

Jefferson City, Missouri

MO0094846

MoDNR Municipal Wastewater Nutrient Optimization Pilot Project

August 2025



Jefferson City Regional Water Reclamation Facility (RWRF)

SBR

Sequencing Batch Reactor

Design Flow: 11.0 MGD

Actual Flow: 7.9 MGD

401 Mokane Road

Jefferson City, MO 65101

Latitude 38.589272

Longitude -92.163578

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Summary of Optimization Efforts:

The Jefferson City RWRF has historically met the Missouri Department of Natural Resources (MoDNR) total-Nitrogen (TN) reduction goal and, at times, at least one of the total phosphorus (TP) goals. The optimization strategies developed with staff input during the MoDNR funded pilot study will likely allow the Jefferson City RWRF to routinely meet MoDNR's TN and TP goals.

Nitrogen Removal

Prior to the MoDNR funded optimization project, Jefferson City's effluent TN was at or below MoDNR's 10 mg/L goal. Because of this, the optimization effort focused on reducing TP to MoDNR's 1.0 mg/L goal while incidentally enhancing TN reduction.

Phosphorus Removal

Utilizing Jefferson City's existing gravity thickeners for Sidestream Phosphorus treatment because of their ability to generate anaerobic condition necessary to generate volatile fatty acids (VFAs) to promote phosphorus release from phosphorus accumulating organisms (PAOs). Sidestream treatment resulted in a TP reduction of approximately 27%; a significant improvement, but not enough to meet MoDNR's 1.0 mg/L goal. Therefore, an alternate strategy was implemented.

As a second strategy for bringing effluent TP low enough to meet MoDNR's goal, the end of aeration air-OFF cycle was extended in one of four SBR basins and, at study's end, implemented in a second SBR basin. An orthophosphate concentration of less than 1.0 mg/L was realized in that basin.

Unfortunately, circumstances prevented the in-plant strategy from being initiated until mid-March 2025, shortly before the end of state funded pilot study. As the air-OFF cycles in more basins are phased in, more TP reduction is anticipated. Enough, perhaps, to meet MoDNR's 1.0 mg/L TP goal.

Nutrient and Energy Reductions

Despite the late switch in operations, the amounts of TN and TP reduced post-optimization was significantly more than reduced pre-optimization as shown in Table 1. The concentration of TN rose an insignificant amount – 0.1 mg/L. Regardless, the mass removed post optimization actually increased because the influent TN concentration rose by 12%. In addition, energy use and cost were reduced even though a large, on-going construction project was also drawing energy through the plant electric meter. Jefferson City is also planning to upgrade to more efficient aeration blowers in the future which will result in further cost savings.

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 10% 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 amount of the increase in flow – 10%.

Table 1 –Nutrient and Energy Reductions

	Pre-Optimization	Post-Optimization	% Improvement
TN – mg/L	8.2	8.3	-1.9
TP – mg/L	2.8	2.1	27
TN – lb/day Removed	1,248	1,460	17
TP – lb/day Removed	197	227	15
Energy Use – kWh/MG	1,215	1,214	0.1
Energy Cost - \$/MG	107	104	3

Costs and Return on Investment

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

MoDNR's cost for optimizing the Jefferson City 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. Jefferson City's costs (as estimated by facility staff) total \$3,871 but are offset by over \$33,967 in energy savings as shown in Table 2. Efficiency of energy use improved by 14%. This means that for every kWh used in treatment, more pollutants are now being removed.

The total cost of optimization was \$500 (\$30,596 - \$30,096), or per \$46 per MGD of treatment capacity. Conventional facility upgrades for nutrient removal typically cost hundreds of thousands, if not millions of dollars per MGD of plant capacity.

Table 2 – Facility Reported Costs

Item	(Cost) / Savings
Instrumentation	(\$1,048)
Lab Supplies	(\$2,519)
Added Personnel Time	0
Other	(\$304)
Energy Savings	\$33,967
Total	\$30,096

As shown in Table 1, the year-long optimization effort resulted in a 212 lb/day (77,380 pounds per year) decrease in TN, and an increased TP removal of 30 lbs/day (10,950 pounds per year). Adding the annual mass of additional increased annual TN lb/day to the annual mass of TP removed (77,380 + 10,950) equals 88,330 lb/yr or, 44 tons/yr of nutrient reduced. Dividing the project cost by the sum of the additional annual mass of TN and TP removed results in pilot project cost of \$0.006 (0.6 cents) per pound per year ($\$500 \div 88,330 \text{ lb/yr}$). In other words, the project was essentially cost neutral.

Initial Optimization Strategy:

Prior to the start of the Optimization Project, the Jefferson City RWRF staff had operated the facility to reduce total nitrogen (TN) to an effluent concentration of less than 10 mg/L, MoDNR's goal. This was done by monitoring and adjusting the dissolved oxygen (DO) concentration, mixed liquor suspended solids (MLSS) concentration, and SBR cycles. The staff at the Jefferson City RWRF are to be commended for early experimentation in nutrient reduction.

Because city employees had a great deal of success in operating their sequencing batch reactors (SBRs) to reduce nitrogen, the focus of the year-long nutrient optimization effort was on total phosphorus (TP) removal. Staff had tried to reduce TP prior to this study - Spring of 2023. They tried reducing air-off time but without a safe harbor provided by MoDNR to experiment, and an increase in ammonia the trial ended

The initial area of focus for TP reduction at the Jefferson City facility was the gravity thickeners – the only location in the plant where sidestream treatment could be isolated. The thickeners allow waste activated sludge (WAS) to thicken prior to de-watering by belt filter presses. As solids sitting in the gravity thickeners thicken in oxygen deficient conditions, “fermentation” is allowed to occur which will produce volatile fatty acids (VFAs) and, in turn, energize phosphorus accumulating organisms (PAOs). Returning a portion of the energized PAOs to the SBRs would, it was believed, enhance biological phosphorus removal.

Historically, all of Jefferson City's gravity-thickened waste activated sludge (WAS) has been sent to the belt press for de-watering and ultimately land applied. The strategy for Jefferson City was to

return approximately ten percent of the thickened solids – rich in energized PAOs - to the SBR basins.

The PAOs in the fermented return sludge are slowly growing, but within six weeks routinely returning a portion of the enriched PAO population in the waste sludge the PAOs should propagate to levels necessary to reduce phosphorus. It was hypothesized that the PAO population in the SBR mixed liquor suspended solids (MLSS) should grow to a level in the SBRs that, during the SBR react (aerobic) cycles, the PAO population should be enough to reduce phosphorus. This type of operation is generally referred to as “sidestream fermentation.”

Jefferson City had an existing mechanism for easily returning the fermented solids – a floor drain at the belt press that was easily operated to return flow from the belt filters to the inlet of the SBRs. The facility also had a solids blow-off line near the drain that allowed for fermented solids from the gravity thickeners to be “wasted” to the floor drain instead of being routed to the belt press. Based on the amount of WAS produced each day, it was determined that around 10% of the WAS would be returned to the SBRs – approximately 5,000 gallons/day. To accommodate the additional solids loading on the SBRs, staff increased wasting from the SBRs by an additional 5,000 gallons per day to maintain the existing MLSS concentration.

A greater than one-third reduction in phosphorus was achieved as the effluent concentration declined from a historical norm of 3 mg/L to 2 mg/L as a rolling annual average. This was a significant reduction, but not enough to meet MoDNR’s 1.0 mg/L effluent total-phosphorus target. Additionally, there was a buildup of scum/frothy foam developing on the basins. The contractor suggested attempting in-line treatment by reducing aeration in the SBR basins, which would allow solids to settle and hopefully create an anaerobic zone. Therefore, in February 2025, sending WAS to the floor drain was ended. There was not enough benefit to continue, and staff wanted to only try one change at a time and focus on in-line “mainstream” strategy.

Modifications to Initial Strategy:

In February 2025, the sidestream operation was terminated and an effort to biologically remove phosphorus utilizing an in-line treatment strategy was initiated. As of the writing of this report, the in-line strategy continues to be in effect.

In brief, the in-line phosphorus removal strategy employed at Jefferson City involves reducing the aeration time in the SBR basins to create a more anaerobic/septic environment in the SBR basins between the oxygen-rich “react” cycles. Prior to this optimization effort, each of the 4 SBR basins was operated in a sequence as follows:

To create stronger septic conditions for VFA production and the energizing of the PAOs living in and with the MLSS in the SBRs, in one of four SBR basins, Jefferson City staff adjusted the aeration time at the end of the third react cycle to extend the 120 minute air-off cycle (60 minutes of air-off settle time plus 60 minutes of air-off decant time).

React Cycle 1 40 min air	React Cycle 2 40 min air	React Cycle 3 40 min air	Settle Cycle 50 min air-off	Decant Cycle 70 min air-off
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The aeration time in the third react cycle of one of four SBR basins was reduced to 30 minutes which resulted in 110 consecutive minutes of aeration followed by 130 consecutive minutes of no aeration as shown below. No mixing occurs when the air is off and solids settle into an ever more septic blanket.

React Cycle 1 40 min air	React Cycle 2 40 min air	React Cycle 3 30 min air-on 10 min air-off	Settle Cycle 50 min air-off	Decant Cycle 70 min air-off
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The shortened air-on time didn't affect ammonia removal or conventional treatment. Consequently, with time, the aeration time in the third react cycle was reduced further to 25 minutes which resulted in an air-off cycle of 135 minutes as shown below.

React Cycle 1 40 min air	React Cycle 2 40 min air	React Cycle 3 25 min air-on 15 min air-off	Settle Cycle 50 min air-off	Decant Cycle 70 min air-off
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An unfortunate series of anomalous incidents – extremely cold weather, wet weather, returning more solids to the SBRs due to inability to land apply the solids, on-site construction interference, and a desire to operate “normally” during startup of their UV unit to comply with permit disinfection requirements – interfered with staff efforts to maintain the shortened aeration cycles. Thus, the reduced aeration scheme was postponed for several weeks.

Several times during the project, high influent flows caused the facility to be operated in High Flow mode – aeration shut off to avoid solids washout and flooding of the UV disinfection equipment, then fully aerating during recovery. This mode of operation temporarily interferes with optimization efforts.

In April, staff began to operate with two SBR basins on the reduced aeration scheme at 10 minutes reduced aeration time. Unfortunately, in early May 2025 a programmable logic controller (PLC) associated with a blower had shut down. Until it could be replaced, staff operated the blower only during the day when the plant was manned to ensure the blower did not overheat. This mode of operation also disrupted the optimization scheme for several days.

Prior to the PLC issue, staff found the plant to be operating well and were prepared to return to the reduced aeration mode in two basins. In mid-May, staff began operating the plant with two of the four SBRs in the following mode:

React Cycle 1 40 min air	React Cycle 2 40 min air	React Cycle 3 25 min air-on 15 min air-off	Settle Cycle 50 min air-off	Decant Cycle 70 min air-off
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Once again wet weather conditions interrupted the optimization effort in early June 2025, however by the second week of June, the plant was back to operating two SBR basins in reduced aeration

mode. The orthophosphate concentration in the flow exiting the two SBRs operated as described above with 105 consecutive minutes of aeration followed by 135 consecutive minutes of no mixing and no aeration dropped to under 1.0 mg/L. However, since the project was nearing its end, it is hoped the City will continue to pursue this mode of operation.

When all four basins are operated with extended air-off cycles, it is anticipated that Jefferson City's effluent total-phosphorus concentration will meet MoDNR's 1.0 mg/L goal.

Ongoing Optimization Strategies for Jefferson City:

- As conditions allow, shorten the air-on time in the third react cycle in all four SBR basins.
- Consider installing additional in-line instrumentation such as ORP (oxidation reduction potential) probes, ammonia, nitrate, and orthophosphate analyzers.
- Continue addressing Infiltration / Inflow (I/I). Until I/I is reduced, Jefferson City will likely struggle to provide consistent nutrient removal.
- Another weather consideration is that of water temperature. Seasonality affects treatment. Periodic adjustments in microbial population, dissolved oxygen settings, and cycle times may be necessary to optimize performance.

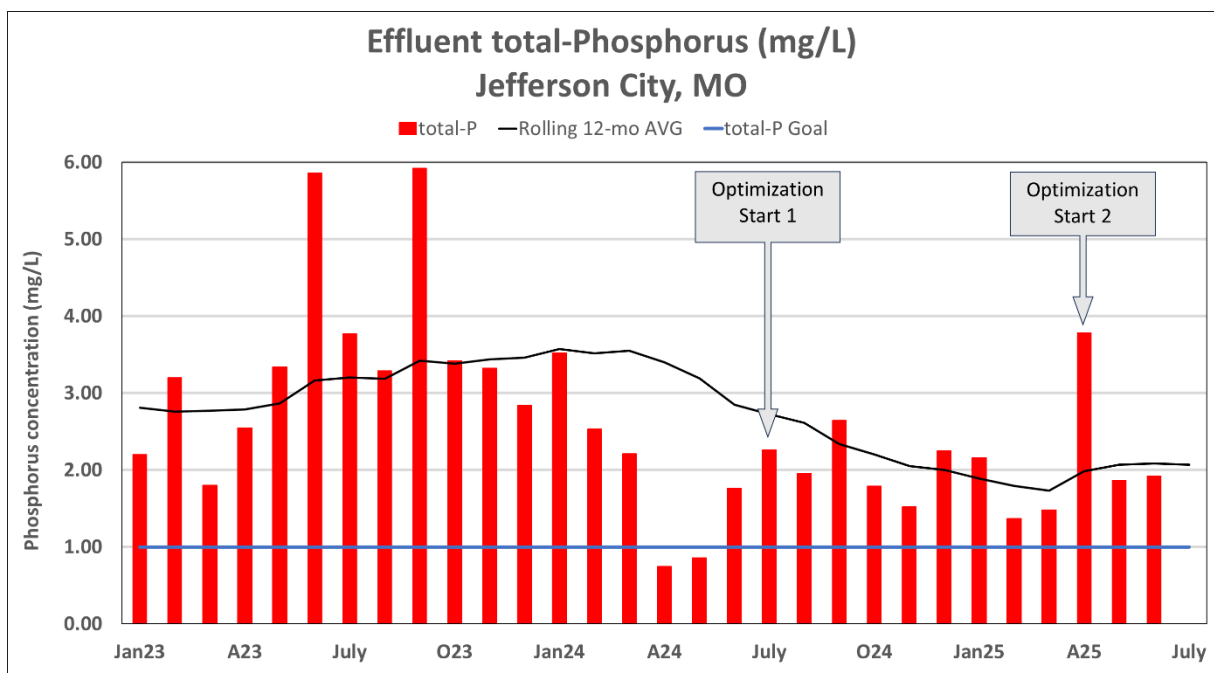
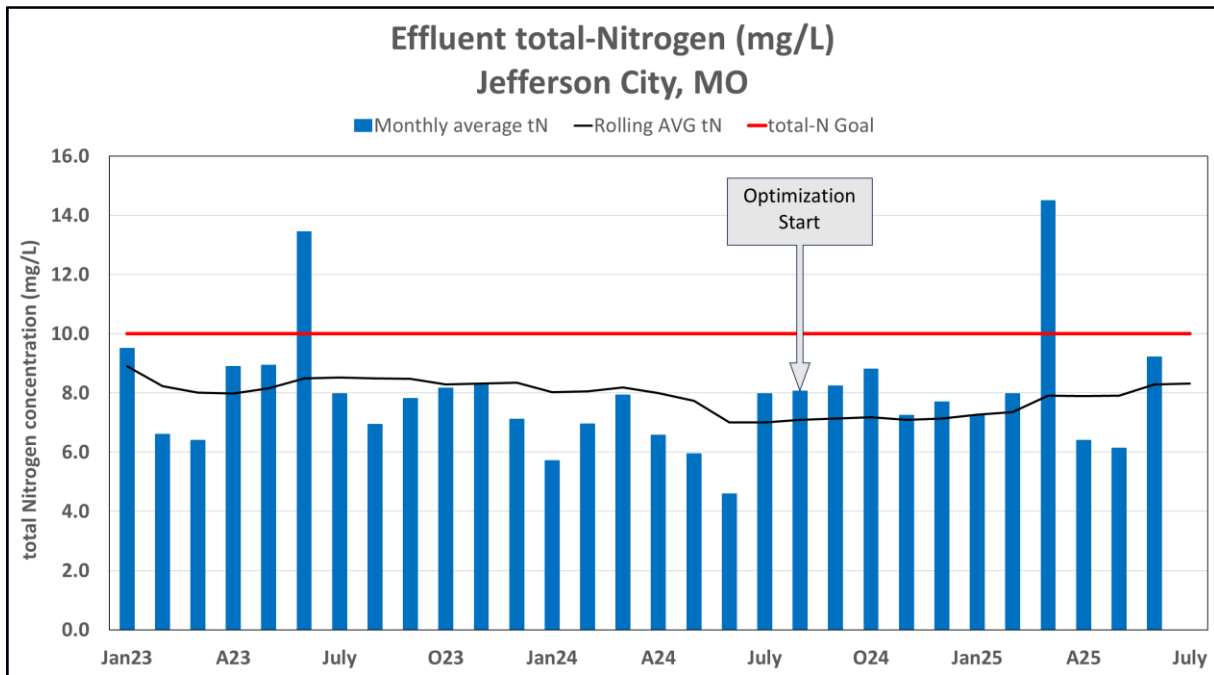
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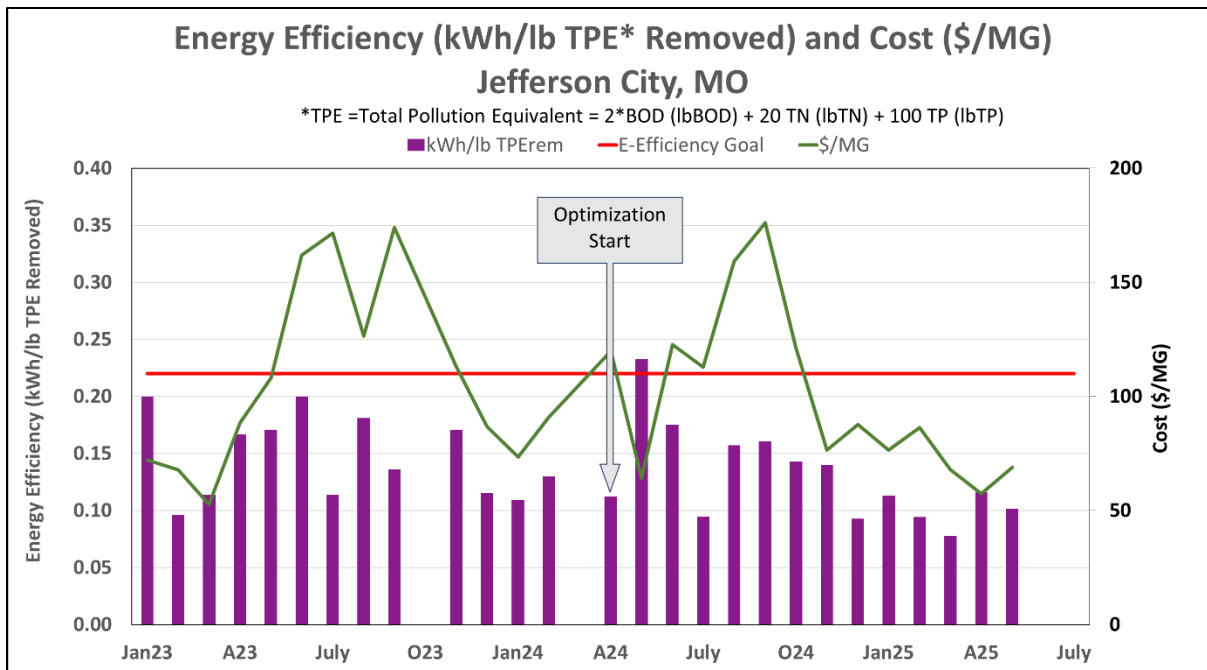
Jefferson City's Regional Water Reclamation Facility operates with a daily average flow of 7.9 MGD versus a design flow of 11 million gallons per day. The treatment facility includes three mechanical bar screens and grit removal followed by four SBR basins. Disinfection is provided by ultraviolet (UV) lamps. The plant has two solids thickening basins, two sludge storage basins, a solids decanter, and belt filter presses. Biosolids are land applied. It should be noted the plant will shortly switch to solids dewatering by centrifuging.

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 15 video call meetings with Jefferson City 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 air-ON, air-OFF cycles of Sequencing Batch Reactors can and should be adjusted to optimize nitrate removal while maintaining effective ammonia removal to achieve TN removal. Frequent testing and periodic adjustments are advised.

For phosphorus removal, the air-OFF cycles can often be extended to provide sufficiently septic conditions for VFA formation and uptake by PAOs.

Sidestream phosphorus removal is a viable option when appropriately sized tankage is available. Sidestream fermenters need to be big enough to provide enough 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.

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.