed of native sand. The planting density will be on 90-cm (3-ft) centers to provide rapid plant establishment and grow-in. The target water depth in FS-2 will be 45 cm (18 in).

Field Scale Cell FS-3 will be planted with an equal mix of southern naiad, coontail, water hyacinth, and duckweed over a bed of native sand. The planting density will be 20,000 liters (5,000 gallons) of each plant species to provide rapid establishment and grow-in. This is a preliminary estimate that will allow good coverage of each species and will be adjusted based on the actual plant propagules at hand. The target water depth in FS-3 will be 90 cm.

Field Scale Cell FS-4 will be planted with a diverse mix of emergent wetland and aquatic plants, including spikerush, southern naiad, and stonewort over native soils. A diversity of opportunistic colonizing plant and algal species are expected and will be welcome in this MIX plant community. This plant diversity will be encouraged by engineering a range of water depths within FS-4. The desired range of water depths will be between 30 and 90 cm (1 to 3 ft).

3.2 Experimental Treatments

A total of 84 unique treatments are recommended for the proposed test program. These include 48 treatments at the Mesocosm scale, 20 treatments at the Test Cell scale, and 16 treatments at the Field-Scale units.

3.2.1 Mesocosm Treatments

for all water quality parameters of interest (see Section 4). Data collected during this operational phase will be used to provide preliminary estimates of nutrient and solids kinetics for each of the tested plant community/sediment combinations, including three controls with no sediment.

Table 2 summarizes the forty-eight (48) proposed Mesocosm treatments, including their unit and treatment identification labels, their proposed duration in months, their mode of operation, their target plant community, their principal substrate, their design water depth, their design hydraulic loading rate (HLR), their nominal hydraulic residence time (nHRT), their physical dimensions, and their key test variables.

The eight Mesocosms will receive different treatments during each of six sequential six- to 10-month operational phases. It is expected that the Mesocosm construction will require about three months and that these systems will be operational after a Phase 1 six-month construction/startup period (Treatment IDs M1-1 through M8-1 construction and plant grow-in).

Mesocosm Phase 2 (Treatment IDs M1-2 through M8-2) will consist of filling the eight mesocosms to a target overflow level and using minimal inflows to keep water at a fixed depth for a period of six months (“Batch” mode of operation). The purpose of this treatment is to determine the lowest achievable nutrient and particulate solids concentrations in each treatment that can be achieved in the open environment. Surface water in these mesocosms will be sampled on a routine basis for all water quality parameters of interest (see Section 4) as well as for estimation of the BAN. As described below, an analytical surrogate test for BAN may be developed during this Phase 2 study period using mesocosm data for calibration.

Mesocosm Phase 3 (Treatment IDs M1-3 through M8-3) will initiate flow-through operation of the eight Mesocosms. An average low HLR of 1.5 cm/d (4.1 in/week) will be the target for the ten-month Phase 3 Mesocosm operation. Based on the target water depths, the range of nHRTs will be from 20 to 60 days. Surface water in these mesocosms will be sampled on a routine basis for all water quality parameters of interest (see Section 4). Data collected during this operational phase will be used to provide preliminary estimates of nutrient and solids kinetics for each of the tested plant community/sediment combinations, including three controls with no sediment.

Mesocosm Phase 4 (Treatment IDs M1-4 through M8-4) will continue flow-through operation of the eight Mesocosms. An average medium HLR of 3.0 cm/d (8.3 in/week) will be the target for the ten-month Phase 4 Mesocosm operation. Based on the target water depths, the range of nHRTs will be from 10 to 30 days. Surface water in these mesocosms will be sampled on a routine basis for all water quality parameters of interest (see Section 4). Data collected during this operational phase will be used to provide preliminary estimates of nutrient and solids kinetics for each of the tested plant community/sediment combinations, including three controls with no sediment.

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Mesocosm Phase 5 (Treatment IDs M1-5 through M8-5) will continue flow-through operation of the eight Mesocosms. An average high HLR of 6.0 cm/d (16 in/week) will be the target for the ten-month Phase 5 Mesocosm operation. Based on the target water depths, the range of nHRTs will be from 5 to 15 days. Surface water in these mesocosms will be sampled on a routine basis for all water quality parameters of interest (see Section 4). Data collected during this operational phase will be used to provide preliminary estimates of nutrient and solids kinetics for each of the tested plant community/sediment combinations, including three controls with no sediment.

Table 2. Proposed C-43 Test Facility Mesocosm Treatments

Unit ID	Treat ID	Phase	Duration (months)	Description	Mode ¹	Plant Community ²	Substrate ³	Water Depth (cm)	HLR ⁴ (cm/d)	Mean nHRT ⁵ (d)	Area (m ²)	Dimensions (m)	Key Test Variables ⁶
M-1	M1-1	1	6	EMV sand startup	Startup	EMV	Sand	30	0	--	12	2.4 x 4.9	C* _{TN} , BAN
M-2	M2-1	1	6	SAV sand startup	Startup	SAV	Sand	60	0	--	12	2.4 x 4.9	C* _{TN} , BAN
M-3	M3-1	1	6	FAV sand startup	Startup	FAV	Sand	90	0	--	12	2.4 x 4.9	C* _{TN} , BAN
M-4	M4-1	1	6	Algae limestone startup	Startup	Algae	Limestone	60	0	--	12	2.4 x 4.9	C* _{TN} , BAN
M-5	M5-1	1	6	OW sand startup	Startup	OW	Sand	90	0	--	12	2.4 x 4.9	C* _{TN} , BAN
M-6	M6-1	1	6	FAV control startup	Startup	FAV	None	90	0	--	12	2.4 x 4.9	C* _{TN} , BAN
M-7	M7-1	1	6	Algae control startup	Startup	Algae	None	60	0	--	12	2.4 x 4.9	C* _{TN} , BAN
M-8	M8-1	1	6	OW control startup	Startup	OW	None	90	0	--	12	2.4 x 4.9	C* _{TN} , BAN
M-1	M1-2	2	6	EMV sand batch	Batch	EMV	Sand	30	0	--	12	2.4 x 4.9	C* _{TN} , BAN
M-2	M2-2	2	6	SAV sand batch	Batch	SAV	Sand	60	0	--	12	2.4 x 4.9	C* _{TN} , BAN
M-3	M3-2	2	6	FAV sand batch	Batch	FAV	Sand	90	0	--	12	2.4 x 4.9	C* _{TN} , BAN
M-4	M4-2	2	6	Algae limestone batch	Batch	Algae	Limestone	60	0	--	12	2.4 x 4.9	C* _{TN} , BAN
M-5	M5-2	2	6	OW sand batch	Batch	OW	Sand	90	0	--	12	2.4 x 4.9	C* _{TN} , BAN
M-6	M6-2	2	6	FAV control batch	Batch	FAV	None	90	0	--	12	2.4 x 4.9	C* _{TN} , BAN
M-7	M7-2	2	6	Algae control batch	Batch	Algae	None	60	0	--	12	2.4 x 4.9	C* _{TN} , BAN
M-8	M8-2	2	6	OW control batch	Batch	OW	None	90	0	--	12	2.4 x 4.9	C* _{TN} , BAN
M-1	M1-3	3	10	EMV sand low flow-thru	Flow-Thru	EMV	Sand	30	1.5	20	12	2.4 x 4.9	N-k values
M-2	M2-3	3	10	SAV sand low flow-thru	Flow-Thru	SAV	Sand	60	1.5	40	12	2.4 x 4.9	N-k values
M-3	M3-3	3	10	FAV sand low flow-thru	Flow-Thru	FAV	Sand	90	1.5	60	12	2.4 x 4.9	N-k values
M-4	M4-3	3	10	Algae limestone low flow-thru	Flow-Thru	Algae	Limestone	60	1.5	40	12	2.4 x 4.9	N-k values
M-5	M5-3	3	10	OW sand low flow-thru	Flow-Thru	OW	Sand	90	1.5	60	12	2.4 x 4.9	N-k values
M-6	M6-3	3	10	FAV control low flow-thru	Flow-Thru	FAV	None	90	1.5	60	12	2.4 x 4.9	N-k values
M-7	M7-3	3	10	Algae control low flow-thru	Flow-Thru	Algae	None	60	1.5	40	12	2.4 x 4.9	N-k values
M-8	M8-3	3	10	OW control low flow-thru	Flow-Thru	OW	None	90	1.5	60	12	2.4 x 4.9	N-k values
M-1	M1-4	4	10	EMV sand medium flow-thru	Flow-Thru	EMV	Sand	30	3	10	12	2.4 x 4.9	N-k values
M-2	M2-4	4	10	SAV sand medium flow-thru	Flow-Thru	SAV	Sand	60	3	20	12	2.4 x 4.9	N-k values
M-3	M3-4	4	10	FAV sand medium flow-thru	Flow-Thru	FAV	Sand	90	3	30	12	2.4 x 4.9	N-k values
M-4	M4-4	4	10	Algae limestone medium flow-thru	Flow-Thru	Algae	Limestone	60	3	20	12	2.4 x 4.9	N-k values
M-5	M5-4	4	10	OW sand medium flow-thru	Flow-Thru	OW	Sand	90	3	30	12	2.4 x 4.9	N-k values
M-6	M6-4	4	10	FAV control medium flow-thru	Flow-Thru	FAV	None	90	3	30	12	2.4 x 4.9	N-k values
M-7	M7-4	4	10	Algae control medium flow-thru	Flow-Thru	Algae	None	60	3	20	12	2.4 x 4.9	N-k values
M-8	M8-4	4	10	OW control medium flow-thru	Flow-Thru	OW	None	90	3	30	12	2.4 x 4.9	N-k values
M-1	M1-5	5	10	EMV sand high flow-thru	Flow-Thru	EMV	Sand	30	6	5	12	2.4 x 4.9	N-k values
M-2	M2-5	5	10	SAV sand high flow-thru	Flow-Thru	SAV	Sand	60	6	10	12	2.4 x 4.9	N-k values
M-3	M3-5	5	10	FAV sand high flow-thru	Flow-Thru	FAV	Sand	90	6	15	12	2.4 x 4.9	N-k values
M-4	M4-5	5	10	Algae limestone high flow-thru	Flow-Thru	Algae	Limestone	60	6	10	12	2.4 x 4.9	N-k values
M-5	M5-5	5	10	OW sand high flow-thru	Flow-Thru	OW	Sand	90	6	15	12	2.4 x 4.9	N-k values
M-6	M6-5	5	10	FAV control high flow-thru	Flow-Thru	FAV	None	90	6	15	12	2.4 x 4.9	N-k values
M-7	M7-5	5	10	Algae control high flow-thru	Flow-Thru	Algae	None	60	6	10	12	2.4 x 4.9	N-k values
M-8	M8-5	5	10	OW control high flow-thru	Flow-Thru	OW	None	90	6	15	12	2.4 x 4.9	N-k values
M-1	M1-6	6	6	EMV sand batch	Batch	EMV	Sand	30	0	--	12	2.4 x 4.9	C* _{TN} , BAN
M-2	M2-6	6	6	SAV sand batch	Batch	SAV	Sand	60	0	--	12	2.4 x 4.9	C* _{TN} , BAN
M-3	M3-6	6	6	FAV sand batch	Batch	FAV	Sand	90	0	--	12	2.4 x 4.9	C* _{TN} , BAN
M-4	M4-6	6	6	Algae limestone batch	Batch	Algae	Limestone	60	0	--	12	2.4 x 4.9	C* _{TN} , BAN
M-5	M5-6	6	6	OW sand batch	Batch	OW	Sand	90	0	--	12	2.4 x 4.9	C* _{TN} , BAN
M-6	M6-6	6	6	FAV control batch	Batch	FAV	None	90	0	--	12	2.4 x 4.9	C* _{TN} , BAN
M-7	M7-6	6	6	Algae control batch	Batch	Algae	None	60	0	--	12	2.4 x 4.9	C* _{TN} , BAN
M-8	M8-6	6	6	OW control batch	Batch	OW	None	90	0	--	12	2.4 x 4.9	C* _{TN} , BAN

Notes:

¹ Operational Mode: startup (includes construction time), batch (make-up water only), flow-thru [at average hydraulic loading rate (HLR)], series (cells-in-series), pulsed (dynamic flow rates)

² Plant Communities: EMV (emergent vegetation), SAV (submerged aquatic vegetation), FAV (floating aquatic vegetation), Algae (filamentous and macro algae), OW (open water), MIX (mixed plant community)

³ Substrate: sand (imported, rinsed, medium-grained sand), native sand (on-site soils), limestone (#57 limerock or equivalent)

⁴ HLR (hydraulic loading rate = flow/area)

⁵ nHRT (nominal hydraulic residence time = water depth/HLR)

⁶ Test Variables: C* (lowest-achievable background concentration), BAN (biologically available nitrogen as determined by treatment system and analytical test), N-kvalues (first-order removal rate constants for TN fractions, including TN, NH₃-N, NO₃+NO₂-N)

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Mesocosm Phase 6 (Treatment IDs M1-6 through M8-6) will consist of maintaining the eight mesocosms at their target overflow level and using minimal inflows to keep water at a fixed depth for a final six-month period (“Batch” mode of operation). The purpose of this treatment is to confirm the C^* values measured with the younger, startup plant communities and soil conditions in each treatment that can be achieved in the open environment. Surface water in these mesocosms will be sampled on a routine basis for all water quality parameters of interest (see Section 4) as well as for estimation of the BAN.

3.2.2 Test Cell Treatments

Table 3 summarizes the 20 proposed Test Cell treatments, including their unit and treatment identification labels, their proposed duration in months, their mode of operation, their target plant community, their principal substrate, their design water depth, their design hydraulic loading rate (HLR), their nominal hydraulic residence time (nHRT), their physical dimensions, and their key test variables.

Table 3. Proposed C-43 Test Facility Test Cell treatments

Unit ID	Treat ID	Phase	Duration (months)	Description	Mode ¹	Plant Community ²	Substrate ³	Water Depth (cm)	HLR ⁴ (cm/d)	Mean nHRT ⁵ (d)	Area (m ²)	Dimensions (m)	Key Test Variables ⁶
TC-1	TC1-1	1	12	EMV shallow startup	Startup	EMV	Native sand	15	0	--	4,000	50 x 80	C^*_{TN} ; BAN
TC-2	TC2-1	1	12	EMV deep startup	Startup	EMV	Native sand	45	0	--	4,000	50 x 80	C^*_{TN} ; BAN
TC-3	TC3-1	1	12	SAV/FAV startup	Startup	SAV/FAV	Native sand	90	0	--	4,000	50 x 80	C^*_{TN} ; BAN
TC-4	TC4-1	1	12	Algae/OW startup	Startup	Algae/OW	Limestone	120	0	--	4,000	50 x 80	C^*_{TN} ; BAN
TC-5	TC5-1	1	12	MIX startup	Startup	EMV/SAV/FAV/Algae	Native sand	30-90	0	--	4,000	50 x 80	C^*_{TN} ; BAN
TC-1	TC1-2	2	12	EMV shallow low flow-thru	Flow-Thru	EMV	Native sand	15	1.5	10	4,000	50 x 80	N-k values
TC-2	TC2-2	2	12	EMV deep low flow-thru	Flow-Thru	EMV	Native sand	45	1.5	30	4,000	50 x 80	N-k values
TC-3	TC3-2	2	12	SAV/FAV low flow-thru	Flow-Thru	SAV/FAV	Native sand	90	1.5	60	4,000	50 x 80	N-k values
TC-4	TC4-2	2	12	Algae/OW low flow-thru	Flow-Thru	Algae/OW	Limestone	120	1.5	80	4,000	50 x 80	N-k values
TC-5	TC5-2	2	12	MIX low flow-thru	Flow-Thru	EMV/SAV/FAV/Algae	Native sand	30-90	1.5	40	4,000	50 x 80	N-k values
TC-1	TC1-3	3	12	EMV shallow medium flow-thru	Flow-Thru	EMV	Native sand	15	3	5	4,000	50 x 80	N-k values
TC-2	TC2-3	3	12	EMV deep medium flow-thru	Flow-Thru	EMV	Native sand	45	3	15	4,000	50 x 80	N-k values
TC-3	TC3-3	3	12	SAV/FAV medium flow-thru	Flow-Thru	SAV/FAV	Native sand	90	3	30	4,000	50 x 80	N-k values
TC-4	TC4-3	3	12	Algae/OW medium flow-thru	Flow-Thru	Algae/OW	Limestone	120	3	40	4,000	50 x 80	N-k values
TC-5	TC5-3	3	12	MIX medium flow-thru	Flow-Thru	EMV/SAV/FAV/Algae	Native sand	30-90	3	20	4,000	50 x 80	N-k values
TC-1	TC1-4	4	12	EMV shallow high flow-thru	Flow-Thru	EMV	Native sand	15	6	2.5	4,000	50 x 80	N-k values
TC-2	TC2-4	4	12	EMV deep high flow-thru	Flow-Thru	EMV	Native sand	45	6	7.5	4,000	50 x 80	N-k values
TC-3	TC3-4	4	12	SAV/FAV high flow-thru	Flow-Thru	SAV/FAV	Native sand	90	6	15	4,000	50 x 80	N-k values
TC-4	TC4-4	4	12	Algae/OW high flow-thru	Flow-Thru	Algae/OW	Limestone	120	6	20	4,000	50 x 80	N-k values
TC-5	TC5-4	4	12	MIX high flow-thru	Flow-Thru	EMV/SAV/FAV/Algae	Native sand	30-90	6	10	4,000	50 x 80	N-k values

Notes:

¹ Operational Mode: startup (includes construction time), batch (make-up water only), flow-thru [at average hydraulic loading rate (HLR)], series (cells-in-series), pulsed (dynamic flow rates)

² Plant Communities: EMV (emergent vegetation), SAV (submerged aquatic vegetation), FAV (floating aquatic vegetation), Algae (filamentous and macro algae), OW (open water), MIX (mixed plant community)

³ Substrate: sand (imported, rinsed, medium-grained sand), native sand (on-site soils), limestone (#57 limerock or equivalent)

⁴ HLR (hydraulic loading rate = flow/area)

⁵ nHRT (nominal hydraulic residence time = water depth/HLR); average depth of 60 cm used to calculate nHRT for TC5

⁶ Test Variables: C^* (lowest-achievable background concentration), BAN (biologically available nitrogen as determined by treatment system and analytical test), N-kvalues (first-order removal rate constants for TN fractions, including TN, NH_3 -N, NO_3 + NO_2 -N)

The five Test Cells will receive different treatments during each of four sequential twelve-month operational phases. It is expected that the Test Cell construction will require up to six months to complete and that these systems will be operational after a Phase 1 twelve-month batch-mode startup period (Treatment IDs TC1-1 through TC5-1 construction and plant grow-in). WSI's prior experience indicates that the treatment units may reach a quasi-steady state in terms of performance within one two years. The large-scale treatments are each twelve months to allow adequate time for internal biological readjustments following changes in HLR, water depth, or nHRT. A four-year operational time span is generally supported as adequate based on the evidence from the full-scale treatment wetlands reviewed in the Task 2 report.

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Test Cell Phase 2 (Treatment IDs TC1-2 through TC5-2) will initiate flow-through operation of the five Test Cells. An average low HLR of 1.5 cm/d (4.1 in/week) will be the target for the twelve-month Test Cell Phase 2 operation. Based on the target water depths, the range of nHRTs will be from 10 to 80 days. Surface water in these Test Cells will be sampled on a routine basis for all water quality parameters of interest (see Section 4). Data collected during this operational phase will be used to provide refined estimates of nutrient and solids kinetics for each of the tested plant community/sediment combinations.

Test Cell Phase 3 (Treatment IDs TC1-3 through TC5-3) will continue flow-through operation of the five Test Cells. An average medium HLR of 3.0 cm/d (8.3 in/week) will be the target for the twelve-month Test Cell Phase 3 operation. Based on the target water depths, the range of nHRTs will be from 5 to 40 days. Surface water in these Test Cells will be sampled on a routine basis for all water quality parameters of interest (see Section 4). Data collected during this operational phase will be used to provide refined estimates of nutrient and solids kinetics for each of the tested plant community/sediment combinations.

Test Cell Phase 4 (Treatment IDs TC1-4 through TC5-4) will continue flow-through operation of the five Test Cells for the final twelve-month operational period. An average high HLR of 6.0 cm/d (16 in/week) will be the target for the twelve-month Test Cell Phase 4 operation. Based on the target water depths, the range of nHRTs will be from 2.5 to 20 days. Surface water in these Test Cells will be sampled on a routine basis for all water quality parameters of interest (see Section 4). Data collected during this operational phase will be used to provide refined estimates of nutrient and solids kinetics for each of the tested plant community/sediment combinations.

3.2.3 Field Scale Treatments

Table 4 summarizes the 16 proposed Field Scale treatments, including their unit and treatment identification labels, their proposed duration in months, their mode of operation, their target plant community, their principal substrate, their design water depth, their design hydraulic loading rate (HLR), their nominal hydraulic residence time (nHRT), their physical dimensions, and their key test variables.

The four Field-Scale Cells will receive different treatments during each of four sequential twelve-month operational phases. It is expected that the Field-Scale Cell construction and plant grow-in will require up to twelve months for completion, and that these systems will not be fully operational until the end of the Phase 1 startup period (Treatment IDs FS1-1 through FS4-1). These Field-Scale Cells will be operated in batch mode during Phase 1.

Field-Scale Phase 2 (Treatment IDs FS1-2 through FS4-2) will initiate flow-through operation in parallel to the four Field-Scale cells. An average low HLR of 1.5 cm/d (4.1 in/week) will be the target for the twelve-month Field-Scale Phase 2 operation. Based on the target water depths, the range of nHRTs will be from 10 to 60 days. Surface water in these Field-Scale Cells will be sampled on a routine basis for all water quality parameters of interest (see Section 4). Data collected during this operational phase will be used to provide refined estimates of nutrient and solids kinetics for each of the tested plant community/sediment combinations.

Table 4. Proposed C-43 Test Facility Field-Scale treatments

Unit ID	Treat ID	Phase	Duration (months)	Description	Mode ¹	Plant Community ²	Substrate ³	Water Depth (cm)	HLR ⁴ (cm/d)	Mean nHRT ⁵ (d)	Area (m ²)	Dimensions (m)	Key Test Variables ⁶
FS-1	FS1-1	1	12	EMV shallow startup	Startup	EMV	Native sand	15	0	--	62,700	190 x 330	C* _{TN} ; BAN
FS-2	FS2-1	1	12	EMV deep startup	Startup	EMV	Native sand	45	0	--	62,700	190 x 330	C* _{TN} ; BAN
FS-3	FS3-1	1	12	SAV/FAV startup	Startup	SAV/FAV	Native sand	90	0	--	62,700	190 x 330	C* _{TN} ; BAN
FS-4	FS4-1	1	12	MIX startup	Startup	EMV/SAV/FAV/Algae	Native sand	30-90	0	--	62,700	190 x 330	C* _{TN} ; BAN
FS-1	FS1-2	2	12	EMV shallow flow-thru	Flow-Thru	EMV	Native sand	15	1.5	10	62,700	190 x 330	N-k values
FS-2	FS2-2	2	12	EMV deep flow-thru	Flow-Thru	EMV	Native sand	45	1.5	30	62,700	190 x 330	N-k values
FS-3	FS3-2	2	12	SAV/FAV flow-thru	Flow-Thru	SAV/FAV	Native sand	90	1.5	60	62,700	190 x 330	N-k values
FS-4	FS4-2	2	12	MIX flow-thru	Flow-Thru	EMV/SAV/FAV/Algae	Native sand	30-90	1.5	40	62,700	190 x 330	N-k values
FS-1	FS1-3	3	12	EMV shallow series	Series	EMV	Native sand	15	6	2.5	62,700	190 x 330	N-k values
FS-2	FS2-3	3	12	EMV deep series	Series	EMV	Native sand	45	6	7.5	62,700	190 x 330	N-k values
FS-3	FS3-3	3	12	SAV/FAV series	Series	SAV/FAV	Native sand	90	6	15	62,700	190 x 330	N-k values
FS-4	FS4-3	3	12	MIX series	Series	EMV/SAV/FAV/Algae	Native sand	30-90	6	10	62,700	190 x 330	N-k values
System		3	12		Series		Native sand	15-90	1.5	35	250,800	190x1320	N-k values
FS-1	FS1-4	4	12	EMV shallow series pulsed	Series/Pulsed	EMV	Native sand	15	2-12	1.3-7.5	62,700	190 x 330	N-k values
FS-2	FS2-4	4	12	EMV deep series pulsed	Series/Pulsed	EMV	Native sand	45	2-12	3.8-23	62,700	190 x 330	N-k values
FS-3	FS3-4	4	12	SAV/FAV series pulsed	Series/Pulsed	SAV/FAV	Native sand	90	2-12	7.5-45	62,700	190 x 330	N-k values
FS-4	FS4-4	4	12	MIX series pulsed	Series/Pulsed	EMV/SAV/FAV/Algae	Native sand	30-90	2-12	5-30	62,700	190 x 330	N-k values
System		4	12		Series/Pulsed		Native sand	15-90	0.5-3	17.5-105	250,800	190x1320	N-k values

Notes:

¹ Operational Mode: startup (includes construction time), batch (make-up water only), flow-thru [at average hydraulic loading rate (HLR)], series (cells-in-series), pulsed (dynamic flow rates)

² Plant Communities: EMV (emergent vegetation), SAV (submerged aquatic vegetation), FAV (floating aquatic vegetation), Algae (filamentous and macro algae), OW (open water), MIX (mixed plant community)

³ Substrate: sand (imported, rinsed, medium-grained sand), native sand (on-site soils), limestone (#57 limrock or equivalent)

⁴ HLR (hydraulic loading rate = flow/area)

⁵ nHRT (nominal hydraulic residence time = water depth/HLR); average depth of 60 cm used to calculate nHRT for FSS

⁶ Test Variables: C* (lowest-achievable background concentration), BAN (biologically available nitrogen as determined by treatment system and analytical test), N-kvalues (first-order removal rate constants for TN fractions, including TN, NH₃-N, NO₃+NO₂-N)

Field-Scale Phase 3 (Treatment IDs FS1-3 through FS4-3) will continue flow-through operation in series through the four Field-Scale Cells. The purpose of this test is to document how low nitrogen and phosphorus concentrations can be driven through multiple cells-in-series. An average system-wide HLR of 1.5 cm/d (6 cm/d per cell [4.1 in/week overall and 16 in/week per cell]) will be continued during the twelve-month Field-Scale Phase 3 operation. Based on the target water depths, the range of nHRTs will be from 2.5 to 15 days or 35 days for the four-cell system. Surface water in these Field-Scale Cells will be sampled on a routine basis for all water quality parameters of interest (see Section 4). Data collected during this operational phase will be used to provide refined estimates of nutrient and solids kinetics for each of the tested plant community/sediment combinations.

Field-Scale Phase 4 (Treatment IDs FS1-4 through FS4-4) will continue series flow-through operation of the four Field-Scale Cells for the final twelve-month operational period. Inflows to these cells will be pulsed (system HLR between 0.5 and 3 cm/d [1.4 to 8.3 in/week]) to provide a twelve-month period of dynamic operation. Based on the target water depths, the range of average cell nHRTs will be from 1.3 to 45 days and the system nHRT will range from 17.5 to 105 days. Surface water in these Field-Scale Cells will be sampled on a routine basis for all water quality parameters of interest (see Section 4). Data collected during this operational phase will be used to provide refined estimates of nutrient and solid kinetics for each of the tested plant community/sediment combinations under dynamic operational conditions. These data are critical for calibrating a dynamic nitrogen model that would be useful during full-scale design.

Section 4.0 Implementation, Sampling, and Analysis Plan

4.1 Introduction

This report recommends a five to six-year period for implementation and completion of the C-43 WQTA Test Facility project (Figure 5). Key phases of the proposed timeline of activities necessary to complete this project include the following (some phases can be completed concurrently):

- System Final Design and Contracting (6 to 12 months)
- System Construction and Startup (12 months)
- System Operation and Monitoring (36 months)
- Final Data Analysis and Reporting (12 months)
- Abandonment and Decommissioning (6 months)

Assuming data are favorable and adequate, the next step after this testing period should be full-scale C-43 WQTA project implementation.

4.2 Test Facility Final Design and Permitting

The final design of the C-43 WQTA Test Facility will include the following components:

- Final site selection
- Grading plan
- Pumping and piping plan
- Mechanical/electrical plan
- Planting plan
- Facilities plan (e.g., fencing, field office, equipment storage, etc.)

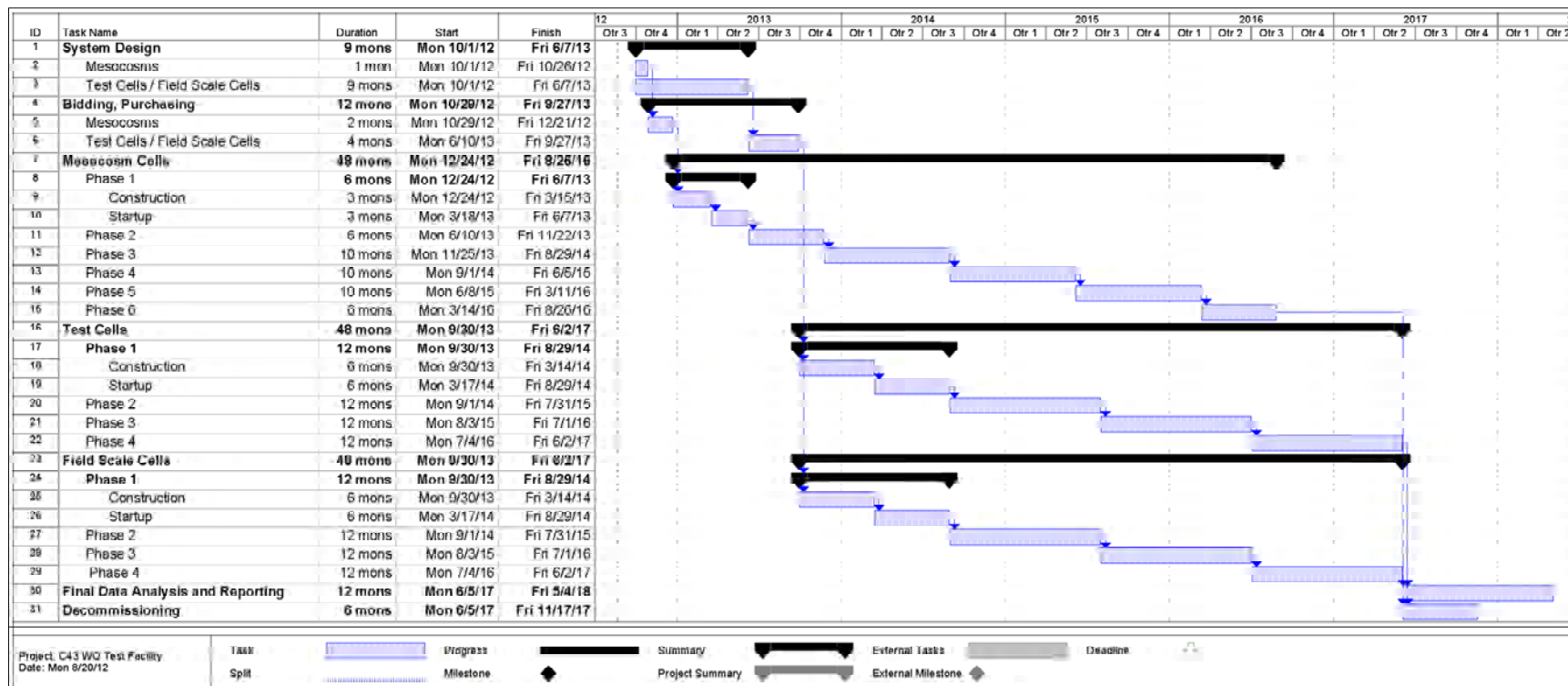
System design can be completed as one unit or can be phased into two parts:

- Mesocosm construction
- Test Cell and Field-Scale Cell construction

Final site selection will need to consider the best location on the BOMA property for the Test Facility in terms of access, water source and discharge point, constructability, and permitting. All necessary federal, state, and local permits will need to be applied for and received prior to project construction.

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Figure 5. Proposed C-43 Water Quality Treatment and Demonstration Project Schedule



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Additional soil testing may be needed to estimate potential infiltration rates for final site selection. The goal is to keep steady-state infiltration rates in the Test Cells and Field-Scale Cells less than about one fourth to one half of the lowest HLR to be tested ($0.25 \times 1.5 \text{ cm/d} = 0.38 \text{ cm/d}$ to $0.5 \times 1.5 \text{ cm/d} = 0.75 \text{ cm/d}$). If estimated steady-state infiltration rates are higher than the 0.75 cm/d target, then the test HLRs can be increased or site soils can be amended with finer soils to reduce rates. Preliminary water balance estimates are recommended for each experimental treatment during final design.

The pumping and piping plan will include the specific location and design of the inlet pump station; pump selection and power needs; pipeline materials, sizes, and alignments; and inlet and outlet structures.

The grading plan will include all site excavation and grading. This will include a graded pad area for the Mesocosms, a graded location for on-site field office and equipment storage, inlet and outlet canals (if needed), excavation and grading of the earthen Test Cells and Field-Scale Cells, and berm construction. Additional soil testing may be required during final design to evaluate the potential for seepage through the berms between and outside of the Test Cells and Field-Scale Cells. If seepage or cross-talk between cells is expected to be excessive, the berms may need to be lined, constructed with lower-permeability cores, or extended in width.

The mechanical/electrical plan will need to include electric service for pumps, on-site field-office (if needed), and monitoring equipment.

The planting plan will include the species of plants, desired propagules, the number of plant propagules, and the desired planting density and methods.

The facilities plan will include the size and type of a temporary field office and associated utilities (e.g., water supply, sewage storage and disposal, power, etc.), and on-site equipment storage.

4.3 System Construction and Startup

Mesocosm construction will require site selection, clearing and grading, installation of a relatively small pump (fuel-powered) and inlet and outlet water lines, purchase of a pre-fabricated head tank and multiple fiberglass Mesocosm tanks, and installation of soils and plants in the Mesocosms. This work can probably be completed in as little as three months. Following an estimated six-month construction/startup period the Mesocosms should be ready for Batch-mode testing. A longer startup period would likely be required if the system construction is completed during the late fall or winter months.

Construction of the larger test systems (Test Cells and Field-Scale Cells) will take longer and can proceed at a slower pace without limiting startup of the Mesocosms. Site preparations should only take about two months following notice-to-proceed. Preliminary grading for this scale project (total construction footprint of about 40 ha (100 ac) will require about three to five months of favorable weather. Final grading will take another two to three months and planting will require about two weeks. Mechanical, electrical, pumping, and piping can be completed concurrently with the earthwork construction activities. These test systems will require about twelve months for construction and initial operational startup.

4.4 System Operation and Monitoring

The test facility treatments were described in Section 3 above. This section of the conceptual design report describes the proposed system operation and monitoring plan.

System operation and monitoring will include the following specific activities:

- Pump station operation and maintenance
- Water flow and level control
- Field data collection
- Analytical sample analysis
- Data entry and validation
- Data storage and processing

4.4.1 Site Operation and Maintenance

The Site Manager will be responsible for pump station operation and maintenance. Depending on reliability of the pump station and electric service, this activity will need to be daily, to no less than three times per week. Routine checks will require observation of pumped inflows, including reading of the inflow totalizer(s); checks for leaks or losses; and routine and as-needed pump and pipeline maintenance. A Pump Station Field Log will be kept to document all visits made by the Site Manager.

Grounds maintenance will include mowing and/or weed eating grassed areas, trash collection and removal, and facility cleaning.

4.4.2 Test System Monitoring

The Site Manager will have the responsibility to check all inflows and water levels in the 17 individual test systems at least three times weekly. If inflows are measured manually, one measurement per week is adequate as long as inflow pump volumes are within specified tolerance limits. An Inflow and Levels Field Log will be kept to document all observations made by the Site Manager.

Field data collection (water temperature, pH, specific conductance, and dissolved oxygen) will be measured at one or more surface water stations weekly in all test units. Table 5 provides a summary of all data collection activities at the C-43 WQTA Test Facility. Detailed tables showing the recommended number of samples for each parameter are included in Appendix A. Continuous field data recording sondes may be used at both inflow and outflow stations and selected interior locations, if budget is adequate. Weekly field parameter measurements at inflow and outflow stations are also recommended. A Field Water Quality Data Log with calibration backup will be kept by the Site Manager to document all measurements of field water quality data.

Water quality and sediment samples collected for off-site laboratory analysis will be collected as per the attached schedule in Table 5. The recommended sampling frequency is based on WSI's experience with similar projects as well as cost considerations. These frequencies should be adequate to develop reliable model parameters for full-scale project design.

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Figure 6 identifies the water quality sampling locations for each of the testing units. Routine analytical parameters, standard methods for analysis, preservation, and their holding times are summarized in Table 6. Figure 7 identifies the field equipment monitoring locations for each of the testing units.

In addition to the field and analytical parameters described above, the following types of physical and biological data collection efforts are also recommended:

- Weather data (continuous total insolation, air temperature, air speed, relative humidity, and rainfall) to be collected at the existing station at S-78
- Water levels (continuous recorders in all test units with two each in the Test and Field-Scale cells)
- Tracer study (annual study in the Test Cell and Field-Scale Cells)
- Plant species and cover estimates (weekly visual surveys; quarterly survey using aerial photography [Field Scale Cells])
- Faunal observations (weekly field notes of faunal uses of the test systems)
- Atmospheric N inputs will be estimated from monthly grab samples at three on-site locations.

4.4.3 Rapid Assessment of Biologically-Available Nitrogen

The District may wish to consider using the C-43 WQTA Test Facility as a platform for developing a new analytical or biological test for rapid estimation of BAN. Such a test could ultimately allow screening of raw water sources for BAN as a first step in full-scale compliance with the CRE TMDL. Two possible approaches to developing a rapid assessment test are described.

The first and ultimately the most cost effective BAN quantification approach might be an analytical laboratory test. The Expert Panel recommended development of a modified standard method for TKN analysis to only oxidize the potentially available organic nitrogen fractions to ammonium without oxidizing the more recalcitrant organic nitrogen forms. A series of weak acids should be considered and tested and the results of these tests compared to the surface water samples from the batch Mesocosm treatments described above. For example, a series of aliquots of a C-43 inflow water sample to the Mesocosms could be partially digested in the laboratory with a series of sulfuric acid dilutions, and the ammonium measured in these subsamples could be compared to the ammonium produced by TKN analysis of the same inflow sample. The difference in concentration between the TKN and each serial acid dilution might provide a range of ammonium concentrations, with the lower concentrations at more dilute digestions and higher concentrations at higher digestion concentrations. This range of concentrations would be compared to the TKN in outflow samples from the various Mesocosm batch treatments to determine which acid treatment most closely predicted the actual level of BAN in the Mesocosms. WSI does not have specific experience developing analytical tests for this purpose. However WSI has worked with the University of Florida (UF) Soil and Water Science Department on utilizing complex analytical procedures for fractionating P forms in the environment. We would recommend that UF or a similar lab be used to conduct the analytical work with input from project scientists.

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Table 5. C-43 Test Facility Monitoring Activities

Parameter	Mesocosms		Test Cells		Field Scale Cells	
	In/Out	Internal	In/Out	Internal	In/Out	Internal
Field Sampling						
Flow	C(I), W	---	C(I)	---	C(I)	---
Water Stage	---	C(I)	C(I)	---	C(I)	---
Field Parameters (Temp, DO, pH, Cond)	C(I), W	W	C(I), W	W	C(I), W	W
Surface Water Quality						
Nitrogen (N) Series	W	---	W	M, Q	W	W, M
Phosphorus (P) Series	M	---	M	Q	W	M
Total organic carbon	M	---	M	Q	W	M
Total suspended solids	W	---	W	M, Q	W	M
Calcium	M	---	M	Q	W	M
Alkalinity	M	---	M	Q	W	M
Sulfate, Total	M	---	M	Q	W	M
Rainfall / Atmospheric Inputs						
Nitrogen (N) Series	M		M		M	
Phosphorus (P) Series	M		M		M	
Tracer Study						
Lithium	---	---	A	---	A	---
Biological Analyses						
Periphyton Cover	W	W	W	W	W	W
Macrophyte Cover	W	W	M	M	M, Q	M, Q
Faunal Observations	---	---	W	W	W	W
Sediments						
Total Kjeldahl N	Q	Q	Q	Q	Q	Q
Phosphorus (P) Series	Q	Q	Q	Q	Q	Q
Total organic carbon	Q	Q	Q	Q	Q	Q
Bulk density	Q	Q	Q	Q	Q	Q
Solids (percent)	Q	Q	Q	Q	Q	Q
Sulfate, Total	Q	Q	Q	Q	Q	Q

Notes:

C(I) = continuous with instrument

W = weekly

M = monthly

Q = quarterly

A = annually

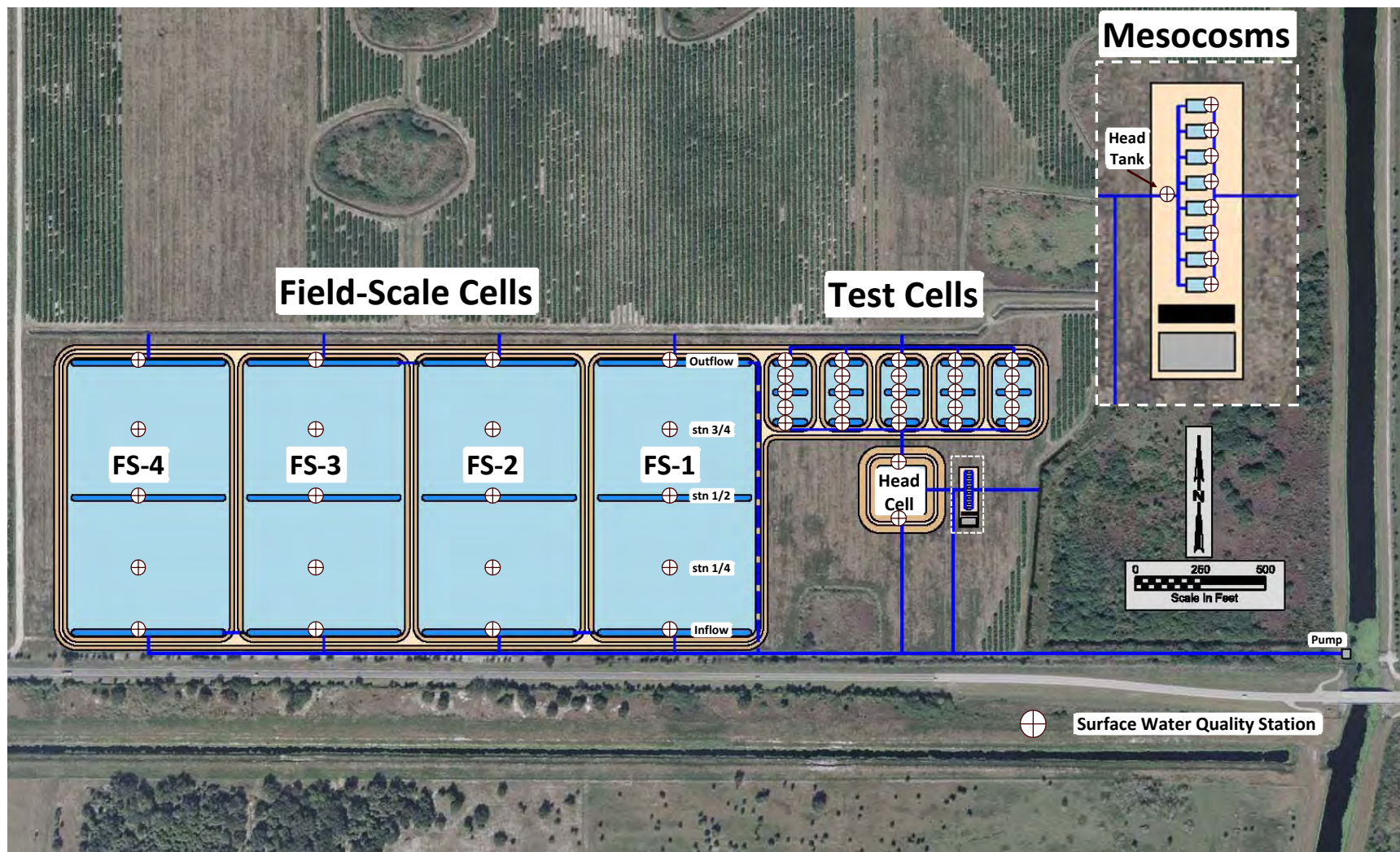


Figure 6. C-43 Test Facility Water Quality Monitoring Stations

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Table 6. C-43 Test Facility Analytical Parameters

Parameter	Method	Preservative	Holding Time
Surface Water Quality			
Ammonia N, Total	EPA 350.1	H ₂ SO ₄ to pH<2; cool (4°C)	28 days
Kjeldahl N, Total	EPA 351.2	H ₂ SO ₄ to pH<2; cool (4°C)	28 days
Nitrate+Nitrite N, Total	EPA 353.2	H ₂ SO ₄ to pH<2; cool (4°C)	28 days
Total P	EPA 365.3 (Spec)	H ₂ SO ₄ to pH<2; cool (4°C)	28 days
Soluble Reactive P	EPA 365.2	cool (4°C)	48 hrs
Total Dissolved P	EPA 365.3 (Spec)	H ₂ SO ₄ to pH<2; cool (4°C)	28 days
Total organic carbon	SM5310B	HCl to pH<2; cool (4°C)	28 days
Total suspended solids	EPA 160.2 - 500mL	cool (4°C)	7 days
Calcium	EPA 200.7/6010 (ICP)	HNO ₃ to pH<2; cool (4°C)	180 days
Alkalinity	EPA 310.1	cool (4°C)	14 days
Lithium	EPA 200.7	HNO ₃ to pH<2; cool (4°C)	180 days
Sulfate, Total	EPA 375.4	cool (4°C)	28 days
Sediments			
Total Kjeldahl N	EPA 351.2	cool (4°C)	28 days
Total P	EPA 365.4	cool (4°C)	28 days
Total Inorganic P	EPA 9056	cool (4°C)	48 hrs
Total organic carbon	EPA 415.1/9060	cool (4°C)	28 days
Bulk density	ASTM C1277	cool (4°C)	28 days
Solids (percent)	SM2540G	cool (4°C)	7 days
Sulfate, Total	EPA 375.4	cool (4°C)	28 days

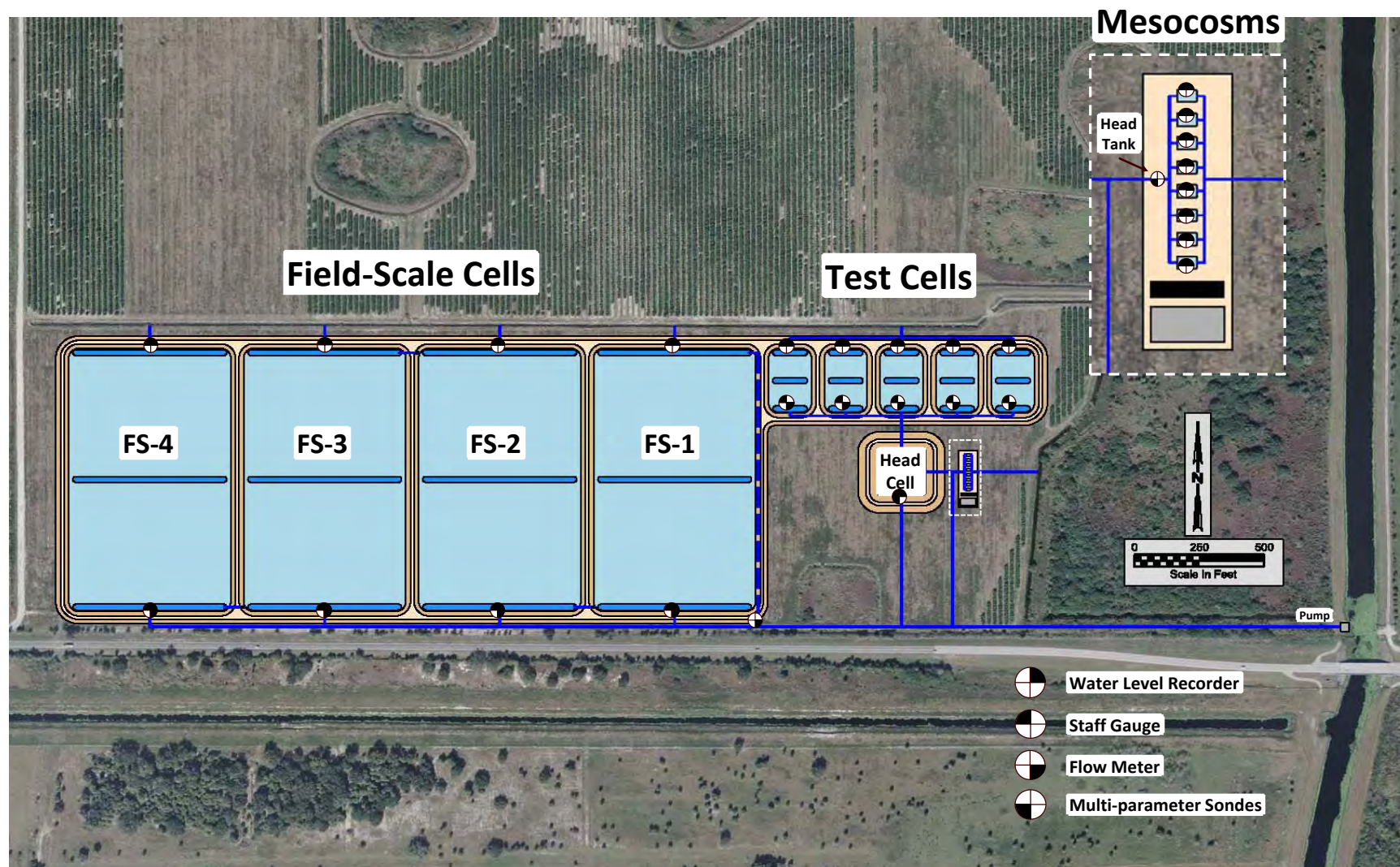


Figure 7. C-43 Test Facility Field Equipment Monitoring Locations

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The second possible method recommended by the Expert Panel to better predict the BAN was the use of a modified FDEP Algal Growth Potential (AGP) test. Based on FDEP's web site (<http://www.dep.state.fl.us/labs/biology/aalimnut.htm>):

"The FDEP Biology Laboratory conducts Algal Growth Potential and Limiting Nutrient algal assays. Algal Growth Potential (AGP) tests and Limiting-Nutrient assays are the most direct and effective ways to determine the amount of nutrients available to organisms in surface waters, and the eutrophication potential of an aquatic system. These methods provide information on the biologically-available nutrients in the water. Few other laboratories in Florida have the capacity or the staff able to perform these highly useful tests. Algal Growth Potential (AGP) assays determine the maximum amount of algal growth that the nutrients in a water sample can support. This test provides a better indication of the potential for algal blooms than can be determined by chemical measurement of nutrient concentrations, because all nutrients in the water are not in a form that can be used by algal. Additionally, there may be substances present in the water that inhibit algal growth. In nature, other factors than nutrient availability can limit the growth of algae, such as the amount of light available, water temperature, or the amount of algal being consumed by algae-eating organisms. However, the AGP assay alerts officials to the potential for algal blooms."

The AGP test incubates the planktonic alga *Selenastrum capricornutum* for fourteen days in flasks filled with sample water under artificial light in a laboratory. At the end of the fourteen-day incubation, the number of algal cells is quantified by use of an automated particle counter. The standard AGP test compares this algal growth between this sample, a deionized water control, and a sample with nitrogen and phosphorus added to allow maximum growth. For the proposed modified AGP test to estimate BAN, the algal growth in a range of surface water samples from the inflow to the outflow of the C-43 Mesocosms would be compared to growth of the algae in the DI control. The difference in algal cell multiplication between these samples would indicate how much algal growth potential might result from any BAN in the water samples. A complete revision of the AGP test for the purpose of the C-43 WQTA Project is not recommended. WSI suggests a discussion between DEP and SFWMD scientists to assess the costs and benefits of adapting this test (with or without modifications) to the specific needs of the C-43 WQTA project.

These two alternative approaches should be critically examined and discussed by District and FDEP staff before inclusion in the C-43 WQTA Test Facility Project. Development of a BAN rapid assessment protocol as part of this project might help with data interpretation and subsequent adaptive management but is not considered critical for developing design guidance and achieving project success. Additional effort beyond the scope of the conceptual plan will be needed to provide a cost estimate for one or both of these suggested assessment methods. For example, development of this cost estimate would include development of a detailed scope of work and budget in cooperation with a research-level analytical laboratory. If a BAN rapid assessment technique can be developed cost effectively within the project budget, then it is recommended.

4.4.4 Data Management and Quality Control

Data entry and validation will need to be conducted on a routine (weekly) basis. All data will be entered into Excel spreadsheets and uploaded into an Access database for long-term storage

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and data manipulation/query. Data validation will include a quality control check to see if data entries from laboratory reports to the database are accurate.

Data storage and processing will be the responsibility of the Site Manager. Data analysis and reporting will need to be conducted by staff with advanced experience.

4.5 Data Analysis and Reporting

Data analysis will proceed concurrently with monitoring. This will allow an adaptive management approach to determining performance and adjusting system management to maximize information gained. Quarterly data summaries are recommended as well as interim and final annual reports.

Types of data analyses that should be accomplished include:

- Data trend plots and analyses
- Water balances by treatment
- Pollutant mass balances
- Calculation of kinetic rate constants
- Non-parametric statistical analyses to detect significant treatment differences and temporal trends

All analyses will be compared to data expectations from similar systems in the literature and in the review of existing systems (Task 2 report).

4.6 Development of a Dynamic Nitrogen Model

The District routinely uses the Dynamic Model for Stormwater Treatment Areas Version 2 (DMSTA2, Walker and Kadlec 2008) to design STAs for phosphorus removal and to forecast future performance based on changes in dominant vegetation community, expansions of treatment area, and/or changing inflow volumes and concentrations. The DMSTA2 provides an excellent framework to begin the development of a dynamic nitrogen model because it already includes a highly flexible water balance component. In theory, the phosphorus dynamics module could be replaced with a nitrogen module. Data sets from the proposed project, and other systems, could be used to calibrate the nitrogen module for the different vegetation community types.

Development of a dynamic nitrogen model is not critical for full-scale design. For example, early STA design relied on more simplistic steady-state models that can be calibrated based on the data to be collected as described above. However the ability to optimize the full-scale design would likely be improved by development of a dynamic nitrogen model using the data collected from the proposed test facility. Additional effort beyond this conceptual design will be needed to provide a realistic cost estimate for model development. If determined to be cost effective and within the overall project budget, it is recommended that the District plan to develop a dynamic nitrogen model, based on DMSTA2, concurrently with the construction and operation of the C-43 Test Facility. It is reasonable to assume that the proposed nitrogen model could be developed and tested within the same five to six year time span of this testing project.

Section 5.0 Conceptual-Level Cost Estimates for Construction, Operation, and Testing

5.1 Introduction

The proposed C-43 WQTA Test Facility described in this report will require a significant financial investment to implement. WSI has considered cost impacts associated with all of the conceptual design elements in this report, including the selection of monitoring stations, parameter lists, and sample collection frequency and the duration of the proposed study. Clearly, costs for this test program could be reduced by cutting back on both the size and complexity of the various test units as well as reducing the sampling and analysis efforts. Costs could also be greatly increased above those estimated in this section by adding design complexity and numbers of sampling stations, increasing sampling frequency and project duration, and increasing lists of analytical parameters to be sampled. Since no target testing budget was provided, the sampling design recommendations in this report are based on WSI's best professional judgment and will need to be refined by the District in light of actual budget constraints.

5.2 Test Facility Conceptual Cost Estimate

Table 7 provides a summary of the conceptual-level capital (engineering and construction) cost estimate for the proposed test facilities described in Section 3 of this report. Unit costs are based on multiple sources including FDOT Item Average Unit Costs (2011 Statewide), vendor quotes and price sheets, WSI's past experience with similar projects, and other sources (CH2M HILL 2010). Appendix B provides an expanded summary table with the cost basis for each line item as well as additional relevant cost data. The estimated total capital cost is \$5.06 million with \$340,000 estimated for engineering and permitting and \$4.72 million for construction. Key assumptions of the cost estimate include the following:

- Earthwork
 - o Embankments are 1.8 m (6 feet) above natural grade with 4.2 m (14-ft) top width and 3:1 side slopes
 - o Earthwork volumes are based on a flat existing grade; actual site topography was not used
 - o Earthwork was not optimized to balance cut and fill
 - o Excess cut material can be stockpiled on the BOMA property
- Sitework
 - o A stabilized access road is included (4.5 m [15-ft width], 1,980 m [6600-ft] length)
 - o Embankment tops are stabilized

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- o A shellrock pad (22.5 m [75-ft] x 70 m [230-ft]) is included for the site trailer, mesocosm tanks, and parking area
 - o The site perimeter (3,000 m [10,000 linear feet]) will be fenced with chain-link and 3-strand barb wire
 - o Embankment side slopes will be hydroseeded
 - o Monitoring boardwalks will be constructed from painted steel scaffold frames with aluminum deck boards
- Buildings
 - o A site trailer and pump house/electrical building are included
- Pumping
 - o The master pump station will be a vendor-provided package system complete with controls. The pump station will be enclosed in a building.
 - o A temporary, fuel-powered pump will be used for interim water supply to the Mesocosm facilities.
- Piping and Appurtenances
 - o Primary force main is above grade 30-cm (12-in) diameter HDPE except at road crossings and embankment penetrations
 - o All embankment pipe penetrations will include seepage collars
 - o Field-scale inflows consist of 15-cm (6-in) HDPE pipe with control valves and flow meters
 - o Field-scale outflows and series-flow connections consist of 45-cm (18-in) diameter HDPE culvert with Agri-drain Inline Water Control Structures
 - o Head Cell inflow piping will consist of 165 m (550 feet) of 15-cm (6-in) HDPE force main with a control valve
 - o Head Cell outflow piping will consist of a 6-inch PVC header with 7.5-cm (3-in) PVC supply lines to each Test Cell
 - o Test Cell inflows will be outfitted with flow meters and control valves
 - o Test Cell outflows will consist of 20-cm (8-in) PVC pipe with Agri-drain Inline Water Control Structures
 - o All cell drainage lines will discharge to the east-west irrigation ditch immediately north of the proposed project footprint
- Wetland Planting
 - o Cells will be planted with nursery-grown or field-harvested material as described in Section 3.1
- Miscellaneous Equipment

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- o Costs are included for likely monitoring equipment needs such as a weather station, water quality sondes, autosamplers, refrigerator, water level recorders, and staff gauges

Field-Scale flow meters include one each on the main pumped supply lines, and one on the auxiliary line to Cell FS-1 when in series-flow. There is one flow meter for each Test Cell. Based on past experience with the SFWMD's PSTA mesocosms, there are no reliable flow meters available that operate at such low flows. Mesocosm flow rates will be measured manually with a stop watch and graduated cylinder. The five autosamplers are intended to be rotated around the site, primarily for tracer studies. Stage recorders are proposed at the head cell (n=1), at the upstream and downstream ends of each Field-Scale Cell (n=8), at the downstream end of each Test Cell (n=5), and in each mesocosm (n=8) for a total of 22.

5.3 Operation, Maintenance, and Test Facility Management Cost Estimate

Operation and maintenance cost estimates include both routine O&M as well as the costs for sample collection and preliminary data analysis. As described above in Section 4, routine O&M will include pump operation and maintenance, maintenance of a weather station, site security, mowing, cleaning, and water level control. Sample collection and data analysis activities were also described in Section 4 above.

It is estimated that two full-time staff will be needed to effectively operate the C-43 WQTA Test Facility and complete all of the O&M and site/data management functions described in this plan. The Site Manager should have a M.S./M.E. degree or equivalent in environmental science/engineering and no less than five years of applicable experience. The second full-time equivalent person should have a job title equivalent to Site Technician and should have a minimum of a B.S./B.E. in environmental science/engineering and at least three years of prior applicable experience. Estimated burdened (3.0 multiplier) rates for these two full-time employees are \$225,000 and \$135,000 per year, respectively, for an estimated total annual labor cost of about \$360,000. Costs for higher-level personnel management and data analysis/reporting are not included in this estimate.

Other O&M costs that are anticipated to be necessary include the following:

- Electrical power consumption for the site trailer;
- Electrical power consumption for the pump station;
- Potable and sanitary services for the site trailer; and
- Phone/internet service for the site trailer.

Estimates for these items are not included in this report.

5.4 Estimated Laboratory Costs

Table 8 summarizes estimated costs for laboratory analytical services¹. These estimates do not include costs for development of an AGP or analytical rapid BAN test. Total estimated analytical costs are approximately \$1.6 million for the 4-year study period. Analytical costs by system scale are estimated to be \$418,000 for the Mesocosms, \$444,000 for the Test Cells, and \$763,000 for the Field-Scale Cells. Detailed costs by testing scale are included in Appendix A. At this time, analytical costs have not been included for trace metals or organics. These parameters can be added at the District's discretion.

5.5 Dynamic Nitrogen Model Development Costs

Costs for development of a dynamic nitrogen model are not included in this report.

¹ Analytical unit costs estimates from Advanced Environmental Laboratories, Inc.



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Table 7. C-43 Test Facility Conceptual Capital Cost Estimate

Category	Description	Quantity	Units	Unit Price	Amount
Earthwork					\$ 1,353,000.00
	Excavation	180,400	CY	\$ 3.00	\$ 541,200.00
	Backfill	120,650	CY	\$ 4.50	\$ 542,925.00
	Hauling	59,750	CY	\$ 4.50	\$ 268,875.00
Sitework					\$ 956,933.33
	Access Road	11,000	SY	\$ 10.00	\$ 110,000.00
	Berm Stabilized Surface	26,300	SY	\$ 10.00	\$ 263,000.00
	Shellrock Pad	2,000	SY	\$ 10.00	\$ 20,000.00
	Chain Link Fence with 3-strand	10,000	LF	\$ 20.00	\$ 200,000.00
	Gates	1	LS	\$ 2,500.00	\$ 2,500.00
	Head Cell Liner	6,667	SY	\$ 11.00	\$ 73,333.33
	Hydroseeding	590,000	SF	\$ 0.05	\$ 29,500.00
	Mesocosm Tanks	8	EA	\$ 6,000.00	\$ 48,000.00
	Head Tank (1,550 gal)	1	EA	\$ 1,000.00	\$ 1,000.00
	Head Tank Stand	1	EA	\$ 2,000.00	\$ 2,000.00
	Agri-drain (8'x18" PVC)	12	EA	\$ 4,000.00	\$ 48,000.00
	Boardwalks	5,700	LF	\$ 28.00	\$ 159,600.00
Buildings					\$ 70,000.00
	Site Trailer	1	LS	\$ 35,000.00	\$ 35,000.00
	Pump/Electrical Building	1	LS	\$ 35,000.00	\$ 35,000.00
Pumping Facilities					\$ 152,500.00
	Master Pump Station and Controls	1	LS	\$ 150,000.00	\$ 150,000.00
	Temporary Mesocosm Pump	1	LS	\$ 2,500.00	\$ 2,500.00
Piping and Appurtenances					\$ 423,250.00
	Main Supply (12" HDPE)	4,600	LF	\$ 45.00	\$ 207,000.00
	Field Scale Inflows (6" HDPE)	1,500	LF	\$ 30.00	\$ 45,000.00
	Field Scale Outflows (18" HDPE)	400	LF	\$ 50.00	\$ 20,000.00
	Field Scale Series Connections (18" HDPE)	300	LF	\$ 50.00	\$ 15,000.00
	Head Cell Inflow (6" HDPE)	550	LF	\$ 30.00	\$ 16,500.00
	Head Cell Outflow (6" PVC)	1,000	LF	\$ 20.00	\$ 20,000.00
	Test Cell Inflows (3" PVC)	150	LF	\$ 3.00	\$ 450.00
	Test Cell Outflows (8" PVC)	1,100	LF	\$ 30.00	\$ 33,000.00
	Head Tank Temporary Supply (4" PVC)	550	LF	\$ 3.00	\$ 1,650.00
	Mesocosm Supply Piping	1	LS	\$ 2,000.00	\$ 2,000.00
	Mesocosm Discharge (4" PVC)	300	LF	\$ 3.00	\$ 900.00
	Seepage Collars	25	EA	\$ 150.00	\$ 3,750.00
	Field Scale Inflow Control Valves	5	EA	\$ 4,000.00	\$ 20,000.00
	Field Scale Flow Meters	5	EA	\$ 2,000.00	\$ 10,000.00
	Field Scale Outflow Gate Valves (18")	10	EA	\$ 1,000.00	\$ 10,000.00
	Field Scale Inflow Gate Valves (6")	4	EA	\$ 400.00	\$ 1,600.00
	Head Cell Inflow Control Valve	1	EA	\$ 4,000.00	\$ 4,000.00
	Head Cell Gate Valve (6")	1	EA	\$ 400.00	\$ 400.00
	Test Cell Inflow Control Valves	5	EA	\$ 250.00	\$ 1,250.00
	Test Cell Flow Meters	5	EA	\$ 1,500.00	\$ 7,500.00
	Test Cell Inflow Gate Valves (3")	5	EA	\$ 50.00	\$ 250.00
	Test Cell Outflow Gate Valves (8")	5	EA	\$ 600.00	\$ 3,000.00
Electrical					\$ 100,000.00
	Power Supply to Site and Pump Station	1	LS	\$ 100,000.00	\$ 100,000.00
Wetland Vegetation					\$ 190,000.00
	Emergent Plants	40	AC	\$ 4,000.00	\$ 160,000.00
	Submerged Aquatic Vegetation	20	AC	\$ 500.00	\$ 10,000.00
	Floating Aquatic Vegetation	20	AC	\$ 1,000.00	\$ 20,000.00
Miscellaneous Equipment					\$ 126,700.00
	Truck	1	EA	\$ 30,000.00	\$ 30,000.00
	Multi-parameter Sondes	5	EA	\$ 8,000.00	\$ 40,000.00
	Autosampler	5	EA	\$ 4,000.00	\$ 20,000.00
	Refrigerator	1	EA	\$ 1,000.00	\$ 1,000.00
	Vented Water Level Recorder	22	EA	\$ 1,500.00	\$ 33,000.00
	Staff Gauges	27	EA	\$ 100.00	\$ 2,700.00
Construction Total					\$ 3,372,383.33
	Overhead	10%			\$ 337,238.33
	Profit	5%			\$ 168,619.17
	Mobilization/Demobilization/Bonding	5%			\$ 168,619.17
	Contingency	20%			\$ 674,476.67
	Engineering and Permitting	10%			\$ 337,238.33
Capital Cost Total					\$ 5,058,575.00

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Table 8. C-43 Test Facility Analytical Laboratory Cost Estimate

Parameter	Number of Samples				Analytical Cost			
	Mesocosms	Test Cells	Field Scale Cells	Total	Mesocosms	Test Cells	Field Scale Cells	Total
Field Sampling								
Flow	3,328	C(I)	C(I)	3,328	\$ -	\$ -	\$ -	\$ -
Water Stage	C(I)	C(I)	C(I)	C(I)	\$ -	\$ -	\$ -	\$ -
Water temperature	4,992	3,120	2,496	10,608	\$ -	\$ -	\$ -	\$ -
Dissolved oxygen	4,992	3,120	2,496	10,608	\$ -	\$ -	\$ -	\$ -
pH	4,992	3,120	2,496	10,608	\$ -	\$ -	\$ -	\$ -
Conductivity	4,992	3,120	2,496	10,608	\$ -	\$ -	\$ -	\$ -
Total Dissolved Solids	4,992	3,120	2,496	10,608	\$ -	\$ -	\$ -	\$ -
Surface Water Quality								
Nitrogen (N) Series								
Total N	2,246	2,074	2,938	7,258	\$ -	\$ -	\$ -	\$ -
Organic N, Total	2,246	2,074	2,938	7,258	\$ -	\$ -	\$ -	\$ -
Ammonia N, Total	2,246	2,074	2,938	7,258	\$ 31,450	\$ 29,030	\$ 41,126	\$ 101,606
Kjeldahl N, Total	2,246	2,074	2,938	7,258	\$ 51,667	\$ 47,693	\$ 67,565	\$ 166,925
Nitrate+Nitrite N, Total	2,246	2,074	2,938	7,258	\$ 38,189	\$ 35,251	\$ 49,939	\$ 123,379
Total Dissolved N	2,246	2,074	2,938	7,258	\$ -	\$ -	\$ -	\$ -
Organic N, Dissolved	2,246	2,074	2,938	7,258	\$ -	\$ -	\$ -	\$ -
Ammonia N, Dissolved	2,246	2,074	2,938	7,258	\$ 31,450	\$ 29,030	\$ 41,126	\$ 101,606
Total Kjeldahl N, Dissolved	2,246	2,074	2,938	7,258	\$ 51,667	\$ 47,693	\$ 67,565	\$ 166,925
Nitrate+Nitrite N, Dissolved	2,246	2,074	2,938	7,258	\$ 38,189	\$ 35,251	\$ 49,939	\$ 123,379
Phosphorus (P) Series								
Total P	2,246	1,882	2,170	6,298	\$ 42,682	\$ 35,750	\$ 41,222	\$ 119,654
Soluble Reactive P	518	730	2,170	3,418	\$ 9,850	\$ 13,862	\$ 41,222	\$ 64,934
Total Dissolved P	518	730	2,170	3,418	\$ 9,850	\$ 13,862	\$ 41,222	\$ 64,934
Total organic carbon	518	730	2,170	3,418	\$ 10,368	\$ 14,592	\$ 43,392	\$ 68,352
Total suspended solids	2,246	2,074	2,170	6,490	\$ 22,464	\$ 20,736	\$ 21,696	\$ 64,896
Calcium ¹	518	730	2,170	3,418	\$ 15,552	\$ 21,888	\$ 65,088	\$ 102,528
Alkalinity	518	730	2,170	3,418	\$ 7,776	\$ 10,944	\$ 32,544	\$ 51,264
Sulfate, Total	518	730	2,170	3,418	\$ 8,813	\$ 12,403	\$ 36,883	\$ 58,099
Rainfall / Atmospheric Inputs								
Nitrogen (N) Series								
Total N	58	58	58	173	\$ -	\$ -	\$ -	\$ -
Organic N, Total	58	58	58	173	\$ -	\$ -	\$ -	\$ -
Ammonia N, Total	58	58	58	173	\$ 806	\$ 806	\$ 806	\$ 2,419
Kjeldahl N, Total	58	58	58	173	\$ 1,325	\$ 1,325	\$ 1,325	\$ 3,974
Nitrate+Nitrite N, Total	58	58	58	173	\$ 979	\$ 979	\$ 979	\$ 2,938
Total Dissolved N	58	58	58	173	\$ -	\$ -	\$ -	\$ -
Organic N, Dissolved	58	58	58	173	\$ -	\$ -	\$ -	\$ -
Ammonia N, Dissolved	58	58	58	173	\$ 806	\$ 806	\$ 806	\$ 2,419
Total Kjeldahl N, Dissolved	58	58	58	173	\$ 1,325	\$ 1,325	\$ 1,325	\$ 3,974
Nitrate+Nitrite N, Dissolved	58	58	58	173	\$ 979	\$ 979	\$ 979	\$ 2,938
Phosphorus (P) Series								
Total P	58	58	58	173	\$ 1,094	\$ 1,094	\$ 1,094	\$ 3,283
Soluble Reactive P	58	58	58	173	\$ 1,094	\$ 1,094	\$ 1,094	\$ 3,283
Total Dissolved P	58	58	58	173	\$ 1,094	\$ 1,094	\$ 1,094	\$ 3,283
Tracer Study								
Lithium ¹	0	1,440	1,152	2,592	\$ -	\$ 43,200	\$ 34,560	\$ 77,760
Biological Analyses								
Periphyton Cover	1,664	1,248	240	3,152	\$ -	\$ -	\$ -	\$ -
Macrophyte Cover	1,664	288	240	2,192	\$ -	\$ -	\$ -	\$ -
	0	0	16	16	\$ -	\$ -	\$ 40,000	\$ 40,000
Faunal Observations	0	1,040	832	1,872	\$ -	\$ -	\$ -	\$ -
Sediments								
Total Kjeldahl N	154	96	154	403	\$ 3,533	\$ 2,208	\$ 3,533	\$ 9,274
Phosphorus (P) Series								
Total P	154	96	154	403	\$ 5,376	\$ 3,360	\$ 5,376	\$ 14,112
Total Inorganic P	154	96	154	403	\$ 3,840	\$ 2,400	\$ 3,840	\$ 10,080
Total organic carbon	154	96	154	403	\$ 11,520	\$ 7,200	\$ 11,520	\$ 30,240
Bulk density	154	96	154	403	\$ 7,680	\$ 4,800	\$ 7,680	\$ 20,160
Solids (percent)	154	96	154	403	\$ 2,304	\$ 1,440	\$ 2,304	\$ 6,048
Sulfate, Total	154	96	154	403	\$ 3,840	\$ 2,400	\$ 3,840	\$ 10,080
Totals	63,507	50,106	63,517	177,130	\$ 417,562	\$ 444,499	\$ 762,688	\$ 1,624,749

Notes:

C(I) = continuous with instrument

¹ = price includes laboratory metals prep charge

Section 6.0 References

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Appendix A

C-43 WQTA Test Facility Sampling Plan



C-43 WQTA Test Facility Conceptual Design – Task 3

Appendix A. C-43 Test Facility – Mesocosm Sampling Plan and Analytical Costs

Parameter	Sampling Period (years)	Sample Frequency					Samples Collected						Number of Samples			Analytical Cost		
		Head Tank	Outflow	Inflow	1/2	Outflow	Head Tank	Outflow	Inflow	1/2	Outflow	Total	Field	QC	Total	Unit (\$/sample)	Total (\$)	
Field Sampling																		
Flow	4.0	---	W	---	W	0	208	0	208	3,328	3,328	0	3,328	\$	-	\$	-	
Water Stage	4.0	---	---	C(I)	---	0	0	0	0	0	0	0	0	\$	-	\$	-	
Water temperature	4.0	C(I)	W	W	W	0	208	208	208	4,992	4,992	0	4,992	\$	-	\$	-	
Dissolved oxygen	4.0	C(I)	W	W	W	0	208	208	208	4,992	4,992	0	4,992	\$	-	\$	-	
pH	4.0	C(I)	W	W	W	0	208	208	208	4,992	4,992	0	4,992	\$	-	\$	-	
Conductivity	4.0	C(I)	W	W	W	0	208	208	208	4,992	4,992	0	4,992	\$	-	\$	-	
Total Dissolved Solids	4.0	C(I)	W	W	W	0	208	208	208	4,992	4,992	0	4,992	\$	-	\$	-	
Surface Water Quality																		
Nitrogen (N) Series																		
Total N	4.0	W	---	---	W	208	0	0	208	1,872	1,872	374	2,246	\$	-	\$	-	
Organic N, Total	4.0	W	---	---	W	208	0	0	208	1,872	1,872	374	2,246	\$	-	\$	-	
Ammonia N, Total	4.0	W	---	---	W	208	0	0	208	1,872	1,872	374	2,246	\$	14	\$	31,450	
Kjeldahl N, Total	4.0	W	---	---	W	208	0	0	208	1,872	1,872	374	2,246	\$	23	\$	51,667	
Nitrate+Nitrite N, Total	4.0	W	---	---	W	208	0	0	208	1,872	1,872	374	2,246	\$	17	\$	38,189	
Total Dissolved N	4.0	W	---	---	W	208	0	0	208	1,872	1,872	374	2,246	\$	-	\$	-	
Organic N, Dissolved	4.0	W	---	---	W	208	0	0	208	1,872	1,872	374	2,246	\$	-	\$	-	
Ammonia N, Dissolved	4.0	W	---	---	W	208	0	0	208	1,872	1,872	374	2,246	\$	14	\$	31,450	
Total Kjeldahl N, Dissolved	4.0	W	---	---	W	208	0	0	208	1,872	1,872	374	2,246	\$	23	\$	51,667	
Nitrate+Nitrite N, Dissolved	4.0	W	---	---	W	208	0	0	208	1,872	1,872	374	2,246	\$	17	\$	38,189	
Phosphorus (P) Series																		
Total P	4.0	W	---	---	W	208	0	0	208	1,872	1,872	374	2,246	\$	19	\$	42,682	
Soluble Reactive P	4.0	M	---	---	M	48	0	0	48	432	432	86	518	\$	19	\$	9,850	
Total Dissolved P	4.0	M	---	---	M	48	0	0	48	432	432	86	518	\$	19	\$	9,850	
Total organic carbon	4.0	M	---	---	M	48	0	0	48	432	432	86	518	\$	20	\$	10,368	
Total suspended solids	4.0	W	---	---	W	208	0	0	208	1,872	1,872	374	2,246	\$	10	\$	22,464	
Calcium ¹	4.0	M	---	---	M	48	0	0	48	432	432	86	518	\$	30	\$	15,552	
Alkalinity	4.0	M	---	---	M	48	0	0	48	432	432	86	518	\$	15	\$	7,776	
Sulfate, Total	4.0	M	---	---	M	48	0	0	48	432	432	86	518	\$	17	\$	8,813	
Rainfall / Atmospheric Inputs																		
Nitrogen (N) Series																		
Total N	4.0	M	---	---	---	48	0	0	0	48	48	10	58	\$	-	\$	-	
Organic N, Total	4.0	M	---	---	---	48	0	0	0	48	48	10	58	\$	-	\$	-	
Ammonia N, Total	4.0	M	---	---	---	48	0	0	0	48	48	10	58	\$	14	\$	806	
Kjeldahl N, Total	4.0	M	---	---	---	48	0	0	0	48	48	10	58	\$	23	\$	1,325	
Nitrate+Nitrite N, Total	4.0	M	---	---	---	48	0	0	0	48	48	10	58	\$	17	\$	979	
Total Dissolved N	4.0	M	---	---	---	48	0	0	0	48	48	10	58	\$	-	\$	-	
Organic N, Dissolved	4.0	M	---	---	---	48	0	0	0	48	48	10	58	\$	-	\$	-	
Ammonia N, Dissolved	4.0	M	---	---	---	48	0	0	0	48	48	10	58	\$	14	\$	806	
Total Kjeldahl N, Dissolved	4.0	M	---	---	---	48	0	0	0	48	48	10	58	\$	23	\$	1,325	
Nitrate+Nitrite N, Dissolved	4.0	M	---	---	---	48	0	0	0	48	48	10	58	\$	17	\$	979	
Phosphorus (P) Series																		
Total P	4.0	M	---	---	---	48	0	0	0	48	48	10	58	\$	19	\$	1,094	
Soluble Reactive P	4.0	M	---	---	---	48	0	0	0	48	48	10	58	\$	19	\$	1,094	
Total Dissolved P	4.0	M	---	---	---	48	0	0	0	48	48	10	58	\$	19	\$	1,094	
Biological Analyses																		
Periphyton Cover	4.0	---	---	W		0	208			1,664	1,664	0	1,664	\$	-	\$	-	
Macrophyte Cover	4.0	---	---	W		0	208			1,664	1,664	0	1,664	\$	-	\$	-	
Sediments																		
Total Kjeldahl N	4.0	---	---	Q		0	16			128	128	26	154	\$	23	\$	3,533	
Phosphorus (P) Series																		
Total P	4.0	---	---	Q		0	16			128	128	26	154	\$	35	\$	5,376	
Total Inorganic P	4.0	---	---	Q		0	16			128	128	26	154	\$	25	\$	3,840	
Total organic carbon	4.0	---	---	Q		0	16			128	128	26	154	\$	75	\$	11,520	
Bulk density	4.0	---	---	Q		0	16			128	128	26	154	\$	50	\$	7,680	
Solids (percent)	4.0	---	---	Q		0	16			128	128	26	154	\$	15	\$	2,304	
Sulfate, Total	4.0	---	---	Q		0	16			128	128	26	154	\$	25	\$	3,840	
Totals											58,192	5,315	63,507				\$417,562	

Notes:

Number of cells = 8

Number of rainfall stations = 1

Sampling period (years) = 4

W = weekly

M = monthly

Q = quarterly

A = annually

C(I) = continuous with instrument

QC = Field QC measures consist of field generated equipment blanks (EB), field-cleaned equipment blanks (FCEB), field blanks (FB), split samples (SS), and replicate samples (RS).

¹ = price includes laboratory metals prep charge



C-43 WQTA Test Facility Conceptual Design – Task 3

Appendix A. C-43 Test Facility – Test Cell Sampling Plan and Analytical Costs

Parameter	Sampling Period (years)	Sample Frequency						Samples Collected							Number of Samples			Analytical Cost	
		Head Cell Outflow					Head Cell Outflow						Total	Field	QC	Total	Unit (\$/sample)	Total (\$)	
			Inflow	1/4	1/2	3/4		Outflow	Inflow	1/4	1/2	3/4							Outflow
Field Sampling																			
Flow	4.0	---	C(I)	---	---	---	C(I)	0	0	0	0	0	0	0	0	0	0	\$	- \$ -
Water Stage	4.0	---	C(I)	---	---	---	C(I)	0	0	0	0	0	0	0	0	0	0	\$	- \$ -
Water temperature	4.0	C(I)	W	---	W	---	W	0	208	0	208	0	208	3,120	3,120	0	3,120	\$	- \$ -
Dissolved oxygen	4.0	C(I)	W	---	W	---	W	0	208	0	208	0	208	3,120	3,120	0	3,120	\$	- \$ -
pH	4.0	C(I)	W	---	W	---	W	0	208	0	208	0	208	3,120	3,120	0	3,120	\$	- \$ -
Conductivity	4.0	C(I)	W	---	W	---	W	0	208	0	208	0	208	3,120	3,120	0	3,120	\$	- \$ -
Total Dissolved Solids	4.0	C(I)	W	---	W	---	W	0	208	0	208	0	208	3,120	3,120	0	3,120	\$	- \$ -
Surface Water Quality																			
Nitrogen (N) Series																			
Total N	4.0	W	Q	Q	M	Q	W	208	16	16	48	16	208	1,728	1,728	346	2,074	\$	- \$ -
Organic N, Total	4.0	W	Q	Q	M	Q	W	208	16	16	48	16	208	1,728	1,728	346	2,074	\$	- \$ -
Ammonia N, Total	4.0	W	Q	Q	M	Q	W	208	16	16	48	16	208	1,728	1,728	346	2,074	\$	14 \$ 29,030
Kjeldahl N, Total	4.0	W	Q	Q	M	Q	W	208	16	16	48	16	208	1,728	1,728	346	2,074	\$	23 \$ 47,693
Nitrate+Nitrite N, Total	4.0	W	Q	Q	M	Q	W	208	16	16	48	16	208	1,728	1,728	346	2,074	\$	17 \$ 35,251
Total Dissolved N	4.0	W	Q	Q	M	Q	W	208	16	16	48	16	208	1,728	1,728	346	2,074	\$	- \$ -
Organic N, Dissolved	4.0	W	Q	Q	M	Q	W	208	16	16	48	16	208	1,728	1,728	346	2,074	\$	- \$ -
Ammonia N, Dissolved	4.0	W	Q	Q	M	Q	W	208	16	16	48	16	208	1,728	1,728	346	2,074	\$	14 \$ 29,030
Total Kjeldahl N, Dissolved	4.0	W	Q	Q	M	Q	W	208	16	16	48	16	208	1,728	1,728	346	2,074	\$	23 \$ 47,693
Nitrate+Nitrite N, Dissolved	4.0	W	Q	Q	M	Q	W	208	16	16	48	16	208	1,728	1,728	346	2,074	\$	17 \$ 35,251
Phosphorus (P) Series																			
Total P	4.0	W	Q	Q	Q	Q	W	208	16	16	16	16	208	1,568	1,568	314	1,882	\$	19 \$ 35,750
Soluble Reactive P	4.0	M	Q	Q	Q	Q	M	48	16	16	16	16	48	608	608	122	730	\$	19 \$ 13,862
Total Dissolved P	4.0	M	Q	Q	Q	Q	M	48	16	16	16	16	48	608	608	122	730	\$	19 \$ 13,862
Total organic carbon	4.0	M	Q	Q	Q	Q	M	48	16	16	16	16	48	608	608	122	730	\$	20 \$ 14,592
Total suspended solids	4.0	W	Q	Q	M	Q	W	208	16	16	48	16	208	1,728	1,728	346	2,074	\$	10 \$ 20,736
Calcium ¹	4.0	M	Q	Q	Q	Q	M	48	16	16	16	16	48	608	608	122	730	\$	30 \$ 21,888
Alkalinity	4.0	M	Q	Q	Q	Q	M	48	16	16	16	16	48	608	608	122	730	\$	15 \$ 10,944
Sulfate, Total	4.0	M	Q	Q	Q	Q	M	48	16	16	16	16	48	608	608	122	730	\$	17 \$ 12,403
Rainfall / Atmospheric Inputs																			
Nitrogen (N) Series																			
Total N	4.0	---	M	---	---	---	---	0	48	0	0	0	0	48	48	10	58	\$	- \$ -
Organic N, Total	4.0	---	M	---	---	---	---	0	48	0	0	0	0	48	48	10	58	\$	- \$ -
Ammonia N, Total	4.0	---	M	---	---	---	---	0	48	0	0	0	0	48	48	10	58	\$	14 \$ 806
Kjeldahl N, Total	4.0	---	M	---	---	---	---	0	48	0	0	0	0	48	48	10	58	\$	23 \$ 1,325
Nitrate+Nitrite N, Total	4.0	---	M	---	---	---	---	0	48	0	0	0	0	48	48	10	58	\$	17 \$ 979
Total Dissolved N	4.0	---	M	---	---	---	---	0	48	0	0	0	0	48	48	10	58	\$	- \$ -
Organic N, Dissolved	4.0	---	M	---	---	---	---	0	48	0	0	0	0	48	48	10	58	\$	- \$ -
Ammonia N, Dissolved	4.0	---	M	---	---	---	---	0	48	0	0	0	0	48	48	10	58	\$	14 \$ 806
Total Kjeldahl N, Dissolved	4.0	---	M	---	---	---	---	0	48	0	0	0	0	48	48	10	58	\$	23 \$ 1,325
Nitrate+Nitrite N, Dissolved	4.0	---	M	---	---	---	---	0	48	0	0	0	0	48	48	10	58	\$	17 \$ 979
Phosphorus (P) Series																			
Total P	4.0	---	M	---	---	---	---	0	48	0	0	0	0	48	48	10	58	\$	19 \$ 1,094
Soluble Reactive P	4.0	---	M	---	---	---	---	0	48	0	0	0	0	48	48	10	58	\$	19 \$ 1,094
Total Dissolved P	4.0	---	M	---	---	---	---	0	48	0	0	0	0	48	48	10	58	\$	19 \$ 1,094
Tracer Study																			
Lithium ¹	4.0	---	---	---	---	---	A	0	0	0	0	0	240	1,200	1,200	240	1,440	\$	30 \$ 43,200
Biological Analyses																			
Periphyton Cover	4.0	W			W			208			208			1,248	1,248	0	1,248	\$	- \$ -
Macrophyte Cover	4.0	M			M			48			48			288	288	0	288	\$	- \$ -
Faunal Observations	4.0	---			W			0			208			1,040	1,040	0	1,040	\$	- \$ -
Sediments																			
Total Kjeldahl N	4.0	---			Q			0			16			80	80	16	96	\$	23 \$ 2,208
Phosphorus (P) Series																			
Total P	4.0	---			Q			0			16			80	80	16	96	\$	35 \$ 3,360
Total Inorganic P	4.0	---			Q			0			16			80	80	16	96	\$	25 \$ 2,400
Total organic carbon	4.0	---			Q			0			16			80	80	16	96	\$	75 \$ 7,200
Bulk density	4.0	---			Q			0			16			80	80	16	96	\$	50 \$ 4,800
Solids (percent)	4.0	---			Q			0			16			80	80	16	96	\$	15 \$ 1,440
Sulfate, Total	4.0	---			Q			0			16			80	80	16	96	\$	25 \$ 2,400
Totals															44,784	5,322	50,106		\$444,499

Notes:

Number of cells = 5

Number of rainfall stations = 1

Sampling period (years) = 4

W = weekly

M = monthly

Q = quarterly

A = annually

C(I) = continuous with instrument

QC = Field QC measures consist of field generated equipment blanks (EB), field-cleaned equipment blanks (FCEB), field blanks (FB), split samples (SS), and replicate samples (RS).

¹ = price includes laboratory metals prep charge



C-43 WQTA Test Facility Conceptual Design – Task 3

Appendix A. C-43 Test Facility – Field Scale Cell Sampling Plan and Analytical Costs

Parameter	Sampling Period (years)	Sample Frequency						Samples Collected								Number of Samples			Analytical Cost	
		Head Cell Outflow	Inflow	1/4	1/2	3/4	Outflow	Head Cell Outflow	Inflow	1/4	1/2	3/4	Outflow	Total	Field	QC	Total	Unit (\$/sample)	Total (\$)	
Field Sampling																				
Flow	4.0	---	C(I)	---	---	---	C(I)	0	0	0	0	0	0	0	0	0	0	0	\$	- \$
Water Stage	4.0	---	C(I)	---	---	---	C(I)	0	0	0	0	0	0	0	0	0	0	0	\$	- \$
Water temperature	4.0	C(I)	W	---	W	---	W	0	208	0	208	0	208	2,496	2,496	0	2,496	\$	- \$	
Dissolved oxygen	4.0	C(I)	W	---	W	---	W	0	208	0	208	0	208	2,496	2,496	0	2,496	\$	- \$	
pH	4.0	C(I)	W	---	W	---	W	0	208	0	208	0	208	2,496	2,496	0	2,496	\$	- \$	
Conductivity	4.0	C(I)	W	---	W	---	W	0	208	0	208	0	208	2,496	2,496	0	2,496	\$	- \$	
Total Dissolved Solids	4.0	C(I)	W	---	W	---	W	0	208	0	208	0	208	2,496	2,496	0	2,496	\$	- \$	
Surface Water Quality																				
Nitrogen (N) Series																				
Total N	4.0	W	M	M	W	M	W	208	48	48	208	48	208	2,448	2,448	490	2,938	\$	- \$	
Organic N, Total	4.0	W	M	M	W	M	W	208	48	48	208	48	208	2,448	2,448	490	2,938	\$	- \$	
Ammonia N, Total	4.0	W	M	M	W	M	W	208	48	48	208	48	208	2,448	2,448	490	2,938	\$	14 \$ 41,126	
Kjeldahl N, Total	4.0	W	M	M	W	M	W	208	48	48	208	48	208	2,448	2,448	490	2,938	\$	23 \$ 67,565	
Nitrate+Nitrite N, Total	4.0	W	M	M	W	M	W	208	48	48	208	48	208	2,448	2,448	490	2,938	\$	17 \$ 49,939	
Total Dissolved N	4.0	W	M	M	W	M	W	208	48	48	208	48	208	2,448	2,448	490	2,938	\$	- \$	
Organic N, Dissolved	4.0	W	M	M	W	M	W	208	48	48	208	48	208	2,448	2,448	490	2,938	\$	- \$	
Ammonia N, Dissolved	4.0	W	M	M	W	M	W	208	48	48	208	48	208	2,448	2,448	490	2,938	\$	14 \$ 41,126	
Total Kjeldahl N, Dissolved	4.0	W	M	M	W	M	W	208	48	48	208	48	208	2,448	2,448	490	2,938	\$	23 \$ 67,565	
Nitrate+Nitrite N, Dissolved	4.0	W	M	M	W	M	W	208	48	48	208	48	208	2,448	2,448	490	2,938	\$	17 \$ 49,939	
Phosphorus (P) Series																				
Total P	4.0	W	M	M	M	M	W	208	48	48	48	48	208	1,808	1,808	362	2,170	\$	19 \$ 41,222	
Soluble Reactive P	4.0	W	M	M	M	M	W	208	48	48	48	48	208	1,808	1,808	362	2,170	\$	19 \$ 41,222	
Total Dissolved P	4.0	W	M	M	M	M	W	208	48	48	48	48	208	1,808	1,808	362	2,170	\$	19 \$ 41,222	
Total organic carbon	4.0	W	M	M	M	M	W	208	48	48	48	48	208	1,808	1,808	362	2,170	\$	20 \$ 43,392	
Total suspended solids	4.0	W	M	M	M	M	W	208	48	48	48	48	208	1,808	1,808	362	2,170	\$	10 \$ 21,696	
Calcium ¹	4.0	W	M	M	M	M	W	208	48	48	48	48	208	1,808	1,808	362	2,170	\$	30 \$ 65,088	
Alkalinity	4.0	W	M	M	M	M	W	208	48	48	48	48	208	1,808	1,808	362	2,170	\$	15 \$ 32,544	
Sulfate, Total	4.0	W	M	M	M	M	W	208	48	48	48	48	208	1,808	1,808	362	2,170	\$	17 \$ 36,883	
Rainfall / Atmospheric Inputs																				
Nitrogen (N) Series																				
Total N	4.0	---	M	---	---	---	---	0	48	0	0	0	0	48	48	10	58	\$	- \$	
Organic N, Total	4.0	---	M	---	---	---	---	0	48	0	0	0	0	48	48	10	58	\$	- \$	
Ammonia N, Total	4.0	---	M	---	---	---	---	0	48	0	0	0	0	48	48	10	58	\$	14 \$ 806	
Kjeldahl N, Total	4.0	---	M	---	---	---	---	0	48	0	0	0	0	48	48	10	58	\$	23 \$ 1,325	
Nitrate+Nitrite N, Total	4.0	---	M	---	---	---	---	0	48	0	0	0	0	48	48	10	58	\$	17 \$ 979	
Total Dissolved N	4.0	---	M	---	---	---	---	0	48	0	0	0	0	48	48	10	58	\$	- \$	
Organic N, Dissolved	4.0	---	M	---	---	---	---	0	48	0	0	0	0	48	48	10	58	\$	- \$	
Ammonia N, Dissolved	4.0	---	M	---	---	---	---	0	48	0	0	0	0	48	48	10	58	\$	14 \$ 806	
Total Kjeldahl N, Dissolved	4.0	---	M	---	---	---	---	0	48	0	0	0	0	48	48	10	58	\$	23 \$ 1,325	
Nitrate+Nitrite N, Dissolved	4.0	---	M	---	---	---	---	0	48	0	0	0	0	48	48	10	58	\$	17 \$ 979	
Phosphorus (P) Series																				
Total P	4.0	---	M	---	---	---	---	0	48	0	0	0	0	48	48	10	58	\$	19 \$ 1,094	
Soluble Reactive P	4.0	---	M	---	---	---	---	0	48	0	0	0	0	48	48	10	58	\$	19 \$ 1,094	
Total Dissolved P	4.0	---	M	---	---	---	---	0	48	0	0	0	0	48	48	10	58	\$	19 \$ 1,094	
Tracer Study																				
Lithium ¹	4.0	---	---	---	---	---	A	0	0	0	0	0	240	960	960	192	1,152	\$	30 \$ 34,560	
Biological Analyses																				
Periphyton Cover	4.0	M			M			48			48			240	240	0	240	\$	- \$	
Macrophyte Cover	4.0	M			M			48			48			240	240	0	240	\$	- \$	
Macrophyte Cover (Aerial)	4.0	---			Q			0			16			16	16	0	16	\$	2,500 \$ 40,000	
Faunal Observations	4.0	---			W			0			208			832	832	0	832	\$	- \$	
Sediments																				
Total Kjeldahl N	4.0	---		Q			Q	0	16			16		128	128	26	154	\$	23 \$ 3,533	
Phosphorus (P) Series																				
Total P	4.0	---		Q			Q	0	16			16		128	128	26	154	\$	35 \$ 5,376	
Total Inorganic P	4.0	---		Q			Q	0	16			16		128	128	26	154	\$	25 \$ 3,840	
Total organic carbon	4.0	---		Q			Q	0	16			16		128	128	26	154	\$	75 \$ 11,520	
Bulk density	4.0	---		Q			Q	0	16			16		128	128	26	154	\$	50 \$ 7,680	
Solids (percent)	4.0	---		Q			Q	0	16			16		128	128	26	154	\$	15 \$ 2,304	
Sulfate, Total	4.0	---		Q			Q	0	16			16		128	128	26	154	\$	25 \$ 3,840	
Totals															55,232	8,285	63,517		\$762,688	

Notes:

Number of cells = 4

Number of rainfall stations = 1

Sampling period (years) = 4

W = weekly

M = monthly

Q = quarterly

A = annually

C(I) = continuous with instrument

QC = Field QC measures consist of field generated equipment blanks (EB), field-cleaned equipment blanks (FCEB), field blanks (FB), split samples (SS), and replicate samples (RS).

¹ = price includes laboratory metals prep charge



Appendix B

C-43 WQTA Test Facility Construction Cost Data



C-43 WQTA Test Facility Conceptual Design – Task 3

Appendix B. C-43 Test Facility – Basis for Construction Unit Costs

Category	Description	Unit Price	Unit Cost Basis	Notes
Earthwork	Excavation	\$ 3.00	FDOT Item Average Unit Cost from 2011/01/01 to 2011/12/31 (Statewide)	Regular excavation
	Backfill	\$ 4.50	FDOT Item Average Unit Cost from 2011/01/01 to 2011/12/31 (Statewide)	Embankment
	Hauling	\$ 4.50	CH2M HILL 2010 Estimate	Initial estimate increased from \$4.41 to \$4.50; stockpiled on site
Sitework	Access Road	\$ 10.00	FDOT Item Average Unit Cost from 2011/01/01 to 2011/12/31 (Statewide)	
	Berm Stabilized Surface	\$ 10.00	FDOT Item Average Unit Cost from 2011/01/01 to 2011/12/31 (Statewide)	
	Shellrock Pad	\$ 10.00	FDOT Item Average Unit Cost from 2011/01/01 to 2011/12/31 (Statewide)	
	Chain Link Fence with 3-strand	\$ 20.00	FDOT Item Average Unit Cost from 2011/01/01 to 2011/12/31 (Statewide)	8' Fence with 3-strand and concrete for posts
	Gates	\$ 2,500.00	FDOT Item Average Unit Cost from 2011/01/01 to 2011/12/31 (Statewide)	12' Dbl and 6' Pedestrian
	Head Cell Liner	\$ 11.00	FDOT Item Average Unit Cost from 2011/01/01 to 2011/12/31 (Statewide)	PVC Impermeable Liner
	Hydroseeding	\$ 0.05	WSI professional judgment	
	Mesocosm Tanks	\$ 6,000.00	Dolphin Fiberglass Products, Inc.	16' x 7'10" x 4'
	Head Tank (1,550 gal)	\$ 1,000.00	USA BlueBook	1,550 gal Green Water Storage Tank
	Head Tank Stand	\$ 2,000.00	WSI professional judgment	
	Agridrain (8'x18" PVC)	\$ 4,000.00	Agridrain Corporation	Inline WCS 8' x 8' PVC, material cost doubled for installation
	Boardwalks	\$ 28.00	Scaffoldmart.com	5x5 frames, 7' cross braces, leg bases, and aluminum planks
Buildings	Site Trailer	\$ 35,000.00	WSI professional judgment	
	Pump/Electrical Building	\$ 35,000.00	WSI professional judgment	
Pumping Facilities	Master Pump Station and Controls	\$ 150,000.00	Watertronics Technical Services	
	Temporary Mesocosm Pump	\$ 2,500.00	USA BlueBook	3" self priming trash pump, gas powered
Piping and Appurtenances	Main Supply (12" HDPE)	\$ 45.00	WSI professional judgment	
	Field Scale Inflows (6" HDPE)	\$ 30.00	FDOT Item Average Unit Cost from 2011/01/01 to 2011/12/31 (Statewide)	Utility Pipe, F&I, PE, Water/Sewer, 8-19.9"
	Field Scale Outflows (18" HDPE)	\$ 50.00	WSI professional judgment	Culvert
	Field Scale Series Connections (18" HDPE)	\$ 50.00	WSI professional judgment	Culvert
	Head Cell Inflow (6" HDPE)	\$ 30.00	FDOT Item Average Unit Cost from 2011/01/01 to 2011/12/31 (Statewide)	Utility Pipe, F&I, PE, Water/Sewer, 8-19.9"
	Head Cell Outflow (6" PVC)	\$ 20.00	WSI professional judgment	Mostly above grade
	Test Cell Inflows (3" PVC)	\$ 3.00	WSI professional judgment	Above Grade
	Test Cell Outflows (8" PVC)	\$ 30.00	FDOT Item Average Unit Cost from 2011/01/01 to 2011/12/31 (Statewide)	Utility Pipe, F&I, PE, Water/Sewer, 8-19.9"
	Head Tank Temporary Supply (4" PVC)	\$ 3.00	WSI professional judgment	Above Grade
	Mesocosm Supply Piping	\$ 2,000.00	WSI professional judgment	Above Grade
	Mesocosm Discharge (4" PVC)	\$ 3.00	WSI professional judgment	Above Grade
	Seepage Collars	\$ 150.00	Agridrain Corporation	6'x6' collar
	Field Scale Inflow Control Valves	\$ 4,000.00	Cla-Val	E-40 Series
	Field Scale Flow Meters	\$ 2,000.00	USA BlueBook	Seametrics WMX Series 104
	Field Scale Outflow Gate Valves (18")	\$ 1,000.00	Agridrain Corporation	PVC Slide Gate Valve VV18 with extensions
	Field Scale Inflow Gate Valves (6")	\$ 400.00	Agridrain Corporation	6" Slide Valterra Valve
	Head Cell Inflow Control Valve	\$ 4,000.00	Cla-Val	E-40 Series
	Head Cell Gate Valve (6")	\$ 400.00	Agridrain Corporation	6" Slide Valterra Valve
	Test Cell Inflow Control Valves	\$ 250.00	USA BlueBook	3" Union ball valve
	Test Cell Flow Meters	\$ 1,500.00	USA BlueBook	Seametrics Paddlewheel Insertion Flow Sensor and FT415 Totalizer
	Test Cell Inflow Gate Valves (3")	\$ 50.00	Agridrain Corporation	3" Slide Valterra Valve
	Test Cell Outflow Gate Valves (8")	\$ 600.00	Agridrain Corporation	8" Slide Valterra Valve
Electrical	Power Supply to Site and Pump Station	\$ 100,000.00	CH2M HILL 2010 Estimate	Initial estimate rounded up
Wetland Vegetation	Emergent Plants	\$ 4,000.00	WSI professional judgment	
	Submerged Aquatic Vegetation	\$ 500.00	WSI professional judgment	
	Floating Aquatic Vegetation	\$ 1,000.00	WSI professional judgment	
Miscellaneous Equipment	Truck	\$ 30,000.00	WSI professional judgment	Std. pickup truck purchased
	Multi-parameter Sondes	\$ 8,000.00	WSI professional judgment	YSI 6920 with pH/ORP, specific conductance, temp, optical DO
	Autosampler	\$ 4,000.00	Fondriest Environmental	Sigma SD900 with 24 1 L bottles
	Refrigerator	\$ 1,000.00	WSI professional judgment	
	Vented Water Level Recorder	\$ 1,500.00	Ben Meadows	YSI Level Scout (2MB) with cable and installation
	Staff Gauges	\$ 100.00	Ben Meadows	Style A 0 - 3.33' and 3.33 - 6.66' each plus mounting

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Miami, FL Tel.: (305) 247-1748 - Fax: (305) 247-8750 - [Email: dolphinfbg@aol.com](mailto:dolphinfbg@aol.com)

RECTANGULAR & SQUARE TANKS WITH FLAT BOTTOM

OUTSIDE LENGTH	OUTSIDE WIDTH	HEIGHT	GALLONS	PRICE
12'	2'	2'	290	\$ 1,155
11'8"	4'4"	2'	658	\$ 1,735
12'4"	3'8"	2'	452	\$ 1,620
12'6"	3'10"	3'	704	\$ 2,130
12'8"	4'	4'	972	\$ 3,220
12'4"	5'8"	2'	738	\$ 2,190
12'6"	5'10"	3'	1,135	\$ 2,810
12'8"	6'	4'	1,565	\$ 3,940
12'4"	7'6"	2'	1,024	\$ 2,655
12'6"	7'8"	3'	1,568	\$ 3,350
12'8"	7'10"	4'	2,161	\$ 4,560
13'8"	3'8"	2'	537	\$ 1,810
13'10"	3'10"	3'	835	\$ 2,340
14'	4'	4'	1,152	\$ 3,520
13'8"	5'8"	2'	875	\$ 2,425
13'10"	5'10"	3'	1,345	\$ 3,075
14'	6'	4'	1,855	\$ 4,290
13'8"	7'6"	2'	1,216	\$ 2,865
13'10"	7'8"	3'	1,860	\$ 3,655
14'	7'10"	4'	2,560	\$ 4,940
15'8"	3'8"	2'	622	\$ 2,065
15'10"	3'10"	3'	965	\$ 2,670
16'	4'	4'	1,332	\$ 3,985
15'8"	5'8"	2'	1,015	\$ 2,740
15'10"	5'10"	3'	1,555	\$ 3,465
16'	6'	4'	2,145	\$ 4,815
15'8"	7'6"	2'	1,408	\$ 3,300
15'10"	7'8"	3'	2,152	\$ 4,100
16'	7'10"	4'	2,959	\$ 5,510
18'	4'8"	2'8"	1,312	\$ 3,500
20'5"	6'6"	2'	1,800	\$ 4,025
23'	7'2"	6'	6,400	\$14,640
23'2"	7'4"	8'	8,500	\$24,265

NOTE: Dimensions are based on overall outside measurements. The inside dimensions may be up to 10" smaller due to the heavy flange around the top of the tank that is necessary to prevent bowing. Call if the inside measurements are critical. Tanks over 24" high are cored on the sides with foam of various thicknesses to prevent bowing and provide insulation. The bottom, of most large tanks, is cored with 3/4" thick foam with a protective fiberglass outer layer, therefore, no concrete slab is required. All tanks listed above are one-piece construction, free standing, and self-supporting with no cross bracing. For proper installation tanks must be fully supported on the bottom. Extra heavy lay-up and box legs are available as options. Other options include skimmer boxes, viewing windows, insulation and lids. Any of the above tanks can be made with less height. A recessed dimple can be fabricated in the tank bottom to flush mount a bulkhead fitting at no additional cost.

NOTE: We can custom build square & rectangular tanks to your specifications. Please call for a quote.



40 Series
(Full Internal Port)
640 Series
(Reduced Internal Port)

Rate of Flow Control Valve

Model 40-01/640-01

- Accurately Limits Flow Rate
- Completely Automatic Operation
- Includes Orifice Plate with Holder
- Optional Check Feature
- Easily Adjusted



The Cla-Val Model 40-01/640-01 Rate of Flow Control Valve prevents excessive flow by limiting flow to a preselected maximum rate, regardless of changing line pressures. It is a hydraulically operated, pilot controlled, diaphragm valve. The pilot control responds to the differential pressure produced across an orifice plate installed downstream of the valve. Accurate control is assured as very small changes in the controlling differential pressure produce immediate corrective action of the main valve. Flow rate adjustments are made by turning an adjusting screw on the pilot control.

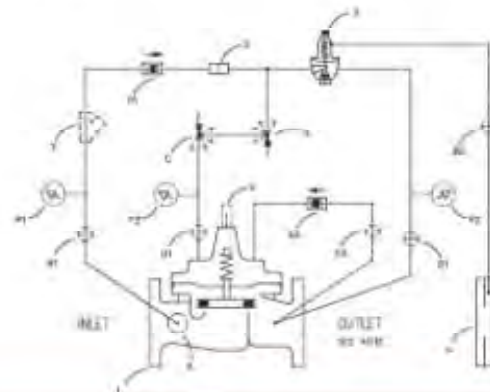
The Model 40-01/640-01 includes an orifice plate with a holder that should be installed one to five pipe diameters downstream of the valve. If the check feature option is added and a pressure reversal occurs, the downstream pressure is admitted into the main valve cover chamber and the valve closes to prevent return flow. See X52E data sheet for sizing selection.

Schematic Diagram

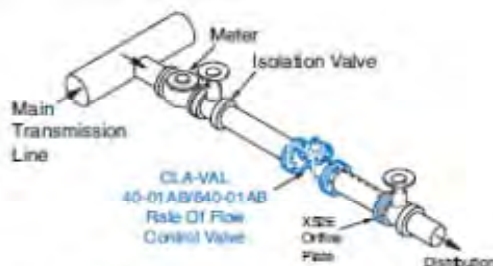
Item	Description
1	Hytrol (Main Valve)
2	X58C Restriction Fitting
3	CDHS18 Differential Control
4	X52E Orifice Plate Assembly

Optional Features

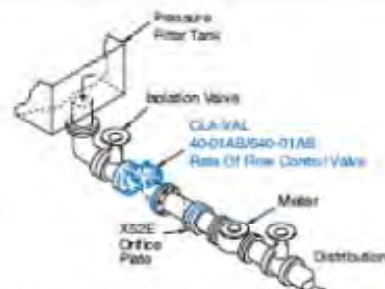
Item	Description
A	X46A Flow Clean Strainer
B	CK2 (Isolation Valve)
C	CV Flow Control (Closing)
D	Check Valves with Isolation Valve
P	X141 Pressure Gauge
S	CV Speed Control (Opening)
V	X101 Valve Position Indicator
Y	X43 "Y" Strainer



Typical Applications



The 40-01/640-01 is typically installed where water supply to a system must be limited to a preset maximum flow rate. The valve is easily set to maintain the maximum allowable flow rate.



The 40-01/640-01 is typically installed as a pressure type filter effluent control valve where a constant flow rate is maintained as head loss through the filter varies.



C-43 WQTA Test Facility Conceptual Design – Task 3

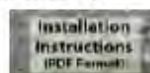


MAIN PRODUCTS SERVICE & AFFILIATES INSIDE TRADER CONVENTIONS NEW ITEMS SMART DRGE SYS

Valves & Gates
Check Valves
Slide Gates/Valves
Flap Gates
Inline Water Level Control Structure
Inlet Water Level Control Structure
Large Diameter Water Level Control Structure
Fish Screens

Agri Drain Inline Water Level Control Structure™

- Structures can be used to manage water level in a variety of applications including ponds, wetlands, manure management, drainage water management, and saturated buffers.
- Rugged 1/2" PVC structure with lockable top.
- Stainless steel screws and custom anodized aluminum corner extrusions are used for strength and durability.
- Stoplogs made of 1/2" PVC, in 5" & 7" heights for adjustability.
- Flexible couplers allow PVC, Corr. HDPE plastic pipe, or other materials to be easily attached. *(Please specify type of pipe when ordering)*
- Annual maintenance of stoplogs is recommended. Remove stoplogs and lubricate the o-ring on each board with white lithium grease. Ensure that there is no debris in the tracks or along the bottom of the structure. Replace your stoplogs after greasing.
- 5-Year Warranty on all standard structures.
- Customized or special orders will carry a 1-year warranty on workmanship and material and have no return policy.
- Please allow up to 2 weeks for shipment.



Flexible rubber connectors with heavy duty stainless steel clamps.

Rubber seal assures a tight fit to prevent leakage.



5" & 7" stoplogs for adjustability. Durable stainless steel lifting hooks.



Typical Installation and Recommended Component Items--

Installing a **bar guard** on our inlet pipe helps prevent debris, rodents, fish and turtles from entering your inlet.

An **anti seep collar** should be installed on both the inlet and outlet side of your structure to prevent water from cutting a path along your pipeline causing erosion.

A **slide gate valve** (not pictured above) installed in front of your structure on the inlet side allows you to completely shut off your water flow allowing you to remove all of your stoplog boards for maintenance and/or cleaning (annual maintenance of stoplogs is recommended).

A **rat guard** needs to be installed on your outlet pipe to avoid rodent entry.

PVC Fish Screens Also Available. See web page or call for details.

more info

Item# Price	Description	List
INLINE02X04P	Inline WCS 2"x4" PVC	\$416.05
INLINE02X06P	Inline WCS 2"x6" PVC	\$424.79

Hours:
Mon-Fri 7am-5pm cst

Location:
1462 340th St.
Adair, IA 50002

Phone:
1-800-232-4742
1-641-742-5211

Fax:
1-800-282-3353
1-641-742-5222

Email:
info@agridrain.com



C-43 WQTA Test Facility Conceptual Design – Task 3

INLINE02X08P	Inline WCS 2"x8" PVC	\$452.09
INLINE02X10P	Inline WCS 2"x10" PVC	\$498.96
INLINE02X12P	Inline WCS 2"x12" PVC	\$602.15
INLINE02X15P	Inline WCS 2"x15" PVC	\$703.38
INLINE02X18P	Inline WCS 2"x18" PVC	\$956.08
INLINE03X04P	Inline WCS 3"x4" PVC	\$470.65
INLINE03X06P	Inline WCS 3"x6" PVC	\$479.39
INLINE03X08P	Inline WCS 3"x8" PVC	\$525.25
INLINE03X10P	Inline WCS 3"x10" PVC	\$590.81
INLINE03X12P	Inline WCS 3"x12" PVC	\$709.88
INLINE03X15P	Inline WCS 3"x15" PVC	\$855.79
INLINE03X18P	Inline WCS 3"x18" PVC	\$1,143.46
INLINE03X24P	Inline WCS 3"x24" PVC	\$1,456.22
INLINE03X24PT	Inline WCS 3"x24" PL Tile	\$1,708.48
INLINE04X04P	Inline WCS 4"x4" PVC	\$525.25
INLINE04X06P	Inline WCS 4"x6" PVC	\$532.90
INLINE04X08P	Inline WCS 4"x8" PVC	\$597.32
INLINE04X10P	Inline WCS 4"x10" PVC	\$683.80
INLINE04X12P	Inline WCS 4"x12" PVC	\$816.48
INLINE04X15P	Inline WCS 4"x15" PVC	\$1,009.39
INLINE04X18P	Inline WCS 4"x18" PVC	\$1,329.62
INLINE04X24P	Inline WCS 4"x24" PVC	\$1,707.29
INLINE04X24PT	Inline WCS 4"x24" PL Tile	\$1,959.55
INLINE05X04P	Inline WCS 5"x4" PVC	\$578.76
INLINE05X06P	Inline WCS 5"x6" PVC	\$588.59
INLINE05X08P	Inline WCS 5"x8" PVC	\$704.02
INLINE05X10P	Inline WCS 5"x10" PVC	\$814.44
INLINE05X12P	Inline WCS 5"x12" PVC	\$970.42
INLINE05X15P	Inline WCS 5"x15" PVC	\$1,162.99
INLINE05X18P	Inline WCS 5"x18" PVC	\$1,444.75
INLINE05X24P	Inline WCS 5"x24" PVC	\$1,958.35
INLINE05X24PT	Inline WCS 5"x24" PL Tile	\$2,210.62
INLINE06X04P	Inline WCS 6"x4" PVC	\$634.45
INLINE06X06P	Inline WCS 6"x6" PVC	\$642.10
INLINE06X08P	Inline WCS 6"x8" PVC	\$743.65
INLINE06X10P	Inline WCS 6"x10" PVC	\$867.51
INLINE06X12P	Inline WCS 6"x12" PVC	\$1,082.34
INLINE06X15P	Inline WCS 6"x15" PVC	\$1,316.60
INLINE06X18P	Inline WCS 6"x18" PVC	\$1,701.94
INLINE06X24P	Inline WCS 6"x24" PVC	\$2,208.20
INLINE06X24PT	Inline WCS 6"x24" PL Tile	\$2,461.69
INLINE08X04P	Inline WCS 8"x4" PVC	\$779.69
INLINE08X06P	Inline WCS 8"x6" PVC	\$788.86
INLINE08X08P	Inline WCS 8"x8" PVC	\$934.48
INLINE08X10P	Inline WCS 8"x10" PVC	\$1,104.97
INLINE08X12P	Inline WCS 8"x12" PVC	\$1,307.39
INLINE08X15P	Inline WCS 8"x15" PVC	\$1,622.60
INLINE08X18P	Inline WCS 8"x18" PVC	\$2,075.48
INLINE08X24P	Inline WCS 8"x24" PVC	\$2,710.34
INLINE08X24PT	Inline WCS 8"x24" PT Tile	\$2,962.60
INLINE10X04P	Inline WCS 10"x4" PVC	\$894.35
INLINE10X06P	Inline WCS 10"x6" PVC	\$903.52
INLINE10X08P	Inline WCS 10"x8" PVC	\$1,088.12
INLINE10X10P	Inline WCS 10"x10" PVC	\$1,299.06
INLINE10X12P	Inline WCS 10"x12" PVC	\$1,532.43
INLINE10X15P	Inline WCS 10"x15" PVC	\$1,928.61
INLINE10X18P	Inline WCS 10"x18" PVC	\$2,447.79
INLINE10X24P	Inline WCS 10"x24" PVC	\$3,211.24
INLINE10X24PT	Inline WCS 10"x24" PL Tile	\$3,464.74
INLINE12X04P	Inline WCS 12"x4" PVC	\$1,009.01
INLINE12X06P	Inline WCS 12"x6" PVC	\$1,017.04
INLINE12X08P	Inline WCS 12"x8" PVC	\$1,241.77
INLINE12X10P	Inline WCS 12"x10" PVC	\$1,493.14

C-43 WQTA Test Facility Conceptual Design – Task 3

Agri Drain
CORPORATION

MAIN PRODUCTS SERVICE & AFFILIATES INSIDE TRADER CONVENTIONS NEW ITEMS SMART DRGE SYS

Valves & Gates

Check Valves
Slide Gates Valves
Flap Gates
Inline Water Level
Control Structure
Inlet Water Level
Control Structure
Large Diameter Water
Level Control Structure
Fish Screens



Gate Valves

Inexpensive valve for industrial, agricultural, and commercial markets.

- Well suited as a drain valve to tanks.
- Attaches to SCH40 PVC pipe.
- Unrestricted flow.
- Quick opening.
- Trouble free simplicity.
- 100% water tested at factory.
- Low cost.
- Quick shut off in low pressure or vacuum lines.
- Sizes available: 1 1/2", 2", 3", 4", 6", 8", 10", and 12"



Hours:
Mon-Fri 7am-5pm cst

Location:
1462 340th St.
Adair, IA 50002

Phone:
1-800-232-4742
1-641-742-5211

Fax:
1-800-282-3353
1-641-742-5222

Email:
info@agridrain.com

Extension Rods Now Available!

- Extension Rod for 1 1/2" - 4" Valve**
- Available in 12", 24", and 36".
 - Aluminum tube with 3 1/2" stud female thread x male thread.
 - Easily threads onto the valve shaft.
 - Handle threads onto the stud.
- Extension Rod for 6" - 8" Valve**
- Available in 12", 36", and 72".
 - Stainless steel rod with cotter pin(s) for assembly.
 - Can attach multiple extensions together to achieve greater height.
- Extension Rod for 10" - 12" Valve**
- Available in 36".
 - Stainless steel rod with cotter pin(s) for assembly.
 - Can attach multiple extensions together to achieve greater height.

Agri Drain Slide Gate Valves

Heavy Duty Quality

- All parts are made out of super tough high density PVC and high quality stainless steel for maximum durability and corrosion resistance.
- Not pressure rated (Approx 8 lbs.).
- All PVC material is 1/2" thick.
- Stubs are SDR 35 PVC Male.
- Sizes Available: 15" and 18". Stubs 4" in length.



Item# Price	Description	List
	24" Ext. for 1 1/2" - 4" Valve	\$8.89
	12" Ext. for 1 1/2" - 4" Valve	\$6.26
TX12T	12" Ext. for 1 1/2" - 4" Valve	\$6.26
TX24T	24" Ext. for 1 1/2" - 4" Valve	\$8.89
TX36T	36" Ext. for 1 1/2" - 4" Valve	\$12.22
TX48T	48" Ext. for 1 1/2" - 4" Valve	\$13.64
VV01.5	1.5" Slide Valtterra Valve	\$14.53
VV02	2" Slide Valtterra Valve	\$31.75
VV03	3" Slide Valtterra Valve	\$36.44
VV04	4" Slide Valtterra Valve	\$92.83
VV06	6" Slide Valtterra Valve	\$379.61
VV08	8" Slide Valtterra Valve	\$531.46
VV10-40	10" Slide Valtterra Valve	\$940.00
VV12-40	12" Slide Valtterra Valve	\$987.50
VV15	15" Slide Gate Valve	\$665.60
VV18	18" Slide Gate Valve	\$750.62
X12-36	36" Ext. for 10" & 12" Valve	\$60.32
X8-12	12" Ext. for 6" & 8" Valve	\$44.42
X8-36	36" Ext. for 6" & 8" Valve	\$56.36
X8-72	72" Ext. for 6" & 8" Valve	\$86.31



C-43 WQTA Test Facility Conceptual Design – Task 3



June 28, 2012

Chris Keller, PE
Wetland Solutions, Inc
2809 NW 161 Court
Gainesville, FL 32609

Subject: Wetland project

Dear Chris,

The following is my review of our discussion and my preliminary sizing of the pump station based on that information.

Maximum flow rate 1700 GPM
Vertical elevation - static head = 20 feet
Force main 4600 feet, using HDPE SDR-11 12" velocity at 1700 GPM $\approx$ 5.00 fps

Static head (elevation) =	20 feet	
Friction head at 1700 GPM = 20.24 lbs/ 46.7 ft	47 ft	
Suction lift = 10 feet	10 ft	
Station losses = 5 PSI	12 ft	
TOTAL Dynamic head	89 ft	Round off to 90' TDH

Selection: Horizontal Centrifugal triplex using three pumps 600 GPM at 90' TDH each. Our model # HCV-25/25/25
I added the optional items that would normally recommend that should be included. Those options can be taken out to reduce the station price.

Items included; Single VFD to operate primary pump, Premium surge protection, space heaters in motors, Air conditioner for panel cooling of VFD, Electronic Butterfly Valve (EBV) backup of VFD for pressure control, Magnetic flow meter, individual HDPE suction lines (40 ft) for each pump with flotation units and foot valves.

Price, net FOB factory with freight included to jobsite, also includes setup at site and formal startup & testing, \$104,830.00

Optional items that I did not include; VFD for each (2 extra) motor \$6,100.; Line reactors for VFD's \$1510.00; WaterVision 5 with Radio modems \$ 7090.00

This will give you a preliminary overview of your pump station requirements. I can provide formal specifications, drawings and details for any of the information provided above.

Thank you for the opportunity to provide this information. If I may provide additional information or assistance please do not hesitate to contact this office.

Sincerely,

Watertronics Technical Services

Roger L. Gibson
Florida District Manager
(desktop/wetland Solutions)

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