Planning and Implementation of the First Full-Scale Reuse Plant in New York State

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ABSTRACT

In 2001, the United States Environmental Protection Agency (USEPA) recommended reducing nitrogen levels in the Peconic Estuary, prompting the Town of Riverhead, NY Wastewater Treatment Plant to consider reusing a portion of its effluent to irrigate an adjacent golf course. In 2007, the New York State Department of Environmental Conservation (NYSDEC) required the plant to reduce its summertime nitrogen discharge by 76.5%, effective 2016.

As a result, the Town decided to upgrade and convert the existing sequencing batch reactor (SBR) system to a unique batch-type membrane bioreactor (MBR) system. In 2016, the two SBR basins were converted into bioreactors, one at a time so that the system could continue handling the full flow and load to the plant during the construction. The system now averages an effluent nitrogen that is 18% below the required limit with 33% of its total 1.5 MGD capacity permitted as wastewater reuse for public irrigation.

KEYWORDS

Reuse, reclaimed water, Total Mass Daily Loading (TMDL), denitrification, Membrane Bio-Reactor (MBR), implementation plan, system upgrade, hollow fiber, Sequencing Batch Reactor (SBR)

INTRODUCTION/BACKGROUND

The Town of Riverhead, NY is in northeastern Long Island and has over 13,000 residents and 150 businesses, which currently generates an average of 4,167 cubic meters per day (m3/d) - 1.1 million gallons per day (mgd) - of wastewater. The town's existing 4,924 m^3/day (1.3 mgd) Advanced Wastewater Treatment Facility (AWTF) was last upgraded in 2000 to an SBR system and was regularly meeting its total nitrogen discharge limit of 15 mg/l to the Peconic River. The upgraded process at that time was designed to meet 10 mg/l of total nitrogen (TN); the permitted summertime nitrogen TMDL was 77 kg (170 lbs).

In 2001, recommendations from the USEPA Peconic Estuary study had included reducing nitrogen loading by all sources to strengthen and maintain the estuary for the future (Minei, 2001). This recommendation prompted the town's sewer district to consider the idea that a portion of plant effluent could be reused as irrigation water on the neighboring County owned

Indian Island Golf Course to reduce the nitrogen loading to the Peconic River. However, New York did not have state standards in place for wastewater reuse for irrigation discharge. So H2M architects + engineers and the Town of Riverhead conducted a research study in 2004 to determine what the standards should be. They reviewed standards from states across the country that were already reusing domestic wastewater, and selected the strictest limits for each effluent parameter. Table 1 lists the limits used by three of these states, as well as the USEPA guidelines at the time.

Table 1: Summary of Reuse Standards in Effect During 2004

Parameter	CA	FL	AZ	2004 EPA Guidelines
Treatment	Tertiary Oxidized Coagulants (If Required) Filtration Disinfection	Secondary Coagulants (If required) Filtration Disinfection	Secondary Coagulants (If required) Filtration Disinfection	Secondary Filtration Disinfection
BOD5	Unspecified	20 mg/L CBOD5 (annual avg)	Unspecified	≤ 10 mg/L
TSS	Unspecified	5 mg/L	Unspecified	≤ 5 mg/L (avg) in lieu of turbidity
Turbidity	2 NTU (24 hr. avg); 5 NTU (Max 5% of 24 hr time); 10 NTU (max)	Unspecified	2 NTU (24 hr. avg); 5 NTU (Max.)	≤ 2 NTU (24 hr avg) 5 NTU (max)
Coliform	Total Coli: 2.2/100 mL (7 day median); 23/100 mL (30 day max); 240/100 mL (max sample)	Fecal Coli: 75% samples below detection; 25/100 mL (max)	Fecal Coli: ND (4 of last 7 days); 23/100 mL (max)	ND/100 mL 14/100 mL (max)

Before getting NYSDEC approval for the new limits, the Town had to prove the limits could be met. To do this, a filtration/disinfection pilot plant was constructed to treat a portion of the existing plant's effluent, and a replica golf course hole was built using the same soils, grasses, and landscaping as the nearby golf course (refer to Figure 1) so that the reuse treated wastewater could be used as irrigant and provide real world test results. Testing was conducted to make sure the pilot could meet the new standards and that there would be no negative impacts to the golf course or its patrons.

Figure 1: Pilot Plant Building (upper left) and Replica Golf Course Hole (lower left)

In 2006, the Town submitted the new limits to NYSDEC, but before the department approved them, it acted on the USEPA's estuary recommendations by modifying the facility's State Pollutant Discharge Elimination System (SPDES) permit to a lower summer effluent nitrogen concentration of 3.2 mg/l, to become effective in 2016. In addition, the design flow was increased to 5,682 m^3/day (1.5 MGD) and the summertime nitrogen TMDL was reduced from 77 to 18 kg (170 to 40 lbs).

Following the mandate, H2M looked at the current plant loadings to see if the existing SBR system would be able to meet the new limits. At that time, the plant was experiencing up to three times the design organic loading and up to two-and-a-half times the design solids and nitrogen loadings, a result of new/repaired collection systems providing less infiltration, and environmentally-friendly toilets, showers, and appliances using less water. The SBR system volume was insufficient to achieve the lower nitrogen limit at the extra flow/loadings, and the plant didn't have the space to add basins. The engineer determined that the SBR system would have to be converted to an alternative system that wouldn't require additional basins. This alternative system would also have to be able to meet the permitted flow and effluent concentrations during the existing process conversion work, through the NYSDEC approved an interim permit that would be in effect during construction that was limited to only the 6-month period between October and May. The interim permit required that the facility effluent contain $CBOD_5$ and TSS concentrations equal to or less than 100 and 60 mg/l, respectively, on an average monthly basis. After the six months, the facility would be required to meet the new monthly average concentrations: 25 mg/l $CBOD_5$, 30 mg/l TSS, 40 lbs/day TN (summer), and 130 lbs/day TN (winter).

A review of the literature available at that time indicated that many plants had faced similar issues. Some of these plants chose to convert their existing SBR system to a fixed-growth system, such as a Moving Bed Biofilm Reactor (MBBR) (Weiss, 2005), an Integrated Fixed-Film Activated Sludge (IFAS) process, or a ballasted clarification system. But the vast majority of the plants converted their SBR system to a flow-through MBR system. However, no plant could be found that converted their SBR system to a batch-type MBR system, though doing so would retain most of the advantages of a batch system (Holland, 2015). Regardless of the selected process, all of the plants struggled to maintain capacity and treatment during the conversion process except for those that had the luxury of bypassing some or all of the flow to a separate treatment facility or temporary mobile units.

METHODOLOGY AND IMPLEMENTATION

Process Selection

To help with the selection process, the Town established several criteria, listed below in order of importance. The new system must:

1. meet the new discharge limits,
2. fit in the space available,
3. reuse existing structures and equipment where practical,
4. use as little supplemental carbon and alkalinity as possible,
5. be easy to operate and operator-friendly, and
6. be able to be reused for irrigation of the adjacent golf course.

The simplest and most cost-effective option was to add a third SBR basin followed by cloth media filtration; however, this option was abandoned early on because it would not fit in the available space, thereby failing to satisfy criterion #2.

Another option was to convert the SBR to a fixed-growth system – such as an MBBR, IFAS, or ballasted clarification system. Fixed-growth systems can operate at higher biomass concentrations than suspended-growth systems (like an SBR) and still allow for good settling, thereby providing the additional biomass needed to achieve the required nitrogen removal without increasing the system volume. However, this option would, like the SBR option, require the addition of some type of tertiary filtration, which may not fit in the available space. This option will also require partitioning the current SBR basins into separate anaerobic, aerobic, and anoxic cells, which means each basin will have to be offline for an extended period during construction and civil costs will be significant.

A third option was to convert the SBR to a conventional flow-through MBR, similar to the system shown in Figure 2 depicting a typical conventional 5-stage MBR for biological nutrient removal (BNR), including the volatile fatty acid (VFA), nitrate, and biomass recycle flows in terms of influent flow (Q). Because low-pressure membranes are used in place of a clarifier or decanter, settling is not needed and the system can operate at a much higher biomass concentration than a conventional activated sludge plant. Therefore, like the fixed-growth option, this option can achieve the required nitrogen removal without increasing the system volume. Unlike the fixed-growth option, this option will not require additional filtration since the membranes will produce an effluent that is much better quality than required for reuse. However, like the fixed-growth option, the existing SBR basins must be partitioned into separate anaerobic, aerobic, and anoxic cells. An additional disadvantage with this option is that the membranes require much more capital than tertiary filters.

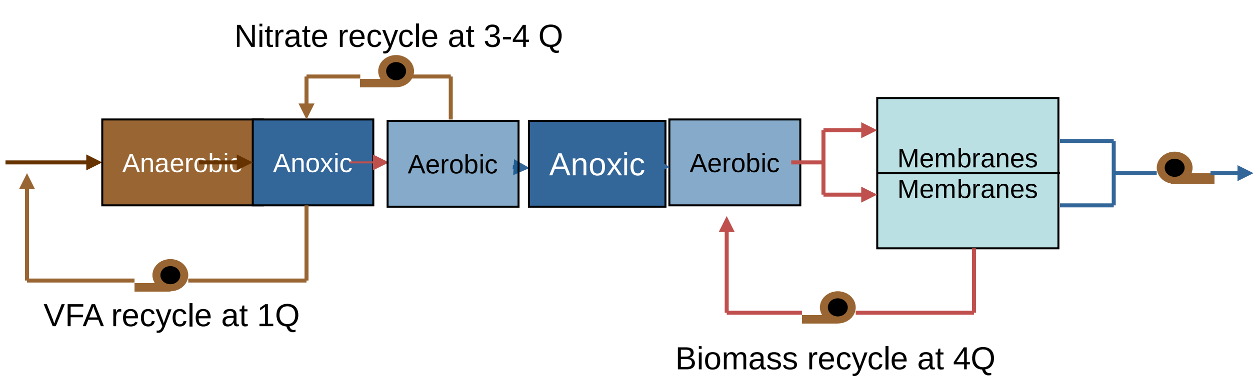

Figure 2: Typical Conventional Flow-Through MBR for Maximum BNR

The final option was to convert the SBR into a batch-style MBR, which is very similar to an SBR only with low-pressure membranes in lieu of decanters and a recycle loop added to control the biomass concentration in the membrane tanks (refer to Figure 3). Like an SBR, the anaerobic, anoxic, and aeration functions are all performed in the same basin, eliminating the need for the VFA and nitrate recycle loops used in the flow-through MBR. The batch-style MBR also has many of the other advantages of an SBR: built-in equalization, no chance of the influent “shortcircuiting" to the effluent (in a two-bioreactor system), and lower usage of coagulant and supplemental carbon and alkalinity. In addition, the bioreactor level can be lowered in a batch-style MBR to better accommodate low flows/loadings. The only drawback to a batch-style MBR is that the variable level in the bioreactors results in slightly less maximum capacity than a flow-through MBR.

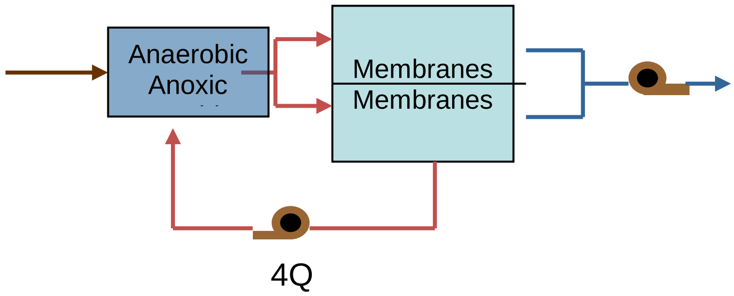

Figure 3: Batch-Style MBR for Maximum BNR

Because of the many advantages of a batch-style MBR, the Town selected to go with this option.

Plan for Reusing Existing Structures and Equipment

Figure 4 shows the SBR treatment process installed in 2000, which consisted of bar screens, grit removal, equalization basin, pump station, (2) SBR basins, (2) post-equalization basins, and an ultraviolet (UV) radiation system. Waste solids from the SBR were dewatered with a gravity belt thickener (GBT) and belt filter press (BFP), with the supernatant transferred back to the bar screens.

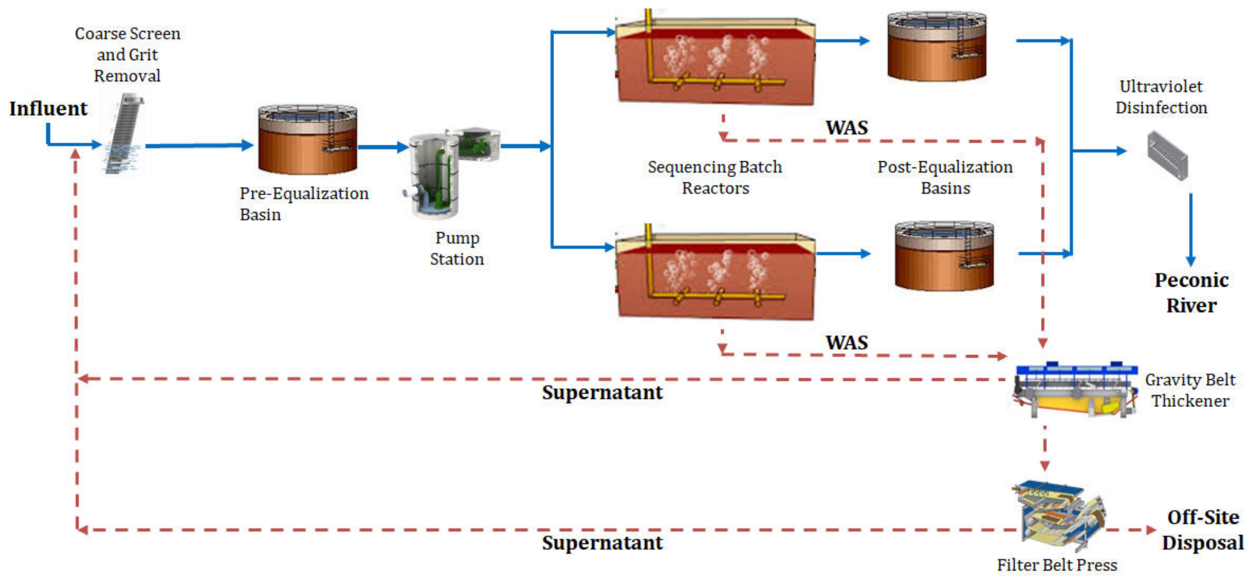

Figure 4: SBR System as Installed in 2000

In converting this system to a batch-style MBR, almost all of these existing structures and equipment were to be reused, though the function of some was to be changed as follows:

- The existing influent coarse screen with bypass bar rack headworks channel was refitted for dual fine screen headworks equipment.
- The exiting pre-equalization tanks were supplemented with additional tankage adjacent and connected to the existing tanks to double the available equalization volume.
- SBR tanks were to be changed to bioreactor tanks.
- The two post-equalization tanks were to be changed to four membrane basins (two per tank), a dry pit pump vault to house five membrane feed pumps, two waste sludge pumps, and a return activated sludge (RAS) flow channel that were all to be added within footprint of the post-equalization tanks.
- An abandoned scavenger effluent filter room was to be changed to the permeate pump room, new laboratory, chief operator's office, and the back end of the plant bathroom.
- The unused trickling filters were to be changed to the reuse water holding tanks.
- The abandoned anaerobic digester boiler and pump room was to be changed to the scavenger and thickened sludge blower room.
- The three existing SBR blowers were to be changed to membrane air scour blowers.

Plan for Acquiring New Equipment

The only pieces of equipment that were not to be reused were the SBR decanters and the influent mechanical rake with bypass bar rack. The decanters were to be removed, and the rake was to be replaced with a dual fine screen with screening washer/compactor in the same location.

As noted earlier, the biomass concentration in the bioreactors was to be increased from that used in the original SBR basins in order to achieve the required nitrogen removal; oxygen transfer into the thicker biomass would be lower such that more air would be needed and eight retrievable fine bubble diffuser racks were to be added to each SBR basin. In addition, more anoxic time would be needed, which would increase the air flow during the shorter aeration steps, requiring bioreactor blowers much larger than the original SBR blowers.

The four membrane tanks will each contain (2) submersible 1500 m^2 ultrafiltration (UF) modules. A module contains 44 rows, each with 9 bundles of 311 hollow fibers. The fibers are constructed of polyvinylidene diflouride (PVDF) and filter the wastewater using an outside-to-inside flow path, enabling the membrane to handle solids concentrations as high as 14 g/l.

The new MBR system would also require equipment that was not needed on the original SBR system: five permeate pumps, a permeate tank, two feed systems for cleaning chemicals, a compressed air system for process valve operation, and various mechanical/motorized valves and instruments. In addition, the plant personnel requested a controls upgrade to allow them to access the system remotely as well as one that could be used to optimize nutrient removal, power/chemical usage, and waste volume by automatically changing process parameters (active mode) or instructing the operator to do so (passive mode), through the use of in line process monitoring probes.

Equipment that employs energy-efficient measures – such as variable frequency driven motors, in-tank probes for real-time process monitoring, and motion sensors for lighting – were added to reduce the overall carbon footprint. Also, 305 m (1,000 feet) of HDPE force main piping was to be purchased to install under the golf course using trenchless directional drilling techniques to get the reuse water to a new golf course irrigation booster pump system; this was planned to eliminate costly rehabilitation of fairways, tees, and greens, that would have been involved with this construction. New equipment will also be added to obtain better control over the treatment operations: wireless connectivity, fiber optic cables, a supervisory control and data acquisition (SCADA) loop with remote access, and more reliable sensors.

Equipment Procurement, Fabrication, and Delivery

With all goals in place, the upgraded plant and resource recovery systems project was estimated to cost $23.5 million, $2 million of that attributed to the resource recovery irrigation system. In 2010, the Town obtains a $2 million NYSDEC grant to defray costs of the project as long as the reuse portion is included. Then in 2013, the Town obtains an $8 million Suffolk County infrastructure grant. For the remainder of the project cost, the New York State Environmental Facilities Corporation (NYSEFC) provided short-term construction funds and a low-interest long term loan.

In 2013, the project was renamed the Water Resource Recovery Facility (WRRF), and the plans and specifications were created and advertised for receiving construction bids. The contract was awarded to R.J. Industries and Welsbach Electrical Corp. of Long Island in early 2014, who ordered the equipment shortly thereafter, including the Aqua-Aerobic® MBR batch-style system. The MBR equipment was procured and delivered to the site in late 2014, with the exception of the (8) 1500-m^2 membrane modules; to avoid damaging the membranes during construction, the membranes were delivered within two weeks of being placed into operation.

Equipment Installation

To keep the plant running as smoothly as possible during the conversion, the equipment was installed in the following order: equipment outside of the SBR/post-equalization basins (except in control room), equipment inside the SBR/post-equalization basins #1, equipment inside the SBR/post-equalization basins #2, and control room equipment. Figure 5 shows the equipment in and around the existing SBR basins that was removed (in red) and installed (in green) to convert them to a batch MBR system.

Installation of the equipment outside of the SBR/post-equalization basins included the following:

- Additional pre-equalization tankage and new pre-equalization pump station and controls to allow for improved equalization flows to the single train SBR system, during the following conversion process.
- The five permeate pumps, two cleaning chemical systems, new laboratory, chief operator's office, and back end of the plant bathroom were installed in the abandoned scavenger effluent filter room.
- The permeate tank was installed just outside the filter room.
- The three new bioreactor blowers were installed next to SBR basin #1.

- The MBR control panel, motor control center, and compressed air system were installed in the new control building.
- The existing SBR air piping was rerouted to where it will connect to the air scour header to the membrane tanks.
- The unused trickling filters were changed into the reuse water holding tanks. These tanks were also temporally used a chlorine contract tanks for the single train SBR/Post equalization tanks during the following conversion process.
- The scavenger and thickened sludge blowers were installed in the abandoned anaerobic digester boiler and pump room.
- The dual fine screen with screening washer/compactor was installed in place of the influent mechanical rake with bypass bar rack.
- Wastewater disinfection system for Peconic River outfall discharge
- Wastewater recovery disinfection system for reuse water irrigation outfall discharge
- Force main piping was installed under the golf course.

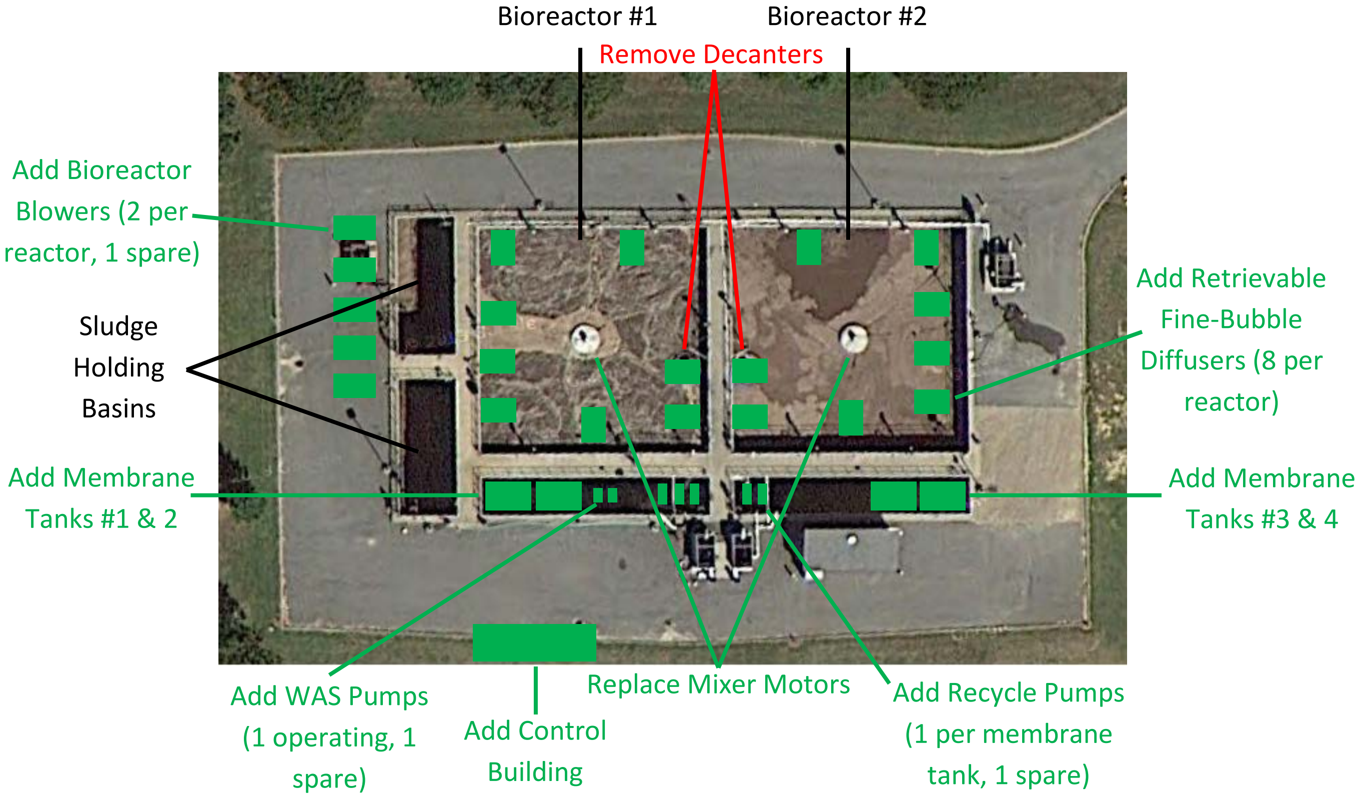

Figure 5: Conversion of SBR to MBR

Once the equipment outside the SBR basins was installed, SBR Basin #2 and Post-Equalization Basin #2 were placed into single-basin mode while the decanter was removed from SBR Basin #1 and the new equipment was installed in the train #1 basins. Once complete, the upgraded train #1 was operated as a single-basin flow-through MBR while similar changes were made to SBR #1 and post-equalization basin #1. When all of the equipment had been installed, the MBR system was placed in normal 2-basin batch mode.

Temporary chlorine disinfection ws utilized during the period with single train SBR/Post Equalization basins use to meet the disinfection requirements for the Peconic River outfall.

RESULTS AND DISCUSSION

Performance During Construction

Prior to the conversion, the SBR system was struggling to meet the original permitted effluent solids and nitrogen limits (10 mg/l each) – as indicated in Table 2 – due to the increased influent concentrations. Once the first SBR basin was converted to a single-train MBR, the system was able to meet the solids limit and the new nitrogen limit (3.2 mg/l). When both trains were placed into batch MBR mode in August of 2016, the solids and nitrogen concentrations dropped even further.

Table 2: System Effluent During Conversion to MBR

	AVG BOD_5 (mg/l)	AVG TSS (mg/l)	AVG TN (mg/l)
EXISTING SBR PROCESS BEFORE CONSTRUCTION	8	10.9	12.5
SINGLE MEMBRANE BIOREACTOR PROCESS TRAIN	< 4	2.7	3.2
DUAL MEMBRANE BIOREACTOR PROCESS TRAIN	< 4	< 1	2.9

Nitrogen Removal

The system is now producing a low-nitrogen effluent. The influent nitrogen averaged 55.6 mg/l for 2017, while the effluent nitrogen averaged 3.0 mg/l, a 94.6% reduction year-round (Figure 6).

Figure 6: Influent and Effluent Total Nitrogen (TN) Concentrations

The average flow for 2017 was 1.16 MG (4,394 m^3/day), with 0.92 MGD (3,228 m^3/day) discharging to the river, resulting in an average daily nitrogen discharge of 23.2 lbs (13.3 kg) (Figure 7).

There are several reasons for this. First, the MBR control system includes the IntelliPro® Process Management System, which can be set up to automatically adjust the time that the WAS pump runs during each MBR cycle in order to maintain a target sludge retention time (SRT), food-to-microorganism (F/M) ratio, or mixed-liquor suspended solids (MLSS). Figure 7 shows a system with the target pounds of MLSS set at about 14,000 lbs per basin and how the IntelliPro adjusts the amount of WAS wasted to achieve this value. The higher the mass of microorganisms in the system, the more ammonia can be converted to nitrate (nitrified) and the more nitrate can be converted to nitrogen gas (denitrified). Through automatic mass control, the MLSS can be maintained at the level that results in the best nitrogen removal.

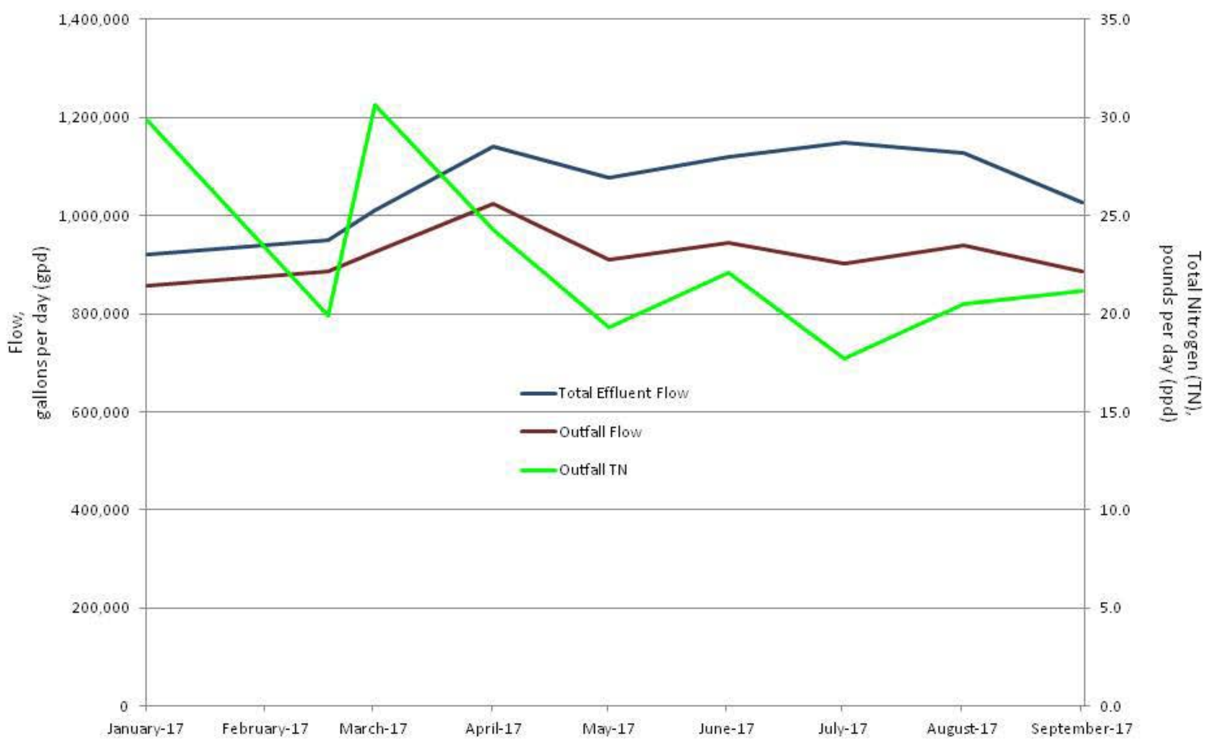

Figure 7: Flows and Total Nitrogen (TN) TMDLs

Figure 8: Example of Automatic Control of Bioreactor MLSS

Another reason for the low nitrogen levels is that the mixing and aeration devices in each bioreactor are separate from each other, such that anaerobic, aerobic, and anoxic conditions can be achieved in each basin simply by leaving the mixer running and turning on and off the aeration blowers. Blower timers in the PLC allow the system to alternate between multiple aerobic and anoxic periods, allowing the total nitrogen level in the basin to drop lower than for flow-through systems with one or two anoxic basins. The batch-style MBR has been able to outperform flow-through MBRs because it allows for more and longer anoxic periods, as shown in Figure 9.

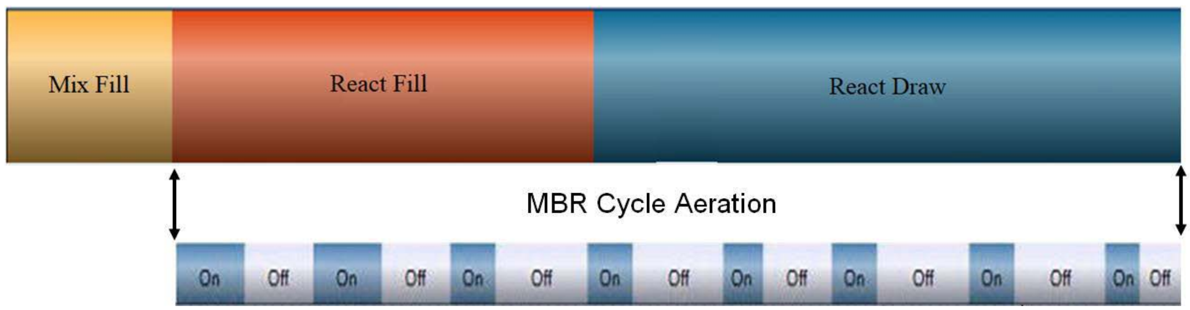

Figure 9: Batch-Style MBR Cycle to Achieve Low Total Nitrogen

Transmembrane Pressures (TMPs)

The transmembrane pressure (TMP) through the membranes has been very low. The average TMP through each membrane basin ranged between 48 – 76 mbar (0.7 and 1.1 psi), indicating very stable operation. Figures 10 through 13 show the TMP for each membrane tank for October and November of 2017; these values are indicative of the TMPs that have been recorded since startup.

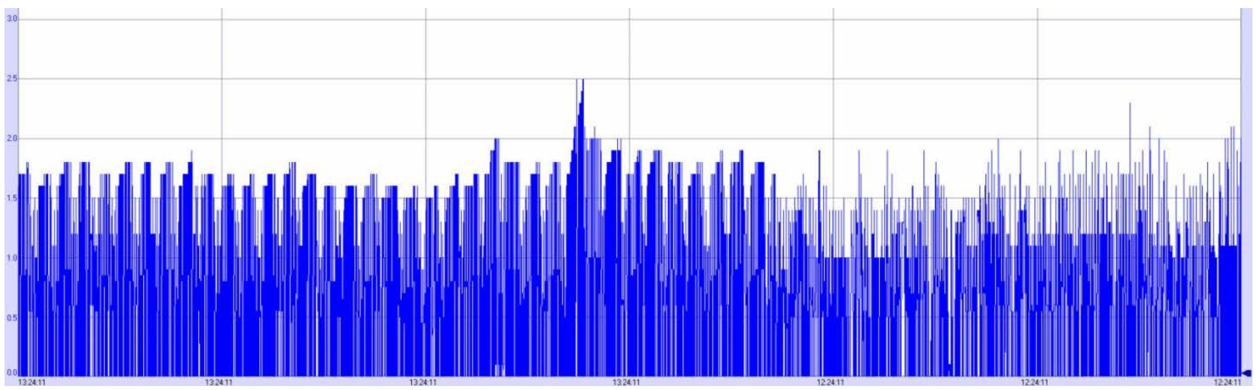

Figure 10: Membrane Tank #1 TMP – Oct-Nov 2017

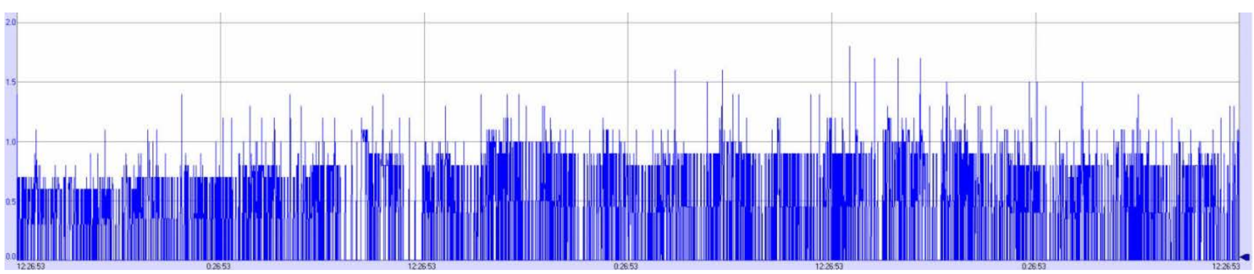

Figure 11: Membrane Tank #2 TMP – Nov 2017

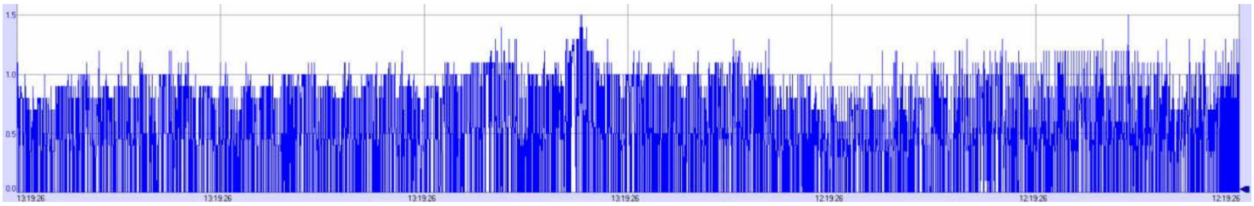

Figure 12: Membrane Tank #3 TMP – Oct - Nov 2017

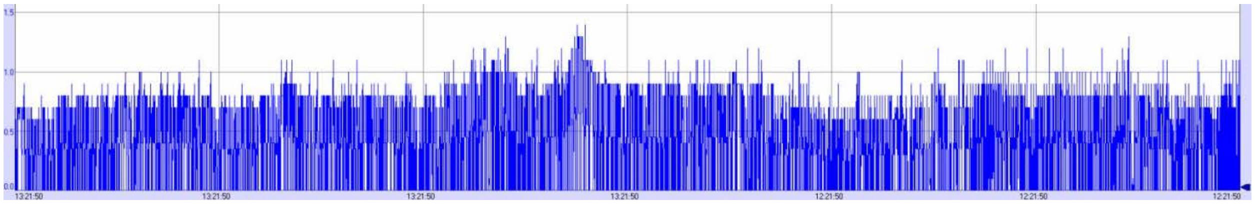

Figure 13: Membrane Tank #4 TMP – Oct - Nov 2017

The reasons for the low TMPs are due to a couple of unique characteristics of the membrane design, as shown in Figure 14. The air scour is injected right into the middle of the fiber bundle and doesn't have to go around a bottom header, and the tops of the membrane fibers are free-floating, not potted into a top header like most other hollow-fiber membranes. This means that the air scour contacts the entire length of the fiber – there are no "dead zones" at the top and bottom where the air has to go around the headers on other membranes. This also means that solids and debris (hair, etc.) can flow freely up through the fibers without collecting on a top header. These two features prevent sludging from occurring and keep the TMPs low.

Figure 14: MBR Membrane Fiber Bundle

CONCLUSIONS

The Town of Riverhead, NY constructed a new $23M facility that repurposed existing tanks/buildings to the fullest extent and is capable of diverting up to 0.45 MGD (1,705 m^3/day) to the adjacent golf course during irrigation seasons, reusing up to 0.1 MGD (379 m^3/day) at the facility year round, and discharging the remainder to the Peconic River. The result was that the Town used 333,000 less cubic meters (88 million less gallons) of water from its aquifer last year. This facility is the first municipal reuse plant in New York State and was completed in time for the 2016 irrigation season and within budget.

The conversion of the existing SBR system into a batch MBR was able to successfully achieve the required nitrogen TMDLs at the current flows and loadings, with an average nitrogen removal of 96.4%. The fact that the single-basin MBR was also able to achieve this is a strong indicator that the two-basin system will continue to do so as the flow approaches the plant's 5,682 m3/d (1.5 mgd) design capacity. The main reasons for this high degree of nitrogen removal are that the control system automatically regulates the mass in the system and that each operating cycle has multiple timed anoxic periods.

The addition of the water resource recovery process to this facility redirected up to 41% of the effluent water each day during the irrigation season from the Peconic River outfall to the wastewater reuse irrigation outfall, further reducing the overall nitrogen discharged to the Peconic Estuary. The nitrogen loading in the irrigation water was dispersed among the planting in and gasses of the golf course taking the place of a portion the normal fertilization requirements for the golf course maintenance. This equated to a further 30% reduction of the loading to the Peconic Estuary beyond what the upgraded treatment facility was already providing.

Lastly, the system operated stably at very low TMPS, averaging 48 – 76 mbar (0.7 and 1.1 psi). The reasons for the low TMPs are that the unique membrane design allows the air scour to contact the entire length of the fibers and has eliminated the top header where sludge and debris can accumulate.

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