Draft Final Report

Demonstration of a Passive On-site Sewage Treatment System and Drain Field for Nitrogen Removal at Wekiva State Park

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Submitted by:

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DISCLAIMER

The opinions, findings, and conclusions expressed in this publication are those of the authors and not necessarily those of the State of Florida Department of Environmental Protection. This report does not promote use of any specific product.

METRIC CONVERSION TABLE

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
LENGTH				
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
AREA				
in^2	squareinches	645.2	square millimeters	mm^2
ft^2	squarefeet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
VOLUME				
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
NOTE: volumes greater than 1000 L shall be shown in m^3				

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
MASS				
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg (or "t")

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
TEMPERATURE (exact degrees)				
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
ILLUMINATION				
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
FORCE and PRESSURE or STRESS				
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
LENGTH				
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
AREA				
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
VOLUME				
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
MASS				
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams	1.103	short tons (2000 lb)	T

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
TEMPERATURE (exact degrees)				
°C	Celsius	1.8C+32	Fahrenheit	°F

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
ILLUMINATION				
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
FORCE and PRESSURE or STRESS				
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per sq. inch	lbf/in^2

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The authors also recognize the assistance and funding from Environmental Conservation Solutions who provided media and the installation of the passive treatment system. The University of Central Florida faculty provided work space, field data collection, analysis of results and research coordination using a team of faculty with water quality, geotechnical, and water resources backgrounds.

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EXECUTIVE SUMMARY

A passive on-site sewage treatment system was installed with a particular design. In this context, passive is defined as not using electricity for treatment or recirculation of the wastewater. Background information, analysis of data, and conclusions for the fate of nutrients in a passive on-site sewage treatment system are included in this report. The information adds to an understanding of how nitrogen can be managed using a passive on-site sewage treatment system. The results show the removal of nitrogen and phosphorus. Equally important is the installation and recommendations for modifications.

For a low cost installation, a 36 mil Reinforced Polypropylene (RPP) liner is used. The details of the installation is found in Appendix A. The installation was time consuming and thus the labor and material cost was high. A water-tight install was obtained and flow through the system was demonstrated by a National Sanitation Foundation (NSF) flow testing procedure.

The degree of short circuiting was estimated by dye tracer studies. The results indicated that there was short-circuiting and lower residence time. Another design could be more cost effective, provided the conversion of ammonia to a nitrogen gas can be maintained.

The average removal of ammonia and TKN was about 50%. The average removal of phosphorus was about 67%. There was minimal (less than 0.1 mg/L) discharge of nitrates. Nitrate concentrations were near zero while total nitrogen was reduced which indicates the biological activity for conversion to a nitrogen gas is occurring, but more conversion is possible. The passive system can be improved to remove more nitrogen and the design and installation should include:

1. The use of a more representative concentration (or higher concentration in this case) of total nitrogen, in the form of TKN from the septic tank.
2. The use of a reactive media (one with more surface area and residual moisture capacity) throughout the system to increase the presence of organisms.
3. An installation not using an RPP liner. This will reduce the time and cost of installation and improve removal.

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1. Project Background and Description

Reduction of nutrients entering aquifers are the focus for water quality and quantity investigations in the State. Nutrients, particularly nitrate, are a rising concern in groundwater for some areas of Florida. The nitrate-nitrogen concentration in some of Florida's springs has risen above 1 mg/L in recent years (Ritter et al. 2007). Hence, environmental issues, such as water body eutrophication in lakes, estuaries, streams, and springs, degradation of groundwater quality, and public health problems, occupy the attention of both the public and those who study nitrates in the environment. This trend of increasing nitrate concentrations can be attributed to rural as well as urban activities which discharge nutrients to groundwater. On-site sewage treatment is one of the many sources that discharge nutrients to groundwater.

Part of the nitrate reduction can be accomplished with the management of nitrogen from on-site sewage treatment. On-site sewage treatment using a septic tank and drainfield are the most used method for individual homes and other sites permitted for discharge to the on-site treatment. Many methods are available for the reduction of on-site nitrogen, but all have an installation cost that is higher than the cost of the current approved use of the common septic tank and drainfield. In addition, many methods for nutrient removal required electrical power. Thus, there is an opportunity to provide information on passive (no power) on-site treatment that removes nitrogen.

On-site passive sewage treatment has been investigated for nutrient removal in the past (Wanielista, et.al., 2008, Wanielista, et.al., 2011). However, these treatment systems were not evaluated with respect to their installation practices. Thus, the opportunity to provide information on the details of a low cost installation procedure and operation was provided using a field site at the Wekiva State Park Ranger's house, Welsh Road, Apopka, FL 32712. The general site map location is shown in Figure 1 and the location of the passive system at Welsh Road is shown in Figure 2. The installation was constrained by the location of a potable well on site as well as the location of an existing septic tank.

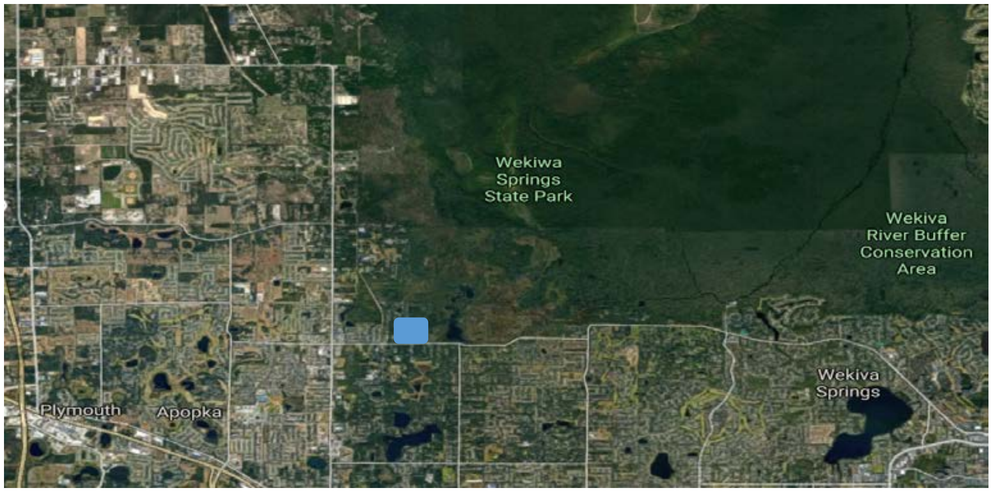


Figure 1. Wekiva State Park Site Map with Location of Passive Treatment Site

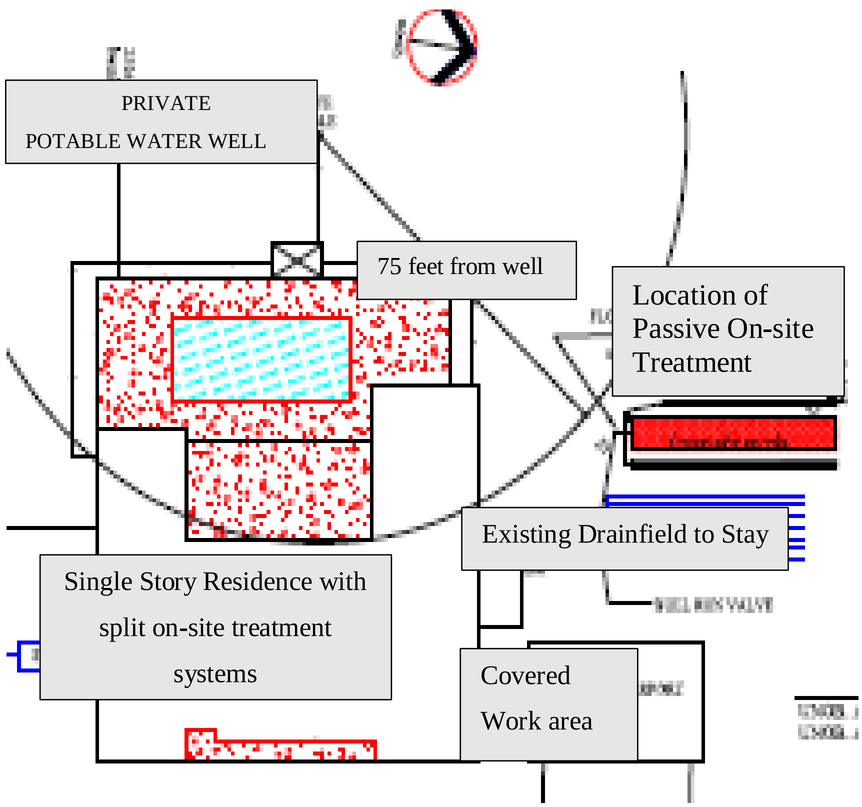


Figure 2 Passive On-site Sewage Treatment System location on Welsh Road, Apopka, Fl

A 36 mil Reinforced Poly Propylene liner (RPP) was chosen to contain the systems because of its low material cost. However, installation was never attempted with the liner and had to be documented. The installation procedures will be addressed in the second chapter of this publication.

2. Passive System Design, Installation and Operation

2.1 Passive System Design

This passive system is defined as one that operates with no process aeration or recycle pumps. Flow through such a passive systems is by gravity alone. The system is composed of unsaturated and saturated media to treat flow from a septic tank, as shown in Figure 1. The passive system is configured to accomplish conversion of organic and ammonia nitrogen to nitrogen gas. Removal is based on the creation of nitrification and denitrification processes in unsaturated and saturated media environments. The media is classified as Bio-sorption Activated Media because it has sorption properties and can support biological activity in a suitable environment.

The concept design and implementation is for the passive system to have an aerobic chamber (unsaturated) followed by an anaerobic chamber (saturated). A longitudinal section of the passive treatment system is shown in Figure 3

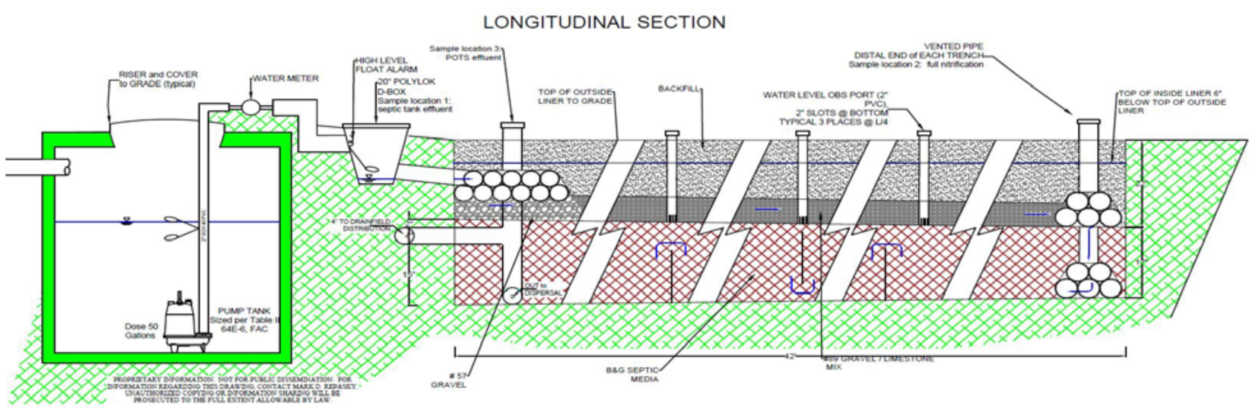


Figure 3. Longitudinal Section of the Passive On-site Sewage Treatment System

DESCRIPTION: *The zones use a 36 mil RPP liner to create a watertight chamber. The unsaturated zone is on top of the saturated zone. Water goes from the unsaturated to the saturated zone using a vertical pipe at the distal (far) end of the system. Water exits into the drainfield at the end of the saturated or anaerobic zone.*

For the anaerobic zone, the design procedure is to calculate a volume of a reactor chamber to attain a residence time of 6 days. The residence time was determined from past research studies (Wanielista, et.al., 2008, Wanielista, et.al., 2011). Input is the average daily flow, media properties, and the geometry of the anaerobic zone. The input data are shown in the gray colored cells of the calculator shown in Figure 4. The actual trench length in the field is 42 feet to accommodate influent and effluent piping. This length is then check against the aerobic zone to determine if sufficient volume is available for nitrification, because for this design, the aerobic zone length must equal the anaerobic zone length. This is an iterative design process.

Length of Anaerobic Trench Given Flow, Trench Geometry and Media Properties					
SITE LOCATION:	**Wekiva Springs Ranger's House**			Marty Wanielista	
Design: Anaerobic zone assumes horizontal flow in the saturated area					
		grey color cells are input			
depth of aerobic area (in)	6	aerobic area included 4 in pipe			
depth of anaerobic (in) =	18	bed width feet =	6		
GPD (average)	200				
Saturated area (SF) =	9	anaerobic area = bottom x depth			
horizontal rate (in/hr)=	12				
anaerobic media porosity	0.44				
anaeorbic res time (days)	6				
What is the volume from the reaction bed given a horizontal infiltration rate, area and time?					
potential treatment volume in one day (gal) =			1620		
example calculation:		infil rate(in/hr)*24 hrs*area (SF)*7.5(G/CF)/12(in/ft)			
What is the length of storage at porosity for treatment in one day of residence?					
anaerobic storage volume per foot of bed (G/FT) =			29.7	gallons per foot	
example calculation:		area (SF)*1 FT*7.5 (G/CF)*porosity			
anaerobic trench length to store one day avg flow (FT) =			6.7	feet per GPD (avg flow)	
example calculation:		average volume (gal)/volume per foot (gal/ft)			
What is the length of anaerobic trench at average daily flow and residence time?					
length of anaerobic trench (feet)			40.4	feet	
example calculation:		GPD(average)*res time (D)/storage per foot (G/FT)			

Figure 4 Design of Anaerobic Trench Given Flow, Geometry and Media Properties

For the aerobic zone, the design procedure follows an oxygen balance. Oxygen must be available for the conversion of ammonia to nitrate. The input ammonia concentration from the septic tank is assumed at 53 mg/L. This can be higher or lower depending on conservation practices within the home (Butler, 2018). The porosity of the media is reduced from 0.4 to 0.2 to recognize that the rock media will not have sufficient surface area to support high microbial populations. The calculator for oxygen balance is shown in Figure 5. The oxygen supply is about equal to what is needed for the conversion. It is equal to what is needed if the ammonia input were 52 mg/L. The residence time is about 2 days. The trench length is 42 feet and 6 feet wide. This is the concluding step in an iterative approach for the design of the passive on-site trench.

What is the length of aerobic zone to convert ammonia to nitrate?

Oxygen Needed

Influent ammonia concentration (NH4) mg/L = 53 Flow g/d= 200

reference: Onsite Sewage Treatment and Disposal Systems, # SL-348, IFAS

Stoichiometry equation: 2NH4 + 3O2 → NO3 + H2O note: NH3 = NH3-N * 1.21589

Oxygen Needed = {(Co/MW NH4)*3/2}}MWO2 141.33333 mg/L

in mg per day = mg/L * flow g/d * liters/g $\boxed{107{,}131}$ mg/d oxygen needed

OxygenAvailable a function of the active micorbial volume in the media (not more than porosity)

Oxygen in the Ground of an onsite disposal field averages 3.7 mg/L range of 2.87 - 4.46

reference: Modeling Subsurface Upflow Wetlands Systems.. Xuan, et.al, Envi Engr Sc, Vol 27 #10, 2010

Volume of aerobic Zone (6 inch depth, 6 foot wide and 42 foot long) = 126 CF

available active volume = 0.2 volume of air in media 25.2 CF

Oxygen available in the Ground for an aerobic reactor bed =

(28.32 L / ft^3) / (22.4 L / mole) x (0.21 (% O2)) x 16 gm / mole = 4.248 gm O2 / ft^3 of air

Using 20.6 % O2 in air Oxygen in aerobic zone is: 4.167085714 gm O2/ft^3 air

Volume of oxygen available in soil is $\boxed{105{,}011}$ mg oxygen available in media

For this bed design ,availble oxygen is approximately equal to that needed.

Residence time is the volume divided by flow = $\boxed{1.9}$ days using a 0.4 porosity

General % of gases in tropic soils

Component	Soil air (%)	Atmosphere (%)
N_2	79.2	79.0
O_2	20.6	20.9
CO_2	0.25	0.03

Source: Russel, E. J., and Appleyard, A. 1915, The atmosphere of the soil, its composition and causes of variation. *J. Agr. Sci.* 7:1–48.

Oxygen content no demand

Depth of sampling in cm	*Oxygen content* Wet Oct.–Jan.	Dry Feb.–May
10	13·7	20·6
25	12·7	19·8
45	12·2	18·8
90	7·6	17·3
120	7·8	16·4

Figure 5 Design of Aerobic Trench to Provided Oxygen for Conversion of Ammonia Nitrogen

2.2 Passive System Installation

For a low cost installation, a 36 mil RPP liner is used. The details of the installation are found in Appendix A. The installation was time consuming and thus the labor cost added to the material cost resulted in a higher than expected total cost. It is also not possible to obtain the exact reactive volume in each of the aerobic and anaerobic zones because of the resulting irregular shape of RPP liner when installed without side wall rigid supports.

2.3 Passive System Operation

There is no need to make any modifications in the flow conditions between the operation of this passive on-site sewage treatment system and a conventional septic tank and drainfield. The same guidelines for operation and maintenance should be followed as noted in the State of Florida requirements for on-site treatment (see State of Florida Department of Health, Chapter 64E-6, F.A.C., Standards for Onsite Sewage Treatment and Disposal Systems). When operated under the guidelines provided, these systems have been known to hydraulically function (not back-up into the source) for at least 20 years. However, some details as related to normal maintenance are specified to prolong operation

- Most sewage discharged from family residences can be treated with a Passive drainfield. However, the following list of substances could adversely affect any system:

  Household products including, paint, varnish, fats, oils, grease, excess organic load through garbage disposal/grinder, any volatile organic compounds (VOC), medicines, heavy cleaning fluids, and water conditioning brine discharge. Hydraulic overload from excessive (more than two) laundry wash cycles per day, and leaky fixtures could also adversely affect the system.

- As with other on-site sewage treatment system, the owner will need to contract with a licensed contractor every two years to inspect accumulated solids (sludge) and floating scum layers (residuals) in the septic tank (note the septic tank is not the passive treatment system, but always is the preprocessing treatment). Solids should be removal if the level encroaches within 18 inches of the base of the outlet device for a one compartment tank, or within 12 inches of the invert of the baffle in a two compartment tank. The outlet device contains an approved filter that should be cleaned at every tank inspection. In addition, routine monitoring of any ponding of effluent on the ground surface above or around the lined chambers, or drainfield, should be performed on a monthly basis. Water usage rate should also be recorded.

- Wastewater flow through this passive sewage treatment system is gravity driven. In cases where elevation and separation conditions prevent gravity from flowing water, a pump may be used to overcome the hydraulic limitations. Should any ponding condition exist that requires more than two sludge extractions per month, the owner should contact the manufacturer and local health departments for repair recommendations.

- In the event that this passive system is to be used intermittently, or if extended periods of non-use are anticipated, the system shall require no additional service. Visual methods and criteria used to identify system malfunction include:

  a. Observation of sealed outlet filter in tank outlet device in the event of a sewage back up into the house sewer line.
  b. Observation of the level of effluent in the first and second observation/sampling ports.
  c. Monitoring port observation of the level of ponding in the top tier chamber.
  d. Observation in the third observation/sampling port.
  e. Observation of the level of effluent in the fourth observation/sampling port.
  f. Observation of the ponding in the final distribution box prior to drainfield dispersal.

- In all cases, a licensed maintenance/service provider should perform and record all activities. In the event of a high water visual and/or audible alarm, if a pump is used for elevation conditions, the owner should check the applicable circuit breaker, and then contact the service provider for continued service as needed. The system is equipped with a data plate affixed to the electrical box or initial sampling port riser to identify the name and address of the service provider.

2.4 Media Analysis

There are four type of media used. In the anaerobic zone, there is a blend of expanded clay, tire crumb, and sand. The blend is used for nutrient control in green roofs, rain gardens, and up-flow filters. It is available from Environmental Conservation Solutions (ECS) in Apopka Florida. The permeability is 196 inches per hour (Standard Method Test for Permeability of Granular Soils (Constant Head AASHTO Designation: T215-14, Technical Section: 1a, Soil and Unbound Recycled Materials). The sieve analysis is shown in Figure 6.

Description of soil		Passive On-Site Anaerobic Zone Media					Sample No.	2
Location	Apopka, FL					Mass of oven dry sample, *W* g		551.80
Tested by	C. Dasny							
Test Date	March 19, 2018			Sampling Date	March 21, 2018			
Sieve No.	**Sieve opening (*mm*)**	**wt. of sieve + media (g)**	**wt. of sieve (g)**	**Mass of soil retained on each sieve, W_n (*g*)**	**Percent of mass retained on each sieve, R_n**	**Cumulative percent retained, $\sum R_n$**	**Percent finer, 100 - $\sum R_n$**	**Comments**
3/4"	19.000	521.26	515.02	6.24	1.1	1.1	98.87	
5/8"	16.000	549.98	513.06	36.92	6.7	7.8	92.18	
1/2"	12.500	718.4	518.15	200.25	36.3	44.1	55.89	
3/8"	9.500	738.46	504.51	233.95	42.4	86.5	13.49	
4	4.750	549.23	484.5	64.73	11.7	98.2	1.76	
8	2.360	449.76	447.41	2.35	0.4	98.7	1.33	
200	0.075	313.47	310.49	2.98	0.5	99.2	0.79	
Pan	--	374.82	371.64	3.18	0.6	99.8		

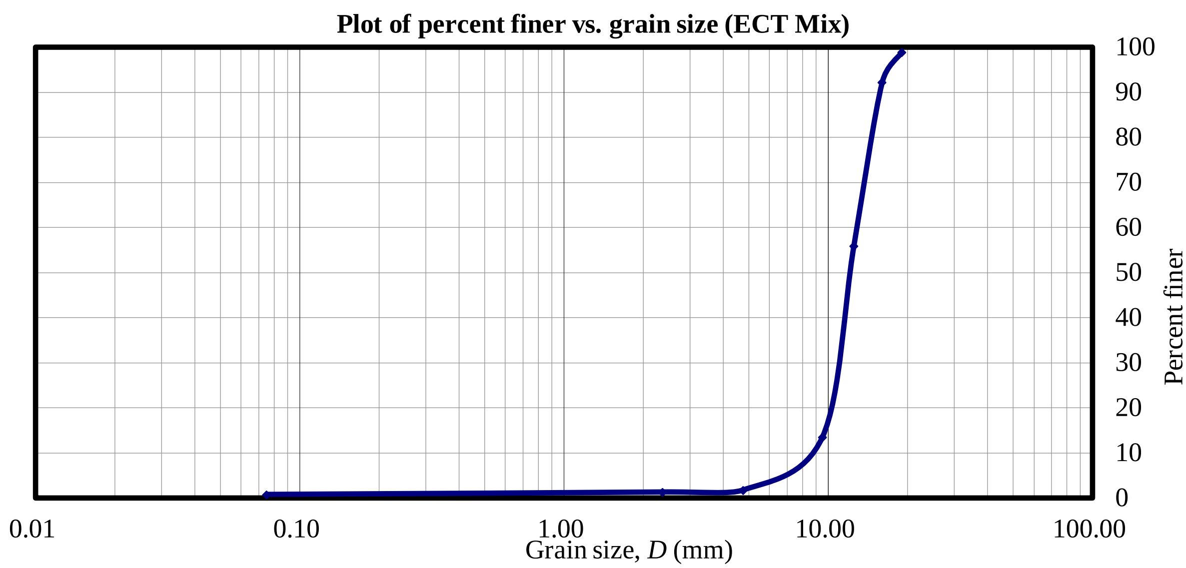


Figure 6 Sieve Analysis for Anaerobic Zone Media

In the aerobic zone, the media is a granite #89 rock. It is also known as pea rock and is available from aggregate supply yards. Crushed concrete is not permitted for use. The permeability is greater than 500 inches per hour. FDOT(2014) defines 89 stone by sieve grading such that there is 100% passing through a ½” screen, 90-100% passing a 3/8 “ screen, 20-55% passing #4 screen, 0-30 passing #8 screen, 0-10 passing #16 screen and 0-5% passing #50 screen.

Lime rock # 89 is added to the aerobic zone to provide alkalinity. It has the same sieve size grading and #89 granite rock and permeability greater than 500 inches per hour. It is also available from aggregate supply yards. It is added at a rate of 7 ft^3 per 100 gpd flow.

To provide stability for the inlet pipes to the aerobic zone, a #57 rock is used beneath the inlet pipes. Crushed concrete is not permitted for use. FDOT (2014) defines #57 stone by sieve grading such that there is 100% passing through 1 ½ " screen, 95-100% passing 1" screen, 25-60% passing ½ ‘" screen, 0-10% passing #4 screen, and 0-5% passing #8 screen

2.5 Hydraulic Performance

Sampling and observations ports were construction to determine back-up during normal and “stress” conditions. Before the system accepted flow from the home, a hydraulic load test was performed to detect if the system would back-up into the home or overflow from the RPP liner. These are standard tests required by the State. The passive system passed the test. The details and results are shown in Appendix B.

3. Effectiveness Evaluation

3.1 Hydraulic Retention Time

Tracer studies are used to estimate the residence time in complex systems. Fluorescent tracer dye was injected into the passive on-site sewage treatment system at port 1; the effluent from the septic tank. Sampling port 2 is downstream of the unsaturated aerobic zone while sampling port 3 is downstream of the saturated anaerobic zone (see Figure 7).

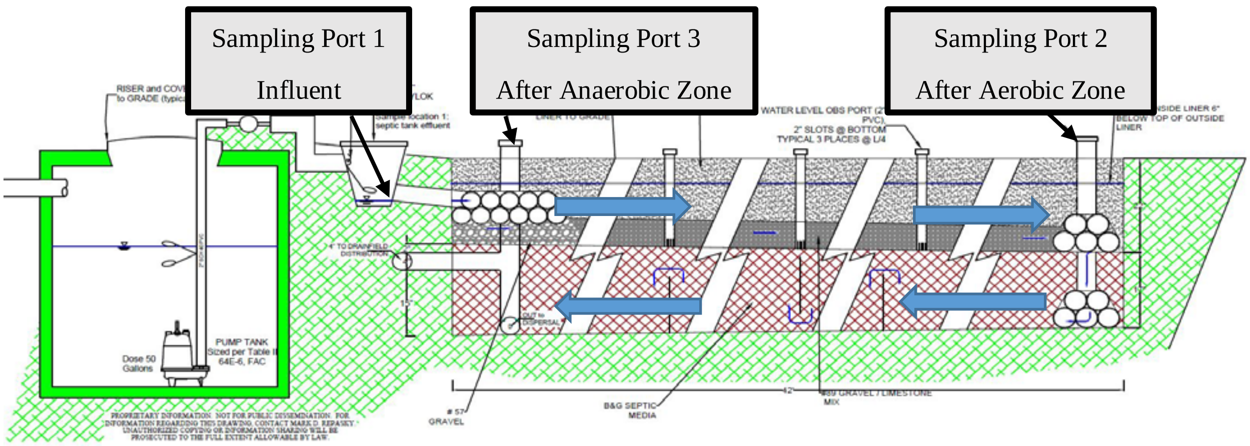


Figure 7 Sampling Port Locations for Both Water Quality and Tracer Study

The time it takes the tracer to travel from port 1 to ports 2 and 3 can be estimated by the concentration measured from the start of injection to the time the dye appears at the downstream ports. The choice of tracer is important as the tracer may have interferences from what is in the water or in the soils. The procedure is to collect water samples from port 2, downstream of the aerobic (unsaturated) zone, and from port 3, downstream of the anaerobic (saturated) zone to determine the concentration of the fluorescent dye and ultimately the peak of that concentration to indicate the residence time in each of the zones.

The procedure for the tracer studies was to inject one liter of fluorescent dye (400 ppb) at Sample Port #1 downstream of the septic tank. A funnel and approximately one meter of clear vinyl plastic tubing were used to deliver the dye sufficiently downstream of Sample Port #1 (see Figure 8), to minimize the potential for backflow of the dye into the holding area of the port. No backflow was observed during the dosing of the dye.

Figure *8* Sample Port #1 – Dye Injection via Funnel and Tubing

Samples were withdrawn from Sample Ports #2 and #3 at different time intervals after the injection at Sample Port #1. Sample Port #2 lies at the downstream end of the aerobic (top/initial) zone. Sample Port #3 lies at the downstream end of the anaerobic (bottom/final) zone.

A calibrated instrument was used, namely an AquaFluor fluorometer, from Turner Designs, Inc. to determine the concentration of Rhodamine dye in the water samples (see Figure 9). The fluorometer is configured specifically to measure the concentration of Rhodamine and Fluorescein dyes (channels A and B, respectively). The unit was calibrated prior to initiation of the field work, using a working standard concentration of 400 ppb dye solution per the manufacturer's recommendations. The working standard was provided by Turner Designs, Inc

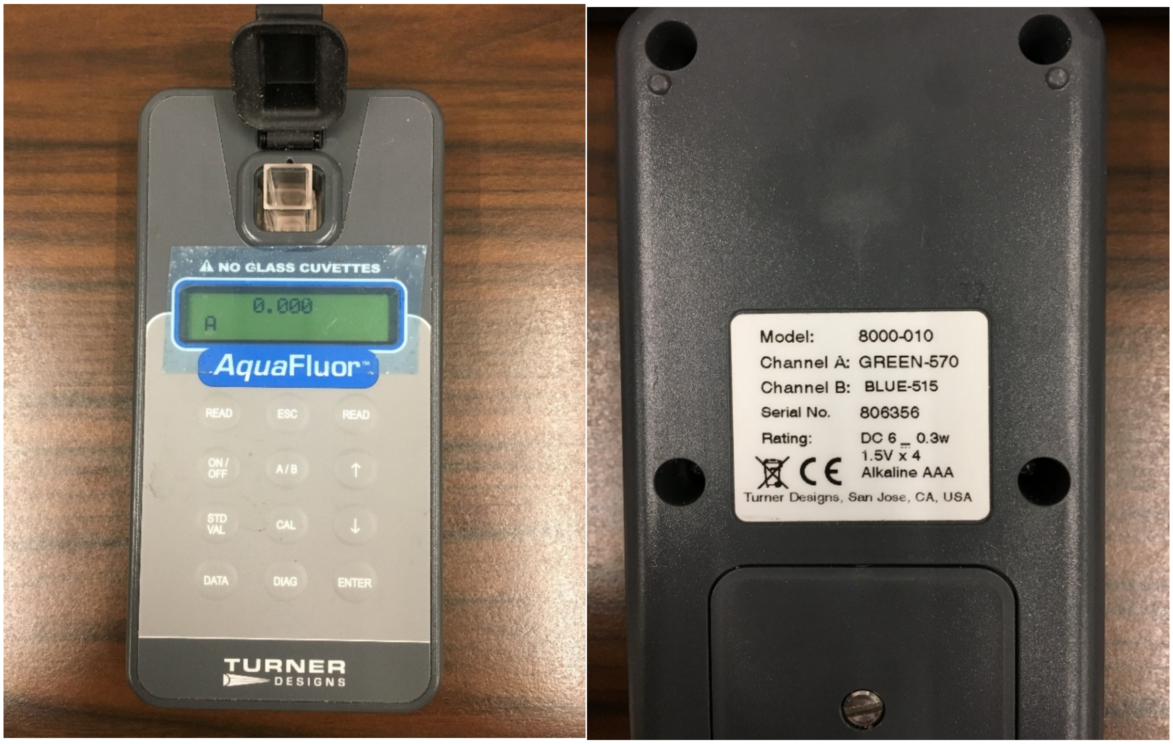


Figure 9 Front of AquaFluor fluorometer (Turner Designs, Inc.) model 8000-010, configured to read Rhodamine and Fluorescein sample levels (left) and opposite side of device (right).

Approximately 2.0-2.5 milliliters of water was drawn for each sample, and deposited into a clean, 10mm x 10mm x 45 mm methacrylate plastic cuvette (see Figure 10). The cuvette was

Figure 10 A 10 x 10 mm x 45 mm methacrylate sample cuvette (measure shown for scale).

then inserted into the sampling port of the AquaFluor fluorometer and a reading was recorded. After each sample was measured and recorded, the cuvette was removed, rinsed thoroughly using deionized water, dried, and then reused for the subsequent sample. At the end of each cycle of sample readings, the cuvette was filled with deionized water and a reading was taken using the fluorometer to confirm that no traces of dye remained. This procedure is common for all tracer testing.

The first tracer study was performed using rhodamine dye over a two week period of time at the end of January 2018. The results did not show a definitive peak. The dye and the fluorometer were changed with the assumption that the dye or the fluorometer were malfunctioning. There is also the possibility that there were water or soil interferences with the dye concentration and by changing the measurement it is possible to check on the method.

The tracer study was repeated using a different tracer, namely fluorescein and a new fluorometer, over a two-week period in late February and early March 2018. The results again were not impressive or definitive. Qualitative samples of the water were taken showing a lower than neutral pH as well as the presence of iron. There is also clay in the media mix of the anaerobic zone but not in the aerobic zone. It has been noted and published that some forms of iron, clay, and less than neutral pH conditions can cause the adsorption of fluorescent dyes (Weidner, et.al, 2011). Thus, it was decided to conduct a tracer study at another near-by site that had exactly the same passive treatment configuration.

The site was located about 6 miles to the east of the Wekiva park. The passive design was exactly the same as at the Ranger's house in terms of residence time. The source of water was from a residential home or the same as the Ranger's house. The residential property is, located at 224 Charles Street, Longwood, Florida in the Sleepy Hollow Subdivision immediately north of State Road 434, east of Interstate 4 (see Figure 11). The study was performed over a two-week period in late February and early March 2018. Water samples were drawn downstream of the aerobic (unsaturated) zone and also downstream of the anaerobic (saturated) zone to determine the concentration of the fluorescent dye and ultimately the peak of that concentration to indicate the residence time in each of the layers.

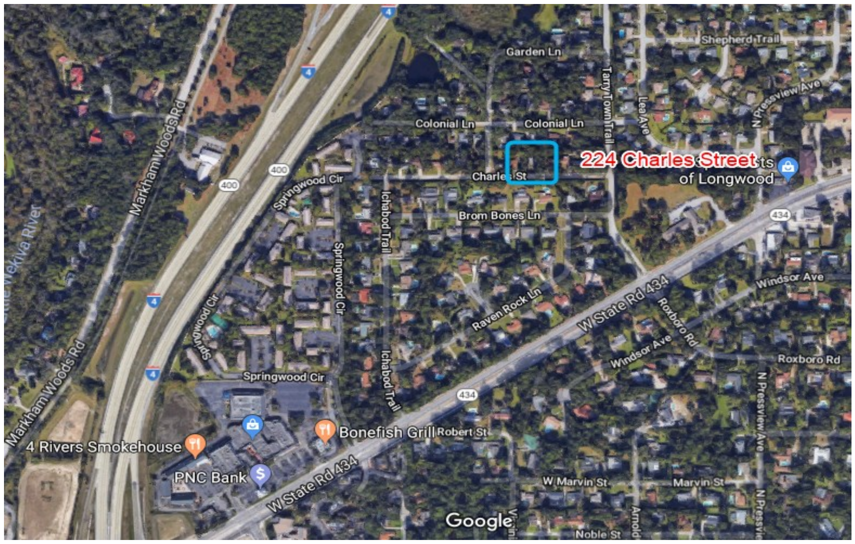


Figure 11 Site map – 224 Charles Street, Longwood, FL

On the first day (injection day), samples were drawn at roughly 45 minute intervals, and then at 24 hour intervals subsequently for two weeks (excluding weekends) for a total of 21 sample cycles. The dye concentrations are shown in Table 1. Additionally, flow gauge readings (See Figure 12) were taken with every sampling cycle (these readings are also included in Table 1).

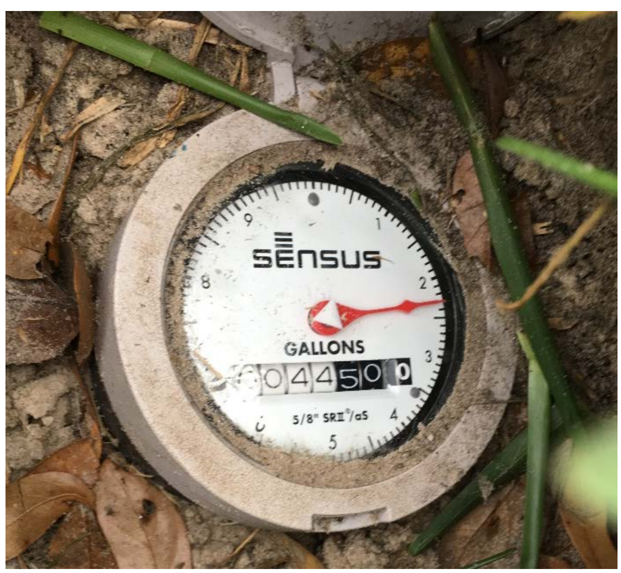


Figure 12 Flow gauge (located downstream of septic tank, prior to flow into passive system.

Table 1. Fluorometer Readings with Time

Date	Time	Hour	Flow Meter	Gallons	SP-2	SP-3
2/20/2018	9:16	0.0	44,502.30	0.0	0.76	0.00
2/20/2018	9:45	0.5	44,502.30	0.0	5.99	1.90
2/20/2018	10:15	1.0	44,502.30	0.0	5.18	5.35
2/20/2018	10:45	1.5	44,502.30	0.0	5.03	4.74
2/20/2018	11:15	2.0	44,502.30	0.0	7.11	7.39
2/20/2018	12:15	3.0	44,502.30	0.0	8.29	5.92
2/20/2018	12:45	3.5	44,502.30	0.0	8.49	6.40
2/20/2018	13:15	4.0	44,502.30	0.0	12.81	8.74
2/20/2018	13:45	4.5	44,502.30	0.0	9.72	4.06
2/20/2018	14:15	5.0	44,502.30	0.0	10.69	7.66
2/20/2018	14:45	5.5	44,502.30	0.0	9.51	10.28
2/20/2018	15:15	6.0	44,502.30	0.0	14.77	10.63
2/21/2018	8:00	22.75	44,748.00	245.7	23.88	11.43
2/22/2018	8:00	46.75	44,971.00	468.7	30.55	11.98
2/23/2018	15:00	77.75	45,262.70	760.4	34.08	20.06
2/26/2018	8:00	142.75	45,905.80	1403.5	25.14	38.27
2/27/2018	8:00	166.75	46,197.30	1695.0	20.13	50.91
2/28/2018	8:00	190.75	46,371.50	1869.2	20.91	36.71
3/1/2018	8:00	214.75	46,546.70	2044.4	24.30	23.09
3/2/2018	14:45	245.5	46,782.60	2280.3	19.91	11.86
3/6/2018	8:15	335.0	47,784.40	3282.1	11.81	17.23

Figure 13 displays the fluorometer readings at Sample Ports 2 and 3 over the course of the two-week study. As shown by the blue line, the dye concentration values at Sample Port 2 peaked on Day 3 (72 hours after dye injection). The design residence time was 2 days. The flow rate however was less than expected (about 280 gpd). The design flow rate was 400 gpd. As indicated by the red line, dye concentration values at Sample Port 3 peaked on approximately Day 7 (168 hours after dye injection). As indicated by the dye concentration values for the anaerobic zone, the residence time was 4 days (7 days minus 3 days). The cumulative residence time was 7 days. The design holding time in the anaerobic zone was 6 days. With the lower flow rates during the dye testing, it is expected that the residence time in the anaerobic zone should be higher. Thus, a redesign of the anaerobic zone to minimize short circuiting is recommended.

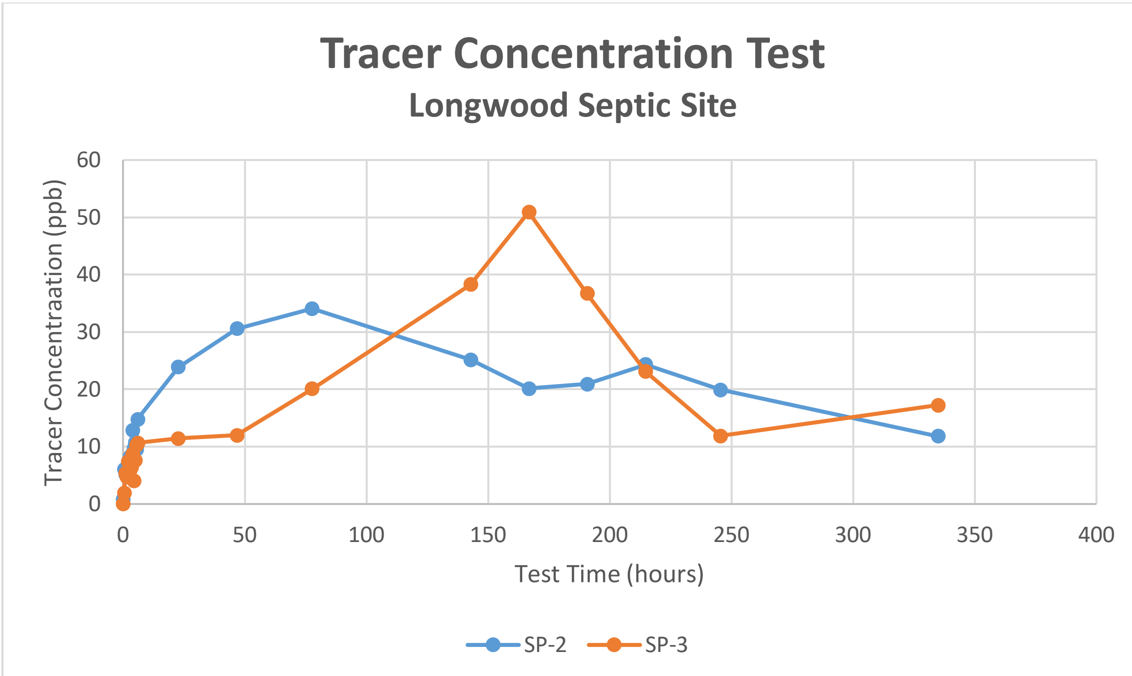


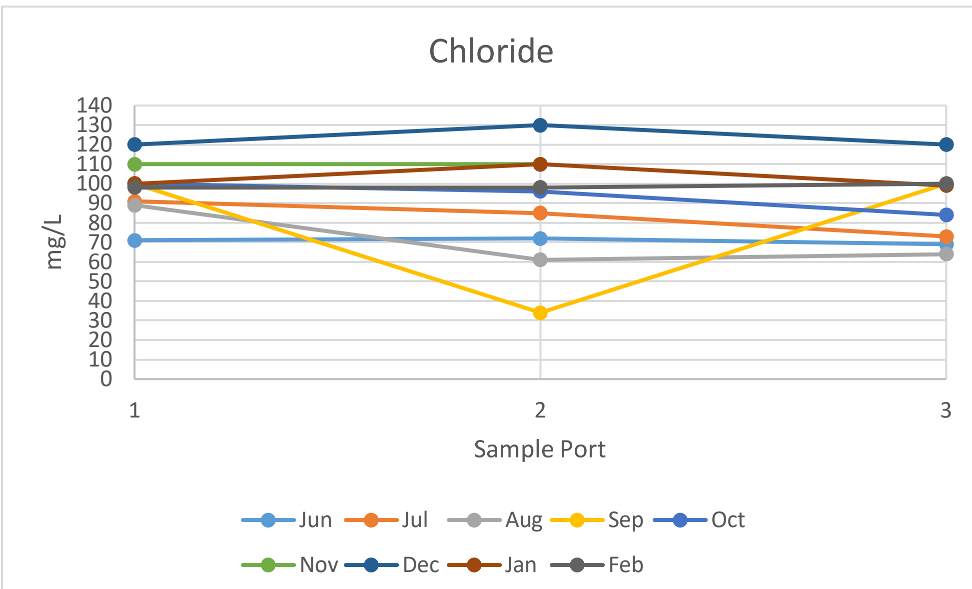
Figure 13 Tracer fluorometer reading with time for Sample Ports 2 and 3.

3.2 Water Quality Effectiveness

Water quality data were collected and analyzed at the Florida Department of Environmental Protection Central Laboratory in Tallahassee. The data and analyses of each parameter are presented to determine the removal effectiveness of the design, given septic tank effluent water.

Chloride is a conservative substance and is used to indicate a difference from the normal or in this case the presence of water with a different chloride signature than sewage. When there is all sewage in the sample, the chloride concentration should not significantly change from one sample port to another. This assumes that another source of water that is potential input to the system, such as percolated rainwater or irrigation has a different chloride concentration. There is no irrigation water on site. Rainwater does have a different chloride concentration. The average concentration in Florida varies from a low in northwest Florida of about 0.5 mg/L to a high in south Florida of about 2.0 mg/L (Gordon, B, 2013). The Chloride data and a graph of the data for each port is shown in Figure 14. The September chloride in port 2 (upper zone) is most likely affected by infiltrating rain water because the chloride concentration is 34 compared to 100. The September value measured for port 2 of the other chemical measures will not be used in evaluating the effectiveness.

Chloride (mg/L)		Port 1	Port 2	Port 3
Jun	2017	71	72	69
Jul		91	85	73
Aug		89	61	64
Sep		100	34	100
Oct		100	96	84
Nov		110	110	
Dec		120	130	120
Jan	2018	100	110	99
Feb		98	98	100



Legend: Port 1 Septic Tank Effluent, Port 2 end of aerobic zone, Port 3 end of anaerobic zone

Figure 14 Chloride Concentration Data for each Sampling Port with Trends by Sample Date.

The Wekiva Springs Rain Gage monthly rainfall depth data are shown in Figure 15 to indicate that in September there was the highest rainfall during the sampling period. The months of June and July do not have the same change in Chloride concentration even with the high rain recorded in these months. This could be explained in June and July by the high frequency of relatively low rainfall depths and/or the ground was not sufficiently saturated to allow deep percolation of the rain water into the aerobic zone of the passive system.

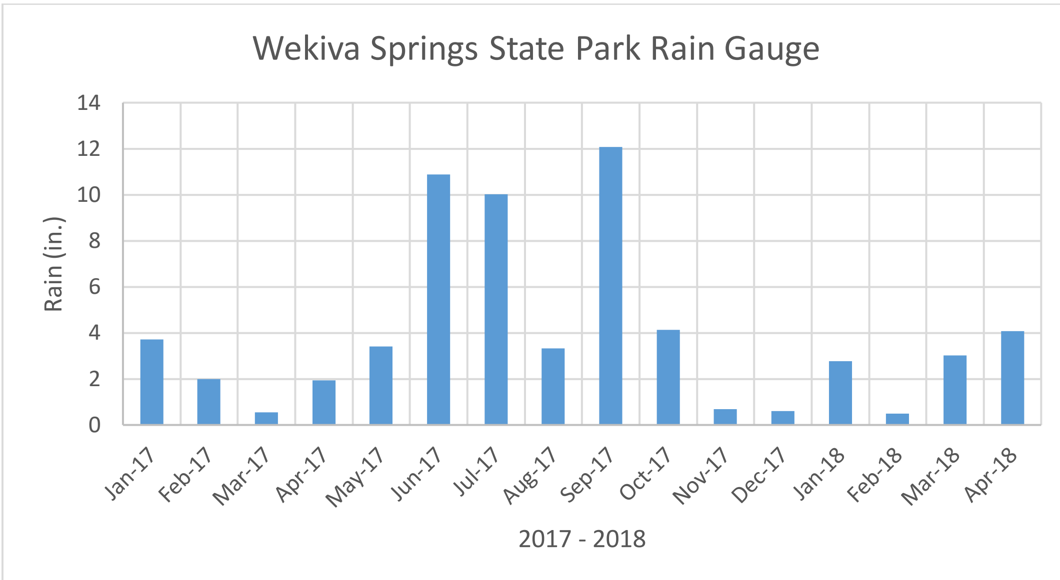
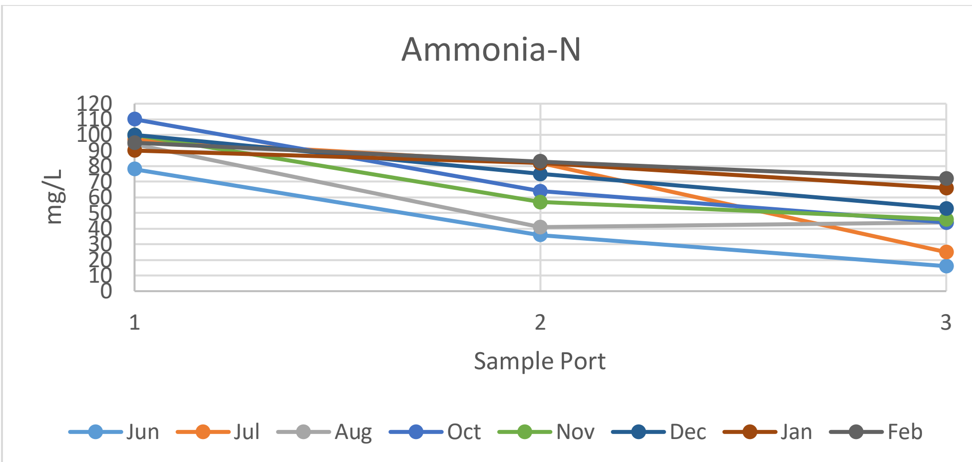


Figure 15 Monthly Rain Depth in the Area of the Sampling Station

The aerobic zone was sized to remove ammonia assuming the input was 53 mg/L of ammonia (see Figure 5). The average input of ammonia-nitrogen was 96 mg/L. The system (aerobic and anaerobic zones) removed on the average 50% of the Septic Tank Effluent concentration (see data of Figure 16), Fifty percent removal is 48 mg/L (96 x .50) not considering the conversion of ammonia to ammonia nitrogen, or the conversion is NH3 = NH3-N x 1.21589. The aerobic zone can be larger in volume to convert the additional ammonia or the media has to be changed in the aerobic zone to promote higher bacteria populations. From A higher rate of removal may be possible using a media with higher surface area so that more organisms can be retained, and additional media moisture can also be retained (O'Reilly, 2012, O'Reilly 2014). The current media is a pea size rock with no significant surface area to house organisms. The nitrate nitrogen is near zero and implies that denitrification is taking place in the system. The data are shown in Table 2.

Ammonia-N (mg/L)		Port 1	Port 2	Port 3	% Rem
Jun	2017	78	36	16	79.5
Jul		97	82	25	74.2
Aug		94	41	44	53.2
Sep		99		65	34.3
Oct		110	64	44	60.0
Nov		100	57	46	54.0
Dec		100	75	53	47.0
Jan	2018	90	82	66	26.7
Feb		95	83	72	24.2
average		96	65	48	50



Legend: Port 1 Septic Tank Effluent, Port 2 end of aerobic zone, Port 3 end of anaerobic zone

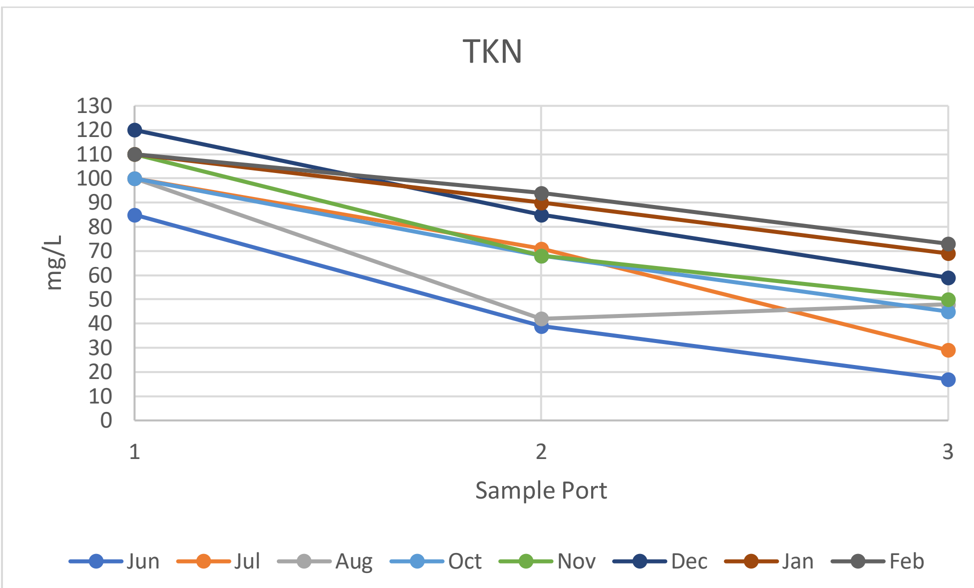
Figure 16 Ammonia-N Concentration data with Removal and Trends by Sampling Date

Table 2 NOX Data and Average Concentrations

NOX (mg/L)		Port 1	Port 2	Port 3
Jun	2017	0.014	0.024	0.006
Jul		0.004	0.004	0.007
Aug		0.013	0.32	0.004
Sep		0.086		0.005
Oct		0.038	0.007	0.004
Nov		0.004	0.005	0.004
Dec		0.014	0.006	0.006
Jan	2018	0.004	0.004	0.004
Feb		0.004	0.005	0.008
average		0.020	0.047	0.005

The TKN data are similar to the ammonia data. The data are shown in Figure 17. Ammonia makes up about 92% of the TKN. The average removal was 52%.

TKN (mg/L)		Port 1	Port 2	Port 3	Port 3 % Rem
Jun	2017	85	39	17	80.0
Jul		100	71	29	71.0
Aug		100	42	48	52.0
Sep		98		67	31.6
Oct		100	68	45	55.0
Nov		110	68	50	54.5
Dec		120	85	59	50.8
Jan	2018	110	90	69	37.3
Feb		110	94	73	33.6
average		104	70	51	52

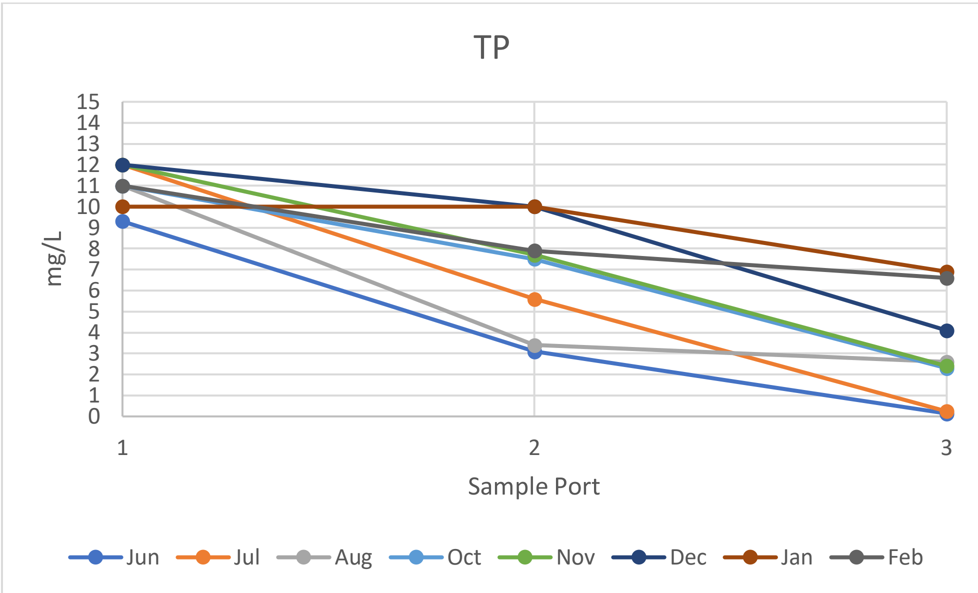


Legend: Port 1 Septic Tank Effluent, Port 2 end of aerobic zone, Port 3 end of anaerobic zone

Figure 17 TKN Concentration data with Removal and Trends by Sampling Date

Phosphorus data and removal are shown in Figure 18. The average removal is 67%. The additional of reactive media with more surface area in the aerobic zone for phosphorus removal will increase the removal over time.

TP (mg/L)		Port 1	Port 2	Port 3	% Rem
Jun	2017	9.3	3.1	0.14	98.5
Jul		12	5.6	0.24	98.0
Aug		11	3.4	2.6	76.4
Sep		11		7.1	35.5
Oct		11	7.5	2.3	79.1
Nov		12	7.7	2.4	80.0
Dec		12	10	4.1	65.8
Jan	2018	10	10	6.9	31.0
Feb		11	7.9	6.6	40.0
average		11.0	6.9	3.6	67



Legend: Port 1 Septic Tank Effluent, Port 2 end of aerobic zone, Port 3 end of anaerobic zone

Figure 18 Phosphorus Concentration data with Removal and Trends by Sampling Date

4. Conclusions

A passive on-site sewage treatment system was constructed to treat the sewage from a residential home in Wekiva Springs State Park, Florida. The system receives the discharge from a septic tank. There is no electrical power required for air introduction or for recycling of the partly treated sewage. Thus, the system is passive in the sense that no electrical power is needed. Flow from the septic tank continues to an unsaturated (aerobic) zone and then to a saturated (anaerobic) zone. The aerobic zone has a pea rock media and is open to the soil column above. The anaerobic zone has reactive media to enhance biological organisms responsible for conversion of ammonia and nitrate.

An installation manual is included in Appendix A. It is recommended that it be strictly followed. However, it is not recommended to use a liner because of the difficulties involved in construction. The liner installed was water-tight, but the labor cost for installation was high. Operation of the system is not different from that of a normal passive drainfield. Nevertheless, operation guidelines are provided.

The system was designed to provide a residence time to convert ammonia to nitrate and nitrate to a gas. The anaerobic saturated zone residence time of 6 days was used. The aerobic unsaturated zone was designed to provide in the media, a pore space volume oxygen that can be used in the transformation of ammonia to nitrate. Design equations founded on basic chemical reactions and a specification of residence time were used. The assumed design ammonia conversion (about 53 mg/L as ammonia) was used based on past average values but the amount of ammonia in the septic tank effluent water was about twice what was expected. The average TKN input was 104 mg/L and the average ammonia nitrogen was 96 mg/L.

The system was tested hydraulically to determine the capacity to flow water or not back-up water. A standard NSF flow procedure was followed. The system passed. Also, a dye tracer study was conducted at the Wekiva location and at another site near-by. The tracer study at the Wekiva site was not conclusive presumably because of interference in the water. From the adjacent passive installation site with the same design, the residence time was 3 days in the aerobic zone and 4 days in the anaerobic zone. The flow from the residence was less than expected, and thus the residence time in the upper unsaturated aerobic zone is greater than the design time of 2 days. However, the residence time in the saturated anaerobic zone is less than expected and indicates short circuiting or by-pass of some of the media. The anaerobic zone should be redesigned to achieve a higher residence time. The use of a liner for system housing is a challenge in obtaining a flow path that interacts with most of the media. For this particular design configuration, other options are needed to increase residence time.

Details as to the specifications of the media and the dimensions of the system used at the Wekiva site are provided. A more reactive media is recommended for use in the aerobic zone. A pea rock was used that has low surface area relative to reactive media.

The Wekiva passive system was constructed to treat 200 gpd. An adjacent passive system was installed using the same design criteria to treat 400 gpd. The system installation and design should be improved to reduce construction cost and extend residence time.

The average removal of ammonia and TKN was about 50%. The average removal of phosphorus was about 67%. There were minimal (less than 0.1 mg/L) discharge of nitrates. No existence of nitrates and no increase in total nitrogen indicates the biological activity for conversion of TKN to a nitrogen gas is occurring. Thus, the life expectancy should be at least equal to that of a conventional drainfield. The passive system can be improved to remove more nitrogen and the design and installation should include:

1. The use of a more representative concentration (or higher concentration in this case) of total nitrogen, in the form of TKN from the septic tank.
2. The use of a reactive media (one with more surface area and residual moisture capacity) throughout the system to increase the presence of organisms.
3. An installation not using an RPP liner.

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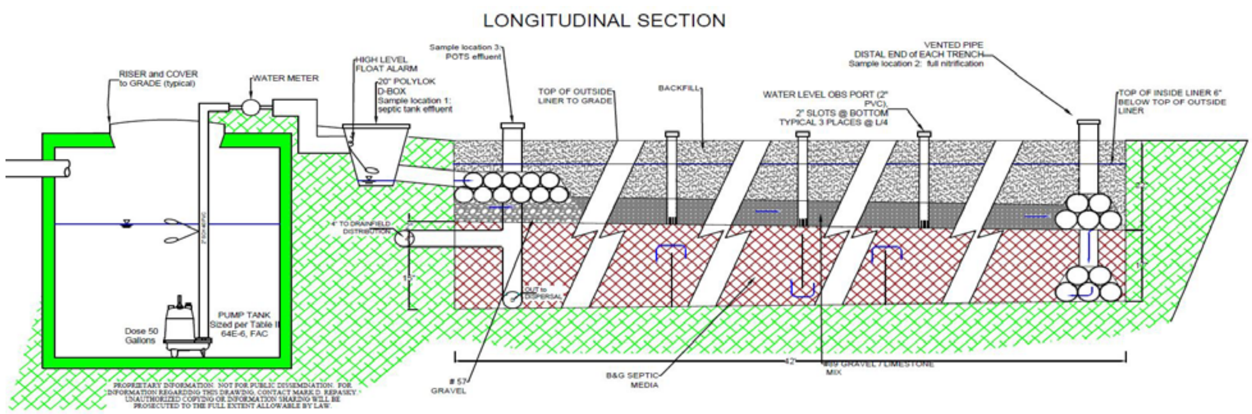
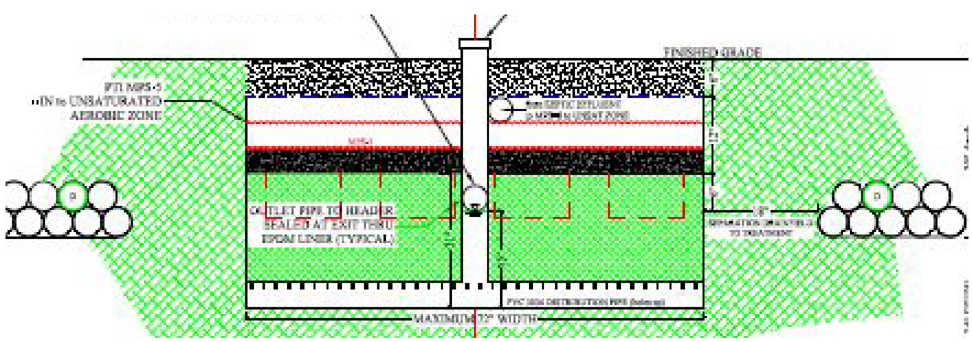
Appendix A: Installation Manual

- Refer to the Construction Drawings for site location. Test the septic tank for leakage and proceed to repair if needed. For the Septic tank, if not already in place, install a SaniTee 416 keyhole weir outlet filter

- A longitudinal section or profile of the passive on-site treatment system is shown below. A cross section is also show beneath the profile. These diagrams assist in an understanding of the installation. Installation procedure is divided into two part, namely the bottom chamber or anaerobic zone and the top chamber or aerobic zone.





Construction of Anaerobic Zone

DESCRIPTION: *The Anaerobic Zone uses a 36 mil Reinforced Poly Propylene (RPP) liner to create a nutrient reducing filter and is located beneath the Aerobic Zone. Water enters through a vertical pipe at the distal (far) end of the system and has a detention time of seven days. Water exits into the drainfield at the end of the Anaerobic Zone.*

Procedure:

1. Excavate trench to length, width, and depth as specified in the design.

2. Install 36 mil RPP outside liner in trench

Certified installer shall weld pipe boots and baffles in place


*** STOP INSTALLATION AND COMPLETE WATER TIGHT ASSESSMENT***

I. Support liner and side walls in an upright position
II. Prevent flow from exiting outlet pipe
III. Support the inlet pipe coming from the septic tank at proper elevation
IV. Fill outside liner with water to invert of influent pipe and measure water elevation with respect to benchmark

V. Wait one hour and measure water elevation again

A water level drop of more than 1/8” per hour shall be considered failing

VI. If water elevation is < 1/8”, empty the outside liner of water and continue installation

3. Install the MPS-5 bundle at the inlet end—which is the end farthest from the septic tank

a. Cut pipe bundle to match width of trench
b. Place across bottom of inlet end of trench
c. Install 4” diameter tee in the center of top pipe of the bundle

   d. Drape filter fabric over MPS-5 per standard

4. Connect Sample Port 2 to tee installed in the top pipe of the bundle. This riser will be cut to align with the Aerobic Zone outlet tee.

   Sample port shall be a 4” diameter PVC pipe

5. Install outlet collection pipe:

   a. Cut collection pipe to match width of trench
   b. Place across bottom of outlet end of trench
   c. Install 4” diameter tee in the center of collection pipe
   d. Drape filter fabric over collection pipe per standard

6. Connect Sample Port 3 to tee installed in collection pipe.

   a. Sample Port shall be a 4” diameter PVC pipe
   b. Install tee to specified height of horizontal outlet pipe

7. Install the horizontal outlet pipe through the RPP liner and into the tee

8. Fill Saturated Zone with B&G Septic media:

   a. Temporarily cap vertical pipes to keep media out
   b. Support side walls and baffles of RPP liner
      Side walls and baffles should remain upright throughout entire filling process

   c. Fill liner with pre-mixed Septic blend in 6” lifts to depth specified
   d. Check for bulging

      Side walls shall be well supported to prevent bulging of the liner when filling.

   e. Once filled, rake flat and confirm baffles, pipe placement, and media depth


9. Dig drainfield trenches and install MPS-9 system

    a. MPS-9 distribution pipe shall connect to effluent collection pipe.
    b. Cover MPS-9 with filter fabric per standard to prevent soil intrusion

10. Connect drainfield header as shown in drawing

Construction of Aerobic Zone

DESCRIPTION: *The Aerobic Zone filter is an open top media filter that is constructed atop the Anaerobic Zone. The bottom, ends, and sides are formed with 36 mil RPP liner. Effluent from the septic tank enters at the near end and is distributed across the width of the filter. The effluent is collected at the distal end of the filter via MPS-5 and drops into the Saturated Zone via a 4" opening, which also houses Sample Port 2.*

Procedure:

1. Lay the 36 mil RPP liner inside of the finished Saturated Filter
   a. Top of inside liner should be at least 6" below the top of the outside liner
   b. Inside liner may be cut down to size

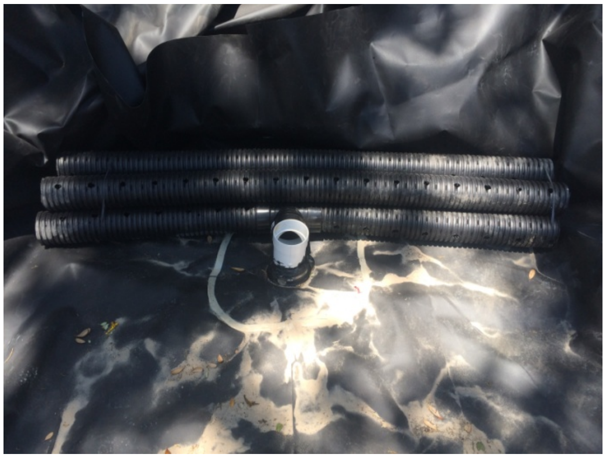

2. Install inlet MPS-11 bundle
   a. Cut pipe bundle to match width of trench
   b. MPS inlet bundle is bedded upon of #57 stone; spread #57 stone at inlet end to support the MPS-5 bundle at the proper inlet elevation
   c. Install a 4" diameter tee offset 5" from centerline of bundle to allow the inlet to pass beside Sample Port 3
   d. Insert the inlet pipe into the tee installed
   e. Drape filter fabric over MPS-11 per standard

3. Spread #89 lime rock evenly, midway throughout base of liner

   Approximately 7 ft^3 of lime rock per 100 gpd flow

4. Install outlet MPS-5

   a. Install tee at center bottom pipe for connection to drop pipe
   b. Drape filter fabric over MPS-5 per PTI standard



5. Install Sample Port 2 riser to grade

    a. Install a 4" diameter tee to Sample Port 2 that was previously cut in step 4
    b. Connect Sample Port 2 tee to MPS-5 bundle tee using 4" diameter PVC pipe.

6. Support side walls of liner

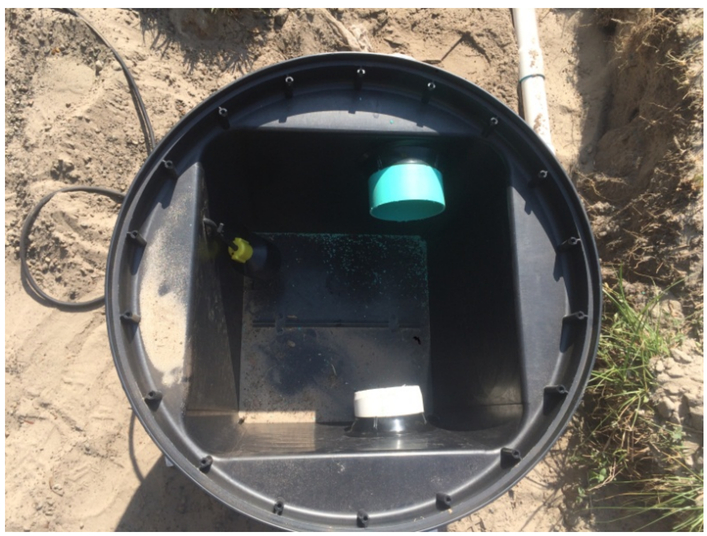
7. Fill Aerobic Zone with #89 gravel

    a. Gravel shall be at least 6" in depth
    b. Support side walls while filling to prevent bulging

8. Install observation ports at quarter lengths along the trench

9. Install and connect Distribution Box (sample location 1) with high water alarm to POTS inlet pipe

   Outlet pipe shall be raised 2” from the bottom of the Distribution Box to allow water to collect for sampling



10. Install Flow Meter

    Flow meter shall be installed between pump tank and distribution box, as specified

11. Backfill with slightly limited fill material

    Ensure that side walls remain upright during the entire back fill process

12. Grade to final elevation

Appendix B: Hydraulic Load Testing

Wekiva Springs Ranger Residence

Information in this appendix is related to National Sanitation Foundation (NSF) hydraulic load testing of the Passive On-Site Treatment System at the Wekiva Springs Ranger Residence (751 E Welch Rd., Apopka, FL). The following data will serve to prove that the passive system at the Wekiva Springs Ranger residence flows water under NSF loading conditions. This implies a low chance of water "backing-up" into the septic tank, as well as a proper functioning system.

NSF Hydraulic Load Testing

Terminology:

OP1= Observation Port 1

OP2= Observation Port 2

OP3= Observation Port 3

SP1= Sample Port 1

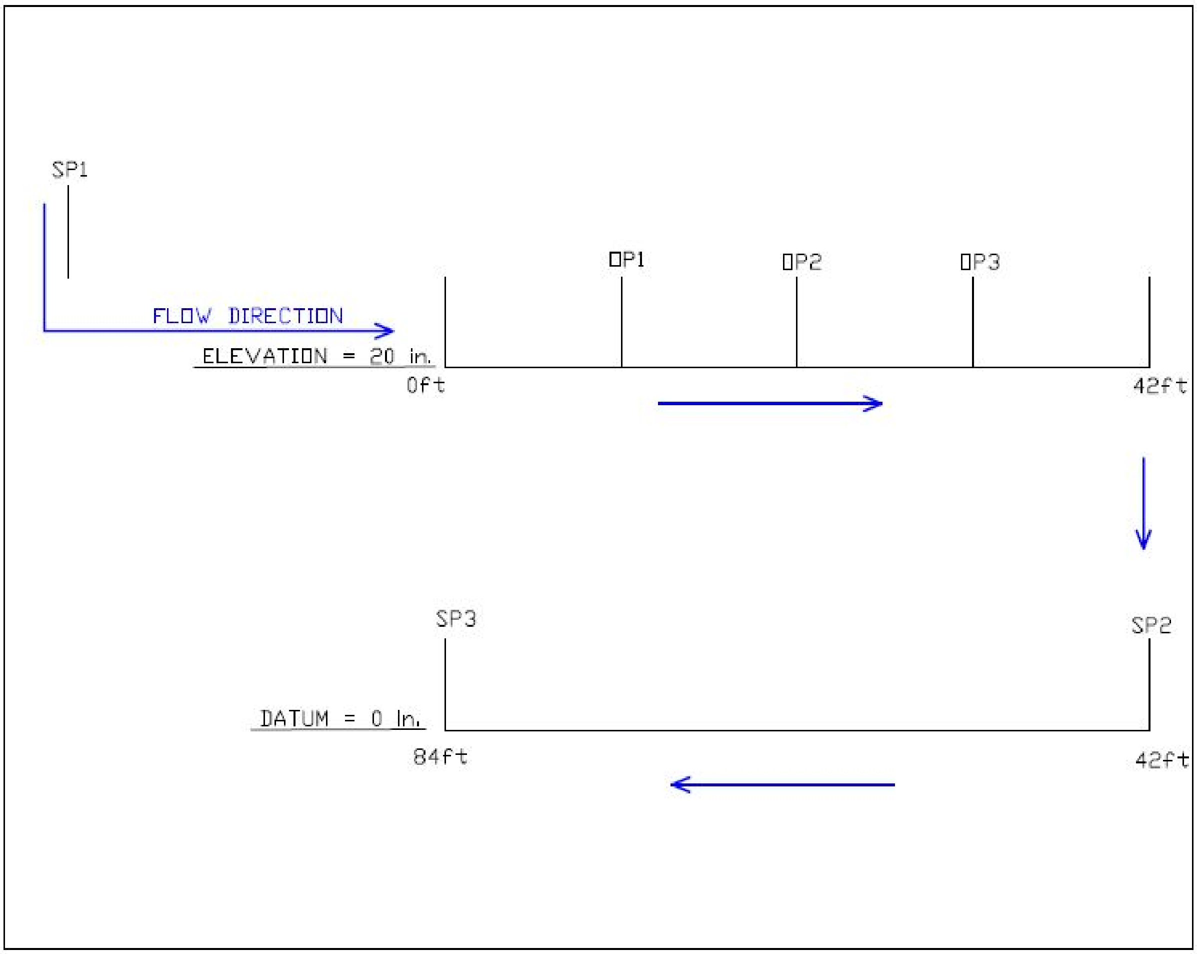
SP2= Sample Port 2

SP3= Sample Port 3

The system was loaded according to the following schedule:

Time Frame	% Rated Daily Hydraulic Capacity
6:00 a.m. to 9:00 a.m.	approximately 35 (70 gallons: 5 gallons every 12.86 min)
11:00 a.m. to 2:00 p.m.	approximately 25 (50 gallons; 5 gallons every 18 min)
5:00 p.m. to 8:00 p.m.	approximately 40 (80 gallons: 5 gallons every 11.25 min)

The figure below illustrates the flow direction of wastewater through both the aerobic zone and anaerobic zone of the POTS drainfield. Water elevation in the system was determined by setting the datum at the bottom of the anaerobic zone to elevation zero. The aerobic zone is installed at a depth of approximately 20 inches from the datum, therefore, water elevation for OP1, OP2, and OP3 begins at about 20 inches.

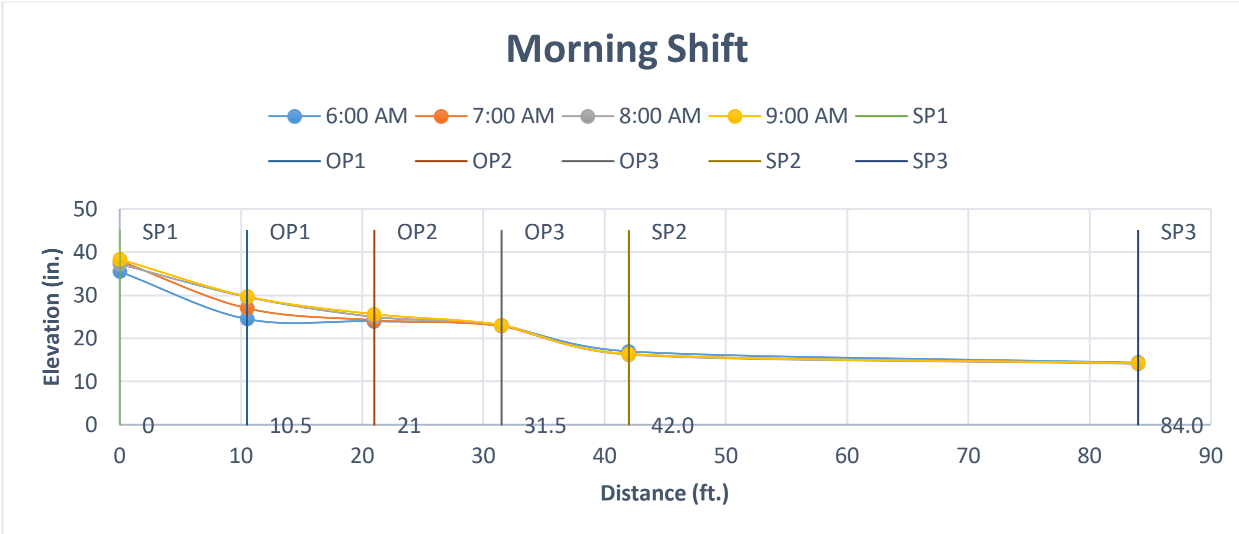


NSF load testing simulation indicates that the passive system can flow water at the required loading rate without backup. Observation Ports 1, 2, and 3 were used to monitor the water elevation in the aerobic zone. As the system is loaded at each shift, the observation ports show an increase in water elevation during each loading interval but recover between shifts (loadings). Observation Port 3 holds a constant pool of water at the base due to the installation of the pipe boot. Wastewater must overflow the lip of the pipe boot before it can drop down into the anaerobic zone for denitrification. Failure of the aerobic zone is identified by backflow into Sample Port 1, which never occurred.

Sample Port 2 was used as the main indicator to determine if the anaerobic zone with the Bold and Gold® Septic Media could accept the appropriate loading rate. Failure criteria required the water elevation in Sample Port 2 to remain below the invert of the pipe boot (approximately 23 inches). The maximum water elevation in Sample Port 2 was 17 inches above the datum suggesting water flowing through the anaerobic zone and meeting the failure criteria.

Field data from Sampling Ports (SP) and Observations Ports (OP)

9/7/2016	Elevation (ft)					
	SP 1	OP 1	OP 2	OP 3	SP 2	SP 3
Distance (ft)	0	10.5	21	31.5	42	84
6:00:00 AM	35.5	24.5	24	23	17	14.375
7:00:00 AM	38	27	24.25	22.875	16.375	14.25
8:00:00 AM	37.25	29.625	25	23.125	16.25	14.125
9:00:00 AM	38.375	29.75	25.625	23.125	16.375	14.25
11:00:00 AM	34.75	26.25	25	23.375	16.125	14
12:00:00 PM	39.125	29.25	25.5	23.25	16.5	14.5
1:00:00 PM	38	29.75	25.875	23.375	16.5	14.25
2:00:00 PM	37.5	29.625	26.125	23.5	16.75	14.375
5:00:00 PM	34.75	26.125	24.875	23.25	16.5	14.25
6:00:00 PM	44	30.75	25.75	23.25	16.625	14.25
7:00:00 PM	41.75	31	26.375	23.5	16.75	14.125
8:00:00 PM	41.875	32	26.75	23.625	16.625	14.375


Morning Shift
6:00 AM
7:00 AM
8:00 AM
9:00 AM
SP1
OP1
OP2
OP3
SP2
SP3
Elevation (in.)
Distance (ft.)
SP1
OP1
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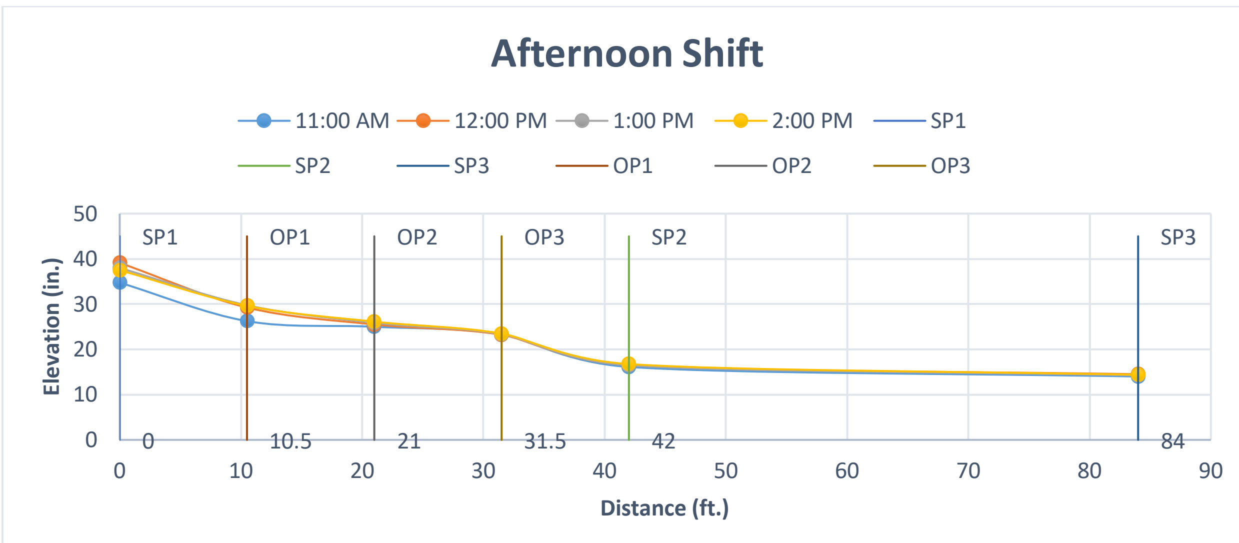
Afternoon Shift
11:00 AM
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2:00 PM
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Elevation (in.)
Distance (ft.)
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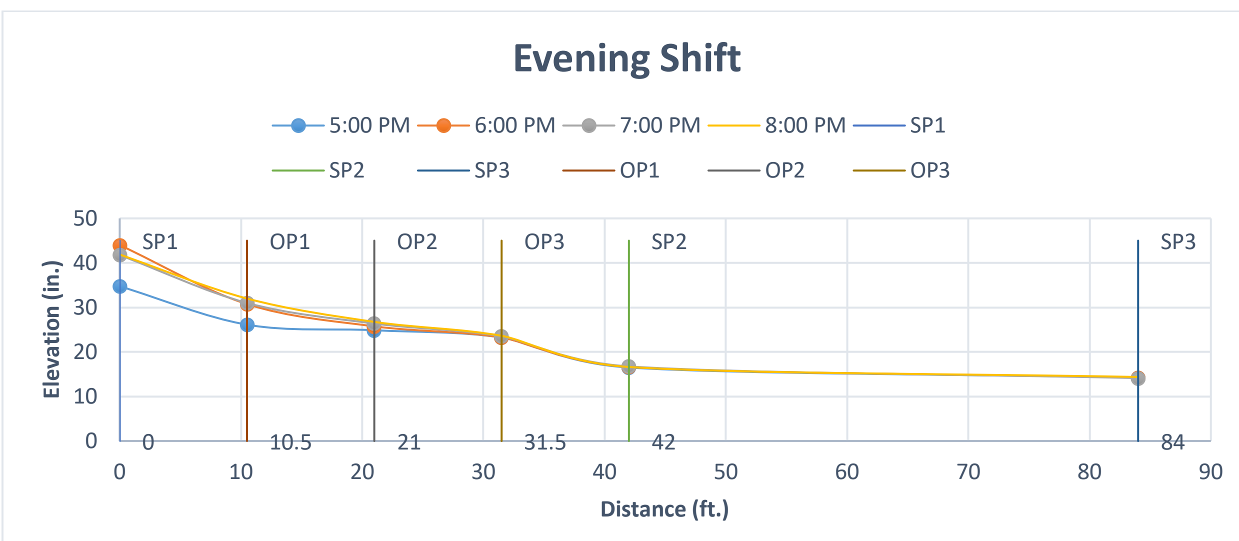
Evening Shift
5:00 PM
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Elevation (in.)
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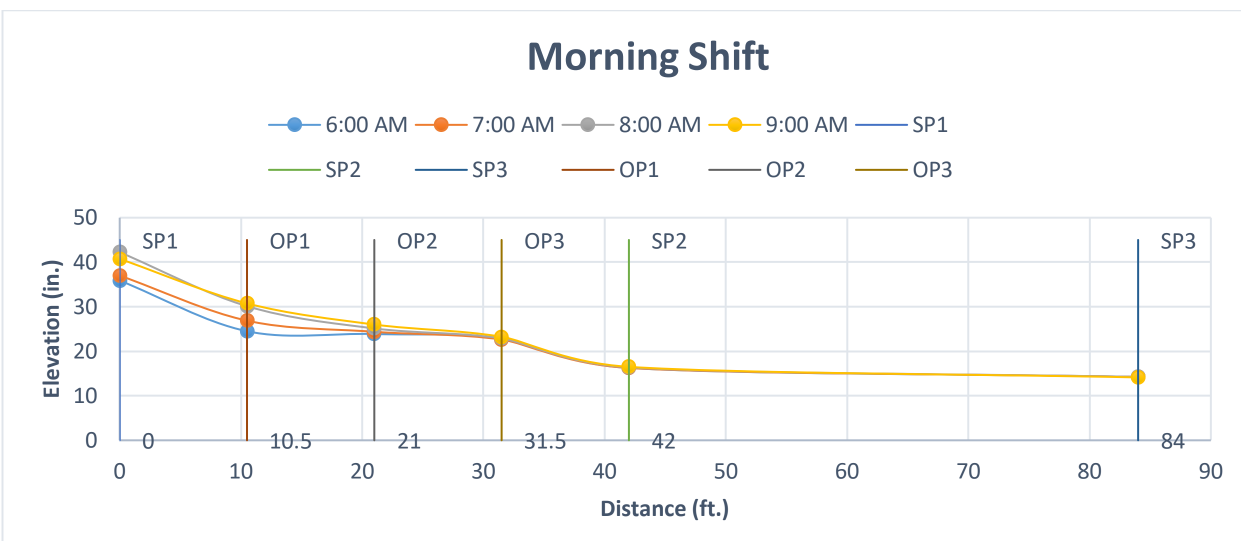
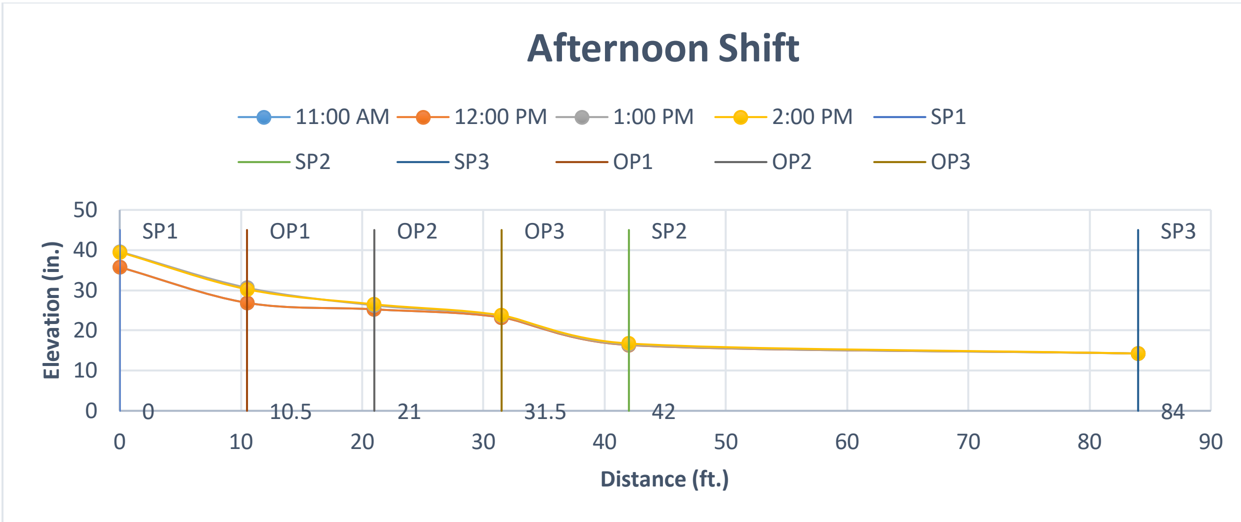
9/8/2016	Elevation (ft)					
	SP 1	OP 1	OP 2	OP 3	SP 2	SP 3
Distance (ft)	0	10.5	21	31.5	42	84
6:00:00 AM	35.875	24.5	23.875	22.875	16.25	14.25
7:00:00 AM	37	26.875	24.375	22.625	16.25	14.25
8:00:00 AM	42.25	30.125	25.125	22.875	16.375	14.25
9:00:00 AM	40.75	30.75	26	23.25	16.5	14.125
11:00:00 AM	35.75	26.875	25.25	23.25	16.375	14.25
12:00:00 PM	41.125	30.25	25.875	23.5	16.375	14.25
1:00:00 PM	39.625	30.625	26.25	23.625	16.5	14.25
2:00:00 PM	39.5	30.25	26.5	23.75	16.75	14.25
5:00:00 PM	35.375	26.25	25	23.25	16.5	14.125
6:00:00 PM	46.25	31.375	25.75	23.25	16.5	14.125
7:00:00 PM	41.5	31.75	26.5	23.625	16.5	14.375
8:00:00 PM	46.375	33	27	23.75	17	14.25




Afternoon Shift
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Elevation (in.)
Distance (ft.)
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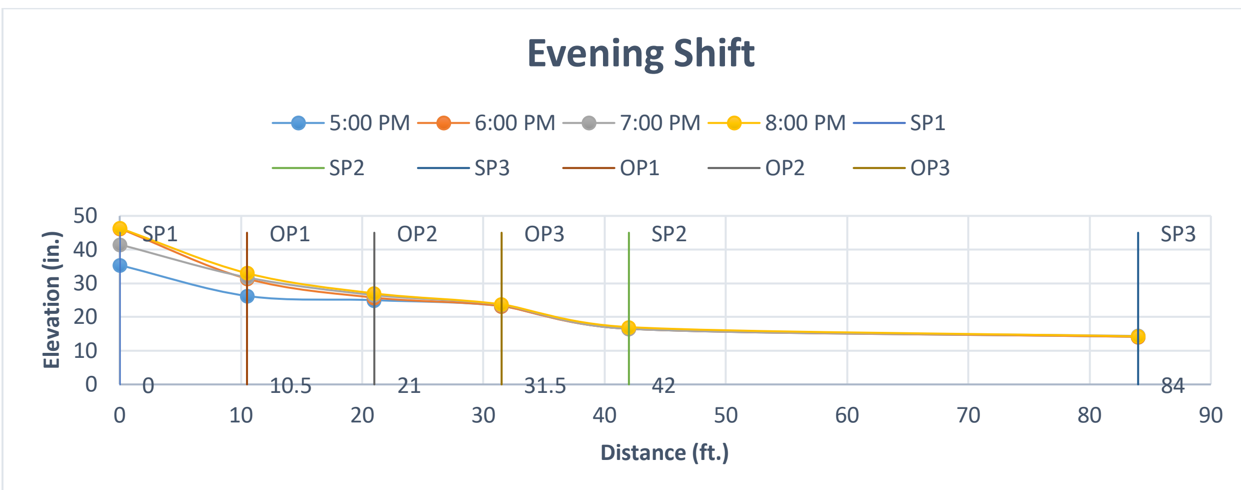
Evening Shift
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Elevation (in.)
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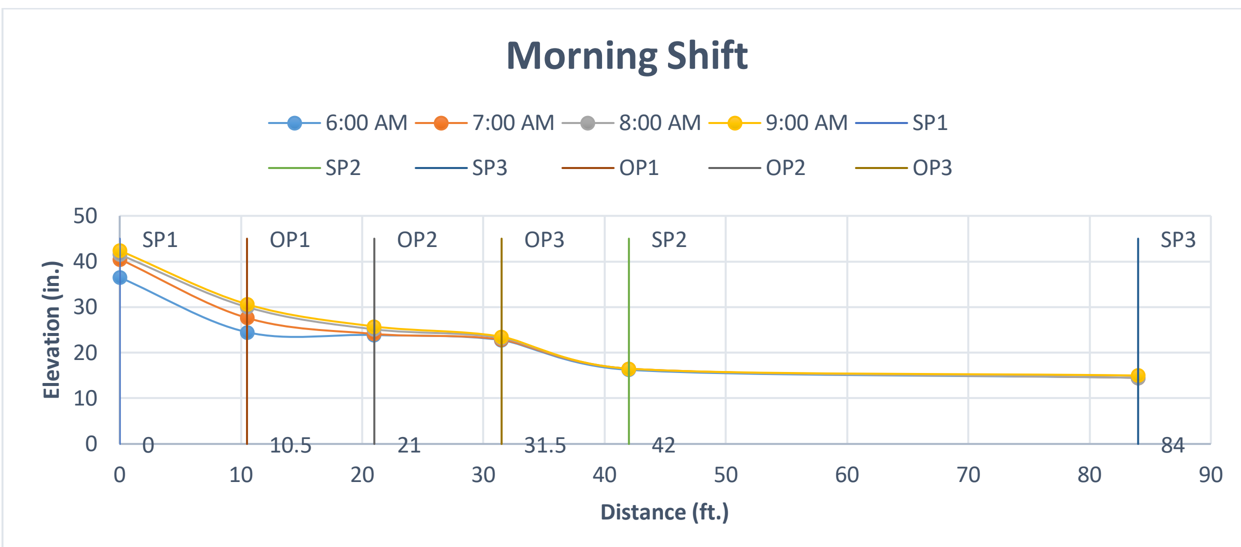
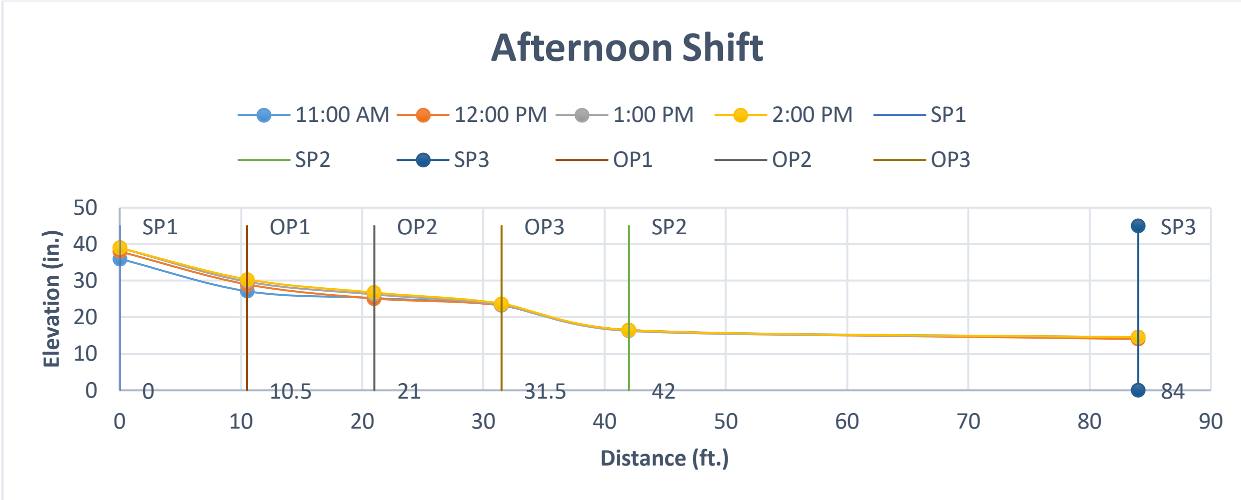
9/9/2016	Elevation (ft)					
	SP 1	OP 1	OP 2	OP 3	SP 2	SP 3
Distance (ft)	0	10.5	21	31.5	42	84
6:00:00 AM	36.5	24.5	23.875	22.75	16.25	14.5
7:00:00 AM	40.5	27.625	24.125	22.875	16.5	14.5
8:00:00 AM	41.5	30	25.125	23.25	16.5	14.5
9:00:00 AM	42.375	30.625	25.75	23.5	16.5	15
11:00:00 AM	36	27.125	25.25	23.25	16.5	14.5
12:00:00 PM	38	29	25.125	23.25	16.5	14
1:00:00 PM	39	29.75	26.25	23.375	16.25	14.5
2:00:00 PM	39	30.375	26.75	23.75	16.5	14.5
5:00:00 PM	35	27.5	25	23.375	16.5	14.625
6:00:00 PM	46	32.25	25.375	23.5	17	14.75
7:00:00 PM	43	32.75	26.75	23.5	16.75	14.5
8:00:00 PM	44.375	33.375	27.5	24.25	16.75	14.5




Afternoon Shift
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Elevation (in.)
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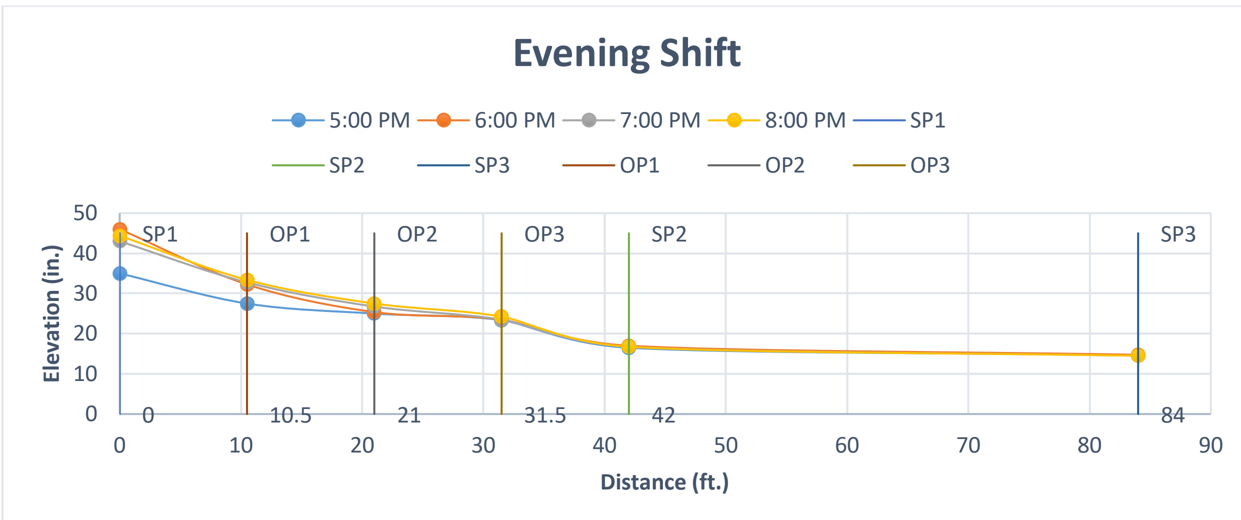
Evening Shift
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Elevation (in.)
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