An Investigation of Options to Improve Wastewater Treatment Infrastructure in the Alligator Creek Watershed

Joe Molenda

Abstract

This study looks at a creek located along the gulf coast in Venice, FL that has been identified as impaired by the Florida Department of Environmental Protection due to nitrogen loading. A high-density neighborhood that treats domestic wastewater through conventional septic systems surrounds the creek. These systems have been identified as a potential source of nitrogen loading into the creek. This study reviews different wastewater treatment strategies that could address this issue including several advanced onsite wastewater systems approved by the Florida Department of Health as well as septic to sewer conversion. Each strategy was evaluated based on 1) feasibility, 2) cost, and 3) ability to remove nitrogen from domestic wastewater. A recommendation was made based on which strategy would best reduce nitrogen entering the creek for the lowest cost and with the least complications. Replacing conventional septic systems with Aerobic Treatment Units (ATUs) was recommended because they were feasible to install on the small parcel sizes that make up the Alligator Creek Watershed. ATUs also had a lower operating and maintenance cost than the septic to sewer conversion strategy, had the same nitrogen reduction potential (>65%), do not require large capital improvement projects to implement, and do not present the risk of producing high-volume spills of untreated wastewater.

Nitrogen Pollution from Domestic Wastewater in Florida

A large debate has loomed over the last few decades around the issue of how to improve wastewater treatment infrastructure to remove nitrogen and protect our waterways. Septic systems have long been pointed to as a cause of water quality degradation in Florida. Research has shown that properly functioning septic systems are effective in reducing pathogens found in domestic wastewater, but nutrients (including nitrogen) are reduced to a lesser extent (Sherblom, 1998). Conventional septic systems operate by creating an anoxic environment in the septic tank stage of treatment that supports anaerobic bacteria that break down organic nitrogen into ammonium in a process known as ammonification. This ammonium rich wastewater then makes its way to the drainfield where aerobic bacteria in the unsaturated soil beneath the drainfield can convert ammonium into nitrate and then nitrate can be converted to nitrogen gas and released to the atmosphere through denitrification. Multiple studies have been conducted on this treatment process and they found conventional septic systems only reduce around 30% of total nitrogen from domestic wastewater before releasing the effluent to the groundwater (Aley et al., 2007; Bedessem et al., 2005). This treated effluent that contains high concentrations of nitrogen can then travel with the groundwater and enter surface waterbodies where it can contribute to nitrogen loading. That is why nitrogen pollution is one of the most prevalent and challenging environmental problems currently facing US coastal waters. Nitrogen pollution has resulted in serious environmental, ecological, economical, and human health problems, such as groundwater contamination, eutrophication, fish kills, harmful algal blooms including red tide, and some shellfish poisoning (USNRC 2000; Howarth 2008; Sayemuzzaman 2015). It is important that aging wastewater infrastructure is constantly monitored and upgraded when necessary to address the threat of nutrient pollution to our environment. Continuing to replace aging wastewater treatment infrastructure with systems that have proven to not effectively address this problem will not only prolong issues such as algal blooms, but also cost homeowners and tax payers more down the road when action is inevitably taken to upgrade conventional septic systems. It is important to establish a master plan to improve wastewater infrastructure now while conventional septic systems are nearing the end of their life so that they are not replaced and then, in the near future, be required by the state or county to be replaced again in order meet new standards that address nutrient pollution. This study's goal is to establish which alternative wastewater treatment strategies could reduce nitrogen from domestic wastewater to the highest degree and be compatible in the Alligator Creek Watershed in terms of both cost and feasibility to install.

Introduction to Alligator Creek Watershed

The Alligator Creek Watershed located in Venice, Florida is a 6,800-acre drainage basin with a 5-mile long creek that runs diagonally from the northeast to southwest into Lemon Bay and then into the surrounding Gulf of Mexico. The headwaters of the creek on the eastern end of the basin are primarily wetlands and surrounded by properties that were developed post-1980s and are served by a sewage collection system. The coastal end of the creek closer to Lemon Bay is tidally influenced and the surrounding properties are served almost entirely by septic systems that were installed starting in the 1950s-1960s. In addition, the coastal end of Alligator Creek was urbanized before the 1980s when stormwater treatment best management practices were required and therefore does not have an effective system in place for stormwater retention and treatment (Sarasota County, 2018). Given the differences between the eastern and western portions of the Alligator Creek drainage basin including hydrology, the period in which they were developed, and the domestic wastewater treatment strategies that are in place, the Florida Department of Environmental Protection (FDEP) divided the watershed into two waterbody ID numbers (WBID) 2030 and 2030A (Figure 1).

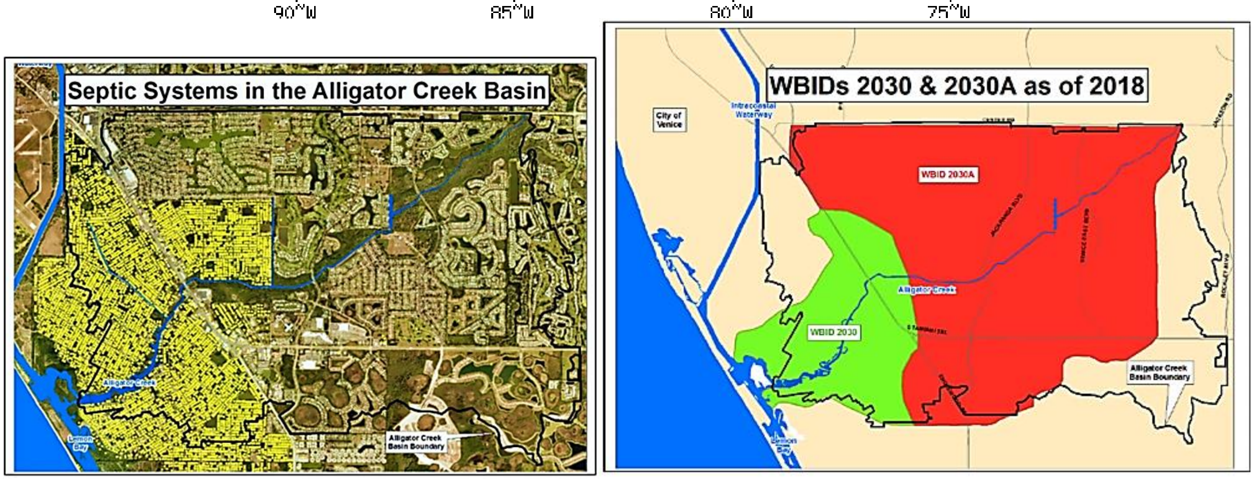


Figure 1: Septic Systems in WBID 2030 (Alligator Creek Watershed)
Source: Sarasota County Government "Alligator Creek WBID 2030 TMDL Implementation Plan."

This study will focus solely on WBID 2030 and how domestic wastewater treatment strategies can be improved in this region.

WBID 2030 contains a high density of single-family residences that were developed starting in the 1950s. Since this watershed was developed so early on, many regulations imposed by the state of Florida in 1983 to address domestic wastewater pollution were not in affect when the homes were built.

This puts a major portion of the basin at risk for not meeting current development standards intended to protect surface water bodies (Figure 2).

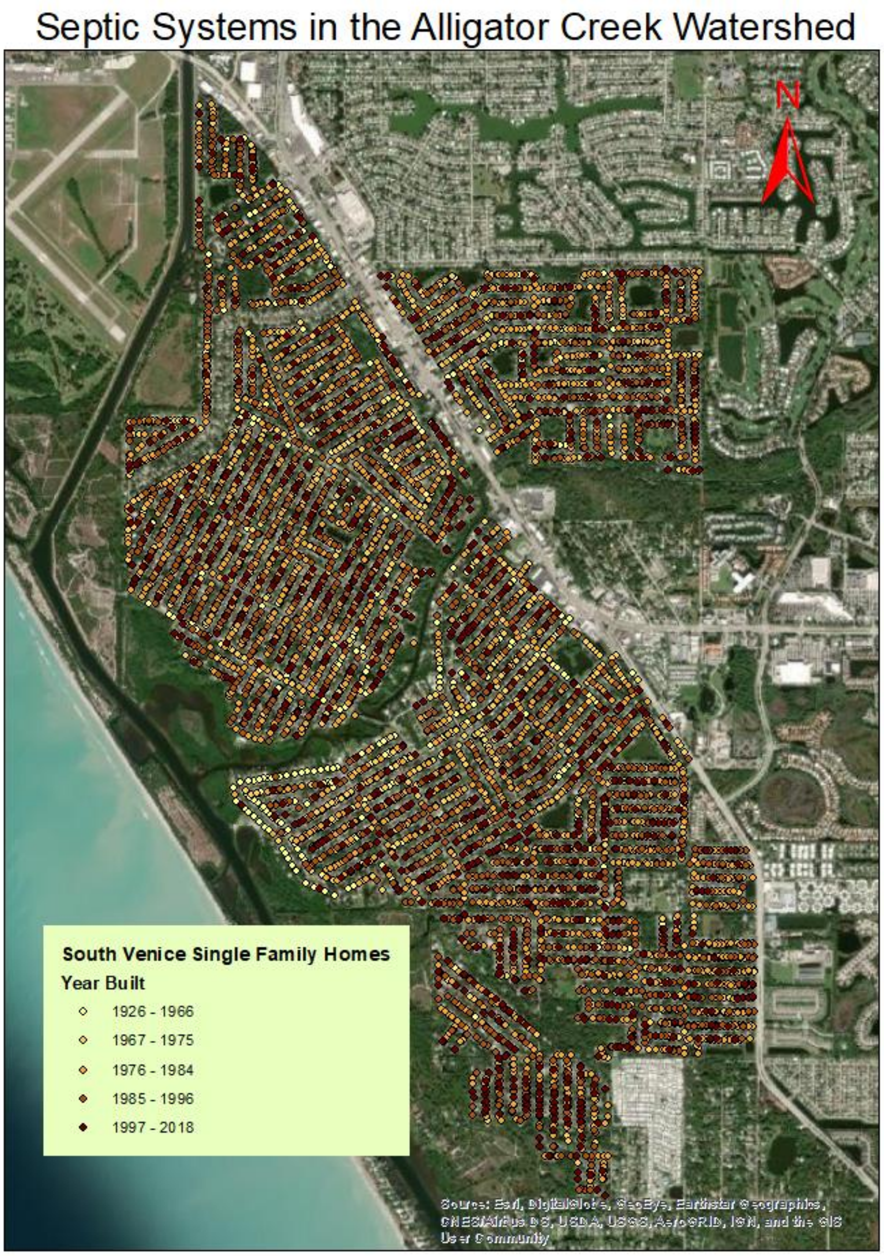


Figure 2: Sarasota County Property Appraiser Data for year homes were built in the Alligator Creek Watershed

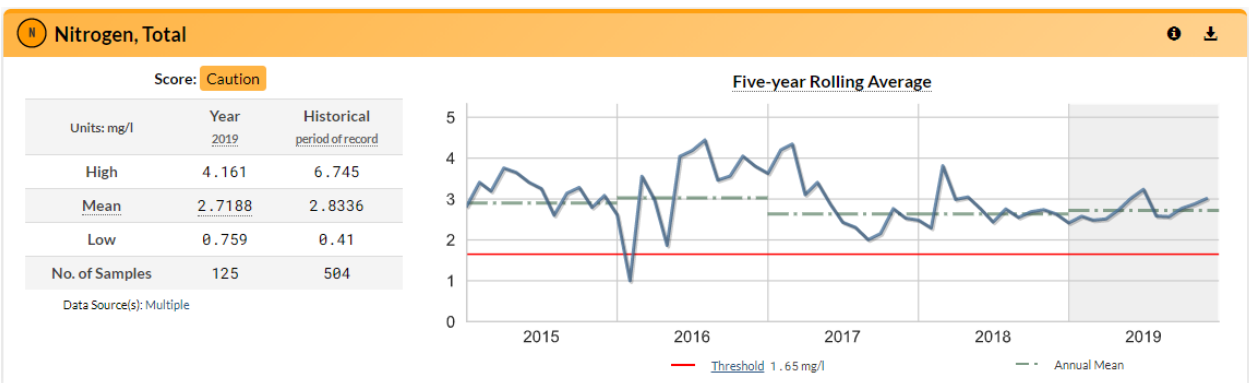
One of these standards accounts for the proper treatment and disposal of domestic wastewater through septic systems. Florida Administrative Code 64e-6 requires septic system drainfields to have at least 2 feet of separation between the bottom of drainfield and the estimated wet season water table. This requirement is in place because aerobic bacteria in the soil below the drainfield require oxygen to carry out nitrification which in turn drives anaerobic bacteria to perform denitrification, a process in which nitrogen from domestic wastewater is converted into nitrogen gas and released to the atmosphere rather than the groundwater (Ursin et al., 2008). This requirement was not established until 1983 and septic systems installed prior to this year were required to have only 6 inches of separation. This has resulted in a large portion of septic systems in WBID 2030 being installed with very little separation from the wet season water table compared to the current standards required by F.A.C 64e-6. This is especially true in areas closest to the coast that were developed first. This is why Sarasota County and the FDEP have recognized these septic systems as a likely contributor of pollutants to Alligator Creek and Lemon Bay, specifically nitrogen (Sarasota County Government, 2018). The Lemon Bay Watershed Management Plan (2010) also estimated that 41% of the septic runoff that enters Lemon Bay comes from Alligator Creek compared to runoff contributed by other watersheds (Table 1).

Table 1 Source of Current Total Volume to Lemon Bay

Basin	Source of Volume						
	Direct Runoff	Baseflow	Direct Rainfall	Point Sources	Irrigation	Septic Tanks	Total Volume
Alligator Creek	27%	30%	0%	7%	46%	41%	24%
Woodmere Creek	5%	6%	0%	29%	9%	19%	5%
Forked Creek	18%	17%	0%	0%	16%	10%	15%
Gottfried Creek	22%	20%	0%	58%	17%	8%	18%
Ainger Creek	19%	14%	0%	0%	4%	1%	14%
Coastal	9%	12%	100%	6%	8%	20%	24%

Source: Sarasota County Government "Lemon Bay Watershed Management Plan"

In 2006, the Environmental Protection Agency (EPA) issued a Total Maximum Daily Load (TMDL) for nutrients entering Alligator Creek through WBID 2030 calling for a 28.2% (1513 kg/year) reduction in total nitrogen coming from Municipal Separate Storm Sewer Systems (MS4s). This TMDL was issued to reduce the excessive nitrogen discharges coming from the creek and entering into Lemon Bay (US EPA Region 4, 2006; Sarasota County Government, 2018). In order to reduce the total nitrogen load entering Alligator Creek, it is important to address non-point sources like septic systems that encompass a large portion of the watershed and not just point sources. Upgrading wastewater treatment in this watershed to a degree that reduces nitrogen (N) more effectively should be considered a priority to improve the water quality of Alligator Creek as well as Lemon Bay. As we can tell by the graph below, the FDEP has recognized this issue and has identified Alligator Creek as impaired for exceeding the maximum allowable N concentration set by the Clean Water Act (1.65 mg/L) (Figure 3).



Units: mg/l	Year 2019	Historical period of record
High	4.161	6.745
Mean	2.7188	2.8336
Low	0.759	0.41
No. of Samples	125	504

Figure 3: Sarasota County Wateratlas: Alligator Creek Condition Report for 2019

Technologies including advanced onsite wastewater treatment systems have become available over the last couple decades and could be a viable solution to this problem. In addition, septic to sewer conversion is also a strategy recommended by the FDEP to improve wastewater treatment. Given the considerable time and planning that would go into executing these wastewater treatment upgrades in a watershed of this size and density, it is important to consider each wastewater treatment strategy by their 1) feasibility, 2) cost, and 3) ability to remove nitrogen from domestic wastewater before deciding which strategy to implement.

Alternative Wastewater Treatment Strategies

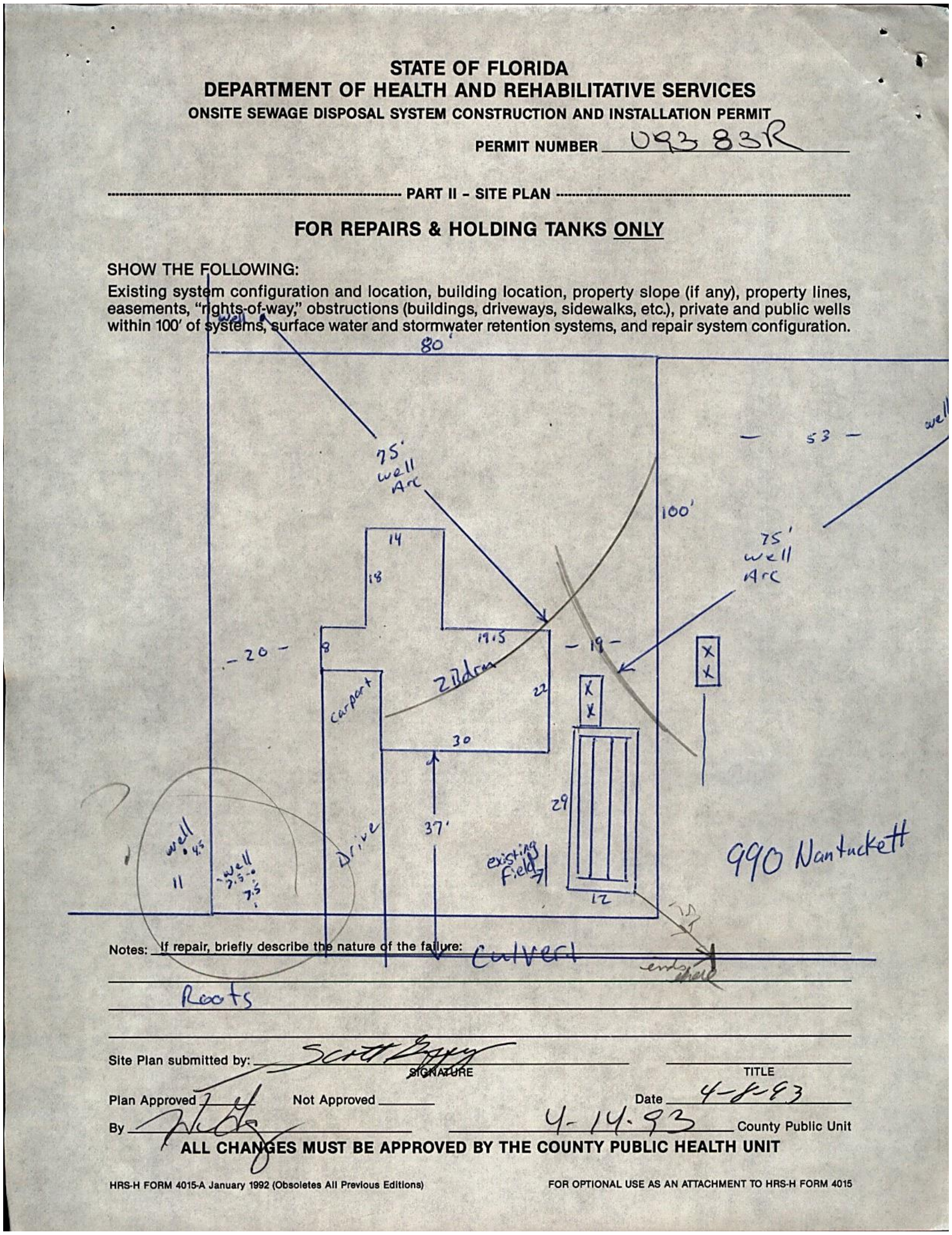
Technologies that have been studied and approved by the Florida Department of Health that reduce nitrogen loading from septic systems include Passive Nitrogen Reduction Systems, In-Ground Nitrogen Reducing Biofilters, and Aerobic Treatment Units. In addition, the Florida Department of Environmental Protection also recommends connecting high density residential neighborhoods, like the one surrounding Alligator Creek, to a centralized wastewater treatment system that treats wastewater at an offsite wastewater treatment facility.

Although all of these strategies are able to treat wastewater to a higher degree than a conventional septic system, we must first consider whether they are practical to implement in the Alligator Creek watershed. One specific challenge that is impossible to overcome for onsite wastewater systems is property size. The median size of the parcels located in our study area, WBID 2030, is 0.235 acres with some parcels as small as 0.19 acres (Hazen and Sawyer, 2002). This factor alone would exclude Passive Nitrogen Reduction Systems (PNRS) and In-Ground Nitrogen Reducing Biofilters as a viable alternative simply because their footprint would be too large to fit on the properties in WBID 2030.

A study of 7 PNRS conducted by Hazen and Sawyer and the Florida Department of Health in 2015 did find that Passive Nitrogen Reducing Systems are effective in reducing nitrogen from wastewater. However, a brief look at their design shows that they operate through a two-stage process, requiring multiple septic tanks as well as multiple drainfield biofilters to achieve their desired wastewater treatment goal. The PNRS with the smallest footprint in this study (BHS-7) requires a primary treatment tank, pump tank, and vertically stacked biofilter. In some cases, this may be feasible in terms of size, but the system showed only a 65% removal of total nitrogen and had a cost of over $25,000 (Hazen and Sawyer, 2015).

As for In-Ground Nitrogen Reducing Biofilters, these systems require a minimum separation of 24'' between the bottom of drainfield and the estimated wet season water table. This presents a challenge when trying to replace an older, conventional septic system with a system that requires this amount of separation from the wet season water table. Systems constructed prior to 1983 were only required to have a 6'' separation from the estimated wet season water table, resulting in the elevation of the lot to be much lower than what is currently required. In fact, the Sarasota County Wastewater Improvement Program study conducted in 2002 found that in the South Venice area, only 24% of all developed parcels (3,052 out of 12,653) had been permitted post 1983 at the time of their study. (Lemon Bay Watershed Management Plan, 2010).

In cases where the estimated wet season water table is only 24'' below existing grade, common for parcels constructed prior to 1983, requirements for In-Ground Nitrogen Reducing Biofilters would mean the bottom of the drainfield would need to be raised to the existing grade. This would require not only a pump tank but also an elevated mound with slopes to act as cover for the drainfield. Florida Administrative Code 64e-6 requires that slopes and shoulders of a mounded drainfield be kept within the owner's property boundaries. This prevents features such as stormwater swales from being altered by the downslopes of a septic system mound. Septic systems are also required to meet minimum setbacks to potable wells which causes a lot of issues for septic installation in WBID 2030 given most parcels depend on private potable wells for their water supply. Below is a site plan that was submitted with a septic permit in 1993 to repair the system for a house that was originally built in 1972 (Figure 4).


STATE OF FLORIDA
DEPARTMENT OF HEALTH AND REHABILITATIVE SERVICES
ONSITE SEWAGE DISPOSAL SYSTEM CONSTRUCTION AND INSTALLATION PERMIT

PERMIT NUMBER U93 83R

PART II – SITE PLAN

FOR REPAIRS & HOLDING TANKS ONLY

SHOW THE FOLLOWING:
Existing system configuration and location, building location, property slope (if any), property lines, easements, "rights-of-way," obstructions (buildings, driveways, sidewalks, etc.), private and public wells within 100' of systems, surface water and stormwater retention systems, and repair system configuration.

Notes: If repair, briefly describe the nature of the failure: Culvert
Roots

Site Plan submitted by: Scott [signature]
SIGNATURE TITLE
Plan Approved ✓ Not Approved ______ Date 4-8-93
By [signature] 4-14-93 County Public Unit
ALL CHANGES MUST BE APPROVED BY THE COUNTY PUBLIC HEALTH UNIT

HRS-H FORM 4015-A January 1992 (Obsoletes All Previous Editions) FOR OPTIONAL USE AS AN ATTACHMENT TO HRS-H FORM 4015

Figure 4: 990 Nantucket Rd, Venice- Site Plan for Septic Repair (1993)
Source: http://septicsearch.carmodyinc.com/Public/DocList.aspx?hdnView=896012

As you can see, the system is surrounded by wells, leaving very little room to expand the footprint as F.A.C 64e-6 requires that existing potable well setbacks be maintained if they are less than 75ft. You will also notice that the septic system is only 5ft away from the neighboring property line and 15ft away from the ditch in front. This leaves very little room to extend slopes and shoulders for a mounded system.

Expanding the footprint of septic systems in WBID 2030 while also meeting well setback requirements and requirements for constructing a mounded drainfield would be difficult and in some cases impossible. That is why this paper will solely focus on Aerobic Treatment Units and Septic to Sewer conversion as a means to improve wastewater treatment in the Alligator Creek watershed. These methods would not require the footprint of the septic system to be expanded and they both have the potential to reduce nitrogen loading in the watershed.

Current Wastewater Treatment Infrastructure in Alligator Creek

To understand the degree at which conventional septic systems are contributing to the nitrogen load to Alligator Creek we must look at several factors including the level of pretreatment of the effluent prior to being released to the drainfield, the drainfield's separation from the wet season water table, and the type of soil beneath the bottom of drainfield including the soil's concentration of organic matter (Badruzzaman et al., 2012; Aley et al., 2007).

Fortunately, numerous field studies have already been conducted to determine the degree of nitrogen removal for a conventional septic system after effluent passes through the septic tank and the drainfield.

One such study was conducted by the Florida Department of Health in 2007 on a 4 bedroom home in Seminole county that produces approximately 300gpd of wastewater and has soil characteristics similar to that of the Alligator Creek watershed as well as hydrology (Aley et al., 2007). The septic system was constructed in 1988 with a 1050-gallon septic tank and two 440 sq ft rock and pipe drainfields over a Eaugallie Myakka Fine Sand soil profile. It was estimated that the bottom of drainfield was at least partially submerged during the wet season, suggesting a 0'' separation from the wet season water table. Although the size of the drainfields in the Alligator Creek watershed are typically only around 300 sq ft, the other characteristics of the Seminole County site are practically identical to that of the septic systems found in the Alligator Creek watershed suggesting there are similarities to the degree of nitrogen removal these systems are able to achieve.

The study was conducted by first using groundwater probes to track the effluent plume from the drainfield as well as the direction of the groundwater flow. Once the extent of the effluent plume was identified sample points were established both beneath the bottom of drainfield and around the septic system site to compare the background groundwater quality with the groundwater quality directly below the drainfield (Figure 5). Samples of effluent were also taken from inside the septic tank.

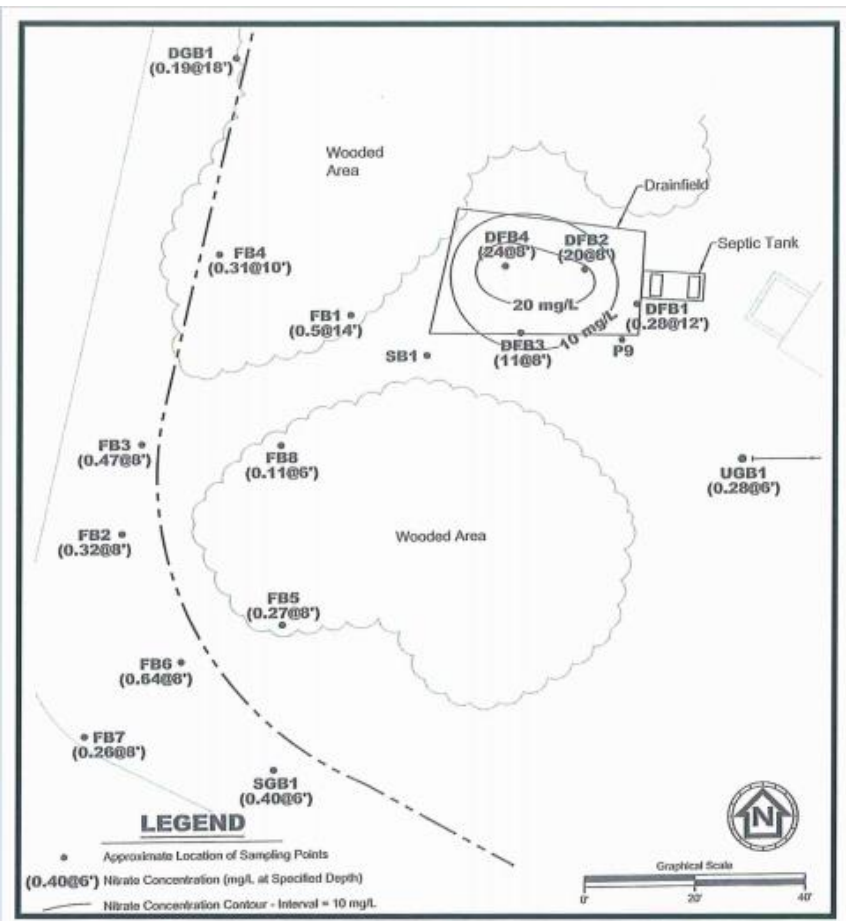


Figure 5: The nitrate plume encountered during the January/February 2007 Seminole County Sampling Event
Source: "Multiple Nitrogen Loading Assessment from Onsite Waste Treatment and Disposal Systems Within the Wekiva River Basin" (2007)

Since denitrification in the drainfield area is the primary process that removes nitrogen from effluent, total nitrogen from the septic tank effluent was compared with the concentration of nitrate/nitrite found in the drainfield area (Table 2).

Seminole County Mean Total Nitrogen Composition					
	Total Nitrogen	Total Kjeldahl Nitrogen (TKN)		Nitrate/Nitrite (as Nitrogen)	
	(mg/L)	(mg/L)	(%)	(mg/L)	(%)
Effluent	74	73.33	99.09	0.55	0.74
Below Drainfield	20	13.3	66.50	6.9	34.50
Background (DGB-1)	2.75	2.65	96.36	0.082	2.98
FB-7	0.76	0.51	67.11	0.25	32.89
FB-8	34.5	34.5	100.00	0.2	0.58
FB-6	10.3	9.43	91.55	0.6	5.83

Table 2: Mean total nitrogen composition in groundwater samples from the Seminole County OWTS site
Source: “Multiple Nitrogen Loading Assessment from Onsite Waste Treatment and Disposal Systems Within the Wekiva River Basin” (2007)

74 mg/L (STE TN conc) – 24 mg/L (highest NO_3 conc below drain field) / 74 mg/L (STE TN conc) = 68% of TN not nitrified or 32% apparent removal by nitrification/denitrification

By subtracting the maximum observed nitrate concentration from below the drainfield, which is assumed to represent the maximum amount of nitrogen reduction and removal, from the mean concentration of total nitrogen in the septic tank effluent (STE), and dividing by the mean concentration of total nitrogen in the STE, the study found that there is a potential for 32% nitrogen removal by nitrification/denitrification, leaving 68% of the TN to be diluted and contributed to mass loading (Aley et al., 2007).

Given the organic content of the soil in this study was low (1.29% average) it is not surprising that only 32% of total N was removed by denitirification. A similar study performed by Bedessem et al. (2005) found 31% N removal through denitrification in the absence of an organic layer. Organic content in the soil is an important factor for denitrification as the carbon present in organic matter feed heterotrophic bacteria responsible for denitrification (Ursin et al., 2008). WBID 2030 is a sandy coastal zone that has very little organic content supported by the fact that 50% of the watershed is classified as an Eaugallie Myakka Fine Sand by the Natural Resources Conservation Services (NRCS Web soil Survey). Therefore, we can assume these figures accurately reflect the nitrogen removal capacity of the conventional septic systems in the Alligator Creek Watershed.

Going a step further using prior research, we assume that the average person in the Alligator Creek watershed produces 68.6 gallons (259.7 liters) of wastewater per day (EPA, 2007) and that the mean total N of the septic tank effluent at each residence is 50 mg/L (EPA, 2007; Aley at al., 2007). We also assume that each household has 3 residents that live there full time.

259.7 liters/person/day x 3 people x 50mg/L= 38,955 mg/day/household

38,955 mg/day/household x 6762 households= 263,413,710 mg/day

263.41 kg/day x 365 day= 96,144 kg/year

96,144 kg/year x 0.68 (percent of N not lost to denitrification) = 65,378 kg/year N loading

Based on these assumptions, we estimate that conventional septic systems in the Alligator Creek watershed contribute a total nitrogen load of 65,378 kg/year.

That is not to say this entire nitrogen load makes its way to the creek. The effluent plume beneath the bottom of drainfield travels along the same flow path as the surrounding groundwater. If the groundwater travels to a stormwater retention structure such as a ditch or retention pond the nitrogen load has the possibility to be taken up by plants or released to the atmosphere via denitrification or volatilization. However, since this watershed was developed so early on, there is not a robust stormwater collection system in place to retain this groundwater and drive N reduction processes. Based on this, we assume much of this N load travels with the groundwater until it enters Alligator Creek or Lemon Bay.

Keep in mind, the EPA in 2006 recommended nitrogen loading from stormwater releases into Alligator Creek be reduced by 1513 kg/year (US EPA Region 4, 2006). This is only 2.3% of the total estimated nitrogen load contributed by septic systems to the watershed.

Converting Conventional Septic Systems to Aerobic Treatment Units

A method practiced in other parts of Florida that has reduced the nitrogen load from septic systems is the requirement of aerobic treatment units (ATUs) for enhanced wastewater treatment in areas where water quality is a concern. In fact, the Department of Environmental Protection established treatment standards for septic systems as part of their Basin Management Action Plan (BMAP) to protect Outstanding Florida Springs in north Florida. The goal of the BMAP is to reduce pollutants to the environment and assist in meeting Total Maximum Daily Load goals including those set for nitrogen. ATUs can help reach this goal as they are more efficient at reducing nitrogen in domestic wastewater than conventional septic systems. ATUs operate using aerobic bacteria at the tank stage of treatment rather than anaerobic bacteria. Aerobic bacteria are more efficient at the break down of organic nitrogen. ATUs also create an environment that supports nitrification so that ammonium in wastewater is converted to nitrate which then can be converted to nitrogen gas through denitrification. Conventional septic systems do not convert ammonium into nitrate until the drainfield stage of treatment and therefore are less efficient at the nitrification/denitrification process that removes nitrogen from wastewater.

To meet BMAP standards set for Outstanding Florida Springs, ATU systems must be certified to NSF 245 standards. This means the ATU has been tested and proven to reduce 50% of nitrogen in wastewater before it leaves the tank. In addition to that, to meet BMAP requirements established by the FDEP, the drainfield must also have 24 inches separation from the wet season water table. But, if the ATU tank is able to reduce 65% of nitrogen, the drainfield is not required to meet the 24-inch separation requirement (Rule 64E-6.012, Florida Administrative Code, 2018).

A list of ATUs in Florida certified to the NSF 245 standard is presented below (Table 3).

NSF Standard 245 (Nitrogen-Reducing) Certified Aerobic Treatment Units (ATUs) in Florida (Rule 64E-6.012, Florida Administrative Code)

Manufacturer	Equipment Series	NSF Tested Model	Third Party Certifying Organization	Florida-Approved NSF 245-Certified Models	Average Total Nitrogen Reduction - NSF 245 Completion Report*	NSF 245 Report Date
Anua	PuraSys	PekaSys CRB1 (PuraSys PS1-4)	NSF International	PS1-5, PS1-6, PS1-7. PS1-8, PS1-9, PS1-10, PS1-11, PS1-12, PS1-13, and PS1-14	58%	July 2011
Aquaklear, Inc.	AquaKlear	AK6S245	Gulf Coast Testing	AK6S245C, AK10S245C	50.8%	October 2010
Bio-Microbics, Inc.	BioBarrier	MBR 0.5	NSF International	MBR 0.5-N; MBR 1.0-N; MBR 1.5-N	79%	October 2011
Bio-Microbics, Inc.	MicroFAST	0.5	NSF International	MicroFast 0.5, 0.625, 0.75, 0.9, 1.5[1]	55%	October 2008
Clearstream Wastewater Systems, Inc.	Clearstream	500 D	Gulf Coast Testing	500D, 500DT, 500DST, 600D, 600DT, 600DC3, 750D, 750DT, 800D, 1000D, 1000DT, 1500D	52.9%	March 2013
Clearstream Wastewater Systems, Inc.	Clearstream	500 DA	Gulf Coast Testing	500DA, 500DAT, 500DAST, 600DA, 600DAT, 600DAC3, 800DA	54.1%	August 2015
Delta Treatment Systems, LLC.	ECOPOD-N	E50-N	NSF International	E50-N, E-50-N-IM1060, E-60-N E-60-N-IM1060, E75-N, E-75-N-IM1060, E100-N, and E-100-N-IM1530	53%	February 2010
Fuji Clean USA	CEN	5	NSF International	CEN 5, 7, 10, 14	74%	April 2015
Jet	Jet-CF	500	Gulf Coast Testing	J-500CF, J-750CF, J-1000CF, J-1250CF, J-1500CF	67%	December 2008 (revised December 2018)
Norweco, Inc.	Singulair TNT	TNT-500	NSF International	Singulair TNT-500**, Singulair Green TNT-500**, Singulair TNT-750**, Singulair TNT 1000, Singulair TNT 1250, Singulair TNT 1500	68%	November 2007
Orenco Systems	Advantex	AX20RTN	NSF International	AX20RTN, AX20N	55%	May 2015

Table 3: NSF 245 certified Aerobic Treatment Units
Source: http://www.floridahealth.gov/environmental-health/onsitesewage/products/_documents/245cert-atu-18.pdf

As we can see from this chart, four manufacturers produce ATUs that reduce total N by >65%. These manufacturers are Bio-Microbics Inc., Fuji Clean USA, Jet, and Norweco, Inc. These results show that replacing a conventional septic tank that reduces little to no nitrogen with an ATU from one of these companies would more than double the nitrogen reduction potential of septic systems in the Alligator Creek watershed.

In terms of feasibility, requiring septic systems in the Alligator Creek Watershed to meet BMAP requirements established by the FDEP is doable. In situations where 24'' separation between the bottom of drainfield and estimated wet season water table (EWSWT) are not achievable due to lot size constrictions, an ATU that reduces >65% total N could be installed and drainfield mounds would not need to be constructed as high. These drainfields would still be required to have 12'' separation between the bottom of drainfield and the EWSWT as required by Sarasota County Ordinance for drainfield replacements.

We have established that the N reduction potential of ATU systems is significantly higher than that of conventional septic systems and they are feasible to install on the properties in WBID 2030. However, it is also important to consider that the mechanical aspect of ATU systems are prone to failure if not properly maintained. A study conducted by the Florida Department of Health assessed the operating status of 469 ATU systems and found that 142 (30%) of these systems were not operating properly. The main reason these systems were not operating properly had to do with the aeration system with the most common conditions being the aerator was not working, the aeration in the aeration tank was not working, power was switched off, or the power indicator was not on (Roeder et. al., 2013). If the aerator for an ATU system is not operating, the system's N reduction potential would not be expected to be any greater than a conventional septic system's given the aerobic microbes in the tank that support the enhanced treatment of the wastewater would not be able to survive without the introduction of oxygen from the aerator.

Another factor that must be considered is the cost of these advanced wastewater treatment systems. Fortunately, a study conducted through the Sarasota South County Wastewater Improvement Program in 2002 by Hazen and Sawyer estimated the capital cost of alternative onsite sewage treatment and disposal systems including for ATUs. The cost for the installation of an ATU and drainfield was estimated to be between $9,200-$10,600 depending on the required mound height of the drainfield. The same study estimated the cost of installing a conventional septic tank and drainfield to be between $6,200-$7,300 (Hazen and Sawyer, 2002). Adjusted for inflation, the estimated cost to install a septic system with an ATU today is between $13,310-$15,336 while the cost for a septic system with a conventional tank would cost between $8,970-$10,561. In other words, it would cost roughly 30%-35% more to replace a failed septic system with an ATU tank and drainfield rather than a conventional septic tank and drainfield.

The initial install is not the only cost to consider when comparing total cost of a conventional septic system and a system with an ATU. The annual operating cost must also be considered. For a conventional septic system, the only real operating costs would be for a pump out every 3-5 years. For a system with an ATU, operating costs would include pump outs, fees for an annual operating permit required by the Health Department, a maintenance contract with a septic company to do biannual checkups on the system as required by the Health Department, and cost to run the aerator and have it serviced. The estimated cost breakdown for this is as follows…

Pump out: $300/5 years= $60/year
Annual Operating Permit= $50/year
Maintenance Agreement= $150/year
Replace aerator: $500/10 years= $50/year
Cost to run aerator= $50/year
Total annual maintenance cost for an ATU= $360/year
(Estimates from inspectapedia.com and Florida Administrative Code 64e-6)

As mentioned before, this investment would more than double the N reduction potential of septic systems in WBID 2030 from an estimated 32% removal to at least 65% N removal with an ATU tank that is in good working order. We also know that these systems are practical to install in WBID 2030 even with small lot sizes. It has been documented that the aerator component of these systems can be prone to failure if not properly maintained. However, this can be addressed by educating the public about the importance of maintaining these systems, imposing fines on homeowners with systems that are out of compliance or offering financial assistance to homeowners that are unable to pay for repairs to their ATU system.

Converting Conventional Septic Systems to Central Sewer

Replacing conventional septic systems with a network of sanitary sewer lines connected to a central wastewater treatment facility has been recommended for this watershed in the past. A study conducted through the Sarasota South County Wastewater Improvement program in 2002 by Hazen and Sawyer looked into replacing conventional septic systems in WBID 2030 with either advanced onsite sewage treatment systems or connecting the parcels to a central sewage collection system that would treat an estimated sewage flow of approximately 1.7 million gallons at the existing Venice Gardens Water Reclaim Facility (Figure 6).

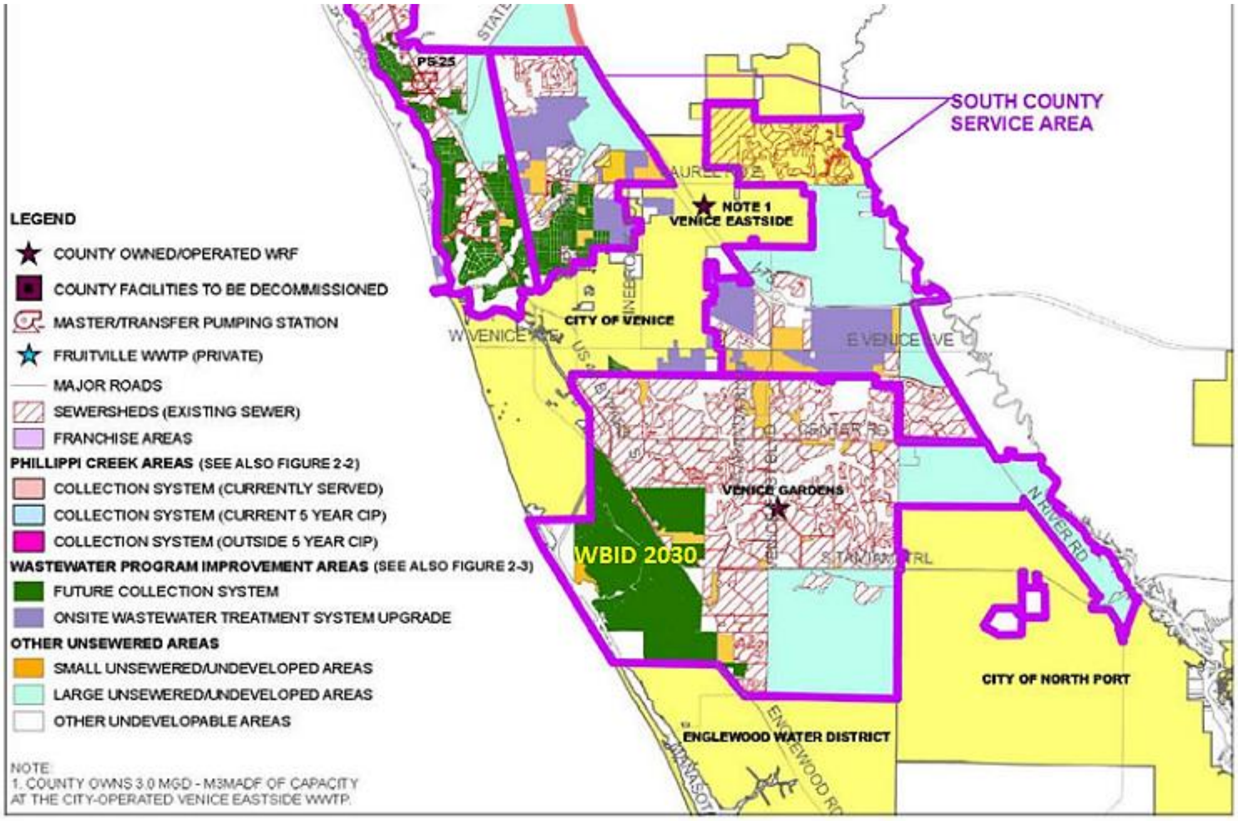


Figure 6: Venice Gardens Water Reclaim Facility
Source: Sarsota County Wastewater Management Report (2009)
https://sire.scgov.net/sirepub/cache/2/o0h4xryz0q5auwmejgnlv0z4/2143161021202002262597 6.PDF

The Venice Gardens WRF is located approximately one mile east of WBID 2030. The facility is identified as a high-level disinfection treatment facility as described by Rule 62-600.440(5), F.A.C. The treated effluent from the Venice Gardens WRF is primarily used for irrigation at neighboring residences and golf courses while a small portion that is not reused is disposed of using deep injection wells (FDEP, 2017). A Discharge Monitoring Report for September 2020 found that the total N concentration of treated wastewater leaving the facility was 18.4 mg/L (FDEP, 2020). In terms of N reduction potential, this is a 64% reduction when compared to the average total N concentration found inside a conventional septic tank (50 mg/L). This is practically the same N reduction potential an NSF 245 certified ATU system can achieve when considering only the tank component of the system. The drainfield of an ATU system is also expected to remove some of the N load through denitrification. Given the fact that the treated wastewater at the Venice Gardens WRF is primarily being dispersed through irrigation, we also expect the N reduction potential to be higher than 64% as N removal processes including uptake, denitrification, and volatilization take place.

The 2002 Hazen and Sawyer study ultimately recommended connecting WBID 2030 to the Venice Gardens WRF via vacuum lines given they had determined this method to be the least costly for a high-density neighborhood like the one encompassing Alligator Creek. The study estimated it would cost $8,700 for each household to connect to the Venice Gardens WRF using vacuum lines. In addition to this, annual operating and maintenance costs for this system was estimated at $64/year for each household (Hazen and Sawyer, 2002). Adjusted for inflation, today this would cost $12,587 for each household to connect to sewer and it would cost $93/year to maintain the sewer connection for each household. In addition, it is presumed that homeowners would be required to pay a monthly utility bill for sewer service. The average utility rate in Sarasota County is about $70/month according to a survey conducted for the City of Sarasota and city-data.com.

It is important to note that this estimate only accounts for the costs to connect the parcels in WBID 2030 to a sewage collection system and does not account for making any upgrades to the Venice Gardens WRF itself. The study assumes that the Venice Gardens WRF has the existing capacity to handle the additional 1.7 million gpd of wastewater coming from WBID 2030 and can treat this additional sewage flow effectively. However, the Annual Use Report for the Venice Gardens WRF submitted to the FDEP on December 27, 2017 indicates that the treatment facility has a permitted capacity of 3.0mgd and that the average flow it accepted at the time was 2.01mgd (FDEP, 2017). This suggests the Venice Gardens WRF is currently too small to handle the additional wastewater load coming from WBID 2030. By Hazen and Sawyers estimate in 2002, the treatment facility would need to be upgraded to handle an additional 700,000 gallons of wastewater if it were to accept the additional load from WBID 2030. To put this in perspective, the last upgrade to the Venice Gardens WRF in 2018 that raised the permitted treatment capacity from 2.0mgd to 3.0mgd cost roughly $4.5 million dollars to execute.

Another cost that was not mentioned in the Hazen and Sawyer study is accounting for groundwater recharge in WBID 2030. Onsite wastewater systems are responsible for creating one of the largest artificial groundwater recharge sources in the state (Ursin and Roeder, 2008). This source of groundwater recharge is especially necessary in WBID 2030 where the primary potable water source comes from private potable wells. If wastewater treatment in WBID 2030 is converted to a central sewer system, the water extracted from over 6000 wells in this watershed would not have a means to be replaced as it is transferred away from the watershed to be treated and disposed of offsite. This would essentially create a net loss of groundwater close to 2 million gpd in the absence of rain in WBID 2030. Maintaining a positive hydraulic gradient that continually recharges the groundwater and lower aquifer is important in reducing the risk of saltwater intrusion along coastal environments. Miami faces this issue as they continually grapple with maintaining elevated groundwater levels to stave off saltwater intrusion from sea level rise as well as meet the increasing water demands of a growing population (Czajkowski et al., 2018). This is an issue that would require more research to determine whether the loss of groundwater recharge in WBID 2030 would affect the hydraulic gradient of the watershed. The negative effects of this would likely not be noticed until the distant future as sea levels rise and the loss of groundwater extends over a long period. However, it is important to consider given the capital and effort it would take to address the issue. It would likely require WBID 2030 to be connected to a central water system so that private wells are no longer needed to support water consumption demands. Connecting over 6,000 houses to central water is another expense that may need to be accounted for when considering connecting WBID 2030 to sewer.

An issue that should also be considered when making the decision to switch WBID 2030 to sewer is the possibility of sewage spill events. Any sewage collection system of this size is expected to experience issues with transmission especially as the infrastructure ages. Depending on where the sewer line is compromised, these spills can be high volume and dispersed over a small, centralized location. This creates tremendous risk to the environment as high volumes of untreated wastewater can enter stormwater structures and inevitably surface waters very quickly. This is especially true during the wet season when runoff can transport this untreated wastewater, making it difficult to recover. The FDEP has recognized this issue and drafted a consent order in 2019 with Sarasota County that addresses unauthorized discharges to ground and surface waters. The Venice Gardens WRF is one of the wastewater treatment facilities mentioned in the consent order for being associated with 21 untreated wastewater spills since 2018 totaling 536,600 gallons (FDEP, 2019).

We know that replacing conventional septic systems in WBID 2030 with a central sewage system that connects to the Venice Gardens WRF would greatly increase N reduction potential of the wastewater load from 32% to at least 64%. In addition, the treated wastewater from WBID 2030 could be used as reclaim water for development projects taking place east of the Venice Gardens WRF. However, utility lines would need to be constructed to transport the reclaim water to the neighborhoods that need it before it can be used to their benefit. In addition to constructing reclaim water line, the Venice Gardens WRF itself would have to be upgraded to support the additional wastewater load coming from WBID 2030. Problems may arise in the future if WBID 2030 is connected to central sewer but not central water as septic systems are a major source of groundwater recharge. More research would need to be done in this area to determine whether the loss of groundwater recharge would have a significant impact on the hydraulic gradient of the watershed. It is possible central water would have to be supplied to WBID 2030 before it can be connected to central sewer to account for this issue. High volume spills from a central wastewater system should also be considered as they pose a tremendous risk to the environment. It seems over time, these spill events will become more likely. Constant monitoring and upkeep of the system can minimize this risk but as we have seen with many sewage collection systems across the state of Florida, as this infrastructure ages, the risk of sewage spill events increases.

Discussion

As time goes on, new wastewater systems that address nutrient pollution are being developed. It is important to constantly evaluate these systems to determine whether they could be used as a tool to combat nutrient pollution to waterbodies that are impaired. Alligator Creek is one of those waterbodies that has been identified as impaired due to high concentrations of nitrogen. To address this issue, wastewater treatment strategies in the Alligator Creek watershed should be reevaluated as conventional septic systems in the watershed do very little to remove nitrogen from domestic wastewater before releasing the effluent to the environment. The Florida Department of Health has approved onsite wastewater systems including Passive Nitrogen Reduction Systems, In-Ground Nitrogen Reducing Biofilters, and Aerobic Treatment Units that address this issue. Although all of these systems are effective in reducing N from wastewater, Passive Nitrogen Reduction Systems and In-Ground Nitrogen Reducing Biofilters require a large footprint to be installed. This creates a challenge in WBID 2030 where the lot sizes are very small (0.19-0.23 acres). Constructing elevated drainfield mounds and maintaining potable well setbacks is difficult and, in most cases, impossible with these types of systems. Septic to sewer conversion is also a strategy recommended by the FDEP to improve wastewater treatment and address N pollution that is feasible in WBID2030. Considering all of the alternative wastewater treatment strategies available, it was found that ATU systems and septic to sewer conversion were the only practical strategies that could be implemented in this watershed in terms of 1) feasibility, 2) cost, and 3) ability to remove nitrogen from domestic wastewater. Both of these strategies have advantages and disadvantages associated with them and these have been highlighted in the table below along with their associated costs (Table 4).

Table 4: Conventional Septic Systems vs. ATU Septic Systems vs. Sewer Connection

Conventional Septic System	ATU Septic System	Sewer Connection
• **32% N Reduction Potential** • **Capital Cost: $8,970-$10,561** • **Maintenance Cost: $60/year** (pump-out every 5 years) • **No electricity required** • **Homeowners responsible for maintenance**	• **>65% N Reduction Potential** • **Capital Cost: $13,310-$15,336** • **Operating and Maintenance Cost: $360/year** • **Aerator prone to failure without upkeep** • **Source of groundwater recharge** • **Electricity required** • **Homeowners responsible for maintenance**	• **>64% N Reduction Potential** • **Capital Cost: $13,252** (Includes upgrade to Venice Garden WRF) • **Operating and Maintenance Cost: $933/year** (Includes monthly utility bill) • **Possibility of high-volume spills** • **Groundwater recharge may be issue if potable wells used for water consumption** • **Electricity required** • **Provides source of reclaim water for new developments** • **Sarasota County responsible for maintenance**

We can see that replacing conventional septic systems in WBID 2030 with either ATU systems or sewer connections would more than double the N removal potential of wastewater treatment in the watershed. We can also see that the capital cost of making this change and enhancing wastewater treatment either by ATU systems or sewer connections would be roughly 30-35% greater than if the situation is left as is and conventional septic systems remain as the primary wastewater treatment strategy. These additional costs may discourage some homeowners from making the conversion to advanced wastewater treatment so policy makers should look into implementing cost-share programs, especially for homeowners that are financially disadvantaged.

Although the capital cost of ATU systems and sewer connections are roughly the same, we estimate annual operating and maintenance costs for sewer connections to be slightly higher than ATU systems mainly due to the assumption that a monthly utility bill would be applied to homeowners connected to sewer. It is also possible that the total costs for sewer connections could be even higher if potable wells are not kept as the primary water supply for the watershed. More research is needed to determine whether the loss of groundwater recharge from septic systems would require central water to be connected to WBID 2030 before this cost is associated with connecting the watershed to sewer.

Another burden that should be considered when switching away from conventional septic systems includes the requirement of electricity. Most conventional septic systems operate using gravity flow and do not required power to function. ATU systems need power to run the aerator so that they are operating at their full treatment potential. The sewer connections recommended for WBID 2030 are vacuum sewer lines and require power to operate the pump system that allows for effluent transmission. In the event of a prolonged power outage, ATU systems could still operate, but would not meet the wastewater treatment goals they were designed for. A vacuum sewage collection system would need a backup power supply in place to operate in the event of a prolonged power outage.

Its also important to note the complications ATU systems and central sewer systems face when compared to conventional septic systems that are less complex. Improperly maintained ATU systems can experience problems with the aerator component of the system, reducing their effectiveness as an advanced wastewater treatment system. However, even without the aerator, some level of wastewater treatment still occurs as the ATU tank acts as a conventional septic tank without the aerator and the partially treated effluent still enters the drainfield for its final treatment. On the other hand, central sewer systems in failure can contribute large volumes of untreated wastewater to the environment. This is especially true for sewage collection systems as they age. A report by GateHouse Media citing sewage spill data from the Florida Department of Environmental Protection from 2009-2019 found that aging sewage systems in the state have released more than 370 million gallons of completely untreated wastewater to the environment (GateHouse Media, 2020). This is important to consider before deciding to connect a high-density watershed like WBID 2030 to an extensive sewage collection system managed by a single entity, Sarasota County. Implementing ATU systems as the wastewater treatment strategy for WBID 2030 would put the responsibility of maintaining the wastewater treatment infrastructure in the watershed on multiple entities, homeowners, rather than solely on Sarasota County. This could lead to better overall maintenance of the wastewater treatment infrastructure. If there are more entities involved in managing the wastewater treatment system of the watershed, then there are more stakeholders involved in managing upkeep and addressing system failures.

Another problem that policy makers should consider when deciding to enhance wastewater treatment in WBID 2030 is how to get homeowners on board with paying more money for a system that, in their eyes, functions the same as a conventional septic system. There are multiple approaches to this and ultimately it would be up to policy makers to decide which approach is best. A common approach taken by many municipalities is implementing policies that dictate when a system is in failure, it must be upgraded and that any new septic systems installed must meet advanced treatment standards. To get an idea of what this would look like, data for the number of repairs and new system permits applied between 2010-2019 in the 34293 area code (WBID 2030) was collected from the Florida Department of Health's Environmental Health Database (Table 5).

Year	Number of Septic Permits	New	Repair
2010	107	9	98
2011	90	7	83
2012	101	12	89
2013	138	15	123
2014	127	29	98
2015	148	21	127
2016	158	34	124
2017	147	41	106
2018	163	47	116
2019	152	36	116

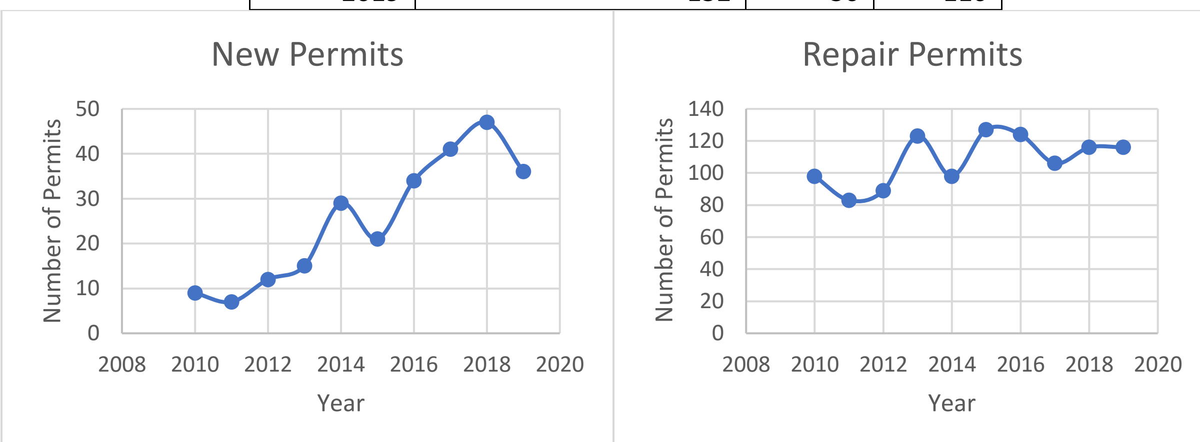


Table 5: Septic permits applied for in 34293 area code (WBID 2030)
Source: Florida Department of Health- Environmental Health Database

We can see based on this data that there has been a steady increase in permit applications for new construction in WBID 2030 while permit applications for repairs have been relatively constant. A policy like the one recommended above could result in over 100 advanced wastewater systems septic systems being installed in place of conventional septic systems every year. Another, more focused strategy could involve identifying which properties in WBID2030 pose the biggest risk in terms of nitrogen pollution to Alligator Creek. This strategy has already been implemented in Sarasota County in the City of North Port along the Myakkahatchee Creek. A study was conducted to determine which properties in proximity to the Myakkahatchee Creek posed the biggest risk and “conservation zones” were established. Any parcels that fall within Conservation Zone 3 are required to have an advanced wastewater treatment system like an ATU where sewer is not available (City of North Ordinance, Chapter 9). This strategy would require field research to be conducted along the Alligator Creek to determine which parcels have the highest potential for N loading. This could include tracking the effluent plumes being discharged from properties near the creek to see how high the N load is that is entering the creek from these plumes. Alternatively, if funding is not available for field research, ArcGIS models including ArcNLET could be used to make this risk assessment. Anybody with an ArcGIS software package can run this model and track groundwater flow, velocity, and direction and estimate how much nitrogen as nitrate is entering Alligator Creek.

Lastly, input from homeowners that live in WBID 2030 should be considered before a decision is made on which wastewater treatment strategy to implement. It would be ideal to provide all of the information about each strategy including costs, advantages, and disadvantages to the homeowners and then conduct a survey on which method they would prefer. Given homeowners are the largest stakeholders in this, it is important their voices are heard.

Conclusions

Considering the costs, advantages, and disadvantages, we determined converting conventional septic systems in WBID 2030 to ATU septic systems would be the most effective way to upgrade wastewater treatment in the watershed and improve the water quality of Alligator Creek. This treatment strategy has the same N reduction potential and capital costs as septic to sewer conversion and at the same time has a lower annual operating and maintenance costs. It would also take less time to implement given the fact that there are no large capital improvement projects associated with installing ATU system. On the other hand, sewage connections for WBID 2030 would require not only a network of transmission lines to be installed but the Venice Gardens WRF would also have to be upgraded to handle the additional wastewater load. There is also the potential that potable wells in WBID 2030 would have to be replaced by a central water system to address groundwater recharge concerns. Connecting the watershed to central sewer does provide the potential benefit that the treated wastewater can be used as a reclaim water source for newly developed neighborhoods. However, the potential risk a central sewer system of this size poses in terms of high-volume sewage spills should not be ignored. The risk a failing central sewage system poses to the environment is much higher compared to the risk a failing ATU system poses. A failed ATU system at least partially treats wastewater before releasing it to the environment while a failing central sewage system does not.

Sources

W.C. Aley IV, M. Mechling, G.S. Pastrana, E.B. Fuller (2007) “Multiple Nitrogen Loading Assessment from Onsite Waste Treatment and Disposal Systems Within the Wekiva River Basin” A Report Prepared for the Florida Department of Health, Tallahassee

Badruzzaman, Mohammad, et al. (2012) “Sources of Nutrients Impacting Surface Waters in Florida: A Review.” Journal of Environmental Management, vol. 109, pp. 80–92., doi:10.1016/j.jenvman.2012.04.040.

Bedessem, M.E., Edgar, T.V., and Roll, R. (2005). “Nitrogen removal in laboratory model leachfields with organic-rich layers”. J. Environ. Qual., 34, 936–942.

City of North Ordinance (Adopted 9-17-1990) Chapter 9, Ord. No.90-28 (Section 8). CONSERVATION RESTRICTED OVERLAY ZONE, MANATEE PROTECTION REGULATIONS. https://www.cityofnorthport.com/Home/ShowDocument?id=9017

Czajkowski, J., Engel, V., Martinez, C., Mirchi, A., Watkins, D., Sukop, M., & Hughes, J. (2017, December 01). Economic impacts of urban flooding in South Florida: Potential consequences of managing groundwater to prevent saltwater intrusion. Retrieved October 21, 2020, from https://www.sciencedirect.com/science/article/pii/S004896971732973X?casa_token=azkDiiI2XOsAAAAA%3ABW4WAYenaStDnc4XPIxm-yWWDqOiNhqvta5Utu5v_cpWjnLyVf1wjdiQCdfWpA1OEfuzwHxm

EPA, (2007) Establishing Treatment Performance Requirements. Chapter 3. US Environmental Protection Agency, Office of Research and Development, Center for Environmental Research Information, Cincinnati OH.

Florida Department of Environmental Protection. (December 27, 2017) Annual Use Report: Southern Sarasota County Regional Reuse System. https://depedms.dep.state.fl.us/Oculus/servlet/search

Florida Department of Environmental Protection (2019) Consent Order https://www.scgov.net/home/showdocument?id=43376

Florida Department of Environmental Protection. Discharge Monitoring Report for September 2020: Venice Gardens Water Reclamation Facility Permit# FLA043494. https://depedms.dep.state.fl.us/Oculus/servlet/search

GateHouse Media, Salman et al. (2020) "Sewer Crisis in Florida – Aging infrastructure and storms contribute to massive spills"

Howarth RW (2008) Coastal nitrogen pollution: a review of sources and trends globally and regionally. Harmful Algea 8:14–20

Sarasota County Government (2018) "Alligator Creek WBID 2030 TMDL Implementation Plan." Sarasota County Wateratlas, www.sarasota.wateratlas.usf.edu/upload/documents/Alligator-Creek-TMDL-Implementation-Plan-4-23-18.pdf

Sarasota County Government (2010) "Lemon Bay Watershed Management Plan" Sarasota County Wateratlas, http://www.sarasota.wateratlas.usf.edu/upload/documents/LemonBayWMP_Aug2010_full.pdf

Roeder, Eberhard and Ursin, Elke (2013) "Managing the "Other" Advanced Sewage Treatment Systems: An Assessment of Florida's Aerobic Treatment Units and Similar On-Site Sewage Treatment Systems" Florida Water Resources Journal, https://fwrj.com/techarticles/0713%20FWRJ_tech2.pdf

Sayemuzzaman, Mohammad & Ye, Ming & Zhu, Yun & Hicks, Richard & Shi, Liangsheng. (2015). "Simulation of Nitrogen Transport in a Surficial Aquifer and Estimation of Nitrogen Load from Septic Systems in the Indian River Lagoon Area, Florida". 1915-1922. 10.1061/9780784479162.187.

Sherblom, P. (1998). Lysimeter research management and support. Report to the Florida State Department of Health Onsite Sewage Program under contracts LPB85 and LPD01. Tallahassee, FL.

Ursin, Elke L, and Eberhard Roeder. (2008) "AN ASSESSMENT OF NITROGEN CONTRIBUTION FROM ONSITE WASTEWATER TREATMENT SYSTEMS (OWTS) IN THE WEKIVA STUDY AREA OF CENTRAL FLORIDA" www.floridahealth.gov/environmental-health/onsite-sewage/research/_documents/wekiva-nowra.pdf.

US EPA Region 4 (2006) "TOTAL MAXIMUM DAILY LOAD (TMDL) For Nutrients, Dissolved Oxygen, and Coliforms In Sarasota Bay/Charlotte Harbor Basin Groups." Sarasota County Wateratlas, Mar. 2006, www.sarasota.wateratlas.usf.edu/upload/documents/TMDLNutsDOColiSaraBayCharHrbMarch2006.pdf.

U.S. NRC (2000) Clean coastal waters: understanding and reducing the effects of nutrient pollution. National Research Council, National Academies Press, Washington, DC