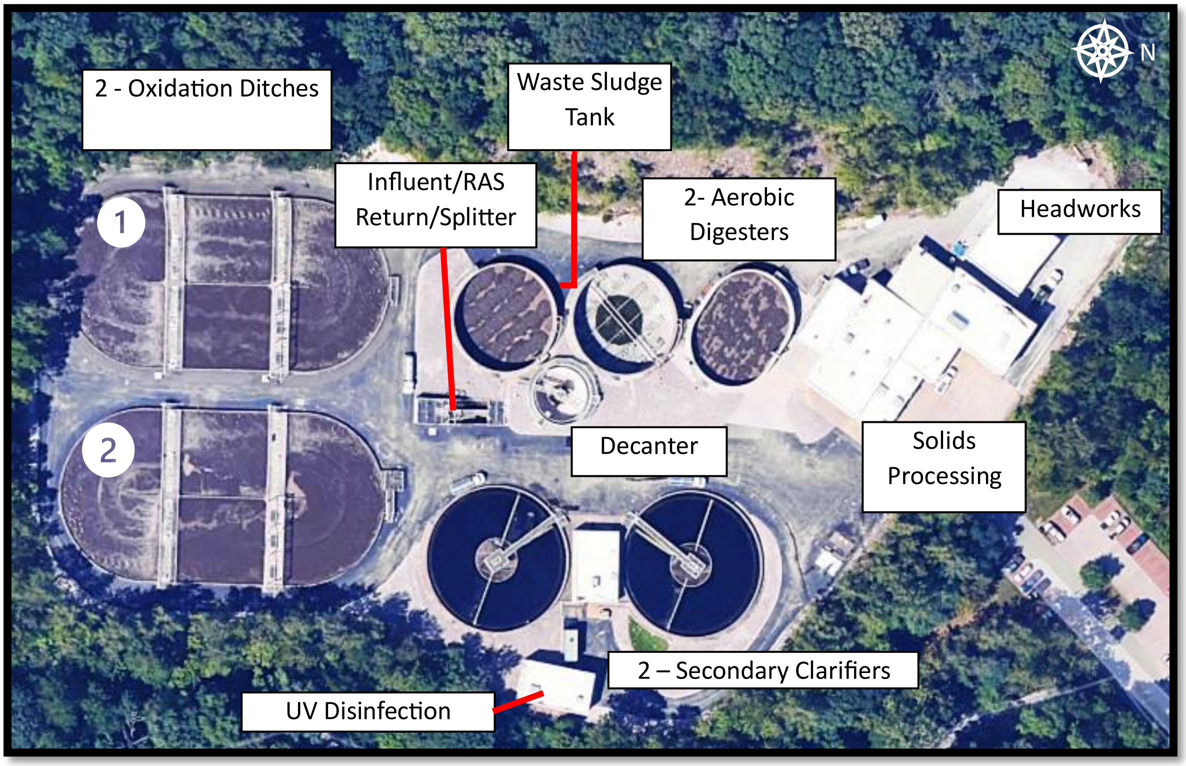
Duckett Cr SD WWTP #2, St Charles, Missouri

MO0116572
MoDNR Municipal Wastewater Nutrient Optimization Pilot Project
August 2025

Duckett Creek SD #2 Wastewater Treatment Plant (WWTP)



Oxidation Ditch

Design Flow: 7.0 MGD
Actual Flow: 4.6 MGD

13 Research Park Dr
St Charles, MO 63303
Latitude 38.693342/ Longitude -90.684867

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Summary of Optimization Efforts:

The Duckett Creek Sewer District Plant #2 WWTP (Duckett Creek) historically discharged total nitrogen (TN) and total phosphorus (TP) at levels significantly above the Missouri Department of Natural Resource (MoDNR) target values. Initial efforts focused on inline TN and TP reduction. Later in the project, sidestream phosphorus reduction was tried, but was not successful. After abandoning the sidestream effort, Duckett Creek staff returned to inline TP reduction which proved successful and routinely met the MoDNR 1 mg/L TP goal.

Nitrogen Removal

The biological treatment at the Duckett Creek WWTP is a typical oxidation ditch process. The WWTP has two ditches that are configured with the same rotor aerator and mixer placement – Figure 1. However, since the influent to each ditch enters at different points in the treatment process, the ditches have different operational characteristics. Each rotor and each mixer can be operated independently; thus different combinations of rotors and mixers were turned off to create the anoxic zones necessary to reduce nitrogen. After optimization, the Duckett Creek WWTP staff consistently reduced TN far below the MoDNR goal of 10 mg/L. In fact, the WWTP averaged TN of 3 mg/L which is at or near the limit of technology for TN treatment.

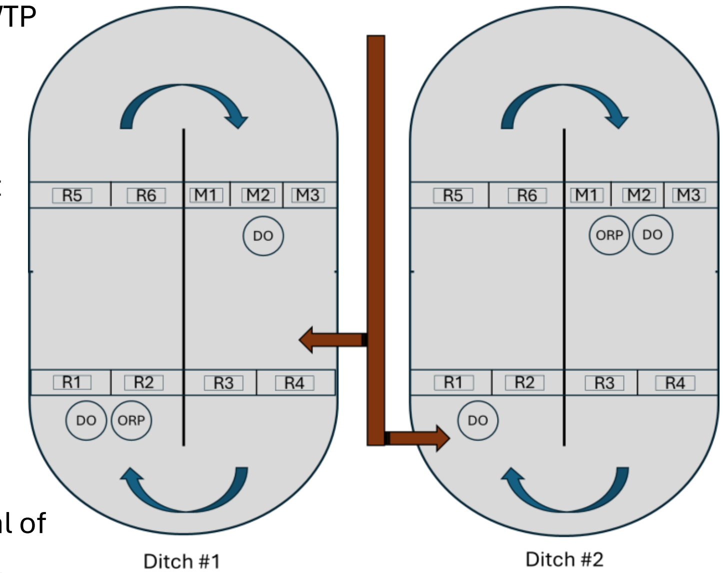


Figure 1 - Duckett Cr #2 Oxidation Ditches

Phosphorus Removal

Phosphorus reduction initially occurred with the inline treatment scheme for nitrogen. Inline treatment tries to establish anaerobic zones by turning off rotors and mixers to allow solids to settle in the bottom of the ditch and become septic or anaerobic. The inline process showed good results, however the plant also had an empty digester that was re-purposed to use as a sidestream fermenter. Due to the large size of the digester and the inability to properly mix solids, sidestream phosphorus treatment was abandoned and inline treatment was re-established. The Duckett Creek WWTP staff routinely met the 1.0 mg/L TP goal.

Nutrient and Energy Reductions

As indicated in Table 1, the Duckett Creek WWTP reduced the concentration of TN and TP in their discharge by 86% and 56%, respectively during the project. The TN of 3.0 mg/L is well below the MoDNR target and is near the limit of technology. The post-optimization TP concentration is 1.7 mg/L. While this is above the 1.0 mg/L target, it is believed the 1.0 mg/L target can be met based on four months at or below the target, with one outlier month in March 2025.

The facility removed 39% more TN mass in terms of pounds per day (lb/day). Optimization reduced the amount of TN by 302 lb/day (1077 – 775 lb/day) equal to 55 tons per year. Equally impressive is that the staff at the WWTF reduced an additional 55% of TP – 60 lb/day (11 tons per year). By reducing the number of operating rotors to achieve both the MoDNR TN and TP targets, the Duckett Creek staff managed to reduce the amount of energy used per MG by nearly 10%.

For all mass-based calculations, the results were normalized for flow to fairly compare pre- and post-optimization since flows during the pilot period were 8% higher than previous flows. Without normalizing for flow, discharging the same concentration (mg/L) pre and post optimization would yield more mass reduced post-optimization simply because of higher flows. Normalization involved reducing the mass removed by the increase in flow – 8%.

Table 1 – Nutrient and Energy Reductions

	Pre-Optimization	Post-Optimization	% Improvement
TN – mg/L	22.4	3.0	86
TP – mg/L	3.9	1.7	56
TN – lb/day Removed	775	1077	39
TP – lb/day Removed	73	113	54
Energy Use – kWh/MG	2,589	2,345	9.4
Energy Cost - $/MG	197	181	8.3

Costs and Return on Investment

Three factors contribute to the cost of optimization: (a) MoDNR's investment in consulting support, (b) Duckett Creek's investment in equipment and instrumentation, and (c) ongoing operational expenses relating to energy (i.e., electricity), chemicals, lab supplies and personnel.

The Duckett Creek SD #2 WWTP had energy savings in cost and kWh, while the efficiency of energy use improved by 27%. This means that for every kWh used in treatment, more pollutants are now being removed.

MoDNR's cost for optimizing the Duckett Creek plant was $30,596, one-eighth of the $244,765 pilot project contract fee awarded to Grant Tech, Inc. and T8 Environmental LLC. One-eighth because there were eight municipal wastewater treatment plants in the pilot study. Duckett Creek's costs (as estimated by facility staff) total $34,904 but are offset by $31,557 in energy savings as shown in Table 2.

Table 2 – Facility Reported Costs

Item	(Cost) / Savings
Instrumentation	($23,656)
Lab Supplies	($5,512)
Added Personnel Time	($4,689)
Other	($1,047)
Energy Savings	$31,557
Total	($3,347)

The total cost of optimization therefore was $33,943 ($30,596 + $3,347), less than $4,850 per MGD of treatment capacity. Conventional facility upgrades for nutrient removal typically cost millions of dollars per MGD of plant capacity.

As shown in Table 1, the year-long optimization effort resulted in an increased TN removal of 302 lbs/day (110,230 pounds per year) and an increased TP removal of 60 lb/day (21,900 pounds per year). Dividing the cost of the project by the sum of the additional annual mass of TN and TP removed results in pilot project cost of $0.25 (25 cents) per pound per year ($33,943 ÷ (110,230 lb/yr + 21,900 lb/yr)).

Initial Optimization Strategy:

The initial Optimization Strategy focused on inline TN reduction. The contractors' experience with oxidation ditch treatment technology showed that significant TN reduction can generally take place in an oxidation ditch. Turning off select rotors can create an anoxic zone for nitrate reduction. Sometimes, solids settling in the bottom of a ditch can create a septic/anaerobic zone for generating volatile fatty acids (VFA) and phosphorous accumulating organisms (PAOs) which can simultaneously reduce phosphorus once returned to aeration. After TN reduction was achieved, an empty digester would be re-purposed for use as a sidestream fermenter to generate VFAs and PAOs and return the energized PAOs to the oxidation ditches.

To reduce nitrogen, the initial scheme focused on turning off rotors in each ditch. Because of the location of the influent to each ditch, the thought was that Ditch 1 could drive nitrate reduction, while Ditch 2 could maintain ammonia removal. Influent has low to no dissolved oxygen (DO), so turning off Rotors 3 and 4 in Ditch 1 (which are immediately downstream of the influent point) would drive nitrate reduction due to minimal DO in the influent and immediately extend the low oxygen environment by turning those rotors off. Conversely, in Ditch 2 the low-DO influent would be immediately exposed to aeration downstream of the influent point.

To start, Rotor 4 in Ditch 1 and Rotor 1 in Ditch 2 were turned off. The mixers were also turned off. TN began to drop while ammonia remained within permitted limits after two weeks. After the initial two-week period, Rotor 3 in Ditch 1 and Rotor 5 in Ditch 2 were also turned off – Figure 2. The goal was to reach an ORP of -100 mV in the minimally aerated portion of each ditch – between the mixers and Rotors 1and 2 in Ditch 1 and between Rotors 5 and 6 and Rotors 3 and 4 in Ditch 2. Within a month TN was reduced by 85% to consistently around 3 mg/L.

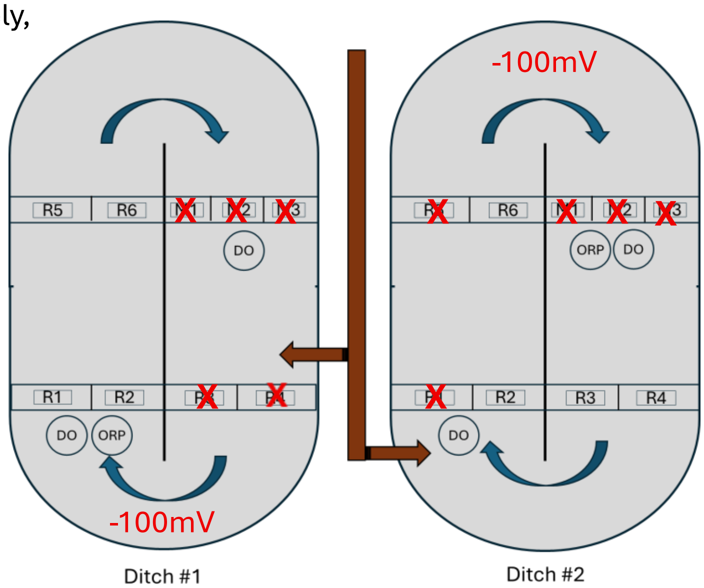


Figure 2 Duckett Cr Initial Optimization

After several weeks, the solids began to excessively build up. To combat the buildup, staff ran a mixer in each ditch for an hour a day which resolved the issue and resulted in excellent ammonia and TN reduction.

TP had concurrently dropped to around 1 mg/L while doing inline treatment for TN. To improve TP reduction, an empty digester was repurposed as a fermenter, and a plan for sidestream TP treatment was developed. The fermenter was partially filled with waste activated sludge (WAS) and allowed to turn septic with an ORP goal of -200 mV. The fermenter had air diffusers already mounted in the bottom of the tank that were used to mix the sludge. Unfortunately, the aerators were a couple of feet above the bottom of tank, so they had to be covered with several feet of WAS to provide mixing. After having time to ferment, a portion of the solids were returned to the ditches via the RAS/Influent structure, and an equivalent amount of WAS was then pumped to the fermenter.

The fermenters were tried for two months and ultimately abandoned. The combination of the large digester and the configuration of the aeration used for mixing allowed the sludge to become too septic and released too much phosphorus. The PAOs in the ditches appeared to be overwhelmed and could not remove all the released phosphorus.

Modifications to Initial Strategy:

With the sidestream treatment experiment abandoned, the focus for TP reduction reverted to inline treatment. Rotors 3 and 4 in Ditch 1 were turned off and one mixer was operated for one hour per day. The mixers were cycled each day – Mixer 1 run the first day, then Mixer 2 the second day, and Mixer 3 the third day before cycling back to Mixer 1 on day four. This scheme produced excellent TN and TP reduction.

Additional aeration was provided (rotors turned back on for short periods) during the extremely cold weather in January and February due to the buildup of scum on the ditches. The additional aeration caused some degradation of TP reduction, however it recovered quickly.

Rotor 6 in Ditch 2 was also turned off for a short period in the Spring of 2025 to spur TP reduction. As the weather and water temperature warmed, Rotor 6 was tuned back on to supply enough oxygen to meet ammonia permit limits, demonstrating the need for seasonal operating parameters.

Ongoing Optimization Strategies for Duckett Cr SD #2:

- Continue to fine tune warm and cold weather operating schemes by altering the run times of the mixers and operating with three rotors off in cold weather and two rotors off in warm weather.
- Continue monitoring and adjusting sludge blanket depths in the final clarifiers to minimize re-release of phosphorus from the solids. Duckett Creek monitored phosphate from the oxidation ditches and the final effluent. At times, phosphate was higher in the final effluent than the ditch effluent indicating some release of phosphorus that had been taken up by the biosolids in the treatment process.
- Near the end of the project, the Duckett SCADA was reprogrammed to allow independent set points for each ditch. Now that the DO probes in each ditch can be used independently for DO control, consider slowly reducing the DO setpoints to drive more TP reduction. Without the

benefit of the MoDNR safety net provision, any reductions in DO should be made in very small increments – 0.1 mg/L. This should save energy and may improve phosphorus reduction.

- Consider installing additional in-line instrumentation such as ammonia, nitrate, and orthophosphate analyzers. These would allow operators to more quickly respond to changes in treatment efficiency.

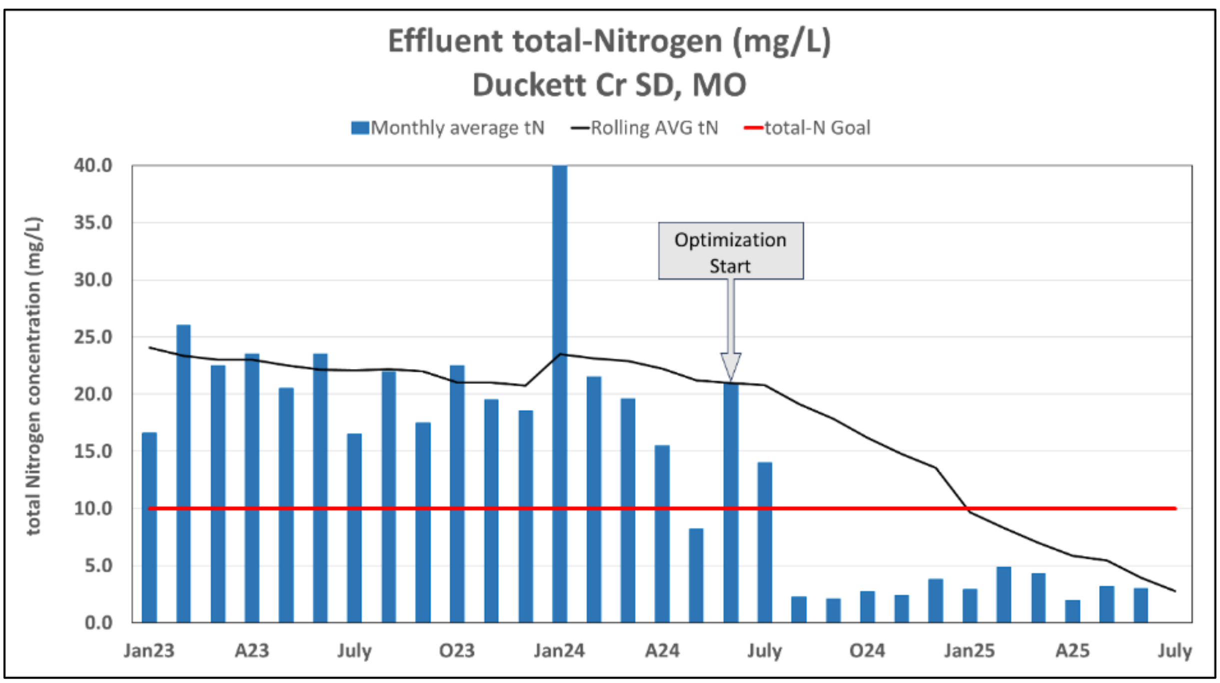
Additional Plant Information:

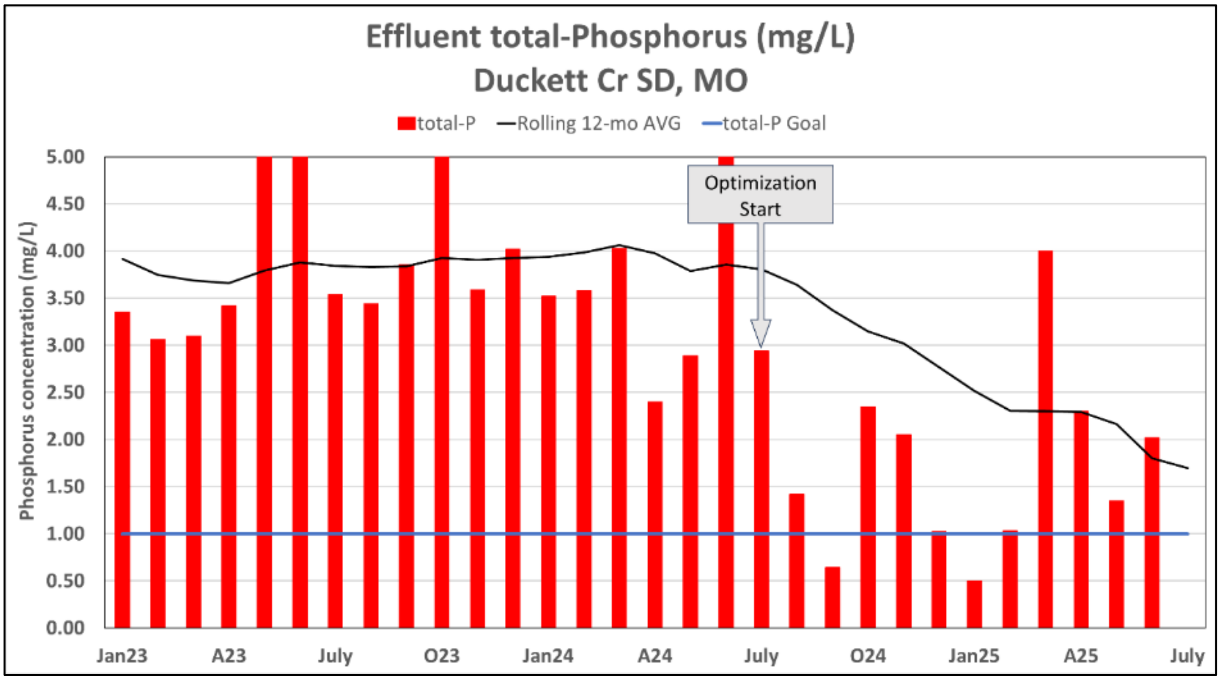
The Duckett Creek SD #2 Wastewater Treatment Plant operates with a daily average flow of 4.6 MGD versus a design flow of 7 million gallons per day. The treatment facility includes a mechanical bar screen and grit removal followed by two oxidation ditch basins and two secondary clarifiers. Disinfection is provided by ultraviolet (UV) lamps. The plant has two aerobic digesters, a sludge storage basin, a solids decanter, and two belt filter presses. Biosolids are land applied.

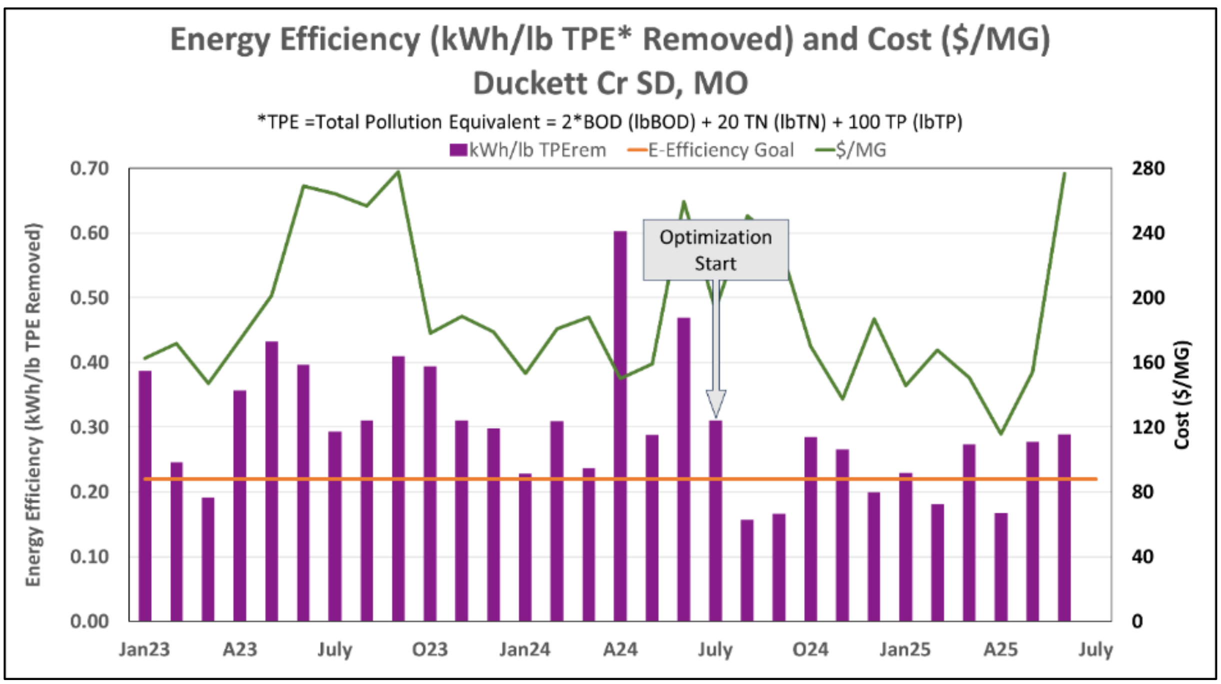
Contractor Information:

The year-long MoDNR funded nutrient optimization study was initiated in May 2024 by Grant Weaver of Grant Tech, Inc. and Mike Tate of T8 Environmental LLC and completed July 2025. The contractors made four site visits and held 19 video call meetings with Duckett Creek plant staff.

Nutrient Removal & Energy Efficiency Graphs:







Lessons Learned / Guidance for Others Considering Optimization:

Facilities not designed for nutrient removal must be operated differently than those designed to achieve nutrient removal. Data beyond that required to meet permit conditions need to be collected and compared against targets. This is also true for most facilities designed for nutrient removal as well.

The Duckett Creek facility provided the operators independent control over each aeration rotor and each mixer, allowing the operators considerable operational flexibility. This is not the case at every facility. The operators were able to take advantage of the flexibility to achieve the MoDNR TN and TP goals by selecting specific rotors to turn on and off. In addition, the Duckett Creek facility had slow speed mixers which allowed keeping solids mixed without aerating. Like the rotors, the mixers are independently controlled and can be turned on and off at various time intervals.

For TN reduction, establishing anoxic zones by reducing aeration is usually possible in oxidation ditch technologies. The nature of the aeration in an oxidation ditch – aeration/mixing rotors in a fixed location followed by stretches of basin that do not have direct aeration-- create an oxygen gradient. For oxidation ditches with multiple rotors – like Duckett Creek – turning off one or more rotors can establish anoxic zones. Oxidation ditches with one rotor usually require turning the single rotor off for a period of time to establish an anoxic zone.

For phosphorus removal, inline treatment can be achieved by the solids settling in areas of low velocity in the ditches. These areas can occur when lowering aeration for TN reduction. The settled solids can often provide sufficiently septic conditions for VFA formation and phosphorus release by PAOs. Once the PAOs are returned to an aerated/oxic zone, they take up all the phosphorus released plus phosphorus in the influent wastewater.

Sidestream phosphorus removal may not be a viable option at Duckett Creek without physically reconfiguring an unused tank with mixing in lieu of the existing aerators mounted more than a foot off the basin floor. If appropriately sized tankage and mixing is available, sidestream fermentation is possible. Sidestream fermenters need to be big enough to provide sufficient retention time and be septic enough for the generation of volatile fatty acids, but not so septic and not so large as to allow the microbes within to decay enough to release too much phosphorus into solution.

As noted earlier, the energy use per MG treated was reduced by 9.42%. Cost per MG treated dropped by 8.3%. One might expect that turning off one-third of the aeration for each ditch might result in greater energy savings, however Duckett Creek staff also utilize DO setpoints to control the operating aerators. Staff noted that with four rotors turned off, the other rotors ran for longer periods to meet the desired DO, resulting in lower energy savings.

Energy efficiency improved by 27%. Energy efficiency is measured by how many weighted pounds of BOD, TN, and TP are removed by each kilowatt-hour of energy input to treatment. Since the Duckett Creek plant is removing much more TN and TP after optimization the energy efficiency is much improved.

An empirical approach to optimization is greatly enhanced with regulatory encouragement and support as was the case with this project. Offers of enforcement discretion are a strong motivator for highly regulated and therefore risk-adverse municipalities to seek optimization opportunities.

Given that Nitrogen and Phosphorus are chronic pollutants, permitting discharges as rolling average mass loadings accommodates day-to-day and month-to-month variability with minimal environmental consequence while accommodating the impacts of infiltration and inflow (I/I), seasonality, and day of week variability in flows and loadings.