Summary Report on Eco Water Technologies

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1.0 Introduction

The first-generation pilot unit with the axial flow centrifugal separator (voraxial) was operated at the Palm Beach County Wastewater Treatment Plant in Pahokee, FL for nine months in 2017. The pilot unit tested was a full size, 250 GPM separation unit using the axial flow centrifugal separator. The ultraviolet (UV) light disinfection and membrane filtration portions of the pilot unit were scaled down as membrane performance on wastewater has been well demonstrated in hundreds of installed systems across the country. It is the physical/chemical separation portion of the Eco System that distinguishes itself from other membrane wastewater systems which utilize aerobic and/or anaerobic biological treatment systems ahead of the membranes.

Since the Pahokee pilot unit was Eco's first, most of its operation was trial and error, and typical wastewater operating parameters such as TSS, CBOD5 and nutrients were difficult to trend. At the conclusion of the test period, using typical nanofiltration membranes, the final effluent was so clean that a sample was sent to Flowers Chemical Laboratories Inc (A NELAC certified independent laboratory) and a full USEPA Safe Drinking Water Primary and Secondary Parameters Test Protocol was analyzed. The test results passed and were well below all the Maximum Contaminant Levels (MCLs) with the exception of the Total Dissolved Solids (TDS) which came out at 514 mg/L versus a primary MCL of 500 mg/L. The full analytical report of this test is included in this report as Appendix A.

The pilot unit was then moved to the Port Saint Lucie (PSL) Wastewater Treatment Plant in late 2017 and operated for approximately two years. During this time, additional research and development led to an improved separation system which utilized various additional components to increase the separation rates.

There were two reasons for moving the pilot plant. The first reason was that the strength of the wastewater influent at PSL was more typical of medium strength municipal wastewater than at Pahokee which was of lower strength due to higher Infiltration/Inflow volume, and the second reason was to test the newly developed (and now standard) combination centrifugal/flotation separation system which is now the standard upon which the separation portion of the second-generation Eco System is based. Following a period of fine tuning, samples were taken of raw effluent and at the influent and effluent of each process/stage. These samples were analyzed by Flowers Chemical Laboratories for the typical wastewater/water operating parameters. Summary graphs of these operational results are shown in Figures 1 – 6. A concurrent sample of the final effluent was taken and tested for the Primary Drinking Water Standards, which passed all MCLs. This analysis is included in the report as Appendix B. An analysis of the sludge produced by the Eco Separation Module is included in this report as Appendix C.

2.0 Setup and Test Sample Locations

The following test sample locations (Port 1 -5) were selected to study the amount of removal of certain contaminants through the separation and filtration processes of the Eco System.

Test Sample Locations	
Port 1	Raw Wastewater Influent
Port 2	Flotation Tank Effluent (S-Series: Eco Separation Module)
Port 3	UF Membranes Effluent After UV (R-Series: Irrigation Grade System)
Port 4	NF/RO Membranes Effluent (M-Series: Indirect Potable Grade System)
Port 5	Sludge from Sludge Blanket in Flotation Tank

Table 1: Test Sample Locations.

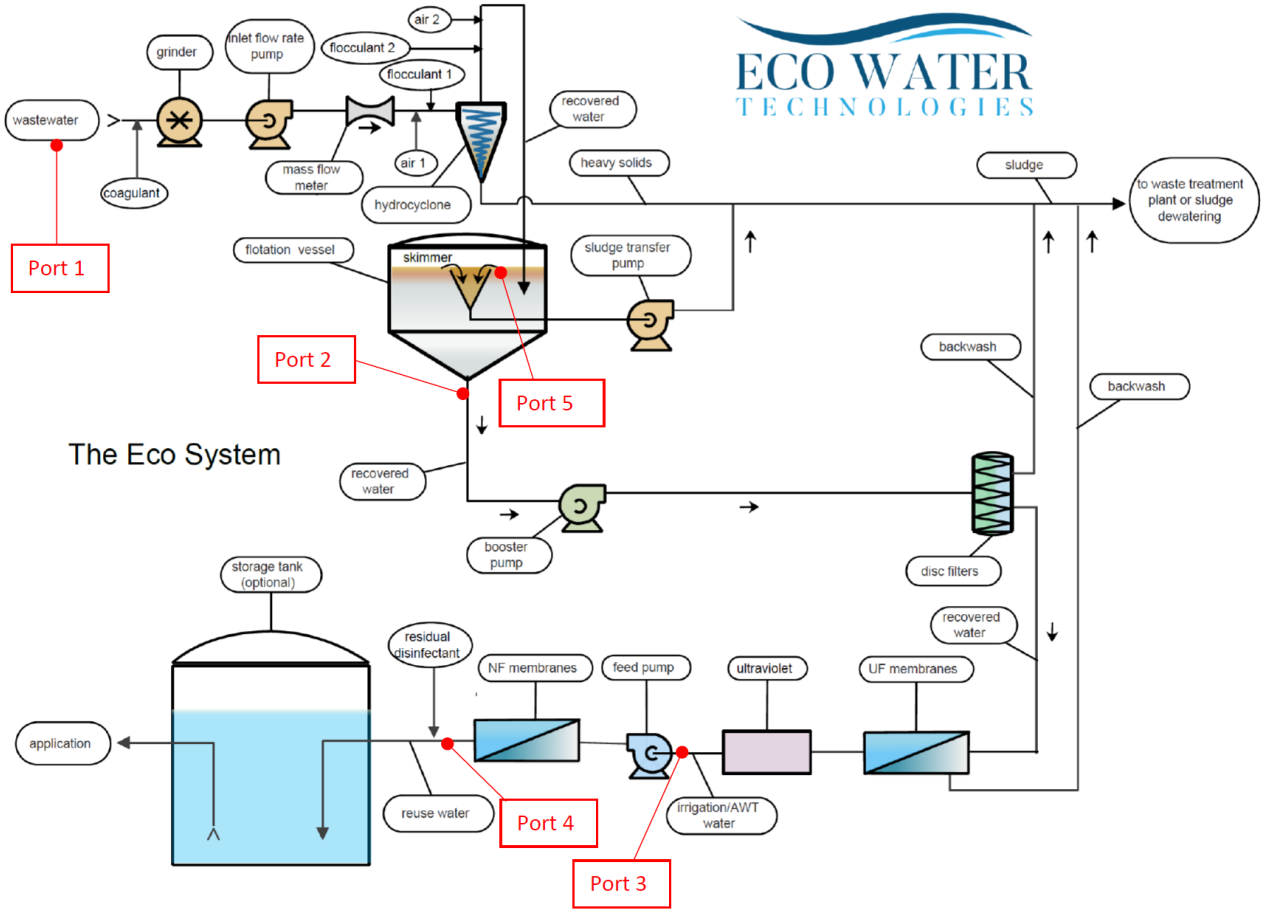

Diagram 1: Process Flow Diagram with Port Locations.

3.0 Results

Port		Port 1	Port 2	Port 3	Port 4
Sample Location		Raw Influent	S-Series Separation Module Effluent	R-Series Irrigation Grade Effluent	M-Series Indirect Potable Effluent
TSS	mg/L	228	13.3	1.0 U*	1.0 U*
CBOD5	mg/L	207.4	49.6	77.6**	3.6
TOC	mg/L	48	-	47.45**	1.13
TDS	mg/L	1140	978	930	134
TKN	mg/L	76.5	-	57.7	12.2
TN		76.6	-	57.8	12.9
TP	mg/L	6.17	1.91	1.66	0.04 U*

* U (Undetectable) – Compound was analyzed for but not detected.
** The UF backwash system before Port 3 was later found to have algae buildup that contaminated the effluent side of the UF membranes causing the values for the CBOD5 and TOC to be significantly skewed higher.

Table 2: Test Results at Port Locations.

Port 5: Sludge		
TS	6.51	%Wt
TKN	3.19	%DW
TN	3.89	
TP	12	%DW
NO3+NO2	0.7	%DW

Table 3: Sludge Test Results.

4.0 Analysis of Results

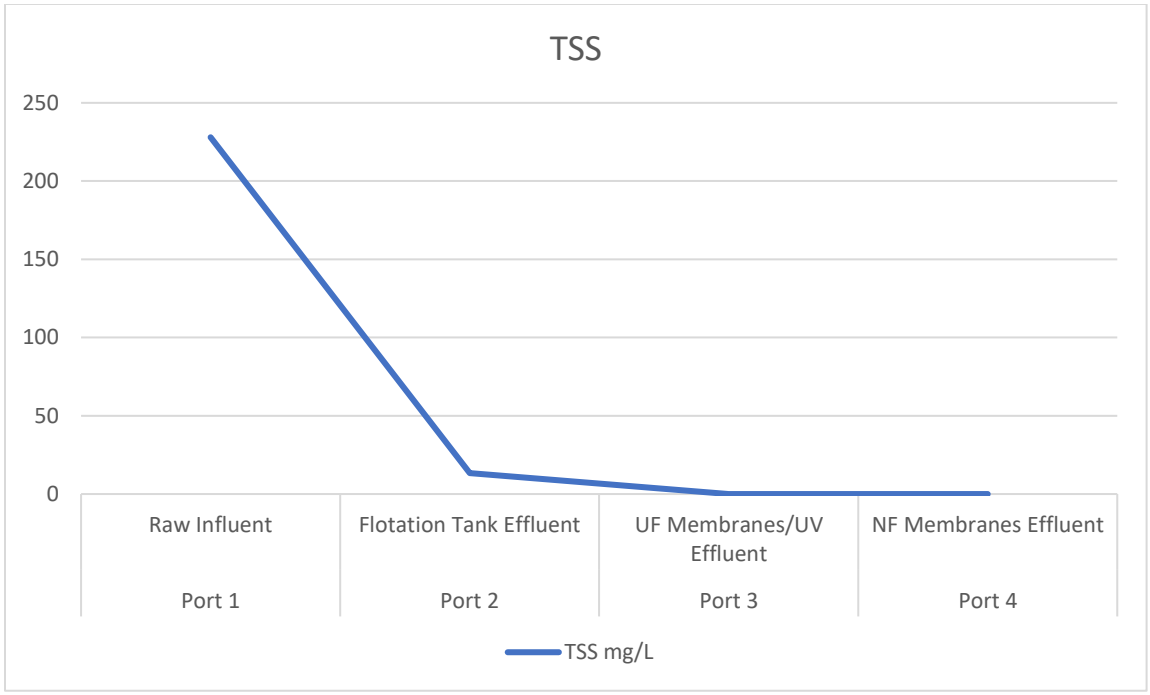

Figure 1: TSS Values at Port Locations.

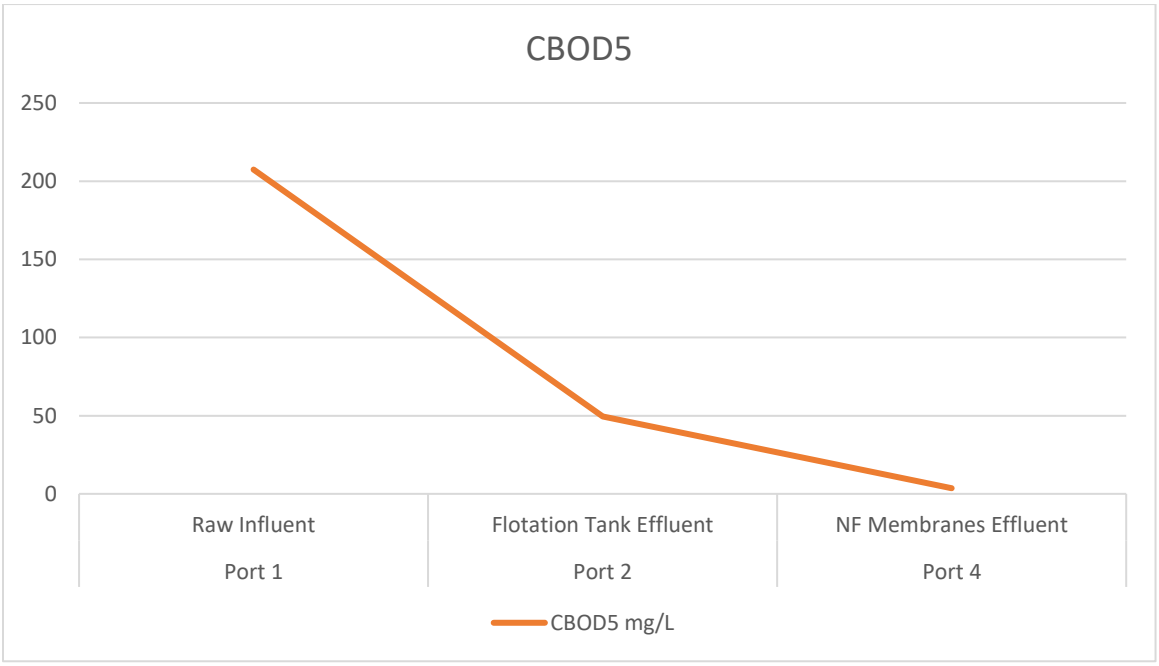

Figure 2: CBOD5 Values at Port Locations.

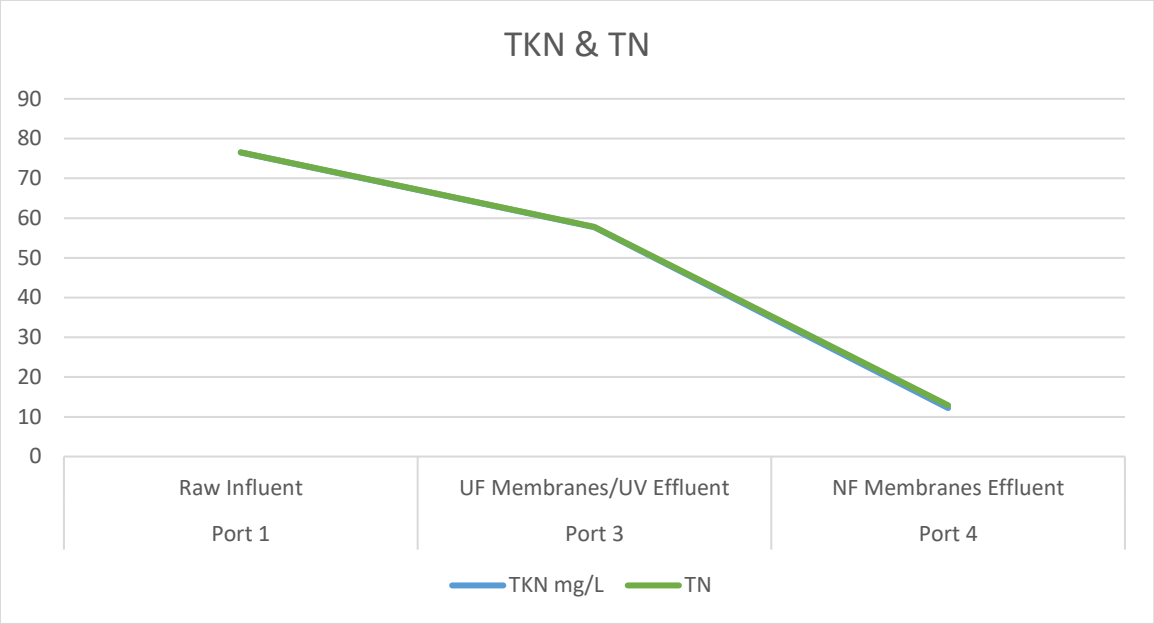

Figure 3: TKN and TN Values at Port Locations.

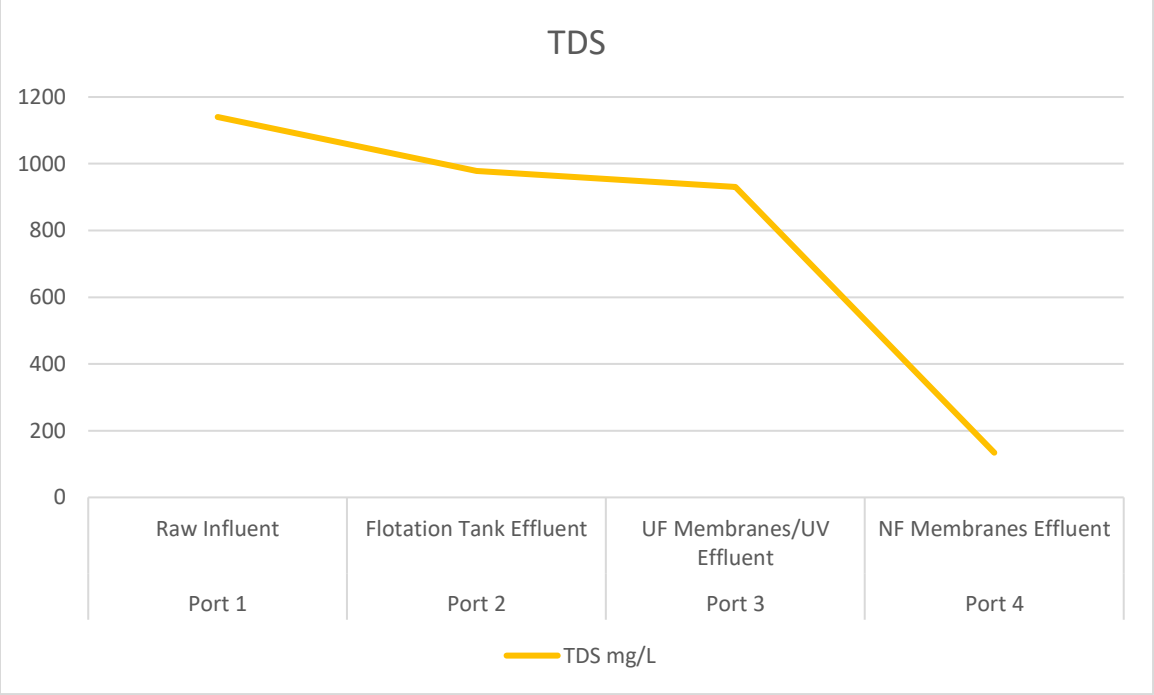

Figure 4: TDS Values at Port Locations.

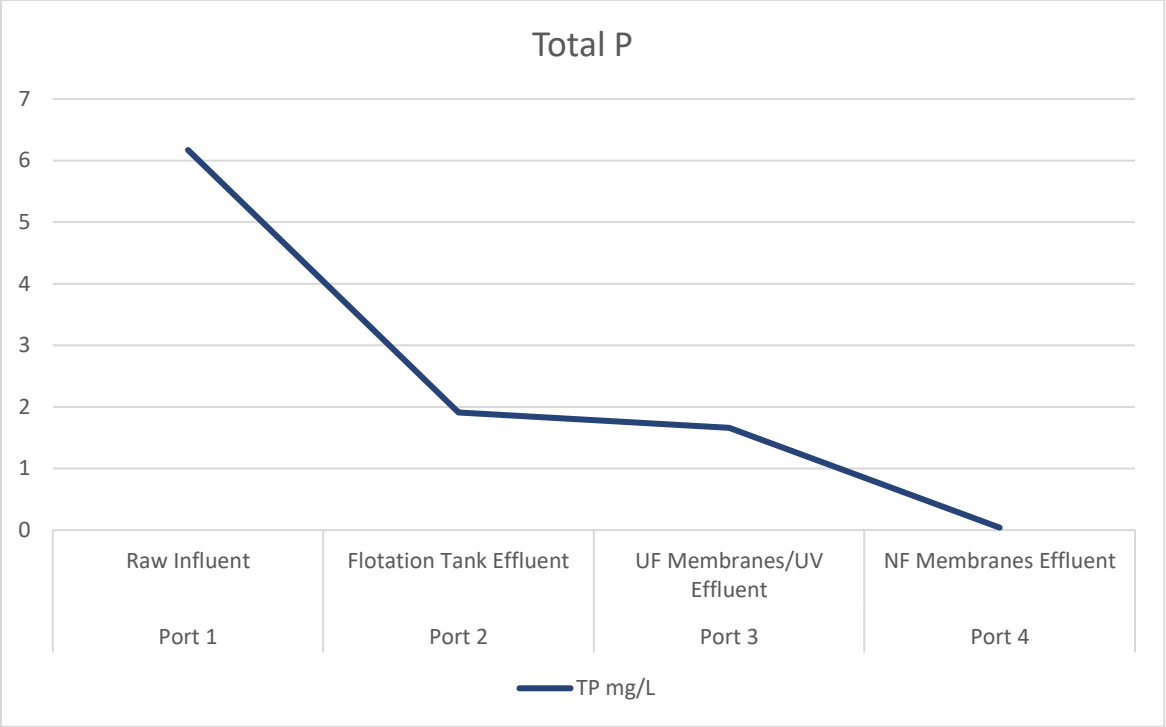

Figure 5: Total P Values for 4 Port Locations.

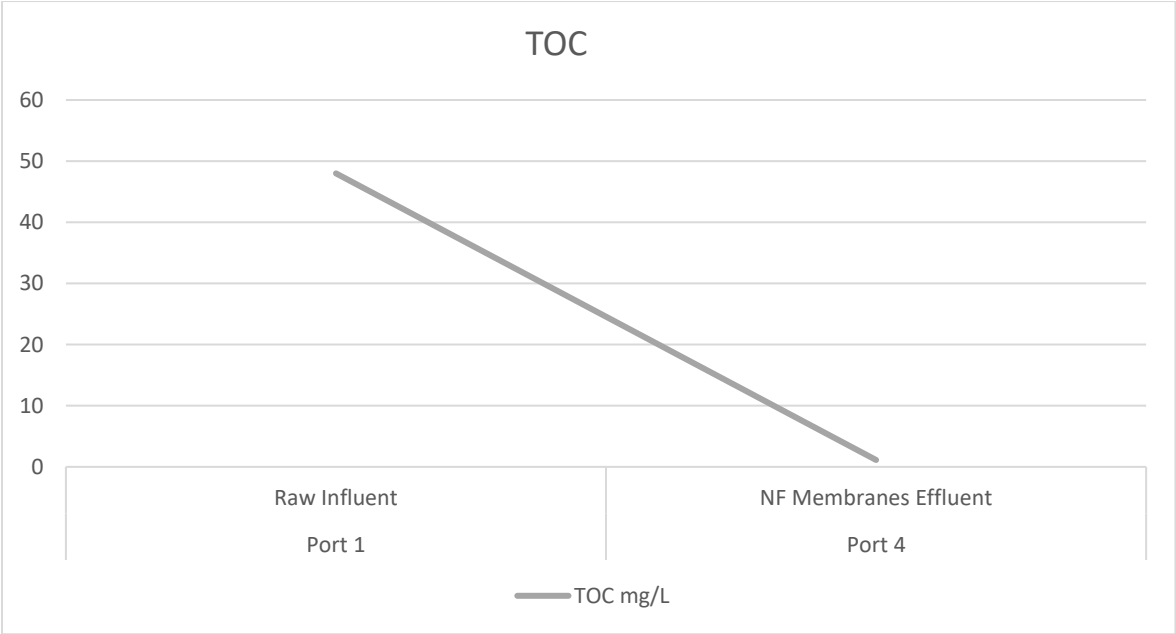

Figure 6: TOC Values at Port Locations.

5.0 Discussion

From the results, the TSS value of the raw wastewater Influent was 228 mg/L. The TSS slightly went up before the hydrocyclone due to the added polymers (coagulant and both flocculant additions), bringing the TSS value to 318 mg/L. The greatest and most significant reduction in TSS occurred at the flotation tank portion of the separation module where the TSS was reduced from 318 mg/L to 13.3 mg/L. The disc filter further reduces the TSS; however, the primary function of the disc filter is to protect the UF membranes by removing any remaining large particles instead of significantly eliminating the remaining TSS. The next significant reduction in TSS occurred at the UF membranes where the TSS was reduced to levels undetected by the laboratory's instrumentation.

The CBOD5 value of the raw wastewater influent was 207 mg/L. A significant reduction occurred in the separation module, first in the hydrocyclone and then removed with the sludge from the flotation tank reducing the CBOD5 value down to 49.6 mg/L. The disc filter further reduced the CBOD5 down to 43.6 mg/L, but a discrepancy occurred with the CBOD5 test data at the UF membranes/UV where it should have further reduced the CBOD5 but instead increased it to 77.6 mg/L. This error may have occurred due to a contaminated UF backwash due to algae growth in the backwash tank used for the unit tested. The algae growth in the backwash tank contaminated the product water effluent side of the UF membranes during backwashes, and consequently, contaminated the UF/UV effluent at Port 3 prior to testing. From there, the NF membranes provided the next significant reduction in CBOD5 and reduced it down to 3.6 mg/L.

The TDS value of the raw wastewater influent was 1140 mg/L. A small but significant amount of TDS was removed in the separation module. Some of the TDS inherently got removed with the settleable and suspended solids sludge from the hydrocyclone and flotation tank. The TDS remains relatively unchanged until it reaches Port 4 after the NF membranes where the TDS was reduced to 134 mg/L.

The TKN and TN values were closely aligned and dependent on each other. The TKN and TN values of the raw wastewater influent were 76.5 mg/L and 76.6 mg/L, respectively. The UF membranes further reduced the TKN and TN down to 57.7 mg/L and 57.8 mg/L, respectively; however, the NF membranes provided the greatest reduction in TKN and TN, down to 12.2 mg/L and 12.9, respectively.

The TP value of the raw wastewater influent was 6.17 mg/L. A large majority of the TP was removed with the sludge from the flotation tank of the separation module, where it was reduced down to 1.91 mg/L. The UF membranes/UV further reduced the TP down to .492 mg/L, and the NF membranes brought the value down to undetectable levels.

The TOC values of the raw wastewater influent is 48 mg/L. A discrepancy occurred with the TOC test data at the UF membranes/UV similar to the CBOD5 values where it should have further reduced the TOC but instead remained relatively unchanged at 47.45 mg/L. This error may have occurred due to a contaminated UF backwash due to algae growth in the backwash tank used for the unit tested. The algae growth in the backwash tank contaminated the product water effluent side of the UF membranes during backwashes, and consequently, contaminated the UF/UV effluent at Port 3 prior to testing. From there, the NF membranes provided the most significant reduction in TOC and reduced it down to 1.13 mg/L.

The sludge produced by the separation module, as detailed in Appendix C, had a TS value of 6.51 %Wt.

6.0 Conclusion

Based on this analysis, the S-Series Eco Separation Module (Port 2) greatly and significantly reduces the TSS, CBOD5 and Total P down to levels useful to many systems and applications, either as a supplemental unit or as a standalone unit to aid in the removal of settleable and suspended solids. More importantly, these significant reductions serve the purpose of reducing these contaminants enough to alleviate the stresses and loading on the UF membranes necessary for further purification, making the UF membranes more efficient and reducing their backwashing while increasing their life and the reliability of filtration systems in general. The effluent after the UF membranes and the ultraviolet light at Port 3 (R-Series Irrigation Grade System) produced irrigation grade/AWT product water, while the accredited laboratory test results determined that the effluent at Port 4 after the NF membranes (M-Series indirect Potable Grade System) met not only the normal non-potable water standards, but they also exceeded both the EPA and the World Health Organization primary and secondary drinking water standards with significant margins.

Appendix A: July 8, 2017 Results - Palm Beach County Wastewater Treatment Plant in Pahokee, FL

	Measurement	Unit	Wastewater Feed	ECO Water
I	Total Suspended Solids (TSS)	mg/L	214	zero
II	Total Dissolved Solids (TDS)	mg/L	1140	134
III	CBOD5	mg/L	72.6	3.6
IV	Total Nitrogen	mg/L	61.9	12.9
V	Total Phophorus	mg/L	6.37	zero
VI	TOC	mg/L	48	1.13
VII	Color	CU	80	zero

	Contaminate	Unit	EPA*	ECO Water**		Contaminate	Unit	EPA	ECO Water**
1	Aluminum	mg/L	0.2	U	18	Mercury	mg/L	0.002	U
2	Barium	mg/L	2	U	19	Antimonoy	mg/L	0.006	U
3	Copper	mg/L	1.3	U	20	Arsenic	mg/L	0.01	U
4	Nickel	mg/L	0.1	U	21	Beryllium	mg/L	0.004	U
5	Silver	mg/L	0.1	0.003	22	Cadmium	mg/L	0.005	U
6	Zinc	mg/L	5	U	23	Chromium	mg/L	0.1	U
7	NO3+NO2	mg/L	11	0.703	21	Lead	mg/L	0.015	U
8	Nitrates (as N)	mg/L	10	0.703	22	Selenium	mg/L	0.05	U
9	Nitrites (as N)	mg/L	1	U	23	Thallium	mg/L	0.002	U
10	Oxamyl (Vydate)	µg/L	0.2	U	24	Endrin	mg/L	0.002	U
11	Foaming Agents (MBAS)	mg/L	0.5	U	25	Manganese	mg/L	0.05	U
12	Fluoride	mg/L	0.4	U	26	Cyanide	mg/L	0.2	U
13	Iron	mg/L	0.3	U	27	Lindane	mg/L	0.0002	U
14	Sodium	mg/L	160	28.1	28	Methoxychlor	mg/L	0.04	U
15	Sulfate	mg/L	250	14.9	29	Toxaphene	mg/L	0.003	U
16	Chloride	mg/L	250	92.1	30	1,2-Dibromoethane	mg/L	0	U
17	Bis(2-ethylhexyl)phthalate	µg/L	0	U	31	1,2-dibromo-3-chloropropane	mg/L	0	U

*EPA Primary or Secondary Drinking Water Maximum Allowable Level of Contamination.
**Contaminates measured in Product Water from wastewater processed with Eco System at Port St. Lucie Water Treatement on 6/4/2019
U = Undetected (below lower limits of lab equipment or not present)

Appendix B: June 4, 2019 Results – Port St. Lucie Water Treatment Plant in Port St. Lucie, FL

	Measurement	Unit	Wastewater Feed	ECO Water
I	Total Suspended Solids (TSS)	mg/L	214	zero
II	Total Dissolved Solids (TDS)	mg/L	1140	134
III	CBOD5	mg/L	72.6	3.6
IV	Total Nitrogen	mg/L	61.9	12.9
V	Total Phophorus	mg/L	6.37	zero
VI	TOC	mg/L	48	1.13
VII	Color	CU	80	zero

	Contaminate	Unit	EPA*	ECO Water**
1	Aluminum	mg/L	0.2	U
2	Barium	mg/L	2	U
3	Copper	mg/L	1.3	U
4	Nickel	mg/L	0.1	U
5	Silver	mg/L	0.1	0.003
6	Zinc	mg/L	5	U
7	NO3+NO2	mg/L	11	0.703
8	Nitrates (as N)	mg/L	10	0.703
9	Nitrites (as N)	mg/L	1	U
10	Oxamyl (Vydate)	µg/L	0.2	U
11	Foaming Agents (MBAS)	mg/L	0.5	U
12	Fluoride	mg/L	0.4	U
13	Iron	mg/L	0.3	U
14	Sodium	mg/L	160	28.1
15	Sulfate	mg/L	250	14.9
16	Chloride	mg/L	250	92.1
17	Bis(2-ethylhexyl)phthalate	µg/L	0	U
18	Mercury	mg/L	0.002	U
19	Antimonoy	mg/L	0.006	U
20	Arsenic	mg/L	0.01	U
21	Beryllium	mg/L	0.004	U
22	Cadmium	mg/L	0.005	U
23	Chromium	mg/L	0.1	U
24	Lead	mg/L	0.015	U
25	Selenium	mg/L	0.05	U
26	Thallium	mg/L	0.002	U
27	Endrin	mg/L	0.002	U
28	Manganese	mg/L	0.05	U
29	Cyanide	mg/L	0.2	U
30	Lindane	mg/L	0.0002	U
31	Methoxychlor	mg/L	0.04	U
32	Toxaphene	mg/L	0.003	U
33	1,2-Dibromoethane	mg/L	0	U
34	1,2-dibromo-3-chloropropane	mg/L	0	U

*EPA Primary or Secondary Drinking Water Maximum Allowable Level of Contamination.
**Contaminates measured in Product Water from wastewater processed with Eco System at Port St. Lucie Water Treatement on 6/4/2019
U = Undetected (below lower limits of lab equipment or not present)

Appendix C: September 18, 2019 Sludge Results – Port St. Lucie Water Treatment Plant

	Measurement	Unit	ECO Sludge
I	Total Solids	%Wt	**6.51**
II	Lab pH	pH	**8.6**
III	TKN (as N)	%DW	**3.19**
IV	Total Nitrogen (as N)	%DW	**3.89**
V	Total Phosphorus (as P)	%DW	**12**
VI	NO_3+NO_2 (as N)	%DW	**0.7**

	Contaminate	Unit	ECO Sludge**
1	Arsenic	mg/kgDW	**U**
2	Cadmium	mg/kgDW	**U**
3	Chromium	mg/kgDW	**5.28**
4	Copper	mg/kgDW	**30.2**
5	Lead	mg/kgDW	**3.52**
6	Molybdenum	mg/kgDW	**3.52**
7	Nickel	mg/kgDW	**3.96**
8	Selenium	mg/kgDW	**U**
9	Zinc	mg/kgDW	**305**
10	Potassium	%DW	**0.0532**
11	Mercury	mg/kgDW	**U**

**Contaminates measured in sludge separated from wastewater processed with Eco System at Port St. Lucie Water Treatment Plant on 9/18/2019

U = Undetected (below lower limits of lab equipment or not present)