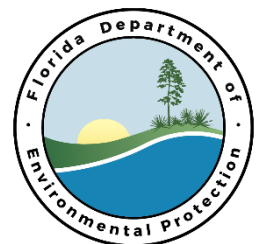


NITROGEN SOURCE INVENTORY AND LOADING ESTIMATES FOR THE WEEKI WACHEE SPRING AND RIVER CONTRIBUTING AREA

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This assessment was conducted by the Florida Department of Environmental Protection Ground Water Management Section of the Water Quality Evaluation and Total Maximum Daily Loads (TMDL) Program to assist in the development and implementation of the Weeki Wachee Spring Basin Management Action Plan (BMAP) to address the TMDL for nitrate. The results of this assessment are based on the information provided in the document.

Disclaimer: Please note that all values listed in this report are rounded, while the actual calculations were completed utilizing whole numbers.

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SUMMARY OF FINDINGS

Weeki Wachee Spring is a first-magnitude spring that discharges water from the karstic Upper Floridan aquifer (UFA), creating the Weeki Wachee River in Hernando County, Florida. The spring discharged an estimated average of 174 cubic feet per second (cfs) from 1935 to 2004. There are a number of other smaller springs and seeps in the Weeki Wachee Spring basin, including Wilderness Spring, Salt Spring, Mud Spring, Hospital Spring, Jenkins Spring, and Little Spring.

Weeki Wachee Spring and Weeki Wachee River were identified as impaired because of ecological imbalances attributed to elevated nutrient concentrations. In 2014, a total maximum daily load (TMDL) of 0.35 milligrams per liter (mg/L) (Dodson and Bridger 2014) was developed to establish water quality restoration thresholds for both the spring and river. Elevated nitrate concentrations in the spring result from current and historical land use practices that have contributed large amounts of nitrogen to groundwater in the spring basin.

The Florida Department of Environmental Protection (DEP) developed a Nitrogen Source Inventory and Loading Tool (NSILT) to provide information on the major sources of nitrogen (atmospheric deposition, wastewater treatment facilities [WWTs], urban fertilizers, septic systems, livestock wastes, agricultural fertilizers) in the groundwater contributing area for Weeki Wachee Spring. In addition, this tool is used to estimate nitrogen loads to groundwater from these sources in the spring contributing area.

NSILT is an ArcGIS- and spreadsheet-based tool that provides spatial estimates of the relative contribution of nitrogen from major nitrogen sources, and accounts for the transport pathways and processes affecting the various forms of nitrogen as they move from the land surface through the soil and geologic strata overlying the UFA.

This report describes the methods, information, and data sources used in developing the NSILT to estimate nitrogen loads to groundwater in the Weeki Wachee Spring contributing area. The information is provided as a planning tool for the development and implementation of a basin management action plan (BMAP), which addresses the nitrate impairment in Weeki Wachee Spring, Weeki Wachee River, and Aripeka Spring.

The NSILT is being used in the BMAP development process to identify source categories and areas where nitrogen source reduction efforts could be focused to achieve the most beneficial effects on water quality for Weeki Wachee Spring and Weeki Wachee River. The total annual nitrogen input to the land surface in the contributing area from all sources is 6.3 million pounds of nitrogen (lb-N). Urban and sports turfgrass fertilizers contributes 30% of the TN input. Other nitrogen sources, in order of decreasing nitrogen inputs to the land surface, include livestock waste (21%), farm fertilizer (19%), atmospheric deposition (18%), septic systems (10%), and wastewater treatment facility (1%).

The NSILT results indicate an estimated total annual load of 1,004,655 pounds of nitrogen to the UFA in the Weeki Wachee Spring groundwater contributing area, representing 16% of the amount of nitrogen inputs to the land surface. Most of the nitrogen in a given year does not reach groundwater due to nitrogen attenuation processes and variations in the rate of aquifer recharge. In areas of the Weeki Wachee springshed where recharge rates are categorized as low (0 to 3 inches per year [in/yr]) medium (3.01 to 10 in/yr) or high (greater than 10 in/yr), the UFA is more vulnerable to contamination than in areas where recharge rates are low.

Groundwater discharge areas were not included in the calculations of nitrogen loads to the groundwater contributing area, as these areas do not contribute nitrogen to the aquifer. To account for variations in recharge rates to the UFA, non-attenuated nitrogen inputs in high rate recharge areas are multiplied by a weighting factor of 0.9, while nitrogen inputs are multiplied by a weighting factor of 0.5 for medium rate recharge areas and 0.1 for low.

The highest estimated nitrogen loads in the groundwater contributing area to Weeki Wachee Spring are from urban turfgrass fertilizer (29%), followed by septic systems (28%) and farm fertilizers (16%). Sources contributing smaller amounts of nitrogen include atmospheric deposition (9%), livestock waste (9%), sport turfgrass fertilizer (4%), and the land application of treated wastewater (4%).

The NSILT results provide a baseline understanding of existing nitrogen loads to groundwater from multiple sources in areas where the Weeki Wachee Spring basin is most susceptible to groundwater contamination. This tool can also be used to evaluate the nitrogen load reduction benefits of various management actions and nitrogen reduction projects at various locations in the Weeki Wachee Spring contributing area.

1. INTRODUCTION

In Florida, springs provide sites of recreational and cultural value as well as sources of potable water, and afford a way to assess regional groundwater quality. Springs integrate groundwater vertically, spatially, and temporally from the Upper Floridan aquifer (UFA) (Bush and Johnston 1988; Katz 1992, 2004; Davis 1996). Rainfall that infiltrates into the subsurface and recharges the aquifer system contains nitrogen and other dissolved chemicals of concern originating from anthropogenic activities at or near the land surface. Groundwater with elevated nitrate concentrations flows toward Weeki Wachee Spring.

Elevated nitrate concentrations in Florida's springs contribute to water quality degradation in their receiving surface waters. This problem will continue if nitrogen inputs are not reduced. Restoration plans to reduce these inputs must include strategies to address the most significant nitrogen sources by obtaining detailed nitrogen loading information from sources in springsheds such as fertilizer applied to cropland and turfgrass, septic tanks, the land application of treated domestic wastewater, atmospheric deposition, and animal wastes.

To identify and quantify the major sources of nitrogen in groundwater contributing areas to springs, the Florida Department of Environmental Protection (DEP) developed the Nitrogen Source Inventory and Loading Tool (NSILT). This tool quantifies nitrogen inputs to the land surface based on the best available, current information on land uses, agricultural practices, urban fertilizer use, waste disposal methods, and atmospheric sources. The NSILT is also used to estimate nitrogen loads to groundwater in the contributing area by taking into account the attenuation of various forms of nitrogen from sources and recharge rates to the UFA. The NSILT results are used in the development and implementation of the basin management action plan (BMAP) for the Coastal Springs of Pasco and Hernando Counties—including Weeki Wachee Spring and River, Wilderness Spring, Salt Spring, Mud Spring, Hospital Spring, Jenkins Spring, and Little Spring—by helping to focus nitrogen source reduction efforts to achieve the greatest improvement in water quality.

1.1 Weeki Wachee Spring and Weeki Wachee River Basin

Weeki Wachee Spring is an historic and world-renowned tourist attraction located in Weeki Wachee Springs State Park. This first-magnitude spring is the primary source of water for the 7-mile-long Weeki Wachee River. Several smaller springs, including Little Spring and Hospital Spring, are located throughout the spring basin and along the river. The Weeki Wachee Spring pool is 165 feet by 210 feet and 45 feet deep over the spring vent. The spring vent is a small opening through exposed limestone rock at a depth of 185 feet (Dodson and Bridger 2014).

In 2009, Weeki Wachee Spring, the Weeki Wachee River, and other springs in the vicinity were verified as impaired because of ecological imbalances attributed to elevated nutrient concentrations. In 2014, a total maximum daily load (TMDL) was developed to establish a water quality restoration threshold for nitrate-N of 0.35 milligrams per liter (mg/L) for both Weeki Wachee Spring and River, and a TMDL of 0.23 mg/L for additional springs, including

Wilderness Spring, Salt Spring, Mud Spring, and Jenkins Spring (Dodson and Bridger 2014; Bridger and Dodson 2015).

Elevated nitrate concentrations in Weeki Wachee and other springs result from current and historical land use practices contributing nitrogen to the UFA, the highly transmissive limestone aquifer that is the source of water flowing from the springs. The NSILT is being used to provide stakeholders with current information on the sources of nitrogen in the Weeki Wachee Spring contributing area and the relative nitrogen contributions of each source to the UFA. More important, the NSILT is being used as a planning tool for the development and implementation of the BMAP for the Coastal Springs of Pasco and Hernando Counties to address the water quality impairment.

1.2 Weeki Wachee Spring Groundwater Contributing Area

Weeki Wachee Spring is located near the Gulf Coast of Florida in Hernando County (**Figure 1**). The groundwater contributing area for the spring lies in Hernando County in the north and Pasco County in the south. This area is largely based on the springshed boundary delineated by the Southwest Florida Water Management District (SWFWMD) (Jones et al. 1997) and is the source of groundwater flowing to Weeki Wachee Spring. The contributing area covers 162,714 acres. Land uses comprise 33% urban landscapes, 24% forested areas, 21% agriculture, and 16% wetlands and marshes. The remaining 6% includes waterbodies, rangeland, and miscellaneous land uses.

The Weeki Wachee Spring contributing area comprises most of the region addressed in the larger BMAP area for coastal springs in Hernando and Pasco Counties, as shown in **Figure 2**. A separate NSILT analysis will be conducted for the groundwater contributing area to Magnolia and Aripeka Springs in fall 2016.

1.3 Hydrogeology and Aquifer Recharge

The Floridan aquifer system in this area is composed of thick sequences of limestone and dolostone of Eocene to Miocene age that are exposed at or very near to (10 to 20 feet) the land surface (Dodson and Bridger 2014). The UFA is the predominant source of water discharging from Weeki Wachee Spring (Jones et al. 1997; Faulkner 1970).

The dissolution of the carbonate rocks that comprise the UFA has created numerous karst features (sinkholes, caves, and conduits) over geologic time in this area. These features, along with a thin layer of sediments overlying the UFA, allow water from the land surface to move directly and relatively rapidly into the aquifer.

Consequently, the movement of groundwater into the UFA responds relatively quickly to changes in rainfall and recharge, and groundwater flows directly to springs where conduits are present. Groundwater discharging from the springs originates from both nearby source areas and more distant areas in the springshed. As a result, Weeki Wachee spring water is a mixture of

groundwater that has resided in the aquifer for varying amounts of time, ranging from days to several decades.

Most of the drainage within the Weeki Wachee springshed is internal, and rainwater that recharges the UFA infiltrates from the land surface directly into closed depressions or through thin overlying sediments into the unconfined limestone of the UFA. Jones *et al.* (1997) and Dodson and Bridger (2014) describe the hydrogeologic framework for this area in greater detail. Recharge rates to the UFA are affected by spatial variations in the hydrogeological characteristics of the surficial aquifer and intermediate confining unit, karst features, and average annual rainfall.

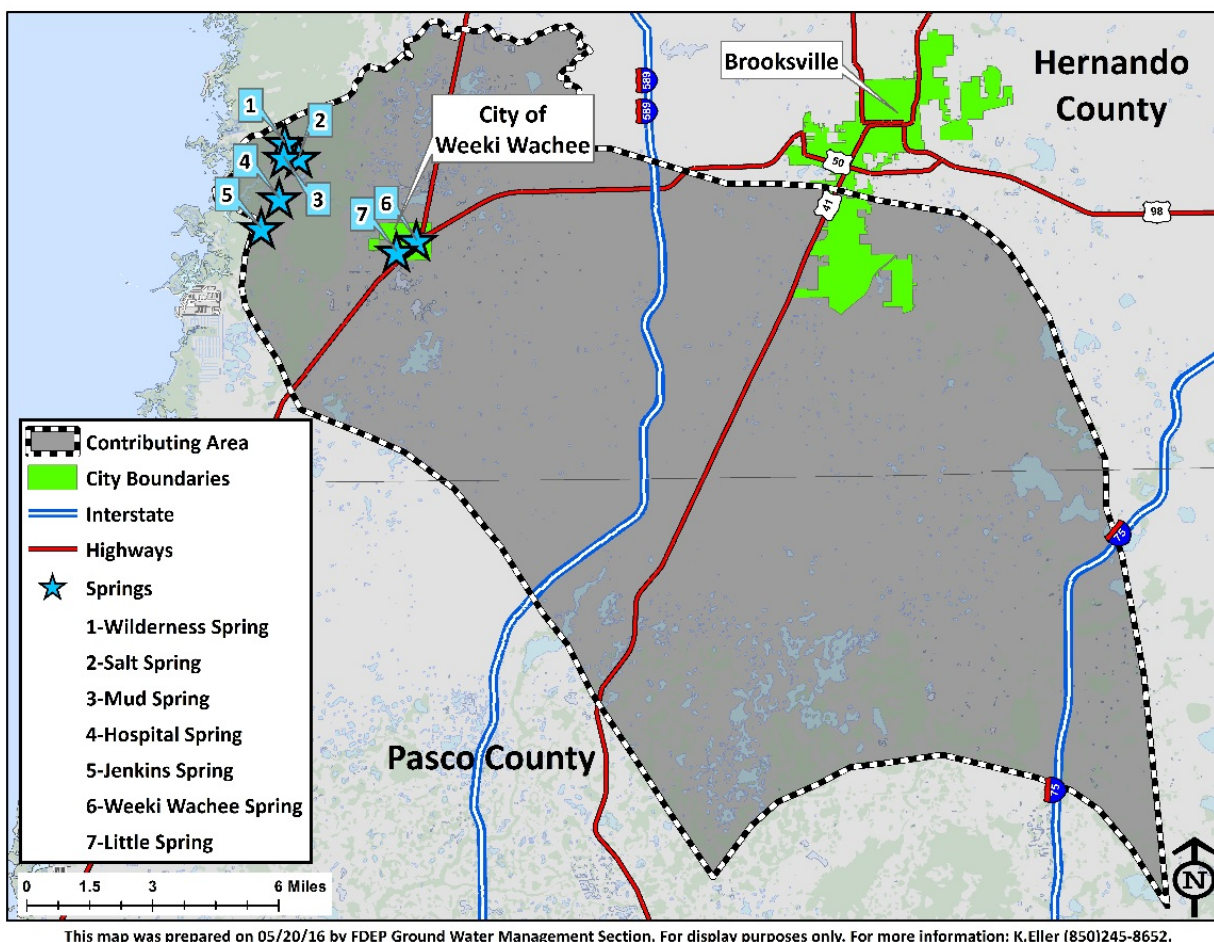


Figure 1: Map showing the Weeki Wachee Spring and Weeki Wachee River contributing area

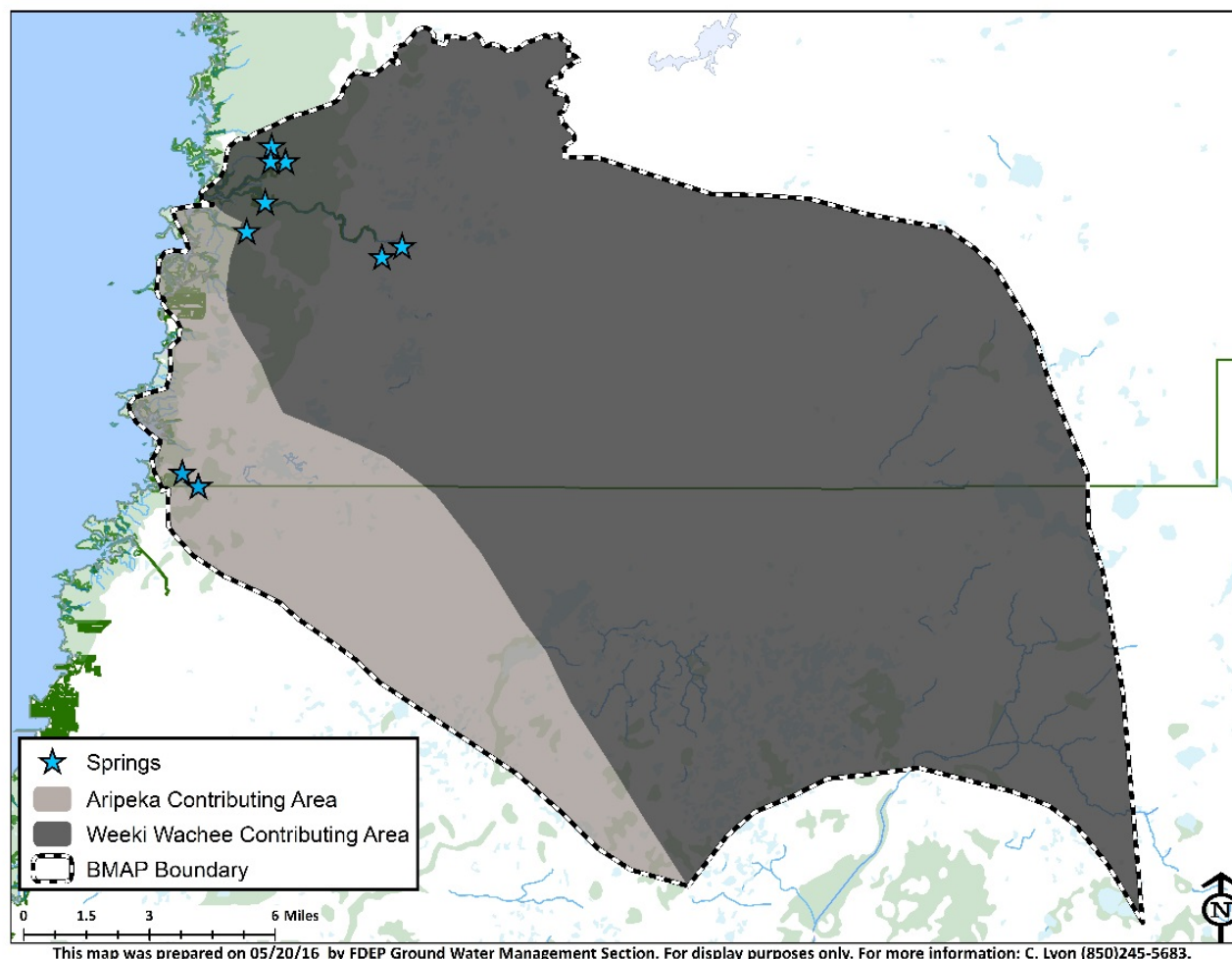


Figure 2: BMAP area for the coastal springs of Pasco and Hernando Counties

In 2002, the U.S. Geological Survey (USGS) developed a numeric model of the intermediate and Floridan aquifer systems based on well data from 1993–94 (Sepulveda 2002). The model area spans over 40,000 square miles of peninsular Florida and is composed of uniform model grid dimensions of 5,000-foot cells. The USGS raster-based data were smoothed to create 3 recharge rate categories in the Weeki Wachee BMAP area: low (0 to 3 inches per year [in/yr]), medium (3.01 to 10 in/yr), and high (10.01 in/yr or greater) (**Figure 3**). The amount of annual recharge affects the transport of nitrogen to the aquifer. Therefore, it is likely that more nitrogen would reach the aquifer annually in high recharge rate areas than in lower recharge rate areas, if both areas were to receive similar nitrogen inputs to the land surface.

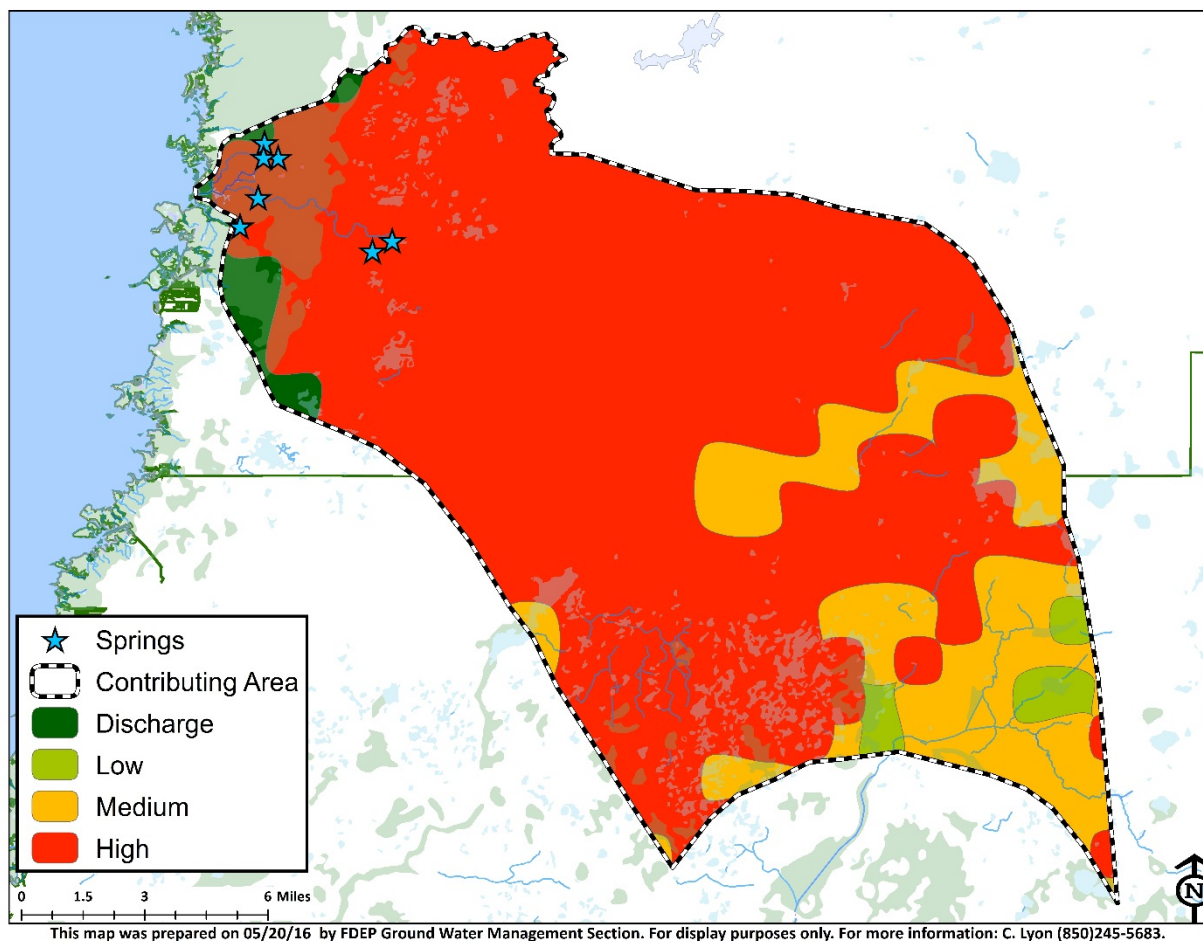


Figure 3: UFA recharge rate categories in the Weeki Wachee Spring contributing area

1.4 Land Use

Land use/land cover (LULC) was assessed with the most recent land use ArcGIS coverages obtained from the SWFWMD and county property appraisers. The Weeki Wachee Spring contributing area lies completely within the SWFWMD boundary. All land use classifications used by the SWFWMD were based on the Florida Land Use/Land Coverage and Forms Classification System (FLUCCS). The 2011 land use was created through the interpretation of digital imagery taken in December 2010. The land use classifications were determined through photo interpretation, editing, and quality check processes. **Table A.2** and **Table A.3** provide additional details of these data.

Additional land use information was obtained from the Hernando and Pasco County property appraisers. Staff from each county property appraiser's office conduct routine field visits to update and verify the land use classification of parcels for tax purposes. These visits occur at least every five years, although most parcels are visited more frequently. This system allows for continual updates and for 2014 data to be used for this analysis (**Table A.4** and **Table A.5**).

For the assessment of current land use, the property appraisers also provided detailed information on the specific agricultural practices used for estimating nitrogen contributions from fertilizer use on farmland. The land use information obtained from property appraisers is designated as "PA" in this report.

2. ESTIMATING NITROGEN INPUTS TO THE LAND SURFACE

Nitrogen inputs to the land surface in the BMAP area were evaluated for atmospheric deposition, wastewater treatment facility (WWTF) land application sites, septic systems, urban and agricultural fertilizer application, and livestock waste. The methods used to estimate nitrogen inputs for each source are based on a detailed synthesis of information, including direct water quality measurements, census data, surveys, wastewater permits, published scientific studies and reports, and information obtained in meetings with agricultural producers.

In many cases, several assumptions and extrapolations were made for estimating nitrogen inputs from each source, and as a result the nitrogen inputs presented in this report are subject to further refinement as more detailed information becomes available. The approach and sources of information used to estimate the annual nitrogen input (in pounds per year [lb-N/yr]) to the land surface for each source category are discussed below.

2.1 Atmospheric Deposition

Atmospheric deposition is largely a diffuse, albeit continual, source of nitrogen. Nitrogen species and other chemical constituents are measured in wet and dry deposition at discrete locations around the U.S. In Florida, the Clean Air Status and Trends Network (CASTNET) has two stations that collect dry deposition data for analysis. Wet deposition data currently are collected at nine stations around the state as part of the National Atmospheric Deposition Program (NADP) National Trends Network (NTN).

Recently, Schwede and Lear (2014) developed a hybrid model for estimating the total atmospheric deposition (TDEP) of nitrogen and sulfur for the entire U.S. Deposition data from several monitoring networks—including CASTNET, the NADP Ammonia Monitoring Network, the Southeastern Aerosol Research and Characterization Network, and modeled data from the Community Multi-Scale Air Quality Model—are combined in a multistep process with National Trends Network wet deposition values to model total deposition in 16-kilometer (km) grid cells.

Multiple TDEP model runs are available, providing atmospheric data for individual and multiple years, with average values calculated for the multiyear models. The TDEP model run used for the NSILT includes data from 2011 to 2013. The total nitrogen (TN) data are available in a nationwide coverage (.e00) file and were converted into ArcGIS shapefiles for the purpose of this analysis. **Figure 4** illustrates the model results for TN deposition in the Weeki Wachee Spring contributing area. The total nitrogen deposition amounts in high, medium, and low recharge rate areas are 923,127 lb-N/yr; 197,713lb-N/yr; and 24,093 lb-N/yr, respectively.

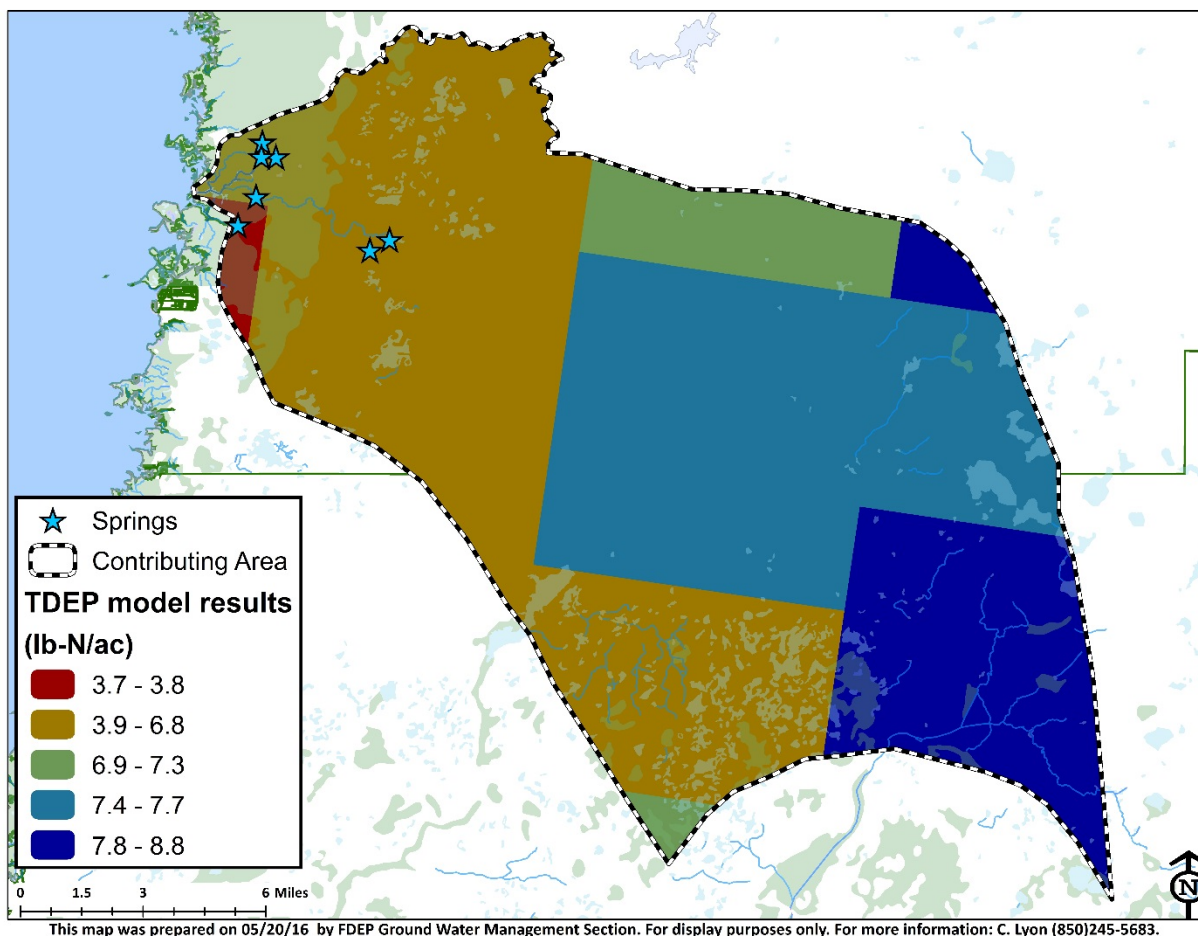


Figure 4: Atmospheric deposition model results used for the NSILT

2.2 Wastewater Treatment Facilities

WWTFs receive and treat domestic wastewater. In the Weeki Wachee Spring contributing area, treated effluent containing nitrogen from WWTFs is discharged to sprayfields, rapid infiltration basins (RIBs), and percolation ponds. While other areas in Florida use reclaimed water from WWTFs for irrigation and fertilization, these practices are not currently being used in this contributing area. There are 14 WWTFs located in the Weeki Wachee Spring contributing area, 3 in Pasco County and the remaining 11 in Hernando County. There are 2 facilities discharging more than 100,000 gallons of treated effluent per day (**Figure 5**). Additionally, there are 2 facilities located outside of the Weeki Wachee contributing area which distribute reclaimed water for irrigation within the contributing area.

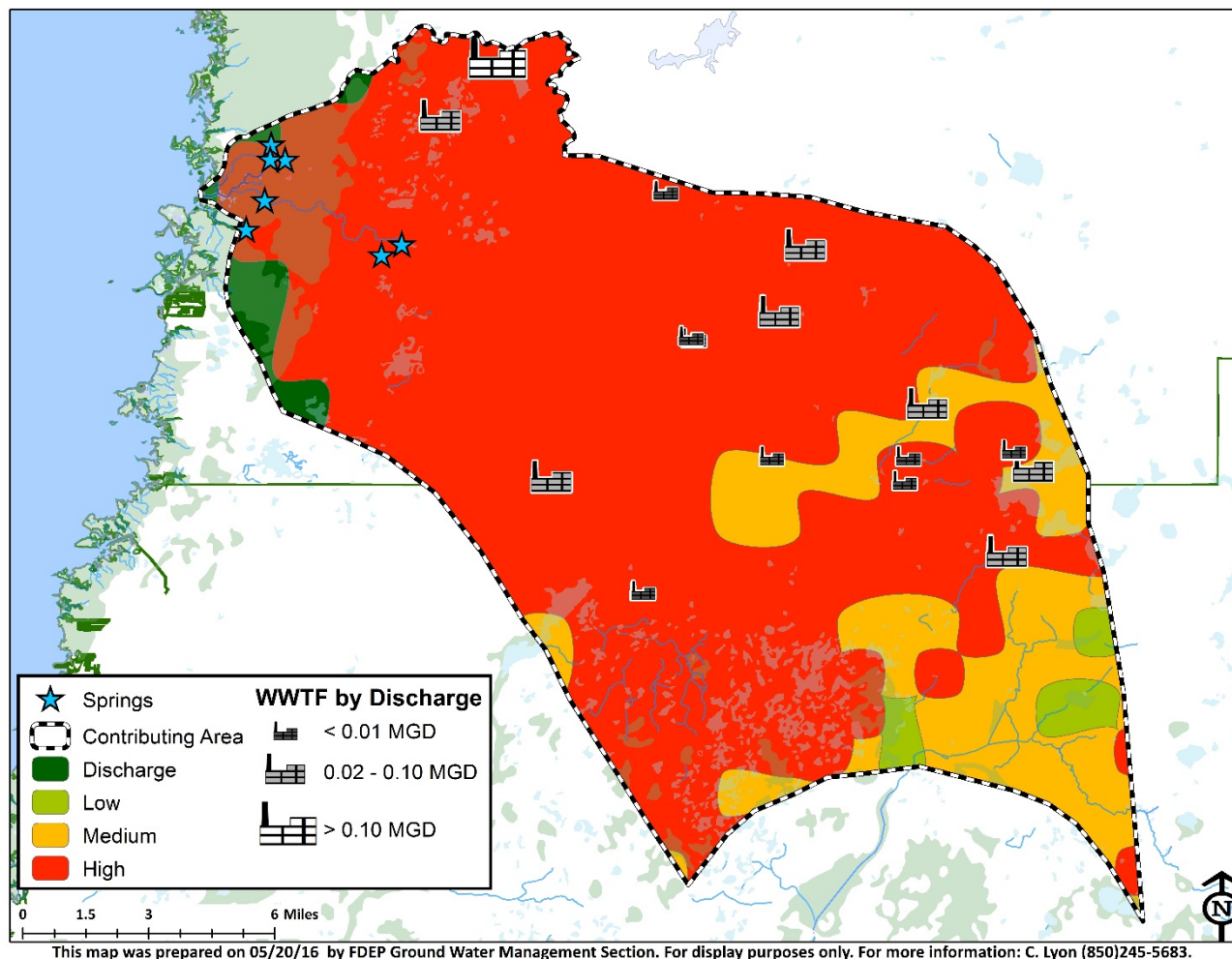


Figure 5: Distribution of WWTFs in the Weeki Wachee Spring contributing area

The required water-quality monitoring varies between facilities depending on permitting requirements, and not all facilities report the same type of data. The annual effluent input of nitrogen to the land surface was estimated using the average TN concentration and the discharge (volume), but this information was not always available for smaller facilities. Smaller WWTFs (<0.1 million gallons per day [MGD] by volume) are not always required to monitor and report TN effluent concentrations, and therefore not all these facilities had data available in the DEP Wastewater Facility Regulation (WAFR) Database.

For these, DEP estimated TN concentrations from nitrate-N ($\text{NO}_3\text{-N}$) data (assuming the $\text{NO}_3\text{-N}$ concentration was 38.5% of the TN based on a 2009 cooperative study with the Water Reuse Foundation of 40 domestic WWTFs across the state). For this calculation, the $\text{NO}_3\text{-N}$ value is divided by 0.385, resulting in an estimated TN concentration. The WWTF data were compiled for each facility and include the most recent complete year of data. The years of data vary with the individual facilities; however, the majority of the data is from 2013 to 2014.

For facilities permitted for the land application of treated wastewater, the reported annual average flows were used to calculate an average discharge for the evaluated year applied to sprayfields, RIBs, and absorption fields. For the purpose of this analysis, absorption fields are included with RIBs because they have similar processes that attenuate nitrogen. The nitrogen inputs for each WWTF were calculated using the average annual TN concentration and the average yearly flow from the facility. The average annual nitrogen inputs from wastewater facilities were estimated for each recharge rate category based on the location of the effluent treatment sites in the contributing area.

Table 1 and **Table 2** summarize the nitrogen input data from facilities in the contributing area. In total, an estimated 39,796 lb-N/yr are applied to the land surface from these facilities in the high recharge rate areas, and an additional 602 lb-N/yr are applied in the medium recharge rate areas. Without any facilities located in the low-recharge areas, there is no attributable nitrogen input to the land surface.

Table 1: Data for Hernando County WWTFs in the Weeki Wachee contributing area

* TN data estimated based on available NO₃ data.

WWTF Name	Facility ID	Treatment Type	Recharge Area	Annual Average TN (mg-N/L)	Annual Flow (MGD)	Nitrogen Input (lb-N/yr)
Hernando Subregional Airport	FLA017223	RIB	High	13.23*	0.74	29,740
Glen Water Reclamation Facility	FLA012069	RIB	High	3.93	0.60	7,228
Camper's Holiday Association	FLA012045	RIB	Medium	10.66*	0.01	389
Lakewood Retreat	FLA017033	Sprayfield	Medium	8.97	0.01	213
Topics RV Community	FLA012065	RIB	High	4.99*	0.01	146
Eckerd Academy	FLA012039	RIB	High	20.78*	0.002	127
Imperial Estates	FLA012059	RIB	High	4.33*	0.01	123
Camp-A-Wyle Resort	FLA012044	RIB	High	4.38*	0.01	115
CoGoP State Campground	FLA012066	RIB	High	17.52*	0.001	70
Big Tree MH and RV Village	FLA012048	RIB Absorption Field	High	0.54*	0.01	19
Eckerd Youth Challenge Program	FLA186830	Sprayfield	High	1.40*	0.002	10

Table 2: Data for Pasco County WWTFs in the Weeki Wachee contributing area

* TN data estimated based on available NO₃ data.

WWTF Name	Facility ID	Treatment Type	Recharge Area	Annual Average TN (mg-N/L)	Annual Flow (MGD)	Nitrogen Input (lb-N/yr)
Travelers Rest	FLA012831	RIB	High	26.08*	0.03	2,171
Big Oaks RV Park	FLA012756	RIB	High	2.83*	0.003	29
Shady Hills Elementary School	FLA012719	RIB	High	9.33*	0.001	20

Additionally, the Spring Hill WWTF (FLA012043), located in Hernando County within the Magnolia and Aripeka Springs contributing area, is permitted to distribute reclaimed water for irrigation. This reuse water is transferred to the Timber Pine Country Club in the Weeki Wachee contributing area and is therefore included in this analysis. Timber Pines comprises a 258-acre area, with 83% located in the high-recharge rate area and the remainder in the discharge area. The golf course uses 1.26 MGD of reclaimed water, with 1.05 MGD applied at a concentration of 16.9 mg-N/L in the high-recharge area, equaling an annual nitrogen input of 53,873 lb-N to the land surface.

Another facility, City of Brooksville Cobb Road WWTF (FLA012036), located in the Chassahowitzka contributing area also transfers reclaimed water into the Weeki Wachee contributing area to the golf course and residential areas of Southern Hills. Approximately 275 acres are irrigated associated with this property and are located in the high recharge rate area of Weeki Wachee. An estimated 0.51 MGD is applied at a concentration of 16.95 mg-N/L (projected TN value) equaling an annual nitrogen input of 26,375 lb-N to the land surface.

2.3 Septic Systems

On-site sewage treatment and disposal systems (OSTDS), commonly referred to as septic systems, are widely used throughout the Weeki Wachee Spring contributing area where municipal sewer is not available. These systems can contribute to elevated nitrogen concentrations in groundwater (Chang et al. 2010).

In 2009, a Florida Department of Health (FDOH) contractor developed a statewide model for estimating the number of septic systems based on tax parcel data and known sewer service areas (Hall and Clancy 2009). The model relied on septic system permit data from FDOH, as well as information from public utilities on their sewer collection systems and service areas, to estimate the type of service provided to individual land parcels not accounted for by a permit or sewer connection. For example, it was assumed that a septic system would be found in an area where sewer service was unlikely. The output of the model is provided in an ArcGIS geodatabase where the locations of both known and probable septic systems can be mapped.

The model may overestimate the number of septic systems. In some parts of Florida, the land use data used by Hall and Clancy (2009) projected future housing development. However, some of the parcels projected by the model to be subdivided remained intact as one parcel with one septic system rather than multiple septic systems. This resulted in a higher estimate of projected septic systems than what is actually in place.

To improve the accuracy of the septic system estimates, the model results were correlated with current land use information from property appraisers. Any parcel containing more than one septic system was further evaluated as follows:

- Parcels identified as single-family residential were reduced to only one septic system per parcel.
- Parcels with three or fewer septic systems and an associated land use likely to contain more than one septic tank (i.e., condominiums, multifamily dwellings, or businesses) were left unchanged.
- All remaining parcels were individually assessed using current aerial imagery to verify or correct the number of septic systems within the parcel boundary.

This final data layer was used to estimate the total number of septic systems for the medium and high recharge rate areas in the contributing area and is referred to as the "modified Hall and Clancy" dataset (**Figure 6**). As more information becomes available, this coverage can be further modified or replaced with more accurate coverage and included in future iterations of the model.

After the number of septic systems in the contributing area was determined, the population served by septic systems was estimated using the [2010 United States Census Bureau data](#) for population and household occupancy in each county. The Census makes a distinction between occupied and nonoccupied households. The county population was divided by the number of occupied households in the county, resulting in an average number of people per occupied household (2.41 in Hernando County and 2.45 in Pasco County).

However, many people with a home septic system potentially have access to a facility connected to a sewer system during their weekly routine (i.e., work, school), reducing nitrogen inputs to the septic system. To estimate the effective number of people per household and the associated nitrogen input to septic systems, population age distribution information was obtained for Hernando and Pasco Counties from the 2010 Census. In Hernando County, 53.0% of the population is of school or working age and, according to the Bureau of Labor Statistics, spends 43.5 hours or 25.9% of the week away from home and therefore are not using the septic system. This effectively reduces the number of people per household using septic systems in Hernando County by 13.7%, resulting in an adjusted number of 2.08 people per household. A similar calculation was made for Pasco County, which has a school or working age population of 60.5%, resulting in an adjusted number of 2.07 people per household (based on a reduction of 15.7%).

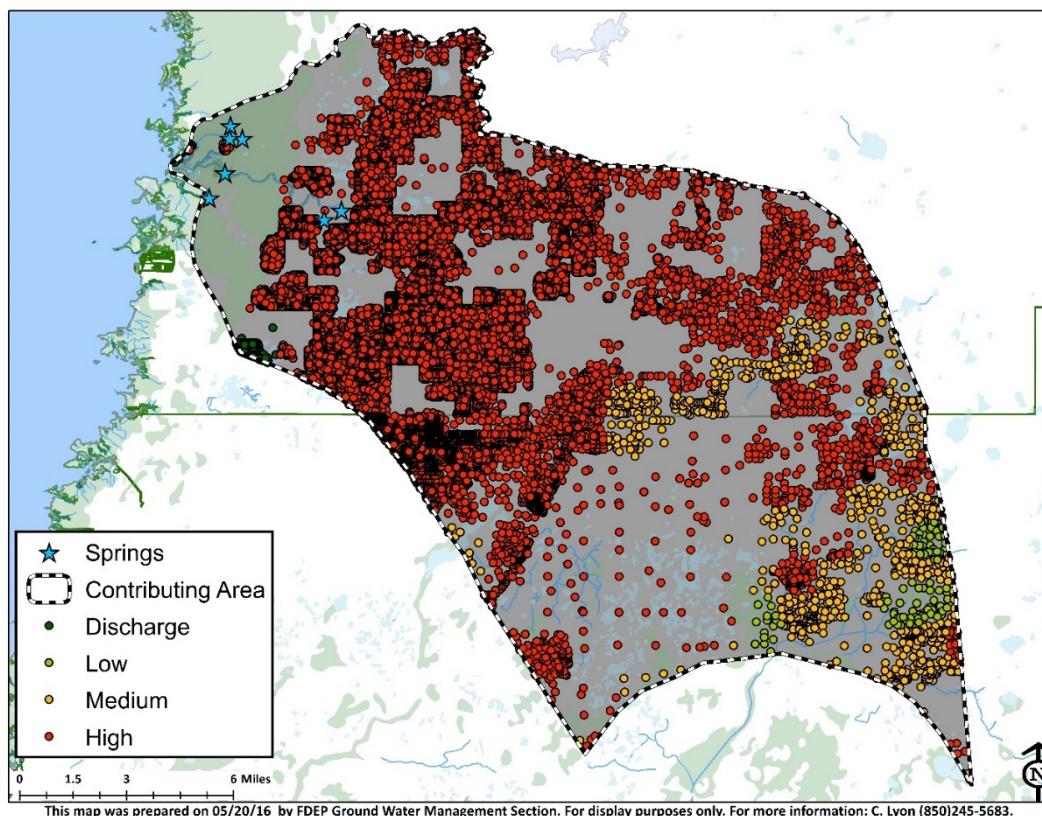


Figure 6: Distribution of septic systems throughout the Weeki Wachee Spring BMAP area

The total population in the Weeki Wachee contributing area served by septic systems was estimated by multiplying the estimated number of people per household by the number of septic systems. Several literature sources have reported a per capita contribution of 9.012 lb-N/yr, and this value was multiplied by the estimated number of people using septic tanks within the different regions of the contributing area (U.S. Environmental Protection Agency [EPA] 2002; Toor et al. 2011; Viers et al. 2012). **Table 3** summarizes the septic system data.

Table 3: Estimated number of septic systems and associated input to the land surface

Land Category	Number of Septic Systems	Estimated Input to Land Surface (lb-N/yr)
Hernando High Recharge	29,768	557,321
Hernando Medium Recharge	310	5,804
Pasco High Recharge	3,206	59,713
Pasco Medium Recharge	780	14,528
Pasco Low Recharge	137	2,552

2.4 Urban Turfgrass Fertilizer

2.4.1 Fertilizer Application Rates

Fertilizers applied to turfgrass typically found in urban areas (including residential lawns and commercial and public green spaces) are referred to as urban turfgrass fertilizers (**Figure 7**). Results from surveys and workshops pertaining to fertilizer application on turfgrass in nearby counties were used to estimate the nitrogen application rates for urban turfgrass in the Weeki Wachee area.

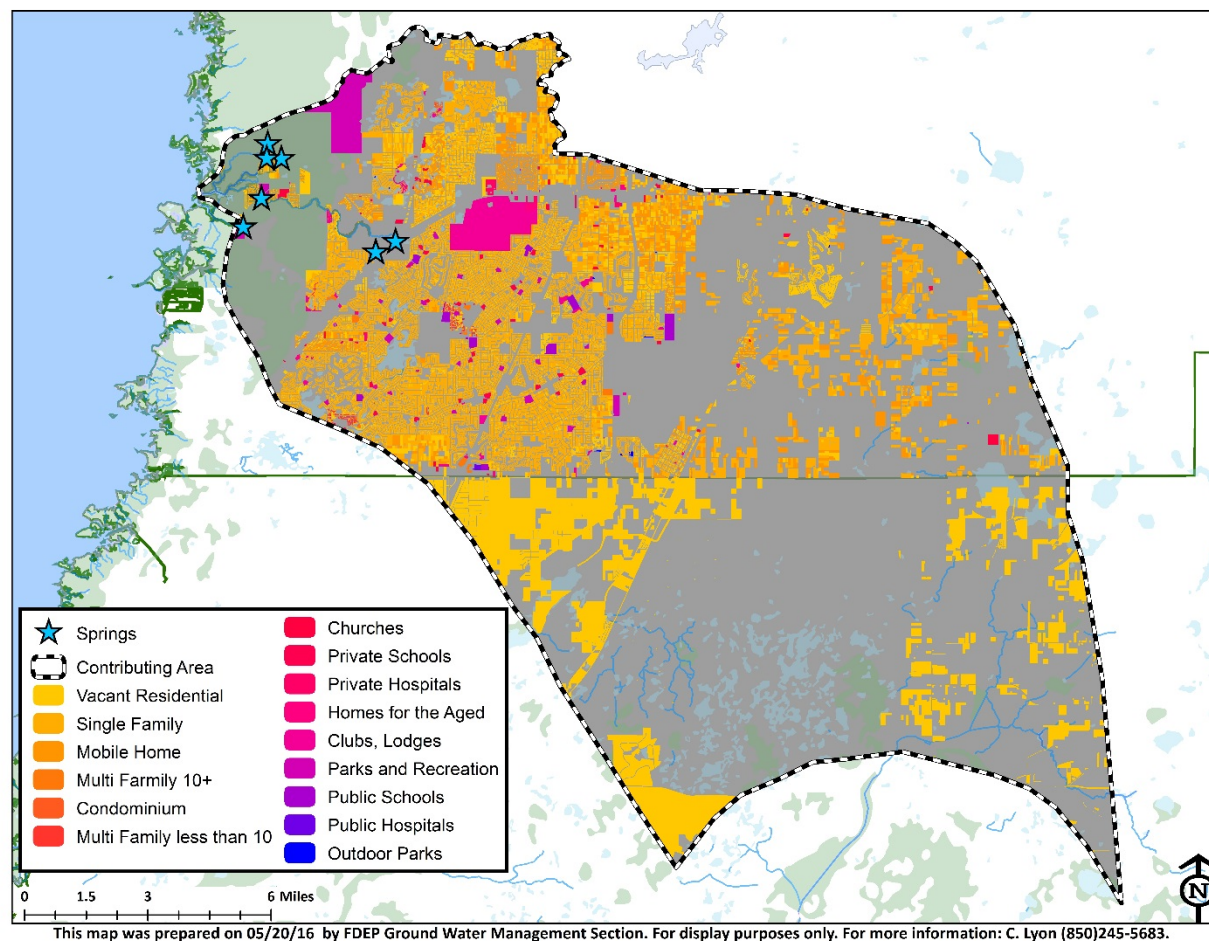


Figure 7: Urban noncommercial lands in the Weeki Wachee Spring contributing area according to county property appraiser data

Fertilizer is applied by either the homeowner or a hired lawn service company on residential properties and on other properties it may be applied by contractors or maintenance staff. In 2008, a SWFWMD contractor conducted a telephone survey about residential fertilizer use in Citrus County and southern Marion County. The results from this survey are used to estimate fertilizer application rates to all urban turfgrass in the Weeki Wachee area. According to the survey (Martin 2008), 68% of the population managed their own lawn care and applied lawn fertilizer 3 times a year at variable rates that may range as high as 45.56 lb-N/ac (**Table 4**). Additionally, 32% of homeowners hired a lawn service company that typically applied fertilizer at rates

consistent with the Green Industries Best Management Practices Manual recommendation of 21.78 lb-N/ac twice a year (Martin 2008; DEP 2010; Downs et al. 2012). Fertilizer application on commercial and public green spaces was assumed to be performed by trained staff using application rates and frequencies similar to those recommended in the Green Industries Best Management Practices Manual.

Table 4: Estimated fertilizer application rates by homeowners from surveys completed in Citrus and Marion Counties

* = Includes homeowners who fertilize based on visual appearance or best judgment.

Basis for Application Rate	% of Population with Homeowner Applying Fertilizer	Estimated Fertilizer Application Rate (lb-N/ac)
BMP Guidelines	15%	21.78
Fertilizer Bag Label	59%	34.78
No Fertilization	11%	0
Other*	16%	43.56

2.4.2 Nonresidential Parcel Estimations

The acreage of public green space parcels receiving fertilizer applications was estimated to obtain nitrogen inputs for each category listed in **Table 5**. Parcel types assessed using the PA data include businesses, hotels, schools, churches, and other facilities. These data were combined with zoning data provided by Hernando and Pasco Counties. The zoning attributed to each parcel contains information on the amount of impervious surfaces (i.e., structures, pavement, etc.), referred to as the "max lot coverage." For each parcel, the max lot coverage was used to estimate the acreage of impervious and pervious land areas. For this analysis, it was assumed that all pervious acreage was fertilized by lawn service companies at the previously mentioned rate and frequency. Details of the PA data and max lot coverages are listed in **Appendix A, Table A.4** through **Table A.7**. **Table 5** summarizes these data.

Table 5: Summary of the fertilizable urban land area and associated N input for nonresidential parcels

* = Parcel type descriptions include forest-parks-recreational, outdoor parkland-recreational, and counties other than public schools.

Parcel Type	Hernando High Recharge (acres)	Pasco High Recharge (acres)	Pasco Medium Recharge (acres)	Pasco Low Recharge (acres)	Total Input (lb-N/yr)
Hotels	22				945
Churches	364	31	13		17,781
Schools	322	8			14,375
Hospitals	87				3,807
Homes for the Aged	97				4,244
Clubs, Lodges, Union Halls	1,558				67,881
Parks and County Land*	1,766	2,270	590	31	202,839
TOTAL	4,217	2,309	603	31	311,871

2.4.3 Residential Parcel Estimations

For residential parcels, including single and multifamily homes, the acreage (pervious area) receiving fertilizer applications was estimated in the same manner as for nonresidential parcels. Prior to applying the fertilizer application rates to the pervious land area, one other factor was taken into account: the probability that a homeowner will fertilize the lawn.

Based on socioeconomic studies, property value can be used as an indicator of turfgrass fertilization in residential areas (Kinzig et al. 2005, Law et al. 2004, Zhou et al. 2008, Cook et al. 2012). The range of property values for single-family homes was evaluated for the Weeki Wachee Spring contributing area and subdivided into three categories: high, medium, and low. **Table 6** lists the estimated probability of fertilization for each property value category.

Table 6: Distribution of property values and the probability of fertilization for the Weeki Wachee Spring contributing area

Property Value Label	Property Value	Probability of Fertilization
High	> \$150,000	90%
Medium	\$50,001 – \$150,000	75%
Low	≤ \$50,000	10%

The probability that a homeowner will fertilize some or all of a property in a given year was based on socioeconomic studies of lawn care trends in urban environments (Kinzig et al. 2005; Grove et al. 2006; Carey et al. 2012). These factors were applied to the pervious acreage of residential properties to adjust the land area presumed to be fertilized. The land area presumed to receive fertilizer applications was multiplied by the annual application rate listed in **Table 4** to obtain the total input of nitrogen to the land surface in residential areas (**Table 7**).

Table 7: Summary of urban fertilizer data attributed to residential parcels

Parcel Type	Hernando High Recharge (acres)	Hernando Medium Recharge (acres)	Pasco High Recharge (acres)	Pasco Medium Recharge (acres)	Pasco Low Recharge (acres)	Total Input (lb-N/yr)
Single-Family Residential	10,461	811	2,092	713	105	1,070,410
Multifamily Residential	153		451	106	6	54,047
Mobile Home	1,894	237	1,275	306	24	281,992
Condominium	4					317
Vacant Residential	918	62	1,245	290	24	
TOTAL	13,431	1,111	5,063	1,414	158	1,406,767

2.5 Sports Turfgrass Fertilizer

Fertilizer applied to sports turfgrass areas is another potential source of nitrogen. These areas fall into two main categories that were evaluated separately: golf courses and sporting facilities such as baseball, football, and soccer; and other fields where fertilizers are likely applied.

To estimate the nitrogen input for golf courses, surveys completed by course managers and superintendents were used to provide basic information about fertilizer practices. Of the golf courses in the contributing area, 44% provided detailed information about fertilizer applications (see **Appendix B** for the survey). The results indicated that golf courses apply nitrogen fertilizer at an average rate of 43.0 lb-N/ac/yr.

For the remaining 56% of the golf courses, the NSILT used a statewide annual average application rate (previously vetted by golf course professionals) of 141.1 lb-N/ac/yr (or 72% of the course area at 4.5 lb-N/1,000 ft²) (Sartain 2002; DEP 2007). In total, all golf courses in the contributing area apply fertilizers at a rate of 194,022 lb N/yr to the land surface in high recharge rate areas and an additional 2,769 lb N/yr in medium recharge rate areas. **Table 8** summarizes the input to the land surface from each golf course in the contributing area.

Table 8: Summary of urban fertilizer input for golf courses

* = Received response to survey.

Golf Club Name	County	High-Recharge Fertilizable Land Area (acres)	Medium- Recharge Fertilizable Land Area (acres)	Average Application Rate (lb-N/ac)	Total Input (lb-N/yr)
Brookridge*	Hernando	187		176	32,844
Glen Lakes*	Hernando	125		7	602
Heather*	Hernando	46		89	4,875
Hernando Oaks*	Hernando	139		141	19,624
High Point*	Hernando	70		78	5,489
Oak Hills	Hernando	184		141	26,029
Rivard	Hernando	95		141	13,469
Seven Hills	Hernando	129		141	18,164
Silverthorn	Hernando	176		141	24,768
Southern Hills Plantation	Hernando	162		141	22,824
Spring Hill	Hernando	159		141	22,374
Timber Pines*	Hernando	215		10	684
Travelers Rest RV*	Pasco	16	20	141	5,045

Sports facilities were assessed based on PA land use data. The parcel types likely to contain these facilities were identified and evaluated based on aerial imagery. In total, 88 acres of land were associated with sporting facilities in the Hernando County high-recharge areas (43 acres in parcel type forest-parks-recreational, and 45 acres in parcel type schools-public-county). It was assumed that these lands are fertilized at rates applied by lawn service companies, as described in **Section 2.4**, resulting in 3,851 lb-N/yr applied to the land surface. **Table 9** summarizes all sports turfgrass fertilizer calculations.

Table 9: Summary of total sports turfgrass fertilizer nitrogen applied to the land surface

Land Type	High Recharge	Medium Recharge	TOTAL
Golf Courses	194,022	2,769	196,791
Sporting Facilities	3,851		3,851
TOTAL	197,872	2,769	200,642

2.6 Livestock Waste

The Weeki Wachee contributing area contains a small number of livestock farms, mostly cow-calf operations. Agricultural practices specific to this area were obtained through meetings with agricultural producers and stakeholders. Typical cattle stocking rates in Hernando and Pasco Counties were estimated as 1 cow per 6 to 8 acres of pasture (based on a stakeholder meeting in Lecanto, Florida, July 2014). The pasture acreage for these operations was estimated using PA data and includes improved, semi-improved, and native pastures. **Table 10** lists the estimated pasture acreage and the associated cattle populations within the contributing area boundary.

For other livestock animals, the populations were estimated using data from the U.S. Department of Agriculture (USDA), which publishes a Census of Agriculture (CoA) every five years. This comprehensive report provides summary data on the agricultural practices and livestock populations for each state and county in the U.S. The 2012 CoA report was used to provide data on livestock populations for this assessment. However, since the CoA reports entire county data, additional analyses were carried out for the groundwater contributing area for Weeki Wachee Spring.

Table 10: PA pasture data and estimated cattle populations based on stocking rates

County	Property Code	PA Land Description	Estimated Improvement	High-Recharge Area (acres)	Medium-Recharge Area (acres)	Low-Recharge Area (acres)	Estimated Cattle Population
Hernando	60	Improved Pastureland	Improved	7,586	1,817		1,344
Pasco	60	Improved Pastureland	Improved	12,137	11,031	1,477	3,521
Pasco	61	Grazing land Soil Capab II	Improved Below Average	700	283	267	179
Pasco	62	Grazing land Soil Capab III	Partially Improved	553	4	100	94
Pasco	63	Grazing land Soil Capab IV	Native	984	370	283	234
Pasco	64	Grazing land Soil Capab V	Native Hammock	2,276	1,151		490
Pasco	65	Grazing land Soil Capab VI	Overflow Prairie	2,525	342		410

To estimate the number of livestock animals in the contributing area, the SWFWMD land use coverage was used to identify land use categories likely to contain livestock, i.e., pastures, feeding operations, and specialty farms. These land areas were totaled for Hernando and Pasco Counties and subdivided by recharge rate category. The livestock area summations were used to calculate a land use percentage for the entire county area for livestock operations in the two recharge rate categories.

These percentages were applied to the populations provided by the CoA to estimate the number of animals in the contributing area and in the medium and high recharge rate areas of Hernando and Pasco Counties (**Table 11** and **Table 12**, respectively). For example, if 10,000 cows were reported for a particular county in the CoA, but only 10% of the livestock lands in that county were inside the BMAP area, it was assumed that the contributing area contained 1,000 cows.

Table 11: WMD land use percentages and miscellaneous livestock population data for Hernando County

Land Category	Land Area (acres)	Land Use %	Horses	Broiler Chickens	Goats	Hogs	Sheep	Turkeys
Hernando County	33,851		2,080	546	1,034	328	318	0
High Recharge	13,447	40%	826	217	411	130	126	
Medium Recharge	8,947	26%	550	144	273	87	84	

Table 12: WMD land use percentages and miscellaneous livestock population data for Pasco County

Land Category	Land Area (acres)	Land Use %	Horses	Broiler Chickens	Goats	Hogs	Sheep	Turkeys
Pasco County	84,673		2,008	604	1,410	165	251	63
High Recharge	18,715	22%	444	134	312	36	55	14
Medium Recharge	17,856	21%	423	127	297	35	53	13
Low Recharge	5,233	6%	124	37	87	10	16	4

Nitrogen waste factors were assigned for each animal type and applied to the estimated livestock populations to estimate the nitrogen input to the land surface. The nitrogen waste factors in lb N/day per animal were as follows: cattle, 0.337; broiler chickens, 0.159; layer chickens, 0.003; goats, 0.035; hogs, 0.190; sheep, 0.198; turkeys, 0.006; and horses, 0.273 (Goolsby et al. 1999; Katz et al. 1999; Chelette et al. 2002; Ruddy et al. 2006; Meyer 2012; Sprague and Gronberg 2013). **Table 13** lists the TN input to the land surface attributable to livestock waste for the medium and high recharge rate areas in the contributing area.

Table 13: Estimated nitrogen applied as animal waste to the land surface in the contributing area

Land Category	Cattle	Horses	Broiler Chickens	Goats	Hogs	Sheep	Turkeys	Total N Input (lb-N/yr)
Hernando–High Recharge	6,027	82,334	12,588	5,247	9,036	9,129		124,362
Hernando–Medium Recharge	1,722	54,781	8,375	3,491	6,012	6,074		80,456
Pasco–High Recharge	336,932	44,225	7,748	3,981	2,529	4,009	30	485,527
Pasco–Medium Recharge	231,611	42,195	7,392	3,799	2,413	3,825	29	373,385
Pasco–Low Recharge	37,380	12,366	2,166	1,113	707	1,121	9	78,928
Total Contributing Area	613,673	192,258	235,901	17,632	20,698	24,160	68	1,142,659

2.7 Farm Fertilizer

Nitrogen in agricultural fertilizer is applied at widely varying rates, depending on the crop, time of year, and individual farm practices. The PA offices in Hernando and Pasco Counties provided detailed information on the types of crops grown in the area. Nitrogen inputs to the land surface were estimated based on the type of crops grown in each PA land use category and the recommended nitrogen application rates for crops by the University of Florida Institute of Food and Agricultural Sciences (UF–IFAS) (Hochmuth and Hanlon 2000, 2010, 2013; Wright et al. 2011; Mylavarapu et al. 2012; Liu et al. 2012). **Table 14** and **Table 15** summarize the nitrogen inputs to the land surface from fertilizers applied to cropland for the medium and high recharge rate areas in the Weeki Wachee Spring contributing area in Hernando and Pasco Counties, respectively.

2.8 Summary of Estimated Nitrogen Inputs to the Land Surface

Figure 8 summarizes the relative contributions of nitrogen (in percent) from the major sources in the Weeki Wachee Spring contributing area. The total annual nitrogen input to the land surface from all sources is 6.3 million lb-N. Urban turf fertilizers comprise 27% of the TN input to the land surface in the contributing area. Other nitrogen sources, in order of decreasing contributions of nitrogen inputs to the land surface, include farm fertilizer (22%), livestock waste (21%), atmospheric deposition (18%), septic systems (10%), sports turfgrass fertilizer (3%), and WWTFs (1%).

Table 14: Summary of crop types and nitrogen application rates for Hernando County in the Weeki Wachee Spring contributing area

Property Code	PA Land Description	Estimated Crop Type	N Application Rate (lb-N/ac)	High-Recharge Area (ac)	Medium-Recharge Area (ac)	Total Input (lb-N/yr)
51	Cropland Soil Capability I	Hay, Berries, Watermelons	80	1,128	565	135,460
60	Improved Pastureland	Improved Pasture	60	7,586	1,817	141,051
66	Orchard Groves	Orchards	150	310	165	71,174
69	Ornamentals	Ornamentals	80	375	14	31,150

Table 15: Summary of crop types and nitrogen application rates for Pasco County in the Weeki Wachee Spring contributing area

Property Code	PA Land Description	Estimated Crop Type	N Application Rate (lb-N/ac)	High-Recharge Area (ac)	Medium-Recharge Area (ac)	Low-Recharge Area (ac)	Total Input (lb-N/yr)
51	Cropland Soil Capability I	Hay Crop	80	939	1,107	242	183,038
53	Cropland Soil Capability III	Hay Crop	80	24	57		6,430
60	Improved Pastureland	Improved Pasture	60	12,137	11,031	2,127	367,487
61	Grazing Land soil Capab II	Improved Below Average	25	700	283	267	7,813
62	Grazing Land soil Capab III	Partial Improved	0	553	4	100	
63	Grazing Land soil Capab IV	Native	0	984	370	283	
64	Grazing Land soil Capab V	Native/Hammock	0	2,276	1,151		
65	Grazing Land soil Capab VI	Marsh Overflow Prairie	0	2,525	342		
66	Orchard Groves	Orchards	150	630	561	147	200,733
69	Ornamentals	Ornamentals	80	172	72		21,954

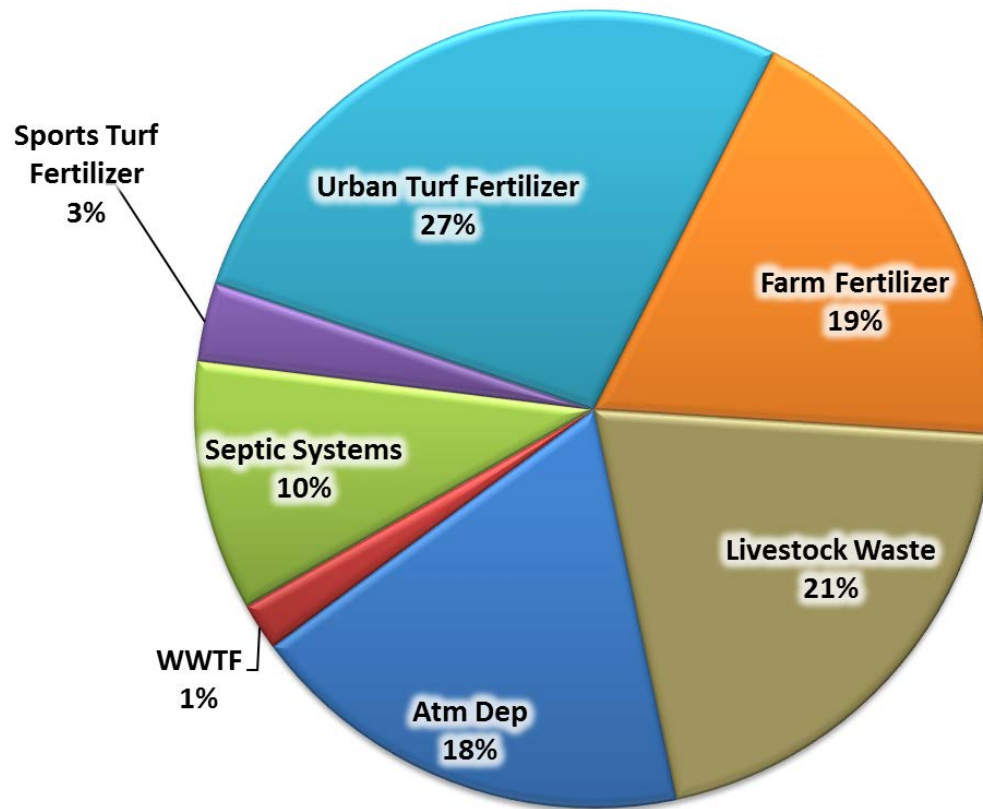


Figure 8: Relative nitrogen inputs to the land surface in the Weeki Wachee Spring contributing area from major anthropogenic source categories in lb-N/yr

3. NITROGEN ATTENUATION AND LOADING TO GROUNDWATER

The movement of nitrogen from the land surface to groundwater is controlled by biological and chemical processes that occur as part of the nitrogen cycle, as well as hydrogeological processes. Many of these processes attenuate (impede or remove) the amount of nitrogen transported to groundwater. An understanding of how water moves through the subsurface and the processes that transform the different forms of nitrogen is essential for estimating nitrogen loading to groundwater from various sources (Liao et al. 2012; Wang et al. 2013).

To estimate the amount of nitrogen loading to the aquifer in the Weeki Wachee Spring contributing area, DEP applied two nitrogen attenuation factors. The specific biochemical attenuation factor (BAF) is applied to each nitrogen source category to account for biochemical processes that remove or transform the different forms of nitrogen. The hydrogeological attenuation factor (HAF) accounts for spatial variations in subsurface geological properties that affect the rate of water recharging the UFA. Both factors control the amount of nitrogen reaching the UFA annually and in the groundwater moving to Weeki Wachee Spring.

3.1 Biochemical Attenuation

Several near-surface biochemical processes increase nitrogen availability for plants, including fixation (the conversion of atmospheric nitrogen to a plant-available form), mineralization (the conversion of organic nitrogen to ammonium), and nitrification (the conversion of ammonium to nitrate). Losses of nitrogen from the root zone can result from denitrification, volatilization, immobilization, and cation exchange (affecting ammonium). These processes occur to varying degrees depending on how the form of nitrogen is introduced, soil properties, and several other factors (Cockx and Simonne 2011; Costa et al. 2002; Horsley Witten Group 2009).

Specific BAFs were used to account for the various processes that affect the movement of nitrogen from each source category in the subsurface and were obtained through an extensive literature review of relevant studies throughout Florida as well as other areas with similar environmental characteristics. Additionally, research scientists in Florida (UF–IFAS, universities, and USDA Agricultural Research Service [ARS]), and local stakeholders provided additional guidance. The biochemical attenuation factors, listed in **Table 16**, represent the average percentage of the nitrogen attenuated or removed by subsurface processes and thus reducing the amount of nitrogen reaching groundwater.

As a first step in estimating loading to groundwater, the nitrogen inputs at the land surface from each category, discussed previously, are multiplied by their respective biochemical attenuation factors (**Table 16**). For example, atmospheric deposition has an average nitrogen attenuation of 90% (mainly from uptake by vegetation). This means that only 10% of the atmospheric nitrogen input to the land surface has the potential to infiltrate to groundwater.

Table 16: BAFs applied to the nitrogen input calculations

* = Both sports and urban turfgrass.

** These percentages represent the average amount of nitrogen removed by the environment over varying soil characteristics.

N Source Category	BAF**	Literature References
Atmospheric Deposition	90%	Katz et al. 2009; Lombardo Associates 2011; Howard T. Odum Florida Springs Institute 2011
WWTFs-RIBs	25%	Merritt and Toth 2006; Sumner and Bradner 1996
WWTFs-Sprayfield	60%	Katz et al. 2009; Lombardo Associates 2011; Howard T. Odum Florida Springs Institute 2011
WWTFs-Reuse	75%	Jordan et al. 1997; Candela et al. 2007; Rahil and Antonopoulos 2007
Urban Fertilizer*	80%	Goolsby et al. 1999; Erikson et al. 2001; Barton and Colmer 2006; Katz et al. 2009
Septic Systems	50%	Poiani et al. 1996; Aravena and Robertson 1998; Tomasko et al. 2001; Corbett et al. 2002; Otis 2007; Toor et al. 2011
Livestock Waste	90%	Dubeux et al. 2007; Silveira et al. 2007; Burns et al. 2009; Dubeux et al. 2009; Obour et al. 2010; Sigua 2010; Sigua et al. 2010; Silveira et al. 2011; Woodard et al. 2011; White-Leech et al. 2013a; White-Leech et al. 2013b
Farm Fertilizer	70%	McNeal et al. 1995; Wang and Alva 1996; Paramasivam and Alva 1997; Newton et al. 1999; Hochmuth 2000a; Hochmuth 2000b; Simonne et al. 2006; He et al. 2011; Liu et al. 2013

3.2 Hydrogeological Attenuation

Any non-attenuated nitrogen remaining (usually in the form of nitrate) after taking into account biochemical attenuation processes can readily leach to groundwater. Leaching to groundwater is a function of the properties of the soil and unsaturated zone, such as composition (particle size, organic matter content), texture, drainage, wetness, and thickness. The rate of groundwater recharge (from rainfall or irrigation water) ultimately controls how rapidly nitrogen moves from below the root zone to the UFA. The amount of water recharging the UFA each year also depends on the amount of rainfall, evapotranspiration, and runoff, in addition to subsurface hydrogeological properties.

The final step in estimating nitrogen loads to groundwater is to account for the additional attenuation associated with the rate of recharge in a given year. The recharge rate can be geospatially assessed and incorporates soil and unsaturated zone properties (recharge rates are based on a USGS recharge map discussed in **Section 1.3, Aquifer Recharge**). Therefore, the rate of recharge to the UFA is used in the NSILT as an aggregated indicator of the various hydrogeological processes that can further attenuate the movement of nitrate to groundwater. In areas with lower annual recharge rates, the vertical movement of water and associated chemical constituents is impeded, which may allow for increased biological uptake and denitrification (Liao et al. 2012; Wang et al. 2013).

In contrast, for areas with higher recharge rates, water spends less time in the soil/root zone, decreasing the opportunity for biochemical attenuation. This likely results in the increased leaching of nitrogen as well as a higher potential for nitrogen transport to the aquifer in a given year (Scanlon et al. 2002; Liao et al. 2012).

Additional nitrogen attenuation factors related to recharge rates were arbitrarily assigned as follows: 90% in high recharge rate areas (≥ 10 in/yr), 50% in medium recharge rate areas (3.01 to 10 in/yr), and 10% in low-recharge areas (0 to 3 in/yr) (Sepulveda 2002). For example, in high-rate recharge areas, 90% of the non-attenuated nitrogen mass is assumed to reach the aquifer in a year, while only 50% of the non-attenuated nitrogen mass is assumed to reach the aquifer annually in medium rate recharge areas. These attenuation factors are based on the recharge characteristics specific to the hydrogeological conditions in the Weeki Wachee Spring contributing area.

3.3 Estimated Nitrogen Loads to Groundwater

Table 17, **Table 18**, and **Table 19** summarize estimated annual nitrogen inputs, attenuation factors, and loads to the UFA, respectively, in the Weeki Wachee Spring contributing area and its recharge-based subdivisions. The results indicate an estimated annual load of 994,496 lb-N to the UFA in the BMAP area, representing 16% of the amount of nitrogen inputs to the land surface. As discussed previously, the difference is due to various nitrogen attenuation processes and variations in the quantity and movement of water recharging the aquifer. The results indicate that the greatest annual load of nitrogen to the UFA in the BMAP area comes from urban turfgrass fertilizers (29% of the total estimated load to groundwater), followed by septic systems at 28%.

Figure 9 shows the relative contribution of estimated annual loads of nitrogen to the UFA by source category. The NSILT results indicate that most of the nitrogen load to groundwater originates from fertilizers and septic systems, which is consistent with nitrogen isotopic and other chemical data. Nitrogen-isotope signatures in water samples collected in 2013 indicated that elevated nitrate-N concentrations in groundwater originate from a mix of both inorganic (fertilizer) and organic (human and animal waste) sources, but with a significant influence from inorganic sources (Dodson and Bridger 2014). Aquifer recharge rates have strongly influenced the loading of nitrogen to the UFA in the groundwater contributing area.

Figure 10 summarizes the estimated nitrogen loads to groundwater for the medium and high recharge rate areas, including a breakdown for each source category. The majority of the nitrogen loading to groundwater in the Weeki Wachee Spring contributing area (90%) occurs in high rate recharge areas. For both the medium and low rate recharge areas, the dominant sources of nitrogen loading to groundwater are livestock waste and farm and urban fertilizers.

Table 17: Estimated inputs to the land surface by nitrogen source category in the Weeki Wachee Spring contributing area (lb-N/yr)

Recharge Category	Atmospheric Deposition	WWTF-RIB	WWTF-Sprayfield	WWTF-Reuse	Septic Systems	Sports Turf Fertilizer	Urban Turf Fertilizer	Farm Fertilizers	Livestock Waste	TOTAL
High	923,127	39,786	10	80,249	617,033	197,872	1,516,859	653,917	737,277	4,766,130
Medium	197,713	389	213		20,332	2,769	190,272	449,232	484,054	1,344,974
Low	24,093				2,552		11,508	65,327	78,928	182,407
TOTAL	1,154,547	40,155	222	80,249	639,916	200,642	1,718,639	1,168,475	1,300,259	6,293,733

Table 18: Average biochemical attenuation factors by source category in the Weeki Wachee Spring contributing area (lb-N/yr)

Recharge Category	Atmospheric Deposition	WWTF-RIB	WWTF-Sprayfield	WWTF-Reuse	Septic Systems	Sports Turf Fertilizer	Urban Turf Fertilizer	Farm Fertilizers	Livestock Waste	TOTAL
BAF	90%	25%	60%	75%	50%	80%	80%	80%	90%	
High	92,313	29,840	4	20,062	308,517	39,574	303,372	130,783	73,728	998,192
Medium	19,771	292	85		10,166	554	38,054	89,846	48,405	207,174
Low	3,371				1,276		2,302	13,065	7,893	26,945
TOTAL	115,455	30,132	89	20,062	319,958	40,128	343,728	233,695	130,026	1,212,249

Table 19: Load to groundwater with recharge factors applied by nitrogen source category in the Weeki Wachee Spring contributing area (lb-N/yr)

[§] = Combination of all WWTF subcategories: RIBs, sprayfields, and reuse.

Recharge Category	HAF	Atmospheric Deposition	WWTF [§]	Septic Systems	Sports Turf Fertilizer	Urban Turf Fertilizer	Farm Fertilizer	Livestock Waste	TOTAL
High	90%	83,081	44,915	277,665	35,617	273,035	117,705	66,355	898,373
Medium	50%	9,886	189	5,083	277	19,027	44,923	24,203	103,587
Low	10%	241		128		230	1,307	789	2,694
TOTAL		93,208	45,105	282,875	35,894	292,292	163,935	91,347	1,004,655

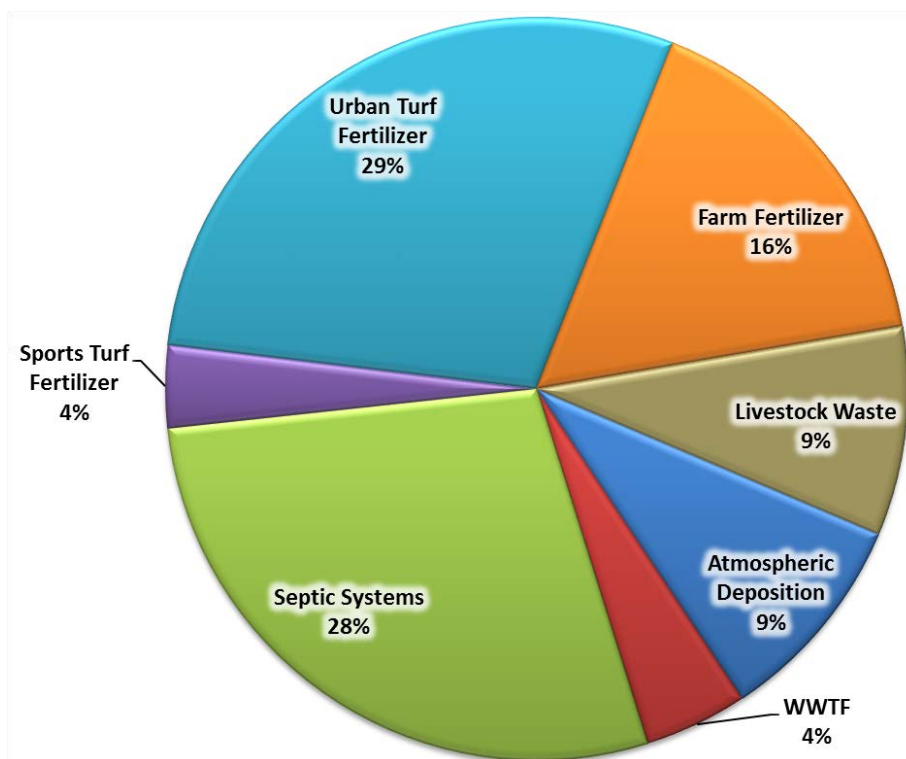


Figure 9: Relative percent contributions of nitrogen loading to groundwater for source categories in the Weeki Wachee Spring contributing area

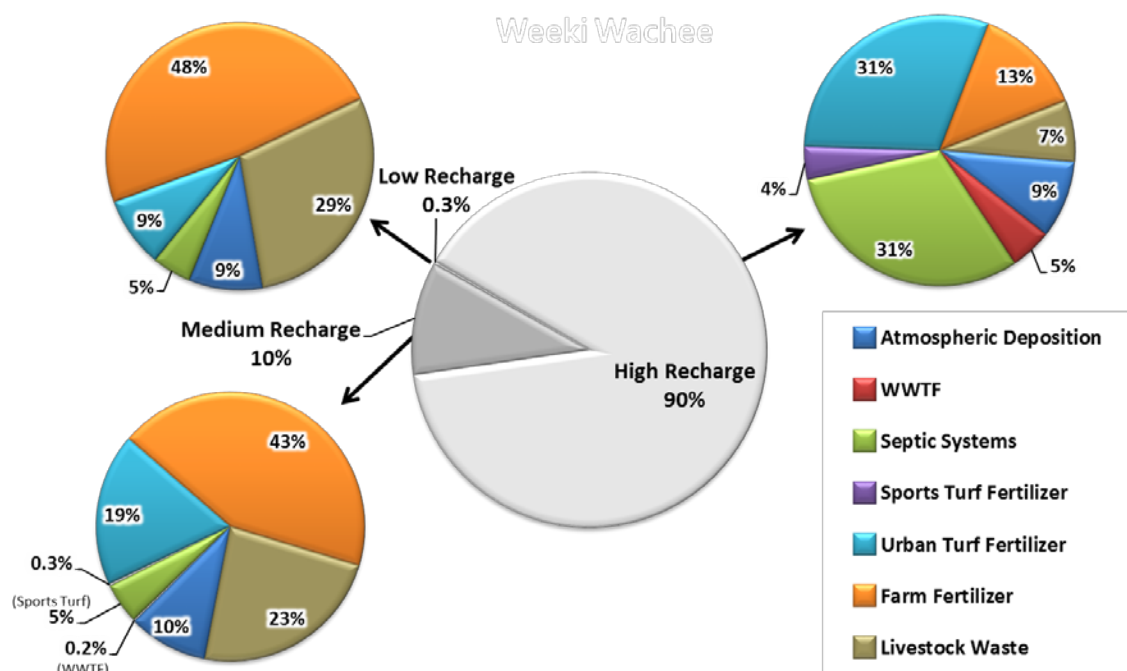


Figure 10: Estimated annual nitrogen loading to groundwater by recharge category

3.4 Accounting for Uncertainty in Nitrogen Attenuation Factors in Estimating Loading to Groundwater

The pie charts (**Figure 9** and **Figure 10**) provide information about the relative contribution of nitrogen loading to groundwater from each source. However, if the contribution from one nitrogen source category were to increase or decrease, the contribution of all the other sources would change proportionally. The amount of nitrogen attenuation for each source can vary substantially, both spatially and with depth in the subsurface, and can affect the amount of nitrogen leaching to groundwater and its relative contribution. The range (or uncertainty) in nitrogen attenuation can result from variability in soil properties, crop types, agricultural practices, nitrogen storage, the volatilization of ammonia to the atmosphere, uptake by vegetation, denitrification, and other removal processes. The density of nitrogen sources can also dramatically affect the attenuation potential of the environment.

Given the relatively large range in nitrogen attenuation for each source, DEP opted to use an average attenuation factor estimated based on land use practices and hydrogeological conditions in the Weeki Wachee Spring contributing area. Greater emphasis was placed on information on nitrogen attenuation from studies in central Florida, other locations in Florida, or areas with very similar soil and vegetation characteristics. **Table 20** lists the range in nitrogen attenuation for each source.

Table 20: Range of environmental attenuation of nitrogen from a detailed literature review

* = Both sports and urban turfgrass.

N Source Category	Minimum BAF	Average BAF Used To Estimate N loads to Groundwater	Maximum BAF
Atmospheric Deposition	85%	90%	95%
WWTFs-RIBs	10%	25%	40%
WWTFs-Sprayfield	50%	60%	75%
WWTFs-Reuse	50%	75%	85%
Septic Systems	40%	50%	75%
Livestock Waste	80%	90%	95%
Farm Fertilizers	50%	70%	85%
Urban Fertilizers*	50%	80%	85%

Using the minimum and maximum BAFs in **Table 20**, DEP estimated a corresponding range of nitrogen loading to groundwater from each source in the contributing area (**Figure 10**).

Even with the relatively large range in nitrogen attenuation for each source, the total estimated nitrogen load to groundwater in the Weeki Wachee springshed greatly exceeds the target load (TMDL) estimated for Weeki Wachee Spring. The target N load is based on the most recent discharge data and the TN concentration discharging from the spring vent.

For Weeki Wachee, the discharge is 185.6 cfs (USGS gauge station 02310545; April 2012–April 2013), and the adopted TMDL is 0.28 mg/L for the spring and river (Dodson and Bridger 2014), resulting in a target nitrogen load of 102,178 lb-N/yr. Using the maximum nitrogen attenuation factors for each source, the total load to groundwater in the contributing area is 635,269 lb-N/yr, which is considerably higher than the TMDL target nitrogen load for Weeki Wachee Spring (Figure 12).

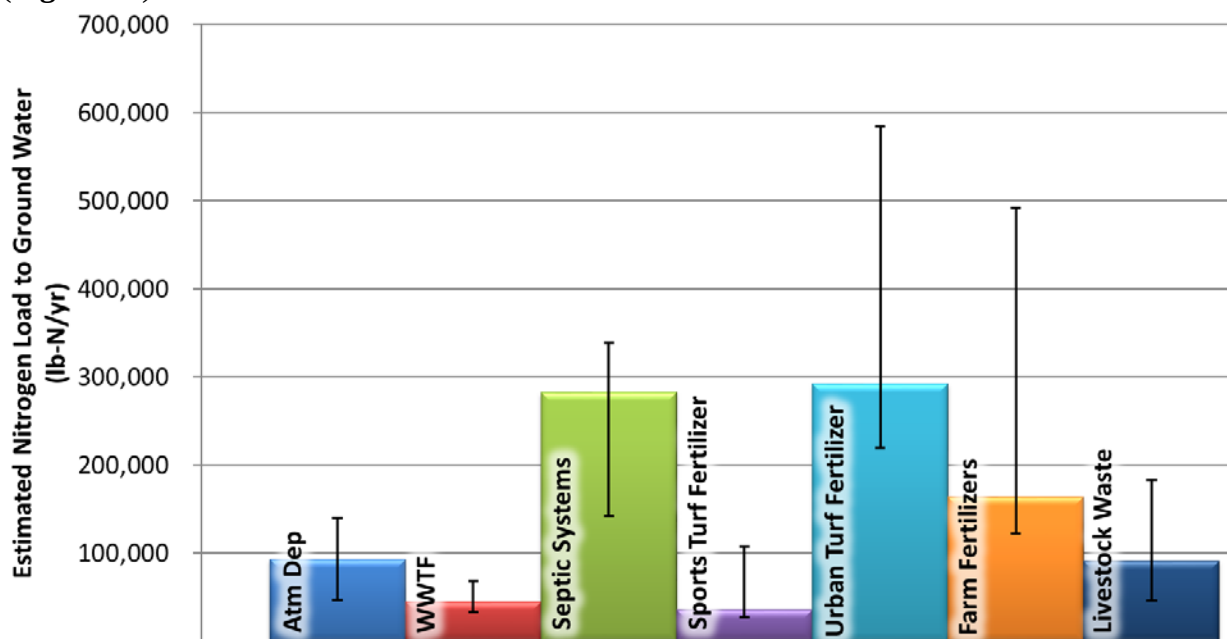


Figure 11: Influence of the range of attenuation factors on estimated nitrogen loads to groundwater from each category in the Weeki Wachee Spring contributing area

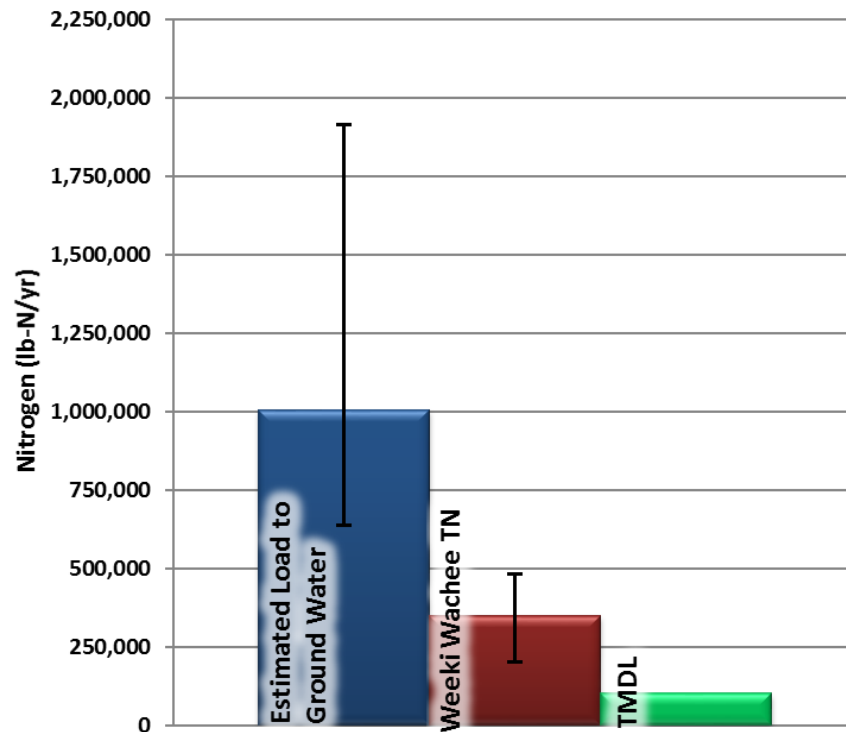


Figure 12: Estimated nitrogen load to groundwater compared with the current nitrogen discharging from Weeki Wachee Spring, Little Spring, and Hospital Spring and the TMDL goal

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APPENDICES

Appendix A: Tables

Table A.1: Useful conversion factors

Convert from	To	Multiply by
Pounds	kilograms	0.4535924
NO₃ milligrams per liter	NO ₃ grams-nitrogen per liter	2.260 X 10 ⁻⁴
NH₄ milligrams per liter	NH ₄ grams-nitrogen per liter	7.765 X 10 ⁻⁴
milligrams	grams	0.001
grams	kilograms	0.001
milligrams	kilograms	1 X 10 ⁻⁶
acre	hectares	0.4046873
square meters	hectares	0.0001
cubic centimeters	liters	0.001
tons	kilograms	907.1847
cubic feet	liters	28.31685
second	year	3.170979 X 10 ⁻⁸
rainfall (centimeters)	rainfall (liters per hectare)	104

Table A.2: Summary of SWFWMD land use data in Hernando County

Land Use Code	Land Use Description	Hernando County	High Recharge	Medium Recharge	Discharge
2100	Cropland and Pastureland	31,912	12,727	8,773	0
2300	Feeding Operations	393	96	0	0
2500	Specialty Farms	1,547	625	174	0
2140	Row Crops	105	96	7	0
2200	Tree Crops	877	229	249	0
2400	Nurseries and Vineyards	1,279	417	105	0
1100	Residential Low Density <2 Dwelling Units	41,835	15,798	2,270	0
1200	Residential Medium Density 2–5 Dwelling Units	24,602	19,448	0	275
1300	Residential High Density	5,388	3,817	52	1,040
1800	Recreational	939	515	0	14
1820	Golf Courses	2,567	1,638	0	212

Table A.3: Summary of SWFWMD land use data in Pasco County

Land Use Code	Land Use Description	Pasco County	High Recharge	Medium Recharge	Low Recharge
2100	Cropland and Pastureland	82,029	18,245	17,652	5,209
2300	Feeding Operations	856	55	135	23
2500	Specialty Farms	1,788	415	69	0
2140	Row Crops	74	9	37	0
2200	Tree Crops	7,371	587	1,091	196
2400	Nurseries and Vineyards	994	223	171	0
1100	Residential Low Density <2 Dwelling Units	54,042	6,982	2,869	729
1200	Residential Medium Density 2–5 Dwelling Units	27,410	3,440	43	43
1300	Residential High Density	27,687	117	49	0
1800	Recreational	1,924	24	0	0
1820	Golf Courses	3,276	36	36	0

Table A.4: Summary of land use provided by the Hernando County property appraiser office

Property Code	Description	High-Recharge Area	Medium-Recharge Area	Discharge Area
0	VACANT RESIDENTIAL	5,495	180	23
1	SINGLE FAMILY	14,371	978	167
2	MOBILE HOME	3,893	340	
3	MULTI FAMILY 10 UNITS OR MORE	110		
4	CONDOMINIUM	24		
5	COOPERATIVES			
6	RETIREMENT HOMES			
7	MISC RES(BOARDING HOMES,CAMPS)			
8	MULTI FAMILY LESS THAN 10 UNIT	75		
10	VACANT COMMERCIAL	526	1	4
11	STORES, 1 STORY	194	1	2
12	STORE/OFFICE/OR RESID COMBIN	15		
13	DEPARTMENT STORE	5		1
15	SHOPPING CENTERS (REGIONAL)	6		
16	SHOPPING CENTERS (COMMUNITY)	51		2
17	OFFICE BUILDINGS, 1 STORY	127		1
18	OFFICE BUILDINGS, MULTI STORY	11		
19	PROFESSIONAL BUILDINGS	189		
20	AIRPORTS, BUS TERM, MARINAS,	1		
21	RESTAURANT AND CAFETERIAS	43		2
22	DRIVE IN RESTAURANTS	17		2
23	FINANCIAL INSTITUTIONS	24		1
25	SERVICE SHOP, RADIO & TV REPIR	4		
26	SERVICE STATIONS	23		
27	AUTO SALES, REPAIR & STORAGE	54		
28	PARKING LOTS, COMM, MH PARKS	47	4	
29	WHOLESALE OUTLETS, PRODUCE	1		
30	FLORIST, GREENHOUSES	3		
32	THEATERS, (ENCLOSED) AUDITORIM	2		
33	NIGHT CLUBS, COCKTAIL LOUNGES	2		
34	BOWLING ALLEYS, SKATING RINKS	3		
35	TOURIST ATTR. OTHER ENTERTNMT	2		
36	CAMPS	4	2	
38	GOLF COURSES, DRIVING RANGES	64		4
39	HOTELS - MOTELS	7		
40	VACANT INDUSTRIAL	22		
41	LIGHT MANUFACTURING	34		
44	PACKING PLANTS, FRUIT & VEGE	1		

Property Code	Description	High-Recharge Area	Medium-Recharge Area	Discharge Area
46	OTHER FOOD PROCESSING, CANDY	1		
48	WAREHOUSING, DISTRIBUTION	145	1	
49	OPEN STORAGE, NEW AND USED	12		
51	CROPLAND SOIL CAPABILITY CLS I	65	40	
54	TIMBER NATURAL STAND	183	26	2
55	TIMBER PLANTED	58	5	
56	TIMBERLAND	2		
59	WOODS - NATIVE PASTURE	95	36	
60	IMPROVED PASTURE LAND	342	98	
65	GRAZING LAND SOIL CAPAB VI	1		
66	ORCHARD GROVES	20	13	
67	POULTRY, BEES, HOGS IN FIELD	3		
69	ORNAMENTALS	22	2	
70	VACANT INSTITUTIONAL	59		1
71	CHURCHES	63		
72	SCHOOLS, COLLEGES PRIVATE	11		
73	HOSPITALS PRIVATELY OWNED	5		
74	HOMES FOR THE AGED	25		
75	CHARITABLE/NON PROFIT	3		
76	MORTUARIES, CEMETERIES, CREMAT	16	2	
77	CLUBS, LODGES, UNION HALLS	67		1
80	VACANT GOVERNMENTAL	82	1	
81	MILITARY	4		
82	FOREST PARKS RECREATIONAL	41		4
83	SCHOOLS - PUBLIC COUNTY	13		
85	HOSPITALS	1		
86	COUNTIES OTHER THAN PUBLIC SCH	59		
87	STATE OTHER THAN MILITARY FORE	134		19
88	FEDERAL OTHER THAN MILITARY	1		
89	MUNICIPAL OTHER THAN PARKS	3		
90	LEASEHOLD INTERESTS	204		
91	UTIL,RR,GAS,COMMUNICATIONS,ELECT	122		2
94	RIGHT OF WAY STREETS/ROADS	586	19	39
95	RIVERS AND LAKES, SUBMERGED	57	1	4
96	DRA,LIFT STAT,MARSH,BORROWPIT	1,324	2	16
97	OUTDOOR PARKLAND/REC	11		
99	ACREAGE NOT CLASSIFIED	365	41	2

Table A.5: Summary of land use provided by the Pasco County property appraiser office

Property Code	Description	High-Recharge Area	Medium-Recharge Area	Low-Recharge Area
0	VACANT RESIDENTIAL	1,824	427	38
1	SINGLE FAMILY	3,029	1,055	157
2	MOBILE HOME	1,912	448	34
3	MULTI FAMILY 10 UNITS OR MORE			
4	CONDOMINIUM			
5	COOPERATIVES			
6	RETIREMENT HOMES			
7	MISC RES(BOARDING HOMES,CAMPS)			
8	MULTI FAMILY LESS THAN 10 UNIT	686	152	10
10	VACANT COMMERCIAL	205	36	1
11	STORES, 1 STORY	10	18	5
12	STORE/OFFICE/OR RESID COMBIN	57	13	0
13	DEPARTMENT STORE			
14	SUPER MARKETS			
15	SHOPPING CENTERS (REGIONAL)			
16	SHOPPING CENTERS (COMMUNITY)			
17	OFFICE BUILDINGS, 1 STORY	4	2	
18	OFFICE BUILDINGS, MULTI STORY	1		
19	PROFESSIONAL BUILDINGS	1	10	
20	AIRPORTS, BUS TERM, MARINAS,			
21	RESTAURANT AND CAFETERIAS			
22	DRIVE IN RESTAURANTS			
23	FINANCIAL INSTITUTIONS			
24	INSURANCE COMPANY NATL REG OFF			
25	SERVICE SHOP, RADIO & TV REPIR	6	4	
26	SERVICE STATIONS			
27	AUTO SALES, REPAIR & STORAGE	4		
28	PARKING LOTS, COMM, MH PARKS	124	33	
29	WHOLESALE OUTLETS, PRODUCE			
30	FLORIST, GREENHOUSES			
31	THEATERS, (DRIVE IN) STADIUMS			
32	THEATERS, (ENCLOSED) AUDITORIM			
33	NIGHT CLUBS, COCKTAIL LOUNGES	2	3	2
34	BOWLING ALLEYS, SKATING RINKS			
35	TOURIST ATTR. OTHER ENTERTNMT			
36	CAMPS			
37	RACE TRACKS, HORSE, AUTO OR DO			
38	GOLF COURSES, DRIVING RANGES			

Property Code	Description	High-Recharge Area	Medium-Recharge Area	Low-Recharge Area
39	HOTELS - MOTELS			
40	VACANT INDUSTRIAL	19	43	
41	LIGHT MANUFACTURING	20	9	
42	HEAVY INDUSTRIAL, HEAVY EQUIP			
43	LUMBER YARDS, SAWMILLS			
44	PACKING PLANTS, FRUIT & VEGE			
45	CANNERIES, FRUIT & VEGETABLE			
46	OTHER FOOD PROCESSING, CANDY			
47	MINERAL PROCESSING, PHOSPHATE	22		
48	WAREHOUSING, DISTRIBUTION	43	51	
49	OPEN STORAGE, NEW AND USED			
50	IMPROVED AGRICULTURAL			
51	CROPLAND SOIL CAPABILITY CLS I	939	1,107	242
52	CROPLAND SOIL CAPABILITY II			
53	CROPLAND SOIL CAPABILITY III	24	57	
54	TIMBER NATURAL STAND	11,015	512	45
55	TIMBER PLANTED	604	311	
56	TIMBERLAND			
57	TIMBERLAND			
58	TIMBERLAND			
59	WOODS - NATIVE PASTURE			
60	IMPROVED PASTURE LAND	12,137	11,031	1,477
61	GRAZING LAND SOIL CAPAB II	700	283	267
62	GRAZING LAND SOIL CAPAB III	553	4	100
63	GRAZING LAND SOIL CAPAB IV	984	370	283
64	GRAZING LAND SOIL CAPAB V	2,276	1,151	
65	GRAZING LAND SOIL CAPAB VI	2,525	342	
66	ORCHARD GROVES	630	561	147
67	POULTRY, BEES, HOGS IN FIELD			
68	DAIRIES, FEED LOTS,PENNED HOGS	432	455	173
69	ORNAMENTALS	172	72	
70	VACANT INSTITUTIONAL	1	1	
71	CHURCHES	31	13	
72	SCHOOLS, COLLEGES PRIVATE			
73	HOSPITALS PRIVATELY OWNED			
74	HOMES FOR THE AGED			
75	CHARITABLE/NON PROFIT			

Table A.6: Hernando County zoning data

Zoning Code	Zoning Description	% Maximum Lot Coverage
AC	AC Agricultural Commercial District	
AG	AG Agricultural District	
AR	AR Agricultural Residential District	
AR1	AR1 Agricultural Residential District	
AR2	AR Agricultural Residential District	
C1	C1 General Commercial District	
C2	C2 Highway Commercial District	
C3	C3 Neighborhood Commercial District	
C4	C4 Heavy Highway Commercial District	
CITY	City	
CM1	CM1 Marine Commercial District	
CM2	CM2 Heavy Marine Commercial District	
CPDP	CPDP (Combined)	
CV	CV Conservation District	
I1	I1 Industrial District	
I2	I2 Heavy Industrial District	
M	M Mining District	
OP	OP Office-Professional District	
PDP(AF)	PDP (Aviation Facilities)	
PDP(CM)	PDP (Commercial Marine)	
PDP(CP)	PDP (Corporate Park)	
PDP(GC)	PDP (General Commercial)	
PDP(GHC)	PDP (General Highway Commercial)	
PDP(HC)	PDP (Highway Commercial)	
PDP(HHC)	PDP (Heavy Highway Commercial)	
PDP(HID)	PDP (Heavy Industrial)	
PDP(IND)	PDP (Industrial)	
PDP(LI)	PDP (Light Industrial)	
PDP(MF)	PDP (Multifamily)	0.35
PDP(MH)	PDP (Mobile Home)	0.35
PDP(NC)	PDP (Neighborhood Commercial)	
PDP(OP)	PDP (Office/Professional)	
PDP(OP)	PDP (Single-Family)	0.35
PDP(PSF)	PDP (Public Service Facility Overlay District)	
PDP(REC)	PDP (Recreational)	
PDP(RR)	PDP (Resort Residential)	0.35
PDP(RUR)	PDP (Rural)	
PDP(SF)	PDP (Single-Family)	0.35
PDP(SU)	PDP (Recreational)	

Zoning Code	Zoning Description	% Maximum Lot Coverage
PDP(SU)	PDP (Single-Family)	
PDP(SU)	PDP (Special Use)	
R1A	R1A Residential District	0.35
R1B	R1B Residential District	0.35
R1C	R1C Residential District	0.35
R1MH	R1MH Residential Single-Family Manufactured Housing	
R2	R2 Residential District	0.35
R2.5	R2.5 Residential District	0.35
R3	R3 Residential District	0.45
R4	R4 Residential District	0.45
RC	RC Recreational Commercial District	
RM	RM Residential Mobile Home District	0.35
RR	Residential District	0.45

Table A.7: Pasco County zoning data

Zoning Code	Zoning Description	% Maximum Lot Coverage
AC	Agricultural District	0.15
AC1	Agricultural District	0.15
AR	Agricultural-Residential District	0.25
AR1	Agricultural-Residential District	0.25
AR5	Agricultural-Residential District	0.3
AR5MH	Agricultural-Mobile Home District	0.3
C1	Neighborhood Commercial District	0.5
C2	General Commercial District	0.5
C3	Commercial/Light Manufacturing District	0.5
ER	Estate-Residential District	0.35
ER1	Estate-Residential District	0.35
I1	Light Industrial Park District	0.5
I2	Light Industrial Park District	0.5
MF1	Multiple Family Medium Density District	0.4
MF2	Multiple Family High Density District	0.55
MF3	Multiple Family High Density District	0.55
PO1	Professional Office District	0.35
PO2	Professional Office District	0.35
R1	Rural Density Residential District	0.35
R1MH	Mobile Home District	0.35
R2	Low Density Residential District	0.65
R2MH	Mobile Home District	0.35
R3	Medium Density Residential District	0.65
R4	High Density Residential District	0.65
RMH	Mobile Home District	0.35

Table A.8: 2012 CoA livestock populations for Hernando and Pasco Counties

CoA Population	Hernando County	Pasco County
Beef Cattle	11,402	21,509
Calves	4,397	8,352
Dairy Cows		1,092
Horses	2,080	2,008
Broiler Chickens		604
Goats	1,034	1410
Hogs	328	165
Sheep	318	251
Turkey		63



Golf Course Questionnaire Florida Department of Environmental Protection Ground Water Management Section 850-245-8652

This survey is designed to gather data on nitrogen (N) application rates. All information is optional, remains confidential and is not utilized for any regulatory purposes.

This form is available electronically, for an e-mail version please contact us at the addresses listed at the bottom.

CONTACT INFORMATION

Name	Are you the course Superintendent?	Preferred Method of Contact
	YES	Email
	NO	Phone
Email Address		Phone Number

GOLF COURSE INFORMATION

Golf Course Name

What is the closest city or town?

Does your golf course follow the BMP manual?

What is the total area of the course?

YES

NO

Sq ft

Acre

GREENS (including practice greens)

Total Area of Greens		Sq ft	Acre
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N Application Rate each Year	per	1000 sq ft	acre
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N Application Rate each Application	per	1000 sq ft	acre
-------------------------------------	-----	------------	------

Number of Applications per Year	What is the type of grass planted?
---------------------------------	------------------------------------

TEES

Total Area of Tees		Sq ft	Acre
N Application Rate each Year	per	1000 sq ft	acre
N Application Rate each Application	per	1000 sq ft	acre
Number of Applications per Year	What is the type of grass planted?		

FAIRWAYS (including driving ranges)

Total Area of Fairways		Sq ft	Acre
N Application Rate each Year	per	1000 sq ft	acre
N Application Rate each Application	per	1000 sq ft	acre
Number of Applications per Year	What is the type of grass planted?		

ROUGH

Total Area of Rough		Sq ft	Acre
N Application Rate each Year	per	1000 sq ft	acre
N Application Rate each Application	per	1000 sq ft	acre
Number of Applications per Year	What is the type of grass planted?		

OTHER AREAS

What is the area of the course sand traps?	Sq ft	What is the area of the course water bodies?	Sq ft
	Acre		Acre

What types of fertilizer are utilized?

Slow Release	Ammonium Nitrate	Urea based
Other		

Does your golf course have a:

Rain Gauge

Weather Station

Neither

Are irrigation rates adjusted
based on rainfall?

YES

NO

Please describe how grass clippings are treated.

REUSE WATER

Is reuse water utilized?

YES

NO, skip remainder of this section

What facility provides reuse water?

Do you know the average N concentration?

YES

NO

If yes, please list

Do you know the volume used per year?

YES

NO

If yes, please list

Are fertilizer rates adjusted based on the N concentration of the reuse water?

YES

NO

If yes, please describe how

Thank you very much for your time. Please send the completed questionnaire to one of the addresses below.

Kirstin Eller: Kirstin.Eller@dep.state.fl.us

Brian Katz: Brian.Katz@dep.state.fl.us

Yesenia Escibano: Yesenia.Escibano@dep.state.fl.us

Ground Water Management Section

Golf Course Questionnaire

2600 Blair Stone Rd MS 3575

Tallahassee, FL 32399

Appendix C: Comparison of Methods and Results for the NSILT and Jones et al. (1997)

In 1997, the SWFWMD Ambient Ground Water Quality Monitoring Program conducted a study to determine the sources of increasing nitrate concentrations in Weeki Wachee Spring (Jones et al. 1997). The study objectives were to delineate the areas where nitrate was entering the aquifer system, identify the land uses contributing nitrate, and determine management actions to slow or reduce nitrate loading to groundwater in the Weeki Wachee Spring contributing area.

This appendix compares the methods and results from the SWFWMD study and the DEP NSILT. In addition, several factors are listed to account for the differences in estimated nitrogen inputs for the two studies. This comparison provides insights into how the relative contributions of nitrogen may have changed for various potential nitrogen sources and land uses over the past 20 years.

Study Area

- The NSILT used the spring contributing area largely based on the Weeki Wachee springshed. This area encompasses 162,714 acres of land with varying degrees of associated recharge. However, the analysis used only data from high-, medium-, and low-recharge areas.
- The Jones et al. (1997) study area comprised 390 square miles, or 249,599 acres, with no acreage estimates for the varying recharge areas.
- The study areas used in both methods were based on the same shape of the springshed and groundwater flow direction to the spring vent. However, the Jones et al. (2007) study area was nearly 50% larger than that of the NSILT study area. This size difference influenced the inputs calculated for each method.

Atmospheric Deposition

- The NSILT used data from the multiyear TDEP model developed by the EPA. The annual nitrogen input to the land surface from atmospheric deposition was 1,144,933 lb-N.
- The SWFWMD study (Jones et al. 1997) used an average wet deposition concentration of 1.0 mg/L of total N, based on 9 rainfall samples collected from a station in northwestern Citrus County, north of Weeki Wachee Spring. Using an average annual rainfall of 56 inches, researchers calculated a total of 1,585 tons/yr, or 3,147,000 lbs, over the entire study area.

- The SWFWMD estimate was larger by 2,002,067 lb-N/yr, likely because of the higher nitrogen concentration in rainfall used in the study. Several factors may have accounted for these differences, including the period when the rainfall was collected or differences in collection and analytical methods.

Septic Systems

- The NSILT relied on the modified estimate of septic systems by Hall and Clancy (2009). An average of 2.08 people contribute to each septic system in Hernando County and 2.07 people in Pasco County. With an annual input of 9.92 lb-N/person, this equaled an input of 20.6 lb-N per septic system. With 34,201 systems in the contributing area, 704,391 lb-N were applied to the land surface every year.
- Jones et al. (2007) estimated 12,400 septic systems within the boundary area based on an aerial imagery survey. With 3 people per household and an average nitrogen input of 55 lb-N/yr per tank, the total input attributable to septic systems was 341 tons/yr or 682,000 lb-N/yr. Additionally, Jones et al. (2007) incorporated the input from the land spreading of septage waste, which was determined to be a very minor source of nitrogen equaling 7.1 tons-N or 1,576 lb-N/yr.
- There were two main differences between these methods: the number of estimated septic systems and the annual input per system. The NSILT analysis included almost 3 times the number of septic systems compared with Jones et al. (1997). This could be attributable to the more accurate counting methods used for the NSILT as well as population growth in the area. Additionally, the annual input per system used by the SWFWMD was over double compared with that used by DEP. The combination of these factors resulted in a similar estimate for septic systems, with a difference of only 22,391 lb-N/yr. The addition of land spreading of septage also increased the Jones et al. (2007) septic system estimation in a minor way, given the small contribution of this source.

Urban Turfgrass Fertilizers

- The NSILT relied on regional fertilizer application rates for the pervious land area associated with urban land uses. The estimated TN input was 1,718,639 lb-N/yr over the 21,991 acres fertilized within the contributing area.

- Jones et al. (1997) used FDACS annual fertilizer sales data. The residential acreage was calculated from land use maps developed from 1990 aerial photography. It was assumed the fertilizer was applied evenly across this acreage, resulting in 426,000 lb-N/yr applied within the Weeki Wachee Spring study area.
- The higher NSILT calculation is likely due to a combination of factors, including the different methods used, the increased urbanization of the area over the past 20 years, and the inclusion of nonresidential urban land uses in the NSILT calculations.

Sports Turfgrass Fertilizer

- For the NSILT, 13 golf courses covering 1,581 acres were identified. A combination of survey data provided by the golf courses and an average application rate of 86.8 lb-N/ac resulted in an input to the land surface of 196,791 lb-N/yr. Calculations for sporting facilities were made based on fertilization rates for lawn service companies. These added 3,851 lb-N/yr, for a total of 200,642 lb-N/yr attributable to sports turfgrass fertilizers.
- Jones et al. (1997) included 10 golf courses covering a total of 853 acres. The authors used an application rate of 260 lb-N/acres based on a study completed in Sarasota Bay, for a total of 222,000 lb-N/yr, or 111 tons-N/yr.
- The difference of 21,358 lb-N/yr was likely due to changing trends in golf course maintenance over the past 20 years. While the golf course acreage was largely in the NSILT area, the application rates were lower, resulting in a lower input to the land surface.

Wastewater Treatment Facilities

- The NSILT used reported effluent data from 14 facilities in the contributing area. These had a combined actual flow of 2.4 MGD, with an average nitrogen concentration of 9.73 mg/L. The annual input attributable to these facilities equaled 40,185 lb-N/yr. An additional 80,249 lb-N is attributed to reclaimed water distribution within the contributing area from facilities in the Magnolia and Aripeka Springs contributing area and the Chassahowitzka Spring contributing area. The assessment did not include input associated with domestic WWTF residuals because of the lack of supporting data.

- Jones et al. (1997) evaluated WWTFs in two different categories: sewage effluent disposal and the land disposal of sludge. The total effluent disposal was estimated by assessing 27 facilities with an average flow of 6.8 MGD. The total input was estimated using an average nitrogen concentration of 40 mg/L, equaling 320,000 lb-N/yr. Additionally, 194,000 lb-N/yr were calculated for the land spreading of sludge in the study area.
- There is a very large difference between the two studies because the Jones et al. (1998) study used the much higher effluent concentration and included the sludge estimate. Additionally, since the first study was completed, considerable advances in waste treatment were made and applied in this area that would contribute to the lower effluent concentration used in the NSILT.

Farm Fertilizers

- To obtain nitrogen inputs from farm fertilizers, the NSILT used property appraiser data, known crops grown in the area, and agricultural producer feedback, as well as UF IFAS–recommended fertilizer application rates. The 39,036 acres of cropland and pastures in the contributing area contributed 1,168,475 lb-N/yr.
- Jones et al. (1997) estimated fertilization for citrus, row crops, and pasturelands. Row crops were calculated based on a fertilizer application rate of 170 lb-N/ac/yr over 423 acres. Citrus fertilization was based on the application of 180 lb-N/ac/yr over 700 acres. Pastureland was estimated using FDACS fertilizer sales data. The amount of fertilizer attributable to row crops and citrus was subtracted from the amount of reported fertilizer sold for farming practices. The remaining fertilizer was assumed to be used for pasture fertilization. The estimated pasture acreage in the study area was not disclosed. In the Weeki Wachee Spring study area, the nitrogen attributed to farm fertilization equaled 722,000 lb-N/yr.
- The results from these two methods were comparable, with a difference of 553,525. The application rates used for the Jones et al. (1997) study were higher; however, the acreage utilized in the NSILT was considerably larger. These differences resulted in a similar estimated nitrogen input for farm fertilizer.

Livestock Waste

- The NSILT included cattle as well as other livestock animals within the BMAP boundary. Based on stocking rates gathered from feedback from cattle farmers, the cattle population was 4,989. Additional livestock animal populations estimated from the 2012 CoA were assigned to the contributing area based on the distribution of livestock lands (such as improved pasture). Daily waste factors were applied based on the nitrogen content for each animal. The total input to the land surface equaled 1,142,659 lb-N/yr.
- The SWFWMD separated livestock waste estimates into 3 different categories: poultry, dairies, and cattle. FDACS estimated the animal populations, and daily waste factors were applied. Poultry produces 0.053 lb-N/day/animal, resulting in an annual input of 856 tons, or 1,712,000 lb-N. Dairy cows produce 0.45 lb-N/day/1,000 lb of body weight, equaling a total input of 98 tons/yr, or 196,000 lb-N/yr. Cattle, which were assumed to represent beef cattle, have a daily waste factor of 0.33 lb-N/1,000 of body weight, with an associated input of 1,015 tons/yr, or 2,030,000 lb-N/yr. The individual Weeki Wachee Spring study area populations were not specified. In total, Jones et al. (1997) calculated livestock waste at 3,938,000 lb-N/yr.
- There was a large difference between these two estimates (2,795,341 lb-N/yr). The daily waste factors used in both studies were comparable and likely did not contribute to the discrepancy. Without knowing the exact population used in the Jones et al. (2007) study, DEP could not directly determine the population differences. However, this was the most likely factor leading to such a large difference. Although poultry farming in Hernando County has dramatically decreased since the 1990s and was not even calculated in the NSILT due to vastly incorrect populations reported in the CoA (see **Section 2.5**), this decrease in poultry farming contributed to a difference of almost 3 million pounds.

Stormwater

- The NSILT did not estimate the influence of stormwater-sourced nitrogen on groundwater.
- Jones et al. (1998) calculated that 76,000 lb-N/yr runs off from golf courses, residential areas, commercial properties, and cropland via stormwater.

Comparison of TN Inputs

The TN inputs to the land surface calculated by Jones et al. (1998) were 9,727,000 lb-N/yr (based on 249,599 acres of land area, resulting in an average of 39 lb-N/ac). The two sources that contributed the highest percentages of nitrogen to the land surface were livestock waste (42%) and atmospheric deposition (33%).

The NSILT estimated TN inputs of 6,293,733 lb-N/yr to the land surface (162,714 acres) in the Weeki Wachee Spring BMAP area, or an average of 39 lb-N/ac. The three sources contributing the largest percentages of nitrogen inputs to the land surface were urban turfgrass fertilizer (27%), atmospheric deposition (18%), and farm fertilizers (19%). **Table C.1** compares the relative percentages calculated using both methods.

As described above, there were notable differences between the two studies in the methods used to estimate nitrogen inputs to the land surface. The biggest differences were attributable to the study area sizes, the development of more accurate methods to identify land uses, and the application of nitrogen for different land use practices.

The SWFWMD study (Jones et al. 1997) provided an important baseline for comparison with the nitrogen inventory for the Weeki Wachee Spring contributing area. Current information on the nitrogen source inventory and nitrogen loads to groundwater generated from the NSILT for the Weeki Wachee Spring BMAP will be used to determine where present-day nitrogen loading to groundwater can be reduced to restore water quality in Weeki Wachee Spring and River.

Table C.1: Comparison of nitrogen input percentages to the land surface calculated by the NSILT and Jones et al. (1997)

N Loading Category	NSILT (2016)	Jones et al. (1997)
Atmospheric Deposition	18%	33%
Septic Systems	10%	7%
WWTFs	1%	2%
Urban Turfgrass Fertilizers	27%	5%
Sports Turfgrass Fertilizers	3%	2%
Farm Fertilizers	19%	8%
Livestock Waste	21%	42%
Stormwater	0%	1%