Maintenance Practices for Stormwater Runoff - Phase 2

Phase 2 Final Report
Submitted May 2015

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Research Center

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DISCLAIMER

METRIC CONVERSION TABLE

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
LENGTH				
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
AREA				
in^2	squareinches	645.2	square millimeters	mm^2
ft^2	squarefeet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
VOLUME				
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
NOTE: volumes greater than 1000 L shall be shown in m^3				

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
MASS				
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg (or "t")

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
TEMPERATURE (exact degrees)				
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
ILLUMINATION				
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
FORCE and PRESSURE or STRESS				
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
LENGTH				
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
AREA				
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
VOLUME				
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
MASS				
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams	1.103	short tons (2000 lb)	T

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
TEMPERATURE (exact degrees)				
°C	Celsius	1.8C+32	Fahrenheit	°F

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
ILLUMINATION				
lx	lux	0.0929	foot-candles	fc
cd/m^2	$candela/m^2$	0.2919	foot-Lamberts	fl

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
FORCE and PRESSURE or STRESS				
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per sq. inch	lbf/in^2

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16. Abstract

Seven wet detention ponds possessing severe maintenance issues were selected from disparate FDOT districts. The maintenance problems ranged from excess littoral zone growth and intense algal blooms to bank erosion and sediment accumulation. Intensive field campaigns were performed to ascertain pollutant levels throughout the water column and in the sediment. Best Management Practices (BMPs) were implemented at each wet detention pond which best addressed that ponds maintenance problem. Sampling campaigns over the time period of Phase 2 were carried out to assess the effectiveness of each BMP.

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EXECUTIVE SUMMARY

Nonpoint source pollution is a primary source of contamination in waterways around the United States. Ever since the Clean Water Act of 1972, the rules and regulations that protect the nation's estuaries, waterways, and lakes are constantly evolving with an ever-increasing stringency, thus accentuating the need to research and assess alternative techniques for the effective treatment of stormwater runoff. The information within this report catalogs the best management practices (BMPs) employed to manage stormwater runoff, as well as the maintenance practices that are inevitably required to keep the BMPs operating at peak performance.

Seven wet detention ponds possessing severe maintenance issues were selected from disparate FDOT districts. The maintenance problems ranged from excess littoral zone growth and intense algal blooms to bank erosion and sediment accumulation. Intensive field campaigns were performed to ascertain pollutant levels throughout the water column and in the sediment. The exhaustive list of potential problem pollutants included nutrients, pesticides, polycyclic aromatic hydrocarbons, *E. coli*, suspended solids, and heavy metals. Analysis of the samples conclusively indicated that excess nutrients were the primary problem shared by ponds spread across the state, which corresponds with the conclusion from section 303(d) of the US EPA's 1998 *List Fact Sheet for Florida* stating that the most common form of surface water impairment is attributed to excessive nutrients.

After extensive field campaigns at each pond for collecting the baseline information, BMPs were installed at the designated ponds which best addressed each pond's maintenance issue. For example, at the Gainesville and Ruskin pond sites, Floating Treatment Wetlands were installed to help remove nutrients from the water column and control the algal blooms. At the Royal Palm site, Tri-Lock, a bank-stabilizing product, was installed to help prevent bank erosion and control total suspended solids concentrations in the water. BMPs ensure a healthy, effective, and aesthetically appealing stormwater pond, yet proper maintenance is required to sustain the desired functionality. The handbook of *Maintenance Practices for Stormwater Runoff* produced by this project will aid the user in selecting the proper BMP for a given scenario, as well as lucidly detailing the manner and frequency for which maintenance practices and techniques are performed for the chosen BMP. Given the proper selection and maintenance of the BMP, the stormwater pond

will properly function with minimal impact on downstream receiving water bodies. As a result, the benefits extend beyond a single pond.

This report finalizes BDK78-977-02 Maintenance Practices for Stormwater Runoff – Phase 1 of the project. The tasks completed within this portion of the project include carrying out, sampling, and monitoring the full-scale field demonstration of the BMPs recommended to the districts for the seven designated ponds as well as production of the handbook of *Best Maintenance Practices for Stormwater Runoff*.

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1. INTRODUCTION AND OBJECTIVES

1.1 Background

Seven wet detention ponds possessing severe maintenance issues were selected from disparate FDOT districts in Phase 1. The locations of the seven study ponds are presented in Table 1 and Figure 1. During the post-BMP sampling period (Phase 2), which spanned from February 2014 to April 2015, a total of three storm and three non-storm samples were taken. Water samples were taken at the inlet and outlet of the pond, in order to evaluate the pond's pollutant removal efficiency as the water travels through the system. For the Gainesville, Clearwater, and Ruskin ponds, both water and sediment samples were taken to obtain a more complete picture of nutrient cycling throughout the pond, which is critical to their particular BMP performance. A summary of the parameters that were analyzed for the water and sediment samples is shown in Table 2. In addition, a number of in situ field measurements were taken at both the inlet and outlet, including pH, dissolved oxygen, chlorophyll-a, and turbidity.

Table 1: Field site data and locations

Pond Site	District	Pond ID	Pond Location
Zolfo Springs	1	F06010-3501-01	27.497928°, -81.7957305°
Gainesville	2	214256-1-72-P001	29.660602°,-82.461857°
East Palatka	2	209965-1-52-01-P001	29.646012°, -81.594925°
Royal Palm Estates	4	SWF 5949	26.678938°, -80.116872°
Orlando	5	75037-3501-02	28.591550°, -81.208487°
Clearwater	7	15040-3517	27.960145°,-82.709490°
Ruskin	7	10120-3511-01	27.497283º, -81.7957305º

Table 2: Summary of parameters analyzed for water and sediment samples

Sample Matrix	Parameters Analyzed
Water	Total Phosphorus (TP), Soluble Reactive Phosphorus (SRP), Total Nitrogen (TN), Ammonia (NH_3), Nitrates/Nitrites (NO_x), Organic Nitrogen (Org. N)
Sediment	Total Nitrogen (TN), Total Phosphorus (TP)

The complete sampling results are provided in Appendix B. The following sections provide discussion of the results, the efficiency of the BMP in removing the target pollutants, and a discussion on maintenance issues and requirements that have been observed to date.

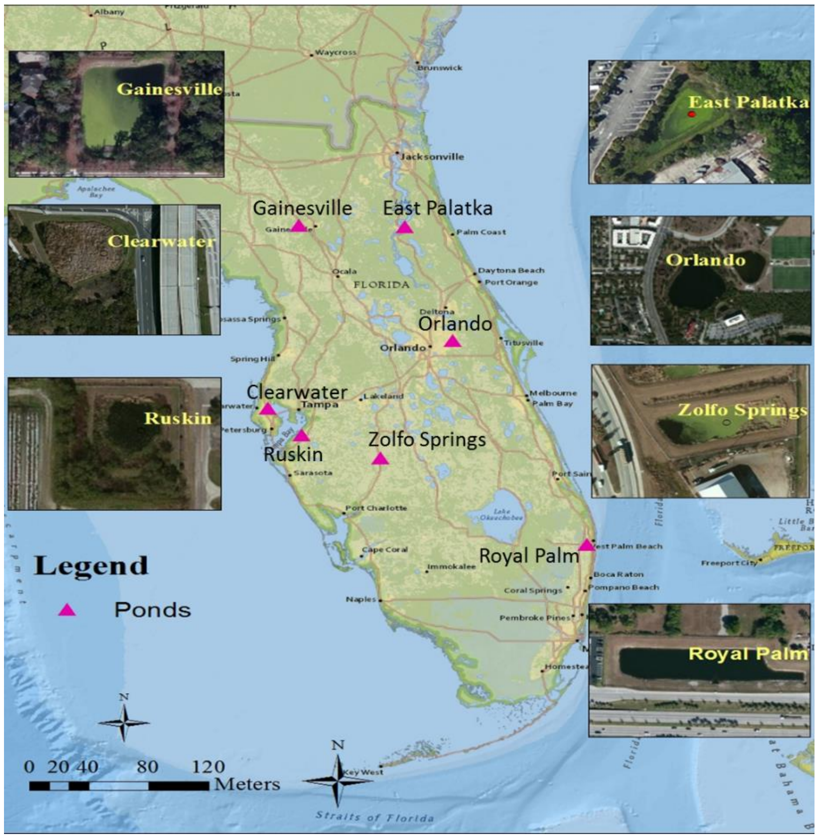

Figure 1: Field research site locations

1.2 Objectives

The objective of Phase 2 was to carry out full-scale implementation and verification of the BMPs recommended for each pond. The BMPs were chosen for each district in a manner that best addressed each pond's maintenance issue. Full-scale implementation of the BMPs entailed, but was not limited to, installation of the BMP, taking water and soil samples after installation of the BMP, observing potential interactions between the BMP and surrounding environment, and maintaining the BMPs so they may operate at full capacity. For example, one maintenance issue for the FTWs was replacing the plants on the floating treatment wetlands. A full-scale plant replacement was conducted for the FTWs at both the Gainesville and Ruskin sites during the final stage of the project period.

The ultimate goal of Phase 2 was to assess the effectiveness of nutrient removal for each BMP at the stormwater wet detention ponds. This research and subsequent findings will help expand the knowledge pertaining to stormwater maintenance issues and shed light on possible new maintenance alternatives.

2. STORMWATER POND STUDY SITES

A summary table of the maintenance issues reported for each pond and the BMP selected for that pond is presented in Table 3.

Table 3: Summary of pond maintenance issues and BMPs

Pond Site	Maintenance Issues	Best Management Practice
Zolfo Springs	Algal growth and overgrown littoral zone	Sloped Media Bed Reactor
Gainesville	Severe algal growth	Floating Treatment Wetlands
East Palatka	Sediment loadings, algal growth, and nuisance vegetation	Floating Media Bed Reactor
Orlando	Algal growth, cattail growth, and nuisance vegetation	Horizontal Media Bed Reactor
Clearwater	Severe cattail growth	Cattail Removal
Ruskin	Severe algal growth and nuisance vegetation	Floating Treatment Wetland
Royal Palm Estates	Bank erosion	Tri-Lock

The following sections will provide an in-depth discussion of each pond's maintenance issues, implementation of BMPs, and the post-BMP nutrient sampling results.

2.1 Zolfo Springs (Pond ID: F06010-3501-01)

2.1.1 Background and Maintenance Issues

This 0.49-acre pond is immediately adjacent to a forest to the east. North of the pond lies a residential area, and a piping warehouse is uphill of the pond to the south. State Road 35 borders the western edge of the pond. Surrounding the pond are grass swales and as the pond reaches max capacity, the excess water is carried through a culvert into the central ditch. The water then flows from the central ditch into the grass swales to the north, east, and west of the pond. Immediate intake locations that feed into the pond are placed along State Road 35. No intake locations were observed on the roads to the north and east of the pond. Apparent algal growth was the only maintenance issue reported for this pond. During the initial site visit the algal growth was readily visible. In addition to the algal problems, there was a heavily overgrown littoral zone. An image of the Zolfo Springs pond is presented in Figure 2.

Figure 2: Zolfo Springs pond

2.1.2 Best Management Practice

The BMP chosen for this pond was a Sloped Media Bed Reactor (SMBR). The treatment media bed reactor was designed to remove nutrients at the Zolfo Springs pond. The media mixture used in the SMBR was 50% 5/8^{ths} expanded clay and 50% tire chunk. The SMBR was chosen for this pond because of its nutrient removal capacity as well as simplicity in installation and operation. The SMBR utilizes solar energy for pump operation, therefor cutting down on potential future expenses and utilizing clean renewable energy. A cross-sectional side view of the SMBR is given below in Figure 3 and a picture of the SMBR in the field in Figure 4.

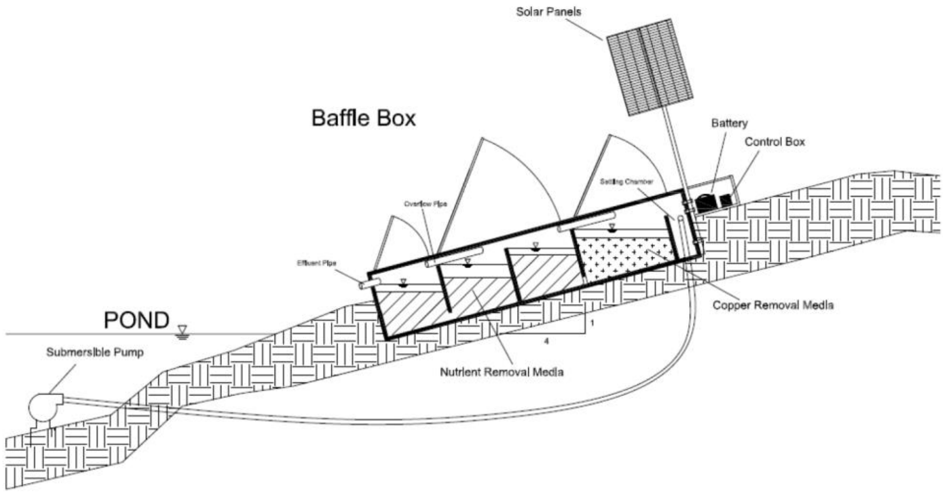

Figure 3: Cross-sectional view of the sloped media bed reactor in the field

Figure 4: Sloped media bed reactor at Zolfo Springs pond

2.1.3 Nutrient Sampling Results

A total of three storm and three non-storm sampling events have been completed for this pond since BMP deployment. A summary of the sampling dates and the most recent rainfall amount is provided in Table 4.

Table 4: Summary of sampling events for Zolfo Springs

Sampling Date	Event Type	Last Recorded Rainfall/Amount
2/13/2014	Non-Storm	2/12/2014 - 0.72 in
3/6/2014	Storm	3/6/2014 – 0.37 in
4/10/2014	Non-Storm	4/8/2014 – 0.55 in
5/14/2014	Non-Storm	5/13/2014 – 0.25 in
7/29/2014	Storm	7/29/2014 – 0.16 in
8/31/2014	Storm	8/31/2014 – 0.45 in

The lab results displaying the ponds removal performance for soluble (Figure 5) and total (Figure 6) nutrient species are presented below. As seen in the below figures, the pond generally appears to consistently remove nitrates/nitrites and ammonia with recorded average removal rates of 74% and 42%, respectively. This may be explained by biological processes which function within the water column and sediments, coupled with frequently recorded low dissolved oxygen measurements which are indicative of denitrifying conditions. The total nitrogen levels appear to remain constant, while the total phosphorus removal efficiency appears to generally remove phosphorus consistently at an average rate of 17% or greater, with the exception of the first sampling date.

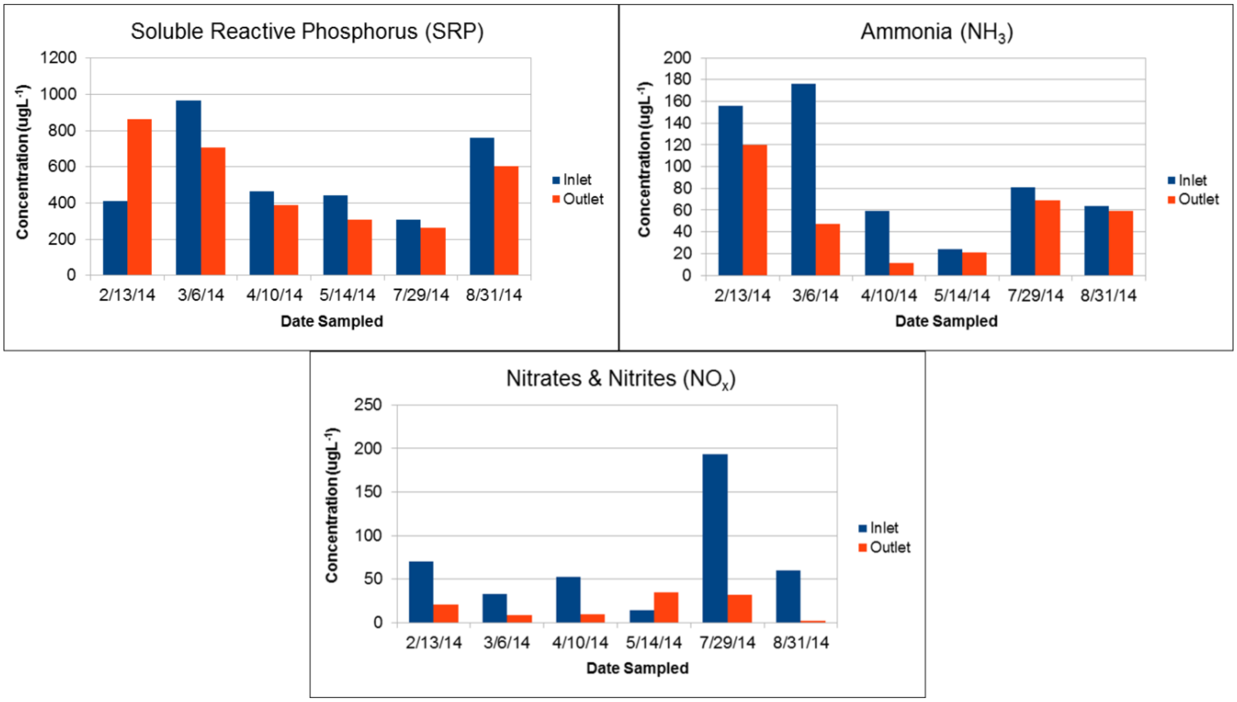

Figure 5: Soluble nutrient levels in the Zolfo pond for the post-BMP condition

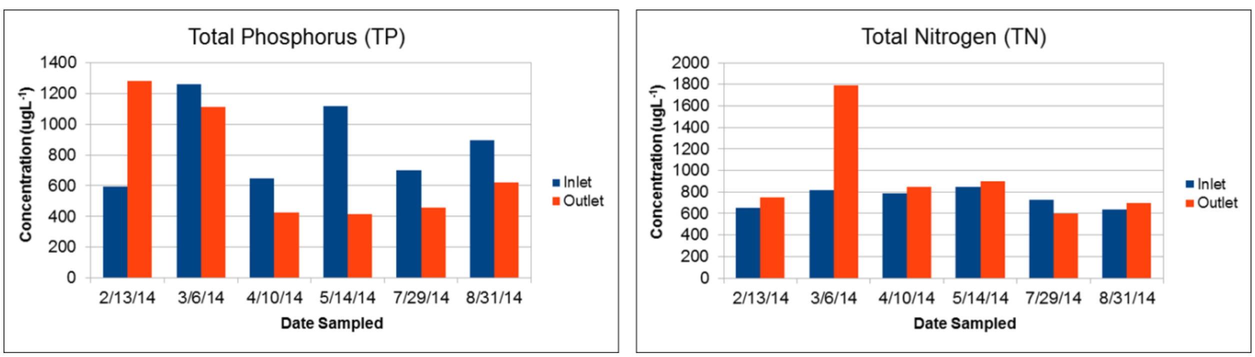

Figure 6: Total nitrogen and total phosphorus levels for the Zolfo pond for the post-BMP condition

2.1.4 Sloped Media Bed Reactor Results

A Sloped Media Bed Reactor (SMBR) was installed approximately one third of the distance from the inlet to the outlet on the south side of the Zolfo Springs pond on April 10, 2014. Samples were collected and processed by ERD laboratories from the inlet and the outlet concentrations for soluble (Figure 7) and total (Figure 8) nutrient species, as presented below. As seen in the data, the SMBR appears to have reasonable removal efficiency for soluble species during the first few months of operation. This may be explained by adsorptive processes of the species to the media. The remaining time appeared to have moderate removal of soluble species, as seen in the case of

Ammonia where removal rates saw a decrease during the time period of June through August. The average removal rates for SRP, NH_3, and NO_x for the 8 sampling dates were 10.7%, 27.7% and 63% respectively. The SMBR appears to have consistent removal of TP, averaging 21.5%, while TN species appear to vary more, however total an average of 28.0%.

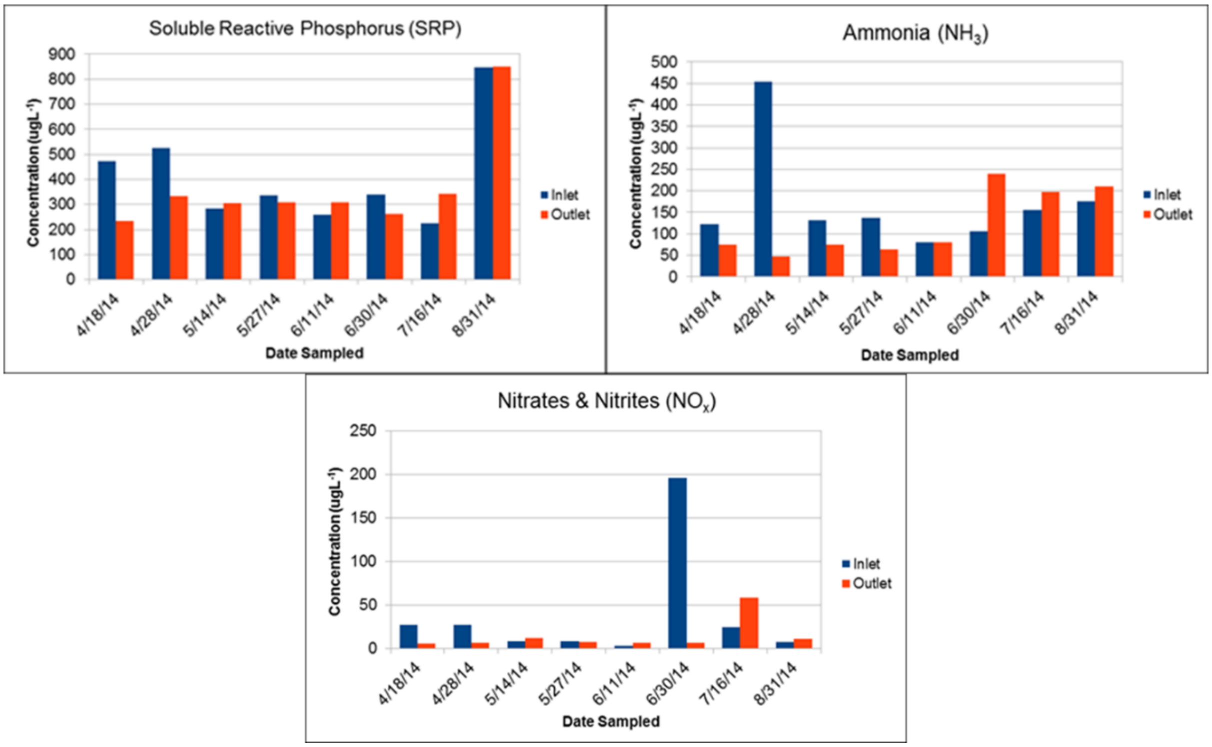

Figure 7: Soluble nutrient levels for SMBR for the post-BMP condition

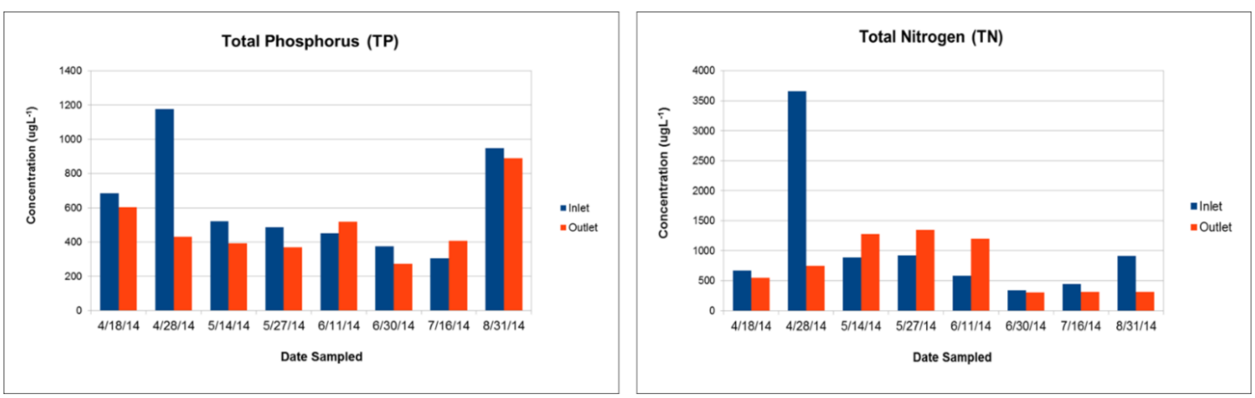

Figure 8: Total nitrogen and total phosphorus levels for SMBR for the post-BMP condition

2.2 Gainesville (Pond ID: 214256-1-72-P001)

2.2.1 Background and Maintenance Issues

This 0.58-acre pond lies at the low point between two hills to the east and west. Runoff pooling at the low point of State Road 26 to the south is discharged into the pond through stormwater piping. District 2 reported major algae growth within the pond, in addition to significant amounts of floating debris. During the initial site visit, the entire surface of the pond was covered in a layer of algae. Since the pond is surrounded by forest that is at higher elevation, the nutrients from the forest floor are collected during storm events and carried downhill into the pond. Bottles and miscellaneous floating debris were also observed on the surface on the pond. The chain-link fence around the pond should prevent debris from entering, which leads one to conclude that the majority of the floatables are being transported in through the stormwater inlet to the pond. An image of the Gainesville pond is presented in Figure 9.

Figure 9: Gainesville pond

2.2.2 Best Management Practice

The BMP chosen for this pond was Floating Treatment Wetlands (FTWs). FTWs were installed at the Gainesville pond on February 4, 2014. FTWs are an innovative and newly emerging BMP for removing nutrients from stormwater wet detention ponds. Plants grow on floating mats, rather than at the bottom of the pond, which enables them to interact with suspended nutrients in the water column. FTWs support the growth of root systems of the floating plants, which offers a large surface area for microbial nutrient removal processes and capture of suspended solids in the water column. FTWs offer an environmental friendly and economical approach for nutrient removal in stormwater wet detention ponds. A cross-sectional representation of a FTW is given below in Figure 10. The plants selected to be placed in pre-cut holes on the mats for this pond were Canna, Juncus, and Agrostis.

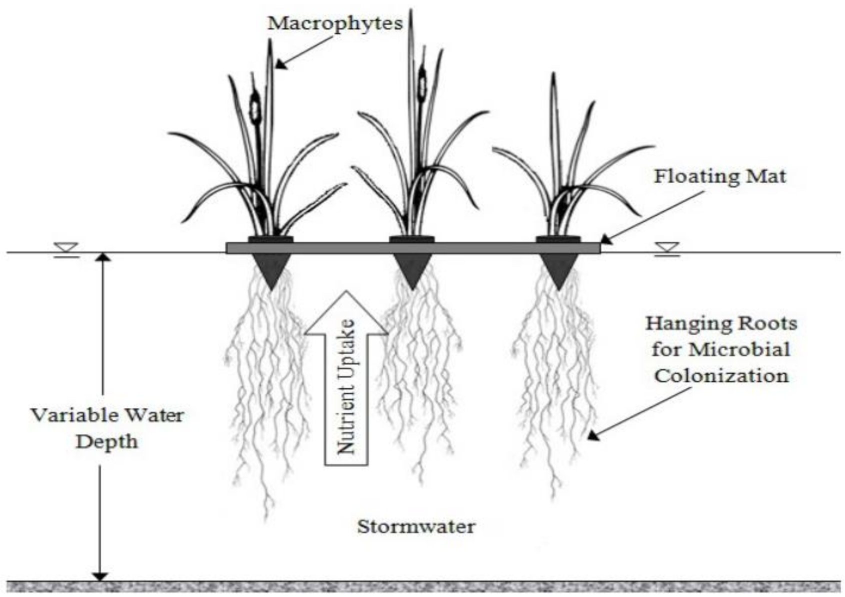

Figure 10: Cross-section view of a typical Floating Treatment Wetland

2.2.3 Nutrient Sampling Results

A total of three storm and three non-storm sampling events have been completed for this pond since BMP deployment. A summary of the sampling dates and the most recent rainfall amount is provided in Table 5.

Table 5: Summary of sampling events for Gainesville

Sampling Date	Event Type	Last Recorded Rainfall/Amount
2/26/2014	Storm	2/26/2014 – 0.63 in
3/17/2014	Storm	3/17/2014 – 2.26 in
4/16/2014	Non-Storm	4/15/2014 – 0.15 in
5/14/2014	Non-Storm	5/3/2014 – 0.20 in
6/24/2014	Non-Storm	6/22/2014 – 0.21 in
7/16/2014	Storm	7/16/2014 – 1.45 in

As the primary removal mechanism of Floating Treatment Wetlands is through direct uptake of dissolved nutrient species, the Post-BMP results for SRP, NO_x, and NH_3 are presented in Figure 11.

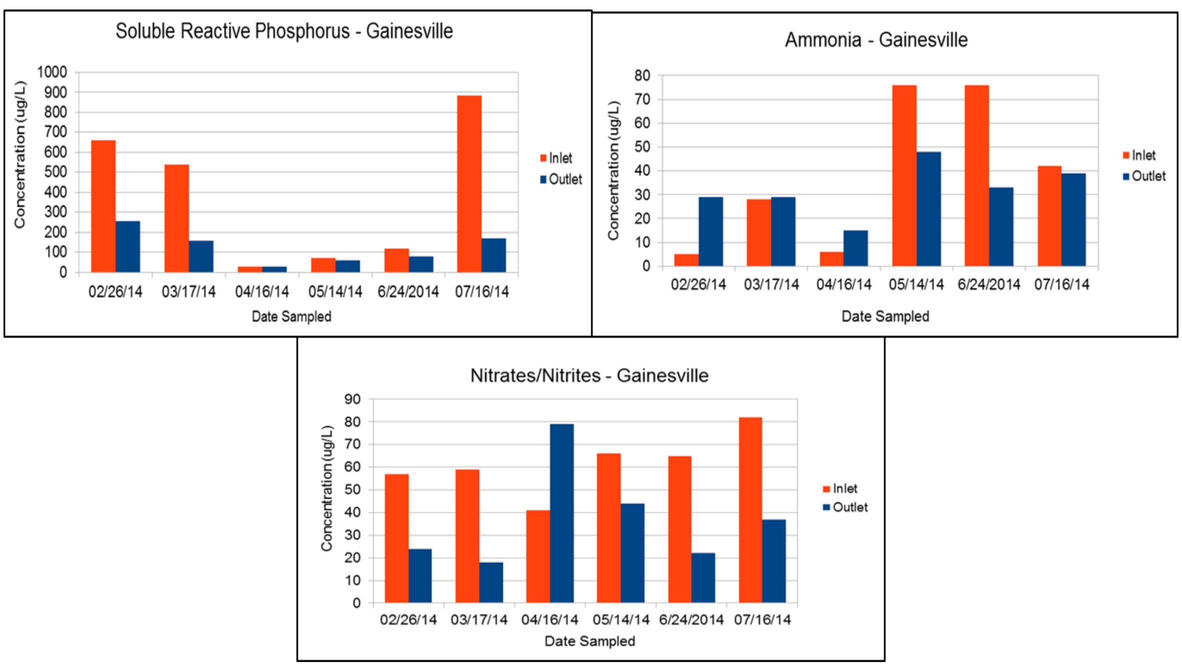

Figure 11: Soluble nutrient levels in the Gainesville pond for the post-BMP condition

In addition, removal efficiencies for the pond in the pre- and post-BMP condition for all nutrient species is presented in Table 6. Removal efficiencies were calculated using a concentration reduction percentage equation, utilizing the data collected at the inlet and outlet pipes of each pond. Removal efficiencies presented in Table 6 are for combined non-storm and storm data sets. Five non-storm samples were taken at Gainesville to represent Pre-BMP conditions from the time period of September 24, 2012 to February 4, 2014.

Table 6: Average nutrient removal efficiencies of the Gainesville pond

	TP	SRP	TN	NH_3	NO_x	Org. N
Pre-BMP	17.9%	12.7%	13.9%	25.7%	45.1%	12.3%
Post-BMP	62.8%	67.5%	-9.1%	17.2%	39.5%	-22.7%

The pond's capacity for phosphorus removal, in both particulate and dissolved forms, has greatly improved with the addition of the FTW to the pond, as evidenced in Table 6. In addition, the pond shows reasonable removal of dissolved species of nitrogen and phosphorus during storm events (Figure 12). The inclusion of three FTWs at this pond assists in nutrient removal during storm events by direct uptake of dissolved species, stabilization of the hydrodynamic pattern throughout the pond, which was observed by Chang et al.[1], and by providing root surface area for particulate matter to attachment.

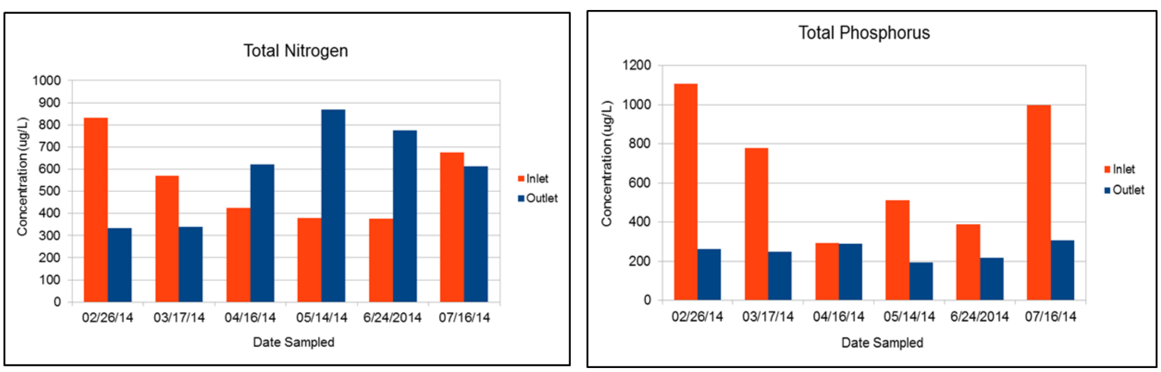

Figure 12: TN (left) and TP (right) concentrations during sampling events for Gainesville

The removal of TN during non-storm events has actually decreased since the addition of the FTWs. The non-storm sampling events taken in April, May, and June saw elevated concentrations of TN at the outlet, despite similar or even smaller concentrations of TN at the inlet

[1] N.-B. Chang, Z. Xuan, Z. Marimon, K. Islam, M. Wanielista, Exploring hydrobiogeochemical processes of floating treatment wetlands in a subtropical stormwater wet detention pond, *Ecological Engineering* 54 (2013) 66–76.

for the storm samples taken in February, March, and July. If this continues to be the observed trend, an additional BMP or additional FTW surface coverage may be necessary for N removal during the summer months.

The only vegetative growth observed at the Gainesville pond prior to BMP deployment was severe algal growth. Since BMP deployment the algal presence in the pond has transitioned to a thick layer of duckweed that covers the entirety of the pond surface. Although the duckweed is still well-established in the pond, suggesting that nutrient levels are still high enough to support their population, it has not established growth on the floating mats, and hence has not interfered with FTW growth. In addition, the placement of the mats in a staggered formation and the use of a single anchor per mat has proven to be effective and no maintenance concerns have been observed to date. A side-by-side comparison of the FTWs from deployment to before plant replacement provided in Figure 13.

Figure 13: FTW plants right after deployment (above) and prior to plant replacement (below) that shows the growth of the plant species

2.2.4 Plant Replacement

A complete replacement of the FTW plants was performed on October 10 and November 5, 2014. On October 10, 2014 all mature plants were removed from the FTWs and bagged for later disposal. On November 5, 2014 seedlings were delivered to the Gainesville pond, placed into the FTWs and the previously collected mature plants were taken away for disposal. The FTWs after plant replacement can be seen in Figure 14. Replacing the plants on FTWs allows us to observe nutrient removal throughout the FTW plant lifecycle and also prevents mature plants that may have otherwise died from falling into the pond, which would re-introduce nutrients back into the water column.

Figure 14: FTW plants after plant replacement

2.2.5 Sediment Sampling Results

The results from the sediment analysis at the Gainesville pond are presented in Figure 15. The Gainesville pond saw good removal of TP in the sediment samples with the exception of the final sample on July 16, 2014. The TN concentrations from inlet to outlet were relatively constant at the Gainesville pond with the exception of the first sample taken on March 17, 2014 were there was a large spike in the outlet sediment TN concentration.

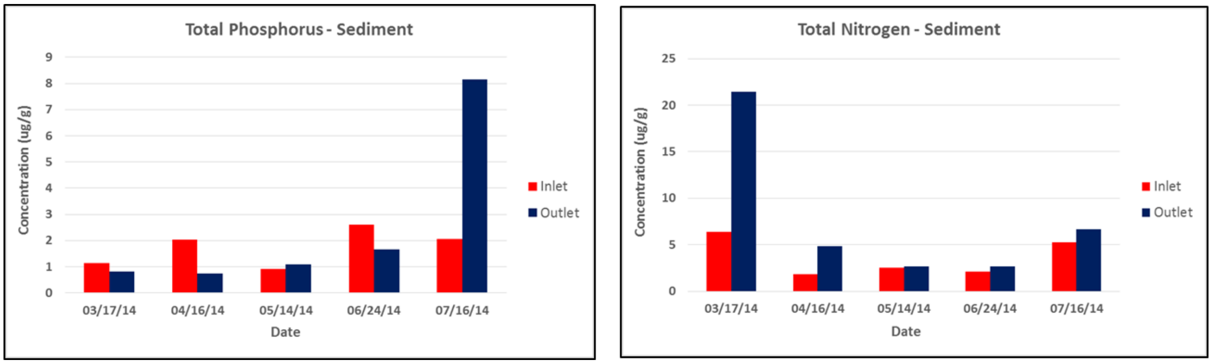

Figure 15: TP (left) and TN (right) sediment concentrations at the Gainesville pond

2.3 East Palatka (Pond ID: 209965-1-52-01-P001)

2.3.1 Background and Maintenance Issues

This 0.11 acre pond has parking lots to the north and south of it. US 17 runs along the western side of the pond and is directly connected to the parking lot to the south. A forested area and stream are downhill from the pond to the east. Sediment loadings, algal growth, and nuisance vegetation were the primary maintenance issues reported for this pond. The algal growth was quite apparent during the initial site visit. There is a mature forest area located across from US 17; this is one possible nutrient source that is contributing to the algae problem. A minor amount of nuisance vegetation was seen in the eastern portion of the pond, yet nuisance vegetation and sediment loading were visible near the pond inlet. An image of the East Palatka pond is presented in Figure 16.

Figure 16: East Palatka pond

2.3.2 Best Management Practice

The BMP chosen for this pond was a Floating Media Bed Reactor (FMBR). The treatment media bed reactor was designed to remove nutrients at the East Palatka pond. The media mixture used in the FMBR was 50% sand, 20% tire crumb, 20% fine expanded clay, and 10% limestone. The media bed reactor was designed to be floatable due to some nuisance vegetation around the pond, so placing the media bed reactor directly in the pond offered the most effective location. The FMBR was deployed at the East Palatka pond on February 13, 2014. The FMBR was chosen for this pond because of its nutrient removal capacity as well as simplicity in installation and operation. The FMBR utilizes solar energy for pump operation, therefor cutting down on potential future expenses and utilizing clean renewable energy. A cross-sectional view of the FMBR is given below in Figure 17 and a picture of the FMBR in the field in Figure 18.

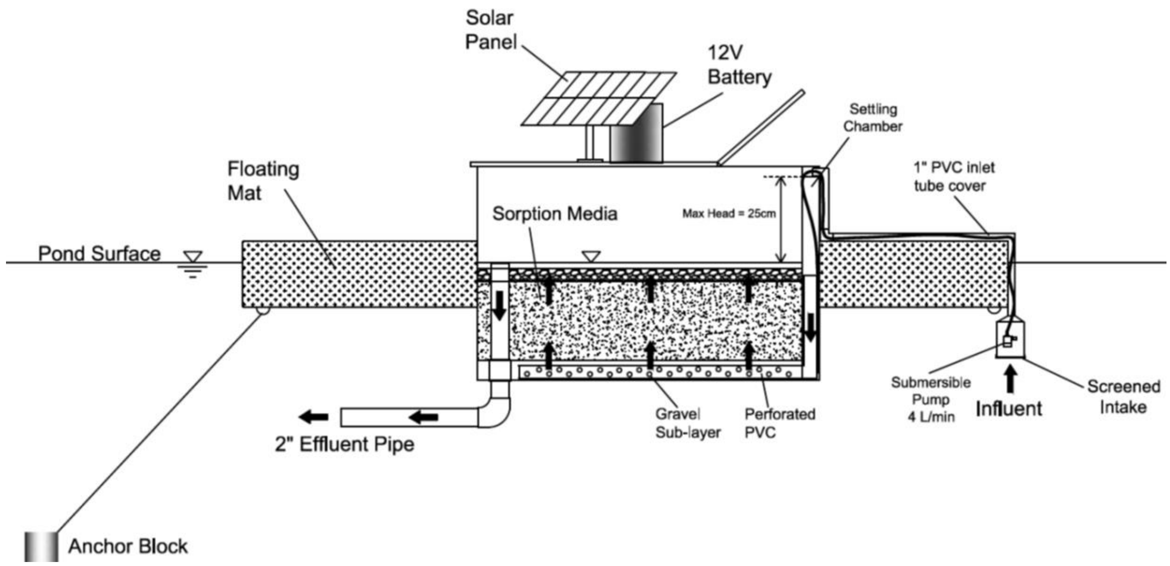

Figure 17: Cross-sectional view of the floating media bed reactor in the field

Figure 18: Floating media bed reactor at the East Palatka pond

2.3.3 Nutrient Sampling Results

A total of three storm and three non-storm sampling events have been completed for this pond since BMP deployment. A summary of the sampling dates and the most recent rainfall amount is provided in Table 7.

Table 7: Summary of sampling events for East Palatka

Sampling Date	Event Type	Last Recorded Rainfall/Amount
2/26/2014	Storm	2/26/2014 – 0.82 in
4/15/2014	Storm	3/31/2014 – 0.61 in
6/5/2014	Non-Storm	6/1/2014 – 0.15 in
6/18/2014	Storm	6/18/2014 – 0.04 in
7/31/2014	Non-Storm	7/29/2014 – 0.02 in
8/21/2014	Non-Storm	8/20/2014 – 0.09 in

The lab results displaying the ponds removal performance for soluble (Figure 19) and total (Figure 20) nutrient species are presented below. As can be seen the pond shows consistent removal efficiency of the soluble species for both SRP, NH_3 and NO_x species, average totaling 2%, 64% and 46% respectively. Removal of SRP appeared to be poorer for the non-storm samples when compared to removal rates during storm events. This could be explained by low concentrations of SRP at the pond inlet, thus making removal rates appear worse than reality because the outlet concentration were still reasonably similar to outlet concentrations during storm events. For the February 26, 2014 sample date the pond had minimal TP removal with an increase for the April 15, 2014 sampling date, average totaling 15%. The TP and TN removal rates are 19% and 17% respectively, which have both improved since the last sampling analysis.

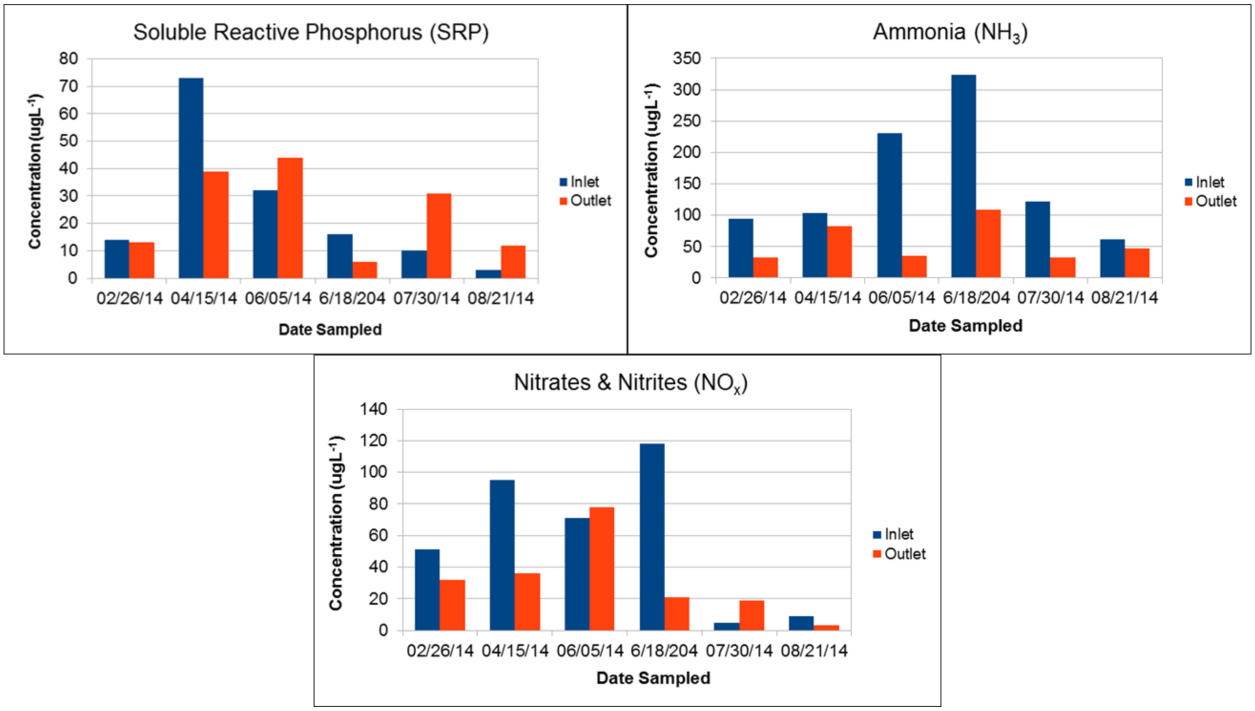

Figure 19: Soluble nutrient levels in the Palatka pond for the post-BMP condition

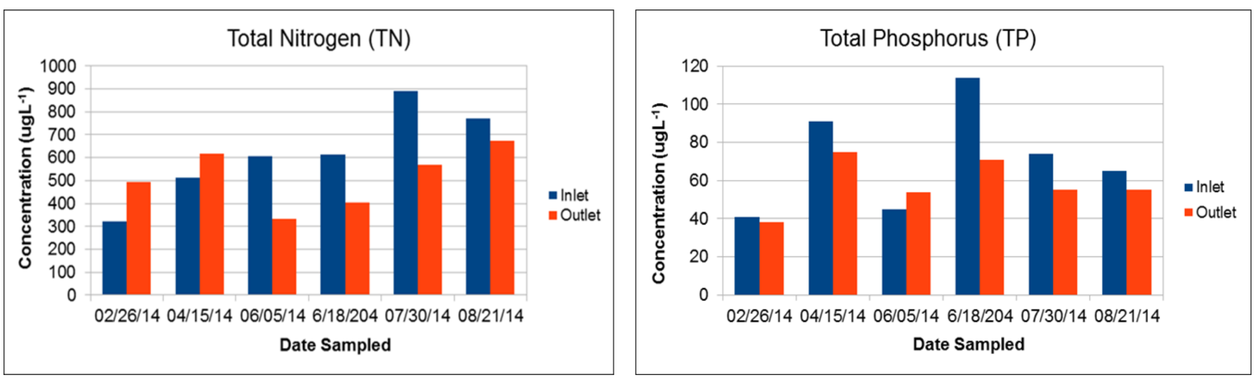

Figure 20: TN (left) and TP (right) levels for the Palatka pond for the post-BMP condition

2.3.4 Floating Media Bed Reactor Results

A Floating Media Bed Reactor (FMBR) was installed approximately two thirds of the distance from the inlet to the outlet in the middle of the pond on February 13, 2014. The lab data for the inlet and the outlet concentrations for soluble (Figure 21) and total (Figure 22) nutrient species are presented below. As seen in the data, the FMBR appears to have good removal efficiency for SRP with a total average reduction of 37.1%. The NO_x and NH_3 species displayed variable removal efficiencies with no clear trend; however removal rates for NO_x were greatest on the dates with the highest inlet NO_x concentrations. This may be explained by varying inlet conditions of dissolved oxygen (DO) from storm events which would affect the biological performance of the media especially with the relatively small size of the pond with two inlets (one of which entering midway), which when combined, typically may result in a higher degree of mixing with highly oxygenated runoff during rainfall events. The FMBR showed a very good and consistent removal of TP, amounting to an average removal efficiency of 52%. Whereas TN displayed varying removal efficiencies totaling 10.4%.

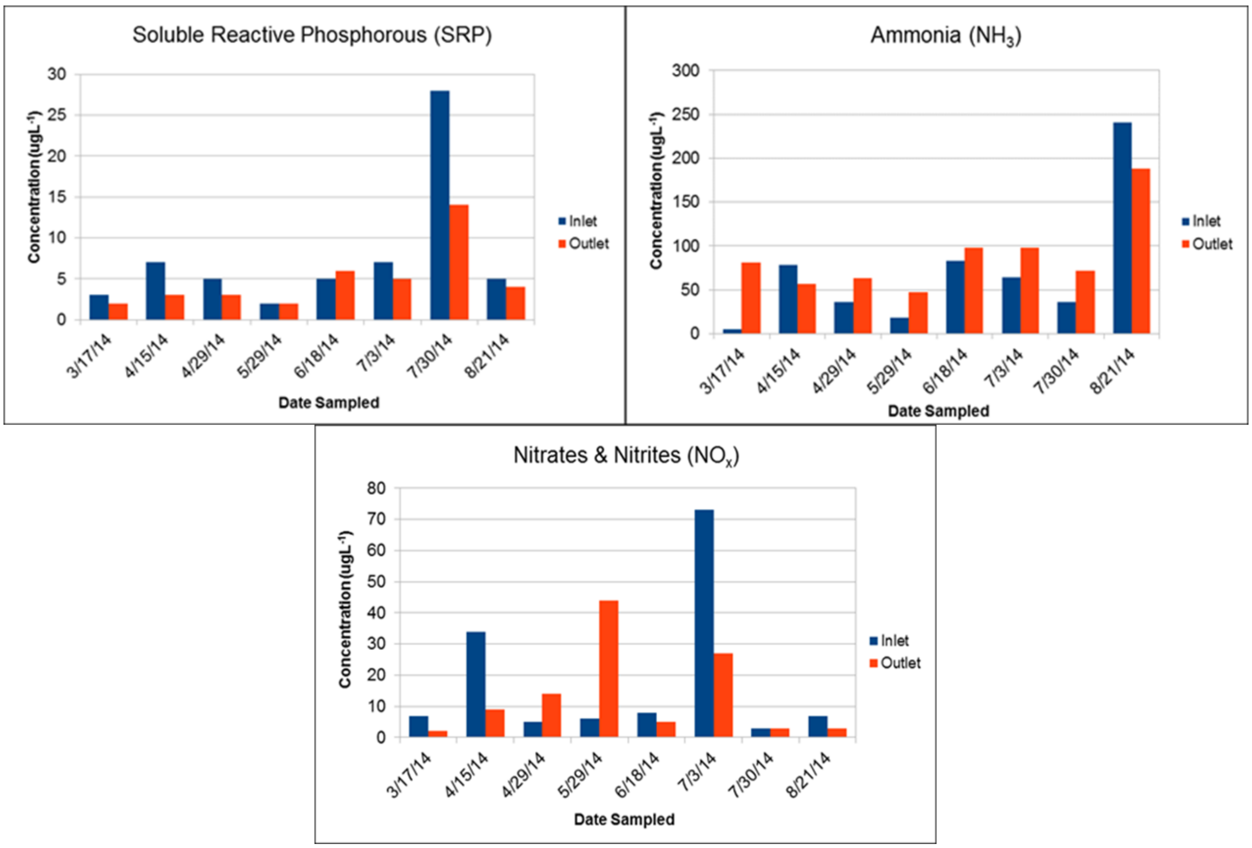

Figure 21: Soluble nutrient levels for FMBR for the post-BMP condition

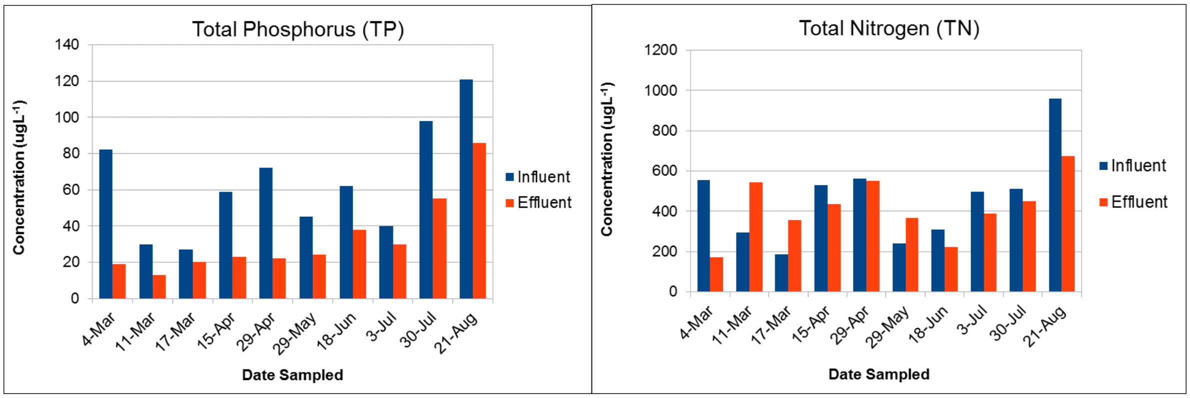

Figure 22: Total nitrogen and total phosphorus levels for FMBR for the post-BMP condition.

2.4 Orlando (Pond ID: SR 434 P2)

2.4.1 Background and Maintenance Issues

This 0.98 acre pond is located in Orlando and the primary maintenance issues reported for the pond were algae and cattail growth as well as a heavily overgrown littoral zone. The initial site visit revealed that the pond was split by a berm. The pond section south of the berm suffered from algae and cattail growth. The pond section north of the berm was heavily overgrown with vegetation and small trees. It was recommended that the nuisance vegetation be removed prior to any BMP implementation. An image of the Orlando pond is presented Figure 23.

Figure 23: Orlando pond

2.4.2 Best Management Practice

The BMP chosen for this pond was a Horizontal Media Bed Reactor (HMBR), which was installed at the site on April 1, 2014. The media mixture used in the HMBR was 50% 5/8^{ths} expanded clay and 50% tire chunk. The HMBR was chosen for this pond because of its nutrient removal capacity as well as simplicity in installation and operation. The HMBR utilizes solar energy for pump operation, therefor cutting down on potential future expenses and utilizing clean renewable energy. A cross-sectional view of the HMBR is given below in Figure 24 and a picture of the HMBR in the field in Figure 25.

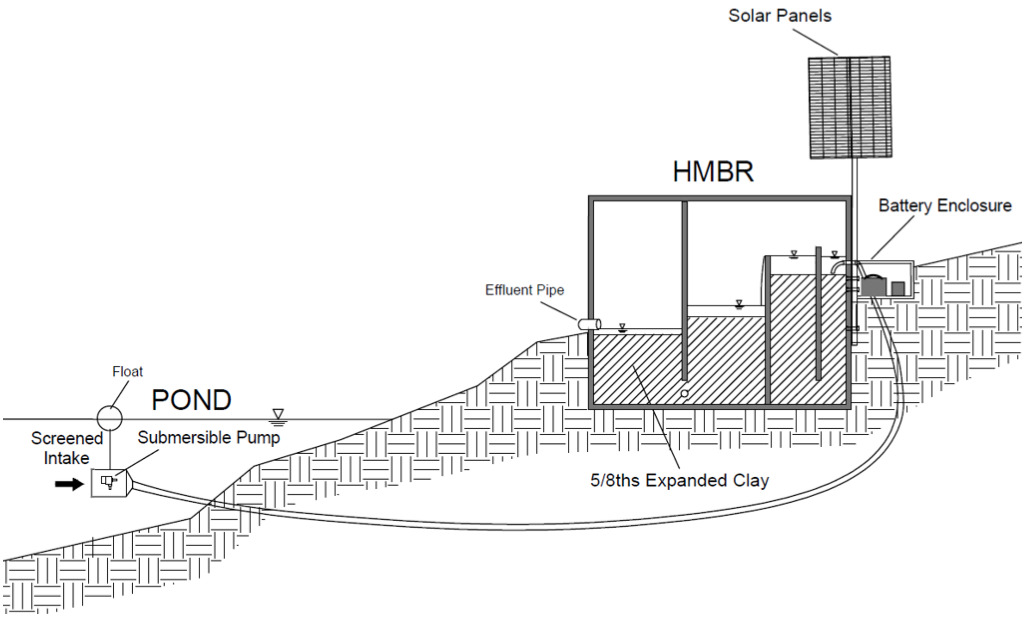

Figure 24: Cross-sectional view of the horizontal media bed reactor in the field

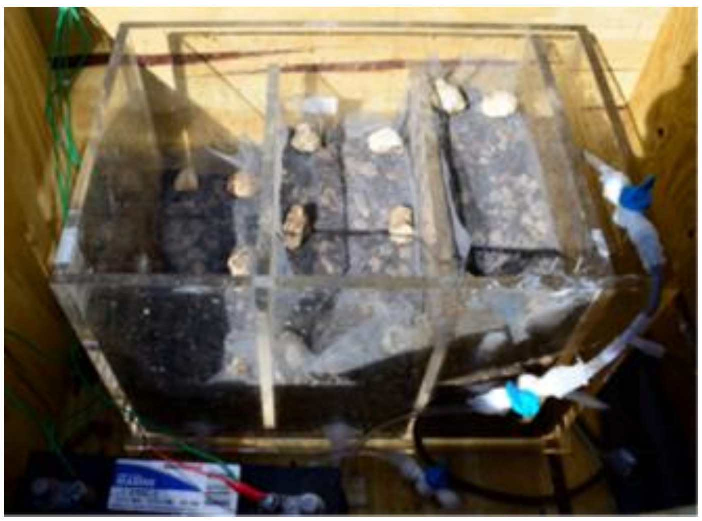

Figure 25: Horizontal media bed reactor at the Orlando pond

2.4.3 Nutrient Sampling Results

A total of three storm and three non-storm sampling events have been completed for this pond since BMP deployment. A summary of the sampling dates and the most recent rainfall amount is provided in Table 8.

Table 8: Summary of sampling events for Orlando

Sampling Date	Event Type	Last Recorded Rainfall/Amount
2/12/2014	Storm	2/12/2014 – 0.69 in
3/17/2014	Storm	3/17/2014 – 0.89 in
4/17/2014	Non-Storm	4/8/2014 – 0.44 in
6/1/2014	Storm	6/1/2014 – 0.34 in
7/3/2014	Non-Storm	7/2/2014 – 0.42 in
8/1/2014	Non-Storm	7/29/2014 – 0.17 in

The lab results displaying the ponds removal performance for soluble (Figure 26) and total (Figure 27) nutrient species are presented below. As can be seen in Figure 26, the pond shows consistent removal efficiency of the NH_3 and NO_x species, 67% and 78%, respectively. The pond displayed good removal efficiencies for both TP and TN, averages totaling 35% and 56%, respectively. The pond did not exhibit effective removal of SRP, but SRP concentrations were much lower at this site than at other pond sites in this study that had issues with excess nutrients.

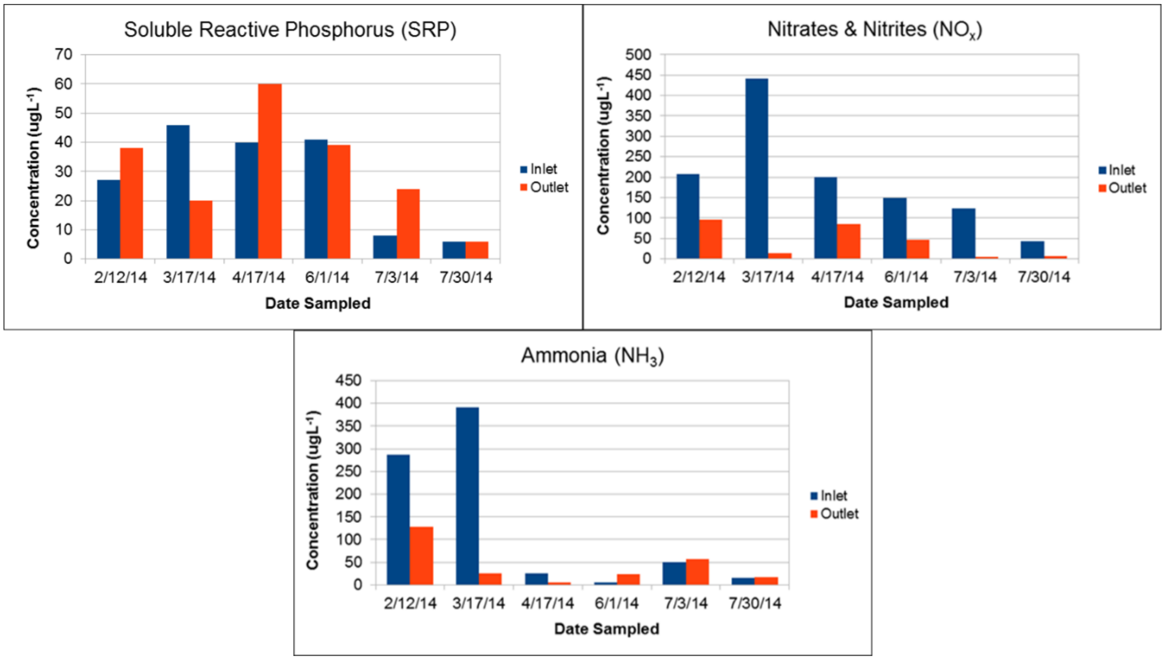

Figure 26: Soluble nutrient levels in the Orlando pond for the post-BMP condition

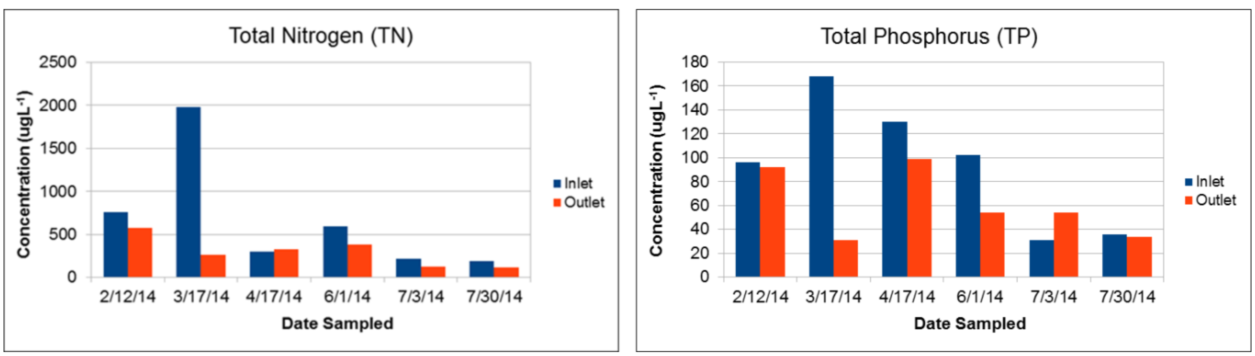

Figure 27: TN (left) and TP (right) levels for the Orlando pond for the post-BMP condition

2.4.4 Horizontal Media Bed Reactor Results

A Horizontal Media Bed Reactor (HMBR) was installed near the inlet of the pond (due to the remainder of the pond being too heavily vegetated for a suitable site) on April 1, 2014. The lab data for the inlet and the outlet concentrations for soluble (Figure 28) and total (Figure 29) nutrient species is presented below. As seen in the data, the HMBR appeared to display relatively consistent removal efficiency for SRP, however, experienced an increase in effluent SRP values as compared with influent during the July 3 and July 30 sampling events. It is not entirely clear why such a release would occur for these non-storm events, however perhaps the highly variable nature of the influent water characteristics could be effecting the filter. Also, SRP concentrations were very low at this site relative to other sites with nutrient problems; so there was not a strong need for SRP removal at this location. NO_x species displayed more consistent removal (63%) compared to the SMBR and FMBR which may be explained by the different media used for the HMBR. The NH_3 species displayed variable removal efficiencies with no clear trend. The HMBR showed a low but consistent removal of TP species amounting to an average removal efficiency of 8.9% and a good average removal efficiency of 26.3% for TN.

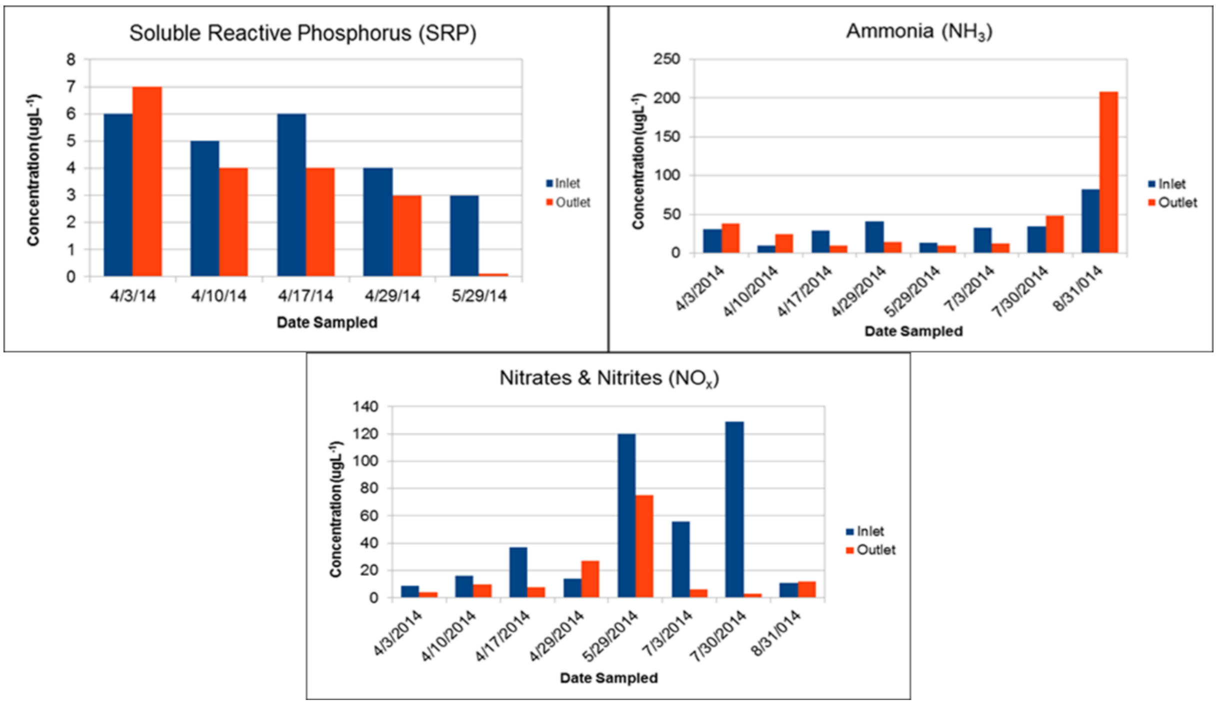

Figure 28: Soluble nutrient levels for HMBR for the post-BMP condition

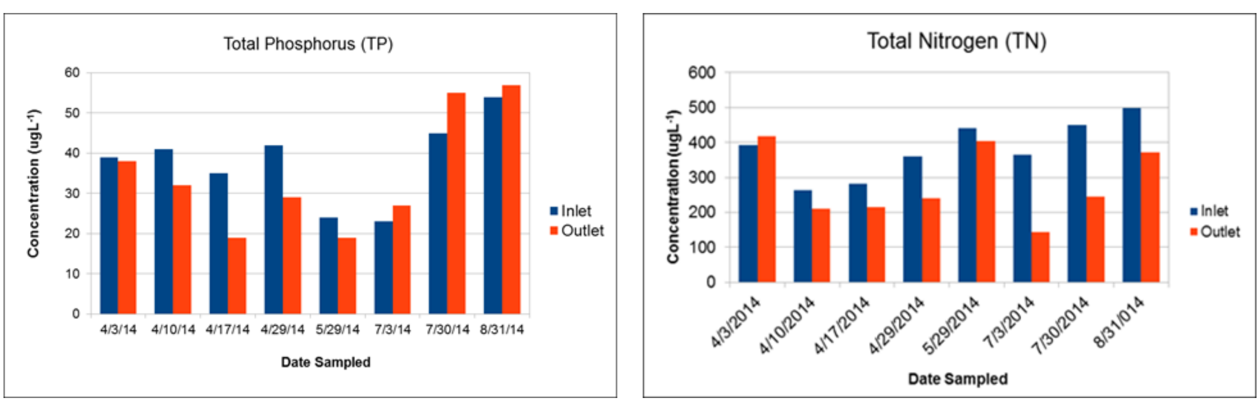

Figure 29: TP (left) and TN (right) levels for HMBR for the post-BMP condition.

2.5 Clearwater (Pond ID: 15040-3517)

2.5.1 Background and Maintenance Issues

This 0.53-acre pond is located adjacent to a highway intersection and a residential park. The area to the west of the pond is a residential park, and a forest borders the southern end of the pond. Hidden beneath the trees in the southwest corner of the pond is a small parking lot. To the north is Gulf-to-Bay Boulevard, and County Road is to the east. With regard to the pond, it has a lengthy grass swale that runs along its perimeter. The inlet to the pond is located on the northwest corner, which is connected to the stormwater drain on Gulf-to-Bay Boulevard. Thick recurrent cattail growth was the major problem reported for this pond. During the initial site visit, it was seen that the entirety of the lake was clogged with cattail. It would appear that the cattail had not been cleared from the pond in recent years. As a result, the pond is covered from inlet to outlet, which has severely reduced the storage volume of the pond. Routine removal of the cattail should occur in order to prevent the nuisance vegetation from taking over the pond. An image of the Clearwater pond is presented in Figure 30.

Figure 30: Clearwater pond

2.5.2 Best Management Practice

The BMP chosen for this pond was clearing and grubbing of the cattail from the pond. The pond was cleared of cattail in September and October of 2012. Removal of cattail was chosen as the BMP for this pond because of the severe reduction in storage volume of the pond, which negatively impacted the pond's nutrient removal capacity.

2.5.3 Nutrient Sampling Results

A total of three storm and three non-storm sampling events have been completed for this pond since BMP deployment. A summary of the sampling dates and the most recent rainfall amount is provided in Table 9.

Table 9: Summary of sampling events for Clearwater

Sampling Date	Event Type	Last Recorded Rainfall/Amount	Maintenance Activities On Date of Sampling
2/26/2014	Non-Storm	2/22/2014 – 0.14 in	Edging and Sweeping
3/12/2014	Storm	3/12/2014 – 0.23 in	None
4/11/2014	Non-Storm	4/8/2014 – 0.35 in	None
5/15/2014	Non-Storm	5/14/2014 – 0.27 in	Edging and Sweeping
6/18/2014	Storm	6/18/2014 – 0.28 in	None
11/8/2014	Storm	11/8/2014 – 0.25 in	None

The TN and TP measurements for all sampling events are presented in Figure 31. The lab data for soluble nutrient species is presented in Figure 32.

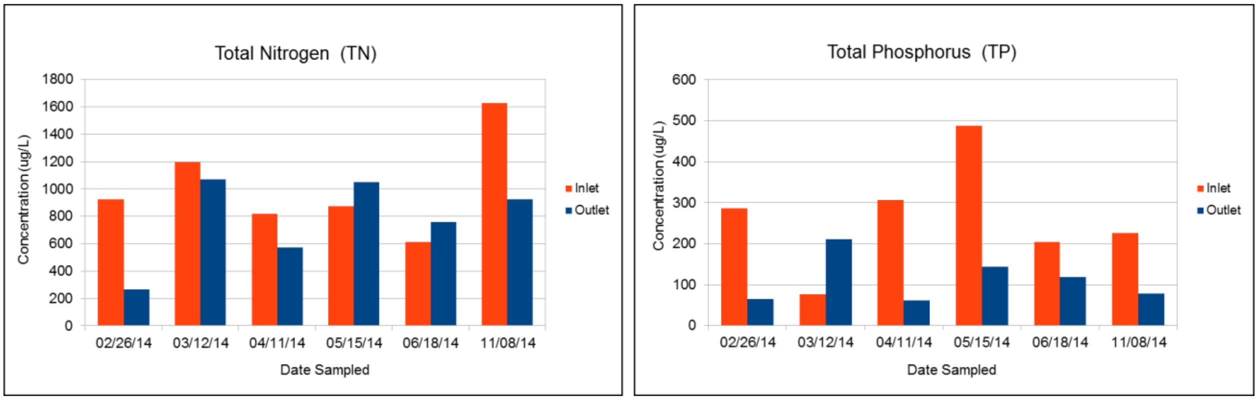

Figure 31: TN (left) and TP (right) levels for the Clearwater pond

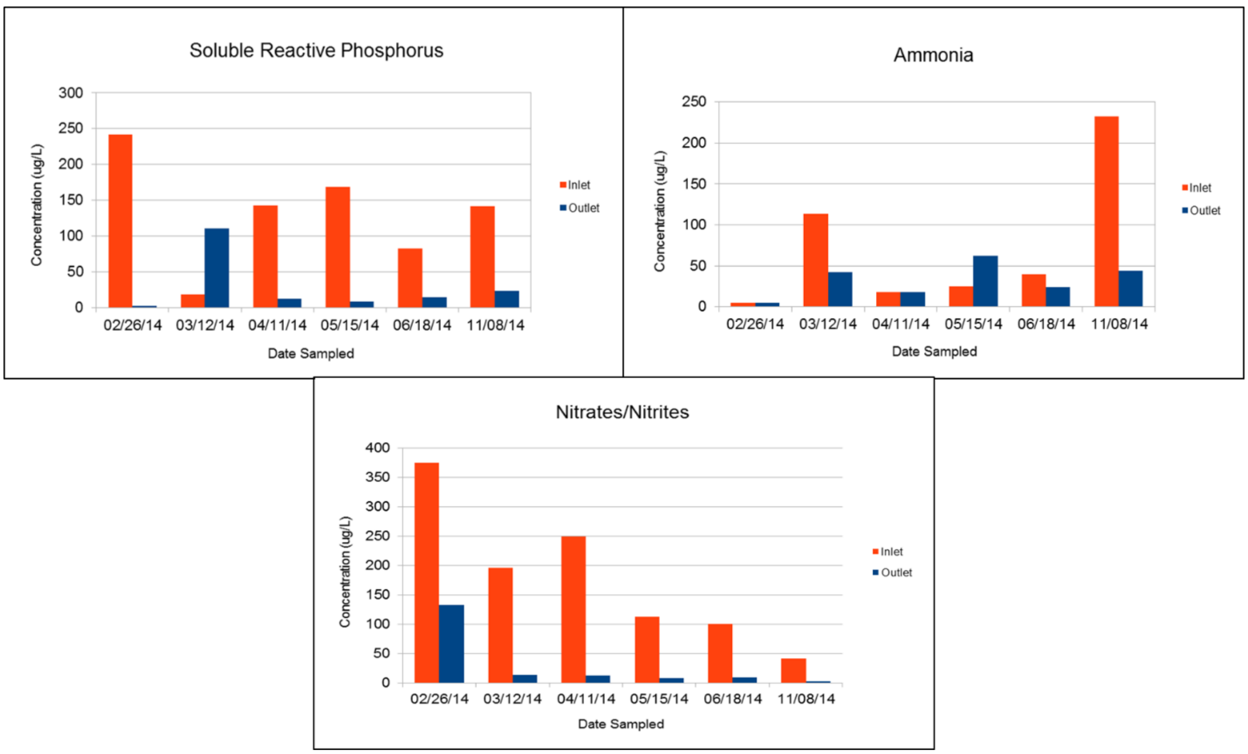

Figure 32: Soluble nutrient species at Clearwater for Post-BMP conditions

Overall, the pond exhibits good removal of TN and TP during non-storm conditions since the clearing and grubbing of the excessive cattail in the pond. However, during the storm event of March 12, 2014, it can be seen that removal of TP was poor when compared to the removal of TN. As the pond is quite shallow throughout, re-suspension of nutrient-rich sediments in the pond likely occurred during the storm event, leading to excessive nutrient levels in the effluent. As the May 15, 2014 non-storm sampling date occurred the day after a rain event, the elevated TN concentration at the outlet was likely due this fact as well. The consistently high TN concentrations near the outlet, as shown in Figure 31, support this explanation. The pond exhibited substantial increases in removal capacity of SRP, ammonia, and nitrates/nitrites, with average removal efficiencies reaching levels of 78%, 55%, and 83% respectively.

The final storm sample for Clearwater was collected on November 8, 2014. During the sampling trip a large quantity of grass clippings were observed in and around the pond outlet. These clippings may contribute to high organic nutrient concentrations, Figure 36 shows that there was a large spike in both TP and TN sediment concentrations near the outlet. A photo of the excessive grass clippings is shown below in Figure 33.

Figure 33: Grass clippings in Clearwater pond outlet

The average pre-BMP and post-BMP nutrient removal efficiencies, presented in Table 10, show that the pond is functioning better in removing both dissolved and particulate nutrients since the removal of the cattail. In particular, SRP and NO_x removal show a dramatic increase, which means that readily-usable nutrient species are being assimilated or converted within the pond and are not being discharged to the receiving water. Three non-storm samples were taken at Clearwater to represent Pre-BMP conditions from the time period of September 19, 2012 to June 3, 2013.

Table 10: Average nutrient removal efficiencies for the Clearwater pond

	TP	**SRP**	**TN**	**NH_3**	**NO_x**	**Org. N**
Pre-BMP	15.5%	-11.3%	-28.0%	0.0%	-25.5%	0.0%
Post-BMP	57.3%	78.7%	23.4%	55.0%	83.2%	6.3%

Early observations of the pond after the removal of the cattail showed that hydrilla and filamentous green algae took hold of the pond, as seen in Figure 34. This could explain why the increase in nutrient removal efficiency was so dramatic after cattail removal. The chlorophyll-a levels at the inlet, shown in Figure 35, did show an increase from February to May 2014, however this is most likely a seasonal fluctuation, attributed to the warmer temperatures. If it is the case that algae are the primary consumers of the nutrients, then the presently observed removal will likely decrease some overtime as the pond ecosystem returns to equilibrium.

Figure 34: Filamentous green algae and hydrilla observed at the Clearwater pond

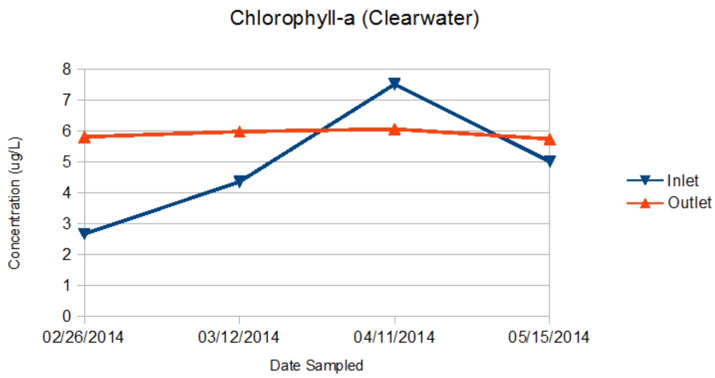

Figure 35: Chlorophyll-a levels in the Clearwater pond

2.5.4 Sediment Sampling Results

The results from the sediment analysis at the Clearwater pond are presented in Figure 36. The Clearwater pond saw good removal rates of TP and TN in the sediment samples across the majority of Phase 2. The results of the final sediment sample taken on November 8, 2014 showed a spike in both TP and TN in the sediment near the outlet. This phenomenon is interesting because there was also large quantities of grass clippings near the outlet of the pond on November 8, 2014. Although the results did not show a spike in TN or TP concentrations for the water samples taken on that day, there may be a correlation between grass clippings and elevated soil nutrient concentrations.

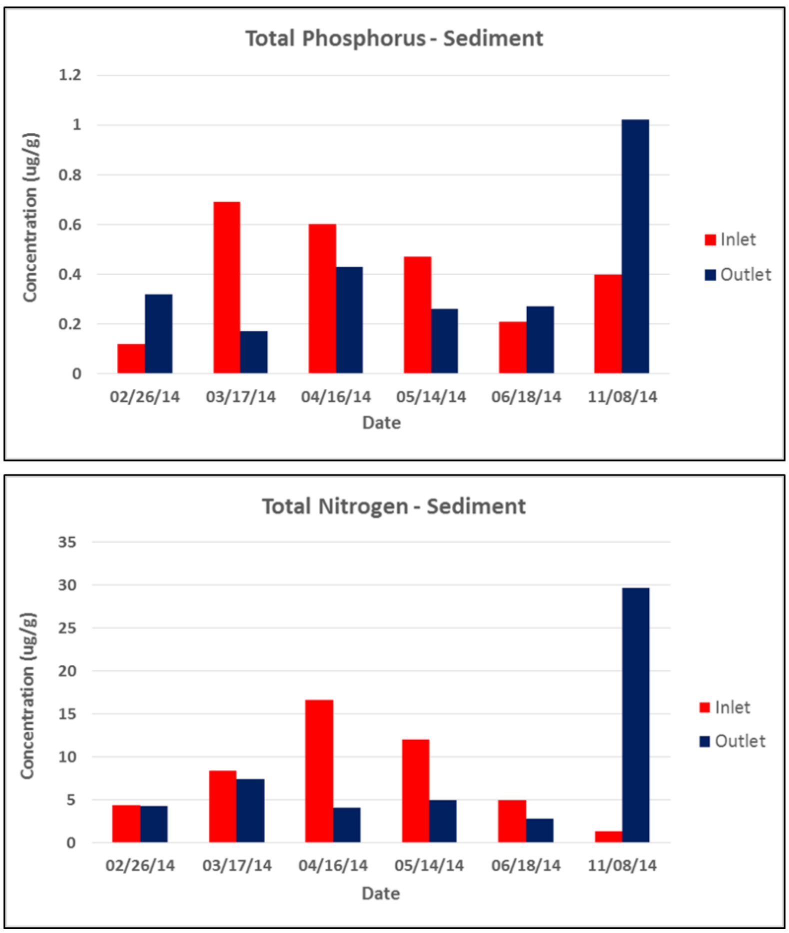

Figure 36: TP (above) and TN (below) sediment concentrations at the Clearwater pond.

2.6 Ruskin (Pond ID: 10120-3511-01)

2.6.1 Background and Maintenance Issues

This 0.31 acre pond has a commercial shopping center to the east of it and a residential neighborhood to the north. The western and southern edges of the pond border a tomato field. This made the pond a prime candidate for selection, because the pond is exposed to very high nutrient concentrations as fertilizers are washed from the tomato field into the pond. A thicket of trees and shrubs are between the agricultural field and the pond, yet algal blooms still appear to be a problem. The brush bordering the pond exhibited significant growth and the littoral zone needed to have excess vegetation removed. Severe algal growth and an overgrown littoral zone were the primary maintenance issues with this pond. An image of the Ruskin pond is presented in Figure 37.

Figure 37: Ruskin pond

2.6.2 Best Management Practice

The BMP chosen for this pond was installation of a Floating Treatment Wetland (FTW). A single FTW was deployed at the Ruskin pond site on January 28, 2014. FTWs are an innovative and newly emerging BMP for removing nutrients from stormwater wet detention ponds. Plants grow on floating mats, rather than at the bottom of the pond, which enables them to interact with suspended nutrients in the water column. FTWs support the growth of root systems of the floating plants, which offers a large surface area for microbial nutrient removal processes and capture of suspended solids in the water column. FTWs offer an environmental friendly and economical approach for nutrient removal in stormwater wet detention ponds. The Ruskin pond had nutrient laden runoff flowing in from the adjacent tomato field and highways, therefore a FTW was chosen because of its nutrient removal capacity. A cross-sectional representation of a FTW is given below in Figure 38. The plants selected to be placed in pre-cut holes on the mats for this pond were Canna, Juncus, and Agrostis.

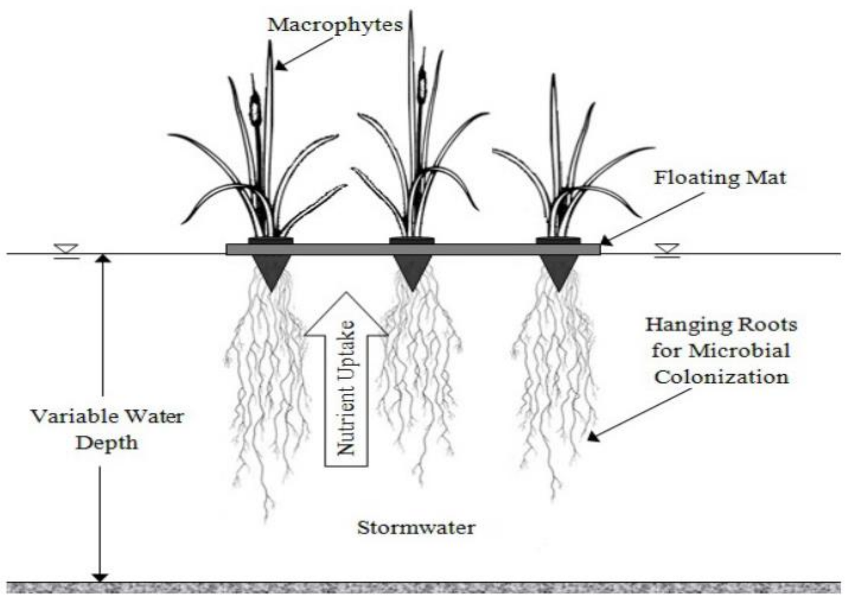

Figure 38: Cross-section view of a typical Floating Treatment Wetland

2.6.3 Nutrient Sampling Results

A total of three storm and three non-storm sampling events were completed for this pond since BMP deployment. A summary of the sampling dates and the most recent rainfall amount is provided in Table 11.

Table 11: Summary of sampling events for Ruskin

Sampling Date	Event Type	Last Recorded Rainfall Amount
2/12/2014	Storm	2/12/2014 – 0.80 in
4/8/2014	Storm	4/8/2014 – 0.35 in
5/5/2014	Non-Storm	6/1/2014 – 0.08 in
6/9/2014	Non-Storm	6/13/2014 – 2.5 in
6/18/2014	Non-Storm	6/21/2014 – 2.0 in
9/2/2014	Storm	9/2/2014 – 2.2 in

As the primary removal mechanism of floating treatment wetlands is through direct uptake of dissolved nutrient species, the results for SRP, NO_x, and NH_3 are presented in Figure 39.

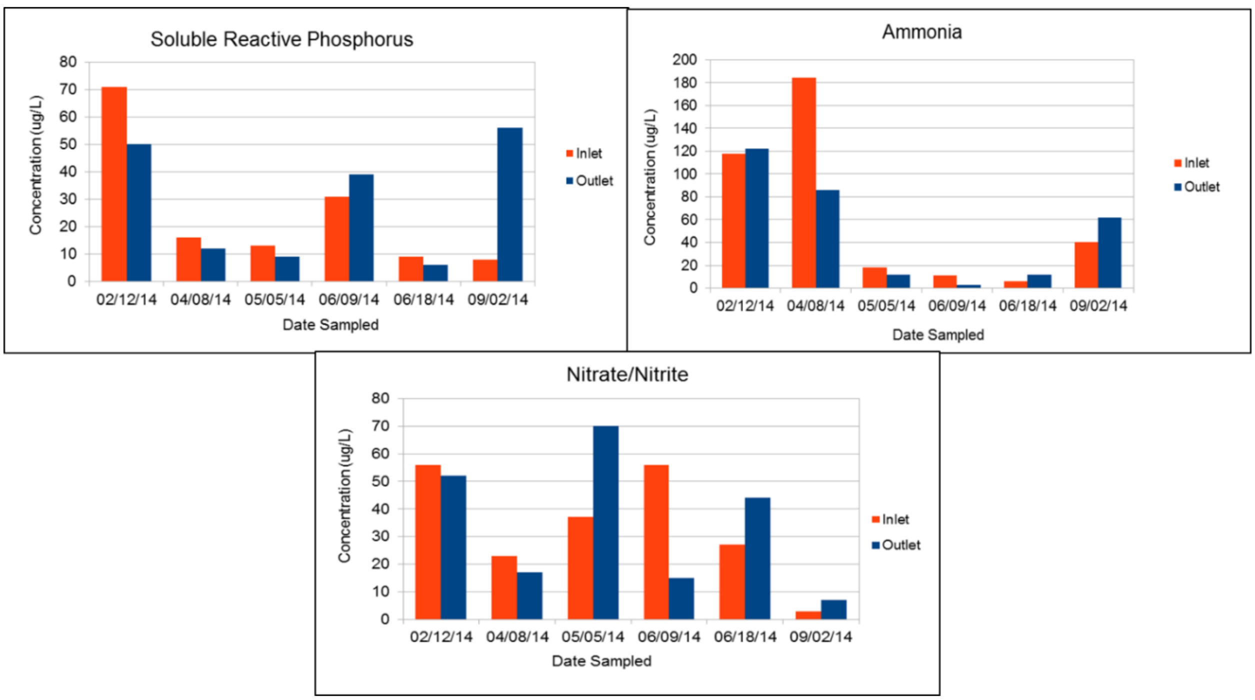

Figure 39: Soluble nutrient levels in the Ruskin pond for the post-BMP condition

In addition, the average removal efficiencies for the pond in the pre- and post-BMP condition is presented in Table 12.

Table 12: Average nutrient removal efficiencies of the Ruskin pond

	TP	SRP	TN	NH_3	NO_x	Org. N
Pre-BMP	-0.6%	-23.0%	-36.7%	-2.9%	-17.7%	56.8%
Post-BMP	-50%	16.2%	22.4%	21.2%	-1.5%	22.8%

In the post-BMP condition, a good improvement in soluble nutrient removal for the pond is exhibited, suggesting that nutrient uptake and assimilation by the FTW is contributing to improving water quality. The total phosphorus and nitrogen concentrations at the inlet and outlet are presented in Figure 40. Total P removal efficiency was greatly reduced in the post-BMP period mainly due to large outlet concentrations during the last two sampling dates. These to sampling dates included both storm and non-storm sampling events that included rainfall amounts in excess of 2 inches and the greater outflow TP concentrations during those dates may have been due to resuspension of sediments and flushing of particulate material on those sampling dates.

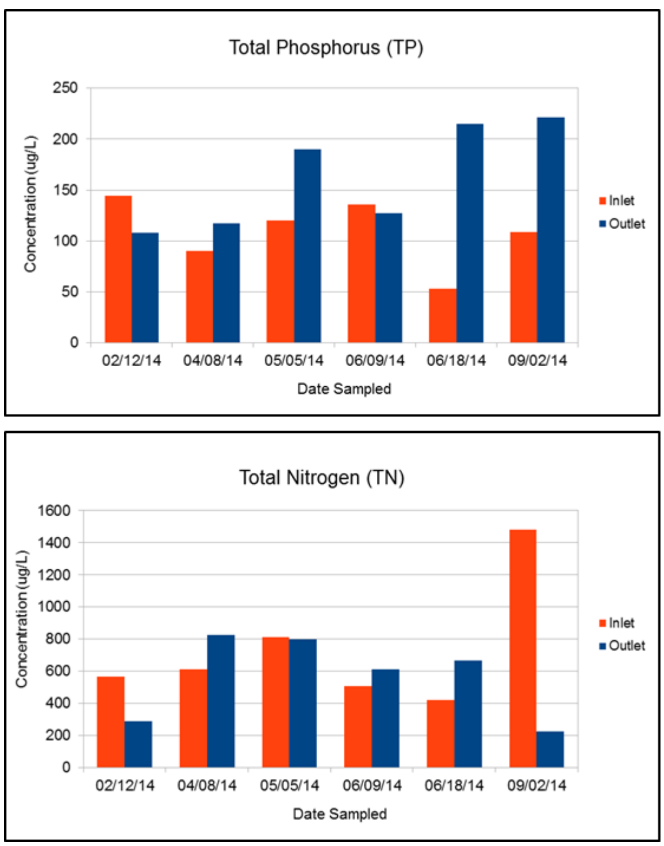

Figure 40: TP (above) and TN (below) for Storm and Non-Storm in Ruskin

2.6.4 Plant Replacement

On September 17, 2014 a plant replacement of the FTW for Ruskin was conducted. This plant replacement entailed removing all mature plants from the FTW and replacing them with seedlings. Pictures of before and after the plant replacement can be seen below in Figure 41. This plant replacement allowed us to compare the efficiency of the FTW through two plant life-cycles and provided information on the optimal point for replacing plants on a FTW. One of the concerns and reasons for conducting this plant replacement was the invasion of unwanted plants onto our FTW. These plants, which can be seen all around the banks of the pond, began growing on the FTW and may have created unwanted competition between the different plant species and possibly impacted the removal of nutrients.

Figure 41: Plant replacement of Ruskin FTW, before (above) and after (below)

2.6.5 Sediment Sampling Results

The results from the sediment analysis at the Ruskin pond are presented in Figure 42. The TP sediment concentrations at the Ruskin pond stayed relatively at equilibrium throughout Phase 2. The sampling date on April 8, 2014 saw a large spike in TP sediment concentrations at both the inlet and outlet, when compared to the remaining data set. The Ruskin site saw poorer removal rates of TN in sediment samples, which is an interesting phenomenon because the water samples saw a substantial improvement in TN removal during the post-BMP time period. The results of final sediment sample taken on September 2, 2014 show large spikes in TP outlet sediment concentrations and TN inlet sediment concentrations. It should be noted that the delivery of the final sediment sample to the lab was delayed, however the sample was preserved throughout the delay in a freezer and should still yield accurate results.

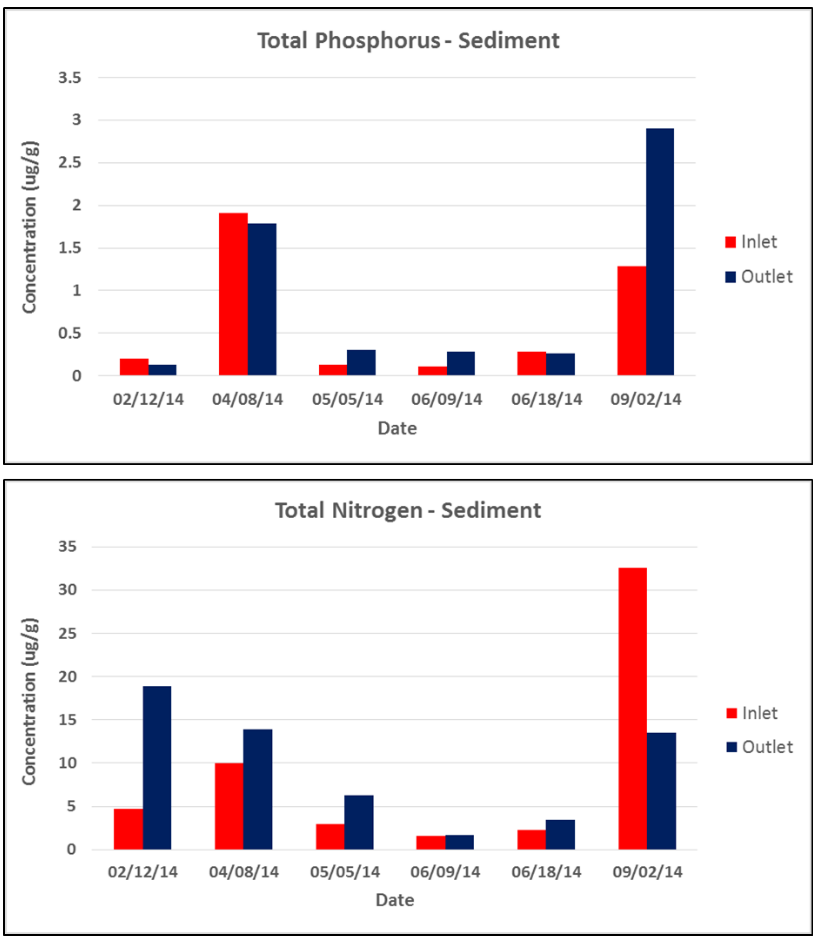

Figure 42: TP (above) and TN (below) sediment concentration at the Ruskin pond

2.7 Royal Palm Estates (Pond ID: SWF 5949)

2.7.1 Background and Maintenance Issues

This 1.69 acre pond is located immediately north of State Road 80. An apartment complex lies to the west of the pond, and a commercial building is to the east. North of the pond is an undeveloped field. Erosion at the inlet structure was the reported problem for this pond. The initial site visit confirmed this. It appeared that the overland flow from State Road 80 was eroding the dirt from around the structure. The primary maintenance issue with this pond was bank erosion which can result in high levels of total suspended solids in the water and lead to unstable slopes surrounding the pond. This pond was selected in order to showcase erosion control BMPs that can be employed when the banks around pond structures are being washed away. An image of the Royal Palm Estates pond is presented in Figure 43.

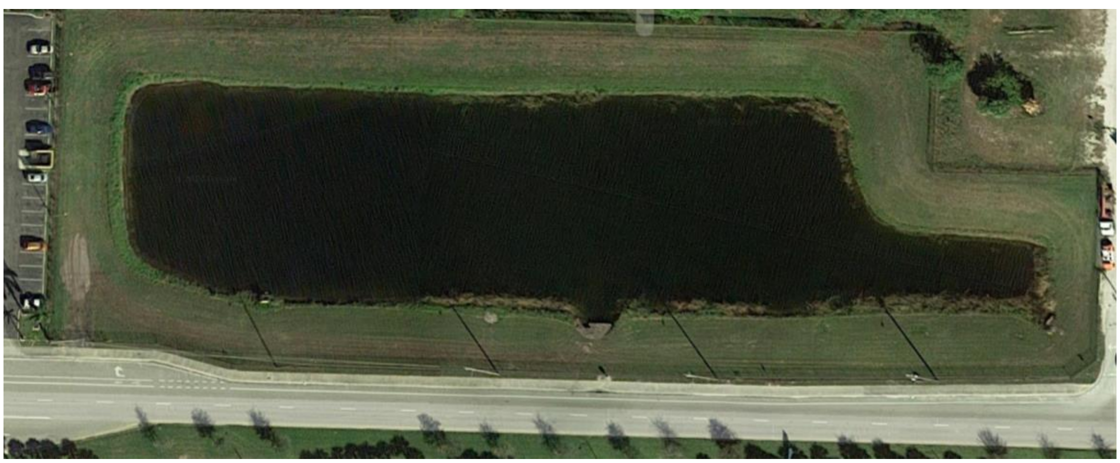

Figure 43: Royal Palm Estates pond

2.7.2 Best Management Practice

The maintenance issue associated with this pond was bank erosion and high levels of total suspended solids in the water column. The BMP installed to address these issues was Tri-Lock. The deployment of the Royal Palm Estates BMP was delayed due to unusually elevated water levels in the pond that had left the inlets submerged. As the selected BMP for this pond was bank stabilization, installation around submerged inlets would not be possible without cost-prohibitive dewatering operations. In late May 2014, UCF received confirmation from FDOT that pond levels had declined to a level acceptable for installation of the bank stabilization.

Tri-Lock was installed at this pond to provide bank stabilization, Tri-Lock is an interlocking, articulated concrete block system that forms a continuous, flexible revetment. The system consists of two types of interlocking pre-cast blocks, which are installed by hand over a geotextile base. The product can be installed on a 2:1 slope and can work around 90-degree corners without cutting blocks, according to the manufacturer's specifications. Although it requires labor-intensive installation, Tri-Lock provides a cost advantage over poured concrete revetments, as it only costs about $4.50 per square foot and it provides aesthetic advantages over rip-rap in that in can be backfilled and seeded to promote vegetative growth. The vendor for this product, which supplied the materials and directed the installation was Midwest Construction, based out of Ft. Myers, Florida.

A site visit and meeting with key FDOT West Palm Beach operations staff occurred during the week of June 1-7. Upon the site visit, it was determined that the Tri-Lock would be necessary through a 10' offset from the back and sides of inlet structure S-145, and a 10' offset in all directions from S-139, in order to provide adequate stability. A measurement of the slopes around these structures revealed that the slopes were steeper than 2:1 throughout most of the proposed revetment area and as steep as 1:1 in some areas, as shown in Figure 44. During the meeting with the operations staff, it was agreed that FDOT would grade the area to a maximum of 2:1 slope and excavate approximately 4” over the site prior to installation, per the vendor's specifications.


Figure 44: Pre-BMP conditions at S-139 (left) and S-145 (right), respectively

On June 23 and 24 FDOT staff conducted the site preparation. On June 25, two representatives directed and assisted a crew of 2 UCF students and 6 FDOT workers in the installation. The site proved to be challenging due to the steep slopes, which were prepared to minimum specifications as constrained by the existing site conditions, and the geometry around S-145. After 5.5 hours of work, about 35% of the installation was completed, as shown in Figure 45.

Figure 45: Tri-Lock installation around S-145 at the conclusion of the first day of work

Work resumed on June 26, with a crew of 4 UCF students and 6 FDOT workers in addition to the 2 representatives from Midwest Construction. After 6 hours of work, the block-laying had been completed and backfilling commenced around structure S-145 as shown in Figure 46. At this point, work concluded for the week, with the remaining work consisting of digging a trench for the anchor rows, laying the block for the anchor rows, backfilling, and placement of rip-rap at the toe of the block in structure S-139.

Figure 46: Tri-Lock installation at S-139 and S-145 at the conclusion of the second day of work

On June 30, FDOT staff excavated the anchor trench around the top of the revetment at both structures and laid down 1-2 rows of block to serve as the anchor row, as directed by the vendor's specifications. The configuration of the anchor trench at both structures is provided in Figure 47. On July 3, FDOT staff completed the backfilling of the trench, backfilling of the block, and grading of the slopes in the area, as shown in Figure 48. The only remaining site work consisted of sodding the disturbed areas, seeding the backfill in the block area, and placement of rip-rap around the toe of the block in structure S-139.

Figure 47: Anchor trench along top of S-139 and S-145

Figure 48: Finished installation of Tri-Lock around S-139 and S-145

Post installation pictures of the two inlets taken on September 16th, 2014 during a site inspection are displayed in Figure 49. The Tri-Lock block system appears to working well with no clear signs of erosion developing around the area. Vegetation can be seen growing around and in between the blocks.

Figure 49: Tri-Lock erosion blocks around S-139 and S-145 80 days following installation

2.7.3 TSS Sampling Results

The sampling events and most recent rainfall data for the Royal Palm pond are summarized in Table 13. A total of three non-storm and three storm samples have been completed for this pond since BMP installation.

Table 13: Summary of sampling events for Royal Palm

Sampling Date	Event Type	Last Recorded Rainfall Amount
7/6/2014	Non-Storm	7/4/2014 – 0.49 in
9/26/2014	Non-Storm	9/24/2014 – 0.50 in
1/19/2015	Non-Storm	1/15/2015 – 0.26 in
2/27/2015	Storm	2/27/2015 – 0.20 in
3/28/2015	Storm	3/27/2014 – 0.73 in
4/2/2015	Storm	4/2/2015 – 0.17 in

Remotely controlled TSS sampling pumps were installed at each of the inlets and the outlet at the Royal Palm site. These sampling pumps enable samples to be collected from a remote location, such as the University of Central Florida campus. They enable samples to be collected during times of interest, such as during or directly following storm events, and retrieved for analysis at a later time. An image of one TSS sampling pump is presented in Figure 50.

Figure 50: TSS Sampling Pump

A site visit to the pond on January 19, 2015 showed continued vegetation growth in and around the Tri-Lock installation area. Pictures of the Tri-Lock and surrounding conditions are presented in Figure 51 and Figure 52. It is interesting to note that the water level has fallen below the level of the Tri-Lock at inlet 1 shown in Figure 51, however the Tri-Lock is still intact and no signs of structural damage were noticeable. Regrowth of vegetation in and around the Tri-Lock blocks is encouraged as the vegetation root systems will aid in bank stabilization, as well as giving the pond more natural looking aesthetics.

Figure 51: Tri-Lock and vegetation growth around inlet 1

Figure 52: Tri-Lock and vegetation growth around inlet 2

The results of TSS sampling at Royal Palm are presented in Figure 53. At first glance it may appear there was a negligible effect after installation of Tri-Lock, however this can be misleading. Baseline samples were taken in June 2014, a summer month, when pond water levels are typically at their greatest. Due to the fact there was more water present in the pond during baseline sampling there may have been more suspended solids in the water, however they were more dispersed, resulting in a dilution effect and possibly lower concentration readings. Sampling to determine the effectiveness of Tri-Lock was carried out from July 2014 to April 2015, which is primarily composed of winter months, when pond water levels are typically at their lowest. Due to low water levels, as seen in Figure 51, the suspended solids were more concentrated and likely resulted in higher concentration readings even though there was the same or even less suspended solids present in the pond. Another interesting note is the large spike in TSS concentration at inlet 1 for the March 28, 2015 sampling date. During the site visit there appeared to be construction activities ongoing at the pond, as seen in Figure 54. It appeared the vegetation along the banks of the pond was being removed, which resulted in the destabilization of surrounding soil and left large quantities of loose soil on the pond banks. These destabilized and loose soils were likely carried into the pond by stormwater runoff, resulting in elevated TSS concentrations for the final two storm events. Due to this, the TSS readings on March 28 and April 2 of 2015 may have been elevated due to construction activities and not representative of normal conditions at the pond following a storm event.

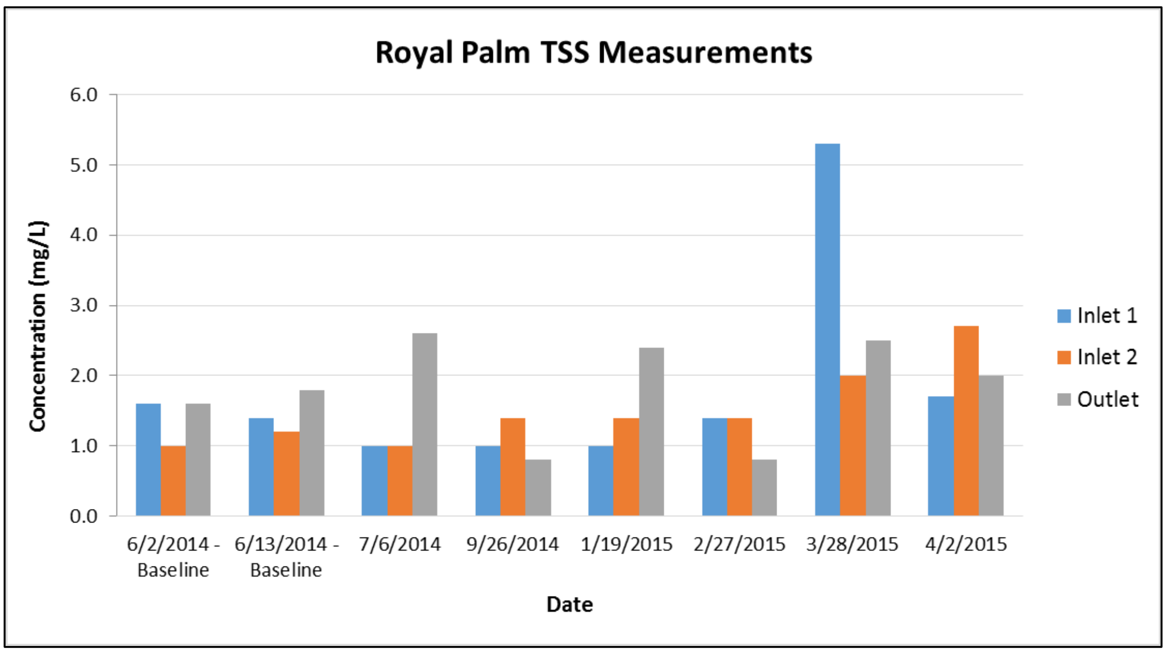

Figure 53: TSS Sampling Results

Figure 54: Construction activities at the Royal Palm pond

3. MAINTENANCE REQUIREMENTS

3.1 Floating Treatment Wetlands

Installation of Floating Treatment Wetlands proved to be a successful BMP for the Gainesville and Ruskin ponds. The Gainesville pond exhibited substantial increases in removal for total phosphorus, and soluble reactive phosphorus, and little change or slight reduction in removal efficiency for ammonia, and nitrates/nitrites. Total nitrogen and organic nitrogen removal rates stayed at equilibrium or slightly decreased. Influxes of nitrogen into the pond may possibly be explained by nitrogen-laden runoff entering the pond from the adjacent highway and residential area. The adjacent residential areas could also be a source of nitrogen runoff through the application of fertilizers. The Ruskin pond exhibited effective removal of total nitrogen, ammonia, and organic nitrogen. Removal rates for total phosphorus, soluble reactive phosphorus, and nitrates/nitrites either stayed at equilibrium or experienced a decrease in removal. Possible explanations for their poor removal include runoff from the adjacent highway and tomato field carrying high concentrations of phosphorus and nitrates/nitrites into the pond due to vehicular exhaust and application of fertilizers, respectively.

It is recommended that the plants on the FTWs be replaced at least once a year to prevent mature plants from dying and re-introducing nutrients back into the water column. For Florida conditions, the replacement is recommended to occur in the fall when the nutrient loading of runoff is generally at a minimum relative to the rainy summer season, and when the plants are entering a more dormant growth phase and senescence. Another improvement for use of FTWs as a BMP is to increase the coverage rate of the ponds. The current coverage area of the Gainesville and Ruskin ponds is roughly 5%. Increasing the coverage rate would offer a greater surface area in the root zone for microbial nutrient removal processes and entrapment of suspended solids. Increasing the coverage area would offer greater nutrient removal capacity, however the cost of installation and plant replacements would increase as well. The cost of installation and maintenance of FTWs as a BMP for stormwater runoff greatly depends on the number of FTWs installed and desired frequency of plant replacements. For example, although the coverage rates for Gainesville and Ruskin are similar there were three FTWs implemented at Gainesville, while Ruskin only had a single FTW installed, due to the Gainesville pond having a much larger surface area. Costs associated with installation and maintenance of three FTWs are much higher than a single FTW due to the required materials, labor, and quantity of plants required. Please refer to section 4.6.11 of the *Best Maintenance Practices for Stormwater Runoff* Handbook for additional information and maintenance practices for FTWs.

3.2 Media Bed Reactors

The sloped, floating, and horizontal media bed reactors proved successful as a BMP at the Zolfo Springs, East Palatka, and Orlando ponds. The Zolfo Springs pond saw improved removal rates for ammonia, nitrates/nitrites, and total phosphorus. Total nitrogen and organic nitrogen showed poorer removal rates, however this can be explained by an abnormality in the data set. The storm event collected on March 6, 2014, showed a spike in total nitrogen and organic nitrogen at the pond outlet that was uncharacteristic when compared to the other sampling events. This event could possibly be explained by roadway contaminants that runoff carried into the pond, fertilizer recently applied nearby that may have been carried into the pond, or other natural events that may have introduced nitrogen to the water column. The East Palatka pond saw positive removal rates for all nutrient species except organic nitrogen. Ammonia was removed from the pond at rates over 60% and nitrates/nitrites removed at over 45%. Organic nitrogen was the only nutrient species with non-positive removal rates, however the final two sampling events on July 30 and August 21, 2014, showed positive removal rates for organic nitrogen. The Orlando pond saw dramatic changes in nutrient removal over the time period of Phase 2 and soluble reactive phosphorus was the only nutrient species that did not see an increase in removal. Ammonia reached removal rates of over 66% and nitrates/nitrites were removed at rates over 78%. The pond also saw substantial increases in total phosphorus and total nitrogen removal, with removal rates reaching 35% and 56% respectively.

It is recommended that twice a year, any sediment buildup be removed from the media bed reactor sedimentation chambers to ensure suitable hydraulic detention times. Inspection of the filters is recommended four times per year, to ensure they are operating properly and no additional maintenance is required. The top layer of sediment and discolored sand should be removed and replaced when the sand filter is visibly clogged. Removal of any trash and debris from the pond should occur as necessary, as to prevent clogging of the submersible pump and improve the pond’s aesthetic value. Replacement of the filter media may eventually be necessary, however this will depend on the characteristic of the runoff and maintenance frequency. It is recommended the batteries inside the media bed reactors be checked during site visits to ensure the solar panel is operating properly and there is sufficient power to operate the pumps. Due to the fact the media bed reactor pumps are powered by solar energy, most of their cost is associated with initial installation. Maintenance costs should be relatively low due to solar energy and recyclable media materials, and will primarily depend on the frequency of media replacement, if necessary. If satisfactory nutrient removal rates are not being achieved at the ponds one strategy that can be implemented is to lower the pumping rate which will increase the hydraulic residence time of the media bed reactors. A larger hydraulic residence time will allow for longer filtration periods and improve nutrient removal rates. Please refer to section 4.6.7 of the *Best Maintenance Practices for Stormwater Runoff* Handbook for additional information and maintenance practices for constructed filters.

3.3 Vegetative Removal

Removal of the overgrown cattail in the Clearwater pond proved effective as a BMP for increasing the nutrient removal capacity of the pond. The pond saw dramatic increases in nutrient removal when compared to pre-BMP conditions for all nutrient species except organic nitrogen. Although the BMP was successful is aiding in nutrient removal there are several maintenance issues that must still be addressed. On the November 8, 2014, sampling trip it was observed that the cattail had regrown throughout the pond. In order to maintain the effective nutrient removal rates demonstrated by the study, the cattail must be removed from the pond when the total accumulated biomass and detritus of the cattail has grown to an unacceptable level and caused a reduction in the volume of the pond. Another maintenance issue observed on the November 8, 2014, trip was large quantities of grass clippings being deposited into the pond as a result of mowing the adjacent grass. A possible solution to this maintenance issue is bagging the grass clippings and taking them away for off-site disposal after the grass has been mowed. Alternatively the mowing pattern could be established to direct the mower discharge away from, rather than into the pond. Disposing of the clippings into the pond may introduce nutrients into the water column that otherwise would not have been there. Please refer to section 4.7.1 and 5.2.2 of the *Best Maintenance Practices for Stormwater Runoff* Handbook for additional information and maintenance practices for vegetation removal and mowing practices respectively.

3.4 Bank Stabilization

Installation of Tri-Lock at the Royal Palm site has shown to assist in stabilization of the banks around inlet 1 and inlet 2 of the pond. Prior to Tri-Lock there was severe bank erosion around these inlets resulting in high concentrations of TSS in the pond as well as compromising the integrity of the inlet structures. Initial sampling results showed a reduction in TSS, indicating the Tri-Lock was working as intended. The final two samples, both storm events, actually showed increases in TSS concentrations, however, this may be attributed to two factors. Firstly, construction activities were observed around the banks of the pond during the March 28, 2015 site visit, as evident in Figure 54. It appeared that excess vegetation was being cleared away from the banks of the pond. These construction activities left large quantities of loose soil on the banks, which may have been carried into the pond during storm events. Secondly, pond water levels decreased significantly during the sampling period compared to baseline sampling conditions. A smaller volume of water in the pond may result in misleading TSS measurements, because the suspended solids will be more concentrated in the pond. Despite these two factors, TSS concentrations remained relatively constant throughout Phase 2, which is a promising result and evidence that the Tri-Lock played a beneficial role in stabilizing the banks and controlling TSS concentrations for the Royal Palm site. Please refer to section 4.6.12 of the *Best Maintenance Practices for Stormwater Runoff* Handbook for additional information and maintenance practices for bank stabilization products.

4. CONCLUSION

Through the effort of rigorous sampling campaigns the treatment efficiencies of the BMPs at the seven designated ponds were monitored throughout 2014 and into early 2015. The full-scale field demonstration of the suggested BMPs was carried out during Phase 2 of the project and resulted in a holistic assessment of maintenance practices for stormwater runoff at these designated ponds. Excess nutrients and suspended solids were the primary cause of the maintenance issues in these ponds. The BMPs that were chosen for each pond addressed the pond's specific maintenance issues and improved nutrient removal in many instances for the first six ponds and lowered total suspended solids concentrations for the Royal Palm Estates pond. The knowledge gained from the BMP research study and field experience detailed within this report alongside with the Stormwater Maintenance Handbook offer a powerful tool for the future stormwater wet detention pond maintenance and mitigating the negative effects of stormwater runoff.

Appendix A: Water Quality Sampling Data

Table 14: Gainesville nutrient data

Gainesville						
Total Phosphorous						
	02/26/14	03/17/14	04/16/14	05/14/14	6/24/2014	07/16/14
Inlet	1105	777	294	510	388	998
Outlet	263	249	288	192	217	305
Soluble Reactive Phosphorous						
	02/26/14	03/17/14	04/16/14	05/14/14	6/24/2014	07/16/14
Inlet	659	537	26	72	119	885
Outlet	254	157	29	60	79	168
Total Nitrogen						
	02/26/14	03/17/14	04/16/14	05/14/14	6/24/2014	07/16/14
Inlet	831	570	426	379	376	676
Outlet	335	340	620	870	776	612
Ammonia						
	02/26/14	03/17/14	04/16/14	05/14/14	6/24/2014	07/16/14
Inlet	5	28	6	76	76	42
Outlet	29	29	15	48	33	39
Nitrates/Nitrites						
	02/26/14	03/17/14	04/16/14	05/14/14	6/24/2014	07/16/14
Inlet	57	59	41	66	65	82
Outlet	24	18	79	44	22	37
Organic Nitrogen						
	02/26/14	03/17/14	04/16/14	05/14/14	6/24/2014	07/16/14
Inlet	774	483	323	237	235	552
Outlet	282	293	576	788	721	536
Notes:						
All concentrations are in µg/L						
(green)	*: non-storm event*					
(blue)	*: storm event*					

Table 15: Ruskin nutrient data

Ruskin						
Total Phosphorous						
	02/12/14	04/08/14	05/05/14	06/09/14	06/18/14	09/02/14
Inlet	144	90	120	136	53	109
Outlet	108	117	190	127	215	221
Soluble Reactive Phosphorous						
	02/12/14	04/08/14	05/05/14	06/09/14	06/18/14	09/02/14
Inlet	71	16	13	31	9	8
Outlet	50	12	9	39	6	56
Total Nitrogen						
	02/12/14	04/08/14	05/05/14	06/09/14	06/18/14	09/02/14
Inlet	567	612	810	507	422	1480
Outlet	289	824	800	611	664	223
Ammonia						
	02/12/14	04/08/14	05/05/14	06/09/14	06/18/14	09/02/14
Inlet	118	184	18	11	6	40
Outlet	122	86	12	3	12	62
Nitrates/Nitrites						
	02/12/14	04/08/14	05/05/14	06/09/14	06/18/14	09/02/14
Inlet	56	23	37	56	27	3
Outlet	52	17	70	15	44	7
Organic Nitrogen						
	02/12/14	04/08/14	05/05/14	06/09/14	06/18/14	09/02/14
Inlet	393	355	755	440	389	1437
Outlet	115	723	718	593	608	154
Notes:						
All concentrations are in µg/L						
(green)	*: non-storm event*					
(blue)	*: storm event*					

Table 16: Clearwater nutrient data

Clearwater						
Total Phosphorous						
	02/26/14	03/12/14	04/11/14	05/15/14	06/18/14	11/08/14
Inlet	286	77	306	488	204	
Outlet	65	210	62	143	119	
Soluble Reactive Phosphorous						
	02/26/14	03/12/14	04/11/14	05/15/14	06/18/14	11/08/14
Inlet	242	18	142	168	82	
Outlet	2	110	12	8	14	
Total Nitrogen						
	02/26/14	03/12/14	04/11/14	05/15/14	06/18/14	11/08/14
Inlet	924	1198	818	874	614	
Outlet	268	1070	570	1052	757	
Ammonia						
	02/26/14	03/12/14	04/11/14	05/15/14	06/18/14	11/08/14
Inlet	5	113	18	25	40	
Outlet	5	42	18	62	24	
Nitrates/Nitrites						
	02/26/14	03/12/14	04/11/14	05/15/14	06/18/14	11/08/14
Inlet	375	196	249	113	100	
Outlet	133	14	13	8	9	
Organic Nitrogen						
	02/26/14	03/12/14	04/11/14	05/15/14	06/18/14	11/08/14
Inlet	549	889	551	736	474	
Outlet	135	1014	539	982	724	
Notes:						
All concentrations are in µg/L						
(green)	*: non-storm event*					
(blue)	*: storm event*					

Table 17: East Palatka nutrient data

East Palatka						
Total Phosphorous						
	02/26/14	**04/15/14**	**06/05/14**	**6/18/204**	**07/30/14**	**08/21/14**
Inlet	41	91	45	114	74	65
Outlet	38	75	54	71	55	55
Precipitation						
Days last storm						
Soluble Reactive Phosphorous						
Inlet	14	73	32	16	10	3
Outlet	13	39	44	6	31	12
Total Nitrogen						
Inlet	321	512	606	612	892	772
Outlet	495	619	334	403	569	673
Ammonia						
Inlet	94	103	231	324	122	62
Outlet	33	82	35	108	33	47
Nitrates/Nitrites						
Inlet	51	95	71	118	5	9
Outlet	32	36	78	21	19	3
Organic Nitrogen						
Inlet	176	314	304	170	701	701
Outlet	430	501	221	274	623	623
Notes:						
All concentrations are in µg/L						
(green)	*: non-storm event*					
(blue)	*: storm event*					

Table 18: Zolfo Springs nutrient data

Zolfo Springs						
Total Phosphorous						
	02/13/14	**03/06/14**	**04/10/14**	**05/14/14**	**07/29/14**	**08/31/14**
Inlet	592	1258	648	1115	699	894
Outlet	1281	1113	424	413	455	623
Precipitation						
Days last storm						
Soluble Reactive Phosphorous						
Inlet	412	967	466	443	306	762
Outlet	864	708	388	308	263	601
Total Nitrogen						
Inlet	652	816	787	849	726	636
Outlet	751	1794	845	897	598	695
Ammonia						
Inlet	156	176	59	24	81	64
Outlet	120	47	11	21	69	59
Nitrates/Nitrites						
Inlet	70	33	52	14	193	60
Outlet	21	9	10	35	32	2
Organic Nitrogen						
Inlet	426	607	676	811	452	512
Outlet	610	1738	824	841	497	634
Notes:						
All concentrations are in µg/L						
(green)	*: non-storm event*					
(blue)	*: storm event*					

Table 19: Orlando nutrient data

Orlando						
Total Phosphorous						
	02/12/14	**03/17/14**	**04/17/14**	**06/01/14**	**07/03/14**	**07/30/14**
Inlet	96	168	130	102	31	36
Outlet	92	31	99	54	54	34
Precipitation	0.69	0.89	0			
Days last storm (>0.2)	0	0	8			
Soluble Reactive Phosphorous						
Inlet	27	46	40	41	8	6
Outlet	38	20	60	39	24	6
Total Nitrogen						
Inlet	763	1981	300	592	220	188
Outlet	576	266	331	384	128	112
Ammonia						
Inlet	286	391	26	6	51	15
Outlet	128	25	5	24	57	18
Nitrates/Nitrites						
Inlet	207	442	200	148	123	42
Outlet	96	14	84	46	4	7
Organic Nitrogen						
Inlet	270	1148	74	438	46	131
Outlet	352	227	244	314	67	87
Notes:						
All concentrations are in μg/L						
(green)	*: non-storm event*					
(blue)	*: storm event*					

Table 20: Royal Palm TSS data

Royal Palm Estates				
Total Suspended Solids				
Date	**6/2/2014**	**6/13/2014**	**7/6/2014**	**9/26/2014**
Inlet #1	1.6	1.4	1.0	
Inlet #2	1.0	1.2	1.0	
Outlet	1.6	1.8	2.6	
Notes:				
All concentrations are in mg/L				
(green)	*: non-storm event*			
(blue)	*: storm event*			

Appendix B: Sediment Sampling Data

Table 21: Gainesville sediment data

Total Phosphorous						
	02/26/14	03/17/14	04/16/14	05/14/14	06/24/14	07/16/14
Inlet	~	1.14	2.03	0.91	2.6	2.06
Outlet	~	0.82	0.73	1.1	1.65	8.16
Soluble Reactive Phosphorous						
	02/26/14	03/17/14	04/16/14	05/14/14	06/24/14	07/16/14
Inlet	~	0.36	0.41	0.18		
Outlet	~	0.91	0.27	0.27		
Total Nitrogen						
	02/26/14	03/17/14	04/16/14	05/14/14	06/24/14	07/16/14
Inlet	~	6.41	1.84	2.53	2.09	5.29
Outlet	~	21.4	4.81	2.66	2.66	6.64
Ammonia						
	02/26/14	03/17/14	04/16/14	05/14/14	06/24/14	07/16/14
Inlet	~	0.53	0.1	0.01		
Outlet	~	5.41	0.14	0.04		
Nitrates/Nitrites						
	02/26/14	03/17/14	04/16/14	05/14/14	06/24/14	07/16/14
Inlet	~	1.12	0.2	0.45		
Outlet	~	0.17	0.17	0.37		
Organic Nitrogen						
	02/26/14	03/17/14	04/16/14	05/14/14	06/24/14	07/16/14
Inlet	~	4.75	4.54	2.07		
Outlet	~	15.8	4.5	2.25		
Notes:						
All concentrations are in µg/L						
	: non-storm event					
	: storm event					

Table 22: Ruskin sediment data

Total Phosphorous						
	02/12/14	04/08/14	05/05/14	06/09/14	06/18/14	09/02/14
Inlet	0.2	1.91	0.13	0.11	0.28	1.29
Outlet	0.13	1.79	0.3	0.28	0.26	2.9
Soluble Reactive Phosphorous						
	02/12/14	04/08/14	05/05/14	06/09/14	06/18/14	09/02/14
Inlet	0.12	1.68	0.01			
Outlet	0.005	2.15	0.09			
Total Nitrogen						
	02/12/14	04/08/14	05/05/14	06/09/14	06/18/14	09/02/14
Inlet	4.69	9.94	2.92	1.59	2.31	32.59
Outlet	18.9	13.9	6.27	1.67	3.48	13.49
Ammonia						
	02/12/14	04/08/14	05/05/14	06/09/14	06/18/14	09/02/14
Inlet	0.89	0.19	0.07			
Outlet	10.6	5.18	0.01			
Nitrates/Nitrites						
	02/12/14	04/08/14	05/05/14	06/09/14	06/18/14	09/02/14
Inlet	2.4	1.71	0.56			
Outlet	7.82	1.92	0.29			
Organic Nitrogen						
	02/12/14	04/08/14	05/05/14	06/09/14	06/18/14	09/02/14
Inlet	1.4	8.03	2.28			
Outlet	0.49	6.78	5.97			
Notes:						
All concentrations are in µg/L						
	: non-storm event					
	: storm event					

Table 23: Clearwater sediment data

Total Phosphorous						
	02/26/14	03/17/14	04/16/14	05/14/14	06/18/14	11/08/14
Inlet	0.12	0.69	0.6	0.47	0.21	0.4
Outlet	0.32	0.17	0.43	0.26	0.27	1.02
Soluble Reactive Phosphorous						
	02/26/14	03/17/14	04/16/14	05/14/14	06/18/14	11/08/14
Inlet	0.02	0.005	0.1	0.1		
Outlet	0.05	0.11	0.06	0.05		
Total Nitrogen						
	02/26/14	03/17/14	04/16/14	05/14/14	06/18/14	11/08/14
Inlet	4.45	8.45	16.7	12.08	5.03	1.37
Outlet	4.32	7.4	4.07	5.04	2.81	29.71
Ammonia						
	02/26/14	03/17/14	04/16/14	05/14/14	06/18/14	11/08/14
Inlet	0.06	0.75	9.23	4.57		
Outlet	0.07	0.93	0.37	2.24		
Nitrates/Nitrites						
	02/26/14	03/17/14	04/16/14	05/14/14	06/18/14	11/08/14
Inlet	1.53	0.26	0.42	0.06		
Outlet	0.67	4.35	0.23	0.1		
Organic Nitrogen						
	02/26/14	03/17/14	04/16/14	05/14/14	06/18/14	11/08/14
Inlet	2.86	7.43	7.07	7.45		
Outlet	3.58	2.13	3.47	2.69		
Notes:						
All concentrations are in µg/L						
(green)	*: non-storm event*					
(cyan)	*: storm event*					

Note: green-shaded dates (02/26/14, 04/16/14, 05/14/14) are non-storm events; cyan-shaded dates (03/17/14, 06/18/14, 11/08/14) are storm events.