Identifying the Feasibility of Canal Recharge for Indirect Potable Reuse: The Plantation Experience

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Table 1. Anticipated Effluent Limits(1)

PARAMETER	CONCENTRATION
Total Nitrogen	< 1.5 mg/l
Total Phosphorus	< 0.02 mg/l
Total Suspended Solids	< 5.0 mg/l
BOD_5	< 5.0 mg/l
Fecal Coliform	Non-Detectable

(1) Anticipated Effluent Limits based on BC Ch27, Article V and FAC 62-302.

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Southeast Florida water utilities are facing some of the largest and most challenging issues they have ever seen. Utilities are being asked to find synergistic solutions to water supply and wastewater effluent disposal and reuse issues. This type of effort has been undertaken in California and is now being seriously evaluated in Florida. Several programs are leading the push down this path, including the Comprehensive Everglades Restoration Program and the Regional Water System Availability Rule.

The South Florida Water Management District approved the proposed Regional Water System Availability Rule, which is aimed at preventing increased reliance on Everglades and Loxahatchee River watershed water bodies by restricting new/increased withdrawals over a base condition that would cause seepage or direct withdrawals from the Regional System. With implementation of the Regional Water Availability Rule, the volume of water available from Southeast Florida's primary source has been quantified and capped for utilities. As a result, Southeast Florida utilities are seeking alternative sources of water.

As an ongoing regional effort to finding alternative water supplies, the city of Plantation and the water management district entered into a cooperative agreement to evaluate recharging the Biscayne Aquifer with highly treated reclaimed water through surface water discharge. Discharging into the East Holloway Canal, which is part of the Old Plantation Water Control District, has been identified as a potential point of recharge to the underground aquifer and ultimately the potable water supply. Because of the sensitivity of the receiving surface water body, the treated effluent would be required to meet several key criteria, including stringent nutrient limits (See Table 1); microconstituent removal; and addressing aquatic toxicity concerns and any endocrine disrupting impacts.

Based on the anticipated effluent limits, several process treatment schemes were evaluated (desk-top level evaluation) as to their potential for meeting the anticipated effluent requirements. The key effluent criteria that drove the process selection were: Total Nitrogen < 1.5 mg/l and Total Phosphorus < 0.02 mg/l. Although these parameters have been identified as the likely drivers regarding treatment, other parameters will need to be met. The effluent quality was estimated for each of the process schemes and the following two options were chosen to be piloted:

- Membrane Bioreactor Scheme (see Figure 1): Primary effluent from the Plantation Wastewater Treatment Facility was treated using Biological Nutrient Removal (BNR), a Membrane Bioreactor (MBR), Reverse Osmosis (RO) and Ultraviolet (UV) disinfection.
- Conventional Treatment Scheme (see Fig-

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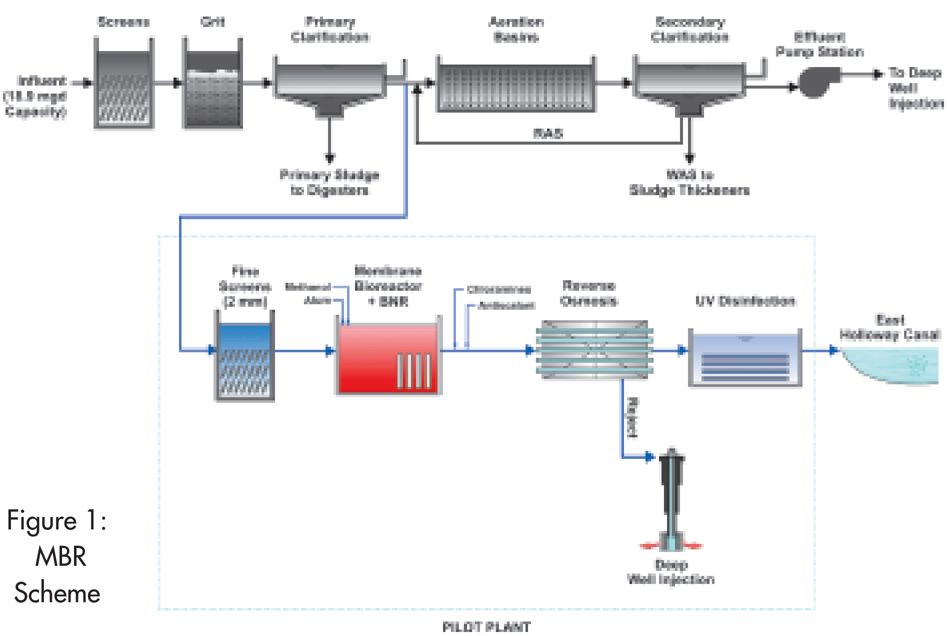

Figure 1: MBR Scheme

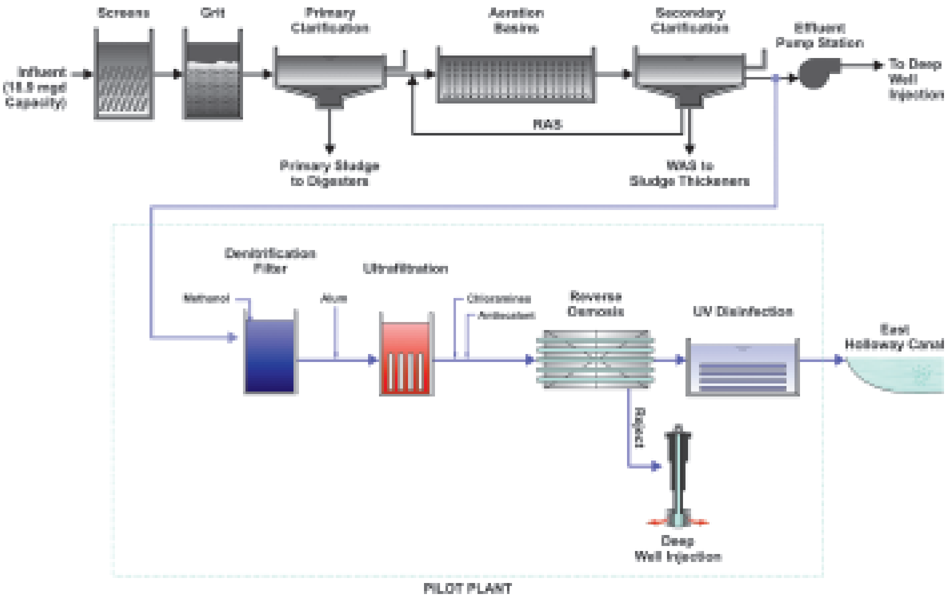

Figure 2: Conventional Treatment Scheme

			BNR + MBR				RO
Test Condition	Description	Duration days	Target MLSS (mg/L)	Target Alum Dose (mg/L)	Target Methanol Dose (mg/L)	Operational Flux Rate (gfd)	Target Flux Rate (gfd)
MBR-1	Biological Nitrogen and Phosphorous Removal	60	7,000	None	None	22	12
MBR-2	Biological Nitrogen and Phosphorous Removal with Chemical Addition	7	7,000	11	20	22	12

Table 2. MBR Scheme: Test Program Summary

			Denitrification Sand Filters		UF/RO/System		
					Alum	UF	RO
Test Condition	Description	Duration (days)	Target Methanol Feed Ratio	Target Loading (gpm/sf)	Target Alum Dose (ppm)	Target Flux Rate (gfd)	Target Flux Rate (gfd)
CONV-1	Low DSF loading rate w/methanol and alum addition	50	3.5:1	2	40	20-25	12
CONV-2	Medium DSF loading rate w/methanol and alum addition	10	3.5:1	3	40	20-25	12
CONV-3	High DSF loading rate w/methanol and alum addition	5	3.5:1	4	80	20-25	12
CONV-4	Medium DSF loading rate w/methanol and alum addition	5	3.5:1	3	80-120	20-25	12
RO-1	Bypass DSF-Nitrified Secondary Effluent/UF/RO	10	None	None	None	20-25	12

Table 3. Conventional Treatment Scheme: Test Program Summary

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ure 2): Nitrified secondary effluent from the treatment facility was treated using; denitrification sand filters (DSF), Ultrafiltration (UF), RO, and UV disinfection.

The relatively unique water quality concerns associated with this effort results in the need to evaluate, through desktop modeling and on-site pilot testing, viable treatment technologies. Primary goals of this pilot testing program were evaluating potential treatment technologies and assessing the feasibility of discharging reclaimed water into the East Holloway Canal near the Plantation Wastewater Treatment Facility, based on anticipated effluent water quality requirements.

Methodology

Plan of Study

A pilot test program was developed in an effort to focus on meeting the project goals and objectives in an expeditious and phased manner. Although the test program was modified during the course of the project, the overall project goal was maintained. The individual pilot test programs for each pilot scheme are summarized in Tables 1 and 2.

Materials and Methods

The flow through the pilot system was approximately 10 gallons per minute. Nutrient levels were measured before and after each treatment unit and at different test conditions to demonstrate compliance with effluent criteria. The removal of microconstituents by these processes and effluent toxicity tests were quantified through five sampling events at three locations in each treatment train: UF effluent, RO influent, and RO effluent.

The following were key parameters evaluated over a period of approximately one year: pH, total nitrogen (TN), total phosphorus (TP), total suspended solids, biochemical oxygen demand, total dissolved solids, particle size distribution, concentrations of selected microconstituents (32 were analyzed), chronic definitive testing on the waterflea (*Ceriodaphnia dubia*) and the fathead minnow (*Pimephales promelas*), E-Screen with MCF-7 cells, yeast estrogen screen, and fathead minnow (*Pimephales promelas*) vitellogenin and steroid assays.

MBR Scheme

The primary goal of this process scheme's testing program was to demonstrate biological nitrogen and phosphorus removal in the MBR followed by treatment using an RO. The BNR configuration was a modified Virginia Initiative Plant (VIP) process (four-stage) primarily focused on biological phosphorus removal and not biological nitrogen removal. As a result, nitrogen removal rates in the MBR pilot will be conservative relative to MBRs designed around nitrogen removal. In order to accelerate the biological seeding time in the MBR, return activated sludge from the Miramar, Florida, Wastewater Treatment Facility was used to seed the MBR pilot because of its high content of Bio-P organisms.

Identifying operational and design criteria for this process scheme was not the primary objective of this pilot; therefore, treatment units generally were not operated under optimal conditions (i.e., most economical). As an example, because of the unforeseen difficulty in throttling the flow through downstream processes, the MBR membrane was operated at much higher flux rates (i.e., 22 gfd) than at a typical full-scale installation. A short test run (MBR-2) using methanol and alum to increase nitrogen and phosphorus removal was developed to identify the highest nutrient removal efficiency for this treatment scheme. Because of the MBR's slow stabilization period, the evaluation of additional testing conditions was not feasible, in light of the project's constrained schedule.

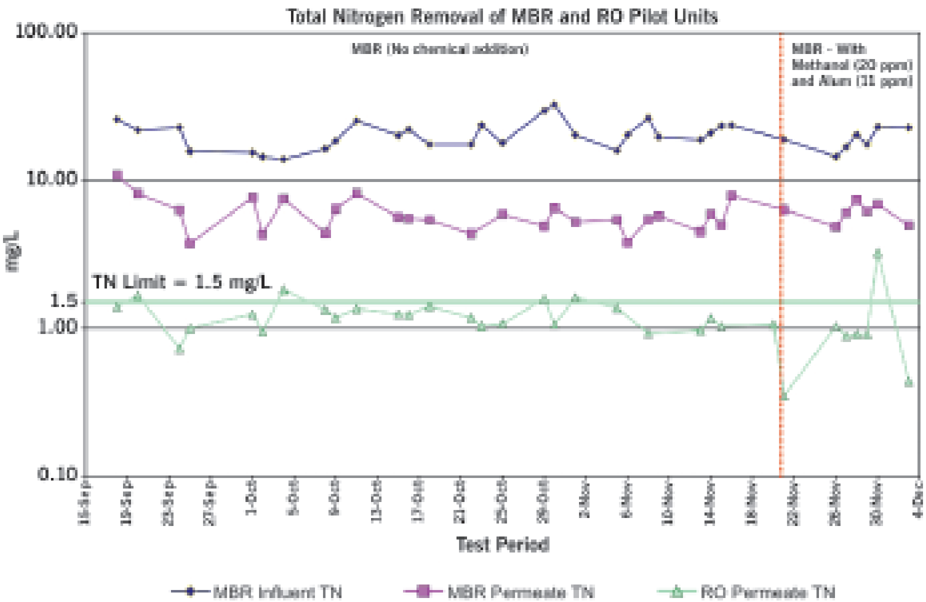

Figure 3: MBR Scheme Total Nitrogen Removal

Conventional Treatment Scheme

The primary goal of this process scheme's testing program was to demonstrate the ability to meet the anticipated limits by conventional treatment with nitrified secondary effluent followed by DSF (with methanol addition), UF (with alum addition), RO, and UV. Unlike the previous process scheme, this pilot scheme uses chemical addition (alum) for phosphorus removal. Because of the DSF's relatively fast stabilization period, more testing conditions were evaluated using different loading rates on the DSF. An additional test condition (RO-1) was evaluated to identify the nutrient reduction through membrane treatment only (bypass DSF).

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Figure 4: MBR Scheme Total Phosphorus Removal

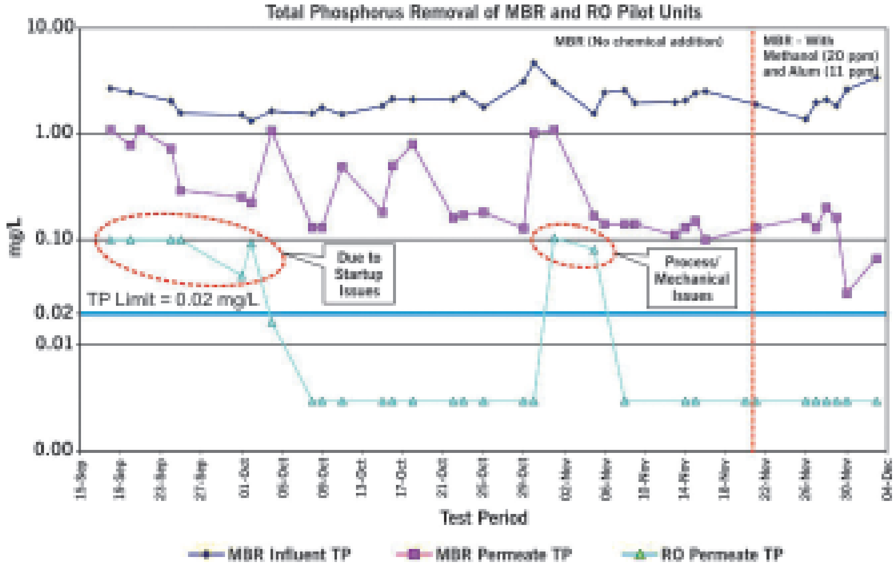
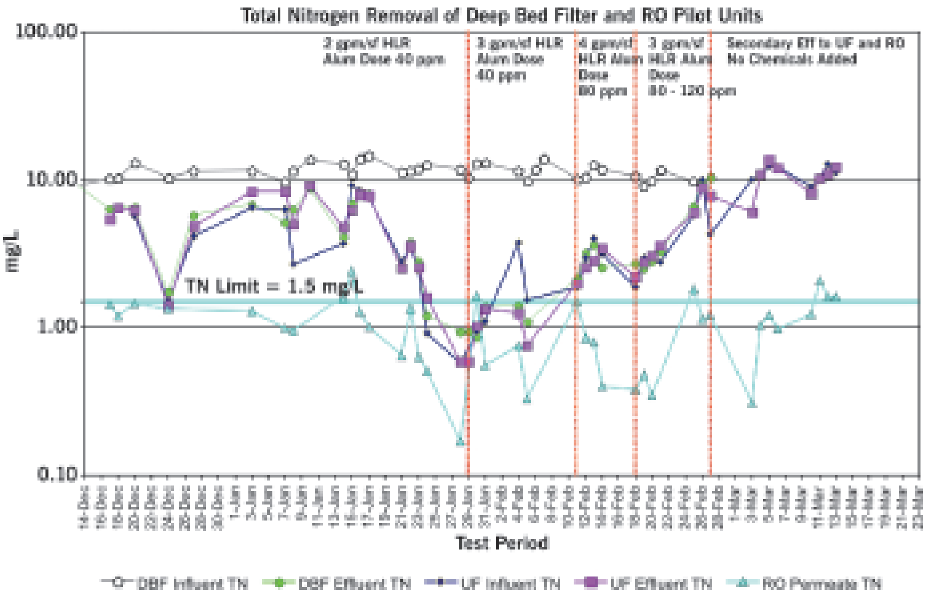
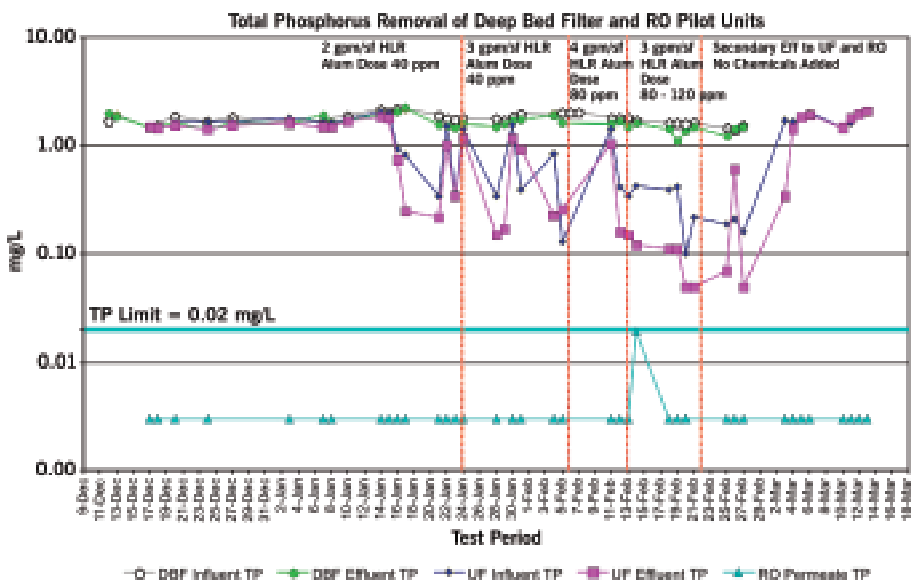


Figure 5: Conventional Treatment Scheme Total Nitrogen Removal





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Results

Results presented in this document are limited to those considered of key importance to the goals of the pilot study and focus on the ability of each process scheme in meeting the anticipated limit criteria.

MBR Scheme Nutrient Removal

Using primary clarifier effluent as pilot plant influent, biological nitrogen and phosphorus removal was tested in the MBR followed by RO treatment. As shown in Figure 3, pilot operation under these test conditions was generally able to meet the effluent TN limit of 1.5 mg/L in most of the samples.

As shown in Figure 4, pilot operation under these test conditions was also generally able to meet the effluent TP limit of 0.02 mg/L in most samples with most of the RO Permeate TP concentration results below the testing method's detection limit (<0.003 mg/L).

Based on pilot test results, this process scheme is a viable option for potential full-scale implementation. This pilot scheme consistently met both TN and TP effluent limits.

Conventional Treatment Scheme Nutrient Removal

Using nitrified secondary effluent as pilot plant influent, nitrogen and phosphorus removal was tested with denitrification sand filtration, ultrafiltration, and RO treatment. As shown in Figure 5, pilot operation under these test conditions was able to meet the effluent TN limit of 1.5 mg/L in most of the samples.

As shown in Figure 6, pilot operation under these test condition were able to meet the effluent TP limit of 0.02 mg/L with most of all of the RO permeate TP concentration results below the testing method's detection limit (<0.003 mg/L).

Based on pilot test results, this process scheme is a viable option for potential full-scale implementation. This pilot scheme consistently met both TN and TP effluent limits.

Microconstituent Testing

During the operation of the pilot plant, microconstituent concentrations for 32 constituents were measured in the RO influent and RO effluent. The results of the microconstituent testing are shown in Figures 7 and 8. Thirteen microconstituents were detected in the RO influent, but almost all microconstituents in the RO effluent were below the detection limits, ex-

Figure 6: Conventional Treatment Scheme Total Phosphorus Removal

cept for bisphenol A (BPA) and tris (1,3-dichloro-2-propyl) phosphate (TDCPP). These two compounds were detected only once during the three sampling events and are potentially due to a sampling error.

Overall, the microconstituent testing showed that the RO membrane system is effective at removing a wide range of compounds. It should be noted that there are several microconstituents that typically are not removed by RO membranes alone which were not tested in this analysis.

Toxicity Testing and Endocrine Disrupting Assays

The toxicity analysis included chronic definitive testing on the waterflea (*Ceriodaphnia dubia*) and the fathead minnow (*Pimephales promelas*), following EPA 821-R-02-013 Test Method 1002.0 and 1000.0, respectively. The RO effluent samples were stabilized prior to toxicity testing by adding minerals to mimic the chemistry of the control water.

The results of the toxicity testing identified that the RO effluent could potentially cause mortality of the test organisms if the effluent is not property stabilized and pretreatment chemical (chloramines and antiscalant) residuals removed. Further research is necessary to identify the best effluent re-stabilization and RO pretreatment practices for full scale implementation of this application (surface water discharge).

In addition to the toxicity tests, several endocrine disrupting assays (E-Screen Bioassay, Yeast Estrogen Screen Bioassay and Fathead Minnow Vitellogenin and Steroid Assays) were conducted to demonstrate the extent to which the various advanced treated effluents possess endocrine disrupting potential. The results of this testing showed that there was no endocrine disrupting impacts to the aquatic organisms.

Figure 7: RO Influent Microconstituent Results

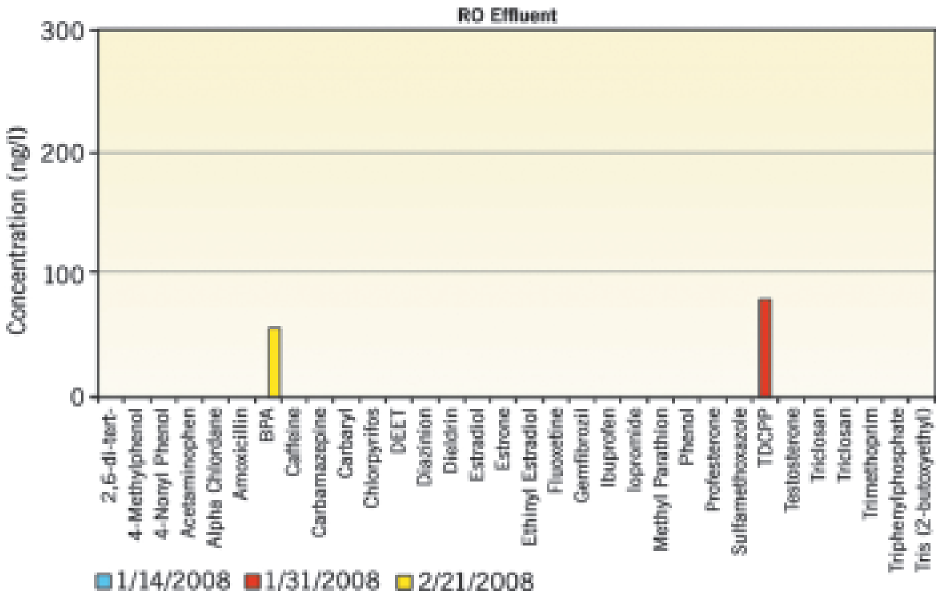
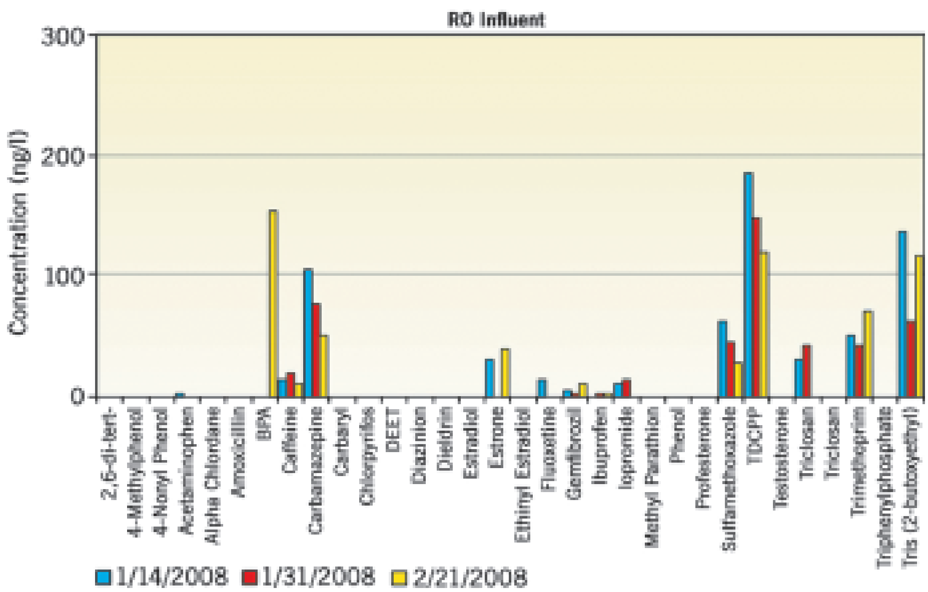


Figure 8: RO Effluent Microconstituent Results



Discussion & Conclusions

The pilot testing was completed in April 2008 and it successfully demonstrated that both process schemes are a viable option for potential full-scale implementation with regard to nutrient removal. Both treated effluents consistently met the anticipated TN and TP effluent limits under varying test conditions, but based on the results, it was evident that chemical and biological nutrient removal technologies alone were not sufficient to meet the stringent nutrient limits and that the use of RO membrane technology is essential for this type of project.

The results of the toxicity testing identified several issues regarding the toxicity of RO effluent on aquatic organisms—specifically, the effects of the type of pretreatment (antiscalant and chloramines) used on the RO system and the re-stabilization/remineralization of effluent needed prior to discharge. These effects will be key issues for full-scale implementation.

The endocrine disruptor assays performed using the RO permeate exhibited no endocrine disrupting effects on the aquatic organisms. The microconstituent testing showed that the majority of the microconstituents were removed by the RO membranes.

Acknowledgement

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