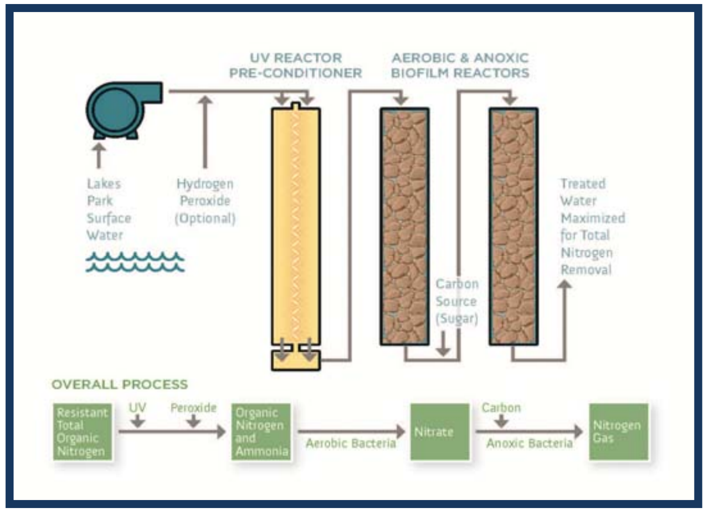
PROGRESS REPORT ON NITROGEN REDUCTION PHASE 1 PILOT TESTING



Prepared for:

LEE COUNTY
SOUTHWEST FLORIDA

Division of Natural Resources
2115 Second Street
Fort Myers, FL 33901

Prepared by:

HSA
ENGINEERS & SCIENTISTS

9110 College Pointe Court
Fort Myers, Florida 33919
Phone: (239) 936-0789
Fax: (239) 936-0819

November 25, 2013

Executive Summary

Reductions in the total nitrogen content of surface waters entering the local Caloosahatchee Estuary have been a long term common goal of Lee County and the South Florida Water Management District (SFWMD). Lee County surface waters contain relatively high amounts of organic nitrogen (50% or more of the total nitrogen) compared to the inorganic nitrogen content. Meaningful treatment technologies aimed at effectively reducing the levels of nitrogen in the surface waters of this area should be focused on converting the existing organic nitrogen to the more bioavailable forms of nitrogen, such as ammonia nitrogen (including ammonia and ammonium), nitrate, and nitrite. The objective of this pilot study was to determine if an in-line UV Lamp can convert organic nitrogen to the more bioavailable ammonia nitrogen form in representative Lee County surface waters.

The UV pilot system was installed in a trailer located at the discharge end of Lakes Park serpentine storm water treatment system in Lee County. The pilot system consists of an intake unit, a Trojan UV reactor, and two columns. Supplemental air was supplied to column 1 to enhance nitrification and lower dissolved oxygen conditions were maintained in column 2 to encourage denitrification. Samples were collected at four locations: feed water, post UV, after column 1, and after column 2, and submitted for analysis. Field parameters were measured onsite.

The primary objective of the pilot study has been met during the first phase of the testing. Ammonia nitrogen increased markedly after the UV reactor, and then decreased after column 1. Ammonia nitrogen in the feed water was 0.008±0.004 mg/L as N, slightly above the MDL. After the UV reactor, ammonia nitrogen increased to 0.060±0.033 mg/L as N, approximately equal to 7.5 times in the feed water. Total nitrogen, organic nitrogen, and dissolved organic nitrogen (DON) showed a general decreasing trend through the system. Organic nitrogen decreased from 0.58±0.06 mg/L as N in the feed water to 0.52±0.05 mg/L as N after the UV reactor, and 0.44±0.21 mg/L as N after column 2. The decrease of organic nitrogen and the increase of ammonia nitrogen after the UV reactor suggested the conversion of organic nitrogen in feed water to the bioavailable ammonia nitrogen form by exposing the feed water to UV irradiation.

The concentrations of total nitrogen, organic nitrogen, ammonia nitrogen, and nitrate/nitrite in the Lakes Park feed water during the pilot testing period were much lower than the levels obtained prior to construction of the filter marsh project at Lakes Park in 2012. Testing with water containing higher concentrations of nitrogen will provide more insightful information on the effectiveness of the UV system and more realistic estimation of this technology's potential. A review of the historical total nitrogen data provided by Lee County environmental staff suggested that the water quality monitoring station CES01 in the Caloosahatchee River Basin, which is located upstream of the water control structure S-79, could be a better testing site with relatively higher concentrations of total organic nitrogen and nitrate/nitrite in the surface water. The water treatment plant site on the Caloosahatchee River appears to be a superior site to perform the additional testing. A separate set of columns will be added into the pilot system as a control and the pilot system will be operated under various specific conditions to test the effect of flow rate on the UV treatment. Adjustment will occur based on the column conditions, water qualities, and preliminary testing results. The move and the additional testing would incur an additional $ 23,000 in costs.

TABLE OF CONTENTS

TABLES

FIGURES

APPENDICES

I. Background and Objectives

It has been estimated that nearly two thirds of all estuaries in the United States are moderately to severely impaired due to eutrophic nutrient (nitrogen and phosphorus) enrichment (PEW Oceans Commission, 2003). In Lee County, reductions in the total nitrogen content of surface waters entering the local Caloosahatchee Estuary have been a long term common goal of the County and the South Florida Water Management District (SFWMD). Many of the agricultural and urban storm waters in the County that ultimately discharge into the Caloosahatchee Estuary contain nitrogen levels on the order of 1 to 2 mg/L total nitrogen whereas studies show that unimpacted waters for the area would contain nitrogen levels more on the order of 0.60 to 0.74 mg/L (Thera et al., 2009).

A significant amount of nutrient reduction research has been conducted over the past two decades on South Florida surface waters that are ultimately discharged to the Everglades National Park as part of the Comprehensive Everglades Restoration Program (CERP). The CERP pilot and prototype field assessments were geared towards removing nutrients; however, phosphorus removal was the primary goal of the research and limited efforts were directed at evaluating effective nitrogen removal techniques or even understanding the degree of bioavailability of the various nitrogen forms. In addition, the majority of the CERP related research was conducted on storm waters located in the Everglades Agricultural Area (EAA). Due to the organic soils of the EAA and the relatively high nitrogen content of the runoff, direct comparison of effective nutrient treatment reduction techniques to Caloosahatchee surface waters containing lower nitrogen levels becomes problematic.

Lee County surface waters contain relatively high amounts of organic N (50% or more of the total N) compared to the inorganic N content. Based on the existing water quality characteristics in the Lee County surface waters, meaningful treatment technologies aimed at effectively reducing the levels of nitrogen in the surface waters of this area should be focused on converting the existing organic nitrogen to the more bioavailable forms of nitrogen, such as ammonia nitrogen (ammonia (NH_3) and ammonium (NH_4^+)), nitrate (NO_3^-), and nitrite (NO_2^-). Included in the list of candidate technologies thought to have the potential to increase these ammonification rates is concentrated ultraviolet (UV) light. Preliminary research had shown that UV light has the potential to cleave (or disassociate) the organic nitrogen into inorganic forms like ammonia nitrogen by simply exposing water samples to the sunlight. Bronk et al. (2010) has indicated that photoproduction of ammonia nitrogen can occur on refractory organic compounds on samples exposed to UV light. Zepp (2003) and Zepp et al. (2007) have written extensively on the photoproduction of nitrate and ammonia nitrogen from chromophoric dissolved organic nitrogen (CDON -- humic materials contributing to the color of surface water). Bushaw-Newton and Moran (1999) have also indicated that photochemical modification of marine humic substances may provide a source of labile nitrogen to estuarine and coastal ecosystems that has not previously been considered.

In order to further evaluate the ammonification potential of UV light in Lee County Waters, HSA proposed to Lee County, a pilot study to evaluate the effects of UV irradiation on the organic nitrogen content of representative surface waters.

HSA was authorized to proceed with the study and the UV pilot unit was constructed and installed at the County's Lakes Park facility. Preliminary data have been obtained from the initial operations of the pilot unit and these data are summarized in the enclosed progress report.

This initial pilot testing was funded by Lee County with a portion of the services provided by HSA Engineers donated as in-kind services, in order to conduct a preliminary assessment on the potential for concentrated UV light to reduce the nutrient content of surface waters. It was intended to be a cursory assessment aimed at answering the fundamental question as to whether UV dosing of surface waters shows any potential treatment benefits.

The proposed Phase I pilot study was aimed at achieving the following specific objectives:

- An in-line UV Lamp that will be used to expose the surface waters to ultraviolet light to determine its ability to convert organic nitrogen to the more bioavailable form of nitrogen such as ammonia nitrogen. Modifying the feed flow rate through the UV unit will be used to determine optimal UV dosage rates.

- Two attached film biological columns installed in series to first convert the ammonia nitrogen to nitrate (nitrify) in the aerobic column, and then to generate nitrogen gas from nitrate (denitrify) in the second anoxic column. These columns will assess the potential for UV irradiation to enhance microbial enzymatic ammonification.

- Several sampling ports along the pilot study to identify change in nitrogen speciation and removal.

II. Pilot Unit Overview and Start Up

The UV pilot equipment was installed in an air conditioned 10' by 14' Office trailer within the County's Lakes Park facility. An aerial photograph of the location of the unit within the Park is provided in Figure 1. Recently completed additions to the Park's serpentine storm water treatment can also be seen in the Figure 1 aerial. The pilot unit was positioned at the discharge end of the serpentine flow way system and it was installed after the construction of the Park's filter marsh system was completed.

Figure 2 provides a schematic diagram of the system components. Figure 3 provides a photograph of the pilot unit housed inside the trailer. A PVC intake line was placed approximately 40 feet from the shoreline. A plastic strainer and a foot valve were placed at a 90 degree downward angle from the intake line and floats were attached to the line. The floats on the intake line keep the sample intake at a constant depth of approximately 18 inches beneath the water surface (total approximate depth of water at the intake location is 3.5-4 feet). A 15-20 gallon per minute centrifugal pump provides a continuous flow of Lake Park surface water to 100 gallon head tank. The purpose of the head tank is to limit particulate striation and supply a completely mixed, representative sample continuously to the pilot unit. The majority of the water in the head tank is returned to Park surface water with a small amount being withdrawn with a peristaltic pump and fed into the UV reactor.

The peristaltic feed pump is capable of providing a range of flows to the UV reactor from 60 to approximately 1000 milliliters per minute (mL/min). The UV unit installed in the trailer is a Trojan UV Max (model G).

The UV lamp is classified as an amalgam, low pressure-high output UV source that delivers a nominal applied dose of 40 milljoules/cm^2. Appendix 1 contains additional manufacturer information on the Trojan UV system. The UV emission rate is fixed and consequently the primary testing variable is UV reactor retention time. The UV reactor static volume is 2.4 liters. At a flow rate of 100 mL/min to the UV lamp for instance, the retention time within the reactor (*e.g.*, amount of time the feed water is exposed to the UV source), is consequently equal to 24 minutes.

After the UV reactor, the treated water serially flows through two 8 inch diameter clear plexi-glass columns packed with graded (0.75 to 1.25 inch diameter), quarried South Florida lime rock. By providing a media to grow attached microbes on the lime rock, it is intended to determine if microbial enzymatic degradation of dissolved organic nitrogen can be enhanced by UV treatment. As the columns are exposed to natural sunlight through the trailer windows, a considerable algal growth has developed on the columns as well. Figure 4 provides a photograph showing the algal growth on the columns after 5 weeks of pilot operation.

The first of the two columns is supplied with supplemental air to enhance nitrification. The second column was established to encourage denitrification under lower dissolved oxygen (*i.e.*, anoxic) conditions. For the denitrification reaction to proceed a source of available carbon is required at an approximate ratio of 3 parts of carbon for each part of nitrate and accordingly the ability to add a dilute solution table sugar (sucrose) to the second column via gravity drip was incorporated into the pilot unit design.

The pilot unit was installed inside the trailer in mid-February and operation commenced at the end of the month. To date the unit has been running nearly continuously a little more than 8 weeks except for a few very brief (i.e., 4-6 hour) downtimes for maintenance and repairs.

III. Initial Pilot Unit Operations and Results Obtained To Date

Operation of the pilot unit commenced on February 25, 2013. Samples have been collected and submitted to the SFWMD Laboratory every other week and the Lee County Environmental Lab (LCEL) twice per week. The four grab sampling locations are provided in the Figure 3 photograph and include:

- Sampling Point 1 – feed water, obtained directly from the top of the head tank;
- Sampling Point 2 – post UV, obtained from the tubing immediately prior to entering into column 1;
- Sampling Point 3 – after column 1, collected from the tubing immediately prior to entering column 2; and,
- Sampling Point 4 – after column 2, obtained from the tubing leading from column 2.

Field parameters including pH, specific conductance (conductivity), temperature, and dissolved oxygen were measured onsite at the same time samples were collected for nutrient analysis and the results are provided in Table 1.

The pH of the feed water for the period of record indicated in Table 1 remained in a very narrow range of 8.0 to 8.3. The pH values for the other sampling locations all were very near the feed pH range and varied from between 7.6 to 8.4. The UV source and the column biological activity had no measurable effect on pH of the water.

The dissolved oxygen (DO) of the feed is representative of a well oxygenated surface water and was equal to or above 7.5 mg/L, near saturation. The feed waters pumped into the trailer and the head tank is filled in an upflow manner thus limiting aeration of the samples from the pumping process – consequently, the measured feed water DO is considered to be representative of the sampling location.

Maintaining a high DO in column 1 (i.e., 4 or greater) will encourage the growth of nitrifying bacteria that convert ammonia nitrogen to nitrate. Attempting to maintain anoxic conditions in column 2 (i.e. $\leq$1 mg/L DO) should support the growth of denitrifying bacteria that convert nitrate to nitrogen gas. The DO of the anoxic column 2 was 6 mg/L or more during the initial phase of the study. Algal growth in this column and DO carried over from column 1 might be responsible for the high DO. As shown in Table 1, the air pump was turned off that was feeding column 1 and the outside of column 2 was covered with opaque material in order to shield the column from the sunlight that will otherwise encourage algal growth and consequently higher oxygen levels. After covering column 2, the DO started to drop and the most recent data indicated it decreased to the range of 2 to 2.5 mg/L. Further reduction of DO to the optimal anoxic range of less than 1 mg/L of DO in column 2 is expected after initiating the denitrification process with appropriate levels of carbon and nitrate. The primary goal of the pilot unit is implied in these latter two sentences: if the UV source can generate additional bioavailable forms of nitrogen (i.e., ammonia nitrogen and nitrate), the microbes in the respective columns should be able to eliminate this additional nitrogen, by producing nitrogen gas and thus reducing the total nitrogen of the surface waters.

The specific conductance (conductivity) of the feed and all other samples has remained in a very narrow range with averages between 678 and 727 micromhos/cm (µmhos/cm). This range of conductivities is representative of freshwaters with low total dissolved solid.

The temperature of the feed water ranged between 19 and 27.4 degree Centigrade. At the low flows initially used in the pilot unit (60-80 mL/min), the post UV water temperature increased approximately 3 degree C and this increase is caused by the heat generated by the UV lamp. As the flow rate is increased (and retention time reduced inside of the UV unit) this temperature differential will be reduced.

Samples have been analyzed for two forms of phosphorus and several forms of nitrogen at both SFWMD Lab and Lee County Environmental Lab. A brief discussion of each form and how they are typically distinguished is provided below:

Ortho Phosphorus and soluble reactive phosphorus are terms often used interchangeably but they are analytically defined somewhat differently. The term ortho phosphorus will be used here to describe the phosphorus fraction that is considered readily bioavailable. Ortho phosphorus samples are filtered through a 0.45 micron filter prior to analysis.

Total Phosphorus represents all phosphorus that is contained in a water sample and that has been digested (*e.g.,* broken down to the ortho form) using heat and strong mineral acids. Dissolved organic phosphorus is the portion of the total that is typically not considered readily bioavailable and is filtered prior to analysis. Organic phosphorus is generally considered the portion of the phosphorus content that is not readily bioavailable (total minus ortho) and includes particulate and dissolved forms. Total dissolved phosphorus is organic and ortho combined that have been filtered through a 0.45 micron filter. By convention, "dissolved" fractions are generally defined as everything that passes through a 0.45 micron filter and "particulate" is the portion that is retained on the same filter and cannot pass through the filter.

Ammonia Nitrogen includes ammonia (NH_3) and ammonium (NH_4^+).

Inorganic Nitrogen includes ammonia nitrogen (NH_3 and NH_4^+), nitrate (NO_3^-), and nitrite (NO_2^-).

Organic Nitrogen is the portion that has been digested (broken down to ammonia nitrogen) using heat and strong mineral acids minus the initial ammonia nitrogen and nitrate and nitrite content.

Dissolved Organic Nitrogen (DON) is the filtered portion of the sample that has been digested minus the initial ammonia nitrogen and nitrate and nitrite content.

Total Kjeldahl Nitrogen (TKN) represents the combined ammonia nitrogen and organic nitrogen content.

Dissolved TKN represents the combined ammonia nitrogen and organic nitrogen forms in the water samples filtered through a 0.45 micron filter.

Total nitrogen is the sum of TKN and nitrate plus nitrite nitrogen forms.

Table 2 provides a summary of the nitrogen and phosphorus analytical testing completed by the SFWMD lab during the initial portion of the pilot program. The analytical results from the Lee County Environmental Lab are reported as Table 3. For the samples collected on the same days and the same times, differences were observed between the two laboratories for the same analyzed parameter (Table 4). For comparison, the analytical methods and the associated method detection limit (MDL) used at both labs for nitrogen and phosphorus are listed in Table 5.

As shown in Table 4, total phosphorus concentrations reported by SFWMD Lab were generally higher than those reported by Lee County Environmental Lab for the same sample. Phosphorus concentrations (total phosphorus, ortho phosphorus, and total dissolved phosphorus) reported by the Lee County Environmental Lab were either below the MDL or labeled with a qualifier “I”, indicating the values are less than or equal to the laboratory’s practical quantitation limit (PQL) and greater than the MDL. For phosphorus analysis, SFWMD Lab uses Standard Methods for the Examination of Water and Wastewater 4500-P F. (SM4500-P F.) (APHA, AWWA, WEF, 2005), while Lee County Environmental Lab uses EPA 365.1 Method (USEPA, 1983). According to the method descriptions and lab reports, the applicable concentration range of SM4500-P F. is 0.001 to 10.0 mg/L as P and the respective MDL is 0.002 mg/L as P; while the applicable concentration range of EPA 365.1 is 0.01-1.0 mg/L as P and the respective MDL is 0.006 mg/L as P. The two different analytical methods applied at these two labs could be the major reason for the differences of phosphorus concentrations observed for the same sample.

The ammonia nitrogen concentrations reported by Lee County Environmental Lab were generally higher than those reported by SFWMD Lab for the same sample, but most of the ammonia nitrogen (NH_3/NH_4^+) data reported by Lee County Environmental Lab were either below the MDL or labeled with a qualifier “I”. For ammonia nitrogen analysis, SFWMD Lab uses Standard Methods for the Examination of Water and Wastewater 4500-NH_3 H. (SM4500-NH_3 H) with an MDL of 0.005 mg/L as N (APHA, AWWA, WEF, 2005), while Lee County Environmental Lab uses EPA 350.1 Method with an MDL of 0.014 mg/L as N (USEPA, 1983). The two different analytical methods applied at these two labs could be the major reason for the differences of ammonia nitrogen concentrations observed for the same sample.

The nitrate and nitrite concentrations were analyzed with Standard Methods for the Examination of Water and Wastewater 4500-NO_3 F. (SM4500-NO_3 F) (APHA, AWWA, WEF, 2005) at SFWMD lab (MDL of 0.005 mg/L as N) and EPA 353.2 Method (USEPA, 1983) at Lee County Environmental Lab (MDL of 0.01 mg/L as N). However, for most of the samples, the nitrate and nitrite concentrations were either below the MDL or labeled with a qualifier “I”.

The TKN concentrations reported by Lee County Environmental Lab were generally higher than those reported by SFWMD Lab for the same sample, as were the dissolved TKN concentrations. Both Labs used EPA 351.2 Method with an MDL of 0.05 mg/L as N. Therefore, the difference of the results for the same sample should be attributed to the systematic error of measurement. Sources of systematic error may include the imperfection of the instrument being used, the imperfect calibration of the instruments, or the mistakes the individual makes while taking the measurement. Systematic error cannot be estimated by comparing multiple measurements, nor reduced by averaging multiple measurements, but it can usually be eliminated if the cause can be identified.

In order to further evaluate the inter laboratory data and conduct a meaningful inter laboratory comparison, HSA would need to conduct a split sample quality assurance assessment on the two labs entailing submittal of duplicate samples, blind duplicate samples and target parameter matrix spiked samples. After this data were collected a rigorous statistical analysis would need to be conducted to determine if the two laboratories were reporting significantly different information. HSA would be happy to discuss conducting this study if it is needed, but it is not included in the scope of services for this pilot study.

The SFWMD lab is specialized in low concentration nutrient analysis and the analytical methods used at the SFWMD lab generally have lower MDLs. The nutrient concentrations in samples of this pilot study were relatively low, approaching the MDLs; therefore, the following discussion is primarily based on the data reported by the SFWMD lab (Table 2). The data reported by the Lee County Environmental Lab were also used for comparison if applicable.

Generally, the water quality parameters of the feed water were stable with small variances over the testing period from February to April 2013. The total phosphorous concentration of the feed water during the testing period was 0.023±0.004 mg/L as P (Table 2). The total nitrogen concentration of the feed water during the testing period was 0.59±0.06 mg/L as N (Table 2). The concentrations of ammonia nitrogen in the feed water during the testing period were very low, 0.008±0.004 mg/L as N (Table 2). Nitrate and nitrite were below the MDL (0.005 mg/L as N) in most samples (Table 2). The concentrations of total nitrogen, ammonia nitrogen, and nitrate and nitrite were much lower than the data obtained prior to the construction of the filter marsh project at Lakes Park in 2012, which were 0.94, 0.15, and 0.15 mg/L as N, respectively (Table 6). The surface water at the pilot unit intake location in Lakes Park can be characterized as having low total nitrogen content and extremely low concentrations of the more bioavailable nitrogen forms of ammonia nitrogen and nitrate/nitrite compared to the water in Caloosahatchee River at the Franklin Locks, which demonstrated an average total nitrogen of 1.62 mg/L as N in the 2012 wet season according to the Hydro database of SFWMD, nearly three times the concentration observed in the samples collected at Lakes Park during the initial pilot testing. The Caloosahatchee River water would conceptually be a much better feed water source for assessing UV technology effectiveness as it has higher concentrations of organic nitrogen that could potentially be less refractory than the lower levels of organic nitrogen observed at Lakes Park.

The trend of total phosphorus in the feed water and samples collected after the UV reactor, after column 1, and after column 2, is presented in Figure 5**.** The data from both SFWMD Lab and Lee County Environmental Lab were compared for the testing period from February 25 to April 22, 2013 with a flow rate in the UV reactor around 60-70 mL/min. The data obtained from Lee County Environmental Lab showed a greater variance compared to the data from SFWMD Lab because 1) samples were submitted to Lee County Environmental Lab more frequently during the same testing period, and thus, more data were used in standard deviation calculation; 2) the MDL of the analytical method used at SFWMD Lab is lower, and thus, more reliable results at the lower concentration range can be expected. The results from both labs showed the similar decreasing trend of total phosphorous in the pilot system, and the decrease is significant after column 1 according to the SFWMD Lab data, suggesting the removal of particle-associated phosphorous in column 1.

The trends of ammonia nitrogen, total nitrogen, organic nitrogen, and DON in the feed water and samples collected after the UV reactor, after column 1, and after column 2, are presented in Figure 6. The data from both SFWMD Lab and Lee County Environmental Lab were compared for the testing period from February 25 to April 22, 2013 with a flow rate in the UV reactor around 60-70 mL/min. The results from both labs showed similar trends of ammonia nitrogen, total nitrogen, organic nitrogen and DON in samples collected at the four sampling locations through the pilot system. Similarly, the data obtained from Lee County Environmental Lab generally showed greater variances than the data from SFWMD Lab. The concentration ranges of total nitrogen, organic nitrogen, and DON measured at Lee County Environmental Lab were generally higher than those measured at SFWMD Lab for the samples collected from the same sampling locations during the same time period, which could be attributed to systematic errors during the measurement as discussed earlier. Ammonia nitrogen increased markedly after the UV reactor, and then decreased in column 1. Based on the SFWMD Lab data (Table 2), ammonia nitrogen in the feed water was 0.008±0.004 mg/L as N, slightly above the MDL. After the UV reactor, ammonia nitrogen increased to 0.060±0.033 mg/L as N, approximately equal to 7.5 times of feed water. Total nitrogen, organic nitrogen, and DON generally showed a decreasing trend, although the change after the UV reactor was not significant in the figures. Based on the SFWMD Lab data (Table 2), organic nitrogen decreased from 0.58±0.06 mg/L as N in the feed water to 0.52±0.05 mg/L as N after the UV reactor, and 0.44±0.21 mg/L as N after column 2. The decrease of organic nitrogen (0.06 mg/L, representing a 10.3 % reduction) and the increase of ammonia nitrogen (0.052 mg/L) after the UV reactor suggested the conversion of organic nitrogen in feed water to the bioavailable ammonia nitrogen form by exposing the feed water to UV irradiation.

The trends of ammonia nitrogen, total nitrogen, organic nitrogen, and DON in the feed water and samples collected after the UV reactor, after column 1, and after column 2, with two different flow rates in the UV reactor are presented in Figure 7**.** Data for the flow rate of 64 mL/min were obtained from the testing period of March 11 to April 22, 2013; while data for the flow rate of 100 mL/min were obtained from the test period of April 24 to May 15, 2013 (Table 3). Only analytical results from Lee County Environmental Lab were used for comparison. Generally, ammonia nitrogen increased markedly after the UV reactor, and then decreased in column 1; however, no significant differences were observed in ammonia nitrogen at each sampling location between the two flow rates, which is likely due to the low concentrations (slightly above the MDL). Total nitrogen, organic nitrogen, and DON showed a general decreasing trend through the system. Significant differences in levels of total nitrogen, organic nitrogen, and DON at each sampling location between two flow rates were observed, respectively, suggesting the variance of water quality during the two testing periods. However, the changed amount of total nitrogen, organic nitrogen, and DON at each sampling location between two flow rates were not significantly different. More tests under controlled conditions at different flow rates through the UV reactor are needed to evaluate the effect of residence time on UV treatment, which determines the UV doses.

IV. Conclusions and Recommendations

In spite of lower than anticipated concentrations of total nitrogen and organic nitrogen in the Lakes Park feed water (and a presumed higher percentage of refractory of DON), the pilot unit has produced preliminary promising results. The decrease of organic nitrogen and the increase of ammonia nitrogen after the UV reactor suggested the conversion of organic nitrogen in feed water to the bioavailable ammonia nitrogen form by exposing the feed water to UV irradiation. A more representative test of the pilot system to reduce the content of organic nitrogen in surface waters would be to move the pilot unit to an area that would have higher concentrations of nitrogen in the water.

The total nitrogen and turbidity data (provided by the Lee County environmental staff) have been evaluated on additional surface water locations, and the station CES01 in the Caloosahatchee River Basin, which is located upstream of the water control structure S-79 (Figure 8), had relatively higher concentrations of total organic nitrogen and nitrate/nitrite. The higher concentrations of total nitrogen observed in the river samples should provide a more realistic test of the technology's potential. The water treatment plant site on the Caloosahatchee River appears to be a superior site to perform the additional testing. Specific recommendations for the testing protocols for the next 5-7 weeks of testing include the following:

1. Collect one sample from the site during the first week of testing and analyze selected parameters, including different forms phosphorus and nitrogen listed in Tables 1-2, and total organic carbon and dissolved organic carbon.
2. Move the pilot unit and its trailer to the new treatment site in the first week of testing and have it ready to resume testing.
3. It has been suggested by Lee County that a separate set of columns be run identical to the columns receiving the UV irradiated water but only using the two additional columns as a control. Setting up and conditioning the control columns will occur in the first and second weeks of testing.
4. Operate the pilot unit under the following specific conditions (adjustment could occur based on the column conditions, water qualities, and preliminary testing results) :

Week	**Unit Flow Rate (mL/min)**	**Sample Frequency/Location**[1]	**Specific Conditions**
3	Varies[2]	Feed water and After UV reactor	UV Lamp on to test the effect of flow rate
4	100	Twice per week – all 4 locations	UV Lamp on, Carbon Feed
5	100	Twice per week – all 4 locations	UV Lamp on, Carbon Feed
6	Optimization	To be determined, depending on the results of previous testing. Test may include another round of operating the system at a different flow rate and collecting samples at all four locations.	
7			

[1]Samples will be tested for parameters listed in Tables 1 and 2.
[2]Flow rate will vary between 100 and 600 mL/min, depending on the feature and operation conditions of the pump.

5. The move and the testing would incur an additional $ 23,000 in costs associated with moving the trailer, re-establishing hurricane tie downs, installing a new intake structure

roughly 30 feet from the shore of the river, purchasing two additional columns and a peristaltic pump, operating the system under various conditions, collecting samples, data analysis and report. Moving the trailer was not in the initial budget; however, the lower than anticipated levels of organic nitrogen and nitrate/nitrite in the Lakes Park samples are believed to limit the ability to obtain informative data to assess the UV irradiation potential.

V. References

APHA, AWWA, WEF, 2005, Standard Methods for the Examination of Water and Wastewater, 21st ed. American Public Health Association, Washington, D.C.

Bronk DA, Roberts QN, Sanderson MP, Canuel EA, Hatcher PG, Mesfioui R, Filippino KC, Mulholland MR, and Love NG, 2010, Effluent Organic Nitrogen(EON): Bioavailability and Photochemical and Salinity – Mediated Release, Environmental Science & Technology, 44(15), 5830-5835.

Bushaw-Newton KL and Moran MA, 1999, Photochemical Formation of Biologically Available Nitrogen from Dissolved Humic Substances in Coastal Marine Systems, Aquatic Microbial Ecology Journal, 18, 285-292.

PEW Oceans Commission, 2003, America's Living Oceans, Charting a Course for Sea Change. Pew Charitable Trust, Philadelphia, PA.

Thera, JC, Duffey, RM, Nelson, JL, 2009, Total Maximum Daily Load (TMDL) Program: Estero Bay, http://itech.fgcu.edu/faculty/ndemers/EsteroWatershedSymp09/Estero%20Bay%20Poster%20-%20TMDL.pdf

USEPA, 1983, Methods for Chemical Analysis of Water and Wastes, USEPA EMSL, Cincinnati, Ohio, EPA-600/4-79-020.

Zepp RG, 2003, Solar UVR and Aquatic Carbon, Nitrogen, Sulfur & Metals Cycles, in UV Effects in Aquatic Organisms and Ecosystems, Helbling E.W. & Zagarese H. (Eds), Royal Society of Chemistry, Cambridge, 137-183.

Zepp RG, Erickson DJ 3rd, Paul ND, Sulzberger B., 2007, Interactive Effect of Solar UV Radiation and Climate Change on Biogeochemical Cycling. Photochemical and Photobiological Sciences, 6(3), 286-300.

Tables

Table 1
Field Parameter Results
Nitrogen Reduction Phase I Pilot Study

Date	Flow Rate (gal/day)	Flow Rate (mL/min)	Sample Location	pH	Temp (°C)	Conductivity (µS/cm)	DO (mg/L)	Notes
2/28/2013	29	76	Feed	-	-	706	-	
			Post UV	-	-	732	-	
			Column 1*	-	-	719	-	
			Column 2**	-	-	685	-	
3/15/2013	23	60	Feed	8.14	25.1	750	8.58	
			Post UV	-	-	-	8.63	
			Column 1*	-	-	-	8.12	
			Column 2**	8.01	24.1	710	7.46	
3/18/2013	23	60	Feed	8.12	23.4	734	7.85	
			Post UV	7.90	31.5	769	-	
			Column 1*	8.09	23.6	938	8.35	
			Column 2**	8.27	24.8	674	6.85	
3/22/2013	23	60	Feed	8.10	23.8	731	7.95	
			Post UV	7.92	30.0	745	-	
			Column 1*	8.12	24.0	680	8.45	
			Column 2**	8.07	24.1	721	8.09	
3/25/2013	25	66	Feed	8.07	25.1	720	-	
			Post UV	7.91	29.4	726	-	
			Column 1*	8.22	24.1	573	-	
			Column 2**	7.71	24.5	722	-	
3/27/2013	23	60	Feed	8.18	19.3	700	8.78	
			Post UV	8.07	21.6	729	11.35	
			Column 1*	8.25	19.3	697	11.47	
			Column 2**	8.07	16.4	820	7.78	
4/1/2013	25	66	Feed	8.17	24	763	8.45	
			Post UV	8.06	26.4	598	-	
			Column 1*	8.24	23.6	734	11.27	
			Column 2**	7.89	23.9	717	8.05	
4/3/2013	25	66	Feed	8.20	25.7	727	8.27	Cleaned the sleeve on April 2.
			Post UV	7.96	27.5	742	-	
			Column 1*	8.36	23.2	636	11.29	
			Column 2**	8.00	24.6	680	8.25	
4/8/2013	30	80	Feed	8.17	25.3	652	-	Changed to the new sleeve. Adjusted flow rate to 60 mL/min.
			Post UV	7.99	28.0	705	-	
			Column 1*	8.19	23.7	656	-	
			Column 2**	8.00	21.6	703	-	
4/10/2013	23	60	Feed	8.15	24.6	700	7.85	
			Post UV	7.97	26.0	714	-	
			Column 1*	8.30	24.8	671	-	
			Column 2**	7.93	24.6	691	6.53	
4/15/2013	23	60	Feed	8.14	24.9	703	7.50	Wrap the second column with aluminium on April 16 to limit the growth of algae
			Post UV	8.00	26.6	710	-	
			Column 1*	8.22	25.4	676	8.92	
			Column 2**	7.94	24.9	708	6.45	
4/17/2013	23	60	Feed	8.12	27.4	704	7.89	DO in the second column started decreasing
			Post UV	7.93	30.6	690	-	
			Column 1*	8.18	24.8	677	9.28	
			Column 2**	7.98	25.4	718	5.78	

Table 1
Field Parameter Results
Nitrogen Reduction Phase I Pilot Study

Date	Flow Rate (gal/day)	Flow Rate (mL/min)	Sample Location		pH	Temp (°C)	Conductivity (µS/cm)	DO (mg/L)	Notes
4/22/2013	25	65	Feed		8.12	25.9	687	7.49	Replaced the tubing between columns with larger diameter tubing and turned off the air pump in column 1. Adjusted the flow to 100 mL/min after sampling on April 22.
			Post UV		7.96	29.4	702	-	
			Column 1*		7.65	25.0	668	7.38	
			Column 2**		7.79	24.4	810	2.52	
Average ± Stdev	27±6	65±7	Feed	Average	8.14	24.54	713.62	8.06	
				Stdev	0.04	1.96	28.63	0.44	
			Post UV	Average	7.97	27.91	713.50	-	
				Stdev	0.06	2.77	42.35	1.92	
			Column 1*	Average	8.17	23.77	693.75	7.21	
				Stdev	0.19	1.64	86.99	0.66	
			Column 2**	Average	7.97	23.61	719.92	4.15	
				Stdev	0.14	2.45	45.12	2.90	
After Increasing the Flow Rate									
4/24/2013	38	100	Feed		8.02	26.1	705	7.75	
			Post UV		8.00	27.4	694	-	
			Column 1*		8.00	24.8	679	7.15	
			Column 2**		7.68	25.1	710	2.72	
4/29/2013	38	100	Feed		8.06	24.7	685	7.50	
			Post UV		8.00	27.0	697	-	
			Column 1*		7.79	23.5	679	5.20	
			Column 2**		7.64	24.4	740	2.20	
5/1/2013	38	100	Feed		8.02	25.4	705	7.56	
			Post UV		8.01	29.4	717	-	
			Column 1*		7.75	25.4	696	7.10	
			Column 2**		7.68	25.0	746	2.62	
5/6/2013	38	100	Feed		8.05	25.0	663	7.83	Replaced the tubing used at the peristaltic pump; reset the flow rate before sampling.
			Post UV		8.04	26.5	649	-	
			Column 1*		7.94	23.5	667	6.50	
			Column 2**		7.87	24.5	698	1.78	
5/8/2013	38	100	Feed		8.28	24.1	637	7.74	
			Post UV		8.00	27.4	679	-	
			Column 1*		8.07	23.4	670	6.96	
			Column 2**		8.09	23.9	742	2.30	
Average ± Stdev	38±0	100±0	Feed	Average	8.09	25.1	679	7.68	
				Stdev	0.11	0.8	29	0.14	
			Post UV	Average	8.01	27.5	687	-	
				Stdev	0.02	1.1	25	-	
			Column 1*	Average	7.91	24.1	678	6.58	
				Stdev	0.14	0.9	11	0.81	
			Column 2**	Average	7.79	24.6	727	2.32	
				Stdev	0.19	0.5	22	0.37	

* Temperature, pH, and conductivity at column 1 were measured with samples collected from the bottom of the column; DO at column 1 was measured at the top of the column.

Table 2
Laboratory Analytical Results - South Florida Water Management District Laboratory (SFWMDL)
Nitrogen Reduction Phase I Pilot Study

Date	Flow Rate (gal/day)	Flow Rate (mL/min)	Sample Location	Sample ID	Phosphorus Forms (mg/L as P)			Nitrogen Forms (mg/L as N)								
					Ortho P (filtered)	Total P	Total Dissolved P (filtered)	NH_3/NH_4^+	TKN	Dissolved TKN (filtered)	NOx (NO_3^- and NO_2^-)	Calculated Total N	Organic N		Dissolved Organic N	
													Calculated	Reduction %	Calculated	Reduction %
2/25/2013	34	90	Feed	HSA-1	U (0.002)	0.03	0.005	0.011	0.69	0.42	U (0.005)	0.693	0.679	-	0.409	-
			Post UV	HSA-2	0.002 i	0.024	0.009	0.033	0.59	0.41	U (0.005)	0.593	0.557	18.0	0.377	7.8
			Post Column 1	HSA-3	U (0.002)	0.012	0.004	0.033	0.47	0.40	U (0.005)	0.473	0.437	21.5	0.367	2.7
			Post Column 2	HSA-4	U (0.002)	0.009	0.004	0.033	0.42	0.39	U (0.005)	0.423	0.387	11.4	0.357	2.7
3/4/2013	29	76	Feed	HSA-1	U (0.002)	0.024	0.006	0.005 i	0.58	0.42	U (0.005)	0.583	0.575	-	0.415	-
			Post UV	HSA-2	0.003 i	0.024	0.008	0.042	0.64	0.47	U (0.005)	0.643	0.598	-	0.428	-
			Post Column 1	HSA-3	U (0.002)	0.008	0.004	0.028	0.41	0.40	U (0.005)	0.413	0.382	-	0.372	-
			Post Column 2	HSA-4	U (0.002)	0.014	0.004	0.028	0.51	0.45	U (0.005)	0.513	0.482	-	0.422	-
3/11/2013	23	60	Feed	HSA-1	U (0.002)	0.022	0.005	0.01	0.58	0.46	U (0.005)	0.583	0.570	-	0.450	-
			Post UV	HSA-2	0.002 i	0.021	0.006	0.057	0.56	0.48	U (0.005)	0.563	0.503	11.8	0.423	6.0
			Post Column 1	HSA-3	U (0.002)	0.007	0.004	0.023	0.45	0.42	U (0.005)	0.453	0.427	15.1	0.397	6.1
			Post Column 2	HSA-4	U (0.002)	0.005	0.003 i	0.028	0.38	0.37	U (0.005)	0.383	0.352	17.6	0.342	13.9
3/25/2013	25	66	Feed	HSA-1	U (0.002)	0.021	0.005	0.012	0.56	0.46	U (0.005)	0.563	0.548	-	0.448	-
			Post UV	HSA-2	0.007 i	0.025	0.011	0.124	0.64	0.54	0.006 i	0.646	0.516	5.8	0.416	7.1
			Post Column 1	HSA-3	U (0.002)	0.007	0.003 i	0.01	0.42	0.35	0.008 i	0.428	0.410	20.5	0.340	18.3
			Post Column 2	HSA-4	0.002 i	0.008	0.005	0.024	0.33	0.31	0.083	0.413	0.306	25.4	0.286	15.9
4/8/2013	30	80	Feed	HSA-1	U (0.002)	0.018	0.006	U (0.005)	0.52	0.49	U (0.005)	0.523	0.518		0.488	
			Post UV	HSA-2	0.002 i	0.015	0.006	0.041	0.5	0.46	U (0.005)	0.503	0.459	11.3	0.419	14.1
			Post Column 1	HSA-3	U (0.002)	0.007	0.003 i	0.009 i	0.39	0.36	0.008 i	0.398	0.381	17.0	0.351	16.2
			Post Column 2	HSA-4	0.002 i	0.005	0.003 i	U (0.005)	0.25	0.24	0.013	0.263	0.248	35.0	0.238	32.2
4/22/2013	25	65	Feed	HSA-1	U (0.002)	0.024	0.006	0.009 i	0.61	0.47	U (0.005)	0.613	0.601	-	0.461	-
			Post UV	HSA-2	0.002 i	0.016	0.005	0.06	0.55	0.48	0.005 i	0.555	0.490	18.5	0.420	8.9
			Post Column 1	HSA-3	0.001	0.01	0.003	0.06	0.47	0.45	0.015	0.485	0.410	16.3	0.39	7.1
			Post Column 2	HSA-4	U (0.002)	0.006	0.003 i	0.044	0.88	0.38	0.029	0.909	0.836	-	0.336	-
Average ± Stdev	28±4	73±11	Feed	Average	0.001	0.023	0.006	0.008	0.59	0.45	0.003	0.593	0.582	-	0.445	
				Stdev	0	0.004	0.001	0.004	0.06	0.03	0	0.057	0.055	-	0.029	
			Post UV	Average	0.003	0.021	0.008	0.060	0.58	0.47	0.004	0.584	0.521	13.1	0.414	8.8
				Stdev	0.002	0.004	0.002	0.033	0.05	0.04	0.002	0.055	0.050	5.3	0.018	3.1
			Post Column 1	Average	0.001	0.009	0.004	0.027	0.43	0.40	0.006	0.441	0.408	18.1	0.370	10.1
				Stdev	0	0.002	0.001	0.019	0.03	0.04	0.005	0.034	0.023	2.8	0.022	6.8
			Post Column 2	Average	0.001	0.008	0.004	0.027	0.46	0.36	0.022	0.484	0.435	22.4	0.330	16.2
				Stdev	0.001	0.003	0.001	0.014	0.22	0.07	0.032	0.223	0.212	10.2	0.063	12.2

Notes:

U- the result is below the method detection limit

I – value reported is less than the practical quantitation limit, and greater than or equal to the method detection limit

All measurements below the detection limit were set to half of the detection limit when used to calculate the mean and standard deviation

All Nitrogen values reported in mg/L as N

All Phosphorus results reported as mg/L as P

NH_3 = Ammonia

NH_4^+= Ammonium

TKN = Total Kjeldahl Nitrogen

NO_3^-/NO_2^- = Nitrate plus Nitrite

gal/day = gallons per day

mL/min = mililiters per minute

Table 3
Laboratory Analytical Results - Lee County Environmental Lab (LCEL)
Nitrogen Reduction Phase I Pilot Study

Date	Flow Rate (gal/day)	Flow Rate (mL/min)	Sample Location	Sample ID	P (mg/L)			N (mg/L)											UV254 (cm^{-1})	Turbidity (NTU)	Color (CU)	pH
					Ortho P (filtered)	Total P	Total Dissolved P (filtered)	NH_3/NH_4^+	TKN	Dissolved TKN (filtered)	NO_3^-	NO_2^-	NO_3^- and NO_2^-	Calculated Total N	Organic N		Dissolved Organic N					
															Calculated	Reduction %	Calculated	Reduction %				
3/11/2013	23	60	Feed	HSALP01	U (0.004)	U (0.006)	0.016 i	U (0.014)	0.77	1.0	U (0.01)	0.005 i	U (0.01)	0.78	0.763	-	0.993	-	0.2234	4.36	17.6	-
			Post UV	HSALP02	U (0.004)	U (0.006)	0.021 i	0.042 i	0.76	0.74	U (0.01)	0.004 i	U (0.01)	0.77	0.718	5.9	0.698	29.7	0.1416	4.16	13.4	-
			Post Column 1	HSALP03	U (0.004)	U (0.006)	0.010 i	U (0.014)	0.62	0.61	U (0.01)	0.004 i	U (0.01)	0.63	0.613	14.6	0.603	13.6	0.1198	1.37	12.1	-
			Post Column 2	HSALP04	0.006 i	0.006 i	U (0.006)	U (0.014)	0.65	0.62	U (0.01)	0.005 i	U (0.01)	0.66	0.643	-4.9	0.613	-1.7	0.1164	1.36	11.8	-
3/13/2013	23	60	Feed	HSALP01	U (0.004)	0.033	0.011 i	0.018 i	1.2	0.84	U (0.01)	U (0.002)	U (0.01)	1.21	1.182	-	0.822	-	0.2225	6.34	18	-
			Post UV	HSALP02	0.007 i	0.023 i	0.018 i	0.048 i	0.91	1.1	U (0.01)	U (0.002)	U (0.01)	0.92	0.862	27.1	1.052	-28.0	0.1603	4.96	16.7	-
			Post Column 1	HSALP03	U (0.004)	0.018 i	U (0.006)	0.039 i	0.95	0.68	U (0.01)	U (0.002)	U (0.01)	0.96	0.911	-5.7	0.641	39.1	0.109	1.02	10.8	-
			Post Column 2	HSALP04	U (0.004)	0.015 i	0.016 i	0.052 i	0.77	0.86	U (0.01)	U (0.002)	U (0.01)	0.78	0.718	21.2	0.808	-26.1	0.1093	1.03	10.8	-
3/18/2013	23	60	Feed	HSALP01	U (0.004)	0.014 i	0.007 i	0.019 i	0.91	0.78	U (0.01)	U (0.002)	U (0.01)	0.92	0.891	-	0.761	-	0.211	4.31	16.7	8.26
			Post UV	HSALP02	U (0.004)	U (0.006)	U (0.006)	0.087	0.86	0.74	U (0.01)	U (0.002)	U (0.01)	0.87	0.773	13.2	0.653	14.2	0.117	1.67	11.3	7.94
			Post Column 1	HSALP03	U (0.004)	U (0.006)	U (0.006)	0.025 i	0.60	0.64	U (0.01)	U (0.002)	U (0.01)	0.61	0.575	25.6	0.615	5.8	0.0999	1.25	11.1	8.23
			Post Column 2	HSALP04	U (0.004)	U (0.006)	U (0.006)	0.032 i	0.36	0.60	U (0.01)	U (0.002)	U (0.01)	0.37	0.328	43.0	0.568	7.6	0.0956	2.51	10.2	8.12
3/25/2013	25	66	Feed	HSALP01	0.005 i	0.014 i	U (0.006)	0.024 i	0.91	0.88	U (0.01)	U (0.003)	U (0.01)	0.92	0.886	-	0.856	-	0.209	5.96	16.2	8.16
			Post UV	HSALP02	0.007 i	0.010 i	U (0.006)	0.029 i	0.86	0.87	U (0.01)	U (0.003)	U (0.01)	0.87	0.831	6.2	0.841	1.8	0.146	4.74	14.8	8.07
			Post Column 1	HSALP03	U (0.004)	0.012 i	U (0.006)	0.040 i	0.66	0.66	U (0.01)	U (0.003)	U (0.01)	0.67	0.620	25.4	0.620	26.3	0.110	1.23	13.6	8.47
			Post Column 2	HSALP04	U (0.004)	0.006 i	U (0.006)	0.045 i	0.39	0.57	U (0.01)	U (0.003)	U (0.01)	0.40	0.345	44.4	0.525	15.3	0.0978	4.21	10.3	7.89
3/27/2013	23	60	Feed	HSALP01	U (0.004)	0.021 i	0.009 i	0.025 i	0.93	0.93	U (0.01)	U (0.003)	U (0.01)	0.94	0.905	-	0.905	-	0.213	6.08	17.3	8.26
			Post UV	HSALP02	U (0.004)	0.025	0.016 i	0.051 i	0.93	0.88	U (0.01)	U (0.003)	U (0.01)	0.94	0.879	2.9	0.829	8.4	0.141	4.61	14.1	8.17
			Post Column 1	HSALP03	U (0.004)	0.008 i	U (0.006)	0.028 i	0.71	0.76	U (0.01)	U (0.003)	U (0.01)	0.72	0.682	22.4	0.732	11.7	0.128	8.80	13.5	8.33
			Post Column 2	HSALP04	U (0.004)	0.011 i	0.011 i	0.030 i	0.52	0.73	U (0.01)	U (0.003)	U (0.01)	0.53	0.490	28.2	0.700	4.4	0.122	2.29	12.7	8.15
4/1/2013	25	66	Feed	HSALP01	U (0.004)	0.022 i	0.009 i	0.023 i	0.97	0.91	U (0.01)	U (0.002)	U (0.01)	0.98	0.947	-	0.887	-	0.210	4.74	15.9	7.7
			Post UV	HSALP02	U (0.004)	0.016 i	0.009 i	0.040 i	1.0	0.80	U (0.01)	U (0.002)	U (0.01)	1.01	0.960	-1.4	0.760	14.3	0.167	4.51	17.0	7.8
			Post Column 1	HSALP03	U (0.004)	0.012 i	0.006 i	0.034 i	0.88	0.70	U (0.01)	U (0.002)	U (0.01)	0.89	0.846	11.9	0.666	12.4	0.130	1.20	16.2	8.0
			Post Column 2	HSALP04	U (0.004)	U (0.006)	0.008 i	U (0.014)	0.53	0.52	U (0.01)	U (0.002)	U (0.01)	0.54	0.523	38.2	0.513	23.0	0.114	2.39	12.4	7.7
4/3/2013	25	66	Feed	HSALP01	U (0.004)	0.015 i	U (0.006)	U (0.014)	0.82	0.66	U (0.01)	U (0.002)	U (0.01)	0.83	0.813	-	0.653	-	0.215	6.28	17.0	8.18
			Post UV	HSALP02	0.013 i	0.015 i	U (0.006)	0.046 i	0.70	0.80	U (0.01)	U (0.002)	U (0.01)	0.71	0.654	19.6	0.754	-15.5	0.128	4.08	13.6	8.04
			Post Column 1	HSALP03	0.011 i	0.015 i	U (0.006)	U (0.014)	0.75	0.65	U (0.01)	U (0.002)	U (0.01)	0.76	0.743	-13.6	0.643	14.7	0.113	1.60	14.7	8.33
			Post Column 2	HSALP04	0.009 i	0.012 i	U (0.006)	U (0.014), J4	0.70	0.65	U (0.01)	U (0.002)	U (0.01)	0.71	0.693	6.7	0.643	0.0	0.111	1.76	12.3	8.06
4/8/2013	30	80	Feed	HSALP01	U (0.004)	0.016 i	0.013 i	0.032 i	0.99	0.88	U (0.01)	U (0.002)	U (0.01)	1.00	0.958	-	0.848	-	0.211	4.06	15.6	8.25
			Post UV	HSALP02	U (0.004)	0.021 i	0.011 i	0.063	0.91	0.76	U (0.01)	U (0.002)	U (0.01)	0.92	0.847	11.6	0.697	17.8	0.133	2.79	11.3	8.11
			Post Column 1	HSALP03	U (0.004)	0.015 i	0.010 i	0.032 i	0.66	0.59	U (0.01)	U (0.002)	U (0.01)	0.67	0.628	25.9	0.558	19.9	0.114	1.15	10.2	8.27
			Post Column 2	HSALP04	U (0.004)	0.013 i	0.011 i	0.017 i	0.50	0.38	U (0.01)	U (0.002)	U (0.01)	0.51	0.483	23.1	0.363	34.9	0.0952	2.19	11.7	8.00
4/10/2013	23	60	Feed	HSALP01	U (0.004)	0.022 i	0.014 i	U (0.014)	0.61	0.53	U (0.01)	U (0.002)	U (0.01)	0.62	0.603	-	0.523	-	0.212	5.22	17.7	8.22
			Post UV	HSALP02	U (0.004)	0.022 i	0.007 i	0.050 i	0.59	0.84	U (0.01)	U (0.002)	U (0.01)	0.60	0.540	10.4	0.790	-51.1	0.120	2.82	14.9	8.07
			Post Column 1	HSALP03	U (0.004)	0.018 i	0.010 i	U (0.014)	0.56	0.45	U (0.01)	U (0.002)	U (0.01)	0.57	0.553	-2.4	0.443	43.9	0.103	0.79	12.0	8.31
			Post Column 2	HSALP04	U (0.004)	0.015 i	U (0.006)	U (0.014)	0.54	0.49	U (0.01)	U (0.003)	U (0.01)	0.55	0.533	3.6	0.483	-9.0	0.0934	0.94	11.2	8.05
4/15/2013	23	60	Feed	HSALP01	U (0.004)	0.019 i	U (0.006)	U (0.014)	1.0	0.57	U (0.01)	U (0.002)	U (0.01)	1.01	0.993	-	0.563	-	0.225	3.69	16.0	8.23
			Post UV	HSALP02	U (0.004)	0.010 i	0.009 i	0.043 i	1.1	0.54	U (0.01)	U (0.002)	U (0.01)	1.11	1.057	-6.4	0.497	11.7	0.1373	2.38	12.0	8.12
			Post Column 1	HSALP03	U (0.004)	U (0.006)	U (0.006)	U (0.014), J3	0.54	0.52	U (0.01)	U (0.002)	U (0.01)	0.55	0.533	49.6	0.513	-3.2	0.1172	0.76 i	12.2	8.32
			Post Column 2	HSALP04	U (0.004)	U (0.006)	U (0.006)	U (0.014)	0.52	0.50	U (0.01)	U (0.002)	U (0.01)	0.53	0.513	3.8	0.493	3.9	0.1104	0.84	10.3	8.09
4/17/2013	23	60	Feed	HSALP01	0.009 i	0.02 i	0.007 i	U (0.014)	0.75	0.63	U (0.01)	U (0.002)	U (0.01)	0.76	0.743	-	0.623	-	0.2268	4.57	18.4	8.19
			Post UV	HSALP02	U (0.004)	0.015 i	U (0.006)	0.043 i	0.88	0.60	U (0.01)	U (0.002)	U (0.01)	0.89	0.837	-12.7	0.557	10.6	0.1423	2.43	14.7	8.07
			Post Column 1	HSALP03	0.007 i	0.011 i	U (0.006)	U (0.014)	0.58	0.52	U (0.01)	U (0.002)	U (0.01)	0.59	0.573	31.5	0.513	7.9	0.1203	1.06	13.6	8.30
			Post Column 2	HSALP04	0.007 i	0.010 i	0.008 i	0.022 i	0.60	0.59	U (0.01)	U (0.002)	U (0.01)	0.61	0.578	-0.9	0.568	-10.7	0.1144	0.805	12.8	8.11
4/22/2013	25	65	Feed	HSALP01	U (0.004)	0.015 i	U (0.006)	U (0.014)	0.69	0.66	U (0.01)	0.003 i	U (0.01)	0.70	0.683	-	0.653	-	0.2260	4.36	17.5	8.18
			Post UV	HSALP02	U (0.004)	0.011 i	U (0.006)	0.041 i	0.85	0.86	U (0.01)	0.004 i	0.011 i	0.86	0.809	-18.4	0.819	-25.4	0.1400	2.61	13.5	8.10
			Post Column 1	HSALP03	U (0.004)	0.006 i	U (0.006)	0.040 i	0.89	0.69	0.017 i	0.005 i	0.022 i	0.91	0.850	-5.1	0.650	20.6	0.1277	1.06	13.8	8.04
			Post Column 2	HSALP04	U (0.004)	0.007 i	U (0.006)	0.027 i	0.87	0.80	U (0.01)	0.006 i	U (0.01)	0.88	0.843	0.8	0.773	-18.9	0.1232	1.26	12.3	7.95
Average ± Stdev	24±2	64±6	Feed	Average	0.003	0.018	0.008	0.015	0.88	0.77	0.005	0.002	0.005	0.89	0.864	-	0.757	-	0.2171	5.00	17.0	8.16
				Stdev	0.002	0.007	0.005	0.009	0.16	0.16	0	0.001	0	0.16	0.155	-	0.150	-	0.0070	0.94	0.9	0.17
			Post UV	Average	0.004	0.015	0.009	0.049	0.86	0.79	0.005	0.002	0.006	0.87	0.814	-	0.746	-	0.1395	3.48	13.9	8.05
				Stdev	0.003	0.007	0.006	0.015	0.13	0.14	0	0.001	0	0.13	0.135	-	0.144	-	0.0145	1.14	1.8	0.11
			Post Column 1	Average	0.003	0.010	0.005	0.023	0.70	0.62	0.006	0.002	0.006	0.71	0.677	-	0.600	-	0.1160	1.77	12.8	8.26
				Stdev	0.003	0.006	0.003	0.015	0.14	0.09	0	0.001	0	0.14	0.130	-	0.080	-	0.0097	2.22	1.7	0.14
			Post Column 2	Average	0.003	0.009	0.006	0.022	0.58	0.61	0.005	0.002	0.005	0.59	0.558	-	0.588	-	0.1086	1.80	11.6	8.01
				Stdev	0.002	0.005	0.004	0.016	0.15	0.14	0	0.002	0	0.15	0.149	-	0.128	-	0.0105	0.99	1.0	0.14

Table 3
Laboratory Analytical Results - Lee County Environmental Lab (LCEL)
Nitrogen Reduction Phase I Pilot Study

Date	Flow Rate (gal/day)	Flow Rate (mL/min)	Sample Location	Sample ID	P (mg/L): Ortho P (filtered)	P (mg/L): Total P	P (mg/L): Total Dissolved P (filtered)	N (mg/L): NH_3/NH_4^+	N (mg/L): TKN	N (mg/L): Dissolved TKN (filtered)	N (mg/L): NO_3^-	N (mg/L): NO_2^-	N (mg/L): NO_3^- and NO_2^-	N (mg/L): Calculated Total N	Organic N: Calculated	Organic N: Reduction %	Dissolved Organic N: Calculated	Dissolved Organic N: Reduction %	UV254 (cm^{-1})	Turbidity (NTU)	Color (CU)	pH
After Increasing the Flow Rate																						
4/24/2013	38	100	Feed	HSALP01	U (0.004)	0.024	0.010 i	U (0.014)	1.2	1.1	U (0.01)	U (0.002)	U (0.01)	1.205	1.193	-	1.093	-	0.2267	4.21	18.7	8.15
			Post UV	HSALP02	U (0.004)	0.009 i	U (0.006)	0.018 i	1.1	1.1	U (0.01)	U (0.002)	U (0.01)	1.105	1.082	9.3	1.082	1.0	0.1624	2.73	17.2	8.10
			Post Column 1	HSALP03	U (0.004)	0.016 i	0.012 i	U (0.014)	1.0	0.94	U (0.01)	U (0.002)	U (0.01)	1.005	0.993	8.2	0.933	13.8	0.1492	1.35	16.5	7.94
			Post Column 2	HSALP04	U (0.004)	0.017 i	0.008 i	U (0.014)	1.0	0.97	U (0.01)	U (0.002)	U (0.01)	1.005	0.993	0	0.963	-3.2	0.1437	1.05	15.7	7.93
4/29/2013	38	100	Feed	HSALP01	0.025	0.035	0.010 i	U (0.014)	1.1	1.0	U (0.01)	U (0.002)	U (0.01)	1.105	1.093	-	0.993	-	0.2271	4.45	18.9	8.16
			Post UV	HSALP02	0.028	0.028	0.020 i	0.181*	1.5	1.3	U (0.01)	0.01*	U (0.01)	1.505	1.319	-20.7	1.119	-12.7	0.1785	3.40	18.7	8.13
			Post Column 1	HSALP03	0.024	0.024	0.009 i	0.031 i	1.0	0.92	U (0.01)	U (0.003)	U (0.01)	1.005	0.969	26.5	0.889	20.6	0.1387	0.567 i	16.6	7.94
			Post Column 2	HSALP04	U (0.004), J4	0.022 i	0.012 i	0.047 i	1.1	0.92	U (0.01)	U (0.002)	U (0.01)	1.105	1.053	-8.7	0.873	1.8	0.1478	1.03	18.8	7.95
5/1/2013	38	100	Feed	HSALP01	U (0.004)	0.028	0.010 i	U (0.014)	1.2	1.0	U (0.01)	U (0.003)	U (0.01)	1.205	1.193	-	0.993	-	0.2303	6.21	18.5	8.10
			Post UV	HSALP02	U (0.004)	0.015 i	0.011 i	0.026 i	1.2	1.1	U (0.01)	U (0.003)	U (0.01)	1.205	1.174	1.6	1.074	-8.2	0.1651	3.57	17.2	8.06
			Post Column 1	HSALP03	U (0.004)	0.014 i	U (0.006)	0.037 i	1.1	1.0	U (0.01)	U (0.003)	U (0.01)	1.105	1.063	9.5	0.963	10.3	0.1541	1.85	18.5	7.90
			Post Column 2	HSALP04	U (0.004)	0.020 i	0.015 i	0.016 i	1.2	1	U (0.01)	U (0.003)	U (0.01)	1.205	1.184	-11.4	0.984	-2.2	0.1458	1.39	15.8	7.93
5/6/2013	38	100	Feed	HSALP01	0.016	0.029	0.018 i	U (0.014)	1.3	1.1	U (0.01)	U (0.002)	U (0.01)	1.305	1.293	-	1.093	-	0.2211	2.75	17.1	8.17
			Post UV	HSALP02	0.016	0.027	0.020 i	0.040 i	1.2	1.0 J4	U (0.01)	U (0.002)	U (0.01)	1.205	1.16	10.3	0.96	12.2	0.1602	2.53	16.4	8.16
			Post Column 1	HSALP03	0.009 i	0.023 i	0.017 i	0.039 i	0.83	0.79	U (0.01)	U (0.004)	U (0.01)	0.835	0.791	31.8	0.751	21.8	0.0925	0.426 i	10.5	8.06
			Post Column 2	HSALP04	U (0.004)	0.016 i	0.016 i	0.078	0.79	0.89	U (0.01)	U (0.002)	U (0.01)	0.795	0.712	10.0	0.812	-8.1	0.1145	0.583 i	14.8	7.94
5/8/2013	38	100	Feed	HSALP01	0.012 i	0.027	0.022 i	0.015 i	1.1	1.1	U (0.01)	U (0.002)	U (0.01)	1.105	1.085	-	1.085	-	0.2236	3.52	18.3	8.2
			Post UV	HSALP02	U (0.004)	0.027	0.011 i	0.060	1.1	0.82	U (0.01)	U (0.002)	U (0.01)	1.105	1.04	4.1	0.76	30.0	0.162	2.53	16.8	8.08
			Post Column 1	HSALP03	U (0.004)	0.018	0.008 i	0.040 i	1.1	1.1	U (0.01)	U (0.002)	U (0.01)	1.105	1.06	-1.9	1.06	-39.5	0.1516	1.91	15.4	8.12
			Post Column 2	HSALP04	U (0.004)	0.014	0.014 i	0.039 i	1.1	0.98	U (0.01)	U (0.002)	U (0.01)	1.105	1.061	-0.1	0.941	11.2	0.1441	1.42	14.7	7.93
5/13/2013	38	100	Feed	HSALP01	0.005 i	0.019 i	U (0.006)	0.019 i	1.3	1.1	U (0.01)	U (0.002)	U (0.01)	1.305	1.281	-	1.081	-	0.2253	4.08	17.8	8.09
			Post UV	HSALP02	0.005 i	0.013 i	U (0.006)	0.041 i	1.2	1.1	U (0.01)	U (0.002)	U (0.01)	1.205	1.159	9.5	1.059	2.0	0.1582	2.85	16.3	8.08
			Post Column 1	HSALP03	U (0.004)	U (0.006)	U (0.006)	0.025 i	0.80	0.76	U (0.01)	U (0.002)	U (0.01)	0.805	0.775	33.1	0.735	30.6	0.1434	1.80	16.0	8.04
			Post Column 2	HSALP04	U (0.004)	U (0.006)	U (0.006)	0.017 i	0.94	0.79	U (0.01)	U (0.002)	U (0.01)	0.945	0.923	-19.1	0.773	-5.2	0.1358	1.31	14.7	7.86
5/15/2013	38	100	Feed	HSALP01	U (0.004)	0.007 i	U (0.006)	U (0.014)	1.3	1.2	U (0.01)	U (0.003)	U (0.01)	1.305	1.293	-	1.193	-	0.2292	4.43	18.2	8.14
			Post UV	HSALP02	0.005 i	0.006 i	U (0.006)	U (0.014)	1.4	0.96	U (0.01)	U (0.003)	U (0.01)	1.405	1.393	-7.7	0.953	20.1	0.2269	3.99	18.4	8.18
			Post Column 1	HSALP03	0.009 i	0.009 i	U (0.006)	U (0.014)	1.1	1.0	U (0.01)	U (0.003)	U (0.01)	1.105	1.093	21.5	0.993	-4.2	0.1727	2.41	17.5	8.01
			Post Column 2	HSALP04	0.008 i	0.008 i	U (0.006)	U (0.014)	1.1	0.99	U (0.01)	U (0.002)	U (0.01)	1.105	1.093	0	0.983	1.0	0.1541	1.95	16.1	7.92
Average ± Stdev	38±0	100±0	Feed	Average	0.009	0.024	0.011	0.010	1.21	1.09	0.005	0.001	0.005	1.219	1.204	-	1.076	-	0.2262	4.24	18.2	8.14
				Stdev	0.009	0.009	0.007	0.005	0.09	0.07	0	0	0	0.090	0.090	-	0.068	-	0.0032	1.06	0.6	0.04
			Post UV	Average	0.008	0.016	0.009	0.047	1.09	0.92	0.004	0.002	0.004	1.092	1.041	-	0.876	-	0.1517	2.70	15.1	7.10
				Stdev	0.010	0.009	0.008	0.059	0.15	0.15	0	0.003	0	0.151	0.125	-	0.123	-	0.0245	0.57	0.9	0.04
			Post Column 1	Average	0.007	0.015	0.008	0.027	0.99	0.93	0.005	0.001	0.005	0.995	0.963	-	0.903	-	0.1432	1.47	15.9	8.00
				Stdev	0.008	0.007	0.005	0.014	0.13	0.12	0	0	0	0.128	0.130	-	0.122	-	0.0248	0.74	2.6	0.08
			Post Column 2	Average	0.003	0.014	0.010	0.030	1.03	0.93	0.005	0.001	0.005	1.038	1.003	-	0.904	-	0.1408	1.25	15.8	7.92
				Stdev	0.002	0.007	0.006	0.026	0.14	0.08	0	0	0	0.135	0.152	-	0.086	-	0.0128	0.42	1.4	0.03
After Turning Off the UV Light																						
5/20/2013	38	100	Feed	HSALP01	0.002	0.031	0.003	0.007	0.74	0.52	0.005	0.001	0.005	0.745	0.733	-	0.513	-	0.2116	4.79	18.5	6.4
			Post UV	HSALP02	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
			Post Column 1	HSALP03	0.007 i	0.027	0.003	0.027 i	0.72	0.6	0.005	0.001	0.005	0.725	0.693	5.5	0.573	-11.7	0.2126	2.35	18.4	6.8
			Post Column 2	HSALP04	0.006 i	0.010 i	0.003	0.007	0.57	0.51	0.005	0.001	0.005	0.575	0.563	18.8	0.503	12.2	0.2103	2.47	17.8	7.0
5/22/2013	38	100	Feed	HSALP01	0.002	0.003	0.003	0.043 i	1.2	1.2	0.005	0.0015	0.005	1.205	1.157	-	1.157	-	0.2303	3.82	14.7	7.5
			Post UV	HSALP02	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
			Post Column 1	HSALP03	0.002	0.032	0.007 i	0.032 i	1.3	1.1	0.005	0.0015	0.005	1.305	1.268	-9.6	1.068	7.7	0.2223	2.45	14.1	7.9
			Post Column 2	HSALP04	0.004 i	0.011	0.003	0.037 i	0.95	1.0	0.005	0.001	0.005	0.955	0.913	28	0.963	9.8	0.2173	2.43	13.4	7.8

Note:
U – the result is below the method detection limit;
I – value reported is less than or equal to, the practical quantitation limit, and greater than or equal to the method detection limit
U, J3 – the compound was analyzed for but not detected. Value failed to meet QC criteria for precision or accuracy.
U, J4 – the compound was analyzed for but not detected. The sample matrix interfered with the ability to meet the accuracy requirement for a matrix spike.
All measurements below the detection limit were set to half of the detection limit when used to calculate the mean and standard deviation
All Nitrogen values reported in mg/L as N
All Phosphorus results reported as mg/L as P

* unexpected data
NH_3 = Ammonia
NH_4^+ = Ammonium
TKN = Total Kjeldahl Nitrogen
NO_3^-/NO_2^- = Nitrate plus Nitrite
gal/day = gallons per day
mL/min = mililiters per minute

Table 4
Laboratory Analytical Results Comparison

Analytical Parameter	Sample Location	3/11/2013		3/25/2013		4/8/2013		4/22/2013	
		LCEL	SFWMDL	LCEL	SFWMDL	LCEL	SFWMDL	LCEL	SFWMDL
Ortho P (filtered)	Feed	U (0.004)	U (0.002)	0.005 i	U (0.002)	U (0.004)	U (0.002)	U (0.004)	U (0.002)
	Post UV	U (0.004)	U (0.002)	0.007 i	0.007 i	U (0.004)	0.002 i	U (0.004)	0.002 i
	Post Column 1	U (0.004)	U (0.002)	U (0.004)	U (0.002)	U (0.004)	U (0.002)	U (0.004)	0.001
	Post Column 2	0.006 i	U (0.002)	U (0.004)	0.002 i	U (0.004)	0.002 i	U (0.004)	U (0.002)
Total P	Feed	U (0.006)	0.022	0.014 i	0.021	0.016 i	0.018	0.015 i	0.024
	Post UV	U (0.006)	0.021	0.010 i	0.025	0.021 i	0.015	0.011 i	0.016
	Post Column 1	U (0.006)	0.007	0.012 i	0.007	0.015 i	0.007	0.006 i	0.01
	Post Column 2	0.006 i	0.005	0.006 i	0.008	0.013 i	0.005	0.007 i	0.006
Total Dissolved P (filtered)	Feed	0.016 i	0.005	U (0.006)	0.005	0.013 i	0.006	U (0.006)	0.006
	Post UV	0.021 i	0.006	U (0.006)	0.011	0.011 i	0.006	U (0.006)	0.005
	Post Column 1	0.010 i	0.004	U (0.006)	0.003 i	0.010 i	0.003 i	U (0.006)	0.003
	Post Column 2	U (0.006)	0.003	U (0.006)	0.005	0.011 i	0.003 i	U (0.006)	0.003 i
NH_3/NH_4^+	Feed	U (0.014)	0.01	0.024 i	0.012	0.032 i	U (0.005)	U (0.014)	0.009 i
	Post UV	0.042 i	0.057	0.029 i	0.124	0.063	0.041	0.041 i	0.06
	Post Column 1	U (0.014)	0.023	0.040 i	0.01	0.032 i	0.009 i	0.040 i	0.06
	Post Column 2	U (0.014)	0.028	0.045 i	0.024	0.017 i	U (0.005)	0.027 i	0.044
TKN	Feed	0.77	0.58	0.91	0.56	0.99	0.52	0.69	0.61
	Post UV	0.76	0.56	0.86	0.64	0.91	0.5	0.85	0.55
	Post Column 1	0.62	0.45	0.66	0.42	0.66	0.39	0.89	0.47
	Post Column 2	0.65	0.38	0.39	0.33	0.50	0.25	0.87	0.88
Dissolved TKN (filtered)	Feed	1.0	0.46	0.88	0.46	0.88	0.49	0.66	0.47
	Post UV	0.74	0.48	0.87	0.54	0.76	0.46	0.86	0.48
	Post Column 1	0.61	0.42	0.66	0.35	0.59	0.36	0.69	0.45
	Post Column 2	0.62	0.37	0.57	0.31	0.38	0.24	0.80	0.38
NO_3^- and NO_2^-	Feed	U (0.01)	U (0.005)	U (0.01)	U (0.005)	U (0.01)	U (0.005)	U (0.01)	U (0.005)
	Post UV	U (0.01)	U (0.005)	U (0.01)	0.006 i	U (0.01)	U (0.005)	0.011 i	0.005 i
	Post Column 1	U (0.01)	U (0.005)	U (0.01)	0.008 i	U (0.01)	0.008 i	0.022 i	0.015
	Post Column 2	U (0.01)	U (0.005)	U (0.01)	0.083	U (0.01)	0.013	U (0.01)	0.029

Table 5
Laboratory Analytical Method Comparison

Parameter	SFWMDL			LCEL		
	Method	MDL	Unit	Method	MDL	Unit
Ortho P	SM4500-P F.	0.002	mg/L as P	EPA 365.1	0.004	mg/L as P
Total P	SM4500-P F.	0.002	mg/L as P	EPA 365.1	0.006	mg/L as P
Total Dissolved P	SM4500P F.	0.002	mg/L as P	EPA 365.1	0.006	mg/L as P
Ammonia Nitrogen (NH_3/NH_4^+)	SM4500-NH_3 H.	0.005	mg/L as N	EPA 350.1	0.014	mg/L as N
TKN	EPA 351.2	0.05	mg/L as N	EPA 351.2	0.05	mg/L as N
Dissolved TKN	EPA 351.2	0.05	mg/L as N	EPA 351.2	0.05	mg/L as N
NOx (NO_3^- and NO_2^-)	SM4500-NO_3 F.	0.005	mg/L as N	EPA 353.2	0.01	mg/L as N

Table 6
Concentrations of Nitrogen Species in Selected Lee County Surface Water

Sampling Site	Sampling Date	Ammonia Nitrogen (mg/L as N)	TKN (mg/L as N)	NO_2/NO_3 (mg/L as N)	Total N (mg/L as N)
Lakes Park	November 2010	0.15	0.79	0.15	0.94
	March/April 2013 Pilot Data[1]	0.008	0.59	0.003	0.59
Franklin Locks S79	May-September 2012[2]	0.32	1.17	0.45	1.62

[1]Average data from Pilot Testing

[2]Average data (source: SFWMD – DB Hydro data base)

Figures

Figure 1. Pilot study location aerial (Lakes Park, Lee County).

Figure 2. Schematic diagram of pilot unit components and sampling locations.

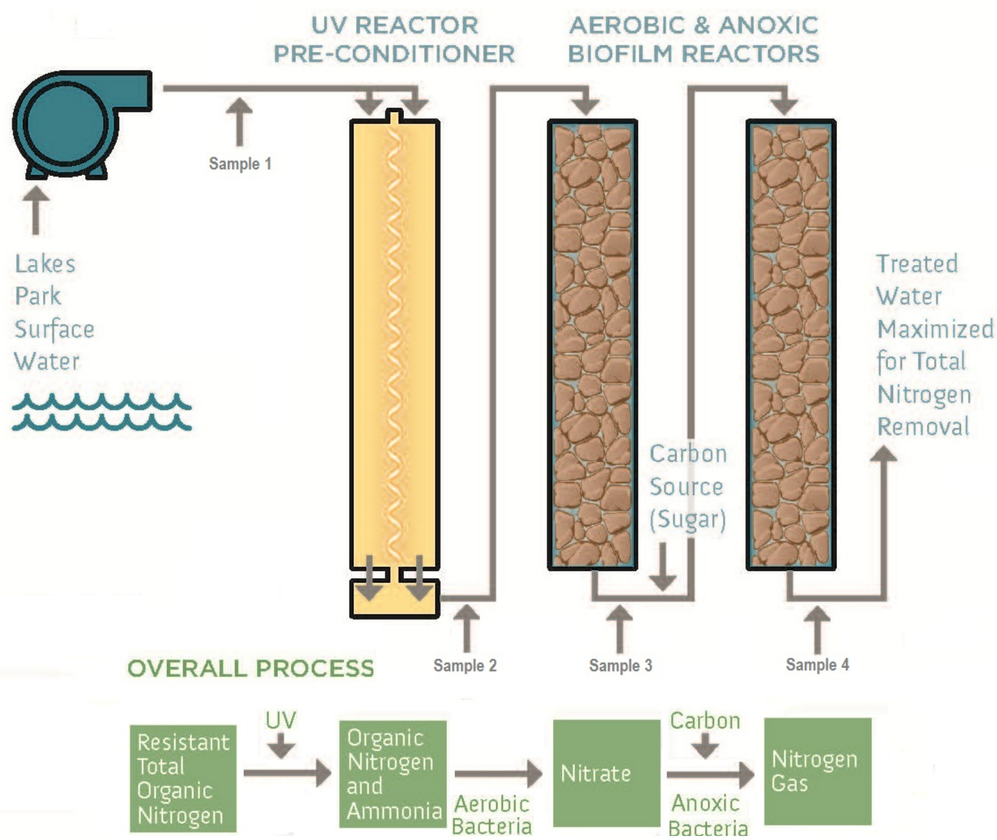


Figure 3. Picture of pilot unit components with sample locations.

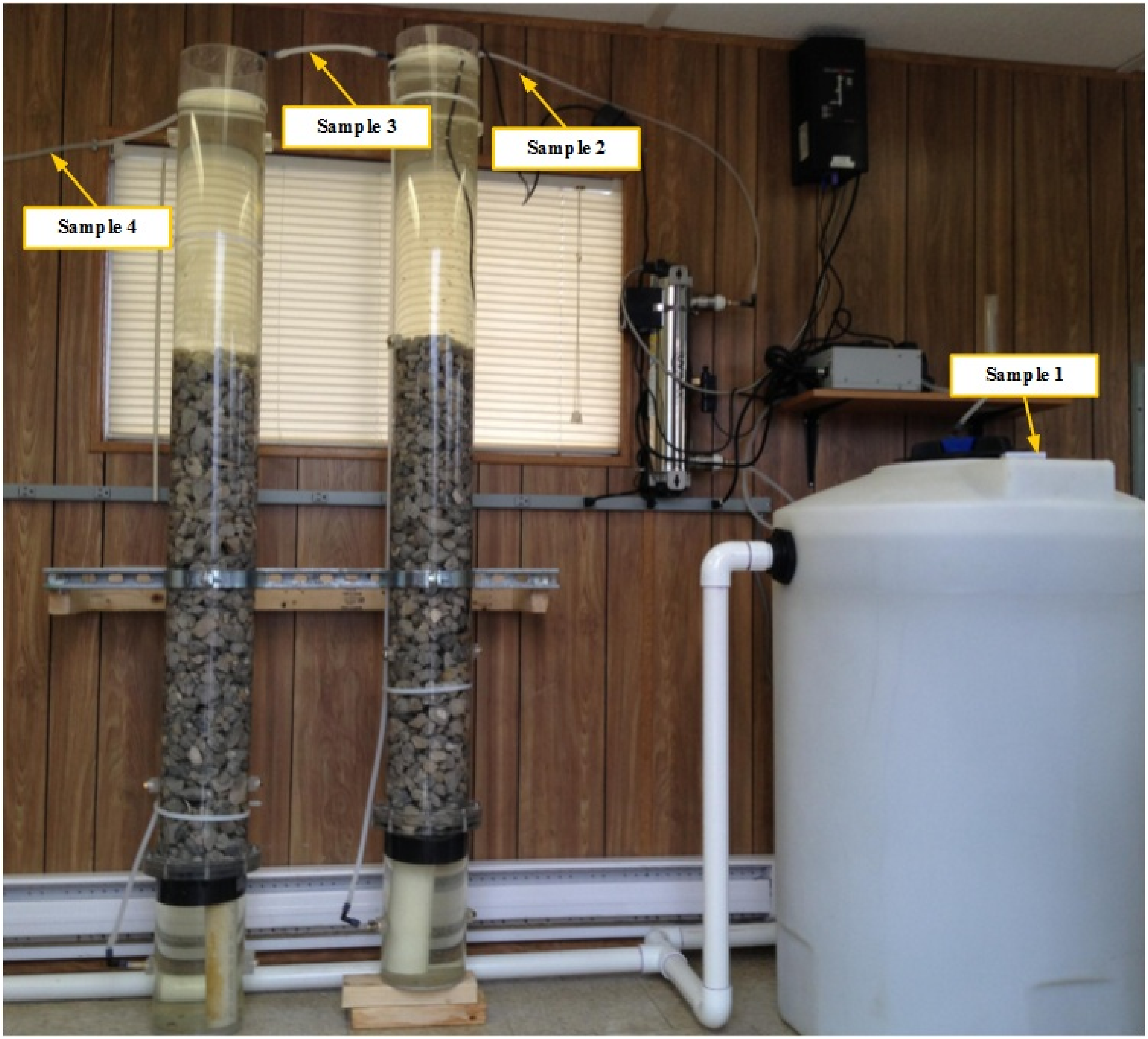


Figure 4. Photo of algae growth on columns.

Figure 5. Trend of total phosphorus in the feed water, after UV reactor, after column 1, and after column 2 for the testing period from February 25 to April 22, 2013 (data of South Florida Water Management District Lab (SFWMDL) were collected from 02/25/2013 to 04/22/2013 with the flow rate of 73±11 mL/min in the UV reactor; data of Lee County Environmental Lab (LCEL) were collected from 03/11/2013 to 04/22/2013 with the flow rate of 65±6 mL/min in the UV reactor). Error bars indicate standard deviation.

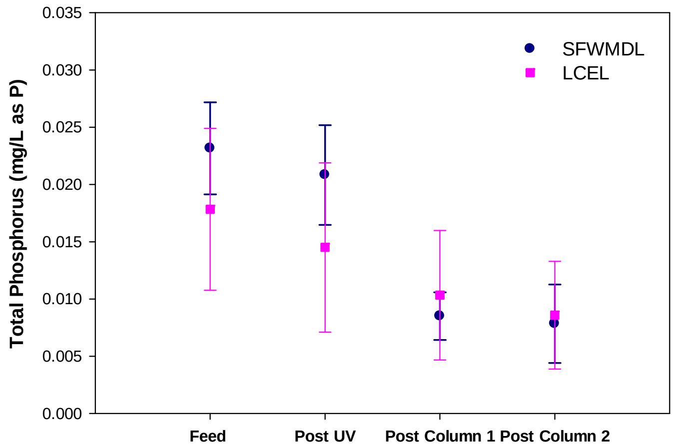


Figure 6. Trends of ammonia nitrogen (a), total nitrogen (b), organic nitrogen (c), and dissolved organic nitrogen (d) in the feed water, after UV reactor, after column 1, and after column 2 for the testing period from February 25 to April 22, 2013 (data of South Florida Water Management District Lab (SFWMDL) were collected from 02/25/2013 to 04/22/2013 with the flow rate of 73±11 mL/min in the UV reactor (Table 2); data of Lee County Environmental Lab (LCEL) were collected from 03/11/2013 to 04/22/2013 with the flow rate of 65±6 mL/min in the UV reactor (Table 3)). Error bars indicate standard deviation.

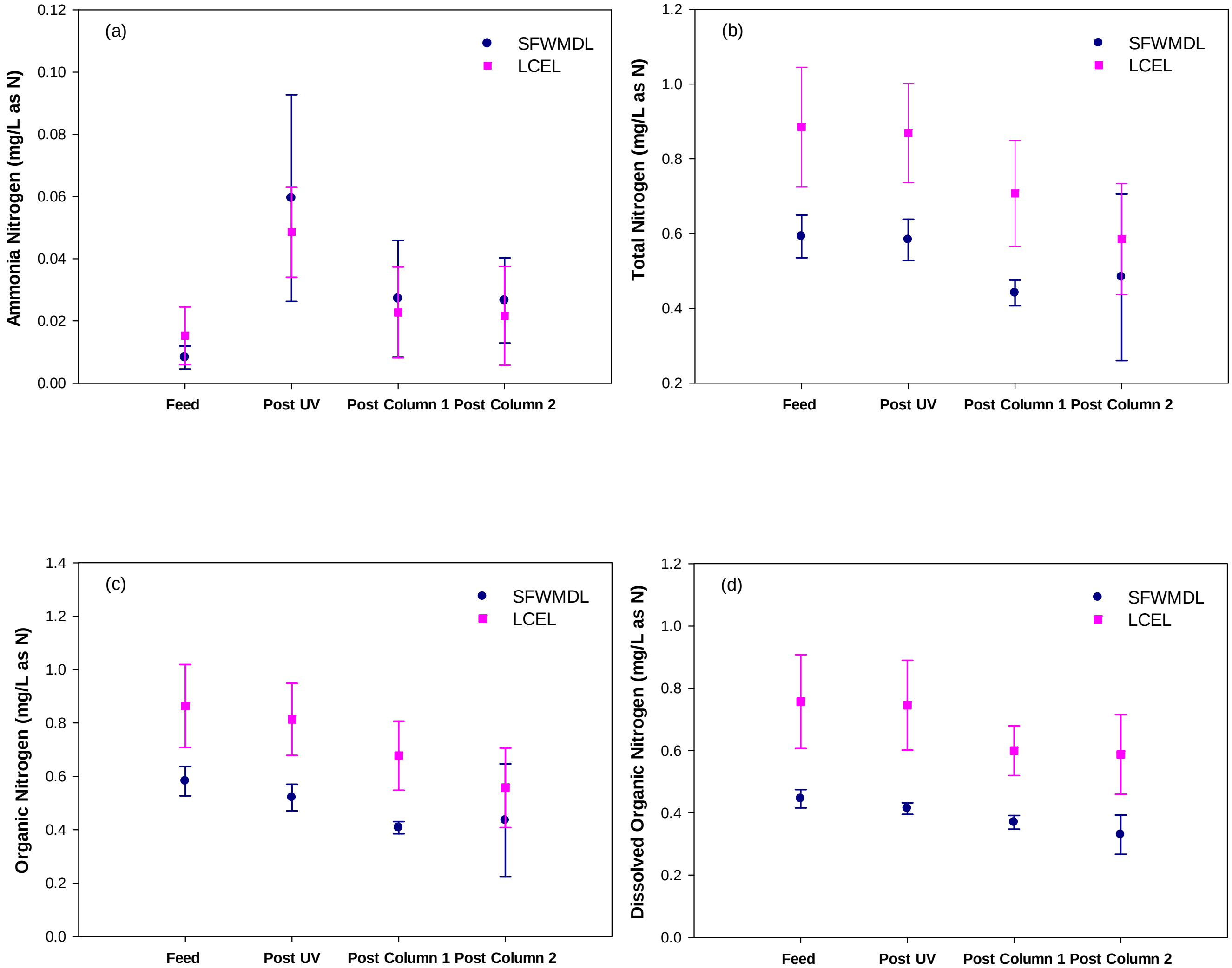


Figure 7. Trends of ammonia nitrogen (a), total nitrogen (b), organic nitrogen (c), and dissolved organic nitrogen (d) in the feed water, after UV reactor, after column 1, and after column 2 at the flow rates of 65 mL/min and 100 mL/min in the UV reactor (data were from Lee County Environmental Lab (LCEL) (Table 3)). Error bars indicate standard deviation.

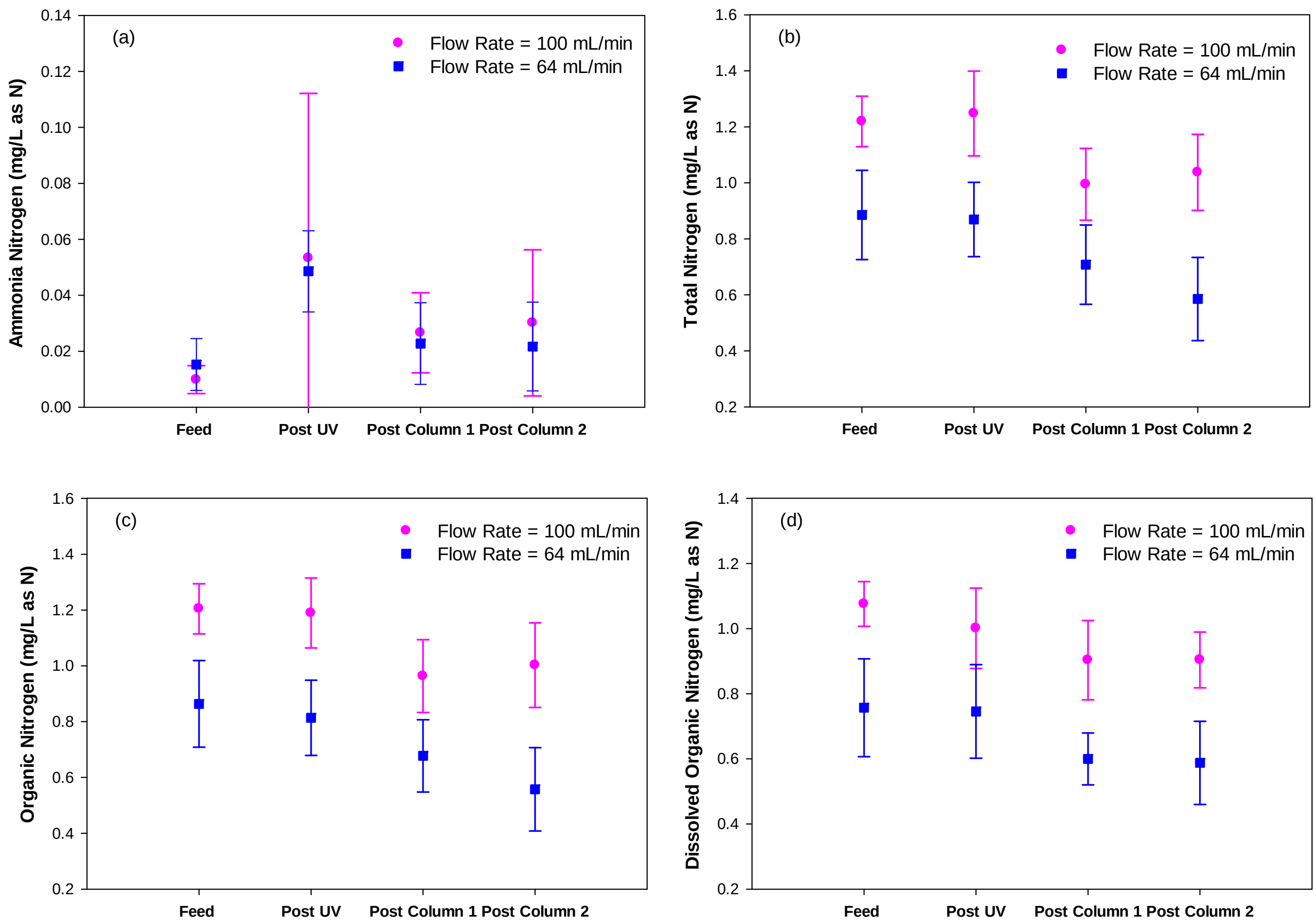
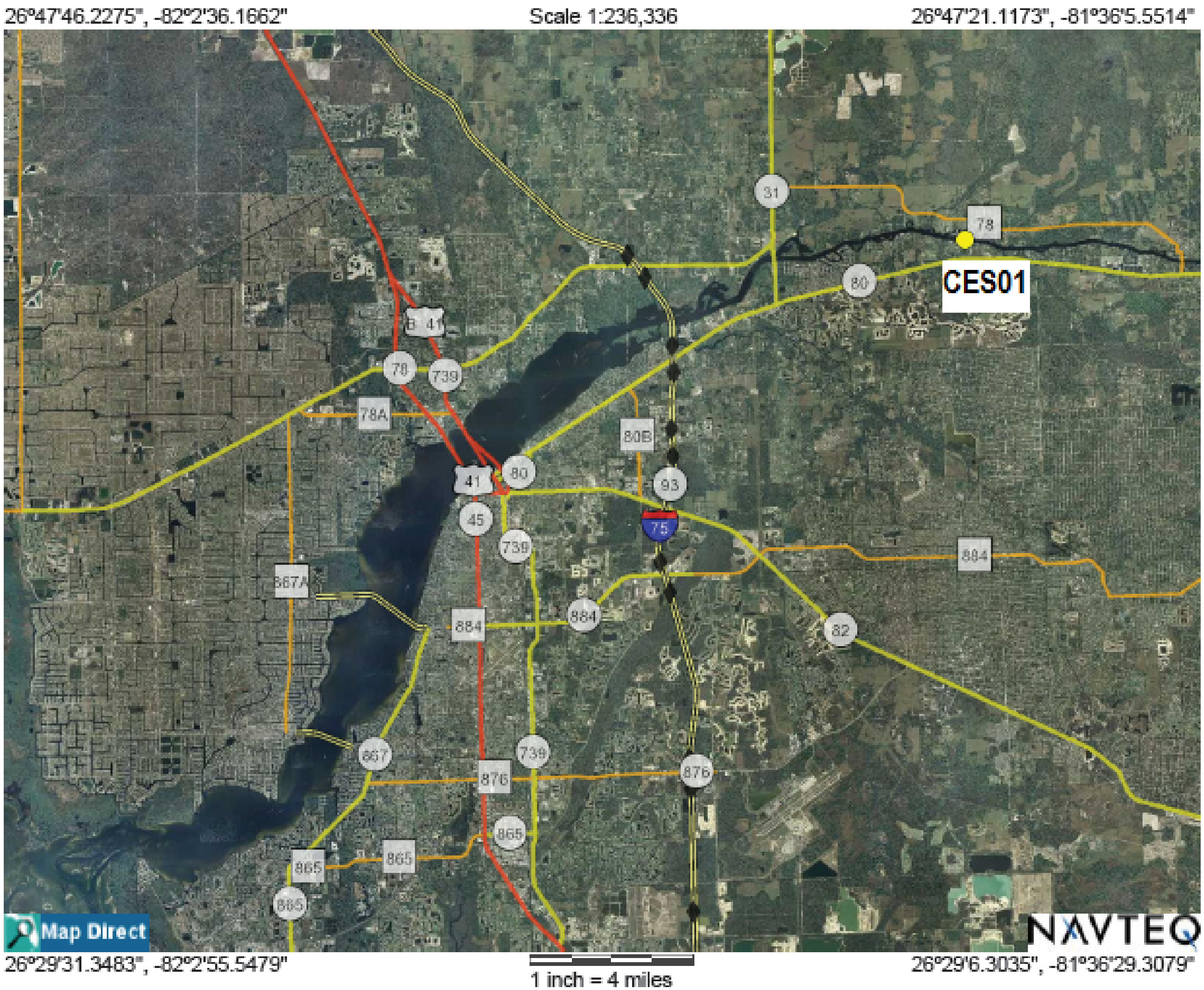


Figure 8. Location of water quality sampling station CES01.



Appendix 1 - Trojan UV Max

TROJANUVMAX™ G, H & J

Go With More Flow.

Flow rates reach up to 45gpm. Even with the high flow capabilities, their footprint is half the size of their predecessors, making installation quicker and easier.

Benefit from Pro Series Product Advances.

Being built from our state-of-the-art Pro Series platform allows the TrojanUVMax G, H & J to share in many of the same product advances such as its incredibly intuitive interface, plug-and-play connections and a sensor confirmation button.

Install in a Wide Range of Water Temperatures.

A revolutionary lamp design provides a constant UV dose in a range of water temperatures, from hot recirculation lines to ice-cold water, giving you the flexibility to install in a variety of site conditions.

WHO IS VIQUA - a Trojan Technologies Company?

VIQUA is a leading water treatment technology company focused on providing our customers – residential and light commercial – confidence in their water. Offering a complete solution package including UV disinfection, water filtration, softeners and ozone products.

WHAT IS UV?

Ultraviolet (UV) light is at the invisible, violet end of the light spectrum. The water treatment industry uses a high-powered form of UV light called UV-C or "germicidal UV" to disinfect water.

WHO USES UV DISINFECTION SYSTEMS?

For more than 30 years, institutions, consumers and businesses have relied on VIQUA's environmentally friendly UV technology to disinfect their water supplies. Top candidates for UV disinfection systems include:

- Rural homes and cottages
- Nursing homes
- Hospitals
- Schools
- Hotels
- Restaurants
- Resorts and holiday camps
- Community water systems

INTUITIVE INTERFACE

Because a picture is worth a thousand words.

SIMPLE CONNECTIONS

With plug-and-play color coded connections, it's as easy as "connect the dots."

Revolutionary Lamp

TWICE THE POWER

The TrojanUVMax G, H & J use a revolutionary lamp with twice the output of current high-output lamps, giving you compact single-lamp systems that are half the size of their predecessors. Size does matter.

TWICE THE LIFE EXPECTANCY

Our revolutionary new lamps last an unprecedented two years, reducing maintenance requirements.

APPLICATIONS: HOSPITALS • SCHOOLS • HOTELS • HOMES & COTTAGES •

COOLER WATER

The CoolTouch significantly reduces water temperature and does not waste any water.

COMBO PORTS

Flexibility to connect to either 1 ¼" NPT or 1" FNPT.

SOLENOID SAFETY

The plug-and-play solenoid stops water flow in the event that water treatment is compromised.

TEST OF SENSOR OPERATION

With the push of a button you can confirm the proper operation of the sensor.

EASY QUARTER-TWIST ASSEMBLY

A quarter-twist to the positive stop and you're done. No tools, no risk of overtightening.

INTEGRATED GROUND

Like a standard plug - no more grounding wires!

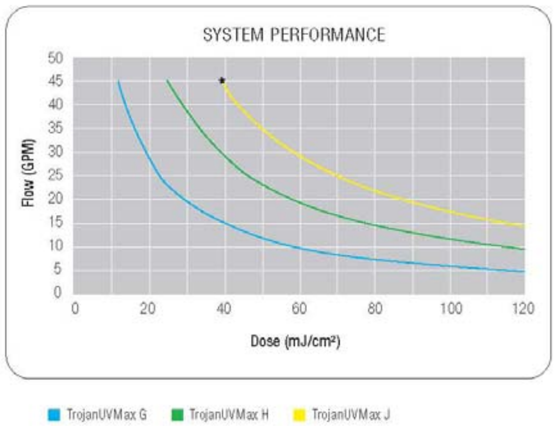
CAMP GROUNDS • NURSING HOMES • RESTAURANTS • COMMUNITY WATER SYSTEMS

General

Colour-coded plug and play connections	Yes
CoolTouch fan	Yes
Sensor with diagnostic test	Optional
Solenoid valve	Optional
Chamber material	316L SST
Rated service life of lamp	2 years
Inlet and outlet	Combo 1 1/4" NPT, 1" FNPT
Controls	
Audible alarm mute button	Yes
New lamp button	Yes
Lamp age indicator	Yes
Lamp operation indicator	Yes
Power supply operation indicator	Yes
Solenoid operation indicator	Yes
Fan operation indicator	Yes
Sensor reading indicator	Yes
Operating Parameters	
Maximum operating presure	100 PSI (689 kPa)
Minimum operating pressure	10 PSI (69 kPa)
Maximum ambient air temperature	104ºF (40ºC)
Minimum ambient air temperature	32ºF (0ºC)
Maximum humidity	100%
Maximum hardness	120 ppm (7 grains per gallon)
Maximum iron	0.3 ppm
Minimum UVT	75%
Installation	Vertical
Certification	cULus LISTED, CE

	G, G Plus	H, H Plus	J, J Plus
Rated flow at dose of 30 mJ/cm²	up to 19 GPM (72 LPM)	20-39 GPM (76-148 LPM)	40-45* GPM (151-170 LPM)
Rated flow at dose of 40 mJ/cm²	up to 15 GPM (57 LPM)	16-29 GPM (61-110 LPM)	30-44 GPM (114-167 LPM)
Electrical			
Voltage	120-240V AC	120-240V AC	120-240V AC
Frequency	50-60 Hz	50-60 Hz	50-60 Hz
Max. current	1.2 Amp	1.6 Amp	2.4 Amp
Max. power consumption	120 Watts	160 Watts	230 Watts
Lamp power consumption	100 Watts	140 Watts	200 Watts
Dimensions			
Chamber	22" x 4" 54 x 10cm	31" x 4" 78 x 10 cm	41" x 4" 103 x 10 cm
Power supply	13" x 6.5" 33 x 16.5cm	13" x 6.5" 33 x 16.5cm	13" x 6.5" 33 x 16.5cm

Flow rates shown are at 85% UVT and End of Lamp Life.
*Inlet/outlet size restricts flow to 45gpm and the dose will be 39mJ/cm²



Warranty

The TrojanUVMax™ G, G Plus, H, H Plus, J, J Plus come with a full five year warranty against manufacturer's defects on the power supply and all electrical components; a ten year guarantee on the UV chamber; and a one year warranty on lamps and sensors.

VIQUA™
A TROJAN TECHNOLOGIES COMPANY
425 Clair Road West Guelph, Ontario, Canada N1L 1R1 T 519 763 1032 F 519 763 5069 www.viqua.com