

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, Groundwater Management Section of the Water Quality Evaluation and Total Maximum Daily Loads (TMDL) Program, to assist in the development and implementation of the *Basin Management Action Plan (BMAP) for the Coastal Springs of Pasco and Hernando Counties* to address the TMDL for nitrate. The results of this assessment are based on the information provided in the document.

This October 2016 update includes changes to the septic system annual loading per person and associated attenuation, based on additional literature reviews. In addition, urban fertilizers were divided into two categories (urban turfgrass fertilizer and sports turfgrass fertilizer) and the methodology was updated to provide data for source categories identified in the Florida Springs and Aquifer Protection Act.

Disclaimer: Please note that all values listed in this report are rounded, while the actual calculations were completed using 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 [WWTfs], urban fertilizers, septic systems, livestock wastes, and agricultural fertilizers) in the groundwater contributing area (or springshed) for Weeki Wachee Spring. In addition, this tool is used to estimate nitrogen loads to groundwater from these sources in the spring contributing area.

The NSILT is an Arc geographic information system (ArcGIS) and spreadsheet-based tool that provides spatial estimates of the relative current contributions 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 Upper Floridan aquifer (UFA). The NSILT does not account for the legacy loads of nitrogen that may already be present in the aquifer and that continue to adversely impact groundwater quality. Several spring basin studies have reported increasing nitrate-N concentrations in groundwater and springs over time. Nitrogen that entered groundwater from past anthropogenic practices may slowly exit the groundwater flow system via springs, given that the average groundwater residence times in large spring basins in Florida is on the order of decades (Katz et al. 1999; Katz 2004; Phelps 2004; Happell et al. 2006; Knowles et al. 2010).

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 estimated total

annual nitrogen input to the land surface in the contributing area from all sources is 5.4 million pounds of nitrogen (lb-N). Livestock waste contributes 24 % of the TN input. Other nitrogen sources and their estimated contributions, in order of decreasing nitrogen inputs to the land surface, include farm fertilizer (22 %), atmospheric deposition (21 %), urban turfgrass fertilizer (15 %), septic systems (12 %), sports turfgrass fertilizer (4 %) and WWTFs (1 %).

The NSILT results indicate an estimated total annual load of 940,143 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 medium (3.01 to 10 inches per year [in/yr]) or high (greater than 10 in/yr), the UFA is more vulnerable to contamination than in areas where recharge rates are low (0 to 3 in/yr).

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 septic systems (30 %), followed by urban turfgrass fertilizer (22 %) and farm fertilizers (17 %). Sources contributing smaller amounts of nitrogen include atmospheric deposition (10 %), livestock waste (10 %), sport turfgrass fertilizer (6 %), and WWTFs (5 %).

The NSILT results provide a baseline understanding of current nitrogen loads to groundwater from existing sources in areas where the Weeki Wachee Spring Basin is likely to contribute the greatest loads of nitrogen 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 locations within 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), the highly transmissive limestone aquifer that is the source of water flowing from the springs (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 systems, 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 current 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 does not account for legacy loads of nitrogen that may already be present in the aquifer and that continues to adversely impact groundwater quality in some areas. Several spring basin studies have reported increasing nitrate-N concentrations in groundwater and springs over time. Nitrogen that entered groundwater from past anthropogenic practices may slowly exit the groundwater flow system via springs, given that the average groundwater residence times in large spring basins in Florida is on the order of decades (Katz et al. 1999; Katz 2004; Phelps 2004; Happell et al. 2006; Knowles et al. 2010).

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, total maximum daily loads (TMDLs) were 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 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 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 northern border of this contributing area coincides with the southern boundary of the Chassahowitzka contributing area, where another NSILT analysis was completed (Eller et al. 2016).

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 has been completed for the groundwater contributing area to Magnolia and Aripeka Springs (Lyon et al 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).

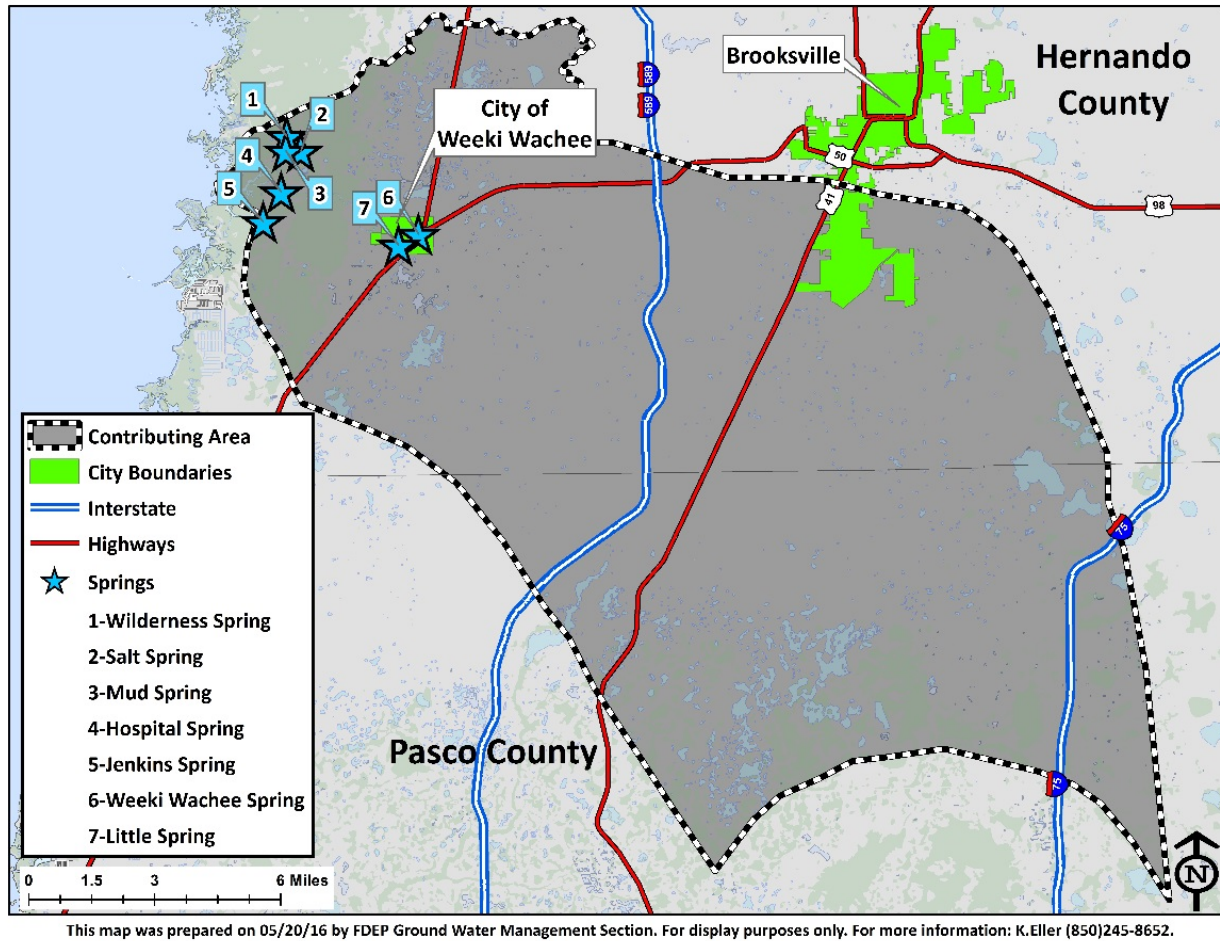


Figure 1: Map showing the Weeki Wachee Spring and Weeki Wachee River contributing area

The dissolution of the carbonate rocks comprising 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, groundwater in 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, water flowing from Weeki Wachee Spring includes 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 hydrogeological 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.

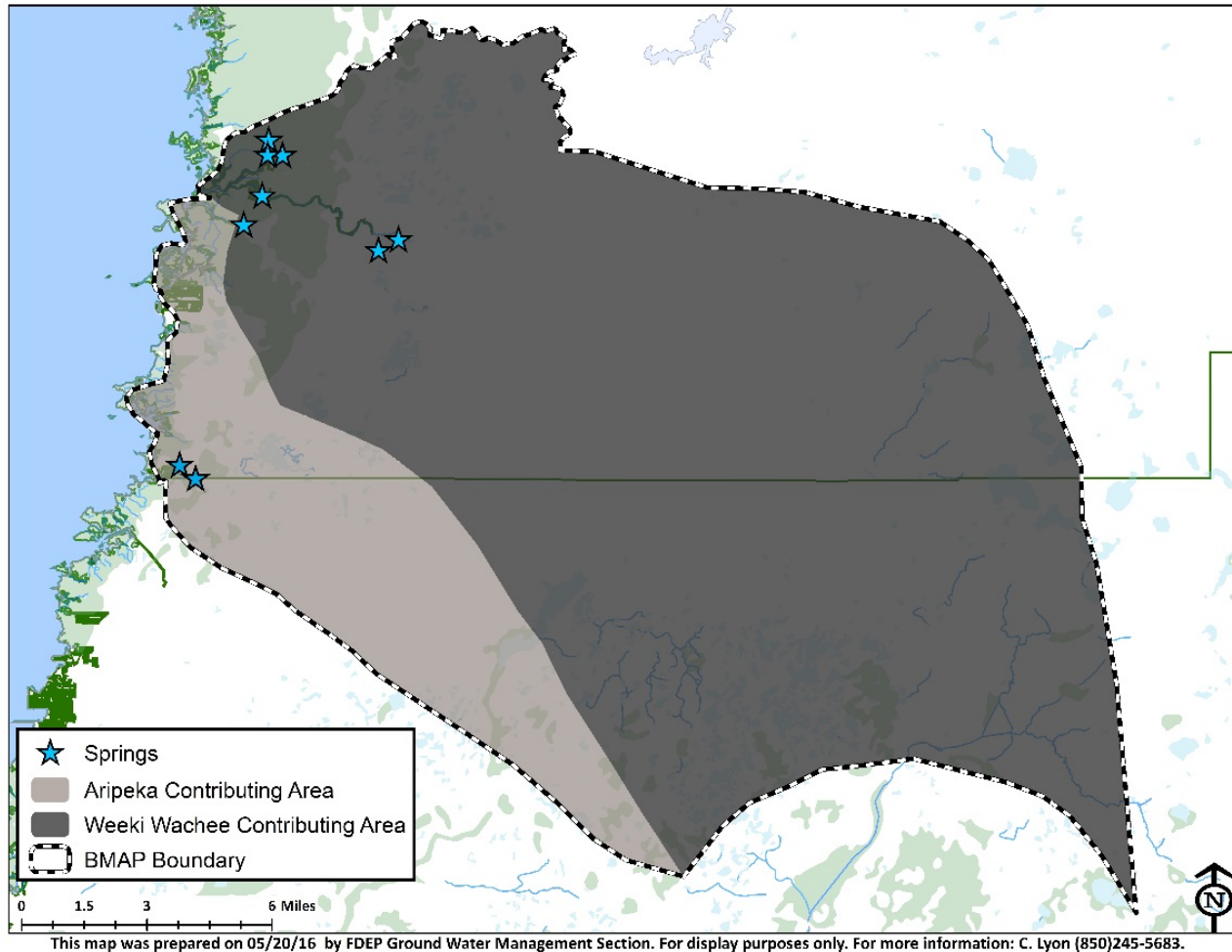


Figure 2: BMAP area for the coastal springs of Pasco and Hernando Counties

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 contributing 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.

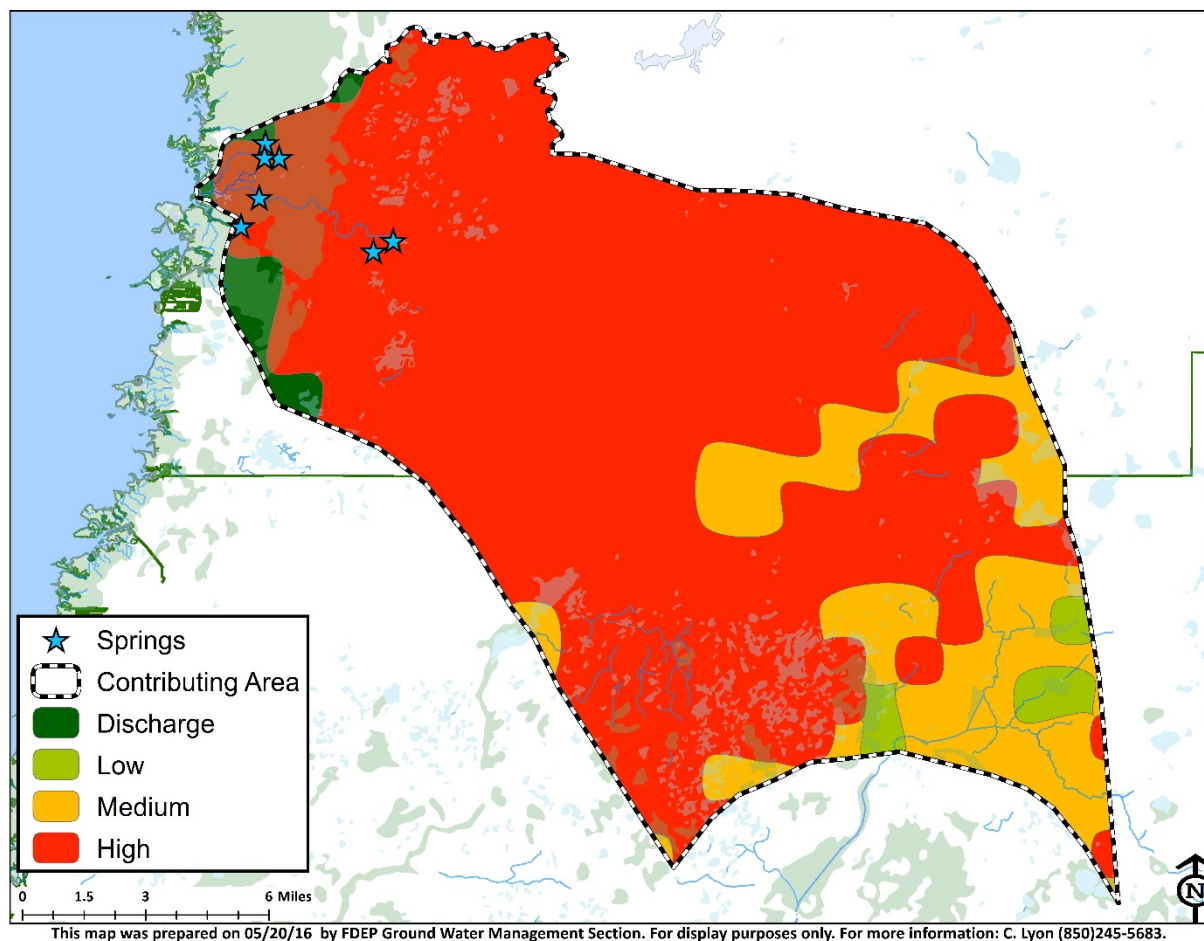


Figure 3: UFA recharge rate categories in the Weeki Wachee Spring contributing area

1.4 Land Use

Land use/land cover (LULC) was assessed with the most recent land use Arc geographic information system (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 estimated for atmospheric deposition, wastewater treatment facilities (WWTFs) land application sites, septic systems, urban and agricultural fertilizer use, and livestock waste. The methods used to estimate nitrogen inputs for these sources are based on a detailed synthesis of information, including direct water quality measurements, Census data, surveys, wastewater facility permits, published scientific studies and reports, and information obtained in meetings with agricultural producers.

For some nitrogen source categories, the nitrogen inputs were calculated using assumptions and extrapolations. In the future, these inputs may be revised if more detailed information becomes available. The approach and sources of information used to estimate the annual input (in pounds per year of nitrogen [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 NTN 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.

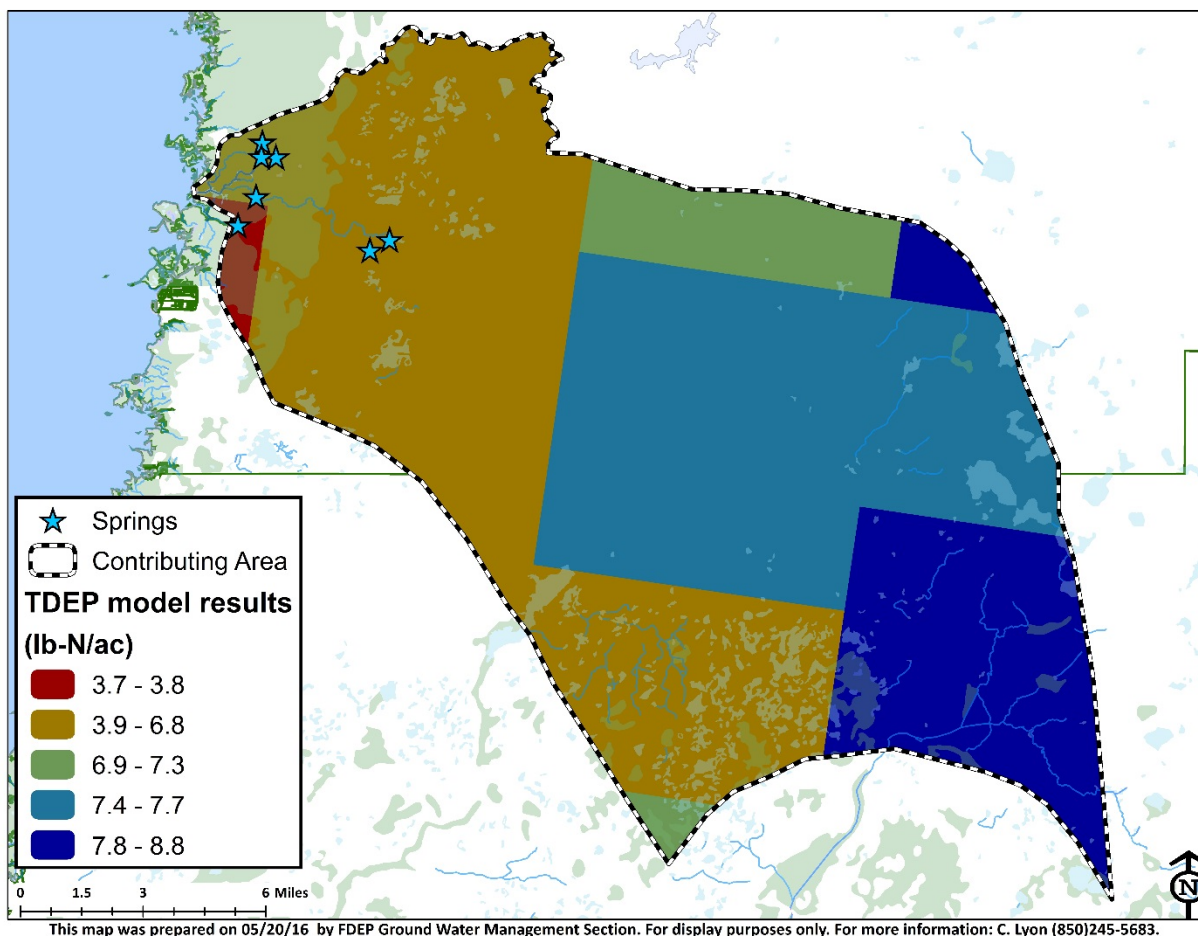


Figure 4: Atmospheric deposition model results used for the NSILT

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, 2 facilities located outside the Weeki Wachee contributing area distribute reclaimed water for irrigation within the contributing area.

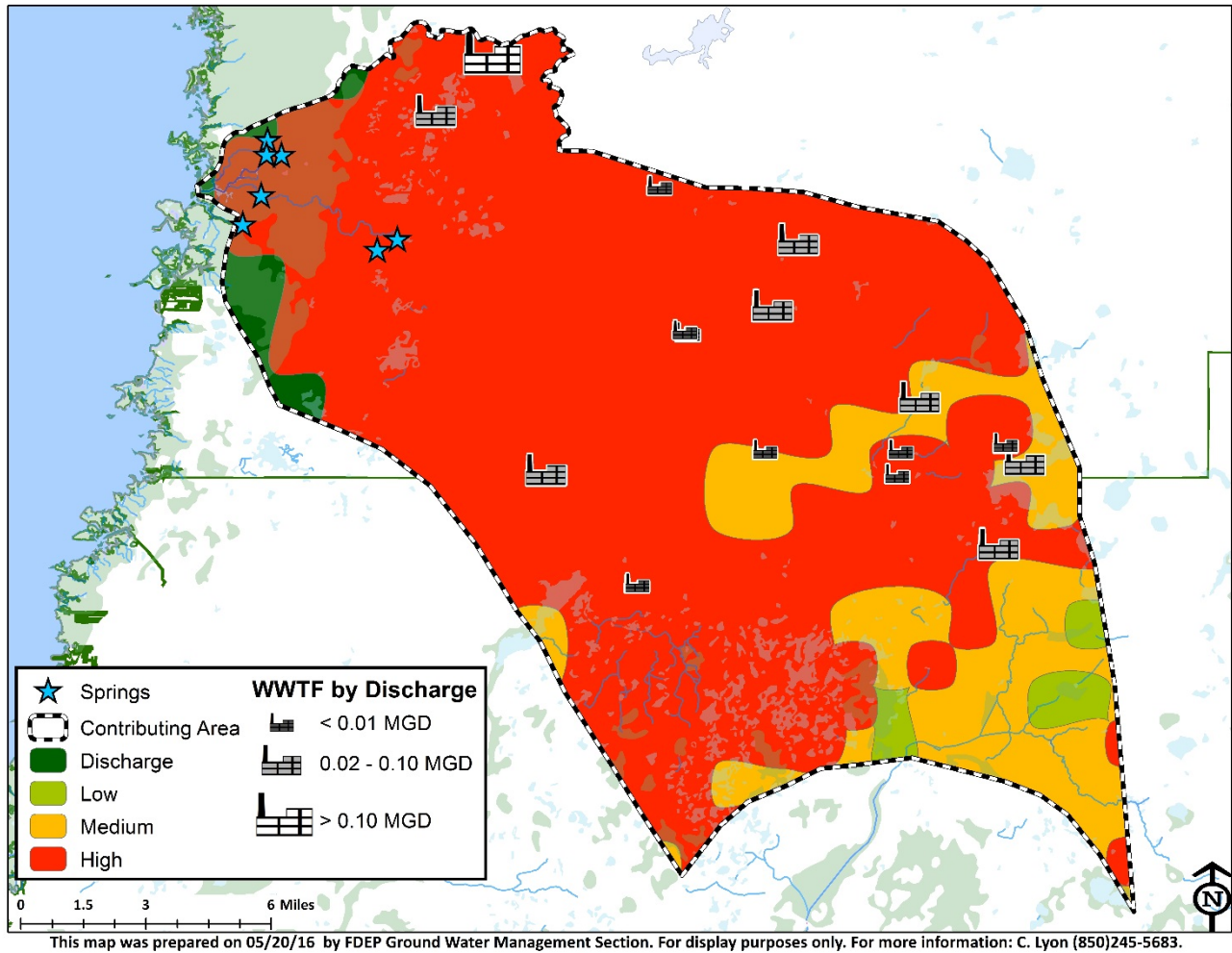


Figure 5: Distribution of WWTFs in the Weeki Wachee Spring contributing area

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 the data from 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. With no 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, the 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 associated with this property are irrigated 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 could 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. The septic system counts using this methodology compare favorably with the results of recently released [Florida Water Management Inventory \(FLWMI\) septic system numbers](#) for Hernando and Pasco Counties by FDOH.

After the number of septic systems in the contributing area was obtained, the population served by septic systems was estimated using the [2010 U.S. Census Bureau data](#) for population and household occupancy in each county. The Census makes a distinction between occupied and unoccupied homes. The county population was divided by the number of occupied homes 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 U.S. Department of Labor [Bureau of Labor Statistics](#), spends 43.5 hours or 25.9 % of the week away from home and therefore is 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 %). For more information, see **Appendix A, Table A.6, Table A.7, and Table A.8.**

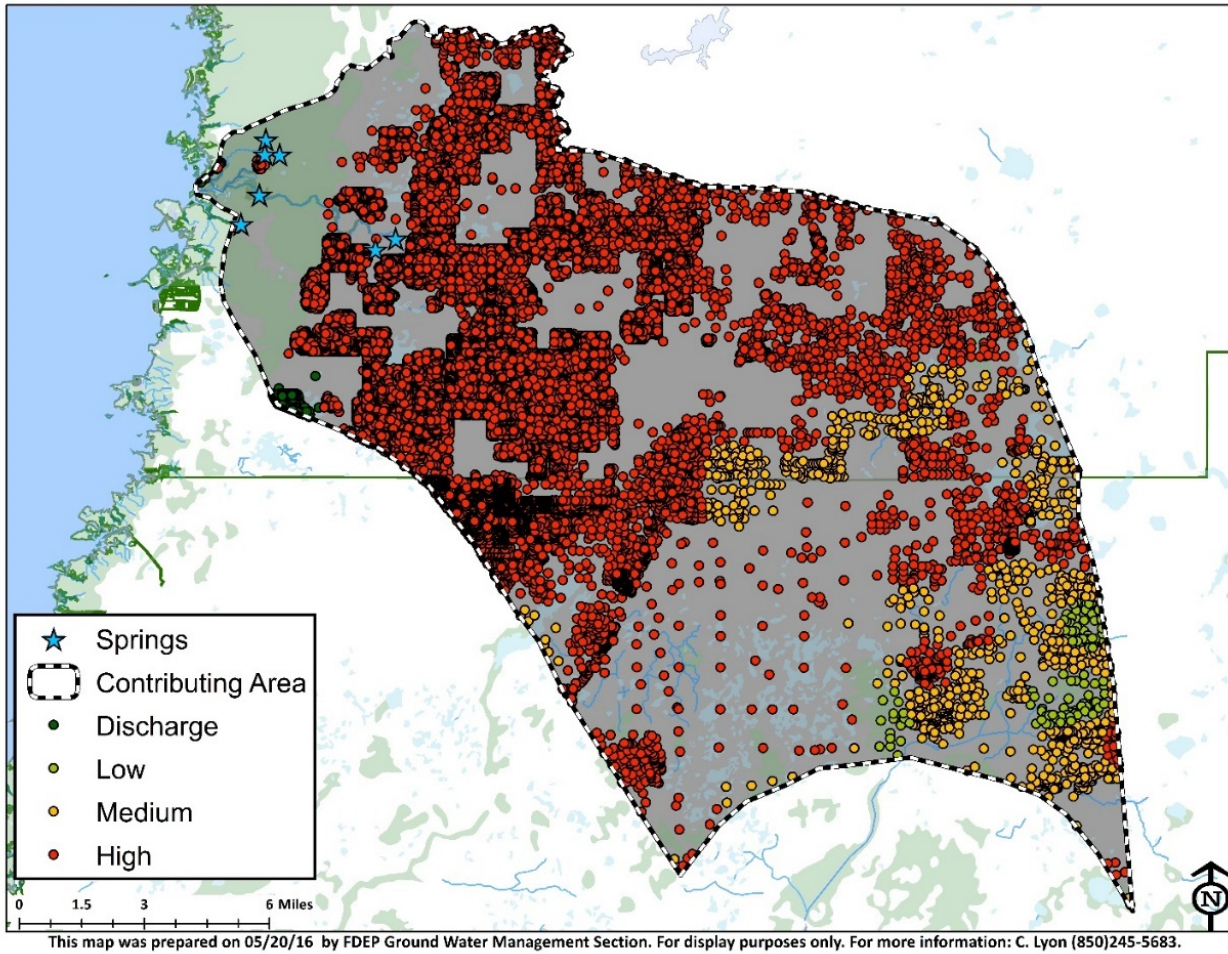


Figure 6: Distribution of septic systems throughout the Weeki Wachee Spring BMAP area

The total population in the Weeki Wachee contributing area served by septic systems was estimated by multiplying the estimated number of people per household (adjusted for estimated actual use) 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. 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 to solicit information about residential fertilizer use in Citrus County and southern Marion County. The results from this survey were used to estimate fertilizer application rates to all urban turfgrass in the BMAP area. According to the survey (Martin 2008), 68 % of the surveyed population applied fertilizer to their own lawns 3 times a year at variable rates that may range as high as 45.56 lb-N/ac (**Table 4**). Additionally, 32 % of the population surveyed hired lawn service companies. Lawn service companies typically apply fertilizer at rates consistent with the *Green Industries Best Management Practices (BMP) 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 lawn service professionals or trained staff using application rates and frequencies similar to those recommended in the *Green Industries BMP Manual*.

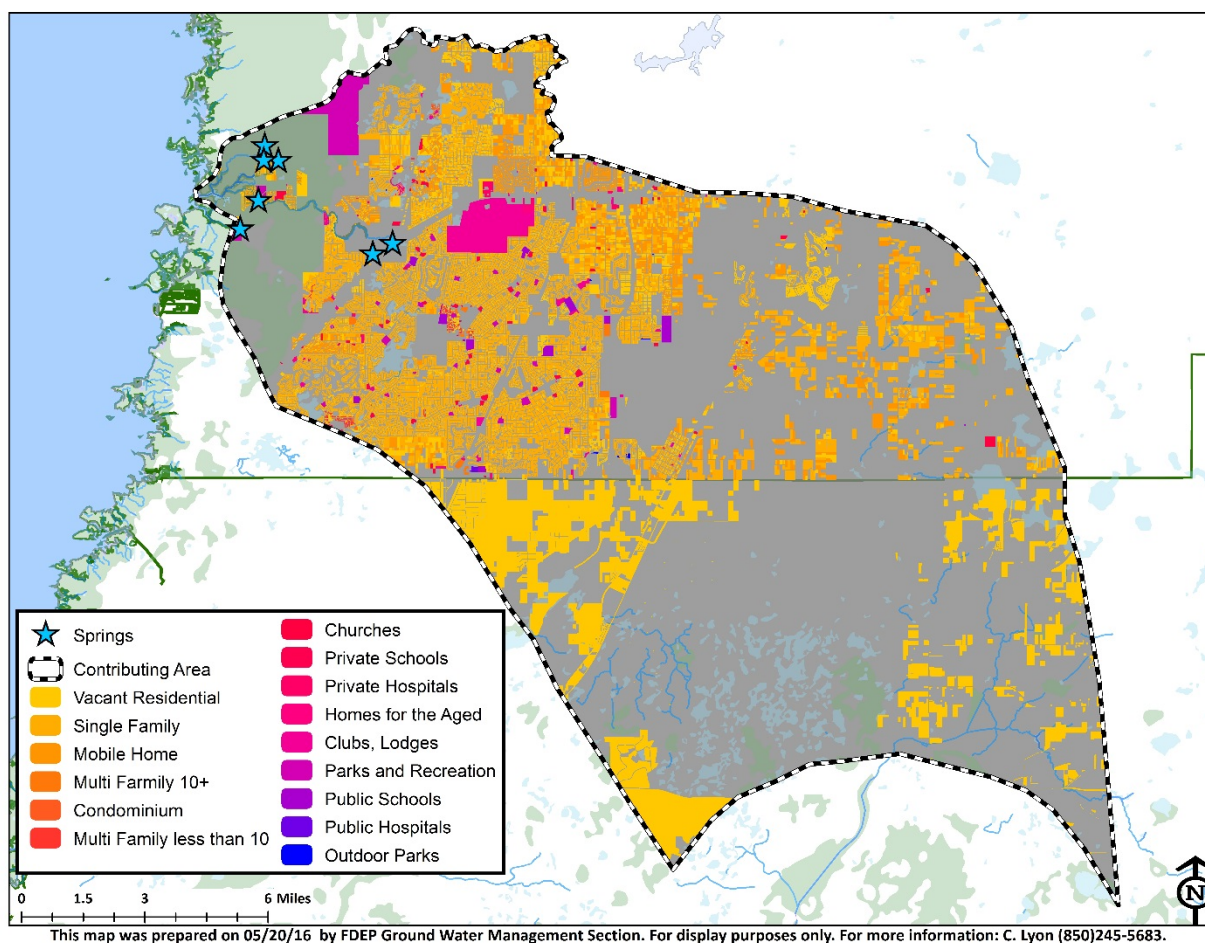


Figure 7: Urban noncommercial lands in the Weeki Wachee Spring contributing area according to county property appraiser data

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

Basis for Application Rate	% of Population and Basis for Fertilizer Rate Selection	Estimated Rate (lb-N/ac)
Green Industry BMP Guidelines	15 %	21.78
Fertilizer Bag Label	74 %	34.78
Do Not Apply Fertilizer	11 %	Not applicable

2.4.2 Nonresidential Parcel Estimations

The acreage of public green space land areas 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 areas 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, Table A.6, and Table A.7. Table 5** summarizes these data.

Table 5: Summary of the fertilizable urban land area and associated nitrogen 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	0	0	0	945
Churches	364	31	13	0	17,781
Schools	322	8	0	0	14,375
Hospitals	87	0	0	0	3,807
Homes for the Aged	97	0	0	0	4,244
Clubs, Lodges, Union Halls	1,558	0	0	0	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 such as single- and multifamily homes, the acreage receiving fertilizer applications is estimated in the same manner as nonresidential parcels. Prior to applying the fertilizer application rates to the pervious land area, two factors are taken into account: (1) the percentage of a property that a homeowner will fertilize, and (2) the probability that a homeowner will use fertilizer.

The majority of homeowners will apply fertilizer to all the pervious area on their property (lawns and beds), but for those with larger lot sizes, this is less likely. For this analysis, it was assumed that the owners of properties with greater than one acre of pervious land area would regularly apply fertilizer to no more than one acre.

As for the probability of a homeowner fertilizing a property, based on socioeconomic studies, property value is generally correlated with landscape fertilization in a residential setting, with higher valued properties receiving more fertilizer (Kinzig et al. 2005; Law et al. 2004; Zhou et al. 2008; Cook et al. 2012). To apply this factor, the range of property values for single-family homes was evaluated for the contributing area and subdivided into three categories based on property value: high, medium, and low. **Table 6** lists the estimated probability of fertilization for each property value category based on the literature.

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 of fertilization percentage represents the probability that a homeowner will fertilize some or all of a property in a given year. These percentages were assigned 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 are applied to the pervious acreage of residential properties to estimate the land area presumed to be fertilized. The land area potentially receiving fertilizer is multiplied by the application rate and frequency listed in **Table 6** to obtain the estimated input of nitrogen in fertilizer to the land surface on residential parcels. **Table 7** summarizes these data. **Appendix B** provides more detailed information on the methodology.

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	7,877	136	765	187	30	528,543
Multifamily Residential	79	0	89	25	3	2,741
Mobile Home	0	0	0	0	0	0
Condominium	5	0	0	0	0	64
Vacant Residential	508	7	201	80	9	
TOTAL	8,469	143	1,055	292	41	540,368

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 facilities for sports 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 golf course superintendents were used to provide basic information about fertilizer practices. Of those surveyed, responses were received from 46 % of the golf courses with detailed information about fertilizer applications (see **Appendix C** 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 54 % of the golf courses in the area, the NSILT used a statewide annual average application rate 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, the estimated input of nitrogen from all golf courses in the

BMAP area was 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 of nitrogen attributed to 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	0	176	32,844
Glen Lakes*	Hernando	125	0	7	602
Heather*	Hernando	46	0	89	4,875
Hernando Oaks*	Hernando	139	0	141	19,624
High Point*	Hernando	70	0	78	5,489
Oak Hills	Hernando	184	0	141	26,029
Rivard	Hernando	95	0	141	13,469
Seven Hills	Hernando	129	0	141	18,164
Silverthorn	Hernando	176	0	141	24,768
Southern Hills Plantation	Hernando	162	0	141	22,824
Spring Hill	Hernando	159	0	141	22,374
Timber Pines*	Hernando	215	0	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 sports facilities were identified and evaluated based on aerial imagery. In total, 88 acres of land were associated with sports 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 turf areas at sports facilities are fertilized at rates applied by lawn service companies, as described in **Section 2.4**, resulting in an estimated 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	0	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. Information on agricultural practices specific to livestock management was 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 (unimproved) pastures. **Table 10** lists the estimated pasture acreage and the associated cattle populations in 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, assumptions of livestock populations in the contributing area were made based on land use coverage.

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	0	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	Semi-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	0	490
Pasco	65	Grazing land Soil Capab VI	Overflow Prairie	2,525	342	0	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 the percentages of countywide livestock areas that occur in the BMAP area and the high-, medium-, and low-recharge areas within it.

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: Water management district 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	100 %	2,080	546	1,034	328	318	0
High Recharge	13,447	40 %	826	217	411	130	126	0
Medium Recharge	8,947	26 %	550	144	273	87	84	0

Table 12: Water management district 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	100 %	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	0	124,362
Hernando–Medium Recharge	1,722	54,781	8,375	3,491	6,012	6,074	0	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 property appraiser 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 property appraiser 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 estimated total annual nitrogen input to the land surface from all sources is 5.4 million lb-N. Livestock waste comprises 24 % 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 %), atmospheric deposition (21 %), urban turfgrass fertilizer (15 %), septic systems (12 %), sports turfgrass fertilizer (4 %), and WWTF land application sites (1 %).

Table 14: Summary of crop types and assumed 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 assumed 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	0	6,430
60	Improved Pastureland	Improved Pasture	60	12,137	11,031	2,127	367,487
61	Grazing Land Soil Capability II	Improved Below Average	25	700	283	267	7,813
62	Grazing Land Soil Capability III	Partial Improved	0	553	4	100	0
63	Grazing Land Soil Capability IV	Native	0	984	370	283	0
64	Grazing Land Soil Capability V	Native/Hammock	0	2,276	1,151	0	0
65	Grazing Land Soil Capability VI	Marsh Overflow Prairie	0	2,525	342	0	0
66	Orchard Groves	Orchards	150	630	561	147	200,733
69	Ornamentals	Ornamentals	80	172	72	0	21,954

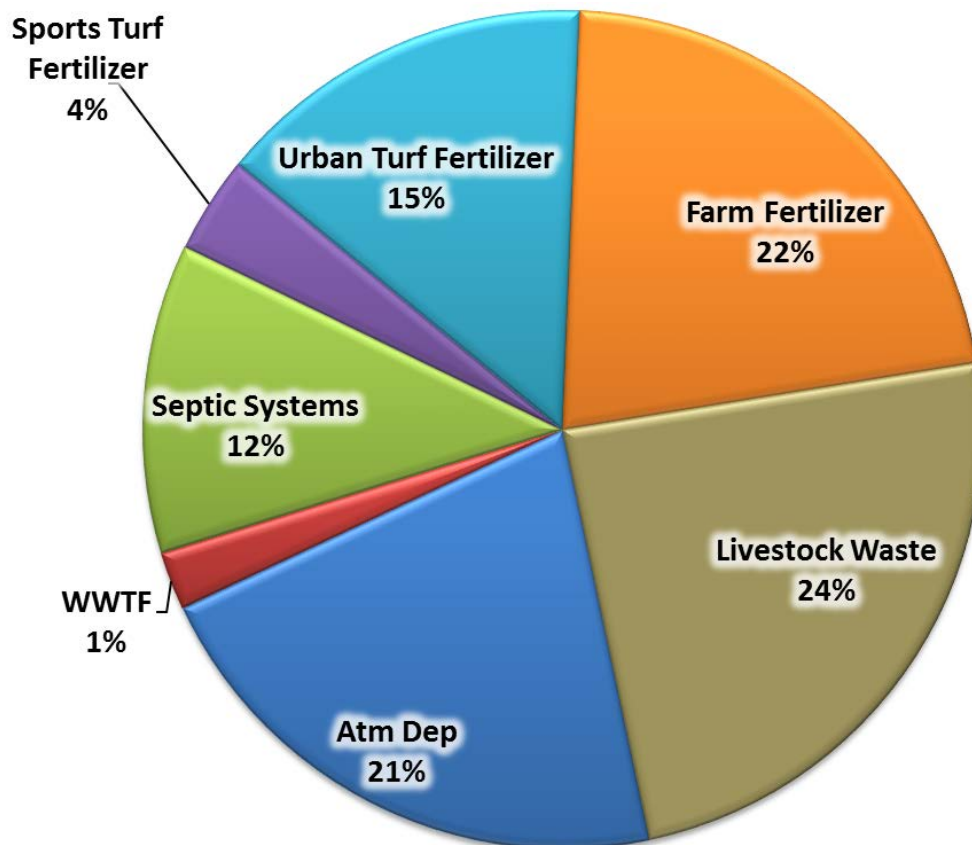


Figure 8: Relative nitrogen inputs to the land surface in the Weeki Wachee Spring contributing area from major anthropogenic source categories in lb-N/yr

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 hydrogeological properties that affect the rate of water infiltrating through geologic media to recharge 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 within the nitrogen cycle 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 conducted in Florida as well as other areas with similar environmental characteristics. Additionally, research scientists in Florida (UF–IFAS, other universities, and USDA Agricultural Research Service [ARS]) and local stakeholders provided additional guidance. The BAFs, listed in **Table 16**, represent the average percentage of the nitrogen attenuated or removed by subsurface processes and not available to leach, 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 BAFs (**Table 16**). For example, atmospheric deposition has an average nitrogen attenuation of 90 % (mainly from uptake by vegetation). This means that 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*	70 %	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	80 %	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

Nitrogen (usually in the form of nitrate) that is not attenuated by biochemical attenuation processes can 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 940,143 lb-N to the UFA in the BMAP area, representing 18 % 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 septic systems (30 % of the total estimated load to groundwater), followed by urban turfgrass fertilizer at 22 %.

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–RIBs	WWTF–Sprayfields	WWTF–Reuse	Septic Systems	Sports Turf Fertilizer	Urban Turf Fertilizer	Farm Fertilizer	Livestock Waste	TOTAL
High	923,127	39,786	10	80,249	617,033	197,872	762,189	653,917	737,277	4,011,461
Medium	197,713	389	213	0	20,332	2,769	26,475	449,232	484,054	1,181,176
Low	24,093	0	0	0	2,552		2,362	65,327	78,928	173,261
TOTAL	1,144,933	40,155	223	80,249	639,916	200,642	791,025	1,168,475	1,300,259	5,366,120

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

Recharge Category	Atmospheric Deposition	WWTF–RIBs	WWTF–Sprayfields	WWTF–Reuse	Septic Systems	Sports Turf Fertilizer	Urban Turf Fertilizer	Farm Fertilizer	Livestock Waste	TOTAL
BAF	90 %	25 %	60 %	75 %	50 %	70 %	70 %	80 %	90 %	
High	92,313	29,840	4	20,062	308,517	59,362	228,657	130,783	73,728	943,265
Medium	19,771	292	85	0	10,166	831	7,942	89,846	48,405	177,339
Low	2,409	0	0	0	1,276	0	709	13,065	7,893	25,352
TOTAL	114,493	30,132	89	20,062	319,958	60,193	237,308	233,695	130,026	1,125,893

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	WWTFs [§]	Septic Systems	Sports Turf Fertilizer	Urban Turf Fertilizer	Farm Fertilizer	Livestock Waste	TOTAL
High	90 %	83,081	44,915	277,665	53,426	205,791	117,705	66,355	848,938
Medium	50 %	9,886	189	5,083	415	3,971	44,923	24,203	88,670
Low	10 %	241	0	128	0	71	1,307	789	2,535
TOTAL		93,208	45,105	282,875	53,841	209,833	163,935	91,347	940,143

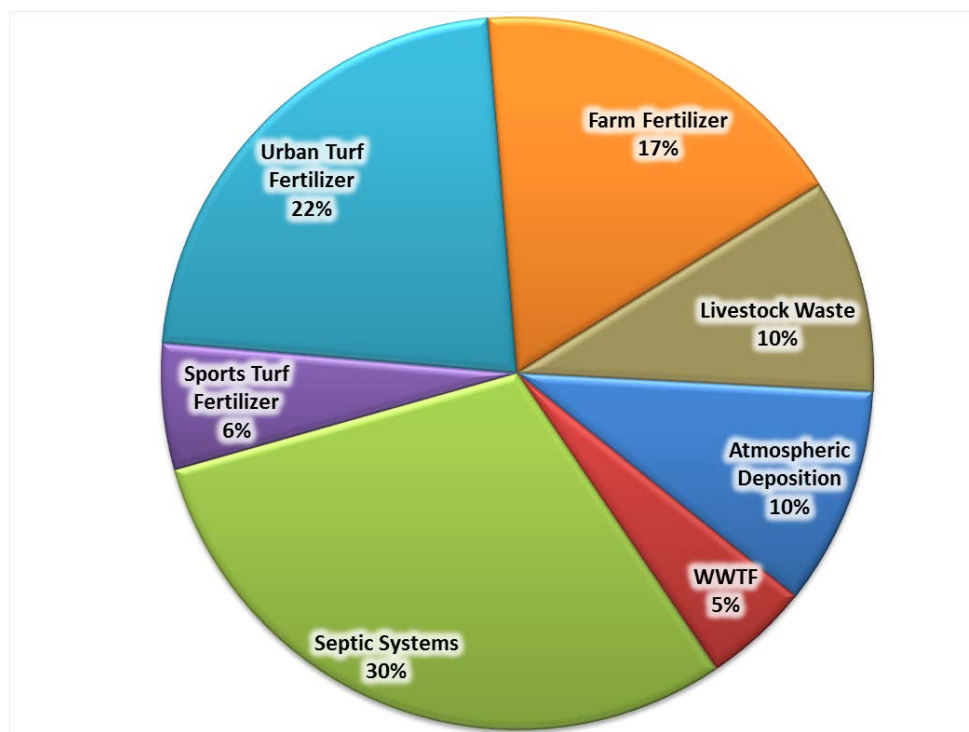


Figure 9: Relative percent contributions of nitrogen loading to groundwater for source categories in the Weeki Wachee Spring contributing area

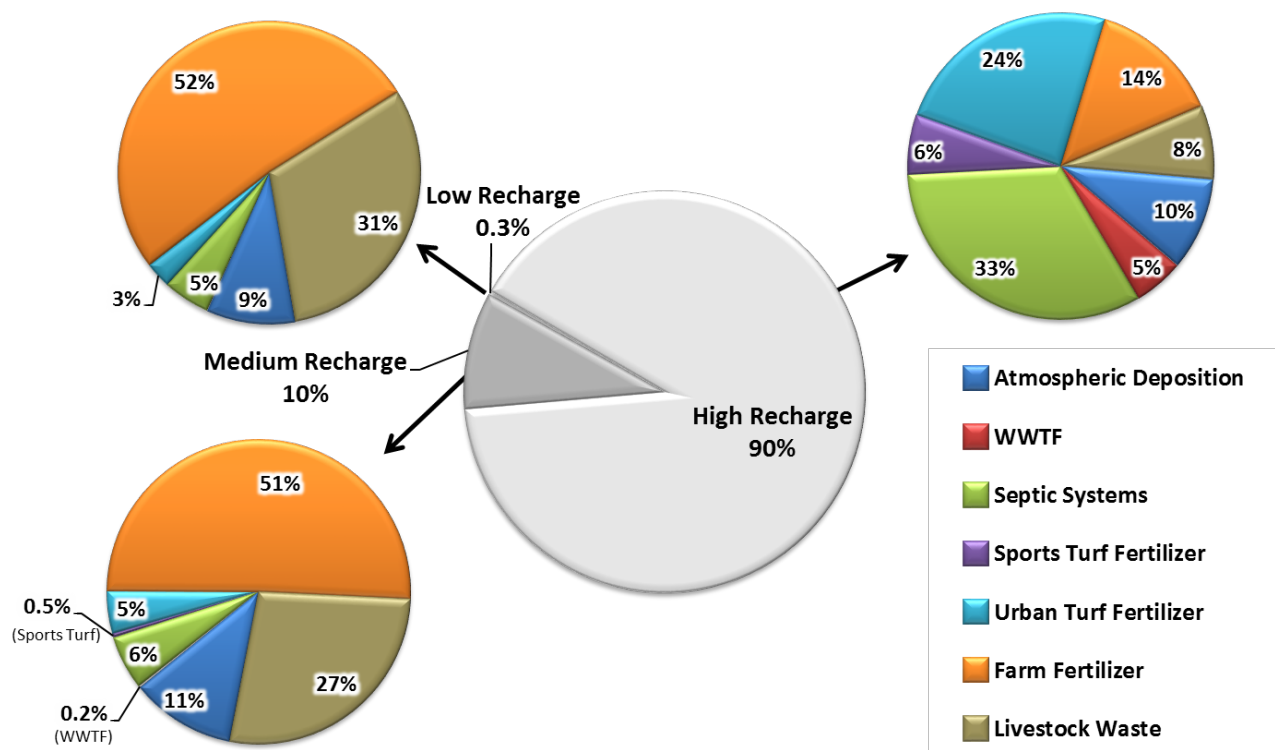


Figure 10: Estimated annual nitrogen loading to groundwater by recharge category

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 nitrogen from 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–Sprayfields	50 %	60 %	75 %
WWTFs–Reuse	50 %	75 %	85 %
Septic Systems	40 %	50 %	75 %
Livestock Waste	80 %	90 %	95 %
Farm Fertilizer	50 %	70 %	85 %
Urban Fertilizer*	50 %	70 %	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 using the largest nitrogen attenuation factors for all sources, the total estimated nitrogen load to groundwater in the Weeki Wachee springshed is still substantially higher than the target load estimated for Weeki Wachee Spring based on the spring TMDL. The target nitrogen load was calculated using on the most recent discharge data and the nitrate concentration in water from the spring vent. For Weeki Wachee, the annual average river discharge is 185.6 cfs (USGS gauge

station 02310545; April 2012–April 2013), and the adopted TMDL is 0.28 mg/L for Weeki Wachee Spring (Dodson and Bridger 2014). Multiplying the discharge times the TMDL concentration results in a target nitrogen load of 102,178 lb-N/yr. Using the maximum nitrogen attenuation factors for each source, the estimated minimum load to groundwater in the contributing area is 520,967 lb-N/yr, which is approximately 5 times greater than the TMDL target nitrogen load for Weeki Wachee Spring (**Figure 12**).

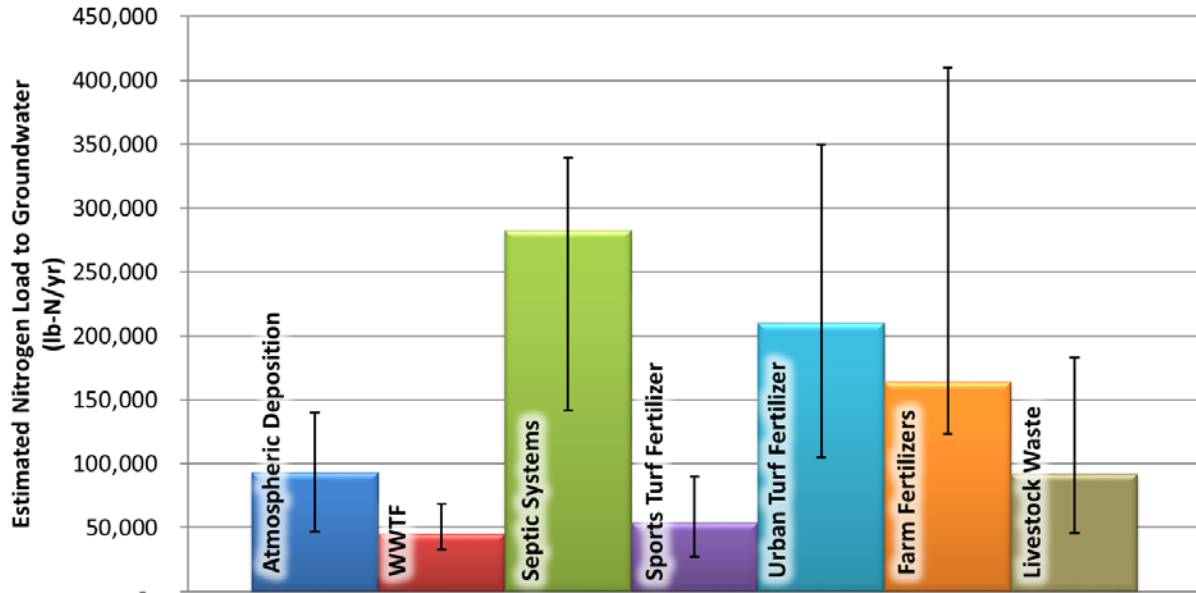


Figure 11: Influence of the range of attenuation factors on estimated nitrogen loads to groundwater from each category in the Weeki Wachee Spring contributing area

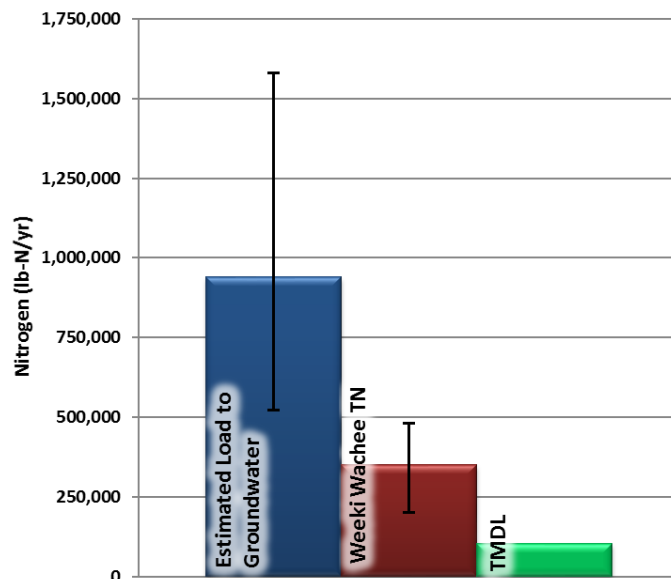


Figure 12: Estimated nitrogen load to groundwater compared with the current nitrogen discharging from Weeki Wachee Spring, Little Spring, and Hospital Spring and the TMDL goal

4. REFERENCES

- Aravena, R., and W.D. Robertson. 1998. Use of multiple isotope tracers to evaluate denitrification in ground water: Study of nitrate from a large-flux septic system plume. *Ground Water* 36(6): 975–982.
- Barton, L., and T.D. Colmer. 2006. Irrigation and fertilizer strategies for minimizing nitrogen leaching from turfgrass. *Agricultural Water Management* 80: 160–175.
- Bridger, K., and J. Dodson. 2015. *Coastal springs of Pasco and Hernando Counties: Magnolia–Aripkeka Springs Group, Jenkins Creek Spring, Wilderness–Mud–Salt Springs Group (WBIDs 1391B, 1389, and 1382G)*. Draft TMDL report. Tallahassee, FL: Florida Department of Environmental Protection.
- Burns, J.C., M.G. Waggener, and D.S. Fisher. 2009. Animal and pasture productivity of 'Coastal' and 'Tifton 44' Bermudagrass at three nitrogen rates and associated soil nitrogen status. *Agronomy Journal* 101 (1): 32–40.
- Bush, P.W., and R.H. Johnston. 1988. *Ground-water hydraulics, regional flow, and ground-water development of the Floridan aquifer system in Florida and parts of Georgia, South Carolina, and Alabama*. U.S. Geological Survey Professional Paper 1403-C.
- Candela, L., S. Fabregat, A. Josa, J. Suriol, N. Vignes, and J. Mas. 2007. Assessment of soil and groundwater impacts by treated urban wastewater reuse: A case study: Application in a golf course (Girona Spain). *Science of the Total Environment* 374: 26–35.
- Carey, R.O., G.J. Hockmuth, C.J. Martinez, T.H. Boyer, and V.D. Nair et al. 2012. A review of turfgrass fertilizer management practices: implications for urban water quality. *HortTechnology* 22(3): 280–291.
- Chang, N.B., M. Wanielista, A. Daranpob, F. Hossain, and Z. Xuan et al. 2010. *Onsite sewage treatment and disposal systems evaluation for nutrient removal*. Tallahassee, FL: Florida Department of Environmental Protection, Bureau of Watershed Restoration.
- Chelette, A.R., T.R. Pratt, and B.G. Katz. 2002. *Nitrate loading as an indicator of nonpoint source pollution in the lower St. Marks–Wakulla Rivers watershed*. Northwest Florida Water Management District Water Resources Special Report 02-1.
- Cockx, E.M., and E.H. Simonne. 2011. *Reduction of the impact of fertilization and irrigation on processes in the nitrogen cycle in vegetable fields with BMPs*. HS948. Gainesville, FL: University of Florida Institute of Food and Agricultural Sciences.
- Cook, E.M., S.J. Hall, and K.L. Larson. 2012. Residential landscapes as social-ecological systems: A synthesis of multi-scalar interactions between people and their home environment. *Urban Ecosyst* 15: 19–52.

- Corbett, D.R., K. Dillon, W. Burnett, and G. Schaefer. 2002. The spatial variability of nitrogen and phosphorus concentration in a sand aquifer influenced by onsite sewage treatment and disposal systems: A case study on St. George Island, Florida. *Environmental Pollution* 117: 337–345.
- Costa, J.E., G. Heufelder, S. Foss, N.P. Milham, and B. Howes. 2002. Nitrogen removal efficiencies of three alternative septic system technologies and a conventional septic system. *Environment Cape Cod* 5(1): 15–24.
- Davis, J.H. 1996. *Hydrogeologic investigation and simulation of ground-water flow in the UFA of north-central Florida and southwestern Georgia and delineation of contributing areas for selected city of Tallahassee, Florida, water-supply wells*. U.S. Geological Survey Water-Resources Investigations Report 95-4296.
- Dodson, J., and Bridger, K. 2014. *Nutrient TMDLs for Weeki Wachee Spring and Weeki Wachee River (WBIDs 1382B and 1382F)*. Final TMDL report. Tallahassee, FL: Florida Department of Environmental Protection.
- Downs, P.E., J. St. Germain, and N. Pick. 2012. *Focus group for northern counties springs study: Final report*. Southwest Florida Water Management District.
- Dubeux, J.C.B., Jr., L.E. Sollenberger, B.W. Mathews, J.M. Scholberg, and H.Q. Santos. 2007. Nutrient cycling in warm-climate grasslands. *Crop Science* 47: 915–928.
- Dubeux, J.C.B., Jr., L.E. Sollenberger, L.A. Gaston, J.M.B. Vendramini, S.M. Interrante, and R.L. Stewart, Jr. 2009. Animal behavior and soil nutrient redistribution in continuously stocked Pensacola bahiagrass pastures managed at different intensities. *Crop Science* 49: 1503–1510.
- Eller, K.T., B.G. Katz, and C. Lyon. 2016. *Nitrogen source inventory and loading estimates for the contributing areas of Homosassa Springs Group and Chassahowitzka Springs Group*. Final report. Tallahassee, FL: Florida Department of Environmental Protection.
- Erikson, J.E., J.L. Cisar, J.C. Volin, and G.H. Snyder. 2001. Comparing nitrogen runoff and leaching between newly established St. Augustine turf and an alternative residential landscape. *Crop Science* 41: 1889–1895.
- Faulkner, G.L. 1970. *Geohydrology of the Cross-Florida Barge Canal with special reference to the Ocala vicinity*. U.S. Geological Survey Water-Resources Investigations Report I-73.
- Florida Department of Environmental Protection. 2007. *Best management practices for the enhancement of environmental water quality on Florida golf courses*. Tallahassee, FL.
- . 2010. *Florida friendly best management practices for protection of water resources by the green industries*. Tallahassee, FL.

- Goolsby, D.A., W.A. Battaglin, G.B. Lawrence, R.S. Artz, and B.T. Aulenbach et al. 1999. *Flux and sources of nutrients in the Mississippi–Atchafalaya River Basin*. National Oceanic and Atmospheric Administration Coastal Ocean Program No. 17.
- Grove, J.M, M.L. Cadenasso, W.R. Burch, S.T.A. Pickett, K. Schwarz, J. O'Neil-Dunne, and M. Wilson. 2006. Data and methods comparing social structure and vegetation structure of urban neighborhoods in Baltimore, Maryland. *Society and Natural Resources* 19: 117–136.
- Hall, P., and S.J. Clancy. 2009. *The Florida statewide inventory of onsite sewage treatment and disposal systems (OSTDS): A report on the status of knowledge of the number and locations of OSTDS in each county and best management practices for improving this knowledge*. Prepared for the Florida Department of Health, Bureau of Onsite Sewage Programs, by EarthSTEPS and GlobalMind.
- Happell, J.D., S. Opsahl, Z. Top, and J.P. Chanton. 2006 Apparent CFC and 3H/3He age differences in water from Floridan aquifer springs. *Journal of Hydrology* 319: 410-426.
- He, J., M.D. Dukes, G.J. Hochmuth, J.W. Jones, and W.D. Graham. 2011. Evaluation of sweet corn yield and nitrogen leaching with CERES-maize considering input parameter uncertainties. *Transaction of the American Society of Agricultural and Biological Engineers* 54(4): 1257–1268.
- Hochmuth, G.J., and E.A. Hanlon. 2000. *IFAS standardized fertilization recommendations for vegetable crops*. Circular 1152. Gainesville, FL: University of Florida Institute of Food and Agricultural Sciences.
- . 2010. *Commercial vegetable fertilization principles*. SL319. Gainesville, FL: University of Florida Institute of Food and Agricultural Sciences.
- . 2013. *A summary of N, P, and K research with watermelon in Florida*. SL 325. Gainesville, FL: University of Florida Institute of Food and Agricultural Sciences.
- Horsley Witten Group. 2009. *Evaluation of turfgrass nitrogen fertilizer leaching rates in soils on Cape Cod, Massachusetts*. Prepared for Brian Dudley, Department of Environmental Protection, Hyannis, MA. Sandwich, MA.
- Howard T. Odom Florida Springs Institute. 2011. *Wakulla Spring—An adaptive management strategy*. Prepared for the Wakulla Springs Working Group. Gainesville, FL.
- Jones, G.W., S.B. Upchurch, K.M. Champion, and D.J. Dewitt. 1997. *Water quality and hydrology of Homosassa, Chassahowitzka, Weeki Wachee, and Aripeka Spring Complexes, Citrus and Hernando Counties, Florida. Origin of increasing nitrate concentrations*. Southwest Florida Water Management District.

- Jordan, M.J., H.J. Nadelhoffer, and B. Fry. 1997. Nitrogen cycling in forest and grass ecosystems irrigated with 15N-enriched wastewater. *Ecological Applications* 7 (3): 864–881.
- Katz, B.G. 1992. *Hydrochemistry of the upper Floridan aquifer, Florida*. U.S. Geological Survey Water-Resources Investigations Report 91-4196.
- . 2004. Sources of nitrate contamination and age of water in large karstic springs of Florida. *Environmental Geology* 46: 689–706.
- Katz, B.G., H.D. Hornsby, J.F. Bohlke, and M.F. Mook. 1999. *Sources and chronology of nitrate contamination in spring waters, Suwannee River Basin, Florida*. U.S. Geological Survey Water-Resources Investigations Report 99-4252.
- Katz, B.G., A.A. Sepulveda, and R.J. Verdi. 2009. Estimating nitrogen loading to ground water and assessing vulnerability to nitrate contamination in a large karstic springs basin, Florida. *Journal of the American Water Resources Association* 45: 3.
- Kinzig, A.P., P. Warren, C. Martin, D. Hope and M. Katti. 2005. The effects of human socioeconomic status and cultural characteristics on urban patterns of biodiversity. *Ecology and Society* 10 (1).
- Knowles, L. 1996. *Estimation of evapotranspiration in the Rainbow Springs and Silver Springs basins in north-central Florida*. U.S. Geological Survey Water-Resources Investigations Report 96-4024.
- Knowles, L., Jr., B.G. Katz, and D.J. Toth. 2010. Using multiple chemical indicators to characterize and determine the age of groundwater from selected vents of the Silver Springs Group, central Florida, USA. *Hydrogeology Journal* 18: 1825–1838.
- Law, N.L., L.E. Band, and J.M. Grove. 2004. Nitrogen input from residential lawn care practices in suburban watersheds in Baltimore County, MD. *Journal of Environmental Planning and Management* 47(5): 737–755.
- Liao, L., C.T. Green, B.A. Bekins, and J.K. Bohlke. 2012. Factors controlling nitrate fluxes in groundwater in agricultural areas. *Water Resources Research* 48: 1–18.
- Liu, G.D., E.H. Simonne, and G.J. Hochmuth. Revised 2013. *Soil and fertilizer management for vegetable production in Florida*. Document HS711. Gainesville, FL: University of Florida Institute of Food and Agricultural Sciences.
- Lombardo Associates. 2011. *Onsite sewage treatment and disposal and management options*. Newton, MA.

- Lyon, C., K.T. Eller, and B.G. Katz. 2016. *Nitrogen source inventory and loading estimates for the Magnolia–Aripeka Springs Group contributing area*. Final report. Tallahassee, FL: Florida Department of Environmental Protection.
- Martin, T. 2008. *Lawn care behavior, Crystal River/Weeki Wachee Spring and Rainbow River survey*. Final report prepared for the Southwest Florida Water Management District.
- McNeal, B.L., C.D. Stanley, W.D. Graham, P.R. Gilreath, D. Downey, and J.F. Creighton. 1995. Nutrient loss trends for vegetable and citrus fields in west-central Florida: 1. Nitrate. *Journal of Environmental Quality* 24(1): 95–100.
- Merritt, M., and D.J. Toth. 2006. *Estimates of upper Floridan aquifer recharge augmentation based on hydraulic and water-quality data (1986–2002) from the Water Conserv II RIB systems, Orange County, Florida*. St. Johns River Water Management Special Publication SJ2006-SP3. Palatka, FL.
- Meyer, L.H. 2012. *Quantifying the role of agriculture and urbanization in the nitrogen cycle across Texas*. University of Texas graduate thesis.
- Mylavarapu, R., D. Wright, G. Kidder, and C.G. Chambliss. 2012. *UF/IFAS standardized fertilization recommendations for agronomic crops*. SL 129. Gainesville, FL: University of Florida Institute of Food and Agricultural Sciences.
- Newton, G.L., J.C. Johnson, Jr., J.G. Davis, G. Vellidis, R.K. Hubbard, and R. Lowrance. 1995. *Nutrient recoveries from varied year-round applications of liquid dairy manure on sprayfields*. 32nd Dairy Production Conference. Gainesville, FL.
- Newton, G.L., G.J. Gascho, G. Vellidis, R.N. Gates, and R.K. Hubbard et al. 1999. *Nutrient balance for triple-crop forage production systems fertilized with dairy manure or commercial fertilizer*. Water Resource Conference. Athens, GA: University of Georgia.
- Obour, A.K., M.L. Silveira, J.M.B. Vendramini, M.B. Adjei, and L.E. Sollenberger. 2010. Evaluating cattle manure application strategies on phosphorus and nitrogen losses from a Florida spodosol. *Agronomy Journal* 102(5): 1511–1520.
- Otis, R.J. 2007. *Estimates of nitrogen loadings to groundwater from onsite wastewater treatment systems in the Wekiva Study Area*. Otis Environmental Consultants, LLC.
- Paramasivam, S., and A.K. Alva. 1997. Leaching of nitrogen forms from controlled-release nitrogen fertilizers. *Communications in Soil Science and Plant Analysis* 28(17&18): 1663–1674.
- Phelps, G.G. 2004. Chemistry of ground water in the Silver Springs basin, Florida, with emphasis on nitrate. U.S. Geological Survey Scientific Investigations Report 2004-5144.

- Poiani, K.A., B.L. Bedord, and M.D. Merrill. 1996. A GIS-based index for relating landscape characteristics to potential nitrogen leaching to wetlands. *Landscape Ecology* 11: 237–255.
- Rahil, M.H., and V.Z. Antonopoulos. 2007. Simulating soil water flow and nitrogen dynamics in a sunflower field irrigated with reclaimed wastewater. *Agricultural Water Management* 92: 142–150.
- Roeder, E. 2008. Sources of nitrogen: Estimates for inputs and loads to ground water in the Wekiva Study Area. *Florida Journal of Environmental Health*.
- Ruddy, B.C., D.L. Lorenz, and D.K. Mueller. 2006. *County-level estimates of nutrient inputs to the land surface of the conterminous United States, 1982–2001*. U.S. Geological Survey Scientific Investigations Report 2006-5012.
- Sartain, J.B. 2002. *Recommendations for N, P, K and Mg for golf course and athletic field fertilization based on Mehlich III extractant*. Document SL191. Gainesville, FL: University of Florida Institute of Food and Agricultural Sciences
- Scanlon, B.R., R.W. Healy, and P.G. Cook. 2002. Choosing appropriate techniques for quantifying groundwater recharge. *Hydrogeology Journal* 10: 18–39.
- Schwede, D.B., and G.G. Lear. 2014. A novel hybrid approach for estimating total deposition in the United States. *Atmospheric Environment* 92: 207–220.
- Sepulveda, N. 2002. *Simulation of ground-water flow in the intermediate and Floridan aquifer systems in peninsular Florida*. U.S. Geological Survey Water-Resources Investigations Report 02-4009.
- Sigua, G.C. 2010. Sustainable cow-calf operations and water quality: A review. *Agron. Sustain. Dev.* 30: 631–648.
- Sigua, G.C., R.K. Hubbard, S.W. Coleman, and M. Williams. 2010. Nitrogen in soils, plants, surface water and shallow groundwater in a bahiagrass pasture of southern Florida, USA. *Nutrient Cycling in Agroecosystems* 86: 175–187.
- Silveira, M.L., V.A. Haby, and A.T. Leonard. 2007. Response of coastal bermudagrass yield and nutrient uptake efficiency to nitrogen sources. *Agronomy Journal* 99: 707–714.
- Silveira, M.L., A.K. Obour, J. Arthington, and L.E. Sollenberger. 2011. The cow-calf industry and water quality in south Florida: A review. *Nutrient Cycling in Agroecosystems* 89: 439–452.

- Simonne, E., M. Dukes, G. Hochmuth, B. Hochmuth, D. Studstill, and A. Gazula, 2006. Monitoring nitrate concentration in shallow wells below a vegetable field. *Proc. Fla. State Hort. Soc.* 119: 226–230.
- Sprague, L.A., and J.M. Gronberg. 2013. Estimation of anthropogenic nitrogen and phosphorus inputs to the land surface of the conterminous United States—1992, 1997, and 2002. U.S. Geological Survey Scientific Investigations Report 2012-5241.
- Sumner, D.M., and L.A. Bradner. 1996. *Hydraulic characteristics and nutrient transport and transformation beneath a rapid infiltration basin, Reedy Creek Improvement District, Orange County, Florida*. U.S. Geological Survey Water-Resources Investigations Report 95-4281.
- Tomasko, D.A., D.L. Bristol, and J.A. Ott. 2001. Assessment of present and future nitrogen loads, water quality, and seagrass (*Thalassia testudinum*) depth distribution in Lemon Bay, Florida. *Estuaries* 24 (6A): 926–938.
- Toor, G.S., M. Lusk, and T. Obreza. 2011. *Onsite sewage treatment and disposal systems: Nitrogen*. SL 348. Gainesville, FL: University of Florida Institute of Food and Agricultural Sciences.
- U.S. Environmental Protection Agency. 2002. *Onsite wastewater treatment systems manual*. EPA/625/R-00/008. Washington, DC: Office of Water.
- Viers, J.H, D. Liptzin, T.S. Rosenstock, W.B. Jensen, and A.D. Hollander et al. 2012. *Nitrogen sources and loading to groundwater*. Technical Report 2. California State Water Resources Control Board.
- Wang, F.L., and A.K. Alva. 1996. Leaching of nitrogen from slow-release urea sources in sandy soils. *Soil Science Society of America Journal* 60: 1454–1458.
- Wang, L., A.S. Butcher, M.E. Stuart, D.C. Gooddy, and J.P. Bloomfield. 2013. The nitrate time bomb: A numerical way to investigate nitrate storage and lag time in the unsaturated zone. *Environmental Geochemistry and Health* 35: 667–681.
- White-Leech, R., K. Liu, L.E. Sollenberger, K.R. Woodard, and S.M. Interrante. 2013a. Excreta deposition on grassland patches. I. Forage harvested, nutritive value, and nitrogen recovery. *Crop Science* 53: 688–695.
- . 2013b. Excreta deposition on grassland patches. II. Spatial pattern and duration of forage responses. *Crop Science* 53: 696–703.
- Woodard, K.R., L.E. Sollenberger, D.A. Graetz, C.G. Chambliss, and J.M. Scholberg. 2006. *Verification of interim BMPs for nitrogen fertilization of hayfields within the Suwannee River Water Management District and confirmation of interim BMPs for maximum*

nitrogen fertilization of hayfields in the Suwannee River Water Management District.
Final report for the Florida Department of Agriculture and Consumer Services projects.

Woodard, K.R., and L.E. Sollenberger. 2011. Broiler litter vs. ammonium nitrate as nitrogen source for bermudagrass hay production: Yield, nutritive value, and nitrate leaching. *Crop Science* 51: 1342–1352.

Wright, D.L., E.B. Whitty, and C.G. Chambliss. 2011. *Fertilization of agronomic crops*. SS-AGR-152. Gainesville, FL: University of Florida Institute of Food and Agricultural Sciences.

Zhou, W., A. Troy, and M. Grove. 2008. Modeling residential lawn fertilization practices: Integrating high resolution remote sensing with socioeconomic data. *Environmental Management* 41: 742–752.

APPENDICES

Appendix A: Tables

Table A.1: Useful conversion factors

Convert from	To	Multiply by
pounds	kilograms	0.4535924
NO ₃ milligrams per liter	NO ₃ grams-nitrogen per liter	2.260 X 10 ⁻⁴
NH ₄ 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	0
3	MULTIFAMILY 10 UNITS OR MORE	110	0	0
4	CONDOMINIUM	24	0	0
5	COOPERATIVES	0	0	0
6	RETIREMENT HOMES	0	0	0
7	MISC RES (BOARDING HOMES, CAMPS)	0	0	0
8	MULTIFAMILY LESS THAN 10 UNIT	75	0	0
10	VACANT COMMERCIAL	526	1	4
11	STORES, 1 STORY	194	1	2
12	STORE/OFFICE/OR RESID COMBIN	15	0	0
13	DEPARTMENT STORE	5	0	1
15	SHOPPING CENTERS (REGIONAL)	6	0	0
16	SHOPPING CENTERS (COMMUNITY)	51	0	2
17	OFFICE BUILDINGS, 1 STORY	127	0	1
18	OFFICE BUILDINGS, MULTISTORY	11	0	0
19	PROFESSIONAL BUILDINGS	189	0	0
20	AIRPORTS, BUS TERM, MARINAS	1	0	0
21	RESTAURANT AND CAFETERIAS	43	0	2
22	DRIVE IN RESTAURANTS	17	0	2
23	FINANCIAL INSTITUTIONS	24	0	1
25	SERVICE SHOP, RADIO & TV REPIR	4	0	0
26	SERVICE STATIONS	23	0	0
27	AUTO SALES, REPAIR & STORAGE	54	0	0
28	PARKING LOTS, COMM, MH PARKS	47	4	0
29	WHOLESALE OUTLETS, PRODUCE	1	0	0
30	FLORIST, GREENHOUSES	3	0	0
32	THEATERS, (ENCLOSED) AUDITORIUM	2	0	0
33	NIGHT CLUBS, COCKTAIL LOUNGES	2	0	0
34	BOWLING ALLEYS, SKATING RINKS	3	0	0
35	TOURIST ATTR. OTHER ENTERTNMT	2	0	0
36	CAMPS	4	2	0
38	GOLF COURSES, DRIVING RANGES	64	0	4
39	HOTELS - MOTELS	7	0	0
40	VACANT INDUSTRIAL	22	0	0
41	LIGHT MANUFACTURING	34	0	0
44	PACKING PLANTS, FRUIT & VEGE	1	0	0

*Nitrogen Source Inventory and Loading Estimates for the Weeki Wachee Spring and River Contributing Area,
October 2016*

Property Code	Description	High-Recharge Area	Medium-Recharge Area	Discharge Area
46	OTHER FOOD PROCESSING, CANDY	1	0	0
48	WAREHOUSING, DISTRIBUTION	145	1	0
49	OPEN STORAGE, NEW AND USED	12	0	0
51	CROPLAND SOIL CAPABILITY CLS I	65	40	0
54	TIMBER NATURAL STAND	183	26	2
55	TIMBER PLANTED	58	5	0
56	TIMBERLAND	2	0	0
59	WOODS - NATIVE PASTURE	95	36	0
60	IMPROVED PASTURE LAND	342	98	0
65	GRAZING LAND SOIL CAPAB VI	1	0	0
66	ORCHARD GROVES	20	13	0
67	POULTRY, BEES, HOGS IN FIELD	3	0	0
69	ORNAMENTALS	22	2	0
70	VACANT INSTITUTIONAL	59	0	1
71	CHURCHES	63	0	0
72	SCHOOLS, COLLEGES PRIVATE	11	0	0
73	HOSPITALS PRIVATELY OWNED	5	0	0
74	HOMES FOR THE AGED	25	0	0
75	CHARITABLE/NON PROFIT	3	0	0
76	MORTUARIES, CEMETERIES, CREMAT	16	2	0
77	CLUBS, LODGES, UNION HALLS	67	0	1
80	VACANT GOVERNMENTAL	82	1	0
81	MILITARY	4	0	0
82	FOREST PARKS RECREATIONAL	41	0	4
83	SCHOOLS - PUBLIC COUNTY	13	0	0
85	HOSPITALS	1	0	0
86	COUNTIES OTHER THAN PUBLIC SCH	59	0	0
87	STATE OTHER THAN MILITARY FORE	134	0	19
88	FEDERAL OTHER THAN MILITARY	1	0	0
89	MUNICIPAL OTHER THAN PARKS	3	0	0
90	LEASEHOLD INTERESTS	204	0	0
91	UTIL, RR, GAS, COMMUNICATIONS, ELECT	122	0	2
94	RIGHT OF WAY STREETS/ROADS	586	19	39
95	RIVERS AND LAKES, SUBMERGED	57	1	4
96	DRA, LIFT STAT, MARSH, BORROW PIT	1,324	2	16
97	OUTDOOR PARKLAND/REC	11	0	0
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	MULTIFAMILY 10 UNITS OR MORE	0	0	0
4	CONDOMINIUM	0	0	0
5	COOPERATIVES	0	0	0
6	RETIREMENT HOMES	0	0	0
7	MISC RES (BOARDING HOMES, CAMPS)	0	0	0
8	MULTIFAMILY 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	0	0	0
14	SUPER MARKETS	0	0	0
15	SHOPPING CENTERS (REGIONAL)	0	0	0
16	SHOPPING CENTERS (COMMUNITY)	0	0	0
17	OFFICE BUILDINGS, 1 STORY	4	2	0
18	OFFICE BUILDINGS, MULTISTORY	1	0	0
19	PROFESSIONAL BUILDINGS	1	10	0
20	AIRPORTS, BUS TERM, MARINAS	0	0	0
21	RESTAURANT AND CAFETERIAS	0	0	0
22	DRIVE IN RESTAURANTS	0	0	0
23	FINANCIAL INSTITUTIONS	0	0	0
24	INSURANCE COMPANY NATL REG OFF	0	0	0
25	SERVICE SHOP, RADIO & TV REPIR	6	4	0
26	SERVICE STATIONS	0	0	0
27	AUTO SALES, REPAIR & STORAGE	4	0	0
28	PARKING LOTS, COMM, MH PARKS	124	33	0
29	WHOLESALE OUTLETS, PRODUCE	0	0	0
30	FLORIST, GREENHOUSES	0	0	0
31	THEATERS, (DRIVE IN) STADIUMS	0	0	0
32	THEATERS, (ENCLOSED) AUDITORIUM	0	0	0
33	NIGHT CLUBS, COCKTAIL LOUNGES	2	3	2
34	BOWLING ALLEYS, SKATING RINKS	0	0	0
35	TOURIST ATTR. OTHER ENTERTNMT	0	0	0
36	CAMPS	0	0	0
37	RACE TRACKS, HORSE, AUTO OR DO	0	0	0

*Nitrogen Source Inventory and Loading Estimates for the Weeki Wachee Spring and River Contributing Area,
October 2016*

Property Code	Description	High-Recharge Area	Medium-Recharge Area	Low-Recharge Area
38	GOLF COURSES, DRIVING RANGES	0	0	0
39	HOTELS - MOTELS	0	0	0
40	VACANT INDUSTRIAL	19	43	0
41	LIGHT MANUFACTURING	20	9	0
42	HEAVY INDUSTRIAL, HEAVY EQUIP	0	0	0
43	LUMBER YARDS, SAWMILLS	0	0	0
44	PACKING PLANTS, FRUIT & VEGE	0	0	0
45	CANNERIES, FRUIT & VEGETABLE	0	0	0
46	OTHER FOOD PROCESSING, CANDY	0	0	0
47	MINERAL PROCESSING, PHOSPHATE	22	0	0
48	WAREHOUSING, DISTRIBUTION	43	51	0
49	OPEN STORAGE, NEW AND USED	0	0	0
50	IMPROVED AGRICULTURAL	0	0	0
51	CROPLAND SOIL CAPABILITY CLS I	939	1,107	242
52	CROPLAND SOIL CAPABILITY II	0	0	0
53	CROPLAND SOIL CAPABILITY III	24	57	0
54	TIMBER NATURAL STAND	11,015	512	45
55	TIMBER PLANTED	604	311	0
56	TIMBERLAND	0	0	0
57	TIMBERLAND	0	0	0
58	TIMBERLAND	0	0	0
59	WOODS - NATIVE PASTURE	0	0	0
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	0
65	GRAZING LAND SOIL CAPAB VI	2,525	342	0
66	ORCHARD GROVES	630	561	147
67	POULTRY, BEES, HOGS IN FIELD	0	0	0
68	DAIRIES, FEED LOTS, PENNED HOGS	432	455	173
69	ORNAMENTALS	172	72	0
70	VACANT INSTITUTIONAL	1	1	0
71	CHURCHES	31	13	0
72	SCHOOLS, COLLEGES PRIVATE	0	0	0
73	HOSPITALS PRIVATELY OWNED	0	0	0
74	HOMES FOR THE AGED	0	0	0
75	CHARITABLE/NON PROFIT	0	0	0

Table A.6: 2010 labor and statistics data for Hernando and Pasco Counties

Category	Hernando County	Pasco County
Total Labor Force	66,470	207,364
Employed Labor Force	57,464	182,593
Unemployed Labor Force	9,006	24,771

Table A.7: 2010 U.S. Census population data for Hernando and Pasco Counties

Population Category	Hernando County	Pasco County
Under 18	34,158	98,573
18 to 64	94,097	269,879
65 or older	44,523	96,245
Total	172,778	464,245

Table A.8: Estimated population data for calculation of effective septic systems population

Population Category	Equation	Hernando County	Pasco County
Nonworking	= 18 to 64 population – employed labor force	36,633	87,286
Retired	= 65 or older	44,523	96,245
School	= under 18	34,158	98,573
Work	= employed labor force	57,464	182,593

Table A.9: Hernando County zoning data

Zoning Code	Zoning Description	% Maximum Lot Coverage
AC	AC Agricultural Commercial District	0 %
AG	AG Agricultural District	0 %
AR	AR Agricultural Residential District	0 %
AR1	AR1 Agricultural Residential District	0 %
AR2	AR Agricultural Residential District	0 %
C1	C1 General Commercial District	0 %
C2	C2 Highway Commercial District	0 %
C3	C3 Neighborhood Commercial District	0 %
C4	C4 Heavy Highway Commercial District	0 %
CITY	City	0 %
CM1	CM1 Marine Commercial District	0 %
CM2	CM2 Heavy Marine Commercial District	0 %
CPDP	CPDP (Combined)	0 %
CV	CV Conservation District	0 %

Zoning Code	Zoning Description	% Maximum Lot Coverage
I1	I1 Industrial District	0 %
I2	I2 Heavy Industrial District	0 %
M	M Mining District	0 %
OP	OP Office-Professional District	0 %
PDP(AF)	PDP (Aviation Facilities)	0 %
PDP(CM)	PDP (Commercial Marine)	0 %
PDP(CP)	PDP (Corporate Park)	0 %
PDP(GC)	PDP (General Commercial)	0 %
PDP(GHC)	PDP (General Highway Commercial)	0 %
PDP(HC)	PDP (Highway Commercial)	0 %
PDP(HHC)	PDP (Heavy Highway Commercial)	0 %
PDP(HID)	PDP (Heavy Industrial)	0 %
PDP(IND)	PDP (Industrial)	0 %
PDP(LI)	PDP (Light Industrial)	0 %
PDP(MF)	PDP (Multifamily)	0.35 %
PDP(MH)	PDP (Mobile Home)	0.35 %
PDP(NC)	PDP (Neighborhood Commercial)	0 %
PDP(OP)	PDP (Office/Professional)	0 %
PDP(OP)	PDP (Single-Family)	0.35 %
PDP(PSF)	PDP (Public Service Facility Overlay District)	0 %
PDP(REC)	PDP (Recreational)	0 %
PDP(RR)	PDP (Resort Residential)	0.35 %
PDP(RUR)	PDP (Rural)	0 %
PDP(SF)	PDP (Single-Family)	0.35 %
PDP(SU)	PDP (Recreational)	0 %
PDP(SU)	PDP (Single-Family)	0 %
PDP(SU)	PDP (Special Use)	0 %
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	0 %
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	0 %
RM	RM Residential Mobile Home District	0.35 %
RR	Residential District	0.45 %

Table A.10: 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.11: 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	0	1,092
Horses	2,080	2,008
Broiler Chickens	0	604
Goats	1,034	1,410
Hogs	328	165
Sheep	318	251
Turkey	0	63

Appendix B. Estimating Fertilized Residential Acreages within the Springs Coast of Florida

This appendix describes the information and GIS methods used to estimate fertilized acreages for residential landscapes in Citrus, Hernando, and Pasco Counties, including single-family residential, multifamily residential, and condominiums.

One of the key components of the method is obtaining the most recent county property appraiser data for residential parcels. Counties populate these data in different ways, and the available datasets may or may not contain all the relevant information. However, as a basis for estimating fertilizer inputs for residential areas in each county, the dataset should include the following:

- **Parcel Identifier:** A number or series of characters that individually identifies a parcel; this may be labeled under a field name such as Parcel ID, Alt Key, or something similar.
- **DOR Code:** A numeric-based land use code used by the Florida Department of Revenue (DOR). If not available, other land use codes can be used, such as PC code or LU code.
- **DOR Code Description:** A description of the land use associated with each numeric DOR code.
- **Zoning Code:** An alphanumeric code that defines the county zoning limits.
- **Zoning Code Description:** A description of the zoning category associated with the alphanumeric zoning code.
- **Max Lot Coverage:** The percentage of a parcel that can be covered by impervious surfaces. This is usually found within zoning data and zoning laws (varies by county).
- **JV:** The "just value," or the assessed value of the property.
- **Parcel Acreage:** The acreage associated with each parcel identifier, calculated using the Calculate Geometry tool.

For these calculations, it is imperative to maintain the original parcel geometry. The impervious and pervious acreages are estimated as follows: the impervious acreage is equal to the total parcel acreage multiplied by the max lot coverage (percent), and the pervious acreage is the remaining land area associated with the parcel. For parcels with pervious areas greater than 1 acre, it is assumed that only 1 acre of land will receive fertilizer because it is unlikely that in most cases large parcel owners will fertilize their entire property. A parcel with a pervious

acreage greater than 1 acre can be identified using an if/then statement in the field calculator and assigning a pervious acreage of 1 acre, while all remaining parcels maintain the previously calculated pervious acreages.

This assumption affects fewer than 10 % of the parcels in the three Springs Coast counties. The distribution of pervious areas for residential parcels (DOR code = 0,1,3,4,5,8) was obtained by exporting the dataset within GIS to Excel and completing a histogram analysis for each county. The results are shown in **Table B.1**, **B.2**, and **B.3** for Citrus County, Hernando County, and Pasco County, respectively.

Table B.1: Pervious parcel size histogram results for Citrus County

Bin	Citrus County Pervious Parcel Acreage	Frequency	Cumulative %
0.25	0–0.25	58,293	48.84 %
0.5	0.26–0.5	30,069	74.03 %
0.75	0.51–0.75	9,810	82.24 %
1	0.76–1.0	9,575	90.27 %
1.5	1.01–1.5	3,646	93.32 %
2	1.51–2.0	2,289	95.24 %
3	2.01–3.0	1,968	96.89 %
4	3.01–4.0	1,644	98.26 %
5	4.01–5.0	959	99.07 %
10	5.01–10	847	99.78 %
20	10.01–20	190	99.94 %
50	20.01–50	60	99.99 %
More	Greater than 50	16	100.00 %

Table B.2: Pervious parcel size histogram results for Hernando County

Bin	Hernando County Pervious Parcel Acreage	Frequency	Cumulative %
0.25	0–0.25	54,425	60.34 %
0.5	0.26–0.5	20,374	82.93 %
0.75	0.51–0.75	4,648	88.08 %
1	0.76–1.0	2,794	91.18 %
1.5	1.01–1.5	1,682	93.05 %
2	1.51–2.0	596	93.71 %
3	2.01–3.0	2,723	96.72 %
4	3.01–4.0	565	97.35 %
5	4.01–5.0	1,106	98.58 %
10	5.01–10	969	99.65 %
20	10.01–20	247	99.93 %
More	greater than 20	67	100.00 %

Table B.3: Pervious parcel size histogram results for Pasco County

Bin	Pasco County Pervious Parcel Acreage	Frequency	Cumulative %
0.25	0–0.25	2,213	39.89 %
0.5	0.26–0.5	452	48.04 %
0.75	0.51–0.75	387	55.01 %
1	0.76–1.0	635	66.46 %
1.5	1.01–1.5	359	72.93 %
2	1.51–2.0	543	82.71 %
3	2.01–3.0	458	90.97 %
4	3.01–4.0	316	96.67 %
5	4.01–5.0	47	97.51 %
10	5.01–10	110	99.50 %
20	10.01–20	21	99.87 %
More	greater than 20	7	100.00 %

The final factor used to estimate the estimated fertilizable acreage is the probability that a homeowner will fertilize a property, which is based on property values (Kinzig et al. 2005; Zhou et al. 2008). According to several socioeconomic studies of fertilizer usage by homeowners, homeowners with high property values are more likely to fertilize their lawns than homeowners with low property values.

Property appraiser data for single-family residential properties were used to assess the ranges of high, medium- and low property values for each Springs Coast county. The single-family residential parcels (DOR code = 1) were selected for each county using a definition query, and the data were exported from GIS to Excel. A histogram was completed on these data to determine the frequency of parcels within different assessed value ranges. **Table B.4** and **Figure B.1** show the distribution of the number of single-family parcels for various ranges of property values in Citrus, Hernando, and Pasco Counties.

Table B.4: Histogram results for the number of parcels for various ranges of property values for Citrus, Hernando, and Pasco Counties

Bin	Property Value Range (\$)	# of Parcels in Citrus County	# of Parcels in Hernando County	# of Parcels in Pasco County	Total # of Parcels in Springs Coast
10000	0–10,000	456	935	154	1,545
20000	10,001–20,000	253	292	683	1,228
30000	20,001–30,000	2,390	1,156	3,750	7,296
40000	30,001–40,000	3,916	2,848	13,032	19,796
50000	40,001–50,000	4,497	4,077	15,652	24,226
60000	50,001–60,000	4,797	5,336	12,276	22,409
70000	60,001–70,000	4,695	5,929	7,943	18,567
80000	70,001–80,000	4,380	6,379	6,461	17,220
90000	80,001–90,000	3,499	5,903	5,642	15,044
100000	90,001–100,000	3,024	5,517	6,641	15,182
110000	100,001–110,000	2,815	4,366	7,117	14,298
120000	110,001–120,000	2,381	3,815	7,788	13,984
130000	120,001–130,000	2,057	3,091	8,320	13,468
140000	130,001–140,000	1,788	2,415	7,814	12,017
150000	140,001–150,000	1,518	1,797	6,998	10,313
160000	150,001–160,000	1,473	1,438	6,286	9,197
170000	160,001–170,000	1,336	1,081	4,565	6,982
180000	170,001–180,000	1,065	937	3,909	5,911
190000	180,001–190,000	967	792	3,451	5,210
200000	190,001–200,000	851	674	3,105	4,630
225000	200,001–225,000	1,482	1,202	5,947	8,631
250000	225,001–250,000	945	684	3,925	5,554
275000	250,001–275,000	688	451	2,766	3,905
300000	275,001–300,000	448	265	1,802	2,515
350000	300,001–350,000	504	284	2,046	2,834
400000	350,001–400,000	270	159	1,007	1,436
450000	400,001–450,000	153	56	608	817
500000	450,001–500,000	114	37	299	450
550000	500,001–550,000	68	24	184	276
600000	550,001–600,000	47	10	97	154
650000	600,001–650,000	24	13	71	108
700000	650,001–700,000	21	6	49	76
More	greater than 700,000	51	15	150	216

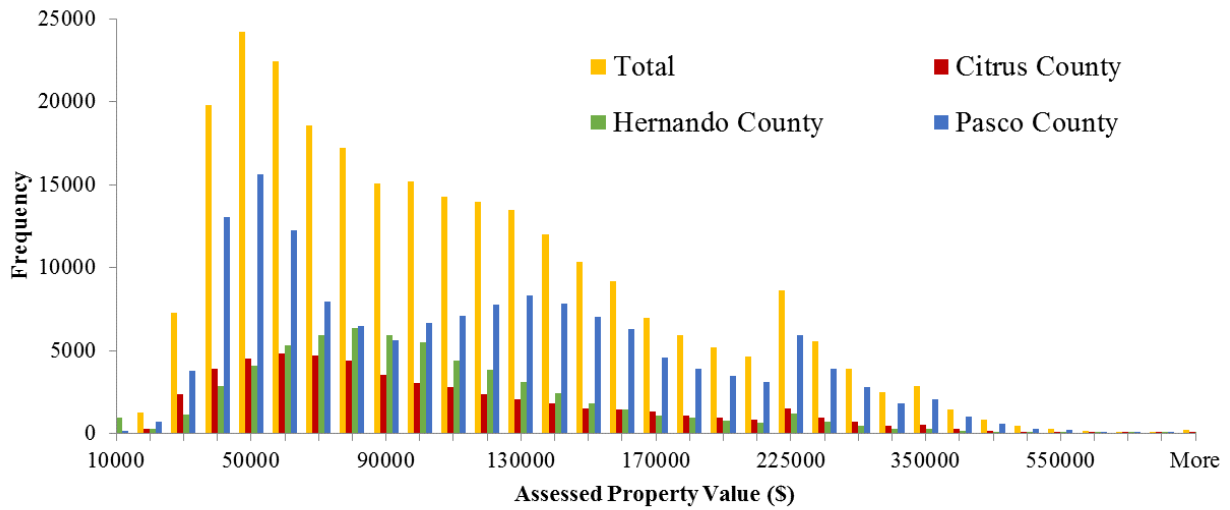


Figure B.1: Parcel frequency based on property value for single-family residential properties in the Springs Coast counties

The property value ranges were selected based on the distribution of property values throughout the counties. Property value categories were assigned as follows: low, less than \$50,000; medium, \$50,001 to \$150,000; and high, greater than \$150,001. Of the single-family residential properties, 57 % fell into the medium property value category, 22 % in the high, and 20 % in the low.

Homeowners with low property values were assigned a low probability (10 %) that they would fertilize their lawn, the medium property values category was assigned a 75 % probability, and the high property values were assigned the highest probability (90 %) (Kinzig et al. 2005; Grove et al. 2006; Carey et al. 2012). These probabilities of fertilization were added to all residential properties in the attributes tables within GIS, and a new field was created to calculate the estimated acreage fertilized for the Springs Coast counties. The fertilized acreage was calculated by multiplying the pervious acreage (with a maximum value of 1 acre) by the probability of fertilization (0.1, 0.75, or 0.9) value. The final nitrogen input calculations for residential fertilizer applications were based on the fertilization application rates described in **Section 2.4** of this report. The residential fertilizer inputs for nitrogen were further subdivided by the recharge rate areas within each BMAP boundary.

Appendix C: Golf Course Questionnaire



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
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?	

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.

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Ground Water Management Section
Golf Course Questionnaire
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Appendix D: 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, totaling 159,622 acres.
- 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 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 contributes to each septic system in Hernando County and an average of 2.07 people in Pasco County. With an annual input of 9.012 lb-N/person, this equaled an input of 20.6 lb-N per septic system. With 34,201 systems in the contributing area, 639,916 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 42,084 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 791,025 lb-N/yr over the 12,140 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 was 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 used 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 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 5,366,120lb-N/yr to the land surface (159,622 acres) in the Weeki Wachee Spring BMAP area, or an average of 34 lb-N/ac. The three sources contributing the largest percentages of nitrogen inputs to the land surface were livestock waste (24 %), farm fertilizer (22 %), and atmospheric deposition (21 %). **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 D.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	21 %	33%
Septic Systems	12 %	7%
WWTFs	1 %	2%
Urban Turfgrass Fertilizers	15 %	5%
Sports Turfgrass Fertilizers	4 %	2%
Farm Fertilizers	22 %	8%
Livestock Waste	24 %	42%
Stormwater	0%	1%