Final Report

December 15, 2022

TDEC Contract for Municipal Wastewater Treatment Facility Optimization, Nutrient Reduction, and Energy Savings

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The Water Planet Company DBA CleanWaterOps

Summary

Over a two-year period, Grant Weaver of Grant Tech joined TDEC staff in working with four Tennessee municipal wastewater treatment facility owners to optimize nutrient removal and energy usage at their treatment facilities. Technical training, data review, in-plant visits, and remote support were provided. The two facilities that remained engaged throughout the process – Oneida and McMinnville – realized measurable improvements.

Oneida. Working with Brett Ward of MTA (University of Tennessee Municipal Technical Advisory Service), Oneida staff – lead by Greg Burchfield – had, prior to the TDEC optimization effort, significantly reduced energy usage and improved nutrient removal. As recommended by Brett Ward, operation of Oneida's oxidation ditches' aeration rotors was changed as follows. Instead of the four rotors running 24/7 as designed, the aeration rotor nearest the influent was turned off and the other three rotors were cycled on for three hours and off for three hours. This change resulted in a big improvement in total-nitrogen removal. Effluent phosphorus has likewise been historically better than average, yet significant seasonal spikes were occurring.

TDEC provided Oneida staff with the use of a spectrophotometer for weekly phosphorus testing. Using the instrument, Oneida staff was able to monitor the impacts of the various operational changes recommended by the team. Optimal phosphorus removal was achieved by turning off the mixers that historically were operated when the aeration rotors cycled off. With less mixing, an anaerobic blanket of settled mixed liquor developed during the rotor-off cycles, creating optimal conditions for biological phosphorus removal. During summer months, the settled sludge became too septic and one of two mixers was operated to eliminate the summertime effluent phosphorus spikes.

Energy savings were realized in two ways. One, cycling the aeration rotors on and off. Two, reducing run time on the two submerged mixers. Quantifying electrical savings, as discussed below, however proved difficult.

McMinnville. Under the supervision of new plant manager Chris Klecker, McMinnville's wastewater treatment plant staff has significantly improved operations by stabilizing plant performance during storm flows.

After cleaning the storage building of inventoried sludge, after bringing both digesters on-line, and after a month of staffing double shifts to dewater and remove sludge, the bacterial population in the aeration tank – the mixed liquor suspended solids (MLSS) – is now one-half of the historical norm. The actuator installed on the mid-ring inlet valve to the oxidation ditch is now fully functioning and in use during storm flows, allowing a much longer retention time in the oxidation ditch to provide more consistent ammonia-nitrogen removal.

The discs on all of the aeration rotors have been replaced as they were slipping due to manufacturing defects. And. With the solids inventory under management, there is no need for two digesters. Both are fully operational but only one of two is now in service.

Harpeth Valley. The optimization team encouraged plant staff to reduce mixing in the pre-anoxic zones of Harpeth Valley's parallel oxidation ditches to create fermentation zones for biological phosphorus removal. After engagement by Harpeth Valley's wastewater staff, most notably Albert Solberg and Brad Roberts, upper management opted to withdraw from the optimization effort before a trial could be performed.

Dickson County. The optimization team visited both Dickson County's White Bluff and Jones Creek wastewater treatment plants. The team's visit to Jones Creek was more learning experience than technical support as the facility has historically provided excellent biological nutrient removal. The McMinnville staff accepted the team's invitation to visit the Jones Creek plant – a facility nearly identical to the McMinnville plant – to see if Dickson County's approach to managing storm flows could be applied to McMinnville.

At the White Bluff wastewater treatment facility, Dickson County staff repurposed an existing, but empty, 2000-gallon tank to create a side-stream fermenter for biological phosphorus removal. After several weeks of operation with no observable improvement in phosphorus removal, treatment plant staff terminated the trials and withdrew from the optimization study.

Training

The seven webinar classes summarized below were presented by Grant Weaver of Grant Tech.

Session 1
Wednesday, February 3, 2021
10:00 AM - Noon Central Time
Optimizing Nitrogen Removal in Activated Sludge WWTPs – Introduction/Overview
What an operator needs to know about the science and technology of biological nitrogen removal. Understanding, identifying, and monitoring aerobic habitats for ammonia-nitrogen conversion to nitrate-nitrogen. Understanding, identifying, and monitoring anoxic habitats for nitrate-nitrogen conversion to nitrogen gas.

Session 2
Wednesday, February 10, 2021
10:00 AM - Noon Central Time
Optimizing Phosphorus Removal in Activated Sludge WWTPs – Introduction/Overview
What an operator needs to know about the science and technology of biological phosphorus removal. Understanding, identifying, and monitoring fermentive habitats for the first phases of biological phosphorus removal. Understanding, identifying, and monitoring aerobic habitats for the final phase of biological phosphorus removal.
Discussions regarding nitrate interference and controlling the re-release of phosphorus.

Session 3
Wednesday, February 17, 2021
10:00 AM - Noon Central Time
Optimizing Nitrogen and Phosphorus Removal in Activated Sludge WWTPs – Case Studies
Review lessons learned during first two sessions followed by illustrations of optimization efforts/opportunities/results achieved at municipal WWTPs across the US.

Session 4
Wednesday, February 24, 20121
10:00 AM - Noon Central Time
Optimizing Nitrogen and Phosphorus Removal in Activated Sludge WWTPs – Oxidation Ditches. Case study discussions of oxidation ditch WWTPs that have optimized phosphorus removal – what, why, how.

Session 5
Wednesday, March 3, 2021
10:00 AM - Noon Central Time
Optimizing Nitrogen and Phosphorus Removal in Activated Sludge WWTPs – SBRs.
Case study discussions of SBR WWTPs that have optimized phosphorus removal – what, why, how.

Session 6
Wednesday, March 10, 2021
10:00 AM - Noon Central Time
Optimizing Nitrogen and Phosphorus Removal in Activated Sludge WWTPs – Conventional Activated Sludge. Case study discussions of conventional activated sludge WWTPS that have optimized phosphorus removal – what, why, how.

Session 7
Wednesday, March 24, 2021
10:00 AM - Noon Central Time
Optimizing Nitrogen and Phosphorus Removal in Activated Sludge WWTPs – Participant Case Studies. A facilitated brainstorming discussion of the participants' treatment plants. For each facility, specific changes in day-to-day operations were discussed.

Site Visits

Monday, April 5, 2021: Initial site visit to Oneida, TN wastewater treatment facility

Tuesday, April 6, 2021: Initial site visit to McMinnville, TN wastewater treatment facility
Wednesday, April 7, 2021: Initial site visit to Harpeth Valley wastewater treatment facility (Nashville, TN)
Thursday, April 8, 2021: Initial site visit to Dickson County wastewater treatment facilities (Dickson, TN & White Bluff, TN)

Wednesday, July 14, 2021: Follow-up visit to Oneida, TN wastewater treatment facility to review data, gain an understanding of the facility, and explore options for operating the facility differently in order to remove nutrients.
Wednesday, July 14, 2021: Follow-up visit to McMinnville, TN wastewater treatment facility to review data, gain an understanding of the facility, and explore options for operating the facility differently in order to remove nutrients.
Thursday, July 15, 2021: Follow-up visit to Harpeth Valley wastewater treatment facility (Nashville, TN) to review data, gain an understanding of the facility, and explore options for operating the facility differently in order to remove nutrients.
Thursday, July 15, 2021: Follow-up visits to Dickson County wastewater treatment facilities (Dickson, TN & White Bluff, TN) to review data, gain an understanding of the facility, and explore options for operating the White Bluff facility differently in order to remove nutrients.

Tuesday, December 14, 2021: Follow-up visit to Oneida, TN wastewater treatment facility to review data, gain an understanding of the facility, and explore options for operating the facility differently in order to remove nutrients.
Wednesday, December 15, 2021: Follow-up visit to McMinnville, TN wastewater treatment facility to review data, gain an understanding of the facility, and explore options for operating the facility differently in order to remove nutrients.
Thursday, December 16, 2021: Follow-up visit to Harpeth Valley wastewater treatment facility (Nashville, TN) to review data, gain an understanding of the facility, and explore options for operating the facility differently in order to remove nutrients.

Guidance Documents

As presented in a progress report and appended to the end of this report, plant specific guidance documents were prepared for the Oneida, McMinnville, Harpeth Valley (Nashville) and White Bluff wastewater treatment facilities as a series of emails. The guidance documents contain detailed recommendations for process changes to improve nitrogen and phosphorus removal as well as energy savings. Including sampling, testing, and recommendations for adjusting various treatment components in order to optimize treatment plant performance, specifically nitrogen and phosphorus removal.

Plant by plant summaries of the optimization efforts follow. For each participating facility, a discussion of the recommendations and implementation follows.

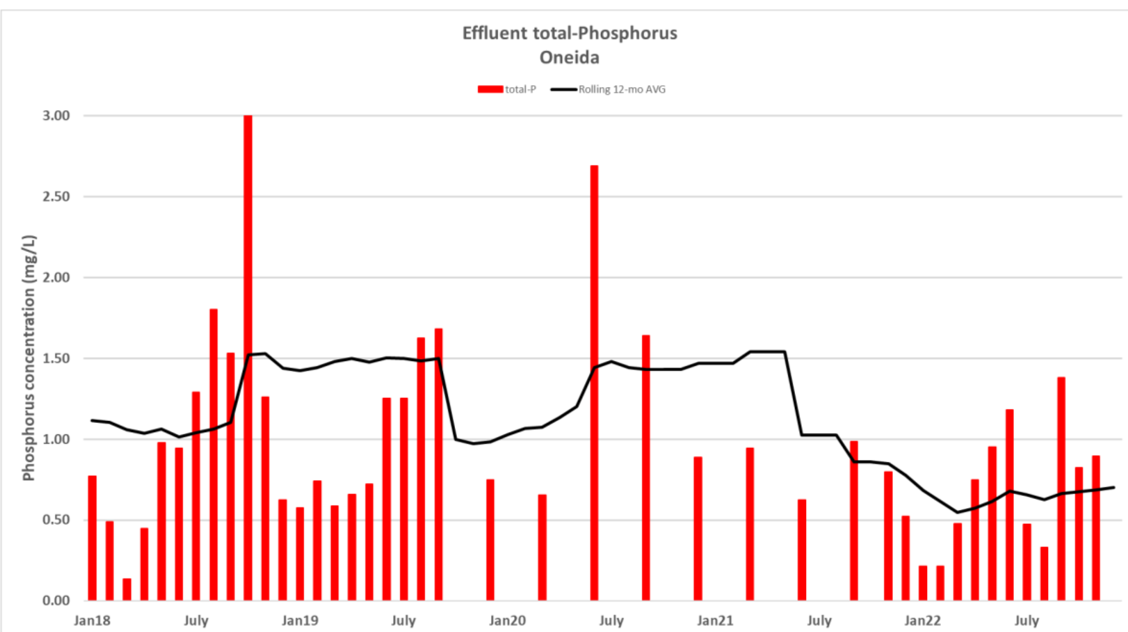
Oneida

By using weekly in-house phosphorus testing results to monitor and adjust treatment, Oneida staff have been able to improve phosphorus removal by both lowering wintertime effluent total-phosphorus and eliminating the summertime spikes while controlling energy usage.

Prior to the optimization team's involvement, Tennessee wastewater wizard Bret Ward provided Oneida with invaluable advice. Advice that Oneida staff put into use. The aeration rotor nearest the influent is kept off and the other three are cycled on for three hours and off for three hours. Resulting in very good nitrogen and phosphorus removal as illustrated in the table that follows.

	BOD	TSS	pH	tN	NH_3	tP
2019	4	7	6.9	6.3	0.4	1.0
2020	3	6	7.1	7.2	0.3	1.5

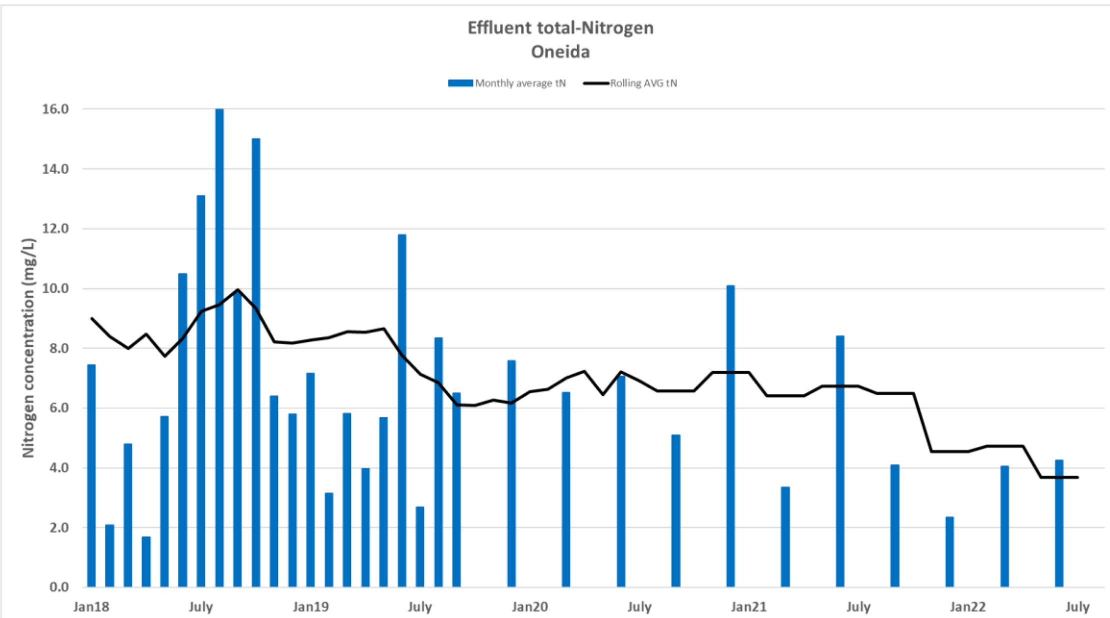
To improve phosphorus removal, plant staff turned down the air-off mixing to allow for some settling of the mixed liquor to occur during the air-off cycles. With the air off for periods of three consecutive hours and minimal mixing, a sludge blanket is created. The bottommost layer of the sludge blanket becomes temporarily septic enough to create the volatile fatty acids (VFAs) that the phosphate accumulating organisms (PAOs) need to thrive. During the air-off cycles VFAs are created and consumed by the PAOs. The energized PAOs multiple during the air-on cycles. As the PAOs grow they pull phosphorus out of solution and concentrate it in their cells. Thereby making soluble phosphorus into a part of the MLSS so that phosphorus is removed as sludge is wasted.



Oneida staff found that there is an optimal amount of mixing for phosphorus removal. Too much mixing and the sludge blanket doesn't become septic enough. Too little mixing and the sludge blanket becomes too septic. During winter months, one of two submersible mixers operating at a

VFD setting of 50% seems to be ideal. During the summer, the one in-service mixer is turned up to 100% to keep the sludge blanket from becoming too septic. Weekly in-house testing using TDEC supplied equipment has proven invaluable in dialing in phosphorus removal. Without these changes, phosphorus might have become an issue as Oneida's flow approaches design capacity. TDEC's goal is 1.0 mg/L at design flow and phosphorus was often above 1.0. Now, however, effluent phosphorus is averaging 0.7-0.8 mg/L.

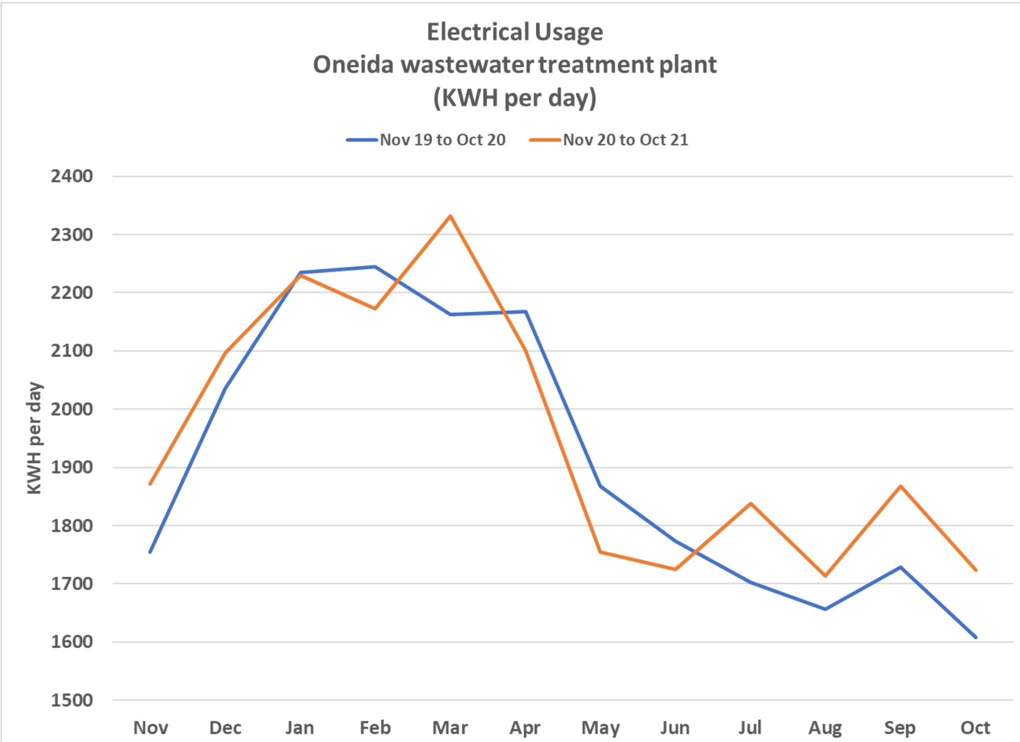
TDEC's nitrogen goal is 8 mg/L at design flow. With an historical average of less than 8 mg/L and a flow that is well below design capacity, nitrogen should not be an issue for Oneida for many years. See the graph below.



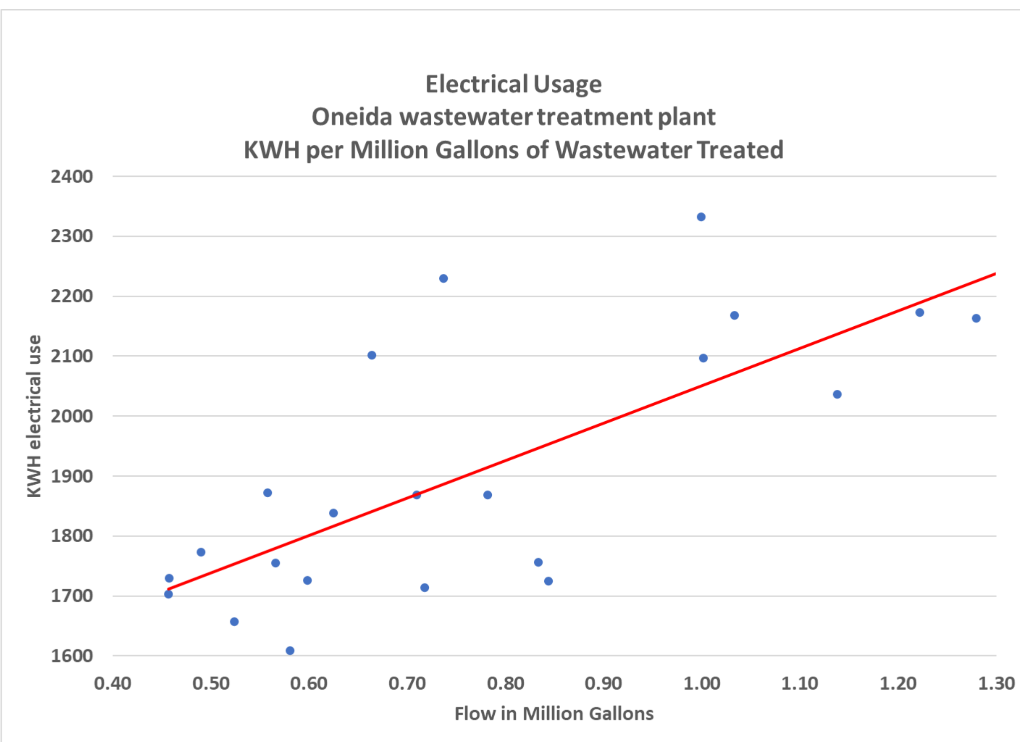
Electrical data were analyzed in an effort to quantify the savings made with operational changes. Fortunately for Oneida but unfortunately for the purposes of this study, the process changes recommended by Brett Ward of the University of Tennessee's Municipal Technical Advisory Service (MTAS) predate the study by several years and "before" and "after" electrical data are not available. The savings were surely substantial as the facility formerly operated with all four of its aeration rotors running 24 hours a day. It now operates with one rotor always off and the other three operating 3 hours on and 3 hours off.

Additional electrical savings did result from the optimization project but the savings were too small to pick up from electric bills. Instead of two submersible mixers operating at full speed around the clock, only one is now operated at a time. And, for much of the year, the one in-service mixer is operated at 50%.

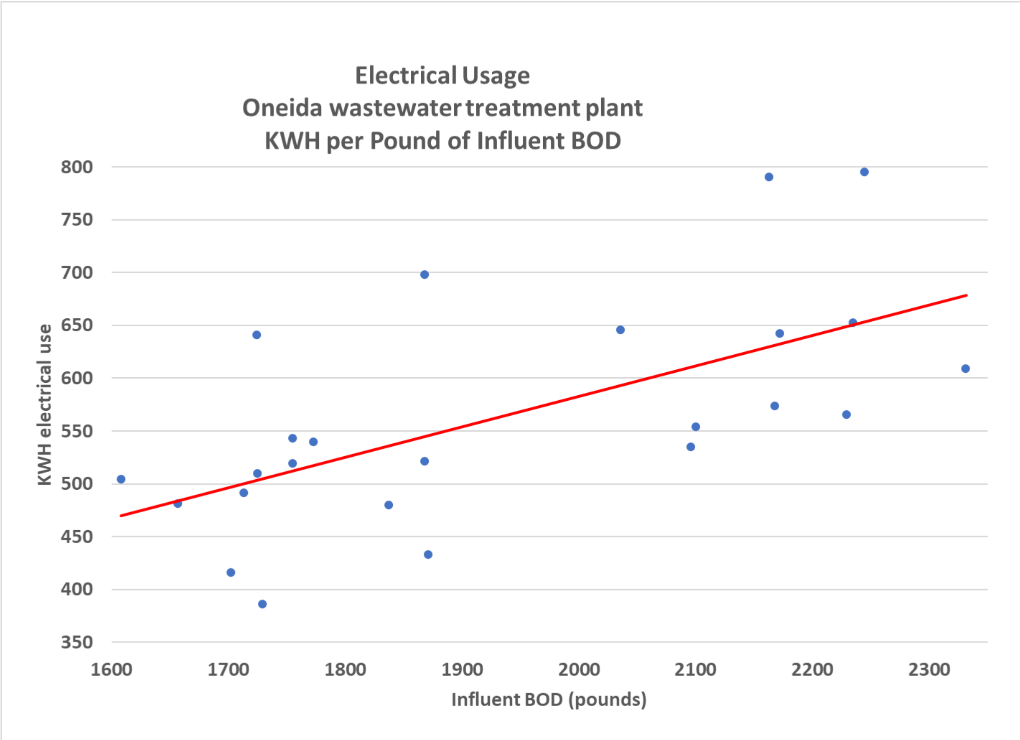
A series of charts follow to illustrate the electrical usage at the Oneida wastewater treatment facility. The first graph shows electrical usage in KWH for the two years of the study. Seasonal impacts are clearly evident.



Why the increase in electrical consumption during winter months? Is the increase flow related? Is it because of increased organic loading on the treatment facility? Is it a combination of the two? Or something else altogether?



The chart on the preceding page makes a strong case for electrical consumption to be related to flow. And. The chart that follows similarly illustrates a strong correlation between influent BOD (organic loading) and electrical use.

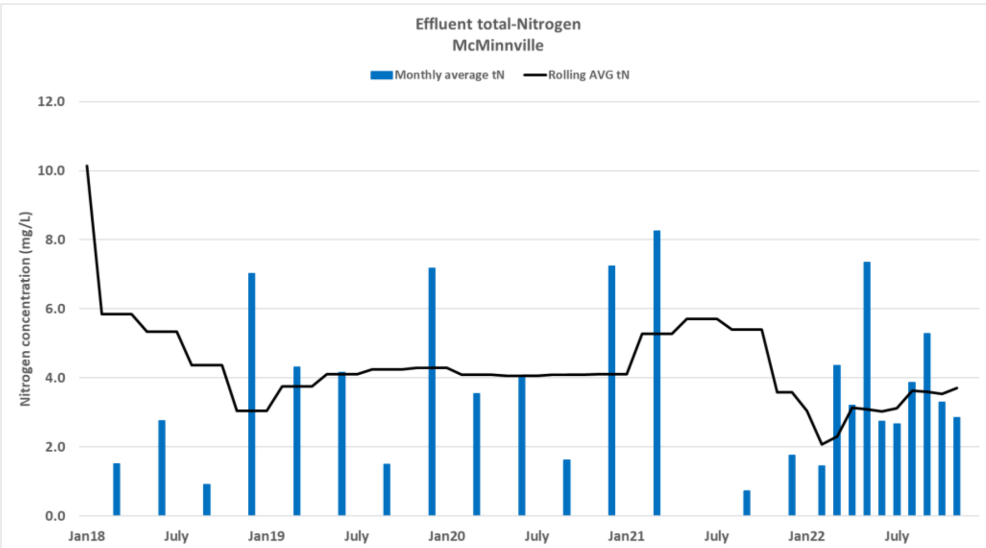


To further reduce electricity, periodic changes in the air-on / air-off cycles may be possible. Oneida staff daily test for ammonia. Using the ammonia results, it may be possible to reduce the air-on times when the ammonia concentration becomes “non detect” and increase the air-on times when the effluent ammonia concentration approaches a target setting.

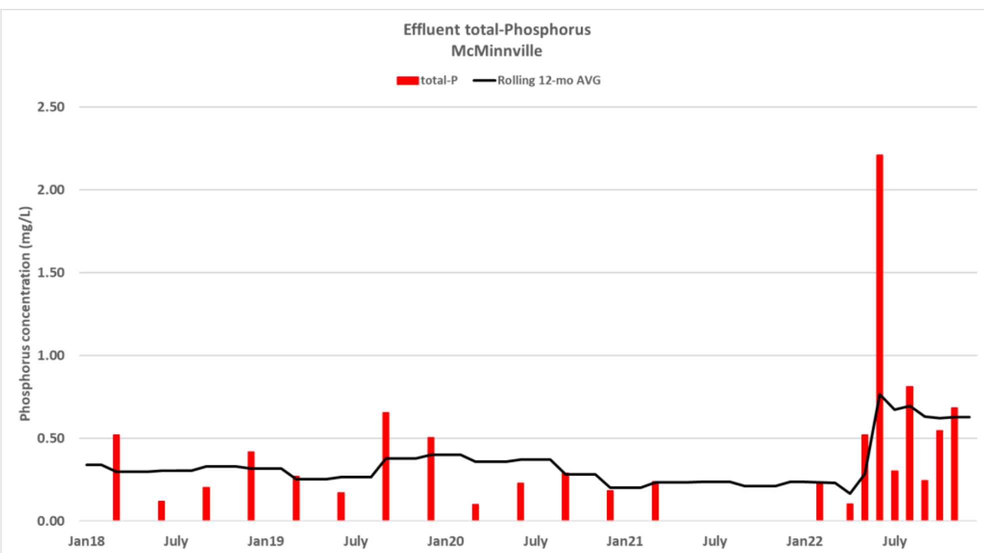
Another energy savings possibility is to aerate the sludge holding tank for only 1-2 hours daily. And, to the extent possible, schedule the aeration to occur at a time of day when the electrical demand charge is at a minimum.

McMinnville

As the charts that follow illustrate, effluent nitrogen and phosphorus were low prior to and throughout the optimization effort. What isn't evident in the data are significant swings in ammonia removal. Effluent nitrogen averages 4 mg/L, a quite low concentration.



Effluent phosphorus is likewise very low, averaging approximately 0.5 mg/L.



The optimization team's recommendations follow. The focus being consistent operations during stormflows, something with which McMinnville historically struggled.

At the study's onset, the mixed liquor suspended solids (MLSS) concentration in McMinnville's Orbal oxidation ditch was 6000 mg/L and higher. During frequent and extended periods of high flow, McMinnville staff opened valving to allow flow to bypass the outer two rings and opened valving to allow all flow into the centermost ring. Doing so had the beneficial impact of minimizing the quantity of solids (as MLSS) flowing into the final clarifiers and thereby minimizing solids washout and maximizing clarifier performance to keep effluent TSS (total suspended solids) to a minimum. The corresponding negative impact was a substantial reduction in hydraulic retention time resulting in poor ammonia removal.

Plant staff resolved the issue by (a) reducing the solids inventory and (b) maximizing treatment during storm flows by bypassing less of the plant for a shorter period of time.

Reducing Solids Inventory
Both aerobic digesters (sludge holding tanks) were put into service. To do this, the out-of-service larger digester was cleaned and the aeration equipment restored to operational status. The inventory of dewatered sludge maintained in the sludge storage building was reduced to near zero by making the sludge available to local farmers at no cost. With both digesters available and the sludge inventory near zero, plant staff operated the sludge dewatering equipment for two shifts versus the normal one-shift, Monday through Friday until the MLSS dropped from over 6000 mg/L to under 3000 mg/L.

Modifying Storm Mode
As the solids inventory was reduced, the existing aeration rotors were all made fully operational and automatic controls were installed on the influent bypass gates. The optimization team coordinated a visit to Dickson County's Jones Creek plant for McMinnville plant staff to see how that facility maximizes treatment during storm flows by their utilization of influent bypass gates. Following the visit, McMinnville staff put the bypass gate on their middle ring into service, including the installation of remote controls. By late 2022 the gate was in use.

Nitrogen
As the preceding graph illustrates, nitrogen removal is rarely bad, often excellent. It is anticipated that the process changes described above will result in more consistent effluent total-nitrogen concentrations.

Phosphorus
The low effluent phosphorus values are believed to be more a result of chemical than biological treatment. Limited in-house orthophosphate testing found the influent concentration to be somewhat higher than that leaving the "anaerobic" outer ring. If the outer ring were working as a fermenter, the orthophosphate concentration leaving that ring would be some three times the influent concentration. Plus, the soluble BOD testing performed by plant personnel showed a really low concentration entering the innermost ring where phosphorus uptake would occur if biological: less than 10 mg/L entering the aerobic zone, not enough to support biological phosphorus removal.

White Bluff (Dickson County)

The 0.5 MGD two ring Orbal-style oxidation ditch receives a typical flow of 0.23 MGD, approximately one-half the design flow. During rain events, the flow can peak at 1.4 MGD.

The facility currently has no total-nitrogen nor total-phosphorus limits. Effluent total-Nitrogen averages 9 mg/L. Effluent total-Phosphorus averages 3 mg/L.

With an effluent ammonia concentration averaging 0.1 mg/L, the facility routinely meets its monthly average ammonia limit of 1.25 mg/L summer and 2.0 mg/L winter.

The facility is equipped with two pairs of rotors, one rotor in the inner ditch ring and one rotor in the outer ring … each pair of rotors is operated by one fixed-speed motor. The operational concept is to establish high dissolved oxygen (DO) conditions in the inner ring for ammonia conversion to nitrate … and to maintain low DO conditions in the outer ring for nitrate conversion to nitrogen gas.

For nitrogen removal, plant staff historically cycled the pair of aeration rotors nearest the influent and return activated sludge (RAS) feed lines for four hours on and four hours off in an effort to strengthen anoxic conditions in the outer ring while maintaining sufficiently aerobic conditions in the inner ring.

The optimization team's recommendations for enhancing biological nutrient removal follow. Included in the discussion is an explanation of efforts made by plant staff to dial in nitrogen and phosphorus removal, including the impact of the changes on treatment performance and energy use.

Nitrogen

For enhanced nitrogen removal, plant staff removed the blades from the outer rotor shaft of the "influent" pair of rotors and relocated the removed blades on the inner rotor shaft. Doing so increased aeration in the inner, aerobic, zone and reduced aeration in the outer, anoxic, zone. The team's recommendation was to operate initially with the same rotor on/off times as had historically been the norm: four hours on / four hours off. And, with time, to consider operating with fewer on hours to enhance nitrate-nitrogen removal. The concept being … more aeration where desired (inner ring) and less aeration where not needed (outer ring) while keeping the same torque on the motor that drives the common aeration shaft.

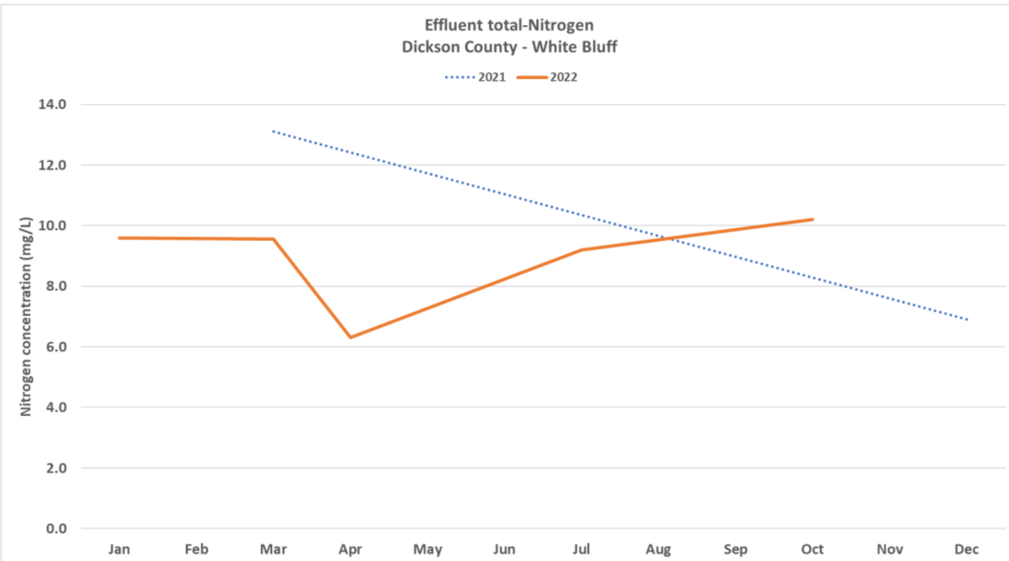
Phosphorus

For enhanced biological phosphorus removal, the following concept was initially discussed. The creation of a fermentive zone in the outer ring by placing two weighted IBC totes with holes cut in them at the bottom of the outer ring halfway downstream of the "influent" pair of rotors and halfway upstream of the continuously operated rotors. Solids settling in the totes, it was believed, would create an anaerobic blanket sufficiently fermentive to produce VFAs (volatile fatty acids) for consumption by PAOs (phosphate accumulating organisms) – bio-P "bugs" – and therefore drive biological phosphorus removal.

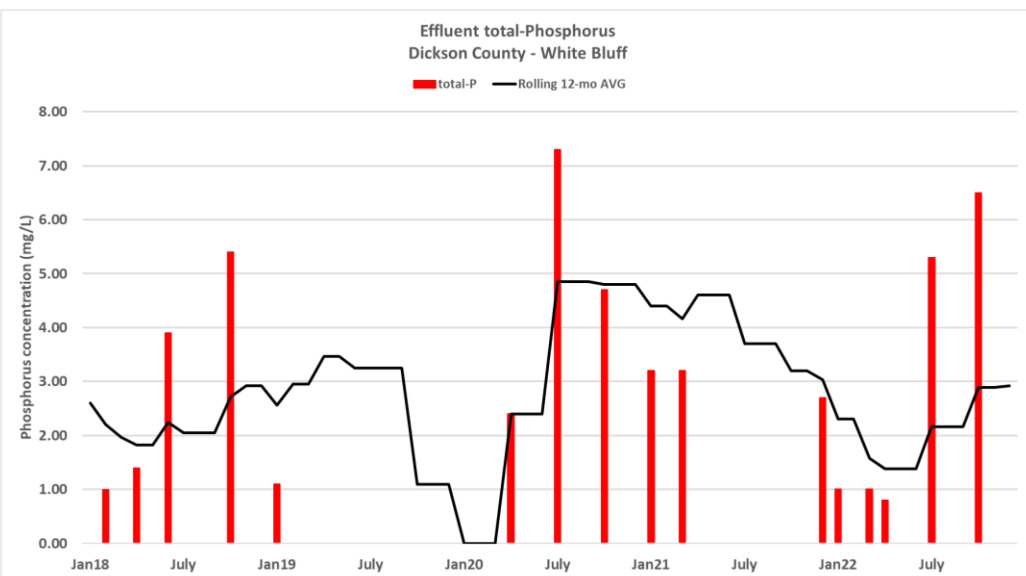
As an alternate (or supplemental) strategy, the following was also discussed. Cycle approximately 300 gallons per day of mixed liquor suspended solids (MLSS) through a periodically mixed, non-aerated tank with a capacity of 1500 to 3000 gallons. Mix the tank contents when dosing daily with MLSS so that solids flow out of the tank back into the ditch – ideally, but not critically, to the inner ring when both aeration motors are operating. The concept being … the tank will serve as a side-stream fermenter to create VFAs and energize PAOs sufficiently to provide phosphorus removal when the mixed liquor is returned to the aeration basin.

Implementation & Results

Plant staff implemented the nitrogen optimization recommendations. Rotor blades were relocated from the anoxic zone to the aerated zone. Very little historical nitrogen data is available. As shown on the chart below however, what data exist show an effluent total-nitrogen typically at, or below, 10 mg/L.



Plant staff opted to proceed with the alternate phosphorus removal strategy. A 1500-gallon tank was installed alongside the oxidation ditch and operated as a fermenter for a period of three months during the summer of 2021 – with a major flood interrupting the optimization effort – during which time mixed liquor was pumped daily into and out of the sidestream fermenter with no observable improvement.



As shown on the graph on the preceding page, there is significant seasonality in effluent total-phosphorus concentration. Wintertime effluent phosphorus averages around 1.0 mg/L while mid to late summer total-P is over 4.0 mg/L and as high as 6 or 7 mg/L. These facts, had they been known at the time of the optimization trials would have proven helpful as the effluent total-P concentration during the late summertime trials was under 3 mg/L. Then the flood hit Dickson County. Ultimately, Dickson County withdrew from the optimization effort in November of 2021.

Harpeth Valley (Nashville)

The team's operational concept for the Harpeth Valley Utility District (HVUD) wastewater treatment facility was focused on enhancing biological phosphorus removal. Specifically, to convert the pre-anoxic zones of the plant's two parallel oxidation ditches to more anaerobic conditions to support the formation of volatile fatty acids (VFAs) and their consumption by phosphate accumulating organisms, PAOs as is being successfully done at the Great Bend, Kansas wastewater treatment plant: https://www.tpomag.com/editorial/2021/06/an-innovative-operations-group-proves-nutrient-reduction-doesnt-have-to-cost-a-fortune. That is, instead of operating all four anoxic mixers continuously, to cycle their operation on and off. Such an approach, it is believed, would provide measurable improvements in phosphorus removal at an electrical savings.

During the initial visit, one of the anoxic mixers was out for repair as HVUD had begun rebuilding all four. A process that understandably took months to complete. While awaiting the completion of the repairs, plant staff engaged with the optimization team by collecting a considerable amount of data. Before the recommendations could be put into effect, HVUD's upper management withdrew from the optimization effort. As a result, the concept was never proven.

The optimization team's recommendations for enhancing biological nutrient removal follow. Included in the discussion is an explanation of efforts made by plant staff to dial in nitrogen and phosphorus removal, including the impact of the changes on treatment performance and energy use.

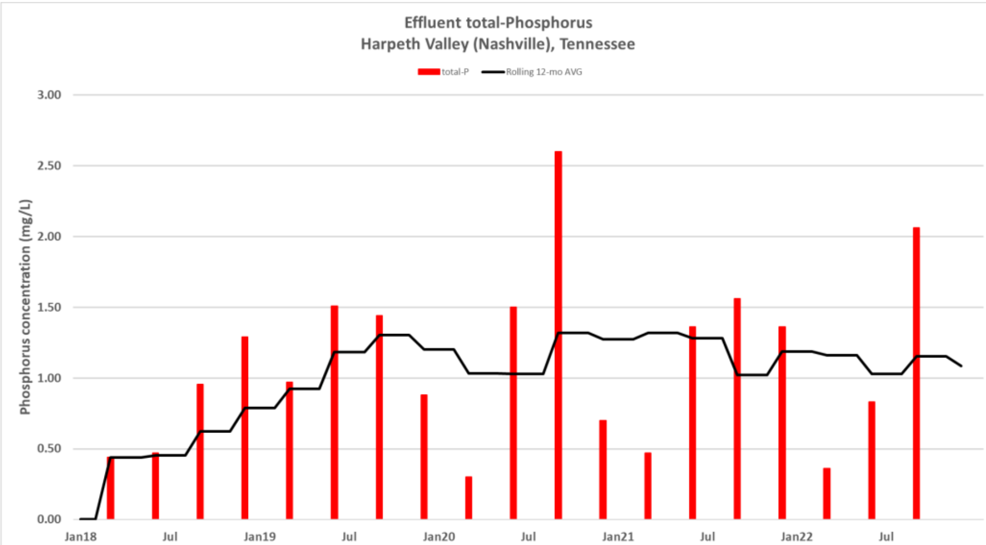
Phosphorus

Early in the study, it was found that the orthophosphate concentration was three times as high in the anoxic zone as in the ditch … ideal for biological phosphorus removal, yet after leaving the anoxic zone, phosphorus was little changed. It is possible that a small amount of enhanced biological phosphorus removal has historically taken place at the HVUD wastewater treatment plant. But too little additional removal to be quantified during the optimization study.

Another possibility, one evaluated at the onset of the study, is the potential of chemical phosphorus removal because the facility receives water treatment plant sludge rich in alum. Testing on the sludge supernate was performed and all involved concluded that the sludge was not providing a measurable reduction in HVUD's phosphorus concentration. More information is provided in the HVUD Guidance Document.

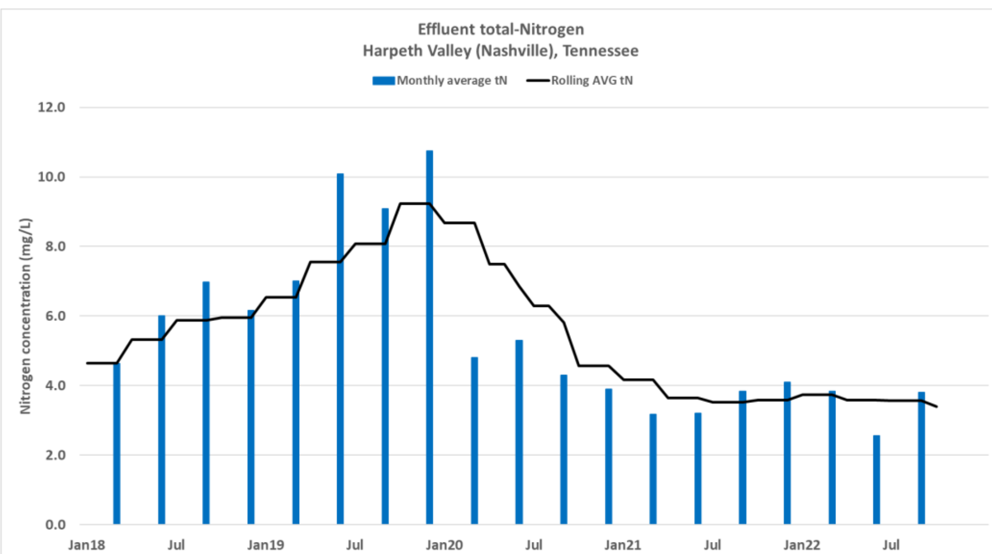
Also as discussed in the appended Guidance Document, HVUD's low effluent phosphorus concentration is likely the result of low influent total-P concentration. What little phosphorus there is in the influent is largely removed as the microbes that exist as mixed liquor are grown. HVUD may be removing a bit more phosphorus than a "typical" activated sludge wastewater treatment plant would be expected to remove but not a lot more.

The optimization trial was unfortunately terminated before the effectiveness of converting the pre-anoxic zone to fermentive conditions could be evaluated. Nonetheless, HVUD's wastewater treatment plant, as the data below show, does a good job of phosphorus removal. Effluent total-phosphorus averages slightly over 1.0 mg/L.



Nitrogen

Throughout the study, HVUD's effluent total-nitrogen numbers were, as the graph below shows, quite good. The reduction in effluent nitrogen from 8-9 mg/L in 2020 to 4 mg/L in 2021 took place prior to the start of the optimization effort. Because of the excellent nitrogen numbers, the study focused entirely on phosphorus removal with an effort to concurrently reduce electrical usage as described in the phosphorus removal section above.



Appendix

Guidance Documents

Guidance Document

White Bluff (Dickson County)

The 0.5 MGD two ring Orbal-style oxidation ditch receives a typical flow of 0.23 MGD, approximately one-half the design flow.
During rain events, the flow can peak to 1.4 MGD.

The facility currently has no total-nitrogen nor total-phosphorus limits.
With an effluent ammonia concentration averaging 0.1 mg/L, the facility routinely meets its monthly average ammonia limit of 1.25 mg/L summer and 2.0 mg/L winter.

Effluent total-Nitrogen averages 9 mg/L.
Effluent total-Phosphorus averages 3 mg/L.

The facility is equipped with two pairs of rotors, one rotor in the inner ditch ring and one rotor in the outer ring … each pair of rotors is operated by one fixed-speed motor.
The operational concept is to establish high dissolved oxygen (DO) conditions in the inner ring for ammonia conversion to nitrate … and to maintain low DO conditions in the outer ring for nitrate conversion to nitrogen gas.

For nitrogen removal, plant staff cycle the pair of aeration rotors nearest the influent and return activated sludge (RAS) feed lines for four hours on and four hours off in an effort to strengthen anoxic conditions in the outer ring while maintaining sufficiently aerobic conditions in the inner ring.

The following operational changes were discussed with staff.

Nitrogen
For enhanced nitrogen removal, remove the blades from the outer rotor shaft of the "influent" pair of rotors and install the removed blades on the inner rotor shaft.
Operate, at least initially, with the same motor on/off cycle of four hours.
With time it will likely prove desirable to operate with fewer on hours.
The concept being … more aeration where desired (inner ring) and less aeration where not needed (outer ring) while keeping the same torque on the motor that drives the common aeration shaft.

Phosphorus
For enhanced biological phosphorus removal, create a fermentive zone in the outer ring by placing two weighted IBC totes with holes cut in them at the bottom of the outer ring halfway downstream of the "influent" pair of rotors and halfway upstream of the continuously operated rotors.
The concept being … solids settling in the totes will create an anaerobic blanket sufficiently fermentive to produce VFAs (volatile fatty acids) for consumption by PAOs (phosphate accumulating organisms) – bio-P "bugs" – and therefore drive biological phosphorus removal.

As an alternate (or supplemental) strategy, the following was also discussed.
Cycle approximately 300 gallons per day of mixed liquor suspended solids (MLSS) through a periodically mixed, non-aerated tank with a capacity of 1500 to 3000 gallons.
Mix the tank contents when dosing daily with MLSS so that solids flow out of the tank back into the ditch – ideally, but not critically, to the inner ring when both aeration motors are operating.

The concept being … the tank will serve as a side-stream fermenter to create VFAs and energize PAOs sufficiently to provide phosphorus removal when the mixed liquor is returned to the aeration basin.

Status

Aeration rotors have been relocated.
Little to no improvement in total-nitrogen removal was observed.
Plant staff opted to proceed with the alternate phosphorus removal strategy.
A 1500-gallon tank was installed alongside the oxidation ditch and mixed liquor is daily pumped into and out of the sidestream fermenter.
As of the writing of this report, no improvement in phosphorus has been observed.

Guidance Document

Harpeth Valley (Nashville)

HVUD should be able to reduce electrical costs while improving phosphorus removal by operating only one of the anoxic zone mixers.
Much as is being done at the Great Bend, KS wastewater treatment plant featured in a recent TPO magazine article: https://www.tpomag.com/editorial/2021/06/an-innovative-operations-group-proves-nutrient-reduction-doesnt-have-to-cost-a-fortune

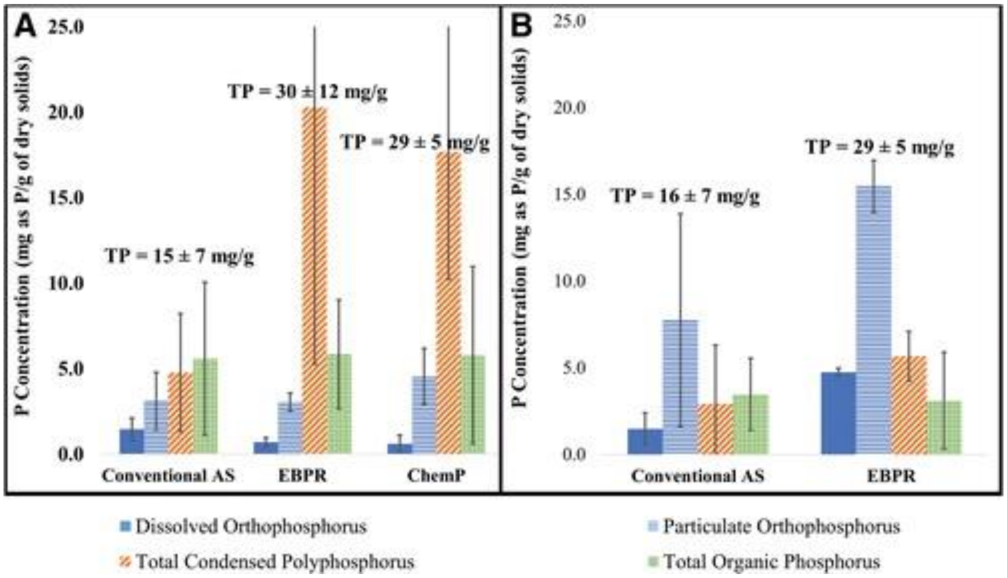
Nitrogen
The nitrogen numbers are really good … something you already knew.
It will be interesting to see if there is always a slight increase in nitrate from oxidation ditch to final effluent.

Phosphorus
Phosphorus is three times as high in the anoxic zone as in the ditch … and after leaving the anoxic zone, phosphorus is little changed.

With an influent averaging 4 mg/L total-P and an average daily flow of 5.7 MGD, the HVUD plant receives **190 pounds** of phosphorus daily.
An average of 8500 pounds of sludge is wasted daily.

Bacteria (and other living organisms) have a phosphorus concentration that is approximately one percent of the dry weight of the bacteria and therefore the waste sludge.
After doing some research, I've concluded that 1.0% is a bit low; 1.5% is a better number.

The following graphs are taken from ***Phosphorus Speciation in Municipal Wastewater Solids and Implications for Phosphorus Recovery*** (11 May 2020) by Felipe Gutierrez, Kerry A. Kinney, and Lynn E. Katz.
Phosphorus concentrations in thickened sludge is shown in graph marked "A."
"B" shows the phosphorus concentration in digested sludge.
Let's concentrate on graph A.
Thickened sludge from Conventional Activated Sludge wastewater treatment plants have a phosphorus concentration averaging 1.5% (graph A: 15 mg/g).



If there is no chemical phosphorus removal at HVUD's wastewater treatment plant …
If there is no enhanced biological phosphorus removal at HVUD's wastewater treatment plant …
If the phosphorus concentration in HVUD's sludge contains a typical 1.5% phosphorus by dry weight (graph A) …

The 8500 pounds of sludge wasted daily at the HVUD wastewater treatment plant contains a little over **125 pounds** of phosphorus (8500 x 0.015).
Leaving approximately **65 pounds** in the effluent (190-125).
That works out to an effluent total-phosphorus concentration of **1.37 mg/L** (65 lbs / (5.7 MGD * 8.34 lbs/g)).

The actual average concentration in the data I have is **0.86 mg/L**.

Meaning, HVUD is removing about 0.5 mg/L more phosphorus than a "typical" activated sludge wastewater treatment plant would be expected to remove.
Possibly, this is speculation, because of the supernatant from the water plant sludge.
I say this because Brad's benchtop test showed some, but very little, phosphorus removal when he mixed water plant sludge with mixed liquor.

Notwithstanding the above, I believe HVUD can produce an effluent with a phosphorus concentration consistently below 0.5 mg/L while saving electricity.
As discussed with Brad, the concept follows.

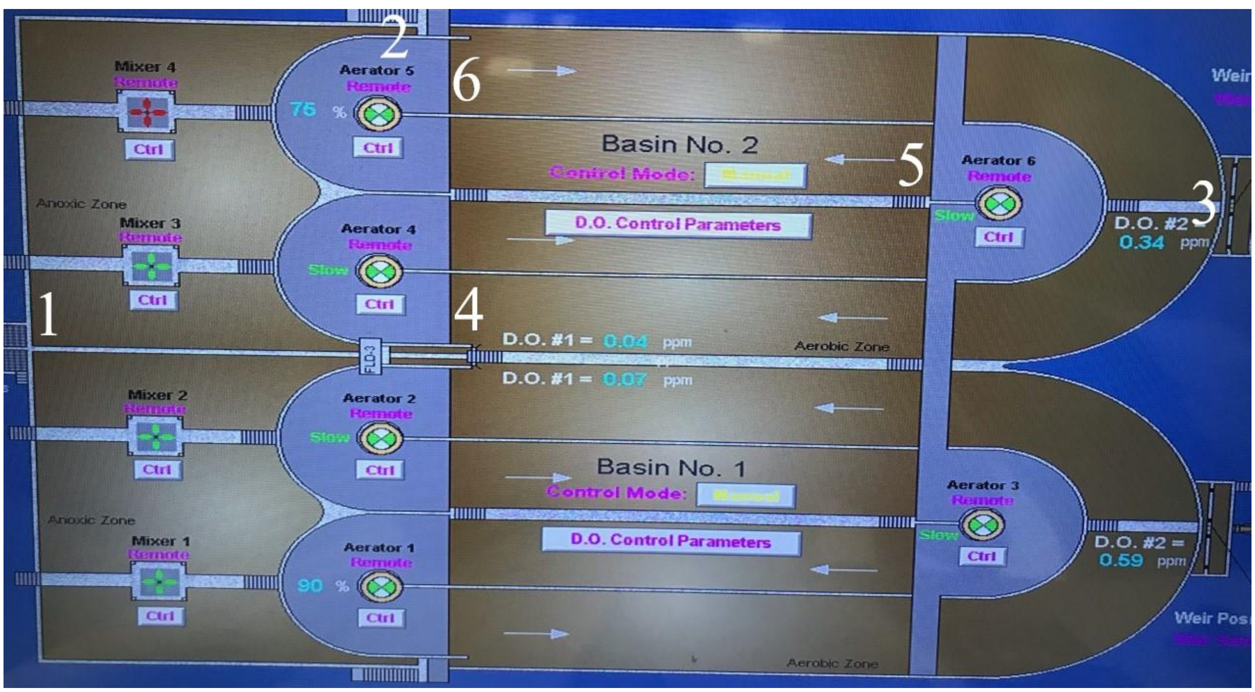
Shut off one of two mixers in each of the anoxic basins.
That is, run one mixer one day and the other mixer the next day.

With one of two mixers off, dead spots will develop.
Some of the sludge with settle to the bottom.

The settled sludge will become septic enough to create a sufficient quantity of volatile fatty acids (VFAs) for the phosphorus accumulating organisms (PAOs) that live in and with the MLSS to become energized in the "anoxic" zone to the extent that they will multiply in the aerobic zone of the ditch.
With time (a few weeks), the PAO population will increase to the point that the effluent orthophosphate concentration will decline and the effluent total-P will be noticeably lower.

Alternating mixing will resuspend the settled sludge sufficiently to keep it from becoming too septic and working as a digester.
To minimize mixer starts, HVUD may want to alternate weekly instead of daily.
The major concern being a reduction of MLSS in the ditch because of settling in the anoxic zone. Something to monitor.

A map of HVUD's oxidation basin follows with sample points labeled.
#0 Influent / Raw wastewater
#1 Beginning of Anoxic Zone
#2 End of Anoxic Zone
#3 Point of Clarifier Feed
#4 Before 1st Aerator (the channel leading into the anoxic zone)
#5 Post 2nd Aeration
#6 Post 3rd Aerator, At Anoxic Mix
#7 After going over the weir at #3 (to see what the concentration is going into the clarifier)
#8 Effluent



The goal is to gather samples periodically throughout the day. Then each week trying a different practice of running the oxidation basin. The HVUD central lab loaned the wastewater treatment facility a Hach DR 5000 Spectrophotometer and a YSI Quatro ORP. Using the DR 5000, the following methods are recommended to measure Nitrogen and Phosphorus levels.

Since the goal of the testing is to determine how the nitrogen and phosphorus concentrations change through the plant, my recommendation is to test for the following three parameters:

- **Ammonia-Nitrogen** (as N) … you'll probably want to buy two ranges of vials – 0 to 2 mg/L and 2-50 mg/L (or thereabouts)
- **Nitrate-Nitrogen** (as N) … you'll want to be able to test as high as 30 mg/L and as low as 1 mg/L
- **Orthophosphate** (as PO4-P … **not** as PO4; this may require resetting the default reading on the spectrophotometer) … you'll want to be able to test as high as 20 mg/L as PO4-P and as low as 0.2 mg/L as PO4-P

I recommend three to five profiles to establish a baseline.
After which you (we, I'll weigh in if you want) reassess and minimize the testing.

The ammonia and nitrate testing will help with dialing in phosphorus removal.
Unless the water plant sludge is chemically removing phosphorus (or maybe even if it is) …
The goal being very low nitrate at location #4 so that the main ditch is removing both ammonia and nitrate and the "anoxic" zone can operate anaerobically for phosphorus removal.

I'm very curious about the supernatant from the water plant sludge.
Is it chemically removing phosphorus?
To answer this question, I'd very much like to see you run jar tests with different ratios of alum sludge decant water and mixed liquor.
Try the following:

- 10% decant water / 90% mixed liquor
- 25% decant water / 75% mixed liquor
- 50% decant water / 50% mixed liquor
- 75% decant water / 25% mixed liquor

Perform an orthophosphate test on the mixed liquor (settled or filtered) before and after mixing with water-plant-sludge-decant water for 60-120-240 minutes to see if the orthophosphate concentration declines.

Guidance Document

McMinnville

Two major concerns:
1. I'd like you to reassess how you waste sludge.
2. And how you manage storm flows.

Sludge wasting
For consistent plant operations, you have to maintain a more constant MLSS (mixed liquor suspended solids) concentration.
As is, the MLSS can climb from a target MLSS of 2800-3200 to over 5000 mg/L.
The solution being, I suspect, changing how you manage the digesters.
Something I'd enjoy discussing with you.

Storm mode
I've worked with a number of oxidation ditches but never operated one myself.
I could be wrong but there seems to be a better way of managing storm flows.
Something I'd enjoy discussing with you.
Dickson County's Jones Creek plant is very similar to McMinnville's.
During storms, a goodly percentage ***but not all*** of the Jones Creek flow is step fed to the ***middle*** (not inner, middle) ring.
As the flow abates, adjustments are made multiple times during the day until all of the flow is again going to the outermost ring.
Jones Creek is producing an effluent with a total-N concentration averaging 3.5 mg/L and a total-P of under 1.0 mg/L … really good numbers.

Lessons learned at Jones Creek … operational changes McMinnville staff will be making to maximize the use of all three rings:

- Utilizing the middle and inner ring during storm flow was noted. They did mention that ammonia removal was still an issue for them after a few days of that configuration as well, but we are thinking that we will be trying that. Also, we realized their return activated sludge pumping capabilities were greater than ours, so we know that if they get a push of solids to their clarifiers then their pumps could sufficiently return those solids to the ditch. However, in our case our return activated sludge pumping capabilities are capped off at 2.5 MGD, so that is a limitation that we will have to monitor during high flows. I'm thinking, we will ease the ditch into this configuration by adding the inside ring, then adding the middle ring the following day if the storm persists, that way the sludge flow to the clarifiers wouldn't be overwhelming.
- We also noted that they adjust the oxidation effluent weir gate in order to raise the depth of water in the ditch during summer months, and they do the opposite during the winter, we have done this starting this week in order to help with D.O. and mixing during the summer months.
- We also noted that they recirculate a ton of water back to their ditch to remove nitrogen, we were hoping we could just adjust the ORP setting in the outside ring in order to help with this, so I've set the ORP to -50 (as opposed to the -150 it was previously set at) In my opinion -150 was a middle ground anyways and wasn't really helping with biological nutrient removal. This change of setpoint will increasing the oxygen in the outside ring, this will take care of some nitrite to nitrate conversion on the front end. Then hopefully, since oxidation ditches are known to simultaneously nitrify and denitrify, we could get some denitrification done in that ring as well

lowering our total nitrogen numbers. This may seem counterintuitive because we are adding air to the outside ring, but this technique has been known to work because it is a carbon rich environment and because of the simultaneous nitrification and denitrification attributes of the oxidation ditch. (Tell me what you think, I've ran this idea passed a guy that's very knowledgeable on these ditches, he works for Evoqua in Wisconsin and in my opinion, he would be an excellent resource for anyone looking for inside info for these ditches, both jones creek and McMinnville have these ditches and clarifiers. his name is Bryce Vandenboom, (262) 521-8434.)

Maintaining a constant MLSS has proven difficult.
How can the optimal MLSS (3000 mg/L) be maintained through all weather conditions?

Optimal MLSS is 3000 mg/l. To maintain the optimal MLSS through all weather conditions we must add the other digester and waste consistently. We will continue to monitor MLSS in the ditch several times a week in order to maintain our target MLSS number. After learning that jones creek wastes around 50,000 gallons a day (they have 3 digesters) regardless of conditions was noted. We do realize that jones creek thickens their sludge to a 1.2 solids concentration to run the belt. Also, their final product goes to a landfill with minimal to no restrictions. Which enables them to run their press more freely. We on the other hand must get our sludge thickened to a 1.7 and have a good quality cake from the belt press in order to maintain a class A biosolid. It is considered an exceptional quality (EQ) biosolid and if its not perfect, then the final product doesn't meet the standard, which cannot happen. Hopefully this helps shed some light on our MLSS numbers being high. We get an increased sludge amount from the chemical from the water plant and we can't just waste a bunch and press it out and haul it to the land fill. We must create an exceptional quality product that goes beyond the regulated standard. If the final pile meets EPA standards for EQ biosolids, its actually still too wet for farmers to be really interested in taking it, so we must get it much dryer than the EPA standards to have a viable product. With the added digester we will be able to maintain our target MLSS at greater frequency. During the rainy season in 2022 we will be working split shifts to run the belt press longer during those couple of months, hoping we won't get behind on solids (which is the trend here) thus being able to maintain our target MLSS rate more often than not. See in the past we have been getting a high MLSS in December thru Feb and taking half the year to catch up, now we will be working split shifts (the guy on call that week works second shift for 1 week in order to have the press run longer "7am-10pm as opposed to 7am-2pm") if we do this for 8 weeks or so, we might evade our high MLSS numbers throughout the year. Another thing to note is, since we produce a fertilizer grade biosolid, we only get rid of it through local farmers, there are several times throughout the year that the farmers either are not in need of the biosolids or don't have the time or manpower to come and get it, this leaves us with a full warehouse and no room to press more solids. When this does happen, we can't waste nearly as much and it becomes a domino effect. We are combatting this by making a list of the biosolid haulers and touching base with them regularly in order to keep the door open for them to haul as often as possible. (This extra information is added so you get a better picture of our limitations)

The new gate to the middle ring and fixes to the digesters will surely help.

New gate is installed already on the middle ring of our ditch, it will be utilized during storm events.

The Digester is our top priority, with the blower install is happening one piece at a time, we have had setbacks with the install, but we remain optimistic and we hope to have a blower and the modified air piping up and running within the next three weeks.

Nitrogen

Nitrogen removal is rarely bad, often excellent.
Not as consistent as could be, likely because of how storm flows affect operations.
Ammonia removal, to no one's surprise, is also inconsistent.

Phosphorus

Thank you for the profile testing info.
The data tell me that the phosphorus removal is more chemical than biological.
I say this because the "as PO4" testing shows the influent to be around 12 mg/L, nearly the same as the concentration leaving the outer ring (10 mg/L as PO4) … no phosphorus release is observed; in fact, the opposite.
And.
The soluble BOD testing you performed showed a really low concentration entering the innermost ring where phosphorus uptake would occur if biological: 4.6 mg/L.
That is not enough soluble BOD, if my theory holds true, to support enhanced biological phosphorus removal.
(Leaving the outermost ring, the soluble BOD was 15 mg/L and the effluent soluble BOD on the sample day was 2.4 mg/L.)

Effluent phosphorus is excellent.
And consistent.
Effluent total-P averages under 0.5 mg/L … including during wet weather when much of the flow has historically bypassed the outermost ring.

I'm of the opinion that effluent phosphorus is low because the PAC (poly-aluminum chloride) laden water treatment plant sludge that is discharged into McMinnville's collection system acts as a chemical precipitant.
By "sludge" I mean both filter backwash and as actual sludge.

After seeing the numbers (no P release in the outside ring), it seems to me that we are receiving the benefits of chemical phosphorus removal. With these low effluent phosphorus numbers, we will not change anything and we will just enjoy the gift from the water plant. After speaking with the water plant, we know that they feed around 400 pounds a day of PAC which is definitely helping with nutrient removal, but can also increase sludge production so there is a tradeoff.

Guidance Document

Oneida

Tennessee wastewater wizard Bret Ward has provided Oneida was invaluable advice.
The aeration rotor nearest the influent is kept off and the other three are cycled on for three hours and off for three hours.
As a result, Oneida is already doing a great job with nitrogen removal.
As the annual averages in the table below illustrate.
Phosphorus removal is also quite good.

	BOD	TSS	pH	tN	NH_3	tP
2019	4	7	6.9	6.3	0.4	1.0
2020	3	6	7.1	7.2	0.3	1.5

TDEC's nitrogen goal is 8 mg/L at design flow; consequently, nitrogen shouldn't be an issue for many years.
Phosphorus, however, could become an issue as Oneida's flow approaches design capacity; TDEC's goal is 1.0 mg/L at design flow.
And, maybe, there are actions that could be taken to provide some electrical savings.

TDEC is making arrangements to provide a loaner spectrophotometer which can be used for phosphorus testing.
(Ammonia and nitrate too, should you desire.)
While the instrument is available, it could prove valuable to add daily orthophosphate testing to your process control routine.
Plant staff are already doing daily ammonia, nitrite and nitrate testing of effluent using test strips.

Once you get the testing vials and ORP probe …
Once you have had an opportunity to get familiar with the testing equipment and have some baseline data …
Here's what I'd like you to try.
As far as testing vials for use with the spectrophotometer, you are on your own.
Neither TDEC nor TAUD will be providing vials.
The good news is … not counting shipping, I'm asking you to spend $428.84.

I would like you to buy the following.
Use them for testing orthophosphate.
That is, do NOT test for total-phosphorus (the vials can be used to test for either).

I'm including the USA BlueBook order numbers.

2 boxes of TNT843 vials (USA BlueBook item #202103), 25 vials per box: $63.79 per box
2 boxes of TNT845 vials (USA BlueBook item #202501), 25 vials per box: $63.85 per box
4 boxes of TNT 846 vials (USA BlueBook item #37967), 25 vials per box: $43.39 per box

When the vials arrive, please let me know.
At that time we can talk about sampling, testing, and which vials to use where.

Once per week, I want Oneida staff to collect samples from the following locations:
Raw/Influent (TNT 846)
Ditch effluent – filtered or settled (TNT 843 or TNT 845)
Final effluent (TNT 843 or TNT 845)
Belt press filtrate (TNT 846)

While you are at the Oneida plant, please have staff collect the four samples listed above and talk Oneida through as they test the samples using the three different kits.
TNT 846: Raw/Influent sample and/or filtrate from belt filter press
TNT 843: MLSS leaving ditch (after settling) and/or final effluent
TNT 845: MLSS leaving ditch (after settling) and/or final effluent

Have Oneida staff record their readings as **PO4-P** and ***not*** the default reading of PO4.
If possible (I don't think it is) set the default readings to PO4-P.

Review the form that they have (hopefully) made for recording data.
If they haven't made a form, I will.
Or you can do so while there.

It is my understanding that TDEC's Tim Hill will be delivering pipettes for your use.
When he is there, I'd like you collect samples from the following locations and test for orthophosphate:
Raw/Influent (TNT 846)
Ditch effluent – filtered or settled (TNT 843 or TNT 845)
Final effluent (TNT 843 or TNT 845)
Belt press filtrate (TNT 846)

Record the readings as **PO4-P** and ***not*** the default reading of PO4.
If possible (I don't think it is) set the default readings to PO4-P.

Write the results on a form of your own making.
If haven't made a form and you'd like help … Tim or I can format a form for your use.
Let either of us know.

Please call me to discuss results while Tim is at the plant.
My number is **860.777.5256**.

And.
For the rest of this year, please test for phosphorus weekly at the four locations.
And send the results to me weekly.
You can …
Scan and email to me at this address.
Or, fax to 860.326.5308.

Or, take a photo and text to my cell: 860.777.5256.
Whatever is easiest for you.

The information gathered during the phosphorus testing will tell us what is going on with phosphorus removal.
We'll be able to understand what is happening on those days when effluent phosphorus is low.
And what is occurring when effluent phosphorus is high.

Then.
Using this information, we'll be able to develop strategies for keeping phosphorus lower, more often.

Process control suggestions
Turn off the mixers when you arrive at the plant and turn them back on when you leave.
Every day.
I don't think this will have any adverse impact on plant operations but if it does, quit turning the mixers off during the day.
(It shouldn't hurt anything if you or anyone else to forgets to turn them on at the end of the day, even over a weekend.)
Collect enough effluent phosphorus data to document conditions with the mixers off during the workday.
And discuss with me.
If what I think happens …
If turning the mixers off isn't creating any problems …
After you have a month of data, turn the mixers off all the time.
And, if you want, run them for an hour at some point in the day to stir up anything that may have settled.
Not that I think you will need to, something we can discuss at a later date.

Here's what I'm hoping this will do.
1. Allow enough settling to create a sufficiently septic sludge blanket during the air-off cycle to boost biological phosphorus removal.
2. Save electricity.

Meanwhile, I'd like you to consider two process changes.
1. Extend the air-on run times when the daily ammonia testing is above your target.
The target that you have historically used 0.5 mg/L (do I have that right?) is probably more conservative than need be.
You can probably use 1.0 mg/L as an upper limit without issue; something for you to discuss with Tim when he is at the plant.
And.
Instead of turning on a fourth aeration rotor when ammonia goes up, I'd like you to try bringing bring down the ammonia by running the three rotors longer and ***not*** bringing on a fourth aeration rotor.
Doing so should result in measurable electrical savings as Oneida won't be penalized for the extra electrical demand.

2. Change air-on / air-off cycles in response to the daily ammonia and nitrate testing.
Unless I'm mistaken, you test effluent ammonia daily using a benchtop instrument and test effluent nitrate daily using test strips.
When the ammonia concentration is consistently low – say for an entire week – you can shorten the air-on cycle without affecting treatment while saving electricity.
When the nitrate concentration is high, you can extend the air-off cycle and save electricity.
Before making any changes, please give me a call.
I don't want you getting goofed up as this can be a bit confusing until you get the hang of it.
Once you get comfortable making aeration changes in response to changes in effluent ammonia and nitrate concentrations, you'll be able to lower their effluent total-N concentration while saving electricity.

Here's what I'm thinking might make phosphorus removal more consistent and keep Oneida below TDEC's threshold sufficiently to avoid the need for chemicals or nutrient related facility upgrade.
Turn off the mechanical mixers in the oxidation ditch for the last one hour of the air-off cycle.
Maybe go so far as to turn them off all of the time with the exception of an hour or two per day during aeration to resuspend any material that may have settled during the prior 24 hours.
And perhaps (something for us to discuss during my next visit) …
Consider turning the sludge holding tank into a fermenter and recycle a portion of the fermented waste sludge back into the oxidation ditch for phosphorus removal.

Energy savings
As an energy savings measure, consider aerating the sludge holding tank for only 1-2 hours daily.
To the extent possible, schedule the aeration to occur at a time of day when the electrical demand charge is at a minimum.