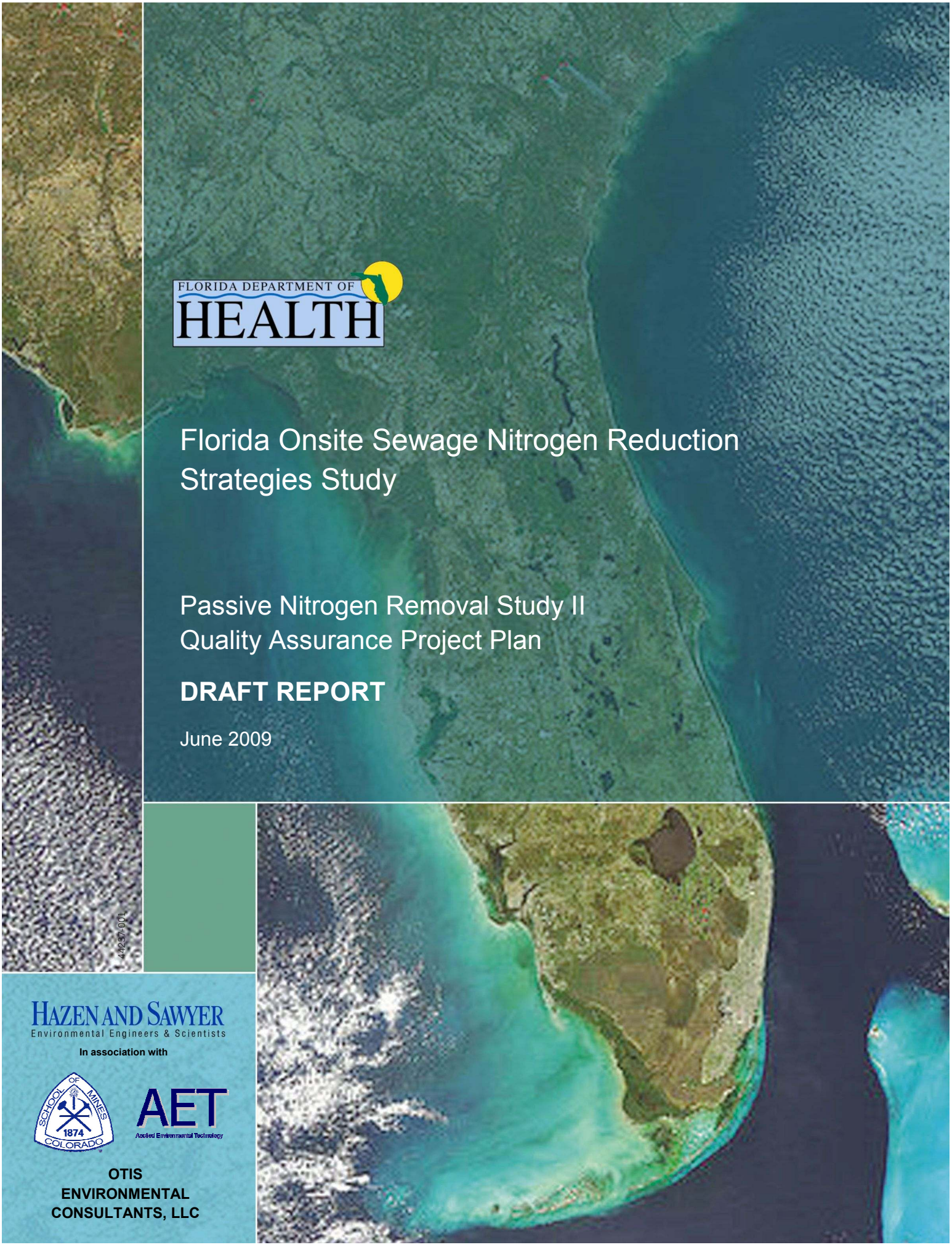

FLORIDA DEPARTMENT OF HEALTH

Florida Onsite Sewage Nitrogen Reduction Strategies Study

Passive Nitrogen Removal Study II Quality Assurance Project Plan

DRAFT REPORT

June 2009

4423.001

HAZEN AND SAWYER
Environmental Engineers & Scientists

In association with

SCHOOL OF MINES 1874 COLORADO

AET
Applied Environmental Technology

OTIS ENVIRONMENTAL CONSULTANTS, LLC

Florida Onsite Sewage Nitrogen Reduction Strategies Study

DRAFT REPORT
Passive Nitrogen Removal Study II
Quality Assurance Project Plan

Prepared for:

Florida Department of Health
Division of Environmental Health
Bureau of Onsite Sewage Programs
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Section 1.0
Project Organization and Management

The Florida Department of Health has contracted to continue the study of passive nitrogen removal (PNRS II) under Task A of the Florida Onsite Sewage Nitrogen Reduction Strategies Study (FOSNRS). PNRS II is a follow up to the previous experimental evaluations of passive nitrogen removal technologies conducted under Contract CORY (Passive Nitrogen Removal Study I). The Passive Nitrogen Removal Study II (PNRS II) will be conducted by Hazen and Sawyer and Applied Environmental Technology, who will perform overall project management, establish and conduct the pilot studies, and who will deliver samples for water quality analyses to an approved analytical laboratory. The contractors will review and interpret the resulting data, adjust the pilot testing program as warranted, and generate a summary report and recommendations. Prudent project management will help minimize changes, ensure project continuity, and avoid delays in the project schedule. This type of project is highly specialized, requiring unusual equipment and services. Therefore it is crucial that adequate project management be used to ensure the success of the project.

Section 2
Problem Definition and Background

A. Project Background

The Florida Department of Health (FDOH) has provided funding to evaluate methods that can be used to enhance nitrogen removal in onsite wastewater systems in a passive and cost effective manner. The Florida Onsite Sewage Nitrogen Reduction Strategies Study (FOSNRS) Task A.13 entails formulating a pilot testing plan to evaluate candidate technologies that can be used to remove nitrogen from septic tank effluent with more passive systems. The purpose of the Passive Nitrogen Removal Study II is to extend and expand into field pilot testing the previous experimental studies of the two-stage biofiltration process that were conducted in PNRS I. PNRS II will perform field testing of candidate media and passive nitrogen reduction treatment systems. The results of PNRS II may be used to develop and implement subsequent evaluations of full-scale systems that will be conducted under Task B of this project.

The *Florida Passive Nitrogen Removal Study Literature Review and Database* proposed the development of a two stage biofilter system for passive removal of total nitrogen from septic tank effluent (Smith et al., 2008). The two stage system consisted of an initial unsaturated media biofilter for ammonification and nitrification, followed in series by a saturated anoxic denitrification biofilter. The system would be deployed between the septic tank and the soil treatment unit (drainfield) or soil dispersal system of new or existing facilities. Nitrogen in septic tank effluent would be substantially removed before wastewater was directed to the soil for treatment or dispersal. Results from the previous experimental studies conducted in PNRS I provided the proof of concept of the two-stage passive nitrogen reduction system.

To perform PNRS II testing, it is desired to conduct studies in a manner that more closely resembles the functioning of actual onsite systems. Actual candidate media should be used, placed in appropriate depths and distribution. Continuous and dosed biofilter operation is preferable, where microbial populations will establish their metabolic activities and perform desired biochemical transformations in response to conditions similar to an operating system. The use of actual septic tank effluent (STE) as feed source is deemed preferable to use of a synthetic analog STE. This Quality Assurance Project Plan (QAPP) describes the methods and procedures that will be used to conduct the passive nitrogen removal evaluations.

B. Candidate Study Sites

Two candidate sites have been identified and arrangements are being sought for their use. The acceptability of the sites must be established, and a single site will be chosen for the study. The chosen site must have a source of actual septic tank effluent or primary effluent, a power supply to pump STE to test biofilters, and power for operation of equipment. Both site locations are isolated from public access and would cause minimal disruption to any activity, and each site has reasonable security. Both sites are in Hillsborough County, Florida, and are identified below.

1. University of Florida Gulf Coast Research and Educational Center (GCREC)

2. University of South Florida Lysimeter Research Facility

Section 3
Project Description

A. Project Purpose

To evaluate candidate media and treatment processes for development of more passive nitrogen removal systems for onsite wastewater treatment.

B. Project Objectives

The objective is to establish pilot passive nitrogen removal systems to evaluate the effectiveness of various media and two-stage biofilter designs in removing total nitrogen from septic tank effluent. The pilot test systems will consist of various configurations of in-tank biofilters and passive in-situ systems. In-tank systems will primarily employ variants of the two-stage biofiltration concepts elucidated in PNRS I. In-situ technology evaluation will include a drip irrigation system for effluent dosing, with emitters located in shallow root zones.

In the two-stage biofilter process, a first stage unsaturated biofilter is followed in series by a second stage biofilter operated in a water saturated mode. Septic tank effluent will be applied to the top of the first stage media, resulting in a downward percolation of wastewater over and through the media biofilter bed. The unsaturated pore spaces in the first stage media will allow air to reach microorganisms attached to the media surfaces, enabling aerobic biochemical reactions to occur. The significant target reactions are aerobic heterotrophic oxidation (by microorganisms that oxidize organic material and reduce biochemical oxygen demand), hydrolysis and ammonification (releasing ammonia), and nitrification (biochemical conversion of ammonia to nitrate and nitrite). Of particular interest are the organic and ammonia nitrogen concentrations in first stage effluent, as well as nitrate and nitrite.

Effluent from the bottom of the first stage biofilter is passed through a saturated anoxic biofilter that contains a reactive media that supplies electron donor for denitrification (reduction of nitrate and nitrite to N_2 gas). The biofiltration systems will be operated over a twelve month period and monitored for nitrogen species and other water quality parameters. Of particular interest are the concentrations of ammonia in first stage effluent and nitrate, nitrite and total nitrogen in the second stage effluent.

The interaction of media with applied wastewater governs the treatment process. Key features affecting nitrogen removal performance include:

1. The effects of hydraulic and nitrogen loading rates, on average daily and per dose basis, on first stage effluent nitrogen concentrations.

2. The effects of first stage media on effluent nitrogen levels.

3. Alkalinity consumption in the first stage and its possible effects on nitrification.

4. The effects of hydraulic and nitrogen loading rates, on average daily basis, on second stage effluent nitrogen concentrations.

5. The effects of second stage media on effluent nitrogen levels.

6. Second stage effluent total nitrogen concentrations and speciation into organic, ammonia, and oxidized nitrogen forms.

7. Alkalinity consumption or restoration in the second stage and its possible effects on denitrification.

8. Use of first stage recycle.

C. Project Tasks and Timeline

Project tasks and preliminary timeline are shown in Table 3.1. The start dates and tasks are contingent upon Recommendations for Process Forward (FOSNRS Task A.14) and may be altered based on the results of Task A.14. The task descriptions provide a template by which the project team will conduct the PNRS II project. The nature of technology demonstration projects will necessitate system and testing modifications during the course of the study. It is important to recognize that operational adaptation is a central feature of pilot testing and process optimization. A typical example is a modification in operation as a result of assessment of performance data, where a higher loading rate is applied to a well functioning system to evaluate performance over a wider loading envelope. The QAPP established initial loading rates for PNRS II systems that may be adjusted as the study progresses, based on ongoing results and the professional judgment of the project team. A degree of discretion must be afforded to the project team to make modifications as warranted. Additionally, longer term operation of successful on-site treatment systems may be warranted. All substantive modifications will be fully communicated to FDOH.

Table 3.1
Project Tasks and Timeline

Task/Activity	Start	Projected Completion
Task 1 PNRS II Infrastructure Design	Week 1	Week 4
Task 2 Procurement of materials and media	Week 4	Week 8
Task 3 Construction of test facility and pilot systems	Week 6	Week 10
Task 4 Operation and monitoring of pilot systems	Week 12	Week 64
Task 5 Preparation of draft report	Week 68	Week 74
Task 6 Preparation of final report	Week 76	Week 80

Task 1: PNRS II Infrastructure Design

A final testing site will be established based on the acceptability of wastewater sources, use of the site for other FOSNRS work elements in Tasks B and C, and establishing site use arrangements. Once test facility infrastructure is designed (Tasks A.17 through A.19), the design of PNRS II infrastructure can begin and will be integrated into the test facility design. The design documents will define the needed materials and construction of the PNRS II testing component.

Task 2: Procurement of Materials and Media

Candidate media for evaluation in Stage 1 (unsaturated) biofilters and Stage 2 (saturated) biofilters are listed in Table 3.2, with physical properties and their sources. Included are media with high water retention and porosity, and the clinoptilolite additionally provides ion exchange capacity. Media will be procured from vendors for use (Table 3.2). Stage 1 media includes expanded clay and clinoptilolite. These have greater than 45% porosity and high water retention. The clinoptilolites have cation exchange capacities of 1.5 to 1.8 meq/g, and will act to retain ammonia ions for enhanced ammonia removal under non-steady flows and higher loading rates. Livlite is an expanded clay with high water retention characteristics. Expanded polystyrene is a very lightweight material that should be quite suitable as a low cost Stage 1 biofilter media.

The Stage 2 electron donor media are elemental sulfur, which will result in an autotrophic denitrification process in the anoxic biofilter; lignocellulosic materials, such as woodchips, which support heterotrophic denitrification, and glycerol, a readily available carbon source for heterotrophic denitrification. Crushed oyster shell and sodium sesquicarbonate will be used as alkalinity sources in sulfur-based denitrification biofilters, as autotrophic sulfur-based denitrification will consume alkalinity. Expanded shale may be in-

cluded as a Stage 2 option for its anion exchange capacity to enhance nitrate removal performance.

Table 3.2
Biofilter Media

Material	Bulk density, lb/ft^3	Particle Size Range	Supplier
Zeo-Pure AMZ 8/20 Clinoptilolite	55	0.8 – 2.3 mm	Ash Meadows, Armagose, NV
Livlite (expanded clay)	41	3 to 5 mm	Big River, Alpharetta, GA
Expanded Polystyrene	0.34 – 1.5	2.2 – 3.6 mm	JSP
Elemental sulfur	77	2 – 4 mm	Georgia Sulfur, Valdosta, GA
Oyster shell	82	3 – 15 mm	Misc. Locations, FL
Sodium Sesquicarbonate T-50	69	1 – 3 mm	Solvay
Lignocellulosic material (woodchips, sawdust)	20 – 28	1 to 5 mm	Robbins Products, Tarrytown, FL
Glycerol	79	-	Greenhunter Energy
ACT-MS ESF-450 Utelite (expanded shale)	54	0.4 – 4.5 mm	ES Filter, Ogden, UT

Task 3: Construction of Test Facility and Pilot Systems

A test facility will be constructed that will provide a source of primary effluent (i.e. septic tank effluent) to the PNRS II systems, as well as dosing regimes, sampling ports, and effluent collection. Design of the test facility will be conducted under FOSNRS Tasks A.17 through A.19. Two types of testing systems will be constructed:

A. Vertical/Horizontal Two-Stage Biological Filtration

B. In-Situ Vegetation/Media Simulators

A. Vertical/Horizontal Two-Stage Biological Filtration

The two-stage biofilters consist of a vertical unsaturated biofilter followed by horizontal saturated denitrification biofilter (Figure 3-1). Primary effluent (i.e. septic tank effluent) is dosed to the upper surface of the Stage 1 biofilter, trickles through the unsaturated media, and then flows by gravity through the saturated denitrification filter. In PNRS II pilot testing, multiple Stage 1 biofilters will be operated in parallel on the same primary effluent, and multiple Stage 2 biofilters will be operated in parallel on the same common Stage 1 effluent.

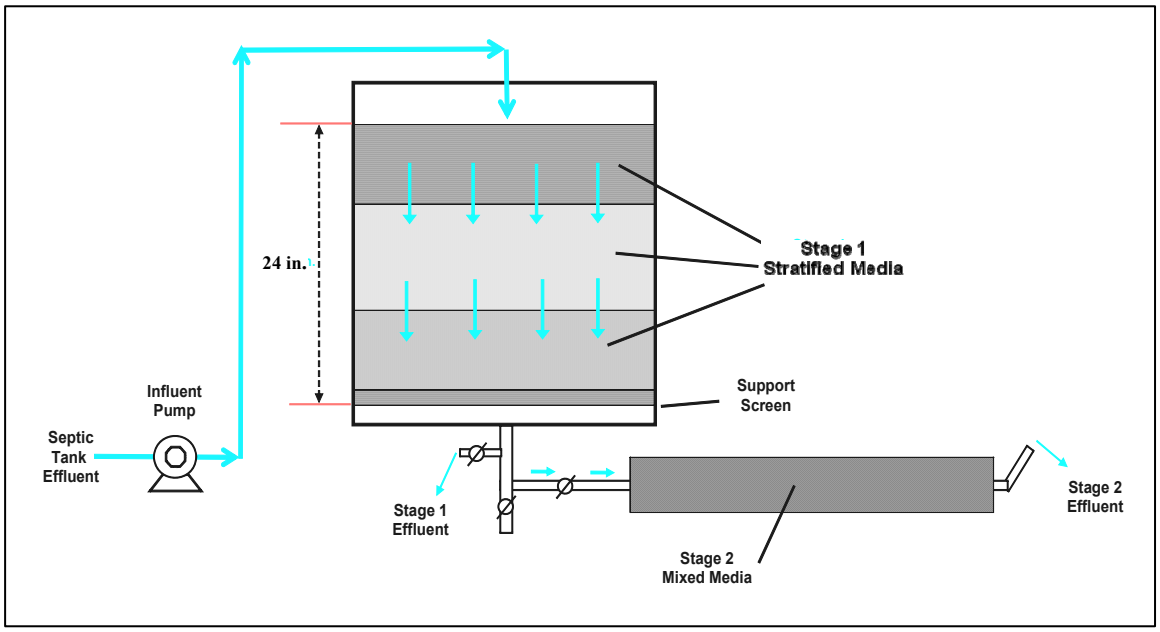


Figure 3-1 Schematic of Vertical/Horizontal Two-Stage Biofiltration

Configuration of the Stage 1 unsaturated biofilters is shown in Table 3.3. Three biofilter media will be examined in PNRS II pilot studies: expanded clay and clinoptilolite, both of which were evaluated in PNRS I, and expanded polystyrene, a readily available low cost and light weight material. Design of the expanded clay and clinoptilolite pilot biofilters was guided by the results of PNRS I. Expanded clay and clinoptilolite biofilters will each be evaluated in 2^2, or 4 units. The 2^2 test matrix consists of two media depths (15 and 30 inch) and single pass and recycle operation (Table 3.3). All expanded clay and clinoptilolite biofilters will employ a two layer stratified design for particle size (Table 3.4). Expanded polystyrene biofilters will be evaluated in a 2^1 test matrix consisting single pass and recycle operation (Table 3.3). All pilot Stage 1 biofilters will be dosed at a 30 minute interval (48 dose/day), the dosing regime that was employed successfully in PNRS I.

The initial hydraulic loading rate to Stage 1 biofilters will be 3 gallon/ft^2-day. It is expected that this loading rate will be progressively increased as performance data is gathered over the course of the study. The PNRS II pilot studies will include recycle systems to delineate total nitrogen removal by pre-denitrification, and the use of two media size stratification and different media depths than were applied in PNRS I. These factors have direct technological and cost savings implications.

Stratification of media based on particle size is based on the expected progression of biochemical reactions within the biofilter. The processes in the upper coarse media layer include adsorption of wastewater particulates and colloids, hydrolysis and release of soluble organics, aerobic utilization of soluble organics, and biomass synthesis. In the upper layer, the biochemical processing of organic matter between doses must keep pace with the newly applied wastewater constituents from each dose. The greatest accumulation of organic and inorganic mass will occur in the upper layer, and the use of larger particle size media will provide greater space for accumulation of solids. Stratified media should enhance the potential for long term operation while maintaining treatment efficiency. The use of finer particle sizes in the lower media depths will provide greater surface area for microbial attachment and physical filtration, the later which could improve removal of pathogens and other wastewater constituents. The coarser sized particles in the upper layer will also filter out larger particulates and protect the underlying finer media. The two layer media size stratification (Table 3.4) is a simplification of the 3 layer design employed in PNRS I; the two layer design will simplify construction and reduce costs.

Table 3.3
Stage 1 Vertical Unsaturated Biofilter Configuration and Initial Operation

Unsaturated Biofilters (Stage 1)					
No.	**Media**	**Biofilter**	**Media Depth, Inches**	**Flow Regime**	**Recycle Ratio α**
1	Expanded Clay	UNSAT-EC-1	15	Single Pass	-
2		UNSAT-EC-2		Recycle	3
3		UNSAT-EC-3	30	Single Pass	-
4		UNSAT-EC-4		Recycle	3
5	Clinoptilolite	UNSAT-CL-1	15	Single Pass	-
6		UNSAT-CL-21		Recycle	3
7		UNSAT-CL-3	30	Single Pass	-
8		UNSAT-CL-4		Recycle	3
9	Polystyrene	UNSAT-PS-1	30 (NS)	Single Pass	-
10		UNSAT-PS-2		Recycle	3

EC: expanded clay, CL: clinoptilolite, PS: polystyrene, α: recycle flowrate/forward flowrate, NS: non-stratified

Specification of pilot hydraulic loading rates was guided by the results of PNRS I. Unsaturated expanded clay and clinoptilolite biofilters both exhibited exceptional performance at 3 gallon/ft^2-day. The PNRS I results suggest that the potential of these media was not fully utilized. The PNRS II pilot study will delineate treatment performance under real world conditions at the PNRS I loading rate of 3 gallon/ft^2-day and at higher loading rates. Higher loading rates translate into a smaller footprint for Stage 2 biofilters and significantly lower construction costs.

Table 3.4
Stage 1 Vertical Unsaturated
Biofilter Media Depth and Stratification

Total media depth, inch	Layer	Media layer depth, inch	Particle diameter, mm
15	Upper	5	1.5 – 2.5
	Lower	10	0.3 – 0.6
30	Upper	10	1.5 – 2.5
	Lower	20	0.3 – 0.6

The Stage 1 biofilters will be supplied with septic tank effluent with a timed dosing of once per one half hour (48 doses/day), as was employed in PNRS I. A centrally located dosing system will be used to distribute primary effluent over the surface of the media of each Stage 1 biofilter. Water will percolate downward through the Stage 1 media, through the support screen, and into a line that conveys biofilter effluent to the common Stage 1 effluent collection chamber. The water elevation in the line below the Stage 1 biofilter will provide hydraulic head for passive movement of water to the common collection chamber. A valve and sample port (with another valve) will be located in the line below the Stage 1 biofilter. In normal biofilter operation, the sample port valve will be closed and the valve leading to the effluent collection chamber will be open. The design of the biofilter system will minimize internal volumes within the connecting piping. At 48 doses per day and 3 gallon/ft^2-day, a single dose will add a volume that is approximately 6% of the water retained within the Stage 1 biofilter bed (Smith et al., 2008).

Configuration of the Stage 2 saturated denitrification biofilters is shown in Table 3.5. The Stage 2 biofilters will be constructed with unstratified mixed media containing elemental sulfur, crushed oyster shell, sodium sesquicarbonate, lignocellulosic materials, and expanded clay (Table 3.5). The use of elemental sulfur with oyster shell was successfully demonstrated in PNRS I. Sodium sesquicarbonate will provide a non-calcium containing alkalinity supply which will reduce the potential for supersaturation of calcium carbonate. The potential use of lignocellulosic materials as a source of organics in denitrification filters was reviewed in the PNRS I literature review. Expanded clay was also evaluated

as microbial attachment medium in PNRS I. Glycerol is a low cost fermentable substrate which serves as a denitrification electron donor.

Stage 2 biofilters will employ non-stratified mixed media of 1 to 2 mm particle size. A preliminary configuration of Stage 2 biofilters is as 6 inch diameter columns of 72 inch length; detailed design will be conducted in Tasks A.15 through A.17. Sample ports will be provided at 1/3 and 2/3 of total biofilter length, which will enable four point longitudinal profiling of nitrogen species and other water quality parameters.

A schematic of the two stage biofiltration pilot apparatus is shown in Figure 3-2. Like PNRS I, the pilot PNRS II biofilter systems will be configured for simplicity of operation, minimal moving parts, and passive gravity flow where possible. The two stage biofilter systems will likely be constructed as above ground Stage 1 filter vessels with gravity flow to the common Stage 1 effluent collection tank, with gravity or pumped flow to the horizontal Stage 2 filters (Figure 3-2). The same primary effluent (i.e. septic tank effluent) will be supplied to the surface of each of the Stage 1 vertical biofilters, which will be placed above ground to allow effluent to flow by gravity to a common Stage 1 effluent tank (Figure 3-2). Flow from the common Stage 1 effluent tank will be directed to the Stage 2 filters with individual control to each Stage 2 filter with pumps and/or valves. The system design will provide independent control of the flowrate to each Stage 2 filter. Stage 2 biofilters will be maintained in saturated mode by the Stage 2 overflow elevation. Stage 2 effluent will be collected via gravity into a Stage 2 collection tank, for management or disposal. Details of design and fabrication of pilot biofilter systems will be addressed in Tasks A.15 through A.17.

Monitoring sample points are septic tank effluent, Stage 1 effluents, the common Stage 2 influent, and Stage 2 effluents (Table A.1). For each monitoring point, separate samples will be collected for field analyses and for laboratory analyses. Field analyses will be performed immediately upon sample collection. Samples for laboratory analyses will be collected by directing samples directly into sample collection containers that are located within iced coolers and that contain any required sample preservatives. Influent and effluent samples will not have contact with any intermediate sample devices. Effluent samples will be maintained in iced coolers and transported to the lab within 24 hours of collection.

Table 3.5
Stage 2 Saturated Denitrification Biofilter
Configuration and Initial Operation

No.	Electron Donor	Biofilter	Media Composition (by volume)	Flowrate gpd	Surface Loading Rate, gal/day-ft^2	Water residence time at 1/3 of length (hour)	Water residence time 2/3 of length (hour)	Water residence time at 100% (hour)
1	Elemental sulfur	DENIT-SU-1	80% SU 20% OS	5	25.5	5.6	11.3	16.9
2		DENIT-SU-2		10	51.0	2.8	5.6	8.5
3		DENIT-SU-3		15	76.4	1.9	3.8	5.6
4		DENIT-SU-4	80% SU 20% NS	5	25.5	5.6	11.3	16.9
5		DENIT-SU-5		10	51.0	2.8	5.6	8.5
6		DENIT-SU-6		15	76.4	1.9	3.8	5.6
7	Lignocellulosic	DENIT-LS-1	60% LS 40% EC	5	25.5	5.6	11.3	16.9
8		DENIT-LS-2		10	51.0	2.8	5.6	8.5
9		DENIT-LS-3		15	76.4	1.9	3.8	5.6
10		DENIT-LS-4	35% LS 65% EC	5	25.5	5.6	11.3	16.9
11		DENIT-LS-5		10	51.0	2.8	5.6	8.5
12		DENIT-LS-6		15	76.4	1.9	3.8	5.6
13	Glycerol	DENIT-GL-1	100% EC	5	25.5	5.6	11.3	16.9
14		DENIT-GL-2		10	51.0	2.8	5.6	8.5
15		DENIT-GL-3		15	76.4	1.9	3.8	5.6

SU: elemental sulfur, LS: lignocellulosic, GL: glycerol, OS: oyster shell, NS: sodium sesquicarbonate, EC: expanded clay

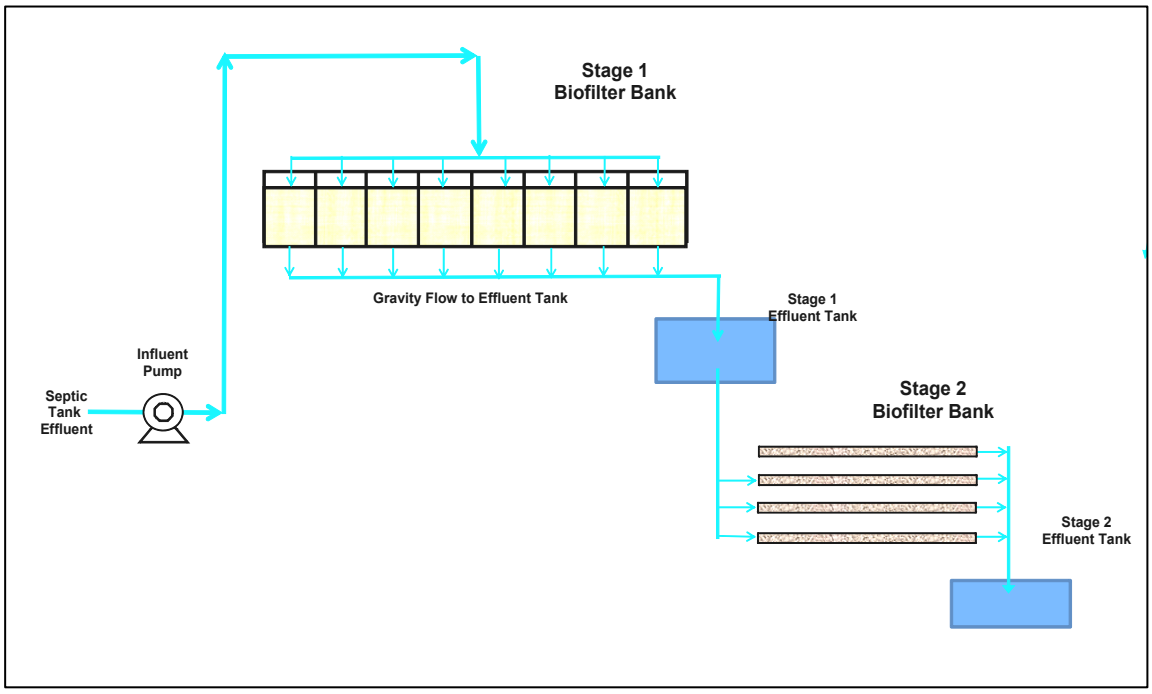


Figure 3-2 Schematic of Pilot Two-Stage Vertical/Horizontal Biofilter Systems

B. In-Situ Vegetative/Media Simulators

In-situ testing will be conducted by the application of primary effluent (i.e. septic tank effluent) and nitrified effluent to in-situ vegetative/media treatment systems. Effluent will be applied using subsurface drip irrigation (STE) or using an innovative capillary seepage matt that has been developed for irrigation of agricultural plants by scientists at the University of Florida Gulf Coast Research and Educational Center (GCREC). A schematic of in-situ simulators is shown in Figure 3-3. Other than the pumping of effluent by subsurface irrigation, the in-situ simulators are completely passive systems.

In INSITU-1, primary effluent (i.e. septic tank effluent) will be applied by subsurface drip irrigation to a near surface location, such that STE will interact with the active root zone of plantings, trickle downward through a 12 in. zone of unsaturated media, and then pass through an underlying zone of natural undisturbed soil (Figure 3-3). The 12 in. unsaturated media zone will consist of an upper layer of expanded clay of 1-2 mm, while the lower media layer will be a mixed media of 0.5 to 1 mm particle size of expanded clay, lignocellulosic material, and elemental sulfur (Table 3.3). The rationale for media size stratification was previously applied in PNRS I. The large size media in the upper

layer assimilate particulates and microbial growth, while finer size media at lower depths provide physical filtration and high surface area for biochemical reaction.

In INSITU-2, primary effluent will first be nitrified through an external in-tank biofiltration process. Nitrified effluent will be applied to a near surface location using drip irrigation over a capillary seepage matt such that nitrified effluent will interact with the active root zone of plantings, trickle downward through a 12 in. zone of unsaturated media, and then pass through an underlying zone of natural undisturbed soil (Figure 3-3). The 12 in. unsaturated media zone will consist of a single layer of 1-2 mm media consisting of expanded clay, lignocellulosic material, and elemental sulfur (Table 3.3).

An innovative feature of the in-situ simulator design is the use of mixed media in unsaturated mode that contains both a high water retention media (expanded clay) and heterotrophic and autotrophic electron donor (Table 3.6). The innovative media mix will provide three electron donor source options for denitrification: wastewater organics, lignocellulosics, and elemental sulfur. The use of solid electron donor media in an unsaturated operational mode will facilitate both aerobic processes (i.e. nitrification) and denitrification in saturated microsites with low redox potential. In a sense, this design will provide an electron donor boost to the simultaneous nitrification/denitrification process that occurs in unsaturated filters with inert media supports.

The goal of this testing is to quantify nitrogen reduction in systems where STE or nitrified effluent is applied with subsurface drip emitter tubing or capillary matt to shallow locations within the subsurface which contain plant root zones, unsaturated media, and electron donor media for enhanced denitrification. Timed dosing to shallow application points in the subsurface could be capable of affecting nitrogen reduction. This potential for in-situ treatment systems, including plant-assisted nitrogen transformations, has not been examined in Florida with innovative systems of this type but is of potentially high significance.

The 2^1 test matrix is shown in Table 3.6. The test matrix consists of subsurface drip irrigation emitter dosing of primary effluent (i.e. septic tank effluent) or nitrified effluent into the root zone of St. Augustine grass, 12 inch of unsaturated media to provide nitrification and denitrification. The in-situ simulators will receive an average hydraulic application rate of 0.50 gallon/ft^2-day on an aerial basis applied at 24 doses/day. Drip emitters will be placed at 12 inch spacings.

Issues that may affect nitrogen reduction are average daily hydraulic application rate, horizontal emitter spacing, doses per day, volume per dose, and the depth at which the bottom of emitter tubes is placed. Emitter tubing is available with spacings of as little as

12 in., which are preferred to typical 24 in. emitter spacings and will be used in this study. The lower emitter spacing results in lower effluent volume per dose at each emitter that are spread more uniformly over the plan area of the dosing zone, thereby increasing the effectiveness of utilization of the total plan area of the receiving surface. Hydraulic application rate affects volume per dose for any given dosing schedule, as interrelated to dosing frequency. As the average daily hydraulic application rate increases, the vegetative/media system will be increasingly challenged to assimilate nitrogen in the applied STE and limit downward nitrogen migration. The depth of emitters and the relationship of emitted effluent to surface vegetation root zones is an ostensibly significant factor affecting total nitrogen reduction. A dosing event can lead to water saturation in a temporally and spatially limited zone that creates oxygen limited conditions that favor denitrification. After saturated conditions end, microenvironments with limited DO can persist and provide continued denitrification. When bulk pore spaces are filled with air, conditions can favor nitrification. Plant roots can exude organic carbon and provide an electron donor rich region. The combination of the supply of organic carbon and reduced nitrogen in the applied STE, the varying saturation and oxygen levels resulting from the dosing regime, and the characteristics of the plant root zone can affect sequential nitrification and denitrification reactions. Downward advective transport of organic carbon and nitrate can create a biologically active denitrification zone of some vertical extent. The interaction of all of these factors will determine the extent to which total nitrogen reduction can be affected by drip application of STE into plant/media systems and the significance of plant processes on overall nitrogen reduction. Detailed design of in-situ simulators will be conducted in Tasks A.15 through A.17.

For all PNRS II pilot units, system shakedown will proceed following fabrication and set up. System integrity and hydraulics will be fully evaluated with clean water. Basic features of system integrity and hydraulic conveyance will be examined, including system leaks, gravity flow conveyance where applicable, operation of pumps and valves, and sample access functionality. Media will be pre-screened where needed, washed at least three times to remove fines, and placed to appropriate depths in the biofilters. Denitrification biofilters will be initially filled with a clean water source which will be displaced upon commencement of operation. Operation on wastewater will proceed and flow monitoring will be commenced.

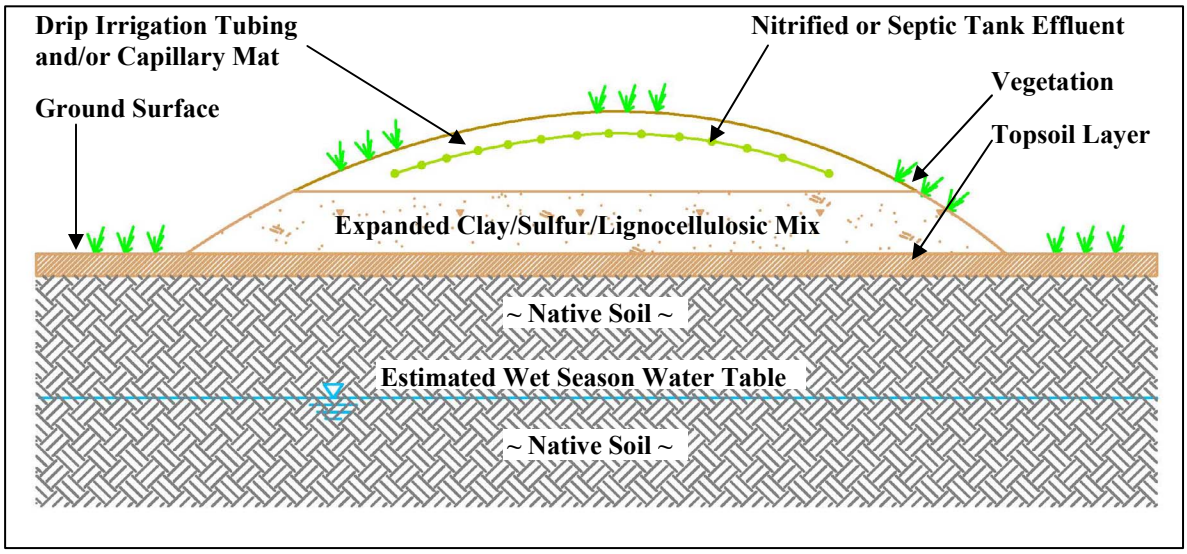


Figure 3-3 Cross-Section Schematic of In-Situ Vegetative Denite - Media Treatment System

Table 3.6
In-Situ Vegetation/Media Simulator Configuration and Operation

No.	In-Situ Simulator	Influent	Flow Application	Unsaturated Media	Saturated Media	Hydraulic Loading Rate, Plan Area Basis, gallon/ft^2-day	Dosing Regime
1	INSITU-1	Primary effluent	Subsurface Drip Irrigation Tubing	5 in. 1-2 mm 100% EC 7 in. 0.5-1 mm 40% EC 30% LS 30% SU	Native soil	0.50	24/day
2	INSITU-2	Nitrified effluent	Drip Irrigation Tubing over Capillary Seepage Matt	12 in. 0.5-1 mm 40% EC 30% LS 30% SU			

SU: elemental sulfur LS: lignocellulosic EC: expanded clay

Task 4: Operation and Monitoring of Pilot Systems

The biofilter systems will be operated over a twelve month period during which eight monitoring events will be conducted. The analytical template is shown in Table 3.7. A detailed analytical description is included in Appendix A. As outlined in Table A.1, there are 23 sampling points and a monitoring analyses structure that employs three analytical

tiers. Tier 1 analytes include field and laboratory parameters that will be monitored at each sample point (up to 23) and at each sample event. Potential monitoring points are STE (1), Stage 1 effluents (10), Stage 2 influent (1), horizontal Stage 2 effluents (9), and in-situ soil/vegetative simulator effluents (2). Tier 1 analytes include field parameters (temperature, pH, dissolved oxygen (DO), and oxidation reduction potential (ORP); the nitrogen series (laboratory parameters) of total kjeldahl nitrogen (TKN), ammonia (NH_3), and oxidized nitrogen (NO_x); five day carbonaceous biochemical oxygen demand (C-BOD_5) and total suspended solids (TSS). Tier 2 analytes are supporting parameters that will be monitored at much reduced frequency at all sample points. Tier 3 parameters will be conducted only on sulfur-based denitrification biofilter sample points. (Table 3.7).

Table 3.7
Analyses Template

Analysis Tier	Number of events	Sample points	Analytes	Total number of analyses
1	8	23 (all)	Temperature	184
			pH	184
			DO	184
			ORP	184
			Alkalinity	184
			TKN	184
			NH_3-N	184
			(NO_3+NO_2)-N	184
			C-BOD_5	184
			TSS	184
2	1 - 4	23 (all)	COD	50
			Total phosphorus	29
3	4 - 8	5 (sulfur systems)	Sulfate	40
			H_2S	16

Task 5: Preparation of Draft Report

A draft report will be prepared describing pilot testing methods and procedures, results of the research, discussion and conclusions, and all monitoring data. The draft report will be submitted to FDOH for review and comment.

Task 6: Preparation of Final Report

A final report will be prepared based on comments from reviewers of the draft report.

Section 4
Quality Objectives and Criteria

The objective of this monitoring program is to evaluate media for passive nitrogen removal from septic tank effluent. The following summarizes the work to be performed:

- Two stage biofilters, redial flow denitrification biofilters and passive in-situ systems will be constructed and operated on primary effluent over a twelve month period.
- The flowrates to each biofilter system provide a range of hydraulic loading rates.
- First stage recycle will be employed to evaluate pre-denitrification.
- Monitoring will be conducted for septic tank effluent, effluent from the Stage 1 (unsaturated) biofilters and effluent from the Stage 2 (saturated) biofilters.
- Field parameters will be monitored at the site. Sample will be collected and transported to the laboratory for analysis of nitrogen species, sulfate and other wet chemistry parameters.
- Operation or configuration of the biofilters will be modified based on analysis of results and adaptive management.
- In-situ soil/vegetative evaluations will be conducted using subsurface drip irrigation technology with emitters located in root zone and monitoring to develop nitrogen concentrations and vertical nitrogen flux.

The monitoring data will be used to calculate:

1. average concentrations and standard deviations of water parameters in septic tank effluent, Stage 1 effluent and Stage 2 effluents;
2. percent removal nitrogen and nitrogen species in Stage 1 biofilters, Stage 2 biofilters and two stage biofilter systems;

3. changes to dissolved oxygen, pH, oxidation reduction potential and alkalinity through biofiltration treatment stages; and

4. average applied hydraulic loading rate, applied loading rates of total nitrogen and nitrogen species.

5. Vertical nitrogen flux in in-situ soil/vegetative systems.

A. Precision and Accuracy

Precision describes the reproducibility of results. Accuracy is the degree of agreement between an observed value and an accepted reference value. Accuracy will be evaluated through the analysis of surrogate spikes, Laboratory Control Samples (LCS), Laboratory Control Sample Duplicates (LCSD), matrix spike samples (MS/MSD) and laboratory internal blind audit samples. Precision and accuracy information is tracked by the laboratory, with acceptable ranges updated periodically. In addition, NELAC requirements include the analysis of proficiency test samples to evaluate precision and accuracy. Analytical methods, precision and accuracy, method detection limits and practical quantification limits are shown in Table 4.1.

Table 4.1
Aqueous Methodology, Precision and Accuracy, Detection Limits

Analyte	Method	Precision, %	Accuracy, %	MDL, ppm	PQL, ppm
Temperature					
pH	SM4500H+B	20	NA	0.1 pH units	0.1 pH units
DO					
ORP					
Turbidity	180.1	20	90-110	0.2 NTU	0.2 NTU
Alkalinity	SM2320 B	20	90-110	5.0	5.0
C-BOD_5	SM5210 B	20	85-115	2.0	2.0
COD	410.4	20	90-110	12.09452	25
TOC	SM5310 B	20	90-110	0.14778	1.0
TSS	SM2540 D	20	90-110	5.0	5.0
TKN	351.2	20	90-110	0.07121	0.5
NH_3-N	350.1	20	90-110	0.02	0.05
(NO_3+NO_2)-N	353.2	20	90-110	0.02541	0.05
Sulfate	300.0	20	90-110	0.05523	0.5
H_2S	SM4500S-E	20	80-120	1.0	1.0
Fecal coliforms	SM9222 B	20	NA	1.0	1.0
Total coliforms	SM9222 B	20	NA	1.0	1.0
Escherichia coli	SM9222 B	20	NA	1.0	1.0

MDL = method detection limit

PQL = practical quantitation limit

B. Representativeness

Representativeness refers to the relationship of a sample taken from a site to be analyzed to the remainder of the sample matrix at the site. The samples will be taken directly from the influents and effluent of the biofilters and will provide representativeness.

C. Comparability

The use of NELAC approved procedures and consistent approved methodologies ensure the comparability of data sets generated by different laboratories.

D. Completeness

Completeness is defined as a measure of the extent to which the data fulfill the data quality objectives of the project. The completeness of the data will be determined during the data validation and verification process.

Section 5
Documentation and Records

All documentation archives will be kept for a minimum of 5 years after the date of project completion as outlined in Table 5.1. Reports and deliverables will be submitted in Word or Excel format.

Table 5.1
Documentation and Records Storage

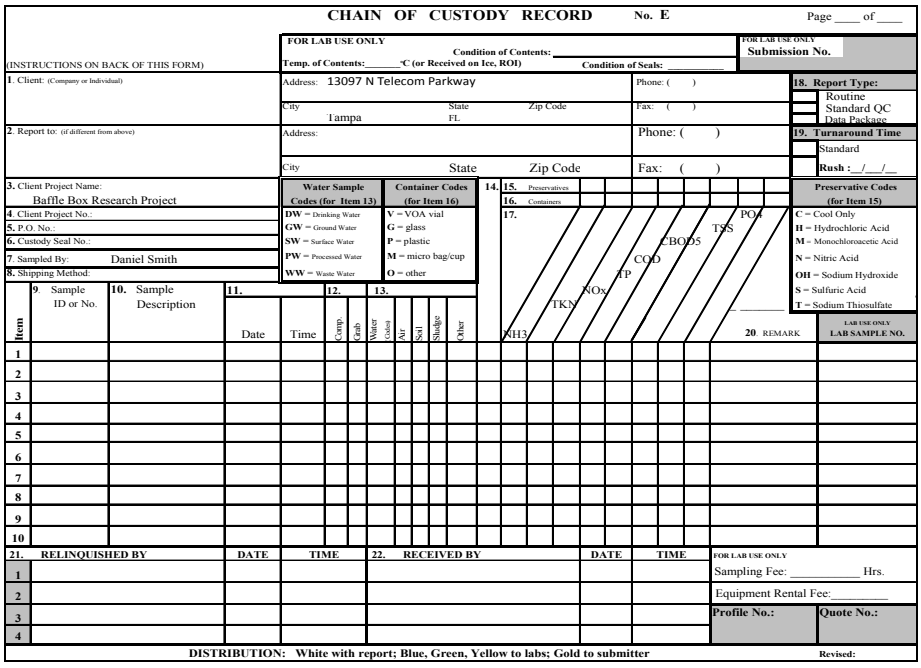
Document/Record	Location	Retention Time	Format
QAPP and revisions	Hazen and Sawyer, AET	5 years after project completion	Paper, electronic
Field notes	Hazen and Sawyer	5 years after project completion	Paper
Chain of custody	Hazen and Sawyer, Lab	5 years after project completion	Paper
Laboratory QA manual	Lab	5 years after project completion	Paper, electronic
Laboratory SOPs	Lab	5 years after project completion	Paper, electronic
Laboratory data reports	Hazen and Sawyer, Lab	5 years after project completion	Paper, electronic
Laboratory equipment maintenance logs	Lab	5 years after project completion	Paper
Laboratory calibration records	Lab	5 years after project completion	Paper, electronic

A. Field Documentation

1. Field Notes
   Field notes will be documented and maintained by field staff.

2. Field Parameters
   Field staff will record specific sample point, date and time of sample collection, parameter name, result and units

3. Sample Collection, Preservation and Transport
   Chain of custody forms and sample tags attached to sample bottles will be supplied by the laboratory. Figure 5-1 depicts a typical chain of custody form. Legal or evidentiary chain of custody as defined in the NELAC standards will be executed.



CHAIN OF CUSTODY RECORD No. E Page ____ of ____

(INSTRUCTIONS ON BACK OF THIS FORM)

FOR LAB USE ONLY
Temp. of Contents:_____°C (or Received on Ice, ROI)
Condition of Contents: _____
Condition of Seals: _____

FOR LAB USE ONLY
Submission No.

1. Client: (Company or Individual)
Address: 13097 N Telecom Parkway
City Tampa State FL Zip Code
Phone: ( )
Fax: ( )

18. Report Type:
Routine
Standard QC
Data Package

2. Report to: (if different from above)
Address:
City State Zip Code
Phone: ( )
Fax: ( )

19. Turnaround Time
Standard
Rush : __/__/__

3. Client Project Name: Baffle Box Research Project
4. Client Project No.:
5. P.O. No.:
6. Custody Seal No.:
7. Sampled By: Daniel Smith
8. Shipping Method:

Water Sample Codes (for Item 13)	Container Codes (for Item 16)
DW = Drinking Water	V = VOA vial
GW = Ground Water	G = glass
SW = Surface Water	P = plastic
PW = Processed Water	M = micro bag/cup
WW = Waste Water	O = other

14. 15. Preservatives
16. Containers
17. TKN NOx NH3 TP COD CBOD5 TSS PO4

Preservative Codes (for Item 15)
C = Cool Only
H = Hydrochloric Acid
M = Monochloroacetic Acid
N = Nitric Acid
OH = Sodium Hydroxide
S = Sulfuric Acid
T = Sodium Thiosulfate

Item	9. Sample ID or No.	10. Sample Description	11. Date	11. Time	12. Comp.	12. Grab	13. Water (Codes)	13. Air	13. Soil	13. Sludge	13. Other	20. REMARK	LAB USE ONLY LAB SAMPLE NO.
1													
2													
3													
4													
5													
6													
7													
8													
9													
10													

	21. RELINQUISHED BY	DATE	TIME	22. RECEIVED BY	DATE	TIME
1						
2						
3						
4						

FOR LAB USE ONLY
Sampling Fee: _____ Hrs.
Equipment Rental Fee:_____
Profile No.: Quote No.:

DISTRIBUTION: White with report; Blue, Green, Yellow to labs; Gold to submitter
Revised:

Figure 5-1 Typical Chain of Custody Form

B. Laboratory Documentation and Reporting

Laboratory deliverables will be submitted in Word or Excel format. Laboratory reports will be issued in accordance with NELAC requirements. Certificates from vendors will be retained, whether from a laboratory or commercial vendor. Records of the lot numbers of reagents and other cleaning supplies, with the inclusive dates for use, will be recorded. Pre-cleaned container packing slips, lot numbers of shipments, and certification statements provided by the vendor will be retained by laboratories. All local, state and federal requirements pertaining to waste storage and disposal will be followed.

C. Archival of Electronically Stored Data

Analytical reports generated will be retained by Hazen and Sawyer and the laboratories performing the analyses.

Section 6
Sampling Process Methodology

A. Site Location

The project will be conducted at one of the sites in Hillsborough County listed in Section 2B.

B. Monitoring and Sampling Frequency and Duration

The biofilter systems will be monitored eight times over a twelve month period.

C. Number of Samples and Matrices

All sampling will be aqueous samples. On each monitoring date, samples will be collected for septic tank effluent, the effluents from Stage 1 biofilters, and the effluents from Stage 2 biofilters. Field analysis will be performed upon sample collection. Aqueous samples for laboratory analysis will be collected in sample containers prepared by the laboratories, maintained in an iced cooler during collection and transport, and transported to the laboratory. Samples will arrive at laboratories within twenty four hours after the completion of collection activities, or as needed for shorter sample hold times. Field analysis will be performed on the same date and for the sample locations taken for aqueous laboratory samples. Samples for field analyses will be collected in separate containers from laboratory samples. Stage 1 and 2 field parameter analyses will be measured in-situ by placing probes directly into collected samples or directly into effluent pipes. Shipping coolers will be supplied and decontaminated by the laboratories. Sample preservation and holding times are provided in Table 6.1. The laboratories will follow all local, state and federal requirements pertaining to waste storage and disposal. No equipment except the sample container will be used to collect the samples, and the sampling equipment will be certified clean by the laboratory providing the equipment. A field blank will be collected for TKN, NH_3 and NO_3+NO_2 for a minimum of 5% of samples collected over the life of the project using distilled water supplied by the laboratories. As a part of its QC, laboratories will perform sample duplicates for a minimum of 5% of samples. Laboratory QC will also include matrix spikes, percent recovery on QC standards, and method blanks.

Table 6.1
Aqueous Matrix Containers, Preservation and Holding Times

Analyte	Method	Minimum Sample Volume	Holding Time	Container Type	Sample Preservation	Preservative Dosage
Physical and Inorganic Parameters						
Alkalinity as CaCO3	310.1/SM2320B	100 mL	14 days	250 mL	4° C	n/a
Ammonia	350.1	25 mL	28 days	250 mL	1:1 H_2SO_4 to pH < 2	1 mL/ 250 mL
BOD / cBOD	SM5210B/405.1	1 L	48 hours	1 L Plastic	4° C	n/a
Chloride	300	50 mL	28 days	250 mL	4° C	n/a
COD	410.4	50 mL	28 days	250 mL	1:1 H_2SO_4 to pH < 2	1 mL/ 250 mL
Hydrogen Sulfide	376.1	500 mL	7 days	500 mL Plastic	Zinc Acetate / NaOH	.1 / .5 gm/ 500 mL
Nitrate/Nitrite-N (NO_X)	SM4500	50 mL	28 days	250 mL	1:1 H_2SO_4 / 4 ° C	l mL/ 250 mL
Nitrate-N	SM4500	50 mL	48 hours	250 mL	4° C	n/a
Nitrite-N	SM4500	50 mL	48 hours	250 mL	4° C	n/a
Organic Nitrogen (calculation)	350.1/351.2	100 mL	28 days	500 mL	1:1 H_2SO_4 to pH < 2	1 mL/ 250 mL
Ortho Phosphorus	365.4/9056/300.0	25 mL	48 hours	250 mL	4° C	n/a
pH	SM4500HB	50 mL	24 hours	250 mL	4° C	n/a
Sulfate	300	10 mL	28 days	250 mL	4° C	n/a
Sulfide	376.1/9030/9034	500 mL	7 days	500 ml	NaOH + Zn Acetate	1 mL/ 500 mL
TKN	351.2	100 mL	28 days	250 mL	1:1 H_2SO_4 to pH < 2	1 mL/ 250 mL
Total Nitrogen (calculation)	300.0/351.2	100 mL	28 days	250 mL	1:1 H_2SO_4 to pH < 2	1 mL/ 250 mL
Total Organic Carbon (TOC)	415.1/SM5310B	25 mL	28 days	125 mL Plastic	HCl to pH < 2 / 4 ° C	.5 mL/ 125 mL
Total Phosphorus	365.2/365.4	50 mL	28 days	250 mL	1:1 H_2SO_4 to pH < 2	1 mL/ 250 mL
Total Suspended Solids	160.2	300 mL	7 days	1 L Plastic	4° C	n/a
Turbidity	180.1	30 mL	48 hours	125 mL Plastic	4° C	n/a

Table 6.1
Aqueous Matrix Containers, Preservation and Holding Times

Analyte	Method	Minimum Sample Volume	Holding Time	Container Type	Sample Preservation	Preservative Dosage
Microbiological Parameters						
Total Coliform (MMO-Mug)	SM9223	100 mL	30 hours	Micro-cup	4° C	n/a
Total Coliform (MF)	SM9222	100 mL	6 hours	Micro-cup	4° C	n/a
Fecal Coliform (MF)	SM9222	100 mL	6 hours	Micro-cup	4° C	n/a
Standard Plate Count	SM9222	100 mL	8 hours (DW)	Micro-cup	4° C	n/a
Standard Plate Count	SM9222	100 mL	6 hours (WW)	Micro-cup	4° C	n/a
Fecal Coliform (MPN)	SM9221	100 g.	24 hours	Micro-cup	4° C	n/a

Short hold times

Minimum volume does not include sample volume needed to perform required quality control parameters

D. Inspection/Acceptance of Supplies and Consumables

1. Sample Containers

To be provided by the laboratory prior to each sampling event.

2. Sample Coolers

To be provided by the laboratory prior to each sampling event.

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Section 7
Data Review, Verification and Validation

A. Data Verification

Data verification is the process for evaluating the completeness, correctness, and conformance of the data set against the methodology. This evaluation is integral to the final report.

B. Data Validation

Data validation is an analyte and sample specific process that determines the quality of the data set relative to the end use. Any data deemed to be unusable for the stated objectives will be identified as such in the final report.

Appendix A
Analytical Schedule

Table A.1
Estimated Number of Analyses at each
Monitoring Point for each Sampling Event

Sample point	Influent (STE)	Vertical Stage 1 effluent	Stage 2 influent	Horizontal sulfur Stage 2 effluent	Horizontal non-sulfur Stage 2 effluent	In-situ vegetative/ media simulator sulfur	In-situ vegetative/ media simulator non-sulfur
No. of sample points	**1**	**10**	**1**	**3**	**6**	**1**	**1**
Analyses	**No. of Sample Events**						
Temp	8	8	8	8	8	8	8
pH	8	8	8	8	8	8	8
DO	8	8	8	8	8	8	8
ORP	8	8	8	8	8	8	8
Alkalinity	8	8	8	8	8	8	8
TKN	8	8	8	8	8	8	8
NH_3	8	8	8	8	8	8	8
NO_x	8	8	8	8	8	8	8
C-BOD_5	8	8	8	8	8	8	8
TSS	8	8	8	8	8	8	8
COD	4	2	4	2	2	2	2
Total P	4	1	4	1	1	1	1
SO_4	0	0	8	8	0	8	0
H_2S	0	0	0	4	0	4	0

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Table A.2
Estimated Total Number of Analyses
at each Monitoring Point over PNRS II Study.

	Influent (STE)	Vertical Stage 1 effluent	Stage 2 influent	Horizontal sulfur Stage 2 effluent	Horizontal non-sulfur Stage 2 effluent	In-situ vegetative/ media simulator sulfur	In-situ vegetative/ media simulator non-sulfur	
	1	10	1	3	6	1	1	
Analyses	**No. of Samples**							**Total Samples**
Temp	8	80	8	24	48	8	8	184
pH	8	80	8	24	48	8	8	184
DO	8	80	8	24	48	8	8	184
ORP	8	80	8	24	48	8	8	184
Alkalinity	8	80	8	24	48	8	8	184
TKN	8	80	8	24	48	8	8	184
NH_3	8	80	8	24	48	8	8	184
NO_x	8	80	8	24	48	8	8	184
C-BOD_5	8	80	8	24	48	8	8	184
TSS	8	80	8	24	48	8	8	184
COD	4	20	4	6	12	2	2	50
Total P	4	10	4	3	6	1	1	29
SO_4	0	0	8	24	0	8	0	40
H_2S	0	0	0	12	0	4	0	16

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Table A.3
Estimated Number of Analyses to be
Conducted for each Sample Event for all Systems

	Number of samples								
	Sample event								
Analyses	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**Sum**
Temp	23	23	23	23	23	23	23	23	184
pH	23	23	23	23	23	23	23	23	184
DO	23	23	23	23	23	23	23	23	184
ORP	23	23	23	23	23	23	23	23	184
Alkalinity	23	23	23	23	23	23	23	23	184
TKN	23	23	23	23	23	23	23	23	184
NH_3	23	23	23	23	23	23	23	23	184
NO_x	23	23	23	23	23	23	23	23	184
C-BOD_5	23	23	23	23	23	23	23	23	184
TSS	23	23	23	23	23	23	23	23	184
COD	23	0	23	0	2	0	2	0	50
Total P	23	0	2	0	2	0	2	0	29
SO_4	5	5	5	5	5	5	5	5	40
H_2S	4	0	4	0	4	0	4	0	16

References

References

Smith, D., R. Otis, and M. Flint (2008) Florida Passive Nitrogen Removal Study Final Report. Submitted to the Florida Department of Health, Tallahassee, Florida, June 26, 2008.

Smith, D. (2008) Florida Passive Nitrogen Removal Study Additional Monitoring. Submitted to the Florida Department of Health, Tallahassee, Florida, November 4, 2008.