A Review of Nitrogen Loading and Treatment Performance Recommendations for Onsite Wastewater Treatment Systems (OWTS) in the Wekiva Study Area

Damann L. Anderson, P.E.
Hazen and Sawyer, P.C.
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1.0 Background

The Wekiva Parkway and Protection Act (WPPA) was signed into law by Governor Bush on June 29, 2004, at Wekiva Springs State Park, in Apopka. The Act authorizes building the Wekiva Parkway and provides protection to the Wekiva River System, including establishment of the Wekiva Study Area (WSA).

The WSA covers about 300,000 acres and includes the surface waters and much of the recharge area to some 27 named springs. These springs discharge an average of 71 million gallons per day. The study area is generally underlain by karst geology, characterized by sinkholes, caves, and springs. Generally, higher topographic regions in the west and south serve to recharge the Floridan Aquifer system that in turn feeds the springs and wetlands in the lower elevations in the central, northern, and eastern regions of the WSA.

The associated land uses in the watersheds, or springsheds of these springs can directly influence their water quality, and nitrogen is one of the specific contaminants of concern due to its eutrophication potential in surface waters.   Available water quality data in the WSA create a complex picture in regards to determining specific cause and effect relationships between land use and nitrogen concentrations in surface and groundwaters. These relationships are made complex not only by the difficult-to-define system of underground conduits feeding each spring, but also by the time it takes water to travel from the ground surface to the aquifer and subsequently to the spring. This time ranges from a few days to greater than 40 years, so the impacts of land use changes made 30 years ago could be observed in a spring today. Likewise, the impact of land use changes made today may not be observed for many years or even decades.

As part of the WPPA, the Florida Department of Health was required to study the efficacy and applicability of onsite wastewater treatment system (OWTS) standards needed to achieve nitrogen reductions protective of groundwater quality within the WSA. The WPPA specifically states that the FDOH consider a more stringent level of wastewater treatment to reduce the level of nitrates as well as implementation of a septic system maintenance and inspection program which includes upgrading certain OWTS permitted prior to 1982 to meet current FDOH standards. The FDOH has put forth proposed rule language pertaining to the WSA in 64E-6.001; and the most recent language proposed as of November 2, 2005, is as follows:

64E-6.001 GENERAL

(1) through (6) No Change

(7) Except in areas scheduled, by an adopted local wastewater facility plan, to be served by a central sewage facility by January 1, 2011, the following standards shall apply to all systems in the Wekiva Study Area as defined in 369.316, F.S., requiring permitting. In the primary and secondary protection zones, or where severely limited material below the "O" horizon is removed in the tertiary protection zone systems shall:

    (a) utilize a performance-based treatment system with a total nitrogen discharge limit of 3.0 milligrams per liter at 24 inches below the bottom of the drainfield, or

    (b) utilize a performance-based treatment system with a total nitrogen discharge limit of 10.0 milligrams per liter at the outlet of the tank and a drip irrigation drainfield installed no more than 9 inches below finished grade.

    (c) not exceed the authorized low sewage flow allowances of 381.0065(4)(a), (b) and (g).

This proposed rule language addresses the WPPA requirement to consider a more stringent level of wastewater treatment, but does not address the implementation of an OWTS maintenance and inspection program with upgrade requirements for non-compliant systems. The FDOH addressed this issue in its December 1, 2004 report by recommending that new regional wastewater management entities be established or existing entities modified to oversee all OWTS in the WSA, and that the EPA Voluntary Management Guidelines; Management Model 4 or 5 be utilized as the basis for an OWTS management program. Existing local governments or special taxing districts were recommended by FDOH to be the management entities responsible for developing and implementing the OWTS management program. These entities could then contract with the private sector for maintenance and inspection services or establish an internal program as desired.

2.0 Purpose and Scope

Several stakeholder groups in the WSA, including the Florida Home Builders Association (FHBA), the Florida Onsite Wastewater Association (FOWA), Metro-Orlando Home Builders Association, and the local Orlando-based Board of Realtors, are concerned as to whether sufficient data exists on OWTS impacts to water quality to justify the considerable cost of the proposed FDOH rules. Hazen and Sawyer was retained by these stakeholders through the Florida Home Builders Association (FHBA) to review available supporting documentation on the issue. Specifically, the available water quality and nitrogen loading data from anthropogenic sources in the Wekiva Study Area was to be reviewed in order to understand the relative significance of nitrogen loading from OWTS, if possible.   The scope of this effort was limited to a review of the available studies and data referenced in the WPPA supporting documents related to water quality issues in the WSA, and to then make a preliminary assessment of OWTS impacts relative to the measures that have been recommended to mitigate these impacts.

3.0 Review of Available Data

A list of the studies and data reviewed as part of this evaluation is found in Section 8.0. The studies and data referenced in the supporting documents for the WPPA consist of studies specific to the WSA and studies that were conducted elsewhere, but were considered comparable in some aspect to conditions in the WSA. No study directly investigating the impact of OWTS on ground or surface water quality within the WSA was identified. Other documents that were referred to as part of this assessment are also listed in Section 8.0 Bibliography.

One of the most important support documents for the implementation of the WPPA requirements is the Wekiva Aquifer Vulnerability Assessment (WAVA), prepared by the Florida Geological Survey (FGS) section of the Florida Department of Environmental Protection (FDEP). FGS prepared the Wekiva Aquifer Vulnerability Assessment (WAVA) based on an established statewide model known as the Florida Aquifer Vulnerability Assessment (FAVA). The WAVA establishes three protection zones within the WSA, a Primary, Secondary, and Tertiary Protection zone. These zones indicate the relative vulnerability of the aquifer underlying the WSA to contamination, with the Primary zone being the most vulnerable areas of the WSA, typically those areas that have relatively thin confinement, high karst-feature density, higher soil permeability, and have the potential to recharge the Floridan aquifer. The secondary and tertiary zones are somewhat less vulnerable to contamination, but still require protection. The tertiary zone includes the areas where the potentiometric surface of the Floridan is greater than the surficial aquifer, which results in springs or flowing wells. These three protection zones can be utilized by the various regulatory agencies to develop regulatory levels consistent with the vulnerability a given area. For example, the most stringent wastewater treatment requirements are proposed for the Primary Protection Zone. **Figure 1** shows the three protection zones in the WAVA.

The most specific studies relative to water quality and nitrogen in the WSA springs were those conducted by the SJRWMD and reported by Toth (1999) and Toth and Fortich (2002). The first study (Toth, 1999) evaluated the water quality of 17 springs in the SJRWMD in 1995-1996 and found the highest nitrate nitrogen concentration in Wekiva Springs (1.92 mg NO_3-N/L). Many other springs in the Wekiva groundwater basin were also found to have elevated nitrate N concentrations relative to the 0.20 mg/L nitrate N value thought to represent background conditions for springs in the region. Using measurements of the delta nitrogen-15 content on the nitrate N, information related to the source of the nitrogen was obtained. Delta nitrogen-15 content is a measurement which can help to differentiate inorganic sources of nitrogen, such as synthetic fertilizers, from organic sources of nitrogen such as animal waste (including human). Based on this analysis, the estimated source of nitrates differed by location of the springs. The elevated nitrate levels found in Sanlando and Starbuck springs were probably due to contamination by animal waste, while the elevated nitrate levels in Rock and Seminole Springs were probably due to contamination from fertilizers. Palm Springs and Wekiva Springs were thought to be affected by a mixture of animal waste and fertilizers.
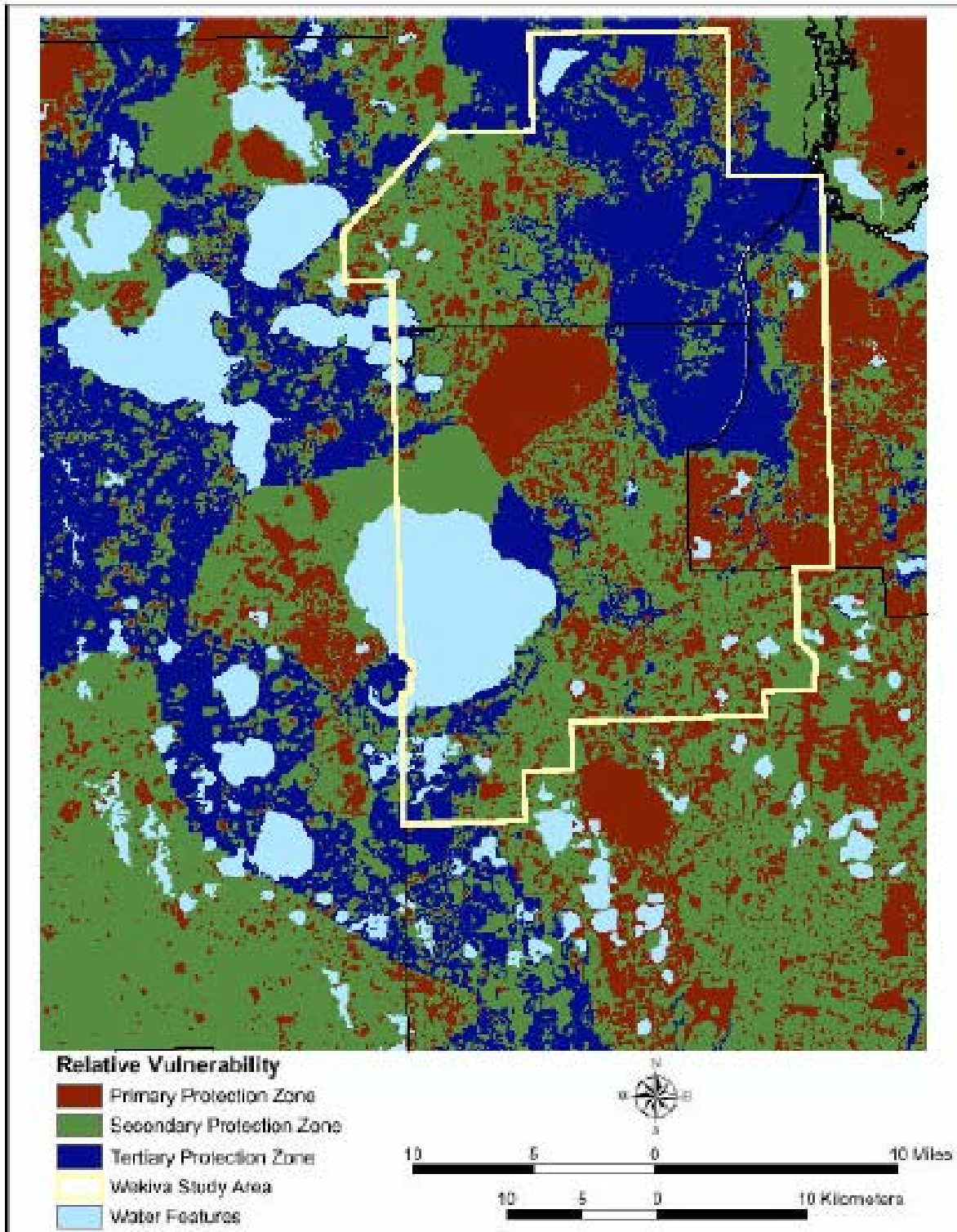
Figure 1. Relative Vulnerability of the Floridan Aquifer System WAVA model showing primary, secondary and tertiary protection zones.

The next study further evaluated nitrate N concentrations in the Wekiva groundwater basin by sampling wells in the basin as well as springs (Toth and Fortich, 2002). Fifty sites in the basin were sampled for nitrate N. This work also utilized isotope concentrations to estimate the source of nitrogen and the age of groundwater in the Wekiva groundwater basin, and correlated the age data with water quality and land use data to develop theories as to the source of nitrogen contamination in the basin. The water quality sampling conducted during this study indicated nitrate nitrogen concentrations in 22 of the 50 sample sites above the background concentration of 0.2 mg NO_3-N/L. The study indicated that the median age for groundwater in e Wekiva groundwater basin was 27.4 years, and that the highest nitrate N concentrations (>5 mg/L) occurring south and west of Lake Apopka were likely due to fertilizer applications for citrus production. At Wekiva springs, however, nitrate-nitrogen concentrations have been declining in recent years, and it was estimated from ^{15}N isotope data that the sources of nitrate contamination were a mixture of animal waste and fertilizers. The age determination for Wekiva Springs water suggested that the nitrate N contamination occurred by processes that took place approximately 17 years prior to the 1999 sampling.

Subsequent work by Toth (2003) looked at 17 additional springs in the SJRWMD and used similar techniques to estimate the age of spring water and source of nitrogen in springs with NO3-N concentrations above 0.20 mg/L. In this study, 5 of the 17 springs sampled were above the background level, the three most impacted springs had concentrations 3 – 5 mg NO_3-N/L. As in the 2002 study, the springs with the highest nitrate levels had the lowest delta nitrogen-15 content, and were thought to have been most impacted by synthetic fertilizers. All 5 of the springs were reported to have some indications of organic nitrogen contribution, presumably animal waste.

The USGS has also conducted groundwater studies in Central Florida recently, most notably the work of O'Reilly (1998), Adamski and Knowles (2001) and Adamski and German (2004). These studies were not focused on the WSA, but were of interest because they evaluated the surficial aquifer as well as the upper Floridan aquifer in Orange and Lake County. The studies evaluated gave an excellent overview of the hydrogeology underlying the WSA and areas surrounding it.

The ground-water flow system beneath the study area is a multi-aquifer system that consists of a thick sequence of highly permeable carbonate rocks overlain by unconsolidated sediments. The hydrogeologic units are the unconfined surficial aquifer system, the intermediate confining unit, and the confined Floridan aquifer system, which consists of two major permeable zones, the Upper and Lower Floridan aquifers, separated by the less permeable middle semiconfining unit. Flow in the surficial aquifer system is dominated regionally by diffuse downward leakage to the Floridan aquifer system and is affected locally by lateral flow systems produced by streams, lakes, and spatial variations in recharge. Ground water in the confined Upper Floridan aquifer system generally flows laterally to the north and east.

4.0 Assessment of Available Data Relative to OWTS

The studies and data available for the WSA provide an excellent summary of the hydrogeologic conditions of the area and a basis for water quality assessments of the resource, especially the Upper Floridan Aquifer.   It is clear from the data available that the water resources of the area are being negatively impacted by man's activities as related to nitrogen contamination. What appears to be lacking, however, are studies directly related to potential nitrogen sources, and the quantitative impact of each on water quality in the region. Such studies are necessary to develop a nitrogen balance for the WSA and to determine the most cost effective solutions to nitrogen reduction, such that optimal reductions can be accomplished for the limited financial resources that will be available. If this is not done, significant funds could be spent on nitrogen reduction strategies that yield minimal benefit.

Since detailed studies of cause and effect relationships for nitrogen contamination are expensive, studies at the planning level could be conducted first to make preliminary estimates of nitrogen source quantities. The results of these analyses could then be used to develop the "first cut" of leading nitrogen contributors, and further, detailed studies of these leading contributors could be used to develop optimal nitrogen reduction strategies.   An example of such a planning level estimate for onsite wastewater treatment systems (OWTS) is provided in the next section. Prior to discussing nitrogen loading from OWTS, however, a brief review of conventional OWTS technology is provided here to ensure common understanding of OWTS function and the terms used in subsequent sections. A detailed discussion of OWTS technology, performance, and management can be found in Anderson and Otis (2000).

Conventional septic tank systems are the most common technology used for OWTSs in the U.S. today and consist of three major components; 1) a septic tank; 2) a subsurface wastewater infiltration system (SWIS), sometimes referred to as a drainfield or leachfield; and 3) the unsaturated soil directly beneath the drainfield. Wastewater from the home or establishment flows to the septic tank and subsequently into the SWIS where it infiltrates the soil. Once in the unsaturated zone, some effluent is lost to evapotranspiration while the remainder is renovated as it percolates to groundwater (**Figure 2**). Since the 1970's, larger versions of conventional OWTS have been increasingly used by clusters of homes and small communities.
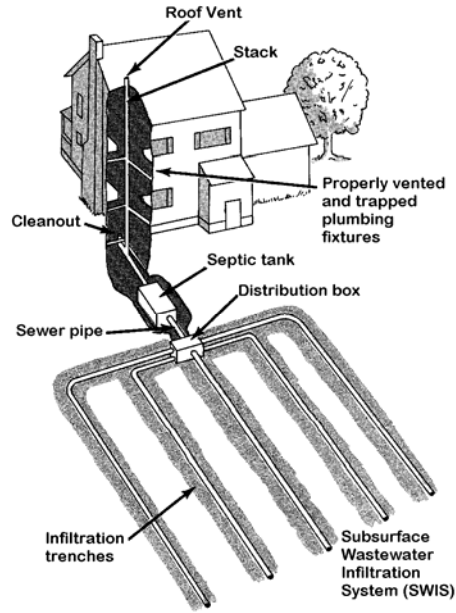
Figure 2. Typical onsite wastewater treatment system (OWTS) with septic tank and trench-type SWIS.

The septic tank provides primary treatment of the wastewater by sedimentation/flotation and sometimes screening, and removes the majority of the settleable solids, as well as grease and other floatable solids. A sludge layer forms at the bottom and a scum layer at the top of the liquid in the septic tank. The retained solids undergo anaerobic digestion in the tank, but eventually build up to where they must be removed. Volatilization of gases from digestion of solids are released in the tank and vented through the building plumbing system or tank outlet. **Figure 3** illustrates a cross section of a typical septic tank, although in Florida, two-chambered tanks or two tanks in series are now required for all new systems.
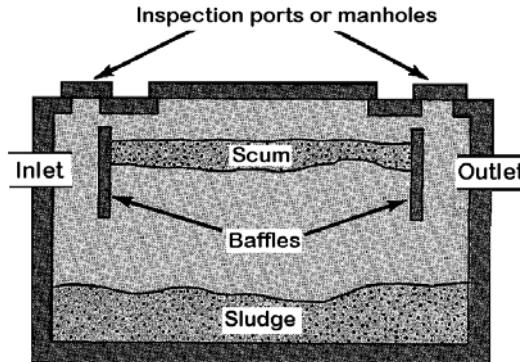

Figure 3. Cross Section of Typical Septic Tank

The subsurface wastewater infiltration system (SWIS) or drainfield delivers the septic tank effluent (STE) to the soil. Numerous types of SWIS exist, including effluent distribution by gravity, pressure, or a combination thereof. Also, various materials are used as media to allow STE distribution and infiltration into the soil. Most commonly gravel is used, but other materials include porous plastic, styrene porous media and various "chamber" systems which simply provide a support for open soil infiltrative area below ground. **Figure 4** provides a section view of a typical SWIS trench with gravity distribution to gravel media.
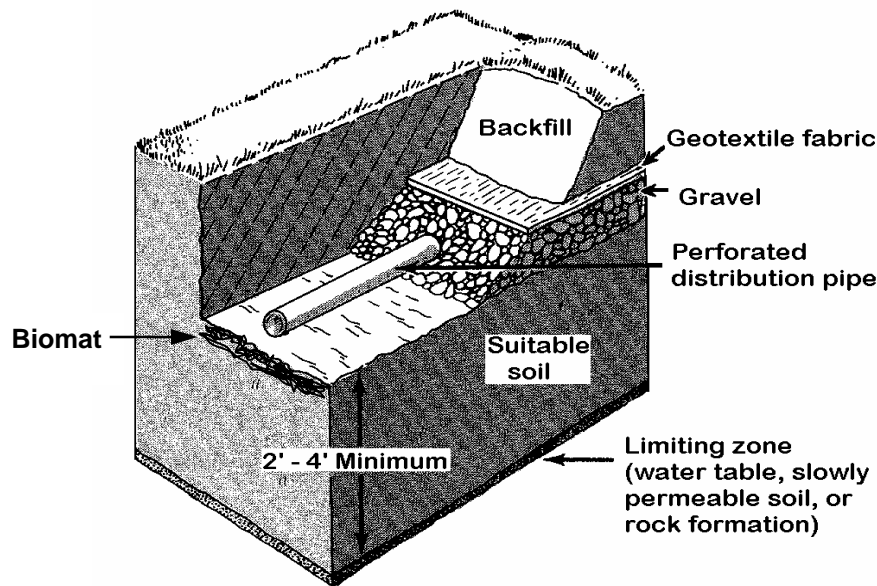

Figure 4. Section view of subsurface wastewater infiltration system (SWIS), trench-type design (From US EPA, 1980).

Physical, chemical, and aerobic and anaerobic biological treatment of STE occurs as it percolates through the unsaturated soil zone to groundwater. Physical straining (filtration) of solid particles occurs by the soil matrix and physical/chemical processes such as ion exchange and adsorption provides removal of dissolved pollutants which react with the soil properties. Other principal mechanisms of treatment in the soil are provided by the attached-growth biological processes which occur as microbial growth develops on the surface of the soil particles. This microbial growth is known as the biomat. An unsaturated zone of 2 - 4 feet is required below the bottom of the SWIS to obtain sufficient treatment levels prior to the effluent's reaching groundwater, and fill must be brought in to meet this requirement if suitable natural soil is not present. The unsaturated soil below the infiltration system is the most critical component of a conventional OWTS. It provides most of the treatment and ultimate disposal of the renovated wastewater provided that suitable, unsaturated soil is present.

4.1 Estimated N-loading by OWTS in the Wekiva Study Area

Nitrogen Loading to Septic Tank: Numerous studies have reported on the nitrogen contribution by individuals to wastewater systems, including OWTS. The U.S. EPA Onsite Wastewater Treatment Systems Manual provides a summary of literature sources for various pollutants, and estimates 11.2 grams of nitrogen per person per day as the average total nitrogen contribution to wastewater (Table 3-8, EPA, 2002). Based on the persons per household estimates for Orange, Seminole and Lake Counties, the average household size is approximately 2.6 persons per household (BEBR, 2004). This equates to an average of 10.6 kg N per home per year (or 23.4 lb. per home per year) discharged to wastewater systems. The FDOH has reported that there are approximately 55,417 OWTS in the WSA, which means that approximately 1.3 million pounds of nitrogen are discharged to OWTS per year.

Nitrogen Reduction by OWTS: If no reduction of nitrogen was provided by an OWTS, we could then compare this number to other estimated sources of N to determine how significant OWTSs are as a source. However, we know that some reduction of nitrogen is provided by OWTS, so we can take the next step in evaluating their impact.

A properly operating and maintained septic tank provides digestion of settled solids and some reduction of nitrogen through volatilization of ammonia and solids removal as septage. Estimates of up to 17% reduction in N content have been reported by U.S. EPA and others (EPA, 1980; Laak, 1982; Pell and Nyberg, 1989). Based on a 10% reduction in the septic tank, we could thus estimate that the 23.4 lb. N per home would be reduced to about 21.1 lbs with proper O&M. This estimate is reasonable based on studies of septic tank effluent flow and quality in Florida as part of the Florida Onsite Sewage Disposal System Research Project, conducted from 1986 – 1993 (Sherman and Anderson, 1991).

Once septic tank effluent is discharged from the septic tank to the subsurface wastewater infiltration system (SWIS), numerous physical, chemical, and biological processes take place in the unsaturated zone below the SWIS. The use of a SWIS for wastewater treatment is limited by characteristics of the selected treatment site. The "soil is the system." Therefore, SWIS performance is difficult to predict and monitor since each site is unique. Successful performance of OWTSs is achieved **only** if sufficient unsaturated soil exists below the SWIS to accept all wastewater it receives and provide sufficient final treatment before reaching groundwater. If failure should occur, environmental damage or health risks can result. Hydraulic failures, caused by excessive clogging of the infiltration zone or insufficient infiltrative surface area, can lead to wastewater backups in the building, or wastewater ponding on the ground surface and runoff from the treatment site into surface waters. Inadequate treatment by the soil matrix or the lack of sufficient soil can result in contamination of groundwater, and ultimately surface water through groundwater discharge. Therefore, the selection and design of a SWIS for wastewater treatment must be based on a thorough site evaluation and understanding of the interactions between applied wastewater, soil, and hydrogeology of the selected site.

Under suitable site conditions, conventional OWTSs are capable of advanced secondary levels of treatment for most domestic wastewater pollutants of concern. When at least two feet of unsaturated soil exist between the SWIS and the water table, BOD_5 removals of > 90%, TSS removals of >95% and fecal coliform reductions of >99% have been demonstrated in laboratory soil columns and OWTSs in the field (University of Wisconsin, 1978; Siegrist et al., 1986; Ebers and Bishofsberger, 1990; WPCF, 1990; Stolt and Reneau, 1991; U.S. EPA, 1992; Guilloteau et al., 1993; Duncan et al., 1994; Anderson et al., 1994).

However, nitrogen removals by conventional OWTSs are highly variable. Nitrogen in raw wastewater and septic tank effluent exists in the organic and ammonium nitrogen forms and is oxidized to nitrate-nitrogen by soil microorganisms as the wastewater percolates through the unsaturated zone. Denitrification takes place during this percolation and reduction in nitrogen concentrations of 10 to 74 percent have been reported in the literature (Sikora and Corey, 1976; Reneau, 1977; Harkin et. al., 1979; Jenssen and Siegrist, 1988; Stewart and Reneau, 1988; Alhajjar et. al., 1989; Siegrist and Jenssen, 1989; Stolt and Reneau, 1991; Degan, et. al., 1991; Mote and Buchanan, 1994; Duncan et al., 1994; Anderson et al., 1994, Chen and Harkin, 1998; Anderson, 1998; Anderson and Otis, 2000; EPA, 2002). The higher nitrogen removals in these studies occurred in dosed effluent systems where alternate wetting and drying cycles encouraged denitrification, where fluctuating water tables provided wetting and drying cycles, and in warmer climates where denitrification proceeds much more rapidly. Nonetheless, nitrate-nitrogen concentrations exceeding the drinking water standard of 10 mg/L as N have been found routinely in groundwater directly below conventional OWTSs (Star and Sawhney, 1980; Cogger and Carlile, 1984; Robertson et al., 1989; Ayres Associates, 1989; Converse et al., 1991; Converse et al., 1994; McNeillie et al., 1994; Anderson et al., 1994).

Based on the above, an estimate of 25% reduction of nitrogen in the unsaturated zone seems reasonable for the Wekiva area. Many systems in the area may remove more than 25% of N applied, but this figure agrees with results from the In-situ Lysimeter Experiments conducted by FDOH on well drained fine sands such Candler Fine Sand (Ayres Associates, 1993, Anderson et. al., 1994). A 25% reduction in the unsaturated zone would reduce the 21.1 pounds of N discharged to the SWIS to approximately 15.8 pounds per household per year discharged to groundwater. For the 55,417 reported OWTS in the WSA, this equates to approximately 876,000 pounds of N annually reaching groundwater below OWTS.

Once nitrate-N enters the groundwater, it has typically been assumed that it travels freely with groundwater and is reduced in concentration by dilution only. However, more recent study has shown that some degree of denitrification usually occurs in relatively shallow surficial aquifers. Denitrification occurs by specific denitrifying bacteria which utilize NO_3-N as an electon receptor under anoxic conditions or in anoxic micro-zones in the saturated soil, converting it to gaseous oxides of nitrogen (NO, N_2O, NO_2) or nitrogen gas (N_2), which are then released to the atmosphere. Denitrification also requires electron donors such as organic carbon, H_2, or reduced forms of sulfur. Organic carbon in the soil or remnant wastewater organic carbon is typically the electron donor as related to denitrification in wastewater treatment. Temperature is

also an important factor. Denitrification decreases markedly below 5 ^{o}C, and generally, a doubling of denitrification rate occurs with each 10 ^{o}C increase in temperature (Hiscock, 1991). Denitrification in Florida should therefore proceed more rapidly than in more northern climates.

There are numerous studies which have reported denitrification in surficial aquifers, however, many are not related specifically to OWTS, and therefore are not typically referenced in the OWTS literature (Bengtsson and Annadotter, 1989; Bradley et. al., 1992; Christensen et. al., 1989; Ekpete and Cornfield, 1965; Gayle et. al., 1989; Hiscock et. al., 1991; Morris et al., 1988; Slater and Capone, 1987; Smith and Duff, 1988; Trudell et. al., 1986; Ward, 1985;). In the agricultural and soil science literature, denitrification in surficial aquifers is generally assumed to occur; it is only the rate of denitrification that is of question. Many OWTS studies have documented reduction of nitrogen to background levels downgradient of the SWIS, but most have assumed this reduction was due to dilution because of the mobile nature of nitrate in solution, and few have followed up with the tedious effort required to determine if dilution is actually responsible or if denitrification played a role al some level. Studies of denitrification specific to OWTS have been documented, however, and several have shown significant reduction or elimination of nitrogen transport within a relatively short distance downgradient (Stewart and Reneau, 1988; Hinson et al., 1994; Anderson, 1998; Chen and Harkin, 1998).

Therefore, there should be some assumption of N-reduction from surficial groundwater denitrification applied to the 876,000 pounds of N per year estimated for OWTS loading. The reduction from denitrification is difficult to estimate however, due to the variability of soil and groundwater conditions in the WSA. This is an area where additional data is needed to refine the estimate of N loading from OWTS. Groundwater monitoring of the surficial aquifer with distance, directly downgradient of OWTS could provide considerable insight and provide the needed refinement to this estimate if conducted properly.

4.2 Assessment of Proposed N-Reduction Requirements for OWTS

As part of the WPPA, the FDOH was responsible for developing recommendations for more stringent levels of wastewater treatment in the Wekiva Study Area. A discussion of their proposed rule language is provided in this section.

Proposed Treatment Technology: The FDOH has proposed rules requiring performance based treatment systems with a nitrogen discharge limit of 10 mg/L at the outlet of the tank. This would be followed by a drip irrigation dispersal system installed no more than 9 inches below finished grade. This rule would require use of an onsite wastewater nutrient reduction system (OWNRS) similar to those required in the Florida Keys, except phosphorus removal would not be required. These systems are relatively complex, mechanical treatment systems that operate similarly to a municipal wastewater treatment plant (WWTP) with biological nitrogen removal. Maintaining consistent performance with this type of system requires considerable attention to operation and maintenance to meet effluent limits of 10 mg/L. Experience in the Florida Keys and elsewhere suggest that systems of this type at individual homes do not

perform as well as expected, especially for nitrogen removal (Roeder, 2005; La Pine Oregon Demonstration Project, 2006). **Figure 5** provides test results for numerous treatment technologies for nitrogen reduction in the La Pine Oregon National Demonstration Project funded by the U.S. EPA.   Fourteen different treatment systems were evaluated, and typically several of each type were installed at individual residences and tested for over 1 year. As the figure shows, only 1 of 14 treatment system types met the project performance standard of 10 mg/L TN and only 4 of 14 treatment system types produced nitrogen effluent values that averaged below 20 mg/L TN. Several systems produced results comparable to septic tank effluent form a conventional OWTS which was monitored as a baseline.   The best performing system was a porous media denitrification unit that utilized precisely the same processes described in section 4.1 for denitrification below SWIS in natural soils, but with an engineered organic carbon rich media.
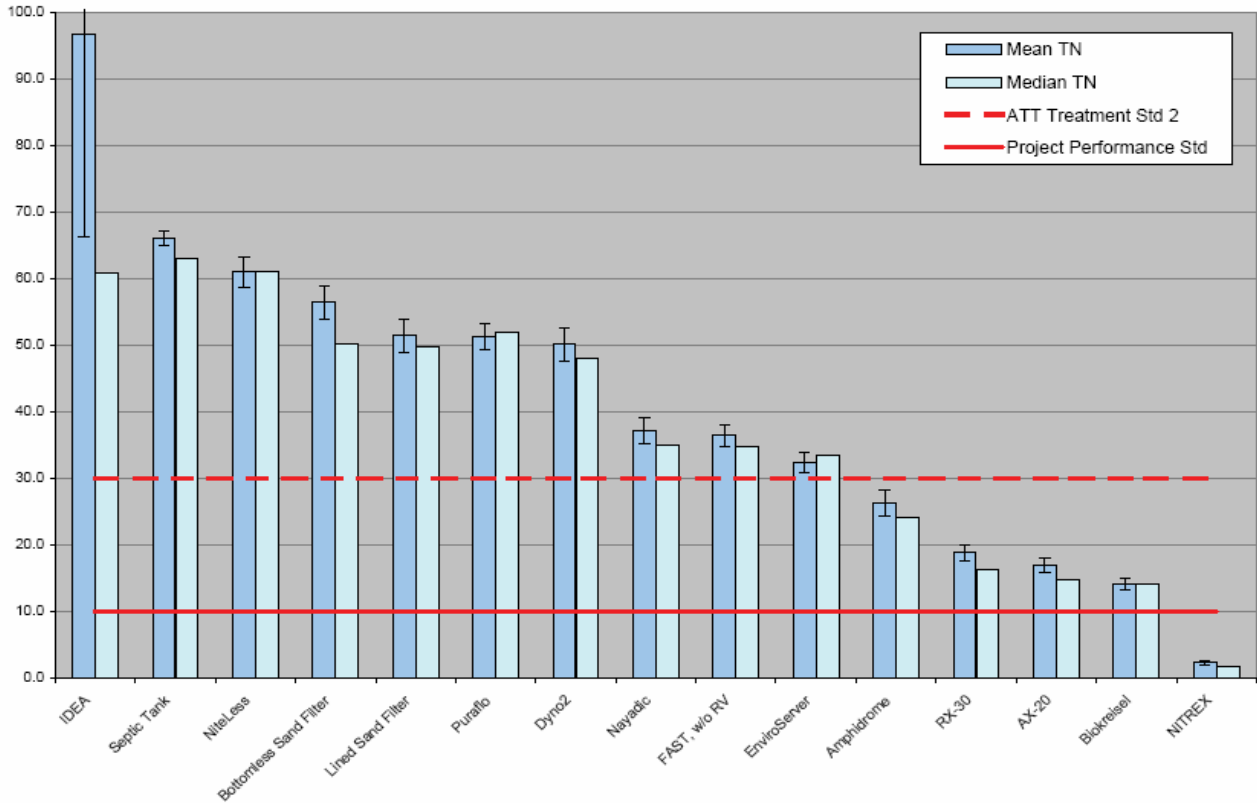

Figure 5. Performance of Advanced Wastewater Treatment Systems in the La Pine National Demonstration Project.

The majority of the systems tested would not have produced a benefit over a conventional OWTS installed in suitable soil. In fact, results of denitrification studies by Degen et. al. (1991) suggest that septic tank effluent (STE) discharged to the unsaturated soil zone result in significantly greater denitrification than nitrified aerobic treatment unit effluent. The reason for

this is the biomat that is formed at the soil infiltrative surface with STE application and the organic carbon available in the STE as a carbon source for denitrification. Aerobic treatment system effluent is typically very low in CBOD, does not create a biomat on the soil surface and has very little organic carbon remaining to be utilized as an electron donor for denitrification.

Life-Cycle Cost: Due to their mechanical complexity, the costs of OWNRS type systems are also significantly higher than conventional or dosed OWTS. Cost data developed during the Monroe County Sanitary Wastewater Master Plan (CH2M Hill, 2000), and the Phillippi Creek Septic System Replacement Project in Sarasota County, Florida (Hazen and Sawyer, 2000; Burden et. al., 2003) were used to estimate the cost of the proposed system for the WSA. An estimated capital cost of approximately $12,000 and an annual O & M cost of approximately $1100 was estimated for the required system. Based on an amortization of the capital cost over 20 years at 7% interest, the total annual cost of such a system to the homeowner would be approximately $2232.71 per year. This yields a cost of $186 per month for each homeowner impacted by the rule. This O & M cost does not include sufficient water quality analyses costs to monitor system operational parameters and which are needed as a basis for operational changes to maintain performance. Quarterly sampling of the system with lab analysis would add approximately $400 per year to this cost.

Based on the actual performance of these units in the field without adequate monitoring and operational adjustments, it would be difficult to justify more than approximately 5 pounds (a 10 to 15 mg/L reduction) of additional N removal over a conventional OWTS discharging to suitable soil. Assuming a 5 pound annual additional decrease in N discharge would result in a cost of $446 per pound of N removed by the required systems. If additional denitrification can be assumed for the conventional system based on soil type or surficial aquifer conditions, then it is likely that very little additional benefit would be achieved by the proposed systems relative to conventional systems.

There are other ways to improve OWTS performance without as much cost. Literally tens of thousands of existing OWTS in Florida installed prior to "modern" code requirements may not have proper separation from groundwater. Establishment of operating permits for all OWTS, with requirements for septic tank maintenance and upgrade of non-compliant systems to current standards would therefore certainly increase the performance of the existing OWTS base. Requiring timed dosing of all systems and shallow drainfield placement would contribute to increased performance as well. Other more passive methods of N removal could also be investigated, such as addition of organic carbon material to drainfield media, or effluent recirculation. The cost and benefit of these alternative strategies would need to be evaluated to determine their overall cost effectiveness for achieving N reduction goals.

5.0 Other Nitrogen Sources in the WSA

Estimates of N loading from other sources in the WSA can be made in similar fashion to the estimate for OWTS in Section 4.0. This section provides some basic data that is readily available and could be used as a starting point by scientists familiar with each of the sources discussed. Numerous other sources would need to be identified and evaluated in the overall process, this section is meant to illustrate how a planning level nitrogen balance for the WSA could be prepared.

5.1 Fertilizers

Numerous studies have referenced fertilizer as the likely source of N contamination of shallow groundwater (Toth, 1999; Toth and Fortich, 2002, Toth, 2003; Katz et al.,1999; Dietrich and Hebert, 1997; Kendall 1998; Hornsby, 1994). As development has increased in Florida and the WSA, fertilizer use has shifted from an agricultural base of use to residential use of fertilizers for lawn and garden application.

The State of Florida Department of Agriculture and Consumer Services (FDACS) tracks fertilizer use in Florida, and produces and annual report entitled "Summary Report of Fertilizer Materials and Fertilizer Mixtures Consumed in Florida". Table 2 below provides excerpts from the 2004 – 2005 annual report along with land area data from the Florida Statistical Abstract (2004).

Table 1. Annual Fertilizer Nitrogen Consumption in Lake, Orange, and Seminole Counties, 2004-2005

County	Land Area (acres)	Total Fertilizer (tons/yr)	N Content (tons/yr)	Ave. N Applied (gross lbs. N/acre/yr)
Lake	609,984	26,796	3,196	10.5
Orange	580,864	74,769	7,498	25.8
Seminole	197,248	33,887	2,506	25.4
TOTALS	1,388,096	135,452	13,200	19.0

Based on this data, approximately 135,452 tons of fertilizers containing 26,400,000 pounds of nitrogen are utilized annually in the three counties. On a gross per acre basis, approximately 25 pounds per acre per year is consumed when all fertilizer N is divided by total land area in the counties. The exception to this is Lake County, because a large portion of Lake County is in the Ocala National Forest, where fertilizer application probably does not occur.

An estimate of fertilizer nitrogen loading for the WSA can then be generated from this data as a starting point for a planning level comparison. Based on the reported land area of 300,000 acres in the WSA and a gross application rate of 25 pounds per acre per year, the estimated N loading from fertilizers would equate to 7.5 million pounds of N per year. This estimate would need to be reduced by estimates of plant uptake, volatilization, and transport efficiencies much

like the OWTS estimate in the previous section, but this could be done by experts in agricultural and soil sciences to develop a better estimate of N loading to groundwater and surface waters.

The gross estimate of 7.5 million pounds annually from fertilizer should be compared to the 1.3 million pounds annually discharged to OWTS to evaluate the relative significance of the two sources.

While N contamination from fertilizer use is often considered an agricultural impact resulting from crop fertilization to increase production, the FDACS data for Lake, Orange and Seminole Counties indicates that approximately 63% of the annual fertilizer N consumption is for non-farm uses. Also, fertilizer use in the three counties increased from 112,325 tons in the1992-93 report compared to 135,452 tons in the 2004-05 report. These data suggest that fertilizer use will probably not decline significantly as development overtakes agricultural acreage.

5.2 Atmospheric Deposition

Atmospheric deposition of nitrogen refers to nitrogen deposited on the land surface in rainfall, dust, dew, or any other atmospheric source. Atmospheric nitrogen generally enters the aquatic environment in one of two forms: inorganic nitrogen that is solubilized in rainwater or particulate organic and mineralized nitrogen that settles by gravity to the surface or is scrubbed from the air by rain. Atmospheric nitrogen deposition thus covers the entire watershed area, and can be a significant component of runoff to lakes, rivers, streams and estuaries. It also infiltrates into soil and can undergo processes similar to wastewater and fertilizer nitrogen as it percolates through the unsaturated soil to groundwater.

Since nitrogen is the major component of the air we breathe, some atmospheric deposition occurs even in remote, pristine environments. However, man's impact on the environment has extended to the atmosphere in the form of air pollution, which emanates from many sources including burning of fossil fuels, fertilizer use, agricultural practices, wastewater treatment, and chemical manufacturing, to name a few. As a result, atmospheric deposition has increased dramatically in recent decades, and generally has the most impact in and around highly urbanized areas.

Most soluble, inorganic nitrogen in atmospheric deposition originates from volatilization of ammonia-nitrogen, increased denitrification and nitrogen fixation from agricultural practices, and combustion of fossil fuels. Ammonia volatilization can occur from chemical manufacturing, application of liquid ammonia fertilizers, manure, sludge and septage application to land, wastewater treatment plant emissions, and other industrial processes. Increased denitrification, primarily from fertilizer use (both inorganic and organic) results in emission of various oxides of nitrogen (NOx) into the atmosphere and also increased nitrogen fixation by crops such as legumes that fix nitrogen from the atmosphere. The burning of fossil fuels in vehicles, power plants, and industrial processes also release considerable quantities of NOx into the

atmosphere in urban areas, which eventually form nitric acid and return to the environment as acid rain or dry deposition.

Without detailed air quality, rainfall, and dry deposition monitoring in the specific area of concern, estimating atmospheric deposition is difficult. Significant work in the area of atmospheric deposition has been accomplished recently through efforts of the National Estuary Program and subsequent state and local estuary programs, where efforts to accurately determine nutrient balances for estuary protection have resulted in considerable data collection in the area of atmospheric deposition. In the Tampa Bay area, nitrogen atmospheric deposition data reported from the Tampa Bay Atmospheric Deposition Study (TBADS) and the Bay Regional Atmospheric Chemistry Experiment (BRACE) estimated that approximately 1.8 million pounds of nitrogen per year were deposited directly to the surface of Tampa Bay in 2001 (Poor, 2002). This estimate did not include the portion of nitrogen loading in stormwater runoff that was due to atmospheric deposition, which may be a larger quantity considering the size of the Tampa Bay watershed.

Rates for atmospheric deposition of nitrogen on an areal basis from available literature ranged from 6.9 to 16.6 pounds of nitrogen per acre per year for urban sites in the U.S. (Poe et. al., 2005, EPA, 1993). Applying these rates to the 300,000 acres of the WSA results in an estimate of 2.1 to 5.0 million pounds of nitrogen per year from atmospheric deposition. As before, this loading would be subject to the same processes described earlier once deposited at land surface. However, since much of the deposition would fall on impermeable surfaces, some of this nitrogen would runoff directly into surface waters.

5.3 Development of a Nitrogen Balance

Other nutrient sensitive areas in Florida and the U.S. have developed nitrogen loading estimates and a nutrient balance for the watershed prior to determining strategies for remediation and protection of the resource. The objective of these nitrogen balance determinations was to quantify each identified source contribution, even if only at a planning level, so that various nitrogen reduction strategies could be evaluated. Financial resources typically do not allow reduction in nitrogen loadings from all sources, so it is important to spend the available dollars where they will do the most good for protection of water quality. For example, it would not be prudent to spend 60% of the available funding to reduce nitrogen loading from sources that only contributed 6% of the problem, when the same expenditure could have reduced nitrogen loading by 20% if focused on a more cost-effective nitrogen reduction strategy.

Figure 6 presents the nitrogen loading developed for Chesapeake Bay, another area of the U.S. that has experienced nutrient loading problems, especially nitrogen. As the figure shows, many sources of nitrogen exist that may not have been immediately obvious without considerable study of the watershed.   Efforts are now underway to develop strategies for nitrogen reduction from major sources.
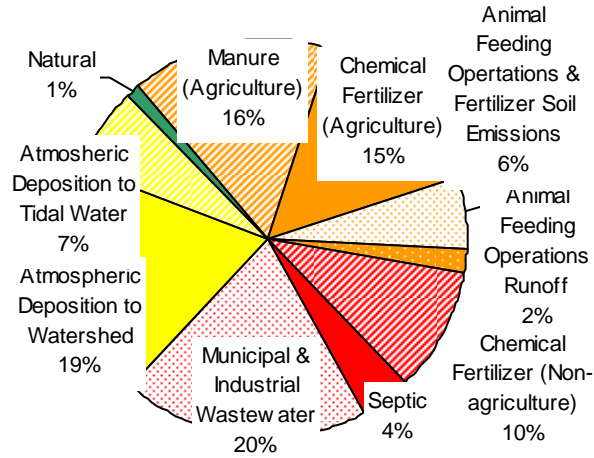
Figure 6. Sources of Nitrogen Loads to Chesapeake Bay.
Source: Chesapeake Bay Program Phase 4.3 Watershed Model.

Figure 7 illustrates the relative contribution to the average N loading from 1990 – 1999 for the area contributing recharge to Wakulla Springs, in Leon and Wakulla Counties (Chelette and Pratt, 2002). This is a karst area similar in many respects to the WSA, and is also experiencing nitrogen concentration increases in the springs. In the case of Wakulla Springs, it appears that wastewater treatment plant effluent and residuals disposal, as well as atmospheric deposition make up a large part of the estimated nitrogen load within the springshed.
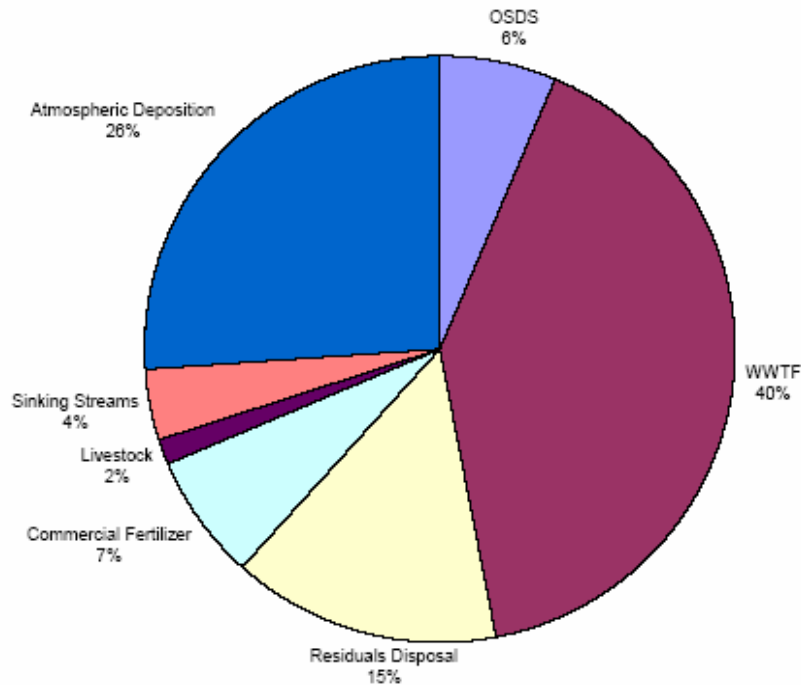

Figure 7. Relative Contribution from Inventoried Nitrogen Sources to the 1990 – 1999 Average N Loading in the Wakulla Springs Contributory Area.

Figure 8 illustrates the N loading to Tampa Bay based on work by the Tampa Bay Estuary Program (Poe et. al., 2005). Non-point source and atmospheric deposition loadings make up the majority of the nitrogen load to Tampa Bay, and stormwater runoff is the primary component of the non-point source contributions. Atmospheric deposition is suspected as a primary component of the stormwater contribution, and estimates of this source are ongoing.

Earlier work by SWFWMD estimated that OWTS were a relatively small component of the total N load to the Bay, at less than 300 tons/year (Ayres Associates, 1995). Efforts in the Tampa Bay Program are focusing on improvements to stormwater treatment and air pollution as nitrogen reduction strategies.
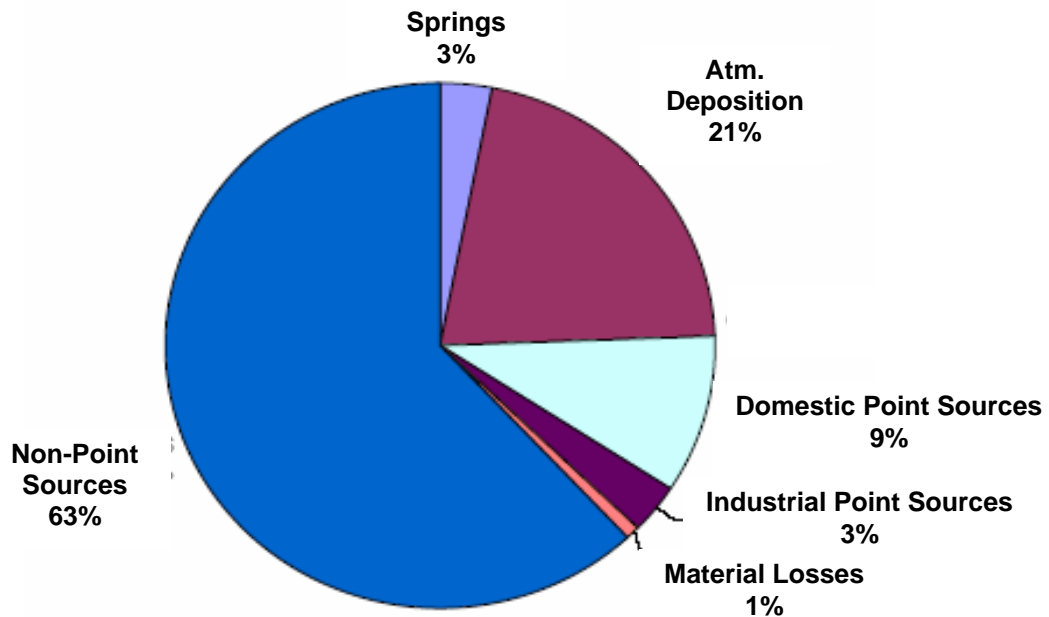

Figure 8. Percentage Contributions from Various Sources to Mean Annual TN Loadings to Tampa Bay for the 1999-2003 period.

6.0 Summary and Conclusions

The Wekiva Parkway and Protection Act (WPPA) was signed into law by Governor Bush on June 29, 2004, at Wekiva Springs State Park, in Apopka. The Act authorizes building the Wekiva Parkway and provides protection to the Wekiva River System, including establishment of the Wekiva Study Area (WSA).

As part of the WPPA, the Florida Department of Health was required to study the efficacy and applicability of onsite wastewater treatment system (OWTS) standards needed to achieve nitrogen reductions protective of groundwater quality within the WSA. The WPPA specifically states that the FDOH consider a more stringent level of wastewater treatment to reduce the level of nitrates as well as implementation of a septic system maintenance and inspection program which includes upgrading certain OWTS permitted prior to 1982 to meet current FDOH standards. The FDOH has put forth proposed rule language pertaining to the WSA in 64E-6.001; and recent language proposed as of November 2, 2005 would require performance-based treatment systems with a total nitrogen discharge limit of 3.0 milligrams per liter at 24 inches below the bottom of the drainfield, or a total nitrogen discharge limit of 10.0 milligrams per liter at the outlet of the tank and a drip irrigation drainfield installed no more than 9 inches below finished grade.

Several stakeholder groups in the WSA have expressed concerns as to whether sufficient data exists on OWTS impacts to water quality to justify the considerable cost of the proposed FDOH rules. Hazen and Sawyer was retained by these stakeholders through the Florida Home Builders Association (FHBA) to review available supporting documentation on the issue. Specifically, the available water quality and nitrogen loading data from anthropogenic sources in the Wekiva Study Area was to be reviewed in order to understand the relative significance of nitrogen loading from properly installed, operated, and maintained OWTS. The scope of this effort was limited to a review of the available studies and data referenced in the WPPA supporting documents related to water quality issues in the WSA, and to then make a preliminary assessment of OWTS impacts relative to the measures that have been recommended to mitigate these impacts.

Based on the documents reviewed and other available data gathered, the following conclusions were developed relative to nitrogen sources, especially OWTS, in the WSA.

1. It is clear from the data available that the water resources of the area are being negatively impacted by man's activities as related to nitrogen contamination. What appears to be lacking, however, are studies directly related to potential nitrogen sources, and the quantitative impact of each on water quality in the region.

2. No studies specific to OWTS nitrogen loading in the WSA were identified. However, based on preliminary estimates of nitrogen loading for OWTS and several other sources developed in this paper, it appears that they are not one of the leading nitrogen loads in the WSA, and this result agrees with other watershed nitrogen balances in Florida and elsewhere. A worst-case nitrogen loading of approximately 1.3 million pounds from

OWTS should be evaluated relative to 7.5 million pounds from fertilizer use and from 2.1 to 5.0 million pounds from atmospheric deposition, annually, for example.

3. The wastewater discharged to conventional OWTS undergoes numerous physical, chemical, and biological processes that serve to renovate the wastewater and reduce the quantity of pollutants that are discharged to groundwater.   In terms of nitrogen, it is likely that the worst-case loading above would be reduced by over 30% or more, depending on soil and groundwater conditions relative to denitrification of nitrate-nitrogen. Reductions of over 70% have been reported in the literature, and the climate in Florida is conducive to higher denitrification rates than more northern locations. More specific study of OWTS in the WSA would be needed to refine an accurate estimate of N loading from OWTS.

4. The FDOH proposed rules would require the use of relatively complex, mechanical treatment systems that operate similarly to a municipal wastewater treatment plant (WWTP) with biological nitrogen removal. Maintaining consistent performance with this type of system requires considerable attention to operation and maintenance to meet effluent limits of 10 mg/L. Experience in the Florida Keys and elsewhere suggest that systems of this type at individual homes do not perform as well as expected, especially for nitrogen removal. Available data indicates that effluent total nitrogen concentrations averaging over 30 mg/L are not unusual for these systems in the field. Thus, experience in the field suggests that the performance-based treatment systems proposed by the FDOH may not significantly reduce nitrogen loadings from OWTS relative to conventional systems that are properly installed, operated and maintained.

5. The cost of these advanced treatment systems are significantly higher that conventional OWTS. It was estimated that the total life cycle cost of such a system would be on the order of $186 per month if capital costs were amortized over a 20 year period and combined with the O&M costs. This cost compares to estimated costs for similar studies in Sarasota and Monroe Counties.

6. The requirement to upgrade OWTS to performance-based systems for nitrogen removal may not be appropriate considering the cost of the systems relative to their benefit. However, without the necessary data to quantify all nitrogen sources, it is impossible to scientifically evaluate the relative contribution of OWTS to the overall nitrogen loading in the WSA, and to evaluate any benefit the FDOH proposed rule might have on water quality.

7.0 Recommendations

It is impossible to scientifically evaluate the relative contribution of OWTS to the overall nitrogen loading in the WSA, and to evaluate any benefit the FDOH proposed rule or any other proposed strategy might have on water quality without the necessary data to quantify all nitrogen sources. Implementation of rules without this knowledge could result in significant funds being spent on nitrogen reduction strategies that yield minimal benefit. Since limited financial resources typically exist for programs such as the WPPA, strategies that yield the lowest cost per pound of nitrogen reduction will provide the greatest protection of water quality in the Wekiva Study Area, and should be the strategies pursued. Therefore, the following recommendations are offered to maximize the reduction of nitrogen from sources in the Wekiva Study Area.

1. Further identify and refine source quantities, first with readily available data. Once estimates for all identified sources have been made, an estimate of existing N loading to ground and surface waters should be generated from literature values or experience in the field.

2. An initial ranking of sources should then be developed, and the largest sources studied in greater detail as necessary to refine the estimates.

3. Refined nitrogen loading estimates should be input into groundwater models or even simple mass balances to see if the N loading values established could reasonably be responsible for the increased nitrogen concentrations identified in groundwater and springs. A study similar to the Lower St. Marks-Wakulla Rivers Watershed study by the NWFWMD (Chelette and Pratt, 2002) would result, and provide considerable additional information with which to base decisions on nitrogen reduction strategies in the WSA.

4. Once agreement on preliminary source quantities has been established, the cost of future nitrogen reduction options should be estimated for each source. Various nitrogen reduction strategies can then be compared on a cost per pound of N basis.

5. In regards to OWTS, there are other strategies recommended to improve performance with less cost., some of which could be implemented without study.

   - Literally tens of thousands of existing OWTS in Florida were installed prior to "modern" code requirements and may not have proper separation from groundwater or surface water. Therefore, establishment of operating permits for all OWTS, with requirements to upgrade non-compliant systems to current standards would certainly increase the performance of the existing OWTS base.

   - Operating permits should also require routine septic tank maintenance, and this would also improve performance.

   - Requiring timed dosing of all systems and shallow drainfield placement would contribute to increased performance as well, especially for nitrogen reduction.

- Other more passive methods of N removal could also be investigated, such as addition of organic carbon material to drainfield media, or effluent recirculation. The cost and benefit of these alternative strategies would need to be evaluated to determine their overall cost effectiveness for achieving N reduction goals.

These recommendations are not a simple exercise, and they are made much more difficult by the complex karst terrain of the Wekiva Study Area. However, if protection of water quality in the WSA is the goal, then a structured, scientific evaluation of all nitrogen sources and their potential for cost-effective reduction is needed to ensure that proposed regulations address those sources that can yield the greatest benefit for the limited dollars available.

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