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Comparison of a modified and traditional rapid infiltration basin for treatment and control of nutrients in wastewater effluent

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COMPARISON OF A MODIFIED AND TRADITIONAL RAPID INFILTRATION BASIN FOR TREATMENT AND CONTROL OF NUTRIENTS IN WASTEWATER EFFLUENT

by

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ABSTRACT

Rapid infiltration basins (RIB) have been historically used in Florida for groundwater recharge, effluent disposal, or a combination of both. However, this technique has proven ineffective in providing nitrogen control unless the RIB is modified in some manner. In this study, a traditional RIB was compared to a modified RIB constructed with manufactured biosorption activated media (BAM) to evaluate nitrate removal from reclaimed water. The RIBs are used for reclaimed and excess storm water disposal. Few, if any, studies have been published where BAM-modified RIBs have been used for this purpose. In this work, a mixture of clay, tire crumb, and sand (CTS) was selected to serve as the BAM material (Bold and Gold™ CTS media). Each RIB was constructed with two feet of either sand or BAM, covering more than 43,600 square feet of surface area. The BAM-modified RIB had an initial 90 pounds per cubic-foot in-place density, and the density of the control RIB approximated about 94 pounds per cubic-foot. Over an eight-month period, loadings to the BAM RIB and control RIB approximated 5.4 million gallons (MG) per acre each. Water samples, collected from lysimeters installed below the 2-foot of sand or BAM materials, were gathered monthly during 2017 (except for September and October due to the impacts of hurricane Irma); these samples were analyzed for water quality to determine nitrate removal. Soil moisture and weather data were also collected over the study period. This study demonstrated the nitrate removal effectiveness of a field-scale BAM-modified RIB as compared to a traditional field-scale sand-based RIB. Results suggest that BAM removed 30 percent more nitrates than the Control (78% and 47%, respectively) under the conditions of the study. Furthermore, BAM removed higher percentages of TN (31%) and TP (62%) than the Control (12% and 28%, respectively).

I dedicate this thesis to learning about and understanding our world better. This would not have been possible without family and friends who love me dearly. You are loved in return, for infinity and beyond.

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LIST OF ABBREVIATIONS

BAM	Biosorption Activated Media
B&G	Bold and Gold™
BNR	Biological Nutrient Removal
CF	Cubic Foot
COD	Carbonaceous Oxygen Demand
DN	Dissolved Nitrogen
DNRA	Dissimilatory Nitrate Reduction to Ammonium
DP	Dissolved Phosphorous
CY	Cubic Yard
FDEP	Florida Department of Environmental Protection
G.W.	Groundwater
LCL	Lower Control Limit
LWL	Lower Warning Limit
MGD	Million Gallons per Day
NOx	Nitrate and Nitrite Combined
NPDOC	Non-pergable Dissolved Organic Carbon
NRC	National Research Council

QAPP	Quality Assurance Project Plan
RIB	Rapid Infiltration Basin
SAT	Soil Aquifer Treatment
SJRWMD	St. Johns River Water Management District
TKN	Total Kjeldahl Nitrogen
TMDL	Total Maximum Daily Loads
TN	Total Nitrogen
TOC	Total Organic Carbon
TP	Total Phosphorus
UCF	University of Central Florida
UCL	Upper Control Limit
USDA	United States Department of Agriculture
USEPA	United States Environmental Protection Agency
UWL	Upper Warning Limit
WEF	Water Environment Federation
WWE	Wastewater Effluent
WRF	Water Reclamation Facility

CHAPTER 1: INTRODUCTION

Background

Rapid infiltration basins (RIB) have been historically used in Florida for groundwater recharge, effluent disposal, or a combination of both. RIBs provide as effective way to recharge groundwater especially in sandy environments. Sand has a higher percolation rate than silt or clay (USDA soil classification), allowing water to permeate more quickly through the soil. Utilizing a RIB for effluent disposal adds one more consideration to the infiltration process. When considering only groundwater recharge, quantity is the focus not quality. The amount of water entering the ground by volume is the main goal of RIBs. Effluent disposal of treated domestic wastewater adds another layer to the goal of groundwater recharge, water quality. To consider water quality entering the groundwater additional understanding and analysis must occur. The quality of the treated wastewater effluent entering the RIBs depends upon the treatment process. The water quality being fed to the RIB plays a role in the quality entering the ground, based solely on concentration levels. Furthermore, the type of sediment in RIBs affects the water quality that eventually enters the groundwater system (surficial and deeper). These are the main aspect of many in RIB systems which can play a role in the quality of water reaching the groundwater system.

Nutrient loadings in wastewater effluent, particularly nitrogen species, have been a concern throughout Florida and is one of the more common constituents as determined by the State that impact springsheds (Holland and Bridger, 2014). Excessive inputs of nitrogen species can be detrimental to many freshwater systems. According to the U.S. Environmental Protection Agency (EPA), (2013), the ammonia content in effluent ranges from 0.1 to 10 mg/L-N and has been shown to impact fish mortality and reproductive health (EPA, 1993). Nitrates may also pose a threat to human health being capable of binding with hemoglobin in infant's red blood cells, causing oxygen deficiency known as Methemoglobinemia, also known as 'blue baby syndrome" (WEF, 2005).

Traditional RIBs have proven ineffective in providing nitrogen control unless the RIB is modified in some manner. In this study, a traditional RIB is compared with a modified RIB that is constructed with manufactured biosorption activated media (BAM) to evaluate nitrate removal from reclaimed water.

Project Overview

In November 2016, the University of Central Florida (UCF) received a grant through the Florida Department of Environmental Protection's Division of Water Restoration Assistance program. UCF was retained to conduct a study to monitor and evaluate the use of a BAM-modified RIB in comparison with a traditional RIB for the purpose of nitrate-nitrogen removal from reclaimed wastewater prior to mixing with groundwater. The project scope (FDEP NS003) contained three components: biological assay, soil characterization and water chemistry. This master's thesis reports on a study that focused on the water quality portion of the grant.

Additionally, the FDEP grant required that a quality assurance project plan (QAPP) be prepared that provided details related to the collection and analysis of water samples for chemical analysis, prior to project commencement (January 2017). In order to implement the study, one of the City of Deland's RIBs was bifurcated with a sediment berm where one side was modified to contain a two-foot deep layer of BAM for the amended soil mix. This is discussed further in the methods section of this thesis document.

Site Location Geology and Regulations

The study RIB site is located in the City of Deland, Florida, near the bent oaks neighborhood (29°0'18.87"N, 81°17'22.22"W). This study site location is important with respect to rapid infiltration of water due to the unique geology found in this region of Florida. The rapid infiltration basins lie in a karst-geological region in Volusia County, Florida. Karst geology is known to be a fast and direct connection from surface-surficial groundwater to deeper groundwater systems. More information on the geology within this specific region of Volusia County can be found in Toth and Katz (2006) and from the St. Johns River Watershed Management District, SJRWMD (2011). Due to the increased infiltration of surface waters to ground water, water quality of the surface water requires more consideration than otherwise. A RIB's main purpose is for fast infiltration of impaired waters into the ground. This additional limited residence time through the initial soil column greatly hinders potential nutrient sorption, uptake or conversion. Placing a RIB in a region with karst geology requires more in-depth analysis of the loaded water's impact on the surrounding ground water system.

Due to increasing nutrient concentrations in water bodies across Florida, the Florida Department of Environmental Protection (FDEP) has developed Total Maximum Daily Load (TMDL) allotments for nutrient additions to the Florida water environment. Multiple studies and restoration activities are occurring in attempt to meet TMDL requirements. Volusia Blue Spring and its spring run lie in Middle St. Johns River Basin and have been marked as impaired with a TMDL created and reported on in 2014 (Holland and Bridger 2014). The TMDL for

Blue Spring focuses specifically on nitrate (Holland and Bridger 2014). The Blue Spring State Park, Orange City, Florida is approximately 5miles, as the crow flies, from the City of DeLand's RIB located in the Bent Oaks neighborhood, DeLand, Florida, Figure 1. The RIBs fall within the springshed boundaries (Holland and Bridger 2014). Due to the geology of the area and the hydrological connections of the RIBs to water bodies with designated TMDLs, the water quality entering the ground in the RIBs was of concern to the City and others.

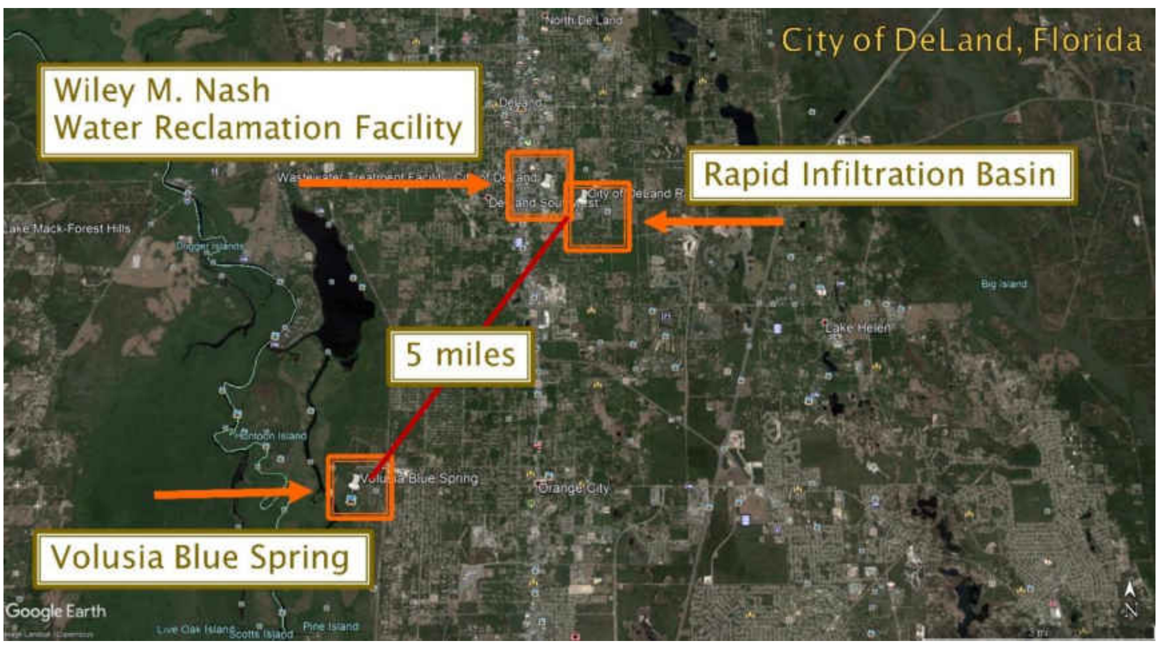

Figure 1. Location of the City of DeLand's WRF and RIBs in Volusia County, Florida. Adapted from Google Earth Image (March 2017) accessed April 2018

Wastewater Facility – Wiley Nash Reclamation Facility

The reclaimed water, for this study, has been provided by the City of DeLand's Wiley M. Nash Water Reclamation Facility, DeLand, Florida. The water source entering the RIBs, for this study, has been designated into two categories: (1) reclaimed wastewater effluent; and (2) stormwater. The reclaimed effluent water used in this study comes from the City of DeLand's Wiley M. Nash Water Reclamation Facility (WRF) located at the Water Utilities Department, 1101 S Amelia Ave, DeLand, FL 32724. The water that leaves the facility is a mixture of treated domestic wastewater and river water. Both of which have been filtered and chlorinated before being stored and distributed, as depicted in the WRF flow diagram Figure 2. The river water is used to supplement the reclaimed water when demands are high and supply is low, such as during the dry-drought season in Florida (approximately November – April).

The City's WRF was founded in 1978 with an initial design to achieve secondary treatment, to lower COD and nutrient levels. This facility was recently updated in design and process with improvement and expansions of the reuse and aeration facilities, with the support of a cost share grant from SJRWMD and FDEP. The facility currently has a traditional secondary wastewater treatment system for biological nutrient removal (BNR) composed of a carrousel oxidation ditch with automated pumps for dissolved oxygen (DO) control. The design capacity is for six million gallons per day (6 MGD) of average flow. Figure 2 displays the flow diagram of the WRF treatment process. The updates to the WRF concluded in February of 2017. Whereas, the study RIB, owed by the City, was altered over the summer of 2016 with the study commencement occurring January 2017. The basins utilized for this study have been employed by the City primarily to discharge excess reclaimed wastewater effluent, and as a means to prevent and Control storm water flooding in the surrounding areas.

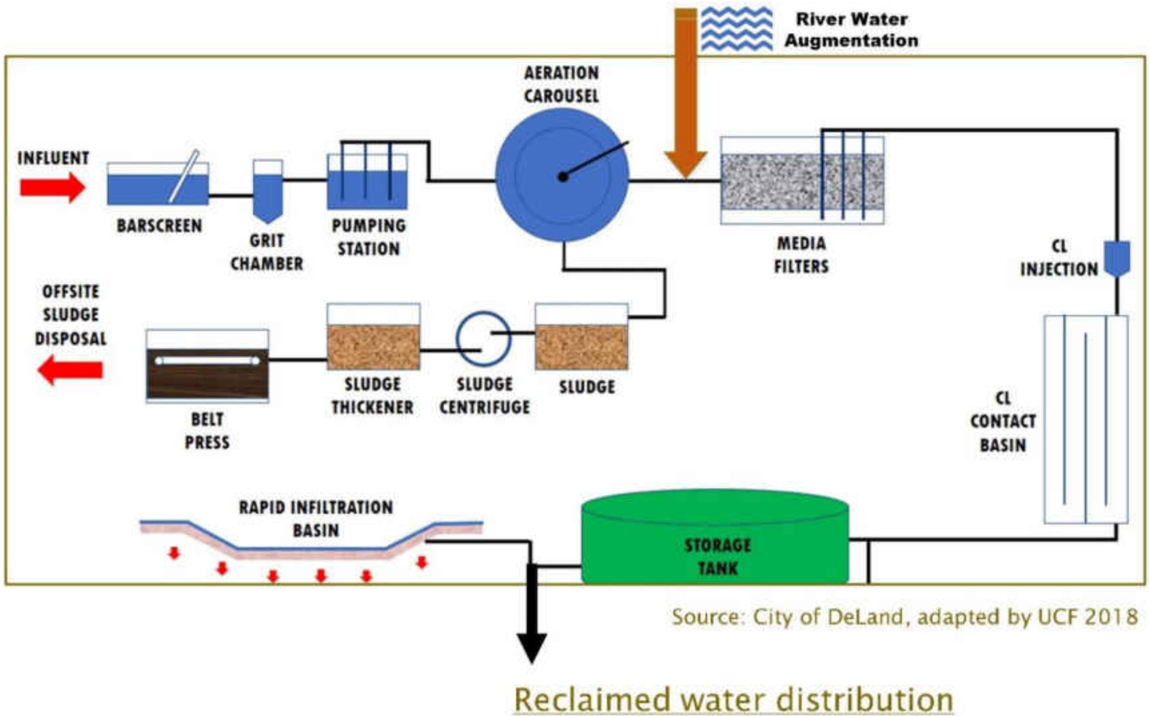

Figure 2. DeLand's Water Reclamation Facility Process Flow Diagram

Adapted from the City of DeLand, 2018.

Water Quality Study Objectives

A primary goal of this study was to compare the nitrate removal efficiency of a traditional RIB with an altered RIB. A quality assurance project plan (QAPP) was developed to accomplish this task, as required by the FDEP. The QAPP lays out the sampling and analysis plan for the purpose of monitoring the RIB effectiveness of being a buffer for groundwater protection from impaired waters. The plan includes water quantity and quality assessments, sediment characterization and weather monitoring. Samples collected from the input (mixture of reclaimed and storm water) and output (lysimeters) have been analyzed for the same chemistry: nitrate (as NOx), total nitrogen (TN, as the sum of TKN and NOx), total phosphorus (TP), organic carbon (as NPDOC), alkalinity (as $CaCO_3$), boron (as a tracer) and nitrogen isotope (15N). The chemical species focused on in this study are displayed in Figure 3, along with an overview of this study depicting a cross-section of the RIB designating the system boundary for the analysis of nutrient removal.

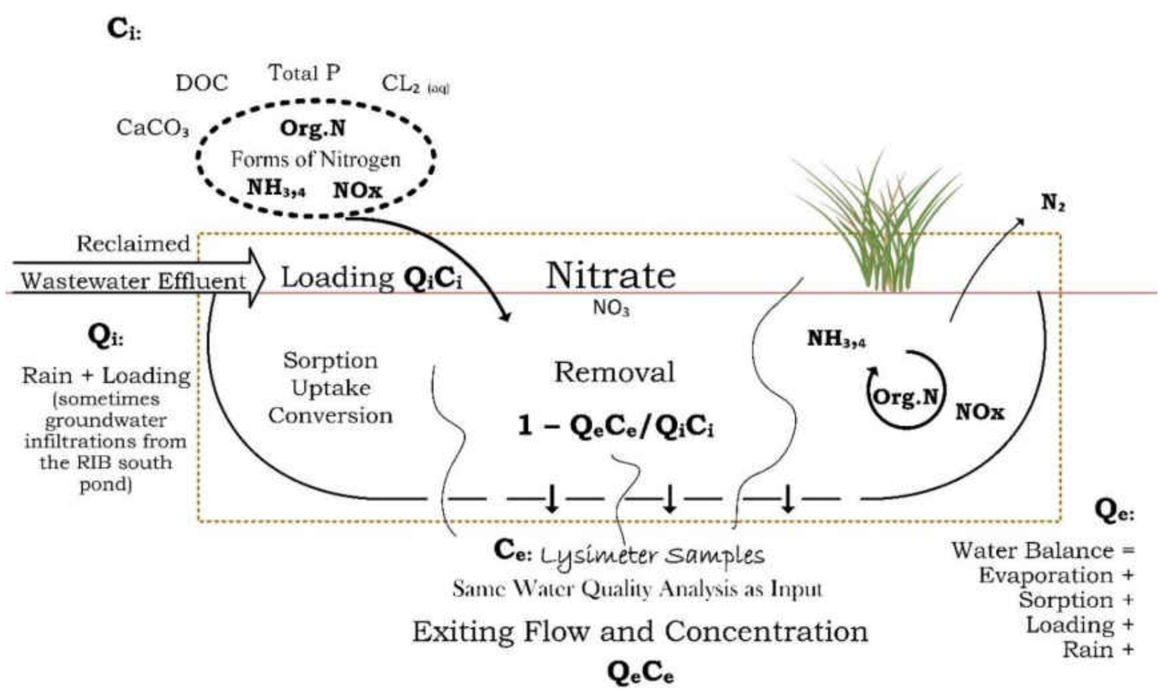

Figure 3. Nitrate Removal Study Overview and Boundaries.

Study boundary indicated by gold dashed-line rectangular box. Grass Stencil from University of Maryland Image Library <http://ian.umces.edu/imagelibrary/displayimage-topd--64-4614.html>.

The mechanisms of nutrient removal that can occur during the water's journey through the treatment media are uptake, sorption and transformation. Nutrient uptake is conducted biologically via plants, microorganisms or other auto- and mixo-trophic life. This form of removal is often temporary as most life goes through cycles of growth and decay. Seasonally, nutrients are taken up and released by this biota. Sorption is another mechanism of removal via retention on the soil media. Phosphorus is known to readily attach to soils via sorption and can accumulate to the point of soil-sorption capacity where removal no-longer occurs. Nitrogen, however, does not experience sorption onto soils to the same extent as phosphorus does; therefore, this mechanism is often assumed negligible. The mechanism for nitrogen removal which targets the nitrate species is transformation. Denitrification is the transformation, biologically, of nitrates to nitrogen gas. This conversion would decrease the total nitrogen mass loading to the groundwater without the potential of accumulation and re-release. This study was performed in order to determine if BAM, a material designed to be biologically active for the purpose of denitrification, could maintain an environment, at field scale and under utility application, to convert nitrates to nitrogen gas.

The other forms of nitrogen transformation exist. The other process that transforms inorganic nitrogen to a gas state is the annamox process by which nitrites are used for the electron acceptor to oxidize ammonium (Bernard et al. 2015). This process may also be occurring in the study, however the data displayed here in is in the form of combined nitrate and nitrite (NO_x), and total Kjeldahl nitrogen (TKN), thus providing the ability to distinguish between nitrate removal via the gas phase or to another dissolved nitrogen phase (DN). TKN is the sum of dissolved organic nitrogen and ammonia/ammonium present. The nitrogen cycle and chemical process is conceptually displayed in Figure 4. Another form of nitrogen transformation that can remove nitrates without removing total nitrogen form the system is dissimilatory nitrate reduction to ammonium (DNRA). This process will also be under observation and will be suggested if TKN increases in the system and if the total nitrogen removal efficiencies are less than the nitrate removal efficiencies.

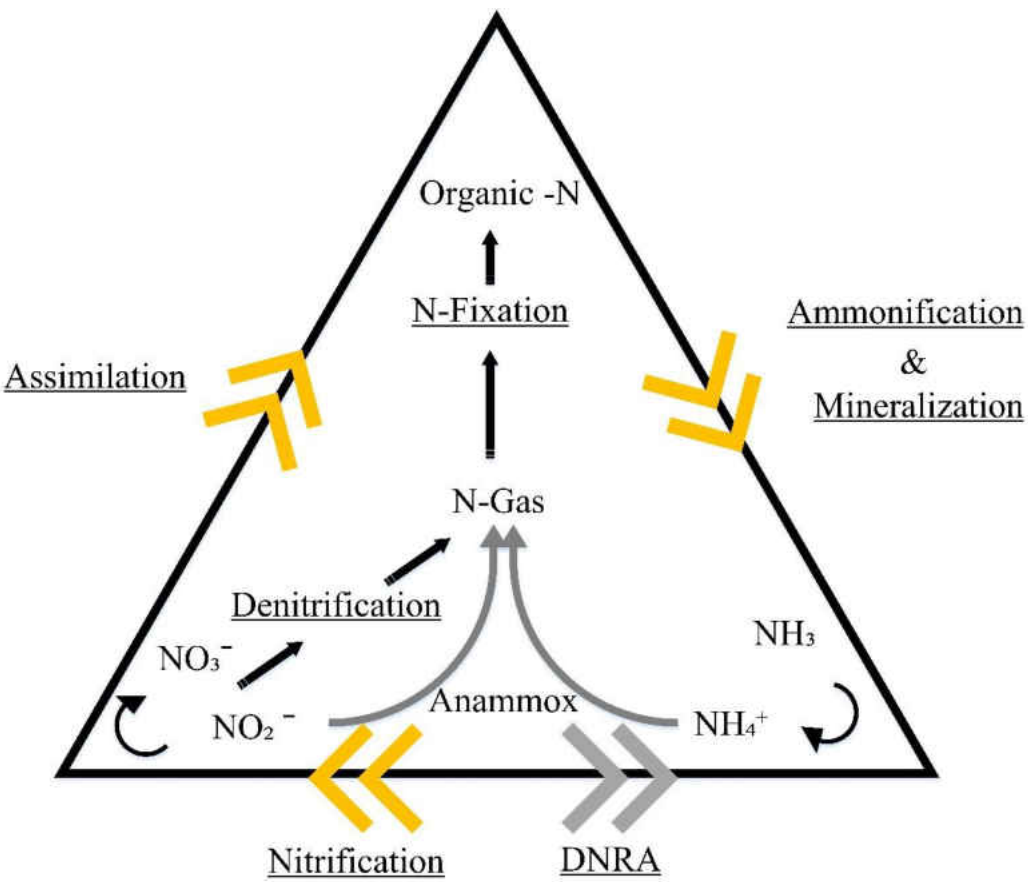

Figure 4. Nitrogen Cycle.

CHAPTER 2: LITERATURE REVIEW

Land Treatment by Rapid Infiltration Basins

For more than a century, rapid infiltration basins (RIBs) have treated wastewater effluent using the soil ecosystem (EPA, 2003). Wastewater is applied to shallow RIBs that have been constructed in areas where porous soils extend deep into the ground or with soils that are highly porous and permeable by water that extend deep into the ground. Treatment mechanisms, as the wastewater moves through the soil matrix, have been shown to be a combination of filtration, adsorption, ion exchange, precipitation, and microbial action. However, soil depth, soil permeability, and depth to groundwater are the more important factors in site evaluation, according to Crites and colleagues (2000).

The use of RIBs is often employed for secondary and tertiary treatment of wastewater, where the purpose of secondary treatment for ground water recharge is referred to as soil aquifer treatment (SAT). While reviewing the literature only a few studies were found that have investigated nitrogen removal by comparing inflow and outflow chemistries. Idelovitch and colleagues (2003) evaluated SAT performance by comparing the difference between the inflow reclaimed water nitrogen content and the outflow at an observation well. The study reported on the 25-year and 15-year use of two different infiltration basin zone recovery wells for treatment of municipal effluent to determine the relative removal efficiencies for a variety of water quality parameters. In general, the average relative removal efficiency for total nitrogen and total phosphorous was 57 percent and 99 percent, respectively. In another study by Le Corre and coworkers (2012), the effective treatment of wastewater plant effluent using managed infiltration basins for aquifer recharge has been shown to be an environmentalfriendly multi-contaminant removal system for nitrogen, organic matter, pathogens and a number of other micropollutants. Similar work by Icekson-Tal and coworkers (2013) revealed that different soil types retard the various forms of nitrogen differently as the effluent moves through the soil. SAT provides a simple method for the enhanced treatment of wastewater reclamation/reuse effluents including indirect potable reuse through use of environmental buffers (Gerrity et al., 2013).

RIBs are highly dependent on the soil and hydrogeological characteristics at a particular site. Due to this, the EPA recommends that the soil have sufficient hydraulic capacity to allow wastewater to percolate through the underlying coarse soil basin bottom and covering media. According to USEPA (2003), for treatment to be accomplished, the top 1.5-3 m (5-10 ft) of soil beneath the basin should be unsaturated at the start of the effluent loading cycle. Also, it was noted that the slope, hydraulic gradient and subsurface conditions were required to allow the percolated water to flow away from the site, so flooding does not occur.

Andres and Sims (2013) conducted a field study on the effects of RIBs on nitrogen and phosphorous content in soils and groundwater in Delaware. This study showed that high hydraulic loads led to flow velocities that did not allow sufficient contact times for effective nitrogen and phosphorous removals. These field-scale findings indicated the need for better site characterization and facility designs to reduce and monitor contaminant loss from RIBS in similar settings. Due to the outcome of this study, one may assume that many RIBs used for stormwater treatment do not provide adequate nitrogen removal. For example, Birch, Fazeli and Matthai (2005) showed that a RIB used for stormwater infiltration of urban stormwater in a Sydney (Australia) suburb was ineffective for total nitrogen treatment. Although the stormwater infiltration basin was ineffective in reducing the concentrations of total nitrogen, the mean removal efficiency for the concentrations of TP and TKN was 51% and 65%, respectively.

According to the National Research Council (2012), water reuse is growing in the United States, especially in the semi-arid regions. Florida is leading the nation, reusing close to one billion cubic meters per year to conserve fresh water supplies (FDEP, 2012). As water reuse increases across the United States, concern with surface water impairment caused by nutrient loading has also increased (Smith, Tilman and Nekola, 1999). These concerns regarding increased nitrogen levels in aquifers in proximity of RIBs prompted modifications to the general system design, such as inclusion of underdrains or wells, or in the case of the current research reported herein, the inclusion of activated media designed to promote microbiological nitrification and denitrification processes.

Biosorption Activated Media Modified Stormwater Infiltration Basins

Most of the research that has historically been conducted using BAM has centered on the treatment of stormwater by modifying infiltration basins or swales (Chang, Wanielista and Henderson, 2010; O'Reilly, Chang and Wanielista, 2012a). Swales are a designed stormwater Control technology with a life expectancy greater than 20 years and are used for nutrient, heavy metals and total solids removal. Swales are sloped land areas that contain vegetation or other media sufficient for pollutant removal. To reduce pollutants, swales function by two principles: physical filtration and infiltration (Wanielista et al., 1992). Swales have been in use for some time; for example, in 1996, France (2002) documented the installation of a two-thousand-foot-long swale to protect Willamette River (Portland, Oregon) from stormwater runoff. That project resulted in 50% total suspended solid (TSS) reduction.

BAM modified swales have been shown to be a feasible treatment method for removing phosphorus from highway runoff (Hood, Chopra and Wanielista, 2013). It was documented that BAM modified swales reduce total phosphorus by 78% than the traditional sandy soil swale systems commonly in practice. A BAM modified basin for stormwater treatment was compared with a native sandy soil for nutrient removal (O'Reilly et al., 2012a). Additionally, BAM was used in a full-scale stormwater infiltration basin and compared to a normal swale using sandy soil for phosphorus removal. Results indicated that BAM provided an increase in the moisture content by 25 percent over that of the previously held ambient soils, similar to Florida sandy soils. The study also showed an increase in denitrification, documenting an average of 80% and 12% removal of TP and phosphate (PO_4), respectively (O'Reilly et al., 2012b).

Xuan and coworkers (2013) mathematically modeled a modified stormwater infiltration basin in north-central Florida with BAM using collected hydrologic and water quality parameters before and after construction for a period of approximately three years. It was determined that denitrification accounted for about one third of the total dissolved nitrogen mass loss from the input source water. Although there exists a significant amount of research that has been conducted related to the use of RIBs as a SAT method for stormwater, there is far less published research regarding the use of BAM-modified RIBs for the treatment of wastewater effluent (reclaimed water).

BAM and alum sludge have been compared for phosphorus removal from water, as phosphorus is known to sorb to various compounds containing aluminum, whether that alum be attached to soils or in water. Duranceau and Biscardi (2014) showed that unlike prior research that focused on using adsorbents to treat wastewater discharges, urban stormwater, or agricultural runoff, BAM and alum sludge were compared for their ability to remove phosphorous directly from river water. Alum sludge and BAM were evaluated by packing 10% of the adsorbent media with 90% sand (by volume) into 15-mm-diameter mini-columns that were fed surface water collected from the Econlockhatchee River near Orlando, FL. The average percent removal of phosphorous was 51% for the alum sludge column and 61% for the BAM column. The adsorptive capacity of the columns was not exhausted after more than 1,300 hrs (over 54 days) of continuous operation, indicating that alum sludge and BAM could be used to treat river water directly. In the current research, BAM was further investigated to treat river water or a mixture of wastewater effluent and river water for removal efficiencies of RIBs.

BAM Composition for this Study

Several BMPs technologies have been developed over the years to improve nutrient contamination Control using BAM (Wanielista et al., 2008). The BAM used in this study is composed mainly of green and recyclable material that is accessible on the market as Bold&Gold™. A few different patents exist for this Bold and Gold™ media which is designated under: *green sorption material mixes for water treatment*, by Dr. Wanielista and others (Patent No. US 8002984 B1). These engineered medias are commonly used for stormwater treatment. Bold&Gold™ was developed by the stormwater academy at University of Central Florida (UCF), Orlando, Florida (Wanielista et al., 2008). The BAM in this study is made up of clay (alum), tire crumb and sand, designated as CTS, one type of Bold and Gold™. The CTS type of Bold and Gold™ media is further discerned by a number 12 or 24 referring to media depth in inches (1 to 2 feet deep). The focus of this thesis project was to monitor the effectiveness of the CTS media over a 2-foot vertical depth (24 inches) for nitrogen and phosphorus removal, highlighted in Table 1.

The BAM is pre-mixed before installation and therefore more homogeneous than natural ambient soils. Thus, removal across an area for nitrate and nitrite species (NOx) using a recently placed material should be relatively more consistent than in natural soils. Wanielista and colleagues (2012) used Bold and Gold™ to achieve up to 47% nitrogen and up to 87% phosphorous from stormwater found in wet detention ponds. A presentation by Mullon, L. G. (2017) and another by Wanielista, Spirio and Earp (2017) compared different BAM options on the market with Bold and Gold™ variations being the most prevalent BAM. The list provides material composition and projected removal efficiencies, Table 1.

Table 1. BAM Media and Projected Removals

Description of Media:		Projected Treatment Performance Removal Efficiencies (%)			Typical Filtration
Media Name	**Material**	**TSS**	**TN**	**TP**	**Rate (in/hr)**
B&G OTE	organics, tire chips, expanded clay	60	45	45	96
B&G ECT3	tire chips, expanded clay	60	45	45	96
B&G ECT	tire chips, expanded clay	70	55	65	96
SAT	sand	85	30	45	2
B&G CTS 12	clay, tire crumb, sand, topsoil	90	60	90	1
B&G CTS 24	clay, tire crumb, sand, topsoil	95	75	95	1

A description sheet of the Bold and Gold™ CTS and other Bold and Gold™ options of the BAM can also be found on the Environmental Conservation Solutions, LLC (Apopka, Florida, 2346 Vulcan Rd, 32703) < https://ecs-water.com/ >. The BAM used in this study is based on other formulations used for stormwater treatment (Chang, 2011, O'Reilly, 2012, Wanielista, 2008). This is a sorption mineral mix that does not decay over time. Numerous different component mixtures have been tested to achieve optimal removal of a variety of pollutants in a variety of settings. This BAM was specifically formulated to remove nitrates, the primary component of nitrogen from the WRF at DeLand. Other formulations to remove the various species of nitrogen are available. Note that this mix requires an anoxic condition to remove nitrates and thus the mix relies on retaining an elevated residual moisture content. Additionally, more removal values are listed for these BAM media from stormwater studies in Table 2.

Table 2. BAM Mixes and Observed Removals.

BAM mixes	TN removal %	TP removal %
Bold and Gold™ ECT	55	65
Bold and Gold™ OTE	45	45
Bold and Gold™ ECT3	45	45
Bold and Gold™ CTS12	60	90
Bold and Gold™ CTS24	75	95
SAT	30	45

Adapted from Wanielista, Spirio and Earp (2017)

CHAPTER 3: METHODOLOGY

The goal of this study is to compare the nitrate removal efficiency of a traditional RIB with an altered RIB. To determine nutrient removal quantities a mass balance has been employed. A mass balance requires nutrient concentrations from water samples entering and leaving the RIB system. The *In* is the reclaimed water designated as impaired water inputs to the RIB, that occur on reclaimed loading events, and the *Out* samples are waters collected after the impaired water runs through the designated two-foot soil column of BAM (altered media) or ambient sandy-soil (Control). The input water was supplied by the city of DeLand from the WRF and pumped to the RIBs from the reclaimed water storage tank. The out samples are collected from lysimeters located under the two-foot layer of treatment media, with the top inlet of the bucket placed at the interface of the study treatment media (2 ft below soil-air interface) and the ambient ground soil.

Mass Balance

The general, basic mass balance, displayed in Eq. 1, is the basis for this research study on nutrient removals. The removal equation, Eq. 2 utilized in this study is a combination of the mass balance equation and an assumption that inflow is equivalent to the outflow of water (no change in flow assumption). The system boundary for the mass balance and removal equations can be seen in the Figure 4, presented in the introduction, designated by the gold dashed-line box. The no change in flow assumption alters the mass removal equation, Eq. 3, to a concentration-based removal efficiency, Eq. 4. The following equations are the mathematical basis for this study.

Basic Mass Balance

$$Accumulation = In - Out + Generation \quad (1)$$

Removal Equations

$$Removal = Out - In \quad (2)$$

Mass Removal

$$Removal\ Efficiency = \frac{Mass\ IN\ (Q_i C_i) - Mass\ OUT\ (Q_e C_e)}{Total\ Mass\ Loaded\ IN\ (Q_i C_i)} \quad (3)$$

Simplified Concentration Removal

$$Removal\ Efficiency = 1 - \frac{Output\ (C_e)}{Input\ (C_i)} \quad (4)$$

There were three optional layouts for this study. Option 1: removal based on concentration, 2: removal based on mass by an addition of a water balance, 3: the RIB system modeled using the HYDRUS software for water infiltration, nutrient dynamics and removal predictions based on soil moisture readings confirmed with infield data. On short time scale, the assumption that there is no change in water flow entering and leaving the RIB is not the best representation of the system (option 1). However, due to time, data collection and financial constraints experienced over this project, option # 1 is presented on in this document. The assumption that the water flow into the RIB is equivalent to the flow out is accurate within reason under the conditions of this study.

Study Site-Setup (RIB)

The rapid infiltration basin (RIB) utilized in this study is owned and operated by the City of DeLand, located at (29°0'18.87"N, 81°17'22.22"W). This location contains two large basins, the North – study basin and the South – back up storage basin. The RIBs can be conceptually thought of as large holes in the ground, or basins, as the top of the bank is at the surrounding ground elevation. The City uses these basins for disposing of excess reclaimed water and stormwater when demand is low and when there is a concern for flooding in the surrounding areas.

Over this study, the RIB is exposed to a mixture of various ratios of treated wastewater effluent and river water. This water is referred to herein as reclaimed water. The excess reclaimed water is pumped from the WRF holding tanks to the RIBs which are half a mile away, as the crow flies, Figure 5.

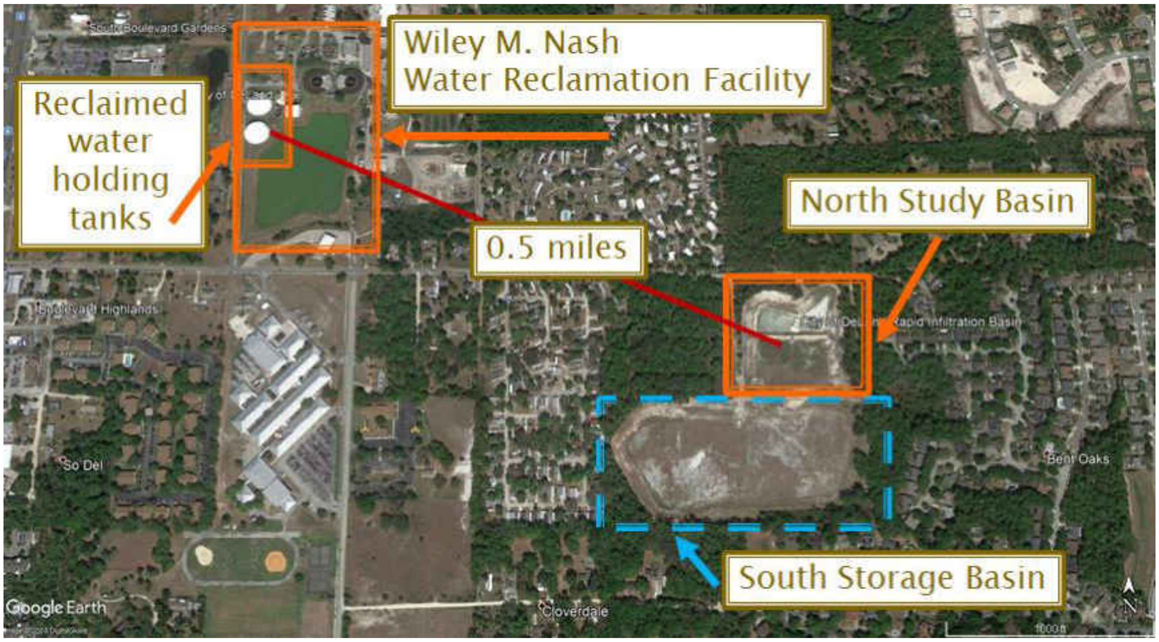

Figure 5. City of DeLand's Water Reclamation Facility and Rapid Infiltration Basin.

The reclaimed water was loaded into the study basin monthly, for ten (out of 12) loading events from January to August 2017 and then January to February 2018. The four-month break in loading occurred due to hurricane Irma's impact in September 2017. Stormwater from hurricane Irma was pumped from surrounding retention basins to the RIBs over a period of time after the impact. This stormwater was then utilized for a stormwater sample that took place in December 2017 and January 2018. The ten loading events and two stormwater sampling events result in the twelve sampling events required by the FDEP for this RIB monitoring project.

The basins used in this study, as flooded September 2017 (Google Earth imagery area calculations), individually cover an area of 4.7 acres for the north – study - basin and 11.6 acres for the south – storage - basin with a sediment constructed embankment 12-20 feet high. The north – study - basin has been transformed, for this project, into two sections by a 6-foot-high sediment berm diving the two study treatments: Traditional - Control pond (sand media) and Altered - treatment pond (BAM media), covering an un-flooded area of 1.8 and 0.9 acres, respectively.

The north pond of the north study basin contains three lysimeters space across the entire pond designated at L1-L3, east to west, as depicted in Figure 6. The south pond of the north study basin contains three lysimeters spaced across the pond designated L6-L4, east to west.

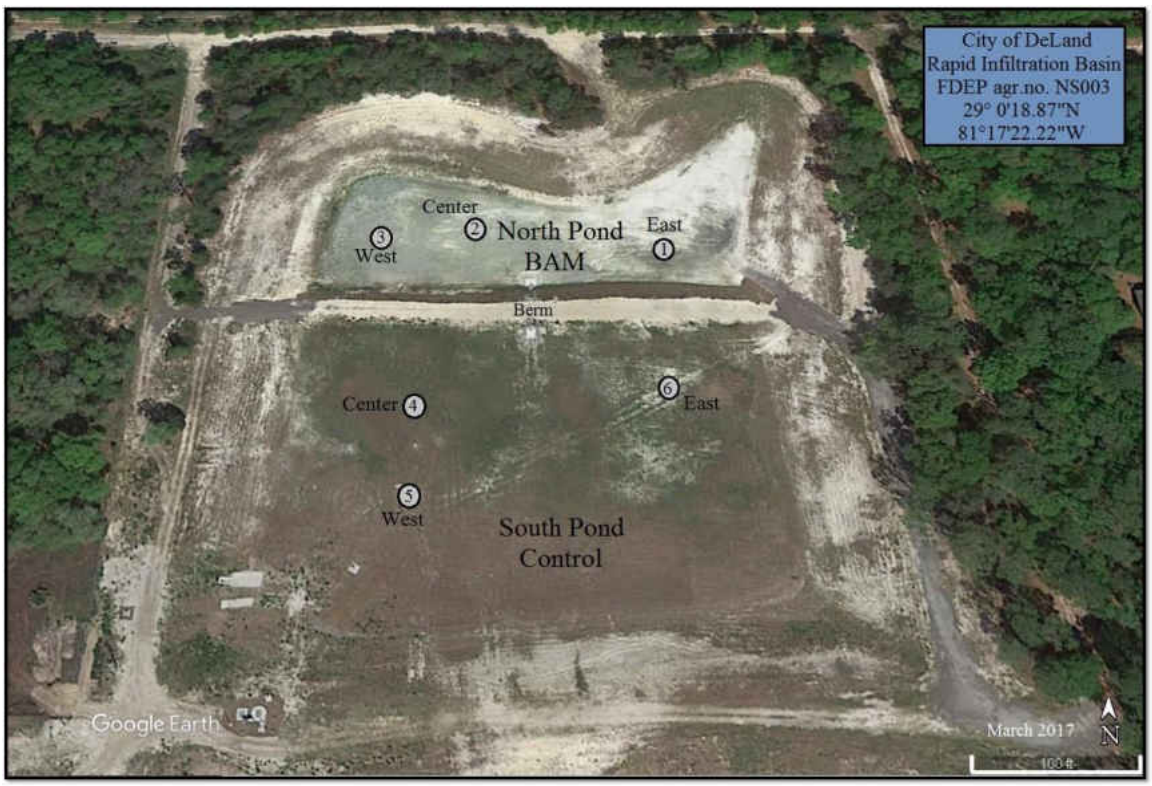

Figure 6. Study Rapid Infiltration Basin (RIB) Set-up.

North Study Basin, DeLand, Florida. Image adapted from Google Earth, March 2017.

Soil Characterization

The soil characterization data presented in this study was conducted by another graduate student at UCF, Sevil Moshfeghi, as part of the soil characterization portion of the larger project this thesis work is based on. The soil composition of the Control pond is more heterogeneous than the BAM pond due to the Control side being natural, ambient, Florida sandy soils. Whereas, the treatment media, BAM, was mixed and installed in the RIB 6 months (July 2016) prior to the start of the study. The installation of the BAM material occurred in July of 2016. Over the course of four days, with approximately 25-30 truckloads per day, a total of 3,227 cubic yards (CY) was placed, Figure 7. The installed BAM averaged about 1 acre of surface area, with the goal of a 2-foot layer of treatment soil. The BAM-modified RIB had an initial 90 pounds per cubic-foot in-place density, and the density of the Control RIB approximated about 94 pounds per cubic-foot.

Figure 7. Installation of BAM in the Treatment Media Pond (July 2016)

The soil composition was measure by depth in both ponds for sand (S%), clay (c%) and organic matter (OM%), Table 3. The soil analysis conducted was the dry test with sieve 40. The BAM material used in this study may contain more clay than what is demonstrated here.

Table 3. Dry Test Soil Analysis

Treatment: Soil Sample	OM %	S %	C %	Sieve 40 (Other %)
Bam, 2 ft.	**0.26**	**80**	**0.62**	**19**
Bam, 3 ft. (below BAM layer)	0.61	66	1.9	31
Control, top soil	**0.48**	**95**	**2.0**	**22**
Control, 2 ft.	**0.46**	**95**	**0.88**	**3.1**
Control, 3 ft. (below Sand layer)	0.15	97	1.8	1.3
Control, deeper than 3 ft. (below Sand layer)	1.5	55	1.4	42

Sand (S%), Clay (c%) and Organic Matter (OM%)

The ambient soil below the 2 ft. of installed study material (Traditional: sand and Altered: BAM) is composed of sandy loam, a sandy clay commonly found in Florida. Both ponds contained a higher clay percentage below the 2 ft. of study media, based on the USDA soil textural triangle interpretation of the dry-test soil analysis, Figure 8.

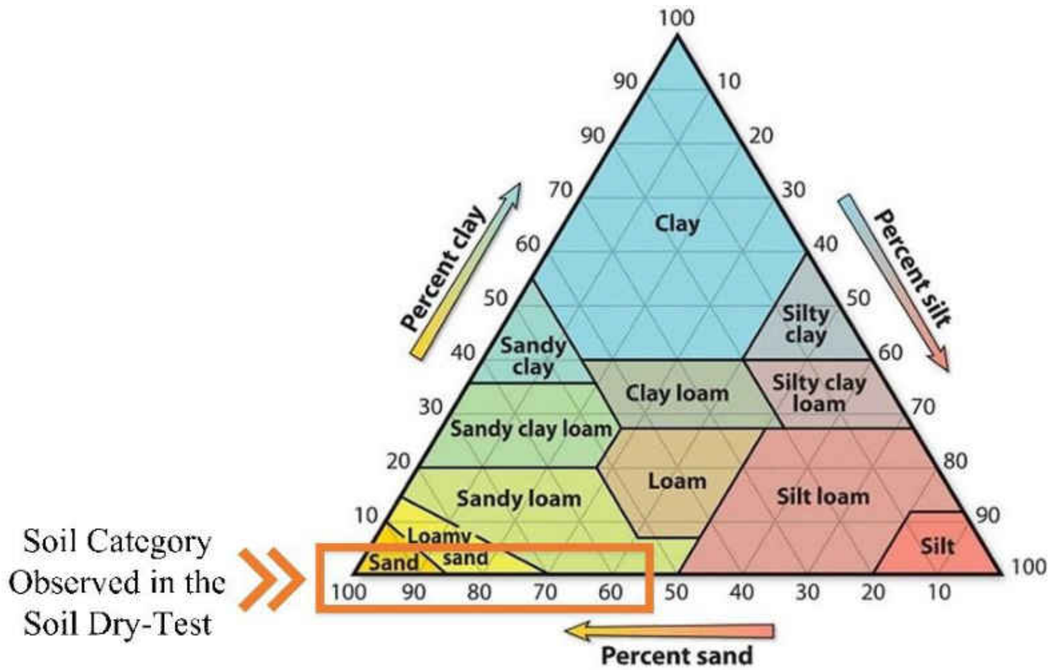

Figure 8. USDA Soil Textural Triangle.

Adapted from Jackson Soil and Water Conservation District, accessed December 2017 from

< https://www.jswcd.org/soil-texture>.

The BAM material is a mixture of clay, tire crumb and sand (CTS) categorized as loamy sand based on the dry-test soil analysis. The tire crumb pieces, present in the BAM, averaged 8.3 +/- 2.4 mm^3 by volume with a range of 1 – 36 mm^3, Figure 9. The version of BAM used in this study, was developed at UCF and registered under the trademark name Bold and Gold™.

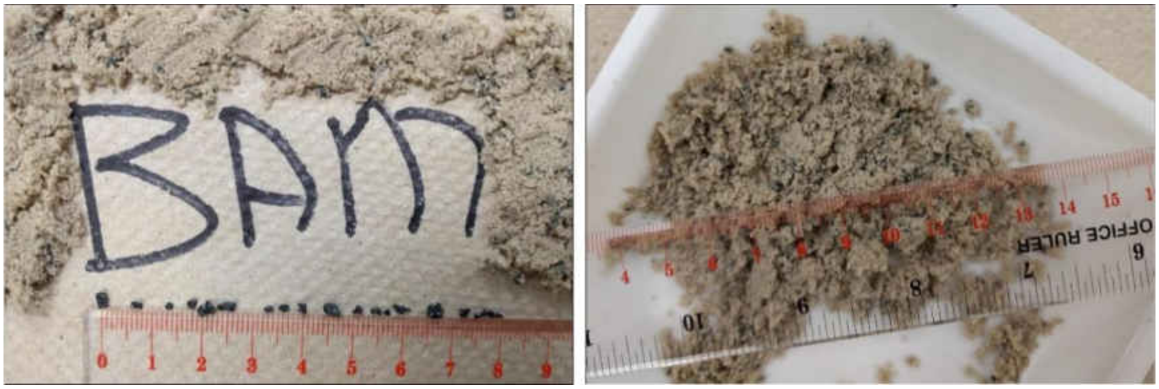

Figure 9. Biosorption Activate Media (BAM): Bold and Gold™ CTS

The BAM selected was approved by the City of DeLand, Florida (City of DeLand, 2017). The media was reported to contain a dry bulk density of 63 pounds per cubic foot and a porosity of 32% at dry conditions without compaction. The BAM product size used in the construction of the modified RIB had more than 2% but less than 6% passing a 200 sieve. The mix will be composed of 85% poorly graded sand and 15% sorption materials by volume. The sorption materials are composed of recycled tire crumb and mined clay that has no less than 99% clay content. Percentages were determined by in place volume. The B&G™ CTS media material had a water holding capacity of at least 10%, and total porosity of 35%. The permeability as measured in UCF's laboratories was greater than 1.0 inch per hour at maximum compaction.

The soil material quantity in both the Control (ambient Sand) and treatment (BAM) ponds is approximately a 2 ft. layer, vertical depth, from the soil surface to ambient soil composition. Figure 10 displays the study RIB vertical soil column, soil characterization and lysimeter placement. The traditional, Control pond, sand depth is partially due to a regulation, in Florida, stating that the rapid infiltration basin (RIB) soil surface must be 2 feet above the ground water table (SJRWMD 2012). The Control pond sand depth measured to 2 feet.

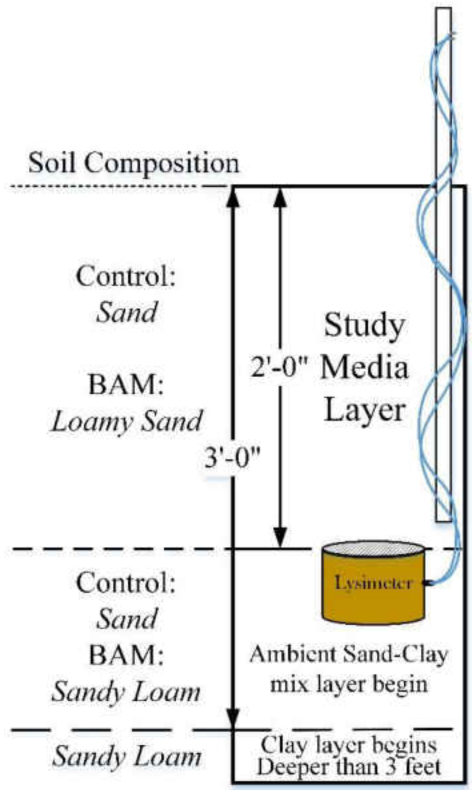

Figure 10. Soil Column and Collection Layout.

Soil composition based on dry test and USDA soil triangle

Observations

RIB Water Coverage

Variation in water coverage and soil saturation occurred across the lysimeters in both the Control and altered-media treatment units. The east lysimeters in both the Control and BAM ponds (L1 and L6) receded out of water before the rest of the lysimeters. Lysimeter L5 was observed to have a miniature stream meandering next to the equipment during sampling events. This stream of water appeared during the rainy season (the month of June – August, Hurricane flooded in September - December) and originate from a few sources: a leaking pipe during south storage basin loading, seepage from the south storage basin through the dividing berm and upwelling groundwater into the southwest end of the Control pond. This stream was observed to puddle and end over the west Control lysimeter, L4, Figure 11.

Figure 11. RIB Field Collection Layout and Water Puddling.
Sample Lysimeters designated with numbers L 1-6, where Control is 4-6 (west to east) and BAM treatment is 1-3 (east to west). The white arrows label soil moisture meters in each study pond.

Infiltration

The Control pond and the BAM pond were loaded at the same time for each loading event. The quality of water loaded to the ponds was equivalent by standing water depth (water head). The goal of ponded water depth was three feet. The initial study events did not have equivalent water heights loaded into both ponds, due to initial calibration and determination of the flow meter and pump system. The loading data displayed in Appendix D, Table D-1 (RIB loading data), presents a summary of the data collected in this specific study.

The infiltration rate of the Control verse BAM ponds was not equivalent. Throughout the study, the BAM pond was observed to decrease in standing water depth less rapidly and reach a dry soil surface later than that of the Control pond, Figure 12.

Figure 12. RIB Infiltration Example

This difference in infiltration rate is most likely due to differences in soil media as well as the construction of the RIBs. During the construction of the BAM pond, the ground soil was compacted purposely to be able to drive trucks on the sand to install the media. Further compaction of the under-soil layer occurred throughout the installation process due to the multitude of trucks and installation vehicles present.

The water quantity, by height, of reclaimed water that infiltrated in the BAM RIB before the density testing was about 10 feet. The amount of water entering the RIB over time shifted and compacted the BAM material to an estimated 97 lb/CF of in-place density. Over an eight-month period (prior to the hurricane impact) the cumulative volume of water from the reclaimed water ponds used for evaluating the BAM RIB was 4.4 million gallons (MG) per acre whereas the volume supplied to the Control (traditional) RIB approximated 4.1 MG per acre.

Hurricane Impact

The hurricane stormwater flooding took approximately five months to drain fully from the study RIB. This was due to constant loading of stormwater, water table mounding under the RIBS and an elevated water table in the surrounding area due to flooding from the hurricane and resultant storms. An example the hurricane impact and a loading event is displayed in Figure 13.

Figure 13. Loading and Hurricane Flooding of Study RIB.

Soil Moisture

Soil moisture for the RIB study was collected by installed soil moisture meters and a data logger per each study unit (Control and BAM pond). There were four soil moisture meters installed per pond at depths of 0.5, 1, 2 and 3 feet. The meter and data logger system used are from the Onset Corporation, documented in the Field Tools section, Table 4.

Model

The infiltration and soil moisture for the study RIB was conceptually modeled using the HYDRUS software program. The HYDRUS model software package (Simunek et al 2006) used here in can be accessed from PC-Progress. The initial development of the HYDRUS code is documented by Šimunek Et al. 1995. Authorship and a history of the development is documented in Simunek et al 2008 and 2012. For further information a brief review of the HYDRUS model and its user interface can be found in Yu and Zheng 2010.

Model Selections and Inputs

The Control and BAM pond were modeled individually with differences in soil characterization. The rest of the input variables were held constant, as the loading and precipitation to the basins was the same relative to a vertical soil column model. The water infiltration (hydraulic) model chosen to use here in was the van Genuchten – Mualem, which is one mathematical formulation for describing the water retention curve. This was chosen over the other hydraulic model, Brook's-Corey, due to the functionality of the HYDRUS program under the settings given. The Brook's-Corey option did not have model convergence and therefore did not provide any prediction results past the first hour of a model designed to predict over 14 days.

The soil layer categories for the model were selected from the standard list given and based on the soil characterization of sand, sandy loam and loamy sand. The soil layers used in the model are displayed in Figure 14. The groundwater table was frequently measured on-site during the implementation of the project as a reference point to support the model. The monitoring well elevation in relation to the soil surface and treatment media bottom is reference in Figure 15.

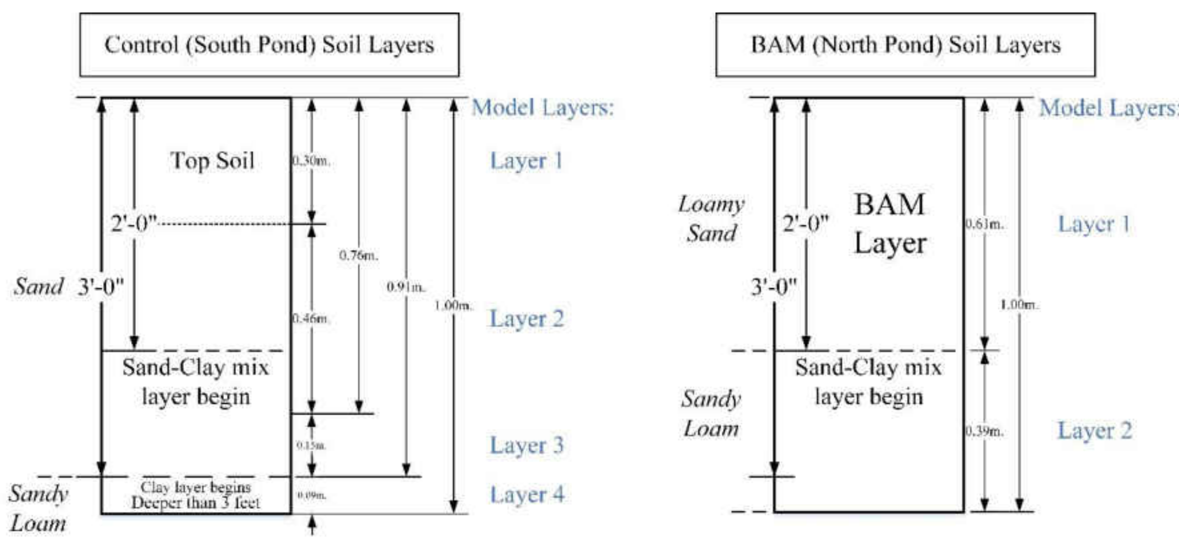

Figure 14. Soil Layers by Treatment Unit for HYDRUS Model

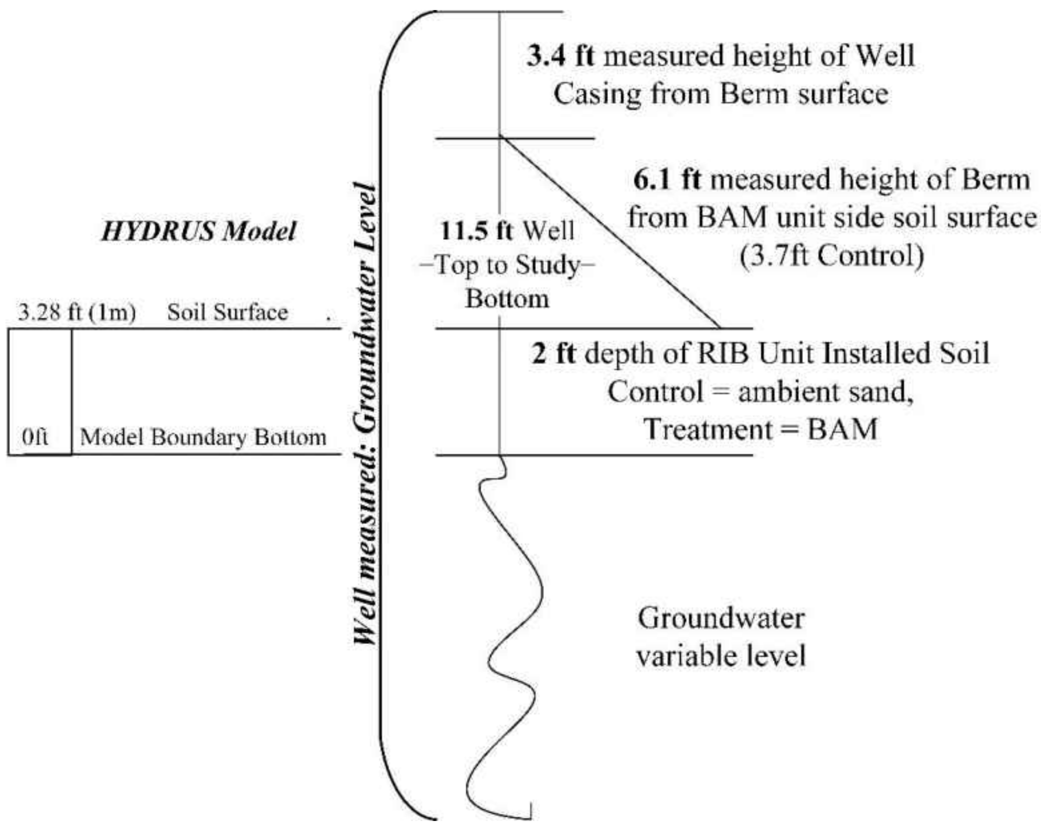

Figure 15. Model Elevation References

Field Tools

The tools and equipment utilized in field for this study are presented in Table 4. The soil moisture, water level loggers, weather station and data loggers were provided by the Biology department and in association with another cooperative grant between the department of civil, environmental and construction engineering (CECE) and biology department. A weather station was installed on the project site, displayed in Figure 16, for collection of precipitation and other water balance data. The monitoring well installed in the study RIB is 16 feet deep and lies 9.5 ft. above the soil. This data is used for the conceptual model and to determine whether there might be ground water influences.

Lysimeters were used to collect the output water for parameter analysis. The lysimeters are 5-gallon plastic buckets with lids designed for water infiltration and sediment exclusion (filter top). The lysimeters were observed to collect fine sediments on the bottom of the bucket, Figure 17. Due to this observation and for chemistry accuracy, a cleaning regime was conducted over the study: after each sampling event the lysimeter water would be expelled fully and prior to each loading the buckets would be rinsed with distilled water. The period of February to April did not experience any distilled water cleaning regime.

Additionally, a City of DeLand staff member (Mr. Larry Nordman) created a tool to assist in opening the data logger box, as there is no standard set tool developed by the Onset HOBO data logger company, Figure 18. This allowed the data logger box to be opened in less than 1 minute where as previously the task could take as long at 30 minutes.

Figure 16. Weather Station and Monitoring Well, Onsite.

Figure 17. Lysimeter Prior to Installation and In-field.

Figure 18. Data Logger Box Tool

Table 4. Field Tools

Purpose	Company	Main website	Field Tool	Product	Model	Cost	Quantity
Water Collection	Soilmoisture Equipment Corp.	http://www. soilmoisture.com /home.php	Lysimeter	Pan Lysimeter - 5 Gallon Bucket	SKU 1960	$ 158	6
			Extraction Kit	Vacuum Hand Pump	SKU 2005G2	$ 204	2
				Erlenmeyer Bottle	SKU 1900K3	$ 269	2
Data Collection	Onset and HOBO	http://www. onsetcomp.com/	Data Logger	HOBO USB Micro Station Data Logger	Part # H21-USB	$ 220	3
				HOBO® U30 Shuttle	Part # U-DT-2	$ 281	1
				Desiccant Replacement Pack for UA-003	Part # DESICCANT5	$ 12	1
				HOBO Water Level (30 ft) Data Logger	Part # U20L-01	$ 299	2
				HOBO® Waterproof Shuttle	Part # U-DTW-1	$ 249	1
			Soil Moisture	10HS Soil Moisture Smart Sensor	Part # S-SMD-M005	$ 139	9
			Weather Station	0.01" Rain Gauge (2m cable) Smart Sensor	Part # S-RGA-M002	$ 410	1
				Wind Speed Smart Sensor	Part # S-WSB-M003	$ 239	1
				Solar Radiation (Silicon Pyranometer) Smart Sensor	Part # S-LIB-M003	$ 210	1
				Solar Radiation Shield	Part # RS3-B	$ 65	1
				Full Cross Arm	Part # M-CAA	$ 72	1
				Mast Level	Part # M-MLA	$ 14	1
And Other						unknown	
				Total Cost Estimated		**$ 6000 +**	

Water Quality Sampling Methods

Samples were collected by the University of Central Florida (UCF) and the City of DeLand NELAC certified Laboratory. The three sample categories that were collected are:

1.) Composite Input: reclaimed water collected every Thursday from the Wednesday-Thursday 24-hour composite sampler, conducted by the City of DeLand Lab,

2.) Day of Loading Input: reclaimed water sampled on the day of loading (DeLand Lab)

3.) Lysimeter Output: water collected from the lysimeters, in the rapid infiltration basin, and

4.) Groundwater: water collection from the onsite monitoring well which occurred intermittently throughout the project. On occasion, a sample would be included with the Lysimeters for nutrient analysis. The monitoring well measure for depth regularly and water quality in field more often than for nutrients, due to project set up of outside (non-UCF) laboratory agreements and funding.

The composite input that the City of DeLand Lab collected, every Thursday for their weekly wastewater effluent water quality was sampled by UCF on the Thursday after loading. The Thursday samples directly prior to and after a loading event were averaged with the day of loading samples for the input value in removal calculations. The lysimeter samples were collected after the first draw, in order minimize contamination by rinsing the tubing and collection device. The analysis conducted are presented in Tables 5-7, which describe the water quality parameters analyzed, the analytical method and limits, sample collection and storage protocols (holding time, preservation, bottle type) and the laboratories which conducted the analysis.

Table 5. Summary of Analytical Methods Used for Characterization of Water Samples (List forms basis of analytical test plan).

Test	Method Reference Number (Standard Method); Instrument	Method Reporting Level (MRL)	Method Detection Level goal (MDL)	Accuracy % Recovery	Precision % RPD max	Holding time (HT)	Sample Vol. (SV)	Container Type (CT)	Preservative
Laboratory Analysis									
Alkalinity	SM:2320 B. Titration Method Bromocresol green/methyl red	5 mg/L as $CaCO_3$	5 mg/L as $CaCO_3$	N/A	<20	24 hrs	100 mL	Glass (capped full, no air)	Cool, 4ºC
Total Organic Carbon (as NP-DOC)	SM:5310C Persulfate - Ultraviolet Oxidation Method/Tekmarr-Dohrmann Phoenix 8000: The UV-Persulfate TOC Analyzer	0.25 mg/L	0.01 mg/L	80-120	<10	48hrs	100mL	Glass	> 2 days Acidify pH < 2 with H3PO4, Cool, 4°C
Field Analysis									
		Range or Resolution	**Calibration Procedures**						
Chlorine, (total and free)	SM:4500-Cl F DPD Colorimetric Method - DR 890 Portable Colorimeter	0-5 mg/L Cl2 range; 0.01 mg/L Cl2 resolution	Checked against manufacturer's internal method (6 pt. curve) and frequent inspection			Analyzed upon collection	20 mL	Glass	Read immediately (within 15 minutes)
Conductivity	SM:2510B; HACH Conductivity Probe; Model 51975-03	0-20 mS Range 1 µS resolution	Prior to analysis with 0.01M KCl to 1413uS based on temperature per Hach method			Analyzed upon collection	Enough to cover probe	Plastic or glass	Analyzed immediately
Oxidation Reduction Potential	SM:2580 Oxidation Reduction Potential measurement in clean water	0.1mV	Prior to analysis with ZoBell's ORP redox solution, per Hach method and manufacturer's instructions.						
pH	SM:45000-H+ B. Electrometric Method - HQ40d Portable pH Meter	0-14 Range, 0.01 resolution	Prior to analysis with commercial pH buffers, pH 4, 7, 10.						
Temperature	SM:2550 B. Laboratory Method - HQ40d Portable Multi-Meter Temp. Probe	0-100 ºC range; 0.1 ºC resolution	Calibrated against NIST-certified thermometer						

This list represents the in-field sample collection by UCF.

Table 6. Summary of Analytical Methods Used for Characterization of Water Samples (List forms basis of analytical test plan).

Test	Method Reference Number (Standard Method); Instrument	Method Reporting Level (LOQ)*	Method Detection Level (MDL)	Accuracy % Recovery	Precision % RPD max	Holding time (HT)	Sample Vol. (SV)	Container Type (CT)	Preservative
Chloride (Cl^-)	SM:4500Cl-E	2 mg-Cl/L	0.0483 mg-Cl/L	-	-	28 days	125 mL	Plastic	None
Conductivity	SM:2510B/ HQ14D HACH Meter	N/A	N/A	N/A	<5	28 days	125 mL	Plastic	Cool, 4ºC
Fecal Coliform	SM:9222D	-	-	-	-	8 hrs	100 mL	Plastic	Cool, 4ºC
Kjeldahl Nitrogen - Total	EPA 351.2/ SM: Lachat QuickChem FIA8000 Autoanalyzer	1.0 mg-N/L	0.282 mg-N/L	80-120	<10	28 days	125 mL	Plastic	Cool, 4°C; Acidify with H2SO4 to pH < 2
Nitrate-Nitrite (NO_x) Total	EPA 353.2 Lachat QuickChem FIA8000 Autoanalyzer	0.4 mg-N/L	0.079 **0.134 mg-N/L	90-110	<10	28 days	125 mL	Plastic	Cool, 4°C; Acidify with H2SO4 to pH < 2
Nitrogen (Total)	Summation of Nitrate-Nitrite and Kjeldahl Nitrogen Analyses	-	-	-	-	-	-	-	-
Phosphate (Total)	EPA 365.4 /SM:4500P E Colorimetric, Lachat QuickChem FIA8000 Autoanalyzer	0.15 mg-P/L	0.036 mg-P/L	80-120	<10	28 days	125 mL	Plastic	Cool, 4°C; Acidify with H2SO4 to pH < 2
pH	SM:45000-H+ B. Electrometric Method/Orion model #710	0.01 units	0.01 units	N/A	±0.1 pH unit	Analyze upon collection	125mL	Plastic	Analyze immediately
Temperature	SM:2550 B. Laboratory Method / HQ40d Portable Temperature Probe	0.1 oC	0.01 oC	N/A	NIST approved	Analyze upon collection	125mL	Plastic	Analyze immediately
Composite Sampler	Collection device: Sigma/Isco Composite Sampler	-	-	-	-	24 hour collection	5 gallon jug	Plastic	Cool

Information collected from the City of DeLand Laboratory QA document files, lab spikes and replicates, and communication with Lab staff.
*Method reporting level for DeLand Lab is the Limit of Quantification (LQ) *MDL change occurred after August 2017.

Table 7. Summary of Analytical Methods Used for Characterization of Water Samples from non-contracted Labs

Test	**Laboratory Name**	**Method Reference Number (Standard Method); Instrument**	**Method Reporting Level (MRL)**	**Method Detection Level goal (MDL)**	**Accuracy % Recovery**	**Precision % RPD max**	**Holding time (HT)**	**Sample Vol. (SV)**	**Container Type (CT)**	**Preservative**
Boron	Advanced Environmental Laboratories (AEL)	EPA 200.7/ SM:3120B. Inductively Coupled Plasma (ICP) and Mass Spectrometer (ICP-MS)	0.005 mg/L	0.005 mg/L	80-120	<20	180 days	250 mL	Plastic, avoid borosilicate glassware	Cool, 4°C; Acidify pH < 2 with HNO3
Boron (isotope)	TetraTech Inc, Laboratory	(Hemming and Hanson, 1994): Negative ion mode in Thermal Ionization Mass Spectrometer	0.001 mg-B/L	0.001 mg-B/L	80-120	+/-1.0	180 days	2000 mL	Plastic	Filter 0.45um cellulose acetate filter or equivalent. Cooling not required, avoid preservation
Nitrogen Isotope	University of California Davis, Stable Isotope Facility (UCDavis SIF)	Isotope ratio mass spectrometer, (USGS 2012)	2uM Nitrate	2uM Nitrate	N/A	≤0.4	1 year	60 mL	Nitrate-Free, HDPE polyethylene or polycarbonate	Filtered ≤0.2uM, Frozen, Shipped frozen

Data Analysis Quality Assurance and Quality Control

Quality assurance and quality control (QAQC) documentation is provided in appendix with the associated laboratory and results.

Accuracy and Precision

Accuracy and precision charts for data analyzed by the University of Central Florida (Non-purgeable Dissolved Organic Carbon) and the City of DeLand (NO_x, TKN, TP, Cl^-) are provided in Appendix A and B respectively. Other Data QAQC can be found in the Appendix associated with that laboratory or organization.

The accuracy charts developed in this study are based on laboratory-fortified matrix (LFM) samples to calculate percent recovery between the sample and laboratory spiked sample, as shown in Equation 5.

$$Percent\ Recovery = \frac{|Spiked\ Sample - Sample|}{Spike} \qquad (5)$$

The units are in mass of the sample and spike as described in standard methods quality control section, 1020B (Eaton Et al. 2005). The range of percent recovery that is acceptable lies with in the upper and lower control limits which represent (+/-) three standard deviations (SD) away from the mean or +/-20% around 100%. The majority of the percent recovery values fall within the upper and lower warning limit, (+/-) two-SD away from the mean or +/-10% around 100%. The spiked sample is targeted to be within 10% of the theoretical, expected value. If the majority fell beyond the warning limits, then the laboratory machine and technique would be evaluated for accuracy.

Precision Control Charts can be developed from a few different statistics measures, such as I-statistic, relative percent difference and relative standard deviation. The precision charts developed in this study are based on relative percent difference between laboratory replicate samples, as show in Equation 6.

$$RPD = \frac{|Sample - Replicate|}{|Sample + Replicate| \div 2} \tag{6}$$

The units are in the units of the analysis. For example, dissolved organic carbon (DOC) analysis provided a result in concentration of mass/volume, mg/L or PPM. The replicate is a repeat of the sample, as a laboratory duplicate, as described in standard methods quality control section, 1020B (Eaton Et al. 2005). The range of RPD that is acceptable falls below the control limit, which is designated by three standard deviations (SD) from the mean of the range. The two samples must be within 10% of each other. The majority of the RPD values fall within the warning limit, two-SD of the range, or 5%. If the majority fell beyond the warning limits then the laboratory machine and technique would be evaluated for accuracy.

Variability and Error

There is variability in every data sample set collected. However, this variability can help determine differences within a treatment or among a treatment and therefore due to that treatment. The variation can also arise due to sampling or analysis error. In this work the standard error of the data set is provided to estimate the variation within a treatment verses between treatments. Standard error is presented in Equation 7.

Standard Error

$$SE = \frac{SD}{\sqrt{n}} \qquad (7)$$

SE – Standard Error

SD – Standard Deviation

n – Sample size

The sample size in this work is dictated from the study layout with to treatment ponds (Control and BAM) containing three lysimeters each, three output collections, that were conducted over 12 loading events, Table 8. The input samples were also gathered in three sets when possible, for the 12 events.

Table 8. Sample Size

Source Water	Control	BAM
Effluent Water (Reclaimed Mixture)	28	29
Storm Water	6	6
Overall (Effluent and Storm Water)	34	35

CHAPTER 4: RESULTS AND DISCUSSIONS

Nitrogen and phosphorus were assessed for removal in reclaimed, wastewater effluent, from the City of DeLand's Water Reclamation Facility (WRF). Nutrient removals for this study were based on an input of reclaimed water sampled at the WRF and output water collected from lysimeters installed under the two-foot zone of the treatment soil layer in the rapid infiltration basin (RIB). The removal values are calculated from concentrations as observed in the input and output samples. During the study, when the input concentrations, loaded to the RIB, were low the percent removals were seen to be negative or near zero. The negative removals are commented in the observations section, as presented herein. The calculated removals contain the negative value observed, as compared to alternative presentation forms where only the values above zero percent are provided. Negative values could suggest leaching, biological expulsion, or an ambient background concentration which may suggest a slower feedback system to loading events with low nutrient levels.

Nutrient Concentrations and Removals

Nitrogen

This research results presented herein relied on analyzing several nitrogen-related chemical species, including Total Kjeldahl Nitrogen (TKN), Nitrate-Nitrite combined (NO_x) and Total Nitrogen (TN) as determined by the sum of TKN and NO_x. The TKN represents the organic and ammonia forms of nitrogen, however the two cannot be individually distinguished. The observed concentration results for TN display a trend that is most closely represented by the NO_x trend, however there were a few loading events that displayed a higher influence on the TN value by the TKN nitrogen species. TN content is displayed in Figure 19, where TKN and

NO_x are presented in Figure 20 and 21, respectively. It is important to note that there were times when the nitrogen content of the loading (input) were low. In these cases, it was found that the samples for those events collected in the lysimeters (output) display higher nitrogen content leaving the RIB than entering the basin. However, as time went on, and low input loadings continued, the nitrogen content exiting the RIB was less than the input; that is, the concentration had reduced. At these low concentrations, the ability to ascertain actual removal efficiencies was difficult as the values were near zero threshold values. However, TKN was observed to be higher in concentration for the output samples over that of the input samples for 9 out of 12 events in both the BAM as well as the Control. This increase in TKN could be due to a portion of the decline in NO_x over this study. It is possible that the data observed in this research could reflect a situation where inorganic nitrogen is transformed to another form (e.g. TKN), rather than complete removal from the system via denitrification (to N_2 gas). The average and median concentrations of NOx in the output samples under the study RIB were 0.83 mg-N/L (+/- 0.33 SE) and 0.07 mg-N/L, respectively, for the BAM pond and 2.23 mg-N/L (+/- 0.48 SE) and 1.51 mg-N/L, respectively, for the Control pond. The BAM was very close to the detection limit for the median value (0.079 mg-N/L for NOx). The average and median concentrations for TKN in the output were 1.59 mg-N/L (+/- 0.14 SE) and 1.58 mg-N/L, respectively, for BAM and 1.51 mg-N/L (+/- 0.15 SE) and 1.53 mg-N/L, respectively, for Control. Total nitrogen (TN) average and median values in the output samples were 2.55 mg-N/L (+/- 0.38) and 2.05 mg-N/L, respectively, for BAM and 3.78 mg-N/L (+/-0.50) and 1.86 mg-N/L, respectively, for the Control pond. The TKN average and median concentrations were similar for both treatments (BAM and Control). The variability between treatments depended on species type and nitrogen content (near detection limits of the analysis).

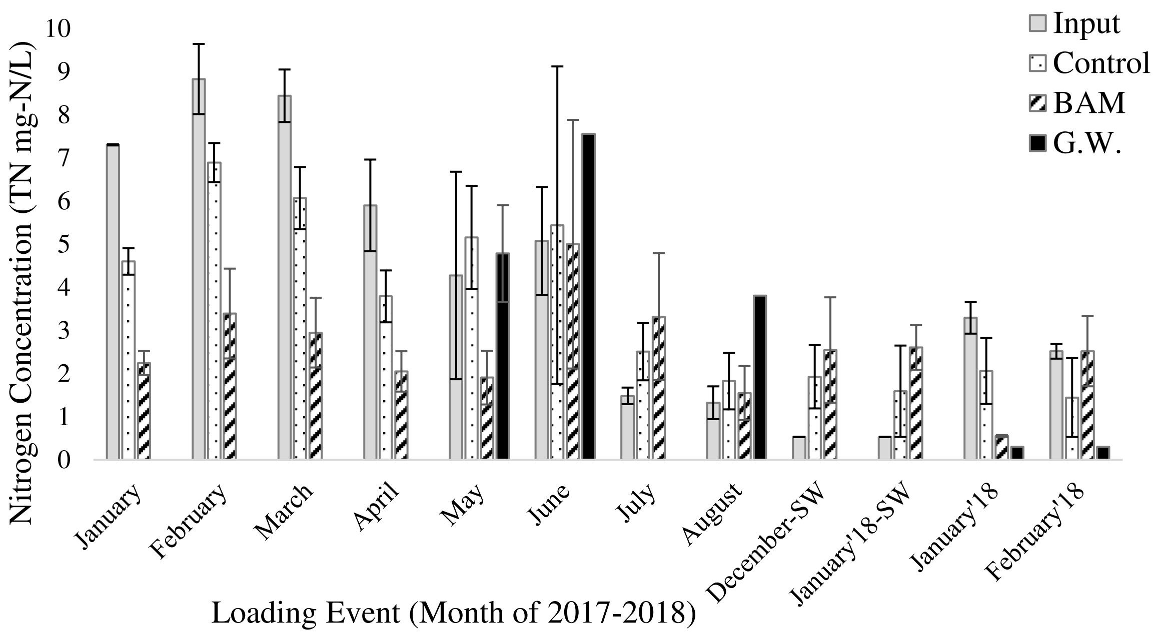

Figure 19. Total Nitrogen Concentrations (TN).

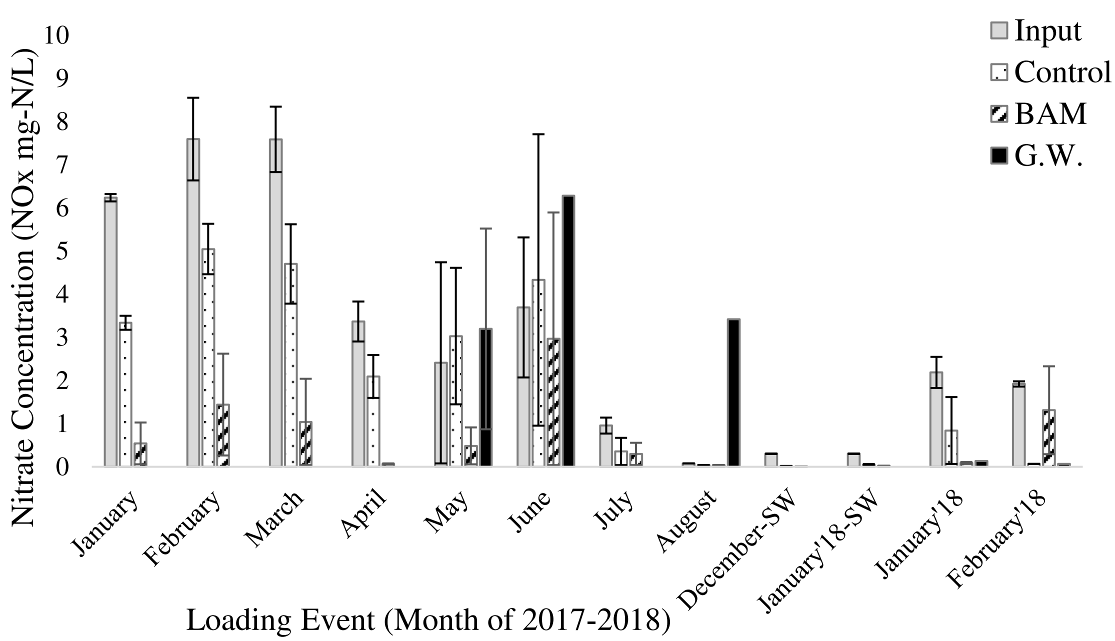

Figure 20. Nitrate-Nitrite Concentrations (NO_x).

Note: Error bars represent 1 SE. G.W. represents groundwater from the onsite monitoring well.

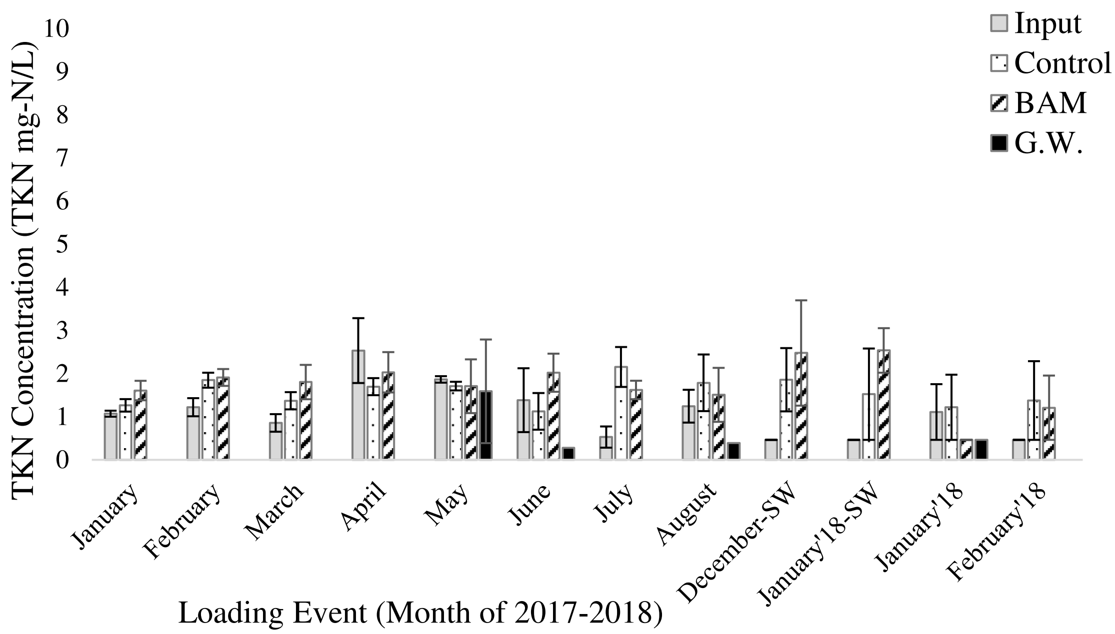

Figure 21. Organic and Ammonia Nitrogen Concentrations (TKN).

Note: Error bars represent 1 SE. G.W. represents groundwater from the onsite monitoring well.

One of the primary motivators for the research was the removal of nitrates from reclaimed water before the contaminant entered the ground water system. This study showed that more than 70% of nitrates were removed with the BAM material, which was 30% more than that of the Control. The nitrate removal efficiencies for the two source water types by treatment pond are displayed in Table 9. Note that these removals include each Lysimeter concentration value, whether that created a negative removal, or was suspect of malfunctioning lysimeters. Suspect data is further discussed in the observations section of the results. As was discussed in the methods section, the percent variation displayed in the removal values in this study is calculated from the standard error. The storm water has a total of 6 samples collected per treatment for two collection events where as the reclaimed water had 28 and 29 for the Control and BAM, respectively. Consequently, this limited sample quantity should be considered when deciphering these results. The sample groups were averaged to provide an average removal for the entire study data set, as described.

Table 9. Nitrate-Nitrite (NO_x) Removals Source Water Comparison

Source Water	Control	BAM
Effluent Water (Reclaimed Mixture)	47% (+/- 10%)	77% (+/- 7%)
Storm Water	90% (+/- 4%)	95% (+/- 1%)
Overall (Effluent and Storm Water)	54% (+/- 8%)	81% (+/- 6%)

In this research, individual nitrogen species removal efficiencies were determined and compared between the treatments for reclaimed water, as shown in Table 10. The TKN average value suggested that leaching could be occurring relative to nitrogen transformation. For example, there were minor positive removals in April and May for both ponds and a removal in June for the Control and January 2018 for the BAM, with variation that sometimes exceeded the removal percentages. The study was conducted form January 2017 to February 2018, with a four month break due to hurricane water loading. The BAM pond showed to remove nitrates at 30% more than the sandy-Control pond, which was at 47%. The total nitrogen removal did not display as high of a removal as the nitrate nitrogen species did. The BAM was 19% more removal of nitrogen than the Control at 12%. The total nitrogen removal which occurred in this study is displayed in a box and whisker type plot, Figure 22.

Table 10. Nitrogen Removal from Reclaimed water in a BAM and Sand RIB.

Nitrogen Species	Control	BAM
TKN	-64% (+/- 29%)	-57% (+/- 22%)
NO_x	47% (+/- 10%)	77% (+/- 7%)
TN	12% (+/- 11%)	31% (+/- 15)

Total Nitrogen (TN), Nitrate-Nitrite Combined (NO_x), Total Kjeldahl Nitrogen (TKN)

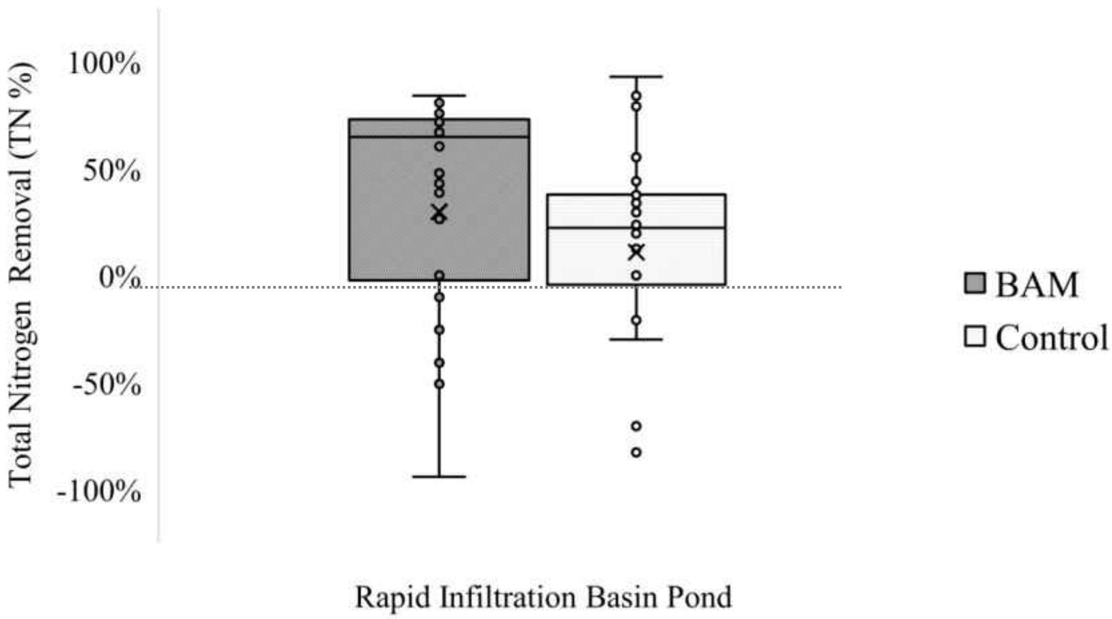

Figure 22. Total Variation in the Total Nitrogen Removal Efficiencies

The results from the nitrogen removal, as calculated based on concentration, indicate that the nitrogen is removed from the source water entering the basin in both the Control and BAM treatment. The results also suggest that the nitrogen removed is released into the atmosphere and not delivered to the groundwater system, as displayed by TN removals. The data clearly shows that nitrate was reduced more effectively using BAM as compared to the Control and is the focus of currently regulatory interests. Hence, nitrate is removed and prevented from entering the groundwater, and considered a success when meeting regulated nitrate concentrations entering the environment. However, the TKN and TN values suggest that removal of overall nitrogen is varied, where the total nitrogen is either being reduced or transformed (generated) to alternative forms by microbiological processes. As an example, one possible direct mechanism that could explain this observation between the nitrogen species is DNRA. Other mechanisms could be uptake and release, as there was a layer of an algal-biomass observed in the ponded water and on the soil surface of both ponds when dry. These observations were not examined as part of the research performed in this current work. In future work, the use of BAM technology would benefit from a mass balance study not present in this effort described herein.

Costs Expended for Full-Scale BAM Treatment in this Study

The purchase and installation of the BAM material approximated $400,000 (FDEP report May 2018), where the BAM material cost of $373,750 represented a purchasing price of $115/CY for 3250 CYs (City of DeLand, 2016). BAM is suggested to last indefinitely as long as the microbial population is functioning, which is qualified to be about 50 years.

Input Concentration Considerations

The nutrient input concentration played a role in the outcome of the quantity of nutrient removed. When the nitrogen concentrations were low, the removal efficiencies were low or negative in value for both the BAM and Control ponds. When the input concentration is larger than 2mg-N/L the removal values are positive. The total nitrogen displayed a positive non-linear trend with an R-squared value of 0.81 for BAM ($Y = 1.55*\ln(X) - 2.02$) and 0.76 for

Control (Y = 0.90*ln(X) – 1.23), Figure 23, A.). The influence of the different nitrogen species is shown in Figure 23, B.) TKN and C.) NOx.

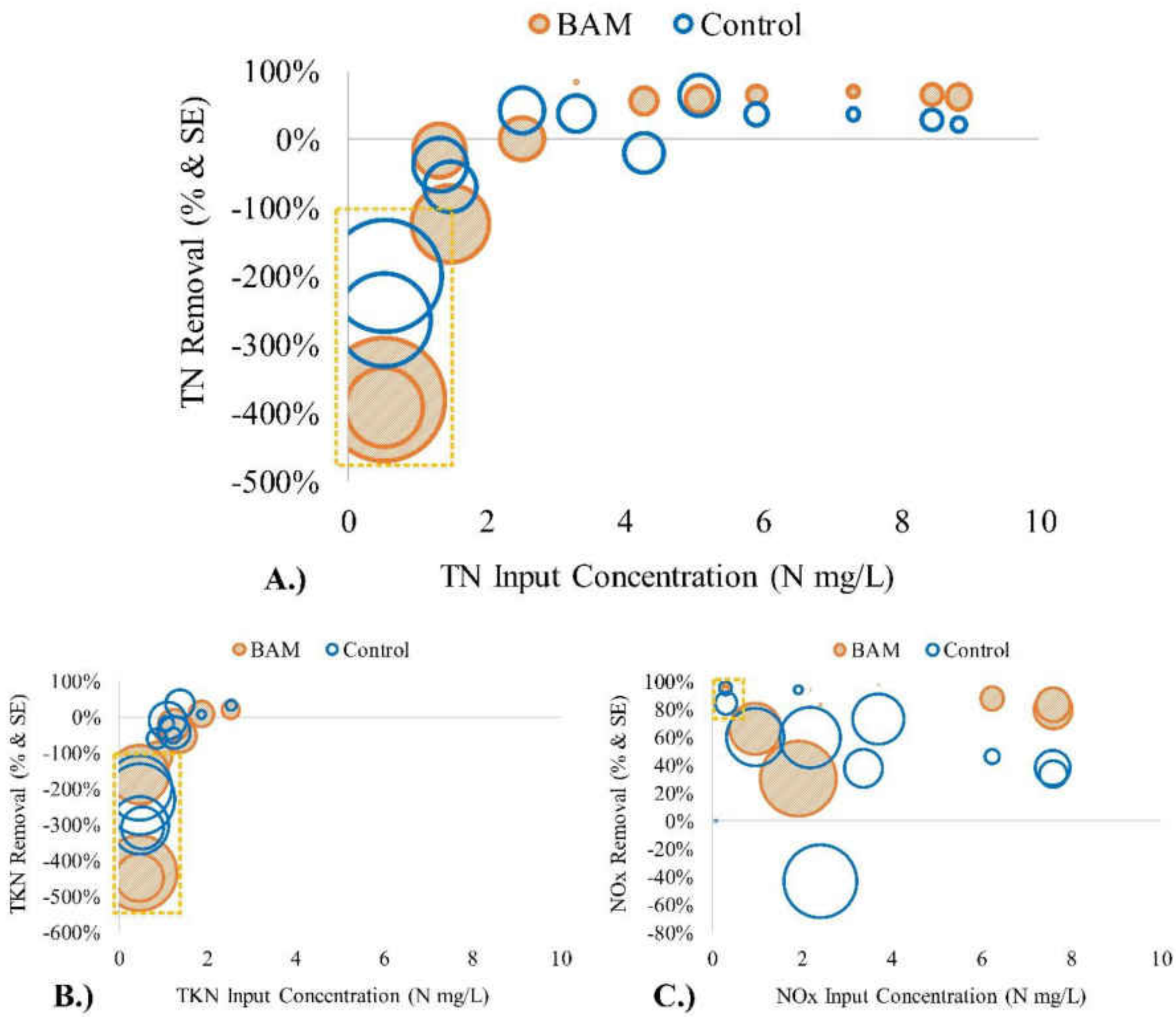

Figure 23. Input Concentration Influence on Removal, Nitrogen: A.) TN, B.) TKN, C.) NOx.

The circle radius is based on one standard error (1 SE) and the yellow dashed boxes represent storm water samples.

Phosphorus

The phosphorus input concentrations were observed to decline as the summer months proceeded, as shown in Figure 24. As was seen in the nitrogen results, phosphorus (P) declined to low levels which complicated removal effectiveness evaluations for three of twelve events; that is, the output P concentrations surpassed that of the input concentrations. Two of these events occurred during storm water loading activities. It is possible that the storm water loading event acted as a wash and rinse of the soil sediments from a buildup of phosphorus. The average and median total phosphorus concentrations observed exiting the study soil layer were 1.28 mg-P/L (+/- 0.14) and 1.18 mg-P/L, respectively, for the BAM pond and 2.07 mg-P/L (+/- 0.20) and 2.05 mg-P/L, respectively, for the Control pond.

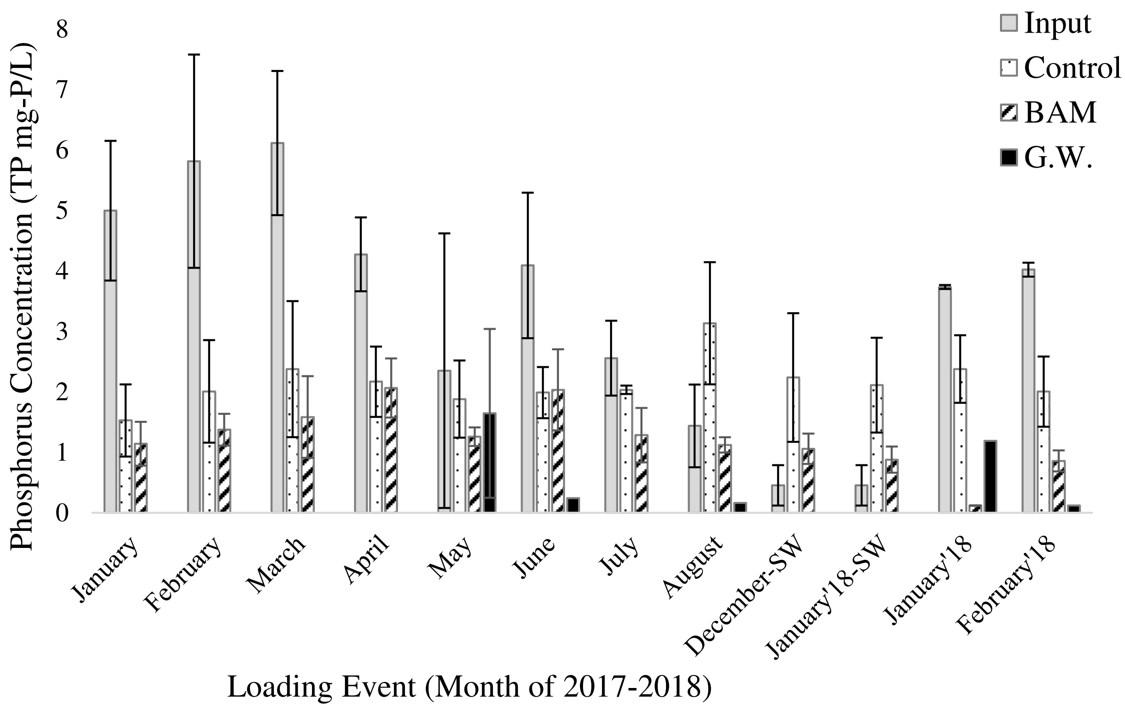

Figure 24. Total Phosphorus Concentrations.

Note: Error bars represent 1 SE. G.W. represents groundwater from the onsite monitoring well.

The standard limit for phosphorus (TP) discharges to the environment from a wastewater treatment facility is 1 mg-P/L, in the state of Florida. The input TP concentrations where higher than 1 mg-P/L for every reclaimed water loading event. The output TP concentrations ranged between 1 and 2 mg-P/L. This demonstrates that both a traditional and altered RIB do provide some removal and protection against phosphorus entering the environment. The phosphorus removal efficiencies are displayed in Table 11 and Figure 25. The most common removal mechanisms for phosphorus is sorption and uptake, most likely representing the removal here.

Table 11. Total Phosphorus Removal

Total Phosphorus	Control	BAM
TP	28% (+/- 13%)	62% (+/- 5%)

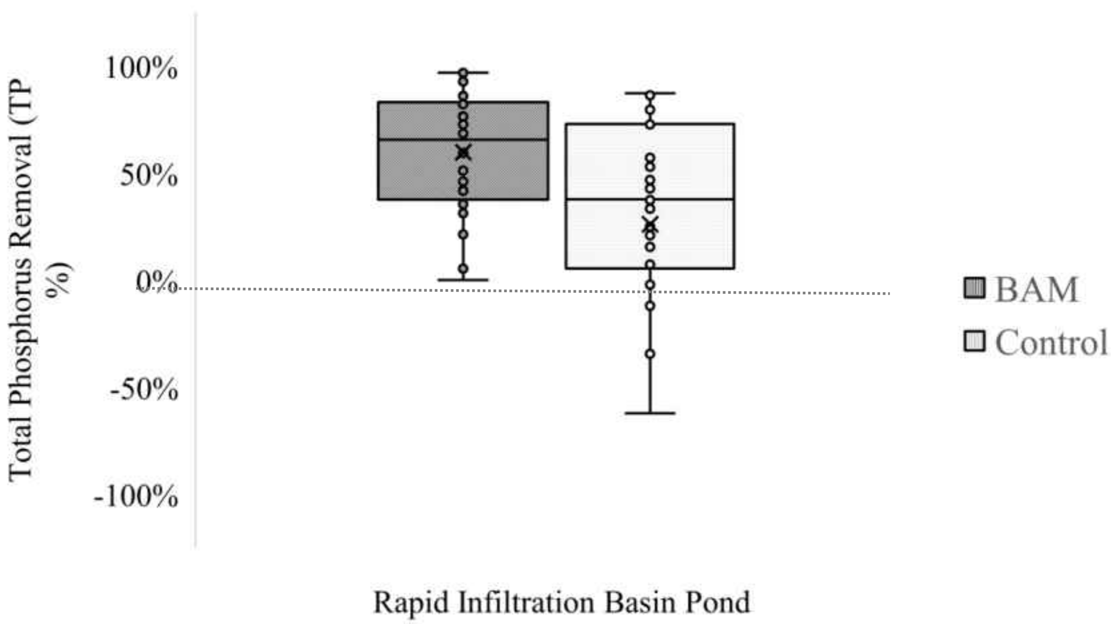

Figure 25. Total Variation in the Total Phosphorus Removal Efficiencies

Input Concentration Considerations

The nutrient input concentration played a role in the outcome of the quantity of nutrient removed. Both nitrogen and phosphorus displayed similar trends when observing total phosphorus or total nitrogen. Low phosphorus concentrations displayed low removal efficiencies or negative efficiencies, such as a leaching event, for both ponds (BAM and Control). Removal of total phosphorus (TP) occurred when input concentration was greater than 2mg-P/L. The TP trend is similar to the TN trend with a positive non-linear relationship between input concentration and removal for both ponds, Figure 26. BAM displayed an R-squared value of 0.88 with a logarithmic equation of $Y = 0.74*\ln(X) - 0.38$, whereas the Control had an R-squared value of 0.94 an equation of $Y = 1.79*\ln(X) - 2.07$.

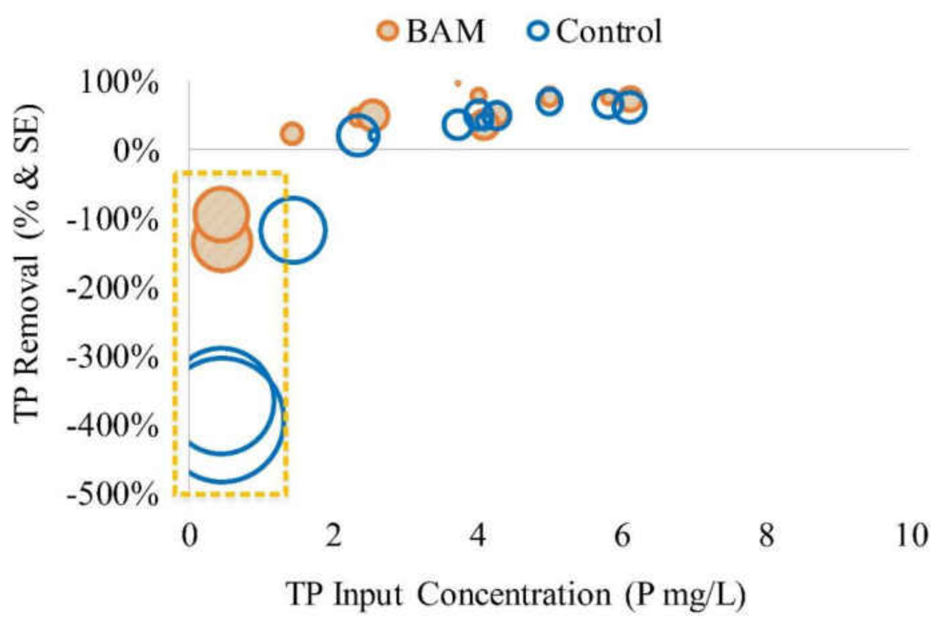

Figure 26. Input Concentration Influence on Removal, Phosphorus.

The circle radius is based on one standard error (1 SE) and the yellow dashed boxes represent storm water samples.

Carbon

Carbon data was collected for this project. Prior to the hurricane event, carbon content was higher exiting the RIB than the loading levels. Similar to phosphorous, it is possible that the storm water loading event acted as a wash and rinse of the soil sediments from a buildup of carbon. However, the BAM showed elevated levels of carbon existing than the Control, as shown in Figure 27. The average and median carbon concentrations observed exiting the study soil layer were 9.98 mg-P/L (+/- 0.94) and 8.00 mg-NPDOC/L, respectively, for the BAM pond and 7.21 mg-NPDOC/L (+/- 0.58) and 7.17 mg-NPDOC/L, respectively, for the Control pond.

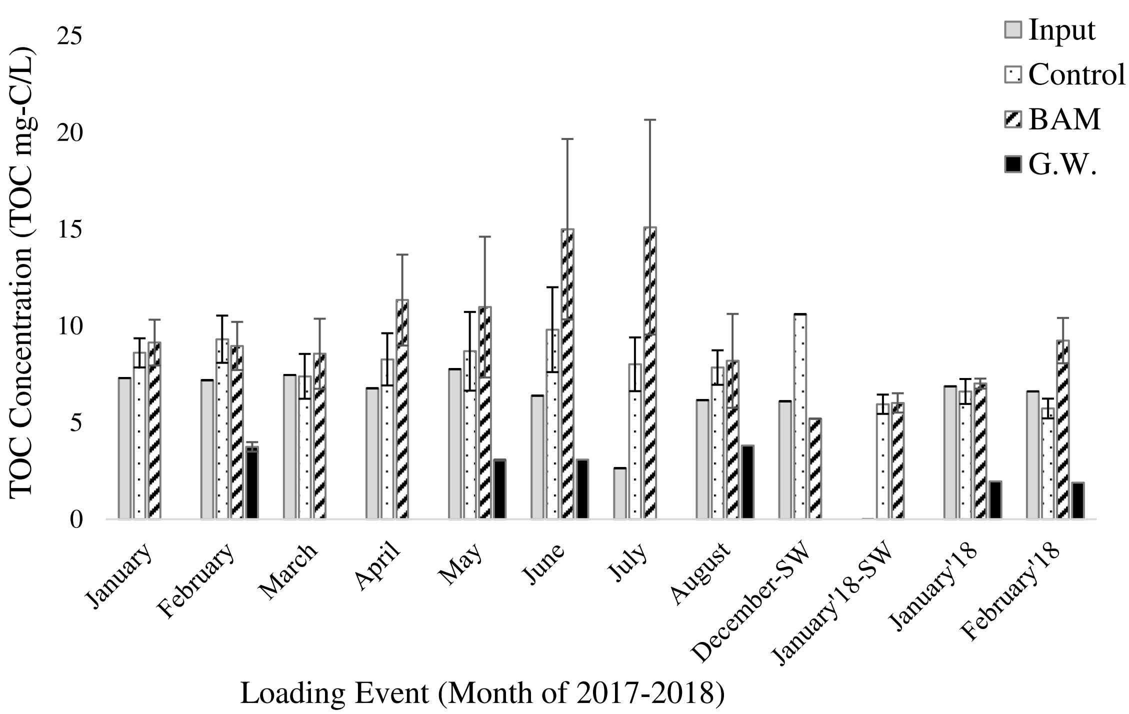

Figure 27. Non-Purgeable Dissolved Organic Carbon Concentrations.

Note: Error bars represent 1 SE. G.W. represents groundwater from the onsite monitoring well.

Boron

Boron is a conservative element in the environment, which researchers have used as a tracer species relative to groundwater flow studies. This provides an opportunity for the use of boron in determining dilution effects. In the literature, chloride has been used for determining impacts to storm water flow and denitrification in soil. However, since the source water in this study is wastewater effluent that is heavily chlorinated, the use of chloride as a tracer was suspect, here. As the chlorine reactions proceed in the environment, chloride ions can be released. The possibility of fluctuations in the chloride ion being due to the chorine reaction made chloride a less than desirable tracer here. Therefore, boron concentrations were gathered from the RIB influent and effluent to observe if dilution effects were present during the conduct of the study, as shown in Table 12. Review of the boron data reveals that dilution was present immediately prior to and after the hurricane event; however, not enough data was collected to provide a complete picture.

Table 12. Boron Concentrations.

Loading Event		Boron(mg/L)							
		Input	**L1**	**L2**	**L3**	**L4**	**L5**	**L6**	**Well**
Month	**January**	0.21		0.16			0.20		
	February	0.18		0.17			0.19		0.22
	March	0.19	0.19	0.13	0.18		0.15	0.19	0.16
	April	0.18	0.19	0.13	0.16		0.18	0.15	
	May	0.16	0.19	0.12	0.16	0.20	0.19	0.16	0.18
	June	0.15	0.16	0.095	0.19	0.17	0.14	0.12	0.20
	July	0.18	0.22	0.13	0.13	0.12	0.16	0.17	
	August	0.16	0.12	0.12	0.046	0.13	0.13	0.14	0.22
	January'18	0.15	0.046	0.040	0.040	0.082	0.090	0.19	0.094
	February'18	0.17	0.10	0.15	0.11	0.09	0.09	0.15	0.08
Statistics	**Min**	0.15	0.05	0.04	0.04	0.08	0.09	0.12	0.08
	Max	0.21	0.22	0.15	0.19	0.20	0.19	0.19	0.22
	Mean	0.17	0.15	0.11	0.13	0.13	0.14	0.16	0.17
	SD	0.019	0.059	0.034	0.058	0.047	0.038	0.024	0.057
	n	10	8	8	8	6	8	8	7
	SE	0.006	0.021	0.012	0.020	0.019	0.013	0.009	0.022
Quartile	**1**	0.16	0.12	0.11	0.09	0.09	0.12	0.15	0.13
	Median	0.18	0.18	0.13	0.15	0.13	0.15	0.16	0.18
	3	0.18	0.19	0.13	0.17	0.16	0.17	0.18	0.21

Observations

Lysimeters

The RIB study ponds were not identical in design due to the construction of the site for this project. Lysimeter 4 failed to deliver a sample one time; additionally, Lysimeter 4 within the Control RIB was replaced after the March sampling because it did not yield sufficient sample. Upon inspection it was found to be only one foot under the bottom of the Control RIB and thus was replaced at the appropriate depth of 2 feet. Another example of a lysimeter failure was when the lid of lysimeter 3 was partially off and sediment (clay soil from the surrounding soil) was found inside; in this specific event, the lid was reset after the sampling event was completed.

Hurricane Storm Water

Hurricane Irma passed central Florida on September 10 and 11, 2017, which impacted the site. The stormwater level in the study RIB (BAM and Control) rose to a level of about 12 feet by September 18 (Figure 13). Stormwater samples were taken on December 18th, 2017 when the stormwater had receded. At this point the Control and BAM ponds were sampled to represent an input value for the next stormwater sample, collected on January 10, 2018. The procedure of lysimeter evacuated between sample dates was the same as when reclaimed water was used, however no distilled water cleaning was possible due to the standing water. The collected stormwater samples were analyzed by ERD, a certified lab within 24 hours after collection. The parameter analyzed by ERD were nitrate and nitrite individually. The results for nitrate removal from stormwater are presented in Table 9, where additional details are provided in Appendix B. Data for phosphorus was not collected during this time.

Soil Moisture

Soil moisture measurements were collected so that qualitative data could be analyzed, and a simple soil moisture model could be compared to actual data. The results provided observational quality assurance for the research project. An example of the soil moisture readings for the treatments during the February 2017 loading event is displayed in Figure 28. The modeled results are compared against the In-field observations for the February loading event, for the Control, Figure 29, and BAM, Figure 30, ponds.

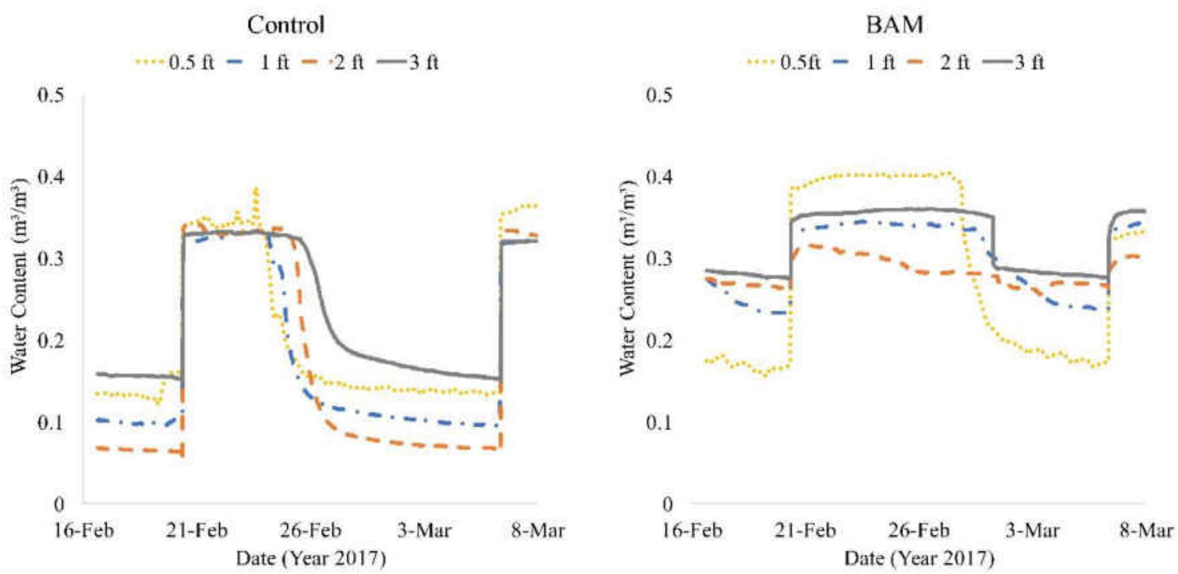

Figure 28. Soil Moisture Trends Observed In-field during the February Loading Event.

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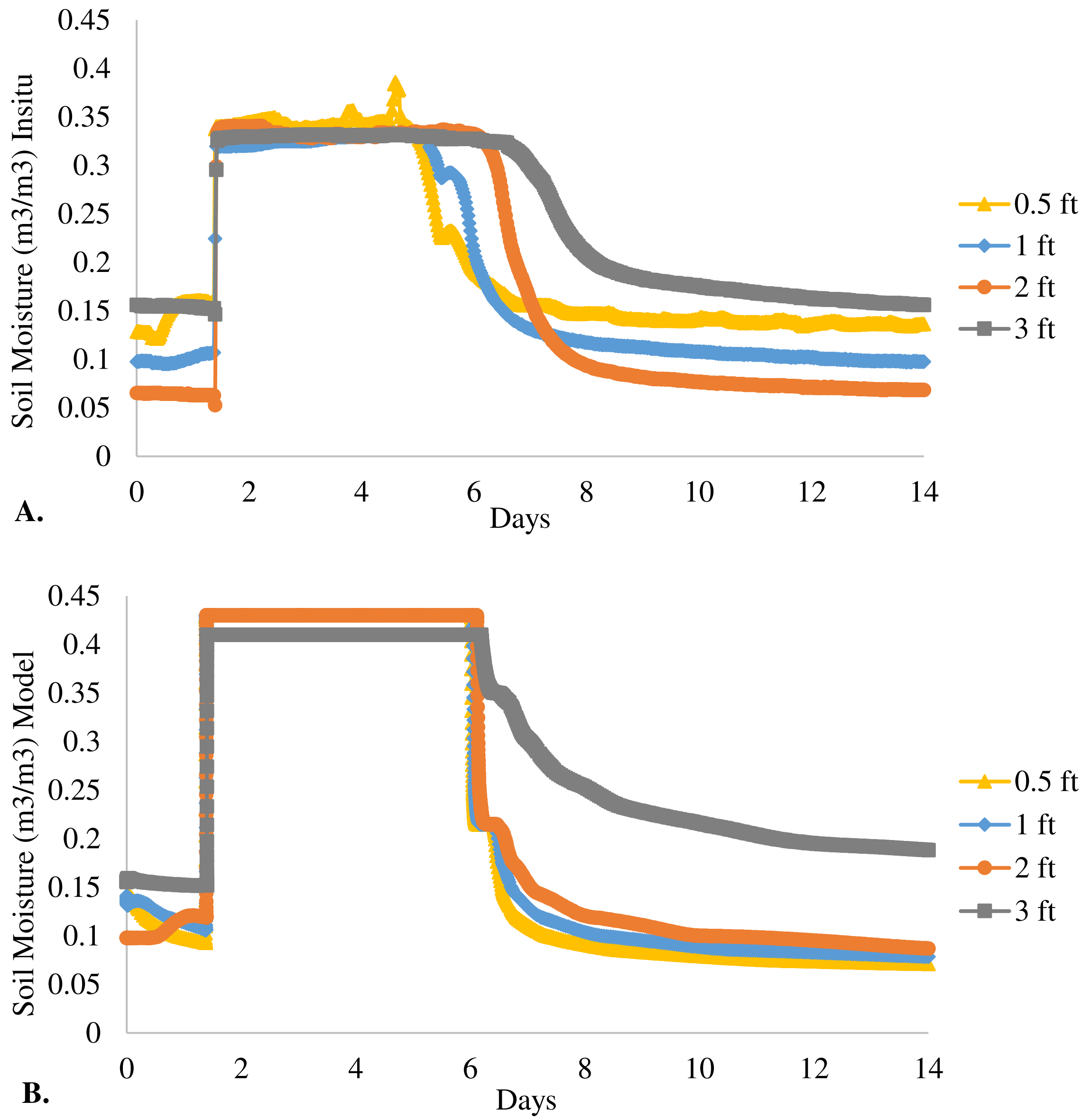

Figure 29. Control Pond Soil Moisture, A. Infield Collection & B. HYDRUS Model.

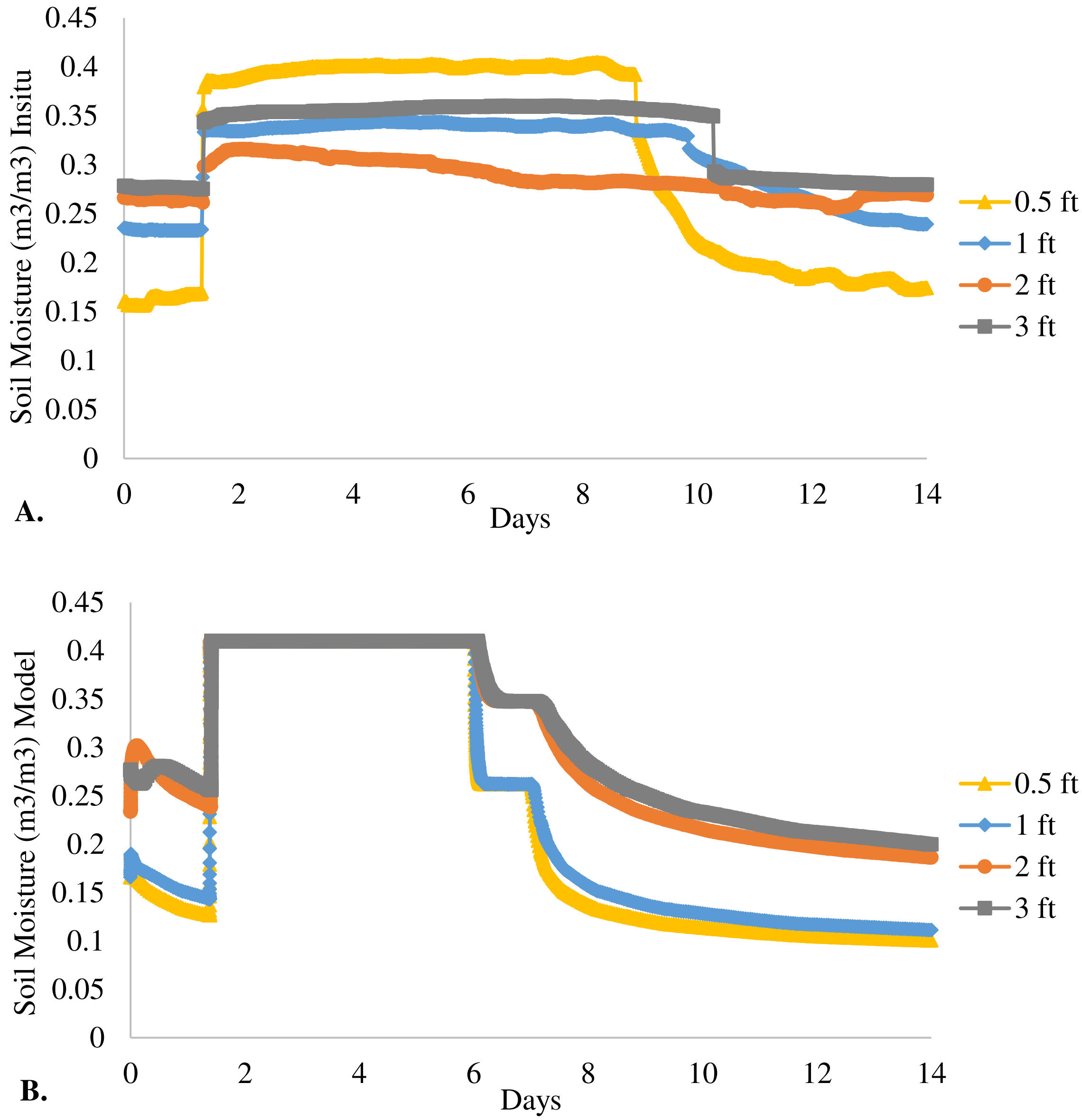

Figure 30. BAM Pond Soil Moisture, A. Infield Collection & B. HYDRUS Model.

Infiltration and Groundwater Levels

The depth of storage or gage heights shown in Figure 31 reflects the rate of loading over time and infiltration. Infiltration is the slope of the decreasing portion of depth over time. The stage data show no noteworthy difference in the stage and infiltration (slope of line) between the Control and the BAM RIB. The area under the stage curve times the area of water storage is the volume of storage. The time to empty the RIBs was about equal.

Also shown in Figure 31 is a comparison to the water table depth as a measure water in a well. The well was in the separation berm between the BAM RIB and the Control RIB. The RIBs were used to store excess stormwater during and immediately after the Hurricane. The depth of storage was greater than the top of the well-used to measure groundwater and was in a flooded condition up until the end of December. Thus, no data on well depths are available during that time. However, in the months of January and February the water table had risen to within 1-2 feet of the bottom of the RIBS. The rate of infiltration during this period decreased to about 0.125 to 0.25 inch/hour.

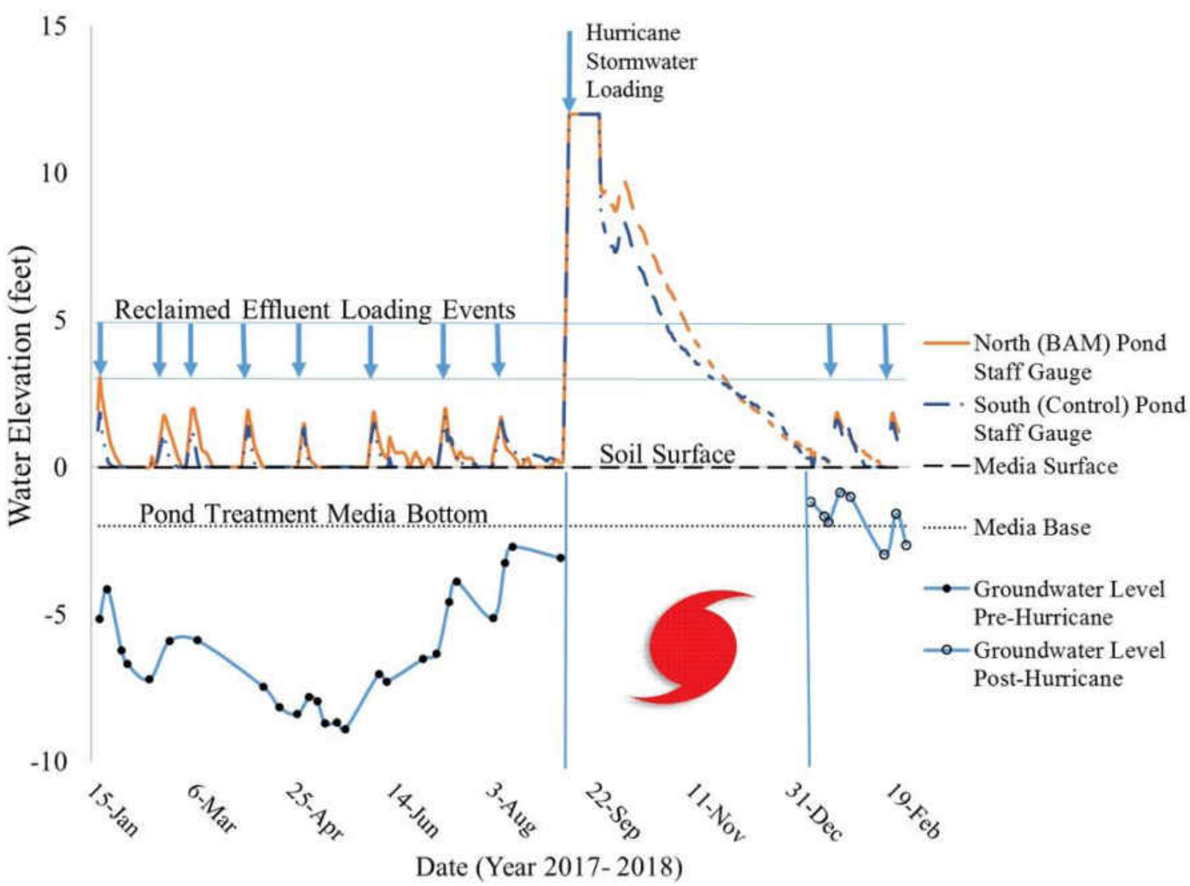

Figure 31. Loading and Water Table Levels

Source water and changes in the facility

Fluctuations in nutrient concentrations entering the study RIBs are seen throughout the study period, Figure 32. The fluctuation in nutrient concentration is a combination of WRF treatment operation optimization of newly updated facilities, river water mixing and source water.

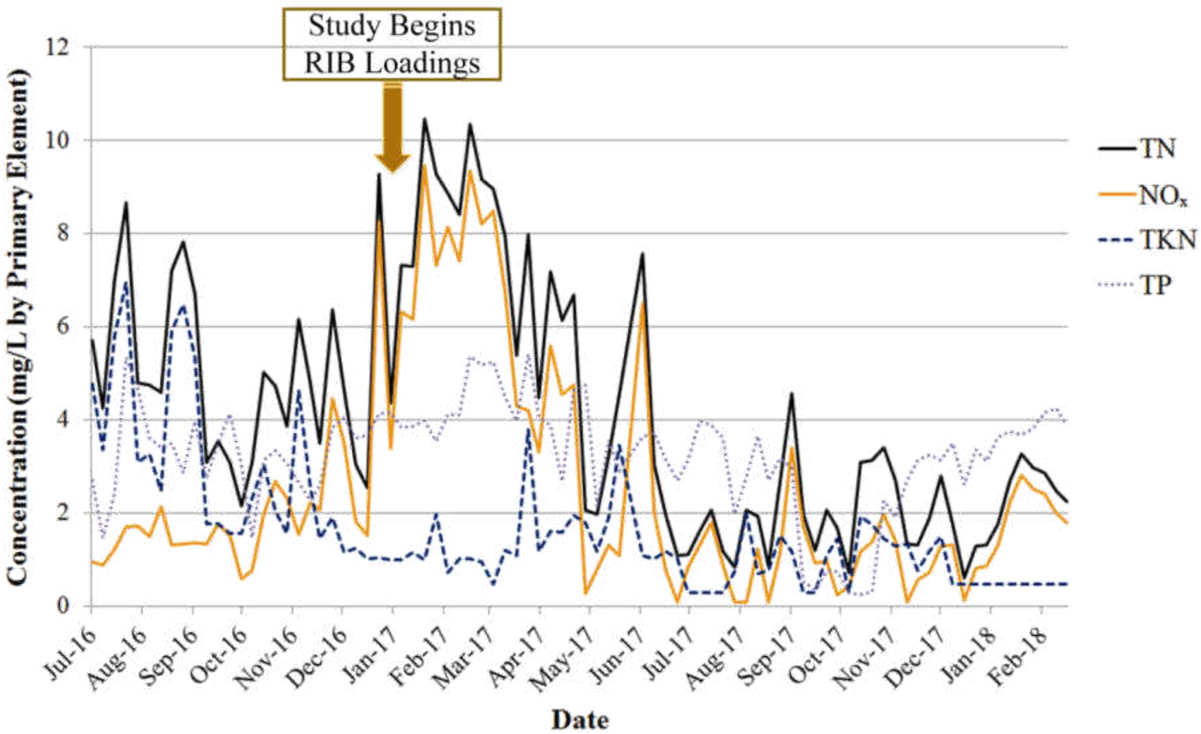

Figure 32. City of DeLand's WRF Reclaimed Water Nutrient Concentrations.

CHAPTER 5: CONCLUSIONS

Rapid infiltration basins (RIB) have been historically used in Florida for groundwater recharge, effluent disposal, or a combination of both. However, this technique has proven ineffective in providing nitrogen control unless the RIB is modified in some manner. In this study, a traditional RIB was compared to a modified RIB constructed with manufactured biosorption activated media (BAM) to evaluate nitrate removal from reclaimed water. The RIBs are used for reclaimed and excess storm water disposal. Few, if any, studies have been published where BAM-modified RIBs have been used for this purpose. In this work, a mixture of clay, tire crumb, and sand (CTS) was selected to serve as the BAM material (Bold and Gold™ CTS media). Each RIB was constructed with two feet of either sand or BAM, covering more than 43,600 square feet of surface area.

A summary of this study's results is depicted in Figure 33. The total nitrogen removal observed, here, in this study as compared to other studies was not consistent. The total nitrogen removal trend, throughout the study period, closely matched the nitrate removal trend with minor impacts due to the variation of total Kjeldahl nitrogen (TKN, organic and ammonia) removal results. Birch, Fazeli and Matthai (2005) showed RIBs to be ineffective in reducing the concentrations of total nitrogen, whereas the mean removal efficiency for the concentrations of TP and TKN was 51% and 65%, respectively. The following conclusions were developed in this study:

1. For the conditions of the study reported on herein, BAM was found to remove nitrate at a greater amount over that of a traditional sand RIB (for conditions where both storm and reclaimed effluent water was present).

2. It was found that at low input nitrate loadings to the RIB no nitrate removal was observed. At low input loadings, there is minimal removal difference between the control and BAM RIB ponds. This suggests that if wastewater facilities or other water sources have low nutrients, then adding BAM may out way the benefits by the cost of purchase and installation of a previously created RIB.

3. Over the course of the study, ecological and human activity occurred within the study basin; the activity may have contributed to observed algal mat growth. Additionally, ant activity, tadpoles, animal excrement, lawn mowing, and other signs of human activity were present at various time during the study period.

This study demonstrated the nitrate removal effectiveness of a field-scale BAM-modified RIB as compared to a traditional field-scale sand-based RIB. Results suggest that BAM removed 78 percent of the nitrates as compared to the control, 47 percent, under the conditions of the study. BAM removed 31 percent of the TN and 62 percent of the TP as compared the control, 12 percent and 28 percent, respectively

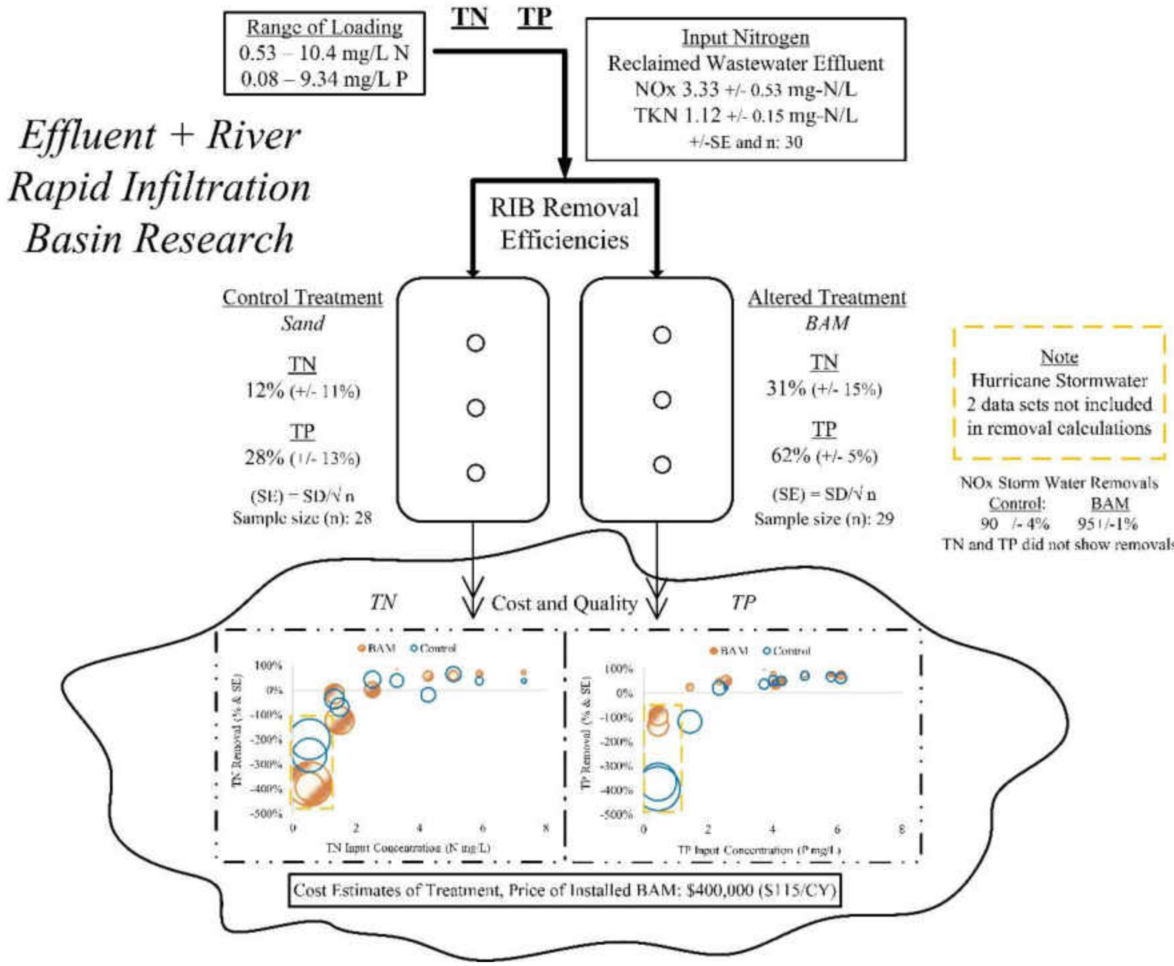

Figure 33. Study Results Summary

APPENDIX A: UNIVERSITY OF CENTRAL FLORIDA DATA

University of Central Florida CECE Environmental Laboratories

Analyses for Non-purgeable Dissolved Organic Carbon (NPDOC), Alkalinity, and sample processing and preparation for Nitrogen Isotope (15N and 18O) were conducted at the University of Central Florida (UCF), Department of Civil, Environmental and Construction Engineering (Dept. CECE), Environmental and Drinking Water Laboratories *by said graduate student of this Thesis.*

Data

Water quality samples collected from the DeLand RIB Lysimeters and Input water January 2017 to February 2018 loading events. The data collection was sampled from each reclaimed-water loading event, with the stormwater events designated with an i asterisks (i). Analysis conducted in field with HACH meter and pH/Temperature/Conductivity/ORP probes. Analysis conducted in lab at University of Central Florida, or sent to Advanced Environmental Laboratories, Eurofins, TetraTech Inc., or Stable Isotope Facility - University of California Davis. Analysis conducted at ERD designated by an asterisks (*). Input samples for this data set represent Thursday Composite samples collected the Thursday after the Monday loading event.

Table A-1. pH (Standard pH units)

Loading Event	pH (pH units) in-field							
	Input	BAM			Control			Monitoring Well
		L1	L2	L3	L4	L5	L6	
January’17	7.28	7.27	7.82	7.51	6.84	7.21	7.6	-
February’17	7.38	7.47	8.56	7.17	6.78	7.07	7.48	6.12
March’17	7.51	8.2	9.68	7.28	-	7.23	7.52	6.10
April’17	7.4	6.83	7.38	7.27	-	7.18	7.32	-
May’17	7.31	6.84	6.99	7.13	6.98	7.29	7.41	6.15
June’17	7.47	6.94	7.4	6.71	7.01	6.95	7.3	6.10
July’17	7.58	6.92	7.1	6.81	6.7	7.13	8.25	-
August’17	7.72	6.72	7.28	6.68	6.72	7.22	7.72	6.54
Hurricane Impact: Stormwater Loading (minimal sampling)								
January'18 [i]	-	6.50[i]	7.18[i]	6.67[i]	6.53[i]	6.67[i]	9.43[i]	-
January'18	7.48	6.78	7.00	6.78	6.73	6.53	7.52	6.67
February'18	7.59	6.65	7.07	6.97	6.71	6.64	8.24	6.60

[i] stormwater

Table A-2. Temperature (°C)

Loading Event	Temperature (° C) in-field							
	Input	BAM			Control			Monitoring Well
		L1	L2	L3	L4	L5	L6	
January’17	20.9	16.3	18.1	17.8	10.8	17.6	16.9	-
February’17	10.3	21.5	22.0	22.4	20.8	22.6	21.5	21.4
March’17	11.9	21.4	20.7	22.5	-	21.5	21.7	21.0
April’17	13.2	23.5	24.1	23.2	-	25.6	24.6	-
May’17	22.8	24.9	26.6	26.2	25.4	26.5	27.1	25.7
June’17	16.8	28.1	28.4	28.7	27.5	27.7	27.9	25.0
July’17	16.3	29.6	31.8	30.4	30.4	30.0	30.9	-
August’17	14.8	29.4	30.9	30.0	29.8	28.4	29.0	26.6
Hurricane Impact: Stormwater Loading (minimal sampling)								
January'18 [i]	-	17.6[i]	17.8[i]	19.9[i]	17.5[i]	17.4[i]	12.7[i]	-
January'18	15.5	18.1	18.8	24.8	17.7	18.6	17.7	20.5
February'18	15.5	-	25.2	23.8	23.2	22.7	24.2	22.1

[i] stormwater

Table A-3. Conductivity (µS/cm)

Loading Event	Conductivity (µS/cm) in-field							
	Input	BAM			Control			Monitoring Well
		L1	L2	L3	L4	L5	L6	
January'17	891	808	689	758	882	819	775	-
February'17	783	815	643	803	778	660	808	697
March'17	834	818	560	722	-	538	767	625
April'17	751	810	686	843	-	680	727	-
May'17	859	957	884	1029	1195	933	959	724
June'17	777	729	385	806	832	609	583	683
July'17	724	608	645	331	370	683	871	-
August'17	679	262	633	154	601	559	635	897
Hurricane Impact: Stormwater Loading (minimal sampling)								
January'18 [i]	-	235[i]	193[i]	237[i]	442[i]	435[i]	343[i]	-
January'18	727	362	329	334	418	406	766	320
February'18	726	531	787	614	453	422	733	328

[i] stormwater

Table A-4. Oxidation Reduction Potential (mV)

Loading Event	Oxidation Reduction Potential (mV) in-field							
	Input	BAM			Control			Monitoring Well
		L1	L2	L3	L4	L5	L6	
January'17	No data before May							
February'17								
March'17								
April'17								
May'17	620.8	55	-109	-39	148	-34	-105	148.1
June'17	678	-116	87	126	-21	149	169	274.7
July'17	597.7	-104	-99	36	56	24	-46	-
August'17	619.5	-74	-8	11	-78	100	97	255.6
Hurricane Impact: Stormwater Loading (minimal sampling)								
January'18 [i]	-	-81[i]	-82[i]	-45[i]	-94[i]	-134[i]	143[i]	-
January'18	645	0	120	21	-93	-90	-55	11
February'18	606	-28	11	83	-107	-111	38	29

[i] stormwater

Table A-5. Non-Purgeable Dissolved Organic Carbon (mg/L)

Loading Event	NPDOC (mg-C/L)							
	Input	BAM			Control			Monitoring Well
		L1	L2	L3	L4	L5	L6	
January'17	7.30	11.50	7.84	8.06	9.96	8.49	7.36	3.99
February'17	7.19	10.83	6.60	9.45	9.08	11.53	7.32	3.50
March'17	7.46	12.16	7.09	6.42	-	8.55	6.23	-
April'17	6.77	10.40	7.81	15.79	-	9.62	6.92	-
May;17	7.76	-	7.33	14.61	-	10.72	6.65	3.09
June'17	6.39	17.34	6.01	21.65	13.46	10.08	5.87	3.07
July'17	2.64	25.75	7.04	12.52	6.27	7.01	10.76	-
August'17	6.16	12.52	7.93	4.12	8.71	6.06	8.76	3.82
Hurricane Impact: Stormwater Loading (minimal sampling)								
December'17 [i]	6.10[i]*	5.2[i]*			10.6[i]*			-
January'18 [i]	-	5.34[i]	6.99[i]	5.72[i]	6.85[i]	5.86[i]	5.13[i]	-
January'18	6.87	7.53	6.80	6.71	6.57	5.51	7.74	1.96
February'18	6.61	11.36	9.04	7.31	5.06	5.39	6.73	1.89

[i] stormwater, * ERD Laboratory data results

Table A-6. Alkalinity (mg/L as $CaCO_3$)

Loading Event	Alkalinity (mg/L as $CaCO_3$)							
	Input	BAM			Control			Monitoring Well
		L1	L2	L3	L4	L5	L6	
January'17	150	197	113	145	138	227	148	160
February'17	135	198	99	153	94	86	143	148
March'17	140	212	108	153	-	86	150	212
April'17	158	197	80	162	-	103	122	-
May;17	147	-	85	181	-	99	153	132
June'17	136	169	80	148	162	92	99	103
July'17	150	172	96	103	52	153	172	-
August'17	135	95	109	71	157	162	133	260
Hurricane Impact: Stormwater Loading (minimal sampling)								
December'17 [i]	100[i]*	82[i]*			128[i]*			-
January'18 [i]	-	69[i]	60[i]	83[i]	139[i]	134[i]	95[i]	-
January'18	139	102	69	83	120	111	180	93
February'18	162	136	116	153	125	102	162	106

[i] stormwater, * ERD Laboratory data results

Quality Assurance and Quality Control

Accuracy and precision results for non-purgeable dissolved organic carbon (NPDOC) analysis are within the control limits of the analysis, charts displayed in Figures A-1 through A-3. Alkalinity replicates are within the control limits of the analysis and the acid equivalency was standardized and checked throughout the process.

Precision and Accuracy Charts (TOC)

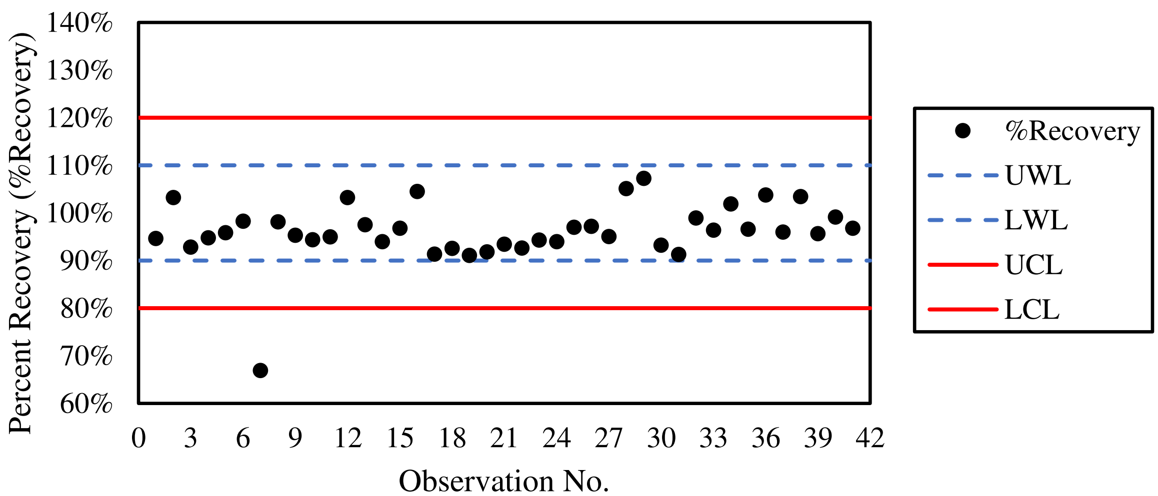

Figure A-1. Accuracy Control Chart for Non-Purgeable Dissolved Organic Carbon (mg/L).

Percent Recovery, displayed in black circles, is based on laboratory-fortified matrix spiked samples from February – August 2017 and January - February 2018 for 41 samples, in lab at UCF. Upper and Lower Warning (UWL, LWL) and Control (UCL, LCL) Limits are designated in dashed blue and solid red lines, respectively.

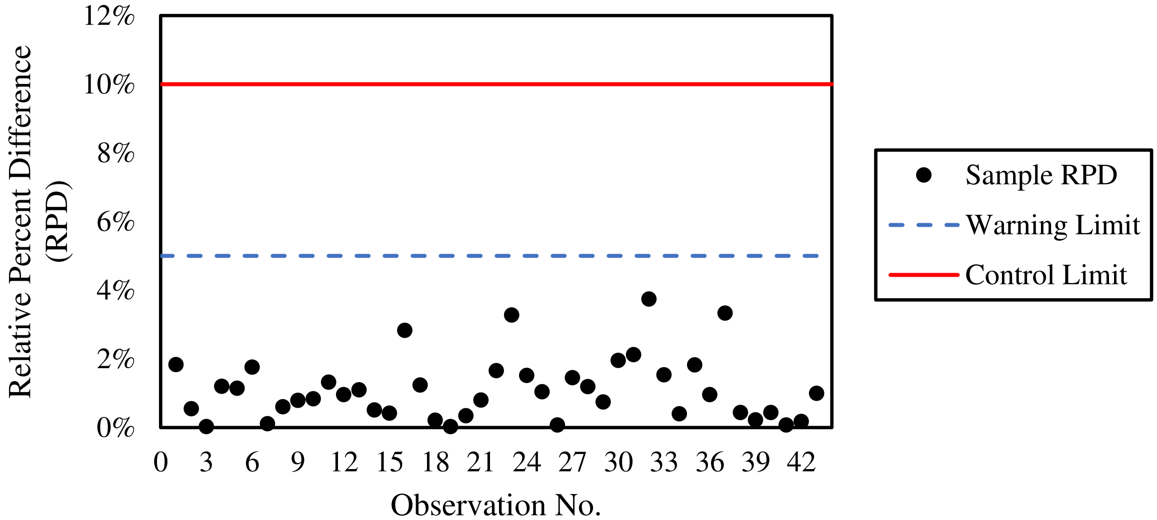

Figure A-2. Precision Control Chart for Non-Purgeable Dissolved Organic Carbon (mg/L).

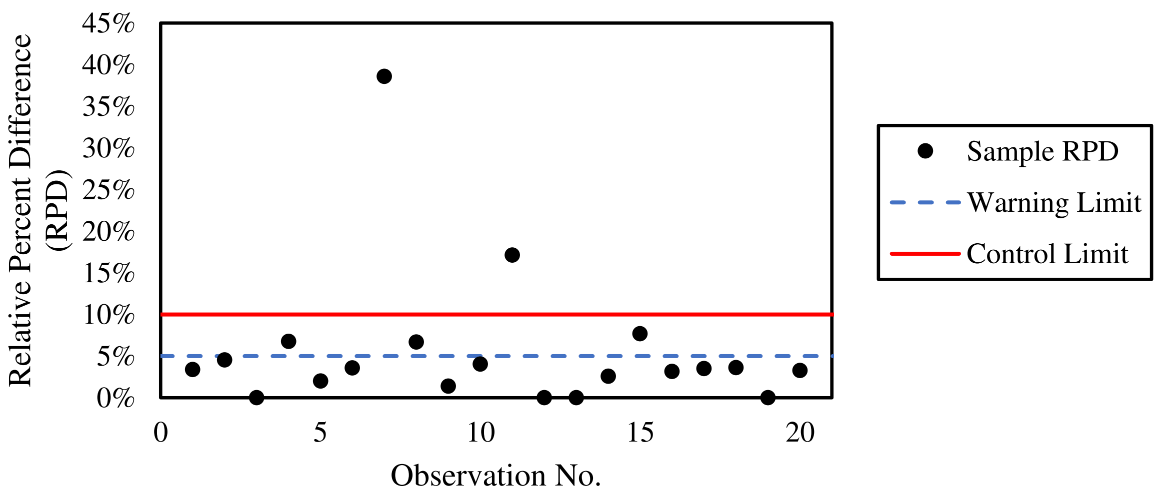

Figure A-3. Precision Control Chart for Alkalinity (mg/L as CaCO3).

Relative Percent Difference (RPD), displayed as black circles, is based on laboratory replicate samples from February – August 2017 and January - February 2018 for 43 sample (Figure A-2) and 20 samples (Figure A-3), in lab at UCF. Warning and Control Limits are designated in dashed blue and solid red lines, respectively.

APPENDIX B:
THE CITY OF DELAND AND ERD LABORATORY DATA

The nutrient data for this FDEP project # NS003 were analyzed by either the City of DeLand Lab or the Environmental Research and Design (ERD) Inc. Lab, both of which are NELAC certified.

<u>City of DeLand NELAC Certified Laboratory Data</u>

The City of DeLand Environmental Services Laboratory (City Lab) is NELAC certified (# E53362) effective July 1, 2016 to June 30, 2017, as required by the Florida Department of Environmental Protection. The City Lab is located at the DeLand Water Utilities Department, 1101 S Amelia Ave, DeLand, FL 32724. The University of Central Florida was entitled to rely on data provided by the City and others without independent verification.

Data

Data collection and analysis for the Project (FDEP# NS003) was conducted January - September 2017 and January - February 2018 for reclaimed wastewater effluent and rapid infiltration basin (RIB) lysimeter samples. These samples were delivered to the City of DeLand Lab for water quality analysis. The break in reclaimed water loading and subsequent sampling that occurred from September – December 2017 was due to hurricane Irma in September 2017. The hurricane produced enough storm water to fill the RIB with more than 12 feet of standing water for a period of approximately four months. These RIBs were loaded with storm water from the surrounding areas until January 2018 when the reclaimed water loading, and sampling resumed.

The DeLand Lab provided UCF with the water quality analysis for 1) the lysimeter samples from the reclaimed water loading and 2) the weekly Thursday 24hr-composited reclaimed water samples (WWE). The DeLand Lab data was provided to the graduate student either directly from the Lab or through the project PI. Initial data provided by DeLand (Table B-2 through B-16) was later re-confirmed for MDL limits and therefore a few data points are stared (*) for changes in MDL from <0.4 mg/L to 0.079 or <0.079 mg/L. The graduate student was entitled to rely on data provided without independent verification.

The City of DeLand Lab relied on the methods for the water quality analysis displayed in Table 6, which can be found in the methods section of this document. The method and instrumentation data limits for changed during the study, due to a shift in staff conducting the designated test at the lab. Laboratory detection limits are based on machine sensitivity, method quantification error and personal quantification error. The error produced varies based on the scale at which analysis occurs (i.e. based on concentration level: lower error with small changes at higher concentrations, whereas larger percent error with small changes at lower concentrations). The nitrate-nitrite detection limit remained constant from January – September 2017 (initial) and December – February 2018 (change), Table B-1.

Table B-1. Nitrate-Nitrite method and detection limit

Parameter	Method/Instrument	Detection Limit
Reclaimed Water (City of DeLand Lab)		
Nitrate-Nitrite (NOx)	EPA Method 353.2: DeLand Lab	0.079 mg/L N (0.134 mg/L)*
Storm Water (ERD Lab)		
Nitrate and Nitrite (NO_3 and NO_2)	Standard Method 4500 F: ERD Lab	0.002 mg/L N

*Detection limit change due to change in laboratory technician (0.134 mg/L).

The following Tables B-2 through B-16 are the water quality results from reclaimed wastewater effluent and lysimeter samples analyzed by the City of DeLand Laboratory (unless otherwise noted). Each table is labeled with the sampling event month (month/day/year).

Table B-2. Event 1 Nutrient Results (January 2017)

	sample date		1/30/2017					
	sample location	Loading	BAM #1	BAM #2	BAM #3	Control #4	Control #5	Control #6
Conductivity	µmhos/cm		865	721	811	924	864	820
Turbidity	NTU		3.41	37.7	4.16	18.5	0.82	2.15
Fecal Coliform	CFU/100ml		15	10	<5	50	815	100
TKN	mg-N/L		2.01	1.58	1.23	1.52	1.25	1.02
Nitrate/Nitrite	mg-N/L		<0.4*	<0.4*	1.51	3.63	3.31	3.07
TN	mg-N/L		2.21	1.78	2.74	5.15	4.56	4.09
Cl-	mg/L		126	122	124	126	127	120
TP	mg-P/L		0.700	0.864	1.86	1.28	0.638	2.66
pH	pH units		7.87	7.96	7.74	7.35	7.63	7.89

*data point BAM #1: <0.079 (0.079/2 = 0.0395) and #2: 0.079 for removal calculations

Table B-3. Event 2 Nutrient Results (February 2017)

	sample date	2/20/17	2/27/2017					
	sample location	Loading	BAM #1	BAM #2	BAM #3	Control #4	Control #5	Control #6
Conductivity	µmhos/cm		867	658	874	816	689	850
Turbidity	NTU		3.21	102	20.6	57.3	1.12	1.40
Fecal Coliform	CFU/100ml		10	2	10	63	643	17
TKN	mg-N/L	1.64	2.29	1.80	1.64	2.19	1.63	1.72
Nitrate/Nitrite	mg-N/L	6.04	0.457	<0.4*	3.79	4.00	5.12	6.02
TN	mg-N/L	7.68	2.75	2.00	5.43	6.19	6.75	7.74
Cl-	mg/L		126	117	125	140	109	126
TP	mg-P/L	4.00	1.830	1.370	0.920	0.792	1.59	3.64
pH	pH units		7.81	8.78	7.35	7.18	7.40	7.71

*data point BAM #2: 0.079

Table B-4. Event 3 Nutrient Results (March 2017)

	sample date	3/6/17	3/13/2017					
	sample location	Loading	BAM #1	BAM #2	BAM #3	Control #4	Control #5	Control #6
Conductivity	µmhos/cm		922	583	782		551	790
Turbidity	NTU		3.13	50	74.2		5.35	1.98
Fecal Coliform	CFU/100ml		5	9	22		3224	6
TKN	mg-N/L	1.15	2.60	1.43	1.38		1.57	1.17
Nitrate/Nitrite	mg-N/L	6.08	<0.4	<0.4	3.04		3.78	5.62
TN	mg-N/L	7.23	2.80	1.63	4.42		5.35	6.79
Cl-	mg/L		133	98.0	113		80.0	112
TP	mg-P/L	4.68	1.530	0.442	2.780		1.25	3.50
pH	pH units		8.73	10.04	7.51		7.39	7.77

*data point BAM #1: <0.079, #2: <0.079.

Table B-5. Event 4 Nutrient Results (April 2017)

	sample date	4/3/17	4/11/2017					
	sample location	Loading	BAM #1	BAM #2	BAM #3	Control #4	Control #5	Control #6
Conductivity	µmhos/cm		859	710	880	1157	741	759
Turbidity	NTU		7.00	12.8	20.3	138	1.28	0.83
Fecal Coliform	CFU/100ml		<1	<1	27	36	870	<1
TKN	mg-N/L	2.64	1.65	1.48	2.96	2.09	1.46	1.54
Nitrate/Nitrite	mg-N/L	2.60	<0.4	<0.4	<0.4	2.58	2.60	1.10
TN	mg-N/L	5.24	1.67	1.50	2.98	4.67	4.06	2.64
Cl-	mg/L		118	132	138	228	122	122
TP	mg-P/L	4.12	2.00	1.25	2.94	1.01	2.64	2.85
pH	pH units	7.64	6.99	7.48	7.46	7.33	7.38	7.51

*data point BAM #1: 0.079, #2: 0.079, #3: <0.079.

Table B-6. Event 5 Nutrient Results (May 2017)

	sample date		5/8/2017					
	sample location	Loading	BAM #1	BAM #2	BAM #3	Control #4	Control #5	Control #6
Conductivity	μmhos/cm		925	887	1064	1223	949	983
Turbidity	NTU		144	36.1	2.72	10.3	0.79	0.52
Fecal Coliform	CFU/100ml		9	4	10	14	1110	5
TKN	mg-N/L		1.01	1.16	2.95	1.80	1.51	1.82
Nitrate/Nitrite	mg-N/L		<0.4	<0.4	<0.4	5.49	3.52	1.34
TN	mg-N/L		1.21	1.36	3.15	7.29	5.03	3.16
Cl-	mg/L		151	178	180	238	173	172
TP	mg-P/L		0.954	1.37	1.45	0.611	2.40	2.63
pH	pH units		6.91	7.25	7.24	7.03	7.24	7.62

*data point BAM #1: 1.34, #2: 0.079, #3: <0.079, Control #6: 0.079.

Table B-7. Event 6 Nutrient Results (June 2017)

	sample date	6/5/17	6/12/2017					
	sample location	Loading	BAM #1	BAM #2	BAM #3	Control #4	Control #5	Control #6
Conductivity	μmhos/cm		762	408	904	920	637	614
Turbidity	NTU		37.7	135	16.9	20.5	0.78	0.23
Fecal Coliform	CFU/100ml		280	140	9	TNTC	1500	65
TKN	mg-N/L	0.282	2.86	1.36	1.84	1.64	1.45	0.282
Nitrate/Nitrite	mg-N/L	3.72	<0.079	<0.079	8.82[i]	11.00[i]	1.91	<0.079
TN	mg-N/L	4.00	2.90	1.40	10.7	12.6	3.36	0.361
Cl-	mg/L	144	108	57.9	118	136	95.9	94.8
TP	mg-P/L	2.74	3.21	2.00	0.889	1.18	2.61	2.17
pH	pH units	7.37	7.06	7.50	6.82	7.03	7.09	7.49

[i]data point reanalyzed and found to be the same. TNTC = too numerous to count.

Table B-8. Event 7 Nutrient Results (July 2017)

	sample date	7/10/17	7/17/2017					
	sample location	Loading	BAM #1	BAM #2	BAM #3	Control #4	Control #5	Control #6
Conductivity	μmhos/cm		638	677	340	379	714	830
Turbidity	NTU		14.0	35.4	10.5	245	2.15	0.62
Fecal Coliform	CFU/100ml		133	10	3	258	1680	260
TKN	mg-N/L	1.02	6.21	1.58	1.27	2.56	1.23	2.67
Nitrate/Nitrite[i]	mg-N/L	0.723	<0.079	<0.079	0.815	0.987	<0.079	<0.079
TN	mg-N/L	1.74	6.25	1.62	2.09	3.55	1.27	2.71
Cl-	mg/L	120	68.6	111	12.8	50.2	86.2	116
TP	mg-P/L	3.23	2.01	1.38	0.459	1.92	2.02	2.16
pH	pH units	7.62	6.96	7.17	6.95	6.43	7.17	8.34

[i]NOx analyzed day of collection, reanalyzed 28 days later. Reanalysis results: (BAM #1: <0.079, #2: <0.079, #3: 0.882, Control #4: 1.08, #5: <0.079, #6: <0.079).

Table B-9. Event 8 Nutrient Results (August 2017)

	sample date	8/7/17	8/14/2017					
	sample location	Loading	BAM #1	BAM #2	BAM #3	Control #4	Control #5	Control #6
Conductivity	μmhos/cm		114	5.03	39.8	78.1	1.62	12.1
Turbidity	NTU		45	680	77	TNTC	TNTC	644
Fecal Coliform	CFU/100ml		2.53	1.62	0.371	3.02	0.780	1.56
TKN	mg-N/L	1.00	<0.079	<0.079	<0.079	<0.079	<0.079	<0.079
Nitrate/Nitrite	mg-N/L	0.079	2.57	1.66	0.411	3.06	0.820	1.60
TN	mg-N/L	1.08	17.1	95.1	1.93	70.0	66.4	78.0
Cl-	mg/L	105	1.08	1.36	0.927	5.14	2.33	1.93
TP	mg-P/L	2.26	6.86	7.48	6.86	6.79	7.35	7.95
pH	pH units	7.40	7.87	7.96	7.74	7.35	7.63	7.89

TNTC = too numerous to count.

Table B-10. Event 9 Nutrient Results (December 2017 – Stormwater)

	sample date		12/18/2017 (Storm water)					
	sample location	Loading	BAM #1	BAM #2	BAM #3	Control #4	Control #5	Control #6
Conductivity	µmhos/cm	Please see RIB Pond Storm Water Sampling	230	236	280	512	514	261
Turbidity	NTU		23.7	2.69	28.3	36.4	17.9	27.0
Fecal Coliform	CFU/100ml		<1	1	<1	<2	<10	<1
TKN	mg-N/L		2.29	<0.463	4.68	2.95	<0.463	2.16
Nitrate/Nitrite	mg-N/L		Please see ERD, samples below detection limit (<0.134)					
TN	mg-N/L		2.36	<0.530	4.75	3.02	<0.530	2.23
Cl-	mg/L		24.2	24.7	22.8	56.3	56.4	27.2
TP	mg-P/L		0.796	0.819	1.56	3.47	3.12	0.119
pH	pH units		6.83	7.04	6.86	6.67	6.86	7.09

Table B-11. Event 10 Nutrient Results (January 2018 – Stormwater)

	sample date		1/10/2018 (Storm water)					
	sample location	Loading	BAM #1	BAM #2	BAM #3	Control #4	Control #5	Control #6
Conductivity	µmhos/cm		233	211	258	466	456	378
Turbidity	NTU		5.06	3.04	2.92	18.8	11.6	1.46
Fecal Coliform	CFU/100ml		<1	1	196	116	74	<1
TKN	mg-N/L		2.01	2.03	3.57	3.64	<0.463	<0.463
Nitrate/Nitrite	mg-N/L		Please see ERD, samples below detection limit (<0.134)					
TN	mg-N/L		2.08	2.10	3.64	3.71	<0.530	<0.530
Cl-	mg/L		23.5	23.4	21.9	48.2	49.0	38.8
TP	mg-P/L		0.696	0.630	1.31	3.41	2.22	0.701
pH	pH units		6.74	7.30	6.86	6.66	6.83	9.51

Table B-12. Event 11 Nutrient Results (January 2018 – Reclaimed Water)

	sample date	1/22/18	1/30/2018					
	sample location	Loading	BAM #1	BAM #2	BAM #3	Control #4	Control #5	Control #6
Conductivity	µmhos/cm		342.2	230.4	278.9	431.1	420	834.2
Turbidity	NTU		3.64	16.1	2.79	8.11	10.6	3.35
Fecal Coliform	CFU/100ml		<1	<1	<1	TNTC	10	41
TKN	mg-N/L	2.4	0.463	0.463	0.463	2.73	0.463	0.463
Nitrate/Nitrite	mg-N/L	1.55	<0.134	0.134	<0.134	<0.134	<0.134	2.39
TN	mg-N/L	3.95	0.53	0.597	0.53	2.8	0.53	2.85
Cl-	mg/L	99.8	30.1	24.5	34.8	47.3	50.6	98.8
TP	mg-P/L	3.78	0.119	0.119	0.119	3.46	2.07	1.6
pH	pH units	7.35	6.85	7.03	6.84	6.71	6.67	7.62

TNTC = too numerous to count.

Table B-13. Event 12 Nutrient Results (February 2018)

	sample date	2/19/18	2/27/2018					
	sample location	Loading	BAM #1	BAM #2	BAM #3	Control #4	Control #5	Control #6
Conductivity	µmhos/cm		547	834	624	481	449	773
Turbidity	NTU		4.58	8.29	0.78	11.0	1.61	0.20
Fecal Coliform	CFU/100ml		6	<1	<1	625	880	<1
TKN	mg-N/L	0.463	2.70	0.463	0.463	3.20	0.463	0.463
Nitrate/Nitrite	mg-N/L	1.92	<0.134	3.33	0.537	<0.134	<0.134	<0.134
TN	mg-N/L	2.83	2.77	3.79	1.00	3.27	0.530	0.530
Cl-	mg/L	95.8	60.6	90.7	82.1	52.6	57.2	100
TP	mg-P/L	3.92	0.952	0.520	1.10	1.89	3.06	1.06
pH	pH units	6.73	6.89	7.12	7.05	6.70	6.78	8.37

Table B-14. Event 9 & 10 RIB Insitu Pond Water Quality Results (DeLand Lab)

	sample date	12/18/2017 (Storm water)	
	sample location	BAM Pond	Control Pond
Conductivity	µmhos/cm	212	343
Turbidity	NTU	11.2	2.20
Fecal Coliform	CFU/100ml	2	<1
TKN	mg-N/L	0.463	0.463
Nitrate/Nitrite	mg-N/L	<0.134	<0.134
TN	mg-N/L	0.530	0.530
Cl-	mg/L	23.8	39.4
TP	mg-P/L	0.119	0.787
pH	pH units	9.45	9.79

Table B-15. Monitoring Well Water Quality Results (insitu groundwater)

	sample date	5/8/2017	6/12/2017	8/7/2017	1/30/2018	1/30/2018	2/27/2018
	sample location	Monitoring Well					
Conductivity	µmhos/cm	730	719	1081	360.5	360.5	360
Turbidity	NTU	33.1	35.1	15.4	120	120	57.9
Fecal Coliform	CFU/100ml	<1	1	0	<1	<1	<1
TKN	mg-N/L	0.387	0.282	0.388	<0.463	<0.463	<0.463
Nitrate/Nitrite	mg-N/L	5.52	6.28	3.42	<0.134	<0.134	<0.134
TN	mg-N/L	5.91	7.56	3.81	0.299	0.299	0.299
Cl-	mg/L	108	114	122	38.5	38.5	37.3
TP	mg-P/L	0.248	0.243	0.161	1.19	1.19	0.119
pH	pH units	6.35	6.43	6.93	6.92	6.92	6.83

Table B-16. Event 6 Relative Nitrogen Species Results (June 2017)

	sample date	6/5/17	6/6/17	6/8/17	6/15/17
	sample location	Chlorinated Effluent	River Influent	Chlorinated Effluent	Chlorinated Effluent
Nitrate	mg-N/L	4.0	<0.025	4.4	2.3
Nitrite	mg-N/L	<0.025	<0.025	<0.025	<0.025
Ammonia	mg-N/L	<0.020	<0.020	<0.020	<0.020

Quality Assurance and Quality Control

Accuracy and precision results for nitrate-nitrite, total Kjeldahl nitrogen, total phosphorus and chloride analysis, conducted by the City of DeLand Laboratory, are within the control limits of the analyses. The accuracy and precision charts are displayed in Figure B-1 through B- 7. Accuracy and precision calculations are described in the methods section of this thesis document.

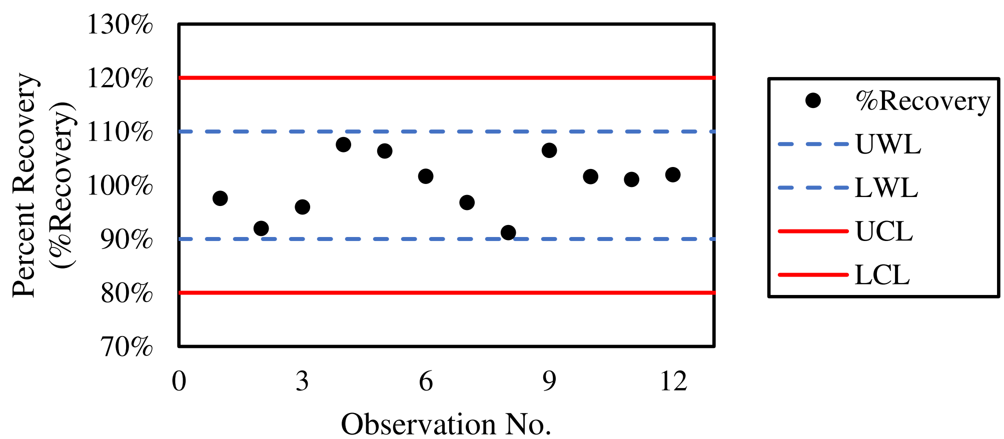

Figure B-1. Accuracy Control Chart for Combined Nitrate-Nitrite Analysis.

Percent Recovery, displayed in black circles, is based on laboratory-fortified matrix spiked samples from February - September 2017 and January - February 2018 for 12 samples conducted by the City of DeLand Laboratory. Upper and Lower Warning (UWL, LWL) and Control (UCL, LCL) Limits are designated in dashed blue and solid red lines, respectively.

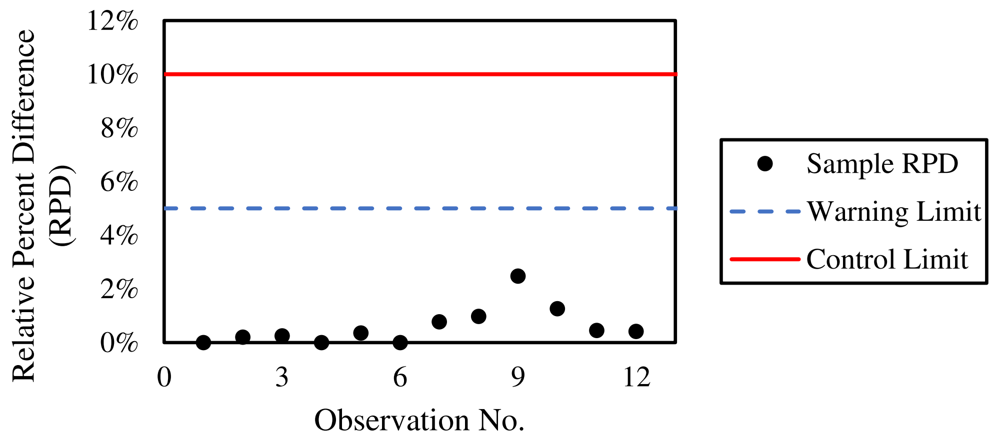

Figure B-2. Precision Control Chart for Combined Nitrate-Nitrite Analysis.

Relative Percent Difference (RPD), displayed as black circles, is based on laboratory replicate samples from February - September 2017 and January - February 2018 for 12 samples conducted by the City of DeLand Laboratory. Warning and Control Limits are designated in dashed blue and solid red lines, respectively.

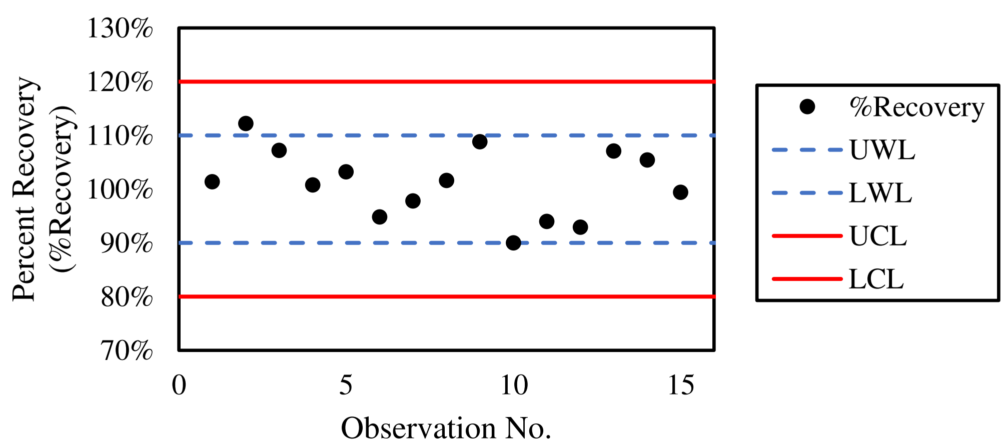

Figure B-3. Accuracy Control Chart for Total Kjeldahl Nitrogen Analysis.

Percent Recovery, displayed in black circles, is based on laboratory-fortified matrix spiked samples from February - September 2017 and January - February 2018 for 15 samples conducted by the City of DeLand Laboratory. Upper and Lower Warning (UWL, LWL) and Control (UCL, LCL) Limits are designated in dashed blue and solid red lines, respectively.

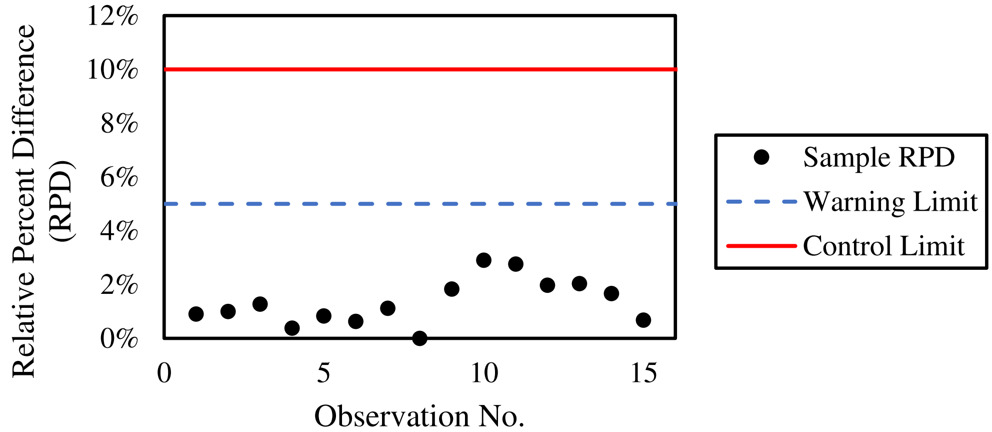

Figure B-4. Precision Control Chart for Total Kjeldahl Nitrogen Analysis.

Relative Percent Difference (RPD), displayed as black circles, is based on laboratory replicate samples from February - September 2017 and January - February 2018 for 15 samples conducted by the City of DeLand Laboratory. Warning and Control Limits are designated in dashed blue and solid red lines, respectively.

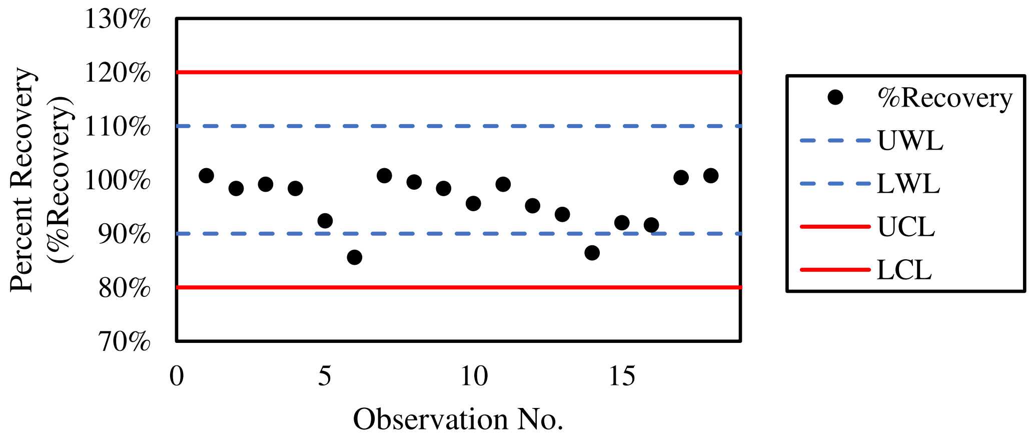

Figure B-5. Accuracy Control Chart for Total Phosphorus Analysis.

Percent Recovery, displayed in black circles, is based on laboratory-fortified matrix spiked samples from February-September 2017 for 18 samples conducted by the City of DeLand Laboratory. Upper and Lower Warning (UWL, LWL) and Control (UCL, LCL) Limits are designated in dashed blue and solid red lines, respectively.

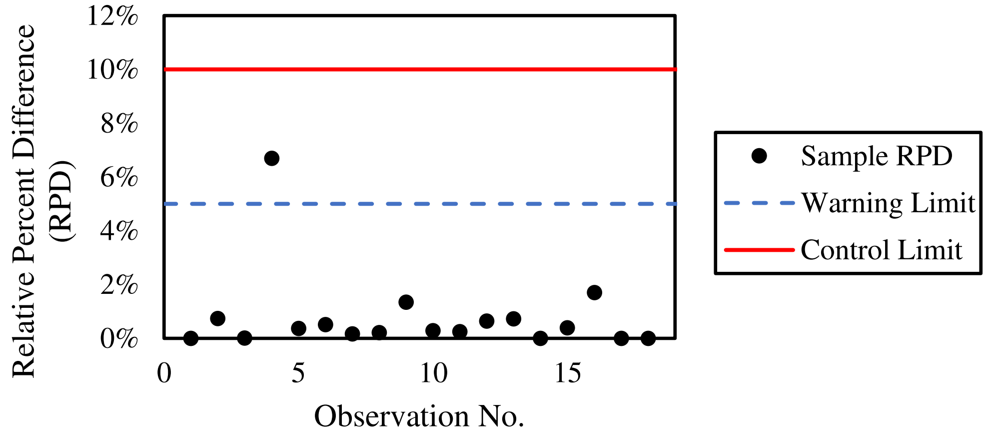

Figure B-6. Precision Control Chart for Total Phosphorus Analysis.

Relative Percent Difference (RPD), displayed as black circles, is based on laboratory replicate samples from February-September 2017 for 18 samples conducted by the City of DeLand Laboratory. Warning and Control Limits are designated in dashed blue and solid red lines, respectively.

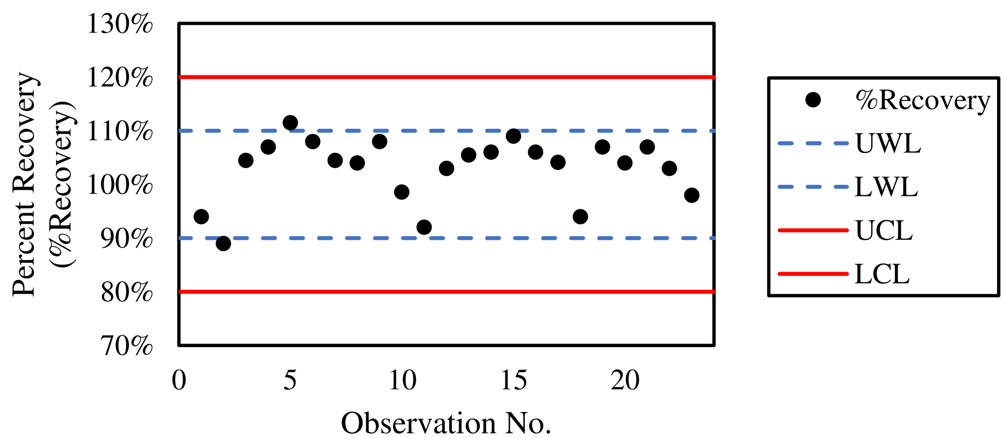

Figure B-7. Accuracy Control Chart for Chloride Analysis.

Percent Recovery, displayed in black circles, is based on laboratory-fortified matrix spiked samples from February-August 2017 for 23 samples conducted by the City of DeLand Laboratory. Upper and Lower Warning (UWL, LWL) and Control (UCL, LCL) Limits are designated in dashed blue and solid red lines, respectively.

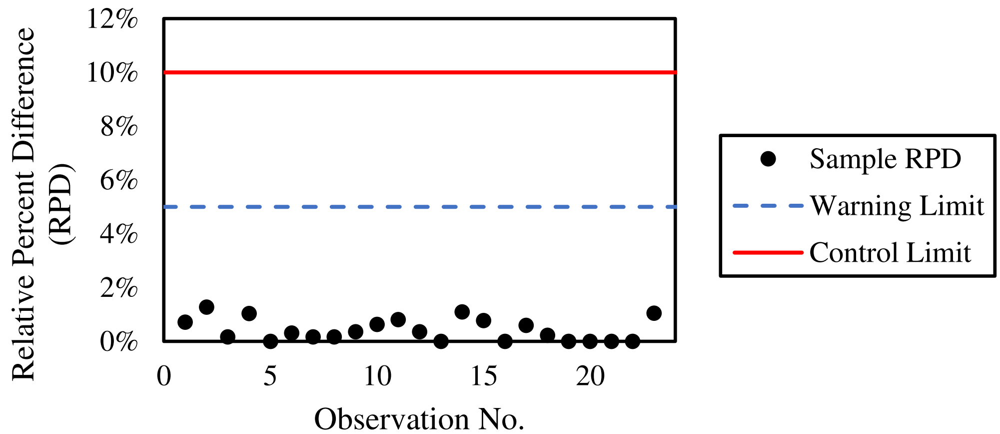

Figure B-8. Precision Control Chart for Chloride Analysis.

Relative Percent Difference (RPD), displayed as black circles, is based on laboratory replicate samples from February-August 2017 for 23 samples conducted by the City of DeLand Laboratory. Warning and Control Limits are designated in dashed blue and solid red lines, respectively.

The next section contains the Chain of Custody for the City of DeLand Lab

City of DeLand Environmental Laboratory
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Company: UCF
Address:
Zip:
Phone: 612-516-9282 Fax:
Client Contact:
Project Name:
Sampled By:
E-Mail Adress:

Method of Shipment: Client Drop
System ID#: NA

FOR LAB USE ONLY

Temperature Checked: Y N (___ °C) ROI
Custody Seals Intact: Y N NA
pH Checked: Y N NA
REPORT#

Preservative: ST/C | U/C | U/C

ANALYSES REQUESTED: Fecal | TP Thoy-[illegible] | pH

Preservation Key
H-Hydrochloric Acid C-COOL
N-Nitric Acid P-Phosphoric Acid
S-Sulfuric Acid ST-Sodium Thiosulfate
SH-Sodium Hydroxide U-Unpreserved

LAB ID #	COLLECTION DATE	COLLECTION TIME	Sample Type*	Matrix **	# containers	SAMPLE DESCRIPTION As Will Appear on Report	Fecal	TP Thoy-[illegible]	pH	COMMENTS
	1/30	9:45	G	GW	3	#1 RIB BAM				
		11:05		4		#2				
		11:15		WWE		#3				
		11:25				#4 RIB Control				
		11:45				#5				
	1/30	12:00				#6				

*Sample Type: G=Grab C=Composite O=Other
** Matrix: S=Solid SL=Sludge DW=Drinking Water GW= Ground Water SW=Surface Water WW=Wastewater M=Marine

RO I= Received On Ice

Relinquished By Jessica Carmier	Relinquished By	Relinquished By
Date/Time 1/30/17 12:30pm	Date/Time	Date/Time
Received By [signature]	Received By	Received By
Date/Time 1/30/17 1230	Date/Time	Date/Time

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Company: UCF
Address:
Zip:
Phone: 612-516-9302 Fax:
Client Contact:
Project Name: NS003 FDED DeLand RIBs
Sampled By: Jessica Cormier + Dylan Atkins
E-Mail Adress: JCormier@Knights.ucf.edu

Method of Shipment: Client Drop
System ID#: NA

FOR LAB USE ONLY

Temperature Checked: (Y) N — ROI (ROI °C)
Custody Seals Intact: Y N NA
pH Checked: Y N NA
REPORT#

Preservative: ST/C U/C U/C

Preservation Key
H-Hydrochloric Acid, C-COOL, N-Nitric Acid, P-Phosphoric Acid, S-Sulfuric Acid, ST-Sodium Thiosulfate, SH-Sodium Hydroxide, U-Unpreserved

ANALYSES REQUESTED

LAB ID #	COLLECTION DATE	COLLECTION TIME	Sample Type*	Matrix **	# containers	SAMPLE DESCRIPTION As Will Appear on Report	Fecal	TKN/NOx/TP	Turb/pH/Cond								COMMENTS
	2/27/17	925	G	GW	3	#1 LYS RIB BAM	✓	✓	✓								
	⎮	945	⎮	⎮	⎮	#2 ⎮	✓	⎮	⎮								
	⎮	1000	⎮	⎮	⎮	#3 ⎮ BAM	✓	⎮	⎮								
	⎮	1020	⎮	⎮	⎮	#4 ⎮ Control	✓	⎮	⎮								
	⎮	1030	⎮	⎮	⎮	#5	✓	⎮	⎮								
	2/27	1045AM	G	GW	3	#6 LYS RIB Control	✓										

*Sample Type: G=Grab C=Composite O=Other
** Matrix: S=Solid SL=Sludge DW=Drinking Water GW= Ground Water SW=Surface Water WW=Wastewater M=Marine

RO I= Received On Ice

Relinquished By	Jessica Cormier	Relinquished By		Relinquished By	
Date/Time	2/27/17 1120	Date/Time		Date/Time	
Received By	[signature]	Received By		Received By	
Date/Time	2/27/17 1120	Date/Time		Date/Time	

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Phone:
Fax:
Client Contact: Dr. Martin Wanielista
Project Name: BAM
Sampled By:
E-Mail Adress:

Method of Shipment: Client Drop
System ID#: NA

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Temperature Checked (Y) N (ROI ___°C)
Custody Seals Intact Y N NA
pH Checked Y N NA
REPORT#

Preservative: S/C

ST/C | N/C | U/C

ANALYSES REQUESTED

Preservation Key
H-Hydrochloric Acid C-COOL
N-Nitric Acid P-Phosphoric Acid
S-Sulfuric Acid ST-Sodium Thiosulfate
SH-Sodium Hydroxide U-Unpreserved

LAB ID #	COLLECTION DATE	COLLECTION TIME	Sample Type*	Matrix **	# containers	SAMPLE DESCRIPTION As Will Appear on Report	Fecal	TKN, TP, Nox	pH,Conductivity Turbidity,Cl-								COMMENTS
	3/13/17	10:00 AM	G	WW	3	#1 RIB BAM	1	1	1								
	3/13/17	10:10 AM	G	WW	3	#2 RIB BAM	1	1	1								
	3/13/17	10:35 AM	G	WW	3	#3 RIB BAM	1	1	1								
			~~G~~	~~WW~~	~~3~~	~~#4 RIB Control~~	1	1	1								
	3/13/17	9:10 AM	G	WW	3	#5 RIB Control	1	1	1								
	3/13/17	9:40 AM	G	WW	3	#6 RIB Control	1	1	1								

*Sample Type: G=Grab C=Composite O=Other

** Matrix: S=Solid SL=Sludge DW=Drinking Water GW= Ground Water SW=Surface Water WW=Wastewater M=Marine

ROI= Received On Ice

Relinquished By [signature]	Relinquished By	Relinquished By
Date/Time 3/13/17 11 AM	Date/Time	Date/Time
Received By [signature]	Received By	Received By
Date/Time 3/13/17 1115	Date/Time	Date/Time

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Phone:
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Client Contact: Dr. Martin Wanielista
Project Name: BAM
Sampled By:
E-Mail Adress:

Method of Shipment: Client Drop
System ID#: NA

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Temperature Checked Y N ROI (ROI °C)
Custody Seals Intact Y N NA
pH Checked Y N NA
REPORT#

Preservative
ST/C S/C U/C

ANALYSES REQUESTED

Preservation Key
H-Hydrochloric Acid C-COOL
N-Nitric Acid P-Phosphoric Acid
S-Sulfuric Acid ST-Sodium Thiosulfate
SH-Sodium Hydroxide U-Unpreserved

LAB ID #	COLLECTION DATE	COLLECTION TIME	Sample Type*	Matrix **	# containers	SAMPLE DESCRIPTION As Will Appear on Report	Fecal	TKN, TP, Nox	pH,Conductivity Turbidity,Cl-	COMMENTS
L1	4/11	1030	G	WW	3	#1 RIB BAM	1	1	1	
L2		1005	G	WW	3	#2 RIB BAM	1	1	1	
L3		950	G	WW	3	#3 RIB BAM	1	1	1	
L4		1115	G	WW	3	#4 RIB Control	1	1	1	
L5		1105	G	WW	3	#5 RIB Control	1	1	1	
L6		1045 AM	G	WW	3	#6 RIB Control	1	1	1	

*Sample Type: G=Grab C=Composite O=Other
** Matrix: S=Solid SL=Sludge DW=Drinking Water GW= Ground Water SW=Surface Water WW=Wastewater M=Marine
ROI= Received On Ice

Relinquished By: Jessica Cormier [signature]
Date/Time: 4/11/17 1130AM
Received By: [signature]
Date/Time: 4/11/17 1130

Relinquished By
Date/Time
Received By
Date/Time

Relinquished By
Date/Time
Received By
Date/Time

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Client Contact: Dr. Martin Wanielista
Project Name: BAM
Sampled By: Jessica & Dylan
E-Mail Adress:

Method of Shipment: Client Drop
System ID#: NA

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Temperature Checked Y N ROI (____°C) | Custody Seals Intact Y N NA | pH Checked Y N NA | **REPORT#**

Preservative: ST/C S/C U/C

Preservation Key: H-Hydrochloric Acid, C-COOL, N-Nitric Acid, P-Phosphoric Acid, S-Sulfuric Acid, ST-Sodium Thiosulfate, SH-Sodium Hydroxide, U-Unpreserved

ANALYSES REQUESTED

LAB ID #	COLLECTION DATE	COLLECTION TIME	Sample Type*	Matrix **	# containers	SAMPLE DESCRIPTION As Will Appear on Report	Fecal	TKN, TP, Nox	pH,Conductivity Turbidity,Cl-								COMMENTS
	5/8/17	930	G	WW	3	#1 RIB BAM	1	1	1								
		945	G	WW	3	#2 RIB BAM	1	1	1								
		1015	G	WW	3	#3 RIB BAM	1	1	1								
		1630	G	WW	3	#4 RIB Control	1	1	1								
		1045	G	WW	3	#5 RIB Control	1	1	1								
	5/8/17	1658	G	WW	3	#6 RIB Control	1	1	1								
	5/8	1125	G	WW	3	Well	1	1	1								

*Sample Type: G=Grab C=Composite O=Other
** Matrix: S=Solid SL=Sludge DW=Drinking Water GW= Ground Water SW=Surface Water WW=Wastewater M=Marine
ROI= Received On Ice

Relinquished By [signature]	Relinquished By	Relinquished By
Date/Time 5/8/17	Date/Time	Date/Time
Received By [signature]	Received By	Received By
Date/Time 5/8/17 1200	Date/Time	Date/Time

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Phone:
Fax:
Client Contact: Dr. Martin Wanielista
Project Name: BAM
Sampled By:
E-Mail Adress:

Method of Shipment: Client Drop
System ID#: NA

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Temperature Checked	ROI	Custody Seals Intact	pH Checked	REPORT#
(Y) N	(4.7 °C)	Y N NA	Y N NA	

Preservative: ST/C S/C U/C

Preservation Key
H-Hydrochloric Acid C-COOL
N-Nitric Acid P-Phosphoric Acid
S-Sulfuric Acid ST-Sodium Thiosulfate
SH-Sodium Hydroxide U-Unpreserved

ANALYSES REQUESTED

LAB ID #	COLLECTION DATE	COLLECTION TIME	Sample Type*	Matrix **	# containers	SAMPLE DESCRIPTION As Will Appear on Report	Fecal	TKN, TP, Nox	pH,Conductivity Turbidity,Cl-								COMMENTS
	6/12	1015	G	WW	3	#1 RIB BAM	1	1	1								
		1040	G	WW	3	#2 RIB BAM	1	1	1								
		1110	G	WW	3	#3 RIB BAM	1	1	1								
		915	G	WW	3	#4 RIB Control	1	1	1								
		940	G	WW	3	#5 RIB Control	1	1	1								
	6/12	10 Am	G	WW	3	#6 RIB Control	1	1	1								
	6/12	917Am	G	GW	3	Well	1	1	1								

*Sample Type: G=Grab C=Composite O=Other
** Matrix: S=Solid SL=Sludge DW=Drinking Water GW= Ground Water SW=Surface Water WW=Wastewater M=Marine
ROI= Received On Ice

Jessica Cormier
Relinquished By [signature]
Date/Time June 12th 2017
Received By [signature]
Date/Time 6/12/17 1145

Relinquished By
Date/Time
Received By
Date/Time

Relinquished By
Date/Time
Received By
Date/Time

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Phone:
Fax:
Client Contact: Dr. Martin Wanielista
Project Name: BAM
Sampled By:
E-Mail Adress:

Method of Shipment: Client Drop
System ID#: NA

FOR LAB USE ONLY

Temperature Checked (Y) N ROI (RO °C) | Custody Seals Intact Y N NA | pH Checked Y N NA | **REPORT#**

Preservative: ST/C S/C U/C

ANALYSES REQUESTED

LAB ID #	DATE	TIME	Sample Type*	Matrix **	# containers	As Will Appear on Report	Fecal	TKN, TP, Nox	pH,Conductivity Turbidity,Cl-	COMMENTS
1	7/17/17	08:00	G	WW	3	#1 RIB BAM	1	1	1	
2	↓	08:10	G	WW	3	#2 RIB BAM	1	1	1	
3	↓	08:20	G	WW	3	#3 RIB BAM	1	1	1	
4	↓	08:35	G	WW	3	#4 RIB Control	1	1	1	
5	↓	08:45	G	WW	3	#5 RIB Control	1	1	1	
6	↓	09:00	G	WW	3	#6 RIB Control	1	1	1	

Preservation Key
H-Hydrochloric Acid C-COOL
N-Nitric Acid P-Phosphoric Acid
S-Sulfuric Acid ST-Sodium Thiosulfate
SH-Sodium Hydroxide U-Unpreserved

*Sample Type: G=Grab C=Composite O=Other
** Matrix: S=Solid SL=Sludge DW=Drinking Water GW= Ground Water SW=Surface Water WW=Wastewater M=Marine
ROI= Received On Ice

Relinquished By: [signature]
Date/Time: 7/17/17 930
Received By: [signature]
Date/Time: 7/17/17 0930

Relinquished By
Date/Time
Received By
Date/Time

Relinquished By
Date/Time
Received By
Date/Time

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Address:
Zip:
Phone:
Fax:
Client Contact: Dr. Martin Wanielista
Project Name: BAM
Sampled By:
E-Mail Adress:

Method of Shipment: Client Drop
System ID#: NA

FOR LAB USE ONLY

Temperature Checked	Custody Seals Intact	pH Checked	REPORT#
Y N (ROI Rcd C)	Y N NA	Y N NA	

Preservative: ST/C, S/C, U/C

Preservation Key
H-Hydrochloric Acid, C-COOL
N-Nitric Acid, P-Phosphoric Acid
S-Sulfuric Acid, ST-Sodium Thiosulfate
SH-Sodium Hydroxide, U-Unpreserved

ANALYSES REQUESTED

LAB ID #	DATE (COLLECTION)	TIME (COLLECTION)	Sample Type*	Matrix **	# containers	SAMPLE DESCRIPTION: As Will Appear on Report	Fecal	TKN, TP, Nox	pH,Conductivity Turbidity,Cl-	COMMENTS
L1	8/14	1115	G	WW	3	#1 RIB BAM	1	1	1	
L2		1100	G	WW	3	#2 RIB BAM	1	1	1	
L3		1045	G	WW	3	#3 RIB BAM	1	1	1	
L4		1014	G	WW	3	#4 RIB Control	1	1	1	
L5		1000	G	WW	3	#5 RIB Control	1	1	1	
L6		935	G	WW	3	#6 RIB Control	1	1	1	
well	8/14	930	G	WW	3	well	1	1	1	

*Sample Type: G=Grab C=Composite O=Other
** Matrix: S=Solid SL=Sludge DW=Drinking Water GW= Ground Water SW=Surface Water WW=Wastewater M=Marine
ROI= Received On Ice

Relinquished By [signature]	Relinquished By	Relinquished By
Date/Time 8/14 1134pm	Date/Time	Date/Time
Received By [signature]	Received By	Received By
Date/Time 8/14/… 1134	Date/Time	Date/Time

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Address:
Zip:
Phone:
Fax:
Client Contact: Dr. Martin Wanielista
Project Name: BAM
Sampled By:
E-Mail Adress:

Method of Shipment: Client Drop
System ID#: NA

FOR LAB USE ONLY

Temperature Checked Y N | ROI (____ °C) | Custody Seals Intact Y N NA | pH Checked Y N NA | **REPORT#**

Preservative: ST/C S/C U/C

Preservation Key: H-Hydrochloric Acid, C-COOL, N-Nitric Acid, P-Phosphoric Acid, S-Sulfuric Acid, ST-Sodium Thiosulfate, SH-Sodium Hydroxide, U-Unpreserved

ANALYSES REQUESTED

LAB ID #	COLLECTION DATE	COLLECTION TIME	Sample Type*	Matrix **	# containers	SAMPLE DESCRIPTION As Will Appear on Report	Fecal	TKN, TP, Nox	pH, Conductivity Turbidity, Cl-								COMMENTS
L1	1/10/18	1020	G	WW	3	#1 RIB BAM	1	1	1								
L2		1035	G	WW	3	#2 RIB BAM	1	1	1								
L3		1100	G	WW	3	#3 RIB BAM	1	1	1								
L4		950	G	WW	3	#4 RIB Control	1	1	1								
L5		935	G	WW	3	#5 RIB Control	1	1	1								
L6	1/10/18	915	G	WW	3	#6 RIB Control	1	1	1								

*Sample Type: G=Grab C=Composite O=Other

** Matrix: S=Solid SL=Sludge DW=Drinking Water GW= Ground Water SW=Surface Water WW=Wastewater M=Marine

ROI= Received On Ice

Relinquished By [signature]	Relinquished By	Relinquished By
Date/Time 1/10/18 1135	Date/Time	Date/Time
Received By [signature]	Received By	Received By
Date/Time 1/10/18 1135	Date/Time	Date/Time

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City of DeLand Environmental Laboratory

1101 S. AMELIA AVE., DELAND, FL 32724
Phone: (386) 626-7256 Fax:(386) 740-6851
NELAC CERT# E53362

USE BALL POINT PEN
PRESS FIRMLY
PRINT LEGIBLY

Laboratory not responsible for omitted information.

Chain-of-Custody and Agreement to Perform Services

Company: UCF
Address:
Zip:
Phone:
Fax:
Client Contact: Dr. Martin Wanielista
Project Name: BAM
Sampled By:
E-Mail Adress:

Method of Shipment: Client Drop
System ID#: NA

FOR LAB USE ONLY

Temperature Checked Y N; ROI (____ °C) | Custody Seals Intact Y N NA | pH Checked Y N NA | **REPORT#**

Preservative: ST/C S/C U/C

Preservation Key: H-Hydrochloric Acid, C-COOL, N-Nitric Acid, P-Phosphoric Acid, S-Sulfuric Acid, ST-Sodium Thiosulfate, SH-Sodium Hydroxide, U-Unpreserved

ANALYSES REQUESTED

LAB ID #	COLLECTION DATE	COLLECTION TIME	Sample Type*	Matrix **	# containers	SAMPLE DESCRIPTION As Will Appear on Report	Fecal	TKN, TP, Nox	pH, Conductivity, Turbidity, Cl-								COMMENTS
L1	1/30/18	11:25	G	WW	3	#1 RIB BAM	1	1	1								
L2		11:50	G	WW	3	#2 RIB BAM	1	1	1								
L3		12:30	G	WW	3	#3 RIB BAM	1	1	1								
L4		1:05pm	G	WW	3	#4 RIB Control	1	1	1								
L5		1:25pm	G	WW	3	#5 RIB Control	1	1	1								
L6		1:45pm	G	WW	3	#6 RIB Control	1	1	1								
Well	1/30/18	11:15	G	GW	3	Well RIB	1	1	1								

*Sample Type: G=Grab C=Composite O=Other

** Matrix: S=Solid SL=Sludge DW=Drinking Water GW= Ground Water SW=Surface Water WW=Wastewater M=Marine

ROI= Received On Ice

Relinquished By [signature]	Relinquished By	Relinquished By
Date/Time 1/30/18 1415	Date/Time	Date/Time
Received By [signature]	Received By	Received By
Date/Time 1/30/18 1415	Date/Time	Date/Time

PAGE 1 of 1

City of DeLand Environmental Laboratory

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Chain-of-Custody and Agreement to Perform Services

Company: UCF
Address:
Zip:
Phone:
Fax:
Client Contact: Dr. Martin Wanielista
Project Name: BAM
Sampled By:
E-Mail Adress:

Method of Shipment: Client Drop
System ID#: NA

FOR LAB USE ONLY

Temperature Checked	ROI	Custody Seals Intact	pH Checked	REPORT#
Y N	(___ °C)	Y N NA	Y N NA	

Preservative: ST/C S/C U/C

Preservation Key: H-Hydrochloric Acid, C-COOL, N-Nitric Acid, P-Phosphoric Acid, S-Sulfuric Acid, ST-Sodium Thiosulfate, SH-Sodium Hydroxide, U-Unpreserved

ANALYSES REQUESTED

LAB ID #	COLLECTION DATE	COLLECTION TIME	Sample Type*	Matrix **	# containers	SAMPLE DESCRIPTION As Will Appear on Report	Fecal	TKN, TP, Nox	pH, Conductivity, Turbidity, Cl-	COMMENTS
L1	2/27/18	10:20 am	G	WW	3	#1 RIB BAM	1	1	1	
L2	2/27/18	10:30 am	G	WW	3	#2 RIB BAM	1	1	1	
L3	2/27/18	10:47 am	G	WW	3	#3 RIB BAM	1	1	1	
L4	2/27/18	11:15 am	G	WW	3	#4 RIB Control	1	1	1	
L5	2/27/18	11:05 am	G	WW	3	#5 RIB Control	1	1	1	
L6	2/27/18	10:43 am	G	WW	3	#6 RIB Control	1	1	1	
Well	2/27/18	10:15 am	G	GW	3	Well R.B	1	1	1	

*Sample Type: G=Grab C=Composite O=Other
** Matrix: S=Solid SL=Sludge DW=Drinking Water GW= Ground Water SW=Surface Water WW=Wastewater M=Marine
ROI= Received On Ice

Relinquished By [signature]
Date/Time 2/27/18 11:45
Received By [signature]
Date/Time 2/27/18 1145

Relinquished By
Date/Time
Received By
Date/Time

Relinquished By
Date/Time
Received By
Date/Time

PAGE 1 of 1

Environmental Research and Design (ERD) Laboratory Data

The ERD laboratory is NELAC certified (# E1031026), as required by the Florida Department of Environmental Protection. The ERD Lab is located at 3419 Trentwood Blvd, Belle Isle (Orlando), Florida 32812-4864.

Data

Storm water samples were collected and analyzed December 2017 and January 2018. The storm water sampling was conducted by the project PI, other UCF graduate students and staff associated with Environmental Conservation Solutions. These storm water samples were delivered to and analyzed by the ERD Lab. The ERD Lab method (SM:4500 F) allowed for lower detection levels of nitrate and nitrite analysis (0.002 mg-N/L). This information is not displayed in the methods section Table 6 (DeLand Lab methods). The lower detection limit was projected to be required for the storm water samples in December 2017 and January 2018, which was proved accurate by values <0.134 mg-N/L. The ERD Lab data was provided to the graduate student through the project PI. The storm water originated from hurricane Irma on September 11th, 2017. The hurricane produced enough storm water to fill the rapid infiltration basin with more than 12 feet of standing water. Additionally, storm water from surrounding holding basins was pumped to the RIB study site for further storage and disposal over the time period of September – December 2017.

ENVIRONMENTAL RESEARCH & DESIGN, INC.
Engineering • Science • Chemistry • Research
3419 Trentwood Blvd. • Suite 102 • Belle Isle (Orlando), FL 32812-4864
Telephone: 407-855-9465 • Fax: 407-826-0419

RESULTS OF LABORATORY ANALYSES CONDUCTED ON WATER SAMPLES COLLECTED FOR THE RIBS PROJECT

SAMPLE ID	DATE COLLECTED	SAMPLE DESCRIPTION	SAMPLE LOCATION	PARAMETER				
				Alkalinity (mg/l)	NO_x (µg/l)	NO_2 (µg/l)	NO_3 (µg/l)	TOC (mg/l)
2193	12/18/17	RIBS (UCF)	Lysimeter 1	x	9	7	2	x
2194	12/18/17	RIBS (UCF)	Lysimeter 2	x	4	4	1	x
2195	12/18/17	RIBS (UCF)	Lysimeter 3	x	7	6	1	x
2196	12/18/17	RIBS (UCF)	Lysimeter 4	x	10	8	2	x
2197	12/18/17	RIBS (UCF)	Lysimeter 5	x	7	3	4	x
2198	12/18/17	RIBS (UCF)	Lysimeter 6	x	27	1	26	x
2201	12/18/17	RIBS (UCF)	Combined Ponds	100	x	x	x	6.1
2202	12/18/17	RIBS (UCF)	BAM Lysimeter	82.0	x	x	x	5.2
2203	12/18/17	RIBS (UCF)	Control Lysimeter	128	x	x	x	10.6
2239	1/10/18	RIBS (UCF)	Lysimeter 1	x	24	21	3	x
2240	1/10/18	RIBS (UCF)	Lysimeter 2	x	14	11	3	x
2241	1/10/18	RIBS (UCF)	Lysimeter 3	x	24	9	15	x
2242	1/10/18	RIBS (UCF)	Lysimeter 4	x	42	27	15	x
2243	1/10/18	RIBS (UCF)	Lysimeter 5	x	22	14	8	x
2244	1/10/18	RIBS (UCF)	Lysimeter 6	x	78	8	70	x

Measured value less than MDL; Listed value is half of MDL

Analytical results presented in this report have been reviewed for compliance with the ENVIRONMENTAL RESEARCH & DESIGN, INC. (ERD) Quality Systems Manual and have been determined to meet applicable method guidelines and standards referenced in the July 2003 National Environmental laboratory Accreditation Program (NELAP) Quality Manual unless otherwise noted. The Analytical Results within these report pages reflect the values obtained from tests performed on samples as received by the laboratory unless indicated differently.

Cassie Revell
Lab Director

NELAC No.
E1031026

UCF\RIBS DATA (DEC 18, 2017, JAN 10, 2018)

APPENDIX C:
OTHER, NON-CONTRACTED LABS DATA

Other, Non-contracted Labs Data

Advanced Environmental Laboratories, i.e. AEL (Altamonte Springs, Florida 327001)

TetraTech, Inc., Boron Isotope Laboratory (Fort Collins, Colorado 80525)

University of California Davis Stable Isotope Facility, i.e. SIF (Davis, California 95616)

Data

Table C-1. Boron (mg/L)

Loading Event	Boron(mg/L)							
	Input	**BAM**			**Control**			**Monitoring Well**
		L1	**L2**	**L3**	**L4**	**L5**	**L6**	
January'17	0.21[T]	0.16[T]			0.20[T]			-
February'17	0.18[T]	0.17[T]			0.19[T]			0.22[T]
March'17	0.19	0.19	0.13	0.18	-	0.15	0.19	0.16
April'17	0.18	0.19	0.13	0.16	-	0.18	0.15	-
May'17	0.16	0.19	0.12	0.16	0.20	0.19	0.16	0.18
June'17	0.15	0.16	0.10	0.19	0.17	0.14	0.12	0.20
July'17	0.18	0.22	0.13	0.13	0.12	0.16	0.17	-
August'17	0.16	0.12	0.12	0.05	0.13	0.13	0.14	0.22
Hurricane Impact: Stormwater Loading (no samples)								
January'18	0.15	0.05	0.04	0.04	0.08	0.09	0.19	0.09
February'18	0.17	0.10	0.15	0.11	0.09	0.09	0.15	0.08

Boron samples analyzed by Advanced Environmental Laboratories and TetraTech, Inc. See the Laboratory's documentation for QAQC.

Table C-2. Boron Isotope (δ11B‰).

Loading Event	Boron Isotope, δ11B‰, (mg/L-boron)							
	Input	**BAM**			**Control**			**Monitoring Well**
		L1	**L2**	**L3**	**L4**	**L5**	**L6**	
January'17	8.7 (0.21)	17.6 (0.16)			14.1 (0.20)			-
February'17	8.8 (0.18)	16.6 (0.17)			14.1 (0.19)			16.9 (0.22)

Boron isotope analyzed by TetraTech, Inc. Two loading events were analyzed. Isotopic calculation is δ11B (‰) = { [(11B/10B)sample – (11B/10B)standard] / (11B/10B)standard } x 1000. See the Laboratory's documentation for QAQA.

Table C-3. Nitrogen Isotope (δ15N‰) from Nitrates in Water

Loading Event	Nitrogen Isotope (δ15N‰) from Nitrates in Water							
	Input	**BAM**			**Control**			**Monitoring Well**
		L1	**L2**	**L3**	**L4**	**L5**	**L6**	
January’17	32	36			29			-
February’17	33	35			31			-
March’17	31	39			33			-
April’17*	41	20			33			-
May’17*	32	25			25			-
June’17	29	30			23			-
		24[Q]	8	30	20	30	33	
July’17	43	18	13[Q]	35	20	19	9[Q]	-
August’17	44	13[Q]			7[Q]			17
Hurricane Impact: Stormwater Loading (minimal sampling)								
January'18	38	12			21			-
February'18	43	21			12			-

Analysis conducted by UCDavis SIF. Note that SIF machine was down and fixed before January’18 sample. Input sample March’17, duplicate, was analyzed with January and February 2018 samples and came back with the same results as initially. Relative Percent Difference (RPD) between duplicate samples ranged from zero to 5%. [Q] Below the limit of quantification (LOQ); *April and May samples were thawed, composited and re-frozen before analysis (suspect data).

Table C-4. Oxygen Isotope (δ18O‰) from Nitrates in Water

Loading Event	Oxygen Isotope (δ18O‰) from Nitrates in Water							
	Input	BAM			Control			Monitoring Well
		L1	L2	L3	L4	L5	L6	
January'17	20	22			17			-
February'17	20	21			18			-
March'17	20	23			17			-
April'17*	24	2			14			-
May'17*	14	11			9			-
June'17	19	9			5			-
		27[Q]	3	9	2	16	16	
July'17	25	15	19[Q]	13	3	4	22[Q]	-1
August'17	22	13[Q]			10[Q]			-
Hurricane Impact: Stormwater Loading (minimal sampling)								
January'18	24	5			7			-
February'18	25	8			8			-

Analysis conducted by UCDavis SIF. Note that SIF machine was down and fixed before January'18 sample. Input sample March'17, duplicate, was analyzed with January and February 2018 samples and came back with the same results as initially. Relative Percent Difference (RPD) between duplicate samples ranged from zero to 21%, with a mean of 3% and 11 out of 28 RPD as 1%. [Q] Below the limit of quantification (LOQ); *April and May samples were thawed, composited and re-frozen before analysis (suspect data).

APPENDIX D:
OTHER DOCUMENTATION

Other Documentation

Documents associated with this project (NS003) accessed from the City of DeLand are listed.

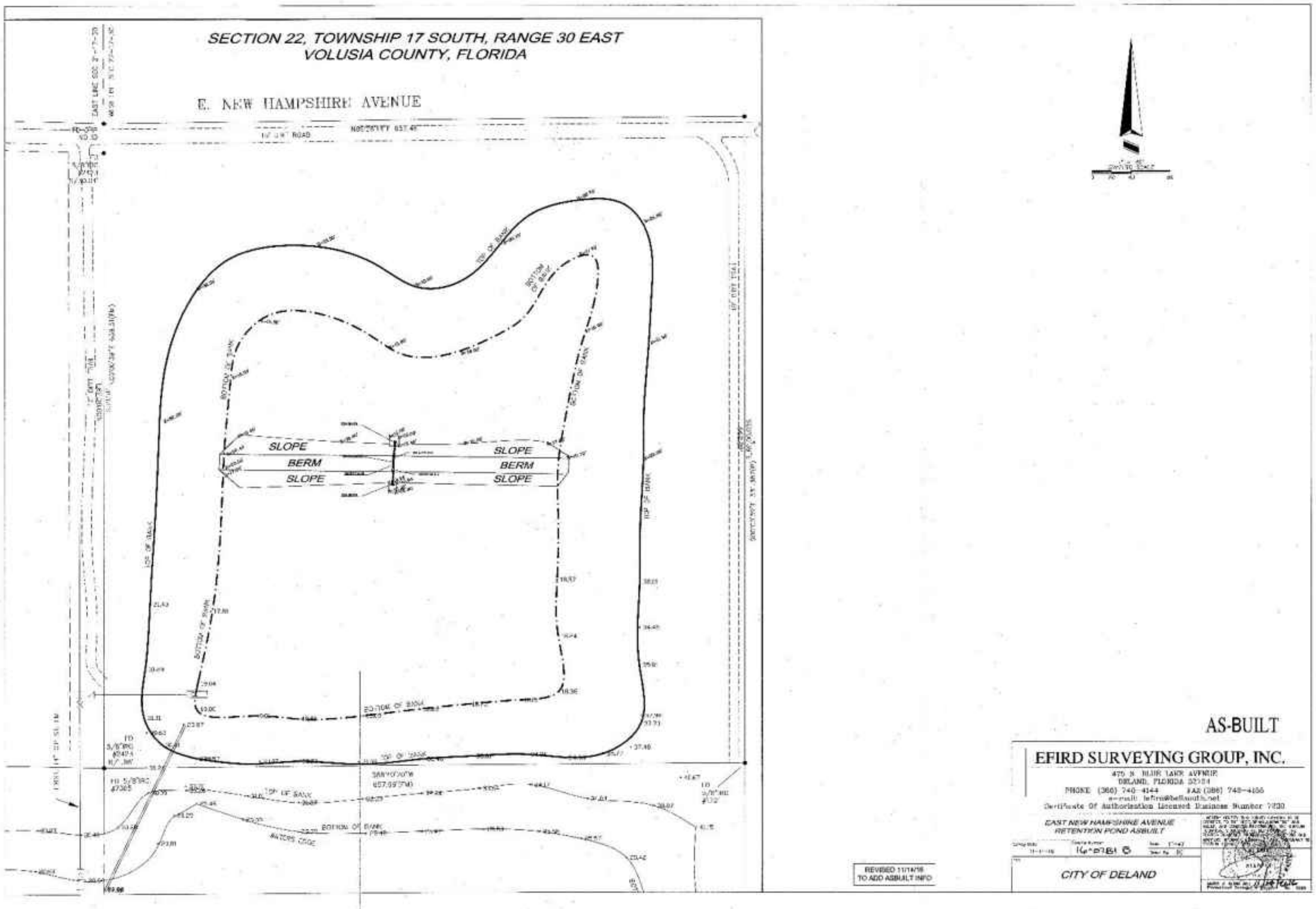
Document List:

Study RIB as Built

BAM Purchase Documentation (City of DeLand, FL 2016 - Request for Commission Action)

RIB Loading Data

Study RIB as BUILT



CITY OF DELAND, FLORIDA
REQUEST FOR COMMISSION ACTION
June 6, 2016

Department: Public Services	**Attachments:**
Subject: Consideration, Sole Source Purchase of Biosorption Activated Media (BAM)	**[X] Letter from Distributor and Price Quotation** **[X] Resolution**
Prepared by: Keith Riger / [signature]	**Approved by:** Michael Pleus [signature]
Department Head - Keith D. Riger, P.E.	**City Manager - Michael Pleus**

SUMMARY/HIGHLIGHT: At its May 2, 2016 meeting, the City Commission approved a Cost Share Agreement with the St. Johns River Water Management District (SJRWMD) to construct a large scale pilot project to remove nitrate-nitrogen from excess reclaimed water discharged to the Rapid Infiltration Basin (RIB) located at the City's Bent Oaks pond area. The treatment process involves an installation of Biosorption Activated Media (BAM), which is a proprietary mixture of clay, recycled rubber tire crumbs and sand. The material will be mixed off-site and delivered to the project. This media, called "Bold and Gold," was developed pursuant to research at the University of Central Florida (UCF), who patented the material and licensed it for distribution to select vendors. As such, it can only be obtained from their sole source vendor and cannot be competitively bid at this time.

STRATEGIC PLAN FOCUS AREA/ACTION STEP: N/A

SUSTAINABILITY: N/A

FISCAL IMPACT: The cost to provide 3,250 cubic yards of "Bold and Gold" BAM is $373,750. The SJRWMD Cost Share Agreement approved by the Commission last month will provide $200,000 in construction funding for this project. Staff anticipates that the Florida Department of Environmental Protection (FDEP) will provide the City with a grant for $100,000 for this project shortly. The City Commission will be asked to accept this FDEP grant at a future meeting. As indicated in staff's May 2nd RCA, the City will be expected to pay $100,000 toward the construction costs of the project plus provide approximately $40,400 in miscellaneous construction and in-kind services. As also mentioned in the May 2nd agenda item for this project, funds are available in the Utility Enterprise Account to pay for the City's share of out-of-pocket costs (approximately $110,000) for this project. This project is not currently budgeted in the current fiscal year and will require a budget amendment.

RECOMMENDATION: Staff recommends that the City Commission approve the attached Sole Source Resolution to purchase "Bold and Gold" BAM from Plastic Tubing Industries, Inc. in the amount of $373,750, subject to receipt and acceptance of a grant from FDEP for $100,000 in additional project funding.

SUBJECT: Consideration, Sole Source Purchase Biosorption Activated Media (BAM)

BACKGROUND/DISCUSSION: N/A

PLASTIC TUBING INDUSTRIES

Incorporated

Manufacturers of Corrugated Plastic Drainage Tubing

Billing:
P.O. BOX 607356
ORLANDO, FL 32860-7356
PHONE: (407) 298-5121

Physical:
2346 VULCAN ROAD
APOPKA, FL 32703
FAX: (407) 578-9393

May 24, 2016

To Whom It May Concern:

Plastic Tubing Industries, Inc. is the sole distributor of the Bold & Gold® biosorption activated media (BAM) used in Rapid Infiltration Basins (RIBs). Feel free to contact me with any questions.

Sincerely,

Chris Bogdan, General Manager
Plastic Tubing Industries, Inc.

Distributed by: Plastic Tubing Industries, Inc
P.O. BOX 607356
Orlando, Fl 32860
(800) 780-5121

www.BoldandGoldMedia.com

www.pti-pipe.com

Bold & Gold® Order Form

Is This Work (Check One)	Private ☐	Public ☐	Municipal ☑

Customer Name:	City of DeLand	
Address:	1102 South Garfield Avenue	
City, State, ZIP:	DeLand, FL 32724	
Phone #:	(386) 626-7197	
Contact Person:	Keith Riger	
	Job #	PO #

Job Name:	Bent Oaks RIB
Jobsite Address:	New Hampshire
City, State, ZIP:	DeLand, FL 32724
County:	Volusia

Property Owner:	
Address:	
City, State, ZIP:	
Phone #:	

General Contractor:	
Address:	
City, State, ZIP	
Contact Person:	

Bonding Information			
Is The Job Bonded?	Yes	☐o	☐no, please leave this section blank
Name of Bonding Company :			
Bonding Agent Name:			
Address:			
City, State, ZIP:			
Phone #:			
Bond #:			

Distributed by:Plastic Tubing Industries, Inc.
P.O. BOX 607356
Orlando, Fl 32860
(800) 780-5121

www.BoldandGoldMedia.com

www.pti-pipe.com

Bold & Gold® Order Form

Quantity (C/Y)	Product Description	Per Unit Co	Total Cost
3,250	Bold & Gold® CTS Media	$115.00	$373,750.00
		Sub Total	$373,750.00
		Sales Tax	EXEMPT
		Total	$373,750.00

* The price includes the Bold & Gold® mixed and delivered to the specified job site.
* PTI is not responsible for the installation of the Bold & Gold®

RESOLUTION NO. 2016 -

A RESOLUTION OF THE CITY COMMISSION OF DELAND, FLORIDA AUTHORIZING A SOLE SOURCE PURCHASE OF BOLD & GOLD BIOSORPTION ACTIVATED MEDIA FROM PLASTIC TUBING INDUSTRIES, INC., THEIR SOLE SOURCE DISTRIBUTOR; AND PROVIDING FOR AN EFFECTIVE DATE.

WHEREAS, the City Commission has determined that there is a legitimate need to purchase Biosorption Activated Media to determine its effectiveness in removing Nitrogen from reclaimed water deposited in rapid infiltration basins to improve groundwater quality that will affect the health, safety and welfare of the citizens of the City of DeLand; and

WHEREAS, the Public Services Director has informed the City Commission that, to the best of his knowledge, there are no other suppliers of this patented product and that Plastic Tubing Industries, Inc. is its only authorized supplier.

NOW, THEREFORD BE IT RESOLVED THE CITY COMMISSION OF DELAND, FLORIDA:

Section 1. The foregoing preamble is hereby incorporated by reference, and the City Commission does hereby determine that Plastic Tubing Industries, Inc., Post Office Box 607356, Orlando, FL 32860, is the sole practicable source of the required Biosorption Activated Media and that the purchase of this material from any other vendor is not feasible and that these findings support a sole source purchase without competitive bidding.

Section 2. The execution of the purchase order to Plastic Tubing Industries, Inc. for 3,250 cubic yards of Bold & Gold biosorption activated media is hereby authorized.

Section 3. This Resolution shall become effective immediately upon its adoption.

PASSED AND DULY ADOPTED this 6th day of June, 2016.

____
Robert F. Apgar
Mayor-Commissioner

ATTEST:

____
Julie A. Hennessy
City Clerk-Auditor

APPROVED AS TO FORM AND LEGALITY:

____
Darren J. Elkind
City Attorney

RIB Loading Data

Table D-1. Study RIB Loading Data

				North (BAM) Pond		South (Control) Pond	
Loading Event	**Date**	**Time**	**Volume**	**Coverage**	**Staff Gauge**	**Coverage**	**Staff Gauge**
(#: Month)	(m/dd/year)	(24 hr)	MG	%	Ft.	%	Ft.
#1: January	1/18/2017	15:30	1.32	97	1.95	65	1.25
	1/19/2017	8:45	0.743	100	3.05	100	1.85
	1/20/2017	16:00	0.26	100	2.4	65	1.2
	1/21/2017		0				
	1/22/2017		0				
	1/23/2017	16:30	0	80	1.25	20	0.20
	1/24/2017	13:30	0	70	0.9	5	0.10
	1/25/2017		0				
	1/26/2017	8:30	0	30	0.5	0	0.0
	1/27/2017	8:30	0	15	0.35	0	0.0
	1/28/2017		0				
	1/29/2017		0				
	1/30/2017	11:15	0	0	0	0	0.0
	1/31/2017	10:00	0	0	0	0	0.0
	2/1/2017	10:30	0	0	0	0	0.0
	2/2/2017	10:30	0	0	0	0	0.0
	2/3/2017	14:30	0	0	0	0	0.0
	2/4/2017		0				
	2/5/2017		0				
	2/6/2017	10:00	0	0	0	0	0.0
	2/7/2017	10:30	0	0	0	0	0.0
	2/8/2017	14:00	0	0	0	0	0.0
	2/9/2017	13:30	0	0	0	0	0.0
	2/10/2017	10:30	0	0	0	0	0.0
	2/11/2017		0				
	2/12/2017		0				
	2/13/2017	11:00	0	0	0	0	0.0
Incidental Loading	2/14/2017	14:30	0.52	15	0.35	5	0.15
	2/15/2017	14:30	0	1	0.1	0	0.0
	2/16/2017	13:30	0	0	0	0	0.0
	2/17/2017		0				
	2/18/2017		0				

				North (BAM) Pond		South (Control) Pond	
Loading Event	**Date**	**Time**	**Volume**	**Coverage**	**Staff Gauge**	**Coverage**	**Staff Gauge**
(#: Month)	(m/dd/year)	(24 hr)	MG	%	Ft.	%	Ft.
	2/19/2017		0				
#2: February	2/20/2017	16:15	0.98	90	1.75	55	1.10
	2/21/2017	11:00	0	85	1.65	35	0.75
	2/22/2017	9:30	0	-	1.35	-	0.40
Rain Occurred	2/22/2017	15:15	0	80	1.4	30	0.50
	2/23/2017	9:30	0	75	1.2	20	0.25
	2/24/2017	10:30	0	70	1	10	0.15
	2/25/2017		0				
	2/26/2017		0				
	2/27/2017	10:30	0	15	0.35	0	0.0
	2/28/2017	14:30	0	2	0.2	0	0.0
	3/1/2017	14:30	0	0	0	0	0.0
	3/2/2017	13:30	0	0	0	0	0.0
	3/3/2017	14:10	0	0	0	0	0.0
	3/4/2017		0				
	3/5/2017		0				
#3: March	3/6/2017	16:00	1.24	95	1.95	60	1.20
	3/7/2017	9:00	0	95	2	55	1.00
	3/8/2017	9:00	0	85	1.65	30	0.60
	3/9/2017	11:00	0	75	1.35	15	0.20
	3/10/2017	11:00	0	70	1	0	0.00
	3/11/2017		0	40	0.6		
	3/12/2017		0				
	3/13/2017	10:30	0	25	0.5	0	0.00
	3/14/2017	11:00	0	20	0.4	0	0.00
	3/15/2017	10:30	0	3	0.25	0	0.00
	3/16/2017	10:30	0	1	0.1	0	0.00
	3/17/2017	9:30	0	0	0	0	0.00
	3/18/2017		0				
	3/19/2017		0				
	3/20/2017	15:30	0	0	0	0	0.00
	3/21/2017	14:00	0	0	0	0	0.00
	3/22/2017	14:00	0	0	0	0	0.00
	3/23/2017	14:30	0	0	0	0	0.00
	3/24/2017	9:15	0	0	0	0	0.00

				North (BAM) Pond		South (Control) Pond	
Loading Event	**Date**	**Time**	**Volume**	**Coverage**	**Staff Gauge**	**Coverage**	**Staff Gauge**
(#: Month)	(m/dd/year)	(24 hr)	MG	%	Ft.	%	Ft.
	3/25/2017		0				
	3/26/2017		0				
	3/27/2017	15:00	0	0	0	0	0.00
	3/28/2017	15:00	0	0	0	0	0.00
	3/29/2017	15:00	0	0	0	0	0.00
	3/30/2017	9:30	0	0	0	0	0.00
	3/31/2017	10:00	0	0	0	0	0.00
	4/1/2017		0				
	4/2/2017		0				
#4: April	4/3/2017	17:00	1.25	95	1.9	65	1.35
	4/4/2017	8:30	0	85	1.6	60	1.00
	4/5/2017	9:30	0	80	1.3	40	0.65
	4/6/2017	11:00	0	70	0.85	20	0.30
	4/7/2017	10:30	0	45	0.6	2	0.05
	4/8/2017		0	25		0	
	4/9/2017		0				
	4/10/2017	9:00	0	1	0.1	0	0.00
	4/11/2017	10:00	0	0	0	0	0.00
	4/12/2017	10:10	0	0	0	0	0.00
	4/13/2017	9:30	0	0	0	0	0.00
	4/14/2017	10:00	0	0	0	0	0.00
	4/15/2017		0				
	4/16/2017		0				
	4/17/2017	11:00	0	0	0	0	0.00
	4/18/2017	14:00	0	0	0	0	0.00
	4/19/2017	14:00	0	0	0	0	0.00
	4/20/2017	11:00	0	0	0	0	0.00
	4/21/2017	14:00	0	0	0	0	0.00
	4/22/2017		0				
	4/23/2017		0				
	4/24/2017	14:00	0	0	0	0	0.00
	4/25/2017	10:30	0	0	0	0	0.00
	4/26/2017	14:30	0	0	0	0	0.00
	4/27/2017	15:00	0	0	0	0	0.00
	4/28/2017	15:30	0	0	0	0	0.00

				North (BAM) Pond		South (Control) Pond	
Loading Event	**Date**	**Time**	**Volume**	**Coverage**	**Staff Gauge**	**Coverage**	**Staff Gauge**
(#: Month)	(m/dd/year)	(24 hr)	MG	%	Ft.	%	Ft.
	4/29/2017		0				
	4/30/2017	Change in meter recording and flow valve setting					
#5: May	5/1/2017	17:00	0.98	80	1.45	65	1.30
	5/2/2017	14:30	0	60	0.95	40	0.75
	5/3/2017	11:00	0	50	0.65	30	0.40
	5/4/2017	14:00	0	15	0.35	2	0.05
	5/5/2017	14:00	0	5	0.2	0	0.00
	5/6/2017		0				
	5/7/2017		0				
	5/8/2017	11:00	0	0	0	0	0.00
	5/9/2017	11:00	0	0	0	0	0.00
	5/10/2017	14:00	0	0	0	0	0.00
	5/11/2017	10:00	0	0	0	0	0.00
	5/12/2017	11:00	0	0	0	0	0.00
	5/13/2017		0				
	5/14/2017		0				
	5/15/2017	14:00	0	0	0	0	0.00
	5/16/2017	15:00	0	0	0	0	0.00
	5/17/2017	10:00	0	0	0	0	0.00
	5/18/2017	14:00	0	0	0	0	0.00
	5/19/2017	11:00	0	0	0	0	0.00
	5/20/2017		0				
	5/21/2017		0				
	5/22/2017	14:00	0	0	0	0	0.00
	5/23/2017	11:00	0	0	0	0	0.00
	5/24/2017	10:00	0	0	0	0	0.00
	5/25/2017	15:00	0	0	0	0	0.00
	5/26/2017	13:00	0	0	0	0	0.00
	5/27/2017		0				
	5/28/2017		0				
	5/29/2017	Holiday					
	5/30/2017	14:00	0	0	0	0	0.00
	5/31/2017	14:00	0	0	0	0	0.00
	6/1/2017	11:00	0	0	0	0	0.00
	6/2/2017	11:00	0	0	0	0	0.00

				North (BAM) Pond		South (Control) Pond	
Loading Event	**Date**	**Time**	**Volume**	**Coverage**	**Staff Gauge**	**Coverage**	**Staff Gauge**
(#: Month)	(m/dd/year)	(24 hr)	MG	%	Ft.	%	Ft.
	6/3/2017		0				
	6/4/2017		0				
	6/5/2017	8:21	-	Filling	0.45	Filling	0.38
	6/5/2017	13:41	-		1.45		1.15
#6: June	6/5/2017	16:58	1.49	95	1.85	75	1.45
	6/6/2017	8:45	0	-	1.7	-	1.15
	6/6/2017	13:45	0	90	1.6	60	1.05
	6/7/2017	9:30	0	75	1.15	45	0.75
	6/8/2017	10:00	0	65	0.9	35	0.55
	6/9/2017	10:30	0	45	0.6	20	0.30
	6/10/2017		0				
	6/11/2017		0				
	6/12/2017	11:00	0	5	0.3	0	0.00
Heavy Rain	6/13/2017	16:00	0	70	1	20	0.30
	6/14/2017	13:30	0	60	0.8	3	0.05
	6/15/2017						
	6/16/2017	9:00	0	30	0.5	0	0.00
	6/17/2017		0				
	6/18/2017		0				
	6/19/2017	14:30	0	30	0.5	0	0.00
	6/20/2017	16:00	0	30	0.5	0	0.00
	6/21/2017	13:30	0	20	0.4	0	0.00
	6/22/2017	15:00	0	5	0.25	0	0.00
	6/23/2017	16:00	0	0	0	0	0.00
	6/24/2017		0				
	6/25/2017		0				
	6/26/2017	16:00	0	30	0.5	2	0.05
	6/27/2017	16:00	0	20	0.35	0	0.00
	6/28/2017	14:00	0	5	0.3	0	0.00
	6/29/2017	15:30	0	1	0.1	0	0.00
	6/30/2017	14:30	0	0	0	0	0.00
	7/1/2017		0				
	7/2/2017		0				
	7/3/2017	9:30	0	10	0.3	0	0.00
	7/4/2017	Holiday					

				North (BAM) Pond		South (Control) Pond	
Loading Event	**Date**	**Time**	**Volume**	**Coverage**	**Staff Gauge**	**Coverage**	**Staff Gauge**
(#: Month)	(m/dd/year)	(24 hr)	MG	%	Ft.	%	Ft.
	7/5/2017	11:30	0	0	0	0	0.00
	7/6/2017	15:00	0	0	0	0	0.00
	7/7/2017	15:00	0	0	0	0	0.00
	7/8/2017		0				
	7/9/2017	Change in flow valve setting					
#7: July	7/10/2017	16:00	1.66		1.5		1.25
	7/11/2017	8:30	0	90	2	80	1.70
	7/12/2017	9:00	0	80	1.55	70	0.90
	7/13/2017		0	70	0.95	60	1.00
	7/14/2017		0	60	0.75	55	0.95
	7/15/2017		0				
	4/16/2017		0				
	7/17/2017		0	10	0.25	20	0.20
	7/18/2017		0	40	0.5	40	0.30
	7/19/2017		0	25	0.5	15	0.20
	7/20/2017		0	15	0.35	5	0.05
	7/21/2017		0	5	0.3	2	0.00
	7/22/2017		0				
	7/23/2017		0				
	7/24/2017		0	5	0.3	5	0.05
	7/25/2017		0	2	0.2	5	0.10
	7/26/2017		0	1	0.1	5	0.10
	7/27/2017		0	0	0	1	0.00
	7/28/2017		0	0	0	0	0.00
	7/29/2017		0				
	7/30/2017		0				
	7/31/2017		0	0	0	0	0.00
	8/1/2017		0	0	0	0	0.00
	8/2/2017		0	0	0	0	0.00
	8/3/2017		0	0	0	0	0.00
	8/4/2017		0	20	0.45	10	0.10
	8/5/2017		0				
	8/6/2017		0				
#8: August	8/7/2017		1.41		1.35		1.20
	8/8/2017		0	90	1.7	80	1.55

				North (BAM) Pond		South (Control) Pond	
Loading Event	**Date**	**Time**	**Volume**	**Coverage**	**Staff Gauge**	**Coverage**	**Staff Gauge**
(#: Month)	(m/dd/year)	(24 hr)	MG	%	Ft.	%	Ft.
	8/9/2017		0	70	1.15	70	1.30
	8/10/2017		0	60	0.75	55	1.05
	8/11/2017		0	50	0.6	50	0.90
	8/12/2017		0				
	8/13/2017		0				
	8/14/2017		0	15	0.4	30	0.60
	8/15/2017		0	5	0.3	20	0.50
	8/16/2017		0	3	0.2	15	0.40
	8/17/2017		0	0	0	10	0.35
	8/18/2017		0	0	0	5	0.20
	8/19/2017		0				
	8/20/2017		0				
	8/21/2017		0	5	0.3	15	0.40
	8/22/2017		0	3	0.2	15	0.45
	8/23/2017		0	0	0	15	0.45
	8/24/2017		0	0	0	15	0.45
	8/25/2017		0	0	0	15	0.40
	8/26/2017		0				
	8/27/2017		0				
	8/28/2017		0	0	0	15	0.35
	8/29/2017		0	0	0	10	0.30
	8/30/2017		0	NR	NR	NR	NR
	8/31/2017		0	0	0	10	0.20
	9/1/2017		0	0	0	15	0.30
	9/2/2017		0				
	9/3/2017		0				
	9/4/2017	Holiday					
	9/5/2017		0	5	0.25	20	0.25
	9/6/2017		0	2	0.15	20	0.30
	9/7/2017		0	2	0.15	20	0.30
	9/8/2017		0	3	0.2	35	0.60
	9/9/2017		0				
# 9 - 10 Storm Water	9/10/2017	Hurricane Irma					
	9/11/2017						
	9/12/2017		0	100	MAX	100	MAX

				North (BAM) Pond		South (Control) Pond	
Loading Event	**Date**	**Time**	**Volume**	**Coverage**	**Staff Gauge**	**Coverage**	**Staff Gauge**
(#: Month)	(m/dd/year)	(24 hr)	MG	%	Ft.	%	Ft.
	9/13/2017		0	100	MAX	100	MAX
	9/14/2017		0	100	MAX	100	MAX
	9/15/2017		0	100	MAX	100	MAX
	9/16/2017		0				
	9/17/2017		0				
	9/18/2017		0	100	MAX	100	MAX
	9/19/2017		0	100	MAX	100	MAX
	9/20/2017		0	100	MAX	100	MAX
	9/21/2017		0	100	MAX	100	MAX
	9/22/2017		0	100	MAX	100	MAX
	9/23/2017		0				
	9/24/2017		0				
	9/25/2017		0	100	MAX	100	MAX
	9/26/2017		0	100	MAX	100	MAX
	9/27/2017		0	100	9.9	100	8.50
	9/28/2017		0	100	9.7	100	8.30
	9/29/2017		0	100	9.40	100	8.00
	9/30/2017		0				
	10/1/2017		0				
	10/2/2017		0	100	8.90	100	7.50
	10/3/2017		0	100	8.90	100	7.50
	10/4/2017		0	100	8.70	100	7.30
	10/5/2017		0	100	8.80	100	7.40
	10/6/2017		0	100	9.20	100	7.80
	10/7/2017		0				
	10/8/2017		0				
	10/9/2017		0	100	9.70	100	8.30
	10/10/2017		0	100	9.50	100	8.10
	10/11/2017		0	100	9.30	100	7.90
	10/12/2017		0	100	9.00	100	7.60
	10/13/2017		0	100	8.80	100	7.40
	10/14/2017		0				
	10/15/2017		0				
	10/16/2017		0	100	8.20	100	6.80
	10/17/2017		0	100	8.10	100	6.70

				North (BAM) Pond		South (Control) Pond	
Loading Event	**Date**	**Time**	**Volume**	**Coverage**	**Staff Gauge**	**Coverage**	**Staff Gauge**
(#: Month)	(m/dd/year)	(24 hr)	MG	%	Ft.	%	Ft.
	10/18/2017		0	100	8.00	100	6.60
	10/19/2017		0	100	7.80	100	6.40
	10/20/2017		0	100	7.60	100	6.20
	10/21/2017		0				
	10/22/2017		0				
	10/23/2017		0	100	7.20	100	5.80
	10/24/2017		0	100	7.10	100	5.70
	10/25/2017		0	100	6.90	100	5.50
	10/26/2017		0	100	6.70	100	5.30
	10/27/2017		0	100	6.60	100	5.20
	10/28/2017		0				
	10/29/2017		0				
	10/30/2017		0	100	6.20	100	4.80
	10/31/2017		0	100	6.00	100	4.60
	11/1/2017		0	100	5.95	100	4.55
	11/2/2017		0	100	5.80	100	4.40
	11/3/2017		0	100	5.70	100	4.30
	11/4/2017		0				
	11/5/2017		0				
	11/6/2017		0	100	5.25	100	4.10
	11/7/2017		0	100	5.10	100	4.00
	11/8/2017		0	100	4.95	100	4.00
	11/9/2017		0	100	4.80	100	3.90
	11/10/2017		0	100	4.65	100	3.80
	11/11/2017		0				
	11/12/2017		0				
	11/13/2017		0	100	4.30	100	3.60
	11/14/2017		0	100	4.20	100	3.50
	11/15/2017		0	100	4.10	100	3.50
	11/16/2017		0				
	11/17/2017		0				
	11/18/2017		0				
	11/19/2017		0				
	11/20/2017		0	100	3.60	100	3.10
	11/21/2017		0	100	3.50	100	3.05

				North (BAM) Pond		South (Control) Pond	
Loading Event	**Date**	**Time**	**Volume**	**Coverage**	**Staff Gauge**	**Coverage**	**Staff Gauge**
(#: Month)	(m/dd/year)	(24 hr)	MG	%	Ft.	%	Ft.
	11/22/2017		0	100	3.40	100	3.00
	11/23/2017		0				
	11/24/2017		0				
	11/25/2017		0				
	11/26/2017		0				
	11/27/2017		0	100	3.10	100	2.85
	11/28/2017		0	100	3.00	100	2.80
	11/29/2017		0	100	2.90	100	2.80
	11/30/2017		0	100	2.80	100	2.70
	12/1/2017		0	100	2.70	100	2.70
	12/2/2017		0				
	12/3/2017		0				
	12/4/2017		0	100	2.50	100	2.50
	12/5/2017		0	100	2.40	100	2.45
	12/6/2017		0	100	2.30	100	2.40
	12/7/2017		0	98	2.25	100	2.35
	12/8/2017		0	98	2.20	100	2.40
	12/9/2017		0				
	12/10/2017		0				
	12/11/2017		0	95	2.10	100	2.20
	12/12/2017		0	95	2.00	98	2.15
	12/13/2017		0	90	1.95	98	2.10
	12/14/2017		0	90	1.90	98	2.10
	12/15/2017		0	85	1.85	95	2.00
	12/16/2017		0				
Stormwater Sampling Event	12/17/2017		0				
	12/18/2017		0	80	1.70	95	1.90
	12/19/2017		0				
	12/20/2017		0	80	1.55	95	1.85
	12/21/2017		0	80	1.50	95	1.80
	12/22/2017		0	75	1.40	90	1.75
	12/23/2017		0				
	12/24/2017		0				
	12/25/2017		0				
	12/26/2017		0				

				North (BAM) Pond		South (Control) Pond	
Loading Event	**Date**	**Time**	**Volume**	**Coverage**	**Staff Gauge**	**Coverage**	**Staff Gauge**
(#: Month)	(m/dd/year)	(24 hr)	MG	%	Ft.	%	Ft.
	12/27/2017		0	70	1.10	80	1.35
	12/28/2017		0	65	1.00	75	1.20
	12/29/2017		0	60	0.95	70	1.10
	12/30/2017		0				
	12/31/2017		0				
	1/1/2018		0				
	1/2/2018		0	50	0.80	40	0.70
	1/3/2018		0	55	0.85	40	0.70
	1/4/2018		0	50	0.80	40	0.60
	1/5/2018		0	35	0.70	20	0.50
	1/6/2018		0				
	1/7/2018		0				
	1/8/2018		0	30	0.60	15	0.30
Stormwater Sampling Event	1/9/2018		0	30	0.60	15	0.30
	1/10/2018		0	30	0.60	15	0.30
	1/11/2018		0				
	1/12/2018		0	20	0.50	10	0.30
	1/13/2018		0				
	1/14/2018		0				
	1/15/2018		0				
	1/16/2018		0	5	0.30	10	0.30
	1/17/2018		0	5	0.30	10	0.30
	1/18/2018		0	3	0.20	5	0.25
	1/19/2018		0	1	0.15	3	0.20
	1/20/2018		0				
	1/21/2018		0				
#11: January	1/22/2018		1.44	70	1.50	60	1.35
	1/23/2018		0	90	1.85	90	1.60
	1/24/2018		0	85	1.70	85	1.50
	1/25/2018		0	65	1.50	60	1.30
	1/26/2018		0	65	1.35	55	1.00
	1/27/2018		0				
	1/28/2018		0				
	1/29/2018		0	60	1.10	60	1.30
	1/30/2018		0	60	1.00	55	1.05

				North (BAM) Pond		South (Control) Pond	
Loading Event	**Date**	**Time**	**Volume**	**Coverage**	**Staff Gauge**	**Coverage**	**Staff Gauge**
(#: Month)	(m/dd/year)	(24 hr)	MG	%	Ft.	%	Ft.
	1/31/2018		0	55	0.85	50	0.85
	2/1/2018		0	50	0.80	45	0.70
	2/2/2018		0	40	0.70	30	0.50
	2/3/2018		0				
	2/4/2018		0				
	2/5/2018		0	20	0.55	10	0.20
	2/6/2018		0	15	0.50	5	0.05
	2/7/2018		0	10	0.40	3	0.02
	2/8/2018		0	10	0.40	3	0.01
	2/9/2018		0	5	0.30	1	0.00
	2/10/2018		0				
	2/11/2018		0				
	2/12/2018		0	1	0.20	1	0.00
	2/13/2018		0	1	0.20	1	0.00
	2/14/2018		0	0	0.00	1	0.00
	2/15/2018		0	0	0.00	1	0.00
	2/16/2018		0	0	0.00	1	0.00
	2/17/2018		0				
	2/18/2018		0				
#12: February	2/19/2018		1.60	95	1.50	95	1.30
	2/20/2018		0	85	1.85	85	1.50
	2/21/2018		0	80	1.60	75	1.25
	2/22/2018		0	70	1.40	65	1.00
	2/23/2018		0	60	1.20	40	0.70
	2/24/2018		0				
	2/25/2018		0				
	2/26/2018		0	30	0.6	2	0.05

REFERENCES

Andres, A.S. and J.T. Sims. (2013). Assessing Potential Impacts of a Wastewater Rapid Infiltration Basin System on Groundwater Quality: A Delaware Case Study. Journal of Environmental Quality. 42:391–404.

Bernard, R. J., B. Mortazavi, and A. A. Kleinhuizen (2015), Dissimilatory nitrate reduction to ammonium (DNRA) seasonally dominates NO 3− reduction pathways in an anthropogenically impacted sub-tropical coastal lagoon, Biogeochemistry, 125(1), 47-64.

Birch, G.F., M.S. Fazeli and C. Matthai. (2005). Efficiency of an Infiltration Basin in Removing Contamininants from Urban Stormwater. Environ. Monitoring and Assessment. 101: 23-3.

City of DeLand, Florida (Official Site). (n.d.). Wastewater Plant Information. Accessed Oct. 25, 2017 from <http://www.deland.org/Pages/DeLandFL_PSUtilities/WWTP>.

City of DeLand, Florida. (2016). Request for Commission Action. DeLand, FL: June 6, 2016.

Crites, R.W. and G. Tchobanoglous. (1998). Small and Decentralized Wastewater Management Systems. New York: McGraw-Hill.

Duranceau, S.J. and P.G. Biscardi. (2015). Comparing Adsorptive Media Use for the Direct Treatment of Phosphorous-Impaired Surface Water. J. Environ. Eng. 141(8): 04015012-1 to 04015012-5.

Eaton, A., Clesceri, L., Rice, E., & Greenberg, A. (2005). Standard Methods for the Examination of Water and Wastewater (21 ed.). Washington: American Public Health Association, American Water Works Association, Water Environment Federation.

France, R. L. (2002). Handbook of water sensitive planning and design: CRC Press.

FDEP, 2009. Development of Numeric Nutrient Criteria for Florida. Tallahassee, FL.

Gerrity, D., Pecson, B., Shane Trussell, R., Rhodes Trussell, R. (2013). Potable reuse treatment trains throughout the world. J. Water Supply Res. Technol. - AQUA 62, 321e338.

Google Earth. (Oct. 2017). City of DeLand Rapid Infiltration Basin Areal Estimates. RIB located near the Bent Oaks Neighborhood off E New Hampshire Ave, DeLand, Volusia County, Florida (29°0'18.87"N, 81°17'22.22"W). Google Earth, February 2018.

Holland, K. and Bridger, K. (2014). Nutrient TMDL for Blue Spring (Volusia County) and Blue Spring Run (Volusia County), WBIDs 28933 and 28933A, Florida Department of Environmental Protection, Tallahassee, FL.

Hood, A., M. Chopra and M. Wanielista. (2013). Assessment of Biosorption Activated Media under Roadside Swales for the Removal of Phosphorus from Stormwater. Water. 5, 53-66.

Hanson, B. R., J. Šimůnek, and J. W. Hopmans. (2006). Evaluation of urea–ammonium–nitrate fertigation with drip irrigation using numerical modeling. Agric. Water Manage., 86(1), 102-113.

Icekson-Tal, N., Michail, M., Kraitzer, T., Elkayam, R., Sherer, D., Shoham, G., (2013). Groundwater Recharge with Municipal Effluent: Recharge Basins Soreq 1, Soreq 2, Yavne 1, Yavne 2, Yavne 3 & Yavne 4: 2013.

Idelovitch, E., Icekson-Tal, N., Avraham, O., Michail, M., (2003). The long-term performance of soil aquifer treatment (SAT) for effluent reuse. Water Sci. Technol. Water Supply 3(4), 239-246.

Le Corre, K., Aharoni, A., Cauwenberghs, J., Chavez, A., Cikurel, H., Ayuso Gabella, M.N., Genthe, B., Gibson, R., Jefferson, B., Jeffrey, P., Jimenez, B., Kazner, C., Masciopinto, C., Page, D., Regel, R., Rinck-Pfeiffer, S., Salgot, M., Steyn, M., van Houtte, E., Tredoux, G., Wintgens, T., Xuzhou, C., Yu, L., Zhao, X. (2012). Water reclamation for aquifer recharge at the eight case study sites: a cross case analysis. In: Kazner, C., Wintgens, T., Dillon, P. (Eds.), Water Reclamation Technologies for Safe Managed Aquifer Recharge. IWA Publishing, pp. 11-32 (Chapter 2).

Mullon, L. G. (2017). Biosorption Activated Media Comparison in Two Modular Wetlands. ASCE Water Resources Seminar, 33rd Annual, April 28th. Geosyntec Consultants.

National Research Council. (2012). Water Reuse: Potential for Expanding the Nation's Water Supply through Reuse of Municipal Wastewater. A report published by the National Academy of Science. Washington D.C.: National Academies Press.

O'Reilly, A.M., N. Chang and M.P. Wanielista. (2012). Cyclic biogeochemical processes and nitrogen fate beneath a subtropical stormwater infiltration basin. Journal of Contaminant Hydrology. 133: 53-75.

O'Reilly, A. M., Wanielista, M. P., Chang, N.-B., Harris, W. G., and Xuan, Z. (2012a). Soil Property Control of Biogeochemical Processes beneath Two Subtropical Stormwater Infiltration Basins. Journal of Environmental Quality, 41(2), 564-581.

O'Reilly, A.M., M.P. Wanielista, N. Chang, Z. Xuan, W.G. Harris. (2012b). Nutrient removal using biosorption activated media: Preliminary biogeochemical assessment of an innovative stormwater infiltration basin. Science of the Total Environment. 432: 227-242.

Parkhurst, D. L. and Appelo, C. A. J. (n.d.). Description of Input and Examples for PHREEQC, version 3 – A Computer Program for Speciation, Batch-Reaction, One-Dimensional Transport and Inverse Geochemical Calculations. USGS. Accessed November 8th, 2017 from < https://wwwbrr.cr.usgs.gov/projects/GWC_coupled/phreeqc/phreeqc3-html/phreeqc3.htm >

Simunek, J., K. Huang, and M. T. Van Genuchten. (1995). The SWMS_3D code for simulating water flow and solute transport in three-dimensional variably-saturated media. US Salinity Laboratory Research Report, 139.

Šimůnek, J., M. T. Van Genuchten, and M. Šejna. (2006). The HYDRUS software package for simulating two-and three-dimensional movement of water, heat, and multiple solutes in variably-saturated media. Technical manual, version, 1, 241.

Šimůnek, J., M. T. van Genuchten, and M. Šejna. (2008). Development and applications of the HYDRUS and STANMOD software packages and related codes. Vadose Zone Journal, 7(2), 587-600.

Šimunek, J., M. T. Van Genuchten, and M. Šejna. (2012). HYDRUS: Model use, calibration, and validation. Transactions of the ASABE, 55(4), 1263-1274.

SJRWMD. (2011). SJ2012-1 Chapter 4. Groundwater Hydrology. Accessed March 2018 from < https://www.sjrwmd.com/documents/technical-reports/technical-publications/2017-2009/>.

SJRWMD. Chapter 40C–42 Florida Administrative Code. In Applicant's Handbook: Regulation of Stormwater Management Systems. Environmental Resource Permits., Revised May 27, 2012; pp. 2.1–2.5.

Smith, V.H., Tilman, G.D., Nekola, J.C. (1999). Eutrophication: impacts of excess nutrient inputs on freshwater, marine, and terrestrial ecosystems. Environmental Pollution 100 (1), 179-196.

Toth, D.J. and Katz, B.G. (2006). Mixing of shallow and deep groundwater as indicated by the chemistry and age of karstic springs. Hydrogeol. J. 14:827-847, doi 10.1007/s10040-005-0478-x

USEPA. (2013). Aquatic Life Ambient Water Quality Criteria for Ammonia – Freshwater 2013. Washington D.C.: U.S. Environmental Protection Agency Office of Water. EPA 822-R-13-001.

USEPA. (2003). Wastewater Technology Fact Sheet. Washington, D.C.: Office of Water Municipal Technology Branch. EPA 832-F-03-025.

USEPA. (1993). Nitrogen Control Manual. Washington, D.C.: U.S. Environmental Protection Agency, Office of Research and Development. EPA-625/R-93-010

US Patent 8002984 B1. Wanielista et al. (2011). Green Sorption Material Mixes for Water Treatment. Filed December 18, 2009.

Wanielista, Spirio and Earp (2017). Biosorption Activated Media (BAM). Presented at the 2017 Design Training Expo.

Wanielista, M., Baldassari, T., Ryan, P., Rivera, B., Shah, T., and Stuart, E. (2008). Feasibility Study of Waste Tire Use in Pollution Control for Stormwater Management, Drainfields and Water Conservation in Florida Seminole County Florida and State DEP.

Wanielista, M.P, N. Chang, M. Chopra, Z Xuan, K. Islam, and Z. Marimon. (2012). Floating Wetland Systems for Nutrient Removal in Stormwater Ponds. FDOT # BDK 78-985-01. Tallahassee, FL.

Wanielista, M., Spirio, C., and Earp, K. (2017). Bio-Sorption Activated Media (BAM). Design Training Expo. Wanielista, M. P., and Yousef, Y. A. (1992). Stormwater management: John Wiley & Sons, Inc

Water Environment Federation (WEF), American Society of Civil Engineers (ASCE), and Water resource Institution. (2005). Biological Nutrient Removal (BNR) Operation in Nine Wastewater Treatment Plants. Water Environment Federation Press, Manual of Practice No. 30, McGraw Hill Publishing, New York.

Xuan, Z., N. Chang, M.P. Wanielista and E.S. Williams. (2013). J. Environ. Qual. 42:1086–1099.

Yu, C. and C. Zheng. (2010). HYDRUS: software for flow and transport modeling in variably saturated media. Groundwater, 48(6), 787-791.