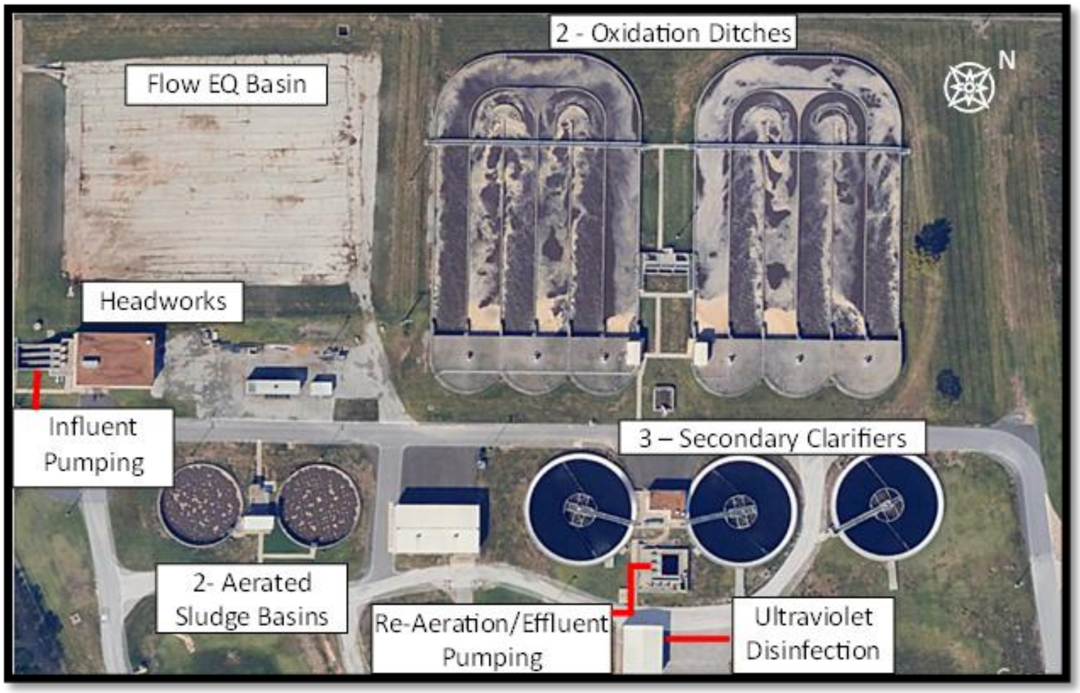
St Peters, Missouri

MO0094846

MoDNR Municipal Wastewater Nutrient Optimization Pilot Project

August 2025

St Peters Spencer Cr Wastewater Treatment Plant (WWTP)



Oxidation Ditch

Design Flow: 9.5 MGD

Actual Flow: 5.6 MGD

100 Ecology Dr
St Peters, MO 63376
Latitude 38.803056/Longitude -90.61

Amy Haddock, Water Environment Services Manager
Rusty Kinion, Director of Plant Operations

Summary of Optimization Efforts:

Nitrogen Removal

The biological treatment at the St Peters WWTP is a Carrousel® oxidation ditch process – sometimes referred to as a "folded" oxidation ditch. The WWTP has two ditches that are configured with the same rotor aerator placement – Figure 1.

The motors on each rotor are variable frequency drive (VFD) and can be operated independently; thus, different combinations of rotors were turned down or turned off altogether to create the anoxic zones necessary to reduce nitrogen. After optimization, the St Peters WWTP staff consistently reduced TN below the MoDNR goal of 10 mg/L.

Phosphorus Removal

Phosphorus reduction initially occurred after dual-purposing the sludge holding tanks to store sludge and to act as sidestream fermenters. While phosphorus reduction was observed, the effluent did not reach the 1.0 mg/L target. It is believed the tanks are too small to provide the hydraulic retention time needed to maximize production of volatile fatty acids (VFAs) and subsequent phosphorus accumulating organisms (PAOs). After several months, the sidestream experiment was abandoned and inline treatment attempted. The St Peters WWTP staff routinely reduced TP to less than 2 mg/L TP with inline treatment.

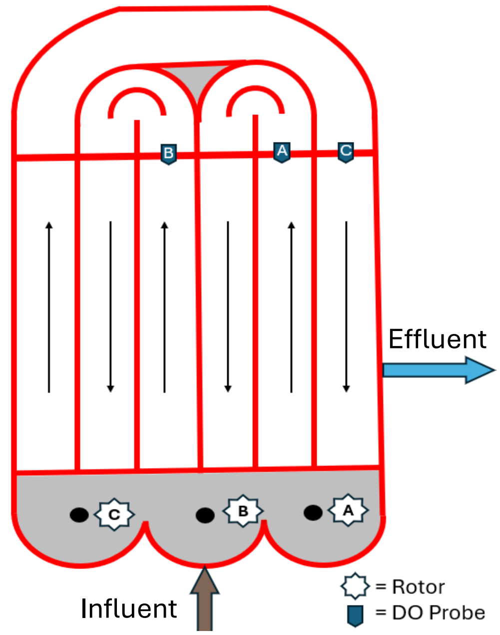


Figure 1 - St Peters Oxidation Ditch

Nutrient and Energy Reductions

As indicated in Table 1, the St Peters Spencer Creek WWTP reduced the concentration of TN and TP in their discharge by 64% and 20%, respectively during the project. The TN of 9.4 mg/L met the MoDNR target. The post-optimization TP concentration is 2.5 mg/L. While this is above the 1.0 mg/L target it represents a significant reduction.

The facility removed an impressive 153% more TN mass in terms of pounds per day (lb/day). Optimization reduced the amount of TN by 894 lb/day (1480 – 586 lb/day) or 163 tons per year. Though not as impressive as TN, the staff at the WWTP reduced an additional 24.6 lb/day (4.5 tons per year) of TP. By reducing the speed of some rotors and cycling others on and off, St Peters achieved the MoDNR TN targets, while managing to reduce the amount of energy used per MG by 18%.

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 – 10%.

Table 1 – Nutrient and Energy Reductions

	Pre-Optimization	Post-Optimization	% Improvement
TN – mg/L	26.2	9.4	64
TN – mg/L	3.1	2.5	20
TN – lb/day	586	1480	153
TP – lb/day	98.0	122.6	25
Energy Use – kWh/MG	2,633	1,984	25
Energy Cost - $/MG	198	162	18

Costs and Return on Investment

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

The St Peters Spencer Creek WWTP had energy savings in cost and kWh, while the efficiency of energy use improved by 44%. This means that for every kWh used in treatment, more pollutants are now being removed.

MoDNR's cost for optimizing the St Peters 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. St Peters' costs (as estimated by facility staff) total $6,241 but were offset by $70,664 in energy savings as shown in Table 2.

Due to significant energy savings, and minimal additional cost for St Peters there was no net cost for the project. The net revenue was $33,827 ($64,423 - $30,596).

Table 2 – Facility Reported Costs

Item	(Cost) / Savings
Instrumentation	($2,470)
Lab Supplies	($3,331)
Added Personnel Time	0
Other	($440)
Energy Savings	$70,664
Total	$64,423

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 or turning down the speed of the 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.

Targets were set for oxidation reduction potential (ORP) values at DO probe locations B and C – Figure 2. The facility controlled the aeration rotors by DO measured in the ditch with permanently mounted probes. To hit the target ORP values, aeration had to be reduced. Each week the facility reduced the DO set points at rotors A and B by 0.2 mg/L with a goal of driving denitrification. Optimal denitrification would be achieved when a nitrate (NO_3) level of 5 mg/L was reached. If needed, rotor B could be turned off entirely for several hours per day.

The plant saw a very rapid drop in NO_3 and TN. TN routinely fell below the MoDNR target value of 10 mg/L. TP reduction was not occurring, indicating that a septic/anaerobic zone was not being established in the ditch. Staff experimented with turning off rotor B for six hours per day, but TP reduction was minimal.

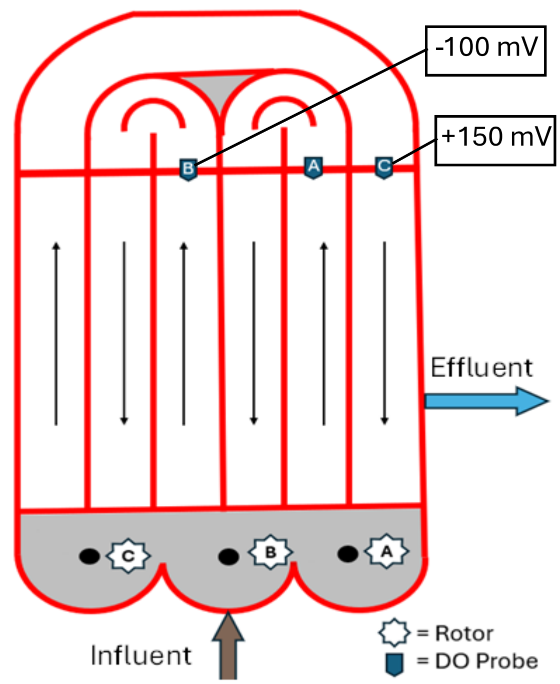


Figure 2 - Initial Optimization

Modifications to Initial Strategy:

After TN reduction was achieved, the aerated sludge holding tanks were dual purposed as sidestream fermenters to generate VFAs and PAOs and return the energized PAOs to the oxidation ditches. This involved holding solids long enough to reach around a -200 mV ORP. If fermentation could be achieved, VFAs would be generated and PAOs would release phosphorus. Returning a portion of those solids (approximately 10% of the volume of waste activated sludge) to the ditches would drive a build up of PAOs and reduction of phosphorus.

The plant staff made an extraordinary effort to maximize the solids holding time in the tanks to generate sufficient PAOs to return to the ditches. However, the sludge storage tanks were too small to generate sufficient phosphorus release. TP was observed, but not to the MoDNR target value of 1 mg/L. Following the sidestream experiment, in-line phosphorus reduction was resumed and routinely achieved values below 2 mg/L.

Staff experimented with different aeration schemes

- Operating with DO set points: A=0.4 mg/L; B=0.1 mg/L; and C=0.8 mg/L did well, reducing TN to less than 10 mg/L and TP to around 2 mg/L.
- Operating with rotors A and B off at the same time for 6 hrs/day when the plant was manned while maintaining a DO set point at 1 to 1.2 mg/L for probe C. This provided some of the best TP removal, however the sludge was not settling well.

Cold weather caused considerable scum to build up in the ditches. Because of submerged discharge in the ditches, the scum continued to build up and caused filamentous growth which led to poor settling sludge. Staff also believed the lower oxygen operations associated with optimization led to poorer settling sludge and began increasing aeration in June 2025.

St Peters staff believe that with some work, they can change the location of the influent from near rotor B to near rotor A. The contractors encouraged that modification. By introducing influent near rotor B, as is currently done, influent enters in the middle of the aeration process. Moving the influent to near rotor A would allow the plant to operate in more of a plug flow mode which would allow for setting up a more continuous oxygen gradient – anaerobic/anoxic/oxic.

Ongoing Optimization Strategies for St Peters:

- Continue to explore introducing influent near rotor A. If this physical modification takes place, look at establishing a DO gradient with DO lowest at probe A, higher at probe B, and highest at probe C. Hopefully, this can be accomplished by controlling the speed rotors (VFD - control). If minimum operating frequency does not drop DO sufficiently, consider turning rotors A and/or B off for several hours per day – starting with 4 hours off.
- Continue to fine tune warm and cold weather operating schemes by altering the rotor speeds/run times with less aeration in cold weather unless scum build up demands more aeration.
- Consider updating the system control and data acquisition (SCADA) system to allow for timers to automatically turn rotors on and off.
- 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.
- Consider exploring methods for removing scum from the tops of the ditches. Spraying with a chlorine solution is an occasional fix, but some type of permanent fix like a skimmer or slotted pipe is desirable if the hydraulics allow.

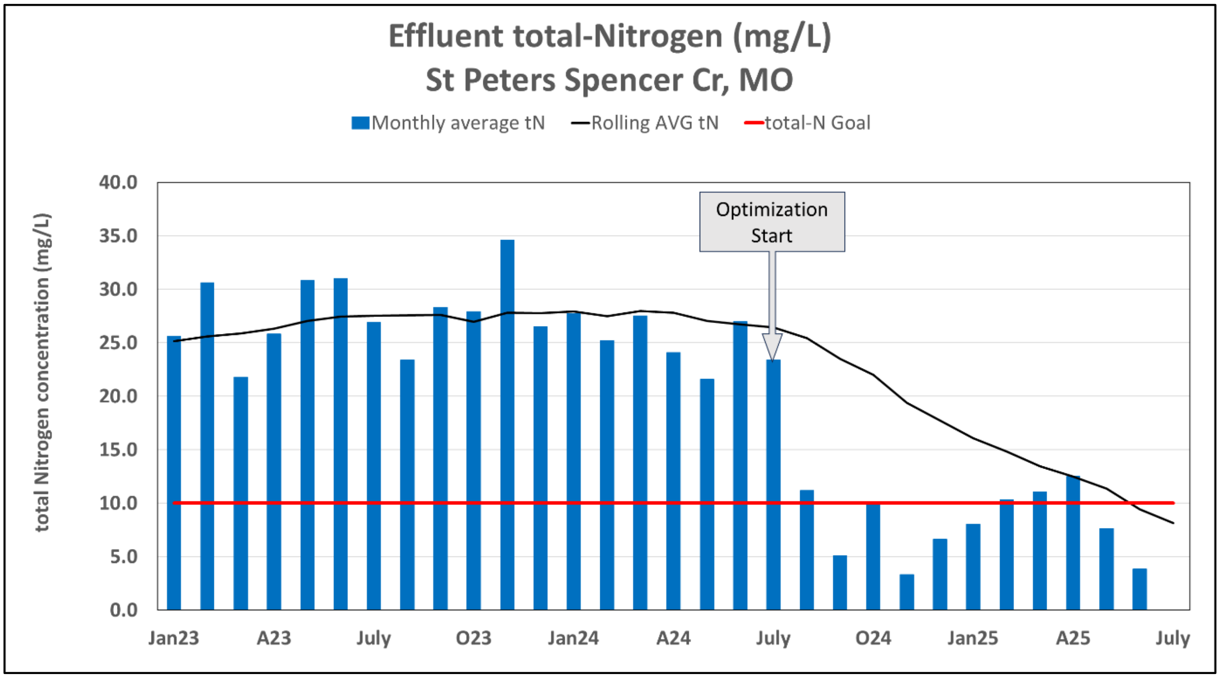
Additional Plant Information:

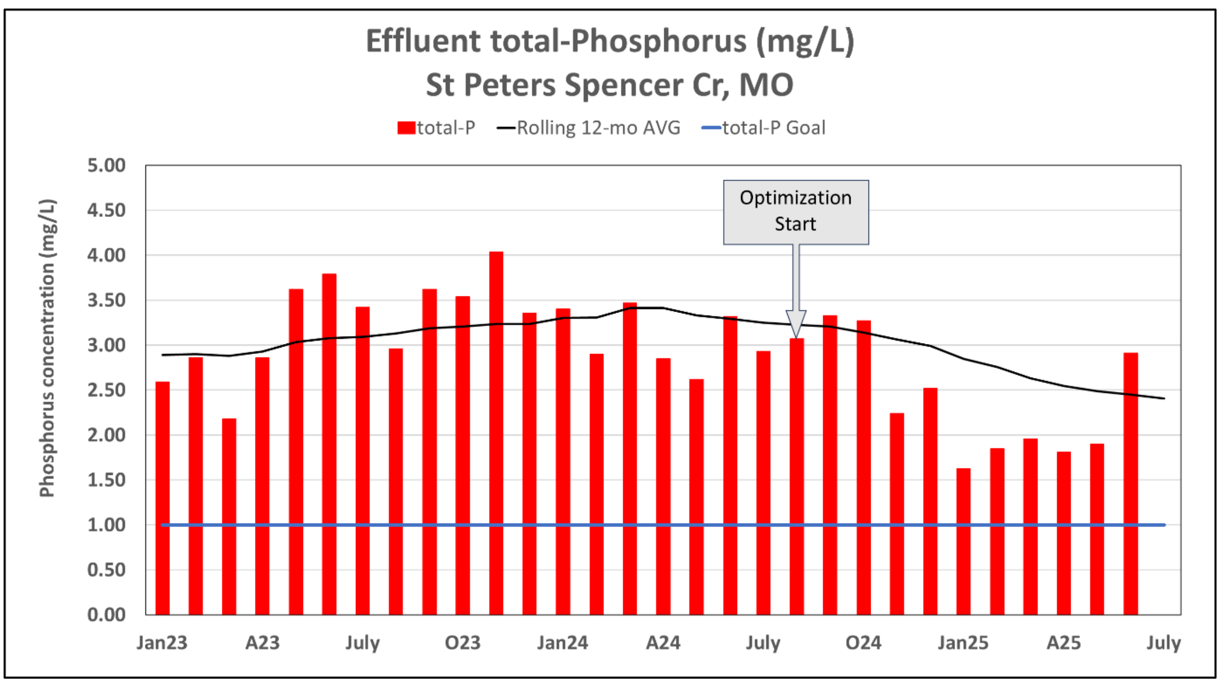
The St Peters Spencer Creek Wastewater Treatment Plant operates with a daily average flow of 5.8 MGD versus a design flow of 9.5 MGD. The treatment facility includes four flow equalization basins, mechanical screening, and grit removal followed by two oxidation ditch basins and three secondary clarifiers. Disinfection is provided by ultraviolet (UV) lamps. The plant has two aerated sludge storage tanks, and two belt filter presses. Biosolids are composted.

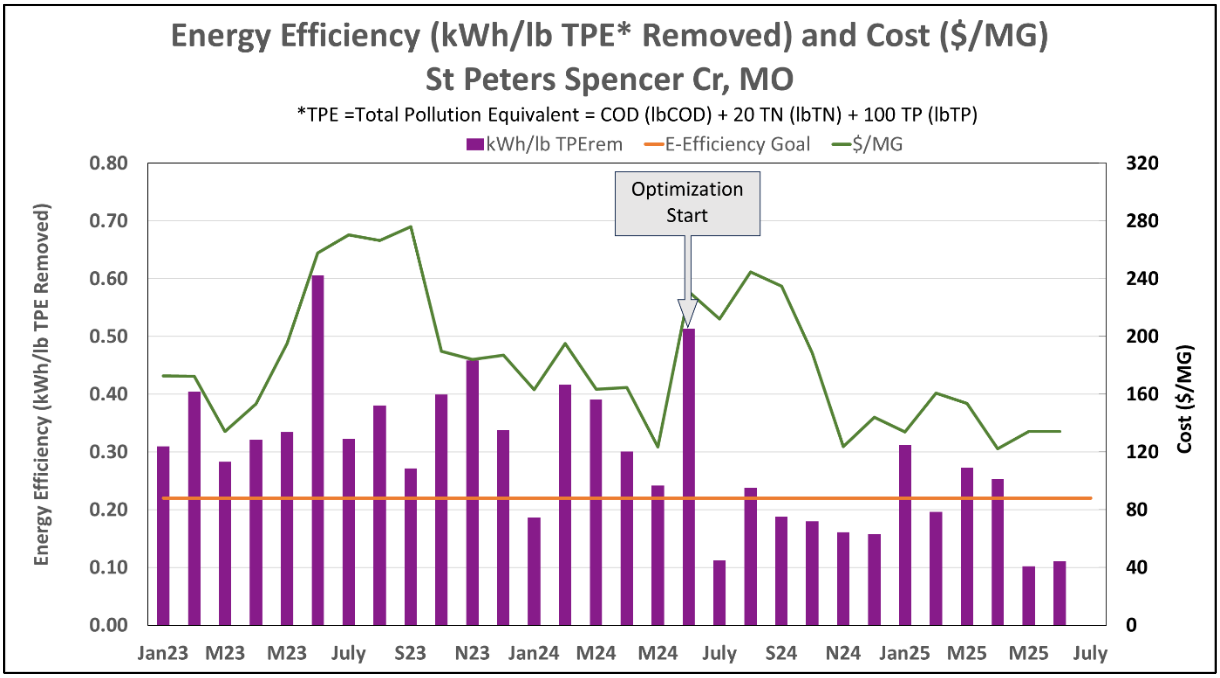
Contractor Information:

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 St Peters' 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 St Peters' facility provided the operators independent control over each aeration rotor allowing operational flexibility in establishing oxic and anoxic zones with the oxidation ditches. They had the flexibility to operate using DO set points for each aerator, as well as turning select aerators on and off. It was found that to maximize optimization for both TN and TP, at least one rotor needed to be turned off for several hours. The operators were able to take advantage of the flexibility to achieve the MoDNR TN goal by selecting specific rotors to turn down or turn on and off.

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. The St Peters' operators have a fairly unique ability to change the influent location to the oxidation ditches and are considering switching the influent location to a point near rotor A. This should allow the operators to create a more uniform DO gradient to provide for better TN and TP reduction.

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. St Peters saw some TP reduction. As stated previously, if the location of the influent is modified, it is hoped more TP reduction can occur.

Sidestream phosphorus removal may not be a viable option at St Peters. 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. The sludge storage tanks do not appear to be large enough to provide the retention time necessary to generate enough VFAs and phosphorus release to build up the quantity of PAOs necessary to achieve a TP concentration of 1 mg/L.

Both TN and TP reduction were impacted by cold weather. The extremely cold winter exacerbated scum formation on the ditch. Whereas many ditch designs have overflow weirs to facilitate effluent (including scum) leaving the ditch, the St Peters' ditches have submerged pipes so the scum floated above the effluent pipes and had no means for removal. Lack of any mechanism to remove scum from the ditches was unexpected and will likely continue to present operational issues at certain times of the year.

As noted earlier, the energy use per MG treated was reduced by 25%. The cost per MG treated dropped by 18%. The cost of energy saved offset the amount of money MoDNR and St Peters put into the project for the St Peters' facility. Both use and cost are remarkable savings and resulted in energy efficiency improving by 44%. 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 St Peters' 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.