ESTIMATES OF NITROGEN LOADINGS TO GROUNDWATER FROM ONSITE WASTEWATER TREATMENT SYSTEMS IN THE WEKIVA STUDY AREA

Task 2 Report

WEKIVA ONSITE NITROGEN CONTRIBUTION STUDY

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INTRODUCTION

The Wekiva River system and associated springs is a highly valued resource by the public. The river and its tributaries have been designated an Outstanding Florida Water, a National Wild and Scenic River, a Florida Wild and Scenic River and a Florida Aquatic reserve. In 1998, the Florida Legislature enacted the Wekiva River Protection Act to protect this valuable natural resource.

The Wekiva Parkway and other roadway improvements west of the Wekiva River system have been planned and are in design. It is anticipated that their implementation will add to the pressures for growth and development that are already impacting surface and groundwater resources in the area. To limit adverse impacts to the area, Governor Bush appointed the Wekiva River Basin Coordinating Committee to coordinate local governments, state and regional agencies and public interests in recommending the most appropriate location of the Parkway. As a result of the recommendations in the “Wekiva River Basin Coordinating Committee Final Report – Recommendations for Enhance Land Use Planning Strategies and Development Standards to Protect Water Resources of the Wekiva River Basin”, the Wekiva Parkway and Protection Act (Part III of Chapter 369, Florida Statutes) was passed by the 2004 Florida Legislature to implement the recommendations of the Committee.

As part of the Wekiva Parkway and Protection Act (WPPA) the Wekiva Study Area (WSA) was established within which certain studies were to be conducted to review and evaluate the effectiveness of water quality and wastewater treatment standards to protect waters in the WSA. Specifically, the Florida Department of Health (FDOH) was directed to study the efficacy and applicability of onsite wastewater treatment systems (OWTS) standards needed to achieve nitrogen reductions protective of groundwater quality within the WSA.

In December of 2004, FDOH published “Wekiva Basin Onsite Sewage Treatment and Disposal System Study”. This report recommended that the FDOH establish a discharge limit of 10 mg/L of total nitrogen for new systems, systems being modified, and existing systems located in the primary and secondary protection zones of the WSA. Also, the report recommended that the economic feasibility of sewering versus nutrient removal upgrades to existing onsite systems be evaluated.

This report raised concerns by homebuilders and realtors who questioned whether documented impacts of onsite treatment system performance on water quality were sufficiently serious to justify the substantial increase in system costs that could be expected to result with the promulgation of the proposed rules. In consideration of their concerns, the Florida Legislature directed FDOH to conduct the “Wekiva Onsite Nitrogen Contribution Study”, to further identify and quantify the nitrogen loading from OWTS within the WSA. The report resulting from this study is “to assess whether OWTS are a significant source of nitrogen to the underlying groundwater relative to other sources and shall recommend a range of possible cost-effective OWTS nitrogen reduction strategies if contributions are significant.”

To fulfill this directive, FDOH's Research Review and Advisory Committee defined four tasks to be completed:

Task 1	Field Study to identify and quantify nitrogen loading at a few sample OWTS in the WSA
Task 2	Categorization and Quantification of Nitrogen Loading from Onsite Wastewater Treatment System Types
Task 3	Assessment if OWTS are a significant source of nitrogen to the underlying groundwater relative to other sources
Task 4	Recommend a range of possible cost-effective OWTS nitrogen reduction strategies if loadings are significant

This report describes the methodology and findings of Task 2.

PURPOSE AND SCOPE OF TASK 2 STUDY

The purpose of Task 2 is to provide estimates of nitrogen loadings to groundwater from OWTS located within the WSA. These estimates are to be used with similar estimates of nitrogen loadings to groundwater from all other significant sources within the WSA to determine what share of the total nitrogen loadings that can be attributed to OWTS. The results are be used to establish appropriate measures that should be undertaken to ensure protection of water quality within the Wekiva River Basin. Separate nitrogen loading estimates are to be provided for each type of OWTS used in the WSA and for each soil mapping unit.

The project was to estimate nitrogen loadings based on existing literature data. The mass of nitrogen was to be estimated at two performance boundaries of each system and soil type; at the end of the last treatment system component prior to discharge to the subsurface wastewater infiltration system (SWIS) and at the groundwater boundary after the wastewater effluent has passed through the vadose zone (unsaturated zone) of the soil. These estimates were to be presented in a summary table with supporting documentation.

PROJECT APPROACH

At the project's outset it was clear that the literature had substantial limitations for completing this task as originally intended. First, most literature data lack accurate wastewater flow data and consequently only report nitrogen concentrations. As a result, the mass contribution of nitrogen cannot be calculated. Second, only effluent concentrations are usually reported so that it is unknown whether the upstream components achieved any removal of the pollutant of interest. Third, when looking at nitrogen removal in the soil, dilution of the nitrogen concentration by soil moisture is seldom estimated by measuring a change in a conservative substance such as chloride. Thus, any reduction in concentration could be due to dilution, adsorption, assimilation, or denitrification but none of these causes of concentration reductions could not be confirmed or quantified. Finally, other environmental conditions that impact nitrogen transformation and removal such as the availability of alkalinity necessary for nitrification, availability of organic carbon necessary for denitrification, or the existence of anoxic or anaerobic environments necessary for denitrification are not measured or reported. These shortcomings limited the value of many of the studies of nitrogen removal by OWTS in predicting the removals by OWTS in the WSA.

As a result of these shortcomings in the onsite wastewater treatment literature, the denitrification process was broken down into its individual requirements to identify those that are critical for the process to occur. By identifying these requirements, a broader range of literature could be used to quantify the minimum requirements necessary for the process to proceed. This allowed better differentiation between soils in estimating the percent removal of nitrogen that would occur under the different conditions encountered in the WSA.

Biological Denitrification

Biological denitrification is a natural process in the cycling of nitrogen in the environment (Figure 1). The soil, particularly in riparian zones and wetlands, is where most natural denitrification occurs. On a global scale, the amount of nitrogen denitrified annually must closely equal the amount of nitrogen fixed each year. The annual fixation of gaseous nitrogen is only a small amount relative to the local stores of previously fixed nitrogen, which cycles within ecosystems. Ignoring the industrial production of fertilizer, combustion of fossil fuels, and the cultivation of nitrogen-fixing crops, the estimate of annual fixation of nitrogen is 140 million metric tons. Fertilizer production, burning of fossil fuels and nitrogen-fixing crops add approximately an equal amount of fixed nitrogen annually. For nitrogen to be continuously recycled in this manner, the capacity of the soil to denitrify nitrogen and return it to its elemental state is large.

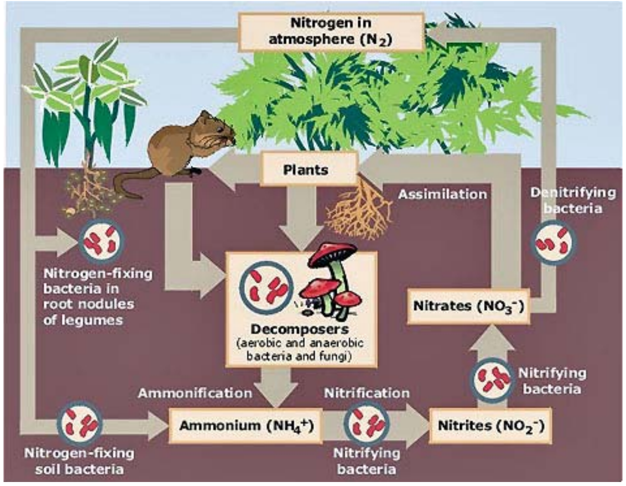

Figure 1: The Nitrogen Cycle

Biological denitrification is a complex process that requires mineralization and nitrification the nitrogen before denitrification can occur. With the decay of organic matter, nitrogen is released into the environment as organic nitrogen (principally proteins and urea). Bacteria and fungi in the soil quickly “mineralize” the organic nitrogen by converting it to ammonium. The ammonium is nitrified by autotrophic bacteria, which use carbon dioxide for their carbon source instead of organic carbon. These bacteria are obligate aerobes that require an aerobic environment because oxygen is used as the final electron acceptor. Since hydrogen ions are created by this reaction, which can lower the pH to levels that inhibit the biological process, it is essential that sufficient alkalinity be available to buffer the soil solution so that nitrification can be complete. After nitrification, heterotrophic bacteria are able to convert the nitrate to gaseous nitrogen and NO_X as they oxidize available organic matter. However, for this conversion, an anoxic or anaerobic environment is required since the oxygen associated with the nitrate is used as the final electron acceptor in oxidizing the organic matter. If either anoxic conditions or organic carbon are not available, denitrification does not proceed via this pathway. Other pathways exist, but they are far less prevalent.

Wastewater treatment works create the conditions necessary to sustain this biochemical reaction where nitrogen removal is required. Several different process trains are used in wastewater treatment plants (Sedlak, 1991) of which two closely mimic the processes that commonly occur in nature. These are called the "simultaneous" and "two sludge" systems (Figures 2 & 3). "Sludge" in this case refers to the active biomass in the process, which provides the treatment. In the simultaneous process the biomass is a mixture of autotrophs (nitrifiers) and facultative heterotrophs (organic degraders & denitrifiers) while in the two sludge system, the two groups of microorganisms are separated in different reactors.

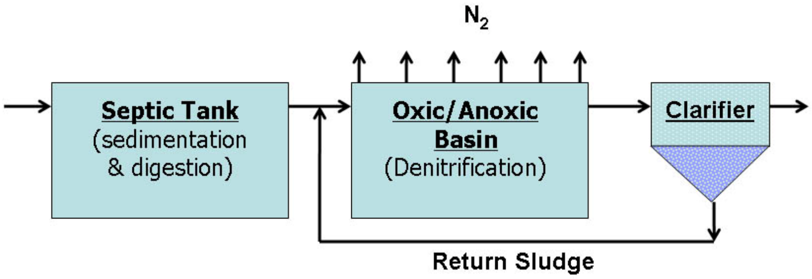

Figure 2: Simultaneous Denitrification System

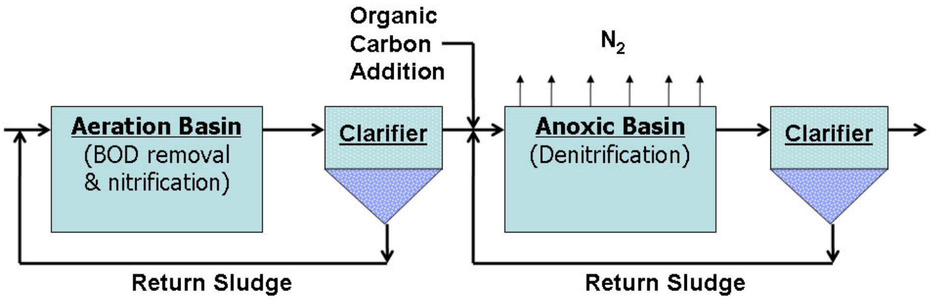

Figure 3: Two Sludge Denitrification System

In the simultaneous system, denitrification is achieved by cycling between oxic and anoxic conditions in a single reactor such that nitrification and denitrification is accomplished "simultaneously" (Figure 2). This process occurs in the soil when wastewater containing ammonium and biodegradable carbon is applied to aerobic soil. In response to the application, facultative heterotrophs quickly degrade the organic carbon and deplete the oxygen in doing so.

The ammonium cannot be nitrified under anoxic conditions, so being a positively charged ion; it may be retained in the biomat at the infiltrative surface or adsorbed by clay minerals in the soil. As the soil drains and reaerates, the autotrophic nitrifiers nitrify the ammonium. Without percolating water available, the nitrate is immobile until the next dose of wastewater. With the addition of new organic carbon, the facultative autotrophs again deplete the oxygen degrading the organic carbon and once the soil is anoxic the heterotrophs turn to the nitrate as a replacement for oxygen for the electron transfer resulting in denitrification.

This simultaneous process has the advantages of having a reliable supply of organic carbon from the wastewater for the denitrification step, lower oxygen requirements, and it recycles the alkalinity needed for nitrification. However, the amount of denitrification can be limited depending on the frequency and duration of the oxic/anoxic fluctuations with respect to the reaction rates. In a field study, which investigated OWTS design and operation that would maximize denitrification, Degen, et al. (1991) found that this simultaneous process performed best because carbon is the limiting factor for denitrification in soil. However for optimum results, the OWTS must be installed in a surface horizon and dosed on a 48 hour interval. Also, these requirements imply that the infiltration system must completely drain between applications of wastewater to allow the infiltrative surface to reaerate.

The two sludge system can achieve nearly complete nitrogen removal because the fluctuating cycle is avoided during which ammonium can by-pass the nitrification step. However, during the nitrification step, nearly all the organic carbon is oxidized, therefore requiring a separate source of organic carbon (Figure 3). As the wastewater is applied to the soil, the heterotrophs degrade the organic carbon in the biomat as before. However, if little clay is present to adsorb the ammonium as the wastewater percolates into the soil, the ammonium will move with it. As the ammonium percolates through the biomat into the vadose zone, oxygen is present for the autotrophs to nitrify the ammonium using carbon dioxide as the carbon source. Nitrate is a very soluble compound so it readily moves with the percolating water deeper into to the soil profile. If the percolate encounters a shallow saturated zone and sufficient organic carbon is available to deplete the oxygen to create an anoxic environment, the facultative heterotrophs then will use the remaining organic carbon for denitrification of the leached nitrate.

This two sludge process has the advantage that it can achieve more complete nitrogen removal but its disadvantages can prevent full denitrification from occurring. This process is very dependent on an external organic carbon source to occur (Bitton, 1994; Degen, et al., 1991; Oakley, 2005; Sedlak, 1991). If the water table is shallow, sufficient organic carbon may be present in the saturated zone from the decay of roots and other soil flora. If the water table is deep, organic matter is less likely to leach to the saturated zone.

A third process model that has been recognized only recently is an anaerobic, autotrophic bacterial process called Anammox. This process occurs when both nitrate and ammonium nitrogen occur together under anoxic or anaerobic conditions (Van de Graaf et al., 1995; 1996; 1997). In this process, the autotrophs reduce the nitrate to nitrogen gas while utilizing the oxygen from the nitrate to oxidize the ammonium to nitrate. Because the bacteria are autotrophs, no organic carbon is required to sustain this process. Anoxic or anaerobic conditions are necessary because if not, the heterotrophs would oxidize the ammonium removing the energy source from the autotrophs. Gable and Fox (2000) and Woods et al. (1999) suspect that the Anommox process could explain why nitrogen removal below large soil aquifer treatment systems (SAT) exceeds what can be attributed to heterotrophic nitrogen removal alone because the organic carbon to nitrogen ratio is typically too low to sustain heterotrophic denitrification. Crites (1985) reports that denitrification below 7 large scale SAT systems in the US was observed to achieve total nitrogen removals of 38 to 93% .

The heterotrophic bacterial process models were used to define the mechanisms and the necessary conditions for biological denitrification to occur. By understanding these, the literature could be reviewed for the occurrence of the requisite conditions in soils from which the potential for nitrogen removal could be estimated. The most critical conditions for which data are available were selected to investigate. These included the soil's internal drainage, depth to saturated conditions, and the availability of organic materials. Internal drainage provides a measure of the soil's permeability and the extent of time that it may be unsaturated. Unsaturated conditions are necessary to aerate the soil to allow the autotrophs to nitrify the ammonium nitrogen. The shallower the depth to the water table, the more likelihood organic matter will be leached to where the soil moisture is high enough to restrict soil reaeration to the point that aerobic organic matter decomposition is inhibited preserving the carbon for heterotrophic denitrification. The availability of organic carbon determines the occurrence and extent of denitrification that will occur. The presence of clay minerals in the soil, which are needed to adsorb and retain ammonium for a single sludge process to occur and the species of the nitrogen applied to the soil were considered as variables in estimating nitrogen contributions.

While Anammox quite likely could contribute substantially to the reduction of nitrogen below OWTS, little is known about the conditions under which it is likely to occur. Until the process requirements are better understood, detection of denitrification via the Anammox process would requires actual monitoring data where the nitrogen reduction by the heterotrophic processes can be separated out. Such data were not available so the estimates of nitrogen removal below OWTS reported in this study may under estimate the actual removals.

REVIEW OF PUBLISHED FIELD STUDIES

Nitrogen in Raw Domestic Wastewater

Onsite wastewater treatment systems consist of two basic components; a pretreatment component and a subsurface wastewater infiltration component (SWIS). The pretreatment component provides partial treatment of the raw wastewater before the wastewater is discharged to the SWIS. Typically, the pretreatment component is a septic tank that provides primary treatment, which removes the settleable and floatable solids in the wastewater and provides partial digestion of the removed solids. Secondary treatment is sometimes added to the pretreatment step to remove specific wastewater pollutants such as organic carbon, ammonium, and nitrate. The SWIS is a dispersal and "polishing" component that further treats the wastewater as it percolates to the groundwater below the OWTS.

It is the SWIS that is the focus of this study. This study is to estimate the nitrogen loadings to the groundwater from OWTS in the WSA. The loading that reaches the groundwater is the difference between the amount of nitrogen in the raw wastewater and the amount of nitrogen removed by the two components of the OWTS. Therefore, the removal of nitrogen in the soil prior to reaching the groundwater will be impacted by not only the amount of nitrogen in the raw wastewater, but also the amount that is removed in the pretreatment step.

Our diets largely determine the amount of nitrogen discharged daily into an OWTS. Nearly 80% of the nitrogen in domestic wastewater is derived from toilet wastes. The remainder is primarily from food preparation. There are various household products that may contain nitrogen compounds but these contribute only minor amounts of nitrogen. Each of us discharge approximately 11.2 gms of nitrogen into wastewater each day (EPA, 2002). Average per capita daily wastewater flows ranged from 50 to 70 gpd (Brown & Caldwell, 1984; Anderson & Siegrist, 1989; Anderson, et al. 1993; Mayer, et al., 1999), which result in a raw wastewater nitrogen concentration of 59 to 42 mg-N/L respectively.

Nitrogen Removal by Pretreatment Units

Estimating the amount of nitrogen removed in the pretreatment component is more difficult. Many data of nitrogen concentrations exist in pretreatment effluents, but these data are seldom associated with measured daily flows so that the daily mass of nitrogen discharged to the soil can not be computed. In a recent study of raw domestic wastewater and septic tank effluent characteristics, cumulative frequency diagrams were used to estimate median and average values of raw wastewater and septic tank effluent nitrogen concentrations, and daily flow data (Lowe, et al., 2007). Although the concentration and flow data are not paired, with number of data points, they can be used to estimate the total mass of nitrogen in both the raw and septic tank effluent. The medians for total nitrogen (TN) in the raw wastewater and septic tank effluent determined from the cumulative frequency diagrams were 63 mg-N/L and 55.4 mg-N/L respectively. The daily flow for both raw and septic tank effluent was 161 gpd. Assuming the average household occupancy of 2.6 persons estimated by the U.S. Census Bureau, the resulting per capita flow is 62 gpd, which is in the middle of the range reported above. However, the mass of nitrogen in the raw wastewater and septic tank effluent compute to be 14.7 and 13.0 gm/day per person respectively. This is nearly 25% and 16% respectively greater than the 11.2 gm/day stated above, which was determined from actual raw wastewater sampling.

Without paired influent and effluent samples, two methods were used to estimate the reduction of TN through a septic tank. The first method used concentrations of nitrogen found in septage and annual per capita septage generation rates (Eikum, 1983; Pell & Nyberg, 1989; Pendowski, et al., 1984; Wiswall, et al., 1984). Assuming a pumpout frequency and an annual nitrogen input from the home, a 10 to 17% removal of nitrogen was estimated. The second used the figures from the Lowe, et al. (2007) study by comparing the raw to the septic tank effluent, which resulted in a 12% removal of nitrogen. Based on these numbers, 15% would be reasonable, to account for typically low daytime home occupancy. Nitrogen removals by other advance pretreatment technologies have been estimated by Anderson and Otis (2000). Typical nitrogen removals for various pretreatment technologies are listed in Table 1.

Nitrogen Removal in Soil

Limitations of Field Studies

Biological denitrification in soils below wastewater infiltration systems, though a complex process that can take several forms, readily occurs where the requisite conditions exist. The extent to which denitrification occurs varies depending on the specific environmental conditions at the particular site, and the design and operation of the OWTS. Numerous investigations into the fate of nitrogen below SWIS have been undertaken. However, the results are quite variable even for sites that appear similar. Gold and Sims (2000) point out the dynamic and open nature of SWIS designs create uncertainties with in-situ studies of the fate of nitrogen in soil. The affects of dispersion, dilution, special variability in soil properties, wastewater infiltration rates, inability to identify a plume, uncertainty of whether the upstream and downstream monitoring locations are in the same flow path, and temperature impacts are a few of the problems that challenge the in-situ studies. As a result, even when small differences in concentrations are observed, the spatial and temporal variability can result in large changes in estimates of the mass loss of nitrogen.

Several investigators have performed rather thorough reviews of the fate of nitrogen below SWIS. Siegrist and Jennsen (1989) reviewed national and international literature for both laboratory and field studies of nitrogen removal in SWIS. Laboratory studies using soil columns showed removals of TN from less than 1 to 84 percent. Hydraulic loadings varied from 5 to 215 cm/day and influent TN concentrations from 16 to 74 mg/L. The field studies were performed on systems installed in sands. As in the case of most field studies, influent flows and TN concentrations were not always accurately known. Estimates of TN removal in these studies ranged from 0 to 94 percent. The investigators noted that high TN removals have been observed but that reasonably comparable studies showed limited removals. Based on their review, they provided a table of what they thought were "achievable nitrogen removal efficiencies" below SWIS (Table 2).

Table 1: Nitrogen removal capabilities of various pretreatment units*
(Anderson & Otis, 2000)

Treatment Technology	Percent TN Removal	Sources
Septic Tank	10-15%	Wiswall, et al., 1984; Pendowski, et al., 1984; Eikum; 1983 Lowe, et al. 2007
Activated Sludge – Extended Aeration	< 30	NSF Standard 40 Test Reports Converse & Converse, 1998
Activated Sludge – Sequencing Batch Reactors	40-75	NSF Standard 40 Test Reports Anderson et al., 1998 Vuoriranta et al., 1993
Fixed Film Activated Sludge	40-75	NSF Standard 40 Test Reports Anderson et al., 1998 Netter et al., 1993
Recirculating Sand/Gravel Filters	40-75	Anderson et al., 1998 Bruken & Piluk, 1994 EPA, 2002 Louden et al., 1985 Piluk & Hao, 1989
Peat Filter	< 40	NSF Standard 40 Test Reports Walsh & Henry, 1998 O'Driscoll et al., 1998 Talbot et al., 1998 McCarthy et al., 1998

***The pretreatment units are typically preceded by a septic tank. Therefore, the percent removals listed for the advanced pretreatment units include the removal provided by the septic tank.

Long (1995) reviewed studies of nitrogen transformations in OWTS to develop a methodology for predicting OWTS nitrogen loadings to the environment. Long also found that in-situ studies were confounded with many known and unknown variables that made data interpretation complicated. His review of the data indicated that soil treatment removes between 23 to 100% of the nitrogen. He correlated greater removals with finer grained soils because anoxic conditions would be achieved more frequently, which also would help to preserve available organic carbon for denitrification. Using this correlation, he estimated TN removals as shown in Table 3.

Table 2: Estimated Total Nitrogen Removals below SWIS (after Siegrist & Jennsen, 1989)

SWIS Type	"Achievable" N Removals	
	"Typical"	Range
Traditional In-Ground	20%	10 – 40%
Mound/Fill	25%	15 – 60%
Systems with Cyclic Loading	50%	30 – 80%

Table 3: Estimates of TN Removal Based on Soil Texture (Long, 1995)

Soil Texture	Estimated TN Removal	Comments
Coarse grained sands	23%	Soils promote rapid carbon and nitrogen oxidation leaving insufficient carbon for denitrification. If anoxic conditions and a source of carbon is available, such as a high or fluctuating water table, TN removal would increase.
Medium grained sands	40%	Soils restrict gas transfer during bulk liquid flow periods to create anoxic conditions.
Fine grained sands	60%	Soils restrict gas transfer for longer periods after bulk flow periods
Silt or clay	70%	Soils further restrict gas transfer and retain nutrienets higher in the soil profile.

In a study investigating the effects of effluent type, effluent loading rate, dosing interval, and temperature on denitrification under SWIS, Degen, et al. (1991) and Stolt and Reneau, Jr., (1991) reviewed published results of other studies that measured denitrification in OWTS. They found denitrification removals varied substantially depending on the type of pretreatment and SWIS design (Table 4).

These reviews show the difficulty of acquiring good field data that will effectively predict the nitrogen removal potential of a similar soil with similar pretreatment. The reported ranges for various soils, OWTS designs and operation are too great and overlapping to be able to differentiate between soil types and systems within the WSA. Therefore, the heterotrophic bacterial denitrification model was used to survey the literature with a focus on process mechanisms and their requisite states to achieve denitrification.

Table 4: Total Nitrogen Removal Found in Various Studies of OWTS (Degen, et al., 1991)

System Type	TN Removal	Source
Traditional	0-35%	Ritter & Eastburn (1988)
Sand filter	71-97%	Wert & Paeth (1985)
Low Pressure Dosing Shallow	46%	Brown & Thomas (1978)
Low Pressure Dosing At-Grade	98%	Stewart & Reneau, Jr. (1988)
Mound	44-86%	Harkin, et al. (1979)

Sorting Soil Series by Nitrogen Removal Potential

The more significant environmental factors that determine whether nitrogen removal occurs and to what extent include the soil's texture, structure, and mineralogy, soil drainage and wetness, depth to a saturated zone and the degree to which it fluctuates, and amount of available organic carbon present. OWTS design and operation factors include the species of nitrogen discharged to the SWIS, the depth and geometry of the infiltrative surface, the daily hydraulic loading and its method of application, whether it is dosed and, if so its frequency.

To facilitate the evaluation of the soils to remove nitrogen in the WSA, the Lake, Orange, and Seminole County soil surveys were used to sort the soil mapping units by three primary soil characteristics that would favor denitrification. These were soil drainage class, organic matter content, and depth to the seasonally high water table. Soils with the greatest potential for denitrification were considered to be those that are moderately well drained to very poorly drained, have a fine loamy texture with clay fines, have a shallow water table, and have organic matter present deeper in the soil profile. Appendix A presents a tabulation of the sorted soil series mapped in the WSA including each soil's taxonomy and pertinent soil characteristics.

Soil Drainage Class: Soil drainage class has been found to be a good indicator of a soil' capacity to remove nitrogen (Gold, et al., 1999). The Natural Resources Conservation Service (NRCS) uses seven drainage classes to describe the "quality" of the soil that allows the downward flow of excess water through it (USDA, 1962). The classes reflect the frequency and duration of periods of soil saturation with water, which are determined in part, by the texture, structure, underlying layers, and elevation of the water table in relation to the addition of water to the soil. Table 5 provides a brief description of each of the classes.

The soil series were sorted into four drainage classes (1. Excessively/Somewhat Excessively; 2. Well; 3. Moderately Well; and 4. Somewhat Poorly/Poorly/Very Poorly). Poorly drained and very poorly drained soils can have a high capacity for nitrogen removal because the saturated zone is shallow, carbon enriched and anoxic while moderately well and well drained soils have a very limited capacity (Groffman et al., 1992; Hansen et al., 1994a, 1994b; Nelson et al., 1995; Parkin & Meisinger, 1989; Simmons et al., 1992). Groundwater in moderately well drained or well drained typically flows deeper within the subsoil and does not intersect the reduced and organic enriched surface horizons. The groups and their expected impacts on denitrification are given in Table 6.

Table 5: NRCS Drainage Classes and Descriptions

Drainage Class	Description
Excessively drained	Water is removed from the soil very rapidly. The soils are very porous. These soils tend to be droughty.
Somewhat excessively drained	Water is removed from the soils rapidly. The soils are sandy and very porous. These soils tend to be droughty but can support some agricultural crops without irrigation.
Well drained	Water is removed from the soil readily but not rapidly. The soils are commonly intermediate in texture and retain optimum amounts of moisture for plant growth after rains.
Moderately well drained	Water is removed from the soil somewhat poorly so that the profile is wet for a small but significant period of time. The soils commonly have a slowly permeable layer within or immediately beneath the solum and/or a shallow water table.
Somewhat poorly drained	Water is removed from the soil slowly enough to keep it wet for significant periods of time. These soils commonly have a slowly permeable layer within the profile and/or a shallow water table. The growth of crops is restricted to a marked degree unless artificial drainage is provided.
Poorly drained	Water is removed so slowly that the soil remains wet for a large part of the time. The water table is commonly at or near the soil surface for a considerable part of the year. They tend to be mucky.
Very poorly drained	Water is removed from the soil so slowly that the water table remains at or on the surface the greater part of the year. They commonly have mucky surfaces.

Organic Matter: Heterotrophic bacterial denitrification is often limited by organic matter (Bradley, et al., 1992; Burford, et al., 1975; Christensen, et al., 1990; Gambrell, R.P., et al., 1975). The organic carbon is necessary as an energy source for bacterial metabolism. Sources of organic matter in soil are either natural, which is continuously replenished in the soil from the decay of vegetative materials or supplied by the wastewater itself. Studies indicate that denitrification is inhibited where the nitrate to dissolved organic carbon ratio is below 0.73 to 1.3 (Burford & Bremmer, 1975).

The amount of organic matter in the soil is greatest in the root zone and above (Paul and Zebarth, 1997; Starr and Gillham 1993). Roots regularly exude carboneous materials and die and decay (Fahey & Hughes, 1994; Hopkins, 1995). Much of the organic carbon is degraded in the vadose zone through natural degradation within 2-3 ft of the ground surface. Organic matter is typically very low (<1%) below about 3 ft in most soils with a deep vadose zone. However spodic soils, which are common in the WAS, have a horizon that is lower in the soil profile that contains organic matter, iron and aluminum. This organic matter would be available for heterotrophic denitrifiers.

Table 6: Drainage Class Grouping and Expected Impacts on Denitrification

Drainage Class Group	Expected Impact on Heterotrophic Denitrification
Excessively/Somewhat excessively	◆ Well aerated soil capable of achieving complete nitrification of applied TKN ◆ Provides little organic carbon and will likely degrade any added organic matter within the aerobic zone ◆ Short retention time
Well	◆ Sufficiently aerated soil capable of achieving complete nitrification ◆ May allow some organic matter to reach a saturated zone where it would be available for denitrification if a shallow water table is present
Moderately well	◆ Sufficiently aerated soil capable of achieving complete nitrification ◆ Denitrification would be enhanced with a fluctuating water table for a “two sludge” process or with slow drainage for a “single sludge” process
Somewhat poorly/Poorly/Very poorly	◆ Ample organic matter for a carbon source and to create anoxic conditions in saturated zones for significant nitrogen reduction ◆ Insufficiently aerated soil to nitrify TKN requiring nitrification of the wastewater prior to application to the soil

To identify the soils which may have sufficient natural organic matter for denitrification, a minimum percent of organic matter by weight of 1% was used below which it was assumed that insufficient organic matter is available to sustain denitrification. However, soil survey data reports typically do not report organic matter for deeper soil horizons. Therefore, the soil profile descriptions were also used to confirm the depths of the reported organic matter and to look for spodic horizons.

Depth to Water Table: Water tables or perched water saturated zones restrict reaeration of the soil. With organic matter present, the saturated zone will become anoxic or anaerobic. This will inhibit nitrification and if nitrate and organic matter are present, will support denitrification. When the air-filled porosity drops below 11 to 14% or the moisture content is greater than 60 to 75% of the soil's water holding capacity, reaeration is sufficiently restricted that anoxic conditions can result (Bremmer and Shaw. 1956; Christensen, et al., 1990; Cogger, et al., 1998; Donahue et al., 1983; Pilot and Patrick, Jr., 1972; Reneau, Jr., 1977; Singer & Munns, 1991; Tucholke et al., 2007).

If the water table is deep, little denitrification seems to occur. In soils with thick unsaturated zones, organic matter may not reach the saturated zone because it is oxidized before it can leach to the water table. Where the ground water depths exceed about one meter, denitrification is greatly reduced (Barton et al., 1999; Starr and Gillham,1993). However, a shallow, fluctuating water table can create the conditions for simultaneous denitrification. This occurs when a seasonally high water table prevents nitrification of the ammonium, which will adsorb to negatively charged clay particles in the soil. The ammonium is held by the soil and after draining and reaerating, the ammonium is nitrified. If organic matter is present and the soil nears saturation again, the nitrate can be denitrified and the newly applied ammonium is adsorbed as before, repeating the process. Cogger et al., 1988; Reneau, 1977, 1979; Walker et al., 1973a).

To identify those soil series with shallow water tables, a seasonally high water table depth of 3.5 ft below ground surface was used. Assuming a maximum depth of an infiltration trench bottom of 18 inches, a separation distance to the seasonally high water table is maintained at 2 ft as required by Chapter 64e-6 of the Florida Administrative Code, Standards for Onsite Sewage Treatment and Disposal Systems. This separation distance is sufficient for nearly complete nitrification of the TKN in the applied wastewater. In very wet soils, it would be necessary to nitrify the wastewater nitrogen prior to application to the infiltration system.

Type of Infiltration System

The type of infiltration system used can affect the soil's potential for nitrogen removal. Traditional in-ground trench systems are installed with their infiltrative surfaces typically below the A horizon where organic matter can be expected to be the highest. At-grade and mound systems are typically installed above the O and A horizon thereby gaining the advantage of having a high organic layer available to create anoxic conditions with organic carbon available (Converse et al., 1999; Harkin et al., 1979). However, in Florida, the OWTS rules require the removal of the O and A horizons, which removes most of the available organic carbon. Also, "digouts", which are systems on sites where a restrictive horizon in the soil profile is removed, can result in reducing a particular soil's nitrogen removal potential because quite often the restrictive horizon removed is a spodic layer, which can have a sufficiently high organic content and be restrictive enough to create a saturated zone where anoxic conditions may be created for denitrification. These types of systems and their installation practices also were taken into account in estimating nitrogen removal potentials.

Estimated Nitrogen Removal Potentials of Soils in the Wekiva Study Area

Appendix B presents the estimated denitrification potentials of the soils in the WSA. The potentials are reported as a range of percent removals that are expected based on the factors that affect biological denitrification processes, which are described above. These estimates are expected to be conservatively low estimates because of the heterogeneity of the soils in each mapping unit and the differences in systems designs, operation and use. Evidence in the literature suggests that other processes other than heterotrophic bacterial denitrification may be active.

Although a few investigators found that their predicted removals were greater than what was measured, most found that their estimates were lower than actual removals.

Further, the fate of nitrogen, once in the ground water, was not addressed in this study. This assessment was limited to estimating the nitrogen removal potential within the vadose zone below the OWTS and the surface of the water table immediately below the infiltration system. However, the literature is replete with studies that have observed significant denitrification in the ground water, which in some cases results in complete removal within a few feet of travel. This limitation of the study must be considered when estimating the contribution of nitrogen from OWTS to surface waters.

Finally, OWTS by their nature are scattered individual sources of nitrogen. As a result, their contributions should not be aggregated because as the percolate plume travels with the groundwater flow, the potential for denitrification to occur always exists. Therefore, systems should not be considered as a source in aggregate, but parsed out depending on various factors such as distance to a point of discharge and soil characteristics and land use along the flow path to the discharge.

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APPENDIX A

DESCRIPTIONS OF THE CHARACTERISTICS OF SOILS IN THE WEKIVA STUDY AREA

DESCRIPTION OF SOIL CHARTERISTICS IN THE WEKIVA STUDY AREA

Drainage Class	Water Table Class	Organic Matter Content Class	Soil Name	Location of Benchmark Description	Drainage and Permeability	Depth (cm)	Horizon	Texture Class	Saturated Hydraulic Conductivity	Organic C %	Organic Matter
E	2	1	**LAKE FINE SAND**	Sumter	Excessive; rapid	0-22	Ap	FS	53.9	1.09	1.87916
			Hyperthermic, coated Typic	Sumter	Excessive; rapid	22-58	C1	FS	53.3	0.26	0.44824
			Quartzipsamments	Sumter	Excessive; rapid	58-99	C2	FS	34.5	0.15	0.2586
				Sumter	Excessive; rapid	99-160	C3	FS	49.3	0.07	0.12068
				Sumter	Excessive; rapid	160-203	C4	FS	48	0.05	0.0862
E	2	1	**PAOLA FINE SAND**	Citrus	Excessive; rapid to very rapid	0-13	A1	FS	27.6	0.71	1.22404
			Hyperthermic, uncoated Spodic	Citrus	Excessive; rapid to very rapid	13-46	C1	FS	28.9	0.47	0.81028
			Quartzipsamments	Citrus	Excessive; rapid to very rapid	46-119	C2	FS	27.3	0.08	0.13792
E	2	1	**ST. LUCIE SAND**	Highlands	Excessive; rapid	0-15	A	S	131.4	0.37	0.63788
			Hyperthermic, uncoated Typic	Highlands	Excessive; rapid	15-79	C	S	129.5	0.11	0.18964
			Quartzipsamments	Highlands	Excessive; rapid	79-142	C	S	103.6	0.09	0.15516
				Highlands	Excessive; rapid	142-203	C	S	112.5	0.1	0.1724
			ST. LUCIE SAND	Indian River	Excessive; very rapid	0-8	A	S	69	0.89	1.53436
			Hyperthermic, uncoated Typic	Indian River	Excessive; very rapid	8-74	C	S	101	0.08	0.13792
			Quartzipsamments	Indian River	Excessive; very rapid	74-140	C	S	124.5	0.03	0.05172
				Indian River	Excessive; very rapid	140-203	C	S	125.4	0.06	0.10344
E	2	2	**ASTATULA FINE SAND**	Citrus	Excessive; rapid to very rapid	0-10	A	FS	23.6	1.04	1.79296
			Hyperthermic, uncoated Typic	Citrus	Excessive; rapid to very rapid	10-36	C1	FS	23.6	0.32	0.55168
			Quartzipsamments	Citrus	Excessive; rapid to very rapid	36-99	C2	FS	27.3	0.1	0.1724
				Citrus	Excessive; rapid to very rapid	99-203	C3	FS	23.7	0.09	0.15516
E	2	2	**CANDLER SAND**	Sumter	Excessive; rapid	0-20	Ap	S	47.3	0.68	1.17232
			Hyperthermic, uncoated Typic	Sumter	Excessive; rapid	20-76	E1	S	108.5	0.14	0.24136
			Quartzipsamments	Sumter	Excessive; rapid	76-127	E2	S	92.7	0.05	0.0862
				Sumter	Excessive; rapid	127-165	EB1	S	66.4	0.02	0.03448
				Sumter	Excessive; rapid	165-203	E/B2	S	38.5	0	0
W	2	1	**APOPKA**								
			Loamy, siliceous, hyperthermic								
			Grossarenic Paleudults								
W	2	2	**ORLANDO**								
MW	1	1	**POMELLO FINE SAND**	Hardee	Moderately well; moderately rapid	0-13	Ap	FS	17.4	1.44	2.48256
			Sandy, siliceous, hyperthermic	Hardee	Moderately well; moderately rapid	13-38	E1	FS	2.3	0.59	1.01716
			Glossarenic Entic Haplohumods	Hardee	Moderately well; moderately rapid	38-117	E2	FS	19.3	0.22	0.37928
				Hardee	Moderately well; moderately rapid	117-147	Bh	FS	1.3	3.05	5.2582
				Hardee	Moderately well; moderately rapid	147-168	E	FS	146.5	0.44	0.75856
				Hardee	Moderately well; moderately rapid	168-203	B`h	FS	3.3	2.68	4.62032

DESCRIPTION OF SOIL CHARTERISTICS IN THE WEKIVA STUDY AREA

	Location of Soil Series in Study Area			Restrictive Horizons					Depth to Water Table (feet)			Organic Matter (%)		
Soil Name	Seminole County	Lake County	Orange County	Dominate Texture	Most Restrictive Horizon Texture	Depth to Restrictive Horizon (inches)	Special Condition	Depth to Special Condition (inches)	Seminole County	Lake County	Orange County	Seminole County	Lake County	Orange County
LAKE FINE SAND		X	X		S					>10	>6		<1.5>	0.5-1
Hyperthermic, coated Typic Quartzipsamments														
PAOLA FINE SAND		X		S	S				>6	>6		<0.5	<0.5>	
Hyperthermic, uncoated Spodic Quartzipsamments														
ST. LUCIE SAND	X	X		S	FS				>6	>6	>6	0-1	<0.5>	0-1
Hyperthermic, uncoated Typic Quartzipsamments														
ST. LUCIE SAND	X	X		S	FS				>6	>6	>6	0-1	<0.5>	0-1
Hyperthermic, uncoated Typic Quartzipsamments														
ASTATULA FINE SAND		X		S	FS				>6	>10		0.5-2	<1.5>	
Hyperthermic, uncoated Typic Quartzipsamments														
CANDLER SAND		X	X	FS	SL	109-115	LS lamellae	67-95			>6			0.5-2
Hyperthermic, uncoated Typic Quartzipsamments														
APOPKA		X		S	SCL	55-84			>6	>6	>6	<2	>1.0	<2
Loamy, siliceous, hyperthermic Grossarenic Paleudults														
ORLANDO		X		FS	FS				>6			2.-5	<3.5> to 2.5	
POMELLO FINE SAND	X	X	X	FS	FS		Spodic	42-54	2-3.5	2.5-3.5	2-3.5	<1	<0.5>	1
Sandy, siliceous, hyperthermic Glossarenic Entic Haplohumods														

				Soil Series Benchmark Profile Description							
Drainage Class	**Water Table Class**	**Organic Matter Content Class**	**Soil Name**	**Location of Benchmark Description**	**Drainage and Permeability**	**Depth (cm)**	**Horizon**	**Texture Class**	**Saturated Hydraulic Conductivity**	**Organic C %**	**Organic Matter**
MW	**2**	**1**	**ARCHBOLD SAND**	Polk	Moderately well; very rapid	0-10	A	S	109	0.22	0.37928
			Hyperthermic, uncoated Typic	Polk	Moderately well; very rapid	10-68	C	S	118	0.04	0.06896
			Quartzipsamments	Polk	Moderately well; very rapid	68-132	C	S	101.2	0.01	0.01724
				Polk	Moderately well; very rapid	132-203	C	S	121	0.02	0.03448
MW	**2**	**1**	**ORSINO FINE SAND**	Putnam	Moderately well; very rapid	0-15	A	FS	56.6	0.43	0.74132
				Putnam	Moderately well; very rapid	15-61	E	FS	52	0.12	0.20688
				Putnam	Moderately well; very rapid	61-91	B/E	FS	66.4	0.21	0.36204
				Putnam	Moderately well; very rapid	91-114	Bw1	FS	51.3	0.17	0.29308
				Putnam	Moderately well; very rapid	114-162	Bw2	FS	32.9	0.08	0.13792
				Putnam	Moderately well; very rapid	162-203	C	FS	31.6	0.02	0.03448
MW	**2**	**1**	**UDORTHENTS**								
MW	**2**	**2**	**FLORAHOME SAND**	Sumter	Moderately well; rapid	0-25	Ap	S	20.4	0.9	1.5516
			Sandy, siliceous, hperthermic	Sumter	Moderately well; rapid	25-51	A2	S	48	0.57	0.98268
			Quartzipsammentic Haplumbrepts	Sumter	Moderately well; rapid	51-84	AC	S	68.3	0.23	0.39652
				Sumter	Moderately well; rapid	84-104	C1	S	65.1	0.18	0.31032
				Sumter	Moderately well; rapid	104-183	C2	S	44.7	0.07	0.12068
				Sumter	Moderately well; rapid	183-203	C3	S	40.1	0.06	0.10344
MW	**2**	**2**	**MILLHOPPER SAND**	Sumter	Moderately well; moderately slow	0-13	Ap	S	18.7	1.06	1.82744
			Loamy, siliceous, hyperthermic	Sumter	Moderately well; moderately slow	13-81	E1	FS	17.3	0.18	0.31032
			Glossarenic Paleudults	Sumter	Moderately well; moderately slow	81-112	E2	FS	18.2	0.05	0.0862
				Sumter	Moderately well; moderately slow	112-127	E3	FS	7.2	0.02	0.03448
				Sumter	Moderately well; moderately slow	127-142	Bt	SCL	2.2	0.03	0.05172
				Sumter	Moderately well; moderately slow	142-183	Btg1	SCL	0.5	0.06	0.10344
				Sumter	Moderately well; moderately slow	183-203	Btg2	SCL	0.6	0.04	0.06896
MW	**2**	**2**	**TAVARES FINE SAND**	Citrus	Moderately well; rapid	0-8	A	FS	20.2	0.83	1.43092
			Hyperthermic, uncoated Typic	Citrus	Moderately well; rapid	8-56	C1	FS	23	0.12	0.20688
			Quartzipsamments	Citrus	Moderately well; rapid	56-104	C1	FS	24.3	0.08	0.13792
				Citrus	Moderately well; rapid	104-160	C2	FS	18.2	0.03	0.05172
				Citrus	Moderately well; rapid	160-203	C3	FS	21.5	0.03	0.05172
			TAVARES FINE SAND	Polk	Moderately well; rapid to very rapid	0-20	Ap	FS	16.2	0.48	0.82752
				Polk	Moderately well; rapid to very rapid	20-43	C1	FS	20.7	0.13	0.22412
				Polk	Moderately well; rapid to very rapid	43-76	C2	FS	31.6	0.2	0.3448
				Polk	Moderately well; rapid to very rapid	76-132	C3	FS	35.5	0.27	0.46548
				Polk	Moderately well; rapid to very rapid	132-203	C4	FS	38.8	0.05	0.0862
P	**1**	**1**	**ADAMSVILLE FINE SAND**	Sumter	Somewhat poor; rapid	0-13	Ap	FS	27.6	0.99	1.70676
			Hyperthermic, uncoated Aquic	Sumter	Somewhat poor; rapid	13-23	C1	FS	38.8	0.45	0.7758
			Qartzipsamments	Sumter	Somewhat poor; rapid	23-43	C2	FS	40.1	0.22	0.37928
				Sumter	Somewhat poor; rapid	43-74	C3	FS	30.3	0.16	0.27584
				Sumter	Somewhat poor; rapid	74-203	C4	FS	blank	0.06	0.10344
			ADAMSVILLE FINE SAND	Citrus	Somewhat poor; rapid	0-18	Ap	FS	21.7	0.81	1.39644
				Citrus	Somewhat poor; rapid	18-51	C1	FS	19.4	0.16	0.27584
				Citrus	Somewhat poor; rapid	51-99	C2	FS	17.7	0.08	0.13792
				Citrus	Somewhat poor; rapid	99-152	C3	FS	20.3	0.01	0.01724
				Citrus	Somewhat poor; rapid	152-203	C3	FS	17.7	0.02	0.03448
P	**1**	**1**	**ARENTS**								

	Location of Soil Series in Study Area			Restrictive Horizons					Depth to Water Table (feet)			Organic Matter (%)		
Soil Name	**Seminole County**	**Lake County**	**Orange County**	**Dominate Texture**	**Most Restrictive Horizon Texture**	**Depth to Restrictive Horizon (inches)**	**Special Condition**	**Depth to Special Condition (inches)**	**Seminole County**	**Lake County**	**Orange County**	**Seminole County**	**Lake County**	**Orange County**
ARCHBOLD SAND			X	FS	FS						3.5-6			0.5-1
Hyperthermic, uncoated Typic Quartzipsamments														
ORSINO FINE SAND		X		FS	FS									
UDORTHENTS	X			Various	Various		Borrow pits							
FLORAHOME SAND			X	FS	FS						4.-6			1.-5
Sandy, siliceous, hperthermic Quartzipsammentic Haplumbrepts														
MILLHOPPER SAND			X	FS	SCL	64-96			3.5-6		3.5-6	0.5-2		0.5-2
Loamy, siliceous, hyperthermic Glossarenic Paleudults														
TAVARES FINE SAND	X	X	X	FS	FS				3.5-6	3.5-5	3.5-6	0.5-2	<0.5>	0.5-2
Hyperthermic, uncoated Typic Quartzipsamments														
TAVARES FINE SAND	X	X	X	FS	FS				3.5-6	3.5-5	3.5-6	0.5-2	<0.5>	0.5-2
ADAMSVILLE FINE SAND	X			FS	FS				2.0-3.5			<2		
Hyperthermic, uncoated Aquic Qartzipsamments														
ADAMSVILLE FINE SAND	X			FS	FS				2.0-3.5			<2		
ARENTS	X			FS	SCL	80	Variable fill		1.5-3.0			<0.5		

				Soil Series Benchmark Profile Description							
Drainage Class	Water Table Class	Organic Matter Content Class	Soil Name	Location of Benchmark Description	Drainage and Permeability	Depth (cm)	Horizon	Texture Class	Saturated Hydraulic Conductivity	Organic C %	Organic Matter
P	1	1	**CASSIA FINE SAND**	Putnam	Somwhat poor, rapid	0-10	A	FS	28.3	0.77	1.32748
				Putnam	Somwhat poor, rapid	10-23	E1	FS	35.5	0.08	0.13792
				Putnam	Somwhat poor, rapid	23-61	E2	FS	35.5	0.06	0.10344
				Putnam	Somwhat poor, rapid	61-71	E3	FS	27.6	0.09	0.15516
				Putnam	Somwhat poor, rapid	71-81	Bh1	FS	34.2	1.35	2.3274
				Putnam	Somwhat poor, rapid	81-96	Bh2	FS	23.1	0.75	1.293
				Putnam	Somwhat poor, rapid	96-117	Bh3	FS	16.4	0.3	0.5172
				Putnam	Somwhat poor, rapid	117-137	C1	FS	22	0.16	0.27584
				Putnam	Somwhat poor, rapid	137-203	C2	FS	29.6	0.07	0.12068
P	1	1	**ZOLFO FINE SAND**	Putnam	Somewhat poor; rapid to moderate	0-15	A	FS	26.6	0.89	1.53436
			Sandy, siliceous, hyperthermic	Putnam	Somewhat poor; rapid to moderate	15-33	E1	FS	25	0.59	1.01716
			Glossarenic Entic Haplohumods	Putnam	Somewhat poor; rapid to moderate	33-81	E2	FS	39.1	0.18	0.31032
				Putnam	Somewhat poor; rapid to moderate	81-135	E3	FS	31.9	0.02	0.03448
				Putnam	Somewhat poor; rapid to moderate	135-162	Bh1	FS	blank	0.08	0.13792
				Putnam	Somewhat poor; rapid to moderate	162-203	Bh2	FS	blank	0.3	0.5172
P	1	2	**ANCLOTE SAND**	Lee	Very poor; rapid	0-20	A1	S	blank	2.76	4.75824
				Lee	Very poor; rapid	20-56	A2	S	blank	1.22	2.10328
				Lee	Very poor; rapid	56-102	C1	S	blank	0.28	0.48272
				Lee	Very poor; rapid	102-203	C2	S	blank	0.08	0.13792
P	1	2	**BASINGER FINE SAND**	DeSoto	Poor; very rapid	0-13	Ap	FS	110.4	2.26	3.89624
			Siliceous, hyperthermic Spodic	DeSoto	Poor; very rapid	13-56	E	FS	21.5	0.08	0.13792
			Psammaquents	DeSoto	Poor; very rapid	56-76	E/Bh	FS	22.4	0.06	0.10344
				DeSoto	Poor; very rapid	76-137	Bh	FS	21.1	0.07	0.12068
				DeSoto	Poor; very rapid	137-203	C	FS	21.7	0.09	0.15516
P	1	2	**BRIGHTON MUCK**								
P	1	2	**CANOVA MUCK**	Indian River	Very poor; rapid in the O, 2A, 2E hori	0-15	Oap	blank	11	50.03	86.25172
			Fine-loamy, siliceous, hyperthermic	Indian River	Very poor; rapid in the O, 2A, 2E hori	15-30	Oap	blank	69.7	31.49	54.28876
			typic Glossaqualfs	Indian River	Very poor; rapid in the O, 2A, 2E hori	30-33	2A	S	blank	3.08	5.30992
				Indian River	Very poor; rapid in the O, 2A, 2E hori	33-53	2E1	S	68.4	0.34	0.58616
				Indian River	Very poor; rapid in the O, 2A, 2E hori	53-61	2E2	S	31.6	0.18	0.31032
				Indian River	Very poor; rapid in the O, 2A, 2E hori	61-86	2Btg1	SCL	0	0.54	0.93096
				Indian River	Very poor; rapid in the O, 2A, 2E hori	86-102	2Btg2	SCL	201	0.21	0.36204
				Indian River	Very poor; rapid in the O, 2A, 2E hori	102-124	2Cgk1	SCL	11.2	0.22	0.37928
				Indian River	Very poor; rapid in the O, 2A, 2E hori	124-142	2Cgk2	SCL	266	0.18	0.31032
				Indian River	Very poor; rapid in the O, 2A, 2E hori	142-203	2Cg	SL	0.2	0.12	0.20688
P	0	2	**CHOBEE FINE SANDY LOAM**	Charlotte	Very poor; very slow	0-13	Oa	blank	blank	29.5666	17.15
			Fine-loamy, siliceaous, hyperthermic	Charlotte	Very poor; very slow	13-38	A	FSL	2.1	5.2582	3.05
			Typic Argiaquolls	Charlotte	Very poor; very slow	38-61	Btg1	FSL	0	3.1894	1.85
				Charlotte	Very poor; very slow	61-71	Btg2	LFS	0	1.87916	1.09
				Charlotte	Very poor; very slow	71-99	Cg1	FSL	0	0.67236	0.39
				Charlotte	Very poor; very slow	99-145	Cg2	LFS	0.1	0.39652	0.23
				Charlotte	Very poor; very slow	145-168	Cg3	LFS	0	0.431	0.25
				Charlotte	Very poor; very slow	168-203	Cg4	LFS	0.3	0.31032	0.18

	Location of Soil Series in Study Area			Restrictive Horizons					Depth to Water Table (feet)			Organic Matter (%)		
Soil Name	**Seminole County**	**Lake County**	**Orange County**	**Dominate Texture**	**Most Restrictive Horizon Texture**	**Depth to Restrictive Horizon (inches)**	**Special Condition**	**Depth to Special Condition (inches)**	**Seminole County**	**Lake County**	**Orange County**	**Seminole County**	**Lake County**	**Orange County**
CASSIA FINE SAND		X		S	S					<1-3.5			<0.5> to 25"	
													<35> to 37"	
													<0.5> below	
ZOLFO FINE SAND			X	FS	FS		Spodic	63-80			2-3.5			0.5-1
Sandy, siliceous, hyperthermic														
Glossarenic Entic Haplohumods														
ANCLOTE SAND		X		FS	FS					0-0.8			<35>	
BASINGER FINE SAND	X		X	FS	FS		Spodic	18-36	(+2)-1		(+2)-1	0.5-20		39090
Siliceous, hyperthermic Spodic														
Psammaquents														
BRIGHTON MUCK	X			MUCK	MUCK	0-80			(+2-0)	0		60-90	<75>	
CANOVA MUCK			X	SCL	MUCK	0-9	SCL @ 22"		(+2-0)		(+2-0)	35-75		35-75
Fine-loamy, siliceous, hyperthermic														
typic Glossaqualfs														
CHOBEE FINE SANDY LOAM			X	LFS	SCL	35-46					0-1			2.-7
Fine-loamy, siliceaous, hyperthermic														
Typic Argiaquolls														

				Soil Series Benchmark Profile Description							
Drainage Class	Water Table Class	Organic Matter Content Class	Soil Name	Location of Benchmark Description	Drainage and Permeability	Depth (cm)	Horizon	Texture Class	Saturated Hydraulic Conductivity	Organic C %	Organic Matter
P	1	2	**EAUGALLIE FINE SAND**	Sumter	Poor; rapid in the A and E horizons; r	0-15	A	FS	12.2	2.36	4.06864
			Sandy, siliceous, hyperthermic Alfic	Sumter	Poor; rapid in the A and E horizons; r	15-28	E1	FS	6.6	1.28	2.20672
			Haplaquods	Sumter	Poor; rapid in the A and E horizons; r	28-58	E2	FS	11.2	0.11	0.18964
				Sumter	Poor; rapid in the A and E horizons; r	58-76	Bh	LFS	9.9	2.32	3.99968
				Sumter	Poor; rapid in the A and E horizons; r	76-119	Bw1	FS	7.2	0.9	1.5516
				Sumter	Poor; rapid in the A and E horizons; r	119-140	Bw2	FS	6.8	0.6	1.0344
				Sumter	Poor; rapid in the A and E horizons; r	140-183	Btg1	SCL	0.1	0.12	0.20688
				Sumter	Poor; rapid in the A and E horizons; r	183-203	Btg2	SCL	blank	0.06	0.10344
P	1	2	**EMERALDA FINE SAND**		Frequently flooded						
			Fine, mixed, hperthermic Mollic								
			Albaqualfs								
P	1	2	**FELDA FINE SAND**	Highlands	Poor; rapid in all horizons except the	0-18	Ap	FS	25.4	1.33	2.29292
			Loamy, siliceous, hperthermic	Highlands	Poor; rapid in all horizons except the	18-36	E1	FS	13.5	0.1	0.1724
			Arenic Ochraqualfs	Highlands	Poor; rapid in all horizons except the	36-53	E2	FS	12.3	0.07	0.12068
				Highlands	Poor; rapid in all horizons except the	53-61	E3	FS	0.6	0.18	0.31032
				Highlands	Poor; rapid in all horizons except the	61-91	Bt	VFSL	0.8	0.08	0.13792
				Highlands	Poor; rapid in all horizons except the	91-117	BC	FS	2.3	0.03	0.05172
				Highlands	Poor; rapid in all horizons except the	117-173	Cg1	FS	3	0.07	0.12068
				Highlands	Poor; rapid in all horizons except the	173-203	Cg2	FS	7.7	0.06	0.10344
P	1	2	**GATOR MUCK**	Indian River	Very poor; rapid in the O, 2A, 2E hori	1-15	OAp	blank	71	50.84	87.64816
			Loamy, siliceous, euic, hyperthermic	Indian River	Very poor; rapid in the O, 2A, 2E hori	15-76	OA	blank	171	56.89	98.07836
			Terric Medisaprists	Indian River	Very poor; rapid in the O, 2A, 2E hori	76-79	2A	LS	blank	3.42	5.89608
				Indian River	Very poor; rapid in the O, 2A, 2E hori	79-86	2E	S	29.6	0.34	0.58616
				Indian River	Very poor; rapid in the O, 2A, 2E hori	86-109	2Btg1	SCL	238	0.59	1.01716
				Indian River	Very poor; rapid in the O, 2A, 2E hori	109-150	2Btg2	SCL	0	0.27	0.46548
				Indian River	Very poor; rapid in the O, 2A, 2E hori	150-175	2Cgk1	SL	0.1	0.14	0.24136
				Indian River	Very poor; rapid in the O, 2A, 2E hori	175-203	2Cgk2	SL	0.1	0.11	0.18964
				Indian River	Very poor; rapid in the O, moderately	0-15	OAp	blank	113.5	43.38	74.78712
				Indian River	Very poor; rapid in the O, moderately	15-66	OA	blank	636	50.78	87.54472
				Indian River	Very poor; rapid in the O, moderately	66-76	2C1	SCL	17	2.11	3.63764
				Indian River	Very poor; rapid in the O, moderately	76-112	2C2	SCL	0.7	0.41	0.70684
				Indian River	Very poor; rapid in the O, moderately	112-124	2C3	SCL	0.6	0.33	0.56892
				Indian River	Very poor; rapid in the O, moderately	124-137	3C1	SCL	0.3	0.27	0.46548
				Indian River	Very poor; rapid in the O, moderately	137-157	3C2	SCL	0.3	0.19	0.32756
				Indian River	Very poor; rapid in the O, moderately	157-203	4C	SCL	0.4	0.12	0.20688
P	1	2	**IMMOKALEE FINE SAND**	DeSoto	Poor; rapid in surface and subsurface	0-13	A	FS	15.8	1.96	3.37904
			Sandy, siliceous, hyperthermic	DeSoto	Poor; rapid in surface and subsurface	13-109	E	FS	20.4	0.06	0.10344
			Arenic Haplaquods	DeSoto	Poor; rapid in surface and subsurface	109-119	Bh1	FS	0.2	2.8	4.8272
				DeSoto	Poor; rapid in surface and subsurface	119-140	Bh2	FS	5	2.36	4.06864
				DeSoto	Poor; rapid in surface and subsurface	140-165	Bh3	LFS	1.9	0.78	1.34472
P	1	2	**MALABAR FINE SAND**	Highlands	Poor; rapid in the upper horizons and	0-10	Ap	FS	30.6	1.26	2.17224
			Loamy, siliceous, hyperthermic	Highlands	Poor; rapid in the upper horizons and	10-36	E	FS	21.4	0.08	0.13792
			Glossarenic Ochraqualfs	Highlands	Poor; rapid in the upper horizons and	36-76	Bw1	FS	16.1	0.08	0.13792
				Highlands	Poor; rapid in the upper horizons and	76-94	Bw2	FS	1.7	0.14	0.24136
				Highlands	Poor; rapid in the upper horizons and	94-112	Bw3	FS	7.1	0.14	0.24136
				Highlands	Poor; rapid in the upper horizons and	112-122	Bw4	FS	2.6	0.11	0.18964
				Highlands	Poor; rapid in the upper horizons and	122-165	Btg	LFS	0.7	0.08	0.13792
				Highlands	Poor; rapid in the upper horizons and	165-203	Btg	FSL	0.3	0.05	0.0862

	Location of Soil Series in Study Area			Restrictive Horizons					Depth to Water Table (feet)			Organic Matter (%)		
Soil Name	Seminole County	Lake County	Orange County	Dominate Texture	Most Restrictive Horizon Texture	Depth to Restrictive Horizon (inches)	Special Condition	Depth to Special Condition (inches)	Seminole County	Lake County	Orange County	Seminole County	Lake County	Orange County
EAUGALLIE FINE SAND			X	FS	SCL	55-61	SPODIC	22-35	0-1			2.-8		
Sandy, siliceous, hyperthermic Alfic Haplaquods														
EMERALDA FINE SAND			X	SCL	SCL	11.-66	FS	0-11		0	0-1		<15> to 6"	3.-10
Fine, mixed, hperthermic Mollic Albaqualfs														
FELDA FINE SAND	X	X	X	FS	FSL	35-43	SHELLS	43-80	(+2)-1	0-10	0-1	1.-6	<1.5>	1.-4
Loamy, siliceous, hperthermic Arenic Ochraqualfs														
GATOR MUCK			X	MUCK	MUCK	0-34	SCL 34-46"				(+2)-1			55-85
Loamy, siliceous, euic, hyperthermic Terric Medisaprists							FS at bottom							
IMMOKALEE FINE SAND	X	X	X	FS	FS		SPODIC	35-54	0-1	0-10	0-1	1.-2	<3.5>	1.-2
Sandy, siliceous, hyperthermic Arenic Haplaquods														
MALABAR FINE SAND	X			FS	SL	45-61			0-1		0-1	1.-2		1.-2
Loamy, siliceous, hyperthermic Glossarenic Ochraqualfs														

				Soil Series Benchmark Profile Description							
Drainage Class	Water Table Class	Organic Matter Content Class	Soil Name	Location of Benchmark Description	Drainage and Permeability	Depth (cm)	Horizon	Texture Class	Saturated Hydraulic Conductivity	Organic C %	Organic Matter
P	1	2	**MYAKKA FINE SAND**	Citrus	Poor; rapid in A horizons, moderate t	0-10	A1	FS	14.1	3.01	5.18924
			Sandy, siliceous, hyperthermic Aeric	Citrus	Poor; rapid in A horizons, moderate t	10-25	A2	FS	34.5	1.25	2.155
			Haplaquods	Citrus	Poor; rapid in A horizons, moderate t	25-68	E	FS	12	0.09	0.15516
				Citrus	Poor; rapid in A horizons, moderate t	68-107	Bh1	FS	0.5	2.55	4.3962
				Citrus	Poor; rapid in A horizons, moderate t	107-140	Bh2	FS	4.5	1.43	2.46532
				Citrus	Poor; rapid in A horizons, moderate t	140-170	Bw	FS	1.9	0.89	1.53436
				Citrus	Poor; rapid in A horizons, moderate t	170-203	B`h	FS	1.4	0.74	1.27576
			MYAKKA FINE SAND	Polk	Poor; rapid in the A and E horizons a	0-18	Ap	FS	38.8	1.34	2.31016
				Polk	Poor; rapid in the A and E horizons a	18-64	E	FS	28	0.1	0.1724
				Polk	Poor; rapid in the A and E horizons a	64-76	Bh1	FS	12.8	1.94	3.34456
				Polk	Poor; rapid in the A and E horizons a	76-91	Bh2	FS	9	0.91	1.56884
				Polk	Poor; rapid in the A and E horizons a	91-150	C	FS	11.2	0.32	0.55168
				Polk	Poor; rapid in the A and E horizons a	150-203	C	FS	9.5	0.41	0.70684
P	1	2	**NITTAW**		Frequently flooded						
			Fine, montmorillonitic, hyperthermic								
			Typic Argiaquolls								
P	1	2	**OCOEE MUCK**								
P	1	2	**OKEELANTA MUCK**								
			Sandy or sandy-skeletal, siliceous,								
			euic, hyperthermic Terric								
P	1	2	**ONA FINE SAND**	Polk	Poor; moderate	0-10	Ap	FS	5.6	4.3	7.4132
			Sandy, Siliceous, hyperthermic Typic	Polk	Poor; moderate	10-25	A	FS	4.3	1.5	2.586
			Haplaquods	Polk	Poor; moderate	25-48	Bh	FS	10.7	1.05	1.8102
				Polk	Poor; moderate	48-61	BE	FS	6.7	0.47	0.81028
				Polk	Poor; moderate	61-67	E	FS	11.2	0.22	0.37928
				Polk	Poor; moderate	67-127	E	FS	6.8	0.14	0.24136
				Polk	Poor; moderate	127-190	Bh1	FS	2.3	0.36	0.62064
				Polk	Poor; moderate	190-203	Bh2	FS	blank	0.37	0.63788
P	1	2	**PLACID FINE SAND**	Lake	Wet						
P	1	2	**POMPANO FINE SAND**	Orange/Seminc	Wet						
			Siliceous, hyperthermic Typic								
			Psammaquents								
P	1	2	**SAMSULA MUCK**	Polk	Very poor; rapid	0-18	OA1	blank	18.4	47.86	82.51064
			Sandy or sandy-skeletal, siliceous,	Polk	Very poor; rapid	18-68	OA2	blank	19.1	57.56	99.23344
			dysic, hperthermic Terric	Polk	Very poor; rapid	68-79	OA3	blank	13.2	54.06	93.19944
				Polk	Very poor; rapid	79-132	C1	S	11.5	0.75	1.293
				Polk	Very poor; rapid	132-203	C1	S	blank	0.3	0.5172
P	1	2	**SANIBEL FINE SAND**	Orange	Wet						
			Sandy, siliceous, hperthermic Histic								
			Humaquepts								
P	1	2	**SEFFNER**	Orange/Seminc	Wet						
			Sandy, siliceous, hyperthermic								
			Quartzipsammentic Haplumbrepts								

	Location of Soil Series in Study Area			Restrictive Horizons					Depth to Water Table (feet)			Organic Matter (%)		
Soil Name	Seminole County	Lake County	Orange County	Dominate Texture	Most Restrictive Horizon Texture	Depth to Restrictive Horizon (inches)	Special Condition	Depth to Special Condition (inches)	Seminole County	Lake County	Orange County	Seminole County	Lake County	Orange County
MYAKKA FINE SAND		X		S	FS		SPODIC	20-36	0-1	0-10		2.-5	<3.5> to 6"	
Sandy, siliceous, hyperthermic Aeric													<0.5> to 20"	
Haplaquods													<15> to 36"	
													<0.5> below	
MYAKKA FINE SAND		X		S	FS		SPODIC	20-36	0-1	0-10		2.-5	<3.5> to 6"	
													<0.5> to 20"	
													<15> to 36"	
													<0.5> below	
NITTAW	X			SC	MUCK	0-7	C 15-52", FS rest		(+2)-1			20-90		
Fine, montmorillonitic, hyperthermic														
Typic Argiaquolls														
OCOEE MUCK		X		MUCK	MUCK	0-38	SAND	30-60		0			<75> to 38"	
OKEELANTA MUCK			X	FS	MUCK	0-31			0-1		(+1)-0	60-85		60-90
Sandy or sandy-skeletal, siliceous,														
euic, hyperthermic Terric														
ONA FINE SAND		X	X	FS	FS		SPODIC	20-Jun		0-10	0-1		<3.5> to 18"	
Sandy, Siliceous, hyperthermic Typic													<0.5> below	
Haplaquods														
PLACID FINE SAND		X		FS	FS				0-10			<15> to 18"		
POMPANO FINE SAND	X	X	X	FS	FS		SPODIC	42-54	2-3.5	30-40	2-3.5	<1	<3.5> in spodic	<1
Siliceous, hyperthermic Typic														
Psammaquents														
SAMSULA MUCK			X	FS	SAPRIC	9.-36			(+2)-0		(+2)-1	>20		>20
Sandy or sandy-skeletal, siliceous,														
dysic, hperthermic Terric														
SANIBEL FINE SAND			X	FS	SAPRIC	0-9			(+2)-0		(+1)-1	20-50		20-50
Sandy, siliceous, hperthermic Histic														
Humaquepts														
SEFFNER	X	X	X	FS	FS				1.5-3.5		1.5-3.5	2		39087
Sandy, siliceous, hyperthermic														
Quartzipsammentic Haplumbrepts														

				Soil Series Benchmark Profile Description							
Drainage Class	**Water Table Class**	**Organic Matter Content Class**	**Soil Name**	**Location of Benchmark Description**	**Drainage and Permeability**	**Depth (cm)**	**Horizon**	**Texture Class**	**Saturated Hydraulic Conductivity**	**Organic C %**	**Organic Matter**
P	**1**	**2**	**SMYRNA SAND**	Highlands	Poor; slow to moderately slow	0-13	Ap	S	18.4	1.42	2.44808
			Sandy siliceous, hyperthermic Aeric	Highlands	Poor; slow to moderately slow	13-38	E	S	14.8	0.14	0.24136
			Haplaquods	Highlands	Poor; slow to moderately slow	38-46	Bh1	S	11.2	2.68	4.62032
				Highlands	Poor; slow to moderately slow	46-56	Bh2	S	34.2	1.09	1.87916
				Highlands	Poor; slow to moderately slow	56-89	BC1	S	18.4	0.19	0.32756
				Highlands	Poor; slow to moderately slow	89-114	BC2	S	10.6	0.2	0.3448
				Highlands	Poor; slow to moderately slow	114-142	C1	S	7.6	0.2	0.3448
				Highlands	Poor; slow to moderately slow	142-203	C2	S	1.3	0.06	0.10344
P	**1**	**2**	**SPARR FINE SAND**	Sumter	Somewhat poor; moderate	0-23	A	FS	18.4	0.66	1.13784
			Loamy, siliceous, hyperthermic Aeric	Sumter	Somewhat poor; moderate	23-43	E1	FS	18.4	0.25	0.431
			Haplaquods	Sumter	Somewhat poor; moderate	43-74	E2	FS	19.8	0.13	0.22412
				Sumter	Somewhat poor; moderate	74-114	E3	FS	26.8	0.04	0.06896
				Sumter	Somewhat poor; moderate	114-130	Bt1	FSL	4.8	0.14	0.24136
				Sumter	Somewhat poor; moderate	130-180	Btg1	SCL	1.6	0.1	0.1724
				Sumter	Somewhat poor; moderate	180-203	Btg2	SCL	0.7	0.08	0.13792
P	**1**	**2**	**ST. JOHNS FINE SAND**	Orange/Seminc	Wet						
			Sandy, siliceous, hyperhtermic Typic								
			Haplaquods								
P	**1**	**2**	**WABASSO FINE SAND**	Polk	Poor; moderate	0-18	Ap	FS	6.3	0.91	1.56884
			Sandy, siliceous, hperthermic Alfic	Polk	Poor; moderate	18-56	E	FS	7.7	0.08	0.13792
			Haplaquods	Polk	Poor; moderate	56-76	Bh	FS	4.5	0.93	1.60332
				Polk	Poor; moderate	76-89	BE	FS	4.6	0.28	0.48272
				Polk	Poor; moderate	89-130	Btg1	SCL	0	0.27	0.46548
				Polk	Poor; moderate	130-170	Btg2	FSL	0	0.1	0.1724
				Polk	Poor; moderate	170-203	Cg	FSL	0.1	0.1	0.1724
P	**1**	**2**	**WAUBERG FINE SAND**		Wet						
			Loamy, siliciwous, hyperhtermic Arenic Albqualfs								
P	**1**	**2**	**WAUCHULA FINE SAND**		Wet						
P	**2**	**2**	**LOCHLOOSA FINE SAND**		Wet						
			Loamy, silieous, hyperthermic Aquic Arenic Paleudult								

	Location of Soil Series in Study Area			Restrictive Horizons					Depth to Water Table (feet)			Organic Matter (%)		
Soil Name	Seminole County	Lake County	Orange County	Dominate Texture	Most Restrictive Horizon Texture	Depth to Restrictive Horizon (inches)	Special Condition	Depth to Special Condition (inches)	Seminole County	Lake County	Orange County	Seminole County	Lake County	Orange County
SMYRNA SAND			X	FS	Crushed Sand	0-6	SPODIC	13-28	(+2)-0		0-1	1.-5		1.-5
Sandy siliceous, hyperthermic Aeric Haplaquods														
SPARR FINE SAND		X		FS	SCL	56-72	FSL/SCL	48-56	<3					
Loamy, siliceous, hyperthermic Aeric Haplaquods														
ST. JOHNS FINE SAND			X	FS	FS		SPODIC	22-42	0-1		0-1	2.-4		2.-4
Sandy, siliceous, hyperhtermic Typic Haplaquods														
WABASSO FINE SAND				FS	LFS/FSL	32-60	SPODIC/SCL	16-28/28-68	0-1	0-10	0-1	1.-4	<1.5>	1.-4
Sandy, siliceous, hperthermic Alfic Haplaquods														
WAUBERG FINE SAND	X		X	SCL	CLAY	63-81	SCL	24-63			0-1			1.-4
Loamy, siliciwous, hyperhtermic Arenic Albqualfs														
WAUCHULA FINE SAND		X		FS	FSL	33-44	SPODIC	22-Dec		0-10			<1.5>	
LOCHLOOSA FINE SAND			X	SCL	SCL	57-69					2.5-5			1.-4
Loamy, silieous, hyperthermic Aquic Arenic Paleudult														

APPENDIX B

ESTIMATED DENITRIFICATION POTENTIALS OF SOILS IN THE WEKIVA STUDY AREA

ESTIMATED DENITRIFICATION POTENTIALS OF SOILS IN THE WEKIVA STUDY AREA

Drainage Class	Water Table Class 1=<3.5 ft 2=>3.5 ft	Organic Matter Class 1=<1.0% 2=>1.0%	Soil Series Taxonomy	Soil Series Description	NRCS "Suitability" Rating for Onsite Treatment	Applied Nitrogen	Estimated TN Removal Potential	Comments	Code Allowed Systems
Execessively / Somewhat Excessively	**2**	**1**	**LAKE FINE SAND** Hyperthermic, coated Typic Quartzipsamments	Excessively drained, rapidly to very rapidly permeable soils formed in thick beds of sand. Water table is >80" deep.	Slight	TKN/NO_3	<10%	Very low organic content Very low moisture content (aerobic)	In-ground traditional system
	2	**1**	**PAOLA FINE SAND** Hyperthermic, uncoated Spodic Quartzipsamments	Very deep, excessively drained, very rapidly permeable upland soils that formed in sandy marine deposits. Water table is >80" deep.	Slight	TKN/NO_3	<10%	Very low organic content Very low moisture content (aerobic)	
	2	**1**	**ST. LUCIE SAND** Hyperthermic, uncoated Typic Quartzipsamments	Very deep, excessively darined, very rapidly permeable soils formed in marine eolian sand. Water table >80" deep.	Slight	TKN/NO_3	<10%	Very low organic content Very low moisture content (aerobic)	
	2	**2**	**ASTATULA FINE SAND** Hyperthermic, uncoated Typic Quartzipsamments	Very deep, excessively drained, rapidly permeable soils formed in eolian and marine sands. Water table >80" deep.	Slight	TKN/NO_3	<10%	Very low organic content Very low moisture content (aerobic)	In-ground traditional system
	2	**2**	**CANDLER SAND** Hyperthermic, uncoated Lamellic Quartzipsamments	Very deep, excessively drained, rapidly permeable soils that formed in thick beds of eolian or marine deposits of coarse textured materials. Short, thin loamy lamella exist below 70". Water table >80" deep.	Slight	TKN/NO_3	<10%	Very low organic content Very low moisture content (aerobic)	
Well	**2**	**1**	**APOPKA SAND** Loamy, siliceous, hyperthermic Grossarenic Paleudults	Very deep, well drained, moderately permeable soils that formed in thick beds of sandy and loamy marine or eolian deposits. Water table >60" deep.	Slight	TKN/NO_3	<10%	Very low organic content Very low moisture content (aerobic)	In-ground traditional system
	2	**2**	**ORLANDO FINE SAND** Siliceous, hyperthermic Humic Psammentic Dystrudepts	Very deep, well drained, rapidly permeable soils that formed in thick deposits of sandy marine or fluvial sediments. Water table >72".	Slight	TKN/NO_3	<10%	Very low organic content Very low moisture content (aerobic)	

Drainage Class	Water Table Class 1=<3.5 ft 2=>3.5 ft	Organic Matter Class 1=<1.0% 2=>1.0%	Soil Series Taxonomy	Soil Series Description	NRCS "Suitability" Rating for Onsite Treatment	Applied Nitrogen	Estimated TN Removal Potential	Comments	Code Allowed Systems
Moderately Well	2	1	**ARCHBOLD SAND** Hyperthermic, uncoated Typic Quartzipsamments	Deep, well drained, very rapidly permeable sandy soils that formed in marine or eolian deposits. Seasonally high water table (June-November) at 42-60" but 60-80" the remainder of the year.	Moderate: wetness	TKN/NO_3	5-15%	Very low organic content Low moisture content (aerobic)	In-ground traditional system with slight amounts of fill added
	2	1	**ORSINO FINE SAND** Hyperthermic, uncoated Spodic Quartzipsamments	Very deep, moderately well drained, very rapidly permeable soils that formed in thick beds of sandy marine or eolian deposits. Water table at 50-60" deep. Spodic horizon at 25".	Severe: wetness	TKN/NO_3	5-15%	Very low organic content Low moisture content (aerobic)	In-ground traditional systems with slight amounts of fill added. Orsino is likely will have soil "digout" and sand replacement.
	2	2	**FLORAHOME SAND** Siliceous, hyperthermic Humic Psammentic Dystrudepts	Deep, moderately well drained, dark sufaced, rapidly permeable soils that formed in sandy marine and eolian deposits. Water table depth at 48-72" for 4-6 months each year receeding to >72 in dry periods.	Moderate: wetness	TKN/NO_3	10-20%	Low organic content Low moisture content (aerobic) Fluctuating water table	In-ground traditional systems
	2	2	**MILLHOPPER SAND** Loamy, siliceous, semiactive, hyperthermic Grossarenic Paleudults	Very deep, moderately well drained, moderately permeable soils that formed in thick beds of sandy and loamy marine sediments. Water table depth is 48-60" for 1-4 months and 60-72" for 2-4 months most years.	Moderate: wetness	TKN/NO_3	10-20%	Low organic content Low moisture content (aerobic) Fluctuating water table	
	2	2	**TAVARES FINE SAND** Hyperthermic, uncoated Typic Quartzipsamments	Very deep, moderately well drained, rapidly permeable soils that formed in sand marine or eolian deposits. Zones of saturation at depths of 40-80".	Moderate: wetness	TKN/NO_3	5-15%	Low organic content Low moisture content (aerobic)	
Somewhat Poorly / Poorly / Very Poorly	1	1	**ADAMSVILLE FINE SAND** Hyperthermic, uncoated Aquic Quartzipsamments	Very deep, somewhat poorly drained, rapidly permeable soils that formed in thick sandy marine sediments. Water table is at 20-40" for 2-6 months of most years and 10-20" for up two weeks in some years. It is within 60" for more than 9 months in most yea	Severe: wetness poor filter	TKN NO3	5-15% 15-30%	Very low organic content below 4" Rapid permeability Fluctuating water table with aquic regime (anoxic)	Filled or Mound systems
	1	1	**CASSIA FINE SAND** Sandy, siliceous, hyperthermic Oxyaquic Alorthods	Very deep, somewhat poorly drained, moderately rapid permeable soils formed in sandy materials. Water table is at 18-42" for about 6 months during most years and will drop to >42" during the driest season.	Severe: wetness	TKN NO3	10-20% 5-25%	Fine sand with shallow water table High organic content in spodic horizon at 2-3 ft. Fluctuating water table	Soil "digout" and Mound systems
	1	1	**POMELLO FINE SAND** Sandy, siliceous, hyperthermic Oxyaquic Alorthods	Very deep, moderately well to somewhat poorly drained soils, which are sandy to depths of >80" that formed in sandy marine sediments. Seasonally high water table is at depths of about 24-42" for 1-4 months during most years.	Severe: ponding poor filter	TKN NO3	10-40% 10-50%	Freely draining Shallow, fluctuating water table at 2-3 ft Spodic horizon high in orga	Soil "digout" and Mound systems or very high Mounds without "digouts".
	1	1	**ZOLFO FINE SAND** Sandy, siliceous, hyperthermic Oxyaquic Alorthods	Very deep, somewhat poorly drained soils that forme in thick beds of sandy marine deposits. Water table is at depths of 24-40" for 2-6 months of the year and up to 10-24" deep for short periods. It is within 60" for more than 9 months most years.	Severe: wetness poor filter	TKN NO3	5-25% 15-35%	Fine sand with shallow water table (2-3.5ft) Spodic horizon at 5-8 ft Fluctuating water table	Mound systems without "digouts"

Drainage Class	Water Table Class 1=<3.5 ft 2=>3.5 ft	Organic Matter Class 1=<1.0% 2=>1.0%	Soil Series Taxonomy	Soil Series Description	NRCS "Suitability" Rating for Onsite Treatment	Applied Nitrogen	Estimated TN Removal Potential	Comments	Code Allowed Systems
	1	2	**ANCLOTE SAND** Sandy, siliceous, hyperthermic Typic Endoaquolls	Very deep, very poorly drained, rapidly permeable fine sandy soils in depressions, drainage way and floodplains. Water table is within 10" of the surface for 6 or more months during most years and recedes to >20" during the driest season.	Severe: ponding wetness poor filter	TKN	5-20%	Very shallow water table (<1ft) High organic content in surface horizon	Mound systems without "digouts". Likely to equire wetlands fill permits from DEP
						NO3	>75%		
	1	2	**BASINGER FINE SAND** Siliceous, hyperthermic Spodic Psammaquents	Very deep, poorly drained and very poorly drained, rapidly permeable soils fromed in sandy marine sediments. Found in sloughs, depressions, and low flats. Water table at depths of <12" 2-6 months annually and 12-30" for periods >6 months. Surface pondi	Severe: wetness ponding poor filter	TKN	5-20%	Very shallow fluctuating water table Very high organic content	Mound systems with "digouts" where spodic horizon exists. Likely to require wetland fill permits from DEP
						NO3	>75%		
	1	2	**BRIGHTON MUCK** Dysic, hyperthermic Typic Haplohemists	Very deep, very poorly drained, moderately rapid to rapidly permeable organic soils in depressions, freshwater marshes and swamps. Organic layer is >54" thick. Water table is above ground surface for 4-6 months.	Severe: subsides flooding wetness	TKN	20-40%	Deep organic surface horizon Very shallow, fluctuating water table	Mound systems without "digouts". Likely to require wetlands fill permits from DEP
						NO3	>90%		
	1	2	**CANOVA MUCK** Fine-loamy, siliceous, superactive, hyperthermic Histic Glossaqualfs	Very deep, very poorly drained, moderately slowly permeable fine sandy and loamy soils in depressions and fresh water swamps and marshes. They are formed in loamy marine sediments. Water table is at the surface or within 10" of the surface for more than	Severe: ponding	TKN	20-40%	Very shallow water table (<1ft) High organic content in surface horizon and the Btg horizon at 32-43"	Mound systems with "O" horizon removed. Likely to require wetlands fill permits from DEP
						NO3	>90%		
	1	2	**CHOBEE FINE SANDY LOAM** Fine-loamy, siliceaous, superactive, hyperthermic Typic Argiaquolls	Very deep, very poorly drained, slowly to vry slowly permeable soils in depressions, flats, and river flood plains that formed in thick beds of loamy marine sediments. Water table within 6" for 1-4 months of the year.	Severe: flooding wetness percs slowly	TKN	10-30%	Very shallow water table High organic content in the surface horizon	Mound systems with "digouts". Likely to require wetlands fill permits from DEP.
						NO3	>90%		
	1	2	**EAUGALLIE FINE SAND** Sandy, siliceous, hyperthermic Alfic Alaquods	Deep or very deep, poorl or very poorly drained, slowly permeable soils in flats, sloughs, and depressionsthat were formed in sandy and loamy marine sediments. The water table rises to within 6-18"of the surface for periods of 1-4 months annually and wit	Severe: wetness	TKN	20-40%	Shallow, fluctuating water table Moderately high organic content near surface in within a spodic horizon at depths >22"	Mound systems with "digouts". Likely to require wetlands fill permits from DEP.
						NO3	>90%		
	1	2	**EMERALDA FINE SAND** Fine, mixed, superactive, hyperthermic Mollic Albaqualfs	Very deep, poorly drained, slowly or very slowly permeable fine sand to sandy clay soils in low areas near lakes and streams that were formed in clayey marine sediments. The water table is at depths of <10" for 6-9 months and saturated most of the year	Severe: flooding wetness percs slowly	TKN	10-30%	Very shallow water table High organic content in the surface horizon	High mounds without "digouts". Likely to require wetlands fill permits from DEP.
						NO3	>90%		

Drainage Class	Water Table Class 1=<3.5 ft 2=>3.5 ft	Organic Matter Class 1=<1.0% 2=>1.0%	Soil Series Taxonomy	Soil Series Description	NRCS "Suitability" Rating for Onsite Treatment	Applied Nitrogen	Estimated TN Removal Potential	Comments	Code Allowed Systems
	1	2	**FELDA FINE SAND** Loamy, siliceous, superactive, hyperthermic Arenic Endoaqualfs	Very deep, poorly drained and very poorly drained, moderately permeable fine sandy soils in drainageways and depressions that formed in stratefied, unconsolidated marine sands and clays. The water table is within 12" of the surface for 2-6 months each ye	Severe: ponding wetness poor filter	TKN	10-30%	Very shallow water table Moderate to high organic content in the surface horizon	High mounds without "digouts". Likely to require wetlands fill permits from DEP.
						NO3	40-60%		
	1	2	**GATOR MUCK** Loamy, siliceous, euic, hyperthermic Terric Haplosaprists	Very poolry drained organic soils that formed in moderately thick beds of hydrophytic plant remains overlying beds of loamy and sandy marine sediments. These soils are always saturated at or above the surface except during extended droughts.	Severe: ponding percs slowly poor filter	TKN	10-30%	Very shallow water table Low organic content below 34"	Mound systems with "O" horizon removed. Likely to require wetlands fill permits from DEP
						NO3	>90%		
	1	2	**IMMOKALEE FINE SAND** Sandy, siliceous, hyperthermic Arenic Alaquods	Deep and very deep, poorly drained and very poorly drained soils that formed in sandy marine sediments that occur in flantwoods and depressions. The water table is at depths of 6-18" for 1-4 months, 18-36" for 2-10 months and below 60" during dry periods	Severe: wetness	TKN	20-40%	Shallow, fluctuating water table Moderately high organic content near surface	Mound systems with optional "digouts" allowed in some cases. May require wetlands fill permits from DEP
						NO3	>90%		
	-	2	**MALABAR FINE SAND** Loamy, siliceous, active, hyperthermic Grossarenic Endoaqualfs	Very deep, poorly to very poorly drained soils in sloughs, shallow depressions and along flood plains in sandy and loamy marine sediments. The water table is within depths of 10" for 2-6 months during most years.	Severe: wetness poor filter	TKN	10-30%	Very shallow water table Low organic content	Mound systems. May require wetlands fill permits from DEP.
						NO3	40-60%		
	1	2	**MYAKKA FINE SAND** Sandy, siliceous, hyperthermic Aeric Alaquods	Deep and very deep, poorly to very poorly drained soils formed in sandy marine deposit, which occur on flatwoods, flood plains, and depressions. The water table is at depths <18" for 1-4 month duration in most years and recedes to depths >40" during very	Severe: ponding wetness poor filter	TKN	40-60%	Shallow, fluctuating water table Moderate organic content	Mound systems with "digouts". Likely to require wetlands fill permits from DEP.
						NO3	>90%		
	1	2	**NITTAW SANDY CLAY** Fine, smectitic, hyperthermic Typic Argiaquolls	Very poorly drained, slowly pwermeable soils that formed in thick deposits of clayey sediments of marine origin, which occur in drainageways, swamps and marshes. They are subjext to standing water above the soil surface for >6 months during late spring,	Severe: ponding percs slowly	TKN	10-30%	Very shallow water table High organic content in "O" and "A" horizons but diminishing quickly with depth	Unsuitable for housing developments
						NO3	>90%		
	1	2	**OCOEE MUCK** Sandy or sandy skeletal, siliceous, dysic, hyperthermic Terric Haplohemists	Deep, very poorly drained soils that fromed in herbaceous organic material and sandy minera material, which occur on flood plains, fresh water marshes, and depressions.	Severe: subsides flooding wetness	TKN	5-20%	Very wet Deep "O" horizon from 0-38"	Mound systems with "O" horizon removed. Likely to require wetlands permits from DEP.
						NO3	>90%		

Drainage Class	Water Table Class 1=<3.5 ft 2=>3.5 ft	Organic Matter Class 1=<1.0% 2=>1.0%	Soil Series Taxonomy	Soil Series Description	NRCS "Suitability" Rating for Onsite Treatment	Applied Nitrogen	Estimated TN Removal Potential	Comments	Code Allowed Systems
Somewhat Poorly / Poorly / Very Poorly	1	2	**OKEELANTA MUCK** Sandy or sandy skeletal, siliceous, euic, hyperthermic Terric Haplosaprists	Very deep, very poorly drained, rapidly permeable soils in large fresh water marshes and small depressional areas, which formed in decomposed hydrophytic non-woody organic material overlying sand. The water table is at depths of <10" below surface or pon	Severe: flooding poor filter wetness	TKN	5-20%	Very wet Deep "O" horizon from 0-31"	Mound sytems with "O" horizon removed. Likely to require wetlands permits from DEP
						NO3	>90%		
	1	2	**ONA FINE SAND** Sandy, siliceous, hyperthermic Typic Alaquods	Poorly drained, moderately permeable soils that formed in thick sand marine sediments, which occur in flatwood areas. The water table is at depths of 10-40" for periods of 4-6 months. It rises to depths of <10" for periods of 1-2 months and may recede t	Severe: wetness poor filter	TKN	10-30%	Shallow, fluctuating water table Moderate organic content above 20"	Mound systems with "digouts"
						NO3	>90%		
	1	2	**PLACID FINE SAND** Sandy, siliceious, hyperthermic Typic Humaquepts	Very deep, very poorly drained, rapidly permeable soils on low flats, depressions, drainageways, and flood plains. The soils formed in sandy marine sediments. The water table ranges in depths from 0-6" for >2 months in most years.	Severe: ponding wetness poor filter	TKN	5-15%	Very shallow water table Moderatly high organic content above 18"	Mound systems without "digouts". Undrained areas may be called surface water.
						NO3	>90%		
	1	2	**POMPANO FINE SAND** Siliceous, hyperthermic Typic Psammaquents	Very deep, very poorlly drained, rapidly permieable soils occuring in depressions, drainageways and broad flats. The soils were formed in thick beds of marine sands. The water table is at depthso f >10" for 2-6 months each year and within depths of 30"	Severe: ponding poor filter	TKN	5-15%	Very shallow, fluctuating water table Low organic content	Mound systems without "digouts".
						NO3	40-60%		
	1	2	**SAMSULA MUCK** Sandy or sandy skeletal, siliceous, dysic, hperthermic Terric Haplosaprists	Very deep, very poorly drained, rapidly permeable soils that formed in moderately thick beds of hydrophytic plant remains underlain by sandy marine sediments. They occur in swamps and flood plains. The water table is at or above the surface except durin	Severe: ponding poor filter	TKN	5-15%	Very shallow water table Sapric soil materials from surface to 36"	Unsuitable for housing developments
						NO3	>90%		
	1	2	**SANIBEL FINE SAND** Sandy, siliceous, hperthermic Histic Humaquepts	Very poorly drained sandy soils with organic surfaces, that formed in rapidly permeable marine sediments, which occur on nearly level and depressional areas. The water table is <10" deep for 6-12 months and is above ground surface 2-6 months during wet s	Severe: ponding poor filter	TKN	5-15%	Very shallow water table High organic content in the "O" and "A" horizons to a depth of 10"	May be classified as surface water. Mound systems on drier sites with "digouts" of "O" horizon.
						NO3	>90%		
	1	2	**SEFFNER FINE SAND** Sandy, siliceous, hyperthermic Aquic Humic Dystrudepts	Very deep, somewhat poorly drained, rapidly permeable soils on rims of depressions and on lower lying flats, which formed in sandy marine sediments. The water table is within depths of 18-42" for 2-4 months and within 60" for >9 months in most years.	Severe: wetness poor filter	TKN	5-15%	Very shallow water table Moderate organic content to 20"	Mound systems without "digouts".
						NO3	>90%		
	1	2	**SMYRNA SAND** Sandy, siliceous, hyperthermic Aeric Alaquods	Very deep, poorly to very poorly drained soils fomremed in thick depsolits of sandy marine materials. The water table is at depths of >18" for 1-4 months and 1240" for more than 6 months	Severe: ponding poor filter	TKN	20-40%	Shallow, fluctuating water table Moderate organic content to 35"	Mound systems. May require wetlands fill permits from DEP.
						NO3	>90%		

Drainage Class	Water Table Class 1=<3.5 ft 2=>3.5 ft	Organic Matter Class 1=<1.0% 2=>1.0%	Soil Series Taxonomy	Soil Series Description	NRCS "Suitability" Rating for Onsite Treatment	Applied Nitrogen	Estimated TN Removal Potential	Comments	Code Allowed Systems
Somewhat Poorly / Poorly / Very Poorly	1	2	**SPARR FINE SAND** Loamy, siliceous, subactive, hyperthermic Grossarenic Paleudults	Very deep, somewhat poorly drained, moderate slowly to slowly permeable fine sandy soils on uplands. They formed in thick beds of sand and loamy marine sediments. The water table is at depths of 20-40" for 1-4 months. The water table is usually perch o	Severe: ponding poor filter	TKN	20-40%	Moderately shallow water table Low to moderate organic content	Filled or Mound systems without "digouts".
						NO3	>90%		
	1	2	**ST. JOHNS FINE SAND** Sandy, siliceous, hyperhtermic TypicAlaquods	Very deep, very poorly or poorly drained, moderately permeable soils on broad flats and depressional areas. These soils formed in sandy marine sediments. The water table is 0-15" below surface for 20-50% of the year but is at 15-30" during periods of lo	Severe: wetness	TKN	20-40%	Shallow, fluctuating water table Spodic horizon with moderate organic content at 22-66"	Mound systems with "digouts".
						NO3	>90%		
	1	2	**WABASSO FINE SAND** Sandy over loamy, siliceous, active, hyperthermic Alfic Alaquods	Deep or very deep, very poorly and poorly drained, very slowly and slowly permeable soils on flatwoods, flood plains, and depressions. They formed in sandy and loam marine sediments. The water table is at depths of 12-40" for more than 6 month and >40"	Severe: wetness poor filter	TKN	20-40%	Moderately shallow, fluctuating water table Low to moderate organic content	Mound systems with "digouts".
						NO3	>90%		
	1	2	**WAUBERG FINE SAND** Loamy, siliceous, active, hyperthermic Arenic Albaqualfs	Poorly drained, very slowly permeable sandy soils that formed in thick beds of loamy marine sediments within large prairie areas and low areas within flatwoods. The water table is at depths of <10" for 3-5 months during most years.	Severe: wetness percs slowly	TKN	5-15%	Very shallow water table Sandy clay loam restrictive horizon at 24" Low to moderate organic c	Mound systems without "digouts".
						NO3	40-60%		
	1	2	**WAUCHULA FINE SAND** Sandy over loamy, siliceous, active hyperthermic Ultic Alaquods	Very deep, very poorly or poorly drained, moderately slow or slowly permeable soils formed in sandy and loamy marine sediments. The water table is at depths of 6-18" for 1-4 month and 10-40" for as long as 6 months but receding to depths of 40" during th	Severe: wetness poor filter	TKN	5-15%	Shallow, fluctuating water table Low organic content	Likely classified as surface water. Mound systems on drier sites.
						NO3	40-60%		
	2	2	**LOCHLOOSA FINE SAND** Loamy, siliceous, semiactive, hyperthermic Aquic Arenic Paleudults	Somewhat poorly drained, slowly permeable soils formed in thick beds fo sandy and loamy marine sediments. The water table is at depths of 30-60" for 1-4 months and recedes to >60" during the drier seasons.	Severe: wetness	TKN	20-40%	Moderatly deep, fluctuating water table Low to moderate organic content	Fill systems without "digouts".
						NO3	40-60%		